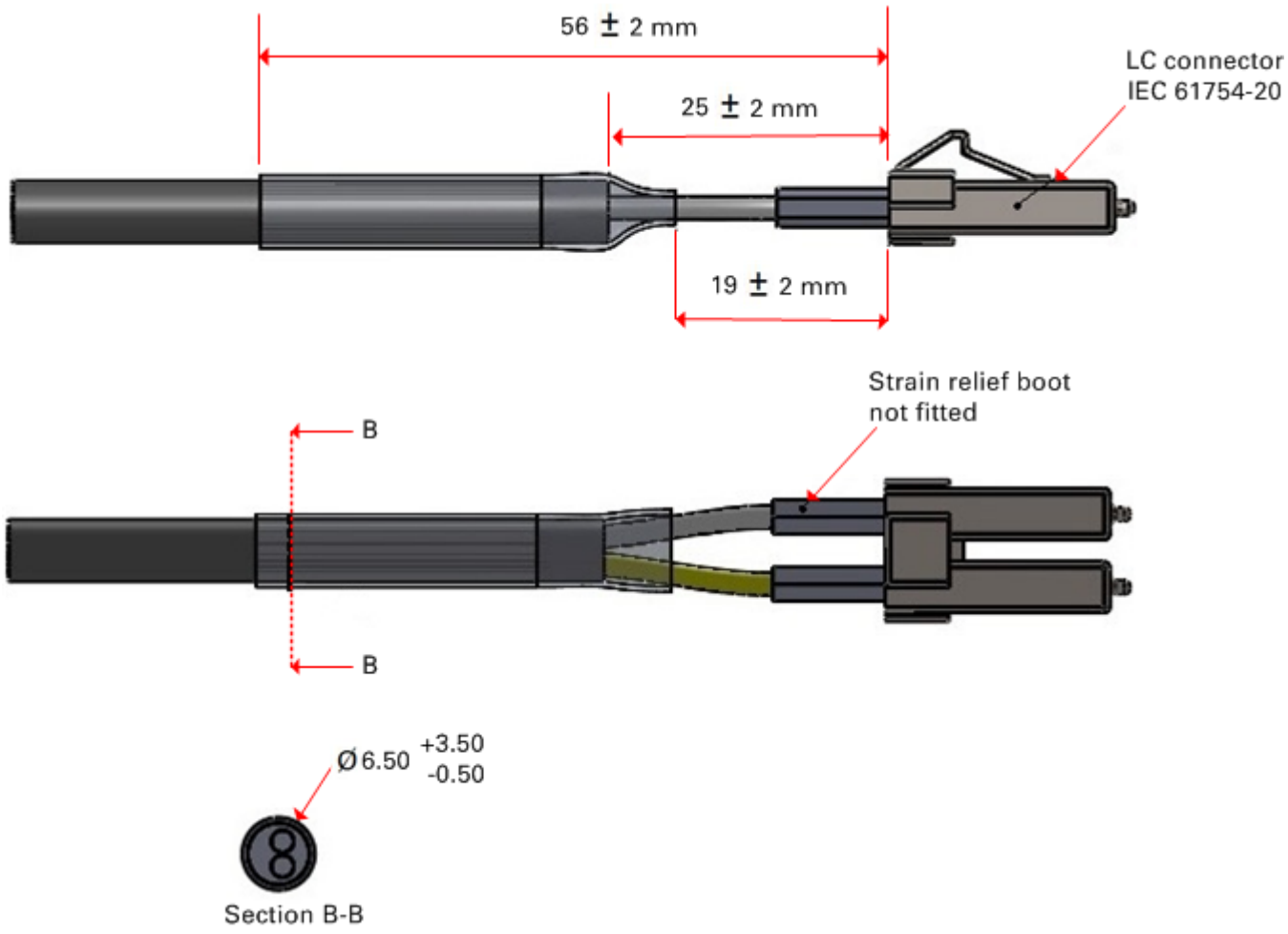
Optical cable and connectors

Order an optical cable with LC connectors from a specialist fabricator, quoting the specification shown in Figure 28. 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 28 Optical optic cable and connector specification



PTP-SYNC unit

PTP-SYNC unit description

The PTP-SYNC unit is an optional component, used to synchronize the ODU TDD frame with a network-wide reference. It measures the difference between the TDD frame timing and a 1 Hz timing reference, and signals this time difference to the ODU. For more information on this feature, refer to TDD synchronization on page 1-26.

The PTP-SYNC unit is a compact indoor unit mounted on a wall, shelf or (using an optional rack mounting adaptor) in a standard 19 inch rack (Figure 30).

The PTP-SYNC unit is connected in line in the drop cable between the AC+DC Power Injector 56V and the ODU, and is collocated with the AC+DC Power Injector 56V. The PTP-SYNC draws power from the drop cable, and does not require a separate power supply.

PTP 670 supports an alternative approach to TDD synchronization using the CMM5 Power and Sync Injector. For further details, refer to TDD synchronization on page 1-26.

Caution

The PTP-SYNC is compatible only with the AC+DC Power Injector 56V.

The AC Power Injector 56V and CMM5 will not work with a PTP-SYNC, and it is likely that a fuse will be blown in the PTP-SYNC if this is attempted.

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

Figure 29 PTP-SYNC kit

Figure 30 PTP-SYNC rack mounting adapter

PTP-SYNC part numbers

Order PTP-SYNC kits and associated components from Cambium Networks (Table 42).

Table 42 PTP-SYNC component part numbers

Cambium description	Cambium part number
PTP-SYNC kit	WB3665
CMU/PTP-SYNC/NIDU 19inch Rack Mount Installation Kit	WB3486

The PTP-SYNC kit contains:

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

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

The PTP-SYNC rack mount kit contains:

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

PTP-SYNC unit interfaces

The PTP-SYNC front panel is illustrated in Figure 31. The annotated interfaces are described in Table 43 and Table 44.

Figure 31 PTP-SYNC front panel

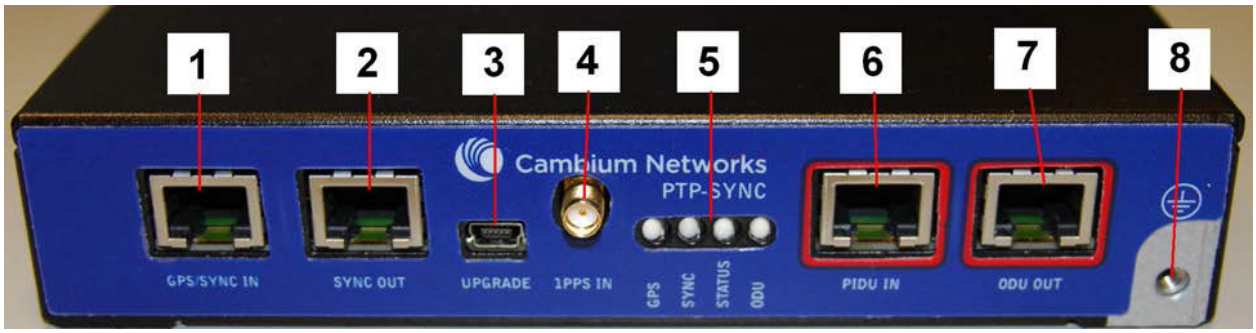


Table 43 PTP-SYNC interface functions

#	Description	Function
1	GPS/SYNC IN	Input from GPS receiver or from the daisy-chained SYNC OUT signal of another PTP-SYNC.
2	SYNC OUT	Output to daisy-chained PTP-SYNC units.
3	USB	Input for software upgrades. Contact Cambium for instructions.
4	1PPS IN	Coaxial alternative to GPS/SYNC IN. Peak input voltage must not exceed 5 V.
5	LED bank	LEDs and their functions are described in Table 44.
6	PIDU IN	Input from PSU.
7	ODU OUT	Output to ODU.
8	Ground stud	For connecting to a ground point.

Table 44 PTP-SYNC LED functions

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

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

PTP-SYNC specifications

The PTP-SYNC unit conforms to the specifications listed in Table 45, Table 46 and Table 47.

Table 45 PTP-SYNC unit physical specifications

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

Table 46 PTP-SYNC unit environmental specifications

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

Table 47 PTP-SYNC unit electrical specifications

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

There are two timing inputs to the PTP-SYNC unit: GPS/SYNC IN (RJ-45) (Table 48) and 1PPS IN (SMA) (Table 49).

Table 48 PTP-SYNC unit timing specifications - GPS/SYNC IN (RJ-45)

Category	Specification
Signal type	Differential 1 Hz signal
Common mode range	–7 V to +7 V, relative to GPS/SYNC IN pin 2 (ground)
Maximum differential voltage	±5 V
Threshold	±0.4 V
Impedance	90 ohms to 110 ohms

Category	Specification
Pulse width	1 µs to 500 ms
Polarity	Reference edge is when pin 3 (PPSA) is positive with respect to pin 6 (PPSB)

Table 49 PTP-SYNC unit timing specifications - 1PPS IN (SMA)

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

The pinouts of the PTP-SYNC unit GPS/SYNC IN port are specified in Table 50.

Table 50 GPS/SYNC IN port pinouts

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

Note

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

Signal polarities

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

GPS receivers

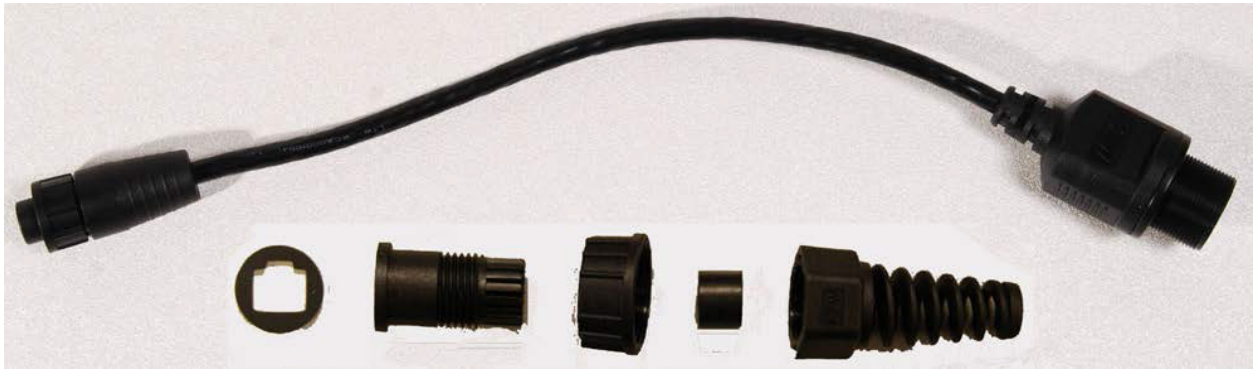
Trimble Acutime™ GG GPS receiver for PTP-SYNC

The GPS receiver (Figure 32) is an optional timing reference source for PTP-SYNC. It provides a 1 Hz signal, accurately synchronized in frequency and phase across the network.

Figure 32 GPS receiver

The GPS receiver is supplier with a GPS adapter cable kit (Figure 33). This avoids the need to fit a 12 way circular connector to the GPS drop cable. The kit contains one adapter cable (GPS receiver circular connector to RJ45 socket) and one RJ45 plug housing.

Figure 33 GPS adapter cable kit



GPS receiver part numbers

Order GPS receivers and associated components from Cambium Networks (Table 51).

Table 51 GPS receiver component part numbers for use with PTP-SYNC

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

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

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

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

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

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

Twelve way circular connector

As an alternative to the GPS adapter cable, the drop cable can be connected directly to the GPS unit via a 12 way circular connector, using the components and tools listed in Table 52.

Table 52 Recommended outdoor connectors for Trimble GPS receiver

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

Universal GPS

For details of the Universal GPS (UGPS) receiver, see *PMP Synchronization Solutions User Guide* available from the Cambium Networks web site.

Network indoor unit (NIDU)

NIDU description

The NIDU (Figure 34) is an optional component that adds up to eight TDM channels (E1 or T1) to a PTP 670 link. It multiplexes and demultiplexes E1, T1 and Ethernet data over the wireless bridge.

The NIDU is an indoor unit that is connected to the PSU (via the ODU port), to network terminating equipment (via the LAN port) and to up to eight E1 or T1 channels (via the E1/T1 ports) using Cat5e cable with RJ45 connectors. It requires a 48V to 60V DC power supply, either from the AC+DC Enhanced Power Injector 56V, the PTP 800 AC-DC Power Supply Converter or another source.

Figure 34 NIDU

Note

To enable E1 or T1 capability over a PTP 670 link, purchase one access key for each link end from Cambium Networks (ODU capability upgrades on page 2-7).

NIDU part numbers

Order NIDUs and associated components from Cambium Networks (Table 53).

Table 53 NIDU component part numbers

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

(*) Optional DC power supply for the NIDU.

NIDU interfaces

The NIDU interfaces are shown in Figure 35 and described in Table 54.

Figure 35 NIDU interfaces

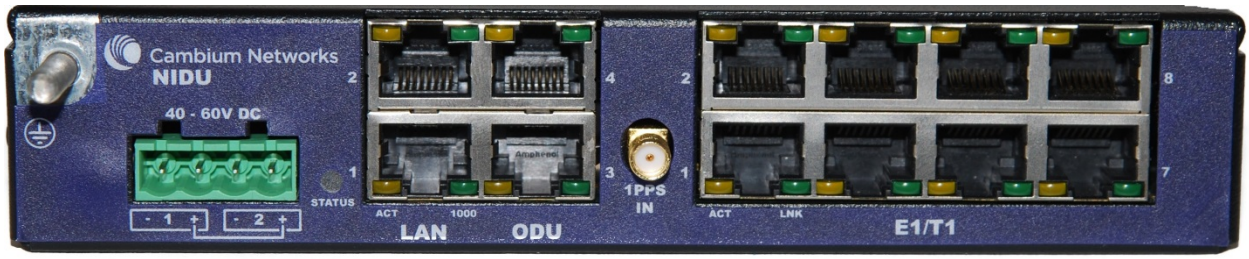


Table 54 NIDU interface functions

Interface	Function
40 – 60V DC	Port 1: DC power input from an independent source or from the AC+DC Enhanced Power Injector 56V. Port 2: Backup power input. The kit includes one four-pin DC connector.
LAN	Gigabit Ethernet RJ45 socket for connecting to network terminating equipment. Use LAN port 1; port 2 is provided for future expansion.
ODU	Gigabit Ethernet RJ45 socket for connecting to the PSU (and so on to the ODU). Use ODU port 3; port 4 is provided for future expansion.
E1/T1	RJ45 sockets for connecting to up to eight E1 or T1 channels. Allocate ports to channels in ascending order (1 to 8).
1PPS IN	Not used. Provided for future expansion.

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

NIDU specifications

The NIDU conforms to the specifications listed in Table 55.

Table 55 NIDU specifications

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

The NIDU TDM interface conforms to the standards listed in TDM network planning on page 3-53.

The pinouts of the NIDU ports are specified in Table 56, Table 57 and Table 58.

Table 56 NIDU LAN port pinouts

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

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

Table 57 NIDU ODU port pinouts

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

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

Table 58 NIDU E1/T1 port pinouts

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

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

Chapter 3: System planning

This chapter provides information to help the user to plan a PTP 670 link.

The following topics are described in this chapter:

- Typical deployment on page 3-2 contains diagrams illustrating typical PTP 670 site deployments.
- Site planning on page 3-11 describes factors to be considered when planning the proposed link end sites, including grounding, lightning protection and equipment location.
- Radio spectrum planning on page 3-20 describes how to plan PTP 670 links to conform to the regulatory restrictions that apply in the country of operation.
- Link planning on page 3-24 describes factors to be taken into account when planning links, such as range, path loss and throughput.
- Planning for connectorized units on page 3-29 describes factors to be taken into account when planning to use connectorized ODUs with external antennas in PTP 670 links.
- Configuration options for TDD synchronization on page 3-31 describes the different configuration options that may be used for implementing TDD synchronization in the PTP 670 Series.
- Data network planning on page 3-36 describes factors to be considered when planning PTP 670 data networks.
- TDM network planning on page 3-53 describes factors to be considered when planning PTP 670 TDM networks.
- Network management planning on page 3-54 describes how to plan for PTP 670 links to be managed remotely using SNMP.
- Security planning on page 3-56 describes how to plan for PTP 670 links to operate in secure mode.
- System threshold, output power and link loss on page 3-65 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 3-86 contains tables and graphs to support calculation of the data rate capacity that can be provided by PTP 670 configurations.

Typical deployment

This section contains diagrams illustrating typical PTP 670 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 36), wall installation (Figure 37) and roof installation (Figure 38).

Figure 36 Mast or tower installation

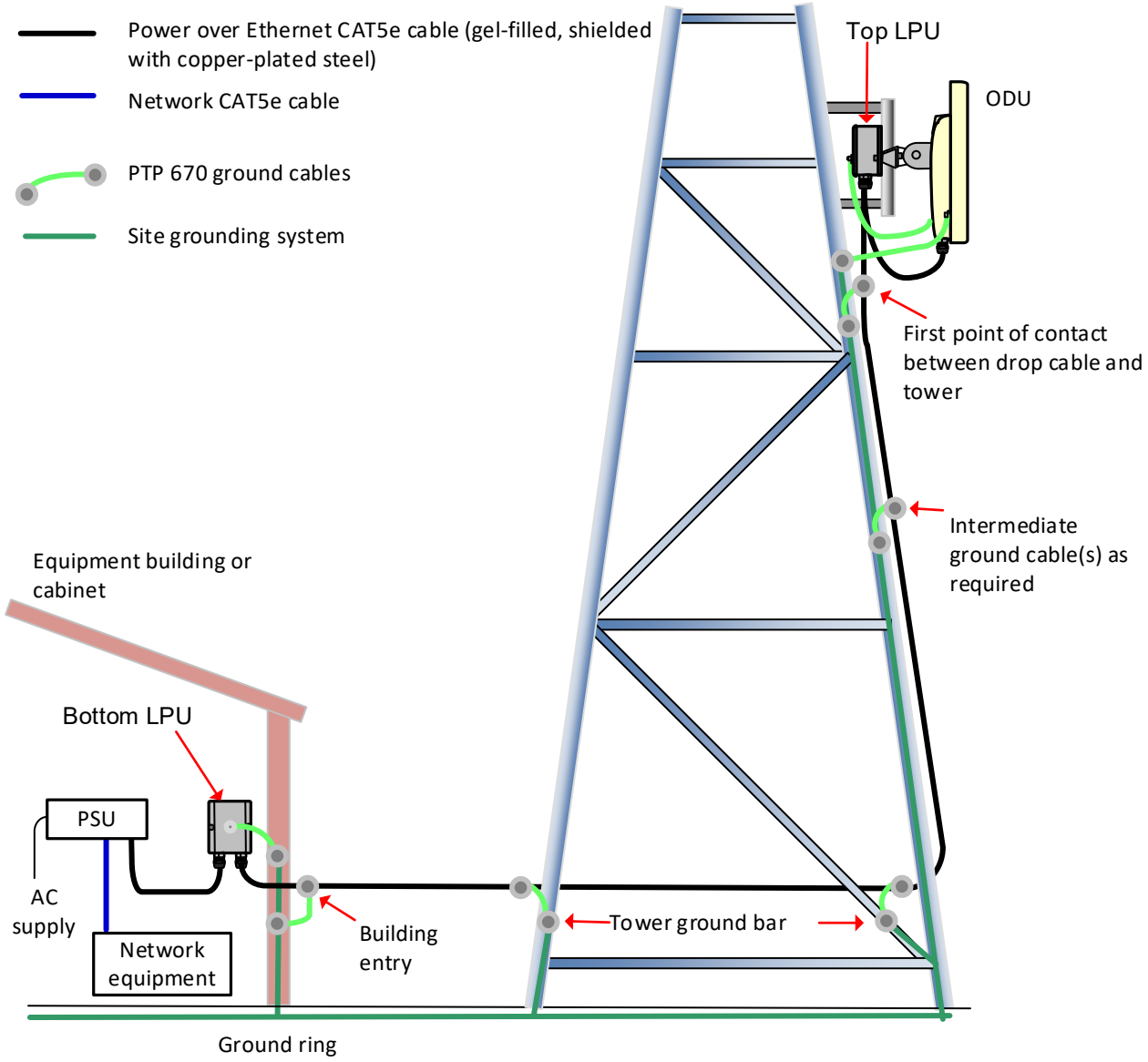


Figure 37 Wall installation

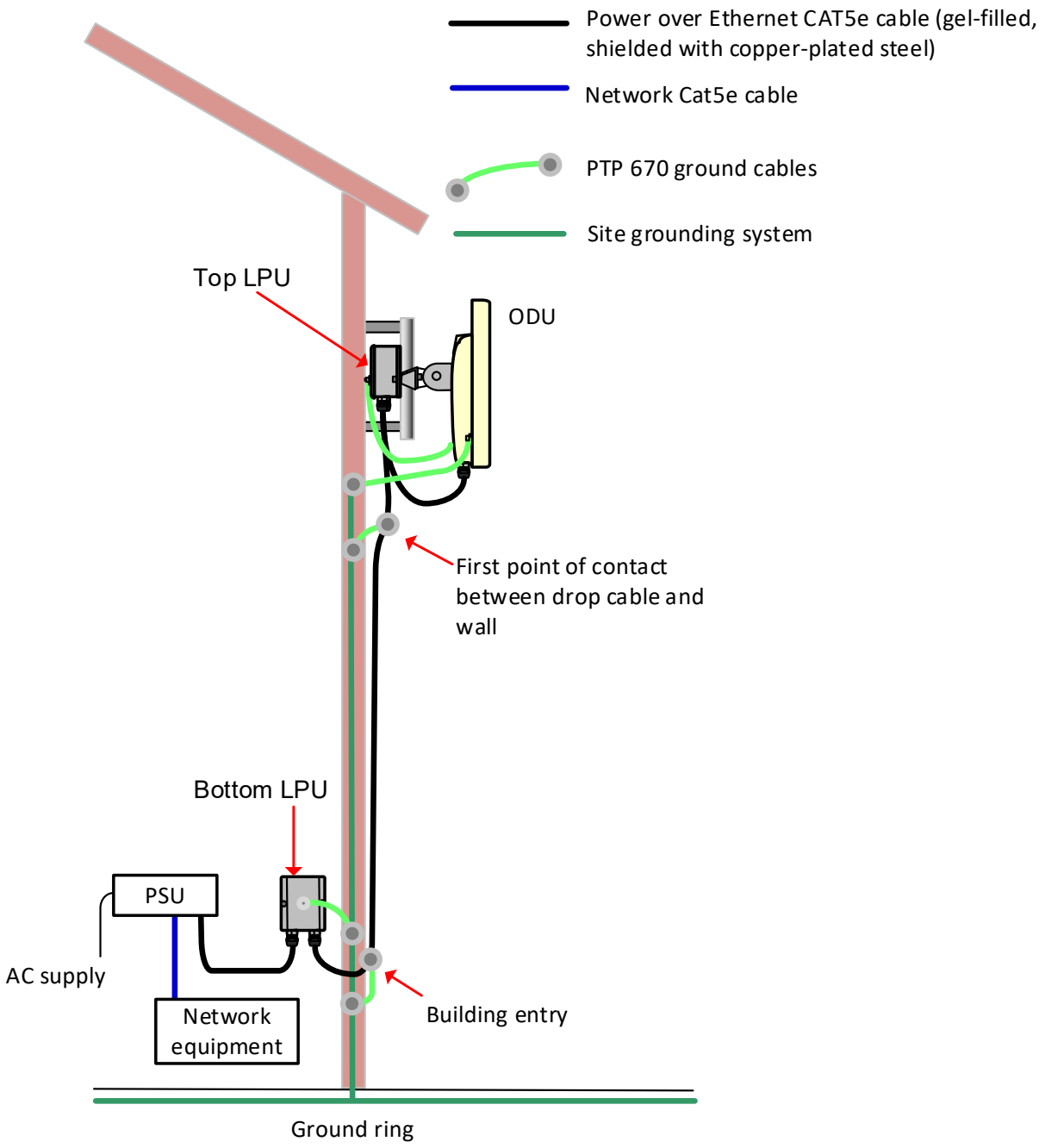
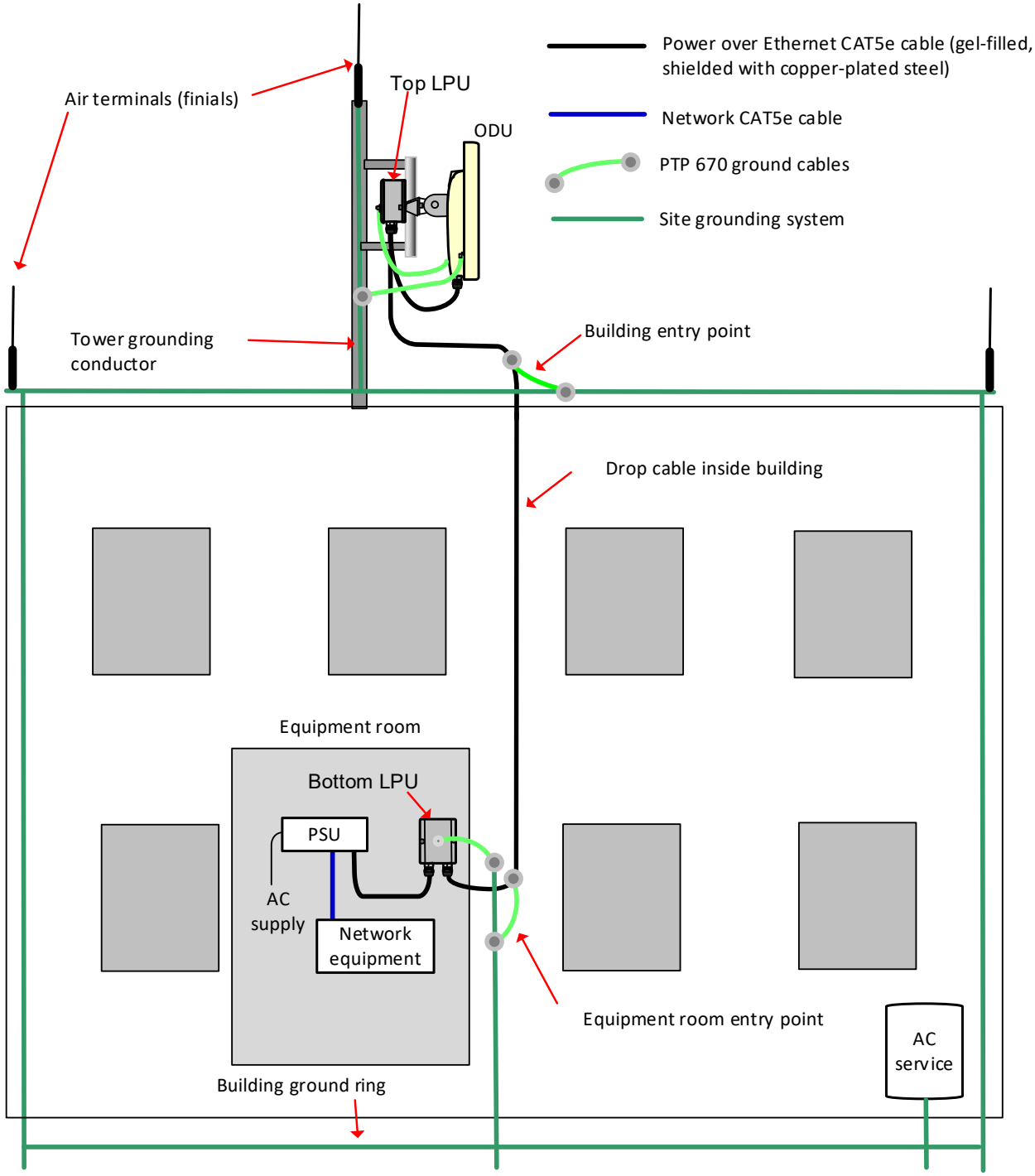


Figure 38 Roof installation



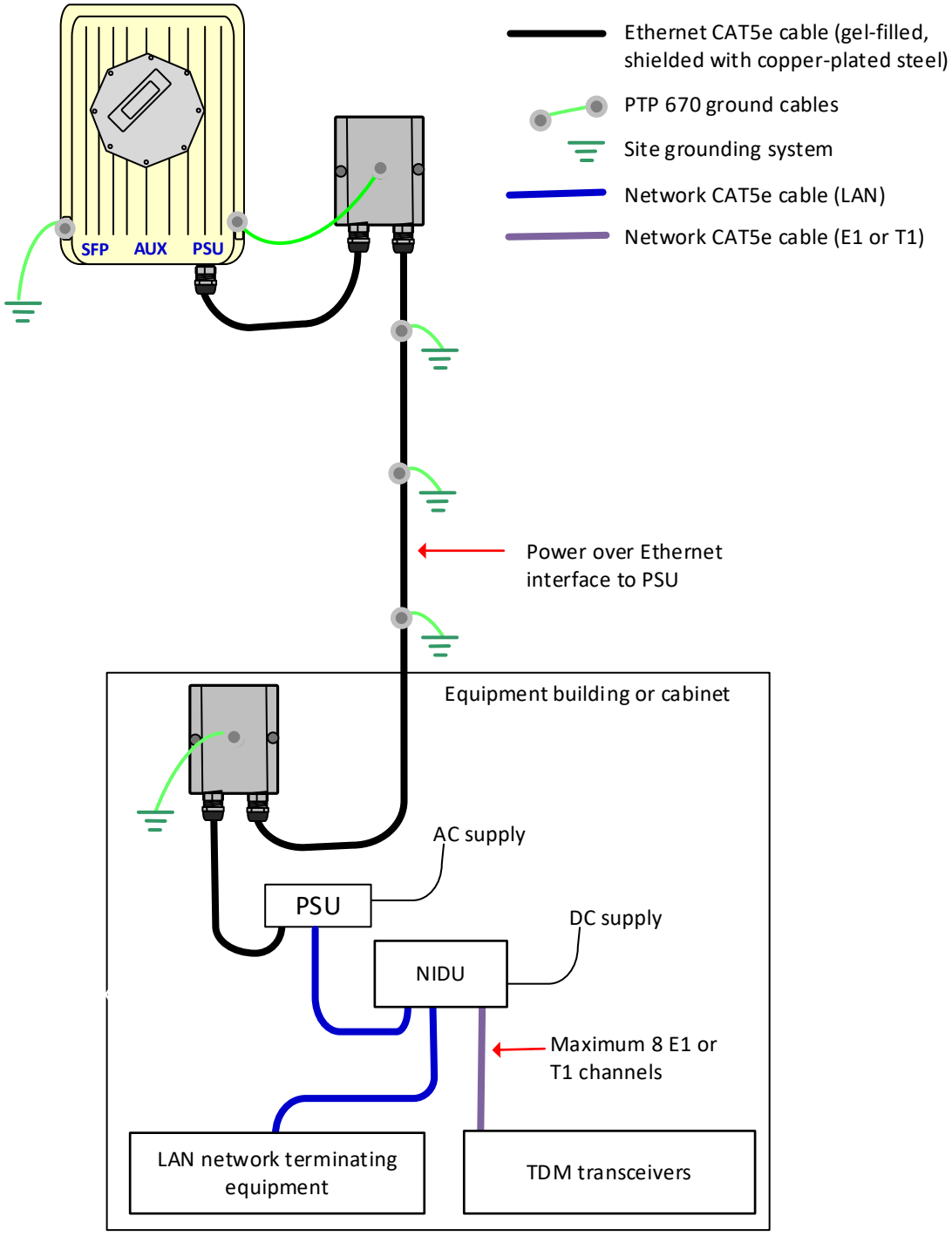
E1 or T1 interfaces

Note

PTP 670 does not support E1 or T1 interfaces in the HCMP topology.

There may be up to eight E1 or T1 channels connected to the ODU via the PSU port, as shown in Figure 39. The NIDU is not compatible with the SFP or AUX ports.

Figure 39 ODU with E1 or T1 interfaces



SFP and Aux Ethernet interfaces

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

- ODU with copper SFP and PSU interfaces – Figure 40
- ODU with optical SFP and PSU interfaces – Figure 41
- ODU with Aux and PSU interfaces – Figure 42

Figure 40 ODU with copper SFP and PSU interfaces

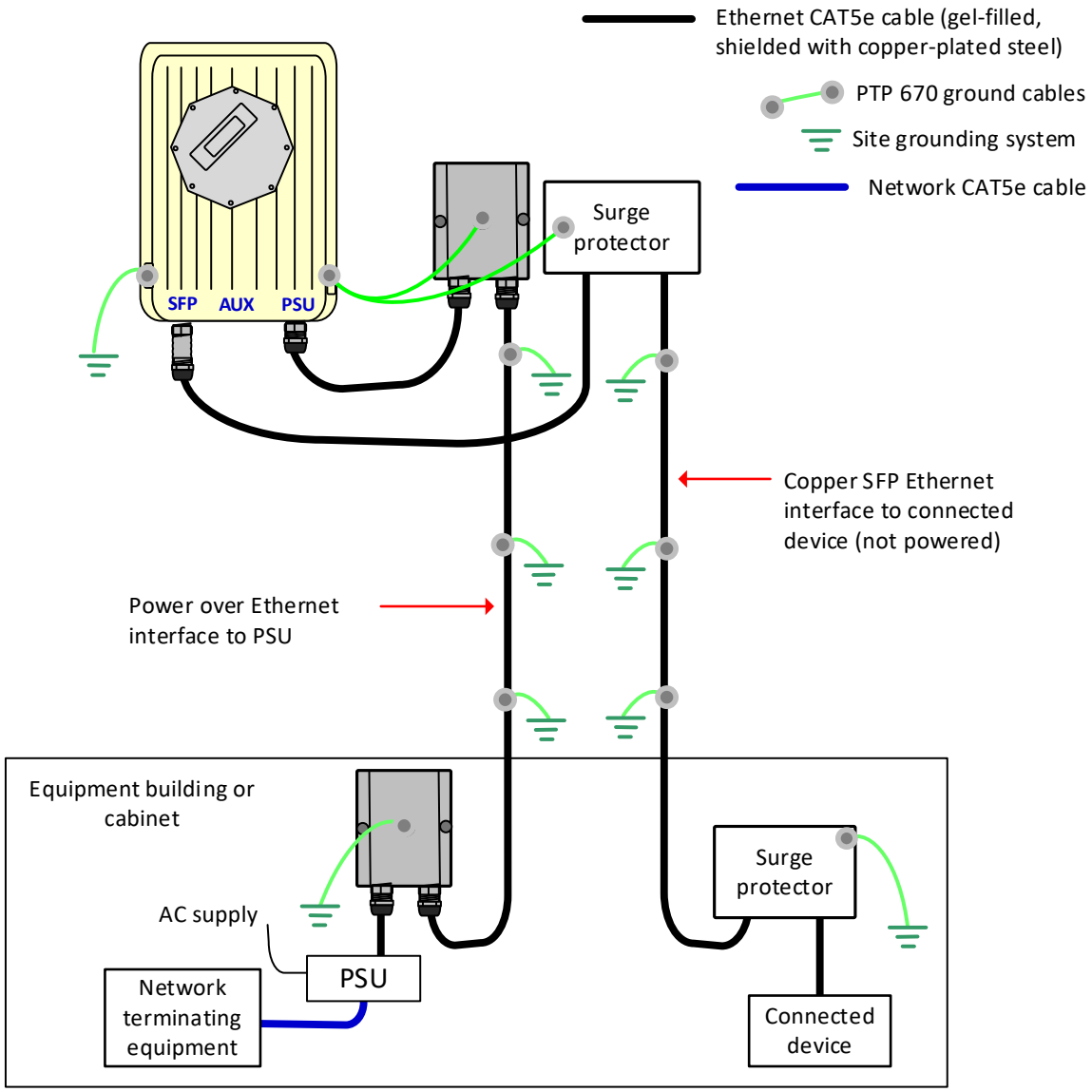


Figure 41 ODU with optical SFP and PSU interfaces

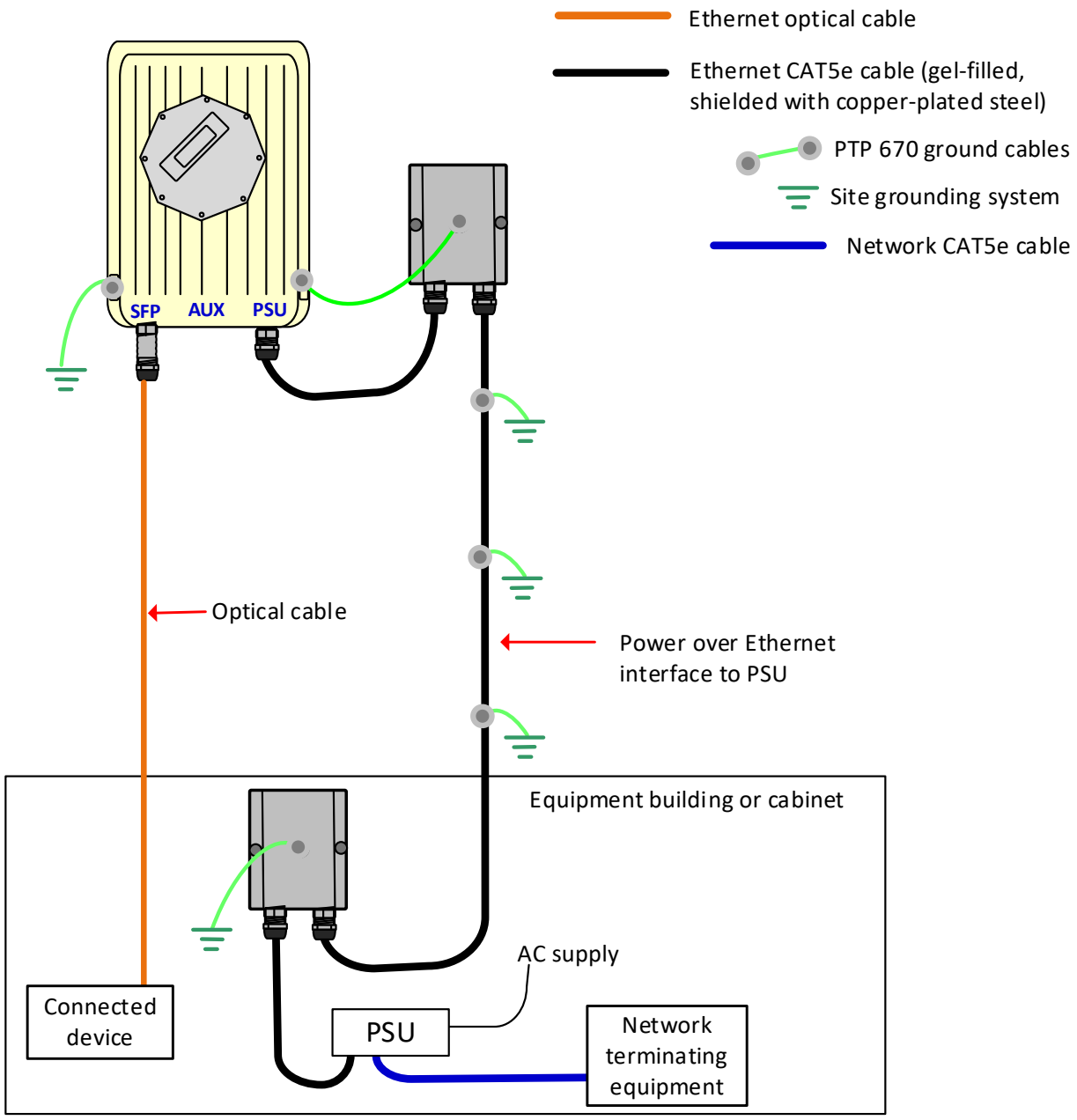
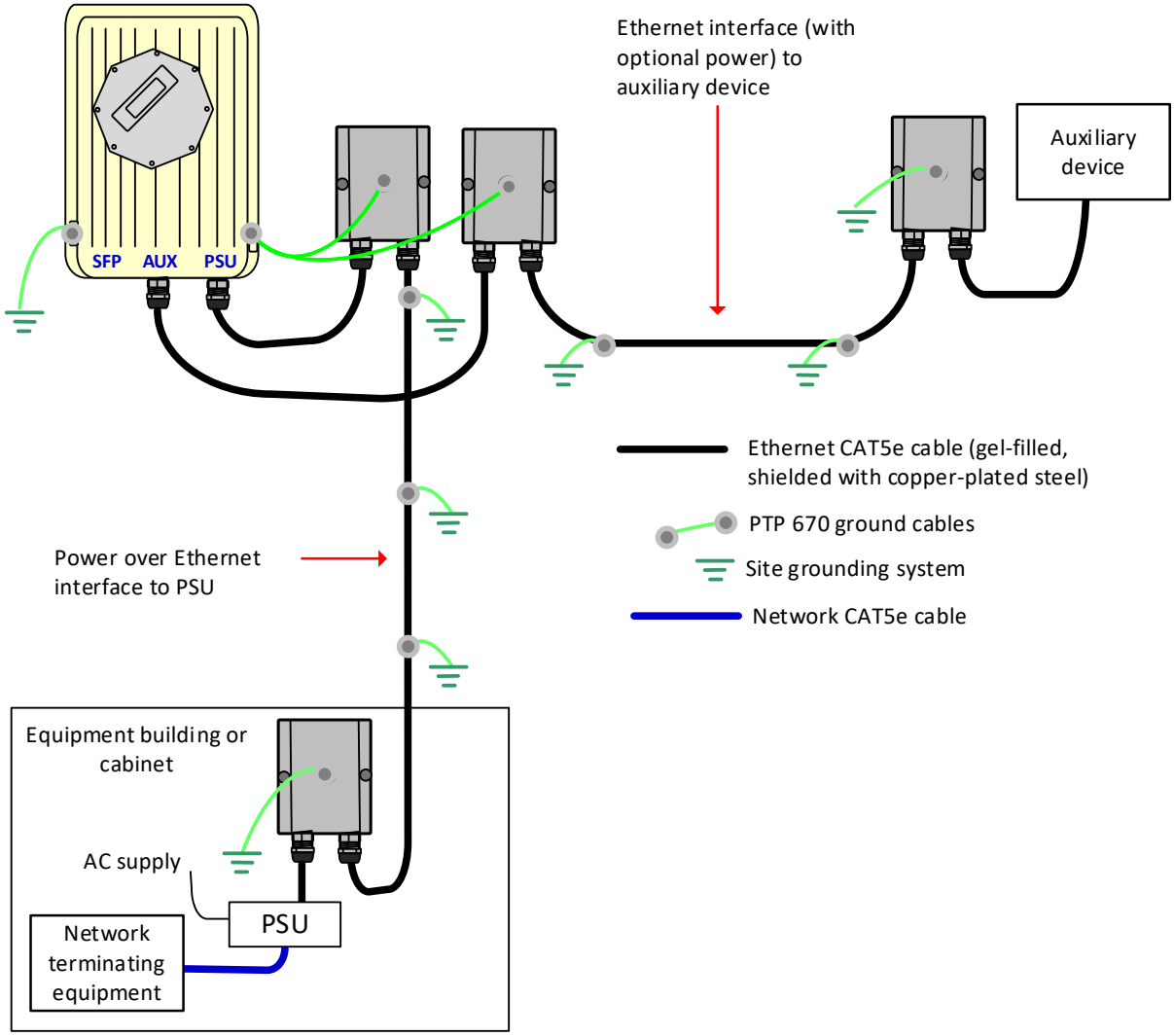


Figure 42 ODU with Aux and PSU interfaces



GPS receiver interfaces

If a GPS receiver is deployed for PTP-SYNC, it may be mounted on the wall of the equipment building (Figure 43) (preferred option), or on a metal tower or mast (Figure 44).

