Cambium
PTP 650 Series
User Guide

System Release 650-01-40

Cambium Networks™

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Contents

About This User Guide

This guide describes the planning, installation, configuration and operation of the Cambium PTP 650 Series of point-to-point wireless Ethernet bridges. It is intended for use by the system designer, system installer and system administrator.

For radio network design, refer to the following chapters:

- Chapter 1: Product description
- Chapter 2: System hardware
- Chapter 3: System planning
- Chapter 4: Legal and regulatory information

For radio equipment installation, refer to the following chapter:

- Chapter 5: Installation

For system configuration, monitoring and fault-finding, refer to the following chapters:

- Chapter 6: Configuration and alignment
- Chapter 7: Operation
- Chapter 8: Troubleshooting

Contacting Cambium Networks

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Purpose

Cambium Networks Point-To-Point (PTP) documents are intended to instruct and assist personnel in the operation, installation and maintenance of the Cambium PTP equipment and ancillary devices. It is recommended that all personnel engaged in such activities be properly trained.

Cambium disclaims all liability whatsoever, implied or express, for any risk of damage, loss or reduction in system performance arising directly or indirectly out of the failure of the customer, or anyone acting on the customer's behalf, to abide by the instructions, system parameters, or recommendations made in this document.

Cross references

References to external publications are shown in italics. Other cross references, emphasized in blue text in electronic versions, are active links to the references.

This document is divided into numbered chapters that are divided into sections. Sections are not numbered, but are individually named at the top of each page, and are listed in the table of contents.

Feedback

We appreciate feedback from the users of our documents. This includes feedback on the structure, content, accuracy, or completeness of our documents. Send feedback to support@cambiumnetworks.com.

Important regulatory information

The PTP 650 product is certified as an unlicensed device in frequency bands where it is not allowed to cause interference to licensed services (called primary users of the bands).

Radar avoidance

In countries where radar systems are the primary band users, the regulators have mandated special requirements to protect these systems from interference caused by unlicensed devices. Unlicensed devices must detect and avoid co-channel operation with radar systems.

The PTP 650 provides detect and avoid functionality for countries and frequency bands requiring protection for radar systems.

Installers and users must meet all local regulatory requirements for radar detection. To meet these requirements, users must install a license key for the correct country during commissioning of the PTP 650. If this is not done, installers and users may be liable to civil and criminal penalties.

Contact the Cambium helpdesk if more guidance is required.

USA and Canada specific information

The USA Federal Communications Commission (FCC) has asked manufacturers to implement special features to prevent interference to weather radar systems that operate in the band 5600 MHz to 5650 MHz. These features must be implemented in all products able to operate outdoors in the band 5470 MHz to 5725 MHz.

Manufacturers must ensure that such radio products cannot be configured to operate outside of FCC rules; specifically it must not be possible to disable or modify the radar protection functions that have been demonstrated to the FCC.

In order to comply with these FCC requirements, Cambium supplies variants of the PTP 650 for operation in the USA or Canada. These variants are only allowed to operate with license keys that comply with FCC/IC rules. In particular, operation of radio channels overlapping the band 5600-5650 MHz is not allowed and these channels are permanently barred.

In addition, other channels may also need to be barred when operating close to weather radar installations.

To ensure compliance with FCC rules (KDB 443999: Interim Plans to Approve UNII Devices Operating in the 5470 - 5725 MHz Band with Radar Detection and DFS Capabilities), follow Avoidance of weather radars (USA only) on page 3-24.

Other variants of the PTP 650 are available for use in the rest of the world, but these variants are not supplied to the USA or Canada except under strict controls, when they are needed for export and deployment outside the USA or Canada.

Renseignements specifiques aux USA et au Canada

La Commission Fédérale des Communications des Etats-Unis (FCC) a demandé aux fabricants de mettre en œuvre des mécanismes spécifiques pour éviter d'interférer avec des systèmes radar fonctionnant dans la bande 5600 MHz à 5650 MHz. Ces mécanismes doivent être mis en œuvre dans tous les produits capables de fonctionner à l'extérieur dans la bande 5470 MHz à 5725 MHz.

Les fabricants doivent s'assurer que les produits de radiocommunications ne peuvent pas être configurés pour fonctionner en dehors des règles de la FCC, en particulier, il ne doit pas être possible de désactiver ou modifier les fonctions de protection des radars qui ont été démontrés de la FCC.

Afin de se conformer à ces exigences de la FCC, Cambium fournit des variantes du PTP 650 exclusivement pour les Etats-Unis ou au Canada. Ces variantes sont autorisés à fonctionner avec des clés de licence qui sont conformes aux règles de la FCC / IC. En particulier, le fonctionnement des canaux de radio qui chevauchent la bande 5600-5650 MHz est interdite et ces canaux sont définitivement exclus.

EU Declaration of Conformity

Hereby, Cambium Networks declares that the Cambium PTP 650 Series Wireless Ethernet Bridge complies with the essential requirements and other relevant provisions of Directive 1999/5/EC. The declaration of conformity may be consulted at:

http://www.cambiumnetworks.com/support/ec-doc

Application firmware

Download the latest PTP 650 Series firmware and install it in the Outdoor Units (ODUs) before deploying the PTP 650 equipment. Instructions for installing firmware are provided in Upgrading software image on page 7-68.

Specific expertise and training for professional installers

To ensure that the PTP 650 is installed and configured in compliance with the requirements of Industry Canada and the FCC, installers must have the radio engineering skills and training described in this section. This is particularly important when installing and configuring a PTP 650 system for operation in the 5.1 GHz and 5.4 GHz UNII bands.

Avoidance of weather radars

The installer must be familiar with the requirements in FCC KDB 443999. Essentially, the installer must be able to:

- Access the FCC data base of weather radar location and channel frequencies.
- Use this information to correctly configure the product (using the GUI) to avoid operation on channels that should be barred according to the guidelines that are contained in the KDB and explained in detail in this user guide.

External antennas

When using a connectorized version of the product (as compared to the version with an integrated antenna), the conducted transmit power may need to be reduced to ensure the regulatory limit on transmitter EIRP is not exceeded. The installer must have an understanding of how to compute the effective antenna gain from the actual antenna gain and the feeder cable losses.

The range of permissible values for maximum antenna gain and feeder cable losses are included in this user guide together with a sample calculation. The product GUI automatically applies the correct conducted power limit to ensure that it is not possible for the installation to exceed the EIRP limit, when the appropriate values for antenna gain and feeder cable losses are entered into the GUI.

Antennas externes

Lorsque vous utilisez une version du produit sans antenne intégrée, il peut être nécessaire de réduire la puissance d'émission pour garantir que la limite réglementaire de puissance isotrope rayonnée équivalente (PIRE) n'est pas dépassée. L'installateur doit avoir une bonne compréhension de la façon de calculer le gain de l'antenne de gain de l'antenne réelle et les pertes dans les câbles de connections.

La plage de valeurs admissibles pour un gain maximal de l'antenne et des pertes de câbles de connections sont inclus dans ce guide d'utilisation avec un exemple de calcul. L'interface utilisateur du produit applique automatiquement la limite de puissance menée correct afin de s'assurer qu'il ne soit pas possible pour l'installation de dépasser la limite PIRE, lorsque les valeurs appropriées pour le gain d'antenne et les pertes de câbles d'alimentation sont entrées dans l'interface utilisateur.

Ethernet networking skills

The installer must have the ability to configure IP addressing on a PC and to set up and control products using a web browser interface.

Lightning protection

To protect outdoor radio installations from the impact of lightning strikes, the installer must be familiar with the normal procedures for site selection, bonding and grounding. Installation guidelines for the PTP 650 can be found in Chapter 2: System hardware and Chapter 5: Installation.

Training

The installer needs to have basic competence in radio and IP network installation. The specific requirements applicable to the PTP 650 should be gained by reading Chapter 5: Installation and Chapter 6: Configuration and alignment and by performing sample set ups at base workshop before live deployments.

Problems and warranty

Reporting problems

If any problems are encountered when installing or operating this equipment, follow this procedure to investigate and report:

1. Search this document and the software release notes of supported releases.
2. Visit the support website.
3. Ask for assistance from the Cambium product supplier.
4. Gather information from affected units, such as any available diagnostic downloads.
5. Escalate the problem by emailing or telephoning support.

Repair and service

If unit failure is suspected, obtain details of the Return Material Authorization (RMA) process from the support website.

Hardware warranty

Cambium's standard hardware warranty is for one (1) year from date of shipment from Cambium Networks or a Cambium distributor. Cambium Networks warrants that hardware will conform to the relevant published specifications and will be free from material defects in material and workmanship under normal use and service. Cambium shall within this time, at its own option, either repair or replace the defective product within thirty (30) days of receipt of the defective product. Repaired or replaced product will be subject to the original warranty period but not less than thirty (30) days.

To register PTP products or activate warranties, visit the support website. For warranty assistance, contact the reseller or distributor.

Caution

Using non-Cambium parts for repair could damage the equipment or void warranty. Contact Cambium for service and repair instructions.

Portions of Cambium equipment may be damaged from exposure to electrostatic discharge. Use precautions to prevent damage.

Security advice

Cambium Networks systems and equipment provide security parameters that can be configured by the operator based on their particular operating environment. Cambium recommends setting and using these parameters following industry recognized security practices. Security aspects to be considered are protecting the confidentiality, integrity, and availability of information and assets. Assets include the ability to communicate, information about the nature of the communications, and information about the parties involved.

In certain instances Cambium makes specific recommendations regarding security practices, however the implementation of these recommendations and final responsibility for the security of the system lies with the operator of the system.

Warnings, cautions, and notes

The following describes how warnings and cautions are used in this document and in all documents of the Cambium Networks document set.

Warnings

Warnings precede instructions that contain potentially hazardous situations. Warnings are used to alert the reader to possible hazards that could cause loss of life or physical injury. A warning has the following format:

Warning

Warning text and consequence for not following the instructions in the warning.

Cautions

Cautions precede instructions and are used when there is a possibility of damage to systems, software, or individual items of equipment within a system. However, this damage presents no danger to personnel. A caution has the following format:

Caution

Caution text and consequence for not following the instructions in the caution.

Notes

A note means that there is a possibility of an undesirable situation or provides additional information to help the reader understand a topic or concept. A note has the following format:

Note

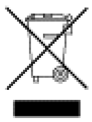
Note text.

Caring for the environment

The following information describes national or regional requirements for the disposal of Cambium Networks supplied equipment and for the approved disposal of surplus packaging.

In EU countries

The following information is provided to enable regulatory compliance with the European Union (EU) directives identified and any amendments made to these directives when using Cambium equipment in EU countries.



Disposal of Cambium equipment

European Union (EU) Directive 2002/96/EC Waste Electrical and Electronic Equipment (WEEE)

Do not dispose of Cambium equipment in landfill sites. For disposal instructions, refer to

http://www.cambiumnetworks.com/support/weee-compliance

Disposal of surplus packaging

Do not dispose of surplus packaging in landfill sites. In the EU, it is the individual recipient's responsibility to ensure that packaging materials are collected and recycled according to the requirements of EU environmental law.

In non-EU countries

In non-EU countries, dispose of Cambium equipment and all surplus packaging in accordance with national and regional regulations.

Chapter 1: Product description

This chapter provides a high level description of products in the PTP 650 series. It describes in general terms the function of the product, the main product variants and the main hardware components. The following topics are described in this chapter:

- Overview of the PTP 650 Series on page 1-2 introduces the key features, typical uses, product variants and components of the PTP 650 series.
- Wireless operation on page 1-6 describes how the PTP 650 wireless link is operated, including modulation modes, power control and spectrum management.
- Ethernet bridging on page 1-21 describes how the PTP 650 controls Ethernet data, in both the customer data and system management networks.
- TDM bridging on page 1-35 describes how TDM traffic (E1 or T1) may be carried over PTP 650 links.
- System management on page 1-38 introduces the PTP 650 management system, including the web interface, installation, configuration, security, alerts and upgrades.

Overview of the PTP 650 Series

This section introduces the key features, typical uses, product variants and components of the PTP 650 series.

Purpose

Cambium PTP 650 Series Bridge products are designed for Ethernet bridging over point-to-point microwave links in unlicensed and lightly-licensed frequency bands between 4.9 GHz and 6.0 GHz. Users must ensure that the PTP 650 Series complies with local operating regulations.

The PTP 650 Series acts as a transparent bridge between two segments of the operator's network. In this sense, it can be treated as a virtual wired connection between two points. The PTP 650 Series forwards 802.3 Ethernet frames destined for the other part of the network and filters frames it does not need to forward. The system is transparent to higher-level protocols such as VLANs and Spanning Tree.

Key features

The PTP 650 is a high performance wireless bridge for Ethernet traffic with a maximum throughput of 450 Mbps. It is capable of operating in line-of-sight (LOS), near-LOS and non-LOS propagation condition. Its maximum LOS range is 200 km. The PTP 650 operates in unlicensed and lightly-licensed frequency bands between 4.9 and 6.0 GHz. It has a very high spectral efficiency of 10 bps/Hz and supports a channel bandwidth of up to 45 MHz. The PTP 650 Integrated ODU has its own flat plate antenna with antenna gain 23 dBi. The PTP 650S and PTP 650L Integrated ODUs have their own flat plate antenna with 19 dBi antenna gain. The PTP 650 Connectorized ODU is designed for use with an external antenna.

The wireless link is TDD based and supports both symmetric and asymmetric TDD configurations.

From an Ethernet point-of-view, the PTP 650 wireless link is a transparent Layer 2 bridge. It supports up to three Gigabit Ethernet ports. Two ports support twisted pair Gigabit Ethernet. One of them is capable of providing power via standard 802.3at PoE to an external device such as a video surveillance camera or a wireless access point. The third port accepts either a twisted pair or fibre GE SFP module.

The PTP 650 Series supports an optional TDM adaptor that allows E1 or T1 telecoms circuits to be bridged over the wireless link.

The PTP 650 Series has extensive quality of service (QoS) classification capability and supports up to eight levels of queues. Management of the unit may be via the same interface as the bridged traffic (in-band management) or on a separate port (out-of-band local or remote management).

PTP 650 and PTP 650S support both synchronous Ethernet and operation as an IEEE 1588-2008 transparent clock.

Table 1 gives a summary of the main PTP 650 characteristics.

Table 1 Main characteristics of the PTP 650 Series

Characteristic	Value
Topology	PTP
Wireless link condition	LOS, near LOS or non-LOS
Range	Up to 200 km
Duplexing	TDD (symmetric and asymmetric)
Connectivity	Ethernet
Synchronous Ethernet	ITU-T G.8262/Y.1362 EEC-Option 1 and EEC-Option 2
Transparent clock	IEEE 1588-2008 compliant
Operating frequencies	4.9 to 6.0 GHz
Channel bandwidth	5, 10, 15, 20, 30, 40 or 45 MHz
High spectral efficiency	Up to 10 bps/Hz
Data rate	Up to 450 Mbps (45 MHz channel BW)
Telecommunications (TDM)	Up to eight E1 or T1 circuits (NIDU required)

Frequency bands

The PTP 650 ODU can be configured by the user to operate in the following bands:

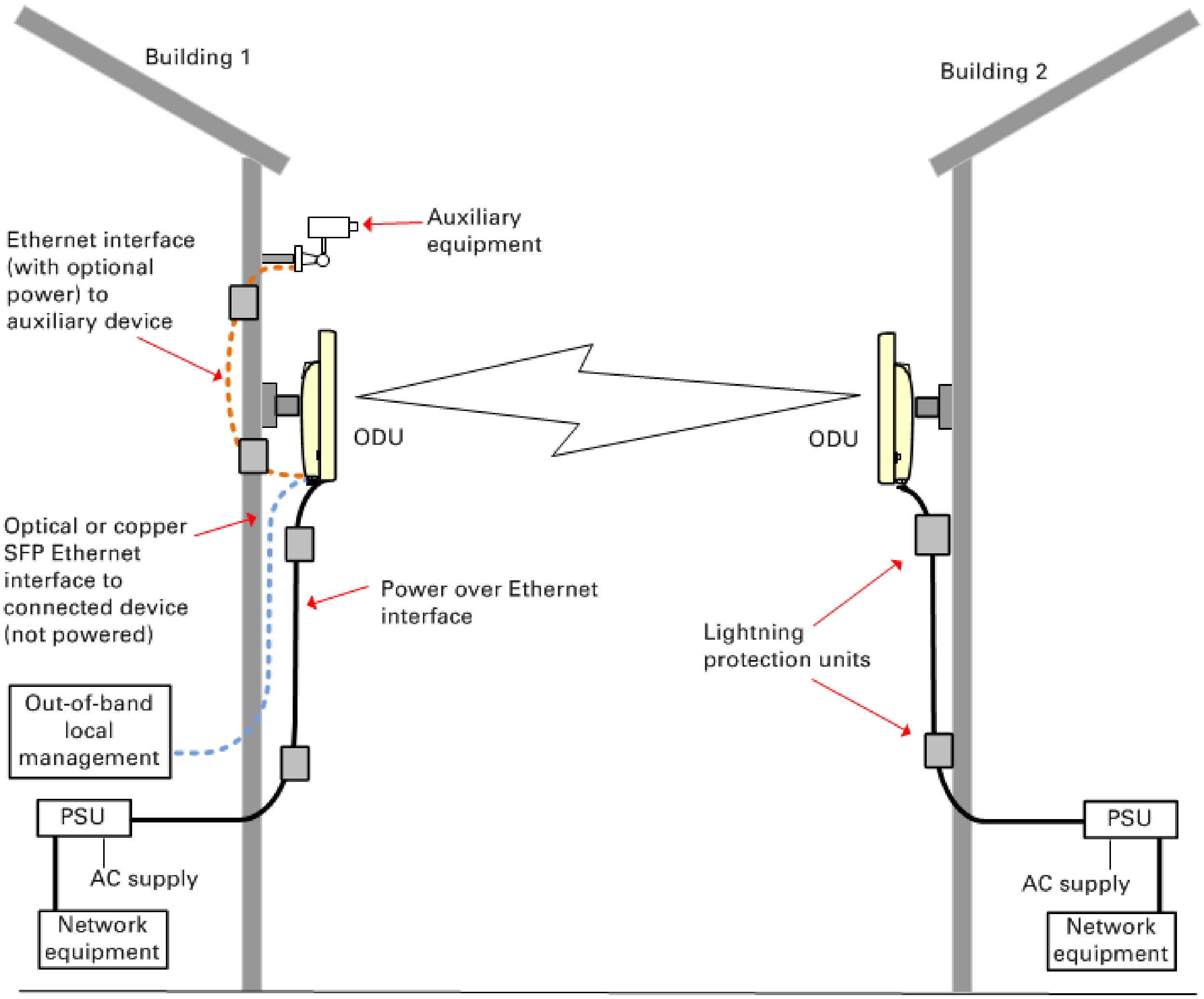
- 4.9 GHz band: 4940 to 4990 MHz
- 5.1 GHz band: 5150 to 5250 MHz
- 5.2 GHz band: 5250 to 5350 MHz
- 5.4 GHz band: 5470 to 5725 MHz
- 5.8 GHz band: 5725 to 5875 MHz

Typical bridge deployment

The PTP 650 is an "all outdoor" solution consisting of a wireless bridge between two sites. Each site installation consists of a PTP 650 Integrated, PTP 650S Integrated, PTP 650L Integrated or PTP 650 Connectorized outdoor unit (ODU) and a power injector (PSU) (Figure 1). The ODU provides the following interfaces:

- PSU port: This provides proprietary power over Ethernet and connection to the management and/or data networks via 100BASE-TX or 1000BASE-T Ethernet. In the basic configuration, this is the only Ethernet connection to the ODU.
- SFP port: This provides an optical or copper Gigabit Ethernet interface for customer data and/or network management.
- Aux port: This provides an optional power and 100BASE-TX or 1000BASE-T Ethernet connection to an IEEE803.2at device such as a video camera or wireless access point.

Figure 1 PTP 650 typical bridge deployment



Hardware overview

The main hardware components of the PTP 650 are as follows:

- Outdoor unit (ODU): The ODU is a self-contained transceiver unit that houses both radio and networking electronics. The PTP 650 ODU is supplied in four configurations:
  - A PTP 650 Integrated ODU attached to a 23 dBi flat plate antenna
  - A PTP 650S Integrated ODU attached to a 19 dBi flat plate antenna
  - A PTP 650L Integrated ODU attached to a 19 dBi flat plate antenna
  - A PTP 650 Connectorized ODU intended to work with separately mounted external antennas.
- The ODU is supplied in the following regional variants:
  - FCC, intended for deployment in the USA and Canada
  - EU, intended for deployment in countries of the European Union or other countries following ETSI regulations
  - Rest of the World (RoW), intended for deployment in countries other than USA and EU countries.
- Power supply unit (PSU): There is a choice of two PSUs:
  - The AC Power Injector is suitable for installations without an auxiliary device.
  - The AC+DC power injector is required when powering from a DC supply or when the PSU is needed to operate at extreme temperatures.
- Antennas and antenna cabling: Connectorized ODUs require external antennas connected using RF cable.
- PTP SYNC unit (optional): One PTP SYNC unit is needed for each link in a network with TDD synchronization. PTP-SYNC must be used with the AC + DC Enhanced Power Injector.
- Network Indoor Unit (NIDU) (optional): The NIDU allows up to eight TDM channels (E1 or T1) to be bridged over a PTP 650 link.
- Ethernet cabling: All configurations require a copper Ethernet Cat5e connection from the ODU (PSU port) to the PSU. Advanced configurations may also require one or both of the following:
  - A copper or optical Ethernet connection from the ODU (SFP port) to network terminating equipment or another device.
  - A copper Ethernet Cat5e connection from the ODU (Aux port) to an auxiliary device.
- Lightning protection unit (LPU): LPUs are installed in the PSU and Aux copper drop cables to provide transient voltage surge suppression.
- Ground cables: ODU, LPUs and outdoor copper Ethernet cables are bonded to the site grounding system using ground cables.

For more information about these components, including interfaces, specifications and Cambium part numbers, refer to Chapter 2: System hardware.

Wireless operation

This section describes how the PTP 650 wireless link is operated, including modulation modes, power control and security.

Time division duplexing

TDD cycle

PTP 650 links operate using Time Division Duplexing (TDD). They use a TDD cycle in which the ODUs alternately transmit and receive TDD bursts. The TDD cycle is illustrated in Figure 2. The steps in the cycle are as follows:

1. The TDD master transmits a burst to the TDD slave.
2. A delay occurs as the master-slave burst propagates over the link.
3. The slave receives the burst from the master.
4. The slave processes the master-slave burst.
5. The slave transmits a burst to the master.
6. A delay occurs as the slave-master burst propagates over the link.
7. The master receives the burst from the slave.
8. The master transmits the next burst to the slave.

The frame duration must be long enough to allow the master to receive the complete burst in 7 before starting to transmit in 8.

TDD frame parameters

The TDD burst duration varies depending on the following:

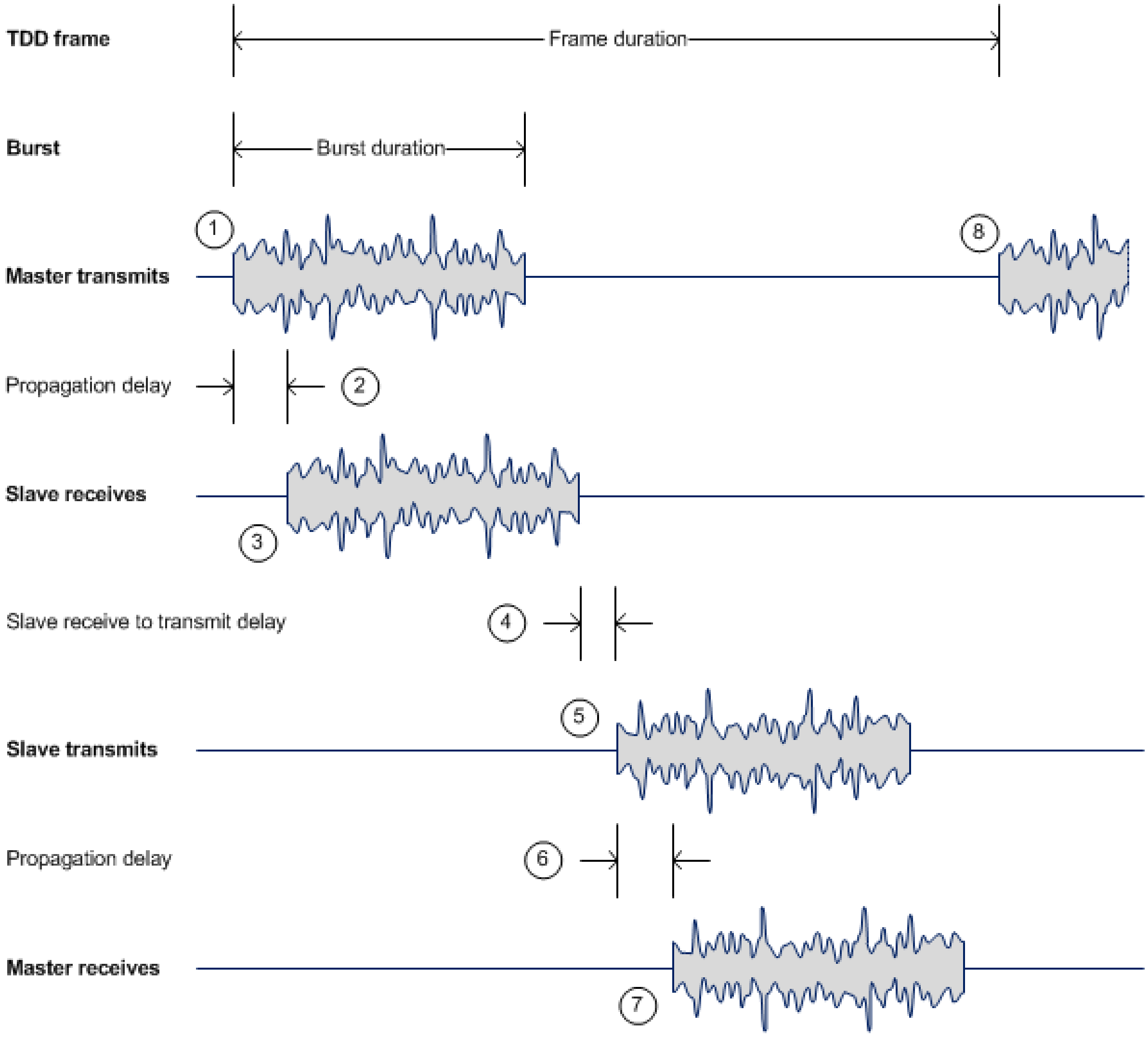
- Channel bandwidth
- Link range
- Link optimization mode
- Link symmetry
- Offered traffic loading.

The TDD frame duration varies depending on the following:

- TDD burst duration master-slave.
- TDD burst duration slave-master.
- Link range.

The propagation delay in Step 2 is necessarily equal to the propagation delay in Step 6, and is determined solely by the link range. There may be added delays between rx and tx on the master and slave to minimize interference, as set up by the link planner or installer.

Figure 2 TDD cycle



Channel selection

The PTP 650 series links are capable of transmitting and receiving on the same channel or on different channels. In other words, the slave-master direction may use a different channel from the master-slave direction. Independent selection of transmit and receive frequencies can be useful in planned networks or for countering interference.

When links operate in radar avoidance regions, each unit monitors its transmit channel for the presence of radar signals. Therefore, the transmit and receive channels are always identical.

Further reading

For information about...	Refer to...
TDD synchronization in PTP networks	TDD synchronization on page 1-19

Link mode optimization

Link mode optimization allows the PTP 650 link to be optimized according to the type of traffic that will be bridged. The link supports two modes, IP Traffic and TDM Traffic.

IP traffic

IP Traffic mode is optimized to provide the maximum possible link capacity. IP Traffic mode is an appropriate choice where applications in the bridged networks provide some measure of reliable transmission, and where very low latency is not critical. IP mode supports both fixed and adaptive link symmetry.

TDM traffic

TDM Traffic mode is optimized to provide the lowest possible latency. TDM Traffic mode additionally implements a more conservative approach to adaptive modulation, leading to lower error rates in fading channels at the expense of slightly lower link capacity. TDM Traffic mode is an appropriate choice for delay intolerant data without reliable transmission (for example voice over IP data). TDM Traffic mode is selected automatically when TDM interfaces are enabled.

Further reading

For information about...	Refer to...
Effect of IP and TDM modes on link symmetry	Link symmetry on page 1-9
Effect of IP and TDM modes on link data throughput capacity	Calculating data rate capacity on page 3-27 Data throughput capacity tables on page 3-70
Effect of IP and TDM modes on system threshold, output power and link loss	System threshold, output power and link loss on page 3-59
How to configure link mode optimization	Wireless Configuration page on page 6-21
Link mode optimization alarms	Alarms on page 7-18

Link symmetry

The PTP 650 series provides eight configuration options for apportioning the available capacity between the two link directions.

- **Symmetric –** The Master and Slave have equal capacity. The PTP 650 series achieves this by allocating an equal Burst Duration for the Master and the Slave.
- **5:1 –** The capacity in the direction Master to Slave is five times that of the direction Slave to Master. The PTP 650 series achieves this by setting the Burst Duration of the Master to five times that of the Slave
- **3:1 –** The capacity in the direction Master to Slave is three times that of the direction Slave to Master. The PTP 650 series achieves this by setting the Burst Duration of the Master to three times that of the Slave.
- **2:1 –** The capacity in the direction Master to Slave is twice that of the direction Slave to Master. The PTP 650 series achieves this by setting the Burst Duration of the Master to twice that of the Slave.
- **1:2 –** The capacity in the direction Slave to Master is twice that of the direction Master to Slave. The PTP 650 series achieves this by setting the Burst Duration of the Slave to twice that of the Master.
- **1:3 –** The capacity in the direction Slave to Master is three times that of the direction Master to Slave. The PTP 650 series achieves this by setting the Burst Duration of the Slave to three times that of the Master.
- **1:5 –** The capacity in the direction Slave to Master is five times that of the direction Master to Slave. The PTP 650 series achieves this by setting the Burst Duration of the Slave to five times that of the Master.
- **Adaptive –** This is only available on the Full license. The capacity allocated to a given link direction is dependent on the offered level of network traffic in both link directions. If the level of offered traffic in both directions is equally high or equally low, the PTP 650 will allocate equal capacity to both directions. If however the offered level of traffic is greater in one direction, it is allocated a greater proportion of the overall link capacity. The PTP 650 series achieves this by increasing (or decreasing) the duration of the Transmit Burst in a given link direction as the offered level of network traffic increases (or decreases) in this same direction. This is done independently for the two directions.

Note

The 5:1, 3:1, 2:1, 1:2, 1:3 and 1:5 modes are not available when TDD synchronization is enabled, or when TDM services are enabled.

Note

Adaptive mode is not available in the following configurations:

- When link mode optimization is set to TDM Traffic (see Link mode optimization on page 1-8).
- When TDD synchronization is enabled.

- In regions where radar avoidance is operational (see Radar avoidance on page 1-15).
- When the ODU is not on a Full license.

Further reading

For information about...	Refer to...
Link symmetry in synchronized networks	TDD synchronization on page 1-19
Effect of link symmetry on link data throughput capacity	Calculating data rate capacity on page 3-27 Data throughput capacity tables on page 3-70
How to configure link symmetry	Wireless Configuration page on page 6-21

Licensed maximum link range (PTP 650S)

The PTP 650S Integrated product variant operates at Full capacity in wireless links with range up to 2.0 km (1.2 miles), reverting to Lite capacity for links with range between 2.0 km and the absolute maximum range 200 km (124 miles). PTP 650S can be operated at Full capacity at any range by purchasing and applying the PTP 650S Upgrade Limited Range to Full Range Software License.

Further reading

For information about...	Refer to...
Link range capability upgrade	Capability upgrades on page 1-53
Effect of link range on data throughput capacity	Calculating data rate capacity on page 3-27 Data throughput capacity tables on page 3-70
How to generate a license key for maximum link range	Generating license keys on page 6-3
How to configure link ranging	Wireless Configuration page on page 6-21
Automatic detection of link range	ODU installation tones on page 6-109

OFDM and channel bandwidth

The PTP 650 series transmits using Orthogonal Frequency Division Multiplexing (OFDM). This wideband signal consists of many equally spaced sub-carriers. Although each sub carrier is modulated at a low rate using conventional modulation schemes, the resultant data rate from the sub-carriers is high. OFDM works exceptionally over a Non-Line-of-Sight (NLoS) channel.

The channel bandwidth of the OFDM signal is configurable to one of the following values: 5, 10, 15, 20, 30, 40 and 45 MHz. Higher bandwidths provide greater link capacity at the expense of using more bandwidth. Systems configured for a narrower channel bandwidth provide better receiver sensitivity and can also be an appropriate choice in deployments where the amount of free spectrum is limited.

Each channel is offset in center frequency from its neighboring channel by 10 or 5 MHz.

Note

The Channel Bandwidth must be configured to the same value at both ends of the link. Not all channel bandwidths are available in all regulatory bands.

Further reading

For information about...	Refer to...
Channel bandwidths per frequency band	General wireless specifications on page 3-21
How to plan for channel bandwidth	Channel bandwidth on page 3-23
Effect of channel bandwidth on link data throughput capacity	Calculating data rate capacity on page 3-27 Data throughput capacity tables on page 3-70
How to generate a license key for greater bandwidth	Generating license keys on page 6-3
How to configure channel bandwidth	Wireless Configuration page on page 6-21
How to monitor channel bandwidth	Spectrum Management on page 7-27

Spectrum management

The spectrum management feature of the PTP 650 Series monitors the available wireless spectrum and directs both ends of the wireless link to operate on a channel with a minimum level of co-channel and adjacent channel interference.

Spectrum management measurements

The PTP 650 Series performs two mean signal measurements per TDD cycle, per channel. This mean measurement represents the mean received signal power for the 40 microsecond measurement period.

The Spectrum Management algorithm collects measurements equally from all channels in the operating band. This process is called the Channel Availability Check (CAC). The CAC uses a round-robin channel selection process to collect an equal amount of measurements from each channel. The CAC measurement process is not altered by the channel barring process. Measurements are still collected for all channels irrespective of the number of barred channels.

Measurement analysis

Spectrum Management uses statistical analysis to process the received peak and mean measurement. The statistical analysis is based on a fixed, one minute, measurement quantization period. Spectrum Management collects data for the specified quantization period and only at the end of the period is the statistical analysis performed.

Statistical summary

The display of statistical measurement on the spectrum management page always shows a statistical summary of all channel measurement. The statistical summary is controlled by the Statistics Window attribute. This attribute defaults to a value of twenty minutes, which means that the mean and percentile values displayed for each channel are calculated over the 20 minute period. All channel decisions are made using the values computed over the statistics window period.

Spectrum management in fixed frequency mode

The transmit and receive frequencies can be fixed in a PTP 650 wireless link. Once fixed frequency mode is configured, the spectrum management software will not attempt to move the wireless link to a channel with lower co-channel and adjacent-channel interference. Therefore this mode of operation is only recommended for deployments where the installer has a good understanding of the prevailing interference environment. Care must also be taken to ensure that the frequency allocations at each end of the link are compatible.

Fixed frequency mode is not available in regions where radar detection is required by the regulations.

Further reading

For information about...	Refer to...
How to perform spectrum management	Spectrum Management on page 7-27

Adaptive modulation

The PTP 650 series can transport data over the wireless link using a number of different modulation modes ranging from 256QAM 0.81 to BPSK 0.63. For a given channel bandwidth and TDD frame structure, each modulation mode transports data at a fixed rate. Also, the receiver requires a minimum signal to noise ratio in order to successfully demodulate a given modulation mode. Although the more complex modulations such as 256QAM 0.81 will transport data at a much higher rate than the less complex modulation modes, the receiver requires a much higher signal to noise ratio.

The PTP 650 series provides an adaptive modulation scheme where the receiver constantly monitors the quality of the received signal and notifies the far end of the link of the optimum modulation mode with which to transmit. In this way, optimum capacity is achieved at all times. This is one of a number of features which allows the PTP 650 to operate in challenging non-line of sight radio channels.

Note

LINKPlanner includes an estimate of mean data rate, the data rate provided by each modulation and the percentage of time spent in each modulation mode.

Further reading

For information about...	Refer to...
Lowest data modulation mode	Lowest Data Modulation Mode on page 1-25
Lowest TDM modulation mode	Lowest TDM modulation mode on page 1-36
Planning for adaptive modulation	Adaptive modulation on page 3-26
Effect of modulation mode on link data throughput capacity	Calculating data rate capacity on page 3-27 Data throughput capacity tables on page 3-70
Effect of modulation mode on system threshold, output power and link loss	System threshold, output power and link loss on page 3-59
How to configure modulation modes	Interface Configuration page on page 6-14 Wireless Configuration page on page 6-21 System Configuration page on page 6-30
Modulation mode when the ODU is armed	Checking that the units are armed on page 6-106
How to view the transmit and receive modulation modes	System Status page on page 7-3 System counters on page 7-52

MIMO

Multiple-Input Multiple-Output (MIMO) techniques provide protection against fading and increase the probability that the receiver will decode a usable signal. When the effects of MIMO are combined with those of OFDM techniques and a high link budget, there is a high probability of a robust connection over a non-line-of-sight path.

The PTP 650 transmits two signals on the same radio frequency, one of which is vertically polarized and the other horizontally polarized. Depending on the channel conditions, the PTP 650 will adapt between two modes of operation:

- **Dual Payload**: When the radio channel conditions allow, the PTP 650 will transmit two different and parallel data streams, one on the vertical channel and one on the horizontal channel. This doubles the capacity of the PTP 650.
- **Single Payload**: As the radio channel becomes more challenging, the PTP 650 has the ability to detect this and switch to a mode which transmits the same data stream on both vertical and horizontal channels. This provides polar diversity and is another key feature which allows the PTP 650 to operate in challenging non- line of sight radio channels.

Lower order modulations (BPSK 0.63 up to QPSK 0.87) only operate in single payload mode. Higher order modulations (16QAM 0.63 to 256QAM 0.81) are available in single payload mode and dual payload mode. The switching between modes is automatically controlled by the adaptive modulation feature described in Adaptive modulation on page 1-13.

Note

The system automatically chooses between dual and single payload to try to increase the capacity of a link. However the user can disable the dual payload mode, forcing the more robust option of single payload.

Further reading

For information about...	Refer to...
How to configure dual or single payload	Wireless Configuration page on page 6-21
Single and dual payload modulation modes	System threshold, output power and link loss on page 3-59
TDM single payload lock feature	TDM on page 7-14

Dynamic spectrum optimization

The PTP 650 series uses an interference mitigation technique known as Dynamic Spectrum Optimization (DSO). Both the Master and Slave continually monitor for interference on all channels and then select the best frequency of operation. This is a dynamic process where the PTP 650 can continually move channels in response to changes in interference. Two modes of operation are available:

- First mode: the two link directions are forced to select the same frequency, determined by the Master.
- Second mode: the frequency of operation can be determined independently for each direction. This mode is not permitted in radar regions.

Further reading

For information about...	Refer to...
Using DSO in PTP networks	Using Dynamic Spectrum Optimization on page 1-18
Planning to use DSO	Frequency selection on page 3-23
How to configure DSO	Wireless Configuration page on page 6-21
Asymmetric DSO in non-radar regions	Spectrum Management Settings on page 7-35

Radar avoidance

In regions where protection of radars is part of the local regulations, the PTP 650 must detect interference from radar-like systems and avoid co-channel operation with these systems.

To meet this requirement, the PTP 650 implements the following features:

- The radar detection algorithm will always scan a usable channel for 60 seconds for radar interference before making the channel an available channel.
- This compulsory channel scan will mean that there is at least 60 seconds service outage every time radar is detected and that the installation time is extended by at least 60 seconds even if no radar is found.
- When operating on a channel, the spectrum management algorithm implements a radar detection function which looks for impulsive interference on the operating channel. If impulsive interference is detected, spectrum management will mark the current operating channel as having detected radar (unavailable channel) and initiate a channel hop to an available channel. The previous operating channel will remain in the unavailable state for thirty minutes after the impulsive interference pulse was detected.
- After the thirty minutes have expired the channel will be returned to the usable channel pool.

There is a secondary requirement for bands requiring radar avoidance. Regulators have mandated that products provide a uniform loading of the spectrum across all devices. In general, this prevents operation with fixed frequency allocations. However:

- ETSI regulations do allow frequency planning of networks (as that has the same effect of spreading the load across the spectrum).
- The FCC does allow channels to be barred if there is actually interference on them.

Fixed frequency allocation is not recommended in radar avoidance regions, as any radar detection would cause a system outage of at least 30 minutes.

Further reading

For information about...	Refer to...
Radar avoidance in the country of operation	License keys and regulatory bands on page 1-17
Planning for mandatory radar detection	Frequency selection on page 3-23
Radar avoidance when aligning antennas	ODU installation tones on page 6-109
Effect of radar detection on spectrum management	Spectrum Expert page in radar avoidance mode on page 7-41

Encryption

The PTP 650 supports optional encryption for data transmitted over the wireless link. The encryption algorithm used is the Advanced Encryption Standard (AES) with 128-bit and 256-bit key size. AES is a symmetric encryption algorithm approved by U.S. Government organizations (and others) to protect sensitive information. The AES implementation in PTP 650 is approved to FIPS-197. Encryption is enabled through the purchase of an upgrade.

Further reading

For information about...	Refer to...
AES requirement for HTTPS/TLS	Transport layer security on page 1-43
AES requirement for SNMPv3 security	User-based security model on page 1-47
Licensing AES encryption	AES license on page 1-50 Capability upgrades on page 1-53
Planning to use AES for HTTPS/TLS	Planning for HTTPS/TLS operation on page 3-51
How to generate AES license keys	Generating license keys on page 6-3
How to configure AES encryption	System Configuration page on page 6-30
How to configure AES encryption for HTTPS/TLS operation	Security menu on page 6-94

License keys and regulatory bands

The PTP 650 license key specifies the country of operation for the ODU, and lists the regulatory bands that are licensed by regulators in that country. If a license key provides access to more than one regulatory band, PTP 650 provides a choice between the available bands. In each regulatory band, PTP 650 sets the following aspects of wireless operation to comply with the applicable regulations:

- Maximum transmit power
- Radar avoidance
- Transmit power reduction in edge channels
- Frequency range
- Channel plan

The country of operation (and thus the supported regulatory bands) can be changed by generating a new license key at the License Key Generator page of the Cambium web-site, and entering the new license key using the Installation Wizard.

Caution

To avoid possible enforcement action by the country regulator, always operate links in accordance with local regulations.

Attention

Pour éviter une éventuelle sanction par le régulateur du pays, utiliser toujours nos liaisons radiofréquences conformément à la réglementation locale.

Further reading

For information about…	Refer to…
Planning PTP 650 links to conform to the regulatory band restrictions	Radio spectrum planning on page 3-21
Radio regulations in the country of operation	Compliance with radio regulations on page 4-27
How to generate a license key for the country of operation	Generating license keys on page 6-3
How to configure the regulatory band	Wireless Configuration page on page 6-21
How to view the regulatory band	System Status page on page 7-3
Regulatory band alarms	Alarms on page 7-18

PTP networks

Using Dynamic Spectrum Optimization

The Dynamic Spectrum Optimization (DSO) feature allows a PTP 650 unit to select wireless channels for a lower level of radio frequency (RF) interference. This approach is appropriate where the network consists of a small number of PTP links, or where the RF interference is predominantly from equipment belonging to other operators.

Using frequency planning

Networks will benefit from the use of fixed channel allocations if (a) the network consists of multiple PTP links, and (b) RF interference predominantly arises from equipment in the same network.

Frequency planning is the exercise of assigning operating channels to PTP units so as to minimize RF interference between links. Frequency planning must consider interference from any PTP unit to any other PTP unit in the network. Low levels of interference normally allow for stable operation and high link capacity.

The frequency planning task is made more straightforward by use of the following techniques:

- Using several different channels
- Separating units located on the same mast
- Using high performance (directional) external antennas

Synchronized networks

TDD synchronization can be used to relax constraints on the frequency planning of PTP networks. Synchronization has the following benefits:

- Allows tighter frequency re-use, and thus wider channel bandwidth.
- Allows more convenient collocation of units on a single mast.
- Allows use of smaller or lower performance antennas.
- Reduces inference, resulting in use of more efficient modulation modes.

In a correctly designed synchronised network, all links are configured with the same TDD frame duration, and the TDD frame contains guard periods longer than the propagation delay between the most distant interfering units.

Each synchronized unit is assigned to one of two phases. A master ODU can be assigned to either phase. A slave ODU must be assigned to a different phase from the associated master ODU. The phase is set by suitable configuration of TDD Frame Offset.

TDD synchronization eliminates RF interference between units in the same phase. This means that frequency planning in a synchronized network is concerned only with interference between units in different phases. Frequency planning is still necessary, but the number of potential interference paths to be considered is halved. Frequency planning in a synchronized TDD network has approximately the same level of complexity as frequency planning in a Frequency Division Duplex (FDD) network.

Further reading

For information about…	Refer to…
How to plan networks	Chapter 3: System planning, or contact your Cambium distributor or re-seller.

TDD synchronization (PTP-SYNC)

Additional hardware is needed to synchronize PTP 650 links. One PTP-SYNC unit is required for each master ODU. The PTP-SYNC unit is connected in line in the drop cable between the PSU and the ODU, and is collocated with the PSU.

Caution

The PTP-SYNC is compatible only with the AC + DC Power Injector.

The AC Power Injector will not work with a PTP-SYNC, and it is likely that a fuse will be blown in the PTP-SYNC if this is attempted.

Timing references for use with PTP-SYNC

PTP-SYNC requires an external timing reference in all but the simplest networks. Up to ten PTP-SYNCs can be connected in a chain to share the timing signal from one timing reference. In the majority of applications, one reference is required for each site that contains PTP 650 master ODUs.

The timing reference can be from any timing system that provides a 1 Hz signal, accurately synchronized in frequency and phase with a network-wide master timing reference. GPS timing receivers are a very practical way of obtaining a suitable reference. The PTP-SYNC is compatible with the Trimble Acutime™ GG and Trimble Acutime™ Gold GPS receivers.

In simple networks where all master ODUs are at a single site, the external reference can be omitted. In this case, one ODU acts as a reference for other collocated units.

Configuring the TDD frame

In synchronized operation, frame duration and burst duration must be configured directly in the web-based management interface. Frame duration must be identical across all links in a synchronized network.

The PTP Link Planner provides a capability for computing suitable frame parameters in a synchronized network. Please refer to the *Link Planner User Guide* for guidance on configuring TDD synchronization.

Link symmetry is always 1:1 in synchronized networks.

Link capacity in synchronized networks

The TDD frame duration is extended in synchronized networks to allow for the propagation delay of the longest link in the network and to incorporate additional guard periods. These guard periods protect against delayed interference from distant units in the same network.

The longer frame duration results in slightly lower link capacity than for an equivalent non-synchronized link with the same channel bandwidth and modulation mode. However, TDD synchronization also reduces interference, and this may allow operation in higher modulation modes. The benefit of operating in a higher modulation mode normally outweighs the penalty of the slightly longer TDD frame.

Further reading

For information about...	Refer to...
The PTP-SYNC unit	PTP-SYNC unit on page 2-48
The GPS receiver	GPS receiver on page 2-54
Typical deployment diagrams for GPS	GPS receiver interfaces on page 3-9
Choosing a site for the PTP-SYNC unit	PTP-SYNC location on page 3-15
Choosing a site for the GPS receiver	GPS receiver location on page 3-16
Use of LINKPlanner for TDD synchronization	LINKPlanner for synchronized networks on page 3-26
TDD synchronization methods that may be implemented using PTP-SYNC	Configuration options for TDD synchronization on page 3-31
How to install a PTP-SYNC unit	Installing a PTP-SYNC unit on page 5-28
How to install an optional GPS receiver	Installing a GPS receiver on page 5-32
How to enable TDD synchronization	Wireless Configuration page on page 6-21
How to configure TDD synchronization	TDD synchronization page (optional) on page 6-27
How to view TDD synchronization status	System Status page on page 7-3
TDD synchronization alarms	Alarms on page 7-18
How to test a PTP-SYNC installation when a fault is suspected	Testing PTP-SYNC on page 8-15

Ethernet bridging

This section describes how the PTP 650 processes Ethernet data, and how Ethernet ports are allocated to the Data Service, Second Data Service, Management Service and Local Management Service..

Ethernet ports

The PTP 650 Series ODU has three Ethernet ports:

- **Main PSU**: The Main PSU port provides a copper Ethernet interface for 100BASE-TX and 1000BASE-T, and accepts power from the AC+DC Enhanced Power Injector or the AC Power Injector to the ODU using a proprietary power over Ethernet (PoE) method.
- **Aux:** The Aux port provides a copper Ethernet interface for 100BASE-TX and 1000BASE-T, and supplies power from the ODU to external equipment using standards-based power over Ethernet (PoE) complying with IEEE 802.3at.
- **SFP:** The SFP port is a small format pluggable receptacle accepting copper or optical plug-in modules supplied as part of the SFP module kit.

Note

The PTP 650 provides flexible interconnection of customer data and network management using several Ethernet ports, but it does not contain a general-purpose Ethernet switch, and it is not possible to forward traffic between the Ethernet ports of the same ODU.

Data and management services

The PTP 650 Series ODU supports four different types of virtual circuits providing data and management services.

Data Service

This point-to-point transparent service carries customer's data between one of the Ethernet ports at the local ODU and one of the Ethernet ports at an associated remote ODU. Every link is configured with exactly one instance of the Data Service.

The Data Service provides comprehensive Quality of Service classification with up to eight queues.

Second Data Service

This optional point-to-point transparent service offers a second virtual circuit for customer's data between one of the Ethernet ports at the local ODU and one of the Ethernet ports at an associated remote ODU. The Data Service and Second Data Service are always mapped to different ports at an ODU. The Data traffic of the two services are distinct and are separately bridged to the appropriate configured remote ODU port.

The Second Data Service is available only with a Full capacity license.

The Second Data Service provides a single class of service, which can be configured to match any of the eight classes of the Data Service.

Management Service

PTP 650 provides options for In-Band and Out-of-Band network management.

The In-Band Management Service connects management systems at both ends of the link with the embedded management agents in the ODUs, accessed using the Ethernet ports selected to the Data Service or the Second Data Service.

The Out-of-Band Management Service connects management systems at both ends of the link with the embedded management agents in the ODUs, accessed using dedicated Ethernet ports.

Note

Out-of-Band Management is not available when the optional Second Data Service is enabled.

The Out-of-Band Management Service provides a single class of service, which can be configured to match any of the eight classes of the Data Service.

Note

The PTP 650 provides flexible interconnection of customer data and network management using several Ethernet ports, but it does not contain a general-purpose Ethernet switch, and it is not possible to forward traffic between the Ethernet ports of the same ODU.

Local Management Service

PTP 650 provides option for local network management.

The Local Management network is isolated from the customer data network. Management frames are not forwarded over the wireless link. The management agents can access only through the OOB Local ports at the respective ODUs.

Further reading

For information about…	Refer to…
A more detailed description of the Data Service	Data Service on page 1-21
A more detailed description of the Second Data Service	Second Data Service on page 1-22
A more detailed description of the Out-of-Band Management Service	Management Service on page 1-22
SFP optical or copper module kits	SFP module kits on page 2-45
The PSU, AUX and SFP ports of the ODU	ODU interfaces on page 2-13
Diagrams showing Ethernet connections	Typical deployment on page 3-2
How to plan the use of Ethernet ports for customer and management traffic	Ethernet interfaces on page 3-35
How to install the Ethernet interfaces to the ODU	Installing the copper Cat5e Ethernet interface on page 5-18 Installing an SFP Ethernet interface on page 5-28 Installing an Aux Ethernet interface on page 5-57
How to configure the ODU Ethernet ports	Interface Configuration page on page 6-14 LAN Configuration page on page 6-34
Ethernet port status attributes	Ethernet / Internet on page 7-6
Ethernet port alarms	Alarms on page 7-18

Data network

Transparent Ethernet service

The PTP 650 Series provides an Ethernet service between one of the Ethernet ports at a local ODU and one of the Ethernet ports at an associated remote ODU. The Ethernet service is based on conventional layer two transparent bridging, and is equivalent to the Ethernet Private Line (EPL) service defined by the Metro Ethernet Forum (MEF).

The service is transparent to untagged frames, standard VLAN frames, priority-tagged frames, provider bridged frames, Q-in-Q frames and provider backbone bridged frames. In each case, the service preserves MAC addresses, VLAN ID, Ethernet priority and Ethernet payload in the forwarded frame. The maximum frame size for bridged frames in the customer network is 9600 bytes.

There is no requirement for the customer data network to be connected to the same Ethernet port at both ends of a wireless link. For example, it is possible to connect the Main PSU port to the customer data network at one end of the link and to connect the Aux port to the customer data network at the other end of the link.

Layer two control protocols

The Data Service in the PTP 650 Series is transparent to layer two control protocols (L2CP) including:

- Spanning tree protocol (STP), rapid spanning tree protocol (RSTP)
- Multiple spanning tree protocol (MSTP)
- Link aggregation control protocol (LACP)
- Link OAM, IEEE 802.3ah
- Port authentication, IEEE 802.1X
- Ethernet local management interface (E-LMI), ITU-T Q.933.
- Link layer discovery protocol (LLDP)
- Multiple registration protocol (MRP)
- Generic attribute registration protocol (GARP)

The PTP 650 Series does not generate or respond to any L2CP traffic.

Quality of service for bridged Ethernet traffic

The PTP 650 Series supports eight traffic queues in the **Data Service** for Ethernet frames waiting for transmission over the wireless link. Ethernet frames are classified by inspection of the Ethernet priority code point in the outermost VLAN tag, the Differentiated Services Code Point (DSCP) in an IPv4 or IPv6 header including DSCP in an IPv4 or IPv6 datagrams encapsulated in PPP and PPPoE headers, or the Traffic Class in an MPLS header.

PTP 650 provides a configurable mapping between Ethernet, IP or MPLS priority and transmission queue, together with a simple way to restore a default mapping based on the recommended default in IEEE 802.1Q-2005. Untagged frames, or frames with an unknown network layer protocol, can be separately classified.

Scheduling for transmission over the wireless link is by strict priority. In other words, a frame at the head of a given queue is transmitted only when all higher priority queues are empty.

Fragmentation

The PTP 650 Series minimizes latency and jitter for high-priority Ethernet traffic by fragmenting Ethernet frames before transmission over the wireless link. The fragment size is selected automatically according to channel bandwidth and modulation mode of the wireless link. Fragments are reassembled on reception, and incomplete Ethernet frames are discarded.

Data port wireless link down alert

The PTP 650 Series provides an optional indication of failure of the wireless link by means of a brief disconnection of the copper or optical data port allocated to the customer data network. The Wireless link down alert can be used to trigger protection switching by Spanning Tree Protocol (STP) or Ethernet Automatic Protection Switching (EAPS) and other higher layer protocols in a redundant network.

Lowest Data Modulation Mode

The PTP 650 ODU can be configured to discard Ethernet frames in the Data Service when the modulation mode is lower than the configured Lowest Data Modulation Mode.

This feature is likely to be useful in networks that have alternate routes, for example in a ring or mesh topology where EAPS or RSTP is used to resolve loops. In this application, Lowest Data Modulation Mode should be set to ensure that an active link will provide at least the minimum necessary capacity for high-priority constant bit rate traffic such as voice over IP or TDM pseudo wire. An active link will be blocked when the capacity falls below the minimum required, triggering a routing change in associated Ethernet switches to bring alternate links into use.

Lowest Data Modulation Mode should normally be set to BPSK 0.63 Single in simply connected tree networks or other topologies that do not have alternative routes.

Further reading

For information about...	Refer to...
Factors to be considered when planning PTP 650 customer data networks	Data network planning on page 3-35
How to configure the Ethernet service	LAN Configuration page on page 6-34
How to configure Ethernet quality of service	QoS Configuration page on page 6-44
How to monitor Ethernet performance	System statistics on page 7-50

Second Data network

Transparent Ethernet service

The PTP 650 Series provides an optional second Ethernet data service between one of the Ethernet ports at a local ODU and one of the Ethernet ports at an associated remote ODU. The Ethernet service is based on conventional layer two transparent bridging. The PTP 650 maintains complete separation between Ethernet traffic in the data service and the second data service.

The service is transparent to untagged frames, standard VLAN frames, priority-tagged frames, provider bridged frames, Q-in-Q frames and provider backbone bridged frames. In each case, the service preserves MAC addresses, VLAN ID, Ethernet priority and Ethernet payload in the forwarded frame. The maximum frame size for bridged frames in the second data service is 2000 bytes.

There is no requirement for the second data service to be connected to the same Ethernet port at both ends of a wireless link. For example, it is possible to connect the Main PSU port to the second data service at one end of the link and to connect the Aux port to the second data service at the other end of the link.

Layer two control protocols

The Second Data Service in the PTP 650 Series is transparent to layer two control protocols (L2CP) including:

- Spanning tree protocol (STP), rapid spanning tree protocol (RSTP)
- Multiple spanning tree protocol (MSTP)
- Link aggregation control protocol (LACP)
- Link OAM, IEEE 802.3ah
- Port authentication, IEEE 802.1X
- Ethernet local management interface (E-LMI), ITU-T Q.933.
- Link layer discovery protocol (LLDP)
- Multiple registration protocol (MRP)
- Generic attribute registration protocol (GARP)

The management service in the PTP 650 Series does not generate or respond to any L2CP traffic.

Quality of service for bridged Ethernet traffic

The PTP 650 Series supports a single traffic queue in the Second Data Service for Ethernet frames waiting for transmission over the wireless link. The priority of the queue can be varied with respect to the eight queues used for the data service.

Fragmentation

Ethernet frames in the PTP 650 Series Second Data Service are always fragmented for transmission over the wireless link, even when the single queue for the Second Data Service has higher priority than all of the data service queues.

Second Data port wireless link down alert

The PTP 650 Series provides an optional indication of failure of the wireless link by means of a brief disconnection of the copper or optical data port allocated to the Second Data Service. The Wireless link down alert can be used to trigger protection switching by Spanning Tree Protocol (STP) or Ethernet Automatic Protection Switching (EAPS) and other higher layer protocols in a redundant network.

Lowest Second Data Modulation Mode

The PTP 650 ODU can be configured to discard Ethernet frames in the Second Data Service when the modulation mode is lower than the configured Lowest Second Data Modulation Mode.

This feature is likely to be useful in networks that have alternate routes, for example in a ring or mesh topology where EAPS or RSTP is used to resolve loops. In this application, Lowest Second Data Modulation Mode should be set to ensure that an active link will provide at least the minimum necessary capacity for high-priority constant bit rate traffic such as voice over IP or TDM pseudo wire. An active link will be blocked when the capacity falls below the minimum required, triggering a routing change in associated Ethernet switches to bring alternate links into use.

Lowest Second Data Modulation Mode should normally be set to BPSK 0.63 Single in simply connected tree networks or other topologies that do not have alternative routes.

Further reading

For information about…	Refer to…
Factors to be considered when planning PTP 650 customer data networks	Data network planning on page 3-35
How to configure the Ethernet Second Data Service	LAN Configuration page on page 6-34
How to configure Ethernet quality of service	QoS Configuration page on page 6-44
How to monitor Ethernet performance	System statistics on page 7-50

Out-of-Band Management Service

Transparent Ethernet service

The PTP 650 Series provides an optional Ethernet service for out-of-band network management between one of the Ethernet ports at a local ODU and one of the Ethernet ports at an associated remote ODU. The Ethernet service is based on conventional layer two transparent bridging. The PTP 650 maintains complete separation between Ethernet traffic in the customer Data Service and the Management Service.

The service is transparent to untagged frames, standard VLAN frames, priority-tagged frames, provider bridged frames, Q-in-Q frames and provider backbone bridged frames. In each case, the service preserves MAC addresses, VLAN ID, Ethernet priority and Ethernet payload in the forwarded frame. The maximum frame size for bridged frames in the management network is 2000 bytes.

There is no requirement for the management network to be connected to the same Ethernet port at both ends of a wireless link. For example, it is possible to connect the Main PSU port to the management network at one end of the link and to connect the Aux port to the management network at the other end of the link.

Layer two control protocols

The Management Service in the PTP 650 Series is transparent to layer two control protocols (L2CP) including:

- Spanning tree protocol (STP), rapid spanning tree protocol (RSTP)
- Multiple spanning tree protocol (MSTP)
- Link aggregation control protocol (LACP)
- Link OAM, IEEE 802.3ah
- Port authentication, IEEE 802.1X
- Ethernet local management interface (E-LMI), ITU-T Q.933.
- Link layer discovery protocol (LLDP)
- Multiple registration protocol (MRP)
- Generic attribute registration protocol (GARP)

The management service in the PTP 650 Series does not generate or respond to any L2CP traffic.

Quality of service for bridged Ethernet traffic

The PTP 650 Series supports a single traffic queue in the Management Service for Ethernet frames waiting for transmission over the wireless link. The priority of the queue can be varied with respect to the eight queues used for the Data Service.

Fragmentation

Ethernet frames in the PTP 650 Series management service are always fragmented for transmission over the wireless link, even when the single queue for the management service has higher priority than all of the customer data queues.

Management port wireless Down Alert

The PTP 650 Series provides an optional indication of failure of the wireless link by means of a brief disconnection of the copper or optical data port allocated to the management network. The Wireless link down alert can be used to trigger protection switching by Spanning Tree Protocol (STP) or Ethernet Automatic Protection Switching (EAPS) and other higher layer protocols in a redundant network.

Lowest Data Modulation Mode

The Lowest Data Modulation Mode attribute does not prevent bridging in the management service. See Lowest Data Modulation Mode on page 1-25.

Further reading

For information about...	Refer to...
Factors to be considered when planning PTP 650 management data networks	Data network planning on page 3-35
How to configure the Ethernet service	LAN Configuration page on page 6-34
How to configure Ethernet quality of service	QoS Configuration page on page 6-44
How to monitor Ethernet performance	System statistics on page 7-50

Ethernet loopback mode

PTP 650 provides a local Ethernet loopback function that can be used to loop traffic between the Aux Port and one of the other Ethernet ports.

Loopback is intended to assist in the commissioning of a camera or other auxiliary device collocated with the PTP 650 ODU. For example, when setting up a camera which will ultimately be connected to the wireless bridge, it may be useful to loop the data back to a second local interface, to assist in the positioning and alignment of the camera.

When ports are configured for Ethernet local loopback, they are temporarily disconnected from their allocated function and connected together internally within the PTP 650 ODU. The Management Service and Local Management Service are disconnected from a port configured for loopback. In this case, it will not be possible to manage the ODU from a local Ethernet port. For this reason the Ethernet loopback is always disabled when the ODU is rebooted or power-cycled, restoring the previous port configuration and any associated management paths.

During loopback operation, the same frame size restrictions that apply to management traffic are present, jumbo frames are not supported and the maximum frame size is restricted to 1536 bytes.

Loopback is able to loop between Ethernet ports operating at different line rates if required, and it is possible to configure a Loopback between ports operating at 1000BASE-T/LX/SX and 100BASE-TX if needed.

Further reading

For information about...	Refer to...
How to configure Ethernet loopback	LAN Configuration page on page 6-34

Protocol model

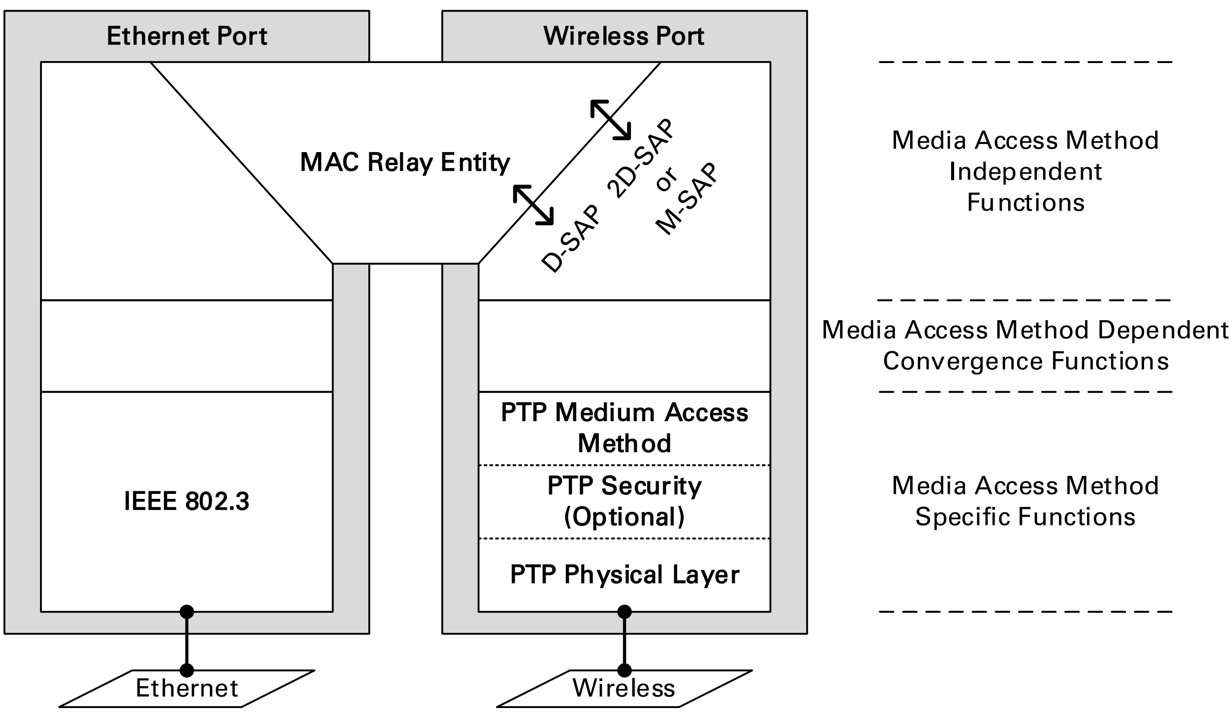
Ethernet bridging behavior at each end of the wireless link is equivalent to a two-port, managed, transparent MAC bridge where the two ports are a wired Ethernet port allocated to the Data Service, Second Data Service, Out-of-Band Management Service, and the Wireless port.

Frames are transmitted at the Wireless port over a proprietary point-to-point circuit-mode link layer between ends of the PTP 650 link. The Wireless Port provides two distinct service access ports (SAPs) where the first is always used for the Data Service, while the second is used by either the Second Data Service or Out-of-Band Management Service.

Ethernet frames received at the Ethernet ports, or generated internally within the management agent, are encapsulated within a lightweight MAC layer for transmission over the wireless link.

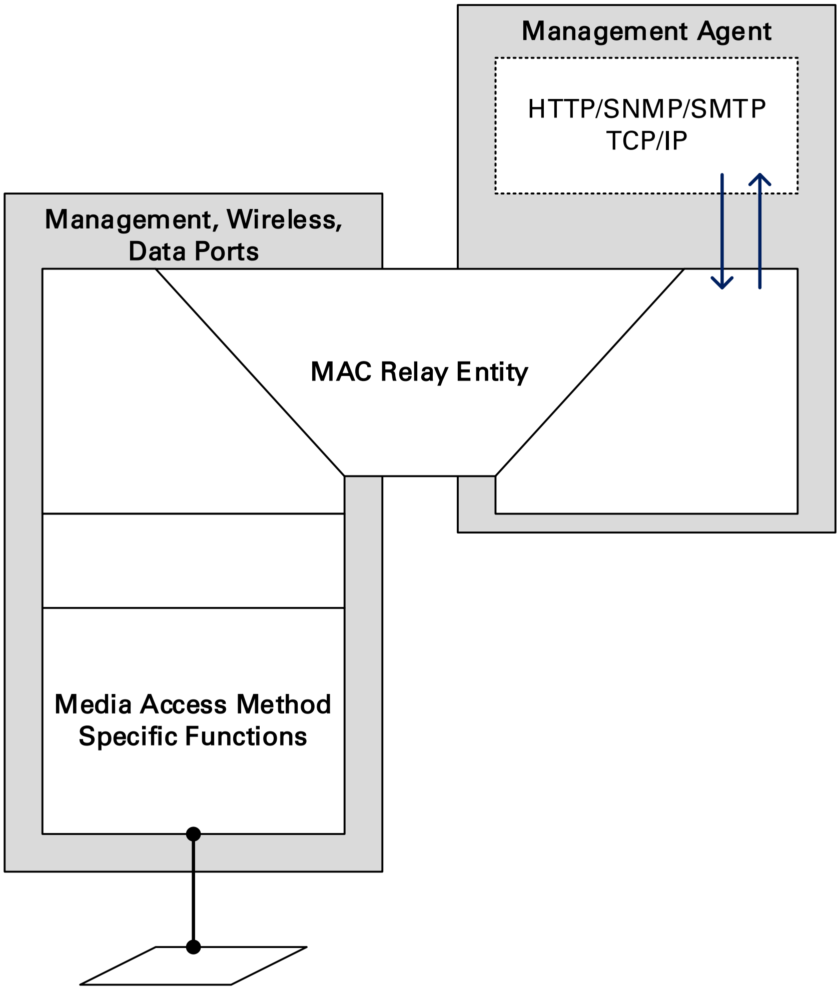
Protocol layers involved in bridging between Ethernet and wireless interfaces are shown in Figure 3. Protocol layers involved in bridging between external interfaces and the management agent are shown in Figure 4. In these figures, the layers have the meanings defined in IEEE 802.1Q-2005.

Figure 3 Protocol layers between Ethernet and wireless interfaces



D-SAP = Data Service Access Point
2D-SAP = Second Data Service Access Point
M-SAP = Management Service Access Point

Figure 4 Protocol layers between external interfaces and the management agent



Further reading

For information about...	Refer to...
Layer two control protocols (L2CPs) identified by PTP 650	Layer two control protocols on page 3-35

Synchronous Ethernet

PTP 650 provides a Synchronous Ethernet function. When enabled, the frequency and phase of the Ethernet clock is transferred to the other end of the radio link, enabling operation as part of an ITU-T G.781 Synchronous Digital Hierarchy.

Synchronisation Status Messages (SSM) are processed and transmitted as specified by ITU-T G.8264 and in Section 5 of G.781.

Further reading

For information about…	Refer to…
Relationship between synchronous Ethernet and TDM	TDM description on page 1-35
Availability of synchronous Ethernet	Capability upgrades on page 1-53
Relationship between synchronous Ethernet and Ethernet port allocation	Additional port allocation rules on page 3-44
How to configure synchronous Ethernet	LAN Configuration page on page 6-34
Upgrading to synchronous Ethernet	Generating license keys on page 6-3
Synchronous Ethernet status indicators	Synchronous Ethernet on page 7-11
Synchronous Ethernet alarms	Alarms on page 7-18

IEEE 1588-2008 Transparent Clock

PTP 650 is capable of operating as an IEEE 1588-2008 Transparent Clock. When operational, IEEE 1588-2008 event frames (Sync, Delay_Req, Pdelay_Req, Pdelay_Resp) have their “Correction Field” adjusted to reflect the residence time of the frame in the system. This results in greatly improved performance of downstream 1588-2008 slave clocks. The Transparent Clock feature is available at the Main PSU Port and at the SFP Port when a fiber SFP module is installed.

Unicast and multicast addressing models are supported, along with UDP over IPv4 or IPv6, and Ethernet communication services. The IEEE 1588 messages can be encapsulated in Untagged, C-tagged, S-tagged, S-C-tagged and C-C-tagged Ethernet frames.

Note

For the most accurate residence time corrections, use Synchronous Ethernet in conjunction with the Transparent Clock feature. In this configuration, PTP 650 uses the Synchronous Ethernet clock to increase the accuracy of 1588 residence time measurements.

Further reading

For information about…	Refer to…
Relationship between IEEE 1588-2008 Transparent Clock and TDM	TDM description on page 1-35
Availability of IEEE 1588-2008 Transparent Clock	Capability upgrades on page 1-53
Relationship between IEEE 1588-2008 Transparent Clock and Ethernet port allocation	Additional port allocation rules on page 3-44
Relationship between IEEE 1588-2008 Transparent Clock and VLAN membership	VLAN membership on page 3-45
Upgrading to IEEE 1588-2008	Generating license keys on page 6-3
How to configure IEEE 1588-2008 Transparent Clock	LAN Configuration page on page 6-34
IEEE 1588-2008 Transparent Clock status indicators	Synchronous Ethernet on page 7-11
IEEE 1588-2008 Transparent Clock alarms	Alarms on page 7-18

TDM bridging

This section describes how TDM traffic (E1 or T1) may be carried over PTP 650 links.

If a NIDU is installed at each link end, the PTP 650 link supports up to eight E1 channels or up to eight T1 channels. The link relays unstructured E1 or T1 data and provides accurate timing transfer.

TDM description

PTP 650 Series bridges up to eight E1 or T1 telecoms circuits over a single-hop PTP 650 wireless link using the optional Network Indoor Unit (NIDU). The NIDU provides the eight TDM interfaces on individual RJ45/RJ48 connectors, together with an Ethernet interface to the operator's data network and a separate Ethernet interface to the PTP 650 Series ODU. One NIDU is required at each end of the link. It operates from a 48 V DC power supply.

TDM circuits established using the NIDUs are structure agnostic, meaning that the circuits can bridge framed or unframed data.

The NIDUs are tightly integrated with associated ODUs providing for simple configuration, accurate timing transfer, low and predictable latency, high efficiency, quick settling time, and a timing-only mode that maintains timing transfer when the wireless link has insufficient capacity to bridge the configured TDM data.

Through timing

TDM bridging in the PTP 650 series uses the "through timing" model. In other words, the clock frequency used for transmitting TDM data is, on average, exactly the same as the clock frequency received at the corresponding TDM port at the remote end of the link. The wander and jitter in the transmit clock complies with applicable requirements of ITU-T G.823 and G.824 without additional external frequency references. Timing transfer is independent between individual circuits, and between transmit and received directions of the same circuit.

NIDUs and TDM

TDM circuits in PTP 650 span a single wireless link. To transmit TDM data across a network segment consisting of several wireless links, use one pair of NIDUs for each wireless link, and interconnect the TDM ports at relay sites.

The NIDU is not a general-purpose TDM multiplexer, and will not interwork with standards-based products from other manufacturers. The NIDU does not support (and does not need to support) internal, external or loop timing modes. The NIDU does not accept (or need) an external frequency reference.

The NIDU is not separately managed, and it does not have an IP address. Instead, the ODU is used to configure and monitor the associated NIDU through the standard HTTP/HTTPS, SNMP, SMTP and syslog interfaces already used by the ODU.

The NIDU always connects to the ODU using the Main PSU port of the ODU. This constrains the flexible allocation of ports to services somewhat.

Timing transfer for TDM circuits

Accurate timing transfer for TDM circuits in the PTP 650 Series is based on the same underlying technology as the IEEE 1588 Transparent Clock and Synchronous Ethernet features. Consequently, the IEEE 588 and Synchronous Ethernet features are not available when TDM bridging is enabled. Similarly, TDM bridging is not available if either IEEE 1588 or Sync E is in use. The Adaptive setting for Link Symmetry is not compatible with TDM bridging.

TDM bridging is a licensed feature, and may require an optional upgrade for the ODU firmware.

Lowest TDM modulation mode

In narrow channel bandwidths and lower modulation modes, the link may have insufficient capacity to relay the E1/T1 payload; in this case, the wireless link continues to carry timing information in order to maintain accurate clock synchronization. The relay of TDM data resumes automatically when the link reaches a suitable modulation mode.

Links that are able to operate consistently in a high modulation mode can take advantage of lower link latency. This option is configured by setting the "Lowest TDM Modulation Mode" during installation. Appropriate settings for this control may be determined by using the LINKPlanner tool. The reduction in latency is achieved by disabling the relay of TDM data in lower modulation modes, and this necessarily results in somewhat lower availability for the TDM circuit. The loss of availability can be estimated using the Link Planner.

The unit will override the user setting of Lowest TDM Modulation Mode if the selected mode has insufficient capacity to carry the TDM data, or if the mode demands very high latency and requires more buffering than the link can provide.

Fixed frequency operation

In the PTP 650 link, data errors may occur during channel changes on an operational link. It may be appropriate to minimize channel-change-related errors in a link carrying TDM traffic by preventing channel changes initiated by DSO. This can be achieved by barring all channels except one in the Spectrum Management page, or alternatively by selecting Fixed Frequency mode. These steps unavoidably disable interference avoidance mechanisms, and should not be taken if the risk of errors due to interference is more severe than the risk due to channel changes.

Fixed frequency operation is not available when radar detection requirements exist in the frequency band. Channel barring is allowed in radar regions, but it is unwise to bar all channels except one, as any radar signals detected on that channel will drop the link for up to 30 minutes.

Ethernet cables for TDM

The Ethernet cables from the ODU via the PSU to the NIDU must be capable of supporting operation at 1000BASE-T. If the ODU port has negotiated a link at 100BASE-T, the NIDU will not send or receive TDM data and will not bridge customer data traffic.

Further reading

For information about…	Refer to…
The hardware required to implement TDM	Network indoor unit (NIDU) on page 2-56
A typical E1 or T1 site deployment	E1 or T1 interfaces on page 3-5
Where to locate the NIDU	NIDU location on page 3-17
TDM interface specifications	Ethernet interfaces on page 3-35
The effect of TDM on data throughput	TDM traffic load on page 3-127
How to install TDM hardware	Installing a NIDU on page 5-42
How to generate TDM (E1 or T1) license keys	Generating license keys on page 6-3
How to install TDM license keys (part of the Installation Wizard)	Software License Key page on page 6-11
How to enable E1 or T1 and configure TDM channels (part of the Installation Wizard)	Interface Configuration page on page 6-14
How to configure NIDU LAN port auto-negotiation	LAN Configuration page on page 6-34
How to configure TDM channels and initiate loopback tests (after installation)	TDM Configuration page on page 6-50
How to enable TDM alarms	Diagnostic Alarms page on page 6-73
The meaning of TDM status attributes	System Status page on page 7-3
The meaning of TDM alarms	Alarms on page 7-18
How to check the NIDU LEDs, perform a TDM loopback test, and check for 1000BASE-T	Testing a TDM link on page 8-18
To find the latency of a TDM link	System Status page, TDM Latency attribute (Table 173) Alternatively, use LINKPlanner

System management

This section introduces the PTP 650 management system, including the web interface, installation, configuration, alerts and upgrades.

Management agent

PTP 650 equipment is managed through an embedded management agent. Management workstations, network management systems or PCs can be connected to this agent using a choice of in-band or out-of-band network management modes. These modes are described in detail in Network management on page 1-39.

The management agent includes a dual IPv4/IPv6 interface at the management agent. The IP interface operates in the following modes:

- IPv4 only (default)
- IPv6 only
- Dual IPv4/IPv6

In the dual IPv4/IPv6 mode, the IP interface is configured with an IPv4 address and an IPv6 address and can operate using both IP versions concurrently. This dual mode of operation is useful when a network is evolving from IPv4 to IPv6.

The management agent supports the following application layer protocols (regardless of the management agent IP mode):

- Hypertext transfer protocol (HTTP)
- HTTP over transport layer security (HTTPS/TLS)
- RADIUS authentication
- TELNET
- Simple network management protocol (SNMP)
- Simple mail transfer protocol (SMTP)
- Simple network time protocol (SNTP)
- System logging (syslog)

Note

PTP 650 supports a single public key certificate for HTTPS. This certificate must be based on an IPv4 or IPv6 address as the Common Name. The Dual IPv4/IPv6 interface should not normally be used when HTTPS is required.

Network management

IPv4 and IPv6 interfaces

The PTP 650 ODU contains an embedded management agent with IPv4 and IPv6 interfaces. Network management communication is exclusively based on IP and associated higher layer transport and application protocols. The default IPv4 address of the management agent is 169.254.1.1. There is no default IPv6 address. The PTP 650 does not require use of supplementary serial interfaces.

MAC address

The management agent end-station MAC address is recorded on the enclosure and is displayed on the Status web page. The MAC address is not configurable by the user.

VLAN membership

The management agent can be configured to transmit and receive frames of one of the following types: untagged, priority-tagged, C-tagged (IEEE 802.1Q) or S-tagged (IEEE 802.1ad). C-tagged and S-tagged frames must be single tagged. The VLAN ID can be 0 (priority tagged) or in the range 1 to 4094.

Ethernet and DSCP priority

The management agent transmits IPv4 and IPv6 management packets with a configurable DSCP value in the range 0 to 63. If the management agent is configured to operate in a management VLAN, the Ethernet frames will be transmitted with a configurable Ethernet priority in the range 0 to 7. The same DSCP and Ethernet priorities are assigned to all management packets generated by the agent. Management frames are multiplexed with customer data frames of the same priority for transmission at the wireless port.

Access to the management agent

The management agent can be reached from any Ethernet port at the local ODU that is allocated to the Management Service or the Local Management Service.

If the wireless link is established, the management agent can also be reached from the remote ODU via an Ethernet port that is allocated to the Management Service.

Management frames are processed by the management agent if (a) the destination MAC address in the frame matches the ODU MAC address, and (b) the VLAN ID in the frame matches the VLAN configuration of the management agent.

If Local Packet Filtering is enabled, unicast frames forwarded to the management agent are filtered, that is, not forwarded in the customer data network or the management network.

MAC address and IP address of the management agent

The MAC address and IP address used by the management agent will be the same at each port that is allocated the Management Service or Local Management Service. The management agent does not provide the function of a dual-homed or multi-homed host. Network designers should take care to ensure that the ODU will not be connected to more than one IP network.

Further examples of useful port allocation schemes are provided in Chapter 3: System planning.

Source address learning

If Local Packet Filtering is enabled, the PTP 650 learns the location of end stations from the source addresses in received management frames. The agent filters transmitted management frames to ensure that the frame is transmitted at the appropriate Ethernet port, or over the wireless link as required to reach the reach the correct end station. If the end station address is unknown, then management traffic is transmitted at each of Ethernet port enabled for management and over the wireless link.

Further reading

For information about...	Refer to...
Planning the IP interface	IP interface on page 3-45
How to configure the IP interface	Interface Configuration page on page 6-14
How to configure the target MAC address	Wireless Configuration page on page 6-21
Planning VLAN membership	VLAN membership on page 3-45
How to configure VLAN for the management interface	Interface Configuration page on page 6-14 LAN Configuration page on page 6-34
Planning the Ethernet and IP (DSCP) priority	Priority for management traffic on page 3-45
Planning the use of Ethernet ports for customer and management traffic	Additional port allocation rules on page 3-44

IPv6

The PTP 650 management agent supports the following IPv6 features:

Neighbor discovery

PTP 650 supports neighbor discovery for IPv6 as specified in RFC 4861 including:

- Neighbor un-reachability detection (NUD),
- Sending and receiving of neighbor solicitation (NS) and neighbor advertisement (NA) messages,
- Processing of redirect functionality.

PTP 650 sends router solicitations, but does not process router advertisements.

Path MTU discovery and packet size

PTP 650 supports path MTU discovery as specified in RFC 1981, and packet fragmentation and reassembly as specified in RFC 2460 and RFC 5722.

ICMP for IPv6

PTP 650 supports ICMPv6 as specified in RFC 4443. PTP 650 does not support RFC 4884 (multi-part messages).

Addressing

The PTP 650 management agent is compatible with the IPv6 addressing architecture specified in RFC 4291. PTP 650 allows static configuration of the following:

- Global unicast address
- IPv6 prefix length
- IPv6 default router.

PTP 650 additionally assigns an automatically configured Link Local address using stateless address auto-configuration (SLAAC) as specified in RFC 4862. PTP 650 does not assign a global unicast IP address using SLAAC.

PTP 650 responds on the standard management agent interfaces (HTTP, HTTPS, syslog, Telnet, SNMP, SMTP, SNTP) using the global unicast address.

Privacy extensions

PTP 650 does not support the privacy extensions specified in RFC 4941.

DHCPv6

PTP 650 does not support address assignment using DHCPv6. The address of the management agent must be configured statically.

Multicast listener discovery for IPv6

The PTP 650 management agent supports Multicast Listener Discovery version 1 (MLDv1) as specified in RFC 2710.

PTP 650 does not support Multicast Listener Discovery version 2 (MLDv2).

Textual representation of IPv6 addresses

PTP 650 allows users to input text-based IP addresses in any valid format defined in RFC 5952. IPv6 addresses are automatically converted by PTP 650 to the preferred compressed form, apart from those using the prefix length on the same line as the address, such as **2000::1/64**.

Security

PTP 650 does not support IP security (IPsec).

Further reading

For information about…	Refer to…
Planning the IPv6 interface	IP interface on page 3-45
How to enable IPv6 capability	Software License Key page on page 6-11
How to configure IPv6	Interface Configuration page on page 6-14 LAN Configuration page on page 6-34

Web server

The PTP 650 management agent contains a web server. The web server supports the HTTP and HTTPS/TLS interfaces.

Web-based management offers a convenient way to manage the PTP 650 equipment from a locally connected computer or from a network management workstation connected through a management network, without requiring any special management software. The web-based interfaces are the only interfaces supported for installation of PTP 650.

Web pages

The web-based management interfaces provide comprehensive web-based fault, configuration, performance and security management functions organized into the following web-pages and groups:

- **Home:** The Home web-page reports Wireless Link Status and basic information needed to identify the link. The Home page additionally lists all active alarm conditions.
- **Status:** The Status web-page reports the detailed status of the PTP 650.

- **System:** These web-pages are used for configuration management, including IP and Ethernet, AES encryption keys, quality of service and software upgrade. The System pages additionally provide detailed counters and diagnostic measurements used for performance management.
- **Installation:** The Installation Wizard is used to install license keys, configure the PTP 650 wireless interface and to arm the unit ready for alignment.
- **Management:** These web-pages are used to configure the network management interfaces.
- **Security:** The Security Wizard is used to configure the HTTPS/TLS interface and other security parameters such as the AES wireless link encryption key and the key of keys for encrypting CSPs on the ODU. The Security Wizard is disabled until AES encryption is enabled by license key.
- **Change Password**: The Change Password web page changes the web interface password of the active user. The User Accounts page is also used to change passwords.
- **Logout:** Allows a user to log out from the web-based interface.

Transport layer security

The HTTPS/TLS interface provides the same set of web-pages as the HTTP interface, but allows HTTP traffic to be encrypted using Transport Layer Security (TLS). PTP 650 uses AES encryption for HTTPS/TLS. Operation of HTTPS/TLS is enabled by purchase of an optional AES upgrade.

HTTPS/TLS requires installation of a private key and a public key certificate where the common name of the subject in the public key certificate is the IP address or host name of the PTP 650 unit. PTP 650 supports certificates with 2048-bit key size.

HTTPS/TLS operation is configured through the web-based interfaces using the Security Wizard.

Note

The PTP 650 has no default public key certificate, and Cambium Networks is not able to generate private keys or public key certificates for specific network applications.

Note

PTP 650 supports a single public key certificate for HTTPS. This certificate must be based on an IPv4 or IPv6 address as the Common Name. Any attempt to use HTTPS without a certificate for the associated IP address will not be secure, and will trigger browser security warnings. It follows from this that the Dual IPv4/IPv6 interface should not normally be used when HTTPS is required.

User account management

PTP 650 allows a network operator to configure a policy for login attempts, the period of validity of passwords and the action taken on expiry of passwords.

Identity-based user accounts

The PTP 650 web-based interface provides two methods of authenticating users:

- Role-based user authentication allows the user, on entry of a valid password, to access all configuration capabilities and controls. This is the default method.
- Identity-based user authentication supports up to 10 users with individual usernames and passwords.

When identity-based user accounts are enabled, a security officer can define from one to ten user accounts, each of which may have one of the three possible roles:

- Security officer.
- System administrator.
- Read only.

Identity-based user accounts are enabled in the Local User Accounts page of the web-based interface.

Password complexity

PTP 650 allows a network operator to enforce a configurable policy for password complexity. Password complexity configuration additionally allows a pre-determined best practice configuration to be set.

SNMP control of passwords

PTP 650 allows the role-based and identity-based passwords for the web-based interface to be updated using the proprietary SNMP MIB. This capability is controlled by the SNMP Control of Passwords, and is disabled by default.

SNMP Control of Passwords can be used together with SNMPv3 to provide a secure means to update passwords from a central network manager. However, password complexity rules are not applied.

Further reading

For information about…	Refer to…
How to log in and use the menu	Using the web interface on page 6-6
Planning the security material needed for HTTPS/TLS.	Security planning on page 3-51
How to configure user accounts	Local User Accounts page on page 6-61

RADIUS authentication

PTP 650 supports remote authentication for users of the web interface using the Remote Authentication Dial-In User Service (RADIUS) with one of the following authentication methods:

- Challenge Handshake Authentication Protocol (CHAP)
- Microsoft CHAP Version 2 (MS-CHAPv2)

PTP 650 supports connections to primary and secondary RADIUS servers. The RADIUS interface is configured through the RADIUS Authentication page of the web-based interfaces.

PTP 650 RADIUS supports the standard Service Type attribute to indicate authentication roles of System Administrator and Read Only together with a vendor specific attribute to indicate authentication roles of Security Officer, System Administrator, and Read Only.

Remote authentication can be used in addition to local authentication, or can be used as a replacement for local authentication. If remote and local authentications are used together, PTP 650 checks log in attempts against locally stored user credentials before submitting a challenge and response for remote authentication. Remote authentication is not attempted if the username and password match locally stored credentials, or fails against the local database.

RADIUS is only available when PTP 650 is configured for Identity-based User Accounts.

Further reading

For information about…	Refer to…
How to plan the use of RADIUS	Planning for RADIUS operation on page 3-57
How to configure RADIUS.	RADIUS Configuration page on page 6-66

SNMP

The management agent supports fault and performance management by means of an SNMP interface. The management agent is compatible with SNMP v1, SNMP v2c, and SNMPv3 using the following Management Information Bases (MIBs):

- RFC-1493. BRIDGE-MIB. dot1dBase group.
- RFC-2233. IF-MIB. Interfaces group, and ifXTable table.
- RFC-3411. SNMP-FRAMEWORK-MIB. snmpEngine group.
- RFC-3412. SNMP-MPD-MIB. snmpMPDStats group.
- RFC-3413. SNMP-TARGET-MIB. snmpTargetObjects group and SNMP-NOTIFICATION-MIB snmpNotifyTable table.
- RFC-3414. SNMP-USER-BASED-SM-MIB. usmStats group and usmUser group.
- RFC-3415. SNMP-VIEW-BASED-ACM-MIB vacmMIBObjects group.
- RFC-3418. SNMPv2-MIB. System group, SNMP group, and set group.
- RFC-3826. SNMP-USM-AES-MIB. usmAesCfb128Protocol OID.

- RFC-4293 IP-MIB, ipForwarding, ipAdEntAddr, ipAdEntIfIndex, ipAdEntNetMask
- PTP 650 Series proprietary MIB.

Further reading

For information about...	Refer to...
How to plan for SNMPv1/2c	Planning for SNMP operation on page 3-49
How to enable SNMP control of HTTP, Telnet and passwords	Web-Based Management page on page 6-58 Step 7: Enter HTTP and Telnet Settings on page 6-102
How to configure SNMPv1 or SNMPv2c	SNMP pages (for SNMPv1/2c) on page 6-90
How to upgrade software remotely using Trivial FTP (TFTP) triggered by SNMP	Upgrading software using TFTP on page 6-115

Simple Network Time Protocol (SNTP)

The clock supplies accurate date and time information to the system. It can be set to run with or without a connection to a network time server (SNTP). It can be configured to display local time by setting the time zone and daylight saving in the Time web page.

If an SNTP server connection is available, the clock can be set to synchronize with the server time at regular intervals. For secure applications, the PTP 650 can be configured to authenticate received NTP messages using an MD5 signature.

Further reading

For information about...	Refer to...
How to plan for SNTP operation	Planning for SNTP operation on page 3-51
How to configure SNTP	Time Configuration page on page 6-74

SNMPv3 security

SNMP Engine ID

PTP 650 supports four different formats for SNMP Engine ID:

- MAC address
- IPv4 address
- Configurable text string
- IPv6 address

SNMPv3 security configuration is re-initialized when the SNMP Engine ID is changed.

User-based security model

PTP 650 supports the SNMPv3 user-based security model (USM) for up to 10 users, with MD5, SHA-1, DES and (subject to the license key) AES protocols in the following combinations:

- No authentication, no privacy,
- MD5, no privacy,
- SHA-1, no privacy,
- MD5, DES,
- SHA-1, DES,
- MD5, AES,
- SHA-1, AES.

Use of AES privacy requires the PTP 650 AES upgrade described in AES license on page 1-50.

View-based access control model

PTP 650 supports the SNMPv3 view-based access control model (VACM) with a single context. The context name is the empty string. The context table is read-only, and cannot be modified by users.

Access to critical security parameters

The SNMPv3 management interface does not provide access to critical security parameters (CSPs) of PTP 650. It is not possible to read or modify AES keys used to encrypt data transmitted at the wireless interface. Neither is it possible to read or modify security parameters associated with TLS protection of the web-based management interface. The recovery mode option to zeroize CSPs does not affect SNMPv3 configuration.

MIB-based management of SNMPv3 security

PTP 650 supports a standards-based approach to configuring SNMPv3 users and views through the SNMP MIB. This approach provides maximum flexibility in terms of defining views and security levels appropriate for different types of user.

PTP 650 provides a default SNMPv3 configuration. This initial configuration is not secure, but it provides the means by which a secure configuration can be created using SNMPv3.

The secure configuration should be configured in a controlled environment to prevent disclosure of the initial security keys necessarily sent as plaintext, or sent as encrypted data using a predictable key. The initial security information should not be configured over an insecure network.

The default configuration is restored when any of the following occurs:

- All ODU configuration data is erased.
- All SNMP users are deleted using the SNMP management interface.
- The SNMP Engine ID Format has been changed.
- The SNMP Engine ID Format is Internet Address AND the Internet Address has been changed.
- The SNMP Engine ID Format is Text String AND the text string has been changed.
- The SNMP Engine ID Format is MAC Address AND configuration has been restored using a file saved from a different unit.
- SNMPv3 Security Management is changed from web-based to MIB-based.

The default user configuration is specified in SNMPv3 default configuration (MIB-based) on page 3-55.

PTP 650 creates the `initial` user and template users with localized authentication and privacy keys derived from the passphrase string `123456789`. Authentication keys for the templates users are fixed and cannot be changed. Any or all of the template users can be deleted.

The default user `initial` is created with a view of the entire MIB, requiring authentication for SET operations. There is no access for template users.

Note

VACM grants access for requests sent with more than the configured security level.

The default user `initial` will have read/write access to the whole of the MIB. This is described in further detail in View-based access control model on page 1-47. The template users have no access to the MIB in the default configuration. User `initial` will normally be used to create one or more additional users with secret authentication and privacy keys, and with appropriate access to the whole of the MIB or to particular views of the MIB according to the operator's security policy. New users must be created by cloning template users. The user `initial` may then be deleted to prevent access using the well-known user name and keys. Alternatively, the keys associated with `initial` may be set to some new secret value.

Web-based management of SNMPv3 security

PTP 650 supports an alternative, web-based approach for configuring SNMPv3 security. In this case, the web-based interface allows users to specify SNMPv3 users, security levels, privacy and authentication protocols, and passphrases. Web-based management will be effective for many network applications, but the capabilities supported are somewhat less flexible than those supported using the MIB-based security management.

Selection of web-based management for SNMPv3 security disables the MIB-based security management.

Web-based management of SNMPv3 security allows for two security roles:

- Read Only
- System Administrator

Read Only and System Administrator users are associated with fixed views allowing access to the whole of the MIB, excluding the objects associated with SNMPv3 security. System Administrators have read/write access as defined in the standard and proprietary MIBs.

Web-based management of SNMPv3 security allows an operator to define the security levels and protocols for each of the security roles; all users with the same role share a common selection of security level and protocols.

Web-based security configuration is re-initialized when any of the following occurs:

- All ODU configuration data is erased.
- The SNMP Engine ID Format has been changed.
- The SNMP Engine ID Format is Internet Address and the Internet Address has been changed.
- The SNMP Engine ID Format is Text String and the text string has been changed.
- The SNMP Engine ID Format is MAC Address and configuration has been restored using a file saved from a different unit.
- SNMPv3 Security Management is changed from MIB-based to web-based.

Additionally, all SNMP user accounts are disabled when the authentication protocol, the privacy protocol, or the security level is changed.

Downgrade of the license key

A possible lockout condition exists if a user downgrades the PTP 650 license key so as to disable the AES capability when SNMPv3 users are configured with AES privacy and VACM is configured to require privacy. In this case, recovery is by either (a) restoring the correct license key, or (b) using recovery mode to rest all configuration and entering new configuration.

Option (b) will cause default users and access configuration to be re-created.

Further reading

For information about…	Refer to…
How to plan for SNMPv3 operation	Planning for SNMPv3 operation on page 3-53
How to configure SNMPv3	SNMP pages (for SNMPv3) on page 6-80

System logging (syslog)

PTP 650 supports the standard syslog protocol to log important configuration changes, status changes and events. The protocol complies with RFC 3164.

PTP 650 creates syslog messages for configuration changes to any attribute that is accessible via the web-based interface, or via the enterprise MIB at the SNMP interface.

PTP 650 additionally creates syslog messages for changes in any status variable displayed in the web-based interface.

PTP 650 creates syslog messages on a number of events (for example successful and unsuccessful attempts to log in to the web-based interface).

PTP 650 can be configured to send syslog messages to one or two standard syslog servers.

Additionally, PTP 650 logs event notification messages locally. Locally-stored event messages survive reboot of the unit, and are overwritten only when the storage capacity is exhausted (approximately 2000 messages). The locally stored events can be reviewed using the web-based user interface.

Only users with Security Officer role are permitted to configure the syslog client. Users with Security Officer, System Administrator or Read Only roles are permitted to review the locally logged event messages.

Further reading

For information about…	Refer to…
Configuring system logging	Syslog Configuration page on page 6-78
Syslog alarms	Alarms on page 7-18
How to view the local log of event messages	Syslog page on page 7-23
How to interpret syslog messages	Format of syslog server messages on page 7-23

AES license

PTP 650 provides optional encryption using the Advanced Encryption Standard (AES). Encryption is not available in the standard PTP 650 system.

AES upgrades are supplied as an access key purchased from your Cambium Point-to-Point distributor or solutions provider. The access key authorizes AES operation for one ODU. Two access keys are needed to operate AES on a link.

AES encryption may be used in the following ways:

- At the wireless port to encrypt data transmitted over the wireless link.
- At the SNMP management interface in the SNMPv3 mode.
- At the HTTPS/TLS management interface.
- At the RADIUS interface when PEAP (MS-CHAPv2) is used as the authentication method.

Two levels of encryption are available to purchase:

- 128-bit: This allows an operator to encrypt all traffic sent over the wireless link using 128-bit encryption.
- 256-bit: This allows an operator to encrypt traffic using either 128-bit or 256-bit encryption.

Encryption must be configured with the same size key in each direction.

AES encryption at the PTP 650 wireless port is based on pre-shared keys. An identical key must be entered at each end of the link.

AES encryption for SNMPv3 or TLS is always based on a 128-bit key, regardless of level enabled in the PTP 650 license key.

Further reading

For information about...	Refer to...
Capability upgrades for AES	Capability upgrades on page 1-53
AES and HTTPS/TLS operation	Planning for HTTPS/TLS operation on page 3-51
AES and SNMPv3 operation	Planning for SNMPv3 operation on page 3-53
How to generate an AES license key	Generating license keys on page 6-3
How to enable AES capability	Software License Key page on page 6-11
How to configure AES encryption	System Configuration page on page 6-30
How to configure security with AES	Security menu on page 6-94

Critical security parameters

The critical security parameters (CSPs) are as follows:

- Key of keys.
- AES encryption keys for the wireless interface.
- Private key for the HTTPS/TLS interface.
- Entropy value for the HTTPS/TLS interface.
- User account passwords for the web-based interface.

CSPs can be reset (zeroized) along with other security-related attributes using the web-based interface.

Further reading

For information about...	Refer to...
How to zeroise CSPs	Zeroize CSPs page on page 6-105
How to zeroise CSPs (recovery mode)	Zeroize Critical Security Parameters on page 7-72

Software upgrade

The management agent supports application software upgrade using either the web-based interface or the SNMP interface.

PTP 650 software images are digitally signed, and the ODU will accept only images that contain a valid Cambium Networks digital signature. The ODU always requires a reboot to complete a software upgrade.

Note

Obtain the application software and this user guide from the support website BEFORE warranty expires.

Caution

ODU software version must be the same at both ends of the link. Limited operation may sometimes be possible with dissimilar software versions, but such operation is not supported by Cambium Networks.

Caution

Take care when upgrading ODU software using the wireless link to a remote ODU. Upgrade the remote unit first, reboot the remote ODU, and then upgrade the local unit to the same software version.

Further reading

For information about…	Refer to…
How to upgrade the software using the web interface	Software Upgrade page on page 6-55
How to upgrade software remotely using Trivial FTP (TFTP) triggered by SNMP	Upgrading software using TFTP on page 6-115

Capability upgrades

ODUs are shipped with a default License Key factory-installed. The default license key enables a limited set of capabilities which depend upon the ODU variant.

Capability upgrades are purchased from Cambium and supplied as access keys. The user then enters the access key into the PTP License Key Generator web page on the support website.

The License Key Generator creates a new license key and delivers it by email. The user then installs the license key using the ODU web interface. License keys are bound to a single ODU and are not transferrable.

Further reading

For information about...	Refer to...
Capabilities of the PTP 650	PTP 650 Integrated or Connectorized ODU on page 2-2
Capabilities of the PTP 650S	PTP 650S Integrated ODU on page 2-6
Capabilities of the PTP 650L	PTP 650L Integrated ODU on page 2-8
Ordering capability upgrades	ODU capability upgrades on page 2-9
How to obtain License Keys	Generating license keys on page 6-3
How to install capability upgrades	Software License Key page on page 6-11

Full capability trial period

A full capability trial period is available for PTP 650 Integrated and PTP 650 Connectorized units that are licensed for “Lite” (up to 125 Mbps) or “Mid” (up to 250 Mbps) data throughput capability. This trial allows the ODU to operate with “Full” capability (up to 450 Mbps) during a 60 day period, reverting to the Lite or Mid capability afterwards. The trial period can be started, paused and resumed from the web interface.

The PTP 650S Integrated ODU always has “Full” capability in a link with range less than 2 km (1.25 miles). The trial period can be used to operate a PTP 650S ODU at “Full” capacity in longer links during the 60 day period.

The PTP 650L Integrated ODU always has Full capability, therefore the trial period is not available.

Further reading

For information about...	Refer to...
How to control the trial period	Software License Key page on page 6-11

Recovery mode

The PTP 650 recovery mode provides a means to recover from serious configuration errors including lost or forgotten passwords and unknown IP addresses.

Recovery mode also allows new main application software to be loaded even when the integrity of the existing main application software image has been compromised. The most likely cause of an integrity problem with the installed main application software is where the power supply has been interrupted during an earlier software upgrade.

The ODU operates in recovery mode in the following circumstances:

- When a checksum error occurs for the main application software image.
- When a power on, power off, power on cycle is applied to the ODU with the power off period being around 5sec.

Recovery mode supports a single IPv4 interface, with IP address 169.254.1.1, and with default link settings. Recovery mode does not support IPv6.

Note

When Recovery has been entered through a power on/off/on cycle, the ODU will revert to normal operation if no web access has been made to the unit within 30 seconds. This prevents the unit remaining inadvertently in recovery following a power outage.

Recovery mode options

Options in recovery mode (IPv4 only) are as follows:

- Load new main application software.
- Reset all configuration data. This option resets IP, Ethernet and security configuration
- Reset IP and Ethernet configuration.
- Reset (zeroize) critical security parameters.
- Reboot with existing software and configuration.

If recovery mode has been entered because of a checksum error, after a 30 second wait the ODU will attempt to reboot with existing software and configuration.

The recovery software image is installed during manufacture of the ODU and cannot be upgraded by operators.

Further reading

For information about...	Refer to...
How to recover from configuration errors or software image corruption	Recovery mode on page 7-66

Chapter 2: System hardware

This chapter describes the hardware components of a PTP 650 link.

The following topics are described in this chapter:

Outdoor unit (ODU)

ODU description

One ODU is required for each link end. The ODU is a self-contained transceiver unit that houses both radio and networking electronics. There are three main types of ODU (described below):

- The standard PTP 650 Integrated or Connectorized ODU.
- The PTP 650S Integrated ODU.
- The PTP 650L Integrated ODU.

All PTP 650, PTP 650S and PTP 650L ODUs are available in three regional variants. Each regional variant is factory-installed to operate in different regulatory bands as follows:

- FCC/IC: regulatory bands 1 (5.8 GHz USA), 13 (5.4 GHz USA), 38 (5.2 GHz USA) and 84 (5.1 GHz USA).
- RoW: regulatory bands 8 (5.4 GHz unrestricted) and 35 (5.8 GHz unrestricted).
- EU: regulatory band 26 (5.4 GHz ETSI).

For details of how to configure the ODUs to operate in other regulatory bands, refer to Generating license keys on page 6-3 and Software License Key page on page 6-11. The list of available bands depends upon the regional variant.

PTP 650 Integrated or Connectorized ODU

The standard PTP 650 Integrated or Connectorized ODU is intended for long-range difficult links and traditional backhaul requirements where high capacity and high link budget are required. It is supplied in two configurations:

- The PTP 650 Integrated ODU is attached to a 23 dBi flat plate antenna (Figure 5)
- The PTP 650 Connectorized ODU is intended to work with separately mounted external antennas (Figure 6). External antennas generally have higher gains than the integrated antennas, allowing the PTP 650 to cope with more difficult radio conditions.

The standard PTP 650 Integrated or Connectorized ODU is factory-installed with “Lite” data throughput capability (up to 125 Mbps). It supports the following capability upgrades (see ODU capability upgrades on page 2-9):

- Data throughput above 125 Mbps
- SFP port operation
- AES encryption
- Synchronous Ethernet and 1588 Transparent Clock
- TDM (E1 or T1) operation
- Group access

Figure 5 PTP 650 Integrated ODU (front and rear views)

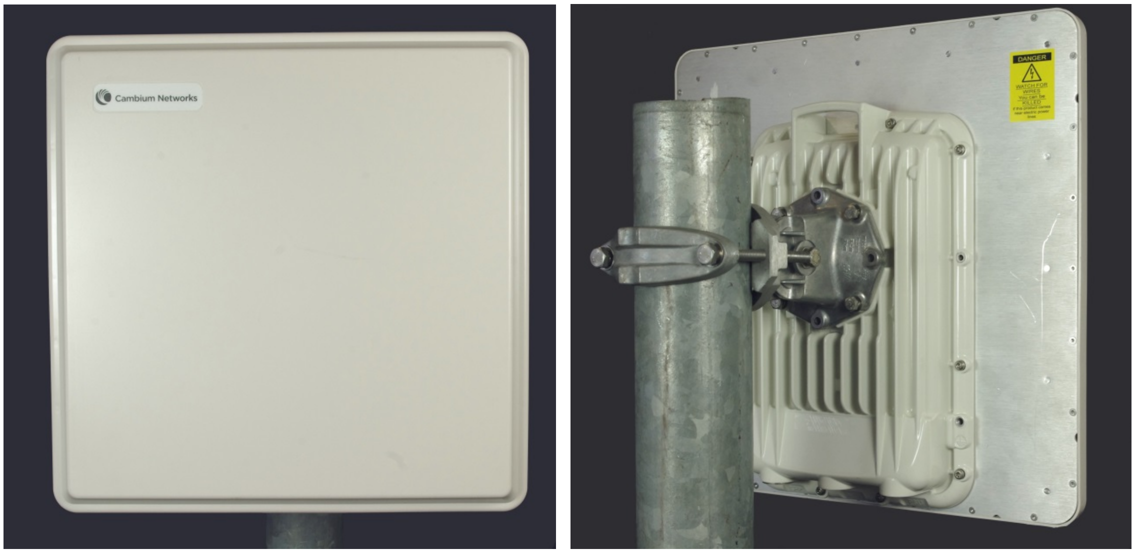


Figure 6 PTP 650 Connectorized ODU (front and rear views)

Note

To determine when to install connectorized units and to calculate their impact on link performance and regulatory limits, see Planning for connectorized units on page 3-29.

To select antennas, RF cables and connectors for connectorized units, see Antennas and antenna cabling on page 2-21.

Attention

Pour déterminer si il est nécessaire d'installer une liaison radiofréquence avec des antennes externes et pour calculer leur impact sur les performances de la liaison et les limites réglementaires, voir Planning for connectorized units page 3-29.

Pour sélectionner les antennes, câbles et connecteurs RF pour les liaisons radiofréquence sans antenne intégrée, voir Antennas and antenna cabling page 2-21.

Full capability trial period

A full capability trial period is available for PTP 650 Integrated or Connectorized ODUs that are licensed for "Lite" (up to 125 Mbps) or "Mid" (up to 250 Mbps) data throughput capability. This trial allows the ODU to operate with "Full" capability (up to 450 Mbps) during a 60 day period, reverting to Lite or Mid capability afterwards. The trial period can be started, paused and resumed from the web interface (Software License Key page on page 6-11).

Individual ODU part numbers

Order PTP 650 Integrated or Connectorized ODUs from Cambium Networks (Table 2). Each of the parts listed in Table 2 includes the following items:

- One 23 dBi integrated ODU or one connectorized ODU.
- With connectorized ODUs only: one connectorized ODU mounting bracket (Figure 8).

Integrated ODUs, when sold individually, are supplied without mounting brackets.

Table 2 PTP 650 Integrated or Connectorized individual ODU part numbers

Cambium description	Cambium part number
PTP 650 (4.9 to 6.05 GHz) Integrated ODU (FCC/IC)	C050065B001
PTP 650 (4.9 to 6.05 GHz) Connectorized ODU (FCC/IC)	C050065B002
PTP 650 (4.9 to 6.05 GHz) Integrated ODU (RoW)	C050065B003
PTP 650 (4.9 to 6.05 GHz) Connectorized ODU (RoW)	C050065B004
PTP 650 (4.9 to 6.05 GHz) Integrated ODU (EU)	C050065B005
PTP 650 (4.9 to 6.05 GHz) Connectorized ODU (EU)	C050065B006

ODU kit part numbers

Order PTP 650 Integrated or Connectorized ODU kits from Cambium Networks (Table 3).

Each of the parts listed in Table 3 includes the following items:

- One 23 dBi integrated ODU or one connectorized ODU.
- One integrated ODU mounting bracket (Figure 8) with a PTP 650 Integrated End kit.
- The PTP 650 Connectorized ODU already includes the connectorized bracket, so this is not included separately in the kit.
- One PSU of the type stated in the Cambium description.
- One line cord, either US (FCC/IC) or EU (EU and RoW).

Table 3 ODU kit part numbers

Cambium description	Cambium part number
PTP 650 Connectorized END with AC Supply (FCC/IC)	C050065H007
PTP 650 Connectorized END with AC+DC Enhanced Supply (FCC/IC)	C050065H008
PTP 650 Integrated END with AC Supply (FCC/IC)	C050065H009
PTP 650 Integrated END with AC+DC Enhanced Supply (FCC/IC)	C050065H010
PTP 650 Connectorized END with AC Supply (RoW)	C050065H011
PTP 650 Connectorized END with AC+DC Enhanced Supply (RoW)	C050065H012
PTP 650 Integrated END with AC Supply (RoW)	C050065H013
PTP 650 Integrated END with AC+DC Enhanced Supply (RoW)	C050065H014
PTP 650 Connectorized END with AC Supply (EU)	C050065H017
PTP 650 Connectorized END with AC+DC Enhanced Supply (EU)	C050065H018
PTP 650 Integrated END with AC Supply (EU)	C050065H019
PTP 650 Integrated END with AC+DC Enhanced Supply (EU)	C050065H020

PTP 650S Integrated ODU

The PTP 650S Integrated ODU is intended for short range high capacity links. The ODU is fitted with a small form-factor 19 dBi flat-plate integrated antenna (Figure 7). It is factory-installed with the following capabilities:

- "Full" data throughput capability (up to 450 Mbps) for links at ranges up to 2.0 km (1.2 miles).
- "Lite" capability (up to 125 Mbps) for ranges between 2.0 km and 200 km (124 miles).
- Synchronous Ethernet.
- IEEE 1588 Transparent Clock.

The PTP 650S Integrated ODU supports the following capability upgrades upgrades (see ODU capability upgrades on page 2-9):

- "Full" (up to 450 Mbps) data throughput capability in links at ranges above 2.0 km (1.2 miles)
- SFP port operation
- AES encryption
- TDM (E1 or T1) operation
- Group access

Figure 7 PTP 650S or PTP 650L Integrated ODU (front and rear views)

Full capability trial period

A full capability trial period is available for PTP 650S Integrated ODUs. This trial allows the ODU to operate with "Full" capability (up to 450 Mbps) in links at ranges above 2.0 km (1.2 miles) during a 60 day period, reverting to the default capability afterwards. The trial period can be started, paused and resumed from the web interface (Software License Key page on page 6-11).

Individual ODU part numbers

Order PTP 650S Integrated ODUs from Cambium Networks (Table 4). Each of the parts listed in Table 4 includes one 19 dBi integrated ODU without mounting brackets.

Table 4 PTP 650S Integrated individual ODU part numbers

Cambium description	Cambium part number
PTP 650S (4.9 to 6.05 GHz) Integrated ODU (FCC/IC)	C050065B015
PTP 650S (4.9 to 6.05 GHz) Integrated ODU (RoW)	C050065B016
PTP 650S (4.9 to 6.05 GHz) Integrated ODU (EU)	C050065B021

ODU kit part numbers

Order PTP 650S Integrated ODU kits from Cambium Networks (Table 5). Each of the parts listed in Table 5 includes the following items:

- One 19 dBi integrated ODU.
- One integrated ODU mounting bracket (Figure 8).
- One PSU of the type stated in the Cambium description.
- One line cord, either US (FCC/IC) or EU (EU and RoW).

Table 5 PTP 650S Integrated ODU kit part numbers

Cambium description	Cambium part number
PTP 650S Integrated END with AC Supply (FCC/IC)	C050065H022
PTP 650S Integrated END with AC+DC Enhanced Supply (FCC/IC)	C050065H023
PTP 650S Integrated END with AC Supply (RoW)	C050065H024
PTP 650S Integrated END with AC+DC Enhanced Supply (RoW)	C050065H025
PTP 650S Integrated END with AC Supply (EU)	C050065H026
PTP 650S Integrated END with AC+DC Enhanced Supply (EU)	C050065H027

PTP 650L Integrated ODU

The PTP 650L Integrated ODU is intended for enterprise access and video surveillance applications that require data throughput up to 100 Mbps. The ODU is fitted with a small form-factor 19 dBi flat-plate integrated antenna. Its external appearance is the same as the PTP 650S Integrated ODU (Figure 7). Although the 650L has the Full capacity variant, capacity is necessarily limited because of the restricted bandwidth.

It is factory-installed with the following capabilities:

- Limited to channel bandwidths of 5 MHz or 10 MHz.
- Data throughput capability up to 100 Mbps.

The PTP 650L Integrated ODU supports the following capability upgrades upgrades (see ODU capability upgrades on page 2-9):

- Operation in channel bandwidths greater than 10 MHz
- SFP port operation
- 128-bit AES encryption (the PTP 650L does not support 256-bit AES Encryption)
- TDM (E1 or T1) operation

Full capability trial period

A full capability trial period is not available for PTP 650L Integrated ODUs.

Individual ODU part numbers

Order PTP 650L Integrated ODUs from Cambium Networks (Table 6). Each of the parts listed in Table 6 includes one 19 dBi integrated ODU without mounting brackets.

Table 6 PTP 650L Integrated individual ODU part numbers

Cambium description	Cambium part number
PTP 650L (4.9 to 6.05 GHz) ODU (FCC)	C050065B029
PTP 650L (4.9 to 6.05 GHz) ODU (RoW)	C050065B030
PTP 650L (4.9 to 6.0 GHz) ODU (EU)	C050065B031

ODU kit part numbers

Order PTP 650L Integrated ODU kits from Cambium Networks (Table 7). Each of the parts listed in Table 7 includes the following items:

- One 19 dBi integrated ODU.
- One integrated ODU mounting bracket (Figure 8).
- One PSU of the type stated in the Cambium description.
- One line cord, either US (FCC/IC) or EU (EU and RoW).

Table 7 PTP 650L Integrated ODU kit part numbers

Cambium description	Cambium part number
PTP 650L END with AC Supply (FCC)	C050065H035
PTP 650L END with AC Supply (RoW-EU Line Cord)	C050065H036
PTP 650L END with AC Supply (RoW-US Line Cord)	C050065H037
PTP 650L END with AC Supply (EU)	C050065H038

ODU capability upgrades

To upgrade a PTP 650, PTP 650S or PTP 650L ODU to one or more new capabilities, order the necessary access keys from Cambium Networks (Table 8). For details of how to install the capability upgrades, refer to Generating license keys on page 6-3 and Software License Key page on page 6-11.

Table 8 Capability upgrades available for PTP 650 Series ODUs

Cambium description (*1)	Access key part number	PTP 650	PTP 650S	PTP 650L
SFP port enabled: access key provided in the SFP module kit (SFP module kits on page 2-45)	n/a	Yes	Yes	Yes
PTP 650 128-bit AES Encryption – per ODU (*2)	C000065K018	Yes	Yes	Yes
PTP 650 256-bit AES Encryption – per ODU (*2)	C000065K019	Yes	Yes	
PTP 650 Lite (Up to 125Mbps) to Mid (Up to 250Mbps) Link Capacity upgrade license per ODU	C000065K021	Yes		
PTP 650 Lite (Up to 125Mbps) to Full (Up to 450Mbps) Link Capacity upgrade license per ODU	C000065K022	Yes		
PTP 650 Mid (Up to 250Mbps) to Full (Up to 450Mbps) Link Capacity upgrade license per ODU	C000065K023	Yes		
PTP 650 Precise Network Timing Software License (per end) (*3)	C000065K040	Yes		
PTP 650S Upgrade Limited Range to Full Range Software License (per end) (*4)	C000065K041		Yes	
PTP 650 8-Port T1/E1 Software License (per END)	C000065K049	Yes	Yes	Yes
PTP 650 Group Access License per END	C000065K053	Yes	Yes	
PTP 650L 10MHz to 30MHz Upgrade License per END	C000065K058			Yes
PTP 650L 30MHz to 45MHz Upgrade License per END	C000065K059			Yes
PTP 650 Second Data Service Support License (*5)	NA	Yes	Yes	Yes

(*1) If the Cambium description contains the words "per ODU" or "per end", then order two upgrades per link.

(*2) Cambium Networks will supply AES upgrades only if there is official permission to export AES encryption to the country of operation.

(*3) This upgrade provides the Synchronous Ethernet and 1588 Transparent Clock features in PTP 650 Integrated or PTP 650 Connectorized ODUs. These features are enabled by default in the PTP 650S Integrated ODU.

(*4) This upgrade provides "Full" (up to 450 Mbps) throughput capability at any range up to 200 km.

(*5) This feature requires a full capacity ODU. If the Second Data Service is not enabled despite full configuration capacity, regenerate the license key using the Cambium license key generator.

ODU accessories

Spare ODU port blanking plugs are available from Cambium Networks (Table 9).

Table 9 ODU accessory part numbers

Cambium description	Cambium part number
PTP 650 Series Blanking Plug Pack (Qty 10)	N000065L036

ODU mounting brackets

The integrated mounting bracket (Figure 8) and connectorized mounting bracket (Figure 9) are used to mount the PTP 650 or PTP 650S or PTP 650L ODUs on poles with diameters in the range 50 to 75 mm (2 to 3 inches). The extended integrated mounting bracket (Figure 10) is used for mounting an integrated or connectorized ODU on poles with a diameter of either 90 mm (3.5 inches) or 115 mm (4.5 inches).

The large diameter extension kit (Figure 11) is be used with the integrated bracket to mount an ODU on a pole with diameter up to 229 mm (9.0 inches). The low profile bracket (Figure 12) is used to mount a PTP 650S or PTP 650L ODU on a pole of diameter 40 mm to 82 mm (1.6 inches to 3.2 inches) or 89 mm to 229 mm ((3.5 inches to 9.0 inches).

Before ordering ODU mounting brackets, be aware of the following:

- Individual integrated ODUs are supplied without a mounting bracket (Table 2).
- Individual connectorized ODUs are supplied with a connectorized mounting bracket (Table 2).
- ODUs in kits are supplied with an integrated or connectorized bracket, as appropriate (Table 3).

If separate ODU mounting brackets are required, order them from Cambium Networks (Table 10).

Figure 8 ODU mounting bracket (integrated)

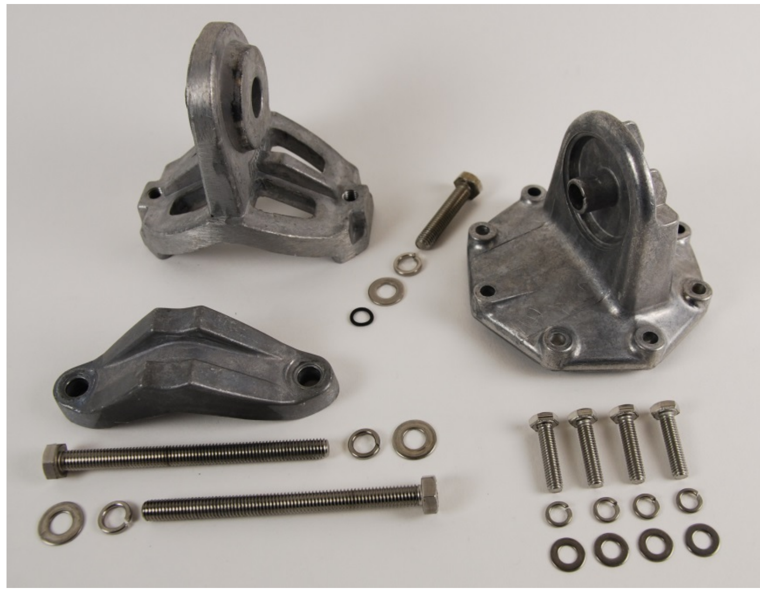


Figure 9 ODU mounting bracket (connectorized)

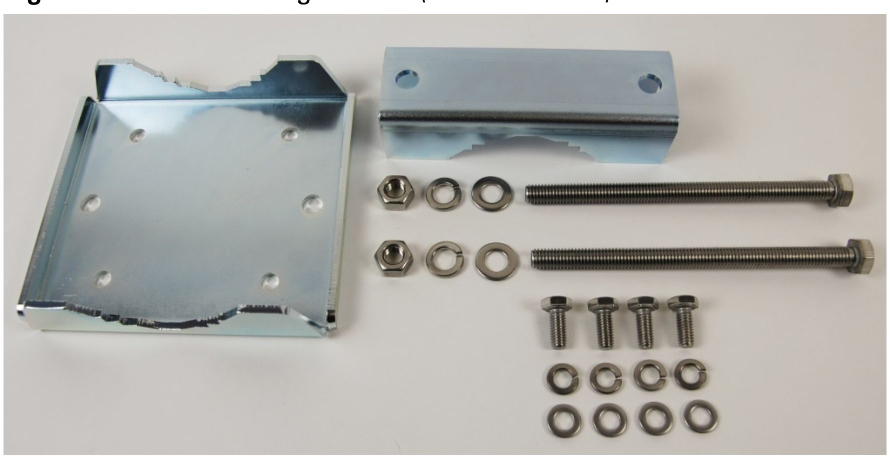


Figure 10 ODU extended integrated mounting bracket

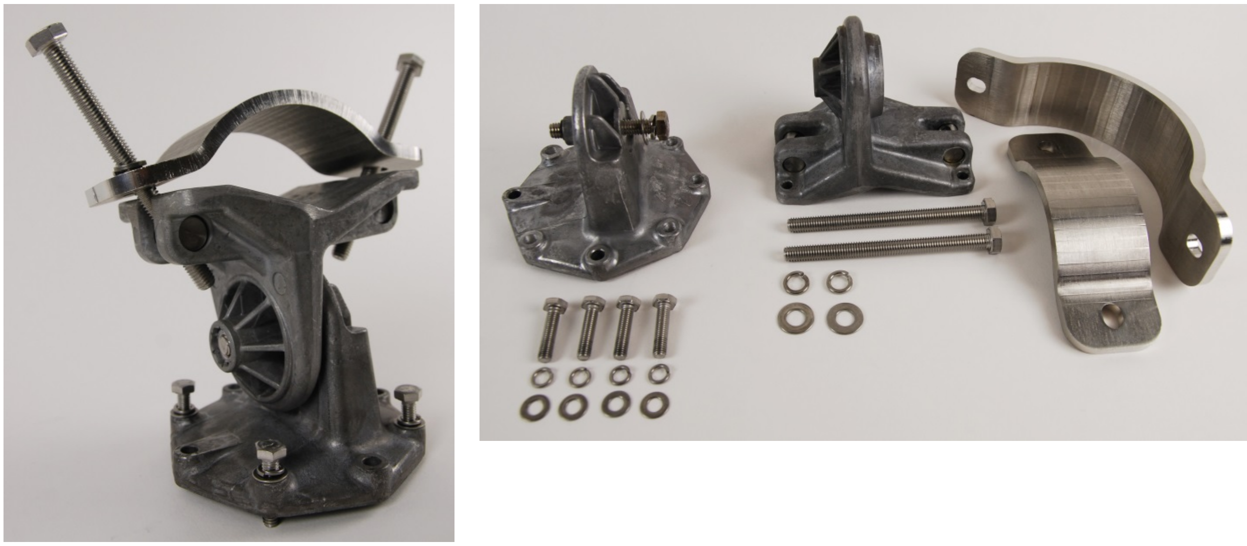


Figure 11 ODU large diameter extension kit

Figure 12 ODU low profile bracket

Table 10 ODU mounting bracket part numbers

Bracket	Pole diameter	ODU variants	Bracket part number
Mounting bracket (integrated)	40 mm to 82 mm (1.6 inches to 3.2 inches)	PTP 650 Integrated PTP 650S Integrated PTP 650L Integrated	N000065L031
Mounting bracket (connectorized)	40 mm to 82 mm (1.6 inches to 3.2 inches)	PTP 650 Connectorized	N000065L032
Extended integrated mounting bracket	89 mm *OR* 114 mm (3.5 inches *OR* 4.5 inches)	PTP 650 Integrated PTP 650S Integrated PTP 650L Integrated PTP 650 Connectorized	N000065L030
Mounting bracket (integrated) with large diameter extension kit	89 mm to 229 mm (3.5 inches to 9.0 inches)	PTP 650 Integrated PTP 650S Integrated PTP 650L Integrated PTP 650 Connectorized	N000065L031 with N000065L042
Low profile bracket	40 mm to 82 mm (1.6 inches to 3.2 inches)	PTP 650S Integrated PTP 650L Integrated	N000065L039
	89 mm to 229 mm (3.5 inches to 9.0 inches)		

The low profile bracket provides elevation adjustment with the PTP 650S Integrated or PTP 650L Integrated ODU of +10° to –5° or +5° to –10°. A larger adjustment range is available using the standard integrated mounting bracket. The connectorized mounting bracket does not provide elevation adjustment.

ODU interfaces

The PSU, AUX and SFP ports are on the rear of the integrated and connectorized ODUs (Figure 13). These interfaces are described in

Table 11. Each of the PSU, AUX and SFP ports can be configured to disable Ethernet traffic, connected in a local loop-back between any two ports, or selected to the following services:

- Data Service
- Second Data Service
- Management Service
- Local Management Service

Figure 13 ODU rear interfaces

Table 11 ODU rear interfaces

Port name	Connector	Interface	Description
Main PSU	RJ45	POE input	Proprietary power over Ethernet (POE).
		100/1000BASE-T Ethernet	Management and/or data.
AUX	RJ45	100/1000BASE-T Ethernet with 802.3at compliant POE out capability	Auxiliary Ethernet port which can be used, for example, to connect and power a video camera or wireless access point. Data and Management Services.
SFP	SFP	Optical or Copper Gigabit Ethernet	Data and Management Services. Plug-in SFP module must be purchased separately.

The front of the connectorized ODU (Figure 14) provides N type female connectors for RF cable interfaces to antennas with horizontal (H) and vertical (V) polarization.

Figure 14 Connectorized ODU antenna interfaces

ODU specifications

The PTP 650 ODU conforms to the specifications listed in Table 12.

Table 12 ODU specifications

Category	Specification
Dimensions	23 dBi integrated: 371 mm (14.6 in) x 371 mm (14.6 in) x 81 mm (3.2 in) 19 dBi integrated: Connectorized: 204 mm (8.0 in) x 318 mm (12.5 in) x 90 mm (3.5 in)
Weight	23 dBi integrated: 4.1 Kg (9.0 lbs) including bracket 19 dBi integrated: Connectorized: 3.1 Kg (6.8 lbs) including bracket
Temperature	-40°C (-40°F) to +60°C (140°F)
Wind loading	200 mph (323 kph) maximum. See ODU wind loading on page 3-14.
Humidity	100% condensing
Liquid and particle ingress	IP66, IP67
UV exposure	10 year operational life (UL746C test evidence)
Static discharge	See Electromagnetic compatibility (EMC) compliance on page 4-22

Power supply units (PSU)

PSU description

The PSU is an indoor unit that is connected to the ODU and network terminating equipment using Cat5e cable with RJ45 connectors. It is also plugged into an AC or DC power supply so that it can inject Power over Ethernet (POE) into the ODU. Choose one of the following PSUs (Figure 15):

- The AC Power Injector (left) accepts an AC input supply only.
- The AC+DC Enhanced Power Injector (right) accepts both AC and DC input, tolerates a greater temperature range, and allows the ODU to support a device on the Aux port, such as a video camera or wireless access point. It also allows the ODU to provide DC power output.

Figure 15 PSU 650 PSUs

Caution

The PSU ODU ports are designed to connect only to PTP 650 ODUs, PTP-SYNC units, NIDUs or LPUs. Do not connect any other equipment, as damage may occur.

Do not connect the PIDU Plus PTP 300/500/600 Series to the PTP 650 ODU or LPU.

Note

Each of the ODU kits listed in Table 3 includes one PSU and one US or EU line cord as stated in the Cambium description.

PSU part numbers

Order PSUs and (for AC power) line cords from Cambium Networks (Table 13).

Table 13 Power supply component part numbers

Cambium description	Cambium part number
PTP 650 AC Power Injector	N000065L001
PTP 650 AC+DC Enhanced Power Injector	C000065L002
US Line Cord Fig 8	N000065L003
UK Line Cord Fig 8	N000065L004
EU Line Cord Fig 8	N000065L005
Australia Line Cord Fig 8	N000065L006

AC Power Injector interfaces

The AC Power Injector interfaces are shown in Figure 16 and described in Table 14.

Figure 16 AC Power Injector interfaces

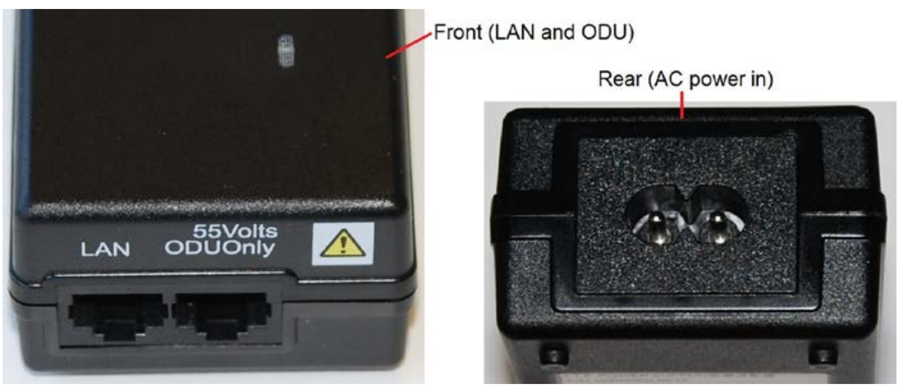


Table 14 AC Power Injector interface functions

Interface	Function
AC power in	AC power input (main supply).
ODU	RJ45 socket for connecting Cat5e cable to ODU.
LAN	RJ45 socket for connecting Cat5e cable to network.
Power (green) LED	Power supply detection

AC+DC Enhanced Power Injector interfaces

The AC+DC Enhanced Power Injector interfaces are shown in Figure 17 and described in Table 15.

Figure 17 AC+DC Enhanced Power Injector interfaces

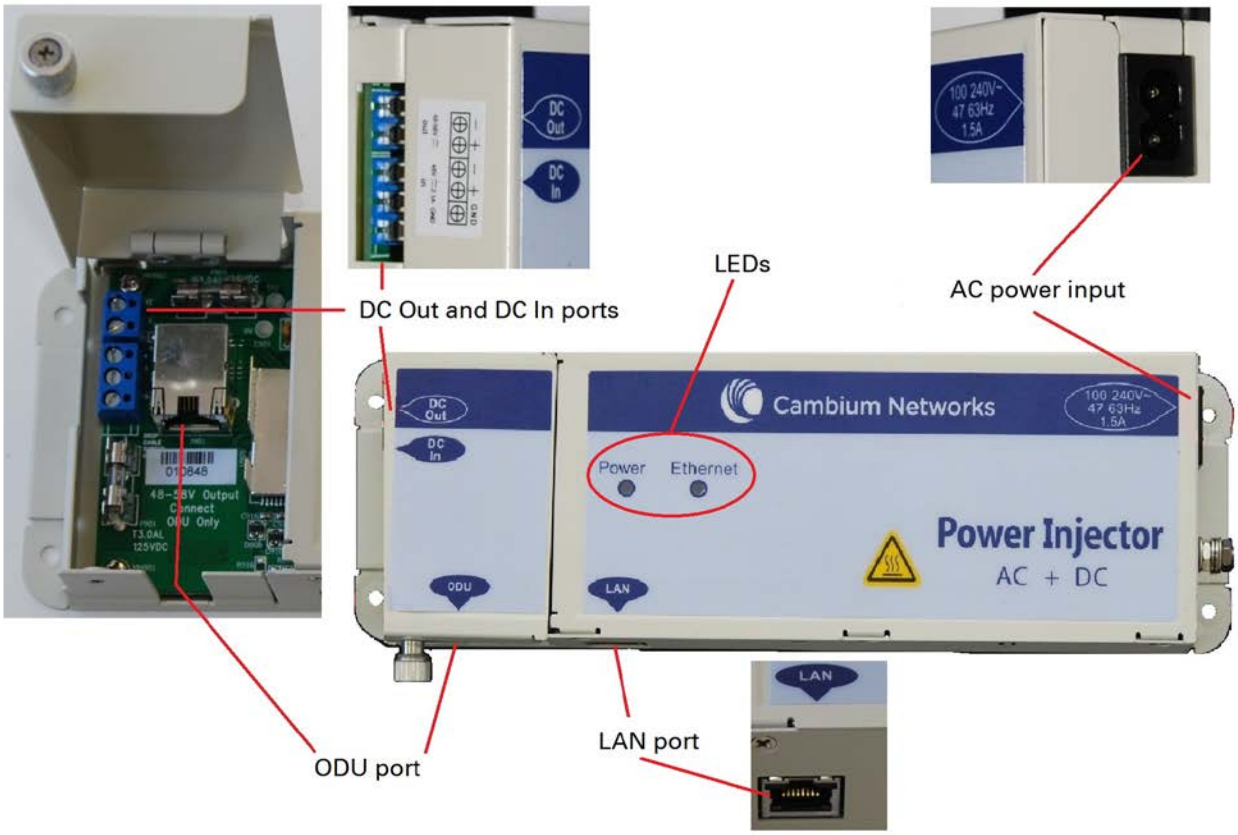


Table 15 AC+DC Enhanced Power Injector interface functions

Interface	Function
100-240V 47-63Hz 1.5A	AC power input (main supply).
DC In	Alternative DC power supply input.
DC Out	DC power output to a second PSU (for power supply redundancy) or to a NIDU.
ODU	RJ45 socket for connecting Cat5e cable to ODU.
LAN	RJ45 socket for connecting Cat5e cable to network.
Power (green) LED	Power supply detection
Ethernet (yellow) LED	Ethernet traffic detection

PSU specifications

The PTP 650 AC Power Injector conforms to the specifications listed in Table 16.

The PTP 650 AC+DC Enhanced Power Injector conforms to the specifications listed in Table 17.

Table 16 AC Power Injector specifications

Category	Specification
Dimensions	137 mm (5.4 in) x 56 mm (2.2 in) x 38 mm (1.5 in)
Weight	0.240 Kg (0.5 lbs)
Temperature	0°C to +40°C
Humidity	90% non-condensing
Waterproofing	Not waterproof
Altitude	Sea level to 5000 meters (16000 ft)
AC Input	Min 90 V AC, 57 – 63 Hz, max 264 V AC, 47 – 53 Hz.
DC output voltage to the ODU	55V +/- 5%
AC connector	IEC-320-C8
Efficiency	Better than 85%, efficiency level 'V'
Over Current Protection	Hiccup current limiting, trip point set between 120% to 150% of full load current
Hold up time	At least 10 milliseconds

Table 17 AC+DC Enhanced Power Injector specifications

Category	Specification
Dimensions	250 mm (9.75 in) x 40 mm (1.5 in) x 80 mm (3 in)
Weight	0.864 Kg (1.9 lbs)
Temperature	-40°C (-40°F) to +60°C (140°F)
Humidity	0 to 90% non-condensing
Waterproofing	Not waterproof
AC Input	90-264 V AC, 47-60 Hz
Alternative DC Input	37-60 V DC
DC Output Voltage	For mains input: 58 V, +2V, -0V For DC input: Output voltage at maximum rated output current, not more than 1.5 V below the DC input voltage. Maximum length of DC output cable: 3 meters.
AC Input connector	IEC-320-C8
DC Output current	1.7A
Efficiency	Better than 84%
Over Current Protection	Hiccup current limiting, trip point set between 120% to 150% of full load current
Hold up time	At least 20 milliseconds
Power factor	Better than 0.9

Antennas and antenna cabling

Antenna requirements

Each connectorized ODU requires one external antenna (normally dual-polar), or if spatial diversity is required, each ODU requires two antennas. These antennas are not supplied by Cambium Networks.

For connectorized units operating in the USA or Canada 4.9 GHz, 5.1 GHz, 5.2 GHz, 5.4 GHz or 5.8 GHz bands, choose external antennas from those listed in FCC and IC approved antennas on page 2-23. Do not install any other antennas. For links in other countries, the listed antennas are advisory, not mandatory.

Note

To determine when to install connectorized units and to calculate their impact on link performance and regulatory limits, see Planning for connectorized units on page 3-29.

RF cable and connectors

RF cable of generic type LMR-400 is required for connecting the ODU to the antenna. N type male connectors are required for connecting the RF cables to the connectorized ODU. Two connectors are required per ODU. Use weatherproof connectors, preferably ones that are supplied with adhesive lined heat shrink sleeves that are fitted over the interface between the cable and connector. Order CNT-400 RF cable and N type male connectors from Cambium Networks (Table 18).

Table 18 RF cable and connector part numbers

Cambium description	Cambium part number
50 Ohm Braided Coaxial Cable - 75 meter	30010194001
50 Ohm Braided Coaxial Cable - 500 meter	30010195001
RF Connector, N, Male, Straight for CNT-400 Cable	09010091001

Note

To select the correct connectors for the antenna end of the RF cable, refer to the antenna manufacturer's instructions.

Antenna accessories

Connectorized ODUs require the following additional components:

- Cable grounding kits: Order one cable grounding kit for each grounding point on the antenna cables. Refer to Lightning protection unit (LPU) and grounding kit

PTP 650 LPUs provide transient voltage surge suppression for PTP 650 installations. Each PSU or Aux drop cable requires two LPUs, one near the ODU and the other near the linked device, usually at the building entry point (Table 28).

Table 28 LPU and grounding kit contents

Lightning protection units (LPUs) LPU grounding point nuts and washers 	ODU to top LPU drop cable (600 mm) EMC strain relief cable glands 
U-bolts, nuts and washers for mounting LPUs 	ODU to top LPU ground cable (M6-M6) 

Bottom LPU ground cable (M6-M10)	ODU to ground cable (M6-M10
	

One LPU and grounding kit (Table 28) is required for the PSU drop cable connection to the ODU. If the ODU is to be connected to an auxiliary device, one additional LPU and grounding kit is required for the Aux drop cable. Order the kits from Cambium Networks (Table 29).

Table 29 LPU and grounding kit part number

Cambium description	Cambium part number
PTP 650 LPU and Grounding Kit (One Kit Per End)	C000065L007

Note

PTP 650 LPUs are not suitable for installation on SFP copper Cat5e Ethernet interfaces. For SFP drop cables, obtain suitable surge protectors from a specialist supplier.

SFP optical Ethernet interfaces do not require surge protectors.

- on page 2-41 for specifications and part numbers.
- Self-amalgamating and PVC tape: Order these items to weatherproof the RF connectors.
- Lightning arrestors: When the connectorized ODU is mounted indoors, lightning arrestors (not PTP 650 LPUs) are required for protecting the antenna RF cables at building entry. One arrestor is required per antenna cable. One example of a compatible lightning arrestor is the Polyphaser LSXL-ME or LSXL (not supplied by Cambium Networks).

FCC and IC approved antennas

For connectorized units operating in the USA or Canada, choose external antennas from Table 19 (4.9 GHz), Table 20 (5.1 GHz – USA only), Table 21 (5.2 GHz), Table 22 (5.4 GHz) or Table 23 (5.8 GHz). These are approved by the FCC for use with the product and are constrained by the following limits for single- or dual-polarization parabolic dish antennas:

- 4.9 GHz – 36.0 dBi per polarization or antenna.
- 5.1 GHz - 34.5 dBi per polarization or antenna.

- 5.2 GHz - 34.9 dBi per polarization or antenna.
- 5.4 GHz - 34.9 dBi per polarization or antenna.
- 5.8 GHz - 37.7 dBi per polarization or antenna.

Details of the regulatory bands are provided in Table 55 on page 3-22.

Caution

Antennas not included in these tables are strictly prohibited for use with the PTP 650 in the specified bands.

Caution

This radio transmitter (IC certification number 109AO-50650) has been approved by Industry Canada to operate with the antenna types listed below with the maximum permissible gain and required antenna impedance for each antenna type indicated. Antenna types not included in this list, having a gain greater than the maximum gain indicated for that type, are strictly prohibited for use with this device.

Antennes approuvées par la FCC et IC

Pour les unités sans antenne intégrée destinées aux Etats-Unis ou au Canada, choisissez des antennes externes dans la Table 19 (4.9 GHz), Table 20 (5.1 GHz – Etats-Unis), Table 21 (5.2 GHz), Table 22 (5.4 GHz) ou la Table 23 (5.8 GHz). Celles-ci sont approuvées par la FCC pour une utilisation avec le produit et sont limitées pour les antennes paraboliques a polarisation simple ou double comme suit:

- 4.9 GHz – 36.0 dBi par polarisation ou l'antenne.
- 5.1 GHz - 34.5 dBi par polarisation ou l'antenne.
- 5.2 GHz - 34.9 dBi par polarisation ou l'antenne.
- 5.4 GHz - 34.9 dBi par polarisation ou l'antenne.
- 5.8 GHz - 37.7 dBi par polarisation ou l'antenne.

Attention

Les antennes qui ne sont pas listées dans ces tableaux sont strictement interdites d'utilisation avec le PTP 650 dans les bandes spécifiées

Attention

Le présent émetteur radio (Numéro de certification IC 109AO-50650) a été approuvé par Industrie Canada pour fonctionner avec les types d'antenne énumérés ci-dessous et ayant un gain admissible maximal et l'impédance requise pour chaque type d'antenne. Les types d'antenne non inclus dans cette liste, ou dont le gain est supérieur au gain maximal indiqué, sont strictement interdits pour l'exploitation de l'émetteur.

