

# **Cambium PTP 650 Series User Guide**

**System Release 650-01-00**



**Cambium Networks**

## **Accuracy**

While reasonable efforts have been made to assure the accuracy of this document, Cambium Networks assumes no liability resulting from any inaccuracies or omissions in this document, or from use of the information obtained herein. Cambium reserves the right to make changes to any products described herein to improve reliability, function, or design, and reserves the right to revise this document and to make changes from time to time in content hereof with no obligation to notify any person of revisions or changes. Cambium does not assume any liability arising out of the application or use of any product, software, or circuit described herein; neither does it convey license under its patent rights or the rights of others. It is possible that this publication may contain references to, or information about Cambium products (machines and programs), programming, or services that are not announced in your country. Such references or information must not be construed to mean that Cambium intends to announce such Cambium products, programming, or services in your country.

## **Copyrights**

This document, Cambium products, and 3<sup>rd</sup> Party software products described in this document may include or describe copyrighted Cambium and other 3<sup>rd</sup> Party supplied computer programs stored in semiconductor memories or other media. Laws in the United States and other countries preserve for Cambium, its licensors, and other 3<sup>rd</sup> Party supplied software certain exclusive rights for copyrighted material, including the exclusive right to copy, reproduce in any form, distribute and make derivative works of the copyrighted material. Accordingly, any copyrighted material of Cambium, its licensors, or the 3<sup>rd</sup> Party software supplied material contained in the Cambium products described in this document may not be copied, reproduced, reverse engineered, distributed, merged or modified in any manner without the express written permission of Cambium. Furthermore, the purchase of Cambium products shall not be deemed to grant either directly or by implication, estoppel, or otherwise, any license under the copyrights, patents or patent applications of Cambium or other 3<sup>rd</sup> Party supplied software, except for the normal non-exclusive, royalty free license to use that arises by operation of law in the sale of a product.

## **Restrictions**

Software and documentation are copyrighted materials. Making unauthorized copies is prohibited by law. No part of the software or documentation may be reproduced, transmitted, transcribed, stored in a retrieval system, or translated into any language or computer language, in any form or by any means, without prior written permission of Cambium.

## **License Agreements**

The software described in this document is the property of Cambium and its licensors. It is furnished by express license agreement only and may be used only in accordance with the terms of such an agreement.

## **High Risk Materials**

Cambium and its supplier(s) specifically disclaim any express or implied warranty of fitness for any high risk activities or uses of its products including, but not limited to, the operation of nuclear facilities, aircraft navigation or aircraft communication systems, air traffic control, life support, or weapons systems ("High Risk Use"). Any High Risk is unauthorized, is made at your own risk and you shall be responsible for any and all losses, damage or claims arising out of any High Risk Use.

© 2013 Cambium Networks Limited. All Rights Reserved.

---

# Contents

---

<b>About This User Guide</b> .....	<b>1</b>
Contacting Cambium Networks .....	1
Purpose .....	2
Cross references .....	2
Feedback .....	2
<b>Important regulatory information</b> .....	<b>3</b>
Radar avoidance .....	3
USA and Canada specific information .....	3
Renseignements spécifiques aux USA et au Canada .....	4
Specific expertise and training required for professional installers .....	4
Avoidance of weather radars .....	4
External antennas.....	5
Antennas externes .....	5
Ethernet networking skills .....	5
Lightning protection.....	5
Training .....	6
<b>Problems and warranty</b> .....	<b>7</b>
Reporting problems .....	7
Repair and service.....	7
Hardware warranty .....	7
<b>Security advice</b> .....	<b>8</b>
<b>Warnings, cautions, and notes</b> .....	<b>9</b>
Warnings.....	9
Cautions .....	9
Notes .....	9
<b>Caring for the environment</b> .....	<b>10</b>
In EU countries .....	10
In non-EU countries .....	10
<b>Chapter 1: Product description</b> .....	<b>1-1</b>
<b>Overview of the PTP 650</b> .....	<b>1-2</b>
Purpose .....	1-2

Key features .....	1-2
Frequency bands .....	1-3
Typical bridge deployment .....	1-4
Hardware overview .....	1-5
Wireless operation .....	1-6
Time division duplexing .....	1-6
Link mode optimization .....	1-8
Link symmetry .....	1-8
OFDM and channel bandwidth .....	1-9
Spectrum management .....	1-9
Adaptive modulation .....	1-10
MIMO .....	1-11
Dynamic spectrum optimization .....	1-12
Radar avoidance .....	1-12
Encryption .....	1-13
License keys and regulatory bands .....	1-13
PTP networks .....	1-14
Ethernet bridging .....	1-15
Ethernet ports .....	1-15
Customer data network .....	1-16
Network management .....	1-18
Ethernet loopback mode .....	1-21
Protocol model .....	1-21
System management .....	1-23
Management agent .....	1-23
IPv6 .....	1-24
Web server .....	1-25
RADIUS authentication .....	1-27
SNMP .....	1-28
Simple Network Time Protocol (SNTP) .....	1-28
SNMPv3 security .....	1-29
System logging (syslog) .....	1-32
AES license .....	1-32
Critical security parameters .....	1-33
Login information .....	1-33
Capability upgrades .....	1-33

Full capability trial period.....	1-34
Software upgrade.....	1-34
Recovery mode.....	1-34
<b>Chapter 2: System hardware.....</b>	<b>2-1</b>
Outdoor unit (ODU) .....	2-2
ODU description .....	2-2
ODU part numbers.....	2-3
ODU mounting brackets .....	2-5
ODU interfaces .....	2-7
ODU specifications.....	2-9
Power supply units (PSU).....	2-10
PSU description.....	2-10
PSU part numbers.....	2-11
AC Power Injector interfaces.....	2-11
AC+DC Enhanced Power Injector interfaces.....	2-12
PSU specifications.....	2-13
Antennas and antenna cabling .....	2-15
Antenna requirements .....	2-15
RF cable and connectors.....	2-15
Antenna accessories .....	2-16
FCC and IC approved antennas.....	2-16
Antennes approuvées par la FCC et IC.....	2-17
Ethernet cabling .....	2-28
Ethernet standards and cable lengths.....	2-28
Outdoor copper Cat5e Ethernet cable .....	2-29
Cable grounding kit.....	2-30
Lightning protection unit (LPU) and grounding kit .....	2-31
RJ45 connectors and spare glands.....	2-32
Cable hoisting grip .....	2-33
Drop cable tester .....	2-34
Indoor Cat5e cable .....	2-34
SFP module kits.....	2-35
Optical cable and connectors .....	2-37
<b>Chapter 3: System planning.....</b>	<b>3-1</b>
Typical deployment .....	3-2
ODU with POE interface to PSU.....	3-2

SFP and Aux Ethernet interfaces .....	3-5
Site planning.....	3-8
Grounding and lightning protection.....	3-8
Lightning protection zones.....	3-8
Site grounding system.....	3-10
ODU and external antenna location .....	3-10
ODU wind loading.....	3-11
PSU DC power supply.....	3-12
PSU location .....	3-12
Drop cable grounding points .....	3-13
LPU location.....	3-13
Multiple LPUs .....	3-14
Radio spectrum planning .....	3-16
General wireless specifications .....	3-16
Regulatory limits .....	3-17
Conforming to the limits.....	3-17
Available spectrum .....	3-18
Channel bandwidth .....	3-18
Frequency selection .....	3-19
Avoidance of weather radars (USA only) .....	3-20
Link planning .....	3-21
PTP LINKPlanner .....	3-21
Range and obstacles .....	3-21
Path loss.....	3-22
Adaptive modulation .....	3-22
Calculating data rate capacity .....	3-23
Planning for connectorized units.....	3-25
When to install connectorized units .....	3-25
Choosing external antennas .....	3-25
Calculating RF cable length (5.8 GHz FCC only) .....	3-26
Data network planning .....	3-27
Ethernet interfaces .....	3-27
Layer 2 control protocols.....	3-27
Ethernet port allocation .....	3-28
VLAN membership.....	3-28
Priority for management traffic .....	3-28

IP interface .....	3-29
Quality of service for bridged Ethernet traffic .....	3-29
“Daisy-chaining” PTP 650 links .....	3-30
Green Ethernet switches.....	3-30
Network management planning.....	3-31
Planning for SNMP operation .....	3-31
Supported diagnostic alarms.....	3-32
Enabling SNMP .....	3-32
Security planning.....	3-33
Planning for Sntp operation .....	3-33
Planning for HTTPS/TLS operation.....	3-33
Planning for SNMPv3 operation .....	3-35
Planning for RADIUS operation .....	3-39
System threshold, output power and link loss.....	3-41
Data throughput capacity tables.....	3-49
<b>Chapter 4: Legal and regulatory information .....</b>	<b>4-1</b>
Cambium Networks end user license agreement.....	4-2
Acceptance of this agreement .....	4-2
Definitions.....	4-2
Grant of license .....	4-2
Conditions of use .....	4-3
Title and restrictions .....	4-4
Confidentiality .....	4-4
Right to use Cambium’s name.....	4-5
Transfer .....	4-5
Updates .....	4-5
Maintenance .....	4-5
Disclaimer .....	4-6
Limitation of liability .....	4-6
U.S. government .....	4-6
Term of license .....	4-7
Governing law .....	4-7
Assignment.....	4-7
Survival of provisions .....	4-7
Entire agreement.....	4-7
Third party software.....	4-7

Compliance with safety standards .....	4-23
Electrical safety compliance .....	4-23
Electromagnetic compatibility (EMC) compliance .....	4-23
Human exposure to radio frequency energy .....	4-24
Compliance with radio regulations .....	4-28
Type approvals .....	4-29
FCC/IC compliance .....	4-30
European Union compliance .....	4-37
<b>Chapter 5: Installation .....</b>	<b>5-1</b>
Safety .....	5-2
Power lines .....	5-2
Working at heights .....	5-2
PSU .....	5-2
Grounding and protective earth .....	5-2
DC supply .....	5-3
Powering down before servicing .....	5-3
Primary disconnect device .....	5-3
External cables .....	5-3
Drop cable tester .....	5-3
RF exposure near the antenna .....	5-3
Minimum separation distances .....	5-4
Grounding and lightning protection requirements .....	5-4
Grounding cable installation methods .....	5-4
Siting ODU and antennas .....	5-4
Installing the ODU and top LPU .....	5-5
Decide how to mount the ODU and top LPU .....	5-5
Prepare ODU for mounting .....	5-6
Integrated ODU .....	5-7
Connectorized ODU .....	5-9
Ground the ODU and top LPU .....	5-10
Install external antennas for a connectorized ODU .....	5-11
Installing the copper Cat5e Ethernet interface .....	5-13
Install the ODU to top LPU drop cable .....	5-13
Install the main drop cable .....	5-15
Install the bottom LPU to PSU drop cable .....	5-18
Test resistance in the drop cable .....	5-20



Installing the PSU.....	5-21
Installing the AC Power Injector .....	5-21
Installing the AC+DC Enhanced Power Injector .....	5-22
Installing an SFP Ethernet interface .....	5-23
Fitting the long cable gland.....	5-25
Inserting the SFP module .....	5-26
Connecting the cable .....	5-29
Fitting the gland .....	5-30
Removing the cable and SFP module .....	5-31
Installing an Aux Ethernet interface .....	5-32
Supplemental installation information .....	5-33
Stripping drop cable .....	5-33
Creating a drop cable grounding point.....	5-34
Weatherproofing an N type connector.....	5-37
Replacing PSU fuses.....	5-40
<b>Chapter 6: Configuration and alignment .....</b>	<b>6-1</b>
Preparing for configuration and alignment.....	6-2
Safety precautions .....	6-2
Regulatory compliance .....	6-2
Selecting configuration options.....	6-3
Generating a License Key.....	6-3
Connecting to the unit .....	6-5
Configuring the management PC .....	6-5
Connecting to the PC and powering up .....	6-6
Using the web interface.....	6-7
Logging into the web interface .....	6-7
Using the menu options .....	6-8
Installation menu .....	6-10
Starting the Installation Wizard .....	6-10
Disarm Installation page.....	6-11
Current Installation Summary page .....	6-11
Software License Key page .....	6-12
Interface Configuration page .....	6-14
Wireless Configuration page.....	6-15
Confirm Installation Configuration page.....	6-20
System menu.....	6-21

System Configuration page .....	6-21
LAN Configuration page .....	6-24
QoS Configuration page .....	6-30
SFP Configuration page .....	6-33
Save and Restore Configuration page .....	6-34
Software Upgrade page .....	6-37
Management menu .....	6-39
Web-Based Management page .....	6-39
Local User Accounts page .....	6-42
RADIUS Configuration page .....	6-47
Webpage Properties page .....	6-49
Email Configuration page .....	6-52
Diagnostic Alarms page .....	6-54
Time Configuration page .....	6-55
Syslog Configuration page .....	6-59
SNMP pages (for SNMPv3) .....	6-61
Current SNMP Summary (for SNMPv3) .....	6-61
Step 1: SNMP Configuration (for SNMPv3) .....	6-62
Step 2: SNMP MIB-II System Objects (for SNMPv3) .....	6-64
Step 3: SNMP User Policy Configuration (for SNMPv3) .....	6-65
Step 4: SNMP User Accounts Configuration (for SNMPv3) .....	6-67
Step 5: SNMP Trap Configuration (for SNMPv3) .....	6-69
Confirm SNMP Configuration (for SNMPv3) .....	6-70
SNMP pages (for SNMPv1/2c) .....	6-71
Current SNMP Summary (for SNMPv1/2c) .....	6-71
Step 1: SNMP Configuration (for SNMPv1/2c) .....	6-71
Step 2: SNMP MIB-II System Objects (for SNMPv1/2c) .....	6-72
Step 3: SNMP Trap Configuration (for SNMPv1/2c) .....	6-73
Confirm SNMP Configuration (for SNMPv1/2c) .....	6-74
Security menu .....	6-75
Preparing for HTTPS/TLS .....	6-75
Security Configuration Wizard page .....	6-76
Step 1: Enter Key of Keys .....	6-77
Step 2: Enter TLS Private Key and Public Certificate .....	6-78
Step 3: Enter User Security Banner .....	6-79
Step 4: Enter Login Information Settings .....	6-80

Step 5: Enter Random Number Entropy Input .....	6-81
Step 6: Enter Wireless Link Encryption Key .....	6-82
Step 7: Enter HTTP and Telnet Settings .....	6-83
Step 8: Commit Security Configuration .....	6-85
Zeroize CSPs page.....	6-86
Aligning antennas .....	6-87
Starting up the units .....	6-87
Checking that the units are armed.....	6-87
Aligning antennas .....	6-88
Aligning separate antennas for spatial diversity.....	6-89
ODU installation tones.....	6-90
Graphical Install page .....	6-92
Disarming the units.....	6-93
Comparing actual to predicted performance .....	6-94
Other configuration tasks .....	6-95
Connecting to the network.....	6-95
Upgrading software using TFTP .....	6-96
<b>Chapter 7: Operation .....</b>	<b>7-1</b>
System summary and status .....	7-2
System Summary page .....	7-2
System Status page .....	7-3
Rebooting and logging out .....	7-9
Login Information page .....	7-9
Reboot Wireless Unit page.....	7-9
Change Password page .....	7-10
Logging out.....	7-11
Alarms, alerts and messages.....	7-12
Alarms .....	7-12
Email alerts .....	7-15
Syslog page .....	7-16
Format of syslog server messages.....	7-17
Configuration and status messages .....	7-17
Event messages.....	7-18
Spectrum management.....	7-20
Spectrum Management page .....	7-20
Interpreting the spectrum management plots .....	7-23

Viewing the active channel history.....	7-29
Viewing historic spectrum management metrics .....	7-30
Barring channels .....	7-31
System statistics .....	7-32
System Statistics page.....	7-32
Wireless Port Counters page.....	7-37
Main Port Counters page.....	7-38
Aux Port Counters page.....	7-40
SFP Port Counters page.....	7-41
Diagnostics Plotter page.....	7-42
Generate Downloadable Diagnostics page.....	7-43
Recovery mode .....	7-44
Entering recovery mode .....	7-44
Upgrading software image.....	7-46
Resetting IP & Ethernet configuration .....	7-47
Erasing configuration.....	7-48
Zeroize Critical Security Parameters page .....	7-50
Rebooting the unit.....	7-51
<b>Chapter 8: Troubleshooting .....</b>	<b>8-1</b>
Testing link end hardware.....	8-2
AC Power Injector LED sequence .....	8-2
AC+DC Enhanced power injector LED sequence .....	8-2
Ethernet packet test.....	8-6
Testing the radio link .....	8-9
No activity .....	8-9
Some activity .....	8-9
Radio and television interference .....	8-10
<b>Glossary .....</b>	<b>I</b>

---

# About This User Guide

---

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

For radio network design, refer to the following chapters:

- [Chapter 1: Product description](#)
- [Chapter 2: System hardware](#)
- [Chapter 3: System planning](#)
- [Chapter 4: Legal and regulatory information](#)

For radio equipment installation, refer to the following chapter:

- [Chapter 5: Installation](#)

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

- [Chapter 6: Configuration and alignment](#)
- [Chapter 7: Operation](#)
- [Chapter 8: Troubleshooting](#)

## Contacting Cambium Networks

Support website:	<a href="http://www.cambiumnetworks.com/support">http://www.cambiumnetworks.com/support</a>
Main website:	<a href="http://www.cambiumnetworks.com">http://www.cambiumnetworks.com</a>
Sales enquiries:	<a href="mailto:solutions@cambiumnetworks.com">solutions@cambiumnetworks.com</a>
Support enquiries:	<a href="mailto:support@cambiumnetworks.com">support@cambiumnetworks.com</a>
Telephone number list:	<a href="http://www.cambiumnetworks.com/contact">http://www.cambiumnetworks.com/contact</a>
Address:	Cambium Networks Limited, Linhay Business Park, Eastern Road, Ashburton, Devon, UK, TQ13 7UP

## 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](mailto:support@cambiumnetworks.com).

## Important regulatory information

---

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

### Radar avoidance

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

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

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

Contact the Cambium helpdesk if more guidance is required.

### USA and Canada specific information

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

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

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

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



#### Note

To ensure compliance with FCC rules (KDB 443999: Interim Plans to Approve UNII Devices Operating in the 5470 - 5725 MHz Band with Radar Detection and DFS Capabilities), follow [Avoidance of weather radars \(USA only\)](#) on page [3-20](#).

---

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

## Renseignements spécifiques aux USA et au Canada

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

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

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

## Specific expertise and training required for professional installers

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

## Avoidance of weather radars

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

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



## External antennas

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

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

## Antennas externes

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

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

## Ethernet networking skills

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

## Lightning protection

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

## Training

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

# Problems and warranty

---

## Reporting problems

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

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

## Repair and service

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

## Hardware warranty

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

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



### Caution

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

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

---

## Security advice

---

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

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

# Warnings, cautions, and notes

---

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

## Warnings

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

**Warning**

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

---

## Cautions

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

**Caution**

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

---

## Notes

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

**Note**

Note text.

---

# Caring for the environment

---

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

## In EU countries

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



## Disposal of Cambium equipment

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

Do not dispose of Cambium equipment in landfill sites. For disposal instructions, refer to <http://www.cambiumnetworks.com/support>

## 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 the PTP 650 product. It describes in general terms the function of the product, the main product variants and the main hardware components. The following topics are described in this chapter:

- [Overview of the PTP 650](#) on page 1-2 introduces the key features, typical uses, product variants and components of the PTP 650.
- [Wireless operation](#) on page 1-6 describes how the PTP 650 wireless link is operated, including modulation modes, power control and spectrum management.
- [Ethernet bridging](#) on page 1-15 describes how the PTP 650 controls Ethernet data, in both the customer data and system management networks.
- [System management](#) on page 1-23 introduces the PTP 650 management system, including the web interface, installation, configuration, security, alerts and upgrades.



# Overview of the PTP 650

---

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

## Purpose

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

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

## Key features

The PTP 650 is a high performance wireless bridge for Ethernet traffic with a maximum throughput of 450 Mbps. It is capable of operating in line-of-sight (LOS), near-LOS and non-LOS propagation condition. Its maximum LOS range is 200 km.

The PTP 650 operates in unlicensed and lightly-licensed frequency bands between 4.9 and 6.0 GHz. It has a very high spectral efficiency of 10 bps/Hz and supports a channel bandwidth of up to 45 MHz. The integrated ODU has its own flat plate antenna. The connectorized ODU is designed for use with an external antenna.

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

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

PTP 650 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 management).

[Table 1](#) gives a summary of the main PTP 650 characteristics.



**Table 1** Main characteristics of the PTP 650 Series

Characteristic	Value
Topology	PTP
Wireless link condition	LOS, near LOS or non-LOS
Range	Up to 200 km
Duplexing	TDD (symmetric and asymmetric)
Connectivity	Ethernet
Operating frequencies	4.9 to 6.0 GHz
Channel bandwidth	5, 10, 15, 20, 30, 40 or 45 MHz
High spectral efficiency	Up to 10 bps/Hz
Data rate	Up to 450 Mbps (45 MHz channel BW)

## Frequency bands

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

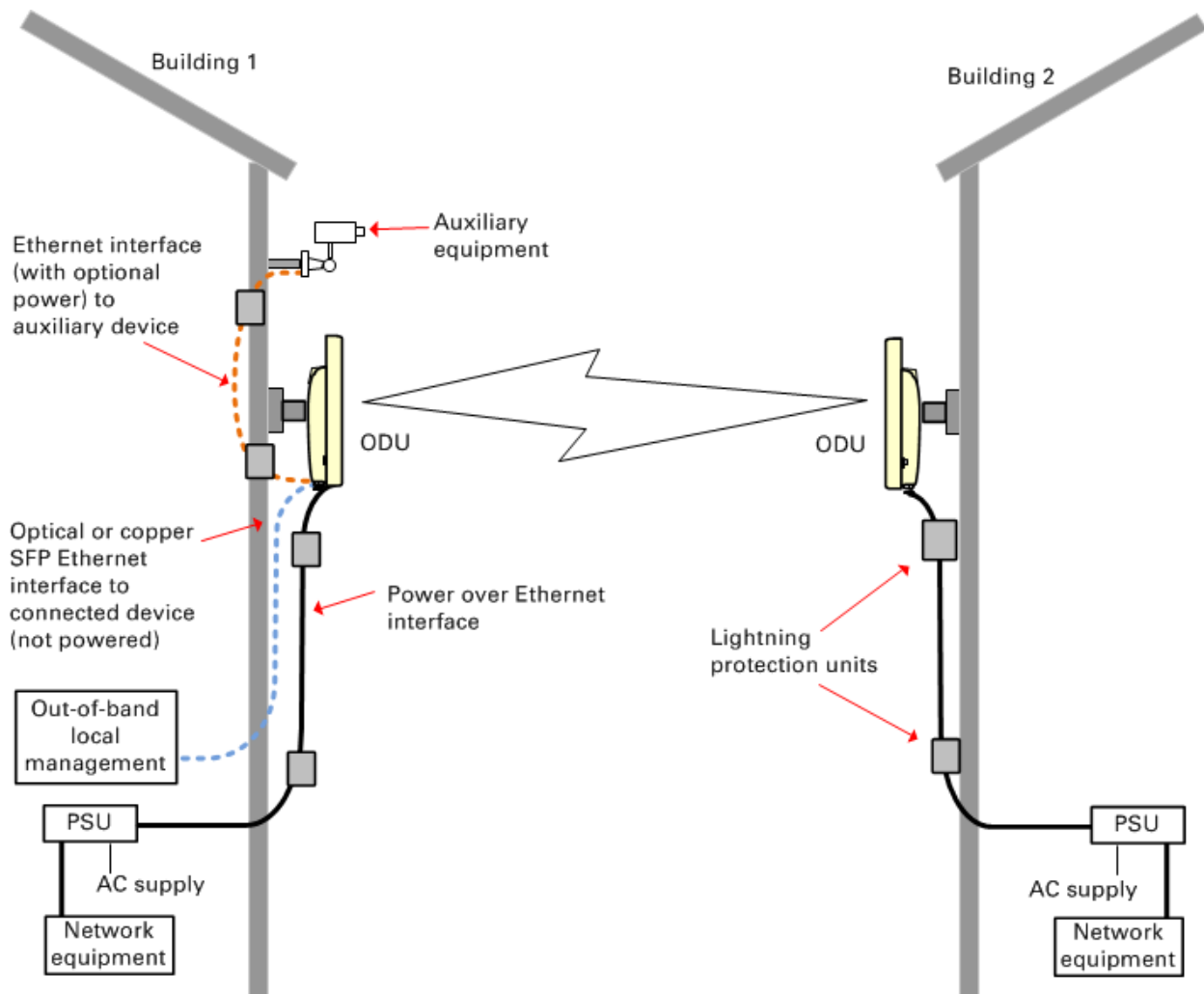
- 4940 to 4990 MHz
- 5150 to 5250 MHz
- 5250 to 5350 MHz
- 5470 to 5725 MHz
- 5725 to 5875 MHz

## Typical bridge deployment

The PTP 650 is an “all outdoor” solution consisting of a wireless bridge between two sites. Each site installation consists of an integrated or connectorized outdoor unit (ODU) and a power injector (PSU) (Figure 1). The ODU provides the following interfaces:

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

**Figure 1** PTP 650 typical bridge deployment



## Hardware overview

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

- **Outdoor unit (ODU):** The ODU is a self-contained transceiver unit that houses both radio and networking electronics. The ODU is supplied in the following product variants:
  - **Integrated or Connectorized:** The ODU may be either Integrated (attached to its own flat plate antenna) or connectorized (without an antenna).
  - **FCC/IC, EU or RoW:** These variants are for deployment in the USA and Canada, the EU and the rest of the world respectively.
- **Power supply unit (PSU):** There is a choice of two PSUs:
  - The AC Power Injector is suitable for installations without an auxiliary device.
  - The AC+DC power injector is required when powering from a DC supply or when the PSU is needed to operate at extreme temperatures.
- **Antennas and antenna cabling:** Connectorized ODUs require external antennas connected using RF cable.
- **Ethernet cabling:** All configurations require a copper Ethernet Cat5e connection from the ODU (PSU port) to the PSU. Advanced configurations may also require one or both of the following:
  - A copper or optical Ethernet connection from the ODU (SFP port) to network terminating equipment or another device.
  - A copper Ethernet Cat5e connection from the ODU (Aux port) to an auxiliary device.
- **Lightning protection unit (LPU):** LPUs are installed in the PSU and Aux copper drop cables to provide transient voltage surge suppression.
- **Ground cables:** ODU, LPUs and outdoor copper Ethernet cables are bonded to the site grounding system using ground cables.

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

# Wireless operation

---

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

## Time division duplexing

### TDD cycle

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

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

### TDD frame parameters

The TDD burst duration varies depending on the following:

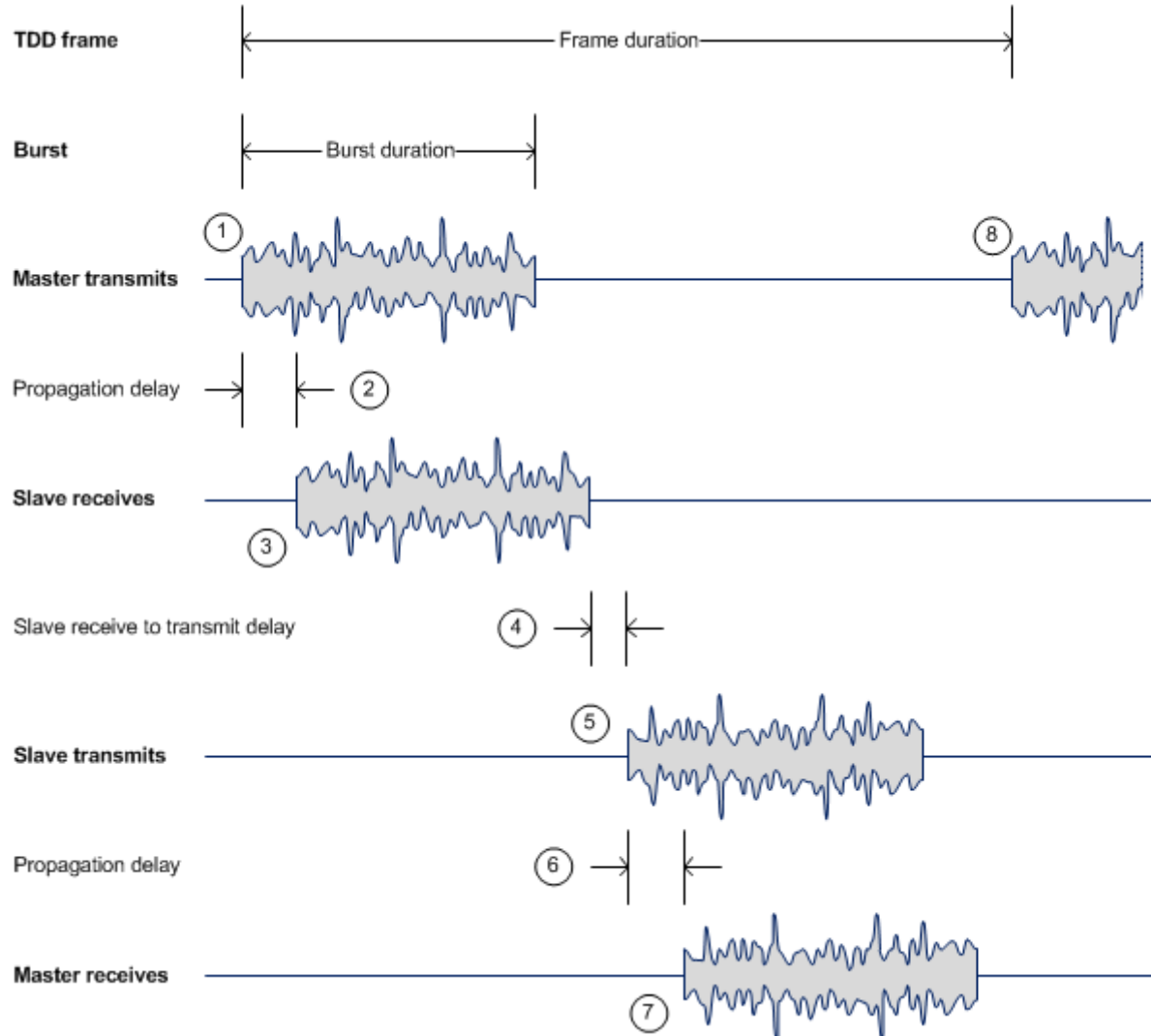
- Channel bandwidth
- Link range
- Link optimization mode
- Link symmetry
- Offered traffic loading.

The TDD frame duration varies depending on the following:

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

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

**Figure 2** TDD cycle



## Channel selection

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

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

## Link mode optimization

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

### IP traffic

IP Traffic mode is optimized to provide the maximum possible link capacity. IP Traffic mode is an appropriate choice where applications in the bridged networks provide some measure of reliable transmission, and where very low latency is not critical. IP mode supports both fixed and adaptive link symmetry (see [Link symmetry](#) on page 1-8).

### 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).

## Link symmetry

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

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

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).
- In regions where radar avoidance is operational (see [Radar avoidance](#) on page 1-12).
- When the ODU is not a Full variant.

## OFDM and channel bandwidth

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

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

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



### Note

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

---

## Spectrum management

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

### Spectrum management measurements

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

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

## Measurement analysis

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

## Statistical summary

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

## Spectrum management in fixed frequency mode

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

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

## Adaptive modulation

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

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



**Note**

PTP 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.

---

## MIMO

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

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

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

Lower order modulations (BPSK 0.63 up to QPSK 0.87) only operate in single payload mode. Higher order modulations (16QAM 0.63 to 256QAM 0.81) are available in single payload mode and dual payload mode. The switching between modes is automatically controlled by the adaptive modulation feature described in [Adaptive modulation](#) on page 1-10.

**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.

---

## Dynamic spectrum optimization

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

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

## Radar avoidance

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

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

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

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

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

**Note**

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

---

## Encryption

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

## License keys and regulatory bands

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

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

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

**Caution**

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

---

**Attention**

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

---

## PTP networks

### Using Dynamic Spectrum Optimization

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

### Using frequency planning

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

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

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

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

For help with planning networks, refer to [Chapter 3: System planning](#), or contact your Cambium distributor or re-seller.

# Ethernet bridging

---

This section describes how the PTP 650 processes Ethernet data, in both the customer and system management networks.

## Ethernet ports

The PTP 650 Series ODU has three Ethernet ports:

- **Main PSU:** The Main PSU port provides a copper Ethernet interface for 100BASE-TX and 1000BASE-T, and accepts power from the AC+DC Enhanced Power Injector or the AC Power Injector to the ODU using a proprietary power over Ethernet (PoE) method.
- **Aux:** The Aux port provides a copper Ethernet interface for 100BASE-TX and 1000BASE-T, and supplies power from the ODU to external equipment using standards-based power over Ethernet (PoE) complying with IEEE 802.3at.
- **SFP:** The SFP port is a small format pluggable receptacle accepting copper or optical plug-in modules supplied as part of the [SFP module kits](#) on page 2-35.

Each of the three Ethernet ports can be allocated for customer data or network management in the following ways:

- **Disabled:** The port is not in use for customer data or network management.
- **Data Only:** The port is connected to the customer data network only.
- **Data and In-Band Management:** The port is connected to the customer data network and to the management agent of the local ODU
- **Out-of-Band Local Management:** The port is connected directly to the management agent of the local ODU.

Port allocation is subject to the following rules:

- One port should be allocated to Data Only or Data and In-Band Management
- The remaining ports should be allocated to Disabled or Out-of-Band Local Management

Further examples of port allocation are provided in [Chapter 3: System planning](#).



### Note

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

---

## Customer data network

### Transparent Ethernet service

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

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

**Note**

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 PTP 650 Series is transparent to layer two control protocols (L2CP) including:

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

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

## Quality of service for bridged Ethernet traffic

The PTP 650 Series supports eight traffic queues 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, or the Traffic Class in an MPLS header.

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

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

## Fragmentation

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

## Wireless link down alert

The PTP 650 Series provides an optional indication of failure of the wireless link by means of a brief disconnection of the copper data port or the 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 Ethernet Modulation Mode

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

## Network management

### IPv4 and IPv6 interfaces

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

### MAC address

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

### VLAN membership

The management agent can be configured to transmit and receive either untagged, priority-tagged, C-tagged (IEEE 802.1Q) or S-tagged (IEEE 802.1ad) frames. 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 DHCP 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 either Data and In-Band Management or Out-of-Band Local Management.

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 Data and In-Band Management.

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.

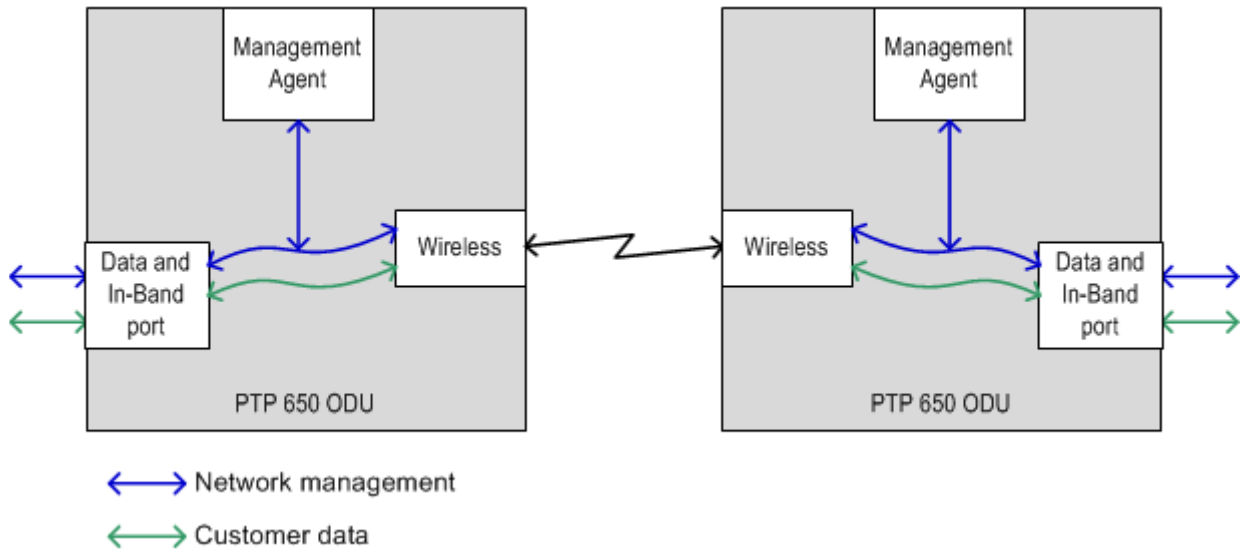
If Local Packet Filtering is enabled, unicast frames forwarded to the management agent as in-band management are filtered, that is, not forwarded in the customer data network.



The Port Allocation options described in [Ethernet ports](#) on page 1-15 allow for several combinations of in-band and out-of-band local management as shown in [Figure 3](#), [Figure 4](#) and [Figure 5](#).

[Figure 3](#) shows a single port allocated to Data and In-Band Management. The in-band management might be connected to a network management center or to a management terminal of an installer or technician.

**Figure 3** In-band management



[Figure 4](#) shows one port allocated to Data Only and one allocated to Out-of-Band Local Management. The local management network (shown in red) is isolated from the customer data network (shown in green). Management frames are not forwarded over the wireless link. The connection to the management agent is solely through the management port of the local ODU.

**Figure 4** Out-of-band local management

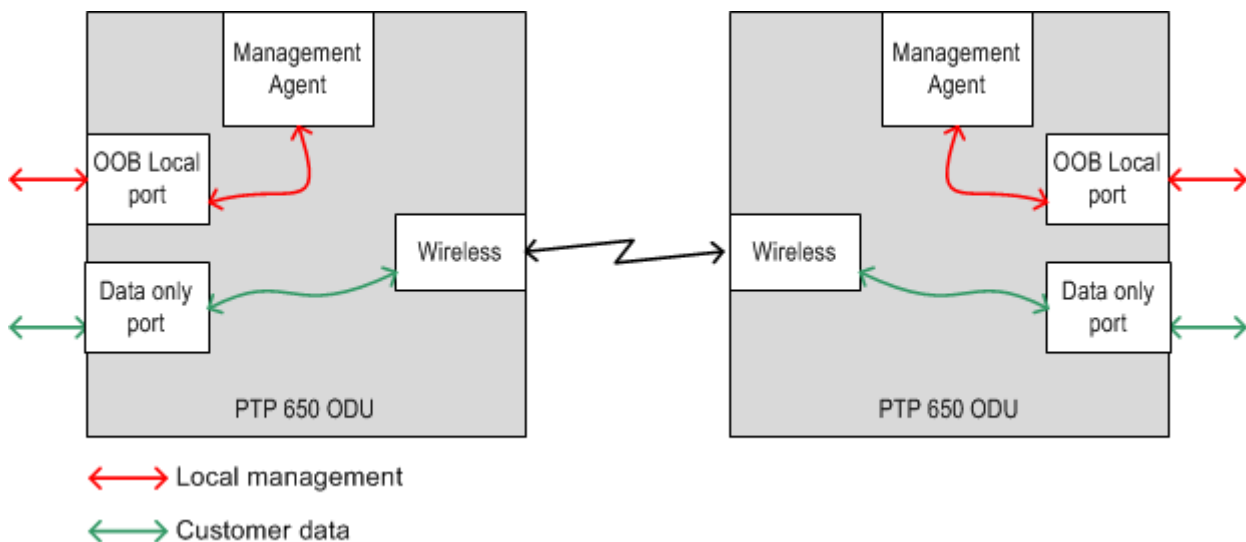
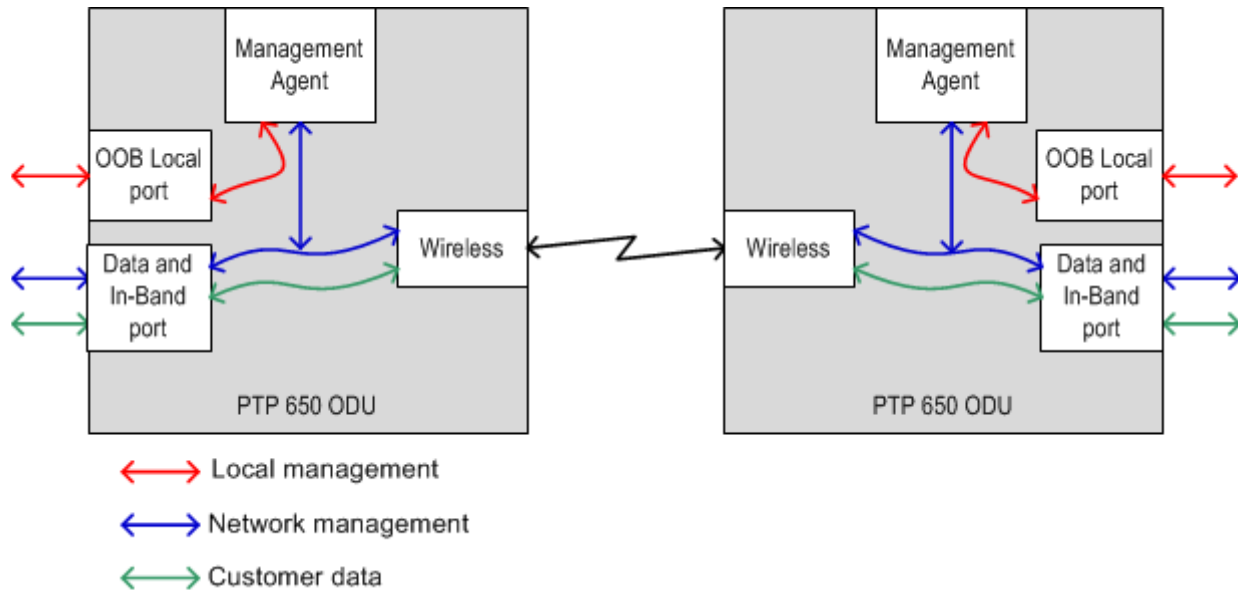


Figure 5 shows a combination of in-band and out-of-band local management. Here, the out-of-band local port might be used to connect a management terminal of an installer or technician, whilst the in-band management is connected to a network management center.

Figure 5 IB and OOB local management



## 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 to In-Band Management or Out-Of-Band Local Management. The management agent does not provide the function of a dual-homed or multi-homed host. Network designers should take care to ensure that the ODU will not be connected to more than one IP network.

Further examples of useful port allocation schemes are provided in [Chapter 3: System planning](#).