Figure 43 GPS receiver wall installation

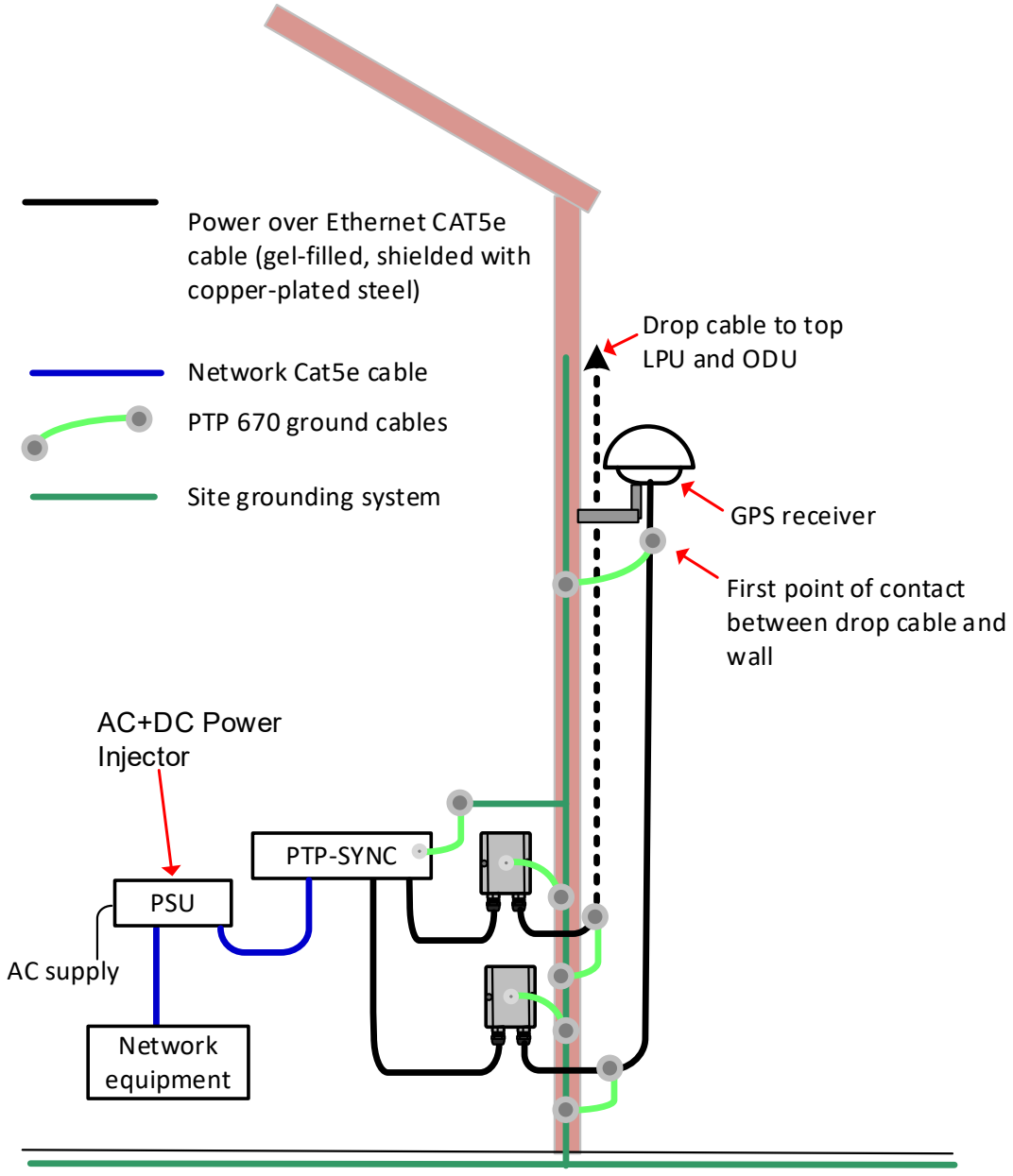
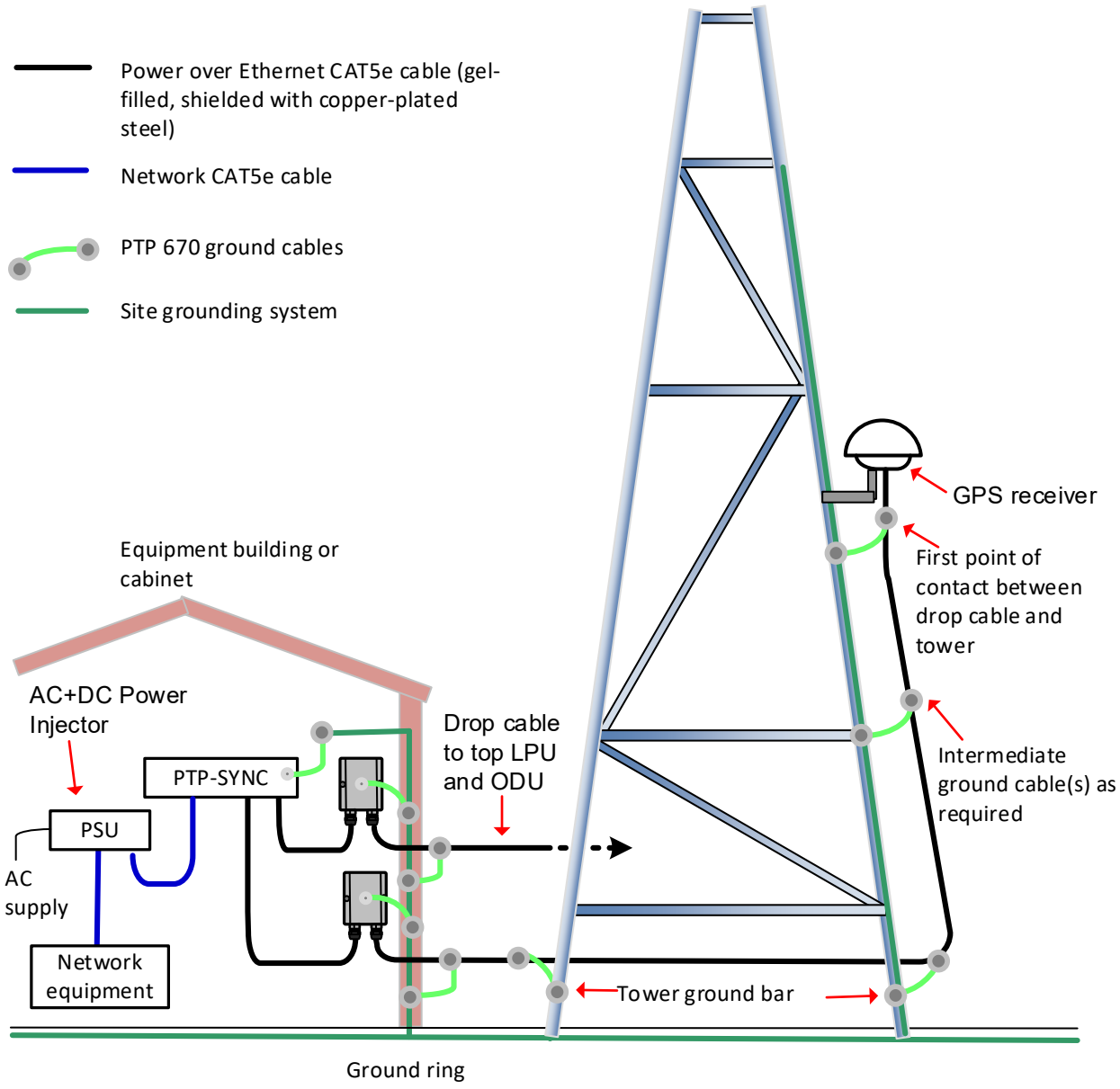


Figure 44 GPS receiver tower or mast installation



Site planning

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

Grounding and lightning protection

Warning

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

Structures, equipment and people must be protected against power surges (typically caused by lightning) by conducting the surge current to ground via a separate preferential solid path. The actual degree of protection required depends on local conditions and applicable local regulations. To adequately protect a PTP 670 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.

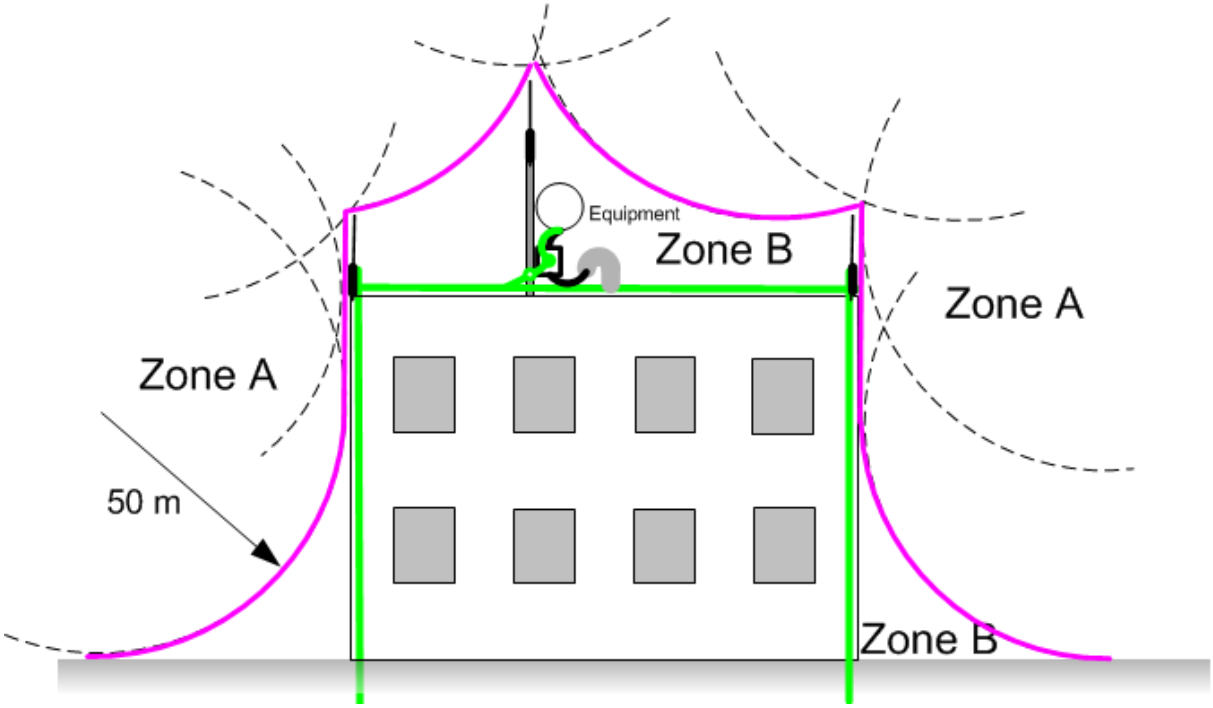
Note

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

Lightning protection zones

Use the rolling sphere method (Figure 45) 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 45 Rolling sphere method to determine the lightning protection zones



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

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

Warning

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

Site grounding system

Confirm that the site has a correctly installed grounding system on a common ground ring with access points for grounding PTP 670 equipment.

If the outdoor equipment is to be installed on the roof of a high building (Figure 38), confirm that the following additional requirements are met:

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

ODU and external antenna location

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

- The equipment is high enough to achieve the best radio path.
- People can be kept a safe distance away from the equipment when it is radiating. The safe separation distances are defined in Calculated distances on page 4-22.
- The equipment is lower than the top of the supporting structure (tower, mast or building) or its lightning air terminal.
- If the ODU is connectorized, select a mounting position that gives it maximum protection from the elements, but still allows easy access for connecting and weatherproofing the cables. To minimize cable losses, select a position where the antenna cable lengths can be minimized. If diverse or two external antennas are being deployed, it is not necessary to mount the ODU at the midpoint of the antennas.

ODU ambient temperature limits

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

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

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

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

Note

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

ODU wind loading

Ensure that the ODU and the structure on which it is mounted are capable of withstanding the prevalent wind speeds at a proposed PTP 670 site. Wind speed statistics should be available from national meteorological offices.

The ODU and its mounting bracket are capable of withstanding wind speeds of up to 325 kph (200 mph).

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

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

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

Applying this formula to the PTP 670 ODUs at different wind speeds, the resulting wind loadings are shown in Table 59

Table 59 ODU wind loading (newtons)

Type of ODU	Max surface area (square meters)	Wind speed (kilometers per hour)				
		225	250	275	300	325
Integrated	0.130	431 N	532 N	644 N	766 N	899 N
Connectorized	0.062	205 N	254 N	307 N	365 N	429 N

Equivalent results in US customary units are shown in Table 60.

Table 60 ODU wind loading (pounds force)

Type of ODU	Max surface area (square feet)	Wind speed (miles per hour)				
		140	155	170	185	200
Integrated	1.40	97 lb	119 lb	143 lb	170 lb	198 lb
Connectorized	0.67	46 lb	57 lb	68 lb	81 lb	95 lb

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

Hazardous locations

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

PSU DC power supply

If using the DC input on the AC+DC Power Injector 56V, 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 AC power supply

Always use an appropriately rated and approved AC supply cord-set in accordance with the regulations of the country of use.

PSU location

Find a location for the PSU (AC Power Injector 56V, AC+DC Enhanced Power Injector 56V or CMM5) that meets the following requirements:

- The AC Power Injector 56V can be mounted on a flat surface.
- The AC+DC Enhanced Power Injector 56V can be mounted on a wall or other flat surface.
- The CMM5 Power and Sync Injector can be installed in a standard 19-inch rack.
- The PSU is kept dry, with no possibility of condensation, flooding or rising damp.
- The PSU is located in an environment where it is not likely to exceed its operational temperature rating, allowing for natural convection cooling.
- The PSU can be connected to the ODU drop cable and network terminating equipment.
- The PSU can be connected to a compatible power supply. AC+DC Enhanced Power Injector 56V: the use of DC supplies of less than 55V will reduce the usable distance between the PSU and ODU.

PTP-SYNC location

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

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

GPS receiver location

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

- It must be possible to protect the installation as described in Grounding and lightning protection on page 3-11.

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

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

Caution

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

Mounting the GPS receiver module on the equipment building

If mounting the GPS receiver for PTP-SYNC on the equipment building (Figure 43), select a position on the wall that meets the following requirements:

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

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

Mounting the GPS receiver module on a metal tower or mast

If mounting the GPS receiver module on a metal tower or mast (Figure 44), select a position that meets the following requirements:

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

NIDU location

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

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

Drop cable grounding points

To estimate how many grounding kits are required for each drop cable, refer to the site installation diagrams (Figure 36 , Figure 37 and Figure 38) 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 36), 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 38), 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 670 LPU (Figure 46). Optical cables do not require LPUs or ground cables (Figure 47).

The copper SFP drop cable requires a bottom surge protector, not a PTP 670 LPU (Figure 48).

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

Figure 46 ODU with PSU, Aux and copper SFP interfaces

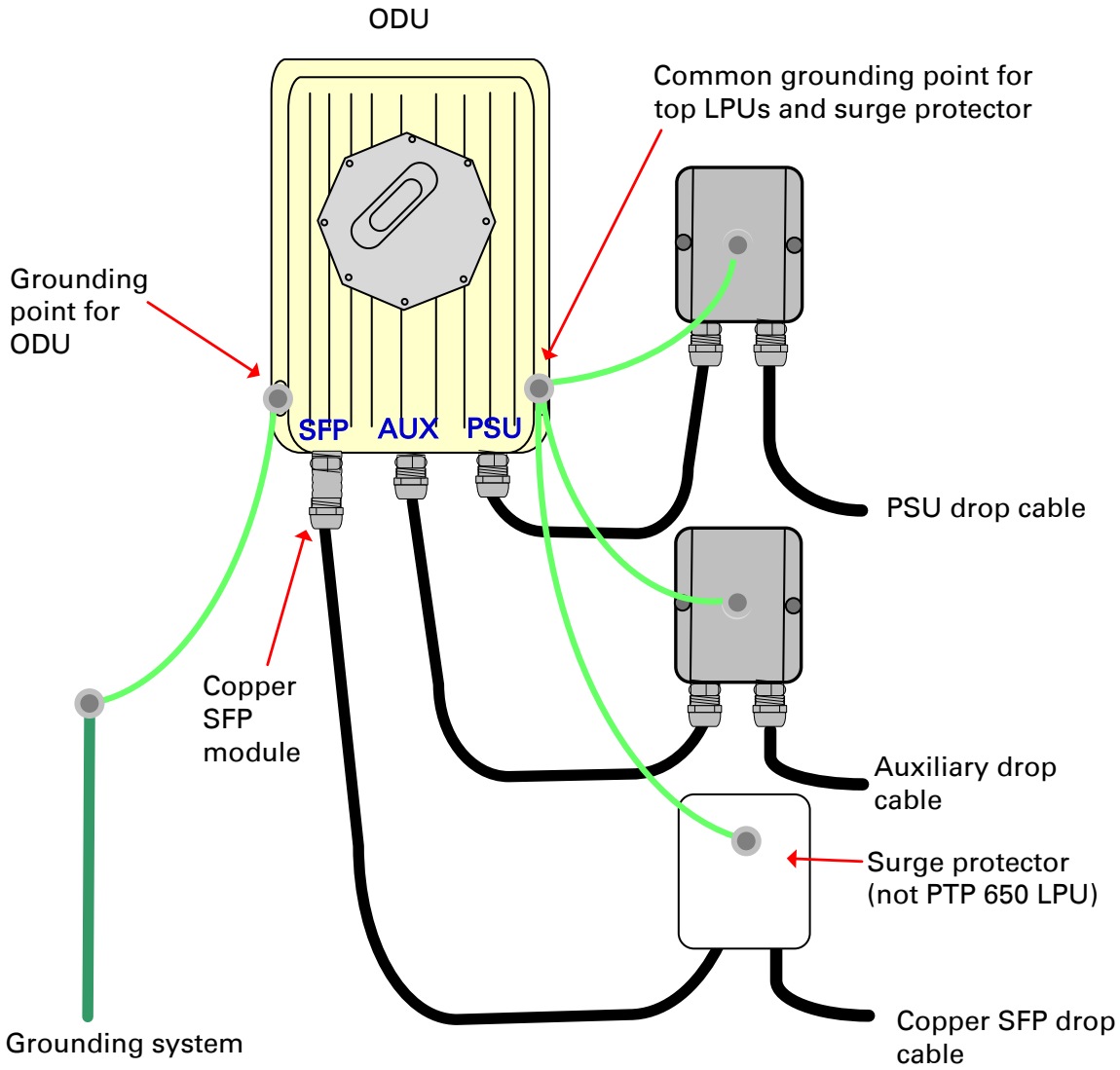


Figure 47 ODU with PSU, Aux and optical SFP interfaces

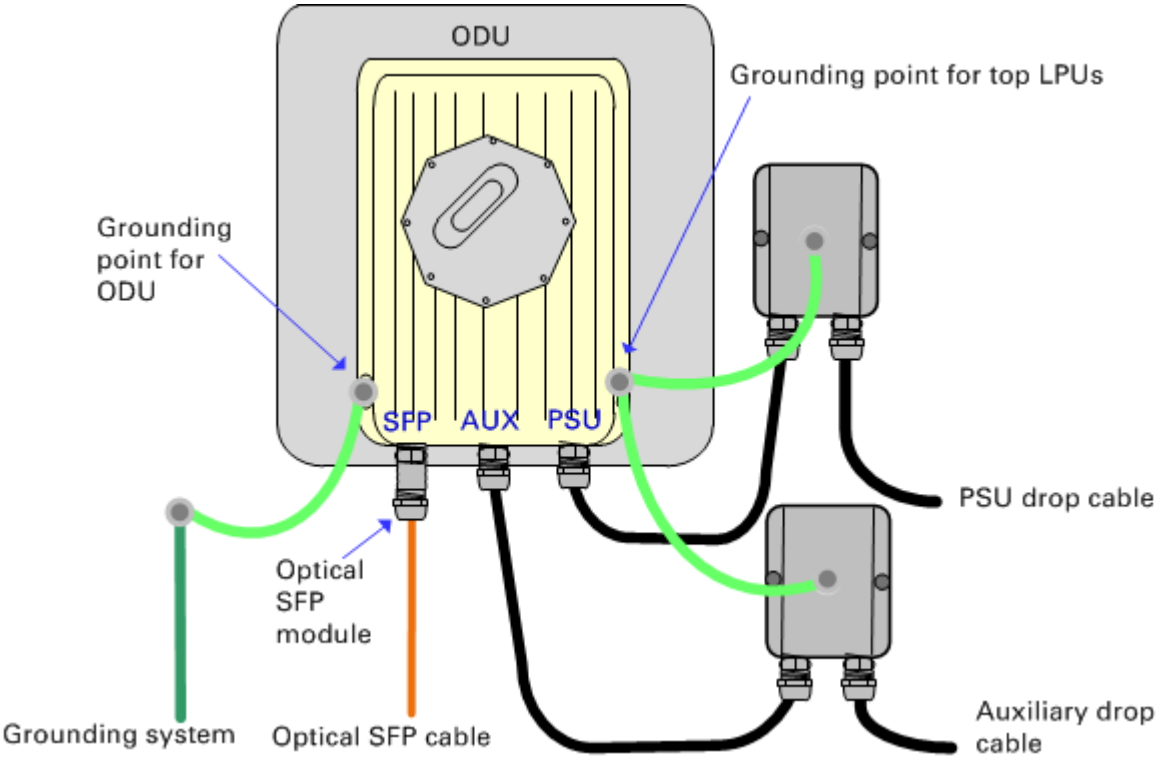
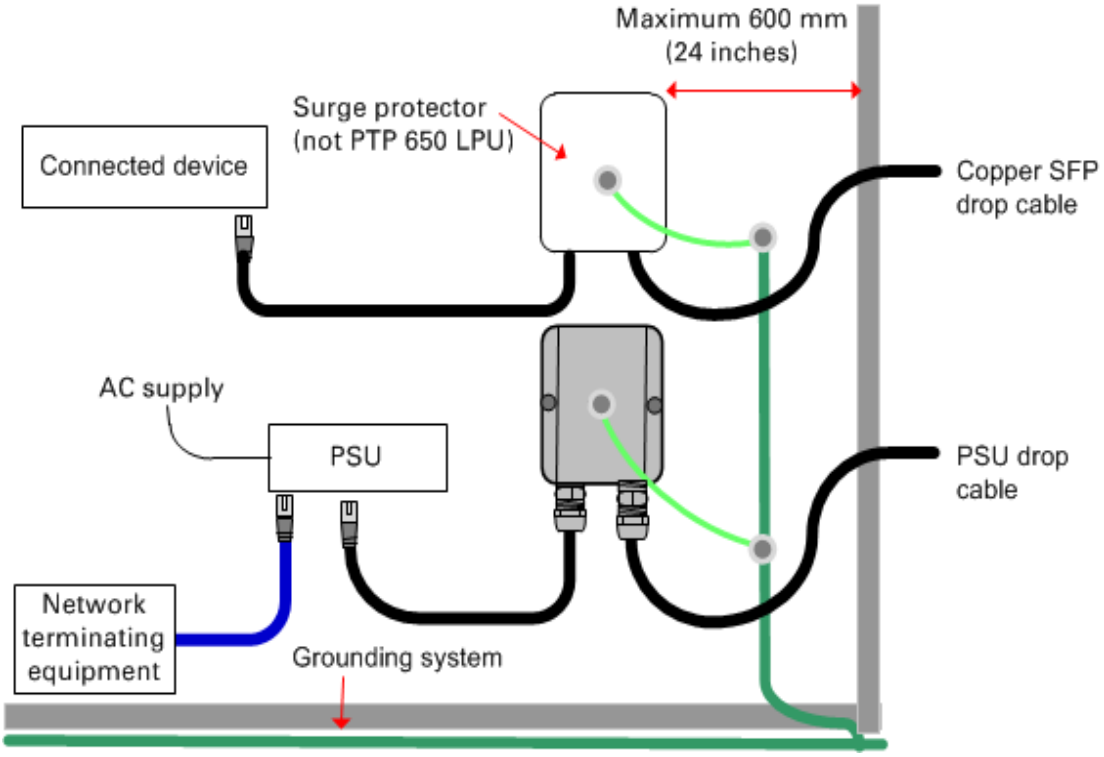


Figure 48 Bottom LPU and surge protector



Radio spectrum planning

This section describes how to plan PTP 670 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 670 link is required.

General wireless specifications

Table 61 lists the wireless specifications that apply to all PTP 670 frequency bands. Table 62 and Table 63 list the wireless specifications that are specific to a single frequency band.

Table 61 PTP 670 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 670 Integrated)
Duplex schemes	Symmetric fixed, asymmetric fixed and adaptive TDD.
Range	Line-of-Sight: 250 km (156 miles). Non-Line-of-Sight: 10 km (6 miles).
Over-the-air encryption	AES 128-bit or 256-bit.
Weather sensitivity	Sensitivity at higher modes may be reduced by adjusting the Adaptive Modulation Threshold.
Error Correction	FEC

Table 62 PTP 670 wireless specifications (per frequency band), 4.8 GHz to 5.9 GHz Variant

Item	4.8 GHz	4.9 GHz	5.1 GHz	5.2 GHz	5.4 GHz	5.8 GHz
RF band (MHz)	4800–4900	4900–4990	5150–5250	5250–5350	5470–5725	5725–5875
Channel bandwidth (MHz)	5, 10, 15, 20, 30, 40, 45	5, 10, 15, 20	5, 10, 15, 20, 30, 40, 45	5, 10, 15, 20, 30, 40, 45	5, 10, 15, 20, 30, 40, 45	5, 10, 15, 20, 30, 40, 45
Typical receiver noise	7.5 dB	7.5 dB	7.5 dB	7.8 dB	7.8 dB	8.1 dB
Typical antenna gain (integrated)	23.0 dBi	23.0 dBi	23.0 dBi	23.0 dBi	23.0 dBi	23.0 dBi
Antenna beamwidth (integrated)	8°	8°	8°	8°	8°	8°

Table 63 PTP 670 wireless specifications (per frequency band), 4.9 GHz to 6.05 GHz Variant

Item	4.9 GHz	5.1 GHz	5.2 GHz	5.4 GHz	5.8 GHz	5.9 GHz
RF band (MHz)	4900–4990	5150–5250	5250–5350	5470–5725	5725–5875	5825–6050
Channel bandwidth (MHz)	5, 10, 15, 20	5, 10, 15, 20, 30, 40, 45	5, 10, 15, 20, 30, 40, 45	5, 10, 15, 20, 30, 40, 45	5, 10, 15, 20, 30, 40, 45	5, 10, 15, 20, 30, 40, 45
Typical receiver noise	6.0 dB	6.0 dB	6.0 dB	6.0 dB	6.0 dB	6.0 dB
Typical antenna gain (integrated)	23.0 dBi	23.0 dBi	23.0 dBi	23.0 dBi	23.0 dBi	23.0 dBi
Antenna beamwidth (integrated)	8°	8°	8°	8°	8°	8°

Regulatory limits

Many countries impose EIRP limits (Allowed EIRP) on products operating in the bands used by the PTP 670 Series. For example, in the 5.4 GHz and 5.8 GHz bands, these limits are calculated as follows:

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

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

Conforming to the limits

Ensure the link is configured to conform to local regulatory requirements by installing license keys for the correct country. When using connectorized ODUs with external antennas, ensure that the antenna gain and feeder loss is configured correctly in the ODU.

Available spectrum

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

Certain regulations have allocated certain channels as unavailable for use:

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

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

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

Channel bandwidth

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

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

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

Note

PTP 670 supports only the 20 and 40 MHz channel bandwidth in the HCMP topology.

Frequency selection

PTP topology in regions without mandatory radar detection

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

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

PTP topology in regions with mandatory radar detection

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

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

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

- For the EU: in specification EN 301-893.
- For the US: in the specification FCC part 15.407 plus the later requirements covered in Important regulatory information on page 3.
- For Canada: in the specification RSS-247.

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

Frequency selection for HCMP topology

In the HCMP topology, the Master supports:

- **Fixed Frequency**

The HCMP Slave supports:

- **Fixed Frequency**
- **Dynamic Spectrum Optimization (DSO)**: This allows the Slave to scan the frequency band to find the associated Master ODU.

HCMP topology cannot be used at present in Regulatory Bands that require DFS (radar detection).

Link planning

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

LINKPlanner

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

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

Range and obstacles

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

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

The PTP 670 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 670 Series will operate at ranges from 100 m (330 ft) to 250 km (156 miles), within four ranging modes: 0-40 km (0-25 miles), 0-100 km (0-62 miles), 0-200 km (0-125 miles), and 0-250 km (0-156 miles). Operation of the system will depend on obstacles in the path between the units. Operation at 40 km (25 miles) or above will require a near line-of-sight path. Operation at 100 m (330 ft) could be achieved with one unit totally obscured from the other unit, but with the penalty of transmitting at higher power in a non-optimal direction, thereby increasing interference in the band.

Note

The maximum range for the HCMP topology is 40 km. The maximum range achieved for a link in the HCMP topology tends to be lower than in the PTP topology because the Master ODU is normally installed with a sector or omni-directional antenna.

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 670 to detect radar signals:

- With integrated antennas, the recommended minimum LoS operating range is 110 meters (360 ft) for 5.2 GHz or 5.4 GHz, and 185 meters (610 ft) for 5.8 GHz. Shorter operating ranges will lead to excessive receiver signal levels.

- With higher gain connectorized antennas, ensure the predicted receiver signal level (from LINKPlanner) is below -53 dBm (for 5.2 GHz or 5.4 GHz) or below -58 dBm (for 5.8 GHz).

LINKPlanner for synchronized networks

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

Path loss

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

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

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

Adaptive modulation

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

For details of the system threshold, output power and link loss for each frequency band in all modulation modes for all available channel bandwidths, refer to System threshold, output power and link loss on page 3-65.

Calculating data rate capacity

The data capacity of a PTP or HCMP link is defined as the maximum end-to-end Ethernet throughput (including Ethernet headers) that it can support, assumed Ethernet frames of 1518 octets.

Data capacity is determined by the following factors:

- Wireless topology (PTP or HCMP)
- TDD Synchronization
- Link Symmetry
- Link Mode Optimization (IP or TDM)
- Modulation Mode
- Channel Bandwidth
- Link Range
- Capacity reserved for TDM operation

Calculation procedure for PTP topology

To calculate the data rate capacity of a PTP 670 link, proceed as follows:

1. Use the tables in Data capacity in PTP topology on page 3-86 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
2. The tables contain data rates for links of zero range. Use the range adjustment graphs to look up the Throughput Factor that must be applied to adjust the data rates for the actual range of the link.
3. Multiply the data rates by the Throughput Factor to give the throughput capacity of the link.
4. Subtract capacity reserved for TDM operation. See TDM traffic load on page 3-127.

Note

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

Calculation procedure for PTP topology with TDD synchronization

The capacity of a PTP link with TDD synchronization can be determined using the LINKPlanner.

Calculation example for PTP topology

Suppose that the link characteristics are:

- 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 123 to look up the data throughput capacity rates:

Tx = 41.30 Mbits/s

Rx = 41.30 Mbits/s

Aggregated = 82.61 Mbits/s

2 Use Figure 85 to look up the Throughput Factor for 1:1, TDM, 10 MHz 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 = 35.52 Mbits/s

Rx = 35.52 Mbits/s

Aggregated = 71.04 Mbits/s

Calculation procedure for HCMP topology

To calculate the data rate capacity of a PTP 670 link, with or without TDD synchronization, proceed as follows:

1 Use Table 129, Table 130 or Table 131 to look up the TDD frame duration for the required combination of:

- Channel bandwidth
- Maximum link range
- Maximum number of Slaves

2 Use Table 132 or Table 133 to look up the one-way data capacity per time slot for the required combination of:

- Channel bandwidth
- TDD frame duration
- Modulation mode

3 The one-way capacity for a single Slave is the capacity per time slot multiplied by the number of timeslots. The aggregate (two-way) capacity for one Slave is the sum of two one-way capacities. The aggregate capacity for the Master is the capacity for one Slave multiplied by the number of Slaves.

Note

The capacity of a link in the HCMP topology depends on the maximum link range configured in the ODU, but does not depend on the range of the individual link. The number of Slaves is the maximum number that can be supported by the Master, and not the number presently connected.

Calculation example for HCMP topology

Suppose that:

- Channel Bandwidth = 40 MHz
- TDD synchronization = Disabled
- Link Symmetry = 2:1 Symmetry
- Maximum number of Slaves = 3
- Maximum Range = 15 km
- Modulation mode = 256QAM 0.81 dual.

The calculation procedure for this example is as follows:

1 Look up TDD Frame Duration in Table 130

TDD Frame Duration = 3145 µs.

2 Look up the time slot capacity in Table 133

Time slot capacity = 35.13 Mbit/s

3 Calculate the capacity of the link

The capacity for the link is 70.26 Mbit/s from Master to Slave, and 35.13 Mbit/s from Slave to Master.

The aggregate capacity for one link is 70.26 Mbit/s + 35.13 Mbit/s = 105.39 Mbit/s.

The aggregate capacity of the HCMP sector with three links is 3 × 105.39 Mbit/s, or 316.17 Mbit/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 670 links.

When to install connectorized units

PTP topology

The majority of radio links can be successfully deployed using the Integrated ODU. However the Integrated ODU may not have sufficient antenna gain in some areas, for example:

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

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

In these areas, use the Connectorized ODU with external antennas.

HCMP topology

The Master ODU in an HCMP sector will normally be installed with a connectorized antenna with sector or omni-directional coverage.

Slave ODUs in an HCMP sector will normally be installed using the Integrated ODU, but might be installed using the Connectorized ODU with external antennas, for example:

- Where the path is heavily obscured by dense woodland on an NLOS link.
- Where there are known to be high levels of interference.

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 Innovation, Science and Economic Development Canada (ISEDC) regulations, this radio transmitter may only operate using an antenna of a type and maximum (or lesser) gain approved for the transmitter by ISEDC. 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'Innovation, Sciences et Développement Economique 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 ISDEC. Dans le but de réduire les risques de brouillage radioélectrique à l'intention des autres utilisateurs, il faut choisir le type d'antenne et son gain de sorte que la puissance isotrope rayonnée équivalente (p.i.r.e.) ne dépasse pas l'intensité nécessaire à l'établissement d'une communication satisfaisante.

Calculating RF cable length (5.8 GHz FCC only)

The 5.8 GHz band FCC approval for the product is based on tests with a cable loss between the ODU and antenna of not less than 1.2 dB. If cable loss is below 1.2 dB with a 1.3 m (4 ft) diameter external antenna, the connectorized PTP 670 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 64 (source: Times Microwave). This data excludes connector losses.

Table 64 RF cable lengths required to achieve 1.2 dB loss at 5.8 GHz

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

Configuration options for TDD synchronization

This section describes the different configuration options that may be used for implementing TDD synchronization in the PTP 670 Series. Schematic diagrams are included.

Using PTP-SYNC

The PTP 670 supports the following TDD synchronization configurations:

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

Caution

The PTP-SYNC is compatible only with the AC+DC Power Injector 56V.

The AC Power Injector 56V and CMM5 will not work with a PTP-SYNC, and it is likely that a fuse will be blown in the PTP-SYNC if this is attempted.

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

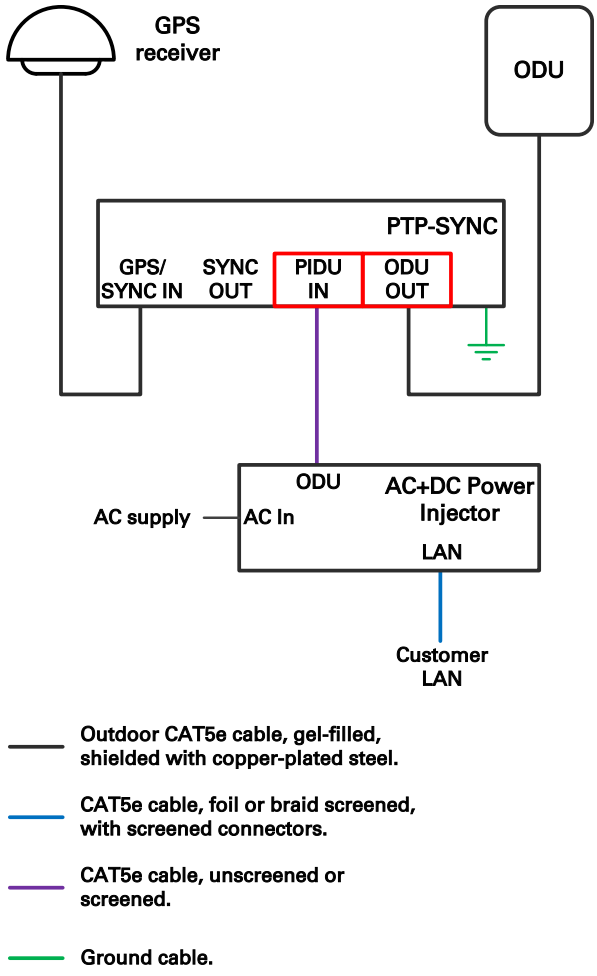
Single PTP link or HCMP sector configuration with PTP-SYNC

Each PTP link or HCMP sector requires one PTP-SYNC unit connected to the Master ODU and one compatible GPS receiver. Use this configuration where a site contains only one TDD master ODU. The GPS receiver and LPU can be replaced by an alternative compatible 1 Hz timing reference (Figure 49).

The wireless configuration settings are:

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

Figure 49 TDD synchronization configuration – single link with PTP-SYNC



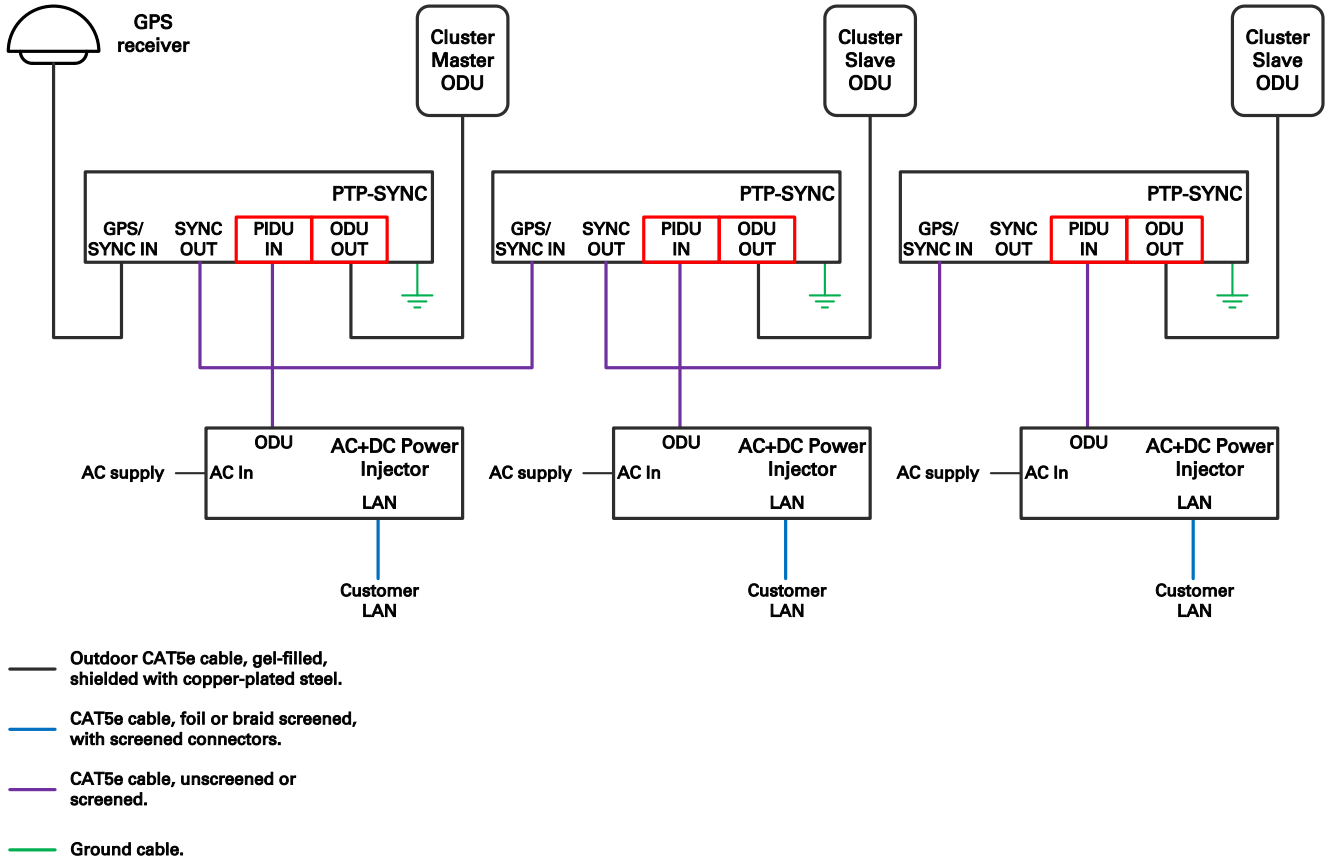
Cluster with PTP-SYNC and GPS receiver

Each PTP link or HCMP sector requires one PTP-SYNC unit. Each site requires one compatible GPS receiver. Collocated PTP-SYNC units are connected together in a daisy-chain. Between two and ten PTP-SYNCs may be chained in this way. Use this configuration where a site contains collocated TDD master ODUs in an extended network and where multiple sites have TDD master ODUs (Figure 50).

The wireless configuration settings are:

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

Figure 50 TDD synchronization configuration – cluster with PTP-SYNC and GPS



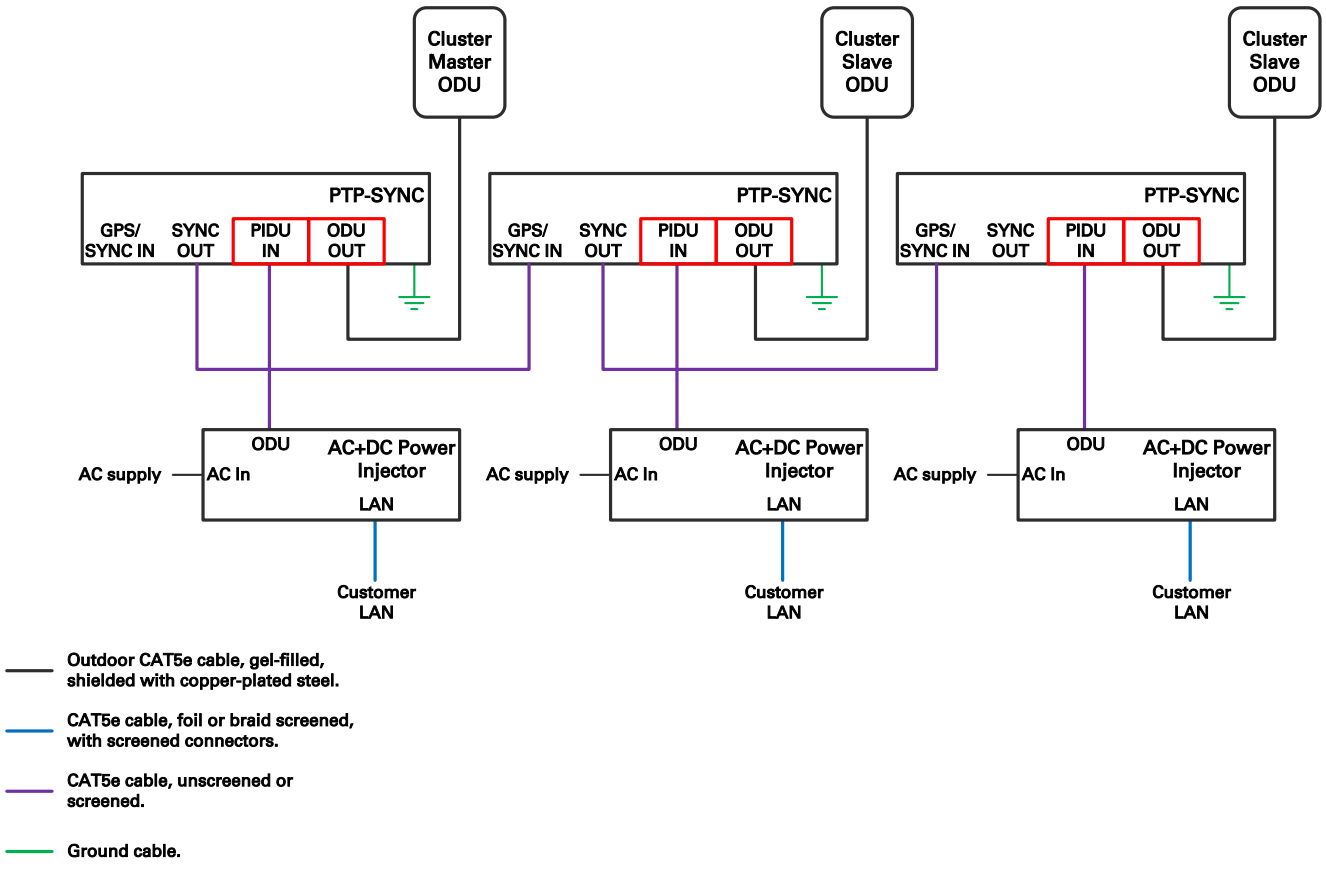
Cluster with PTP-SYNC and no GPS receiver

Each PTP link or HCMP sector requires one PTP-SYNC unit. PTP-SYNC units are connected together in a daisy-chain. Between two and ten PTP-SYNCs may be chained in this way. One ODU is designated as a cluster master. Use this configuration where all master ODUs are collocated at a single site. As this configuration does not require a GPS receiver, it provides additional flexibility, particularly in applications requiring rapid deployment (Figure 51).

The wireless configuration settings are:

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

Figure 51 TDD synchronization configuration – cluster with PTP-SYNC and no GPS



Using CMM5

Each ODU must be connected to the CMM5 Power and Sync Injector. The CMM5 Power and Sync Injector must be connected directly or indirectly to a UGPS receiver.

The wireless configuration settings are:

- Master Slave Mode = **Master** (all ODUs in cluster).
- TDD Synchronization Mode = **Enabled**.
- TDD Sync Device = **Cambium Sync Injector**.
- Cambium Sync Input Port = **Main PSU**.
- Cambium Sync Output Port = **None**.

Using a direct connection between ODUs

Interconnect the Aux ports of two ODUs using the standard outdoor Ethernet cable.

Configure one ODU to provide a free-running reference with the following settings:

- Master Slave Mode = **Master** (all ODUs in cluster).
- TDD Synchronization Mode = **Enabled**.
- TDD Sync Device = **Cambium Sync Injector**.
- Cambium Sync Input Port = **Internal**.
- Cambium Sync Output Port = **Aux**.

Configure a second ODU to synchronize with the first ODU with the following settings:

- Master Slave Mode = **Master** (all ODUs in cluster).
- TDD Synchronization Mode = **Enabled**.
- TDD Sync Device = **Cambium Sync Injector**.
- Cambium Sync Input Port = **Aux**.
- Cambium Sync Output Port = **None**.

Data network planning

This section describes factors to be considered when planning PTP 670 data networks.

Ethernet interfaces

The PTP 670 Ethernet ports conform to the specifications listed in Table 71.

Table 65 PTP 670 Ethernet bridging specifications

Ethernet Bridging	Specification
Protocol	IEEE802.1; IEEE802.1p; IEEE802.3 compatible
QoS	PTP topology: Eight wireless interface priority queues based on these standards: IEEE 802.1p, IEEE 802.1Q, IEEE 802.1ah, IEEE 802.1ad, DSCP IPv4, DSCP IPv6, MPLS TC, DSCP in PPP Session Stage HCMP topology: Four wireless interface priority queues based on these standards: IEEE 802.1p, IEEE 802.1Q, IEEE 802.1ah, IEEE 802.1ad, DSCP IPv4, DSCP IPv6, MPLS TC, DSCP in PPP Session Stage
Interfaces	100BASE-TX, 1000BASE-T, 1000BASE-SX, 1000BASE-LX MDI/MDIX auto crossover supported
Max Ethernet frame size	PTP topology: 9600 bytes HCMP topology: 2000 bytes
Service classes for traffic	PTP topology: Eight classes HCMP topology: Four classes

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

Layer two control protocols

PTP 670 identifies layer two control protocols (L2CPs) from the Ethernet destination address or Ethertype of bridged frames. The QoS classification can be separately configured for these protocols.