Table 19 Antennas permitted for deployment in USA/Canada – 4.9 GHz

Manufacturer	Antenna type	Nominal gain (dBi)	Parabolic dish	Cambium part number
RadioWaves	Radio Waves 6-foot Parabolic, SP6-5.2	36	Y	
RadioWaves	Radio Waves 6-foot Dual-Pol Parabolic, SPD6-5.2	35.7	Y	RDH4506B
RadioWaves	Radio Waves 6-foot Dual-Pol Parabolic, SPD6-4.7	35.6	Y	RDH4502A
RadioWaves	Radio Waves 6-foot Parabolic, SP6-4.7	35.6	Y	
RadioWaves	Radio Waves 6-foot Dual-Pol Parabolic, HPD6-5.2NS	35.6	Y	RDH4511B
RadioWaves	Radio Waves 6-foot Dual-Pol Parabolic, HPD6-4.7	35.4	Y	RDH4515A

Manufacturer	Antenna type	Nominal gain (dBi)	Parabolic dish	Cambium part number
RadioWaves	Radio Waves 4-foot Dual-Pol Parabolic, SPD4-4.7	32.6	Y	RDH4501A
RadioWaves	Radio Waves 4-foot Parabolic, SP4-4.7	32.6	Y	N000000D002A
RadioWaves	Radio Waves 4-foot Dual-Pol Parabolic, SPD4-5.2	32.6	Y	RDH4505B
RadioWaves	Radio Waves 4-foot Dual-Pol Parabolic, HPD4-5.2NS	32.6	Y	RDH4510B
RadioWaves	Radio Waves 4-foot Parabolic, SP4-5.2	32.6	Y	
RadioWaves	Radio Waves 4-foot Dual-Pol Parabolic, HPD4-4.7	32.4	Y	RDH4516A
RadioWaves	Radio Waves 3-foot Dual-Pol Parabolic, HPD3-5.2NS	32.3	Y	RDH4509B
RadioWaves	Radio Waves 3-foot Parabolic, SP3-5.2	31.4	Y	RDH4513B
RadioWaves	Radio Waves 3-foot Dual-Pol Parabolic, SPD3-5.2	31.1	Y	RDH4504B
RadioWaves	Radio Waves 3-foot Dual-Pol Parabolic, SPD3-4.7	30	Y	RDH4500A
RadioWaves	Radio Waves 3-foot Parabolic, SP3-4.7	30	Y	N000000D005A
RadioWaves	Radio Waves 3-foot Dual-Pol Parabolic, HPD3-4.7	29.8	Y	RDH4517A
Gabriel	Gabriel 2.5-foot Standard Dual QuickFire Parabolic, QFD2.5-49-N	29.7	Y	
Gabriel	Gabriel 2.5-foot Standard QuickFire Parabolic, QF2.5-49-N	29.7	Y	
RadioWaves	Radio Waves 2-foot Parabolic, SP2-5.2	29	Y	
RadioWaves	Radio Waves 2-foot Dual-Pol Parabolic, HPD2-5.2NS	28.8	Y	RDH4508B
MTI	MTI 2-foot Dual-Pol, MT-486013/N	28.5	Y	
MTI	MTI 2-foot Single-Pol, MT-466009/N	28.5	Y	
RadioWaves	Radio Waves 2-foot Dual-Pol Parabolic, SPD2-5.2	28.1	Y	RDH4503B
Gabriel	Gabriel 2-foot Standard Dual QuickFire Parabolic, QFD2-49-N	27.7	Y	

Manufacturer	Antenna type	Nominal gain (dBi)	Parabolic dish	Cambium part number
Gabriel	Gabriel 2-foot Standard QuickFire Parabolic, QF2-49-N	27.7	Y	
RadioWaves	Radio Waves 2-foot Dual-Pol Parabolic, SPD2-4.7	26.6	Y	RDH4499A
RadioWaves	Radio Waves 2-foot Parabolic, SP2-4.7	26.6	Y	N000000D001A
RadioWaves	Radio Waves 2-foot Dual-Pol Parabolic, HPD2-4.7	26.4	Y	RDH4518A
MARS	MA-WS54-50R Flat Plate (Dual-Pol)	23	N	Integrated
Andrew	Andrew 1.25-foot Flat Panel Dual, UBXP375-4-1	21	N	
Andrew	Andrew 1-foot Flat Panel Single, UBP300-4-1	21	N	
RadioWaves	Radio Waves 1-foot Dual-Pol Parabolic, HPLPD1-4.7	20.8	Y	RDH4519A
MARS	Small Form Factor Flat Plate Antenna MA-EM56-DP19CM.	19	N	Integrated
Laird	60 Sectorized (Dual-Pol)	17	N	
Laird	90 Sectorized (Dual-Pol)	17	N	
RadioWaves	Radio Waves 90 Sectorized (Dual-Pol), SEC-47D-90-16	16	N	N000000D003
KPPA	OMNI (Dual-Pol)	13	N	
RadioWaves	Radio Waves Omni Dual-Pol, OMND-4.8-9	9	N	

Table 20 Antennas permitted for deployment in USA only – 5.1 GHz

Manufacturer	Antenna type	Nominal gain (dBi)	Parabolic dish	Cambium part number
Andrew	Andrew 4-foot Dual-Pol Parabolic, PX4F-52	34.5	Y	RDG4453B
Andrew	Andrew 4-foot Parabolic, P4F-52	34.5	Y	RDH4524A
Gabriel	Gabriel 4-foot Standard QuickFire Parabolic, QF4-52-N	34.4	Y	
Gabriel	Gabriel 4-foot Standard QuickFire Parabolic, QF4-52-N-RK	34.4	Y	
RadioWaves	Radio Waves 4-foot Parabolic, SP4-5.2	34.4	Y	
Gabriel	Gabriel 4-foot Standard Dual QuickFire Parabolic, QFD4-52-N	34.3	Y	
Gabriel	Gabriel 4-foot Standard Dual QuickFire Parabolic, QFD4-52-N-RK	34.3	Y	
RadioWaves	Radio Waves 4-foot Dual-Pol Parabolic, HPD4-5.2NS	34.3	Y	RDH4510B
Gabriel	Gabriel 4-foot High Performance QuickFire Parabolic, HQF4-52-N	34	Y	
RadioWaves	Radio Waves 4-foot Dual-Pol Parabolic, SPD4-5.2	34	Y	RDH4505B
Gabriel	Gabriel 4-foot High Performance Dual QuickFire Parabolic, HQFD4-52-N	33.9	Y	
RFS	RFS 4-foot HP Parabolic, SDF4-52AN	33.5	Y	
RFS	RFS 4-foot Parabolic, SPF4-52AN	33.5	Y	
Andrew	Andrew 3-foot Dual-Pol Parabolic, PX3F-52	33	Y	
Andrew	Andrew 3-foot Parabolic, P3F-52	33	Y	
StellaDoradus	StellaDoradus 4-foot Single-Pol, 56 PSD113	32	Y	
RadioWaves	Radio Waves 3-foot Dual-Pol Parabolic, HPD3-5.2NS	31.9	Y	RDH4509B
RadioWaves	Radio Waves 3-foot Parabolic, SP3-5.2	31	Y	RDH4513B
Gabriel	Gabriel 2.5-foot Standard QuickFire Parabolic, QF2.5-52-N	30.8	Y	

Manufacturer	Antenna type	Nominal gain (dBi)	Parabolic dish	Cambium part number
Gabriel	Gabriel 2.5-foot Standard Dual QuickFire Parabolic, QFD2.5-52-N	30.7	Y	
RadioWaves	Radio Waves 3-foot Dual-Pol Parabolic, SPD3-5.2	30.7	Y	RDH4504B
Andrew	Andrew 2-foot Dual-Pol Parabolic, PX2F-52	29	Y	
Andrew	Andrew 2-foot Parabolic, P2F-52	29	Y	
MTI	MTI 3-foot Single-Pol, MT-487000/N	28.6	Y	
RadioWaves	Radio Waves 2-foot Parabolic, SP2-5.2	28.6	Y	
RadioWaves	Radio Waves 2-foot Dual-Pol Parabolic, HPD2-5.2NS	28.4	Y	RDH4508B
Gabriel	Gabriel 2-foot Standard QuickFire Parabolic, QF2-52-N	28.1	Y	
Gabriel	Gabriel 2-foot Standard QuickFire Parabolic, QF2-52-N-RK	28.1	Y	
MTI	MTI 2-foot Dual-Pol, MT-486013/N	28.1	Y	
MTI	MTI 2-foot Single-Pol, MT-466009/N	28.1	Y	
Gabriel	Gabriel 2-foot Standard Dual QuickFire Parabolic, QFD2-52-N	28	Y	
Gabriel	Gabriel 2-foot Standard Dual QuickFire Parabolic, QFD2-52-N-RK	28	Y	
Gabriel	Gabriel 2-foot High Performance QuickFire Parabolic, HQF2-52-N	27.8	Y	
Gabriel	Gabriel 2-foot High Performance Dual QuickFire Parabolic, HQFD2-52-N	27.7	Y	
RadioWaves	Radio Waves 2-foot Dual-Pol Parabolic, SPD2-5.2	27.7	Y	RDH4503B
RFS	RFS 2-foot Parabolic, SPF2-52AN	27.5	Y	
StellaDoradus	StellaDoradus 2-foot Single-Pol, 56 PSD61	26.6	Y	
MARS	MA-WS54-50R Flat Plate (Dual-Pol)	23	N	Integrated
MTI	MTI 15 inch Dual-Pol Flat Panel, MT-485025/NVH	23	N	

Manufacturer	Antenna type	Nominal gain (dBi)	Parabolic dish	Cambium part number
Andrew	Andrew 1.25-foot Flat Panel Dual, UBXP375-4-1	20.6	N	
Andrew	Andrew 1-foot Flat Panel Single, UBP300-4-1	20.6	N	
MARS	Small Form Factor Flat Plate Antenna Part # MA-EM56-DP19CM.	19	N	Integrated
Laird	60 Sectorized (Dual-Pol)	17	N	
Laird	90 Sectorized (Dual-Pol)	17	N	
KPPA	OMNI (Dual-Pol)	13	N	

Table 21 Antennas permitted for deployment in USA/Canada – 5.2 GHz

Manufacturer	Antenna type	Nominal gain (dBi)	Parabolic dish	Cambium part number
Andrew	Andrew 4-foot Dual-Pol Parabolic, PX4F-52	34.9	Y	RDG4453B
Andrew	Andrew 4-foot Parabolic, P4F-52	34.9	Y	RDH4524A
Gabriel	Gabriel 4-foot Standard QuickFire Parabolic, QF4-52-N	34.8	Y	
Gabriel	Gabriel 4-foot Standard QuickFire Parabolic, QF4-52-N-RK	34.8	Y	
RadioWaves	Radio Waves 4-foot Parabolic, SP4-5.2	34.8	Y	
Gabriel	Gabriel 4-foot Standard Dual QuickFire Parabolic, QFD4-52-N	34.7	Y	
Gabriel	Gabriel 4-foot Standard Dual QuickFire Parabolic, QFD4-52-N-RK	34.7	Y	
RadioWaves	Radio Waves 4-foot Dual-Pol Parabolic, HPD4-5.2NS	34.7	Y	RDH4510B
Gabriel	Gabriel 4-foot High Performance QuickFire Parabolic, HQF4-52-N	34.4	Y	
RadioWaves	Radio Waves 4-foot Dual-Pol Parabolic, SPD4-5.2	34.4	Y	RDH4505B
Gabriel	Gabriel 4-foot High Performance Dual QuickFire Parabolic, HQFD4-52-N	34.3	Y	

Manufacturer	Antenna type	Nominal gain (dBi)	Parabolic dish	Cambium part number
RFS	RFS 4-foot HP Parabolic, SDF4-52AN	33.9	Y	
RFS	RFS 4-foot Parabolic, SPF4-52AN	33.9	Y	
Andrew	Andrew 3-foot Dual-Pol Parabolic, PX3F-52	33.4	Y	
Andrew	Andrew 3-foot Parabolic, P3F-52	33.4	Y	
StellaDoradus	StellaDoradus 4-foot Single-Pol, 56 PSD113	32.4	Y	
RadioWaves	Radio Waves 3-foot Dual-Pol Parabolic, HPD3-5.2NS	32.3	Y	RDH4509B
RadioWaves	Radio Waves 3-foot Parabolic, SP3-5.2	31.4	Y	RDH4513B
Gabriel	Gabriel 2.5-foot Standard QuickFire Parabolic, QF2.5-52-N	31.2	Y	
Gabriel	Gabriel 2.5-foot Standard Dual QuickFire Parabolic, QFD2.5-52-N	31.1	Y	
RadioWaves	Radio Waves 3-foot Dual-Pol Parabolic, SPD3-5.2	31.1	Y	RDH4504B
Andrew	Andrew 2-foot Dual-Pol Parabolic, PX2F-52	29.4	Y	
Andrew	Andrew 2-foot Parabolic, P2F-52	29.4	Y	
MTI	MTI 3-foot Single-Pol, MT-487000/N	29	Y	
RadioWaves	Radio Waves 2-foot Parabolic, SP2-5.2	29	Y	
RadioWaves	Radio Waves 2-foot Dual-Pol Parabolic, HPD2-5.2NS	28.8	Y	RDH4508B
Gabriel	Gabriel 2-foot Standard QuickFire Parabolic, QF2-52-N	28.5	Y	
Gabriel	Gabriel 2-foot Standard QuickFire Parabolic, QF2-52-N-RK	28.5	Y	
MTI	MTI 2-foot Dual-Pol, MT-486013/N	28.5	Y	
MTI	MTI 2-foot Single-Pol, MT-466009/N	28.5	Y	
Gabriel	Gabriel 2-foot Standard Dual QuickFire Parabolic, QFD2-52-N	28.4	Y	
Gabriel	Gabriel 2-foot Standard Dual QuickFire Parabolic, QFD2-52-N-RK	28.4	Y	

Manufacturer	Antenna type	Nominal gain (dBi)	Parabolic dish	Cambium part number
Gabriel	Gabriel 2-foot High Performance QuickFire Parabolic, HQF2-52-N	28.2	Y	
Gabriel	Gabriel 2-foot High Performance Dual QuickFire Parabolic, HQFD2-52-N	28.1	Y	
RadioWaves	Radio Waves 2-foot Dual-Pol Parabolic, SPD2-5.2	28.1	Y	RDH4503B
RFS	RFS 2-foot Parabolic, SPF2-52AN	27.9	Y	
StellaDoradus	StellaDoradus 2-foot Single-Pol, 56 PSD61	27	Y	
MARS	MA-WS54-50R Flat Plate (Dual-Pol)	23	N	Integrated
MTI	MTI 15 inch Dual-Pol Flat Panel, MT-485025/NVH	23	N	
Andrew	Andrew 1.25-foot Flat Panel Dual, UBXP375-4-1	21	N	
Andrew	Andrew 1-foot Flat Panel Single, UBP300-4-1	21	N	
MARS	Small Form Factor Flat Plate Antenna MA-EM56-DP19CM.	19	N	Integrated
Laird	60 Sectorized (Dual Pol)	17	N	
Laird	90 Sectorized (Dual Pol)	17	N	
KPPA	OMNI (Dual-Pol)	13	N	

Table 22 Antennas permitted for deployment in USA/Canada – 5.4 GHz

Manufacturer	Antenna type	Nominal gain (dBi)	Parabolic dish	Cambium part number
Andrew	Andrew 4-foot Dual-Pol Parabolic, PX4F-52	34.9	Y	RDG4453B
Andrew	Andrew 4-foot Parabolic, P4F-52	34.9	Y	RDH4524A
Gabriel	Gabriel 4-foot Standard QuickFire Parabolic, QF4-52-N	34.8	Y	
Gabriel	Gabriel 4-foot Standard QuickFire Parabolic, QF4-52-N-RK	34.8	Y	
RadioWaves	Radio Waves 4-foot Parabolic, SP4-5.2	34.8	Y	

Manufacturer	Antenna type	Nominal gain (dBi)	Parabolic dish	Cambium part number
Gabriel	Gabriel 4-foot Standard Dual QuickFire Parabolic, QFD4-52-N	34.7	Y	
Gabriel	Gabriel 4-foot Standard Dual QuickFire Parabolic, QFD4-52-N-RK	34.7	Y	
RadioWaves	Radio Waves 4-foot Dual-Pol Parabolic, HPD4-5.2NS	34.7	Y	RDH4510B
Gabriel	Gabriel 4-foot High Performance QuickFire Parabolic, HQF4-52-N	34.4	Y	
RadioWaves	Radio Waves 4-foot Dual-Pol Parabolic, SPD4-5.2	34.4	Y	RDH4505B
Gabriel	Gabriel 4-foot High Performance Dual QuickFire Parabolic, HQFD4-52-N	34.3	Y	
RFS	RFS 4-foot HP Parabolic, SDF4-52AN	33.9	Y	
RFS	RFS 4-foot Parabolic, SPF4-52AN	33.9	Y	
Andrew	Andrew 3-foot Dual-Pol Parabolic, PX3F-52	33.4	Y	
Andrew	Andrew 3-foot Parabolic, P3F-52	33.4	Y	
StellaDoradus	StellaDoradus 4-foot Single-Pol, 56 PSD113	32.4	Y	
RadioWaves	Radio Waves 3-foot Dual-Pol Parabolic, HPD3-5.2NS	32.3	Y	RDH4509B
RadioWaves	Radio Waves 3-foot Parabolic, SP3-5.2	31.4	Y	RDH4513B
Gabriel	Gabriel 2.5-foot Standard QuickFire Parabolic, QF2.5-52-N	31.2	Y	
Gabriel	Gabriel 2.5-foot Standard Dual QuickFire Parabolic, QFD2.5-52-N	31.1	Y	
RadioWaves	Radio Waves 3-foot Dual-Pol Parabolic, SPD3-5.2	31.1	Y	RDH4504B
Andrew	Andrew 2-foot Dual-Pol Parabolic, PX2F-52	29.4	Y	
Andrew	Andrew 2-foot Parabolic, P2F-52	29.4	Y	
MTI	MTI 3-foot Single-Pol, MT-487000/N	29	Y	
RadioWaves	Radio Waves 2-foot Parabolic, SP2-5.2	29	Y	
RadioWaves	Radio Waves 2-foot Dual-Pol Parabolic, HPD2-5.2NS	28.8	Y	RDH4508B

Manufacturer	Antenna type	Nominal gain (dBi)	Parabolic dish	Cambium part number
Gabriel	Gabriel 2-foot Standard QuickFire Parabolic, QF2-52-N	28.5	Y	
Gabriel	Gabriel 2-foot Standard QuickFire Parabolic, QF2-52-N-RK	28.5	Y	
MTI	MTI 2-foot Dual-Pol, MT-486013/N	28.5	Y	
MTI	MTI 2-foot Single-Pol, MT-466009/N	28.5	Y	
Gabriel	Gabriel 2-foot Standard Dual QuickFire Parabolic, QFD2-52-N	28.4	Y	
Gabriel	Gabriel 2-foot Standard Dual QuickFire Parabolic, QFD2-52-N-RK	28.4	Y	
Gabriel	Gabriel 2-foot High Performance QuickFire Parabolic, HQF2-52-N	28.2	Y	
Gabriel	Gabriel 2-foot High Performance Dual QuickFire Parabolic, HQFD2-52-N	28.1	Y	
RadioWaves	Radio Waves 2-foot Dual-Pol Parabolic, SPD2-5.2	28.1	Y	RDH4503B
RFS	RFS 2-foot Parabolic, SPF2-52AN	27.9	Y	
StellaDoradus	StellaDoradus 2-foot Single-Pol, 56 PSD61	27	Y	
MARS	MA-WS54-50R Flat Plate (Dual-Pol)	23	N	Integrated
MTI	MTI 15 inch Dual-Pol Flat Panel, MT-485025/NVH	23	N	
Andrew	Andrew 1.25-foot Flat Panel Dual, UBXP375-4-1	21	N	
Andrew	Andrew 1-foot Flat Panel Single, UBP300-4-1	21	N	
MARS	Small Form Factor Flat Plate Antenna MA-EM56-DP19CM.	19	N	Integrated
Laird	60 Sectorized (Dual-Pol)	17	N	
Laird	90 Sectorized (Dual-Pol)	17	N	
KPPA	OMNI (Dual-Pol)	13	N	

Table 23 Antennas permitted for deployment in USA/Canada – 5.8 GHz

Manufacturer	Antenna type	Nominal gain (dBi)	Parabolic dish	Cambium part number
Gabriel	Gabriel 6-foot Standard Dual QuickFire Parabolic, QFD6-52-N	37.7	Y	
Gabriel	Gabriel 6-foot Standard QuickFire Parabolic, QF6-52-N	37.7	Y	
RadioWaves	Radio Waves 6-foot Dual-Pol Parabolic, HPD6-5.2NS	37.7	Y	RDH4511B
RadioWaves	Radio Waves 6-foot Parabolic, SP6-2/5	37.7	Y	
RadioWaves	Radio Waves 6-foot Parabolic, SP6-5.2	37.7	Y	
Andrew	Andrew 6-foot Dual-Pol Parabolic, PX6F-52	37.6	Y	
Andrew	Andrew 6-foot Parabolic, P6F-52	37.6	Y	RDH4525A
RadioWaves	Radio Waves 6-foot Dual-Pol Parabolic, SPD6-5.2	37.5	Y	RDH4506B
Gabriel	Gabriel 6-foot High Performance QuickFire Parabolic, HQF6-52-N	37.4	Y	
RFS	RFS 6-foot HP Parabolic, SDF6-52AN	37.4	Y	
RFS	RFS 6-foot Parabolic, SPF6-52AN	37.4	Y	
Gabriel	Gabriel 6-foot High Performance Dual QuickFire Parabolic, HQFD6-52-N	37.3	Y	
Andrew	Andrew 4-foot Dual-Pol Parabolic, PX4F-52	34.9	Y	RDG4453B
Andrew	Andrew 4-foot Parabolic, P4F-52	34.9	Y	RDH4524A
Gabriel	Gabriel 4-foot Standard QuickFire Parabolic, QF4-52-N	34.8	Y	
Gabriel	Gabriel 4-foot Standard QuickFire Parabolic, QF4-52-N-RK	34.8	Y	
RadioWaves	Radio Waves 4-foot Parabolic, SP4-5.2	34.8	Y	
Gabriel	Gabriel 4-foot Standard Dual QuickFire Parabolic, QFD4-52-N	34.7	Y	
Gabriel	Gabriel 4-foot Standard Dual QuickFire Parabolic, QFD4-52-N-RK	34.7	Y	
RadioWaves	Radio Waves 4-foot Dual-Pol Parabolic, HPD4-5.2NS	34.7	Y	RDH4510B
RadioWaves	Radio Waves 4-foot Parabolic, SP4-2/5	34.6	Y	

Manufacturer	Antenna type	Nominal gain (dBi)	Parabolic dish	Cambium part number
Gabriel	Gabriel 4-foot High Performance QuickFire Parabolic, HQF4-52-N	34.4	Y	
RadioWaves	Radio Waves 4-foot Dual-Pol Parabolic, SPD4-5.2	34.4	Y	RDH4505B
Gabriel	Gabriel 4-foot High Performance Dual QuickFire Parabolic, HQFD4-52-N	34.3	Y	
RFS	RFS 4-foot HP Parabolic, SDF4-52AN	33.9	Y	
RFS	RFS 4-foot Parabolic, SPF4-52AN	33.9	Y	
Andrew	Andrew 3-foot Dual-Pol Parabolic, PX3F-52	33.4	Y	
Andrew	Andrew 3-foot Parabolic, P3F-52	33.4	Y	
StellaDoradus	StellaDoradus 4-foot Single-Pol, 56 PSD113	32.4	Y	
RadioWaves	Radio Waves 3-foot Dual-Pol Parabolic, HPD3-5.2NS	32.3	Y	RDH4509B
RadioWaves	Radio Waves 3-foot Parabolic, SP3-2/5	31.4	Y	
RadioWaves	Radio Waves 3-foot Parabolic, SP3-5.2	31.4	Y	RDH4513B
Gabriel	Gabriel 2.5-foot Standard QuickFire Parabolic, QF2.5-52-N	31.2	Y	
Gabriel	Gabriel 2.5-foot Standard Dual QuickFire Parabolic, QFD2.5-52-N	31.1	Y	
RadioWaves	Radio Waves 3-foot Dual-Pol Parabolic, SPD3-5.2	31.1	Y	RDH4504B
Andrew	Andrew 2-foot Dual-Pol Parabolic, PX2F-52	29.4	Y	
Andrew	Andrew 2-foot Parabolic, P2F-52	29.4	Y	
MTI	MTI 3-foot Single-Pol, MT-487000/N	29	Y	
RadioWaves	Radio Waves 2-foot Parabolic, SP2-5.2	29	Y	
RadioWaves	Radio Waves 2-foot Dual-Pol Parabolic, HPD2-5.2NS	28.8	Y	RDH4508B
Gabriel	Gabriel 2-foot Standard QuickFire Parabolic, QF2-52-N	28.5	Y	
Gabriel	Gabriel 2-foot Standard QuickFire Parabolic, QF2-52-N-RK	28.5	Y	
MTI	MTI 2-foot Dual-Pol, MT-486013/N	28.5	Y	

Manufacturer	Antenna type	Nominal gain (dBi)	Parabolic dish	Cambium part number
MTI	MTI 2-foot Single-Pol, MT-466009/N	28.5	Y	
Gabriel	Gabriel 2-foot Standard Dual QuickFire Parabolic, QFD2-52-N	28.4	Y	
Gabriel	Gabriel 2-foot Standard Dual QuickFire Parabolic, QFD2-52-N-RK	28.4	Y	
RadioWaves	Radio Waves 2-foot Parabolic, SP2-2/5	28.3	Y	
Gabriel	Gabriel 2-foot High Performance QuickFire Parabolic, HQF2-52-N	28.2	Y	
Gabriel	Gabriel 2-foot High Performance Dual QuickFire Parabolic, HQFD2-52-N	28.1	Y	
RadioWaves	Radio Waves 2-foot Dual-Pol Parabolic, SPD2-5.2	28.1	Y	RDH4503B
RFS	RFS 2-foot Parabolic, SPF2-52AN	27.9	Y	
StellaDoradus	StellaDoradus 2-foot Single-Pol, 56 PSD61	27	Y	
MARS	MA-WS54-50R Flat Plate (Dual-Pol)	23	N	Integrated
MTI	MTI 15 inch Dual-Pol Flat Panel, MT-485025/NVH	23	N	
RFS	RFS 1-foot Flat Panel, MA0528-23AN	23	N	
Andrew	Andrew 1.25-foot Flat Panel Dual, UBXP375-4-1	21	N	
Andrew	Andrew 1-foot Flat Panel Single, UBP300-4-1	21	N	
MARS	Small Form Factor Flat Plate Antenna MA-EM56-DP19CM.	19	N	Integrated
Laird	60 Sectorized (Dual-Pol)	17	N	
Laird	90 Sectorized (Dual-Pol)	17	N	
KPPA	OMNI (Dual-Pol)	13	N	

Ethernet cabling

Ethernet standards and cable lengths

All configurations require a copper Ethernet connection from the ODU (PSU port) to the PSU. Advanced configurations may also require one or both of the following:

- A copper Ethernet connection from the ODU (Aux port) to an auxiliary device.
- An optical or copper Ethernet connection from the ODU (SFP port) to network terminating equipment or a linked ODU.

Table 24 specifies, for each type of PSU and power supply, the maximum permitted PSU drop cable length.

Table 25 specifies, for Aux and copper SFP interfaces, the Ethernet standards supported and the maximum permitted drop cable lengths.

Note

For optical SFP interfaces, refer to SFP module kits on page 2-45 for details of the Ethernet standards supported and maximum permitted cable lengths.

Table 24 PSU drop cable length restrictions

Type of PSU installed	Power supply to PSU	Ethernet supported (*1)	Power output to auxiliary device	Maximum cable length (*2)
AC Power Injector	AC mains	100BASE-TX 1000BASE-T	No	100 m (330 ft)
AC+DC Enhanced power injector	AC mains	No (*3)	No	300 m (990 ft)
	48 V dc	No (*3)	No	300 m (990 ft)
	AC mains	100BASE-TX 1000BASE-T	Yes	100 m (330 ft)
	48 V dc	100BASE-TX 1000BASE-T	Yes	100 m (330 ft)

(*1) 10BASE-T is not supported by PTP 650.

(*2) Maximum length of Ethernet cable from ODU to network terminating equipment via PSU.

(*3) Ethernet is provided via optical SFP interface.

Table 25 Aux and copper SFP Ethernet standards and cable length restrictions

ODU drop cable	Power over Ethernet	Ethernet supported (*1)	Maximum cable length (*2)
Aux – auxiliary device	POE to auxiliary device	100BASE-TX 1000BASE-T	100 m (330 ft)
	None	100BASE-TX	100 m (330 ft)
SFP (copper) – linked device	None	100BASE-TX	100 m (330 ft)

(*1) 10BASE-T is not supported by PTP 650.

(*2) Maximum length of Ethernet cable from the ODU to the linked device.

Outdoor copper Cat5e Ethernet cable

For copper Cat5e Ethernet connections from the ODU to the PSU, LPUs and other devices, use Cat5e cable that is gel-filled and shielded with copper-plated steel, for example Superior Essex type BBDGe. This is known as "drop cable" (Figure 18).

Caution

Always use Cat5e cable that is gel-filled and shielded with copper-plated steel. Alternative types of drop cable are not supported by Cambium Networks.

Order Superior Essex type BBDGe cable from Cambium Networks (Table 26). Other lengths of this cable are available from Superior Essex.

Figure 18 Outdoor drop cable

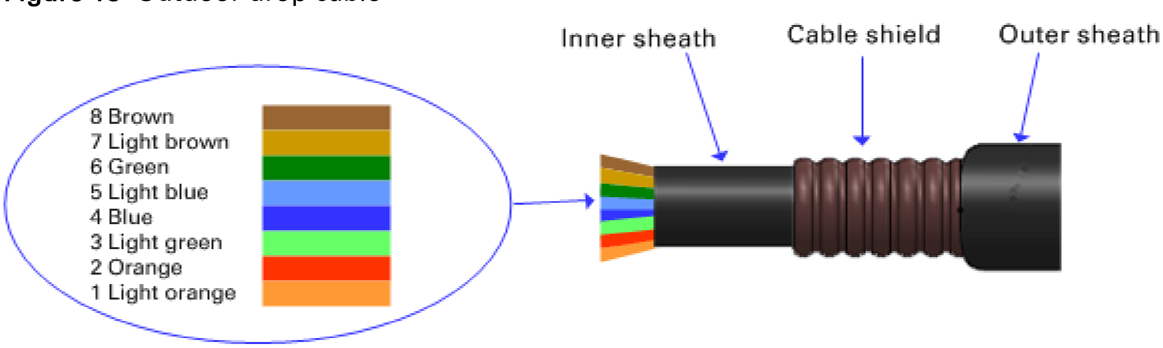


Table 26 Drop cable part numbers

Cambium description	Cambium part number
1000 ft Reel Outdoor Copper Clad CAT5E	WB3175
328 ft (100 m) Reel Outdoor Copper Clad CAT5E	WB3176

Cable grounding kit

Copper drop cable shields must be bonded to the grounding system in order to prevent lightning creating a potential difference between the structure and cable, which could cause arcing, resulting in fire risk and damage to equipment. Optical cables do not require grounding.

One grounding kit (Figure 19) is required for each grounding point on the PSU, Aux and copper SFP drop cables. Order cable grounding kits from Cambium Networks (Figure 28).

Caution

To provide adequate protection, all grounding cables must be a minimum size of 10 mm^2 csa (8AWG), preferably 16 mm^2 csa (6AWG), or 25 mm^2 csa (4AWG).

Figure 19 Cable grounding kit

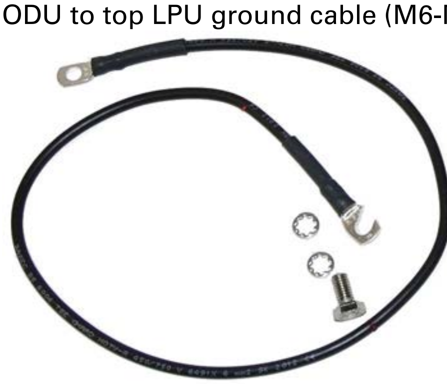
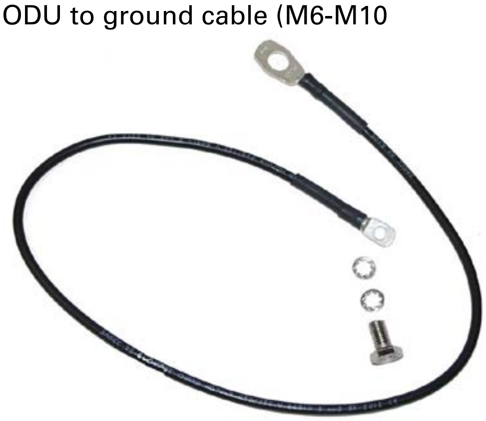
Table 27 Cable grounding kit part numbers

Cambium description	Cambium part number
Cable Grounding Kits For 1/4" And 3/8" Cable	01010419001

Lightning protection unit (LPU) and grounding kit

PTP 650 LPUs provide transient voltage surge suppression for PTP 650 installations. Each PSU or Aux drop cable requires two LPUs, one near the ODU and the other near the linked device, usually at the building entry point (Table 28).

Table 28 LPU and grounding kit contents

Lightning protection units (LPUs) LPU grounding point nuts and washers 	ODU to top LPU drop cable (600 mm) EMC strain relief cable glands 
U-bolts, nuts and washers for mounting LPUs 	ODU to top LPU ground cable (M6-M6) 
Bottom LPU ground cable (M6-M10) 	ODU to ground cable (M6-M10 

One LPU and grounding kit (Table 28) is required for the PSU drop cable connection to the ODU. If the ODU is to be connected to an auxiliary device, one additional LPU and grounding kit is required for the Aux drop cable. Order the kits from Cambium Networks (Table 29).

Table 29 LPU and grounding kit part number

Cambium description	Cambium part number
PTP 650 LPU and Grounding Kit (One Kit Per End)	C000065L007

Note

PTP 650 LPUs are not suitable for installation on SFP copper Cat5e Ethernet interfaces. For SFP drop cables, obtain suitable surge protectors from a specialist supplier.

SFP optical Ethernet interfaces do not require surge protectors.

LPU for GPS drop cables

When a GPS receiver is the timing reference source for PTP-SYNC (optional), an LPU must be installed near the point at which the GPS drop cable enters the building. A single LPU from the PTP 650 LPU and Grounding Kit (C000065L007) (Table 28) is suitable. Alternatively, the single LPU kit for PTP 250/300/500 (Figure 20) could be used.

Figure 20 LPU kit used for GPS receiver drop cables

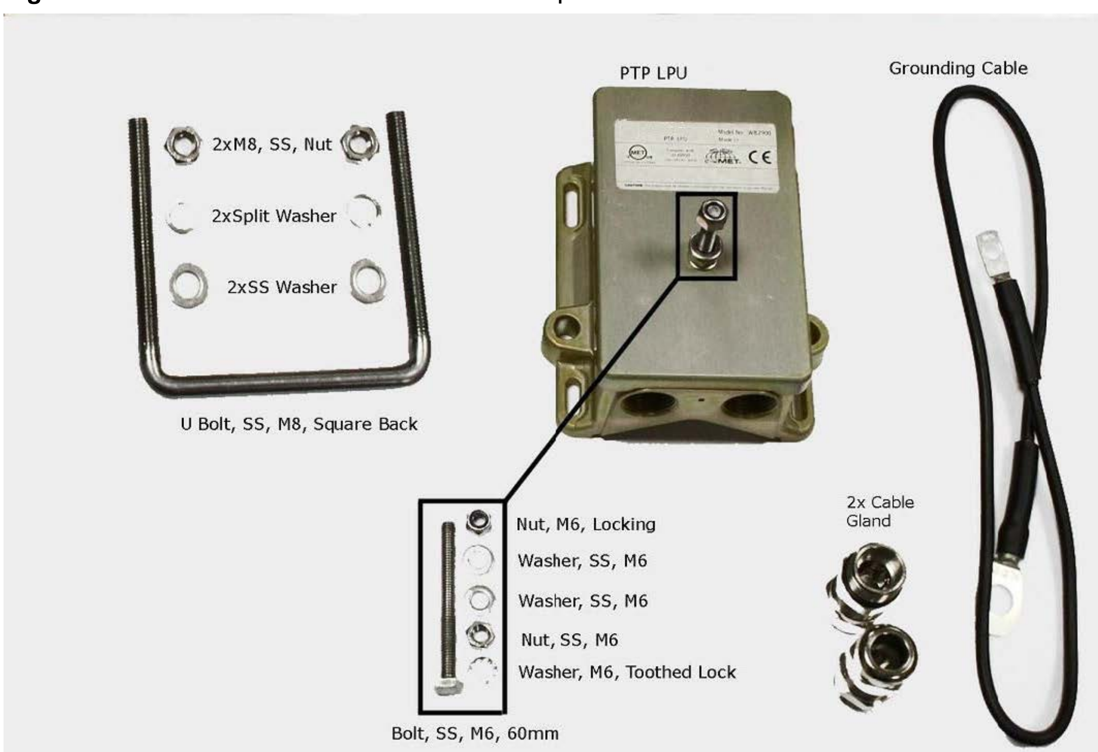


Table 30 LPU and grounding kit part number – Use with GPS receiver drop cable only

Cambium description	Cambium part number
LPU End Kit PTP 250/300/500	WB2978

RJ45 connectors and spare glands

RJ45 connectors are required for plugging Cat5e cables into ODUs, LPUs, PSUs and other devices. Order RJ45 connectors and crimp tool from Cambium Networks (Table 31).

Note

The RJ45 connectors and crimp tool listed in Table 31 work with Superior Essex type BBDGe cable (as supplied by Cambium Networks). They may not work with other types of cable.

The ODU is supplied with one environmental sealing gland for the drop cable. However, this is not suitable when surge protection is required: EMC glands must be used instead. EMC strain relief cable glands (quantity 5) are included in the LPU and grounding kit (Figure 21). These are identified with a black sealing nut. If extra glands are required, order them from Cambium Networks (in packs of 10) (Table 31).

One long EMC strain relief gland (Figure 25) is included in each SFP module kit. This is longer than the standard cable gland as it must house an SFP module plugged into the ODU.

Figure 21 Cable gland

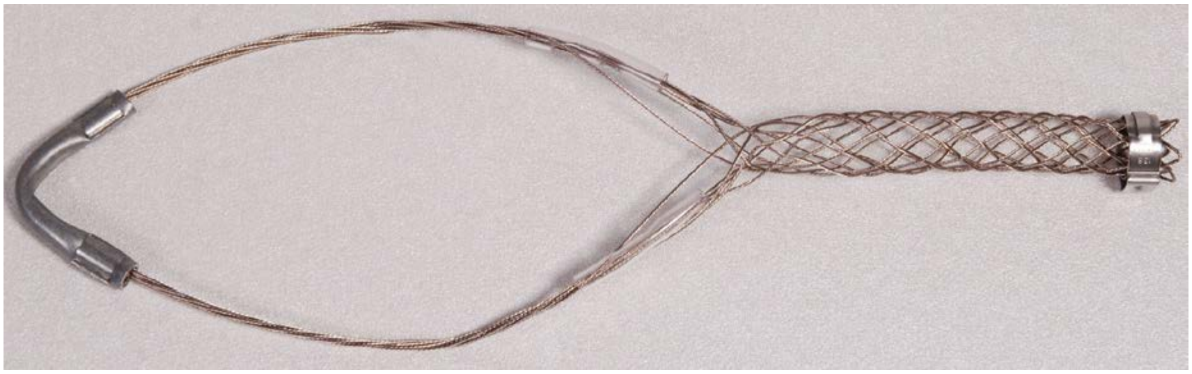
Table 31 RJ45 connector and spare gland part numbers

Cambium description	Cambium part number
Tyco/AMP, Mod Plug RJ45, 100 pack	WB3177
Tyco/AMP Crimp Tool	WB3211
RJ-45 Spare Grounding Gland - PG16 size (Qty. 10)	N000065L033

Cable hoisting grip

One or more grips are required for hoisting the drop cable up to the ODU without damaging the gland or RJ45 plug (Figure 22). They are not supplied by Cambium Networks.

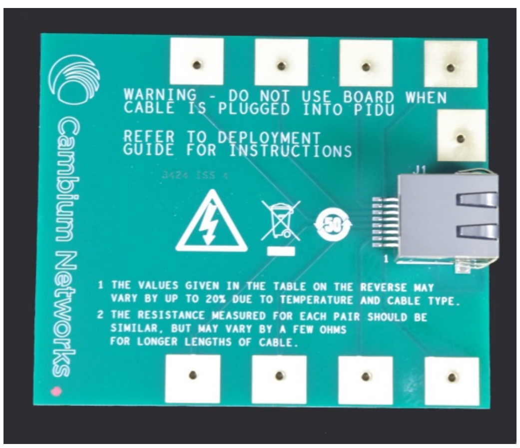
Figure 22 Cable hoisting grip



Drop cable tester

The drop cable tester is an optional item for testing the resistances between the RJ45 pins of the drop cable (Figure 23). Order it by completing the order form on the support website (see Contacting Cambium Networks on page 1).

Figure 23 Drop cable tester



Indoor Cat5e cable

To connect the PSU to network terminating equipment, use indoor Cat5e cable. The ODU network connection implements automatic MDI/MDI-X sensing and pair swapping, allowing connection to networking equipment that requires cross-over cables (MDI-X networks) or straight-through cables (MDI Networks).

SFP module kits

SFP module kits allow connection of a PTP 650 Series ODU to a network over a Gigabit Ethernet interface in one of the following full-duplex modes:

- Optical Gigabit Ethernet: 1000BASE-LX or 1000BASE-SX
- Copper Gigabit Ethernet: 100BASE-TX or 1000BASE-T

Order SFP module kits from Cambium Networks (Table 32).

Table 32 SFP module kit part numbers

Cambium description	Cambium part number
PTP 650 Optical 1000BASE-LX Ethernet SFP Module	C000065L008
PTP 650 Optical 1000BASE-SX Ethernet SFP Module	C000065L009
PTP 650 Twisted Pair 1000BASE-T Ethernet SFP Module	C000065L010

To compare the capabilities of the two optical SFP modules, refer to Table 33 and Table 34.

Table 33 Optical 1000BASE-LX Ethernet SFP Module (part number C000065L008)

Core/ cladding (microns)	Mode	Bandwidth at 1310 nm (MHz/km)	Maximum length of optical interface	Insertion loss (dB)
62.5/125	Multi	500	550 m (1800 ft)	1.67
50/125	Multi	400	550 m (1800 ft)	0.07
50/125	Multi	500	550 m (1800 ft)	1.19
10/125	Single	N/A	5000 m (16400 ft)	0.16

Table 34 Optical 1000BASE-SX Ethernet SFP Module (part number C000065L009)

Core/ cladding (microns)	Mode	Bandwidth at 850 nm (MHz/km)	Maximum length of optical interface	Insertion loss (dB)
62.5/125	Multi	160	220 m (720 ft)	2.38
62.5/125	Multi	200	275 m (900 ft)	2.6
50/125	Multi	400	500 m (1640 ft)	3.37
50/125	Multi	500	550 m (1800 ft)	3.56

The upgrade kits contain the following components:

- Optical or copper SFP transceiver module (Figure 24)
- Long EMC strain relief cable gland (Figure 25)
- The *PTP 650 Series SFP Interface Upgrade Guide*
- License key instructions and unique Access Key

Figure 24 Optical or copper SFP transceiver module

Figure 25 Long cable gland

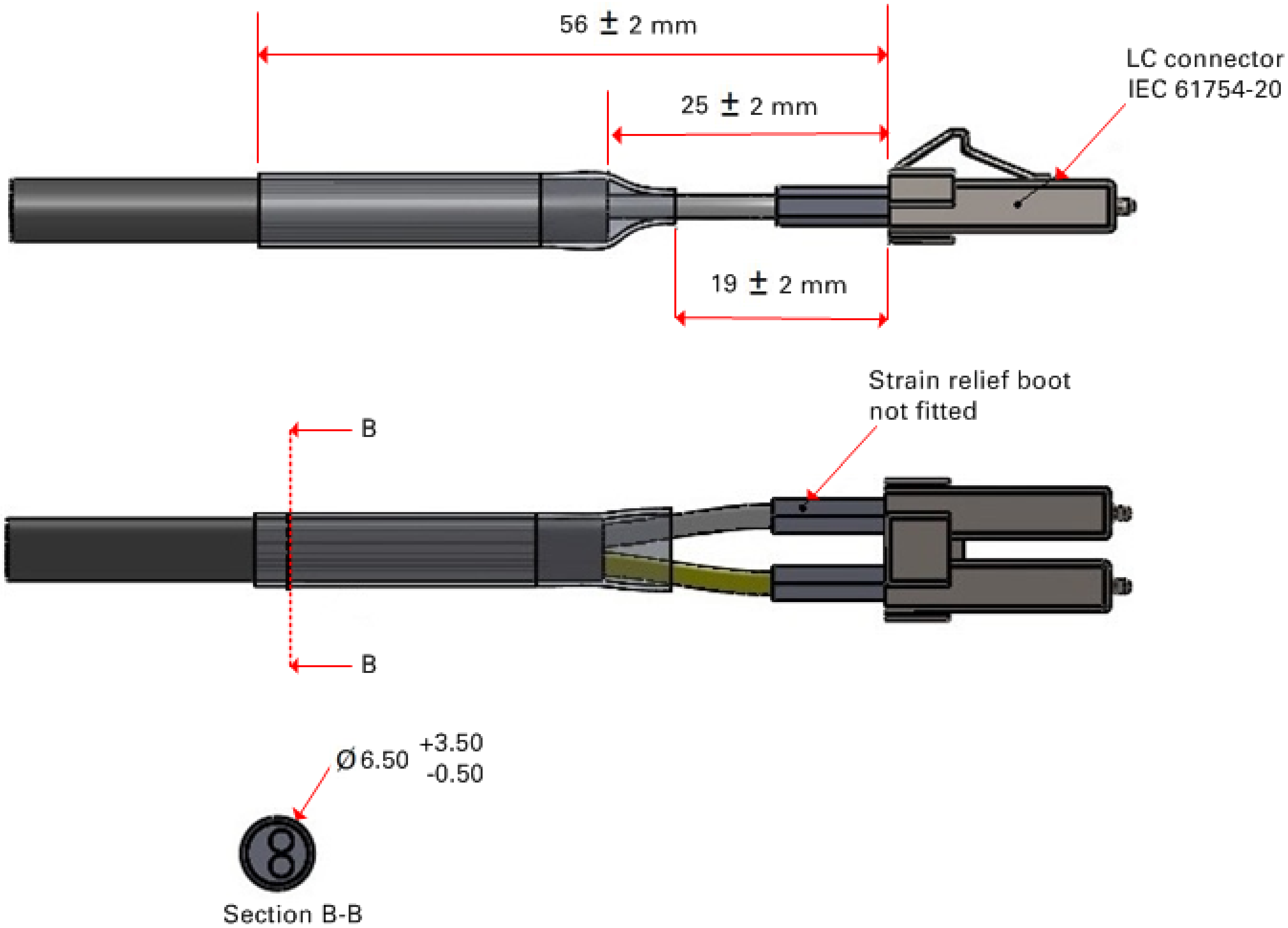
Note

PTP 650 does not support the Synchronous Ethernet or 1588 Transparent Clock features using copper SFP transceivers.

Optical cable and connectors

Order an optical cable with LC connectors from a specialist fabricator, quoting the specification shown in Figure 26. It must be the correct length to connect the ODU to the other device. LC connectors should be supplied with dust caps to prevent dust build up.

Figure 26 Optical optic cable and connector specification



PTP-SYNC unit

PTP-SYNC unit description

The PTP-SYNC unit (Figure 27) is an optional component. It is required when TDD synchronization is implemented using PTP-SYNC. It measures the difference between the TDD frame timing and a 1 Hz timing reference, and signals this time difference to the ODU. For more information on this feature, refer to TDD synchronization on page 1-19.

The PTP-SYNC unit is powered using standard power-over-Ethernet from the PSU. One PTP-SYNC unit is required for each synchronized link.

The PTP-SYNC unit is a compact indoor unit mounted on a wall, shelf or (using an optional rack mounting adaptor) in a standard 19 inch rack (Figure 28).

Figure 27 PTP-SYNC kit

Figure 28 PTP-SYNC rack mounting adapter

PTP-SYNC part numbers

Order PTP-SYNC kits and associated components from Cambium Networks (Table 35).

Table 35 PTP-SYNC component part numbers

Cambium description	Cambium part number
PTP-SYNC kit	WB3665
PTP800 CMU / PTP-SYNC 19” rack mount installation kit	WB3486

The PTP-SYNC kit contains:

- 1 x PTP-SYNC unit
- 1 x M4 pan screw
- 2 x M4 washers
- 2 x M3 (6mm) torx drive screws
- 1 x lug for unit ground (cable not supplied)
- 1 x Cat5e cable (length 1 meter)
- Installation guide

If the 1 meter Cat5e cable supplied with the PTP-SYNC kit is not long enough, order a longer length of Cat5e cable, up to 2 meters long.

The PTP-SYNC rack mount kit contains:

- 1 x rack bracket
- 8 x M3 washers
- 8 x M3 screws
- 1 x rack mount blank plate
- 8 x M5 nuts
- 8 x M5 washers
- 2 x rack handles

PTP-SYNC unit interfaces

The PTP-SYNC front panel is illustrated in Figure 29. The annotated interfaces are described in Table 36 and Table 37.

Figure 29 PTP-SYNC front panel

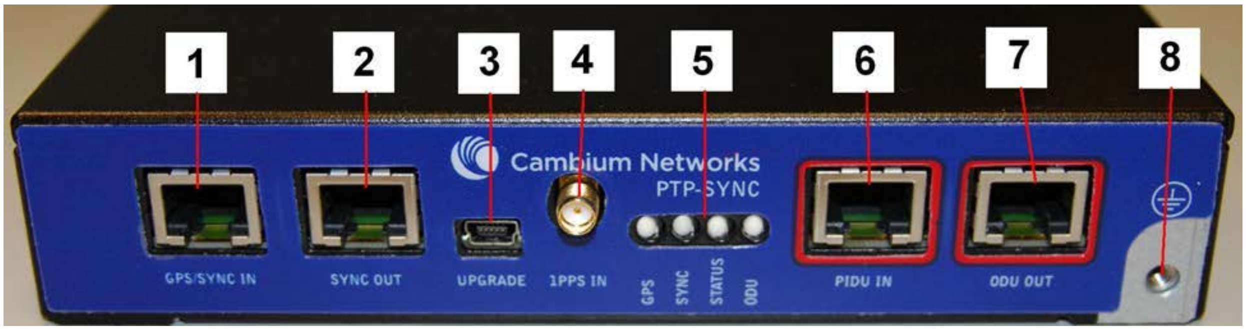


Table 36 PTP-SYNC interface functions

#	Description	Function
1	GPS/SYNC IN	Input from GPS receiver or from the daisy-chained SYNC OUT signal of another PTP-SYNC.
2	SYNC OUT	Output to daisy-chained PTP-SYNC units.
3	USB	Input for software upgrades. Contact Cambium for instructions.
4	1PPS IN	Coaxial alternative to GPS/SYNC IN. Peak input voltage must not exceed 5 V.
5	LED bank	LEDs and their functions are described in Table 37.
6	PIDU IN	Input from PSU.
7	ODU OUT	Output to ODU.
8	Ground stud	For connecting to a ground point.

Table 37 PTP-SYNC LED functions

LED	Function
GPS	GPS satellite data detection.
SYNC	SYNC OUT port data detection.
STATUS	Power and satellite lock detection.
ODU	ODU signal detection.

For a full list of LED states and fault-finding actions, refer to Testing PTP-SYNC on page 8-15.

PTP-SYNC specifications

The PTP-SYNC unit conforms to the specifications listed in Table 38, Table 39 and Table 40.

Table 38 PTP-SYNC unit physical specifications

Category	Specification
Dimensions	Width excluding ears 174 mm (6.69 in) Width including ears 196 mm (7.54 in) Height 31.5 mm (1.21 in) Depth 79 mm (3.04 in)
Weight	0.485 Kg (1.1 lbs)

Table 39 PTP-SYNC unit environmental specifications

Category	Specification
Temperature	-40°C (-40°F) to +60°C (140°F) Suitable for use indoors, or outdoors within a weatherproofed cabinet.
Humidity	0 to 95% non-condensing
Waterproofing	Not waterproof

Table 40 PTP-SYNC unit electrical specifications

Category	Specification
Power supply	Integrated with PSU
Power consumption	1.5 W max (extra power is required to supply a GPS receiver)

There are two timing inputs to the PTP-SYNC unit: GPS/SYNC IN (RJ-45) (Table 41) and 1PPS IN (SMA) (Table 42).

Table 41 PTP-SYNC unit timing specifications - GPS/SYNC IN (RJ-45)

Category	Specification
Signal type	Differential 1 Hz signal
Common mode range	–7 V to +7 V, relative to GPS/SYNC IN pin 2 (ground)
Maximum differential voltage	±5 V
Threshold	±0.4 V
Impedance	90 ohms to 110 ohms
Pulse width	1 μs to 500 ms
Polarity	Reference edge is when pin 3 (PPSA) is positive with respect to pin 6 (PPSB)

Table 42 PTP-SYNC unit timing specifications - 1PPS IN (SMA)

Category	Specification
Signal type	1 Hz signal
Pulse	Positive pulse, reference edge is rising edge
Maximum voltage	5 V
Threshold	0.4 V to 0.6 V
Input impedance	45 ohms to 55 ohms
Pulse width	1μs to 500ms

The pinouts of the PTP-SYNC unit GPS/SYNC IN port are specified in Table 43.

Table 43 GPS/SYNC IN port pinouts

Pin no.	Connector pinout signal name	Signal description
Pin 1	12VGPS	12 V output to GPS receiver module, 250 mA max
Pin 2	GND	Ground
Pin 3	GPS_1PPSA	1 Hz pulse input
Pin 4	GPS_RXDA	GPS receive data
Pin 5	GPS_RXDB	GPS receive data
Pin 6	GPS_1PPSB	1 Hz pulse input
Pin 7	GPS_TXDA	GPS transmit data
Pin 8	GPS_TXDB	GPS transmit data

Note

The GPS_1PPS, GPS_RXD and GPS_TXD signals conform to International Telecommunication Union (ITU) recommendation V.11 (RS422)

Signal polarities

A 1 PPS timing datum is detected when GPS_1PPSA goes positive relative to GPS_1PPSB. A serial data start bit is detected when GPS_RXDA (or GPS_TXDA) goes positive relative to GPS_RXDB (or GPS_TXDB).

GPS receiver

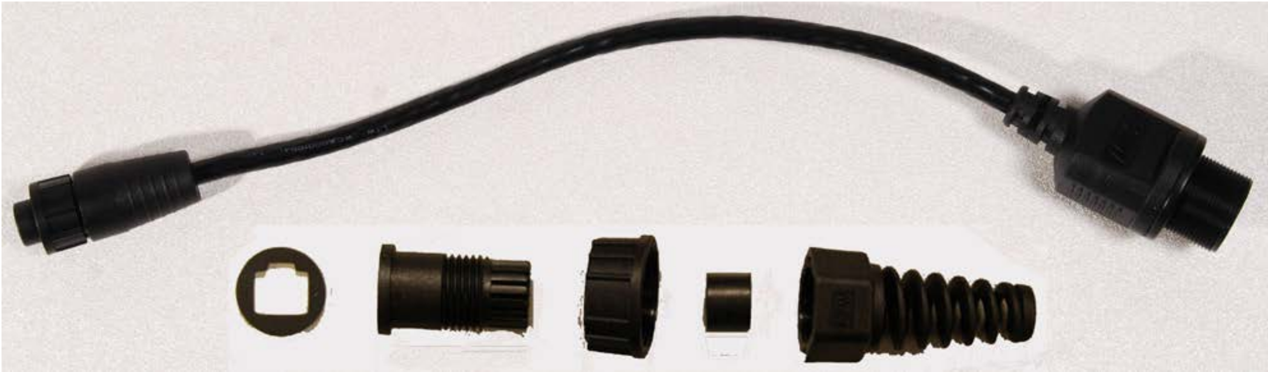
GPS receiver description

The GPS receiver (Figure 30) is an optional timing reference source for PTP-SYNC. It provides a 1 Hz signal, accurately synchronized in frequency and phase across the network.

Figure 30 GPS receiver

The GPS receiver is supplier with a GPS adapter cable kit (Figure 31). This avoids the need to fit a 12 way circular connector to the GPS drop cable. The kit contains one adapter cable (GPS receiver circular connector to RJ45 socket) and one RJ45 plug housing.

Figure 31 GPS adapter cable kit



GPS receiver part numbers

Order GPS receivers and associated components from Cambium Networks (Table 44).

Table 44 GPS receiver component part numbers

Cambium description	Cambium part number
Trimble Acutime™ GG GPS receiver	WB4141
PTP-SYNC <-> Trimble Adapter Cable (*1)	WB3961
1000 ft Reel Outdoor Copper Clad CAT5E (*2)	WB3175
328 ft (100 m) Reel Outdoor Copper Clad CAT5E (*2)	WB3176
Tyco/AMP, Mod Plug RJ45, 100 pack (*3)	WB3177
Tyco/AMP Crimp Tool (*3)	WB3211
Cable Grounding Kits For 1/4" And 3/8" Cable (*4)	01010419001
LPU End Kit PTP 250/300/500 (*5)	WB2978D

(*1) This adapter cable is included with the GPS receiver (part number WB4141).

(*2) Other lengths of this BBDGe drop cable are available from Superior Essex.

(*3) The RJ45 connectors and crimp tool only work with Superior Essex type BBDGe cable.

(*4) One grounding kit is required per drop cable grounding point.

(*5) One LPU kit is required per GPS receiver.

Twelve way circular connector

As an alternative to the GPS adapter cable, the drop cable can be connected directly to the GPS unit via a 12 way circular connector, using the components and tools listed in Table 45.

Table 45 Recommended outdoor connectors for Trimble GPS receiver

Item	Manufacturer	Part number
12 way circular connector	Deutsch	IMC26-2212X
Size 22 crimp socket	Deutsch	6862-201-22278
Crimp tool	Daniels Manufacturing Corp	MH860
Positioner	Daniels Manufacturing Corp	86-5
Insertion / extraction tool	Deutsch	6757-201-2201
Adaptor	Deutsch	IMC2AD
Self amalgamating tape		

Network indoor unit (NIDU)

NIDU description

The NIDU (Figure 32) is an optional component that adds up to eight TDM channels (E1 or T1) to a PTP 650 link. It multiplexes and demultiplexes E1, T1 and Ethernet data over the wireless bridge.

The NIDU is an indoor unit that is connected to the PSU (via the ODU port), to network terminating equipment (via the LAN port) and to up to eight E1 or T1 channels (via the E1/T1 ports) using Cat5e cable with RJ45 connectors. It requires a 48V to 60V DC power supply, either from the PTP 650 AC+DC Enhanced Power Injector, the PTP 800 AC-DC Power Supply Converter or another source.

Figure 32 NIDU

Note

To enable E1 or T1 capability over a PTP 650 link, purchase one access key for each link end from Cambium Networks (ODU capability upgrades on page 2-9).

NIDU part numbers

Order NIDUs and associated components from Cambium Networks (Table 46).

Table 46 NIDU component part numbers

Cambium description	Cambium part number
Network Indoor Unit (One per END)	C000065L043
NIDU - DC Power Connector Spare (10 pack)	C000065L044
CMU/PTP-SYNC/NIDU 19inch Rack Mount Installation Kit	WB3486
PTP 800 AC-DC Power Supply Converter (*)	WB3622

(*) Optional DC power supply for the NIDU.

NIDU interfaces

The NIDU interfaces are shown in Figure 33 and described in Table 47.

Figure 33 NIDU interfaces

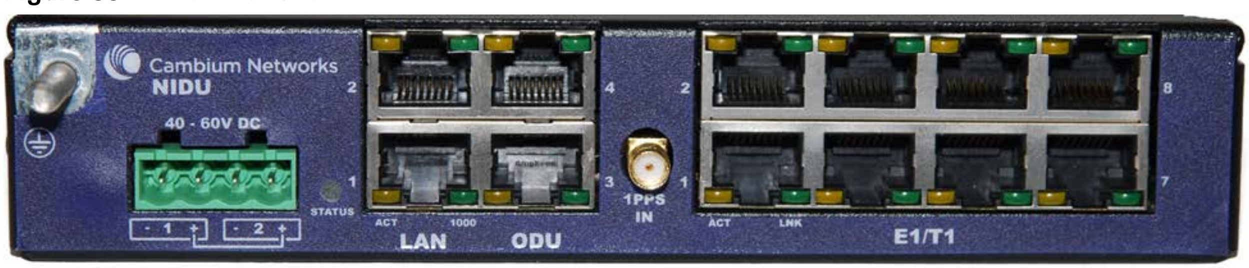


Table 47 NIDU interface functions

Interface	Function
40 – 60V DC	Port 1: DC power input from an independent source or from the AC+DC Enhanced Power Injector. Port 2: Backup power input. The kit includes one four-pin DC connector.
LAN	Gigabit Ethernet RJ45 socket for connecting to network terminating equipment. Use LAN port 1; port 2 is provided for future expansion.
ODU	Gigabit Ethernet RJ45 socket for connecting to the PSU (and so on to the ODU). Use ODU port 3; port 4 is provided for future expansion.
E1/T1	RJ45 sockets for connecting to up to eight E1 or T1 channels. Allocate ports to channels in ascending order (1 to 8).
1PPS IN	Not used. Provided for future expansion.

For a full list of LED states and fault-finding actions, refer to Testing a TDM link on page 8-18.

NIDU specifications

The NIDU conforms to the specifications listed in Table 48.

Table 48 NIDU specifications

Category	Specification
Dimensions	Width 172 mm (6.8 in) Height 32 mm (1.3 in) Depth 218 mm (8.6 in)
Weight	0.88 kg (1.95 lb)
Temperature	-40°C (-40°F) to +60°C (+140°F) Suitable for use indoors, or outdoors within a weatherproofed cabinet.
Humidity	0 to 95%, non-condensing
Waterproofing	Not waterproof
DC Input	+48 V to +60 V DC
Power consumption	<8 W

The NIDU TDM interface conforms to the standards listed in TDM network planning on page 3-48.

The pinouts of the NIDU ports are specified in Table 49, Table 50 and Table 51.

Table 49 NIDU LAN port pinouts

Pin no.	Connector pinout signal name (*)	Signal description
Pin 1	LAN_PHYn_PAIR1+	Gigabit tx/rx pair 1
Pin 2	LAN_PHYn_PAIR1-	Gigabit tx/rx pair 1
Pin 3	LAN_PHYn_PAIR2+	Gigabit tx/rx pair 2
Pin 4	LAN_PHYn_PAIR3+	Gigabit tx/rx pair 3
Pin 5	LAN_PHYn_PAIR3-	Gigabit tx/rx pair 3
Pin 6	LAN_PHYn_PAIR2-	Gigabit tx/rx pair 2
Pin 7	LAN_PHYn_PAIR4+	Gigabit tx/rx pair 4
Pin 8	LAN_PHYn_PAIR4-	Gigabit tx/rx pair 4

(*) “n” refers to the LAN port number (1 or 2).

Table 50 NIDU ODU port pinouts

Pin no.	Connector pinout signal name (*)	Signal description
Pin 1	ODU_PHYn_PAIR1+	Gigabit tx/rx pair 1
Pin 2	ODU_PHYn_PAIR1-	Gigabit tx/rx pair 1
Pin 3	ODU_PHYn_PAIR2+	Gigabit tx/rx pair 2
Pin 4	ODU_PHYn_PAIR3+	Gigabit tx/rx pair 3
Pin 5	ODU_PHYn_PAIR3-	Gigabit tx/rx pair 3
Pin 6	ODU_PHYn_PAIR2-	Gigabit tx/rx pair 2
Pin 7	ODU_PHYn_PAIR4+	Gigabit tx/rx pair 4
Pin 8	ODU_PHYn_PAIR4-	Gigabit tx/rx pair 4

(*) “n” refers to the ODU port number (3 or 4).

Table 51 NIDU E1/T1 port pinouts

Pin no.	Connector pinout signal name (*)	Signal description
Pin 1	RJ_RRINGn	Receive signal
Pin 2	RJ_RTIPn	Receive signal
Pin 3		Not used
Pin 4	RJ_TRINGn	Transmit signal
Pin 5	RJ_TTIPn	Transmit signal
Pin 6		Not used
Pin 7		Not used
Pin 8		Not used

(*) “n” refers to the E1/T1 port number (1 to 8).

Chapter 3: System planning

This chapter provides information to help the user to plan a PTP 650 link.

The following topics are described in this chapter:

- Typical deployment on page 3-2 contains diagrams illustrating typical PTP 650 site deployments.
- Site planning on page 3-11 describes factors to be considered when planning the proposed link end sites, including grounding, lightning protection and equipment location.
- Radio spectrum planning on page 3-21 describes how to plan PTP 650 links to conform to the regulatory restrictions that apply in the country of operation.
- Link planning on page 3-25 describes factors to be taken into account when planning links, such as range, path loss and throughput.
- Planning for connectorized units on page 3-29 describes factors to be taken into account when planning to use connectorized ODUs with external antennas in PTP 650 links.
- Configuration options for TDD synchronization on page 3-31 describes the different configuration options that may be used for implementing TDD synchronization in the PTP 650 Series.
- Data network planning on page 3-35 describes factors to be considered when planning PTP 650 data networks.
- TDM network planning on page 3-48 describes factors to be considered when planning PTP 650 TDM networks.
- Network management planning on page 3-49 describes how to plan for PTP 650 links to be managed remotely using SNMP.
- Security planning on page 3-51 describes how to plan for PTP 650 links to operate in secure mode.
- System threshold, output power and link loss on page 3-59 contains tables that specify the system threshold (dBm), output power (dBm) and maximum link loss (dB) per channel bandwidth and modulation mode.
- Data throughput capacity tables on page 3-70 contains tables and graphs to support calculation of the data rate capacity that can be provided by PTP 650 configurations.

Typical deployment

This section contains diagrams illustrating typical PTP 650 site deployments.

ODU with POE interface to PSU

In the basic configuration, there is only one Ethernet interface, a copper Cat5e power over Ethernet (POE) from the PSU to the ODU (PSU port), as shown in the following diagrams: mast or tower installation (Figure 34), wall installation (Figure 35) and roof installation (Figure 36).

Figure 34 Mast or tower installation

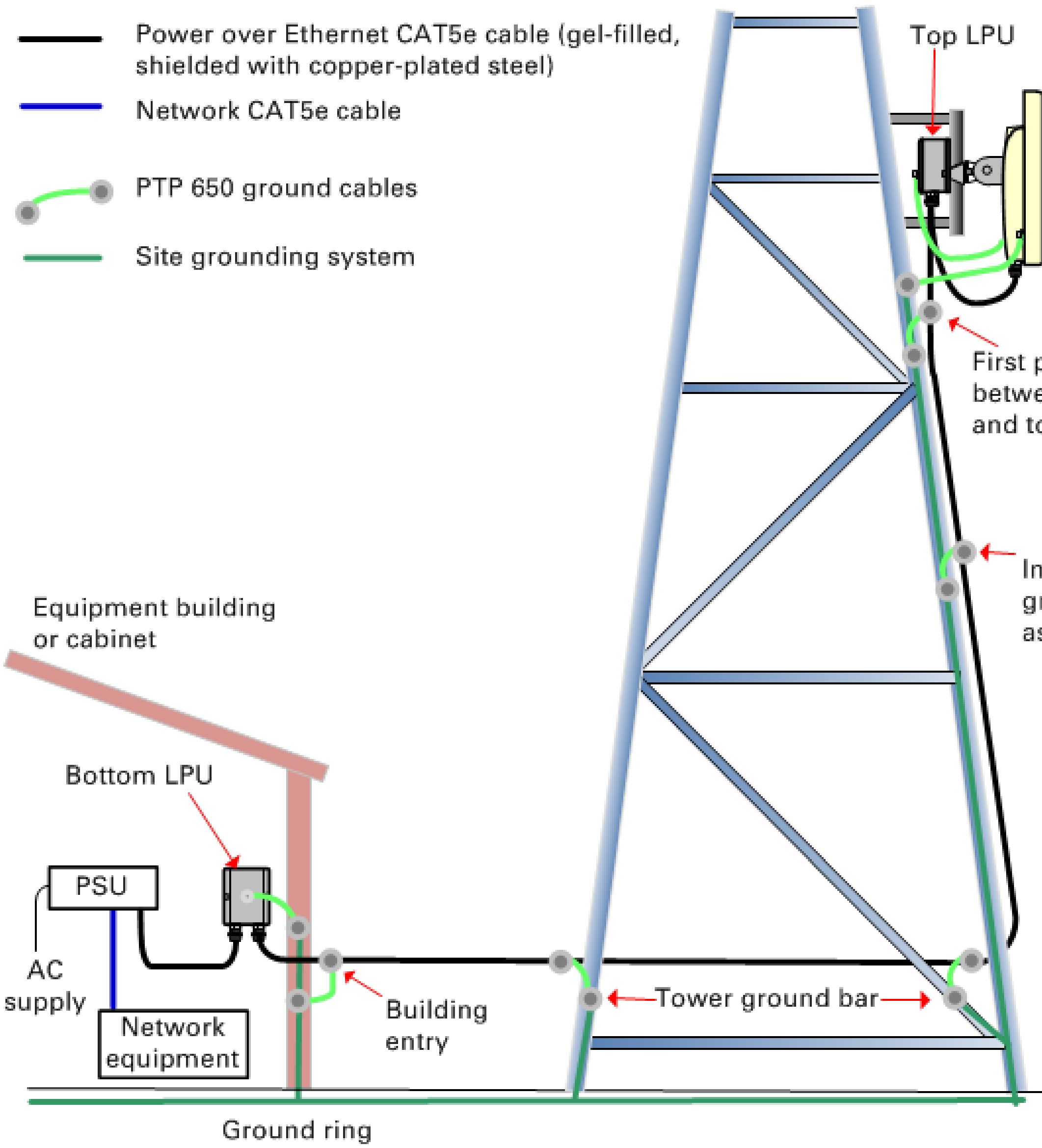


Figure 35 Wall installation

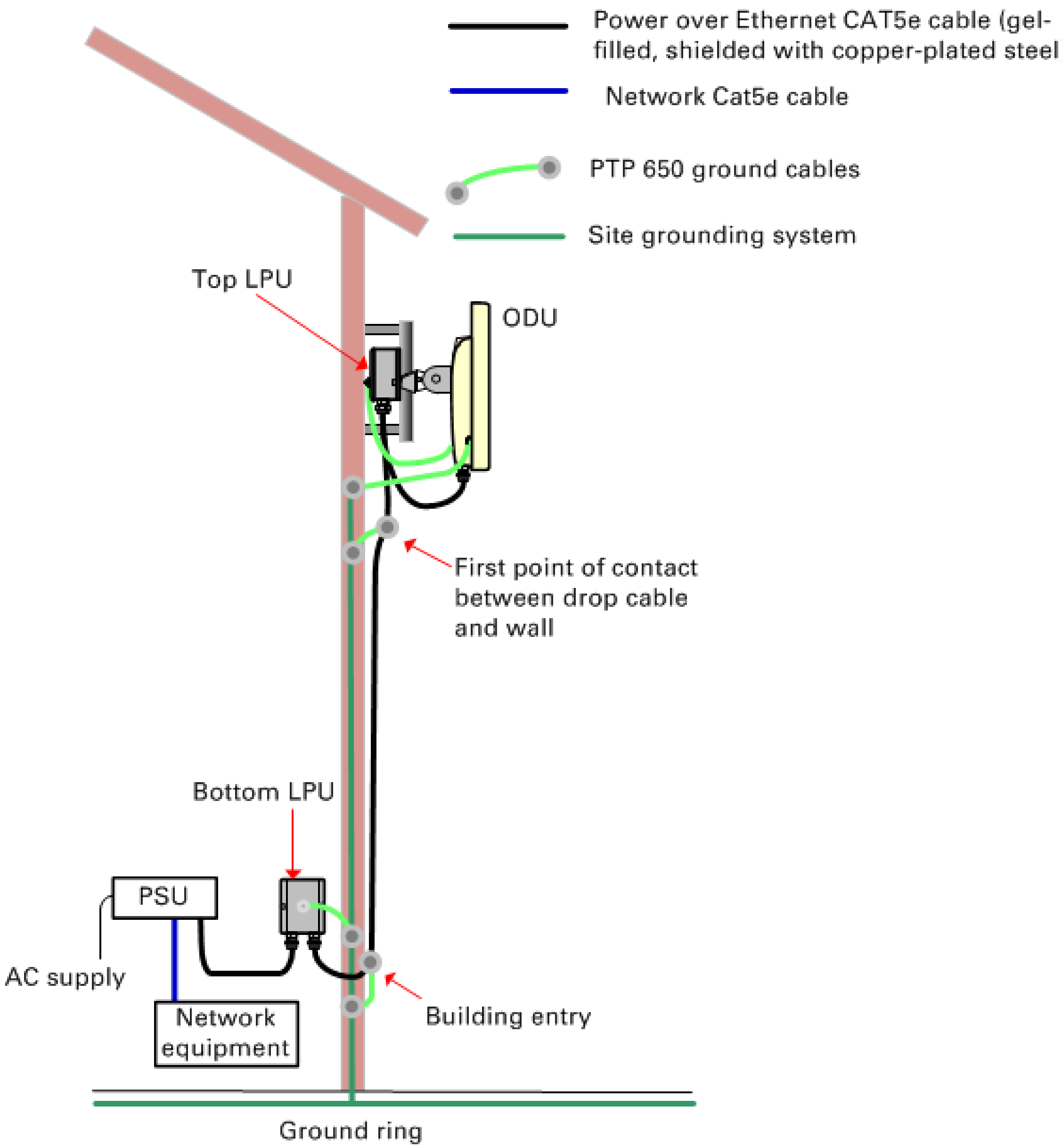
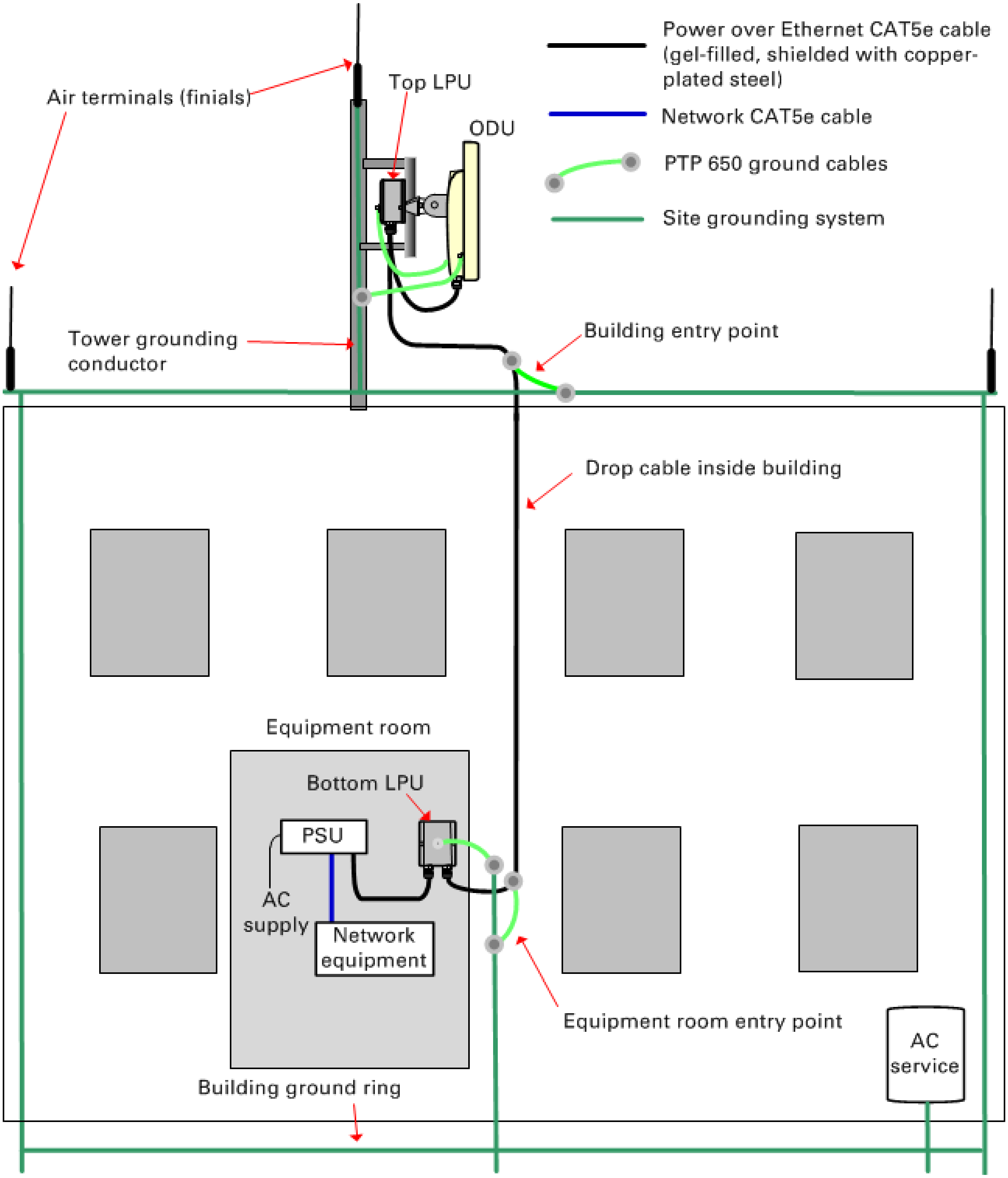


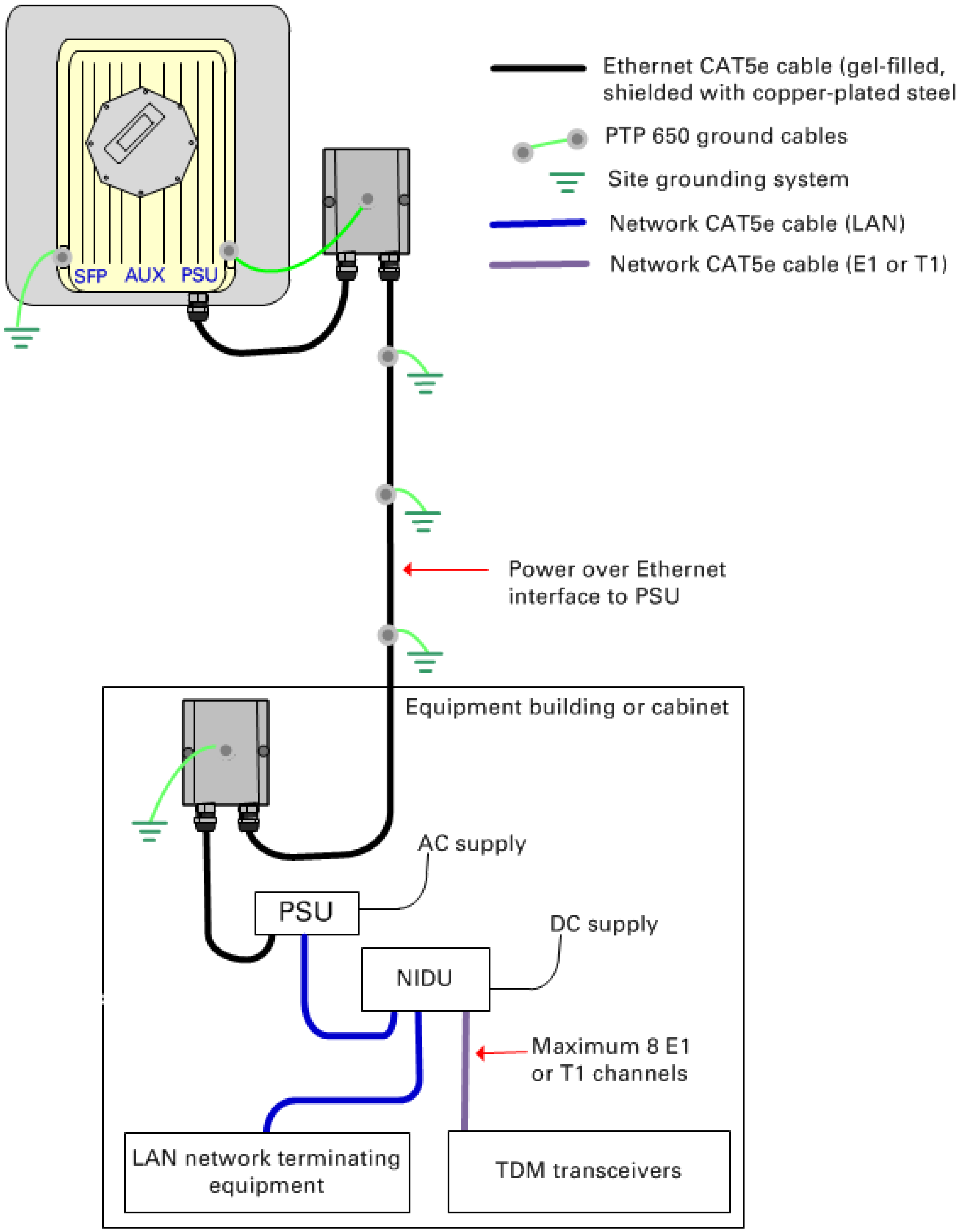
Figure 36 Roof installation



E1 or T1 interfaces

There may be up to eight E1 or T1 channels connected to the ODU via the PSU port, as shown in Figure 37. The NIDU is not compatible with the SFP or AUX ports.

Figure 37 ODU with E1 or T1 interfaces



SFP and Aux Ethernet interfaces

There may be one or two additional Ethernet interfaces connected to the ODU: one to the SFP port (copper or optical) and one to the Aux port, as shown in the following diagrams:

- ODU with copper SFP and PSU interfaces – Figure 38
- ODU with optical SFP and PSU interfaces – Figure 39
- ODU with Aux and PSU interfaces – Figure 40

Figure 38 ODU with copper SFP and PSU interfaces

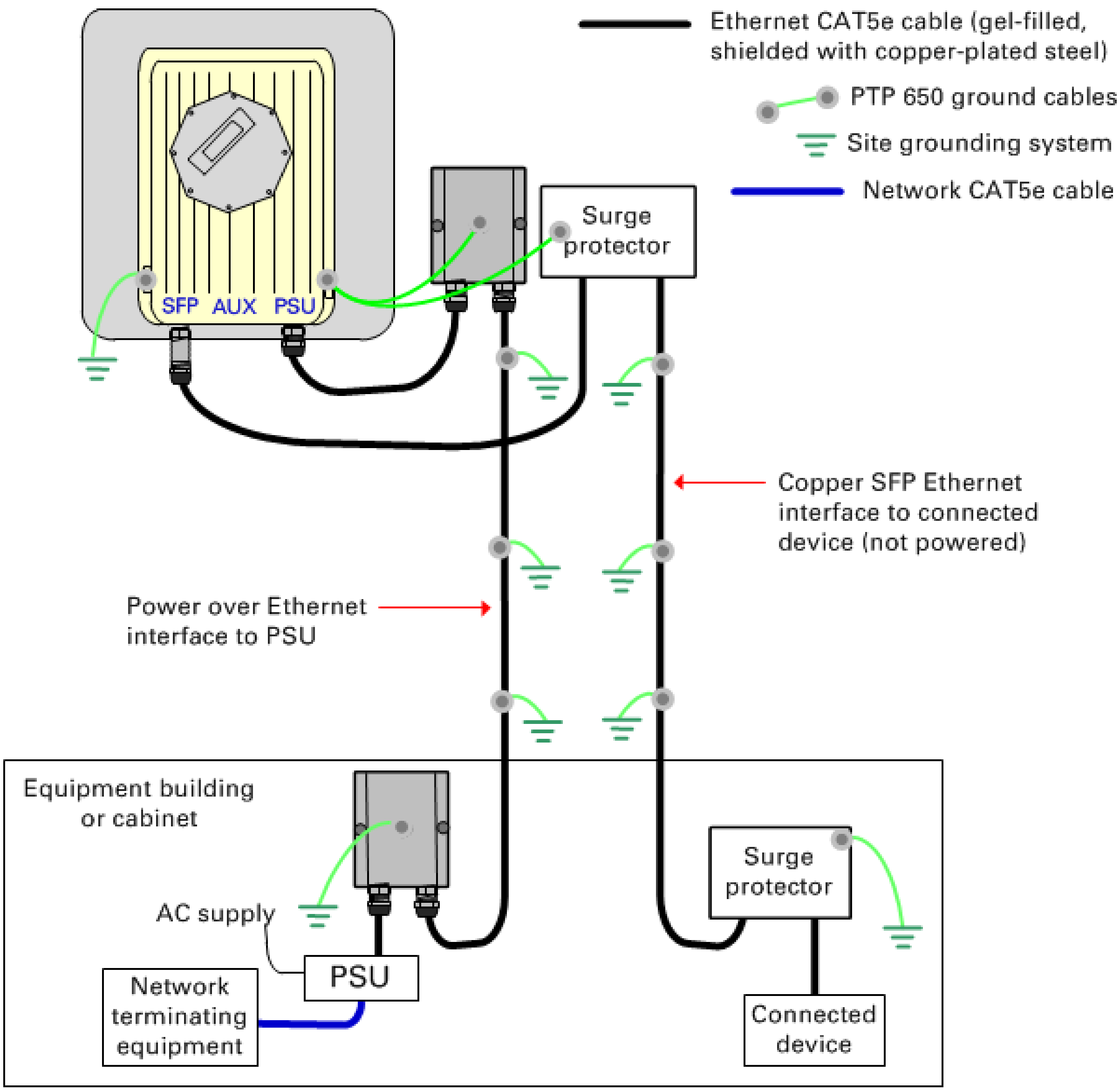


Figure 39 ODU with optical SFP and PSU interfaces

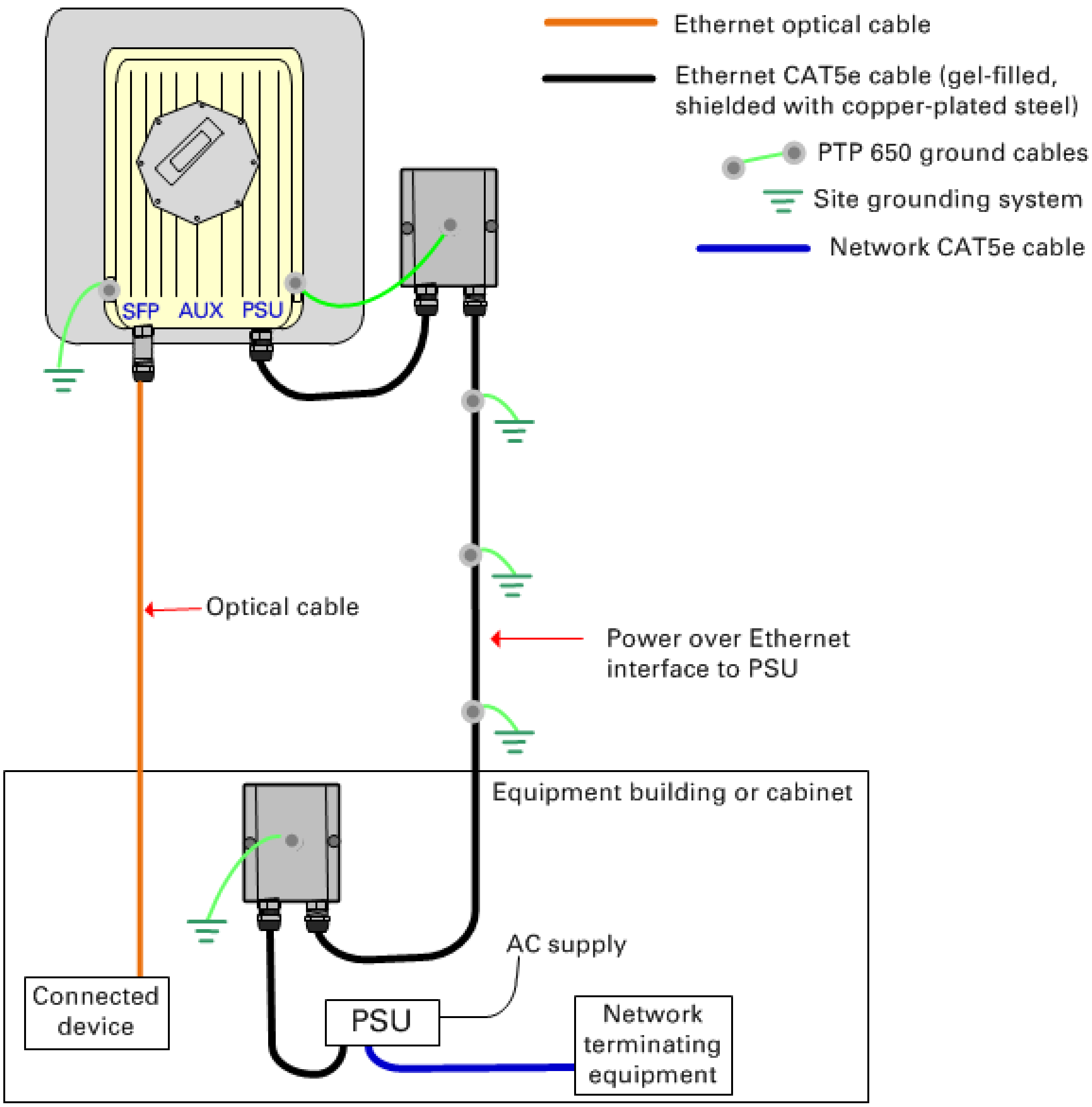
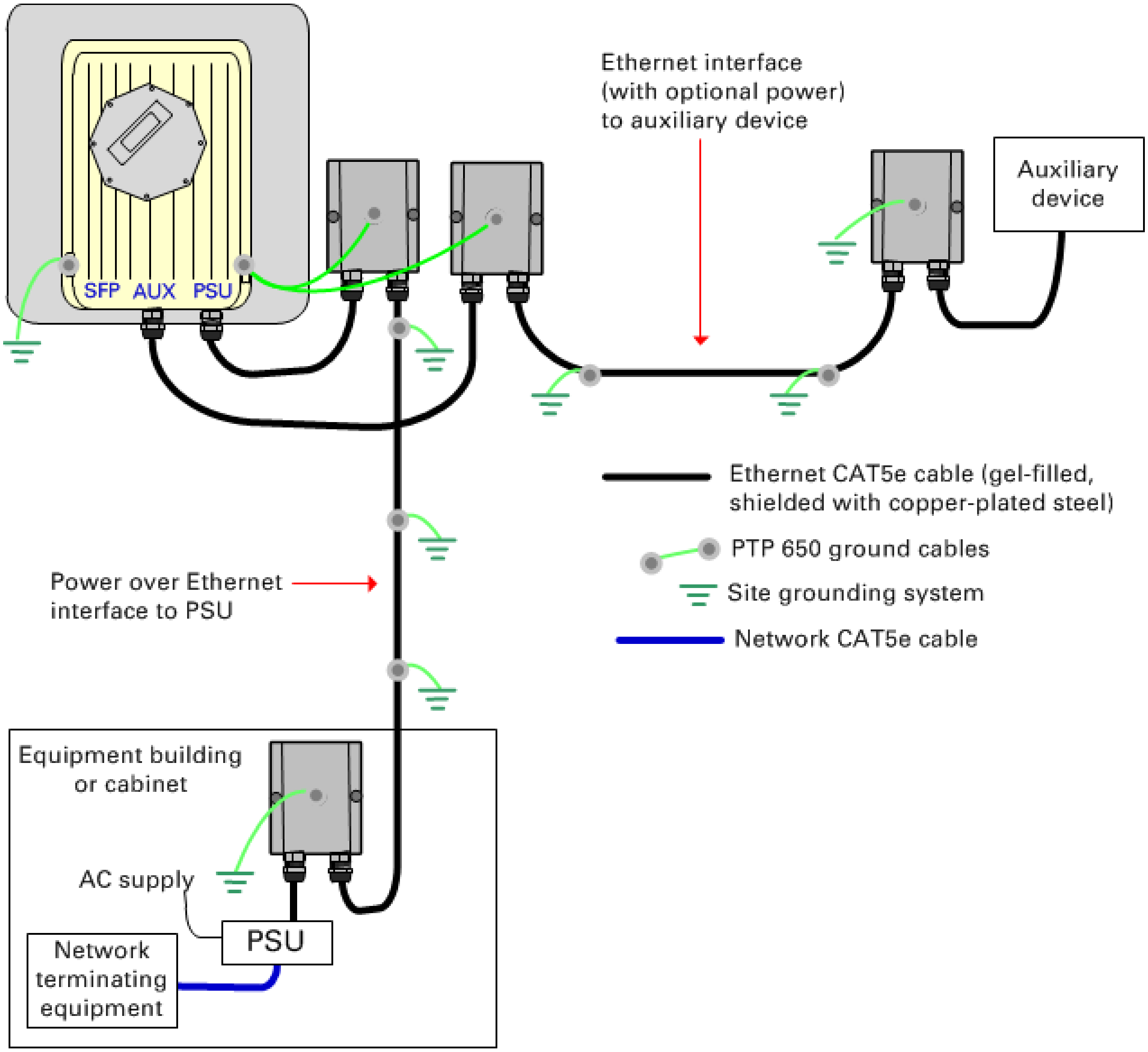


Figure 40 ODU with Aux and PSU interfaces



GPS receiver interfaces

If a GPS receiver is deployed for PTP-SYNC, it may be mounted on the wall of the equipment building (Figure 41) (preferred option), or on a metal tower or mast (Figure 42).

Figure 41 GPS receiver wall installation

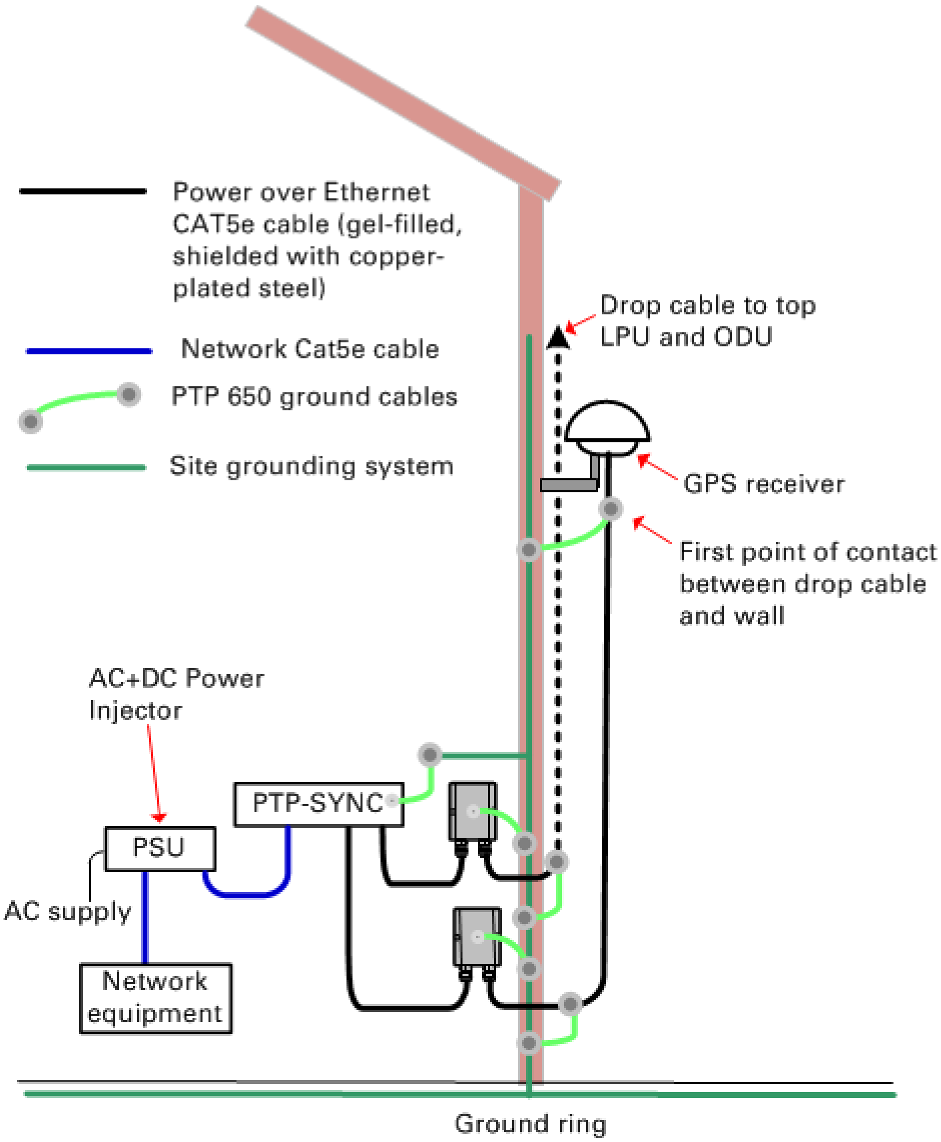
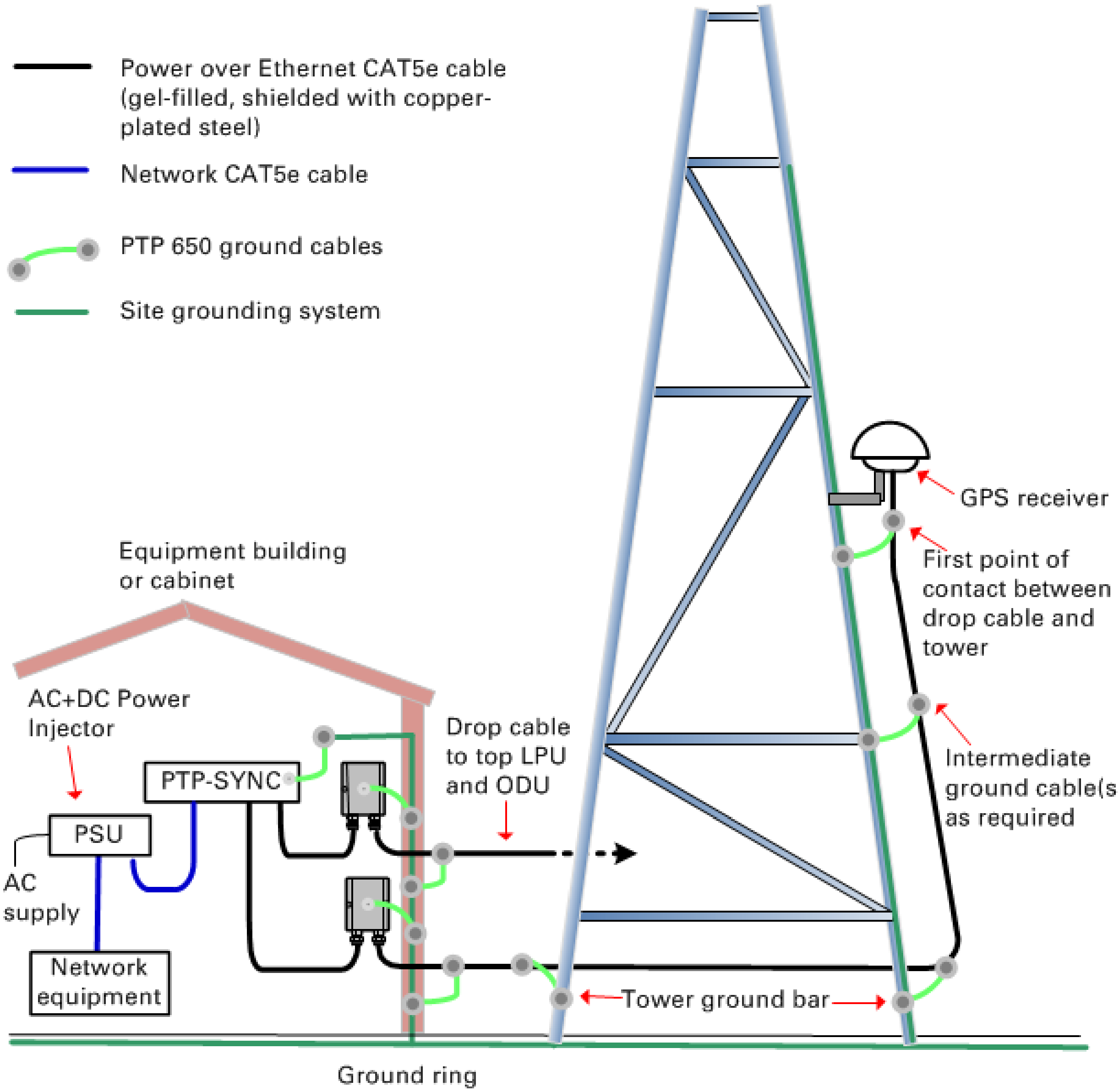


Figure 42 GPS receiver tower or mast installation



Site planning

This section describes factors to be considered when planning the proposed link end sites, including grounding, lightning protection and equipment location for the ODU, PSU and PTP-SYNC unit (if installed).

Grounding and lightning protection

Warning

Electro-magnetic discharge (lightning) damage is not covered under warranty. The recommendations in this guide, when followed correctly, give the user the best protection from the harmful effects of EMD. However 100% protection is neither implied nor possible.

Structures, equipment and people must be protected against power surges (typically caused by lightning) by conducting the surge current to ground via a separate preferential solid path. The actual degree of protection required depends on local conditions and applicable local regulations. To adequately protect a PTP 650 installation, both ground bonding and transient voltage surge suppression are required.

Full details of lightning protection methods and requirements can be found in the international standards IEC 61024-1 and IEC 61312-1, the U.S. National Electric Code ANSI/NFPA No. 70-1984 or section 54 of the Canadian Electric Code.

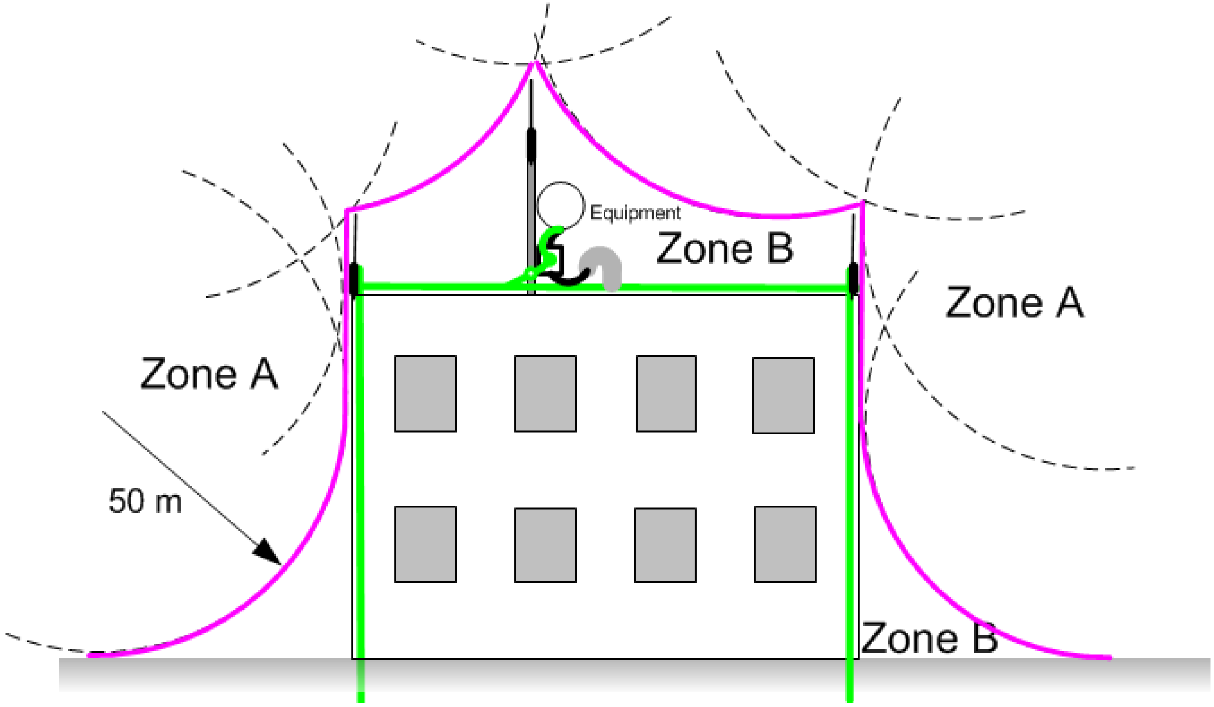
Note

International and national standards take precedence over the requirements in this guide.

Lightning protection zones

Use the rolling sphere method (Figure 43) to determine where it is safe to mount equipment. An imaginary sphere, typically 50 meters in radius, is rolled over the structure. Where the sphere rests against the ground and a strike termination device (such as a finial or ground bar), all the space under the sphere is considered to be in the zone of protection (Zone B). Similarly, where the sphere rests on two finials, the space under the sphere is considered to be in the zone of protection.

Figure 43 Rolling sphere method to determine the lightning protection zones



Zone A: In this zone a direct lightning strike is possible. Do not mount equipment in this zone.

Zone B: In this zone, direct EMD (lightning) effects are still possible, but mounting in this zone significantly reduces the possibility of a direct strike. Mount equipment in this zone.

Warning

Never mount equipment in Zone A. Mounting in Zone A may put equipment, structures and life at risk.

Site grounding system

Confirm that the site has a correctly installed grounding system on a common ground ring with access points for grounding PTP 650 equipment.

If the outdoor equipment is to be installed on the roof of a high building (Figure 36), confirm that the following additional requirements are met:

- A grounding conductor is installed around the roof perimeter to form the main roof perimeter lightning protection ring.
- Air terminals are installed along the length of the main roof perimeter lightning protection ring, typically every 6.1m (20ft).
- The main roof perimeter lightning protection ring contains at least two down conductors connected to the grounding electrode system. The down conductors should be physically separated from one another, as far as practical.

ODU and external antenna location

Find a location for the ODU (and external antenna for connectorized units) that meets the following requirements:

- The equipment is high enough to achieve the best radio path.
- People can be kept a safe distance away from the equipment when it is radiating. The safe separation distances are defined in Calculated distances on page 4-24.
- The equipment is lower than the top of the supporting structure (tower, mast or building) or its lightning air terminal.
- If the ODU is connectorized, select a mounting position that gives it maximum protection from the elements, but still allows easy access for connecting and weatherproofing the cables. To minimize cable losses, select a position where the antenna cable lengths can be minimized. If diverse or two external antennas are being deployed, it is not necessary to mount the ODU at the midpoint of the antennas.

ODU ambient temperature limits

Select a location where the ODU can operate within safe ambient temperature limits.

The ODU must be mounted in a Restricted Access Location (as defined in EN 60950-1) if the operating ambient temperature may exceed 40°C, including solar radiation.

If the ambient temperature never exceeds 40°C, the temperature of the external metal case parts of the ODU will not exceed the touch temperature limit of 70°C.

If the ambient temperature never exceeds 60°C, the temperature of the external metal case parts of the ODU will not exceed the touch temperature limit of 90°C.

Note

A restricted access location is defined (in EN 60950-1) as one where access may only be gained by use of a tool or lock and key, or other means of security, and access is controlled by the authority responsible for the location. Access must only be gained by persons who have been instructed about the reasons for the restrictions applied to the location and about any precautions that must be taken. Examples of permissible restricted access locations are a lockable equipment room or a lockable cabinet.

ODU wind loading

Ensure that the ODU and the structure on which it is mounted are capable of withstanding the prevalent wind speeds at a proposed PTP 650 site. Wind speed statistics should be available from national meteorological offices.

The ODU and its mounting bracket are capable of withstanding wind speeds of up to 323 kph (200 mph).

Wind blowing on the ODU will subject the mounting structure to significant lateral force. The magnitude of the force depends on both wind strength and surface area of the ODU. Wind loading is estimated using the following formulae:

- Force (in kilogrammes) = $0.1045aV^2$
  where:
  - "a" is the surface area in square meters, and
  - "V" is the wind speed in meters per second.
- Force (in pounds) = $0.0042Av^2$
  where:
  - "A" is the surface area in square feet, and
  - "v" is the wind speed in miles per hour.

Applying these formulae to the PTP 650 ODU at different wind speeds, the resulting wind loadings are shown in Table 52 and Table 53.

Table 52 ODU wind loading (Kg)

Type of ODU	Max surface area (square meters)	Wind speed (meters per second)				
		30	40	50	60	70
Integrated	0.130	12 Kg	22 Kg	34 Kg	49 Kg	66 Kg
Connectorized	0.093	9 Kg	16 Kg	24 Kg	35 Kg	48 Kg

Table 53 ODU wind loading (lb)

Type of ODU	Max surface area (square feet)	Wind speed (miles per hour)				
		80	100	120	140	150
Integrated	1.36	37 lb	57 lb	82 lb	146 lb	229 lb
Connectorized	1.00	27 lb	42 lb	61 lb	108 lb	168 lb

For a connectorized ODU, add the wind loading of the external antenna to that of the ODU. The antenna manufacturer should be able to quote wind loading.

PSU DC power supply

If using the DC input on the AC+DC power injector, ensure that the DC power supply meets the following requirements:

- The voltage and polarity must be correct and must be applied to the correct PSU terminals.
- The power source must be rated as Safety Extra Low Voltage (SELV).
- The power source must be rated to supply at least 1.5A continuously.
- The power source cannot provide more than the Energy Hazard Limit as defined by IEC/EN/UL60950-1, Clause 2.5, Limited Power (The Energy Hazard Limit is 240VA).

PSU location

Find a location for the PSU (AC Power Injector or AC+DC Enhanced Power Injector) that meets the following requirements:

- The AC+DC Enhanced Power Injector can be mounted on a wall or other flat surface. The AC Power Injector can be mounted on a flat surface.
- The PSU is kept dry, with no possibility of condensation, flooding or rising damp.
- The PSU is located in an environment where it is not likely to exceed its operational temperature rating, allowing for natural convection cooling.
- The PSU can be connected to the ODU drop cable and network terminating equipment.
- The PSU can be connected to a compatible power supply. AC+DC Enhanced Power Injector: the use of DC supplies of less than 55V will reduce the usable distance between the PSU and ODU.

PTP-SYNC location

If PTP-SYNC is to be installed, consider the following factors when selecting a site:

- Indoor location with no possibility of condensation.
- Accessibility for viewing status indicators.
- The maximum cable length between the PSU and the PTP-SYNC is 2 m (6 ft).

GPS receiver location

Mount the GPS receiver for PTP-SYNC at a location that meets the following requirements:

- It must be possible to protect the installation as described in Grounding and lightning protection on page 3-11.
- It must have an un-interrupted view of at least half of the sky. For a receiver mounted on a wall there must be no other significant obstructions in the view of the sky.
- It must be mounted at least 1 m (3 ft), preferably 2 m (6 ft), away from other GPS receiving equipment.
- It must not be sited in the field of radiation of co-located radio communications equipment and should be positioned at a distance of at least 3 m (10 ft) away.

Mount the GPS receiver on the wall of the equipment building, if there is a suitable location on the wall that can meet these requirements. Failing that, mount it on a metal tower or mast.

Mounting the GPS receiver module on the equipment building

If mounting the GPS receiver for PTP-SYNC on the equipment building (Figure 41), select a position on the wall that meets the following requirements:

- It must be below the roof height of the equipment building or below the height of any roof-mounted equipment (such as air conditioning plant).
- It must be below the lightning air terminals.
- It must not project more than 600mm (24 inches) from the wall of the building.

If these requirements cannot all be met, then the module must be mounted on a metal tower or mast.

Mounting the GPS receiver module on a metal tower or mast

If mounting the GPS receiver module on a metal tower or mast (Figure 42), select a position that meets the following requirements:

- It must not be mounted any higher than is necessary to receive an adequate signal from four GPS satellites.
- It must be protected by a nearby lightning air terminal that projects farther out from the tower than the GPS receiver module.

NIDU location

Find a location for the NIDU that meets the following requirements:

- The NIDU can be mounted in a cabinet rack or on a flat surface.
- The NIDU is kept dry, with no possibility of condensation, flooding or rising damp.
- The NIDU is located in an environment where it is not likely to exceed its operational temperature rating, allowing for natural convection cooling.
- The NIDU can be connected to the PSU, LAN network terminating equipment and TDM transceivers.
- The NIDU can be connected to a compatible DC power supply.

Drop cable grounding points

To estimate how many grounding kits are required for each drop cable, refer to the site installation diagrams (Figure 34 , Figure 35 and Figure 36) and use the following criteria:

- The drop cable shield must be grounded near the ODU at the first point of contact between the drop cable and the mast, tower or building.
- The drop cable shield must be grounded at the building entry point.

For mast or tower installations (Figure 34), use the following additional criteria:

- The drop cable shield must be grounded at the bottom of the tower, near the vertical to horizontal transition point. This ground cable must be bonded to the tower or tower ground bus bar (TGB), if installed.
- If the tower is greater than 61 m (200 ft) in height, the drop cable shield must be grounded at the tower midpoint, and at additional points as necessary to reduce the distance between ground cables to 61 m (200 ft) or less.
- In high lightning-prone geographical areas, the drop cable shield must be grounded at spacing between 15 to 22 m (50 to 75 ft). This is especially important on towers taller than 45 m (150 ft).

For roof installations (Figure 36), use the following additional criteria:

- The drop cable shield must be bonded to the building grounding system at its top entry point (usually on the roof).
- The drop cable shield must be bonded to the building grounding system at the entry point to the equipment room.

LPU location

Find a location for the top LPU that meets the following requirements:

- There is room to mount the LPU, either on the ODU mounting bracket or on the mounting pole below the ODU.
- The drop cable length between the ODU and top LPU must not exceed 600 mm.
- There is access to a metal grounding point to allow the ODU and top LPU to be bonded in the following ways: top LPU to ODU; ODU to grounding system.

Find a location for the bottom LPU that meets the following requirements:

- The bottom LPU can be connected to the drop cable from the ODU.
- The bottom LPU is within 600 mm (24 in) of the point at which the drop cable enters the building, enclosure or equipment room within a larger building.
- The bottom LPU can be bonded to the grounding system.

Multiple LPUs

If two or three drop cables are connected to the ODU, the PSU and Aux drop cables each require their own top LPU, and the copper SFP drop cable requires a top surge protector, not a PTP 650 LPU (Figure 44). Optical cables do not require LPUs or ground cables (Figure 45).

The copper SFP drop cable requires a bottom surge protector, not a PTP 650 LPU (Figure 46).

The Aux drop cable may require an LPU near the auxiliary device.

Figure 44 ODU with PSU, Aux and copper SFP interfaces

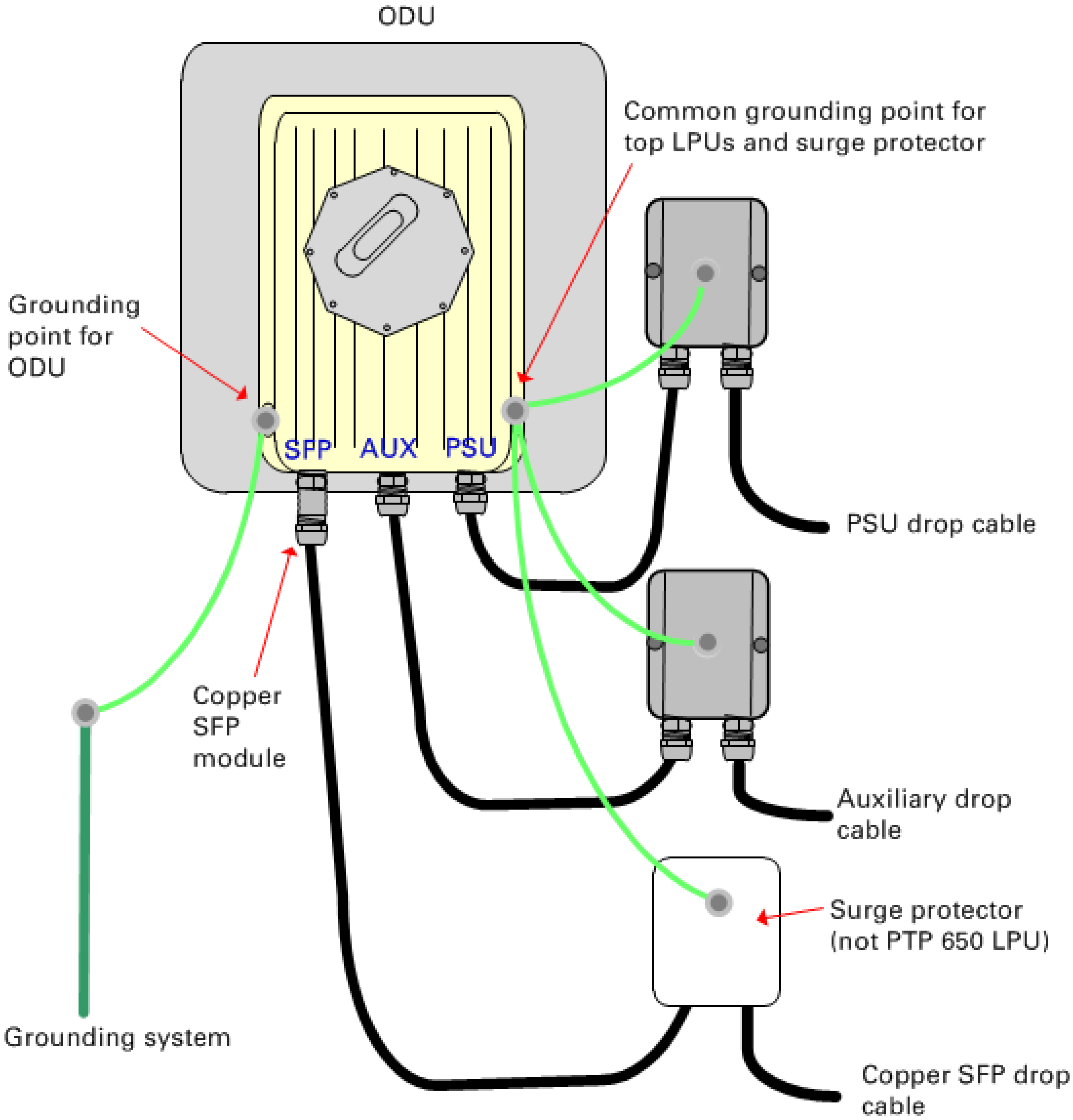


Figure 45 ODU with PSU, Aux and optical SFP interfaces

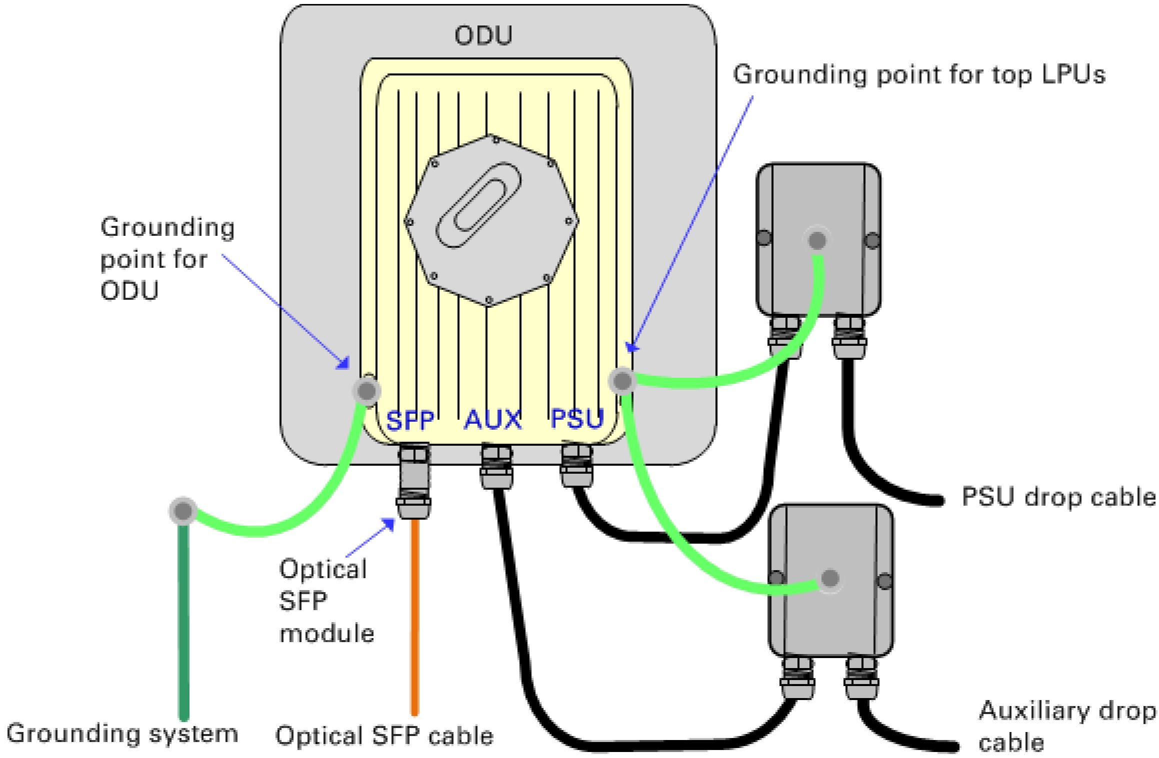
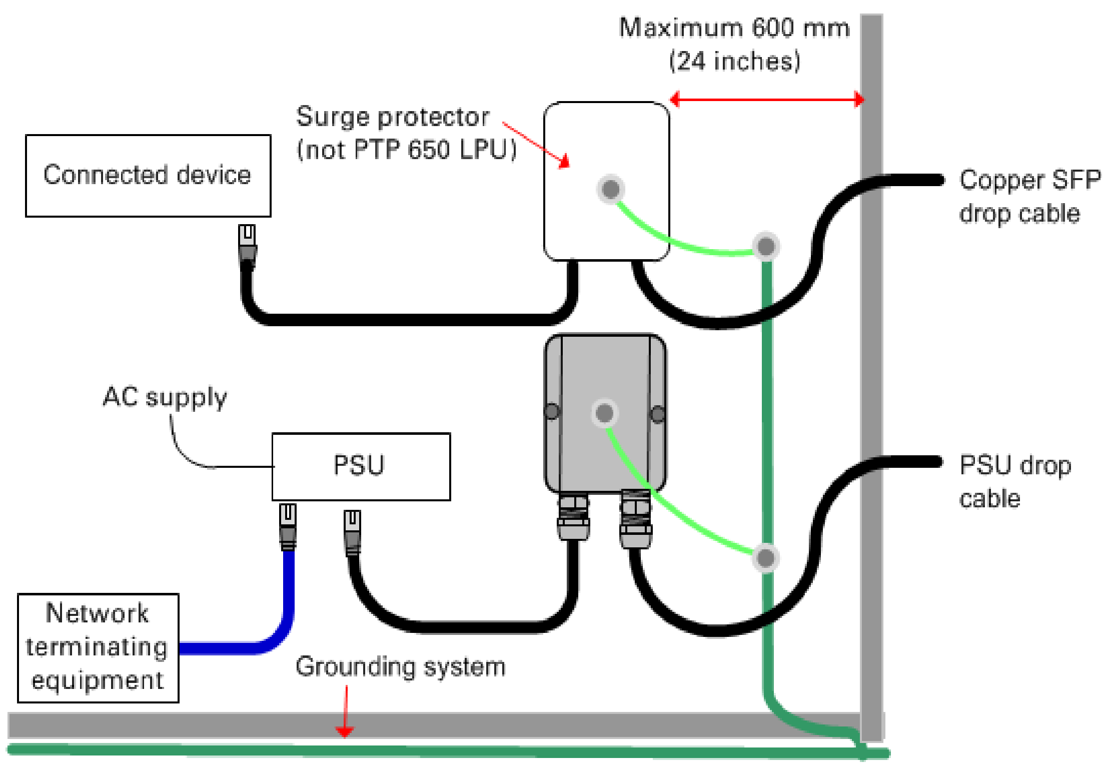


Figure 46 Bottom LPU and surge protector



Radio spectrum planning

This section describes how to plan PTP 650 links to conform to the regulatory restrictions that apply in the country of operation.

Caution

It is the responsibility of the user to ensure that the PTP product is operated in accordance with local regulatory limits.

Note

Contact the applicable radio regulator to find out whether or not registration of the PTP 650 link is required.

General wireless specifications

Table 54 lists the wireless specifications that apply to all PTP 650 frequency bands. Table 55 lists the wireless specifications that are specific to a single frequency band.

Table 54 PTP 650 wireless specifications (all variants)

Item	Specification
Channel selection	Manual selection (fixed frequency). Dynamic frequency selection (DFS or DFS with DSO) is available in radar avoidance regions.
Manual power control	To avoid interference to other users of the band, maximum power can be set lower than the default power limit.
Integrated antenna type	23 dBi Flat plate antenna (PTP 650) or 19 dBi Flat plate antenna (PTP 650S or PTP 650L).
Duplex schemes	Symmetric fixed, asymmetric fixed and, for the Full license only, adaptive TDD.
Range	Line-of-Sight: 200 km (125 miles). Non-Line-of-Sight: 10 km (6 miles).
Over-the-air encryption	AES 128-bit or 256-bit.
Weather sensitivity	Sensitivity at higher modes may be reduced by adjusting the Adaptive Modulation Threshold.
Error Correction	FEC

Table 55 PTP 650 wireless specifications (per frequency band)

Item	4.9 GHz	5.1 GHz	5.2 GHz	5.4 GHz	5.8 GHz
RF band (MHz)	4900–4990	5150–5250	5250–5350	5470–5725	5725–5875
Channel bandwidth (MHz)	5, 10, 15, 20	5, 10, 15, 20, 30, 40, 45	5, 10, 15, 20, 30, 40, 45	5, 10, 15, 20, 30, 40, 45	5, 10, 15, 20, 30, 40, 45
Typical receiver noise	6 dB	6 dB	6 dB	6 dB	6 dB
Typical antenna gain (integrated)	23 dBi	23 dBi	23 dBi	23 dBi	23 dBi
Antenna beamwidth (integrated)	8°	8°	8°	8°	8°

Regulatory limits

Many countries impose EIRP limits (Allowed EIRP) on products operating in the bands used by the PTP 650 Series. For example, in the 5.4 GHz and 5.8 GHz bands, these limits are calculated as follows:

- In the 5.4 GHz band (5470 MHz to 5725 MHz), the EIRP must not exceed the lesser of 30 dBm or (17 + 10 x Log Channel width in MHz) dBm.
- In the 5.8 GHz band (5725 MHz to 5875 MHz), the EIRP must not exceed the lesser of 36 dBm or (23 + 10 x Log Channel width in MHz) dBm.

Some countries (for example the USA) impose conducted power limits on products operating in the 5.8 GHz band.

Conforming to the limits

Ensure the link is configured to conform to local regulatory requirements by installing license keys for the correct country. In the following situations, the license key does not prevent operation outside the regulations:

- When using connectorized ODUs with external antennas, the regulations may require the maximum transmit power to be reduced.
- When installing 5.2 GHz or 5.4 GHz links in the USA, it may be necessary to avoid frequencies used by Terminal Doppler Weather Radar (TDWR) systems. For more information, refer to Avoidance of weather radars (USA only) on page 3-24.

Available spectrum

The available spectrum for operation depends on the regulatory band. When configured with the appropriate license key, the unit will only allow operation on those channels which are permitted by the regulations.

Certain regulations have allocated certain channels as unavailable for use:

- ETSI has allocated part of the 5.4 GHz band to weather radar.
- UK and some other European countries have allocated part of the 5.8 GHz band to Road Transport and Traffic Telematics (RTTT) systems.

The number and identity of channels barred by the license key and regulatory band is dependent on the channel bandwidth and channel raster selected.

Barred channels are indicated by a "No Entry" symbol displayed on the Spectrum Management web page (Spectrum Expert page in radar avoidance mode on page 7-41).

Channel bandwidth

Select the required channel bandwidth for the link. The selection depends upon the regulatory band selected.

The wider the channel bandwidth, the greater the capacity. As narrower channel bandwidths take up less spectrum, selecting a narrow channel bandwidth may be a better choice when operating in locations where the spectrum is very busy.

Both ends of the link must be configured to operate on the same channel bandwidth.

Frequency selection

Regions without mandatory radar detection

In regions that do not mandate DFS, choose **DSO** or **Fixed Frequency**:

- **Dynamic Spectrum Optimization (DSO)**: In this mode, the unit monitors the spectrum looking for the channel with the lowest level of interference. Statistical techniques are used to select the most appropriate transmit and receive channels. The unit can be configured such that it operates in DSO mode, but does not operate on selected channels. This allows a frequency plan to be implemented in cases where multiple links are installed in close proximity.
- **Fixed Frequency**: In this mode, the unit must be configured with a single fixed transmit frequency and a single fixed receive frequency. These may set to the same value or to different values. This mode should only be considered in exceptional circumstances, for example where it is known that are no sources of interference on the selected channels.

Regions with mandatory radar detection

In regions that mandate DFS, the unit first ensures that there is no radar activity on a given channel for a period of 60 seconds before radiating on that channel. Once a channel has been selected for operation, the unit will continually monitor for radar activity on the operating channel. If detected, it will immediately cease radiating and attempt to find a new channel. In DFS regions, choose **DFS** or **DFS with DSO**:

- **Dynamic Frequency Selection (DFS)**: Once a channel is selected, the unit will only attempt to find an alternative channel if radar activity has been detected on the operating channel.
- **DFS with DSO**: In addition to switching channels on detection of radar, the unit will also switch to a channel which has a significantly lower level of interference than the current channel of operation. Before radiating on the newly selected channel, the unit must again ensure that there is no radar activity on the new channel for a period of 60 seconds. This mode therefore provides the benefit of switching to a channel with lower interference but at the expense of an outage of approximately 60 to 120 seconds. For this reason, the threshold for switching channels is greater than when DSO is operating in a non-radar region.

Radar avoidance requirements in the 5.4 GHz band are defined as follows:

- For the EU: in specification EN 301-893.
- For the US: in the specification FCC part 15.407 plus the later requirements covered in Important Regulatory Information in this User Guide.
- For Canada: in the specification RSS210 Annex 9.

Radar avoidance at 5.8 GHz is applicable to EU operation (not FCC/IC) and the requirements are defined in EN 302 502 v1.2.1.

Avoidance of weather radars (USA only)

To comply with FCC rules (KDB 443999: Interim Plans to Approve UNII Devices Operating in the 5470 - 5725 MHz Band with Radar Detection and DFS Capabilities), units which are installed within 35 km (22 miles) of a Terminal Doppler Weather Radar (TDWR) system (or have a line of sight propagation path to such a system) must be configured to avoid any frequency within +30 MHz or –30 MHz of the frequency of the TDWR device. This requirement applies even if the master is outside the 35 km (22 miles) radius but communicates with outdoor clients which may be within the 35 km (22 miles) radius of the TDWRs. If interference is not eliminated, a distance limitation based on line-of-sight from TDWR will need to be used. Devices with bandwidths greater than 20 MHz may require greater frequency separation.

When planning a link in the USA, visit http://spectrumbridge.com/udia/home.aspx, enter the location of the planned link and search for TDWR radars. If a TDWR system is located within 35 km (22 miles) or has line of sight propagation to the PTP device, perform the following tasks:

- Register the installation on http://spectrumbridge.com/udia/home.aspx.
- Make a list of channel center frequencies that must be barred, that is, those falling within +30 MHz or –30 MHz of the frequency of the TDWR radars.

The affected channels must be barred as described in Barring channels on page 7-44.

Link planning

This section describes factors to be taken into account when planning links, such as range, obstacles path loss and throughput. LINKPlanner is recommended.

LINKPlanner

The Cambium LINKPlanner software and user guide may be downloaded from the support website (see Contacting Cambium Networks on page 1).

LINKPlanner imports path profiles and predicts data rates and reliability over the path. It allows the system designer to try different antenna heights and RF power settings. It outputs an installation report that defines the parameters to be used for configuration, alignment and operation. Use the installation report to compare predicted and actual link performance.

Range and obstacles

Calculate the range of the link and identify any obstacles that may affect radio performance.

Perform a survey to identify all the obstructions (such as trees or buildings) in the path and to assess the risk of interference. This information is necessary in order to achieve an accurate link feasibility assessment.

The PTP 650 Series is designed to operate in Non-Line-of-Sight (NLoS) and Line-of-Sight (LoS) environments. An NLOS environment is one in which there is no optical line-of-sight, that is, there are obstructions between the antennas.

The PTP 650 Series will operate at ranges from 100 m (330 ft) to 200 km (125 miles), within 3 modes: 0-40 km (0-25 miles), 0-100 km (0-62 miles) and 0-200 km (0-124 miles). Operation of the system will depend on obstacles in the path between the units. Operation at 40 km (25 miles) or above will require a near line-of-sight path. Operation at 100 m (330 ft) could be achieved with one unit totally obscured from the other unit, but with the penalty of transmitting at higher power in a non-optimal direction, thereby increasing interference in the band.

LoS links in radar regions

When planning an LoS link to operate in a radar detection region, ensure that receiver signal level is low enough to allow the PTP 650 to detect radar signals:

- With integrated antennas, the recommended minimum LoS operating range is 110 meters (360 ft) for 5.2 GHz or 5.4 GHz, and 185 meters (610 ft) for 5.8 GHz. Shorter operating ranges will lead to excessive receiver signal levels.
- With higher gain connectorized antennas, ensure the predicted receiver signal level (from LINKPlanner) is below -53 dBm (for 5.2 GHz or 5.4 GHz) or below -58 dBm (for 5.8 GHz).

LINKPlanner for synchronized networks

TDD synchronization should be planned using LINKPlanner. This will provide the necessary TDD frame parameter values which are required to complete a synchronized installation. Please refer to the *LINKPlanner User Guide*.

Path loss

Path loss is the amount of attenuation the radio signal undergoes between the two ends of the link. The path loss is the sum of the attenuation of the path if there were no obstacles in the way (Free Space Path Loss), the attenuation caused by obstacles (Excess Path Loss) and a margin to allow for possible fading of the radio signal (Fade Margin). The following calculation needs to be performed to judge whether a particular link can be installed:

$$L_{free\_space} + L_{excess} + L_{fade} + L_{seasonal} < L_{capability}$$

Where:	Is:
L_{free_space}	Free Space Path Loss (dB)
L_{excess}	Excess Path Loss (dB)
L_{fade}	Fade Margin Required (dB)
$L_{seasonal}$	Seasonal Fading (dB)
$L_{capability}$	Equipment Capability (dB)

Adaptive modulation

Adaptive modulation ensures that the highest throughput that can be achieved instantaneously will be obtained, taking account of propagation and interference. When the link has been installed, web pages provide information about the link loss currently measured by the equipment, both instantaneously and averaged. The averaged value will require maximum seasonal fading to be added, and then the radio reliability of the link can be computed. For minimum error rates on TDM links, the maximum modulation mode should be limited to 64QAM 0.75.

For details of the system threshold, output power and link loss for each frequency band in all modulation modes for all available channel bandwidths, refer to System threshold, output power and link loss on page 3-59.

Calculating data rate capacity

The data rate capacity of a PTP link is defined as the maximum end-to-end Ethernet throughput (including Ethernet headers) that it can support. It is assumed that Ethernet frames are 1518 octet. Data rate capacity is determined by the following factors:

- Licensed data throughput capability (ODU license: Lite, Mid or Full; for PTP 650L, use Full)
- Link Symmetry
- Link Mode Optimization (IP or TDM)
- Modulation Mode
- Channel Bandwidth
- Link Range
- Capacity reserved for TDM operation

Calculation procedure

To calculate the data rate capacity of a PTP 650 link, proceed as follows:

1. Use the tables in Data throughput capacity tables on page 3-70 to look up the data throughput capacity rates (Tx, Rx and Both) for the required combination of:
   - Link Symmetry
   - Link Mode Optimization
   - Modulation Mode
   - Channel Bandwidth
   - Capacity License (Full, Mid or Lite)
2. The tables contain data rates for links of zero range. Use the range adjustment graphs in Data throughput capacity tables on page 3-70 to look up the Throughput Factor that must be applied to adjust the data rates for the actual range of the link.
3. Multiply the data rates by the Throughput Factor to give the throughput capacity of the link.
4. Subtract capacity reserved for TDM operation. See TDM traffic load on page 3-127.

Note

The data rates for adaptive symmetry apply to the most asymmetric case where the link has significant offered traffic in one direction only. The data rates for adaptive symmetry with bidirectional offered traffic are the same as those for link symmetry 1:1 with link optimization IP.

Calculation example

Suppose that the link characteristics are:

- PTP 650 variant = Mid
- Link Symmetry = 1:1
- Link Mode Optimization = TDM
- Modulation Mode = 64QAM 0.92 Dual
- Channel Bandwidth = 10 MHz
- Link Range = 60 km

The calculation procedure for this example is as follows:

1. Use Table 96 to look up the data throughput capacity rates:

   Tx = 23 Mbits/s

   Rx = 23 Mbits/s

   Aggregated = 46 Mbits/s

2. Use Figure 75 to look up the Throughput Factor for 1:1, TDM, 10 MHz, Mid and Link Range 60 km. The factor is 0.86.

3. Multiply the rates from Step 1 by the Throughput Factor from Step 2 to give the throughput capacity of the link:

   Tx = 19.8 Mbits/s

   Rx = 19.8 Mbits/s

   Aggregated = 39.6 Mbits/s

Planning for connectorized units

This section describes factors to be taken into account when planning to use connectorized ODUs with external antennas in PTP 650 links.

When to install connectorized units

The majority of radio links can be successfully deployed with the integrated ODU. However the integrated units may not be sufficient in some areas, for example:

- Where the path is heavily obscured by dense woodland on an NLOS link.
- Where long LOS links (>23 km or >14 miles) are required.
- Where there are known to be high levels of interference.

LINKPlanner can be used to identify these areas of marginal performance.

In these areas, connectorized ODUs and external antennas should be used.

Choosing external antennas

When selecting external antennas, consider the following factors:

- The required antenna gain.
- Ease of mounting and alignment.
- Antenna polarization:
  - For a simple installation process, select one dual-polarization antenna (as the integrated antenna) at each end.
  - To achieve spatial diversity, select two single-polarization antennas at each end. Spatial diversity provides additional fade margin on very long LOS links where there is evidence of correlation of the fading characteristics on Vertical and Horizontal polarizations.

Note

Enter the antenna gain and cable loss into the Installation Wizard, if the country selected has an EIRP limit, the corresponding maximum transmit power will be calculated automatically by the unit.

Note

Under Industry Canada regulations, this radio transmitter may only operate using an antenna of a type and maximum (or lesser) gain approved for the transmitter by Industry Canada. To reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the equivalent isotropically radiated power (EIRP) is not more than that necessary for successful communication.

Conformément à la réglementation d'Industrie Canada, le présent émetteur radio peut fonctionner avec une antenne d'un type et d'un gain maximal (ou inférieur) approuvé pour l'émetteur par Industrie Canada. Dans le but de réduire les risques de brouillage radioélectrique à l'intention des autres utilisateurs, il faut choisir le type d'antenne et son gain de sorte que la puissance isotrope rayonnée équivalente (p.i.r.e.) ne dépasse pas l'intensité nécessaire à l'établissement d'une communication satisfaisante.

Calculating RF cable length (5.8 GHz FCC only)

The 5.8 GHz band FCC approval for the product is based on tests with a cable loss between the ODU and antenna of not less than 1.2 dB. If cable loss is below 1.2 dB with a 1.3 m (4 ft) diameter external antenna, the connectorized PTP 650 may exceed the maximum radiated spurious emissions allowed under FCC 5.8 GHz rules.

Cable loss depends mainly upon cable type and length. To meet or exceed the minimum loss of 1.2 dB, use cables of the type and length specified in Table 56 (source: Times Microwave). This data excludes connector losses.

Table 56 RF cable lengths required to achieve 1.2 dB loss at 5.8 GHz

RF cable type	Minimum cable length
LMR100	0.6 m (1.9 ft)
LMR200	1.4 m (4.6 ft)
LMR300	2.2 m (7.3 ft)
LMR400	3.4 m (11.1 ft)
LMR600	5.0 m (16.5 ft)

Configuration options for TDD synchronization

This section describes the different configuration options that may be used for implementing TDD synchronization in the PTP 650 Series. Schematic diagrams are included.

The PTP 650 supports the following TDD synchronization configurations:

- Single link configuration with PTP-SYNC on page 3-32.
- Cluster with PTP-SYNC and GPS receiver on page 3-33.
- Cluster with PTP-SYNC and no GPS receiver on page 3-34.

Caution

The PTP-SYNC is compatible only with the AC + DC Power Injector.

The AC Power Injector will not work with a PTP-SYNC, and it is likely that a fuse will be blown in the PTP-SYNC if this is attempted.

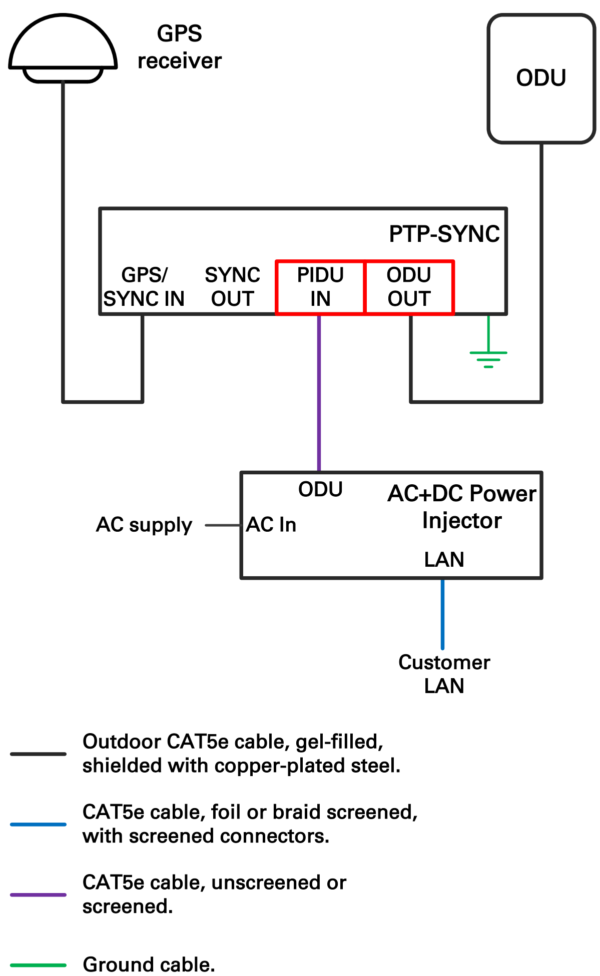
Single link configuration with PTP-SYNC

Each link requires one PTP-SYNC unit connected to the master ODU and one compatible GPS receiver. Use this configuration where a site contains only one TDD master ODU. The GPS receiver and LPU can be replaced by an alternative compatible 1 Hz timing reference (Figure 47).

The wireless configuration settings are:

- Master Slave Mode = **Master**.
- TDD Sync Device = **PTPSYNC**.
- Cluster Master Slave = **Cluster Master**.
- PTP Sync Site Reference = **GPS/1PPS External**.

Figure 47 TDD synchronization configuration – single link with PTP-SYNC



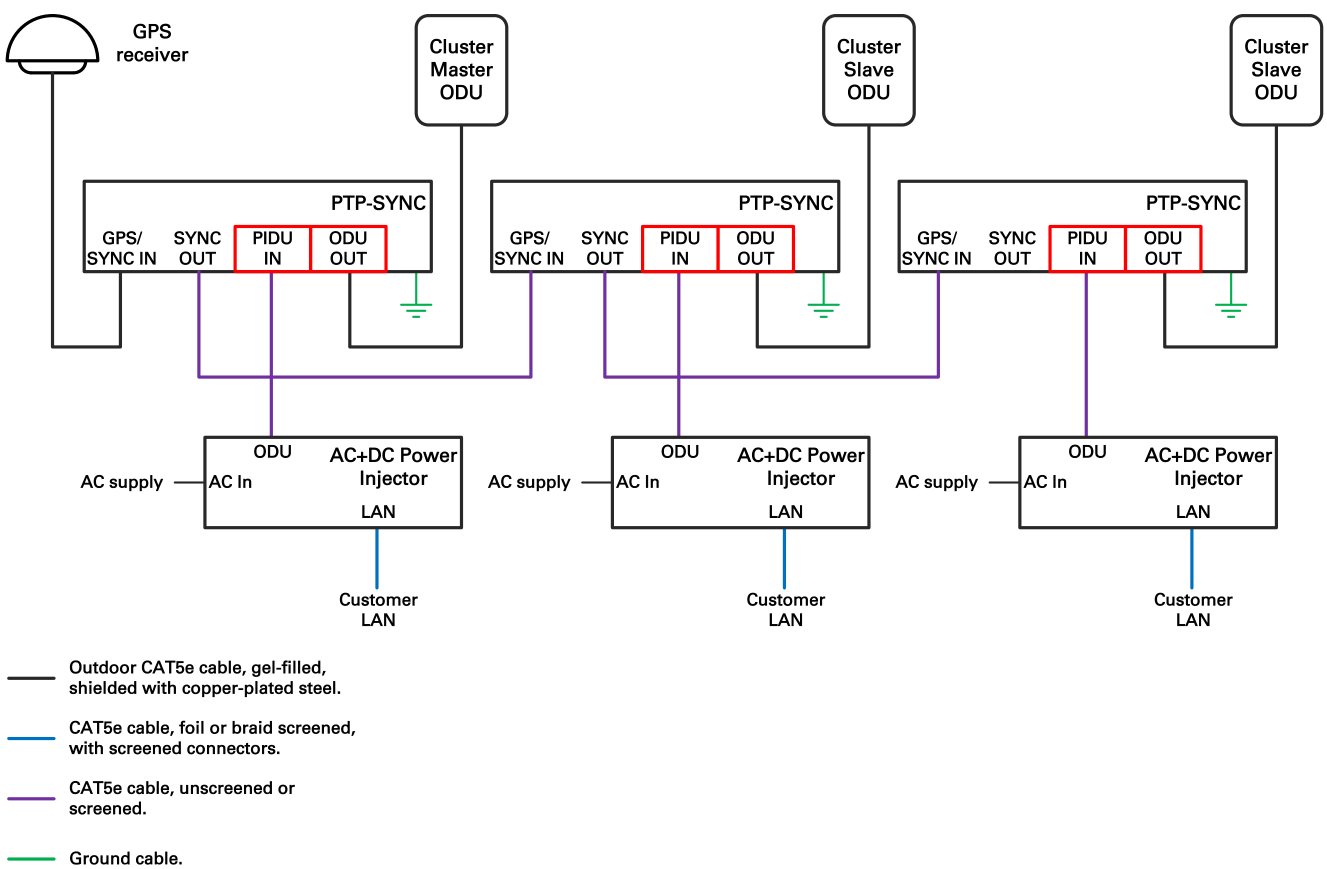
Cluster with PTP-SYNC and GPS receiver

Each link requires one PTP-SYNC unit. Each site requires one compatible GPS receiver. Collocated PTP-SYNC units are connected together in a daisy-chain. Between two and ten PTP-SYNCs may be chained in this way. Use this configuration where a site contains collocated TDD master ODUs in an extended network and where multiple sites have TDD master ODUs (Figure 48).