## Source address learning

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

## Ethernet loopback mode

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

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

When ports are configured for Ethernet local loopback, they are temporarily disconnected from their allocated function and connected together internally within the PTP 650 ODU. Out-of-band local management is disconnected from the management agent, and the In-band management path will also be un-available if one of the loopback ports has been allocated for Data and in-band management. 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.

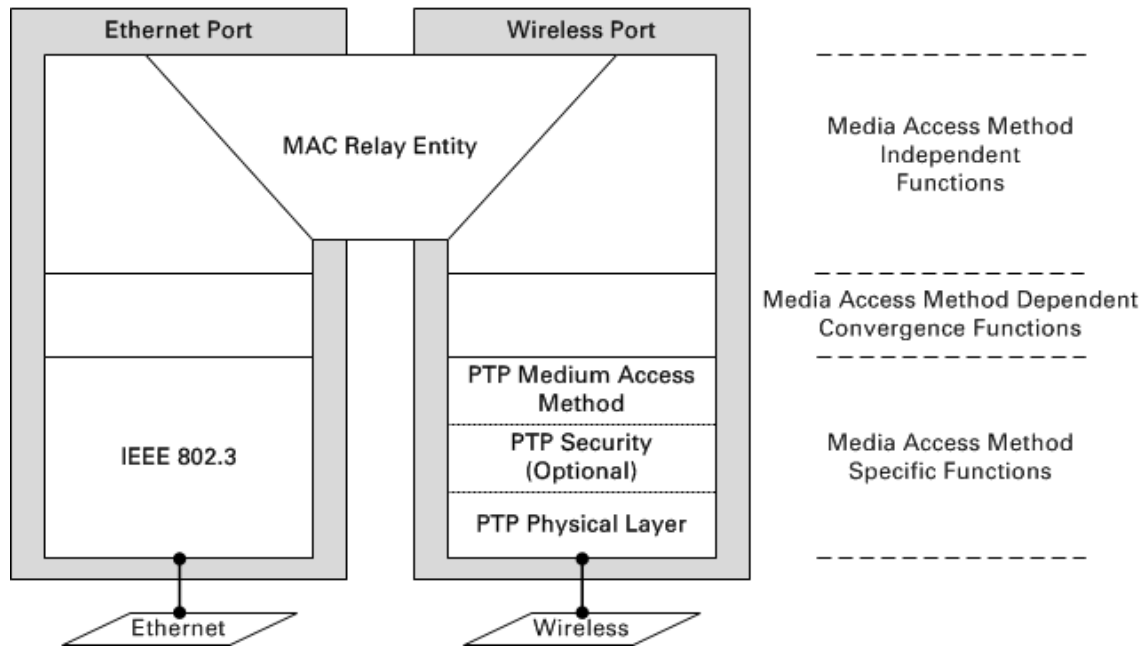
## Protocol model

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 Ethernet Port and Wireless Port.

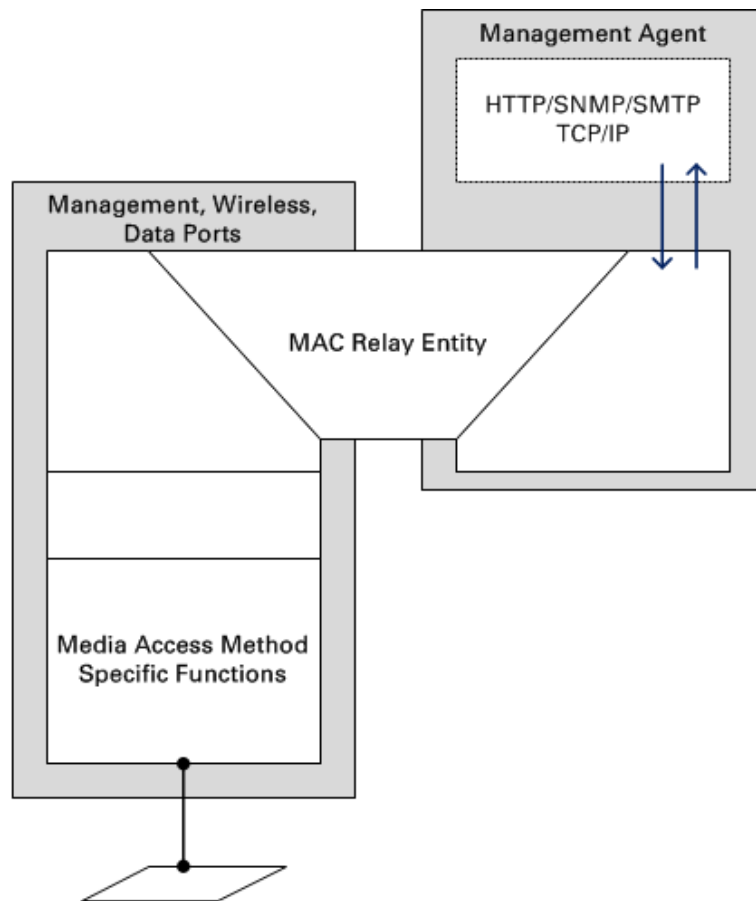
Frames are transmitted at the Wireless port over a proprietary point-to-point circuit-mode link layer between ends of the PTP 650 link. Ethernet frames received at the Ethernet port, or generated internally within the management agent, are encapsulated within a lightweight MAC layer for transmission over the wireless link.

Protocol layers involved in bridging between Ethernet and wireless interfaces are shown in [Figure 6](#). Protocol layers involved in bridging between external interfaces and the management agent are shown in [Figure 7](#). In these figures, the layers have the meanings defined in IEEE 802.1Q-2005.

**Figure 6** Protocol layers between Ethernet and wireless interfaces



**Figure 7** Protocol layers between external interfaces and the management agent



# System management

---

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

## Management agent

PTP 650 equipment is managed through an embedded management agent. Management workstations, network management systems or PCs can be connected to this agent using a choice of in-band or out-of-band local modes. These modes are described in detail in [Network management](#) on page 1-18.

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

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

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

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

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

**Note**

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

---

## IPv6

The PTP 650 management agent supports the following IPv6 features:

### Neighbor discovery

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

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

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

### Path MTU discovery and packet size

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

### ICMP for IPv6

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

### Addressing

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

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

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

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

### Privacy extensions

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

## DHCPv6

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

## Multicast listener discovery for IPv6

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

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

## Textual representation of IPv6 addresses

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

## Security

PTP 650 does not support IP security (IPsec).

## Web server

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

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

## Web pages

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

- **Home:** The Home web-page reports Wireless Link Status and basic information needed to identify the link. The Home page additionally lists all active alarm conditions.
- **Status:** The Status web-page reports the detailed status of the PTP 650.
- **System:** These web-pages are used for configuration management, including IP and Ethernet, AES encryption keys, quality of service and software upgrade. The System pages additionally provide detailed counters and diagnostic measurements used for performance management.

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

## Transport layer security

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

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

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

Details of the security material needed for HTTPS/TLS are provided in [Security planning](#) on page 3-33.



### Note

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



### Note

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

---

## User account management

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



## Identity-based user accounts

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

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

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

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

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

## Password complexity

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

## SNMP control of passwords

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

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

## RADIUS authentication

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

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

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

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

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

RADIUS is only available when PTP 650 is configured for Identity-based User Accounts. For more information, refer to [Planning for RADIUS operation](#) on page 3-39.

## SNMP

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

- RFC-1493. BRIDGE-MIB. dot1dBase group.
- RFC-2233. IF-MIB. Interfaces group, and ifXTable table.
- RFC-3411. SNMP-FRAMEWORK-MIB. snmpEngine group.
- RFC-3412. SNMP-MPD-MIB. snmpMPDStats group.
- RFC-3413. SNMP-TARGET-MIB. snmpTargetObjects group and SNMP-NOTIFICATION-MIB snmpNotifyTable table.
- RFC-3414. SNMP-USER-BASED-SM-MIB. usmStats group and usmUser group.
- RFC-3415. SNMP-VIEW-BASED-ACM-MIB vacmMIBObjects group.
- RFC-3418. SNMPv2-MIB. System group, SNMP group, and set group.
- RFC-3826. SNMP-USM-AES-MIB. usmAesCfb128Protocol OID.
- RFC-4293 IP-MIB, ipForwarding, ipAdEntAddr, ipAdEntIfIndex, ipAdEntNetMask
- PTP 650 Series proprietary MIB.

## Simple Network Time Protocol (SNTP)

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

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

## SNMPv3 security

### SNMP Engine ID

PTP 650 supports four different formats for SNMP Engine ID:

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

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

### User-based security model

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

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

Use of AES privacy requires the PTP 650 AES upgrade described in [AES license](#) on page 1-32.

### View-based access control model

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

### Access to critical security parameters

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

## MIB-based management of SNMPv3 security

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

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

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

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

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

The default user configuration is specified in [SNMPv3 default configuration \(MIB-based\)](#) on page 3-37.

PTP 650 creates the `initial` user and template users with localized authentication and privacy keys derived from the passphrase string 123456789. Authentication keys for the template 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 1-29. The template users have no access to the MIB in the default configuration. User `initial` will normally be used to create one or more additional users with secret authentication and privacy keys, and with appropriate access to the whole of the MIB or to particular views of the MIB according to the operator's security policy. New users must be created by cloning template users. The user `initial` may then be deleted to prevent access using the well-known user name and keys. Alternatively, the keys associated with `initial` may be set to some new secret value.

## Web-based management of SNMPv3 security

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

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

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

- Read Only
- System Administrator

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

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

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

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

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

## Downgrade of the license key

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

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

## System logging (syslog)

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

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

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

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

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

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

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

## AES license

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

AES upgrades are supplied as an access key purchased from your Cambium Point-to-Point distributor or solutions provider. The access key authorizes AES operation for one ODU. Two access keys are needed to operate AES on a link. The upgrade is applied by entering an access key together with the MAC address of the target ODU into the PTP License Key Generator web page, which may be accessed from the support website.

The License Key Generator creates a new license key that is delivered by email. The license key must be installed on the ODU. When the license key is installed, the ODU must be rebooted before AES can be enabled. Once applied, the AES upgrade is bound to a single ODU and is not transferrable.

AES encryption may be used in the following ways:

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

Two levels of encryption are available to purchase:

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

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

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

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

## Critical security parameters

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 erased (zeroized) using the Zeroize CSPs page of the web-based interface or by selecting the Zeroize CSPs option in Recovery mode.

## Login information

PTP 650 optionally provides details of the most recent successful login, and the most recent unsuccessful login attempt, for each user of the web-based interface.

## Capability upgrades

ODUs are shipped with “Lite” data throughput capability, that is, up to 125 Mbps. Cambium Networks supply capability upgrades to upgrade ODU to “Mid” (up to 250 Mbps) or “Full” (up to 450 Mbps) capability. ODU are shipped without AES encryption capability. Cambium Networks supply capability upgrades to upgrade ODU to 128-bit or 256-bit AES Encryption.

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

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

## Full capability trial period

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

## Software upgrade

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

PTP 650 software images are digitally signed, and the ODU will accept only images that contain a valid Cambium Networks PTP 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.

---

## Recovery mode

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

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

The ODU operates in recovery mode in the following circumstances:

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

Recovery mode supports a single IPv4 interface, with IP address 169.254.1.1. 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 and Ethernet configuration, and erases (zeroizes) critical security parameters.
  - Reset IP and Ethernet configuration.
  - Erase (zeroize) critical security parameters.
  - Reboot with existing software and configuration.
- 

**Note**

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.

---

## Chapter 2: System hardware

---

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

The following topics are described in this chapter:

- [Outdoor unit \(ODU\)](#) on page [2-2](#)
- [Power supply units \(PSU\)](#) on page [2-10](#)
- [Antennas and antenna cabling](#) on page [2-15](#)
- [Ethernet cabling](#) on page [2-28](#)

# Outdoor unit (ODU)

---

## ODU description

The ODU is a self-contained transceiver unit that houses both radio and networking electronics.

The ODU is supplied in two configurations: An integrated ODU attached to either 23dBi (PTP 650) or 19dBi (PTP 650s) flat plate antenna, and a connectorized ODU intended to work with separately mounted external antennas. External antennas generally have higher gains than the integrated antennas, and the combination of connectorized units and higher gain antennas can cope with more difficult radio conditions.

**Figure 8** PTP 650 Series ODUs (integrated and connectorized)



## ODU part numbers

One ODU is required for each link end. Order ODUs and ODU kits from Cambium Networks ([Table 2](#) and [Table 3](#)).



### 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 3-25.

To select antennas, RF cables and connectors for connectorized units, see [Antennas and antenna cabling](#) on page 2-15.



### 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 3-25.

Pour sélectionner les antennes, câbles et connecteurs RF pour les liaisons radiofréquence sans antenne intégrée, voir [Antennas and antenna cabling](#) page 2-15.

Choose the correct regional variant: one is for use in regions where FCC or IC licensing restrictions apply (FCC/IC), one is for use in ETSI countries (EU), and the other is for the rest of the world (RoW).

## Individual ODUs

Each of the parts listed in [Table 2](#) includes the following items:

- One 23 dBi integrated ODU (PTP 650), one 19 dBi integrated ODU (PTP 650s) or one connectorized ODU.
- With connectorized ODUs only: one connectorized ODU mounting bracket ([Figure 9](#)).

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

**Table 2** ODU part numbers

Cambium description	Cambium part number
PTP 650 (4.9 to 6.05 GHz) Integrated ODU (FCC/IC)	C050065B001
PTP 650 (4.9 to 6.05 GHz) Connectorized ODU (FCC/IC)	C050065B002
PTP 650s (4.9 to 6.05 GHz) Integrated ODU (FCC/IC)	C050065B015
PTP 650 (4.9 to 6.05 GHz) Integrated ODU (RoW)	C050065B003
PTP 650 (4.9 to 6.05 GHz) Connectorized ODU (RoW)	C050065B004

Cambium description	Cambium part number
PTP 650s (4.9 to 6.05 GHz) Integrated ODU (RoW)	C050065B016
PTP 650 (4.9 to 6.05 GHz) Integrated ODU (EU)	C050065B005
PTP 650 (4.9 to 6.05 GHz) Connectorized ODU (EU)	C050065B006
PTP 650s (4.9 to 6.05 GHz) Integrated ODU (EU)	C050065B021

## ODU kits

Each of the parts listed in [Table 3](#) includes the following items:

- One 23 dBi integrated ODU (PTP 650), one 19 dBi integrated ODU (PTP 650s) or one connectorized ODU.
- One integrated or connectorized ODU mounting bracket ([Figure 9](#)), as appropriate.
- One PSU of the type stated in the Cambium description.
- One line cord, either US (FCC/IC) or EU (EU and RoW).

**Table 3** ODU kit part numbers

Cambium description	Cambium part number
PTP 650 Connectorized END with AC Supply (FCC/IC)	C050065H007
PTP 650 Connectorized END with AC+DC Enhanced Supply (FCC/IC)	C050065H008
PTP 650 Integrated END with AC Supply (FCC/IC)	C050065H009
PTP 650 Integrated END with AC+DC Enhanced Supply (FCC/IC)	C050065H010
PTP 650 Connectorized END with AC Supply (RoW)	C050065H011
PTP 650 Connectorized END with AC+DC Enhanced Supply (RoW)	C050065H012
PTP 650 Integrated END with AC Supply (RoW)	C050065H013
PTP 650 Integrated END with AC+DC Enhanced Supply (RoW)	C050065H014
PTP 650 Connectorized END with AC Supply (EU)	C050065H017
PTP 650 Connectorized END with AC+DC Enhanced Supply (EU)	C050065H018
PTP 650 Integrated END with AC Supply (EU)	C050065H019
PTP 650 Integrated END with AC+DC Enhanced Supply (EU)	C050065H020
PTP 650s Integrated END with AC Supply (FCC/IC)	C050065H022
PTP 650s Integrated END with AC+DC Enhanced Supply (FCC/IC)	C050065H023
PTP 650s Integrated END with AC Supply (RoW)	C050065H024

Cambium description	Cambium part number
PTP 650s Integrated END with AC+DC Enhanced Supply (RoW)	C050065H025
PTP 650s Integrated END with AC Supply (EU)	C050065H026
PTP 650s Integrated END with AC+DC Enhanced Supply (EU)	C050065H027

## Accessories

Spare ODU port blanking plugs are available from Cambium Networks ([Table 4](#)).

**Table 4** ODU accessory part numbers

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

## ODU mounting brackets

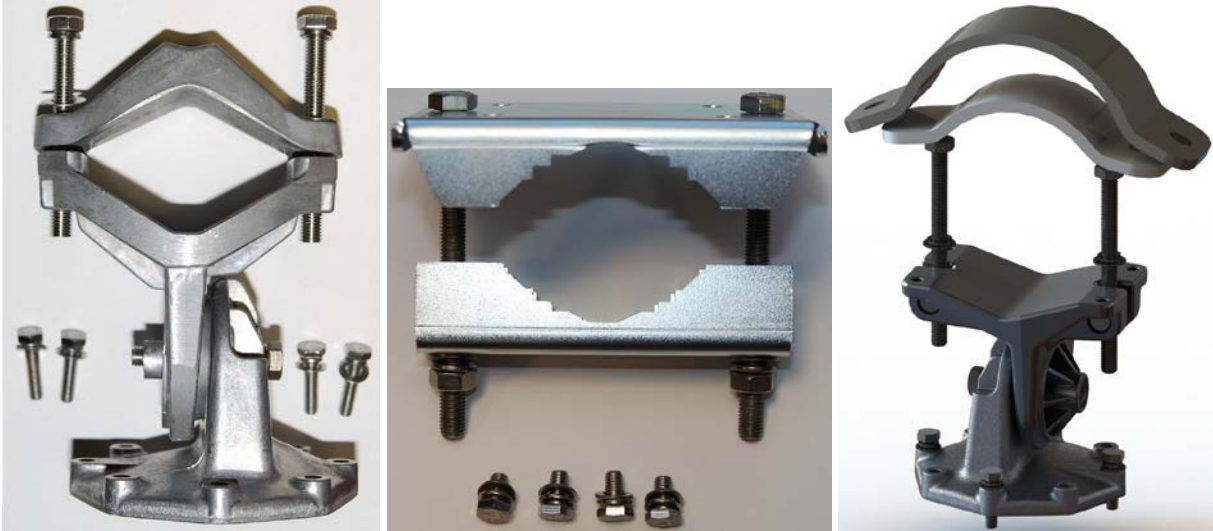
The integrated and connectorized mounting brackets ([Figure 9](#)) are used to mount the ODU on poles with diameters in the range 50 to 75 mm (2 to 3 inches). The extended mounting bracket ([Figure 9](#)) is used for mounting an integrated or connectorized ODU on poles with a diameter of either 90 mm (3.5 inches) or 115 mm (4.5 inches).

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

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

If separate ODU mounting brackets are required, order them from Cambium Networks ([Table 5](#)).

**Figure 9** ODU mounting brackets (integrated, connectorized and extended)



**Table 5** ODU mounting bracket part numbers

Pole diameter	ODU type	Cambium description	Cambium part number
From 50 to 75 mm (2 to 3 inches)	Integrated	PTP 650 Mounting Bracket (integrated)	N000065L031
	Connectorized	PTP 650 Mounting Bracket (connectorized)	N000065L032
Either 90 mm (3.5 inches) or 115 mm (4.5 inches)	Integrated and connectorized	Extended Diameter Mast mounting kit 3.5" and 4.5"	N000065L030

## ODU interfaces

The PSU, AUX and SFP ports are on the rear of the integrated and connectorized ODUs ([Figure 10](#)). These interfaces are described in [Table 6](#). Each of the PSU, AUX and SFP ports can be configured to disable Ethernet traffic or to carry the following Ethernet traffic:

- Wireless bridge data
- Wireless bridge data and in-band management
- Out-of-band local management
- Local loop-back between any two ports

**Figure 10** ODU rear interfaces



**Table 6** ODU rear interfaces

Port name	Connector	Interface	Description
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.
SFP	SFP	Optical or Copper Gigabit Ethernet	OOB management, user data, user data with IB management, ODU-to-ODU. Plug-in SFP module must be purchased separately.

The front of the connectorized ODU ([Figure 11](#)) provides N type female connectors for RF cable interfaces to antennas with horizontal (H) and vertical (V) polarization.

**Figure 11** Connectorized ODU antenna interfaces

## ODU specifications

The PTP 650 ODU conforms to the specifications listed in [Table 7](#).

**Table 7** ODU specifications

Category	Specification
Dimensions	23 dBi integrated: 371 mm (14.6 in) x 371 mm (14.6 in) x 81 mm (3.2 in) 19 dBi integrated: Connectorized: 204 mm (8.0 in) x 318 mm (12.5 in) x 90 mm (3.5 in)
Weight	23 dBi integrated: 4.1 Kg (9.0 lbs) including bracket 19 dBi integrated: Connectorized: 3.1 Kg (6.8 lbs) including bracket
Temperature	-40°C (-40°F) to +60°C (140°F)
Wind loading	200 mph (323 kph) maximum. See <a href="#">ODU wind loading</a> on page 3-11.
Humidity	100% condensing
Waterproofing	IP66, IP67
UV exposure	10 year operational life (UL746C test evidence)
Static discharge	See <a href="#">Electromagnetic compatibility (EMC) compliance</a> on page 4-23

# Power supply units (PSU)

---

## PSU description

The PSU is an indoor unit that is connected to the ODU and network terminating equipment using Cat5e cable with RJ45 connectors. It is also plugged into an AC or DC power supply so that it can inject Power over Ethernet (POE) into the ODU. Choose one of the following PSUs (Figure 12):

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

Figure 12 PSU 650 PSUs



### Caution

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

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



### Note

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

## PSU part numbers

Order PSUs and (for AC power) line cords from Cambium Networks ([Table 8](#)).

**Table 8** Power supply component part numbers

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

## AC Power Injector interfaces

The AC Power Injector interfaces are shown in [Figure 13](#) and described in [Table 9](#).

**Figure 13** AC Power Injector interfaces



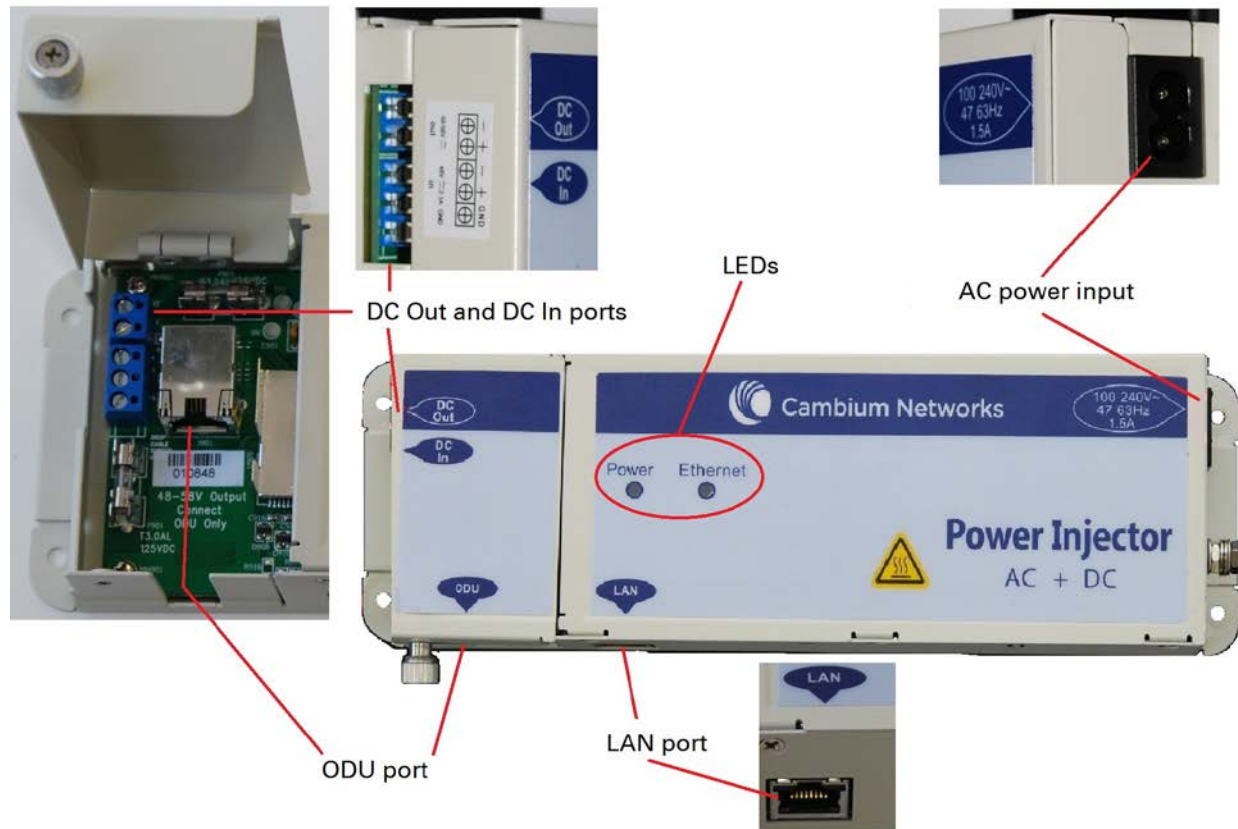
**Table 9** AC Power Injector interface functions

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

## AC+DC Enhanced Power Injector interfaces

The AC+DC Enhanced Power Injector interfaces are shown in [Figure 14](#) and described in [Table 10](#).

**Figure 14** AC+DC Enhanced Power Injector interfaces



**Table 10** 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).
ODU	RJ45 socket for connecting Cat5e cable to ODU.
LAN	RJ45 socket for connecting Cat5e cable to network.
Power (green) LED	Power supply detection
Ethernet (yellow) LED	Ethernet traffic detection

## PSU specifications

The PTP 650 AC Power Injector conforms to the specifications listed in [Table 11](#).

The PTP 650 AC+DC Enhanced Power Injector conforms to the specifications listed in [Table 12](#).

**Table 11** AC Power Injector specifications

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

**Table 12** AC+DC Enhanced Power Injector specifications

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

# Antennas and antenna cabling

---

## Antenna requirements

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

For connectorized units operating in the USA or Canada 4.9 GHz, 5.2 GHz, 5.4 GHz or 5.8 GHz bands, choose external antennas from those listed in [FCC and IC approved antennas](#) on page 2-16. 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 3-25.

## RF cable and connectors

RF cable of type CNT-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 RF cable and N type male connectors from Cambium Networks ([Table 13](#)).

**Table 13** 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 [Cable grounding kit](#) on page 2-30 for specifications and part numbers.
- Self-amalgamating and PVC tape: Order these items to weatherproof the RF connectors.
- Lightning arrestors: When the connectorized ODU is mounted indoors, lightning arrestors (not PTP 650 LPU) are required for protecting the antenna RF cables at building entry. One arrestor is required per antenna cable. One example of a compatible lightning arrestor is the Polyphaser LSXL-ME or LSXL (not supplied by Cambium Networks).

## FCC and IC approved antennas

For connectorized units operating in the USA or Canada, choose external antennas from [Table 14](#) (4.9 GHz), [Table 15](#) (5.2 GHz), [Table 16](#) (5.4 GHz) or [Table 17](#) (5.8 GHz). These are approved by the FCC for use with the product and are constrained by the following limits for single- or dual-polarization parabolic dish antennas:

- 4.9 GHz – 36.0 dBi per polarization or antenna.
- 5.2 GHz - 34.9 dBi per polarization or antenna.
- 5.4 GHz - 34.9 dBi per polarization or antenna.
- 5.8 GHz - 37.7 dBi per polarization or antenna.

Details of the regulatory bands are provided in [Table 31](#) on page 3-17.



### Caution

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



### Caution

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

---

## Antennes approuvées par la FCC et IC

Pour les unités sans antenne intégrée destinées aux Etats-Unis ou au Canada, choisissez des antennes externes dans la [Table 14](#) (4.9 GHz), [Table 15](#) (5.2 GHz), [Table 16](#) (5.4 GHz) ou la [Table 17](#) (5.8 GHz). Celles-ci sont approuvées par la FCC pour une utilisation avec le produit et sont limitées pour les antennes paraboliques a polarisation simple ou double comme suit:

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



### Attention

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



### Attention

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

**Table 14** Antennas permitted for deployment in USA/Canada – 4.9 GHz

Manufacturer	Antenna type	Nominal gain (dBi)	Parabolic dish	Cambium part number
RadioWaves	Radio Waves 6-foot Parabolic, SP6-5.2	36	Y	
RadioWaves	Radio Waves 6-foot Dual-Pol Parabolic, SPD6-5.2	35.7	Y	RDH4506B
RadioWaves	Radio Waves 6-foot Dual-Pol Parabolic, SPD6-4.7	35.6	Y	RDH4502A
RadioWaves	Radio Waves 6-foot Parabolic, SP6-4.7	35.6	Y	
RadioWaves	Radio Waves 6-foot Dual-Pol Parabolic, HPD6-5.2NS	35.6	Y	RDH4511B
RadioWaves	Radio Waves 6-foot Dual-Pol Parabolic, HPD6-4.7	35.4	Y	RDH4515A
RadioWaves	Radio Waves 4-foot Dual-Pol Parabolic,	32.6	Y	RDH4501A

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

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

**Table 15** Antennas permitted for deployment in USA/Canada – 5.2 GHz

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

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

<b>Manufacturer</b>	<b>Antenna type</b>	<b>Nominal gain (dBi)</b>	<b>Parabolic dish</b>	<b>Cambium part number</b>
RadioWaves	Radio Waves 2-foot Dual-Pol Parabolic, HPD2-5.2NS	28.8	Y	RDH4508B
Gabriel	Gabriel 2-foot Standard QuickFire Parabolic, QF2-52-N	28.5	Y	
Gabriel	Gabriel 2-foot Standard QuickFire Parabolic, QF2-52-N-RK	28.5	Y	
MTI	MTI 2-foot Dual-Pol, MT-486013/N	28.5	Y	
MTI	MTI 2-foot Single-Pol, MT-466009/N	28.5	Y	
Gabriel	Gabriel 2-foot Standard Dual QuickFire Parabolic, QFD2-52-N	28.4	Y	
Gabriel	Gabriel 2-foot Standard Dual QuickFire Parabolic, QFD2-52-N-RK	28.4	Y	
Gabriel	Gabriel 2-foot High Performance QuickFire Parabolic, HQF2-52-N	28.2	Y	
Gabriel	Gabriel 2-foot High Performance Dual QuickFire Parabolic, HQFD2-52-N	28.1	Y	
RadioWaves	Radio Waves 2-foot Dual-Pol Parabolic, SPD2-5.2	28.1	Y	RDH4503B
RFS	RFS 2-foot Parabolic, SPF2-52AN	27.9	Y	
StellaDoradus	StellaDoradus 2-foot Single-Pol, 56 PSD61	27	Y	
MARS	MA-WS54-50R Flat Plate (Dual-Pol)	23	N	Integrated
MTI	MTI 15 inch Dual-Pol Flat Panel, MT-485025/NVH	23	N	
Andrew	Andrew 1.25-foot Flat Panel Dual, UBXP375-4-1	21	N	
Andrew	Andrew 1-foot Flat Panel Single, UBP300-4-1	21	N	
MARS	Small Form Factor Flat Plate Antenna MA-EM56-DP19CM.	19	N	Integrated
Laird	60 Sectorized (Dual Pol)	17	N	
Laird	90 Sectorized (Dual Pol)	17	N	
KPPA	OMNI (Dual-Pol)	13	N	

**Table 16** Antennas permitted for deployment in USA/Canada – 5.4 GHz

Manufacturer	Antenna type	Nominal gain (dBi)	Parabolic dish	Cambium part number
Andrew	Andrew 4-foot Dual-Pol Parabolic, PX4F-52	34.9	Y	RDG4453B
Andrew	Andrew 4-foot Parabolic, P4F-52	34.9	Y	RDH4524A
Gabriel	Gabriel 4-foot Standard QuickFire Parabolic, QF4-52-N	34.8	Y	
Gabriel	Gabriel 4-foot Standard QuickFire Parabolic, QF4-52-N-RK	34.8	Y	
RadioWaves	Radio Waves 4-foot Parabolic, SP4-5.2	34.8	Y	
Gabriel	Gabriel 4-foot Standard Dual QuickFire Parabolic, QFD4-52-N	34.7	Y	
Gabriel	Gabriel 4-foot Standard Dual QuickFire Parabolic, QFD4-52-N-RK	34.7	Y	
RadioWaves	Radio Waves 4-foot Dual-Pol Parabolic, HPD4-5.2NS	34.7	Y	RDH4510B
Gabriel	Gabriel 4-foot High Performance QuickFire Parabolic, HQF4-52-N	34.4	Y	
RadioWaves	Radio Waves 4-foot Dual-Pol Parabolic, SPD4-5.2	34.4	Y	RDH4505B
Gabriel	Gabriel 4-foot High Performance Dual QuickFire Parabolic, HQFD4-52-N	34.3	Y	
RFS	RFS 4-foot HP Parabolic, SDF4-52AN	33.9	Y	
RFS	RFS 4-foot Parabolic, SPF4-52AN	33.9	Y	
Andrew	Andrew 3-foot Dual-Pol Parabolic, PX3F-52	33.4	Y	
Andrew	Andrew 3-foot Parabolic, P3F-52	33.4	Y	
StellaDoradus	StellaDoradus 4-foot Single-Pol, 56 PSD113	32.4	Y	
RadioWaves	Radio Waves 3-foot Dual-Pol Parabolic, HPD3-5.2NS	32.3	Y	RDH4509B
RadioWaves	Radio Waves 3-foot Parabolic, SP3-5.2	31.4	Y	RDH4513B
Gabriel	Gabriel 2.5-foot Standard QuickFire Parabolic, QF2.5-52-N	31.2	Y	
Gabriel	Gabriel 2.5-foot Standard Dual QuickFire	31.1	Y	

Manufacturer	Antenna type	Nominal gain (dBi)	Parabolic dish	Cambium part number
	Parabolic, QFD2.5-52-N			
RadioWaves	Radio Waves 3-foot Dual-Pol Parabolic, SPD3-5.2	31.1	Y	RDH4504B
Andrew	Andrew 2-foot Dual-Pol Parabolic, PX2F-52	29.4	Y	
Andrew	Andrew 2-foot Parabolic, P2F-52	29.4	Y	
MTI	MTI 3-foot Single-Pol, MT-487000/N	29	Y	
RadioWaves	Radio Waves 2-foot Parabolic, SP2-5.2	29	Y	
RadioWaves	Radio Waves 2-foot Dual-Pol Parabolic, HPD2-5.2NS	28.8	Y	RDH4508B
Gabriel	Gabriel 2-foot Standard QuickFire Parabolic, QF2-52-N	28.5	Y	
Gabriel	Gabriel 2-foot Standard QuickFire Parabolic, QF2-52-N-RK	28.5	Y	
MTI	MTI 2-foot Dual-Pol, MT-486013/N	28.5	Y	
MTI	MTI 2-foot Single-Pol, MT-466009/N	28.5	Y	
Gabriel	Gabriel 2-foot Standard Dual QuickFire Parabolic, QFD2-52-N	28.4	Y	
Gabriel	Gabriel 2-foot Standard Dual QuickFire Parabolic, QFD2-52-N-RK	28.4	Y	
Gabriel	Gabriel 2-foot High Performance QuickFire Parabolic, HQF2-52-N	28.2	Y	
Gabriel	Gabriel 2-foot High Performance Dual QuickFire Parabolic, HQFD2-52-N	28.1	Y	
RadioWaves	Radio Waves 2-foot Dual-Pol Parabolic, SPD2-5.2	28.1	Y	RDH4503B
RFS	RFS 2-foot Parabolic, SPF2-52AN	27.9	Y	
StellaDoradus	StellaDoradus 2-foot Single-Pol, 56 PSD61	27	Y	
MARS	MA-WS54-50R Flat Plate (Dual-Pol)	23	N	Integrated
MTI	MTI 15 inch Dual-Pol Flat Panel, MT-485025/NVH	23	N	
Andrew	Andrew 1.25-foot Flat Panel Dual, UBXP375-4-1	21	N	
Andrew	Andrew 1-foot Flat Panel Single, UBP300-	21	N	



Manufacturer	Antenna type	Nominal gain (dBi)	Parabolic dish	Cambium part number
	4-1			
MARS	Small Form Factor Flat Plate Antenna MA-EM56-DP19CM.	19	N	Integrated
Laird	60 Sectorized (Dual-Pol)	17	N	
Laird	90 Sectorized (Dual-Pol)	17	N	
KPPA	OMNI (Dual-Pol)	13	N	

**Table 17** Antennas permitted for deployment in USA/Canada – 5.8 GHz

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

Manufacturer	Antenna type	Nominal gain (dBi)	Parabolic dish	Cambium part number
Gabriel	Gabriel 4-foot Standard QuickFire Parabolic, QF4-52-N-RK	34.8	Y	
RadioWaves	Radio Waves 4-foot Parabolic, SP4-5.2	34.8	Y	
Gabriel	Gabriel 4-foot Standard Dual QuickFire Parabolic, QFD4-52-N	34.7	Y	
Gabriel	Gabriel 4-foot Standard Dual QuickFire Parabolic, QFD4-52-N-RK	34.7	Y	
RadioWaves	Radio Waves 4-foot Dual-Pol Parabolic, HPD4-5.2NS	34.7	Y	RDH4510B
RadioWaves	Radio Waves 4-foot Parabolic, SP4-2/5	34.6	Y	
Gabriel	Gabriel 4-foot High Performance QuickFire Parabolic, HQF4-52-N	34.4	Y	
RadioWaves	Radio Waves 4-foot Dual-Pol Parabolic, SPD4-5.2	34.4	Y	RDH4505B
Gabriel	Gabriel 4-foot High Performance Dual QuickFire Parabolic, HQFD4-52-N	34.3	Y	
RFS	RFS 4-foot HP Parabolic, SDF4-52AN	33.9	Y	
RFS	RFS 4-foot Parabolic, SPF4-52AN	33.9	Y	
Andrew	Andrew 3-foot Dual-Pol Parabolic, PX3F-52	33.4	Y	
Andrew	Andrew 3-foot Parabolic, P3F-52	33.4	Y	
StellaDoradus	StellaDoradus 4-foot Single-Pol, 56 PSD113	32.4	Y	
RadioWaves	Radio Waves 3-foot Dual-Pol Parabolic, HPD3-5.2NS	32.3	Y	RDH4509B
RadioWaves	Radio Waves 3-foot Parabolic, SP3-2/5	31.4	Y	
RadioWaves	Radio Waves 3-foot Parabolic, SP3-5.2	31.4	Y	RDH4513B
Gabriel	Gabriel 2.5-foot Standard QuickFire Parabolic, QF2.5-52-N	31.2	Y	
Gabriel	Gabriel 2.5-foot Standard Dual QuickFire Parabolic, QFD2.5-52-N	31.1	Y	
RadioWaves	Radio Waves 3-foot Dual-Pol Parabolic, SPD3-5.2	31.1	Y	RDH4504B
Andrew	Andrew 2-foot Dual-Pol Parabolic, PX2F-52	29.4	Y	

Manufacturer	Antenna type	Nominal gain (dBi)	Parabolic dish	Cambium part number
Andrew	Andrew 2-foot Parabolic, P2F-52	29.4	Y	
MTI	MTI 3-foot Single-Pol, MT-487000/N	29	Y	
RadioWaves	Radio Waves 2-foot Parabolic, SP2-5.2	29	Y	
RadioWaves	Radio Waves 2-foot Dual-Pol Parabolic, HPD2-5.2NS	28.8	Y	RDH4508B
Gabriel	Gabriel 2-foot Standard QuickFire Parabolic, QF2-52-N	28.5	Y	
Gabriel	Gabriel 2-foot Standard QuickFire Parabolic, QF2-52-N-RK	28.5	Y	
MTI	MTI 2-foot Dual-Pol, MT-486013/N	28.5	Y	
MTI	MTI 2-foot Single-Pol, MT-466009/N	28.5	Y	
Gabriel	Gabriel 2-foot Standard Dual QuickFire Parabolic, QFD2-52-N	28.4	Y	
Gabriel	Gabriel 2-foot Standard Dual QuickFire Parabolic, QFD2-52-N-RK	28.4	Y	
RadioWaves	Radio Waves 2-foot Parabolic, SP2-2/5	28.3	Y	
Gabriel	Gabriel 2-foot High Performance QuickFire Parabolic, HQF2-52-N	28.2	Y	
Gabriel	Gabriel 2-foot High Performance Dual QuickFire Parabolic, HQFD2-52-N	28.1	Y	
RadioWaves	Radio Waves 2-foot Dual-Pol Parabolic, SPD2-5.2	28.1	Y	RDH4503B
RFS	RFS 2-foot Parabolic, SPF2-52AN	27.9	Y	
StellaDoradus	StellaDoradus 2-foot Single-Pol, 56 PSD61	27	Y	
MARS	MA-WS54-50R Flat Plate (Dual-Pol)	23	N	Integrated
MTI	MTI 15 inch Dual-Pol Flat Panel, MT-485025/NVH	23	N	
RFS	RFS 1-foot Flat Panel, MA0528-23AN	23	N	
Andrew	Andrew 1.25-foot Flat Panel Dual, UBXP375-4-1	21	N	
Andrew	Andrew 1-foot Flat Panel Single, UBP300-4-1	21	N	

<b>Manufacturer</b>	<b>Antenna type</b>	<b>Nominal gain (dBi)</b>	<b>Parabolic dish</b>	<b>Cambium part number</b>
MARS	Small Form Factor Flat Plate Antenna MA-EM56-DP19CM.	19	N	Integrated
Laird	60 Sectorized (Dual-Pol)	17	N	
Laird	90 Sectorized (Dual-Pol)	17	N	
KPPA	OMNI (Dual-Pol)	13	N	

# Ethernet cabling

## Ethernet standards and cable lengths

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

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

**Table 18** specifies, for each type of PSU and power supply, the maximum permitted PSU drop cable length.

**Table 19** specifies, for Aux and copper SFP interfaces, the Ethernet standards supported and the maximum permitted drop cable lengths.



### Note

For optical SFP interfaces, the Ethernet standards supported and maximum permitted cable lengths are specified in [SFP module kits](#) on page 2-35.

**Table 18** PSU drop cable length restrictions

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

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

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

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

**Table 19** Aux and copper SFP Ethernet standards and cable length restrictions

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

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

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

## Outdoor copper Cat5e Ethernet cable

For copper Cat5e Ethernet connections from the ODU to the PSU, LPUs and other devices, use Cat5e cable that is gel-filled and shielded with copper-plated steel, for example Superior Essex type BBDGe. This is known as “drop cable” (Figure 15).