Table 66 Destination address in layer two control protocols

Destination address	Protocol
01-80-c2-00-00-00 to 01-80-c2-00-00-0f	IEEE 802.1 bridge protocols
01-80-c2-00-00-20 to 01-80-c2-00-00-2f	IEEE 802.1 Multiple Registration Protocol (MRP)

01-80-c2-00-00-30 to 01-80-c2-00-00-3f	IEEE 802.1ag, Connectivity Fault Management (CFM)
01-19-a7-00-00-00 to 01-19-a7-00-00-ff	Ring Automatic Protection Switching (R-APS)
00-e0-2b-00-00-04	Ethernet Automatic Protection Switching (EAPS)

Table 67 Ethertype in layer two control protocols

Ethertype	Protocol
0x8863	PPP over Ethernet Discovery

Ethernet port allocation for PTP topology

Port allocation rules

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

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

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

Mapping of ports and services

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

Table 68 Combinations of services at one ODU in PTP topology

Service combination	Figure
Data + Local Management	Figure 52
Data + Local Management + Local Management	Figure 53
Data with In-Band Management	Figure 54
Data with In-Band Management + Local Management	Figure 55
Data with In-Band Management + Local Management + Local Management	Figure 56
Data + Out-of-Band Management	Figure 57

Service combination	Figure
Data + Out-of-Band Management + Local Management	Figure 58
Data with In-Band Management + Second Data	Figure 59
Data with In-Band Management + Second Data + Local Management	Figure 60
Data + Second Data with In-Band Management	Figure 61
Data + Second Data with In-Band Management + Local Management	Figure 62
Data + Second Data + Local Management	Figure 63

Figure 52 to Figure 63 illustrate the internal routing of Ethernet traffic in the twelve combinations of services listed in Table 68.

Figure 52 Ports and Services: Data + Local

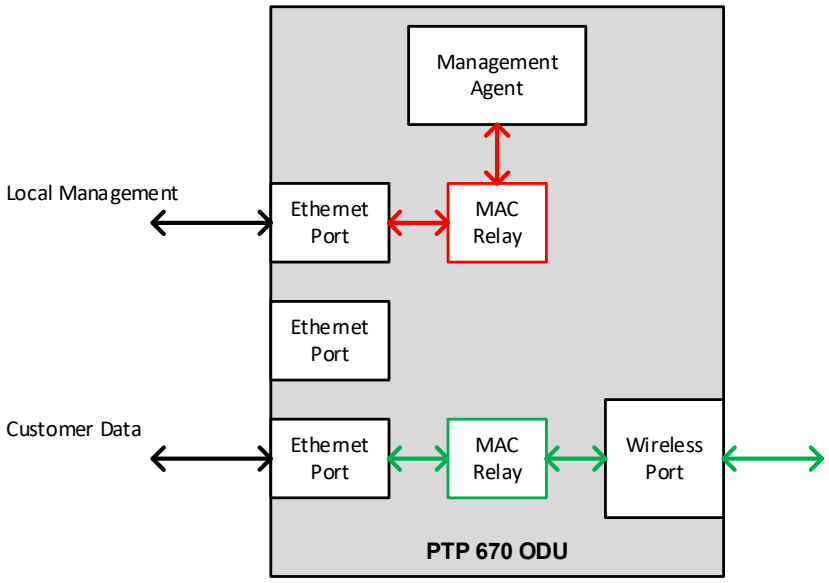


Figure 53 Ports and Services: Data + Local + Local

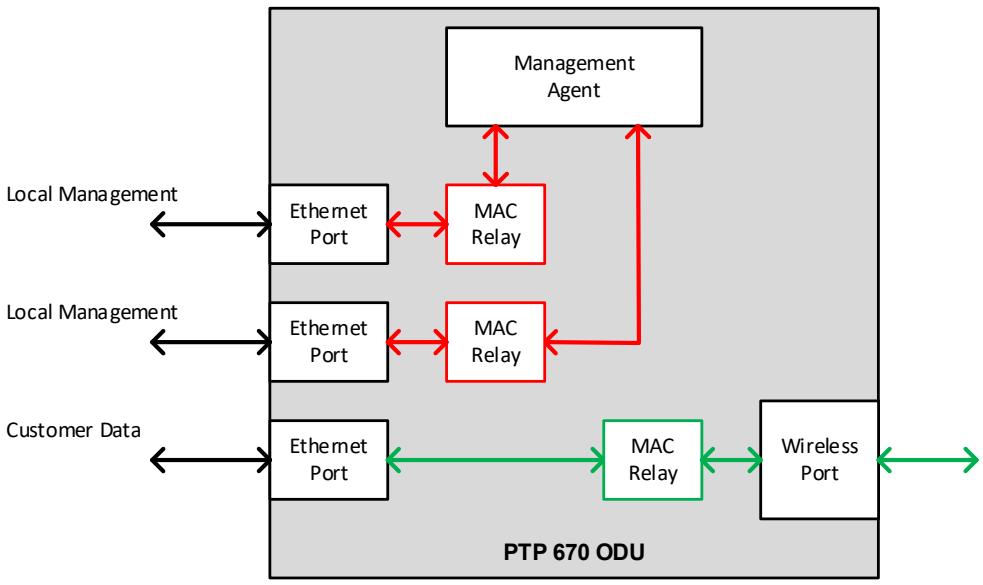


Figure 54 Ports and Services: Data/In-Band

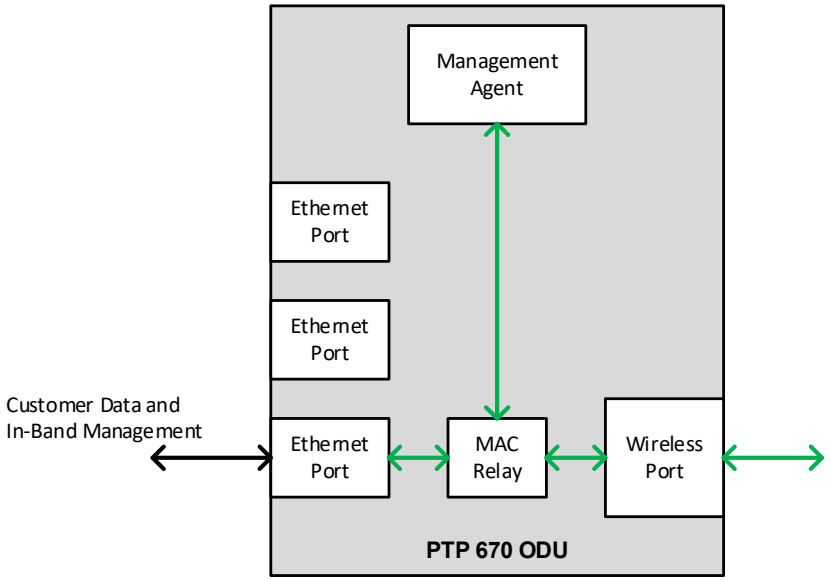


Figure 55 Ports and Services: Data/In-Band + Local

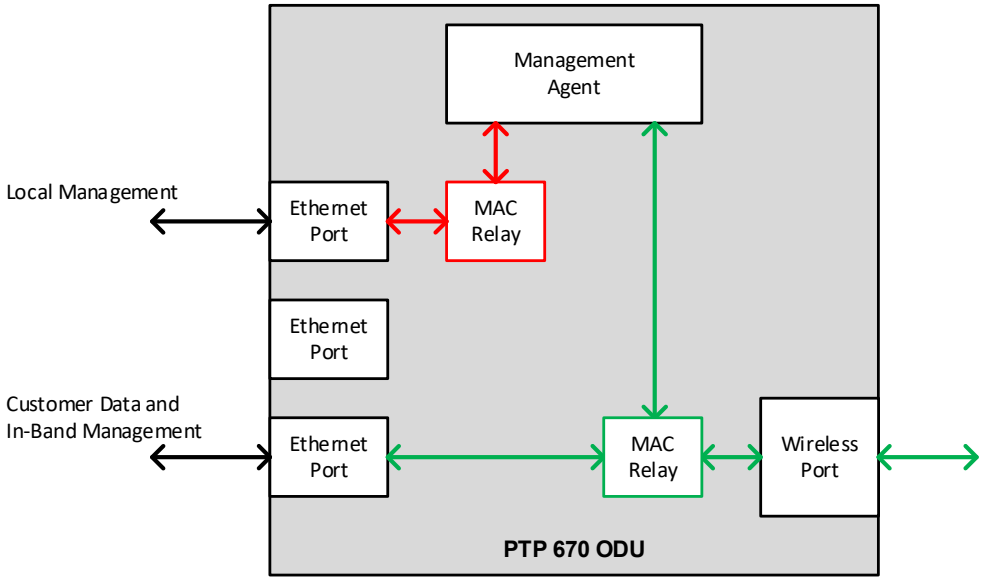


Figure 56 Ports and Services: Data/In-Band + Local + Local

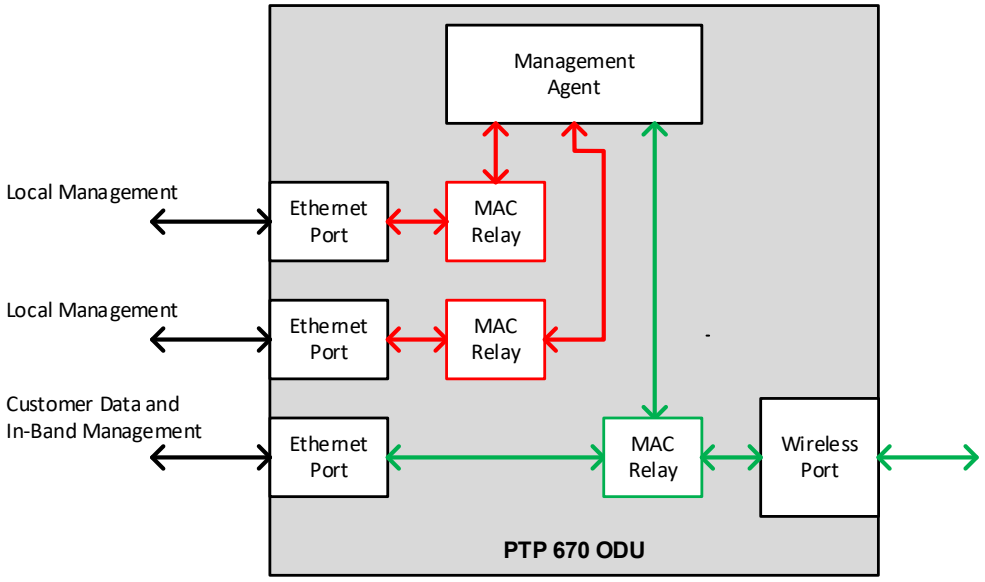


Figure 57 Ports and Services: Data + Out-Of-Band

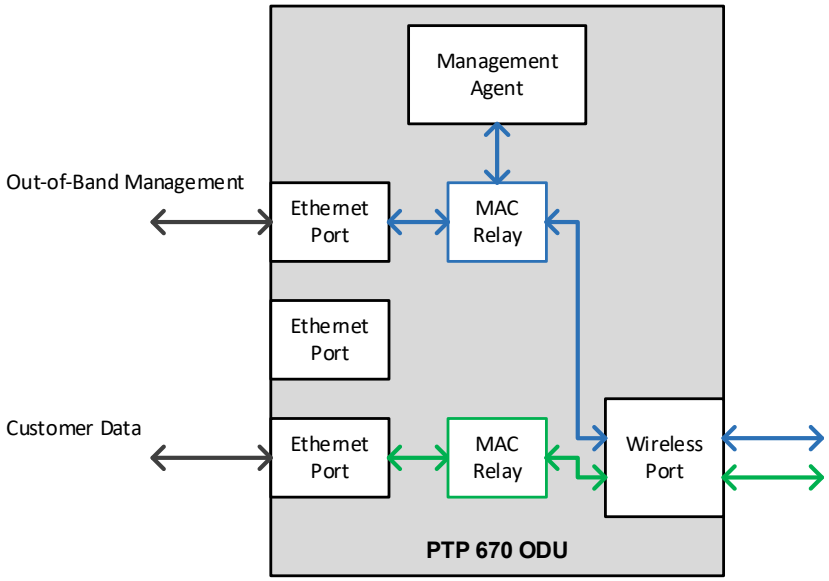


Figure 58 Ports and Services: Data + Out-Of-Band + Local

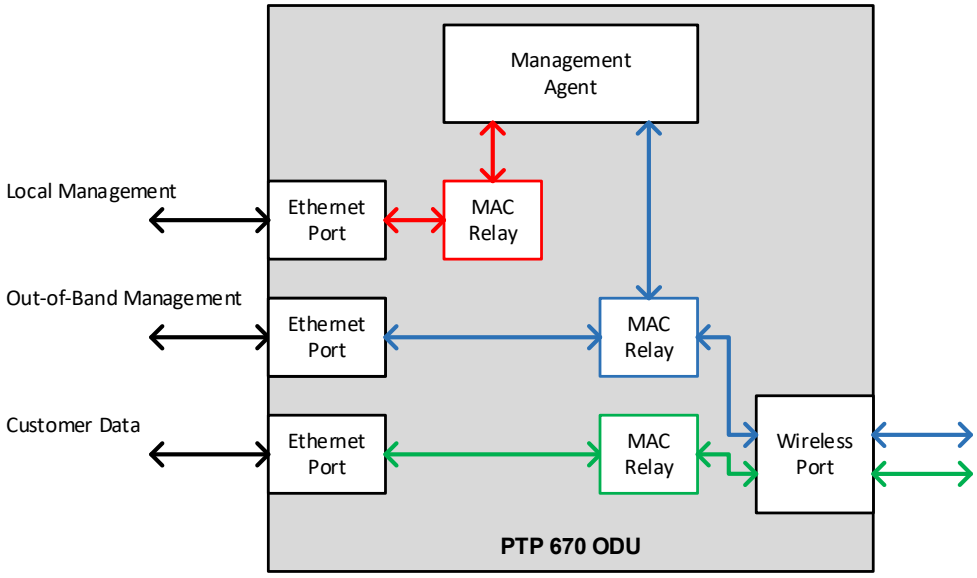


Figure 59 Ports and Services: Data/In-Band + Second Data

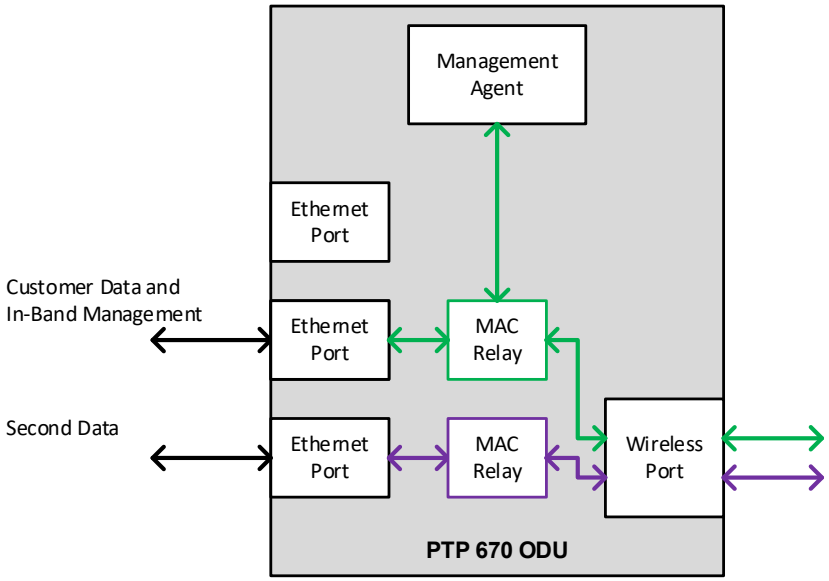


Figure 60 Ports and Services: Data/In-Band + Second Data + Local

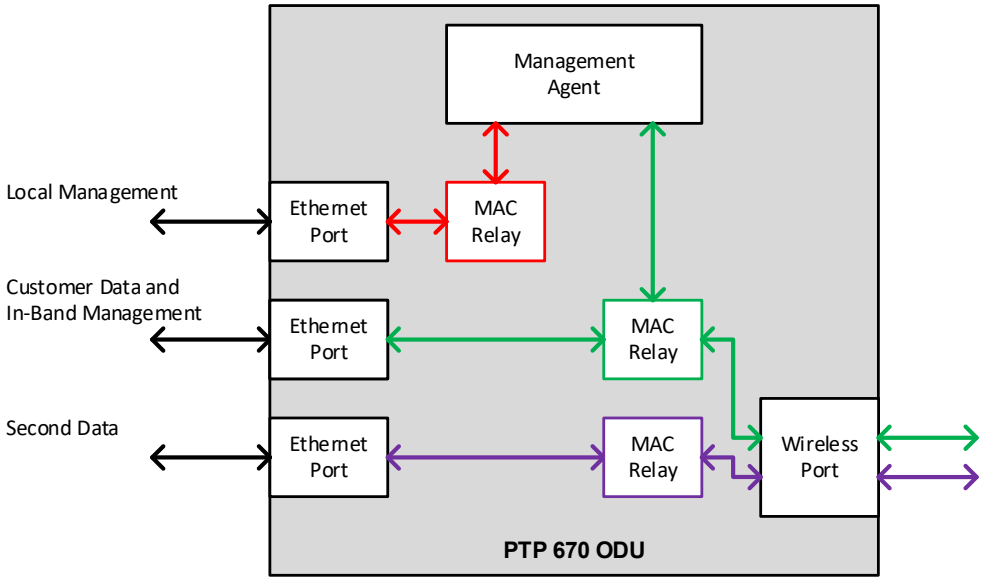


Figure 61 Ports and Services: Data + Second Data/In-Band

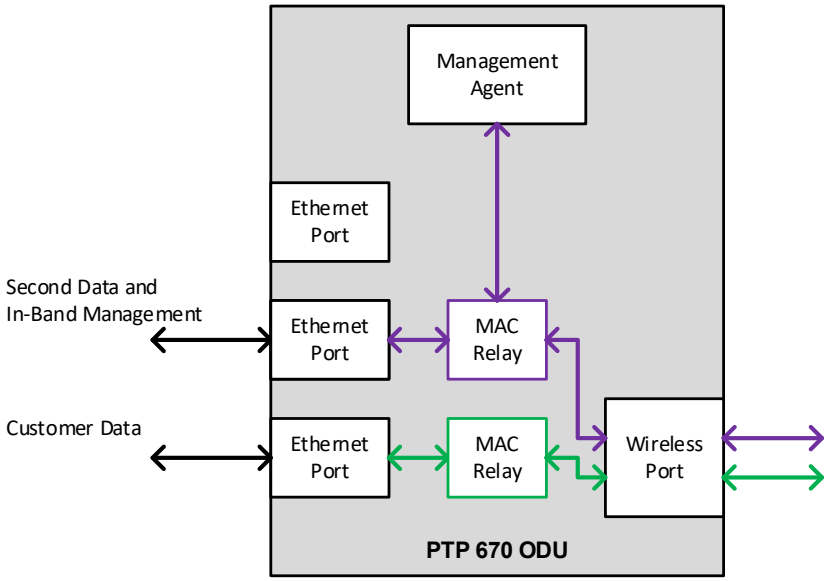


Figure 62 Ports and Services: Data + Second Data/In-Band + Local

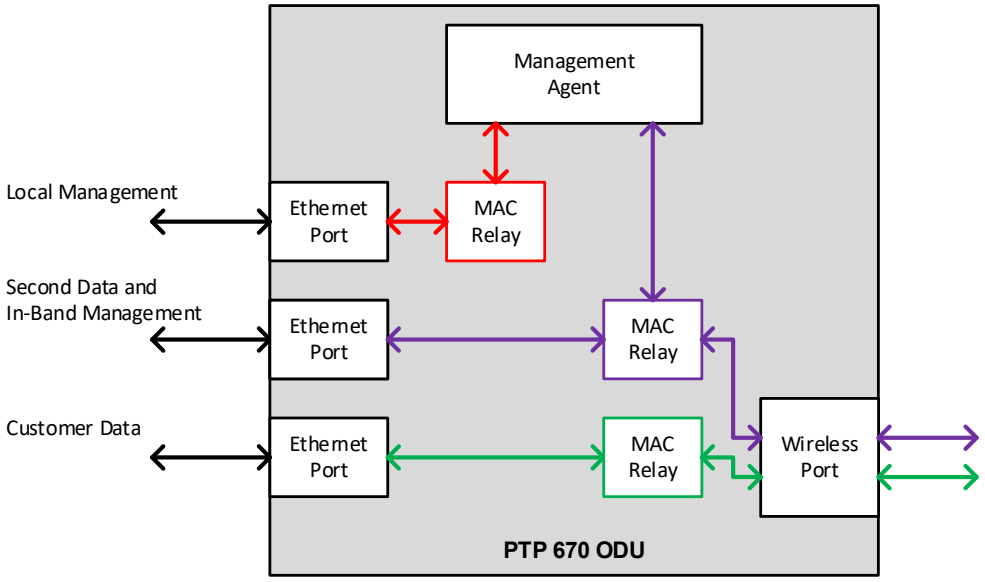
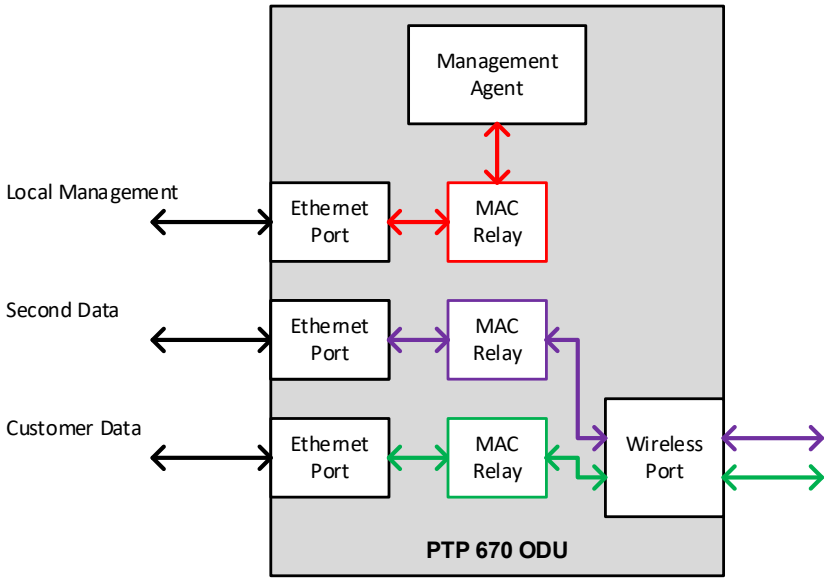


Figure 63 Ports and Services: Data + Second Data + Local



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

PTP 670 allows twelve different combinations of services at each ODU. Local Management can be used at one end or both ends of the link independently. Allowing for optional Local Management, the twelve combinations listed in Table 68 on page 3-37 reduce to a list of six combinations of Data, In-Band Management, Out-of-Band Management and Second Data as follows:

Table 69 Combinations of services with optional Local Management

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

Ensure that the same service combination from Table 69 is used at both ends of the link.

Warning

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

Mapping services to physical Ethernet ports

In general, the three physical Ethernet ports (Main PSU, Aux and SFP) are interchangeable. Allowing for the freedom to choose the physical Ethernet ports, the six combinations in Table 69 give rise to a much larger number of different permutations (actually 63 of them).

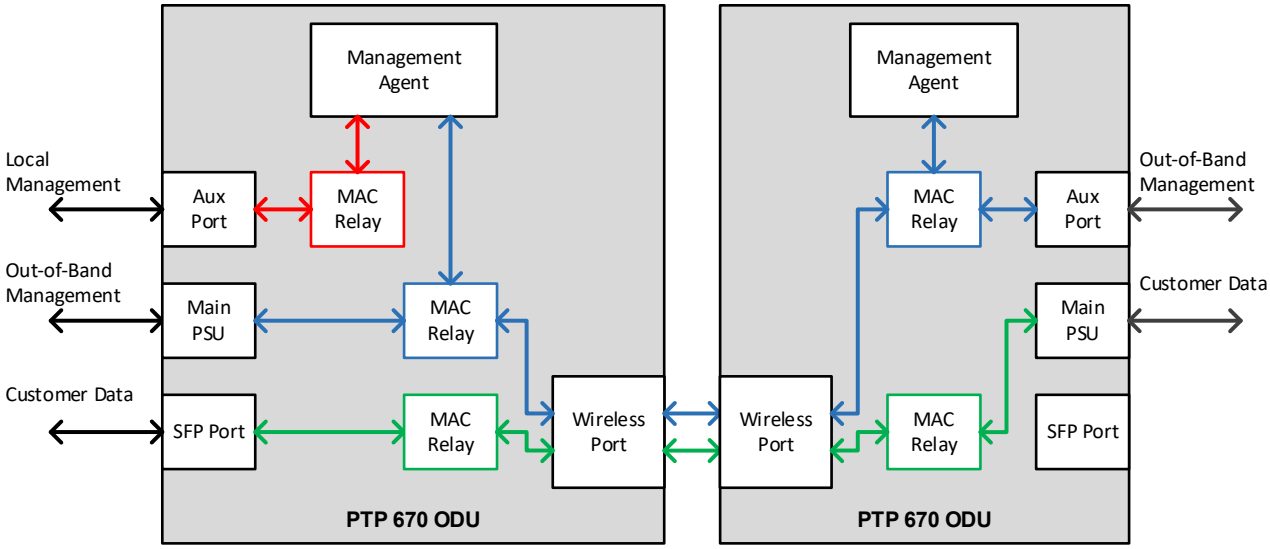
There is no objection to mapping the services to different physical ports at the two ends of the link, providing that the same row of Table 69 is used at each end.

For example, Figure 64 shows a link where the combination of services is from the third row of Table 69. Local Management is provided at one end only. The Management Service maps the Main PSU Port at one end and the Aux Port at the other end. The Data Service maps to the SFP Port at one end of the link and to the Main PSU Port at the other end of the link.

Note

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

Figure 64 Example of independent mapping of services to ports



Additional port allocation rules

The three Ethernet ports are generally interchangeable, except for some specific additional rules listed below:

- If the TDM interface (E1 or T1) is enabled, ensure that only the Main PSU port is allocated to **Data Service**
- If the system is to be used in a Synchronous Ethernet hierarchy, ensure that the upstream timing source is connected to the Main PSU or Fiber SFP ports (downstream devices can be connected to any port)
- If the system is operating as an IEEE 1588-2008 Transparent Clock, ensure the data path traverses only the Main PSU or Fiber SFP ports at both ends of the link.

Note

The Main PSU port is always used to supply power to the ODU, even when it is not allocated to a data or management service.

Note

The procedure for configuring these ports at the web interface is described in LAN Configuration page on page 6-43.

Note

Transparent Clock is not supported over the Aux Port and SFP port with Copper connectivity.

Ethernet port allocation for HCMP topology

Port allocation rules

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

- Map the **Data Service** to at least one of the available wired Ethernet ports.
- Map the **Management Service** to **In-Band**, or to any combination of the remaining unused Ethernet ports. If the Management Service is mapped to **In-Band**, it shares all of the ports selected for the Data Service. The Management Service can be disabled by mapping to **None**.
- Map the **Local Management Service** to any combination of the remaining unused Ethernet ports. The Local Management Service can be disabled by mapping to **None**.

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

Mapping of ports and services

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

Table 70 Combinations of services for one ODU in HCMP topology

Service combination			Figure
Port #1	**Port #2**	**Port #3**	
Data	Local Management		
Data	Local Management	Local Management	Figure 65
Data	Out-of-Band Management		
Data	Out-of-Band Management	Out-of-Band Management	Figure 66
Data	Out-of-Band Management	Local Management	Figure 67
Data	Data	Out-of-Band Management	Figure 68
Data	Data	Local Management	Figure 69
Data with In-Band			
Data with In-Band	Local Management		
Data with In-Band	Local Management	Local Management	Figure 70
Data with In-Band	Data with In-Band		
Data with In-Band	Data with In-Band	Local Management	Figure 71
Data with In-Band	Data with In-Band	Data with In-Band	Figure 72

Figure 65 to Figure 72 illustrate the internal routing of Ethernet traffic in eight three-port combinations of the services listed in Table 70.

Figure 65 Ports and Services: Data + Local + Local

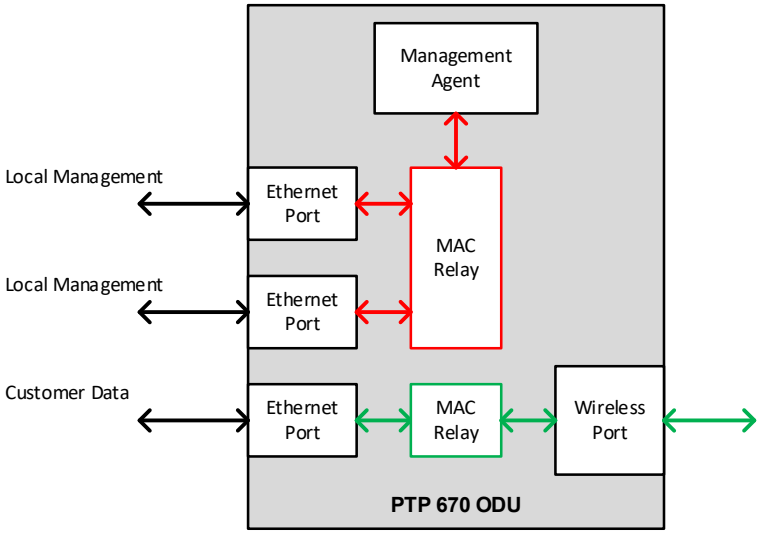


Figure 66 Ports and Services: Data + Out-of-Band + Out-of-Band

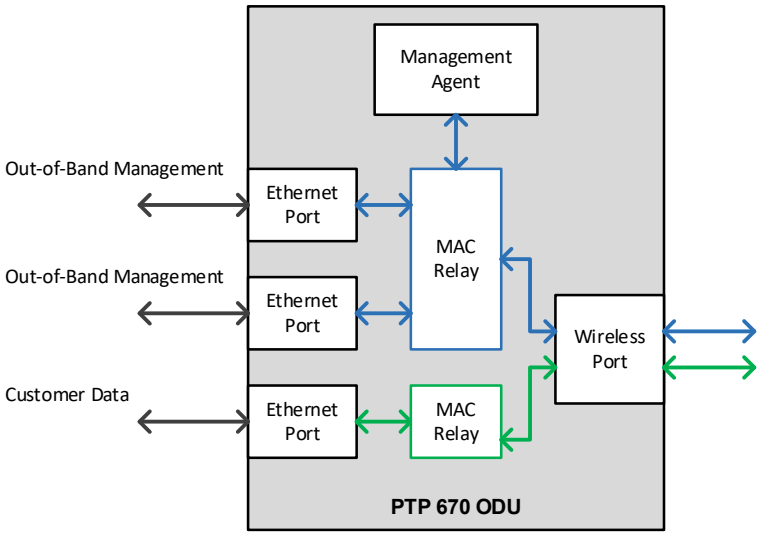


Figure 67 Ports and Services: Data + Out-of-Band + Local

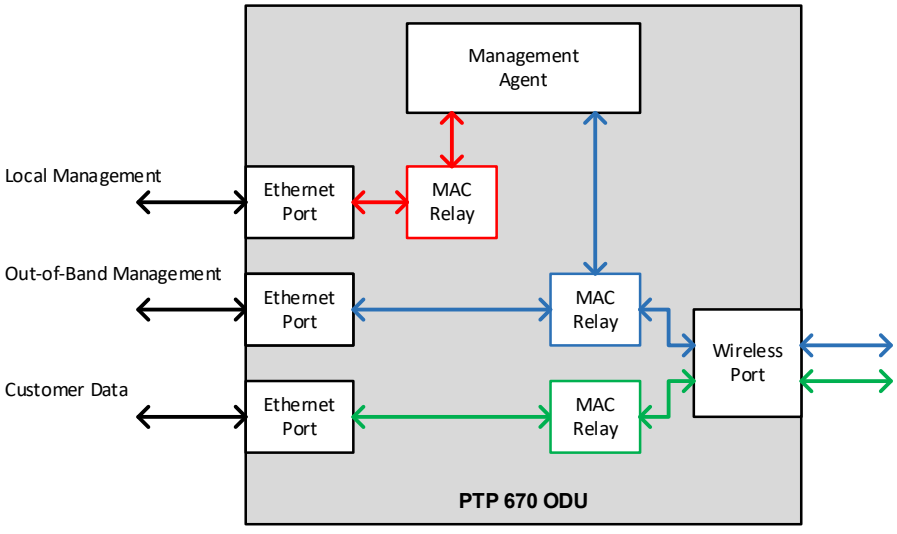


Figure 68 Ports and Services: Data + Data + Out-of-Band

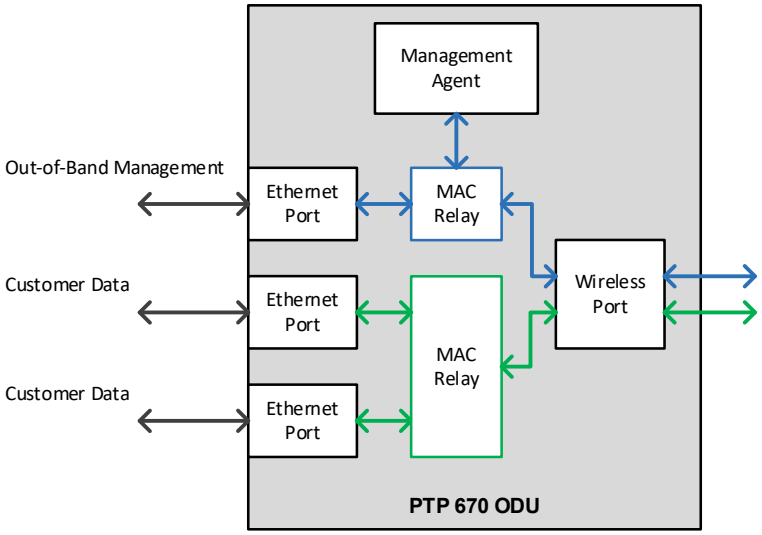


Figure 69 Ports and Services: Data + Data + Local

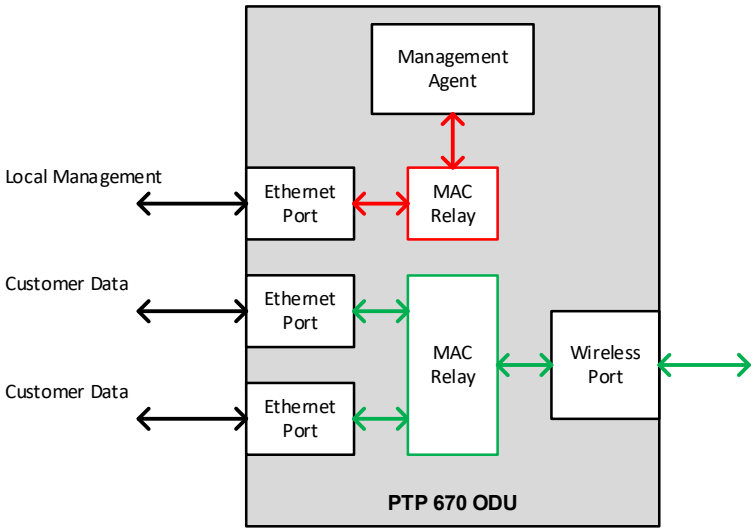


Figure 70 Ports and Services: Data/In-Band + Local + Local

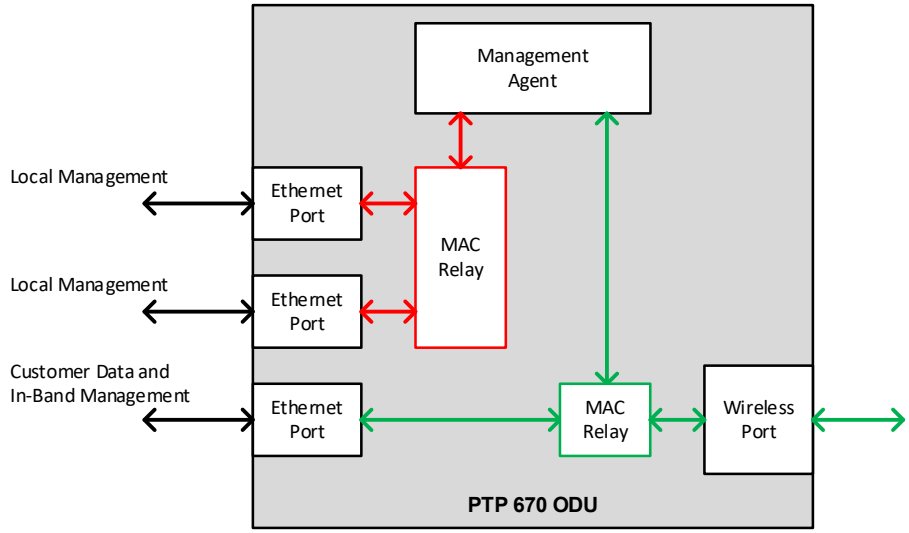


Figure 71 Ports and Services: Data/In-Band + Data/In-Band + Local

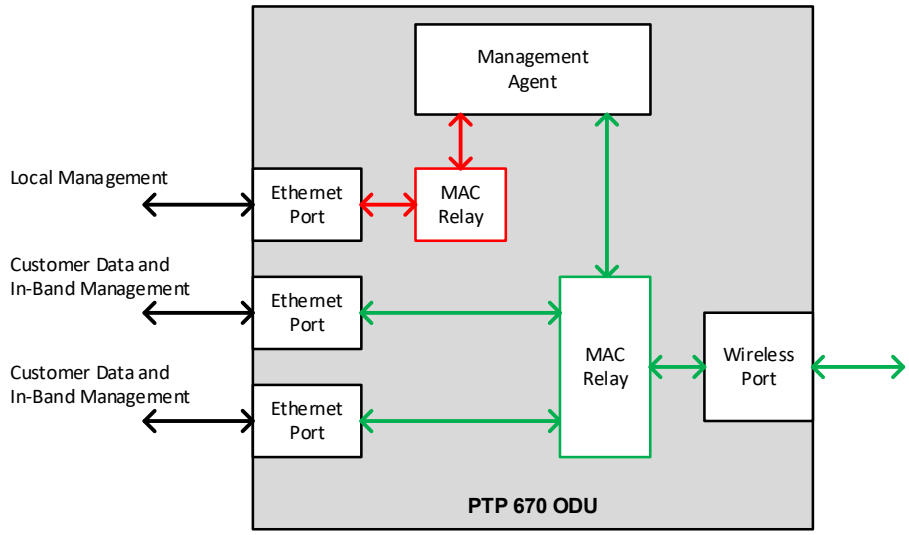
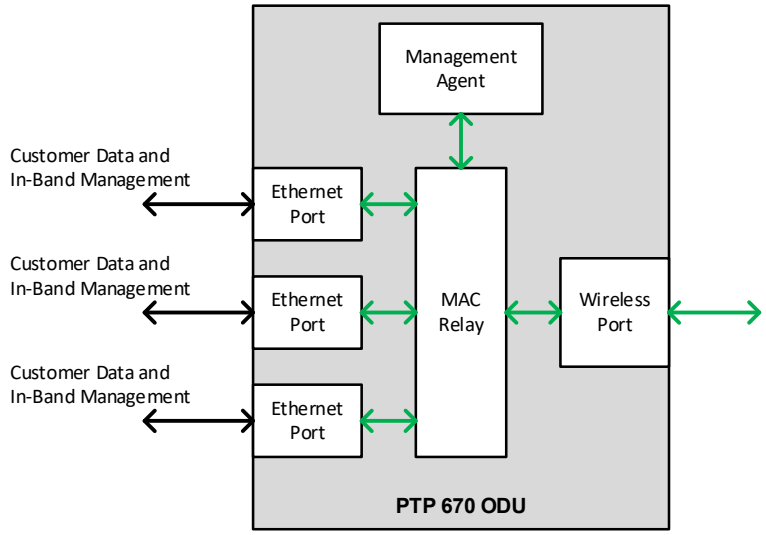


Figure 72 Ports and Services: Data/In-Band + Data/In-Band + Data/In-Band



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

PTP 670 supports flexible allocation of ports to services, and this allocation may be different at the two ends of the link. However, the management service configuration must be compatible between the two ends of the link. Ensure that both ends of the link are configured for In-Band management, or both ends are configured for Out-of-Band Management, or the management services is disabled at both ends.

Warning

Do not mix In-band and Out-of-Band management in the same link.

VLAN membership

Decide if the IP interface of the ODU management agent will be connected in a VLAN. If so, decide if this is a standard (IEEE 802.1Q) VLAN or provider bridged (IEEE 802.1ad) VLAN, and select the VLAN ID for this VLAN.

Use of a separate management VLAN is strongly recommended. Use of the management VLAN helps to ensure that the ODU management agent cannot be accessed by customers.

If the system is to operate as an IEEE 1588-2008 Transparent Clock, decide if residence time corrections should be made to:

- All 1588 event frames, regardless of VLAN membership, or
- Only 1588 event frames in a specific customer bridged VLAN, or
- Only 1588 event frames in a specific provider bridged VLAN

Priority for management traffic

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

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

IP interface

Select the IP version for the IP interface of the ODU management agent. PTP 670 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 670 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.

In the PTP topology, PTP 670 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.

In the HCMP topology the general arrangement is similar but the ODU provides four queues for traffic awaiting transmission in each of the wireless links.

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 670 queues.

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

IP/MPLS priority scheme

IP priority is determined by the DSCP value encoded in the ToS field in IPv4 and Traffic Class in IPv6. PTP 670 can locate the DSCP value in IP headers encapsulated within VLAN tags and/or PPP and PPPoE headers. The DSCP field provides 64 levels of priority. PTP 670 selects a suitable mapping from these DSCP values to the eight PTP 670 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 670 queues.

"Daisy-chaining" PTP 670 links

When connecting two or more PTP 670 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 670 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 2-30.
- 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 2-30.
- 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 2-36.

Green Ethernet switches

Do not connect PTP 670 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 670 PSU.

TDM network planning

This section describes factors to be considered when planning PTP 670 TDM networks.

Caution

If the ODU port has negotiated a link at 100BASE-T, the NIDU will not send or receive TDM data, and will not bridge customer data traffic. Ensure that the Ethernet drop cable between the ODU and the PSU, and the network cable between the PSU and the NIDU, will reliably support operation at 1000BASE-T.

Note

TDM operation is not supported in the HCMP topology.

The NIDU TDM ports conform to the specifications listed in Table 71.

Table 71 PTP 670 TDM interface specifications (if NIDU installed)

TDM Bridging	Specification
TDM ports	8 E1 or 8 T1 ITU-T Recommendation G.703 (10/1998) – Series G: "Transmission Systems and Media, Digital Systems and Networks; "Physical/electrical characteristics of hierarchical digital Interfaces".
Timing	ITU-T Recommendation G.823 (03/2000) – Series G: "Transmission Systems and Media, Digital Systems and Networks; The control of jitter and wander within digital networks which are based on the 2048 kbits/s hierarchy". ITU-T Recommendation G.824 (03/2000) – Series G: "Transmission Systems and Media, Digital Systems and Networks; The control of jitter and wander within digital networks which are based on the 1544 kbit/s hierarchy".
Ethernet	IEEE 802.3 2012 – IEEE Standard for Information technology – Telecommunications and information – exchange between systems – Local and metropolitan area networks – Specific requirements.
Line coding	AMI, B8ZS/HDB3
Line resistance	100 / 120 Ohm
E1/T1 latency (one way)	Typically 1 to 3 ms depending on range, bandwidth, modulation mode and number of E1/T1 port. Use LINKPlanner to calculate E1/T1 latency.

Network management planning

This section describes how to plan for PTP 670 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 670 Series proprietary MIB

Note

The proprietary MIBs are provided in the PTP 670 Series software download files in the support website (see Contacting Cambium Networks on page 1).

Supported diagnostic alarms

PTP 670 supports the diagnostic alarms listed in Table 207.

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 670 links to operate in secure mode.

Planning for SNTP operation

Note

PTP 670 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.

Using the Security Wizard

Basic wireless encryption can be configured without using the Security Wizard, by using only the System Configuration page and optionally the Authorization Control page. For other security features, use the Security Wizard.

Plan to use the Security Wizard for the following:

- To install optional user-supplied device certificates for TLS-RSA. User-supplied device certificates provide enhanced security for TLS-RSA.
- To configure the Key of Keys. The Key of Keys is used to encrypt non-volatile Critical Security Parameters for storage in the ODU. The Key of Keys is erased by the Zeroize CSPs action, meaning that stored CSPs cannot later be accessed, even by an attacker with internal access to the ODU memory.
- To configure Entropy. Entropy is an externally-generated random number used as a seed in many of the cryptographic methods implemented within the ODU. Generate Entropy in an approved random number generator and install in the ODU to enhance security in wireless encryption and HTTPS/TLS.
- To configure an optional banner providing warnings and notices to be read by the user before logging in to the ODU.

Table 72 Security Wizard attributes

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.
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.
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.

Planning for wireless encryption

AES license

Ensure that both ODUs have an AES license that allows the required key size for wireless encryption. The 128-bit AES license allows 128-bit encryption. The 256-bit AES license allows 128-bit and 256-bit encryption.

TLS-RSA can be used without an AES license, but this option supports only authentication and authorization, but not encryption.

Encryption algorithms

Select one of the three supported Encryption Algorithms:

- TLS-RSA
- TLS-PSK 128-bit
- TLS-PSK 256-bit

Configure the same algorithm at both ends of the link.

TLS-RSA provides authentication and authorization in any ODU. This option additionally provides encryption if both ODUs have an AES license.

TLS-PSK 128-bit provides authentication, authorization and encryption using a 128-bit pre-shared key. TLS-PSK 128-bit requires the 128-bit or 256-bit AES license.

TLS-PSK 256-bit provides authentication, authorization and encryption using a 256-bit pre-shared key. TLS-PSK 256-bit requires the 256-bit AES license.

TLS-RSA

Determine TLS Minimum Security Level. This is the smallest key size that will be allowed in a link between Master and Slave. For example, if the Master has TLS Minimum Security Level of 128-bit AES and the Slave has no AES license then the link cannot be established.

In a network where all links must be encrypted, set TLS Minimum Security Level to TLS RSA 128-bit or TLS RSA 256-bit to prevent inadvertent connection of unencrypted links.

Select Factory-installed or User-supplied device certificates. Factory-installed certificates are convenient because they can be used without needing to generate any additional cryptographic material. Generate and install User-supplied certificates where the additional security of 2048-bit key size is required, or where there is an operational requirement to be able to zeroize the certificates in the event that the ODU may be compromised.

For Group Access, select Whitelist or Blacklist operation. The selection of Whitelist and Blacklist is independent of the selection of Factory or User-provided certificates.

Note

The default combination of Blacklist and Factory certificates offers limited benefits in a deployed network, because the system will authorize any genuine PTP 670 ODU. Use the Whitelist and/or User-supplied certificates to ensure that access is allowed only for trusted ODUs.