The wireless configuration settings are:

- Master Slave Mode = **Master** (all ODUs in cluster).
- TDD Sync Device = **PTPSYNC** (all ODUs in cluster).
- Cluster Master Slave = **Cluster Master** (first ODU) and **Cluster Slave** (others).
- PTP Sync Site Reference = **GPS/1PPS External** (all ODUs in cluster).

Figure 48 TDD synchronization configuration – cluster with PTP-SYNC and GPS



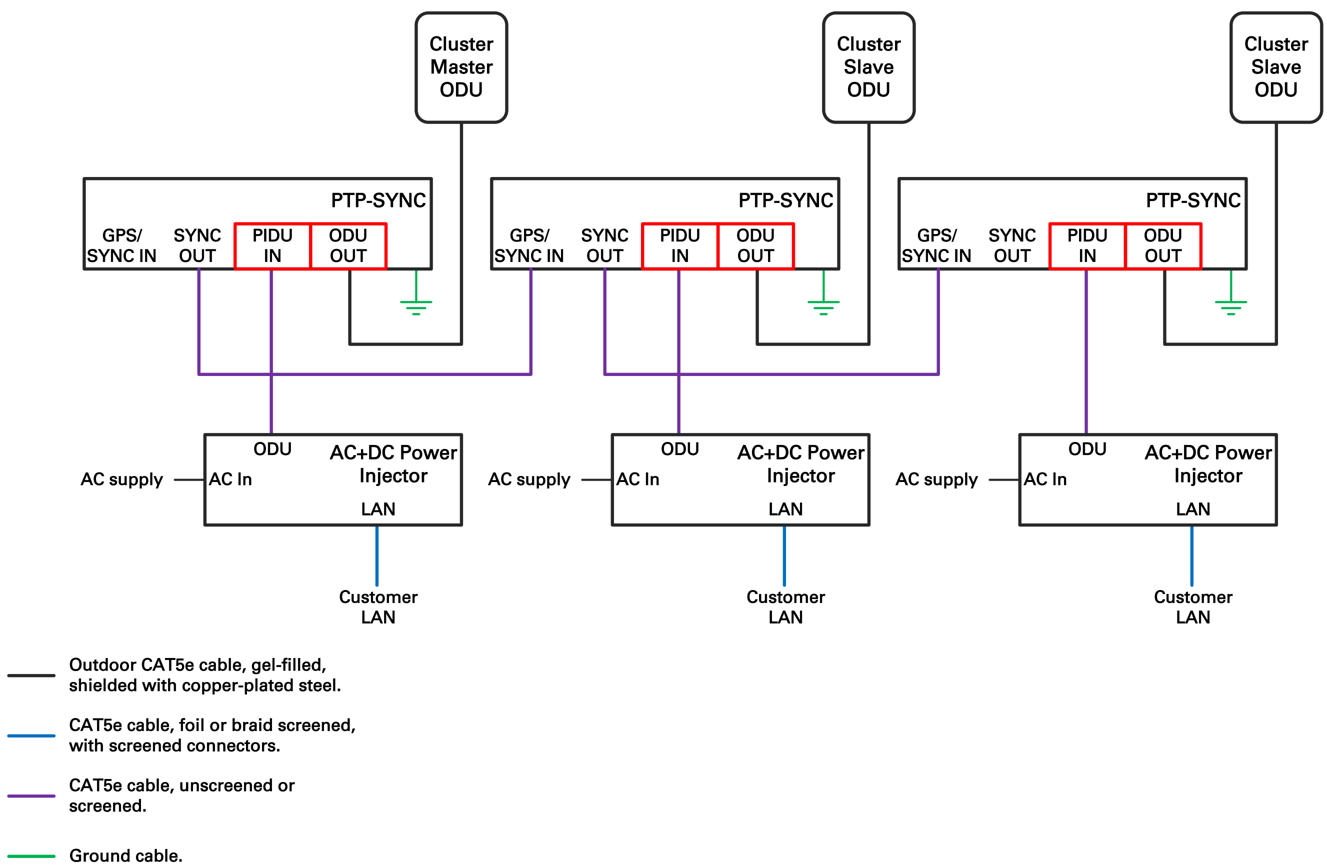
Cluster with PTP-SYNC and no GPS receiver

Each link requires one PTP-SYNC unit. PTP-SYNC units are connected together in a daisy-chain. Between two and ten PTP-SYNCs may be chained in this way. One ODU is designated as a cluster master. Use this configuration where all master ODUs are collocated at a single site. As this configuration does not require a GPS receiver, it provides additional flexibility, particularly in applications requiring rapid deployment (Figure 49).

The wireless configuration settings are:

- Master Slave Mode = **Master** (all ODUs in cluster).
- TDD Sync Device = **PTPSYNC** (all ODUs in cluster).
- Cluster Master Slave = **Cluster Master** (first ODU) and **Cluster Slave** (others).
- PTP Sync Site Reference = **Internal** (all ODUs in cluster).

Figure 49 TDD synchronization configuration – cluster with PTP-SYNC and no GPS



Data network planning

This section describes factors to be considered when planning PTP 650 data networks.

Ethernet interfaces

The PTP 650 Ethernet ports conform to the specifications listed in Table 61.

Table 57 PTP 650 Ethernet bridging specifications

Ethernet Bridging	Specification
Protocol	IEEE802.1; IEEE802.1p; IEEE802.3 compatible
QoS	Eight wireless interface priority queues based on these standards: IEEE 802.1p, IEEE 802.1Q, IEEE 802.1ah, IEEE 802.1ad, DSCP IPv4, DSCP IPv6, MPLS TC, DSCP in PPP Session Stage
Interfaces	100BASE-TX, 1000BASE-T, 1000BASE-SX, 1000BASE-LX MDI/MDIX auto crossover supported
Max Ethernet frame size	9600 bytes
Service classes for traffic	8 classes

Practical Ethernet rates depend on network configuration and higher layer protocols. Over the air throughput is capped to the rate of the Ethernet interface at the receiving end of the link.

Layer two control protocols

PTP 650 identifies layer two control protocols (L2CPs) from the Ethernet destination address of bridged frames. The QoS classification can be separately configured for these protocols.

Table 58 Destination address in layer two control protocols

Destination address	Protocol
01-80-c2-00-00-00 to 01-80-c2-00-00-0f	IEEE 802.1 bridge protocols
01-80-c2-00-00-20 to 01-80-c2-00-00-2f	IEEE 802.1 Multiple Registration Protocol (MRP)
01-80-c2-00-00-30 to 01-80-c2-00-00-3f	IEEE 802.1ag, Connectivity Fault Management (CFM)
01-19-a7-00-00-00 to 01-19-a7-00-00-ff	Ring Automatic Protection Switching (R-APS)
00-e0-2b-00-00-04	Ethernet Automatic Protection Switching (EAPS)

Ethernet port allocation

Port allocation rules

Decide how the three ODU Ethernet ports will be allocated to customer Data Service, Second Data Service, Management Service and Local Management Service based on the following rules:

- Map the **Data Service** to one of the three wired Ethernet ports.
- If required, map the optional **Second Data Service** to one of the remaining wired Ethernet ports. If the Second Data Service is not required, select **None**. The Second Data Service is available only in ODUs with a Full capacity license.
- If required, map the **Management Service** to one of the Ethernet ports, otherwise select **None**. The Management Service will be In-Band if it shares a port with the Data Service or Second Data Service, otherwise it will be Out-of-Band. Out-of-Band Management is not available when the Second Data Service is enabled.
- If required, enable the **Local Management Service** on one or more of the remaining unused Ethernet ports.

The LAN Configuration page ensures that the Management Agent can always be reached using either the **Management Service** or the **Local Management Service**.

Mapping of ports and services

The rules described above allow for the following twelve distinct combinations of services:

Table 59 Combinations of services

Service combination	Figure
Data + Local Management	Figure 50
Data + Local Management + Local Management	Figure 51
Data + In-Band Management	Figure 52
Data + In-Band Management + Local Management	Figure 53
Data + In-Band Management + Local Management + Local Management	Figure 54
Data + Out-of-Band Management	Figure 55
Data + Out-of-Band Management + Local Management	Figure 56
Data + Second Data + In-Band Management (with Data)	Figure 57
Data + Second Data + In-Band Management (with Data) + Local Management	Figure 58
Data + Second Data + In-Band Management (with Second Data)	Figure 59
Data + Second Data + In-Band Management (with Second Data) + Local Management	Figure 60
Data + Second Data + Local Management	Figure 61

Figure 50 to Figure 61 illustrate the internal routing of Ethernet traffic in the twelve combinations of services listed in Table 59.

Figure 50 Ports and Services: Data + Local Management

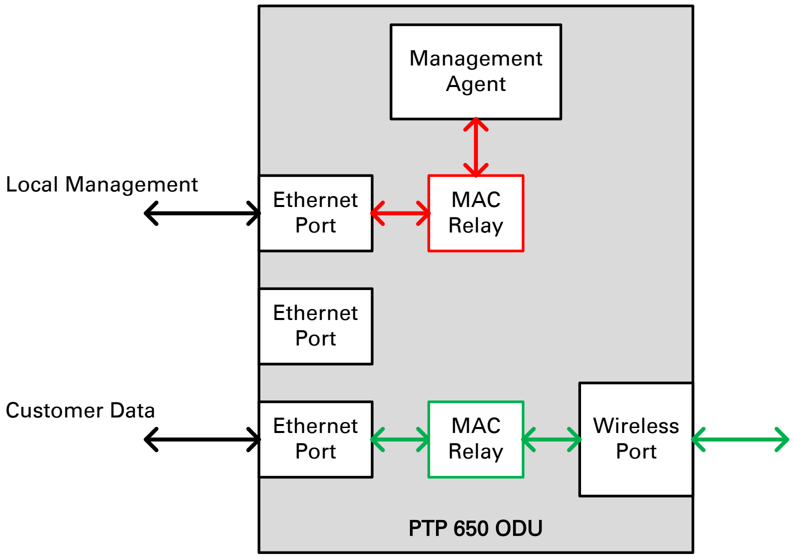


Figure 51 Ports and Services: Data + Local Management + Local Management

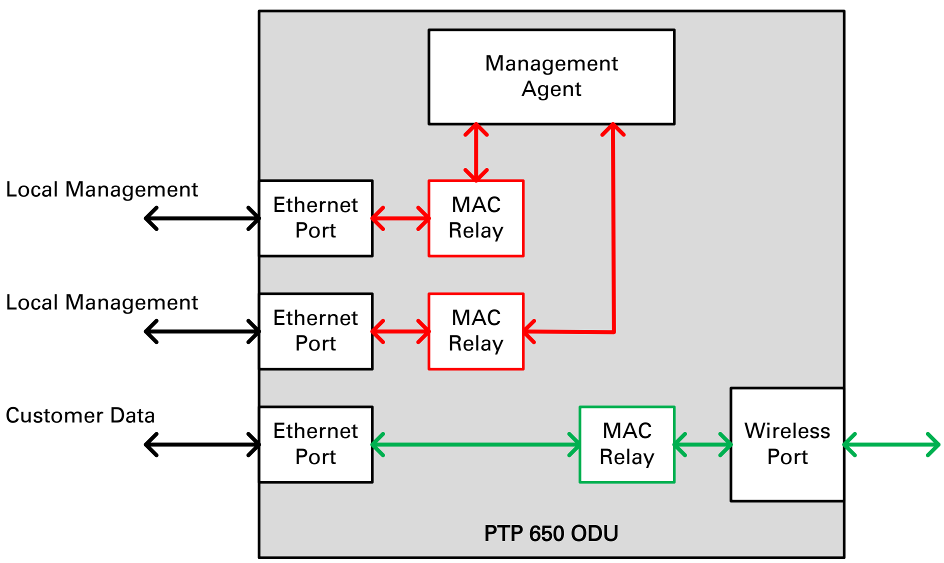


Figure 52 Ports and Services: Data + In-Band Management

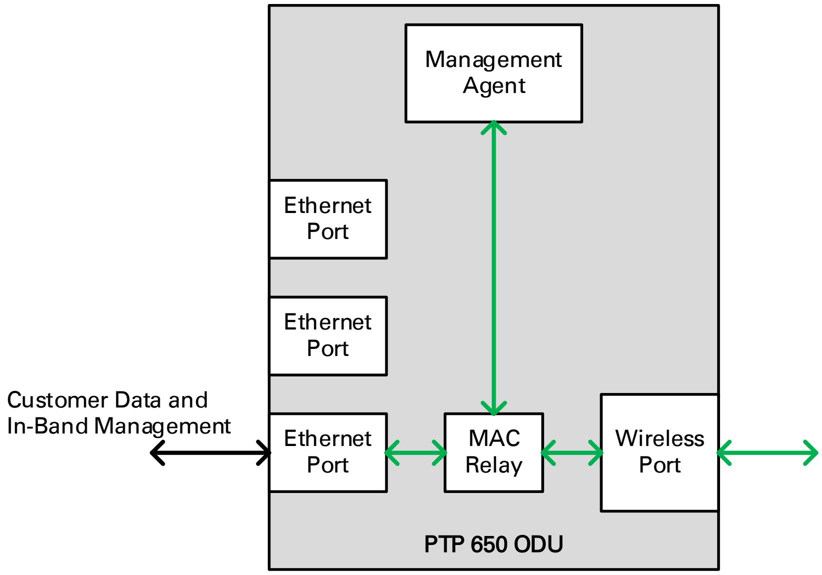


Figure 53 Ports and Services: Data + In-Band Management + Local Management

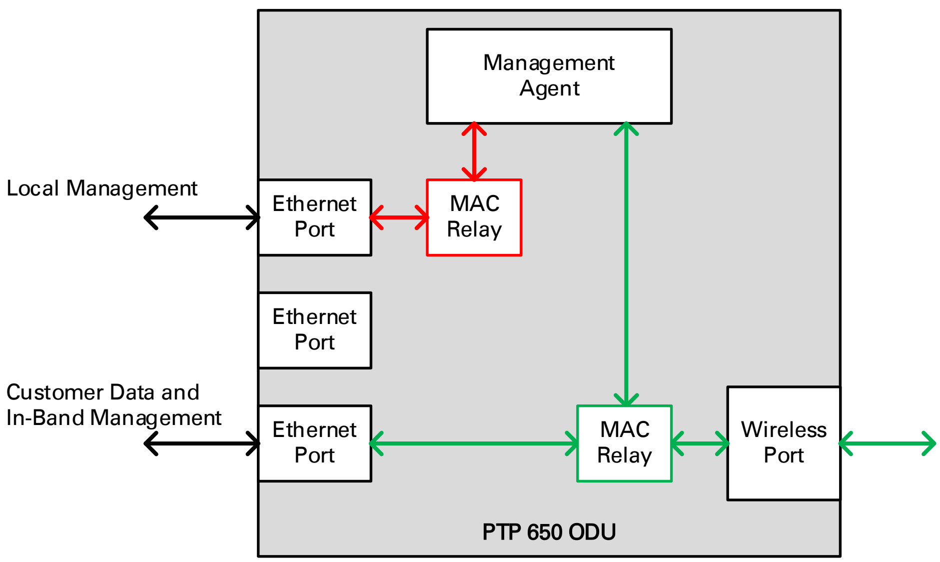


Figure 54 Ports and Services: Data + In-Band Management + Local Management + Local Management

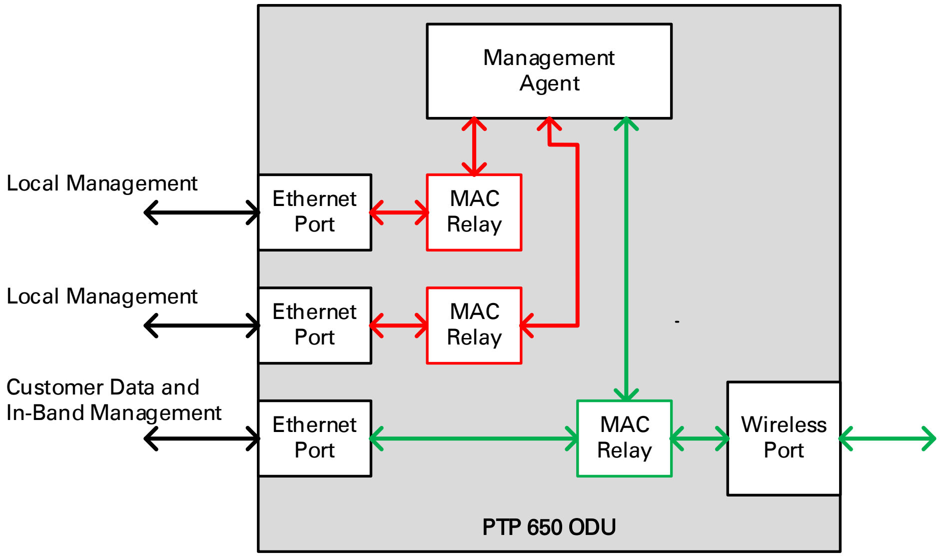


Figure 55 Ports and Services: Data + Out-Of-Band Management

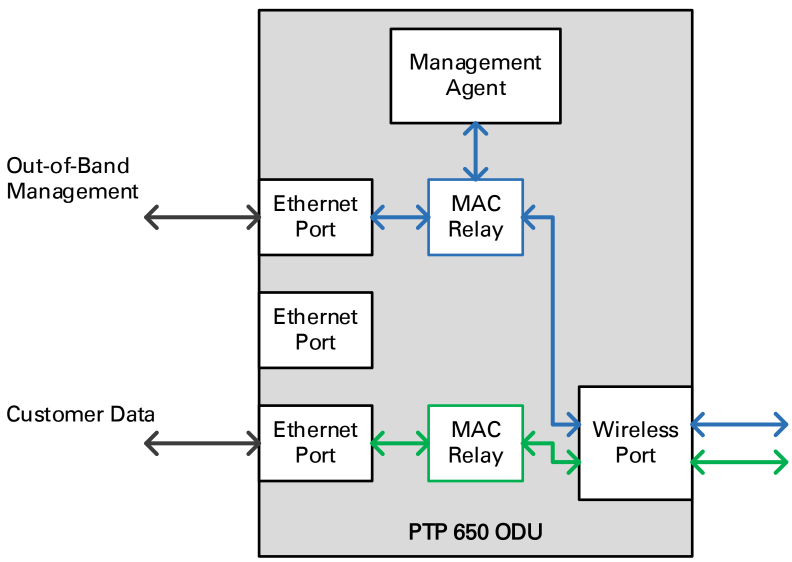


Figure 56 Ports and Services: Data + Out-Of-Band Management + Local Management

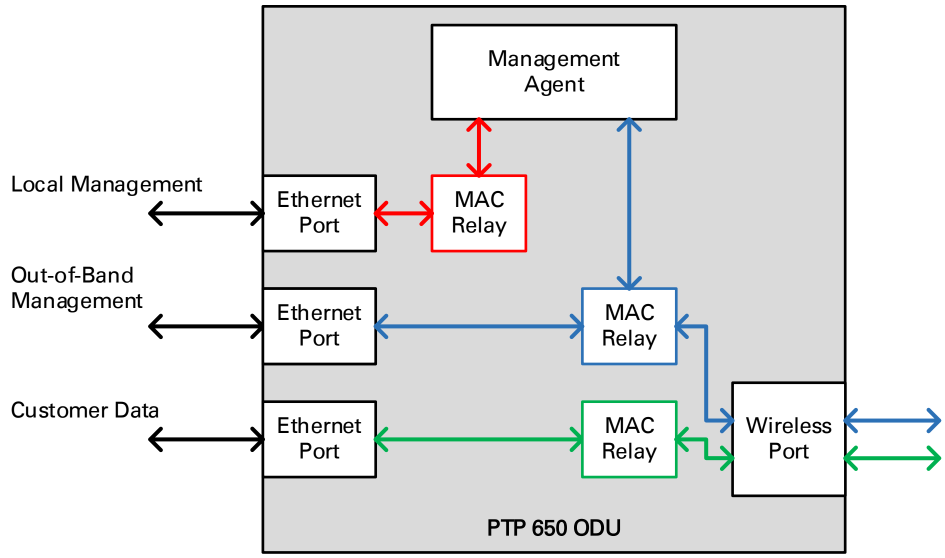


Figure 57 Ports and Services: Data + Second Data + In-Band Management (with Data)

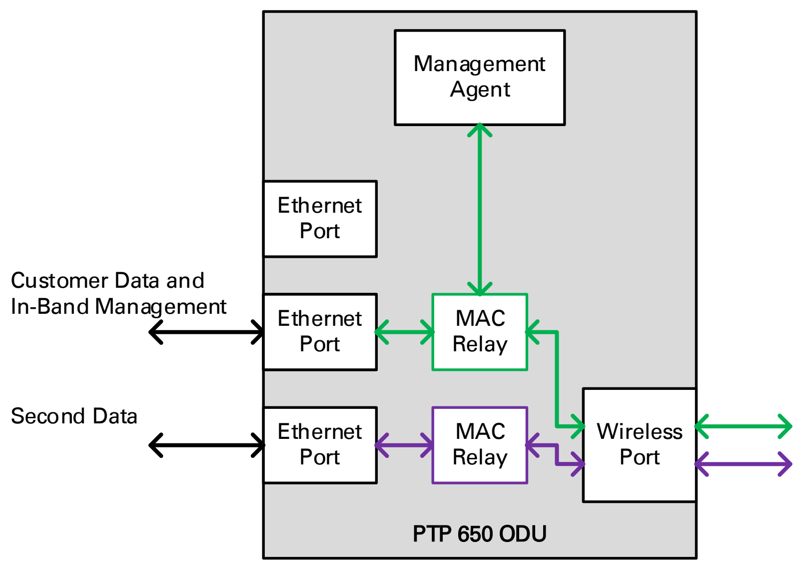


Figure 58 Ports and Services: Data + Second Data + In-Band Management (with Data) + Local Management

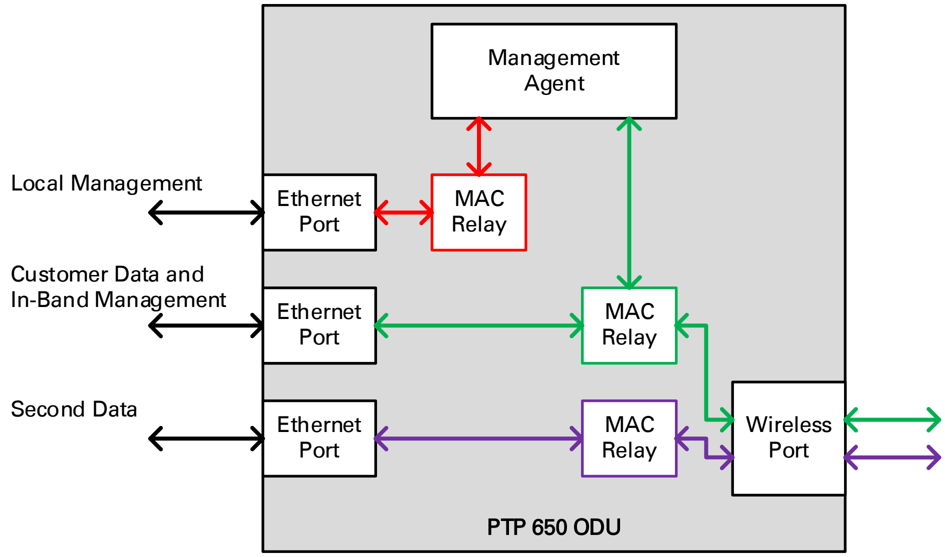


Figure 59 Ports and Services: Data + Second Data + In-Band Management (with Second Data)

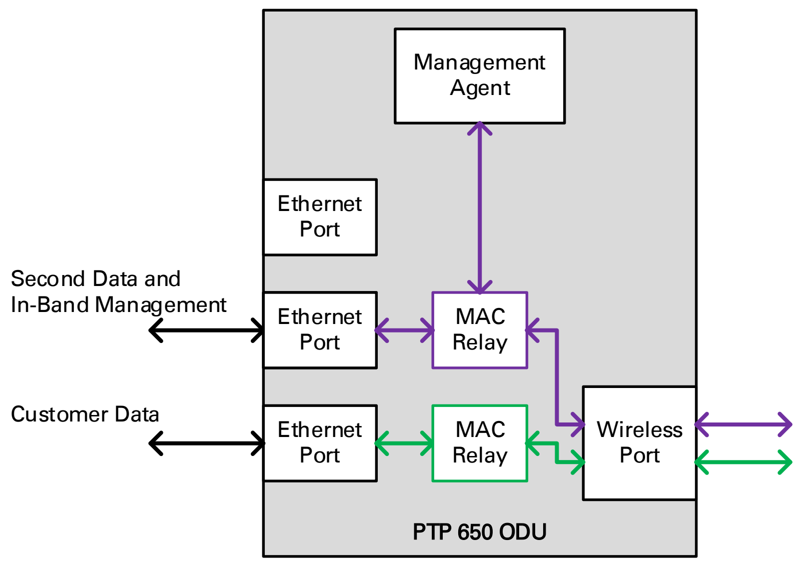


Figure 60 Ports and Services: Data + Second Data + In-Band Management (with Second Data) + Local Management

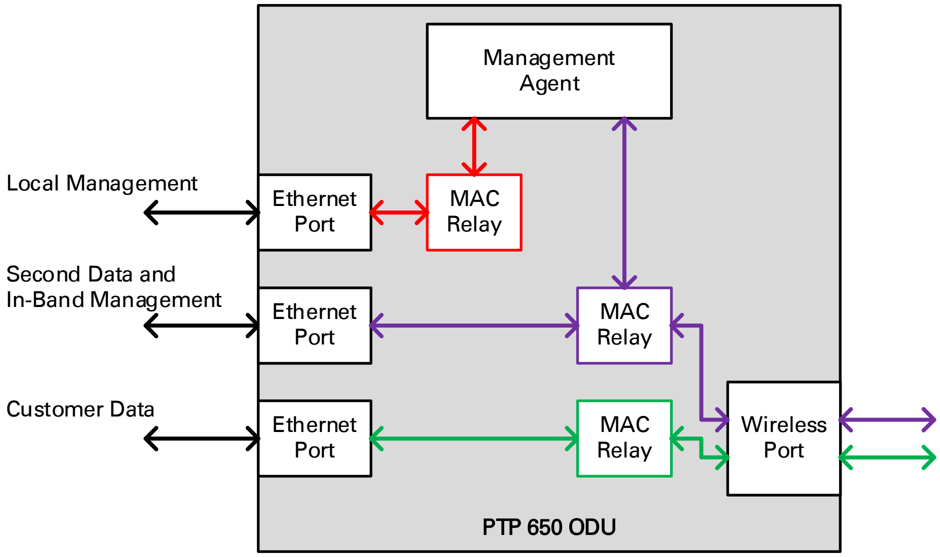
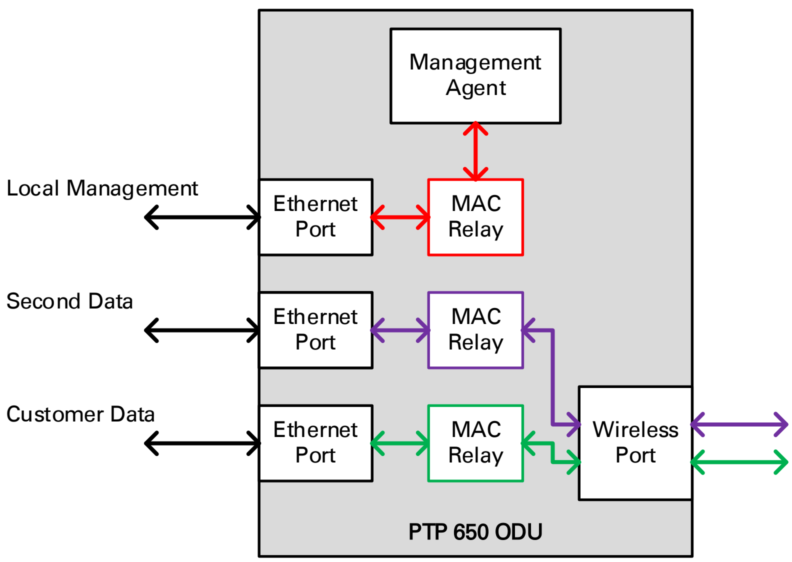


Figure 61 Ports and Services: Data + Second Data + Local Management



Use a compatible combination of services at both ends of the link

PTP 650 allows twelve different combinations of services at each ODU. Local Management can be used at one end or both ends of the link independently. Allowing for optional Local Management, the twelve combinations listed in Table 59 on page 3-36 reduce to a list of six combinations of Data, In-Band Management, Out-of-Band Management and Second Data as follows:

Table 60 Combinations of services with optional Local Management

Service combination
Data + Local Management + [Local Management]
Data + In-Band Management + [Local Management] + [Local Management]
Data + Out-of-Band Management + [Local Management]
Data + Second Data + In-Band Management (with Data) + [Local Management]
Data + Second Data + In-Band Management (with Second Data) + [Local Management]
Data + Second Data + Local Management

Ensure that the same service combination from Table 60 is used at both ends of the link.

Warning

Take care to avoid selecting different combinations of services at the two ends of the link.

Mapping services to physical Ethernet ports

In general, the three physical Ethernet ports (Main PSU, Aux and SFP) are interchangeable. Allowing for the freedom to choose the physical Ethernet ports, the six combinations in Table 60 give rise to a much larger number of different permutations (actually 63 of them).

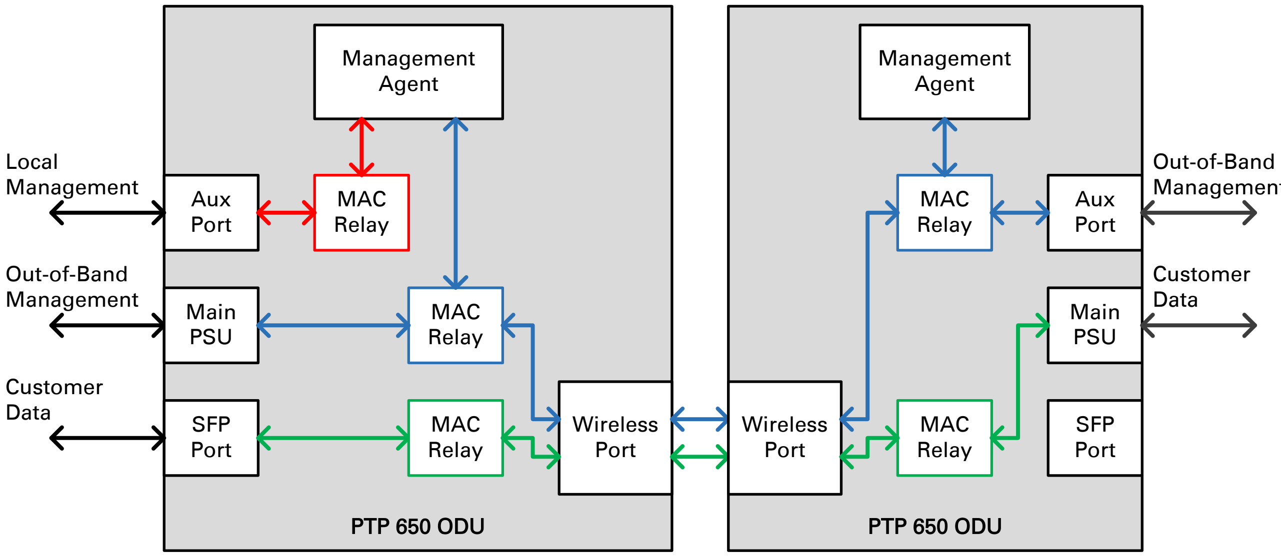
There is no objection to mapping the services to different physical ports at the two ends of the link, providing that the same row of Table 60 is used at each end.

For example, Figure 62 shows a link where the combination of services is from the third row of Table 60. Local Management is provided at one end only. The Management Service maps the Main PSU Port at one end and the Aux Port at the other end. The Data Service maps to the SFP Port at one end of the link and to the Main PSU Port at the other end of the link.

Note

SFP will only be shown as an option when SFP Port Support is enabled via the licence key.

Figure 62 Example of independent mapping of services to ports



Additional port allocation rules

The three Ethernet ports are generally interchangeable, except for some specific additional rules listed below:

- If the TDM interface (E1 or T1) is enabled, ensure that only the Main PSU port is allocated to **Data Service**
- If the system is to be used in a Synchronous Ethernet hierarchy, ensure that the upstream timing source is connected to the Main PSU port (downstream devices can be connected to any port)
- If the system is operating as an IEEE 1588-2008 Transparent Clock, ensure the data path traverses only the Main PSU or Fiber SFP ports at both ends of the link.

Note

The Main PSU port is always used to supply power to the ODU, even when it is not allocated to a data or management service.

Note

The procedure for configuring these ports at the web interface is described in Ethernet port allocation on page 3-36.

Note

Transparent Clock is not supported over the Aux Port and SFP port with Copper connectivity.

VLAN membership

Decide if the IP interface of the ODU management agent will be connected in a VLAN. If so, decide if this is a standard (IEEE 802.1Q) VLAN or provider bridged (IEEE 802.1ad) VLAN, and select the VLAN ID for this VLAN.

Use of a separate management VLAN is strongly recommended. Use of the management VLAN helps to ensure that the ODU management agent cannot be accessed by customers.

If the system is to operate as an IEEE 1588-2008 Transparent Clock, decide if residence time corrections should be made to:

- All 1588 event frames, regardless of VLAN membership, or
- Only 1588 event frames in a specific customer bridged VLAN, or
- Only 1588 event frames in a specific provider bridged VLAN

Priority for management traffic

Choose the Ethernet and IP (DSCP) priority for management traffic generated within the ODU management agent. The priority should be selected so as to be consistent with existing policy on priority of management traffic in the network. Use of a high priority is strongly recommended to ensure that management traffic is not discarded if the link is overloaded.

Ensure that the priority assigned to management traffic is consistent with the quality of service scheme configured for bridged Ethernet traffic. If QoS for bridged traffic is based on the IP/MPLS scheme, set the DSCP management priority to map to a high priority queue. If QoS for bridged traffic is based on the Ethernet scheme, set the VLAN management priority to map to a high priority queue.

IP interface

Select the IP version for the IP interface of the ODU management agent. PTP 650 can operate in IPv4 mode, IPv6 mode, or in a dual IPv4/IPv6 mode. Choose one IPv4 address and/or one IPv6 address for the IP interface of the ODU management agent. The IP address or addresses must be unique and valid for the connected network segment and VLAN.

Find out the correct subnet mask (IPv4) or prefix length (IPv6) and gateway IP address for this network segment and VLAN.

Ensure that the design of the data network permits bidirectional routing of IP datagrams between network management systems and the ODUs. For example, ensure that the gateway IP address identifies a router or other gateway that provides access to the rest of the data network.

Quality of service for bridged Ethernet traffic

Decide how quality of service will be configured in PTP 650 to minimize frame loss and latency for high priority traffic. Wireless links often have lower data capacity than wired links or network equipment like switches and routers, and quality of service configuration is most critical at network bottlenecks.

PTP 650 provides eight queues for traffic waiting for transmission over the wireless link. Q0 is the lowest priority queue and Q7 is the highest priority queue. Traffic is scheduled using strict priority; in other words, traffic in a given queue is transmitted when all higher-priority queues are empty.

Layer 2 control protocols

Select the transmission queue for each of the recognised layer 2 control protocols (L2CP). These protocols are essential to correct operation of the Ethernet network, and are normally mapped to a high priority queue. Ethernet frames that match one of the recognized L2CPs are not subject to the Ethernet and IP/MPLS classification described below.

Priority schemes

Select the priority scheme based on Ethernet priority or IP/MPLS priority to match QoS policy in the rest of the data network. Ethernet priority is also known as Layer 2 or link layer priority. IP/MPLS priority is also known as Layer 3 or network layer priority.

Ethernet priority scheme

Ethernet priority is encoded in a VLAN tag. Use the Ethernet priority scheme if the network carries traffic in customer or service provider VLANs, and the priority in the VLAN tag has been set to indicate the priority of each type of traffic. Select a suitable mapping from the Ethernet priority to the eight PTP 650 queues.

An advantage of Ethernet priority is that any VLAN-tagged frame can be marked with a priority, regardless of the higher-layer protocols contained within the frame. A disadvantage of Ethernet priority is that the priority in the frame must be regenerated whenever traffic passes through a router.

IP/MPLS priority scheme

IP priority is determined by the DSCP value encoded in the ToS field in IPv4 and Traffic Class in IPv6. PTP 650 can locate the DSCP value in IP headers encapsulated within VLAN tags and/or PPP and PPPoE headers. The DSCP field provides 64 levels of priority. PTP 650 selects a suitable mapping from these DSCP values to the eight PTP 650 queues.

The advantages of IP priority are that priority in the IP header is normally propagated transparently through a router, also the DSCP field supports a large number of distinct priority code points. A disadvantage of DSCP is that frames receive a single default classification if they contain a network layer protocol other than IPv4 or IPv6. This is controlled by the user setting the Unknown Network Layer Protocol queue value in the same QoS Configuration page under IP/MPLS QoS.

MPLS priority is encoded in the traffic class (TC) field in the outermost MPLS label. Select a suitable mapping from MPLS TC to the eight PTP 650 queues.

“Daisy-chaining” PTP 650 links

When connecting two or more PTP 650 links together in a network (daisy-chaining), do not install direct copper Cat5e connections between the PSUs. Each PSU must be connected to the network terminating equipment using the LAN port. To daisy-chain PTP 650 links, install each ODU-to-ODU link using one of the following solutions:

- A copper Cat5e connection between the Aux ports of two ODUs. For details of the Ethernet standards supported and maximum permitted cable lengths, see Ethernet standards and cable lengths on page 2-38.
- A copper Cat5e connection between the Aux port of one ODU and the SFP port of the next ODU (using a copper SFP module). For details of the Ethernet standards supported and maximum permitted cable lengths, see Ethernet standards and cable lengths on page 2-38.
- Optical connections between the ODUs (SFP ports) using optical SFP modules at each ODU. For details of the Ethernet standards supported and maximum permitted cable lengths, see SFP module kits on page 2-45.

Green Ethernet switches

Do not connect PTP 650 units to Ethernet networking products that control the level of the transmitted Ethernet signal based on the measured length of the Ethernet link, for example Green Ethernet products manufactured by D-Link Corporation. The Ethernet interfaces in these networking products do not work correctly when connected directly to the PTP 650 PSU.

TDM network planning

This section describes factors to be considered when planning PTP 650 TDM networks.

Caution

If the ODU port has negotiated a link at 100BASE-T, the NIDU will not send or receive TDM data, and will not bridge customer data traffic. Ensure that the Ethernet drop cable between the ODU and the PSU, and the network cable between the PSU and the NIDU, will reliably support operation at 1000BASE-T.

The PTP 650 TDM ports conform to the specifications listed in Table 61.

Table 61 PTP 650 TDM interface specifications (if NIDU installed)

TDM Bridging	Specification
TDM ports	8 E1 or 8 T1 ITU-T Recommendation G.703 (10/1998) – Series G: "Transmission Systems and Media, Digital Systems and Networks; "Physical/electrical characteristics of hierarchical digital Interfaces".
Timing	ITU-T Recommendation G.823 (03/2000) – Series G: "Transmission Systems and Media, Digital Systems and Networks; The control of jitter and wander within digital networks which are based on the 2048 kbits/s hierarchy". ITU-T Recommendation G.824 (03/2000) – Series G: "Transmission Systems and Media, Digital Systems and Networks; The control of jitter and wander within digital networks which are based on the 1544 kbit/s hierarchy".
Ethernet	IEEE 802.3 2012 – IEEE Standard for Information technology – Telecommunications and information – exchange between systems – Local and metropolitan area networks – Specific requirements.
Line coding	AMI, B8ZS/HDB3
Line resistance	100 / 120 Ohm
E1/T1 latency (one way)	Typically 1 to 3 ms depending on range, bandwidth, modulation mode and number of E1/T1 port. Use LINKPlanner to calculate E1/T1 latency.

Network management planning

This section describes how to plan for PTP 650 links to be managed remotely using SNMP.

Planning for SNMP operation

The supported notifications are as follows:

- Cold start
- Wireless Link Up/Down
- Channel Change
- DFS Impulse Interference
- Authentication Failure
- Main PSU Port Up Down
- Aux Port Up Down
- SFP Port Up Down

Ensure that the following MIBs are loaded on the network management system.

- RFC-1493. BRIDGE-MIB
- RFC-2233. IF-MIB
- RFC-3411. SNMP-FRAMEWORK-MIB
- RFC-3412. SNMP-MPD-MIB
- RFC-3413. SNMP-TARGET-MIB
- RFC-3414. SNMP-USER-BASED-SM-MIB
- RFC-3415. SNMP-VIEW-BASED-ACM-MIB
- RFC-3418. SNMPv2-MIB
- RFC-3826. SNMP-USM-AES-MIB
- RFC-4293 IP-MIB
- PTP 650 Series proprietary MIB

Note

The proprietary MIBs are provided in the PTP 650 Series software download files in the support website (see Contacting Cambium Networks on page 1).

Supported diagnostic alarms

PTP 650 supports the diagnostic alarms listed in Table 175.

The web-based interface may be used to enable or disable generation of each supported SNMP notification or diagnostic alarm.

Enabling SNMP

Enable the SNMP interface for use by configuring the following attributes in the SNMP Configuration page:

- SNMP State (default disabled)
- SNMP Version (default SNMPv1/2c)
- SNMP Port Number (default 161)

Security planning

This section describes how to plan for PTP 650 links to operate in secure mode.

Planning for SNTP operation

Note

PTP 650 does not have a battery-powered clock, so the set time is lost each time the ODU is powered down. To avoid the need to manually set the time after each reboot, use SNTP server synchronization.

Before starting to configure Simple Network Time Protocol (SNTP):

- Identify the time zone and daylight saving requirements that apply to the system.
- If SNTP server synchronization is required, identify the details of one or two SNTP servers: IP address, port number and server key.
- Decide whether or not to authenticate received NTP messages using an MD5 signature.

Planning for HTTPS/TLS operation

Before starting to configure HTTPS/TLS operation, ensure that the cryptographic material listed in Table 62 is available.

Table 62 HTTPS/TLS security material

Item	Description	Quantity required
Key of Keys	An encryption key generated using a cryptographic key generator. The key length is dictated by the installed license key. License keys with AES-128 will require a key of keys of 128-bits. License keys with AES-256 will require a key of keys of 256-bits. The key output should be in ASCII hexadecimal characters.	Two per link. For greater security, each link end should be allocated a unique Key of Keys.

Item	Description	Quantity required
TLS Private Key and Public Certificates	An RSA private key of size 2048 bits, generated in either PKCS#1 or PKCS#5 format, unencrypted, and encoded in the ASN.1 DER format. An X.509 certificate containing an RSA public key, generated in either PKCS#1 or PKCS#5 format, unencrypted, and encoded in the ASN.1 DER format. The public key certificate must have Common Name equal to the IPv4 or IPv6 address of the ODU. The public key certificate must form a valid pair with the private key.	Two pairs per link. These items are unique to IP address.
User Defined Security Banner	The banner provides warnings and notices to be read by the user before logging in to the ODU. Use text that is appropriate to the network security policy.	Normally one per link. This depends upon network policy.
Entropy Input	This must be of size 512 bits (128 hexadecimal characters), output from a random number generator.	Two per link. For greater security, each link end should be allocated a unique Entropy Input.
Wireless Link Encryption Key for AES	An encryption key generated using a cryptographic key generator. The key length is dictated by the selected AES encryption algorithm (128 or 256 bits).	One per link. The same encryption key is required at each link end.
Port numbers for HTTP, HTTPS and Telnet	Port numbers allocated by the network.	As allocated by network.

Planning for SNMPv3 operation

SNMP security mode

Decide how SNMPv3 security will be configured.

MIB-based security management uses standard SNMPv3 MIBs to configure the user-based security model and the view-based access control model. This approach provides considerable flexibility, allowing a network operator to tailor views and security levels appropriate for different types of user. MIB-based security management may allow a network operator to take advantage of built-in security management capabilities of existing network managers.

Web-based security management allows an operator to configure users, security levels, privacy and authentication protocols, and passphrases using the PTP 650 web-based management interface. The capabilities supported are somewhat less flexible than those supported using the MIB-based security management, but will be sufficient in many applications. Selection of web-based management for SNMPv3 security disables the MIB-based security management. PTP 650 does not support concurrent use of MIB-based and web-based management of SNMPv3 security.

Web-based management of SNMPv3 security

Initial configuration of SNMPv3 security is available only to HTTP or HTTPS/TLS user accounts with security role of Security Officer.

Identify the minimum security role of HTTP or HTTPS/TLS user accounts that will be permitted access for web-based management of SNMPv3 security. The following roles are available:

- System Administrator
- Security Officer

Identify the format used for SNMP Engine ID. The following formats are available:

- MAC address (default)
- IPv4 address
- Text string
- IPv6 address

If SNMP Engine ID will be based on a text string, identify the text string required by the network management system. This is often based on some identifier that survives replacement of the PTP hardware.

Identify the user names and security roles of initial SNMPv3 users. Two security roles are available:

- Read Only
- System Administrator

Identify the security level for each of the security roles. Three security levels are available: (a) No authentication, no privacy; (b) Authentication, no privacy; (c) Authentication, privacy.

If authentication is required, identify the protocol. Two authentication protocols are available: MD5 or SHA.

If privacy will be used, identify the protocol. Two privacy protocols are available: DES or AES (an AES 128-bit or 256-bit capability upgrade must be purchased).

If authentication or authentication and privacy protocols are required, identify passphrases for each protocol for each SNMP user. It is considered good practice to use different passphrases for authentication and privacy. Passphrases must have length between 8 and 32 characters, and may contain any of the characters listed in Table 63.

Table 63 Permitted character set for SNMPv3 passphrases

Character	Code	Character	Code
<space>	32	;	59
!	33	<	60
“	34	=	61
#	35	>	62
$	36	?	63
%	37	@	64
&	38	A..Z	65..90
'	39	[	91
(	40	\	92
)	41	]	93
*	42	^	94
+	43	_	95
,	44	`	96
-	45	a..z	97..122
.	46	{	123
/	47	|	124
0..9	48..57	}	125
:	58	~	126

Identify up to two SNMP users that will be configured to receive notifications (traps). Identify the Internet address (IPv4 or IPv6) and UDP port number of the associated SNMP manager.

SNMPv3 default configuration (MIB-based)

When SNMPv3 MIB-based Security Mode is enabled, the default configuration for the `usmUserTable` table is based on one initial user and four template users as listed in Table 64.

Table 64 Default SNMPv3 users

Object	Entry 1
Name	initial
SecurityName	initial
AuthProtocol	usmHMACMD5AuthProtocol
PrivProtocol	usmDESPrivProtocol
StorageType	nonVolatile

Object	Entry 2	Entry 3
Name	templateMD5_DES	templateSHA_DES
SecurityName	templateMD5_DES	templateSHA_DES
AuthProtocol	usmHMACMD5AuthProtocol	usmHMACSAHAuthProtocol
PrivProtocol	usmDESPrivProtocol	usmDESPrivProtocol
StorageType	nonVolatile	nonVolatile

Object	Entry 4	Entry 5
Name	templateMD5_AES	templateSHA_AES
SecurityName	templateMD5_AES	templateSHA_AES
AuthProtocol	usmHMACMD5AuthProtocol	usmHMACSHAAuthProtocol
PrivProtocol	usmAESPrivProtocol	usmAESPrivProtocol
StorageType	nonVolatile	nonVolatile

VACM default configuration

The default user `initial` is assigned to VACM group `initial` in the `vacmSecurityToGroupTable` table. The template users are not assigned to a group.

PTP 650 creates default view trees and access as shown in Table 65 and Table 66.

Table 65 Default VACM view trees

Object	Entry 1	Entry 2
ViewName	internet	restricted
Subtree	1.3.6.1	1.3.6.1
Mask	""	""
Type	included	included
StorageType	nonVolatile	nonvolatile

Table 66 Default data fill for access table

Object	Entry 1	Entry 2
GroupName	initial	initial
ContextPrefix	""	""
SecurityLevel	authNoPriv	noAuthNoPriv
ContextMatch	exact	exact
ReadViewName	internet	restricted
WriteViewName	internet	""
NotifyViewName	internet	restricted
StorageType	nonVolatile	nonVolatile

Planning for RADIUS operation

Configure RADIUS where remote authentication is required for users of the web-based interface. Remote authentication has the following advantages:

- Control of passwords can be centralized.
- Management of user accounts can be more sophisticated. For example; users can be prompted by a network manager to change passwords at regular intervals. As another example, passwords can be checked for inclusion of dictionary words and phrases.
- Passwords can be updated without reconfiguring multiple network elements.
- User accounts can be disabled without reconfiguring multiple network elements.

Remote authentication has one significant disadvantage in a wireless link product such as PTP 650. If the wireless link is down, a unit on the remote side of the broken link may be prevented from contacting a RADIUS Server, with the result that users are unable to access the web-based interface.

One useful strategy would be to combine RADIUS authentication for normal operation with a single locally-authenticated user account for emergency use.

PTP 650 provides a choice of the following authentication methods:

- CHAP
- MS-CHAPv2

Ensure that the authentication method selected in PTP 650 is supported by the RADIUS server.

RADIUS attributes

If the standard RADIUS attribute session-timeout (Type 27) is present in a RADIUS response, PTP 650 sets a maximum session length for the authenticated user. If the attribute is absent, the maximum session length is infinite.

If the standard RADIUS attribute idle-timeout (Type 28) is present in a RADIUS response, PTP 650 overrides the Auto Logout Timer with this value in the authenticated session.

If the vendor-specific RADIUS attribute auth-role is present in a RADIUS response, PTP 650 selects the role for the authenticated user according to auth-role. The supported values of auth-role are as follows:

- 0: Invalid role. The user is not admitted.
- 1: Read Only
- 2: System Administrator
- 3: Security Officer

If the vendor-specific auth-role attribute is absent, but the standard service-type (Type 6) attribute is present, PTP 650 selects the role for the authenticated user according to service-type. The supported values of service-type are as follows:

- Login(1): Read Only
- Administrative(6): System Administrator
- NAS Prompt(7): Read Only

If the auth-role and service-type attributes are absent, PTP 650 selects the Read Only role.

The auth-role vendor-specific attribute is defined in Table 67.

Table 67 Definition of auth-role vendor-specific attribute

Field	Length	Value	Notes
Type	1	26	Vendor-specific attribute.
Length	1	12	Overall length of the attribute.
Vendor ID	4	17713	The same IANA code used for the SNMP enterprise MIB.
Vendor Type	1	1	auth-role
Vendor Length	1	4	Length of the attribute specific part.
Attribute-Specific	4	0..3	Integer type (32-bit unsigned). Supported values: invalid-role(0), readonly-role(1), system-admin-role(2), security-officer-role(3).

System threshold, output power and link loss

Use the following tables to look up the system threshold (dBm), output power (dBm) and maximum link loss (dB) per channel bandwidth and modulation mode:

Band	Mode	System threshold and output power (dBm)	Maximum link loss (dB)
4.9 GHz	IP	Table 68	Table 69
	TDM	Table 70	Table 71
5.1 GHz and 5.2 GHz	IP	Table 72	Table 73
	TDM	Table 74	Table 75
5.4 GHz	IP	Table 76	Table 77
	TDM	Table 78	Table 79
5.8 GHz	IP	Table 80	Table 81
	TDM	Table 82	Table 83
5.9 GHz	IP	Table 84	Table 85
	TDM	Table 86	Table 87

Note

Maximum link loss has been calculated assuming use of the integrated antenna in PTP 650 Integrated ODUs. Adjust the maximum link loss for alternative antennas by adding (*G* – 23) for each antenna, where *G* is the antenna gain.

Table 68 4.9 GHz IP mode: system threshold per channel bandwidth and output power (P) (dBm)

Modulation mode	5 MHz	10 MHz	15 MHz	20 MHz	P (all bands)
BPSK 0.63 single	-96.6	-95.1	-93.3	-92.0	27
QPSK 0.63 single	-93.5	-92.0	-90.2	-88.9	26
QPSK 0.87 single	-89.4	-87.9	-86.2	-84.9	26
16QAM 0.63 single	-87.1	-85.6	-83.8	-82.6	25
16QAM 0.63 dual	-83.2	-81.7	-79.9	-78.7	25
16QAM 0.87 single	-82.6	-81.1	-79.4	-78.1	25
16QAM 0.87 dual	-79.6	-78.1	-76.3	-75.0	25
64QAM 0.75 single	-79.6	-78.1	-76.3	-75.1	24
64QAM 0.75 dual	-76.5	-75.0	-73.2	-71.9	24
64QAM 0.92 single	-75.7	-74.2	-72.4	-71.2	24
64QAM 0.92 dual	-72.4	-70.9	-69.2	-67.9	24
256QAM 0.81 single	-72.4	-70.9	-69.1	-67.9	23
256QAM 0.81 dual	-68.9	-67.3	-65.6	-64.3	23

Table 69 4.9 GHz IP mode: maximum link loss per channel bandwidth (dB)

Modulation mode	5 MHz	10 MHz	15 MHz	20 MHz
BPSK 0.63 single	169.6	168.1	166.3	165.0
QPSK 0.63 single	165.5	164.0	162.2	160.9
QPSK 0.87 single	161.4	159.9	158.2	156.9
16QAM 0.63 single	158.1	156.6	154.8	153.6
16QAM 0.63 dual	154.2	152.7	150.9	149.7
16QAM 0.87 single	153.6	152.1	150.4	149.1
16QAM 0.87 dual	150.6	149.1	147.3	146.0
64QAM 0.75 single	149.6	148.1	146.3	145.1
64QAM 0.75 dual	146.5	145.0	143.2	141.9
64QAM 0.92 single	145.7	144.2	142.4	141.2
64QAM 0.92 dual	142.4	140.9	139.2	137.9
256QAM 0.81 single	141.4	139.9	138.1	136.9
256QAM 0.81 dual	137.9	136.3	134.6	133.3

Table 70 4.9 GHz TDM mode:system threshold per channel bandwidth and output power (P) (dBm)

Modulation mode	5 MHz	10 MHz	15 MHz	20 MHz	P (all bands)
BPSK 0.63 single	-96.6	-95.1	-93.3	-92.0	27
QPSK 0.63 single	-90.4	-88.9	-87.2	-85.9	26
QPSK 0.87 single	-86.4	-84.9	-83.1	-81.9	26
16QAM 0.63 single	-84.1	-82.6	-80.8	-79.5	25
16QAM 0.63 dual	-80.1	-78.6	-76.8	-75.6	25
16QAM 0.87 single	-79.5	-78.0	-76.2	-75.0	25
16QAM 0.87 dual	-76.4	-74.8	-73.1	-71.8	25
64QAM 0.75 single	-76.3	-74.8	-73.0	-71.7	24
64QAM 0.75 dual	-73.0	-71.5	-69.8	-68.5	24
64QAM 0.92 single	-73.9	-72.3	-70.6	-69.3	24
64QAM 0.92 dual	-70.5	-69.0	-67.2	-65.9	24
256QAM 0.81 single	-72.4	-70.9	-69.1	-67.9	23
256QAM 0.81 dual	-68.9	-67.3	-65.6	-64.3	23

Table 71 4.9 GHz TDM mode: maximum link loss per channel bandwidth (dB)

Modulation mode	5 MHz	10 MHz	15 MHz	20 MHz
BPSK 0.63 single	169.6	168.1	166.3	165.0
QPSK 0.63 single	162.4	160.9	159.2	157.9
QPSK 0.87 single	158.4	156.9	155.1	153.9
16QAM 0.63 single	155.1	153.6	151.8	150.5
16QAM 0.63 dual	151.1	149.6	147.8	146.6
16QAM 0.87 single	150.5	149.0	147.2	146.0
16QAM 0.87 dual	147.4	145.8	144.1	142.8
64QAM 0.75 single	146.3	144.8	143.0	141.7
64QAM 0.75 dual	143.0	141.5	139.8	138.5
64QAM 0.92 single	143.9	142.3	140.6	139.3
64QAM 0.92 dual	140.5	139.0	137.2	135.9
256QAM 0.81 single	141.4	139.9	138.1	136.9
256QAM 0.81 dual	137.9	136.3	134.6	133.3

Table 72 5.1/5.2 GHz IP mode: system threshold per channel bandwidth and o/p power (P) (dBm)

Modulation mode	5 MHz	10 MHz	15 MHz	20 MHz	30 MHz	40 MHz	45 MHz	P (all bands)
BPSK 0.63 single	-95.8	-94.3	-92.5	-91.3	-89.5	-88.3	-87.8	27
QPSK 0.63 single	-92.7	-91.2	-89.4	-88.2	-86.4	-85.2	-84.7	26
QPSK 0.87 single	-88.7	-87.2	-85.4	-84.2	-82.4	-81.2	-80.7	26
16QAM 0.63 single	-86.4	-84.9	-83.1	-81.9	-80.1	-78.8	-78.3	25
16QAM 0.63 dual	-82.4	-80.9	-79.2	-77.9	-76.2	-74.9	-74.4	25
16QAM 0.87 single	-81.9	-80.4	-78.6	-77.4	-75.6	-74.4	-73.8	25
16QAM 0.87 dual	-78.8	-77.3	-75.6	-74.3	-72.6	-71.3	-70.8	25
64QAM 0.75 single	-78.9	-77.4	-75.6	-74.3	-72.6	-71.3	-70.8	24
64QAM 0.75 dual	-75.8	-74.3	-72.5	-71.2	-69.5	-68.2	-67.7	24
64QAM 0.92 single	-75.0	-73.5	-71.7	-70.5	-68.7	-67.5	-67.0	24
64 QAM 0.92 dual	-71.8	-70.3	-68.5	-67.3	-65.5	-64.3	-63.7	24
256QAM 0.81 single	-71.8	-70.3	-68.6	-67.3	-65.6	-64.3	-63.8	23
256QAM 0.81 dual	-68.4	-66.9	-65.1	-63.8	-62.1	-60.8	-60.3	23

Table 73 5.1 GHz and 5.2 GHz IP mode: maximum link loss per channel bandwidth (dB)

Modulation mode	5 MHz	10 MHz	15 MHz	20 MHz	30 MHz	40 MHz	45 MHz
BPSK 0.63 single	168.8	167.3	165.5	164.3	162.5	161.3	160.8
QPSK 0.63 single	164.7	163.2	161.4	160.2	158.4	157.2	156.7
QPSK 0.87 single	160.7	159.2	157.4	156.2	154.4	153.2	152.7
16QAM 0.63 single	157.4	155.9	154.1	152.9	151.1	149.8	149.3
16QAM 0.63 dual	153.4	151.9	150.2	148.9	147.2	145.9	145.4
16QAM 0.87 single	152.9	151.4	149.6	148.4	146.6	145.4	144.8
16QAM 0.87 dual	149.8	148.3	146.6	145.3	143.6	142.3	141.8
64QAM 0.75 single	148.9	147.4	145.6	144.3	142.6	141.3	140.8
64QAM 0.75 dual	145.8	144.3	142.5	141.2	139.5	138.2	137.7
64QAM 0.92 single	145.0	143.5	141.7	140.5	138.7	137.5	137.0
64 QAM 0.92 dual	141.8	140.3	138.5	137.3	135.5	134.3	133.7
256QAM 0.81 single	140.8	139.3	137.6	136.3	134.6	133.3	132.8
256QAM 0.81 dual	137.4	135.9	134.1	132.8	131.1	129.8	129.3

Table 74 5.1/5.2 GHz TDM mode: system threshold per channel bandwidth and o/p pwr (P) (dBm)

Modulation mode	5 MHz	10 MHz	15 MHz	20 MHz	30 MHz	40 MHz	45 MHz	P (all bands)
BPSK 0.63 single	-95.8	-94.3	-92.5	-91.3	-89.5	-88.3	-87.8	27
QPSK 0.63 single	-89.7	-88.2	-86.4	-85.2	-83.4	-82.2	-81.7	26
QPSK 0.87 single	-85.7	-84.2	-82.4	-81.1	-79.4	-78.1	-77.6	26
16QAM 0.63 single	-83.3	-81.8	-80.1	-78.8	-77.0	-75.8	-75.3	25
16QAM 0.63 dual	-79.4	-77.8	-76.1	-74.8	-73.1	-71.8	-71.3	25
16QAM 0.87 single	-78.8	-77.2	-75.5	-74.2	-72.5	-71.2	-70.7	25
16QAM 0.87 dual	-75.7	-74.1	-72.4	-71.1	-69.4	-68.1	-67.6	25
64QAM 0.75 single	-75.6	-74.1	-72.3	-71.1	-69.3	-68.1	-67.5	24
64QAM 0.75 dual	-72.4	-70.9	-69.1	-67.9	-66.1	-64.9	-64.3	24
64QAM 0.92 single	-73.2	-71.7	-70.0	-68.7	-66.9	-65.7	-65.2	24
64 QAM 0.92 dual	-69.9	-68.4	-66.6	-65.4	-63.6	-62.4	-61.8	24
256QAM 0.81 single	-71.8	-70.3	-68.6	-67.3	-65.6	-64.3	-63.8	23
256QAM 0.81 dual	-68.4	-66.9	-65.1	-63.8	-62.1	-60.8	-60.3	23

Table 75 5.1 GHz and 5.2 GHz TDM mode: maximum link loss per channel bandwidth (dB)

Modulation mode	5 MHz	10 MHz	15 MHz	20 MHz	30 MHz	40 MHz	45 MHz
BPSK 0.63 single	168.8	167.3	165.5	164.3	162.5	161.3	160.8
QPSK 0.63 single	161.7	160.2	158.4	157.2	155.4	154.2	153.7
QPSK 0.87 single	157.7	156.2	154.4	153.1	151.4	150.1	149.6
16QAM 0.63 single	154.3	152.8	151.1	149.8	148.0	146.8	146.3
16QAM 0.63 dual	150.4	148.8	147.1	145.8	144.1	142.8	142.3
16QAM 0.87 single	149.8	148.2	146.5	145.2	143.5	142.2	141.7
16QAM 0.87 dual	146.7	145.1	143.4	142.1	140.4	139.1	138.6
64QAM 0.75 single	145.6	144.1	142.3	141.1	139.3	138.1	137.5
64QAM 0.75 dual	142.4	140.9	139.1	137.9	136.1	134.9	134.3
64QAM 0.92 single	143.2	141.7	140.0	138.7	136.9	135.7	135.2
64 QAM 0.92 dual	139.9	138.4	136.6	135.4	133.6	132.4	131.8
256QAM 0.81 single	140.8	139.3	137.6	136.3	134.6	133.3	132.8
256QAM 0.81 dual	137.4	135.9	134.1	132.8	131.1	129.8	129.3

Table 76 5.4 GHz IP mode: system threshold per channel bandwidth and output power (P) (dBm)

Modulation mode	5 MHz	10 MHz	15 MHz	20 MHz	30 MHz	40 MHz	45 MHz	P (all bands)
BPSK 0.63 single	-96.6	-94.6	-92.8	-91.5	-89.8	-88.5	-88.0	27
QPSK 0.63 single	-93.5	-91.5	-89.7	-88.4	-86.7	-85.4	-84.9	26
QPSK 0.87 single	-89.4	-87.4	-85.7	-84.4	-82.7	-81.4	-80.9	26
16QAM 0.63 single	-87.1	-85.1	-83.4	-82.1	-80.3	-79.1	-78.6	25
16QAM 0.63 dual	-83.2	-81.2	-79.4	-78.2	-76.4	-75.2	-74.6	25
16QAM 0.87 single	-82.6	-80.6	-78.9	-77.6	-75.9	-74.6	-74.1	25
16QAM 0.87 dual	-79.6	-77.6	-75.8	-74.6	-72.8	-71.6	-71.0	25
64QAM 0.75 single	-79.6	-77.6	-75.8	-74.6	-72.8	-71.6	-71.1	24
64QAM 0.75 dual	-76.5	-74.5	-72.7	-71.5	-69.7	-68.5	-68.0	24
64QAM 0.92 single	-75.8	-73.8	-72.0	-70.7	-69.0	-67.7	-67.2	24
64 QAM 0.92 dual	-72.5	-70.5	-68.8	-67.5	-65.8	-64.5	-64.0	24
256QAM 0.81 single	-72.6	-70.6	-68.8	-67.6	-65.8	-64.6	-64.0	23
256QAM 0.81 dual	-69.1	-67.1	-65.3	-64.1	-62.3	-61.1	-60.6	23

Table 77 5.4 GHz IP mode: maximum link loss per channel bandwidth (dB)

Modulation mode	5 MHz	10 MHz	15 MHz	20 MHz	30 MHz	40 MHz	45 MHz
BPSK 0.63 single	169.6	167.6	165.8	164.5	162.8	161.5	161.0
QPSK 0.63 single	165.5	163.5	161.7	160.4	158.7	157.4	156.9
QPSK 0.87 single	161.4	159.4	157.7	156.4	154.7	153.4	152.9
16QAM 0.63 single	158.1	156.1	154.4	153.1	151.3	150.1	149.6
16QAM 0.63 dual	154.2	152.2	150.4	149.2	147.4	146.2	145.6
16QAM 0.87 single	153.6	151.6	149.9	148.6	146.9	145.6	145.1
16QAM 0.87 dual	150.6	148.6	146.8	145.6	143.8	142.6	142.0
64QAM 0.75 single	149.6	147.6	145.8	144.6	142.8	141.6	141.1
64QAM 0.75 dual	146.5	144.5	142.7	141.5	139.7	138.5	138.0
64QAM 0.92 single	145.8	143.8	142.0	140.7	139.0	137.7	137.2
64 QAM 0.92 dual	142.5	140.5	138.8	137.5	135.8	134.5	134.0
256QAM 0.81 single	141.6	139.6	137.8	136.6	134.8	133.6	133.0
256QAM 0.81 dual	138.1	136.1	134.3	133.1	131.3	130.1	129.6

Table 78 5.4 GHz TDM mode: system threshold per channel bandwidth and output power (P)(dBm)

Modulation mode	5 MHz	10 MHz	15 MHz	20 MHz	30 MHz	40 MHz	45 MHz	P (all bands)
BPSK 0.63 single	-96.6	-94.6	-92.8	-91.5	-89.8	-88.5	-88.0	27
QPSK 0.63 single	-90.5	-88.4	-86.7	-85.4	-83.7	-82.4	-81.9	26
QPSK 0.87 single	-86.4	-84.4	-82.6	-81.4	-79.6	-78.4	-77.9	26
16QAM 0.63 single	-84.1	-82.1	-80.3	-79.1	-77.3	-76.0	-75.5	25
16QAM 0.63 dual	-80.1	-78.1	-76.3	-75.1	-73.3	-72.1	-71.6	25
16QAM 0.87 single	-79.5	-77.5	-75.7	-74.5	-72.7	-71.5	-71.0	25
16QAM 0.87 dual	-76.4	-74.4	-72.6	-71.4	-69.6	-68.4	-67.9	25
64QAM 0.75 single	-76.3	-74.3	-72.6	-71.3	-69.6	-68.3	-67.8	24
64QAM 0.75 dual	-73.1	-71.1	-69.4	-68.1	-66.4	-65.1	-64.6	24
64QAM 0.92 single	-74.0	-72.0	-70.2	-69.0	-67.2	-65.9	-65.4	24
64 QAM 0.92 dual	-70.6	-68.6	-66.9	-65.6	-63.9	-62.6	-62.1	24
256QAM 0.81 single	-72.6	-70.6	-68.8	-67.6	-65.8	-64.6	-64.0	23
256QAM 0.81 dual	-69.1	-67.1	-65.3	-64.1	-62.3	-61.1	-60.6	23

Table 79 5.4 GHz TDM mode: maximum link loss per channel bandwidth (dB)

Modulation mode	5 MHz	10 MHz	15 MHz	20 MHz	30 MHz	40 MHz	45 MHz
BPSK 0.63 single	169.6	167.6	165.8	164.5	162.8	161.5	161.0
QPSK 0.63 single	162.5	160.4	158.7	157.4	155.7	154.4	153.9
QPSK 0.87 single	158.4	156.4	154.6	153.4	151.6	150.4	149.9
16QAM 0.63 single	155.1	153.1	151.3	150.1	148.3	147.0	146.5
16QAM 0.63 dual	151.1	149.1	147.3	146.1	144.3	143.1	142.6
16QAM 0.87 single	150.5	148.5	146.7	145.5	143.7	142.5	142.0
16QAM 0.87 dual	147.4	145.4	143.6	142.4	140.6	139.4	138.9
64QAM 0.75 single	146.3	144.3	142.6	141.3	139.6	138.3	137.8
64QAM 0.75 dual	143.1	141.1	139.4	138.1	136.4	135.1	134.6
64QAM 0.92 single	144.0	142.0	140.2	139.0	137.2	135.9	135.4
64 QAM 0.92 dual	140.6	138.6	136.9	135.6	133.9	132.6	132.1
256QAM 0.81 single	141.6	139.6	137.8	136.6	134.8	133.6	133.0
256QAM 0.81 dual	138.1	136.1	134.3	133.1	131.3	130.1	129.6

Table 80 5.8 GHz IP mode: system threshold per channel bandwidth and output power (P) (dBm)

Modulation mode	5 MHz	10 MHz	15 MHz	20 MHz	30 MHz	40 MHz	45 MHz	P (all bands)
BPSK 0.63 single	-96.8	-94.8	-93.0	-91.8	-90.0	-88.8	-88.3	27
QPSK 0.63 single	-93.7	-91.7	-89.9	-88.7	-86.9	-85.7	-85.2	26
QPSK 0.87 single	-89.7	-87.7	-85.9	-84.7	-82.9	-81.7	-81.1	26
16QAM 0.63 single	-87.4	-85.4	-83.6	-82.3	-80.6	-79.3	-78.8	25
16QAM 0.63 dual	-83.4	-81.4	-79.6	-78.4	-76.6	-75.4	-74.9	25
16QAM 0.87 single	-82.9	-80.8	-79.1	-77.8	-76.1	-74.8	-74.3	25
16QAM 0.87 dual	-79.8	-77.8	-76.0	-74.8	-73.0	-71.8	-71.2	25
64QAM 0.75 single	-79.8	-77.8	-76.0	-74.8	-73.0	-71.8	-71.2	24
64QAM 0.75 dual	-76.7	-74.7	-72.9	-71.6	-69.9	-68.6	-68.1	24
64QAM 0.92 single	-75.8	-73.8	-72.1	-70.8	-69.1	-67.8	-67.3	24
64 QAM 0.92 dual	-72.5	-70.5	-68.8	-67.5	-65.8	-64.5	-64.0	24
256QAM 0.81 single	-72.5	-70.5	-68.7	-67.4	-65.7	-64.4	-63.9	23
256QAM 0.81 dual	-68.8	-66.8	-65.0	-63.8	-62.0	-60.8	-60.3	23

Table 81 5.8 GHz IP mode: maximum link loss per channel bandwidth (dB)

Modulation mode	5 MHz	10 MHz	15 MHz	20 MHz	30 MHz	40 MHz	45 MHz
BPSK 0.63 single	169.8	167.8	166.0	164.8	163.0	161.8	161.3
QPSK 0.63 single	165.7	163.7	161.9	160.7	158.9	157.7	157.2
QPSK 0.87 single	161.7	159.7	157.9	156.7	154.9	153.7	153.1
16QAM 0.63 single	158.4	156.4	154.6	153.3	151.6	150.3	149.8
16QAM 0.63 dual	154.4	152.4	150.6	149.4	147.6	146.4	145.9
16QAM 0.87 single	153.9	151.8	150.1	148.8	147.1	145.8	145.3
16QAM 0.87 dual	150.8	148.8	147.0	145.8	144.0	142.8	142.2
64QAM 0.75 single	149.8	147.8	146.0	144.8	143.0	141.8	141.2
64QAM 0.75 dual	146.7	144.7	142.9	141.6	139.9	138.6	138.1
64QAM 0.92 single	145.8	143.8	142.1	140.8	139.1	137.8	137.3
64 QAM 0.92 dual	142.5	140.5	138.8	137.5	135.8	134.5	134.0
256QAM 0.81 single	141.5	139.5	137.7	136.4	134.7	133.4	132.9
256QAM 0.81 dual	137.8	135.8	134.0	132.8	131.0	129.8	129.3

Table 82 5.8 GHz TDM mode: system threshold per channel bandwidth and output power (P)(dBm)

Modulation mode	5 MHz	10 MHz	15 MHz	20 MHz	30 MHz	40 MHz	45 MHz	P (all bands)
BPSK 0.63 single	-96.8	-94.8	-93.0	-91.8	-90.0	-88.8	-88.3	27
QPSK 0.63 single	-90.7	-88.7	-86.9	-85.7	-83.9	-82.7	-82.2	26
QPSK 0.87 single	-86.7	-84.6	-82.9	-81.6	-79.9	-78.6	-78.1	26
16QAM 0.63 single	-84.3	-82.3	-80.5	-79.3	-77.5	-76.3	-75.8	25
16QAM 0.63 dual	-80.3	-78.3	-76.5	-75.3	-73.5	-72.3	-71.8	25
16QAM 0.87 single	-79.7	-77.7	-75.9	-74.7	-72.9	-71.7	-71.1	25
16QAM 0.87 dual	-76.6	-74.5	-72.8	-71.5	-69.8	-68.5	-68.0	25
64QAM 0.75 single	-76.4	-74.4	-72.7	-71.4	-69.6	-68.4	-67.9	24
64QAM 0.75 dual	-73.2	-71.2	-69.4	-68.2	-66.4	-65.1	-64.6	24
64QAM 0.92 single	-74.0	-72.0	-70.2	-68.9	-67.2	-65.9	-65.4	24
64 QAM 0.92 dual	-70.5	-68.5	-66.7	-65.5	-63.7	-62.5	-62.0	24
256QAM 0.81 single	-72.5	-70.5	-68.7	-67.4	-65.7	-64.4	-63.9	23
256QAM 0.81 dual	-68.8	-66.8	-65.0	-63.8	-62.0	-60.8	-60.3	23

Table 83 5.8 GHz TDM mode: maximum link loss per channel bandwidth (dB)

Modulation mode	5 MHz	10 MHz	15 MHz	20 MHz	30 MHz	40 MHz	45 MHz
BPSK 0.63 single	169.8	167.8	166.0	164.8	163.0	161.8	161.3
QPSK 0.63 single	162.7	160.7	158.9	157.7	155.9	154.7	154.2
QPSK 0.87 single	158.7	156.6	154.9	153.6	151.9	150.6	150.1
16QAM 0.63 single	155.3	153.3	151.5	150.3	148.5	147.3	146.8
16QAM 0.63 dual	151.3	149.3	147.5	146.3	144.5	143.3	142.8
16QAM 0.87 single	150.7	148.7	146.9	145.7	143.9	142.7	142.1
16QAM 0.87 dual	147.6	145.5	143.8	142.5	140.8	139.5	139.0
64QAM 0.75 single	146.4	144.4	142.7	141.4	139.6	138.4	137.9
64QAM 0.75 dual	143.2	141.2	139.4	138.2	136.4	135.1	134.6
64QAM 0.92 single	144.0	142.0	140.2	138.9	137.2	135.9	135.4
64 QAM 0.92 dual	140.5	138.5	136.7	135.5	133.7	132.5	132.0
256QAM 0.81 single	141.5	139.5	137.7	136.4	134.7	133.4	132.9
256QAM 0.81 dual	137.8	135.8	134.0	132.8	131.0	129.8	129.3

Table 84 5.9 GHz IP mode: system threshold per channel bandwidth and output power (P) (dBm)

Modulation mode	5 MHz	10 MHz	15 MHz	20 MHz	30 MHz	40 MHz	45 MHz	P (all bands)
BPSK 0.63 single	-95.8	-94.3	-92.5	-91.3	-89.5	-88.3	-87.8	27
QPSK 0.63 single	-92.7	-91.2	-89.4	-88.2	-86.4	-85.2	-84.7	26
QPSK 0.87 single	-88.7	-87.2	-85.4	-84.2	-82.4	-81.1	-80.6	26
16QAM 0.63 single	-86.3	-84.8	-83.1	-81.8	-80.1	-78.8	-78.3	25
16QAM 0.63 dual	-82.4	-80.9	-79.1	-77.9	-76.1	-74.9	-74.3	25
16QAM 0.87 single	-81.8	-80.3	-78.5	-77.3	-75.5	-74.3	-73.8	25
16QAM 0.87 dual	-78.7	-77.2	-75.5	-74.2	-72.4	-71.2	-70.7	25
64QAM 0.75 single	-78.7	-77.2	-75.4	-74.2	-72.4	-71.2	-70.7	24
64QAM 0.75 dual	-75.5	-74.0	-72.3	-71.0	-69.3	-68.0	-67.5	24
64QAM 0.92 single	-74.6	-73.1	-71.3	-70.1	-68.3	-67.1	-66.6	24
64 QAM 0.92 dual	-71.2	-69.7	-67.9	-66.7	-64.9	-63.7	-63.2	24
256QAM 0.81 single	-70.9	-69.4	-67.7	-66.4	-64.7	-63.4	-62.9	23
256QAM 0.81 dual	-67.0	-65.5	-63.7	-62.5	-60.7	-59.5	-58.9	23

Table 85 5.9 GHz IP mode: maximum link loss per channel bandwidth (dB)

Modulation mode	5 MHz	10 MHz	15 MHz	20 MHz	30 MHz	40 MHz	45 MHz
BPSK 0.63 single	168.8	167.3	165.5	164.3	162.5	161.3	160.8
QPSK 0.63 single	164.7	163.2	161.4	160.2	158.4	157.2	156.7
QPSK 0.87 single	160.7	159.2	157.4	156.2	154.4	153.1	152.6
16QAM 0.63 single	157.3	155.8	154.1	152.8	151.1	149.8	149.3
16QAM 0.63 dual	153.4	151.9	150.1	148.9	147.1	145.9	145.3
16QAM 0.87 single	152.8	151.3	149.5	148.3	146.5	145.3	144.8
16QAM 0.87 dual	149.7	148.2	146.5	145.2	143.4	142.2	141.7
64QAM 0.75 single	148.7	147.2	145.4	144.2	142.4	141.2	140.7
64QAM 0.75 dual	145.5	144.0	142.3	141.0	139.3	138.0	137.5
64QAM 0.92 single	144.6	143.1	141.3	140.1	138.3	137.1	136.6
64 QAM 0.92 dual	141.2	139.7	137.9	136.7	134.9	133.7	133.2
256QAM 0.81 single	139.9	138.4	136.7	135.4	133.7	132.4	131.9
256QAM 0.81 dual	136.0	134.5	132.7	131.5	129.7	128.5	127.9

Table 86 5.9 GHz TDM mode: system threshold per channel bandwidth and output power (P)(dBm)

Modulation mode	5 MHz	10 MHz	15 MHz	20 MHz	30 MHz	40 MHz	45 MHz	P (all bands)
BPSK 0.63 single	-95.8	-94.3	-92.5	-91.3	-89.5	-88.3	-87.8	27
QPSK 0.63 single	-89.7	-88.2	-86.4	-85.2	-83.4	-82.2	-81.6	26
QPSK 0.87 single	-85.6	-84.1	-82.4	-81.1	-79.4	-78.1	-77.6	26
16QAM 0.63 single	-83.3	-81.8	-80.0	-78.8	-77.0	-75.7	-75.2	25
16QAM 0.63 dual	-79.3	-77.8	-76.0	-74.7	-73.0	-71.7	-71.2	25
16QAM 0.87 single	-78.6	-77.1	-75.3	-74.1	-72.3	-71.1	-70.5	25
16QAM 0.87 dual	-75.4	-73.9	-72.2	-70.9	-69.1	-67.9	-67.4	25
64QAM 0.75 single	-75.2	-73.7	-72.0	-70.7	-68.9	-67.7	-67.2	24
64QAM 0.75 dual	-71.9	-70.4	-68.6	-67.4	-65.6	-64.4	-63.8	24
64QAM 0.92 single	-72.6	-71.1	-69.3	-68.1	-66.3	-65.1	-64.6	24
64 QAM 0.92 dual	-69.0	-67.5	-65.7	-64.5	-62.7	-61.4	-60.9	24
256QAM 0.81 single	-70.9	-69.4	-67.7	-66.4	-64.7	-63.4	-62.9	23
256QAM 0.81 dual	-67.0	-65.5	-63.7	-62.5	-60.7	-59.5	-58.9	23

Table 87 5.9 GHz TDM mode: maximum link loss per channel bandwidth (dB)

Modulation mode	5 MHz	10 MHz	15 MHz	20 MHz	30 MHz	40 MHz	45 MHz
BPSK 0.63 single	168.8	167.3	165.5	164.3	162.5	161.3	160.8
QPSK 0.63 single	161.7	160.2	158.4	157.2	155.4	154.2	153.6
QPSK 0.87 single	157.6	156.1	154.4	153.1	151.4	150.1	149.6
16QAM 0.63 single	154.3	152.8	151.0	149.8	148.0	146.7	146.2
16QAM 0.63 dual	150.3	148.8	147.0	145.7	144.0	142.7	142.2
16QAM 0.87 single	149.6	148.1	146.3	145.1	143.3	142.1	141.5
16QAM 0.87 dual	146.4	144.9	143.2	141.9	140.1	138.9	138.4
64QAM 0.75 single	145.2	143.7	142.0	140.7	138.9	137.7	137.2
64QAM 0.75 dual	141.9	140.4	138.6	137.4	135.6	134.4	133.8
64QAM 0.92 single	142.6	141.1	139.3	138.1	136.3	135.1	134.6
64 QAM 0.92 dual	139.0	137.5	135.7	134.5	132.7	131.4	130.9
256QAM 0.81 single	139.9	138.4	136.7	135.4	133.7	132.4	131.9
256QAM 0.81 dual	136.0	134.5	132.7	131.5	129.7	128.5	127.9

Data throughput capacity tables

Use the following tables to look up the data throughput rates (Mbits/s) that are achieved when two PTP 650 ODUs are linked and the link distance (range) is 0 km:

PTP 650 variant	Link symmetry	Link optimization	Table
Full	1:1	IP	Table 88
		TDM	Table 89
	2:1	IP	Table 90
		TDM	Table 91
	3:1	IP	Table 92
	5:1	IP	Table 93
	Adaptive	IP	Table 94
Mid	1:1	IP	Table 95
		TDM	Table 96
	2:1	IP	Table 97
		TDM	Table 98
	3:1	IP	Table 99
	5:1	IP	Table 100
Lite	1:1	IP	Table 101
		TDM	Table 102
	2:1	IP	Table 103
		TDM	Table 104
	3:1	IP	Table 105
	5:1	IP	Table 106

Use the following range adjustment graphs to look up the link range and find the throughput factor that must be applied to adjust the 0 km data throughput rates:

Link symmetry	Link optimization	Bandwidth			
		45 MHz	40 MHz	30 MHz	20 MHz
1:1	IP	Figure 63	Figure 64	Figure 65	Figure 66
	TDM	Figure 70	Figure 71	Figure 72	Figure 73
2:1	IP	Figure 77	Figure 78	Figure 79	Figure 80
	TDM	Figure 83	Figure 84	Figure 85	Figure 86
3:1	IP	Figure 89	Figure 90	Figure 91	Figure 92
5:1	IP	Figure 95	Figure 96	Figure 97	-
Adaptive	IP	Figure 98	Figure 99	Figure 100	Figure 101

Link symmetry	Link optimization	Bandwidth		
		15 MHz	10 MHz	5 MHz
1:1	IP	Figure 67	Figure 68	Figure 69
	TDM	Figure 74	Figure 75	Figure 76
2:1	IP	Figure 81	Figure 82	-
	TDM	Figure 87	Figure 88	-
3:1	IP	Figure 93	Figure 94	-
5:1	IP	-	-	-
Adaptive	IP	Figure 102	Figure 103	-

Note

Throughput for link symmetry 5:1, 3:1 and 2:1 are the same as 1:5, 1:3, and 1:2; but the Tx and Rx data rates are swapped.

Table 88 Throughput at zero link range (Mbit/s), Full, symmetry 1:1, optimization IP

Modulation mode	45 MHz (Tx/Rx/Aggregate)			40 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	226.1	226.1	452.2	206.3	206.3	412.6
64QAM 0.92 dual	190.5	190.5	381.0	173.8	173.8	347.6
64QAM 0.75 dual	155.7	155.7	311.3	142.0	142.0	284.1
16QAM 0.87 dual	121.1	121.1	242.2	110.5	110.5	221.0
16QAM 0.63 dual	87.1	87.1	174.1	79.4	79.4	158.9
256QAM 0.81 single	113.0	113.0	226.1	103.1	103.1	206.3
64QAM 0.92 single	95.2	95.2	190.5	86.9	86.9	173.8
64QAM 0.75 single	77.8	77.8	155.7	71.0	71.0	142.0
16QAM 0.87 single	60.5	60.5	121.1	55.2	55.2	110.5
16QAM 0.63 single	43.5	43.5	87.0	39.7	39.7	79.4
QPSK 0.87 single	30.3	30.3	60.5	27.6	27.6	55.2
QPSK 0.63 single	21.8	21.8	43.5	19.9	19.9	39.7
BPSK 0.63 single	10.9	10.9	21.8	9.9	9.9	19.9

Modulation mode	30 MHz (Tx/Rx/Aggregate)			20 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	151.1	151.1	302.2	100.0	100.0	200.1
64QAM 0.92 dual	127.3	127.3	254.6	84.3	84.3	168.6
64QAM 0.75 dual	104.0	104.0	208.1	68.9	68.9	137.8
16QAM 0.87 dual	80.9	80.9	161.9	53.6	53.6	107.2
16QAM 0.63 dual	58.2	58.2	116.4	38.5	38.5	77.0
256QAM 0.81 single	75.5	75.5	151.1	50.0	50.0	100.0
64QAM 0.92 single	63.7	63.7	127.3	42.1	42.1	84.3
64QAM 0.75 single	52.0	52.0	104.0	34.4	34.4	68.9
16QAM 0.87 single	40.5	40.5	80.9	26.8	26.8	53.6
16QAM 0.63 single	29.1	29.1	58.2	19.3	19.3	38.5
QPSK 0.87 single	20.2	20.2	40.5	13.4	13.4	26.8
QPSK 0.63 single	14.5	14.5	29.1	9.6	9.6	19.3
BPSK 0.63 single	7.3	7.3	14.5	4.8	4.8	9.6

Modulation mode	15 MHz (Tx/Rx/Aggregate)			10 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	75.4	75.4	150.7	50.1	50.1	100.2
64QAM 0.92 dual	63.5	63.5	127.0	42.2	42.2	84.4
64QAM 0.75 dual	51.9	51.9	103.8	34.5	34.5	69.0
16QAM 0.87 dual	40.4	40.4	80.7	26.8	26.8	53.7
16QAM 0.63 dual	29.0	29.0	58.0	19.3	19.3	38.6
256QAM 0.81 single	37.7	37.7	75.4	25.0	25.0	50.1
64QAM 0.92 single	31.7	31.7	63.5	21.1	21.1	42.2
64QAM 0.75 single	25.9	25.9	51.9	17.2	17.2	34.5
16QAM 0.87 single	20.2	20.2	40.4	13.4	13.4	26.8
16QAM 0.63 single	14.5	14.5	29.0	9.6	9.6	19.3
QPSK 0.87 single	10.1	10.1	20.2	6.7	6.7	13.4
QPSK 0.63 single	7.3	7.3	14.5	4.8	4.8	9.6
BPSK 0.63 single	3.6	3.6	7.2	2.4	2.4	4.8

Modulation mode	5 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	24.2	24.2	48.4
64QAM 0.92 dual	20.4	20.4	40.8
64QAM 0.75 dual	16.7	16.7	33.3
16QAM 0.87 dual	13.0	13.0	25.9
16QAM 0.63 dual	9.3	9.3	18.6
256QAM 0.81 single	12.1	12.1	24.2
64QAM 0.92 single	10.2	10.2	20.4
64QAM 0.75 single	8.3	8.3	16.7
16QAM 0.87 single	6.5	6.5	13.0
16QAM 0.63 single	4.7	4.7	9.3
QPSK 0.87 single	3.2	3.2	6.5
QPSK 0.63 single	2.3	2.3	4.7
BPSK 0.63 single	1.2	1.2	2.3

Table 89 Throughput at zero link range (Mbit/s), Full, symmetry 1:1, optimization TDM

Modulation mode	45 MHz (Tx/Rx/Aggregate)			40 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	202.1	202.1	404.1	186.1	186.1	372.1
64QAM 0.92 dual	170.2	170.2	340.5	156.8	156.8	313.5
64QAM 0.75 dual	139.1	139.1	278.2	128.1	128.1	256.2
16QAM 0.87 dual	108.2	108.2	216.5	99.7	99.7	199.3
16QAM 0.63 dual	77.8	77.8	155.6	71.6	71.6	143.3
256QAM 0.81 single	101.0	101.0	202.1	93.0	93.0	186.1
64QAM 0.92 single	85.1	85.1	170.2	78.4	78.4	156.8
64QAM 0.75 single	69.6	69.6	139.1	64.0	64.0	128.1
16QAM 0.87 single	54.1	54.1	108.2	49.8	49.8	99.7
16QAM 0.63 single	38.9	38.9	77.8	35.8	35.8	71.6
QPSK 0.87 single	27.1	27.1	54.1	24.9	24.9	49.8
QPSK 0.63 single	19.4	19.4	38.9	17.9	17.9	35.8
BPSK 0.63 single	9.7	9.7	19.4	9.0	9.0	17.9

Modulation mode	30 MHz (Tx/Rx/Aggregate)			20 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	140.9	140.9	281.7	96.0	96.0	192.0
64QAM 0.92 dual	118.7	118.7	237.4	80.9	80.9	161.7
64QAM 0.75 dual	97.0	97.0	194.0	66.1	66.1	132.2
16QAM 0.87 dual	75.5	75.5	150.9	51.4	51.4	102.8
16QAM 0.63 dual	54.2	54.2	108.5	37.0	37.0	73.9
256QAM 0.81 single	70.4	70.4	140.9	48.0	48.0	96.0
64QAM 0.92 single	59.3	59.3	118.7	40.4	40.4	80.9
64QAM 0.75 single	48.5	48.5	97.0	33.0	33.0	66.1
16QAM 0.87 single	37.7	37.7	75.4	25.7	25.7	51.4
16QAM 0.63 single	27.1	27.1	54.2	18.5	18.5	37.0
QPSK 0.87 single	18.9	18.9	37.7	12.8	12.8	25.7
QPSK 0.63 single	13.6	13.6	27.1	9.2	9.2	18.5
BPSK 0.63 single	6.8	6.8	13.6	4.6	4.6	9.2

Modulation mode	15 MHz (Tx/Rx/Aggregate)			10 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	72.9	72.9	145.8	49.1	49.1	98.2
64QAM 0.92 dual	61.4	61.4	122.8	41.4	41.4	82.8
64QAM 0.75 dual	50.2	50.2	100.4	33.8	33.8	67.6
16QAM 0.87 dual	39.0	39.0	78.1	26.3	26.3	52.6
16QAM 0.63 dual	28.1	28.1	56.1	18.9	18.9	37.8
256QAM 0.81 single	36.4	36.4	72.9	24.6	24.6	49.1
64QAM 0.92 single	30.7	30.7	61.4	20.7	20.7	41.4
64QAM 0.75 single	25.1	25.1	50.2	16.9	16.9	33.8
16QAM 0.87 single	19.5	19.5	39.0	13.2	13.2	26.3
16QAM 0.63 single	14.0	14.0	28.1	9.5	9.5	18.9
QPSK 0.87 single	9.8	9.8	19.5	6.6	6.6	13.1
QPSK 0.63 single	7.0	7.0	14.0	4.7	4.7	9.5
BPSK 0.63 single	3.5	3.5	7.0	2.4	2.4	4.7

Modulation mode	5 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	24.2	24.2	48.4
64QAM 0.92 dual	20.4	20.4	40.8
64QAM 0.75 dual	16.7	16.7	33.3
16QAM 0.87 dual	13.0	13.0	25.9
16QAM 0.63 dual	9.3	9.3	18.6
256QAM 0.81 single	12.1	12.1	24.2
64QAM 0.92 single	10.2	10.2	20.4
64QAM 0.75 single	8.3	8.3	16.7
16QAM 0.87 single	6.5	6.5	13.0
16QAM 0.63 single	4.7	4.7	9.3
QPSK 0.87 single	3.2	3.2	6.5
QPSK 0.63 single	2.3	2.3	4.7
BPSK 0.63 single	1.2	1.2	2.3

Table 90 Throughput at zero link range (Mbit/s), Full, symmetry 2:1, optimization IP

Modulation mode	45 MHz (Tx/Rx/Aggregate)			40 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	299.7	149.9	449.6	273.6	136.8	410.5
64QAM 0.92 dual	252.5	126.3	378.8	230.5	115.3	345.8
64QAM 0.75 dual	206.4	103.2	309.6	188.4	94.2	282.6
16QAM 0.87 dual	160.6	80.3	240.8	146.6	73.3	219.8
16QAM 0.63 dual	115.4	57.7	173.1	105.4	52.7	158.0
256QAM 0.81 single	149.9	74.9	224.8	136.8	68.4	205.2
64QAM 0.92 single	126.3	63.1	189.4	115.3	57.6	172.9
64QAM 0.75 single	103.2	51.6	154.8	94.2	47.1	141.3
16QAM 0.87 single	80.3	40.1	120.4	73.3	36.6	109.9
16QAM 0.63 single	57.7	28.9	86.6	52.7	26.3	79.0
QPSK 0.87 single	40.1	20.1	60.2	36.6	18.3	55.0
QPSK 0.63 single	28.9	14.4	43.3	26.3	13.2	39.5
BPSK 0.63 single	14.4	7.2	21.6	13.2	6.6	19.7

Modulation mode	30 MHz (Tx/Rx/Aggregate)			20 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	200.5	100.2	300.7	133.4	66.7	200.1
64QAM 0.92 dual	168.9	84.5	253.4	112.4	56.2	168.6
64QAM 0.75 dual	138.0	69.0	207.1	91.8	45.9	137.8
16QAM 0.87 dual	107.4	53.7	161.1	71.5	35.7	107.2
16QAM 0.63 dual	77.2	38.6	115.8	51.4	25.7	77.0
256QAM 0.81 single	100.2	50.1	150.4	66.7	33.3	100.0
64QAM 0.92 single	84.5	42.2	126.7	56.2	28.1	84.3
64QAM 0.75 single	69.0	34.5	103.5	45.9	23.0	68.9
16QAM 0.87 single	53.7	26.8	80.5	35.7	17.9	53.6
16QAM 0.63 single	38.6	19.3	57.9	25.7	12.8	38.5
QPSK 0.87 single	26.8	13.4	40.3	17.9	8.9	26.8
QPSK 0.63 single	19.3	9.6	28.9	12.8	6.4	19.3
BPSK 0.63 single	9.6	4.8	14.5	6.4	3.2	9.6

Modulation mode	15 MHz (Tx/Rx/Aggregate)			10 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	100.5	50.2	150.7	66.3	33.2	99.5
64QAM 0.92 dual	84.7	42.3	127.0	55.9	27.9	83.8
64QAM 0.75 dual	69.2	34.6	103.8	45.7	22.8	68.5
16QAM 0.87 dual	53.8	26.9	80.7	35.5	17.8	53.3
16QAM 0.63 dual	38.7	19.3	58.0	25.5	12.8	38.3
256QAM 0.81 single	50.2	25.1	75.4	33.2	16.6	49.8
64QAM 0.92 single	42.3	21.2	63.5	27.9	14.0	41.9
64QAM 0.75 single	34.6	17.3	51.9	22.8	11.4	34.3
16QAM 0.87 single	26.9	13.5	40.4	17.8	8.9	26.6
16QAM 0.63 single	19.3	9.7	29.0	12.8	6.4	19.2
QPSK 0.87 single	13.5	6.7	20.2	8.9	4.4	13.3
QPSK 0.63 single	9.7	4.8	14.5	6.4	3.2	9.6
BPSK 0.63 single	4.8	2.4	7.2	3.2	1.6	4.8

Table 91 Throughput at zero link range (Mbit/s), Full, symmetry 2:1, optimization TDM

Modulation mode	45 MHz (Tx/Rx/Aggregate)			40 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	280.8	140.4	421.2	257.7	128.9	386.6
64QAM 0.92 dual	236.6	118.3	354.8	217.1	108.6	325.7
64QAM 0.75 dual	193.3	96.7	290.0	177.4	88.7	266.1
16QAM 0.87 dual	150.4	75.2	225.6	138.0	69.0	207.1
16QAM 0.63 dual	108.1	54.1	162.2	99.2	49.6	148.8
256QAM 0.81 single	140.4	70.2	210.6	128.9	64.4	193.3
64QAM 0.92 single	118.3	59.1	177.4	108.6	54.3	162.8
64QAM 0.75 single	96.7	48.3	145.0	88.7	44.4	133.1
16QAM 0.87 single	75.2	37.6	112.8	69.0	34.5	103.5
16QAM 0.63 single	54.1	27.0	81.1	49.6	24.8	74.4
QPSK 0.87 single	37.6	18.8	56.4	34.5	17.3	51.8
QPSK 0.63 single	27.0	13.5	40.5	24.8	12.4	37.2
BPSK 0.63 single	13.5	6.8	20.3	12.4	6.2	18.6

Modulation mode	30 MHz (Tx/Rx/Aggregate)			20 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	193.1	96.5	289.6	130.6	65.3	195.9
64QAM 0.92 dual	162.7	81.3	244.0	110.1	55.0	165.1
64QAM 0.75 dual	132.9	66.5	199.4	89.9	45.0	134.9
16QAM 0.87 dual	103.4	51.7	155.1	70.0	35.0	104.9
16QAM 0.63 dual	74.3	37.2	111.5	50.3	25.1	75.4
256QAM 0.81 single	96.5	48.3	144.8	65.3	32.7	98.0
64QAM 0.92 single	81.3	40.7	122.0	55.0	27.5	82.5
64QAM 0.75 single	66.5	33.2	99.7	45.0	22.5	67.4
16QAM 0.87 single	51.7	25.8	77.5	35.0	17.5	52.5
16QAM 0.63 single	37.2	18.6	55.7	25.1	12.6	37.7
QPSK 0.87 single	25.8	12.9	38.8	17.5	8.7	26.2
QPSK 0.63 single	18.6	9.3	27.9	12.6	6.3	18.9
BPSK 0.63 single	9.3	4.6	13.9	6.3	3.1	9.4

Modulation mode	15 MHz (Tx/Rx/Aggregate)			10 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	98.8	49.4	148.2	66.3	33.2	99.5
64QAM 0.92 dual	83.2	41.6	124.9	55.9	27.9	83.8
64QAM 0.75 dual	68.0	34.0	102.0	45.7	22.8	68.5
16QAM 0.87 dual	52.9	26.5	79.4	35.5	17.8	53.3
16QAM 0.63 dual	38.0	19.0	57.1	25.5	12.8	38.3
256QAM 0.81 single	49.4	24.7	74.1	33.2	16.6	49.8
64QAM 0.92 single	41.6	20.8	62.4	27.9	14.0	41.9
64QAM 0.75 single	34.0	17.0	51.0	22.8	11.4	34.3
16QAM 0.87 single	26.5	13.2	39.7	17.8	8.9	26.6
16QAM 0.63 single	19.0	9.5	28.5	12.8	6.4	19.2
QPSK 0.87 single	13.2	6.6	19.8	8.9	4.4	13.3
QPSK 0.63 single	9.5	4.8	14.3	6.4	3.2	9.6
BPSK 0.63 single	4.8	2.4	7.1	3.2	1.6	4.8

Table 92 Throughput at zero link range (Mbit/s), Full, symmetry 3:1, optimization IP

Modulation mode	45 MHz (Tx/Rx/Aggregate)			40 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	337.21	112.40	449.62	307.87	102.62	410.49
64QAM 0.92 dual	284.11	94.70	378.81	259.39	86.46	345.85
64QAM 0.75 dual	232.17	77.39	309.56	211.97	70.66	282.63
16QAM 0.87 dual	180.62	60.21	240.83	164.90	54.97	219.87
16QAM 0.63 dual	129.84	43.28	173.12	118.55	39.51	158.06
256QAM 0.81 single	168.60	56.20	224.80	153.93	51.31	205.24
64QAM 0.92 single	142.05	47.35	189.40	129.69	43.23	172.92
64QAM 0.75 single	116.08	38.69	154.78	105.98	35.33	141.31
16QAM 0.87 single	90.31	30.10	120.41	82.45	27.48	109.93
16QAM 0.63 single	64.92	21.64	86.56	59.27	19.76	79.03
QPSK 0.87 single	45.15	15.05	60.20	41.22	13.74	54.96
QPSK 0.63 single	32.46	10.82	43.27	29.63	9.88	39.51
BPSK 0.63 single	16.23	5.41	21.63	14.81	4.94	19.75

Modulation mode	30 MHz (Tx/Rx/Aggregate)			20 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	225.01	75.00	300.02	148.50	49.50	198.00
64QAM 0.92 dual	189.58	63.19	252.77	125.11	41.70	166.82
64QAM 0.75 dual	154.92	51.64	206.56	102.24	34.08	136.32
16QAM 0.87 dual	120.52	40.17	160.70	79.54	26.51	106.05
16QAM 0.63 dual	86.64	28.88	115.52	57.18	19.06	76.24
256QAM 0.81 single	112.51	37.50	150.01	74.25	24.75	98.99
64QAM 0.92 single	94.79	31.60	126.38	62.56	20.85	83.41
64QAM 0.75 single	77.46	25.82	103.28	51.12	17.04	68.16
16QAM 0.87 single	60.26	20.09	80.34	39.77	13.25	53.02
16QAM 0.63 single	43.32	14.44	57.76	28.59	9.53	38.12
QPSK 0.87 single	30.13	10.04	40.17	19.88	6.63	26.51
QPSK 0.63 single	21.66	7.22	28.88	14.29	4.76	19.05
BPSK 0.63 single	10.83	3.61	14.43	7.14	2.38	9.52

Modulation mode	15 MHz (Tx/Rx/Aggregate)			10 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	112.09	37.36	149.45	75.14	25.04	100.18
64QAM 0.92 dual	94.44	31.48	125.91	63.30	21.10	84.40
64QAM 0.75 dual	77.17	25.72	102.89	51.73	17.24	68.97
16QAM 0.87 dual	60.04	20.01	80.05	40.24	13.41	53.66
16QAM 0.63 dual	43.16	14.38	57.54	28.93	9.64	38.57
256QAM 0.81 single	56.04	18.68	74.72	37.57	12.52	50.09
64QAM 0.92 single	47.22	15.74	62.95	31.65	10.55	42.20
64QAM 0.75 single	38.58	12.86	51.44	25.86	8.62	34.48
16QAM 0.87 single	30.02	10.00	40.02	20.12	6.71	26.83
16QAM 0.63 single	21.58	7.19	28.77	14.46	4.82	19.28
QPSK 0.87 single	15.01	5.00	20.01	10.06	3.35	13.41
QPSK 0.63 single	10.79	3.59	14.38	7.23	2.41	9.64
BPSK 0.63 single	5.39	1.80	7.19	3.61	1.20	4.82

Table 93 Throughput at zero link range (Mbit/s), Full, symmetry 5:1, optimization IP

Modulation mode	45 MHz (Tx/Rx/Aggregate)			40 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	374.68	74.93	449.62	335.20	67.04	402.24
64QAM 0.92 dual	315.68	63.13	378.81	282.42	56.48	338.90
64QAM 0.75 dual	257.97	51.59	309.56	230.79	46.16	276.95
16QAM 0.87 dual	200.69	40.14	240.83	179.54	35.91	215.45
16QAM 0.63 dual	144.27	28.85	173.12	129.07	25.81	154.88
256QAM 0.81 single	187.34	37.47	224.80	167.60	33.52	201.12
64QAM 0.92 single	157.84	31.57	189.40	141.21	28.24	169.45
64QAM 0.75 single	128.98	25.79	154.78	115.39	23.08	138.47
16QAM 0.87 single	100.34	20.07	120.41	89.77	17.95	107.72
16QAM 0.63 single	72.13	14.43	86.56	64.53	12.90	77.44
QPSK 0.87 single	50.17	10.03	60.20	44.88	8.98	53.86
QPSK 0.63 single	36.06	7.21	43.27	32.26	6.45	38.71
BPSK 0.63 single	18.03	3.60	21.63	16.13	3.22	19.35

Modulation mode	30 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	248.23	49.64	297.87
64QAM 0.92 dual	209.14	41.83	250.96
64QAM 0.75 dual	170.90	34.18	205.08
16QAM 0.87 dual	132.96	26.59	159.55
16QAM 0.63 dual	95.58	19.11	114.69
256QAM 0.81 single	124.11	24.82	148.93
64QAM 0.92 single	104.57	20.91	125.48
64QAM 0.75 single	85.45	17.09	102.54
16QAM 0.87 single	66.48	13.29	79.77
16QAM 0.63 single	47.79	9.56	57.34
QPSK 0.87 single	33.24	6.65	39.88
QPSK 0.63 single	23.89	4.78	28.67
BPSK 0.63 single	11.94	2.39	14.33

Table 94 Throughput at zero link range (Mbit/s), Full, symmetry adaptive, optimization IP

Modulation mode	45 MHz (Tx/Rx/Aggregate)			40 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	407.9	40.8	448.7	367.9	40.9	408.8
64QAM 0.92 dual	343.7	34.4	378.0	310.0	34.4	344.4
64QAM 0.75 dual	280.8	28.1	308.9	253.3	28.1	281.4
16QAM 0.87 dual	218.5	21.8	240.3	197.1	21.9	218.9
16QAM 0.63 dual	157.1	15.7	172.8	141.7	15.7	157.4
256QAM 0.81 single	204.0	20.4	224.3	183.9	20.4	204.4
64QAM 0.92 single	171.8	17.2	189.0	155.0	17.2	172.2
64QAM 0.75 single	140.4	14.0	154.5	126.6	14.1	140.7
16QAM 0.87 single	109.2	10.9	120.2	98.5	10.9	109.5
16QAM 0.63 single	78.5	7.9	86.4	70.8	7.9	78.7
QPSK 0.87 single	54.6	5.5	60.1	49.3	5.5	54.7
QPSK 0.63 single	39.3	3.9	43.2	35.4	3.9	39.3
BPSK 0.63 single	19.6	2.0	21.6	17.7	2.0	19.7

Modulation mode	30 MHz (Tx/Rx/Aggregate)			20 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	262.5	37.5	300.0	159.4	39.8	199.2
64QAM 0.92 dual	221.2	31.6	252.8	134.3	33.6	167.9
64QAM 0.75 dual	180.7	25.8	206.6	109.7	27.4	137.2
16QAM 0.87 dual	140.6	20.1	160.7	85.4	21.3	106.7
16QAM 0.63 dual	101.1	14.4	115.5	61.4	15.3	76.7
256QAM 0.81 single	131.3	18.7	150.0	79.7	19.9	99.6
64QAM 0.92 single	110.6	15.8	126.4	67.1	16.8	83.9
64QAM 0.75 single	90.4	12.9	103.3	54.9	13.7	68.6
16QAM 0.87 single	70.3	10.0	80.3	42.7	10.7	53.4
16QAM 0.63 single	50.5	7.2	57.8	30.7	7.7	38.4
QPSK 0.87 single	35.2	5.0	40.2	21.3	5.3	26.7
QPSK 0.63 single	25.3	3.6	28.9	15.3	3.8	19.2
BPSK 0.63 single	12.6	1.8	14.4	7.7	1.9	9.6

Modulation mode	15 MHz (Tx/Rx/Aggregate)			10 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	120.2	30.0	150.2	66.3	33.2	99.5
64QAM 0.92 dual	101.2	25.3	126.6	55.9	27.9	83.8
64QAM 0.75 dual	82.7	20.7	103.4	45.7	22.8	68.5
16QAM 0.87 dual	64.4	16.1	80.5	35.5	17.8	53.3
16QAM 0.63 dual	46.3	11.6	57.8	25.5	12.8	38.3
256QAM 0.81 single	60.1	15.0	75.1	33.2	16.6	49.8
64QAM 0.92 single	50.6	12.7	63.3	27.9	14.0	41.9
64QAM 0.75 single	41.4	10.3	51.7	22.8	11.4	34.3
16QAM 0.87 single	32.2	8.0	40.2	17.8	8.9	26.6
16QAM 0.63 single	23.1	5.8	28.9	12.8	6.4	19.2
QPSK 0.87 single	16.1	4.0	20.1	8.9	4.4	13.3
QPSK 0.63 single	11.6	2.9	14.5	6.4	3.2	9.6
BPSK 0.63 single	5.8	1.4	7.2	3.2	1.6	4.8

Table 95 Throughput at zero link range (Mbit/s), Mid, symmetry 1:1, optimization IP

Modulation mode	45 MHz (Tx/Rx/Aggregate)			40 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	127.0	127.0	254.0	116.0	116.0	232.0
64QAM 0.92 dual	107.0	107.0	214.0	97.0	97.0	194.0
64QAM 0.75 dual	87.0	87.0	174.0	80.0	80.0	160.0
16QAM 0.87 dual	68.0	68.0	136.0	62.0	62.0	124.0
16QAM 0.63 dual	49.0	49.0	98.0	44.0	44.0	88.0
256QAM 0.81 single	63.0	63.0	126.0	58.0	58.0	116.0
64QAM 0.92 single	53.0	53.0	106.0	49.0	49.0	98.0
64QAM 0.75 single	44.0	44.0	88.0	40.0	40.0	80.0
16QAM 0.87 single	34.0	34.0	68.0	31.0	31.0	62.0
16QAM 0.63 single	24.0	24.0	48.0	22.0	22.0	44.0
QPSK 0.87 single	17.0	17.0	34.0	15.0	15.0	30.0
QPSK 0.63 single	12.0	12.0	24.0	11.0	11.0	22.0
BPSK 0.63 single	6.0	6.0	12.0	6.0	6.0	12.0

Modulation mode	30 MHz (Tx/Rx/Aggregate)			20 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	85.0	85.0	170.0	56.0	56.0	112.0
64QAM 0.92 dual	71.0	71.0	142.0	47.0	47.0	94.0
64QAM 0.75 dual	58.0	58.0	116.0	39.0	39.0	78.0
16QAM 0.87 dual	45.0	45.0	90.0	30.0	30.0	60.0
16QAM 0.63 dual	33.0	33.0	66.0	22.0	22.0	44.0
256QAM 0.81 single	42.0	42.0	84.0	28.0	28.0	56.0
64QAM 0.92 single	36.0	36.0	72.0	24.0	24.0	48.0
64QAM 0.75 single	29.0	29.0	58.0	19.0	19.0	38.0
16QAM 0.87 single	23.0	23.0	46.0	15.0	15.0	30.0
16QAM 0.63 single	16.0	16.0	32.0	11.0	11.0	22.0
QPSK 0.87 single	11.0	11.0	22.0	8.0	8.0	16.0
QPSK 0.63 single	8.0	8.0	16.0	5.0	5.0	10.0
BPSK 0.63 single	5.0	5.0	10.0	4.8	4.8	9.6

Modulation mode	15 MHz (Tx/Rx/Aggregate)			10 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	42.0	42.0	84.0	28.0	28.0	56.0
64QAM 0.92 dual	36.0	36.0	72.0	24.0	24.0	48.0
64QAM 0.75 dual	29.0	29.0	58.0	19.0	19.0	38.0
16QAM 0.87 dual	23.0	23.0	46.0	15.0	15.0	30.0
16QAM 0.63 dual	16.0	16.0	32.0	11.0	11.0	22.0
256QAM 0.81 single	21.0	21.0	42.0	14.0	14.0	28.0
64QAM 0.92 single	18.0	18.0	36.0	12.0	12.0	24.0
64QAM 0.75 single	15.0	15.0	30.0	10.0	10.0	20.0
16QAM 0.87 single	11.0	11.0	22.0	8.0	8.0	16.0
16QAM 0.63 single	8.0	8.0	16.0	5.0	5.0	10.0
QPSK 0.87 single	6.0	6.0	12.0	5.0	5.0	10.0
QPSK 0.63 single	5.0	5.0	10.0	4.8	4.8	9.6
BPSK 0.63 single	3.6	3.6	7.2	2.4	2.4	4.8

Modulation mode	5 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	14.0	14.0	28.0
64QAM 0.92 dual	11.0	11.0	22.0
64QAM 0.75 dual	9.0	9.0	18.0
16QAM 0.87 dual	7.0	7.0	14.0
16QAM 0.63 dual	5.0	5.0	10.0
256QAM 0.81 single	7.0	7.0	14.0
64QAM 0.92 single	6.0	6.0	12.0
64QAM 0.75 single	5.0	5.0	10.0
16QAM 0.87 single	5.0	5.0	10.0
16QAM 0.63 single	4.7	4.7	9.3
QPSK 0.87 single	3.2	3.2	6.5
QPSK 0.63 single	2.3	2.3	4.7
BPSK 0.63 single	1.2	1.2	2.3

Table 96 Throughput at zero link range (Mbit/s), Mid, symmetry 1:1, optimization TDM

Modulation mode	45 MHz (Tx/Rx/Aggregate)			40 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	113.0	113.0	226.0	104.0	104.0	208.0
64QAM 0.92 dual	95.0	95.0	190.0	88.0	88.0	176.0
64QAM 0.75 dual	78.0	78.0	156.0	72.0	72.0	144.0
16QAM 0.87 dual	61.0	61.0	122.0	56.0	56.0	112.0
16QAM 0.63 dual	44.0	44.0	88.0	40.0	40.0	80.0
256QAM 0.81 single	57.0	57.0	114.0	52.0	52.0	104.0
64QAM 0.92 single	48.0	48.0	96.0	44.0	44.0	88.0
64QAM 0.75 single	39.0	39.0	78.0	36.0	36.0	72.0
16QAM 0.87 single	30.0	30.0	60.0	28.0	28.0	56.0
16QAM 0.63 single	22.0	22.0	44.0	20.0	20.0	40.0
QPSK 0.87 single	15.0	15.0	30.0	14.0	14.0	28.0
QPSK 0.63 single	11.0	11.0	22.0	10.0	10.0	20.0
BPSK 0.63 single	5.0	5.0	10.0	5.0	5.0	10.0

Modulation mode	30 MHz (Tx/Rx/Aggregate)			20 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	79.0	79.0	158.0	54.0	54.0	108.0
64QAM 0.92 dual	66.0	66.0	132.0	45.0	45.0	90.0
64QAM 0.75 dual	54.0	54.0	108.0	37.0	37.0	74.0
16QAM 0.87 dual	42.0	42.0	84.0	29.0	29.0	58.0
16QAM 0.63 dual	30.0	30.0	60.0	21.0	21.0	42.0
256QAM 0.81 single	39.0	39.0	78.0	27.0	27.0	54.0
64QAM 0.92 single	33.0	33.0	66.0	23.0	23.0	46.0
64QAM 0.75 single	27.0	27.0	54.0	19.0	19.0	38.0
16QAM 0.87 single	21.0	21.0	42.0	14.0	14.0	28.0
16QAM 0.63 single	15.0	15.0	30.0	10.0	10.0	20.0
QPSK 0.87 single	11.0	11.0	22.0	7.0	7.0	14.0
QPSK 0.63 single	8.0	8.0	16.0	5.0	5.0	10.0
BPSK 0.63 single	5.0	5.0	10.0	4.6	4.6	9.2

Modulation mode	15 MHz (Tx/Rx/Aggregate)			10 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	41.0	41.0	82.0	28.0	28.0	56.0
64QAM 0.92 dual	34.0	34.0	68.0	23.0	23.0	46.0
64QAM 0.75 dual	28.0	28.0	56.0	19.0	19.0	38.0
16QAM 0.87 dual	22.0	22.0	44.0	15.0	15.0	30.0
16QAM 0.63 dual	16.0	16.0	32.0	11.0	11.0	22.0
256QAM 0.81 single	20.0	20.0	40.0	14.0	14.0	28.0
64QAM 0.92 single	17.0	17.0	34.0	12.0	12.0	24.0
64QAM 0.75 single	14.0	14.0	28.0	9.0	9.0	18.0
16QAM 0.87 single	11.0	11.0	22.0	7.0	7.0	14.0
16QAM 0.63 single	8.0	8.0	16.0	5.0	5.0	10.0
QPSK 0.87 single	5.0	5.0	10.0	5.0	5.0	10.0
QPSK 0.63 single	5.0	5.0	10.0	4.7	4.7	9.5
BPSK 0.63 single	3.5	3.5	7.0	2.4	2.4	4.7

Modulation mode	5 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	14.0	14.0	28.0
64QAM 0.92 dual	11.0	11.0	22.0
64QAM 0.75 dual	9.0	9.0	18.0
16QAM 0.87 dual	7.0	7.0	14.0
16QAM 0.63 dual	5.0	5.0	10.0
256QAM 0.81 single	7.0	7.0	14.0
64QAM 0.92 single	6.0	6.0	12.0
64QAM 0.75 single	5.0	5.0	10.0
16QAM 0.87 single	5.0	5.0	10.0
16QAM 0.63 single	4.7	4.7	9.3
QPSK 0.87 single	3.2	3.2	6.5
QPSK 0.63 single	2.3	2.3	4.7
BPSK 0.63 single	1.2	1.2	2.3

Table 97 Throughput at zero link range (Mbit/s), Mid, symmetry 2:1, optimization IP

Modulation mode	45 MHz (Tx/Rx/Aggregate)			40 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	168.0	84.0	252.0	153.0	77.0	230.0
64QAM 0.92 dual	141.0	71.0	212.0	129.0	65.0	194.0
64QAM 0.75 dual	116.0	58.0	174.0	106.0	53.0	159.0
16QAM 0.87 dual	90.0	45.0	135.0	82.0	41.0	123.0
16QAM 0.63 dual	65.0	32.0	97.0	59.0	30.0	89.0
256QAM 0.81 single	84.0	42.0	126.0	77.0	38.0	115.0
64QAM 0.92 single	71.0	35.0	106.0	65.0	32.0	97.0
64QAM 0.75 single	58.0	29.0	87.0	53.0	26.0	79.0
16QAM 0.87 single	45.0	22.0	67.0	41.0	21.0	62.0
16QAM 0.63 single	32.0	16.0	48.0	30.0	15.0	45.0
QPSK 0.87 single	22.0	11.0	33.0	21.0	10.0	31.0
QPSK 0.63 single	16.0	8.0	24.0	15.0	7.0	22.0
BPSK 0.63 single	8.0	5.0	13.0	7.0	5.0	12.0

Modulation mode	30 MHz (Tx/Rx/Aggregate)			20 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	112.0	56.0	168.0	75.0	37.0	112.0
64QAM 0.92 dual	95.0	47.0	142.0	63.0	31.0	94.0
64QAM 0.75 dual	77.0	39.0	116.0	51.0	26.0	77.0
16QAM 0.87 dual	60.0	30.0	90.0	40.0	20.0	60.0
16QAM 0.63 dual	43.0	22.0	65.0	29.0	14.0	43.0
256QAM 0.81 single	56.0	28.0	84.0	37.0	19.0	56.0
64QAM 0.92 single	47.0	24.0	71.0	31.0	16.0	47.0
64QAM 0.75 single	39.0	19.0	58.0	26.0	13.0	39.0
16QAM 0.87 single	30.0	15.0	45.0	20.0	10.0	30.0
16QAM 0.63 single	22.0	11.0	33.0	14.0	7.0	21.0
QPSK 0.87 single	15.0	8.0	23.0	10.0	5.0	15.0
QPSK 0.63 single	11.0	5.0	16.0	7.0	5.0	12.0
BPSK 0.63 single	5.0	4.8	9.8	5.0	3.2	8.2

Modulation mode	15 MHz (Tx/Rx/Aggregate)			10 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	56.0	28.0	84.0	37.0	19.0	56.0
64QAM 0.92 dual	47.0	24.0	71.0	31.0	16.0	47.0
64QAM 0.75 dual	39.0	19.0	58.0	26.0	13.0	39.0
16QAM 0.87 dual	30.0	15.0	45.0	20.0	10.0	30.0
16QAM 0.63 dual	22.0	11.0	33.0	14.0	7.0	21.0
256QAM 0.81 single	28.0	14.0	42.0	19.0	9.0	28.0
64QAM 0.92 single	24.0	12.0	36.0	16.0	8.0	24.0
64QAM 0.75 single	19.0	10.0	29.0	13.0	6.0	19.0
16QAM 0.87 single	15.0	8.0	23.0	10.0	5.0	15.0
16QAM 0.63 single	11.0	5.0	16.0	7.0	5.0	12.0
QPSK 0.87 single	8.0	5.0	13.0	5.0	4.4	9.4
QPSK 0.63 single	5.0	4.8	9.8	5.0	3.2	8.2
BPSK 0.63 single	4.8	2.4	7.2	3.2	1.6	4.8

Table 98 Throughput at zero link range (Mbit/s), Mid, symmetry 2:1, optimization TDM

Modulation mode	45 MHz (Tx/Rx/Aggregate)			40 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	157.0	79.0	236.0	144.0	72.0	216.0
64QAM 0.92 dual	132.0	66.0	198.0	122.0	61.0	183.0
64QAM 0.75 dual	108.0	54.0	162.0	99.0	50.0	149.0
16QAM 0.87 dual	84.0	42.0	126.0	77.0	39.0	116.0
16QAM 0.63 dual	61.0	30.0	91.0	56.0	28.0	84.0
256QAM 0.81 single	79.0	39.0	118.0	72.0	36.0	108.0
64QAM 0.92 single	66.0	33.0	99.0	61.0	30.0	91.0
64QAM 0.75 single	54.0	27.0	81.0	50.0	25.0	75.0
16QAM 0.87 single	42.0	21.0	63.0	39.0	19.0	58.0
16QAM 0.63 single	30.0	15.0	45.0	28.0	14.0	42.0
QPSK 0.87 single	21.0	11.0	32.0	19.0	10.0	29.0
QPSK 0.63 single	15.0	8.0	23.0	14.0	7.0	21.0
BPSK 0.63 single	8.0	5.0	13.0	7.0	5.0	12.0

Modulation mode	30 MHz (Tx/Rx/Aggregate)			20 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	108.0	54.0	162.0	73.0	37.0	110.0
64QAM 0.92 dual	91.0	46.0	137.0	62.0	31.0	93.0
64QAM 0.75 dual	74.0	37.0	111.0	50.0	25.0	75.0
16QAM 0.87 dual	58.0	29.0	87.0	39.0	20.0	59.0
16QAM 0.63 dual	42.0	21.0	63.0	28.0	14.0	42.0
256QAM 0.81 single	54.0	27.0	81.0	37.0	18.0	55.0
64QAM 0.92 single	46.0	23.0	69.0	31.0	15.0	46.0
64QAM 0.75 single	37.0	19.0	56.0	25.0	13.0	38.0
16QAM 0.87 single	29.0	14.0	43.0	20.0	10.0	30.0
16QAM 0.63 single	21.0	10.0	31.0	14.0	7.0	21.0
QPSK 0.87 single	14.0	7.0	21.0	10.0	5.0	15.0
QPSK 0.63 single	10.0	5.0	15.0	7.0	5.0	12.0
BPSK 0.63 single	5.0	4.6	9.6	5.0	3.1	8.1

Modulation mode	15 MHz (Tx/Rx/Aggregate)			10 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	55.0	28.0	83.0	37.0	19.0	56.0
64QAM 0.92 dual	47.0	23.0	70.0	31.0	16.0	47.0
64QAM 0.75 dual	38.0	19.0	57.0	26.0	13.0	39.0
16QAM 0.87 dual	30.0	15.0	45.0	20.0	10.0	30.0
16QAM 0.63 dual	21.0	11.0	32.0	14.0	7.0	21.0
256QAM 0.81 single	28.0	14.0	42.0	19.0	9.0	28.0
64QAM 0.92 single	23.0	12.0	35.0	16.0	8.0	24.0
64QAM 0.75 single	19.0	10.0	29.0	13.0	6.0	19.0
16QAM 0.87 single	15.0	7.0	22.0	10.0	5.0	15.0
16QAM 0.63 single	11.0	5.0	16.0	7.0	5.0	12.0
QPSK 0.87 single	7.0	5.0	12.0	5.0	4.4	9.4
QPSK 0.63 single	5.0	4.8	9.8	5.0	3.2	8.2
BPSK 0.63 single	4.8	2.4	7.1	3.2	1.6	4.8

Table 99 Throughput at zero link range (Mbit/s), Mid, symmetry 3:1, optimization IP

Modulation mode	45 MHz (Tx/Rx/Aggregate)			40 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	189.00	63.00	252.00	172.00	57.00	229.00
64QAM 0.92 dual	159.00	53.00	212.00	145.00	48.00	193.00
64QAM 0.75 dual	130.00	43.00	173.00	119.00	40.00	159.00
16QAM 0.87 dual	101.00	34.00	135.00	92.00	31.00	123.00
16QAM 0.63 dual	73.00	24.00	97.00	66.00	22.00	88.00
256QAM 0.81 single	94.00	31.00	125.00	86.00	29.00	115.00
64QAM 0.92 single	80.00	27.00	107.00	73.00	24.00	97.00
64QAM 0.75 single	65.00	22.00	87.00	59.00	20.00	79.00
16QAM 0.87 single	51.00	17.00	68.00	46.00	15.00	61.00
16QAM 0.63 single	36.00	12.00	48.00	33.00	11.00	44.00
QPSK 0.87 single	25.00	8.00	33.00	23.00	8.00	31.00
QPSK 0.63 single	18.00	6.00	24.00	17.00	6.00	23.00
BPSK 0.63 single	9.00	5.00	14.00	8.00	4.94	12.94

Modulation mode	30 MHz (Tx/Rx/Aggregate)			20 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	126.00	42.00	168.00	83.00	28.00	111.00
64QAM 0.92 dual	106.00	35.00	141.00	70.00	23.00	93.00
64QAM 0.75 dual	87.00	29.00	116.00	57.00	19.00	76.00
16QAM 0.87 dual	67.00	22.00	89.00	45.00	15.00	60.00
16QAM 0.63 dual	49.00	16.00	65.00	32.00	11.00	43.00
256QAM 0.81 single	63.00	21.00	84.00	42.00	14.00	56.00
64QAM 0.92 single	53.00	18.00	71.00	35.00	12.00	47.00
64QAM 0.75 single	43.00	14.00	57.00	29.00	10.00	39.00
16QAM 0.87 single	34.00	11.00	45.00	22.00	7.00	29.00
16QAM 0.63 single	24.00	8.00	32.00	16.00	5.00	21.00
QPSK 0.87 single	17.00	6.00	23.00	11.00	5.00	16.00
QPSK 0.63 single	12.00	5.00	17.00	8.00	4.76	12.76
BPSK 0.63 single	6.00	3.61	9.61	5.00	2.38	7.38

Modulation mode	15 MHz (Tx/Rx/Aggregate)			10 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	63.00	21.00	84.00	42.00	14.00	56.00
64QAM 0.92 dual	53.00	18.00	71.00	35.00	12.00	47.00
64QAM 0.75 dual	43.00	14.00	57.00	29.00	10.00	39.00
16QAM 0.87 dual	34.00	11.00	45.00	23.00	8.00	31.00
16QAM 0.63 dual	24.00	8.00	32.00	16.00	5.00	21.00
256QAM 0.81 single	31.00	10.00	41.00	21.00	7.00	28.00
64QAM 0.92 single	26.00	9.00	35.00	18.00	6.00	24.00
64QAM 0.75 single	22.00	7.00	29.00	14.00	5.00	19.00
16QAM 0.87 single	17.00	6.00	23.00	11.00	5.00	16.00
16QAM 0.63 single	12.00	5.00	17.00	8.00	4.82	12.82
QPSK 0.87 single	8.00	5.00	13.00	6.00	3.35	9.35
QPSK 0.63 single	6.00	3.59	9.59	5.00	2.41	7.41
BPSK 0.63 single	5.00	1.80	6.80	3.61	1.20	4.82

Table 100 Throughput at zero link range (Mbit/s), Mid, symmetry 5:1, optimization IP

Modulation mode	45 MHz (Tx/Rx/Aggregate)			40 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	374.68	74.93	449.62	335.20	67.04	402.24
64QAM 0.92 dual	315.68	63.13	378.81	282.42	56.48	338.90
64QAM 0.75 dual	257.97	51.59	309.56	230.79	46.16	276.95
16QAM 0.87 dual	200.69	40.14	240.83	179.54	35.91	215.45
16QAM 0.63 dual	144.27	28.85	173.12	129.07	25.81	154.88
256QAM 0.81 single	187.34	37.47	224.80	167.60	33.52	201.12
64QAM 0.92 single	157.84	31.57	189.40	141.21	28.24	169.45
64QAM 0.75 single	128.98	25.79	154.78	115.39	23.08	138.47
16QAM 0.87 single	100.34	20.07	120.41	89.77	17.95	107.72
16QAM 0.63 single	72.13	14.43	86.56	64.53	12.90	77.44
QPSK 0.87 single	50.17	10.03	60.20	44.88	8.98	53.86
QPSK 0.63 single	36.06	7.21	43.27	32.26	6.45	38.71
BPSK 0.63 single	18.03	3.60	21.63	16.13	3.22	19.35

Modulation mode	30 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	248.23	49.64	297.87
64QAM 0.92 dual	209.14	41.83	250.96
64QAM 0.75 dual	170.90	34.18	205.08
16QAM 0.87 dual	132.96	26.59	159.55
16QAM 0.63 dual	95.58	19.11	114.69
256QAM 0.81 single	124.11	24.82	148.93
64QAM 0.92 single	104.57	20.91	125.48
64QAM 0.75 single	85.45	17.09	102.54
16QAM 0.87 single	66.48	13.29	79.77
16QAM 0.63 single	47.79	9.56	57.34
QPSK 0.87 single	33.24	6.65	39.88
QPSK 0.63 single	23.89	4.78	28.67
BPSK 0.63 single	11.94	2.39	14.33

Table 101 Throughput at zero link range (Mbit/s), Lite, symmetry 1:1, optimization IP

Modulation mode	45 MHz (Tx/Rx/Aggregate)			40 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	63.0	63.0	126.0	58.0	58.0	116.0
64QAM 0.92 dual	53.0	53.0	106.0	49.0	49.0	98.0
64QAM 0.75 dual	44.0	44.0	88.0	40.0	40.0	80.0
16QAM 0.87 dual	34.0	34.0	68.0	31.0	31.0	62.0
16QAM 0.63 dual	24.0	24.0	48.0	22.0	22.0	44.0
256QAM 0.81 single	32.0	32.0	64.0	29.0	29.0	58.0
64QAM 0.92 single	27.0	27.0	54.0	24.0	24.0	48.0
64QAM 0.75 single	22.0	22.0	44.0	20.0	20.0	40.0
16QAM 0.87 single	17.0	17.0	34.0	15.0	15.0	30.0
16QAM 0.63 single	12.0	12.0	24.0	11.0	11.0	22.0
QPSK 0.87 single	8.0	8.0	16.0	8.0	8.0	16.0
QPSK 0.63 single	6.0	6.0	12.0	6.0	6.0	12.0
BPSK 0.63 single	5.0	5.0	10.0	5.0	5.0	10.0

Modulation mode	30 MHz (Tx/Rx/Aggregate)			20 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	42.0	42.0	84.0	28.0	28.0	56.0
64QAM 0.92 dual	36.0	36.0	72.0	24.0	24.0	48.0
64QAM 0.75 dual	29.0	29.0	58.0	19.0	19.0	38.0
16QAM 0.87 dual	23.0	23.0	46.0	15.0	15.0	30.0
16QAM 0.63 dual	16.0	16.0	32.0	11.0	11.0	22.0
256QAM 0.81 single	21.0	21.0	42.0	14.0	14.0	28.0
64QAM 0.92 single	18.0	18.0	36.0	12.0	12.0	24.0
64QAM 0.75 single	15.0	15.0	30.0	10.0	10.0	20.0
16QAM 0.87 single	11.0	11.0	22.0	8.0	8.0	16.0
16QAM 0.63 single	8.0	8.0	16.0	5.0	5.0	10.0
QPSK 0.87 single	6.0	6.0	12.0	5.0	5.0	10.0
QPSK 0.63 single	5.0	5.0	10.0	5.0	5.0	10.0
BPSK 0.63 single	5.0	5.0	10.0	4.8	4.8	9.6

Modulation mode	15 MHz (Tx/Rx/Aggregate)			10 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	21.0	21.0	42.0	14.0	14.0	28.0
64QAM 0.92 dual	18.0	18.0	36.0	12.0	12.0	24.0
64QAM 0.75 dual	15.0	15.0	30.0	10.0	10.0	20.0
16QAM 0.87 dual	11.0	11.0	22.0	8.0	8.0	16.0
16QAM 0.63 dual	8.0	8.0	16.0	5.0	5.0	10.0
256QAM 0.81 single	11.0	11.0	22.0	7.0	7.0	14.0
64QAM 0.92 single	9.0	9.0	18.0	6.0	6.0	12.0
64QAM 0.75 single	7.0	7.0	14.0	5.0	5.0	10.0
16QAM 0.87 single	6.0	6.0	12.0	5.0	5.0	10.0
16QAM 0.63 single	5.0	5.0	10.0	5.0	5.0	10.0
QPSK 0.87 single	5.0	5.0	10.0	5.0	5.0	10.0
QPSK 0.63 single	5.0	5.0	10.0	4.8	4.8	9.6
BPSK 0.63 single	3.6	3.6	7.2	2.4	2.4	4.8

Modulation mode	5 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	7.0	7.0	14.0
64QAM 0.92 dual	6.0	6.0	12.0
64QAM 0.75 dual	5.0	5.0	10.0
16QAM 0.87 dual	5.0	5.0	10.0
16QAM 0.63 dual	5.0	5.0	10.0
256QAM 0.81 single	5.0	5.0	10.0
64QAM 0.92 single	5.0	5.0	10.0
64QAM 0.75 single	5.0	5.0	10.0
16QAM 0.87 single	5.0	5.0	10.0
16QAM 0.63 single	4.7	4.7	9.3
QPSK 0.87 single	3.2	3.2	6.5
QPSK 0.63 single	2.3	2.3	4.7
BPSK 0.63 single	1.2	1.2	2.3

Table 102 Throughput at zero link range (Mbit/s), Lite, symmetry 1:1, optimization TDM

Modulation mode	45 MHz (Tx/Rx/Aggregate)			40 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	57.0	57.0	114.0	52.0	52.0	104.0
64QAM 0.92 dual	48.0	48.0	96.0	44.0	44.0	88.0
64QAM 0.75 dual	39.0	39.0	78.0	36.0	36.0	72.0
16QAM 0.87 dual	30.0	30.0	60.0	28.0	28.0	56.0
16QAM 0.63 dual	22.0	22.0	44.0	20.0	20.0	40.0
256QAM 0.81 single	28.0	28.0	56.0	26.0	26.0	52.0
64QAM 0.92 single	24.0	24.0	48.0	22.0	22.0	44.0
64QAM 0.75 single	19.0	19.0	38.0	18.0	18.0	36.0
16QAM 0.87 single	15.0	15.0	30.0	14.0	14.0	28.0
16QAM 0.63 single	11.0	11.0	22.0	10.0	10.0	20.0
QPSK 0.87 single	8.0	8.0	16.0	7.0	7.0	14.0
QPSK 0.63 single	5.0	5.0	10.0	5.0	5.0	10.0
BPSK 0.63 single	5.0	5.0	10.0	5.0	5.0	10.0

Modulation mode	30 MHz (Tx/Rx/Aggregate)			20 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	39.0	39.0	78.0	27.0	27.0	54.0
64QAM 0.92 dual	33.0	33.0	66.0	23.0	23.0	46.0
64QAM 0.75 dual	27.0	27.0	54.0	19.0	19.0	38.0
16QAM 0.87 dual	21.0	21.0	42.0	14.0	14.0	28.0
16QAM 0.63 dual	15.0	15.0	30.0	10.0	10.0	20.0
256QAM 0.81 single	20.0	20.0	40.0	13.0	13.0	26.0
64QAM 0.92 single	17.0	17.0	34.0	11.0	11.0	22.0
64QAM 0.75 single	14.0	14.0	28.0	9.0	9.0	18.0
16QAM 0.87 single	11.0	11.0	22.0	7.0	7.0	14.0
16QAM 0.63 single	8.0	8.0	16.0	5.0	5.0	10.0
QPSK 0.87 single	5.0	5.0	10.0	5.0	5.0	10.0
QPSK 0.63 single	5.0	5.0	10.0	5.0	5.0	10.0
BPSK 0.63 single	5.0	5.0	10.0	4.6	4.6	9.2

Modulation mode	15 MHz (Tx/Rx/Aggregate)			10 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	20.0	20.0	40.0	14.0	14.0	28.0
64QAM 0.92 dual	17.0	17.0	34.0	12.0	12.0	24.0
64QAM 0.75 dual	14.0	14.0	28.0	9.0	9.0	18.0
16QAM 0.87 dual	11.0	11.0	22.0	7.0	7.0	14.0
16QAM 0.63 dual	8.0	8.0	16.0	5.0	5.0	10.0
256QAM 0.81 single	10.0	10.0	20.0	7.0	7.0	14.0
64QAM 0.92 single	9.0	9.0	18.0	6.0	6.0	12.0
64QAM 0.75 single	7.0	7.0	14.0	5.0	5.0	10.0
16QAM 0.87 single	5.0	5.0	10.0	5.0	5.0	10.0
16QAM 0.63 single	5.0	5.0	10.0	5.0	5.0	10.0
QPSK 0.87 single	5.0	5.0	10.0	5.0	5.0	10.0
QPSK 0.63 single	5.0	5.0	10.0	4.7	4.7	9.5
BPSK 0.63 single	3.5	3.5	7.0	2.4	2.4	4.7

Modulation mode	5 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	7.0	7.0	14.0
64QAM 0.92 dual	6.0	6.0	12.0
64QAM 0.75 dual	5.0	5.0	10.0
16QAM 0.87 dual	5.0	5.0	10.0
16QAM 0.63 dual	5.0	5.0	10.0
256QAM 0.81 single	5.0	5.0	10.0
64QAM 0.92 single	5.0	5.0	10.0
64QAM 0.75 single	5.0	5.0	10.0
16QAM 0.87 single	5.0	5.0	10.0
16QAM 0.63 single	4.7	4.7	9.3
QPSK 0.87 single	3.2	3.2	6.5
QPSK 0.63 single	2.3	2.3	4.7
BPSK 0.63 single	1.2	1.2	2.3

Table 103 Throughput at zero link range (Mbit/s), Lite, symmetry 2:1, optimization IP

Modulation mode	45 MHz (Tx/Rx/Aggregate)			40 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	84.0	42.0	126.0	77.0	38.0	115.0
64QAM 0.92 dual	71.0	35.0	106.0	65.0	32.0	97.0
64QAM 0.75 dual	58.0	29.0	87.0	53.0	26.0	79.0
16QAM 0.87 dual	45.0	22.0	67.0	41.0	21.0	62.0
16QAM 0.63 dual	32.0	16.0	48.0	30.0	15.0	45.0
256QAM 0.81 single	42.0	21.0	63.0	38.0	19.0	57.0
64QAM 0.92 single	35.0	18.0	53.0	32.0	16.0	48.0
64QAM 0.75 single	29.0	14.0	43.0	26.0	13.0	39.0
16QAM 0.87 single	22.0	11.0	33.0	21.0	10.0	31.0
16QAM 0.63 single	16.0	8.0	24.0	15.0	7.0	22.0
QPSK 0.87 single	11.0	6.0	17.0	10.0	5.0	15.0
QPSK 0.63 single	8.0	5.0	13.0	7.0	5.0	12.0
BPSK 0.63 single	5.0	5.0	10.0	5.0	5.0	10.0

Modulation mode	30 MHz (Tx/Rx/Aggregate)			20 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	56.0	28.0	84.0	37.0	19.0	56.0
64QAM 0.92 dual	47.0	24.0	71.0	31.0	16.0	47.0
64QAM 0.75 dual	39.0	19.0	58.0	26.0	13.0	39.0
16QAM 0.87 dual	30.0	15.0	45.0	20.0	10.0	30.0
16QAM 0.63 dual	22.0	11.0	33.0	14.0	7.0	21.0
256QAM 0.81 single	28.0	14.0	42.0	19.0	9.0	28.0
64QAM 0.92 single	24.0	12.0	36.0	16.0	8.0	24.0
64QAM 0.75 single	19.0	10.0	29.0	13.0	6.0	19.0
16QAM 0.87 single	15.0	8.0	23.0	10.0	5.0	15.0
16QAM 0.63 single	11.0	5.0	16.0	7.0	5.0	12.0
QPSK 0.87 single	8.0	5.0	13.0	5.0	5.0	10.0
QPSK 0.63 single	5.0	5.0	10.0	5.0	5.0	10.0
BPSK 0.63 single	5.0	4.8	9.8	5.0	3.2	8.2

Modulation mode	15 MHz (Tx/Rx/Aggregate)			10 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	28.0	14.0	42.0	19.0	9.0	28.0
64QAM 0.92 dual	24.0	12.0	36.0	16.0	8.0	24.0
64QAM 0.75 dual	19.0	10.0	29.0	13.0	6.0	19.0
16QAM 0.87 dual	15.0	8.0	23.0	10.0	5.0	15.0
16QAM 0.63 dual	11.0	5.0	16.0	7.0	5.0	12.0
256QAM 0.81 single	14.0	7.0	21.0	9.0	5.0	14.0
64QAM 0.92 single	12.0	6.0	18.0	8.0	5.0	13.0
64QAM 0.75 single	10.0	5.0	15.0	6.0	5.0	11.0
16QAM 0.87 single	8.0	5.0	13.0	5.0	5.0	10.0
16QAM 0.63 single	5.0	5.0	10.0	5.0	5.0	10.0
QPSK 0.87 single	5.0	5.0	10.0	5.0	4.4	9.4
QPSK 0.63 single	5.0	4.8	9.8	5.0	3.2	8.2
BPSK 0.63 single	4.8	2.4	7.2	3.2	1.6	4.8

Table 104 Throughput at zero link range (Mbit/s), Lite, symmetry 2:1, optimization TDM

Modulation mode	45 MHz (Tx/Rx/Aggregate)			40 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	79.0	39.0	118.0	72.0	36.0	108.0
64QAM 0.92 dual	66.0	33.0	99.0	61.0	30.0	91.0
64QAM 0.75 dual	54.0	27.0	81.0	50.0	25.0	75.0
16QAM 0.87 dual	42.0	21.0	63.0	39.0	19.0	58.0
16QAM 0.63 dual	30.0	15.0	45.0	28.0	14.0	42.0
256QAM 0.81 single	39.0	20.0	59.0	36.0	18.0	54.0
64QAM 0.92 single	33.0	17.0	50.0	30.0	15.0	45.0
64QAM 0.75 single	27.0	14.0	41.0	25.0	12.0	37.0
16QAM 0.87 single	21.0	11.0	32.0	19.0	10.0	29.0
16QAM 0.63 single	15.0	8.0	23.0	14.0	7.0	21.0
QPSK 0.87 single	11.0	5.0	16.0	10.0	5.0	15.0
QPSK 0.63 single	8.0	5.0	13.0	7.0	5.0	12.0
BPSK 0.63 single	5.0	5.0	10.0	5.0	5.0	10.0

Modulation mode	30 MHz (Tx/Rx/Aggregate)			20 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	54.0	27.0	81.0	37.0	18.0	55.0
64QAM 0.92 dual	46.0	23.0	69.0	31.0	15.0	46.0
64QAM 0.75 dual	37.0	19.0	56.0	25.0	13.0	38.0
16QAM 0.87 dual	29.0	14.0	43.0	20.0	10.0	30.0
16QAM 0.63 dual	21.0	10.0	31.0	14.0	7.0	21.0
256QAM 0.81 single	27.0	14.0	41.0	18.0	9.0	27.0
64QAM 0.92 single	23.0	11.0	34.0	15.0	8.0	23.0
64QAM 0.75 single	19.0	9.0	28.0	13.0	6.0	19.0
16QAM 0.87 single	14.0	7.0	21.0	10.0	5.0	15.0
16QAM 0.63 single	10.0	5.0	15.0	7.0	5.0	12.0
QPSK 0.87 single	7.0	5.0	12.0	5.0	5.0	10.0
QPSK 0.63 single	5.0	5.0	10.0	5.0	5.0	10.0
BPSK 0.63 single	5.0	4.6	9.6	5.0	3.1	8.1

Modulation mode	15 MHz (Tx/Rx/Aggregate)			10 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	28.0	14.0	42.0	19.0	9.0	28.0
64QAM 0.92 dual	23.0	12.0	35.0	16.0	8.0	24.0
64QAM 0.75 dual	19.0	10.0	29.0	13.0	6.0	19.0
16QAM 0.87 dual	15.0	7.0	22.0	10.0	5.0	15.0
16QAM 0.63 dual	11.0	5.0	16.0	7.0	5.0	12.0
256QAM 0.81 single	14.0	7.0	21.0	9.0	5.0	14.0
64QAM 0.92 single	12.0	6.0	18.0	8.0	5.0	13.0
64QAM 0.75 single	10.0	5.0	15.0	6.0	5.0	11.0
16QAM 0.87 single	7.0	5.0	12.0	5.0	5.0	10.0
16QAM 0.63 single	5.0	5.0	10.0	5.0	5.0	10.0
QPSK 0.87 single	5.0	5.0	10.0	5.0	4.4	9.4
QPSK 0.63 single	5.0	4.8	9.8	5.0	3.2	8.2
BPSK 0.63 single	4.8	2.4	7.1	3.2	1.6	4.8