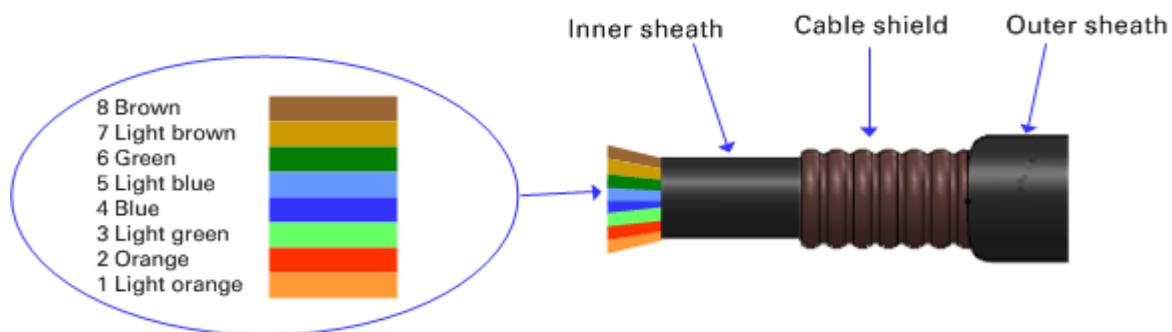


### Caution

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

Order Superior Essex type BBDGe cable from Cambium Networks (Table 20). Other lengths of this cable are available from Superior Essex.

**Figure 15** Outdoor drop cable



**Table 20** 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 16](#)) is required for each grounding point on the PSU, Aux and copper SFP drop cables. Order cable grounding kits from Cambium Networks ([Table 21](#)).



### Caution

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

**Figure 16** Cable grounding kit**Table 21** Cable grounding kit part numbers

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

## Lightning protection unit (LPU) and grounding kit

PTP 650 LPUs provide transient voltage surge suppression for PTP 650 installations. Each PSU or Aux drop cable requires two LPUs, one near the ODU and the other near the linked device, usually at the building entry point (Table 22).

**Table 22** 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 22) 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 23).

**Table 23** LPU and grounding kit part number

Cambium description	Cambium part number
PTP 650 LPU and Grounding Kit	C000065L007



**Note**

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

SFP optical Ethernet interfaces do not require surge protectors.

## 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 24).



**Note**

The RJ45 connectors and crimp tool listed in Table 24 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 17). These are identified with a black sealing nut. If extra glands are required, order them from Cambium Networks (in packs of 10) (Table 24).

One long EMC strain relief gland (Figure 21) 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 17** Cable gland

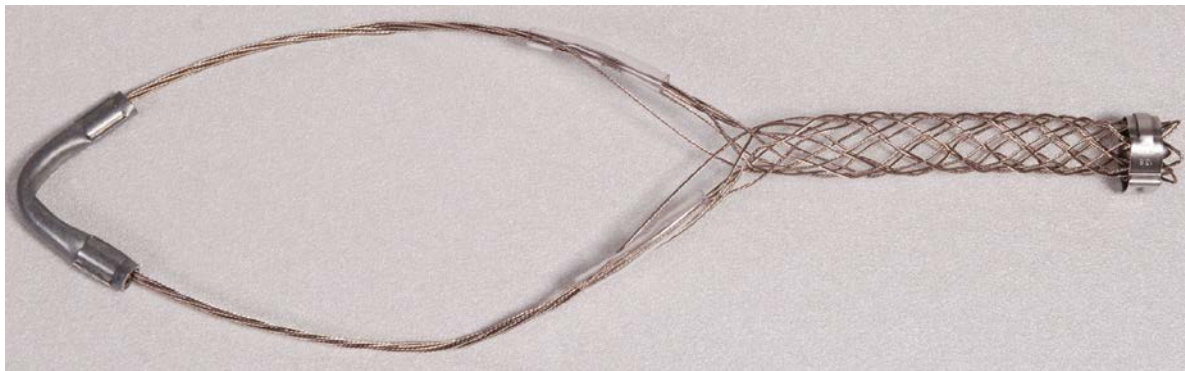


**Table 24** RJ45 connector and spare gland part numbers

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

## Cable hoisting grip

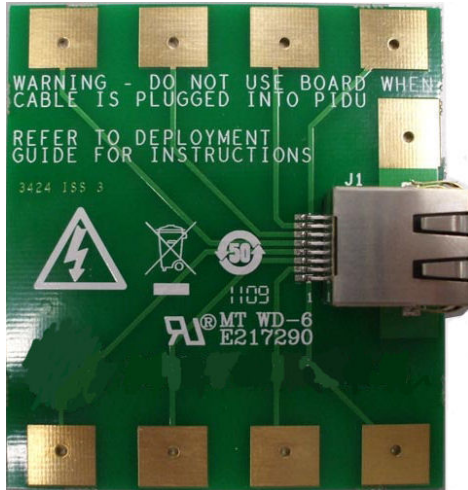
One or more grips are required for hoisting the drop cable up to the ODU without damaging the gland or RJ45 plug ([Figure 18](#)). They are not supplied by Cambium Networks.

**Figure 18** Cable hoisting grip

## Drop cable tester

The drop cable tester is an optional item for testing the resistances between the RJ45 pins of the drop cable (Figure 19). Order it by completing the order form on the support website (see [Contacting Cambium Networks](#) on page 1).

**Figure 19** Drop cable tester



## Indoor Cat5e cable

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

## SFP module kits

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

- Optical Gigabit Ethernet: 1000BaseLX or 1000BaseSX
- Copper Gigabit Ethernet: 100BASE-TX or 1000BASE-T

Order SFP module kits from Cambium Networks ([Table 25](#)).

**Table 25** SFP module kit part numbers

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

To compare the capabilities of the two optical SFP modules, refer to [Table 26](#) and [Table 27](#).

**Table 26** Optical 1000BaseLX Ethernet SFP Module (part number C000065L008)

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

**Table 27** Optical 1000BaseSX Ethernet SFP Module (part number C000065L009)

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

The upgrade kits contain the following components:

- Optical or copper SFP transceiver module (Figure 20)
- Long EMC strain relief cable gland (Figure 21)
- The *PTP 650 Series SFP Interface Upgrade Guide*
- License key instructions and unique Access Key

**Figure 20** Optical or copper SFP transceiver module



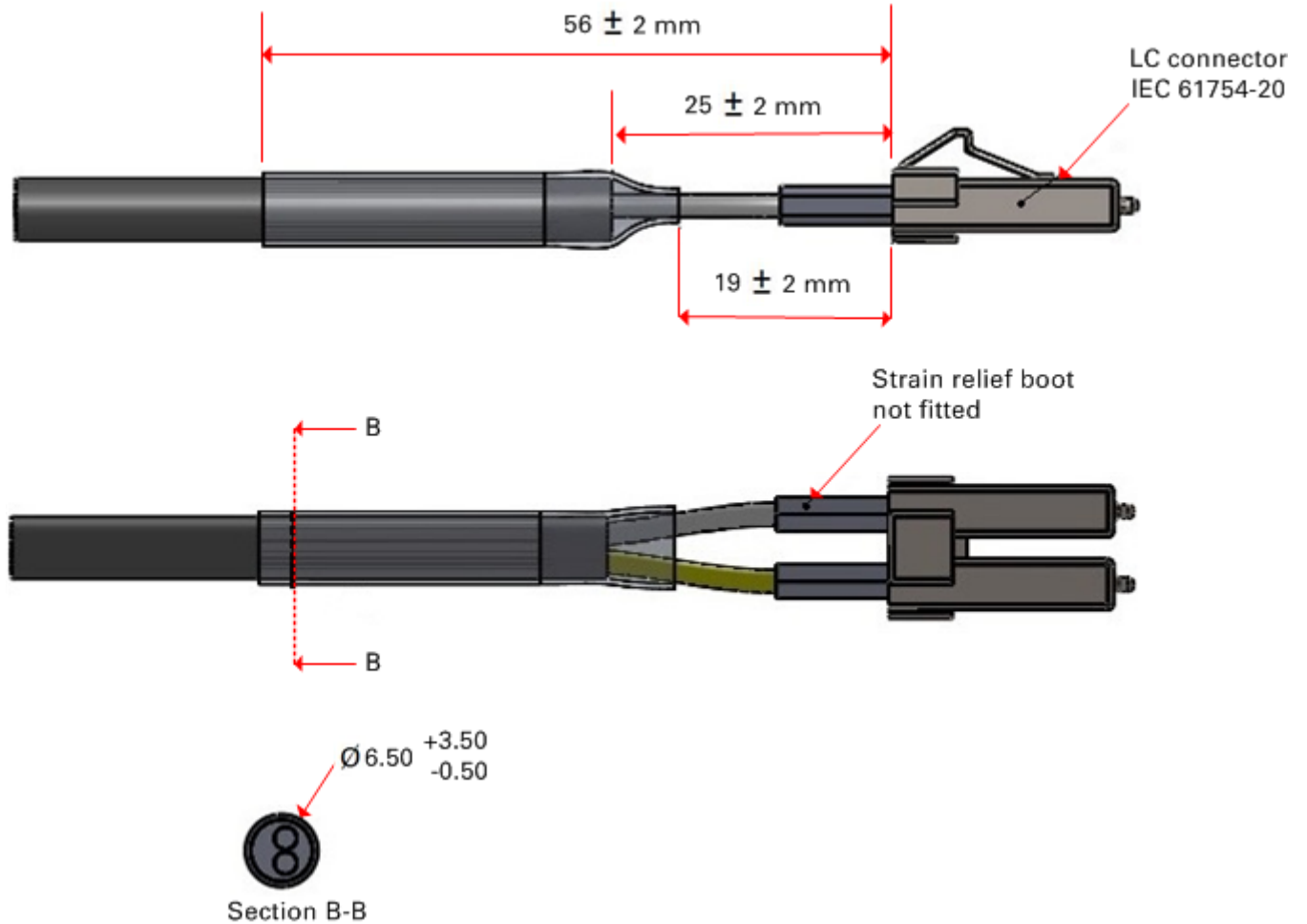
**Figure 21** Long cable gland



## Optical cable and connectors

Order an optical cable with LC connectors from a specialist fabricator, quoting the specification shown in [Figure 22](#). 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 22** Optical optic cable and connector specification



---

## Chapter 3: System planning

---

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

The following topics are described in this chapter:

- [Typical deployment](#) on page 3-2 contains diagrams illustrating typical PTP 650 site deployments.
- [Site planning](#) on page 3-8 describes factors to be considered when planning the proposed link end sites, including grounding, lightning protection and equipment location.
- [Radio spectrum planning](#) on page 3-16 describes how to plan PTP 650 links to conform to the regulatory restrictions that apply in the country of operation.
- [Link planning](#) on page 3-21 describes factors to be taken into account when planning links, such as range, path loss and throughput.
- [Planning for connectorized units](#) on page 3-25 describes factors to be taken into account when planning to use connectorized ODUs with external antennas in PTP 650 links.
- [Data network planning](#) on page 3-27 describes factors to be considered when planning PTP 650 data networks.
- [Network management planning](#) on page 3-31 describes how to plan for PTP 650 links to be managed remotely using SNMP.
- [Security planning](#) on page 3-33 describes how to plan for PTP 650 links to operate in secure mode.
- [System threshold, output power and link loss](#) on page 3-41 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 3-49 contains tables and graphs to support calculation of the data rate capacity that can be provided by PTP 650 configurations.

## Typical deployment

This section contains diagrams illustrating typical PTP 650 site deployments.

### ODU with POE interface to PSU

In the basic configuration, there is only one Ethernet interface, a copper Cat5e power over Ethernet (POE) from the PSU to the ODU (PSU port), as shown in the following diagrams: mast or tower installation (Figure 23), wall installation (Figure 24) and roof installation (Figure 25).

**Figure 23** Mast or tower installation

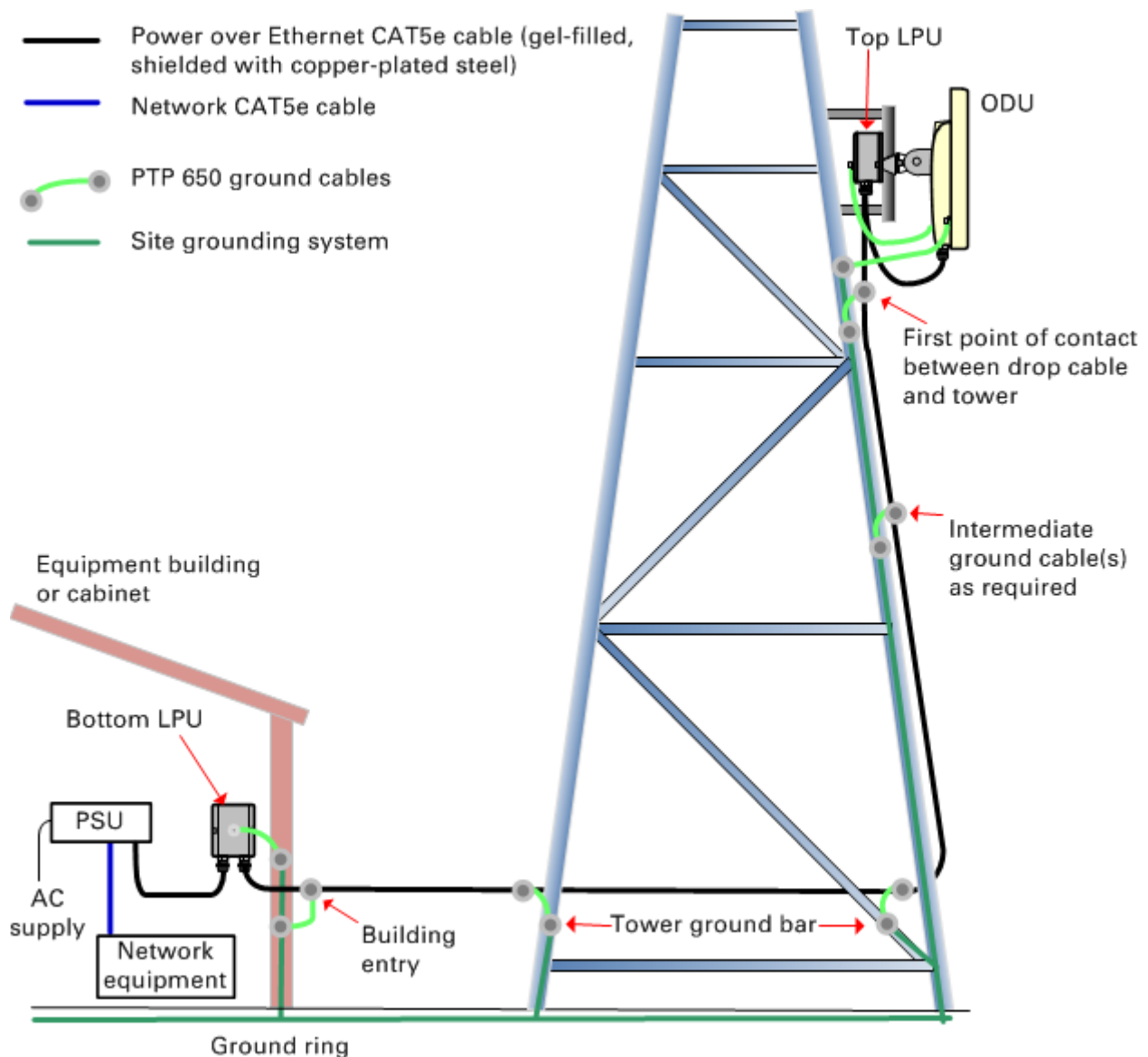




Figure 24 Wall installation

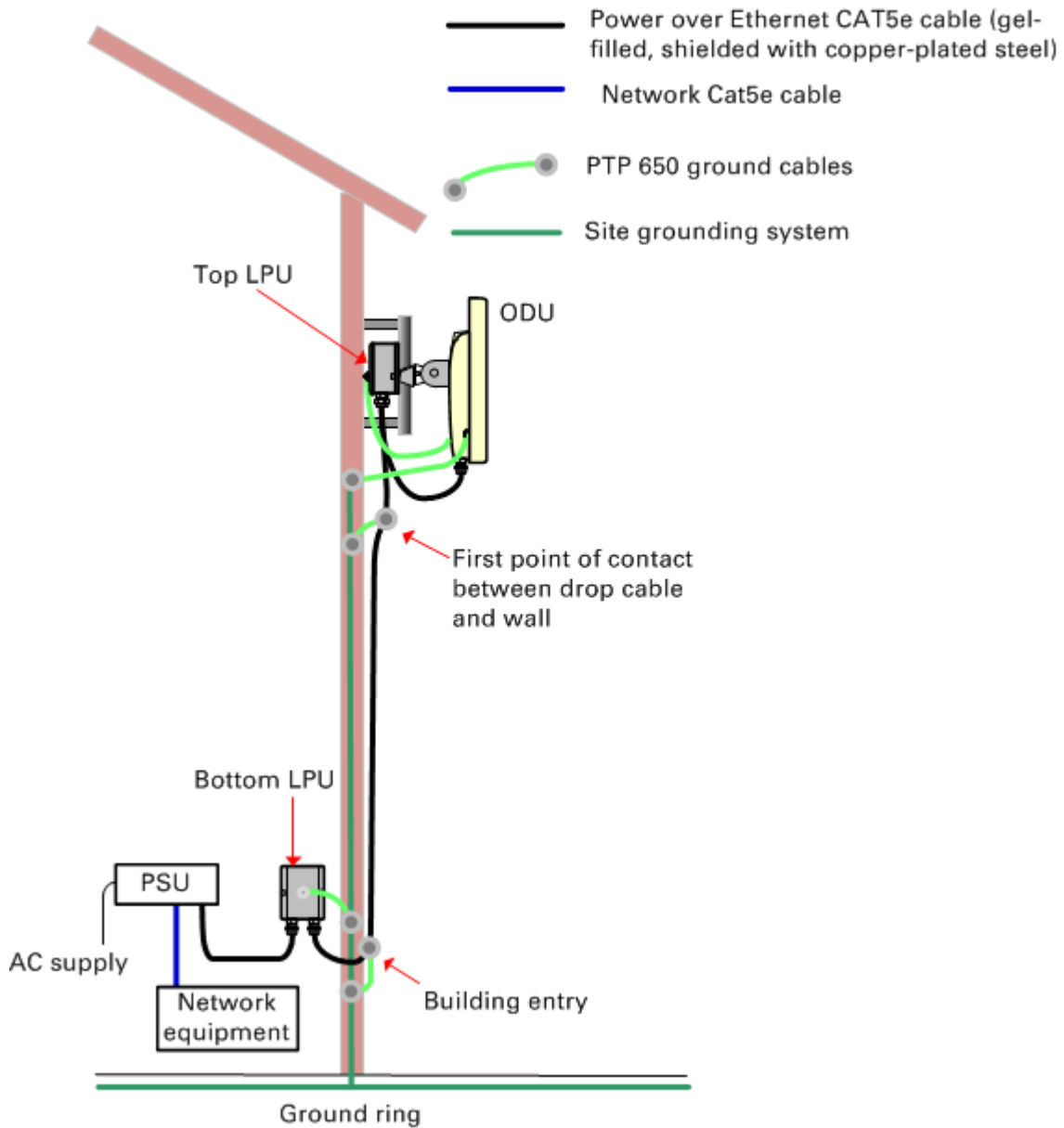
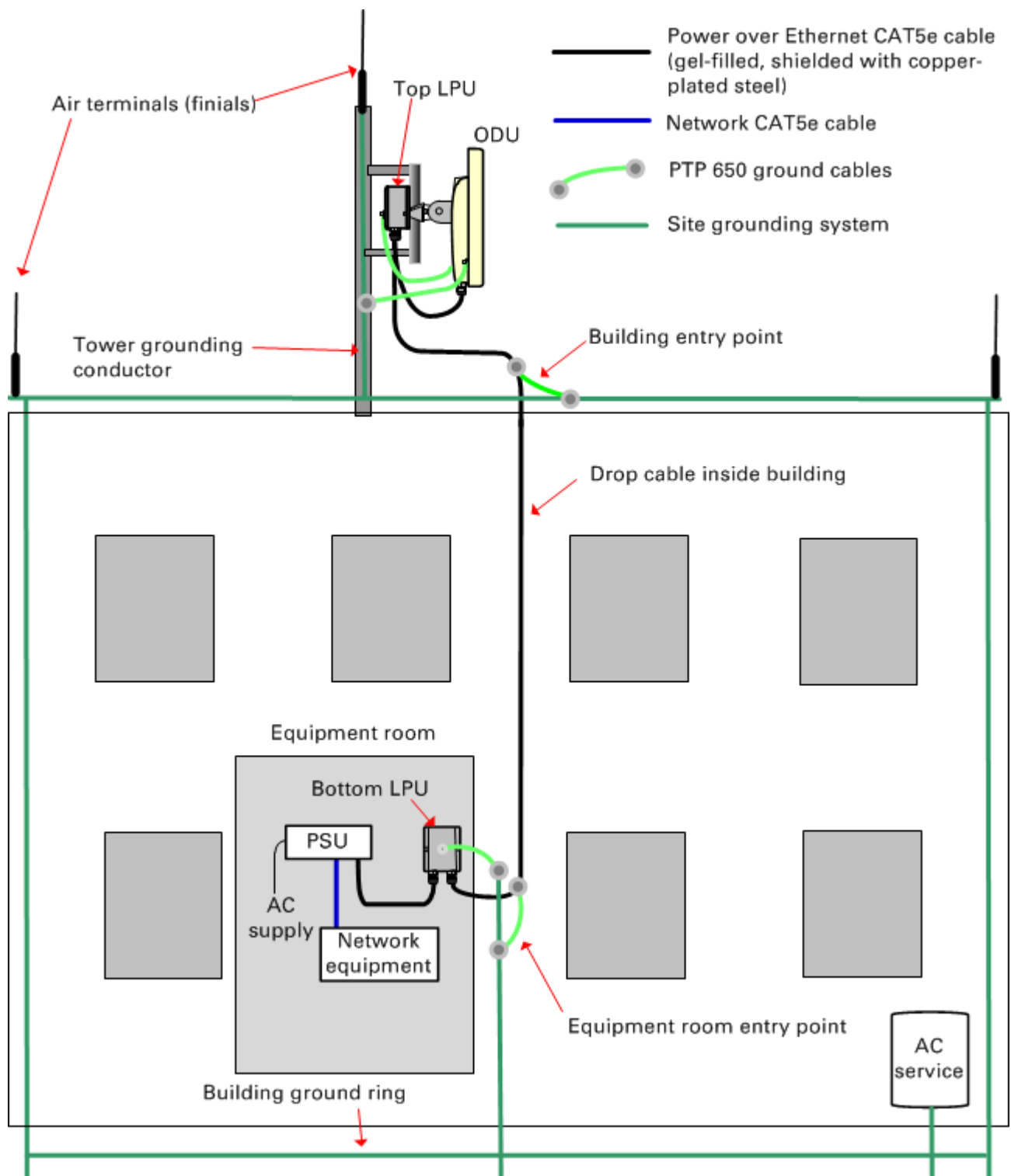


Figure 25 Roof installation

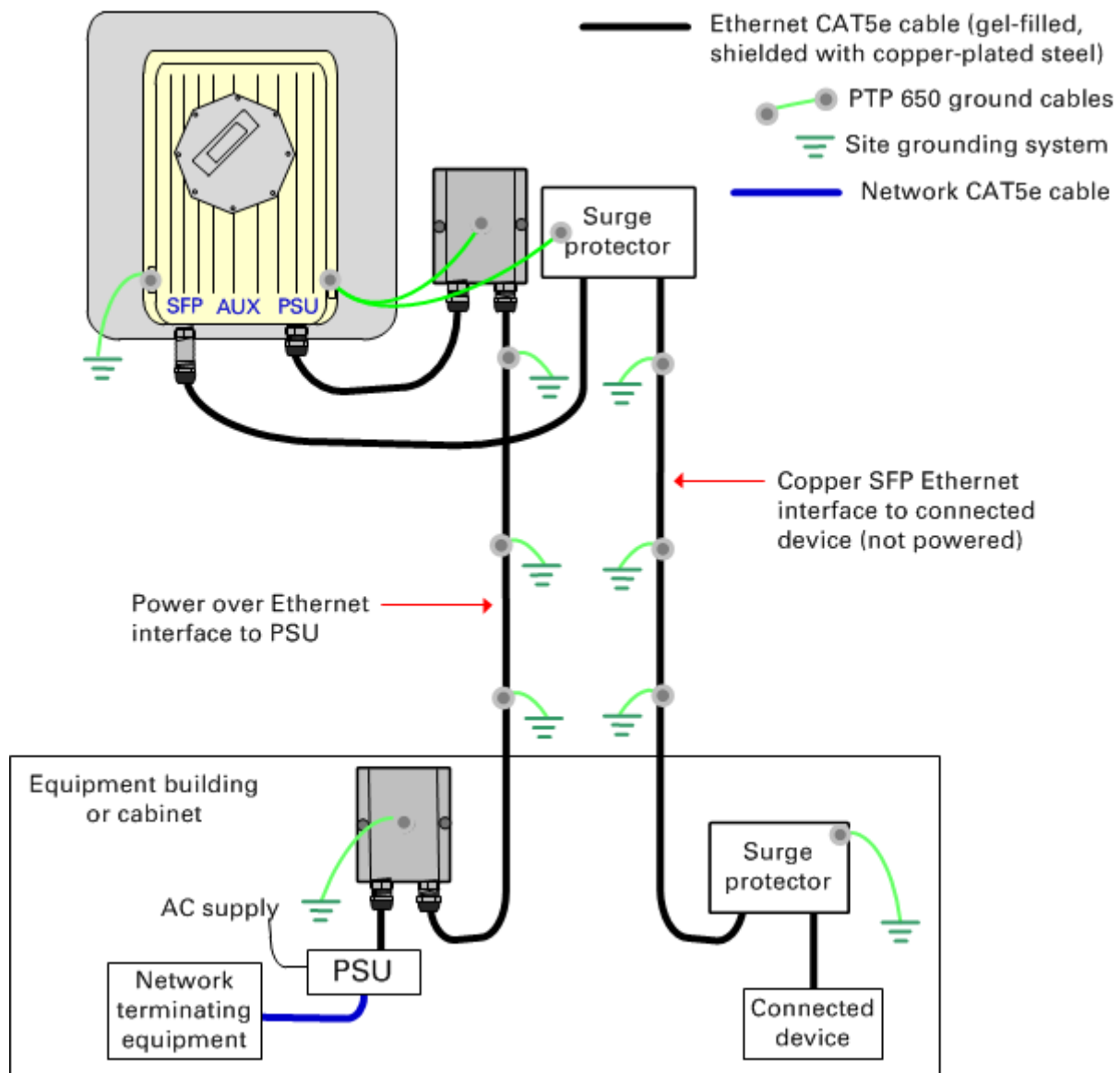


## SFP and Aux Ethernet interfaces

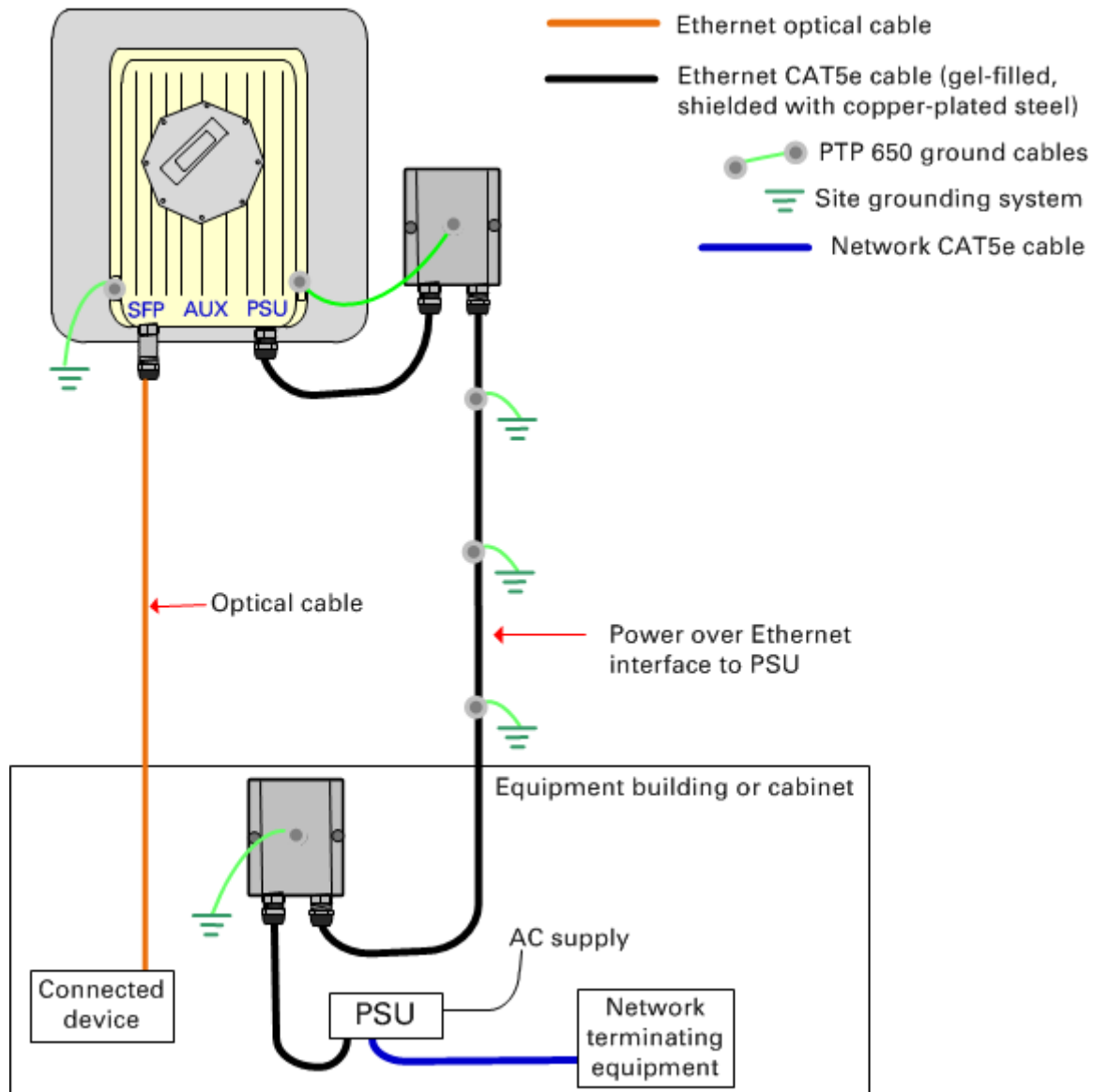
There may be one or two additional Ethernet interfaces connected to the ODU: one to the SFP port (copper or optical) and one to the Aux port, as shown in the following diagrams:

- ODU with copper SFP and PSU interfaces – [Figure 26](#)
- ODU with optical SFP and PSU interfaces – [Figure 27](#)
- ODU with Aux and PSU interfaces – [Figure 28](#)

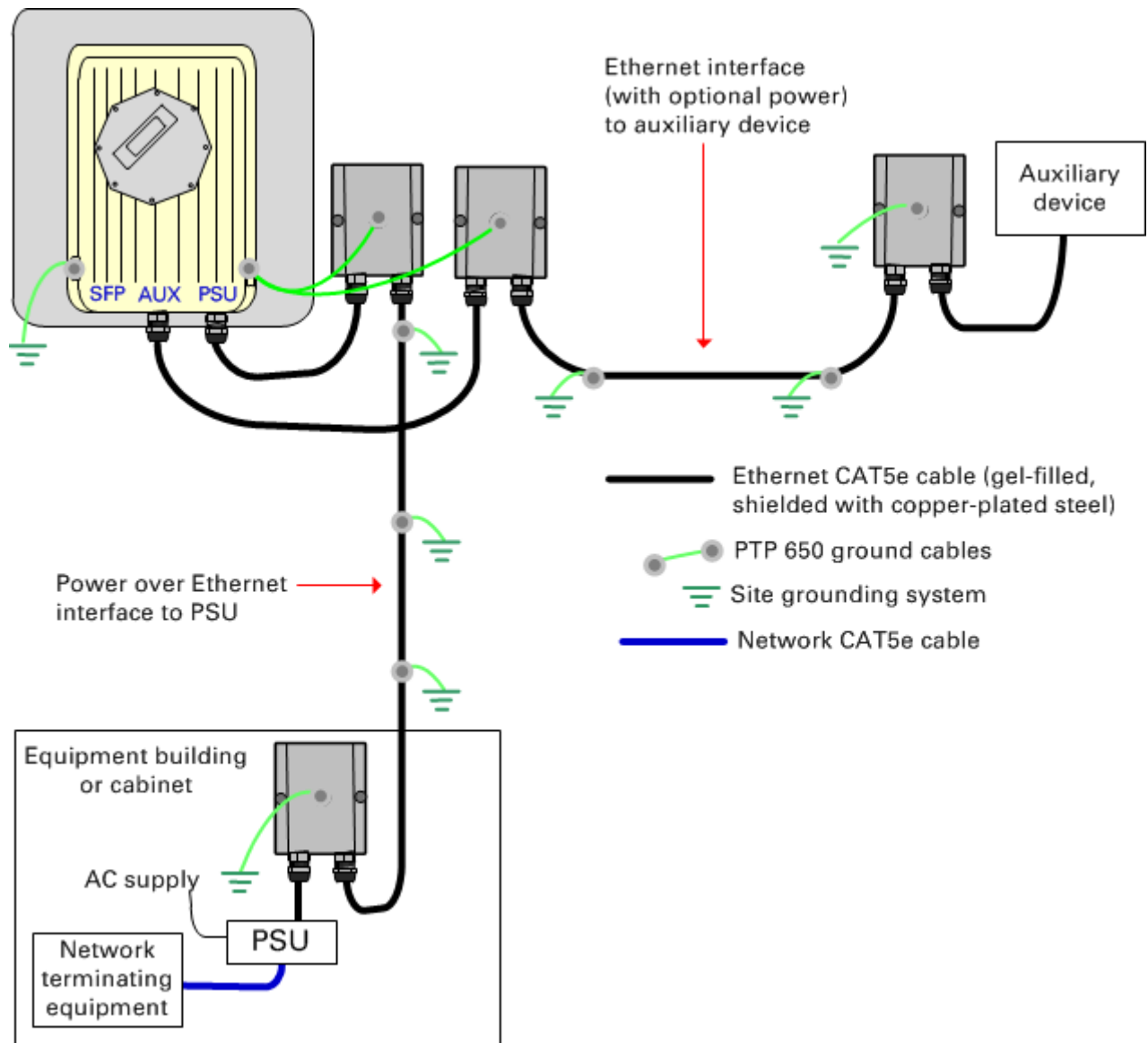
**Figure 26** ODU with copper SFP and PSU interfaces



**Figure 27** ODU with optical SFP and PSU interfaces



**Figure 28** ODU with Aux and PSU interfaces



# Site planning

---

This section describes factors to be considered when planning the proposed link end sites, including grounding, lightning protection and equipment location.

## Grounding and lightning protection

---



### Warning

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

---

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

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

---



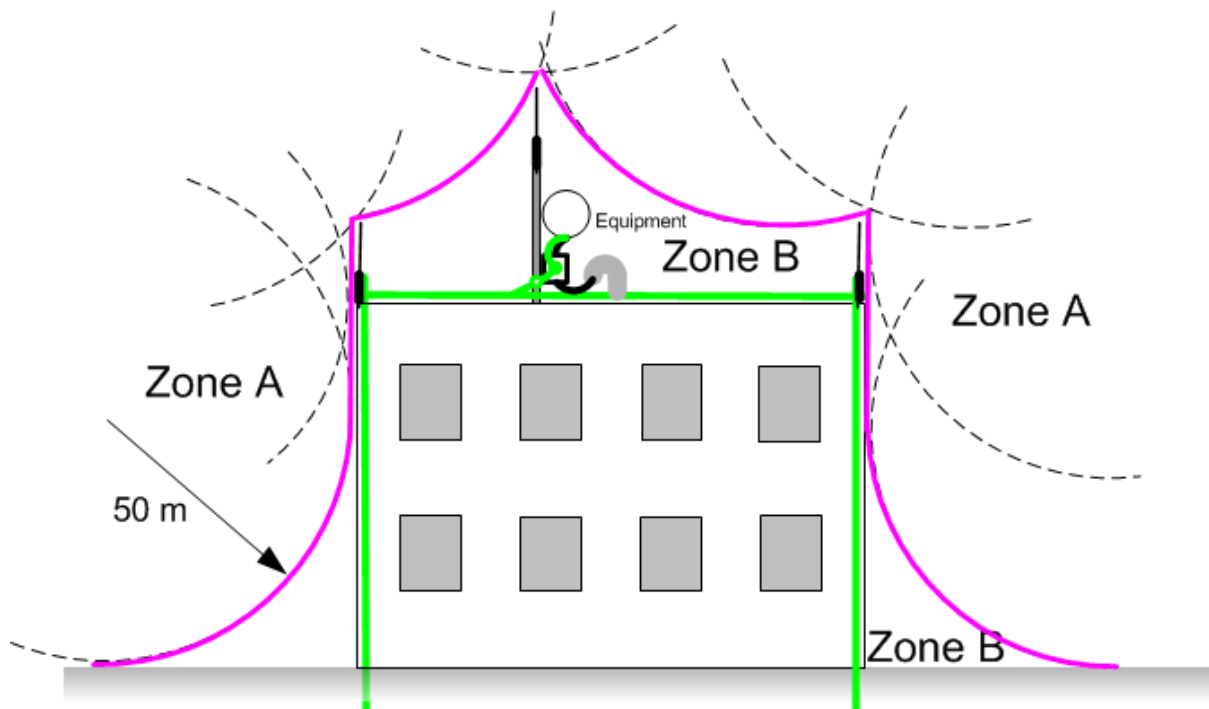
### Note

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

---

## Lightning protection zones

Use the rolling sphere method ([Figure 29](#)) 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 29** Rolling sphere method to determine the lightning protection zones

Assess locations on masts, towers and buildings to determine if the location is in Zone A or Zone B:

- Zone A: In this zone a direct lightning strike is possible. Do not mount equipment in this zone.
- Zone B: In this zone, direct EMD (lightning) effects are still possible, but mounting in this zone significantly reduces the possibility of a direct strike. Mount equipment in this zone.



### Warning

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

## Site grounding system

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

If the outdoor equipment is to be installed on the roof of a high building ([Figure 25](#)), 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 [4-25](#).
- 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 wind loading

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

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

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

$$\text{Force (in kilogrammes)} = 0.1045aV^2$$

**Where:**

a

**Is:**

surface area in square meters

V

wind speed in meters per second

$$\text{Force (in pounds)} = 0.0042Av^2$$

**Where:**

A

**Is:**

surface area in square feet

v

wind speed in miles per hour

Applying these formulae to the PTP 650 ODU at different wind speeds, the resulting wind loadings are shown in [Table 28](#) and [Table 29](#).

**Table 28** ODU wind loading (Kg)

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

**Table 29** ODU wind loading (lb)

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

**Note**

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

## PSU DC power supply

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

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

## PSU location

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

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

Find a location for the AC+DC Enhanced power injector where it can be connected to a mains or DC power supply. The use of DC supplies of less than 55V will reduce the usable distance between the PSU and ODU.

## Drop cable grounding points

To estimate how many grounding kits are required for each drop cable, refer to the site installation diagrams (Figure 23 , Figure 24 and Figure 25) 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 23), 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 25), use the following additional criteria:

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

## LPU location

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

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

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

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

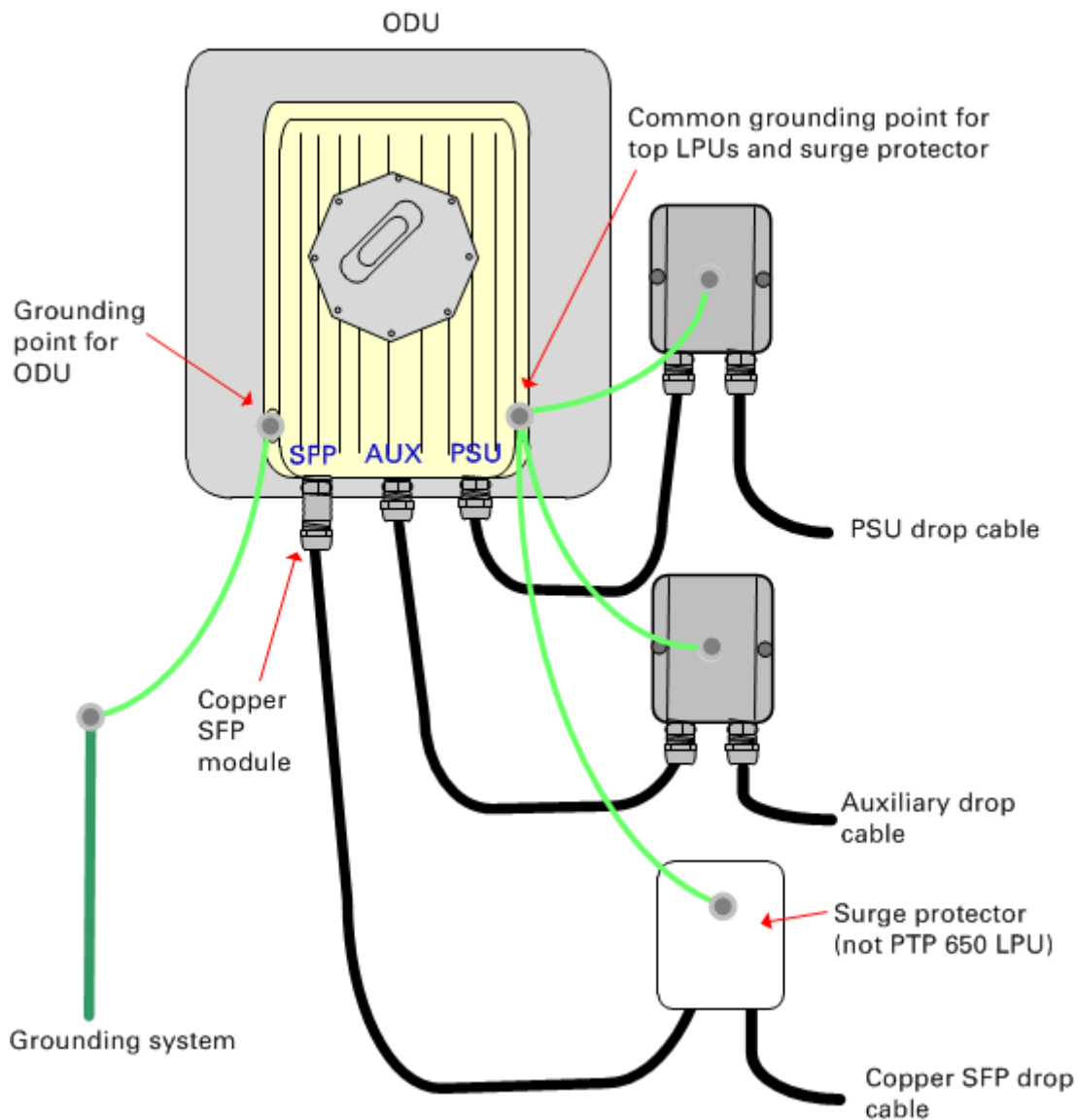
## Multiple LPUs

If two or three drop cables are connected to the ODU, the PSU and Aux drop cables each require their own top LPU, and the copper SFP drop cable requires a top surge protector, not a PTP 650 LPU (Figure 30). Optical cables do not require LPUs or ground cables (Figure 31).