A disadvantage of TLS-RSA is that the Whitelist must be updated if new hardware is introduced to the network. This may require access to both ends of the link. Consider using TLS-PSK if it is important to replace hardware without needing access to both ends of the link.

TLS-RSA is not available if Access Method is configured for Link Name Access.

Install User-supplied device certificates using the Security Wizard.

Table 73 User-supplied device certificates for wireless encryption

Item	Description	Quntity required
Device Private Key and Public Certificates	An RSA private key of size 2048 bits, generated in either PKCS#1 or PKCS#5 format, unencrypted, and encoded in the ASN.1 DER format. An X.509 certificate containing a 2048-bit RSA public key, signed using SHA-256, generated in either PKCS#1 or PKCS#5 format, unencrypted, and encoded in the ASN.1 DER format. The public key certificate must have Common Name equal to the MAC address of the ODU as a string of 12 hexadecimal characters without punctuation. The public key certificate must form a valid pair with the private key.	Two pairs per link. These items are unique to the MAC address.

Item	Description	Quntity required
Root CA Public Certificate	The self-signed public key certificate for the Root CA that signed the Device Certificate in the remote ODU. The Root CA must form a certificate chain with the Device Certificate without intermediate certificates.	Normally one per network.

TLS-PSK

Select the key size for the pre-shared key. This must be supported by AES licenses at each end of the link.

TLS-PSK can be used with Access Method of Link Access, Link Name Access and Group Access.

Ensure that the following cryptographic material is available.

Table 74 Pre-shared Key for wireless encryption

Item	Description	Quntity required
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.

Planning for HTTPS/TLS operation

Before starting to configure HTTPS/TLS operation, ensure that the cryptographic material listed in Table 75 is available.

Table 75 HTTPS/TLS security material

Item	Description	Quantity required
TLS Private Key and Public Certificates	An RSA private key of size 2048 bits, generated in either PKCS#1 or PKCS#5 format, unencrypted, and encoded in the ASN.1 DER format. An X.509 certificate containing a 2048-bit RSA public key, signed using SHA-256, generated in either PKCS#1 or PKCS#5 format, unencrypted, and encoded in the ASN.1 DER format. The public key certificate must have Common Name equal to the IPv4 or IPv6 address of the ODU. The public key certificate must form a valid pair with the private key.	Two pairs per link. These items are unique to IP address.

Planning for protocols and ports

Detemine the protocols that will be enabled at the Management Agent, and the port numbers to be used.

Table 76 Protocol and port settings

Item	Description	Quantity required
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 670 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 670 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 77.

Table 77 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 78.

Table 78 Default SNMPv3 users

Object	Entry 1
Name	initial
SecurityName	initial
AuthProtocol	usmHMACMD5AuthProtocol
PrivProtocol	usmDESPrivProtocol
StorageType	nonVolatile

Object	Entry 2	Entry 3
Name	templateMD5_DES	templateSHA_DES
SecurityName	templateMD5_DES	templateSHA_DES
AuthProtocol	usmHMACMD5AuthProtocol	usmHMACSAHAuthProtocol
PrivProtocol	usmDESPrivProtocol	usmDESPrivProtocol
StorageType	nonVolatile	nonVolatile

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

VACM default configuration

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

PTP 670 creates default view trees and access as shown in Table 79 and Table 80.

Table 79 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 80 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 670. 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 670 provides a choice of the following authentication methods:

- CHAP

- MS-CHAPv2

Ensure that the authentication method selected in PTP 670 is supported by the RADIUS server.

RADIUS attributes

If the standard RADIUS attribute session-timeout (Type 27) is present in a RADIUS response, PTP 670 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 670 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 670 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 670 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 670 selects the Read Only role.

The auth-role vendor-specific attribute is defined in Table 81.

Table 81 Definition of auth-role vendor-specific attribute

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

System threshold, output power and link loss

Use the following tables to look up the system threshold (dBm), output power (dBm) and maximum link loss (dB) per channel bandwidth and modulation mode:

Frequency Variant	Band	Mode	System threshold and output power (dBm)	Maximum link loss (dB)
4.8 GHz to 5.9 GHz	4.8 GHz	IP	Table 82	Table 83
		TDM	Table 84	Table 85
	4.9 GHz	IP	Table 86	Table 87
		TDM	Table 88	Table 89
	5.1 GHz and 5.2 GHz	IP	Table 90	Table 91
		TDM	Table 92	Table 93
	5.4 GHz	IP	Table 94	Table 95
		TDM	Table 96	Table 97
	5.8 GHz	IP	Table 98	Table 99
		TDM	Table 100	Table 101
4.9 GHz to 6.05 GHz	4.9 GHz	IP	Table 102	Table 103
		TDM	Table 104	Table 105
	5.1 GHz and 5.2 GHz	IP	Table 106	Table 107
		TDM	Table 108	Table 109
	5.4 GHz	IP	Table 110	Table 111
		TDM	Table 112	Table 113
	5.8 GHz	IP	Table 114	Table 115
		TDM	Table 116	Table 117
	5.9 GHz	IP	Table 118	Table 119
		TDM	Table 120	Table 121

Note

Maximum link loss has been calculated assuming use of the integrated antenna in PTP 670 Integrated ODUs. Adjust the maximum link loss for alternative antennas by adding (G – 23) for each antenna, where G is the antenna gain of the alternative antenna.

4.8 GHz to 5.9 GHz Frequency Variant

Table 82 4.8 GHz IP mode: system threshold per channel bandwidth and output power (dBm)

Modulation mode	5 MHz	10 MHz	15 MHz	20 MHz	30 MHz	40 MHz	45 MHz	P (all bands)
BPSK 0.63 single	-93.5	-92.0	-90.2	-89.0	-87.2	-86.0	-85.5	28
QPSK 0.63 single	-90.0	-88.5	-86.7	-85.5	-83.7	-82.5	-82.0	27
QPSK 0.87 single	-86.0	-84.5	-82.7	-81.5	-79.7	-78.5	-77.9	26
16QAM 0.63 single	-84.1	-82.6	-80.8	-79.5	-77.8	-76.5	-76.0	25
16QAM 0.63 dual	-81.0	-79.5	-77.8	-76.5	-74.8	-73.5	-73.0	25
16QAM 0.87 single	-79.4	-77.9	-76.1	-74.8	-73.1	-71.8	-71.3	24
16QAM 0.87 dual	-76.3	-74.8	-73.0	-71.8	-70.0	-68.8	-68.3	24
64QAM 0.75 single	-76.4	-74.9	-73.1	-71.9	-70.1	-68.9	-68.4	23
64QAM 0.75 dual	-73.3	-71.8	-70.0	-68.8	-67.0	-65.8	-65.3	23
64QAM 0.92 single	-72.6	-71.1	-69.4	-68.1	-66.3	-65.1	-64.6	23
64 QAM 0.92 dual	-69.4	-67.9	-66.1	-64.8	-63.1	-61.8	-61.3	23
256QAM 0.81 single	-69.4	-67.9	-66.1	-64.8	-63.1	-61.8	-61.3	23
256QAM 0.81 dual	-65.8	-64.3	-62.5	-61.3	-59.5	-58.3	-57.8	23

Table 83 4.8 GHz IP mode: maximum link loss per channel bandwidth (dB)

Modulation mode	5 MHz	10 MHz	15 MHz	20 MHz	30 MHz	40 MHz	45 MHz
BPSK 0.63 single	167.5	166.0	164.2	163.0	161.2	160.0	159.5
QPSK 0.63 single	163.0	161.5	159.7	158.5	156.7	155.5	155.0
QPSK 0.87 single	158.0	156.5	154.7	153.5	151.7	150.5	149.9
16QAM 0.63 single	155.1	153.6	151.8	150.5	148.8	147.5	147.0
16QAM 0.63 dual	150.6	149.0	147.3	146.0	144.3	143.0	142.5
16QAM 0.87 single	149.4	147.9	146.1	144.8	143.1	141.8	141.3
16QAM 0.87 dual	146.3	144.8	143.0	141.8	140.0	138.8	138.3
64QAM 0.75 single	145.4	143.9	142.1	140.9	139.1	137.9	137.4
64QAM 0.75 dual	142.3	140.8	139.0	137.8	136.0	134.8	134.3
64QAM 0.92 single	141.6	140.1	138.4	137.1	135.3	134.1	133.6
64 QAM 0.92 dual	138.4	136.9	135.1	133.8	132.1	130.8	130.3
256QAM 0.81 single	138.4	136.9	135.1	133.8	132.1	130.8	130.3
256QAM 0.81 dual	134.8	133.3	131.5	130.3	128.5	127.3	126.8

Table 84 4.8 GHz TDM mode: system threshold per channel bandwidth and output power (dBm)

Modulation mode	5 MHz	10 MHz	15 MHz	20 MHz	30 MHz	40 MHz	45 MHz	P (all bands)
BPSK 0.63 single	-93.5	-92.0	-90.2	-89.0	-87.2	-86.0	-85.5	26
QPSK 0.63 single	-87.0	-85.5	-83.7	-82.5	-80.7	-79.5	-79.0	25
QPSK 0.87 single	-83.0	-81.4	-79.7	-78.4	-76.7	-75.4	-74.9	24
16QAM 0.63 single	-81.0	-79.5	-77.7	-76.5	-74.7	-73.5	-73.0	23
16QAM 0.63 dual	-78.0	-76.5	-74.7	-73.4	-71.7	-70.4	-69.9	23
16QAM 0.87 single	-76.2	-74.7	-72.9	-71.7	-69.9	-68.7	-68.2	23
16QAM 0.87 dual	-73.1	-71.6	-69.8	-68.6	-66.8	-65.6	-65.0	23
64QAM 0.75 single	-73.1	-71.6	-69.8	-68.6	-66.8	-65.6	-65.1	23
64QAM 0.75 dual	-69.9	-68.4	-66.6	-65.3	-63.6	-62.3	-61.8	23
64QAM 0.92 single	-70.8	-69.3	-67.5	-66.3	-64.5	-63.3	-62.8	23
64 QAM 0.92 dual	-67.4	-65.9	-64.1	-62.9	-61.1	-59.9	-59.4	23
256QAM 0.81 single	-69.4	-67.9	-66.1	-64.8	-63.1	-61.8	-61.3	23
256QAM 0.81 dual	-65.8	-64.3	-62.5	-61.3	-59.5	-58.3	-57.8	23

Table 85 4.8 GHz TDM mode: maximum link loss per channel bandwidth (dB)

Modulation mode	5 MHz	10 MHz	15 MHz	20 MHz	30 MHz	40 MHz	45 MHz
BPSK 0.63 single	165.5	164.0	162.2	161.0	159.2	158.0	157.5
QPSK 0.63 single	158.0	156.5	154.7	153.5	151.7	150.5	150.0
QPSK 0.87 single	153.0	151.4	149.7	148.4	146.7	145.4	144.9
16QAM 0.63 single	150.0	148.5	146.7	145.5	143.7	142.5	142.0
16QAM 0.63 dual	145.5	144.0	142.2	141.0	139.2	137.9	137.4
16QAM 0.87 single	145.2	143.7	141.9	140.7	138.9	137.7	137.2
16QAM 0.87 dual	142.1	140.6	138.8	137.6	135.8	134.6	134.0
64QAM 0.75 single	142.1	140.6	138.8	137.6	135.8	134.6	134.1
64QAM 0.75 dual	138.9	137.4	135.6	134.3	132.6	131.3	130.8
64QAM 0.92 single	139.8	138.3	136.5	135.3	133.5	132.3	131.8
64 QAM 0.92 dual	136.4	134.9	133.1	131.9	130.1	128.9	128.4
256QAM 0.81 single	138.4	136.9	135.1	133.8	132.1	130.8	130.3
256QAM 0.81 dual	134.8	133.3	131.5	130.3	128.5	127.3	126.8

Table 86 4.9 GHz IP mode: system threshold per channel bandwidth and output power (P) (dBm)

Modulation mode	5 MHz	10 MHz	15 MHz	20 MHz	30 MHz	40 MHz	45 MHz	P (all bands)
BPSK 0.63 single	-93.6	-92.1	-90.3	-89.1	-87.3	-86.1	-85.6	28
QPSK 0.63 single	-90.1	-88.6	-86.8	-85.6	-83.8	-82.6	-82.1	27
QPSK 0.87 single	-86.1	-84.6	-82.8	-81.6	-79.8	-78.6	-78.0	26
16QAM 0.63 single	-84.2	-82.7	-80.9	-79.6	-77.9	-76.6	-76.1	25
16QAM 0.63 dual	-81.1	-79.6	-77.9	-76.6	-74.9	-73.6	-73.1	25
16QAM 0.87 single	-79.5	-78.0	-76.2	-74.9	-73.2	-71.9	-71.4	24
16QAM 0.87 dual	-76.4	-74.9	-73.1	-71.9	-70.1	-68.9	-68.4	24
64QAM 0.75 single	-76.5	-75.0	-73.2	-72.0	-70.2	-69.0	-68.5	23
64QAM 0.75 dual	-73.4	-71.9	-70.1	-68.9	-67.1	-65.9	-65.4	23
64QAM 0.92 single	-72.7	-71.2	-69.5	-68.2	-66.4	-65.2	-64.7	23
64 QAM 0.92 dual	-69.5	-68.0	-66.2	-64.9	-63.2	-61.9	-61.4	23
256QAM 0.81 single	-69.5	-68.0	-66.2	-64.9	-63.2	-61.9	-61.4	23
256QAM 0.81 dual	-65.9	-64.4	-62.6	-61.4	-59.6	-58.4	-57.9	23

Table 87 4.9 GHz IP mode: maximum link loss per channel bandwidth (dB)

Modulation mode	5 MHz	10 MHz	15 MHz	20 MHz	30 MHz	40 MHz	45 MHz
BPSK 0.63 single	167.6	166.1	164.3	163.1	161.3	160.1	159.6
QPSK 0.63 single	163.1	161.6	159.8	158.6	156.8	155.6	155.1
QPSK 0.87 single	158.1	156.6	154.8	153.6	151.8	150.6	150.0
16QAM 0.63 single	155.2	153.7	151.9	150.6	148.9	147.6	147.1
16QAM 0.63 dual	150.7	149.1	147.4	146.1	144.4	143.1	142.6
16QAM 0.87 single	149.5	148.0	146.2	144.9	143.2	141.9	141.4
16QAM 0.87 dual	146.4	144.9	143.1	141.9	140.1	138.9	138.4
64QAM 0.75 single	145.5	144.0	142.2	141.0	139.2	138.0	137.5
64QAM 0.75 dual	142.4	140.9	139.1	137.9	136.1	134.9	134.4
64QAM 0.92 single	141.7	140.2	138.5	137.2	135.4	134.2	133.7
64 QAM 0.92 dual	138.5	137.0	135.2	133.9	132.2	130.9	130.4
256QAM 0.81 single	138.5	137.0	135.2	133.9	132.2	130.9	130.4
256QAM 0.81 dual	134.9	133.4	131.6	130.4	128.6	127.4	126.9

Table 88 4.9 GHz TDM mode: system threshold per channel bandwidth and output power (dBm)

Modulation mode	5 MHz	10 MHz	15 MHz	20 MHz	30 MHz	40 MHz	45 MHz	P (all bands)
BPSK 0.63 single	-93.6	-92.1	-90.3	-89.1	-87.3	-86.1	-85.6	26
QPSK 0.63 single	-87.1	-85.6	-83.8	-82.6	-80.8	-79.6	-79.1	25
QPSK 0.87 single	-83.1	-81.5	-79.8	-78.5	-76.8	-75.5	-75.0	24
16QAM 0.63 single	-81.1	-79.6	-77.8	-76.6	-74.8	-73.6	-73.1	23
16QAM 0.63 dual	-78.1	-76.6	-74.8	-73.5	-71.8	-70.5	-70.0	23
16QAM 0.87 single	-76.3	-74.8	-73.0	-71.8	-70.0	-68.8	-68.3	23
16QAM 0.87 dual	-73.2	-71.7	-69.9	-68.7	-66.9	-65.7	-65.1	23
64QAM 0.75 single	-73.2	-71.7	-69.9	-68.7	-66.9	-65.7	-65.2	23
64QAM 0.75 dual	-70.0	-68.5	-66.7	-65.4	-63.7	-62.4	-61.9	23
64QAM 0.92 single	-70.9	-69.4	-67.6	-66.4	-64.6	-63.4	-62.9	23
64 QAM 0.92 dual	-67.5	-66.0	-64.2	-63.0	-61.2	-60.0	-59.5	23
256QAM 0.81 single	-69.5	-68.0	-66.2	-64.9	-63.2	-61.9	-61.4	23
256QAM 0.81 dual	-65.9	-64.4	-62.6	-61.4	-59.6	-58.4	-57.9	23

Table 89 4.9 GHz TDM mode: maximum link loss per channel bandwidth (dB)

Modulation mode	5 MHz	10 MHz	15 MHz	20 MHz	30 MHz	40 MHz	45 MHz
BPSK 0.63 single	165.6	164.1	162.3	161.1	159.3	158.1	157.6
QPSK 0.63 single	158.1	156.6	154.8	153.6	151.8	150.6	150.1
QPSK 0.87 single	153.1	151.5	149.8	148.5	146.8	145.5	145.0
16QAM 0.63 single	150.1	148.6	146.8	145.6	143.8	142.6	142.1
16QAM 0.63 dual	145.6	144.1	142.3	141.1	139.3	138.0	137.5
16QAM 0.87 single	145.3	143.8	142.0	140.8	139.0	137.8	137.3
16QAM 0.87 dual	142.2	140.7	138.9	137.7	135.9	134.7	134.1
64QAM 0.75 single	142.2	140.7	138.9	137.7	135.9	134.7	134.2
64QAM 0.75 dual	139.0	137.5	135.7	134.4	132.7	131.4	130.9
64QAM 0.92 single	139.9	138.4	136.6	135.4	133.6	132.4	131.9
64 QAM 0.92 dual	136.5	135.0	133.2	132.0	130.2	129.0	128.5
256QAM 0.81 single	138.5	137.0	135.2	133.9	132.2	130.9	130.4
256QAM 0.81 dual	134.9	133.4	131.6	130.4	128.6	127.4	126.9

Table 90 5.1/5.2 GHz IP mode: system threshold per channel bandwidth and output power (dBm)

Modulation mode	5 MHz	10 MHz	15 MHz	20 MHz	30 MHz	40 MHz	45 MHz	P (all bands)
BPSK 0.63 single	-93.6	-92.1	-90.3	-89.1	-87.3	-86.1	-85.6	28
QPSK 0.63 single	-90.1	-88.6	-86.8	-85.6	-83.8	-82.6	-82.1	27
QPSK 0.87 single	-86.1	-84.6	-82.8	-81.6	-79.8	-78.6	-78.0	26
16QAM 0.63 single	-84.2	-82.7	-80.9	-79.7	-77.9	-76.6	-76.1	25
16QAM 0.63 dual	-81.1	-79.6	-77.9	-76.6	-74.9	-73.6	-73.1	25
16QAM 0.87 single	-79.5	-78.0	-76.2	-75.0	-73.2	-72.0	-71.4	24
16QAM 0.87 dual	-76.4	-74.9	-73.2	-71.9	-70.1	-68.9	-68.4	24
64QAM 0.75 single	-76.6	-75.0	-73.3	-72.0	-70.3	-69.0	-68.5	23
64QAM 0.75 dual	-73.5	-71.9	-70.2	-68.9	-67.2	-65.9	-65.4	23
64QAM 0.92 single	-72.8	-71.3	-69.5	-68.3	-66.5	-65.3	-64.8	23
64 QAM 0.92 dual	-69.6	-68.1	-66.3	-65.1	-63.3	-62.1	-61.5	23
256QAM 0.81 single	-69.6	-68.1	-66.4	-65.1	-63.3	-62.1	-61.6	23
256QAM 0.81 dual	-66.2	-64.7	-62.9	-61.6	-59.9	-58.6	-58.1	23

Table 91 5.1/5.2 GHz IP mode: maximum link loss per channel bandwidth (dB)

Modulation mode	5 MHz	10 MHz	15 MHz	20 MHz	30 MHz	40 MHz	45 MHz
BPSK 0.63 single	167.6	166.1	164.3	163.1	161.3	160.1	159.6
QPSK 0.63 single	163.1	161.6	159.8	158.6	156.8	155.6	155.1
QPSK 0.87 single	158.1	156.6	154.8	153.6	151.8	150.6	150.0
16QAM 0.63 single	155.2	153.7	151.9	150.7	148.9	147.6	147.1
16QAM 0.63 dual	150.7	149.1	147.4	146.1	144.4	143.1	142.6
16QAM 0.87 single	149.5	148.0	146.2	145.0	143.2	142.0	141.4
16QAM 0.87 dual	146.4	144.9	143.2	141.9	140.1	138.9	138.4
64QAM 0.75 single	145.6	144.0	142.3	141.0	139.3	138.0	137.5
64QAM 0.75 dual	142.5	140.9	139.2	137.9	136.2	134.9	134.4
64QAM 0.92 single	141.8	140.3	138.5	137.3	135.5	134.3	133.8
64 QAM 0.92 dual	138.6	137.1	135.3	134.1	132.3	131.1	130.5
256QAM 0.81 single	138.6	137.1	135.4	134.1	132.3	131.1	130.6
256QAM 0.81 dual	135.2	133.7	131.9	130.6	128.9	127.6	127.1

Table 92 5.1/5.2 GHz TDM mode: system threshold per channel bandwidth and output power (dBm)

Modulation mode	5 MHz	10 MHz	15 MHz	20 MHz	30 MHz	40 MHz	45 MHz	P (all bands)
BPSK 0.63 single	-93.6	-92.1	-90.3	-89.1	-87.3	-86.1	-85.6	26
QPSK 0.63 single	-87.1	-85.6	-83.8	-82.6	-80.8	-79.6	-79.1	25
QPSK 0.87 single	-83.1	-81.6	-79.8	-78.5	-76.8	-75.5	-75.0	24
16QAM 0.63 single	-81.1	-79.6	-77.9	-76.6	-74.8	-73.6	-73.1	23
16QAM 0.63 dual	-78.1	-76.6	-74.8	-73.6	-71.8	-70.6	-70.0	23
16QAM 0.87 single	-76.3	-74.8	-73.1	-71.8	-70.1	-68.8	-68.3	23
16QAM 0.87 dual	-73.2	-71.7	-70.0	-68.7	-67.0	-65.7	-65.2	23
64QAM 0.75 single	-73.3	-71.8	-70.0	-68.7	-67.0	-65.7	-65.2	23
64QAM 0.75 dual	-70.1	-68.6	-66.8	-65.5	-63.8	-62.5	-62.0	23
64QAM 0.92 single	-71.0	-69.5	-67.8	-66.5	-64.7	-63.5	-63.0	23
64 QAM 0.92 dual	-67.7	-66.2	-64.4	-63.2	-61.4	-60.2	-59.6	23
256QAM 0.81 single	-69.6	-68.1	-66.4	-65.1	-63.3	-62.1	-61.6	23
256QAM 0.81 dual	-66.2	-64.7	-62.9	-61.6	-59.9	-58.6	-58.1	23

Table 93 5.1/5.2 GHz TDM mode: maximum link loss per channel bandwidth (dB)

Modulation mode	5 MHz	10 MHz	15 MHz	20 MHz	30 MHz	40 MHz	45 MHz
BPSK 0.63 single	165.6	164.1	162.3	161.1	159.3	158.1	157.6
QPSK 0.63 single	158.1	156.6	154.8	153.6	151.8	150.6	150.1
QPSK 0.87 single	153.1	151.6	149.8	148.5	146.8	145.5	145.0
16QAM 0.63 single	150.1	148.6	146.9	145.6	143.8	142.6	142.1
16QAM 0.63 dual	145.6	144.1	142.3	141.1	139.3	138.1	137.6
16QAM 0.87 single	145.3	143.8	142.1	140.8	139.1	137.8	137.3
16QAM 0.87 dual	142.2	140.7	139.0	137.7	136.0	134.7	134.2
64QAM 0.75 single	142.3	140.8	139.0	137.7	136.0	134.7	134.2
64QAM 0.75 dual	139.1	137.6	135.8	134.5	132.8	131.5	131.0
64QAM 0.92 single	140.0	138.5	136.8	135.5	133.7	132.5	132.0
64 QAM 0.92 dual	136.7	135.2	133.4	132.2	130.4	129.2	128.6
256QAM 0.81 single	138.6	137.1	135.4	134.1	132.3	131.1	130.6
256QAM 0.81 dual	135.2	133.7	131.9	130.6	128.9	127.6	127.1

Table 94 5.4 GHz IP mode: system threshold per channel bandwidth and output power (dBm)

Modulation mode	5 MHz	10 MHz	15 MHz	20 MHz	30 MHz	40 MHz	45 MHz	P (all bands)
BPSK 0.63 single	-93.6	-91.6	-89.8	-88.6	-86.8	-85.6	-85.1	28
QPSK 0.63 single	-90.1	-88.1	-86.3	-85.1	-83.3	-82.1	-81.6	27
QPSK 0.87 single	-86.1	-84.1	-82.3	-81.1	-79.3	-78.1	-77.5	26
16QAM 0.63 single	-84.2	-82.2	-80.4	-79.2	-77.4	-76.1	-75.6	25
16QAM 0.63 dual	-81.1	-79.1	-77.4	-76.1	-74.4	-73.1	-72.6	25
16QAM 0.87 single	-79.5	-77.5	-75.7	-74.5	-72.7	-71.5	-70.9	24
16QAM 0.87 dual	-76.4	-74.4	-72.7	-71.4	-69.6	-68.4	-67.9	24
64QAM 0.75 single	-76.6	-74.5	-72.8	-71.5	-69.8	-68.5	-68.0	23
64QAM 0.75 dual	-73.5	-71.4	-69.7	-68.4	-66.7	-65.4	-64.9	23
64QAM 0.92 single	-72.8	-70.8	-69.0	-67.8	-66.0	-64.8	-64.3	23
64 QAM 0.92 dual	-69.6	-67.6	-65.8	-64.6	-62.8	-61.6	-61.0	23
256QAM 0.81 single	-69.6	-67.6	-65.9	-64.6	-62.8	-61.6	-61.1	23
256QAM 0.81 dual	-66.2	-64.2	-62.4	-61.1	-59.4	-58.1	-57.6	23

Table 95 5.4 GHz IP mode: maximum link loss per channel bandwidth (dB)

Modulation mode	5 MHz	10 MHz	15 MHz	20 MHz	30 MHz	40 MHz	45 MHz
BPSK 0.63 single	167.6	165.6	163.8	162.6	160.8	159.6	159.1
QPSK 0.63 single	163.1	161.1	159.3	158.1	156.3	155.1	154.6
QPSK 0.87 single	158.1	156.1	154.3	153.1	151.3	150.1	149.5
16QAM 0.63 single	155.2	153.2	151.4	150.2	148.4	147.1	146.6
16QAM 0.63 dual	150.7	148.6	146.9	145.6	143.9	142.6	142.1
16QAM 0.87 single	149.5	147.5	145.7	144.5	142.7	141.5	140.9
16QAM 0.87 dual	146.4	144.4	142.7	141.4	139.6	138.4	137.9
64QAM 0.75 single	145.6	143.5	141.8	140.5	138.8	137.5	137.0
64QAM 0.75 dual	142.5	140.4	138.7	137.4	135.7	134.4	133.9
64QAM 0.92 single	141.8	139.8	138.0	136.8	135.0	133.8	133.3
64 QAM 0.92 dual	138.6	136.6	134.8	133.6	131.8	130.6	130.0
256QAM 0.81 single	138.6	136.6	134.9	133.6	131.8	130.6	130.1
256QAM 0.81 dual	135.2	133.2	131.4	130.1	128.4	127.1	126.6

Table 96 5.4 GHz TDM mode: system threshold per channel bandwidth and output power (dBm)

Modulation mode	5 MHz	10 MHz	15 MHz	20 MHz	30 MHz	40 MHz	45 MHz	P (all bands)
BPSK 0.63 single	-93.6	-91.6	-89.8	-88.6	-86.8	-85.6	-85.1	26
QPSK 0.63 single	-87.1	-85.1	-83.3	-82.1	-80.3	-79.1	-78.6	25
QPSK 0.87 single	-83.1	-81.1	-79.3	-78.0	-76.3	-75.0	-74.5	24
16QAM 0.63 single	-81.1	-79.1	-77.4	-76.1	-74.3	-73.1	-72.6	23
16QAM 0.63 dual	-78.1	-76.1	-74.3	-73.1	-71.3	-70.1	-69.5	23
16QAM 0.87 single	-76.3	-74.3	-72.6	-71.3	-69.6	-68.3	-67.8	23
16QAM 0.87 dual	-73.2	-71.2	-69.5	-68.2	-66.5	-65.2	-64.7	23
64QAM 0.75 single	-73.3	-71.3	-69.5	-68.2	-66.5	-65.2	-64.7	23
64QAM 0.75 dual	-70.1	-68.1	-66.3	-65.0	-63.3	-62.0	-61.5	23
64QAM 0.92 single	-71.0	-69.0	-67.3	-66.0	-64.2	-63.0	-62.5	23
64 QAM 0.92 dual	-67.7	-65.7	-63.9	-62.7	-60.9	-59.7	-59.1	23
256QAM 0.81 single	-69.6	-67.6	-65.9	-64.6	-62.8	-61.6	-61.1	23
256QAM 0.81 dual	-66.2	-64.2	-62.4	-61.1	-59.4	-58.1	-57.6	23

Table 97 5.4 GHz TDM mode: maximum link loss per channel bandwidth (dB)

Modulation mode	5 MHz	10 MHz	15 MHz	20 MHz	30 MHz	40 MHz	45 MHz
BPSK 0.63 single	165.6	163.6	161.8	160.6	158.8	157.6	157.1
QPSK 0.63 single	158.1	156.1	154.3	153.1	151.3	150.1	149.6
QPSK 0.87 single	153.1	151.1	149.3	148.0	146.3	145.0	144.5
16QAM 0.63 single	150.1	148.1	146.4	145.1	143.3	142.1	141.6
16QAM 0.63 dual	145.6	143.6	141.8	140.6	138.8	137.6	137.1
16QAM 0.87 single	145.3	143.3	141.6	140.3	138.6	137.3	136.8
16QAM 0.87 dual	142.2	140.2	138.5	137.2	135.5	134.2	133.7
64QAM 0.75 single	142.3	140.3	138.5	137.2	135.5	134.2	133.7
64QAM 0.75 dual	139.1	137.1	135.3	134.0	132.3	131.0	130.5
64QAM 0.92 single	140.0	138.0	136.3	135.0	133.2	132.0	131.5
64 QAM 0.92 dual	136.7	134.7	132.9	131.7	129.9	128.7	128.1
256QAM 0.81 single	138.6	136.6	134.9	133.6	131.8	130.6	130.1
256QAM 0.81 dual	135.2	133.2	131.4	130.1	128.4	127.1	126.6

Table 98 5.8 GHz IP mode: system threshold per channel bandwidth and output power (dBm)

Modulation mode	5 MHz	10 MHz	15 MHz	20 MHz	30 MHz	40 MHz	45 MHz	P (all bands)
BPSK 0.63 single	-93.1	-91.1	-89.3	-88.1	-86.3	-85.1	-84.6	28
QPSK 0.63 single	-89.6	-87.6	-85.8	-84.6	-82.8	-81.6	-81.1	27
QPSK 0.87 single	-85.6	-83.6	-81.8	-80.6	-78.8	-77.6	-77.0	26
16QAM 0.63 single	-83.7	-81.7	-79.9	-78.6	-76.9	-75.6	-75.1	25
16QAM 0.63 dual	-80.6	-78.6	-76.9	-75.6	-73.9	-72.6	-72.1	25
16QAM 0.87 single	-78.9	-76.9	-75.2	-73.9	-72.2	-70.9	-70.4	24
16QAM 0.87 dual	-75.9	-73.9	-72.1	-70.9	-69.1	-67.8	-67.3	24
64QAM 0.75 single	-76.0	-74.0	-72.2	-71.0	-69.2	-67.9	-67.4	23
64QAM 0.75 dual	-72.9	-70.8	-69.1	-67.8	-66.1	-64.8	-64.3	23
64QAM 0.92 single	-72.1	-70.1	-68.4	-67.1	-65.4	-64.1	-63.6	23
64 QAM 0.92 dual	-68.8	-66.8	-65.1	-63.8	-62.1	-60.8	-60.3	23
256QAM 0.81 single	-68.8	-66.8	-65.0	-63.7	-62.0	-60.7	-60.2	23
256QAM 0.81 dual	-65.1	-63.1	-61.3	-60.1	-58.3	-57.1	-56.6	23

Table 99 5.8 GHz IP mode: maximum link loss per channel bandwidth (dB)

Modulation mode	5 MHz	10 MHz	15 MHz	20 MHz	30 MHz	40 MHz	45 MHz
BPSK 0.63 single	167.1	165.1	163.3	162.1	160.3	159.1	158.6
QPSK 0.63 single	162.6	160.6	158.8	157.6	155.8	154.6	154.1
QPSK 0.87 single	157.6	155.6	153.8	152.6	150.8	149.6	149.0
16QAM 0.63 single	154.7	152.7	150.9	149.6	147.9	146.6	146.1
16QAM 0.63 dual	150.1	148.1	146.4	145.1	143.4	142.1	141.6
16QAM 0.87 single	148.9	146.9	145.2	143.9	142.2	140.9	140.4
16QAM 0.87 dual	145.9	143.9	142.1	140.9	139.1	137.8	137.3
64QAM 0.75 single	145.0	143.0	141.2	140.0	138.2	136.9	136.4
64QAM 0.75 dual	141.9	139.8	138.1	136.8	135.1	133.8	133.3
64QAM 0.92 single	141.1	139.1	137.4	136.1	134.4	133.1	132.6
64 QAM 0.92 dual	137.8	135.8	134.1	132.8	131.1	129.8	129.3
256QAM 0.81 single	137.8	135.8	134.0	132.7	131.0	129.7	129.2
256QAM 0.81 dual	134.1	132.1	130.3	129.1	127.3	126.1	125.6

Table 100 5.8 GHz TDM mode: system threshold per channel bandwidth and output power (dBm)

Modulation mode	5 MHz	10 MHz	15 MHz	20 MHz	30 MHz	40 MHz	45 MHz	P (all bands)
BPSK 0.63 single	-93.1	-91.1	-89.3	-88.1	-86.3	-85.1	-84.6	26
QPSK 0.63 single	-86.6	-84.6	-82.8	-81.6	-79.8	-78.6	-78.0	25
QPSK 0.87 single	-82.5	-80.5	-78.8	-77.5	-75.8	-74.5	-74.0	24
16QAM 0.63 single	-80.6	-78.6	-76.8	-75.6	-73.8	-72.6	-72.1	23
16QAM 0.63 dual	-77.6	-75.5	-73.8	-72.5	-70.8	-69.5	-69.0	23
16QAM 0.87 single	-75.8	-73.8	-72.0	-70.7	-69.0	-67.7	-67.2	23
16QAM 0.87 dual	-72.6	-70.6	-68.9	-67.6	-65.9	-64.6	-64.1	23
64QAM 0.75 single	-72.6	-70.6	-68.8	-67.6	-65.8	-64.6	-64.1	23
64QAM 0.75 dual	-69.3	-67.3	-65.6	-64.3	-62.6	-61.3	-60.8	23
64QAM 0.92 single	-70.3	-68.3	-66.5	-65.2	-63.5	-62.2	-61.7	23
64 QAM 0.92 dual	-66.8	-64.8	-63.0	-61.8	-60.0	-58.8	-58.3	23
256QAM 0.81 single	-68.8	-66.8	-65.0	-63.7	-62.0	-60.7	-60.2	23
256QAM 0.81 dual	-65.1	-63.1	-61.3	-60.1	-58.3	-57.1	-56.6	23

Table 101 5.8 GHz TDM mode: maximum link loss per channel bandwidth (dB)

Modulation mode	5 MHz	10 MHz	15 MHz	20 MHz	30 MHz	40 MHz	45 MHz
BPSK 0.63 single	165.1	163.1	161.3	160.1	158.3	157.1	156.6
QPSK 0.63 single	157.6	155.6	153.8	152.6	150.8	149.6	149.0
QPSK 0.87 single	152.5	150.5	148.8	147.5	145.8	144.5	144.0
16QAM 0.63 single	149.6	147.6	145.8	144.6	142.8	141.6	141.1
16QAM 0.63 dual	145.1	143.1	141.3	140.0	138.3	137.0	136.5
16QAM 0.87 single	144.8	142.8	141.0	139.7	138.0	136.7	136.2
16QAM 0.87 dual	141.6	139.6	137.9	136.6	134.9	133.6	133.1
64QAM 0.75 single	141.6	139.6	137.8	136.6	134.8	133.6	133.1
64QAM 0.75 dual	138.3	136.3	134.6	133.3	131.6	130.3	129.8
64QAM 0.92 single	139.3	137.3	135.5	134.2	132.5	131.2	130.7
64 QAM 0.92 dual	135.8	133.8	132.0	130.8	129.0	127.8	127.3
256QAM 0.81 single	137.8	135.8	134.0	132.7	131.0	129.7	129.2
256QAM 0.81 dual	134.1	132.1	130.3	129.1	127.3	126.1	125.6

4.9 GHz to 6.05 GHz Frequency Variant

Table 102 4.9 GHz IP mode: system threshold per channel bandwidth and output power (dBm)

Modulation mode	5 MHz	10 MHz	15 MHz	20 MHz	P (all bands)
BPSK 0.63 single	-96.6	-95.1	-93.3	-92.0	27
QPSK 0.63 single	-93.5	-92.0	-90.2	-88.9	26
QPSK 0.87 single	-89.4	-87.9	-86.2	-84.9	26
16QAM 0.63 single	-87.1	-85.6	-83.8	-82.6	25
16QAM 0.63 dual	-83.2	-81.7	-79.9	-78.7	25
16QAM 0.87 single	-82.6	-81.1	-79.4	-78.1	25
16QAM 0.87 dual	-79.6	-78.1	-76.3	-75.0	25
64QAM 0.75 single	-79.6	-78.1	-76.3	-75.1	24
64QAM 0.75 dual	-76.5	-75.0	-73.2	-71.9	24
64QAM 0.92 single	-75.7	-74.2	-72.4	-71.2	24
64QAM 0.92 dual	-72.4	-70.9	-69.2	-67.9	24
256QAM 0.81 single	-72.4	-70.9	-69.1	-67.9	23
256QAM 0.81 dual	-68.9	-67.3	-65.6	-64.3	23

Table 103 4.9 GHz IP mode: maximum link loss per channel bandwidth (dB)

Modulation mode	5 MHz	10 MHz	15 MHz	20 MHz
BPSK 0.63 single	169.6	168.1	166.3	165.0
QPSK 0.63 single	165.5	164.0	162.2	160.9
QPSK 0.87 single	161.4	159.9	158.2	156.9
16QAM 0.63 single	158.1	156.6	154.8	153.6
16QAM 0.63 dual	154.2	152.7	150.9	149.7
16QAM 0.87 single	153.6	152.1	150.4	149.1
16QAM 0.87 dual	150.6	149.1	147.3	146.0
64QAM 0.75 single	149.6	148.1	146.3	145.1
64QAM 0.75 dual	146.5	145.0	143.2	141.9
64QAM 0.92 single	145.7	144.2	142.4	141.2
64QAM 0.92 dual	142.4	140.9	139.2	137.9
256QAM 0.81 single	141.4	139.9	138.1	136.9
256QAM 0.81 dual	137.9	136.3	134.6	133.3

Table 104 4.9 GHz TDM mode: system threshold per channel bandwidth and output power (dBm)

Modulation mode	5 MHz	10 MHz	15 MHz	20 MHz	P (all bands)
BPSK 0.63 single	-96.6	-95.1	-93.3	-92.0	27
QPSK 0.63 single	-90.4	-88.9	-87.2	-85.9	26
QPSK 0.87 single	-86.4	-84.9	-83.1	-81.9	26
16QAM 0.63 single	-84.1	-82.6	-80.8	-79.5	25
16QAM 0.63 dual	-80.1	-78.6	-76.8	-75.6	25
16QAM 0.87 single	-79.5	-78.0	-76.2	-75.0	25
16QAM 0.87 dual	-76.4	-74.8	-73.1	-71.8	25
64QAM 0.75 single	-76.3	-74.8	-73.0	-71.7	24
64QAM 0.75 dual	-73.0	-71.5	-69.8	-68.5	24
64QAM 0.92 single	-73.9	-72.3	-70.6	-69.3	24
64QAM 0.92 dual	-70.5	-69.0	-67.2	-65.9	24
256QAM 0.81 single	-72.4	-70.9	-69.1	-67.9	23
256QAM 0.81 dual	-68.9	-67.3	-65.6	-64.3	23

Table 105 4.9 GHz TDM mode: maximum link loss per channel bandwidth (dB)

Modulation mode	5 MHz	10 MHz	15 MHz	20 MHz
BPSK 0.63 single	169.6	168.1	166.3	165.0
QPSK 0.63 single	162.4	160.9	159.2	157.9
QPSK 0.87 single	158.4	156.9	155.1	153.9
16QAM 0.63 single	155.1	153.6	151.8	150.5
16QAM 0.63 dual	151.1	149.6	147.8	146.6
16QAM 0.87 single	150.5	149.0	147.2	146.0
16QAM 0.87 dual	147.4	145.8	144.1	142.8
64QAM 0.75 single	146.3	144.8	143.0	141.7
64QAM 0.75 dual	143.0	141.5	139.8	138.5
64QAM 0.92 single	143.9	142.3	140.6	139.3
64QAM 0.92 dual	140.5	139.0	137.2	135.9
256QAM 0.81 single	141.4	139.9	138.1	136.9
256QAM 0.81 dual	137.9	136.3	134.6	133.3

Table 106 5.1/5.2 GHz IP mode: system threshold per channel bandwidth and output power (dBm)

Modulation mode	5 MHz	10 MHz	15 MHz	20 MHz	30 MHz	40 MHz	45 MHz	P (all bands)
BPSK 0.63 single	-95.8	-94.3	-92.5	-91.3	-89.5	-88.3	-87.8	27
QPSK 0.63 single	-92.7	-91.2	-89.4	-88.2	-86.4	-85.2	-84.7	26
QPSK 0.87 single	-88.7	-87.2	-85.4	-84.2	-82.4	-81.2	-80.7	26
16QAM 0.63 single	-86.4	-84.9	-83.1	-81.9	-80.1	-78.8	-78.3	25
16QAM 0.63 dual	-82.4	-80.9	-79.2	-77.9	-76.2	-74.9	-74.4	25
16QAM 0.87 single	-81.9	-80.4	-78.6	-77.4	-75.6	-74.4	-73.8	25
16QAM 0.87 dual	-78.8	-77.3	-75.6	-74.3	-72.6	-71.3	-70.8	25
64QAM 0.75 single	-78.9	-77.4	-75.6	-74.3	-72.6	-71.3	-70.8	24
64QAM 0.75 dual	-75.8	-74.3	-72.5	-71.2	-69.5	-68.2	-67.7	24
64QAM 0.92 single	-75.0	-73.5	-71.7	-70.5	-68.7	-67.5	-67.0	24
64 QAM 0.92 dual	-71.8	-70.3	-68.5	-67.3	-65.5	-64.3	-63.7	24
256QAM 0.81 single	-71.8	-70.3	-68.6	-67.3	-65.6	-64.3	-63.8	23
256QAM 0.81 dual	-68.4	-66.9	-65.1	-63.8	-62.1	-60.8	-60.3	23

Table 107 5.1 GHz and 5.2 GHz IP mode: maximum link loss per channel bandwidth (dB)

Modulation mode	5 MHz	10 MHz	15 MHz	20 MHz	30 MHz	40 MHz	45 MHz
BPSK 0.63 single	168.8	167.3	165.5	164.3	162.5	161.3	160.8
QPSK 0.63 single	164.7	163.2	161.4	160.2	158.4	157.2	156.7
QPSK 0.87 single	160.7	159.2	157.4	156.2	154.4	153.2	152.7
16QAM 0.63 single	157.4	155.9	154.1	152.9	151.1	149.8	149.3
16QAM 0.63 dual	153.4	151.9	150.2	148.9	147.2	145.9	145.4
16QAM 0.87 single	152.9	151.4	149.6	148.4	146.6	145.4	144.8
16QAM 0.87 dual	149.8	148.3	146.6	145.3	143.6	142.3	141.8
64QAM 0.75 single	148.9	147.4	145.6	144.3	142.6	141.3	140.8
64QAM 0.75 dual	145.8	144.3	142.5	141.2	139.5	138.2	137.7
64QAM 0.92 single	145.0	143.5	141.7	140.5	138.7	137.5	137.0
64 QAM 0.92 dual	141.8	140.3	138.5	137.3	135.5	134.3	133.7
256QAM 0.81 single	140.8	139.3	137.6	136.3	134.6	133.3	132.8
256QAM 0.81 dual	137.4	135.9	134.1	132.8	131.1	129.8	129.3

Table 108 5.1/5.2 GHz TDM mode: system threshold per channel bandwidth and output power (dBm)

Modulation mode	5 MHz	10 MHz	15 MHz	20 MHz	30 MHz	40 MHz	45 MHz	P (all bands)
BPSK 0.63 single	-95.8	-94.3	-92.5	-91.3	-89.5	-88.3	-87.8	27
QPSK 0.63 single	-89.7	-88.2	-86.4	-85.2	-83.4	-82.2	-81.7	26
QPSK 0.87 single	-85.7	-84.2	-82.4	-81.1	-79.4	-78.1	-77.6	26
16QAM 0.63 single	-83.3	-81.8	-80.1	-78.8	-77.0	-75.8	-75.3	25
16QAM 0.63 dual	-79.4	-77.8	-76.1	-74.8	-73.1	-71.8	-71.3	25
16QAM 0.87 single	-78.8	-77.2	-75.5	-74.2	-72.5	-71.2	-70.7	25
16QAM 0.87 dual	-75.7	-74.1	-72.4	-71.1	-69.4	-68.1	-67.6	25
64QAM 0.75 single	-75.6	-74.1	-72.3	-71.1	-69.3	-68.1	-67.5	24
64QAM 0.75 dual	-72.4	-70.9	-69.1	-67.9	-66.1	-64.9	-64.3	24
64QAM 0.92 single	-73.2	-71.7	-70.0	-68.7	-66.9	-65.7	-65.2	24
64 QAM 0.92 dual	-69.9	-68.4	-66.6	-65.4	-63.6	-62.4	-61.8	24
256QAM 0.81 single	-71.8	-70.3	-68.6	-67.3	-65.6	-64.3	-63.8	23
256QAM 0.81 dual	-68.4	-66.9	-65.1	-63.8	-62.1	-60.8	-60.3	23