Table 105 Throughput at zero link range (Mbit/s), Lite, symmetry 3:1, optimization IP

Modulation mode	45 MHz (Tx/Rx/Aggregate)			40 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	94.00	31.00	125.00	86.00	29.00	115.00
64QAM 0.92 dual	80.00	27.00	107.00	73.00	24.00	97.00
64QAM 0.75 dual	65.00	22.00	87.00	59.00	20.00	79.00
16QAM 0.87 dual	51.00	17.00	68.00	46.00	15.00	61.00
16QAM 0.63 dual	36.00	12.00	48.00	33.00	11.00	44.00
256QAM 0.81 single	47.00	16.00	63.00	43.00	14.00	57.00
64QAM 0.92 single	40.00	13.00	53.00	36.00	12.00	48.00
64QAM 0.75 single	33.00	11.00	44.00	30.00	10.00	40.00
16QAM 0.87 single	25.00	8.00	33.00	23.00	8.00	31.00
16QAM 0.63 single	18.00	6.00	24.00	17.00	6.00	23.00
QPSK 0.87 single	13.00	5.00	18.00	12.00	5.00	17.00
QPSK 0.63 single	9.00	5.00	14.00	8.00	5.00	13.00
BPSK 0.63 single	5.00	5.00	10.00	5.00	4.94	9.94

Modulation mode	30 MHz (Tx/Rx/Aggregate)			20 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	63.00	21.00	84.00	42.00	14.00	56.00
64QAM 0.92 dual	53.00	18.00	71.00	35.00	12.00	47.00
64QAM 0.75 dual	43.00	14.00	57.00	29.00	10.00	39.00
16QAM 0.87 dual	34.00	11.00	45.00	22.00	7.00	29.00
16QAM 0.63 dual	24.00	8.00	32.00	16.00	5.00	21.00
256QAM 0.81 single	32.00	11.00	43.00	21.00	7.00	28.00
64QAM 0.92 single	27.00	9.00	36.00	18.00	6.00	24.00
64QAM 0.75 single	22.00	7.00	29.00	14.00	5.00	19.00
16QAM 0.87 single	17.00	6.00	23.00	11.00	5.00	16.00
16QAM 0.63 single	12.00	5.00	17.00	8.00	5.00	13.00
QPSK 0.87 single	8.00	5.00	13.00	6.00	5.00	11.00
QPSK 0.63 single	6.00	5.00	11.00	5.00	4.76	9.76
BPSK 0.63 single	5.00	3.61	8.61	5.00	2.38	7.38

Modulation mode	15 MHz (Tx/Rx/Aggregate)			10 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	31.00	10.00	41.00	21.00	7.00	28.00
64QAM 0.92 dual	26.00	9.00	35.00	18.00	6.00	24.00
64QAM 0.75 dual	22.00	7.00	29.00	14.00	5.00	19.00
16QAM 0.87 dual	17.00	6.00	23.00	11.00	5.00	16.00
16QAM 0.63 dual	12.00	5.00	17.00	8.00	5.00	13.00
256QAM 0.81 single	16.00	5.00	21.00	11.00	5.00	16.00
64QAM 0.92 single	13.00	5.00	18.00	9.00	5.00	14.00
64QAM 0.75 single	11.00	5.00	16.00	7.00	5.00	12.00
16QAM 0.87 single	8.00	5.00	13.00	6.00	5.00	11.00
16QAM 0.63 single	6.00	5.00	11.00	5.00	4.82	9.82
QPSK 0.87 single	5.00	5.00	10.00	5.00	3.35	8.35
QPSK 0.63 single	5.00	3.59	8.59	5.00	2.41	7.41
BPSK 0.63 single	5.00	1.80	6.80	3.61	1.20	4.82

Table 106 Throughput at zero link range (Mbit/s), Lite, symmetry 5:1, optimization IP

Modulation mode	45 MHz (Tx/Rx/Aggregate)			40 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	105.00	21.00	126.00	94.00	19.00	113.00
64QAM 0.92 dual	88.00	18.00	106.00	79.00	16.00	95.00
64QAM 0.75 dual	72.00	14.00	86.00	65.00	13.00	78.00
16QAM 0.87 dual	56.00	11.00	67.00	50.00	10.00	60.00
16QAM 0.63 dual	40.00	8.00	48.00	36.00	7.00	43.00
256QAM 0.81 single	52.00	10.00	62.00	47.00	9.00	56.00
64QAM 0.92 single	44.00	9.00	53.00	40.00	8.00	48.00
64QAM 0.75 single	36.00	7.00	43.00	32.00	6.00	38.00
16QAM 0.87 single	28.00	6.00	34.00	25.00	5.00	30.00
16QAM 0.63 single	20.00	5.00	25.00	18.00	5.00	23.00
QPSK 0.87 single	14.00	5.00	19.00	13.00	5.00	18.00
QPSK 0.63 single	10.00	5.00	15.00	9.00	5.00	14.00
BPSK 0.63 single	5.00	3.60	8.60	5.00	3.22	8.22

Modulation mode	30 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	70.00	14.00	84.00
64QAM 0.92 dual	59.00	12.00	71.00
64QAM 0.75 dual	48.00	10.00	58.00
16QAM 0.87 dual	37.00	7.00	44.00
16QAM 0.63 dual	27.00	5.00	32.00
256QAM 0.81 single	35.00	7.00	42.00
64QAM 0.92 single	29.00	6.00	35.00
64QAM 0.75 single	24.00	5.00	29.00
16QAM 0.87 single	19.00	5.00	24.00
16QAM 0.63 single	13.00	5.00	18.00
QPSK 0.87 single	9.00	5.00	14.00
QPSK 0.63 single	7.00	4.78	11.78

BPSK 0.63 single	5.00	2.39	7.39

Figure 63 Range adjustment for PTP 650, symmetry 1:1, optimization IP, bandwidth 45 MHz

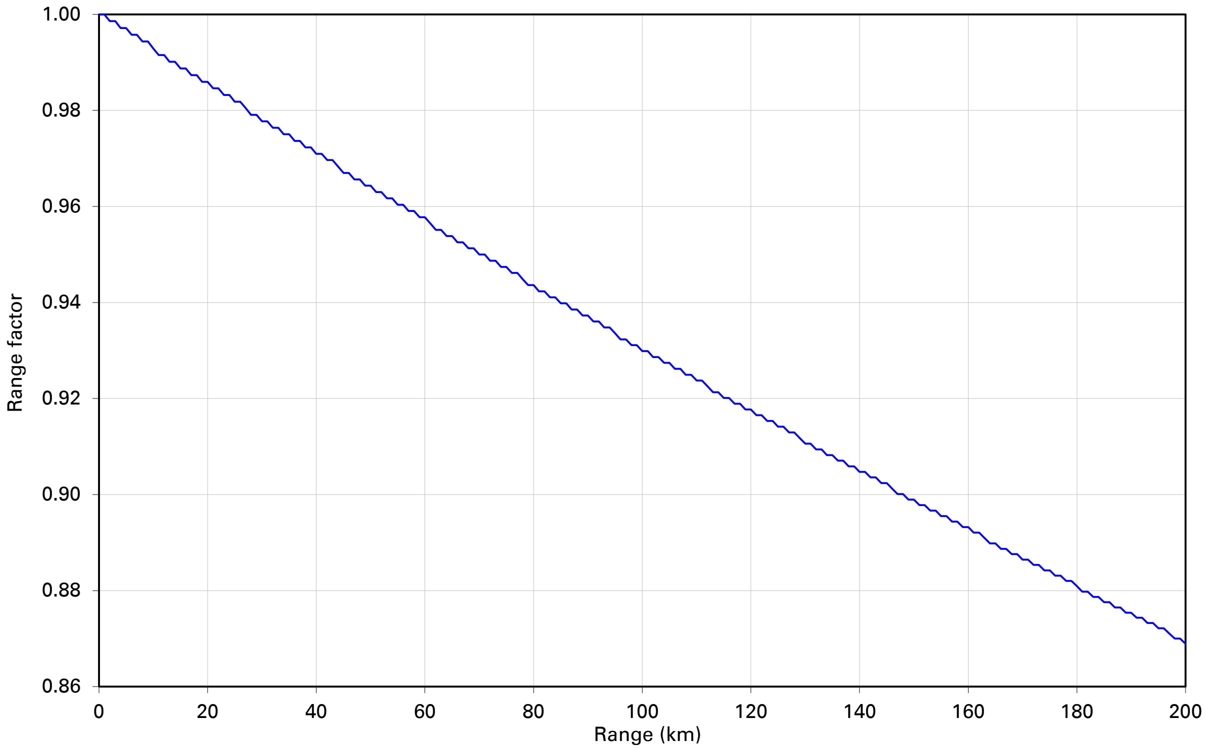


Figure 64 Range adjustment for PTP 650, symmetry 1:1, optimization IP, bandwidth 40 MHz

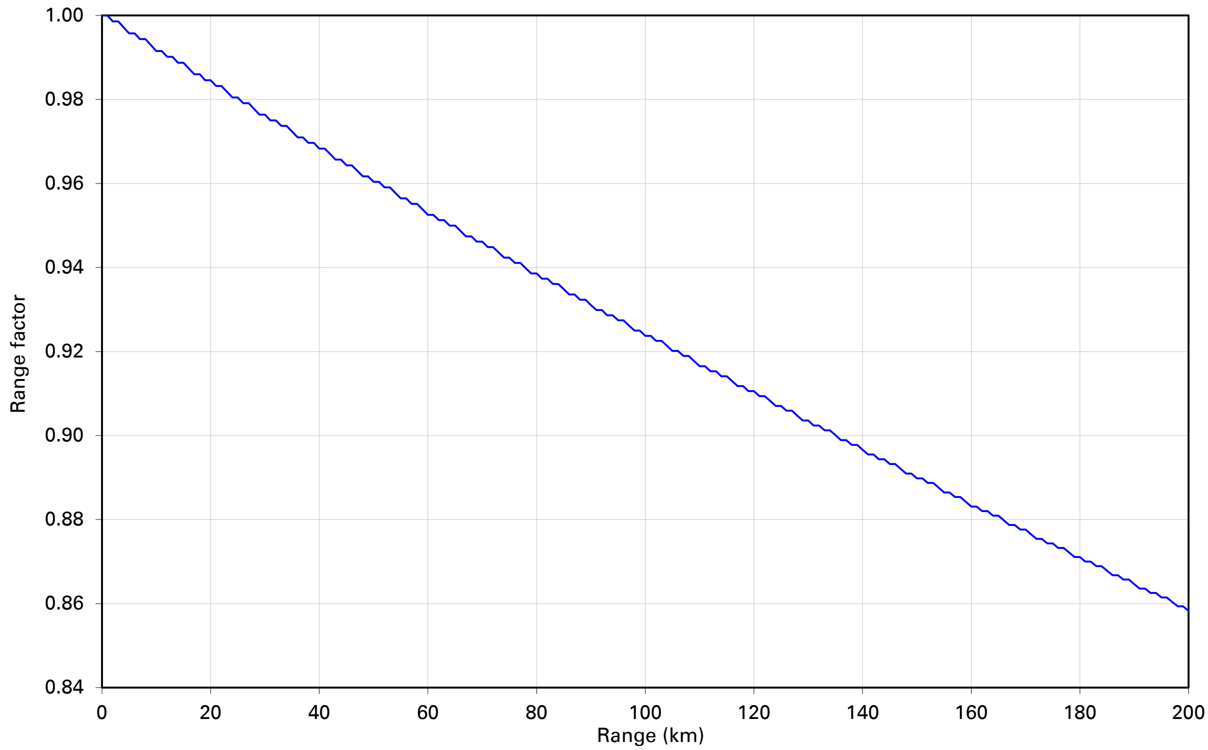


Figure 65 Range adjustment for PTP 650, symmetry 1:1, optimization IP, bandwidth 30 MHz

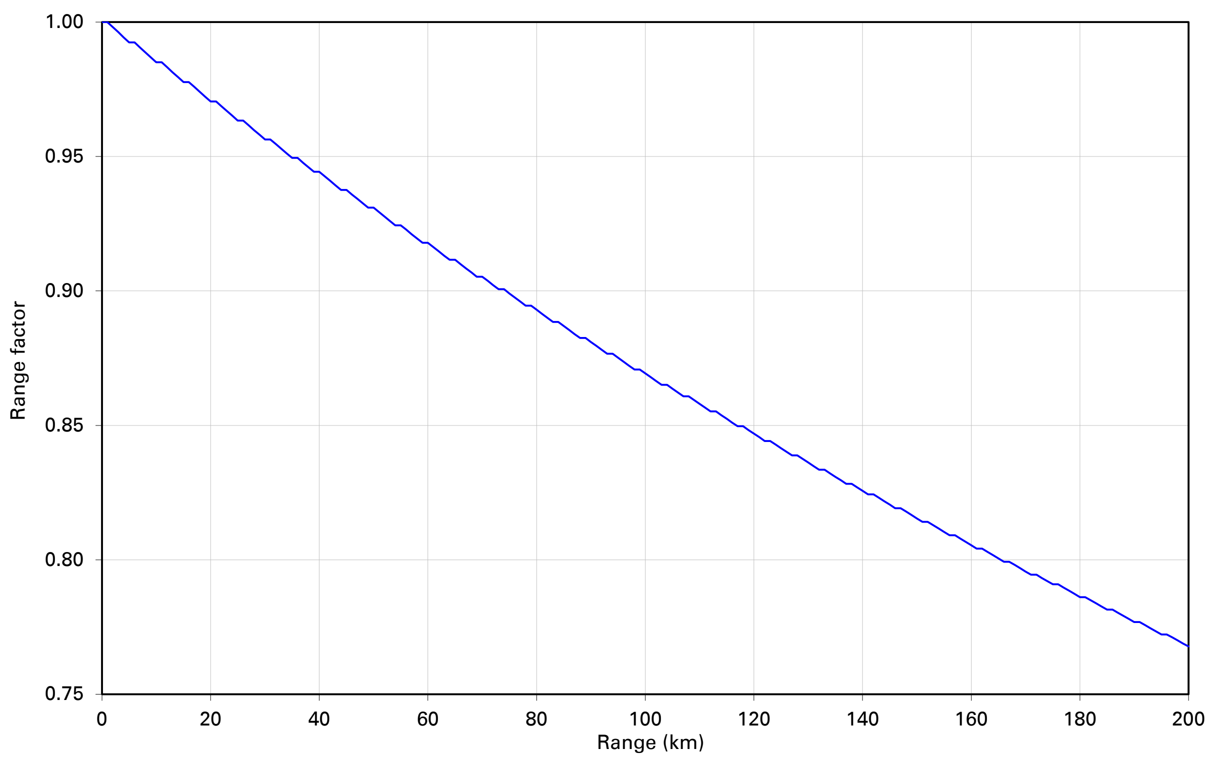


Figure 66 Range adjustment for PTP 650, symmetry 1:1, optimization IP, bandwidth 20 MHz

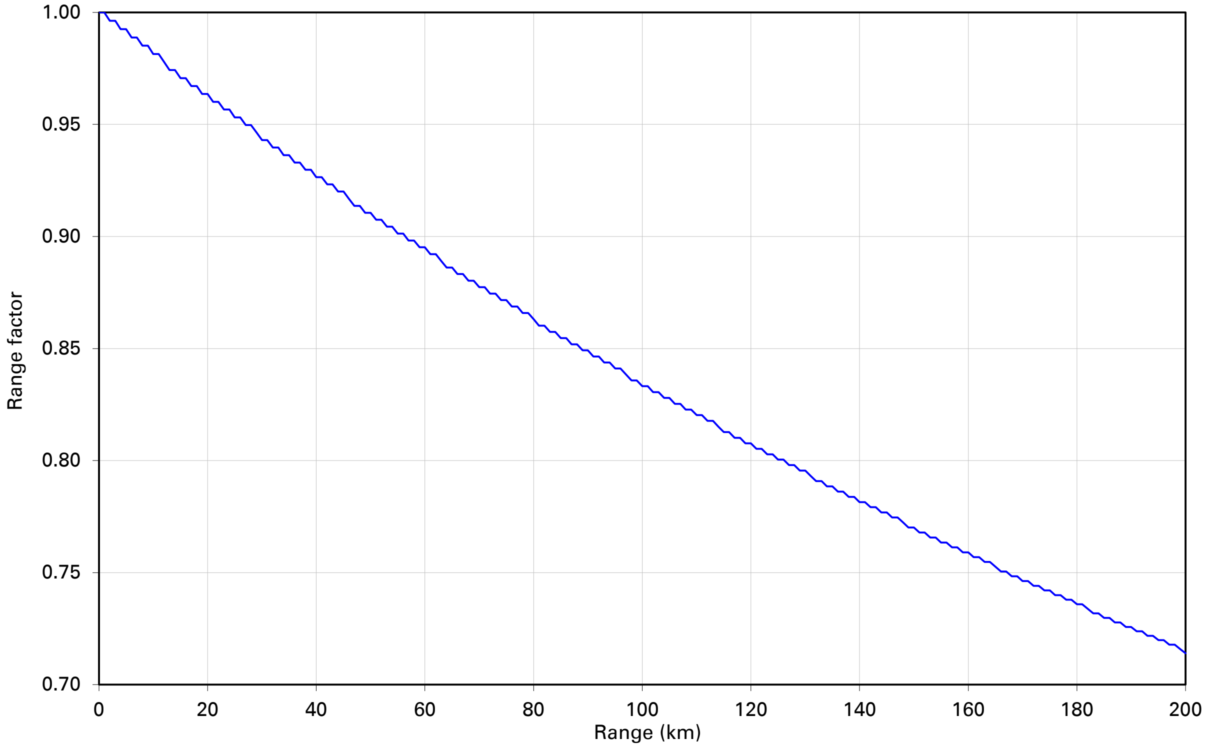


Figure 67 Range adjustment for PTP 650, symmetry 1:1, optimization IP, bandwidth 15 MHz

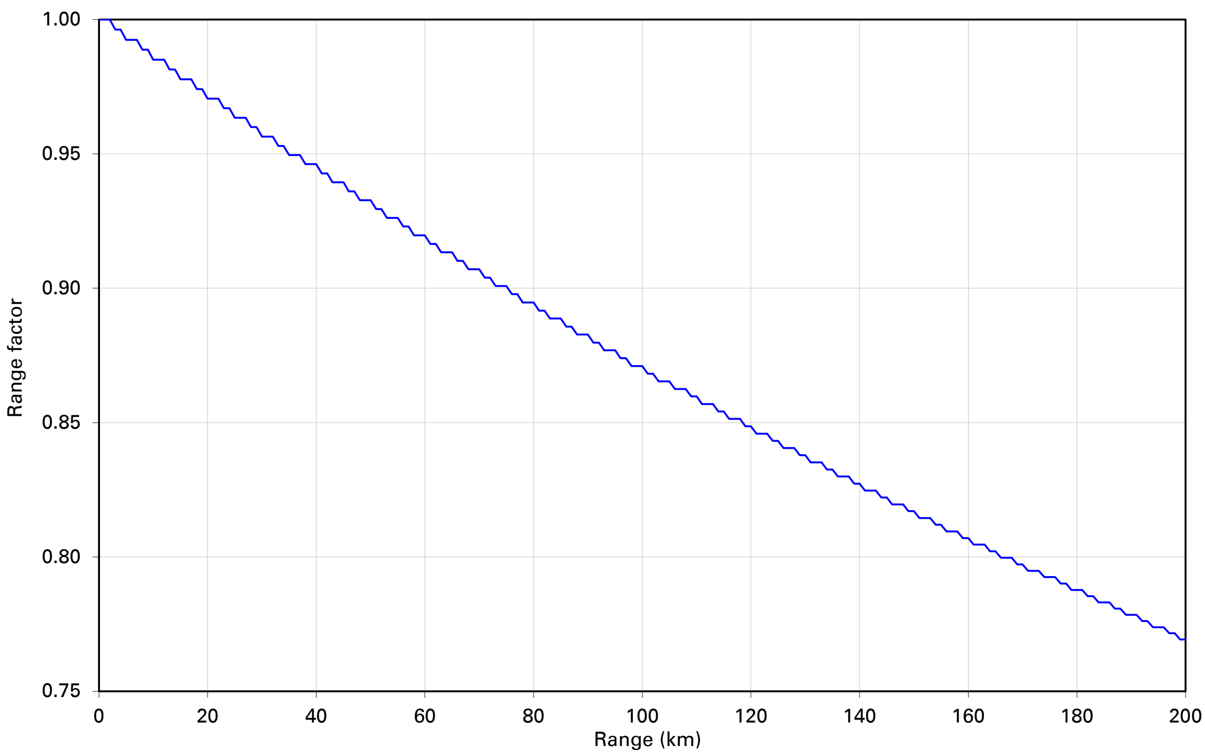


Figure 68 Range adjustment for PTP 650, symmetry 1:1, optimization IP, bandwidth 10 MHz

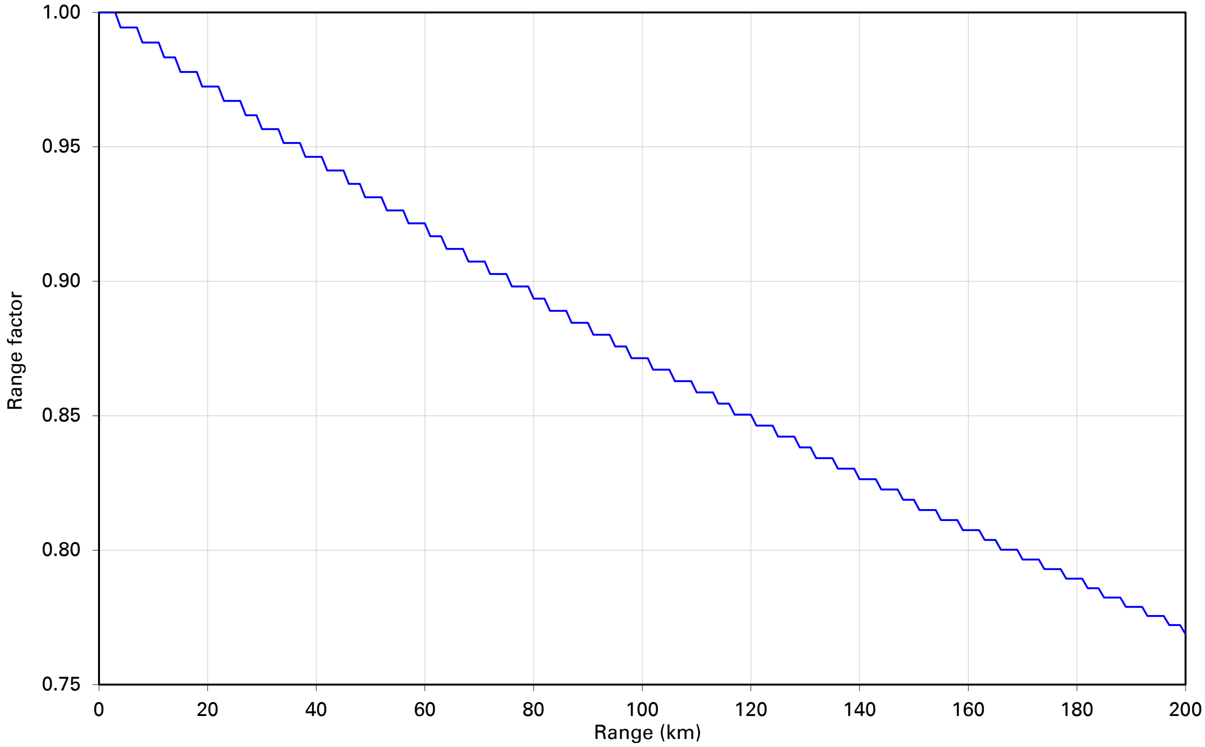


Figure 69 Range adjustment for PTP 650, symmetry 1:1, optimization IP, bandwidth 5 MHz

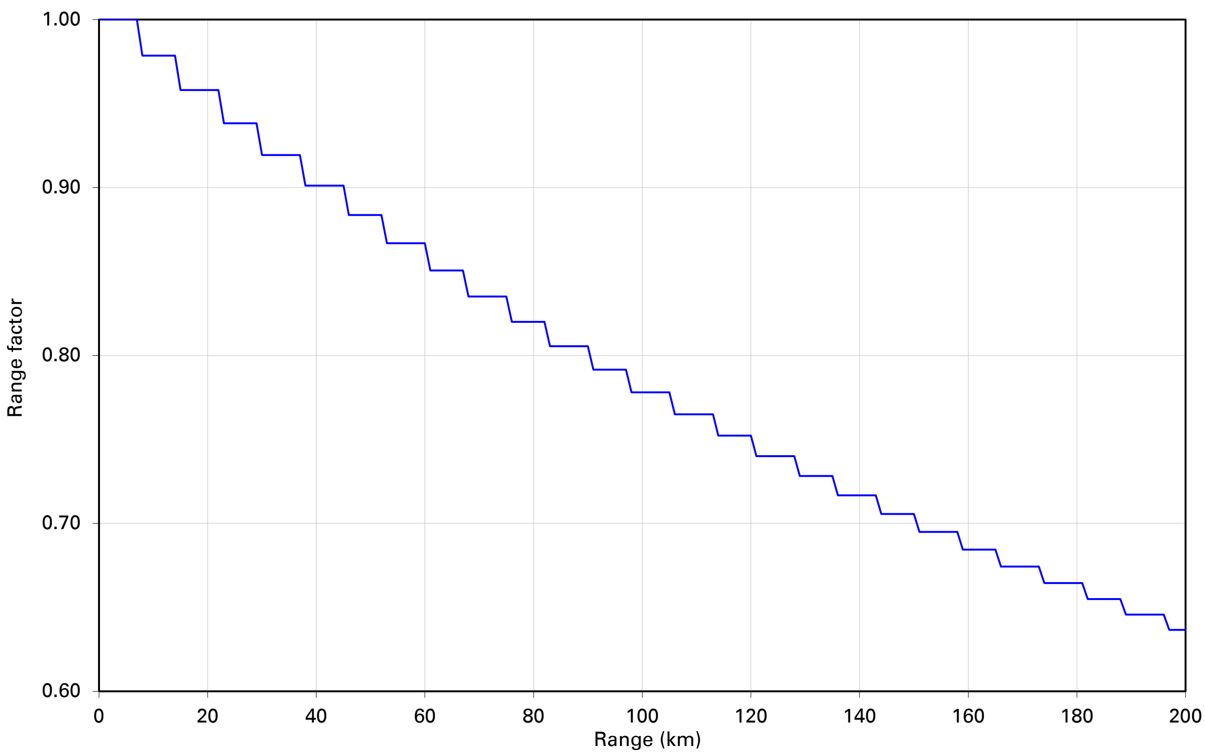


Figure 70 Range adjustment for PTP 650, symmetry 1:1, optimization TDM, bandwidth 45 MHz

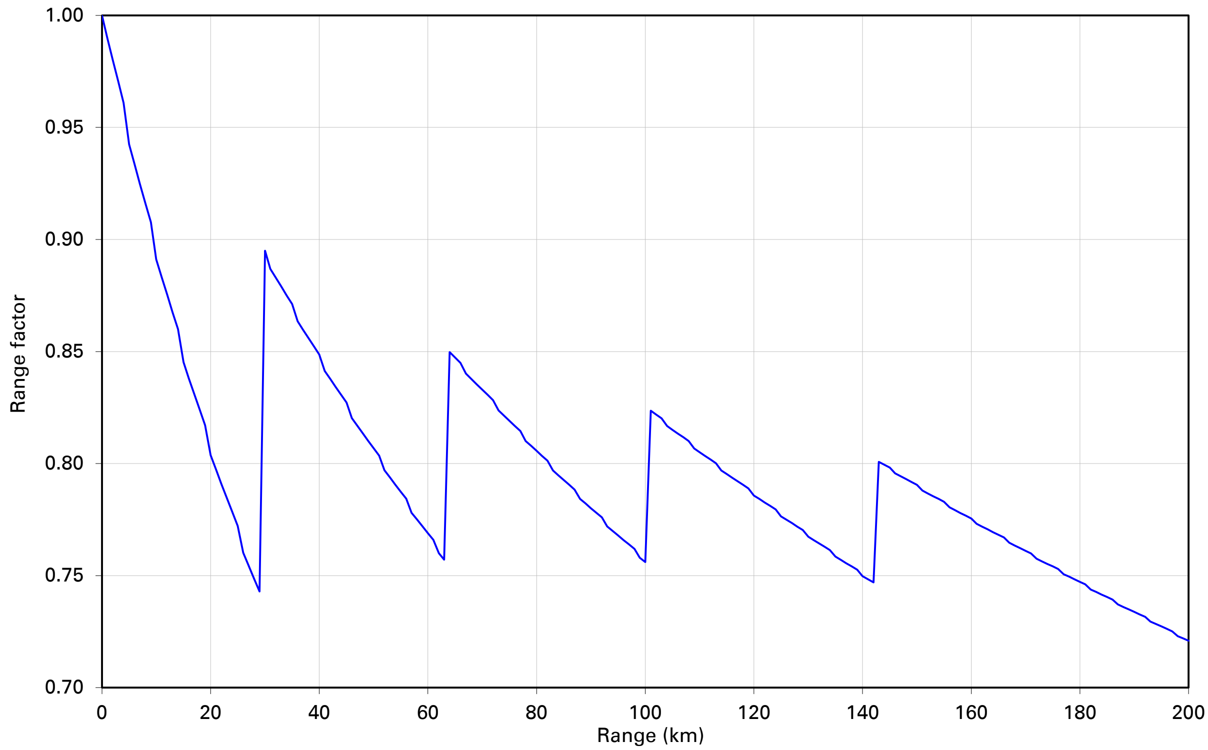


Figure 71 Range adjustment for PTP 650, symmetry 1:1, optimization TDM, bandwidth 40 MHz

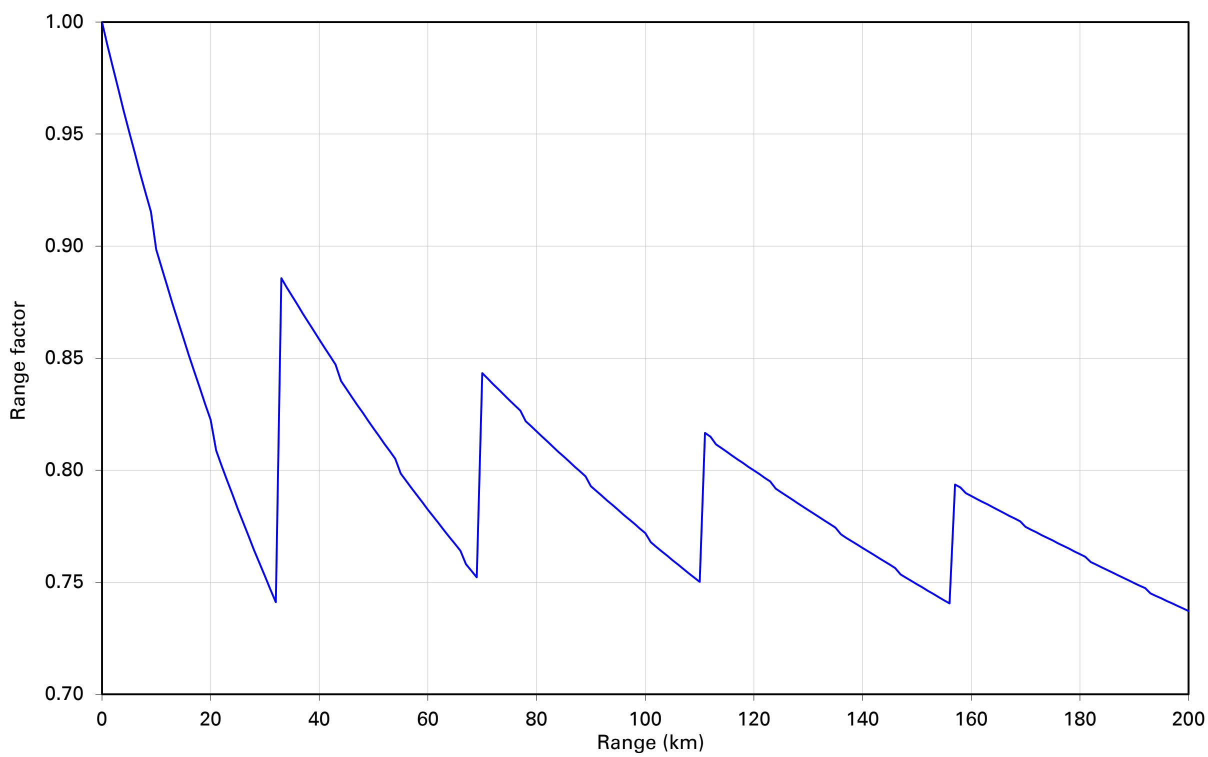


Figure 72 Range adjustment for PTP 650, symmetry 1:1, optimization TDM, bandwidth 30 MHz

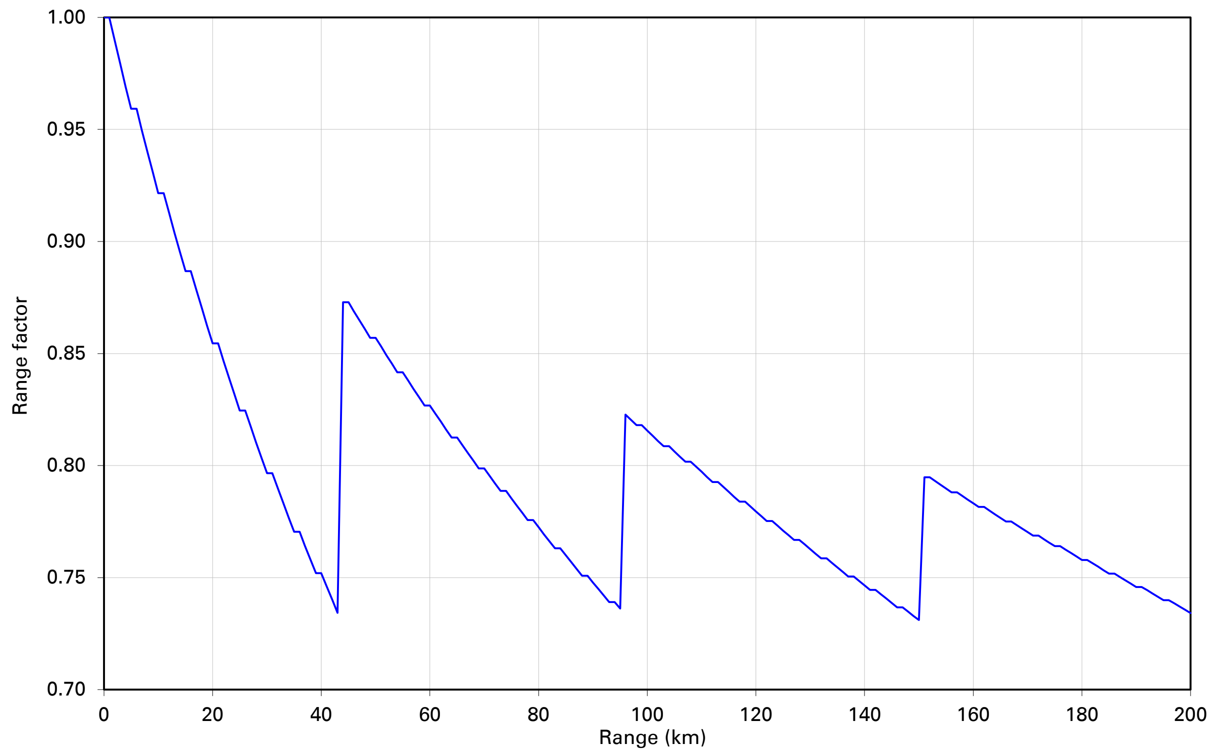


Figure 73 Range adjustment for PTP 650, symmetry 1:1, optimization TDM, bandwidth 20 MHz

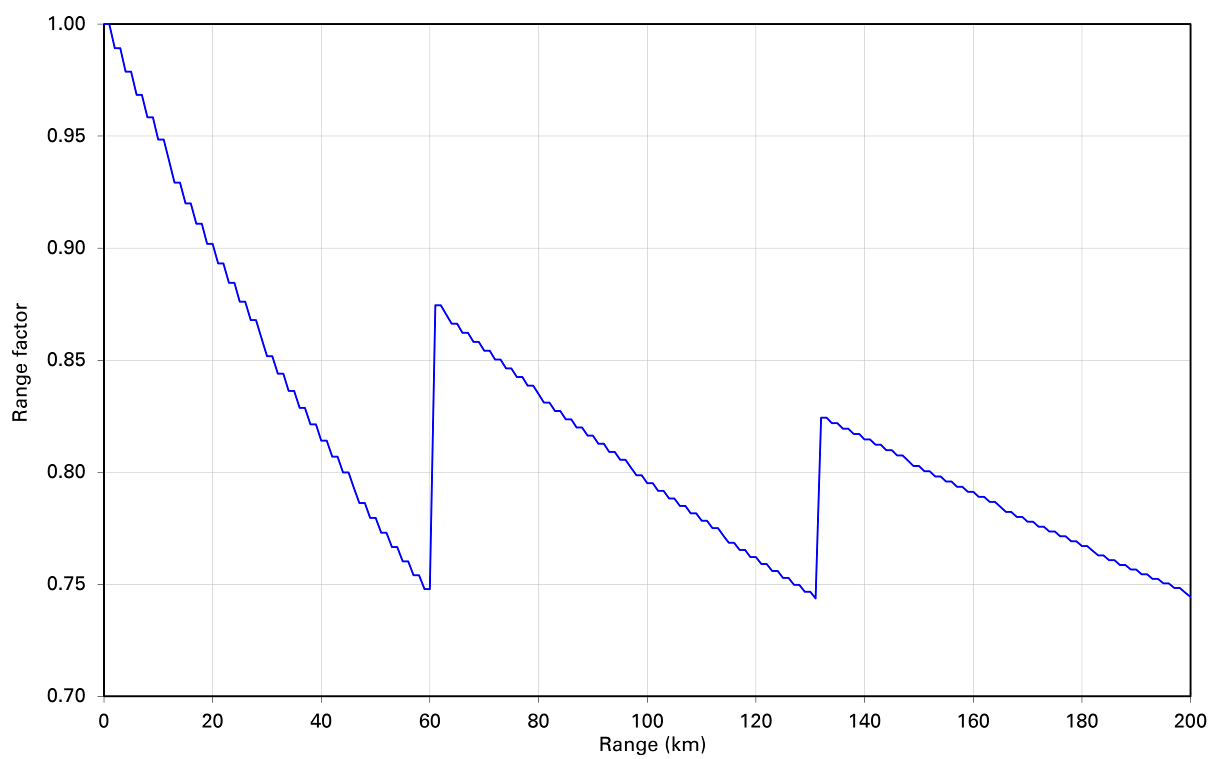


Figure 74 Range adjustment for PTP 650, symmetry 1:1, optimization TDM, bandwidth 15 MHz

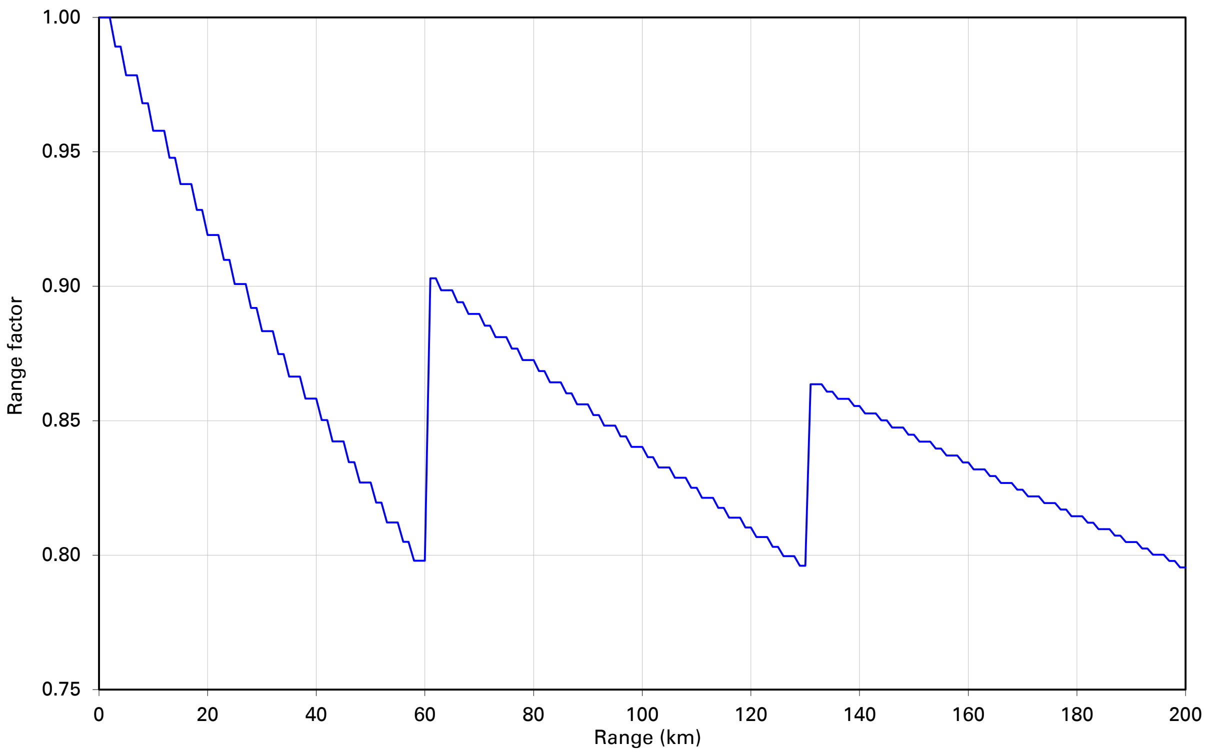


Figure 75 Range adjustment for PTP 650, symmetry 1:1, optimization TDM, bandwidth 10 MHz

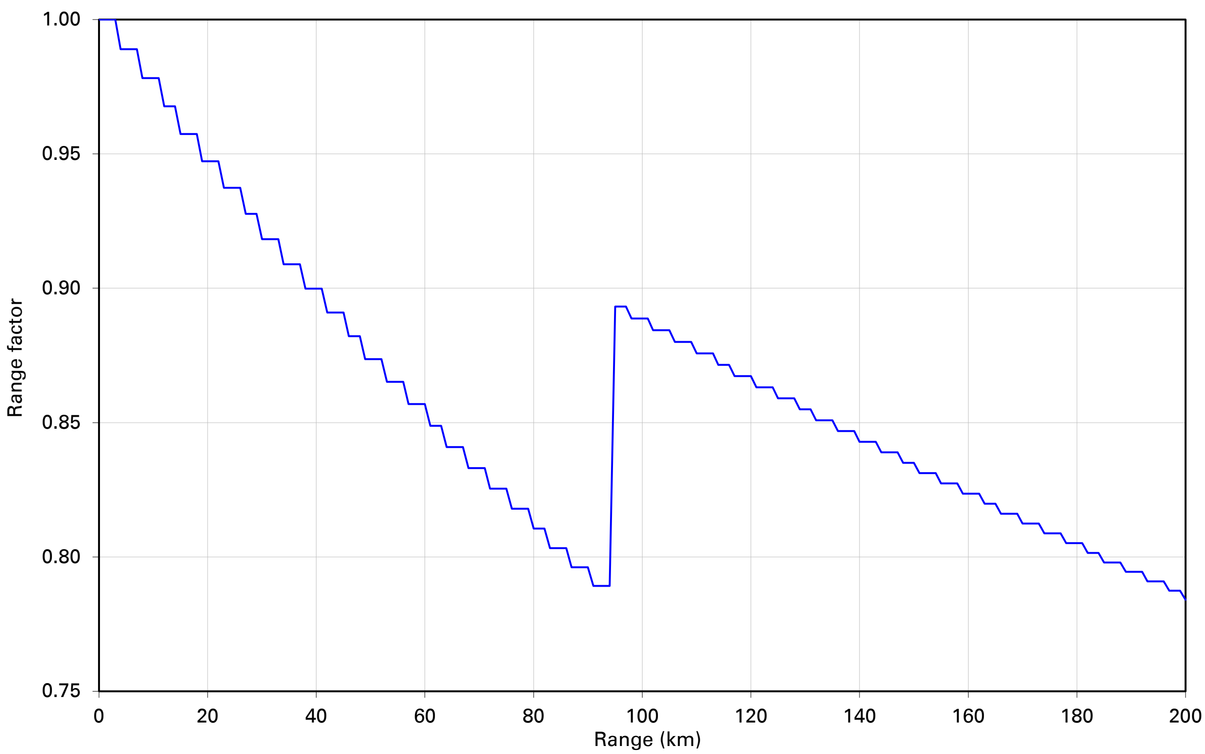


Figure 76 Range adjustment for PTP 650, symmetry 1:1, optimization TDM, bandwidth 5 MHz

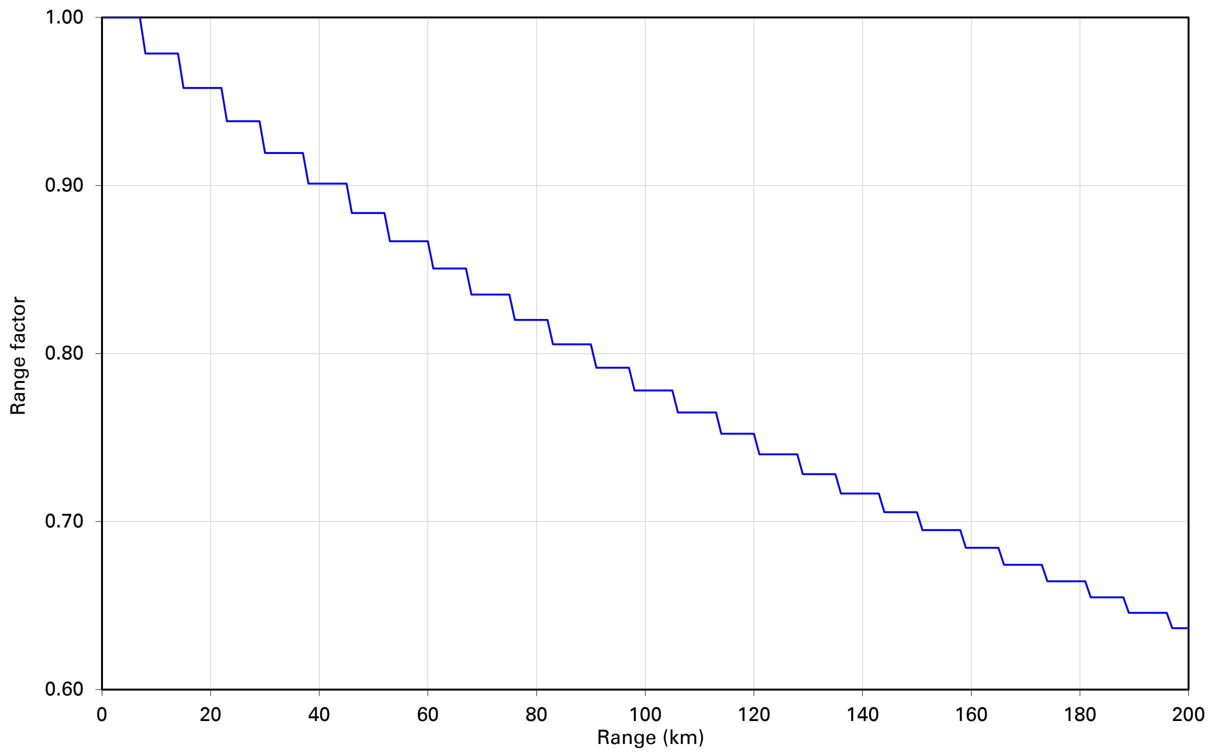


Figure 77 Range adjustment for PTP 650, symmetry 2:1, optimization IP, bandwidth 45 MHz

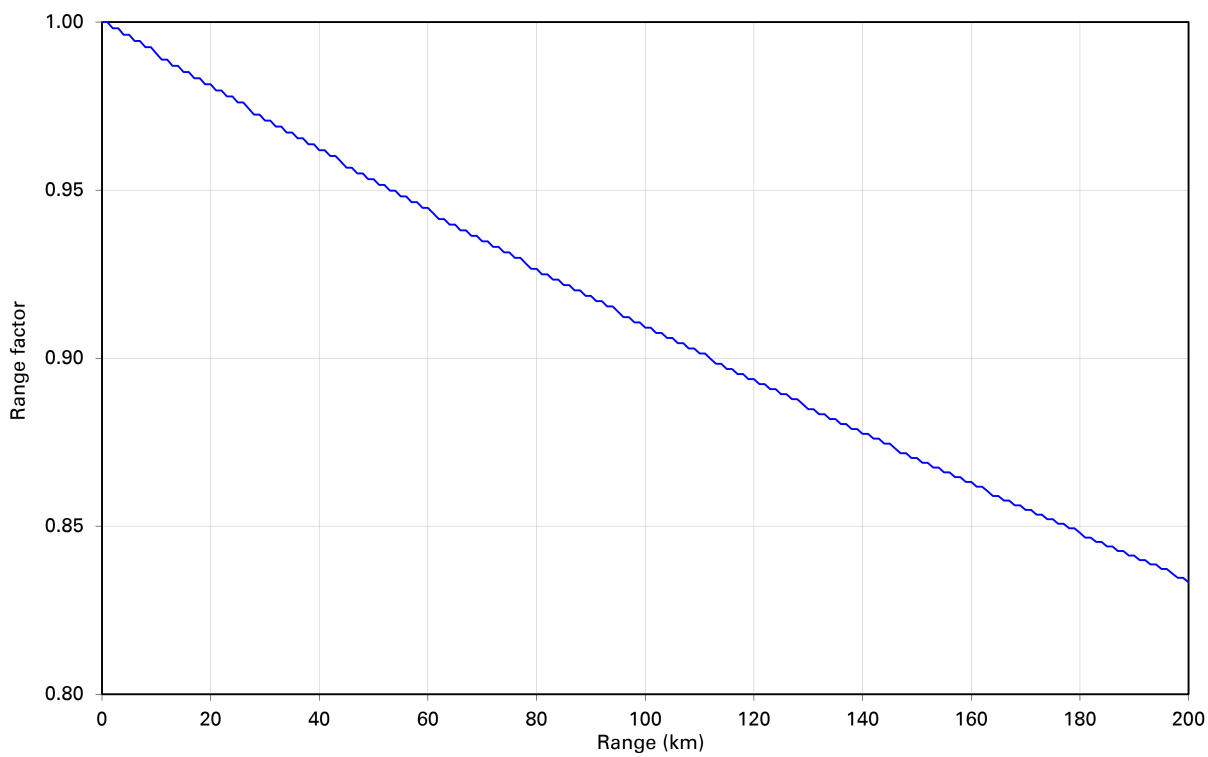


Figure 78 Range adjustment for PTP 650, symmetry 2:1, optimization IP, bandwidth 40 MHz

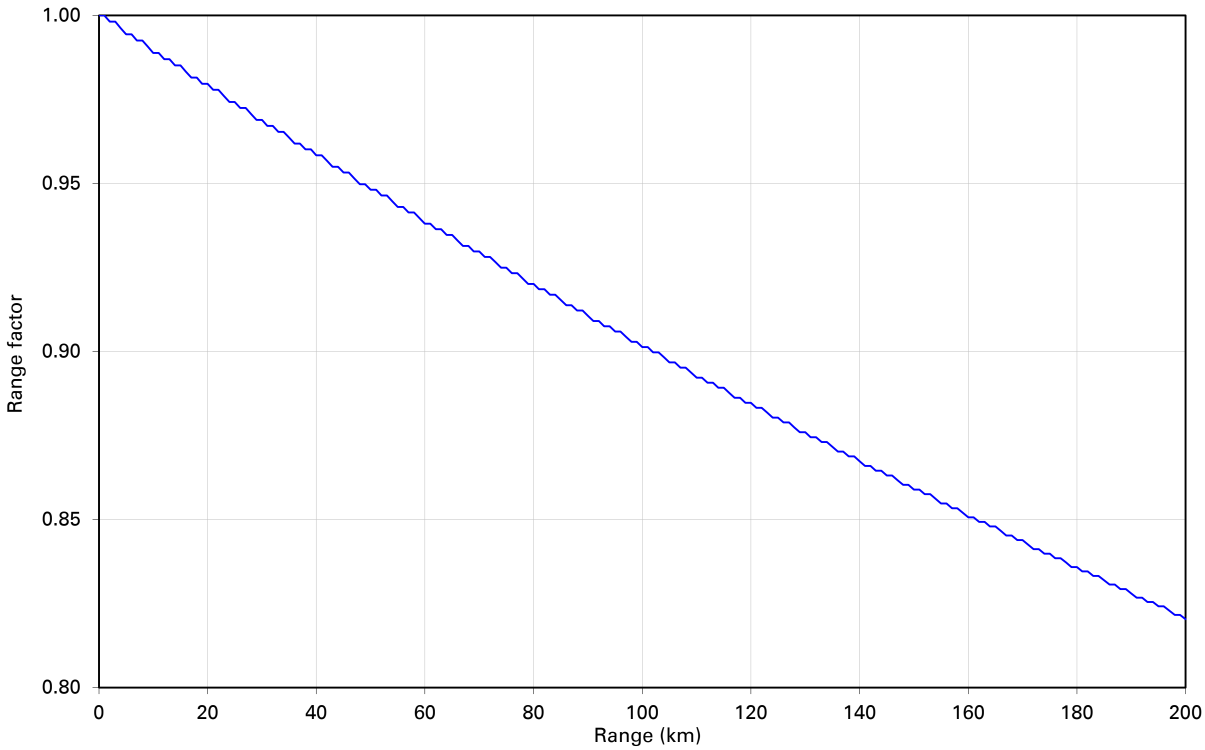


Figure 79 Range adjustment for PTP 650, symmetry 2:1, optimization IP, bandwidth 30 MHz

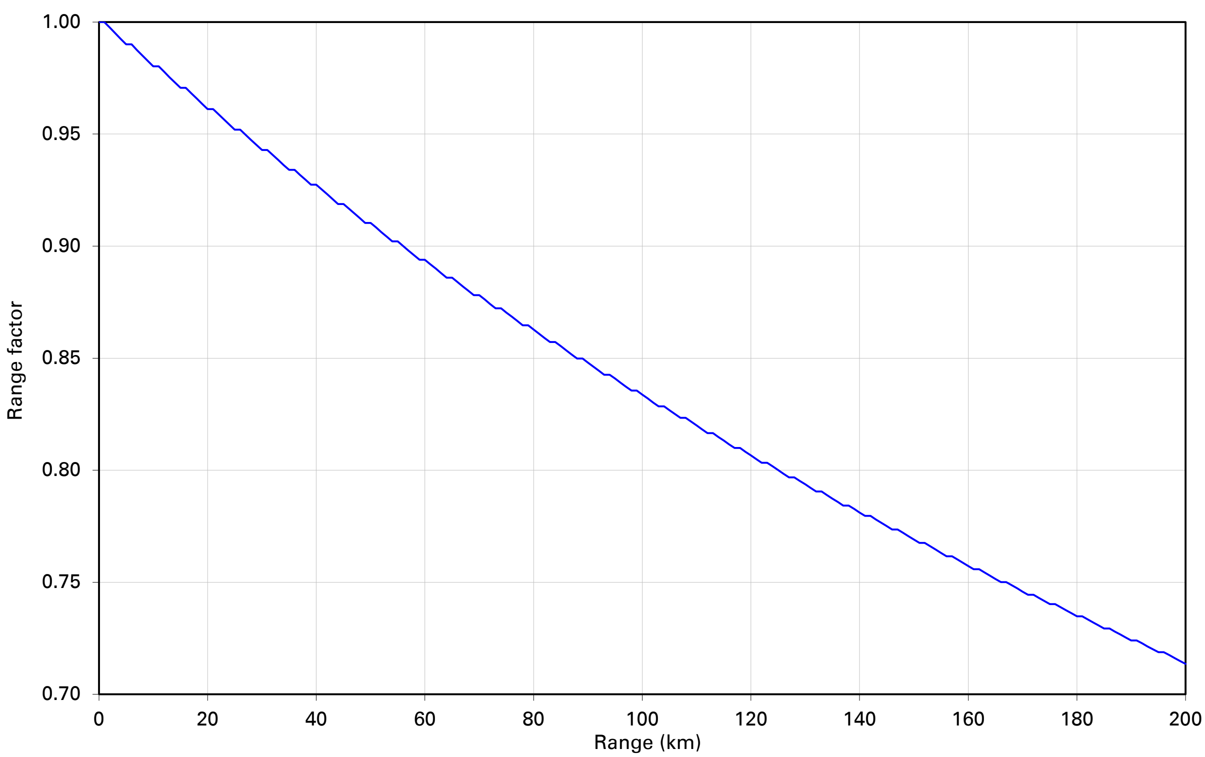


Figure 80 Range adjustment for PTP 650, symmetry 2:1, optimization IP, bandwidth 20 MHz

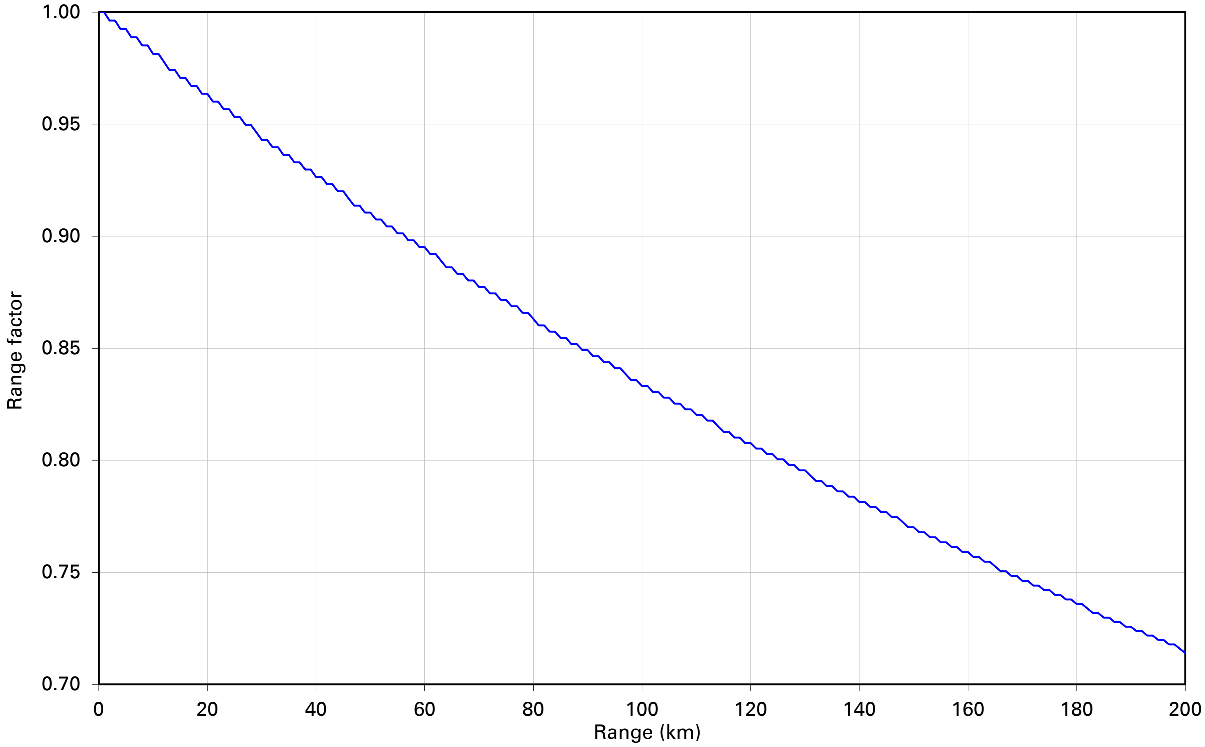


Figure 81 Range adjustment for PTP 650, symmetry 2:1, optimization IP, bandwidth 15 MHz

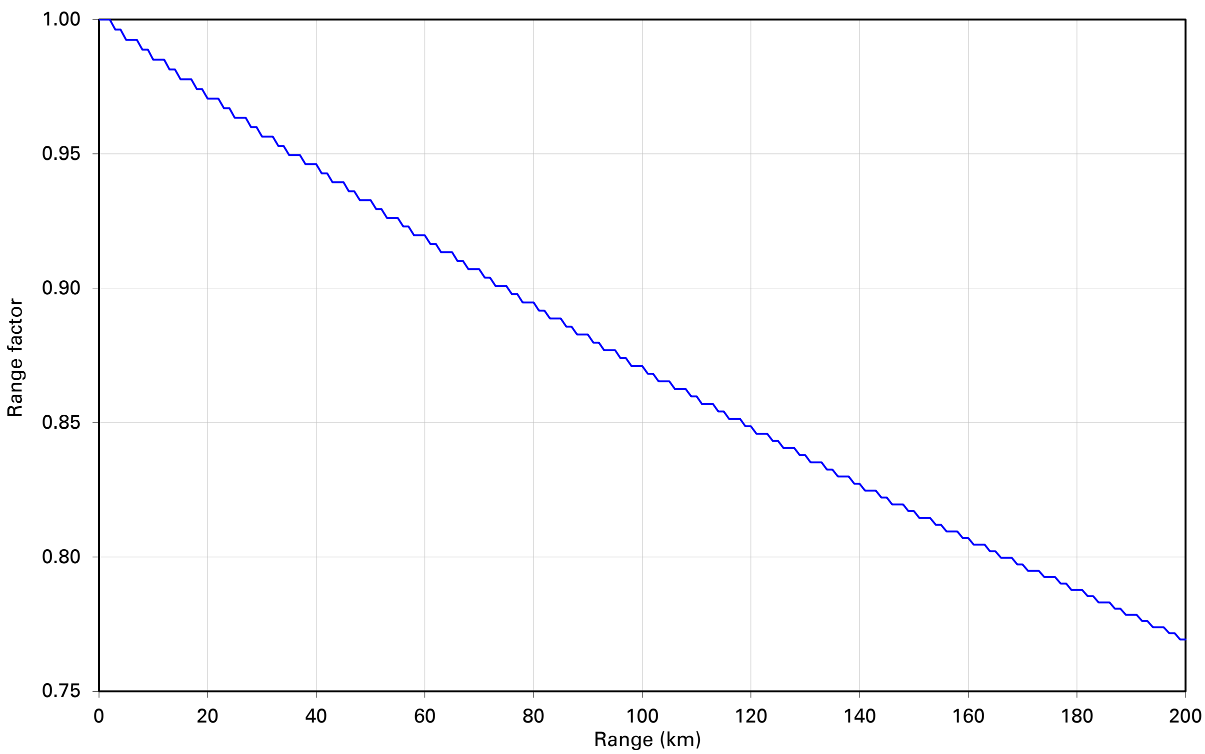


Figure 82 Range adjustment for PTP 650, symmetry 2:1, optimization IP, bandwidth 10 MHz

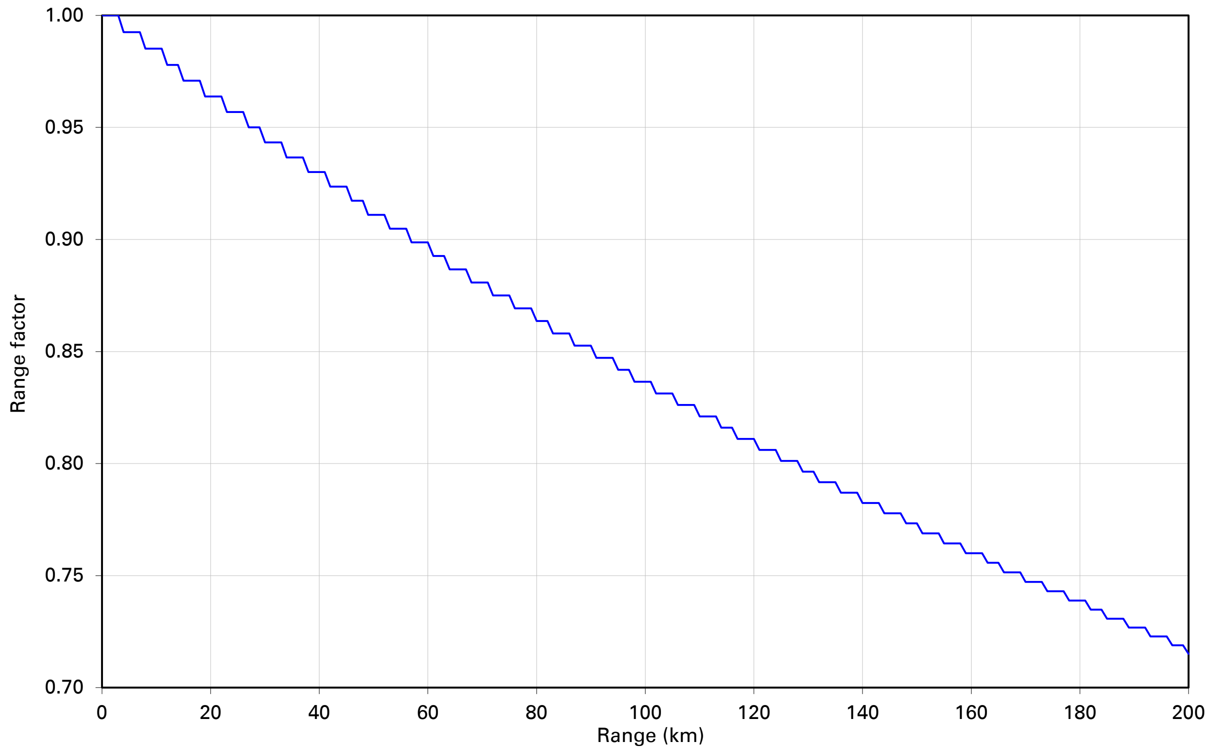


Figure 83 Range adjustment for PTP 650, symmetry 2:1, optimization TDM, bandwidth 45 MHz

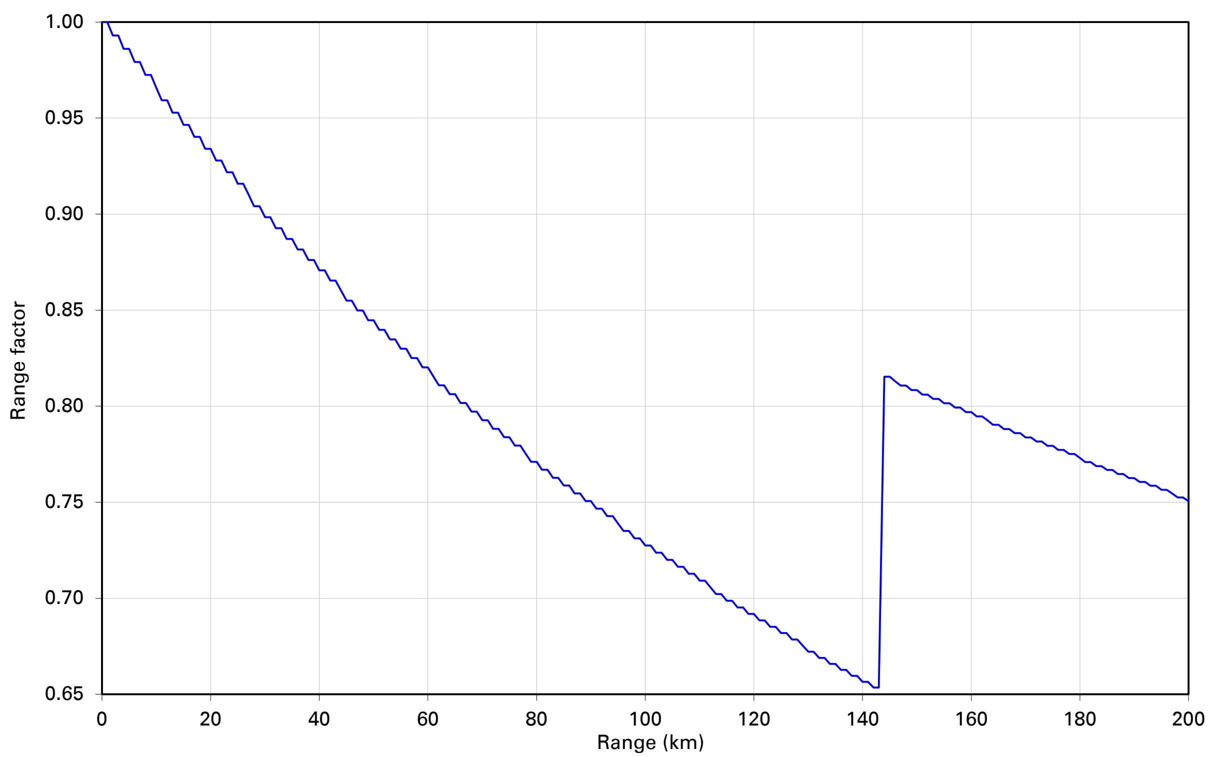


Figure 84 Range adjustment for PTP 650, symmetry 2:1, optimization TDM, bandwidth 40 MHz

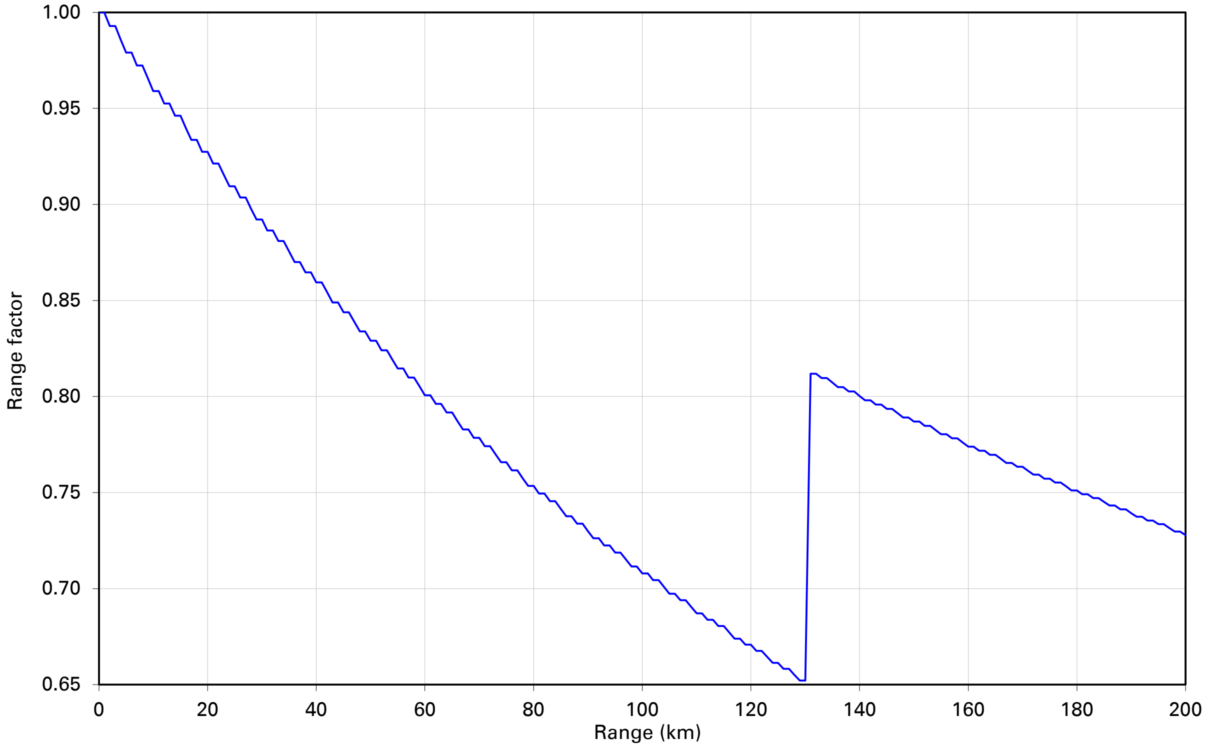


Figure 85 Range adjustment for PTP 650, symmetry 2:1, optimization TDM, bandwidth 30 MHz

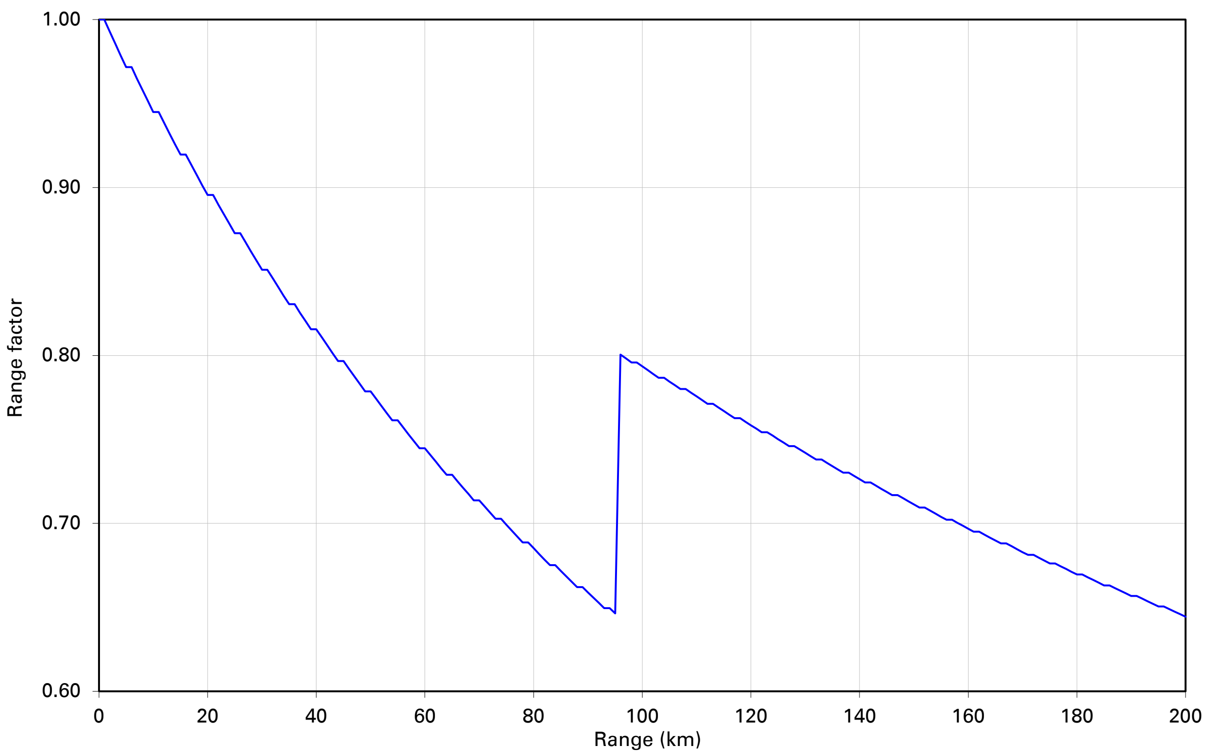


Figure 86 Range adjustment for PTP 650, symmetry 2:1, optimization TDM, bandwidth 20 MHz

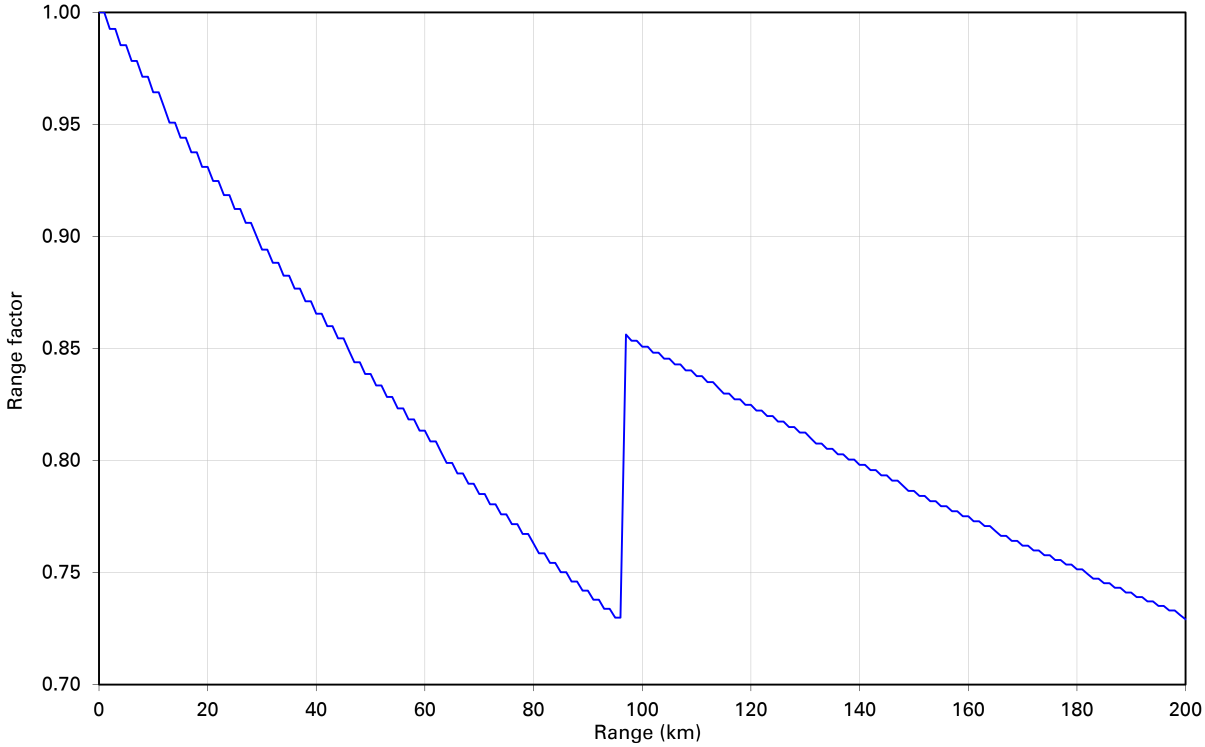


Figure 87 Range adjustment for PTP 650, symmetry 2:1, optimization TDM, bandwidth 15 MHz

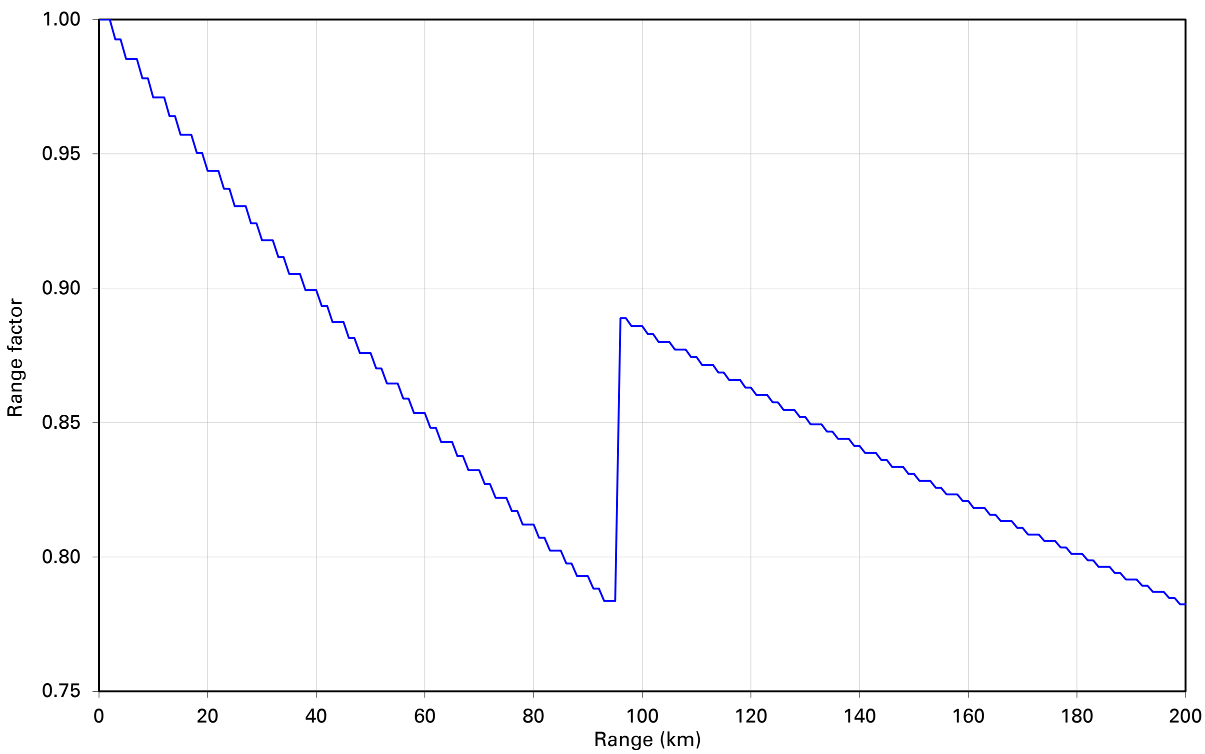


Figure 88 Range adjustment for PTP 650, symmetry 2:1, optimization TDM, bandwidth 10 MHz

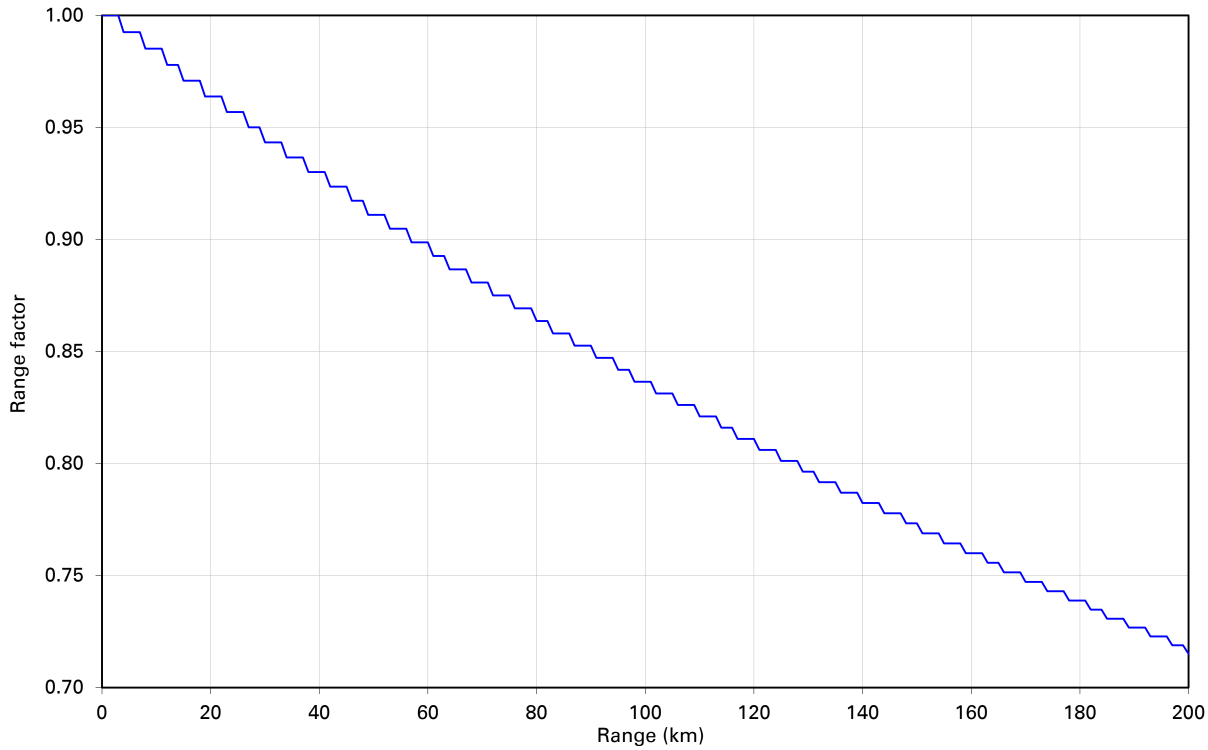


Figure 89 Range adjustment for PTP 650, symmetry 3:1, optimization IP, bandwidth 45 MHz

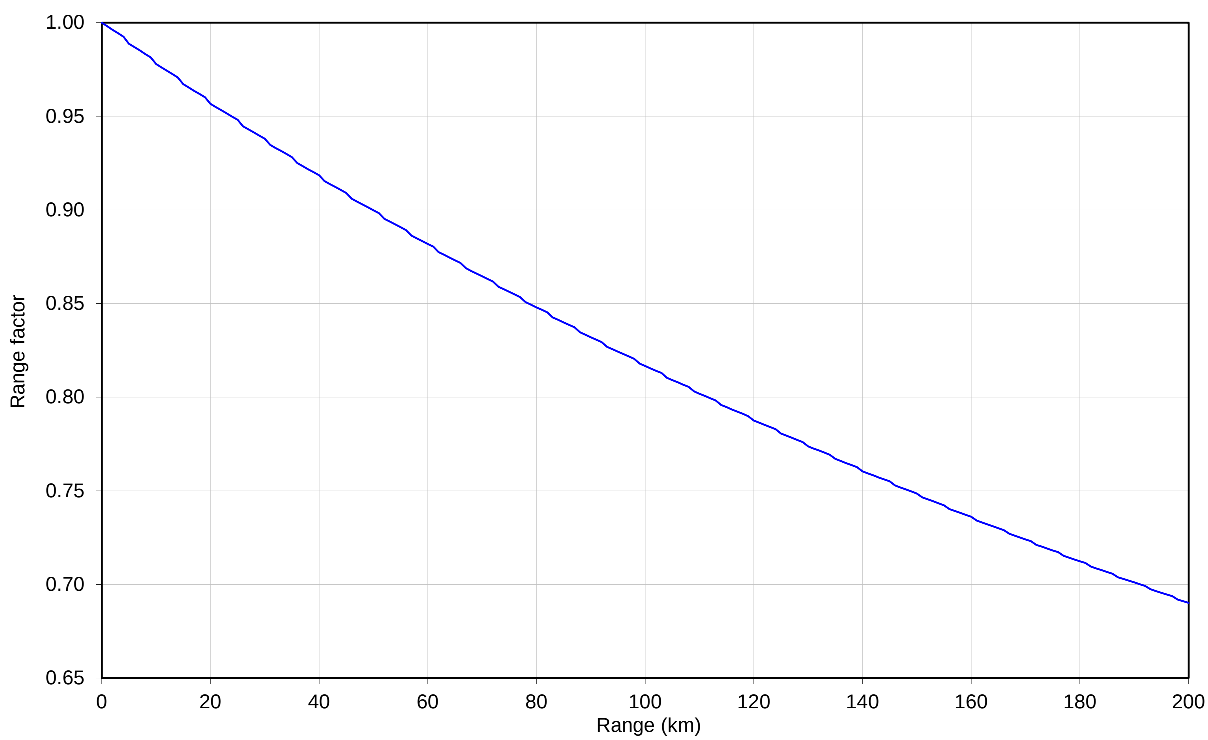


Figure 90 Range adjustment for PTP 650, symmetry 3:1, optimization IP, bandwidth 40 MHz

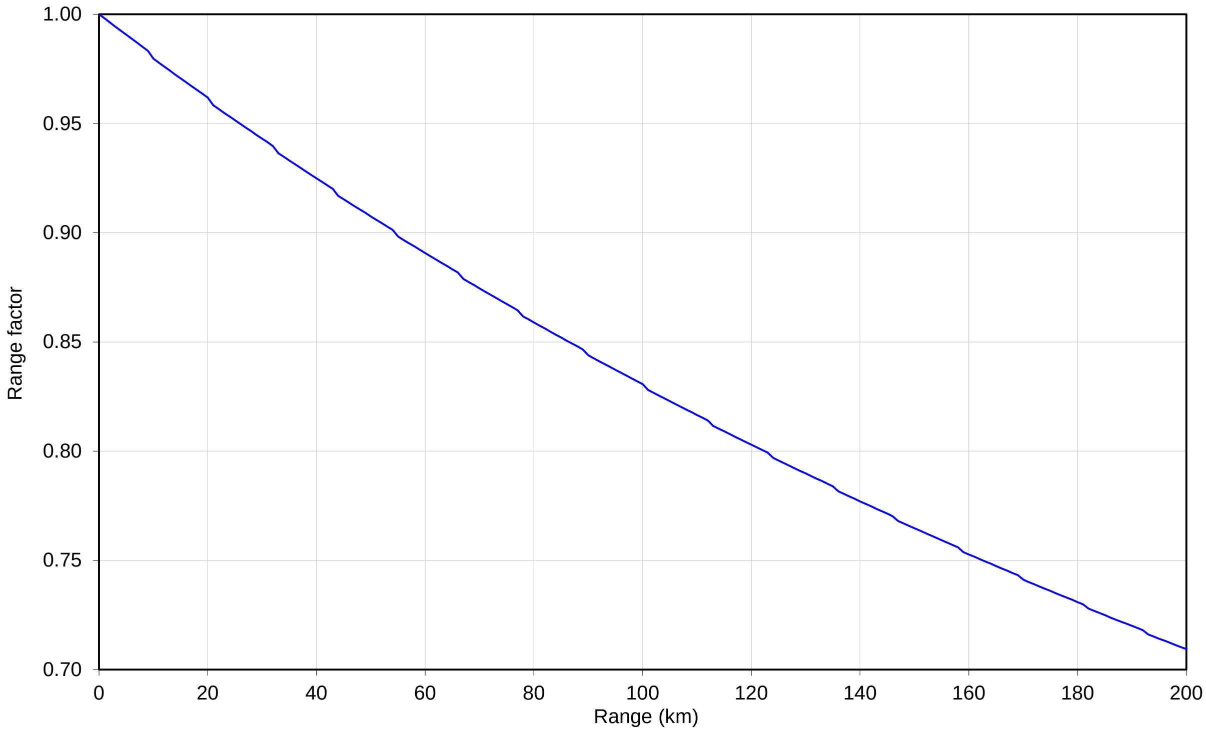


Figure 91 Range adjustment for PTP 650, symmetry 3:1, optimization IP, bandwidth 30 MHz

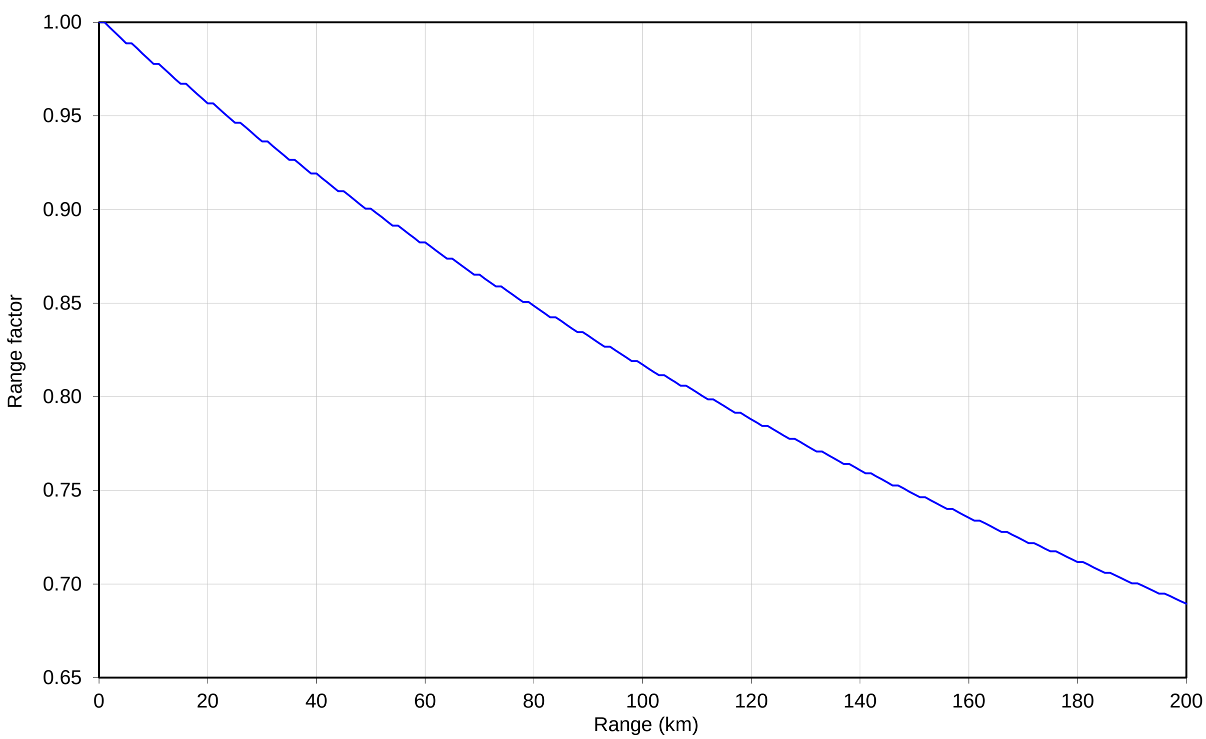


Figure 92 Range adjustment for PTP 650, symmetry 3:1, optimization IP, bandwidth 20 MHz

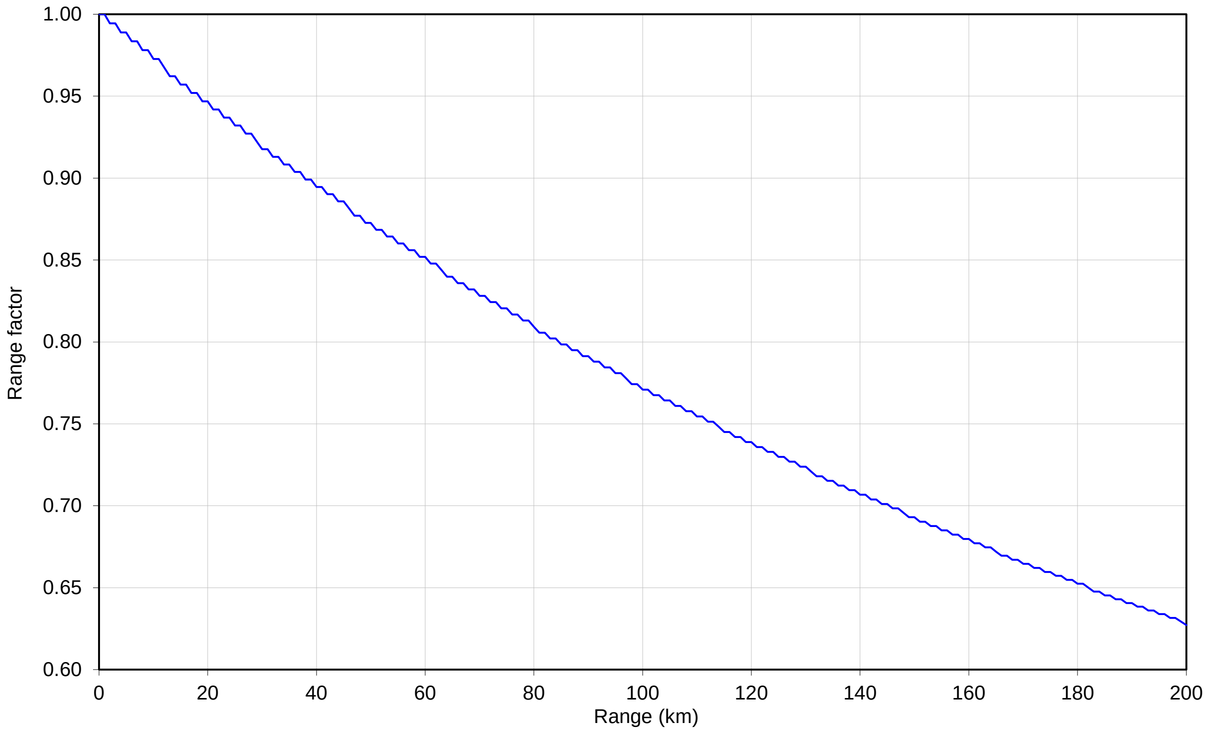


Figure 93 Range adjustment for PTP 650, symmetry 3:1, optimization IP, bandwidth 15 MHz

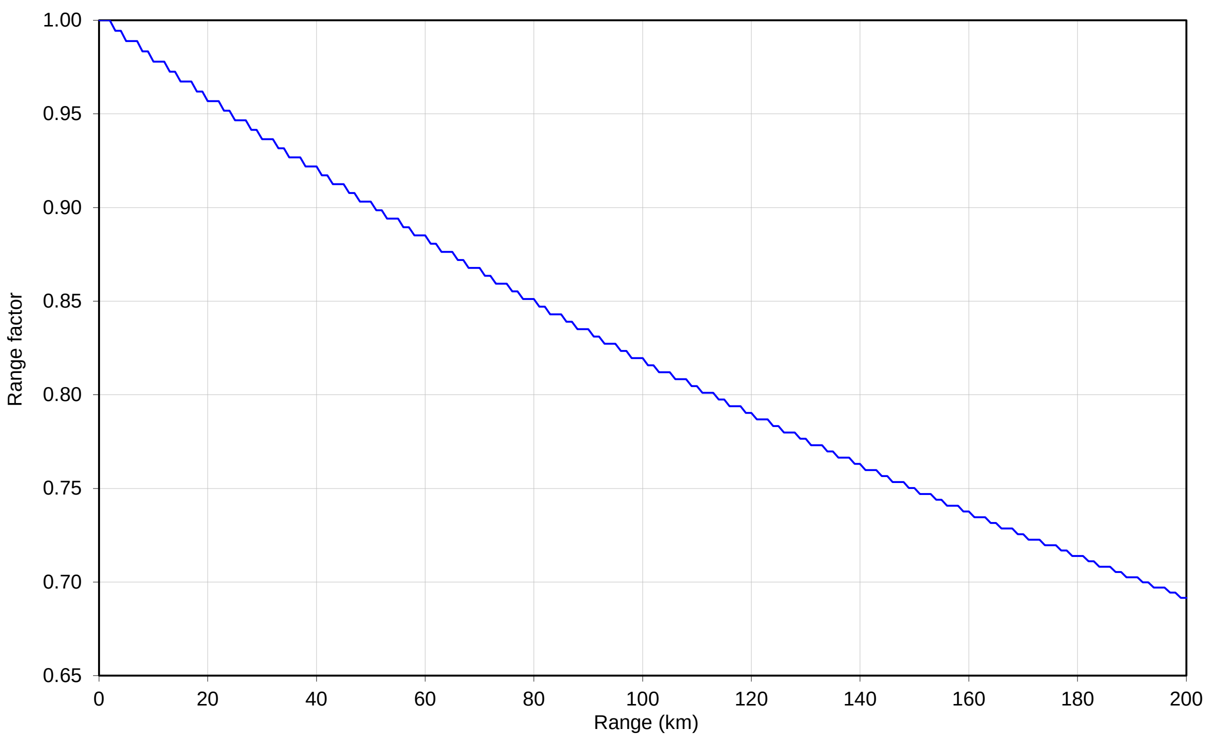


Figure 94 Range adjustment for PTP 650, symmetry 3:1, optimization IP, bandwidth 10 MHz

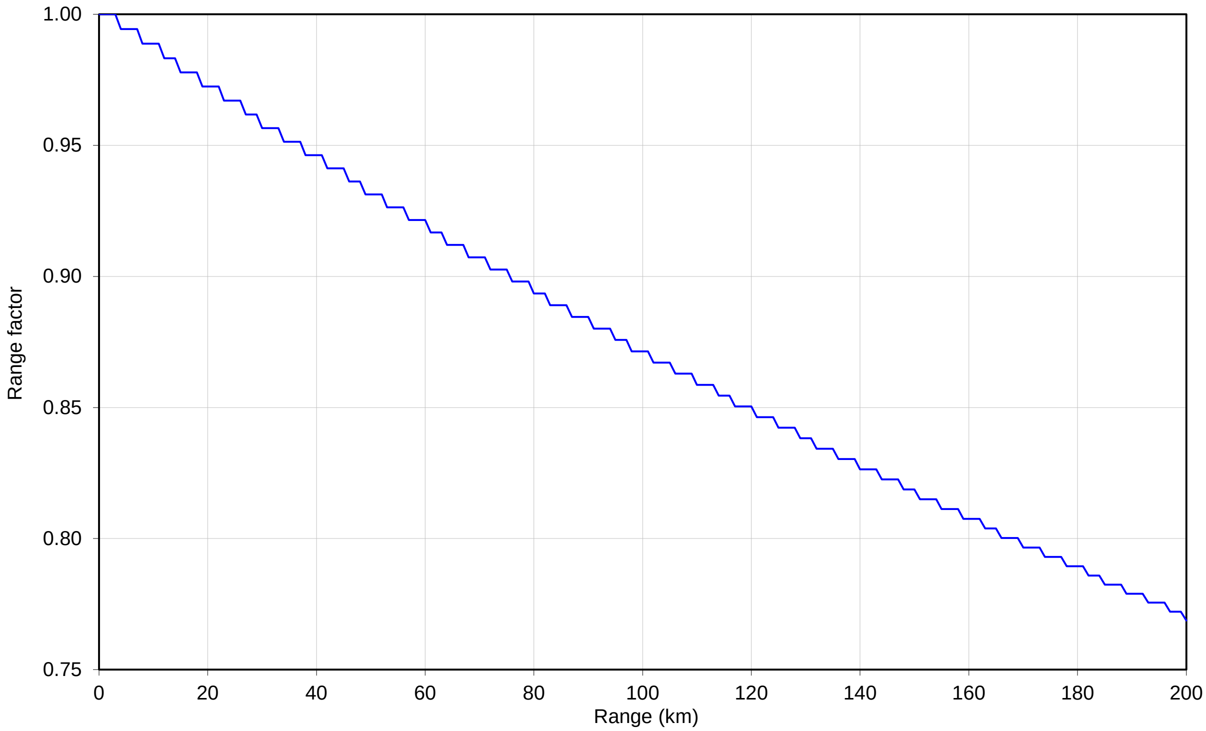


Figure 95 Range adjustment for PTP 650, symmetry 5:1, optimization IP, bandwidth 45 MHz

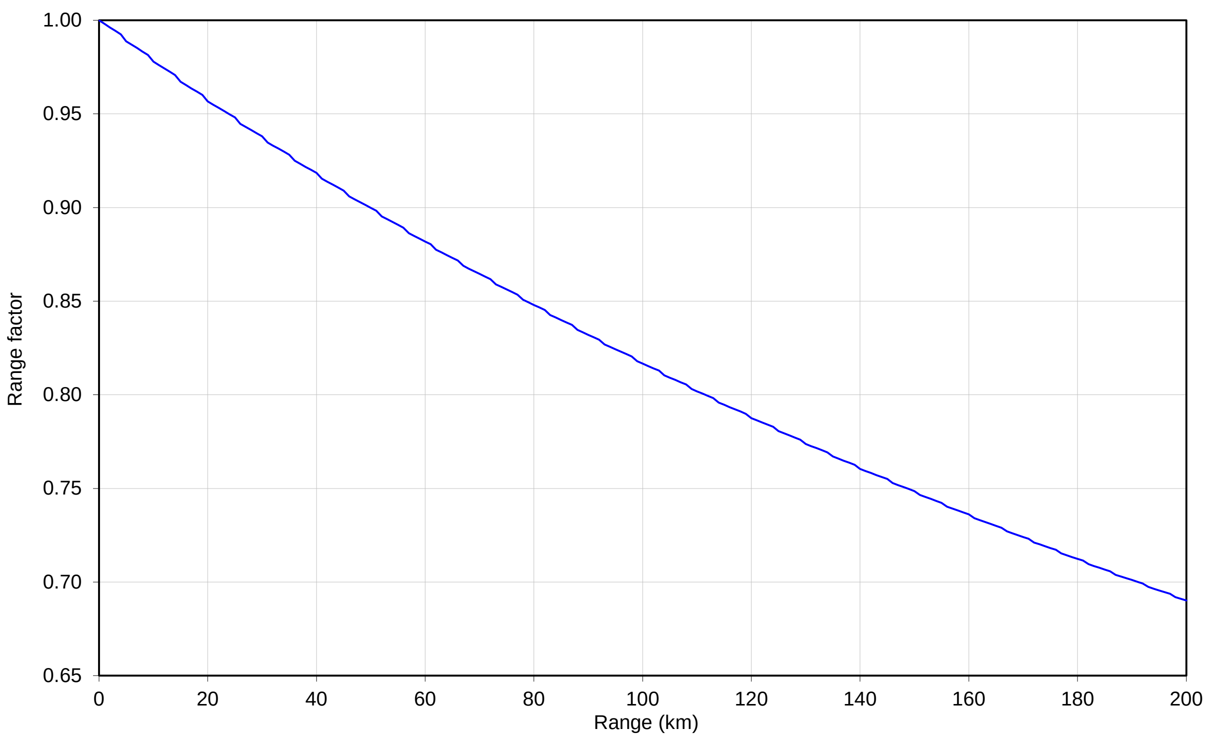


Figure 96 Range adjustment for PTP 650, symmetry 5:1, optimization IP, bandwidth 40 MHz

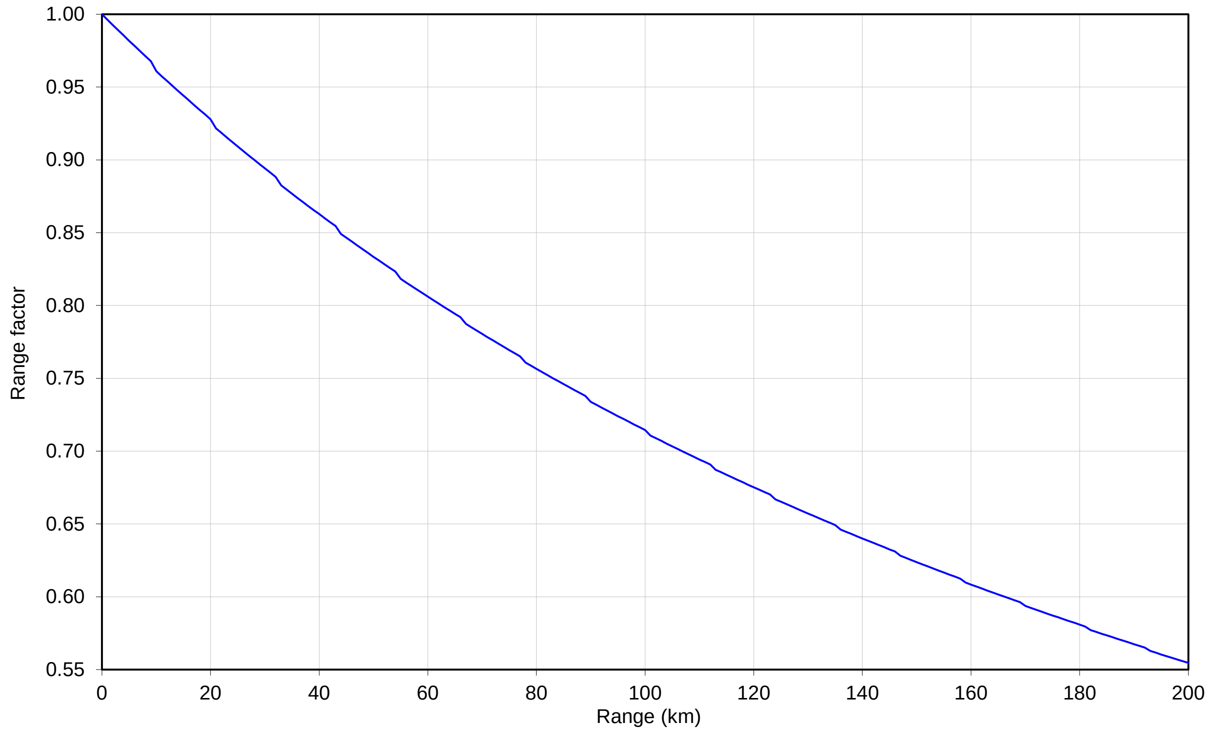


Figure 97 Range adjustment for PTP 650, symmetry 5:1, optimization IP, bandwidth 30 MHz

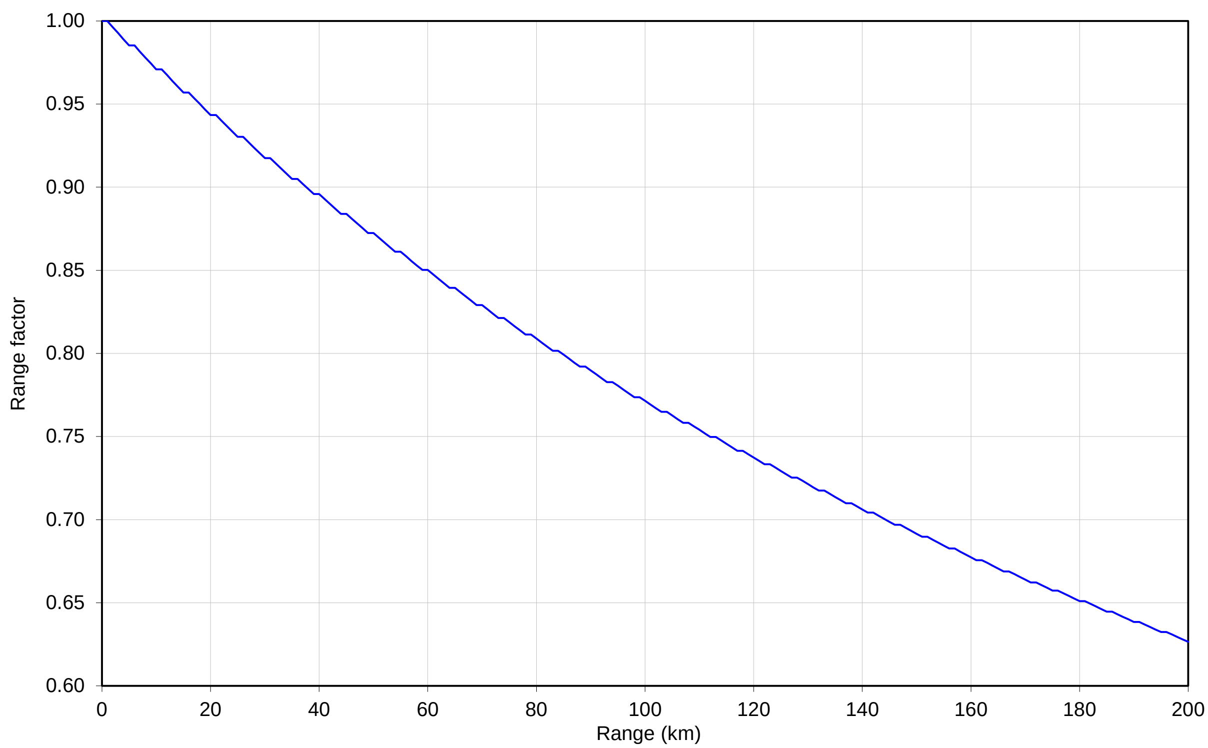


Figure 98 Range adjustment for PTP 650, adaptive, optimization IP, bandwidth 45 MHz

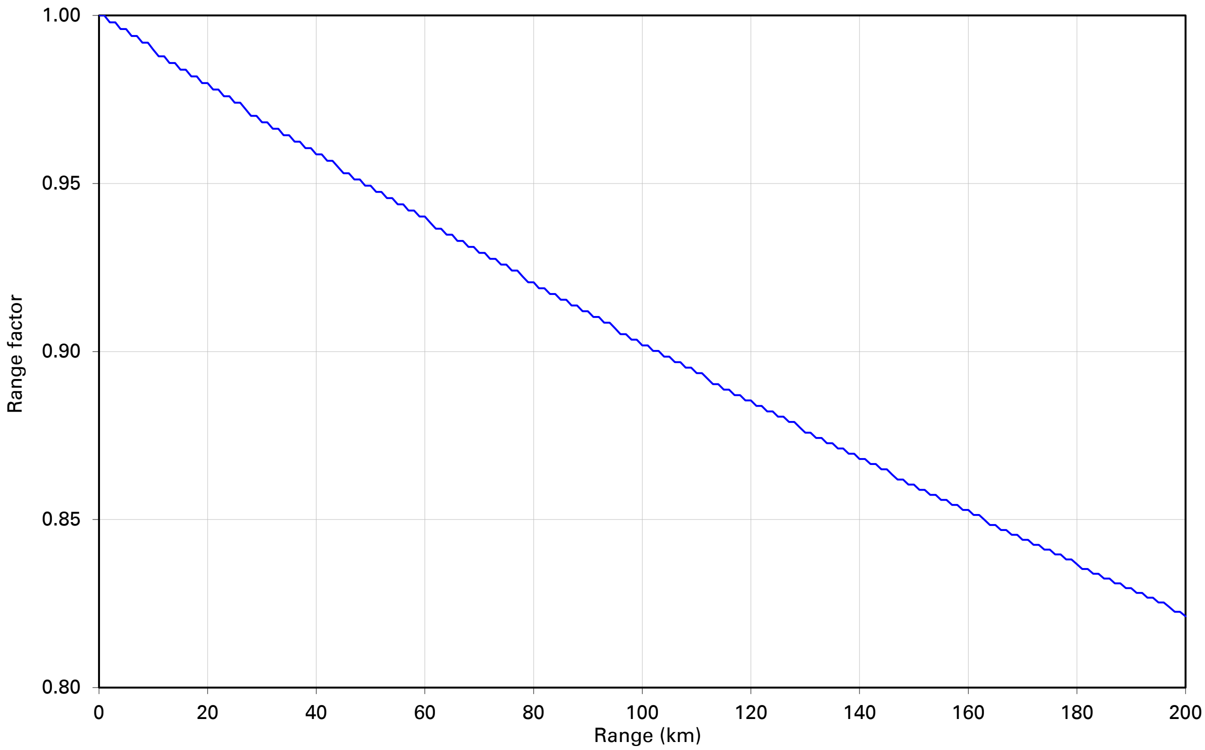


Figure 99 Range adjustment for PTP 650, adaptive, optimization IP, bandwidth 40 MHz

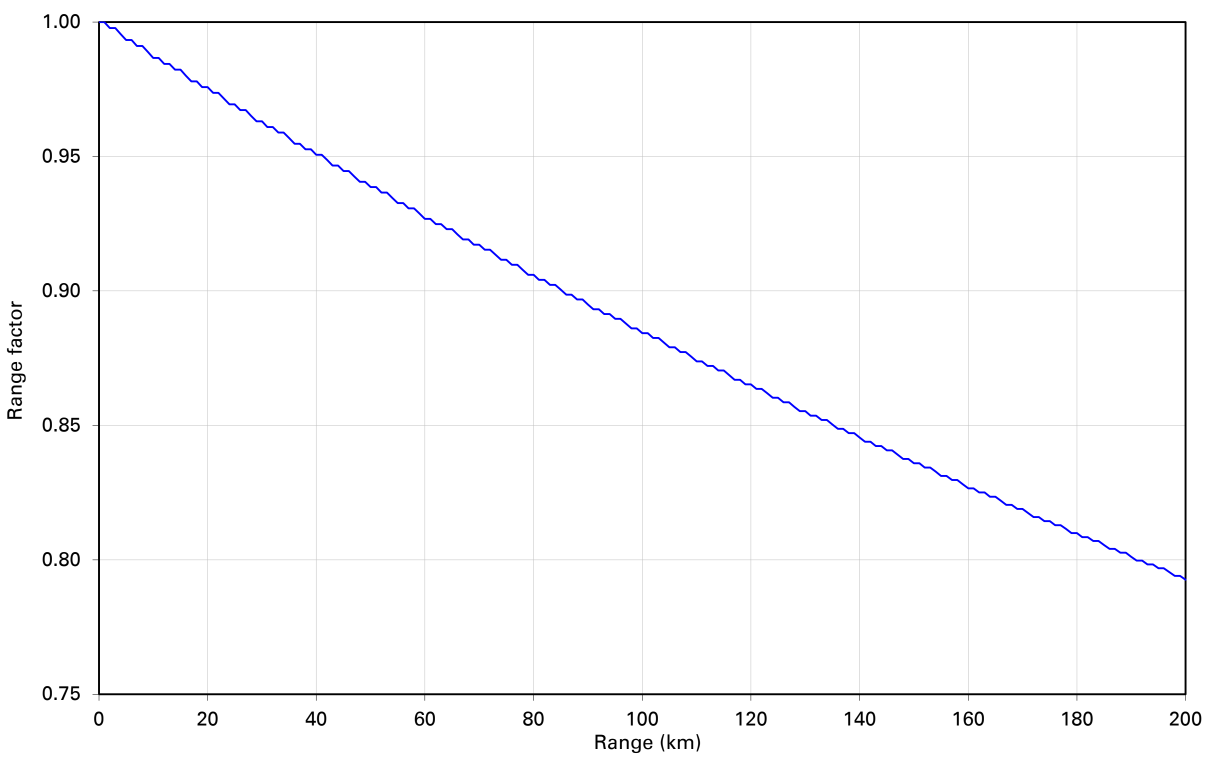


Figure 100 Range adjustment for PTP 650, adaptive, optimization IP, bandwidth 30 MHz

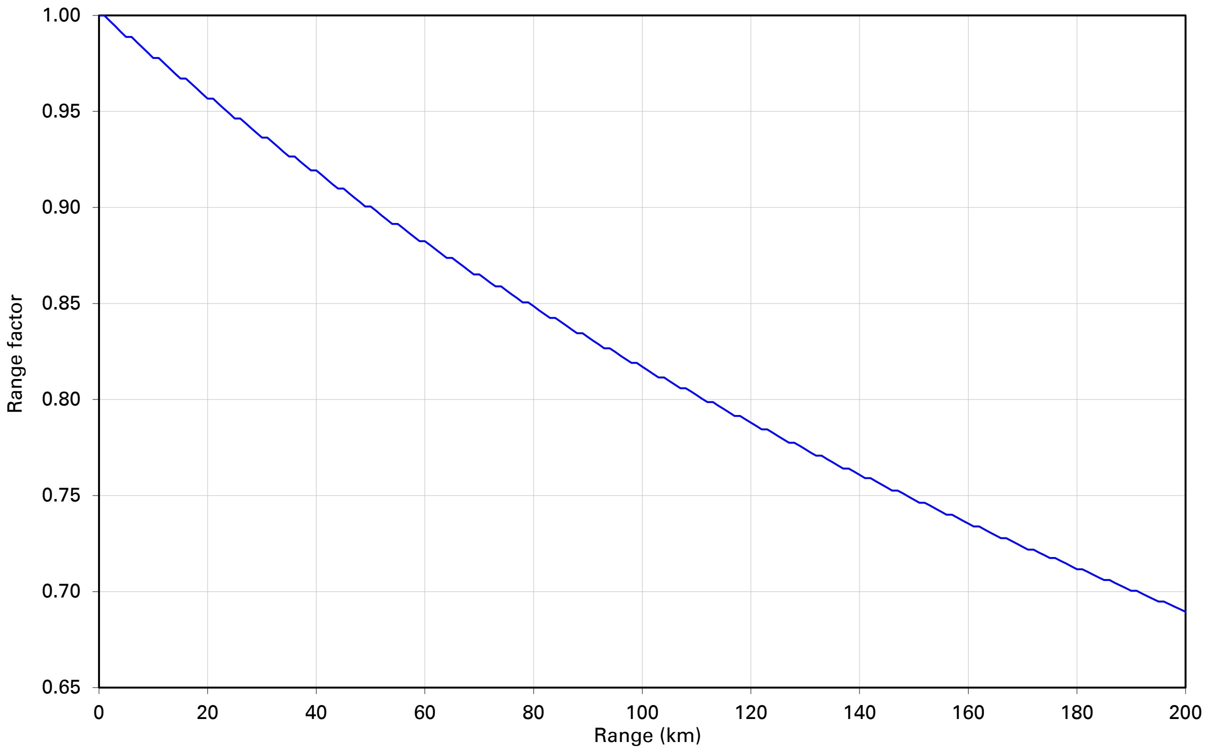


Figure 101 Range adjustment for PTP 650, adaptive, optimization IP, bandwidth 20 MHz

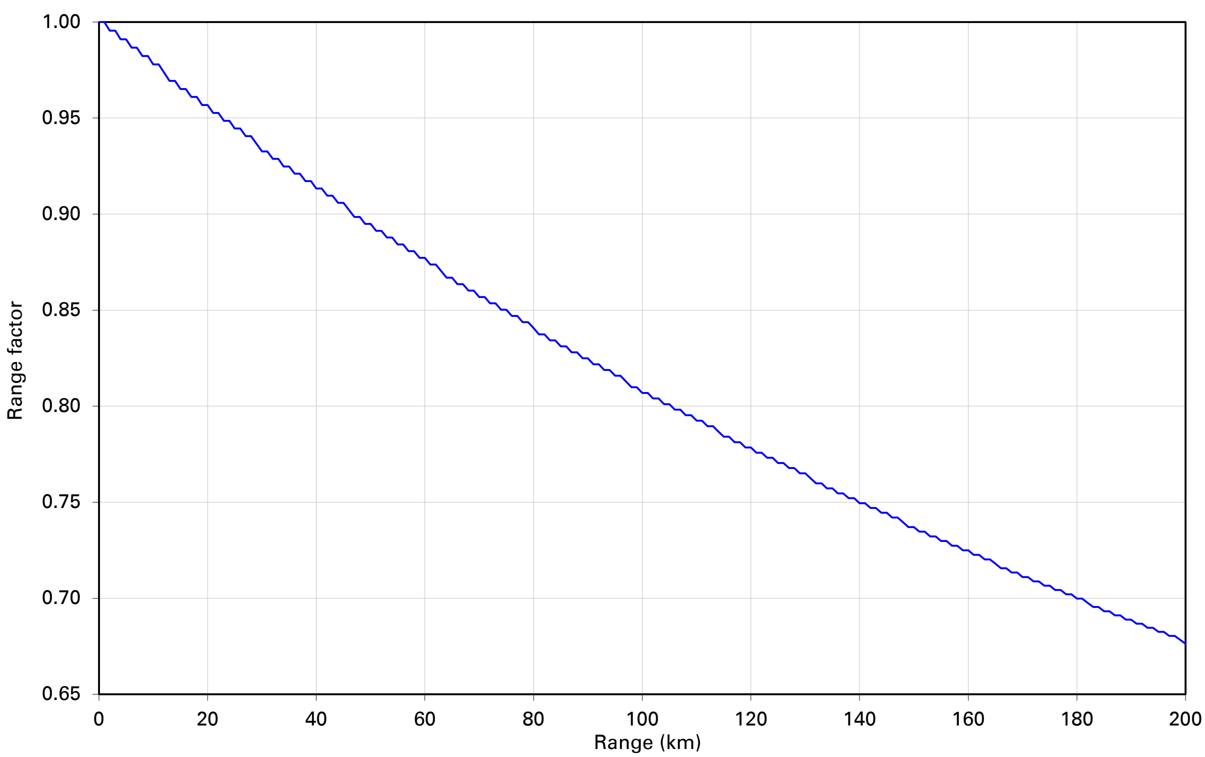


Figure 102 Range adjustment for PTP 650, adaptive, optimization IP, bandwidth 15 MHz

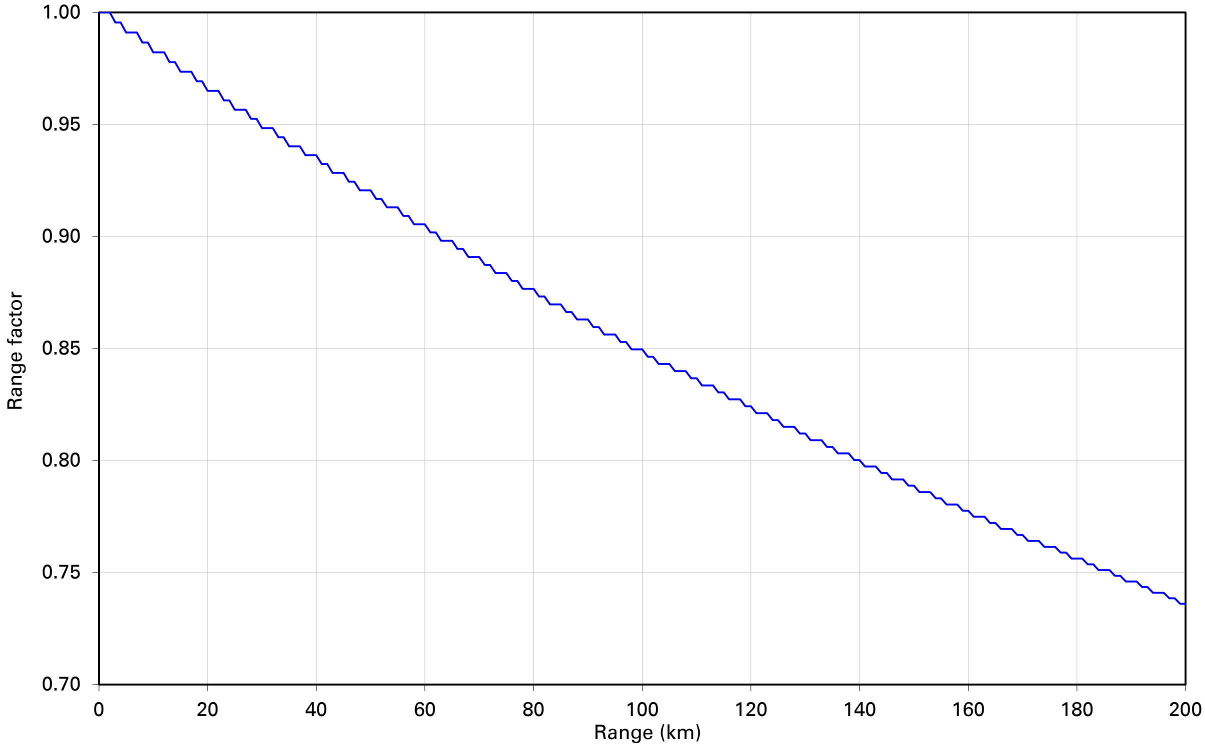
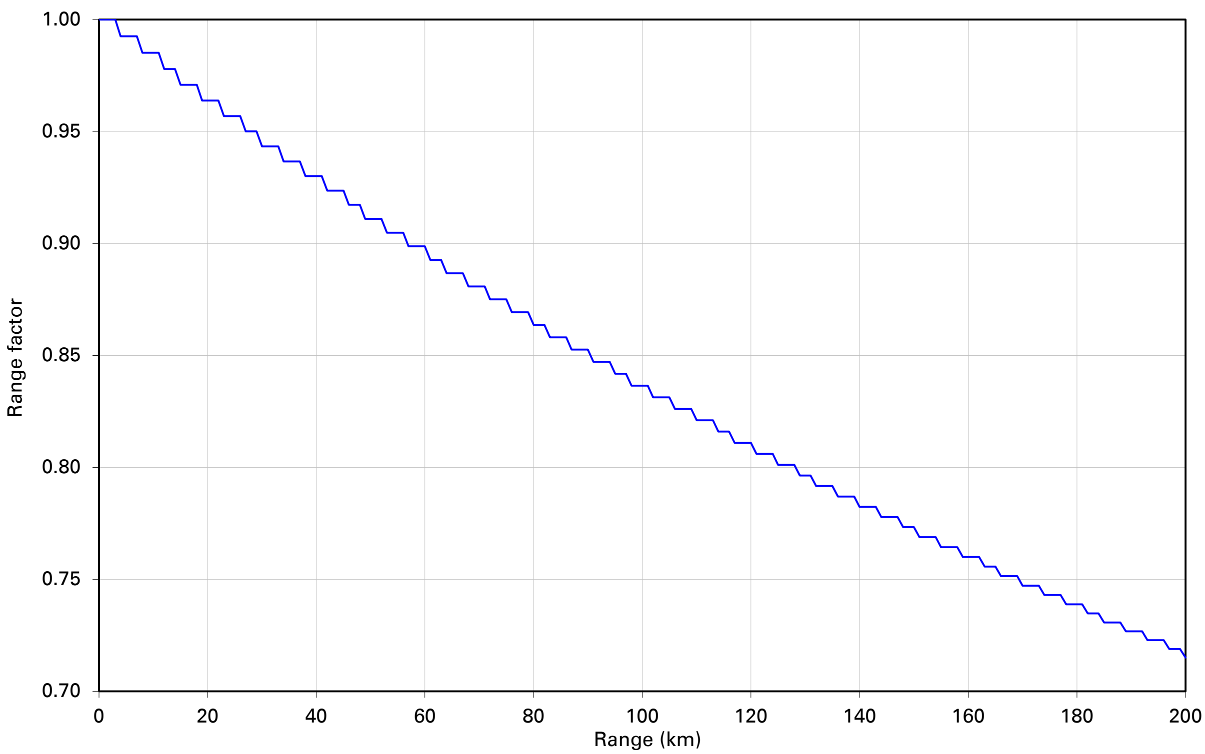


Figure 103 Range adjustment for PTP 650, adaptive, optimization IP, bandwidth 10 MHz



TDM traffic load

Encapsulated data

The NIDU supports separate management and TDM data protocol interfaces. The management interface is between the NIDU and a directly-connected ODU. The TDM data interface is between peer NIDUs. The ODU does not interact with the TDM data protocol, except in as much as it provides a separate high priority queue for encapsulated TDM data at the wireless interface.

The resulting traffic load for encapsulated TDM data is shown in Table 107.

Table 107 TDM traffic load

Channels	Octets per Ethernet frame	E1 data rate (Mbit/s)	T1 data rate (Mbit/s)
1	90	2.940	2.217
2	157	5.145	3.879
3	224	7.414	5.590
4	291	9.619	7.252
5	358	11.824	8.915
6	425	14.030	10.577
7	492	16.235	12.239
8	559	18.440	13.902

In the best case (eight channels) the encapsulation has an efficiency of 91.6%.

Timing only

The resulting TDM traffic load in timing-only operation is shown in Table 108.

Table 108 TDM traffic load in timing-only

Channels	Octets per Ethernet frame	E1 data rate (Mbit/s)	T1 data rate (Mbit/s)
1	64	0.512	0.386
2	64	0.512	0.386
3	64	0.512	0.386
4	64	0.512	0.386
5	64	0.512	0.386
6	64	0.512	0.386
7	65	0.520	0.392
8	71	0.568	0.428

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Zlib

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February 14, 2009

Bzip2

Julian Seward, jseward@bzip.org

USB library functions

Atmel Corporation

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Apache

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D3 JS library

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Compliance with safety standards

This section lists the safety specifications against which the PTP 650 has been tested and certified. It also describes how to keep RF exposure within safe limits.

Electrical safety compliance

The PTP 650 hardware has been tested for compliance to the electrical safety specifications listed in Table 109.

Table 109 PTP 650 safety compliance specifications

Region	Standard
USA	UL 60950-1, 2nd Edition; UL60950-22
Canada	CAN/CSA C22.2 No.60950-1-07, 2nd Edition; CAN/CSA C22.2 No.60950-22-07
EU	EN 60950-1:2006 + Amendment 12:2011, EN 60950-22
International	CB certified to IEC 60950-1: 2005 (modified); IEC 60950-22: 2005 (modified)

Electromagnetic compatibility (EMC) compliance

The PTP 650 complies with European EMC Specification EN301 489-1 with testing carried out to the detailed requirements of EN301 489-4.

Note

For EN 61000-4-2: 1995 to 2009 Electro Static Discharge (ESD), Class 2, 8 kV air, 4 kV contact discharge, the PTP 650 has been tested to ensure immunity to 15 kV air and 8 kV contact.

Table 110 lists the EMC specification type approvals that have been granted for PTP 650 products.

Table 110 EMC emissions compliance

Region	Specification (Type Approvals)
Europe	ETSI EN301 489-4

Human exposure to radio frequency energy

Relevant standards (USA and EC) applicable when working with RF equipment are:

- ANSI IEEE C95.1-1991, IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz.
- Council recommendation of 12 July 1999 on the limitation of exposure of the general public to electromagnetic fields (0 Hz to 300 GHz) (1999/519/EC) and respective national regulations.
- *Directive 2004/40/EC of the European Parliament and of the Council of 29 April 2004* on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (electromagnetic fields) (18th individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC).
- US FCC limits for the general population. See the FCC web site at http://www.fcc.gov, and the policies, guidelines, and requirements in Part 1 of Title 47 of the Code of Federal Regulations, as well as the guidelines and suggestions for evaluating compliance in FCC OET Bulletin 65.
- Health Canada limits for the general population. See the Health Canada web site at http://www.hc-sc.gc.ca/ewh-semt/pubs/radiation/99ehd-dhm237/limits-limites_e.html and Safety Code 6.
- EN 50383:2002 to 2010 Basic standard for the calculation and measurement of electromagnetic field strength and SAR related to human exposure from radio base stations and fixed terminal stations for wireless telecommunication systems (110 MHz - 40 GHz).
- BS EN 50385:2002 Product standard to demonstrate the compliances of radio base stations and fixed terminal stations for wireless telecommunication systems with the basic restrictions or the reference levels related to human exposure to radio frequency electromagnetic fields (110 MHz – 40 GHz) – general public.
- ICNIRP (International Commission on Non-Ionizing Radiation Protection) guidelines for the general public. See the ICNIRP web site at http://www.icnirp.de/ and Guidelines for Limiting Exposure to Time-Varying Electric, Magnetic, and Electromagnetic Fields.

Power density exposure limit

Install the radios for the PTP 650 family of PTP wireless solutions so as to provide and maintain the minimum separation distances from all persons.

The applicable power density exposure limit for RF energy in the 4.9, 5.4 and 5.8 GHz frequency bands is **10 W/m^2**. For more information, see Human exposure to radio frequency energy on page 4-23.

Calculation of power density

The following calculation is based on the ANSI IEEE C95.1-1991 method, as that provides a worst case analysis. Details of the assessment to EN50383:2002 can be provided, if required.

Peak power density in the far field of a radio frequency point source is calculated as follows:

$$S = \frac{P.G}{4\pi d^2}$$

Where:	Is:
S	power density in W/m^2
P	maximum average transmit power capability of the radio, in W
G	total Tx gain as a factor, converted from dB
d	distance from point source, in m

Rearranging terms to solve for distance yields:

$$d = \sqrt{\frac{P.G}{4\pi.S}}$$

Calculated distances

Table 111 shows calculated minimum separation distances, recommended distances and resulting margins for each frequency band and antenna combination. These are conservative distances that include compliance margins. At these and greater separation distances, the power density from the RF field is below generally accepted limits for the general population.

Calcul des distances pour la conformité aux limites de radiation radiofréquence

La Table 111 indique les distances minimales de séparation calculées, les distances recommandées et les marges de sécurité qui en découlent pour chaque bande de fréquence et chaque antenne. Ces distances comprennent les marges de sécurité recommandées par les régulateurs. À ces distance et des distance supérieures, la densité de puissance du champ de radiofréquence est inférieur aux limites généralement admises pour la population.

Table 111 Minimum safe distances

Band	Antenna	Tx burst (W) (*1)	P (W) (*2)	G (*3)	S (W/m²) (*4)	D (m) (*5)
4.9 GHz	Integrated (23.0 dBi)	0.25	0.2	200	10	0.47
	Parabolic 6 ft (36.0 dBi)	0.2	0.16	2818	10	1.89
	Sectorized (17.0 dBi)	0.25	0.2	35.5	10	0.24
	Omni (13.0 dBi)	0.25	0.2	14	10	0.15
5.1 GHz	Integrated (23.0 dBi)	0.025	0.02	200	10	0.18
	Parabolic 4 ft (34.5 dBi)	0.1	0.079	1995	10	1.12
	Sectorized (17.0 dBi)	0.08	0.006	35.5	10	0.04
	Omni (13.0 dBi)	0.025	0.02	14	10	0.05
5.2 GHz, 5.4 GHz	Integrated (23.0 dBi)	0.005	0.004	200	10	0.08
	Parabolic 4 ft (34.9 dBi)	0.0005	0.001	2188	10	0.08
	Sectorized (17.0 dBi)	0.008	0.006	35.5	10	0.04
	Omni (13.0 dBi)	0.025	0.02	14	10	0.05
5.8 GHz	Integrated (23.0 dBi)	0.646	0.513	200	10	0.9
	Parabolic 6 ft (38.1 dBi)	0.646	0.513	4571	10	4.32
	Sectorized (17.0 dBi)	0.1	0.079	35.5	10	0.15
	Omni (13.0 dBi)	0.25	0.2	14	10	0.15

(*1) Tx burst: maximum average transmit power in burst (Watt)

puissance d'émission maximale moyenne instantanée (Watt)

(*2) P: maximum average transmit power capability of the radio including cable loss (Watt)

capacité de puissance d'émission moyenne maximale de la radio comprenant la perte dans les câble de connexion (W)

(*3) G: total transmit gain as a factor, converted from dB

gain total d'émission, converti à partir de la valeur en dB

(*4) S: power density (W/m^2)

densité de puissance (W/m^2)

(*5) d: minimum distance from point source (meters)

distance minimale de source ponctuelle (en mètres)

Note

Gain of antenna in dBi = 10*log(G).

The regulations require that the power used for the calculations is the maximum power in the transmit burst subject to allowance for source-based time-averaging.

At 5.4 GHz and EU 5.8 GHz, the products are generally limited to a fixed EIRP which can be achieved with the Integrated Antenna. The calculations above assume that the maximum EIRP allowed by the regulations is being transmitted.

Note

If there are no EIRP limits in the country of deployment, use the distance calculations for FCC 5.8 GHz for all frequency bands.

At FCC 5.8 GHz, for antennas between 0.6m (2ft) and 1.8m (6ft), alter the distance proportionally to the antenna gain.

Remarque

Gain de l'antenne en dBi = 10 * log (G).

Les règlements exigent que la puissance utilisée pour les calculs soit la puissance maximale de la rafale de transmission soumis à une réduction pour prendre en compte le rapport cyclique pour les signaux modulés dans le temps.

Pour une opération dans la CEE dans les bandes 5,4 GHz et 5,8 GHz, les produits sont généralement limités à une PIRE qui peut être atteinte avec l'antenne intégrée. Les calculs ci-dessus supposent que la PIRE maximale autorisée par la réglementation est atteinte.

Remarque

Si aucune limite de PIRE existe pour le pays de déploiement, utilisez les calculs de distance pour FCC 5,8 GHz pour toutes les bandes de fréquence.

Pour la band FCC 5,8 GHz et les antennes entre 0,6 m (2 pieds) et 1,8 m (6 pieds), modifier la distance proportionnellement au gain de l'antenne.

Compliance with radio regulations

This section describes how the PTP 650 complies with the radio regulations that are in force in various countries.

Caution

Where necessary, the end user is responsible for obtaining any National licenses required to operate this product and these must be obtained before using the product in any particular country. Contact the appropriate national administrations for details of the conditions of use for the bands in question and any exceptions that might apply.

Caution

Changes or modifications not expressly approved by Cambium Networks could void the user's authority to operate the system.

Caution

For the connectorized version of the product and in order to reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the Effective Isotropically Radiated Power (EIRP) is not more than that permitted for successful communication.

Attention

Le cas échéant, l'utilisateur final est responsable de l'obtention des licences nationales nécessaires pour faire fonctionner ce produit. Celles-ci doivent être obtenus avant d'utiliser le produit dans un pays particulier. Contactez les administrations nationales concernées pour les détails des conditions d'utilisation des bandes en question, et toutes les exceptions qui pourraient s'appliquer

Attention

Les changements ou modifications non expressément approuvés par les réseaux de Cambium pourraient annuler l'autorité de l'utilisateur à faire fonctionner le système.

Attention

Pour la version du produit avec une antenne externe, et afin de réduire le risque d'interférence avec d'autres utilisateurs, le type d'antenne et son gain doivent être choisis afin que la puissance isotrope rayonnée équivalente (PIRE) ne soit pas supérieure au minimum nécessaire pour établir une liaison de la qualité requise.

Type approvals

The system has been tested against various local technical regulations and found to comply. Table 112 to Table 116 list the radio specification type approvals that have been granted for PTP 650 products.

Some of the frequency bands in which the system operates are “license exempt” and the system is allowed to be used provided it does not cause interference. In these bands, the licensing authority does not guarantee protection against interference from other products and installations.

Table 112 Radio certifications (4.9 GHz)

Region	Regulatory approvals
USA	FCC 47 CFR Part 90
Canada	IC RSS-211, Issue 4
Europe	Europe EN302 625; V1.1.1 Broadband Disaster Relief (BBDR)
Brazil	ANATEL Certification No: 0934-06-3277

Table 113 Radio certifications (5.1 GHz)

Region	Regulatory approvals
USA	FCC 47 CFR Part 15 E

Table 114 Radio certifications (5.2 GHz)

Region	Regulatory approvals
USA	FCC 47 CFR Part 15 E
Canada	IC RSS-210 Issue 8, Annex 9 (or latest)

Table 115 Radio certifications (5.4 GHz)

Region	Regulatory approvals
USA	FCC 47 CFR Part 15 E
Canada	IC RSS-210 Issue 8, Annex 9 (or latest)
Europe	ETSI EN301 893 v1.6.1

Table 116 Radio certifications (5.8 GHz)

Region	Regulatory approvals
USA	FCC 47 CFR Part 15 C
Canada	IC RSS-210 Issue 8, Annex 8 (or latest)
Denmark	Radio Interface 00 007
Eire	ComReg 02/71R4
Germany	Order No 47/2007
Iceland	ETSI EN302 502 v1.2.1
Finland	ETSI EN302 502 v1.2.1
Greece	ETSI EN302 502 v1.2.1
Liechtenstein	ETSI EN302 502 v1.2.1
Norway	REG 2009-06-02 no. 580
Portugal	ETSI EN302 502 v1.2.1
Serbia	ETSI EN302 502 v1.2.1
Spain	CNAF 2010
Switzerland	ETSI EN302 502 v1.2.1
UK	UK IR 2007

FCC/IC compliance

The PTP 650 complies with the regulations that are in force in the USA and Canada.

Caution

If this equipment does cause interference to radio or television reception, refer to Radio and television interference on page 8-14 for corrective actions.

Attention

Si cet équipement cause des interférences à la réception radio ou télévision, reportez-vous a la section Radio and television interference page 8-14 pour déterminer comment remédier au problème.

FCC product labels

FCC identifiers are reproduced on the product labels for the FCC/IC regional variant (Figure 104 and Figure 105).

Figure 104 FCC and IC certifications on integrated ODU product labels

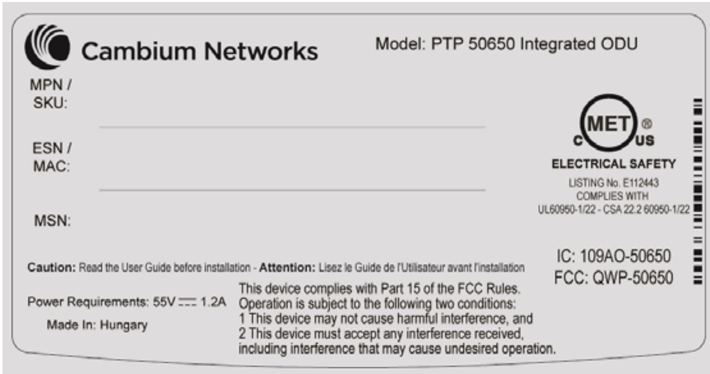
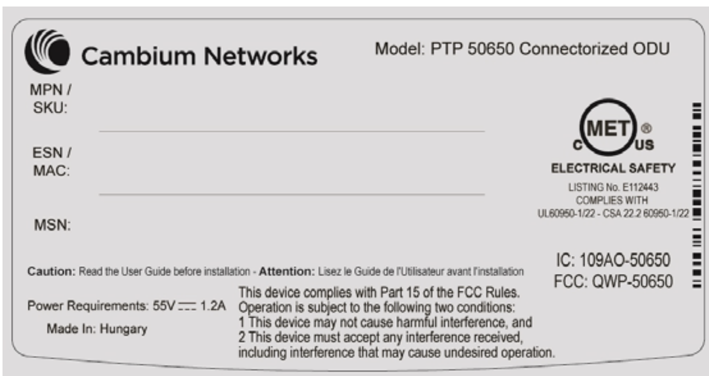


Figure 105 FCC and IC certifications on connectorized ODU product labels



Industry Canada product labels

Industry Canada Certification Numbers are reproduced on the product labels for the FCC/IC regional variant (Figure 104 and Figure 105) and also on the Rest of the World (RoW) regional variant (Figure 106 and Figure 107).

Figure 106 IC certification on integrated ODU product labels

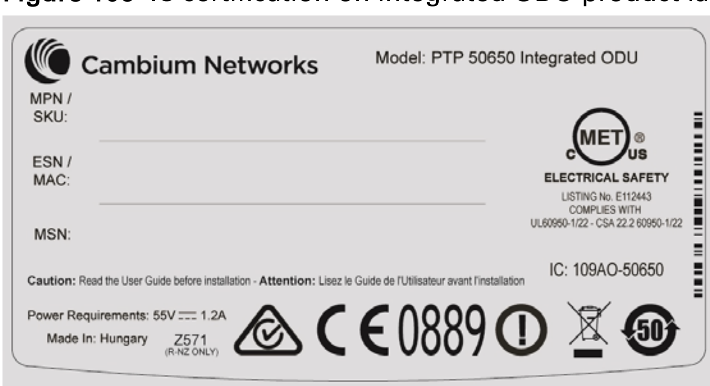
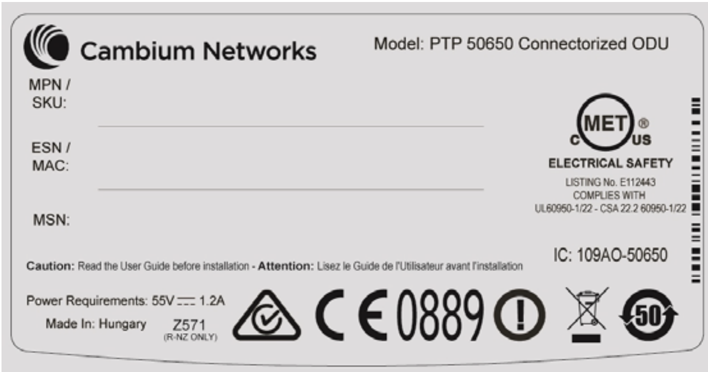


Figure 107 IC certification on connectorized ODU product labels



4.9 GHz FCC and IC notification

The system has been approved under FCC Part 90 and Industry Canada RSS-111 for Public Safety Agency usage. The installer or operator is responsible for obtaining the appropriate site licenses before installing or using the system.