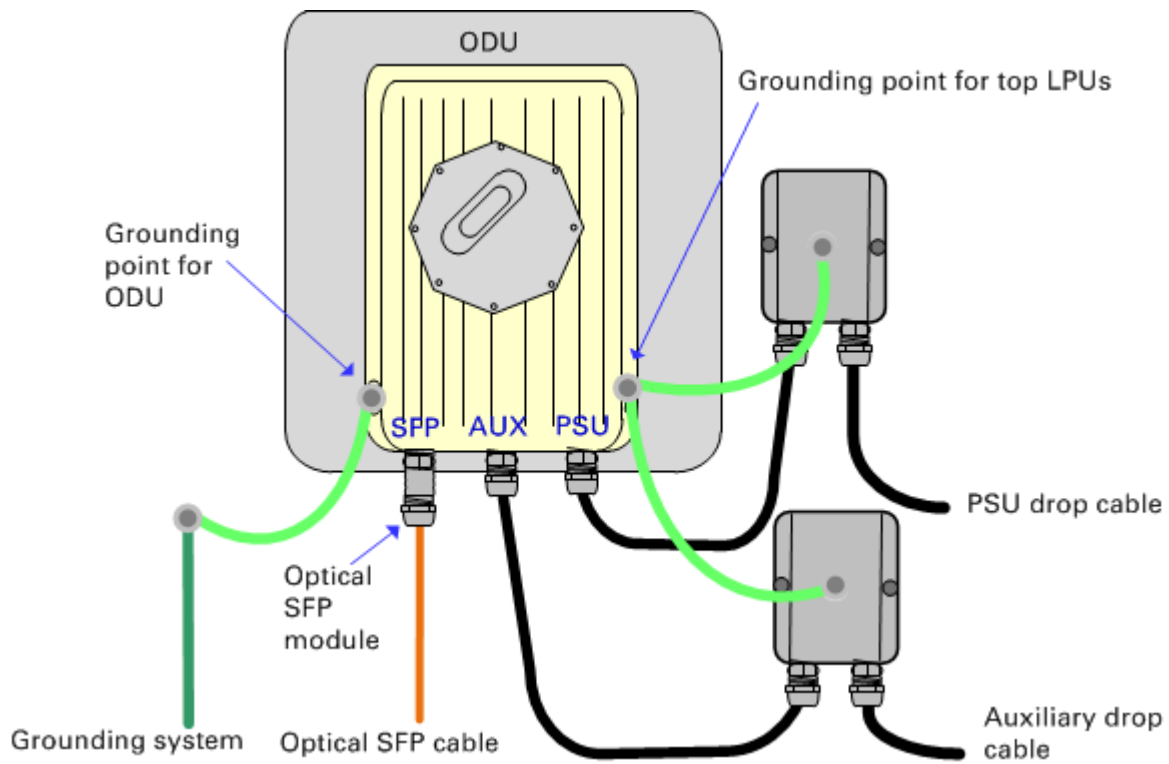
The copper SFP drop cable requires a bottom surge protector, not a PTP 650 LPU (Figure 32).

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

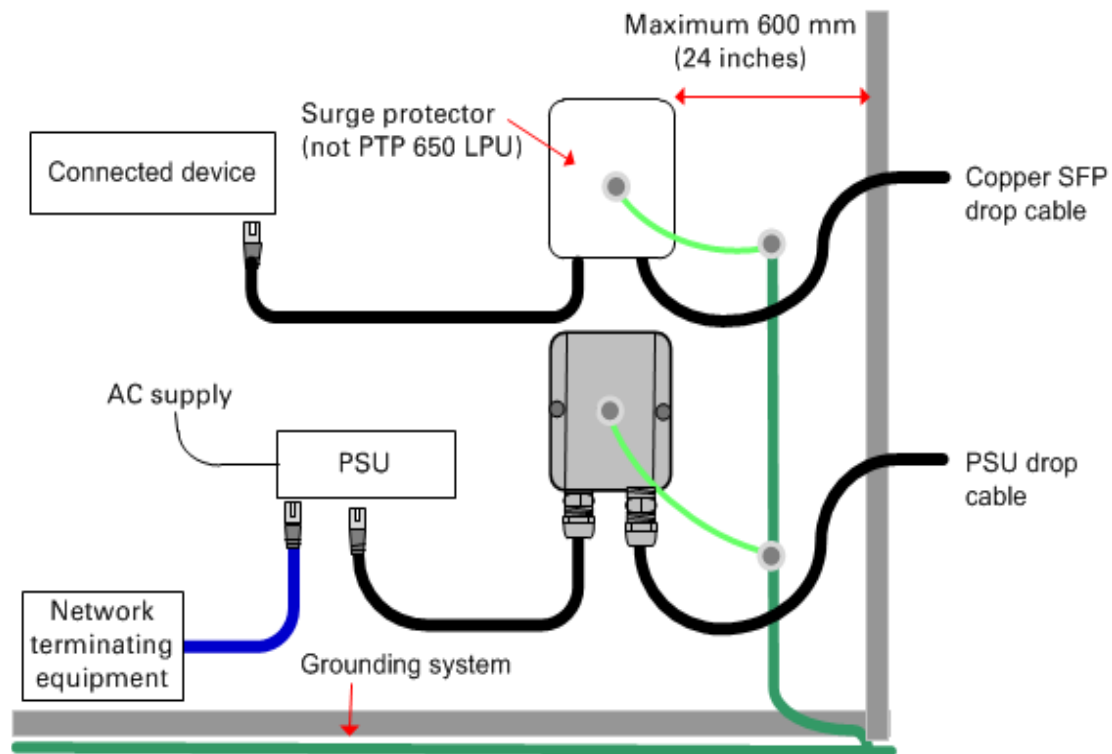
**Figure 30** ODU with PSU, Aux and copper SFP interfaces



**Figure 31** ODU with PSU, Aux and optical SFP interfaces



**Figure 32** Bottom LPU and surge protector



# Radio spectrum planning

---

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



### Caution

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



### Note

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

## General wireless specifications

[Table 30](#) lists the wireless specifications that apply to all PTP 650 frequency bands. [Table 31](#) lists the wireless specifications that are specific to a single frequency band.

**Table 30** PTP 650 wireless specifications (all variants)

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

**Table 31** PTP 650 wireless specifications (per frequency band)

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

## Regulatory limits

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

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

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

## Conforming to the limits

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

- When using connectorized ODUs with external antennas, the regulations may require the maximum transmit power to be reduced.
- When installing 5.2 GHz or 5.4 GHz links in the USA, it may be necessary to avoid frequencies used by Terminal Doppler Weather Radar (TDWR) systems. For more information, refer to [Avoidance of weather radars \(USA only\)](#) on page 3-20.

## 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.



### Note

In Italy, general authorization is required for any 5.4 GHz radio link that is used outside the operator's own premises. It is the responsibility of the installer or operator to have the link authorized. Details may be found at:

[http://www.sviluppoeconomico.gov.it/index.php?option=com\\_content&view=article&idmenu=672&idarea1=593&andor=AND&idarea2=1052&id=68433&sectionid=1,16&viewType=1&showMenu=1&showCat=1&idarea3=0&andorcat=AND&partebassaType=0&idareaCalendario1=0&MvediT=1&idarea4=0&showArchiveNewsBotton=0&directionidUser=0](http://www.sviluppoeconomico.gov.it/index.php?option=com_content&view=article&idmenu=672&idarea1=593&andor=AND&idarea2=1052&id=68433&sectionid=1,16&viewType=1&showMenu=1&showCat=1&idarea3=0&andorcat=AND&partebassaType=0&idareaCalendario1=0&MvediT=1&idarea4=0&showArchiveNewsBotton=0&directionidUser=0)

The form to be used for general authorization may be found at:

[http://www.sviluppoeconomico.gov.it/images/stories/mise\\_extra/Allegato%20n19.doc](http://www.sviluppoeconomico.gov.it/images/stories/mise_extra/Allegato%20n19.doc)

Certain regulations have allocated certain channels as unavailable for use:

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

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

Barred channels are indicated by a "No Entry" symbol displayed on the Spectrum Management web page ([Spectrum management in radar avoidance mode](#) on page 7-27).

## 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 there are no sources of interference on the selected channels.

### Regions with mandatory radar detection

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

In DFS regions, choose **DFS** or **DFS with DSO**:

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

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

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

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

## Avoidance of weather radars (USA only)

To comply with FCC rules (KDB 443999: Interim Plans to Approve UNII Devices Operating in the 5470 - 5725 MHz Band with Radar Detection and DFS Capabilities), units which are installed within 35 km (22 miles) of a Terminal Doppler Weather Radar (TDWR) system (or have a line of sight propagation path to such a system) must be configured to avoid any frequency within +30 MHz or -30 MHz of the frequency of the TDWR device. This requirement applies even if the master is outside the 35 km (22 miles) radius but communicates with outdoor clients which may be within the 35 km (22 miles) radius of the TDWRs.

If interference is not eliminated, a distance limitation based on line-of-sight from TDWR will need to be used. Devices with bandwidths greater than 20 MHz may require greater frequency separation.

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

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

The affected channels must be barred as described in [Barring channels](#) on page 7-31.

# Link planning

---

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

## PTP LINKPlanner

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

PTP 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. The installation report can be used to compare the predicted and actual performance of the link.

## Range and obstacles

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

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

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

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

## LoS links in radar regions

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

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

## 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 3-41.

## 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 1500 octet. Data rate capacity is determined by the following factors:

- Licensed data throughput capability (ODU variant: Lite, Mid or Full)
- Link Symmetry
- Link Mode Optimization (IP or TDM)
- Modulation Mode
- Channel Bandwidth
- Link Range

### Calculation procedure

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

- 1 Use the tables in [Data throughput capacity tables](#) on page 3-49 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

The tables contain data rates for PTP 650 Full only.

- 2 The tables contain data rates for links of zero range. Use the range adjustment graphs in [Data throughput capacity tables](#) on page 3-49 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.



#### Note

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

---

## Calculation example

Suppose that the link characteristics are:

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

The calculation procedure for this example is as follows:

- 1 Use [Table 55](#) to look up the data throughput capacity rates:

Tx = 23 Mbits/s

Rx = 23 Mbits/s

Aggregated = 46 Mbits/s

- 2 Use [Figure 40](#) to look up the Throughput Factor for 1:1, TDM, 10 MHz, Mid and Link Range 60 km. The factor is 0.86.

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

Tx = 19.8 Mbits/s

Rx = 19.8 Mbits/s

Aggregated = 39.6 Mbits/s

# Planning for connectorized units

---

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

## When to install connectorized units

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

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

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

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

## Choosing external antennas

When selecting external antennas, consider the following factors:

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



### Note

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

---

**Note**

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

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

## Calculating RF cable length (5.8 GHz FCC only)

The 5.8 GHz band FCC approval for the product is based on tests with a cable loss between the ODU and antenna of not less than 1.2 dB. If cable loss is below 1.2 dB with a 1.3 m (6 ft) diameter external antenna, the connectorized PTP 650 may exceed the maximum radiated spurious emissions allowed under FCC 5.8 GHz rules.

Cable loss depends mainly upon cable type and length. To meet or exceed the minimum loss of 1.2 dB, use cables of the type and length specified in [Table 32](#) (source: Times Microwave). This data excludes connector losses.

**Table 32** 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)



# Data network planning

---

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

## Ethernet interfaces

The PTP 650 Ethernet ports conform to the specifications listed in [Table 33](#).

**Table 33** PTP 650 Ethernet bridging specifications

Ethernet Bridging	Specification
Protocol	IEEE802.1; IEEE802.1p; IEEE802.3 compatible
QoS	Eight wireless interface priority queues based on these standards: IEEE 802.1p, IEEE 802.1Q, IEEE 802.1ah, IEEE 802.1ad, DSCP IPv4, DSCP IPv6, MPLS TC
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 2 control protocols

PTP 650 identifies L2 control protocols from the Ethernet destination address of bridged frames:

**Table 34** Destination address in layer 2 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

Decide how the three Ethernet ports will be allocated to the customer data network, in-band management and out-of-band local management, based on the following rules:

- Ensure that one port is allocated to Data Only or Data and In-Band Management. This port should be associated with the customer data network.
- Ensure that the remaining ports are set to Disabled or Out-of-Band Local Management.
- Ensure that at least one port is allocated for in-band or out-of-band network management. This port should be associated with the management network.



### Note

The Main PSU port is always used to supply power to the ODU, even when it is Disabled for the purpose of Ethernet port allocation.

---

## 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.

## Priority for management traffic

Choose the Ethernet and IP (DSCP) priority for management traffic generated within the ODU management agent. The priority should be selected so as to be consistent with existing policy on priority of management traffic in the network. Use of a high priority is strongly recommended to ensure that management traffic is not discarded if the link is overloaded.

Ensure that the priority assigned to management traffic is consistent with the quality of service scheme configured for bridged Ethernet traffic. If QoS for bridged traffic is based on the IP/MPLS scheme, set the DSCP management priority to map to a high priority queue. If QoS for bridged traffic is based on the Ethernet scheme, set the VLAN management priority to map to a high priority queue.

## IP interface

Select the IP version for the IP interface of the ODU management agent. PTP 650 can operate in IPv4 mode, IPv6 mode, or in a dual IPv4/IPv6 mode. Choose one IPv4 address and/or one IPv6 address for the IP interface of the ODU management agent. The IP address or addresses must be unique and valid for the connected network segment and VLAN.

Find out the correct subnet mask (IPv4) or prefix length (IPv6) and gateway IP address for this network segment and VLAN.

Ensure that the design of the data network permits bidirectional routing of IP datagrams between network management systems and the ODUs. For example, ensure that the gateway IP address identifies a router or other gateway that provides access to the rest of the data network.

## Quality of service for bridged Ethernet traffic

Decide how quality of service will be configured in PTP 650 to minimize frame loss and latency for high priority traffic. Wireless links often have lower data capacity than wired links or network equipment like switches and routers, and quality of service configuration is most critical at network bottlenecks.

PTP 650 provides eight queues for traffic waiting for transmission over the wireless link. Q0 is the lowest priority queue and Q7 is the highest priority queue. Traffic is scheduled using strict priority; in other words, traffic in a given queue is transmitted when all higher-priority queues are empty.

## Layer 2 control protocols

Select the transmission queue for each of the recognised layer 2 control protocols (L2CP). These protocols are essential to correct operation of the Ethernet network, and are normally mapped to a high priority queue. Ethernet frames that match one of the recognized L2CPs are not subject to the Ethernet and IP/MPLS classification described below.

## Priority schemes

Select the priority scheme based on Ethernet priority or IP/MPLS priority to match QoS policy in the rest of the data network. Ethernet priority is also known as Layer 2 or link layer priority. IP/MPLS priority is also known as Layer 3 or network layer priority.

## Ethernet priority scheme

Ethernet priority is encoded in a VLAN tag. Use the Ethernet priority scheme if the network carries traffic in customer or service provider VLANs, and the priority in the VLAN tag has been set to indicate the priority of each type of traffic. Select a suitable mapping from the Ethernet priority to the eight PTP 650 queues.

An advantage of Ethernet priority is that any VLAN-tagged frame can be marked with a priority, regardless of the higher-layer protocols contained within the frame. A disadvantage of Ethernet priority is that the priority in the frame must be regenerated whenever traffic passes through a router.

## IP/MPLS priority scheme

IP priority is encoded in the DSCP value encoded in the ToS field in IPv4 and Traffic Class in IPv6. The DSCP field provides 64 levels of priority. Determine the DSCP values used in the network and select a suitable mapping from these DSCP values to the eight PTP 650 queues.

The advantages of IP priority are that priority in the IP header is normally propagated transparently through a router, also the DSCP field supports a large number of distinct priority code points. A disadvantage of DSCP is that frames receive a single default classification if they contain a network layer protocol other than IPv4 or IPv6. This is controlled by the user setting the Unknown Network Layer Protocol queue value in the same QoS Configuration page under IP/MPLS QoS.

MPLS priority is encoded in the traffic class (TC) field in the outermost MPLS label. Select a suitable mapping from MPLS TC to the eight PTP 650 queues.

## “Daisy-chaining” PTP 650 links

When connecting two or more PTP 650 links together in a network (daisy-chaining), do not install direct copper Cat5e connections between the PSUs. Each PSU must be connected to the network terminating equipment using the LAN port. To daisy-chain PTP 650 links, install each ODU-to-ODU link using one of the following solutions:

- A copper Cat5e connection between the Aux ports of two ODUs. For details of the Ethernet standards supported and maximum permitted cable lengths, see [Ethernet standards and cable lengths](#) on page 2-28.
- 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 2-28.
- 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 2-35.

## Green Ethernet switches

Do not connect PTP 650 units to Ethernet networking products that control the level of the transmitted Ethernet signal based on the measured length of the Ethernet link, for example Green Ethernet products manufactured by D-Link Corporation. The Ethernet interfaces in these networking products do not work correctly when connected directly to the PTP 650 PSU.

# Network management planning

---

This section describes how to plan for PTP 650 links to be managed remotely using SNMP.

## Planning for SNMP operation

The supported notifications are as follows:

- Cold start
- Wireless Link Up/Down
- Channel Change
- DFS Impulse Interference
- Authentication Failure
- Main PSU Port Up Down
- Aux Port Up Down
- SFP Port Up Down

Ensure that the following MIBs are loaded on the network management system.

- RFC-1493. BRIDGE-MIB
- RFC-2233. IF-MIB
- RFC-3411. SNMP-FRAMEWORK-MIB
- RFC-3412. SNMP-MPD-MIB
- RFC-3413. SNMP-TARGET-MIB
- RFC-3414. SNMP-USER-BASED-SM-MIB
- RFC-3415. SNMP-VIEW-BASED-ACM-MIB
- RFC-3418. SNMPv2-MIB
- RFC-3826. SNMP-USM-AES-MIB
- RFC-4293 IP-MIB
- PTP 650 Series proprietary MIB



### Note

The proprietary MIBs are provided in the PTP 650 Series software download files in the support website (see [Contacting Cambium Networks](#) on page 1).

---

## Supported diagnostic alarms

PTP 650 supports the diagnostic alarms listed in [Table 108](#).

The web-based interface may be used to enable or disable generation of each supported SNMP notification or diagnostic alarm.

## Enabling SNMP

Enable the SNMP interface for use by configuring the following attributes in the SNMP Configuration page:

- SNMP State (default disabled)
- SNMP Version (default SNMPv1/2c)
- SNMP Port Number (default 161)

# Security planning

---

This section describes how to plan for PTP 650 links to operate in secure mode.

## Planning for SNTP operation



### Note

PTP 650 does not have a battery-powered clock, so the set time is lost each time the ODU is powered down. To avoid the need to manually set the time after each reboot, use SNTP server synchronization.

Before starting to configure Simple Network Time Protocol (SNTP):

- Identify the time zone and daylight saving requirements that apply to the system.
- If SNTP server synchronization is required, identify the details of one or two SNTP servers: IP address, port number and server key.
- Decide whether or not to authenticate received NTP messages using an MD5 signature.

## Planning for HTTPS/TLS operation

Before starting to configure HTTPS/TLS operation, ensure that the cryptographic material listed in [Table 35](#) is available.

**Table 35** 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	<p>An RSA private key of size 2048 bytes, generated in either PKCS#1 or PKCS#5 format, unencrypted, and encoded in the ASN.1 DER format.</p> <p>An X.509 certificate containing an RSA public key, generated in either PKCS#1 or PKCS#5 format, unencrypted, and encoded in the ASN.1 DER format.</p> <p>The public key certificate must have Common Name equal to the IPv4 or IPv6 address of the ODU.</p> <p>The public key certificate must form a valid pair with the private key.</p>	Two pairs per link. These items are unique to IP address.
User Defined Security Banner	The banner provides warnings and notices to be read by the user before logging in to the ODU. Use text that is appropriate to the network security policy.	Normally one per link. This depends upon network policy.
Entropy Input	This must be of size 512 bits (128 hexadecimal characters), output from a random number generator.	Two per link. For greater security, each link end should be allocated a unique Entropy Input.
Wireless Link Encryption Key for AES	An encryption key generated using a cryptographic key generator. The key length is dictated by the selected AES encryption algorithm (128 or 256 bits).	One per link. The same encryption key is required at each link end.
Port numbers for HTTP, HTTPS and Telnet	Port numbers allocated by the network.	As allocated by network.



## Planning for SNMPv3 operation

### SNMP security mode

Decide how SNMPv3 security will be configured.

MIB-based security management uses standard SNMPv3 MIBs to configure the user-based security model and the view-based access control model. This approach provides considerable flexibility, allowing a network operator to tailor views and security levels appropriate for different types of user. MIB-based security management may allow a network operator to take advantage of built-in security management capabilities of existing network managers.

Web-based security management allows an operator to configure users, security levels, privacy and authentication protocols, and passphrases using the PTP 650 web-based management interface. The capabilities supported are somewhat less flexible than those supported using the MIB-based security management, but will be sufficient in many applications. Selection of web-based management for SNMPv3 security disables the MIB-based security management. PTP 650 does not support concurrent use of MIB-based and web-based management of SNMPv3 security.

### Web-based management of SNMPv3 security

Initial configuration of SNMPv3 security is available only to HTTP or HTTPS/TLS user accounts with security role of Security Officer.

Identify the minimum security role of HTTP or HTTPS/TLS user accounts that will be permitted access for web-based management of SNMPv3 security. The following roles are available:

- System Administrator
- Security Officer

Identify the format used for SNMP Engine ID. The following formats are available:

- MAC address (default)
- IPv4 address
- Text string
- IPv6 address

If SNMP Engine ID will be based on a text string, identify the text string required by the network management system. This is often based on some identifier that survives replacement of the PTP hardware.

Identify the user names and security roles of initial SNMPv3 users. Two security roles are available:

- Read Only
- System Administrator

Identify the security level for each of the security roles. Three security levels are available: (a) No authentication, no privacy; (b) Authentication, no privacy; (c) Authentication, privacy.

If authentication is required, identify the protocol. Two authentication protocols are available: MD5 or SHA.

If privacy will be used, identify the protocol. Two privacy protocols are available: DES or AES (an AES 128-bit or 256-bit capability upgrade must be purchased).

If authentication or authentication and privacy protocols are required, identify passphrases for each protocol for each SNMP user. It is considered good practice to use different passphrases for authentication and privacy. Passphrases must have length between 8 and 32 characters, and may contain any of the characters listed in [Table 36](#).

**Table 36** 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 37](#).

**Table 37** 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	usmHMACSHAAuthProtocol
PrivProtocol	usmDESPrivProtocol	usmDESPrivProtocol
StorageType	nonVolatile	nonVolatile

Object	Entry 4	Entry 5
Name	templateMD5_AES	templateSHA_AES
SecurityName	templateMD5_AES	templateSHA_AES
AuthProtocol	usmHMACMD5AuthProtocol	usmHMACSHAAuthProtocol
PrivProtocol	usmAESPrivProtocol	usmAESPrivProtocol
StorageType	nonVolatile	nonVolatile

## VACM default configuration

The default user `initial` is assigned to VACM group `initial` in the `vacmSecurityToGroupTable` table. The template users are not assigned to a group.

PTP 650 creates default view trees and access as shown in [Table 38](#) and [Table 39](#).

**Table 38** 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 39** Default data fill for access table

Object	Entry 1	Entry 2
GroupName	initial	initial
ContextPrefix	""	""
SecurityLevel	authNoPriv	noAuthNoPriv
ContextMatch	exact	exact
ReadViewName	internet	restricted
WriteViewName	internet	""
NotifyViewName	internet	restricted
StorageType	nonVolatile	nonVolatile

## Planning for RADIUS operation

Configure RADIUS where remote authentication is required for users of the web-based interface. Remote authentication has the following advantages:

- Control of passwords can be centralized.
- Management of user accounts can be more sophisticated. For example; users can be prompted by a network manager to change passwords at regular intervals. As another example, passwords can be checked for inclusion of dictionary words and phrases.
- Passwords can be updated without reconfiguring multiple network elements.
- User accounts can be disabled without reconfiguring multiple network elements.

Remote authentication has one significant disadvantage in a wireless link product such as PTP 650. If the wireless link is down, a unit on the remote side of the broken link may be prevented from contacting a RADIUS Server, with the result that users are unable to access the web-based interface.

One useful strategy would be to combine RADIUS authentication for normal operation with a single locally-authenticated user account for emergency use.

PTP 650 provides a choice of the following authentication methods:

- CHAP
- MS-CHAPv2

Ensure that the authentication method selected in PTP 650 is supported by the RADIUS server.

## RADIUS attributes

If the standard RADIUS attribute session-timeout (Type 27) is present in a RADIUS response, PTP 650 sets a maximum session length for the authenticated user. If the attribute is absent, the maximum session length is infinite.

If the standard RADIUS attribute idle-timeout (Type 28) is present in a RADIUS response, PTP 650 overrides the Auto Logout Timer with this value in the authenticated session.

If the vendor-specific RADIUS attribute auth-role is present in a RADIUS response, PTP 650 selects the role for the authenticated user according to auth-role. The supported values of auth-role are as follows:

- 0: Invalid role. The user is not admitted.
- 1: Read Only
- 2: System Administrator
- 3: Security Officer

If the vendor-specific auth-role attribute is absent, but the standard service-type (Type 6) attribute is present, PTP 650 selects the role for the authenticated user according to service-type. The supported values of service-type are as follows:

- Login(1): Read Only
- Administrative(6): System Administrator
- NAS Prompt(7): Read Only

If the auth-role and service-type attributes are absent, PTP 650 selects the Read Only role.

The auth-role vendor-specific attribute is defined in [Table 40](#).

**Table 40** Definition of auth-role vendor-specific attribute

Field	Length	Value	Notes
Type	1	26	Vendor-specific attribute.
Length	1	12	Overall length of the attribute.
Vendor ID	4	17713	The same IANA code used for the SNMP enterprise MIB.
Vendor Type	1	1	auth-role
Vendor Length	1	4	Length of the attribute specific part.
Attribute-Specific	4	0..3	Integer type (32-bit unsigned). Supported values: invalid-role(0), readonly-role(1), system-admin-role(2), security-officer-role(3).

## System threshold, output power and link loss

The following tables specify the system threshold (dBm), output power (dBm) and maximum link loss (dB) per channel bandwidth and modulation mode:

- [Table 41](#) - 4.9 GHz - IP mode
- [Table 42](#) - 4.9 GHz - TDM mode
- [Table 45](#) - 5.4 GHz - IP mode
- [Table 46](#) - 5.4 GHz - TDM mode
- [Table 47](#) - 5.8 GHz - IP mode
- [Table 48](#) - 5.8 GHz - TDM mode

**Table 41** 4.9 GHz - IP mode - threshold, power and link loss

Modulation mode	System threshold (dBm) per channel bandwidth		Output power (dBm)	Maximum link loss (dB) per channel bandwidth	
	10 MHz	20 MHz	All bands	10 MHz	20 MHz
BPSK 0.63 single	-95.7	-92.5	+27	168.7	165.5
QPSK 0.63 single	-90.0	-88.4	+26	163.0	161.4
QPSK 0.87 single	-86.9	-84.8	+26	159.9	157.8
16QAM 0.63 single	-84.7	-82.8	+25	156.7	154.8
16QAM 0.63 dual	-81.8	-79.1	+25	153.8	151.1
16QAM 0.87 single	-80.5	-78.1	+25	152.5	150.1
16QAM 0.87 dual	-77.6	-75.1	+25	149.6	147.1
64QAM 0.75 single	-77.3	-75.0	+24	148.3	146.0
64QAM 0.75 dual	-74.7	-72.1	+24	145.7	143.1
64QAM 0.92 single	-73.2	-70.7	+24	144.2	141.7
64QAM 0.92 dual	-70.2	-67.6	+24	141.2	138.6
256QAM 0.81 single	-69.9	-67.5	+23	138.9	136.5
256QAM 0.81 dual	-66.8	-64.1	+23	135.8	133.1

**Table 42** 4.9 GHz - TDM mode - threshold, power and link loss

Modulation mode	System threshold (dBm) per channel bandwidth		Output power (dBm)	Maximum link loss (dB) per channel bandwidth	
	10 MHz	20 MHz	All bands	10 MHz	20 MHz
BPSK 0.63 single	-92.5	-93.4	27	165.5	166.4
QPSK 0.63 single	-87.6	-86.1	26	160.6	159.1
QPSK 0.87 single	-84.2	-82.0	26	157.2	155.0
16QAM 0.63 single	-81.6	-79.7	25	153.6	151.7
16QAM 0.63 dual	-78.4	-76.2	25	150.4	148.2
16QAM 0.87 single	-77.4	-75.0	25	149.4	147.0
16QAM 0.87 dual	-74.4	-71.7	25	146.4	143.7
64QAM 0.75 single	-73.5	-71.3	24	144.5	142.3
64QAM 0.75 dual	-71.1	-68.3	24	142.1	139.3
64QAM 0.92 single	-69.6	-67.0	24	140.6	138.0
64QAM 0.92 dual	-66.9	-64.3	24	137.9	135.3
256QAM 0.81 single	-69.4	-67.2	23	138.4	136.2
256QAM 0.81 dual	-64.3	-63.2	23	133.3	132.2



**Table 43** 5.2 GHz - IP mode - threshold, power and link loss

Modulation mode	System threshold (dBm) per channel bandwidth				Output power (dBm)	Maximum link loss (dB) per channel bandwidth			
	10 MHz	20 MHz	40 MHz	45 MHz		All bands	10 MHz	20 MHz	40 MHz
BPSK 0.63 single	-96.3	-93.4	-90.7	-90.1	27	169.3	166.4	163.7	163.1
QPSK 0.63 single	-90.8	-88.8	-85.7	-85.2	26	163.8	161.8	158.7	158.2
QPSK 0.87 single	-87.2	-85.3	-82.0	-81.2	26	160.2	158.3	155.0	154.2
16QAM 0.63 single	-85.2	-83.2	-79.9	-79.3	25	157.2	155.2	151.9	151.3
16QAM 0.63 dual	-81.9	-79.6	-76.4	-76.2	25	153.9	151.6	148.4	148.2
16QAM 0.87 single	-81.0	-78.7	-75.4	-74.8	25	153.0	150.7	147.4	146.8
16QAM 0.87 dual	-77.9	-75.1	-72.0	-72.1	25	149.9	147.1	144.0	144.1
64QAM 0.75 single	-77.7	-75.7	-72.4	-71.7	24	148.7	146.7	143.4	142.7
64QAM 0.75 dual	-75.1	-72.1	-69.1	-69.1	24	146.1	143.1	140.1	140.1
64QAM 0.92 single	-73.7	-71.5	-68.3	-67.4	24	144.7	142.5	139.3	138.4
64 QAM 0.92 dual	-70.7	-67.9	-64.9	-64.5	24	141.7	138.9	135.9	135.5
256QAM 0.81 single	-70.5	-68.6	-65.4	-64.9	23	139.5	137.6	134.4	133.9
256QAM 0.81 dual	-67.7	-64.9	-61.8	-62.0	23	136.7	133.9	130.8	131.0

**Table 44** 5.2 GHz - TDM mode - threshold, power and link loss

Modulation mode	System threshold (dBm) per channel bandwidth				Output power (dBm)	Maximum link loss (dB) per channel bandwidth			
	10 MHz	20 MHz	40 MHz	45 MHz		All bands	10 MHz	20 MHz	40 MHz
BPSK 0.63 single	-96.4	-93.5	-90.3	-90.0	27	169.4	166.5	163.3	163.0
QPSK 0.63 single	-87.9	-86.4	-83.2	-82.8	26	160.9	159.4	156.2	155.8
QPSK 0.87 single	-84.8	-82.4	-79.1	-78.7	26	157.8	155.4	152.1	151.7
16QAM 0.63 single	-82.6	-80.0	-76.9	-76.4	25	154.6	152.0	148.9	148.4
16QAM 0.63 dual	-78.7	-76.3	-73.4	-73.0	25	150.7	148.3	145.4	145.0
16QAM 0.87 single	-78.2	-75.6	-72.3	-71.9	25	150.2	147.6	144.3	143.9
16QAM 0.87 dual	-74.8	-72.0	-69.0	-68.9	25	146.8	144.0	141.0	140.9
64QAM 0.75 single	-74.3	-72.0	-68.9	-68.5	24	145.3	143.0	139.9	139.5
64QAM 0.75 dual	-71.3	-68.6	-65.7	-65.6	24	142.3	139.6	136.7	136.6
64QAM 0.92 single	-70.1	-68.0	-65.0	-64.5	24	141.1	139.0	136.0	135.5
64 QAM 0.92 dual	-67.3	-64.6	-61.1	-61.6	24	138.3	135.6	132.1	132.6
256QAM 0.81 single	-70.5	-68.2	-65.0	-64.7	23	139.5	137.2	134.0	133.7
256QAM 0.81 dual	-66.9	-64.1	-61.3	-61.2	23	135.9	133.1	130.3	130.2

**Table 45** 5.4 GHz - IP mode - threshold, power and link loss

Modulation mode	System threshold (dBm) per channel bandwidth				Output power (dBm)	Maximum link loss (dB) per channel bandwidth			
	10 MHz	20 MHz	40 MHz	45 MHz		All bands	10 MHz	20 MHz	40 MHz
BPSK 0.63 single	-96.3	-93.4	-90.7	-90.1	27	169.3	166.4	163.7	163.1
QPSK 0.63 single	-90.8	-88.8	-85.7	-85.2	26	163.8	161.8	158.7	158.2
QPSK 0.87 single	-87.2	-85.3	-82.0	-81.2	26	160.2	158.3	155.0	154.2
16QAM 0.63 single	-85.2	-83.2	-79.9	-79.3	25	157.2	155.2	151.9	151.3
16QAM 0.63 dual	-81.9	-79.6	-76.4	-76.2	25	153.9	151.6	148.4	148.2
16QAM 0.87 single	-81.0	-78.7	-75.4	-74.8	25	153.0	150.7	147.4	146.8
16QAM 0.87 dual	-77.9	-75.1	-72.0	-72.1	25	149.9	147.1	144.0	144.1
64QAM 0.75 single	-77.7	-75.7	-72.4	-71.7	24	148.7	146.7	143.4	142.7
64QAM 0.75 dual	-75.1	-72.1	-69.1	-69.1	24	146.1	143.1	140.1	140.1
64QAM 0.92 single	-73.7	-71.5	-68.3	-67.4	24	144.7	142.5	139.3	138.4
64 QAM 0.92 dual	-70.7	-67.9	-64.9	-64.5	24	141.7	138.9	135.9	135.5
256QAM 0.81 single	-70.5	-68.6	-65.4	-64.9	23	139.5	137.6	134.4	133.9
256QAM 0.81 dual	-67.7	-64.9	-61.8	-62.0	23	136.7	133.9	130.8	131.0

**Table 46** 5.4 GHz - TDM mode - threshold, power and link loss

Modulation mode	System threshold (dBm) per channel bandwidth				Output power (dBm)	Maximum link loss (dB) per channel bandwidth			
	10 MHz	20 MHz	40 MHz	45 MHz		All bands	10 MHz	20 MHz	40 MHz
BPSK 0.63 single	-96.4	-93.5	-90.3	-90.0	27	169.4	166.5	163.3	163.0
QPSK 0.63 single	-87.9	-86.4	-83.2	-82.8	26	160.9	159.4	156.2	155.8
QPSK 0.87 single	-84.8	-82.4	-79.1	-78.7	26	157.8	155.4	152.1	151.7
16QAM 0.63 single	-82.6	-80.0	-76.9	-76.4	25	154.6	152.0	148.9	148.4
16QAM 0.63 dual	-78.7	-76.3	-73.4	-73.0	25	150.7	148.3	145.4	145.0
16QAM 0.87 single	-78.2	-75.6	-72.3	-71.9	25	150.2	147.6	144.3	143.9
16QAM 0.87 dual	-74.8	-72.0	-69.0	-68.9	25	146.8	144.0	141.0	140.9
64QAM 0.75 single	-74.3	-72.0	-68.9	-68.5	24	145.3	143.0	139.9	139.5
64QAM 0.75 dual	-71.3	-68.6	-65.7	-65.6	24	142.3	139.6	136.7	136.6
64QAM 0.92 single	-70.1	-68.0	-65.0	-64.5	24	141.1	139.0	136.0	135.5
64 QAM 0.92 dual	-67.3	-64.6	-61.1	-61.6	24	138.3	135.6	132.1	132.6
256QAM 0.81 single	-70.5	-68.2	-65.0	-64.7	23	139.5	137.2	134.0	133.7
256QAM 0.81 dual	-66.9	-64.1	-61.3	-61.2	23	135.9	133.1	130.3	130.2

**Table 47** 5.8 GHz - IP mode - threshold, power and link loss

Modulation mode	System threshold (dBm) per channel bandwidth				Output power (dBm)	Maximum link loss (dB) per channel bandwidth			
	10 MHz	20 MHz	40 MHz	45 MHz		All bands	10 MHz	20 MHz	40 MHz
BPSK 0.63 single	-95.8	-92.9	-89.6	-89.4	27	168.8	165.9	162.6	162.4
QPSK 0.63 single	-90.3	-87.9	-85.3	-85.0	26	163.3	160.9	158.3	158.0
QPSK 0.87 single	-87.3	-84.5	-81.4	-81.0	26	160.3	157.5	154.4	154.0
16QAM 0.63 single	-85.2	-82.5	-79.2	-78.9	25	157.2	154.5	151.2	150.9
16QAM 0.63 dual	-81.4	-79.0	-75.7	-75.3	25	153.4	151.0	147.7	147.3
16QAM 0.87 single	-80.6	-77.8	-74.8	-74.6	25	152.6	149.8	146.8	146.6
16QAM 0.87 dual	-77.3	-74.4	-71.4	-71.1	25	149.3	146.4	143.4	143.1
64QAM 0.75 single	-77.3	-74.8	-71.7	-71.4	24	148.3	145.8	142.7	142.4
64QAM 0.75 dual	-74.5	-71.5	-68.5	-68.2	24	145.5	142.5	139.5	139.2
64QAM 0.92 single	-73.4	-70.7	-67.7	-67.5	24	144.4	141.7	138.7	138.5
64 QAM 0.92 dual	-70.0	-67.1	-64.2	-64.0	24	141.0	138.1	135.2	135.0
256QAM 0.81 single	-70.1	-67.4	-64.8	-64.4	23	139.1	136.4	133.8	133.4
256QAM 0.81 dual	-67.0	-64.0	-61.2	-60.8	23	136.0	133.0	130.2	129.8

**Table 48** 5.8 GHz - TDM mode - threshold, power and link loss

Modulation mode	System threshold (dBm) per channel bandwidth				Output power (dBm)	Maximum link loss (dB) per channel bandwidth			
	10 MHz	20 MHz	40 MHz	45 MHz		All bands	10 MHz	20 MHz	40 MHz
BPSK 0.63 single	-96.4	-92.7	-90.2	-89.6	27	169.4	165.7	163.2	162.6
QPSK 0.63 single	-87.5	-86.0	-83.2	-82.7	26	160.5	159.0	156.2	155.7
QPSK 0.87 single	-84.3	-81.9	-79.0	-78.4	26	157.3	154.9	152.0	151.4
16QAM 0.63 single	-81.9	-79.6	-76.6	-76.2	25	153.9	151.6	148.6	148.2
16QAM 0.63 dual	-78.2	-76.0	-73.0	-72.6	25	150.2	148.0	145.0	144.6
16QAM 0.87 single	-77.7	-75.0	-72.1	-71.6	25	149.7	147.0	144.1	143.6
16QAM 0.87 dual	-74.0	-71.4	-69.0	-68.2	25	146.0	143.4	141.0	140.2
64QAM 0.75 single	-73.8	-71.4	-68.8	-68.2	24	144.8	142.4	139.8	139.2
64QAM 0.75 dual	-70.7	-68.0	-65.7	-64.9	24	141.7	139.0	136.7	135.9
64QAM 0.92 single	-69.8	-67.2	-64.8	-64.2	24	140.8	138.2	135.8	135.2
64 QAM 0.92 dual	-66.7	-63.8	-61.2	-60.3	24	137.7	134.8	132.2	131.3
256QAM 0.81 single	-70.0	-67.3	-64.7	-64.3	23	139.0	136.3	133.7	133.3
256QAM 0.81 dual	-66.2	-63.5	-61.1	-60.3	23	135.2	132.5	130.1	129.3

## Data throughput capacity tables

Use the following tables to look up the data throughput rates (Mbits/s) that are achieved when two PTP 650 ODUs are linked and the link distance (range) is 0 km:

PTP 650 variant	Link symmetry	Link optimization	Table
Full	1:1	IP	<a href="#">Table 49</a>
		TDM	<a href="#">Table 50</a>
	2:1	IP	<a href="#">Table 51</a>
		TDM	<a href="#">Table 52</a>
	Adaptive	IP	<a href="#">Table 53</a>
	Mid	1:1	IP
TDM			<a href="#">Table 55</a>
2:1		IP	<a href="#">Table 56</a>
		TDM	<a href="#">Table 57</a>
Adaptive		IP	<a href="#">Table 58</a>
Lite		1:1	IP
	TDM		<a href="#">Table 60</a>
	2:1	IP	<a href="#">Table 61</a>
		TDM	<a href="#">Table 62</a>
	Adaptive	IP	<a href="#">Table 63</a>

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	20 MHz	10 MHz
1:1	IP	<a href="#">Figure 33</a>	<a href="#">Figure 34</a>	<a href="#">Figure 35</a>	<a href="#">Figure 36</a>
	TDM	<a href="#">Figure 37</a>	<a href="#">Figure 38</a>	<a href="#">Figure 39</a>	<a href="#">Figure 40</a>
2:1	IP	<a href="#">Figure 41</a>	<a href="#">Figure 42</a>	<a href="#">Figure 43</a>	<a href="#">Figure 44</a>
	TDM	<a href="#">Figure 45</a>	<a href="#">Figure 46</a>	<a href="#">Figure 47</a>	<a href="#">Figure 48</a>
Adaptive	IP	<a href="#">Figure 49</a>	<a href="#">Figure 50</a>	<a href="#">Figure 51</a>	<a href="#">Figure 52</a>

Throughput for link symmetry 2:1 is the same as 1:2, but the Tx and Rx data rates are swapped.

