Cambium PTP 700 Series User Guide

System Release 700-01-00

Cambium Networks™

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Contents

About This User Guide

This guide describes the planning, installation, configuration and operation of the Cambium PTP 700 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 700 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 700 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 700. 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 specific information

Caution

This device complies with Part 15 of the FCC Rules. Operation is subject to the following two conditions:

- This device may not cause harmful interference, and
- This device must accept any interference received, including interference that may cause undesired operation.

The USA Federal Communications Commission (FCC) requires 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 700 for operation in the USA. These variants are only allowed to operate with license keys that comply with FCC rules.

Other variants of the PTP 700 are available for use in the rest of the world, but these variants are not supplied to the USA except under strict controls, when they are needed for export and deployment outside the USA.

Canada specific information

Caution

This device complies with Industry Canada's licence-exempt RSSs. 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.

Industry Canada requires 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 IC rules; specifically it must not be possible to disable or modify the radar protection functions that have been demonstrated to IC.

In order to comply with these IC requirements, Cambium supplies variants of the PTP 700 for operation in Canada. These variants are only allowed to operate with license keys that comply with IC rules. In particular, operation of radio channels overlapping the band 5600 MHz to 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.

Other variants of the PTP 700 are available for use in the rest of the world, but these variants are not supplied to Canada except under strict controls, when they are needed for export and deployment outside Canada.

Renseignements specifiques au Canada

Attention

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.

Industry Canada (IC) 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 IC, en particulier, il ne doit pas être possible de désactiver ou modifier les fonctions de protection des radars qui ont été démontrés à IC.

Afin de se conformer à ces exigences de IC, Cambium fournit des variantes du PTP 700 exclusivement pour le Canada. Ces variantes ne permettent pas à l'équipement de fonctionner en dehors des règles de 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 700 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 700 Series firmware and install it in the Outdoor Units (ODUs) before deploying the PTP 700 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 700 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 700 system for operation in the 5.1 GHz and 5.4 GHz UNII bands.

External antennas

When using an external connectorized antenna (as compared to the integrated antenna in the Conectorized+Integrated platform variant), 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 700 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 700 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 700 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 700 Series on page 1-2 introduces the key features, typical uses, product variants and components of the PTP 700 series.
- Wireless operation on page 1-6 describes how the PTP 700 wireless link is operated, including modulation modes, power control and spectrum management.
- Ethernet bridging on page 1-20 describes how the PTP 700 controls Ethernet data, in both the customer data and system management networks.
- TDM bridging on page 1-33 describes how TDM traffic (E1 or T1) may be carried over PTP 700 links.
- System management on page 1-36 introduces the PTP 700 management system, including the web interface, installation, configuration, security, alerts and upgrades.
- FIPS 140-2 mode on page 1-52 describes the (optional) FIPS 140-2 approved mode of operation.

Overview of the PTP 700 Series

This section introduces the key features, typical uses, product variants and components of the PTP 700 series.

Purpose

Cambium PTP 700 Series Bridge products are designed for Ethernet bridging over point-to-point microwave links in licensed, unlicensed and lightly-licensed frequency bands between 4400 MHz and 5875 MHz. Users must ensure that the PTP 700 Series complies with local operating regulations.

The PTP 700 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 700 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 700 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 250 km. The PTP 700 operates in licensed, unlicensed and lightly-licensed frequency bands between 4400 MHz and 5875 MHz. It has a very high spectral efficiency of 10 bps/Hz and supports a channel bandwidth of up to 45 MHz. The PTP 700 Connectorized ODU is designed for use with an external antenna. The PTP 700 Connectorized+Integrated ODU can be used with an external antenna or with an integrated 22 dBi flat plate antenna.

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

From an Ethernet point-of-view, the PTP 700 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 700 Series supports an optional TDM adaptor that allows E1 or T1 telecoms circuits to be bridged over the wireless link.

The PTP 700 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 700 supports both synchronous Ethernet and operation as an IEEE 1588-2008 transparent clock.

Table 1 gives a summary of the main PTP 700 characteristics.

Table 1 Main characteristics of the PTP 700 Series

Characteristic	Value
Topology	PTP
Wireless link condition	LOS, near LOS or non-LOS
Range	Up to 250 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	4400 MHz to 5875 MHz
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)
Security	FIPS 140-2 Level 2

Frequency bands

The PTP 700 ODU can be configured by the user to operate in the following bands:

- 4.7 GHz band: 4400 to 5000 MHz
- 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

Note

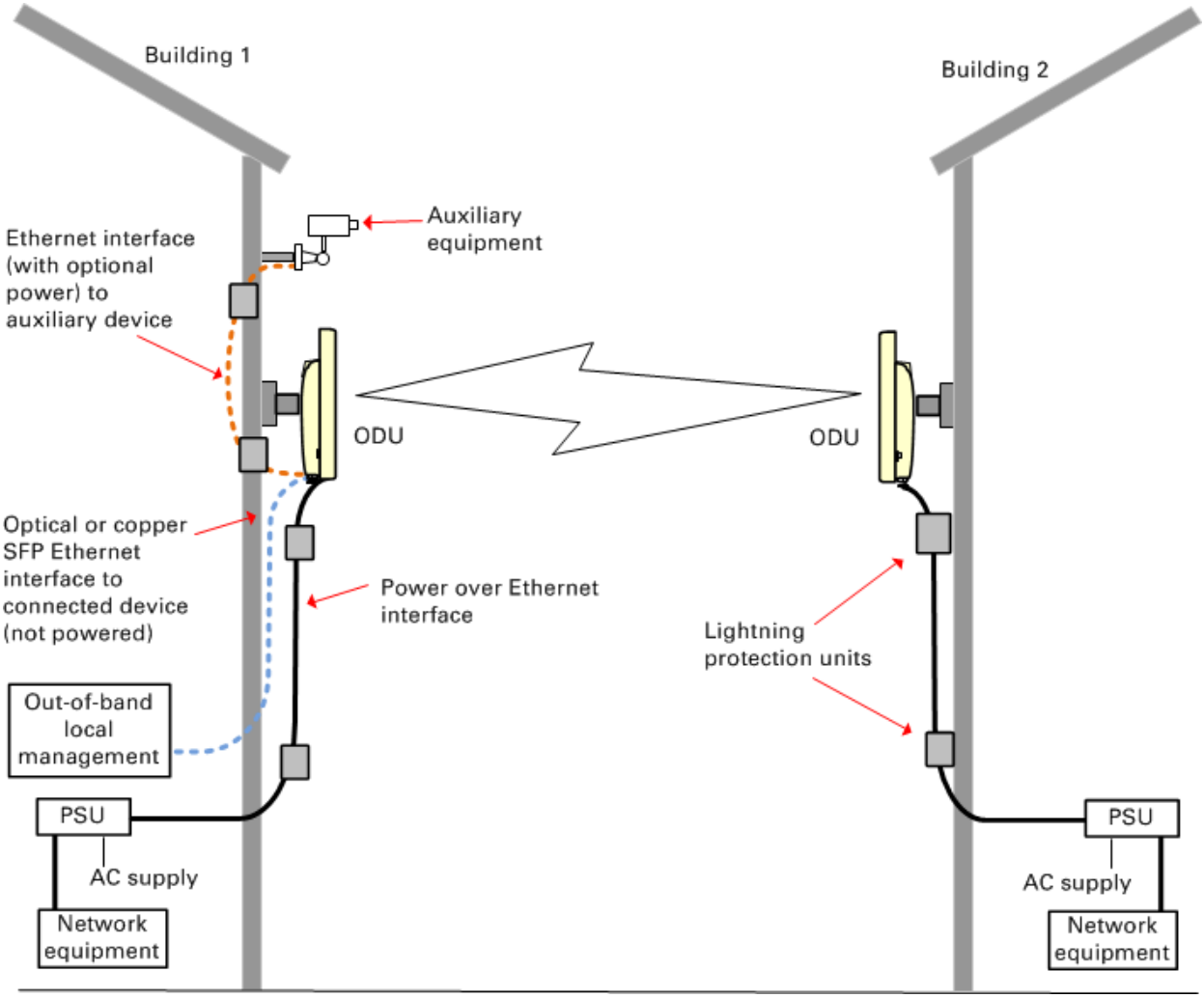
The supported frequency coverage may be restricted in some country licenses to comply with the applicable regulations.

Typical bridge deployment

The PTP 700 is an "all outdoor" solution consisting of a wireless bridge between two sites. Each site installation consists of a PTP 700 Connectorized outdoor unit (ODU) or a PTP 700 Connectorized+Integrated 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 700 typical bridge deployment



Hardware overview

The main hardware components of the PTP 700 are as follows:

- Outdoor unit (ODU): The ODU is a self-contained transceiver unit that houses both radio and networking electronics. The PTP 700 ODU is supplied in two configurations:
  - A PTP 700 Connectorized ODU intended to work with separately mounted external antennas.
  - A PTP 700 Connectorized+Integrated ODU intended to work with either separately mounted external antennas or with an integrated 22 dBi flat plate antenna.
- The ODU is supplied in the following regional variants:
  - FCC, intended for deployment in the USA
  - European Union (EU), intended for deployment in countries of the European Union or other countries following ETSI regulations
  - Industry Canada (IC), intended for deployment in Canada
  - Global, intended for deployment in countries other than USA, Canada and EU countries.
- Power supply unit (PSU): The AC+DC power injector powers the ODU from an AC or DC supply.
- 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 700 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 700 wireless link is operated, including modulation modes, power control and security.

Time division duplexing

TDD cycle

PTP 700 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:

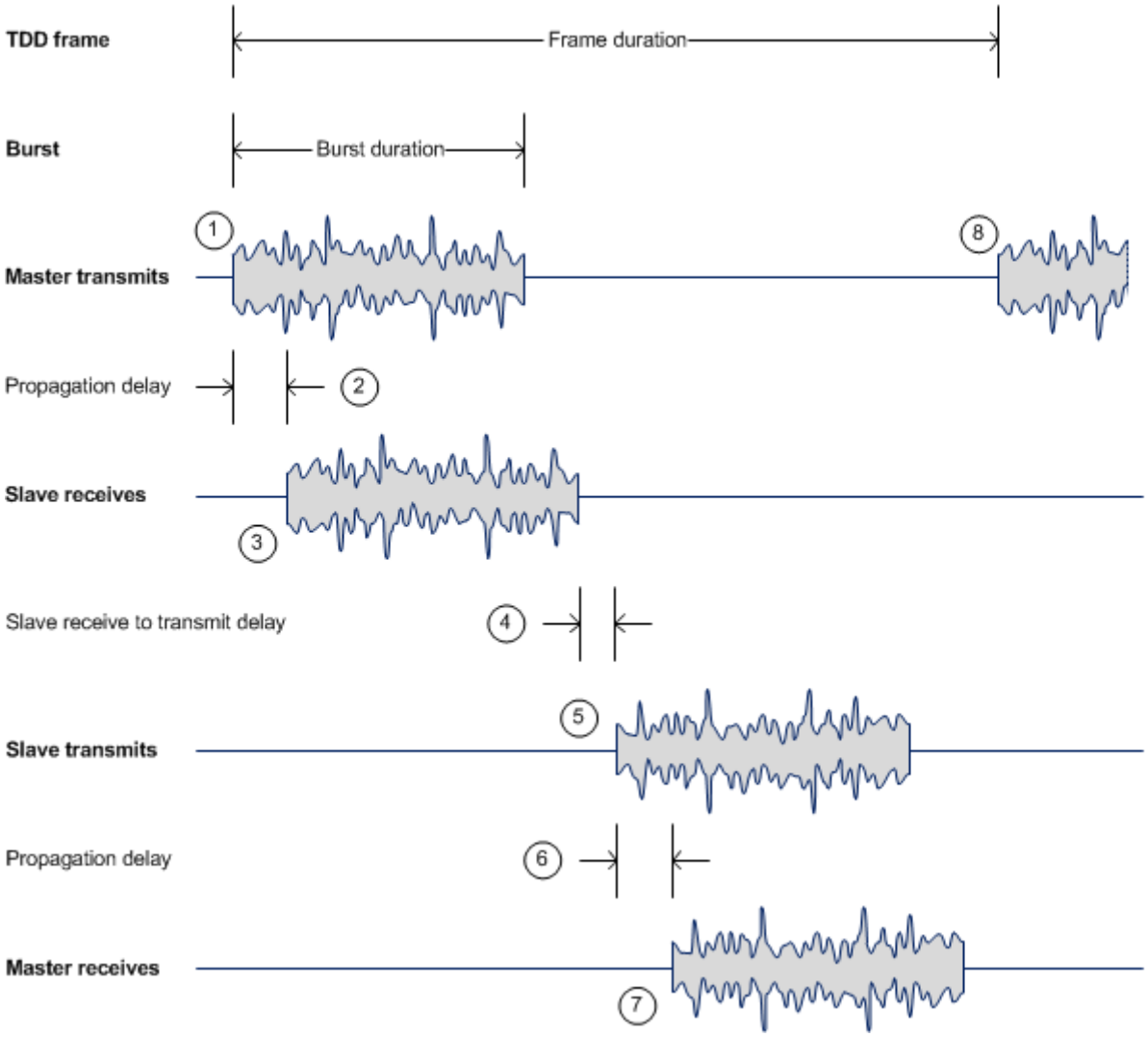
- Channel bandwidth
- Link range
- Link optimization mode
- Link symmetry
- Offered traffic loading.

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 700 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 1-17

Link mode optimization

Link mode optimization allows the PTP 700 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 1-8
Effect of IP and TDM modes on link data throughput capacity	Calculating data rate capacity on page 3-26 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 6-22
Link mode optimization alarms	Alarms on page 7-17

Link symmetry

The PTP 700 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 700 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 700 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 700 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 700 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 700 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 700 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 700 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 700 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 700 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 1-14).
- 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 1-17
Effect of link symmetry on link data throughput capacity	Calculating data rate capacity on page 3-26 Data throughput capacity tables on page 3-70
How to configure link symmetry	Wireless Configuration page on page 6-22

Further reading

For information about...	Refer to...
Link range capability upgrade	Capability upgrades on page 1-50
Effect of link range on data throughput capacity	Calculating data rate capacity on page 3-26 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 6-22
Automatic detection of link range	ODU installation tones on page 6-108

OFDM and channel bandwidth

The PTP 700 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 3-20
How to plan for channel bandwidth	Channel bandwidth on page 3-22
Effect of channel bandwidth on link data throughput capacity	Calculating data rate capacity on page 3-26 Data throughput capacity tables on page 3-70
How to configure channel bandwidth	Wireless Configuration page on page 6-22
How to monitor channel bandwidth	Spectrum Management on page 7-26

Spectrum management

The spectrum management feature of the PTP 700 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 700 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 Expert and Spectrum Management pages always shows a statistical summary of all channel measurement. The mean and percentile values displayed for each channel are calculated over a 20 minute statistics window 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 700 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 7-26

Adaptive modulation

The PTP 700 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 700 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 700 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 1-23
Lowest TDM modulation mode	Lowest TDM modulation mode on page 1-34
Planning for adaptive modulation	Adaptive modulation on page 3-25
Effect of modulation mode on link data throughput capacity	Calculating data rate capacity on page 3-26 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 6-15 Wireless Configuration page on page 6-22 System Configuration page on page 6-30
Modulation mode when the ODU is armed	Checking that the units are armed on page 6-105
How to view the transmit and receive modulation modes	System Status page on page 7-3 System counters on page 7-53

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 700 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 700 will adapt between two modes of operation:

- **Dual Payload**: When the radio channel conditions allow, the PTP 700 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 700.
- **Single Payload**: As the radio channel becomes more challenging, the PTP 700 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 700 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 1-12.

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 6-22
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 7-13

Dynamic spectrum optimization

The PTP 700 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 700 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 1-16
Planning to use DSO	Frequency selection on page 3-22
How to configure DSO	Wireless Configuration page on page 6-22
Asymmetric DSO in non-radar regions	Spectrum Management Settings on page 7-33

Radar avoidance

In regions where protection of radars is part of the local regulations, the PTP 700 must detect interference from radar-like systems and avoid co-channel operation with these systems.

To meet this requirement, the PTP 700 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 1-15
Planning for mandatory radar detection	Frequency selection on page 3-22
Radar avoidance when aligning antennas	ODU installation tones on page 6-108
Effect of radar detection on spectrum management	Spectrum Expert page in radar avoidance mode on page 7-38

Encryption

The PTP 700 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 700 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 1-41
AES requirement for SNMPv3 security	User-based security model on page 1-44
Licensing AES encryption	AES license on page 1-47 Capability upgrades on page 1-50
Planning to use AES for HTTPS/TLS	Planning for HTTPS/TLS operation on page 3-50
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 6-90

License keys and regulatory bands

The PTP 700 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 700 provides a choice between the available bands. In each regulatory band, PTP 700 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 700 links to conform to the regulatory band restrictions	Radio spectrum planning on page 3-20
Radio regulations in the country of operation	Compliance with radio regulations on page 4-25
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 6-22
How to view the regulatory band	System Status page on page 7-3
Regulatory band alarms	Alarms on page 7-17

PTP networks

Using Dynamic Spectrum Optimization

The Dynamic Spectrum Optimization (DSO) feature allows a PTP 700 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 700 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 AC + DC Power Injector and the ODU, and is collocated with the AC + DC Power Injector.

Caution

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

The PTP 650 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.

PTP-SYNC is not compatible with standards-based power-over-Ethernet (PoE).

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 700 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 2-44
The GPS receiver	GPS receiver on page 2-50
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 3-15
Use of LINKPlanner for TDD synchronization	LINKPlanner for synchronized networks on page 3-25
TDD synchronization methods that may be implemented using PTP-SYNC	Configuration options for TDD synchronization on page 3-30
How to install a PTP-SYNC unit	Installing a PTP-SYNC unit on page 5-25
How to install an optional GPS receiver	Installing a GPS receiver on page 5-29
How to enable TDD synchronization	Wireless Configuration page on page 6-22
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 7-17
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 700 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 700 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 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 700 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 700 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 700 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 700 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 700 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 1-20

For information about...	Refer to...
A more detailed description of the Second Data Service	Second Data Service on page 1-21
A more detailed description of the Out-of-Band Management Service	Management Service on page 1-21
SFP optical or copper module kits	SFP module kits on page 2-41
The PSU, AUX and SFP ports of the ODU	ODU interfaces on page 2-12
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 3-34
How to install the Ethernet interfaces to the ODU	Installing the copper Cat5e Ethernet interface on page 5-15 Installing an SFP Ethernet interface on page 5-25 Installing an Aux Ethernet interface on page 5-54
How to configure the ODU Ethernet ports	Interface Configuration page on page 6-15 LAN Configuration page on page 6-34
Ethernet port status attributes	Ethernet / Internet on page 7-6
Ethernet port alarms	Alarms on page 7-17

Data network

Transparent Ethernet service

The PTP 700 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 700 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 700 Series does not generate or respond to any L2CP traffic.

Quality of service for bridged Ethernet traffic

The PTP 700 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 700 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 700 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 700 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 700 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 700 customer data networks	Data network planning on page 3-34
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 7-51

Second Data network

Transparent Ethernet service

The PTP 700 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 700 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 700 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 700 Series does not generate or respond to any L2CP traffic.

Quality of service for bridged Ethernet traffic

The PTP 700 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 700 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 700 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 700 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 700 customer data networks	Data network planning on page 3-34
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 7-51

Out-of-Band Management Service

Transparent Ethernet service

The PTP 700 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 700 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 700 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 700 Series does not generate or respond to any L2CP traffic.

Quality of service for bridged Ethernet traffic

The PTP 700 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 700 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 700 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 1-23.

Further reading

For information about...	Refer to...
Factors to be considered when planning PTP 700 management data networks	Data network planning on page 3-34
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 7-51

Ethernet loopback mode

PTP 700 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 700 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 700 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

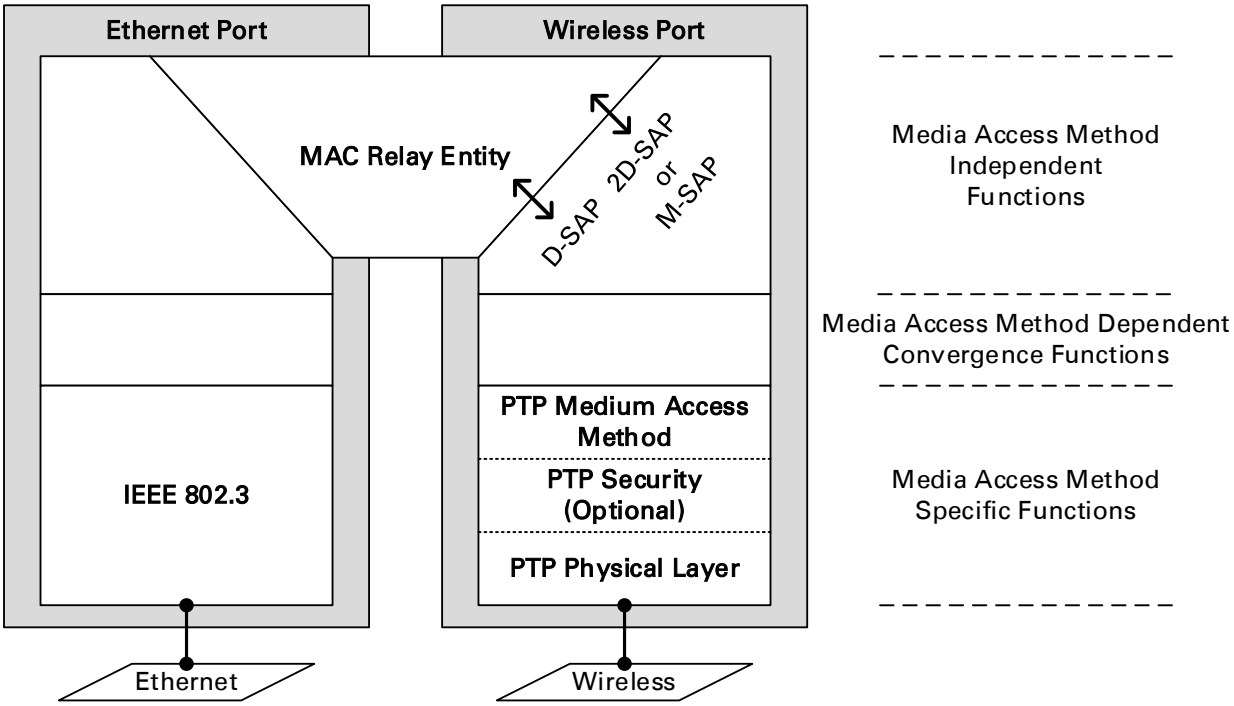
Ethernet bridging behavior at each end of the wireless link is equivalent to a two-port, managed, transparent MAC bridge where the two ports are a wired Ethernet port allocated to the Data Service, Second Data Service, Out-of-Band Management Service, and the Wireless port.

Frames are transmitted at the Wireless port over a proprietary point-to-point circuit-mode link layer between ends of the PTP 700 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.

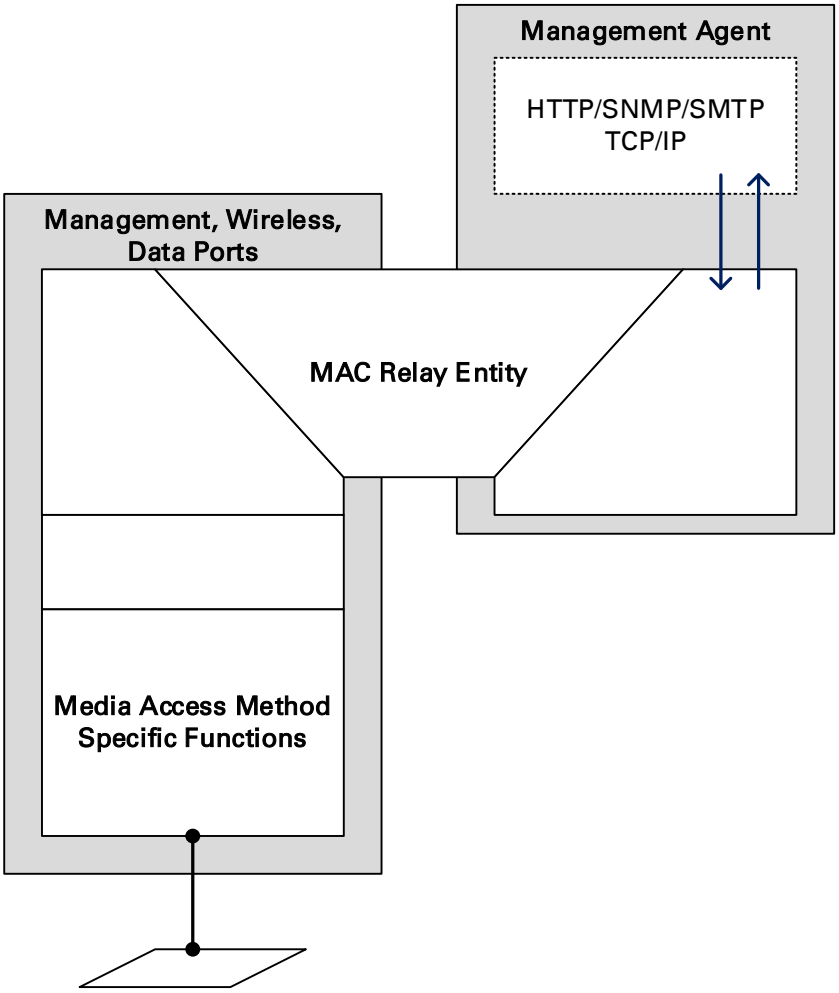
Protocol layers involved in bridging between Ethernet and wireless interfaces are shown in Figure 3. Protocol layers involved in bridging between external interfaces and the management agent are shown in Figure 4. In these figures, the layers have the meanings defined in IEEE 802.1Q-2005.

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 700	Layer two control protocols on page 3-34

Synchronous Ethernet

PTP 700 can be configured to relay a Synchronous Ethernet frequency reference across the wireless link, supporting operation as part of an ITU-T G.781 Synchronous Digital Hierarchy. A single PTP 700 link has at least two, and up to six, active Ethernet ports. When the link is synchronised to an external frequency reference, one of the Main PSU ports receives the reference (acting a Sync E slave port) and the remaining active ports transmit the frequency reference (acting as Sync E master ports).

In an established link, if the ODU detects a valid reference at the Main SFP port at the local end, or at the Main SFP port at the remote end, it relays the reference received at this port to all of the remaining Ethernet ports. If the ODU detects a valid reference at both ends of the link, it selects the best reference. If the ODU does not detect any valid reference at either end of the link, it operates in a free-running or holdover mode.

If the wireless link is down, the ODU configured as the TDD Master can relay the reference received at the Main PSU port to the remaining ports. The ODU configured as the TDD Slave does not forward the reference frequency until the link is established.

PTP 700 makes the selection of the best incoming reference based on the Quality Level (QL) in Synchronization Status Messages (SSMs) received at the nominated ports. SSMs are processed and transmitted as specified by ITU-T G.8264 and in Section 5 of G.781.

Note

PTP 700 does not support Synchronous Ethernet on a copper SFP module.

Further reading

For information about...	Refer to...
Relationship between synchronous Ethernet and TDM	TDM description on page 1-33
Availability of synchronous Ethernet	Capability upgrades on page 1-50
Relationship between synchronous Ethernet and Ethernet port allocation	Additional port allocation rules on page 3-43
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 7-10
Synchronous Ethernet alarms	Alarms on page 7-17
Synchronous Ethernet status	SyncE Status page on page 7-61

IEEE 1588-2008 Transparent Clock

PTP 700 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 700 uses the Synchronous Ethernet clock to increase the accuracy of 1588 residence time measurements.

Note

PTP 700 does not support IEEE 1588 Transparent Clock on a copper SFP module.

Further reading

For information about...	Refer to...
Relationship between IEEE 1588-2008 Transparent Clock and TDM	TDM description on page 1-33
Availability of IEEE 1588-2008 Transparent Clock	Capability upgrades on page 1-50
Relationship between IEEE 1588-2008 Transparent Clock and Ethernet port allocation	Additional port allocation rules on page 3-43
Relationship between IEEE 1588-2008 Transparent Clock and VLAN membership	VLAN membership on page 3-44
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 7-10
IEEE 1588-2008 Transparent Clock alarms	Alarms on page 7-17

TDM bridging

This section describes how TDM traffic (E1 or T1) may be carried over PTP 700 links.

If a NIDU is installed at each link end, the PTP 700 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 700 Series bridges up to eight E1 or T1 telecoms circuits over a single-hop PTP 700 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 700 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 700 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 700 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 700 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 700 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 Expert or Spectrum Management pages, 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 2-52
A typical E1 or T1 site deployment	E1 or T1 interfaces on page 3-5
Where to locate the NIDU	NIDU location on page 3-16
TDM interface specifications	Ethernet interfaces on page 3-34
The effect of TDM on data throughput	TDM traffic load on page 3-113
How to install TDM hardware	Installing a NIDU on page 5-39
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 6-12
How to enable E1 or T1 and configure TDM channels (part of the Installation Wizard)	Interface Configuration page on page 6-15
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 6-70
The meaning of TDM status attributes	System Status page on page 7-3
The meaning of TDM alarms	Alarms on page 7-17
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 166) Alternatively, use LINKPlanner

System management

This section introduces the PTP 700 management system, including the web interface, installation, configuration, alerts and upgrades.

Management agent

PTP 700 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 1-37.

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 700 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 700 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 700 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 700 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 3-44
How to configure the IP interface	Interface Configuration page on page 6-15
How to configure the target MAC address	Wireless Configuration page on page 6-22
Planning VLAN membership	VLAN membership on page 3-44
How to configure VLAN for the management interface	Interface Configuration page on page 6-15 LAN Configuration page on page 6-34
Planning the Ethernet and IP (DSCP) priority	Priority for management traffic on page 3-44
Planning the use of Ethernet ports for customer and management traffic	Additional port allocation rules on page 3-43

IPv6

The PTP 700 management agent supports the following IPv6 features:

Neighbor discovery

PTP 700 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 700 sends router solicitations, but does not process router advertisements.

Path MTU discovery and packet size

PTP 700 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 700 supports ICMPv6 as specified in RFC 4443. PTP 700 does not support RFC 4884 (multi-part messages).

Addressing

The PTP 700 management agent is compatible with the IPv6 addressing architecture specified in RFC 4291. PTP 700 allows static configuration of the following:

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

PTP 700 additionally assigns an automatically configured Link Local address using stateless address auto-configuration (SLAAC) as specified in RFC 4862. PTP 700 does not assign a global unicast IP address using SLAAC.

PTP 700 responds on the standard management agent interfaces (HTTP, HTTPS, syslog, Telnet, SNMP, SMTP, SNTP) using the global unicast address.

Privacy extensions

PTP 700 does not support the privacy extensions specified in RFC 4941.

DHCPv6

PTP 700 does not support address assignment using DHCPv6. The address of the management agent must be configured statically.

Multicast listener discovery for IPv6

The PTP 700 management agent supports Multicast Listener Discovery version 1 (MLDv1) as specified in RFC 2710.

PTP 700 does not support Multicast Listener Discovery version 2 (MLDv2).

Textual representation of IPv6 addresses

PTP 700 allows users to input text-based IP addresses in any valid format defined in RFC 5952. IPv6 addresses are automatically converted by PTP 700 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 700 does not support IP security (IPsec).

Further reading

For information about...	Refer to...
Planning the IPv6 interface	IP interface on page 3-44
How to enable IPv6 capability	Software License Key page on page 6-12
How to configure IPv6	Interface Configuration page on page 6-15 LAN Configuration page on page 6-34

Web server

The PTP 700 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 700 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 700.

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 700.
- **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 700 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 700 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 700 unit. PTP 700 supports certificates with 2048-bit key size.

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

Note

The PTP 700 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 700 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 700 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 700 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 700 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 700 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 is automatically and permanently disabled in the FIPS 140-2 mode.

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 3-50
How to configure user accounts	Local User Accounts page on page 6-60

RADIUS authentication

PTP 700 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 700 supports connections to primary and secondary RADIUS servers. The RADIUS interface is configured through the RADIUS Authentication page of the web-based interfaces.

PTP 700 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 700 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 700 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 3-56
How to configure RADIUS.	RADIUS Configuration page on page 6-65

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 700 Series proprietary MIB.

Further reading

For information about...	Refer to...
How to plan for SNMPv1/2c	Planning for SNMP operation on page 3-48
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 6-98
How to configure SNMPv1 or SNMPv2c	SNMP pages (for SNMPv1/2c) on page 6-86
How to upgrade software remotely using Trivial FTP (TFTP) triggered by SNMP	Upgrading software using TFTP on page 6-114

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 700 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 3-50
How to configure SNTP	Time Configuration page on page 6-71

SNMPv3 security

SNMP Engine ID

PTP 700 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 700 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 700 AES upgrade described in AES license on page 1-47.

View-based access control model

PTP 700 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 700. 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 700 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 700 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 3-54.

PTP 700 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 1-44. 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 700 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 700 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 3-51
How to configure SNMPv3	SNMP pages (for SNMPv3) on page 6-77

System logging (syslog)

PTP 700 supports the standard syslog protocol to log important configuration changes, status changes and events. The protocol complies with RFC 3164.

PTP 700 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 700 additionally creates syslog messages for changes in any status variable displayed in the web-based interface.

PTP 700 creates syslog messages on a number of events (for example successful and unsuccessful attempts to log in to the web-based interface).

PTP 700 can be configured to send syslog messages to one or two standard syslog servers.

Additionally, PTP 700 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 6-75
Syslog alarms	Alarms on page 7-17
How to view the local log of event messages	Syslog page on page 7-22
How to interpret syslog messages	Format of syslog server messages on page 7-22

AES license

PTP 700 provides optional encryption using the Advanced Encryption Standard (AES). Encryption is not available in the standard PTP 700 system.

AES upgrades are purchased from your Cambium Point-to-Point distributor or solutions provider. The upgrade authorizes AES operation for one ODU. Two upgrades 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.

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 700 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 700 license key.

Further reading

For information about...	Refer to...
Capability upgrades for AES	Capability upgrades on page 1-50
AES and HTTPS/TLS operation	Planning for HTTPS/TLS operation on page 3-50
AES and SNMPv3 operation	Planning for SNMPv3 operation on page 3-51
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 6-12
How to configure AES encryption	System Configuration page on page 6-30
How to configure security with AES	Security menu on page 6-90

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 6-101
How to zeroise CSPs (recovery mode)	Zeroize Critical Security Parameters on page 7-71

Software upgrade

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

PTP 700 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 6-54
How to upgrade software remotely using Trivial FTP (TFTP) triggered by SNMP	Upgrading software using TFTP on page 6-114

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 an Entitlement Certificate, delivered by email. One Entitlement Certificate can deliver multiple upgrades. Follow the instructions in the certificate to redeem the purchased upgrade products at the Cambium Support Center.

Individual upgrades can then be activated by specifying the MAC address of a PTP 700 ODU. For each upgrade activated, the Support Center creates a new license key and delivers it by email. Install the license key using the ODU web interface to enable the purchased capability in the ODU.

Note

License keys are bound to a single ODU and are not transferrable.

Further reading

For information about...	Refer to...
Capabilities of the PTP 700 Connectorized ODU	PTP 700 Connectorized ODU on page 2-3
Capabilities of the PTP 700 Connectorized+Integrated ODU	PTP 700 Connectorized+Integrated ODU on page 2-5
Ordering capability upgrades	ODU capability upgrades on page 2-8
How to obtain License Keys	Generating license keys on page 6-3
How to install capability upgrades	Software License Key page on page 6-12

Full capability trial period

A full capability trial period is available for PTP 700 units that are licensed for “Lite” (up to 225 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 capability afterwards. The trial period can be started, paused and resumed from the web interface.

Further reading

For information about...	Refer to...
How to control the trial period	Software License Key page on page 6-12

Recovery mode

The PTP 700 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

FIPS 140-2 mode

This section describes the (optional) FIPS 140-2 cryptographic mode of operation.

PTP 700 provides an optional secure cryptographic mode of operation validated to Level 2 of Federal Information Processing Standards (FIPS) Publication 140-2.

FIPS 140-2 approved mode

PTP 700 operates in the FIPS 140-2 approved mode whenever a validated version of the special FIPS software is installed in the PTP 700 ODU.

Caution

Use the following NIST web site to confirm that the FIPS software has been validated:

http://csrc.nist.gov/groups/STM/cmvp/documents/140-1/140val-all.htm

The special FIPS software image can be identified by a `FIPS-` prefix to the filename, for example: `FIPS-PTP700-01-00.DLD2`.

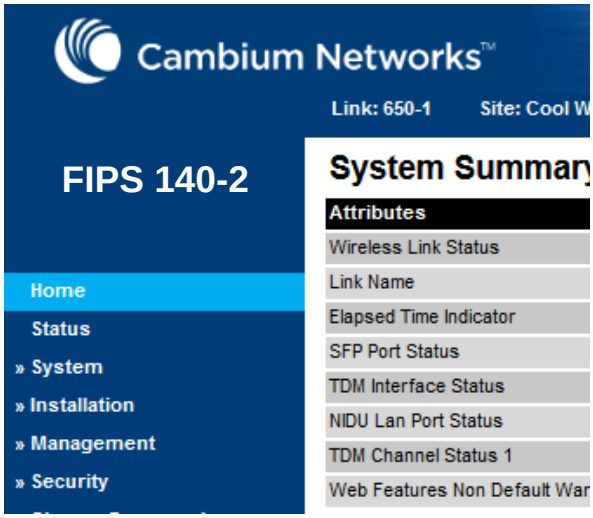
Note

PTP 700 will not upload the FIPS software unless the unit is licensed for 128-bit or 256-bit AES encryption and for FIPS operation.

Indication of FIPS 140-2 approved mode

The FIPS 140-2 approved mode is indicated by the "FIPS 140-2" text displayed at the top of the navigation bar in the web-based interface, as shown in Figure 5.

Figure 5 Indication of FIPS 140-2 capability



Enforced configuration in FIPS approved mode

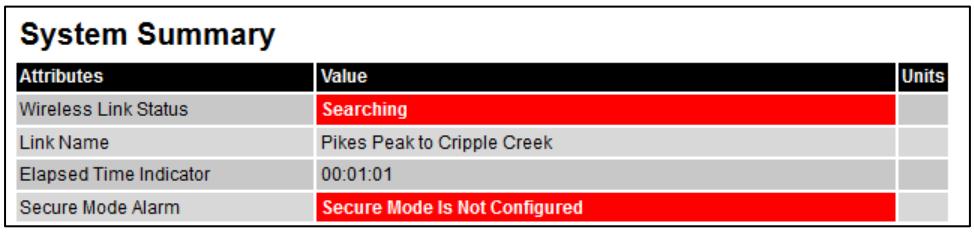
When the PTP 700 ODU operates in the FIPS approved mode, the following configuration settings are automatically enforced:

- Identity-based user accounts is Enabled.
- Telnet management interface is Disabled.
- SNMP control of HTTP and Telnet is Disabled.
- SNMP control of passwords is Disabled.
- TFTP client is Disabled.

Secure mode alarm

The Secure mode alarm indicates that the unit is operating in the FIPS approved mode, but that it has not been configured correctly for FIPS 140-2 operation. The secure mode alarm appears in the System Summary page as shown in Figure 6.

Figure 6 Secure mode alarm in the System Summary page

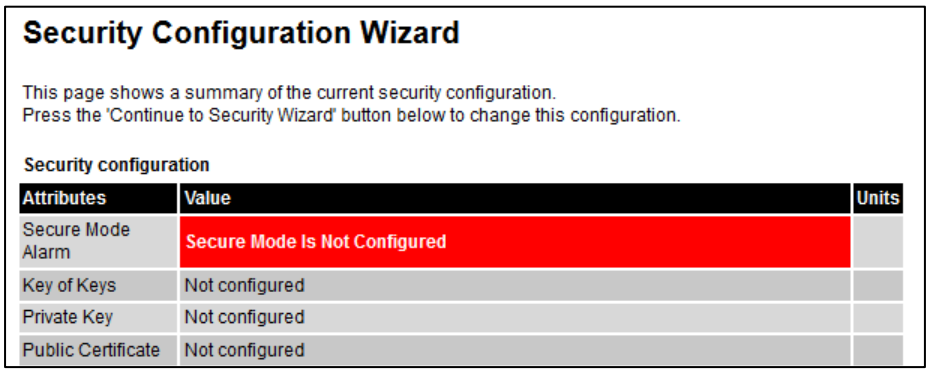


System Summary

Attributes	Value	Units
Wireless Link Status	Searching	
Link Name	Pikes Peak to Cripple Creek	
Elapsed Time Indicator	00:01:01	
Secure Mode Alarm	Secure Mode Is Not Configured	

The Secure mode alarm is also displayed in the first page of the Security Wizard as shown in Figure 7.

Figure 7 Secure mode alarm in the Security Wizard



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
Secure Mode Alarm	Secure Mode Is Not Configured	
Key of Keys	Not configured	
Private Key	Not configured	
Public Certificate	Not configured	

Security configuration for FIPS approved mode

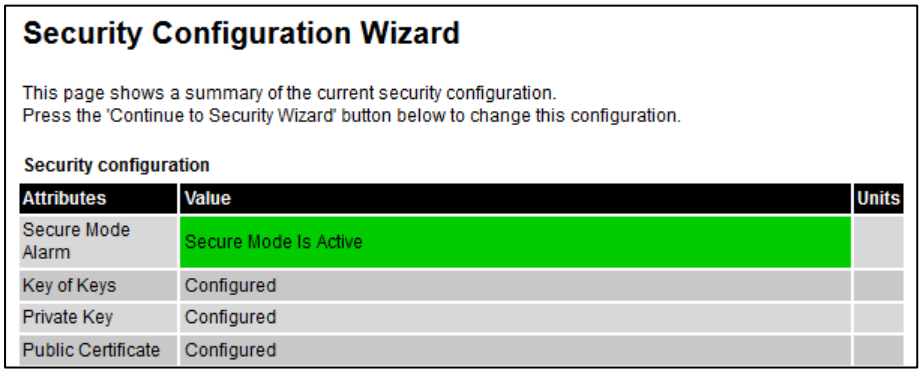
The security configuration for the FIPS approved mode consists of the following:

- The HTTPS/TLS management interface must be correctly configured, including:
  - Key of keys (128-bit or 256-bit to match the AES license)
  - Entropy (512-bit)
  - Private key (2048-bit RSA key size)

  - Public key certificate (2048-bit RSA key size, signed using SHA-256 Secure Hash Algorithm)
- The HTTP management interface must be Disabled
- AES encryption must be configured and enabled at the wireless interface.

When the security configuration is completed correctly, the Secure mode alarm is cleared from the System Summary page and the Security Wizard displays the Active state as shown in Figure 8.

Figure 8 Secure mode active



Further reading

For information about...	Refer to...
Cryptographic material needed for FIPS operation	Planning for FIPS 140-2 operation on page 3-57
Installing license keys	Software License Key page on page 6-12
Loading software images	Software Upgrade page on page 6-55
Configuring the ODU for FIPS operation	Configuring security for FIPS 140-2 applications on page 6-102

Exiting from the FIPS operational state

A PTP 700 ODU in the FIPS operation state can be prepared to accept new security configuration by zeroizing critical security parameters (CSPs). The unit remains in the FIPS approved mode.

Further reading

For information about...	Refer to...
Zeroizing the CSPs	Zeroize CSPs page on page 6-101

Reverting to the standard (non-FIPS) mode

A FIPS 140-2 capable ODU can be used in standard (non-FIPS) mode by loading a standard (non-FIPS) software image and rebooting.

The critical security parameters (CSPs) are zeroized when the unit is no longer FIPS 140-2 capable.

Further reading

For information about...	Refer to...
Exiting the FIPS approved mode	Managing security on page 7-50

Chapter 2: System hardware

This chapter describes the hardware components of a PTP 700 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.

Hardware platform variants

PTP 700 ODUs are available in two different hardware platform variants:

- PTP 700 Connectorized ODU
- PTP 700 Connectorized+Integrated ODU

Regional variants

Each of the PTP 700 hardware platform variants is available in three different regional variants.

The regional variants are supplied with default country licenses as follows:

- FCC: "USA" country license with regulatory bands:
  - 1 "5.8 GHz FCC"
  - 12 "5.4 GHz FCC U-NII 2C (no weather radar)"
  - 14 "4.9 GHz Public Safety, USA/Canada"
  - 38 "5.2 GHz FCC U-NII 2A"
  - 82 "4.7 GHz NTIA"
  - 84 "5.1 GHz FCC U-NII 1"
- Global: "Other" country license with regulatory bands:
  - 8 "5.4 GHz unrestricted"
  - 35 "5.8 GHz unrestricted"
  - 61 "4.9 GHz unrestricted"
  - 62 "5.2 GHz unrestricted"
  - 81 "4.7 GHz NATO Band IV"
- EU: "EU" country license with regulatory band:
  - 26 "5.4 GHz ETSI"
- IC: "Canada" country license with regulatory bands:
  - 1 "5.8 GHz FCC"
  - 13 "5.4 GHz FCC U-NII 2C"
  - 14 "4.9 GHz Public Safety, USA/Canada"
  - 38 "5.2 GHz FCC U-NII 2A"

For details of how to configure the ODUs to operate with other country licenses, refer to Generating license keys on page 6-3 and Software License Key page on page 6-12. The list of available countries depends upon the regional variant. The list of available regulatory bands depends on the country.

Capacity variants

Many of the PTP 700 ODU variants are available with the Lite or Full capacity license. ODUs licensed for Lite capacity can be licensed for the Full capacity by purchase of an upgrade (see ODU capability upgrades on page 2-8).

PTP 700 Connectorized ODU

The PTP 700 Connectorized ODU is intended to work with separately mounted external antennas (Figure 9). External antennas generally have higher gains than the integrated antennas, allowing the PTP 700 to cope with more difficult radio conditions.

Figure 9 PTP 700 Connectorized ODU (front and rear views)

Note

To determine when to install external antennas and to calculate their impact on link performance and regulatory limits, see Planning for connectorized units on page 3-28.

To select antennas, RF cables and connectors for connectorized units, see Antennas and antenna cabling on page 2-18.

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 3-28.

Pour sélectionner les antennes, câbles et connecteurs RF pour les liaisons radiofréquence sans antenne intégrée, voir Antennas and antenna cabling page 2-18.

Capacity and capability licensing

PTP 700 ODUs are available with "Lite" data throughput capability (up to 225 Mbps) or "Full" data throughput capability (up to 450 Mbps). ODUs additionally support the following capability upgrades (see ODU capability upgrades on page 2-8):

- Data throughput above 225 Mbps
- SFP port operation
- AES encryption
- Synchronous Ethernet and 1588 Transparent Clock
- TDM (E1 or T1) operation
- Group access

Full capability trial period

A full capability trial period is available for PTP 700 ODUs that are licensed for "Lite" (up to 225 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 capability afterwards. The trial period can be started, paused and resumed from the web interface (Software License Key page on page 6-12).

Individual ODU part numbers

Order PTP 700 Connectorized ODUs from Cambium Networks (Table 4). Each of the parts listed in Table 4 includes the following items:

- One Connectorized ODU
- One connectorized ODU mounting bracket (Figure 11).

Table 2 PTP 700 Connectorized individual ODU part numbers

Cambium description	Cambium part number
PTP 700 Connectorized ODU (FCC)	C045070B001
PTP 700 Connectorized ODU (Global)	C045070B003
PTP 700 Connectorized ODU (EU)	C045070B005

Cambium description	Cambium part number
PTP 700 Connectorized ODU (IC)	C045070B025
PTP 700 Lite Connectorized ODU (FCC)	C045070B007
PTP 700 Lite Connectorized ODU (Global)	C045070B009
PTP 700 Lite Connectorized ODU (EU)	C045070B011
PTP 700 Lite Connectorized ODU (IC)	C045070B027

ODU kit part numbers

Order PTP 700 Connectorized ODU kits from Cambium Networks (Table 5).

Each of the parts listed in Table 5 includes the following items:

- One Connectorized ODU
- One AC+DC Power Injector PSU.
- One line cord, either US or EU as indicated.

The PTP 700 Connectorized ODU already includes the connectorized bracket, so this is not included separately in the kit.

Table 3 ODU kit part numbers for Connectorized ODUs

Cambium description	Cambium part number
PTP 700 Connectorized END (FCC)	C045070H001
PTP 700 Connectorized END - US Line Cord (Global)	C045070H004
PTP 700 Connectorized END - EU Line Cord (Global)	C045070H007
PTP 700 Connectorized END (EU)	C045070H010
PTP 700 Connectorized END (IC)	C045070H015
PTP 700 Lite Connectorized END - US Line Cord (Global)	C045070H013

PTP 700 Connectorized+Integrated ODU

The PTP 700 Connectorized+Integrated ODU provides a choice between using external antennas, similar to the Connectorized ODU, or a 22 dBi integrated antenna (Figure 10). The integrated antenna offers a convenient and easily-deployed solution where the additional gain of external antennas is not needed.

Figure 10 PTP 700 Connectorized+Integrated ODU (front and rear views)

Note

To determine when to install external antennas and to calculate their impact on link performance and regulatory limits, see Planning for connectorized units on page 3-28.

To select antennas, RF cables and connectors for connectorized units, see Antennas and antenna cabling on page 2-18.

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 3-28.

Pour sélectionner les antennes, câbles et connecteurs RF pour les liaisons radiofréquence sans antenne intégrée, voir Antennas and antenna cabling page 2-18.

Capacity and capability licensing

PTP 700 ODUs are available with "Lite" data throughput capability (up to 225 Mbps) or "Full" data throughput capability (up to 450 Mbps). ODUs additionally support the following capability upgrades (see ODU capability upgrades on page 2-8):

- Data throughput above 225 Mbps
- SFP port operation
- AES encryption
- Synchronous Ethernet and 1588 Transparent Clock
- TDM (E1 or T1) operation
- Group access

Full capability trial period

A full capability trial period is available for PTP 700 ODUs that are licensed for "Lite" (up to 225 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 capability afterwards. The trial period can be started, paused and resumed from the web interface (Software License Key page on page 6-12).

Individual ODU part numbers

Order PTP 700 Connectorized+Integrated ODUs from Cambium Networks (Table 4). Each of the parts listed in Table 4 includes the following items:

- One Connectorized+Integrated ODU.

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

Table 4 PTP 700 Connectorized+Integrated individual ODU part numbers

Cambium description	Cambium part number
PTP 700 Connectorized+Integrated ODU (FCC)	C045070B002
PTP 700 Connectorized+Integrated ODU (Global)	C045070B004
PTP 700 Connectorized+Integrated ODU (EU)	C045070B006
PTP 700 Connectorized+Integrated ODU (IC)	C045070B026
PTP 700 Lite Connectorized+Integrated ODU (FCC)	C045070B008
PTP 700 Lite Connectorized+Integrated ODU (Global)	C045070B010
PTP 700 Lite Connectorized+Integrated ODU (EU)	C045070B012
PTP 700 Lite Connectorized+Integrated ODU (IC)	C045070B028

ODU kit part numbers

Order PTP 700 Connectorized+Integrated ODU kits from Cambium Networks (Table 5).

Each of the parts listed in Table 5 includes the following items:

- One Connectorized+Integrated ODU.
- One integrated ODU mounting bracket (Figure 11).
- One AC+DC Power Injector PSU.
- One line cord, either US or EU as indicated.

Table 5 ODU kit part numbers for Connectorized+Integrated ODUs

Cambium description	Cambium part number
PTP 700 Connectorized+Integrated END (FCC)	C045070H002
PTP 700 Connectorized+Integrated END - US Line Cord (Global)	C045070H005
PTP 700 Connectorized+Integrated END - EU Line Cord (Global)	C045070H008
PTP 700 Connectorized+Integrated END (EU)	C045070H011
PTP 700 Connectorized+Integrated END (IC)	C045070H016
PTP 700 Lite Connectorized+Integrated END - US Line Cord (Global)	C045070H014

ODU capability upgrades

To upgrade a PTP 700 ODU to one or more new capabilities, order the necessary upgrades from Cambium Networks (Table 6). 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 6-12.