Utilisation de la bande 4.9 GHz FCC et IC

Le système a été approuvé en vertu de FCC Part 90 et Industrie Canada RSS-111 pour l'utilisation par l'Agence de la Sécurité publique. L'installateur ou l'exploitant est responsable de l'obtention des licences de appropriées avant d'installer ou d'utiliser le système.

5.1 GHz FCC notification

This device complies with part 15E of the US FCC Rules and Regulations. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) This device must accept any interference received, including interference that may cause undesired operation.

For the connectorized version of the product and in order to reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the equivalent isotropically radiated power (EIRP) is not more than that permitted by the regulations. The transmitted power must be reduced to achieve this requirement.

5.2 GHz and 5.4 GHz FCC and IC notification

This device complies with part 15E of the US FCC Rules and Regulations and with Industry Canada RSS-210 Annex 9. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) This device must accept any interference received, including interference that may cause undesired operation. In Canada, users should be cautioned to take note that high power radars are allocated as primary users (meaning they have priority) of 5250 – 5350 MHz and 5650 – 5850 MHz and these radars could cause interference and/or damage to license-exempt local area networks (LELAN).

For the connectorized version of the product and in order to reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the equivalent isotropically radiated power (EIRP) is not more than that permitted by the regulations. The transmitted power must be reduced to achieve this requirement.

Utilisation de la bande 5.4 GHz FCC et IC

Cet appareil est conforme à la Section 15E de la réglementation FCC aux États-Unis et aux règlementations et avec Industrie Canada RSS-210 Annexe 9. Son fonctionnement est soumis aux deux conditions suivantes: (1) Ce dispositif ne doit pas causer d'interférences nuisibles, et (2) Cet appareil doit tolérer toute interférence reçue, y compris les interférences pouvant entraîner un fonctionnement indésirable. Au Canada, les utilisateurs doivent prendre garde au fait que les radars à haute puissance sont considères comme les utilisateurs prioritaires de 5250 à 5350 MHz et 5650 à 5850 MHz et ces radars peuvent causer des interférences et / ou interférer avec un réseau local ne nécessitant pas de licence.

Pour la version du produit avec antenne externe et afin de réduire le risque d'interférence avec d'autres utilisateurs, le type d'antenne et son gain doivent être choisis afin que la puissance isotrope rayonnée équivalente (PIRE) ne soit pas supérieure à celle permise par la règlementation. Il peut être nécessaire de réduire la puissance transmise doit être réduite pour satisfaire cette exigence.

5.8 GHz FCC notification

This device complies with part 15C of the US FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) This device must accept any interference received, including interference that may cause undesired operation.

5.8 GHz IC notification

RSS-GEN issue 3 (7.1.3) Licence-Exempt Radio Apparatus:

> This device complies with Industry Canada license-exempt RSS standard(s). Operation is subject to the following two conditions: (1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.
>
> *Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes : (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.*

In Canada, high power radars are allocated as primary users (meaning they have priority) of the 5650 – 5850 MHz spectrum. These radars could cause interference or damage to license-exempt local area network (LE-LAN) devices.

Au Canada, les radars à haute puissance sont désignés comme utilisateurs principaux (ils ont la priorité) de la 5650 - spectre 5850 MHz. Ces radars peuvent causer des interférences et / ou interférer avec un réseau local ne nécessitant pas de licence.

5.1 GHz band edge channel power reduction

Equivalent isotropic radiated power (EIRP) is restricted in edge channels when the PTP 650 is operated the 5.1 GHz band with the USA country license. The amount of EIRP reduction has been determined during regulatory testing and cannot be changed by professional installers or end users. Units intended for the USA market are locked for use in the USA and cannot be operated under the regulations for other regulatory domains.

The PTP 650 takes into account the antenna gain and cable loss configured by the professional installer in the web-based interface to limit the EIRP to ensure regulatory compliance. No additional action is required by the installer to reduce transmitter power in band edge channels.

The maximum EIRP in band edge channels for the USA 5.1 GHz band is listed in Table 117.

Table 117 Edge channel power reduction in regulatory band 84

Channel Bandwidth	Channel Frequency	Maximum EIRP
5 MHz	Below 5158 MHz	26 dBm
	5158 to 5200 MHz	30 dBm
	Above 5200 MHz	33 dBm
10 MHz	Below 5164	23 dBm
	5164 and above	31 dBm
15 MHz	Below 5170	23 dBm
	5170 to 5181	31 dBm
	Above 5181	37 dBm

Channel Bandwidth	Channel Frequency	Maximum EIRP
20 MHz	Below 5175	23 dBm
	5175 to 5187	30 dBm
	Above 5187	36 dBm
30 MHz	Below 5187	24 dBm
	5187 to 5200	30 dBm
	Above 5200	35 dBm
40 MHz	Below 5200	24 dBm
	5200 and above	30 dBm
45 MHz	Below 5205	23 dBm
	5205 and above	30 dBm

5.2 GHz band edge channel power reduction

Equivalent isotropic radiated power (EIRP) is restricted in edge channels when the PTP 650 is operated the 5.2 GHz band with the USA or Canada country license. The amount of EIRP reduction has been determined during regulatory testing and cannot be changed by professional installers or end users. Units intended for the USA and Canada market are locked for use in the USA or Canada and cannot be operated under the regulations for other regulatory domains.

The PTP 650 takes into account the antenna gain and cable loss configured by the professional installer in the web-based interface to limit the EIRP to ensure regulatory compliance. No additional action is required by the installer to reduce transmitter power in band edge channels.

The maximum EIRP in band edge channels for the USA and Canada 5.2 GHz band is listed in Table 118.

Table 118 Edge channel power reduction in regulatory band 38

Channel Bandwidth	Channel Frequency	Maximum EIRP
5 MHz	Below 5256.0 MHz	24 dBm
	Above 5344.0 MHz	24 dBm
10 MHz	Below 5260.0 MHz	23 dBm
	Above 5337.0 MHz	23 dBm
15 MHz	Below 5267.0 MHz	22 dBm
	Above 5330.0 MHz	22 dBm
20 MHz	Below 5271.0 MHz	25 dBm
	Above 5325.0 MHz	21 dBm

Channel Bandwidth	Channel Frequency	Maximum EIRP
30 MHz	Below 5280.0 MHz	25 dBm
	Above 5308.0 MHz	23 dBm
40 MHz	Below 5290.0 MHz	24 dBm
	Above 5299.0 MHz	20 dBm
45 MHz	Below 5295.0 MHz	24 dBm
	Above 5295.0 MHz	20 dBm

5.4 GHz band edge channel power reduction

Equivalent isotropic radiated power (EIRP) is restricted in edge channels when the PTP 650 is operated the 5.4 GHz band with the USA or Canada country license. The amount of EIRP reduction has been determined during regulatory testing and cannot be changed by professional installers or end users. Units intended for the USA and Canada market are locked for use in the USA or Canada and cannot be operated under the regulations for other regulatory domains.

The PTP 650 takes into account the antenna gain and cable loss configured by the professional installer in the web-based interface to limit the EIRP to ensure regulatory compliance. No additional action is required by the installer to reduce transmitter power in band edge channels.

The maximum EIRP in band edge channels for the USA and Canada 5.4 GHz band is listed in Table 119.

Réduction de puissance aux bords de la bande 5.4 GHz

La Puissance isotrope rayonnée équivalente (PIRE) est limitée dans les canaux en bord de la bandes lorsque le PTP 650 est configuré pour utiliser la band 5,4 GHz aux les Etats-Unis ou au Canada. La réduction de la PIRE a été déterminée lors de tests réglementaires et ne peut être changée par des installateurs professionnels ou les utilisateurs. Les PTP 650 destinées aux USA et Canada sont limitées pour opérer exclusivement aux États-Unis ou au Canada et ne peuvent pas être configurés pour adhérer à la réglementation d’autres pays.

Le PTP 650 prend en compte le gain de l'antenne et les pertes des câbles de connexion configurés par l'installateur professionnel via l'interface graphique pour limiter la PIRE pour assurer la conformité à la réglementation en vigueur. Aucune action supplémentaire n'est requise par l'installateur afin de réduire la puissance d'émission dans les canaux aux bords de bande.

La PIRE maximale dans les canaux aux bords de bande 5,4 GHz pour les Etats-Unis et le Canada est listée dans la Table 119.

Table 119 Edge channel power reduction in regulatory bands 12 and 13

Channel Bandwidth	Channel Frequency	Maximum EIRP
5 MHz	Below 5476.0 MHz	24 dBm
	Above 5720.0 MHz	24 dBm
10 MHz	Below 5478.0 MHz	27 dBm
	Above 5715.0 MHz	25 dBm
15 MHz	Below 5480.0 MHz	29 dBm
	Above 5709.0 MHz	26 dBm
20 MHz	Below 5482.0 MHz	30 dBm
	Above 5704.0 MHz	23 dBm
30 MHz	Below 5492.0 MHz	27 dBm
	Above 5694.0 MHz	25 dBm
40 MHz	Below 5500.0 MHz	28 dBm
	Above 5691.0 MHz	24 dBm
45 MHz	Below 5508.0 MHz	24 dBm
	Above 5686.0 MHz	22 dBm

5.8 GHz band edge channel power reduction

Transmitter power is restricted in edge channels when the PTP 650 is operated the 5.8 GHz band with the USA or Canada country license. The amount of transmitter power reduction has been determined during regulatory testing and cannot be changed by professional installers or end users. Units intended for the USA and Canada market are locked for use in the USA or Canada and cannot be operated under the regulations for other regulatory domains.

The maximum transmitter power in band edge channels for the FCC 5.8 GHz band is listed in Table 120.

Réduction de puissance aux bords de la bande 5.8 GHz

La Puissance isotrope rayonnée équivalente (PIRE) est limitée dans les canaux en bord de la bandes lorsque le PTP 650 est configuré pour utiliser la band 5,8 GHz aux les Etats-Unis ou au Canada. La réduction de la PIRE a été déterminée lors de tests réglementaires et ne peut être changée par des installateurs professionnels ou les utilisateurs. Les PTP 650 destinées aux USA et Canada sont limitées pour opérer exclusivement aux États-Unis ou au Canada et ne peuvent pas être configurés pour adhérer à la réglementation d'autres pays.

La PIRE maximale dans les canaux aux bords de bande 5,4 GHz pour les Etats-Unis et le Canada est listée dans la Table 120.

Table 120 Edge channel power reduction in regulatory band 1

Channel Bandwidth	Channel Frequency	Maximum conducted power
5 MHz	Below 5733.0 MHz	24 dBm
	Above 5838.0 MHz	24 dBm
10 MHz	Below 5737.0 MHz	25 dBm
	Above 5837.0 MHz	25 dBm
15 MHz	Below 5740.0 MHz	25 dBm
	Above 5835.0 MHz	25 dBm
20 MHz	Below 5742.0 MHz	25 dBm
	Above 5832.0 MHz	25 dBm
30 MHz	Below 5752.0 MHz	25 dBm
	Above 5822.0 MHz	25 dBm
40 MHz	Below 5765.0 MHz	25 dBm
	Above 5810.0 MHz	25 dBm
45 MHz	Below 5778.0 MHz	23 dBm
	Above 5795.0 MHz	22 dBm

Selection of antennas

For guidance on the selection of dedicated external antennas refer to Choosing external antennas on page 3-29.

For a list of antennas submitted to the FCC and IC for use with the PTP 650 refer to FCC and IC approved antennas on page 2-23.

Note

Under Industry Canada regulations, this radio transmitter may only operate using an antenna of a type and maximum (or lesser) gain approved for the transmitter by Industry Canada. To reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the equivalent isotropically radiated power (EIRP) is not more than that necessary for successful communication.

Remarque

Conformément à la réglementation d'Industrie Canada, le présent émetteur radio peut fonctionner avec une antenne d'un type et d'un gain maximal (ou inférieur) approuvé pour l'émetteur par Industrie Canada. Dans le but de réduire les risques de brouillage radioélectrique à l'intention des autres utilisateurs, il faut choisir le type d'antenne et son gain de sorte que la puissance isotrope rayonnée équivalente (p.i.r.e.) ne dépasse pas l'intensité nécessaire à l'établissement d'une communication satisfaisante.

European Union compliance

The PTP 650 complies with the regulations that are in force in the European Union.

Warning

This is a Class A product. In a domestic environment this product may cause radio interference, in which case the user may be required to take adequate measures.

If this equipment does cause interference to radio or television reception, refer to Radio and television interference on page 8-14 for corrective actions.

EU product labels

The European R&TTE directive 1999/5/EC Certification Number is reproduced on the product labels (Figure 108 and Figure 109).

Figure 108 European Union certification on integrated product label

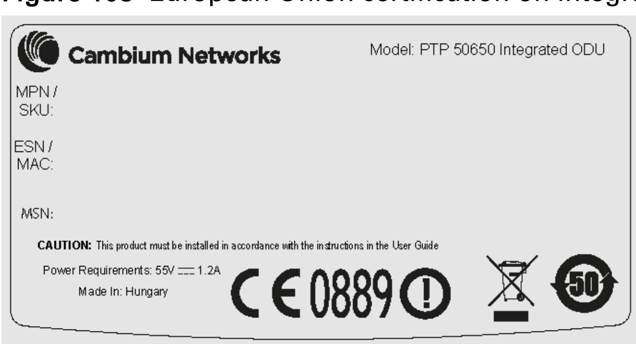
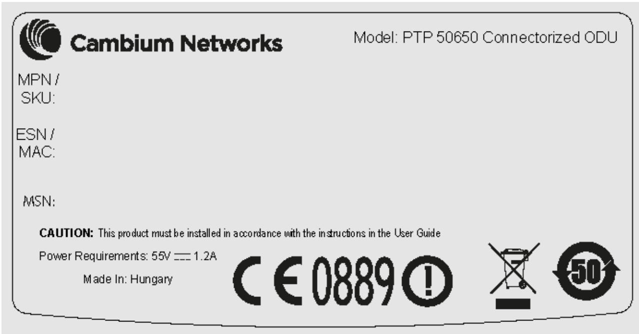


Figure 109 European Union certification on connectorized product label



5.4 GHz European Union notification

The PTP 650 product is a two-way radio transceiver suitable for use in Broadband Wireless Access System (WAS), Radio Local Area Network (RLAN), or Fixed Wireless Access (FWA) systems. It is a Class 1 device and uses operating frequencies that are harmonized throughout the EU member states. The operator is responsible for obtaining any national licenses required to operate this product and these must be obtained before using the product in any particular country.

Hereby, Cambium Networks declares that the PTP 650 product complies with the essential requirements and other relevant provisions of Directive 1999/5/EC. The declaration of conformity may be consulted at the support website (see Contacting Cambium Networks on page 1).

5.8 GHz European Union notification

The PTP 650 is a Class 2 device as it operates on frequencies that are not harmonized across the EU. Currently the product may only be operated in the countries listed in Table 116. However, the regulatory situation in Europe is changing and the radio spectrum may become available in other countries in future. See www.ero.dk for further information. The operator is responsible for obtaining any national licenses required to operate this product and these must be obtained before using the product in any particular country.

Caution

This equipment operates as a secondary application, so it has no rights against harmful interference, even if generated by similar equipment, and must not cause harmful interference on systems operating as primary applications.

Hereby, Cambium Networks declares that the PTP 650 product complies with the essential requirements and other relevant provisions of Directive 1999/5/EC. The declaration of conformity may be consulted at the support website (see Contacting Cambium Networks on page 1).

5.8 GHz operation in the UK

The PTP 650 Connectorized product has been notified for operation in the UK, and when operated in accordance with instructions for use it is compliant with UK Interface Requirement IR2007. For UK use, installations must conform to the requirements of IR2007 in terms of EIRP spectral density against elevation profile above the local horizon in order to protect Fixed Satellite Services. The frequency range 5795-5815 MHz is assigned to Road Transport & Traffic Telematics (RTTT) in the U.K. and shall not be used by FWA systems in order to protect RTTT devices. UK Interface Requirement IR2007 specifies that radiolocation services shall be protected by a Dynamic Frequency Selection (DFS) mechanism to prevent co-channel operation in the presence of radar signals.

Chapter 5: Installation

This chapter describes how to install and test the hardware for a PTP 650 link. It contains the following topics:

- Safety on page 5-2 contains important safety guidelines that must be observed by personnel installing or operating PTP 650 equipment.
- ODU variants and mounting bracket options on page 5-6 provides details of six different bracket options, including the type of ODu and range of pole diameters supported by each option.
- Installing the ODU and top LPU on page 5-7 describes how to mount and ground an integrated or connectorized ODU, how to mount and ground the top LPU.
- Install external antennas for a connectorized ODU on page 5-16 describes how to mount and connect an external antenna for the connectorized ODU.
- Installing the copper Cat5e Ethernet interface on page 5-18 describes how to install the copper Cat5e power over Ethernet interface from the ODU (PSU port) to the PSU.
- Installing the PSU on page 5-26 describes how to install a power supply unit for the PTP 650, either the AC Power Injector or the AC+DC Enhanced Power Injector.
- Installing a PTP-SYNC unit on page 5-28 describes how to install a PTP-SYNC unit for TDD synchronization.
- Installing a GPS receiver on page 5-32 describes how to install a GPS receiver as the timing reference source for PTP-SYNC.
- Installing a NIDU on page 5-42 describes how to install a network indoor unit (NIDU) for TDM (T1 or E1) interfaces.
- Installing an SFP Ethernet interface on page 5-28 describes how to install an optical or copper Cat5e Ethernet interface from the ODU (SFP port) to a connected device.
- Installing an Aux Ethernet interface on page 5-57 describes how to install a copper Cat5e Ethernet interface from the ODU (Aux port) to a connected device.
- Supplemental installation information on page 5-58 contains detailed installation procedures that are not included in the above topics, such as how to strip cables, create grounding points and weatherproof connectors.

Note

These instructions assume that LPUs are being installed from the PTP 650 LPU and grounding kit (Cambium part number C000065L007). If the installation does not require LPUs, adapt these instructions as appropriate.

If LPUs are being installed, only use the five black-capped EMC cable glands supplied in the LPU and grounding kit. The silver-capped cable glands supplied in the ODU kits must only be used in PTP 650 installations which do not require LPUs.

Safety

Warning

To prevent loss of life or physical injury, observe the following safety guidelines. In no event shall Cambium Networks be liable for any injury or damage caused during the installation of the Cambium PTP 650. Ensure that only qualified personnel install a PTP 650 link.

Power lines

Exercise extreme care when working near power lines.

Working at heights

Exercise extreme care when working at heights.

PSU

Always use one of the Cambium PTP 650 Series power supply units (PSU) to power the ODU. Failure to use a Cambium supplied PSU could result in equipment damage and will invalidate the safety certification and may cause a safety hazard.

Grounding and protective earth

The Outdoor Unit (ODU) must be properly grounded to protect against lightning. It is the user's responsibility to install the equipment in accordance with national regulations. In the USA follow the requirements of the National Electrical code NFPA 70-2005 and 780-2004 *Installation of Lightning Protection Systems*. In Canada, follow Section 54 of the *Canadian Electrical Code*. These codes describe correct installation procedures for grounding the outdoor unit, mast, lead-in wire and discharge unit, size of grounding conductors and connection requirements for grounding electrodes. Other regulations may apply in different countries and therefore it is recommended that installation of the outdoor unit be contracted to a professional installer.

DC supply

To power the ODU from a DC supply, use the AC+DC Enhanced Power Injector (PSU) (Cambium part number C000065L002). Ensure that the DC power supply meets the requirements specified in PSU DC power supply on page 3-15.

Powering down before servicing

Before servicing PTP 650 equipment, always switch off the power supply and unplug it from the PSU.

Do not disconnect the RJ45 drop cable connectors from the ODU while the PSU is connected to the power supply. Always remove the AC or DC input power from the PSU.

Primary disconnect device

The main power supply is the primary disconnect device. The AC+DC Enhanced power injector is fused on the DC input. Some installations will also require an additional circuit breaker or isolation switch to be fitted in the DC supply.

External cables

Safety may be compromised if outdoor rated cables are not used for connections that will be exposed to the outdoor environment. For outdoor copper Cat5e Ethernet interfaces, always use Cat5e cable that is gel-filled and shielded with copper-plated steel. Alternative types of drop cable are not supported by Cambium Networks.

Drop cable tester

The PSU output voltage may be hazardous in some conditions, for example in wet weather. Do NOT connect the drop cable tester to the PSU, either directly or via LPUs.

Grounding PTP-SYNC

In order to meet the safety requirements for deployment in Australia and New Zealand (AS/NZS 60950-1), the PTP-SYNC unit, if deployed, must be grounded to a Protective Ground in accordance with Local Electrical Regulations.

RF exposure near the antenna

Strong radio frequency (RF) fields will be present close to the antenna when the transmitter is on. Always turn off the power to the ODU before undertaking maintenance activities in front of the antenna.

Minimum separation distances

Ensure that personnel are not exposed to unsafe levels of RF energy. The units start to radiate RF energy as soon as they are powered up. Never work in front of the antenna when the ODU is powered. Install the ODUs so as to provide and maintain the minimum separation distances from all persons. For minimum separation distances, see Calculated distances on page 4-24.

Grounding and lightning protection requirements

Ensure that the installation meets the requirements defined in Grounding and lightning protection on page 3-11.

Grounding cable installation methods

To provide effective protection against lightning induced surges, observe these requirements:

- Grounding conductor runs are as short, straight and smooth as possible, with bends and curves kept to a minimum.
- Grounding cables must not be installed with drip loops.
- All bends must have a minimum radius of 200 mm (8 in) and a minimum angle of 90°. A diagonal run is preferable to a bend, even though it does not follow the contour or run parallel to the supporting structure.
- All bends, curves and connections must be routed towards the grounding electrode system, ground rod, or ground bar.
- Grounding conductors must be securely fastened.
- Braided grounding conductors must not be used.
- Approved bonding techniques must be used for the connection of dissimilar metals.

Siting ODUs and antennas

ODUs, external antennas and GPS receivers for PTP-SYNC are not designed to survive direct lightning strikes. For this reason they must be installed in Zone B as defined in Lightning protection zones on page 3-11. Mounting in Zone A may put equipment, structures and life at risk.

Thermal Safety

The ODU enclosure may be hot to the touch when in operation. The ODU must not be operated in ambient temperatures exceeding 40°C unless mounted in a Restricted Access Location. For more information, see ODU ambient temperature limits on page 3-13.

Warning

Do not install the ODU in a location where the ambient temperature could exceed 40°C unless this is a Restricted Access Location as defined by EN 60950-1.

Alerte

L'unité externe ne doit pas être installée dans un endroit où la température ambiante est supérieure à 40C à moins que l'accès soit limité au personnel autorisé.

ODU variants and mounting bracket options

Mounting bracket options

The PTP 650 series supports five mounting bracket options. Select the optimum mounting bracket arrangement based on the pole diameter and the ODU variant:

Table 121 ODU mounting bracket part numbers

Bracket	Pole diameter	ODU variants	Bracket part number
Mounting bracket (integrated)	40 mm to 82 mm (1.6 inches to 3.2 inches)	PTP 650 Integrated PTP 650S Integrated PTP 650L Integrated	N000065L031
Mounting bracket (connectorized)	40 mm to 82 mm (1.6 inches to 3.2 inches)	PTP 650 Connectorized	N000065L032
Extended integrated mounting bracket	89 mm *OR* 114 mm (3.5 inches *OR* 4.5 inches)	PTP 650 Integrated PTP 650S Integrated PTP 650L Integrated PTP 650 Connectorized	N000065L030
Mounting bracket (integrated) with large diameter extension kit	89 mm to 229 mm (3.5 inches to 9.0 inches)	PTP 650 Integrated PTP 650S Integrated PTP 650L Integrated PTP 650 Connectorized	N000065L031 with N000065L042
Low profile bracket	40 mm to 82 mm (1.6 inches to 3.2 inches)	PTP 650S Integrated PTP 650L Integrated	N000065L039
	89 mm to 229 mm (3.5 inches to 9.0 inches)		

The low profile bracket provides elevation adjustment with the PTP 650S and PTP 650L Integrated ODUs of +10° to –5° or +5° to –10°. A larger adjustment range is available using the standard integrated mounting bracket. The connectorized mounting bracket does not provide elevation adjustment.

Note

The connectorized mounting bracket is included with the PTP 650 Connectorized ODU. Order a bracket separately for PTP 650 or PTP 650S Integrated or PTP 650L Integrated ODUs.

Installing the ODU and top LPU

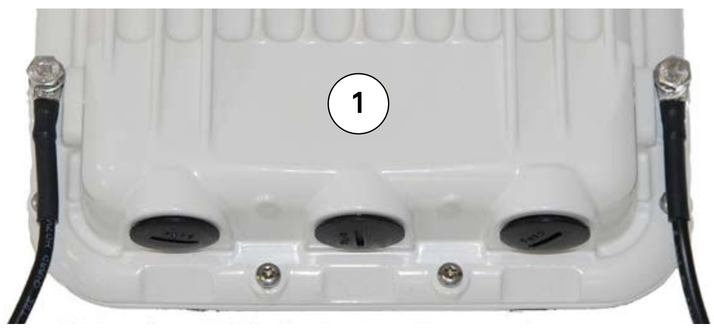
To install the ODU and top LPU, use the following procedures:

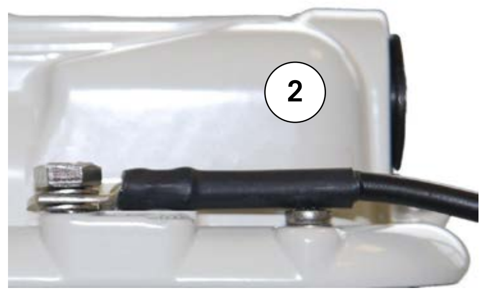
- Attach ground cables to the ODU on page 5-7
- Mount the ODU on the mast on page 5-7
- Mount the top LPU on page 5-14
- Interconnect and ground the ODU and top LPU on page 5-14

Attach ground cables to the ODU

1 Fasten one ground cable to each ODU grounding point using the M6 (small) lugs: one is for the top LPU (M6 lug at other end) and the other is for the tower or building (M10 lug at other end). It does not matter which cable goes on which ODU grounding point.

2 Tighten both ODU grounding bolts to a torque of 5 Nm (3.9 lb ft).





Mount the ODU on the mast

Select the most appropriate bracket mounting arrangement from the options listed in Mounting bracket options on page 5-6. Refer to individual procedures below for each of the options:

- Mounting bracket (integrated) on page 5-8
- Mounting bracket (connectorized) on page 5-9
- Extended integrated mounting bracket on page 5-10
- Mounting bracket (integrated) with large diameter extension kit on page 5-11
- Low profile bracket on small diameter pole on page 5-12
- Low profile bracket on large pole on page 5-13

The procedure for the Mounting bracket (connectorized) can be readily adapted to attach the ODU to a horizontal pole of similar size.

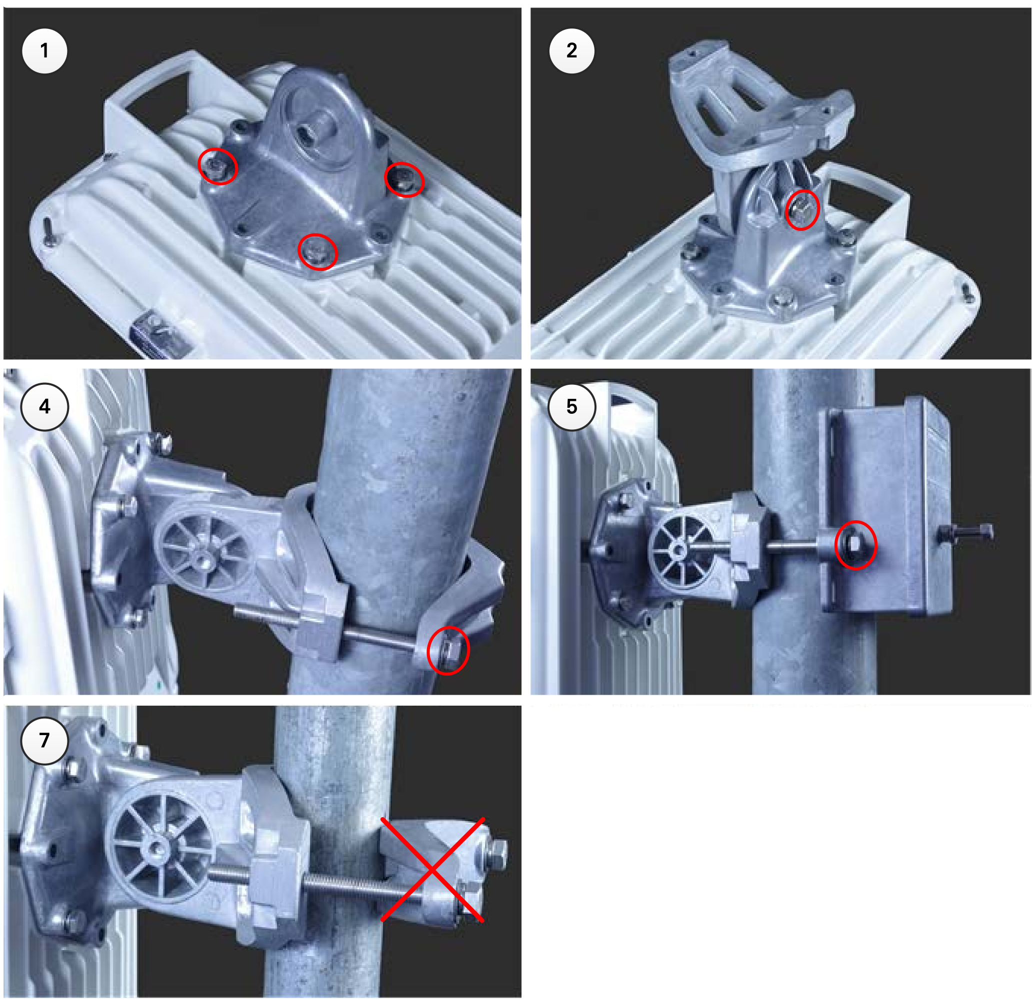
The procedure for the Mounting bracket (integrated) and the Extended integrated mounting bracket can be adapted to attach the ODU to a suitable horizontal pole, but the adjustment of azimuth angle is necessarily limited compared with an installation on a vertical pole.

Mounting bracket (integrated)

Caution

Do not reverse the bracket clamp, as this arrangement may lead to failure of the assembly. Do not over-tighten the bolts as this may lead to failure of the assembly.

1. Fix the mounting plate to the back of the ODU using the four bolts, and spring and plain washers provided. Tighten the bolts to a torque setting of 5.0 Nm (3.7 lb ft).
2. Attach the bracket body to the mounting plate using the M8 bolt, spring and plain washers.
3. Hoist the ODU to the mounting position.
4. Attach the bracket body to the pole using the bracket clamp, M8 bolts, and spring and plain washers. For back-to-back mounting, use the LPU in place of the clamp.
5. Adjust the elevation and azimuth to achieve visual alignment. Tighten all three bracket bolts to a torque of 8.0 Nm (6.0 lb ft).



Mounting bracket (connectorized)

1 Identify the square cavities in the casting on the back of the ODU. These cavities will be used to accommodate the heads of two M8 bracket bolts.

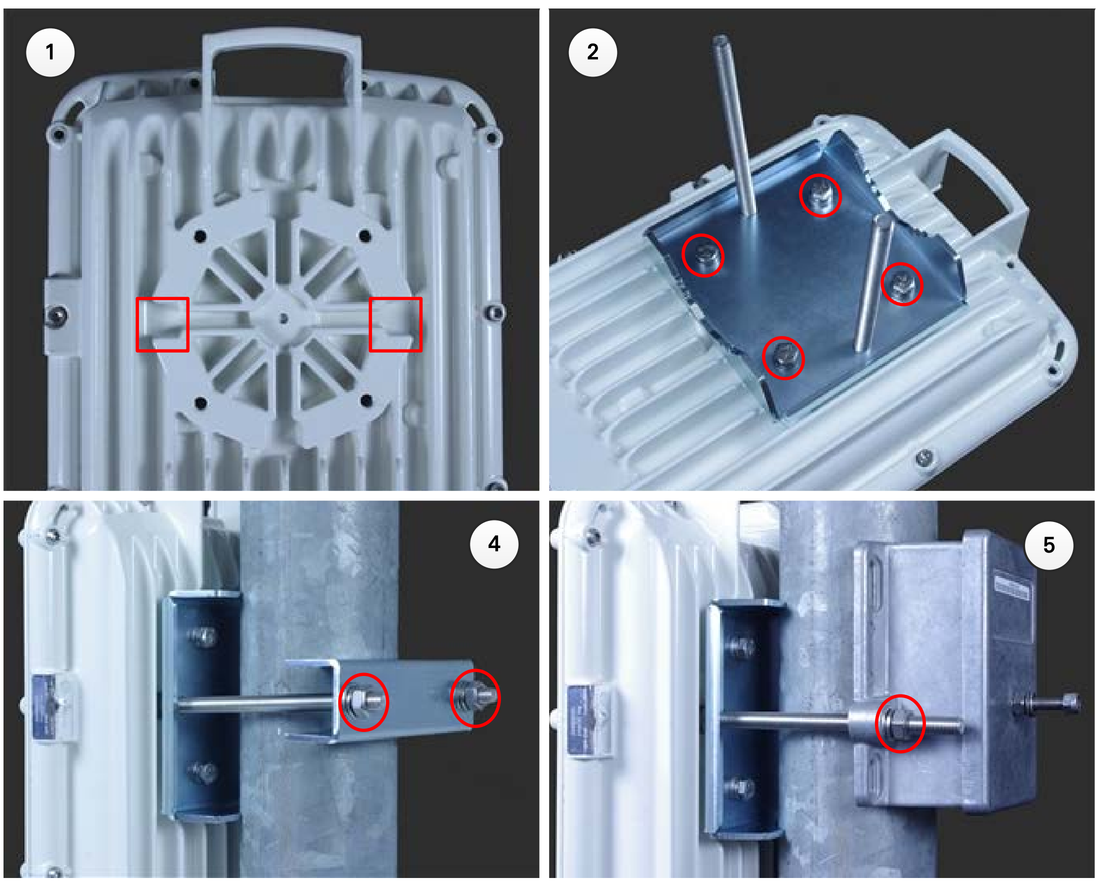
2 Fix the mounting plate to the ODU using the four M6 bolts, and spring and plain washers provided. Ensure that the M8 bolts are correctly held between the mounting plate and the ODU. Tighten the M6 bolts to a torque setting of 5.0 Nm (3.7 lb ft).

3 Hoist the ODU to the mounting position.

4 Attach the bracket body to the pole using the bracket clamp, spring and plain washers, and M8 nuts.

5 Alternatively, use the LPU in place of the clamp to provide a back-to-back arrangement.

6 Tighten the two M8 bracket bolts to a torque setting of 8.0 Nm (6.0 lb ft). Do not over-tighten the bolts as this may lead to failure of the assembly.



Extended integrated mounting bracket

1 Fix the mounting plate to the back of the ODU using the four M6 bolts, and spring and plain washers provided. Tighten the bolts to a torque setting of 5.0 Nm (3.7 lb ft). The step is common with the standard integrated bracket.

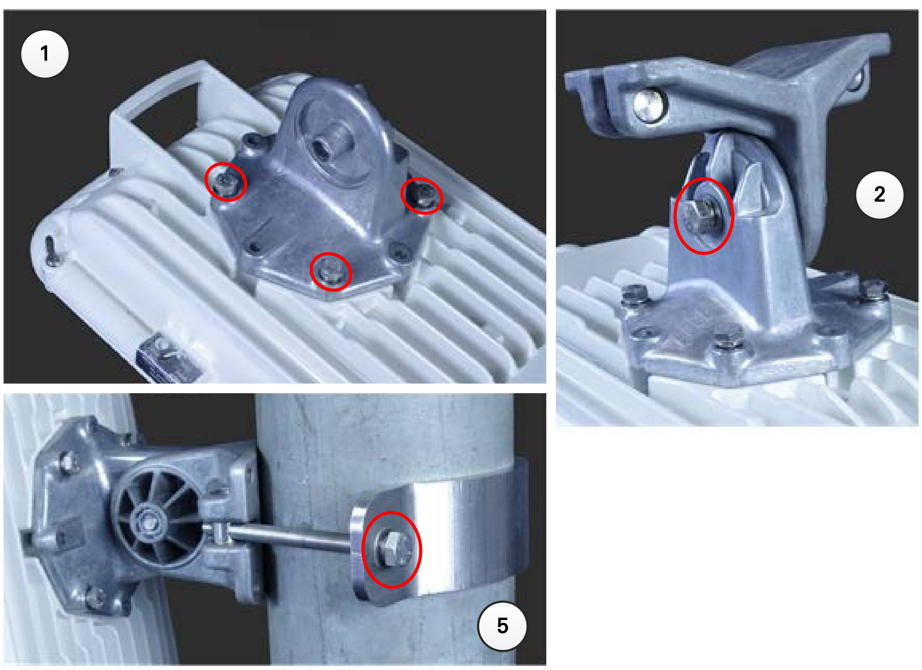
2 Attach the bracket body of the extended bracket on the mounting plate on the ODU to using the M8 bolt and spring and plain washer.

3 Hoist the ODU to the mounting position.

4 Select the correct clamp. The larger clamp is intended for poles of diameter 114 mm (4.5 inches). The smaller clamp is intended for poles of diameter 89 mm (3.5 inches).

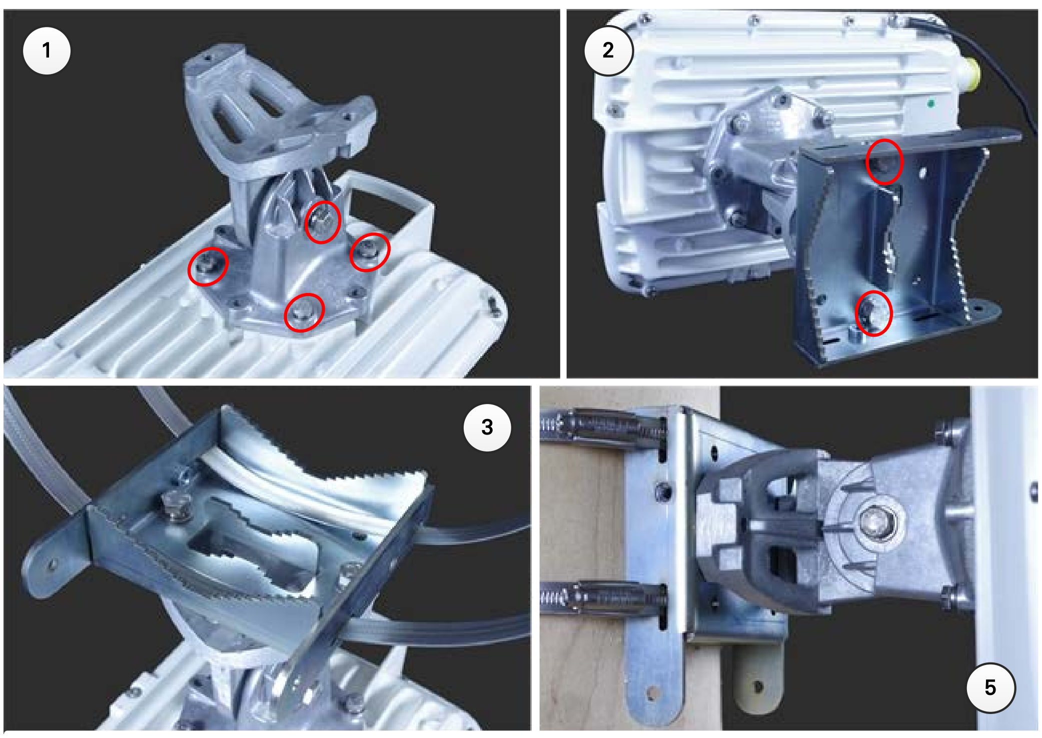
5 Attach the bracket body to the pole using the selected bracket clamp, washers and M8 bolts.

6 Adjust the elevation and azimuth to achieve visual alignment. Tighten all three M8 bracket bolts to a torque setting of 8.0 Nm (6.0 lb ft). Do not over-tighten the bolts as this may lead to failure of the assembly.



Mounting bracket (integrated) with large diameter extension kit

1. Fix the mounting plate to the back of the ODU using the bolts and washers provided. Tighten the four bolts to a torque setting of 5.0 Nm (3.7 lb ft). Attach the bracket body to the mounting plate using the M8 bolt and spring and plain washer. This is equivalent to the first two steps for the standard integrated bracket.
2. Attach the adaptor plate of the large diameter extension kit to the bracket body using the bolts and washers provided. Tighten the two bolts to a torque setting of 5.0 Nm (3.7 lb ft).
3. Feed the Jubilee straps through the slots in the adaptor plate.
4. Hoist the ODU to the mounting position.
5. Attach the adaptor plate to the pole using the Jubilee straps.
6. Adjust the azimuth to achieve visual alignment. Tighten the Jubilee straps to a torque setting of 6.0 Nm (4.5 lb ft).
7. Adjust the elevation to achieve visual alignment. Tighten M8 bracket bolt to a torque setting of 8.0 Nm (6.0 lb ft). Do not over-tighten this bolt as this may lead to failure of the assembly.



Low profile bracket on small diameter pole

1 Fix the low profile bracket to the back of the ODU using the M6 bolts and washers provided. Tighten the four bolts to a torque setting of 5.0 Nm (3.7 lb ft).

2 Pass the M8 coach bolts through the square holes in the hinged portion of the bracket. Close the bracket. Two M6 bolts should pass through slots in the fixed portion of the bracket. Ensure that the spring and plain washers of the M6 bolts are on the outside of the bracket assembly. Tighten the four M6 bolts to ensure that the bracket cannot open accidentally.

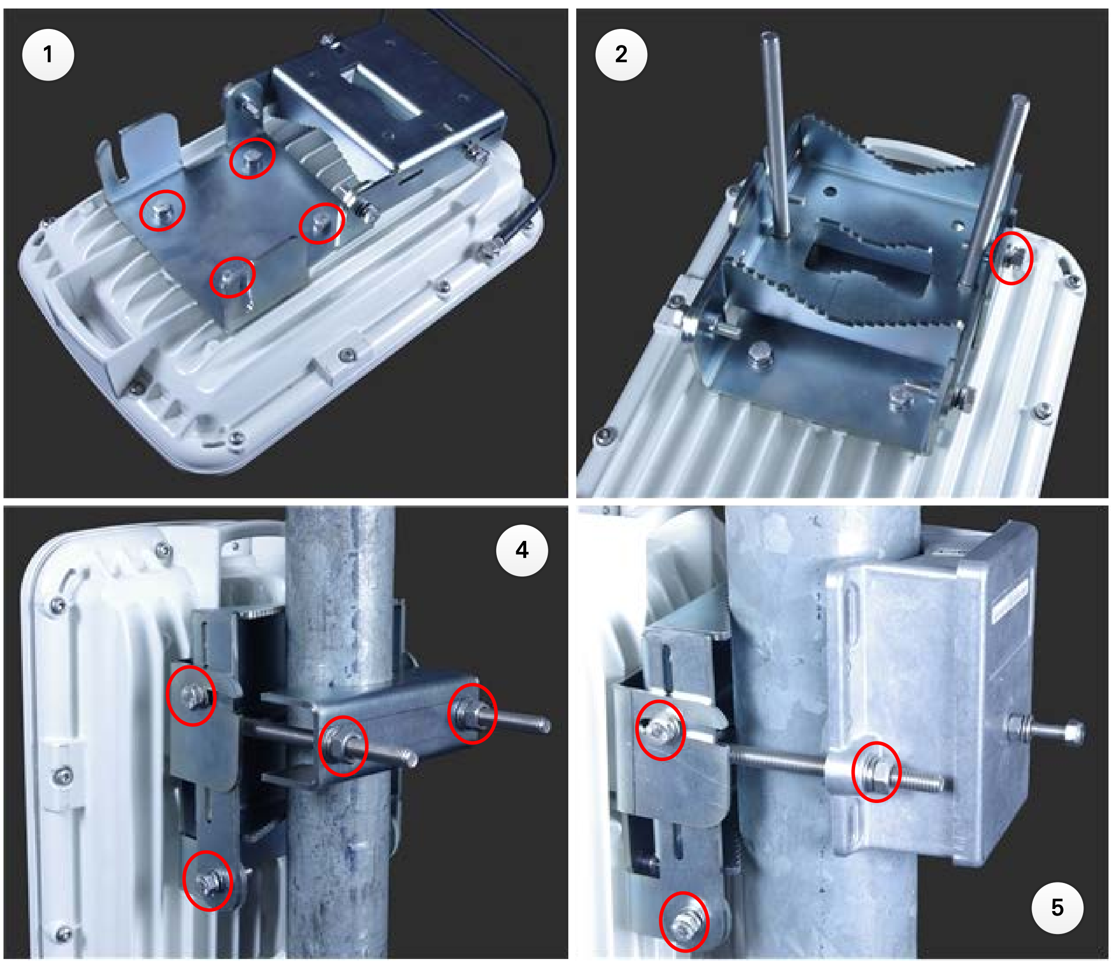
3 Hoist the ODU to the mounting position.

4 Attach the bracket to the pole using the bracket clamp, washers and M8 nuts.

5 Alternatively, use the LPU in place of the clamp to provide a back-to-back arrangement.

6 Adjust the azimuth to achieve visual alignment. Tighten the two M8 bracket nuts to a torque setting of 8.0 Nm (6.0 lb ft). Do not over-tighten these nuts as this may lead to failure of the assembly.

7 Adjust the elevation to achieve visual alignment. Tighten the four M6 bolts to a torque setting of 5.0 Nm (3.7 lb ft).



Low profile bracket on large pole

1 Fix the low profile bracket to the back of the ODU using the M6 bolts and washers provided. Tighten the four bolts to a torque setting of 5.0 Nm (3.7 lb ft). This step is common with the low profile bracket on a smaller diameter pole.

2 Close the bracket. Two M6 bolts should pass through slots in the fixed portion of the bracket. Ensure that the spring and plain washers of the M6 bolts are on the outside of the bracket assembly. Tighten the four M6 bolts to ensure that the bracket cannot open accidentally. Feed the Jubilee straps through the slots in the adaptor plate. This is similar to the procedure for the large diameter extension kit.

3 Hoist the ODU to the mounting position.

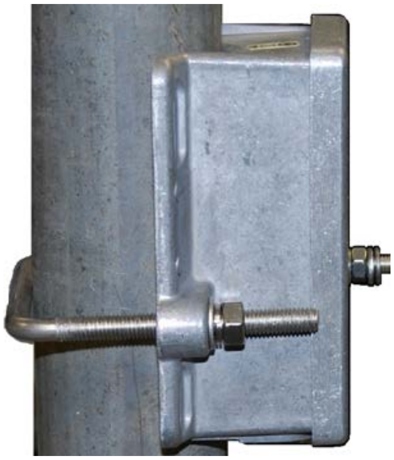
4 Attach the bracket to the pole using the Jubilee straps.

5 Adjust the azimuth to achieve visual alignment. Tighten the Jubilee straps to a torque setting of 6.0 Nm (4.5 lb ft).

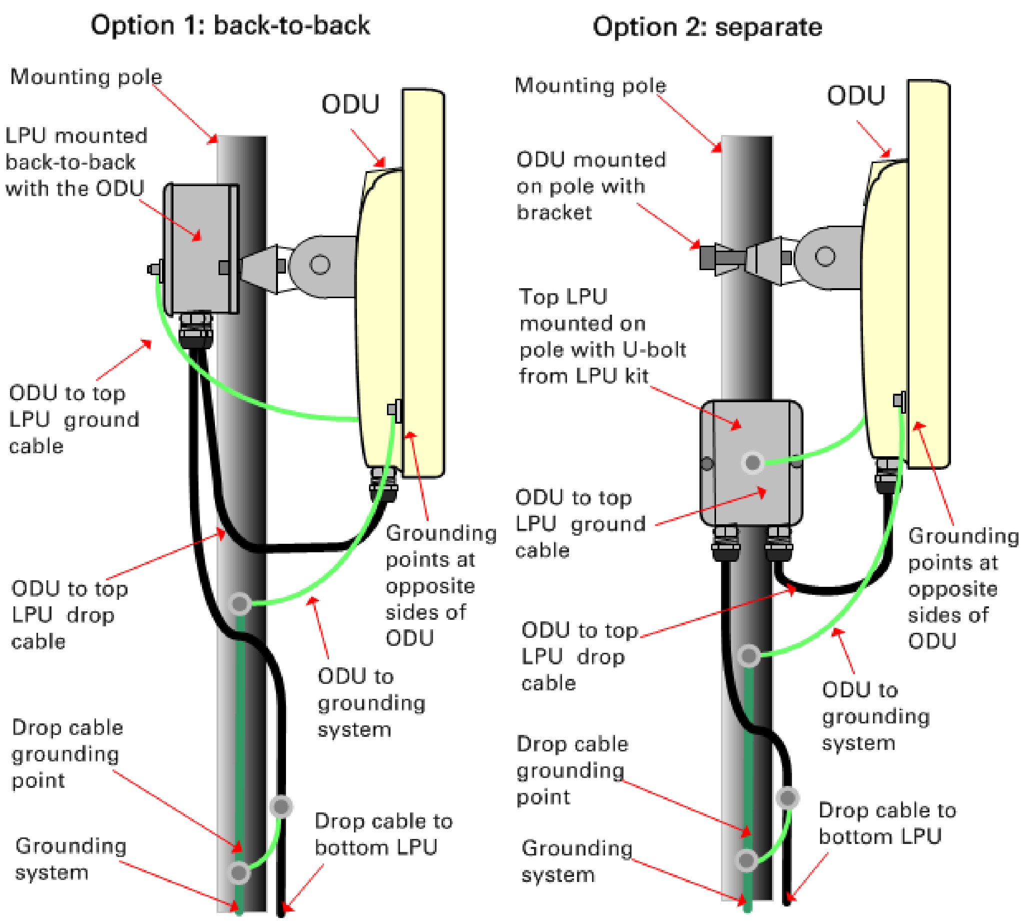
6 Adjust the elevation to achieve visual alignment. Tighten the four M6 bolts to a torque setting of 5.0 Nm (3.7 lb ft).

Mount the top LPU

1 For separate LPU mounting, use the U-bolt bracket from the LPU kit to mount the top LPU on the pole below the ODU. Tighten to a torque setting of 7.0 Nm (5.2 lb ft):



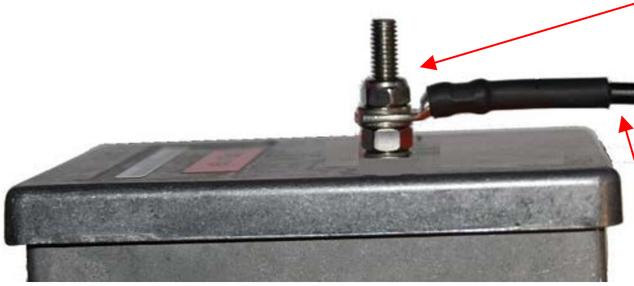
Interconnect and ground the ODU and top LPU



Caution

Do not attach grounding cables to the ODU mounting bracket bolts, as this arrangement will not provide full protection.

1 Fasten the ODU grounding cable to the top LPU using the M6 (small) lug. Tighten both nuts to a torque of 5 Nm (3.9 lb ft):



2 Select a tower or building grounding point within 0.3 meters (1 ft) of the ODU bracket. Remove paint from the surface and apply anti-oxidant compound. Fasten the ODU grounding cable to this point using the M10 (large) lug.

3 If local regulations mandate the independent grounding of all devices, add a third ground cable to connect the top LPU directly to the grounding system.

Install external antennas for a connectorized ODU

To mount and connect an external antenna for the connectorized ODU, proceed as follows:

1 Mount the antenna(s) according to manufacturer's instructions. When using separate antennas to achieve spatial diversity, mount one with Horizontal polarization and the other with Vertical polarization.

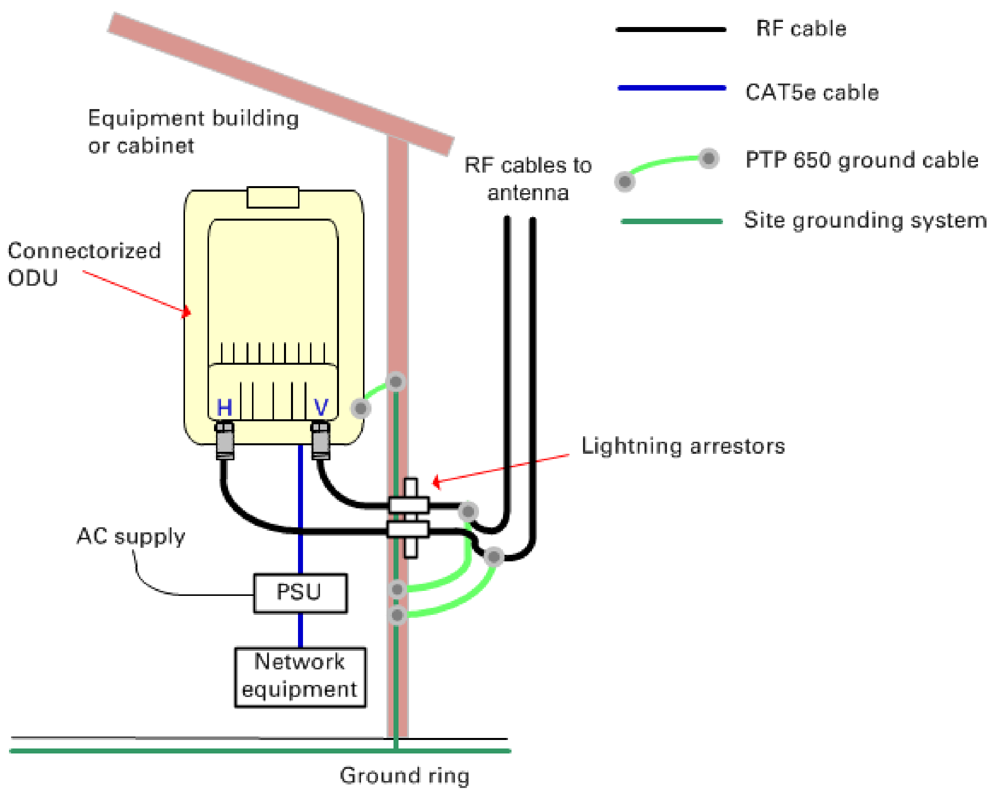
2 Connect the ODU V and H interfaces to the antenna(s) with RF cable of type LMR-400 (Cambium part numbers 30010194001 and 30010195001) and N type connectors (Cambium part number 09010091001). Tighten the N type connectors to a torque setting of 1.7 Nm (1.3 lb ft).

3 If the ODU is mounted indoors, install lightning arrestors at the building entry point:

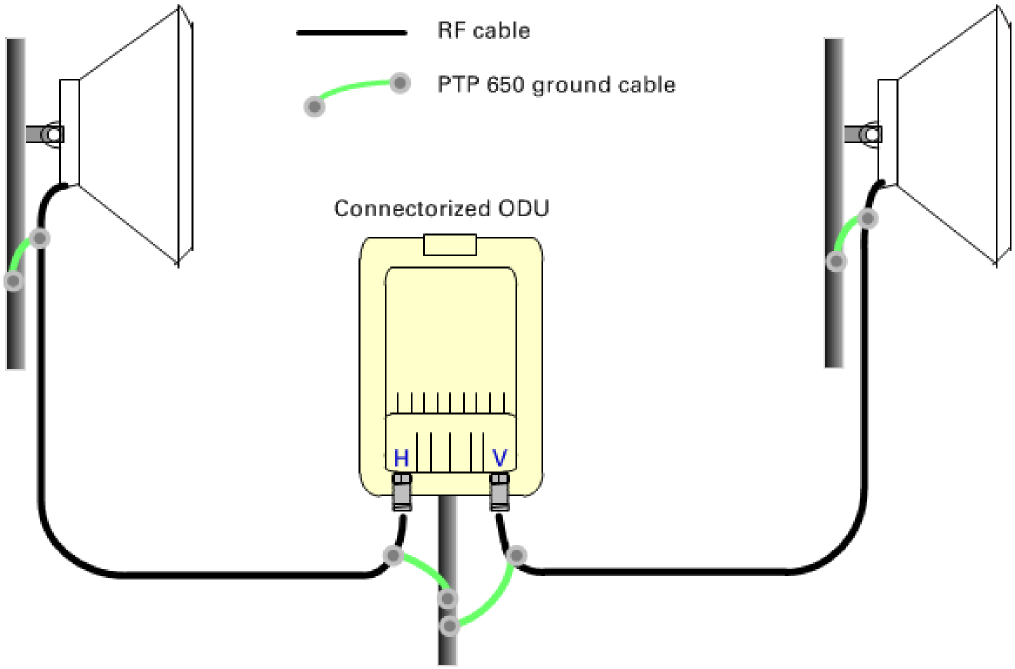
4 Form drip loops near the lower ends of the antenna cables. These ensure that water is not channeled towards the connectors.

5 If the ODU is mounted outdoors, weatherproof the N type connectors (when antenna alignment is complete) using PVC tape and self-amalgamating rubber tape.

6 Weatherproof the antenna connectors in the same way (unless the antenna manufacturer specifies a different method).



7 Ground the antenna cables to the supporting structure within 0.3 meters (1 foot) of the ODU and antennas using the Cambium grounding kit (part number 01010419001):



8 Fix the antenna cables to the supporting structure using site approved methods. Ensure that no undue strain is placed on the ODU or antenna connectors. Ensure that the cables do not flap in the wind, as flapping cables are prone to damage and induce unwanted vibrations in the supporting structure.

Installing the copper Cat5e Ethernet interface

To install the copper Cat5e Ethernet interface, use the following procedures:

- Install the ODU to top LPU drop cable on page 5-18
- Install the main drop cable on page 5-20
- Install the bottom LPU to PSU drop cable on page 5-23
- Test resistance in the drop cable on page 5-25

Caution

To avoid damage to the installation, do not connect or disconnect the drop cable when power is applied to the PSU or network terminating equipment.

Caution

Do not connect the SFP or Aux drop cables to the PSU, as this may damage equipment.

Caution

Always use Cat5e cable that is gel-filled and shielded with copper-plated steel. Alternative types of Cat5e cable are not supported by Cambium Networks. Cambium Networks supply this cable (Cambium part numbers WB3175 and WB3176), RJ45 connectors (Cambium part number WB3177) and a crimp tool (Cambium part number WB3211). The LPU and grounding kit contains a 600 mm length of this cable.

Install the ODU to top LPU drop cable

Fit glands to the ODU to top LPU drop cable

Fit EMC strain relief cable glands (with black caps) to both ends of the 600 mm length of pre-terminated cable. These parts are supplied in the LPU and grounding kit.

1. Disassemble the gland and thread each part onto the cable (the rubber bung is split). Assemble the spring clip and the rubber bung:

2 Fit the parts into the body and lightly screw on the gland nut (do not tighten it):

Connect the drop cable to the ODU (PSU port) and LPU

1 (a) Plug the RJ45 connector into the socket in the unit, ensuring that it snaps home.
(b) Fit the gland body to the RJ45 port and tighten it to a torque of 5.5 Nm (4.3 lb ft):

(a)

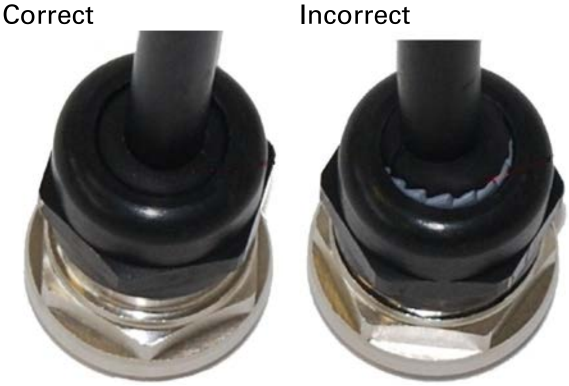
(b)

2 (a) Fit the gland nut and tighten until the rubber seal closes on the cable. (b) Do not over-tighten the gland nut, as there is a risk of damage to its internal components:

(a)

(b)

Correct Incorrect



Disconnect the drop cable from the LPU or ODU

Use this procedure if it is necessary to remove an EMC strain relief cable gland and RJ45 connector from the ODU (as illustrated) or LPU.

1 (a) Remove the gland nut. Wiggle the drop cable to release the tension of the gland body. When the tension in the gland body is released, a gap opens at the point show. Unscrew the gland body.
(b) Use a small screwdriver to press the RJ45 locking tab, then remove the RJ45 connector.

(a)

(b)

Install the main drop cable

Warning

The metal screen of the drop cable is very sharp and may cause personal injury.

- ALWAYS wear cut-resistant gloves (check the label to ensure they are cut resistant).
- ALWAYS wear protective eyewear.
- ALWAYS use a rotary blade tool to strip the cable (DO NOT use a bladed knife).

Warning

Failure to obey the following precautions may result in injury or death:

- Use the proper hoisting grip for the cable being installed. If the wrong hoisting grip is used, slippage or insufficient gripping strength will result.
- Do not reuse hoisting grips. Used grips may have lost elasticity, stretched, or become weakened. Reusing a grip can cause the cable to slip, break, or fall.
- The minimum requirement is one hoisting grip for each 60 m (200 ft) of cable.

Cut to length and fit hoisting grips

1 Cut the main drop cable to length from the top LPU to the bottom LPU.

2 Slide one or more hoisting grips onto the top end of the drop cable.

3 Secure the hoisting grip to the cable using a special tool, as recommended by the manufacturer.

Terminate with RJ45 connectors and glands

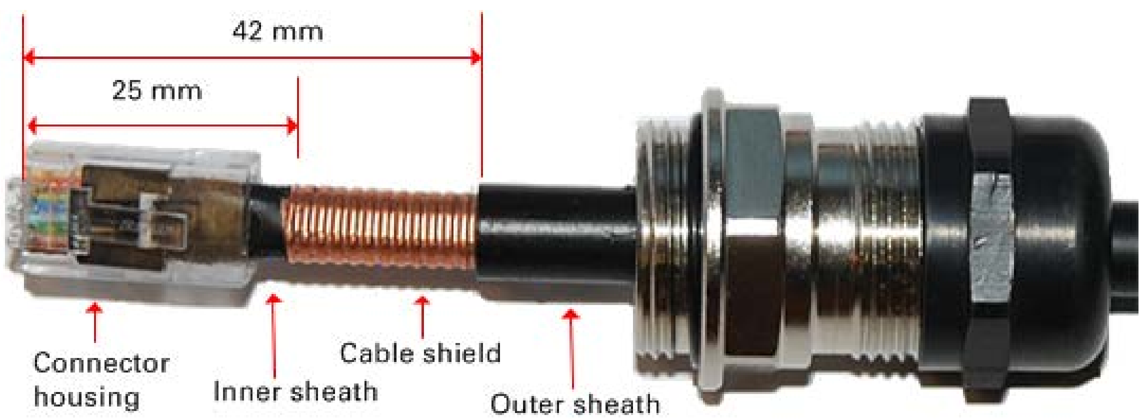
Caution

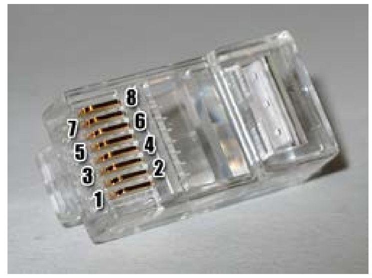
Check that the crimp tool matches the RJ45 connector, otherwise the cable or connector may be damaged.

1 Thread the cable gland (with black cap) onto the main drop cable.

2 Strip the cable outer sheath and fit the RJ45 connector load bar.

3 Fit the RJ45 connector housing as shown. To ensure there is effective strain relief, locate the cable inner sheath under the connector housing tang. Do not tighten the gland nut:



Pin	Color (Supplied cable)	Color (Conventional)	Pins on plug face
1	Light Orange	White/Orange	
2	Orange	Orange	
3	Light Green	White/Green	
4	Blue	Blue	
5	Light Blue	White/Blue	
6	Green	Green	
7	Light Brown	White/Brown	
8	Brown	Brown	

Hoist and fix the main drop cable

Warning

Failure to obey the following precautions may result in injury or death:

- Use the hoisting grip to hoist one cable only. Attempting to hoist more than one cable may cause the hoisting grip to break or the cables to fall.
- Do not use the hoisting grip for lowering cable unless the clamp is securely in place.
- Maintain tension on the hoisting grip during hoisting. Loss of tension can cause dangerous movement of the cable and result in injury or death to personnel.
- Do not release tension on the grip until after the grip handle has been fastened to the supporting structure.
- Do not apply any strain to the RJ45 connectors.

Caution

Do not lay the drop cable alongside a lightning air terminal.

1. Hoist the top end of the main drop cable up to the top LPU, following the hoist manufacturer's instructions. When the cable is in position, fasten the grip handle to the supporting structure and remove the hoist line.
2. Connect the main drop cable to the top LPU by following the procedure Connect the drop cable to the ODU (PSU port) and LPU on page 5-19.
3. Run the main drop cable to the site of the bottom LPU.
4. Attach the main drop cable to the supporting structure using site approved methods.

Ground the main drop cable

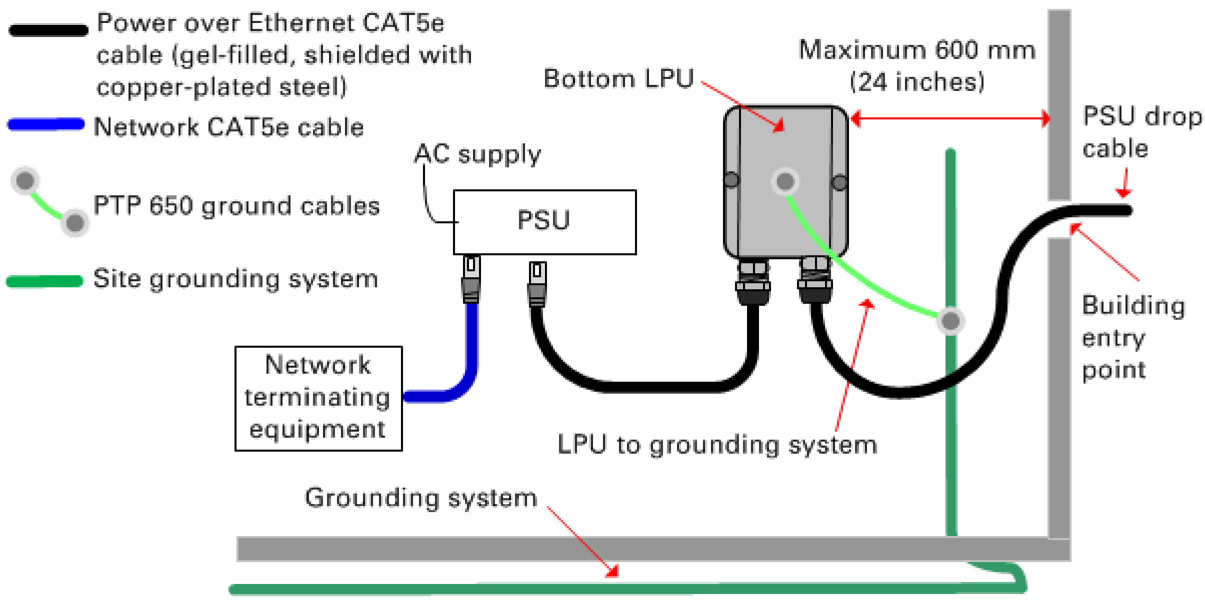
At all required grounding points, connect the screen of the main drop cable to the metal of the supporting structure using the cable grounding kit (Cambium part number 01010419001).

Install the bottom LPU to PSU drop cable

Install the bottom LPU

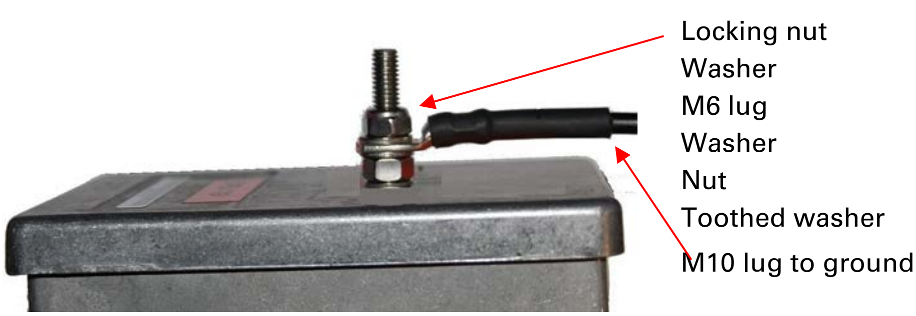
Install the bottom LPU, ground it, and connect it to the main drop cable.

1 Select a mounting point for the bottom LPU within 600 mm (24 in) of the building entry point. Mount the LPU vertically with cable glands facing downwards.



2 Connect the main drop cable to the bottom LPU by following the procedure Connect the drop cable to the ODU (PSU port) and LPU on page 5-19.

3 Fasten one ground cable to the bottom LPU using the M6 (small) lug. Tighten both nuts to a torque of 5 Nm (3.9 lb ft):



4 Select a building grounding point near the LPU bracket. Remove paint from the surface and apply anti-oxidant compound. Fasten the LPU ground cable using the M10 (large) lug.

Install the LPU to PSU drop cable

Use this procedure to terminate the bottom LPU to PSU drop cable with RJ45 connectors at both ends, and with a cable gland at the LPU end.

Warning

The metal screen of the drop cable is very sharp and may cause personal injury. ALWAYS wear cut-resistant gloves (check the label to ensure they are cut resistant). ALWAYS wear protective eyewear. ALWAYS use a rotary blade tool to strip the cable, not a bladed knife.

Caution

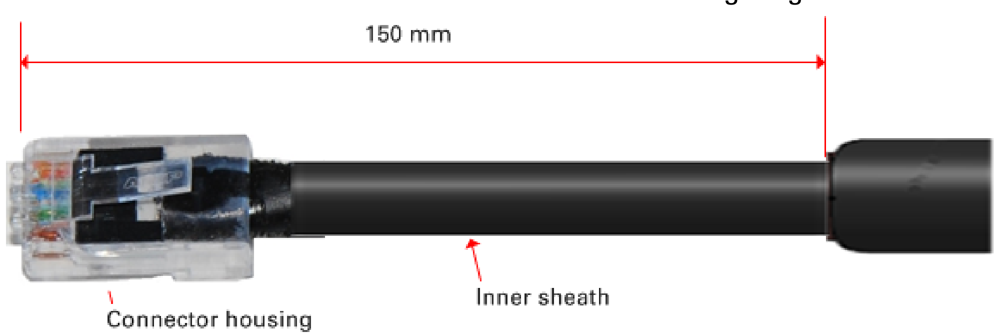
Check that the crimp tool matches the RJ45 connector, otherwise the cable or connector may be damaged.

1 Cut the drop cable to the length required from bottom LPU to PSU.

2 **At the LPU end only**:

- Fit one cable gland and one RJ45 connector by following the procedure Terminate with RJ45 connectors and glands on page 5-21.
- Connect this cable and gland to the bottom LPU by following the procedure Connect the drop cable to the ODU (PSU port) and LPU on page 5-19.

4 **At the PSU end only**: Do not fit a cable gland. Strip the cable outer sheath and fit the RJ45 connector load bar. Fit the RJ45 connector housing. To ensure there is effective strain relief, locate the cable inner sheath under the connector housing tang:



Test resistance in the drop cable

Connect the bottom end of the copper Cat5e drop cable to a PTP drop cable tester and test that the resistances between pins are within the correct limits, as specified in the table below. If any of the tests fail, examine the drop cable for wiring faults. Order the PTP drop cable tester from the support website (http://www.cambiumnetworks.com/support).

Measure the resistance between…	Enter measured resistance	To pass test, resistance must be…	Circle "Pass" or "Fail"	Additional tests and notes
Pins 1 and 2	Ohms	<20 Ohms (60 Ohms) (*1)	Pass Fail	Resistances must be within 10% of each other (*2). Circle "Pass" or "Fail": Pass Fail
Pins 3 and 6	Ohms	<20 Ohms (60 Ohms) (*1)	Pass Fail	
Pins 4 and 5	Ohms	<20 Ohms (60 Ohms) (*1)	Pass Fail	
Pins 7 and 8	Ohms	<20 Ohms (60 Ohms) (*1)	Pass Fail	
Pin 1 and screen (ODU ground)	K Ohms	>100K Ohms	Pass Fail	These limits apply regardless of cable length.
Pin 8 and screen (ODU ground)	K Ohms	>100K Ohms	Pass Fail	

(*1) A resistance of 20 Ohms is the maximum allowed when the cable is carrying Ethernet. A resistance of 60 Ohms is the maximum allowed when the cable is carrying only power to the ODU (when Ethernet is carried by one of the other ODU interfaces).

(*2) Ensure that these resistances are within 10% of each other by multiplying the lowest resistance by 1.1 – if any of the other resistances are greater than this, the test has failed.

Installing the PSU

Install one of the following types of PSU (as specified in the installation plan):

- PTP 650 AC Power Injector (Cambium part number N000065L001). Refer to Installing the AC Power Injector on page 5-26.
- PTP 650 AC+DC Enhanced Power Injector (Cambium part number C000065L002). Refer to Installing the AC+DC Enhanced Power Injector on page 5-27.

Caution

As the PSU is not waterproof, locate it away from sources of moisture, either in the equipment building or in a ventilated moisture-proof enclosure. Do not locate the PSU in a position where it may exceed its temperature rating.

Caution

Do not plug any device other than a PTP 650 ODU into the ODU port of the PSU. Other devices may be damaged due to the non-standard techniques employed to inject DC power into the Ethernet connection between the PSU and the ODU.

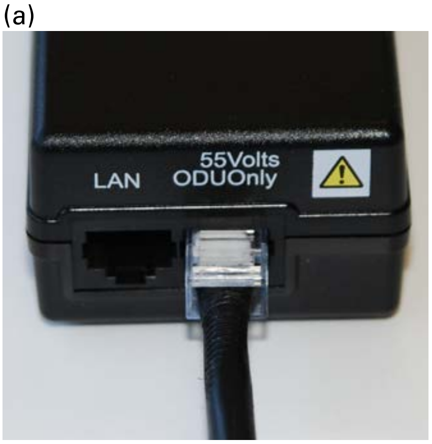
Do not plug any device other than a Cambium PTP 650 PSU into the PSU port of the ODU. Plugging any other device into the PSU port of the ODU may damage the ODU and device.

Installing the AC Power Injector

Follow this procedure to install the AC Power Injector (Cambium part number N000065L001):

1. Form a drip loop on the PSU end of the LPU to PSU drop cable. The drip loop ensures that any moisture that runs down the cable cannot enter the PSU.
2. (a) Place the AC Power Injector on a horizontal surface. Plug the LPU to PSU drop cable into the PSU port labeled ODU. (b) When the system is ready for network connection, connect the network Cat5e cable to the LAN port of the PSU:

(a)

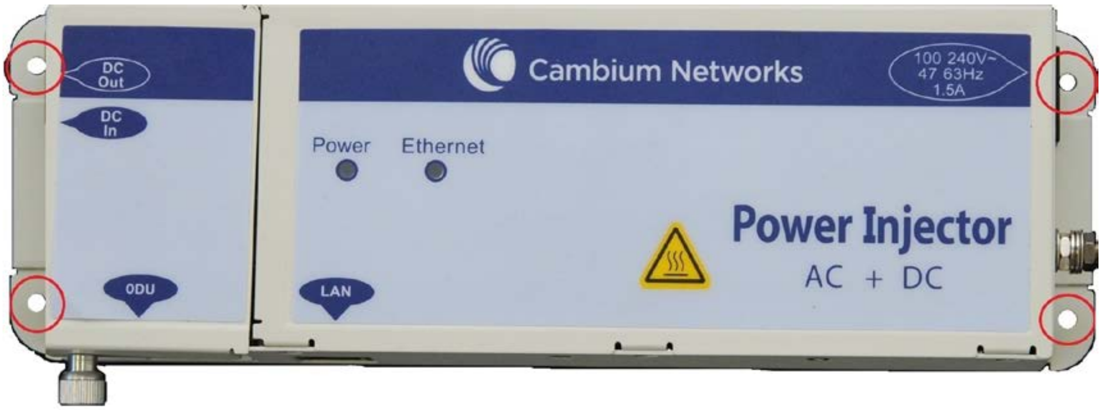


(b)

Installing the AC+DC Enhanced Power Injector

Follow this procedure to install the AC+DC Enhanced Power Injector (Cambium part number C000065L002):

1. Mount the AC+DC power injector by screwing it to a vertical or horizontal surface using the four screw holes (circled):



2. Form a drip loop on the PSU end of the LPU to PSU drop cable. The drip loop ensures that any moisture that runs down the cable into the cabinet or enclosure cannot enter the PSU.

3. (a) Undo the retaining screw, hinge back the cover and plug the drop cable or the cable from the PTP-SYNC into the port. (b) Close the cover and secure with the screw. (c) When the system is ready for network connection, connect the network Cat5e cable to the LAN port of the PSU:

(a)

(b) and (c)

Installing a PTP-SYNC unit

To install a PTP-SYNC unit (for TDD synchronization), use the following procedures:

- Mounting the PTP-SYNC unit on page 5-28
- Connecting up the PTP-SYNC unit on page 5-29
- Powering up the PTP-SYNC installation on page 5-31

Caution

The PTP-SYNC unit must be installed indoors in a non-condensing environment, otherwise it will be prone to water damage.

Caution

To protect the PTP-SYNC from damage, disconnect the power supply from the PSU before connecting up the PTP-SYNC.

Mounting the PTP-SYNC unit

Use this procedure to install the PTP-SYNC unit in the equipment building, either in a rack or on a wall.

- Racking mounting option: fix the PTP-SYNC to the rack mount using the M3 screws from the rack mount installation kit (Figure 110).
- Wall mounting option: mount the PTP-SYNC vertically with interfaces and cabling facing downwards (Figure 111).

Figure 110 PTP-SYNC mounted in a rack

Figure 111 PTP-SYNC mounted on a wall

Connecting up the PTP-SYNC unit

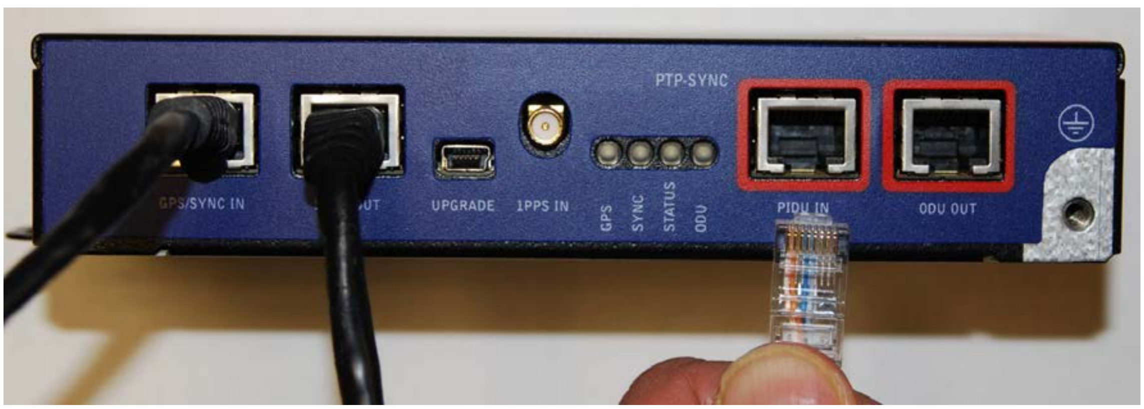
Use this procedure to connect the PTP-SYNC to the AC+DC Power Injector, ODU, GPS receiver (if fitted), and LPU (if fitted).

1 Disconnect the power supply from the AC+DC Power Injector.

2 If using GPS, connect the cable from the GPS unit to the GPS/SYNC IN port.

3 To link clustered PTP-SYNC units, connect the SYNC OUT port of the first PTP-SYNC to the GPS/SYNC IN port of the second PTP-SYNC in the chain. Repeat for subsequent PTP-SYNC units in the chain.

4 Connect the cable from the PSU to the PIDU IN port. A suitable 1 meter cable is included in the PTP-SYNC kit.



5 Connect the cable from the ODU to the ODU OUT port.

6 Use a grounding cable to connect the ground stud of the PTP-SYNC to the master ground bar of the building, or to the rack ground bar.

Powering up the PTP-SYNC installation

Use this procedure to power up the PTP-SYNC installation.

Caution

Ensure that all cables are connected to the correct interfaces of the PTP SYNC unit and the GPS receiver (if used). Ensure that the installation is correctly grounded Failure to do so may result in damage to the equipment.

1 Connect the power supply to the PSU.

2 Within 90 seconds, the PTP-SYNC STATUS LED should blink once every second to show that satellite lock has been achieved.

3 If the system does not operate correctly, refer to Testing PTP-SYNC on page 8-15.

Installing a GPS receiver

To install a GPS receiver as the timing reference source for PTP-SYNC, use the following procedures:

- Mounting the GPS receiver on page 5-32
- Preparing the GPS drop cable on page 5-32
- Assembling an RJ45 plug and housing for GPS on page 5-33
- Assembling a 12 way circular connector on page 5-35
- Connecting the GPS drop cable on page 5-39
- Top grounding point for GPS adapter cable on page 5-40
- Installing and connecting the GPS LPU on page 5-41

Caution

Prior to power-up of equipment, ensure that all cables are connected to the correct interfaces of the PTP-SYNC unit and the GPS receiver module. Failure to do so may result in damage to the equipment.

Mounting the GPS receiver

Mount the GPS receiver (following manufacturer's instructions) upon either an external wall (Figure 41) or a metal tower or mast (Figure 42).

Preparing the GPS drop cable

Use this procedure to make the main drop cable that will connect the GPS receiver to its bottom LPU. GPS drop cables do not require top LPUs.

Caution

Always use Cat5e cable that is gel-filled and shielded with copper-plated steel. Alternative types of cable are not supported by Cambium.

1. Measure the distance from the GPS receiver to the LPU site at building entry.
2. Cut the required length of drop cable.
3. Attach one or more hoisting grips to the top end of the cable, as described in Install the main drop cable on page 5-20.

4 Fit a suitable GPS connector to the top end of the drop cable:

- If a GPS adapter cable kit is available, attach the plug housing and an RJ45 plug to the top end of the main GPS drop cable, as described in Assembling an RJ45 plug and housing for GPS on page 5-33.
- If a GPS adapter cable kit is not available, fit a 12 way circular connector to the top end of the main drop cable as described in Assembling a 12 way circular connector on page 5-35.

5 Hoist the GPS drop cable safely up a tower or building, as described in Install the main drop cable. on page 5-20.

Assembling an RJ45 plug and housing for GPS

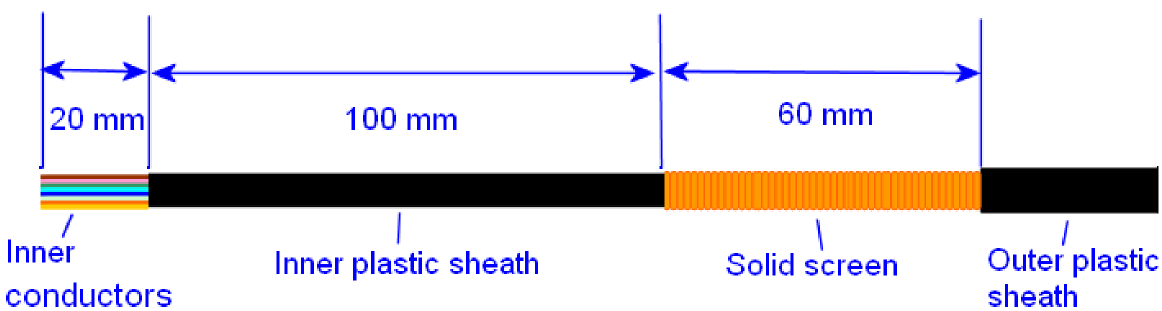
Use this procedure to assemble the plug housing over the end of the drop cable. This procedure is only performed when a GPS adapter cable kit is available. This kit is used to connect the Trimble Acutime™ GG GPS receiver or the Trimble Acutime™ Gold GPS receiver to the GPS drop cable.

The kit contains an adapter cable (GPS receiver circular connector to RJ45 socket) and an RJ45 plug housing. The plug housing should be assembled over the end of the drop cable to provide a sealed connection to the adapter cable.

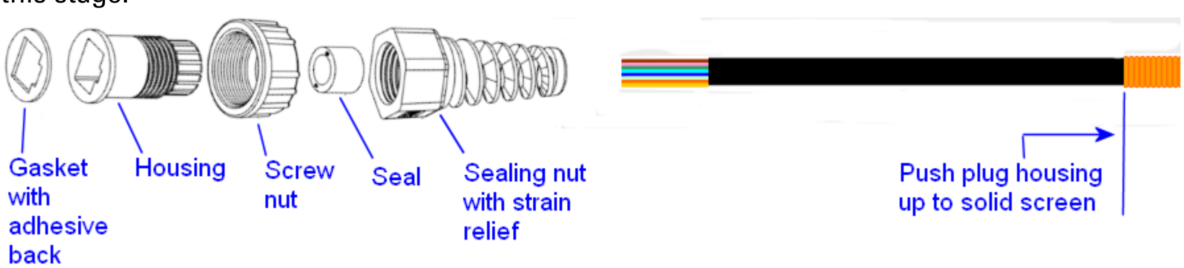
Note

These instructions are for the preparation of the Cambium-supplied drop cable type (Superior Essex BBDGE). Other types of cable may need different preparation methods.

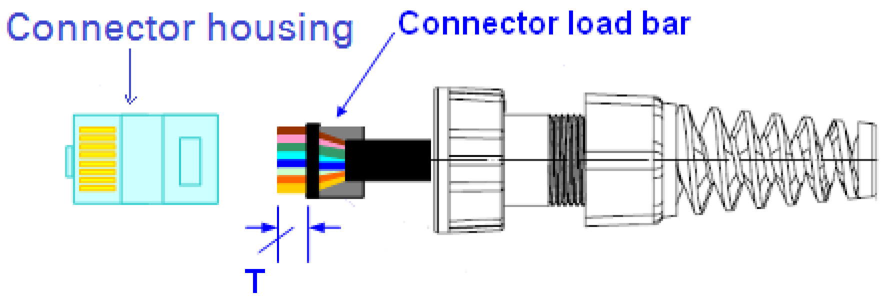
1 Prepare the top end of the GPS drop cable.



2 Install plug housing from the converter kit onto the prepared cable. Do not tighten the nuts at this stage.



3 Install the RJ45 crimp plug.



Start with tails over-length to assist insertion into load bar, then trim them to 5 mm (T).
Connect the RJ45 pins to the following conductors (Superior Essex BBDGe colors):

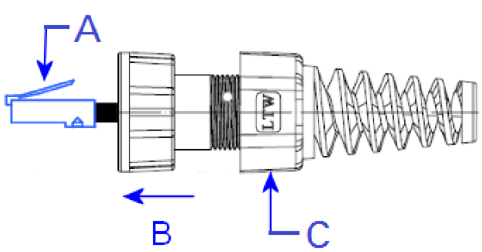
Pin 8 Brown
Pin 7 Light Brown
Pin 6 Green
Pin 5 Light Blue
Pin 4 Blue
Pin 3 Light Green
Pin 2 Orange
Pin 1 Light Orange

4 Assemble plug housing:

Depress the RJ45 locking tab (A).

Slide the plug housing assembly (B) over the RJ45 plug.

Tighten the sealing nut (C). This is easier to fully tighten when the plug housing is mated to the socket of the adapter cable.



5 Check the assembly. This is an exampled of an assembled plug housing on the end of a drop cable:

Assembling a 12 way circular connector

Use this procedure to connect the GPS drop cable to a 12 way circular connector. This procedure is only performed when a GPS adapter cable kit is NOT available.

Note

This procedure requires a soldering iron and solder.

Caution

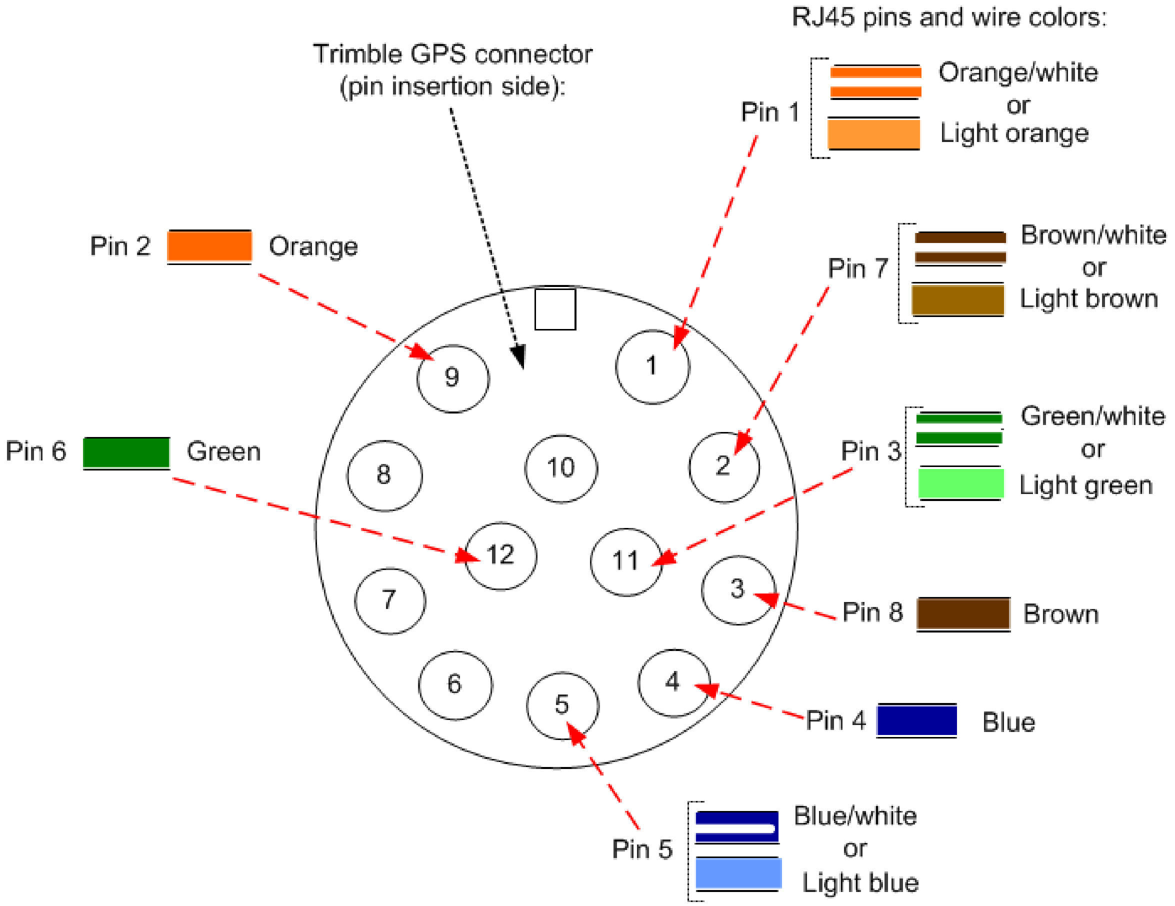
The drop cable has solid copper conductors. There are a limited number of times each conductor can be bent before it fatigues and fails.

Table 122 shows how the 12 way circular connector locations map to the PTP-SYNC RJ45 pins. Figure 112 illustrates this mapping.

Table 122 GPS 12 way circular connector to RJ45 pin mappings

GPS connector location	Function	Cat5e wire color		PTP-SYNC (J10) RJ45 pin	PTP-SYNC signal name
		Conventional	Supported drop cable		
1	DC Pwr (12V)	Orange/White	Light Orange	1	12VGPS
2	RxB-	Brown/White	Light Brown	7	GPS_TXDA
3	RxB+	Brown	Brown	8	GPS_TXDB
4	TxB-	Blue	Blue	4	GPS_RXDA
5	TxB+	Blue/White	Light Blue	5	GPS_RXDB
6	RxA-	N.C	N.C	---	
7	RxA+	N.C	N.C	---	
8	TxA-	N.C	N.C	---	
9	DC Ground	Orange	Orange	2	GND
10	TxA+	N.C	N.C	---	
11	Tx1PPS+	Green/White	Light Green	3	GPS_1PPSA
12	Tx1PPS-	Green	Green	6	GPS_1PPSB

Figure 112 Inserting RJ45 pins into the 12 way circular connector



1 Prepare the drop cable end as follows:

- Bare back the cable outer and copper screen to 50mm.
- Bare back the cable inner to 17mm.
- Un-twist the cable pairs.
- Strip the individual conductors to 5mm.

2 Fit the plug outer, associated boot, and boot insert.

3 Connect the socket contacts using either of the following techniques:

- **Crimp**: Crimp the socket contacts onto each of the conductors using the correct crimp tool and positioner, setting the wire size selector to “3” for 24AWG wire.

- **Solder**: When soldering the socket contacts onto each of the conductors, ensure that there is no solder or flux residue on the outside of the contact. Care should also be taken that the individual conductor insulation does not peel back with the soldering heat, allowing possible shorts when assembled into the plug shell.

4 Fit four dummy contacts into the unused 12 way circular connector locations (6, 7, 8 and 10), to provide strength and sealing. Push the contacts in from the pin insertion side.

Pin insertion side: Plug mating side:

5 Insert the eight RJ45 contact pins into the pin insertion side of the 12 way circular connector in accordance with Figure 112.

It is easiest to insert the pins from the center out, in descending order of Trimble location number, that is, 12, 11, 9, 5, 4, 3, 2, 1. Push the contacts in so that the shoulder on the contact fits into the hole in the plug shell. When all contacts have been fitted, push them in further to engage with the locking mechanism in the plug shell. This can be done by applying pressure to the contact with a small diameter stiff object, such as tweezers.

Note

If a contact is pushed in to the point where the locking mechanism engages before all of the contacts have been inserted it will limit the amount of room available to fit the remaining contacts, requiring harder bends to be applied.

6 Fit the plug to its shell. The plastic ring fits inside the rubber boot and ensures a tight fit when the plug body is clipped onto the plug shell. Be aware that the plug body is a hard push fit onto the plug shell.

7 Fit the strain relief clip.

Connecting the GPS drop cable

Use this procedure to connect the GPS drop cable to the GPS unit and supporting structure.

1 If a GPS adapter cable is available, use it to connect the main GPS drop cable to the GPS unit:

2 If a GPS adapter cable is not available, connect the main GPS drop cable to the GPS unit via a 12 way circular connector. Weatherproof the connection as follows:

- Wrap a layer of self-amalgamating tape, starting 25mm below the bared back outer of the cable and finishing at the GPS housing.
- Wrap a layer of PVC tape, starting just below the start of the self-amalgamating tape and finishing at the GPS housing, overlapping at half width.
- Repeat with four more layers of PVC tape alternating the start and finish ends.

3 Lay the main drop cable as far as the building entry point, ensuring there is enough length to extend through the wall of the building to the LPU.

4 Attach the main GPS drop cable to the supporting structure using site approved methods.

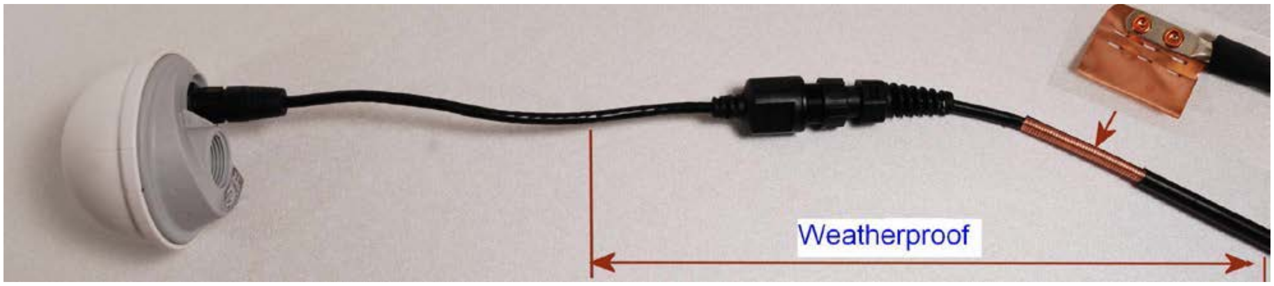
5 Ground the GPS drop cable to the supporting structure at the points shown in Figure 41 (wall installation) or Figure 42 (mast or tower installation):

- For standard grounding instructions, see Creating a drop cable grounding point on page 5-59.
- If a GPS adapter cable has been installed, see Top grounding point for GPS adapter cable on page 5-40.

Top grounding point for GPS adapter cable

If a GPS adapter cable has been installed (Figure 113), use this procedure to ground the drop cable at the point where the solid screen is already exposed, and weatherproof both the ground cable joint and the RJ45 connection.

Figure 113 Grounding and weatherproofing requirements for GPS adapter cable



Follow the procedure described in Creating a drop cable grounding point on page 5-59, but observe the following differences:

- There is no need to remove 60mm (2.5inches) of the drop cable outer sheath, as this has already been done.
- Wrap the top layer of self-amalgamating tape around the complete assembly (not just the ground cable joint), including the RJ45 connection with the GPS adapter cable (Figure 114).
- Wrap all five layers of PVC tape around the complete assembly (Figure 115). Wrap the layers in alternate directions: (1st) bottom to top; (2nd) top to bottom; (3rd) bottom to top; (4th) top to bottom; (5th) bottom to top. The edges of each layer should be 25mm (1 inch) above (A) and 25 mm (1 inch) below (B) the previous layer.
- Check that the joint between the GPS adapter cable, drop cable and ground cable is fully weatherproofed (Figure 116).

Figure 114 Wrapping self-amalgamating tape around the GPS adapter cable joint

Figure 115 Wrapping PVC tape around the GPS adapter cable joint

Figure 116 Grounding and weatherproofing example for GPS adapter cable

Installing and connecting the GPS LPU

Install and ground the GPS drop cable LPU at the building (or cabinet) entry point, and install the LPU-PTP-SYNC drop cable, as described in Install the bottom LPU on page 5-23.

Connect this cable to the PTP-SYNC unit as described in Connecting up the PTP-SYNC unit on page 5-29.

Installing a NIDU

To install a NIDU (for TDM), use the following procedures:

- Mounting the NIDU on page 5-42
- Connecting the NIDU to the PSU, LAN and TDM cables on page 5-43
- Connecting the NIDU to a DC power supply on page 5-45

Mounting the NIDU

Mount the NIDU in the equipment building, either in a rack or on a horizontal surface:

- Racking mounting option: fix the NIDU to the rack mount using the M3 screws from the rack mount installation kit (Figure 117). The rack can hold either two NIDUs or one NIDU and one PTP-SYNC unit.
- Horizontal option: place the NIDU on a horizontal surface.

Figure 117 Two NIDUs mounted in a rack

Connecting the NIDU to the PSU, LAN and TDM cables

Caution

Always connect the NIDU to the Main PSU port of the ODU via the PSU. The TDM service will not operate if the NIDU is connected to the Aux or SFP port of the ODU.

Caution

If the ODU port has negotiated a link at 100BASE-T, the NIDU will not send or receive TDM data and will not bridge customer data traffic. Ensure that the Ethernet drop cable between the ODU and the PSU, and the network cable between the PSU and the NIDU, will reliably support operation at 1000BASE-T.

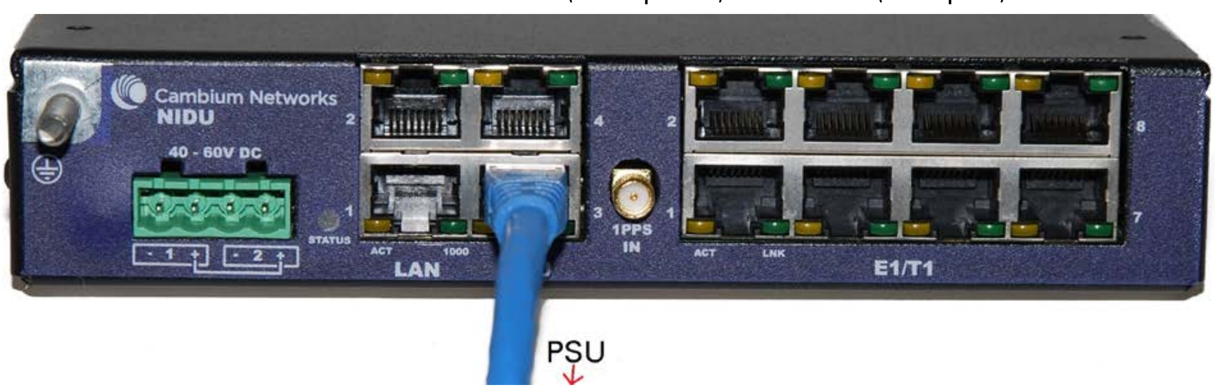
Note

Use the E1/T1 ports in ascending numeric sequence, for example: if there is one E1/T1 channel, use port 1; if are three E1/T1 channels, use ports 1, 2 and 3.

Use this procedure to connect the NIDU to the PSU, LAN and TDM transceivers.

1 Disconnect the power supply from the PSU.

2 Connect an indoor Cat5e cable from the NIDU (ODU port 3) to the PSU (LAN port):



3 Connect an indoor Cat5e cable from the NIDU (LAN port 1) to the Ethernet network terminating equipment:

4 Connect up to eight indoor Cat5e cables (with RJ48 connectors) from the NIDU (E1/T1 ports) to the local TDM transceivers:

5 Use an M5 nut and washer to connect the grounding cable lug to the NIDU ground bolt. Connect the other end of the grounding cable to the master ground bar of the building or rack.

Connecting the NIDU to a DC power supply

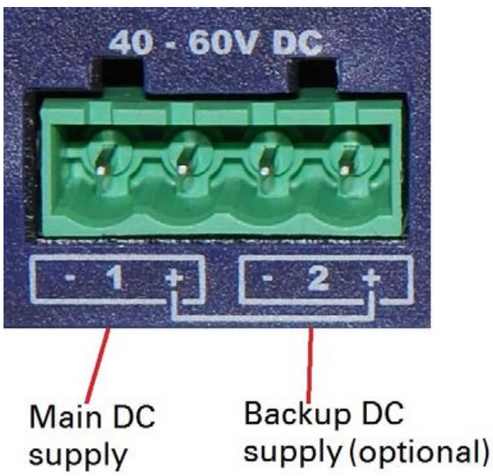
Caution

Do not power up the NIDU until site installation is complete, otherwise equipment may be damaged.

Main and backup DC supplies

The NIDU requires a 40 V – 60 V DC power supply. The NIDU DC interface provides inputs for a main and a backup DC power supply (Figure 118). The main DC supply (port 1) is mandatory, but the backup (port 2) is optional.

Figure 118 NIDU DC interface



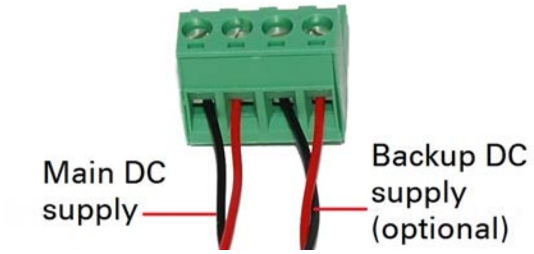
Use one of the following power supply options for the NIDU:

- The PTP 650 AC+DC Enhanced Power Injector (Cambium part number C000065L002) with optional backup.
- An independent DC supply (if available) with optional backup.
- The PTP 800 AC-DC Power Supply Converter (Cambium part number WB3622).

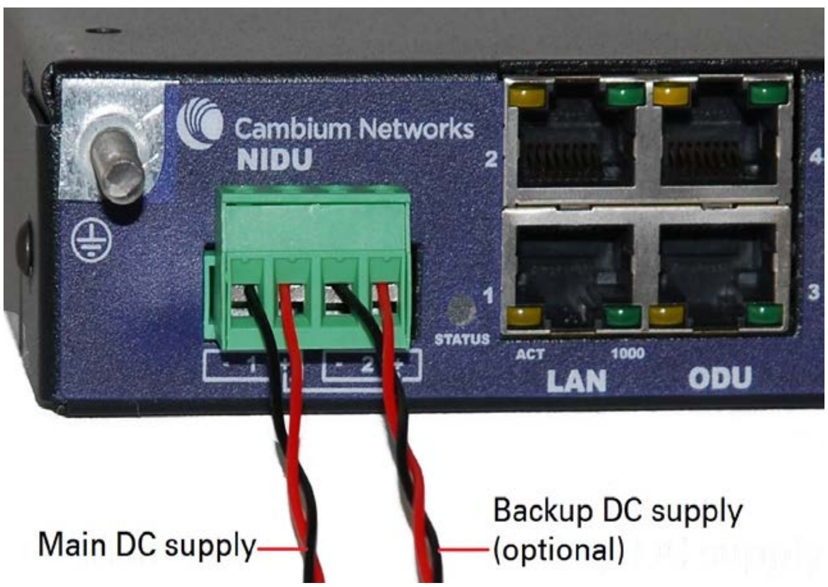
Using the DC power connector

Use this procedure to connect the NIDU to the PTP 650 AC+DC Enhanced Power Injector (Cambium part number C000065L002) or to an independent DC supply with an optional backup DC supply:

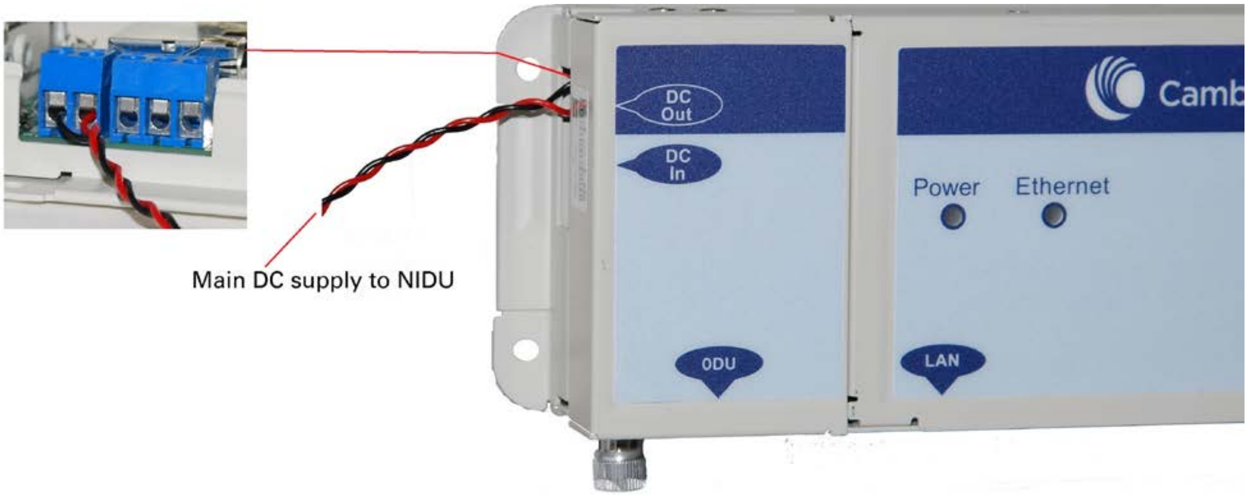
1. Strip the two wires of the main DC supply cable and screw them into the first and second terminals of the DC power connector (Cambium part number C000065L044). The first terminal is negative (black wire) and the second is positive (red wire). If a backup supply is required, use the third and fourth terminals of the connector:



2. Plug the DC power connector into the NIDU DC interface:



3 Connect the main DC supply cable to its power source. If this supply is from the AC+DC Enhanced Power Injector, the DC Out first terminal is negative (black wire) and the second is positive (red wire):



4 Connect the backup DC supply cable to its power source.

Using the PTP 800 AC-DC Power Supply Converter

If a suitable AC mains supply is available, use the PTP 800 AC-DC Power Supply Converter (Cambium part number WB3622) to power the NIDU (Figure 119). This includes a DC power connector that plugs into both ports of the NIDU DC interface.

Figure 119 NIDU powered by the PTP 800 AC-DC Power Supply Converter

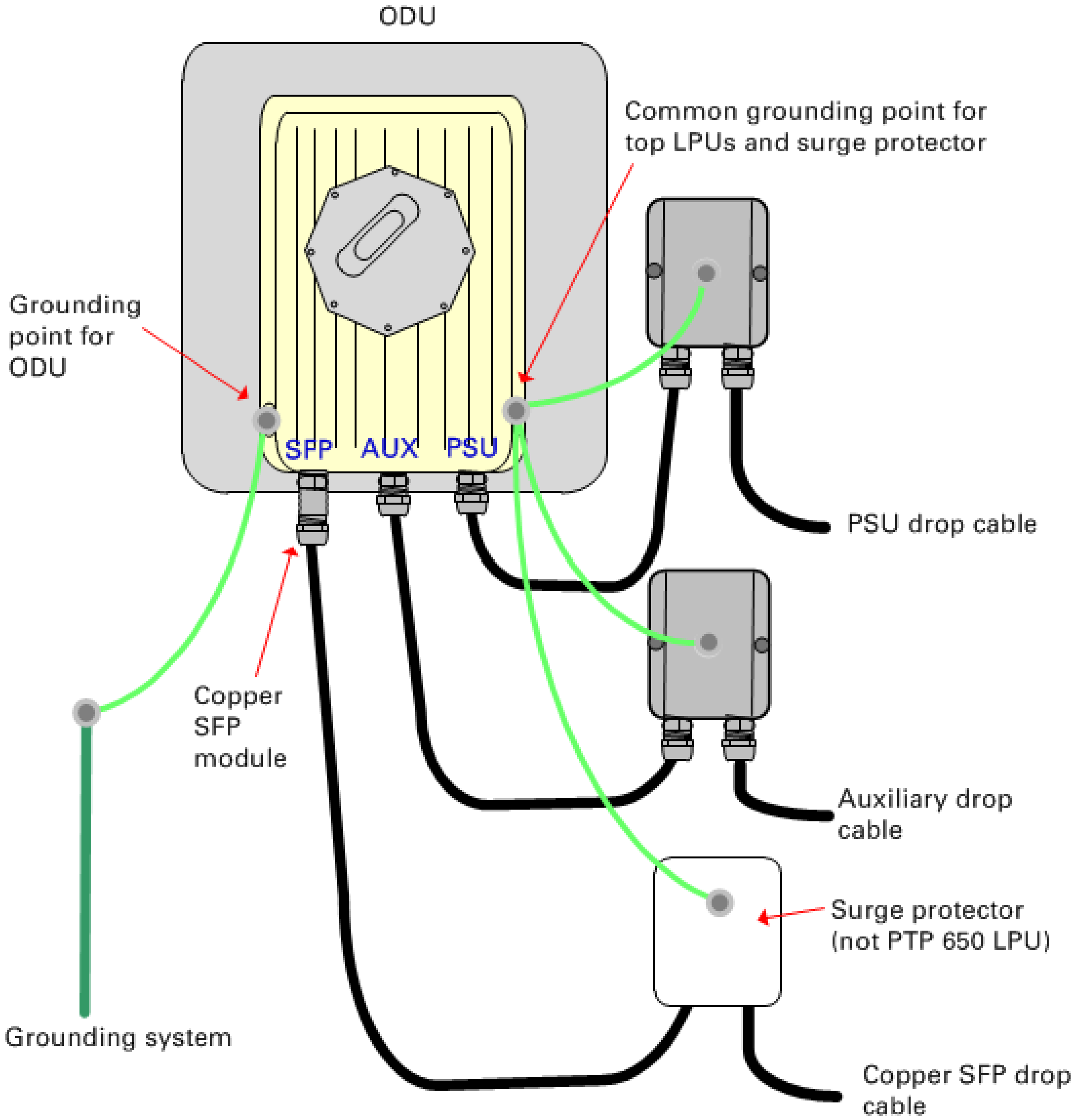
Installing an SFP Ethernet interface

In more advanced configurations, there may be an optical or copper Cat5e Ethernet interface connected to the SFP port of the ODU. Refer to Typical deployment on page 3-2 for diagrams of these configurations.

Adapt the installation procedures in this chapter as appropriate for SFP interfaces, noting the following differences from a PSU interface:

- Install an optical or copper SFP module in the ODU (SFP port) and connect the SFP optical or copper cable into this module using the long cable gland from the SFP module kit. This is described in the following procedures:
    - Fitting the long cable gland on page 5-50
    - Inserting the SFP module on page 5-51
    - Connecting the cable on page 5-53
    - Fitting the gland on page 5-54
    - Removing the cable and SFP module on page 5-56
- Optical cables do not require LPUs or ground cables.
- At the remote end of an SFP drop cable, use an appropriate termination for the connected device.
- If the connected device is outdoors, not in the equipment building or cabinet, adapt the grounding instructions as appropriate.
- PTP 650 LPUs are not suitable for installation on SFP copper Cat5e interfaces. For SFP drop cables, obtain suitable surge protectors from a specialist supplier.
- Ground the top LPUs and surge protector to the same point on the ODU (Figure 120).

Figure 120 ODU with copper Cat5e connections to all three Ethernet ports



Fitting the long cable gland

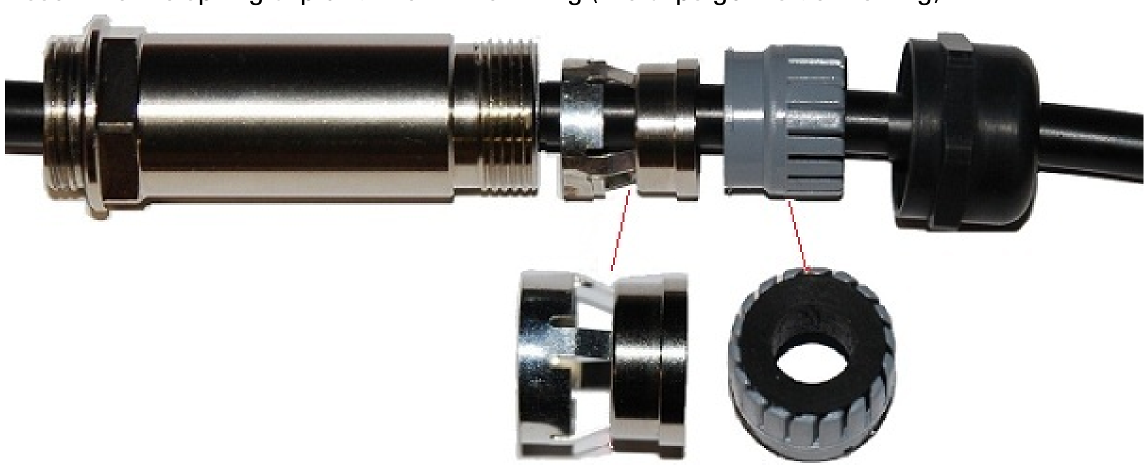
Optical SFP interface: Disassemble the long cable gland and thread its components over the LC connector at the ODU end as shown below.

Copper Cat5e SFP interface: Disassemble the long cable gland and thread its components over the RJ45 connector at the ODU end as shown below.

1 Disassemble the gland:

2 Thread each part onto the cable (the rubber bung is split):

3 Assemble the spring clip and the rubber bung (the clips go inside the ring):



4 Fit the parts into the body and lightly screw on the gland nut (do not tighten it):

Optical

Copper

Inserting the SFP module

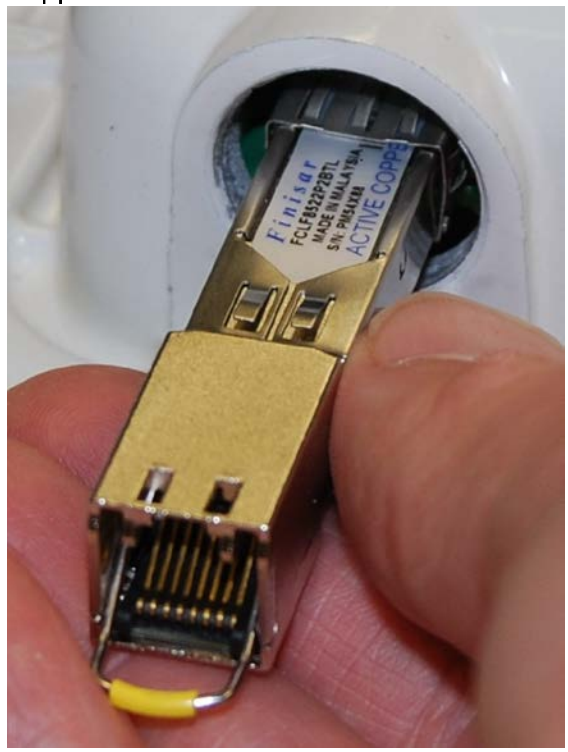
To insert the SFP module into the ODU, proceed as follows:

1 Remove the blanking plug from the SFP port of the ODU:

2 Insert the SFP module into the SFP receptacle with the label up:

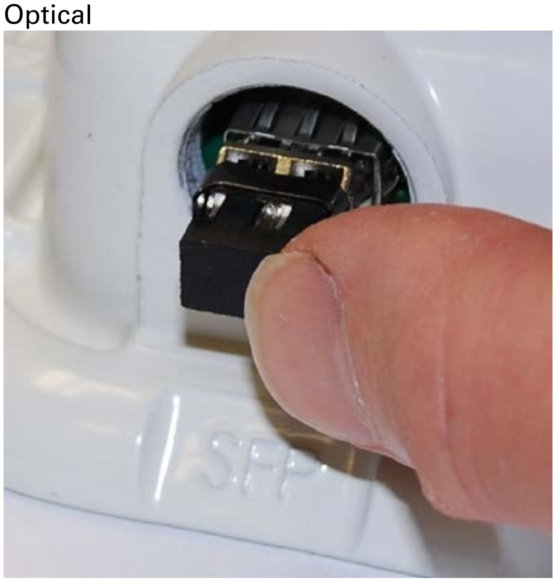
Optical

Copper

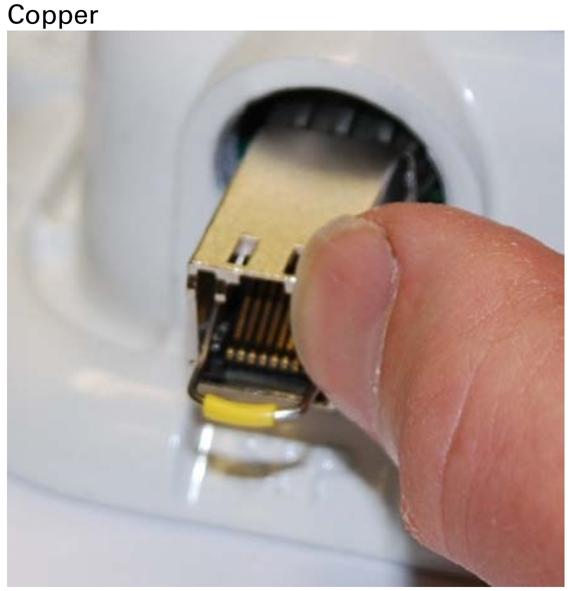


3 Push the module home until it clicks into place:

Optical



Copper



4 Rotate the latch to the locked position:

Optical

Copper

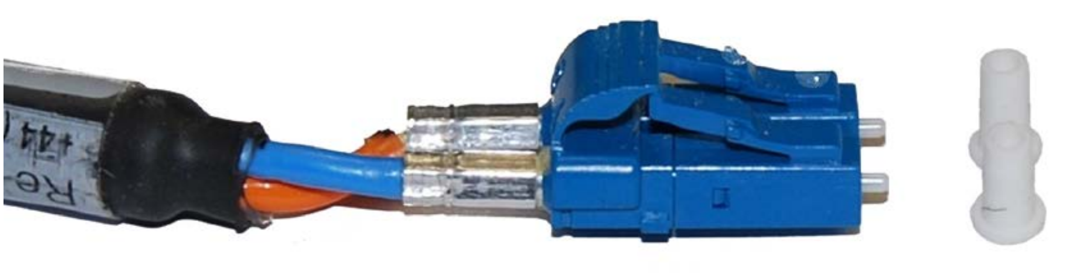
Connecting the cable

Caution

The fiber optic cable assembly is very delicate. To avoid damage, handle it with extreme care. Ensure that the fiber optic cable does not twist during assembly, especially when fitting and tightening the weatherproofing gland.

Do not insert the power over Ethernet drop cable from the PSU into the SFP module, as this will damage the module.

1 Remove the LC connector dust caps from the ODU end (optical cable only):



2 Plug the connector into the SFP module, ensuring that it snaps home:

Optical

Copper

Fitting the gland

1 Fit the gland body to the SFP port and tighten it to a torque of 5.5 Nm (4.3 lb ft)

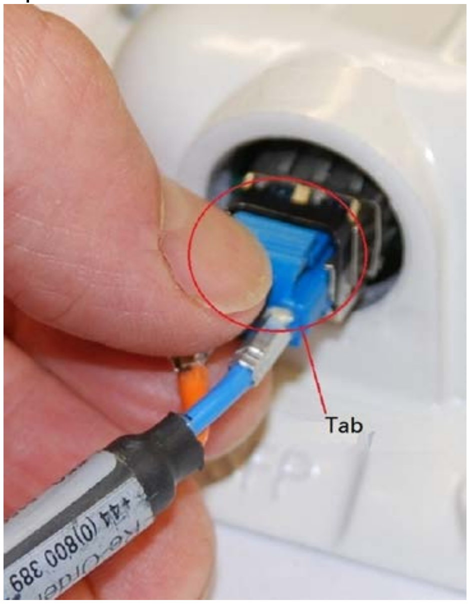
2 Fit the gland nut and tighten until the rubber seal closes on the cable. Do not over-tighten the gland nut, as there is a risk of damage to its internal components:

Removing the cable and SFP module

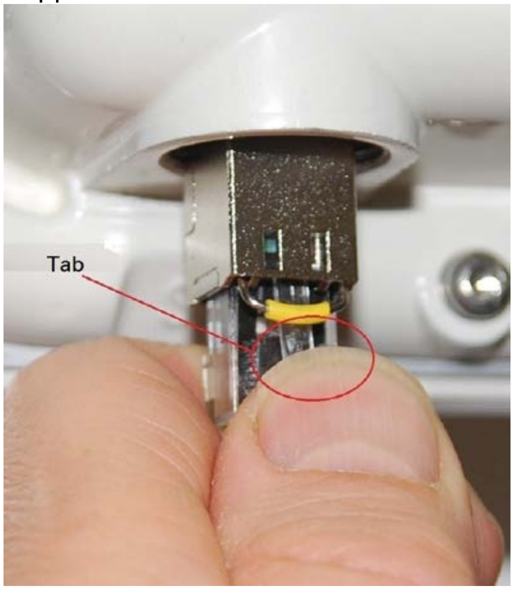
Do not attempt to remove the module without disconnecting the cable, otherwise the locking mechanism in the ODU will be damaged.

1 Remove the cable connector by pressing its release tab before pulling it out:

Optical

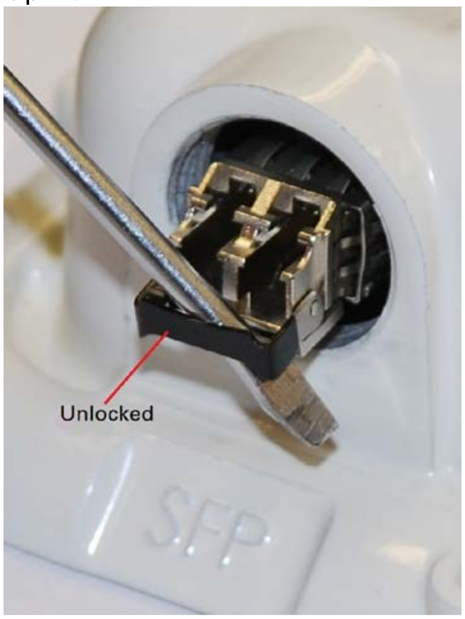


Copper

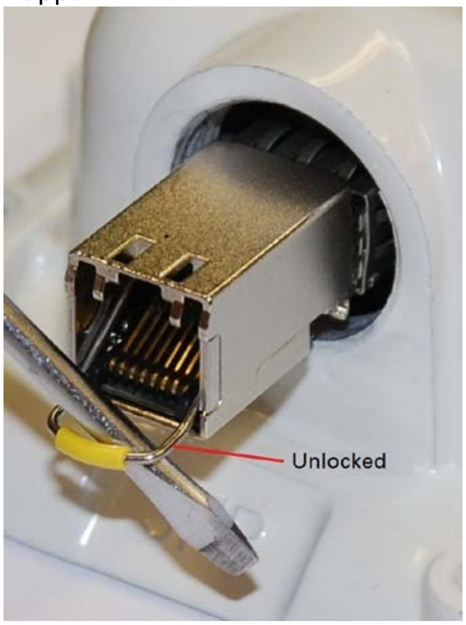


2 Rotate the latch to the unlocked position. Extract the module by using a screwdriver:

Optical



Copper



Installing an Aux Ethernet interface

In more advanced configurations, there may be a copper Cat5e Ethernet interface connected to the Aux port of the ODU. Refer to Typical deployment on page 3-2 for a diagram of this configuration.

Adapt the installation procedures in this chapter as appropriate for the Aux interface, noting the following differences:

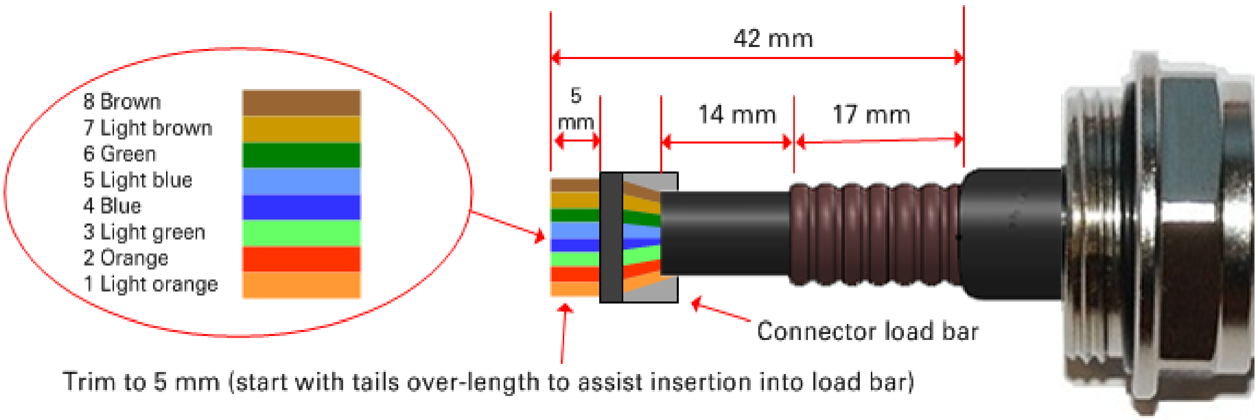
- At the remote end of the Aux drop cable, use an appropriate termination for the connected device (for example, a video camera or wireless access point).
- If the connected device is outdoors, not in the equipment building or cabinet, adapt the grounding instructions as appropriate.
- Ground the top LPUs and surge protector to the same point on the ODU (Figure 120).

Supplemental installation information

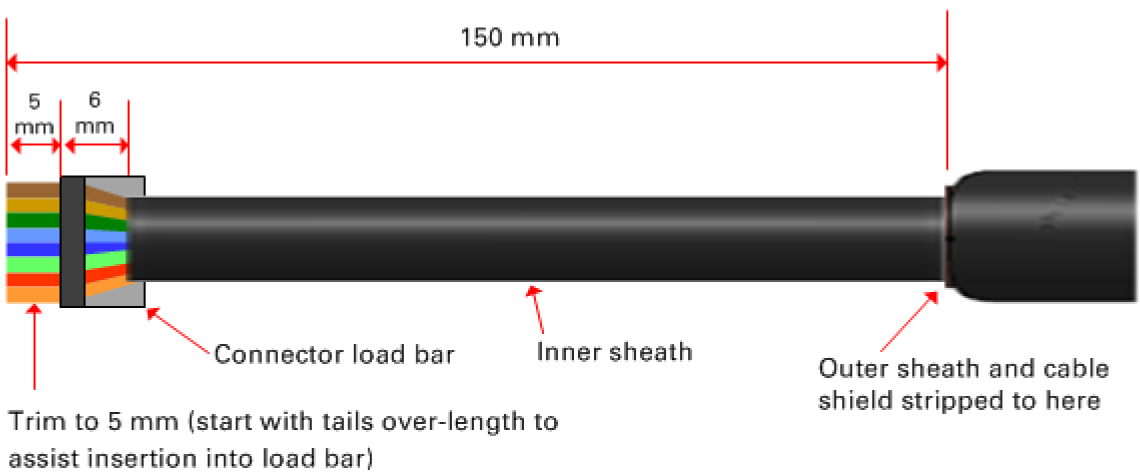
This section contains detailed installation procedures that are not included in the above topics, such as how to strip cables, create grounding points and weatherproof connectors.

Stripping drop cable

When preparing drop cable for connection to the PTP 650 ODU or LPU, use the following measurements:



When preparing drop cable for connection to the PTP 650 PSU (without a cable gland), use the following measurements:

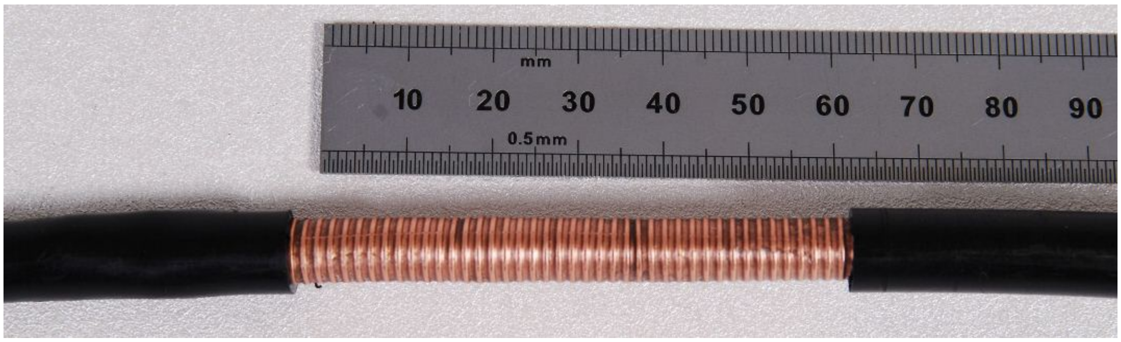


Creating a drop cable grounding point

Use this procedure to connect the screen of the main drop cable to the metal of the supporting structure using the cable grounding kit (Cambium part number 01010419001).

To identify suitable grounding points, refer to Drop cable grounding points on page 3-17.

1 Remove 60 mm (2.5 inches) of the drop cable outer sheath.



2 Cut 38mm (1.5 inches) of rubber tape (self-amalgamating) and fit to the ground cable lug. Wrap the tape completely around the lug and cable.

3 Fold the ground wire strap around the drop cable screen and fit cable ties.

4 Tighten the cable ties with pliers. Cut the surplus from the cable ties.

5 Cut a 38mm (1.5 inches) section of self-amalgamating tape and wrap it completely around the joint between the drop and ground cables.

6 Use the remainder of the self-amalgamating tape to wrap the complete assembly. Press the tape edges together so that there are no gaps.

7 Wrap a layer of PVC tape from bottom to top, starting from 25 mm (1 inch) below and finishing 25 mm (1 inch) above the edge of the self-amalgamating tape, over lapping at half width.

8 Repeat with a further four layers of PVC tape, always overlapping at half width. Wrap the layers in alternate directions (top to bottom, then bottom to top). The edges of each layer should be 25mm (1 inch) above (A) and 25 mm (1 inch) below (B) the previous layer.

9 Prepare the metal grounding point of the supporting structure to provide a good electrical contact with the grounding cable clamp. Remove paint, grease or dirt, if present. Apply anti-oxidant compound liberally between the two metals.

10 Clamp the bottom lug of the grounding cable to the supporting structure using site approved methods. Use a two-hole lug secured with fasteners in both holes. This provides better protection than a single-hole lug.

Weatherproofing an N type connector

Use this procedure to weatherproof the N type connectors fitted to the connectorized ODU and external antenna (if recommended by the antenna manufacturer).

1 Ensure the connection is tight. A torque wrench should be used if available:

2 Wrap the connection with a layer of 19 mm (0.75 inch) PVC tape, starting 25 mm (1 inch) below the connector body. Overlap the tape to half-width and extend the wrapping to the body of the LPU. Avoid making creases or wrinkles:

3 Smooth the tape edges:

4 Cut a 125mm (5 inches) length of rubber tape (self-amalgamating):

5 Expand the width of the tape by stretching it so that it will wrap completely around the connector and cable:

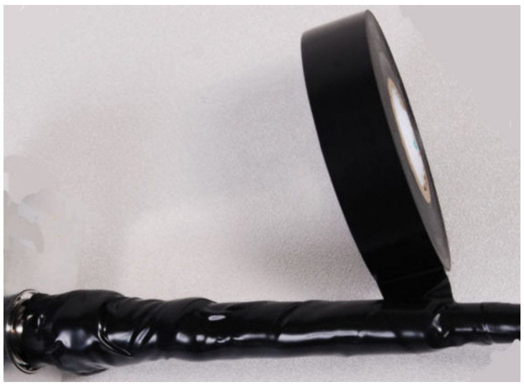
6 Press the tape edges together so that there are no gaps. The tape should extend 25 mm (1 inch) beyond the PVC tape:

7 Wrap a layer of 50 mm (2 inch) PVC tape from bottom to top, starting from 25 mm (1 inch) below the edge of the self-amalgamating tape, overlapping at half width.

8 Repeat with a further four layers of 19 mm (0.75 inch) PVC tape, always overlapping at half width. Wrap the layers in alternate directions:

- Second layer: top to bottom.
- Third layer: bottom to top.
- Fourth layer: top to bottom.
- Fifth layer: bottom to top.

The bottom edge of each layer should be 25 mm (1 inch) below the previous layer.



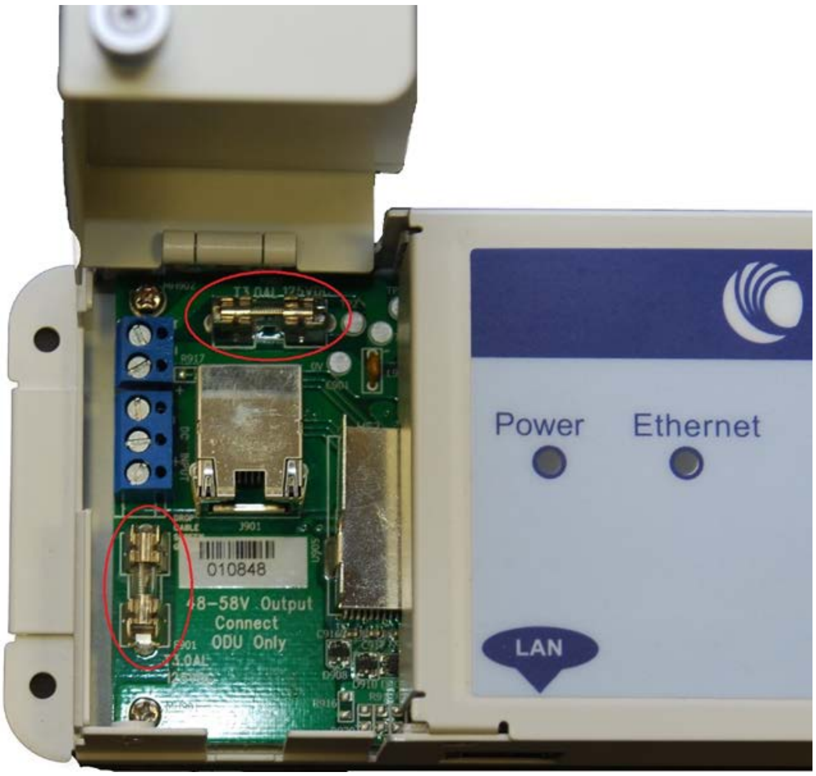
9 Check the completed weatherproof connection:

Replacing PSU fuses

The AC+ DC Enhanced Power Injector contains two replaceable fuses. These fuses protect the positive and negative grounded DC input voltages. If an incorrect power supply (that is, not in the range 37V to 60V DC) is connected to the DC input terminals, one or both fuses may blow.

Both fuses are 3 Amp slow-blow, for example Littlefuse part number 0229003.

To replace these fuses, undo the retaining screw and hinge back the cover as indicated:



Note

No other fuses are replaceable in the AC+DC Enhanced Power Injector.

Note

The AC Power Injector does not contain replaceable fuses.

Chapter 6: Configuration and alignment

This chapter describes how to use the web interface to configure the PTP 650 link. It also describes how to align antennas. This chapter contains the following topics:

Preparing for configuration and alignment

This section describes the checks to be performed before proceeding with unit configuration and antenna alignment.

Safety precautions

All national and local safety standards must be followed while configuring the units and aligning the antennas.

Warning

Ensure that personnel are not exposed to unsafe levels of RF energy. The units start to radiate RF energy as soon as they are powered up. Respect the safety standards defined in Compliance with safety standards on page 4-22, in particular the minimum separation distances.

Observe the following guidelines:

- Never work in front of the antenna when the ODU is powered.
- Always power down the PSU before connecting or disconnecting the drop cable from the PSU, ODU or LPU.

Regulatory compliance

All applicable radio regulations must be followed while configuring the units and aligning the antennas. For more information, refer to Compliance with radio regulations on page 4-27.

Caution

If the system designer has provided a list of channels to be barred for TDWR radar avoidance, the affected channels must be barred before the units are allowed to radiate on site, otherwise the regulations will be infringed. To bar these channels, follow the procedure Barring channels on page 7-44.

Attention

Si le concepteur du système a fourni une liste de canaux à interdire pour éviter les radars TDWR, les cannaux concernées doivent être interdits avant que les unités sont autorisées à émettre sur le site, sinon la réglementation peut être enfreinte. Pour bloquer ces canaux, suivez la procédure Barring channels page 7-44.

Selecting configuration options

Use the installation report to determine which configuration options are required. Refer to LINKPlanner on page 3-25.

Generating license keys

To obtain License Keys for capabilities that are not factory-installed, proceed as follows:

1. Identify and purchase access keys for the required capability upgrades by referring to ODU capability upgrades on page 2-9.
2. Obtain the MAC Address of the ODU (it is on the System Status page).
3. Go to the Cambium Support web page (see Contacting Cambium Networks on page 1) and navigate to the **Cambium Networks License Key Generator**.
4. Enter the MAC Address and Access Key.
5. If the ODU is to operate in a regulatory band that is not factory-installed, select the required regulatory band from the list. The contents of this list depend upon ODU regional variant.
6. Select any other required capabilities from those that are available.
7. Submit the web form. Cambium will send the License Key by email.

Use the Software License Key page to configure the ODU with newlicense keys (Software License Key page on page 6-11).

Connecting to the unit

This section describes how to connect the unit to a management PC and power it up.

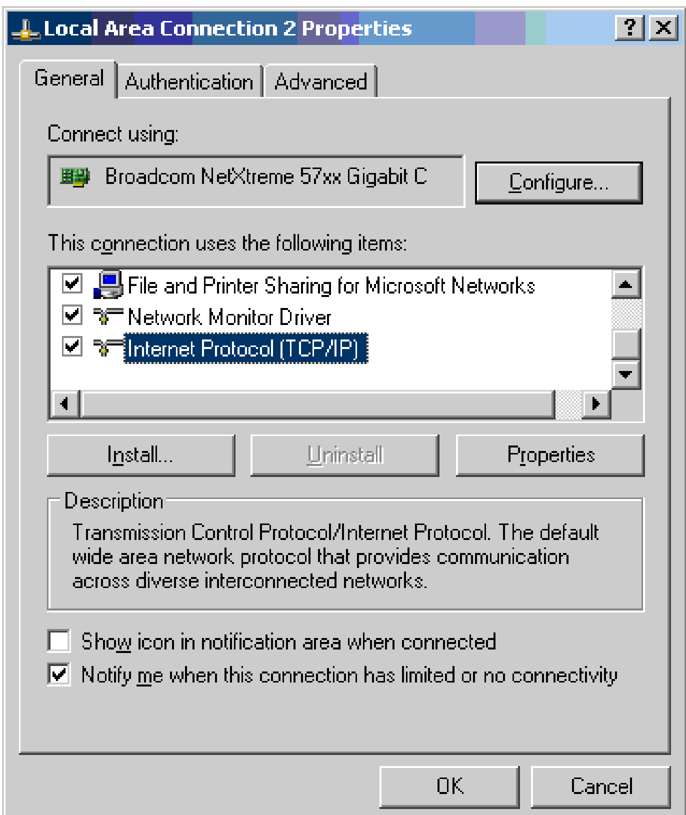
Configuring the management PC

Use this procedure to configure the local management PC to communicate with the PTP 650.

Procedure:

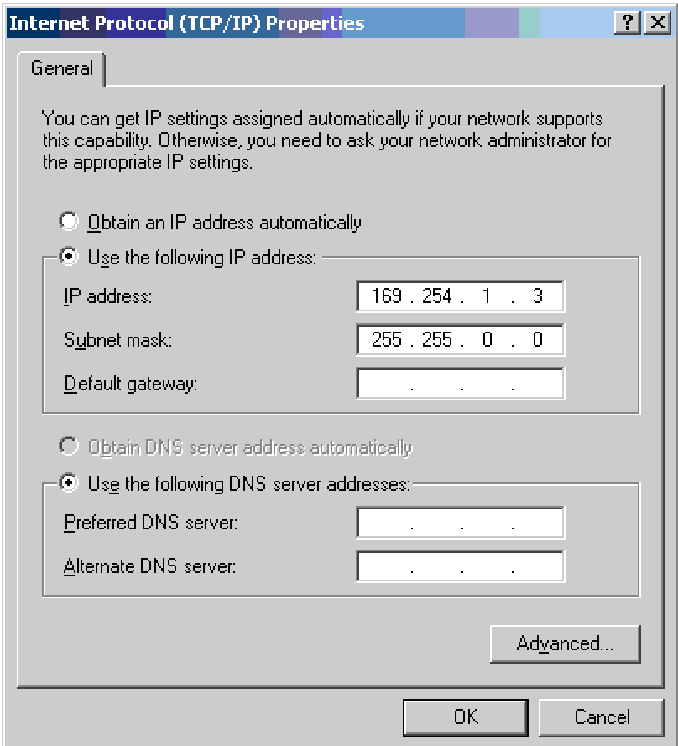
1 Select **Properties** for the Ethernet port. In Windows 7 this is found in **Control Panel > Network and Internet > Network Connections > Local Area Connection.**

2 Select **Internet Protocol (TCP/IP)**:



3 Click **Properties.**

4 Enter an IP address that is valid for the 169.254.X.X network, avoiding 169.254.0.0 and 169.254.1.1. A good example is 169.254.1.3:



5 Enter a subnet mask of 255.255.0.0. Leave the default gateway blank.

Connecting to the PC and powering up

Use this procedure to connect a management PC and power up the PTP 650.

Procedure:

1 Check that the ODU and PSU are correctly connected.

2 Connect the PC Ethernet port to the LAN port of the PSU using a standard (not crossed) Ethernet cable.

3 Apply mains or battery power to the PSU. The green Power LED should illuminate continuously.

4 After about 45 seconds, check that the orange Ethernet LED starts with 10 slow flashes.

5 Check that the Ethernet LED then illuminates continuously. If the Power and Ethernet LEDs do not illuminate correctly, refer to Testing link end hardware on page 8-7.

Using the web interface

This section describes how to log into the PTP 650 web interface and use its menus.

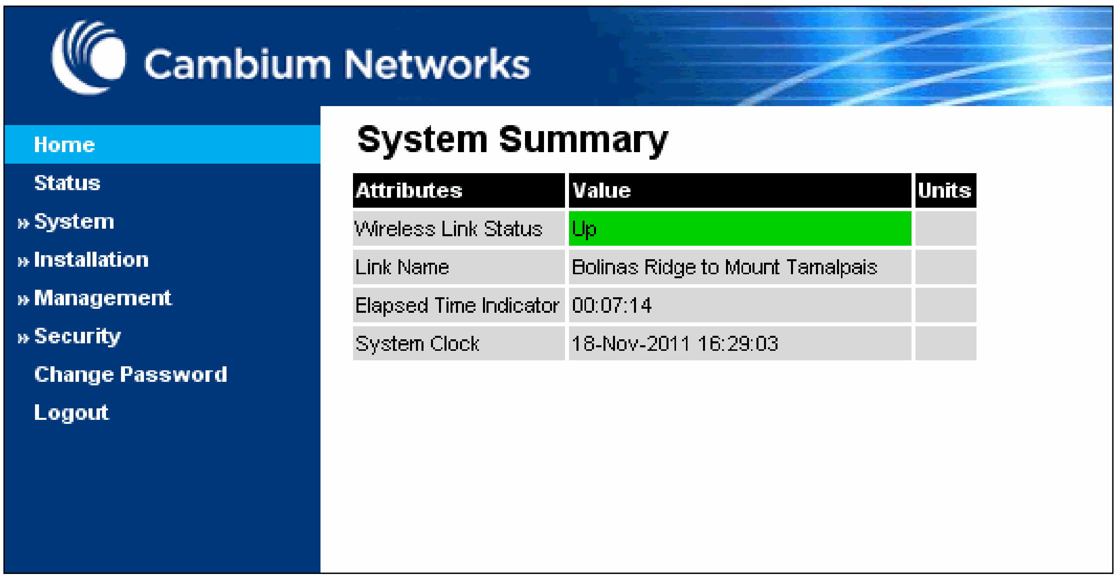
Logging into the web interface

Use this procedure to log into the web interface as a system administrator.