**Table 49** Throughput at zero link range (Mbit/s), Full, symmetry 1:1, optimization IP

<b>Modulation mode</b>	<b>45 MHz (Tx/Rx/Aggregate)</b>			<b>40 MHz (Tx/Rx/Aggregate)</b>		
256QAM 0.81 dual	226.1	226.1	452.2	206.3	206.3	412.6
64QAM 0.92 dual	190.5	190.5	381.0	173.8	173.8	347.6
64QAM 0.75 dual	155.7	155.7	311.3	142.0	142.0	284.1
16QAM 0.87 dual	121.1	121.1	242.2	110.5	110.5	221.0
16QAM 0.63 dual	87.1	87.1	174.1	79.4	79.4	158.9
256QAM 0.81 single	113.0	113.0	226.1	103.1	103.1	206.3
64QAM 0.92 single	95.2	95.2	190.5	86.9	86.9	173.8
64QAM 0.75 single	77.8	77.8	155.7	71.0	71.0	142.0
16QAM 0.87 single	60.5	60.5	121.1	55.2	55.2	110.5
16QAM 0.63 single	43.5	43.5	87.0	39.7	39.7	79.4
QPSK 0.87 single	30.3	30.3	60.5	27.6	27.6	55.2
QPSK 0.63 single	21.8	21.8	43.5	19.9	19.9	39.7
BPSK 0.63 single	10.9	10.9	21.8	9.9	9.9	19.9
<b>Modulation mode</b>	<b>20 MHz (Tx/Rx/Aggregate)</b>			<b>10 MHz (Tx/Rx/Aggregate)</b>		
256QAM 0.81 dual	100.0	100.0	200.1	50.1	50.1	100.2
64QAM 0.92 dual	84.3	84.3	168.6	42.2	42.2	84.4
64QAM 0.75 dual	68.9	68.9	137.8	34.5	34.5	69.0
16QAM 0.87 dual	53.6	53.6	107.2	26.8	26.8	53.7
16QAM 0.63 dual	38.5	38.5	77.0	19.3	19.3	38.6
256QAM 0.81 single	50.0	50.0	100.0	25.0	25.0	50.1
64QAM 0.92 single	42.1	42.1	84.3	21.1	21.1	42.2
64QAM 0.75 single	34.4	34.4	68.9	17.2	17.2	34.5
16QAM 0.87 single	26.8	26.8	53.6	13.4	13.4	26.8
16QAM 0.63 single	19.3	19.3	38.5	9.6	9.6	19.3
QPSK 0.87 single	13.4	13.4	26.8	6.7	6.7	13.4
QPSK 0.63 single	9.6	9.6	19.3	4.8	4.8	9.6
BPSK 0.63 single	4.8	4.8	9.6	2.4	2.4	4.8

Tx/Rx/Aggregate columns contain the transmit, receive and aggregate data rates per bandwidth.



**Table 50** Throughput at zero link range (Mbit/s), Full, symmetry 1:1, optimization TDM

<b>Modulation mode</b>	<b>45 MHz (Tx/Rx/Aggregate)</b>			<b>40 MHz (Tx/Rx/Aggregate)</b>		
256QAM 0.81 dual	202.1	202.1	404.1	186.1	186.1	372.1
64QAM 0.92 dual	170.2	170.2	340.5	156.8	156.8	313.5
64QAM 0.75 dual	139.1	139.1	278.2	128.1	128.1	256.2
16QAM 0.87 dual	108.2	108.2	216.5	99.7	99.7	199.3
16QAM 0.63 dual	77.8	77.8	155.6	71.6	71.6	143.3
256QAM 0.81 single	101.0	101.0	202.1	93.0	93.0	186.1
64QAM 0.92 single	85.1	85.1	170.2	78.4	78.4	156.8
64QAM 0.75 single	69.6	69.6	139.1	64.0	64.0	128.1
16QAM 0.87 single	54.1	54.1	108.2	49.8	49.8	99.7
16QAM 0.63 single	38.9	38.9	77.8	35.8	35.8	71.6
QPSK 0.87 single	27.1	27.1	54.1	24.9	24.9	49.8
QPSK 0.63 single	19.4	19.4	38.9	17.9	17.9	35.8
BPSK 0.63 single	9.7	9.7	19.4	9.0	9.0	17.9
<b>Modulation mode</b>	<b>20 MHz (Tx/Rx/Aggregate)</b>			<b>10 MHz (Tx/Rx/Aggregate)</b>		
256QAM 0.81 dual	96.0	96.0	192.0	49.1	49.1	98.2
64QAM 0.92 dual	80.9	80.9	161.7	41.4	41.4	82.8
64QAM 0.75 dual	66.1	66.1	132.2	33.8	33.8	67.6
16QAM 0.87 dual	51.4	51.4	102.8	26.3	26.3	52.6
16QAM 0.63 dual	37.0	37.0	73.9	18.9	18.9	37.8
256QAM 0.81 single	48.0	48.0	96.0	24.6	24.6	49.1
64QAM 0.92 single	40.4	40.4	80.9	20.7	20.7	41.4
64QAM 0.75 single	33.0	33.0	66.1	16.9	16.9	33.8
16QAM 0.87 single	25.7	25.7	51.4	13.2	13.2	26.3
16QAM 0.63 single	18.5	18.5	37.0	9.5	9.5	18.9
QPSK 0.87 single	12.8	12.8	25.7	6.6	6.6	13.1
QPSK 0.63 single	9.2	9.2	18.5	4.7	4.7	9.5
BPSK 0.63 single	4.6	4.6	9.2	2.4	2.4	4.7

Tx/Rx/Aggregate columns contain the transmit, receive and aggregate data rates per bandwidth.

**Table 51** Throughput at zero link range (Mbit/s), Full, symmetry 2:1, optimization IP

<b>Modulation mode</b>	<b>45 MHz (Tx/Rx/Aggregate)</b>			<b>40 MHz (Tx/Rx/Aggregate)</b>		
256QAM 0.81 dual	299.7	149.9	449.6	273.6	136.8	410.5
64QAM 0.92 dual	252.5	126.3	378.8	230.5	115.3	345.8
64QAM 0.75 dual	206.4	103.2	309.6	188.4	94.2	282.6
16QAM 0.87 dual	160.6	80.3	240.8	146.6	73.3	219.8
16QAM 0.63 dual	115.4	57.7	173.1	105.4	52.7	158.0
256QAM 0.81 single	149.9	74.9	224.8	136.8	68.4	205.2
64QAM 0.92 single	126.3	63.1	189.4	115.3	57.6	172.9
64QAM 0.75 single	103.2	51.6	154.8	94.2	47.1	141.3
16QAM 0.87 single	80.3	40.1	120.4	73.3	36.6	109.9
16QAM 0.63 single	57.7	28.9	86.6	52.7	26.3	79.0
QPSK 0.87 single	40.1	20.1	60.2	36.6	18.3	55.0
QPSK 0.63 single	28.9	14.4	43.3	26.3	13.2	39.5
BPSK 0.63 single	14.4	7.2	21.6	13.2	6.6	19.7
<b>Modulation mode</b>	<b>20 MHz (Tx/Rx/Aggregate)</b>			<b>10 MHz (Tx/Rx/Aggregate)</b>		
256QAM 0.81 dual	133.4	66.7	200.1	66.3	33.2	99.5
64QAM 0.92 dual	112.4	56.2	168.6	55.9	27.9	83.8
64QAM 0.75 dual	91.8	45.9	137.8	45.7	22.8	68.5
16QAM 0.87 dual	71.5	35.7	107.2	35.5	17.8	53.3
16QAM 0.63 dual	51.4	25.7	77.0	25.5	12.8	38.3
256QAM 0.81 single	66.7	33.3	100.0	33.2	16.6	49.8
64QAM 0.92 single	56.2	28.1	84.3	27.9	14.0	41.9
64QAM 0.75 single	45.9	23.0	68.9	22.8	11.4	34.3
16QAM 0.87 single	35.7	17.9	53.6	17.8	8.9	26.6
16QAM 0.63 single	25.7	12.8	38.5	12.8	6.4	19.2
QPSK 0.87 single	17.9	8.9	26.8	8.9	4.4	13.3
QPSK 0.63 single	12.8	6.4	19.3	6.4	3.2	9.6
BPSK 0.63 single	6.4	3.2	9.6	3.2	1.6	4.8

Tx/Rx/Aggregate columns contain the transmit, receive and aggregate data rates per bandwidth.

**Table 52** Throughput at zero link range (Mbit/s), Full, symmetry 2:1, optimization TDM

<b>Modulation mode</b>	<b>45 MHz (Tx/Rx/Aggregate)</b>			<b>40 MHz (Tx/Rx/Aggregate)</b>		
256QAM 0.81 dual	280.8	140.4	421.2	257.7	128.9	386.6
64QAM 0.92 dual	236.6	118.3	354.8	217.1	108.6	325.7
64QAM 0.75 dual	193.3	96.7	290.0	177.4	88.7	266.1
16QAM 0.87 dual	150.4	75.2	225.6	138.0	69.0	207.1
16QAM 0.63 dual	108.1	54.1	162.2	99.2	49.6	148.8
256QAM 0.81 single	140.4	70.2	210.6	128.9	64.4	193.3
64QAM 0.92 single	118.3	59.1	177.4	108.6	54.3	162.8
64QAM 0.75 single	96.7	48.3	145.0	88.7	44.4	133.1
16QAM 0.87 single	75.2	37.6	112.8	69.0	34.5	103.5
16QAM 0.63 single	54.1	27.0	81.1	49.6	24.8	74.4
QPSK 0.87 single	37.6	18.8	56.4	34.5	17.3	51.8
QPSK 0.63 single	27.0	13.5	40.5	24.8	12.4	37.2
BPSK 0.63 single	13.5	6.8	20.3	12.4	6.2	18.6
<b>Modulation mode</b>	<b>20 MHz (Tx/Rx/Aggregate)</b>			<b>10 MHz (Tx/Rx/Aggregate)</b>		
256QAM 0.81 dual	130.6	65.3	195.9	66.3	33.2	99.5
64QAM 0.92 dual	110.1	55.0	165.1	55.9	27.9	83.8
64QAM 0.75 dual	89.9	45.0	134.9	45.7	22.8	68.5
16QAM 0.87 dual	70.0	35.0	104.9	35.5	17.8	53.3
16QAM 0.63 dual	50.3	25.1	75.4	25.5	12.8	38.3
256QAM 0.81 single	65.3	32.7	98.0	33.2	16.6	49.8
64QAM 0.92 single	55.0	27.5	82.5	27.9	14.0	41.9
64QAM 0.75 single	45.0	22.5	67.4	22.8	11.4	34.3
16QAM 0.87 single	35.0	17.5	52.5	17.8	8.9	26.6
16QAM 0.63 single	25.1	12.6	37.7	12.8	6.4	19.2
QPSK 0.87 single	17.5	8.7	26.2	8.9	4.4	13.3
QPSK 0.63 single	12.6	6.3	18.9	6.4	3.2	9.6
BPSK 0.63 single	6.3	3.1	9.4	3.2	1.6	4.8

Tx/Rx/Aggregate columns contain the transmit, receive and aggregate data rates per bandwidth.

**Table 53** Throughput at zero link range (Mbit/s), Full, symmetry adaptive, optimization IP

<b>Modulation mode</b>	<b>45 MHz (Tx/Rx/Aggregate)</b>			<b>40 MHz (Tx/Rx/Aggregate)</b>		
256QAM 0.81 dual	407.9	40.8	448.7	367.9	40.9	408.8
64QAM 0.92 dual	343.7	34.4	378.0	310.0	34.4	344.4
64QAM 0.75 dual	280.8	28.1	308.9	253.3	28.1	281.4
16QAM 0.87 dual	218.5	21.8	240.3	197.1	21.9	218.9
16QAM 0.63 dual	157.1	15.7	172.8	141.7	15.7	157.4
256QAM 0.81 single	204.0	20.4	224.3	183.9	20.4	204.4
64QAM 0.92 single	171.8	17.2	189.0	155.0	17.2	172.2
64QAM 0.75 single	140.4	14.0	154.5	126.6	14.1	140.7
16QAM 0.87 single	109.2	10.9	120.2	98.5	10.9	109.5
16QAM 0.63 single	78.5	7.9	86.4	70.8	7.9	78.7
QPSK 0.87 single	54.6	5.5	60.1	49.3	5.5	54.7
QPSK 0.63 single	39.3	3.9	43.2	35.4	3.9	39.3
BPSK 0.63 single	19.6	2.0	21.6	17.7	2.0	19.7
<b>Modulation mode</b>	<b>20 MHz (Tx/Rx/Aggregate)</b>			<b>10 MHz (Tx/Rx/Aggregate)</b>		
256QAM 0.81 dual	159.4	39.8	199.2	66.3	33.2	99.5
64QAM 0.92 dual	134.3	33.6	167.9	55.9	27.9	83.8
64QAM 0.75 dual	109.7	27.4	137.2	45.7	22.8	68.5
16QAM 0.87 dual	85.4	21.3	106.7	35.5	17.8	53.3
16QAM 0.63 dual	61.4	15.3	76.7	25.5	12.8	38.3
256QAM 0.81 single	79.7	19.9	99.6	33.2	16.6	49.8
64QAM 0.92 single	67.1	16.8	83.9	27.9	14.0	41.9
64QAM 0.75 single	54.9	13.7	68.6	22.8	11.4	34.3
16QAM 0.87 single	42.7	10.7	53.4	17.8	8.9	26.6
16QAM 0.63 single	30.7	7.7	38.4	12.8	6.4	19.2
QPSK 0.87 single	21.3	5.3	26.7	8.9	4.4	13.3
QPSK 0.63 single	15.3	3.8	19.2	6.4	3.2	9.6
BPSK 0.63 single	7.7	1.9	9.6	3.2	1.6	4.8

Tx/Rx/Aggregate columns contain the transmit, receive and aggregate data rates per bandwidth.

**Table 54** Throughput at zero link range (Mbit/s), Mid, symmetry 1:1, optimization IP

<b>Modulation mode</b>	<b>45 MHz (Tx/Rx/Aggregate)</b>			<b>40 MHz (Tx/Rx/Aggregate)</b>		
256QAM 0.81 dual	127.0	127.0	254.0	116.0	116.0	232.0
64QAM 0.92 dual	107.0	107.0	214.0	97.0	97.0	194.0
64QAM 0.75 dual	87.0	87.0	174.0	80.0	80.0	160.0
16QAM 0.87 dual	68.0	68.0	136.0	62.0	62.0	124.0
16QAM 0.63 dual	49.0	49.0	98.0	44.0	44.0	88.0
256QAM 0.81 single	63.0	63.0	126.0	58.0	58.0	116.0
64QAM 0.92 single	53.0	53.0	106.0	49.0	49.0	98.0
64QAM 0.75 single	44.0	44.0	88.0	40.0	40.0	80.0
16QAM 0.87 single	34.0	34.0	68.0	31.0	31.0	62.0
16QAM 0.63 single	24.0	24.0	48.0	22.0	22.0	44.0
QPSK 0.87 single	17.0	17.0	34.0	15.0	15.0	30.0
QPSK 0.63 single	12.0	12.0	24.0	11.0	11.0	22.0
BPSK 0.63 single	6.0	6.0	12.0	6.0	6.0	12.0
<b>Modulation mode</b>	<b>20 MHz (Tx/Rx/Aggregate)</b>			<b>10 MHz (Tx/Rx/Aggregate)</b>		
256QAM 0.81 dual	56.0	56.0	112.0	28.0	28.0	56.0
64QAM 0.92 dual	47.0	47.0	94.0	24.0	24.0	48.0
64QAM 0.75 dual	39.0	39.0	78.0	19.0	19.0	38.0
16QAM 0.87 dual	30.0	30.0	60.0	15.0	15.0	30.0
16QAM 0.63 dual	22.0	22.0	44.0	11.0	11.0	22.0
256QAM 0.81 single	28.0	28.0	56.0	14.0	14.0	28.0
64QAM 0.92 single	24.0	24.0	48.0	12.0	12.0	24.0
64QAM 0.75 single	19.0	19.0	38.0	10.0	10.0	20.0
16QAM 0.87 single	15.0	15.0	30.0	8.0	8.0	16.0
16QAM 0.63 single	11.0	11.0	22.0	5.0	5.0	10.0
QPSK 0.87 single	8.0	8.0	16.0	5.0	5.0	10.0
QPSK 0.63 single	5.0	5.0	10.0	4.8	4.8	9.6
BPSK 0.63 single	4.8	4.8	9.6	2.4	2.4	4.8

Tx/Rx/Aggregate columns contain the transmit, receive and aggregate data rates per bandwidth.

**Table 55** Throughput at zero link range (Mbit/s), Mid, symmetry 1:1, optimization TDM

Modulation mode	45 MHz (Tx/Rx/Aggregate)			40 MHz (Tx/Rx/Aggregate)		
	256QAM 0.81 dual	113.0	113.0	226.0	104.0	104.0
64QAM 0.92 dual	95.0	95.0	190.0	88.0	88.0	176.0
64QAM 0.75 dual	78.0	78.0	156.0	72.0	72.0	144.0
16QAM 0.87 dual	61.0	61.0	122.0	56.0	56.0	112.0
16QAM 0.63 dual	44.0	44.0	88.0	40.0	40.0	80.0
256QAM 0.81 single	57.0	57.0	114.0	52.0	52.0	104.0
64QAM 0.92 single	48.0	48.0	96.0	44.0	44.0	88.0
64QAM 0.75 single	39.0	39.0	78.0	36.0	36.0	72.0
16QAM 0.87 single	30.0	30.0	60.0	28.0	28.0	56.0
16QAM 0.63 single	22.0	22.0	44.0	20.0	20.0	40.0
QPSK 0.87 single	15.0	15.0	30.0	14.0	14.0	28.0
QPSK 0.63 single	11.0	11.0	22.0	10.0	10.0	20.0
BPSK 0.63 single	5.0	5.0	10.0	5.0	5.0	10.0
Modulation mode	20 MHz (Tx/Rx/Aggregate)			10 MHz (Tx/Rx/Aggregate)		
	256QAM 0.81 dual	54.0	54.0	108.0	28.0	28.0
64QAM 0.92 dual	45.0	45.0	90.0	23.0	23.0	46.0
64QAM 0.75 dual	37.0	37.0	74.0	19.0	19.0	38.0
16QAM 0.87 dual	29.0	29.0	58.0	15.0	15.0	30.0
16QAM 0.63 dual	21.0	21.0	42.0	11.0	11.0	22.0
256QAM 0.81 single	27.0	27.0	54.0	14.0	14.0	28.0
64QAM 0.92 single	23.0	23.0	46.0	12.0	12.0	24.0
64QAM 0.75 single	19.0	19.0	38.0	9.0	9.0	18.0
16QAM 0.87 single	14.0	14.0	28.0	7.0	7.0	14.0
16QAM 0.63 single	10.0	10.0	20.0	5.0	5.0	10.0
QPSK 0.87 single	7.0	7.0	14.0	5.0	5.0	10.0
QPSK 0.63 single	5.0	5.0	10.0	4.7	4.7	9.5
BPSK 0.63 single	4.6	4.6	9.2	2.4	2.4	4.7

Tx/Rx/Aggregate columns contain the transmit, receive and aggregate data rates per bandwidth.

**Table 56** Throughput at zero link range (Mbit/s), Mid, symmetry 2:1, optimization IP

<b>Modulation mode</b>	<b>45 MHz (Tx/Rx/Aggregate)</b>			<b>40 MHz (Tx/Rx/Aggregate)</b>		
256QAM 0.81 dual	168.0	84.0	252.0	153.0	77.0	230.0
64QAM 0.92 dual	141.0	71.0	212.0	129.0	65.0	194.0
64QAM 0.75 dual	116.0	58.0	174.0	106.0	53.0	159.0
16QAM 0.87 dual	90.0	45.0	135.0	82.0	41.0	123.0
16QAM 0.63 dual	65.0	32.0	97.0	59.0	30.0	89.0
256QAM 0.81 single	84.0	42.0	126.0	77.0	38.0	115.0
64QAM 0.92 single	71.0	35.0	106.0	65.0	32.0	97.0
64QAM 0.75 single	58.0	29.0	87.0	53.0	26.0	79.0
16QAM 0.87 single	45.0	22.0	67.0	41.0	21.0	62.0
16QAM 0.63 single	32.0	16.0	48.0	30.0	15.0	45.0
QPSK 0.87 single	22.0	11.0	33.0	21.0	10.0	31.0
QPSK 0.63 single	16.0	8.0	24.0	15.0	7.0	22.0
BPSK 0.63 single	8.0	5.0	13.0	7.0	5.0	12.0
<b>Modulation mode</b>	<b>20 MHz (Tx/Rx/Aggregate)</b>			<b>10 MHz (Tx/Rx/Aggregate)</b>		
256QAM 0.81 dual	75.0	37.0	112.0	37.0	19.0	56.0
64QAM 0.92 dual	63.0	31.0	94.0	31.0	16.0	47.0
64QAM 0.75 dual	51.0	26.0	77.0	26.0	13.0	39.0
16QAM 0.87 dual	40.0	20.0	60.0	20.0	10.0	30.0
16QAM 0.63 dual	29.0	14.0	43.0	14.0	7.0	21.0
256QAM 0.81 single	37.0	19.0	56.0	19.0	9.0	28.0
64QAM 0.92 single	31.0	16.0	47.0	16.0	8.0	24.0
64QAM 0.75 single	26.0	13.0	39.0	13.0	6.0	19.0
16QAM 0.87 single	20.0	10.0	30.0	10.0	5.0	15.0
16QAM 0.63 single	14.0	7.0	21.0	7.0	5.0	12.0
QPSK 0.87 single	10.0	5.0	15.0	5.0	4.4	9.4
QPSK 0.63 single	7.0	5.0	12.0	5.0	3.2	8.2
BPSK 0.63 single	5.0	3.2	8.2	3.2	1.6	4.8

Tx/Rx/Aggregate columns contain the transmit, receive and aggregate data rates per bandwidth.

**Table 57** Throughput at zero link range (Mbit/s), Mid, symmetry 2:1, optimization TDM

<b>Modulation mode</b>	<b>45 MHz (Tx/Rx/Aggregate)</b>			<b>40 MHz (Tx/Rx/Aggregate)</b>		
256QAM 0.81 dual	157.0	79.0	236.0	144.0	72.0	216.0
64QAM 0.92 dual	132.0	66.0	198.0	122.0	61.0	183.0
64QAM 0.75 dual	108.0	54.0	162.0	99.0	50.0	149.0
16QAM 0.87 dual	84.0	42.0	126.0	77.0	39.0	116.0
16QAM 0.63 dual	61.0	30.0	91.0	56.0	28.0	84.0
256QAM 0.81 single	79.0	39.0	118.0	72.0	36.0	108.0
64QAM 0.92 single	66.0	33.0	99.0	61.0	30.0	91.0
64QAM 0.75 single	54.0	27.0	81.0	50.0	25.0	75.0
16QAM 0.87 single	42.0	21.0	63.0	39.0	19.0	58.0
16QAM 0.63 single	30.0	15.0	45.0	28.0	14.0	42.0
QPSK 0.87 single	21.0	11.0	32.0	19.0	10.0	29.0
QPSK 0.63 single	15.0	8.0	23.0	14.0	7.0	21.0
BPSK 0.63 single	8.0	5.0	13.0	7.0	5.0	12.0
<b>Modulation mode</b>	<b>20 MHz (Tx/Rx/Aggregate)</b>			<b>10 MHz (Tx/Rx/Aggregate)</b>		
256QAM 0.81 dual	73.0	37.0	110.0	37.0	19.0	56.0
64QAM 0.92 dual	62.0	31.0	93.0	31.0	16.0	47.0
64QAM 0.75 dual	50.0	25.0	75.0	26.0	13.0	39.0
16QAM 0.87 dual	39.0	20.0	59.0	20.0	10.0	30.0
16QAM 0.63 dual	28.0	14.0	42.0	14.0	7.0	21.0
256QAM 0.81 single	37.0	18.0	55.0	19.0	9.0	28.0
64QAM 0.92 single	31.0	15.0	46.0	16.0	8.0	24.0
64QAM 0.75 single	25.0	13.0	38.0	13.0	6.0	19.0
16QAM 0.87 single	20.0	10.0	30.0	10.0	5.0	15.0
16QAM 0.63 single	14.0	7.0	21.0	7.0	5.0	12.0
QPSK 0.87 single	10.0	5.0	15.0	5.0	4.4	9.4
QPSK 0.63 single	7.0	5.0	12.0	5.0	3.2	8.2
BPSK 0.63 single	5.0	3.1	8.1	3.2	1.6	4.8

Tx/Rx/Aggregate columns contain the transmit, receive and aggregate data rates per bandwidth.



**Table 58** Throughput at zero link range (Mbit/s), Mid, symmetry adaptive, optimization IP

<b>Modulation mode</b>	<b>45 MHz (Tx/Rx/Aggregate)</b>			<b>40 MHz (Tx/Rx/Aggregate)</b>		
256QAM 0.81 dual	228.0	23.0	251.0	206.0	23.0	229.0
64QAM 0.92 dual	192.0	19.0	211.0	174.0	19.0	193.0
64QAM 0.75 dual	157.0	16.0	173.0	142.0	16.0	158.0
16QAM 0.87 dual	122.0	12.0	134.0	110.0	12.0	122.0
16QAM 0.63 dual	88.0	9.0	97.0	79.0	9.0	88.0
256QAM 0.81 single	114.0	11.0	125.0	103.0	11.0	114.0
64QAM 0.92 single	96.0	10.0	106.0	87.0	10.0	97.0
64QAM 0.75 single	79.0	8.0	87.0	71.0	8.0	79.0
16QAM 0.87 single	61.0	6.0	67.0	55.0	6.0	61.0
16QAM 0.63 single	44.0	5.0	49.0	40.0	5.0	45.0
QPSK 0.87 single	31.0	5.0	36.0	28.0	5.0	33.0
QPSK 0.63 single	22.0	3.9	25.9	20.0	3.9	23.9
BPSK 0.63 single	11.0	2.0	13.0	10.0	2.0	12.0
<b>Modulation mode</b>	<b>20 MHz (Tx/Rx/Aggregate)</b>			<b>10 MHz (Tx/Rx/Aggregate)</b>		
256QAM 0.81 dual	89.0	22.0	111.0	37.0	19.0	56.0
64QAM 0.92 dual	75.0	19.0	94.0	31.0	16.0	47.0
64QAM 0.75 dual	61.0	15.0	76.0	26.0	13.0	39.0
16QAM 0.87 dual	48.0	12.0	60.0	20.0	10.0	30.0
16QAM 0.63 dual	34.0	9.0	43.0	14.0	7.0	21.0
256QAM 0.81 single	45.0	11.0	56.0	19.0	9.0	28.0
64QAM 0.92 single	38.0	9.0	47.0	16.0	8.0	24.0
64QAM 0.75 single	31.0	8.0	39.0	13.0	6.0	19.0
16QAM 0.87 single	24.0	6.0	30.0	10.0	5.0	15.0
16QAM 0.63 single	17.0	5.0	22.0	7.0	5.0	12.0
QPSK 0.87 single	12.0	5.0	17.0	5.0	4.4	9.4
QPSK 0.63 single	9.0	3.8	12.8	5.0	3.2	8.2
BPSK 0.63 single	5.0	1.9	6.9	3.2	1.6	4.8

Tx/Rx/Aggregate columns contain the transmit, receive and aggregate data rates per bandwidth.

**Table 59** Throughput at zero link range (Mbit/s), Lite, symmetry 1:1, optimization IP

<b>Modulation mode</b>	<b>45 MHz (Tx/Rx/Aggregate)</b>			<b>40 MHz (Tx/Rx/Aggregate)</b>		
256QAM 0.81 dual	63.0	63.0	126.0	58.0	58.0	116.0
64QAM 0.92 dual	53.0	53.0	106.0	49.0	49.0	98.0
64QAM 0.75 dual	44.0	44.0	88.0	40.0	40.0	80.0
16QAM 0.87 dual	34.0	34.0	68.0	31.0	31.0	62.0
16QAM 0.63 dual	24.0	24.0	48.0	22.0	22.0	44.0
256QAM 0.81 single	32.0	32.0	64.0	29.0	29.0	58.0
64QAM 0.92 single	27.0	27.0	54.0	24.0	24.0	48.0
64QAM 0.75 single	22.0	22.0	44.0	20.0	20.0	40.0
16QAM 0.87 single	17.0	17.0	34.0	15.0	15.0	30.0
16QAM 0.63 single	12.0	12.0	24.0	11.0	11.0	22.0
QPSK 0.87 single	8.0	8.0	16.0	8.0	8.0	16.0
QPSK 0.63 single	6.0	6.0	12.0	6.0	6.0	12.0
BPSK 0.63 single	5.0	5.0	10.0	5.0	5.0	10.0
<b>Modulation mode</b>	<b>20 MHz (Tx/Rx/Aggregate)</b>			<b>10 MHz (Tx/Rx/Aggregate)</b>		
256QAM 0.81 dual	28.0	28.0	56.0	14.0	14.0	28.0
64QAM 0.92 dual	24.0	24.0	48.0	12.0	12.0	24.0
64QAM 0.75 dual	19.0	19.0	38.0	10.0	10.0	20.0
16QAM 0.87 dual	15.0	15.0	30.0	8.0	8.0	16.0
16QAM 0.63 dual	11.0	11.0	22.0	5.0	5.0	10.0
256QAM 0.81 single	14.0	14.0	28.0	7.0	7.0	14.0
64QAM 0.92 single	12.0	12.0	24.0	6.0	6.0	12.0
64QAM 0.75 single	10.0	10.0	20.0	5.0	5.0	10.0
16QAM 0.87 single	8.0	8.0	16.0	5.0	5.0	10.0
16QAM 0.63 single	5.0	5.0	10.0	5.0	5.0	10.0
QPSK 0.87 single	5.0	5.0	10.0	5.0	5.0	10.0
QPSK 0.63 single	5.0	5.0	10.0	4.8	4.8	9.6
BPSK 0.63 single	4.8	4.8	9.6	2.4	2.4	4.8

Tx/Rx/Aggregate columns contain the transmit, receive and aggregate data rates per bandwidth.

**Table 60** Throughput at zero link range (Mbit/s), Lite, symmetry 1:1, optimization TDM

Modulation mode	45 MHz (Tx/Rx/Aggregate)			40 MHz (Tx/Rx/Aggregate)		
	256QAM 0.81 dual	57.0	57.0	114.0	52.0	52.0
64QAM 0.92 dual	48.0	48.0	96.0	44.0	44.0	88.0
64QAM 0.75 dual	39.0	39.0	78.0	36.0	36.0	72.0
16QAM 0.87 dual	30.0	30.0	60.0	28.0	28.0	56.0
16QAM 0.63 dual	22.0	22.0	44.0	20.0	20.0	40.0
256QAM 0.81 single	28.0	28.0	56.0	26.0	26.0	52.0
64QAM 0.92 single	24.0	24.0	48.0	22.0	22.0	44.0
64QAM 0.75 single	19.0	19.0	38.0	18.0	18.0	36.0
16QAM 0.87 single	15.0	15.0	30.0	14.0	14.0	28.0
16QAM 0.63 single	11.0	11.0	22.0	10.0	10.0	20.0
QPSK 0.87 single	8.0	8.0	16.0	7.0	7.0	14.0
QPSK 0.63 single	5.0	5.0	10.0	5.0	5.0	10.0
BPSK 0.63 single	5.0	5.0	10.0	5.0	5.0	10.0
Modulation mode	20 MHz (Tx/Rx/Aggregate)			10 MHz (Tx/Rx/Aggregate)		
	256QAM 0.81 dual	27.0	27.0	54.0	14.0	14.0
64QAM 0.92 dual	23.0	23.0	46.0	12.0	12.0	24.0
64QAM 0.75 dual	19.0	19.0	38.0	9.0	9.0	18.0
16QAM 0.87 dual	14.0	14.0	28.0	7.0	7.0	14.0
16QAM 0.63 dual	10.0	10.0	20.0	5.0	5.0	10.0
256QAM 0.81 single	13.0	13.0	26.0	7.0	7.0	14.0
64QAM 0.92 single	11.0	11.0	22.0	6.0	6.0	12.0
64QAM 0.75 single	9.0	9.0	18.0	5.0	5.0	10.0
16QAM 0.87 single	7.0	7.0	14.0	5.0	5.0	10.0
16QAM 0.63 single	5.0	5.0	10.0	5.0	5.0	10.0
QPSK 0.87 single	5.0	5.0	10.0	5.0	5.0	10.0
QPSK 0.63 single	5.0	5.0	10.0	4.7	4.7	9.5
BPSK 0.63 single	4.6	4.6	9.2	2.4	2.4	4.7

Tx/Rx/Aggregate columns contain the transmit, receive and aggregate data rates per bandwidth.

**Table 61** 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)		
	Tx	Rx	Aggregate	Tx	Rx	Aggregate
256QAM 0.81 dual	84.0	42.0	126.0	77.0	38.0	115.0
64QAM 0.92 dual	71.0	35.0	106.0	65.0	32.0	97.0
64QAM 0.75 dual	58.0	29.0	87.0	53.0	26.0	79.0
16QAM 0.87 dual	45.0	22.0	67.0	41.0	21.0	62.0
16QAM 0.63 dual	32.0	16.0	48.0	30.0	15.0	45.0
256QAM 0.81 single	42.0	21.0	63.0	38.0	19.0	57.0
64QAM 0.92 single	35.0	18.0	53.0	32.0	16.0	48.0
64QAM 0.75 single	29.0	14.0	43.0	26.0	13.0	39.0
16QAM 0.87 single	22.0	11.0	33.0	21.0	10.0	31.0
16QAM 0.63 single	16.0	8.0	24.0	15.0	7.0	22.0
QPSK 0.87 single	11.0	6.0	17.0	10.0	5.0	15.0
QPSK 0.63 single	8.0	5.0	13.0	7.0	5.0	12.0
BPSK 0.63 single	5.0	5.0	10.0	5.0	5.0	10.0
Modulation mode	20 MHz (Tx/Rx/Aggregate)			10 MHz (Tx/Rx/Aggregate)		
	Tx	Rx	Aggregate	Tx	Rx	Aggregate
256QAM 0.81 dual	37.0	19.0	56.0	19.0	9.0	28.0
64QAM 0.92 dual	31.0	16.0	47.0	16.0	8.0	24.0
64QAM 0.75 dual	26.0	13.0	39.0	13.0	6.0	19.0
16QAM 0.87 dual	20.0	10.0	30.0	10.0	5.0	15.0
16QAM 0.63 dual	14.0	7.0	21.0	7.0	5.0	12.0
256QAM 0.81 single	19.0	9.0	28.0	9.0	5.0	14.0
64QAM 0.92 single	16.0	8.0	24.0	8.0	5.0	13.0
64QAM 0.75 single	13.0	6.0	19.0	6.0	5.0	11.0
16QAM 0.87 single	10.0	5.0	15.0	5.0	5.0	10.0
16QAM 0.63 single	7.0	5.0	12.0	5.0	5.0	10.0
QPSK 0.87 single	5.0	5.0	10.0	5.0	4.4	9.4
QPSK 0.63 single	5.0	5.0	10.0	5.0	3.2	8.2
BPSK 0.63 single	5.0	3.2	8.2	3.2	1.6	4.8

Tx/Rx/Aggregate columns contain the transmit, receive and aggregate data rates per bandwidth.

**Table 62** Throughput at zero link range (Mbit/s), Lite, symmetry 2:1, optimization TDM

<b>Modulation mode</b>	<b>45 MHz (Tx/Rx/Aggregate)</b>			<b>40 MHz (Tx/Rx/Aggregate)</b>		
256QAM 0.81 dual	79.0	39.0	118.0	72.0	36.0	108.0
64QAM 0.92 dual	66.0	33.0	99.0	61.0	30.0	91.0
64QAM 0.75 dual	54.0	27.0	81.0	50.0	25.0	75.0
16QAM 0.87 dual	42.0	21.0	63.0	39.0	19.0	58.0
16QAM 0.63 dual	30.0	15.0	45.0	28.0	14.0	42.0
256QAM 0.81 single	39.0	20.0	59.0	36.0	18.0	54.0
64QAM 0.92 single	33.0	17.0	50.0	30.0	15.0	45.0
64QAM 0.75 single	27.0	14.0	41.0	25.0	12.0	37.0
16QAM 0.87 single	21.0	11.0	32.0	19.0	10.0	29.0
16QAM 0.63 single	15.0	8.0	23.0	14.0	7.0	21.0
QPSK 0.87 single	11.0	5.0	16.0	10.0	5.0	15.0
QPSK 0.63 single	8.0	5.0	13.0	7.0	5.0	12.0
BPSK 0.63 single	5.0	5.0	10.0	5.0	5.0	10.0
<b>Modulation mode</b>	<b>20 MHz (Tx/Rx/Aggregate)</b>			<b>10 MHz (Tx/Rx/Aggregate)</b>		
256QAM 0.81 dual	37.0	18.0	55.0	19.0	9.0	28.0
64QAM 0.92 dual	31.0	15.0	46.0	16.0	8.0	24.0
64QAM 0.75 dual	25.0	13.0	38.0	13.0	6.0	19.0
16QAM 0.87 dual	20.0	10.0	30.0	10.0	5.0	15.0
16QAM 0.63 dual	14.0	7.0	21.0	7.0	5.0	12.0
256QAM 0.81 single	18.0	9.0	27.0	9.0	5.0	14.0
64QAM 0.92 single	15.0	8.0	23.0	8.0	5.0	13.0
64QAM 0.75 single	13.0	6.0	19.0	6.0	5.0	11.0
16QAM 0.87 single	10.0	5.0	15.0	5.0	5.0	10.0
16QAM 0.63 single	7.0	5.0	12.0	5.0	5.0	10.0
QPSK 0.87 single	5.0	5.0	10.0	5.0	4.4	9.4
QPSK 0.63 single	5.0	5.0	10.0	5.0	3.2	8.2
BPSK 0.63 single	5.0	3.1	8.1	3.2	1.6	4.8

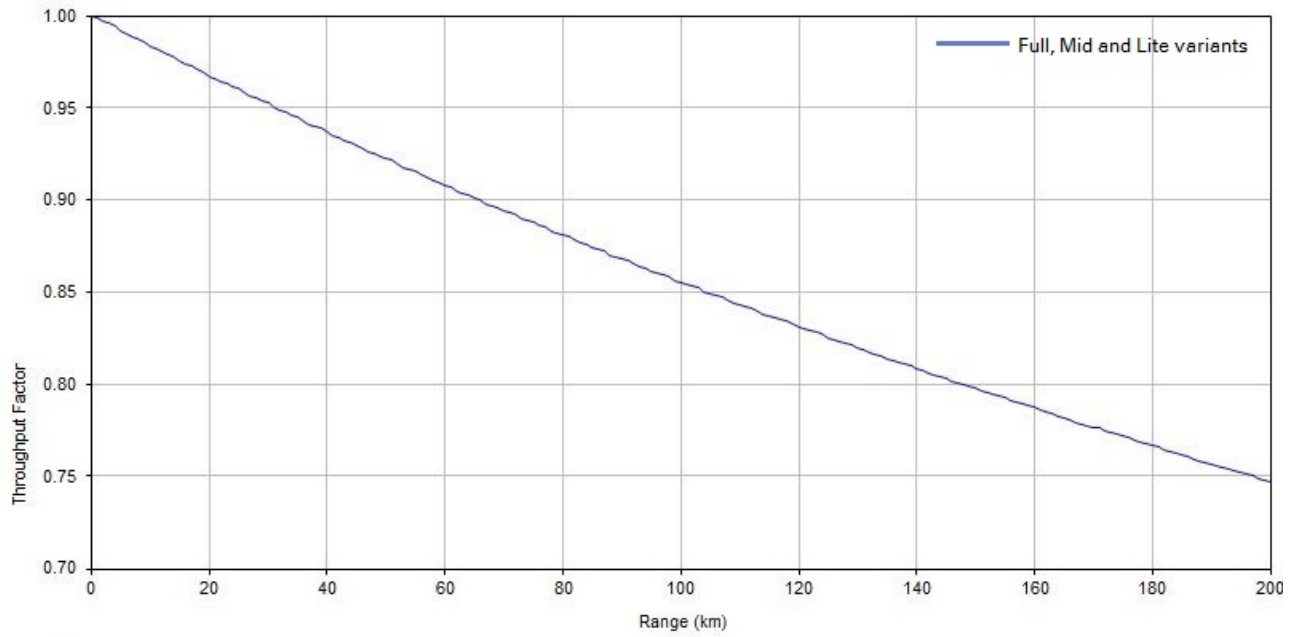
Tx/Rx/Aggregate columns contain the transmit, receive and aggregate data rates per bandwidth.