Table 109 5.1 GHz and 5.2 GHz TDM mode: maximum link loss per channel bandwidth (dB)

Modulation mode	5 MHz	10 MHz	15 MHz	20 MHz	30 MHz	40 MHz	45 MHz
BPSK 0.63 single	168.8	167.3	165.5	164.3	162.5	161.3	160.8
QPSK 0.63 single	161.7	160.2	158.4	157.2	155.4	154.2	153.7
QPSK 0.87 single	157.7	156.2	154.4	153.1	151.4	150.1	149.6
16QAM 0.63 single	154.3	152.8	151.1	149.8	148.0	146.8	146.3
16QAM 0.63 dual	150.4	148.8	147.1	145.8	144.1	142.8	142.3
16QAM 0.87 single	149.8	148.2	146.5	145.2	143.5	142.2	141.7
16QAM 0.87 dual	146.7	145.1	143.4	142.1	140.4	139.1	138.6
64QAM 0.75 single	145.6	144.1	142.3	141.1	139.3	138.1	137.5
64QAM 0.75 dual	142.4	140.9	139.1	137.9	136.1	134.9	134.3
64QAM 0.92 single	143.2	141.7	140.0	138.7	136.9	135.7	135.2
64 QAM 0.92 dual	139.9	138.4	136.6	135.4	133.6	132.4	131.8
256QAM 0.81 single	140.8	139.3	137.6	136.3	134.6	133.3	132.8
256QAM 0.81 dual	137.4	135.9	134.1	132.8	131.1	129.8	129.3

Table 110 5.4 GHz IP mode: system threshold per channel bandwidth and output power (dBm)

Modulation mode	5 MHz	10 MHz	15 MHz	20 MHz	30 MHz	40 MHz	45 MHz	P (all bands)
BPSK 0.63 single	-96.6	-94.6	-92.8	-91.5	-89.8	-88.5	-88.0	27
QPSK 0.63 single	-93.5	-91.5	-89.7	-88.4	-86.7	-85.4	-84.9	26
QPSK 0.87 single	-89.4	-87.4	-85.7	-84.4	-82.7	-81.4	-80.9	26
16QAM 0.63 single	-87.1	-85.1	-83.4	-82.1	-80.3	-79.1	-78.6	25
16QAM 0.63 dual	-83.2	-81.2	-79.4	-78.2	-76.4	-75.2	-74.6	25
16QAM 0.87 single	-82.6	-80.6	-78.9	-77.6	-75.9	-74.6	-74.1	25
16QAM 0.87 dual	-79.6	-77.6	-75.8	-74.6	-72.8	-71.6	-71.0	25
64QAM 0.75 single	-79.6	-77.6	-75.8	-74.6	-72.8	-71.6	-71.1	24
64QAM 0.75 dual	-76.5	-74.5	-72.7	-71.5	-69.7	-68.5	-68.0	24
64QAM 0.92 single	-75.8	-73.8	-72.0	-70.7	-69.0	-67.7	-67.2	24
64 QAM 0.92 dual	-72.5	-70.5	-68.8	-67.5	-65.8	-64.5	-64.0	24
256QAM 0.81 single	-72.6	-70.6	-68.8	-67.6	-65.8	-64.6	-64.0	23
256QAM 0.81 dual	-69.1	-67.1	-65.3	-64.1	-62.3	-61.1	-60.6	23

Table 111 5.4 GHz IP mode: maximum link loss per channel bandwidth (dB)

Modulation mode	5 MHz	10 MHz	15 MHz	20 MHz	30 MHz	40 MHz	45 MHz
BPSK 0.63 single	169.6	167.6	165.8	164.5	162.8	161.5	161.0
QPSK 0.63 single	165.5	163.5	161.7	160.4	158.7	157.4	156.9
QPSK 0.87 single	161.4	159.4	157.7	156.4	154.7	153.4	152.9
16QAM 0.63 single	158.1	156.1	154.4	153.1	151.3	150.1	149.6
16QAM 0.63 dual	154.2	152.2	150.4	149.2	147.4	146.2	145.6
16QAM 0.87 single	153.6	151.6	149.9	148.6	146.9	145.6	145.1
16QAM 0.87 dual	150.6	148.6	146.8	145.6	143.8	142.6	142.0
64QAM 0.75 single	149.6	147.6	145.8	144.6	142.8	141.6	141.1
64QAM 0.75 dual	146.5	144.5	142.7	141.5	139.7	138.5	138.0
64QAM 0.92 single	145.8	143.8	142.0	140.7	139.0	137.7	137.2
64 QAM 0.92 dual	142.5	140.5	138.8	137.5	135.8	134.5	134.0
256QAM 0.81 single	141.6	139.6	137.8	136.6	134.8	133.6	133.0
256QAM 0.81 dual	138.1	136.1	134.3	133.1	131.3	130.1	129.6

Table 112 5.4 GHz TDM mode: system threshold per channel bandwidth and output power (dBm)

Modulation mode	5 MHz	10 MHz	15 MHz	20 MHz	30 MHz	40 MHz	45 MHz	P (all bands)
BPSK 0.63 single	-96.6	-94.6	-92.8	-91.5	-89.8	-88.5	-88.0	27
QPSK 0.63 single	-90.5	-88.4	-86.7	-85.4	-83.7	-82.4	-81.9	26
QPSK 0.87 single	-86.4	-84.4	-82.6	-81.4	-79.6	-78.4	-77.9	26
16QAM 0.63 single	-84.1	-82.1	-80.3	-79.1	-77.3	-76.0	-75.5	25
16QAM 0.63 dual	-80.1	-78.1	-76.3	-75.1	-73.3	-72.1	-71.6	25
16QAM 0.87 single	-79.5	-77.5	-75.7	-74.5	-72.7	-71.5	-71.0	25
16QAM 0.87 dual	-76.4	-74.4	-72.6	-71.4	-69.6	-68.4	-67.9	25
64QAM 0.75 single	-76.3	-74.3	-72.6	-71.3	-69.6	-68.3	-67.8	24
64QAM 0.75 dual	-73.1	-71.1	-69.4	-68.1	-66.4	-65.1	-64.6	24
64QAM 0.92 single	-74.0	-72.0	-70.2	-69.0	-67.2	-65.9	-65.4	24
64 QAM 0.92 dual	-70.6	-68.6	-66.9	-65.6	-63.9	-62.6	-62.1	24
256QAM 0.81 single	-72.6	-70.6	-68.8	-67.6	-65.8	-64.6	-64.0	23
256QAM 0.81 dual	-69.1	-67.1	-65.3	-64.1	-62.3	-61.1	-60.6	23

Table 113 5.4 GHz TDM mode: maximum link loss per channel bandwidth (dB)

Modulation mode	5 MHz	10 MHz	15 MHz	20 MHz	30 MHz	40 MHz	45 MHz
BPSK 0.63 single	169.6	167.6	165.8	164.5	162.8	161.5	161.0
QPSK 0.63 single	162.5	160.4	158.7	157.4	155.7	154.4	153.9
QPSK 0.87 single	158.4	156.4	154.6	153.4	151.6	150.4	149.9
16QAM 0.63 single	155.1	153.1	151.3	150.1	148.3	147.0	146.5
16QAM 0.63 dual	151.1	149.1	147.3	146.1	144.3	143.1	142.6
16QAM 0.87 single	150.5	148.5	146.7	145.5	143.7	142.5	142.0
16QAM 0.87 dual	147.4	145.4	143.6	142.4	140.6	139.4	138.9
64QAM 0.75 single	146.3	144.3	142.6	141.3	139.6	138.3	137.8
64QAM 0.75 dual	143.1	141.1	139.4	138.1	136.4	135.1	134.6
64QAM 0.92 single	144.0	142.0	140.2	139.0	137.2	135.9	135.4
64 QAM 0.92 dual	140.6	138.6	136.9	135.6	133.9	132.6	132.1
256QAM 0.81 single	141.6	139.6	137.8	136.6	134.8	133.6	133.0
256QAM 0.81 dual	138.1	136.1	134.3	133.1	131.3	130.1	129.6

Table 114 5.8 GHz IP mode: system threshold per channel bandwidth and output power (dBm)

Modulation mode	5 MHz	10 MHz	15 MHz	20 MHz	30 MHz	40 MHz	45 MHz	P (all bands)
BPSK 0.63 single	-96.8	-94.8	-93.0	-91.8	-90.0	-88.8	-88.3	27
QPSK 0.63 single	-93.7	-91.7	-89.9	-88.7	-86.9	-85.7	-85.2	26
QPSK 0.87 single	-89.7	-87.7	-85.9	-84.7	-82.9	-81.7	-81.1	26
16QAM 0.63 single	-87.4	-85.4	-83.6	-82.3	-80.6	-79.3	-78.8	25
16QAM 0.63 dual	-83.4	-81.4	-79.6	-78.4	-76.6	-75.4	-74.9	25
16QAM 0.87 single	-82.9	-80.8	-79.1	-77.8	-76.1	-74.8	-74.3	25
16QAM 0.87 dual	-79.8	-77.8	-76.0	-74.8	-73.0	-71.8	-71.2	25
64QAM 0.75 single	-79.8	-77.8	-76.0	-74.8	-73.0	-71.8	-71.2	24
64QAM 0.75 dual	-76.7	-74.7	-72.9	-71.6	-69.9	-68.6	-68.1	24
64QAM 0.92 single	-75.8	-73.8	-72.1	-70.8	-69.1	-67.8	-67.3	24
64 QAM 0.92 dual	-72.5	-70.5	-68.8	-67.5	-65.8	-64.5	-64.0	24
256QAM 0.81 single	-72.5	-70.5	-68.7	-67.4	-65.7	-64.4	-63.9	23
256QAM 0.81 dual	-68.8	-66.8	-65.0	-63.8	-62.0	-60.8	-60.3	23

Table 115 5.8 GHz IP mode: maximum link loss per channel bandwidth (dB)

Modulation mode	5 MHz	10 MHz	15 MHz	20 MHz	30 MHz	40 MHz	45 MHz
BPSK 0.63 single	169.8	167.8	166.0	164.8	163.0	161.8	161.3
QPSK 0.63 single	165.7	163.7	161.9	160.7	158.9	157.7	157.2
QPSK 0.87 single	161.7	159.7	157.9	156.7	154.9	153.7	153.1
16QAM 0.63 single	158.4	156.4	154.6	153.3	151.6	150.3	149.8
16QAM 0.63 dual	154.4	152.4	150.6	149.4	147.6	146.4	145.9
16QAM 0.87 single	153.9	151.8	150.1	148.8	147.1	145.8	145.3
16QAM 0.87 dual	150.8	148.8	147.0	145.8	144.0	142.8	142.2
64QAM 0.75 single	149.8	147.8	146.0	144.8	143.0	141.8	141.2
64QAM 0.75 dual	146.7	144.7	142.9	141.6	139.9	138.6	138.1
64QAM 0.92 single	145.8	143.8	142.1	140.8	139.1	137.8	137.3
64 QAM 0.92 dual	142.5	140.5	138.8	137.5	135.8	134.5	134.0
256QAM 0.81 single	141.5	139.5	137.7	136.4	134.7	133.4	132.9
256QAM 0.81 dual	137.8	135.8	134.0	132.8	131.0	129.8	129.3

Table 116 5.8 GHz TDM mode: system threshold per channel bandwidth and output power (dBm)

Modulation mode	5 MHz	10 MHz	15 MHz	20 MHz	30 MHz	40 MHz	45 MHz	P (all bands)
BPSK 0.63 single	-96.8	-94.8	-93.0	-91.8	-90.0	-88.8	-88.3	27
QPSK 0.63 single	-90.7	-88.7	-86.9	-85.7	-83.9	-82.7	-82.2	26
QPSK 0.87 single	-86.7	-84.6	-82.9	-81.6	-79.9	-78.6	-78.1	26
16QAM 0.63 single	-84.3	-82.3	-80.5	-79.3	-77.5	-76.3	-75.8	25
16QAM 0.63 dual	-80.3	-78.3	-76.5	-75.3	-73.5	-72.3	-71.8	25
16QAM 0.87 single	-79.7	-77.7	-75.9	-74.7	-72.9	-71.7	-71.1	25
16QAM 0.87 dual	-76.6	-74.5	-72.8	-71.5	-69.8	-68.5	-68.0	25
64QAM 0.75 single	-76.4	-74.4	-72.7	-71.4	-69.6	-68.4	-67.9	24
64QAM 0.75 dual	-73.2	-71.2	-69.4	-68.2	-66.4	-65.1	-64.6	24
64QAM 0.92 single	-74.0	-72.0	-70.2	-68.9	-67.2	-65.9	-65.4	24
64 QAM 0.92 dual	-70.5	-68.5	-66.7	-65.5	-63.7	-62.5	-62.0	24
256QAM 0.81 single	-72.5	-70.5	-68.7	-67.4	-65.7	-64.4	-63.9	23
256QAM 0.81 dual	-68.8	-66.8	-65.0	-63.8	-62.0	-60.8	-60.3	23

Table 117 5.8 GHz TDM mode: maximum link loss per channel bandwidth (dB)

Modulation mode	5 MHz	10 MHz	15 MHz	20 MHz	30 MHz	40 MHz	45 MHz
BPSK 0.63 single	169.8	167.8	166.0	164.8	163.0	161.8	161.3
QPSK 0.63 single	162.7	160.7	158.9	157.7	155.9	154.7	154.2
QPSK 0.87 single	158.7	156.6	154.9	153.6	151.9	150.6	150.1
16QAM 0.63 single	155.3	153.3	151.5	150.3	148.5	147.3	146.8
16QAM 0.63 dual	151.3	149.3	147.5	146.3	144.5	143.3	142.8
16QAM 0.87 single	150.7	148.7	146.9	145.7	143.9	142.7	142.1
16QAM 0.87 dual	147.6	145.5	143.8	142.5	140.8	139.5	139.0
64QAM 0.75 single	146.4	144.4	142.7	141.4	139.6	138.4	137.9
64QAM 0.75 dual	143.2	141.2	139.4	138.2	136.4	135.1	134.6
64QAM 0.92 single	144.0	142.0	140.2	138.9	137.2	135.9	135.4
64 QAM 0.92 dual	140.5	138.5	136.7	135.5	133.7	132.5	132.0
256QAM 0.81 single	141.5	139.5	137.7	136.4	134.7	133.4	132.9
256QAM 0.81 dual	137.8	135.8	134.0	132.8	131.0	129.8	129.3

Table 118 5.9 GHz IP mode: system threshold per channel bandwidth and output power (dBm)

Modulation mode	5 MHz	10 MHz	15 MHz	20 MHz	30 MHz	40 MHz	45 MHz	P (all bands)
BPSK 0.63 single	-95.8	-94.3	-92.5	-91.3	-89.5	-88.3	-87.8	27
QPSK 0.63 single	-92.7	-91.2	-89.4	-88.2	-86.4	-85.2	-84.7	26
QPSK 0.87 single	-88.7	-87.2	-85.4	-84.2	-82.4	-81.1	-80.6	26
16QAM 0.63 single	-86.3	-84.8	-83.1	-81.8	-80.1	-78.8	-78.3	25
16QAM 0.63 dual	-82.4	-80.9	-79.1	-77.9	-76.1	-74.9	-74.3	25
16QAM 0.87 single	-81.8	-80.3	-78.5	-77.3	-75.5	-74.3	-73.8	25
16QAM 0.87 dual	-78.7	-77.2	-75.5	-74.2	-72.4	-71.2	-70.7	25
64QAM 0.75 single	-78.7	-77.2	-75.4	-74.2	-72.4	-71.2	-70.7	24
64QAM 0.75 dual	-75.5	-74.0	-72.3	-71.0	-69.3	-68.0	-67.5	24
64QAM 0.92 single	-74.6	-73.1	-71.3	-70.1	-68.3	-67.1	-66.6	24
64 QAM 0.92 dual	-71.2	-69.7	-67.9	-66.7	-64.9	-63.7	-63.2	24
256QAM 0.81 single	-70.9	-69.4	-67.7	-66.4	-64.7	-63.4	-62.9	23
256QAM 0.81 dual	-67.0	-65.5	-63.7	-62.5	-60.7	-59.5	-58.9	23

Table 119 5.9 GHz IP mode: maximum link loss per channel bandwidth (dB)

Modulation mode	5 MHz	10 MHz	15 MHz	20 MHz	30 MHz	40 MHz	45 MHz
BPSK 0.63 single	168.8	167.3	165.5	164.3	162.5	161.3	160.8
QPSK 0.63 single	164.7	163.2	161.4	160.2	158.4	157.2	156.7
QPSK 0.87 single	160.7	159.2	157.4	156.2	154.4	153.1	152.6
16QAM 0.63 single	157.3	155.8	154.1	152.8	151.1	149.8	149.3
16QAM 0.63 dual	153.4	151.9	150.1	148.9	147.1	145.9	145.3
16QAM 0.87 single	152.8	151.3	149.5	148.3	146.5	145.3	144.8
16QAM 0.87 dual	149.7	148.2	146.5	145.2	143.4	142.2	141.7
64QAM 0.75 single	148.7	147.2	145.4	144.2	142.4	141.2	140.7
64QAM 0.75 dual	145.5	144.0	142.3	141.0	139.3	138.0	137.5
64QAM 0.92 single	144.6	143.1	141.3	140.1	138.3	137.1	136.6
64 QAM 0.92 dual	141.2	139.7	137.9	136.7	134.9	133.7	133.2
256QAM 0.81 single	139.9	138.4	136.7	135.4	133.7	132.4	131.9
256QAM 0.81 dual	136.0	134.5	132.7	131.5	129.7	128.5	127.9

Table 120 5.9 GHz TDM mode: system threshold per channel bandwidth and output power (dBm)

Modulation mode	5 MHz	10 MHz	15 MHz	20 MHz	30 MHz	40 MHz	45 MHz	P (all bands)
BPSK 0.63 single	-95.8	-94.3	-92.5	-91.3	-89.5	-88.3	-87.8	27
QPSK 0.63 single	-89.7	-88.2	-86.4	-85.2	-83.4	-82.2	-81.6	26
QPSK 0.87 single	-85.6	-84.1	-82.4	-81.1	-79.4	-78.1	-77.6	26
16QAM 0.63 single	-83.3	-81.8	-80.0	-78.8	-77.0	-75.7	-75.2	25
16QAM 0.63 dual	-79.3	-77.8	-76.0	-74.7	-73.0	-71.7	-71.2	25
16QAM 0.87 single	-78.6	-77.1	-75.3	-74.1	-72.3	-71.1	-70.5	25
16QAM 0.87 dual	-75.4	-73.9	-72.2	-70.9	-69.1	-67.9	-67.4	25
64QAM 0.75 single	-75.2	-73.7	-72.0	-70.7	-68.9	-67.7	-67.2	24
64QAM 0.75 dual	-71.9	-70.4	-68.6	-67.4	-65.6	-64.4	-63.8	24
64QAM 0.92 single	-72.6	-71.1	-69.3	-68.1	-66.3	-65.1	-64.6	24
64 QAM 0.92 dual	-69.0	-67.5	-65.7	-64.5	-62.7	-61.4	-60.9	24
256QAM 0.81 single	-70.9	-69.4	-67.7	-66.4	-64.7	-63.4	-62.9	23
256QAM 0.81 dual	-67.0	-65.5	-63.7	-62.5	-60.7	-59.5	-58.9	23

Table 121 5.9 GHz TDM mode: maximum link loss per channel bandwidth (dB)

Modulation mode	5 MHz	10 MHz	15 MHz	20 MHz	30 MHz	40 MHz	45 MHz
BPSK 0.63 single	168.8	167.3	165.5	164.3	162.5	161.3	160.8
QPSK 0.63 single	161.7	160.2	158.4	157.2	155.4	154.2	153.6
QPSK 0.87 single	157.6	156.1	154.4	153.1	151.4	150.1	149.6
16QAM 0.63 single	154.3	152.8	151.0	149.8	148.0	146.7	146.2
16QAM 0.63 dual	150.3	148.8	147.0	145.7	144.0	142.7	142.2
16QAM 0.87 single	149.6	148.1	146.3	145.1	143.3	142.1	141.5
16QAM 0.87 dual	146.4	144.9	143.2	141.9	140.1	138.9	138.4
64QAM 0.75 single	145.2	143.7	142.0	140.7	138.9	137.7	137.2
64QAM 0.75 dual	141.9	140.4	138.6	137.4	135.6	134.4	133.8
64QAM 0.92 single	142.6	141.1	139.3	138.1	136.3	135.1	134.6
64 QAM 0.92 dual	139.0	137.5	135.7	134.5	132.7	131.4	130.9
256QAM 0.81 single	139.9	138.4	136.7	135.4	133.7	132.4	131.9
256QAM 0.81 dual	136.0	134.5	132.7	131.5	129.7	128.5	127.9

Data throughput capacity tables

Data capacity in PTP topology

Use the following tables to look up the data throughput rates (Mbits/s) that are achieved when two PTP 670 ODUs are linked and the link distance (range) is 0 km:

Link symmetry	Link optimization	Table
1:1	IP	Table 122
	TDM	Table 123
2:1	IP	Table 124
	TDM	Table 125
3:1	IP	Table 126
5:1	IP	Table 127
Adaptive	IP	Table 128

Use the following range adjustment graphs to look up the link range and find the throughput factor that must be applied to adjust the 0 km data throughput rates:

Link symmetry	Link optimization	Bandwidth			
		45 MHz	40 MHz	30 MHz	20 MHz
1:1	IP	Figure 73	Figure 74	Figure 75	Figure 76
	TDM	Figure 80	Figure 81	Figure 82	Figure 83
2:1	IP	Figure 87	Figure 88	Figure 89	Figure 90
	TDM	Figure 93	Figure 94	Figure 95	Figure 96
3:1	IP	Figure 99	Figure 100	Figure 101	Figure 102
5:1	IP	Figure 105	Figure 106	Figure 107	-
Adaptive	IP	Figure 108	Figure 109	Figure 110	Figure 111

Link symmetry	Link optimization	Bandwidth		
		15 MHz	10 MHz	5 MHz
1:1	IP	Figure 77	Figure 78	Figure 79
	TDM	Figure 84	Figure 85	Figure 86
2:1	IP	Figure 91	Figure 92	-
	TDM	Figure 97	Figure 98	-
3:1	IP	Figure 103	Figure 104	-
5:1	IP	-	-	-
Adaptive	IP	Figure 112	Figure 113	-

Note

Throughput for link symmetry 5:1, 3:1 and 2:1 are the same as 1:5, 1:3, and 1:2; but the Tx and Rx data rates are interchanged.

Table 122 Throughput at zero link range (Mbit/s), symmetry 1:1, optimization IP

Modulation mode	45 MHz (Tx/Rx/Aggregate)			40 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	225.85	225.85	451.70	206.11	206.11	412.22
64QAM 0.92 dual	190.29	190.29	380.57	173.65	173.65	347.30
64QAM 0.75 dual	155.50	155.50	311.00	141.91	141.91	283.81
16QAM 0.87 dual	120.97	120.97	241.94	110.40	110.40	220.79
16QAM 0.63 dual	86.96	86.96	173.93	79.36	79.36	158.72
256QAM 0.81 single	112.92	112.92	225.85	103.05	103.05	206.10
64QAM 0.92 single	95.14	95.14	190.28	86.82	86.82	173.65
64QAM 0.75 single	77.75	77.75	155.50	70.95	70.95	141.90
16QAM 0.87 single	60.48	60.48	120.97	55.20	55.20	110.39
16QAM 0.63 single	43.48	43.48	86.96	39.68	39.68	79.36
QPSK 0.87 single	30.24	30.24	60.48	27.60	27.60	55.19
QPSK 0.63 single	21.74	21.74	43.48	19.84	19.84	39.68
BPSK 0.63 single	10.87	10.87	21.73	9.92	9.92	19.83

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

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

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

Table 123 Throughput at zero link range (Mbit/s), symmetry 1:1, optimization TDM

Modulation mode	45 MHz (Tx/Rx/Aggregate)			40 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	198.59	198.59	397.18	184.89	184.89	369.78
64QAM 0.92 dual	167.32	167.32	334.64	155.77	155.77	311.55
64QAM 0.75 dual	136.73	136.73	273.46	127.30	127.30	254.59
16QAM 0.87 dual	106.37	106.37	212.74	99.03	99.03	198.06
16QAM 0.63 dual	76.47	76.47	152.93	71.19	71.19	142.38
256QAM 0.81 single	99.29	99.29	198.59	92.44	92.44	184.89
64QAM 0.92 single	83.66	83.66	167.32	77.89	77.89	155.77
64QAM 0.75 single	68.36	68.36	136.73	63.65	63.65	127.29
16QAM 0.87 single	53.18	53.18	106.37	49.51	49.51	99.03
16QAM 0.63 single	38.23	38.23	76.46	35.59	35.59	71.19
QPSK 0.87 single	26.59	26.59	53.18	24.76	24.76	49.51
QPSK 0.63 single	19.11	19.11	38.23	17.79	17.79	35.59
BPSK 0.63 single	9.56	9.56	19.11	8.90	8.90	17.79

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

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

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

Table 124 Throughput at zero link range (Mbit/s), symmetry 2:1, optimization IP

Modulation mode	45 MHz (Tx/Rx/Aggregate)			40 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	299.34	149.67	449.01	273.32	136.66	409.98
64QAM 0.92 dual	252.20	126.10	378.30	230.28	115.14	345.42
64QAM 0.75 dual	206.10	103.05	309.15	188.18	94.09	282.27
16QAM 0.87 dual	160.34	80.17	240.50	146.40	73.20	219.59
16QAM 0.63 dual	115.26	57.63	172.89	105.24	52.62	157.86
256QAM 0.81 single	149.67	74.83	224.50	136.66	68.33	204.98
64QAM 0.92 single	126.10	63.05	189.15	115.14	57.57	172.71
64QAM 0.75 single	103.05	51.52	154.57	94.09	47.04	141.13
16QAM 0.87 single	80.17	40.08	120.25	73.20	36.60	109.79
16QAM 0.63 single	57.63	28.81	86.44	52.62	26.31	78.93
QPSK 0.87 single	40.08	20.04	60.12	36.60	18.30	54.89
QPSK 0.63 single	28.81	14.40	43.22	26.31	13.15	39.46
BPSK 0.63 single	14.40	7.20	21.60	13.15	6.57	19.73

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

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

Table 125 Throughput at zero link range (Mbit/s), symmetry 2:1, optimization TDM

Modulation mode	45 MHz (Tx/Rx/Aggregate)			40 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	277.41	138.71	416.12	256.58	128.29	384.87
64QAM 0.92 dual	233.73	116.86	350.59	216.18	108.09	324.27
64QAM 0.75 dual	191.00	95.50	286.50	176.66	88.33	264.99
16QAM 0.87 dual	148.59	74.29	222.88	137.43	68.72	206.15
16QAM 0.63 dual	106.82	53.41	160.23	98.80	49.40	148.19
256QAM 0.81 single	138.70	69.35	208.05	128.29	64.14	192.43
64QAM 0.92 single	116.86	58.43	175.29	108.09	54.04	162.13
64QAM 0.75 single	95.50	47.75	143.25	88.33	44.16	132.49
16QAM 0.87 single	74.29	37.15	111.44	68.71	34.36	103.07
16QAM 0.63 single	53.41	26.70	80.11	49.40	24.70	74.09
QPSK 0.87 single	37.15	18.57	55.72	34.36	17.18	51.53
QPSK 0.63 single	26.70	13.35	40.05	24.70	12.35	37.04
BPSK 0.63 single	13.35	6.67	20.02	12.35	6.17	18.52

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

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

Table 126 Throughput at zero link range (Mbit/s), symmetry 3:1, optimization IP

Modulation mode	45 MHz (Tx/Rx/Aggregate)			40 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	336.76	112.25	449.01	307.48	102.49	409.98
64QAM 0.92 dual	283.73	94.57	378.30	259.06	86.35	345.42
64QAM 0.75 dual	231.86	77.29	309.15	211.70	70.57	282.27
16QAM 0.87 dual	180.38	60.12	240.50	164.70	54.90	219.59
16QAM 0.63 dual	129.67	43.22	172.89	118.40	39.46	157.86
256QAM 0.81 single	168.38	56.12	224.50	153.74	51.25	204.98
64QAM 0.92 single	141.86	47.29	189.15	129.53	43.18	172.71
64QAM 0.75 single	115.93	38.64	154.57	105.85	35.28	141.13
16QAM 0.87 single	90.19	30.06	120.25	82.35	27.45	109.79
16QAM 0.63 single	64.83	21.61	86.44	59.20	19.73	78.93
QPSK 0.87 single	45.09	15.03	60.12	41.17	13.72	54.89
QPSK 0.63 single	32.41	10.80	43.22	29.60	9.86	39.46
BPSK 0.63 single	16.20	5.40	21.60	14.80	4.93	19.73

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

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

Table 127 Throughput at zero link range (Mbit/s), symmetry 5:1, optimization IP

Modulation mode	45 MHz (Tx/Rx/Aggregate)			40 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	374.18	74.83	449.01	334.38	66.87	401.25
64QAM 0.92 dual	315.25	63.05	378.30	281.72	56.34	338.07
64QAM 0.75 dual	257.62	51.52	309.15	230.22	46.04	276.26
16QAM 0.87 dual	200.42	40.08	240.50	179.10	35.82	214.92
16QAM 0.63 dual	144.08	28.81	172.89	128.75	25.75	154.50
256QAM 0.81 single	187.09	37.42	224.50	167.19	33.44	200.62
64QAM 0.92 single	157.63	31.52	189.15	140.86	28.17	169.03
64QAM 0.75 single	128.81	25.76	154.57	115.11	23.02	138.13
16QAM 0.87 single	100.21	20.04	120.25	89.55	17.91	107.46
16QAM 0.63 single	72.04	14.41	86.44	64.37	12.87	77.25
QPSK 0.87 single	50.10	10.02	60.12	44.77	8.95	53.73
QPSK 0.63 single	36.02	7.20	43.22	32.18	6.44	38.62
BPSK 0.63 single	18.00	3.60	21.60	16.09	3.22	19.31

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

Table 128 Throughput at zero link range (Mbit/s), symmetry adaptive, optimization IP

Modulation mode	45 MHz (Tx/Rx/Aggregate)			40 MHz (Tx/Rx/Aggregate)		
256QAM 0.81 dual	406.48	40.65	447.12	367.38	40.82	408.20
64QAM 0.92 dual	342.47	34.25	376.71	309.53	34.39	343.92
64QAM 0.75 dual	279.86	27.98	307.85	252.95	28.10	281.05
16QAM 0.87 dual	217.72	21.77	239.49	196.78	21.86	218.64
16QAM 0.63 dual	156.51	15.65	172.16	141.46	15.72	157.18
256QAM 0.81 single	203.24	20.32	223.56	183.69	20.41	204.10
64QAM 0.92 single	171.23	17.12	188.35	154.76	17.19	171.96
64QAM 0.75 single	139.93	13.99	153.92	126.47	14.05	140.52
16QAM 0.87 single	108.86	10.88	119.74	98.39	10.93	109.32
16QAM 0.63 single	78.25	7.82	86.08	70.73	7.86	78.58
QPSK 0.87 single	54.43	5.44	59.87	49.19	5.46	54.66
QPSK 0.63 single	39.12	3.91	43.04	35.36	3.93	39.29
BPSK 0.63 single	19.56	1.95	21.51	17.68	1.96	19.64

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

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

Figure 73 Range adjustment for PTP 670, symmetry 1:1, optimization IP, bandwidth 45 MHz

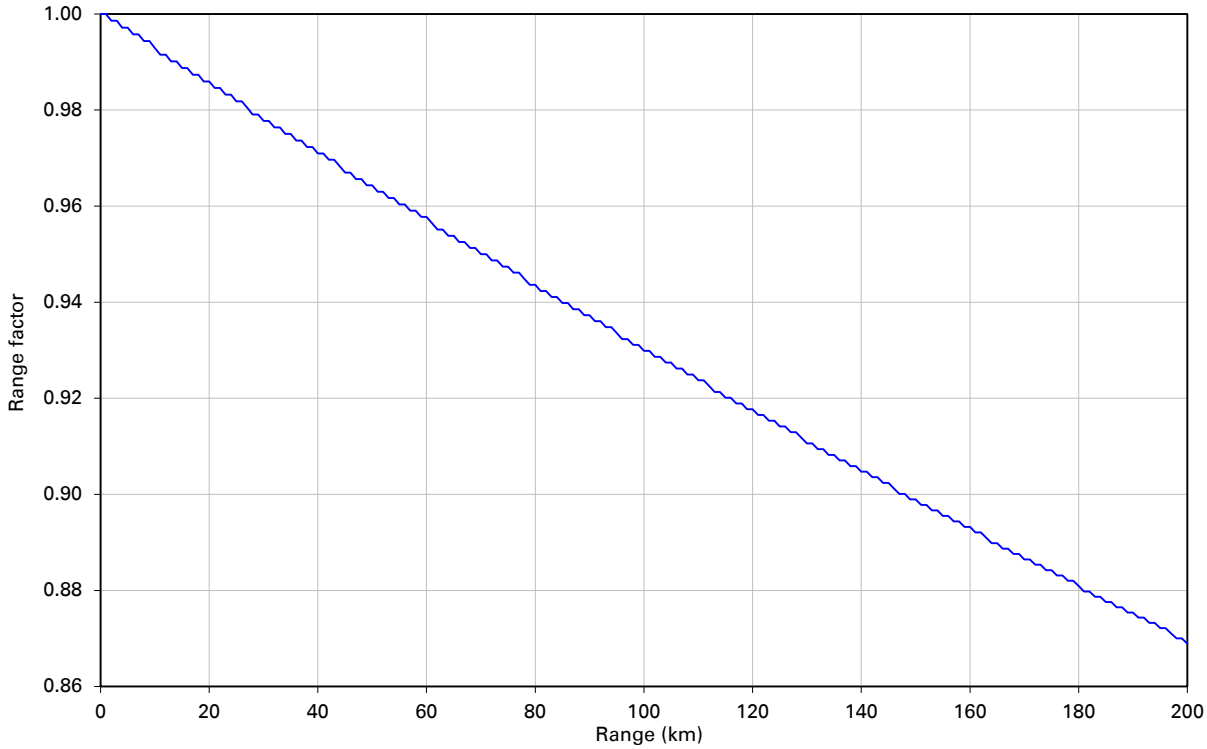


Figure 74 Range adjustment for PTP 670, symmetry 1:1, optimization IP, bandwidth 40 MHz

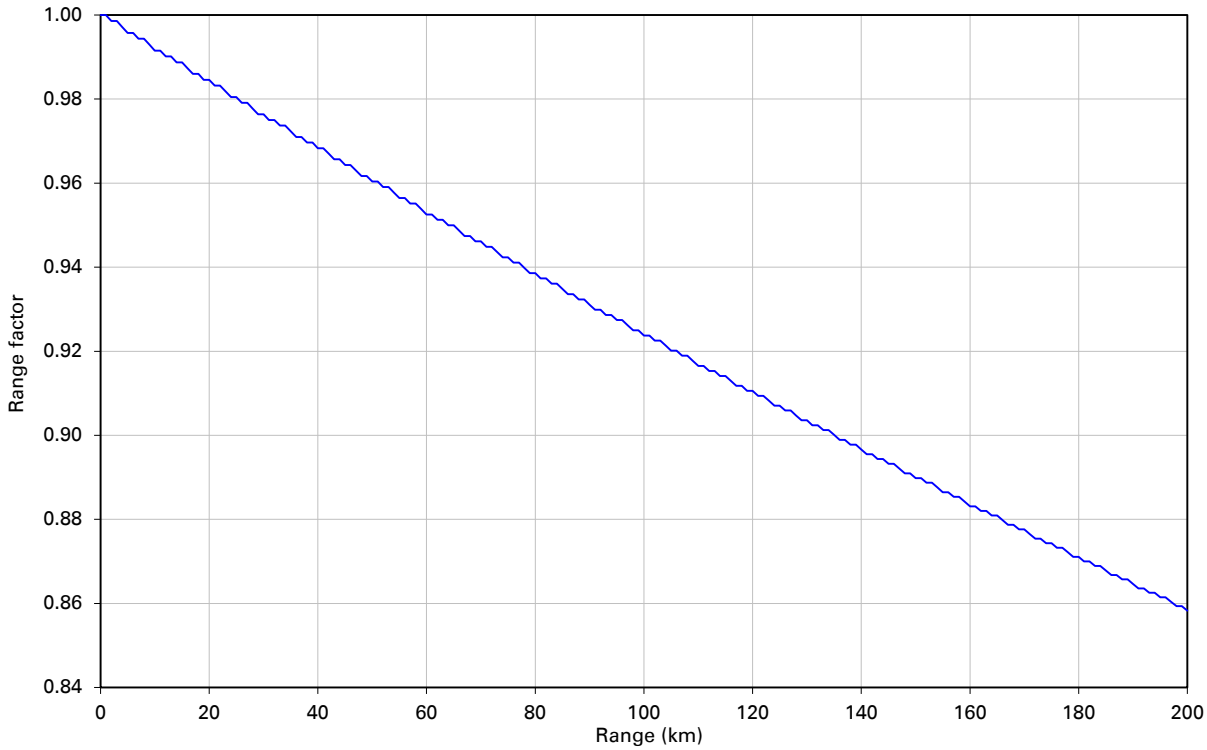


Figure 75 Range adjustment for PTP 670, symmetry 1:1, optimization IP, bandwidth 30 MHz

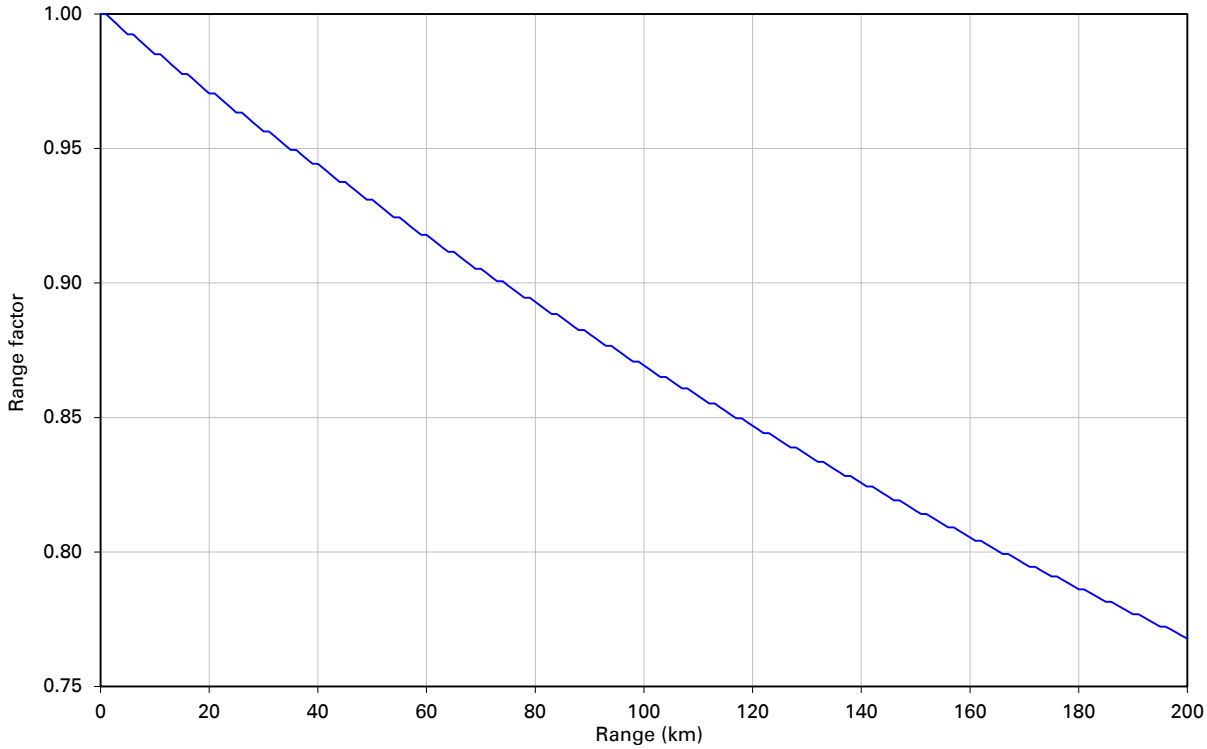


Figure 76 Range adjustment for PTP 670, symmetry 1:1, optimization IP, bandwidth 20 MHz

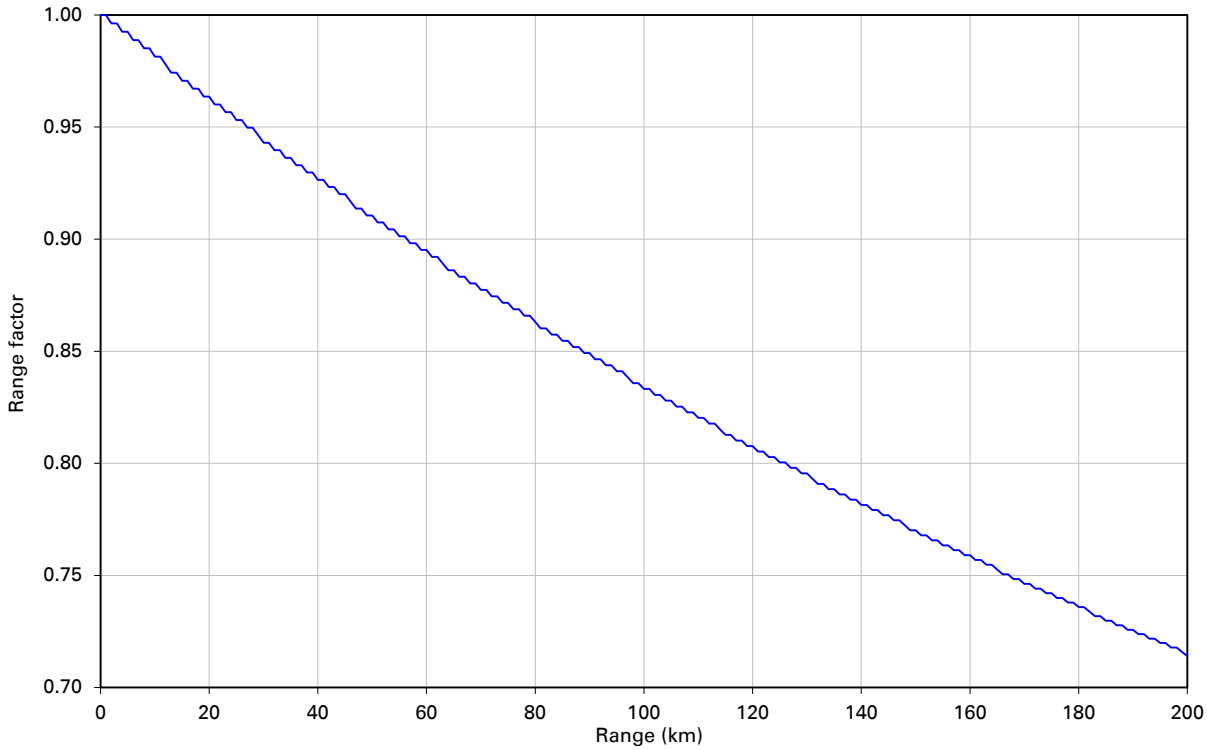


Figure 77 Range adjustment for PTP 670, symmetry 1:1, optimization IP, bandwidth 15 MHz

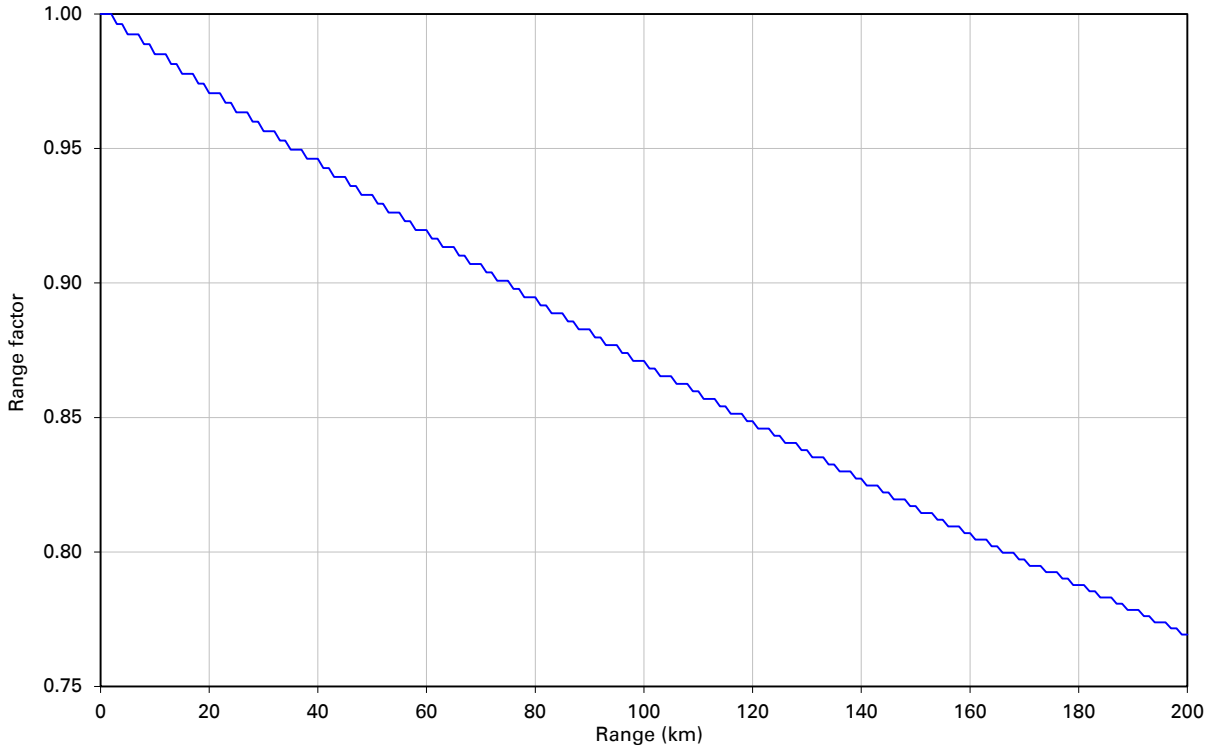


Figure 78 Range adjustment for PTP 670, symmetry 1:1, optimization IP, bandwidth 10 MHz