Table 6 Capability upgrades available for PTP 700 Series ODUs

Cambium description (*1)	Part number
PTP 700 128-bit AES Encryption – per END (*2)	C000070K001A
PTP 700 256-bit AES Encryption – per END (*2)	C000070K002A
PTP 700 Precise Network Timing Software License - per END	C000070K003A
PTP 700 Group Access Software License - per END	C000070K004A
PTP 700 FIPS 140-2 Upgrade including 128-bit AES - per END	C000070K005A
PTP 700 FIPS 140-2 Upgrade including 256-bit AES - per END	C000070K006A
PTP 700 Lite to Full Upgrade - per END	C000070K008A
8-Port T1/E1 Software License (per END).	C000065K049A

(*1) 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.

ODU accessories

Spare ODU port blanking plugs are available from Cambium Networks (Table 7).

Table 7 ODU accessory part numbers

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

ODU mounting brackets

The integrated mounting bracket (Figure 11) and connectorized mounting bracket (Figure 12) are used to mount the PTP 700 ODUs on poles with diameters in the range 50 to 75 mm (2 to 3 inches). The extended integrated mounting bracket (Figure 13) is used for mounting an 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 14) is be used with the integrated bracket to mount an ODU on a pole with diameter up to 229 mm (9.0 inches).

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

- Individual Connectorized+Integrated ODUs are supplied without a mounting bracket (Table 4).
- Individual Connectorized ODUs are supplied with a connectorized mounting bracket (Table 4).
- ODUs in kits are supplied with an integrated or connectorized bracket, as appropriate (Table 5).

If separate ODU mounting brackets are required, order them from Cambium Networks (Table 8).

Figure 11 ODU mounting bracket (integrated)

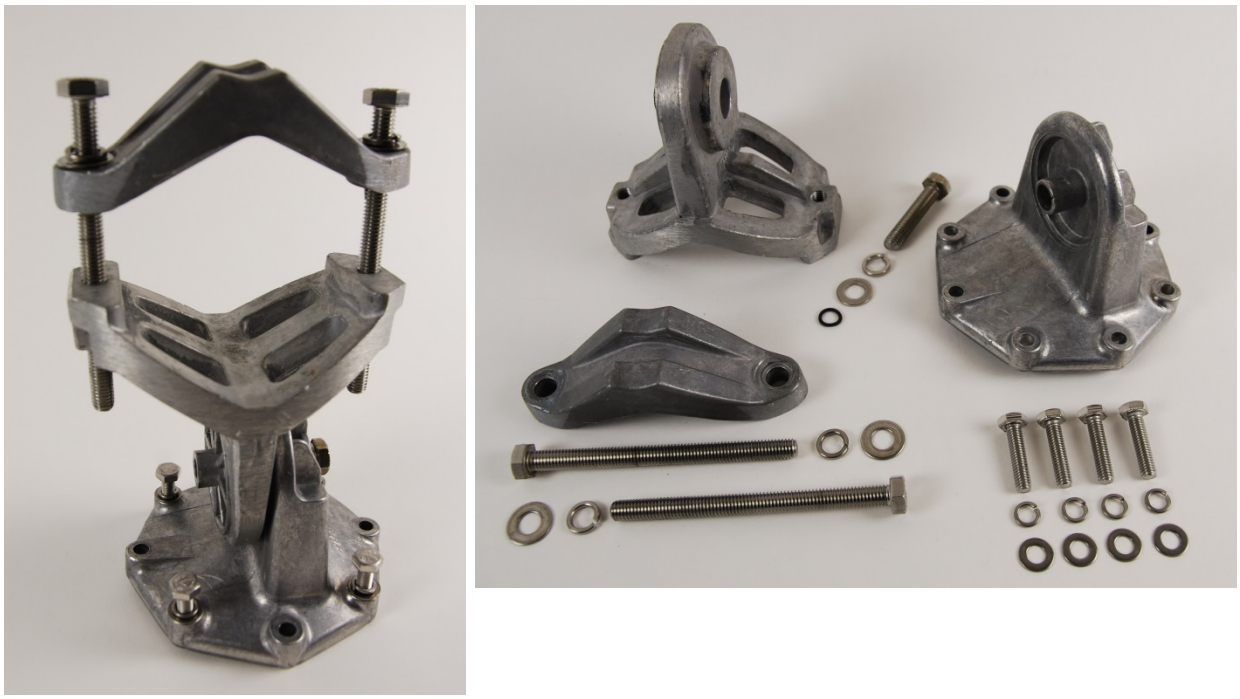


Figure 12 ODU mounting bracket (connectorized)

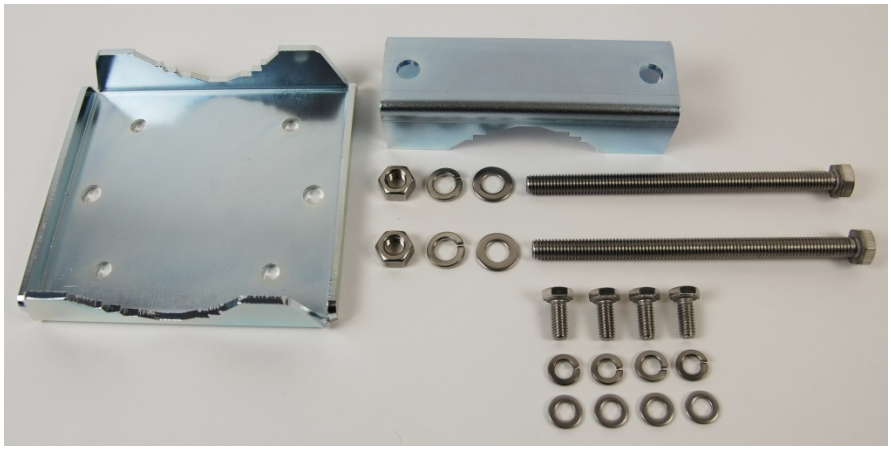


Figure 13 ODU extended integrated mounting bracket

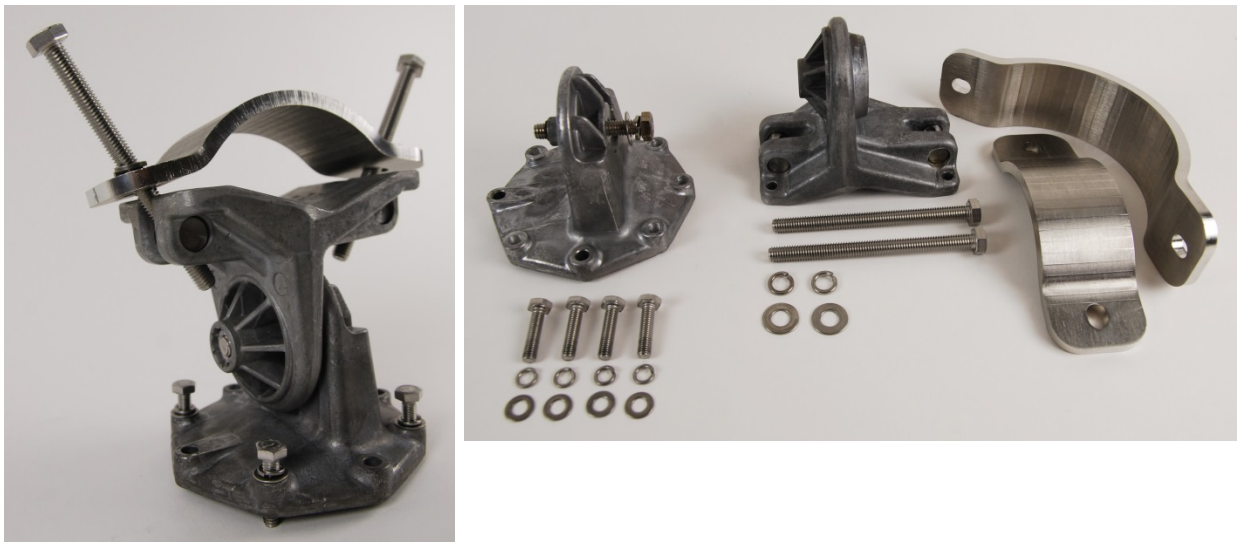


Figure 14 ODU large diameter extension kit

Table 8 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 700 Connectoized+Integrated	N000065L031
Mounting bracket (connectorized)	40 mm to 82 mm (1.6 inches to 3.2 inches)	PTP 700 Connectorized PTP 700 Connectoized+Integrated	N000065L032
Extended integrated mounting bracket	89 mm *OR* 114 mm (3.5 inches *OR* 4.5 inches)	PTP 700 Connectorized PTP 700 Connectoized+Integrated	N000065L030
Mounting bracket (integrated) with large	89 mm to 229 mm (3.5 inches to 9.0	PTP 700 Connectorized PTP 700	N000065L031 with

Bracket	Pole diameter	ODU variants	Bracket part number
diameter extension kit	inches)	Connectoized+Integrated	N000065L042

ODU interfaces

The PSU, AUX and SFP ports are on the rear of the ODUs (Figure 15). These interfaces are described in Table 9. 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 15 ODU rear interfaces

Table 9 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 16) provides N type female connectors for RF cable interfaces to antennas with horizontal (H) and vertical (V) polarization.

Figure 16 Connectorized ODU antenna interfaces

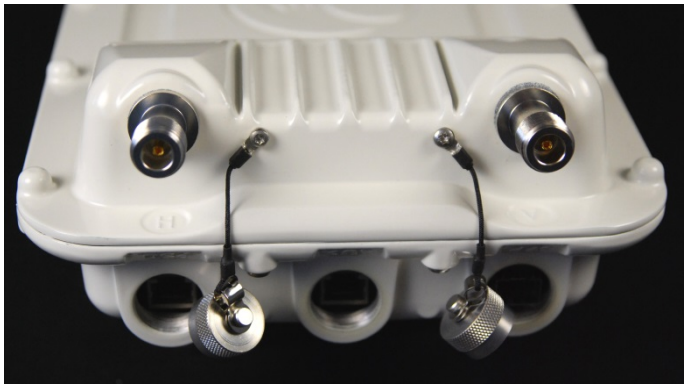


Figure 17 Connectorized+Integrated ODU antenna interfaces

ODU specifications

The PTP 700 ODU conforms to the specifications listed in Table 10.

Table 10 ODU specifications

Category	Specification
Dimensions	Connectorized+Integrated: 371 mm (14.6 in) x 430 mm (16.9 in) x 98 mm (3.9 in) Connectorized: 204 mm (8.0 in) x 318 mm (12.5 in) x 98 mm (3.9 in)
Weight	Connectorized+Integrated: 4.1 kg (9.0 lbs) excluding bracket Connectorized: 3.1 Kg (6.8 lbs) including bracket

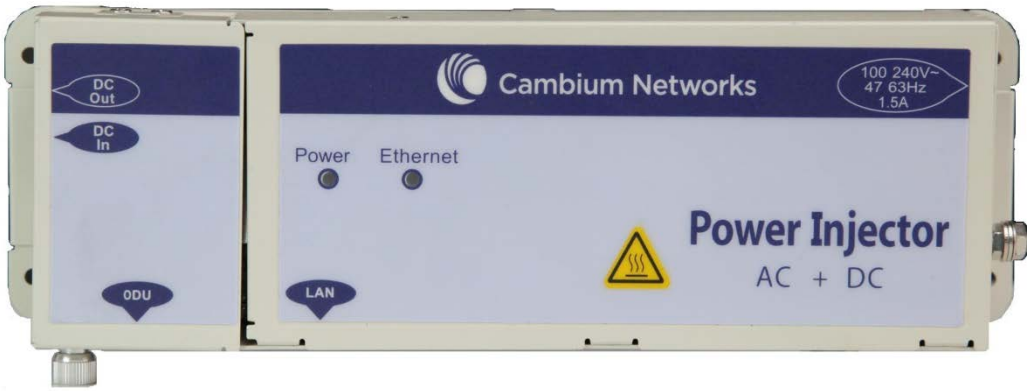
Temperature	-40°C (-40°F) to +60°C (140°F)
Wind loading	200 mph (323 kph) maximum. See ODU wind loading on page 3-14.
Humidity	100% condensing
Liquid and particle ingress	IP66, IP67
UV exposure	10 year operational life (UL746C test evidence)
Static discharge	See Electromagnetic compatibility (EMC) compliance on page 4-20

Power supply units (PSU)

PSU description

The AC+DC Power Injector 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 18):

Figure 18 AC+DC Power Injector



Caution

The PSU ODU ports are designed to connect only to PTP 700 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 700 ODU or LPU.

Note

Each of the ODU kits listed in Table 5 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 11).

Table 11 Power supply component part numbers

Cambium description	Cambium part number
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+DC Enhanced Power Injector interfaces

The AC+DC Enhanced Power Injector interfaces are shown in Figure 19 and described in Table 12.

Figure 19 AC+DC Enhanced Power Injector interfaces

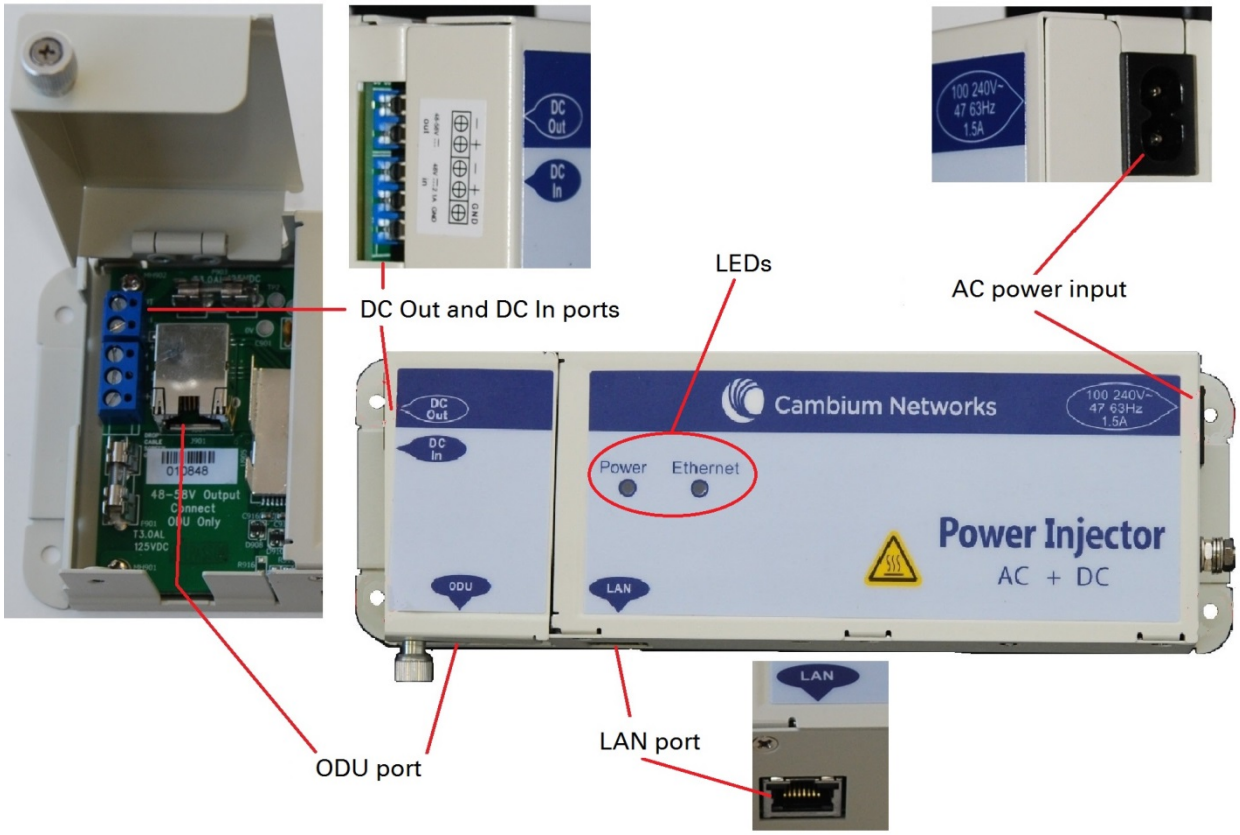


Table 12 AC+DC Enhanced Power Injector interface functions

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 AC+DC Enhanced Power Injector conforms to the specifications listed in Table 13.

Table 13 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 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 approved antennas on page 2-19. Do not install any other antennas.

For connectorized units operating in the Canada 4.9 GHz, 5.2 GHz, 5.4 GHz or 5.8 GHz bands, choose external antennas from those listed in IC approved antennas on page 2-27. 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 3-28.

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 14).

Table 14 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 on page 2-38 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 700 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 approved antennas

For connectorized units operating in the USA, choose external antennas from Table 15 (4.9 GHz), Table 16 (5.1 GHz), Table 17 (5.2 GHz), Table 18 (5.4 GHz) or Table 19 (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 – 37.2 dBi per polarization or antenna.
- 5.1 GHz – 34.5 dBi per polarization or antenna.
- 5.2 GHz – 34.5 dBi per polarization or antenna.
- 5.4 GHz – 28.5 dBi per polarization or antenna.
- 5.8 GHz – 37.7 dBi per polarization or antenna.

Caution

Antennas not included in these tables are strictly prohibited for use with the PTP 700 in the specified bands.

Table 15 Antennas permitted for deployment in USA – 4.9 GHz

Manufacturer	Antenna type	Nominal gain (dBi)	Cambium part number
Radio Waves	6-foot Parabolic, SP6-5.2	36.1	
Radio Waves	6-foot Dual-Pol Parabolic, SPD6-4.7	36.0	RDH4502
Radio Waves	6-foot Parabolic, SP6-4.7	36.0	
Radio Waves	6-foot Dual-Pol Parabolic, HPD6-4.7	35.8	RDH4515
Radio Waves	6-foot Dual-Pol Parabolic, SPD6-5.2	35.7	RDH4506
Radio Waves	6-foot Dual-Pol Parabolic, HPD6-5.2NS	35.6	RDH4511
Radio Waves	4-foot Dual-Pol Parabolic, SPD4-4.7	33.0	RDH4501
Radio Waves	4-foot Parabolic, SP4-4.7	33.0	N000000D002
Radio Waves	4-foot Parabolic, SP4-5.2	32.9	

Manufacturer	Antenna type	Nominal gain (dBi)	Cambium part number
Radio Waves	4-foot Dual-Pol Parabolic, HPD4-5.2NS	32.8	RDH4510
Radio Waves	4-foot Dual-Pol Parabolic, HPD4-4.7	32.8	RDH4516
Radio Waves	4-foot Dual-Pol Parabolic, SPD4-5.2	32.7	RDH4505
Radio Waves	3-foot Dual-Pol Parabolic, SPD3-4.7	30.4	RDH4500
Radio Waves	3-foot Parabolic, SP3-4.7	30.4	N000000D005
Radio Waves	3-foot Dual-Pol Parabolic, HPD3-4.7	30.2	RDH4517
Gabriel	Gabriel2.5-foot Standard Dual QuickFire Parabolic, QFD2.5-49-N	29.7	
Gabriel	Gabriel2.5-foot Standard QuickFire Parabolic, QF2.5-49-N	29.7	
Radio Waves	3-foot Parabolic, SP3-5.2	29.6	RDH4513
Radio Waves	3-foot Dual-Pol Parabolic, HPD3-5.2NS	29.4	RDH4509
Radio Waves	3-foot Dual-Pol Parabolic, SPD3-5.2	29.4	RDH4504
MTI	2-foot Dual-Pol, MT-486013/N	28.5	
MTI	2-foot Single-Pol, MT-466009/N	28.0	
Gabriel	2-foot Standard Dual QuickFire Parabolic, QFD2-49-N	27.7	
Gabriel	2-foot Standard QuickFire Parabolic, QF2-49-N	27.7	
Radio Waves	2-foot Parabolic, SP2-5.2	27.1	
Radio Waves	2-foot Dual-Pol Parabolic, SPD2-4.7	27.0	RDH4499
Radio Waves	2-foot Dual-Pol Parabolic, HPD2-5.2NS	26.9	RDH4508
Radio Waves	2-foot Parabolic, SP2-4.7	26.9	N000000D001
Radio Waves	2-foot Dual-Pol Parabolic, HPD2-4.7	26.8	RDH4518
Radio Waves	2-foot Dual-Pol Parabolic, SPD2-5.2	26.3	RDH4503
MARS	MA-WS54-50R Flat Plate (Dual-Pol)	23	Integrated
Radio Waves	1-foot Dual-Pol Parabolic, HPLPD1-4.7	20.8	RDH4519
MARS	Small Form Factor Flat Plate Antenna MA-EM56-DP19CM.	19.0	Integrated
Laird	60 Sectorized (Dual-Pol)	17.0	
Laird	90 Sectorized (Dual-Pol)	17.0	
Radio Waves	90 Sectorized (Dual-Pol), SEC-47D-90-16	16.4	N000000D003
KPPA	KPPA-5.7-DPOMA OMNI (Dual-Pol)	13	

Manufacturer	Antenna type	Nominal gain (dBi)	Cambium part number
Radio Waves	Omni Dual-Pol, OMND-4.8-9	9.0	

Table 16 Antennas permitted for deployment in USA – 5.1 GHz

Manufacturer	Antenna type	Nominal gain (dBi)	Cambium part number
Andrew	4-foot Dual-Pol Parabolic, PX4F-52	34.5	RDG4453B
Andrew	4-foot Parabolic, P4F-52	34.5	RDH4524A
Gabriel	4-foot Standard QuickFire Parabolic, QF4-52-N	34.4	
Gabriel	4-foot Standard QuickFire Parabolic, QF4-52-N-RK	34.4	
Radio Waves	4-foot Parabolic, SP4-5.2	34.4	
Gabriel	4-foot Standard Dual QuickFire Parabolic, QFD4-52-N	34.3	
Gabriel	4-foot Standard Dual QuickFire Parabolic, QFD4-52-N-RK	34.3	
Radio Waves	4-foot Dual-Pol Parabolic, HPD4-5.2NS	34.3	RDH4510B
Gabriel	4-foot High Performance QuickFire Parabolic, HQF4-52-N	34	
Radio Waves	4-foot Dual-Pol Parabolic, SPD4-5.2	34	RDH4505B
Gabriel	4-foot High Performance Dual QuickFire Parabolic, HQFD4-52-N	33.9	
RFS	4-foot HP Parabolic, SDF4-52AN	33.5	
RFS	4-foot Parabolic, SPF4-52AN	33.5	
Andrew	3-foot Dual-Pol Parabolic, PX3F-52	33	
Andrew	3-foot Parabolic, P3F-52	33	
Stella Doradus	4-foot Single-Pol, 56 PSD113	32	
Radio Waves	3-foot Dual-Pol Parabolic, HPD3-5.2NS	31.9	RDH4509B
Radio Waves	3-foot Parabolic, SP3-5.2	31	RDH4513B
Gabriel	2.5-foot Standard QuickFire Parabolic, QF2.5-52-N	30.8	
Gabriel	2.5-foot Standard Dual QuickFire Parabolic, QFD2.5-52-N	30.7	
RadioWaves	3-foot Dual-Pol Parabolic, SPD3-5.2	30.7	RDH4504B
Andrew	2-foot Dual-Pol Parabolic, PX2F-52	29	

Manufacturer	Antenna type	Nominal gain (dBi)	Cambium part number
Andrew	2-foot Parabolic, P2F-52	29	
MTI	3-foot Single-Pol, MT-487000/N	28.6	
Radio Waves	2-foot Parabolic, SP2-5.2	28.6	
MTI	2-foot Dual-Pol, MT-486013-NVH	28.5	
MARS	2 foot Flat plate MA-WA56-DP-28N	28.5	
Radio Waves	2-foot Dual-Pol Parabolic, HPD2-5.2NS	28.4	RDH4508B
Gabriel	2-foot Standard QuickFire Parabolic, QF2-52-N	28.1	
Gabriel	2-foot Standard QuickFire Parabolic, QF2-52-N-RK	28.1	
MTI	2-foot Single-Pol, MT-466009/N	28.1	
Gabriel	2-foot Standard Dual QuickFire Parabolic, QFD2-52-N	28	
Gabriel	2-foot Standard Dual QuickFire Parabolic, QFD2-52-N-RK	28	
Gabriel	2-foot High Performance QuickFire Parabolic, HQF2-52-N	27.8	
Gabriel	2-foot High Performance Dual QuickFire Parabolic, HQFD2-52-N	27.7	
Radio Waves	2-foot Dual-Pol Parabolic, SPD2-5.2	27.7	RDH4503B
RFS	2-foot Parabolic, SPF2-52AN	27.5	
Stella Doradus	2-foot Single-Pol, 56 PSD61	26.6	
MTI	15 inch Dual-Pol Flat Panel, MT-485025/NVH	23	
MTI	MT-465027CVH Flat Plate Antenna	22	Integrated
Andrew	1.25-foot Flat Panel Dual, UBXP375-4-1	20.6	
Andrew	1-foot Flat Panel Single, UBP300-4-1	20.6	
Laird	60 Sectorized (Dual-Pol)	17	
Laird	90 Sectorized (Dual-Pol)	17	
KPPA	KPPA-5.7-DPOMA Omni (Dual-Pol)	13	
MARS	MA-WO56-DP10 Omni	10	

Table 17 Antennas permitted for deployment in USA – 5.2 GHz

Manufacturer	Antenna type	Nominal gain (dBi)	Cambium part number
Andrew	4-foot Dual-Pol Parabolic, PX4F-52	34.5	RDG4453B
Andrew	4-foot Parabolic, P4F-52	34.5	RDH4524A
Radio Waves	4-foot Dual-Pol Parabolic, SPD4-5.2	34.4	RDH4505B
RFS	4-foot HP Parabolic, SDF4-52AN	33.9	
RFS	4-foot Parabolic, SPF4-52AN	33.9	
Andrew	3-foot Dual-Pol Parabolic, PX3F-52	33.4	
Andrew	3-foot Parabolic, P3F-52	33.4	
Stella Doradus	4-foot Single-Pol, 56 PSD113	32.4	
Radio Waves	3-foot Dual-Pol Parabolic, HPD3-5.2NS	32.3	RDH4509B
Radio Waves	3-foot Parabolic, SP3-5.2	31.4	RDH4513B
Gabriel	2.5-foot Standard QuickFire Parabolic, QF2.5-52-N	31.2	
Gabriel	2.5-foot Standard Dual QuickFire Parabolic, QFD2.5-52-N	31.1	
Radio Waves	3-foot Dual-Pol Parabolic, SPD3-5.2	31.1	RDH4504B
Andrew	2-foot Dual-Pol Parabolic, PX2F-52	29.4	
Andrew	2-foot Parabolic, P2F-52	29.4	
MTI	3-foot Single-Pol, MT-487000/N	29	
Radio Waves	2-foot Parabolic, SP2-5.2	29	
Radio Waves	2-foot Dual-Pol Parabolic, HPD2-5.2NS	28.8	RDH4508B
Gabriel	2-foot Standard QuickFire Parabolic, QF2-52-N	28.5	
Gabriel	2-foot Standard QuickFire Parabolic, QF2-52-N-RK	28.5	
MTI	2-foot Dual-Pol, MT-486013/N	28.5	
MTI	2-foot Single-Pol, MT-466009/N	28.5	
Gabriel	2-foot Standard Dual QuickFire Parabolic, QFD2-52-N	28.4	
Gabriel	2-foot Standard Dual QuickFire Parabolic, QFD2-52-N-RK	28.4	
Gabriel	2-foot High Performance QuickFire Parabolic, HQF2-52-N	28.2	
Gabriel	2-foot High Performance Dual QuickFire Parabolic, HQFD2-52-N	28.1	

Manufacturer	Antenna type	Nominal gain (dBi)	Cambium part number
Radio Waves	2-foot Dual-Pol Parabolic, SPD2-5.2	28.1	RDH4503B
RFS	2-foot Parabolic, SPF2-52AN	27.9	
Stella Doradus	2-foot Single-Pol, 56 PSD61	27	
MTI	15 inch Dual-Pol Flat Panel, MT-485025/NVH	23	
MTI	MT-465027CVH Flat Plate Antenna	22	Integrated
Andrew	1.25-foot Flat Panel Dual, UBXP375-4-1	21	
Andrew	1-foot Flat Panel Single, UBP300-4-1	21	
Laird	60 Sectorized (Dual Pol)	17	
Laird	90 Sectorized (Dual Pol)	17	
KPPA	KPPA-5.7-DPOMA Omni (Dual-Pol)	13	
MARS	MA-WO56-DP10 Omni	10.0	

Table 18 Antennas permitted for deployment in USA – 5.4 GHz

Manufacturer	Antenna type	Nominal gain (dBi)	Cambium part number
MTI	MTI 2-foot Dual-Pol, MT-486013/N	28.5	
MTI	MTI 2-foot Single-Pol, MT-466009/N	28.5	
Gabriel	2-foot Standard Dual QuickFire Parabolic, QFD2-52-N	28.4	
Gabriel	2-foot Standard Dual QuickFire Parabolic, QFD2-52-N-RK	28.4	
Gabriel	2-foot High Performance QuickFire Parabolic, HQF2-52-N	28.2	
Gabriel	2-foot High Performance Dual QuickFire Parabolic, HQFD2-52-N	28.1	
Radio Waves	2-foot Dual-Pol Parabolic, SPD2-5.2	28.1	RDH4503B
RFS	2-foot Parabolic, SPF2-52AN	27.9	
Stella Doradus	2-foot Single-Pol, 56 PSD61	27	
MTI	15 inch Dual-Pol Flat Panel, MT-485025/NVH	23	
MTI	MT-465027CVH Flat Plate Antenna	22	Integrated
Andrew	1.25-foot Flat Panel Dual, UBXP375-4-1	21	
Andrew	1-foot Flat Panel Single, UBP300-4-1	21	

Manufacturer	Antenna type	Nominal gain (dBi)	Cambium part number
Laird	60 Sectorized (Dual-Pol)	17	
Laird	90 Sectorized (Dual-Pol)	17	
KPPA	KPPA-5.7-DPOMA Omni (Dual-Pol)	13	
MARS	MA-WO56-DP10 Omni	10.0	

Table 19 Antennas permitted for deployment in USA – 5.8 GHz

Manufacturer	Antenna type	Nominal gain (dBi)	Cambium part number
Gabriel	6-foot Standard Dual QuickFire Parabolic, QFD6-52-N	37.7	
Gabriel	6-foot Standard QuickFire Parabolic, QF6-52-N	37.7	
Radio Waves	6-foot Dual-Pol Parabolic, HPD6-5.2NS	37.7	RDH4511
Radio Waves	6-foot Parabolic, SP6-2/5	37.7	
Radio Waves	6-foot Parabolic, SP6-5.2	37.7	
Andrew	6-foot Dual-Pol Parabolic, PX6F-52	37.6	
Andrew	6-foot Parabolic, P6F-52	37.6	RDH4525
Radio Waves	6-foot Dual-Pol Parabolic, SPD6-5.2	37.5	RDH4506
Gabriel	6-foot High Performance QuickFire Parabolic, HQF6-52-N	37.4	
RFS	6-foot HP Parabolic, SDF6-52AN	37.4	
RFS	6-foot Parabolic, SPF6-52AN	37.4	
Gabriel	6-foot High Performance Dual QuickFire Parabolic, HQFD6-52-N	37.3	
Andrew	4-foot Dual-Pol Parabolic, PX4F-52	34.9	RDG4453
Andrew	4-foot Parabolic, P4F-52	34.9	RDH4524
Gabriel	4-foot Standard QuickFire Parabolic, QF4-52-N	34.8	
Gabriel	4-foot Standard QuickFire Parabolic, QF4-52-N-RK	34.8	
Radio Waves	4-foot Parabolic, SP4-5.2	34.8	
Gabriel	4-foot Standard Dual QuickFire Parabolic, QFD4-52-N	34.7	
Gabriel	4-foot Standard Dual QuickFire Parabolic, QFD4-52-N-RK	34.7	

Manufacturer	Antenna type	Nominal gain (dBi)	Cambium part number
Radio Waves	4-foot Dual-Pol Parabolic, HPD4-5.2NS	34.7	RDH4510
Radio Waves	4-foot Parabolic, SP4-2/5	34.6	
Gabriel	4-foot High Performance QuickFire Parabolic, HQF4-52-N	34.4	
Radio Waves	4-foot Dual-Pol Parabolic, SPD4-5.2	34.4	RDH4505
Gabriel	4-foot High Performance Dual QuickFire Parabolic, HQFD4-52-N	34.3	
RFS	4-foot HP Parabolic, SDF4-52AN	33.9	
RFS	4-foot Parabolic, SPF4-52AN	33.9	
Andrew	3-foot Dual-Pol Parabolic, PX3F-52	33.4	
Andrew	3-foot Parabolic, P3F-52	33.4	
Stella Doradus	4-foot Single-Pol, 56 PSD113	32.4	
Radio Waves	3-foot Dual-Pol Parabolic, HPD3-5.2NS	32.3	RDH4509
Radio Waves	3-foot Parabolic, SP3-2/5	31.4	
Radio Waves	3-foot Parabolic, SP3-5.2	31.4	RDH4513
Gabriel	2.5-foot Standard QuickFire Parabolic, QF2.5-52-N	31.2	
Gabriel	2.5-foot Standard Dual QuickFire Parabolic, QFD2.5-52-N	31.1	
Radio Waves	3-foot Dual-Pol Parabolic, SPD3-5.2	31.1	RDH4504
Andrew	2-foot Dual-Pol Parabolic, PX2F-52	29.4	
Andrew	2-foot Parabolic, P2F-52	29.4	
MTI	3-foot Single-Pol, MT-487000/N	29	
Radio Waves	2-foot Parabolic, SP2-5.2	29	
Radio Waves	2-foot Dual-Pol Parabolic, HPD2-5.2NS	28.8	RDH4508
Gabriel	2-foot Standard QuickFire Parabolic, QF2-52-N	28.5	
Gabriel	2-foot Standard QuickFire Parabolic, QF2-52-N-RK	28.5	
MTI	2-foot Dual-Pol, MT-486013/N	28.5	
MTI	2-foot Single-Pol, MT-466009/N	28.5	
Gabriel	2-foot Standard Dual QuickFire Parabolic, QFD2-52-N	28.4	

Manufacturer	Antenna type	Nominal gain (dBi)	Cambium part number
Gabriel	2-foot Standard Dual QuickFire Parabolic, QFD2-52-N-RK	28.4	
Radio Waves	2-foot Parabolic, SP2-2/5	28.3	
Gabriel	2-foot High Performance QuickFire Parabolic, HQF2-52-N	28.2	
Gabriel	2-foot High Performance Dual QuickFire Parabolic, HQFD2-52-N	28.1	
Radio Waves	2-foot Dual-Pol Parabolic, SPD2-5.2	28.1	RDH4503
RFS	2-foot Parabolic, SPF2-52AN	27.9	
Stella Doradus	2-foot Single-Pol, 56 PSD61	27	
MARS	MA-WS54-50R Flat Plate (Dual-Pol)	23	Integrated
MTI	15 inch Dual-Pol Flat Panel, MT-485025/NVH	23	
RFS	1-foot Flat Panel, MA0528-23AN	23	
Andrew	1.25-foot Flat Panel Dual, UBXP375-4-1	21	
Andrew	1-foot Flat Panel Single, UBP300-4-1	21	
MARS	Small Form Factor Flat Plate Antenna MA-EM56-DP19CM.	19	Integrated
Laird	60 Sectorized (Dual-Pol)	17	
Laird	90 Sectorized (Dual-Pol)	17	
KPPA	KPPA-5.7-DPOMA OMNI (Dual-Pol)	13	

IC approved antennas

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

- 4.9 GHz – 37.2 dBi maximum per polarization.
- 5.2 GHz – 28.5 dBi maximum per polarization.
- 5.4 GHz – 28.5 dBi maximum per polarization.
- 5.8 GHz – 38.1 dBi maximum per polarization.

Caution

Antennas not included in these tables are strictly prohibited for use with the PTP 700 in the specified bands.

Caution

This radio transmitter (IC certification number 109AO-45700) 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 IC

Pour les unités sans antenne intégrée destinées au Canada, choisissez des antennes externes dans la list ci-dessous. Ces antennes paraboliques a polarisation simple ou double sont approuvées par IC pour une utilisation avec le produit comme suit:

- 4.9 GHz – 37.2 dBi par polarisation maximum.
- 5.2 GHz – 28.5 dBi par polarisation maximum.
- 5.4 GHz – 28.5 dBi par polarisation maximum.
- 5.8 GHz – 38.1 dBi par polarisation maximum.

Attention

Les antennes qui ne sont pas listées dans ces tableaux sont strictement interdites d'utilisation avec le PTP 700 dans les bandes spécifiées

Attention

Le présent émetteur radio (Numéro de certification IC 109AO-45700) 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 20 Antennas permitted for deployment in Canada – 4.9 GHz

Manufacturer	Antenna type	Nominal gain (dBi)	Cambium part number
Gabriel	6ft Standard QuickFire Parabolic QF6-49-N	37.2	
Radio Waves	6-foot Parabolic, SP6-5.2	36.1	
Radio Waves	6-foot Dual-Pol Parabolic, SPD6-4.7	36.0	RDH4502
Radio Waves	6-foot Parabolic, SP6-4.7	36.0	
Radio Waves	6-foot Dual-Pol Parabolic, HPD6-4.7	35.8	RDH4515

Manufacturer	Antenna type	Nominal gain (dBi)	Cambium part number
Radio Waves	6-foot Dual-Pol Parabolic, SPD6-5.2	35.7	RDH4506
Radio Waves	6-foot Dual-Pol Parabolic, HPD6-5.2NS	35.6	RDH4511
Radio Waves	4-foot Dual-Pol Parabolic, SPD4-4.7	33.0	RDH4501
Radio Waves	4-foot Parabolic, SP4-4.7	33.0	N000000D002
Radio Waves	4-foot Parabolic, SP4-5.2	32.9	
Radio Waves	4-foot Dual-Pol Parabolic, HPD4-5.2NS	32.8	RDH4510
Radio Waves	4-foot Dual-Pol Parabolic, HPD4-4.7	32.8	RDH4516
Radio Waves	4-foot Dual-Pol Parabolic, SPD4-5.2	32.7	RDH4505
Radio Waves	3-foot Dual-Pol Parabolic, SPD3-4.7	30.4	RDH4500
Radio Waves	3-foot Parabolic, SP3-4.7	30.4	N000000D005
Radio Waves	3-foot Dual-Pol Parabolic, HPD3-4.7	30.2	RDH4517
Gabriel	2.5-foot Standard Dual QuickFire Parabolic, QFD2.5-49-N	29.7	
Gabriel	2.5-foot Standard QuickFire Parabolic, QF2.5-49-N	29.7	
Radio Waves	3-foot Parabolic, SP3-5.2	29.6	RDH4513
Radio Waves	3-foot Dual-Pol Parabolic, HPD3-5.2NS	29.4	RDH4509
Radio Waves	3-foot Dual-Pol Parabolic, SPD3-5.2	29.4	RDH4504
MTI	2-foot Dual-Pol, MT-486013/N	28.5	
MTI	2-foot Single-Pol, MT-466009/N	28.0	
Gabriel	2-foot Standard Dual QuickFire Parabolic, QFD2-49-N	27.7	
Gabriel	2-foot Standard QuickFire Parabolic, QF2-49-N	27.7	
Radio Waves	2-foot Parabolic, SP2-5.2	27.1	
Radio Waves	2-foot Dual-Pol Parabolic, SPD2-4.7	27.0	RDH4499
Radio Waves	2-foot Dual-Pol Parabolic, HPD2-5.2NS	26.9	RDH4508
Radio Waves	2-foot Parabolic, SP2-4.7	26.9	N000000D001
Radio Waves	2-foot Dual-Pol Parabolic, HPD2-4.7	26.8	RDH4518
Radio Waves	2-foot Dual-Pol Parabolic, SPD2-5.2	26.3	RDH4503
MARS	MA-WS54-50R Flat Plate (Dual-Pol)	23	Integrated
MTI	Flat Plate Antenna, 4400MHz to 6050MHz	22	Integrated
Radio Waves	1-foot Dual-Pol Parabolic, HPLPD1-4.7	20.8	RDH4519

Manufacturer	Antenna type	Nominal gain (dBi)	Cambium part number
Laird	60 Sectorized (Dual-Pol)	17.0	
Laird	90 Sectorized (Dual-Pol)	17.0	
Radio Waves	90 Sectorized (Dual-Pol), SEC-47D-90-16	16.4	N000000D003
KPPA	Omni KPPA-5.7-DPOMA	13.0	
MARS	MA-WO56-DP10	10.0	
Radio Waves	Omni Dual-Pol, OMND-4.8-9	9.0	

Table 21 Antennas permitted for deployment in Canada – 5.2 GHz

Manufacturer	Antenna type	Nominal gain (dBi)	Cambium part number
MARS	External 2 ft flat plate MA-WA56-DP-28N	28.5	
MTI	2-foot Dual-Pol, MT-486013/N	28.5	
MTI	2-foot Single-Pol, MT-466009/N	28.5	
Gabriel	2-foot Standard Dual QuickFire Parabolic, QFD2-52-N	28.4	
Gabriel	2-foot Standard Dual QuickFire Parabolic, QFD2-52-N-RK	28.4	
Gabriel	2-foot High Performance QuickFire Parabolic, HQF2-52-N	28.2	
Gabriel	2-foot High Performance Dual QuickFire Parabolic, HQFD2-52-N	28.1	
RadioWaves	2-foot Dual-Pol Parabolic, SPD2-5.2	28.1	RDH4503B
RFS	2-foot Parabolic, SPF2-52AN	27.9	
Stella Doradus	2-foot Single-Pol, 56 PSD61	27	
MARS	MA-WS54-50R Flat Plate (Dual-Pol)	23	Integrated
MTI	MT-465027CVH, Flat Plate Antenna	22	Integrated
Andrew	1.25-foot Flat Panel Dual, UBXP375-4-1	21	
Andrew	1-foot Flat Panel Single, UBP300-4-1	21	
Laird	60 Sectorized (Dual Pol)	17	
Laird	90 Sectorized (Dual Pol)	17	
KPPA	KPPA-5.7-DPOMA OMNI (Dual-Pol)	13	
MARS	MA-WO56-DP10	10.0	

Table 22 Antennas permitted for deployment in Canada – 5.4 GHz

Manufacturer	Antenna type	Nominal gain (dBi)	Cambium part number
Gabriel	2-foot Standard QuickFire Parabolic, QF2-52-N	28.5	
Gabriel	2-foot Standard QuickFire Parabolic, QF2-52-N-RK	28.5	
MARS	External 2 ft flat plate MA-WA56-DP-28N	28.5	
MTI	2-foot Dual-Pol, MT-486013/N	28.5	
MTI	2-foot Single-Pol, MT-466009/N	28.5	
Gabriel	2-foot Standard Dual QuickFire Parabolic, QFD2-52-N	28.4	
Gabriel	2-foot Standard Dual QuickFire Parabolic, QFD2-52-N-RK	28.4	
Gabriel	2-foot High Performance QuickFire Parabolic, HQF2-52-N	28.2	
Gabriel	2-foot High Performance Dual QuickFire Parabolic, HQFD2-52-N	28.1	
Radio Waves	2-foot Dual-Pol Parabolic, SPD2-5.2	28.1	RDH4503B
RFS	2-foot Parabolic, SPF2-52AN	27.9	
Stella Doradus	2-foot Single-Pol, 56 PSD61	27	
MARS	MA-WS54-50R Flat Plate (Dual-Pol)	23	Integrated
MTI	MT-465027CVH, Flat Plate Antenna	22	Integrated
Andrew	1.25-foot Flat Panel Dual, UBXP375-4-1	21	
Andrew	1-foot Flat Panel Single, UBP300-4-1	21	
Laird	60 Sectorized (Dual-Pol)	17	
Laird	90 Sectorized (Dual-Pol)	17	
KPPA	KPPA-5.7-DPOMA OMNI (Dual-Pol)	13	
MARS	MA-WO56-DP10	10.0	

Table 23 Antennas permitted for deployment in Canada – 5.8 GHz

Manufacturer	Antenna type	Nominal gain (dBi)	Cambium part number
Andrew	6-foot Dual-Pol Parabolic, PX6F-52	38.1	
Radio Waves	6-foot Dual-Pol Parabolic, HPD6-5.2NS	37.7	RDH4511
Radio Waves	6-foot Parabolic, SP6-2/5	37.7	

Manufacturer	Antenna type	Nominal gain (dBi)	Cambium part number
Radio Waves	6-foot Parabolic, SP6-5.2	37.7	
Andrew	6-foot Parabolic, P6F-52	37.6	RDH4525
Radio Waves	6-foot Dual-Pol Parabolic, SPD6-5.2	37.5	RDH4506
Gabriel	6-foot High Performance QuickFire Parabolic, HQF6-52-N	37.4	
RFS	6-foot HP Parabolic, SDF6-52AN	37.4	
RFS	6-foot Parabolic, SPF6-52AN	37.4	
Gabriel	6-foot High Performance Dual QuickFire Parabolic, HQFD6-52-N	37.3	
Andrew	4-foot Dual-Pol Parabolic, PX4F-52	34.9	RDG4453
Andrew	4-foot Parabolic, P4F-52	34.9	RDH4524
Gabriel	4-foot Standard QuickFire Parabolic, QF4-52-N	34.8	
Gabriel	4-foot Standard QuickFire Parabolic, QF4-52-N-RK	34.8	
Radio Waves	4-foot Parabolic, SP4-5.2	34.8	
Gabriel	4-foot Standard Dual QuickFire Parabolic, QFD4-52-N	34.7	
Gabriel	4-foot Standard Dual QuickFire Parabolic, QFD4-52-N-RK	34.7	
Radio Waves	4-foot Dual-Pol Parabolic, HPD4-5.2NS	34.7	RDH4510
Radio Waves	4-foot Parabolic, SP4-2/5	34.6	
Gabriel	4-foot High Performance QuickFire Parabolic, HQF4-52-N	34.4	
Radio Waves	4-foot Dual-Pol Parabolic, SPD4-5.2	34.4	RDH4505
Gabriel	4-foot High Performance Dual QuickFire Parabolic, HQFD4-52-N	34.3	
RFS	4-foot HP Parabolic, SDF4-52AN	33.9	
RFS	4-foot Parabolic, SPF4-52AN	33.9	
Andrew	3-foot Dual-Pol Parabolic, PX3F-52	33.4	
Andrew	3-foot Parabolic, P3F-52	33.4	
Stella Doradus	4-foot Single-Pol, 56 PSD113	32.4	
Radio Waves	3-foot Dual-Pol Parabolic, HPD3-5.2NS	32.3	RDH4509
Radio Waves	3-foot Parabolic, SP3-2/5	31.4	

Manufacturer	Antenna type	Nominal gain (dBi)	Cambium part number
Radio Waves	3-foot Parabolic, SP3-5.2	31.4	RDH4513
Gabriel	2.5-foot Standard QuickFire Parabolic, QF2.5-52-N	31.2	
Gabriel	2.5-foot Standard Dual QuickFire Parabolic, QFD2.5-52-N	31.1	
Radio Waves	3-foot Dual-Pol Parabolic, SPD3-5.2	31.1	RDH4504
Andrew	2-foot Dual-Pol Parabolic, PX2F-52	29.4	
Andrew	2-foot Parabolic, P2F-52	29.4	
MTI	3-foot Single-Pol, MT-487000/N	29	
Radio Waves	2-foot Parabolic, SP2-5.2	29	
Radio Waves	2-foot Dual-Pol Parabolic, HPD2-5.2NS	28.8	RDH4508
MARS	External 2 ft flat plate, MA-WA56-DP-28N	28.5	
Gabriel	2-foot Standard QuickFire Parabolic, QF2-52-N	28.5	
Gabriel	2-foot Standard QuickFire Parabolic, QF2-52-N-RK	28.5	
MTI	2-foot Dual-Pol, MT-486013/N	28.5	
MTI	2-foot Single-Pol, MT-466009/N	28.5	
Gabriel	2-foot Standard Dual QuickFire Parabolic, QFD2-52-N	28.4	
Gabriel	2-foot Standard Dual QuickFire Parabolic, QFD2-52-N-RK	28.4	
Radio Waves	2-foot Parabolic, SP2-2/5	28.3	
Gabriel	2-foot High Performance QuickFire Parabolic, HQF2-52-N	28.2	
Gabriel	2-foot High Performance Dual QuickFire Parabolic, HQFD2-52-N	28.1	
Radio Waves	2-foot Dual-Pol Parabolic, SPD2-5.2	28.1	RDH4503
RFS	2-foot Parabolic, SPF2-52AN	27.9	
Stella Doradus	2-foot Single-Pol, 56 PSD61	27	
MARS	MA-WS54-50R Flat Plate (Dual-Pol)	23	Integrated
MTI	MT-465027CVH, Flat Plate Antenna	22	Integrated
MTI	15 inch Dual-Pol Flat Panel, MT-485025/NVH	23	
RFS	1-foot Flat Panel, MA0528-23AN	23	

Manufacturer	Antenna type	Nominal gain (dBi)	Cambium part number
Andrew	1.25-foot Flat Panel Dual, UBXP375-4-1	21	
Andrew	1-foot Flat Panel Single, UBP300-4-1	21	
Laird	60 Sectorized (Dual-Pol)	17	
Laird	90 Sectorized (Dual-Pol)	17	
KPPA	KPPA-5.7-DPOMA OMNI (Dual-Pol)	13	
MARS	MA-WO56-DP10	10.0	

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 2-41 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+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 700.

(*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 700.

(*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 20).

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 for the PTP 700.

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

Figure 20 Outdoor drop cable

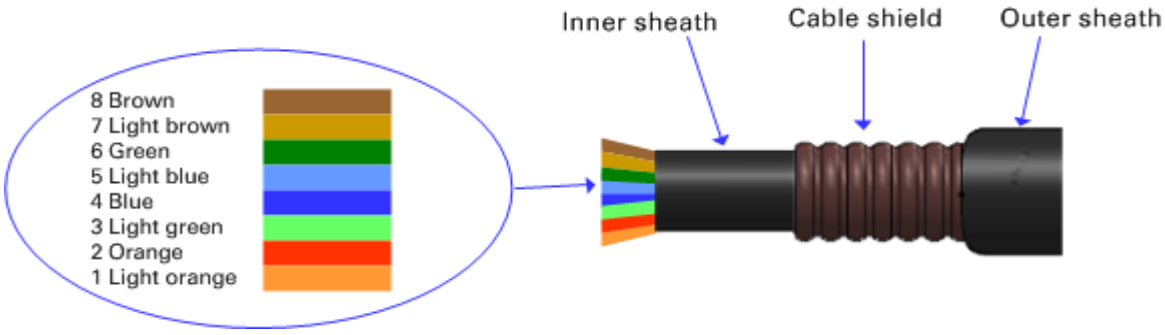


Table 26 Drop cable part numbers

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 21) is required for each grounding point on the PSU, Aux and copper SFP drop cables. Order cable grounding kits from Cambium Networks (Figure 29).

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 21 Cable grounding kit

Table 27 Cable grounding kit part numbers

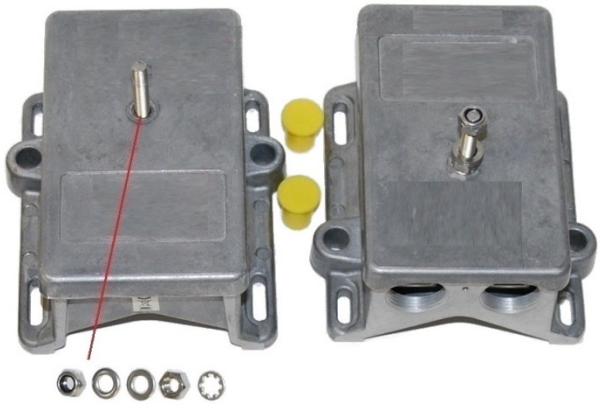
Cambium description	Cambium part number
Cable Grounding Kits For 1/4" And 3/8" Cable	01010419001

Lightning protection unit (LPU) and grounding kit

PTP 700 LPUs provide transient voltage surge suppression for PTP 700 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
LPU and Grounding Kit (One Kit Per End)	C000065L007

Note

PTP 700 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 LPU and Grounding Kit (C000065L007) (Table 28) is suitable. Alternatively, the single LPU kit for PTP 250/300/500 (Figure 22) could be used.