Procedure:

1 Start the web browser from the management PC.

2 Type the IP address of the unit into the address bar. The factory default IP address is **169.254.1.1**. Press ENTER. The web interface menu and System Summary page are displayed:



3 On the menu, click **System**. The login page is displayed with Password only (the default) or with Username and Password (if identity-based user accounts have been enabled):

4 Enter Username (if requested) and Password (the default is blank) and click **Login**.

Using the menu options

Use the menu navigation bar in the left panel to navigate to each web page. Some of the menu options are only displayed for specific system configurations. Use Table 123 to locate information about using each web page.

Table 123 Menu options and web pages

Main menu	Menu option	Web page information
Home		System Summary page on page 7-2
Status		System Status page on page 7-3
System		
	Configuration	System Configuration page on page 6-30
	LAN Configuration	LAN Configuration page on page 6-34
	QoS Configuration	QoS Configuration page on page 6-44
	SFP Configuration	SFP Configuration page on page 6-48
	TDM Configuration	TDM Configuration page on page 6-50
	Save and Restore	Save and Restore Configuration page on page 6-52
	Reset Configuration	Reset Configuration page on page 6-54
	Spectrum Expert or Spectrum Management	Spectrum Management on page 7-27
	Statistics	System Statistics page on page 7-50 Comparing actual to predicted performance on page 6-113
	Wireless Port Counters	Wireless Port Counters page on page 7-55 Test Ethernet packet errors reported by ODU on page 8-11
	Main Port Counters	Main Port Counters page on page 7-56
	Aux Port Counters	Aux Port Counters page on page 7-59
	SFP Port Counters	SFP Port Counters page on page 7-60
	SyncE Status	SyncE Status page on page 7-61
	Diagnostics Plotter	Diagnostics Plotter page on page 7-64
	CSV Download	Generate Downloadable Diagnostics page on page 7-65

Main menu	Menu option	Web page information
	Cable Diagnostics	Cable Diagnostics on page 8-2
	Software Upgrade	Software Upgrade page on page 6-55
	Reboot	Reboot Wireless Unit page on page 7-16
Installation		Installation menu on page 6-9
	Graphical Install	Graphical Install page on page 6-111
Management		
	Web	Web-Based Management page on page 6-58
	Local User Accounts	Local User Accounts page on page 6-61
	RADIUS Configuration	RADIUS Configuration page on page 6-66
	Login Information	Login Information page on page 7-16
	Web Properties	Webpage Properties page on page 6-68
	SNMP	SNMP pages (for SNMPv3) on page 6-80 SNMP pages (for SNMPv1/2c) on page 6-90
	Email	Email Configuration page on page 6-71
	Diagnostic Alarms	Diagnostic Alarms page on page 6-73
	Time	Time Configuration page on page 6-74
	Syslog	Syslog page on page 7-23
	Syslog Configuration	Syslog Configuration page on page 6-78
Security		Security menu on page 6-94
	Zeroize CSPs	Zeroize CSPs page on page 6-105
Change Password		Change Password page on page 7-17
Logout		Logging out on page 7-17

Installation menu

This section describes how to use the Installation Wizard to complete the essential system configuration tasks that must be performed on a new link.

Caution

If the system designer has provided a list of channels to be barred for TDWR radar avoidance, the affected channels must be barred before the units are allowed to radiate on site, otherwise the regulations will be infringed. To bar these channels, follow the procedure Barring channels on page 7-44.

Starting the Installation Wizard

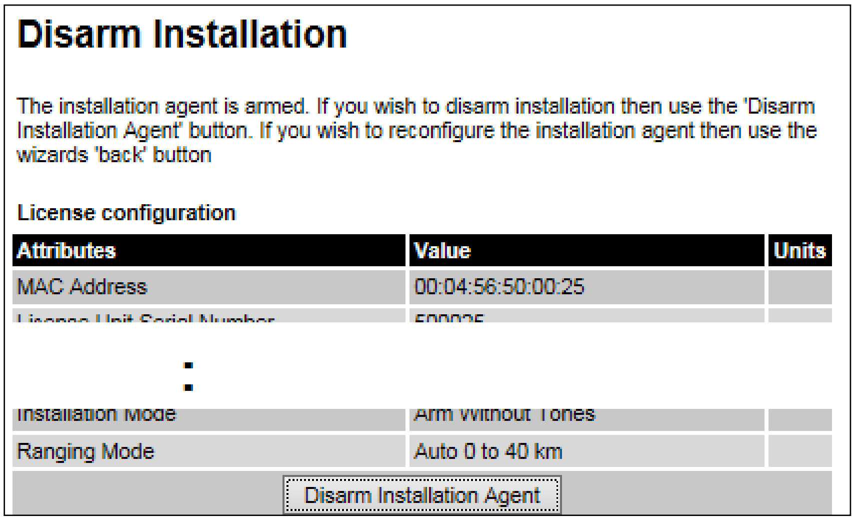
To start the Installation Wizard: on the menu, click **Installation**. The response depends upon the state of the unit:

- If the unit is newly installed, the Software License Key page is displayed. Continue at Software License Key page on page 6-11.
- If the unit is armed for alignment, the Disarm Installation page is displayed. Continue at Disarm Installation page on page 6-10.
- If the unit is not armed, the Current Installation Summary page is displayed. Continue at Current Installation Summary page on page 6-10.

Disarm Installation page

Menu option: **Installation** (Figure 121). This page is displayed only when unit is armed.

Figure 121 Disarm Installation page (top and bottom of page shown)

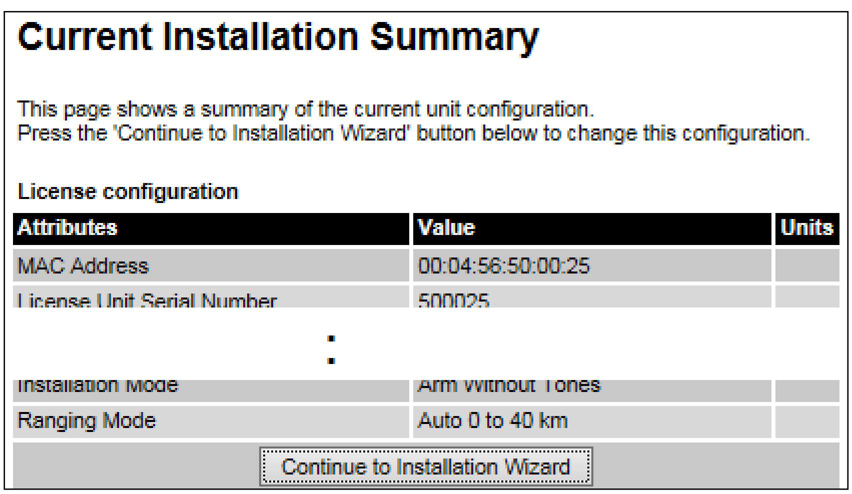


To disarm the unit, click **Disarm Installation Agent**.

Current Installation Summary page

Menu option: **Installation** (Figure 122). This page is displayed only when unit is not armed.

Figure 122 Current Installation Summary page (top and bottom of page shown)



Click **Continue to Installation Wizard**.

Software License Key page

Menu option: **Installation**. Use this page to configure the unit with a new License Key and to review the capabilities of an installed License Key. The appearance of this page varies depending upon which capabilities are enabled by the entered license key. For example, Figure 123 shows the licensed capabilities for a PTP 650S in the USA market with a Full Capability Trial License, whereas Figure 124 shows TDM support, IPv6 and other capabilities. Use the Cambium Networks License Key Generator to generate new License Keys (Generating license keys on page 6-3).

Figure 123 Software License Key page (PTP 650S USA market)

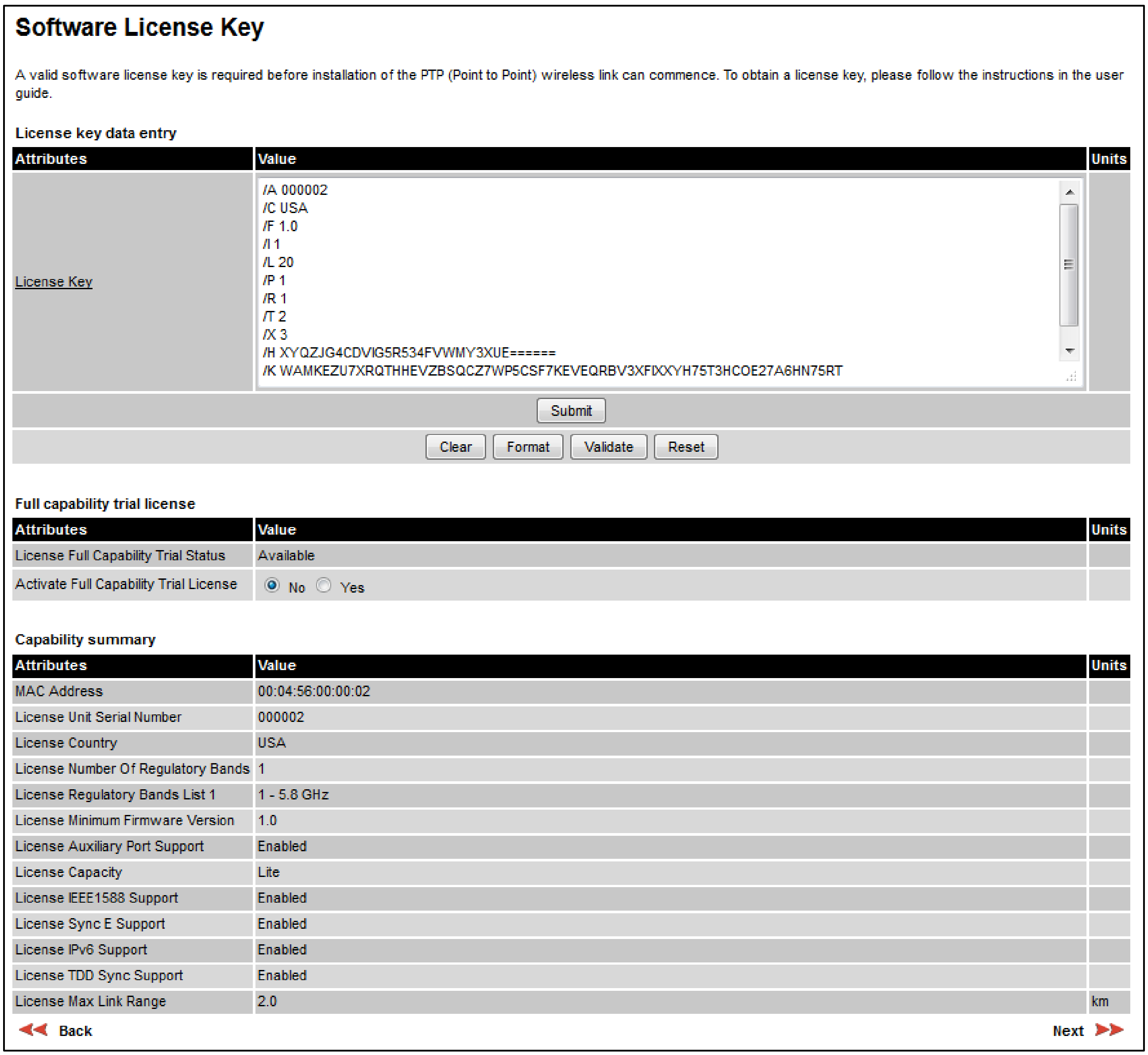
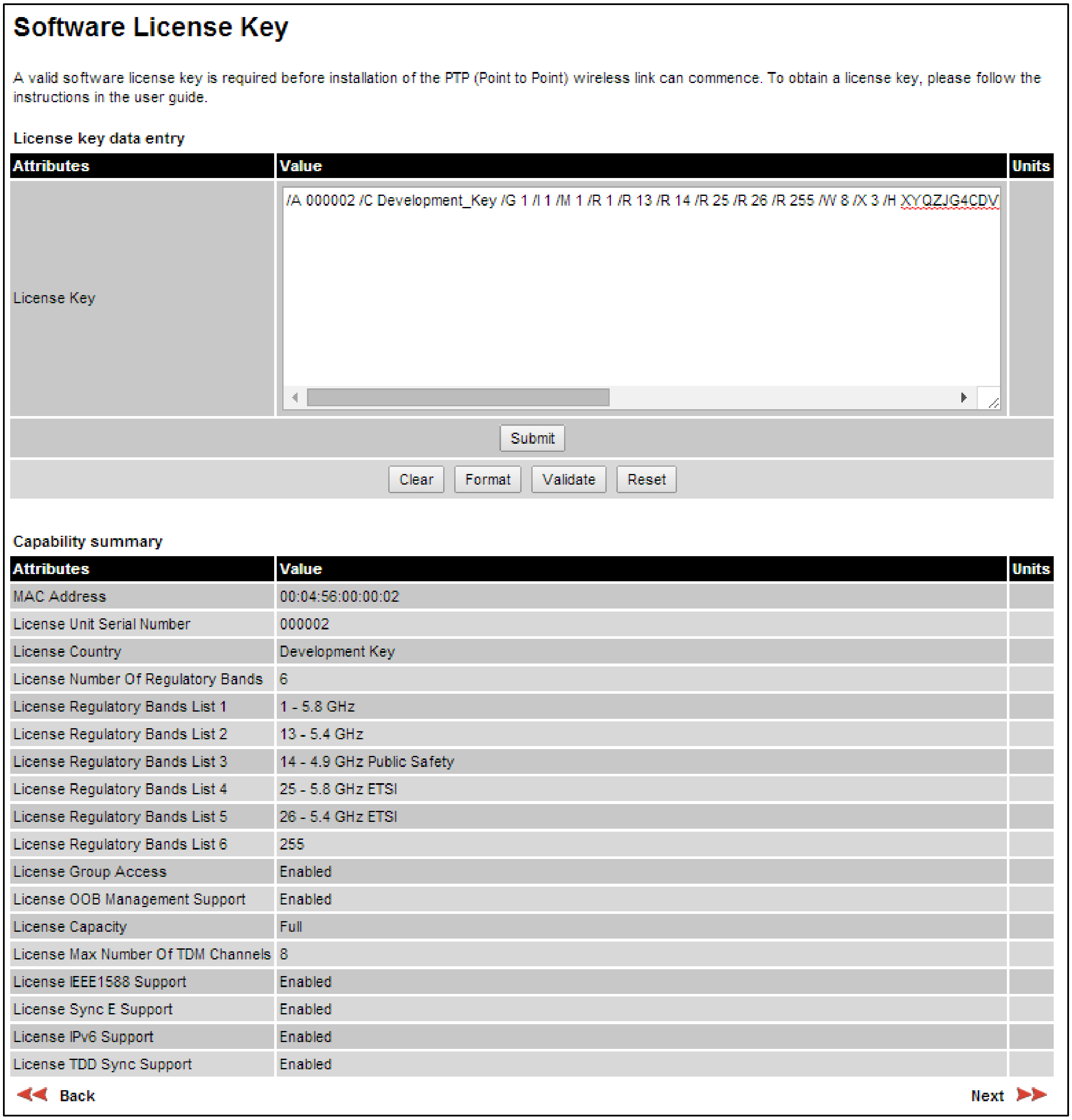


Figure 124 Software License Key page (TDM, IPv6 and other capabilities)



Software License Key

A valid software license key is required before installation of the PTP (Point to Point) wireless link can commence. To obtain a license key, please follow the instructions in the user guide.

License key data entry

Attributes	Value	Units
License Key	/A 000002 /C Development_Key /G 1 /I 1 /M 1 /R 1 /R 13 /R 14 /R 25 /R 26 /R 255 /W 8 /X 3 /H XYQZJG4CDV	

Submit

Clear Format Validate Reset

Capability summary

Attributes	Value	Units
MAC Address	00:04:56:00:00:02	
License Unit Serial Number	000002	
License Country	Development Key	
License Number Of Regulatory Bands	6	
License Regulatory Bands List 1	1 - 5.8 GHz	
License Regulatory Bands List 2	13 - 5.4 GHz	
License Regulatory Bands List 3	14 - 4.9 GHz Public Safety	
License Regulatory Bands List 4	25 - 5.8 GHz ETSI	
License Regulatory Bands List 5	26 - 5.4 GHz ETSI	
License Regulatory Bands List 6	255	
License Group Access	Enabled	
License OOB Management Support	Enabled	
License Capacity	Full	
License Max Number Of TDM Channels	8	
License IEEE1588 Support	Enabled	
License Sync E Support	Enabled	
License IPv6 Support	Enabled	
License TDD Sync Support	Enabled	

Back Next

Procedures:

Note

Full capability is available only when both ODUs have the trial active or are already licensed to operate with that capacity.

When the trial has started, the Software License Key page displays the Trial Period Remaining attribute (Figure 126). This shows the number of days remaining before the full capability trial period expires.

To enter a new License Key, proceed as follows:

- To clear the existing License Key (if present), click **Clear**.
- To format the new License Key: copy it from the Cambium notification email, paste it into the License Key box and click **Format**. The page is redisplayed with the License Key formatted.
- To enter the new License Key, click **Submit**. The page is redisplayed with the Capability Summary updated.

To control the full capability trial (Lite and Mid licenses only), proceed as follows:

- If License Full Capability Trial Status is **Available** (Figure 125), start the full capability trial period by setting Activate Full Capability Trial License to **Yes**.
- If License Full Capability Trial Status is **Active** (Figure 126), suspend the full capability trial period by setting Stop Full Capability Trial License to **Yes**.
- If License Full Capability Trial Status is **Inactive** (Figure 127), resume the full capability trial period by setting Start Full Capability Trial License to **Yes**.

To continue with the Installation Wizard, click **Next**.

Figure 125 Software License Key page (extract) with full capability trial available

Full capability trial license

Attributes	Value	Units
License Full Capability Trial Status	Available	
Activate Full Capability Trial License	◉ No ○ Yes	

Figure 126 Software License Key page (extract) with full capability trial active

Full capability trial license

Attributes	Value	Units
License Full Capability Trial Status	Active	
Trial Period Remaining	60	Days
Stop Full Capability Trial License	◉ No ○ Yes	

Figure 127 Software License Key page (extract) with full capability trial inactive

Full capability trial license

Attributes	Value	Units
License Full Capability Trial Status	Inactive	
Trial Period Remaining	60	Days
Start Full Capability Trial License	◉ No ○ Yes	

Interface Configuration page

Menu option: **Installation**. Use this page to update the IP interface attributes.

The appearance of this page varies depending upon which capabilities have been enabled by license key. For example, Figure 128 shows the attributes that are displayed when IPv6, Aux Port, SFP Port, Second Data Service and Out-of-Band Management support are enabled, whereas Figure 129 shows the attributes that are displayed when IPv6 and TDM support are enabled.

Caution

Before configuring a VLAN for management interfaces, ensure that the VLAN is accessible, otherwise the unit will be inaccessible after the next reboot.

Note

TDM support is only available when the following are all true:

- The installed software version is at least 50650-01-20 (Software Upgrade page on page 6-55).
- An E1/T1 license key has been generated (Generating license keys on page 6-3) and submitted (Software License Key page on page 6-11).

Note

NIDUs can be installed at both link ends without enabling TDM (set TDM Interface to **None**). LAN data will be bridged successfully, but TDM data will be ignored.

Note

Synchronous Ethernet and IEEE 1588 Transparent Clock are disabled when TDM is enabled (LAN Configuration page on page 6-34).

Note

When TDM is enabled and connected at one link end, up to two minutes may elapse before the TDM link is established (this is known as the settling period). Do not attempt to change the TDM configuration during this settling period.

Procedure:

- Review and update the IP and VLAN attributes (Table 124).
- Review and update the TDM attributes (Table 125) (if available).
- To continue with the Installation Wizard, click **Next** or **Submit Interface Configuration**.

Figure 128 Interface Configuration page (IPv6, Aux, SFP, Second Data Service and OOB support)

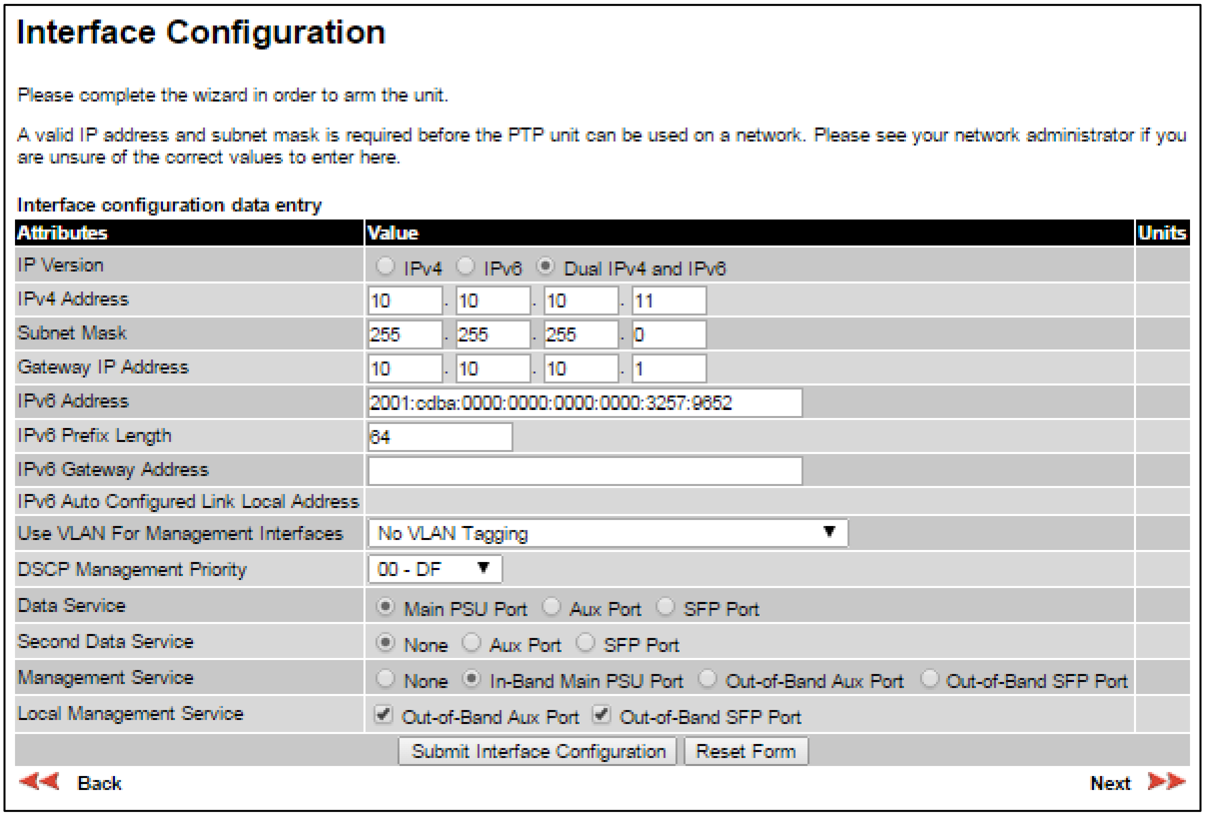


Figure 129 Interface Configuration page (TDM support)

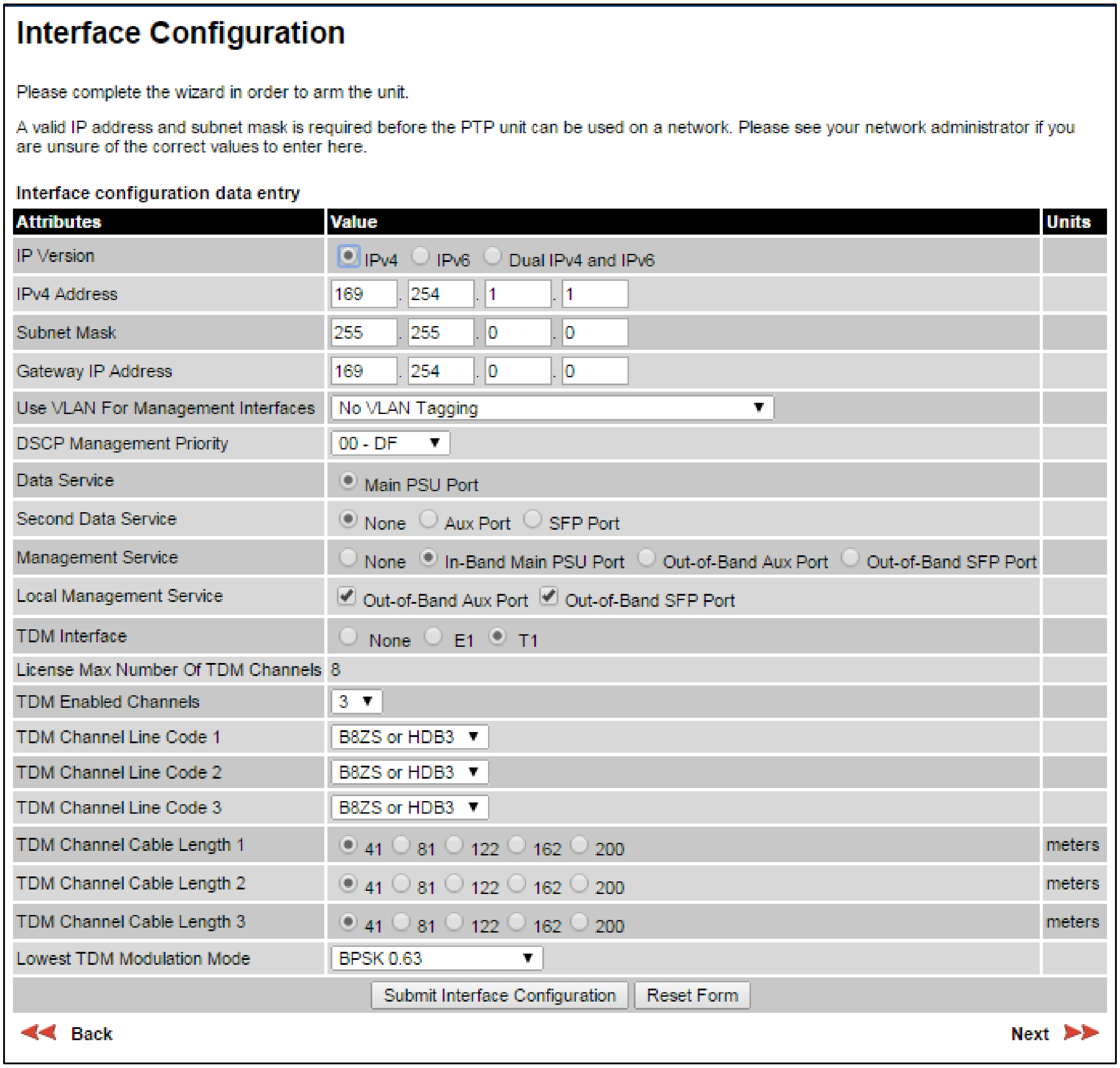


Table 124 Interface Configuration attributes

Attribute	Meaning
IP Version	The internet protocols to be supported by this ODU: **IPv4:** IPv4 protocols only. IPv4 attributes are displayed. **IPv6:** IPv6 protocols only. IPv6 attributes are displayed. **Dual IPv4 and IPv6:** Both IPv4 and IPv6 protocols. IPv4 and IPv6 attributes are displayed.

Attribute	Meaning
IPV4 Address	The IPv4 internet protocol address. This address is used by the family of Internet protocols to uniquely identify this unit on a network.
Subnet Mask	The address range of the connected IPv4 network.
Gateway IP Address	The IPv4 address of a computer on the current network that acts as an IPv4 gateway. A gateway acts as an entrance and exit to frames from and to other networks.
IPv6 Address	The IPv6 internet protocol address. This address is used by the family of Internet protocols to uniquely identify this unit on a network.
IPv6 Prefix Length	Length of the IPv6 subnet prefix (default 64 bits).
IPv6 Gateway Address	The IPv6 address of a computer on the current network that acts as an IPv6 gateway. A gateway acts as an entrance and exit to frames from and to other networks. It is usual to use the link-local address of the gateway.
IPv6 Auto Configured Link Local Address	The link-local address of the IPv6 gateway (displayed only, not updateable).
Use VLAN For Management Interfaces	VLAN tagging options for the management interfaces: **No VLAN Tagging** **IEEE 802.1Q Tagged (C-Tag, Type 8100)** **IEEE 802.1ad Tagged (S-Tag or B-Tag, Type 88a8)** Ensure that the configured VLAN is accessible, otherwise it will not be possible to access the unit following the next reboot. The PTP 650 management function is only compatible with single VLAN tagged frames. Any management frame with two or more tags will be ignored.
VLAN Management VID	Only displayed when Use VLAN for Management Interfaces is not set to **No VLAN Tagging**. The VLAN VID (range 0 to 4094) that will be included in Ethernet frames generated by the management interfaces.
VLAN Management Priority	Only displayed when Use VLAN for Management Interfaces is not set to **No VLAN Tagging**. The VLAN priority (range 0 to 7) that will be included in Ethernet frames generated by the management interfaces.
DSCP Management Priority	Differentiated Services Code Point (DSCP) value to be inserted in the IP header of all IP datagrams transmitted by the management interface.

Attribute	Meaning
Data Service	The port selection for the Data Service: **Main PSU Port**: The Data Service is connected to the Main PSU Port **Aux Port**: The Data Service is connected to the Aux Port **SFP Port**: The Data Service is connected to the SFP Port The Aux Port and SFP Port options are displayed if these ports are enabled in the license key. The Data Service must always be assigned to one of the three wired ports. For more help Configuring port allocations, see on page 6-20.
Second Data Service	The port allocation for the Second Data Service: **None:** The Second Data Service is disabled. **Main PSU Port**: The Second Data Service is connected to the Main PSU Port **Aux Port**: The Second Data Service is connected to the Aux Port **SFP Port**: The Second Data Service is connected to the SFP Port This attribute is only displayed when the Second Data Service support is license key enabled. The port allocated to the Data Service is not available for allocation to the Second Data Service. For more help, see Ethernet port allocation on page 3-36.
Management Service	The port allocation for the end-to-end Management Service: **None:** The Management Service is disabled. **In-Band Main PSU Port, Out-of-Band Main PSU Port:** The Management Service is connected to the Main PSU Port. **In-Band Aux Port, Out-of-Band Aux Port:** The Management Service is connected to the Aux Port. **In-Band SFP Port, Out-of-Band SFP Port:** The Management Service is connected to the SFP Port. If a port is already connected to the Data Service or the Second Data Service then the option will be displayed as In-Band... otherwise the option will be displayed as Out-of-Band... For more help, see Ethernet port allocation on page 3-36.

Attribute	Meaning
Local Management Service	Any port not already selected to the Data, Second Data or Management Service is available for connection as an out-of-band port for the Local Management Service. Ports already selected to the Data, Second Data or Management services are not displayed as options. For more help, see Ethernet port allocation on page 3-36.

Configuring port allocations with TDM

When TDM is enabled, the Data Service is mapped to the Main PSU Port with no other options presented to the user. Mapping of the Second Data Service, Management Service and Local Management Service have standard options consistent with the Data Service mapping.

Table 125 Interface Configuration TDM attributes

Attribute	Meaning
TDM Interface	Only displayed when TDM is enabled by license key. The type of TDM interface that is activated. **None**: TDM is disabled. **E1**: The E1 TDM interface is activated. **T1**: The T1 TDM interface is activated.
License Max Number of TDM Channels	Only displayed when TDM Interface is set to **E1** or **T1**. The maximum number of TDM channels (E1 or T1) allowed under the installed license key.
TDM Enabled Channels	Only displayed when TDM Interface is set to **E1** or **T1**. Select the number of E1 or T1 channels that are to be enabled over the wireless bridge (1 to 8).
TDM Channel Line Code n	Only displayed when TDM Interface is set to **E1** or **T1**. Select the line code of the transceiver connected to NIDU E1/T1 channel "n" (where "n" is in the range 1 to 8).
TDM Channel Cable Length n	Only displayed when TDM Interface is set to **T1**. This control compensates for the high frequency attenuation in T1 cables. Equalization is automatic in the E1 interface. Select the nearest approximation to the length of cable connecting the transceiver to NIDU T1 channel "n" (where "n" is in the range 1 to 8).

Attribute	Meaning
Lowest TDM Modulation Mode	Only displayed when TDM Interface is set to **E1** or **T1**. The lowest modulation mode at which TDM data can be sent. If the link cannot sustain TDM data in this mode then the effective lowest modulation mode may differ. In conjunction with the LINKPlanner tool, this setting may be used to optimize the latency for links which operate in consistently high modulation modes. High data rate links are able to support lower latencies.

Configuring port allocations

The Interface Configuration page controls the allocation of the Main PSU Port, Aux Port and SFP Port to the Data Service, Second Data Service, Management Service and Local Management Service.

PTP 650 supports exactly one instance of the Data Service, and this service is always mapped to one of the three wired ports. It is not possible to operate a link without any port selected to the Data Service.

PTP 650 supports zero or one instances of the optional Second Data Service. The Second Data Service is enabled by a license key field, and is automatically licensed in any unit with a Full capacity license. The Second Data Service can be disabled or mapped to any available port, except for the port already allocated to the Data Service.

PTP 650 supports zero or one instances of the optional Management Service. The Management Service can be used to access the management agent at the local unit. If the wireless link is established, the Management Service can also be used to access the management agent at the remote unit and other devices connected in the remote management network. The Management Service can be mapped to a port that is already used for the Data Service or Second Data Service to provide In-Band Management. Alternatively, the Management Service can be allocated to a dedicated port to provide Out-of-Band Management.

PTP 650 also supports an optional Local Management Service, providing a connection from a wired port to the local management agent. Any port not already selected is available for selection to the Local Management Service. The Local Management Service does not connect across the wireless link.

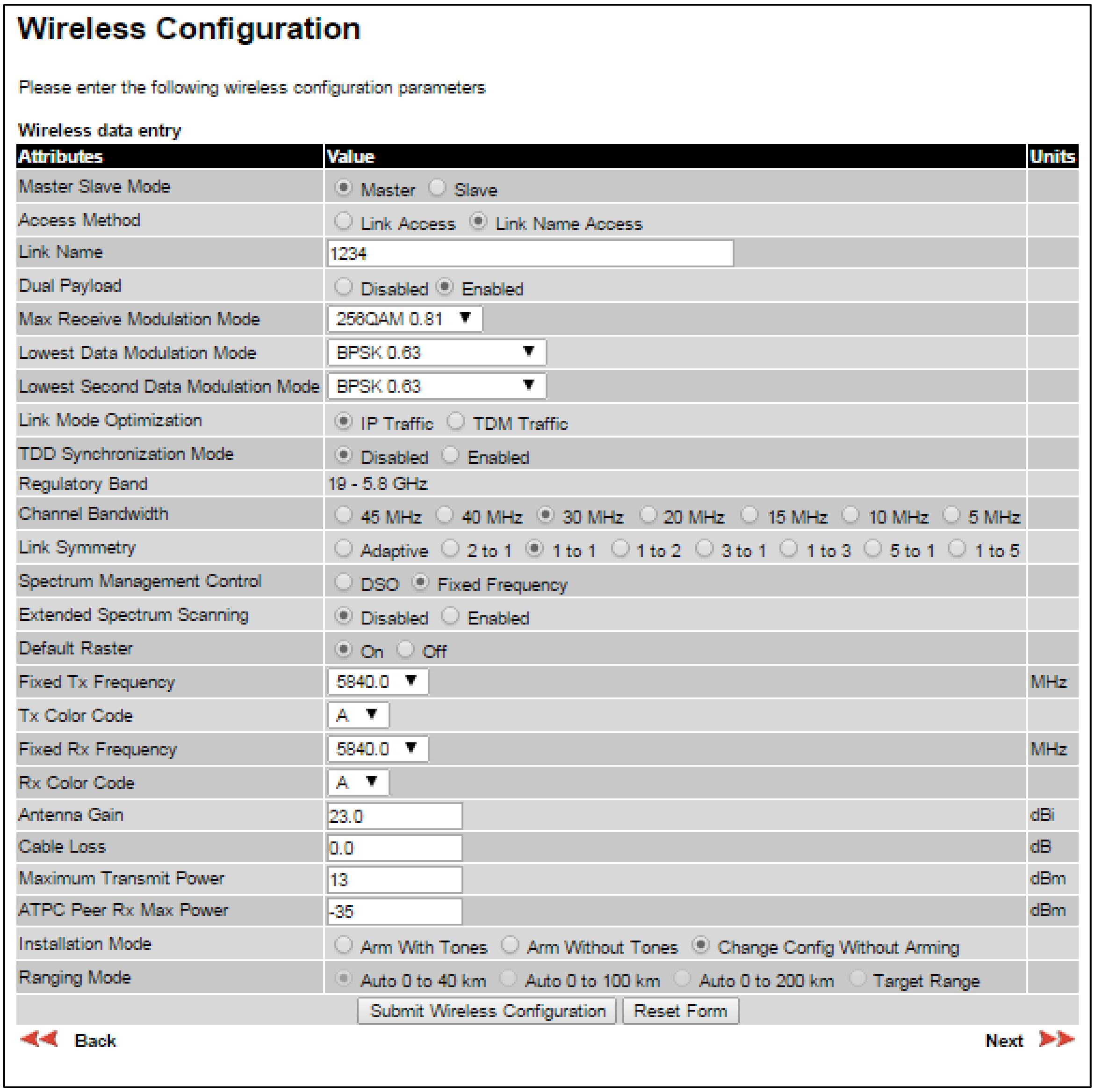
The PTP 650 must always be manageable through one of three ports. Therefore it is not possible to disable the Management Service unless at least one port is allocated to the Local Management Service.

Wireless Configuration page

Menu option: **Installation** (Figure 130).

This page is part of the Installation Wizard. Use it to update the wireless attributes.

Figure 130 Wireless Configuration page



Procedure:

- Update the attributes (Table 126).
- To save any changes and continue with the Installation Wizard, click **Next** or click **Submit Wireless Configuration**.

Caution

The lower center frequency attribute must be configured to the same value for both the Master and Slave, otherwise the wireless link will fail to establish. The only way to recover from this situation is to modify the Lower Center Frequency attributes so that they are identical on both the master and slave units.

Note

When configuring a linked pair of units, use the Master Slave Mode to ensure that one unit is **Master** and the other is **Slave**.

Table 126 Wireless Configuration attributes

Attribute	Meaning
Master Slave Mode	**Master:** The unit controls the point-to-point link and its maintenance. On startup, the Master transmits until a link with the Slave is made. **Slave:** The unit listens for its peer and only transmits when the peer has been identified.
Access Method	ODUs must be configured in pairs before a link can be established. Access Method determines how paired ODUs will recognize each other. **Link Access:** Each ODU must be configured with Target MAC Address equal to the MAC Address of the other unit. **Link Name Access:** Both ODUs must be configured with the same Link Name. **Group Access:** Only displayed when a Group Access license key has been generated (Generating license keys on page 6-3) and submitted (Software License Key page on page 6-11). Both ODUs must be configured with the same Group ID attributes.
Target MAC Address	Only displayed when Access Method is set to **Link Access**. This is the MAC Address of the peer unit that will be at the other end of the wireless link. This is used by the system to ensure the unit establishes a wireless link to the correct peer. The MAC Address can be found embedded within the serial number of the unit. The last six characters of the serial number are the last three bytes of the unit's MAC address.
Link Name	Only displayed when Access Method is set to **Link Name Access**. Link Name may consist of letters (A-Z and a-z), numbers (0-9), spaces, and the following special characters: (),-.,:<=>[]_{} Link Name must be same at both ends and different to site name.
Group Id	Only displayed when Access Method is set to **Group Access**. A link can only be established between units that have identical Group IDs.

Attribute	Meaning
Dual Payload	**Disabled:** The link maximizes robustness against fading and interference. **Enabled:** The link attempts to reach maximum throughput at the expense of robustness against fading and interference.
Max Receive Modulation Mode	The maximum mode the unit will use as its adaptive modulation. By default the Max Receive Modulation Mode is the highest mode available. For minimum error rates, set the maximum modulation mode to the minimum necessary to carry the required traffic.
Lowest Data Modulation Mode	The lowest modulation mode that must be achieved before the link is allowed to bridge customer data Ethernet frames. This does not affect the bridging of management data: if out-of-band remote management is enabled, this will continue regardless of modulation mode.
Lowest Second Data Modulation Mode	The lowest modulation mode that must be achieved before the link is allowed to bridge Ethernet frames in the Second Data Service. This attribute is displayed when the Second Data Service is enabled.
Link Mode Optimization	**IP Traffic:** The link is optimized for IP traffic to provide the maximum possible link capacity. **TDM Traffic:** The link is optimized for TDM traffic to provide the lowest possible latency. This is the only available setting when TDM is enabled (Interface Configuration page on page 6-14).
TDD Synchronization Mode	**Disabled:** The link does not employ TDD synchronization. **Enabled:** The link employs TDD synchronization. This is configured in the Installation Wizard; see TDD synchronization page (optional) on page 6-27. For a basic description, see TDD synchronization on page 1-19. When TDD Synchronization Mode is set to **Enabled**, the following restrictions apply: Ranging Mode and Target Range are disabled, and Link Symmetry is limited to **1 to 1**.
Regulatory Band	The regulatory band selected from the list in the license key.
Channel Bandwidth	Bandwidth of the transmit and receive radio channels.

Attribute	Meaning
Link Symmetry	Only displayed when Master Slave Mode is set to **Master**. **Adaptive**: Allows link symmetry to vary dynamically in response to offered traffic load. This is not supported in the following cases: • Where radar avoidance is mandated in the region. • Link Mode Optimization is set to **TDM Traffic**. **"5 to 1"**, **"3 to 1**, **"2 to 1"**, "**1 to 1"**, "**1 to 2"**, **"1 to 3"** or **"1 to 5"**: There is a fixed division between transmit and receive time in the TDD frame of the master ODU. The first number in the ratio represents the time allowed for the transmit direction and the second number represents the time allowed for the receive direction. The appropriate matching Link Symmetry is set at the slave ODU automatically. For example, if Link Symmetry is set to "**2 to 1"** at the master ODU, then the slave ODU will be set automatically as "**1 to 2"**. In this example, the master-slave direction has double the capacity of the slave-master direction. When TDM is enabled (Interface Configuration page on page 6-14), Link Symmetry is limited to "**1 to 1**".
Spectrum Management Control	In regions that do not mandate DFS (radar detection), the options are: **DSO** **Fixed Frequency** In regions that mandate DFS (radar detection), the options are: **DFS** **DFS with DSO** This attribute is disabled if the regulatory requirement is fixed frequency only.
Extended Spectrum Scanning	Enables scanning of the entire frequency spectrum supported by the device (4900 MHz to 6050 MHz). **Disabled:** The extended Spectrum Scanning is disabled. **Enabled:** The extended Spectrum Scanning is enabled. **Caution** Extended Spectrum Scanning increases DSO performance. Do not leave Extended Spectrum Scanning enabled during normal operation.
Lower Center Frequency	The center frequency (MHz) of the lowest channel that may be used by this link. Not displayed when Spectrum Management Control is set to **Fixed Frequency.** Use this attribute to slide the available channels up and down the band.

Attribute	Meaning
Default Raster	This is only displayed when Spectrum Management Control is set to **Fixed Frequency**. Limits frequency selection to the unit's default raster setting.
Fixed Tx Frequency, Fixed Rx Frequency	This is only displayed when Spectrum Management Control is set to **Fixed Frequency**. The settings must be compatible at each end of the link. Once configured, the spectrum management software will not attempt to move the wireless link to a channel with lower co-channel or adjacent channel interference. Therefore this mode of operation is only recommended for deployments where the installer has a good understanding of the prevailing interference environment.
Tx Color Code, Rx Color Code	Tx Color Code and Rx Color Code may be used to minimize interference in a dense network of synchronized PTP 650 units where some of the units are operating on the same frequency. When this type of network is designed, the Color Code values are normally specified in the link planning report. In all other cases, Cambium Networks recommend that Tx Color Code and Rx Color Code are left at the default value of **A**. The value of Tx Color Code MUST always match the value of Rx Color Code at the other end of the link.
Antenna Gain	Only displayed when the ODU is connectorized. Gain of the remote antenna.
Cable Loss	Only displayed when the ODU is connectorized. Loss in the ODU-antenna RF cable. If there is a significant difference in length of the RF cables for the two antenna ports, then the average value should be entered.
Maximum Transmit Power	The maximum power (dBm) at which the unit will transmit, configurable in steps of 1 dB. Its maximum value is controlled by the selected combination of Regulatory Band, Bandwidth and (for connectorized units) Antenna Gain and Cable Loss. Set this attribute to the value specified in the installation report (LINKPlanner).
Installation Mode	**Arm With Tones**: Audio tones will be emitted during antenna alignment (the recommended option). **Arm Without Tones**: Audio tones will not be emitted during antenna alignment. **Change Config Without Arming**: Configuration changes will be made without arming the ODU for alignment.

Attribute	Meaning
Ranging Mode	This can only be modified if Installation Mode is **Arm With Tones** or **Arm Without Tones**. **Auto..**: During alignment, the wireless units use algorithms to calculate link range. To implement automatic ranging, select a value that corresponds to the estimated maximum range of the link: **Auto 0 to 40 km** (0 to 25 miles). **Auto 0 to 100km** (0 to 62 miles). **Auto 0 to 200km** (0 to 125 miles). **Target Range**: During alignment, the wireless units use the approximate link distance (entered in Target Range) to calculate link range. The main advantage of Target Range mode is that it reduces the time taken by the units to range. If preferred, range functions can be configured to operate in miles, as described in Webpage Properties page on page 6-68.
Target Range	Only available when Ranging Mode is set to **Target Range**. The approximate distance between the two wireless units to within ± 1 km. Enter the same value at both ends of the link.

TDD synchronization page (optional)

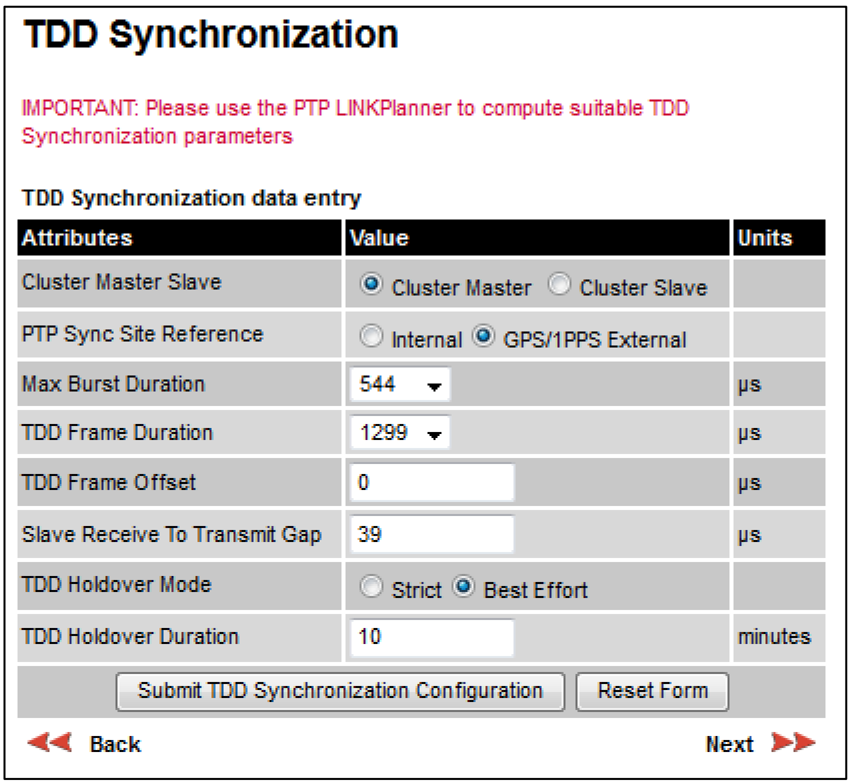
If TDD Synchronization Mode is set to **Enabled** in the Step 2: Wireless Configuration page, the Step 3: TDD Synchronization page (Figure 131) is the third Installation Wizard page.

For more information on the available options, refer to Configuration options for TDD synchronization on page 3-31.

Procedure:

- Update the attributes (Table 127).
- Click **Next**.

Figure 131 Step 3: TDD Synchronization page



Note

The data required to populate this page is available in LINKPlanner.

Table 127 TDD Synchronization attributes

Attribute	Meaning
Cluster Master Slave	**Cluster Master**: The first ODU in the synchronization chain. **Cluster Slave**: The second or subsequent ODU in the chain.
PTP-SYNC Site Reference	**Internal**: Standalone operation with no external timing reference. **GPS/1PPS External**: An external GPS receiver will provide a 1 pps timing reference.
Max Burst Duration	The maximum duration of the burst opportunity. Select a value in the range **544** to **2176** microseconds.
TDD Frame Duration	Select a value in the range **1299** to **2747** microseconds.
TDD Frame Offset	The delay of the start of the TDD frame from the epoch of the external timing reference. This permits the design of synchronized networks in which the phase of the TDD frame is independent of the master/slave function. Enter a value in the range from zero to one microsecond less than the TDD Frame Duration.
Slave Receive To Transmit Gap	The duration of the gap between receive and transmit at the slave ODU.
TDD Holdover Mode	Only displayed when Cluster Master Slave is set to **Cluster Master**. **Strict**: The unit will not transmit when synchronization is lost. **Best Effort**: The unit will synchronize when there is a reference signal, but otherwise will operate in unsynchronized mode.
TDD Holdover Duration	Only displayed when Cluster Master Slave is set to **Cluster Master**. Specifies duration of holdover period following loss of the external timing reference for TDD synchronization. Default value **10** minutes, maximum **60** minutes.

Confirm Installation Configuration page

Menu option: **Installation** (Figure 132). Use this page to review and confirm the updated wireless configuration of the unit.

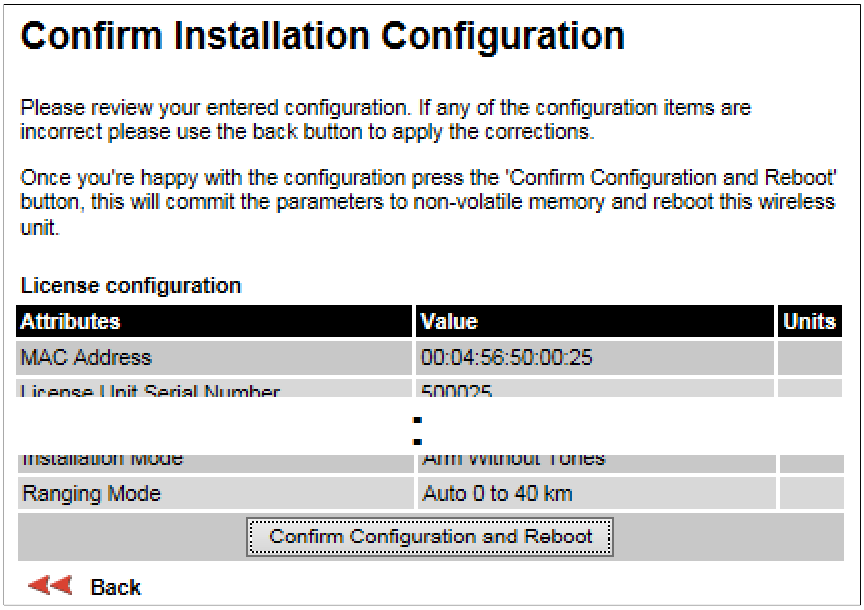


Figure 132 Confirm Installation Configuration page (top and bottom of page shown)

Procedure:

- To undo or correct any updates, click **Back**.
- To confirm the updates and arm the installation, click **Confirm Configuration and Reboot** and click **OK** to reboot the unit.
- If IP Address, Subnet Mask or Gateway IP Address have been changed: reconfigure the local management PC to use an IP address that is valid for the network. Refer to Configuring the management PC on page 6-4.
- If IP Address has been changed, use the new IP address to log into the unit.

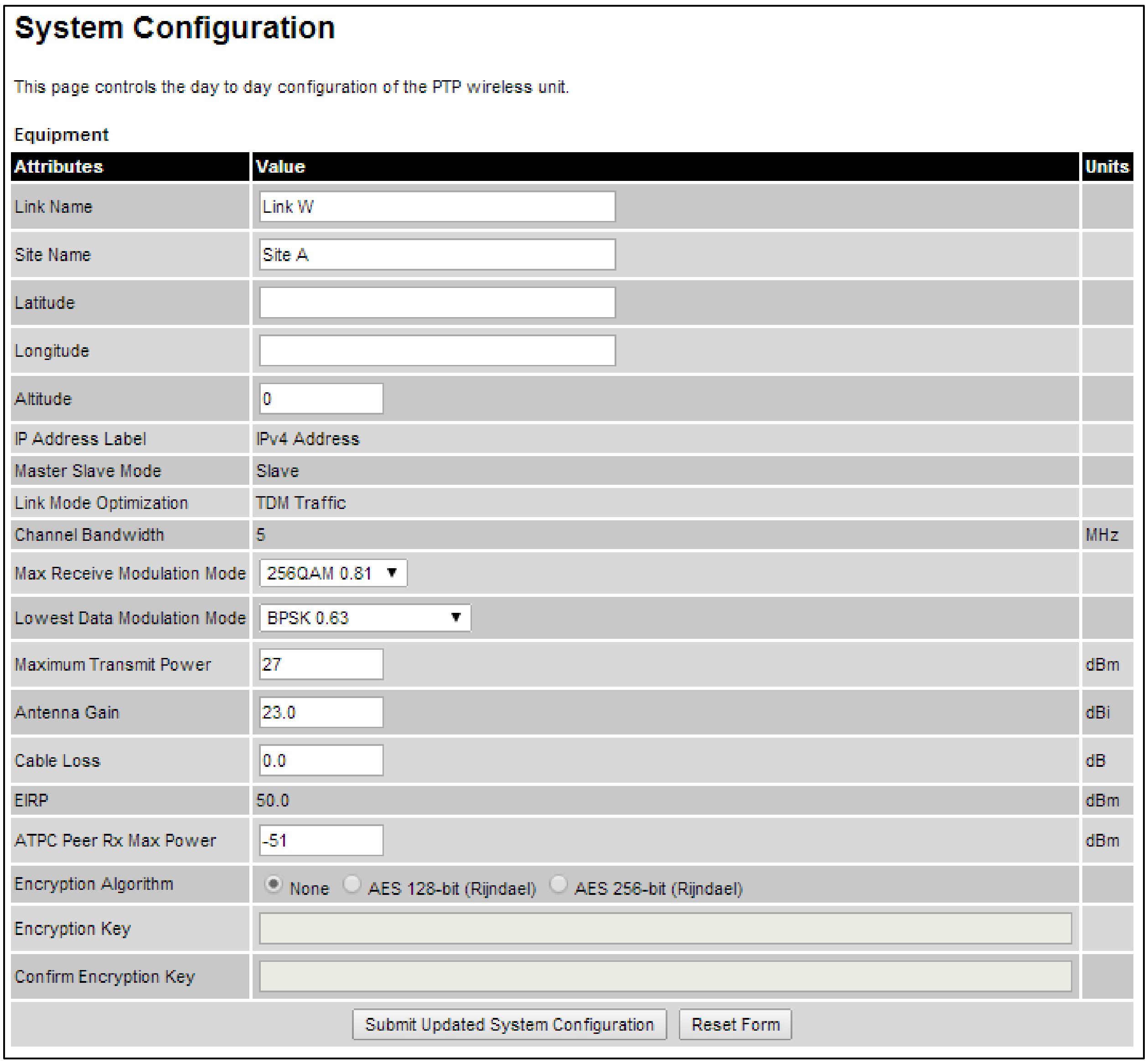
System menu

This section describes how to configure the IP and Ethernet interfaces of the PTP 650 unit.

System Configuration page

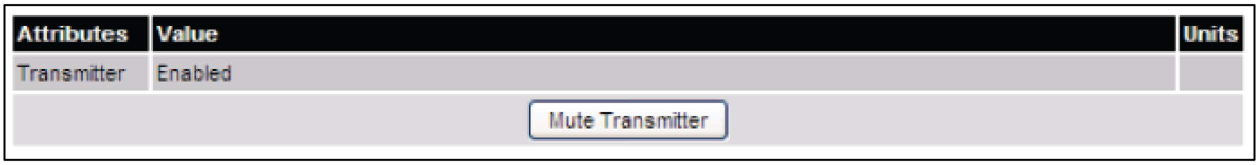
Menu option: **System > Configuration** (Figure 133). Use this page to enable AES encryption and to review and update key wireless attributes of the unit.

Figure 133 System Configuration page



If the ODU is a Master unit and Transmitter Mute Control is enabled (Webpage Properties page on page 6-68), the Mute Transmitter control is displayed at the top of this page (Figure 134).

Figure 134 Mute Transmitter control in System Configuration page



Caution

Configuring link encryption over an operational link will necessitate a service outage. Therefore, the configuration process should be scheduled during a period of low link utilization.

Procedure:

- If AES encryption is required but the System Configuration page does not contain the Encryption Algorithm or Encryption Key attributes, then order the necessary AES capability upgrade, generate a license key and enter it on the Software License Key page (Software License Key page on page 6-11).
- Update the attributes (Table 128).
- To save changes, click **Submit Updated System Configuration**.
- If a reboot request is displayed, click **Reboot Wireless Unit** and **OK** to confirm.

Table 128 System Configuration attributes

Attribute	Meaning
Transmitter	Only displayed when the ODU is a Master unit and Transmitter Mute Control is enabled. Use the **Mute Transmitter** control to toggle between **Muted** and **Enabled**. **Muted:** The ODU will not radiate and will not forward Ethernet frames between the wireless interface and the Ethernet ports. **Enabled**: The ODU is allowed by the user to radiate and will forward Ethernet frames between the wireless interface and the Ethernet ports.
Link Name	Link Name may consist of letters (A-Z and a-z), numbers (0-9), spaces, and the following special characters: (),-.,:<=>[]_{}. Link Name must be same at both ends and different to site name.
Site Name	User defined name for the site, with additional notes (if required).
Latitude	The latitude of the ODU, measured in decimal degrees. This attribute has no internal function.

Attribute	Meaning
Longitude	The longitude of the ODU, measured in decimal degrees. This attribute has no internal function.
Altitude	The altitude of the ODU, measured in meters. This attribute has no internal function.
IP Address Label	Read only. The IP Address version used to identify the unit in SMTP messages, fault logs and other system outputs. **IPv4** or **IPv6**: The unit is identified using its IPv4 or IPv6 Address. These options are only available when IP Version is set to **Dual IPv4 and IPv6** in the in the LAN Configuration page (Table 129).
Master Slave Mode	**Master:** The unit is a Master, that is, it controls the point-to-point link and its maintenance. On startup, the Master transmits until a link with the Slave is made. **Slave:** The unit is a Slave, that is, it listens for its peer and only transmits when the peer has been identified. Read only.
Link Mode Optimization	**IP Traffic:** The link is optimized for IP traffic to provide the maximum possible link capacity. **TDM Traffic:** The link is optimized for TDM traffic to provide the lowest possible latency. Read only.
Channel Bandwidth	Bandwidth of the transmit and receive radio channels. Read only.
Max Receive Modulation Mode	The maximum mode the unit will use as its adaptive modulation. By default the Max Receive Modulation Mode is the highest mode available. For minimum error rates, set the maximum modulation mode to the minimum necessary to carry the required traffic.
Lowest Data Modulation Mode	The lowest modulation mode that must be achieved before the link is allowed to bridge customer data Ethernet frames. This does not affect the bridging of management data: if out-of-band remote management is enabled, this will continue regardless of modulation mode.
Max Transmit Power	The maximum power (dBm) at which the unit will transmit, configurable in steps of 1 dB. Its maximum value is controlled by the combination of the selected Regulatory Band, Bandwidth and (for connectorized units) Antenna Gain and Cable Loss. Set this attribute to the value specified in the installation report (LINKPlanner).
Antenna Gain	Only displayed when the ODU is connectorized. Gain of the remote antenna.

Attribute	Meaning
Cable Loss	Only displayed when the ODU is connectorized. Loss in the ODU-antenna RF cable. If there is a significant difference in length of the RF cables for the two antenna ports, then the average value should be entered.
EIRP	Only displayed when the ODU is connectorized. Effective Isotropic Radiated Power (EIRP) describes the strength of the radio signal leaving the wireless unit. Use it to verify that the link configuration (Max Transmit Power, Antenna Gain and Cable Loss) does not exceed any applicable regulatory limit. Read only.
ATPC Peer Rx Max Power	ATPC maximum receive power level at the remote ODU. In a radar avoidance area this is calculated by the software and cannot be changed. In a non-radar avoidance area this can be set manually.
Encryption Algorithm	Only displayed when an AES encryption license key has been generated (Generating license keys on page 6-3) and submitted (Software License Key page on page 6-11). Values are: **None**, **AES 128-bit** or **AES 256-bit**. Use the same setting at both link ends.
Encryption Key	Only displayed when AES encryption is enabled by license key. The key consists of 32 or 64 case-insensitive hexadecimal characters. Use the same key at both link ends.
Confirm Encryption Key	Only displayed when AES encryption is enabled by license key. Retype the Encryption Key.

LAN Configuration page

Menu option: **System > Configuration > LAN Configuration**. Use this page to control how users connect to the PTP 650 web interface, either from a locally connected computer or from a management network.

The appearance of this page varies depending upon which features have been enabled by license key. For example, Figure 135 shows the attributes that are displayed when Aux Port, Second Data Service and Out-of-Band Management Service, support are enabled, whereas Figure 136 shows the attributes that are displayed when TDM support is enabled.

Caution

Before configuring a VLAN for management interfaces, ensure that the VLAN is accessible, otherwise the unit will be inaccessible after the next reboot.

Caution

Before configuring in-band management, ensure that the Master and Slave units are configured with different IP addresses, otherwise the management agent will not be able to distinguish the two units.

Caution

Auto-negotiation and forced Ethernet configuration:

- To operate an Ethernet link at a fixed speed, set Auto Negotiation to **Enabled** and limit Auto Neg Advertisement to the desired speed. If constrained auto-negotiation fails, set Auto Negotiation to **Disabled** (forced Ethernet configuration) as a last resort.
- Both ends of an Ethernet link must be configured identically, because forced and auto-negotiation are not compatible: a mixed configuration will cause a duplex mismatch, resulting in greatly reduced data capacity.
- The Auto Neg Advertisement or Forced Configuration data rates must be within the capability of the Ethernet link partner, otherwise loss of service will occur.

Note

When TDM is enabled (Interface Configuration page on page 6-14), the following restrictions are automatically applied:

- Main PSU Port Auto Negotiation is set to **Enabled**.
- Main PSU Port Auto Neg Advertisement is set to **1000 Mbps Full Duplex**.
- Main PSU Port Auto MDIX is set to **Enabled**.

Figure 135 LAN Configuration page (Aux and OOB support)

LAN Configuration

This page controls the LAN configuration of the PTP wireless unit.

Attributes	Value	Units
IP Interface		
IP Version	◉ IPv4 ○ IPv6 ○ Dual IPv4 and IPv6	
IPv4 Address	10 . 10 . 10 . 11	
Subnet Mask	255 . 255 . 0 . 0	
Gateway IP Address	10 . 10 . 10 . 0	
Use VLAN For Management Interfaces	No VLAN Tagging ▼	
DSCP Management Priority	00 - DF ▼	
Data Service	◉ Main PSU Port ○ Aux Port ○ SFP Port	
Second Data Service	○ None ◉ Aux Port ○ SFP Port	
Management Service	○ None ◉ In-Band Main PSU Port ○ In-Band Aux Port	
Local Management Service	☑ Out-of-Band SFP Port	
Ethernet Loopback Mode	◉ Disabled ○ Aux to Main PSU ○ Aux to SFP	
Data Port Wireless Down Alert	◉ Disabled ○ Enabled	
Second Data Port Wireless Down Alert	◉ Disabled ○ Enabled	
Main PSU Port		
Main PSU Port Auto Negotiation	○ Disabled ◉ Enabled	
Main PSU Port Auto Neg Advertisement	☑ 1000 Mbps Full Duplex	
	☑ 100 Mbps Full Duplex	
Main PSU Port Auto Mdix	○ Disabled ◉ Enabled	
Aux Port		
Aux Port Auto Negotiation	○ Disabled ◉ Enabled	
Aux Port Auto Neg Advertisement	☑ 1000 Mbps Full Duplex	
	☑ 100 Mbps Full Duplex	
Aux Port Auto Mdix	○ Disabled ◉ Enabled	
Aux Port Power Over Ethernet Output	◉ Disabled ○ Enabled	
Bridging		
Local Packet Filtering	○ Disabled ◉ Enabled	
Data Port Pause Frames	◉ Tunnel ○ Discard	
Second Data Port Pause Frames	○ Tunnel ◉ Discard	
Synchronous Ethernet		
Sync E Tracking	◉ Disabled ○ Enabled	
IEEE 1588		
Transparent Clock	◉ Disabled ○ Enabled	

Submit Updated System Configuration | Reset Form

Figure 136 LAN Configuration page (TDM support)

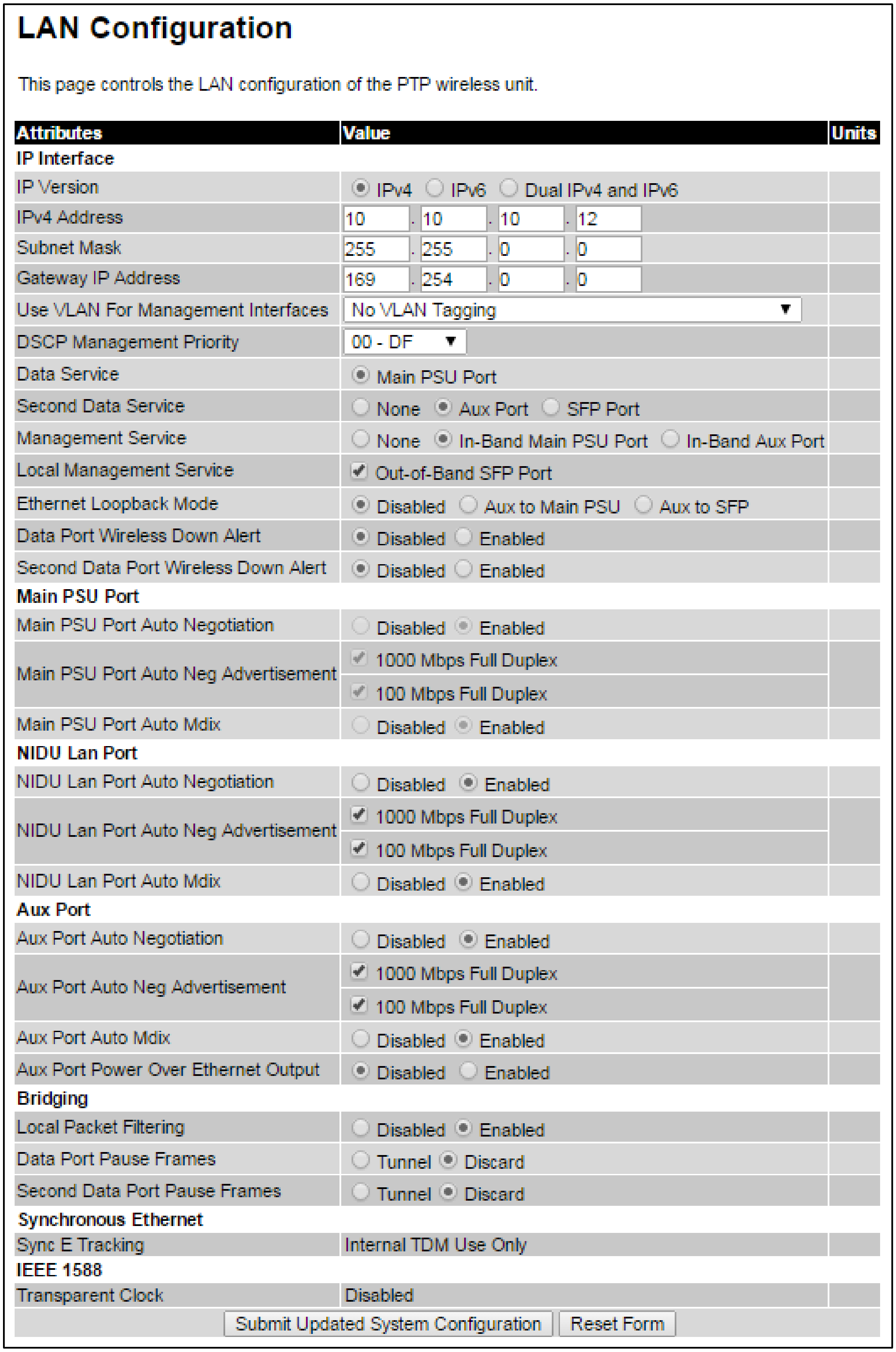
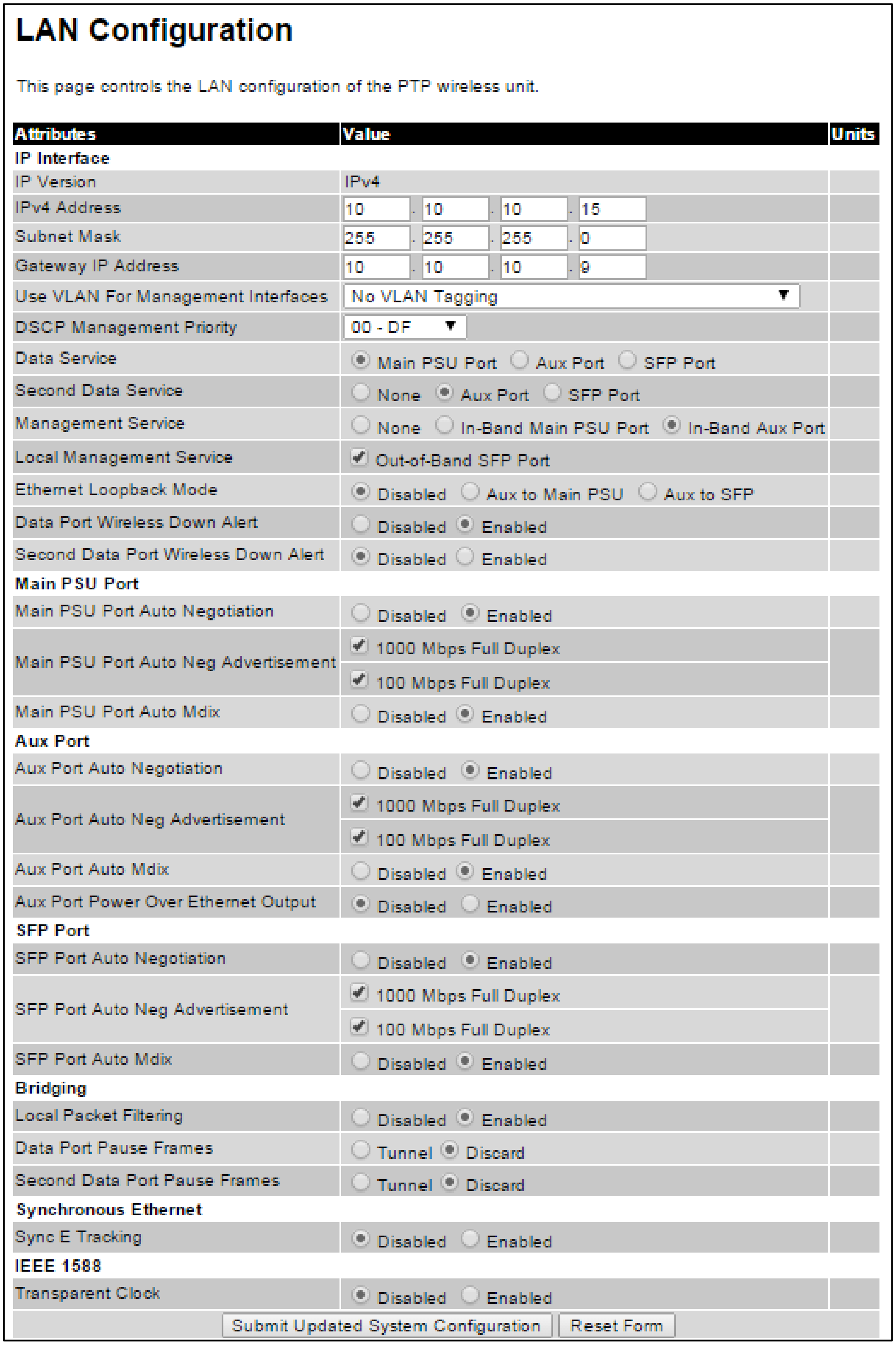


Figure 137 LAN Configuration page (SFP support)



LAN Configuration

This page controls the LAN configuration of the PTP wireless unit.

Attributes	Value	Units
IP Interface		
IP Version	IPv4	
IPv4 Address	10 . 10 . 10 . 15	
Subnet Mask	255 . 255 . 255 . 0	
Gateway IP Address	10 . 10 . 10 . 9	
Use VLAN For Management Interfaces	No VLAN Tagging	
DSCP Management Priority	00 - DF	
Data Service	Main PSU Port / Aux Port / SFP Port	
Second Data Service	None / Aux Port / SFP Port	
Management Service	None / In-Band Main PSU Port / In-Band Aux Port	
Local Management Service	Out-of-Band SFP Port	
Ethernet Loopback Mode	Disabled / Aux to Main PSU / Aux to SFP	
Data Port Wireless Down Alert	Disabled / Enabled	
Second Data Port Wireless Down Alert	Disabled / Enabled	
Main PSU Port		
Main PSU Port Auto Negotiation	Disabled / Enabled	
Main PSU Port Auto Neg Advertisement	1000 Mbps Full Duplex	
	100 Mbps Full Duplex	
Main PSU Port Auto Mdix	Disabled / Enabled	
Aux Port		
Aux Port Auto Negotiation	Disabled / Enabled	
Aux Port Auto Neg Advertisement	1000 Mbps Full Duplex	
	100 Mbps Full Duplex	
Aux Port Auto Mdix	Disabled / Enabled	
Aux Port Power Over Ethernet Output	Disabled / Enabled	
SFP Port		
SFP Port Auto Negotiation	Disabled / Enabled	
SFP Port Auto Neg Advertisement	1000 Mbps Full Duplex	
	100 Mbps Full Duplex	
SFP Port Auto Mdix	Disabled / Enabled	
Bridging		
Local Packet Filtering	Disabled / Enabled	
Data Port Pause Frames	Tunnel / Discard	
Second Data Port Pause Frames	Tunnel / Discard	
Synchronous Ethernet		
Sync E Tracking	Disabled / Enabled	
IEEE 1588		
Transparent Clock	Disabled / Enabled	

Submit Updated System Configuration | Reset Form

Procedure:

1 Review and update the attributes: IP Interface (Table 129); Main PSU or Aux Port (Table 130); Bridging (Table 132).

2 To save changes, click **Submit Updated System Configuration**. The system may reboot.

3 If Main PSU Port is selected for **Data Service** only (and not for **Management Service**), connect management PC to the port (Aux or SFP) that was selected for Management or Local Management Service

4 If IP Address, Subnet Mask or Gateway IP Address have been changed, reconfigure the local management PC to use an IP address that is valid for the network. Refer to Configuring the management PC on page 6-4.

5 If IP Address has been changed, use the new IP address to log into the unit.

Table 129 IP interface attributes

Attribute	Meaning
IP Version	Defined in Table 124.
IPv4 Address	Defined in Table 124.
Subnet Mask	Defined in Table 124.
Gateway IP Address	Defined in Table 124.
IPv6 Address	Defined in Table 124.
IPv6 Prefix Length	Defined in Table 124.
IPv6 Gateway Address	Defined in Table 124.
IPv6 Auto Configured Link Local Address	Defined in Table 124.
Use VLAN For Management Interfaces	Defined in Table 124.
VLAN Management VID	Defined in Table 124.
VLAN Management Priority	Defined in Table 124.
DSCP Management Priority	Defined in Table 124.
Data Service	Defined in Table 124. For more help, see Ethernet port allocation on page 3-36.
Second Data Service	Defined in Table 124. For more help, see Ethernet port allocation on page 3-36.

Attribute	Meaning
Management Service	Defined in Table 124. For more help, see Ethernet port allocation on page 3-36.
Local Management Service	Defined in Table 124 For more help, see Ethernet port allocation on page 3-36.
Ethernet Loopback Mode	Sets a temporary loopback between the selected ports. The loopback is disabled on a reboot. This mode is provided to allow access to a device connected to the local ODU Aux port via either the main PSU or SFP port. Loopback does not work with jumbo frames: the maximum frame size is 1536 bytes in loopback.
Data Port Wireless Down Alert	**Disabled:** The data Ethernet link will not be dropped when the wireless link drops. **Enabled:** The Data Ethernet link will be dropped briefly when the wireless link drops. This signals to the connected network equipment that this link is no longer available. Connected Ethernet switches can be configured to forward Ethernet frames on an alternative path identified using the Spanning Tree Protocol (STP). When TDM is enabled, the link is dropped briefly at the NIDU LAN port, and not at the ODU.
Second Data Port Wireless Down Alert	**Disabled:** The Second Data Ethernet link will not be dropped when the wireless link drops. **Enabled:** The Second Data Ethernet link will be dropped briefly when the wireless link drops. This signals to the connected network equipment that this link is no longer available. Connected Ethernet switches can be configured to forward Ethernet frames on an alternative path identified using the Spanning Tree Protocol (STP). When TDM is enabled, the link is dropped briefly at the NIDU LAN port, and not at the ODU.
Management Port Wireless Down Alert	Only displayed when an Out-of-Band Port is selected for Management Service. **Disabled:** The management Ethernet link will not be dropped when the wireless link drops. **Enabled:** The management Ethernet link will be dropped briefly when the wireless link drops. This signals to the connected network equipment that this link is no longer available. Connected Ethernet switches can be configured to forward Ethernet frames on an alternative path identified using the Spanning Tree Protocol (STP).

Attribute	Meaning
Management Network Access Enabled	Only displayed when one of the Port selection attributes (Main PSU, Aux or SFP) is set to **Out-of-Band Management Service** and **Second Data Service** is disabled or set to None. **Yes:** The local out-of-band management interface can be used to access the remote management network. **No**: The local out-of-band management interface cannot be used to access the remote management network.

Table 130 Main PSU Port, NIDU LAN Port and Aux Port attributes

Attribute	Meaning
Auto Negotiation	**Disabled:** Configuration of the Ethernet interface is forced. **Enabled:** Configuration of the Ethernet interface is automatically negotiated (default). This is the preferred setting. Use the same setting for the Ethernet link partner.
Auto Neg Advertisement	Only displayed when Auto Negotiation is set to **Enabled**. The data rate that the auto-negotiation mechanism will advertise as available on the Ethernet interface (1000 Mbps or 100 Mbps Full Duplex). Select a data rate that is within the capability of the Ethernet link partner. Use the same setting for the Ethernet link partner.
Forced Configuration	Only displayed when Auto Negotiation is set to **Disabled**. This forces the speed and duplex setting of the Ethernet interface. Over-the-air throughput will be capped to the rate of the Ethernet interface at the receiving end of the link. Select a data rate that is within the capability of the link partner. Use the same setting at both ends.
Auto Mdix	**Disabled:** The Auto Medium Dependent Interface (MDI)/Medium Dependent Interface Crossover (MDIX) capability is disabled. **Enabled:** The Auto Medium Dependent Interface (MDI)/Medium Dependent Interface Crossover (MDIX) capability is enabled.
Power Over Ethernet Output	Aux port only. **Disabled:** The ODU does not supply power to the auxiliary device. **Enabled:** The ODU supplies power to the auxiliary device.

Table 131 SFP Port (connected with copper module) attributes

Attribute	Meaning

Attribute	Meaning
SFP Port Auto Negotiation	**Disabled:** Configuration of the Ethernet interface is forced. This is to be used as a last resort only if auto-negotiation fails. **Enabled:** Configuration of the Ethernet interface is automatically negotiated (default). This is the preferred setting.
SFP Port Auto Neg Advertisement	Only displayed when SFP Port Auto Negotiation is set to **Enabled** and SFP port is connected with copper module. The data rate that the auto-negotiation mechanism will advertise as available on the Ethernet interface (1000 Mbps or 100 Mbps Full Duplex). Select a data rate that is within the capability of the Ethernet link partner. Use the same setting for the Ethernet link partner.
Forced Configuration	Only displayed when SFP Port Auto Negotiation is set to **Disabled** and SFP port is connected with copper module. This forces the speed and duplex setting of the Ethernet interface. Over-the-air throughput will be capped to the rate of the Ethernet interface at the receiving end of the link. Select a data rate that is within the capability of the Ethernet link partner. Use the same setting for the Ethernet link partner.
Auto Mdix	Only displayed when SFP port is connected with copper module. **Disabled:** The Auto Medium Dependent Interface (MDI)/Medium Dependent Interface Crossover (MDIX) capability is disabled. **Enabled:** The Auto Medium Dependent Interface (MDI)/Medium Dependent Interface Crossover (MDIX) capability is enabled.

Table 132 Bridging attributes

Attribute	Meaning
Local Packet Filtering	**Enabled:** The management agent learns the location of end stations from the source addresses in received management frames. The agent filters transmitted management frames to ensure that the frame is transmitted at the Ethernet (data or management) port, or over the wireless link. If the end station address is unknown, then management traffic is transmitted at the Ethernet port and over the wireless link. In the Local Management Service, management frames are not transmitted over the wireless link, and so address learning is not active.
Data Port Pause Frames	Controls whether the bridge tunnels or discards Layer 2 pause frames arriving at the Data port. Such frames are identified by the destination MAC Address being equal to 01-80-C2-00-00-01.

Attribute	Meaning
Second Data Port Pause Frames	**Tunnel:** The Layer 2 pause frames arriving at the port selected for Second Data Service will be bridged across to the port selected for Second Data Service on remote device over the wireless link. **Discard**: The Layer 2 pause frames arriving at the port selected for Second Data Service will be dropped.

Table 133 Synchronous Ethernet attributes

Attribute	Meaning
Sync E Tracking	**Disabled**: The synchronous Ethernet feature is disabled. Synchronization Status Messages received at the Main PSU port will be discarded. **Enabled**: The synchronous Ethernet feature is enabled. **Internal TDM Use Only**: Sync E Tracking is enabled, but is being used internally as part of the TDM feature. Sync E is not available to relay synchronization between external network equipment.
Sync E Equipment Clock	**EEC-Option 1**: Select this option if the equipment is operating in a 2048 kbit/s synchronisation hierarchy (ITU-T G.813 Option 1) **EEC-Option 2**: Select this option if the equipment is operating in a 1544 kbit/s synchronisation hierarchy (Type IV clock from ITU-T G.812)
Main PSU Port QL Rx Overwrite	This control provides the facility to overwrite the Quality Level (QL) of received Synchronisation Status Messages (SSM). It may be useful in a test environment, or for interworking with equipment that does not generate SSMs. **Disabled:** The recommended setting, the QL of received SSMs is unmodified. "**QL-PRC**" or "**QL-SSU A / QL-TNC**" or "**QL-SSU B**" or "**QL-EEC1 / QL-SEC**" or "**QL-DNU / QL-DUS**": The overwritten value of the QL. Where two QLs are given, the QL used is dependent upon the setting of "Sync E Equipment Clock" type.
Main PSU Port SSM Tx	**Disabled**: SSMs are not transmitted from the Main PSU port. Disabling SSMs may be useful in a test environment. **Enabled**: SSMs are transmitted from the Main PSU port (normal operation)
Aux Port SSM Tx	**Disabled**: SSMs are not transmitted from the Aux Port. Disabling SSMs may be useful in a test environment. **Enabled**: SSMs are transmitted from the Aux Port (normal operation)

Attribute	Meaning
SFP Port SSM Tx	**Disabled**: SSMs are not transmitted from the SFP port. Disabling SSMs may be useful in a test environment. **Enabled**: SSMs are transmitted from the SFP port (normal operation)

Table 134 IEEE 1588 attributes

Attribute	Meaning
Transparent Clock	**Disabled**: The Transparent Clock function is disabled. IEEE 1588-2008 event frames will be forwarded, but residence time corrections will not be made. **Enabled**: The Transparent Clock function is enabled. Residence time corrections will be made to IEEE 1588-2008 event frames.
Transparent Clock Port	This specifies the transparent clock source port. It can be Main PSU or SFP Fiber. Only the ports allocated for Data / Second Data Path show up for selection.
Transparent Clock VLAN	**All**: The recommended setting. Residence time corrections will be made to all IEEE 1588-2008 event frames, regardless of any VLAN encapsulation. **S-Tagged**: Residence time corrections are only made to event frames tagged with a service tag equal to “Transparent Clock VID”. **C-Tagged**: Residence time corrections are only made to event frames double tagged and with a customer tag equal to “Transparent Clock VID”.
Transparent Clock VID	The VLAN Identifier (VID) used with “Transparent Clock VLAN” to restrict residence time corrections to IEEE 1588-2008 event frames in a specific VLAN.

QoS Configuration page

Menu option: **System > Configuration > QoS Configuration** (Figure 138 or Figure 139 or Figure 140). Use this page to control the quality of service configuration. Classification may be based on fields in the Ethernet header (Layer 2) or in the network header (Layer 3). The unit recognizes two network layer protocols: IP and MPLS.

Figure 138 QoS Configuration page (Ethernet)

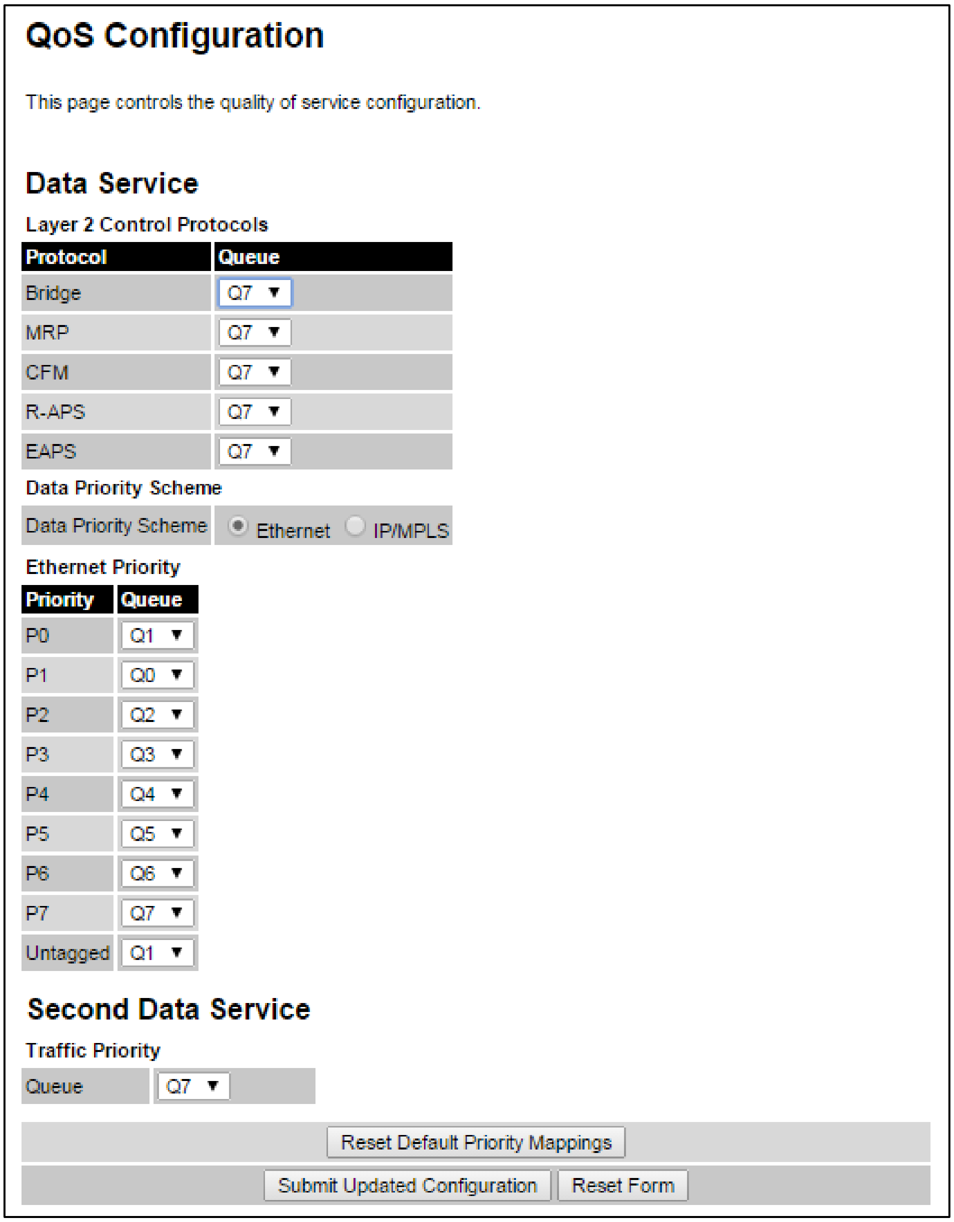


Figure 139 QoS Configuration page (IP/MPLS)

QoS Configuration

This page controls the quality of service configuration.

Data Service

Layer 2 Control Protocols

Protocol	Queue
Bridge	Q7
MRP	Q7
CFM	Q7
R-APS	Q7
EAPS	Q7

Data Priority Scheme

Data Priority Scheme	○ Ethernet ◉ IP/MPLS

Unknown Network Layer Protocol

Unknown Protocol	Q1

IP DSCP

DSCP	Queue	DSCP	Queue	DSCP	Queue	DSCP	Queue
00 - DF	Q1	16 - CS2	Q3	32 - CS4	Q4	48 - CS6	Q7
01	Q1	17	Q1	33	Q1	49	Q1
02	Q1	18 - AF21	Q3	34 - AF41	Q4	50	Q1
03	Q1	19	Q1	35	Q1	51	Q1
04	Q1	20 - AF22	Q3	36 - AF42	Q4	52	Q1
05	Q1	21	Q1	37	Q1	53	Q1
06	Q1	22 - AF23	Q3	38 - AF43	Q4	54	Q1
07	Q1	23	Q1	39	Q1	55	Q1
08 - CS1	Q0	24 - CS3	Q3	40 - CS5	Q5	56 - CS7	Q1
09	Q1	25	Q1	41	Q1	57	Q1
10 - AF11	Q2	26 - AF31	Q3	42	Q1	58	Q1
11	Q1	27	Q1	43	Q1	59	Q1
12 - AF12	Q2	28 - AF32	Q3	44 - VA	Q6	60	Q1
13	Q1	29	Q1	45	Q1	61	Q1
14 - AF13	Q2	30 - AF33	Q3	46 - EF	Q6	62	Q1
15	Q1	31	Q1	47	Q1	63	Q1

MPLS Traffic Class

MPLS	Queue
TC 0	Q0
TC 1	Q1
TC 2	Q2
TC 3	Q3
TC 4	Q4
TC 5	Q5
TC 6	Q6
TC 7	Q7

Second Data Service

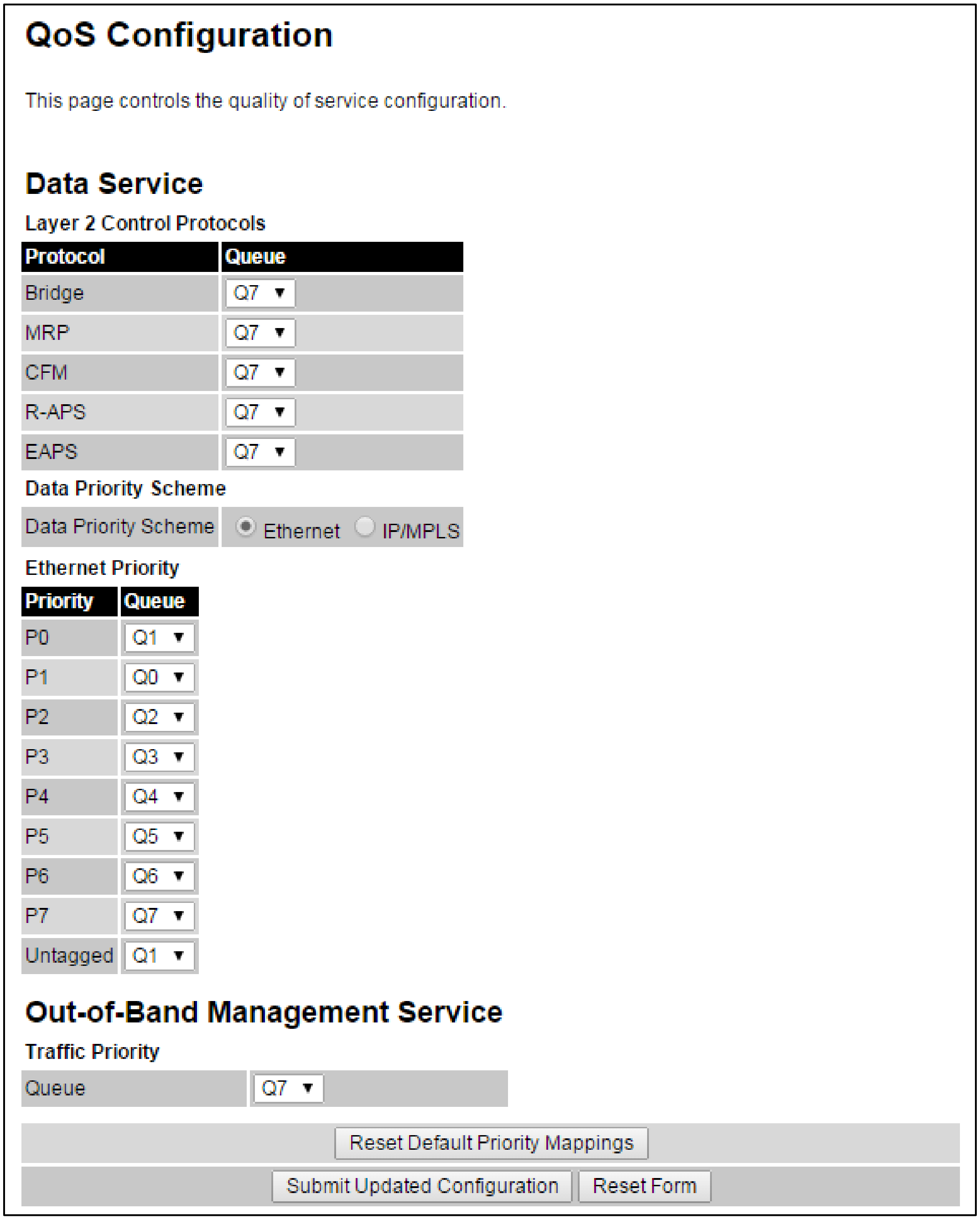
Traffic Priority

Queue	Q7

Reset Default Priority Mappings

Submit Updated Configuration | Reset Form

Figure 140 QoS Configuration page showing Out-of-Band Management



Procedures:

- Review and update the attributes (Table 135, Table 136 and Table 137).
- To use IEEE 802.1Q classification rules, click **Reset Default Priority Mappings**.
- To save changes, click: **Submit Updated Configuration**.

Note

Priority mapping must be configured the same at both Master and Slave units on the wireless link.

Table 135 QoS Configuration attributes – Data Service

Attribute	Meaning
Bridge MRP CFM R-APS EAPS	The classification of each layer 2 control protocol (L2CP) to an egress queue at the wireless port.
Data Priority Scheme	**Ethernet**: Classification is based on fields in the Ethernet header (Layer 2). **IP/MPLS**: Classification is based on fields in the network header (Layer 3). IP includes IPv4 and IPv6.
Unknown Protocol	Only displayed when Priority Scheme is **IP/MPLS**. The classification of unknown network protocols (that is, not IP or MPLS) to an egress queue at the wireless port.
Ethernet Priority	Ethernet priority mapping to Queue

Table 136 QoS Configuration attributes – Second Data Service

Attribute	Meaning
Queue	Set a priority egress queue for Second Data Service traffic classification

Table 137 QoS Configuration attributes –Out-of-Band Managment Service

Attribute	Meaning
Queue	Only displayed when one ODU port is allocated to **Out-of-Band Management** and **Second Data Service** port is not allocated (Configuring port allocations on page 6-20). The classification of out-of-band management traffic to an egress queue at the wireless port.

SFP Configuration page

Menu option: **System > Configuration > SFP Configuration**.

This page is only available when the ODU detects an optical (Figure 141) or copper (Figure 142) SFP module in the SFP port. Use it to configure the way in which the unit connects to the network via the SFP interface.

Figure 141 SFP Configuration page (optical SFP module)

SFP Configuration

This page controls the SFP configuration of the PTP wireless unit.

Attributes	Value	Units
SFP Port Auto Negotiation	○ Disabled ◉ Enabled	
Sfp Vendor Name	JDSU	
Sfp Vendor OUI	00:01:9c	
Sfp Part Number	PLRXPL-VI-S24-22	
Sfp Revision Level	1	
Sfp Laser Wavelength	850	
Sfp Serial Number	CA51QA098	
Sfp Date Code	101214	

Figure 142 SFP Configuration page (copper SFP module)

SFP Configuration

This page controls the SFP configuration of the PTP wireless unit.

Attributes	Value	Units
SFP Port Auto Negotiation	○ Disabled ◉ Enabled	
SFP Port Auto Neg Advertisement	☑ 1000 Mbps Full Duplex ☑ 100 Mbps Full Duplex	
SFP Port Auto Mdix	○ Disabled ◉ Enabled	
Sfp Vendor Name	FINISAR CORP.	
Sfp Vendor OUI	00:90:65	
Sfp Part Number	FCLF8522P2BTL	
Sfp Revision Level	A	
Sfp Serial Number	PM54X88	
Sfp Date Code	120205	

Submit Updated System Configuration | Reset Form

Procedure (only applies when copper SFP module is installed)**:**

- Update the attributes
    - o When optical SFP module is installed (Table 141).
    - o When copper SFP module is installed (Table 139)
- To save changes, click **Submit Updated System Configuration**.

Table 138 SFP Configuration (Optical module) attributes

Attribute	Meaning
SFP Port Auto Negotiation	**Disabled:** Configuration of the Ethernet interface is forced. This is to be used as a last resort only if auto-negotiation fails. **Enabled:** Configuration of the Ethernet interface is automatically negotiated (default). This is the preferred setting.

Table 139 SFP Configuration (copper SFP module) attributes

Attribute	Meaning
SFP Port Auto Negotiation	**Disabled:** Configuration of the fiber interface is forced. This is to be used as a last resort only if auto-negotiation fails. **Enabled:** Configuration of the fiber interface is automatically negotiated (default). This is the preferred setting.
SFP Port Auto Neg Advertisement	Only displayed when SFP Port Auto Negotiation is set to **Enabled**. The data rate that the auto-negotiation mechanism will advertise as available on the Ethernet interface (1000 Mbps or 100 Mbps Full Duplex). Select a data rate that is within the capability of the Ethernet link partner. Use the same setting for the Ethernet link partner.
Forced Configuration	Only displayed when SFP Port Auto Negotiation is set to **Disabled**. This forces the speed and duplex setting of the Ethernet interface. Over-the-air throughput will be capped to the rate of the Ethernet interface at the receiving end of the link. Select a data rate that is within the capability of the Ethernet link partner. Use the same setting for the Ethernet link partner.
Auto Mdix	**Disabled:** The Auto Medium Dependent Interface (MDI)/Medium Dependent Interface Crossover (MDIX) capability is disabled. **Enabled:** The Auto Medium Dependent Interface (MDI)/Medium Dependent Interface Crossover (MDIX) capability is enabled.

TDM Configuration page

Menu option: **System > Configuration > TDM Configuration** (Figure 143).

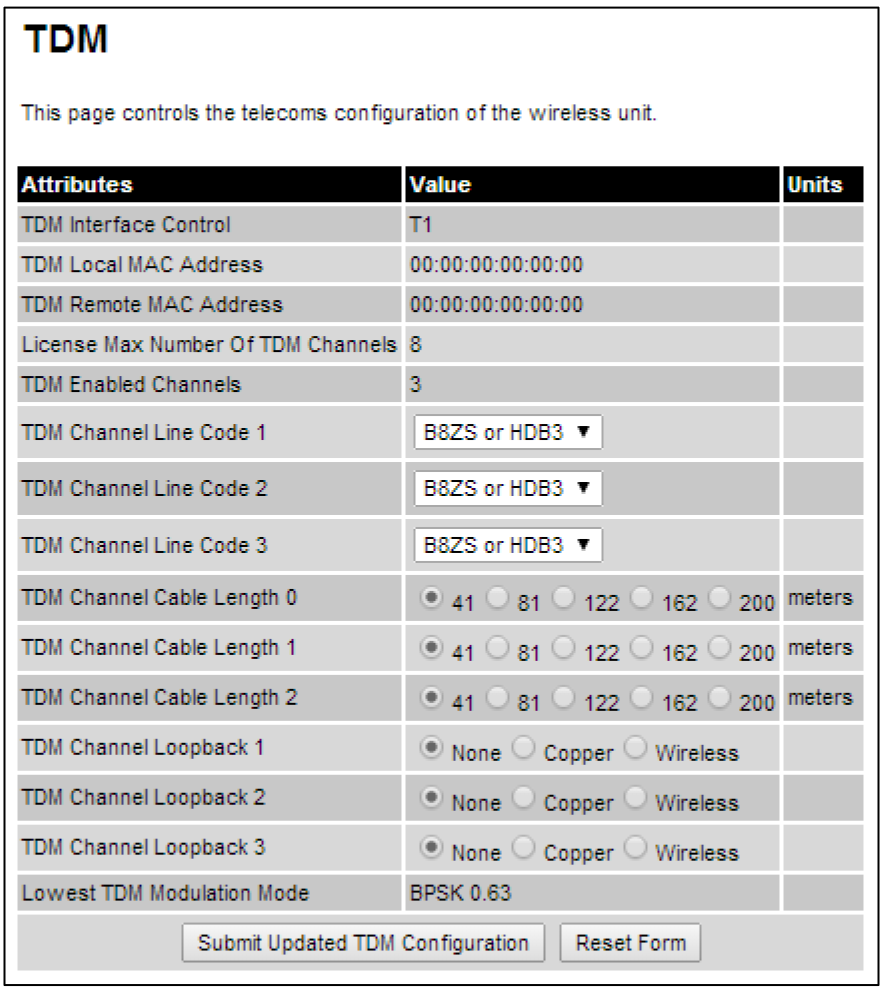
Use this page to control how the unit handles E1 or T1 channels over the wireless bridge.

This page is only available when the TDM interface is enabled and the unit is rebooted (Interface Configuration page on page 6-14).

Procedure:

- Update the attributes (Table 140).
- To save changes, click **Submit Updated TDM Configuration**.

Figure 143 TDM Configuration page (T1 option shown)



TDM

This page controls the telecoms configuration of the wireless unit.

Attributes	Value	Units
TDM Interface Control	T1	
TDM Local MAC Address	00:00:00:00:00:00	
TDM Remote MAC Address	00:00:00:00:00:00	
License Max Number Of TDM Channels	8	
TDM Enabled Channels	3	
TDM Channel Line Code 1	B8ZS or HDB3	
TDM Channel Line Code 2	B8ZS or HDB3	
TDM Channel Line Code 3	B8ZS or HDB3	
TDM Channel Cable Length 0	41 81 122 162 200	meters
TDM Channel Cable Length 1	41 81 122 162 200	meters
TDM Channel Cable Length 2	41 81 122 162 200	meters
TDM Channel Loopback 1	None Copper Wireless	
TDM Channel Loopback 2	None Copper Wireless	
TDM Channel Loopback 3	None Copper Wireless	
Lowest TDM Modulation Mode	BPSK 0.63	

Submit Updated TDM Configuration | Reset Form

Table 140 TDM Configuration attributes

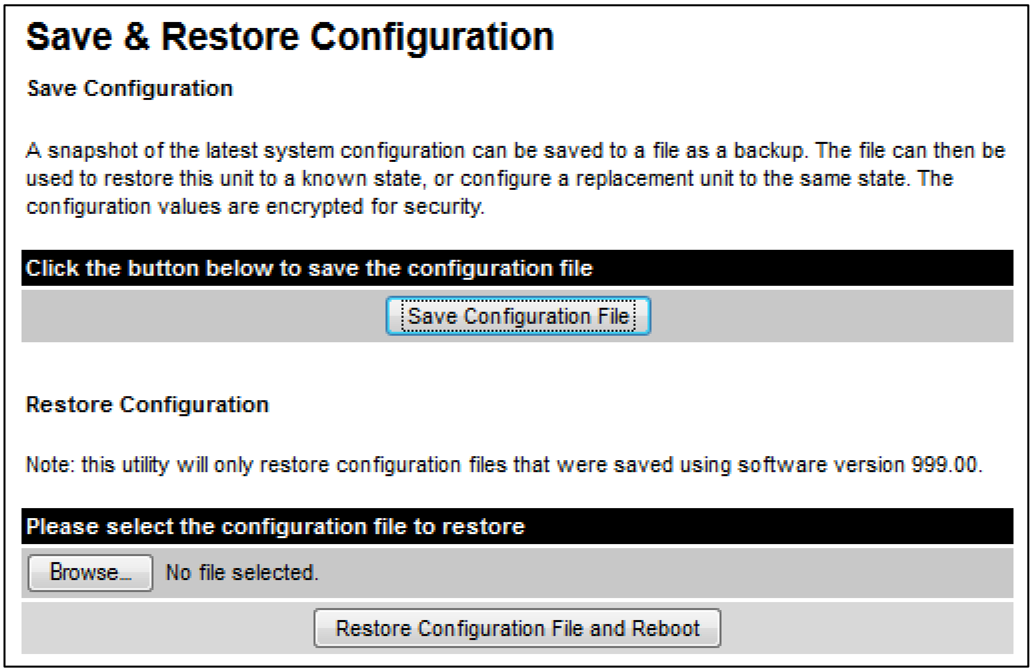
Attribute	Meaning
TDM Interface Control	Display only. Defined in Table 125.
TDM Local MAC Address	Display only. MAC address of the local NIDU.
TDM Remote MAC Address	Display only. MAC address of the remote NIDU.
License Max Number of TDM Channels	Display only. Defined in Table 125.
TDM Enabled Channels	Display only. Defined in Table 125.
TDM Channel Line Code n	Defined in Table 125.
TDM Channel Cable Length n	Defined in Table 125.
TDM Channel Loopback n	Select the loopback status of TDM channel “n” (where “n” is in the range 1 to 8). **None**: Normal operation, no testing is required. **Copper**: Sends the TDM data received from the local transceiver and NIDU back on the same TDM channel. This may be used in conjunction with a Bit Error Rate Tester to confirm that the correct connections have been made between the transceiver, NIDU and ODU. This mode cannot be used for resistance tests, as it is only capable of looping back valid TDM signals. **Wireless**: Sends the TDM data received from the wireless link back across the link on the same TDM channel. The link may be checked using, for example, a Bit Error Rate Tester to ensure that no errors are detected.
Lowest TDM Modulation Mode	Display only. Defined in Table 125.

Save and Restore Configuration page

Menu option: **System > Configuration > Save And Restore** (Figure 144).

Use the Save & Restore Configuration page to take a snapshot of the latest system configuration as a backup. The file can then be used to restore this unit to a known state, or to configure a replacement unit to the same state. The configuration values are encrypted for security.

Figure 144 Save & Restore Configuration page



Save the system configuration in the following situations:

- After a new unit has been fully configured as described in this chapter.
- After any change has been made to the configuration.
- Before upgrading the unit to a new software version.
- After upgrading the unit to a new software version.

Note

The restore is only guaranteed to work if the installed software version has not been changed since the configuration file was saved. This is why the configuration should always be saved immediately after upgrading the software version.

Note

The license key is restored automatically if the configuration file is saved and then loaded on the same unit. However, the license key is not restored if the configuration file is loaded on a different unit. Before restoring configuration to a different PTP 650 unit, ensure that a valid license key is installed (with optional capabilities enabled where appropriate).

Most of the configuration can be restored from the backup. However, certain attributes that were part of the configuration are not saved or restored automatically. Use the web interface to reconfigure the following attributes:

- Usernames, passwords and roles for the web-based interface.
- Key of Keys
- HTTPS Entropy
- HTTPS Private Key
- HTTPS Public Key Certificate
- HTTP Access Enabled
- HTTPS Access Enabled
- Telnet Access Enabled
- HTTP Port Number
- HTTPS Port Number
- Telnet Port Number
- Encryption Algorithm
- Encryption Key
- SNMP Control Of HTTP And Telnet
- SNMP Control of Passwords

Procedures:

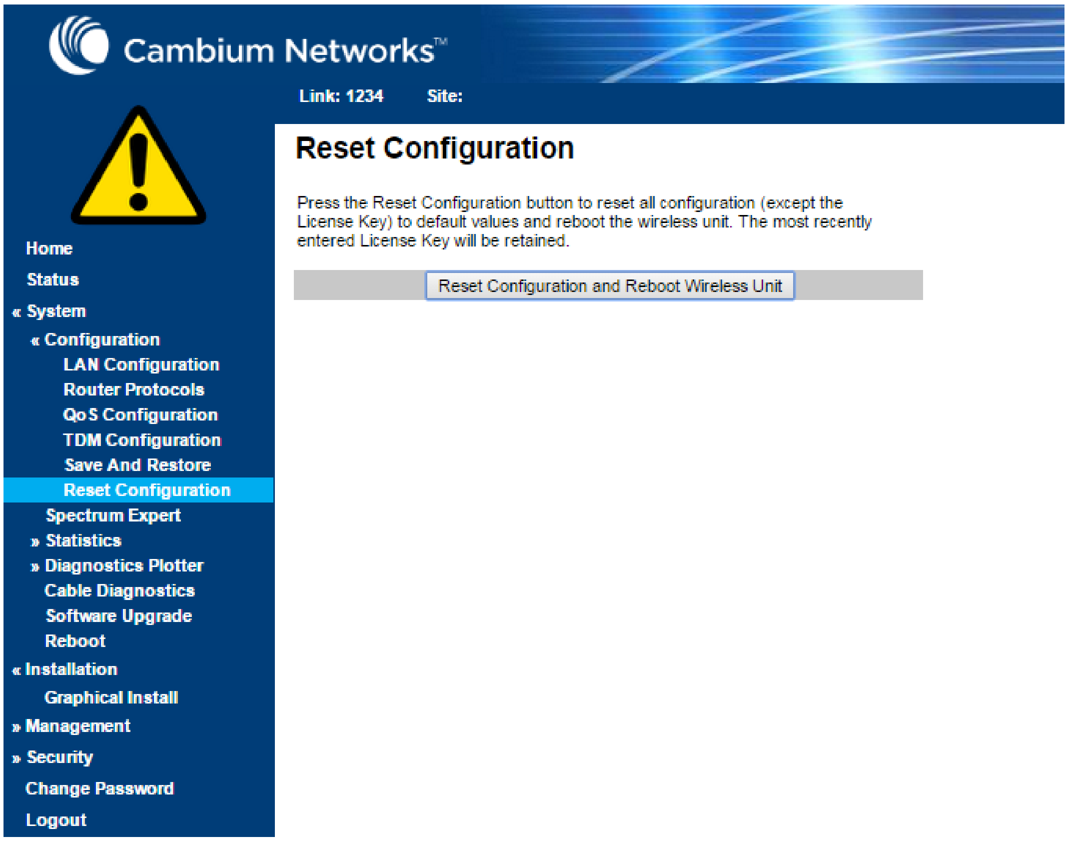
- To save the configuration:
  - Click Save Configuration File.
  - Save the file. The default filename is in the format **MAC-mm-mm-mm_IP-iii-iii-iii-iii.cfg**, where **mm-mm-mm** is MAC address of unit and **iii-iii-iii-iii** is Internet address of unit.
- To restore the configuration:
  - Click **Browse** and navigate to the PC folder containing the saved configuration file (.cfg).
  - Click **Restore Configuration File and Reboot**.
  - Click **OK** to confirm the restore. The configuration file is uploaded and used to reconfigure the new unit to the same state as the old unit. On completion, the unit reboots.

Reset Configuration page

Menu option: **System > Configuration > Reset Configuration**. Use this page to reset the ODU configuration to default settings, retaining the most recently entered License Key (Figure 145).

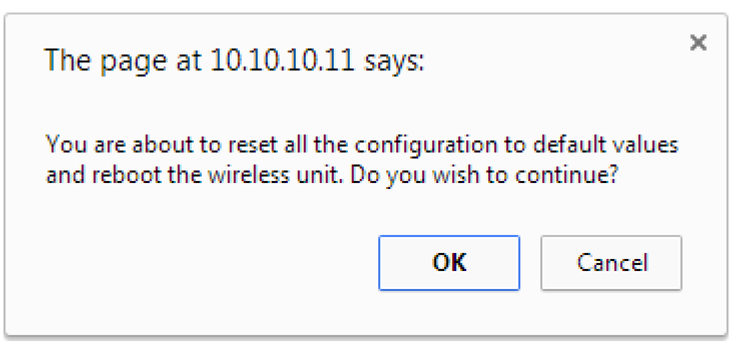
The Reset Configuration page resets the configuration to default settings. After successful execution of Reset Configuration, the ODU reboots and is then accessible via the default IP address (i.e. 169.254.1.1).

Figure 145 Reset Configuration page



Procedure:

- Click **Reset Configuration**. The user pop up box is displayed to reconfirm:



- Click **OK** to restore configuration to the default settings and reboot of unit.

Further reading

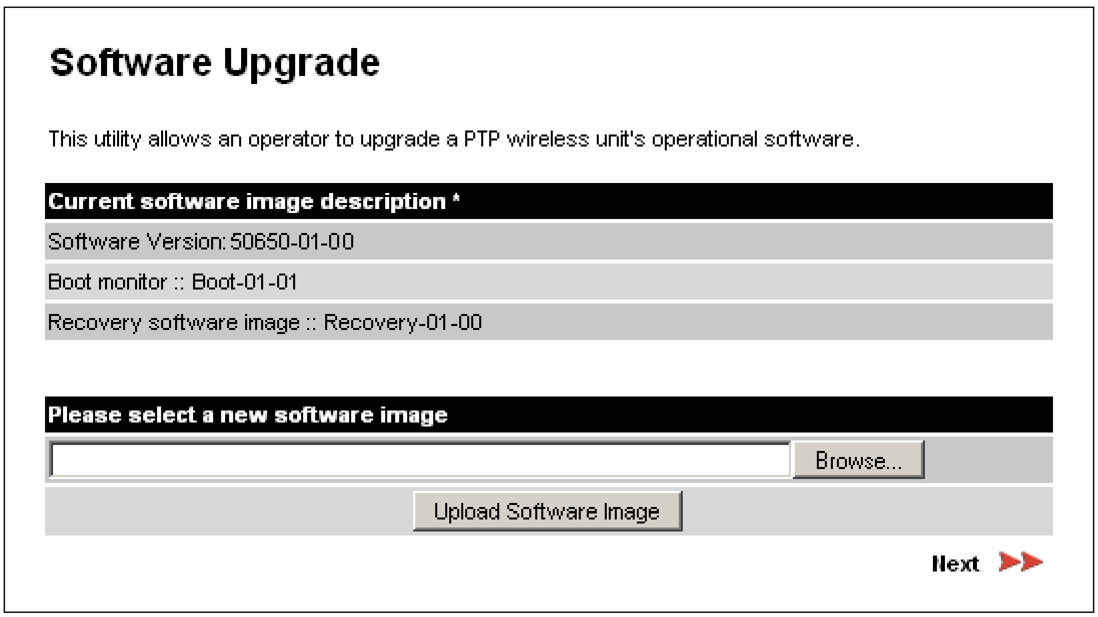
For information about…	Refer to…
Erase Configuration	Use this option to erase the entire configuration of the unit. Refer to Resetting all configuration data on page 7-70.

Software Upgrade page

Menu option: **System > Software Upgrade** (Figure 146).

Use this page to upgrade the unit to a new version of PTP 650 operational software.

Figure 146 Software Upgrade page



Caution

Ensure that the correct units are upgraded, as units cannot easily be downgraded afterwards.

Caution

Software version must be the same at both ends of the link. Limited operation may sometimes be possible with dissimilar software versions, but such operation is not supported by Cambium Networks.

Caution

If the link is operational, upgrade the remote end of the link first, then upgrade the local end. Otherwise, the remote end may not be accessible.

Preparation:

- Go to the Cambium Support web page (see Contacting Cambium Networks on page 1) and navigate to **Point-to-Point Software and Documentation**, **PTP 650 Series**.
- If the support web page contains a later Software Version than that installed on the PTP 650 unit, perform the procedure below.

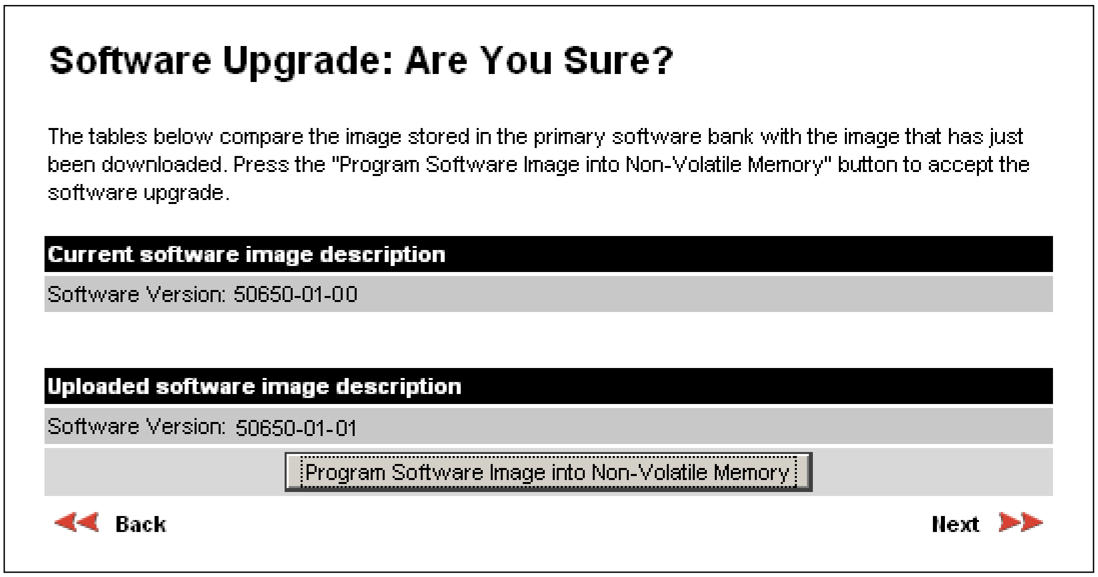
Procedure:

1 Save the system configuration; see Save and Restore Configuration page on page 6-52.

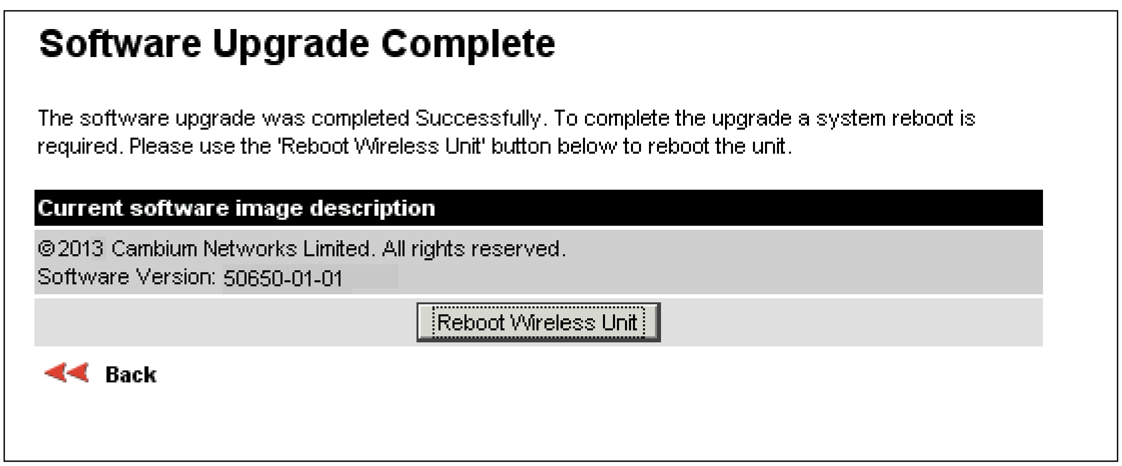
2 On the Cambium Support web page, select the latest PTP 650 software image (dld2 file) and save it to the local management PC.

3 On the Software Upgrade page, click **Browse**. Navigate to the folder containing the downloaded software image and click **Open**.

4 Click **Upload Software Image.** The Software Upgrade Confirmation page is displayed:



5 Click **Program Software Image into Non-Volatile Memory**. The Progress Tracker page is displayed. On completion, the Software Upgrade Complete page is displayed:



6 Click **Reboot Wireless Unit**, then click **OK** to confirm. The unit reboots with the new software installed.

7 Save the post-upgrade system configuration; see Save and Restore Configuration page on page 6-52.

Management menu

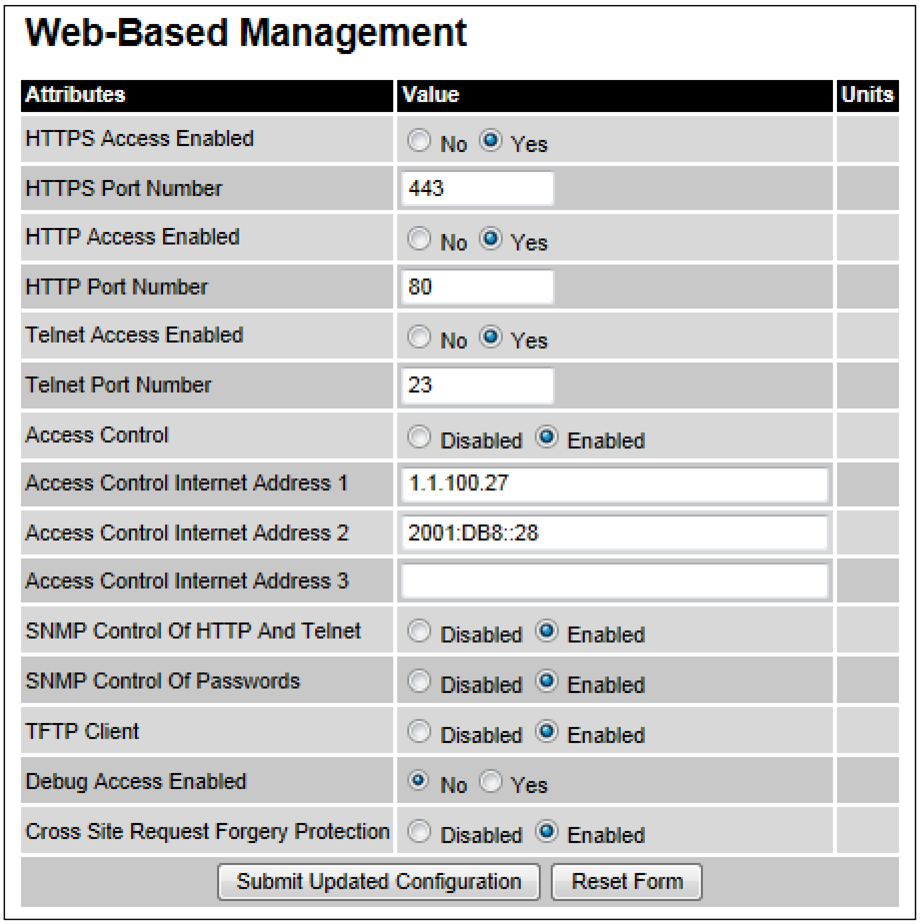
This section describes how to configure web-based management of the PTP 650 unit.

Web-Based Management page

Menu option: **Management > Web** (Figure 147).

Use this page to configure web-based management of the unit.

Figure 147 Web-Based Management page



Caution

If the HTTP, HTTPS, Telnet and SNMP interfaces are all disabled, then it will be necessary to use the Recovery image to reset IP & Ethernet Configuration back to defaults to re-enable the interfaces.

Note

The HTTP and Telnet interfaces should be disabled if the HTTPS interface is configured. (Preparing for HTTPS/TLS page 6-94).

Procedure:

- Review and update the attributes (Table 141).
- To save changes, click **Submit Updated Configuration**.

Table 141 Web-Based Management attributes

Attribute	Meaning
HTTPS Access Enabled	Only displayed when HTTPS is configured. **No:** The unit will not respond to any requests on the HTTPS port. **Yes:** The unit will respond to requests on the HTTPS port.
HTTPS Port Number	Only displayed when HTTPS is configured. The port number for HTTPS access. A value of zero means the wireless unit uses the default port.
HTTP Access Enabled	**No:** The unit will not respond to any requests on the HTTP port. **Yes:** The unit will respond to requests on the HTTP port. Remote management via HTTPS is not affected by this setting.
HTTP Port Number	The port number for HTTP access. A value of zero means the wireless unit uses the default port.
Telnet Access Enabled	**No:** The unit will not respond to any requests on the Telnet port. **Yes:** The unit will respond to requests on the Telnet port.
Telnet Port Number	The port number for Telnet access. A value of zero means the wireless unit uses the default port.
Access Control	Enables or disables access control to web-based management by Internet Address.
Access Control Internet Address 1/2/3	A list of up to three IPv4 or IPv6 Addresses permitted to perform web-based management. Only displayed when Access Control is set to **Enabled**.
SNMP Control of HTTP And Telnet	**Disabled:** Neither HTTP nor Telnet can be controlled remotely via SNMP. **Enabled:** Both HTTP and Telnet can be controlled remotely via SNMP.

Attribute	Meaning
SNMP Control of Passwords	**Enabled:** Passwords for identity-based user accounts in the web-based interface can be updated via SNMP. This option can be used together with SNMPv3 to provide a secure means to update passwords from a central network manager. **Disabled**: Passwords for identity-based user accounts can be updated only via the web-based interface (default).
TFTP Client	**Disabled:** The unit will not respond to any TFTP software download requests. **Enabled:** Software can be downloaded via TFTP, as described in Upgrading software using TFTP on page 6-115.
Debug Access Enabled	**Yes:** Cambium Technical Support is allowed to access the system to investigate faults.
Cross Site Request Forgery Protection	**Enabled:** The system is protected against cross-site request forgery attacks at the web-based interface.

Local User Accounts page

Menu option: **Management > Web > Local User Accounts**.

The contents of this page depend upon the setting of Identity Based User Accounts: **Disabled** (Figure 148) or **Enabled** (Figure 149).

Use this page to ensure that user access to the web-based management interface is controlled in accordance with the network operator's security policy. The Identity Based User Accounts option allows multiple users (from one to ten) to access the unit with one of three levels of access: Security Officer, System Administrator and Read Only. If Identity Based User Accounts are **Enabled**, this procedure may only be performed by a Security Officer.

Note

Local User Account Names, Roles and Passwords are critical security parameters that can be rest from the Zeroize CSPs page (Zeroize CSPs page on page 6-105**).**

Figure 148 Local User Accounts page (Identity Based User Accounts disabled)

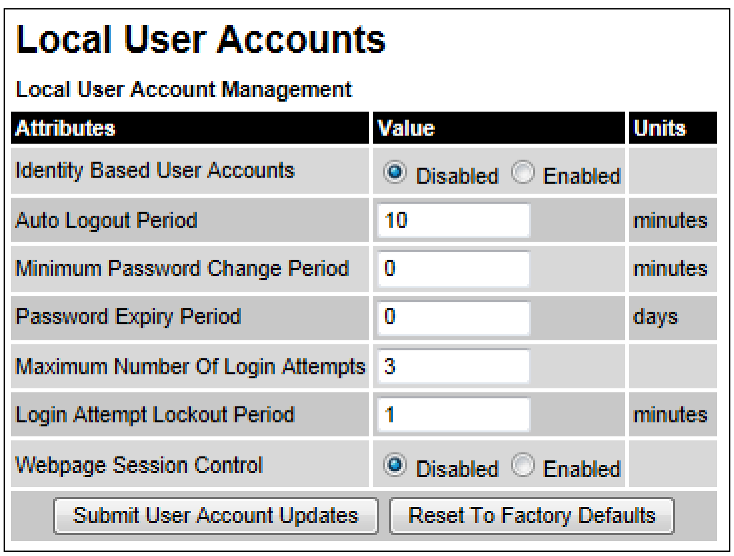
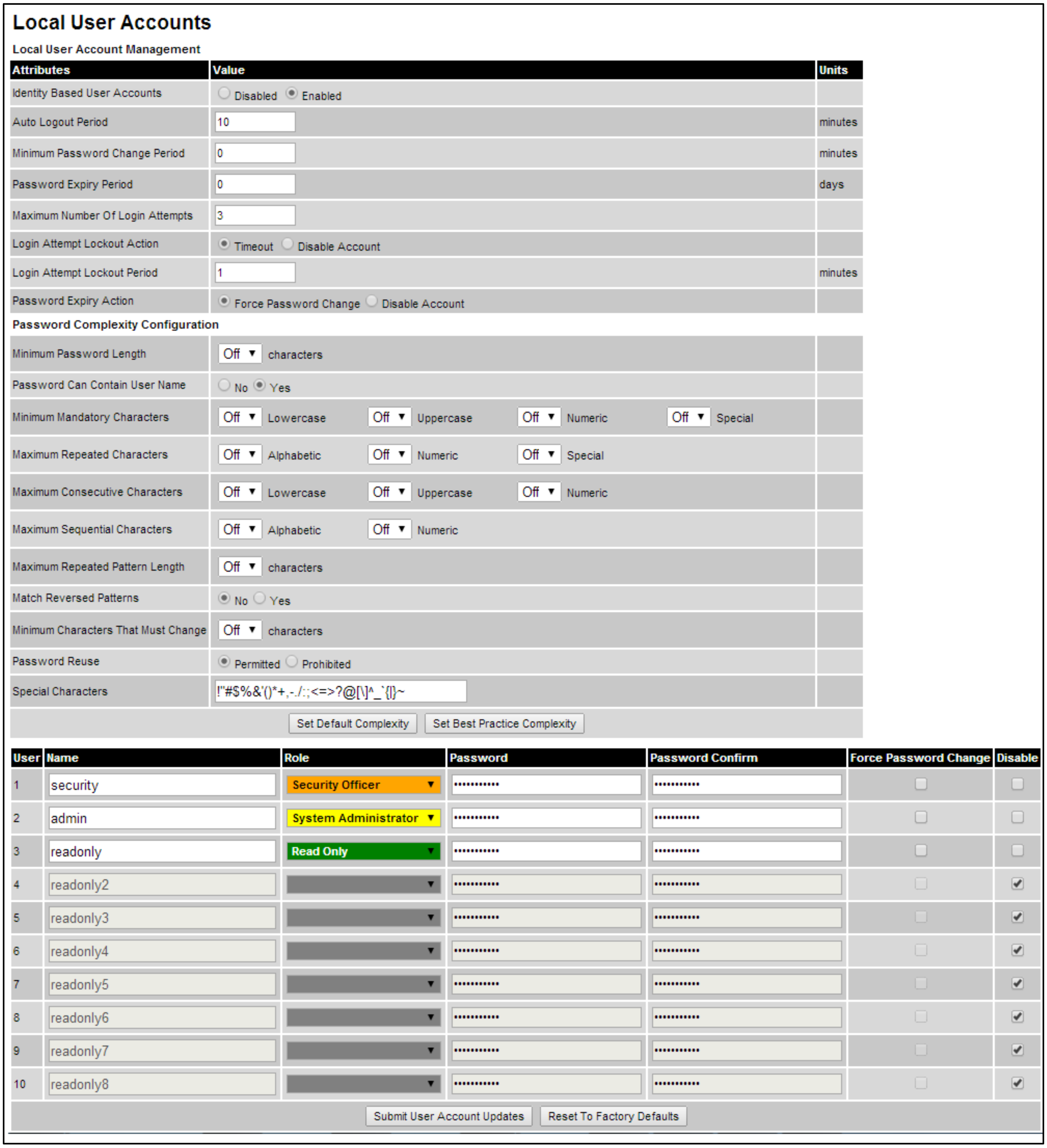


Figure 149 Local User Accounts page (Identity Based User Accounts enabled)



Procedure:

- Choose whether to set Identity Based User Accounts to **Disabled** or **Enabled**.
- Review and update the Local User Account Management attributes (Table 142).
- If Identity Based User Accounts is set to **Enabled:**
    - o Review and update the Password Complexity Configuration attributes (Table 143). To reset all attributes to the best practice values, click **Set Best Practice Complexity**. To return to default values, click **Set Default Complexity.**
    - o Review and update up to 10 identity-based user accounts (Table 144).
- If any attributes have been updated, click **Submit User Account Updates**.

Table 142 Local User Account Management attributes

Attribute	Meaning
Identity Based User Accounts	**Disabled**: Access to the web interface is controlled by a single system administration password. **Enabled**: Up to 10 users may access the unit.
Auto Logout Period	The time without user activity that elapses before a user is automatically logged out (minutes). A value of zero disables this feature.
Minimum Password Change Period	The minimum time that elapses before a user is allowed to change a password (minutes). A value of zero disables this feature.
Password Expiry Period	The time that elapses before a password expires (days). A value of zero disables this feature.
Maximum Number of Login Attempts	The maximum number of login attempts (with incorrect password) that are allowed before a user is locked out. Also, the maximum number of password change attempts before a user is locked out.
Login Attempt Lockout Action	Only displayed when Identity Based User Accounts is **Enabled**. **Timeout**: When a user is locked out, the user is allowed to log in again after a specified period. **Disabled**: When a user is locked out, the user is disabled.
Login Attempt Lockout Period	Only displayed when Identity Based User Accounts is **Disabled**. The time that elapses before a locked out user is allowed to log in again (minutes). Only displayed when Login Attempt Lockout Action is set to **Timeout**.
Password Expiry Action	Only displayed when Identity Based User Accounts is **Enabled**. The action to be taken by the PTP 650 when a password expires.

Table 143 Password Complexity Configuration attributes

Attribute	Meaning	Best practice
Minimum Password Length	The minimum number of characters required in passwords.	10
Password Can Contain User Name	**No**: Passwords must not contain the user name. **Yes**: Passwords may contain the user name.	No
Minimum Mandatory Characters	The minimum number of lowercase, uppercase, numeric and special characters required in passwords. For example, if all values are set to **2**, then **FredBloggs** will be rejected, but **FredBloggs(25)** will be accepted.	2
Maximum Repeated Characters	The maximum number of consecutive repeated alphabetic, numeric and special characters permitted in passwords. For example, if all values are set to **2**, then **aaa**, **XXX**, **999** and **$$$** will be rejected, but **aa**, **XX**, **99** or **$$** will be accepted.	2
Maximum Consecutive Characters	The maximum number of consecutive lowercase, uppercase and numeric characters permitted in passwords. For example, if all values are set to **5**, then **ALFRED**, **neuman** and **834030** will be rejected.	5
Maximum Sequential Characters	The maximum number of alphabetic and numeric characters permitted in passwords. For example, if set to **3**, then **abcd**, **WXYZ** and **0123** will be rejected, but **abc**, **xyz** and **123** will be accepted.	3
Maximum Repeated Pattern Length	The maximum sequence of characters that can be repeated consecutively in passwords. For example, if set to **3**, then **BlahBlah** and **31st31st** will be rejected, but **TicTicTock** and **GeeGee** will be accepted. **Blah-Blah** will be accepted because the two sequences are not consecutive.	3
Match Reversed Patterns	**No**: Reversed patterns are not checked. **Yes**: Reversed patterns are checked. For example, if Maximum Repeated Pattern Length is set to **3** and Match Reversed Patterns is set to **Yes**, then **AB1221BA** will be rejected.	Yes
Minimum Characters That Must Change	The minimum number of password characters that must change every time a password is updated.	4
Password Reuse	**Permitted**: A user may reuse a previous password. **Prohibited**: A user must not reuse a previous password.	Prohibited

Attribute	Meaning	Best practice
Special Characters	User defined set of special characters used in password construction. The only characters permitted in a password are: (a-z), (A-Z), (0-9) and any of the special characters entered here.	!"%&'()*+,-./:;<=>?

Table 144 Identity-based user accounts attributes

Attribute	Meaning
Name	Enter a user name.
Role	Select a role from the list: **Security Officer, System Administrator** or **Read Only**.
Password	Enter a password for the user. Passwords must comply with the complexity rules (Table 143).
Password Confirm	Retype the password to confirm.
Force Password Change	Force this user to change their password when they next log on.
Disable	Tick the box to disable a user account.

Note

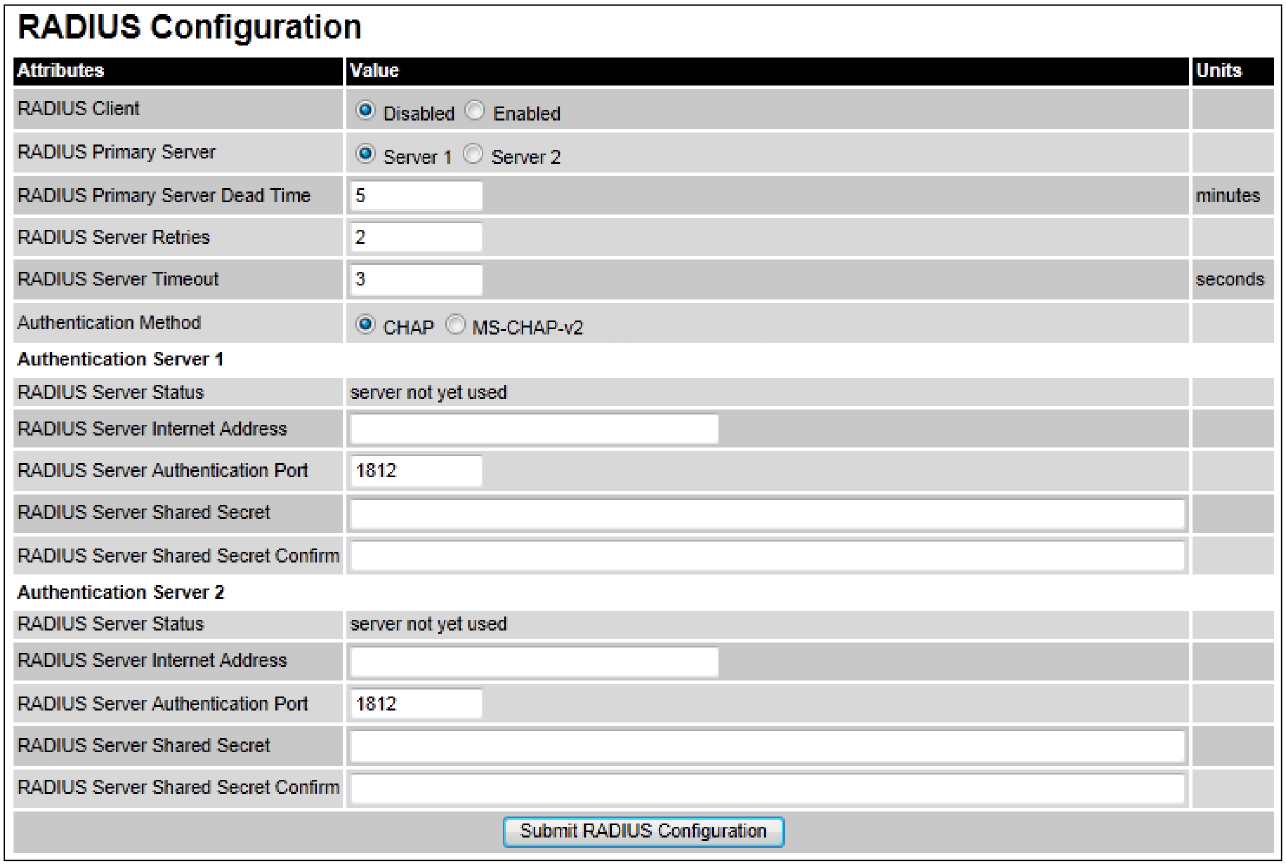
At least one user must be assigned the Security Officer role. If RADIUS is enabled, then this rule is relaxed, in which case the RADIUS server(s) SHOULD be configured with at least one user with **Security Officer** privileges.

RADIUS Configuration page

Menu option: **Management > Web > Radius Configuration** (Figure 150).

Use this page to configure RADIUS authentication. RADIUS authentication is only available when PTP 650 is configured for Identity-based User Accounts and when RADIUS servers are connected to the network.

Figure 150 RADIUS Configuration page



RADIUS Configuration

Attributes	Value	Units
RADIUS Client	Disabled Enabled	
RADIUS Primary Server	Server 1 Server 2	
RADIUS Primary Server Dead Time	5	minutes
RADIUS Server Retries	2	
RADIUS Server Timeout	3	seconds
Authentication Method	CHAP MS-CHAP-v2	
Authentication Server 1		
RADIUS Server Status	server not yet used	
RADIUS Server Internet Address		
RADIUS Server Authentication Port	1812	
RADIUS Server Shared Secret		
RADIUS Server Shared Secret Confirm		
Authentication Server 2		
RADIUS Server Status	server not yet used	
RADIUS Server Internet Address		
RADIUS Server Authentication Port	1812	
RADIUS Server Shared Secret		
RADIUS Server Shared Secret Confirm		
	Submit RADIUS Configuration	

Note

Only users with **Security Officer** role are permitted to configure RADIUS authentication.

Note

When RADIUS is enabled, the Security Officer may disable all user accounts.

Note

At least one user with Security Officer privileges must exist and be enabled, in order to disable the RADIUS client.

Procedure:

- Update the attributes (Table 145).
- Click **Submit RADIUS Configuration**.

Table 145 RADIUS Authentication attributes

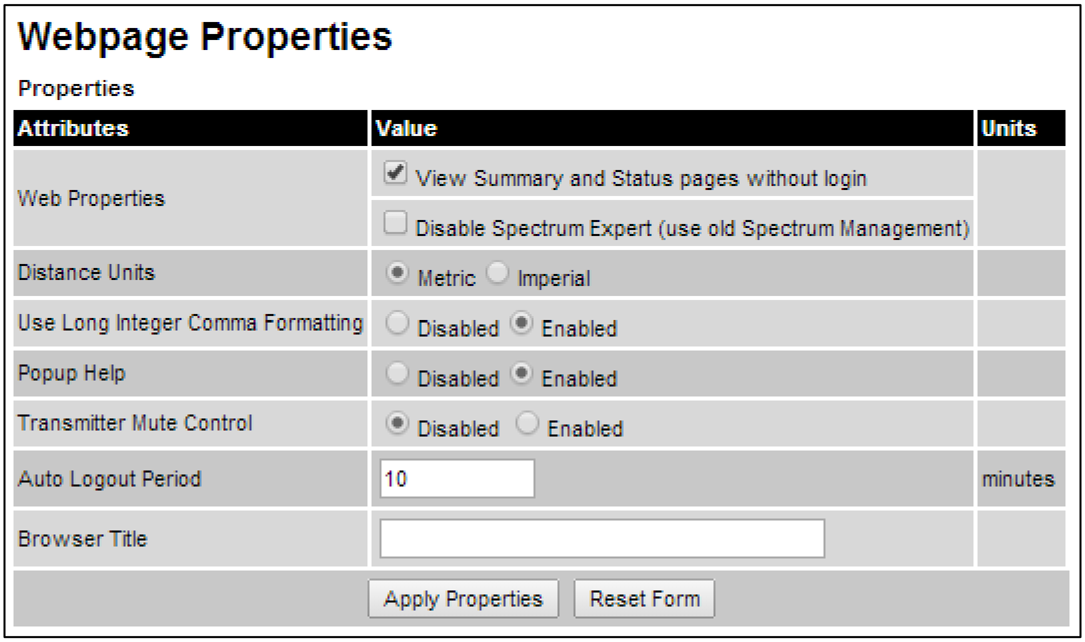
Attribute	Meaning
RADIUS Client Enabled	**Enabled:** PTP 650 users may be authenticated via the RADIUS servers. **Disabled**: RADIUS authentication is not used. This may only be selected if at least one user with Security Officer privileges exists.
RADIUS Primary Server	Specifies the primary server, determining the order in which the servers are tried.
RADIUS Primary Server Dead Time	Time (in minutes) to hold off trying to communicate with a previously unavailable RADIUS server. Setting the value to zero disables the timer.
RADIUS Server Retries	Number of times the PTP 650 will retry after a RADIUS server fails to respond to an initial request.
RADIUS Server Timeout	Time (in seconds) the PTP 650 will wait for a response from a RADIUS server.
Authentication Method	Method used by RADIUS to authenticate users.
Authentication Server 1 and 2:	
RADIUS Server Status	The status of the RADIUS server. This contains the time of the last test and an indication of success or failure. If the Authentication Server attributes are incorrect, the displayed status is “server config not valid”.
RADIUS Server Internet Address	IPv4 or IPv6 address of the RADIUS server.
RADIUS Server Authentication Port	Network port used by RADIUS server for authentication services.
RADIUS Server Shared Secret	Shared secret used in RADIUS server communications. May contain alphabetic, numeric, special characters or spaces, but not extended unicode characters. The maximum length is 127 characters.
RADIUS Server Shared Secret Confirm	Shared secret confirmation.