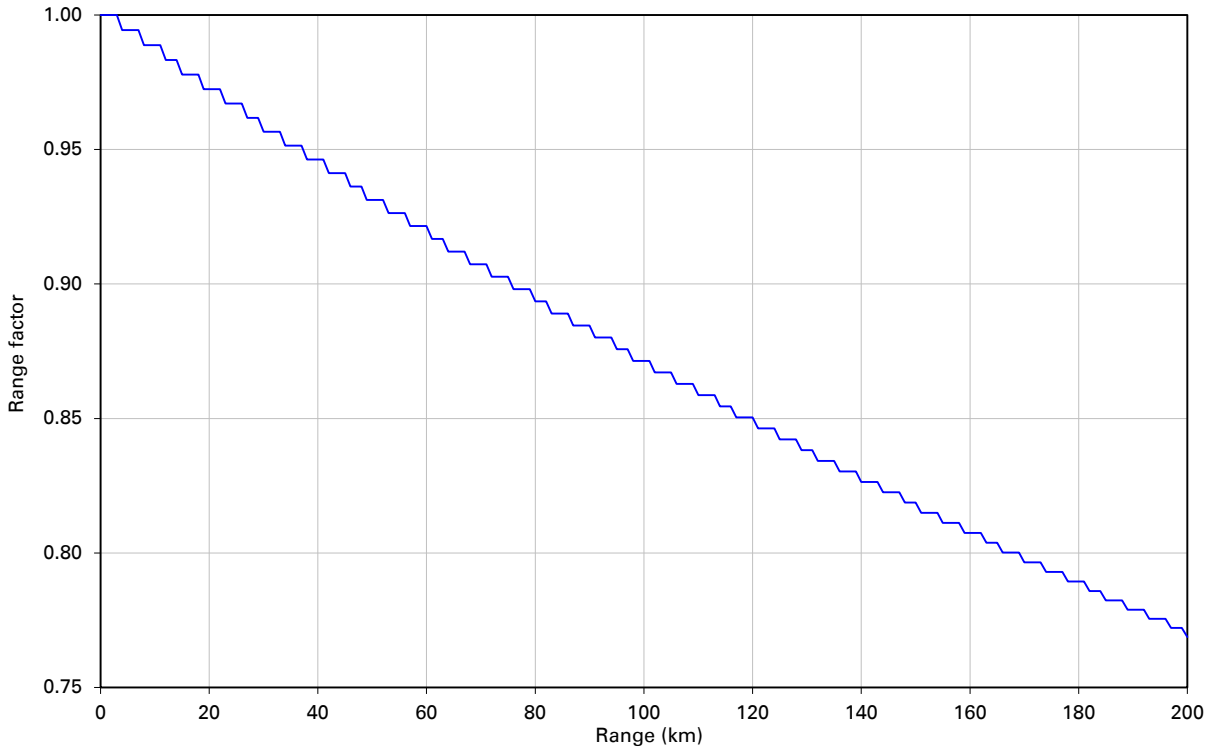


Figure 79 Range adjustment for PTP 670, symmetry 1:1, optimization IP, bandwidth 5 MHz

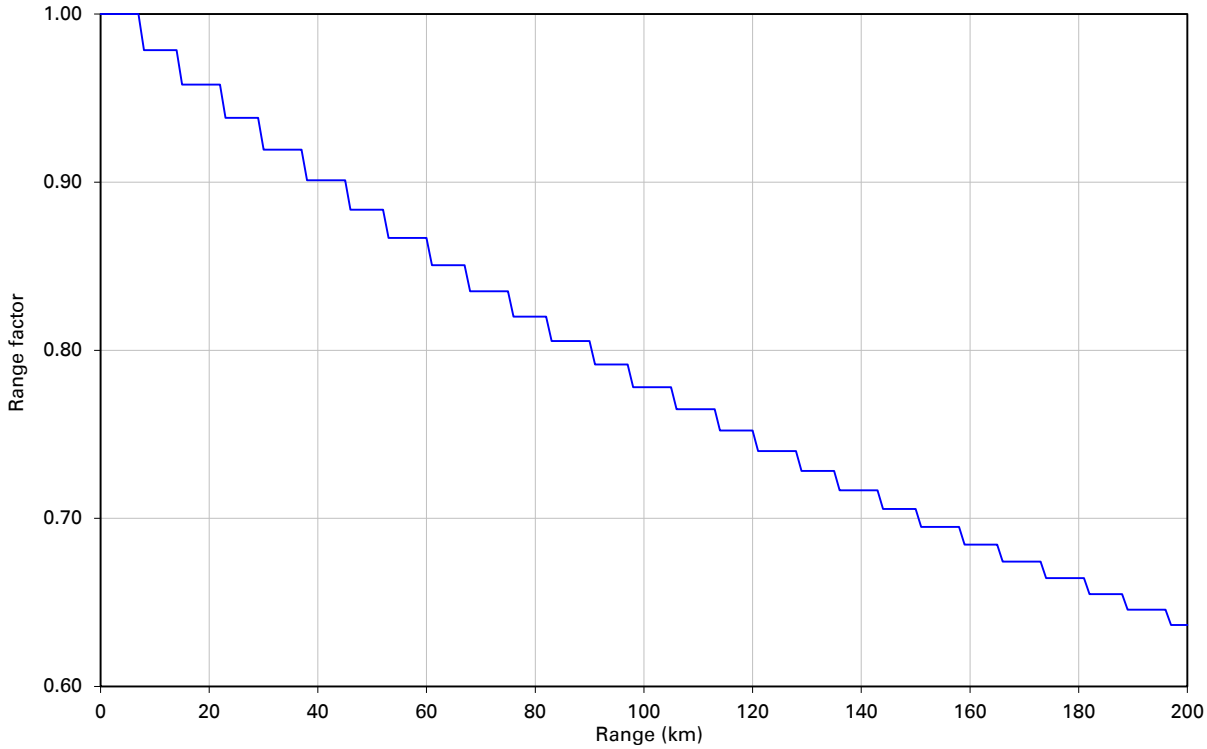


Figure 80 Range adjustment for PTP 670, symmetry 1:1, optimization TDM, bandwidth 45 MHz

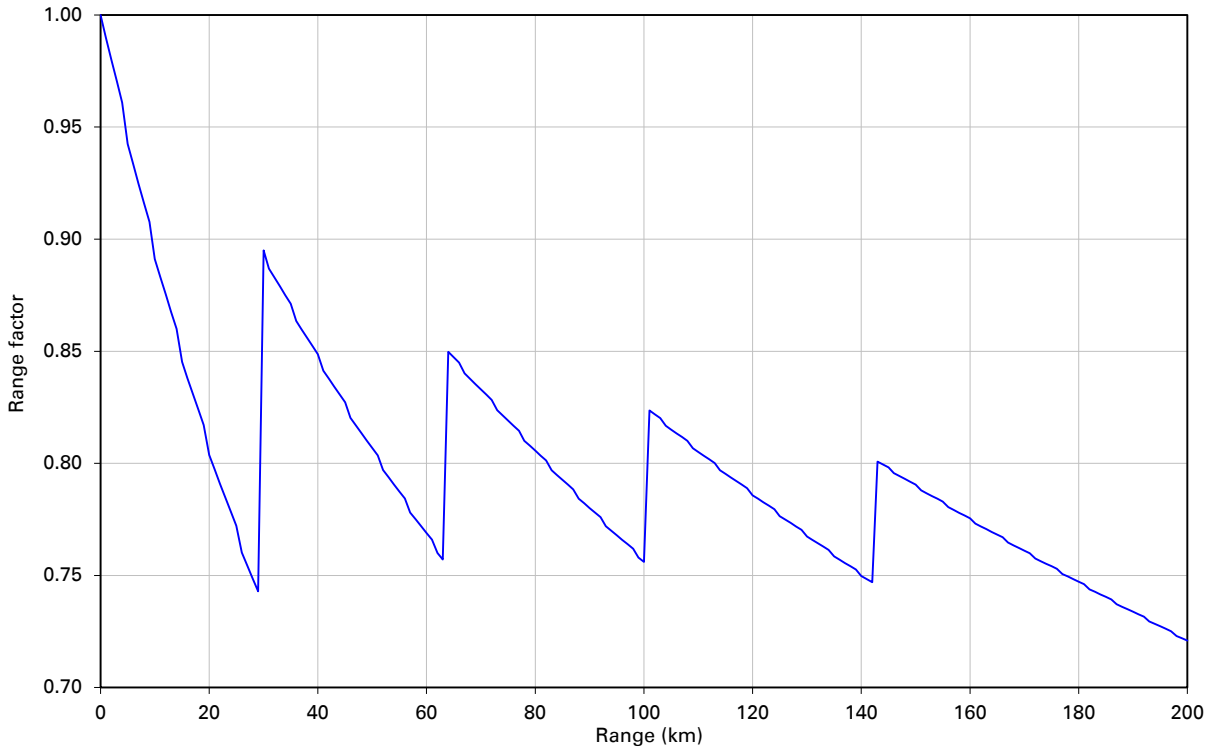


Figure 81 Range adjustment for PTP 670, symmetry 1:1, optimization TDM, bandwidth 40 MHz

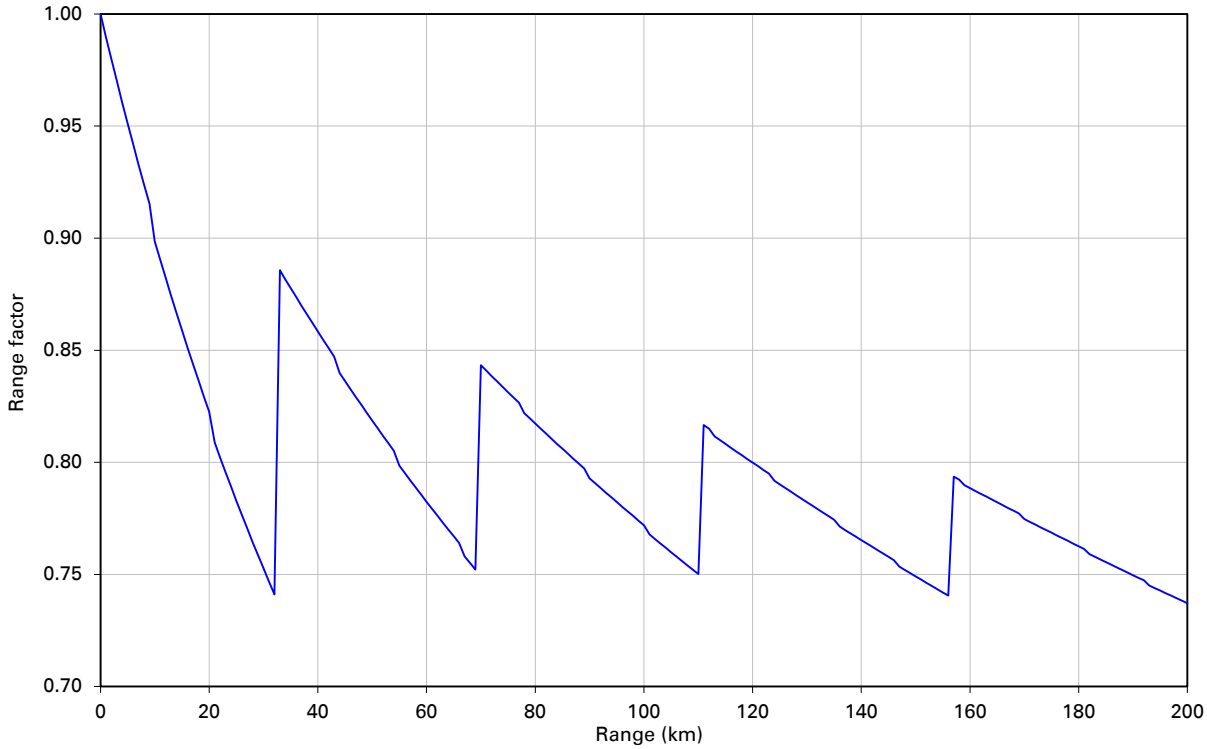


Figure 82 Range adjustment for PTP 670, symmetry 1:1, optimization TDM, bandwidth 30 MHz

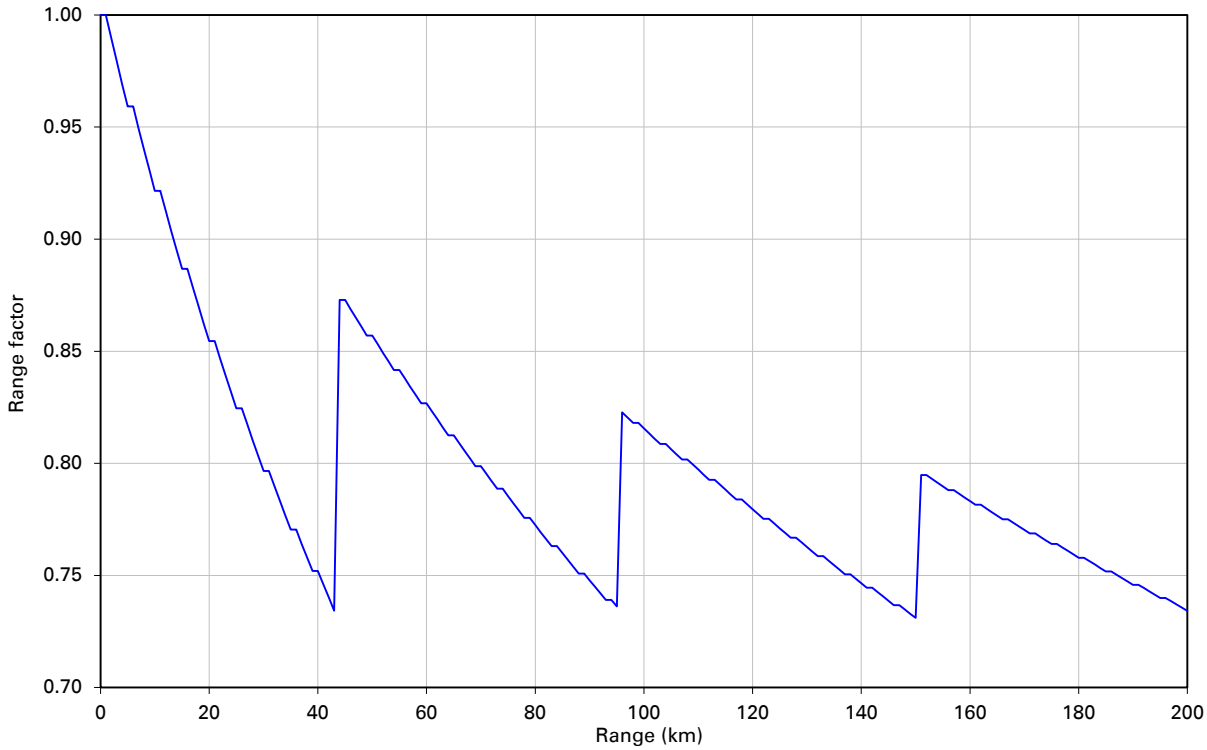


Figure 83 Range adjustment for PTP 670, symmetry 1:1, optimization TDM, bandwidth 20 MHz

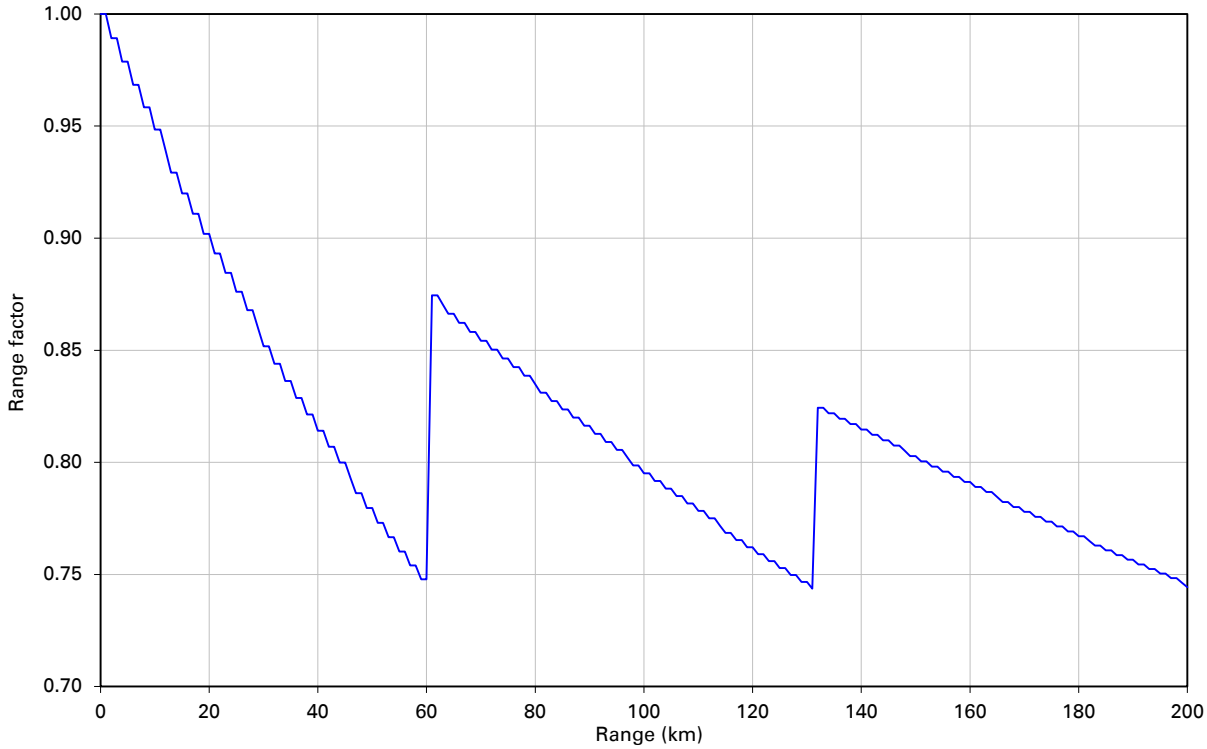


Figure 84 Range adjustment for PTP 670, symmetry 1:1, optimization TDM, bandwidth 15 MHz

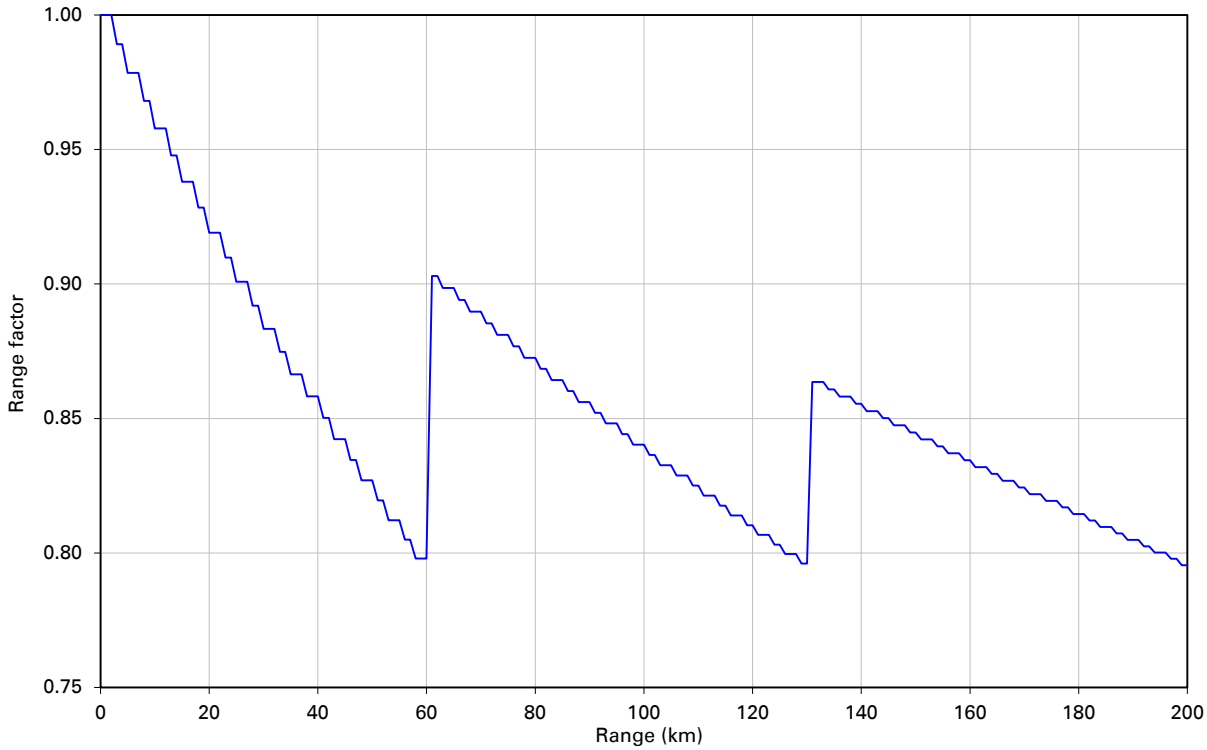


Figure 85 Range adjustment for PTP 670, symmetry 1:1, optimization TDM, bandwidth 10 MHz

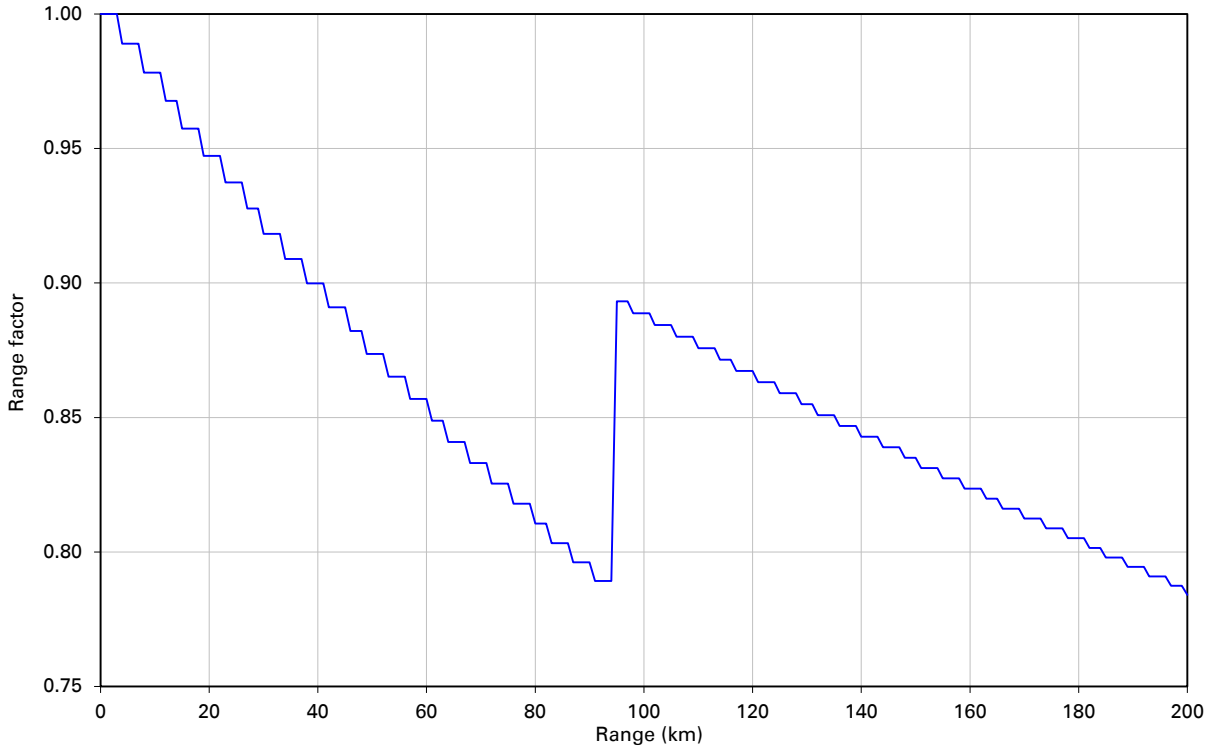


Figure 86 Range adjustment for PTP 670, symmetry 1:1, optimization TDM, bandwidth 5 MHz

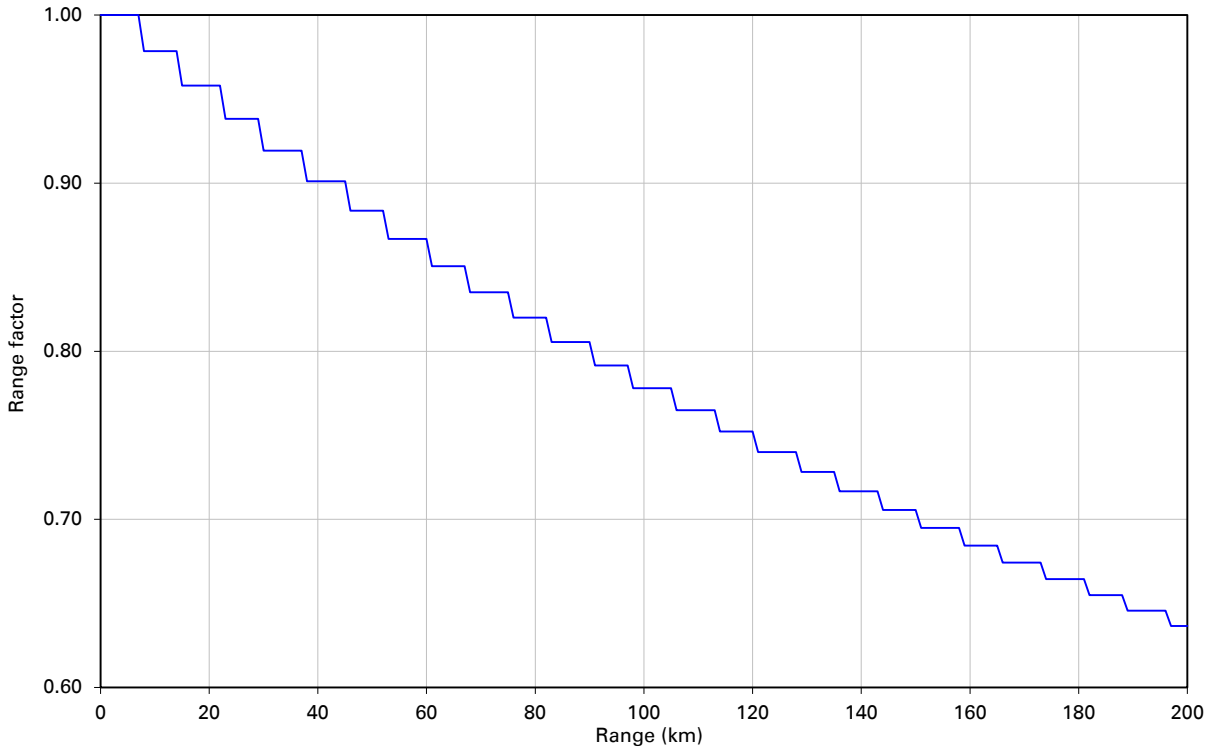


Figure 87 Range adjustment for PTP 670, symmetry 2:1, optimization IP, bandwidth 45 MHz

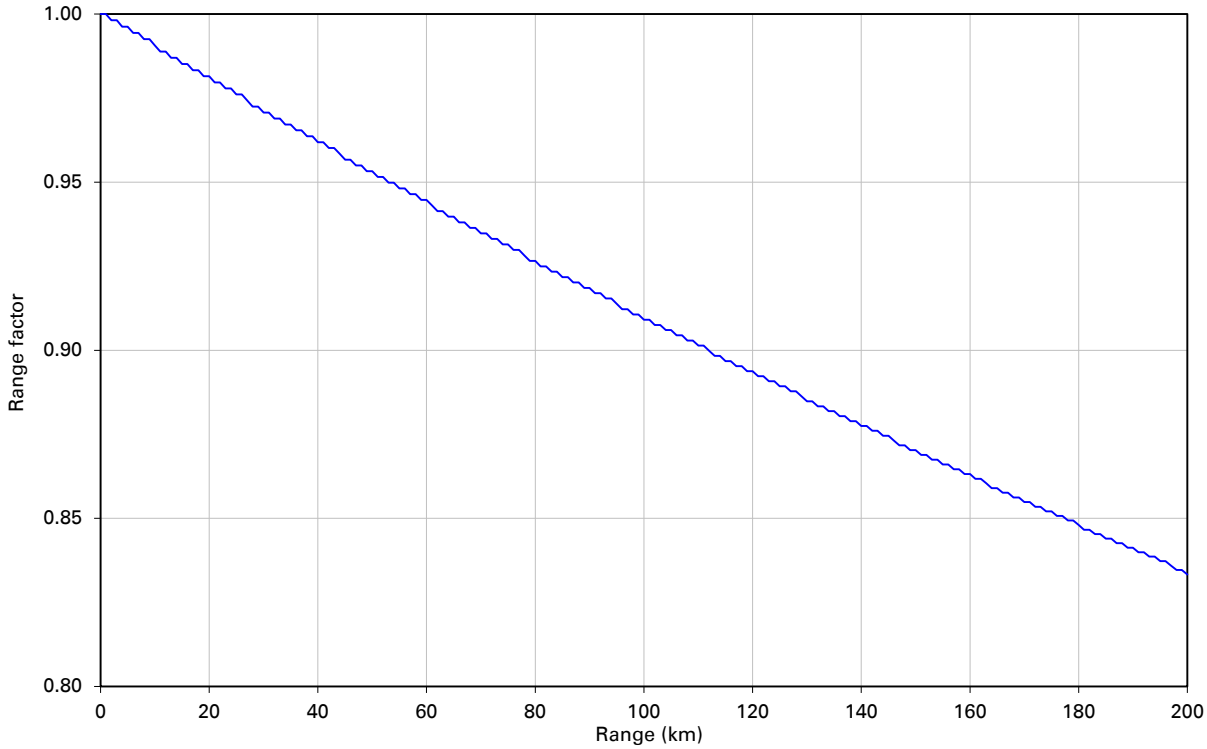


Figure 88 Range adjustment for PTP 670, symmetry 2:1, optimization IP, bandwidth 40 MHz

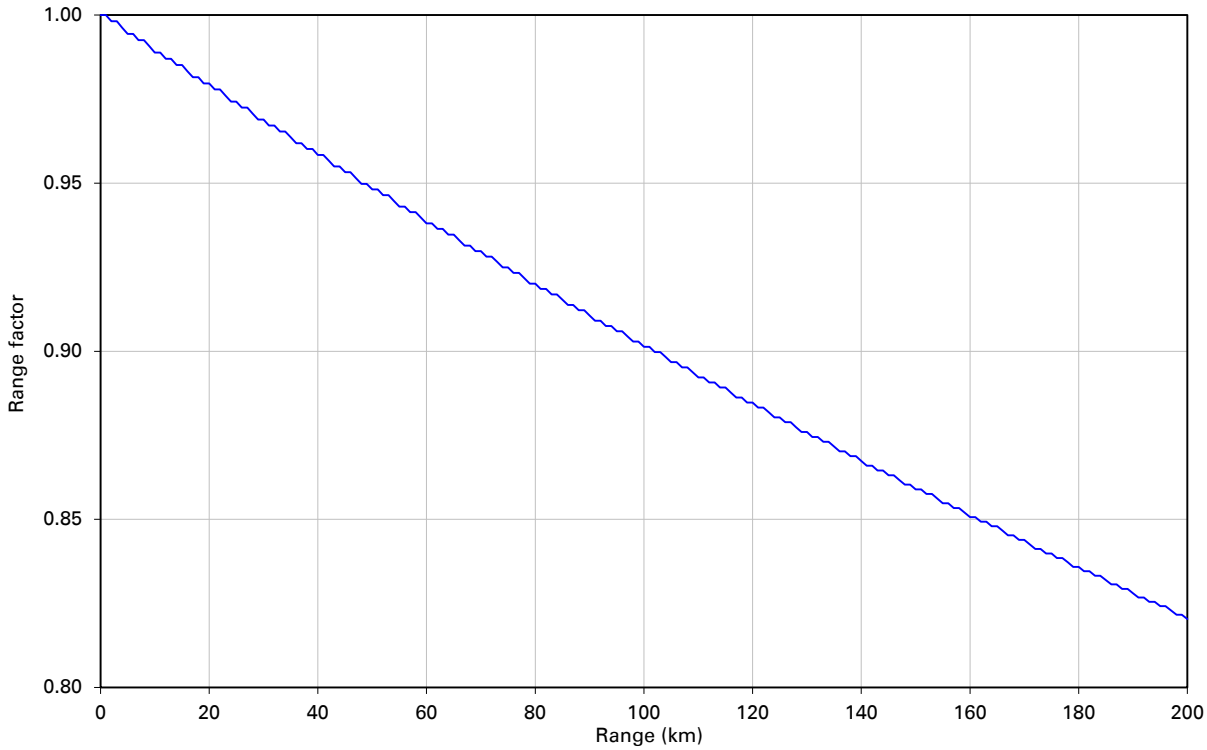


Figure 89 Range adjustment for PTP 670, symmetry 2:1, optimization IP, bandwidth 30 MHz

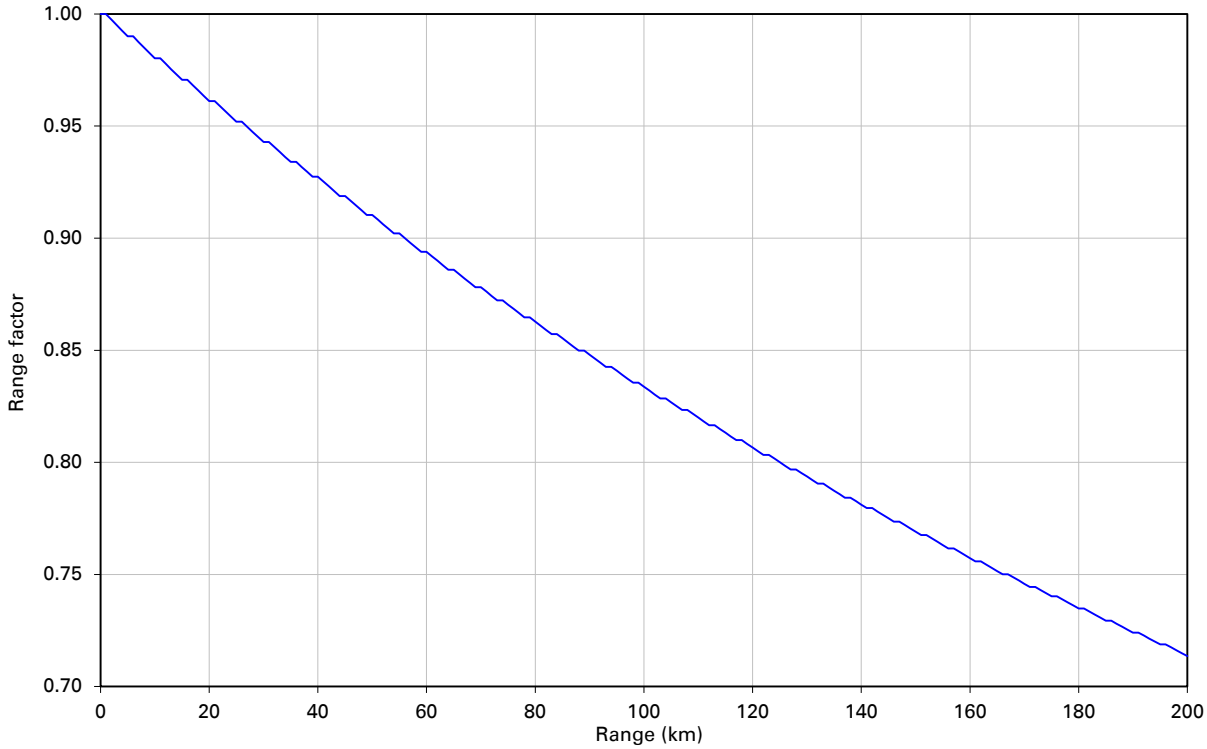


Figure 90 Range adjustment for PTP 670, symmetry 2:1, optimization IP, bandwidth 20 MHz

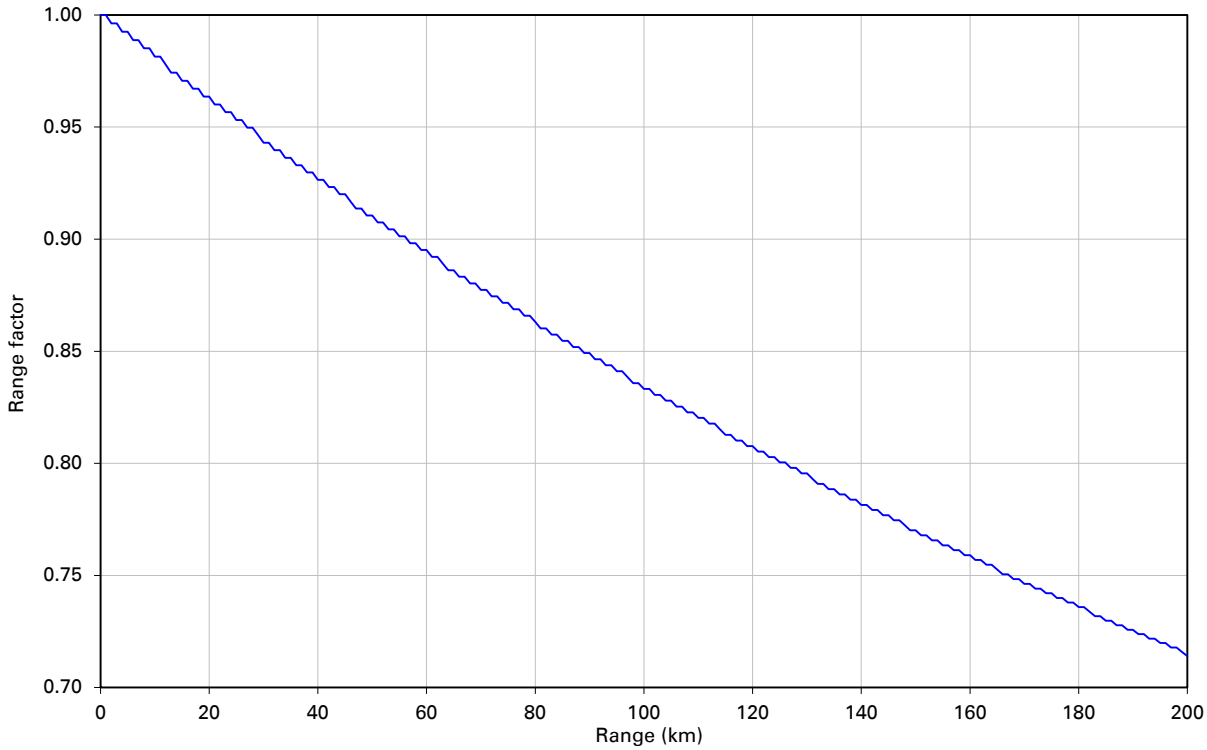


Figure 91 Range adjustment for PTP 670, symmetry 2:1, optimization IP, bandwidth 15 MHz

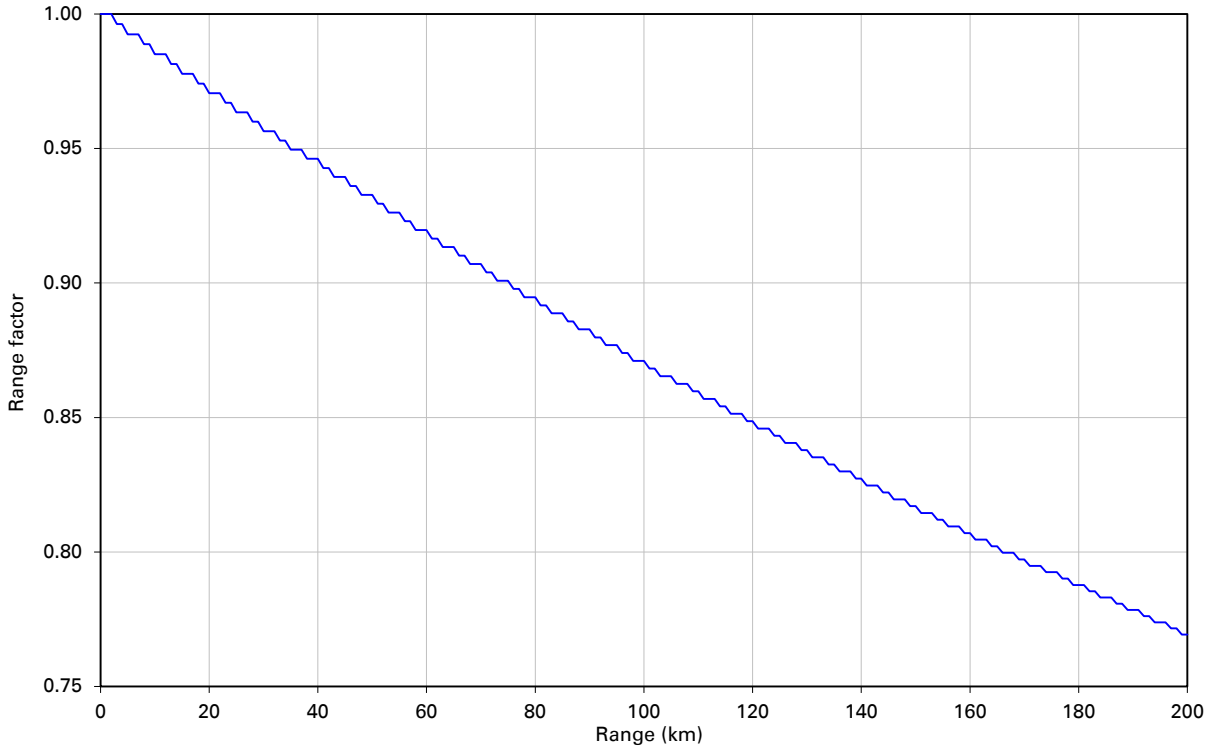


Figure 92 Range adjustment for PTP 670, symmetry 2:1, optimization IP, bandwidth 10 MHz

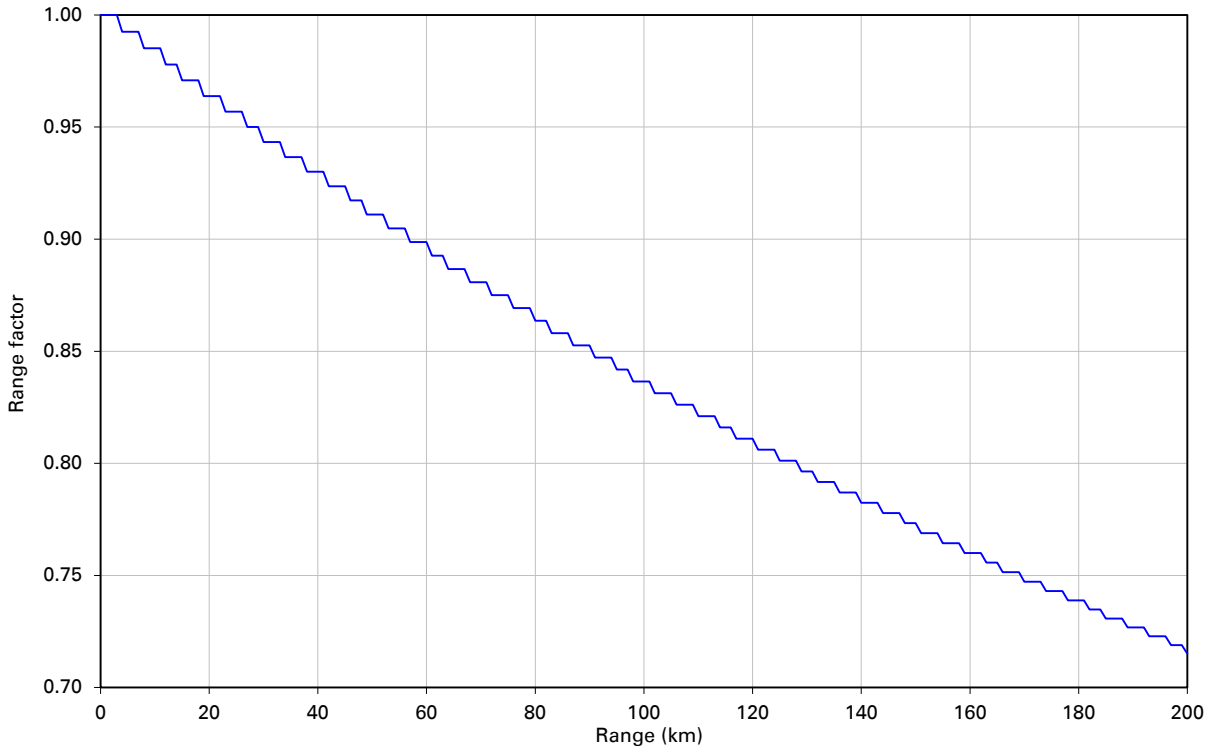


Figure 93 Range adjustment for PTP 670, symmetry 2:1, optimization TDM, bandwidth 45 MHz