Figure 22 LPU kit used for GPS receiver drop cables

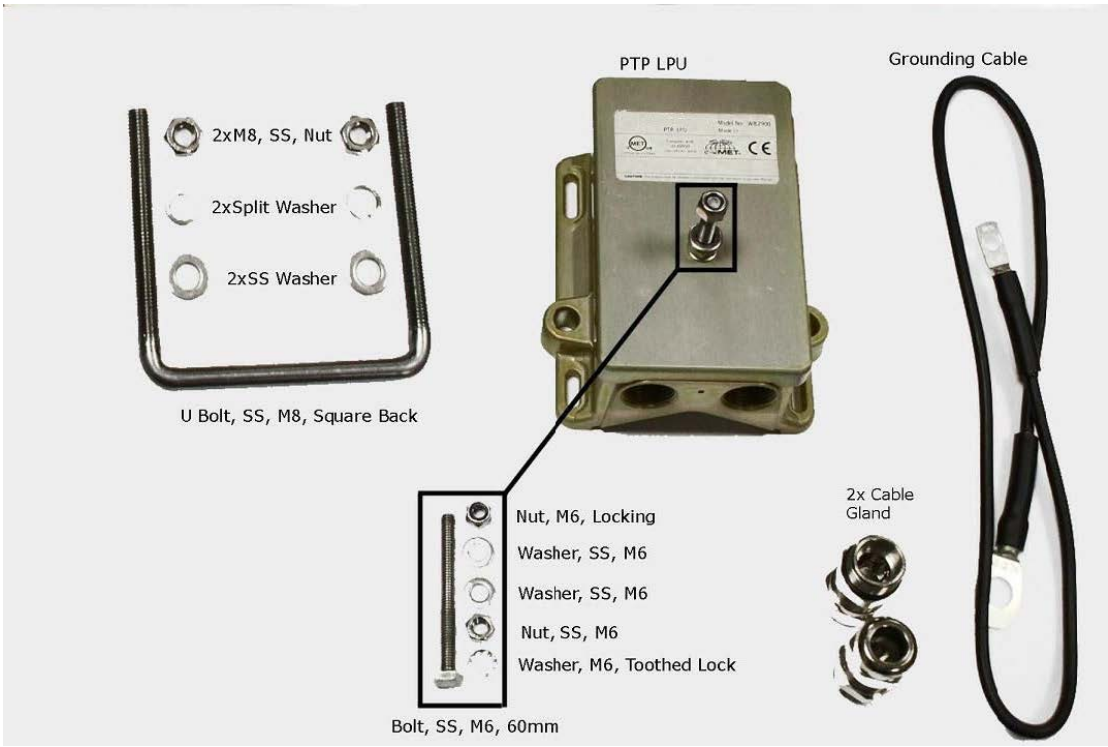


Table 30 LPU and grounding kit part number – Use with GPS receiver drop cable only

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 23). 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 26) 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 23 Cable gland

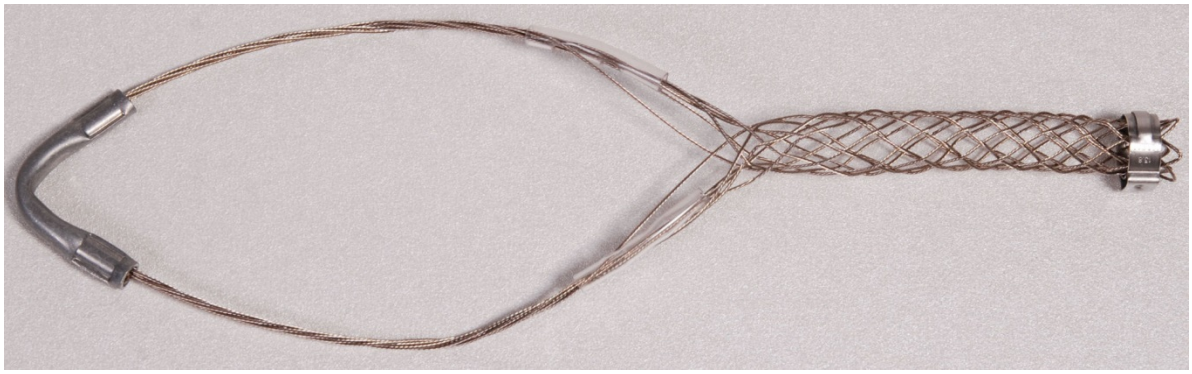
Table 31 RJ45 connector and spare gland part numbers

Cambium description	Cambium part number
Tyco/AMP, Mod Plug RJ45 Unscreened, 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 24). They are not supplied by Cambium Networks.

Figure 24 Cable hoisting grip



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 700 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
Single Mode Optical SFP Interface per ODU	C000065L008
Multi-mode Optical SFP Interface per ODU	C000065L009
Gig-Ethernet SFP Interface per ODU	C000065L010

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

Table 33 Single Mode Optical SFP Interface (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 Multi-mode Optical SFP Interface (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 25)
- Long EMC strain relief cable gland (Figure 26)
- The *PTP 700 Series SFP Interface Upgrade Guide*
- License key instructions and unique Access Key

Figure 25 Optical or copper SFP transceiver module

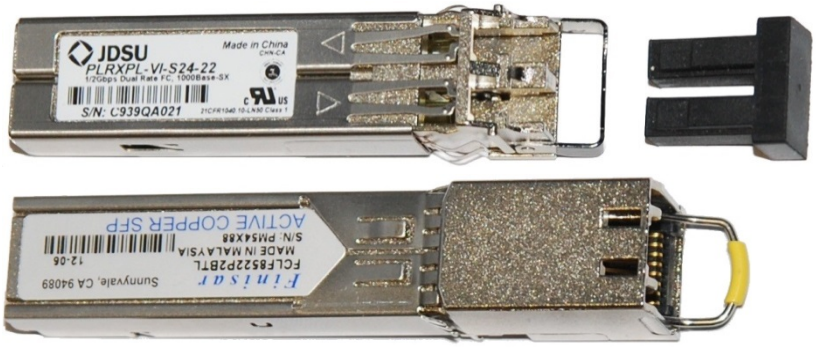


Figure 26 Long cable gland

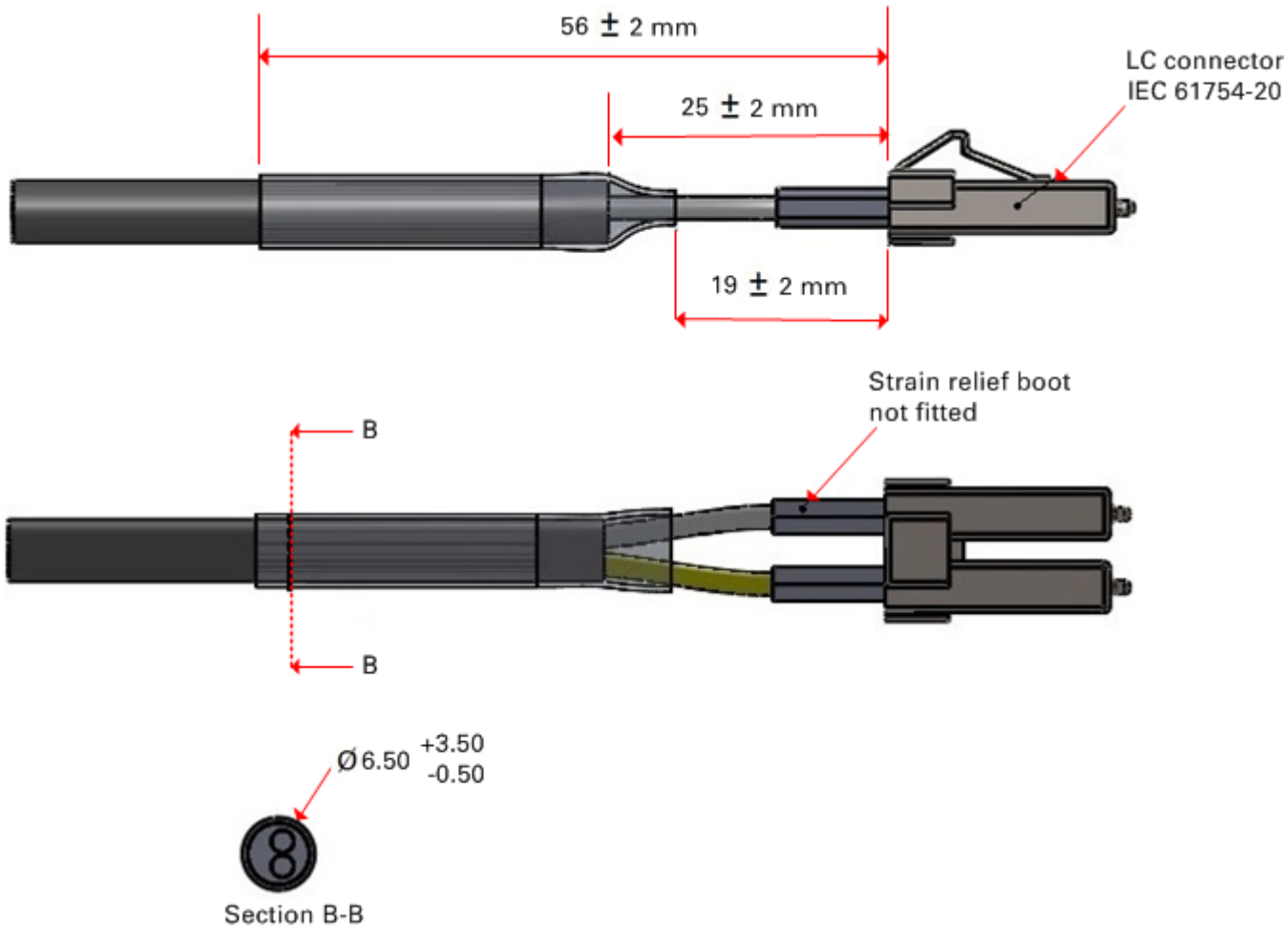
Note

PTP 700 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 27. 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 27 Optical optic cable and connector specification



PTP-SYNC unit

PTP-SYNC unit description

The PTP-SYNC unit 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 1-17.

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 29).

The PTP-SYNC unit is connected in line in the drop cable between the AC + DC Power Injector and the ODU, and is collocated with the AC + DC Power Injector. The PTP-SYNC draws power from the drop cable, and does not require a separate power supply.

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.

PTP-SYNC is not compatible with standards-based power-over-Ethernet (PoE).

Figure 28 PTP-SYNC kit

Figure 29 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
CMU/PTP-SYNC/NIDU 19inch 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 30. The annotated interfaces are described in Table 36 and Table 37.

Figure 30 PTP-SYNC front panel

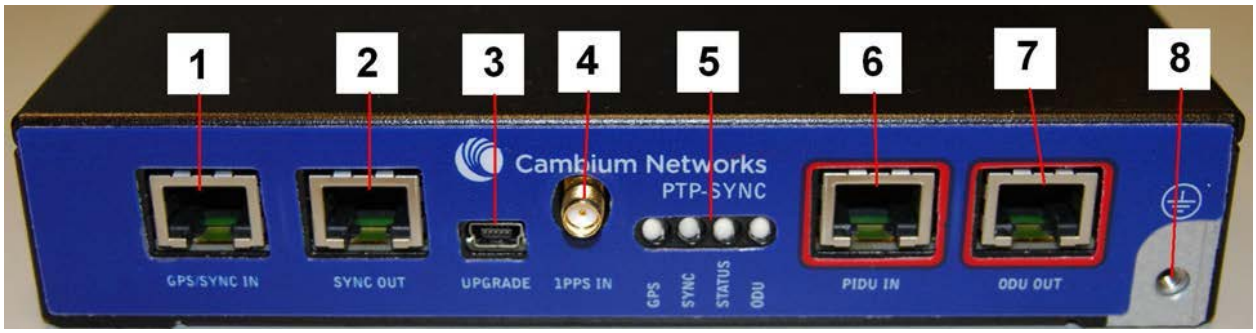


Table 36 PTP-SYNC interface functions

#	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

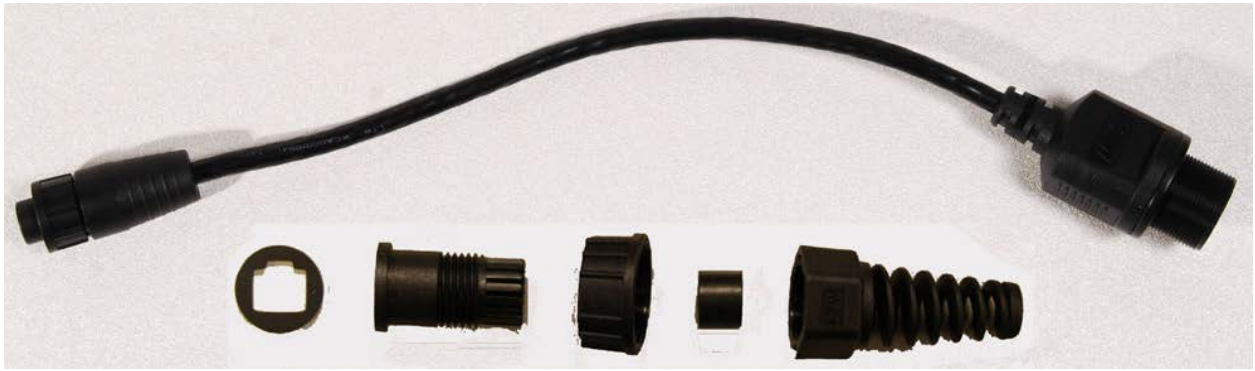
GPS receiver description

The GPS receiver (Figure 31) 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 31 GPS receiver

The GPS receiver is supplier with a GPS adapter cable kit (Figure 32). 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 32 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 Unscreened, 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 33) is an optional component that adds up to eight TDM channels (E1 or T1) to a PTP 700 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 AC+DC Enhanced Power Injector, the PTP 800 AC-DC Power Supply Converter or another source.

Figure 33 NIDU

Note

To enable E1 or T1 capability over a PTP 700 link, purchase one access key for each link end from Cambium Networks (ODU capability upgrades on page 2-8).

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 34 and described in Table 47.

Figure 34 NIDU interfaces

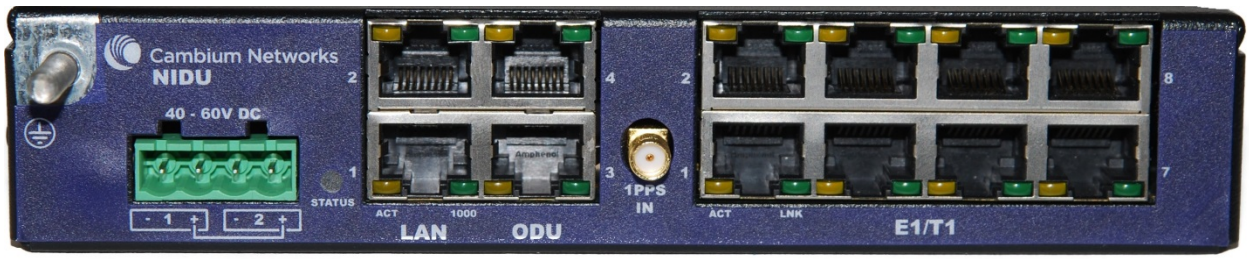


Table 47 NIDU interface functions

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 3-47.

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 700 link.

The following topics are described in this chapter:

- Typical deployment on page 3-2 contains diagrams illustrating typical PTP 700 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 3-20 describes how to plan PTP 700 links to conform to the regulatory restrictions that apply in the country of operation.
- Link planning on page 3-24 describes factors to be taken into account when planning links, such as range, path loss and throughput.
- Planning for connectorized units on page 3-28 describes factors to be taken into account when planning to use connectorized ODUs with external antennas in PTP 700 links.
- Configuration options for TDD synchronization on page 3-30 describes the different configuration options that may be used for implementing TDD synchronization in the PTP 700 Series.
- Data network planning on page 3-34 describes factors to be considered when planning PTP 700 data networks.
- TDM network planning on page 3-47 describes factors to be considered when planning PTP 700 TDM networks.
- Network management planning on page 3-48 describes how to plan for PTP 700 links to be managed remotely using SNMP.
- Security planning on page 3-50 describes how to plan for PTP 700 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 700 configurations.

Typical deployment

This section contains diagrams illustrating typical PTP 700 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 35), wall installation (Figure 36) and roof installation (Figure 37).

Figure 35 Mast or tower installation

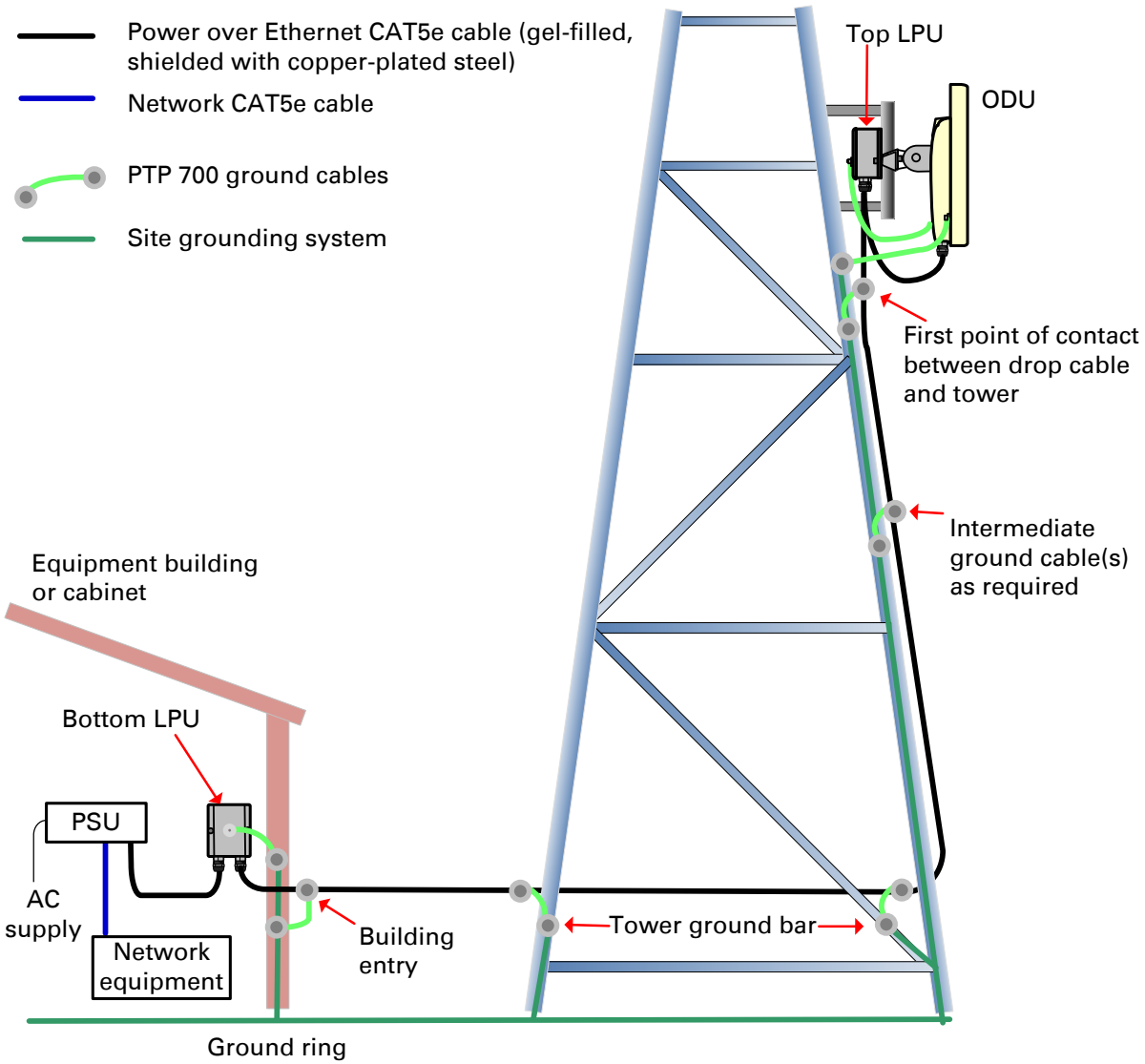


Figure 36 Wall installation

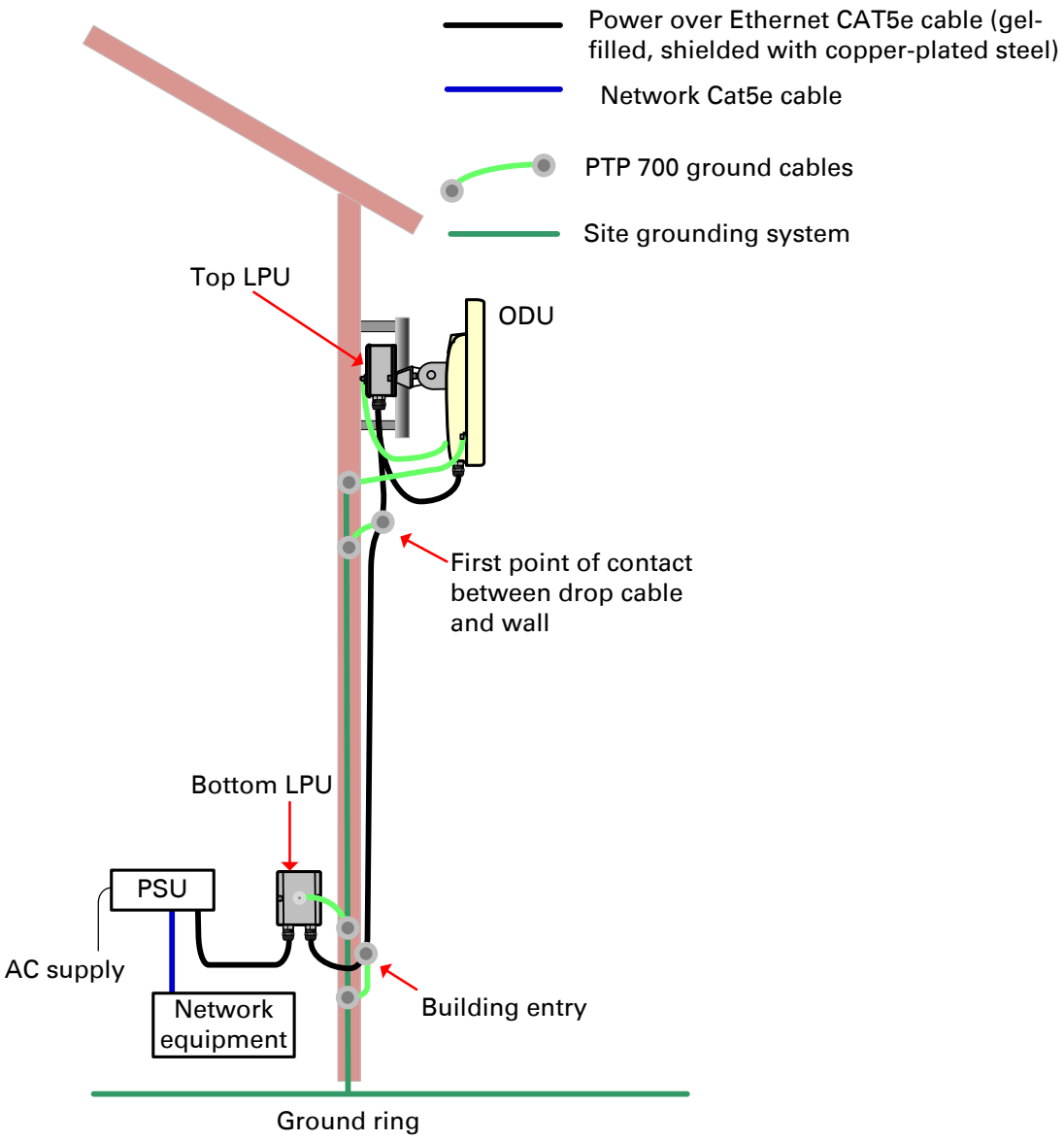
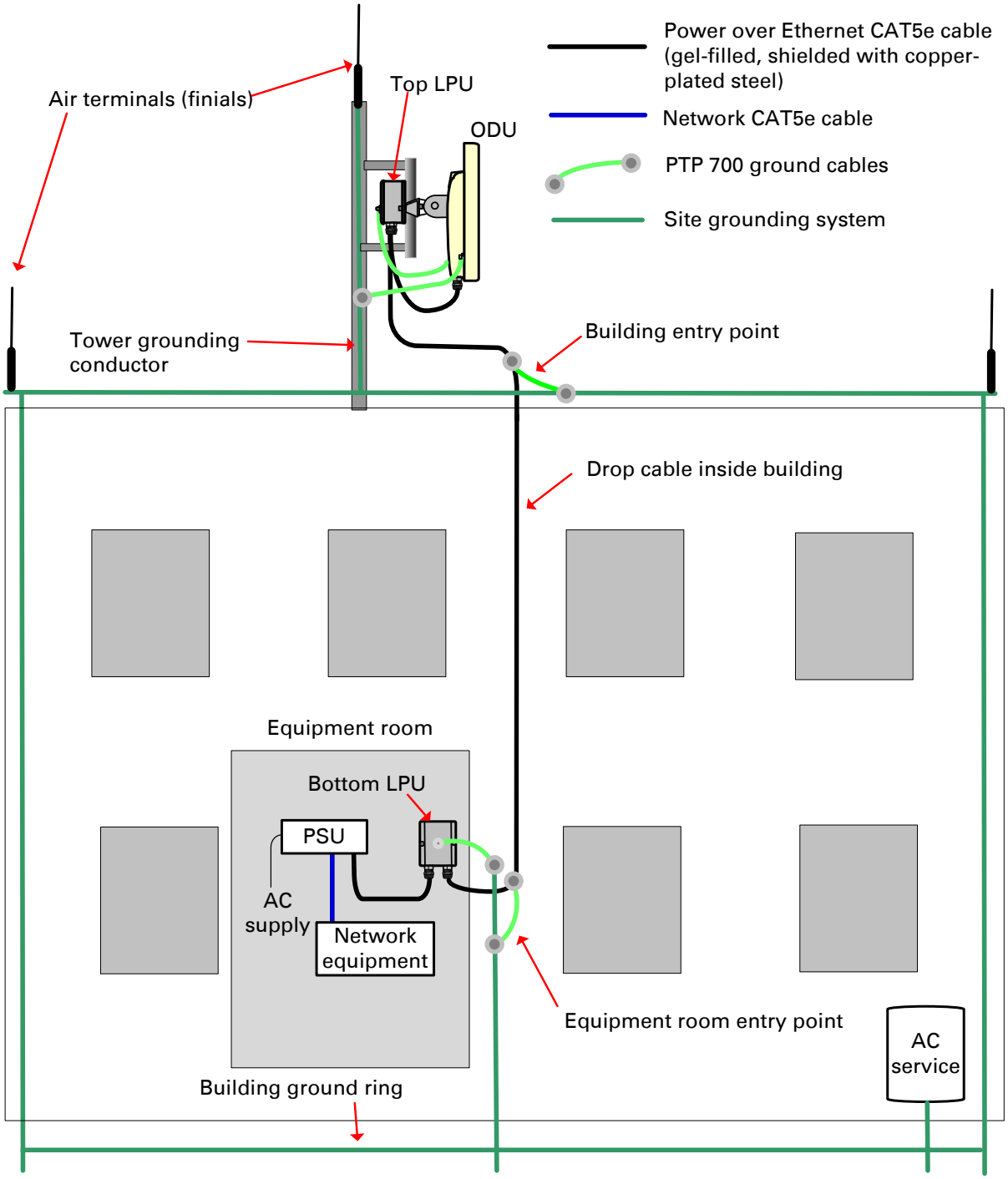


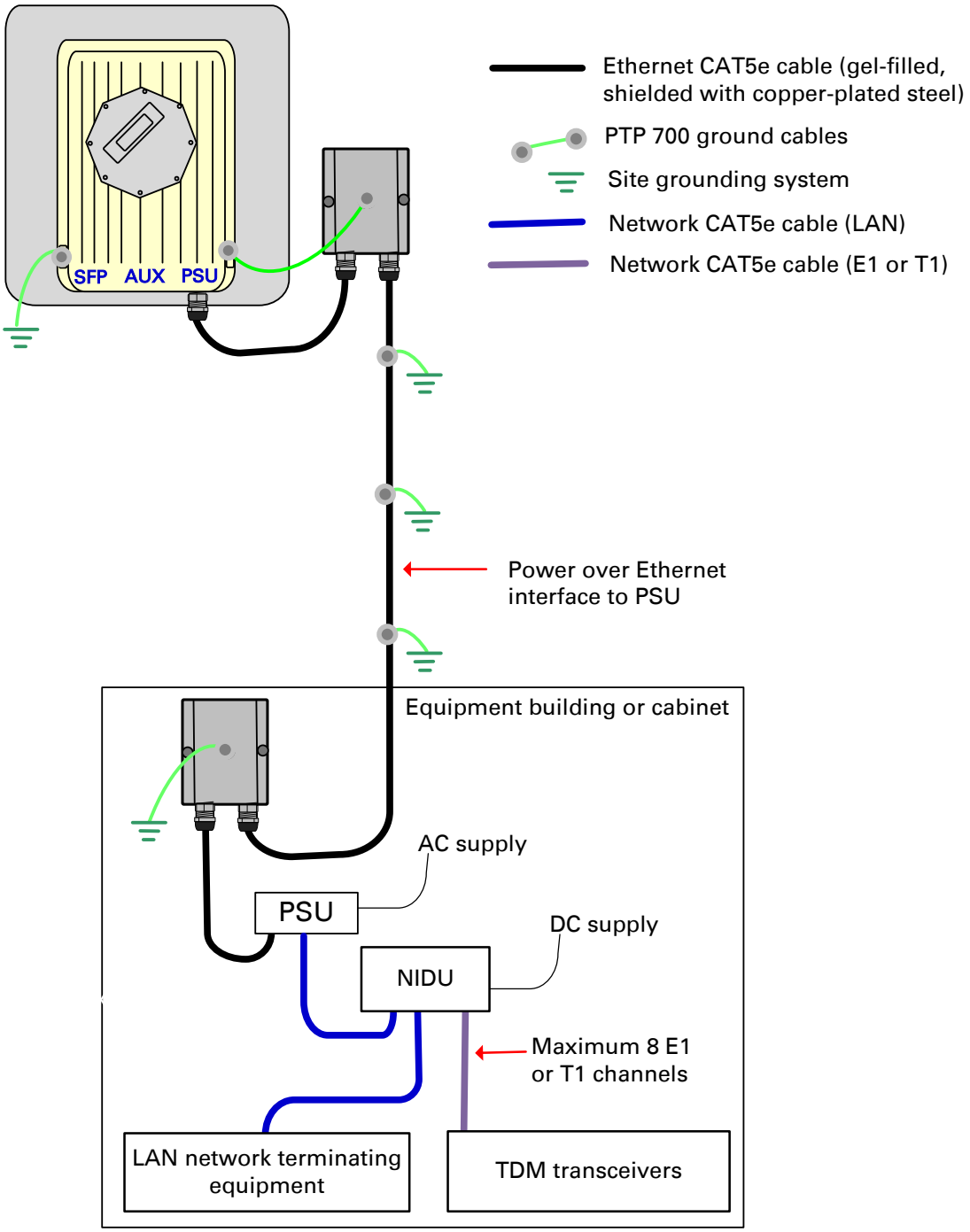
Figure 37 Roof installation



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 38. The NIDU is not compatible with the SFP or AUX ports.

Figure 38 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 39
- ODU with optical SFP and PSU interfaces – Figure 40
- ODU with Aux and PSU interfaces – Figure 41

Figure 39 ODU with copper SFP and PSU interfaces

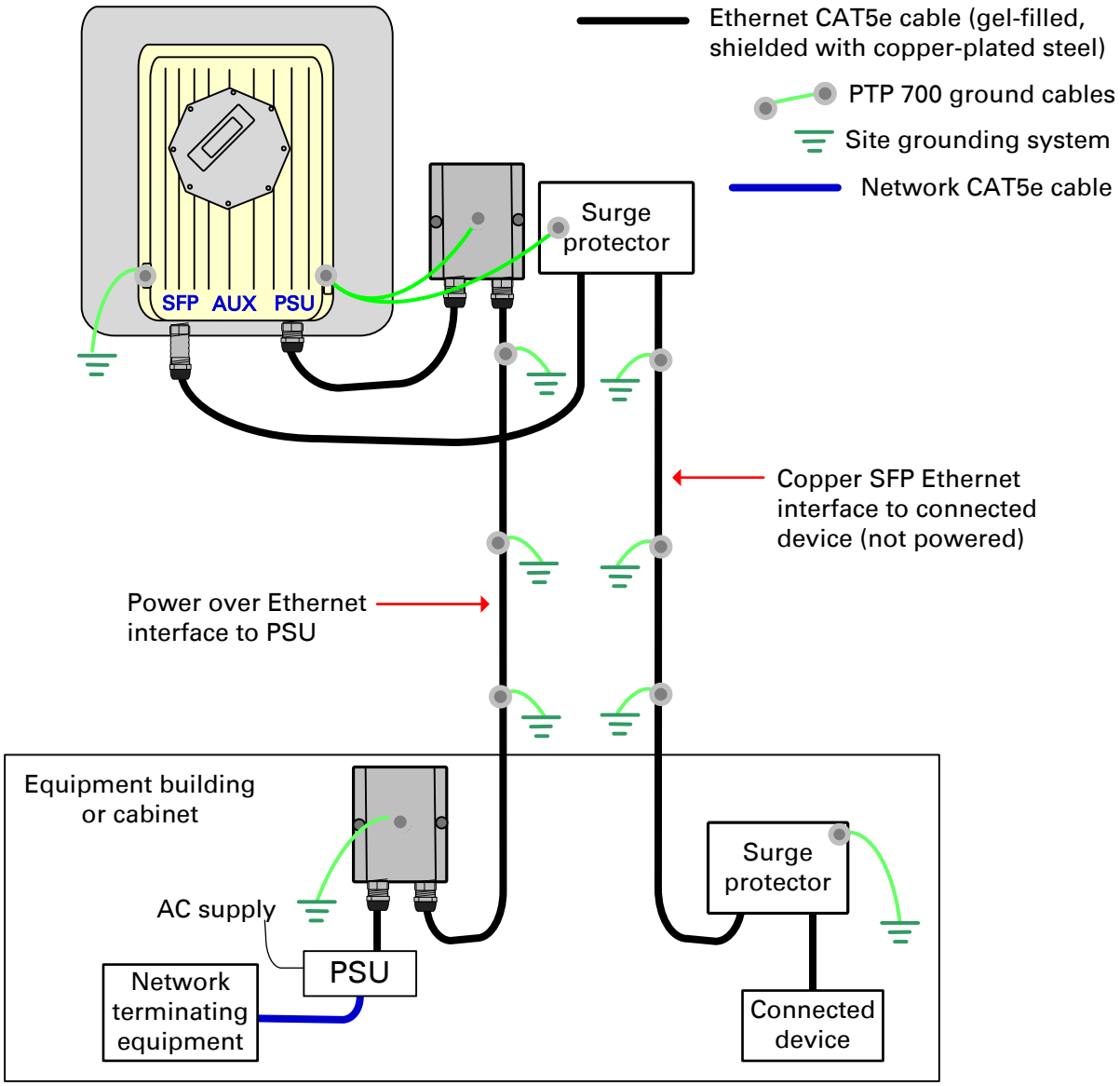


Figure 40 ODU with optical SFP and PSU interfaces

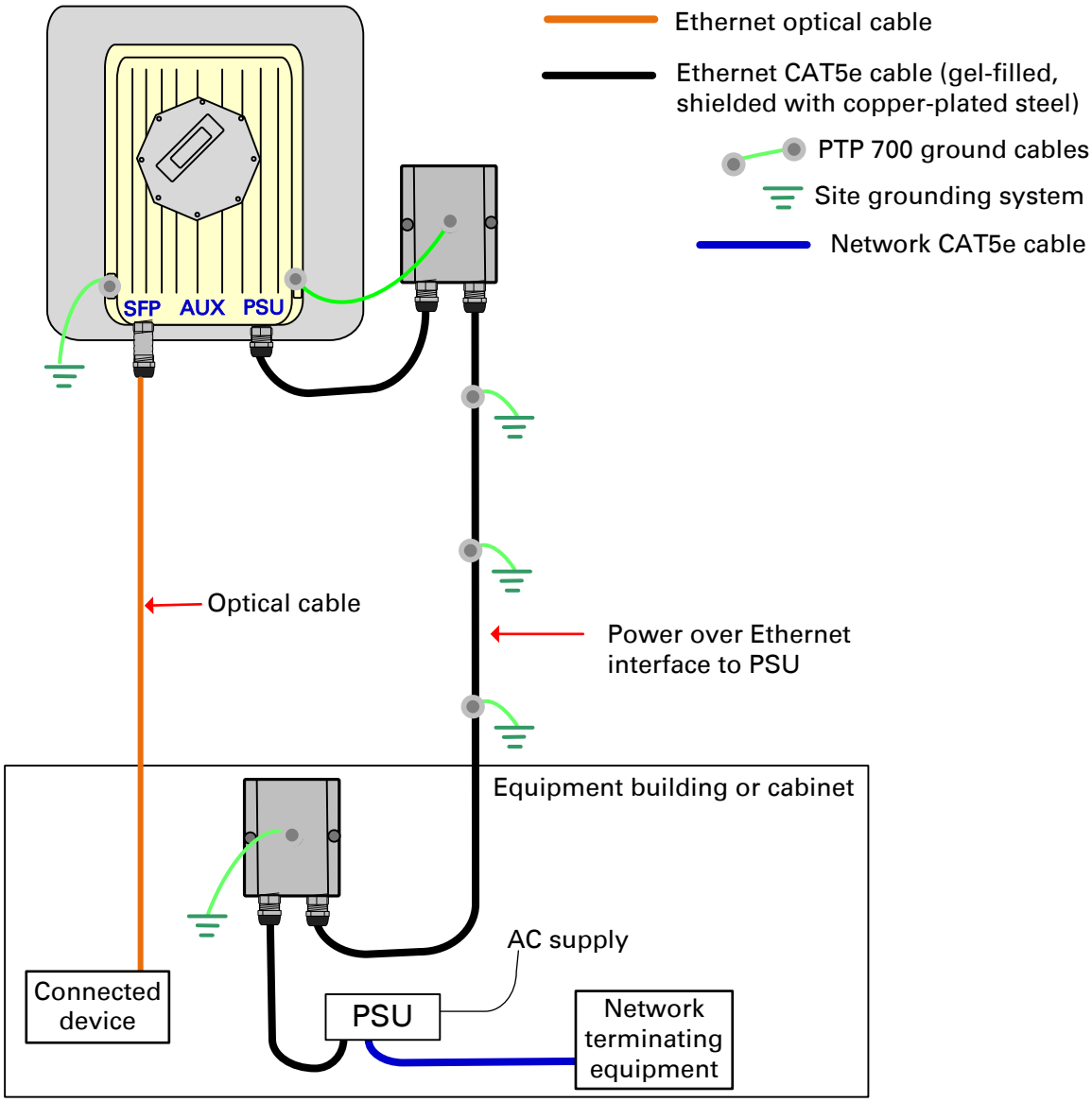
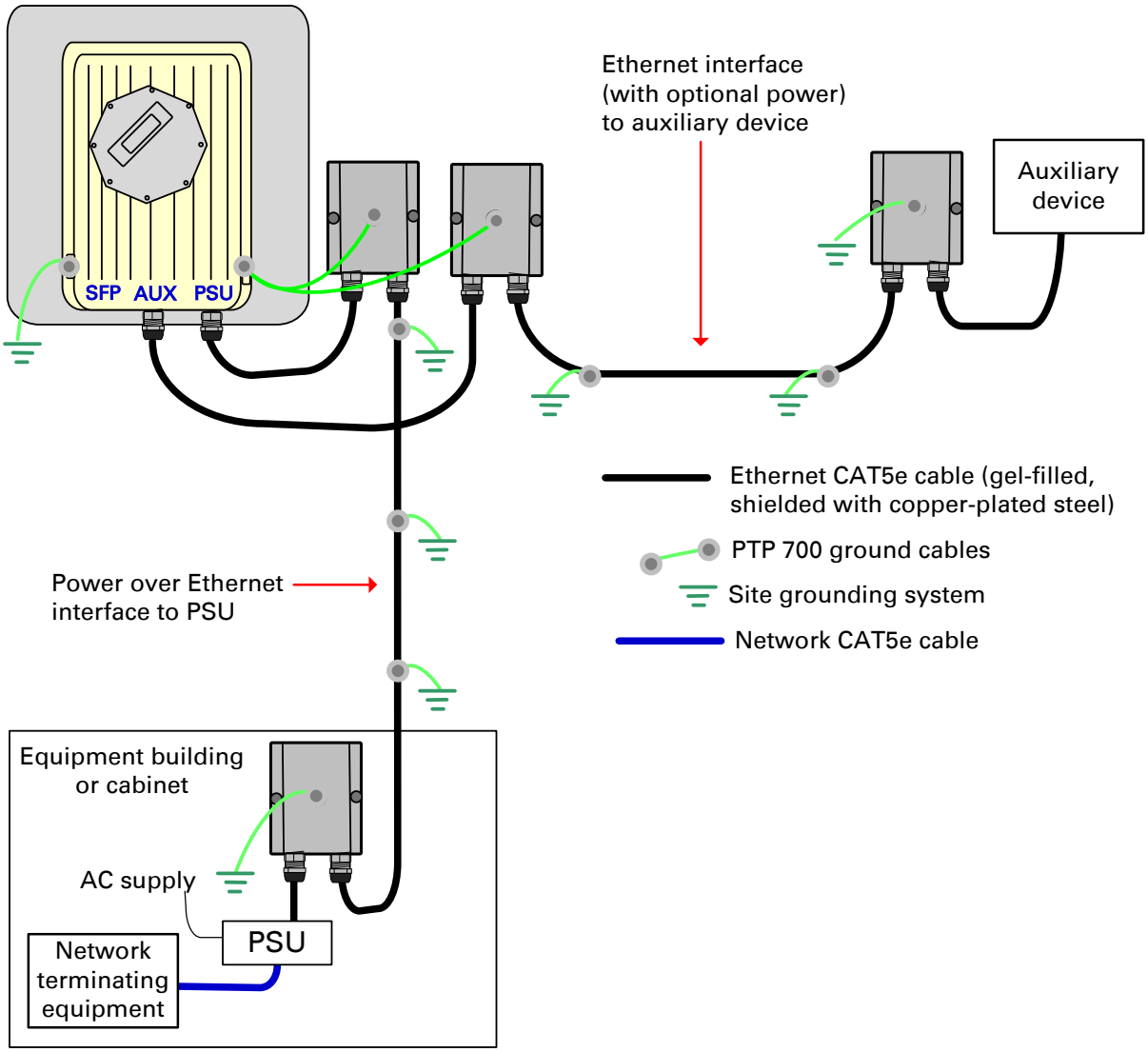


Figure 41 ODU with Aux and PSU interfaces



GPS receiver interfaces

If a GPS receiver is deployed for PTP-SYNC, it may be mounted on the wall of the equipment building (Figure 42) (preferred option), or on a metal tower or mast (Figure 43).

Figure 42 GPS receiver wall installation

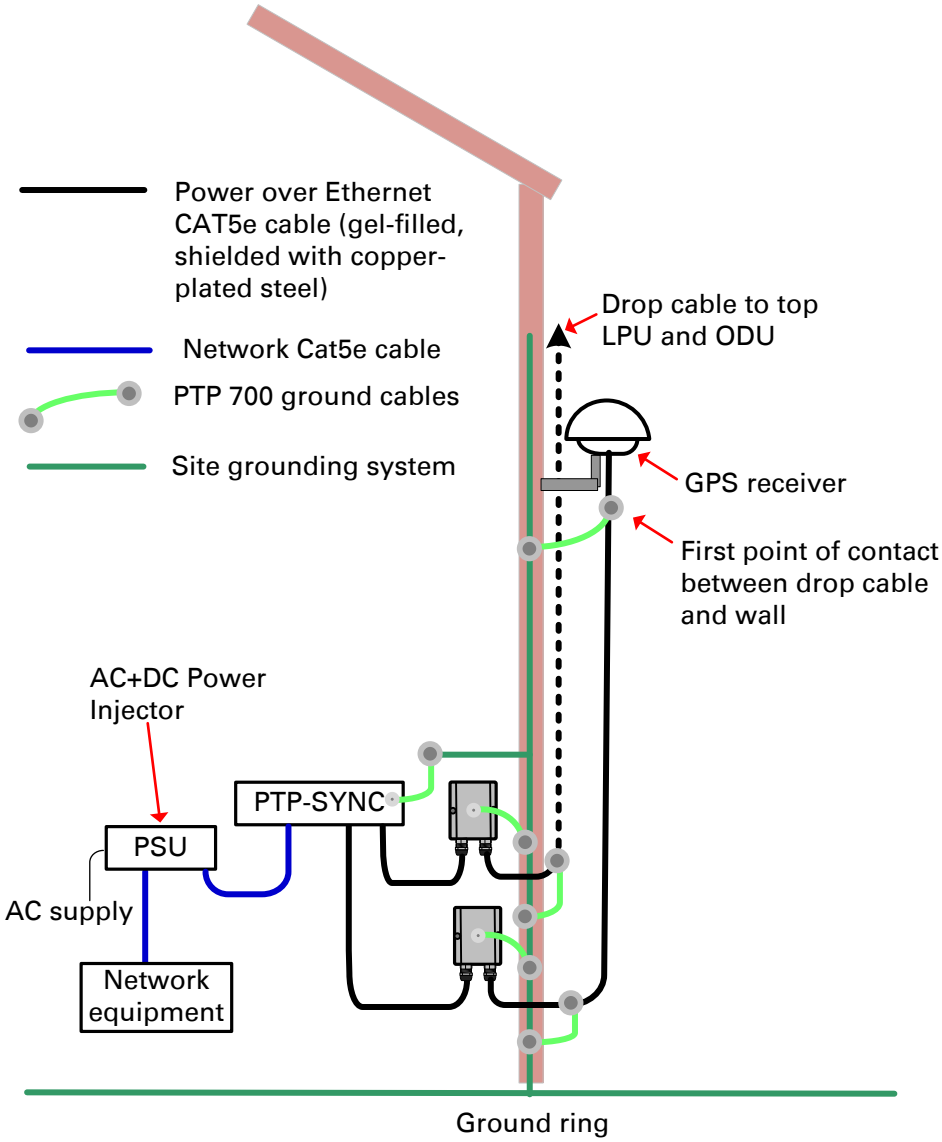
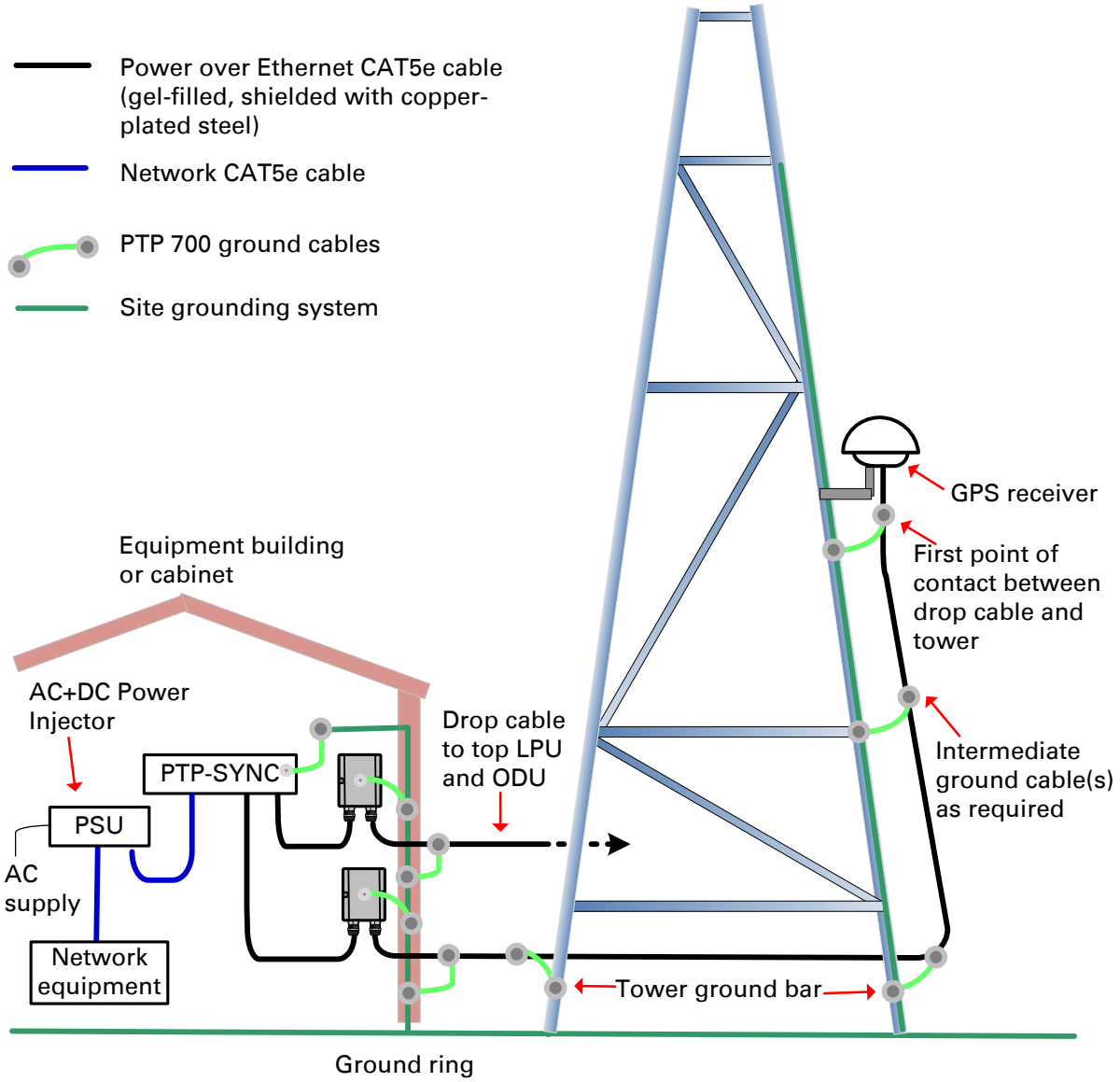


Figure 43 GPS receiver tower or mast installation



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 700 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.