Webpage Properties page

Menu option: **Management > Web > Web Properties** (Figure 151).

Use this page to control the display of the web interface.

Figure 151 Webpage Properties page



Procedure:

- Update the attributes (Table 146).
- Click Apply Properties.

Table 146 Webpage Properties attributes

Attribute	Meaning
Web Properties	**View Summary and Status pages without login**: • If ticked (the default setting), users can view the Summary and Status web pages without entering a password. • If not ticked, users must enter a password before viewing the Summary and Status pages. This is only effective if the System Administration Password has been set, see Change Password page on page 7-17. **Disable Spectrum Expert (use old Spectrum Management):** • If not ticked (the default setting), the System Menu includes Spectrum Expert (not Spectrum Management). • If ticked, the System Menu includes Spectrum Management (not Spectrum Expert).

Attribute	Meaning
Distance Units	**Metric:** Distances are displayed in kilometers or meters. **Imperial:** Distances are displayed in miles or feet.
Use Long Integer Comma Formatting	**Disabled:** Long integers are displayed thus: 1234567. **Enabled:** Long integers are displayed thus: 1,234,567.
Popup Help	**Disabled:** Web page popup help is not displayed. **Enabled:** Web page popup help is displayed.
Transmitter Mute Control	**Disabled:** Hides the Enable Transmission attribute. **Enabled:** Shows the Enable Transmission attribute (System Configuration page on page 6-30).
Send HTTPS Close Notify Alerts	Only displayed when HTTPS is configured. Controls whether or not the HTTPS server sends TLS Close Notify Alerts before it shuts down each socket. **Disabled**: TLS Close Notify Alerts are not sent before closing each socket. This is the default because these alerts can cause problems with some browsers (e.g. Internet Explorer) **Enabled**: TLS Close Notify Alerts are sent before closing each socket.
Auto Logout Period	Only displayed if role-based user accounts are in use. Automatic logout period in minutes. If there is no user activity within this time, the user is required to log in again. Think this is only displayed when not using identity based user accounts.
Browser Title	By default, web browser tab titles display PTP 650 model, page title and IP address in one of the following formats: **Cambium PTP 50650 - <current page> (IP=<ipAddress>)** **Cambium PTP 50650S - <current page> (IP=<ipAddress>)** **Cambium PTP 50650L - <current page> (IP=<ipAddress>)** To change the default text, enter simple text and optional variables (prefixed with a $ character). The full list of variables is in Table 147.

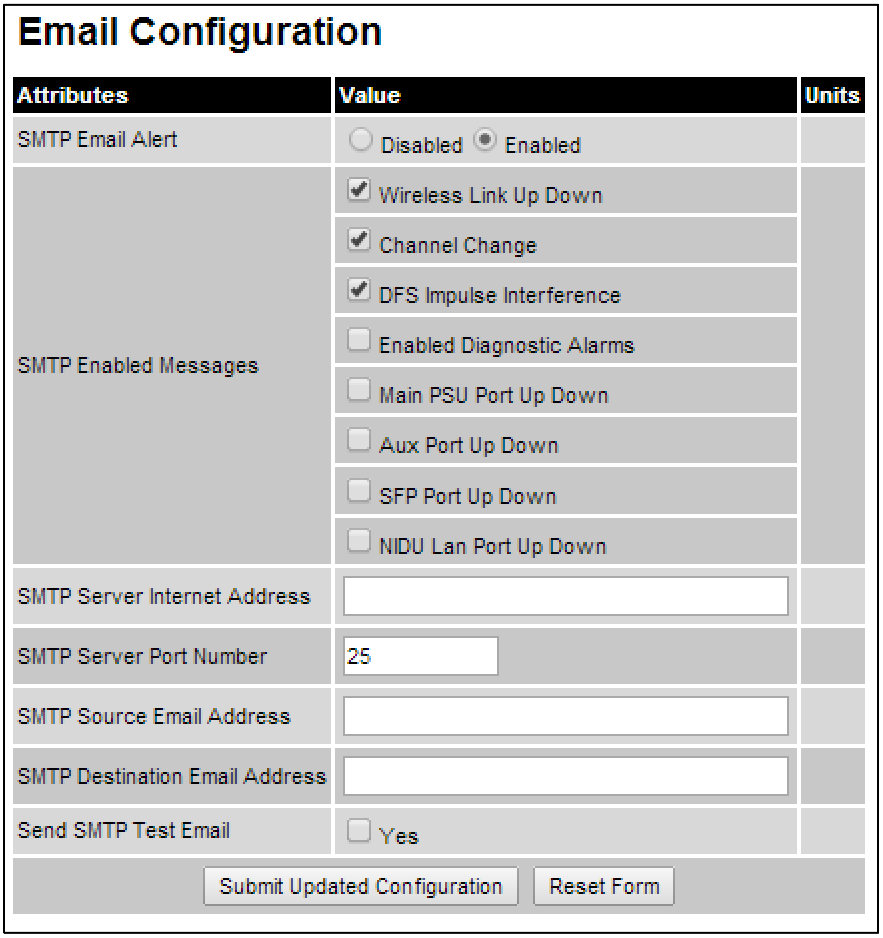
Table 147 Browser Title attribute variables

Variable	Meaning
$siteName	Site Name, as set in the System Configuration page (Table 128).
$linkName	Link Name, as set in the System Configuration page (Table 128).
$masterSlaveMode	Master Slave Mode, as set in the Step 2: Wireless Configuration page (Table 126).
$ipAddress	IP Address currently used to identify the ODU, either IPv4 or IPv6 Address, depending upon the setting of IP Address Label in the System Configuration page (Table 128): • **IPv4**: $ipAddress = $ipv4Address • **IPv6**: $ipAddress = $ipv6Address (if not blank) or $ipv6LinkLocalAddress
$ipv4Address	IPv4 Address of the ODU, as set in the LAN Configuration page (Table 129).
$ipv6Address	IPv6 Address of the ODU, as set in the LAN Configuration page (Table 129).
$ipv6LinkLocalAddress	IPv6 Auto Configured Link Local Address of the ODU. This cannot be updated, but it can be viewed in the LAN Configuration page (Table 129).
$sysName	Sys Name for this SNMP managed node, as set in the Step 2: SNMP MIB-II System Objects page (Table 153).
$productName	The product variant, for example **Cambium PTP 50650** or **Cambium PTP 50650S**. Not updateable.
$pageName	Name of the page currently being browsed.

Email Configuration page

Menu option: **Management** > **Email** (Figure 152). Use this page to enable the PTP 650 to generate Simple Mail Transfer Protocol (SMTP) email messages to notify the system administrator when certain events occur.

Figure 152 Email Configuration page



Procedure:

- Update the attributes (Table 148).
- Click **Submit Updated Configuration**. The Configuration Change Reboot dialog is displayed.
- Click **Reboot Wireless Unit** and click **OK**. The reboot progress message is displayed. On completion, the unit restarts.

Table 148 Email Configuration attributes

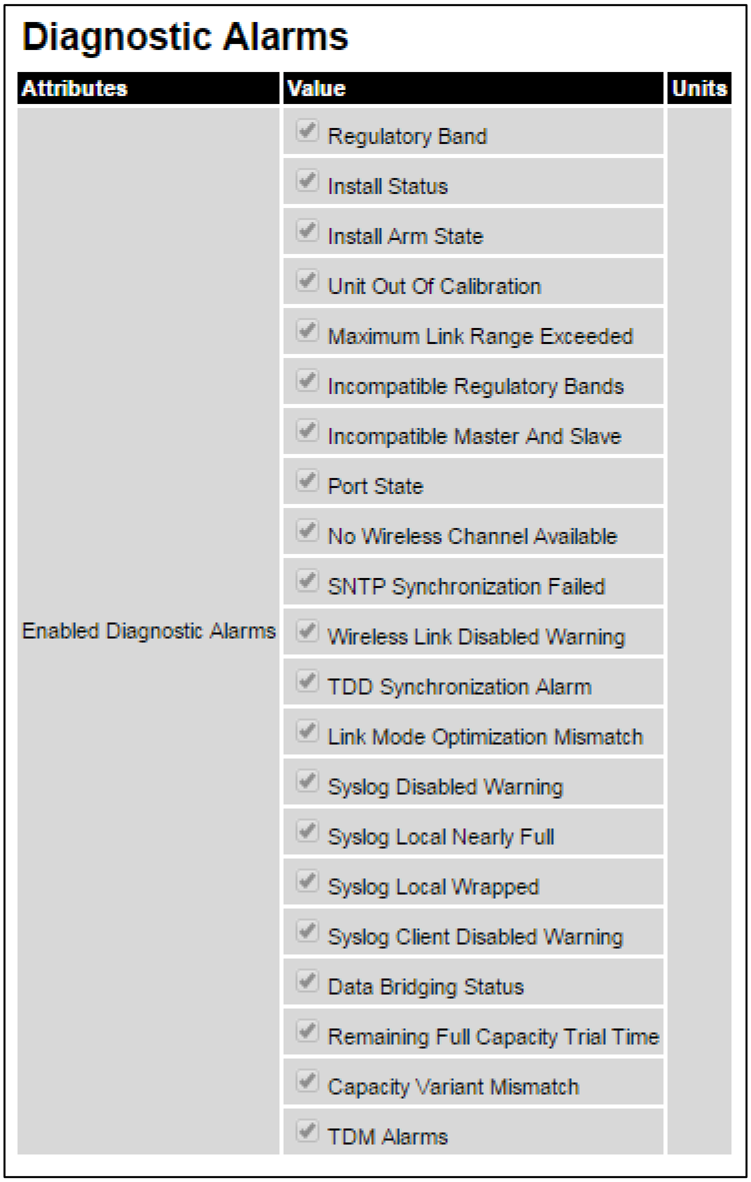
Attribute	Meaning
SMTP Email Alert	Controls the activation of the SMTP client.
SMTP Enabled Messages	The SMTP Enabled Messages attribute controls which email alerts the unit will send.
SMTP Server Internet Address	The IPv4 or IPv6 Address of the networked SMTP server.
SMTP Server Port Number	The SMTP Port Number is the port number used by the networked SMTP server. By convention the default value for the port number is 25.
SMTP Source Email Address	The email address used by the PTP 650 Series to log into the SMTP server. This must be a valid email address that will be accepted by your SMTP Server.
SMTP Destination Email Address	The email address to which the PTP 650 Series will send the alert messages.
Send SMTP Test Email	Generate and send an email in order to test the SMTP settings. The tick box will self-clear when **Submit** is clicked.

Diagnostic Alarms page

Menu option: **Management** > **Diagnostic Alarms** (Figure 153).

Use this page to select which diagnostic alarms will be notified to the system administrator.

Figure 153 Diagnostic Alarms page



Diagnostic Alarms

Attributes	Value	Units
Enabled Diagnostic Alarms	Regulatory Band	
	Install Status	
	Install Arm State	
	Unit Out Of Calibration	
	Maximum Link Range Exceeded	
	Incompatible Regulatory Bands	
	Incompatible Master And Slave	
	Port State	
	No Wireless Channel Available	
	SNTP Synchronization Failed	
	Wireless Link Disabled Warning	
	TDD Synchronization Alarm	
	Link Mode Optimization Mismatch	
	Syslog Disabled Warning	
	Syslog Local Nearly Full	
	Syslog Local Wrapped	
	Syslog Client Disabled Warning	
	Data Bridging Status	
	Remaining Full Capacity Trial Time	
	Capacity Variant Mismatch	
	TDM Alarms	

Procedure:

- Tick the required alarms. These alarms are described in Alarms on page 7-18.
- Click **Submit Updated Configuration**.

Time Configuration page

Menu option: **Management > Time** (Figure 154 and Figure 155). Use this page to set the real-time clock of the PTP 650.

Setting the real-time clock manually

Use this procedure to keep time without connecting to a networked time server.

If SNTP is disabled, it will be necessary to reset the time manually after each system reboot.

Procedure:

- Set SNTP State to **Disabled** (Figure 154).
- Review and update the manual clock attributes (Table 149).
- Click **Submit Updated Configuration**.

Figure 154 Time Configuration page (SNTP disabled)

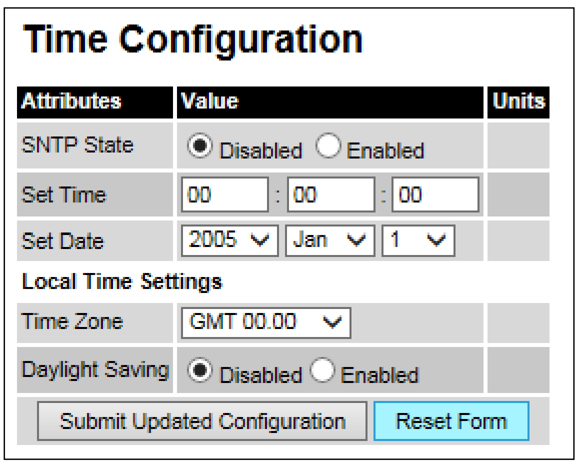


Table 149 Manual clock attributes

Attribute	Meaning
SNTP State	**Disabled:** the PTP 650 will keep time without connecting to a networked time server.
Set Time	Set hours, minutes and seconds.
Set Date	Set year, month and day.
Time Zone	Set the time zone offset from Greenwich Mean Time (GMT). To set the clock to UTC time, set Time Zone to **GMT 00.00**.
Daylight Saving	**Disabled:** There is no offset for daylight saving time. **Enabled:** System clock is moved forward one hour to adjust for daylight saving time. To set the clock to UTC time, set Daylight Saving to **Disabled**.

Setting the real-time clock to synchronize using SNTP

Use this procedure to synchronize the unit with a networked time server:

Procedure:

- Set the SNTP State attribute to **Enabled** (Figure 155).
- Review and update the SNTP clock attributes (Table 150).
- Click **Submit Updated Configuration**.

Figure 155 Time Configuration page (SNTP enabled)

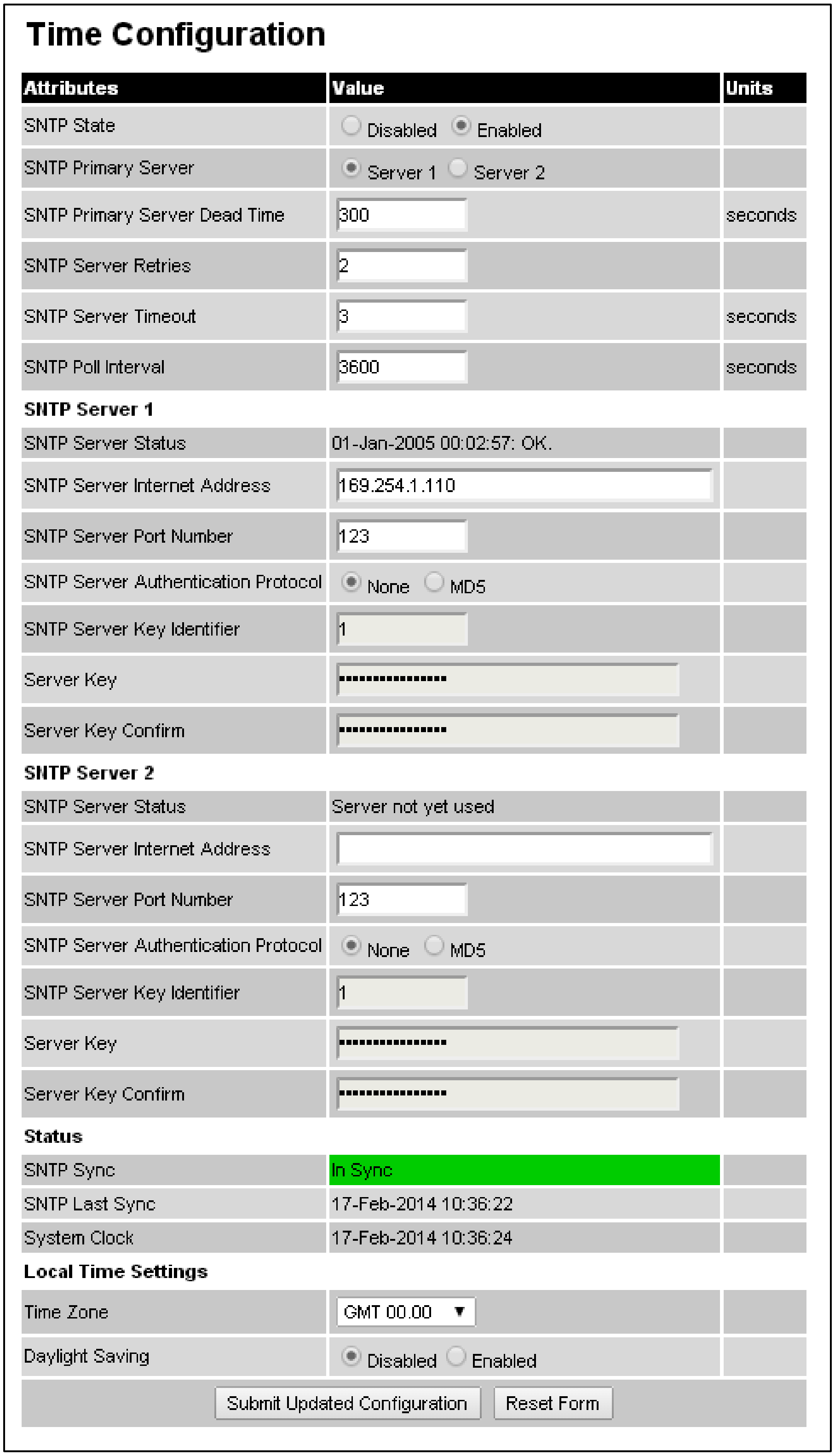


Table 150 SNTP clock attributes

Attribute	Meaning
SNTP State	**Enabled:** the ODU will obtain accurate date and time updates from a networked time server.
SNTP Primary Server	Specifies the primary SNTP server, determining the order in which the servers are tried.
SNTP Primary Server Dead Time	Time (in seconds) to wait before retrying communications with an unresponsive primary SNTP server. Setting the value to zero disables the timer.
SNTP Server Retries	Number of times the PTP will retry after an SNTP server fails to respond.
SNTP Server Timeout	Time (in seconds) the PTP will wait for a response from an SNTP server.
SNTP Poll Interval	The SNTP server polling interval.
SNTP Server 1 and 2:	
SNTP Server Status	Status message reflecting the state of communications with the SNTP server.
SNTP Server Internet Address	The IPv4 or IPv6 Address of the networked SNTP server.
SNTP Server Port Number	The port number of the networked SNTP server. By convention the default value for the port number is 123.
SNTP Server Authentication Protocol	Authentication protocol to be used with this SNTP server (**None** or **MD5**).
SNTP Server Key Identifier	SNTP key identifier. A key of zeros is reserved for testing.
Server Key	Key used to authenticate SNTP communications.
Server Key Confirm	Must match the Server Key.
SNTP Sync	This shows the current status of SNTP synchronization. If **No Sync** is displayed, then review the SNTP Server Internet Address and Port Number. A change of state may generate an SNMP trap or SMTP email alert.
SNTP Last Sync	This shows the date and time of the last SNTP synchronization.
System Clock	This displays the local time, allowing for the Time Zone and Daylight Saving settings.
Local Time Settings:	

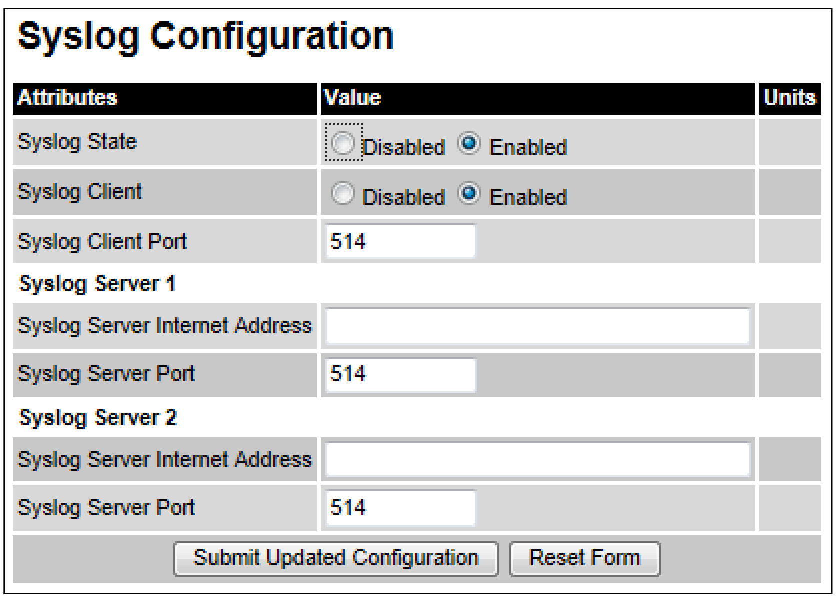
Attribute	Meaning
Time Zone	Set the time zone offset from Greenwich Mean Time (GMT). To set the clock to UTC time, set Time Zone to **GMT 00.00**.
Daylight Saving	**Disabled:** Daylight saving adjustments will not be applied to the time. **Enabled:** Daylight saving adjustments will be applied to the time, according to local rules. To set the clock to UTC time, set Daylight Saving to **Disabled**.

Syslog Configuration page

Menu option: **Management** > **Syslog** > **Syslog configuration** (Figure 156).

Use this page to configure system logging. Only users with **Security Officer** role are permitted to configure the syslog client.

Figure 156 Syslog Configuration page



Note

To record Coordinated Universal Time (UTC time) in syslog messages, use the Time Configuration page to set Time Zone to **GMT 00.00** and Daylight Saving to **Disabled** (Time Configuration page on page 6-74).

Procedure:

- Update the attributes (Table 151).
- Click **Submit Updated Configuration**.

Table 151 Syslog Configuration attributes

Attribute	Meaning
Syslog State	When system logging is enabled, log entries are added to the internal log and (optionally) transmitted as UDP messages to one or two syslog servers.
Syslog Client	**Enabled:** Event messages are logged. **Disabled:** Event messages are not logged.
Syslog Client Port	The client port from which syslog messages are sent.
Syslog Server 1 and 2:	
Syslog Server Internet Address	The IPv4 or IPv6 Address of the syslog server. Delete the IP address to disable logging on the syslog server.
Syslog Server Port	The server port at which syslog messages are received.

SNMP pages (for SNMPv3)

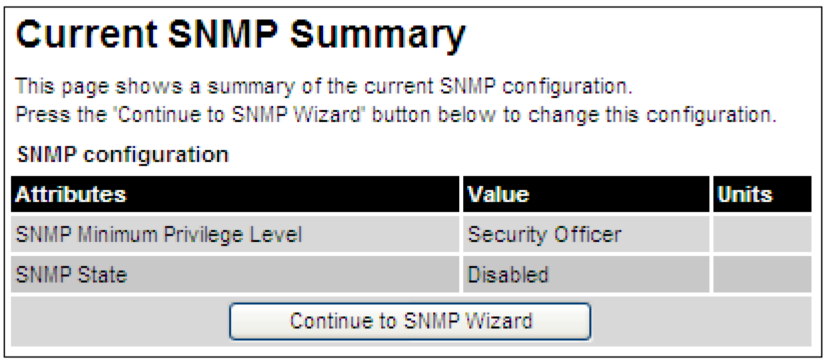
This section describes how to configure Simple Network Management Protocol version 3 (SNMPv3) traps using the SNMP Wizard.

Current SNMP Summary (for SNMPv3)

Menu option: **Management > SNMP** (Figure 157).

Use this page to review the current SNMP configuration and start the SNMP Wizard.

Figure 157 Current SNMP Summary page (when SNMP is disabled)



Procedure:

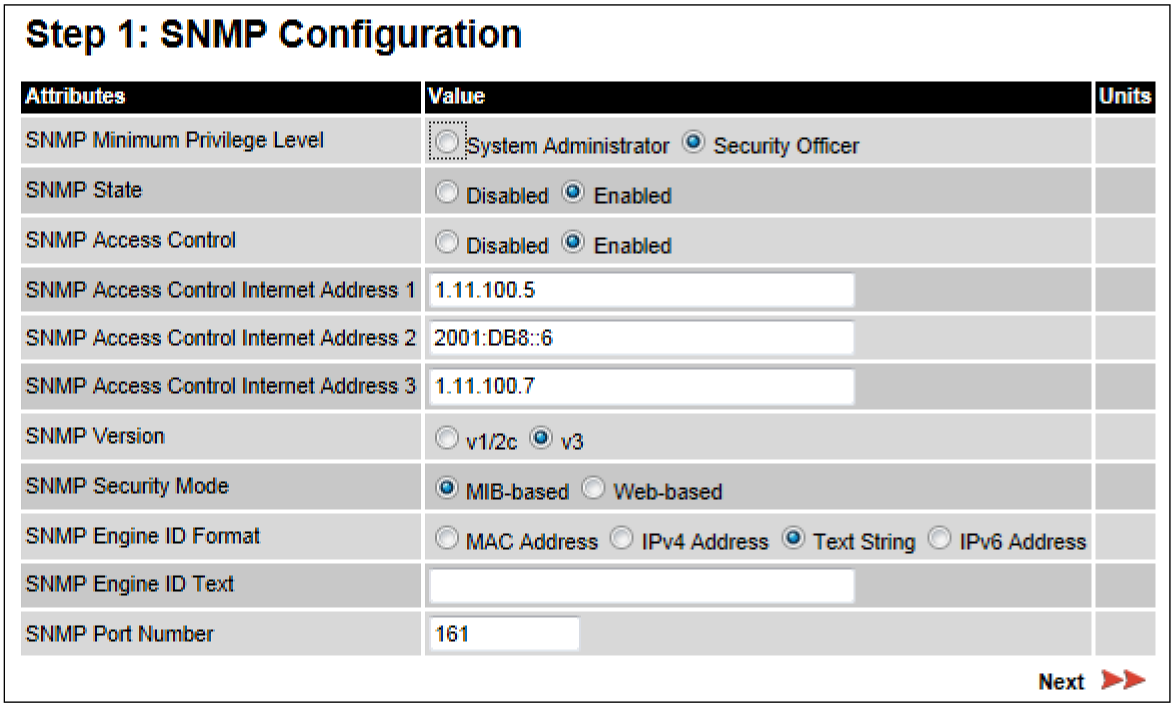
- Review the summary.
- If any updates are required, click **Continue to SNMP Wizard**.

Step 1: SNMP Configuration (for SNMPv3)

Menu option: **Management > SNMP**. Part of the SNMP Wizard (Figure 158).

Use this page to enable SNMP, select SNMPv3 and configure access to the SNMP server.

Figure 158 Step 1: SNMP Configuration page (for SNMPv3)



Step 1: SNMP Configuration

Attributes	Value	Units
SNMP Minimum Privilege Level	○ System Administrator ◉ Security Officer	
SNMP State	○ Disabled ◉ Enabled	
SNMP Access Control	○ Disabled ◉ Enabled	
SNMP Access Control Internet Address 1	1.11.100.5	
SNMP Access Control Internet Address 2	2001:DB8::6	
SNMP Access Control Internet Address 3	1.11.100.7	
SNMP Version	○ v1/2c ◉ v3	
SNMP Security Mode	◉ MIB-based ○ Web-based	
SNMP Engine ID Format	○ MAC Address ○ IPv4 Address ◉ Text String ○ IPv6 Address	
SNMP Engine ID Text		
SNMP Port Number	161	

Next

Procedure:

- Set SNMP State to **Enabled.**
- Set SNMP Version to **v3**. The page is redisplayed with SNMPv3 attributes.
- Update the attributes (Table 152).
- Click **Next.**

Table 152 Step 1: SNMP Configuration attributes (for SNMPv3)

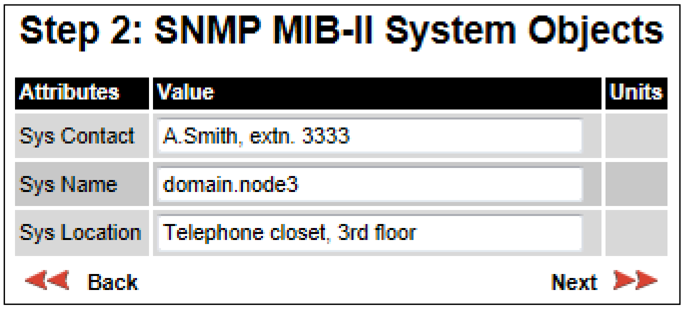
Attribute	Meaning
SNMP Minimum Privilege Level	Minimum security level which is permitted to administer SNMP security settings. Only displayed when Identity Based User Accounts are **Enabled** on the User Accounts page (Table 142).
SNMP State	Enables or disables SNMP.
SNMP Access Control	Enables or disables access control to SNMP management by IP address.
SNMP Access Control Internet Address 1/2/3	A list of up to three IPv4 or IPv6 Addresses permitted to perform SNMP management. Only displayed when SNMP Access Control is set to **Enabled**.
SNMP Version	SNMP protocol version: **v1/2c** or **v3**.
SNMP Security Mode	**MIB-based**: SNMPv3 security parameters are managed via SNMP MIBs. **Web-based**: SNMPv3 security parameters are not available over SNMP, but instead are configured using the SNMP Accounts page, as described in Step 3: SNMP User Policy Configuration (for SNMPv3) on page 6-84.
SNMP Engine ID Format	Specifies whether the Engine ID is generated from the **MAC Address**, **IP4 Address**, **Text String** or **IPv6 Address**.
SNMP Engine ID Text	Only enabled when SNMP Engine ID Format is set to **Text String**. Text used to generate the SNMP Engine ID.
SNMP Port Number	The port that the SNMP agent is listening to for commands from a management system.

Step 2: SNMP MIB-II System Objects (for SNMPv3)

Menu option: **Management > SNMP**. Part of the SNMP Wizard (Figure 159).

Use this page to enter details of the SNMP managed node.

Figure 159 Step 2: SNMP MIB-II System Objects page (for SNMPv3)



Procedure:

- Update the attributes (Table 153).
- Click **Next.**
- The next step depends upon which SNMP Security Mode was selected in the Step 1: SNMP Configuration page:
  - o If **Web-based**, go to Step 3: SNMP User Policy Configuration (for SNMPv3) on page 6-84.
  - o If **MIB-based**, go to Confirm SNMP Configuration (for SNMPv3) on page 6-89.

Table 153 Step 2: SNMP MIB-II System Objects attributes (for SNMPv3)

Attribute	Meaning
Sys Contact	The name of the contact person for this managed node, together with information on how to contact this person.
Sys Name	An administratively-assigned name for this managed node. By convention, this is the fully qualified domain name of the node.
Sys Location	The physical location of this node, for example **Telephone closet, 3rd floor**.

Step 3: SNMP User Policy Configuration (for SNMPv3)

Menu option: **Management > SNMP**. Part of the SNMP Wizard (Figure 160).

This page is only displayed when SNMP Security Mode is set to **Web-based** in the Step 1: SNMP Configuration page. Use this page to configure which authentication and privacy protocols are required for SNMP users with roles **System administrator** and **Read only**.

Procedure:

- Update the attributes (Table 154).
- Click **Next**.

Figure 160 Step 3: SNMP User Policy Configuration page (for SNMPv3)

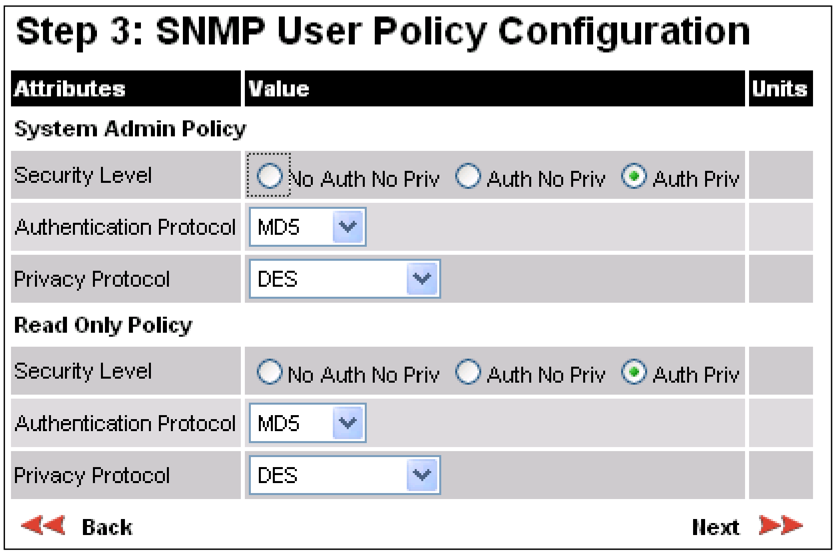


Table 154 Step 3: SNMP User Policy Configuration attributes (for SNMPv3)

Attribute	Meaning
Security Level	Defines the security level and associated protocols that are required to allow SNMP users to access the PTP 650. **No Auth No Priv**: Users are not required to use authentication or privacy protocols. **Auth No Priv**: Users are required to use only authentication protocols. **Auth Priv**: Users are required to use both authentication and privacy protocols.

Attribute	Meaning
Authentication Protocol	The authentication protocol to be used to access the PTP 650 via SNMP. This is disabled when Security Level is set to **Auth No Priv**. **MD5**: Message Digest Algorithm is used. **SHA**: NIST FIPS 180-1, Secure Hash Algorithm SHA-1 is used.
Privacy Protocol	The privacy protocol to be used to access the PTP 650 via SNMP. This is disabled when Security Level is set to **No Auth No Priv** or **Auth No Priv**. **DES**: Data Encryption Standard (DES) symmetric encryption protocol. **AES**: Advanced Encryption Standard (AES) cipher algorithm.

Note

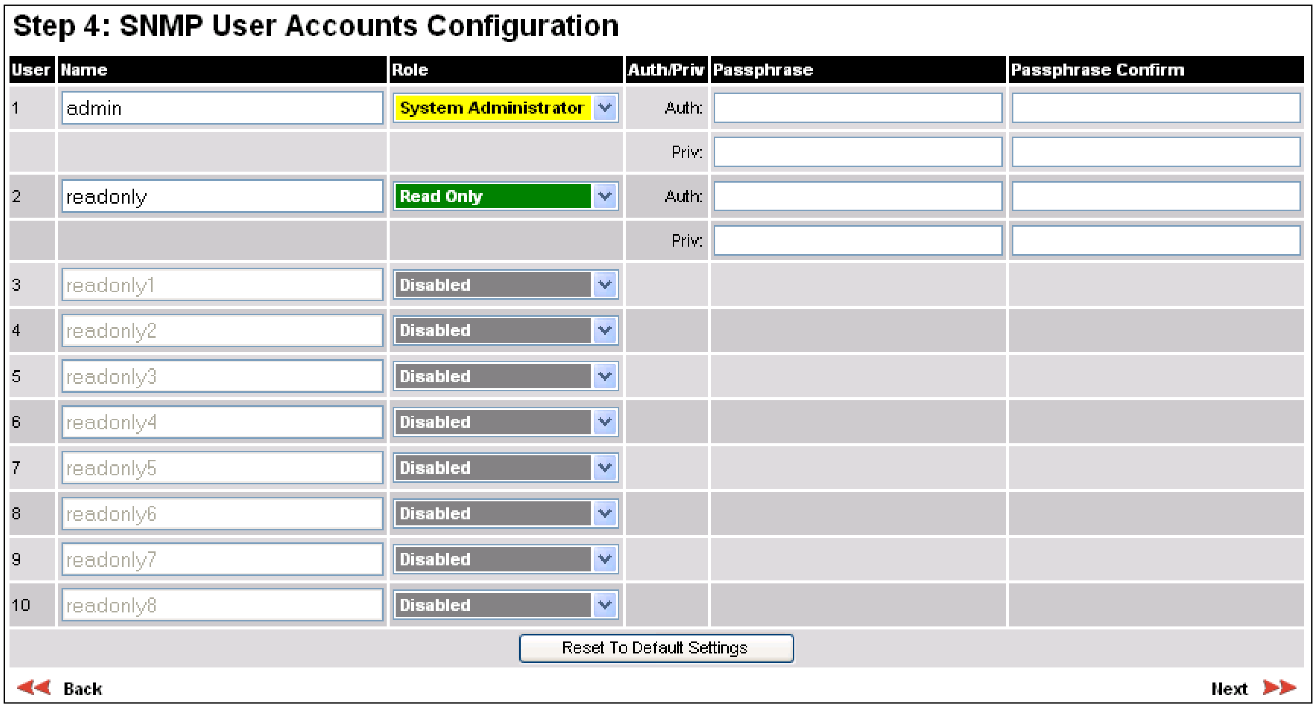
A user configured to use AES privacy protocol will not be able to transmit and receive encrypted messages unless the license key enables the AES capability.

Step 4: SNMP User Accounts Configuration (for SNMPv3)

Menu option: **Management > SNMP**. Part of the SNMP Wizard (Figure 161).

This page is only displayed when SNMP Security Mode is set to **Web-based** in the Step 1: SNMP Configuration page. Use this page to update the SNMP user accounts.

Figure 161 Step 4: SNMP User Accounts Configuration page (for SNMPv3)



Procedure:

- Update the individual user attributes (Table 155) for up to 10 SNMP users.
- Click **Next.**

Table 155 Step 4: SNMP User Accounts Configuration attributes (for SNMPv3)

Attribute	Meaning
Name	Name to be used by the SNMP user to access the system.
Role	Selects which of the two web-based security profiles are applied to this user: **System administrator** or **Read only**. Select **Disabled** to disable the SNMP account.
Auth/Priv	Indicates whether the Passphrase applies to authentication or privacy protocols.

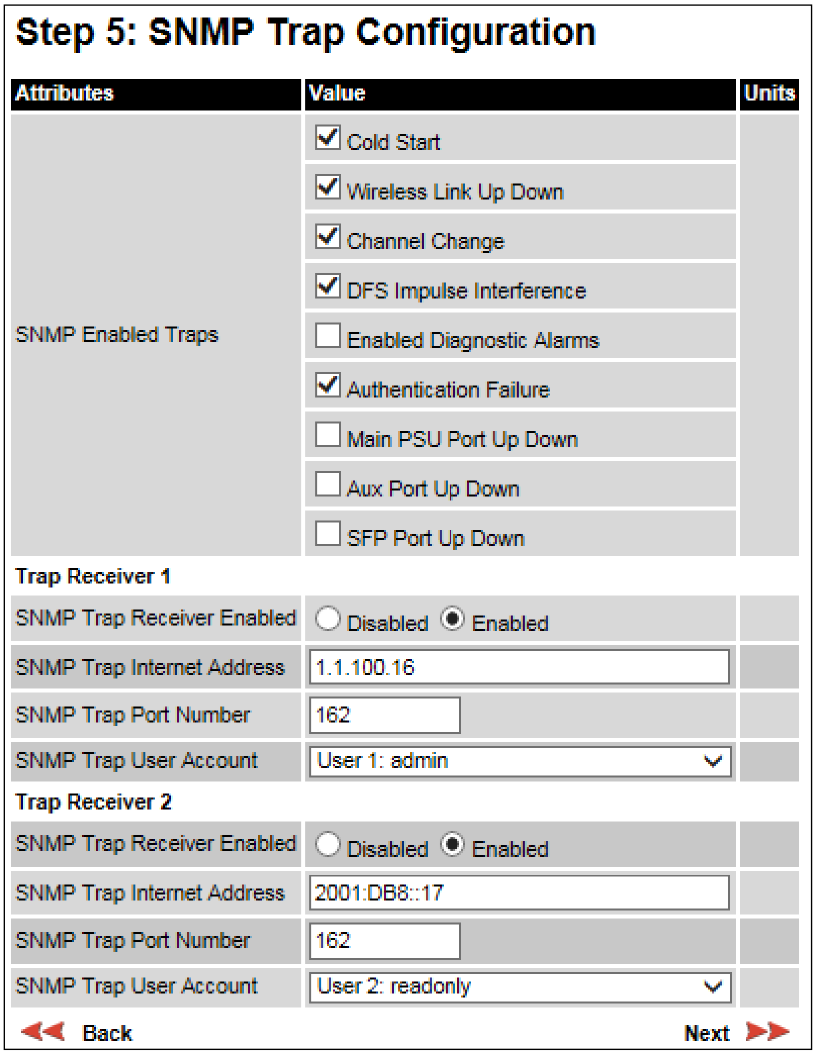
Attribute	Meaning
Passphrase	The phrase to be entered by this SNMP user to access the system using an authentication or privacy protocol. Length must be between 8 and 32 characters. May contain spaces. The Auth Passphrase is hidden when Security Level for this user's Role is set to **No Auth No Priv**. The Priv Passphrase is hidden when Security Level for this user's Role is set to **No Auth No Priv** or **Auth No Priv**.
Passphrase Confirm	Passphrase must be reentered to confirm it has been correctly typed.

Step 5: SNMP Trap Configuration (for SNMPv3)

Menu option: **Management > SNMP**. Part of the SNMP Wizard (Figure 162).

This page is only displayed when SNMP Security Mode is set to **Web-based** in the Step 1: SNMP Configuration page. Use this page to configure the events that will generate SNMP traps and to set up trap receivers.

Figure 162 Step 5: SNMP Trap Configuration page (for SNMPv3)



Procedure:

- Update the attributes (Table 156).
- Click **Next**.

Table 156 Step 5: SNMP Trap Configuration attributes (for SNMPv3)

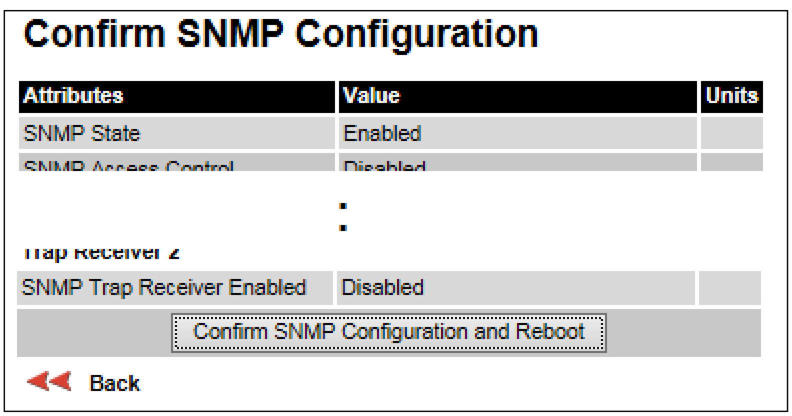
Attribute	Meaning
SNMP Enabled Traps	Select the events that will generate SNMP traps.
SNMP Trap Receiver 1 and SNMP Trap Receiver 2:	
SNMP Trap Receiver Enabled	**Disabled**: SNMP traps are not sent to the corresponding SNMP Trap Receiver (1 or 2). **Enabled**: SNMP traps are sent to the corresponding SNMP Trap Receiver (1 or 2).
SNMP Trap Internet Address	The IPv4 or IPv6 Address of the SNMP server (trap receiver). This is normally the network management system, but it may be a separate trap receiver.
SNMP Trap Port Number	The server port at which SNMP traps are received.
SNMP Trap User Account	The user name (and associated protocols) to use when sending SNMP traps to the server.

Confirm SNMP Configuration (for SNMPv3)

Menu option: **Management > SNMP**. Part of the SNMP Wizard (Figure 163).

Use this page to review and confirm the updated SNMPv3 configuration of the unit.

Figure 163 Confirm SNMP Configuration page (for SNMPv3) (top and bottom of page shown)



Procedure:

- To ensure that the changes take effect, click **Confirm SNMP Configuration and Reboot**. The unit reboots and the changes take effect.

SNMP pages (for SNMPv1/2c)

This section describes how to configure Simple Network Management Protocol version 1 or 2c (SNMPv1 or SNMPv2c) traps using the SNMP Wizard.

Current SNMP Summary (for SNMPv1/2c)

Menu option: **Management > SNMP** (Figure 157).

Use this page to review the current SNMP configuration and start the SNMP Wizard.

Procedure:

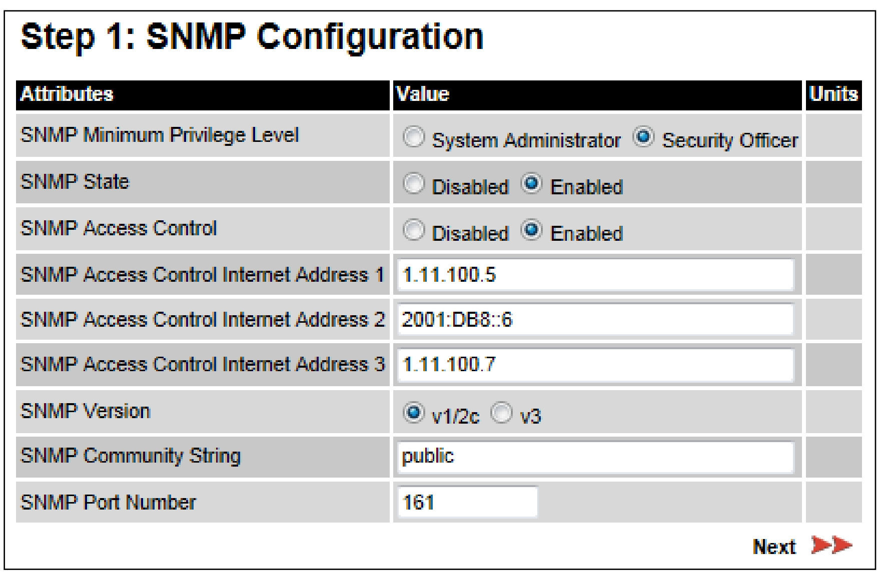
- Review the summary.
- If any updates are required, click **Continue to SNMP Wizard**.

Step 1: SNMP Configuration (for SNMPv1/2c)

Menu option: **Management > SNMP**. Part of the SNMP Wizard (Figure 164).

Use this page to enable SNMP, select SNMPv1/2c and configure access to the SNMP server.

Figure 164 Step 1: SNMP Configuration page (for SNMPv1/2c)



Step 1: SNMP Configuration

Attributes	Value	Units
SNMP Minimum Privilege Level	System Administrator ◉ Security Officer	
SNMP State	Disabled ◉ Enabled	
SNMP Access Control	Disabled ◉ Enabled	
SNMP Access Control Internet Address 1	1.11.100.5	
SNMP Access Control Internet Address 2	2001:DB8::6	
SNMP Access Control Internet Address 3	1.11.100.7	
SNMP Version	◉ v1/2c v3	
SNMP Community String	public	
SNMP Port Number	161	

Next

Procedure:

- Set SNMP State to **Enabled**.
- Set SNMP Version to **v1/2c**. The page is redisplayed with SNMPv1/2c attributes.
- Update the attributes (Table 157).
- Click **Next**.

Table 157 Step 1: SNMP Configuration attributes (for SNMPv1/2c)

Attribute	Meaning
SNMP Minimum Privilege Level	Minimum security level which is permitted to administer SNMP security settings. Only displayed when Identity Based User Accounts are **Enabled** on the User Accounts page (Table 142).
SNMP State	Enables or disables SNMP.
SNMP Access Control	Enables or disables access control to SNMP management by IP address.
SNMP Access Control Internet Address 1/2/3	A list of up to three IPv4 or IPv6 Addresses permitted to perform SNMP management. Only displayed when SNMP Access Control is set to **Enabled**.
SNMP Version	SNMP protocol version: **v1/2c** or **v3**.
SNMP Community String	The SNMP community string acts like a password between the network management system and the distributed SNMP clients (PTP 650 ODUs). Only if the community string is configured correctly on all SNMP entities can the flow of management information take place. By convention the default value is set to **public**.
SNMP Port Number	Enter the port that the SNMP agent is listening to for commands from a management system.

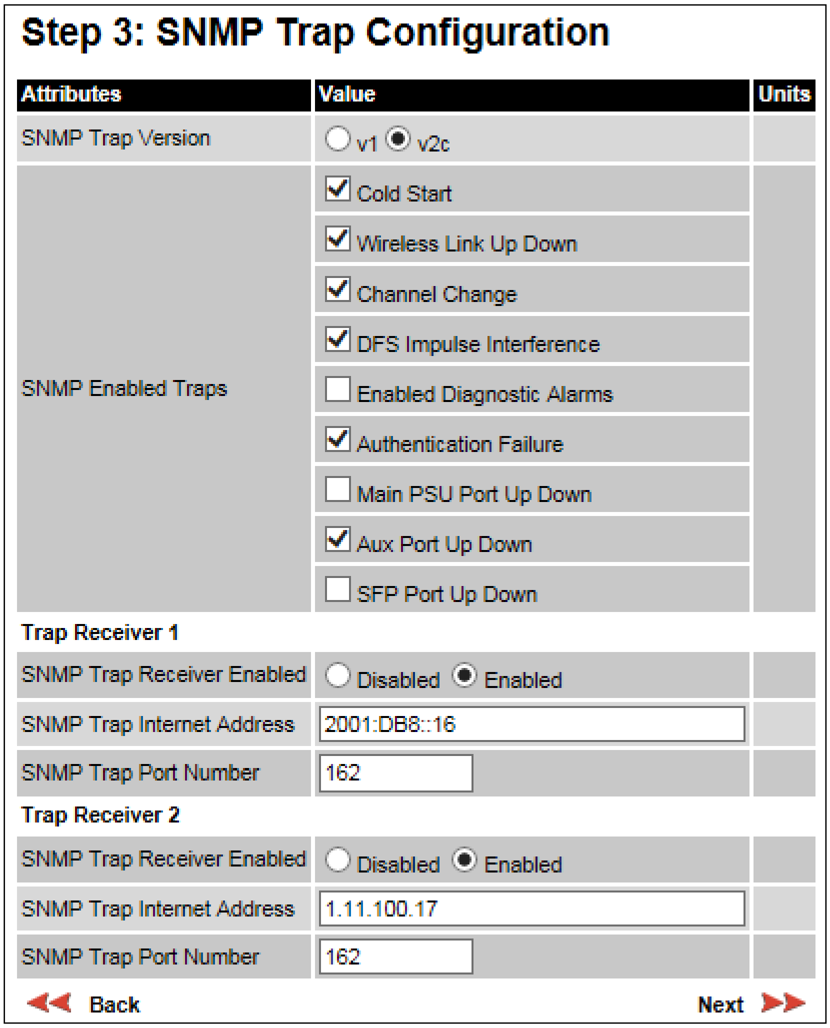
Step 2: SNMP MIB-II System Objects (for SNMPv1/2c)

Menu option: **Management > SNMP**. Part of the SNMP Wizard (Figure 159). Use this page to enter details of the SNMP managed node. Update the attributes (Table 153) and click **Next**.

Step 3: SNMP Trap Configuration (for SNMPv1/2c)

Menu option: **Management > SNMP**. Part of the SNMP Wizard (Figure 165).

Figure 165 Step 3: SNMP Trap Configuration page (for SNMPv1/2c)



Step 3: SNMP Trap Configuration

Attributes	Value	Units
SNMP Trap Version	○ v1 ◉ v2c	
SNMP Enabled Traps	☑ Cold Start	
	☑ Wireless Link Up Down	
	☑ Channel Change	
	☑ DFS Impulse Interference	
	☐ Enabled Diagnostic Alarms	
	☑ Authentication Failure	
	☐ Main PSU Port Up Down	
	☑ Aux Port Up Down	
	☐ SFP Port Up Down	
Trap Receiver 1		
SNMP Trap Receiver Enabled	○ Disabled ◉ Enabled	
SNMP Trap Internet Address	2001:DB8::16	
SNMP Trap Port Number	162	
Trap Receiver 2		
SNMP Trap Receiver Enabled	○ Disabled ◉ Enabled	
SNMP Trap Internet Address	1.11.100.17	
SNMP Trap Port Number	162	

Back **Next**

Procedure:

- Update the attributes (Table 158).
- Click **Next**.

Table 158 Step 3: SNMP Trap Configuration attributes (for SNMPv1/2c)

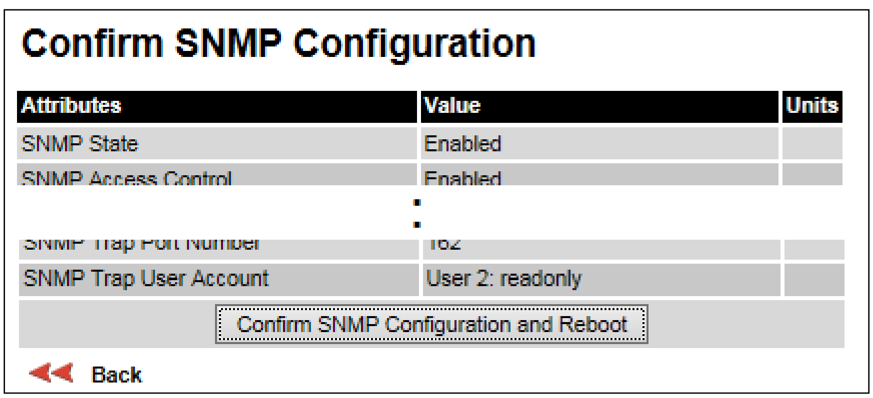
Attribute	Meaning
SNMP Trap Version	Select the SNMP protocol version to use for SNMP traps: **v1** or **v2c**.
SNMP Enabled Traps	Select the events that will generate SNMP traps.
SNMP Trap Receiver Enabled	**Disabled**: SNMP traps are not sent to the corresponding SNMP Trap Receiver (1 or 2). **Enabled**: SNMP traps are sent to the corresponding SNMP Trap Receiver (1 or 2).
SNMP Trap Internet Address	The IPv4 or IPv6 Address of the SNMP server (trap receiver). This is normally the network management system, but it may be a separate trap receiver.
SNMP Trap Port Number	The server port at which SNMP traps are received.

Confirm SNMP Configuration (for SNMPv1/2c)

Menu option: **Management > SNMP**. Part of the SNMP Wizard (Figure 166).

Use this page to review and confirm the updated SNMPv1/2c configuration of the unit.

Figure 166 Confirm SNMP Configuration page (for SNMPv1/2c) (top and bottom of page shown)



Procedure:

- To ensure that the changes take effect, click **Confirm SNMP Configuration and Reboot**. The unit reboots and the changes take effect.

Security menu

This section describes how to configure HTTPS/TLS security using the Security Wizard.

Caution

Ensure that the operator's security requirements are configured before connecting the PTP 650 to the network. Otherwise, security may be compromised.

Preparing for HTTPS/TLS

Before running the Security Configuration Wizard, obtain the necessary cryptographic material and ensure that the unit has AES capability. For more information, refer to Planning for HTTPS/TLS operation on page 3-51.

Procedure:

1. Ensure that the following cryptographic material has been generated:
   - Key Of Keys
   - TLS Private Key and Public Certificates (for the correct IP address)
   - User Defined Security Banner
   - Random Number Entropy Input
2. Order the necessary AES capability upgrade, generate a license key (Generating license keys on page 6-3) and enter it on the Software License Key page (Software License Key page on page 6-11).
3. Identify the Port numbers for HTTPS, HTTP and Telnet.
4. Ensure that the web browsers used are enabled for HTTPS/TLS operation.
5. On the Local User Accounts page (Local User Accounts page on page 6-61), check that:
   - Either: Identity Based User Accounts are set to **Disabled**,
   - Or: Identity Based User Accounts are set to **Enabled** and the current user's role is **Security Officer**.

Security Configuration Wizard page

Menu option: **Security**. Displayed only when AES encryption is enabled by license key (Figure 167). Use this page to review the current security configuration of the unit.

Figure 167 Security Configuration Wizard page

Security Configuration Wizard

This page shows a summary of the current security configuration.
Press the 'Continue to Security Wizard' button below to change this configuration.

Security configuration

Attributes	Value	Units
Key of Keys	Configured	
Private Key	Configured	
Public Certificate	Configured	
User Defined Security Banner	Lorem ipsum dolor sit amet, consectetur adipisicing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua. Ut enim ad minim veniam, quis nostrud exercitation ullamco laboris nisi ut aliquip ex ea commodo consequat. Duis aute irure dolor in reprehenderit in voluptate velit esse cillum dolore eu fugiat nulla pariatur. Excepteur sint occaecat cupidatat non proident, sunt in culpa qui officia deserunt mollit anim id est laborum.	
Require Acknowledgement Of Notices	Yes	
Display Login Information	Yes	
DRNG Entropy	Configured	
Wireless Encryption Key	Not configured	
HTTPS Port Number	443	
HTTP Access Enabled	Yes	
HTTP Port Number	80	
Telnet Access Enabled	Yes	
Telnet Port Number	23	
SNMP Control Of HTTP And Telnet	Disabled	
TFTP Client	Disabled	
Debug Access Enabled	Yes	
Cross Site Request Forgery Protection	Enabled	

Continue to Security Wizard

Procedure:

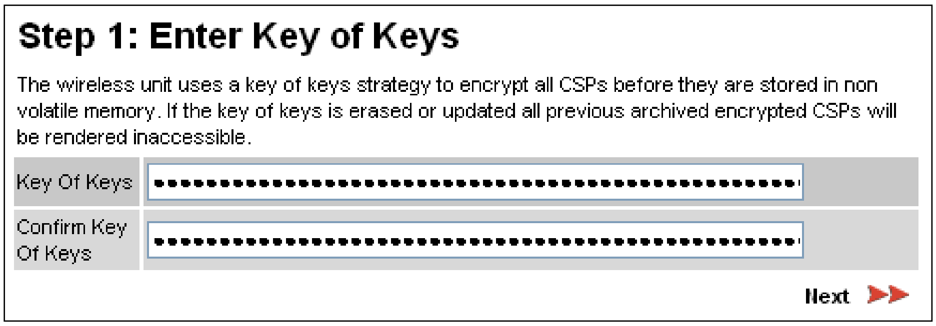
- To continue with the Security Wizard, click **Continue to Security Wizard**.

Step 1: Enter Key of Keys

Menu option: **Security**. Part of the Security Wizard (Figure 168).

Use this page to enter a Key of Keys to encrypt all critical security parameters (CSPs) before they are stored in non-volatile memory.

Figure 168 Step 1: Enter Key of Keys page



Caution

Erasing or changing the key of keys resets all CSPs.

Procedure:

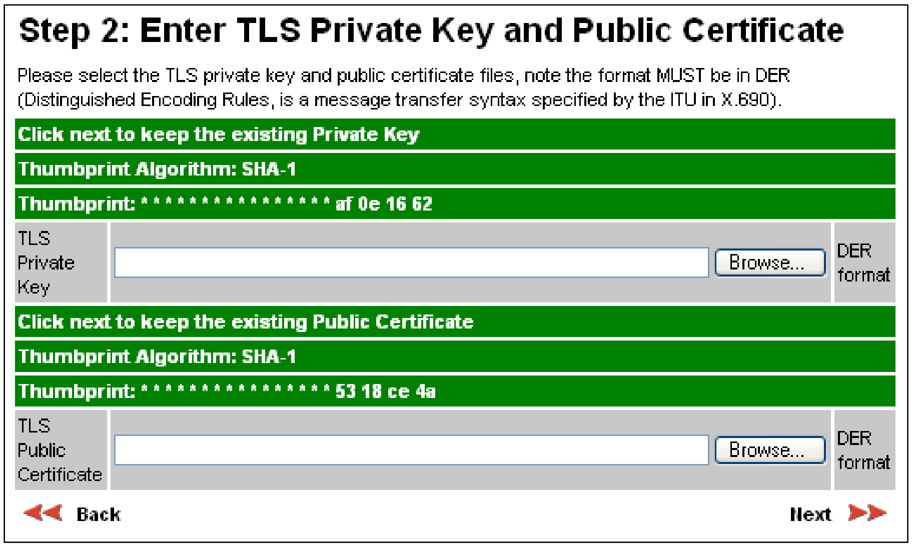
- Enter and confirm the generated Key of Keys.
- Click **Next**.

Step 2: Enter TLS Private Key and Public Certificate

Menu option: **Security**. Part of the Security Wizard (Figure 169).

Use this page to select and upload the TLS Private Key and Public Certificate files.

Figure 169 Step 2: Enter TLS Private Key and Public Certificate page



Caution

If the certificates expire, your web browser will display security warnings. Always investigate the cause of security warnings, and rectify errors in the content or expiry of certificates where necessary. Do not accept or ignore web browser security warnings.

Procedure:

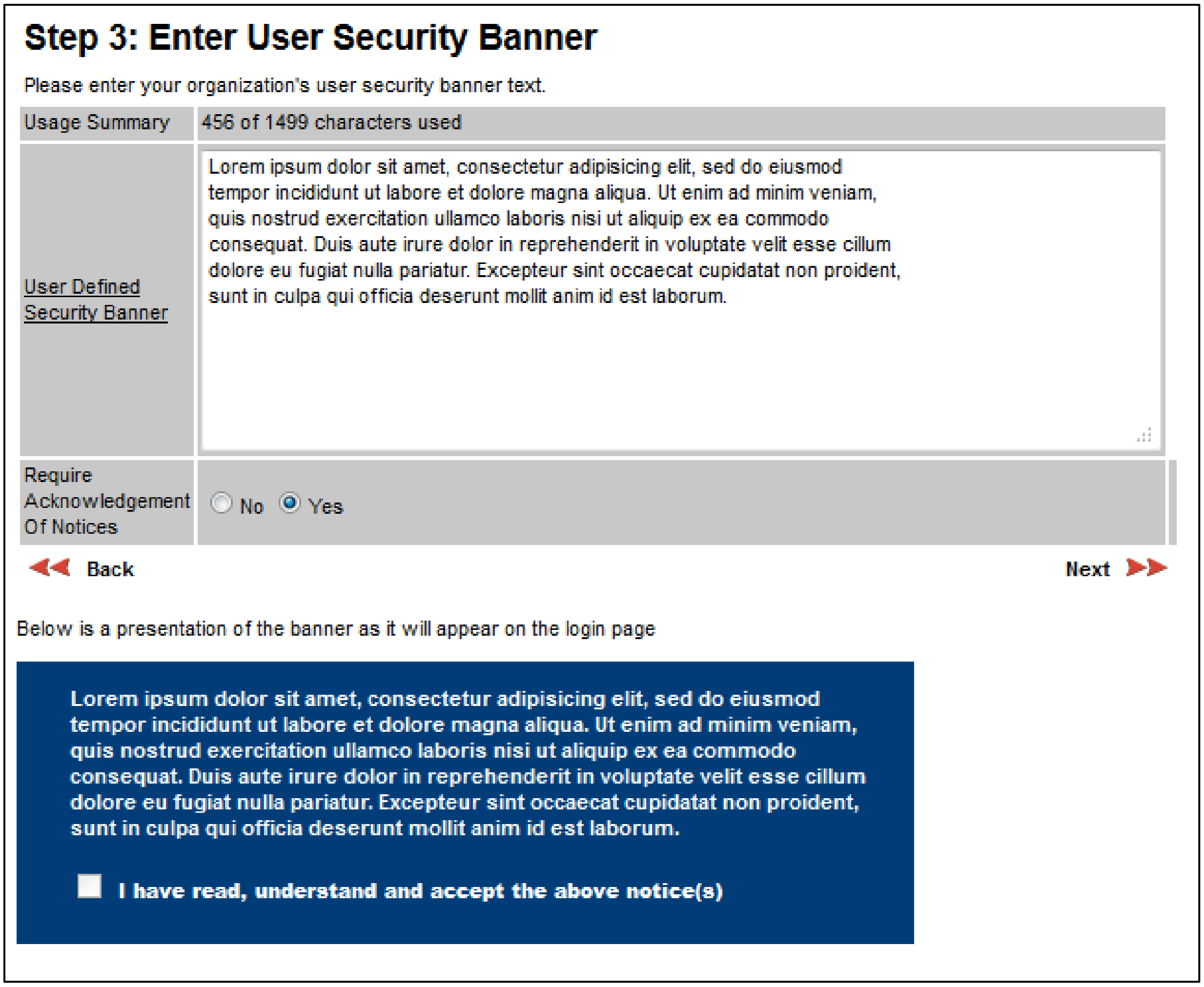
- If a valid TLS private key exists, then an SHA-1 thumbprint of the key is displayed. If this key is correct, then take no action. Otherwise, click **Browse** and select the generated private key file (.der).
- If a valid TLS public certificate exists, then an SHA-1 thumbprint of the certificate is displayed. If this certificate is correct, then take no action. Otherwise, click **Browse** and select the generated certificate file (.der).
- Click **Next.**

Step 3: Enter User Security Banner

Menu option: **Security**. Part of the Security Wizard (Figure 170).

Use this page to enter a banner that will be displayed every time a user attempts to login to the wireless unit.

Figure 170 Step 3: Enter User Security Banner page



Procedure:

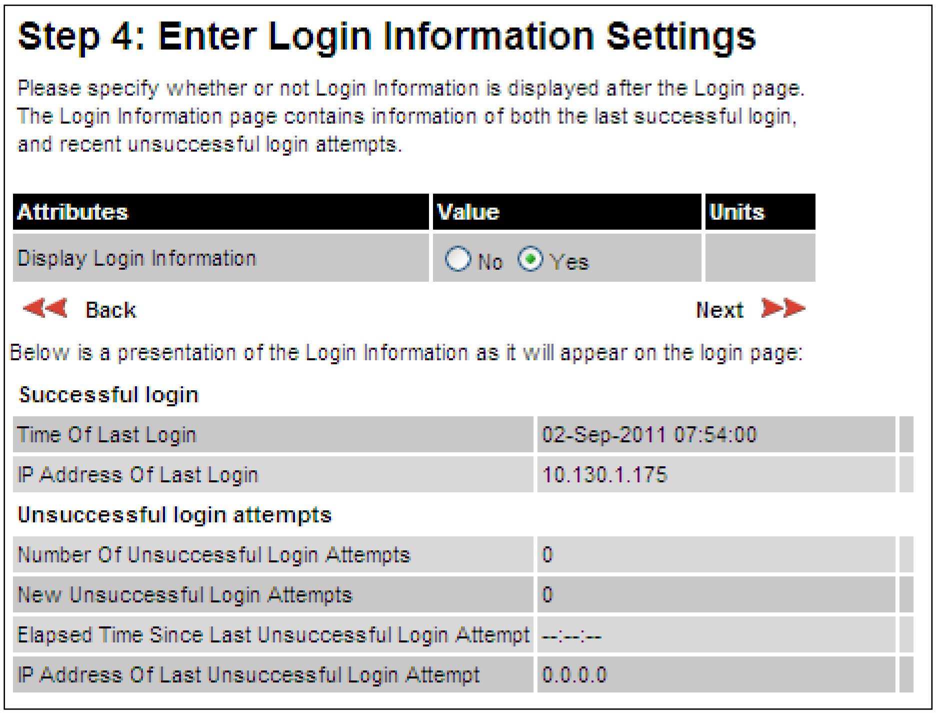
- Update the User Defined Security Banner (optional).
- Set the Acknowledgement to **No** or **Yes**.
- Click **Next.**

Step 4: Enter Login Information Settings

Menu option: **Security**. Part of the Security Wizard (Figure 171).

Use this page to choose whether or not to display information about previous login attempts when the user logs into the web interface.

Figure 171 Step 4: Enter Login Information Settings page



Procedure:

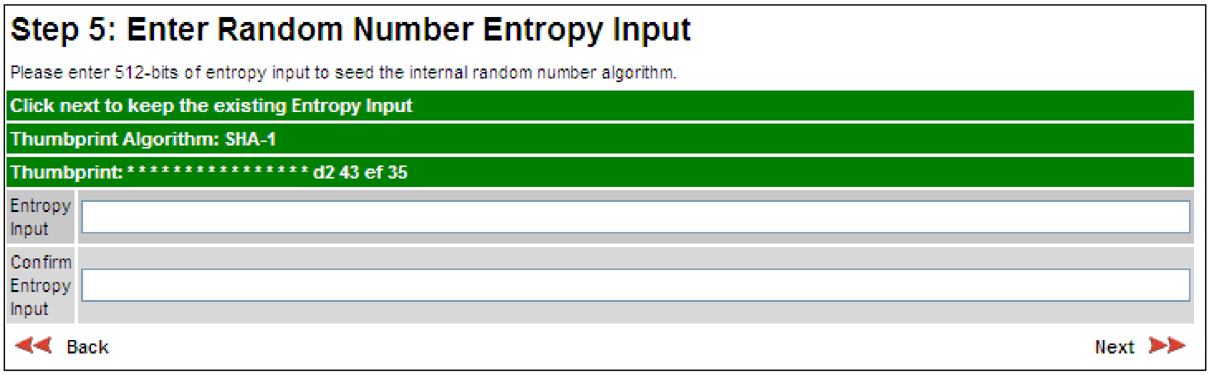
- Set Display Login Information to **No** or **Yes**.
- Click **Next.**

Step 5: Enter Random Number Entropy Input

Menu option: **Security**. Part of the Security Wizard (Figure 172).

Use this page to enter entropy input to seed the internal random number algorithm.

Figure 172 Step 5: Random Number Entropy Input page



Procedure:

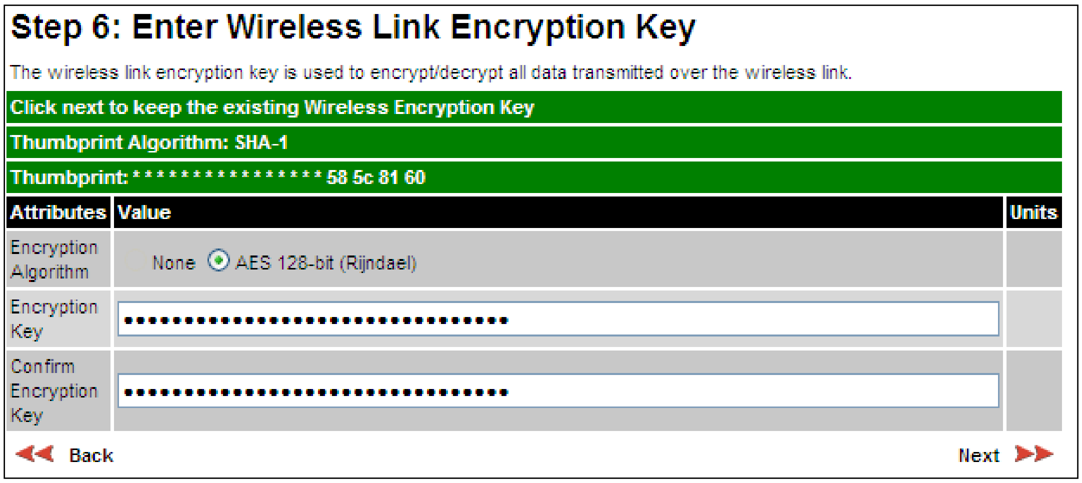
- If valid entropy input exists, then an SHA-1 thumbprint of the input is displayed. If this input is correct, then take no action. Otherwise, enter the generated input in the Entropy Input and Confirm Entropy Input fields.
- Click **Next.**

Step 6: Enter Wireless Link Encryption Key

Menu option: **Security**. Part of the Security Wizard (Figure 173).

Use this page to enable AES encryption and enter the encryption key. The wireless link encryption key is used to encrypt all traffic over the PTP 650 wireless link.

Figure 173 Step 6: Enter Wireless Link Encryption Key page



Procedure:

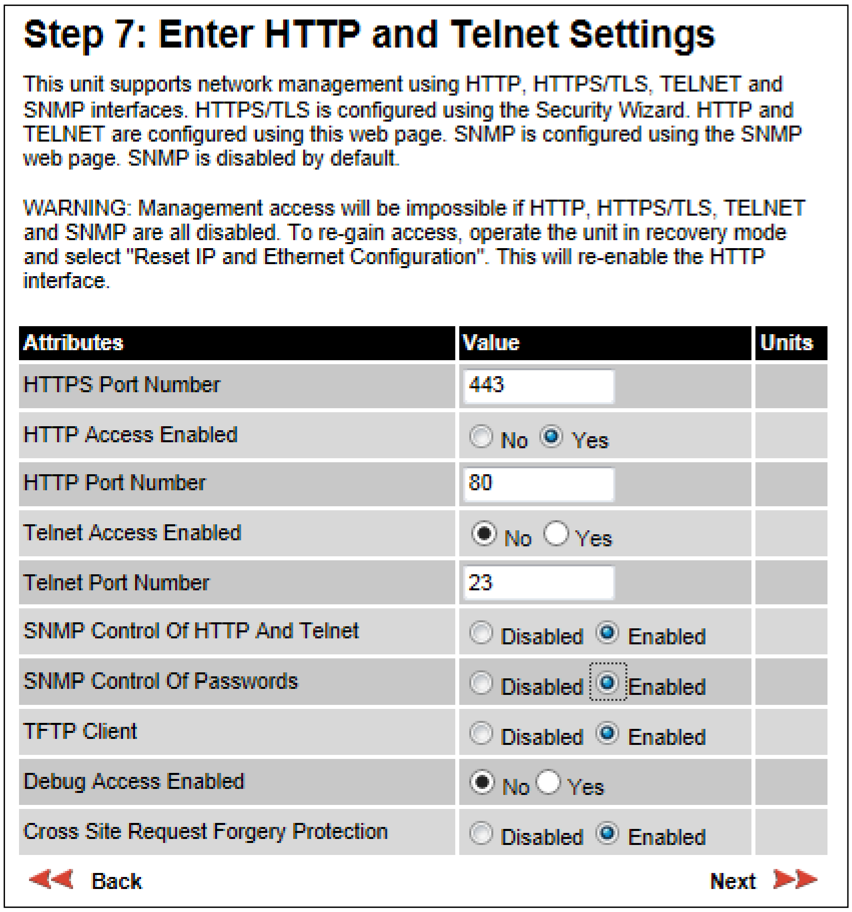
- Select the applicable value in the Encryption Algorithm field. If a valid encryption key exists, then an SHA-1 thumbprint of the key is displayed. If this key is correct, then take no action. Otherwise, enter the generated key in the Wireless Link Encryption Key and Confirm Wireless Link Encryption Key fields.
- Click **Next**.

Step 7: Enter HTTP and Telnet Settings

Menu option: **Security**. Part of the Security Wizard (Figure 174).

Use this page to configure network management of the PTP 650 using one or more of the following methods: HTTPS, HTTP, Telnet or SNMP.

Figure 174 Step 7: Enter HTTP and Telnet Settings page



Caution

If HTTPS, HTTP, Telnet and SNMP are all disabled, management access will be impossible until the unit is placed in recovery mode.

Note

If HTTP, Telnet and SNMP are all disabled, the secure web server becomes the only management tool for the ODU web interface. To reenter the web interface after Step 7 of the Security Wizard, use the URL **https://aa.bb.cc.dd** (where aa.bb.cc.dd is the IP address of the unit).

Procedure:

- Review and update the HTTP and Telnet attributes (Table 159) and click **Next**.

Table 159 HTTP and Telnet attributes

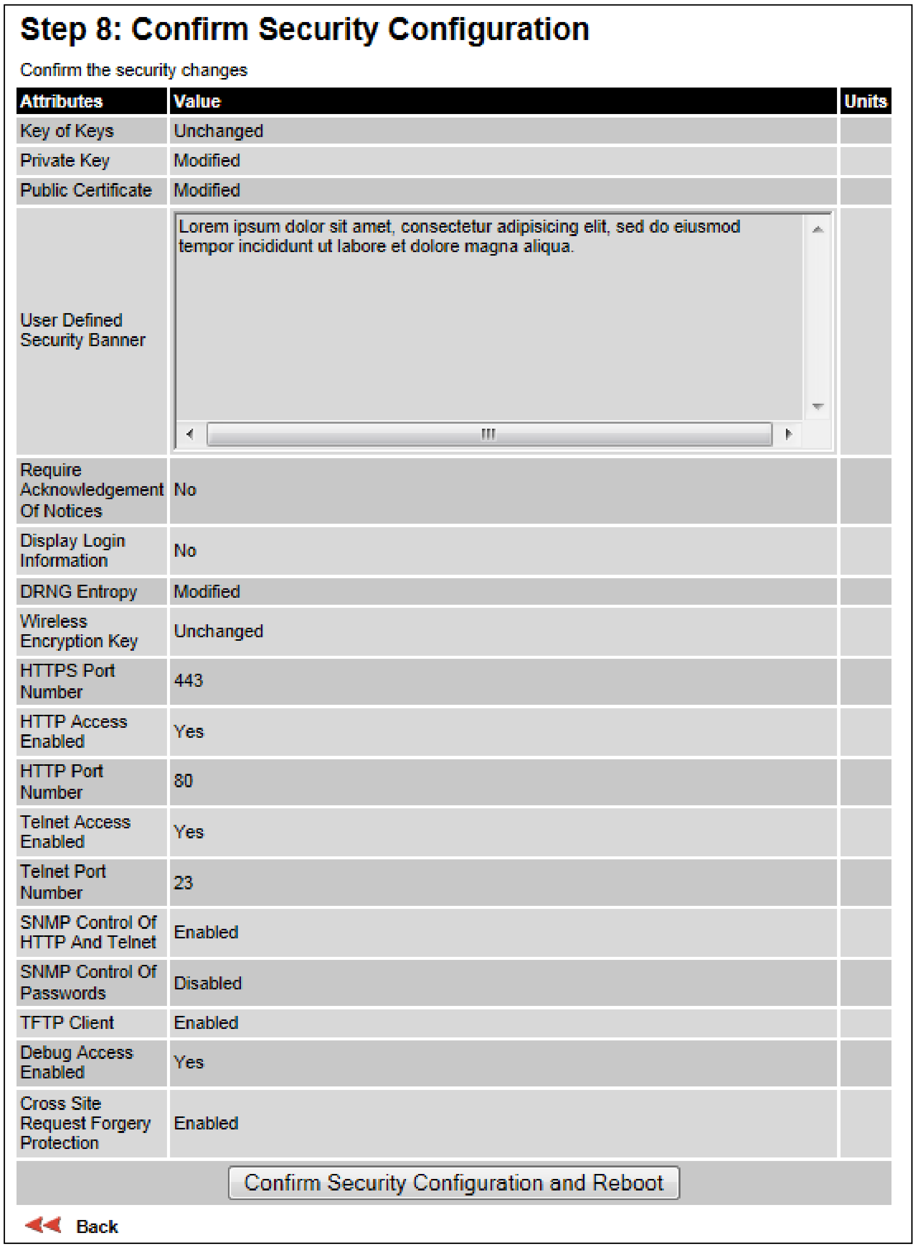
Attribute	Meaning
HTTPS Port Number	The port number for HTTPS access. Zero means use the default port.
HTTP Access Enabled	**No**: The unit will not respond to any requests on the HTTP port. **Yes**: The unit will respond to requests on the HTTP port. Remote management via HTTPS is not affected by this setting.
HTTP Port Number	The port number for HTTP access. Zero means use the default port.
Telnet Access Enabled	**No**: The unit will not respond to any requests on the Telnet port. **Yes**: The unit will respond to requests on the Telnet port.
Telnet Port Number	The port number for Telnet access. Zero means use the default port.
SNMP Control of HTTP And Telnet	**Disabled**: Neither HTTP nor Telnet can be controlled remotely via SNMP. **Enabled**: Both HTTP and Telnet can be controlled remotely via SNMP.
SNMP Control of Passwords	**Enabled:** Passwords for identity-based user accounts in the web-based interface can be updated via SNMP. Use this with SNMPv3 to provide secure password updating from a central network manager. **Disabled**: Passwords for identity-based user accounts can be updated only via the web-based interface (default).
TFTP Client	**Enabled**: The unit will respond to TFTP software download requests.
Debug Access Enabled	**Yes**: Cambium Technical Support is allowed to access the system to investigate faults.
Cross Site Request Forgery Protection	**Enabled**: The system is protected against cross-site request forgery attacks at the web-based interface.

Step 8: Commit Security Configuration

Menu option: **Security**. Part of the Security Wizard (Figure 175).

Use this page to review and confirm the updated security configuration of the unit.

Figure 175 Step 8: Commit Security Configuration page



Step 8: Confirm Security Configuration

Confirm the security changes

Attributes	Value	Units
Key of Keys	Unchanged	
Private Key	Modified	
Public Certificate	Modified	
User Defined Security Banner	Lorem ipsum dolor sit amet, consectetur adipisicing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua.	
Require Acknowledgement Of Notices	No	
Display Login Information	No	
DRNG Entropy	Modified	
Wireless Encryption Key	Unchanged	
HTTPS Port Number	443	
HTTP Access Enabled	Yes	
HTTP Port Number	80	
Telnet Access Enabled	Yes	
Telnet Port Number	23	
SNMP Control Of HTTP And Telnet	Enabled	
SNMP Control Of Passwords	Disabled	
TFTP Client	Enabled	
Debug Access Enabled	Yes	
Cross Site Request Forgery Protection	Enabled	

Confirm Security Configuration and Reboot

Back

Procedure:

- Review all changes that have been made in the Security Wizard.
- To ensure that the changes take effect, click **Commit Security Configuration and Reboot**. The unit reboots and the changes take effect.

Note

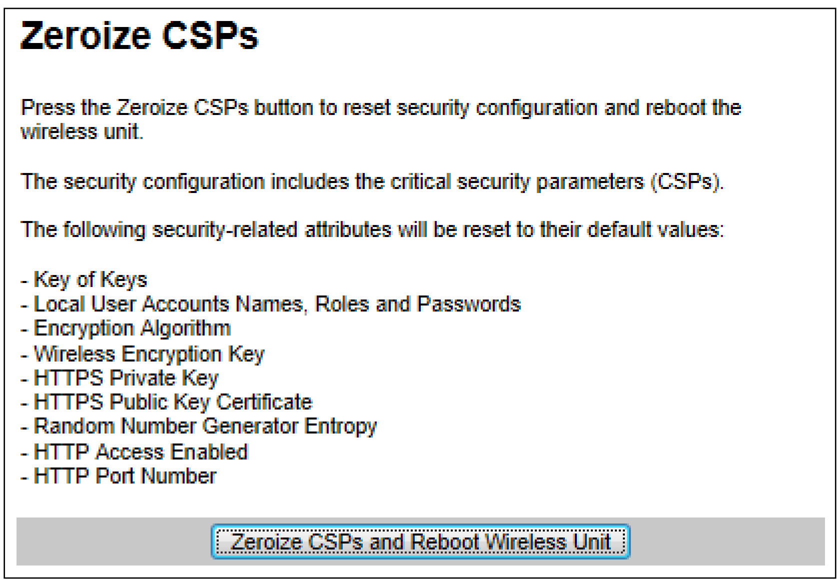
If the Key of keys is entered or modified in the Security Wizard, user accounts are reset when **Commit Security Configuration and Reboot** is clicked. It is then necessary to reconfigure them.

Zeroize CSPs page

Menu option: **Security** > **Zeroize CSPs** (Figure 176).

Use this page if it is necessary to reset the security configuration to default values.

Figure 176 Zeroize CSPs page



Procedure:

- Click **Zeroize CSPs and Reboot Wireless Unit**.
- Confirm the reboot.

Aligning antennas

This section describes how to align the antennas in a PTP 650 link, use the web interface to assist with alignment, and check wireless performance after alignment.

Before performing this task, check that hardware installation is complete (apart from the network connections) at both the Master and Slave sites.

Starting up the units

Use this procedure to connect one of the units to a management PC and start up both units.

Procedure:

1 Select the unit from which this process is to be controlled; either Master or Slave. This is the "local" unit.

2 Check that the management PC is connected to the local unit, powered up and logged on as described in Connecting to the unit on page 6-4.

4 Power up the remote unit.

5 Log into the local unit as described in Logging into the web interface on page 6-6.

Checking that the units are armed

Use this procedure to confirm that the units are in the armed state, ready for alignment.

In the armed state, the modulation mode is fixed at BPSK 0.63 Single, the TDD frame duration is extended to allow the link to acquire at unknown range, and the transmit power is automatically adjusted for optimum operation.

Procedure:

- Select menu option **Home**. The System Summary page is displayed.
- Check that the Install Arm State is set to **Armed**.
- If the units are not armed, execute the installation wizard as described in Installation menu on page 6-9.

Aligning antennas

Use this procedure to align linked antennas (master and slave), whether integrated or connectorized. The goal of antenna alignment is to find the center of the main beam. This is done by adjusting the antennas while monitoring the receive signal level.

Preparation:

Ensure that the following parameters are available:

- Location of both sites (latitude and longitude).
- Bearing to the other end of the link for both sites.
- Prediction of receive signal level for both ends of the link.
- Prediction of link loss.

LINKPlanner provides all of these parameters in the form of an installation report.

If a connectorized ODU is installed at either site with two separate antennas for spatial diversity, refer to Aligning separate antennas for spatial diversity on page 6-108 before starting alignment.

Note

For improved radio performance, mount the integrated ODU at 45 degrees to the vertical; this ensures that side-lobe levels are minimized for interference transmitted or received at zero elevation.

To achieve best results, make small incremental changes to elevation and azimuth.

Caution

The action of tightening the mounting bolts can alter antenna alignment. This can be helpful when fine-tuning alignment, but it can also lead to misalignment. To prevent misalignment, continue to monitor receive signal level during final tightening of the bolts.

Procedure:

1. At each end of the link, adjust the antenna to point at the other end of the link. This should be done with the aid of a compass.
2. Without moving the master antenna, adjust the elevation and azimuth of the slave antenna to achieve the highest receive signal level using one of the following methods:
   - ODU installation tones on page 6-109
   - Graphical Install page on page 6-111
3. Without moving the Slave antenna, adjust the elevation and azimuth of the Master antenna to achieve the highest receive signal level (using one of the above methods).
4. Repeat steps 2 and 3 as necessary to fine-tune the alignment to find the center of the beam.

5 When the antennas have been aligned on the center of the beam, verify that the receive level is within the predicted range (from the installation report). If this is not the case, go back to step 2.

The current value of receive level can be verified by using the graphical installation method (see Graphical Install page on page 6-111) or by selecting menu option **Status** and monitoring the Receive Power attribute on the System Status page.

6 If after repeated attempts to align, the receive level still does not lie within the predicted range, this may be because the data provided to the prediction tool (such as LINKPlanner) is inaccurate. For example estimates of path obstructions, antenna heights or site locations may be inaccurate. Check this data and update the prediction as necessary.

7 Once the antennas have been aligned correctly, tighten the integrated ODU (or connectorized antenna) mountings. To ensure that the action of tightening does not alter antenna alignment, continue to monitor received signal level.

Aligning separate antennas for spatial diversity

Use this procedure if a connectorized ODU is installed at either site with two separate antennas for spatial diversity.

Procedure:

1 Connect the horizontal polarization antenna to the ODU, disconnect the vertical polarization antenna, then perform Aligning antennas on page 6-107.

2 Connect the vertical polarization antenna to the ODU, disconnect the horizontal polarization antenna, then perform Aligning antennas on page 6-107.

3 Re-connect the horizontal polarization antennas. The received signal level should increase.

4 Weatherproof the antenna connections at the "H" and "V" interfaces of the ODUs, as described in Weatherproofing an N type connector on page 5-62.

ODU installation tones

This is the first of two methods that may be used to monitor receive signal level during antenna alignment.

The ODU emits audible tones during installation to assist with alignment. The pitch of the alignment tone is proportional to the received power of the wireless signals. Adjust the alignment of the unit in both azimuth and elevation until the highest pitch tone is achieved.

Note

When using ODU installation tones to align connectorized antennas, it may not be possible to hear the tones. To overcome this problem, either use an assistant, or use a stethoscope to give a longer reach.

The tones and their meanings are described in Table 160. In each of the states detailed in the table, align the unit to give the highest pitch tone. The term "wanted signal" refers to that of the peer unit being installed.

Table 160 ODU installation tones

State Name	Tone Description	State Description	Pitch Indication
Free Channel Search	Regular beep	Executing band scan	N/A
Scanning	Slow broken tone	Not demodulating the wanted signal	Rx Power
Synchronized	Fast broken tone	Demodulating the wanted signal	Rx Power
Registered	Solid tone	Both Master and Slave units exchanging Radio layer MAC management messages	Rx Power

Caution

If, when in the Synchronized or Registered state, the tone varies wildly, there may be interference or a fast fading link. Installing in this situation may not give a reliable link. Investigate the cause of the problem.

During alignment, the installation tones should exhibit the following behavior:

- **Band scan:** When first started up and from time to time, the Master unit will carry out a band scan to determine which channels are not in use. During this time, between 10 and 15 seconds, the Master unit will not transmit and as a consequence of this neither will the Slave unit. During this time the installation tone on the master unit will drop back to the band scan state, and the Slave unit will drop back to the Scanning state with the pitch of the tone set to the background noise level. Alignment of the unit should cease during this time.
- **Radar detection:** If the unit is operating where mandatory radar avoidance algorithms are implemented, the ranging behavior may be affected. The Master has to monitor the initially chosen channel for 60 seconds to make sure it is clear of radar signals before transmitting. If a radar signal is detected during any of the installation phases, a further compulsory 60 seconds channel scan will take place as the master unit attempts to locate a new channel that is free of radar interference.
- **Ranging:** The PTP 650 Series does not require the user to enter the link range. The Master unit typically takes less than 60 seconds to determine the length of the link being installed. The Master unit will remain in the Scanning state until the range of the link has been established. The Master unit will only move to the Synchronized state when the range of the link has been established.

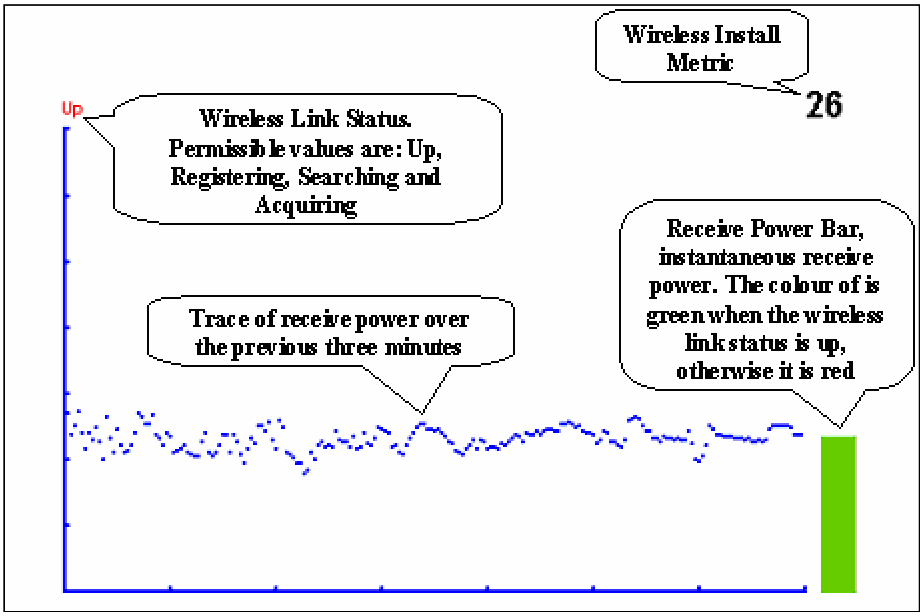
  The Slave unit does not have a ranging process. The slave unit will change to the Synchronized state as soon as the wanted signal is demodulated.
- **Retrying same channel:** If, at the end of the ranging period, the Registered state is not achieved due to interference or other reasons, the Master unit will retry twice more on the same channel before moving to another available channel. Should this occur it may take a number of minutes to establish a link in the Registered state.

Graphical Install page

Menu option: **Installation > Graphical Install** (Figure 177).

This is the second of two methods that may be used to monitor receive signal level during antenna alignment.

Figure 177 Graphical Install page



Procedure:

- Check that Wireless Link Status (top left) is “Up”, “Registering”, “Searching” or “Acquiring”.
- While slowly sweeping the antenna, monitor the trace of receive power over the last three minutes.
- Monitor the Receiver Power Bar (bottom right). Green signifies that the wireless link is up and red signifies all other states.
- Monitor the Wireless Install Metric (top right). This is the instantaneous receive power in dBm + 110.

Note

To access the PDA version of the graphical installation tool, use this URL - **http://<ip-address>/pda.cgi**. This link is only available to system administrators.

Disarming the units

When antenna alignment is complete, use this procedure to disarm both units in the link in order to:

- Turn off the audible alignment aid.
- Enable adaptive modulation.
- Fully enable spectrum management features (such as DSO, if configured).
- Clear unwanted installation information from the various systems statistics.
- Store the link range for fast link acquisition on link drop.
- Enable higher data rates.

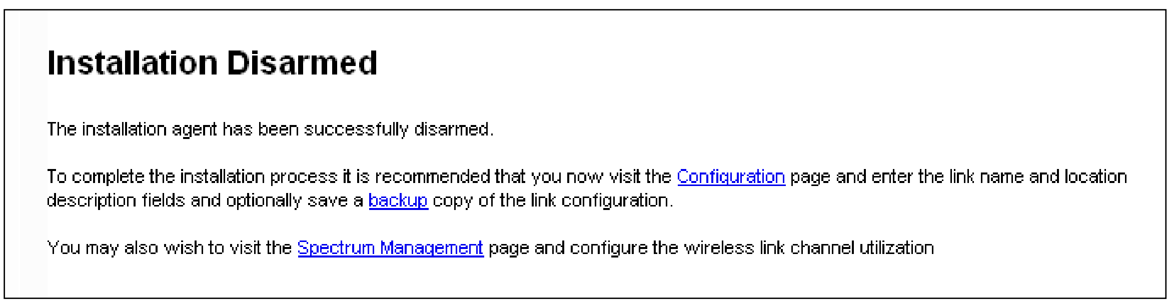
Note

After 24 hours, the units will be disarmed automatically, provided that they are armed and that the link is up.

Procedure:

- Select menu option **Installation.** The Disarm Installation page is displayed (Figure 121).
- Click **Disarm Installation Agent**. The confirmation page is displayed (Figure 178).

Figure 178 Optional post-disarm configuration



Comparing actual to predicted performance

For at least one hour of operation after disarming, use this procedure to monitor the link to check that it is achieving predicted levels of performance. LINKPlanner provides the prediction in the form of an installation report.

Procedure:

- Select menu option **System > Statistics**. The System Statistic page is displayed (Figure 179).
- Monitor the following attributes:
  - Link Loss
  - Transmit Data Rate
  - Receive Data Rate

Figure 179 Statistics to be monitored after alignment

System Statistics

Attributes	Value	Units
System Histograms		
Transmit Power	25.0, 17.5, -15.0, 14.0	dBm
Receive Power	-37.2, -64.0, -110.0, -51.3	dBm
Vector Error	7.2, -19.6, -31.0, -29.4	dB
Link Loss	110.8, 79.6, 0.0, 107.3	dB
Signal Strength Ratio	0.7, 0.0, -1.0, 0.0	dB
Transmit Data Rate	20.40, 14.73, 0.00, 20.40	Mbps
Receive Data Rate	20.40, 9.14, 0.00, 20.40	Mbps
Aggregate Data Rate	40.80, 23.88, 0.00, 40.80	Mbps
Histogram Measurement Period	00:07:46	

Reset System Histogram Measurement Period

For more information on the System Statistics page, refer to System Statistics page on page 7-50.

Other configuration tasks

This section describes other configuration tasks.

Connecting to the network

Use this procedure to complete and test network connections.

Procedure:

1 If a management PC is connected directly to the PTP 650, disconnect it.

2 Confirm that all ODU Ethernet interface cables (PSU, SFP and Aux) are connected to the correct network terminating equipment or devices.

If Main PSU Port Allocation is set to **Disabled** in the LAN Configuration page), it is not necessary to connect the PSU LAN port to network terminating equipment.

3 Test that the unit is reachable from the network management system by opening the web interface to the management agent, or by requesting ICMP echo response packets using the Ping application. For in-band management, test that both units are reachable from one PC.

If the network management system is remote from the sites, either ask co-workers at the management center to perform this test, or use remote login to the management system.

4 Test the data network for correct operation across the wireless link. This may be by requesting ICMP echo response packets between hosts in the connected network segments, or by some more structured use of network testing tools.

5 Monitor the Ethernet ports and wireless link to confirm that they are running normally. For instructions, see System Summary page on page 7-2 and System Status page on page 7-3.

Upgrading software using TFTP

Use this procedure to upgrade software remotely using Trivial FTP (TFTP) triggered by SNMP.

Procedure:

1. Check that the TFTP client is enabled. Refer to Web-Based Management page on page 6-58.
2. Set tFTP attributes as described in Table 161.
3. Monitor tFTP attributes as described in Table 162.
4. Reboot the ODU as described in Rebooting the unit on page 7-73.

Table 161 Setting tFTP attributes

Attribute	Meaning
tFTPServerInternetAddress	The IPv4 or IPv6 address of the TFTP server from which the TFTP software upgrade file Name will be retrieved. For example, to set the TFTP server IP address for the unit at 10.10.10.10 to the IPv4 address 10.10.10.1, enter this command: **`snmpset_d.exe -v 2c -c public 10.10.10.10 .iso.3.6.1.4.1.17713.7.9.19.0 a 10.10.10.1`**
tFTPServerPortNumber	This setting is optional. The port number of the TFTP server from which the TFTP software upgrade file name will be retrieved (default=69).
tFTPSoftwareUpgrade FileName	The filename of the software upgrade to be loaded from the TFTP server. For example, to set the TFTP software upgrade filename on 10.10.10.10 to "B1095.dld", enter this command: **`snmpset_d.exe -v 2c -c public 10.10.10.10 .iso.3.6.1.4.1.17713.7.9.7.0 s B1095.dld`**
tFTPStartSoftware Upgrade	Write “1” to this attribute to start the TFTP software upgrade process. The attribute will be reset to 0 when the upgrade process has finished. For example, enter this command: **`snmpset_d.exe -v 2c -c public 10.10.10.10 .iso.3.6.1.4.1.17713.7.9.8.0 i 1`**

Table 162 Monitoring tFTP attributes

Attribute	Meaning
tFTPSoftwareUpgradeStatus	This is the current status of the TFTP software upgrade process. Values: idle(0) uploadinprogress(1) uploadsuccessfulprogrammingFLASH(2) upgradesuccessfulreboottorunthenewsoftwareimage(3) upgradefailed(4). For example, enter this command: **snmpget_d.exe -v 2c -c public 10.10.10.10 .iso.3.6.1.4.1.17713.7.9.9.0**
tFTPSoftwareUpgradeStatus Text	This describes the status of the TFTP software upgrade process, including any error details. For example, enter this command: **snmpget_d.exe -v 2c -c public 10.10.10.10 .iso.3.6.1.4.1.17713.7.9.10.0**
tFTPSoftwareUpgradeStatus AdditionalText	This is used if tFTPSoftwareUpgradeStatusText is full and there are more than 255 characters to report. It contains additional text describing the status of the TFTP software upgrade process, including any error details. For example, enter this command: **snmpget_d.exe -v 2c -c public 10.10.10.10 .iso.3.6.1.4.1.17713.7.9.11.0**

Chapter 7: Operation

This chapter provides instructions for operators of the PTP 650 wireless Ethernet bridge.

The following topics are described in this chapter:

System summary and status

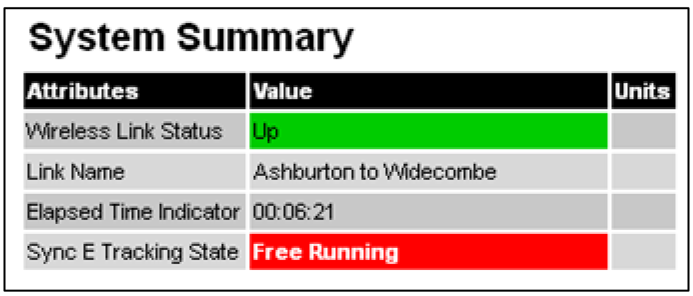
This section describes how to use the summary and status pages to monitor the status of the Ethernet ports and wireless link.

System Summary page

Menu option: **Home** (Figure 180).

This page contains a high level summary of the status of the wireless link and associated equipment. Whenever system alarms are outstanding, a yellow warning triangle is displayed on the navigation bar, and the alarm condition is listed. In the example in Figure 180, there is one alarm, and this is for the Sync E Tracking State.

Figure 180 System Summary page



Procedure:

- Review the attributes (Table 163).
- Check that the Wireless Link Status is "Up" on both units. If it is not "Up", review any uncleared system alarms: these are displayed below the System Clock attribute. For more information, refer to Alarms on page 7-18.

Table 163 System Summary attributes

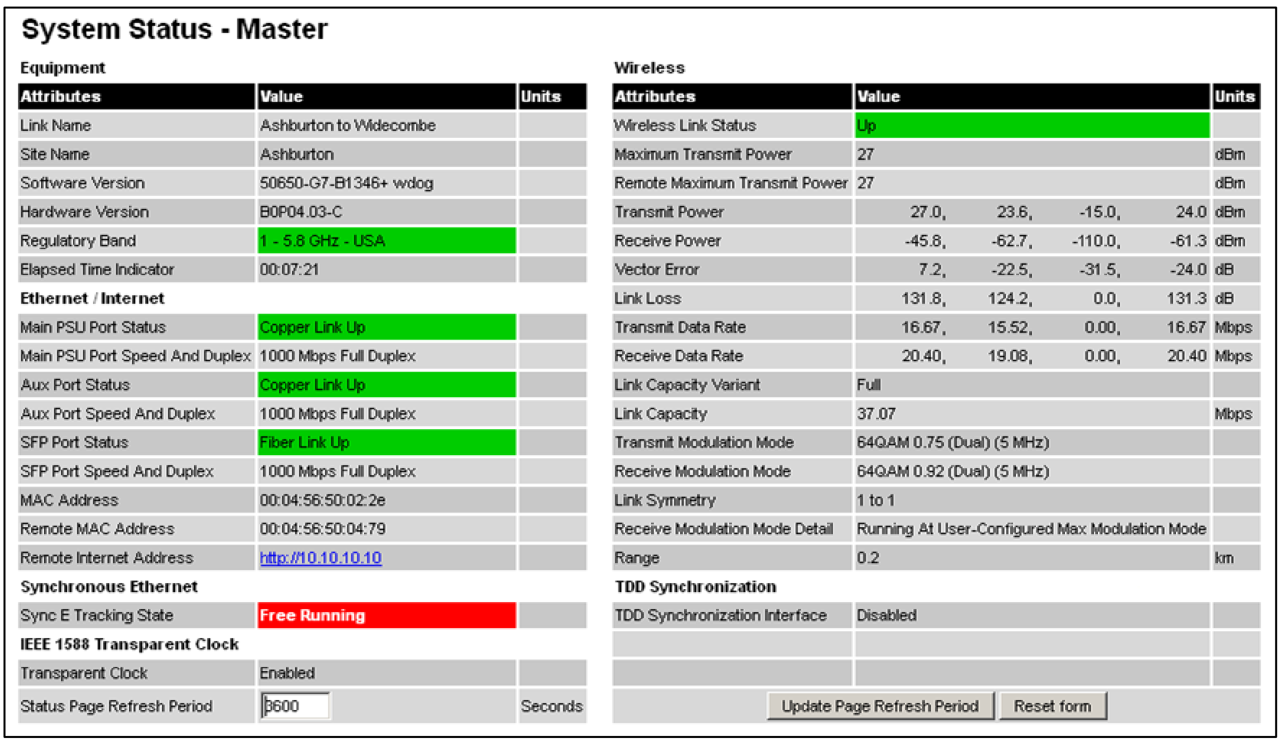
Attribute	Meaning
Wireless Link Status	Current status of the wireless link. A green background with status text "Up" means that the point-to-point link is established. A red background with suitable status text (for example "Searching") indicates that the link is not established.
Link Name	The name of the PTP link, as set in the System Configuration page.

Attribute	Meaning
Elapsed Time Indicator	The time (hh:mm:ss) that has elapsed since the last system reboot. The system can reboot for several reasons, for example, commanded reboot from the system reboot webpage, or a power cycle of the equipment.
System Clock	The system clock presented as local time, allowing for zone and daylight saving (if set).

System Status page

Menu option: **Status** (Figure 181). This page provides a detailed view of the operation of the PTP 650 link from both the wireless and network perspectives.

Figure 181 System Status page



System Status - Master

Equipment

Attributes	Value	Units
Link Name	Ashburton to Widecombe	
Site Name	Ashburton	
Software Version	50650-G7-B1346+ wdog	
Hardware Version	B0P04.03-C	
Regulatory Band	1 - 5.8 GHz - USA	
Elapsed Time Indicator	00:07:21	
Ethernet / Internet		
Main PSU Port Status	Copper Link Up	
Main PSU Port Speed And Duplex	1000 Mbps Full Duplex	
Aux Port Status	Copper Link Up	
Aux Port Speed And Duplex	1000 Mbps Full Duplex	
SFP Port Status	Fiber Link Up	
SFP Port Speed And Duplex	1000 Mbps Full Duplex	
MAC Address	00:04:56:50:02:2e	
Remote MAC Address	00:04:56:50:04:79	
Remote Internet Address	http://10.10.10.10	
Synchronous Ethernet		
Sync E Tracking State	Free Running	
IEEE 1588 Transparent Clock		
Transparent Clock	Enabled	
Status Page Refresh Period	3600	Seconds

Wireless

Attributes	Value	Units
Wireless Link Status	Up	
Maximum Transmit Power	27	dBm
Remote Maximum Transmit Power	27	dBm
Transmit Power	27.0, 23.6, -15.0, 24.0	dBm
Receive Power	-45.8, -62.7, -110.0, -61.3	dBm
Vector Error	7.2, -22.5, -31.5, -24.0	dB
Link Loss	131.8, 124.2, 0.0, 131.3	dB
Transmit Data Rate	16.67, 15.52, 0.00, 16.67	Mbps
Receive Data Rate	20.40, 19.08, 0.00, 20.40	Mbps
Link Capacity Variant	Full	
Link Capacity	37.07	Mbps
Transmit Modulation Mode	64QAM 0.75 (Dual) (5 MHz)	
Receive Modulation Mode	64QAM 0.92 (Dual) (5 MHz)	
Link Symmetry	1 to 1	
Receive Modulation Mode Detail	Running At User-Configured Max Modulation Mode	
Range	0.2	km
TDD Synchronization		
TDD Synchronization Interface	Disabled	

Update Page Refresh Period Reset form

The two PTP 650 Series units are arranged in a master and slave relationship. The roles of the units in this relationship are displayed in the page title. The master unit will always have the title "`- Master`", and the slave will always have "`- Slave`" appended to the "`Systems Status`" page title.

Note

Link Symmetry is configured at the master ODU only. The appropriate matching Link Symmetry is set at the slave ODU automatically. For example, if Link Symmetry is configured as **2 to 1** at the master ODU, then the slave ODU will be set automatically as **1 to 2**. In this example, the master-slave direction has double the capacity of the slave-master direction.

If TDM is configured, the System Status page displays NIDU LAN Port and TDM attibutes (Figure 182).

Figure 182 System Status page with TDM configured

System Status - Master

Equipment

Attributes	Value	Units
Link Name	link5	
Site Name		
Software Version	50650-G7-B1439+ wdog	
Hardware Version	B0P03.00-C	
Regulatory Band	255 - Development Key	
Elapsed Time Indicator	00:08:56	
Ethernet / Internet		
Main PSU Port Status	Copper Link Up	
Main PSU Port Speed And Duplex	1000 Mbps Full Duplex	
NIDU Lan Port Status	Copper Link Up	
NIDU Lan Port Speed And Duplex	1000 Mbps Full Duplex	
Aux Port Status	Copper Link Up	
Aux Port Speed And Duplex	1000 Mbps Full Duplex	
SFP Port Status	Fiber Link Up	
SFP Port Speed And Duplex	1000 Mbps Full Duplex	
MAC Address	00:04:56:50:00:a9	
Remote MAC Address	00:04:56:50:02:2e	
Remote Internet Address	http://169.254.1.2	
Synchronous Ethernet		
Sync E Tracking State	Free Running	

Wireless

Attributes	Value	Units
Wireless Link Status	Up	
Maximum Transmit Power	10	dBm
Remote Maximum Transmit Power	10	dBm
Transmit Power	10.0, 10.0, 10.0, 10.0	dBm
Receive Power	-54.1, -54.3, -54.5, -54.5	dBm
Vector Error	-30.8, -31.9, -32.8, -31.7	dB
Link Loss	110.4, 110.3, 110.3, 110.4	dB
Transmit Data Rate	24.22, 24.22, 24.22, 24.22	Mbps
Receive Data Rate	24.22, 24.22, 24.22, 24.22	Mbps
Link Capacity Variant	Full	
Link Capacity	48.43	Mbps
Transmit Modulation Mode	256QAM 0.81 (Dual) (5 MHz)	
Receive Modulation Mode	256QAM 0.81 (Dual) (5 MHz)	
Link Symmetry	1 to 1	
Receive Modulation Mode Detail	Running At Maximum Receive Mode	
Range	0.2	km
TDD Synchronization		
TDD Synchronization Interface	Disabled	

TDM

Attributes	Value	Units	Attributes	Value	Units
TDM Interface Control	E1		TDM Interface Status	OK	
TDM Single Payload Lock	Disabled		TDM Latency	0	µs
TDM Channel Status 1	Up		TDM Channel Status 2	Up	
TDM Channel Status 3	Up		TDM Channel Status 4	Up	
TDM Channel Status 5	Up		TDM Channel Status 6	Up	
TDM Channel Status 7	Up		TDM Channel Status 8	Up	
Status Page Refresh Period	3600	Seconds	Update Page Refresh Period	Reset form	

Procedures:

- Confirm that the Ethernet Link Status attributes are green and set to **Copper Link Up** or **Fiber Link Up**.

Equipment

The Equipment section of the System Status page contains the attributes described in Table 164.

Table 164 System Status attributes - Equipment

Attribute	Meaning
Link Name	The link name is allocated by the system administrator and is used to identify the equipment on the network. The link name attribute is limited to a maximum size of 63 ASCII characters.
Site Name	The site name is allocated by the system administrator and can be used as a generic scratch pad to describe the location of the equipment or any other equipment related notes. The site name attribute is limited to a maximum size of 63 ASCII characters.
Software Version	The version of PTP 650 software installed on the equipment.
Hardware Version	The PTP 650 hardware version. Formatted as “vvvv-C” or “vvvv-I” where vvvv is the version of the printed circuit card. The “-C” suffix indicates a PTP 650 Connectorized unit. The “-I” suffix indicates a PTP 650 Integrated or PTP 650S Integrated or PTP 650L Integrated unit.
Regulatory Band	This is used by the system to constrain the wireless to operate within regulatory regime of a particular band and country. The license key provides the capability to operate in one or more regulatory bands. The Installation Wizard is used to choose one of those bands.
Elapsed Time Indicator	The elapsed time indicator attribute presents the total time in years, days, hours, minutes and seconds since the last system restart. The system can restart for several reasons, for example commanded reboot from the system reboot web page, or a power cycle of the equipment.

Ethernet / Internet

The Ethernet / Internet section of the System Status page contains the attributes described in Table 165.

Table 165 System Status attributes – Ethernet / Internet

Attribute	Meaning
Main PSU Port Status	The current status of the Ethernet link to the PSU port: • Green "`Copper Link Up`": The Ethernet link is established. • Red "`Down`": The Ethernet link is not established.
Main PSU Port Speed and Duplex	The negotiated speed and duplex setting of the Ethernet link to the PSU port. The speed setting is specified in Mbps.
NIDU LAN Port Status	The current status of the Ethernet link to the NIDU LAN port: • Green "`Copper Link Up`": The Ethernet link is established. • Red "`Down`": The Ethernet link is not established.
NIDU LAN Port Speed and Duplex	The negotiated speed and duplex setting of the Ethernet link to the NIDU LAN port. The speed setting is specified in Mbps.
Aux Port Status	The current status of the Ethernet link to the Aux port: • Green "`Copper Link Up`": The Ethernet link is established. • Red "`Down`": The Ethernet link is not established.
Aux Port Speed and Duplex	The negotiated speed and duplex setting of the Ethernet link to the Aux port. The speed setting is specified in Mbps.
SFP Port Status	The current status of the Ethernet link to the SFP port: • Green "`Fiber Link Up`": The Ethernet link is established. • Red "`Down`": The Ethernet link is not established.
SFP Port Speed and Duplex	The negotiated speed and duplex setting of the Ethernet link to the SFP port. The speed setting is specified in Mbps.
MAC Address	The MAC Address of this unit.
Remote MAC Address	The MAC Address of the peer unit. If the link is down, this is set to "`Not available`".
Remote Internet Address	The Internet Address of the peer unit. To open the web interface of the peer unit, click on the hyperlink. If the link is down, this is set to "`Not available`". Depending on the settings of IP Version (Table 129) and IP Address Label (Table 128), this may be either an IPv4 or an IPv6 address.

Wireless

The Wireless section of the System Status page contains the attributes described in Table 166.

Table 166 System Status attributes – Wireless

Attribute	Meaning
Wireless Link Status	The current status of the wireless link: • Green "Up": A point-to-point wireless link is established. • Red "Down": The wireless link is not established.
Maximum Transmit Power	The maximum transmit power that the local wireless unit is permitted to use to sustain a link.
Remote Maximum Transmit Power	The maximum transmit power that the remote wireless unit is permitted to use to sustain a link.
Transmit Power	The maximum, mean, minimum and latest measurements of Transmit Power (dBm). See System histograms on page 7-50.
Receive Power	The maximum, mean, minimum and latest measurements of Receive Power (dBm). See System histograms on page 7-50.
Vector Error	The maximum, mean, minimum and latest measurements of Vector Error (dB). See System histograms on page 7-50. Vector Error compares the received signals In phase / Quadrature (IQ) modulation characteristics to an ideal signal to determine the composite error vector magnitude. The expected range for Vector Error is approximately -2 dB (NLOS link operating at sensitivity limit on BPSK 0.67) to -33 dB (short LOS link running 256 QAM 0.83).

Attribute	Meaning
Link Loss	The maximum, mean, minimum and latest measurements of Link Loss (dB). See System histograms on page 7-50. The link loss is the total attenuation of the wireless signal between the two point-to-point units. The link loss calculation is: $$P_{ll} = P_{T_x} - P_{R_x} + g_{T_x} + g_{R_x} - c_{T_x} - c_{R_x}$$ Where: P_{ll} = Link Loss (dB) P_{T_x} = Transmit power of the remote wireless unit (dBm) P_{R_x} = Received signal power at the local unit (dBm) g_{T_x}, g_{R_x} = Antenna gain at the remote and local units respectively (dBi). This is the gain of the integrated or connectorized antenna. c_{T_x}, c_{R_x} = Cable loss at the remote and local units respectively (dB). It is RF cable loss which connects ODU to Connectorized antenna. For connectorized ODUs, the link loss calculation is modified to allow for the increased antenna gains at each end of the link.
Transmit Data Rate	The maximum, mean, minimum and latest measurements of Transmit Data Rate (Mbps). See System histograms on page 7-50.
Receive Data Rate	The maximum, mean, minimum and latest measurements of Receive Data Rate (Mbps). See System histograms on page 7-50.
Link Capacity Variant	Indicates whether the installed license key is Lite, Mid or Full. When a link is established, this attribute shows the lower of the license keys at each end. For example, if this end is Full and the other end is Lite, it shows "Lite". To see the installed key, go to the Installation Wizard.
Link Capacity	The maximum aggregate data rate capacity available for user traffic, assuming the units have been connected using Gigabit Ethernet. The link capacity is variable and depends on the prevailing wireless conditions as well as the distance (range) between the two wireless units.
Transmit Modulation Mode	The modulation mode currently being used on the transmit channel.
Receive Modulation Mode	The modulation mode currently being used on the receive channel.
Link Symmetry	A ratio that expresses the division between transmit and receive time in the TDD frame. The first number in the ratio represents the time allowed for the transmit direction and the second number represents the time allowed for the receive direction.

Attribute	Meaning
Receive Modulation Mode Detail	The receive modulation mode in use. For a list of values and their meanings, see Table 167.
Range	The range between the PTP 650 Series ODUs. This is displayed in kilometers by default, but can be changed to miles by updating the Distance Units attribute to imperial, as described in Webpage Properties page on page 6-68.

Table 167 Receive Modulation Mode Detail values and meanings

Value	Meaning
`Running At Maximum Receive Mode`	The link is operating at maximum modulation mode in this channel and maximum throughput has been obtained.
`Running At User-Configured Max Modulation Mode`	The maximum modulation mode has been capped by the user and the link is operating at this cap.
`Restricted Because Installation Is Armed`	The Installation Wizard has been run and the unit is armed, forcing the link to operate in the lowest modulation mode. To remove this restriction, re-run the Installation Wizard to disarm the unit.
`Restricted Because Of Byte Errors On The Wireless Link`	The receiver has detected data errors on the radio and reduced the modulation mode accordingly. The radio may achieve a higher modulation mode as shown by the vector error, but there is some other error source, probably RF interference.
`Restricted Because Channel Change Is In Progress`	This is a transient event where the modulation mode is temporarily reduced during a channel change.
`Limited By The Wireless Conditions`	The radio is running at the maximum achievable modulation mode given the current wireless conditions shown by the vector error. The radio is capable of reaching a higher modulation mode if wireless conditions (vector error) improve.

Synchronous Ethernet

The Synchronous Ethernet section of the System Status page contains the attributes described in Table 168.

Table 168 System Status attributes – Synchronous Ethernet

Attribute	Meaning
Sync E Tracking State	The state of frequency tracking in Synchronous Ethernet. For a list of values and their meanings, see Table 169. In normal operation, with the Synchronous Ethernet feature enabled and a valid timing source present, one end of the link should be in the "`Locked Local, Holdover Acquired State`", the other end should be in the "`Locked Remote, Holdover Acquired`" state. Further status information for the Synchronous Ethernet features is available in the Sync E Status page. See SyncE Status page on page 7-61.

Table 169 Sync E Tracking State values and meanings

Value	Meaning
`Disabled`	The synchronous Ethernet feature is disabled.
`Acquiring Wireless Lock`	Synchronous Ethernet is not operational because the wireless link is establishing.
`Free Running`	Synchronous Ethernet is operational, but with no timing source or history. This is a temporary state.
`Locked Local, Acquiring Holdover`	Sync E tracking has locked to a synchronisation signal from a cabled Ethernet port on the local ODU. This is a temporary state until the unit has acquired holdover history.
`Locked Local, Holdover Acquired`	Sync E tracking has locked to a synchronisation signal from a cabled Ethernet port on the local ODU and has acquired holdover history.
`Holdover`	There is currently no source for the tracking loop, but previously the tracking loop was in a Locked, Holdover Acquired state. The system is using the last known good frequency.
`Locked Remote, Acquiring Holdover`	The tracking loop has locked to a synchronisation signal from the remote ODU. This is a temporary state until the unit has acquired holdover history.
`Locked Remote, Holdover Acquired`	The tracking loop has locked to a synchronisation signal form the remote ODU and has acquired holdover history.

TDD Synchronization

The TDD Synchronization section of the System Status page contains the attributes described in Table 170.

Table 170 System Status attributes – TDD Synchronization

Attribute	Meaning
TDD Synchronization Status	The status of TDD synchronization. Displayed at a TDD Master if TDD synchronization is active. For a list of values and their meanings, see Table 171.

Table 171 TDD Synchronization Status values and meanings

Value	Meaning
`Inactive`	TDD Synchronization has been administratively disabled. This value is not displayed in the System Status page, but can be determined from the SNMP MIB. TDD Synchronization Status is always in the Inactive state at a TDD Slave unit.
`Cluster Timing Master`	The ODU has been configured as a Cluster Master with an internal reference, and is communicating correctly with the PTP SYNC unit.
`Initialising`	The wireless link is down, and the master ODU is attempting to synchronize the TDD frame structure with an external 1 pps reference. Synchronization proceeds more rapidly in this state than in the Acquiring Lock state, because the TDD master does not need to consider the ability of the TDD slave to track changes in frame timing.
`PTP-SYNC Not Connected`	The ODU is not able to communicate with the PTP SYNC unit.
`Locked`	The master ODU has locked the TDD frame structure to the 1 pps reference received at the input of the PTP-SYNC unit. The ODU may be a Cluster Master or a Cluster Slave. The ODU is transmitting.

Value	Meaning
`Holdover (No GPS Sync In)`	The 1 pps reference has been lost at the input to the PTP-SYNC unit, and the ODU in a free running state. The ODU is transmitting. If the reference input is not restored, the Holdover state will terminate automatically after a period set by TDD Holdover Duration.
`Holdover`	The ODU is a Cluster Slave and the 1 pps reference has been lost at the input to an upstream PTP-SYNC unit. The ODU is locked to an upstream ODU that is in the Holdover (No GPS Sync In) state. The ODU is transmitting. If the reference input is not restored at the upstream PTP-SYNC unit, the Holdover state will terminate automatically after a period set by TDD Holdover Duration.
`Not Synchronized (No GPS Sync In)`	The 1 pps reference has been lost at the input to the PTP-SYNC unit and the holdover period has expired. If the ODU is configured for TDD Holdover Mode = Best Effort then the ODU will be transmitting, otherwise it will be muted.
`Not Synchronized`	The ODU is a Cluster Slave and the 1 pps reference has been lost at the input to an upstream PTP-SYNC unit. The holdover period has expired. If the ODU is configured for TDD Holdover Mode = Best Effort then the ODU will be transmitting, otherwise it will be muted.
`Acquiring Lock`	The wireless link is up and the master ODU is attempting to synchronize the TDD frame structure with an external 1 pps reference. Frame timing changes at the TDD master are constrained to allow for tracking by the TDD slave. This state is not allowed when TDD Holdover Mode = Strict.

IEEE 1588 Transparent Clock

The IEEE 1588 Transparent Clock section of the System Status page contains the attributes described in Table 172.

Table 172 System Status attributes – IEEE 1588 Transparent Clock

Attribute	Meaning
Transparent Clock	Indicates if the IEEE 1588 transparent clock feature is enabled.

TDM

The TDM section of the System Status page contains the attributes described in Table 173.

Note

When TDM is enabled and connected at one link end, up to two minutes may elapse before the TDM link is established (this is known as the settling period). Do not attempt to change the TDM configuration during this settling period.

Table 173 System Status attributes – TDM

Attribute	Meaning
TDM Interface Control	The type of TDM interface that is activated (None, E1 or T1). This is set on the Interface Configuration page.
TDM Interface Status	The current status of the Ethernet link between the NIDU (ODU port) and the ODU (PSU port) (OK or Not Connected). • Green "OK": The Ethernet link is established. • Red "Not Connected": The Ethernet link is not established.
TDM Single Payload Lock	The current status of the single payload locking feature: • "Enabled": The ODU will prevent transition from Single Payload modes to the higher Dual Payload modes. The ODU applies this lock when it calculates that such a transition would pass through modes which cannot carry telecoms data. • "Applied": The ODU is actively preventing these transitions. • "Disabled": The wireless will transition to the faster Dual Payload modes as soon as the conditions are appropriate.
TDM Latency	The end-to-end latency of the TDM service between TDM ports at the NIDUs (μs).
TDM Channel Status n	The current status of the TDM service between NIDU port "n" at the local NIDU and the corresponding port at the remote NIDU. For a list of values and their meanings, see Table 174.

Table 174 TDM Channel Status values and meanings

Value	Meaning
`Up`	TDM data is being bridged between the TDM ports on local and remote NIDUs (green background).
`No Signal (Local)`	No TDM data is being received at the TDM port on the local NIDU.
`No Signal (Remote)`	No TDM data is being received at the corresponding TDM port on the remote NIDU.
`No Signal (Local and Remote)`	No TDM data is being received at the associated TDM ports on local and remote NIDUs.
`No Signal (Local and Remote Timing)`	No TDM data is being received at the TDM port on the local NIDU. TDM data is being received at the TDM port on the remote NIDU. The modulation mode of the link is too low to support bridging of TDM data in the remote to local direction, but the transmit clock at TDM port of the local NIDU is synchronised to the clock received at the TDM port on the remote NIDU.
`Remote Timing`	TDM data is being received at the TDM port on the local and remote NIDUs. The modulation mode of the link is too low to support bridging of TDM data in either direction. The transmit clocks at the TDM ports on local and remote NIDUs are synchronized to the clocks received at the TDM ports on (respectively) the remote and local NIDUs.
`Disabled`	The TDM link is not established. This may be because the wireless link is down, or because the TDM service is acquiring synchronization.

Rebooting and logging out

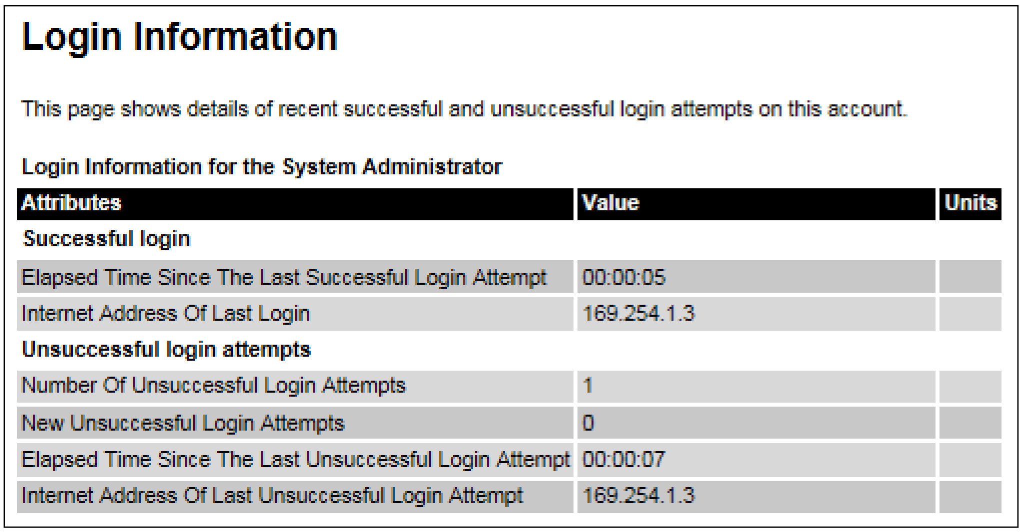
This section describes how to reboot the unit and log out of the web interface.

Login Information page

Menu option: **Management > Web > Login Information** (Figure 183).

Use this page to show recent successful and unsuccessful login attempts on this account.

Figure 183 Login Information page



Login Information

This page shows details of recent successful and unsuccessful login attempts on this account.

Login Information for the System Administrator

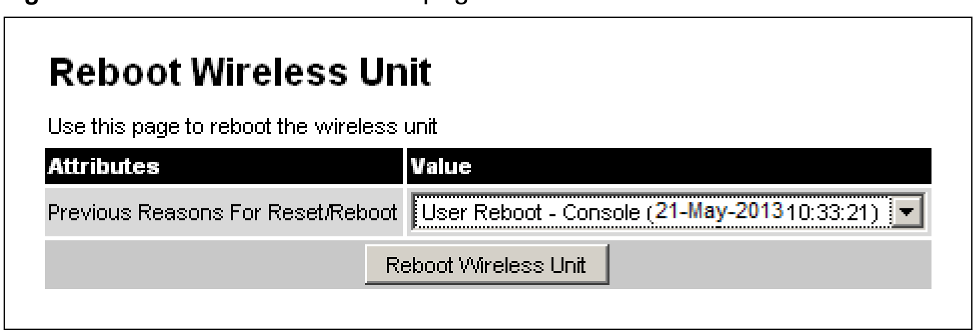
Attributes	Value	Units
Successful login		
Elapsed Time Since The Last Successful Login Attempt	00:00:05	
Internet Address Of Last Login	169.254.1.3	
Unsuccessful login attempts		
Number Of Unsuccessful Login Attempts	1	
New Unsuccessful Login Attempts	0	
Elapsed Time Since The Last Unsuccessful Login Attempt	00:00:07	
Internet Address Of Last Unsuccessful Login Attempt	169.254.1.3	

Reboot Wireless Unit page

Menu option: **System > Reboot** (Figure 184).

Use this page to reboot the ODU or view a list of previous reboot reasons.

Figure 184 Reboot Wireless Unit page



Reboot Wireless Unit

Use this page to reboot the wireless unit

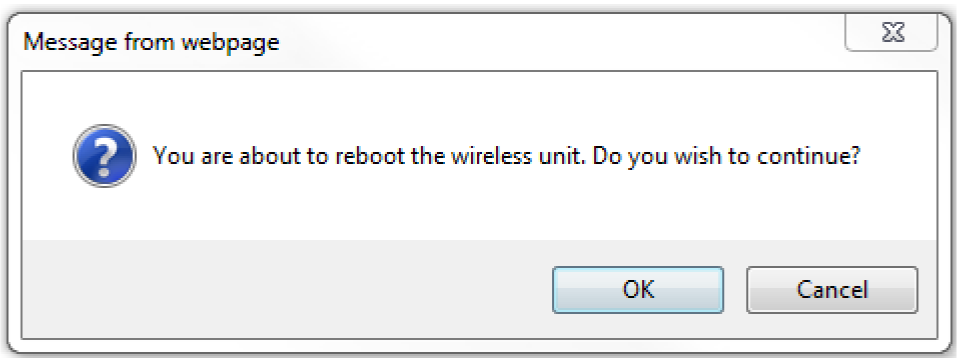
Attributes	Value
Previous Reasons For Reset/Reboot	User Reboot - Console (21-May-2013 10:33:21)

Reboot Wireless Unit

Procedure:

- Use the drop-down list to view the Previous Reasons For Reset/Reboot.
- If a reboot is required:
  - o Click **Reboot Wireless Unit**. The Reboot Confirmation dialog is displayed (Figure 185).
  - o Click **OK**. The reboot progress message is displayed. On completion, the unit restarts.

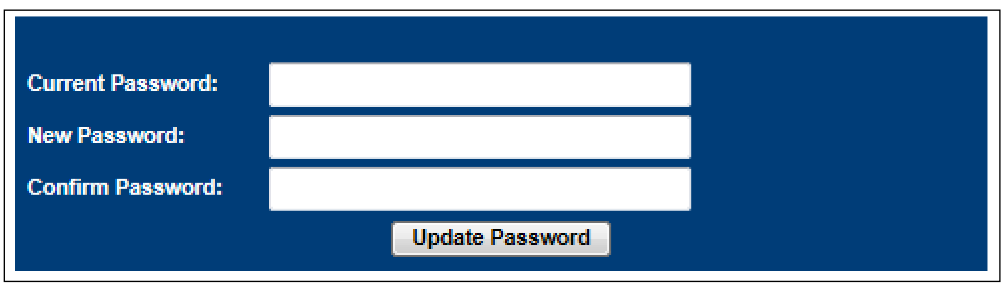
Figure 185 Reboot confirmation pop up



Change Password page

Menu option: **Change Password** (Figure 186). Use this page to change a personal password.

Figure 186 Change Password page (System Administration example)



A security officer can change the passwords of other users using the User Accounts page, as described in Local User Accounts page on page 6-61.

Procedure:

- Enter and confirm the new password (the default is blank). The new password must comply with the complexity rules (Table 143).

Logging out

To maintain security, always log out at the end of a session: on the menu, click **Logout**.

The unit will log out automatically if there is no user activity for a set time, but this depends upon Auto Logout Period in the Webpage Properties page (Figure 151).

Alarms, alerts and messages

This section describes how to use alarms, alerts and syslog messages to monitor the status of a PTP 650 link.

Alarms

Whenever system alarms are outstanding, a yellow warning triangle is displayed on the navigation bar. The warning triangle is visible from all web pages.

Procedure:

- Click the warning triangle (or menu option **Home**) to return to the System Summary page and view the alarms. If the warning triangle disappears when it is clicked, it indicates that the outstanding alarms have been cleared.

The example in Figure 187 shows the warning triangle in the navigation bar and an alarm displayed in the System Summary page. The alarms are defined in Table 175.

A change of state in most alarms generates an SNMP trap or an SMTP email alert.

Figure 187 Alarm warning triangle

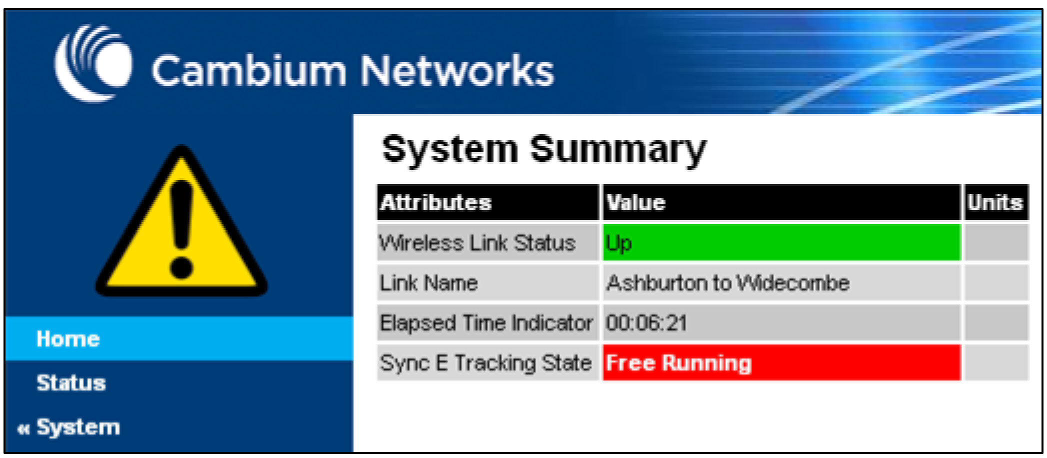


Table 175 System alarms

Alarm	Meaning
Aux Port Configuration Mismatch	Ethernet fragments (runt packets) have been detected when the Aux port is in full duplex. This indicates an auto-negotiation or forced configuration mismatch.
Aux Port Disabled Warning	The Aux port link has been administratively disabled via the SNMP Interface.
Aux Port PoE Output Status	The Aux port link is down. The most likely cause is that the unit has no Ethernet cable plugged into its Aux port.
Aux Port Status	The Aux port link is down. The most likely cause is that the unit has no Ethernet cable plugged into its Aux port.
Cable Diagnostics Warning	"`Test In Progress`" means that the Cable Diagnostics test has been initiated on one or more ports and is in progress.
Capacity Variant Mismatch	The link ends are different capability variants, for example, one is Full and the other is Med.
Data Bridging Status	This alarm depends on Lowest Data Modulation Mode. "`Disabled`" means that the link has stopped bridging Ethernet frames because the Lowest Data Modulation Mode is not being achieved or because the wireless link is down.
Second Data Bridging Status	This alarm depends on Lowest Second Data Modulation Mode. "`Disabled`" means that the link has stopped bridging Ethernet frames because the Lowest Second Data Modulation Mode is not being achieved or because the wireless link is down.
Install Status	Signaling was received with the wrong MAC address. It is very unusual to detect this, because units with wrongly configured Target MAC Address will normally fail to establish a wireless link. However, rare circumstances may establish a partial wireless link and detect this situation.
Install Arm State	A wireless unit is in installation mode. After installation, the wireless unit should be disarmed. This will increase the data-carrying capacity and stop the installation tone generator. The wireless link is disarmed from the "Installation" process, see Disarming the units on page 6-112.

Alarm	Meaning
Incompatible Regulatory Bands	The two linked units have different Regulatory Bands. To clear this alarm, obtain and install license keys for the correct country and select the same Regulatory Band at each end of the link.
Incompatible Master and Slave	The master and slave ends of the wireless link are different hardware products, or have different software versions. It is very unusual to detect this because incompatible units will normally fail to establish a wireless link. However, some combinations may establish a partial wireless link and detect this situation.
Link Mode Optimization Mismatch	The Master and Slave ODUs are configured to use different link mode optimization methods (one is set to IP and the other TDM).
Main PSU Port Configuration Mismatch	Ethernet fragments (runt packets) have been detected when the PSU port is in full duplex. This indicates an auto-negotiation or forced configuration mismatch.
Main PSU Port Disabled Warning	The PSU port link has been administratively disabled via the SNMP Interface.
Main PSU Port Status	The PSU port link is down. The most likely cause is that the unit has no Ethernet cable plugged into its Aux port.
NIDU LAN Port Status	The Ethernet link between the NIDU (LAN port) and the Ethernet network terminating equipment is not established.
No Wireless Channel Available	Spectrum Management was unable to locate a suitable wireless channel to operate on.
Port Allocation Mismatch	The local and remote ODUs have different services configured.The following alarms are raised on the port configuration mismatch - • **Mismatch in Second Data Service:** The Second Data Service is configured at the local unit but it is not configured at the remote unit or vice versa. • **Mismatch in Out of Band Remote Management Service**: The Out of Band Management Service is configured at the local unit but it is not configured at the remote unit or vice versa.
Regulatory Band	The installed license key contains an invalid Regulatory Band. The wireless unit is prohibited from operating outside the regulated limits.

Alarm	Meaning
Remaining Full Capacity Time Trial	Time remaining on the full capability trial period. Activated when seven days or less of the trial period remain.
Remote Transparent Clock Compatibility	The local and remote units have different IEEE 1588 transparent clock configurations. Both units must have the same configuration for the feature to work correctly.
SFP Error	A non-OK value indicates that the SFP link is down. There are two possible causes: • Either: the fiber link has been installed but disabled (because the license key does not include SFP support), • Or: the SFP link could not be established even though an SFP carrier was detected (due perhaps to a cabling fault or the link is disabled at the link partner).
SFP Port Configuration Mismatch	Ethernet fragments (runt packets) have been detected when the SFP port is in full duplex. This indicates an auto-negotiation or forced configuration mismatch.
SFP Port Disabled Warning	The SFP port link has been administratively disabled via the SNMP Interface.
SFP Port Status	The SFP port link is down. The most likely cause is that the unit has no Ethernet cable plugged into its SFP port.
SNTP Synchronization failed	SNTP has been enabled but the unit is unable to synchronize with the specified SNTP server.
Sync E tracking state	The state of the Synchronous Ethernet feature, if there is a problem.
Syslog Client Enabled/Disabled Warning	The local syslog client has been enabled or disabled.
Syslog Enabled/ Disabled Warning	The local log of event messages has been enabled or disabled.
Syslog Local Nearly Full	The local log of event messages is nearly full.
Syslog Local Wrapped	The local log of event messages is full and is now being overwritten by new messages.
TDM Channel Status n	The Ethernet link between the NIDU (E1/T1 port “n”) and the local TDM transceiver is not established.
TDM Channel Loopback n	TDM channel “n” is currently undergoing a loopback test.

Alarm	Meaning
TDD Synchronization Alarm	The reference signal for TDD Synchronization is absent and the ODU is now in holdover with more than 80% of the holdover period elapsed (**Reference Signal Lost**) or the ODU has reached the end of the configured holdover period and may not be correctly synchronized with the remaining units in the wireless network (**Synchronization Lost**). If TDD Synchronization Alarm = Synchronization Lost and TDD Holdover Mode = Strict, the ODU will be muted and the wireless link will be down.
Transparent Clock Source Port Alarm	If SFP was the selected transparent clock source port but the media did not negotiate to Fiber.
Unit Out Of Calibration	The unit is out of calibration and must be returned to the factory using the RMA process for re-calibration.
Wireless Link Disabled Warning	The wireless link has been administratively disabled via the SNMP Interface. The wireless interface MIB-II ifAdminStatus attribute has been set to **DOWN**. To enable the Ethernet interface, set the ifAdminStatus attribute to **UP**.

Email alerts

The management agent can be configured to generate alerts by electronic mail when certain events occur. The alerts are defined in Table 176.

Table 176 Email alerts

Alert	Meaning
Wireless Link Up Down	There has been a change in the status of the wireless link.
Channel Change	DFS has forced a change of channel.
DFS Impulse Interference	DFS has detected impulse interference.
Enabled Diagnostic Alarms	Diagnostic alarms have been enabled.
Main PSU Port Up Down	There has been a change in the status of the PSU data port.
Aux Port Up Down	There has been a change in the status of the Aux port.
SFP Port Up Down	There has been a change in the status of the SFP port.
NIDU LAN Port Up Down	There has been a change in the status of the NIDU LAN port.

Syslog page

Menu option: **Management > Syslog** (Figure 188).

Use this page to view the local log of event messages.

Figure 188 Syslog local log

Entry	Relative Time	Timestamp	Facility	Priority	Text
989	00:00:05	Sep 02 13:27:21	Security	Info	event; auth_login; Web user=Geri; from=10.130.1.73; port=443; connection=HTTPS; authentication=local;
988	00:00:17	Sep 02 13:27:09	Security	Info	event; auth_login; Web user=MelC; from=10.130.1.175; port=443; connection=HTTPS; authentication=local;
987	00:00:56	Sep 02 13:26:28	Security	Info	event; auth_logout; Web user=Geri; from=10.130.1.175; port=443; connection=HTTPS; authentication=local;
986	00:01:05	Sep 02 13:26:19	Security	Info	event; auth_login; Web user=Geri; from=10.130.1.175; port=443; connection=HTTPS; authentication=local;
985	00:01:51	Sep 02 13:25:35	NTP	Warning	status; SNTP Sync; was=No Sync; now=In Sync;

Note

For more information about system logging, refer to:

- System logging (syslog) on page 1-50 describes the system logging feature.
- Syslog Configuration page on page 6-78 describes how to enable system logging.

Format of syslog server messages

PTP 650 generates syslog messages in this format:

```
SP = “ ” = %x20
CO = “:” = %x3A
SC = “;” = %x3B
LT = “<” = %x3C
GT = “>” = %x3E
syslog = pri header SP message
pri = LT “1”-“182” GT
header = timestamp SP hostname
timestamp = month SP days SP hours “:” minutes “:” seconds
```

```
month = “Jan”|“Feb”|“Mar”|“Apr”|“May”|“Jun”|
“Jul”|“Aug”|“Sep”|“Oct”|“Nov”|“Dec”
days = “ 1”-“31”
hours = “00”-“23”
minutes = seconds = “00”-“59”
hostname = “0.0.0.0”-“255.255.255.255”
message = “PTP650” CO SP (configuration | status | event)
configuration = “configuration” SC SP attribute-name SC SP (“Web
user”|“SNMP user”|“SNTP”) SC SP “was=” previous-value SC SP “now=”
new-value SC
status = “status” SC SP attribute-name SC SP “was=” previous-value SC
SP “now=” new-value SC
event = “event” SC SP identifier SC SP event-message-content SC
```

Configuration and status messages

Configuration and status messages contain all of the relevant attributes.

This is an example of a configuration message:

```
PTP650: configuration; IP Address; Web user; was=10.10.10.10;
now=169.254.1.1;
```

This is an example of a status message:

```
PTP650: status; Data Port Status; was=Down; now=Up;
```

Event messages

Event messages are listed in Table 177. Definition of abbreviations:

SC = ";"

SP = " "

This is an example of an event message:

```
PTP650: event; auth_login; web user=MarkT; from=169.254.1.1; port=80;
connection=HTTP; authentication=local;
```

Table 177 Event messages

Facility	Severity	Identifier	Message content
security(4)	warning(4)	auth_idle	"Web user=" user-name SC SP "from=" IP-address SC SP "port=" port-number SC SP "connection=" ("HTTP" | "HTTPS") SC SP "authentication=" ("local" | "RADIUS") SC
security(4)	info(6)	auth_login	
security(4)	warning(4)	auth_login_failed	
security(4)	warning(4)	auth_login_locked	

Facility	Severity	Identifier	Message content
security(4)	info(6)	auth_logout	
kernel(0)	warning(4)	cold_start	"PTP wireless bridge has reinitialized, reason=" reset-reason SC
security(4)	warning(4)	License_update	"License Key updated" SC
syslog(5)	warning(4)	log_full	"Syslog local flash log is 90% full" SC
syslog(5)	warning(4)	log_wrap	"Syslog local flash log has wrapped" SC
security(4)	info(6)	radius_auth	"RADIUS user=" user-name SC SP "server " ("1" | "2") " at " IP-address SP "succeeded" SC
security(4)	warning(4)	radius_auth_fail	"RADIUS user=" user-name SC SP "server " ("1" | "2") " at " IP-address SP ("failed" | "succeeded" | "failed (no response)") SC
security(4)	alert(1)	resource_low	"Potential DoS attack on packet ingress " ("warning" | "cleared") SC
security(4)	warning(4)	sec_zeroize	"Critical Security Parameters (CSPs) zeroized" SC
local6(22)	warning(4)	snmpv3_asn1	"ASN.1 parse error" SC
security(4)	warning(4)	snmpv3_auth	"Authentication failure" SC
local6(22)	warning(4)	snmpv3_decryption	"Decryption failure" SC
local6(22)	warning(4)	snmpv3_engine_id	"Unknown engine ID" SC
local6(22)	warning(4)	snmpv3_sec_level	"Unknown security level" SC
kernel(0)	warning(4)	sys_reboot	"System Reboot, reason=" reset-reason SC
security(4)	warning(4)	sys_software _upgrade	"Software upgraded from " software-version " to " software-version SC
local6(22)	warning(4)	telnet_idle	"Telnet user=" user-name SC SP "from=" IP-address SC SP "port=" port-number SC
local6(22)	info(6)	telnet_login	
local6(22)	warning(4)	telnet_login_failed	
local6(22)	info(6)	telnet_logout	
local6(22)	info(6)	tftp_complete	"TFTP software upgrade finished" SC
local6(22)	info(6)	tftp_failure	"TFTP software upgrade failed, reason=" reason SC

Facility	Severity	Identifier	Message content
local6(22)	info(6)	tftp_start	"TFTP software upgrade started" SC
NTP(12)	info(6)	time_auth	"SNTP authentication succeeded at IP-address=" IP-address SC SP "port-number=" port SC
NTP(12)	warning(4)	time_auth_failed	"SNTP authentication failed at IP-address=" IP-address SC SP "port-number=" port SC
NTP(12)	warning(4)	time_conn_failed	"SNTP connection failed at IP-address=" IP-address SC SP "port-number=" port SC SP "reason=" reason SC

Spectrum Management

This section describes how to use the Spectrum Management pages to monitor the radio spectrum usage of the PTP 650 link.