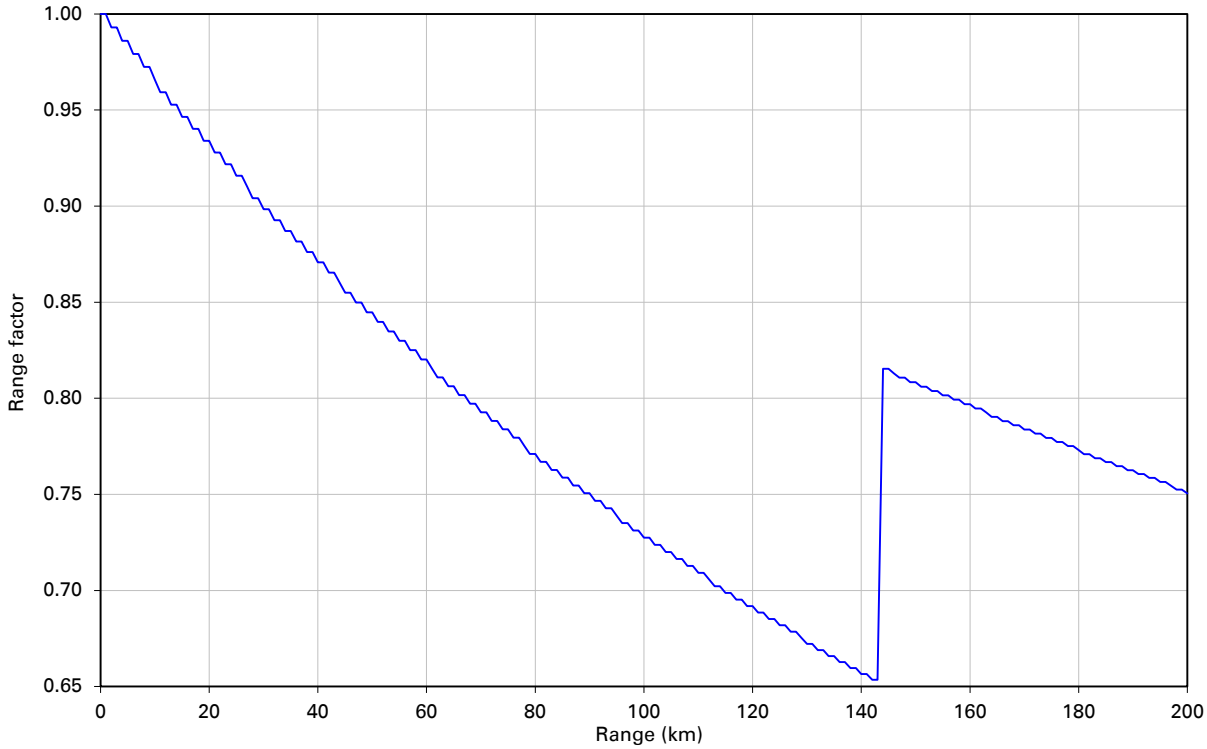


Figure 94 Range adjustment for PTP 670, symmetry 2:1, optimization TDM, bandwidth 40 MHz

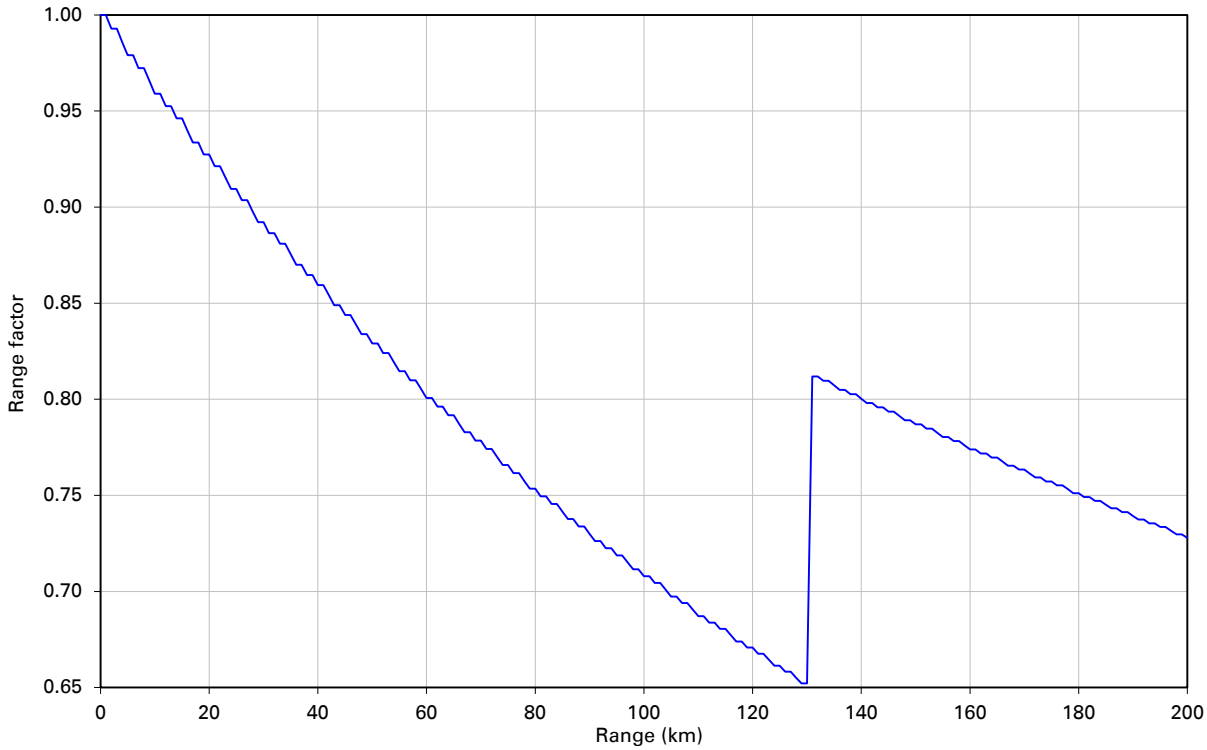


Figure 95 Range adjustment for PTP 670, symmetry 2:1, optimization TDM, bandwidth 30 MHz

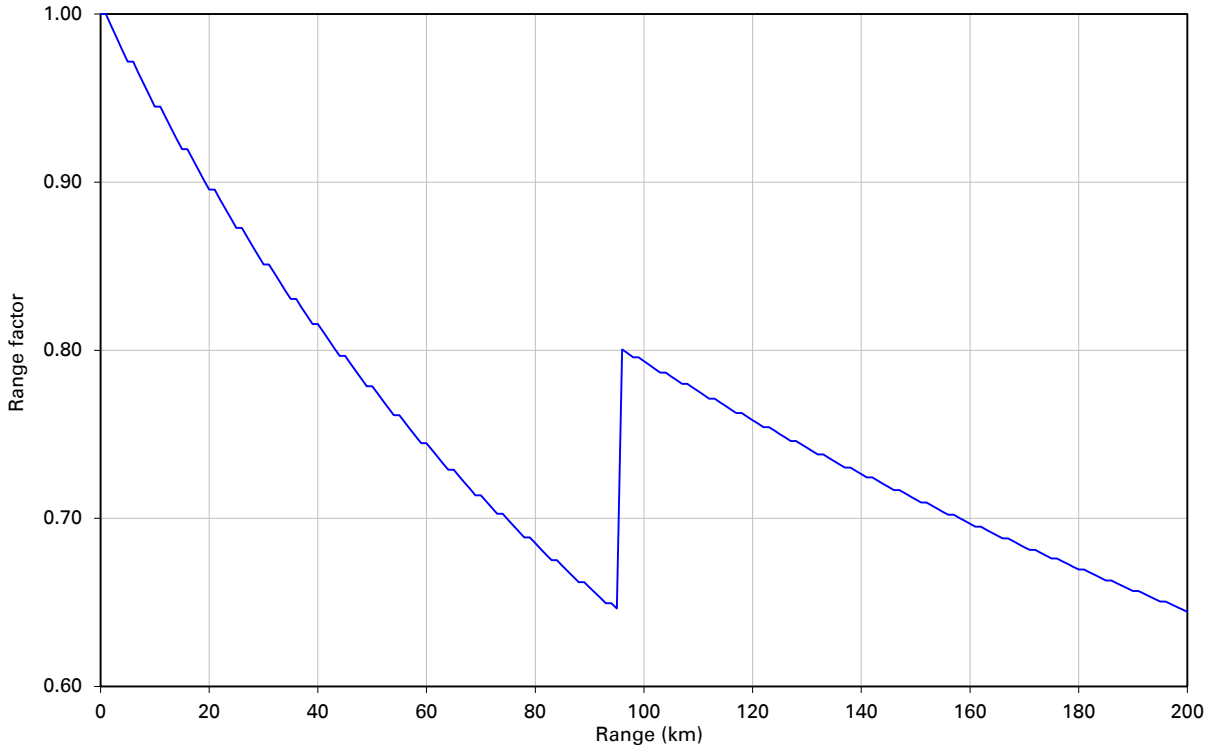


Figure 96 Range adjustment for PTP 670, symmetry 2:1, optimization TDM, bandwidth 20 MHz

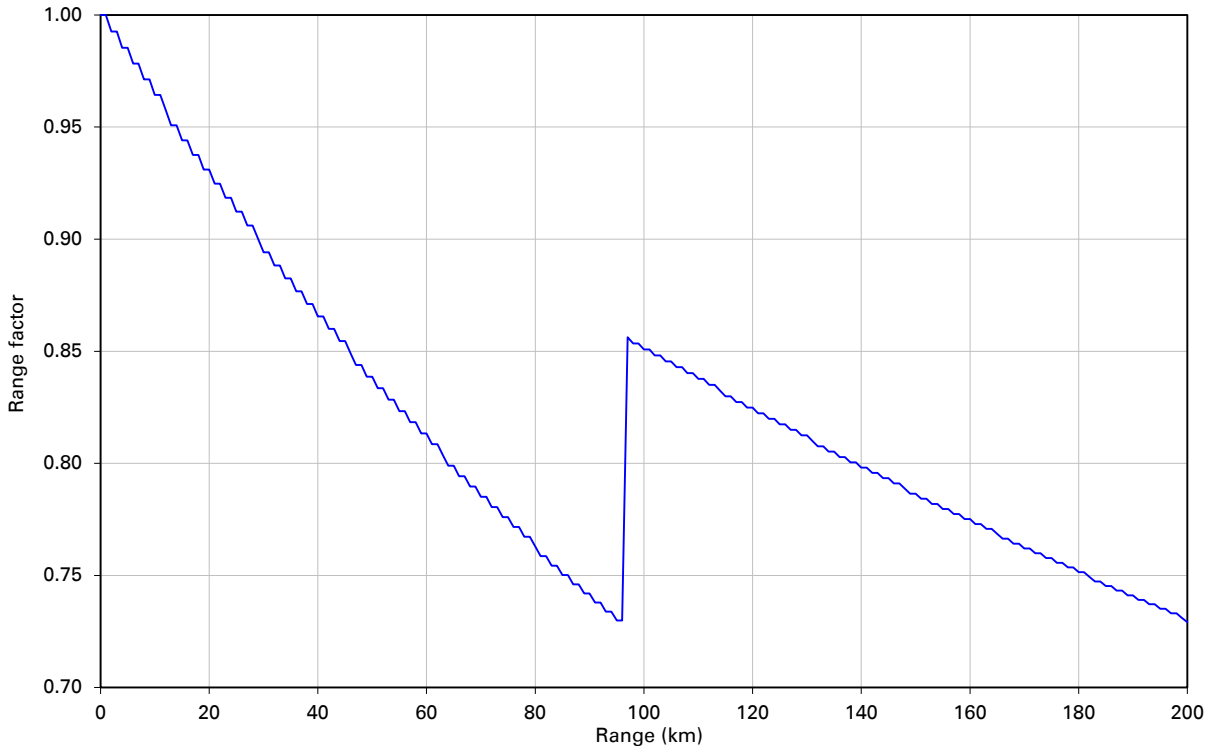


Figure 97 Range adjustment for PTP 670, symmetry 2:1, optimization TDM, bandwidth 15 MHz

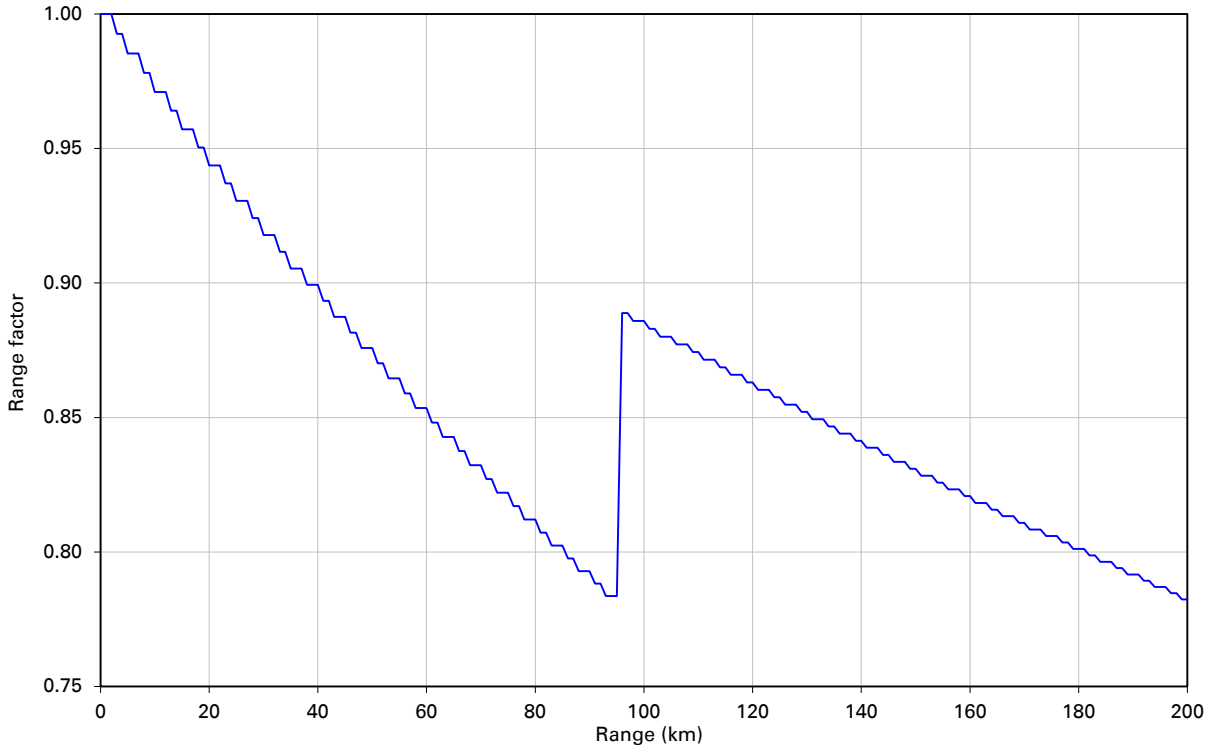


Figure 98 Range adjustment for PTP 670, symmetry 2:1, optimization TDM, bandwidth 10 MHz

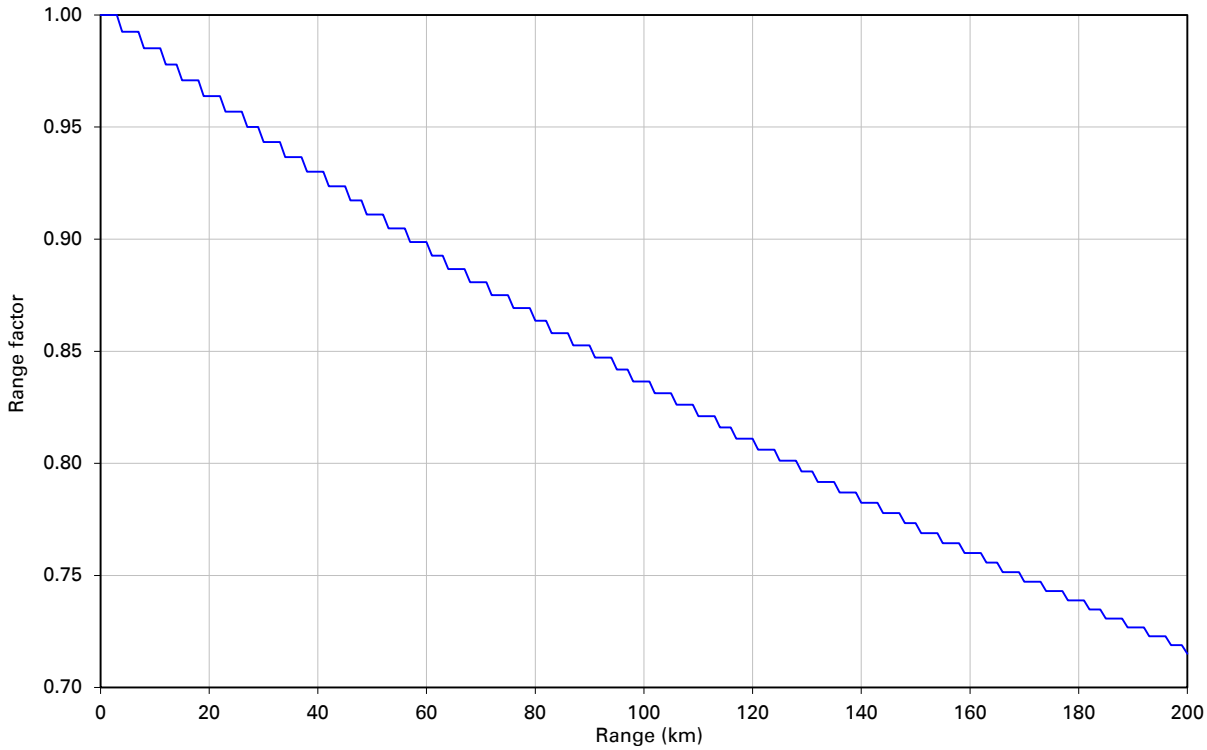


Figure 99 Range adjustment for PTP 670, symmetry 3:1, optimization IP, bandwidth 45 MHz

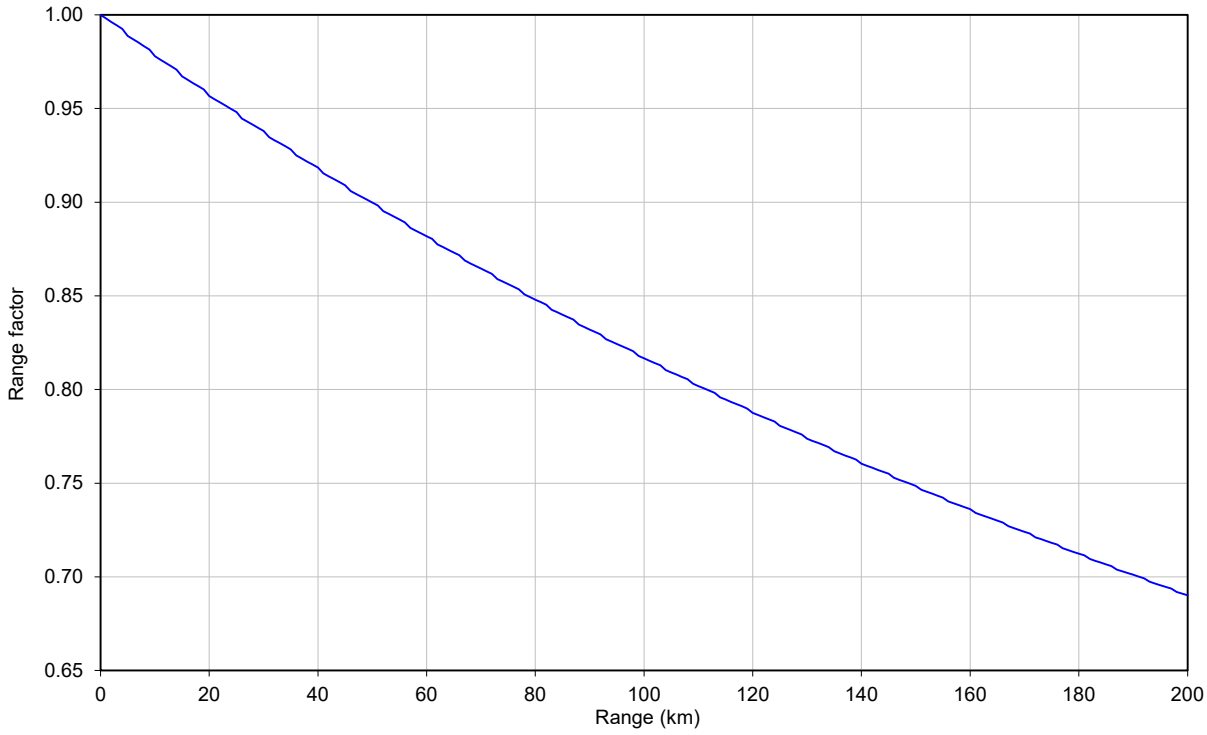


Figure 100 Range adjustment for PTP 670, symmetry 3:1, optimization IP, bandwidth 40 MHz

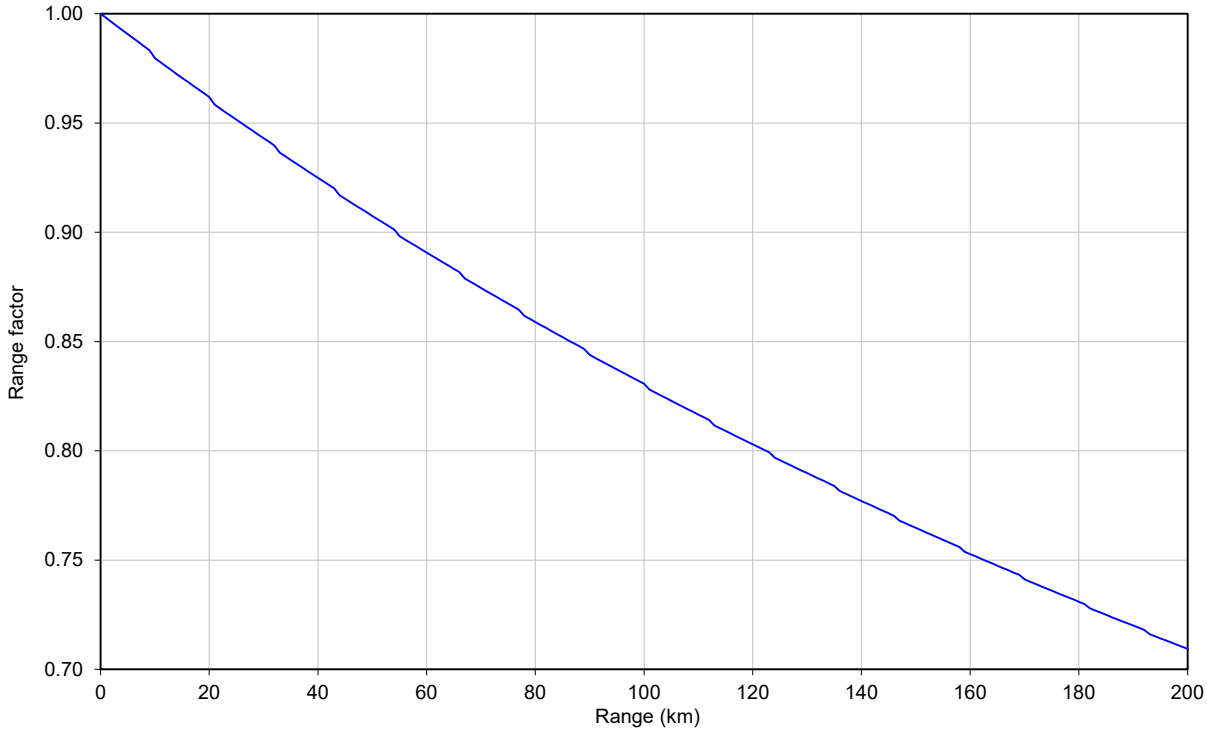


Figure 101 Range adjustment for PTP 670, symmetry 3:1, optimization IP, bandwidth 30 MHz

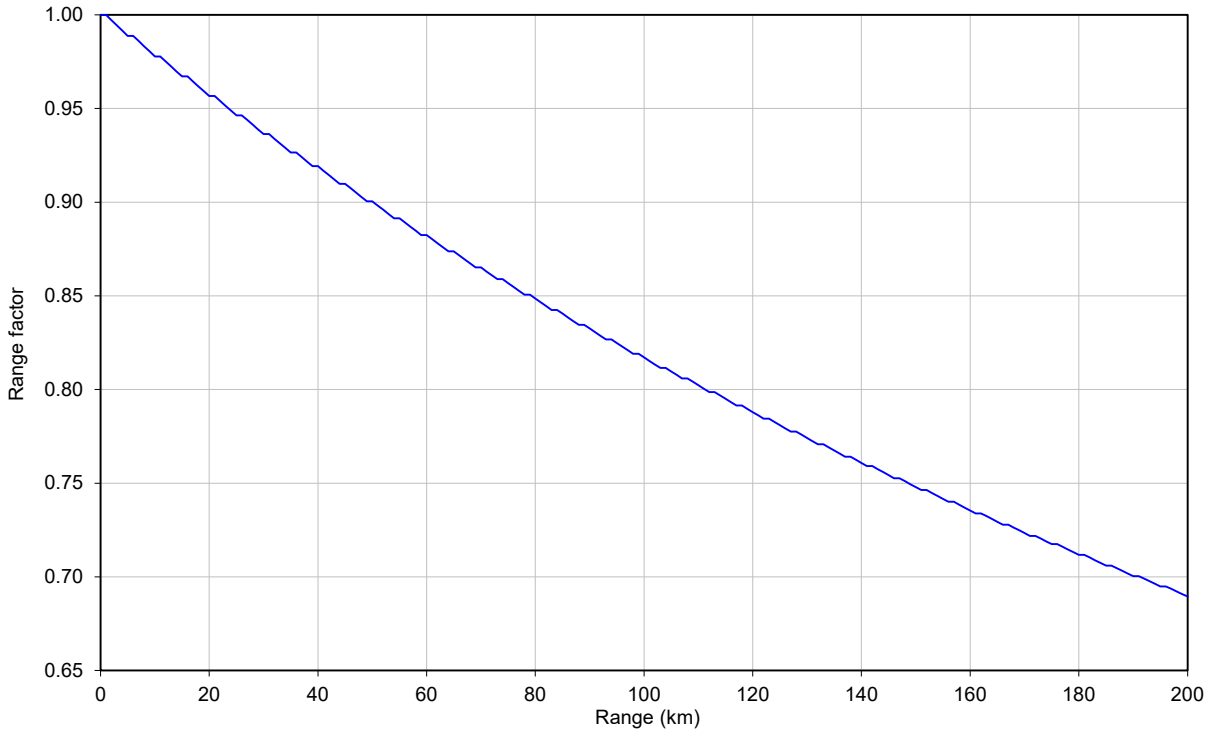


Figure 102 Range adjustment for PTP 670, symmetry 3:1, optimization IP, bandwidth 20 MHz

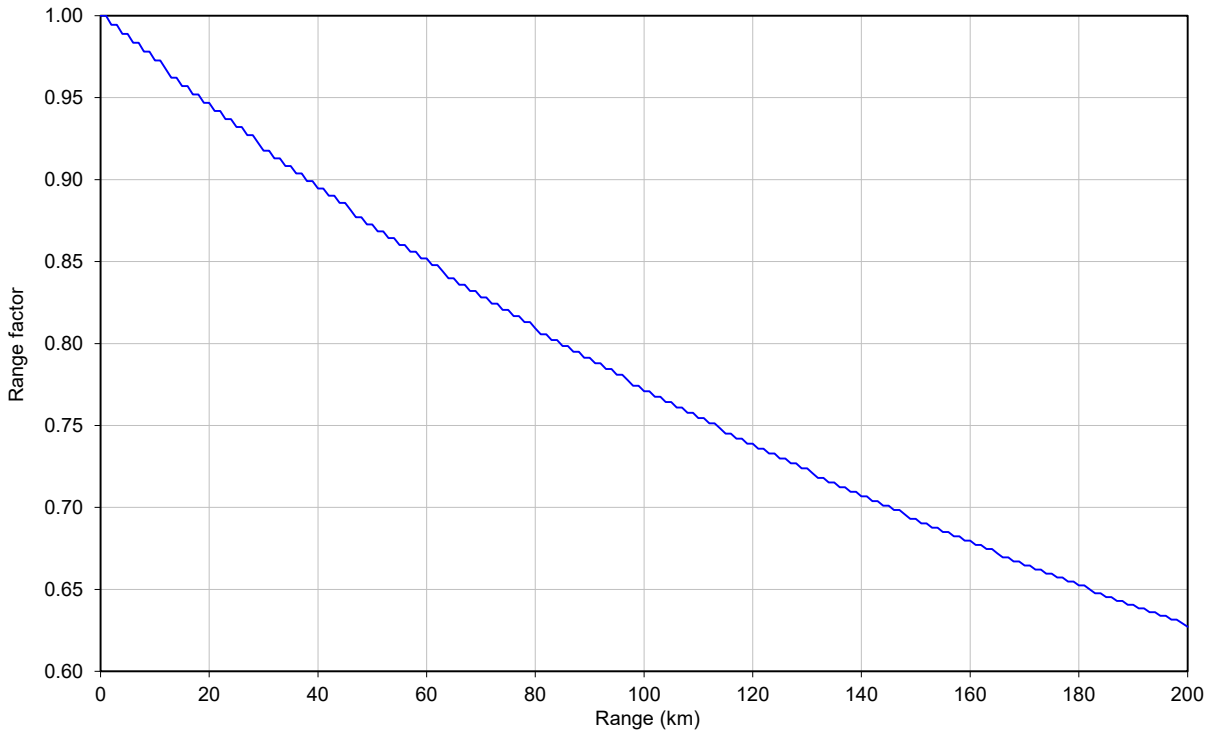


Figure 103 Range adjustment for PTP 670, symmetry 3:1, optimization IP, bandwidth 15 MHz

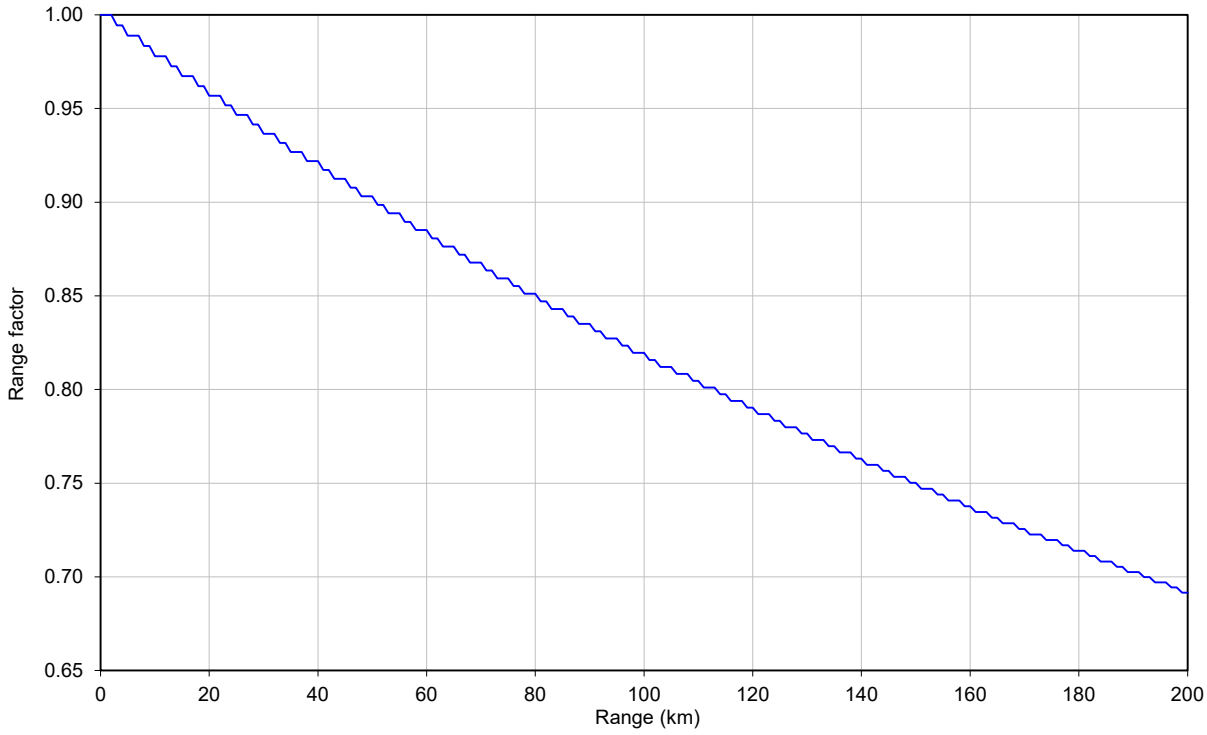


Figure 104 Range adjustment for PTP 670, symmetry 3:1, optimization IP, bandwidth 10 MHz

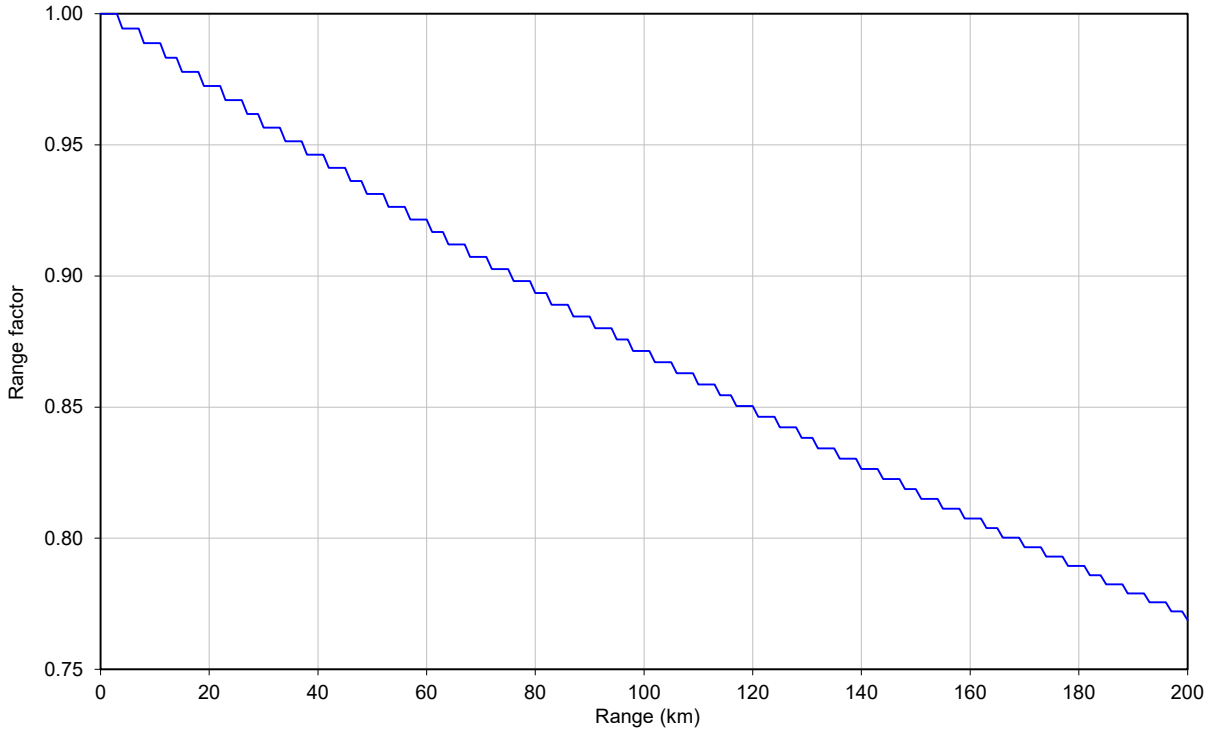


Figure 105 Range adjustment for PTP 670, symmetry 5:1, optimization IP, bandwidth 45 MHz

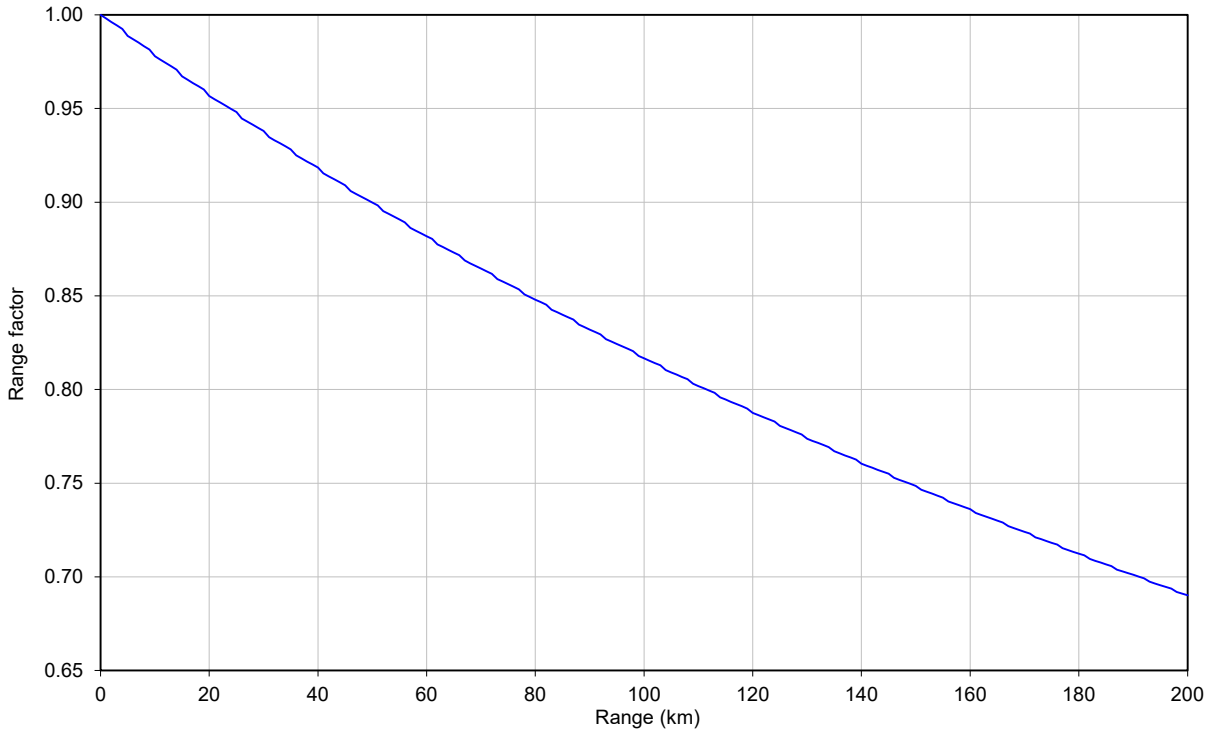


Figure 106 Range adjustment for PTP 670, symmetry 5:1, optimization IP, bandwidth 40 MHz

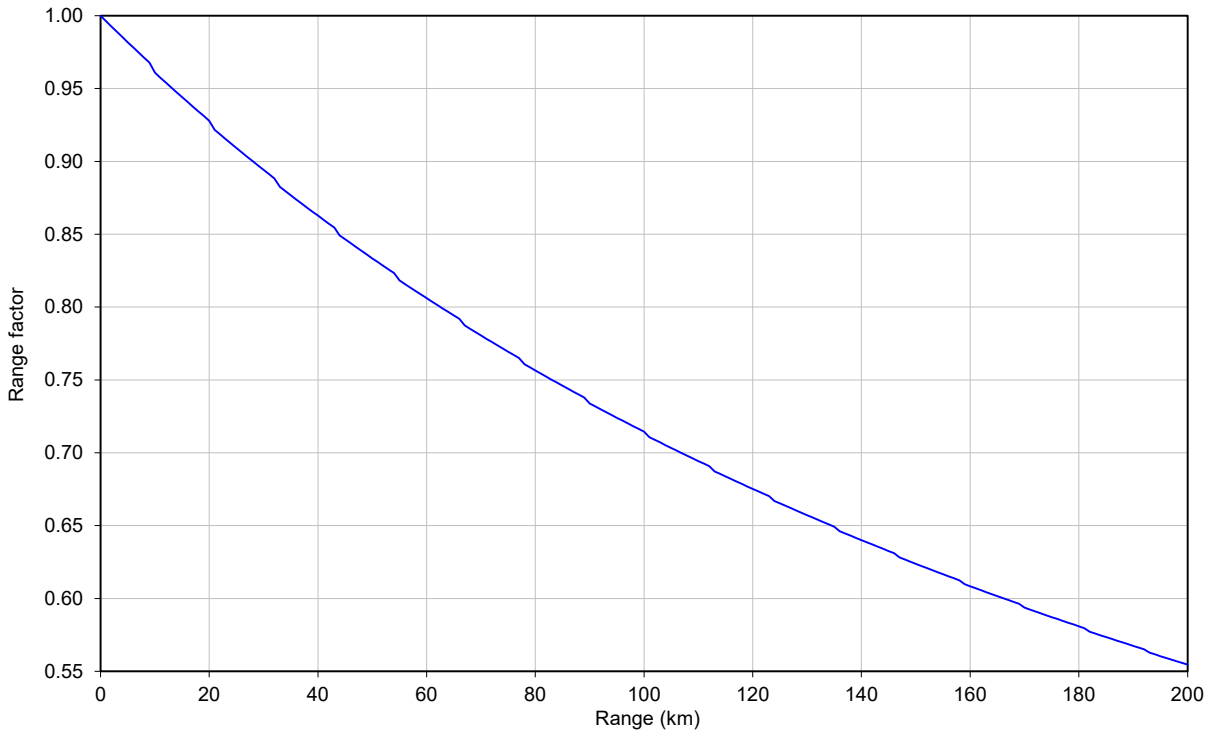


Figure 107 Range adjustment for PTP 670, symmetry 5:1, optimization IP, bandwidth 30 MHz

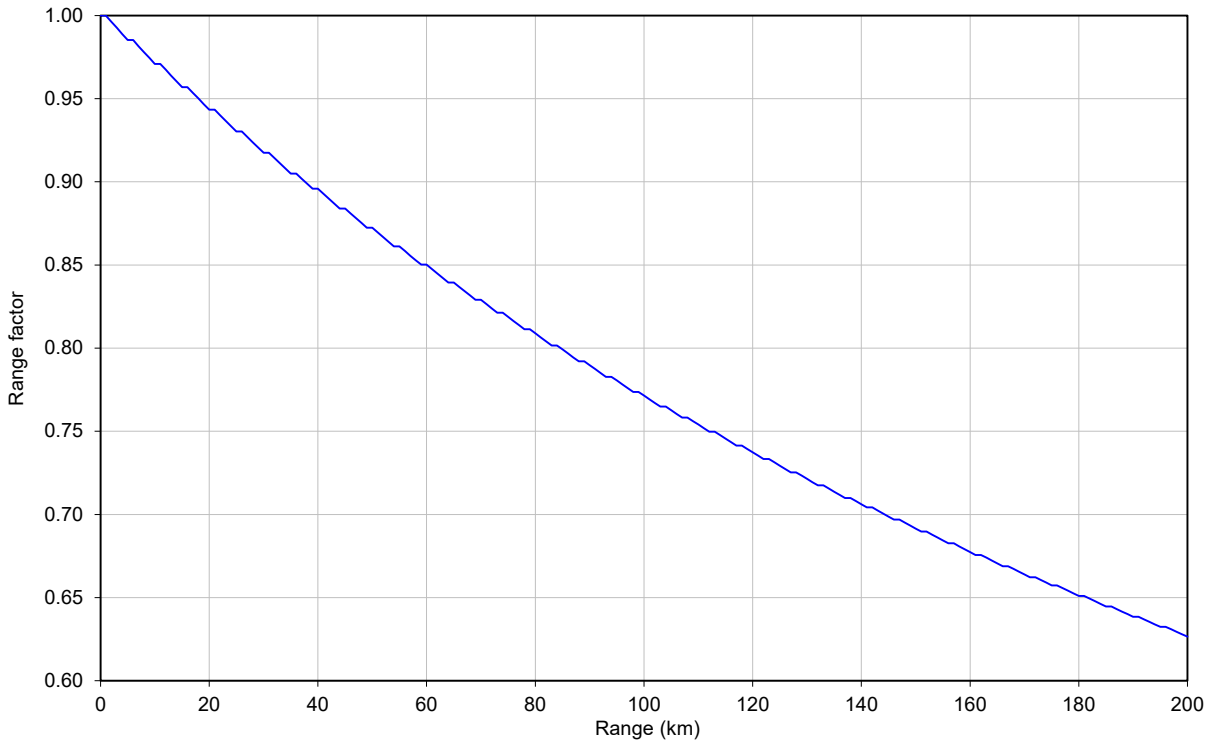


Figure 108 Range adjustment for PTP 670, adaptive, optimization IP, bandwidth 45 MHz

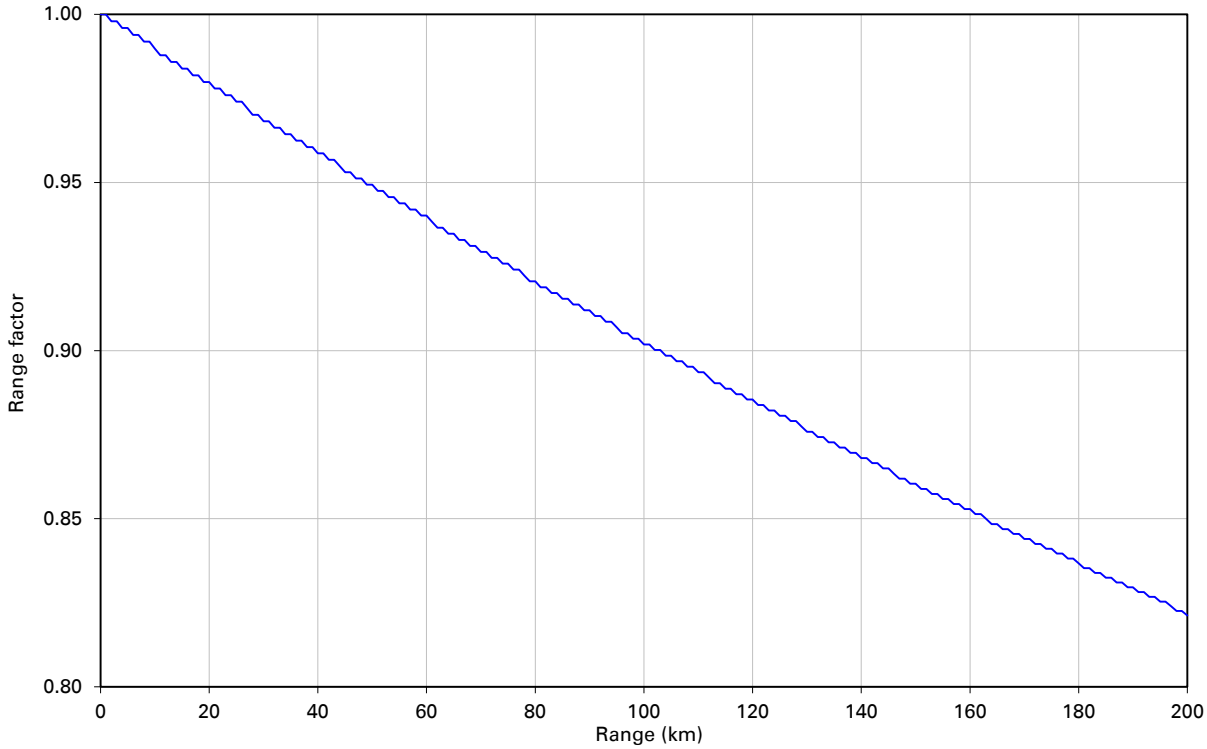


Figure 109 Range adjustment for PTP 670, adaptive, optimization IP, bandwidth 40 MHz