**Table 63** Throughput at zero link range (Mbit/s), Lite, symmetry adaptive, optimization IP

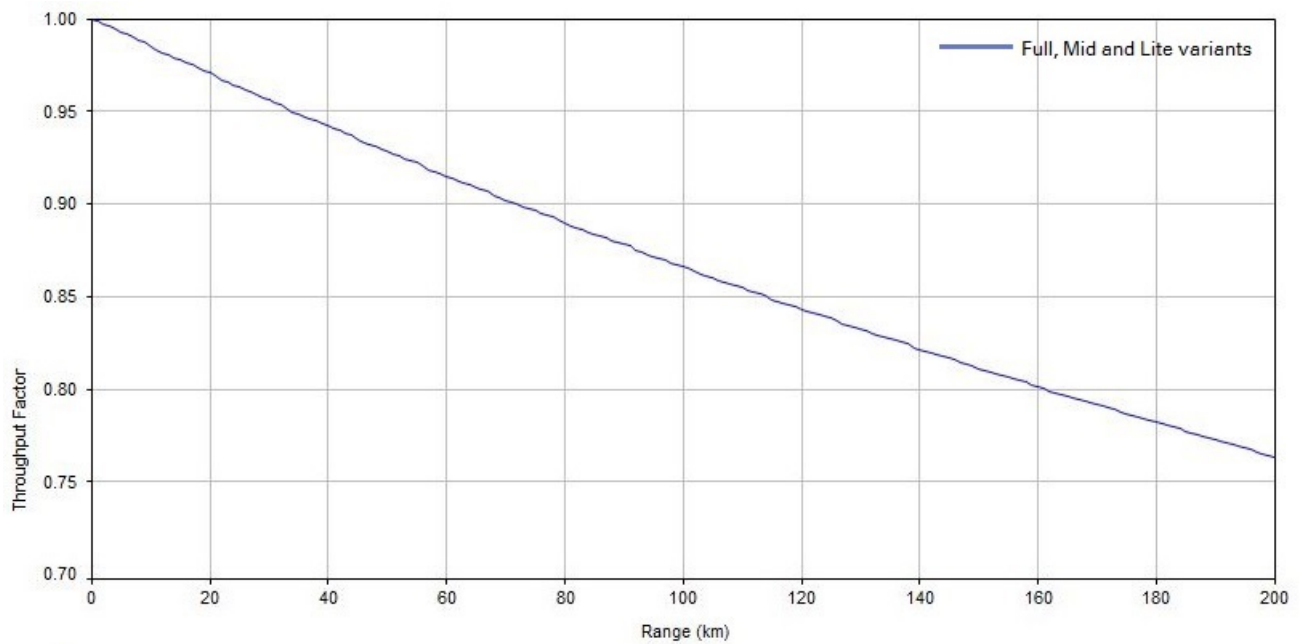
Modulation mode	45 MHz (Tx/Rx/Aggregate)			40 MHz (Tx/Rx/Aggregate)		
	Tx	Rx	Aggregate	Tx	Rx	Aggregate
256QAM 0.81 dual	114.0	11.0	125.0	103.0	11.0	114.0
64QAM 0.92 dual	96.0	10.0	106.0	87.0	10.0	97.0
64QAM 0.75 dual	79.0	8.0	87.0	71.0	8.0	79.0
16QAM 0.87 dual	61.0	6.0	67.0	55.0	6.0	61.0
16QAM 0.63 dual	44.0	5.0	49.0	40.0	5.0	45.0
256QAM 0.81 single	57.0	6.0	63.0	52.0	6.0	58.0
64QAM 0.92 single	48.0	5.0	53.0	43.0	5.0	48.0
64QAM 0.75 single	39.0	5.0	44.0	35.0	5.0	40.0
16QAM 0.87 single	31.0	5.0	36.0	28.0	5.0	33.0
16QAM 0.63 single	22.0	5.0	27.0	20.0	5.0	25.0
QPSK 0.87 single	15.0	5.0	20.0	14.0	5.0	19.0
QPSK 0.63 single	11.0	3.9	14.9	10.0	3.9	13.9
BPSK 0.63 single	5.0	2.0	7.0	5.0	2.0	7.0
Modulation mode	20 MHz (Tx/Rx/Aggregate)			10 MHz (Tx/Rx/Aggregate)		
	Tx	Rx	Aggregate	Tx	Rx	Aggregate
256QAM 0.81 dual	45.0	11.0	56.0	19.0	9.0	28.0
64QAM 0.92 dual	38.0	9.0	47.0	16.0	8.0	24.0
64QAM 0.75 dual	31.0	8.0	39.0	13.0	6.0	19.0
16QAM 0.87 dual	24.0	6.0	30.0	10.0	5.0	15.0
16QAM 0.63 dual	17.0	5.0	22.0	7.0	5.0	12.0
256QAM 0.81 single	22.0	6.0	28.0	9.0	5.0	14.0
64QAM 0.92 single	19.0	5.0	24.0	8.0	5.0	13.0
64QAM 0.75 single	15.0	5.0	20.0	6.0	5.0	11.0
16QAM 0.87 single	12.0	5.0	17.0	5.0	5.0	10.0
16QAM 0.63 single	9.0	5.0	14.0	5.0	5.0	10.0
QPSK 0.87 single	6.0	5.0	11.0	5.0	4.4	9.4
QPSK 0.63 single	5.0	3.8	8.8	5.0	3.2	8.2
BPSK 0.63 single	5.0	1.9	6.9	3.2	1.6	4.8

Tx/Rx/Aggregate columns contain the transmit, receive and aggregate data rates per bandwidth.

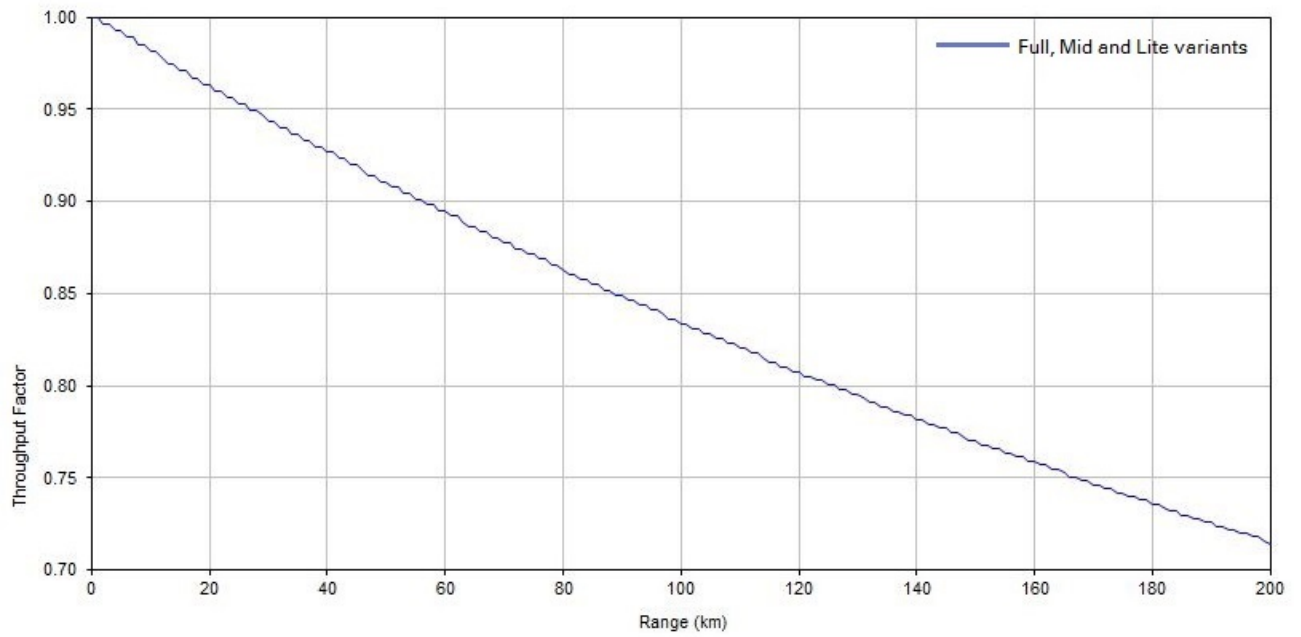
**Figure 33** Range adjustment for PTP 650, symmetry 1:1, optimization IP, bandwidth 45 MHz



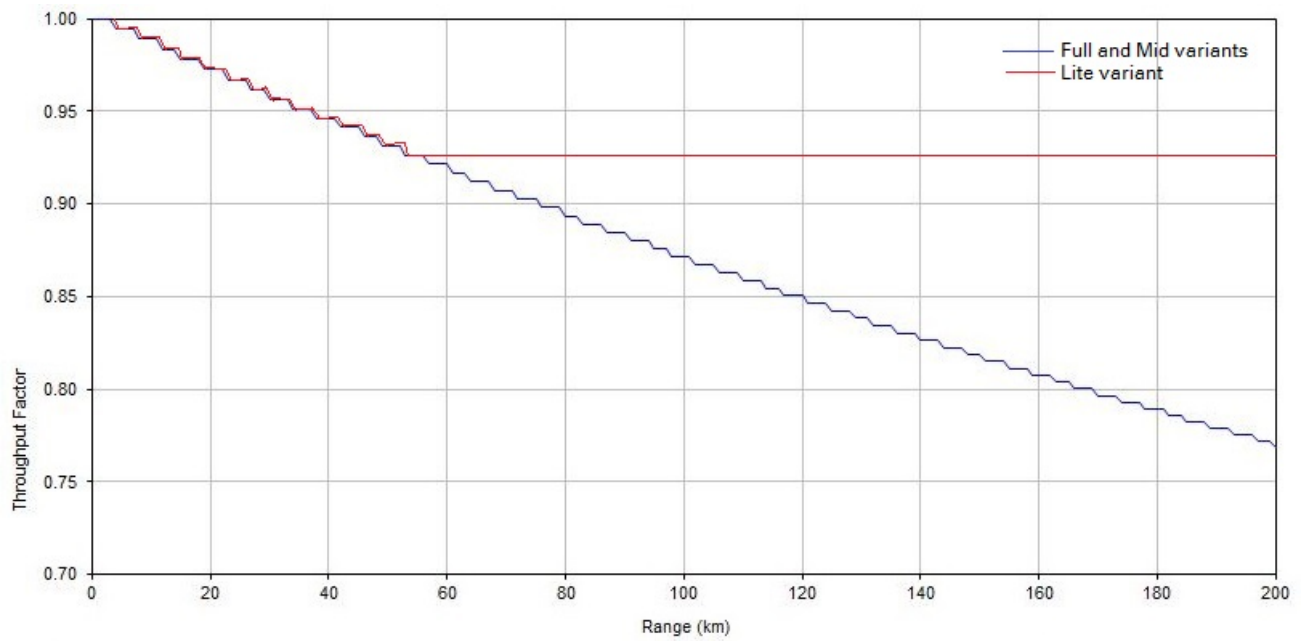
**Figure 34** Range adjustment for PTP 650, symmetry 1:1, optimization IP, bandwidth 40 MHz



**Figure 35** Range adjustment for PTP 650, symmetry 1:1, optimization IP, bandwidth 20 MHz

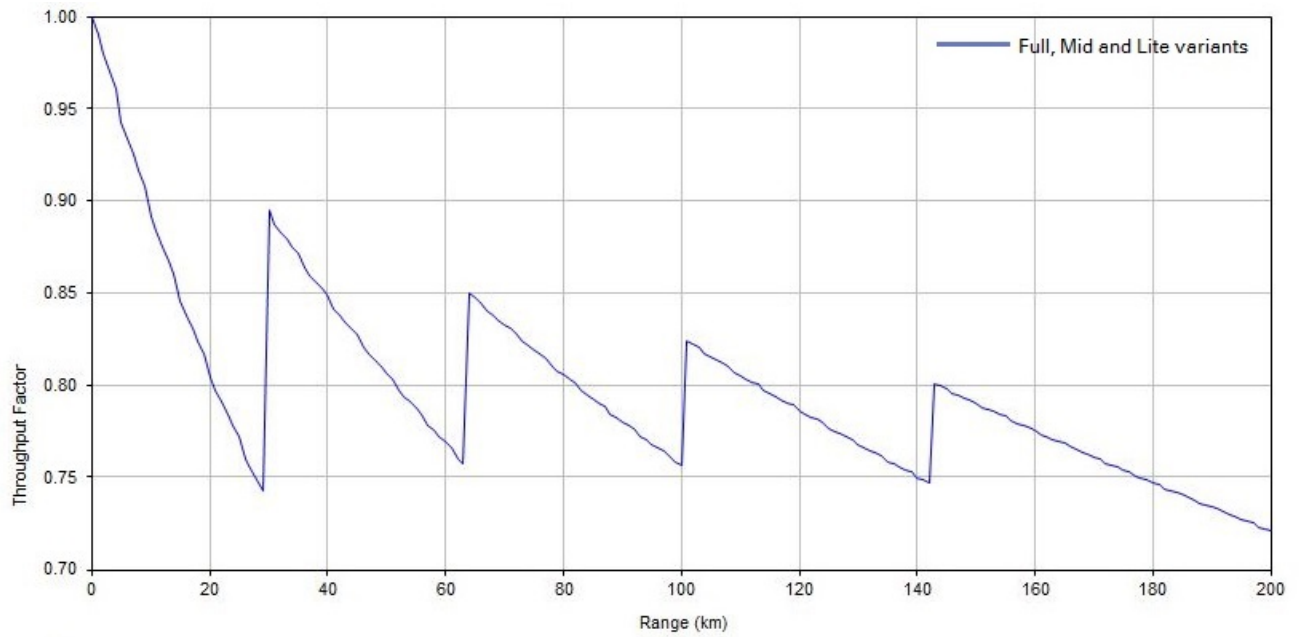


**Figure 36** Range adjustment for PTP 650, symmetry 1:1, optimization IP, bandwidth 10 MHz

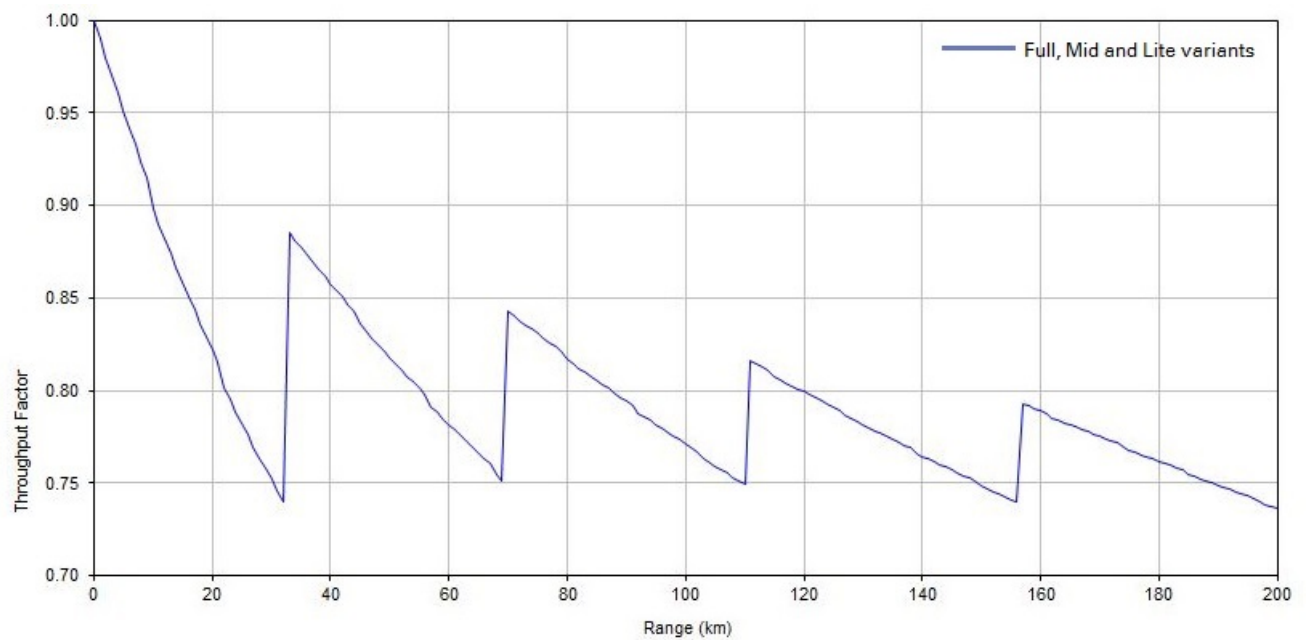




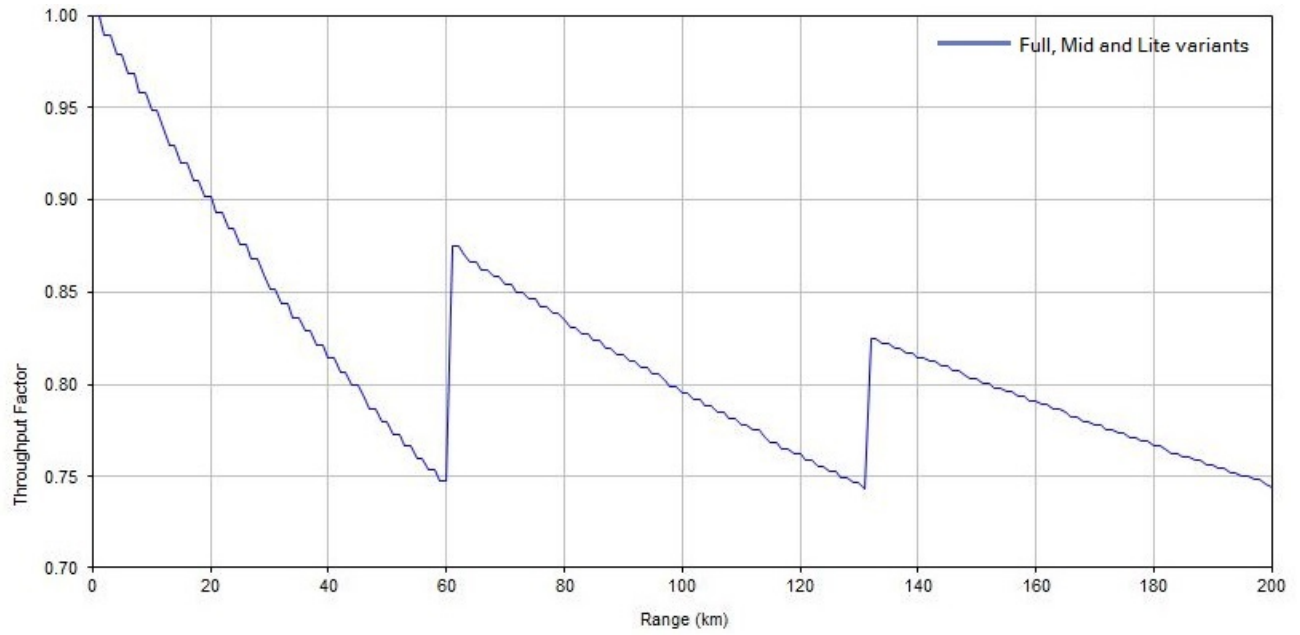
**Figure 37** Range adjustment for PTP 650, symmetry 1:1, optimization TDM, bandwidth 45 MHz



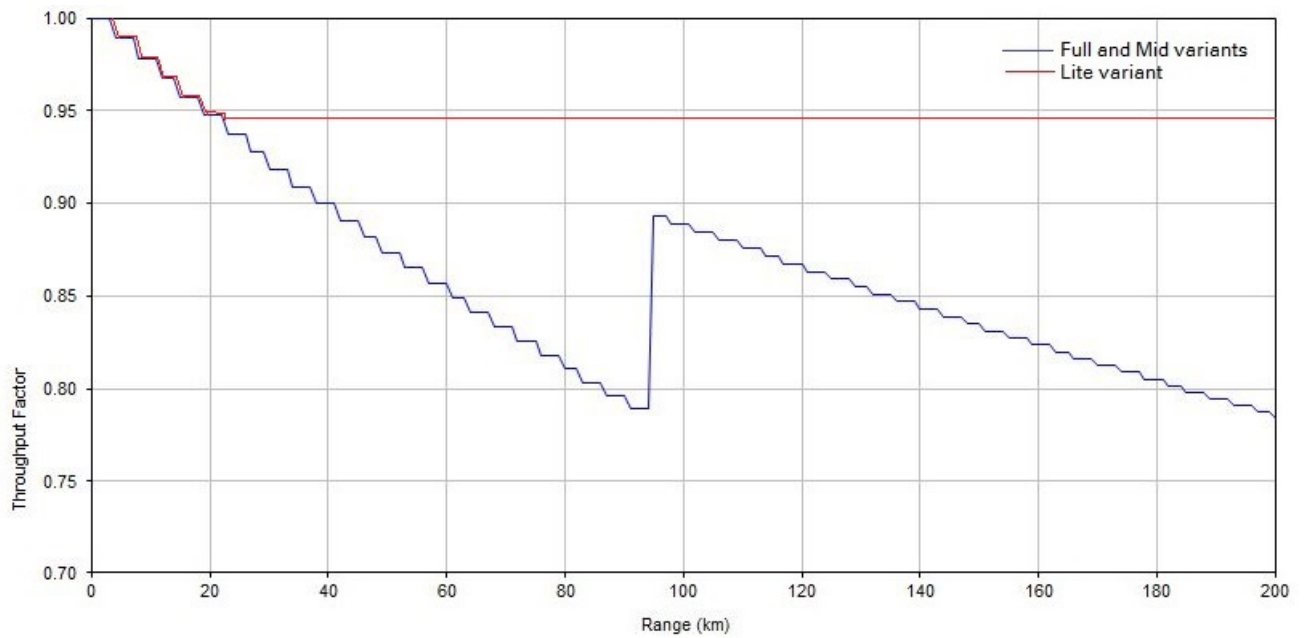
**Figure 38** Range adjustment for PTP 650, symmetry 1:1, optimization TDM, bandwidth 40 MHz



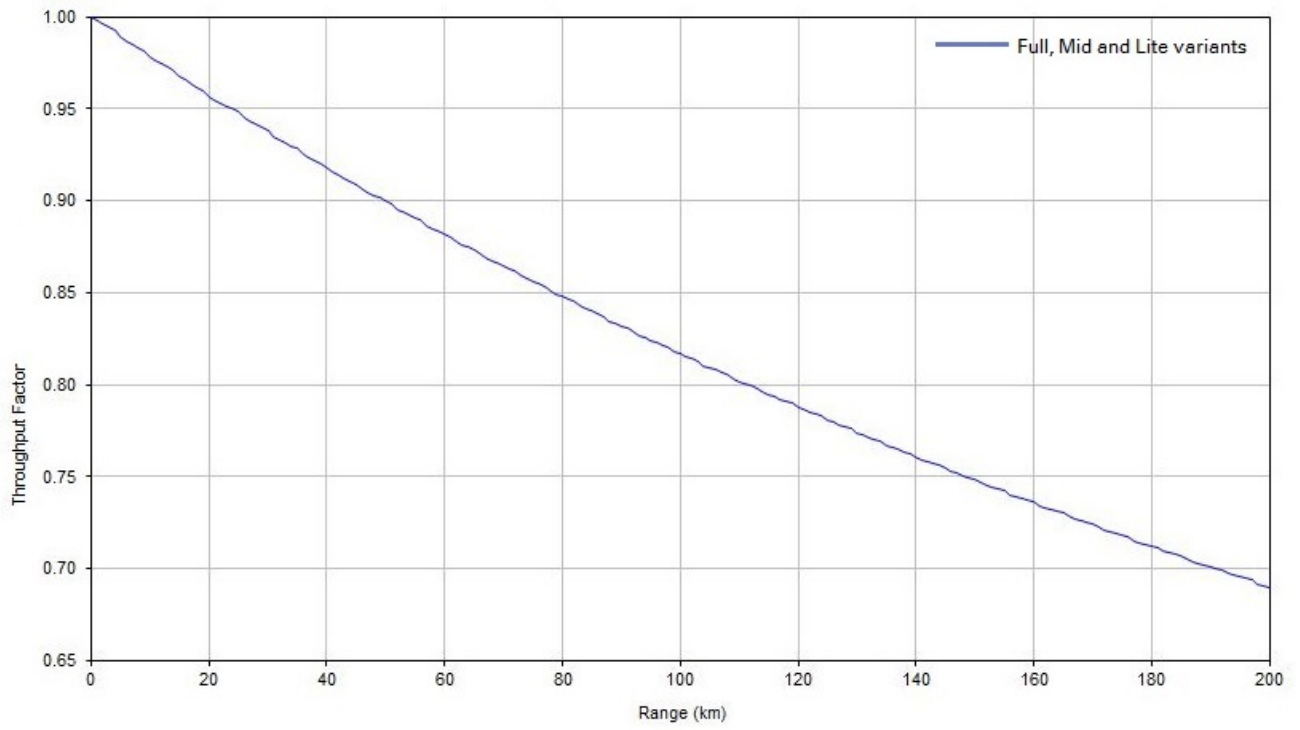
**Figure 39** Range adjustment for PTP 650, symmetry 1:1, optimization TDM, bandwidth 20 MHz



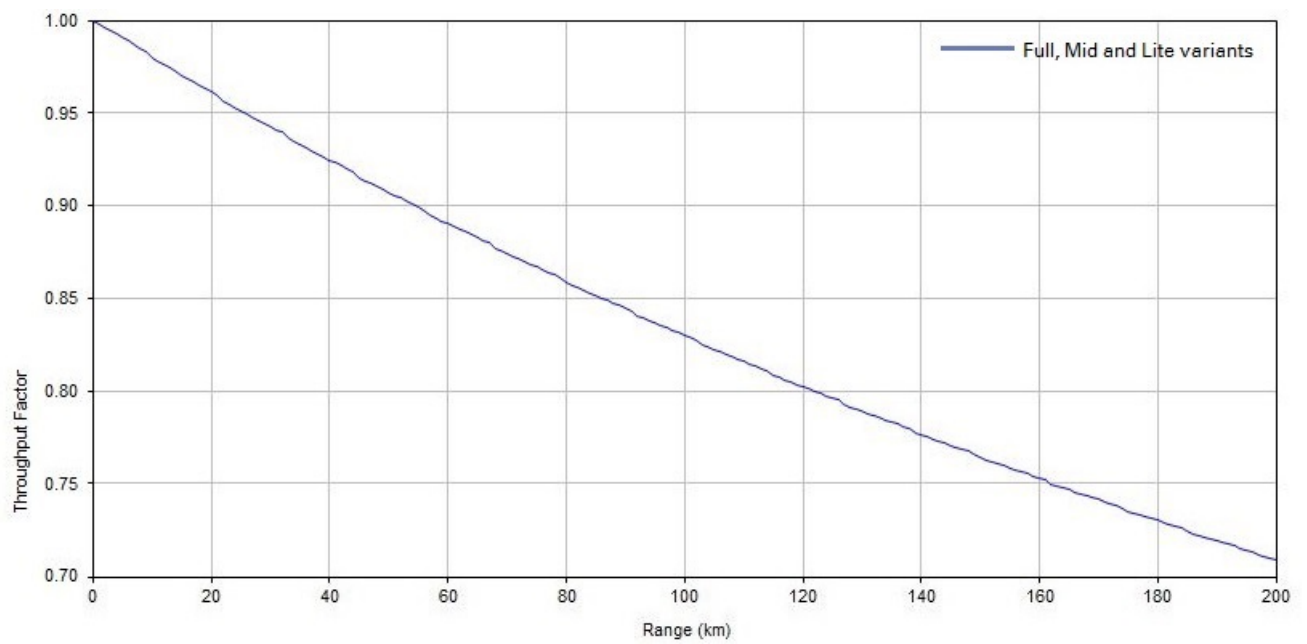
**Figure 40** Range adjustment for PTP 650, symmetry 1:1, optimization TDM, bandwidth 10 MHz



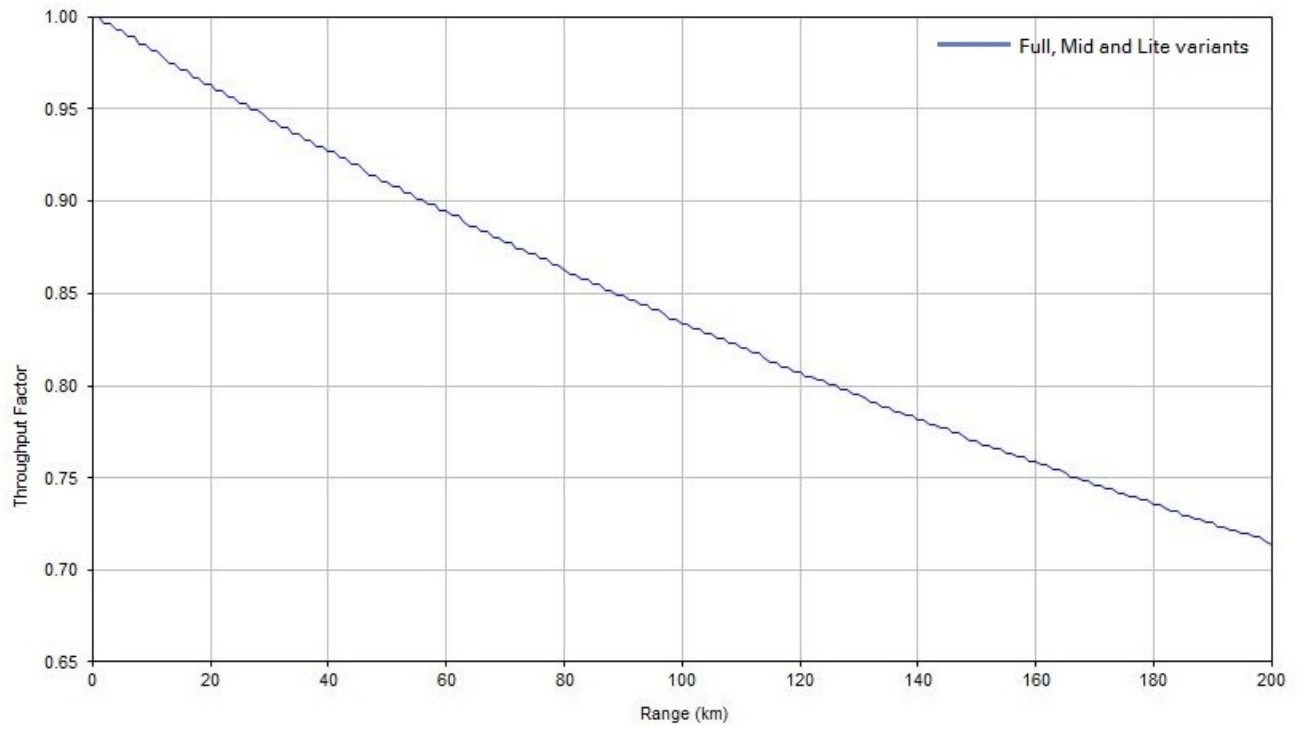
**Figure 41** Range adjustment for PTP 650, symmetry 2:1, optimization IP, bandwidth 45 MHz



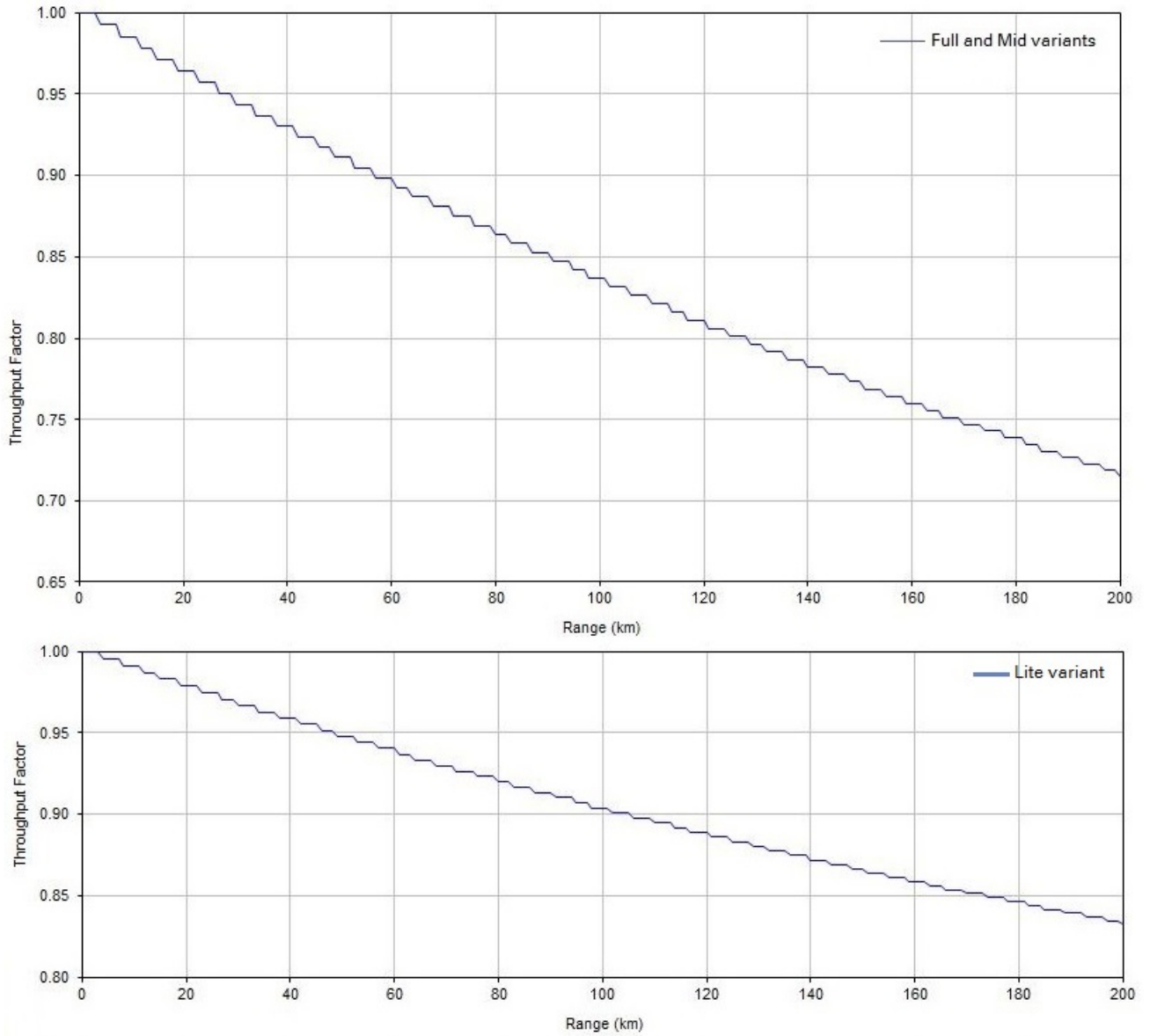
**Figure 42** Range adjustment for PTP 650, symmetry 2:1, optimization IP, bandwidth 40 MHz



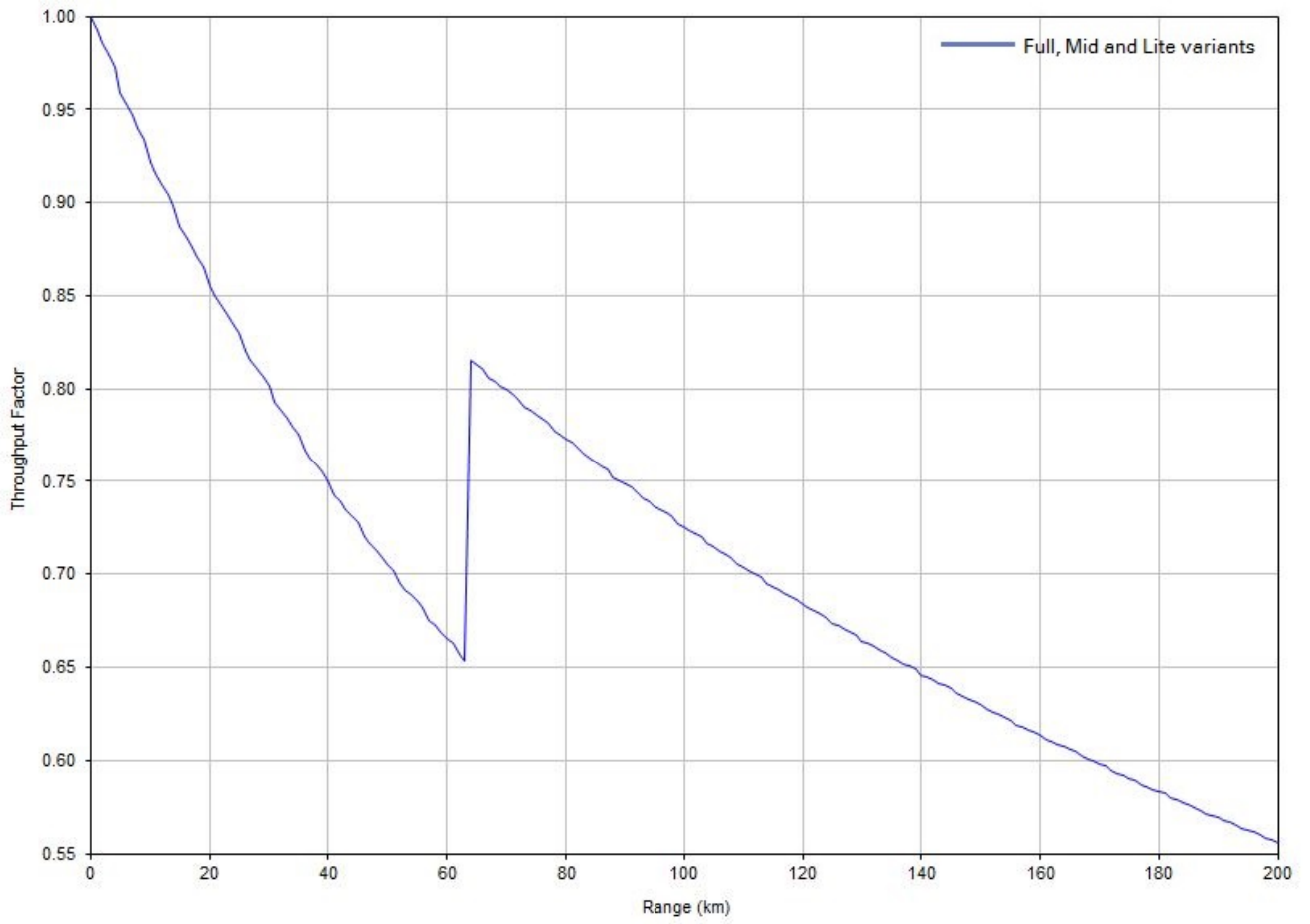
**Figure 43** Range adjustment for PTP 650, symmetry 2:1, optimization IP, bandwidth 20 MHz



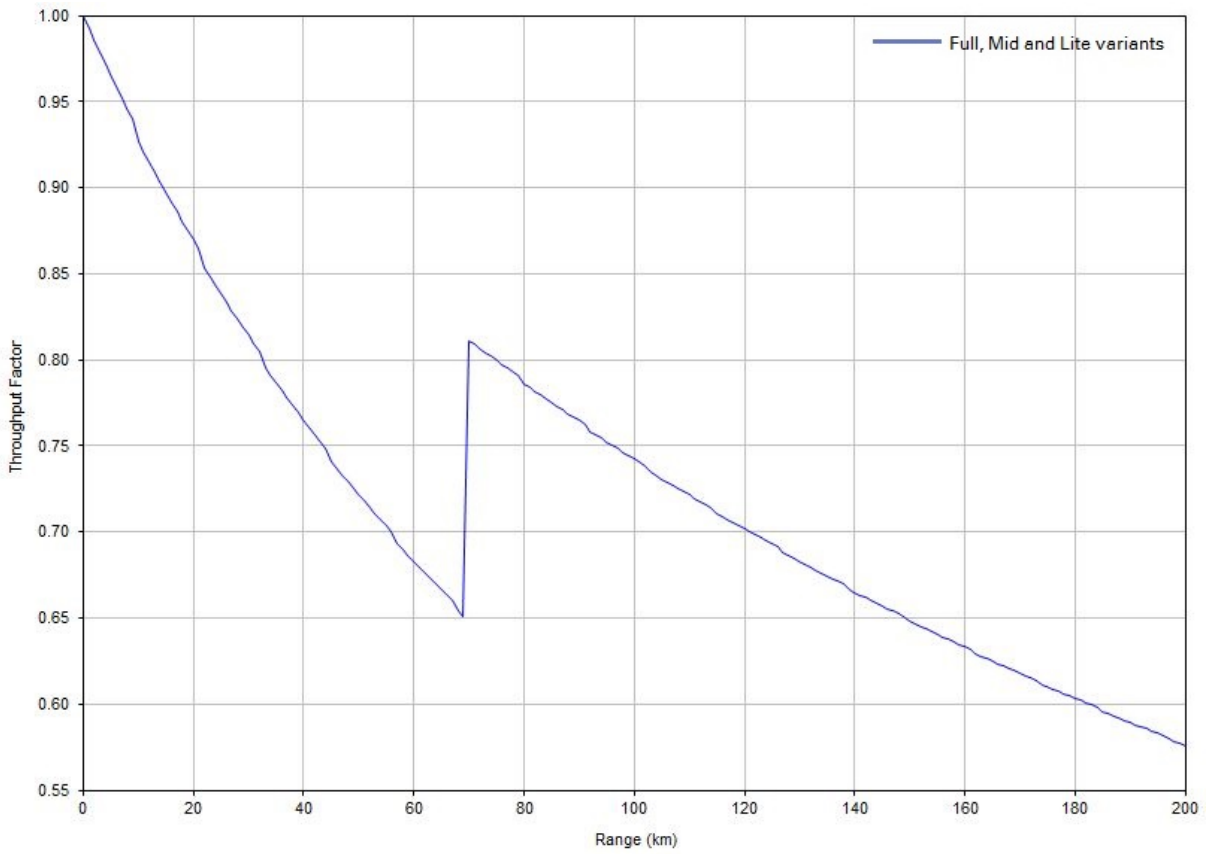
**Figure 44** Range adjustment for PTP 650, symmetry 2:1, optimization IP, bandwidth 10 MHz



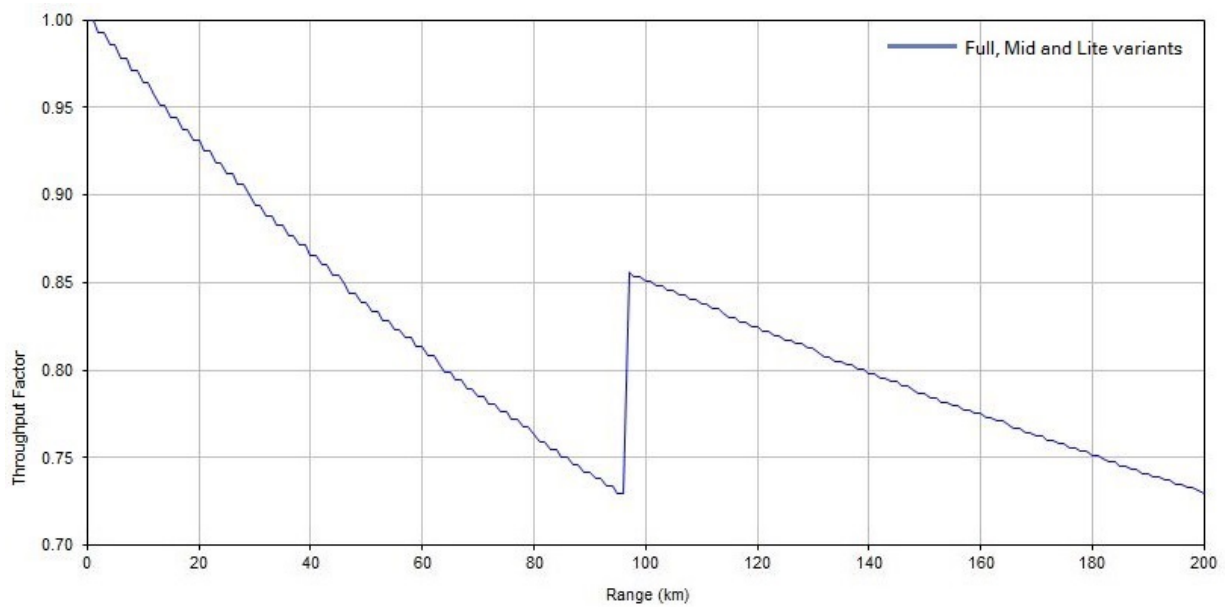
**Figure 45** Range adjustment for PTP 650, symmetry 2:1, optimization TDM, bandwidth 45 MHz