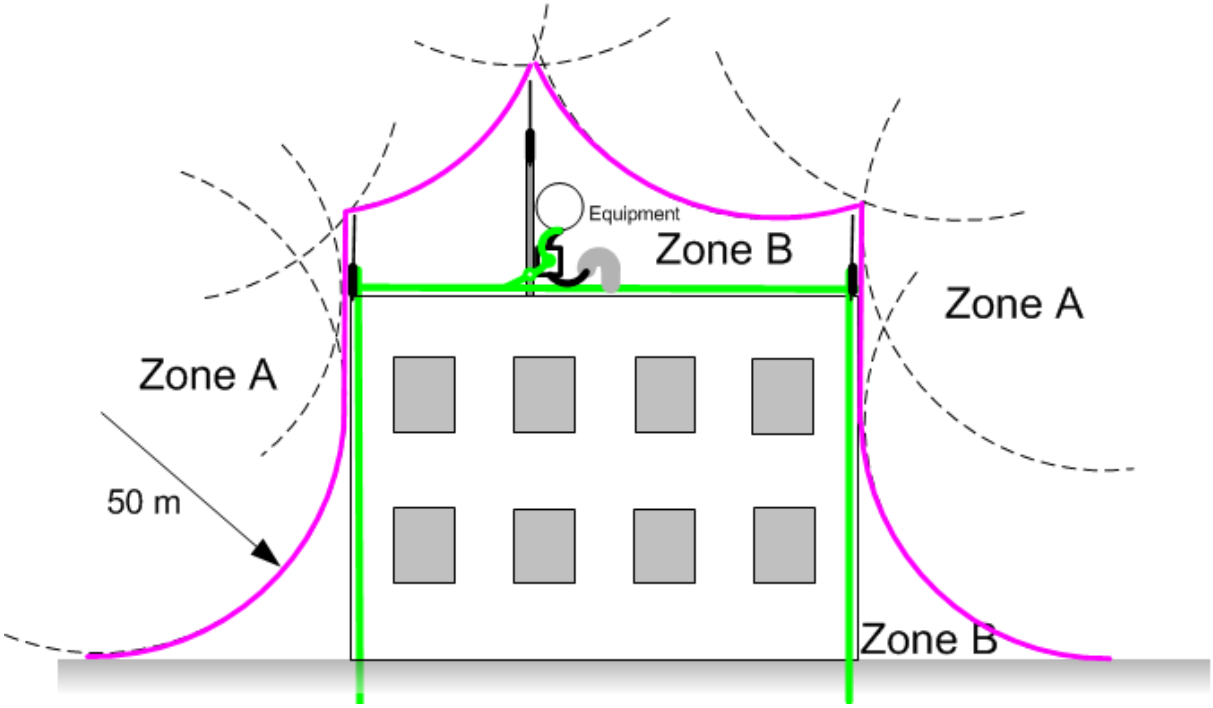
Note

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

Lightning protection zones

Use the rolling sphere method (Figure 44) 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 44 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 700 equipment.

If the outdoor equipment is to be installed on the roof of a high building (Figure 37), 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 4-22.
- 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 700 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 325 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 the variant of the ODU. Wind loading is estimated using the following formulae:

- Force (in newtons) = $0.5 \times \rho \times V^2 \times A \times C_d$
  - "ρ" is the density of air = 1.225 kg/m^3,
  - "V" is the wind speed in meters per second,
  - "A" is the projected surface area of the ODU in square meters, and
  - "C_d" is the drag coefficient = 1.385.

The drag coefficient has been measured when the cover plate or antenna is perpendicular to the air flow.

Applying this formula to the PTP 700 ODUs at different wind speeds, the resulting wind loadings are shown in Table 52

Table 52 ODU wind loading (newtons)

Type of ODU	Max surface area (square meters)	Wind speed (kilometers per hour)				
		225	250	275	300	325
Connectorized+Integrated	0.160	530 N	655 N	792 N	943 N	1106 N
Connectorized	0.062	205 N	254 N	307 N	365 N	429 N

Equivalent results in US customary units are shown in Table 53.

Table 53 ODU wind loading (pounds force)

Type of ODU	Max surface area (square feet)	Wind speed (miles per hour)				
		140	155	170	185	200
Connectorized+Integrated	1.72	120 lb	147 lb	176 lb	209 lb	244 lb
Connectorized	0.67	46 lb	57 lb	68 lb	81 lb	95 lb

If an external antenna is installed, add the wind loading of the antenna to that of the ODU. The antenna manufacturer should be able to quote wind loading.

Hazardous locations

Check that the ODUs will not be exposed to hazardous gases, as defined by HAZLOC (USA) and ATEX (Europe) regulations.

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 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 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.

Caution

The GPS receiver is not approved for operation in locations where gas hazards exist, as defined by HAZLOC (USA) and ATEX (Europe).

Mounting the GPS receiver module on the equipment building

If mounting the GPS receiver for PTP-SYNC on the equipment building (Figure 42), 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 43), 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 35 , Figure 36 and Figure 37) 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 35), 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 37), 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 700 LPU (Figure 45). Optical cables do not require LPUs or ground cables (Figure 46).

The copper SFP drop cable requires a bottom surge protector, not a PTP 700 LPU (Figure 47).

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

Figure 45 ODU with PSU, Aux and copper SFP interfaces

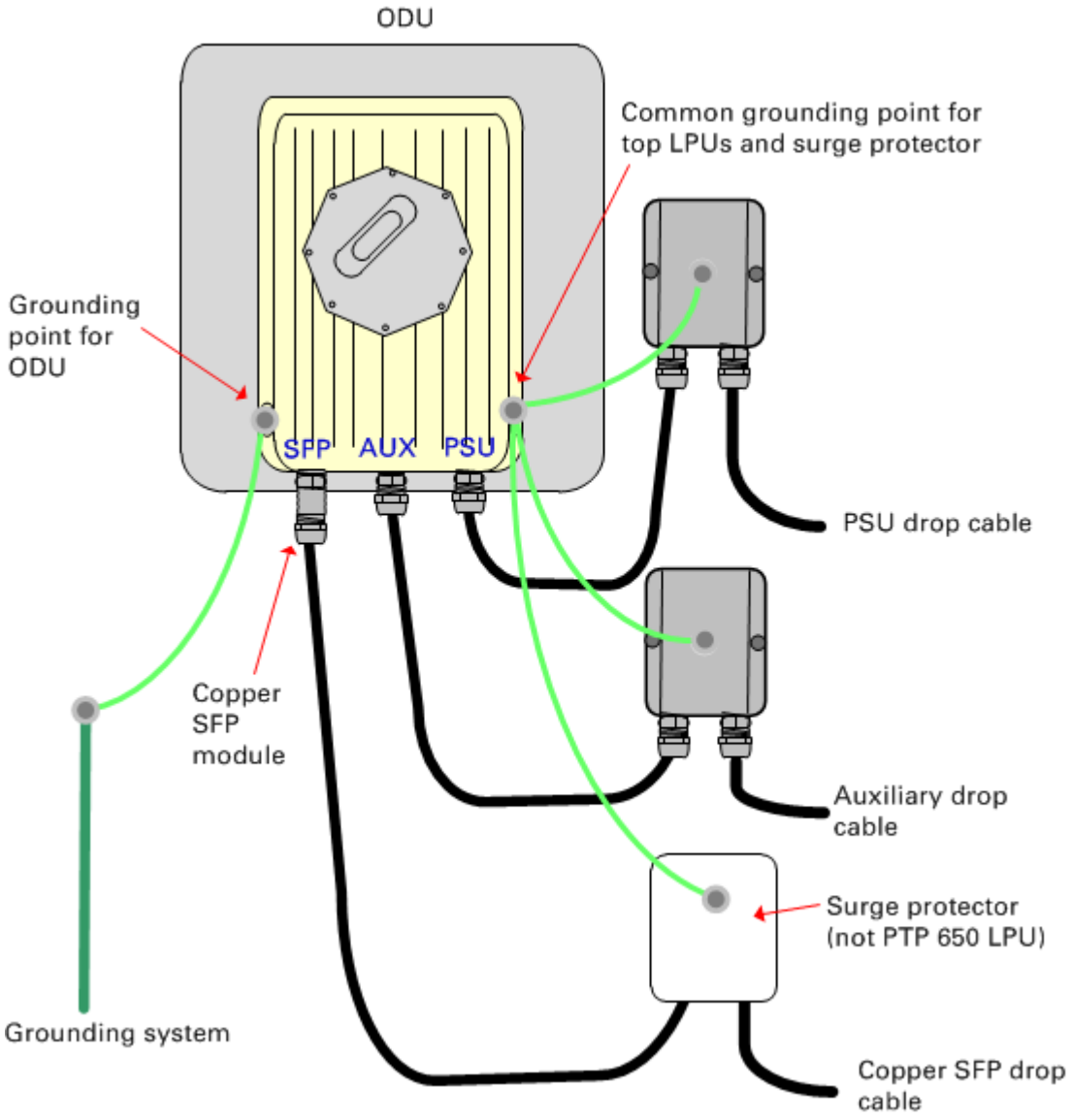


Figure 46 ODU with PSU, Aux and optical SFP interfaces

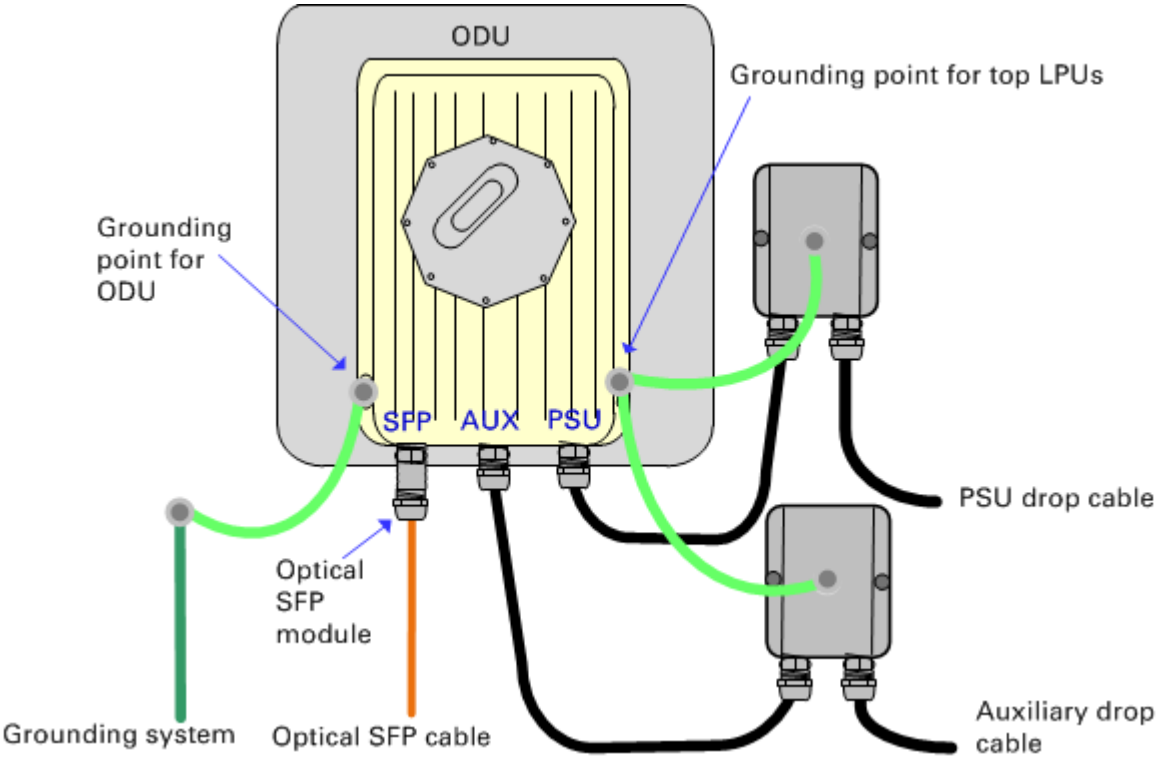
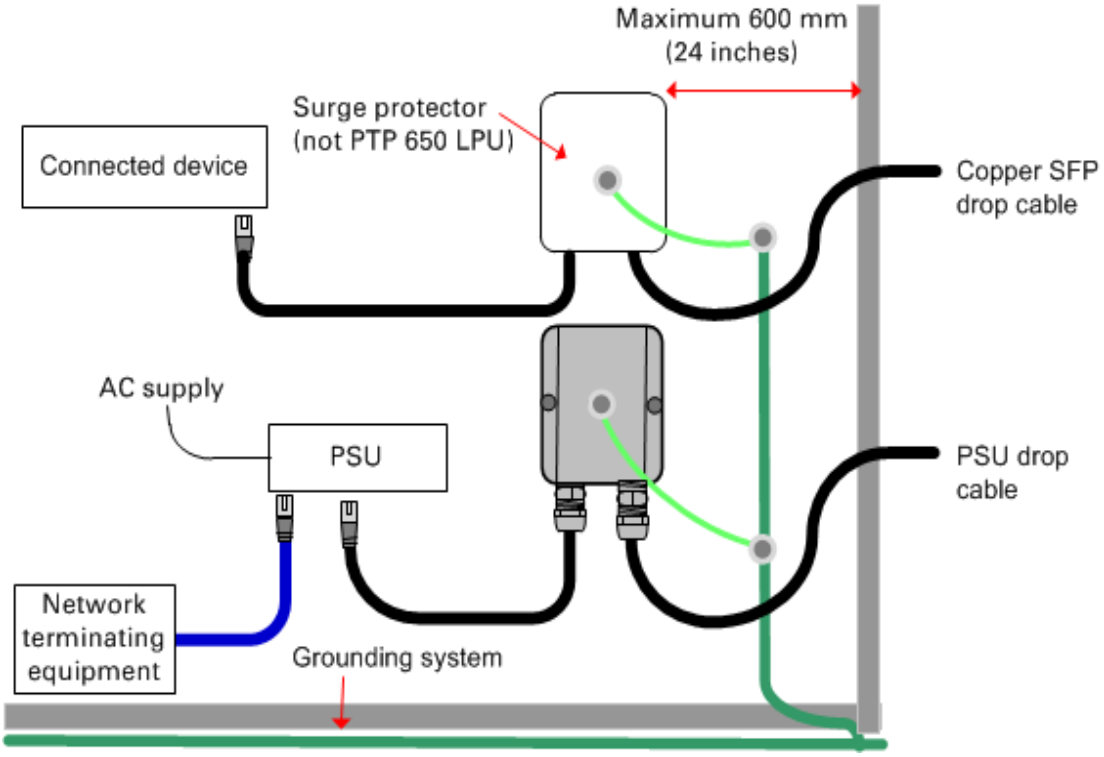


Figure 47 Bottom LPU and surge protector



Radio spectrum planning

This section describes how to plan PTP 700 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 700 link is required.

General wireless specifications

Table 54 lists the wireless specifications that apply to all PTP 700 frequency bands. Table 55 lists the wireless specifications that are specific to a single frequency band.

Table 54 PTP 700 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	22 dBi Flat plate antenna (PTP 700 Connectorized+Integrated)
Duplex schemes	Symmetric fixed, asymmetric fixed and, for the Full license only, adaptive TDD.
Range	Line-of-Sight: 250 km (156 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 700 wireless specifications (per frequency band)

Item	4.7 GHz	4.9 GHz	5.1 GHz	5.2 GHz	5.4 GHz	5.8 GHz
RF band (MHz)	4400–5000	4900–4990	5150–5250	5250–5350	5470–5725	5725–5875
Channel bandwidth (MHz)	5, 10, 15, 20, 30, 40, 45	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	7.5 dB	7.5 dB	7.5 dB	7.8 dB	7.8 dB	8.1 dB
Typical antenna gain (integrated)	22.0 dBi	22.0 dBi	22.0 dBi	22.0 dBi	22.0 dBi	22.0 dBi
Antenna beamwidth (integrated)	8°	8°	8°	8°	8°	8°

Regulatory limits

Many countries impose EIRP limits (Allowed EIRP) on products operating in the bands used by the PTP 700 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. When using connectorized ODUs with external antennas, ensure that the antenna gain and feeder loss is configured correctly in the ODU.

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 Expert and Spectrum Management web pages (Spectrum Expert page in radar avoidance mode on page 7-38).

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 on page 3.
- For Canada: in the specification RSS-247.

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.

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 700 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 700 Series will operate at ranges from 100 m (330 ft) to 250 km (156 miles), within four ranging modes: 0-40 km (0-25 miles), 0-100 km (0-62 miles), 0-200 km (0-125 miles), and 0-250 km (0-156 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 700 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: Full or Lite)
- 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 700 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 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 3-113.

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 700 variant = Lite
- 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 = 21 Mbits/s

Rx = 21 Mbits/s

Aggregated = 42 Mbits/s

2 Use Figure 76 to look up the Throughput Factor for 1:1, TDM, 10 MHz, Lite 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 = 18.1 Mbits/s

Rx = 18.1 Mbits/s

Aggregated = 36.1 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 700 links.

When to install connectorized units

The majority of radio links can be successfully deployed with the integrated antenna in the Connectorized+Integrated ODU. However the integrated antenna 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 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 700 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 700 Series. Schematic diagrams are included.

The PTP 700 supports the following TDD synchronization configurations:

- Single link configuration with PTP-SYNC on page 3-31.
- Cluster with PTP-SYNC and GPS receiver on page 3-32.
- Cluster with PTP-SYNC and no GPS receiver on page 3-33.

Caution

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

The PTP 650 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.

PTP-SYNC is not compatible with standards-based power-over-Ethernet (PoE).

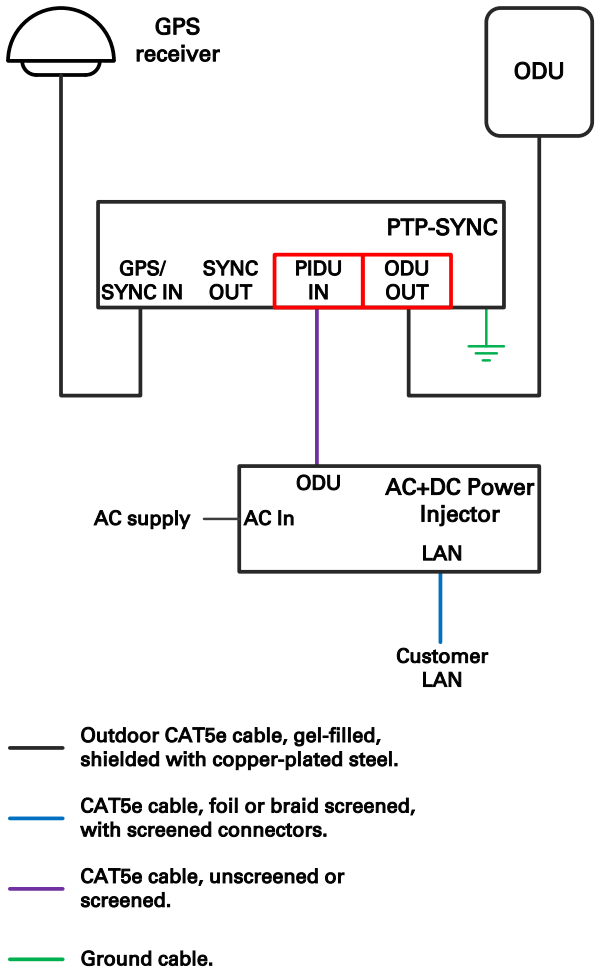
Single link configuration with PTP-SYNC

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 48).

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 48 TDD synchronization configuration – single link with PTP-SYNC



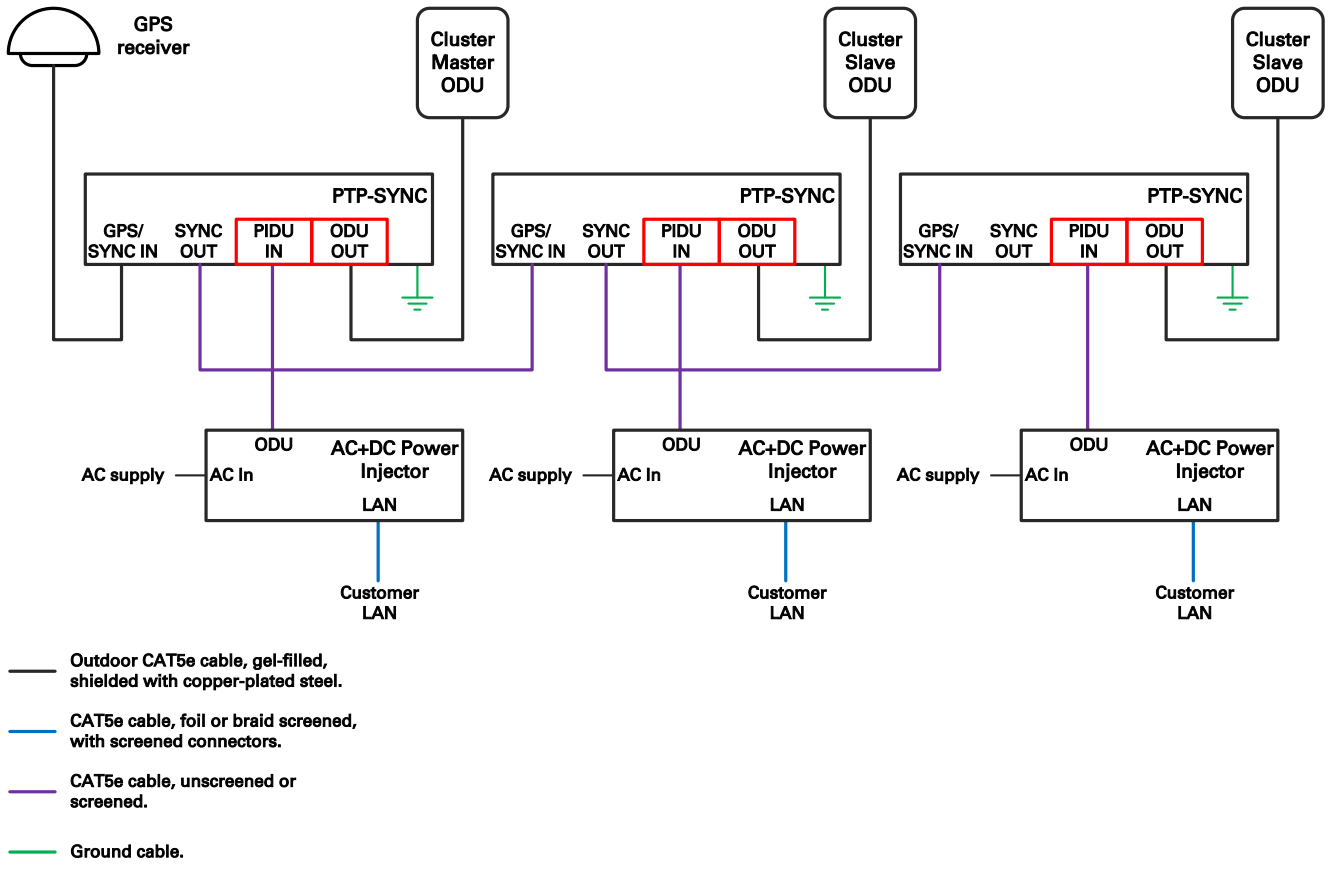
Cluster with PTP-SYNC and GPS receiver

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 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 = **GPS/1PPS External** (all ODUs in cluster).

Figure 49 TDD synchronization configuration – cluster with PTP-SYNC and GPS



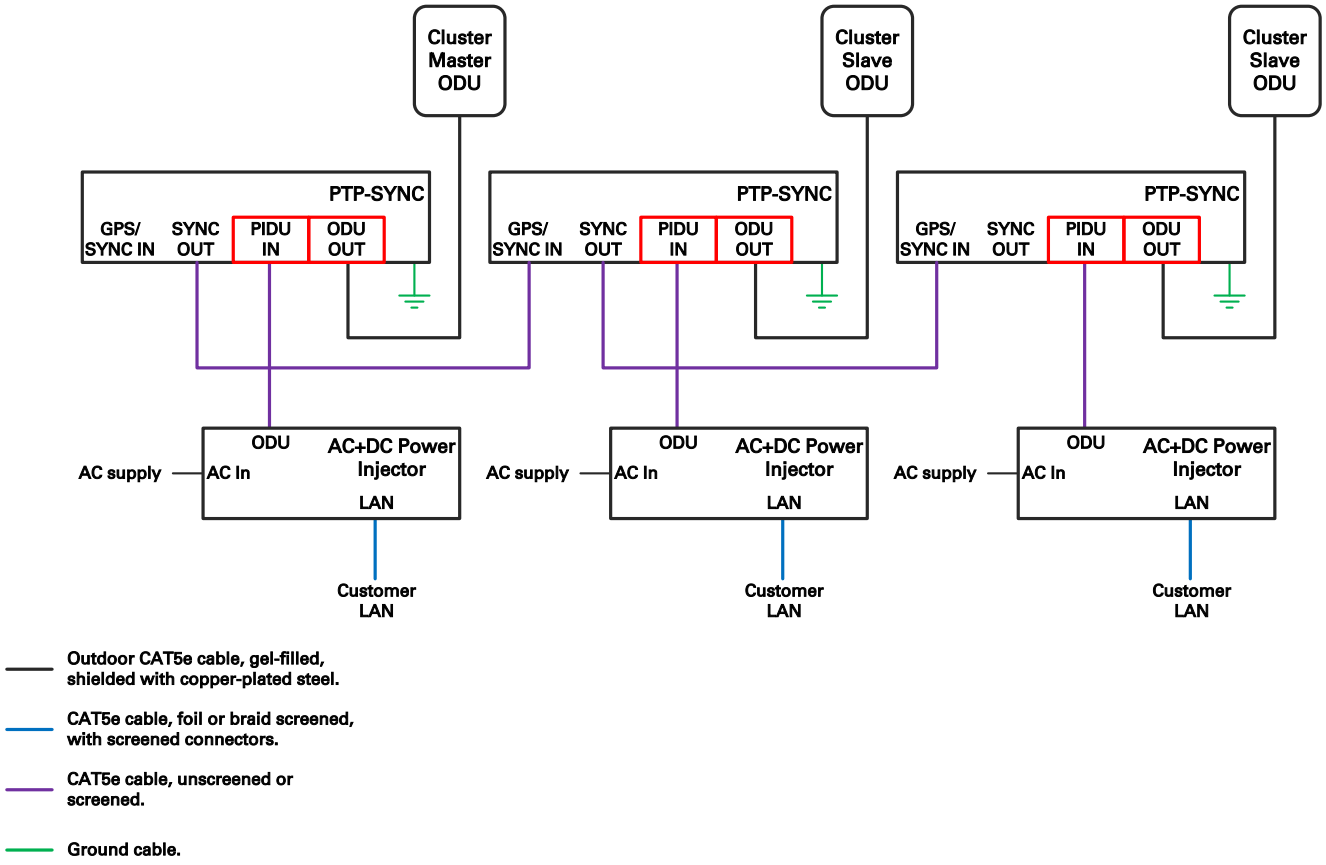
Cluster with PTP-SYNC and no GPS receiver

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 50).

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



Data network planning

This section describes factors to be considered when planning PTP 700 data networks.

Ethernet interfaces

The PTP 700 Ethernet ports conform to the specifications listed in Table 61.

Table 57 PTP 700 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 700 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 51
Data + Local Management + Local Management	Figure 52
Data + In-Band Management	Figure 53
Data + In-Band Management + Local Management	Figure 54
Data + In-Band Management + Local Management + Local Management	Figure 55
Data + Out-of-Band Management	Figure 56
Data + Out-of-Band Management + Local Management	Figure 57
Data + Second Data + In-Band Management (with Data)	Figure 58
Data + Second Data + In-Band Management (with Data) + Local Management	Figure 59
Data + Second Data + In-Band Management (with Second Data)	Figure 60
Data + Second Data + In-Band Management (with Second Data) + Local Management	Figure 61
Data + Second Data + Local Management	Figure 62

Figure 51 to Figure 62 illustrate the internal routing of Ethernet traffic in the twelve combinations of services listed in Table 59.

Figure 51 Ports and Services: Data + Local Management

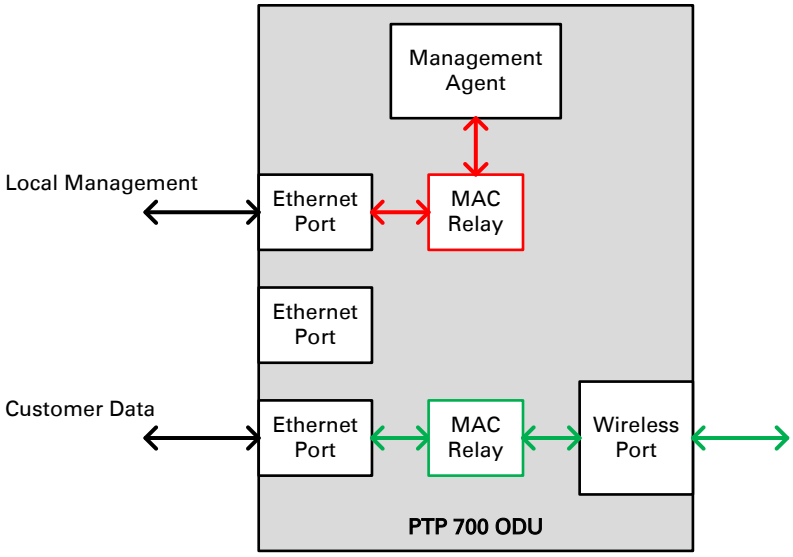


Figure 52 Ports and Services: Data + Local Management + Local Management

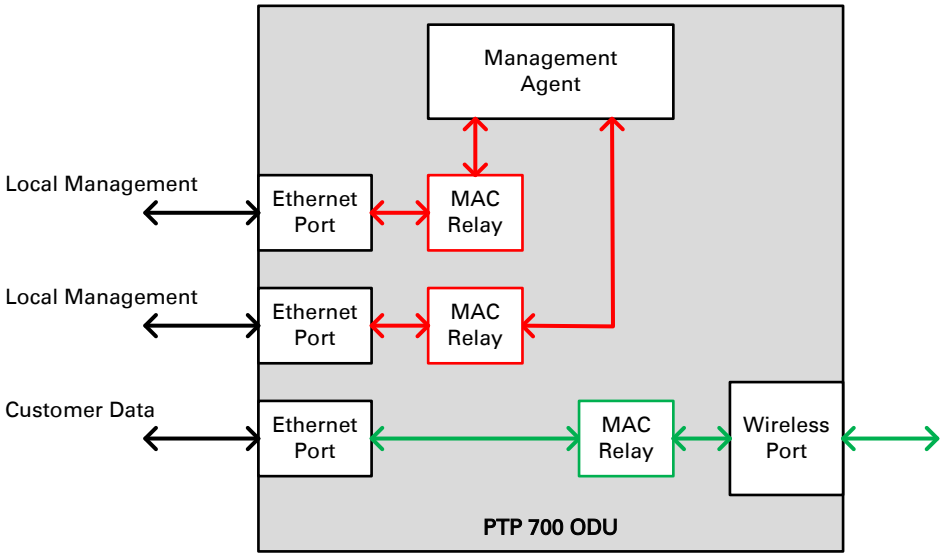


Figure 53 Ports and Services: Data + In-Band Management

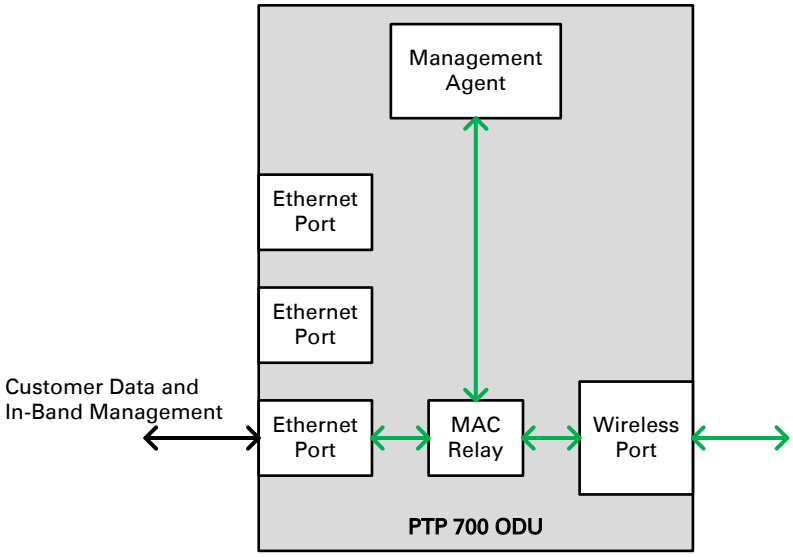


Figure 54 Ports and Services: Data + In-Band Management + Local Management

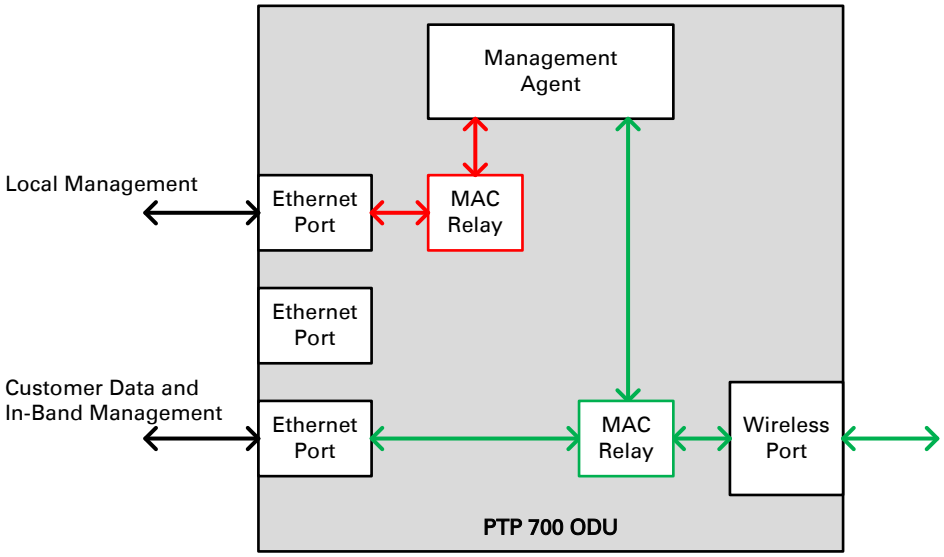


Figure 55 Ports and Services: Data + In-Band Management + Local Management + Local Management

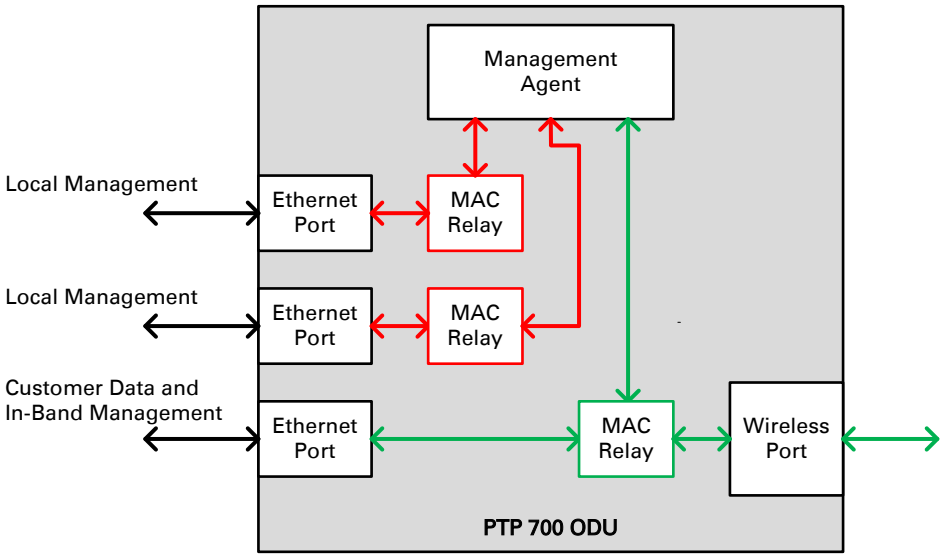


Figure 56 Ports and Services: Data + Out-Of-Band Management

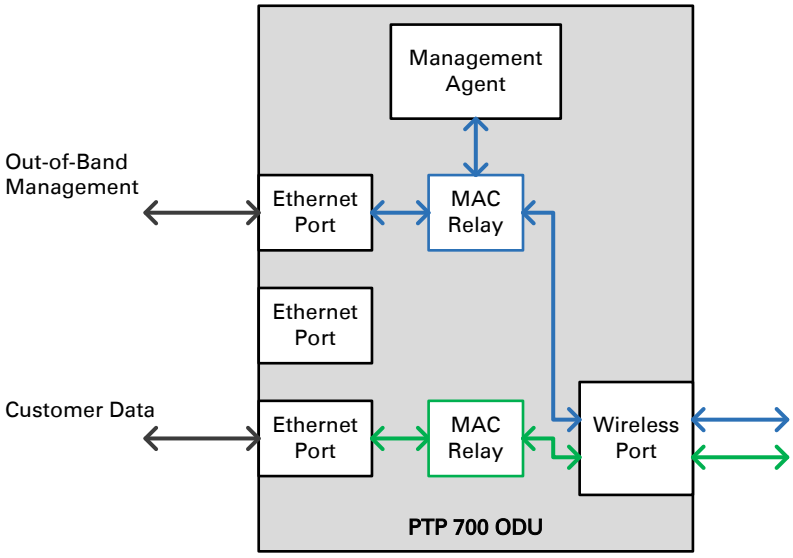


Figure 57 Ports and Services: Data + Out-Of-Band Management + Local Management

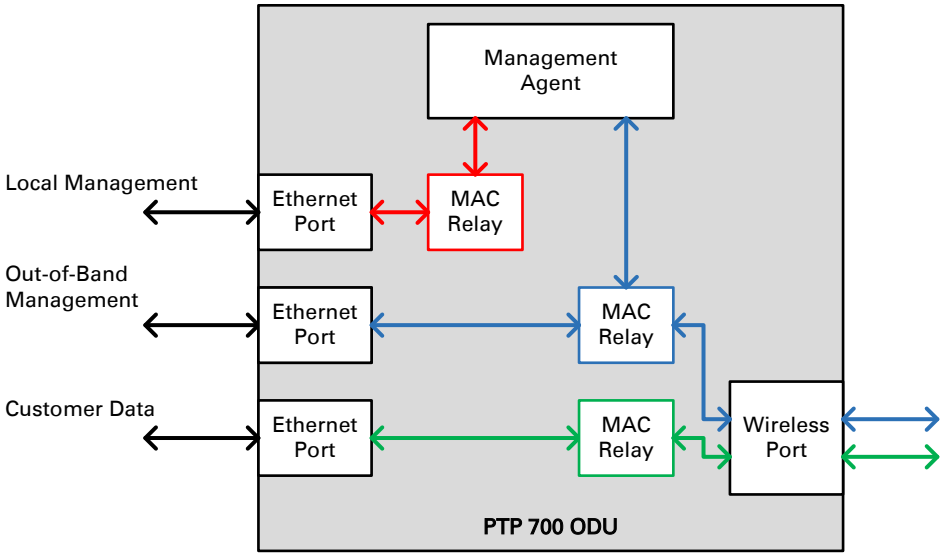


Figure 58 Ports and Services: Data + Second Data + In-Band Management (with Data)

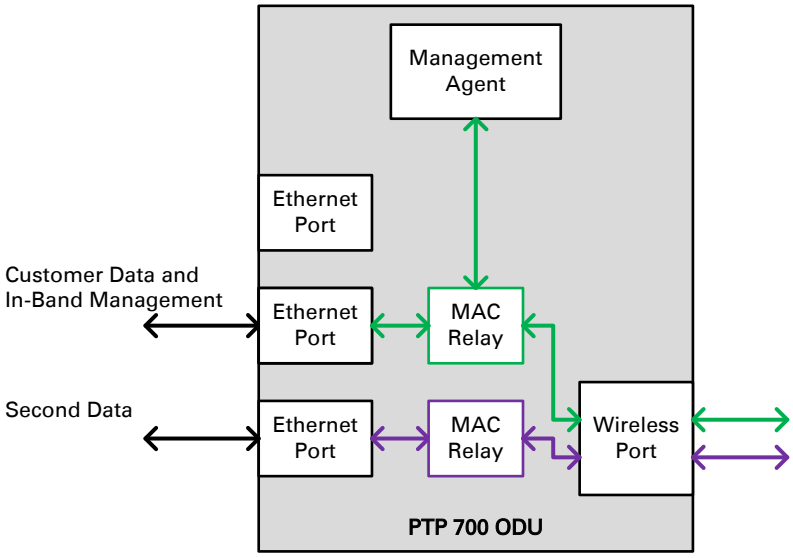


Figure 59 Ports and Services: Data + Second Data + In-Band Management (with Data) + Local Management

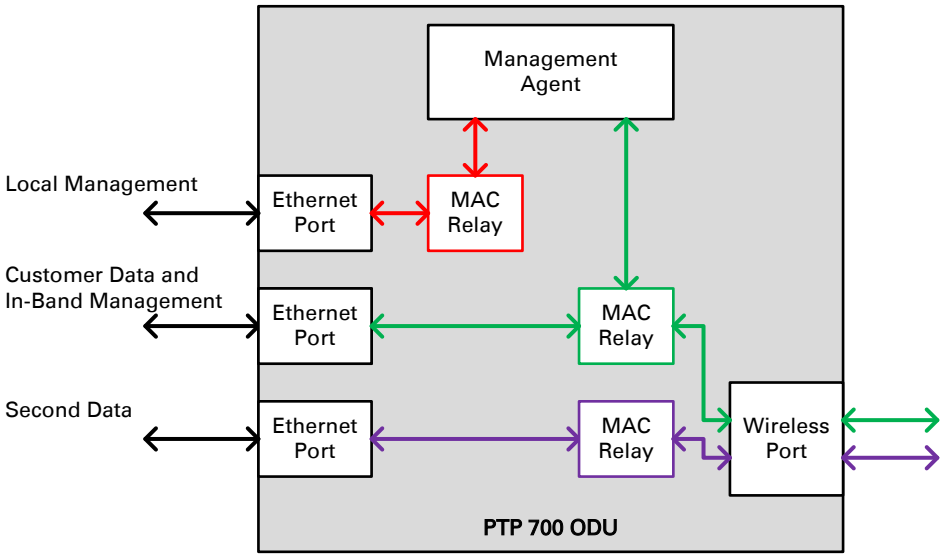


Figure 60 Ports and Services: Data + Second Data + In-Band Management (with Second Data)

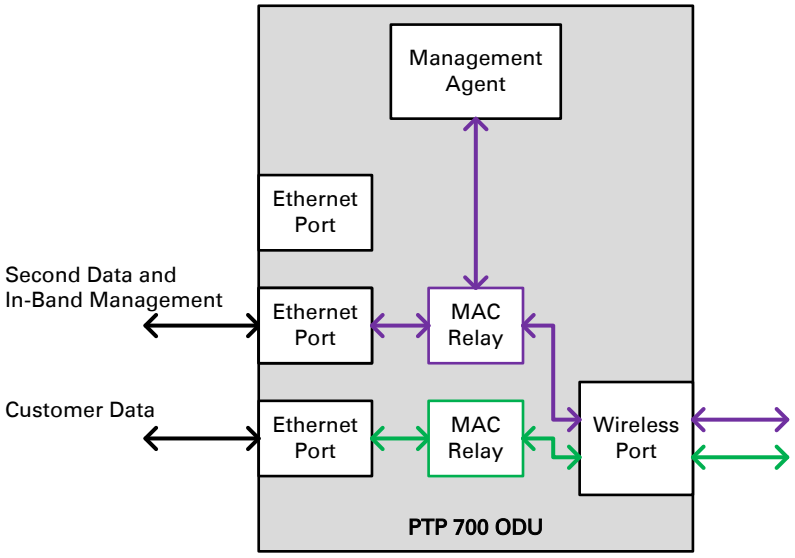


Figure 61 Ports and Services: Data + Second Data + In-Band Management (with Second Data) + Local Management

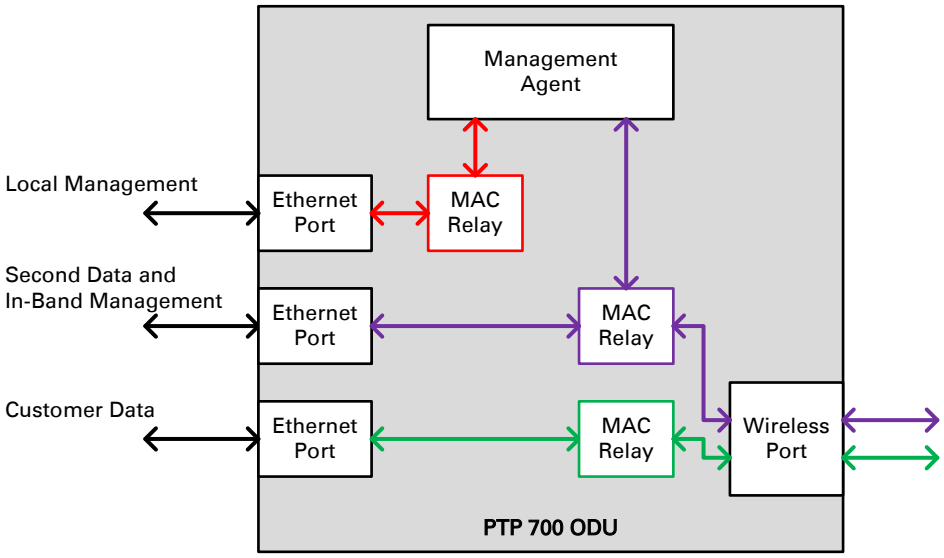
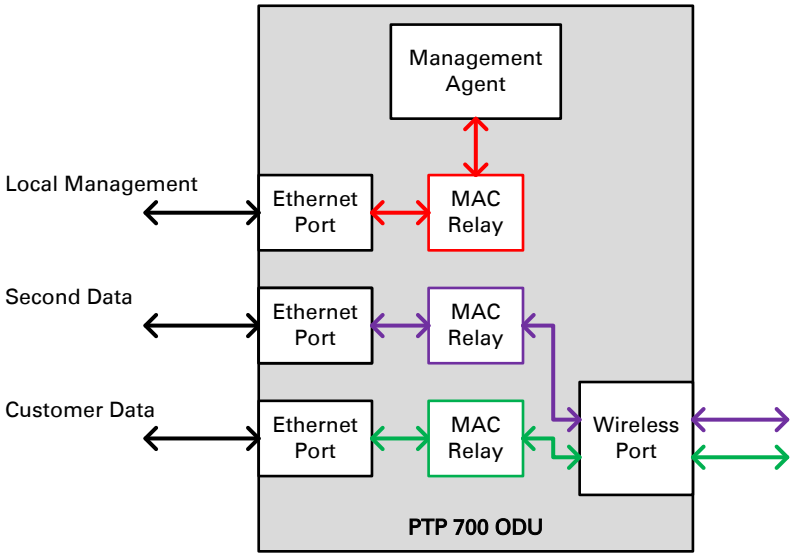


Figure 62 Ports and Services: Data + Second Data + Local Management



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

PTP 700 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 3-35 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).

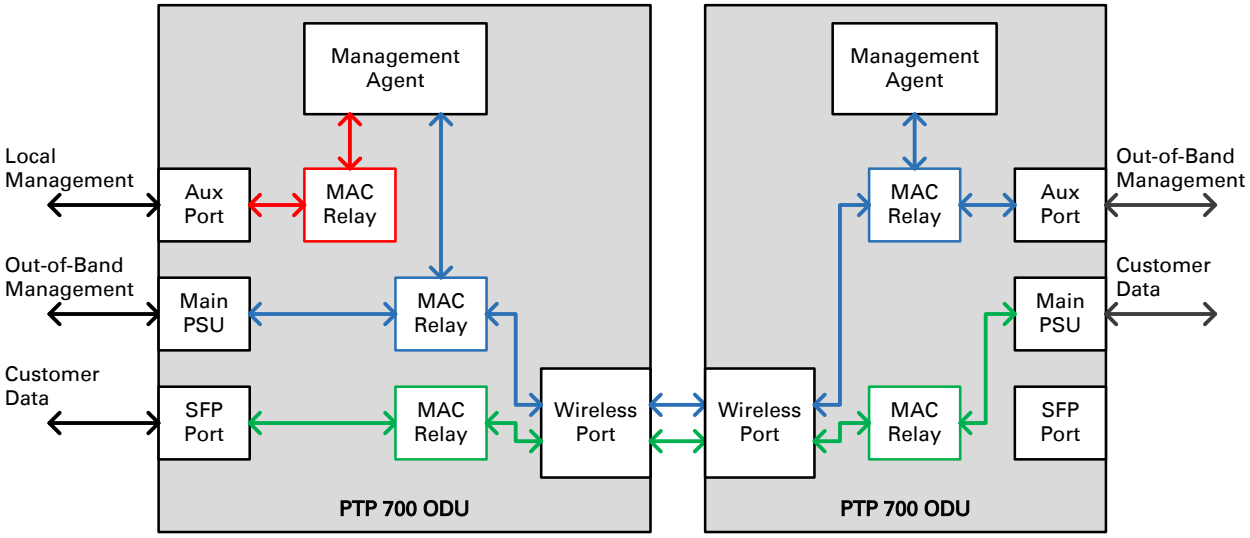
There is no objection to mapping the services to different physical ports at the two ends of the link, providing that the same row of Table 60 is used at each end.

For example, Figure 63 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 63 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 3-35.

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 700 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 700 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 700 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 700 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 700 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 700 selects a suitable mapping from these DSCP values to the eight PTP 700 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 700 queues.

“Daisy-chaining” PTP 700 links

When connecting two or more PTP 700 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 700 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 2-35.
- 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 2-35.
- 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 2-41.

Green Ethernet switches

Do not connect PTP 700 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 700 PSU.

TDM network planning

This section describes factors to be considered when planning PTP 700 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 700 TDM ports conform to the specifications listed in Table 61.

Table 61 PTP 700 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 700 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 700 Series proprietary MIB

Note

The proprietary MIBs are provided in the PTP 700 Series software download files in the support website (see Contacting Cambium Networks on page 1).

Supported diagnostic alarms

PTP 700 supports the diagnostic alarms listed in Table 168.

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 700 links to operate in secure mode.

Planning for SNTP operation

Note

PTP 700 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 a 2048-bit RSA public key, signed using SHA-256, 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 700 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 700 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 700 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 700. 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 700 provides a choice of the following authentication methods:

- CHAP
- MS-CHAPv2

Ensure that the authentication method selected in PTP 700 is supported by the RADIUS server.

Note

RADIUS is not permitted in FIPS 140-2 applications. Ensure that the RADIUS feature is disabled in FIPS 140-2 approved mode.

RADIUS attributes

If the standard RADIUS attribute session-timeout (Type 27) is present in a RADIUS response, PTP 700 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 700 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 700 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 700 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 700 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).

Planning for FIPS 140-2 operation

If the link is to operate in FIPS 140-2 secure mode, ensure that the following cryptographic material is generated using a FIPS-approved cryptographic generator:

- Key of Keys
- TLS Private Key and Public Certificates, RSA 2048-bit key size, signed using the SHA-256 Secure Hash Algorithm.
- Entropy Input
- Wireless Link Encryption Key for AES

Ensure that the web browsers used are enabled for HTTPS/TLS operation using FIPS-approved cipher specifications.

Ensure that following attributes of user accounts for the web-based management interface have been configured to match the operator's network security policy:

- Auto Logout Period.
- Maximum Number of Login Attempts.
- Login Attempt Lockout.
- Minimum Password Change Period.
- Password Expiry Period.
- Webpage Session Control

Ensure that the following are configured:

- Password complexity rules reset to best practice values.

- User account passwords compliant with the network security policy.
- RADIUS authentication disabled.

Caution

Configure all of the above correctly to ensure that PTP 600 is operating in compliance with the FIPS 140-2 validation.

Further reading

For information about...	Refer to...
Generating security material for the HTTPS/TLS interface	Planning for HTTPS/TLS operation on page 3-50

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)
4.7 GHz	IP	Table 68	Table 69
	TDM	Table 70	Table 71
4.9 GHz	IP	Table 72	Table 73
	TDM	Table 74	Table 75
5.1 GHz and 5.2 GHz	IP	Table 76	Table 77
	TDM	Table 78	Table 79
5.4 GHz	IP	Table 80	Table 81
	TDM	Table 82	Table 83
5.8 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 700 Connectorized+Integrated ODUs. Adjust the maximum link loss for alternative antennas by adding (G – 22) for each antenna, where G is the antenna gain of the alternative antenna.