Spectrum Expert and Spectrum Management pages

There are two alternative web pages providing access the spectrum monitoring information:

- the Spectrum Expert page, and
- the Spectrum Management page.

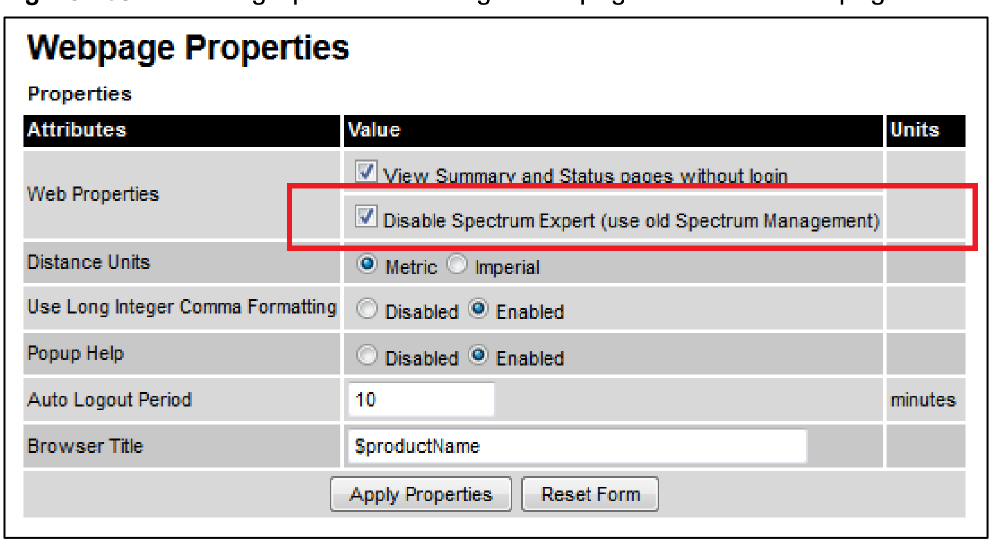
The Spectrum Expert page is the default as it is effectively a superset of the Spectrum Management page. However, it makes use of features only available in the most recent web browsers. It also requires additional data to be sent across the wireless link, thus reducing the capacity available for other types of traffic when the page is displayed.

Note

Internet Explorer 8 does not support the HTTP features used in the Spectrum Expert page.

For these reasons, the PTP 650 Series may be configured to use the Spectrum Management page instead of the Spectrum Expert page. This is done by checking the **Disable Spectrum Expert (use old Spectrum Management)** control in the **Web Property** attribute under the **Management > Web > Web Properties** menu, as shown in Figure 189.

Figure 189 Disabling Spectrum Management page advanced web page



Note

When configured to use the Spectrum Expert page, the PTP 650 is capable of automatically detecting whether the browser accessing the unit supports the required features. If it does not, the Spectrum Management page will be returned instead of the spectrum Expert page. Internet Explorer 8 is not compatible with the Spectrum Expert page.

Spectrum Expert page

Menu option: **System > Spectrum Expert**

This page is used to view and configure spectrum usage.

The Spectrum Expert page displays the following plots:

- The Local Receive Spectrum, and
- The Peer Receive Spectrum.

The Spectrum Expert page has two display modes:

- Standard Display mode – The 'Standard' Display mode is the mode which displays only the operational subband channels (shown in Figure 190). In this mode, the Extended Spectrum Scanning attribute could be Enabled but the Extended display box could be un-checked.

  It has further two types of plot:

  - Standard Display mode without realtime line
  - Standard Display mode with realtime line

- Extended Display mode – The 'Extended' Display Mode shows the entire DSO Full Band range of channels along with highlighted operational channels (shown in Figure 191). In this mode, the Extended Spectrum Scanning attribute is Enabled.

  This mode also has two types of plot:

  - Extended Display mode without realtime line
  - Extended Display mode with realtime line

The Extended display mode selection checkbox appears when the Extended Spectrum Scanning attribute is set to Enabled.

See Interpreting the receive spectrum plot on page 7-36 for details on the how to interpret these plots.

Caution

It is recommended not to leave the ODU with Extended Spectrum Scanning enabled during normal operation due to reduction in DSO CAC response in the operating band.

Standard Display mode

Figure 190 Spectrum Expert page – Standard Display mode

Extended Display Mode

Figure 191 Spectrum Expert page – Extended Display mode

Note

Figure 190 shows the default layout for a unit configured as a Master. On a unit configured as Slave, some of the controls at the bottom of the page are not available. In the remainder of this section, the screen shots shown are for the Master Unit.

Note

For Spectrum Expert Extended Display mode, Extended Spectrum Scanning is Enabled and Display mode is set to Extended.

Standard Display with extended layout

The page layout may be changed from the compact layout to the extended layout by clicking on the **Show Details** hyperlink on the top right of the page shown in Figure 190.

This hyperlink is only visible when the Extended Display checkbox in Spectrum Expert Display Mode is not selected.

A screen shot of the Spectrum Expert page in the extended layout is shown in Figure 192. It displays the following additional plots:

- The Local Timeseries, and
- The Peer Timeseries.

These plots are on the right of the corresponding Receive Spectrum plots. See Selecting a Channel and a Time period on page 7-45 for details on the timeseries plots.

Clicking on the **Hide Details** hyperlink returns to the compact layout.

Figure 192 Spectrum Expert page with Receive Spectrum and Timeseries for both Local and Peer

Full layout

The page layout may be extended further to give access to more information on either or both the local and the peer interference spectra.

For the local interference spectrum, clicking on the **Local Interference Waterfall** hyperlink below the Local Receive Spectrum plot shows:

- The Local Interference Waterfall plot, if the Local TimeSeries was not shown (Figure 193), or
- The Local Interference Waterfall and the Histogram plots otherwise (Figure 194).

The same can be done for the peer section of the page.

Details on how to interpret the Interference Waterfall and Histogram plots are provided in sections Interpreting the Interference Waterfall plot on page 7-47 and Interpreting the histogram plot on page 7-49 respectively.

Figure 193 Spectrum Expert page showing the Receive Spectrum and Interference Waterfall for the Local unit

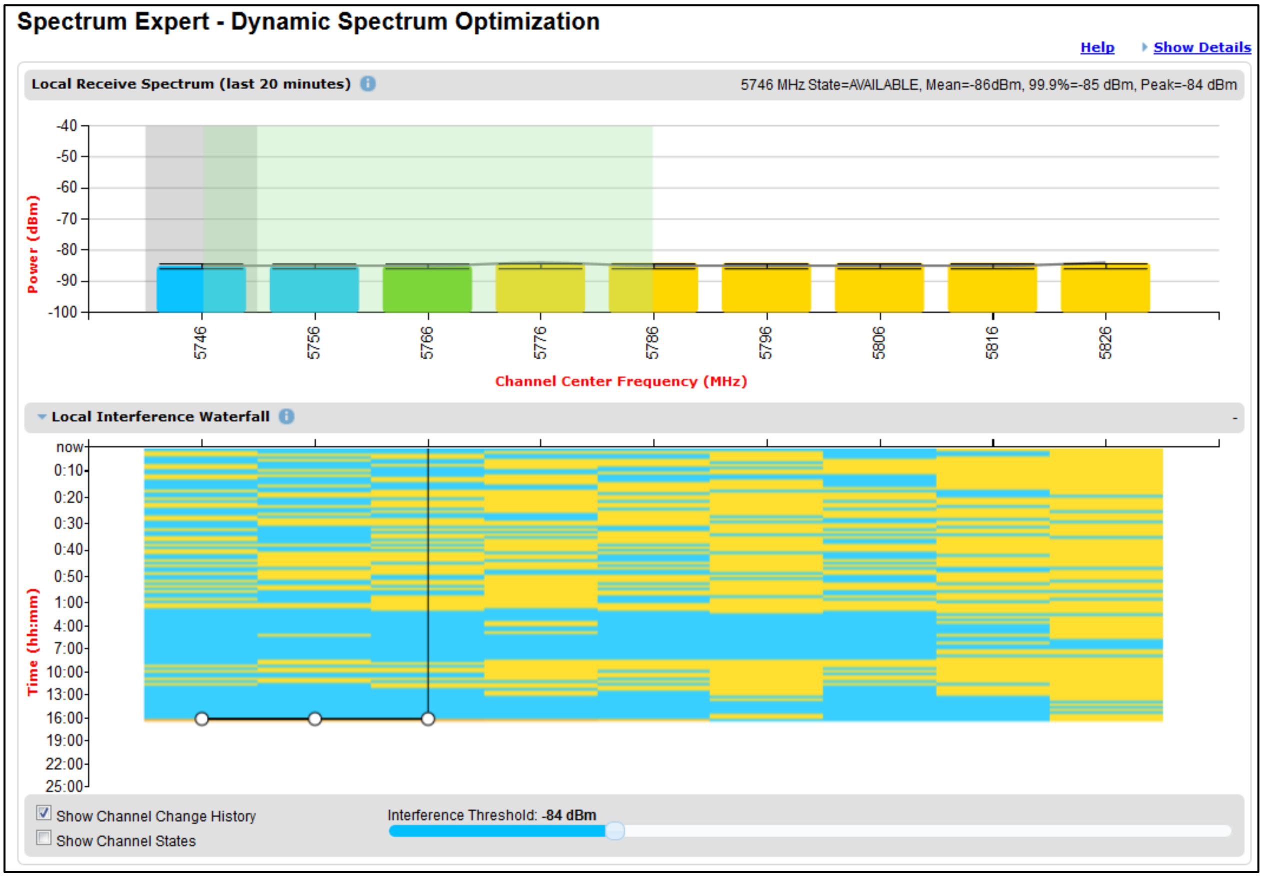


Figure 194 Spectrum Expert page showing the Receive Spectrum, Timeseries, Interference Waterfall and Histogram for the Local unit

Spectrum Management page

Menu option: **System > Spectrum Management**

Note that this page is only shown when the Spectrum Expert page has been disabled, as explained in Spectrum Expert and Spectrum Management pages on page 7-27.

Use this page to view and configure spectrum usage. The width of the vertical green bar represents the channel width (10 MHz illustrated).

Note

The extended view is available only in Spectrum Expert, and not in Spectrum Management.

Figure 195 Spectrum Management page (Master unit)

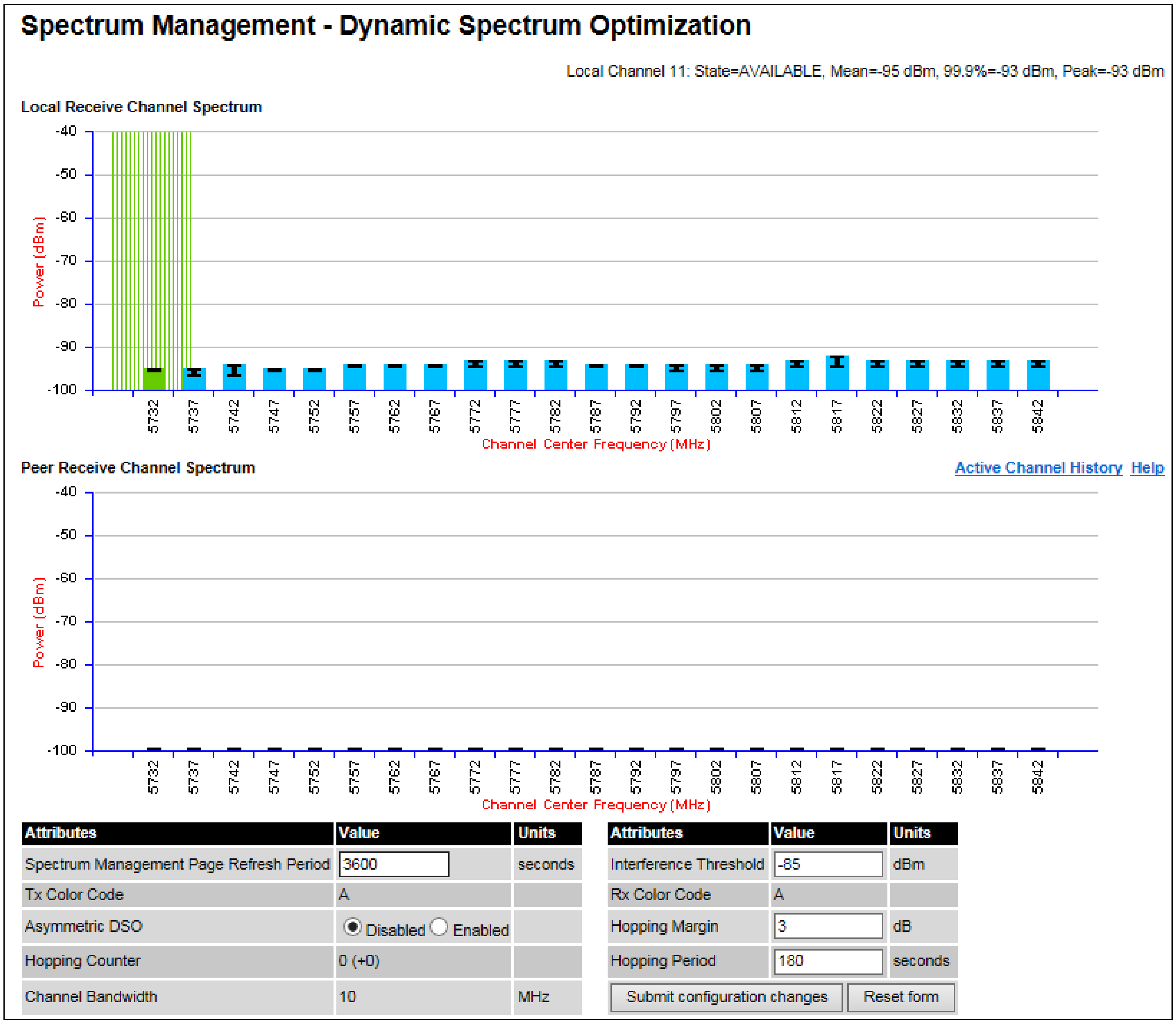


Figure 195 shows the Spectrum Management page layout for a unit configured as a Master. On a unit configured as Slave, some of the controls at the bottom of the page are not available.

Spectrum Management Settings

All spectrum management configuration changes are applied at the master ODU only. These changes are then sent from the master to the slave, so that both master and slave keep identical copies of spectrum management configuration. It is therefore possible to swap master and slave roles on an active PTP 650 link without modifying Spectrum Management configuration.

The default channelization can be modified by varying the lower center frequency attribute in the installation wizard, as described in Wireless Configuration page on page 6-21.

Note

Before attempting to improve the performance of the spectrum management algorithm by changing the default configuration, consult the Cambium Point-to-Point distributor or one of the system field support engineers.

Procedure:

- Review the configuration attributes (Table 178)
- Update the attributes as required. At the slave unit, only Page Refresh Period can be updated.
- To save changes, click Submit configuration changes.

Table 178 Spectrum Management attributes

Attribute	Meaning
Spectrum Expert Display Mode	**Realtime:** When set to Realtime, an additional line appears on the Receive Spectrum plots showing the most recent measurements of interference level for every channel **Extended:** Extended Display mode is visible only when Extended Scanning is enabled. This control is available in the Spectrum Expert page only.
Extended Spectrum Scanning	**Enabled:** Enables scanning of entire DSO full band channels. **Disabled:** Only the operational subband channels are scanned. This control is available in the Spectrum Expert page only.
Spectrum Management Page Refresh Period	The page refreshes automatically according to the setting entered here (in seconds). This control is available in the Spectrum Management page only.
Hopping Margin	Uses this margin when making a channel hop decision. If the interference level of the target channel is lower than that of the active channel by at least the Hopping Margin, the link will hop to the target channel. The default setting is 3 dB in non-radar regions, or 10 dB in radar regions.

Attribute	Meaning
Asymmetric DSO	Only displayed in non-radar regions when DSO is enabled. The default configuration of symmetric operation constrains the link to operate symmetrically, using the same transmit and receive channels. When in symmetric mode the slave unit will always follow the master. If the master moves to a new channel the slave will hop to the same channel. When the Point-to-Point link is configured as an asymmetric link both the master and slave are free to select the best channel from their own set of local interference metrics.
Spectrum Management Control	Only displayed in radar regions. The options are **DFS** and **DFS with DSO**.
Hopping Period	The Spectrum Management algorithm evaluates the metrics every "Hopping Period" seconds (180 seconds by default) looking for a channel with lower levels of interference. If a better channel is located, Spectrum Management performs an automated channel hop. If SNMP or SMTP alerts are enabled an SNMP TRAP or an email alert is sent warning the system administrator of the channel change.
Hopping Counter (not configurable)	This is used to record the number of channel hops. The number in the (+) brackets indicates the number of channel changes since the last screen refresh.
Interference Threshold	Spectrum Management uses the interference threshold to perform instantaneous channel hops. If the measured interference on a channel exceeds the specified threshold, then DSO will instruct the wireless to immediately move to a better channel. If a better channel cannot be found the PTP 650 Series will continue to use the current active channel. (Default –85 dBm).
Channel Bandwidth (not configurable)	This shows the value of the variable channel bandwidth selected.
Tx Color Code (not configurable)	This shows the Tx Color Code selected during Installation.
Rx Color Code (not configurable)	This shows the Rx Color Code selected during Installation.

Interpreting the receive spectrum plot

The Spectrum Expert page has two graphical plots:

- Local Receive Spectrum
- Peer Receive Spectrum

A more detailed example of one of these plots is shown in Figure 190.

For more information, select the **Help** hyperlink at the top right of the Spectrum Expert page and follow the instructions.

X axis and Y axis

The X-axis shows a stylized view of the selectable wireless channels. Note that the distance between adjacent channels may be smaller than the channel bandwidth. If this is the case, adjacent channels overlap. Channels are displayed separately for clarity. The axis is labeled using the channel center frequencies in MHz. The Y-axis shows the interference power levels from –100 to –40 dBm.

Channel states

The active channel (Channel 9 in Figure 190) is always marked using hatched green and white lines on the Spectrum Management page or solid green on the Spectrum Expert page. The width of the hatching is directly proportional the channel bandwidth or spectral occupancy of the channel.

The individual channel metrics are displayed using a colored bar and an "I" bar. The colored bar represents the channel state (Table 179).

Table 179 Channel states represented in the spectrum management plot

Color	State	Meaning
Green	Active	The channel is currently in use, hosting the wireless link.
Orange	Interference	The channel has interference above the interference threshold.
Blue	Available	The channel has an interference level below the interference threshold and is considered by the Spectrum Management algorithm suitable for hosting the Point-to-Point link.
Light Grey	Barred	The system administrator has barred this channel from use. For improved visibility, an additional red "lock" symbol is used to indicate that a channel is barred but The lock is not shown in Extended view.
Red	Radar Detected	A radar signal has been detected and operation on this channel is currently not allowed.
Dark Grey	Region Barred	Extended scanned channels outside the range of configured operational subband channels

Key metrics

The “I” bar and top of the colored bar represent three key metrics (Table 180). The vertical part of the “I” bar represents the statistical spread between the peak and the mean of the statistical distribution.

The arithmetic mean is the true power mean and not the mean of the values expressed in dBm.

Spectrum Management uses the 99.9% Percentile as the prime interference measurement. All subsequent references to interference level refer to this percentile measurement.

Table 180 Key metrics represented in the spectrum management plot

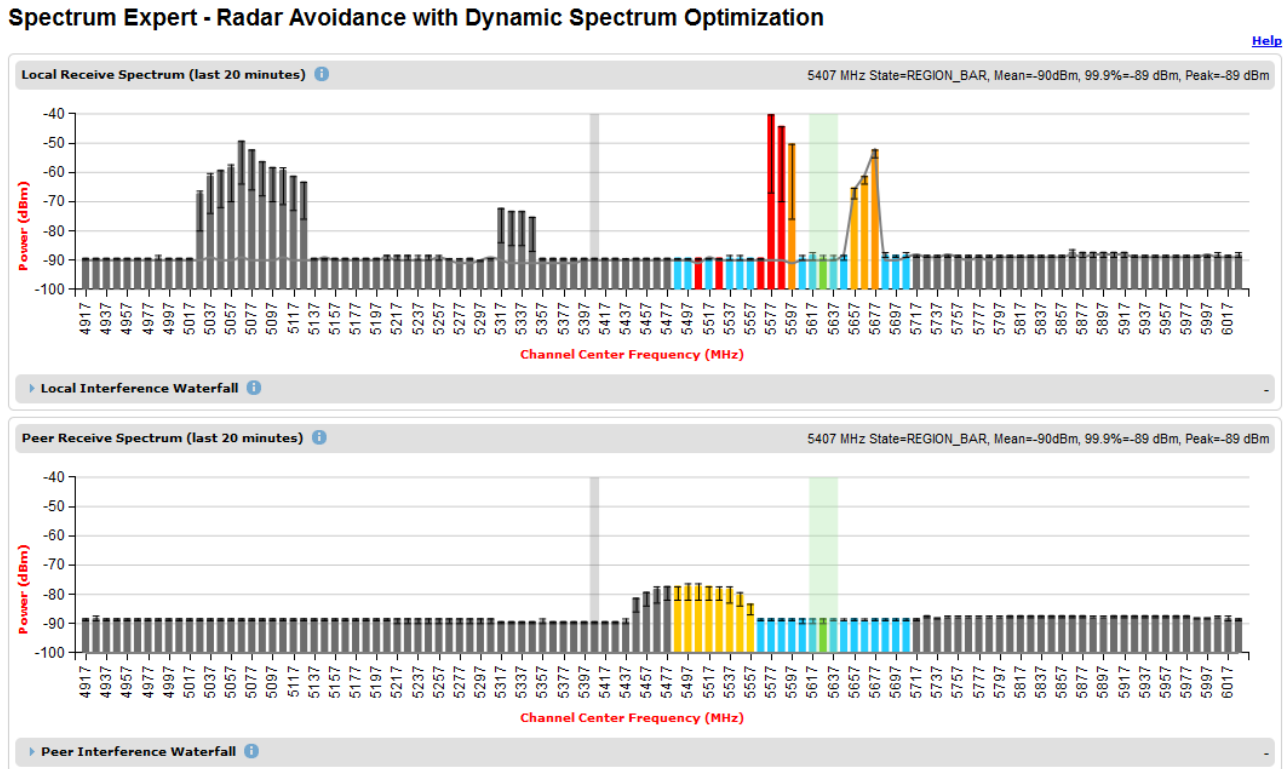
Metric	Description	How represented
Peak of Means	The largest mean interference measurement encountered during the quantization period. The peak of means is useful for detecting slightly longer duration spikes in the interference environment.	Upper horizontal bar.
Mean of Means	The arithmetic mean of the measured means during a quantization period. The mean of means is a coarse measure of signal interference and gives an indication of the average interference level measured during the quantization period. The metric is not very good at predicting intermittent interference and is included to show the spread between the Mean of Means, the 99.9% Percentile and the Peak of Means.	Lower horizontal bar.
99.9% Percentile of the Means	The value of mean interference measurement which 99.9% of all mean measurements fall below, during the quantization period. The 99.9% percentile metric is useful for detecting short duration repetitive interference that by its very nature has a minimal effect of the mean of means.	Top of the colored bar.
Realtime interference level	The arithmetic mean of the power measured during the last quantization period. The quantization period is two seconds.	Countinuous line.

Spectrum Expert page in fixed frequency mode

When the link is operating in fixed frequency mode, the Spectrum Expert page uses two visual cues (Figure 196). The main page title has the "`Fixed Frequency Mode`" suffix and the selected channels are identified by a red capital "F".

Figure 196 Spectrum Expert page for Fixed Frequency – Standard display mode

Figure 197 Spectrum Expert page for Fixed Frequency – Extended display mode



Attributes	Value	Units
Spectrum Expert Display Mode	☑ Realtime ☑ Extended	
Extended Spectrum Scanning	○ Disabled ◉ Enabled	
Tx Color Code	A	
Spectrum Management Control	○ DFS ◉ DFS with DSO	
Hopping Counter	0	
Channel Bandwidth	30	MHz

Attributes	Value	Units
Interference Threshold	-85	dBm
Rx Color Code	A	
Hopping Margin	10	dB
Hopping Period	180	seconds
Submit configuration changes	Reset form	

Channel barring is disabled in fixed frequency mode; it is not required as dynamic channel hopping is prohibited in this mode.

The only controls available to the master are the Spectrum Expert Display Mode and Interference Threshold attributes. They will have no effect on the operation of the wireless link and will only effect the generation of the channel spectrum graphics.

Spectrum Expert page in radar avoidance mode

When the link is operating in radar avoidance mode, the Spectrum Expert page (Figure 198) contains the following additional information:

- The main page title has the "`Radar Avoidance`" suffix.
- The only controls available to the master are the Interference Threshold attribute. This has no effect on the operation of the wireless link and will only affect the generation of the channel spectrum graphics.
- Extra color coding of the interference histogram is provided (Table 181).

Figure 198 Spectrum Expert page with radar avoidance – Standard Display

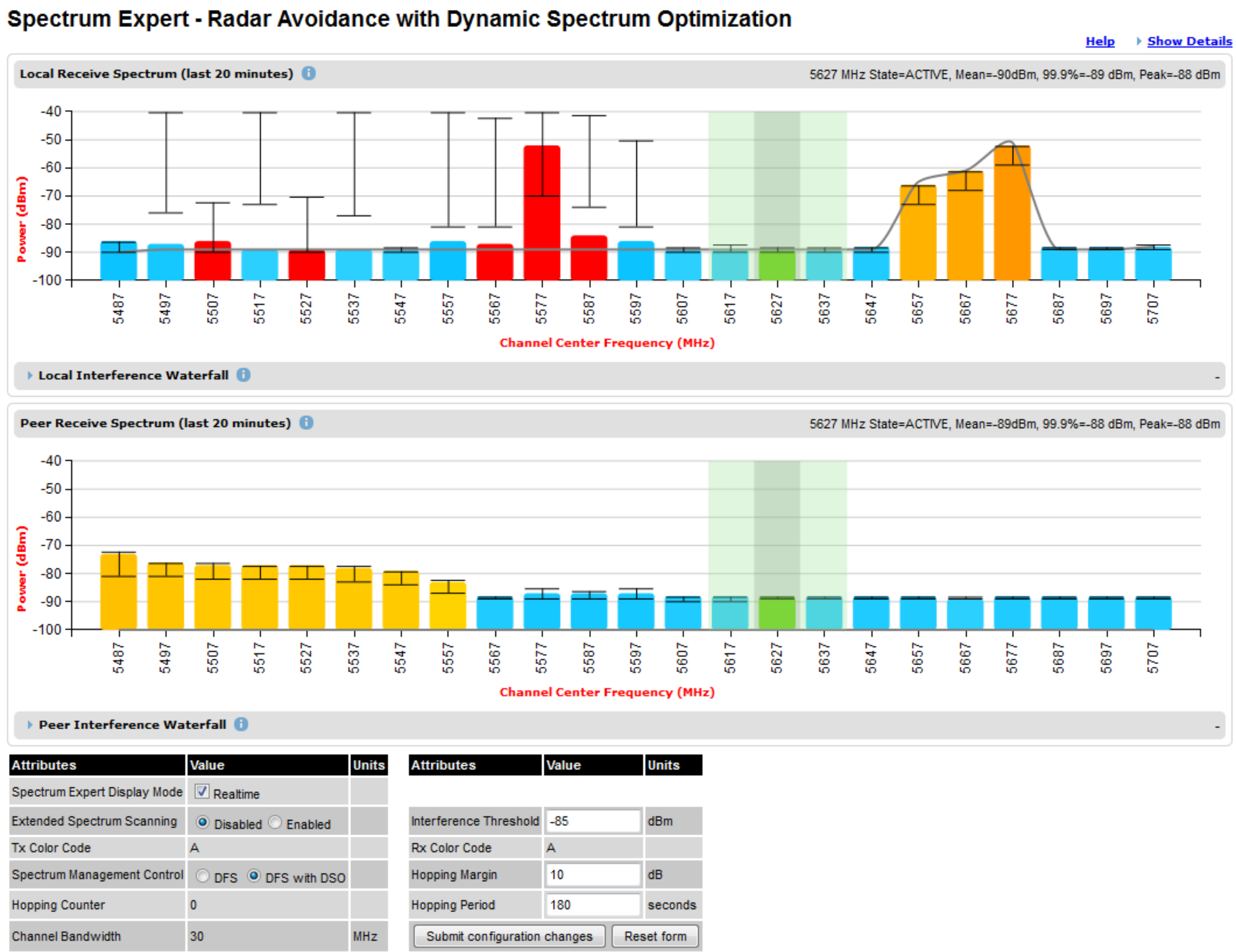
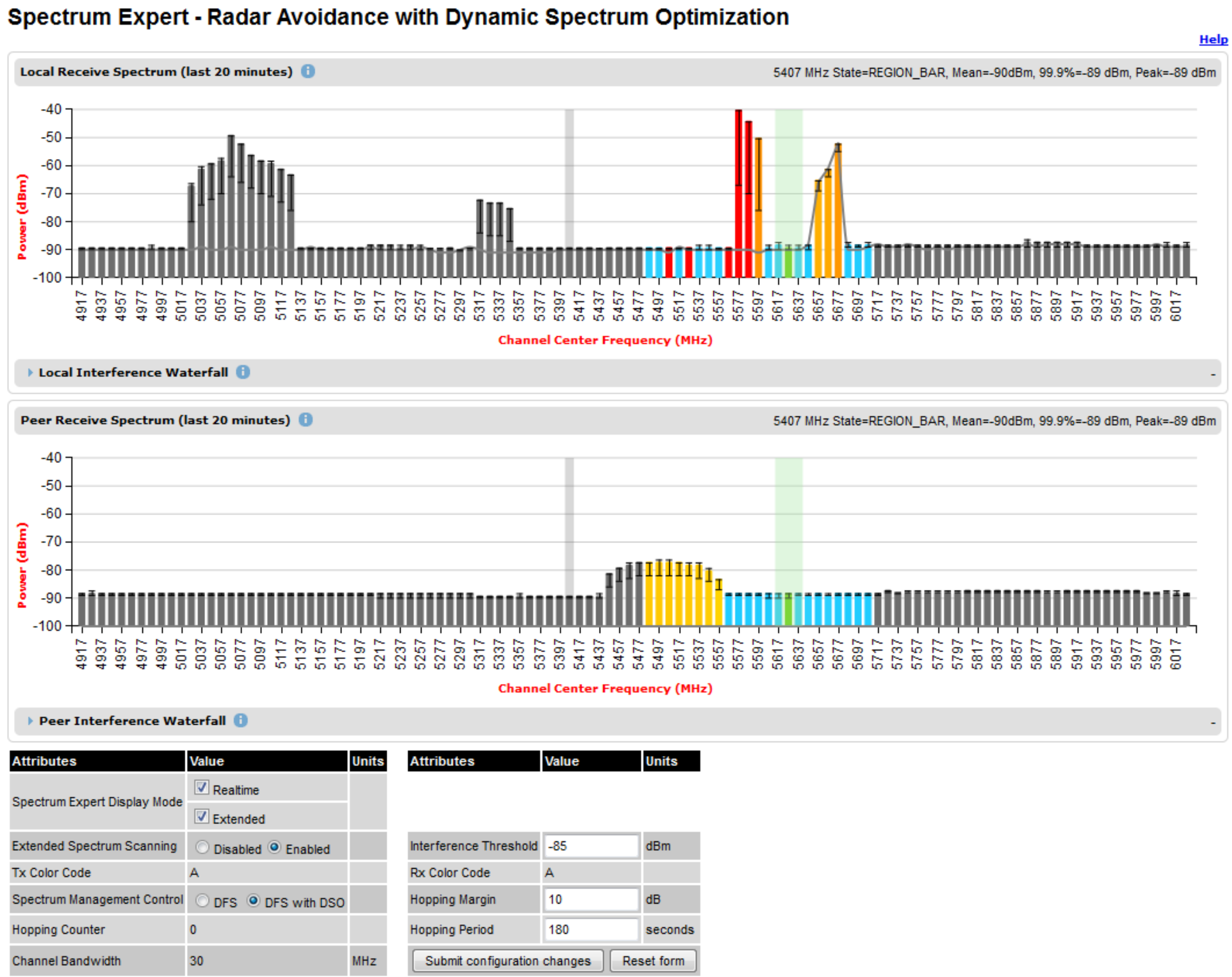


Figure 199 Spectrum Expert page with radar avoidance – Extended Display



When operating with RTTT (Road transport and Traffic Telematics) Avoidance enabled or other regulatory restrictions on channel usage, all channels marked with a "no entry" symbol with their associated statistics colored black are the prohibited channels. These channels are never used to host the wireless link, but CAC measurements are still taken so that adjacent channel biases can be calculated correctly and so the user can see if other equipment is in use.

Table 181 Channel states in the Spectrum Expert plot (radar avoidance)

Color	State and color	Meaning
Green	Active	This channel is currently in use hosting the Point-to-Point wireless link.
Orange	Interference	This channel has interference above the interference threshold

Color	State and color	Meaning
Blue	Available	This channel has an interference level below the interference threshold and is considered by the Spectrum Management algorithm suitable for hosting the Point-to-Point link
Dark grey	Barred	The system administrator has barred this channel from use. Because the low signal levels encountered when a unit is powered up in a laboratory environment prior to installation (which makes the grey of the channel bar difficult to see). An additional red "lock" symbol is used to indicate that a channel is barred.
Light grey	Unavailable	This channel needs to be monitored for one minute and found free of radar signal before it can be used for transmitting.
Red	Radar Detected	Impulsive Radar Interference has been detected on this channel and the channel is unavailable for 30 minutes. At the end of the 30 minute period a Channel Availability Check is required to demonstrate no radar signals remain on this channel before it can be used for the radio link.
Black	Region Bar	This channel has been barred from use by the local region regulator

Barring channels

To comply with FCC rules, bar any channels that may interfere with TDWR radars. This must be done before the units are allowed to radiate on site. The system designer will have provided a list of any affected channels, based on the instructions in Avoidance of weather radars (USA only) on page 3-24.

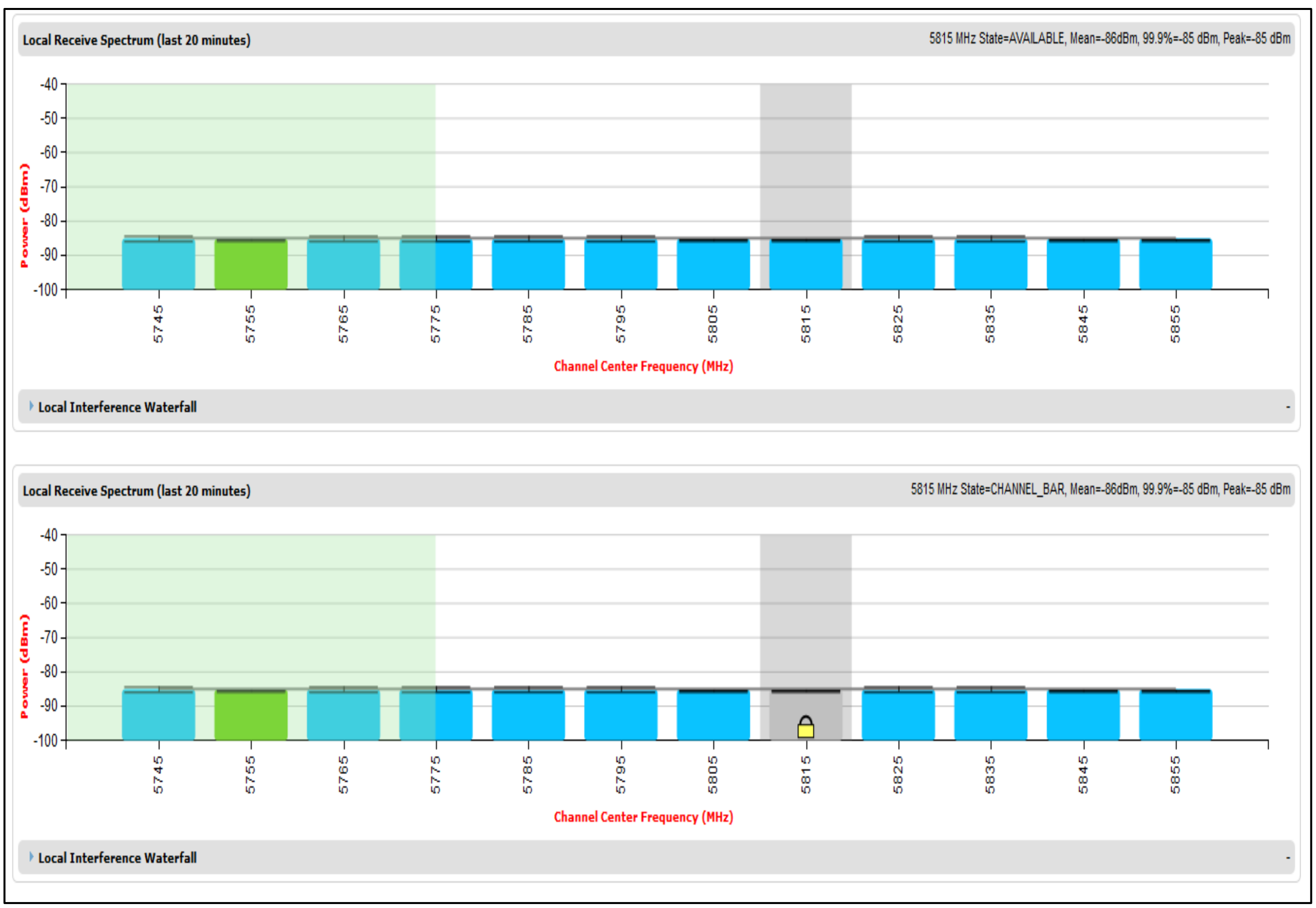
Procedure:

- Log into the Master unit.
- Select menu option **System > Spectrum Expert**. The Spectrum Management Expert page is displayed.
- Double click on the appropriate channel center frequencies on the Local or Peer Receive Spectrum plots. The example in Figure 200 shows how to bar one channel (5816 MHz).
- When the confirmation dialog is displayed, click **OK**.

Note

The channels cannot be barred in the extended view.

Figure 200 Barring a channel



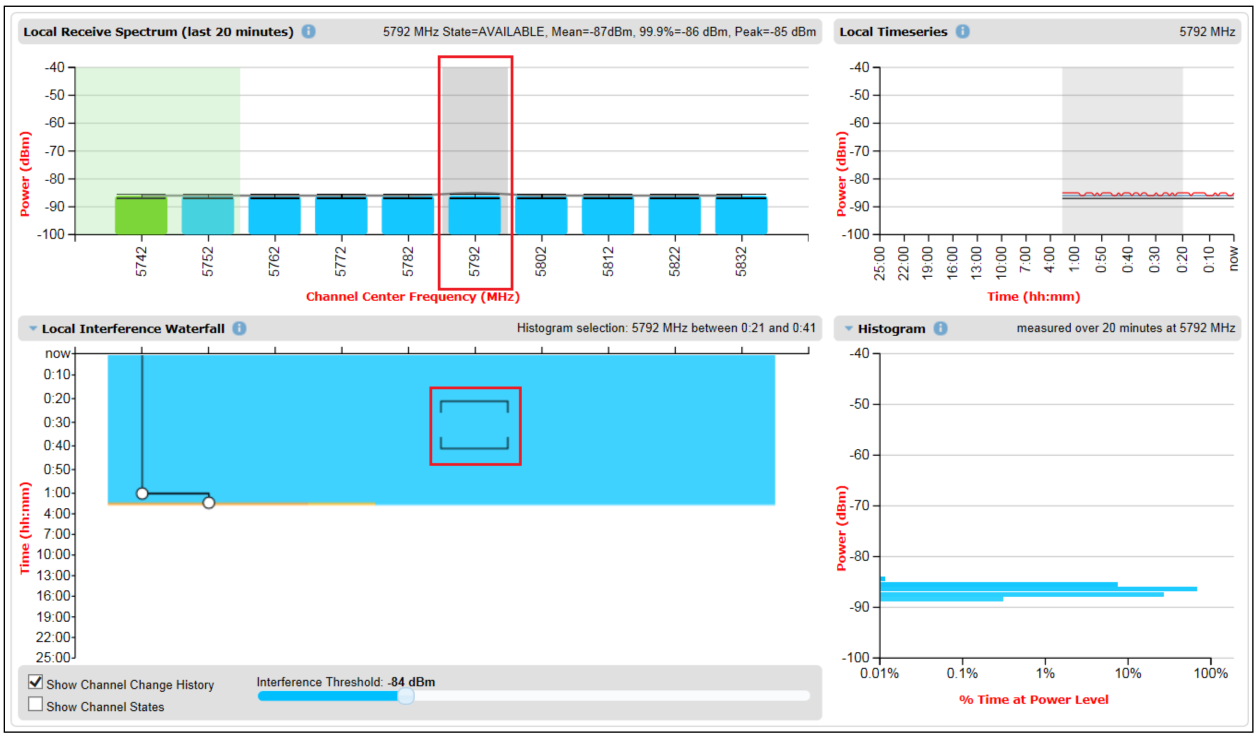
Selecting a Channel and a Time period

The Timeseries plot uses measurements for the selected channel. The Histogram plot uses measurements for the selected channel and the selected measurement period.

To select a channel on the Receive Spectrum Page, click within the plot, move the cursor horizontally to the channel you want to select and click to confirm the selection.

The Selected channel is shown with a grey background. The Selected Channel is centred on 5792 MHz in Figure 201.

Figure 201 Selecting a channel on the Receive Spectrum



To select a channel and a period on the Interference Waterfall, click within the plot, move the cursor horizontally to the channel you want to select, and vertically to the period you want to select, and click to confirm you selection.

The selected channel and period are shown graphically on the Interference Waterfall between two horizontal brackets, as show in Figure 201. They are also indicated in text form right above the Interference Waterfall.

Interpreting the timeseries plot

This plot displays the interference measurements of all previous measurement quantization periods for the selected channel, up to a maximum of 25 h (Figure 202).

The channel is selected as described in Selecting a Channel and a Time period. The center frequency of the selected channel is indicated in MHz at the top right of the Timeseries plot.

The colored lines represent interference measurements, with the color map provided in Table 182.

A white background indicates the measurement period which is used to generate the Receive Spectrum plot. Typically, only the last 20 min are used, although any period of time where the wireless link has been down is excluded.

Figure 202 Spectrum Expert, Timeseries plot

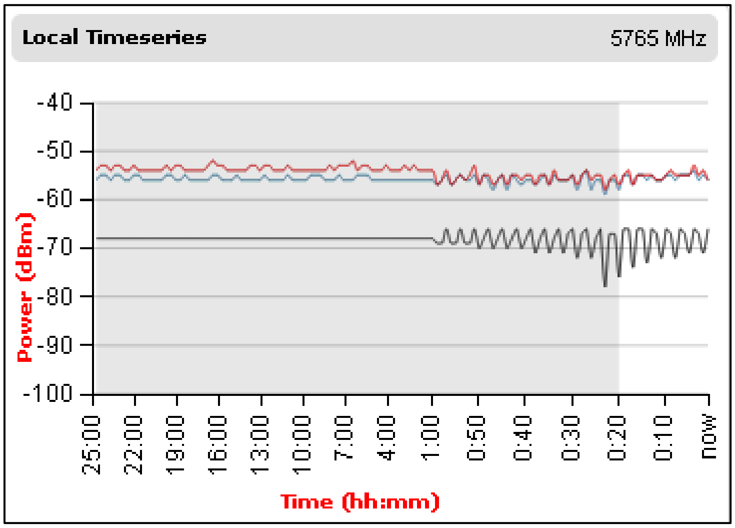


Table 182 Interference represented in the time series plot

Color	Meaning
RED	Peak of Means interference measurement
BLACK	99.9% percentile of means interference measurement
BLUE	Mean of Means interference measurement

Interpreting the Interference Waterfall plot

The Interference Waterfall indicates the level of interference for all the channels in the band over the last 25 h. Figure 203 shows a screen capture example.

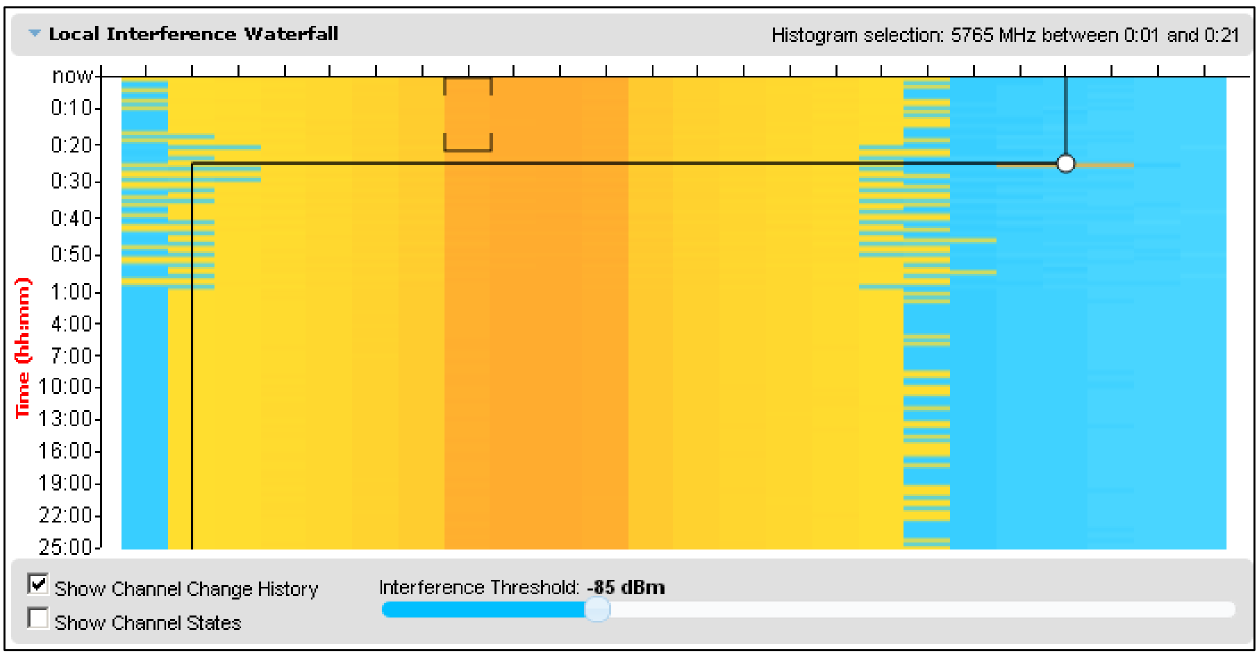
The channel and measurement period are selected as described in Selecting a Channel and a Time period on page 7-45 The center frequency of the selected channel and the time period are indicated at the top right of the Interefrence Waterfall plot.

The X-axis corresponds to the channel center frequency and is horizontally aligned with the Receive Spectrum plot.

The Y-axis corresponds to the time in the past in hours and minutes, with the most recent period being at the top of the plot.

Each channel and measurement period is indicated using the color scale given in Table 179.

Figure 203 Spectrum Expert, Interference Waterfall plot



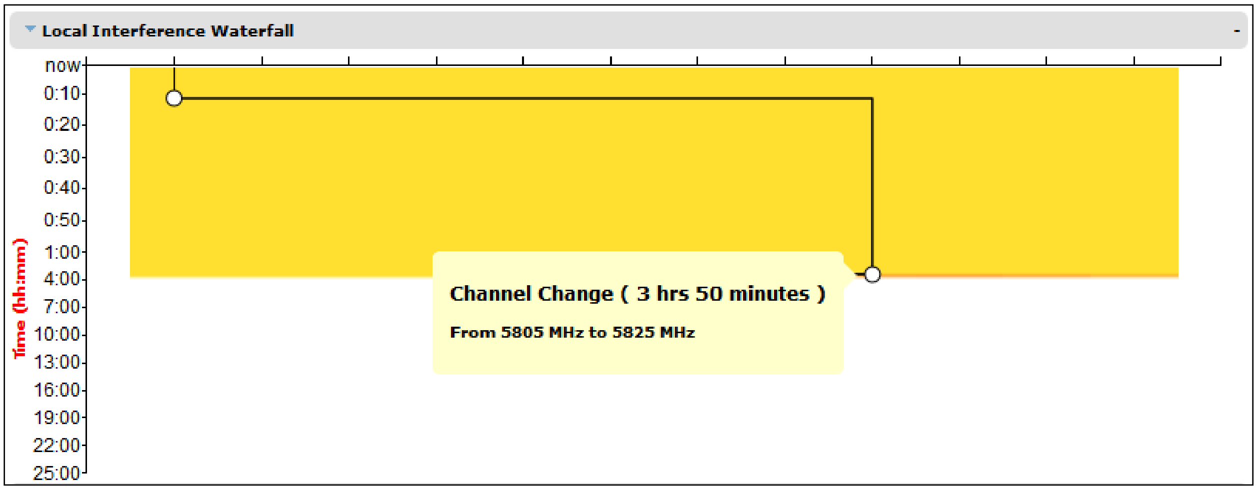
Setting the interference threshold

The interference threshold may be set using the sliding control located directly below the Interference Waterfall plot. This is an alternative to the method described in Spectrum Management Settings on page 7-35. For either method, the change to the Interference Threshold is not taken into account until the Submit button is clicked.

Viewing the active channel history

To display the active channel history, tick the Show Channel Change History control right below the Interference Waterfall plot. The active channel history over the last 25 hours is plotted as a black line overlay on the Interference Waterfall plot. A circle is displayed every time the active channel has changed. By hovering above the circle, the reason for the channel change is indicted, as shown in Figure 204.

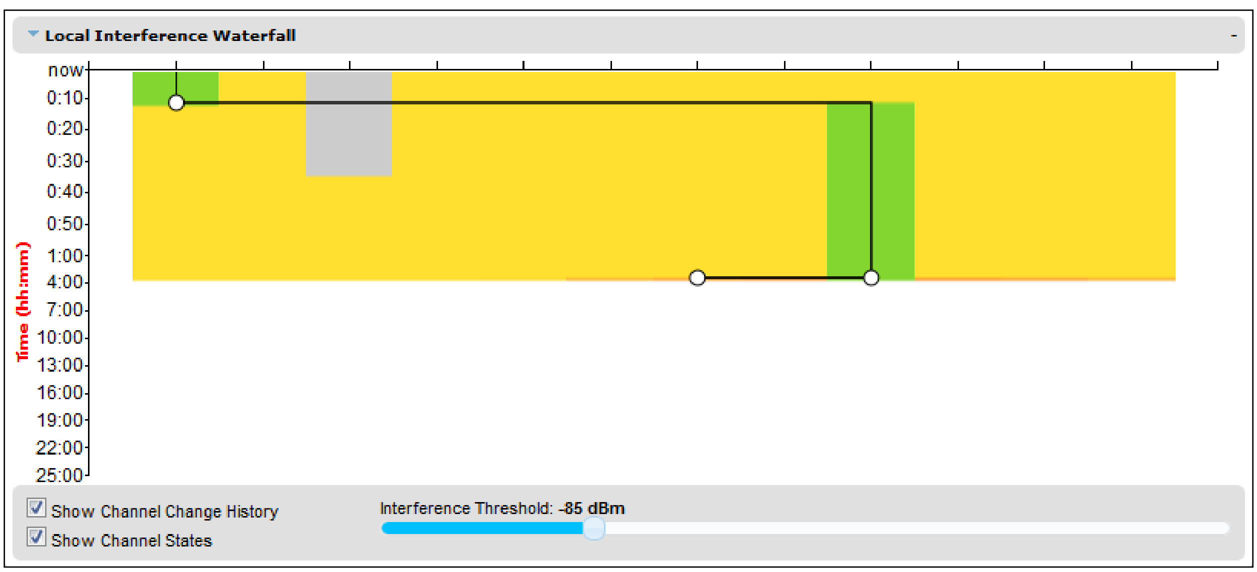
Figure 204 Spectrum Expert, Interference Waterfall with active channel history



Viewing the channel states

To display the Channel States, tick the Show Channel State control right below the Interference Waterfall plot. Figure 205 shows an example of the Interference Waterfall when the Channel States are displayed. The colors used are the same as for the Spectrum Management page (Channel states on page 7-37).

Figure 205 Spectrum Expert page, Interference Waterfall plot with channel states



Interpreting the histogram plot

The histogram plot indicates the percentage of the measurements in the selected measurement period where the interference level for the selected channel is at a given level (Figure 206).

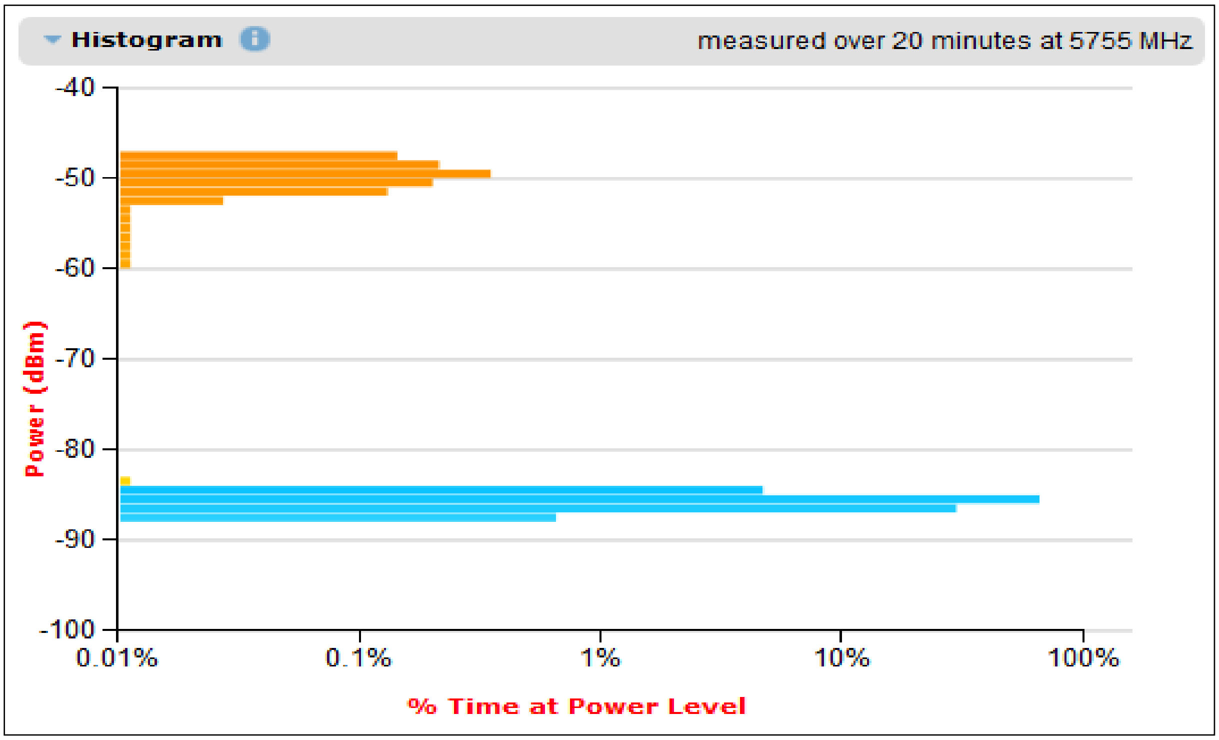
The channel and measurement period are selected as described in Selecting a Channel and a Time period on page 7-45 The combined selection is indicated graphically by a pair of brackets in the Waterfall plot, and in text form on the top right of the Histogram plot, as shown in Figure 205.

The X-axis corresponds to a percentage of the measurements in the measurement period on a logarithmic scale.

The Y-axis corresponds to actual interference level in dBm.

The bar for each each power level is of the same color as in the Interference Waterfall plot.

Figure 206 Spectrum Expert page, histogram plot



System statistics

This section describes how to use the system statistics pages to manage the performance of the PTP 650 link, use the following web pages:

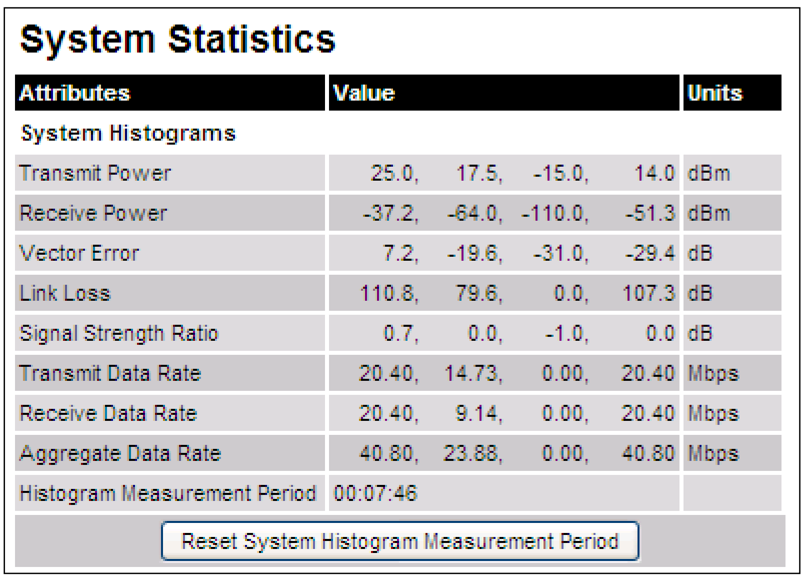
System Statistics page

Menu option: **System > Statistics**. Use this page to check system statistics.

System histograms

The System Histograms section of the System Statistics page (Figure 207) contains eight diagnostic attributes that are presented as arrays of four elements (Table 183).

Figure 207 System Histograms section of the System Statistics page



System Statistics

Attributes	Value	Units
System Histograms		
Transmit Power	25.0, 17.5, -15.0, 14.0	dBm
Receive Power	-37.2, -64.0, -110.0, -51.3	dBm
Vector Error	7.2, -19.6, -31.0, -29.4	dB
Link Loss	110.8, 79.6, 0.0, 107.3	dB
Signal Strength Ratio	0.7, 0.0, -1.0, 0.0	dB
Transmit Data Rate	20.40, 14.73, 0.00, 20.40	Mbps
Receive Data Rate	20.40, 9.14, 0.00, 20.40	Mbps
Aggregate Data Rate	40.80, 23.88, 0.00, 40.80	Mbps
Histogram Measurement Period	00:07:46	

Reset System Histogram Measurement Period

The element arrays represent the following:

- Max: The maximum value measured over the last hour.
- Mean: The mean of a set of values recorded at one second intervals over the last hour.
- Min: The minimum value measured over the last hour.
- Latest: The latest value measured.

The values are calculated over the time that has elapsed since the link was established or since the measurement period was reset.

Use the Diagnostics Plotter page on page 7-64 to plot these attributes against time. Use the Generate Downloadable Diagnostics page on page 7-65 to extract historical data for these attributes to a CSV file.

Procedure:

- To reset and restart measurement, click **Reset System Histograms and Measurement Period**.

Table 183 System Histogram attributes in the System Statistics page

Attribute	Meaning
Transmit Power	The transmit power histogram, calculated over a one hour period.
Receive Power	The receive power histogram, calculated over a one hour period.
Vector Error	The vector error measurement compares (over a one hour period) the received signal IQ modulation characteristics to an ideal signal to determine the composite vector error magnitude.
Link Loss	Link loss calculated (over a one hour period) as follows: Peer_Tx_Power (dBm) – Local_Rx_Power (dBm) + 2 x Antenna_Pattern (dBi)
Signal Strength Ratio	The Signal Strength Ratio (calculated over a one hour period) is: Power received by the vertical antenna input (dB) ÷ Power received by the horizontal antenna input (dB) This ratio is presented as: max, mean, min, and latest. The max, min and latest are true instantaneous measurements; the mean is the mean of a set of one second means. Signal Strength Ratio is an aid to debugging a link. If it has a large positive or negative value then investigate the following potential problems: • An antenna coaxial lead may be disconnected. • When spatial diversity is employed, the antenna with the lower value may be pointing in the wrong direction. • When a dual polar antenna is deployed, the antenna may be directed using a side lobe rather than the main lobe. When there is a reflection from water on the link and spatial diversity is employed, then one expects large, slow swings in Signal Strength Ratio . This indicates the antenna system is doing exactly as intended.
Transmit, Receive and Aggregate Data Rates	The data rates in the transmit direction, the receive direction and in both directions, expressed in Mbps (max, mean, min, and latest). The max, min and latest are true instantaneous measurements. The mean is the mean of a set of one second means.
Histogram Measurement Period	The time over which the system histograms were collected.

System counters

The System Counters section of the System Statistics page (Figure 208) contains Data Port Counters (Table 184), Management Agent Counters (Table 186) and Wireless Port Counters and Performance Information (Table 187).

Figure 208 System Counters section of the System Statistics page

Attributes	Value	Units
Data Port Counters		
Tx Frames	197 (+197)	
Rx Frames	248 (+248)	
Second Data Port Counters		
Tx Frames	14 (+14)	
Rx Frames	3 (+3)	
Management Agent Counters		
Packets To Internal Stack	203 (+206)	
Packets From Internal Stack	293 (+293)	
Wireless Port Counters and Performance Information		
Tx Frames	100 (+100)	
Rx Frames	104 (+104)	
Link Symmetry	1 to 1	
Link Capacity	226.65	Mbps
Transmit Modulation Mode	256QAM 0.81 (Single) (30 MHz)	
Receive Modulation Mode	256QAM 0.81 (Dual) (30 MHz)	
Receive Modulation Mode Detail	Running At User-Configured Max Modulation Mode	
Wireless Link Availability	100.0000	%
Data Bridging Availability	100.0000	%
Byte Error Ratio	1.355e-8	
Counter Measurement Period	00:01:32	
	Reset System Counters	

Procedure:

- To reset all system counters to zero, click **Reset System Counters**.

The packet counter attributes each contain a number in parentheses; this shows the number of packets received since the last page refresh.

Table 184 Data Port Counters

Attribute	Meaning
Tx Frames	The total number of good frames the bridge has sent for transmission through the port selected for Data Service
Rx Frames	The total number of good frames the bridge has received through the port selected for Data Service

Table 185 Second Data Port Counters

Attribute	Meaning
Tx Frames	The total number of good frames the bridge has sent for transmission through the port selected for Second Data Service
Rx Frames	The total number of good frames the bridge has received through the port selected for Second Data Service

Table 186 Management Agent Counters

Attribute	Meaning
Packets To Internal Stack	The total number of good packets the bridge has transmitted to the internal stack (for example, ARP, PING and HTTP requests).
Packets From Internal Stack	The total number of good packets the bridge has received from the internal stack (ARP responses, PING replies, HTTP responses).

Table 187 Wireless Port Counters and Performance Information

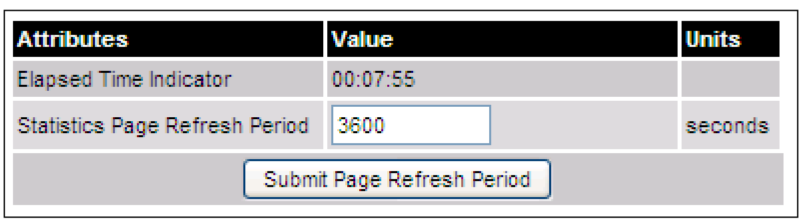
Attribute	Meaning
Tx Frames	Total number of good frames on the Data path, the bridge has sent for transmission through the wireless interface.
Rx Frames	Total number of good frames on the Data path, the bridge has received from the wireless interface.
Tx Frame Management	Total number of good managment frames, the bridge has sent for transmission through the wireless interface
Tx Frame Second Data	Total number of good frames on the Second Data path, the bridge has sent for transmission through the wireless interface
Link Symmetry	Ratio between transmit and receive time in the TDD frame. The first number is the time allowed for the transmit direction and the second number is the time allowed for the receive direction.
Link Capacity	The maximum aggregate data capacity available for user traffic under the current radio link conditions, assuming the units have been connected using Gigabit Ethernet. The sum of the displayed Transmit and Receive data rates may be lower than this figure if the link is not fully loaded by the current traffic profile.
Transmit Modulation Mode	The modulation mode currently being used on the transmit channel. The number in brackets after the modulation mode and coding rate string is the effective data rate available to all MAC layer protocols.

Attribute	Meaning
Receive Modulation Mode	The modulation mode currently being used on the receive channel. The number in brackets after the modulation mode and coding rate string is the effective data rate available to all MAC layer protocols.
Receive Modulation Mode Detail	The receive modulation mode in use. For a list of values and their meanings, see Table 167.
Wireless Link Availability	Wireless link availability calculated since the last system counters reset.
Ethernet Bridging Availability	Link availability for bridging Ethernet traffic calculated since the last reset of the system counters. This is the percentage of time in which the Ethernet Bridging Status attribute has been set to "`Enabled`".
Byte Error Ratio	The ratio of detected Byte errors to the total number of bytes since the last system reboot. This measurement is made continually using null frames when there is no user data to transport.
Counter Measurement Period	The time over which the system counters were collected.

Other attributes

The bottom section of the System Statistics page (Figure 209) contains two attributes (Table 188).

Figure 209 Other attributes section of the System Statistics page



Procedure:

- After updating the Statistics Page Refresh Period field, click **Submit Page Refresh Period**.

Table 188 Other attributes in the System Statistics page

Attribute	Meaning
Elapsed Time Indicator	Elapsed time since the last system reboot.
Statistics Page Refresh Period	The statistics page refreshes automatically according to the setting entered here (in seconds).

Wireless Port Counters page

Menu option: **System > Statistics > Wireless Port Counters** (Figure 210).

Use this page to check the Ethernet performance of the wireless bridge.

Figure 210 Wireless Port Counters page

Wireless Port Counters

Attributes	Value	Units	Attributes	Value	Units
Tx Frames	132 (+32)		Rx Frames	491 (+387)	
			Rx Frames With Crc Error	0 (+0)	
Tx Frames Q0	0 (+0)		Rx Frames Q0	0 (+0)	
Tx Frames Q1	125 (+125)		Rx Frames Q1	160 (+160)	
Tx Frames Q2	0 (+0)		Rx Frames Q2	0 (+0)	
Tx Frames Q3	0 (+0)		Rx Frames Q3	0 (+0)	
Tx Frames Q4	0 (+0)		Rx Frames Q4	0 (+0)	
Tx Frames Q5	0 (+0)		Rx Frames Q5	0 (+0)	
Tx Frames Q6	0 (+0)		Rx Frames Q6	0 (+0)	
Tx Frames Q7	7 (+7)		Rx Frames Q7	331 (+331)	
Tx Drops Q0	0 (+0)				
Tx Drops Q1	0 (+0)				
Tx Drops Q2	0 (+0)				
Tx Drops Q3	0 (+0)				
Tx Drops Q4	0 (+0)				
Tx Drops Q5	0 (+0)				
Tx Drops Q6	0 (+0)				
Tx Drops Q7	0 (+0)				
Tx Frames Second Data	3 (+3)		Rx Frames Second Data	198 (+198)	
Tx Drops Second Data	0 (+0)				

Attributes	Value	Units	Attributes	Value	Units
Counter Page Refresh Period	3600	seconds	Counter Measurement Period	00:05:38	
Submit Page Refresh Period			Reset System Counters		

Note

If the ODU is configured for OOB Remote Management Service, the OOB Management counters will be displayed instead of Second Data counters (i.e. Tx Frames Management → Tx Frames Second Data, Tx Drops Management → Tx Drops Second Data, and Rx Frames Management → Rx Frames Second Data)

Procedure:

- Review the attributes (Table 189).
- To change the refresh period, update the Counter Page Refresh Period attribute and click **Submit Page Refresh Period**.
- To reset all counters to zero, click **Reset System Counters**.

Table 189 Wireless Port Counters attributes

Attribute	Meaning
Tx/Rx Frames	Number of frames transmitted and received over the wireless bridge.
Rx Frames With Crc Error	Number of received frames with CRC errors.
Tx/Rx Frames Q0…Q7	Number of transmitted and received frames for each Traffic Class.
Tx Drops Q0…Q7	Number of transmitted frames dropped for each Traffic Class.
Rx Drops Q0…Q7	Total number of frames dropped due to the lack of sufficient capacity in the receive buffer, for each Traffic Class.
Rx Frames Second Data	Total number of frames received at the wireless port in the Out-of-Band management queue

Main Port Counters page

Menu option: **System > Statistics > Main Port Counters** (Figure 211). Use this page to check the Ethernet performance of the PSU port. The displayed counters vary depending on which port is being used to bridge the traffic.

Figure 211 Main Port Counters page (when main port is bridging traffic)

Main Port Counters

Attributes	Value	Units	Attributes	Value	Units
Tx Octets	684,506 (+684,506)		Rx Octets	398,584 (+398,584)	
Tx Frames	6,177 (+2)		Rx Frames	6,044 (+2)	
Tx Drops	0 (+0)		Rx Frames With Crc Error	0 (+0)	
Tx Broadcasts	5,368 (+5,368)		Rx Broadcasts	5,554 (+5,554)	
Tx IEEE1588 Event Frames	0 (+0)		Rx IEEE1588 Event Frames	0 (+0)	
			Rx Frames Undersize	0 (+0)	
Tx Frames 64 Bytes	5,912 (+5,912)		Rx Frames 64 Bytes	5,968 (+5,968)	
Tx Frames 65 To 127 Bytes	41 (+41)		Rx Frames 65 To 127 Bytes	57 (+57)	
Tx Frames 128 To 255 Bytes	17 (+17)		Rx Frames 128 To 255 Bytes	2 (+2)	
Tx Frames 256 To 511 Bytes	6 (+6)		Rx Frames 256 To 511 Bytes	11 (+11)	
Tx Frames 512 To 1023 Bytes	4 (+4)		Rx Frames 512 To 1023 Bytes	2 (+2)	
Tx Frames 1024 To 1600 Bytes	197 (+197)		Rx Frames 1024 To 1600 Bytes	4 (+4)	
Tx Frames 1601 To Max Bytes	0 (+0)		Rx Frames 1601 To Max Bytes	0 (+0)	
			Rx Frames Oversize	0 (+0)	
			Rx Pause Frames	0 (+0)	

Attributes	Value	Units	Attributes	Value	Units
Counter Page Refresh Period	3600	seconds	Counter Measurement Period	00:08:09	
Submit Page Refresh Period			Reset System Counters		

Procedure:

- Review the attributes (Table 190).
- To change the refresh period, update the Counter Page Refresh Period attribute and click **Submit Page Refresh Period**.
- To reset all counters to zero, click **Reset System Counters**.

Table 190 Main Port Counters attributes

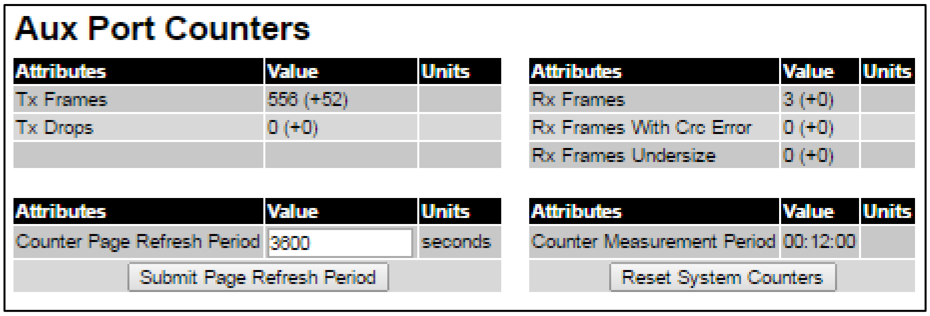
Attribute	Meaning
Tx/Rx Octets	Total number of octets (bytes) transmitted and received over the interface.
Tx/Rx Frames	Total number of frames transmitted and received over the interface. This includes both good and bad frames.
Tx Drops	Total number of transmit frames dropped.
Rx Frames With Crc Error	Total number of received frames with CRC errors.
Tx/Rx Broadcasts	Total number of good transmitted and received broadcast packets.
Tx/Rx IEEE1588 Event Frames	Only displayed when IEEE 1588 Transparent Clock is enabled. Total number of transmitted or received IEEE 1588 Event frames
Tx/Rx Frames TDM	Only displayed when TDM is enabled. Total number of transmitted or received TDM (E1 or T1) frames.
Rx Frames Undersize	Total number of frames received that are less than 64 bytes.
Tx/Rx Frames 64 Bytes	Total number 64 byte frames transmitted and received.
Tx/Rx Frames xxxx to yyyy Bytes	Total number of frames transmitted and received in the size range xxxx to yyyy bytes.
Tx/Rx Frames 1601 to Max bytes	Total number of frames transmitted and received in the size range 1601 to maximum bytes.
Rx Frames Oversize	Total number of frames received that are greater than the maximum number of bytes.
Rx Pause Frames	Total number of received pause frames.

Aux Port Counters page

Menu option: System > Statistics > **Aux Port Counters** (Figure 212).

Use this page to check the Ethernet performance of the Aux port.

Figure 212 Aux Port Counters page (when Aux port is is allocated to the Local Management Service)



Procedure:

- Review the attributes (Table 191).
- To change the refresh period, update the Counter Page Refresh Period attribute and click **Submit Page Refresh Period.**
- To reset all counters to zero, click **Reset System Counters.**

Table 191 Aux Port Counters attributes

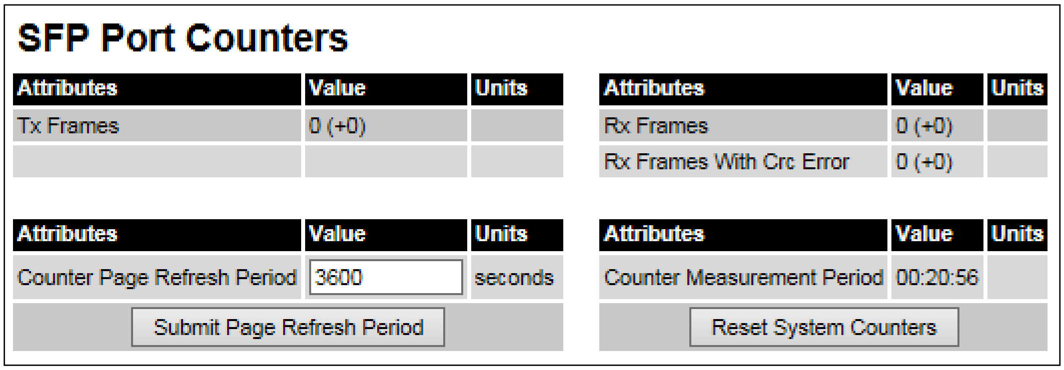
Attribute	Meaning
Tx/Rx Frames	Total number of frames transmitted and received over the interface. This includes both good and bad frames.
Rx Frames With Crc Error	Total number of received frames with CRC errors.
Tx Drops	Number of frames dropped due to excessive collision, late collision or frame ageing
Rx Frames Undersize	Number of short frames (<64 Bytes) with or without a valid CRC

SFP Port Counters page

Menu option: System > Statistics > **SFP Port Counters** (Figure 213).

Use this page to check the Ethernet performance of the SFP port.

Figure 213 SFP Port Counters page (when SFP port is allocated to the Local Management Service)



Procedure:

- Update the attributes (Table 192).
- To change the refresh period, update the Counter Page Refresh Period attribute and click **Submit Page Refresh Period**.
- To reset all counters to zero, click **Reset System Counters**.

Table 192 SFP Port Counters attributes

Attribute	Meaning
Tx/Rx Frames	Total number of frames transmitted and received over the interface. This includes both good and bad frames.
Rx Frames With Crc Error	Total number of received frames with CRC errors.

SyncE Status page

Menu option: System > Statistics > **SyncE Status**

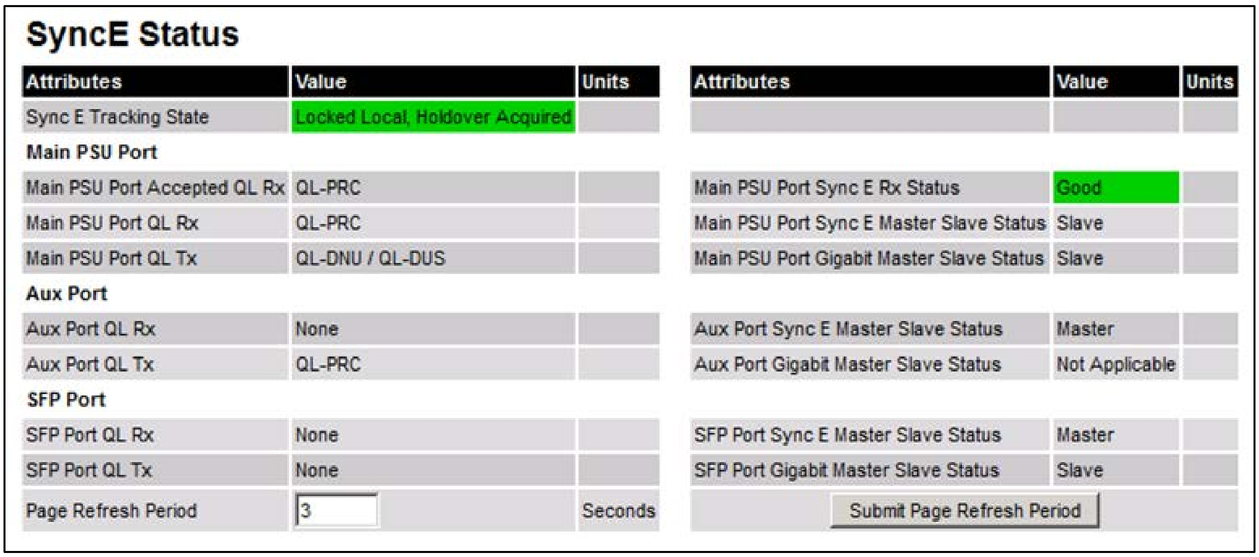
Use this page to monitor the state of the Synchronous Ethernet function.

Note

When TDM is enabled (TDM Configuration page on page 6-50), the following restrictions are automatically applied:

- The SyncE Status page is hidden.
- Main PSU Port Sync E Master Slave Status is set to **Master**.
- Main PSU Port Gigabit Master Slave Status is set to **Master**.

Figure 214 SyncE Status page



Procedure:

- Review the attributes
- To change the refresh period, update the Page Refresh Period attribute and click **Submit Page Refresh Period**

Table 193 Sync E Status attributes

Attribute	Meaning
Sync E Tracking State	The state of the Synchronous Ethernet state machine. See Table 194 for further details.
Main PSU Port Accepted QL Rx	The "accepted" QL received by the Main PSU Port. This should be the same as Main PSU Port QL Rx, unless: • an "Overwrite" has been configured • the system is starting up or recovering from an exception
Main PSU Port QL Rx	The QL currently being received at the Main PSU Port
Main PSU Port QL Tx	The QL currently being transmitted at the Main PSU Port
Main PSU Port SyncE Rx Status	The overall status of the incoming synchronous Ethernet signal on the Main PSU port. This port is available as a valid synchronization source if the status is **Good**. The port may potentially be a valid source in the near future if the status is **Wait-to-Restore**.
Main PSU Port Sync E Master Slave Status	This attribute indicates if the Main PSU Port is operating as a Synchronous Ethernet master (providing a source of timing for downstream devices) or slave (receiving a source of timing from an upstream device).
Main PSU Port Gigabit Master Slave Status	This attribute indicates if the Main PSU Port's Gigabit Ethernet physical interface is operating as a master (generating a clock) or slave (locking to a clock generated at the other end of the Ethernet link).
Aux Port QL Rx	The QL currently being received on the Aux Port
Aux Port Accepted QL Rx	The "accepted" QL received by the Aux Port. This should be the same as Aux Port QL Rx, unless the system is starting up or recovering from an exception
Aux Port QL Tx	The QL currently being transmitted at the Aux Port
Aux Port Sync E Master Slave Status	The Aux Port operates as a Synchronous Ethernet master (providing a source of timing for downstream devices).
Aux Port Gigabit Master Slave Status	This attribute indicates if the Aux Port's Gigabit Ethernet physical interface is operating as a master (generating a clock) or slave (locking to a clock generated at the other end of the Ethernet link).
SFP Port QL Rx	The QL currently being received on the SFP Port
SFP Port Accepted QL Rx	The "accepted" QL received by the SFP Port. This should be the same as SFP Port QL Rx, unless the system is starting up or recovering from an exception

Attribute	Meaning
SFP Port QL Tx	The QL currently being transmitted at the SFP Port
SFP Port Sync E Master Slave Status	The Aux Port operates as a Synchronous Ethernet master (providing a source of timing for downstream devices).
SFP Port Gigabit Master Slave Status	This attribute indicates if the SFP Port's Gigabit Ethernet physical interface is operating as a master (generating a clock) or slave (locking to a clock generated at the other end of the Ethernet link).

The "Sync E Tracking State" attribute can take the following values:

Table 194 Sync E Tracking State

Value	Meaning
Disabled	The synchronous Ethernet feature is disabled.
Acquiring Wireless Lock	Synchronous Ethernet is not operational because real-time clocks have not completed alignment.
Free Running	Synchronous Ethernet is operational, but with no timing source or history. This is a temporary state.
Locked Local, Acquiring Holdover	Sync E tracking has locked to a synchronisation signal from a cabled Ethernet port on the local ODU. This is a temporary state until the unit has acquired holdover history.
Locked Local, Holdover Acquired	Sync E tracking has locked to a synchronisation signal from a cabled Ethernet port on the local ODU and has acquired holdover history.
Holdover	There is currently no source for the tracking loop, but previously the tracking loop was in a Locked, Holdover Acquired state. The system is using the last known good frequency.
Locked Remote, Acquiring Holdover	The tracking loop has locked to a synchronisation signal from the remote ODU. This is a temporary state until the unit has acquired holdover history.
Locked Remote, Holdover Acquired	The tracking loop has locked to a synchronisation signal form the remote ODU and has acquired holdover history.

In normal operation, with the Synchronous Ethernet feature enabled and a valid timing source present, one end of the link should be in the "Locked Local, Holdover Acquired State", the other end should be in the "Locked Remote, Holdover Acquired" state.

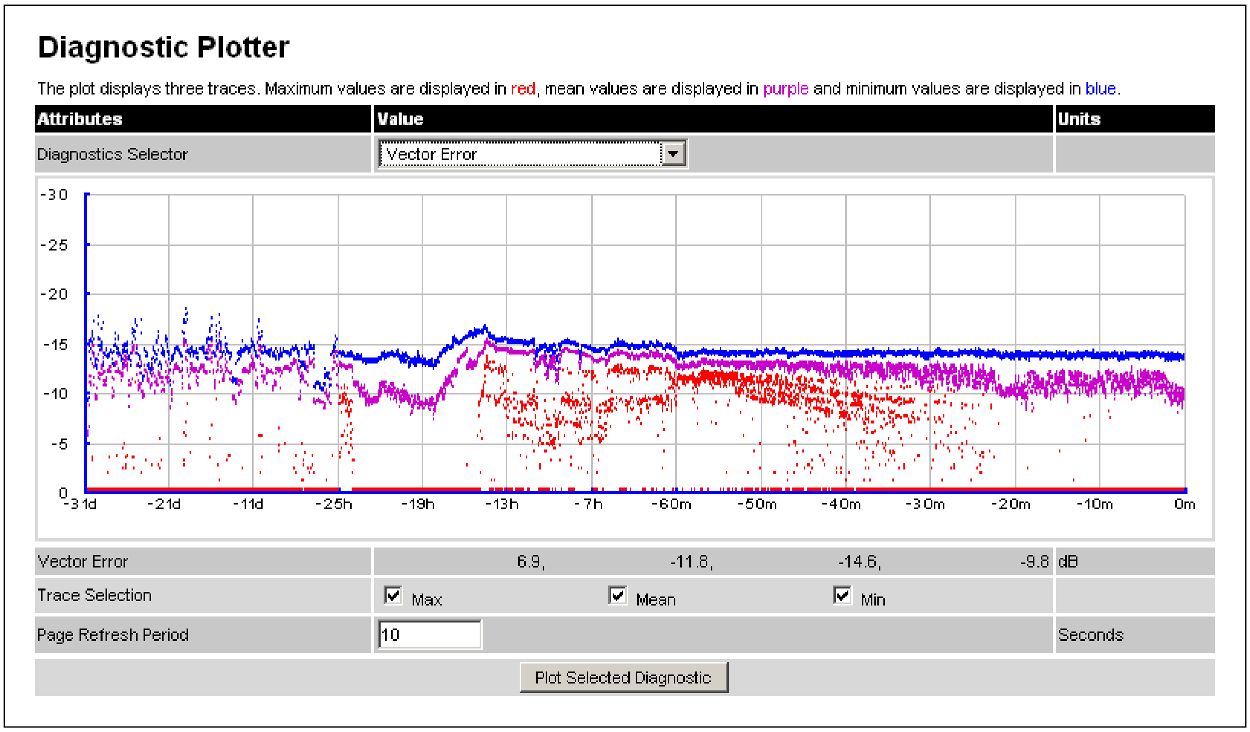
The Sync E Tracking State attribute remains in the Acquiring Wireless Lock state for a period of time after the wireless link has established whilst the two ODUs establish precise synchronization. The duration of this period depends on channel bandwidth, varying from less than one minute at 45 MHz, up to two minutes for 5 MHz.

Diagnostics Plotter page

Menu option: **System** > **Diagnostics Plotter** (Figure 215).

Use this page to monitor the performance of an operational PTP 650 link over time.

Figure 215 Diagnostic Plotter page



Procedure:

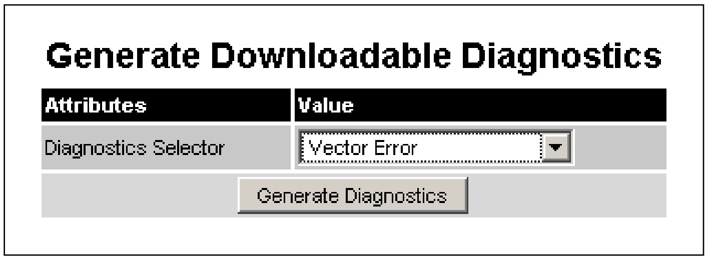
- Select a diagnostic from the Diagnostics Selector drop-down list. These are the same as the System Histogram attributes in the System Statistics page (Table 183).
- Tick the required Trace Selection boxes: Max, Mean and Min.
- Update the Page Refresh Period as required. The default period is 3600 seconds (1 hour). To monitor the performance of a link in real time, select a much shorter period, for example 60 seconds.
- Click **Plot Selected Diagnostic**. The selected diagnostic trace is displayed in the graph. Maximum values are displayed in red, mean values are displayed in purple and minimum values are displayed in blue.

Generate Downloadable Diagnostics page

Menu option: **System > Diagnostics Plotter > CSV Download** (Figure 216).

Use this page to download diagnostics data to a CSV file.

Figure 216 Generate Downloadable Diagnostics page



Procedure:

- Select a diagnostic from the Diagnostics Selector drop-down list.
- Click **Generate Diagnostics**. The Generate Downloadable Diagnostics page is redisplayed with the name of the generated CSV file.
- Click on the CSV file name and save the CSV file to the hard drive of the local computer.
- Open the CSV file in MS Excel and use it to generate reports and diagrams. The CSV file contains at most 5784 entries, recorded over a 32 day period:
    - o 3600 entries recorded in the last hour.
    - o 1440 entries recorded in the previous 24 hours.
    - o 744 entries recorded in the previous 31 days.

Recovery mode

This section describes how to recover a PTP 650 unit from configuration errors or software image corruption.

Entering recovery mode

Use this procedure to enter recovery mode manually.

Note

The unit may enter recovery mode automatically, in response to some failures.

Note

Once the unit has entered recovery, it will switch back to normal operation if no access has been made to the recovery web page within 30 seconds.

Procedure:

1. Apply power to PSU for at least 10 seconds.
2. Remove power for two seconds.
3. Re-apply power to the PSU.
4. When the unit is in recovery mode, access the web interface by entering the default IP address **169.254.1.1**. The Recovery Image Warning page is displayed:

5. Click on the warning page image. The Recovery Option Page is displayed (Figure 217).
6. Review the Software Version and Recovery Reason (Table 195).
7. Select a recovery option (Table 196).

Figure 217 Recovery Options page

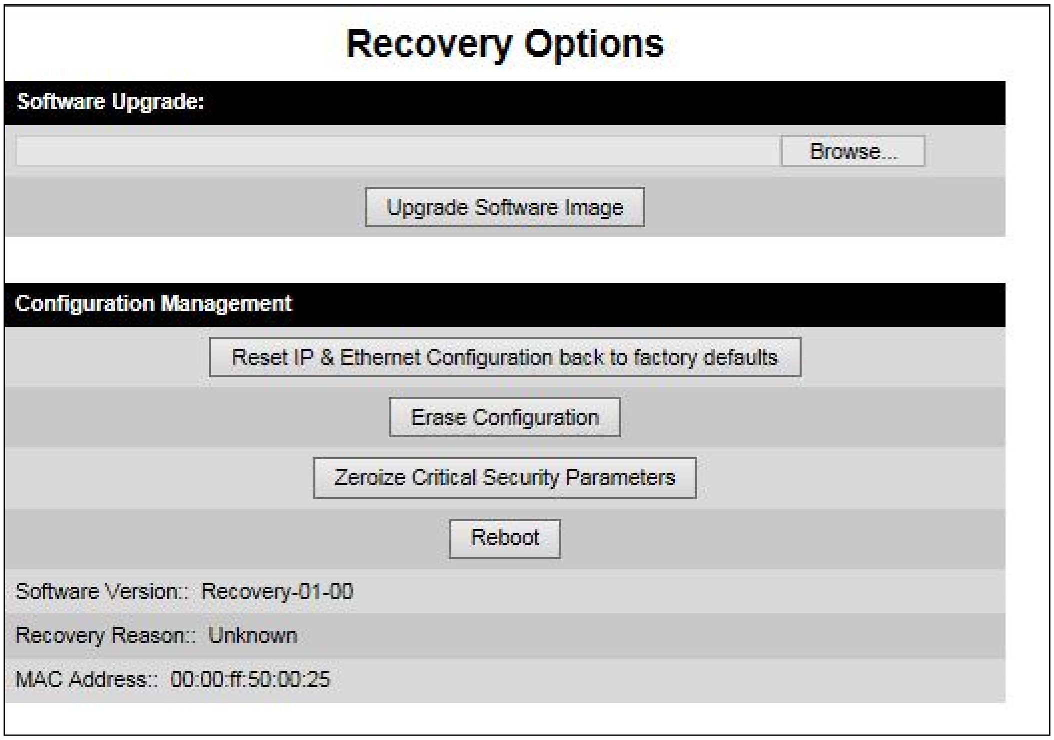


Table 195 Recovery Options attributes

Attribute	Meaning
Software Version	The software version of the recovery operating system permanently installed during manufacture.
Recovery Reason	The reason the unit is operating in Recovery mode, for example “Invalid or corrupt image”. “Unknown” usually means there has been a power outage.
MAC Address	The MAC address of the unit programmed during manufacture.

Table 196 Recovery Options buttons

Button	Purpose
Upgrade Software Image	Use this option to restore a working software version when software corruption is suspected, or when an incorrect software image has been loaded. Refer to Upgrading software image on page 7-68.
Reset IP & Ethernet Configuration back to factory defaults	Use this option to reset the IP and Ethernet attributes to factory defaults. Refer to Resetting IP & Ethernet configuration on page 7-69.
Erase Configuration	Use this option to reset the entire configuration of the unit to factory defaults. Refer to Resetting all configuration data on page 7-70.
Zeroize Critical Security Parameters	Use this option to reset the security configuration to default values. Refer to Zeroize Critical Security Parameters on page 7-72.
Reboot	Use this option to reboot the unit. Refer to Rebooting the unit on page 7-73.

Upgrading software image

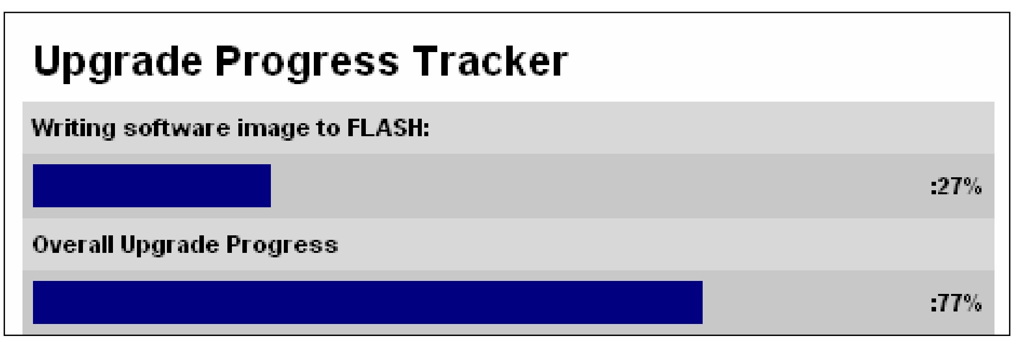
Use this option to restore a working software image from the Recovery Options page (Figure 217).

Procedure:

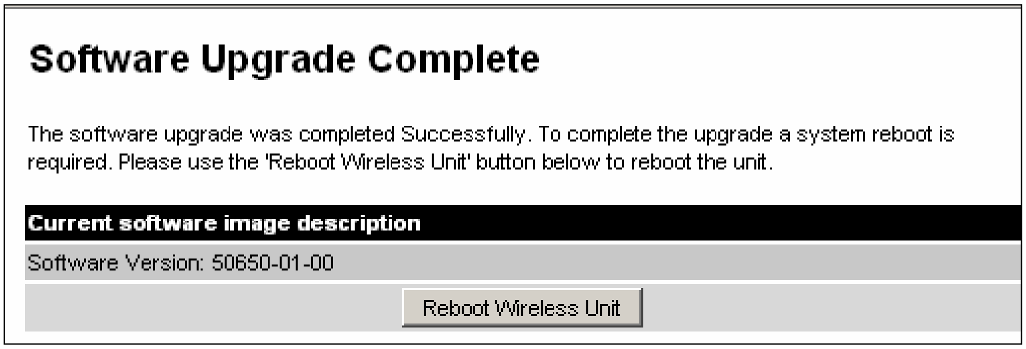
1 Click **Browse**.

2 Navigate to the required software image. This may be the most recent image if software corruption is suspected, or an older image if an incorrect image has just been loaded. Click on the image and click **Open**.

3 Click **Upgrade Software Image**. The Confirmation page is displayed. Click **Program Software Image into Non-Volatile Memory**. The Upgrade Progress Tracker page is displayed:



4 When the Software Upgrade Complete page is displayed, check that the correct image has been downloaded:



5 Click **Reboot Wireless Unit**. When the “`Are you sure?`” message is displayed, click **OK**.

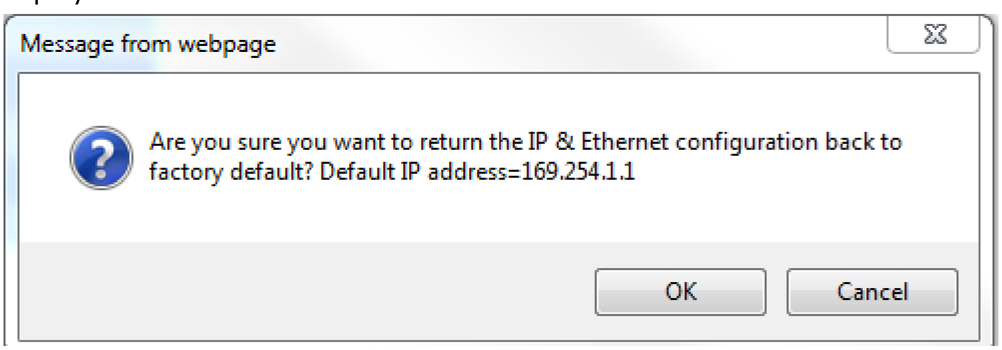
6 The unit will now reboot and restart in normal operational mode, and the link should recover. If the unit or link fails to recover, refer to Testing link end hardware on page 8-7.

Resetting IP & Ethernet configuration

Use this option in the Recovery Options page to reset IPv4, IPv6 and Ethernet configuration to default values (Figure 217). This procedure resets the IP Version attribute to **IPv4**. It also resets the IPv6 configuration.

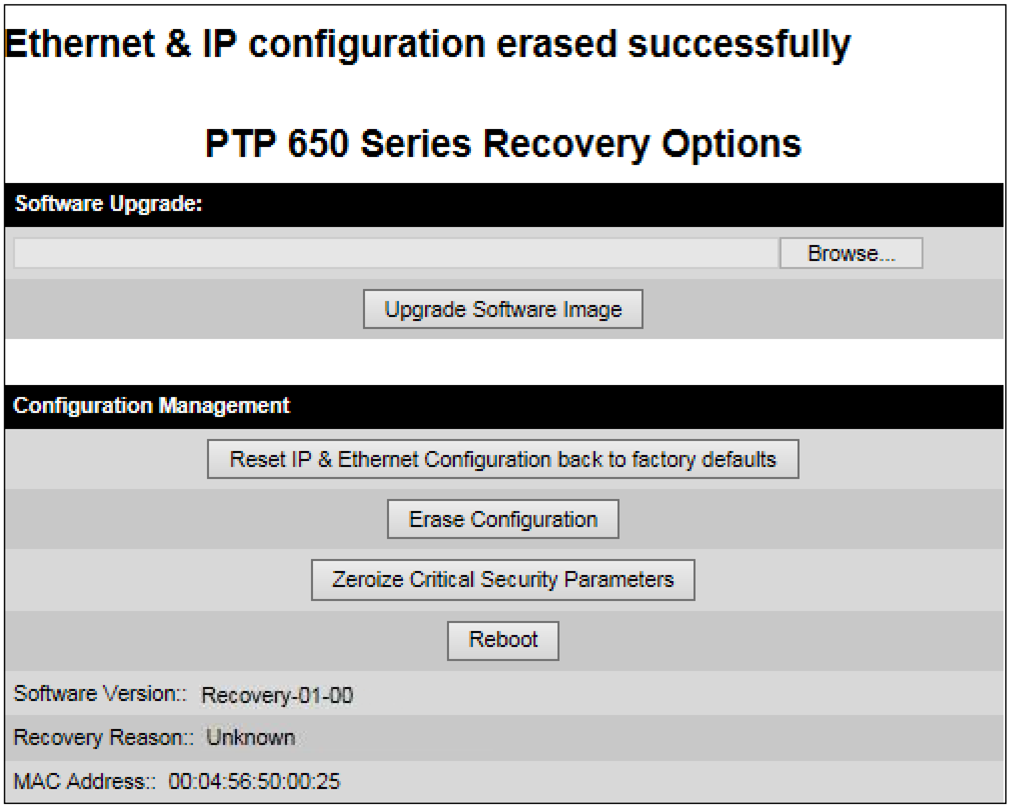
Procedure:

1 Click **Reset IP & Ethernet Configuration back to factory defaults**. The reset pop up box is displayed:



2 Record the IP address, as it will be needed to log into the unit after recovery.

3 Click **OK**. The reset confirmation page is displayed:



4 Click **Reboot**. When the "`Are you sure you want to REBOOT this unit?`" message is displayed, click **OK**.

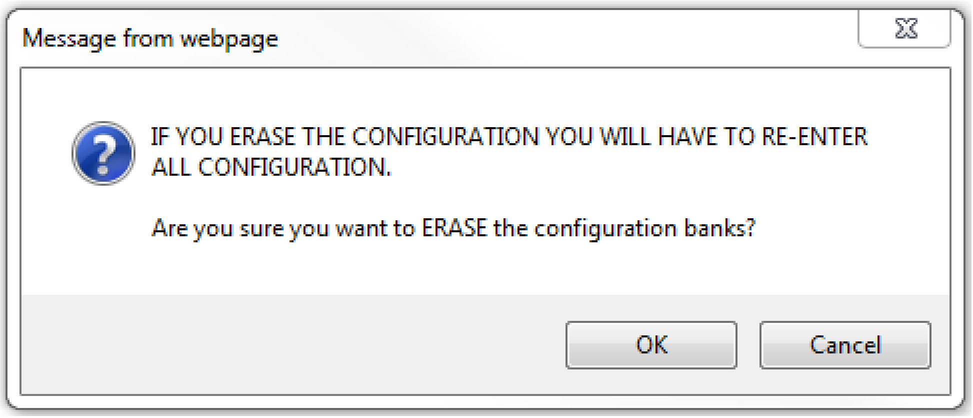
5 The unit will now reboot. The unit should now start up in normal mode but with the IP and Ethernet configuration reset to factory defaults. If the unit fails to recover, refer to Testing link end hardware on page 8-7 and Cable Diagnostics on page 8-2.

Resetting all configuration data

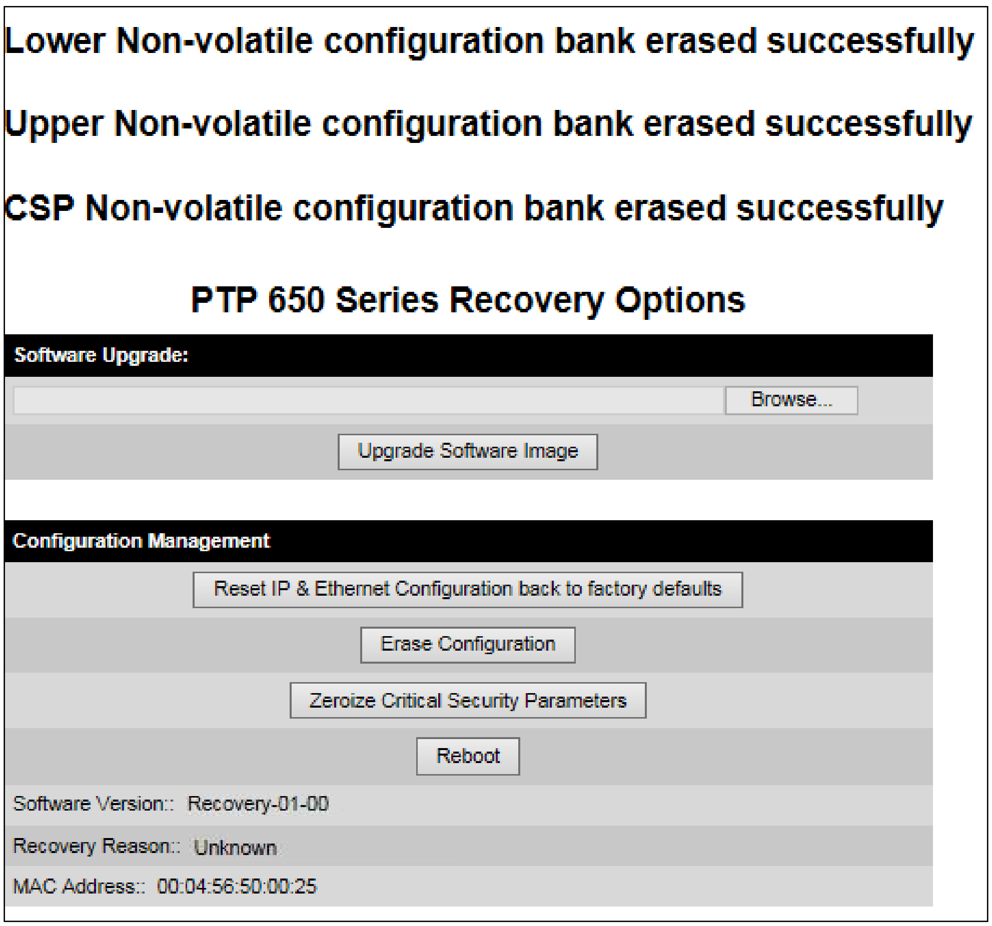
Use this option in the Recovery Options page to reset the entire configuration of the unit (including IP, Ethernet and CSPs) to default values (Figure 217).

Procedure:

1 Click **Erase Configuration**. The erase pop up box is displayed:



2 Click **OK**. The erase confirmation page is displayed:



3 Click **Reboot**. When the confirmation message is displayed, click **OK**.

4 The unit reboots and starts up in normal mode but with all configuration reset to default values. If the unit fails to start up, refer to Testing link end hardware on page 8-7 and and Cable Diagnostics on page 8-2.

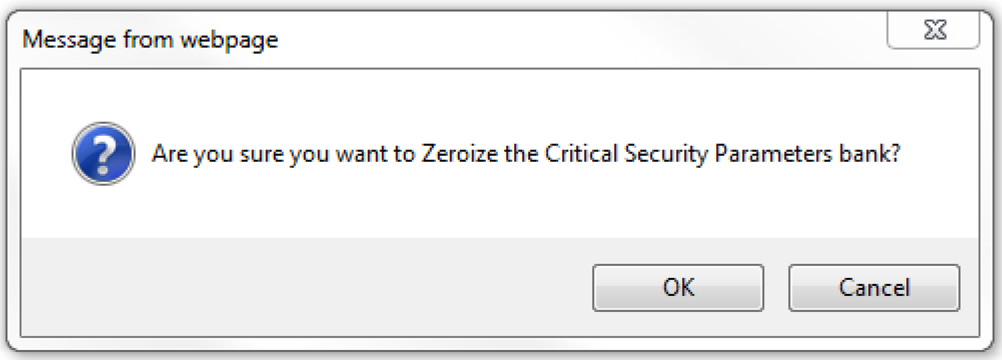
Zeroize Critical Security Parameters

Use this option in the Recovery Options page to reset the security configuration of the unit to default values (Figure 217). This action includes the following attributes:

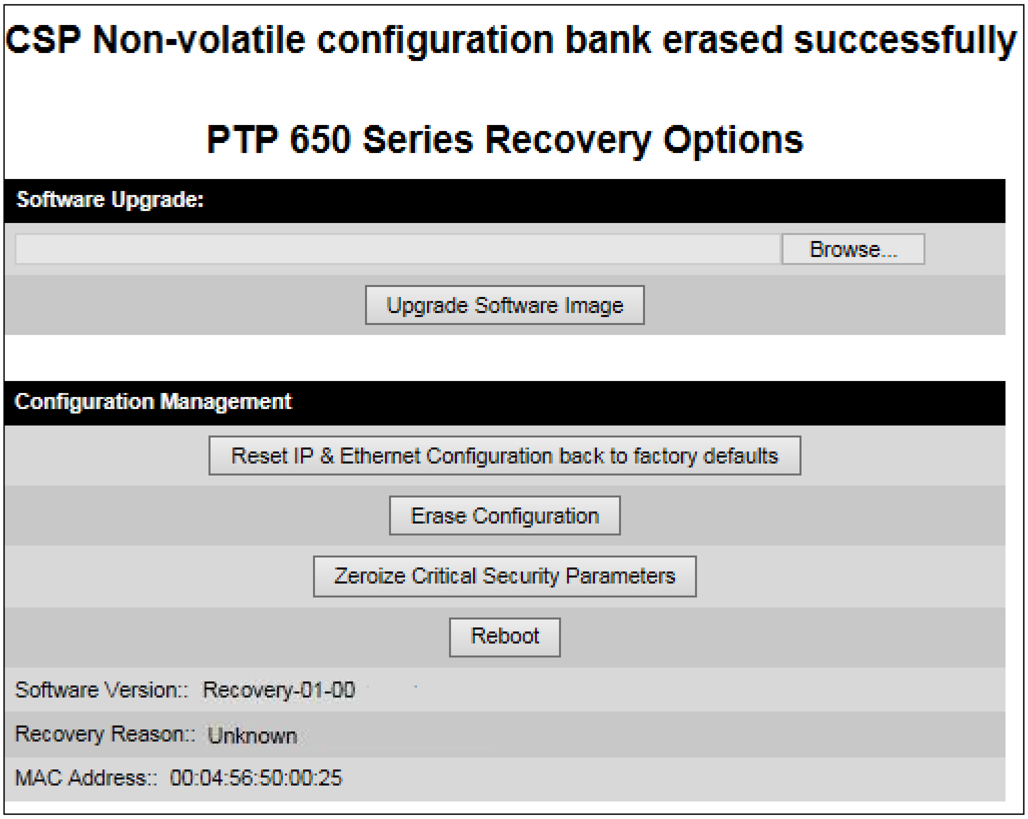
- Key of Keys
- Local User Accounts Names, Roles and Passwords
- Encryption Algorithm
- Wireless Encryption Key
- HTTPS Private Key
- HTTPS Public Key Certificate
- Random Number Generator Entropy
- HTTP Access Enabled
- HTTP Port Number

Procedure:

1 Click **Zeroize Critical Security Parameters**. The confirmation pop up box is displayed:



2 Click **OK**. The zeroize CSPs confirmation page is displayed:



3 Click **Reboot**. When the "`Are you sure you want to REBOOT this unit?`" message is displayed, click **OK**.

4 The unit will now reboot. The unit should now start up in normal mode but with the security configuration reset to default values. If the unit fails to recover, refer to Testing link end hardware on page 8-7 and Cable Diagnostics on page 8-2.

Rebooting the unit

Use this option to reboot the unit from the Recovery Options page (Figure 217).

Procedure:

- Click **Reboot**.
- When the "`Are you sure you want to REBOOT this unit?`" message is displayed, click **OK**. The unit will now reboot. The unit should now start up in normal operational mode. If the unit fails to start up, refer to Testing link end hardware on page 8-7.

Chapter 8: Troubleshooting

This chapter contains procedures for identifying and correcting faults in a PTP 650 link. These procedures can be performed either on a newly installed link, or on an operational link if communication is lost, or after a lightning strike.

The following topics are described in this chapter:

- Cable Diagnostics on page 8-2 describes how to perform cable diagnostics test to detect cabling related faults.
- Testing link end hardware on page 8-7 describes how to test the link end hardware, either when it fails on startup, or after a lightning strike.
- Testing the radio link on page 8-13 describes how to test the link when there is no radio communication, or when it is unreliable, or when the data throughput rate is too low.
- Testing PTP-SYNC on page 8-15 describes how to test the PTP-SYNC unit and its connections when the PTP-SYNC LEDs do not illuminate correctly, or when a synchronization fault is suspected.
- Testing a TDM link on page 8-18 describes how to check the NIDU LEDs and how to perform a TDM loopback test.

Cable Diagnostics

This section describes how to diagnose cable faults.

The Cable Diagnostics feature may be used to test Ethernet cables connected to the Main PSU port and the Aux port. The feature uses Time Domain Reflectometry (TDR) technology to test individual twisted pairs in the cable, to identify open circuit and short circuit faults, and indicate the approximate location of the fault:

- Open circuit – An open circuit is detected when the impedance is greater than 300 ohms.
- Short circuit – A short circuit is detected when the impedance is less than 33 ohms.
- Approximate location of the fault - The fault location is reported as a distance from the ODU along the cable, and is accurate to +/- 2 meters (6.5 feet).

Note

- The cable diagnostics results are provided only as a guide.
- The feature reliably detects all open circuit and short circuit faults in cable pairs, but it is not possible to reliably detect short circuit faults between wires in different cable pairs. Except for that specific circumstance, an OK result for all pairs means the cable is good.
- The presence of LPUs can affect the accuracy and reliability of the results.

Before initiating the test, confirm that all outdoor drop cables (that is those that connect the ODU to equipment inside the building) are specified as supported, as defined in Outdoor copper Cat5e Ethernet cable on page 2-39.

Test scenarios

The Cable Diagnostics test may be performed in following scenarios:

Scenarios	Actions
Main PSU port "Down"	Check for physical Ethernet cable connectivity between Power over Ethernet (PoE) and Customer Data Network (or LAN). If the cable connectivity is OK, Perform Cable Diagnostics test.
Aux port "Down"	Check for physical Ethernet cable connectivity between ODU and Customer Data Network or Management Agent. If the cable connectivity is OK, Perform Cable Diagnostics test.
Main PSU or Aux port is "Up" but the Ethernet speed is noticed slow	There is a possibility that one or more cable pairs have intermittent contact with the RJ45 connector pin. This could result in intermittent communication errors.

	Follow procedure Ethernet packet test. If Ethernet Rx Crc and Align counter is greater than ten (>10), Perform Cable Diagnostics test. If Packet Error Rate is greater than 1 in 1 million, Perform Cable Diagnostics test. If Number of lost packets are less than two (<2) after performing Test ping packet loss, perform Cable Diagnostics test. Otherwise check the ODU's parameter configurations.

Cable Diagnostics test

Menu option: **System > Cable Diagnostics**

The Cable Diagnostics feature determines a fault in a cable and its approximate location based on Time Domain Reflectometry (TDR).

When the test is initiated for the selected port(s), the ODU sends a known signal (+1V) over the twisted pair cable. The transmitted signal will travel down the cable until it reflects off a fault. The magnitude of the reflection and the time it takes for the reflection to come back can be used to calculate the distance to the fault on the cable. For example, a +1V reflection will indicate an open close to the PHY and a -1V reflection will indicate a short close to the PHY.

Based on the returned signal, the radio identifies the cable status and estimates the distance of the fault. The result of the cable test will be displayed.

The cable diagnostics test can be carried out for Main PSU and AUX ports. This test is not supported for SFP port.

Caution

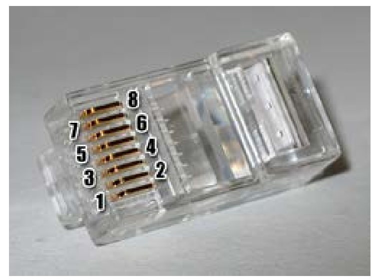
- On the Main PSU port, the presence of LPUs can affect the accuracy of the cable diagnostics results for some cable configurations. When a fault is detected, the feature reports the distance corresponding to the final TDR signal reflection. In configurations where there is a short cable from the ODU to the first LPU (< 2m), and a moderately long cable to the second LPU (30m), the final TDR signal reflection may come from one of the LPUs itself, rather than the fault. For example, a fault in the first short cable may be reported at or near the second LPU.
- On the Aux port, the presence of LPUs can affect the reliability of the cable diagnostics results for many cable configurations. Frequently, open circuit faults may be reported when the cable is OK, and fault distances may be reported corresponding to the LPU locations. Cable diagnostics tests on the Aux port should be repeated a number of times to establish a pattern.

Note

All cable diagnostics results should be verified with an external cable tester before remedial action is taken.

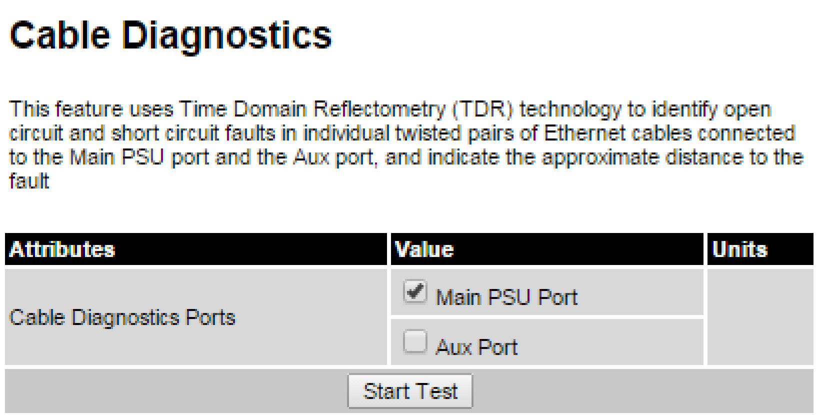
All four twisted pairs of the cable are tested separately and results are displayed for each pair. The pin to pair mapping of a cable is shown in Table 197.

Table 197 Pin to pair mapping of a cable (T568B termination)

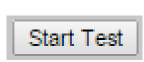
Pin	Pair	Wire	Color (Supplied cable)	Color (Conventional)	Pins on plug face
1	2	1	Light Orange	White/Orange	
2	2	2	Orange	Orange	
3	3	1	Light Green	White/Green	
4	1	2	Blue	Blue	
5	1	1	Light Blue	White/Blue	
6	3	2	Green	Green	
7	4	1	Light Brown	White/Brown	
8	4	2	Brown	Brown	

Procedure

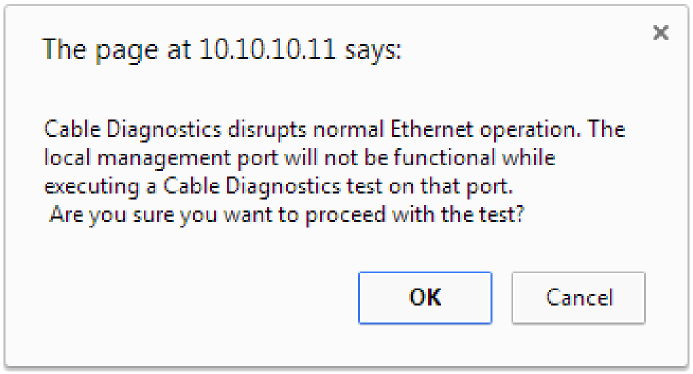
1 Select ports for cable diagnostics test:



2 Click "Start Test" button to begin the test:



3 The confirmation pop up box is displayed. Click the "OK" button to proceed with the test:

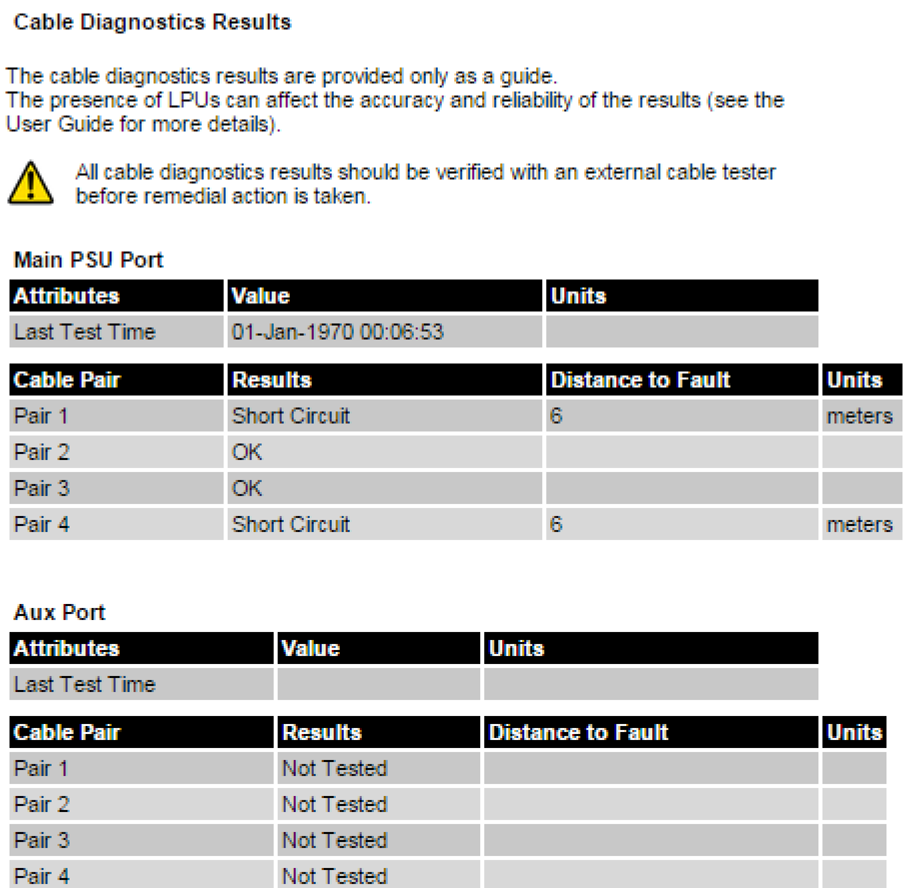


Note

The Local Management port connection will be lost when the local management port is under test. However the management port will be accessible when the other ports are under test.

Resubmit the web page after 10 seconds when testing the management port.

4 On completion of the test, the results are displayed :



Cable Diagnostics Results

The cable diagnostics results are provided only as a guide.
The presence of LPUs can affect the accuracy and reliability of the results (see the User Guide for more details).

All cable diagnostics results should be verified with an external cable tester before remedial action is taken.

Main PSU Port

Attributes	Value	Units
Last Test Time	01-Jan-1970 00:06:53	

Cable Pair	Results	Distance to Fault	Units
Pair 1	Short Circuit	6	meters
Pair 2	OK		
Pair 3	OK		
Pair 4	Short Circuit	6	meters

Aux Port

Attributes	Value	Units
Last Test Time		

Cable Pair	Results	Distance to Fault	Units
Pair 1	Not Tested		
Pair 2	Not Tested		
Pair 3	Not Tested		
Pair 4	Not Tested		

Note

The last test performed results are shown for user reference purpose.

Table 198 Cable Diagnostics attributes

Attribute	Meaning
Cable Diagnostics Ports	Select ports on which Cable Diagnostics must be executed.
Last Test Time	The date and time when a Cable Diagnostics test was last executed successfully.
Cable Pair	The result of the most recent execution of cable diagnostics on a cable pair. There are four twisted pairs in each Cat5 cable. The cable diagnostics test is performed on each pair of the cable.
Results	**OK**: Reported when the test is passed for a respective cable pair. **Open Circuit**: Reported when the impedance is greater than 330 ohms. **Short Circuit:** Reported when impedance is less than 33 ohms.
Distance	The estimate of the distance from the ODU to the fault detected on the cable pair during the most recent execution of Cable Diagnostics. Fault in cables longer than 160 meters (525 feet) may not be detected. The error margin is +/- 2 meters (6.5 feet).
Units	Unit of cable length in meters.

Testing link end hardware

This section describes how to test the link end hardware when it fails on startup or during operation.

Before testing link end hardware, confirm that all outdoor drop cables, that is those that connect the ODU to equipment inside the building, are of the supported type, as defined in Outdoor copper Cat5e Ethernet cable on page 2-39.

AC Power Injector LED sequence

When the AC Power Injector is connected to the AC mains, the Power (green) LED should illuminate within 5 seconds of connection. If this does not happen, the AC injector is either not receiving power from the AC mains or there is a fault on the drop cable causing the power injector to sense an over current condition on the ODU output connector.

Action: Remove the ODU cable from the PSU and observe the effect on the power LED:

- If the power LED does not illuminate, confirm that the mains supply is working, for example check the plug and fuse (if fitted). If the power supply is working, report a suspected PSU fault to Cambium Networks.
- If the Power LED does illuminate, perform Test resistance in the drop cable on page 5-25.

AC+DC Enhanced power injector LED sequence

For the AC+DC Enhanced power injector, the expected power-up LED sequence is:

- The Power (green) LED illuminates steadily.
- After about 45 seconds, the Ethernet (yellow) LED blinks slowly 10 times.
- The Ethernet (yellow) LED illuminates steadily, then blinks randomly to show Ethernet activity.

If this sequence does not occur, take appropriate action depending on the LED states:

- Power LED is off on page 8-8
- Power LED is blinking on page 8-8
- Ethernet LED did not blink 10 times on page 8-8
- Ethernet LED blinks ten times then stays off on page 8-9
- Ethernet LED blinks irregularly on page 8-9 (for example a short blink followed by a long blink)
- Power LED is on, Ethernet LED blinks randomly on page 8-9

If a fault is suspected in the ODU-PSU drop cable, perform Test resistance in the drop cable on page 5-25.

Power LED is off

Meaning: Either the PSU is not receiving power from the AC/DC outlet, or there is a wiring fault in the ODU cable.

Action: Remove the ODU cable from the PSU and observe the effect on the Power LED:

- If the Power LED does not illuminate, confirm that the mains power supply is working, for example, check the plug and fuse (if fitted). If the power supply is working, report a suspected PSU fault to Cambium Networks.
- If the Power LED does illuminate, perform Test resistance in the drop cable on page 5-25.

Power LED is blinking

Meaning: The PSU is sensing there is an overload on the ODU port; this could be caused by a wiring error on the drop cable or a faulty ODU.

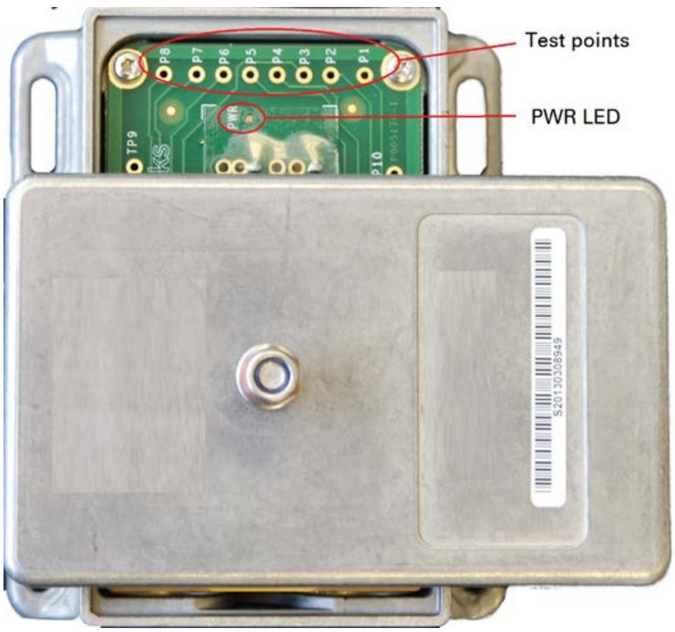
Action: Remove the ODU cable from the PSU. Check that pins 4&5 and 7&8 are not crossed with pins 1&2 and 3&6. Check that the resistance between pins 1&8 is greater than 100K ohms. If either check fails, replace or repair the ODU cable.

Ethernet LED did not blink 10 times

Meaning: The ODU flashes the LED on the AC+DC Enhanced Power Injector 10 times to show that the ODU is powered and booted correctly.

Action:

1. Remove the ODU cable from the PSU. Examine it for signs of damage. Check that the ODU cable resistances are correct, as specified in Test resistance in the drop cable on page 5-25. If the ODU cable is suspect, replace it.
2. Use the LPU (if installed) to check that power is available on the cable to the ODU. Access the connections by rotating the LPU lid as shown (slacken the lid nut but do not remove it):



4 Check that test point P1 on the LPU PCB corresponds to pin 1 on the RJ45. Repeat for points P2 to P8. This test is only valid if both the PSU and the ODU are disconnected.

5 Reconnect the ODU cable to the PSU.

6 Check that the PWR LED near the top right of the LPU PCB is illuminated to indicate power in the Ethernet cable.

7 If any test fails, replace or repair the cable that connects the PSU to the LPU or ODU.

Ethernet LED blinks ten times then stays off

Meaning: There is no Ethernet traffic between the PSU and ODU.

Action: The fault may be in the LAN or ODU cable:

- Confirm that Ethernet traffic is connected to the AC+DC injector LAN port, confirm the cable is not faulty, replace if necessary.
- If the LAN connection to the AC+DC power injector is working, check the drop cable is correctly wired using a suitable cable tester. Repeat the drop cable tests on page Test resistance in the drop cable on page 5-25.

Ethernet LED blinks irregularly

Meaning: If the Ethernet LED blinks irregularly, for example two rapid blinks followed by a longer gap, this indicates that the ODU has booted in recovery mode. The causes may be: installation wiring, or a corrupt ODU software load, or sufficient time has not been allowed between a repeat power up.

Action: Refer to Recovery mode on page 7-66.

Power LED is on, Ethernet LED blinks randomly

Meaning: Both LEDs are in their normal states, implying that the PSU is receiving power from the AC/DC outlet and there is normal Ethernet traffic between the PSU and ODU.

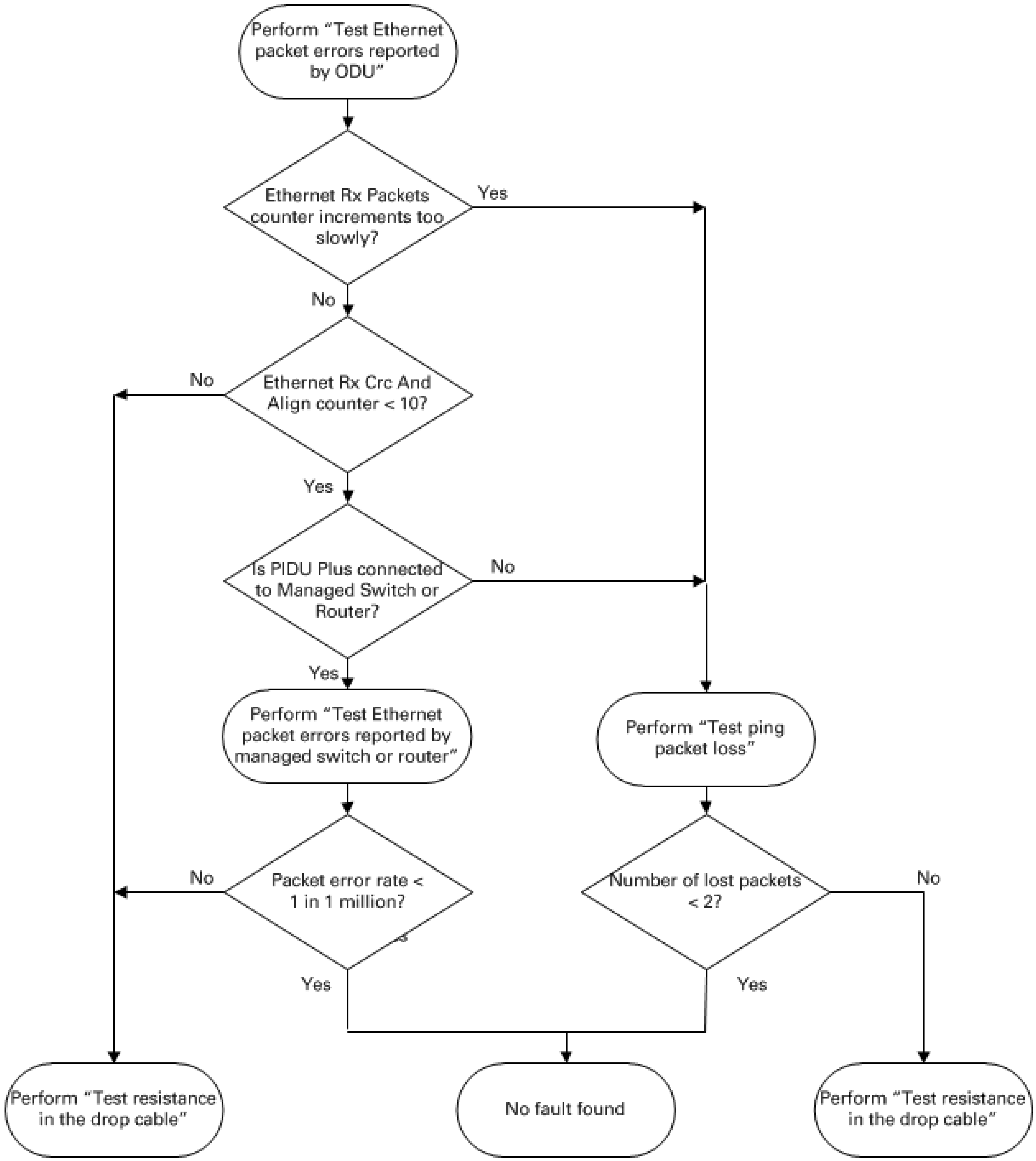
Action: If, in spite of this, a fault is suspected in the link end hardware:

- If the Ethernet connection to the network is only 100BASE-TX, when 1000BASE-T is expected: remove the ODU cable from the PSU, examine it, and check that the wiring to pins 4&5 and 7&8 is correct and not crossed.
- Perform Ethernet packet test on page 8-10.

Ethernet packet test

Follow the Ethernet packet test flowchart (Figure 218) and procedures below.

Figure 218 Ethernet packet test flowchart



Test Ethernet packet errors reported by ODU

Log into the unit and click **Administration**, **Statistics**, **Detailed Counters**. Click **Reset System Counters** at the bottom of the page and wait until the Ethernet Rx Packets counter has reached 1 million (the count will only update when the page is refreshed. If the counter does not increment or increments too slowly, because for example the PTP 650 is newly installed and there is no offered Ethernet traffic, then abandon this procedure and consider using the procedure Test ping packet loss on page 8-11.

Read the Ethernet Rx Crc And Align counter. The test has passed if this is less than 10.

Test Ethernet packet errors reported by managed switch or router

If the ODU is connected to a managed Ethernet switch or router, it may be possible to monitor the error rate of Ethernet packets. Please refer to the user guide of the managed network equipment. The test has passed if the rate of packet errors reported by the managed Ethernet switch or router is less than 10 in 1 million packets.

Test ping packet loss

Using a computer, it is possible to generate and monitor packets lost between the PSU and the ODU. This can be achieved by executing the Command Prompt application which is supplied as standard with Windows and MAC operating systems.

Caution

This procedure disrupt network traffic carried by the PTP 650 under test:

Procedure:

1 Ensure that the IP address of the computer is configured appropriately for connection to the PTP 650 under test, and does not clash with other devices connected to the network.

2 If the PSU is connected to an Ethernet switch or router then connect the computer to a spare port, if available.

3 If it is not possible to connect the computer to a spare port of an Ethernet switch or router, then the PSU will need to be disconnected from the network in order to execute this test:

- Disconnect the PSU from the network.
- Connect the computer directly to the LAN port of the PSU.

4 On the computer, open the Command Prompt application.

5 Send 1000 ping packets of length 1500 bytes. The process will take 1000 seconds, which is approximately 17 minutes.

If the computer is running a Windows operating system, this is achieved by typing (for an IPv6 address, use the **`ping6`** command):

```
ping –n 1000 –l 1500 <ipaddress>
```

where <ipaddress> is the IP address of the PTP 650 ODU under test.

If the computer is running a MAC operating system, this is achieved by typing:

```
ping –c 1000 –s 1492 <ipaddress>
```

where <ipaddress> is the IP address of the PTP 650 ODU under test.

6 Record how many Ping packets have been lost. This is reported by Command Prompt on completion of the test.

The test has passed if the number of lost packets is less than 2.

Testing the radio link

This section describes how to test the link when there is no radio communication, when it is unreliable, when the data throughput rate is too low, or when a unit is causing radio or TV interference. It may be necessary to test the units at both ends of the link.

No activity

If there is no wireless activity, proceed as follows:

1. Check for Alarm conditions on Home page.
2. Check that the software at each end of the link is the same version.
3. Check that the Target Mac address is correctly configured at each end of the link.
4. Check Range.
5. Check Tx Power.
6. Check License keys to ensure that both units are the same product variant.
7. Check Master/Slave status for each unit and ensure that one unit is Master and the other unit is slave.
8. Check that the link is not obstructed or the ODU misaligned.
9. Check the DFS page at each end of the link and establish that there is a quiet wireless channel to use.
10. If there are no faults found in the configuration and there is absolutely no wireless signal, retry the installation procedure.
11. If this does not work then report a suspected ODU fault to Cambium Networks.

Some activity

If there is some activity but the link is unreliable or does not achieve the data rates required, proceed as follows:

1. Check that the interference has not increased using the DSO measurements.
2. If a quieter channel is available check that it is not barred.
3. Check that the path loss is low enough for the communication rates required.
4. Check that the ODU has not become misaligned.

Radio and television interference

If a PTP 650 unit is interfering with radio or television reception (this can be determined by turning the equipment off and on), attempt the following corrective actions:

- Realign or relocate the antenna.
- Increase the separation between the affected equipment and antenna.
- Connect the ODU and PSU power supply into a power outlet on a circuit different from that to which the receiver is connected.
- Contact Cambium Point-to-Point for assistance.

Testing PTP-SYNC

This section describes how to test the PTP-SYNC unit and its connections when the PTP-SYNC LEDs do not illuminate correctly, or when a synchronization fault is suspected.

Checking the PTP-SYNC LEDs

If a fault is suspected in the PTP-SYNC or GPS hardware, check the PTP-SYNC LED states and use Table 199 to choose the correct test procedure.

Table 199 PTP-SYNC indicator LED states

LED	State	Description and test procedure
GPS	Off	No GPS satellite data being received at the GPS/SYNC IN port. Refer to GPS LED does not illuminate or blink on clustered units on page 8-17.
	On steady or blink	GPS satellite data being received.
SYNC	Off	No data being received at the SYNC OUT port.
	On steady or blink	Data being received at the SYNC OUT port. The SYNC LED does not normally illuminate, even in cluster configurations.
STATUS	Off	No power. Refer to LEDs do not illuminate on page 8-16.
	On steady	Power but no satellite lock. Refer to STATUS LED is on steady on page 8-16.
	Blink	Power and satellite lock at either the GPS/SYNC IN or 1PPS IN port.
	Double blink	Possible fault in GPS/SYNC IN or 1PPS IN cables. Refer to STATUS LED double-blinks on page 8-16.
ODU	Off	No signal being received from the ODU. Refer to ODU LED does not illuminate within 90 seconds on page 8-16.
	On	Communication with the ODU is established.
	Blink red	Error in communication with ODU. Refer to ODU LED blinks red on page 8-16,

LEDs do not illuminate

Meaning: The PTP-SYNC unit is not powered up.

Action: Ensure that there is a cable connection between the PSU ODU interface and the PIDU IN interface of the PTP-SYNC unit. Confirm that the PSU is powered up.

STATUS LED is on steady

Meaning: There is power but no satellite lock. This probably indicates that a 1PPS synchronization pulse is not detected by the PTP-SYNC unit.

Action: Depending on system configuration, take one of the following actions:

- System using a GPS receiver module - Ensure that there is a cable connection between the PTP-SYNC GPS/SYNC IN interface and the LPU, also that there is a cable connection between the LPU and the GPS receiver module. Check that the GPS receiver module has an uninterrupted view of the sky.
- System using an alternative 1PPS timing source - Ensure that there is a cable connection between the PTP-SYNC GPS/SYNC IN or 1PPS IN interface and the 1PPS timing source.
- On cluster slave units – Ensure that there is a cable connection between the slave GPS/SYNC IN interface and the SYNC OUT interface of the preceding unit in the chain.

STATUS LED double-blinks

Meaning: There may be a fault in the GPS/SYNC IN or 1PPS IN cables.

Action: Check the GPS wiring in accordance with Table 43.

ODU LED does not illuminate within 90 seconds

Meaning: There may be no communication between PTP-SYNC and ODU.

Action: Ensure that the PTP-SYNC ODU OUT interface is connected to the ODU (and LPUs if installed) via the drop cable.

ODU LED blinks red

Meaning: Error in communication with ODU. Possible causes are: fault in the ODU or PSU cable, maximum recommended cable lengths exceeded, or TDD synchronization is not enabled at the ODU.

Action: Confirm that the ODU and PSU cables are not too long: see Ethernet standards and cable lengths on page 2-38. Check the ODU cable wiring by following the procedure described in Test resistance in the drop cable on page 5-25.

GPS LED does not illuminate or blink on clustered units

Meaning: This indicates a fault only when the timing source is a GPS receiver.

Action: Table 200 describes the action to be taken depending upon the behavior of the GPS LEDs at the master and slave(s).

Table 200 Clustered PTP-SYNC units - GPS LEDs Fault-finding

Cluster timing source	GPS LED on master	GPS LED on slave(s)	Diagnosis
GPS receiver providing NMEA data	Blink	Blink	OK
	Off	Any	Fault in GPS unit or GPS cable
	Blink	Off	Fault in daisy chain cable
Alternative 1PPS source, no NMEA data	Off	Off	OK
	Off	On	Fault in alternative 1PPS source
One ODU is cluster timing master	Off	Off	OK

Testing a TDM link

This section describes how to check the NIDU LEDs and how to perform a TDM loopback test.

Checking the NIDU LEDs

If a fault is suspected in the NIDU, check the NIDU LED states and use Table 201 to choose the correct test procedure.

Table 201 NIDU indicator LED states

Port	LED	State	Description and test procedure
LAN	Green	On steady	Normal state: Ethernet 1000BaseT signal detected.
		Off	Abormal state: Ethernet signal detected but not 1000BaseT.
	Amber	Blink	Normal state: data activity detected.
		On steady	Abormal state: alarm signal received.
ODU	Green	On steady	Normal state: Ethernet 1000BaseT signal detected
		Off	Abormal state: Ethernet signal detected but not 1000BaseT.
	Amber	Blink	Normal state: data activity detected.
		On steady	Abormal state: alarm signal received.
E1/T1	Green	On steady	Normal state: TDM signal detected
	Amber	Blink	Normal state: TDM data activity detected.
	Amber	On steady	Abnormal state: no TDM data activity detected.

Performing a TDM loopback test

The loopback test allows a TDM data stream to be looped back at the copper or wireless interface. A typical T1 or E1 installation test includes a copper loopback on the local unit followed by a wireless loopback on the remote unit.

Note

The TDM Configuration page is only available when the TDM interface is enabled and the unit is rebooted (Interface Configuration page on page 6-14).

Procedure:

- Select menu option **System > Configuration > TDM Configuration** (Figure 143).
- Set the TDM Channel Loopback n attribute (where "n" is in the range 1 to 8) to **Copper** or **Wireless** (Table 140).
- Click **Submit Updated TDM Configuration**.
- Perform loopback tests. The System Summary page displays alarms indicating the presence of loopbacks on each affected TDM channel (Alarms on page 7-18).
- Set the TDM Channel Loopback n attribute (where "n" is in the range 1 to 8) to **None** (Table 140).
- Click **Submit Updated TDM Configuration**.

Checking for 1000BASE-T operation

If the ODU port has negotiated a link at 100BASE-T, the NIDU will not send or receive TDM data and will not bridge customer data traffic. Check that the Ethernet drop cable between the ODU and the PSU, and the network cable between the PSU and the NIDU have successfully negotiated operation at 1000BASE-T. On the System Status page, review Main PSU Port Speed and Duplex (Figure 182) and confirm that it is set to **1000 Mbps Full Duplex**.

Glossary

Term	Definition
AES	Advanced Encryption Standard
ANSI	American National Standards Institution
ARP	Address Resolution Protocol
ATPC	Automatic Transmit Power Control
Aux	Auxiliary
BBDR	Broadband Disaster Relief
BPSK	Binary Phase Shift Keying
BW	Bandwidth
CFM	Connection Fault Management
CHAP	Challenge Handshake Authentication Protocol
CSP	Critical Security Parameter
DC	Direct Current
DER	Distinguished Encoding Rules
DES	Data Encryption Standard
DFS	Dynamic Frequency Selection
DHCP	Dynamic Host Configuration Protocol
DSCP	Differentiated Services Code Point
DSO	Dynamic Spectrum Optimization
EAPS	Ethernet Automatic Protection Switching
EIRP	Equivalent Isotropic Radiated Power
EMC	Electromagnetic Compatibility
EMD	Electro-Magnetic Discharge
EPL	Ethernet Private Line
ETSI	European Telecommunications Standards Institute
EU	European Union
FAQ	Frequently Asked Question
FCC	Federal Communications Commission

Term	Definition
FIPS	Federal Information Processing Standards
GARP	Generic Attribute Registration Protocol
GE	Gigabit Ethernet
GUI	Graphical User Interface
HTTP	Hypertext Transfer Protocol
IB	In-Band
IC	Industry Canada
ICMP	Internet Control Message Protocol
ICNIRP	International Commission on Non-Ionizing Radiation Protection
IEEE	Institute of Electrical and Electronic Engineers
IP	Internet Protocol
IPSec	Internet Protocol Security
ISM	Industrial Scientific and Medical
ITPE	Initial Transmit Power Estimate
KDB	Knowledge Database
L2CP	Layer Two Control Protocols
LACP	Link Aggregation Control Protocol
LLDP	Link Layer Discovery Protocol
LAN	Local Area Network
LOS	Line-of-Sight (clear line-of-sight, and Fresnel zone is clear)
LPU	Lightning Protection Unit
MAC	Medium Access Control Layer
MDI (-X)	Medium Dependent Interface (-Crossover)
MEF	Metro Ethernet Forum
MIB	Management Information Base
MIMO	Multiple-Input Multiple-Output
MLD	Multicast Listener Discovery
MPLS	Multiprotocol Label Switching
MRP	Multiple Registration Protocol
MSTP	Multiple Spanning Tree Protocol

Term	Definition
MTU	Maximum Transmission Unit
NA	Neighbor Advertisement
NIDU	Network Indoor Unit
NLOS	Non-Line-of-Sight
NMEA	National Marine Electronics Association
NS	Neighbor Solicitation
NTP	Network Time Protocol
NUD	Neighbor Un-reachability Detection
ODU	Outdoor Unit
OFDM	Orthogonal Frequency Division Multiplex
OOB	Out-of-Band
PC	IBM Compatible Personal Computer
PEAP	Protected Extensible Authentication Protocol
PIDU	Powered Indoor Unit
POE	Power over Ethernet
PSU	Power Supply Unit
PTP	Point-to-Point
QAM	Quadrature Amplitude Modulation
QoS	Quality of Service
QPSK	Quadrature Phase Shift Keying
R-APS	Ring Automatic Protection Switching
RADIUS	Remote Authentication Dial-In Service
RAM	Random Access Memory
RF	Radio Frequency
RFC	Request for Comments
RoW	Rest of World
RMA	Return Material Authorization
RSSI	Received Signal Strength Indication
RSTP	Rapid Spanning Tree Protocol
SELV	Safety Extra Low Voltage

Term	Definition
SFP	Small Form-factor Pluggable
SLAAC	Stateless Address Auto-configuration
SMTP	Simple Mail Transport Protocol
SNMP	Simple Network Management Protocol
SNTP	Simple Network Time Protocol
STP	Spanning Tree Protocol
Syslog	System Logging
TC	Traffic Class
TCP	Transmission Control Protocol
TDD	Time Division Duplexing
TDM	Time Division Multiplexing
TDWR	Terminal Doppler Weather Radar
TGB	Tower Ground Bus bar
TLS	Transport Layer Security
UNII	Unlicensed National Information Infrastructure
URL	Universal Resource Location
USM	User-based Security Model
UTC time	Coordinated Universal Time
UTP	Unshielded Twisted Pair
UV	Ultraviolet
VACM	View-based Access Control Model
VLAN	Virtual Local Area Network
WEEE	Waste Electrical and Electronic Equipment