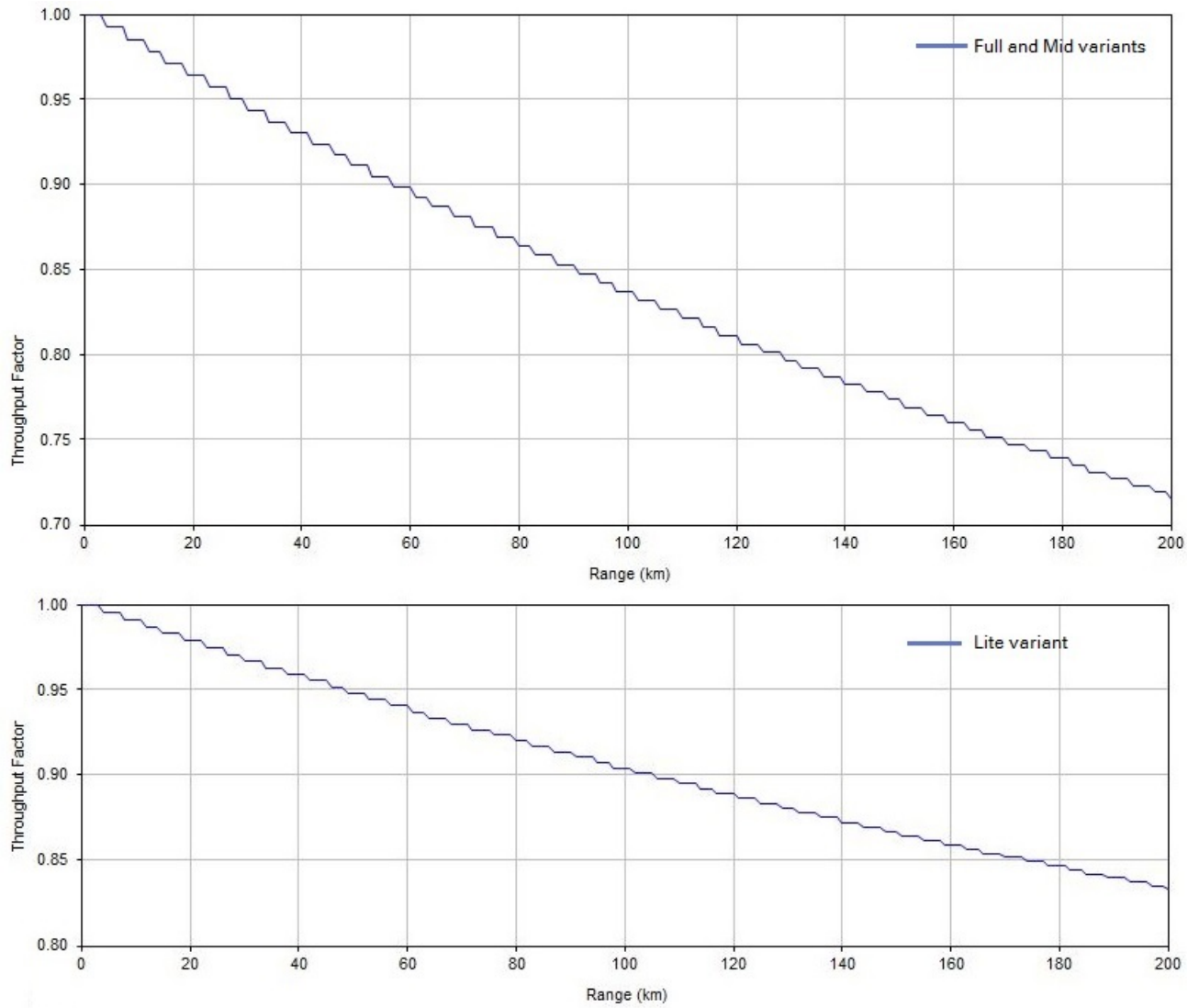
**Figure 46** Range adjustment for PTP 650, symmetry 2:1, optimization TDM, bandwidth 40 MHz



**Figure 47** Range adjustment for PTP 650, symmetry 2:1, optimization TDM, bandwidth 20 MHz

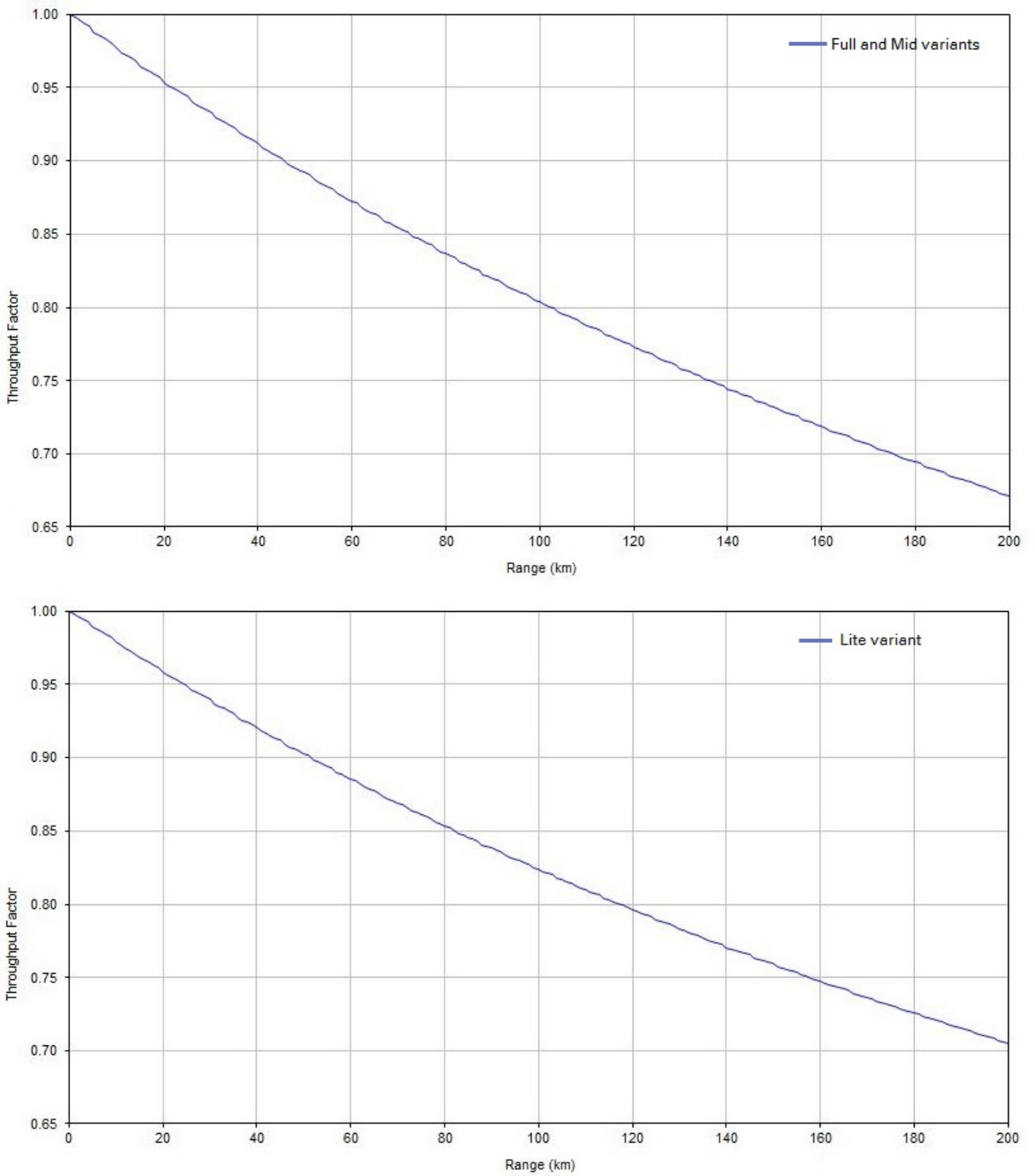


**Figure 48** Range adjustment for PTP 650, symmetry 2:1, optimization TDM, bandwidth 10 MHz

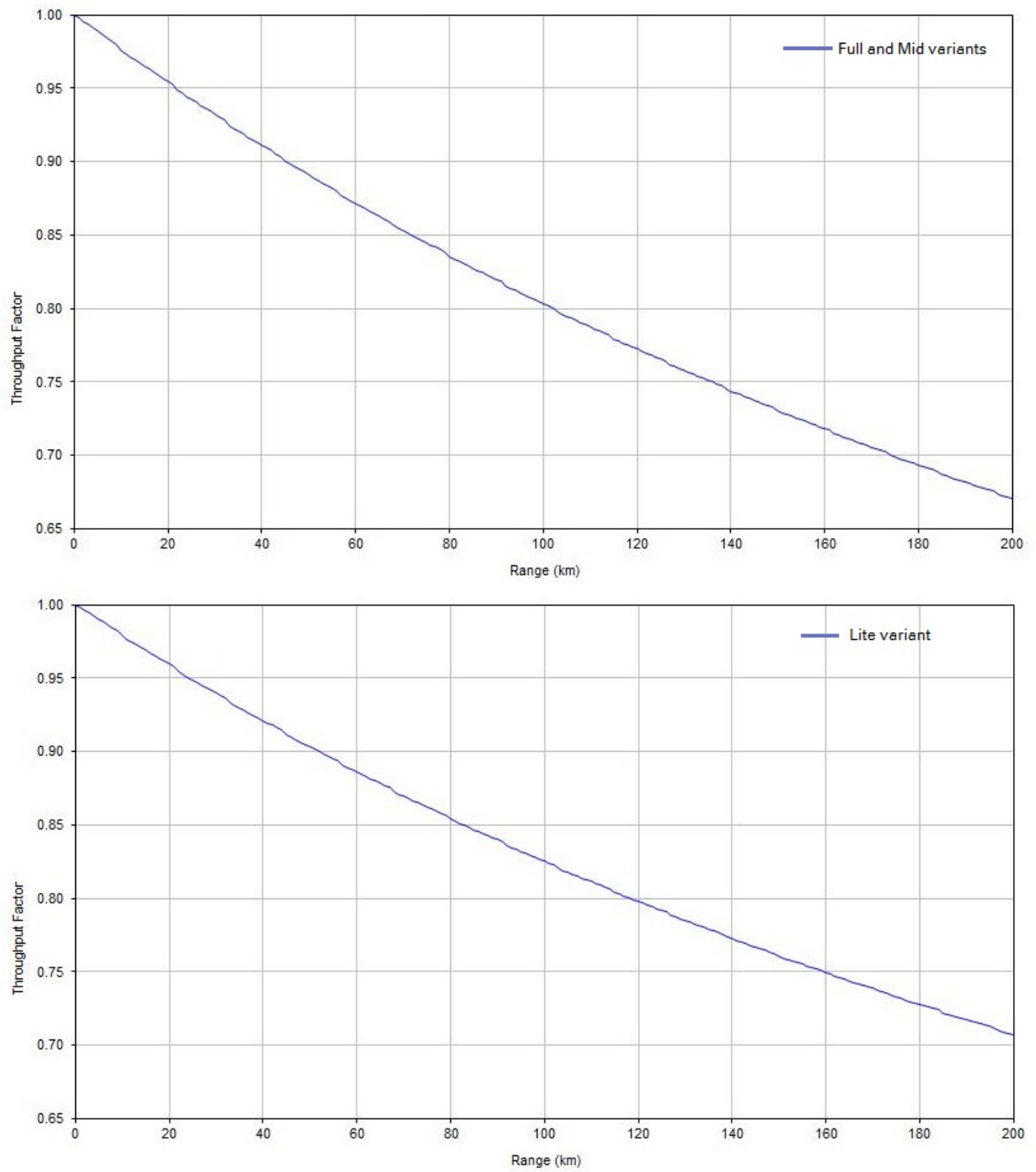




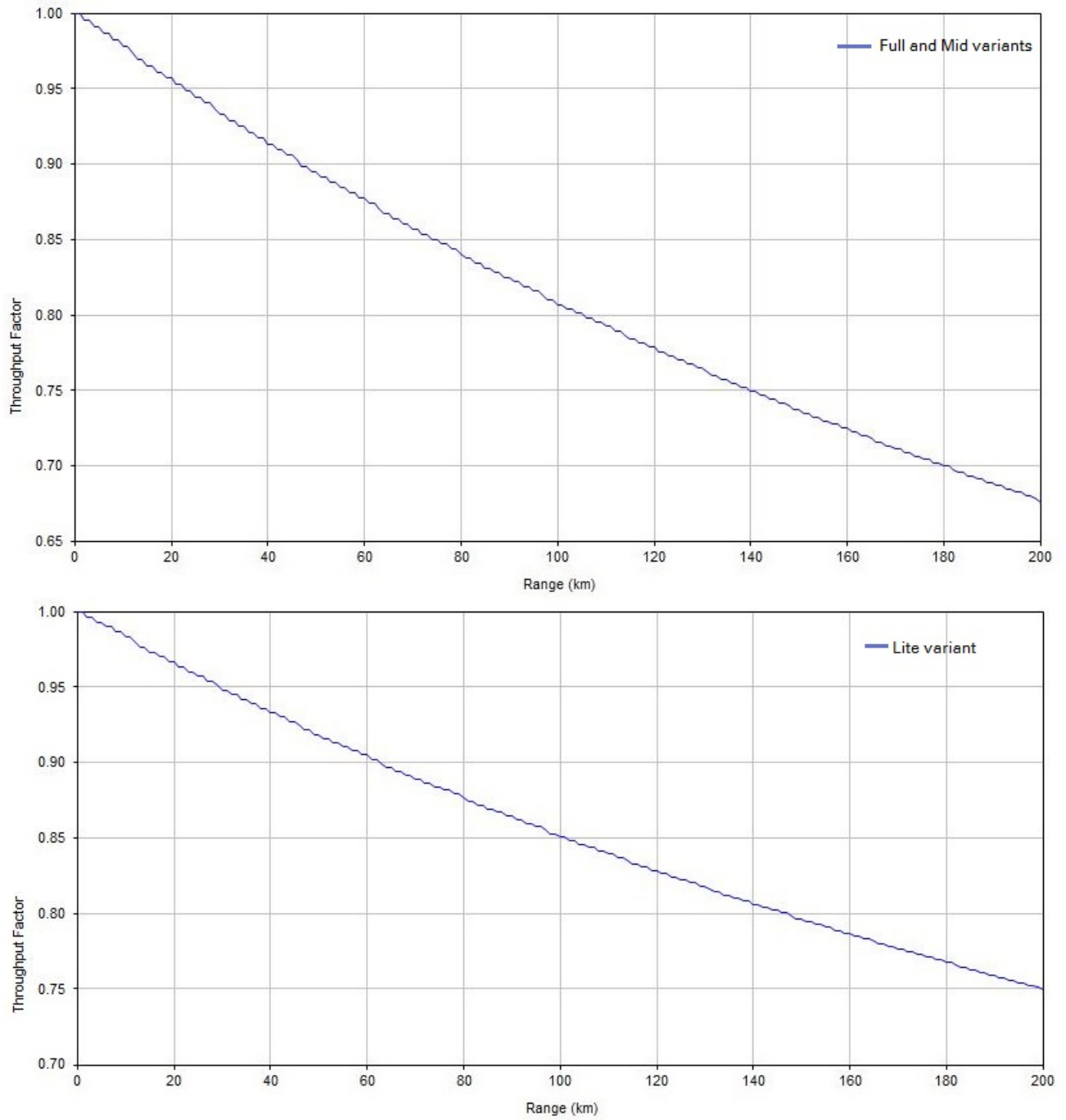
**Figure 49** Range adjustment for PTP 650, adaptive, optimization IP, bandwidth 45 MHz



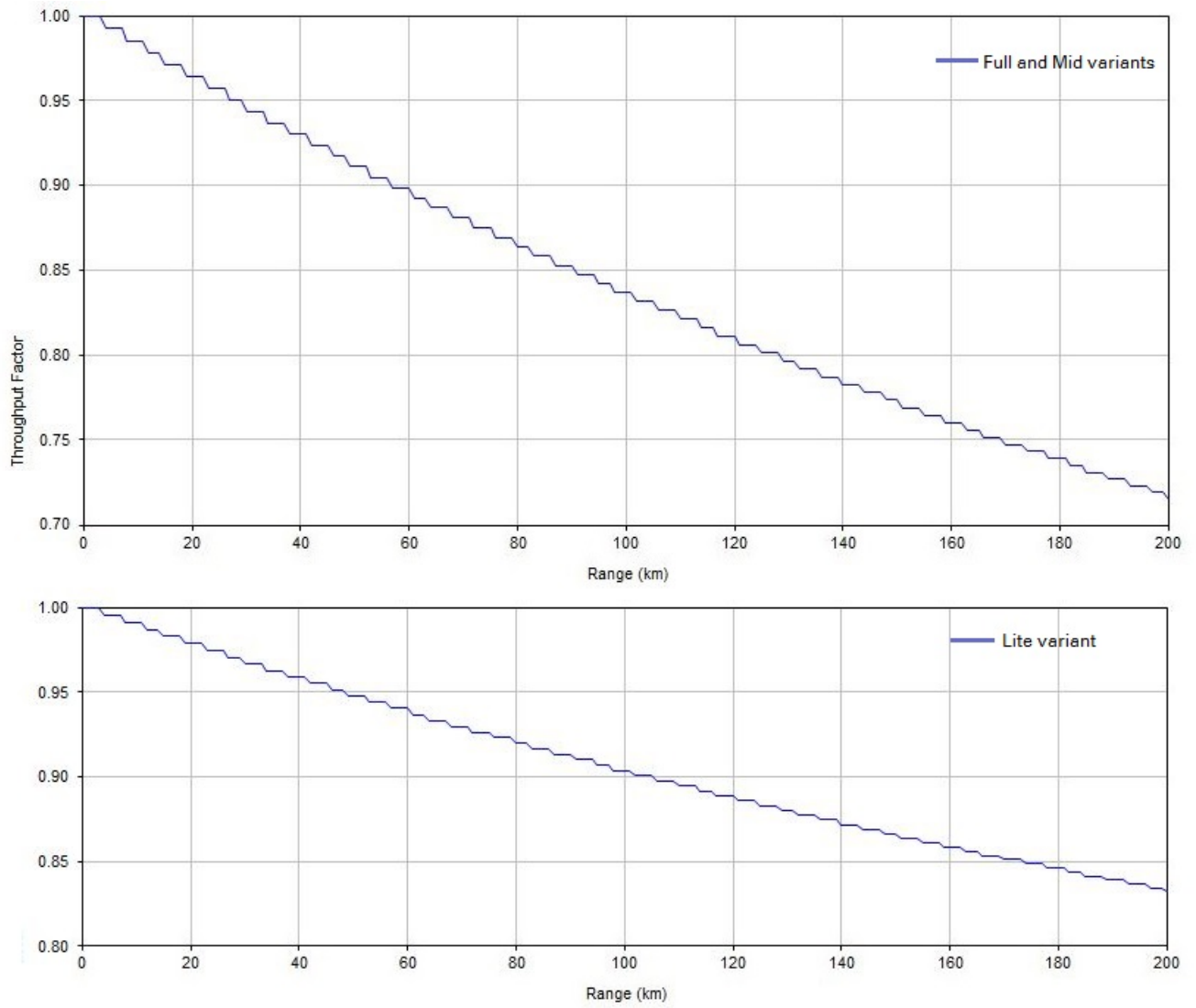
**Figure 50** Range adjustment for PTP 650, adaptive, optimization IP, bandwidth 40 MHz



**Figure 51** Range adjustment for PTP 650, adaptive, optimization IP, bandwidth 20 MHz



**Figure 52** Range adjustment for PTP 650, adaptive, optimization IP, bandwidth 10 MHz



---

## Chapter 4: Legal and regulatory information

---

This chapter provides end user license agreements and regulatory notifications.



### Caution

Intentional or unintentional changes or modifications to the equipment must not be made unless under the express consent of the party responsible for compliance. Any such modifications could void the user's authority to operate the equipment and will void the manufacturer's warranty.



### Attention

Changements ou modifications intentionnels ou non de l'équipement ne doivent pas être entrepris sans l'autorisation de l'organisme responsable de la déclaration de conformité. Ces modifications ou changements pourraient invalider le droit de l'utilisateur à utiliser cet appareil et annuleraient la garantie du fabricant.

---

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 650 Series products.
- [Compliance with safety standards](#) on page 4-23 lists the safety specifications against which the PTP 650 has been tested and certified. It also describes how to keep RF exposure within safe limits.
- [Compliance with radio regulations](#) on page 4-28 describes how the PTP 650 complies with the radio regulations that are in force in various countries, and contains notifications made to regulatory bodies for the PTP 650.

# Cambium Networks end user license agreement

---

## Acceptance of this agreement

In connection with Cambium Networks' delivery of certain proprietary software or products containing embedded or pre-loaded proprietary software, or both, Cambium Networks is willing to license this certain proprietary software and the accompanying documentation to you only on the condition that you accept all the terms in this End User License Agreement ("Agreement").

IF YOU DO NOT AGREE TO THE TERMS OF THIS AGREEMENT, DO NOT USE THE PRODUCT OR INSTALL THE SOFTWARE. INSTEAD, YOU MAY, FOR A FULL REFUND, RETURN THIS PRODUCT TO THE LOCATION WHERE YOU ACQUIRED IT OR PROVIDE WRITTEN VERIFICATION OF DELETION OF ALL COPIES OF THE SOFTWARE. ANY USE OF THE SOFTWARE, INCLUDING BUT NOT LIMITED TO USE ON THE PRODUCT, WILL CONSTITUTE YOUR ACCEPTANCE TO THE TERMS OF THIS AGREEMENT.

## Definitions

In this Agreement, the word "Software" refers to the set of instructions for computers, in executable form and in any media, (which may include diskette, CD-ROM, downloadable internet, hardware, or firmware) licensed to you. The word "Documentation" refers to electronic or printed manuals and accompanying instructional aids licensed to you. The word "Product" refers to Cambium Networks' fixed wireless broadband devices for which the Software and Documentation is licensed for use.

## Grant of license

Cambium Networks Limited ("Cambium") grants you ("Licensee" or "you") a personal, nonexclusive, non-transferable license to use the Software and Documentation subject to the Conditions of Use set forth in "**Conditions of use**" and the terms and conditions of this Agreement. Any terms or conditions relating to the Software and Documentation appearing on the face or reverse side of any purchase order, purchase order acknowledgment or other order document that are different from, or in addition to, the terms of this Agreement will not be binding on the parties, even if payment is accepted.

## Conditions of use

Any use of the Software and Documentation outside of the conditions set forth in this Agreement is strictly prohibited and will be deemed a breach of this Agreement.

1. Only you, your employees or agents may use the Software and Documentation. You will take all necessary steps to insure that your employees and agents abide by the terms of this Agreement.
2. You will use the Software and Documentation (i) only for your internal business purposes; (ii) only as described in the Software and Documentation; and (iii) in strict accordance with this Agreement.
3. You may use the Software and Documentation, provided that the use is in conformance with the terms set forth in this Agreement.
4. Portions of the Software and Documentation are protected by United States copyright laws, international treaty provisions, and other applicable laws. Therefore, you must treat the Software like any other copyrighted material (for example, a book or musical recording) except that you may either: (i) make 1 copy of the transportable part of the Software (which typically is supplied on diskette, CD-ROM, or downloadable internet), solely for back-up purposes; or (ii) copy the transportable part of the Software to a PC hard disk, provided you keep the original solely for back-up purposes. If the Documentation is in printed form, it may not be copied. If the Documentation is in electronic form, you may print out 1 copy, which then may not be copied. With regard to the copy made for backup or archival purposes, you agree to reproduce any Cambium Networks copyright notice, and other proprietary legends appearing thereon. Such copyright notice(s) may appear in any of several forms, including machine-readable form, and you agree to reproduce such notice in each form in which it appears, to the extent it is physically possible to do so. Unauthorized duplication of the Software or Documentation constitutes copyright infringement, and in the United States is punishable in federal court by fine and imprisonment.
5. You will not transfer, directly or indirectly, any product, technical data or software to any country for which the United States Government requires an export license or other governmental approval without first obtaining such license or approval.

## Title and restrictions

If you transfer possession of any copy of the Software and Documentation to another party outside of the terms of this agreement, your license is automatically terminated. Title and copyrights to the Software and Documentation and any copies made by you remain with Cambium Networks and its licensors. You will not, and will not permit others to: (i) modify, translate, decompile, bootleg, reverse engineer, disassemble, or extract the inner workings of the Software or Documentation, (ii) copy the look-and-feel or functionality of the Software or Documentation; (iii) remove any proprietary notices, marks, labels, or logos from the Software or Documentation; (iv) rent or transfer all or some of the Software or Documentation to any other party without Cambium's prior written consent; or (v) utilize any computer software or hardware which is designed to defeat any copy protection device, should the Software and Documentation be equipped with such a protection device. If the Software and Documentation is provided on multiple types of media (such as diskette, CD-ROM, downloadable internet), then you will only use the medium which best meets your specific needs, and will not loan, rent, lease, or transfer the other media contained in the package without Cambium's written consent. Unauthorized copying of the Software or Documentation, or failure to comply with any of the provisions of this Agreement, will result in automatic termination of this license.

## Confidentiality

You acknowledge that all Software and Documentation contain valuable proprietary information and trade secrets and that unauthorized or improper use of the Software and Documentation will result in irreparable harm to Cambium Networks for which monetary damages would be inadequate and for which Cambium Networks will be entitled to immediate injunctive relief. If applicable, you will limit access to the Software and Documentation to those of your employees and agents who need to use the Software and Documentation for your internal business purposes, and you will take appropriate action with those employees and agents to preserve the confidentiality of the Software and Documentation, using the same degree of care to avoid unauthorized or improper disclosure as you use for the protection of your own proprietary software, but in no event less than reasonable care.

You have no obligation to preserve the confidentiality of any proprietary information that: (i) was in the public domain at the time of disclosure; (ii) entered the public domain through no fault of yours; (iii) was given to you free of any obligation to keep it confidential; (iv) is independently developed by you; or (v) is disclosed as required by law provided that you notify Cambium Networks prior to such disclosure and provide Cambium Networks with a reasonable opportunity to respond.



## Right to use Cambium's name

Except as required in “**Conditions of use**”, you will not, during the term of this Agreement or thereafter, use any trademark of Cambium Networks, or any word or symbol likely to be confused with any Cambium Networks trademark, either alone or in any combination with another word or words.

## Transfer

The Software and Documentation may not be transferred to another party without the express written consent of Cambium Networks, regardless of whether or not such transfer is accomplished by physical or electronic means. Cambium's consent may be withheld at its discretion and may be conditioned upon transferee paying all applicable license fees and agreeing to be bound by this Agreement.

## Updates

During the first 12 months after purchase of a Product, or during the term of any executed Maintenance and Support Agreement for the Product, you are entitled to receive Updates. An “Update” means any code in any form which is a bug fix, patch, error correction, or minor enhancement, but excludes any major feature added to the Software. Updates are available for download at the support website.

Major features may be available from time to time for an additional license fee. If Cambium Networks makes available to you major features and no other end user license agreement is provided, then the terms of this Agreement will apply.

## Maintenance

Except as provided above, Cambium Networks is not responsible for maintenance or field service of the Software under this Agreement.

## Disclaimer

CAMBIUM NETWORKS DISCLAIMS ALL WARRANTIES OF ANY KIND, WHETHER EXPRESS, IMPLIED, STATUTORY, OR IN ANY COMMUNICATION WITH YOU. CAMBIUM NETWORKS SPECIFICALLY DISCLAIMS ANY WARRANTY INCLUDING THE IMPLIED WARRANTIES OF MERCHANTABILITY, NONINFRINGEMENT, OR FITNESS FOR A PARTICULAR PURPOSE. THE SOFTWARE AND DOCUMENTATION ARE PROVIDED "AS IS." CAMBIUM NETWORKS DOES NOT WARRANT THAT THE SOFTWARE WILL MEET YOUR REQUIREMENTS, OR THAT THE OPERATION OF THE SOFTWARE WILL BE UNINTERRUPTED OR ERROR FREE, OR THAT DEFECTS IN THE SOFTWARE WILL BE CORRECTED. CAMBIUM NETWORKS MAKES NO WARRANTY WITH RESPECT TO THE CORRECTNESS, ACCURACY, OR RELIABILITY OF THE SOFTWARE AND DOCUMENTATION. Some jurisdictions do not allow the exclusion of implied warranties, so the above exclusion may not apply to you.

## Limitation of liability

IN NO EVENT SHALL CAMBIUM NETWORKS BE LIABLE TO YOU OR ANY OTHER PARTY FOR ANY DIRECT, INDIRECT, GENERAL, SPECIAL, INCIDENTAL, CONSEQUENTIAL, EXEMPLARY OR OTHER DAMAGE ARISING OUT OF THE USE OR INABILITY TO USE THE PRODUCT (INCLUDING, WITHOUT LIMITATION, DAMAGES FOR LOSS OF BUSINESS PROFITS, BUSINESS INTERRUPTION, LOSS OF BUSINESS INFORMATION OR ANY OTHER PECUNIARY LOSS, OR FROM ANY BREACH OF WARRANTY, EVEN IF CAMBIUM NETWORKS HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES. (Some states do not allow the exclusion or limitation of incidental or consequential damages, so the above exclusion or limitation may not apply to you.) IN NO CASE SHALL CAMBIUM'S LIABILITY EXCEED THE AMOUNT YOU PAID FOR THE PRODUCT.

## U.S. government

If you are acquiring the Product on behalf of any unit or agency of the U.S. Government, the following applies. Use, duplication, or disclosure of the Software and Documentation is subject to the restrictions set forth in subparagraphs (c) (1) and (2) of the Commercial Computer Software – Restricted Rights clause at FAR 52.227-19 (JUNE 1987), if applicable, unless being provided to the Department of Defense. If being provided to the Department of Defense, use, duplication, or disclosure of the Products is subject to the restricted rights set forth in subparagraph (c) (1) (ii) of the Rights in Technical Data and Computer Software clause at DFARS 252.227-7013 (OCT 1988), if applicable. Software and Documentation may or may not include a Restricted Rights notice, or other notice referring specifically to the terms and conditions of this Agreement. The terms and conditions of this Agreement will each continue to apply, but only to the extent that such terms and conditions are not inconsistent with the rights provided to you under the aforementioned provisions of the FAR and DFARS, as applicable to the particular procuring agency and procurement transaction.

## Term of license

Your right to use the Software will continue in perpetuity unless terminated as follows. Your right to use the Software will terminate immediately without notice upon a breach of this Agreement by you. Within 30 days after termination of this Agreement, you will certify to Cambium Networks in writing that through your best efforts, and to the best of your knowledge, the original and all copies, in whole or in part, in any form, of the Software and all related material and Documentation, have been destroyed, except that, with prior written consent from Cambium Networks, you may retain one copy for archival or backup purposes. You may not sublicense, assign or transfer the license or the Product, except as expressly provided in this Agreement. Any attempt to otherwise sublicense, assign or transfer any of the rights, duties or obligations hereunder is null and void.

## Governing law

This Agreement is governed by the laws of the United States of America to the extent that they apply and otherwise by the laws of the State of Illinois.

## Assignment

This agreement may not be assigned by you without Cambium's prior written consent.

## Survival of provisions

The parties agree that where the context of any provision indicates an intent that it survives the term of this Agreement, then it will survive.

## Entire agreement

This agreement contains the parties' entire agreement regarding your use of the Software and may be amended only in writing signed by both parties, except that Cambium Networks may modify this Agreement as necessary to comply with applicable laws.

## Third party software

The software may contain one or more items of Third-Party Software supplied by other third-party suppliers. The terms of this Agreement govern your use of any Third-Party Software UNLESS A SEPARATE THIRD-PARTY SOFTWARE LICENSE IS INCLUDED, IN WHICH CASE YOUR USE OF THE THIRD-PARTY SOFTWARE WILL THEN BE GOVERNED BY THE SEPARATE THIRD-PARTY LICENSE.

## Trademarks

Java™ Technology and/or J2ME™ : Java and all other Java-based marks are trademarks or registered trademarks of Sun Microsystems, Inc. in the U.S. and other countries.

UNIX® : UNIX is a registered trademark of The Open Group in the United States and other countries.

## Net SNMP

Various copyrights apply to this package, listed in various separate parts below. Please make sure that you read all the parts.

---- Part 1: CMU/UCD copyright notice: (BSD like) ----

Copyright 1989, 1991, 1992 by Carnegie Mellon University

Derivative Work - 1996, 1998-2000

Copyright 1996, 1998-2000 The Regents of the University of California

All Rights Reserved

Permission to use, copy, modify and distribute this software and its documentation for any purpose and without fee is hereby granted, provided that the above copyright notice appears in all copies and that both that copyright notice and this permission notice appear in supporting documentation, and that the name of CMU and The Regents of the University of California not be used in advertising or publicity pertaining to distribution of the software without specific written permission.

CMU AND THE REGENTS OF THE UNIVERSITY OF CALIFORNIA DISCLAIM ALL WARRANTIES WITH REGARD TO THIS SOFTWARE, INCLUDING ALL IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS. IN NO EVENT SHALL CMU OR THE REGENTS OF THE UNIVERSITY OF CALIFORNIA BE LIABLE FOR ANY SPECIAL, INDIRECT OR CONSEQUENTIAL DAMAGES OR ANY DAMAGES WHATSOEVER RESULTING FROM THE LOSS OF USE, DATA OR PROFITS, WHETHER IN AN ACTION OF CONTRACT, NEGLIGENCE OR OTHER TORTIOUS ACTION, ARISING OUT OF OR IN CONNECTION WITH THE USE OR PERFORMANCE OF THIS SOFTWARE.

---- Part 2: Networks Associates Technology, Inc copyright notice (BSD) ----

Copyright © 2001-2003, Networks Associates Technology, Inc

All rights reserved.

Redistribution and use in source and binary forms, with or without modification, are permitted provided that the following conditions are met:

- Redistributions of source code must retain the above copyright notice, this list of conditions and the following disclaimer.

- Redistributions in binary form must reproduce the above copyright notice, this list of conditions and the following disclaimer in the documentation and/or other materials provided with the distribution.
- Neither the name of the Networks Associates Technology, Inc nor the names of its contributors may be used to endorse or promote products derived from this software without specific prior written permission.

THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDERS OR CONTRIBUTORS BE LIABLE FOR ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES; LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.

---- Part 3: Cambridge Broadband Ltd. copyright notice (BSD) -----

Portions of this code are copyright © 2001-2003, Cambridge Broadband Ltd.

All rights reserved.

Redistribution and use in source and binary forms, with or without modification, are permitted provided that the following conditions are met:

- Redistributions of source code must retain the above copyright notice, this list of conditions and the following disclaimer.
- Redistributions in binary form must reproduce the above copyright notice, this list of conditions and the following disclaimer in the documentation and/or other materials provided with the distribution.
- The name of Cambridge Broadband Ltd. may not be used to endorse or promote products derived from this software without specific prior written permission.

THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDER "AS IS" AND ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER BE LIABLE FOR ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES; LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.

---- Part 4: Sun Microsystems, Inc. copyright notice (BSD) -----

Copyright © 2003 Sun Microsystems, Inc., 4150 Network Circle, Santa Clara,

California 95054, U.S.A. All rights reserved.

Use is subject to license terms below.

This distribution may include materials developed by third parties.

Sun, Sun Microsystems, the Sun logo and Solaris are trademarks or registered trademarks of Sun Microsystems, Inc. in the U.S. and other countries.

Redistribution and use in source and binary forms, with or without modification, are permitted provided that the following conditions are met:

- Redistributions of source code must retain the above copyright notice, this list of conditions and the following disclaimer.
- Redistributions in binary form must reproduce the above copyright notice, this list of conditions and the following disclaimer in the documentation and/or other materials provided with the distribution.
- Neither the name of the Sun Microsystems, Inc. nor the names of its contributors may be used to endorse or promote products derived from this software without specific prior written permission.

THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDERS OR CONTRIBUTORS BE LIABLE FOR ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES; LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.

---- Part 5: Sparta, Inc copyright notice (BSD) -----

Copyright © 2003-2008, Sparta, Inc

All rights reserved.

Redistribution and use in source and binary forms, with or without modification, are permitted provided that the following conditions are met:

- Redistributions of source code must retain the above copyright notice, this list of conditions and the following disclaimer.
- Redistributions in binary form must reproduce the above copyright notice, this list of conditions and the following disclaimer in the documentation and/or other materials provided with the distribution.
- Neither the name of Sparta, Inc nor the names of its contributors may be used to endorse or promote products derived from this software without specific prior written permission.

THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDERS OR CONTRIBUTORS BE LIABLE FOR ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES; LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.

---- Part 6: Cisco/BUPTNIC copyright notice (BSD) ----

Copyright © 2004, Cisco, Inc and Information Network

Center of Beijing University of Posts and Telecommunications.

All rights reserved.

Redistribution and use in source and binary forms, with or without modification, are permitted provided that the following conditions are met:

- Redistributions of source code must retain the above copyright notice, this list of conditions and the following disclaimer.
- Redistributions in binary form must reproduce the above copyright notice, this list of conditions and the following disclaimer in the documentation and/or other materials provided with the distribution.
- Neither the name of Cisco, Inc, Beijing University of Posts and Telecommunications, nor the names of their contributors may be used to endorse or promote products derived from this software without specific prior written permission.

THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDERS OR CONTRIBUTORS BE LIABLE FOR ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES; LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.

---- Part 7: Fabasoft R&D Software GmbH & Co KG copyright notice (BSD) ----

Copyright © Fabasoft R&D Software GmbH & Co KG, 2003

oss@fabasoft.com

Author: Bernhard Penz

Redistribution and use in source and binary forms, with or without modification, are permitted provided that the following conditions are met:

- Redistributions of source code must retain the above copyright notice, this list of conditions and the following disclaimer.
- Redistributions in binary form must reproduce the above copyright notice, this list of conditions and the following disclaimer in the documentation and/or other materials provided with the distribution.
- The name of Fabasoft R&D Software GmbH & Co KG or any of its subsidiaries, brand or product names may not be used to endorse or promote products derived from this software without specific prior written permission.

THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDER "AS IS" AND ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER BE LIABLE FOR ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES; LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.

## OpenSSL

Copyright (c) 1998-2008 The OpenSSL Project. All rights reserved.

Redistribution and use in source and binary forms, with or without modification, are permitted provided that the following conditions are met:

1. Redistributions of source code must retain the above copyright notice, this list of conditions and the following disclaimer.
2. Redistributions in binary form must reproduce the above copyright notice, this list of conditions and the following disclaimer in the documentation and/or other materials provided with the distribution.
3. All advertising materials mentioning features or use of this software must display the following acknowledgment:

"This product includes software developed by the OpenSSL Project for use in the OpenSSL Toolkit. (<http://www.openssl.org/>)"

4. The names "OpenSSL Toolkit" and "OpenSSL Project" must not be used to endorse or promote products derived from this software without prior written permission. For written permission, please contact [openssl-core@openssl.org](mailto:openssl-core@openssl.org).

5. Products derived from this software may not be called "OpenSSL" nor may "OpenSSL" appear in their names without prior written permission of the OpenSSL Project.

6. Redistributions of any form whatsoever must retain the following acknowledgment:

"This product includes software developed by the OpenSSL Project for use in the OpenSSL Toolkit (<http://www.openssl.org/>)"



THIS SOFTWARE IS PROVIDED BY THE OpenSSL PROJECT "AS IS" AND ANY EXPRESSED OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE DISCLAIMED. IN NO EVENT SHALL THE OpenSSL PROJECT OR ITS CONTRIBUTORS BE LIABLE FOR ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES; LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.

This product includes cryptographic software written by Eric Young (eay@cryptsoft.com). This product includes software written by Tim Hudson (tjh@cryptsoft.com).

Original SSLeay License

Copyright © 1995-1998 Eric Young (eay@cryptsoft.com)

All rights reserved.

This package is an SSL implementation written by Eric Young (eay@cryptsoft.com). The implementation was written so as to conform with Netscape's SSL.

This library is free for commercial and non-commercial use as long as the following conditions are adhered to. The following conditions apply to all code found in this distribution, be it the RC4, RSA, lhash, DES, etc., code; not just the SSL code. The SSL documentation included with this distribution is covered by the same copyright terms except that the holder is Tim Hudson (tjh@cryptsoft.com).

Copyright remains Eric Young's, and as such any Copyright notices in the code are not to be removed.

If this package is used in a product, Eric Young should be given attribution as the author of the parts of the library used. This can be in the form of a textual message at program startup or in documentation (online or textual) provided with the package.

Redistribution and use in source and binary forms, with or without modification, are permitted provided that the following conditions are met:

1. Redistributions of source code must retain the copyright notice, this list of conditions and the following disclaimer.
2. Redistributions in binary form must reproduce the above copyright notice, this list of conditions and the following disclaimer in the documentation and/or other materials provided with the distribution.
3. All advertising materials mentioning features or use of this software must display the following acknowledgement:

"This product includes cryptographic software written by Eric Young (eay@cryptsoft.com)"

The word 'cryptographic' can be left out if the routines from the library being used are not cryptographic related.

4. If you include any Windows specific code (or a derivative thereof) from the apps directory (application code) you must include an acknowledgement:

"This product includes software written by Tim Hudson (tjh@cryptsoft.com)"

THIS SOFTWARE IS PROVIDED BY ERIC YOUNG "AS IS" AND ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE DISCLAIMED. IN NO EVENT SHALL THE AUTHOR OR CONTRIBUTORS BE LIABLE FOR ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES; LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.