Table 68 4.7 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	-94.3	-92.8	-91.0	-89.8	-88.0	-86.8	-86.3	27
QPSK 0.63 single	-91.2	-89.7	-87.9	-86.7	-84.9	-83.7	-83.2	26
QPSK 0.87 single	-87.2	-85.7	-83.9	-82.7	-80.9	-79.7	-79.1	26
16QAM 0.63 single	-84.9	-83.4	-81.6	-80.3	-78.6	-77.3	-76.8	25
16QAM 0.63 dual	-80.9	-79.4	-77.7	-76.4	-74.6	-73.4	-72.9	25
16QAM 0.87 single	-80.4	-78.9	-77.1	-75.9	-74.1	-72.8	-72.3	25
16QAM 0.87 dual	-77.3	-75.8	-74.0	-72.8	-71.0	-69.8	-69.3	25
64QAM 0.75 single	-77.3	-75.8	-74.1	-72.8	-71.0	-69.8	-69.3	24
64QAM 0.75 dual	-74.2	-72.7	-70.9	-69.7	-67.9	-66.7	-66.2	24
64QAM 0.92 single	-73.4	-71.9	-70.2	-68.9	-67.1	-65.9	-65.4	24
64 QAM 0.92 dual	-70.2	-68.7	-66.9	-65.6	-63.9	-62.6	-62.1	24
256QAM 0.81 single	-70.2	-68.7	-66.9	-65.6	-63.9	-62.6	-62.1	23
256QAM 0.81 dual	-66.6	-65.1	-63.3	-62.1	-60.3	-59.1	-58.6	23

Table 69 4.7 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	163.9	162.4	160.6	159.4	157.6	156.4	155.9
QPSK 0.63 single	159.8	158.3	156.5	155.3	153.5	152.3	151.8
QPSK 0.87 single	155.8	154.3	152.5	151.3	149.5	148.3	147.7
16QAM 0.63 single	152.5	151.0	149.2	147.9	146.2	144.9	144.4
16QAM 0.63 dual	148.5	147.0	145.3	144.0	142.2	141.0	140.5
16QAM 0.87 single	148.0	146.5	144.7	143.5	141.7	140.4	139.9
16QAM 0.87 dual	144.9	143.4	141.6	140.4	138.6	137.4	136.9
64QAM 0.75 single	143.9	142.4	140.7	139.4	137.6	136.4	135.9
64QAM 0.75 dual	140.8	139.3	137.5	136.3	134.5	133.3	132.8
64QAM 0.92 single	140.0	138.5	136.8	135.5	133.7	132.5	132.0
64 QAM 0.92 dual	136.8	135.3	133.5	132.2	130.5	129.2	128.7
256QAM 0.81 single	135.8	134.3	132.5	131.2	129.5	128.2	127.7
256QAM 0.81 dual	132.2	130.7	128.9	127.7	125.9	124.7	124.2

Table 70 4.7 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	-94.3	-92.8	-91.0	-89.8	-88.0	-86.8	-86.3	27
QPSK 0.63 single	-88.2	-86.7	-84.9	-83.7	-81.9	-80.7	-80.2	26
QPSK 0.87 single	-84.2	-82.6	-80.9	-79.6	-77.9	-76.6	-76.1	26
16QAM 0.63 single	-81.8	-80.3	-78.5	-77.3	-75.5	-74.3	-73.8	25
16QAM 0.63 dual	-77.8	-76.3	-74.6	-73.3	-71.6	-70.3	-69.8	25
16QAM 0.87 single	-77.2	-75.7	-73.9	-72.7	-70.9	-69.7	-69.2	25
16QAM 0.87 dual	-74.1	-72.6	-70.8	-69.6	-67.8	-66.6	-66.1	25
64QAM 0.75 single	-74.0	-72.5	-70.7	-69.5	-67.7	-66.5	-66.0	24
64QAM 0.75 dual	-70.8	-69.3	-67.5	-66.3	-64.5	-63.3	-62.7	24
64QAM 0.92 single	-71.6	-70.1	-68.3	-67.1	-65.3	-64.1	-63.6	24
64 QAM 0.92 dual	-68.2	-66.7	-64.9	-63.7	-61.9	-60.7	-60.2	24
256QAM 0.81 single	-70.2	-68.7	-66.9	-65.6	-63.9	-62.6	-62.1	23
256QAM 0.81 dual	-66.6	-65.1	-63.3	-62.1	-60.3	-59.1	-58.6	23

Table 71 4.7 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	163.9	162.4	160.6	159.4	157.6	156.4	155.9
QPSK 0.63 single	156.8	155.3	153.5	152.3	150.5	149.3	148.8
QPSK 0.87 single	152.8	151.2	149.5	148.2	146.5	145.2	144.7
16QAM 0.63 single	149.4	147.9	146.1	144.9	143.1	141.9	141.4
16QAM 0.63 dual	145.4	143.9	142.2	140.9	139.2	137.9	137.4
16QAM 0.87 single	144.8	143.3	141.5	140.3	138.5	137.3	136.8
16QAM 0.87 dual	141.7	140.2	138.4	137.2	135.4	134.2	133.7
64QAM 0.75 single	140.6	139.1	137.3	136.1	134.3	133.1	132.6
64QAM 0.75 dual	137.4	135.9	134.1	132.9	131.1	129.9	129.3
64QAM 0.92 single	138.2	136.7	134.9	133.7	131.9	130.7	130.2
64 QAM 0.92 dual	134.8	133.3	131.5	130.3	128.5	127.3	126.8
256QAM 0.81 single	135.8	134.3	132.5	131.2	129.5	128.2	127.7
256QAM 0.81 dual	132.2	130.7	128.9	127.7	125.9	124.7	124.2

Table 72 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	30 MHz	40 MHz	45 MHz	P (all bands)
BPSK 0.63 single	-94.3	-92.8	-91.0	-89.8	-88.0	-86.8	-86.3	27
QPSK 0.63 single	-91.2	-89.7	-87.9	-86.7	-84.9	-83.7	-83.2	26
QPSK 0.87 single	-87.2	-85.7	-83.9	-82.7	-80.9	-79.7	-79.1	26
16QAM 0.63 single	-84.9	-83.4	-81.6	-80.3	-78.6	-77.3	-76.8	25
16QAM 0.63 dual	-80.9	-79.4	-77.7	-76.4	-74.6	-73.4	-72.9	25
16QAM 0.87 single	-80.4	-78.9	-77.1	-75.9	-74.1	-72.8	-72.3	25
16QAM 0.87 dual	-77.3	-75.8	-74.0	-72.8	-71.0	-69.8	-69.3	25
64QAM 0.75 single	-77.3	-75.8	-74.1	-72.8	-71.0	-69.8	-69.3	24
64QAM 0.75 dual	-74.2	-72.7	-70.9	-69.7	-67.9	-66.7	-66.2	24
64QAM 0.92 single	-73.4	-71.9	-70.2	-68.9	-67.1	-65.9	-65.4	24
64 QAM 0.92 dual	-70.2	-68.7	-66.9	-65.6	-63.9	-62.6	-62.1	24
256QAM 0.81 single	-70.2	-68.7	-66.9	-65.6	-63.9	-62.6	-62.1	23
256QAM 0.81 dual	-66.6	-65.1	-63.3	-62.1	-60.3	-59.1	-58.6	23

Table 73 4.9 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	164.3	162.8	161.0	159.8	158.0	156.8	156.3
QPSK 0.63 single	160.2	158.7	156.9	155.7	153.9	152.7	152.2
QPSK 0.87 single	156.2	154.7	152.9	151.7	149.9	148.7	148.1
16QAM 0.63 single	152.9	151.4	149.6	148.3	146.6	145.3	144.8
16QAM 0.63 dual	148.9	147.4	145.7	144.4	142.6	141.4	140.9
16QAM 0.87 single	148.4	146.9	145.1	143.9	142.1	140.8	140.3
16QAM 0.87 dual	145.3	143.8	142.0	140.8	139.0	137.8	137.3
64QAM 0.75 single	144.3	142.8	141.1	139.8	138.0	136.8	136.3
64QAM 0.75 dual	141.2	139.7	137.9	136.7	134.9	133.7	133.2
64QAM 0.92 single	140.4	138.9	137.2	135.9	134.1	132.9	132.4
64 QAM 0.92 dual	137.2	135.7	133.9	132.6	130.9	129.6	129.1
256QAM 0.81 single	136.2	134.7	132.9	131.6	129.9	128.6	128.1
256QAM 0.81 dual	132.6	131.1	129.3	128.1	126.3	125.1	124.6

Table 74 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	30 MHz	40 MHz	45 MHz	P (all bands)
BPSK 0.63 single	-94.3	-92.8	-91.0	-89.8	-88.0	-86.8	-86.3	27
QPSK 0.63 single	-88.2	-86.7	-84.9	-83.7	-81.9	-80.7	-80.2	26
QPSK 0.87 single	-84.2	-82.6	-80.9	-79.6	-77.9	-76.6	-76.1	26
16QAM 0.63 single	-81.8	-80.3	-78.5	-77.3	-75.5	-74.3	-73.8	25
16QAM 0.63 dual	-77.8	-76.3	-74.6	-73.3	-71.6	-70.3	-69.8	25
16QAM 0.87 single	-77.2	-75.7	-73.9	-72.7	-70.9	-69.7	-69.2	25
16QAM 0.87 dual	-74.1	-72.6	-70.8	-69.6	-67.8	-66.6	-66.1	25
64QAM 0.75 single	-74.0	-72.5	-70.7	-69.5	-67.7	-66.5	-66.0	24
64QAM 0.75 dual	-70.8	-69.3	-67.5	-66.3	-64.5	-63.3	-62.7	24
64QAM 0.92 single	-71.6	-70.1	-68.3	-67.1	-65.3	-64.1	-63.6	24
64 QAM 0.92 dual	-68.2	-66.7	-64.9	-63.7	-61.9	-60.7	-60.2	24
256QAM 0.81 single	-70.2	-68.7	-66.9	-65.6	-63.9	-62.6	-62.1	23
256QAM 0.81 dual	-66.6	-65.1	-63.3	-62.1	-60.3	-59.1	-58.6	23

Table 75 4.9 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	164.3	162.8	161.0	159.8	158.0	156.8	156.3
QPSK 0.63 single	157.2	155.7	153.9	152.7	150.9	149.7	149.2
QPSK 0.87 single	153.2	151.6	149.9	148.6	146.9	145.6	145.1
16QAM 0.63 single	149.8	148.3	146.5	145.3	143.5	142.3	141.8
16QAM 0.63 dual	145.8	144.3	142.6	141.3	139.6	138.3	137.8
16QAM 0.87 single	145.2	143.7	141.9	140.7	138.9	137.7	137.2
16QAM 0.87 dual	142.1	140.6	138.8	137.6	135.8	134.6	134.1
64QAM 0.75 single	141.0	139.5	137.7	136.5	134.7	133.5	133.0
64QAM 0.75 dual	137.8	136.3	134.5	133.3	131.5	130.3	129.7
64QAM 0.92 single	138.6	137.1	135.3	134.1	132.3	131.1	130.6
64 QAM 0.92 dual	135.2	133.7	131.9	130.7	128.9	127.7	127.2
256QAM 0.81 single	136.2	134.7	132.9	131.6	129.9	128.6	128.1
256QAM 0.81 dual	132.6	131.1	129.3	128.1	126.3	125.1	124.6

Table 76 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	-94.3	-92.8	-91.0	-89.8	-88.0	-86.8	-86.3	27
QPSK 0.63 single	-91.2	-89.7	-87.9	-86.7	-84.9	-83.7	-83.2	26
QPSK 0.87 single	-87.2	-85.7	-83.9	-82.7	-80.9	-79.7	-79.2	26
16QAM 0.63 single	-84.9	-83.4	-81.6	-80.4	-78.6	-77.3	-76.8	25
16QAM 0.63 dual	-80.9	-79.4	-77.7	-76.4	-74.7	-73.4	-72.9	25
16QAM 0.87 single	-80.4	-78.9	-77.1	-75.9	-74.1	-72.9	-72.3	25
16QAM 0.87 dual	-77.3	-75.8	-74.1	-72.8	-71.1	-69.8	-69.3	25
64QAM 0.75 single	-77.4	-75.8	-74.1	-72.8	-71.1	-69.8	-69.3	24
64QAM 0.75 dual	-74.3	-72.8	-71.0	-69.7	-68.0	-66.7	-66.2	24
64QAM 0.92 single	-73.5	-72.0	-70.2	-69.0	-67.2	-66.0	-65.5	24
64 QAM 0.92 dual	-70.3	-68.8	-67.0	-65.8	-64.0	-62.8	-62.2	24
256QAM 0.81 single	-70.3	-68.8	-67.1	-65.8	-64.0	-62.8	-62.3	23
256QAM 0.81 dual	-66.9	-65.4	-63.6	-62.3	-60.6	-59.3	-58.8	23

Table 77 5.1/5.2 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	165.3	163.8	162.0	160.8	159.0	157.8	157.3
QPSK 0.63 single	161.2	159.7	157.9	156.7	154.9	153.7	153.2
QPSK 0.87 single	157.2	155.7	153.9	152.7	150.9	149.7	149.2
16QAM 0.63 single	153.9	152.4	150.6	149.4	147.6	146.3	145.8
16QAM 0.63 dual	149.9	148.4	146.7	145.4	143.7	142.4	141.9
16QAM 0.87 single	149.4	147.9	146.1	144.9	143.1	141.9	141.3
16QAM 0.87 dual	146.3	144.8	143.1	141.8	140.1	138.8	138.3
64QAM 0.75 single	145.4	143.8	142.1	140.8	139.1	137.8	137.3
64QAM 0.75 dual	142.3	140.8	139.0	137.7	136.0	134.7	134.2
64QAM 0.92 single	141.5	140.0	138.2	137.0	135.2	134.0	133.5
64 QAM 0.92 dual	138.3	136.8	135.0	133.8	132.0	130.8	130.2
256QAM 0.81 single	137.3	135.8	134.1	132.8	131.0	129.8	129.3
256QAM 0.81 dual	133.9	132.4	130.6	129.3	127.6	126.3	125.8

Table 78 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	-94.3	-92.8	-91.0	-89.8	-88.0	-86.8	-86.3	27
QPSK 0.63 single	-88.2	-86.7	-84.9	-83.7	-81.9	-80.7	-80.2	26
QPSK 0.87 single	-84.2	-82.7	-80.9	-79.6	-77.9	-76.6	-76.1	26
16QAM 0.63 single	-81.8	-80.3	-78.6	-77.3	-75.5	-74.3	-73.8	25
16QAM 0.63 dual	-77.9	-76.3	-74.6	-73.3	-71.6	-70.3	-69.8	25
16QAM 0.87 single	-77.3	-75.7	-74.0	-72.7	-71.0	-69.7	-69.2	25
16QAM 0.87 dual	-74.2	-72.6	-70.9	-69.6	-67.9	-66.6	-66.1	25
64QAM 0.75 single	-74.1	-72.6	-70.8	-69.6	-67.8	-66.5	-66.0	24
64QAM 0.75 dual	-70.9	-69.4	-67.6	-66.4	-64.6	-63.4	-62.8	24
64QAM 0.92 single	-71.7	-70.2	-68.5	-67.2	-65.4	-64.2	-63.7	24
64 QAM 0.92 dual	-68.4	-66.9	-65.1	-63.9	-62.1	-60.9	-60.3	24
256QAM 0.81 single	-70.3	-68.8	-67.1	-65.8	-64.0	-62.8	-62.3	23
256QAM 0.81 dual	-66.9	-65.4	-63.6	-62.3	-60.6	-59.3	-58.8	23

Table 79 5.1/5.2 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	165.3	163.8	162.0	160.8	159.0	157.8	157.3
QPSK 0.63 single	158.2	156.7	154.9	153.7	151.9	150.7	150.2
QPSK 0.87 single	154.2	152.7	150.9	149.6	147.9	146.6	146.1
16QAM 0.63 single	150.8	149.3	147.6	146.3	144.5	143.3	142.8
16QAM 0.63 dual	146.9	145.3	143.6	142.3	140.6	139.3	138.8
16QAM 0.87 single	146.3	144.7	143.0	141.7	140.0	138.7	138.2
16QAM 0.87 dual	143.2	141.6	139.9	138.6	136.9	135.6	135.1
64QAM 0.75 single	142.1	140.6	138.8	137.6	135.8	134.5	134.0
64QAM 0.75 dual	138.9	137.4	135.6	134.4	132.6	131.4	130.8
64QAM 0.92 single	139.7	138.2	136.5	135.2	133.4	132.2	131.7
64 QAM 0.92 dual	136.4	134.9	133.1	131.9	130.1	128.9	128.3
256QAM 0.81 single	137.3	135.8	134.1	132.8	131.0	129.8	129.3
256QAM 0.81 dual	133.9	132.4	130.6	129.3	127.6	126.3	125.8

Table 80 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	-94.6	-92.6	-90.8	-89.6	-87.8	-86.6	-86.1	27
QPSK 0.63 single	-91.5	-89.5	-87.7	-86.5	-84.7	-83.5	-83.0	26
QPSK 0.87 single	-87.5	-85.5	-83.7	-82.5	-80.7	-79.5	-79.0	26
16QAM 0.63 single	-85.2	-83.2	-81.4	-80.2	-78.4	-77.1	-76.6	25
16QAM 0.63 dual	-81.2	-79.2	-77.5	-76.2	-74.5	-73.2	-72.7	25
16QAM 0.87 single	-80.7	-78.7	-76.9	-75.7	-73.9	-72.7	-72.1	25
16QAM 0.87 dual	-77.6	-75.6	-73.9	-72.6	-70.9	-69.6	-69.1	25
64QAM 0.75 single	-77.7	-75.6	-73.9	-72.6	-70.9	-69.6	-69.1	24
64QAM 0.75 dual	-74.6	-72.6	-70.8	-69.5	-67.8	-66.5	-66.0	24
64QAM 0.92 single	-73.8	-71.8	-70.0	-68.8	-67.0	-65.8	-65.3	24
64 QAM 0.92 dual	-70.6	-68.6	-66.8	-65.6	-63.8	-62.6	-62.0	24
256QAM 0.81 single	-70.6	-68.6	-66.9	-65.6	-63.8	-62.6	-62.1	23
256QAM 0.81 dual	-67.2	-65.2	-63.4	-62.1	-60.4	-59.1	-58.6	23

Table 81 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	167.6	165.6	163.8	162.6	160.8	159.6	159.1
QPSK 0.63 single	163.5	161.5	159.7	158.5	156.7	155.5	155.0
QPSK 0.87 single	159.5	157.5	155.7	154.5	152.7	151.5	151.0
16QAM 0.63 single	156.2	154.2	152.4	151.2	149.4	148.1	147.6
16QAM 0.63 dual	152.2	150.2	148.5	147.2	145.5	144.2	143.7
16QAM 0.87 single	151.7	149.7	147.9	146.7	144.9	143.7	143.1
16QAM 0.87 dual	148.6	146.6	144.9	143.6	141.9	140.6	140.1
64QAM 0.75 single	147.7	145.6	143.9	142.6	140.9	139.6	139.1
64QAM 0.75 dual	144.6	142.6	140.8	139.5	137.8	136.5	136.0
64QAM 0.92 single	143.8	141.8	140.0	138.8	137.0	135.8	135.3
64 QAM 0.92 dual	140.6	138.6	136.8	135.6	133.8	132.6	132.0
256QAM 0.81 single	139.6	137.6	135.9	134.6	132.8	131.6	131.1
256QAM 0.81 dual	136.2	134.2	132.4	131.1	129.4	128.1	127.6

Table 82 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	-94.6	-92.6	-90.8	-89.6	-87.8	-86.6	-86.1	27
QPSK 0.63 single	-88.5	-86.5	-84.7	-83.5	-81.7	-80.5	-80.0	26
QPSK 0.87 single	-84.5	-82.5	-80.7	-79.4	-77.7	-76.4	-75.9	26
16QAM 0.63 single	-82.1	-80.1	-78.4	-77.1	-75.3	-74.1	-73.6	25
16QAM 0.63 dual	-78.2	-76.1	-74.4	-73.1	-71.4	-70.1	-69.6	25
16QAM 0.87 single	-77.6	-75.5	-73.8	-72.5	-70.8	-69.5	-69.0	25
16QAM 0.87 dual	-74.5	-72.4	-70.7	-69.4	-67.7	-66.4	-65.9	25
64QAM 0.75 single	-74.4	-72.4	-70.6	-69.4	-67.6	-66.3	-65.8	24
64QAM 0.75 dual	-71.2	-69.2	-67.4	-66.2	-64.4	-63.2	-62.6	24
64QAM 0.92 single	-72.0	-70.0	-68.3	-67.0	-65.2	-64.0	-63.5	24
64 QAM 0.92 dual	-68.7	-66.7	-64.9	-63.7	-61.9	-60.7	-60.1	24
256QAM 0.81 single	-70.6	-68.6	-66.9	-65.6	-63.8	-62.6	-62.1	23
256QAM 0.81 dual	-67.2	-65.2	-63.4	-62.1	-60.4	-59.1	-58.6	23

Table 83 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	167.6	165.6	163.8	162.6	160.8	159.6	159.1
QPSK 0.63 single	160.5	158.5	156.7	155.5	153.7	152.5	152.0
QPSK 0.87 single	156.5	154.5	152.7	151.4	149.7	148.4	147.9
16QAM 0.63 single	153.1	151.1	149.4	148.1	146.3	145.1	144.6
16QAM 0.63 dual	149.2	147.1	145.4	144.1	142.4	141.1	140.6
16QAM 0.87 single	148.6	146.5	144.8	143.5	141.8	140.5	140.0
16QAM 0.87 dual	145.5	143.4	141.7	140.4	138.7	137.4	136.9
64QAM 0.75 single	144.4	142.4	140.6	139.4	137.6	136.3	135.8
64QAM 0.75 dual	141.2	139.2	137.4	136.2	134.4	133.2	132.6
64QAM 0.92 single	142.0	140.0	138.3	137.0	135.2	134.0	133.5
64 QAM 0.92 dual	138.7	136.7	134.9	133.7	131.9	130.7	130.1
256QAM 0.81 single	139.6	137.6	135.9	134.6	132.8	131.6	131.1
256QAM 0.81 dual	136.2	134.2	132.4	131.1	129.4	128.1	127.6

Table 84 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	-94.8	-92.8	-91.0	-89.8	-88.0	-86.8	-86.3	27
QPSK 0.63 single	-91.7	-89.7	-87.9	-86.7	-84.9	-83.7	-83.2	26
QPSK 0.87 single	-87.7	-85.7	-83.9	-82.7	-80.9	-79.7	-79.1	26
16QAM 0.63 single	-85.4	-83.4	-81.6	-80.3	-78.6	-77.3	-76.8	25
16QAM 0.63 dual	-81.4	-79.4	-77.6	-76.4	-74.6	-73.4	-72.9	25
16QAM 0.87 single	-80.9	-78.8	-77.1	-75.8	-74.1	-72.8	-72.3	25
16QAM 0.87 dual	-77.8	-75.8	-74.0	-72.8	-71.0	-69.8	-69.2	25
64QAM 0.75 single	-77.8	-75.8	-74.0	-72.8	-71.0	-69.8	-69.2	24
64QAM 0.75 dual	-74.7	-72.7	-70.9	-69.6	-67.9	-66.6	-66.1	24
64QAM 0.92 single	-73.8	-71.8	-70.1	-68.8	-67.1	-65.8	-65.3	24
64 QAM 0.92 dual	-70.5	-68.5	-66.8	-65.5	-63.8	-62.5	-62.0	24
256QAM 0.81 single	-70.5	-68.5	-66.7	-65.4	-63.7	-62.4	-61.9	23
256QAM 0.81 dual	-66.8	-64.8	-63.0	-61.8	-60.0	-58.8	-58.3	23

Table 85 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	165.8	163.8	162.0	160.8	159.0	157.8	157.3
QPSK 0.63 single	161.7	159.7	157.9	156.7	154.9	153.7	153.2
QPSK 0.87 single	157.7	155.7	153.9	152.7	150.9	149.7	149.1
16QAM 0.63 single	154.4	152.4	150.6	149.3	147.6	146.3	145.8
16QAM 0.63 dual	150.4	148.4	146.6	145.4	143.6	142.4	141.9
16QAM 0.87 single	149.9	147.8	146.1	144.8	143.1	141.8	141.3
16QAM 0.87 dual	146.8	144.8	143.0	141.8	140.0	138.8	138.2
64QAM 0.75 single	145.8	143.8	142.0	140.8	139.0	137.8	137.2
64QAM 0.75 dual	142.7	140.7	138.9	137.6	135.9	134.6	134.1
64QAM 0.92 single	141.8	139.8	138.1	136.8	135.1	133.8	133.3
64 QAM 0.92 dual	138.5	136.5	134.8	133.5	131.8	130.5	130.0
256QAM 0.81 single	137.5	135.5	133.7	132.4	130.7	129.4	128.9
256QAM 0.81 dual	133.8	131.8	130.0	128.8	127.0	125.8	125.3

Table 86 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	-94.8	-92.8	-91.0	-89.8	-88.0	-86.8	-86.3	27
QPSK 0.63 single	-88.7	-86.7	-84.9	-83.7	-81.9	-80.7	-80.2	26
QPSK 0.87 single	-84.7	-82.6	-80.9	-79.6	-77.9	-76.6	-76.1	26
16QAM 0.63 single	-82.3	-80.3	-78.5	-77.3	-75.5	-74.3	-73.8	25
16QAM 0.63 dual	-78.3	-76.3	-74.5	-73.3	-71.5	-70.3	-69.8	25
16QAM 0.87 single	-77.7	-75.7	-73.9	-72.7	-70.9	-69.6	-69.1	25
16QAM 0.87 dual	-74.6	-72.5	-70.8	-69.5	-67.8	-66.5	-66.0	25
64QAM 0.75 single	-74.4	-72.4	-70.7	-69.4	-67.6	-66.4	-65.9	24
64QAM 0.75 dual	-71.2	-69.2	-67.4	-66.1	-64.4	-63.1	-62.6	24
64QAM 0.92 single	-72.0	-70.0	-68.2	-66.9	-65.2	-63.9	-63.4	24
64 QAM 0.92 dual	-68.5	-66.5	-64.7	-63.5	-61.7	-60.5	-60.0	24
256QAM 0.81 single	-70.5	-68.5	-66.7	-65.4	-63.7	-62.4	-61.9	23
256QAM 0.81 dual	-66.8	-64.8	-63.0	-61.8	-60.0	-58.8	-58.3	23

Table 87 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	165.8	163.8	162.0	160.8	159.0	157.8	157.3
QPSK 0.63 single	158.7	156.7	154.9	153.7	151.9	150.7	150.2
QPSK 0.87 single	154.7	152.6	150.9	149.6	147.9	146.6	146.1
16QAM 0.63 single	151.3	149.3	147.5	146.3	144.5	143.3	142.8
16QAM 0.63 dual	147.3	145.3	143.5	142.3	140.5	139.3	138.8
16QAM 0.87 single	146.7	144.7	142.9	141.7	139.9	138.6	138.1
16QAM 0.87 dual	143.6	141.5	139.8	138.5	136.8	135.5	135.0
64QAM 0.75 single	142.4	140.4	138.7	137.4	135.6	134.4	133.9
64QAM 0.75 dual	139.2	137.2	135.4	134.1	132.4	131.1	130.6
64QAM 0.92 single	140.0	138.0	136.2	134.9	133.2	131.9	131.4
64 QAM 0.92 dual	136.5	134.5	132.7	131.5	129.7	128.5	128.0
256QAM 0.81 single	137.5	135.5	133.7	132.4	130.7	129.4	128.9
256QAM 0.81 dual	133.8	131.8	130.0	128.8	127.0	125.8	125.3

Data throughput capacity tables

Use the following tables to look up the data throughput rates (Mbits/s) that are achieved when two PTP 700 ODUs are linked and the link distance (range) is 0 km:

PTP 700 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
Lite	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

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 64	Figure 65	Figure 66	Figure 67
	TDM	Figure 71	Figure 72	Figure 73	Figure 74
2:1	IP	Figure 78	Figure 79	Figure 80	Figure 81
	TDM	Figure 84	Figure 85	Figure 86	Figure 87
3:1	IP	Figure 90	Figure 91	Figure 92	Figure 93
5:1	IP	Figure 96	Figure 97	Figure 98	-
Adaptive	IP	Figure 99	Figure 100	Figure 101	Figure 102

Link symmetry	Link optimization	Bandwidth		
		15 MHz	10 MHz	5 MHz
1:1	IP	Figure 68	Figure 69	Figure 70
	TDM	Figure 75	Figure 76	Figure 77
2:1	IP	Figure 82	Figure 83	-
	TDM	Figure 88	Figure 89	-
3:1	IP	Figure 94	Figure 95	-
5:1	IP	-	-	-
Adaptive	IP	Figure 103	Figure 104	-

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 interchanged.

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	225.85	225.85	451.70	206.11	206.11	412.22
64QAM 0.92 dual	190.29	190.29	380.57	173.65	173.65	347.30
64QAM 0.75 dual	155.50	155.50	311.00	141.91	141.91	283.81
16QAM 0.87 dual	120.97	120.97	241.94	110.40	110.40	220.79
16QAM 0.63 dual	86.96	86.96	173.93	79.36	79.36	158.72
256QAM 0.81 single	112.92	112.92	225.85	103.05	103.05	206.10
64QAM 0.92 single	95.14	95.14	190.28	86.82	86.82	173.65
64QAM 0.75 single	77.75	77.75	155.50	70.95	70.95	141.90
16QAM 0.87 single	60.48	60.48	120.97	55.20	55.20	110.39
16QAM 0.63 single	43.48	43.48	86.96	39.68	39.68	79.36
QPSK 0.87 single	30.24	30.24	60.48	27.60	27.60	55.19
QPSK 0.63 single	21.74	21.74	43.48	19.84	19.84	39.68
BPSK 0.63 single	10.87	10.87	21.73	9.92	9.92	19.83

Modulation mode	30 MHz (Tx/Rx/Aggregate)			20 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	150.96	150.96	301.92	99.93	99.93	199.86
64QAM 0.92 dual	127.19	127.19	254.38	84.19	84.19	168.38
64QAM 0.75 dual	103.94	103.94	207.87	68.80	68.80	137.60
16QAM 0.87 dual	80.86	80.86	161.72	53.52	53.52	107.05
16QAM 0.63 dual	58.13	58.13	116.25	38.48	38.48	76.95
256QAM 0.81 single	75.48	75.48	150.96	49.96	49.96	99.92
64QAM 0.92 single	63.59	63.59	127.19	42.09	42.09	84.19
64QAM 0.75 single	51.97	51.97	103.93	34.40	34.40	68.80
16QAM 0.87 single	40.43	40.43	80.86	26.76	26.76	53.52
16QAM 0.63 single	29.06	29.06	58.12	19.24	19.24	38.47
QPSK 0.87 single	20.21	20.21	40.43	13.38	13.38	26.76
QPSK 0.63 single	14.53	14.53	29.06	9.62	9.62	19.23
BPSK 0.63 single	7.26	7.26	14.53	4.81	4.81	9.61

Modulation mode	15 MHz (Tx/Rx/Aggregate)			10 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	75.29	75.29	150.58	50.04	50.04	100.09
64QAM 0.92 dual	63.43	63.43	126.87	42.16	42.16	84.33
64QAM 0.75 dual	51.84	51.84	103.67	34.46	34.46	68.91
16QAM 0.87 dual	40.33	40.33	80.65	26.80	26.80	53.61
16QAM 0.63 dual	28.99	28.99	57.98	19.27	19.27	38.54
256QAM 0.81 single	37.64	37.64	75.29	25.02	25.02	50.04
64QAM 0.92 single	31.72	31.72	63.43	21.08	21.08	42.16
64QAM 0.75 single	25.92	25.92	51.83	17.23	17.23	34.45
16QAM 0.87 single	20.16	20.16	40.32	13.40	13.40	26.80
16QAM 0.63 single	14.49	14.49	28.99	9.63	9.63	19.27
QPSK 0.87 single	10.08	10.08	20.16	6.70	6.70	13.40
QPSK 0.63 single	7.25	7.25	14.49	4.82	4.82	9.63
BPSK 0.63 single	3.62	3.62	7.24	2.41	2.41	4.81

Modulation mode	5 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	24.17	24.17	48.35
64QAM 0.92 dual	20.37	20.37	40.73
64QAM 0.75 dual	16.64	16.64	33.29
16QAM 0.87 dual	12.95	12.95	25.89
16QAM 0.63 dual	9.31	9.31	18.61
256QAM 0.81 single	12.09	12.09	24.17
64QAM 0.92 single	10.18	10.18	20.36
64QAM 0.75 single	8.32	8.32	16.64
16QAM 0.87 single	6.47	6.47	12.94
16QAM 0.63 single	4.65	4.65	9.30
QPSK 0.87 single	3.24	3.24	6.47
QPSK 0.63 single	2.33	2.33	4.65
BPSK 0.63 single	1.16	1.16	2.32

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	198.59	198.59	397.18	184.89	184.89	369.78
64QAM 0.92 dual	167.32	167.32	334.64	155.77	155.77	311.55
64QAM 0.75 dual	136.73	136.73	273.46	127.30	127.30	254.59
16QAM 0.87 dual	106.37	106.37	212.74	99.03	99.03	198.06
16QAM 0.63 dual	76.47	76.47	152.93	71.19	71.19	142.38
256QAM 0.81 single	99.29	99.29	198.59	92.44	92.44	184.89
64QAM 0.92 single	83.66	83.66	167.32	77.89	77.89	155.77
64QAM 0.75 single	68.36	68.36	136.73	63.65	63.65	127.29
16QAM 0.87 single	53.18	53.18	106.37	49.51	49.51	99.03
16QAM 0.63 single	38.23	38.23	76.46	35.59	35.59	71.19
QPSK 0.87 single	26.59	26.59	53.18	24.76	24.76	49.51
QPSK 0.63 single	19.11	19.11	38.23	17.79	17.79	35.59
BPSK 0.63 single	9.56	9.56	19.11	8.90	8.90	17.79

Modulation mode	30 MHz (Tx/Rx/Aggregate)			20 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	140.16	140.16	280.32	95.65	95.65	191.29
64QAM 0.92 dual	118.09	118.09	236.17	80.58	80.58	161.17
64QAM 0.75 dual	96.50	96.50	193.00	65.85	65.85	131.70
16QAM 0.87 dual	75.07	75.07	150.14	51.23	51.23	102.46
16QAM 0.63 dual	53.97	53.97	107.93	36.83	36.83	73.65
256QAM 0.81 single	70.08	70.08	140.16	47.82	47.82	95.64
64QAM 0.92 single	59.04	59.04	118.09	40.29	40.29	80.58
64QAM 0.75 single	48.25	48.25	96.50	32.92	32.92	65.85
16QAM 0.87 single	37.53	37.53	75.07	25.61	25.61	51.23
16QAM 0.63 single	26.98	26.98	53.96	18.41	18.41	36.82
QPSK 0.87 single	18.77	18.77	37.53	12.81	12.81	25.61
QPSK 0.63 single	13.49	13.49	26.98	9.20	9.20	18.41
BPSK 0.63 single	6.74	6.74	13.49	4.60	4.60	9.20

Modulation mode	15 MHz (Tx/Rx/Aggregate)			10 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	72.69	72.69	145.38	49.03	49.03	98.05
64QAM 0.92 dual	61.24	61.24	122.49	41.30	41.30	82.61
64QAM 0.75 dual	50.05	50.05	100.09	33.75	33.75	67.51
16QAM 0.87 dual	38.93	38.93	77.87	26.26	26.26	52.52
16QAM 0.63 dual	27.99	27.99	55.98	18.88	18.88	37.75
256QAM 0.81 single	36.34	36.34	72.69	24.51	24.51	49.02
64QAM 0.92 single	30.62	30.62	61.24	20.65	20.65	41.30
64QAM 0.75 single	25.02	25.02	50.04	16.88	16.88	33.75
16QAM 0.87 single	19.47	19.47	38.93	13.13	13.13	26.26
16QAM 0.63 single	13.99	13.99	27.99	9.44	9.44	18.87
QPSK 0.87 single	9.73	9.73	19.46	6.56	6.56	13.13
QPSK 0.63 single	7.00	7.00	13.99	4.72	4.72	9.43
BPSK 0.63 single	3.50	3.50	6.99	2.36	2.36	4.71

Modulation mode	5 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	24.17	24.17	48.35
64QAM 0.92 dual	20.37	20.37	40.73
64QAM 0.75 dual	16.64	16.64	33.29
16QAM 0.87 dual	12.95	12.95	25.89
16QAM 0.63 dual	9.31	9.31	18.61
256QAM 0.81 single	12.09	12.09	24.17
64QAM 0.92 single	10.18	10.18	20.36
64QAM 0.75 single	8.32	8.32	16.64
16QAM 0.87 single	6.47	6.47	12.94
16QAM 0.63 single	4.65	4.65	9.30
QPSK 0.87 single	3.24	3.24	6.47
QPSK 0.63 single	2.33	2.33	4.65
BPSK 0.63 single	1.16	1.16	2.32

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	299.34	149.67	449.01	273.32	136.66	409.98
64QAM 0.92 dual	252.20	126.10	378.30	230.28	115.14	345.42
64QAM 0.75 dual	206.10	103.05	309.15	188.18	94.09	282.27
16QAM 0.87 dual	160.34	80.17	240.50	146.40	73.20	219.59
16QAM 0.63 dual	115.26	57.63	172.89	105.24	52.62	157.86
256QAM 0.81 single	149.67	74.83	224.50	136.66	68.33	204.98
64QAM 0.92 single	126.10	63.05	189.15	115.14	57.57	172.71
64QAM 0.75 single	103.05	51.52	154.57	94.09	47.04	141.13
16QAM 0.87 single	80.17	40.08	120.25	73.20	36.60	109.79
16QAM 0.63 single	57.63	28.81	86.44	52.62	26.31	78.93
QPSK 0.87 single	40.08	20.04	60.12	36.60	18.30	54.89
QPSK 0.63 single	28.81	14.40	43.22	26.31	13.15	39.46
BPSK 0.63 single	14.40	7.20	21.60	13.15	6.57	19.73

Modulation mode	30 MHz (Tx/Rx/Aggregate)			20 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	200.25	100.13	300.38	133.24	66.62	199.86
64QAM 0.92 dual	168.72	84.36	253.08	112.26	56.13	168.38
64QAM 0.75 dual	137.88	68.94	206.81	91.73	45.87	137.60
16QAM 0.87 dual	107.26	53.63	160.89	71.37	35.68	107.05
16QAM 0.63 dual	77.11	38.55	115.66	51.30	25.65	76.95
256QAM 0.81 single	100.12	50.06	150.19	66.62	33.31	99.92
64QAM 0.92 single	84.36	42.18	126.54	56.13	28.06	84.19
64QAM 0.75 single	68.94	34.47	103.40	45.87	22.93	68.80
16QAM 0.87 single	53.63	26.81	80.44	35.68	17.84	53.52
16QAM 0.63 single	38.55	19.27	57.83	25.65	12.82	38.47
QPSK 0.87 single	26.81	13.41	40.22	17.84	8.92	26.76
QPSK 0.63 single	19.27	9.64	28.91	12.82	6.41	19.23
BPSK 0.63 single	9.64	4.82	14.45	6.41	3.20	9.61

Modulation mode	15 MHz (Tx/Rx/Aggregate)			10 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	100.39	50.19	150.58	66.27	33.13	99.40
64QAM 0.92 dual	84.58	42.29	126.87	55.83	27.91	83.75
64QAM 0.75 dual	69.12	34.56	103.67	45.63	22.81	68.44
16QAM 0.87 dual	53.77	26.88	80.65	35.49	17.75	53.24
16QAM 0.63 dual	38.65	19.33	57.98	25.52	12.76	38.27
256QAM 0.81 single	50.19	25.10	75.29	33.13	16.57	49.70
64QAM 0.92 single	42.29	21.14	63.43	27.91	13.96	41.87
64QAM 0.75 single	34.56	17.28	51.83	22.81	11.40	34.22
16QAM 0.87 single	26.88	13.44	40.32	17.75	8.87	26.62
16QAM 0.63 single	19.33	9.66	28.99	12.76	6.38	19.13
QPSK 0.87 single	13.44	6.72	20.16	8.87	4.43	13.31
QPSK 0.63 single	9.66	4.83	14.49	6.38	3.19	9.56
BPSK 0.63 single	4.83	2.41	7.24	3.19	1.59	4.78

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	277.41	138.71	416.12	256.58	128.29	384.87
64QAM 0.92 dual	233.73	116.86	350.59	216.18	108.09	324.27
64QAM 0.75 dual	191.00	95.50	286.50	176.66	88.33	264.99
16QAM 0.87 dual	148.59	74.29	222.88	137.43	68.72	206.15
16QAM 0.63 dual	106.82	53.41	160.23	98.80	49.40	148.19
256QAM 0.81 single	138.70	69.35	208.05	128.29	64.14	192.43
64QAM 0.92 single	116.86	58.43	175.29	108.09	54.04	162.13
64QAM 0.75 single	95.50	47.75	143.25	88.33	44.16	132.49
16QAM 0.87 single	74.29	37.15	111.44	68.71	34.36	103.07
16QAM 0.63 single	53.41	26.70	80.11	49.40	24.70	74.09
QPSK 0.87 single	37.15	18.57	55.72	34.36	17.18	51.53
QPSK 0.63 single	26.70	13.35	40.05	24.70	12.35	37.04
BPSK 0.63 single	13.35	6.67	20.02	12.35	6.17	18.52

Modulation mode	30 MHz (Tx/Rx/Aggregate)			20 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	192.39	96.19	288.58	130.32	65.16	195.48
64QAM 0.92 dual	162.09	81.04	243.13	109.80	54.90	164.70
64QAM 0.75 dual	132.46	66.23	198.69	89.73	44.86	134.59
16QAM 0.87 dual	103.05	51.52	154.57	69.80	34.90	104.70
16QAM 0.63 dual	74.08	37.04	111.12	50.18	25.09	75.27
256QAM 0.81 single	96.19	48.09	144.29	65.16	32.58	97.74
64QAM 0.92 single	81.04	40.52	121.56	54.90	27.45	82.35
64QAM 0.75 single	66.23	33.11	99.34	44.86	22.43	67.29
16QAM 0.87 single	51.52	25.76	77.28	34.90	17.45	52.35
16QAM 0.63 single	37.04	18.52	55.55	25.09	12.54	37.63
QPSK 0.87 single	25.76	12.88	38.64	17.45	8.72	26.17
QPSK 0.63 single	18.52	9.26	27.77	12.54	6.27	18.81
BPSK 0.63 single	9.26	4.63	13.88	6.27	3.13	9.40

Modulation mode	15 MHz (Tx/Rx/Aggregate)			10 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	98.62	49.31	147.94	66.27	33.13	99.40
64QAM 0.92 dual	83.09	41.55	124.64	55.83	27.91	83.75
64QAM 0.75 dual	67.90	33.95	101.85	45.63	22.81	68.44
16QAM 0.87 dual	52.83	26.41	79.24	35.49	17.75	53.24
16QAM 0.63 dual	37.97	18.99	56.96	25.52	12.76	38.27
256QAM 0.81 single	49.31	24.65	73.97	33.13	16.57	49.70
64QAM 0.92 single	41.55	20.77	62.32	27.91	13.96	41.87
64QAM 0.75 single	33.95	16.97	50.92	22.81	11.40	34.22
16QAM 0.87 single	26.41	13.20	39.62	17.75	8.87	26.62
16QAM 0.63 single	18.99	9.49	28.48	12.76	6.38	19.13
QPSK 0.87 single	13.20	6.60	19.81	8.87	4.43	13.31
QPSK 0.63 single	9.49	4.74	14.24	6.38	3.19	9.56
BPSK 0.63 single	4.74	2.37	7.12	3.19	1.59	4.78

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	336.76	112.25	449.01	307.48	102.49	409.98
64QAM 0.92 dual	283.73	94.57	378.30	259.06	86.35	345.42
64QAM 0.75 dual	231.86	77.29	309.15	211.70	70.57	282.27
16QAM 0.87 dual	180.38	60.12	240.50	164.70	54.90	219.59
16QAM 0.63 dual	129.67	43.22	172.89	118.40	39.46	157.86
256QAM 0.81 single	168.38	56.12	224.50	153.74	51.25	204.98
64QAM 0.92 single	141.86	47.29	189.15	129.53	43.18	172.71
64QAM 0.75 single	115.93	38.64	154.57	105.85	35.28	141.13
16QAM 0.87 single	90.19	30.06	120.25	82.35	27.45	109.79
16QAM 0.63 single	64.83	21.61	86.44	59.20	19.73	78.93
QPSK 0.87 single	45.09	15.03	60.12	41.17	13.72	54.89
QPSK 0.63 single	32.41	10.80	43.22	29.60	9.86	39.46
BPSK 0.63 single	16.20	5.40	21.60	14.80	4.93	19.73

Modulation mode	30 MHz (Tx/Rx/Aggregate)			20 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	224.71	74.90	299.61	148.23	49.41	197.64
64QAM 0.92 dual	189.32	63.11	252.43	124.89	41.63	166.52
64QAM 0.75 dual	154.71	51.57	206.28	102.06	34.02	136.08
16QAM 0.87 dual	120.36	40.12	160.48	79.40	26.46	105.86
16QAM 0.63 dual	86.52	28.84	115.36	57.08	19.02	76.10
256QAM 0.81 single	112.35	37.45	149.80	74.12	24.70	98.82
64QAM 0.92 single	94.66	31.55	126.21	62.44	20.81	83.26
64QAM 0.75 single	77.36	25.78	103.14	51.03	17.01	68.04
16QAM 0.87 single	60.18	20.06	80.24	39.70	13.23	52.93
16QAM 0.63 single	43.26	14.42	57.68	28.54	9.51	38.05
QPSK 0.87 single	30.09	10.03	40.12	19.85	6.61	26.46
QPSK 0.63 single	21.63	7.21	28.84	14.27	4.75	19.02
BPSK 0.63 single	10.81	3.60	14.41	7.13	2.38	9.51

Modulation mode	15 MHz (Tx/Rx/Aggregate)			10 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	111.94	37.31	149.25	75.07	25.02	100.09
64QAM 0.92 dual	94.31	31.43	125.74	63.25	21.08	84.33
64QAM 0.75 dual	77.07	25.69	102.76	51.68	17.23	68.91
16QAM 0.87 dual	59.96	19.98	79.94	40.21	13.40	53.61
16QAM 0.63 dual	43.10	14.37	57.47	28.90	9.63	38.54
256QAM 0.81 single	55.97	18.65	74.62	37.53	12.51	50.04
64QAM 0.92 single	47.15	15.72	62.87	31.62	10.54	42.16
64QAM 0.75 single	38.53	12.84	51.38	25.84	8.61	34.45
16QAM 0.87 single	29.98	9.99	39.97	20.10	6.70	26.80
16QAM 0.63 single	21.55	7.18	28.73	14.45	4.82	19.27
QPSK 0.87 single	14.99	4.99	19.98	10.05	3.35	13.40
QPSK 0.63 single	10.77	3.59	14.36	7.22	2.41	9.63
BPSK 0.63 single	5.38	1.79	7.18	3.61	1.20	4.81

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	374.18	74.83	449.01	334.38	66.87	401.25
64QAM 0.92 dual	315.25	63.05	378.30	281.72	56.34	338.07
64QAM 0.75 dual	257.62	51.52	309.15	230.22	46.04	276.26
16QAM 0.87 dual	200.42	40.08	240.50	179.10	35.82	214.92
16QAM 0.63 dual	144.08	28.81	172.89	128.75	25.75	154.50
256QAM 0.81 single	187.09	37.42	224.50	167.19	33.44	200.62
64QAM 0.92 single	157.63	31.52	189.15	140.86	28.17	169.03
64QAM 0.75 single	128.81	25.76	154.57	115.11	23.02	138.13
16QAM 0.87 single	100.21	20.04	120.25	89.55	17.91	107.46
16QAM 0.63 single	72.04	14.41	86.44	64.37	12.87	77.25
QPSK 0.87 single	50.10	10.02	60.12	44.77	8.95	53.73
QPSK 0.63 single	36.02	7.20	43.22	32.18	6.44	38.62
BPSK 0.63 single	18.00	3.60	21.60	16.09	3.22	19.31

Modulation mode	30 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	247.78	49.56	297.34
64QAM 0.92 dual	208.76	41.75	250.52
64QAM 0.75 dual	170.60	34.12	204.72
16QAM 0.87 dual	132.72	26.54	159.26
16QAM 0.63 dual	95.41	19.08	114.49
256QAM 0.81 single	123.89	24.78	148.67
64QAM 0.92 single	104.38	20.87	125.26
64QAM 0.75 single	85.30	17.06	102.36
16QAM 0.87 single	66.36	13.27	79.63
16QAM 0.63 single	47.70	9.54	57.24
QPSK 0.87 single	33.18	6.63	39.81
QPSK 0.63 single	23.85	4.77	28.62
BPSK 0.63 single	11.92	2.38	14.31

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	406.48	40.65	447.12	367.38	40.82	408.20
64QAM 0.92 dual	342.47	34.25	376.71	309.53	34.39	343.92
64QAM 0.75 dual	279.86	27.98	307.85	252.95	28.10	281.05
16QAM 0.87 dual	217.72	21.77	239.49	196.78	21.86	218.64
16QAM 0.63 dual	156.51	15.65	172.16	141.46	15.72	157.18
256QAM 0.81 single	203.24	20.32	223.56	183.69	20.41	204.10
64QAM 0.92 single	171.23	17.12	188.35	154.76	17.19	171.96
64QAM 0.75 single	139.93	13.99	153.92	126.47	14.05	140.52
16QAM 0.87 single	108.86	10.88	119.74	98.39	10.93	109.32
16QAM 0.63 single	78.25	7.82	86.08	70.73	7.86	78.58
QPSK 0.87 single	54.43	5.44	59.87	49.19	5.46	54.66
QPSK 0.63 single	39.12	3.91	43.04	35.36	3.93	39.29
BPSK 0.63 single	19.56	1.95	21.51	17.68	1.96	19.64

Modulation mode	30 MHz (Tx/Rx/Aggregate)			20 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	262.16	37.45	299.61	159.17	39.79	198.96
64QAM 0.92 dual	220.88	31.55	252.43	134.11	33.53	167.63
64QAM 0.75 dual	180.50	25.78	206.28	109.59	27.40	136.99
16QAM 0.87 dual	140.42	20.06	160.48	85.26	21.31	106.57
16QAM 0.63 dual	100.95	14.42	115.36	61.29	15.32	76.61
256QAM 0.81 single	131.08	18.72	149.80	79.58	19.89	99.48
64QAM 0.92 single	110.44	15.78	126.21	67.05	16.76	83.81
64QAM 0.75 single	90.25	12.89	103.14	54.79	13.70	68.49
16QAM 0.87 single	70.21	10.03	80.24	42.63	10.66	53.28
16QAM 0.63 single	50.47	7.21	57.68	30.64	7.66	38.30
QPSK 0.87 single	35.10	5.01	40.12	21.31	5.33	26.64
QPSK 0.63 single	25.23	3.60	28.84	15.32	3.83	19.15
BPSK 0.63 single	12.61	1.80	14.41	7.66	1.91	9.57

Modulation mode	15 MHz (Tx/Rx/Aggregate)			10 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	120.04	30.01	150.04	66.27	33.13	99.40
64QAM 0.92 dual	101.13	25.28	126.42	55.83	27.91	83.75
64QAM 0.75 dual	82.65	20.66	103.31	45.63	22.81	68.44
16QAM 0.87 dual	64.29	16.07	80.37	35.49	17.75	53.24
16QAM 0.63 dual	46.22	11.55	57.77	25.52	12.76	38.27
256QAM 0.81 single	60.02	15.00	75.02	33.13	16.57	49.70
64QAM 0.92 single	50.57	12.64	63.21	27.91	13.96	41.87
64QAM 0.75 single	41.32	10.33	51.65	22.81	11.40	34.22
16QAM 0.87 single	32.15	8.03	40.18	17.75	8.87	26.62
16QAM 0.63 single	23.11	5.78	28.88	12.76	6.38	19.13
QPSK 0.87 single	16.07	4.02	20.09	8.87	4.43	13.31
QPSK 0.63 single	11.55	2.89	14.44	6.38	3.19	9.56
BPSK 0.63 single	5.77	1.44	7.22	3.19	1.59	4.78

Table 95 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	113.00	113.00	226.00	103.00	103.00	206.00
64QAM 0.92 dual	95.00	95.00	190.00	87.00	87.00	174.00
64QAM 0.75 dual	78.00	78.00	156.00	71.00	71.00	142.00
16QAM 0.87 dual	60.00	60.00	120.00	55.00	55.00	110.00
16QAM 0.63 dual	43.00	43.00	86.00	40.00	40.00	80.00
256QAM 0.81 single	56.00	56.00	112.00	52.00	52.00	104.00
64QAM 0.92 single	48.00	48.00	96.00	43.00	43.00	86.00
64QAM 0.75 single	39.00	39.00	78.00	35.00	35.00	70.00
16QAM 0.87 single	30.00	30.00	60.00	28.00	28.00	56.00
16QAM 0.63 single	22.00	22.00	44.00	20.00	20.00	40.00
QPSK 0.87 single	15.00	15.00	30.00	14.00	14.00	28.00
QPSK 0.63 single	11.00	11.00	22.00	10.00	10.00	20.00
BPSK 0.63 single	5.00	5.00	10.00	5.00	5.00	10.00

Modulation mode	30 MHz (Tx/Rx/Aggregate)			20 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	75.00	75.00	150.00	50.00	50.00	100.00
64QAM 0.92 dual	64.00	64.00	128.00	42.00	42.00	84.00
64QAM 0.75 dual	52.00	52.00	104.00	34.00	34.00	68.00
16QAM 0.87 dual	40.00	40.00	80.00	27.00	27.00	54.00
16QAM 0.63 dual	29.00	29.00	58.00	19.00	19.00	38.00
256QAM 0.81 single	38.00	38.00	76.00	25.00	25.00	50.00
64QAM 0.92 single	32.00	32.00	64.00	21.00	21.00	42.00
64QAM 0.75 single	26.00	26.00	52.00	17.00	17.00	34.00
16QAM 0.87 single	20.00	20.00	40.00	13.00	13.00	26.00
16QAM 0.63 single	15.00	15.00	30.00	10.00	10.00	20.00
QPSK 0.87 single	10.00	10.00	20.00	7.00	7.00	14.00
QPSK 0.63 single	7.00	7.00	14.00	5.00	5.00	10.00
BPSK 0.63 single	5.00	5.00	10.00	4.81	4.81	9.61

Modulation mode	15 MHz (Tx/Rx/Aggregate)			10 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	38.00	38.00	76.00	25.00	25.00	50.00
64QAM 0.92 dual	32.00	32.00	64.00	21.00	21.00	42.00
64QAM 0.75 dual	26.00	26.00	52.00	17.00	17.00	34.00
16QAM 0.87 dual	20.00	20.00	40.00	13.00	13.00	26.00
16QAM 0.63 dual	14.00	14.00	28.00	10.00	10.00	20.00
256QAM 0.81 single	19.00	19.00	38.00	13.00	13.00	26.00
64QAM 0.92 single	16.00	16.00	32.00	11.00	11.00	22.00
64QAM 0.75 single	13.00	13.00	26.00	9.00	9.00	18.00
16QAM 0.87 single	10.00	10.00	20.00	7.00	7.00	14.00
16QAM 0.63 single	7.00	7.00	14.00	5.00	5.00	10.00
QPSK 0.87 single	5.00	5.00	10.00	5.00	5.00	10.00
QPSK 0.63 single	5.00	5.00	10.00	4.82	4.82	9.63
BPSK 0.63 single	3.62	3.62	7.24	2.41	2.41	4.81

Modulation mode	5 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	12.00	12.00	24.00
64QAM 0.92 dual	10.00	10.00	20.00
64QAM 0.75 dual	8.00	8.00	16.00
16QAM 0.87 dual	6.00	6.00	12.00
16QAM 0.63 dual	5.00	5.00	10.00
256QAM 0.81 single	6.00	6.00	12.00
64QAM 0.92 single	5.00	5.00	10.00
64QAM 0.75 single	5.00	5.00	10.00
16QAM 0.87 single	5.00	5.00	10.00
16QAM 0.63 single	4.65	4.65	9.30
QPSK 0.87 single	3.24	3.24	6.47
QPSK 0.63 single	2.33	2.33	4.65
BPSK 0.63 single	1.16	1.16	2.32

Table 96 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	99.00	99.00	198.00	92.00	92.00	184.00
64QAM 0.92 dual	84.00	84.00	168.00	78.00	78.00	156.00
64QAM 0.75 dual	68.00	68.00	136.00	64.00	64.00	128.00
16QAM 0.87 dual	53.00	53.00	106.00	50.00	50.00	100.00
16QAM 0.63 dual	38.00	38.00	76.00	36.00	36.00	72.00
256QAM 0.81 single	50.00	50.00	100.00	46.00	46.00	92.00
64QAM 0.92 single	42.00	42.00	84.00	39.00	39.00	78.00
64QAM 0.75 single	34.00	34.00	68.00	32.00	32.00	64.00
16QAM 0.87 single	27.00	27.00	54.00	25.00	25.00	50.00
16QAM 0.63 single	19.00	19.00	38.00	18.00	18.00	36.00
QPSK 0.87 single	13.00	13.00	26.00	12.00	12.00	24.00
QPSK 0.63 single	10.00	10.00	20.00	9.00	9.00	18.00
BPSK 0.63 single	5.00	5.00	10.00	5.00	5.00	10.00

Modulation mode	30 MHz (Tx/Rx/Aggregate)			20 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	70.00	70.00	140.00	48.00	48.00	96.00
64QAM 0.92 dual	59.00	59.00	118.00	40.00	40.00	80.00
64QAM 0.75 dual	48.00	48.00	96.00	33.00	33.00	66.00
16QAM 0.87 dual	38.00	38.00	76.00	26.00	26.00	52.00
16QAM 0.63 dual	27.00	27.00	54.00	18.00	18.00	36.00
256QAM 0.81 single	35.00	35.00	70.00	24.00	24.00	48.00
64QAM 0.92 single	30.00	30.00	60.00	20.00	20.00	40.00
64QAM 0.75 single	24.00	24.00	48.00	16.00	16.00	32.00
16QAM 0.87 single	19.00	19.00	38.00	13.00	13.00	26.00
16QAM 0.63 single	13.00	13.00	26.00	9.00	9.00	18.00
QPSK 0.87 single	9.00	9.00	18.00	6.00	6.00	12.00
QPSK 0.63 single	7.00	7.00	14.00	5.00	5.00	10.00
BPSK 0.63 single	5.00	5.00	10.00	4.60	4.60	9.20

Modulation mode	15 MHz (Tx/Rx/Aggregate)			10 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	36.00	36.00	72.00	25.00	25.00	50.00
64QAM 0.92 dual	31.00	31.00	62.00	21.00	21.00	42.00
64QAM 0.75 dual	25.00	25.00	50.00	17.00	17.00	34.00
16QAM 0.87 dual	19.00	19.00	38.00	13.00	13.00	26.00
16QAM 0.63 dual	14.00	14.00	28.00	9.00	9.00	18.00
256QAM 0.81 single	18.00	18.00	36.00	12.00	12.00	24.00
64QAM 0.92 single	15.00	15.00	30.00	10.00	10.00	20.00
64QAM 0.75 single	13.00	13.00	26.00	8.00	8.00	16.00
16QAM 0.87 single	10.00	10.00	20.00	7.00	7.00	14.00
16QAM 0.63 single	7.00	7.00	14.00	5.00	5.00	10.00
QPSK 0.87 single	5.00	5.00	10.00	5.00	5.00	10.00
QPSK 0.63 single	5.00	5.00	10.00	4.72	4.72	9.43
BPSK 0.63 single	3.50	3.50	6.99	2.36	2.36	4.71

Modulation mode	5 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	12.00	12.00	24.00
64QAM 0.92 dual	10.00	10.00	20.00
64QAM 0.75 dual	8.00	8.00	16.00
16QAM 0.87 dual	6.00	6.00	12.00
16QAM 0.63 dual	5.00	5.00	10.00
256QAM 0.81 single	6.00	6.00	12.00
64QAM 0.92 single	5.00	5.00	10.00
64QAM 0.75 single	5.00	5.00	10.00
16QAM 0.87 single	5.00	5.00	10.00
16QAM 0.63 single	4.65	4.65	9.30
QPSK 0.87 single	3.24	3.24	6.47
QPSK 0.63 single	2.33	2.33	4.65
BPSK 0.63 single	1.16	1.16	2.32

Table 97 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	150.00	75.00	225.00	137.00	68.00	205.00
64QAM 0.92 dual	126.00	63.00	189.00	115.00	58.00	173.00
64QAM 0.75 dual	103.00	52.00	155.00	94.00	47.00	141.00
16QAM 0.87 dual	80.00	40.00	120.00	73.00	37.00	110.00
16QAM 0.63 dual	58.00	29.00	87.00	53.00	26.00	79.00
256QAM 0.81 single	75.00	37.00	112.00	68.00	34.00	102.00
64QAM 0.92 single	63.00	32.00	95.00	58.00	29.00	87.00
64QAM 0.75 single	52.00	26.00	78.00	47.00	24.00	71.00
16QAM 0.87 single	40.00	20.00	60.00	37.00	18.00	55.00
16QAM 0.63 single	29.00	14.00	43.00	26.00	13.00	39.00
QPSK 0.87 single	20.00	10.00	30.00	18.00	9.00	27.00
QPSK 0.63 single	14.00	7.00	21.00	13.00	7.00	20.00
BPSK 0.63 single	7.00	5.00	12.00	7.00	5.00	12.00

Modulation mode	30 MHz (Tx/Rx/Aggregate)			20 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	100.00	50.00	150.00	67.00	33.00	100.00
64QAM 0.92 dual	84.00	42.00	126.00	56.00	28.00	84.00
64QAM 0.75 dual	69.00	34.00	103.00	46.00	23.00	69.00
16QAM 0.87 dual	54.00	27.00	81.00	36.00	18.00	54.00
16QAM 0.63 dual	39.00	19.00	58.00	26.00	13.00	39.00
256QAM 0.81 single	50.00	25.00	75.00	33.00	17.00	50.00
64QAM 0.92 single	42.00	21.00	63.00	28.00	14.00	42.00
64QAM 0.75 single	34.00	17.00	51.00	23.00	11.00	34.00
16QAM 0.87 single	27.00	13.00	40.00	18.00	9.00	27.00
16QAM 0.63 single	19.00	10.00	29.00	13.00	6.00	19.00
QPSK 0.87 single	13.00	7.00	20.00	9.00	5.00	14.00
QPSK 0.63 single	10.00	5.00	15.00	6.00	5.00	11.00
BPSK 0.63 single	5.00	4.82	9.82	5.00	3.20	8.20

Modulation mode	15 MHz (Tx/Rx/Aggregate)			10 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	50.00	25.00	75.00	33.00	17.00	50.00
64QAM 0.92 dual	42.00	21.00	63.00	28.00	14.00	42.00
64QAM 0.75 dual	35.00	17.00	52.00	23.00	11.00	34.00
16QAM 0.87 dual	27.00	13.00	40.00	18.00	9.00	27.00
16QAM 0.63 dual	19.00	10.00	29.00	13.00	6.00	19.00
256QAM 0.81 single	25.00	13.00	38.00	17.00	8.00	25.00
64QAM 0.92 single	21.00	11.00	32.00	14.00	7.00	21.00
64QAM 0.75 single	17.00	9.00	26.00	11.00	6.00	17.00
16QAM 0.87 single	13.00	7.00	20.00	9.00	5.00	14.00
16QAM 0.63 single	10.00	5.00	15.00	6.00	5.00	11.00
QPSK 0.87 single	7.00	5.00	12.00	5.00	4.43	9.43
QPSK 0.63 single	5.00	4.83	9.83	5.00	3.19	8.19
BPSK 0.63 single	4.83	2.41	7.24	3.19	1.59	4.78

Table 98 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	139.00	69.00	208.00	128.00	64.00	192.00
64QAM 0.92 dual	117.00	58.00	175.00	108.00	54.00	162.00
64QAM 0.75 dual	95.00	48.00	143.00	88.00	44.00	132.00
16QAM 0.87 dual	74.00	37.00	111.00	69.00	34.00	103.00
16QAM 0.63 dual	53.00	27.00	80.00	49.00	25.00	74.00
256QAM 0.81 single	69.00	35.00	104.00	64.00	32.00	96.00
64QAM 0.92 single	58.00	29.00	87.00	54.00	27.00	81.00
64QAM 0.75 single	48.00	24.00	72.00	44.00	22.00	66.00
16QAM 0.87 single	37.00	19.00	56.00	34.00	17.00	51.00
16QAM 0.63 single	27.00	13.00	40.00	25.00	12.00	37.00
QPSK 0.87 single	19.00	9.00	28.00	17.00	9.00	26.00
QPSK 0.63 single	13.00	7.00	20.00	12.00	6.00	18.00
BPSK 0.63 single	7.00	5.00	12.00	6.00	5.00	11.00

Modulation mode	30 MHz (Tx/Rx/Aggregate)			20 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	96.00	48.00	144.00	65.00	33.00	98.00
64QAM 0.92 dual	81.00	41.00	122.00	55.00	27.00	82.00
64QAM 0.75 dual	66.00	33.00	99.00	45.00	22.00	67.00
16QAM 0.87 dual	52.00	26.00	78.00	35.00	17.00	52.00
16QAM 0.63 dual	37.00	19.00	56.00	25.00	13.00	38.00
256QAM 0.81 single	48.00	24.00	72.00	33.00	16.00	49.00
64QAM 0.92 single	41.00	20.00	61.00	27.00	14.00	41.00
64QAM 0.75 single	33.00	17.00	50.00	22.00	11.00	33.00
16QAM 0.87 single	26.00	13.00	39.00	17.00	9.00	26.00
16QAM 0.63 single	19.00	9.00	28.00	13.00	6.00	19.00
QPSK 0.87 single	13.00	6.00	19.00	9.00	5.00	14.00
QPSK 0.63 single	9.00	5.00	14.00	6.00	5.00	11.00
BPSK 0.63 single	5.00	4.63	9.63	5.00	3.13	8.13

Modulation mode	15 MHz (Tx/Rx/Aggregate)			10 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	49.00	25.00	74.00	33.00	17.00	50.00
64QAM 0.92 dual	42.00	21.00	63.00	28.00	14.00	42.00
64QAM 0.75 dual	34.00	17.00	51.00	23.00	11.00	34.00
16QAM 0.87 dual	26.00	13.00	39.00	18.00	9.00	27.00
16QAM 0.63 dual	19.00	9.00	28.00	13.00	6.00	19.00
256QAM 0.81 single	25.00	12.00	37.00	17.00	8.00	25.00
64QAM 0.92 single	21.00	10.00	31.00	14.00	7.00	21.00
64QAM 0.75 single	17.00	8.00	25.00	11.00	6.00	17.00
16QAM 0.87 single	13.00	7.00	20.00	9.00	5.00	14.00
16QAM 0.63 single	9.00	5.00	14.00	6.00	5.00	11.00
QPSK 0.87 single	7.00	5.00	12.00	5.00	4.43	9.43
QPSK 0.63 single	5.00	4.74	9.74	5.00	3.19	8.19
BPSK 0.63 single	4.74	2.37	7.12	3.19	1.59	4.78

Table 99 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	168.00	56.00	224.00	154.00	51.00	205.00
64QAM 0.92 dual	142.00	47.00	189.00	130.00	43.00	173.00
64QAM 0.75 dual	116.00	39.00	155.00	106.00	35.00	141.00
16QAM 0.87 dual	90.00	30.00	120.00	82.00	27.00	109.00
16QAM 0.63 dual	65.00	22.00	87.00	59.00	20.00	79.00
256QAM 0.81 single	84.00	28.00	112.00	77.00	26.00	103.00
64QAM 0.92 single	71.00	24.00	95.00	65.00	22.00	87.00
64QAM 0.75 single	58.00	19.00	77.00	53.00	18.00	71.00
16QAM 0.87 single	45.00	15.00	60.00	41.00	14.00	55.00
16QAM 0.63 single	32.00	11.00	43.00	30.00	10.00	40.00
QPSK 0.87 single	23.00	8.00	31.00	21.00	7.00	28.00
QPSK 0.63 single	16.00	5.00	21.00	15.00	5.00	20.00
BPSK 0.63 single	8.00	5.00	13.00	7.00	4.93	11.93

Modulation mode	30 MHz (Tx/Rx/Aggregate)			20 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	112.00	37.00	149.00	74.00	25.00	99.00
64QAM 0.92 dual	95.00	32.00	127.00	62.00	21.00	83.00
64QAM 0.75 dual	77.00	26.00	103.00	51.00	17.00	68.00
16QAM 0.87 dual	60.00	20.00	80.00	40.00	13.00	53.00
16QAM 0.63 dual	43.00	14.00	57.00	29.00	10.00	39.00
256QAM 0.81 single	56.00	19.00	75.00	37.00	12.00	49.00
64QAM 0.92 single	47.00	16.00	63.00	31.00	10.00	41.00
64QAM 0.75 single	39.00	13.00	52.00	26.00	9.00	35.00
16QAM 0.87 single	30.00	10.00	40.00	20.00	7.00	27.00
16QAM 0.63 single	22.00	7.00	29.00	14.00	5.00	19.00
QPSK 0.87 single	15.00	5.00	20.00	10.00	5.00	15.00
QPSK 0.63 single	11.00	5.00	16.00	7.00	4.75	11.75
BPSK 0.63 single	5.00	3.60	8.60	5.00	2.38	7.38

Modulation mode	15 MHz (Tx/Rx/Aggregate)			10 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	56.00	19.00	75.00	38.00	13.00	51.00
64QAM 0.92 dual	47.00	16.00	63.00	32.00	11.00	43.00
64QAM 0.75 dual	39.00	13.00	52.00	26.00	9.00	35.00
16QAM 0.87 dual	30.00	10.00	40.00	20.00	7.00	27.00
16QAM 0.63 dual	22.00	7.00	29.00	14.00	5.00	19.00
256QAM 0.81 single	28.00	9.00	37.00	19.00	6.00	25.00
64QAM 0.92 single	24.00	8.00	32.00	16.00	5.00	21.00
64QAM 0.75 single	19.00	6.00	25.00	13.00	5.00	18.00
16QAM 0.87 single	15.00	5.00	20.00	10.00	5.00	15.00
16QAM 0.63 single	11.00	5.00	16.00	7.00	4.82	11.82
QPSK 0.87 single	7.00	4.99	11.99	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	1.79	6.79	3.61	1.20	4.81

Table 100 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	187.00	37.00	224.00	167.00	33.00	200.00
64QAM 0.92 dual	158.00	32.00	190.00	141.00	28.00	169.00
64QAM 0.75 dual	129.00	26.00	155.00	115.00	23.00	138.00
16QAM 0.87 dual	100.00	20.00	120.00	90.00	18.00	108.00
16QAM 0.63 dual	72.00	14.00	86.00	64.00	13.00	77.00
256QAM 0.81 single	94.00	19.00	113.00	84.00	17.00	101.00
64QAM 0.92 single	79.00	16.00	95.00	70.00	14.00	84.00
64QAM 0.75 single	64.00	13.00	77.00	58.00	12.00	70.00
16QAM 0.87 single	50.00	10.00	60.00	45.00	9.00	54.00
16QAM 0.63 single	36.00	7.00	43.00	32.00	6.00	38.00
QPSK 0.87 single	25.00	5.00	30.00	22.00	5.00	27.00
QPSK 0.63 single	18.00	5.00	23.00	16.00	5.00	21.00
BPSK 0.63 single	9.00	3.60	12.60	8.00	3.22	11.22

Modulation mode	30 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	124.00	25.00	149.00
64QAM 0.92 dual	104.00	21.00	125.00
64QAM 0.75 dual	85.00	17.00	102.00
16QAM 0.87 dual	66.00	13.00	79.00
16QAM 0.63 dual	48.00	10.00	58.00
256QAM 0.81 single	62.00	12.00	74.00
64QAM 0.92 single	52.00	10.00	62.00
64QAM 0.75 single	43.00	9.00	52.00
16QAM 0.87 single	33.00	7.00	40.00
16QAM 0.63 single	24.00	5.00	29.00
QPSK 0.87 single	17.00	5.00	22.00
QPSK 0.63 single	12.00	4.77	16.77
BPSK 0.63 single	6.00	2.38	8.38

Figure 64 Range adjustment for PTP 700, symmetry 1:1, optimization IP, bandwidth 45 MHz

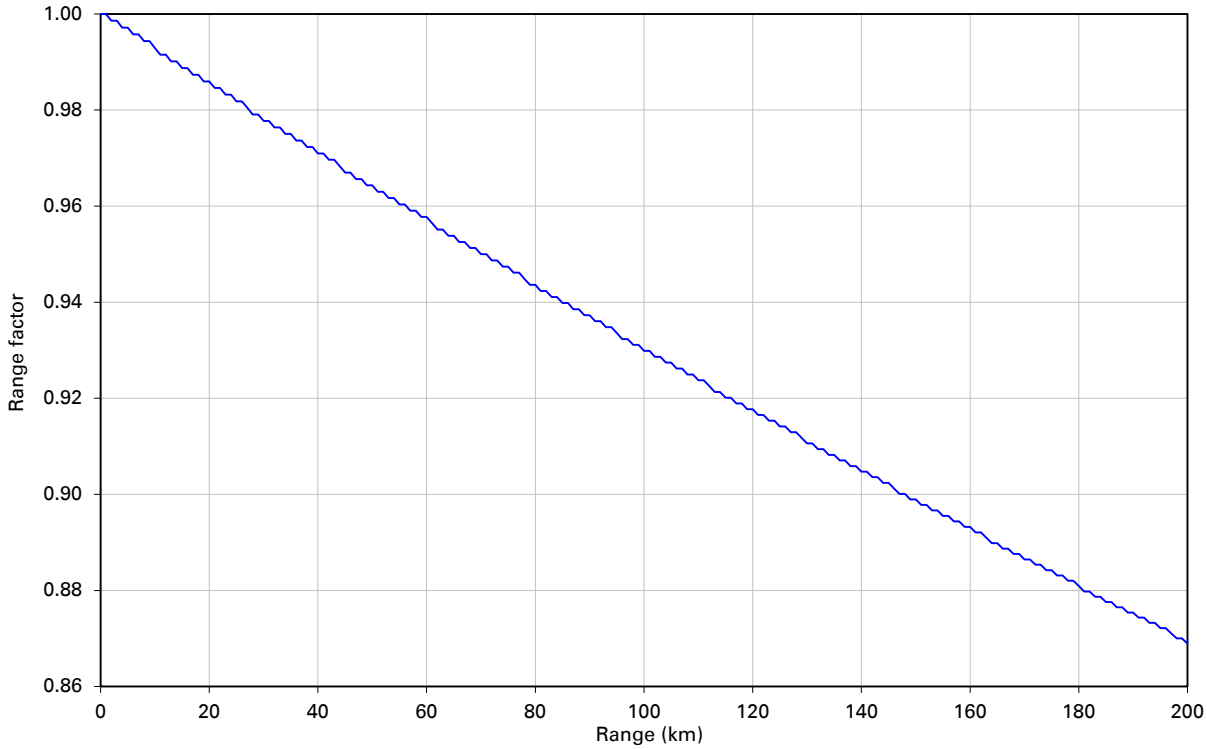


Figure 65 Range adjustment for PTP 700, symmetry 1:1, optimization IP, bandwidth 40 MHz

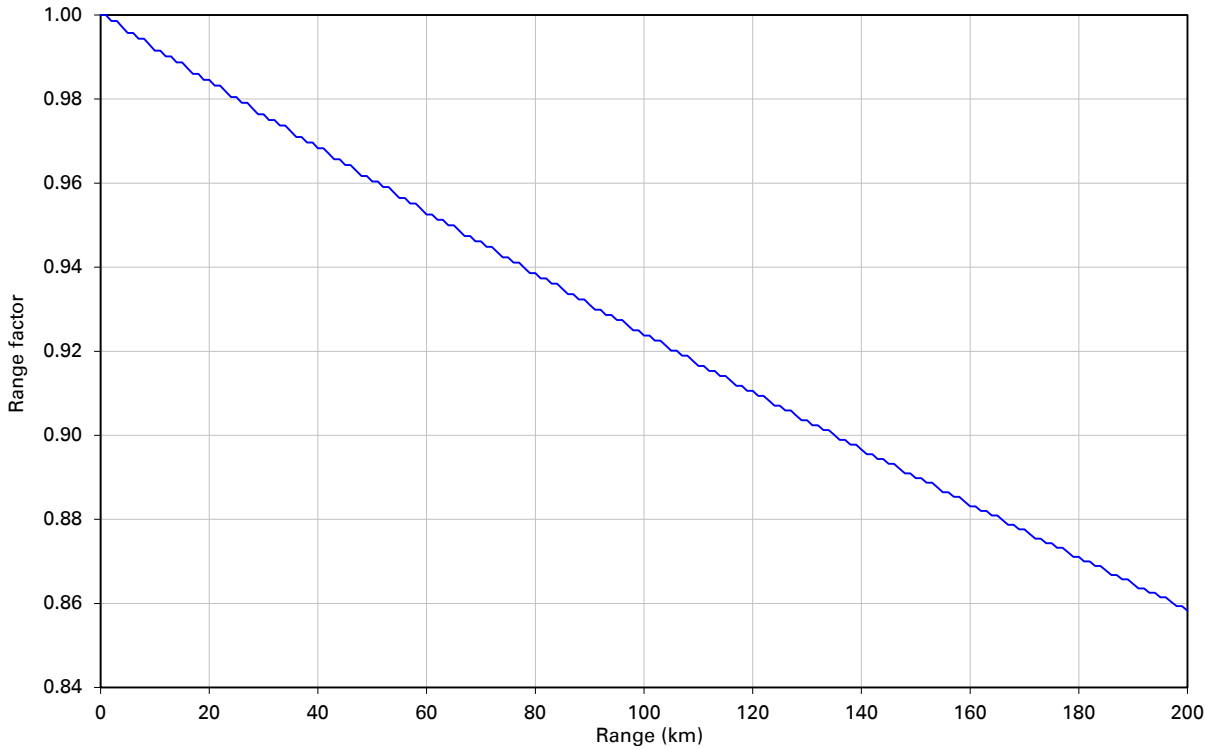


Figure 66 Range adjustment for PTP 700, symmetry 1:1, optimization IP, bandwidth 30 MHz

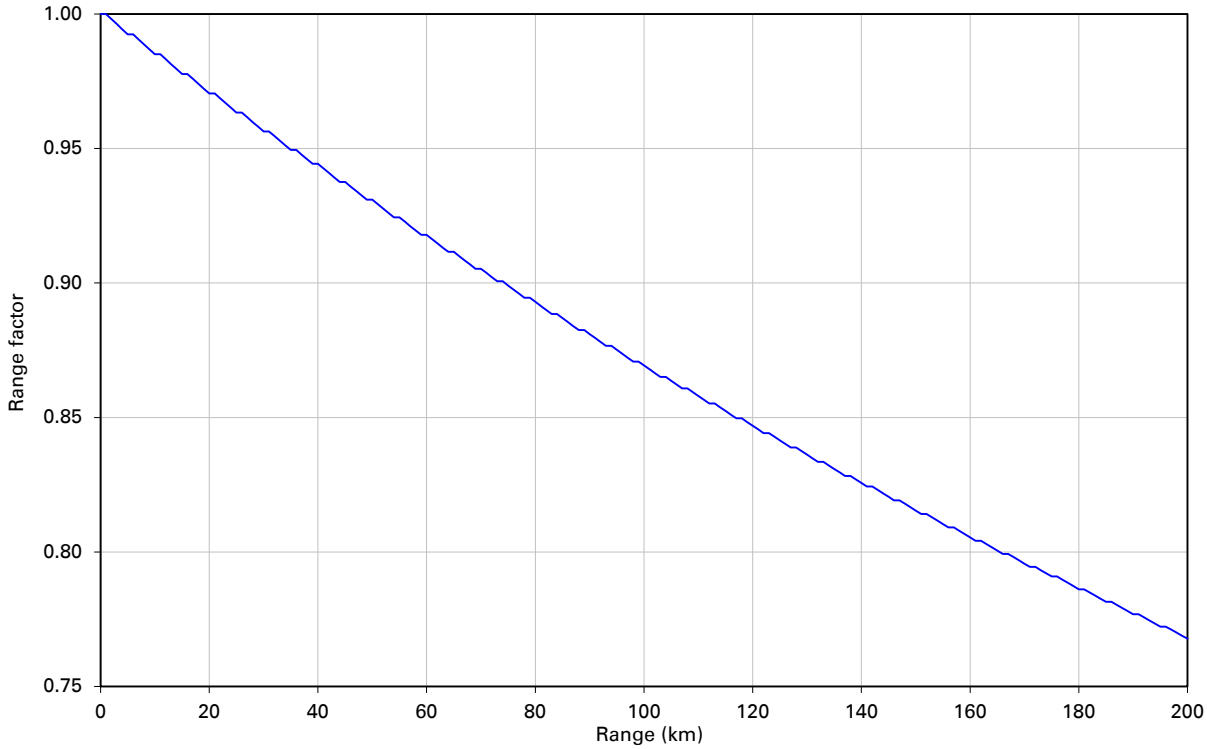


Figure 67 Range adjustment for PTP 700, symmetry 1:1, optimization IP, bandwidth 20 MHz

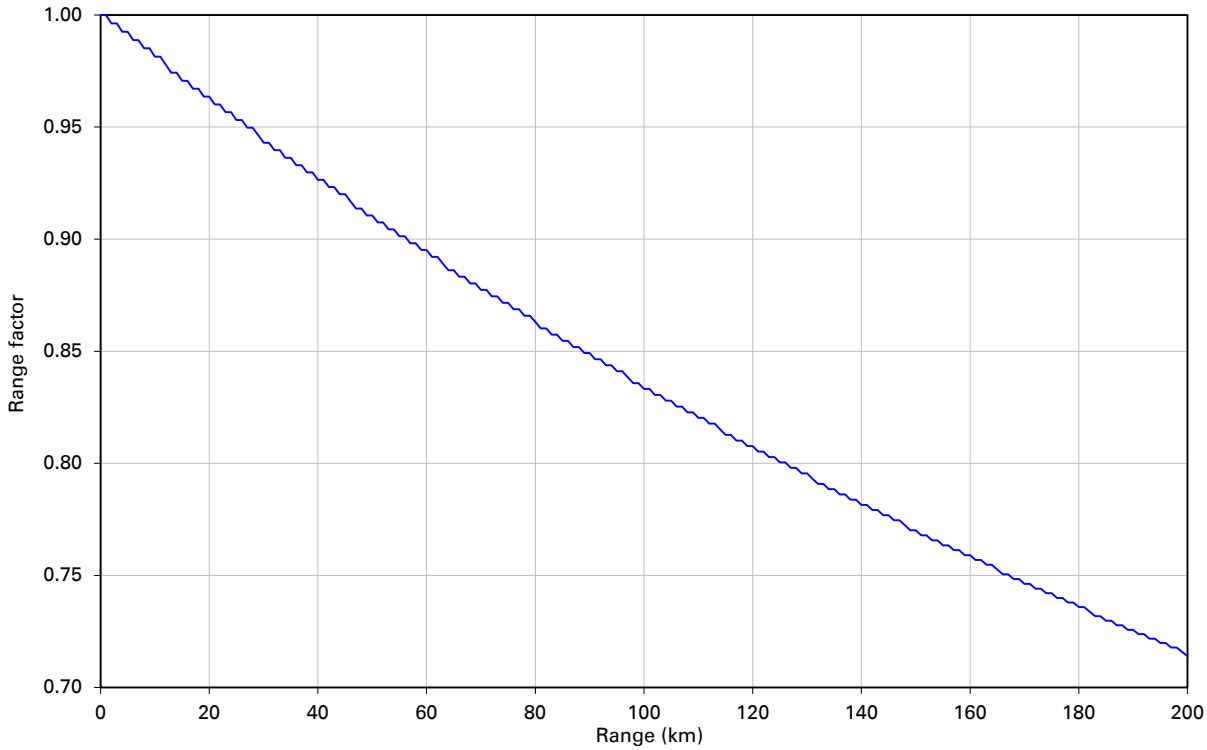


Figure 68 Range adjustment for PTP 700, symmetry 1:1, optimization IP, bandwidth 15 MHz

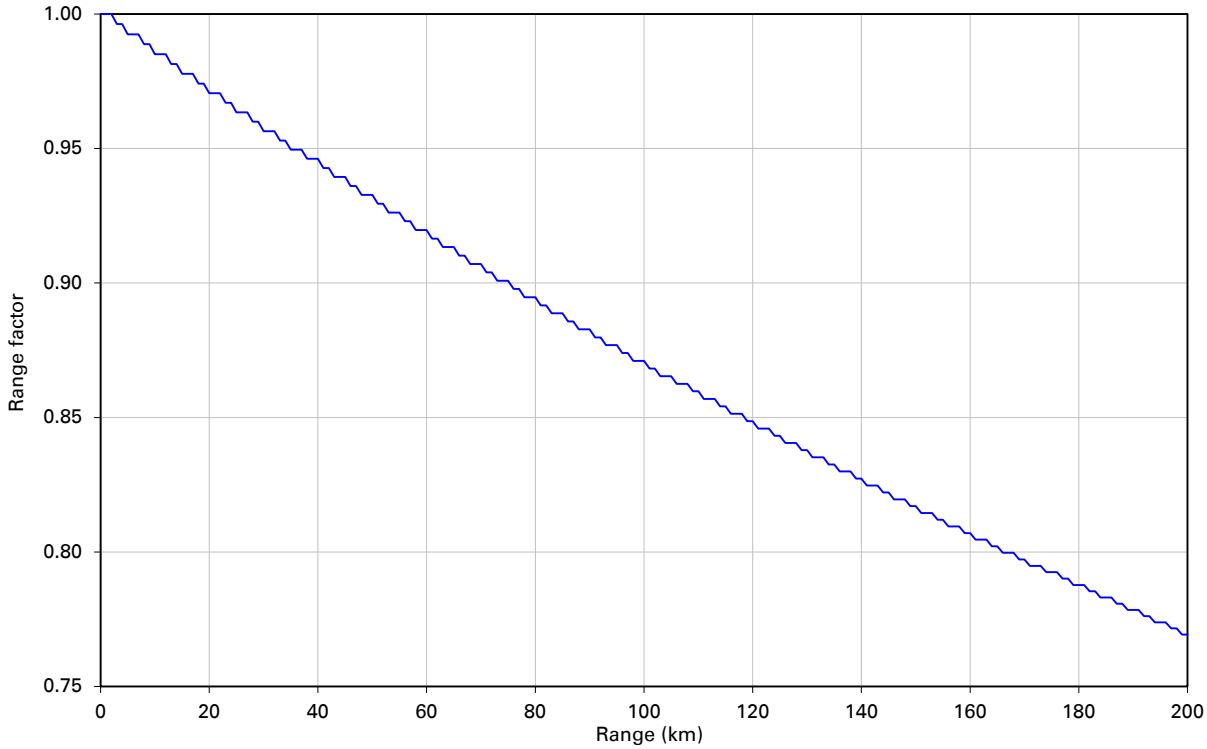


Figure 69 Range adjustment for PTP 700, symmetry 1:1, optimization IP, bandwidth 10 MHz

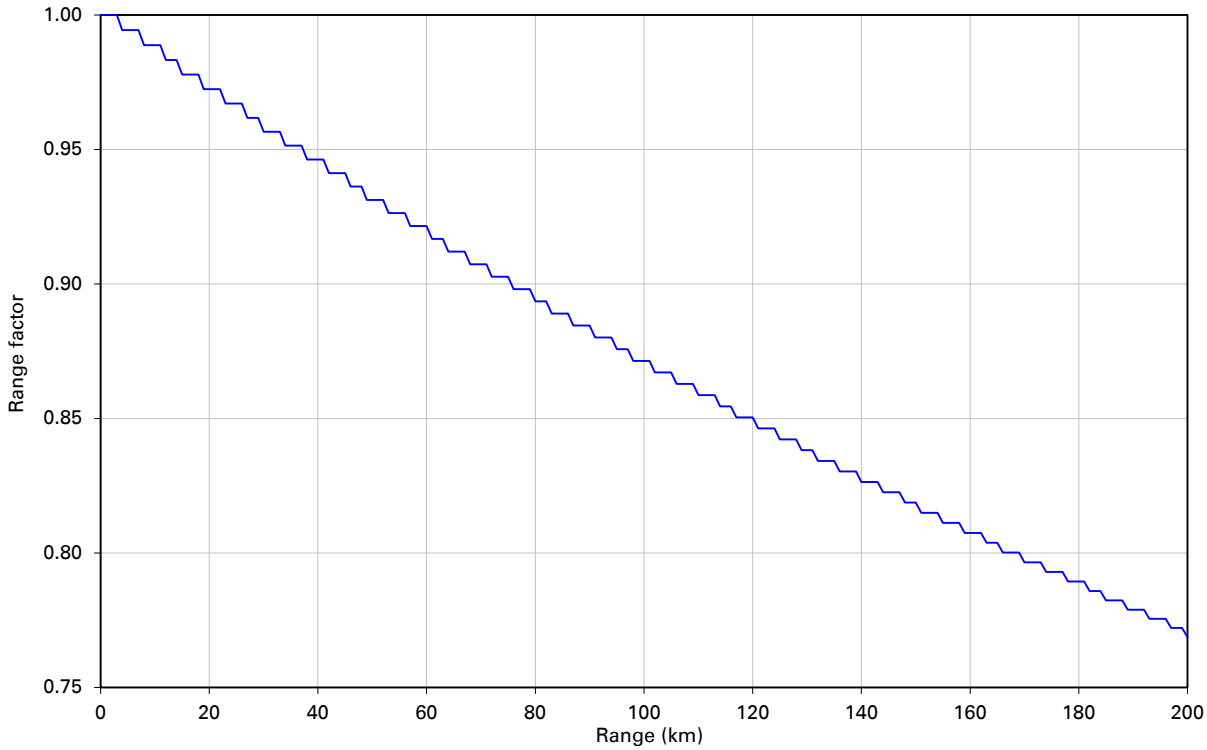


Figure 70 Range adjustment for PTP 700, symmetry 1:1, optimization IP, bandwidth 5 MHz

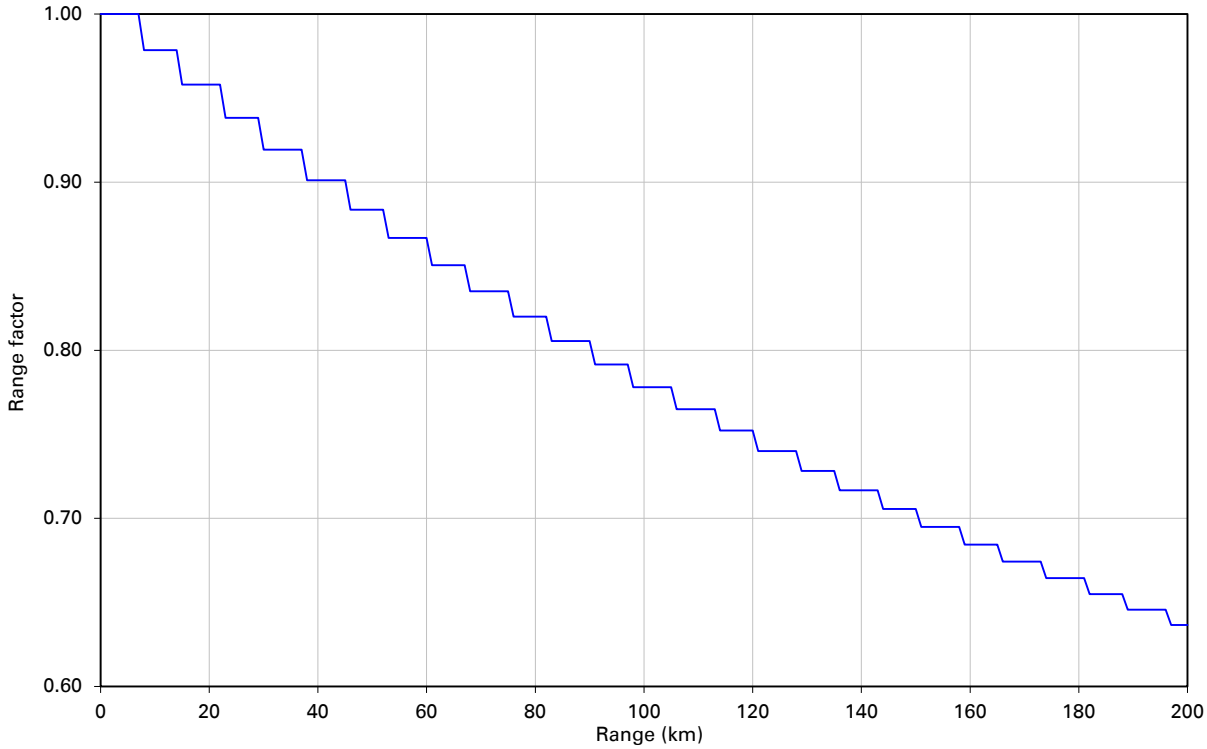


Figure 71 Range adjustment for PTP 700, symmetry 1:1, optimization TDM, bandwidth 45 MHz

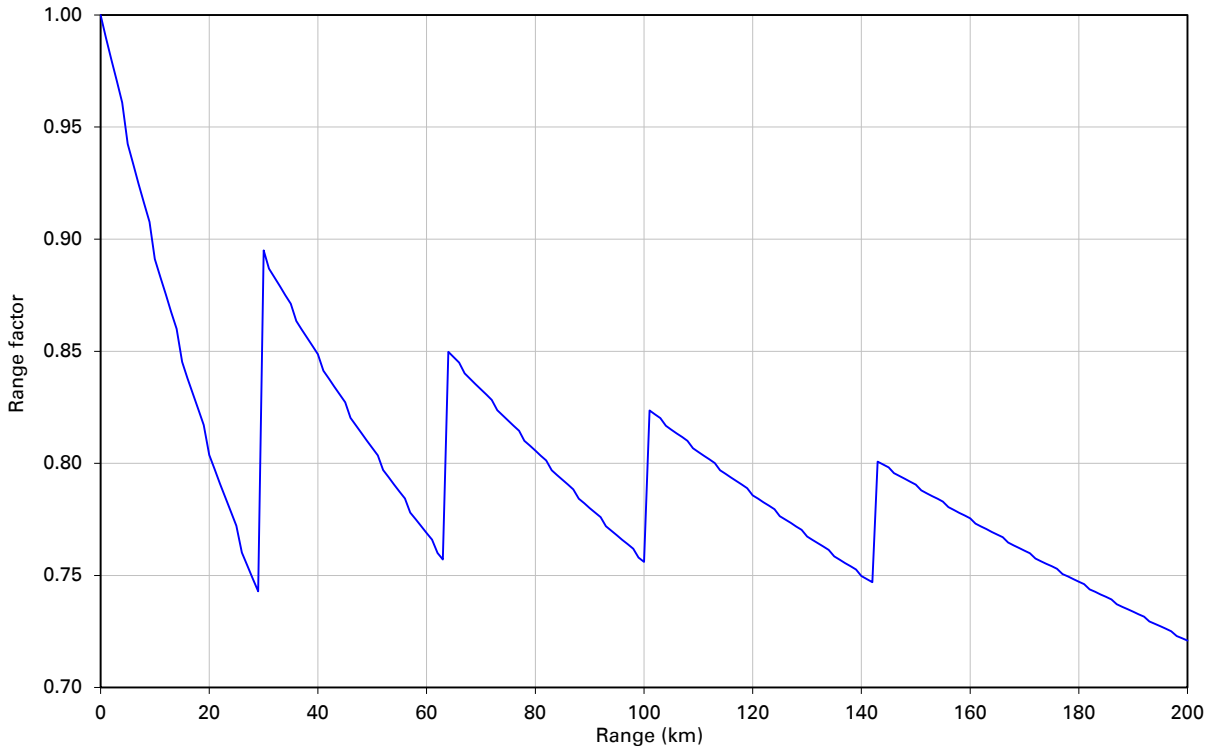


Figure 72 Range adjustment for PTP 700, symmetry 1:1, optimization TDM, bandwidth 40 MHz

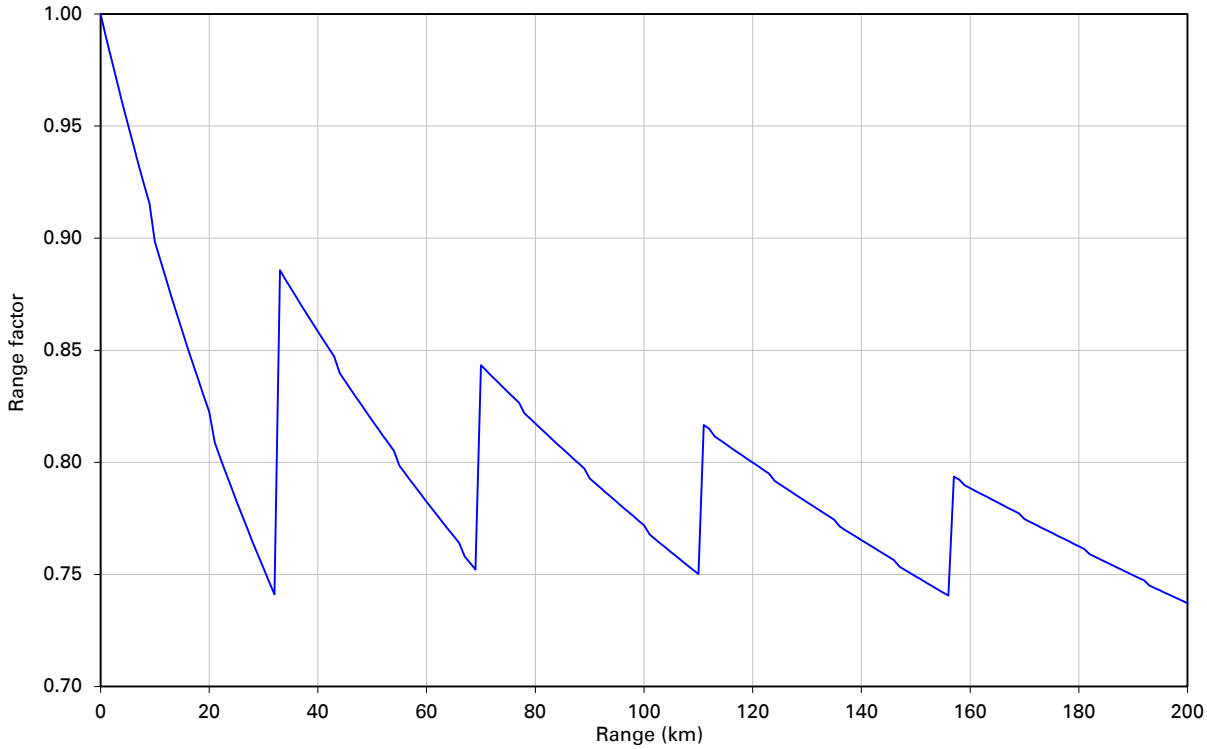


Figure 73 Range adjustment for PTP 700, symmetry 1:1, optimization TDM, bandwidth 30 MHz

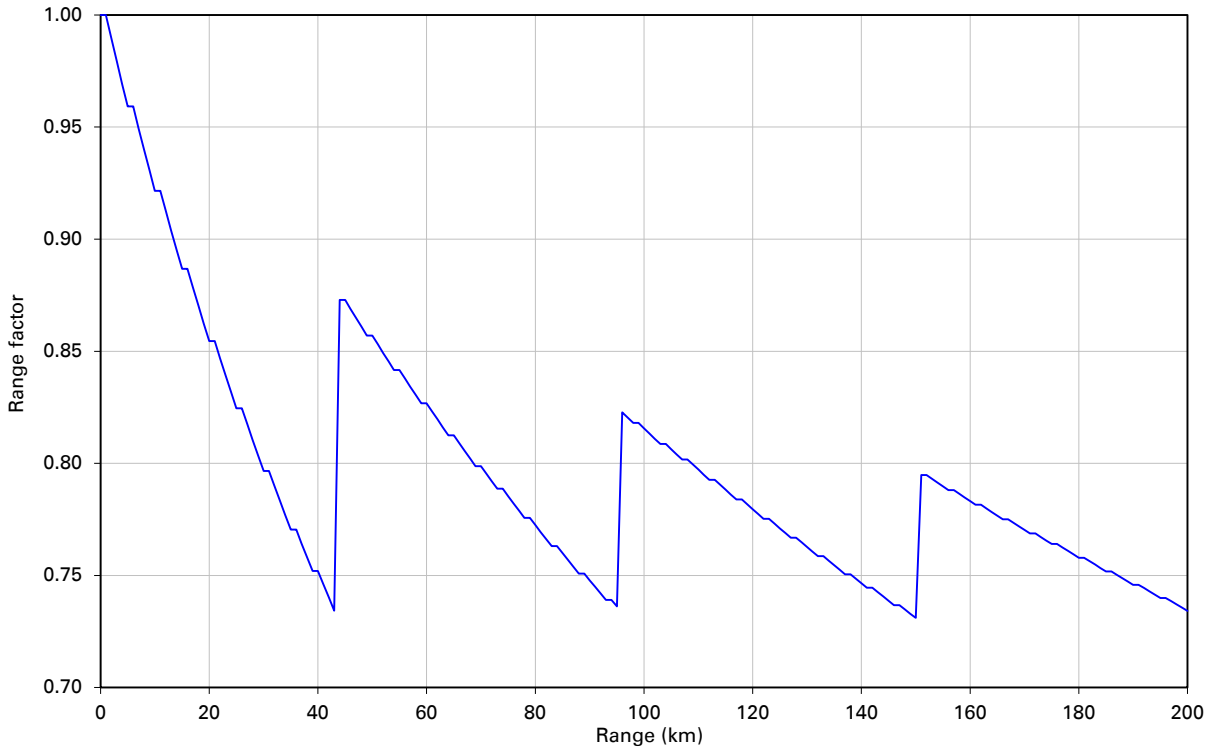


Figure 74 Range adjustment for PTP 700, symmetry 1:1, optimization TDM, bandwidth 20 MHz

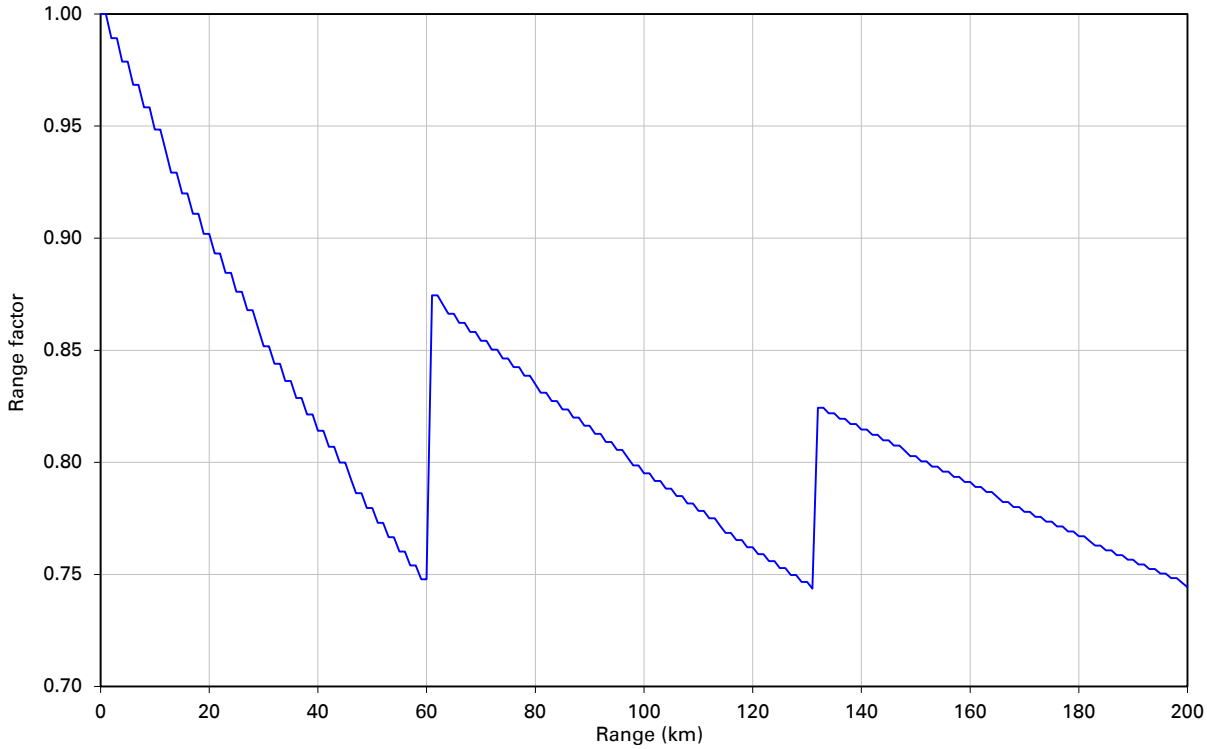


Figure 75 Range adjustment for PTP 700, symmetry 1:1, optimization TDM, bandwidth 15 MHz