The license and distribution terms for any publically available version or derivative of this code cannot be changed. i.e. this code cannot simply be copied and put under another distribution license [including the GNU Public License.]

## Zlib

Copyright © 1995-2005 Jean-loup Gailly and Mark Adler

This software is provided 'as-is', without any express or implied warranty. In no event will the authors be held liable for any damages arising from the use of this software.

Permission is granted to anyone to use this software for any purpose, including commercial applications, and to alter it and redistribute it freely, subject to the following restrictions:

1. The origin of this software must not be misrepresented; you must not claim that you wrote the original software. If you use this software in a product, an acknowledgment in the product documentation would be appreciated but is not required.
2. Altered source versions must be plainly marked as such, and must not be misrepresented as being the original software.
3. This notice may not be removed or altered from any source distribution.

Jean-loup Gailly [jloup@gzip.org](mailto:jloup@gzip.org)

Mark Adler [madler@alumni.caltech.edu](mailto:madler@alumni.caltech.edu)

## Libpng

libpng versions 1.2.6, August 15, 2004, through 1.2.35, February 14, 2009, are Copyright © 2004, 2006-2008 Glenn Randers-Pehrson, and are distributed according to the same disclaimer and license as libpng-1.2.5 with the following individual added to the list of Contributing Authors

Cosmin Truta

libpng versions 1.0.7, July 1, 2000, through 1.2.5 - October 3, 2002, are Copyright © 2000-2002 Glenn Randers-Pehrson, and are distributed according to the same disclaimer and license as libpng-1.0.6 with the following individuals added to the list of Contributing Authors

Simon-Pierre Cadieux

Eric S. Raymond

Gilles Vollant

and with the following additions to the disclaimer:

There is no warranty against interference with your enjoyment of the library or against infringement. There is no warranty that our efforts or the library will fulfil any of your particular purposes or needs. This library is provided with all faults, and the entire risk of satisfactory quality, performance, accuracy, and effort is with the user.

libpng versions 0.97, January 1998, through 1.0.6, March 20, 2000, are Copyright © 1998, 1999 Glenn Randers-Pehrson, and are distributed according to the same disclaimer and license as libpng-0.96, with the following individuals added to the list of Contributing Authors:

Tom Lane

Glenn Randers-Pehrson

Willem van Schaik

libpng versions 0.89, June 1996, through 0.96, May 1997, are Copyright © 1996, 1997 Andreas Dilger

Distributed according to the same disclaimer and license as libpng-0.88, with the following individuals added to the list of Contributing Authors:

John Bowler

Kevin Bracey

Sam Bushell

Magnus Holmgren

Greg Roelofs

Tom Tanner

libpng versions 0.5, May 1995, through 0.88, January 1996, are Copyright © 1995, 1996 Guy Eric Schalnat, Group 42, Inc.

For the purposes of this copyright and license, "Contributing Authors" is defined as the following set of individuals:

Andreas Dilger

Dave Martindale

Guy Eric Schalnat

Paul Schmidt

Tim Wegner

The PNG Reference Library is supplied "AS IS". The Contributing Authors and Group 42, Inc. disclaim all warranties, expressed or implied, including, without limitation, the warranties of merchantability and of fitness for any purpose. The Contributing Authors and Group 42, Inc. assume no liability for direct, indirect, incidental, special, exemplary, or consequential damages, which may result from the use of the PNG Reference Library, even if advised of the possibility of such damage.

Permission is hereby granted to use, copy, modify, and distribute this source code, or portions hereof, for any purpose, without fee, subject to the following restrictions:

1. The origin of this source code must not be misrepresented.
2. Altered versions must be plainly marked as such and must not be misrepresented as being the original source.
3. This Copyright notice may not be removed or altered from any source or altered source distribution.

The Contributing Authors and Group 42, Inc. specifically permit, without fee, and encourage the use of this source code as a component to supporting the PNG file format in commercial products. If you use this source code in a product, acknowledgment is not required but would be appreciated.

A "png\_get\_copyright" function is available, for convenient use in "about" boxes and the like:

```
printf("%s",png_get_copyright(NULL));
```

Also, the PNG logo (in PNG format, of course) is supplied in the files "pngbar.png" and "pngbar.jpg (88x31) and "pngnow.png" (98x31).

Libpng is OSI Certified Open Source Software. OSI Certified Open Source is a certification mark of the Open Source Initiative.

Glenn Randers-Pehrson

glennrp at users.sourceforge.net

February 14, 2009

## **Bzip2**

This program, "bzip2", the associated library "libbzip2", and all documentation, are copyright (C) 1996-2007 Julian R Seward. All rights reserved.

Redistribution and use in source and binary forms, with or without modification, are permitted provided that the following conditions are met:

1. Redistributions of source code must retain the above copyright notice, this list of conditions and the following disclaimer.
2. The origin of this software must not be misrepresented; you must not claim that you wrote the original software. If you use this software in a product, an acknowledgment in the product documentation would be appreciated but is not required.
3. Altered source versions must be plainly marked as such, and must not be misrepresented as being the original software.
4. The name of the author may not be used to endorse or promote products derived from this software without specific prior written permission.

THIS SOFTWARE IS PROVIDED BY THE AUTHOR "AS IS" AND ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE DISCLAIMED. IN NO EVENT SHALL THE AUTHOR BE LIABLE FOR ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES; LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.

Julian Seward, [jseward@bzip.org](mailto:jseward@bzip.org)

## **USB library functions**

Atmel Corporation

2325 Orchard Parkway  
San Jose, Ca 95131

Copyright (c) 2004 Atmel

# Apache

Apache License  
Version 2.0, January 2004  
<http://www.apache.org/licenses/>

## TERMS AND CONDITIONS FOR USE, REPRODUCTION, AND DISTRIBUTION

### 1. Definitions.

"License" shall mean the terms and conditions for use, reproduction, and distribution as defined by Sections 1 through 9 of this document.

"Licensor" shall mean the copyright owner or entity authorized by the copyright owner that is granting the License.

"Legal Entity" shall mean the union of the acting entity and all other entities that control, are controlled by, or are under common control with that entity. For the purposes of this definition, "control" means (i) the power, direct or indirect, to cause the direction or management of such entity, whether by contract or otherwise, or (ii) ownership of fifty percent (50%) or more of the outstanding shares, or (iii) beneficial ownership of such entity.

"You" (or "Your") shall mean an individual or Legal Entity exercising permissions granted by this License.

"Source" form shall mean the preferred form for making modifications, including but not limited to software source code, documentation source, and configuration files.

"Object" form shall mean any form resulting from mechanical transformation or translation of a Source form, including but not limited to compiled object code, generated documentation, and conversions to other media types.

"Work" shall mean the work of authorship, whether in Source or Object form, made available under the License, as indicated by a copyright notice that is included in or attached to the work (an example is provided in the Appendix below).

"Derivative Works" shall mean any work, whether in Source or Object form, that is based on (or derived from) the Work and for which the editorial revisions, annotations, elaborations, or other modifications represent, as a whole, an original work of authorship. For the purposes of this License, Derivative Works shall not include works that remain separable from, or merely link (or bind by name) to the interfaces of, the Work and Derivative Works thereof.

"Contribution" shall mean any work of authorship, including the original version of the Work and any modifications or additions to that Work or Derivative Works thereof, that is intentionally submitted to Licensor for inclusion in the Work by the copyright owner or by an individual or Legal Entity authorized to submit on behalf of

the copyright owner. For the purposes of this definition, "submitted" means any form of electronic, verbal, or written communication sent to the Licensor or its representatives, including but not limited to communication on electronic mailing lists, source code control systems, and issue tracking systems that are managed by, or on behalf of, the Licensor for the purpose of discussing and improving the Work, but excluding communication that is conspicuously marked or otherwise designated in writing by the copyright owner as "Not a Contribution."

"Contributor" shall mean Licensor and any individual or Legal Entity on behalf of whom a Contribution has been received by Licensor and subsequently incorporated within the Work.

2. Grant of Copyright License. Subject to the terms and conditions of this License, each Contributor hereby grants to You a perpetual, worldwide, non-exclusive, no-charge, royalty-free, irrevocable copyright license to reproduce, prepare Derivative Works of, publicly display, publicly perform, sublicense, and distribute the Work and such Derivative Works in Source or Object form.
3. Grant of Patent License. Subject to the terms and conditions of this License, each Contributor hereby grants to You a perpetual, worldwide, non-exclusive, no-charge, royalty-free, irrevocable (except as stated in this section) patent license to make, have made, use, offer to sell, sell, import, and otherwise transfer the Work, where such license applies only to those patent claims licensable by such Contributor that are necessarily infringed by their Contribution(s) alone or by combination of their Contribution(s) with the Work to which such Contribution(s) was submitted. If You institute patent litigation against any entity (including a cross-claim or counterclaim in a lawsuit) alleging that the Work or a Contribution incorporated within the Work constitutes direct or contributory patent infringement, then any patent licenses granted to You under this License for that Work shall terminate as of the date such litigation is filed.
4. Redistribution. You may reproduce and distribute copies of the Work or Derivative Works thereof in any medium, with or without modifications, and in Source or Object form, provided that You meet the following conditions:
  - (a) You must give any other recipients of the Work or Derivative Works a copy of this License; and
  - (b) You must cause any modified files to carry prominent notices stating that You changed the files; and
  - (c) You must retain, in the Source form of any Derivative Works that You distribute, all copyright, patent, trademark, and attribution notices from the Source form of the Work, excluding those notices that do not pertain to any part of the Derivative Works; and
  - (d) If the Work includes a "NOTICE" text file as part of its distribution, then any Derivative Works that You distribute must include a readable copy of the attribution notices contained within such NOTICE file, excluding those notices that do not

pertain to any part of the Derivative Works, in at least one of the following places: within a NOTICE text file distributed as part of the Derivative Works; within the Source form or documentation, if provided along with the Derivative Works; or, within a display generated by the Derivative Works, if and wherever such third-party notices normally appear. The contents of the NOTICE file are for informational purposes only and do not modify the License. You may add Your own attribution notices within Derivative Works that You distribute, alongside or as an addendum to the NOTICE text from the Work, provided that such additional attribution notices cannot be construed as modifying the License.

You may add Your own copyright statement to Your modifications and may provide additional or different license terms and conditions for use, reproduction, or distribution of Your modifications, or for any such Derivative Works as a whole, provided Your use, reproduction, and distribution of the Work otherwise complies with the conditions stated in this License.

5. Submission of Contributions. Unless You explicitly state otherwise, any Contribution intentionally submitted for inclusion in the Work by You to the Licensor shall be under the terms and conditions of this License, without any additional terms or conditions. Notwithstanding the above, nothing herein shall supersede or modify the terms of any separate license agreement you may have executed with Licensor regarding such Contributions.
6. Trademarks. This License does not grant permission to use the trade names, trademarks, service marks, or product names of the Licensor, except as required for reasonable and customary use in describing the origin of the Work and reproducing the content of the NOTICE file.
7. Disclaimer of Warranty. Unless required by applicable law or agreed to in writing, Licensor provides the Work (and each Contributor provides its Contributions) on an "AS IS" BASIS, WITHOUT WARRANTIES OR CONDITIONS OF ANY KIND, either express or implied, including, without limitation, any warranties or conditions of TITLE, NON-INFRINGEMENT, MERCHANTABILITY, or FITNESS FOR A PARTICULAR PURPOSE. You are solely responsible for determining the appropriateness of using or redistributing the Work and assume any risks associated with Your exercise of permissions under this License.
8. Limitation of Liability. In no event and under no legal theory, whether in tort (including negligence), contract, or otherwise, unless required by applicable law (such as deliberate and grossly negligent acts) or agreed to in writing, shall any Contributor be liable to You for damages, including any direct, indirect, special, incidental, or consequential damages of any character arising as a result of this License or out of the use or inability to use the Work (including but not limited to damages for loss of goodwill, work stoppage, computer failure or malfunction, or any and all other commercial damages or losses), even if such Contributor has been advised of the possibility of such damages.
9. Accepting Warranty or Additional Liability. While redistributing the Work or Derivative Works thereof, You may choose to offer,



and charge a fee for, acceptance of support, warranty, indemnity, or other liability obligations and/or rights consistent with this License. However, in accepting such obligations, You may act only on Your own behalf and on Your sole responsibility, not on behalf of any other Contributor, and only if You agree to indemnify, defend, and hold each Contributor harmless for any liability incurred by, or claims asserted against, such Contributor by reason of your accepting any such warranty or additional liability.

END OF TERMS AND CONDITIONS

APPENDIX: How to apply the Apache License to your work.

To apply the Apache License to your work, attach the following boilerplate notice, with the fields enclosed by brackets "[ ]" replaced with your own identifying information. (Don't include the brackets!) The text should be enclosed in the appropriate comment syntax for the file format. We also recommend that a file or class name and description of purpose be included on the same "printed page" as the copyright notice for easier identification within third-party archives.

Copyright [yyyy] [name of copyright owner]

Licensed under the Apache License, Version 2.0 (the "License");  
you may not use this file except in compliance with the License.  
You may obtain a copy of the License at

<http://www.apache.org/licenses/LICENSE-2.0>

Unless required by applicable law or agreed to in writing, software distributed under the License is distributed on an "AS IS" BASIS, WITHOUT WARRANTIES OR CONDITIONS OF ANY KIND, either express or implied. See the License for the specific language governing permissions and limitations under the License.

## D3 JS library

Copyright (c) 2013, Michael Bostock

All rights reserved.

Redistribution and use in source and binary forms, with or without modification, are permitted provided that the following conditions are met:

\* Redistributions of source code must retain the above copyright notice, this list of conditions and the following disclaimer.

\* Redistributions in binary form must reproduce the above copyright notice, this list of conditions and the following disclaimer in the documentation and/or other materials provided with the distribution.

\* The name Michael Bostock may not be used to endorse or promote products derived from this software without specific prior written permission.

THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE DISCLAIMED. IN NO EVENT SHALL MICHAEL BOSTOCK BE LIABLE FOR ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES; LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE

## Compliance with safety standards

---

This section lists the safety specifications against which the PTP 650 has been tested and certified. It also describes how to keep RF exposure within safe limits.

### Electrical safety compliance

The PTP 650 hardware has been tested for compliance to the electrical safety specifications listed in [Table 64](#).

**Table 64** PTP 650 safety compliance specifications

Region	Standard
USA	UL 60950-1, 2nd Edition; UL60950-22
Canada	CAN/CSA C22.2 No.60950-1-07, 2nd Edition; CAN/CSA C22.2 No.60950-22-07
EU	EN 60950-1:2006 + Amendment 12:2011, EN 60950-22
International	CB certified to IEC 60950-1: 2005 (modified); IEC 60950-22: 2005 (modified)

### Electromagnetic compatibility (EMC) compliance

The PTP 650 complies with European EMC Specification EN301 489-1 with testing carried out to the detailed requirements of EN301 489-4.



**Note**

For EN 61000-4-2: 1995 to 2009 Electro Static Discharge (ESD), Class 2, 8 kV air, 4 kV contact discharge, the PTP 650 has been tested to ensure immunity to 15 kV air and 8 kV contact.

[Table 65](#) lists the EMC specification type approvals that have been granted for PTP 650 products.

**Table 65** EMC emissions compliance

Region	Specification (Type Approvals)
Europe	ETSI EN301 489-4

## Human exposure to radio frequency energy

Relevant standards (USA and EC) applicable when working with RF equipment are:

- ANSI IEEE C95.1-1991, IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz.
- Council recommendation of 12 July 1999 on the limitation of exposure of the general public to electromagnetic fields (0 Hz to 300 GHz) (1999/519/EC) and respective national regulations.
- *Directive 2004/40/EC of the European Parliament and of the Council of 29 April 2004 on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (electromagnetic fields) (18th individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC).*
- US FCC limits for the general population. See the FCC web site at <http://www.fcc.gov>, and the policies, guidelines, and requirements in Part 1 of Title 47 of the Code of Federal Regulations, as well as the guidelines and suggestions for evaluating compliance in FCC OET Bulletin 65.
- Health Canada limits for the general population. See the Health Canada web site at [http://www.hc-sc.gc.ca/ewh-semt/pubs/radiation/99ehd-dhm237/limits-limités\\_e.html](http://www.hc-sc.gc.ca/ewh-semt/pubs/radiation/99ehd-dhm237/limits-limités_e.html) and Safety Code 6.
- EN 50383:2002 to 2010 Basic standard for the calculation and measurement of electromagnetic field strength and SAR related to human exposure from radio base stations and fixed terminal stations for wireless telecommunication systems (110 MHz - 40 GHz).
- BS EN 50385:2002 Product standard to demonstrate the compliances of radio base stations and fixed terminal stations for wireless telecommunication systems with the basic restrictions or the reference levels related to human exposure to radio frequency electromagnetic fields (110 MHz – 40 GHz) – general public.
- ICNIRP (International Commission on Non-Ionizing Radiation Protection) guidelines for the general public. See the ICNIRP web site at <http://www.icnirp.de/> and Guidelines for Limiting Exposure to Time-Varying Electric, Magnetic, and Electromagnetic Fields.

### Power density exposure limit

Install the radios for the PTP 650 family of PTP wireless solutions so as to provide and maintain the minimum separation distances from all persons.

The applicable power density exposure limit for RF energy in the 4.9, 5.4 and 5.8 GHz frequency bands is **10 W/m<sup>2</sup>**. For more information, see [Human exposure to radio frequency energy](#) on page 4-24.

## Calculation of power density

The following calculation is based on the ANSI IEEE C95.1-1991 method, as that provides a worst case analysis. Details of the assessment to EN50383:2002 can be provided, if required.

Peak power density in the far field of a radio frequency point source is calculated as follows:

$$S = \frac{P \cdot G}{4\pi d^2}$$

**Where:**

**Is:**

S	power density in W/m <sup>2</sup>
P	maximum average transmit power capability of the radio, in W
G	total Tx gain as a factor, converted from dB
d	distance from point source, in m

Rearranging terms to solve for distance yields:

$$d = \sqrt{\frac{P \cdot G}{4\pi \cdot S}}$$

## Calculated distances

[Table 66](#) shows calculated minimum separation distances, recommended distances and resulting margins for each frequency band and antenna combination. These are conservative distances that include compliance margins. At these and greater separation distances, the power density from the RF field is below generally accepted limits for the general population.

Explanation of terms used in [Table 66](#):

Tx burst – maximum average transmit power in burst (Watt)

P – maximum average transmit power capability of the radio including cable loss (Watt)

G – total transmit gain as a factor, converted from dB

S – power density (W/m<sup>2</sup>)

d – minimum distance from point source (meters)

## Calcul des distances pour la conformité aux limites de radiation radiofréquence

La [Table 66](#) indique les distances minimales de séparation calculées, les distances recommandées et les marges de sécurité qui en découlent pour chaque bande de fréquence et chaque antenne. Ces distances comprennent les marges de sécurité recommandées par les régulateurs. À ces distance et des distance supérieures, la densité de puissance du champ de radiofréquence est inférieur aux limites généralement admises pour la population.

Explication des termes utilisés dans la [Table 66](#):

Tx burst - puissance d'émission maximale moyenne instantanée (Watt)

P - capacité de puissance d'émission moyenne maximale de la radio comprenant la perte dans les câble de connexion(W)

G - gain total d'émission, converti à partir de la valeur en dB

S - densité de puissance (W/m<sup>2</sup>)

d - distance minimale de source ponctuelle (en mètres)

**Table 66** Minimum safe distances

Band	Antenna	Tx burst (W)	P (W)	G	S (W/m <sup>2</sup> )	d (m)
4.9 GHz	Integrated (23.0 dBi)	0.25	0.2	200	10	0.56
	Parabolic 6 ft (36.0 dBi)	0.2	0.16	2818	10	1.89
	Sectorized (17.0 dBi)	0.25	0.2	35.5	10	0.24
	Omni (13.0 dBi)	0.25	0.2	14	10	0.15
5.2 GHz, 5.4 GHz	Integrated (23.0 dBi)	0.005	0.004	200	10	0.08
	Parabolic 4 ft (34.9 dBi)	0.0005	0.0004	2188	10	0.08
	Sectorized (17.0 dBi)	0.008	0.006	35.5	10	0.04
	Omni (13.0 dBi)	0.025	0.02	14	10	0.05
5.8 GHz	Integrated (23.0 dBi)	0.646	0.513	200	10	0.9
	Parabolic 6 ft (38.1 dBi)	0.646	0.513	4571	10	4.32
	Sectorized (17.0 dBi)	0.1	0.08	35.5	10	0.15
	Omni (13.0 dBi)	0.25	0.2	14	10	0.15

**Note**

Gain of antenna in dBi =  $10 \cdot \log(G)$ .

The regulations require that the power used for the calculations is the maximum power in the transmit burst subject to allowance for source-based time-averaging.

At 5.4 GHz and EU 5.8 GHz, the products are generally limited to a fixed EIRP which can be achieved with the Integrated Antenna. The calculations above assume that the maximum EIRP allowed by the regulations is being transmitted.

---

**Note**

If there are no EIRP limits in the country of deployment, use the distance calculations for FCC 5.8 GHz for all frequency bands.

At FCC 5.8 GHz, for antennas between 0.6m (2ft) and 1.8m (6ft), alter the distance proportionally to the antenna gain.

---

**Remarque**

Gain de l'antenne en dBi =  $10 \cdot \log(G)$ .

Les règlements exigent que la puissance utilisée pour les calculs soit la puissance maximale de la rafale de transmission soumis à une réduction pour prendre en compte le rapport cyclique pour les signaux modulés dans le temps.

Pour une opération dans la CEE dans les bandes 5,4 GHz et 5,8 GHz, les produits sont généralement limités à une PIRE qui peut être atteinte avec l'antenne intégrée. Les calculs ci-dessus supposent que la PIRE maximale autorisée par la réglementation est atteinte.

---

**Remarque**

Si aucune limite de PIRE existe pour le pays de déploiement, utilisez les calculs de distance pour FCC 5,8 GHz pour toutes les bandes de fréquence.

Pour la band FCC 5,8 GHz et les antennes entre 0,6 m (2 pieds) et 1,8 m (6 pieds), modifier la distance proportionnellement au gain de l'antenne.

---

# Compliance with radio regulations

---

This section describes how the PTP 650 complies with the radio regulations that are in force in various countries.

**Caution**

Where necessary, the end user is responsible for obtaining any National licenses required to operate this product and these must be obtained before using the product in any particular country. Contact the appropriate national administrations for details of the conditions of use for the bands in question and any exceptions that might apply.

**Caution**

Changes or modifications not expressly approved by Cambium Networks could void the user's authority to operate the system.

**Caution**

For the connectorized version of the product and in order to reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the Effective Isotropically Radiated Power (EIRP) is not more than that permitted for successful communication.

**Attention**

Le cas échéant, l'utilisateur final est responsable de l'obtention des licences nationales nécessaires pour faire fonctionner ce produit. Celles-ci doivent être obtenus avant d'utiliser le produit dans un pays particulier. Contactez les administrations nationales concernées pour les détails des conditions d'utilisation des bandes en question, et toutes les exceptions qui pourraient s'appliquer

**Attention**

Les changements ou modifications non expressément approuvés par les réseaux de Cambium pourraient annuler l'autorité de l'utilisateur à faire fonctionner le système.

**Attention**

Pour la version du produit avec une antenne externe, et afin de réduire le risque d'interférence avec d'autres utilisateurs, le type d'antenne et son gain doivent être choisis afin que la puissance isotrope rayonnée équivalente (PIRE) ne soit pas supérieure au minimum nécessaire pour établir une liaison de la qualité requise.

---



## Type approvals

The system has been tested against various local technical regulations and found to comply. The frequency band in which the system operates is “license exempt” and the system is allowed to be used provided it does not cause interference. The licensing authority does not guarantee protection against interference from other products and installations. [Table 67](#) to [Table 70](#) list the radio specification type approvals that have been granted for PTP 650 products.

**Table 67** Radio certifications (4.9 GHz)

Region	Regulatory approvals
USA	FCC 47 CFR Part 90
Canada	IC RSS-211, Issue 4
Europe	Europe EN302 625; V1.1.1 Broadband Disaster Relief (BBDR)

**Table 68** Radio certifications (5.2 GHz)

Region	Regulatory approvals
USA	FCC 47 CFR Part 15 E
Canada	IC RSS-210 Issue 8, Annex 9 (or latest)

**Table 69** Radio certifications (5.4 GHz)

Region	Regulatory approvals
USA	FCC 47 CFR Part 15 E
Canada	IC RSS-210 Issue 8, Annex 9 (or latest)
Europe	ETSI EN301 893 v1.6.1

**Table 70** Radio certifications (5.8 GHz)

Region	Regulatory approvals
USA	FCC 47 CFR Part 15 C
Canada	IC RSS-210 Issue 8, Annex 8 (or latest)
Denmark	Radio Interface 00 007
Eire	ComReg 02/71R4
Germany	Order No 47/2007
Iceland	ETSI EN302 502 v1.2.1

Region	Regulatory approvals
Finland	ETSI EN302 502 v1.2.1
Greece	ETSI EN302 502 v1.2.1
Liechtenstein	ETSI EN302 502 v1.2.1
Norway	REG 2009-06-02 no. 580
Portugal	ETSI EN302 502 v1.2.1
Serbia	ETSI EN302 502 v1.2.1
Spain	CNAF 2010
Switzerland	ETSI EN302 502 v1.2.1
UK	UK IR 2007

## FCC/IC compliance

The PTP 650 complies with the regulations that are in force in the USA and Canada.



### Caution

If this equipment does cause interference to radio or television reception, refer to [Radio and television interference](#) on page 8-10 for corrective actions.



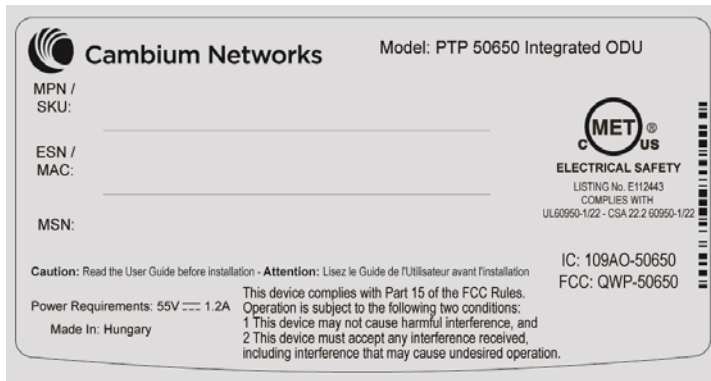
### Attention

Si cet équipement cause des interférences à la réception radio ou télévision, reportez-vous à la section [Radio and television interference](#) page 8-10 pour déterminer comment remédier au problème.

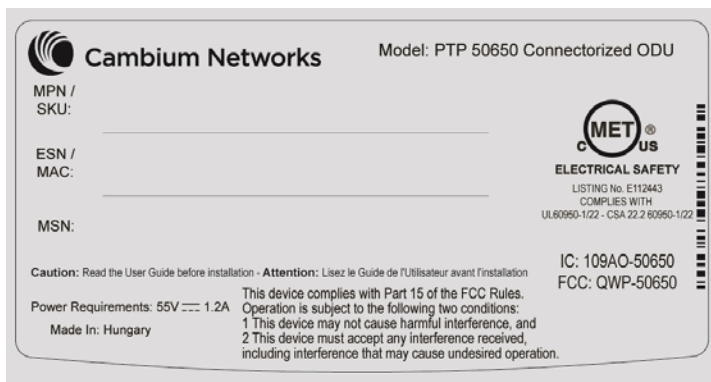
## FCC product labels

FCC identifiers are reproduced on the product labels for the FCC/IC regional variant ([Figure 53](#) and [Figure 54](#)).

**Figure 53** FCC and IC certifications on integrated ODU product label



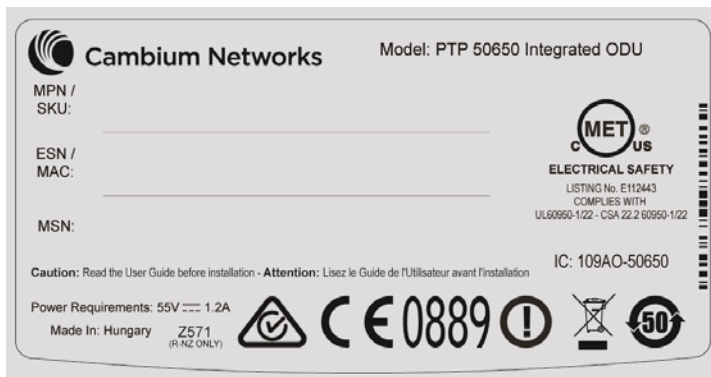
**Figure 54** FCC and IC certifications on connectorized ODU product label

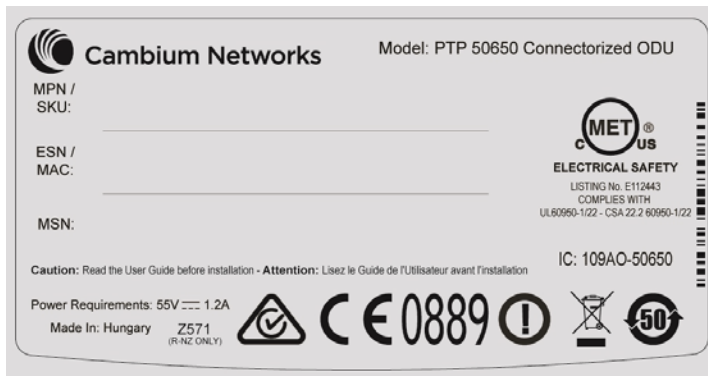


## Industry Canada product labels

Industry Canada Certification Numbers are reproduced on the product labels for the FCC/IC regional variant (Figure 53 and Figure 54) and also on the Rest of the World (RoW) regional variant (Figure 55 and Figure 56).

**Figure 55** IC certification on integrated ODU product label



**Figure 56** IC certification on connectorized ODU product label

## 4.9 GHz FCC and IC notification

The system has been approved under FCC Part 90 and Industry Canada RSS-111 for Public Safety Agency usage. The installer or operator is responsible for obtaining the appropriate site licenses before installing or using the system.

## Utilisation de la bande 4.9 GHz FCC et IC

Le système a été approuvé en vertu de FCC Part 90 et Industrie Canada RSS-111 pour l'utilisation par l'Agence de la Sécurité publique. L'installateur ou l'exploitant est responsable de l'obtention des licences de appropriées avant d'installer ou d'utiliser le système.

## 5.2 GHz and 5.4 GHz FCC and IC notification

This device complies with part 15E of the US FCC Rules and Regulations and with Industry Canada RSS-210 Annex 9. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) This device must accept any interference received, including interference that may cause undesired operation. In Canada, users should be cautioned to take note that high power radars are allocated as primary users (meaning they have priority) of 5250 – 5350 MHz and 5650 – 5850 MHz and these radars could cause interference and/or damage to license-exempt local area networks (LELAN).

For the connectorized version of the product and in order to reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the equivalent isotropically radiated power (EIRP) is not more than that permitted by the regulations. The transmitted power must be reduced to achieve this requirement.

## Utilisation de la bande 5.4 GHz FCC et IC

Cet appareil est conforme à la Section 15E de la réglementation FCC aux États-Unis et aux réglementations et avec Industrie Canada RSS-210 Annexe 9. Son fonctionnement est soumis aux deux conditions suivantes: (1) Ce dispositif ne doit pas causer d'interférences nuisibles, et (2) Cet appareil doit tolérer toute interférence reçue, y compris les interférences pouvant entraîner un fonctionnement indésirable. Au Canada, les utilisateurs doivent prendre garde au fait que les radars à haute puissance sont considérés 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 réglementation. Il peut être nécessaire de réduire la puissance transmise doit être réduite pour satisfaire cette exigence.

### 5.8 GHz FCC notification

This device complies with part 15C of the US FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) This device must accept any interference received, including interference that may cause undesired operation.

### 5.8 GHz IC notification

RSS-GEN issue 3 (7.1.3) Licence-Exempt Radio Apparatus:

This device complies with Industry Canada license-exempt RSS standard(s). Operation is subject to the following two conditions: (1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

*Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes : (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.*

In Canada, high power radars are allocated as primary users (meaning they have priority) of the 5650 – 5850 MHz spectrum. These radars could cause interference or damage to license-exempt local area network (LE-LAN) devices.

Au Canada, les radars à haute puissance sont désignés comme utilisateurs principaux (ils ont la priorité) de la 5650 - spectre 5850 MHz. Ces radars peuvent causer des interférences et / ou interférer avec un réseau local ne nécessitant pas de licence.

## 5.2 GHz band edge channel power reduction

Equivalent isotropic radiated power (EIRP) is restricted in edge channels when the PTP 650 is operated the 5.2 GHz band with the USA or Canada country license. The amount of EIRP reduction has been determined during regulatory testing and cannot be changed by professional installers or end users. Units intended for the USA and Canada market are locked for use in the USA or Canada and cannot be operated under the regulations for other regulatory domains.

The PTP 650 takes into account the antenna gain and cable loss configured by the professional installer in the web-based interface to limit the EIRP to ensure regulatory compliance. No additional action is required by the installer to reduce transmitter power in band edge channels.

The maximum EIRP in band edge channels for the USA and Canada 5.2 GHz band is listed in [Table 71](#).

**Table 71** Edge channel power reduction in regulatory band 38

Channel Bandwidth	Channel Frequency	Maximum EIRP
5 MHz	Below 5256.0 MHz	24 dBm
	Above 5344.0 MHz	24 dBm
10 MHz	Below 5260.0 MHz	23 dBm
	Above 5337.0 MHz	23 dBm
15 MHz	Below 5267.0 MHz	22 dBm
	Above 5330.0 MHz	22 dBm
20 MHz	Below 5271.0 MHz	25 dBm
	Above 5325.0 MHz	21 dBm
30 MHz	Below 5280.0 MHz	25 dBm
	Above 5308.0 MHz	23 dBm
40 MHz	Below 5290.0 MHz	24 dBm
	Above 5299.0 MHz	20 dBm
45 MHz	Below 5295.0 MHz	24 dBm
	Above 5295.0 MHz	20 dBm

## 5.4 GHz band edge channel power reduction

Equivalent isotropic radiated power (EIRP) is restricted in edge channels when the PTP 650 is operated the 5.4 GHz band with the USA or Canada country license. The amount of EIRP reduction has been determined during regulatory testing and cannot be changed by professional installers or end users. Units intended for the USA and Canada market are locked for use in the USA or Canada and cannot be operated under the regulations for other regulatory domains.

The PTP 650 takes into account the antenna gain and cable loss configured by the professional installer in the web-based interface to limit the EIRP to ensure regulatory compliance. No additional action is required by the installer to reduce transmitter power in band edge channels.

The maximum EIRP in band edge channels for the USA and Canada 5.4 GHz band is listed in [Table 72](#).

### Réduction de puissance aux bords de la bande 5.4 GHz

La Puissance isotrope rayonnée équivalente (PIRE) est limitée dans les canaux en bord de la bandes lorsque le PTP 650 est configuré pour utiliser la band 5,4 GHz aux les Etats-Unis ou au Canada. La réduction de la PIRE a été déterminée lors de tests réglementaires et ne peut être changée par des installateurs professionnels ou les utilisateurs. Les PTP 650 destinées aux USA et Canada sont limitées pour opérer exclusivement aux États-Unis ou au Canada et ne peuvent pas être configurés pour adhérer à la réglementation d'autres pays.

Le PTP 650 prend en compte le gain de l'antenne et les pertes des câbles de connexion configurés par l'installateur professionnel via l'interface graphique pour limiter la PIRE pour assurer la conformité à la réglementation en vigueur. Aucune action supplémentaire n'est requise par l'installateur afin de réduire la puissance d'émission dans les canaux aux bords de bande.

La PIRE maximale dans les canaux aux bords de bande 5,4 GHz pour les Etats-Unis et le Canada est listée dans la [Table 72](#).

**Table 72** Edge channel power reduction in regulatory bands 12 and 13

Channel Bandwidth	Channel Frequency	Maximum EIRP
5 MHz	Below 5476.0 MHz	24 dBm
	Above 5720.0 MHz	24 dBm
10 MHz	Below 5478.0 MHz	27 dBm
	Above 5715.0 MHz	25 dBm
15 MHz	Below 5480.0 MHz	29 dBm
	Above 5709.0 MHz	26 dBm
20 MHz	Below 5482.0 MHz	30 dBm
	Above 5704.0 MHz	23 dBm
30 MHz	Below 5492.0 MHz	27 dBm

Channel Bandwidth	Channel Frequency	Maximum EIRP
40 MHz	Above 5694.0 MHz	25 dBm
	Below 5500.0 MHz	28 dBm
45 MHz	Above 5691.0 MHz	24 dBm
	Below 5508.0 MHz	24 dBm
	Above 5686.0 MHz	22 dBm

## 5.8 GHz band edge channel power reduction

Transmitter power is restricted in edge channels when the PTP 650 is operated the 5.8 GHz band with the USA or Canada country license. The amount of transmitter power reduction has been determined during regulatory testing and cannot be changed by professional installers or end users. Units intended for the USA and Canada market are locked for use in the USA or Canada and cannot be operated under the regulations for other regulatory domains.

The maximum transmitter power in band edge channels for the FCC 5.8 GHz band is listed in [Table 73](#).

## Réduction de puissance aux bords de la bande 5.8 GHz

La Puissance isotrope rayonnée équivalente (PIRE) est limitée dans les canaux en bord de la bandes lorsque le PTP 650 est configuré pour utiliser la band 5,8 GHz aux les Etats-Unis ou au Canada. La réduction de la PIRE a été déterminée lors de tests réglementaires et ne peut être changée par des installateurs professionnels ou les utilisateurs. Les PTP 650 destinées aux USA et Canada sont limitées pour opérer exclusivement aux États-Unis ou au Canada et ne peuvent pas être configurés pour adhérer à la réglementation d'autres pays.

La PIRE maximale dans les canaux aux bords de bande 5,4 GHz pour les Etats-Unis et le Canada est listée dans la [Table 73](#).

**Table 73** 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



Channel Bandwidth	Channel Frequency	Maximum conducted power
30 MHz	Above 5832.0 MHz	25 dBm
	Below 5752.0 MHz	25 dBm
40 MHz	Above 5822.0 MHz	25 dBm
	Below 5765.0 MHz	25 dBm
45 MHz	Above 5810.0 MHz	25 dBm
	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 3-25.

For a list of antennas submitted to the FCC and IC for use with the PTP 650 refer to [FCC and IC approved antennas](#) on page 2-16.



### Note

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



### Remarque

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

## European Union compliance

The PTP 650 complies with the regulations that are in force in the European Union.



### Warning

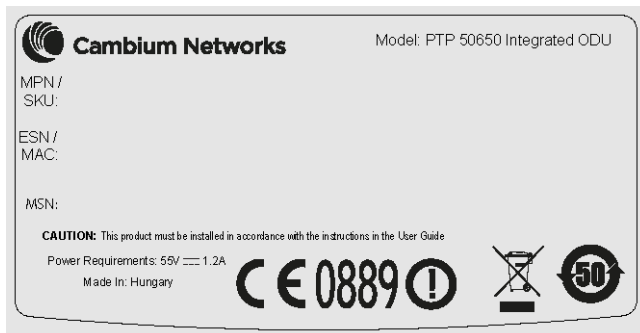
This is a Class A product. In a domestic environment this product may cause radio interference, in which case the user may be required to take adequate measures.

If this equipment does cause interference to radio or television reception, refer to [Radio and television interference](#) on page 8-10 for corrective actions.

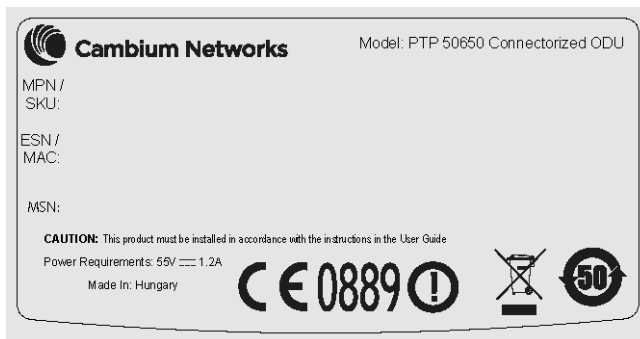
## EU product labels

The European R&TTE directive 1999/5/EC Certification Number is reproduced on the product labels ([Figure 57](#) and [Figure 58](#)).

**Figure 57** European Union certification on integrated product label



**Figure 58** European Union certification on connectorized product label



## 5.4 GHz European Union notification

The PTP 650 product is a two-way radio transceiver suitable for use in Broadband Wireless Access System (WAS), Radio Local Area Network (RLAN), or Fixed Wireless Access (FWA) systems. It is a Class 1 device and uses operating frequencies that are harmonized throughout the EU member states. The operator is responsible for obtaining any national licenses required to operate this product and these must be obtained before using the product in any particular country.

Hereby, Cambium Networks declares that the PTP 650 product complies with the essential requirements and other relevant provisions of Directive 1999/5/EC. The declaration of conformity may be consulted at the support website (see [Contacting Cambium Networks](#) on page 1).

## 5.8 GHz European Union notification

The PTP 650 is a Class 2 device as it operates on frequencies that are not harmonized across the EU. Currently the product may only be operated in the countries listed in [Table 70](#). However, the regulatory situation in Europe is changing and the radio spectrum may become available in other countries in future. See [www.ero.dk](http://www.ero.dk) for further information. The operator is responsible for obtaining any national licenses required to operate this product and these must be obtained before using the product in any particular country.



### Caution

This equipment operates as a secondary application, so it has no rights against harmful interference, even if generated by similar equipment, and must not cause harmful interference on systems operating as primary applications.

---

Hereby, Cambium Networks declares that the PTP 650 product complies with the essential requirements and other relevant provisions of Directive 1999/5/EC. The declaration of conformity may be consulted at the support website (see [Contacting Cambium Networks](#) on page 1).

## 5.8 GHz operation in the UK

The PTP 650 connectorized product has been notified for operation in the UK, and when operated in accordance with instructions for use it is compliant with UK Interface Requirement IR2007. For UK use, installations must conform to the requirements of IR2007 in terms of EIRP spectral density against elevation profile above the local horizon in order to protect Fixed Satellite Services. The frequency range 5795-5815 MHz is assigned to Road Transport & Traffic Telematics (RTTT) in the U.K. and shall not be used by FWA systems in order to protect RTTT devices. UK Interface Requirement IR2007 specifies that radiolocation services shall be protected by a Dynamic Frequency Selection (DFS) mechanism to prevent co-channel operation in the presence of radar signals.