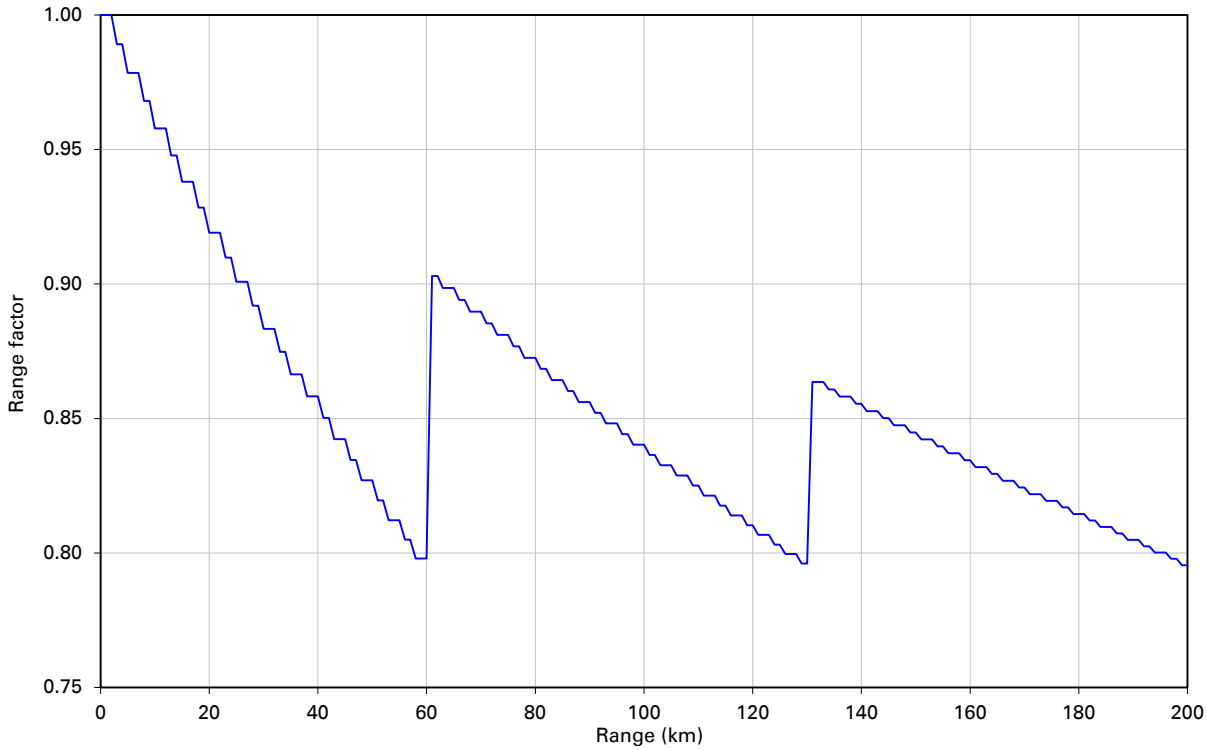


Figure 76 Range adjustment for PTP 700, symmetry 1:1, optimization TDM, bandwidth 10 MHz

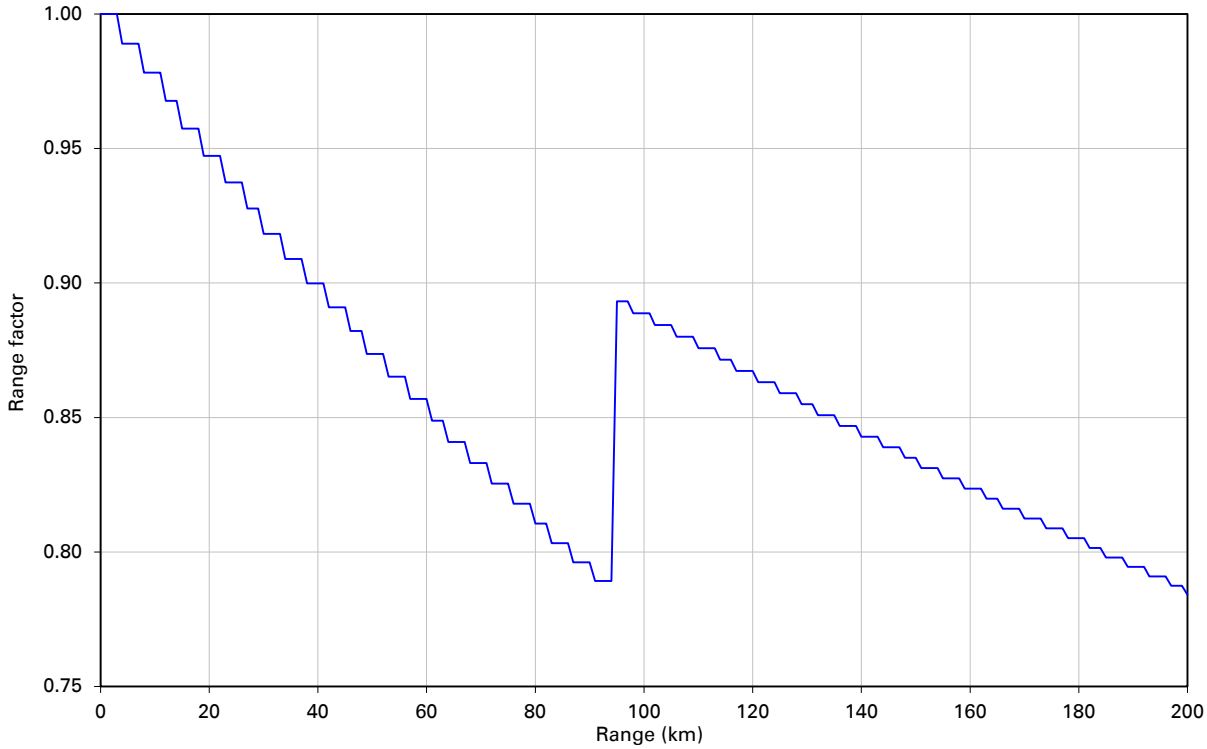


Figure 77 Range adjustment for PTP 700, symmetry 1:1, optimization TDM, bandwidth 5 MHz

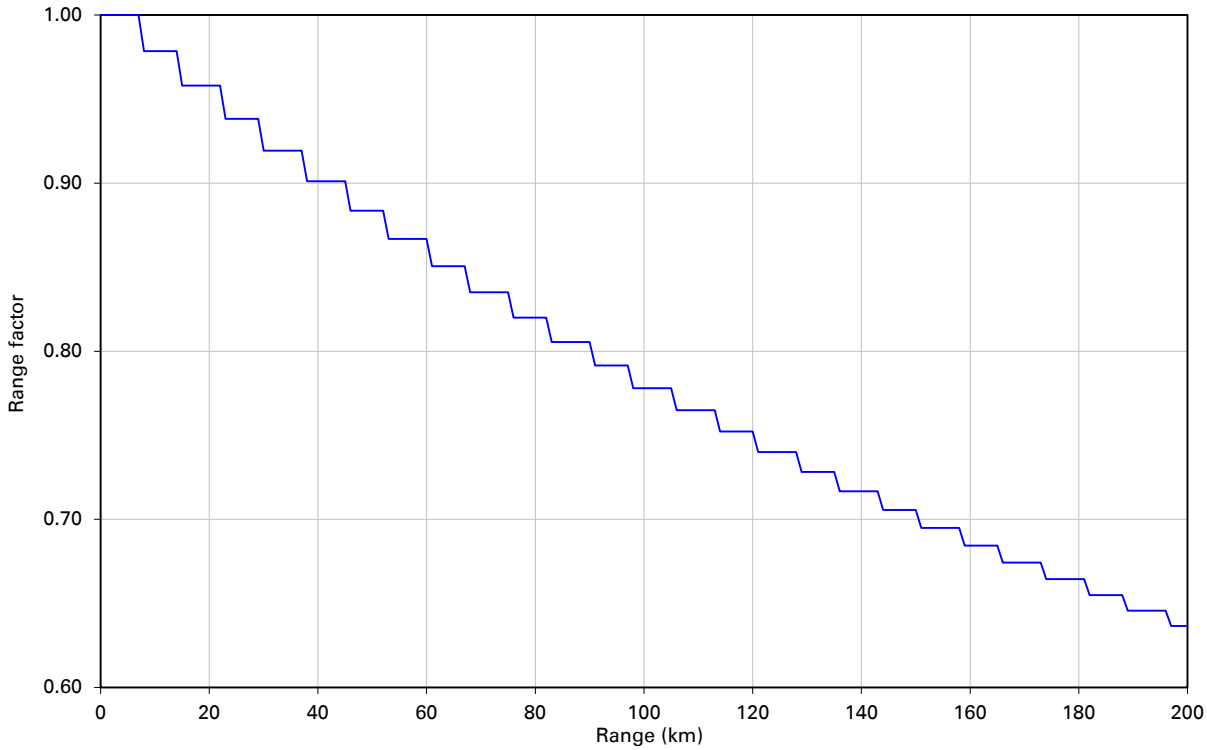


Figure 78 Range adjustment for PTP 700, symmetry 2:1, optimization IP, bandwidth 45 MHz

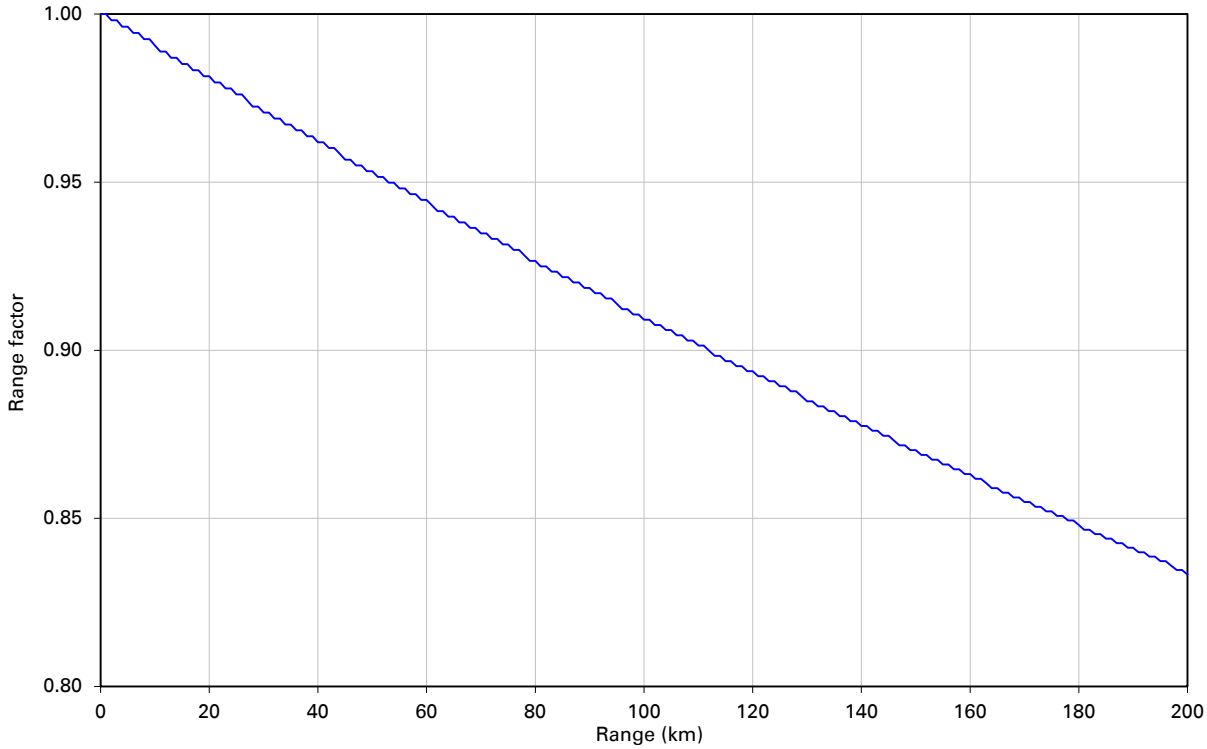


Figure 79 Range adjustment for PTP 700, symmetry 2:1, optimization IP, bandwidth 40 MHz

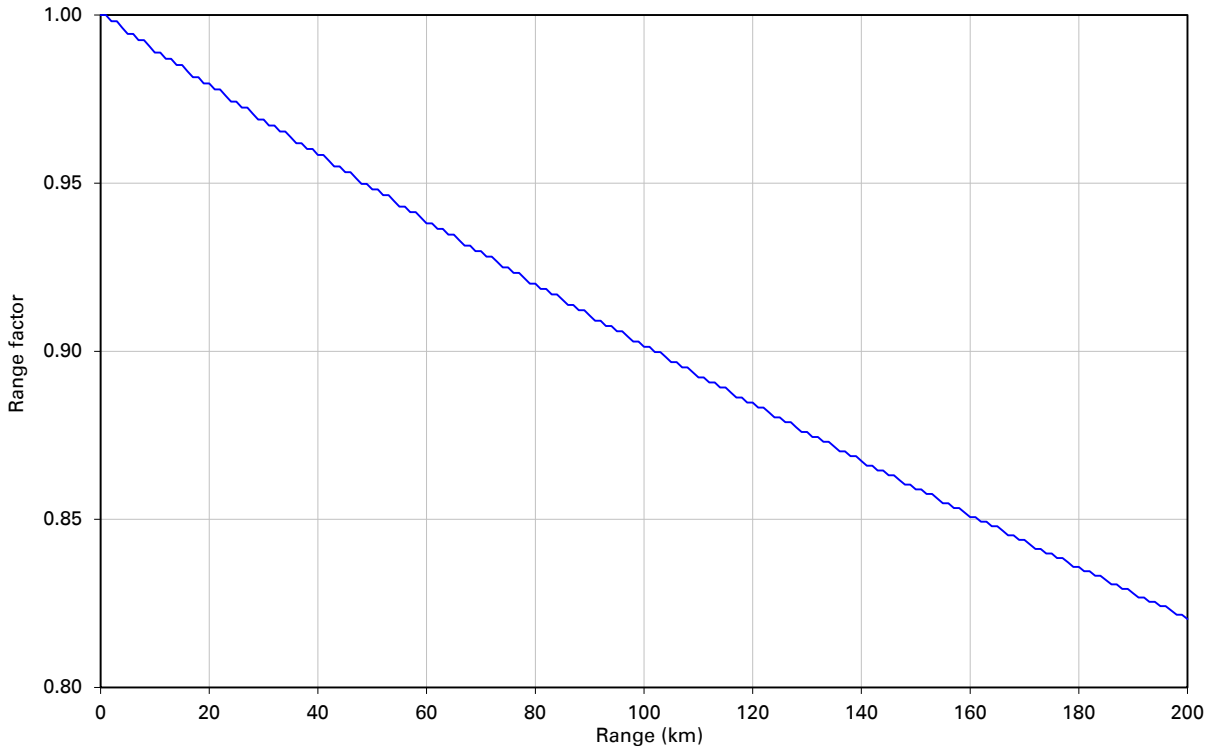


Figure 80 Range adjustment for PTP 700, symmetry 2:1, optimization IP, bandwidth 30 MHz

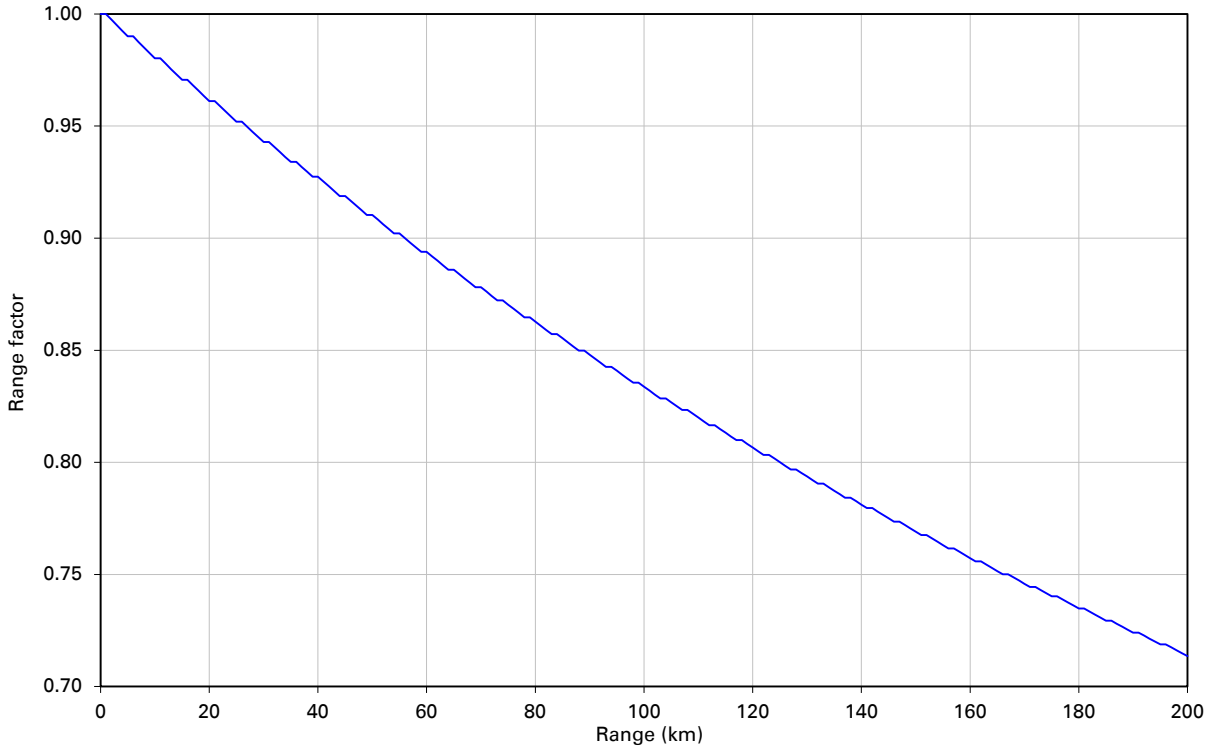


Figure 81 Range adjustment for PTP 700, symmetry 2:1, optimization IP, bandwidth 20 MHz

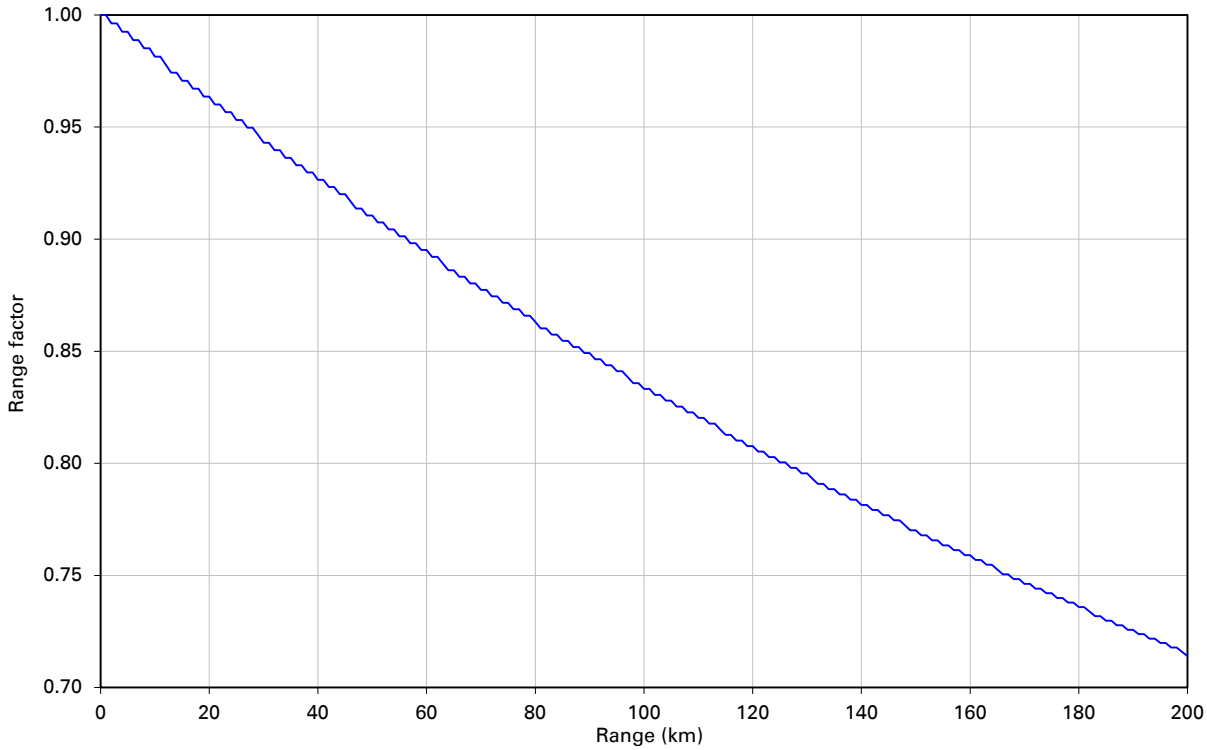


Figure 82 Range adjustment for PTP 700, symmetry 2:1, optimization IP, bandwidth 15 MHz

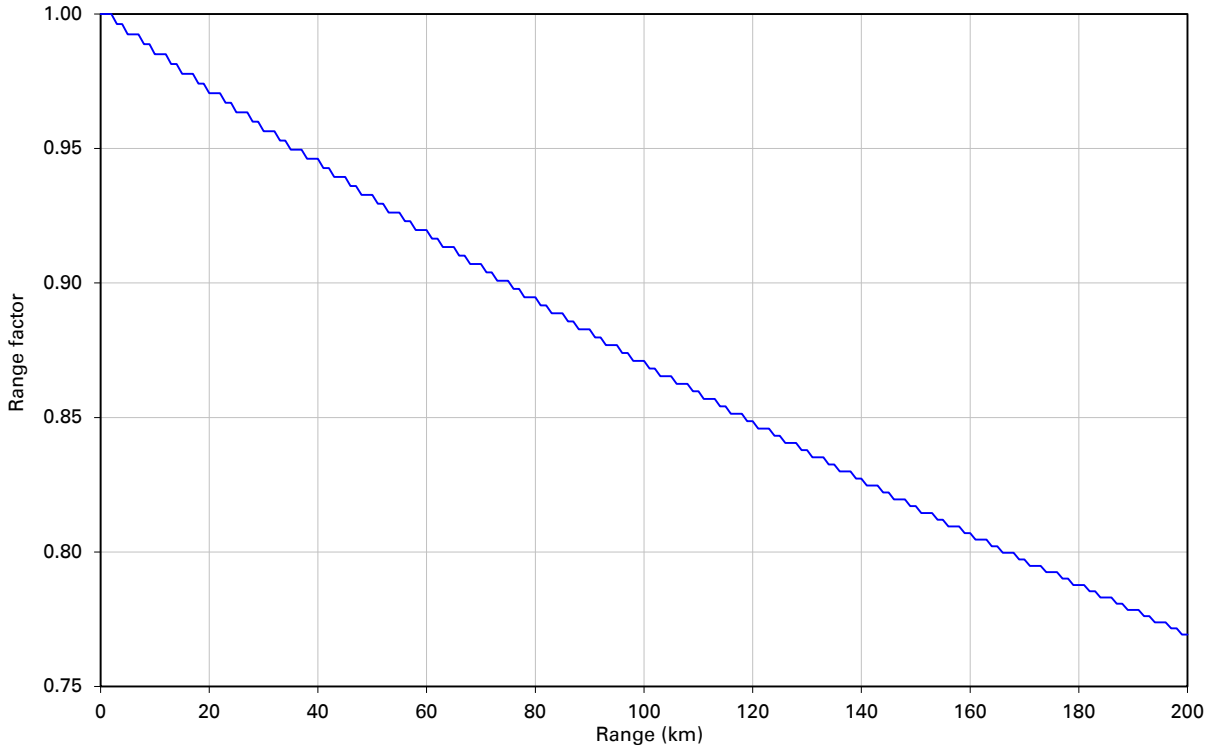


Figure 83 Range adjustment for PTP 700, symmetry 2:1, optimization IP, bandwidth 10 MHz

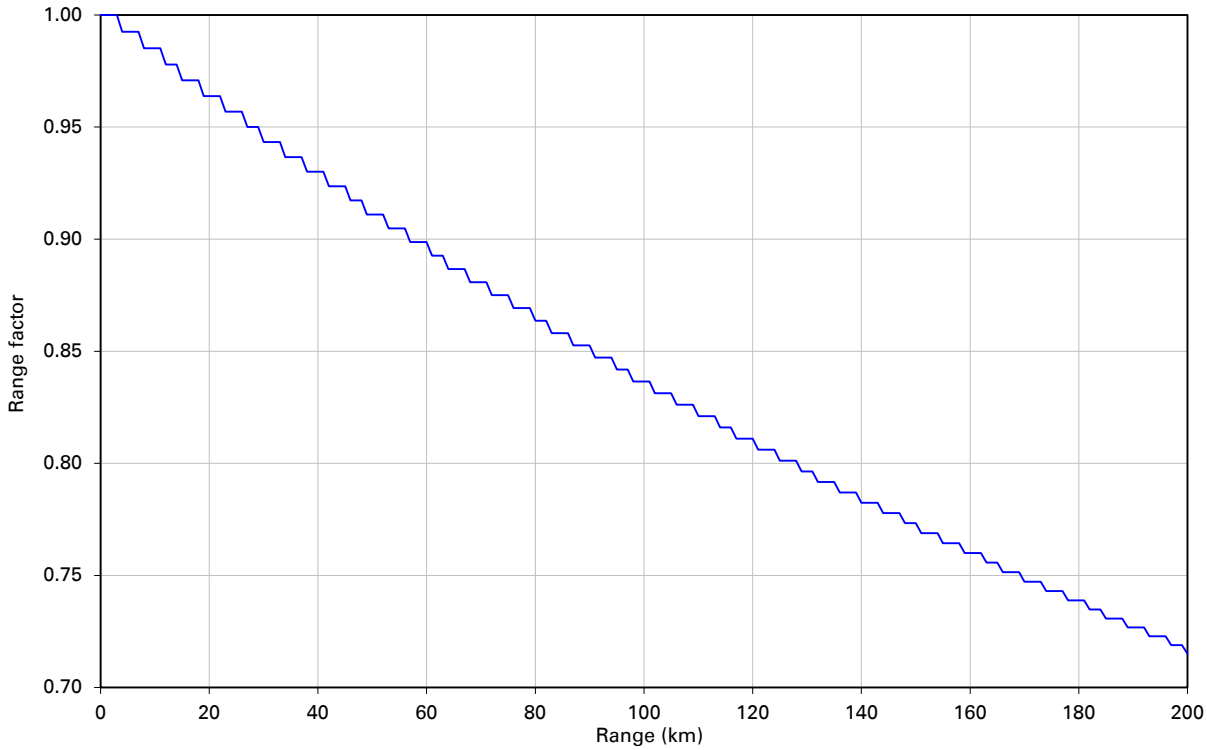


Figure 84 Range adjustment for PTP 700, symmetry 2:1, optimization TDM, bandwidth 45 MHz

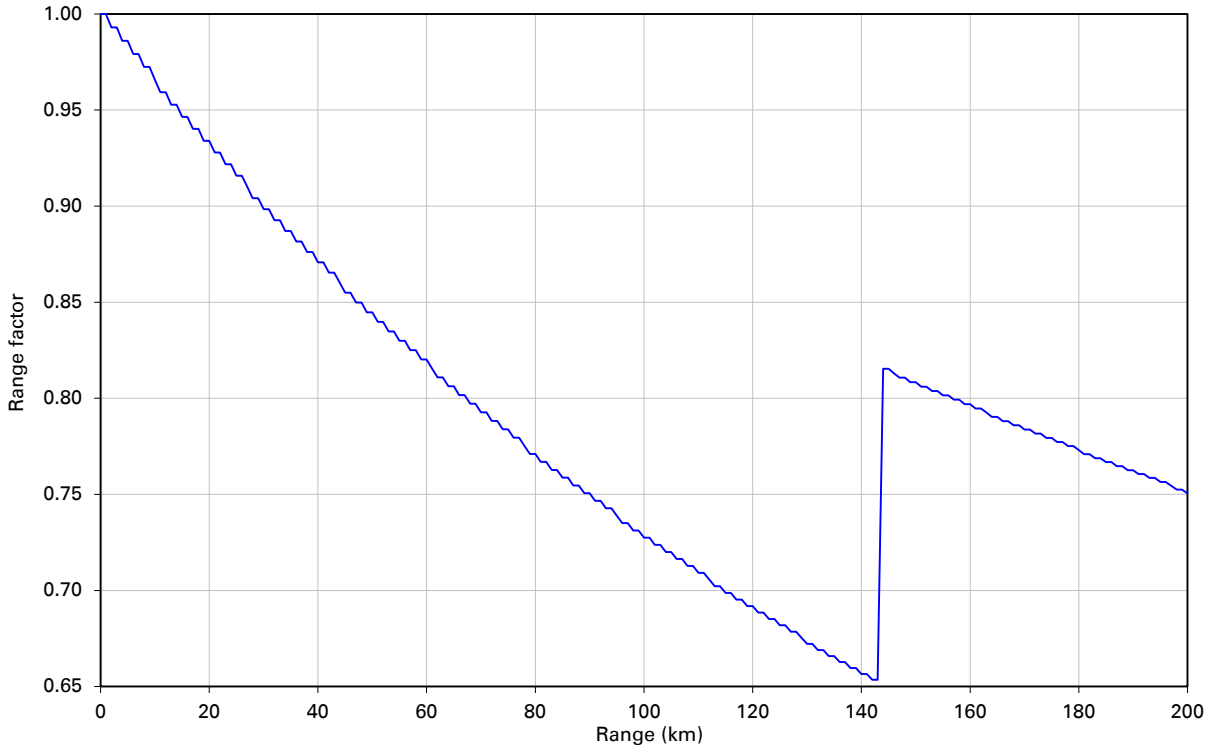


Figure 85 Range adjustment for PTP 700, symmetry 2:1, optimization TDM, bandwidth 40 MHz

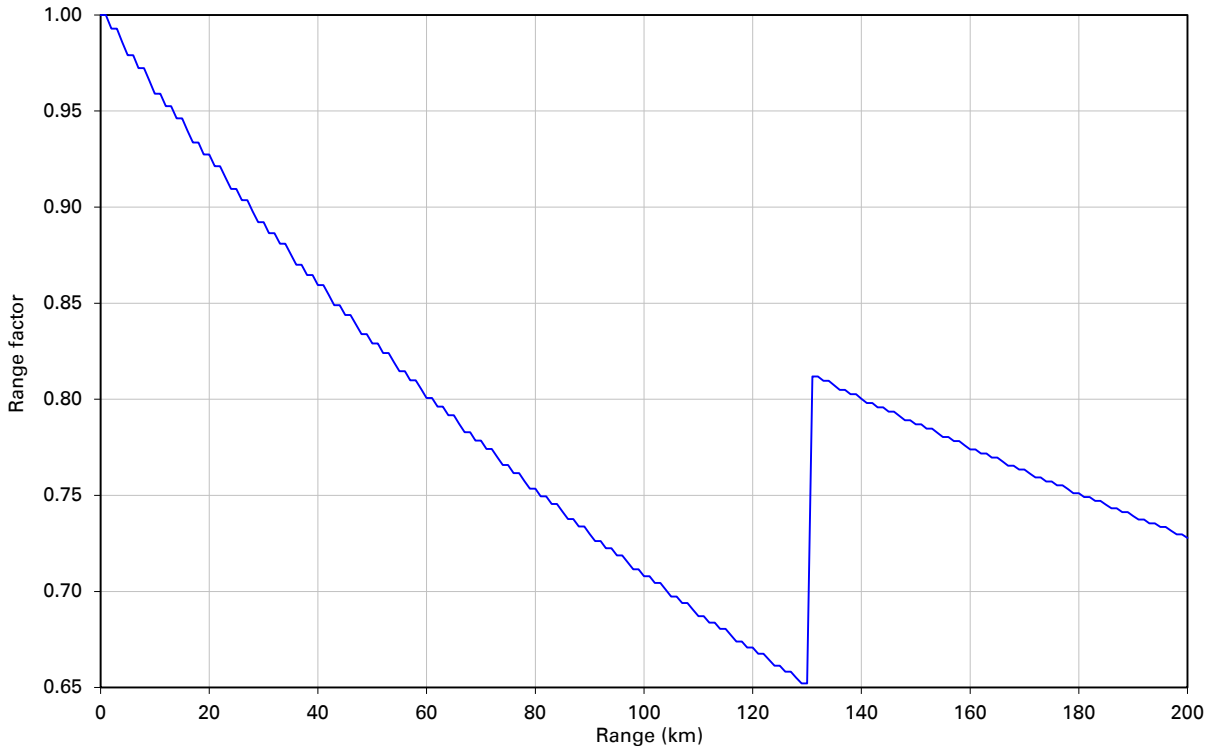


Figure 86 Range adjustment for PTP 700, symmetry 2:1, optimization TDM, bandwidth 30 MHz

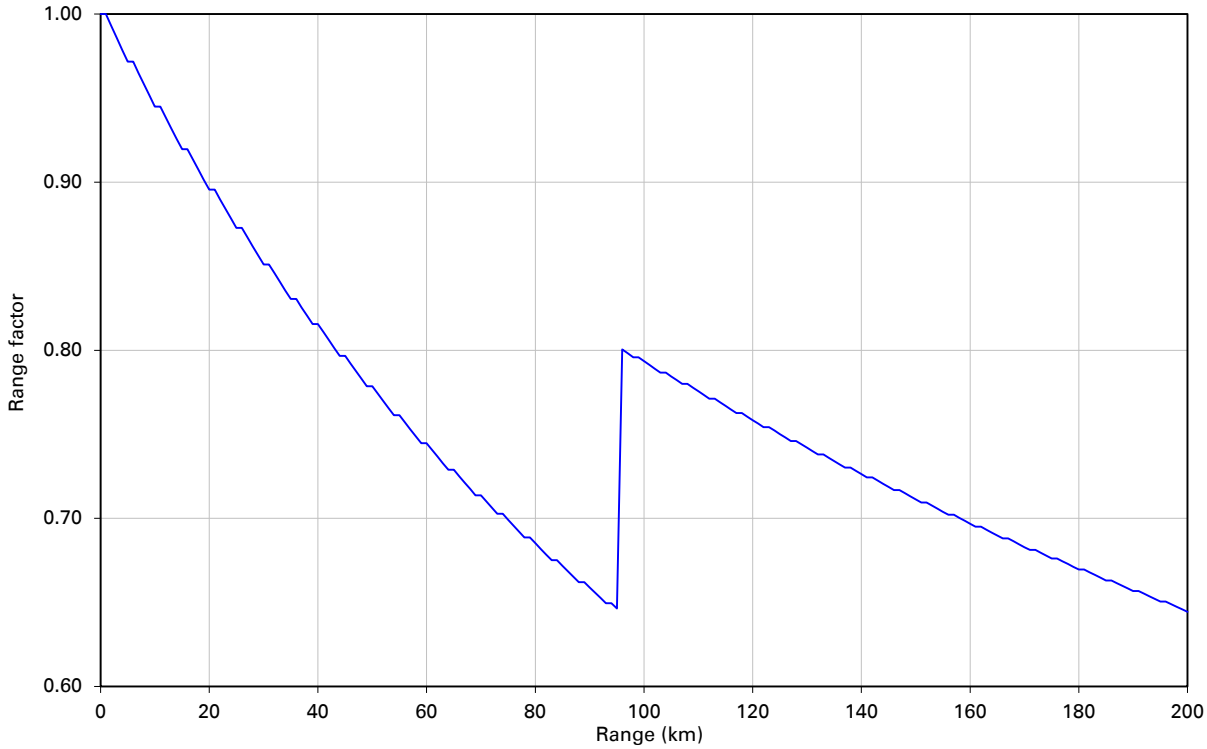


Figure 87 Range adjustment for PTP 700, symmetry 2:1, optimization TDM, bandwidth 20 MHz

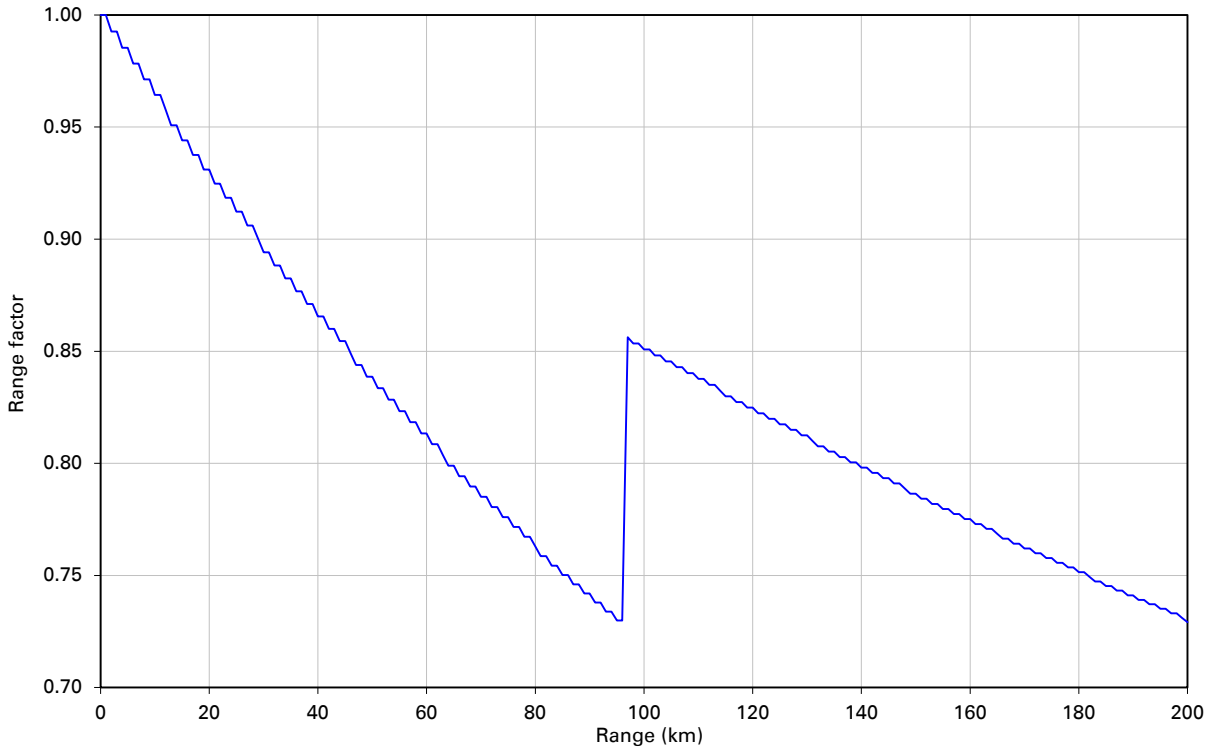


Figure 88 Range adjustment for PTP 700, symmetry 2:1, optimization TDM, bandwidth 15 MHz

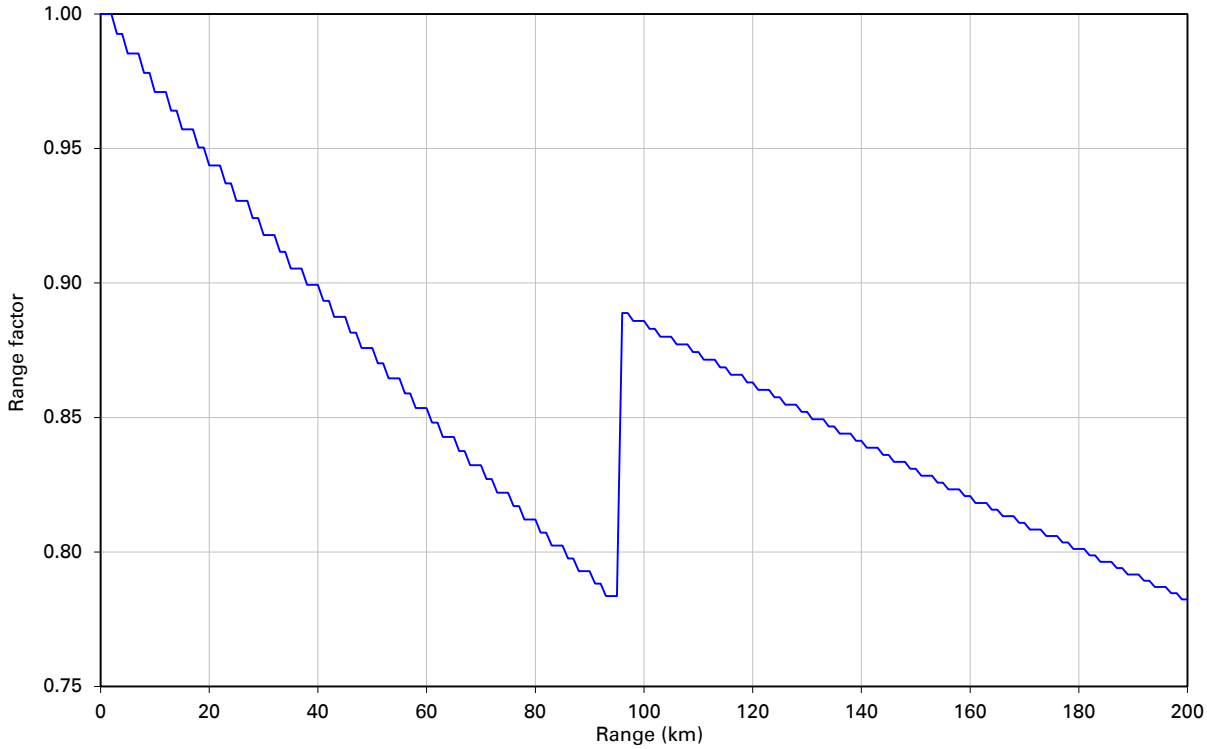


Figure 89 Range adjustment for PTP 700, symmetry 2:1, optimization TDM, bandwidth 10 MHz

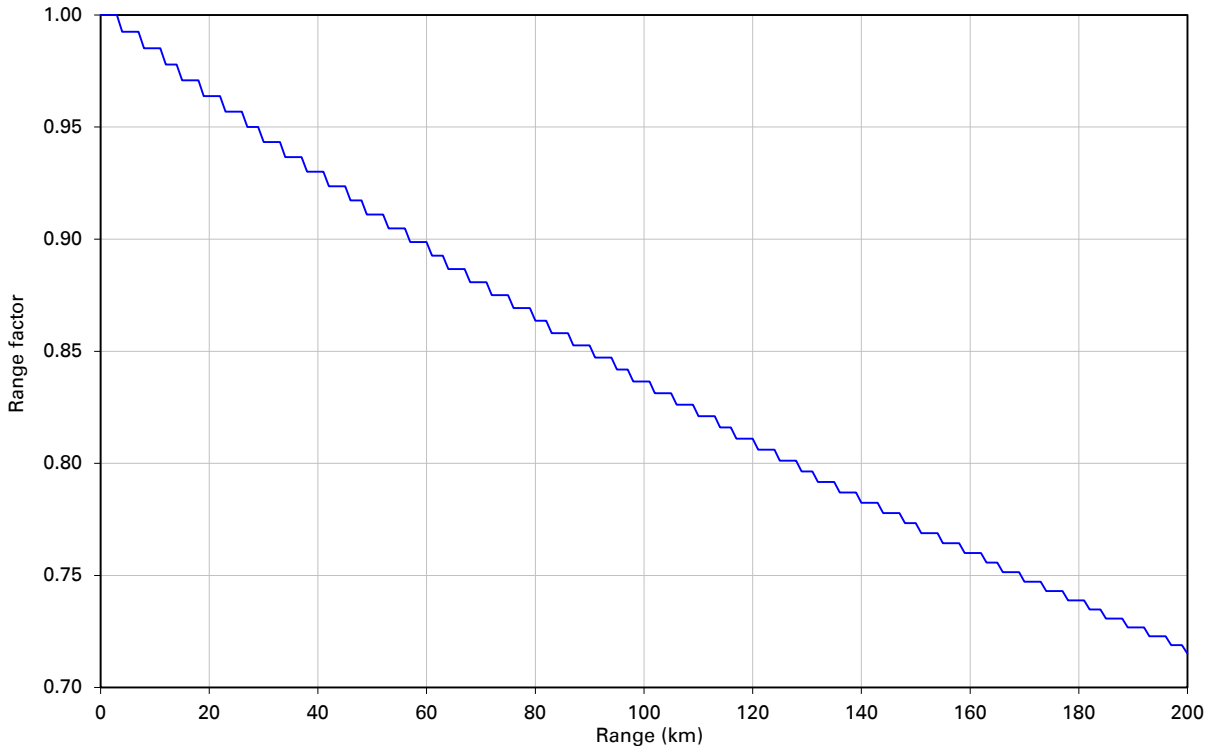


Figure 90 Range adjustment for PTP 700, symmetry 3:1, optimization IP, bandwidth 45 MHz

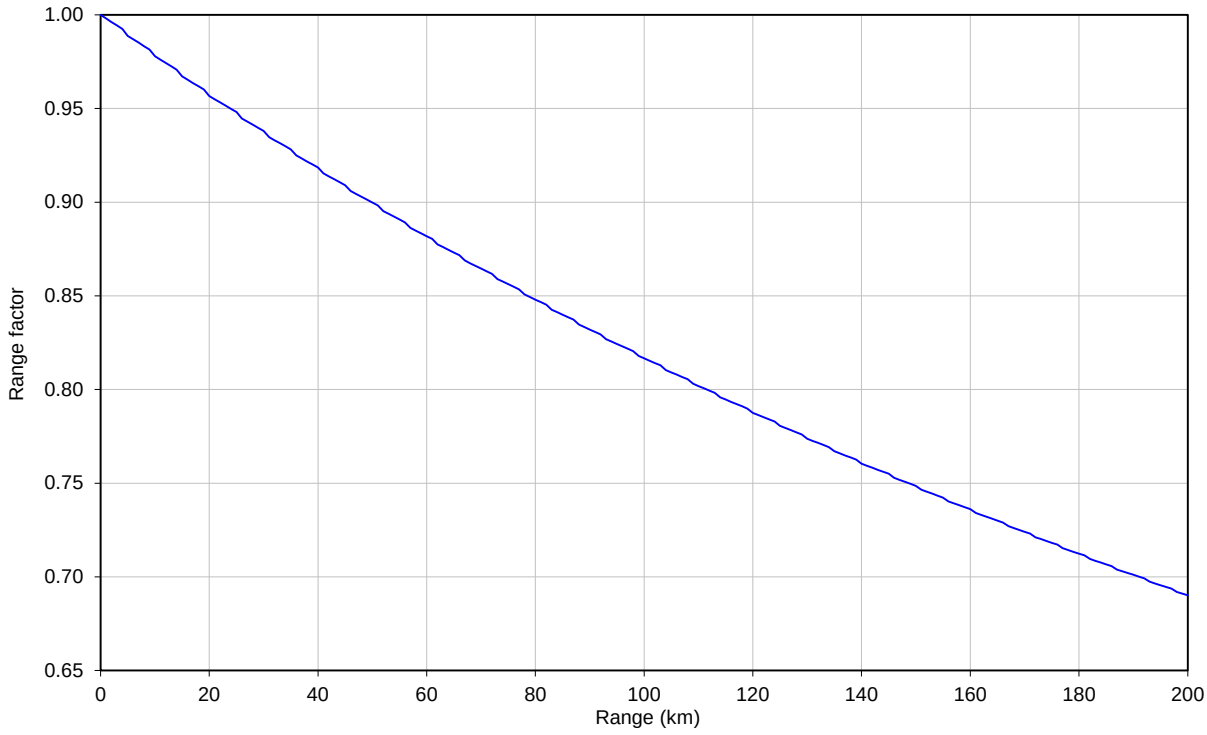


Figure 91 Range adjustment for PTP 700, symmetry 3:1, optimization IP, bandwidth 40 MHz

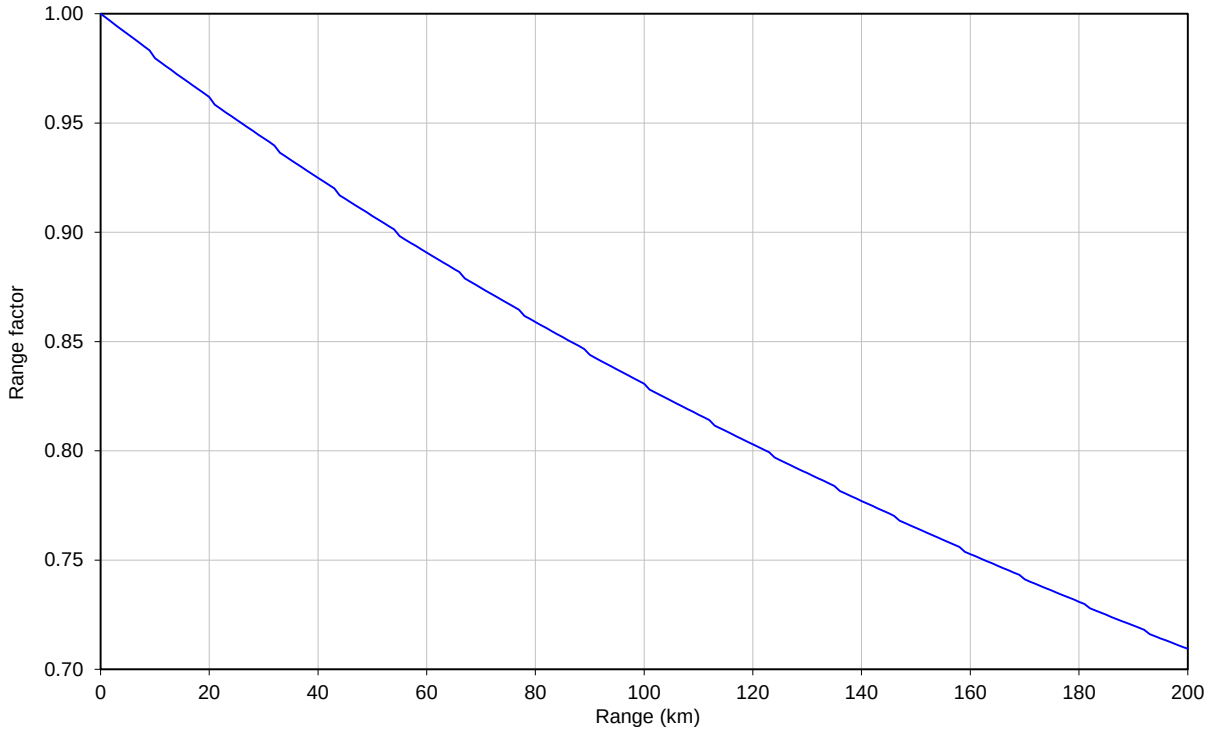


Figure 92 Range adjustment for PTP 700, symmetry 3:1, optimization IP, bandwidth 30 MHz

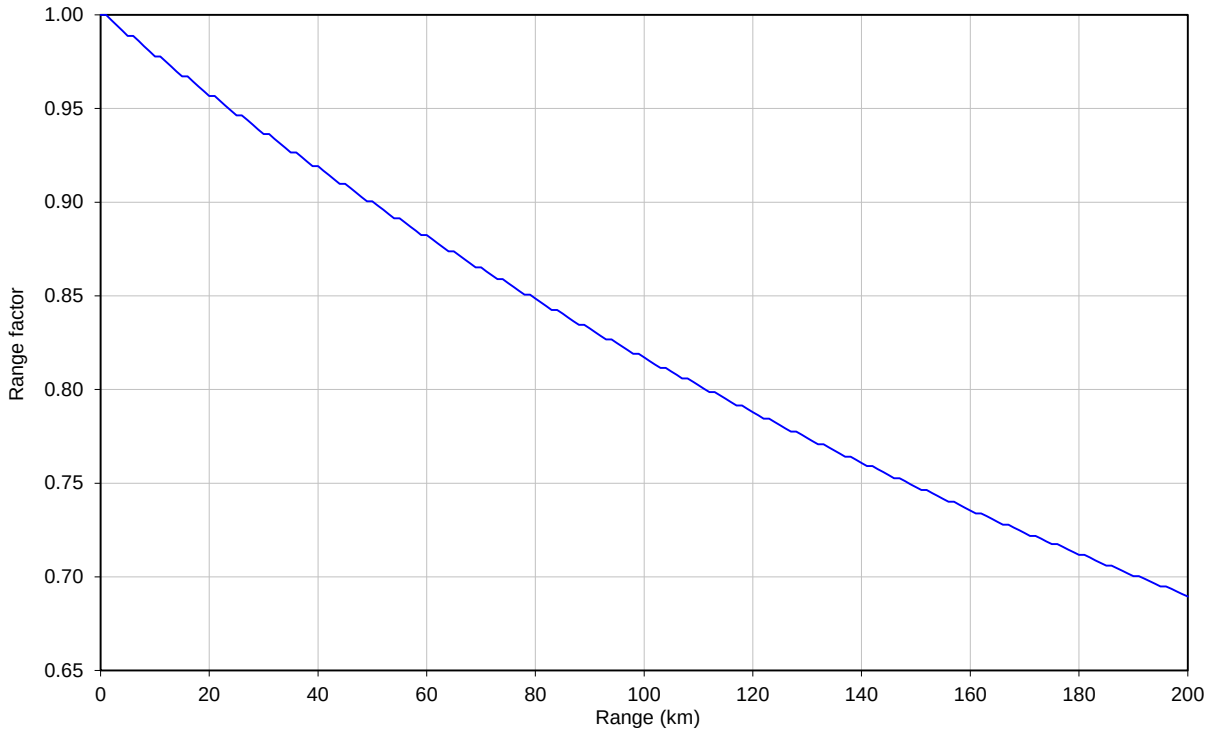


Figure 93 Range adjustment for PTP 700, symmetry 3:1, optimization IP, bandwidth 20 MHz

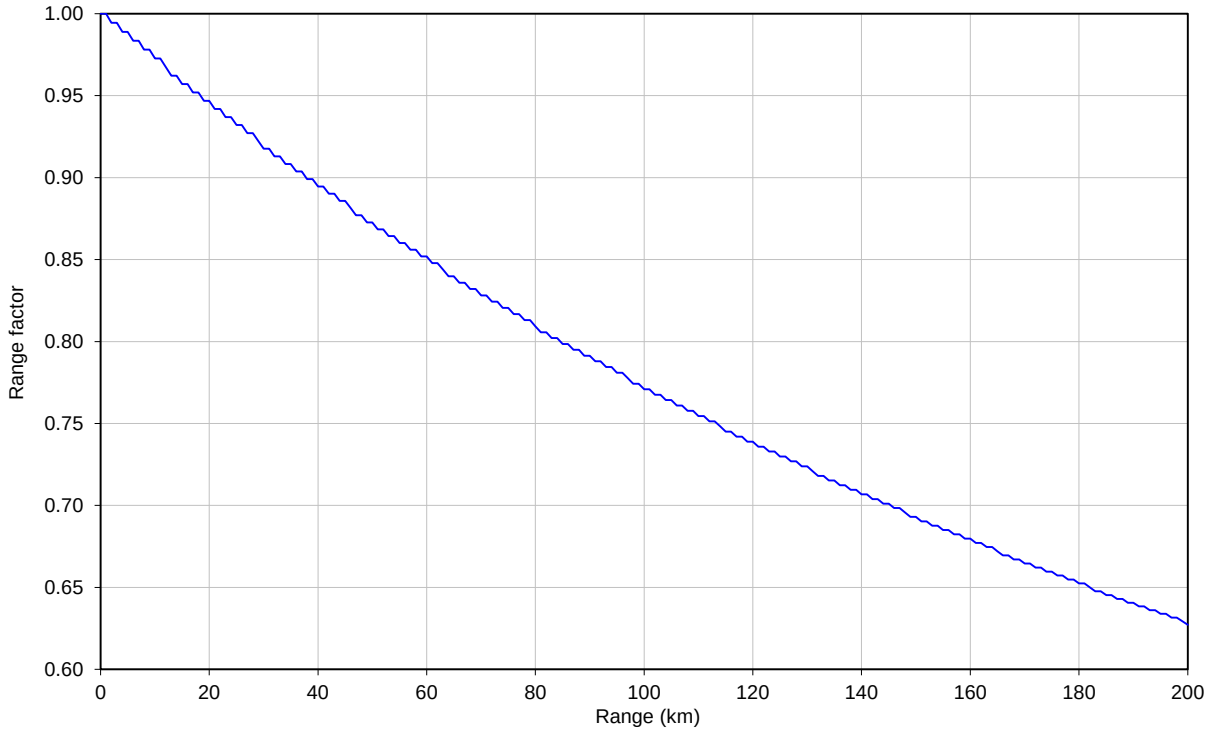


Figure 94 Range adjustment for PTP 700, symmetry 3:1, optimization IP, bandwidth 15 MHz

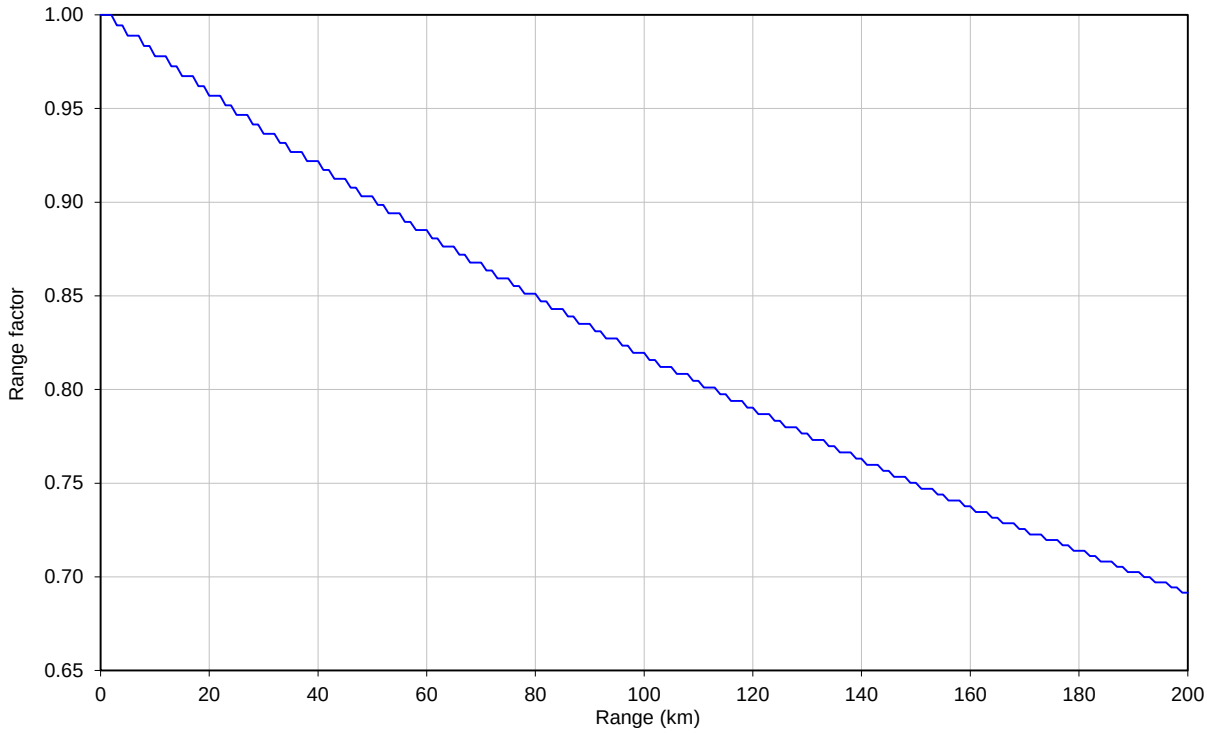


Figure 95 Range adjustment for PTP 700, symmetry 3:1, optimization IP, bandwidth 10 MHz

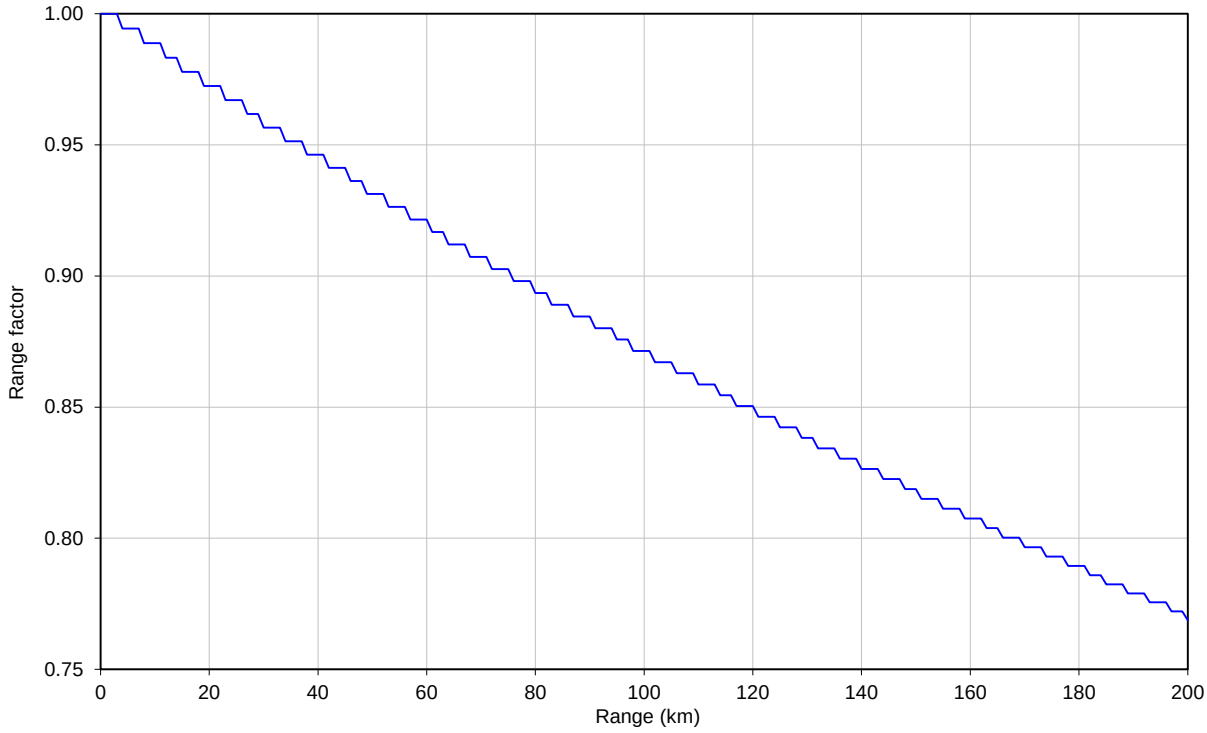


Figure 96 Range adjustment for PTP 700, symmetry 5:1, optimization IP, bandwidth 45 MHz

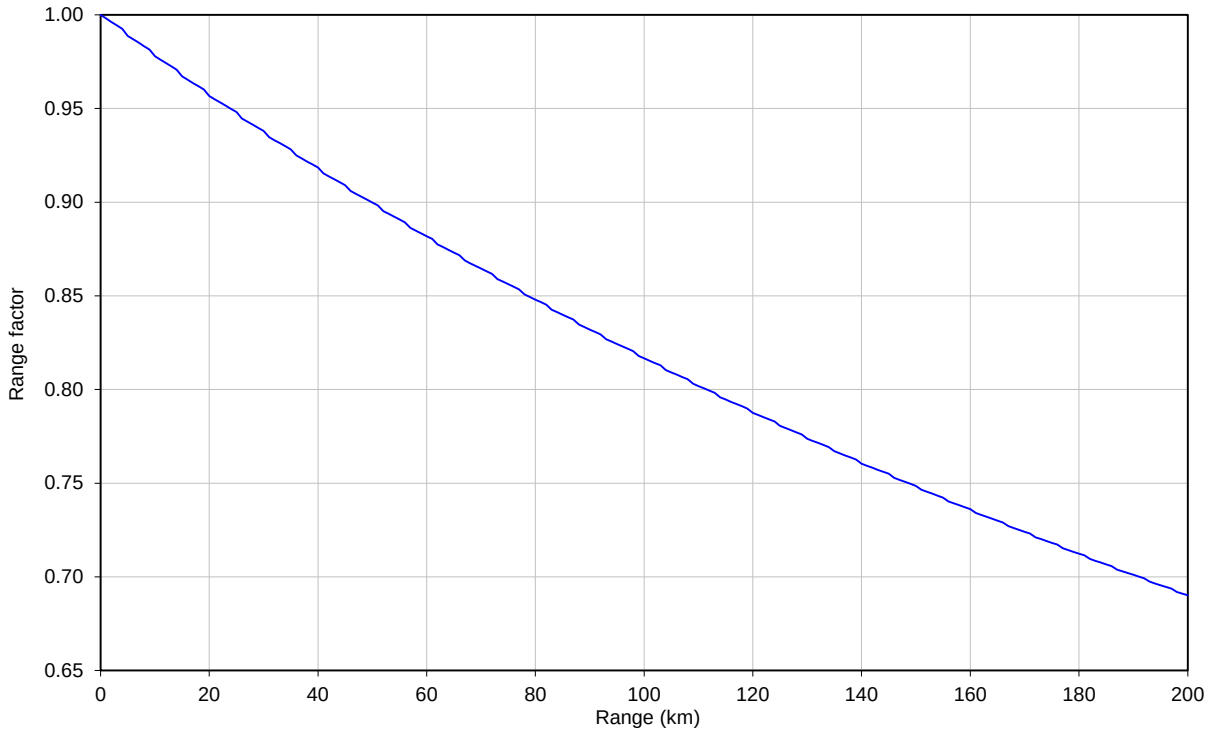


Figure 97 Range adjustment for PTP 700, symmetry 5:1, optimization IP, bandwidth 40 MHz

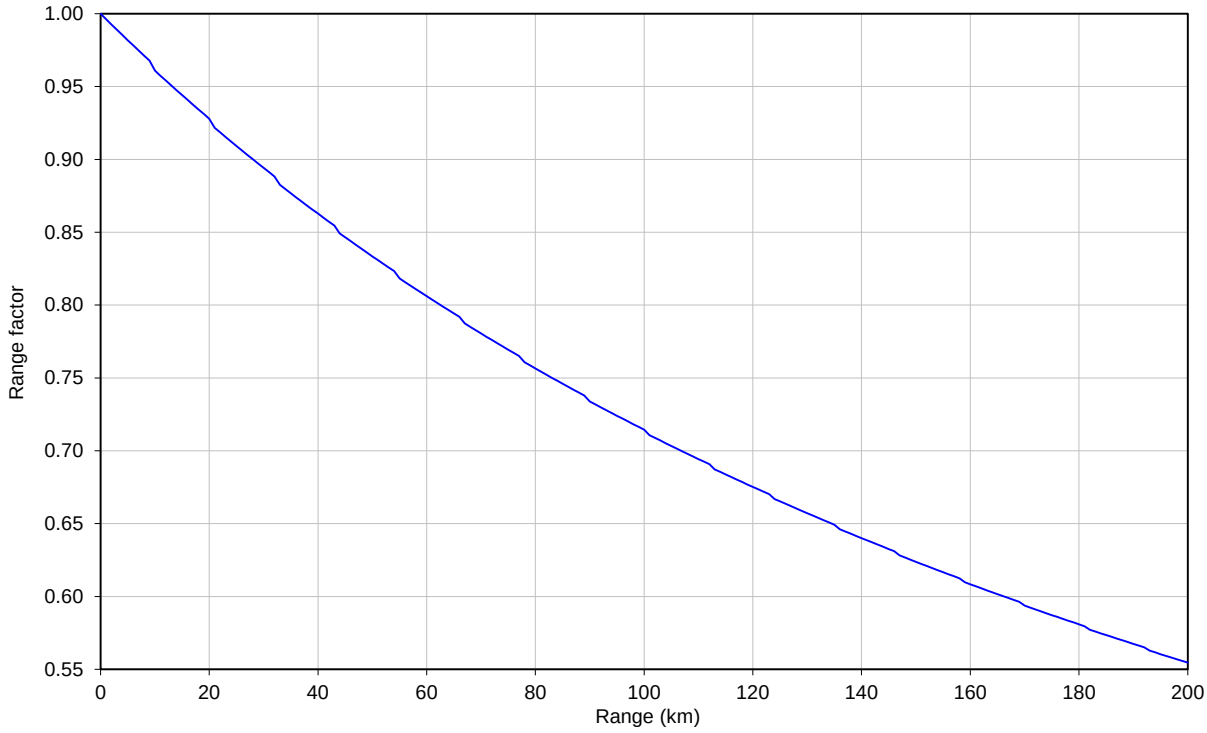


Figure 98 Range adjustment for PTP 700, symmetry 5:1, optimization IP, bandwidth 30 MHz

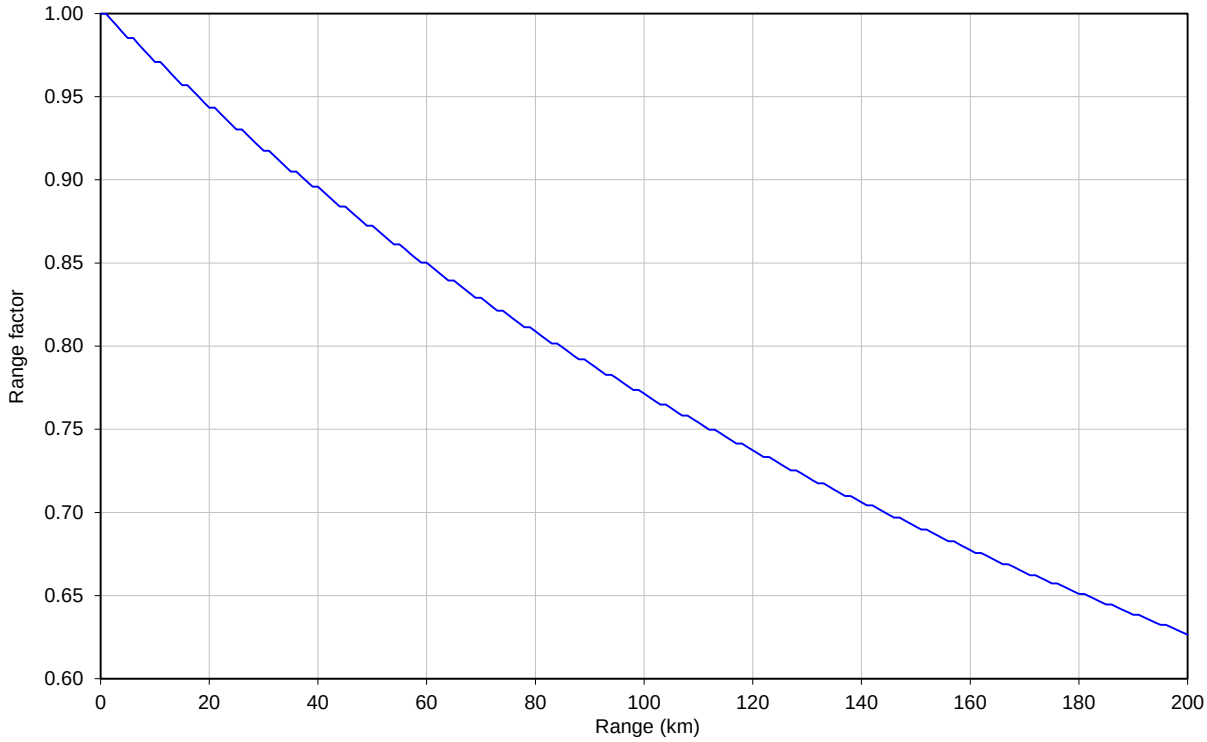


Figure 99 Range adjustment for PTP 700, adaptive, optimization IP, bandwidth 45 MHz

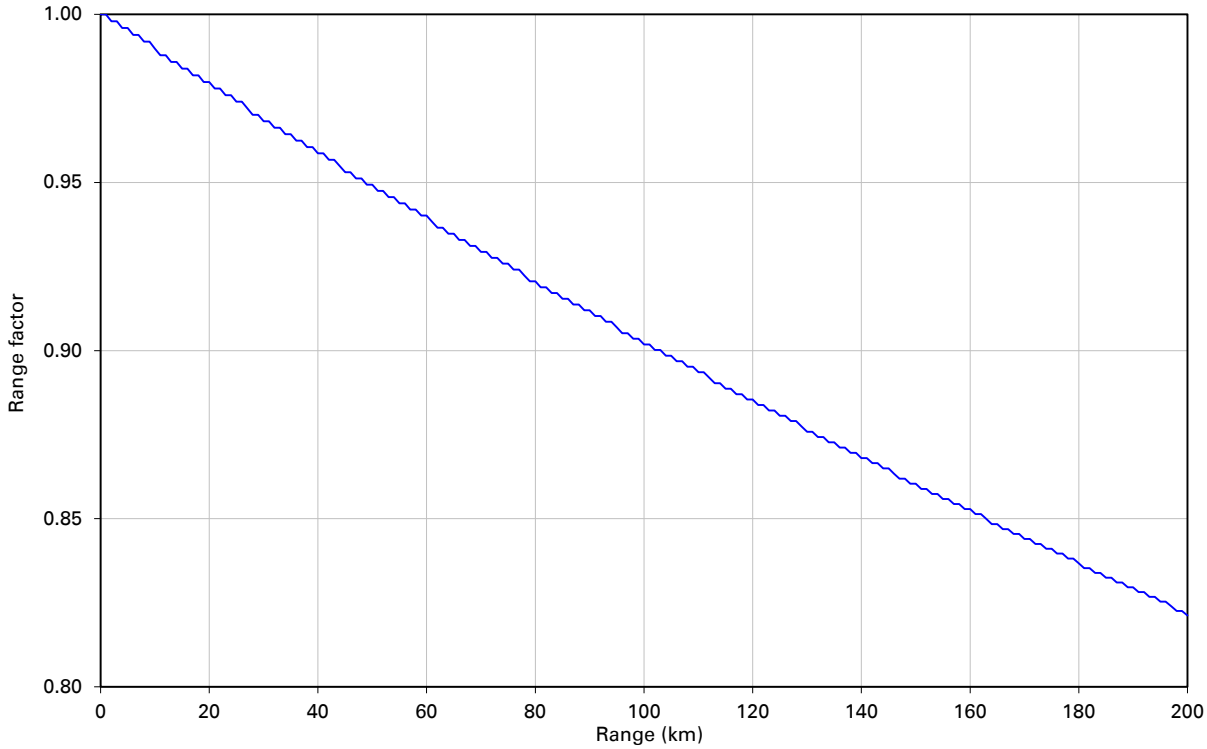


Figure 100 Range adjustment for PTP 700, adaptive, optimization IP, bandwidth 40 MHz

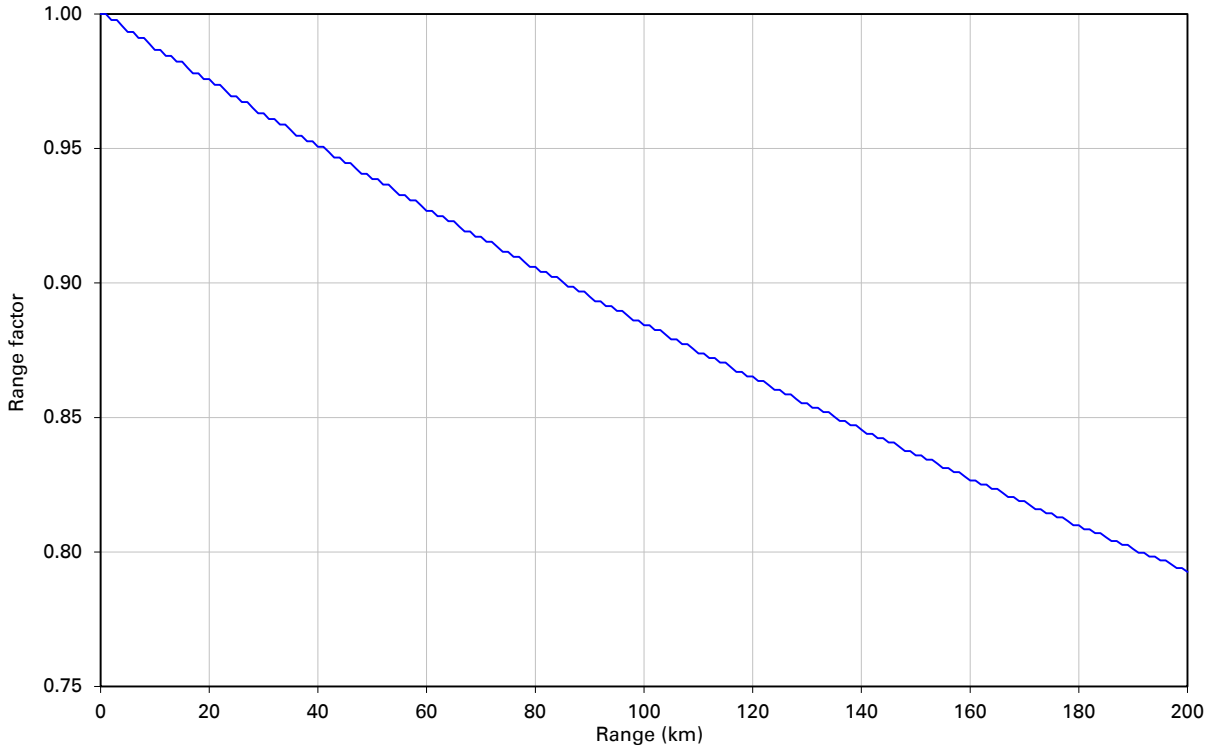


Figure 101 Range adjustment for PTP 700, adaptive, optimization IP, bandwidth 30 MHz

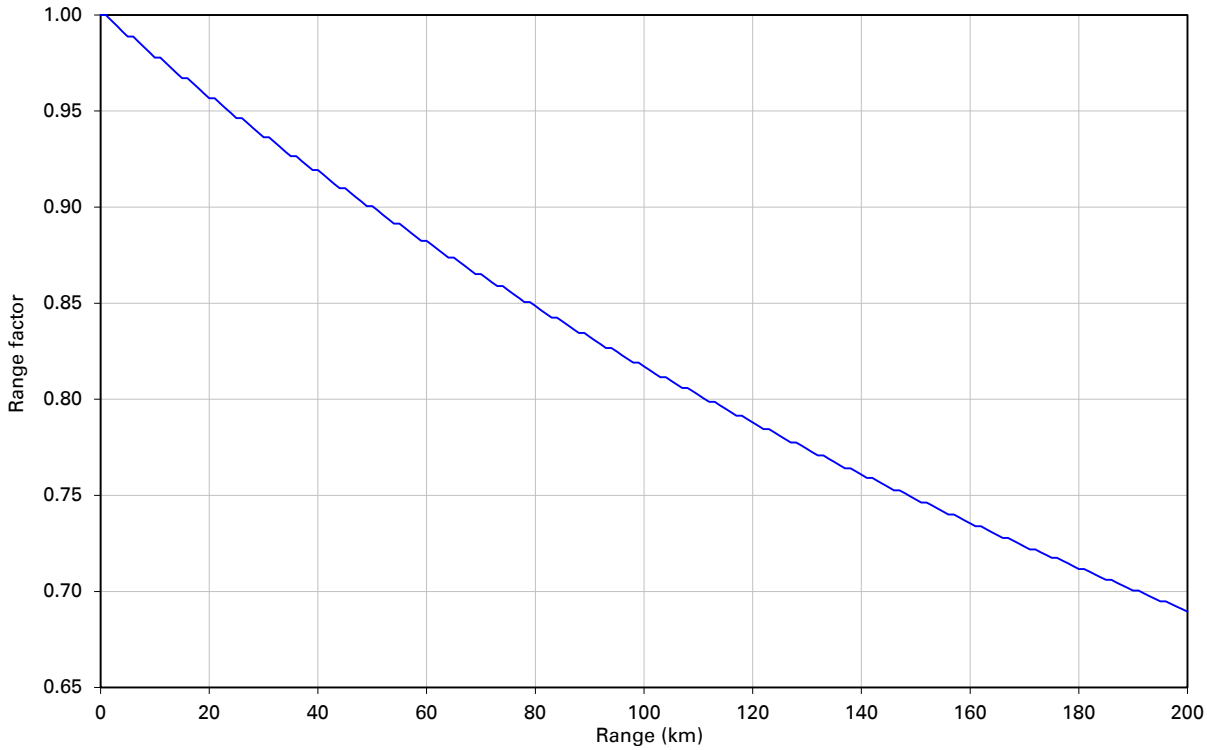


Figure 102 Range adjustment for PTP 700, adaptive, optimization IP, bandwidth 20 MHz

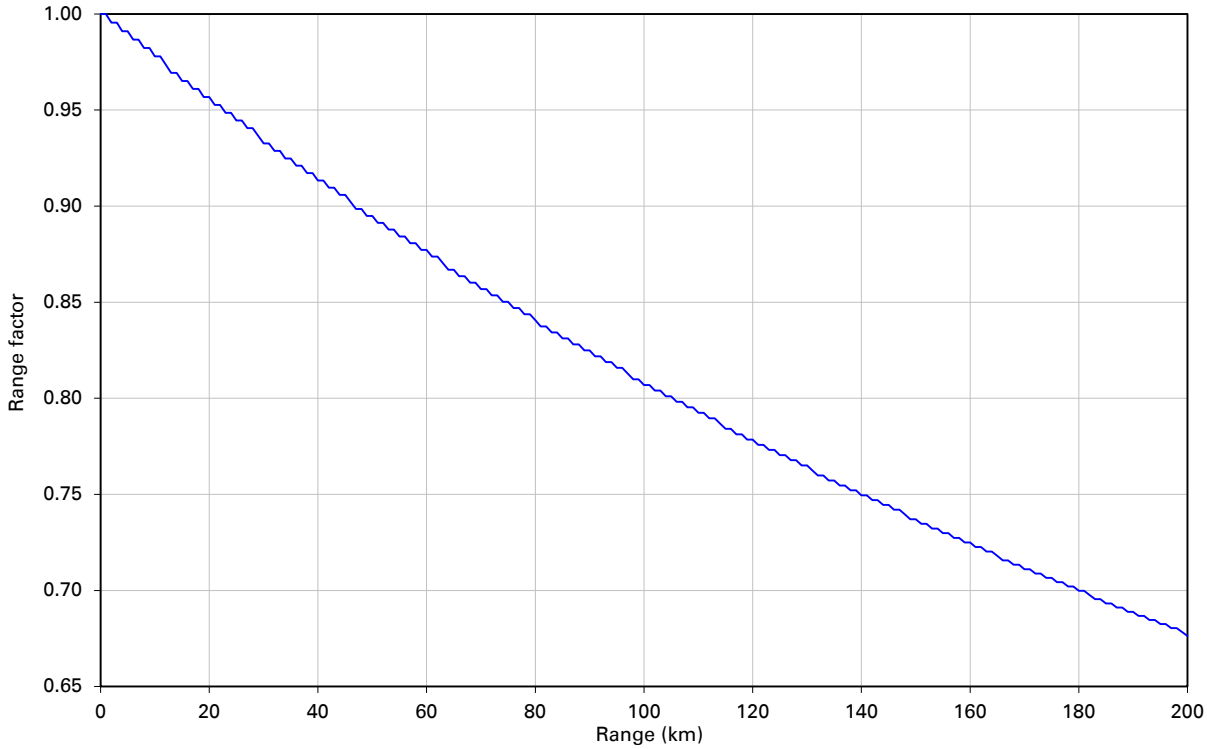


Figure 103 Range adjustment for PTP 700, adaptive, optimization IP, bandwidth 15 MHz

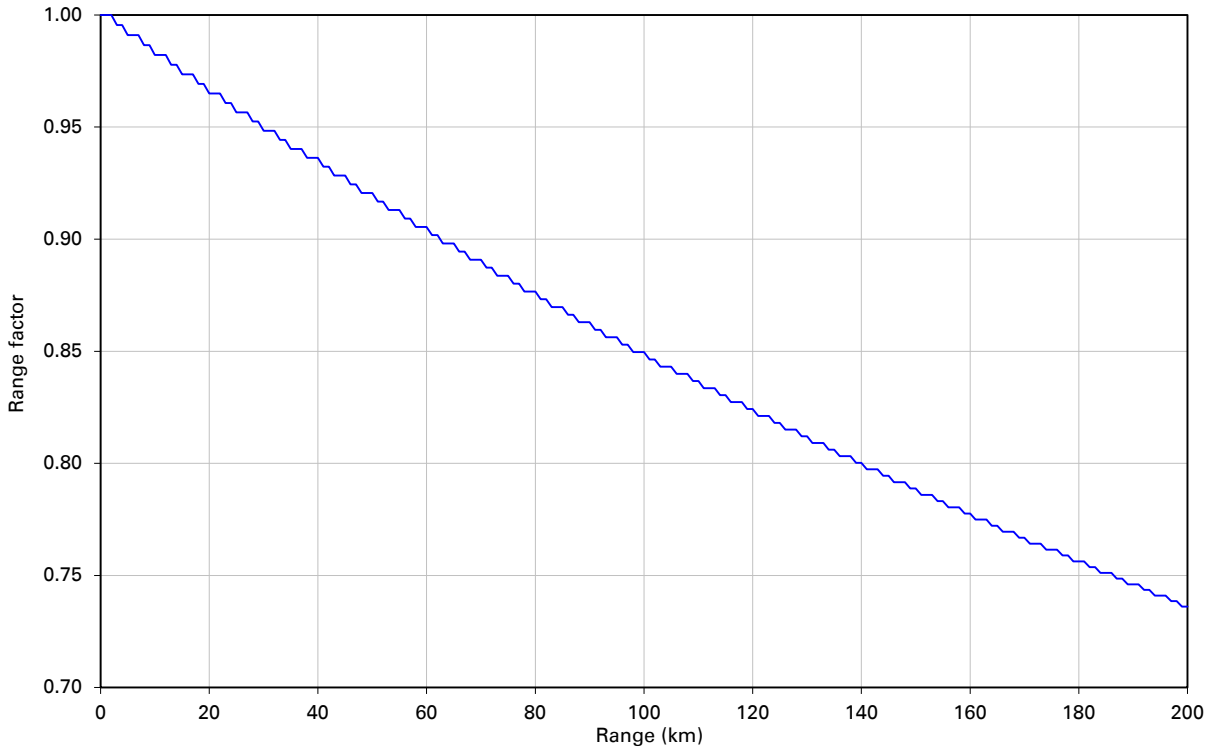
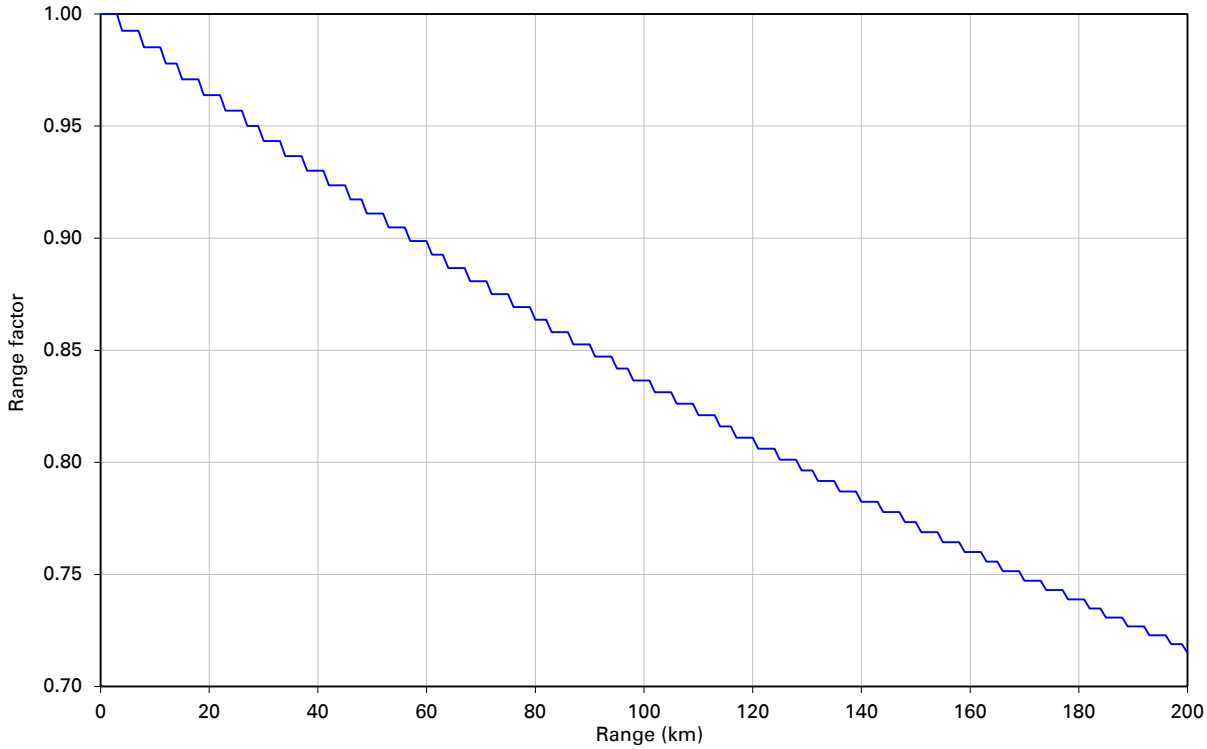


Figure 104 Range adjustment for PTP 700, adaptive, optimization IP, bandwidth 10 MHz



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 101.

Table 101 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 102.

Table 102 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

Chapter 4: Legal and regulatory information

This chapter provides end user license agreements and regulatory notifications.

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The following topics are described in this chapter:

- Cambium Networks end user license agreement on page 4-2 contains the Cambium and third party license agreements for the PTP 700 Series products.
- Compliance with safety standards on page 4-20 lists the safety specifications against which the PTP 700 has been tested and certified. It also describes how to keep RF exposure within safe limits.
- Compliance with radio regulations on page 4-25 describes how the PTP 700 complies with the radio regulations that are in force in various countries, and contains notifications made to regulatory bodies for the PTP 700.

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Julian Seward, jseward@bzip.org

USB library functions

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Compliance with safety standards

This section lists the safety specifications against which the PTP 700 has been tested and certified. It also describes how to keep RF exposure within safe limits.

Electrical safety compliance

The PTP 700 hardware has been tested for compliance to the electrical safety specifications listed in Table 103.

Table 103 PTP 700 safety compliance specifications

Region	Standard
USA	UL 60950-1, 2nd Edition; UL60950-22
Canada	CSA-C22.2 NO. 60950-1-07 (R2012) CSA-C22.2 NO. 60950-22-07 (R2012)
EU	EN 60950-1:2006 + Amendment 12:2011, EN 60950-22
	IEC 60950-1, IEC60950-22

Electromagnetic compatibility (EMC) compliance

The PTP 700 complies with European EMC Specification EN301 489-1 with testing carried out to the detailed requirements of EN301 489-17.

Note

For EN 61000-4-2: 1995 to 2009 Electro Static Discharge (ESD), Class 2, 8 kV air, 4 kV contact discharge, the PTP 700 has been tested to ensure immunity to 15 kV air and 8 kV contact.

Table 104 lists the EMC specification type approvals that have been granted for PTP 700 products.

Table 104 EMC compliance

Region	Specification (Type Approvals)
Europe	ETSI EN301 489-17

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 2013/35/EU of the European Parliament and of the Council of 26 June 2013* on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (electromagnetic fields) (20th individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC) and repealing Directive 2004/40/EC
- 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.
- 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 700 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 between 4400 MHz and 5875 MHz is **10 W/m^2**.

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:

$$S = \frac{PG}{4\pi d^2}$$

Where:

- S is the power density in W/m^2
- P is the average transmit power capability of the radio in W, equal to the configured maximum transmitter power as a linear number, multiplied by 0.8 to account for the worst case transmit/receive ratio
- G is the effective antenna gain, including cable losses, expressed as a linear number (not in dBi)
- d is the distance from the antenna

Rearranging terms to solve for distance yields:

$$d = \sqrt{\frac{PG}{4\pi S}}$$

Calculated distances

Table 105 shows calculated minimum separation distances each frequency band and for the highest gain antenna of each type, assuming that the equipment is operating at the maximum transmit power for PTP 700. 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 105 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. 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 105 Minimum safe distances for PTP 700 at maximum transmitter power

Antenna	P (W) (*1)	G (*2)	d (m) (*3)
Parabolic 6 ft (38.1 dBi)	0.635	5248.1	5.15
Parabolic 4 ft (35.3 dBi)	0.635	3388.4	3.73
Flat plate 2 ft (28.5 dBi)	0.635	575.4	1.71
Integrated (21.0 dBi)	0.635	125.9	0.80
Sectorized (17.0 dBi)	0.635	40.7	0.45
Omni (13.0 dBi)	0.635	16.2	0.29

(*1) P: maximum average transmit power capability of the radio (Watt)

capacité de puissance d'émission moyenne maximale de la radio (Watt)

(*2) G: total transmit gain as a factor, converted from dB, including 0.9 dB cable loss for connectorised antennas

gain total d'émission, converti à partir de la valeur en dB prenant en compte une perte de 0.9 dB correspondant aux câbles de connexion nécessaire pour les antennes externes

(*3) d: minimum distance from the antenna (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.

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.

Minimum separation distances for other transmitter powers and antenna gains

The minimum separation distances can be calculated for any transmit power or antenna gain using the formula provided in Calculation of power density on page 4-22.

In many deployments, the antenna gains will be lower than the maximum listed in Table 105 and the transmitter power will be reduced to comply with applicable regulations; in such cases, the minimum separation distances will be significantly reduced compared with the results in Table 105.

Minimum separation distances in FCC bands

The minimum separation distances for operation in FCC regulatory bands are listed in Table 106.

Table 106 Minimum safe distances for FCC bands

Band	Antenna	P (W) (*1)	G (*2)	d (m) (*3)
4.9 GHz	Parabolic 6 ft (37.2 dBi)	0.127	4265.8	2.07
	Flat Plate (28.0 dBi)	0.326	512.9	1.15
	Sectorized (17.0 dBi)	0.333	40.7	0.33
	Omni (13.0 dBi)	0.333	16.2	0.21
5.1 GHz	Parabolic 4 ft (34.5 dBi)	0.025	2290.9	0.61
	Flat Plate (28.5 dBi)	0.020	575.4	0.27
	Sectorized (17.0 dBi)	0.028	40.7	0.09
	Omni (13.0 dBi)	0.158	16.2	0.13
5.2 GHz	Parabolic 4 ft (34.5 dBi)	0.0002	2290.9	0.07
	Flat Plate (28.5 dBi)	0.0011	575.4	0.07
	Sectorized (17.0 dBi)	0.016	40.7	0.07
	Omni (13.0 dBi)	0.040	16.2	0.07
5.4 GHz	Parabolic 2 ft (28.5 dBi)	0.0011	575.4	0.07
	Flat Plate (28.5 dBi)	0.0009	707.9 (*4)	0.07
	Sectorized (17.0 dBi)	0.016	40.7	0.07
	Omni (13.0 dBi)	0.040	16.2	0.07
5.8 GHz	Parabolic 6 ft (38.1 dBi)	0.635	5248.1	5.15
	Parabolic 4 ft (35.3 dBi)	0.635	3388.4	3.73
	Flat Plate (28.5 dBi)	0.635	575.4	1.71
	Sectorized (17.0 dBi)	0.080	40.7	0.16
	Omni (13.0 dBi)	0.201	16.2	0.16

(*1) P: maximum average transmit power capability of the radio (Watt)

(*2) G: total transmit gain as a factor, converted from dB, including 0.9 dB cable loss for connectorised antennas

(*3) d: minimum distance from antenna (meters)

(*4) The antenna is supplied with fixed cables, and the cable loss is included in the effective antenna gain.

Compliance with radio regulations

This section describes how the PTP 700 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 107 to Table 111 list the radio specification type approvals that have been granted for PTP 700 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 107 Radio certifications (4.9 GHz)

Region	Regulatory approvals
USA	FCC 47 CFR Part 90
Canada	IC RSS-111, Issue 5

Table 108 Radio certifications (5.1 GHz)

Region	Regulatory approvals
USA	FCC 47 CFR Part 15E

Table 109 Radio certifications (5.2 GHz)

Region	Regulatory approvals
USA	FCC 47 CFR Part 15E
Canada	IC RSS-247 Issue 1

Table 110 Radio certifications (5.4 GHz)

Region	Regulatory approvals
USA	FCC 47 CFR Part 15E
Canada	IC RSS-247 Issue 1

Table 111 Radio certifications (5.8 GHz)

Region	Regulatory approvals
USA	FCC 47 CFR Part 15E
Canada	IC RSS-210 Issue 8, Annex 8

FCC compliance

The PTP 700 complies with the regulations that are in force in the USA.

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.

FCC product labels

FCC identifiers are reproduced on the product labels for the FCC regional variant (Figure 105 and Figure 106).

Figure 105 FCC certifications on Connectorized+Integrated ODU product labels

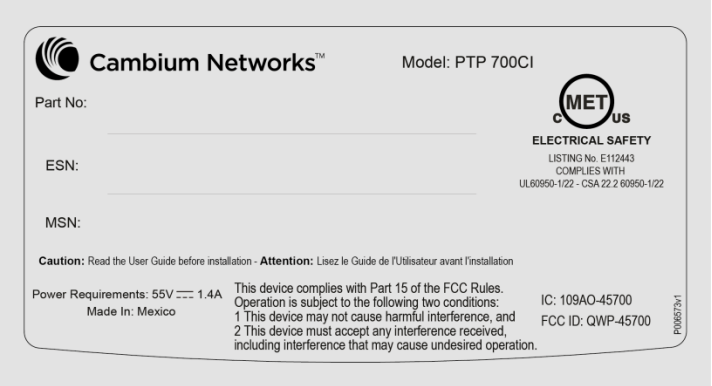
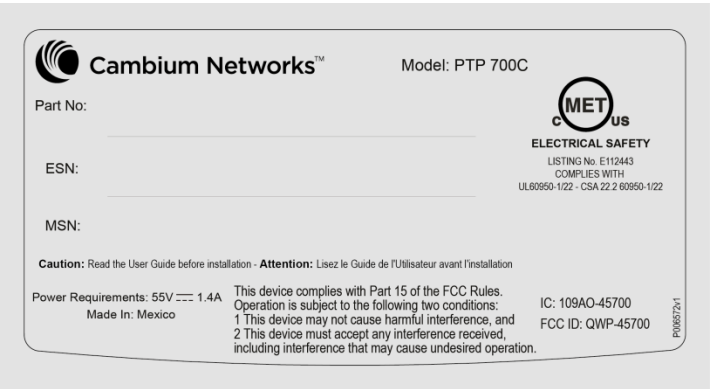


Figure 106 FCC certifications on Connectorized ODU product labels



4.9 GHz FCC notification

The system has been approved under FCC Part 90 for Public Safety Agency usage. The installer or operator is responsible for obtaining the appropriate site licenses before installing or using the system.

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 band edge channel power reduction

Transmitter power is restricted in edge channels when the PTP 700 is operated the 5.8 GHz band with the USA 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 market are locked for use in the USA 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 112.

Table 112 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 3-28.

For a list of antennas submitted to the FCC for use with the PTP 700 refer to FCC approved antennas on page 2-19.

IC compliance

The PTP 700 complies with the regulations that are in force in 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.

IC product labels

IC identifiers are reproduced on the product labels for the IC regional variant (Figure 107 and Figure 108).

Figure 107 IC certifications on Connectorized+Integrated ODU product labels

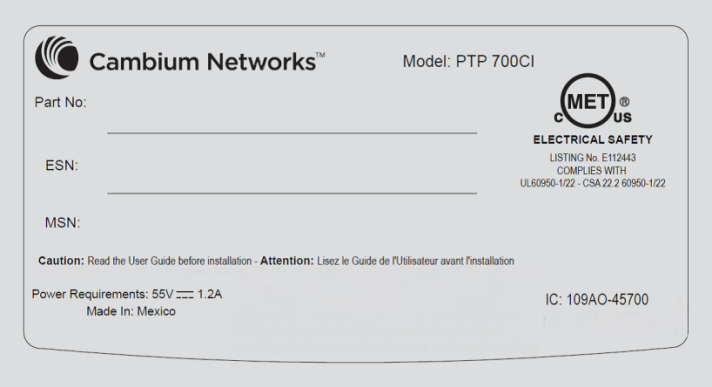
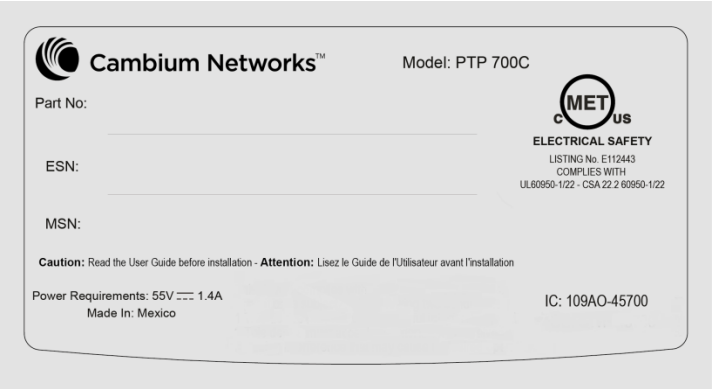


Figure 108 IC certifications on Connectorized ODU product labels



4.9 GHz IC notification

The system has been approved under 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 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.

5.2 GHz and 5.4 GHz IC notification

This device complies with Industry Canada RSS-247. 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. 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 IC

Cet appareil est conforme à Industrie Canada RSS-247. 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. 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 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.

5.4 GHz band edge channel power reduction

Equivalent isotropic radiated power (EIRP) is restricted in edge channels when the PTP 700 is operated the 5.4 GHz band with the 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 Canada market are locked for use in Canada and cannot be operated under the regulations for other regulatory domains.

The PTP 700 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 Canada 5.4 GHz band is listed in Table 113.

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 700 est configuré pour utiliser la band 5,4 GHz 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 700 destinées au Canada sont verouillés pour opérer exclusivement au Canada et ne peuvent pas être configurés pour adhérer à la réglementation d'autres pays.

Le PTP 700 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 le Canada est listée dans la Table 113.

Table 113 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

Channel Bandwidth	Channel Frequency	Maximum EIRP
	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 700 is operated the 5.8 GHz band with the 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 Canada market are locked for use in Canada and cannot be operated under the regulations for other regulatory domains.

The maximum transmitter power in band edge channels for the Canada 5.8 GHz band is listed in Table 112.

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 700 est configuré pour utiliser la band 5,8 GHz 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 700 destinés au Canada sont verouillés pour opérer exclusivement 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 le Canada est listée dans la Table 112.

Selection of antennas

For guidance on the selection of dedicated external antennas refer to Choosing external antennas on page 3-28.

For a list of antennas submitted to the IC for use with the PTP 700 refer to

IC approved antennas on page 2-27.

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.