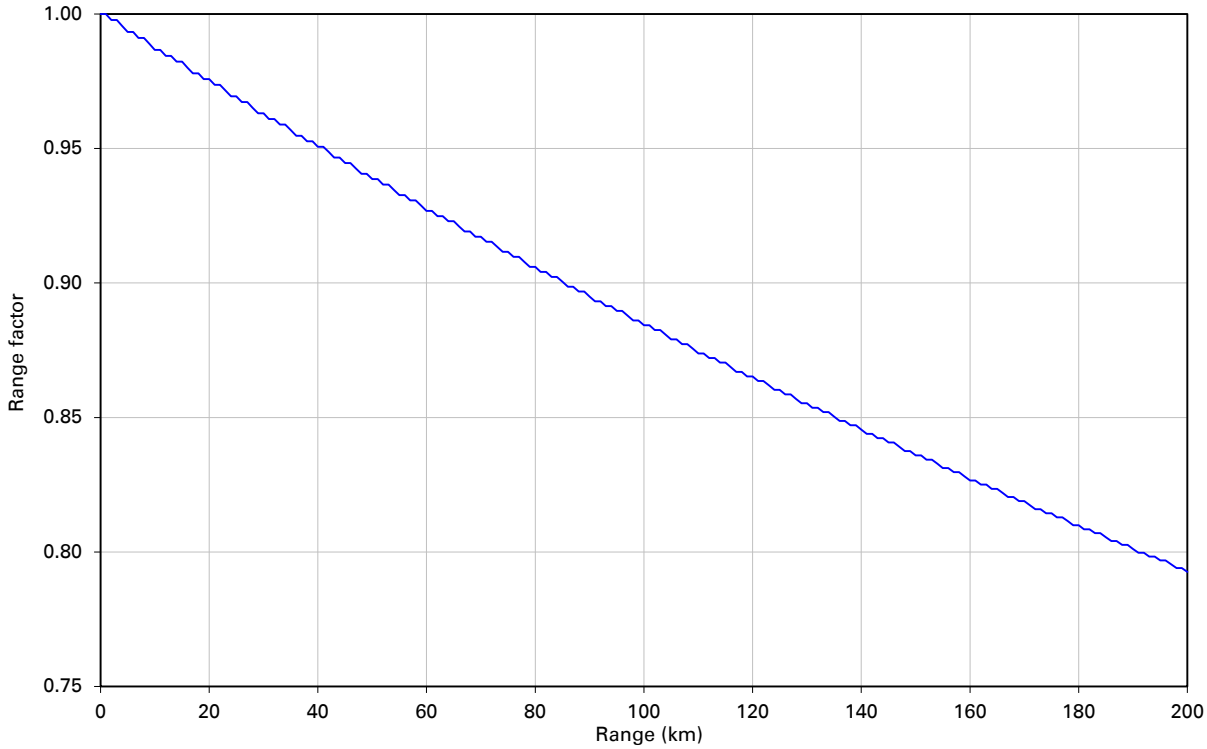


Figure 110 Range adjustment for PTP 670, adaptive, optimization IP, bandwidth 30 MHz

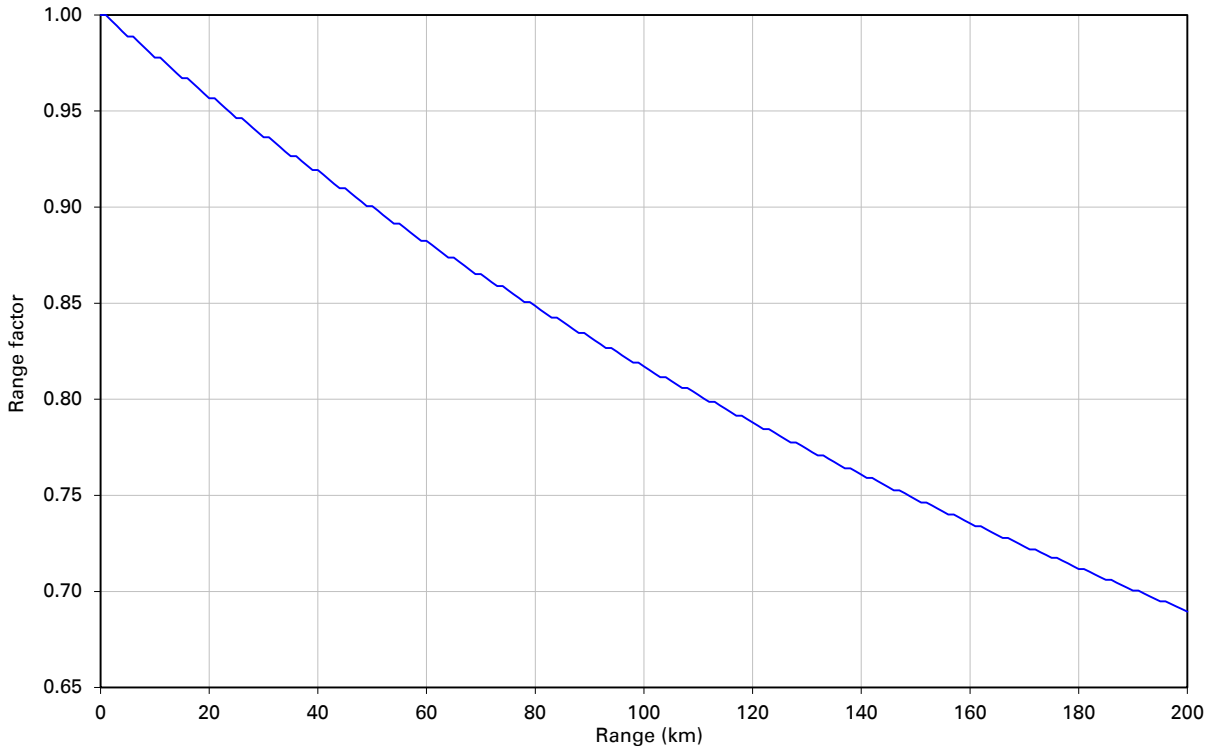


Figure 111 Range adjustment for PTP 670, adaptive, optimization IP, bandwidth 20 MHz

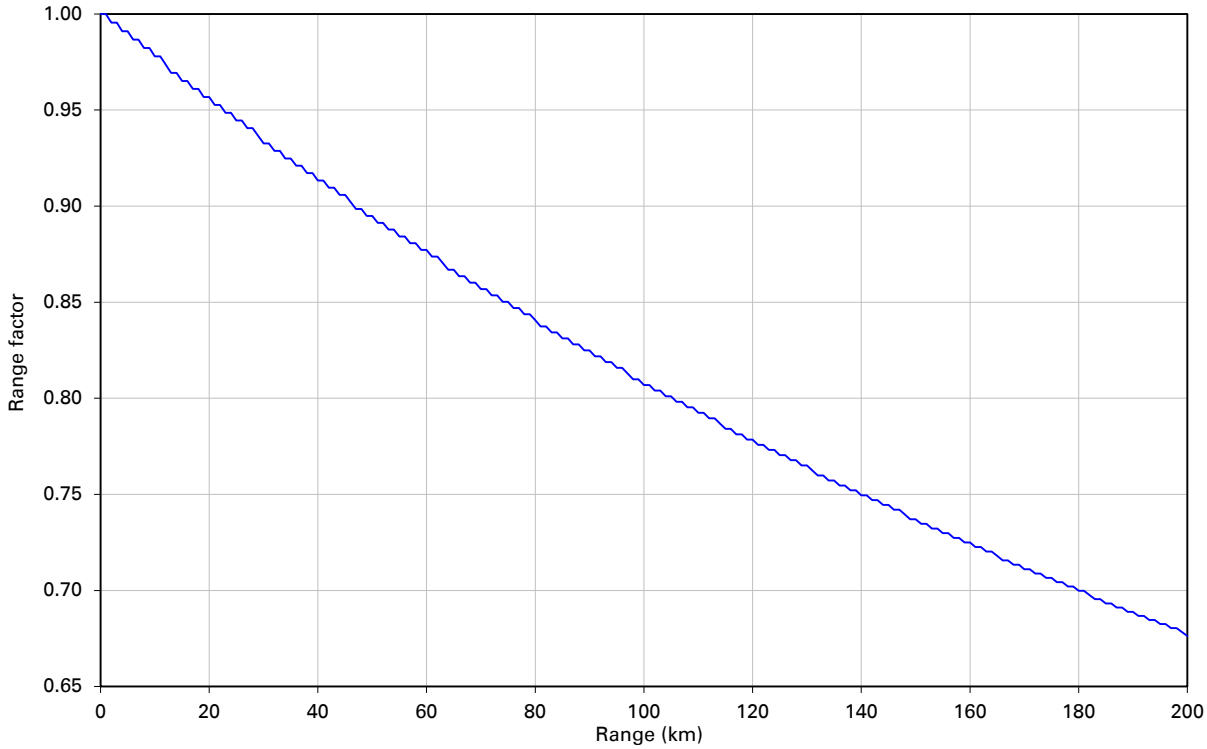


Figure 112 Range adjustment for PTP 670, adaptive, optimization IP, bandwidth 15 MHz

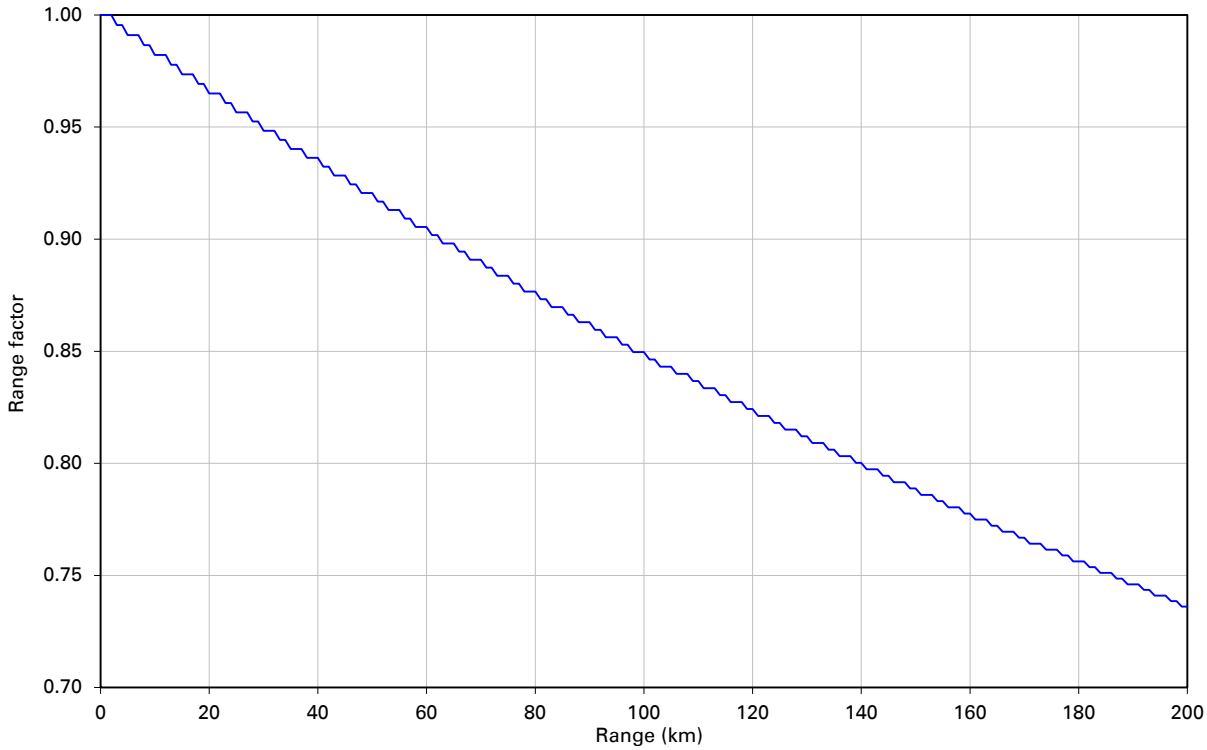
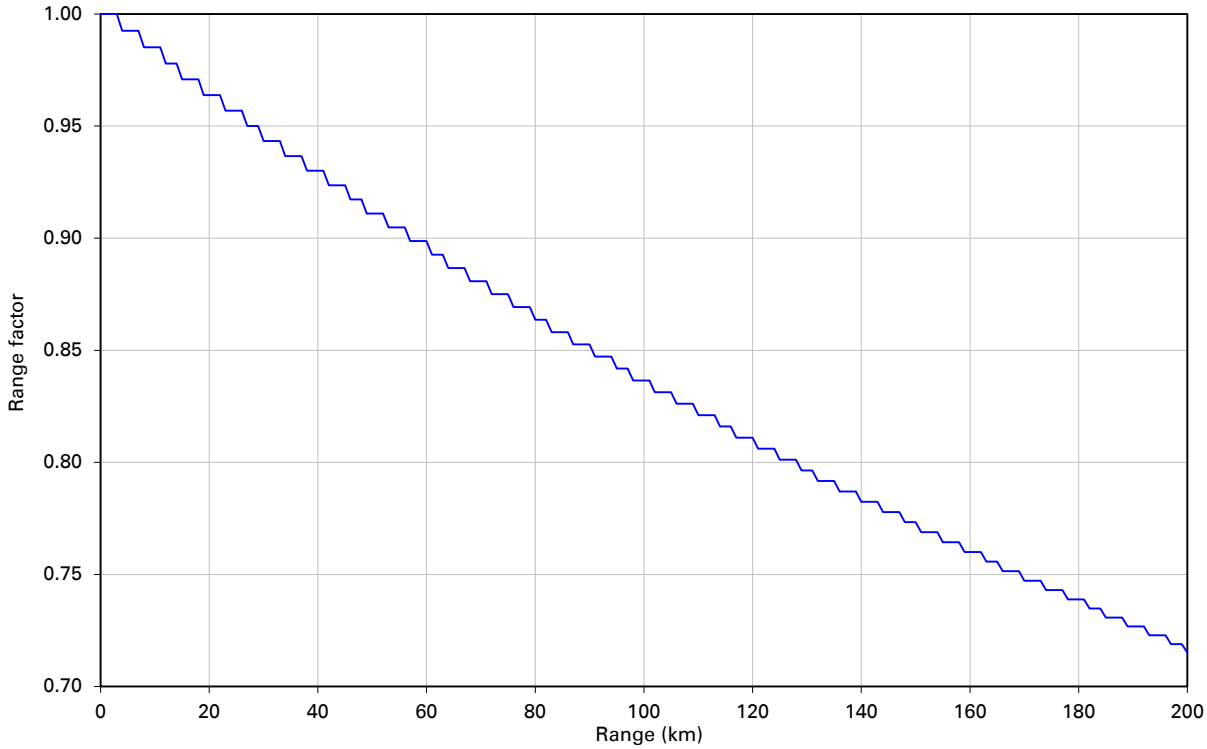


Figure 113 Range adjustment for PTP 670, adaptive, optimization IP, bandwidth 10 MHz



Data capacity in HCMP topology

Use the tables in this section to look up the TDD frame duration as a function of bandwidth, number of Slaves and Link Symmetry. Then look up one-way capacity (Mbit/s) achieved in each time slot of an HCMP sector as a function of frame duration and modulation mode.

The one-way capacity for a single Slave is the capacity per time slot multiplied by the number of timeslots. The aggregate (two-way) capacity for one Slave is the sum of two one-way capacities. The aggregate capacity for the Master is the capacity for one Slave multiplied by the number of Slaves.

Determine the frame duration from the following tables:

Channel Bandwidth	TDD Synchronization	Frame Duration Table	Capacity Table
20 MHz	Disabled	Table 129	Table 132
	Enabled		
40 MHz	Disabled	Table 130	Table 133
	Enabled	Table 131	

Table 129 HCMP frame duration, 20 MHz Channel Bandwidth

Number of Slaves	Link symmetry	Maximum range	Frame Duration
Two	1:1	5.0 km to 16.3 km	2747 µs
		16.4 km to 32.6 km	2882 µs
		32.7 km to 40.0 km	3012 µs
	1:2 and 2:1	5.0 km to 8.1 km	4000 µs
		8.2 km to 32.6 km	4184 µs
		32.7 km to 40.0 km	4367 µs
	1:3 and 3:1	5.0 km to 32.6 km	5495 µs
		32.7 km to 40.0 km	5714 µs
Three	1:1	5.0 km to 8.1 km	4000 µs
		8.2 km to 32.6 km	4184 µs
		32.7 km to 40.0 km	4367 µs
	1:2 and 2:1	5.0 km to 16.3 km	6024 µs
		16.4 km to 40.0 km	6410 µs
Four	1:1	5.0 km to 32.6 km	5495 µs
		32.7 km to 40.0 km	5714 µs

Table 130 HCMP frame duration, 40 MHz Channel Bandwidth, without TDD Sync

Number of Slaves	Link symmetry	Maximum range	Frame Duration
Two	1:1	5.0 km to 7.9 km	1370 µs
		8.0 km to 15.9 km	1439 µs
		16.0 km to 27.9 km	1504 µs
		28.0 km to 35.8 km	1575 µs
		35.9 km to 40.0 km	1623 µs
	1:2 and 2:1	5.0 km to 15.9 km	2079 µs
		16.0 km to 31.8 km	2179 µs
		31.9 km to 40.0 km	2283 µs
	1:3 and 3:1	5.0 km to 19.9 km	2747 µs
		20.0 km to 39.8 km	2882 µs
		39.9 km to 40.0 km	3012 µs
	1:4 and 4:1	5.0 km to 7.9 km	3311 µs
		8.0 km to 31.8 km	3460 µs
		31.9 km to 40.0 km	3610 µs
Three	1:1	5.0 km to 15.9 km	2079 µs
		16.0 km to 31.8 km	2179 µs
		31.9 km to 40.0 km	2283 µs
	1:2 and 2:1	5.0 km to 11.9 km	3012 µs
		12.0 km to 31.8 km	3145 µs
		31.9 km to 40.0 km	3311 µs
	1:3 and 3:1	5.0 km to 15.9 km	4000 µs
		16.0 km to 40.0 km	4184 µs
	1:4 and 4:1	5.0 km to 23.9 km	5000 µs
		24.0 km to 40.0 km	5236 µs
Four	1:1	5.0 km to 19.9 km	2747 µs
		20.0 km to 39.8 km	2882 µs
		39.9 km to 40.0 km	3012 µs
	1:2 and 2:1	5.0 km to 15.9 km	4000 µs
		16.0 km to 40.0 km	4184 µs
	1:3 and 3:1	5.0 km to 7.9 km	5236 µs
		8.0 km to 40.0 km	5495 µs

Number of Slaves	Link symmetry	Maximum range	Frame Duration
Five	1:1	5.0 km to 7.9 km	3311 µs
		8.0 km to 31.8 km	3460 µs
		31.9 km to 40.0 km	3610 µs
	1:2 and 2:1	5.0 km to 23.9 km	5000 µs
		24.0 km to 40.0 km	5236 µs
Six	1:1	5.0 km to 15.9 km	4000 µs
		16.0 km to 40.0 km	4184 µs
	1:2 and 2:1	5.0 km to 31.8 km	6024 µs
		31.9 km to 40.0 km	6410 µs
Seven	1:1	5.0 km to 39.8 km	4785 µs
		39.9 km to 40.0 km	5000 µs
Eight	1:1	5.0 km to 7.9 km	5236 µs
		8.0 km to 40.0 km	5495 µs

Table 131 HCMP frame duration, 40 MHz Channel Bandwidth, with TDD Sync

Number of Slaves	Link symmetry	Maximum range	Frame Duration
Two	1:1	5.0 km to 7.9 km	1370 µs
		8.0 km to 40.0 km	2000 µs
	1:2 and 2:1	5.0 km to 40.0 km	2283 µs
	1:3 and 3:1	5.0 km to 19.9 km	2747 µs
		20.0 km to 40.0 km	4000 µs
	1:4 and 4:1	5.0 km to 40.0 km	4000 µs
Three	1:1	5.0 km to 40.0 km	2283 µs
	1:2 and 2:1	5.0 km to 40.0 km	4000 µs
	1:3 and 3:1	5.0 km to 15.9 km	4000 µs
		16.0 km to 40.0 km	4184 µs
	1:4 and 4:1	5.0 km to 40.0 km	5495 µs
Four	1:1	5.0 km to 19.9 km	2747 µs
		20.0 km to 40.0 km	4000 µs
	1:2 and 2:1	5.0 km to 15.9 km	4000 µs
		16.0 km to 40.0 km	4184 µs
	1:3 and 3:1	5.0 km to 40.0 km	5495 µs
Five	1:1	5.0 km to 40.0 km	4000 µs
	1:2 and 2:1	5.0 km to 40.0 km	5495 µs
Six	1:1	5.0 km to 15.9 km	4000 µs
		16.0 km to 40.0 km	4184 µs
	1:2 and 2:1	5.0 km to 31.8 km	6024 µs
Seven	1:1	5.0 km to 40.0 km	5495 µs
Eight	1:1	5.0 km to 40.0 km	5495 µs

Table 132 Throughput (Mbit/s) per time slot in HCMP topology, 20 MHz Channel Bandwidth

	Frame duration					
Modulation mode	**2747 µs**	**2882 µs**	**3012 µs**	**4000 µs**	**4184 µs**	**4367 µs**
256QAM 0.81 dual	40.22	38.34	36.68	27.62	26.41	25.30
64QAM 0.92 dual	33.89	32.30	30.90	23.27	22.25	21.32
64QAM 0.75 dual	27.69	26.39	25.25	19.02	18.18	17.42
16QAM 0.87 dual	21.54	20.53	19.65	14.79	14.14	13.55
16QAM 0.63 dual	15.49	14.76	14.12	10.64	10.17	9.74
256QAM 0.81 single	20.11	19.17	18.34	13.81	13.20	12.65
64QAM 0.92 single	16.94	16.15	15.45	11.64	11.12	10.66
64QAM 0.75 single	13.85	13.20	12.63	9.51	9.09	8.71
16QAM 0.87 single	10.77	10.27	9.82	7.40	7.07	6.78
16QAM 0.63 single	7.74	7.38	7.06	5.32	5.08	4.87
QPSK 0.87 single	5.38	5.13	4.91	3.70	3.54	3.39
QPSK 0.63 single	3.87	3.69	3.53	2.66	2.54	2.43
BPSK 0.63 single	1.93	1.84	1.76	1.33	1.27	1.22

	Frame duration			
Modulation mode	**5495 µs**	**5714 µs**	**6024 µs**	**6410 µs**
256QAM 0.81 dual	20.11	19.34	18.34	17.24
64QAM 0.92 dual	16.94	16.29	15.45	14.52
64QAM 0.75 dual	13.84	13.31	12.63	11.87
16QAM 0.87 dual	10.77	10.36	9.82	9.23
16QAM 0.63 dual	7.74	7.44	7.06	6.64
256QAM 0.81 single	10.05	9.67	9.17	8.62
64QAM 0.92 single	8.47	8.14	7.73	7.26
64QAM 0.75 single	6.92	6.66	6.31	5.93
16QAM 0.87 single	5.38	5.18	4.91	4.62
16QAM 0.63 single	3.87	3.72	3.53	3.32
QPSK 0.87 single	2.69	2.59	2.46	2.31
QPSK 0.63 single	1.93	1.86	1.76	1.66
BPSK 0.63 single	0.97	0.93	0.88	0.83

Table 133 Throughput (Mbit/s) per time slot in HCMP topology, 40 MHz Channel Bandwidth

	Frame duration					
Modulation mode	**1370 µs**	**1439 µs**	**1504 µs**	**1575 µs**	**1623 µs**	**2000 µs**
256QAM 0.81 dual	80.65	76.78	73.46	70.15	68.07	55.24
64QAM 0.92 dual	67.95	64.69	61.89	59.10	57.35	46.54
64QAM 0.75 dual	55.52	52.86	50.58	48.30	46.87	38.03
16QAM 0.87 dual	43.20	41.12	39.35	37.57	36.46	29.59
16QAM 0.63 dual	31.05	29.56	28.29	27.01	26.21	21.27
256QAM 0.81 single	40.32	38.39	36.73	35.07	34.04	27.62
64QAM 0.92 single	33.97	32.34	30.95	29.55	28.68	23.27
64QAM 0.75 single	27.76	26.43	25.29	24.15	23.43	19.02
16QAM 0.87 single	21.60	20.56	19.67	18.79	18.23	14.79
16QAM 0.63 single	15.53	14.78	14.14	13.50	13.11	10.63
QPSK 0.87 single	10.80	10.28	9.84	9.39	9.11	7.40
QPSK 0.63 single	7.76	7.39	7.07	6.75	6.55	5.32
BPSK 0.63 single	3.88	3.69	3.53	3.38	3.28	2.66

	Frame duration					
Modulation mode	**2079 µs**	**2179 µs**	**2283 µs**	**2747 µs**	**2882 µs**	**3012 µs**
256QAM 0.81 dual	53.14	50.70	48.39	40.22	38.34	36.68
64QAM 0.92 dual	44.77	42.72	40.77	33.89	32.30	30.91
64QAM 0.75 dual	36.59	34.91	33.32	27.69	26.39	25.26
16QAM 0.87 dual	28.46	27.16	25.92	21.54	20.53	19.65
16QAM 0.63 dual	20.46	19.52	18.63	15.49	14.76	14.12
256QAM 0.81 single	26.57	25.35	24.20	20.11	19.17	18.34
64QAM 0.92 single	22.39	21.36	20.39	16.94	16.15	15.45
64QAM 0.75 single	18.29	17.45	16.66	13.85	13.20	12.63
16QAM 0.87 single	14.23	13.58	12.96	10.77	10.27	9.82
16QAM 0.63 single	10.23	9.76	9.32	7.74	7.38	7.06
QPSK 0.87 single	7.12	6.79	6.48	5.39	5.13	4.91
QPSK 0.63 single	5.11	4.88	4.66	3.87	3.69	3.53
BPSK 0.63 single	2.56	2.44	2.33	1.94	1.84	1.76

	Frame duration					
Modulation mode	**3145 µs**	**3311 µs**	**3460 µs**	**3610 µs**	**4000 µs**	**4184 µs**
256QAM 0.81 dual	35.13	33.37	31.93	30.61	27.62	26.41
64QAM 0.92 dual	29.60	28.11	26.90	25.79	23.27	22.25
64QAM 0.75 dual	24.19	22.97	21.99	21.07	19.02	18.18
16QAM 0.87 dual	18.82	17.87	17.10	16.39	14.79	14.14
16QAM 0.63 dual	13.53	12.85	12.30	11.78	10.64	10.17
256QAM 0.81 single	17.56	16.68	15.97	15.30	13.81	13.20
64QAM 0.92 single	14.80	14.06	13.45	12.89	11.64	11.12
64QAM 0.75 single	12.09	11.49	10.99	10.54	9.51	9.09
16QAM 0.87 single	9.41	8.94	8.55	8.20	7.40	7.07
16QAM 0.63 single	6.76	6.42	6.15	5.89	5.32	5.08
QPSK 0.87 single	4.70	4.47	4.28	4.10	3.70	3.54
QPSK 0.63 single	3.38	3.21	3.07	2.95	2.66	2.54
BPSK 0.63 single	1.69	1.61	1.54	2.33	1.33	1.27

Modulation mode	**4785 µs**	**5000 µs**	**5236 µs**	**5495 µs**	**6024 µs**	**6410 µs**
256QAM 0.81 dual	23.09	22.10	21.10	20.11	18.34	17.24
64QAM 0.92 dual	19.45	18.62	17.78	16.94	15.45	14.52
64QAM 0.75 dual	15.90	15.21	14.53	13.84	12.63	11.87
16QAM 0.87 dual	12.37	11.84	11.30	10.77	9.82	9.23
16QAM 0.63 dual	8.89	8.51	8.12	7.74	7.06	6.64
256QAM 0.81 single	11.54	11.05	10.55	10.05	9.17	8.62
64QAM 0.92 single	9.73	9.31	8.89	8.47	7.73	7.26
64QAM 0.75 single	7.95	7.61	7.26	6.92	6.31	5.93
16QAM 0.87 single	6.18	5.92	5.65	5.38	4.91	4.62
16QAM 0.63 single	4.45	4.25	4.06	3.87	3.53	3.32
QPSK 0.87 single	3.09	2.96	2.83	2.69	2.46	2.31
QPSK 0.63 single	2.22	2.13	2.03	1.94	1.77	1.66
BPSK 0.63 single	1.11	1.06	1.02	0.97	0.88	0.83

TDM traffic load

Encapsulated data

The NIDU supports separate management and TDM data protocol interfaces. The management interface is between the NIDU and a directly-connected ODU. The TDM data interface is between peer NIDUs. The ODU does not interact with the TDM data protocol, except in as much as it provides a separate high priority queue for encapsulated TDM data at the wireless interface.

The wireless capacity sacrificed to carry the encapsulated TDM data is shown in Table 134.

Table 134 TDM traffic load

Channels	Octets per Ethernet frame	E1 data rate (Mbit/s)	T1 data rate (Mbit/s)
1	90	2.94	2.22
2	157	5.08	3.83
3	224	7.22	5.45
4	291	9.36	7.06
5	358	11.50	8.67
6	425	13.65	10.29
7	492	15.79	11.90
8	559	17.93	13.52

In the best case (eight channels) the encapsulation has an efficiency of 91.6%.

Timing only

The resulting TDM traffic load in timing-only operation is shown in Table 135.

Table 135 TDM traffic load in timing-only

Channels	Octets per Ethernet frame	E1 data rate (Mbit/s)	T1 data rate (Mbit/s)
1	64	0.53	0.40
2	64	0.53	0.40
3	64	0.53	0.40
4	64	0.53	0.40
5	64	0.53	0.40
6	64	0.53	0.40
7	65	0.54	0.40
8	71	0.58	0.44

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USB library functions

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D3 JS library

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Compliance with safety standards

This section lists the safety specifications against which the PTP 670 has been tested and certified. It also describes how to keep RF exposure within safe limits.

Electrical safety compliance

The PTP 670 hardware has been tested for compliance to the electrical safety specifications listed in Table 136.

Table 136 PTP 670 safety compliance specifications

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

Electromagnetic compatibility (EMC) compliance

The PTP 670 complies with European EMC Specification EN301 489-1 with testing carried out to the detailed requirements of EN301 489-17.

Note

For EN 61000-4-2: 1995 to 2009 Electro Static Discharge (ESD), Class 2, 8 kV air, 4 kV contact discharge, the PTP 670 has been tested to ensure immunity to 15 kV air and 8 kV contact.

Table 137 lists the EMC specification type approvals that have been granted for PTP 670 products.

Table 137 EMC compliance

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

Human exposure to radio frequency energy

Relevant standards (USA and EC) applicable when working with RF equipment are:

- ANSI IEEE C95.1-1991, IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz.
- Council recommendation of 12 July 1999 on the limitation of exposure of the general public to electromagnetic fields (0 Hz to 300 GHz) (1999/519/EC) and respective national regulations.
- *Directive 2013/35/EU of the European Parliament and of the Council of 26 June 2013* on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (electromagnetic fields) (20th individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC) and repealing Directive 2004/40/EC
- US FCC limits for the general population. See the FCC web site at http://www.fcc.gov, and the policies, guidelines, and requirements in Part 1 of Title 47 of the Code of Federal Regulations.
- Health Canada limits for the general population. See the Health Canada web site at http://www.hc-sc.gc.ca/ewh-semt/pubs/radiation/99ehd-dhm237/limits-limites_e.html and Safety Code 6.
- EN 50383:2002 to 2010 Basic standard for the calculation and measurement of electromagnetic field strength and SAR related to human exposure from radio base stations and fixed terminal stations for wireless telecommunication systems (110 MHz - 40 GHz).
- BS EN 50385:2002 Product standard to demonstrate the compliances of radio base stations and fixed terminal stations for wireless telecommunication systems with the basic restrictions or the reference levels related to human exposure to radio frequency electromagnetic fields (110 MHz – 40 GHz) – general public.
- ICNIRP (International Commission on Non-Ionizing Radiation Protection) guidelines for the general public. See the ICNIRP web site at http://www.icnirp.de/ and Guidelines for Limiting Exposure to Time-Varying Electric, Magnetic, and Electromagnetic Fields.

Power density exposure limit

Install the radios for the PTP 670 family of PTP wireless solutions so as to provide and maintain the minimum separation distances from all persons.

The applicable power density exposure limit for RF energy between 4800 MHz and 6050 MHz is **10 W/m^2**.

Calculation of power density

The following calculation is based on the ANSI IEEE C95.1-1991 method, as that provides a worst case analysis. Details of the assessment to EN50383:2002 can be provided, if required.

Peak power density in the far field of a radio frequency point source is calculated as follows:

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

Where:

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

Rearranging terms to solve for distance yields:

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

Calculated distances

Table 138 shows calculated minimum separation distances each frequency band and for the highest gain antenna of each type, assuming that the equipment is operating at the maximum transmit power for PTP 670. At these and greater separation distances, the power density from the RF field is below generally accepted limits for the general population.

Calcul des distances pour la conformité aux limites de radiation radiofréquence

La Table 138 indique les distances minimales de séparation calculées, les distances recommandées et les marges de sécurité qui en découlent pour chaque bande de fréquence et chaque antenne. À ces distance et des distance supérieures, la densité de puissance du champ de radiofréquence est inférieur aux limites généralement admises pour la population.

Table 138 Minimum safe distances for PTP 670 at maximum transmitter power

Antenna	P (W) (*1)	G (*2)	S (W/m²)	d (m) (*3)
Parabolic 6 ft (38.1 dBi)	0.635	5248.1	10	5.15
Parabolic 4 ft (35.3 dBi)	0.635	3388.4	10	3.73
Flat plate 2 ft (28.5 dBi)	0.635	575.4	10	1.71
Integrated (21.0 dBi)	0.635	125.9	10	0.80
Sectorized (17.0 dBi)	0.635	40.7	10	0.45
Omni (13.0 dBi)	0.635	16.2	10	0.29

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

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

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

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

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

distance minimale de source ponctuelle (en mètres)

Note

Gain of antenna in dBi = 10*log(G).

The regulations require that the power used for the calculations is the maximum power in the transmit burst subject to allowance for source-based time-averaging.

Remarque

Gain de l'antenne en dBi = 10*log(G).

Les règlements exigent que la puissance utilisée pour les calculs soit la puissance maximale de la rafale de transmission soumis à une réduction pour prendre en compte le rapport cyclique pour les signaux modulés dans le temps.

Minimum separation distances for other transmitter powers, antenna gains and power densities

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

In many deployments, the antenna gains will be lower than the maximum listed in Table 138 and the transmitter power will be reduced to comply with applicable regulations; in such cases, the minimum separation distances will be significantly reduced compared with the results in Table 138.

Minimum separation distances in FCC bands

The minimum separation distances for operation in FCC regulatory bands are listed in Table 139.

Table 139 Minimum safe distances for FCC bands

Band	Antenna	P (W) (*1)	G (*2)	S (W/m^2)	d (m) (*3)
4.9 GHz	Parabolic 6 ft (36.0 dBi)	0.127	3235.9	10	1.81
	Integrated (23.0 dBi)	0.326	199.5	10	0.72
	Sectorized (17.0 dBi)	0.333	40.7	10	0.33
	Omni (13.0 dBi)	0.333	16.2	10	0.21
5.1 GHz	Parabolic 4 ft (34.5 dBi)	0.025	2290.9	10	0.16
	Integrated (23.0 dBi)	0.020	199.5	10	0.16
	Sectorized (17.0 dBi)	0.028	40.7	10	0.16
	Omni (13.0 dBi)	0.158	16.2	10	0.16
5.2 GHz	Parabolic 4 ft (34.5 dBi)	0.0002	2290.9	10	0.08
	Integrated (23.0 dBi)	0.0011	199.5	10	0.08
	Sectorized (17.0 dBi)	0.016	40.7	10	0.07
	Omni (13.0 dBi)	0.040	16.2	10	0.07
5.4 GHz	Parabolic 4 ft (28.5 dBi)	0.0011	2290.9	10	0.08
	Integrated (23.0 dBi)	0.0009	199.5	10	0.08
	Sectorized (17.0 dBi)	0.016	40.7	10	0.07
	Omni (13.0 dBi)	0.040	16.2	10	0.07
5.8 GHz	Parabolic 6 ft (38.1 dBi)	0.635	5248.1	10	4.59
	Parabolic 4 ft (35.3 dBi)	0.635	2754.2	10	3.33
	Integrated (23.0 dBi)	0.635	199.5	10	0.90
	Sectorized (17.0 dBi)	0.080	40.7	10	0.16
	Omni (13.0 dBi)	0.201	16.2	10	0.16

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

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

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

Minimum separation distances in ISEDC bands

The minimum separation distances for operation in ISEDC regulatory bands are listed in Table 140.

Table 140 Minimum safe distances for ISEDC bands

Band	Antenna	P (W) (*1)	G (*2)	S (W/m^2) (*3)	d (m) (*4)
4.9 GHz	Parabolic 6 ft (36.0 dBi)	0.127	3235.9	8.76	1.93
	Integrated (23.0 dBi)	0.326	199.5	8.76	0.77
	Sectorized (17.0 dBi)	0.333	40.7	8.76	0.35
	Omni (13.0 dBi)	0.333	16.2	8.76	0.22
5.1 GHz	Parabolic 4 ft (34.5 dBi)	0.025	2290.9	9.01	0.17
	Integrated (23.0 dBi)	0.020	199.5	9.01	0.17
	Sectorized (17.0 dBi)	0.028	40.7	9.01	0.17
	Omni (13.0 dBi)	0.158	16.2	9.01	0.17
5.2 GHz	Parabolic 4 ft (34.5 dBi)	0.0002	2290.9	9.13	0.08
	Integrated (23.0 dBi)	0.0011	199.5	9.13	0.08
	Sectorized (17.0 dBi)	0.016	40.7	9.13	0.08
	Omni (13.0 dBi)	0.040	16.2	9.13	0.08
5.4 GHz	Parabolic 4 ft (28.5 dBi)	0.0011	2290.9	9.39	0.08
	Integrated (23.0 dBi)	0.0009	199.5	9.39	0.08
	Sectorized (17.0 dBi)	0.016	40.7	9.39	0.07
	Omni (13.0 dBi)	0.040	16.2	9.39	0.07
5.8 GHz	Parabolic 6 ft (38.1 dBi)	0.635	5248.1	9.69	4.66
	Parabolic 4 ft (35.3 dBi)	0.635	2754.2	9.69	3.38
	Integrated (23.0 dBi)	0.635	199.5	9.69	0.91
	Sectorized (17.0 dBi)	0.080	40.7	9.69	0.16
	Omni (13.0 dBi)	0.201	16.2	9.69	0.16

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

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

(*3) S: Safe limit in W/m^2 as specified in RS-102 Issue 5.

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

Compliance with radio regulations

This section describes how the PTP 670 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.

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Attention

Les changements ou modifications non expressément approuvés par les réseaux de Cambium pourraient annuler l'autorité de l'utilisateur à faire fonctionner le système.

Attention

Pour la version du produit avec une antenne externe, et afin de réduire le risque d'interférence avec d'autres utilisateurs, le type d'antenne et son gain doivent être choisis afin que la puissance isotrope rayonnée équivalente (PIRE) ne soit pas supérieure au minimum nécessaire pour établir une liaison de la qualité requise.

Type approvals

The system has been tested against various local technical regulations and found to comply. Table 141 to Table 145 list the radio specification type approvals that have been granted for PTP 670 products.

Some of the frequency bands in which the system operates are “license exempt” and the system is allowed to be used provided it does not cause interference. In these bands, the licensing authority does not guarantee protection against interference from other products and installations.

Table 141 Radio certifications (4.9 GHz)

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

Table 142 Radio certifications (5.1 GHz)

Region	Regulatory approvals
USA	FCC 47 CFR Part 15E
Canada	SMSE-013-17

Table 143 Radio certifications (5.2 GHz)

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

Table 144 Radio certifications (5.4 GHz)

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

Table 145 Radio certifications (5.8 GHz)

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

FCC compliance

The PTP 670 complies with the regulations that are in force in the USA.

Caution

If this equipment does cause interference to radio or television reception, refer to Radio and television interference on page 8-14 for corrective actions.

FCC product labels

The FCC identifiers for the PTP 670 Series are provided in Table 146.

Table 146 FCC IDs

Product	ID
PTP 670 (4.9 to 6.05 GHz) Integrated 23 dBi ODU (FCC) PTP 670 (4.9 to 6.05 GHz) Connectorized ODU (FCC)	QWP-50670
PTP 670 (4.9 to 5.9 GHz) ATEX/HAZLOC Integrated 23 dBi ODU (FCC) PTP 670 (4.9 to 5.9 GHz) ATEX/HAZLOC Connectorized ODU (FCC)	QWP-50670-EX

FCC identifiers are reproduced on the product labels for the FCC regional variant (Figure 114 and Figure 115).

Figure 114 FCC certifications on standard ODU product labels

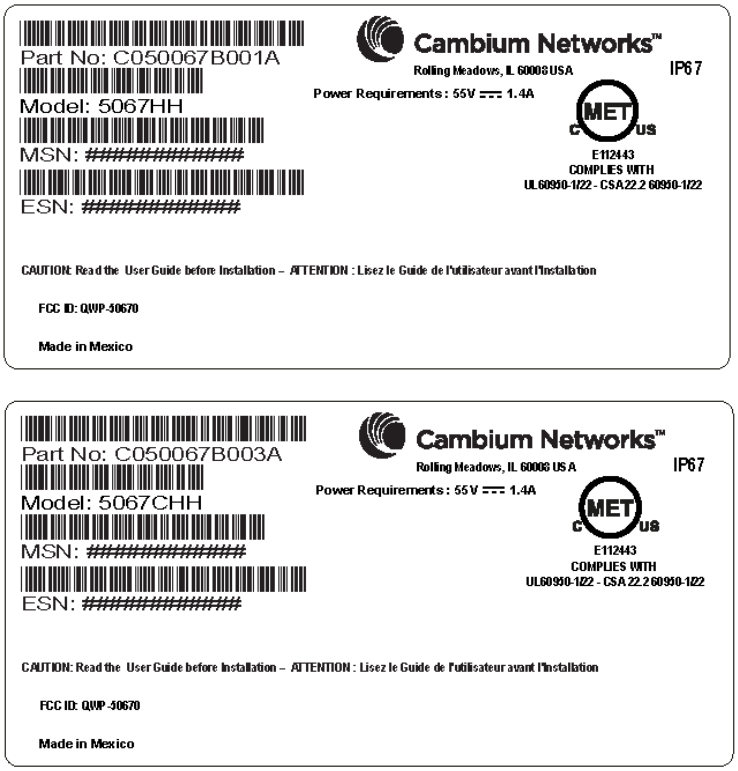
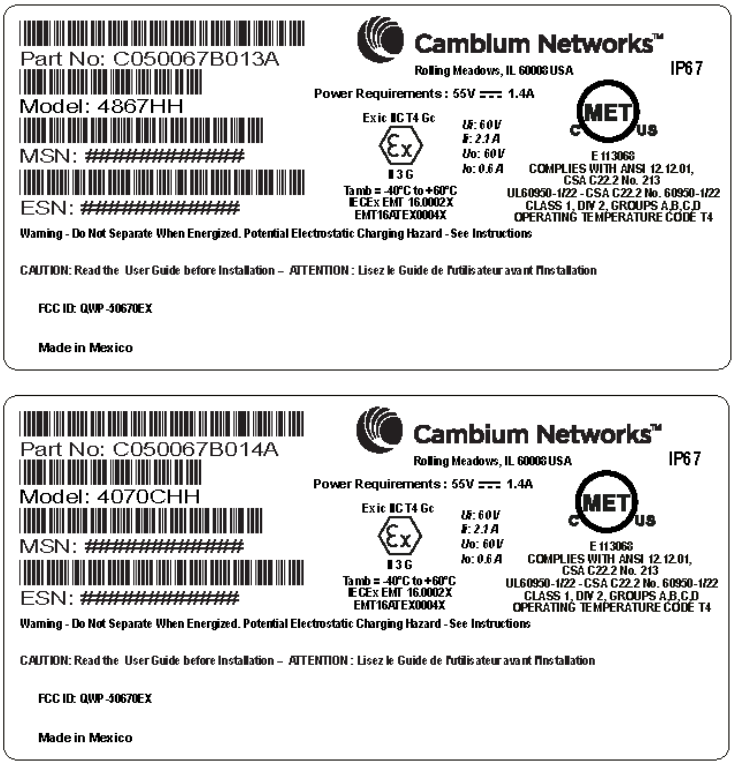


Figure 115 FCC certifications on ATEX/HAZLOC ODU product labels



4.9 GHz FCC notification

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

5.8 GHz FCC notification

This device complies with part 15C of the US FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) This device must accept any interference received, including interference that may cause undesired operation.

5.8 GHz band edge channel power reduction

Transmitter power is restricted in edge channels when the PTP 670 is operated the 5.8 GHz band with the USA country license. The amount of transmitter power reduction has been determined during regulatory testing and cannot be changed by professional installers or end users. Units intended for the USA market are locked for use in the USA and cannot be operated under the regulations for other regulatory domains.

The maximum transmitter power in band edge channels for the FCC 5.8 GHz band is listed in Table 147.

Table 147 Edge channel power reduction in regulatory band 1

Channel Bandwidth	Channel Frequency	Maximum conducted power
5 MHz	Below 5733.0 MHz	24 dBm

Channel Bandwidth	Channel Frequency	Maximum conducted power
	Above 5838.0 MHz	24 dBm
10 MHz	Below 5737.0 MHz	25 dBm
	Above 5837.0 MHz	25 dBm
15 MHz	Below 5740.0 MHz	25 dBm
	Above 5835.0 MHz	25 dBm
20 MHz	Below 5742.0 MHz	25 dBm
	Above 5832.0 MHz	25 dBm
30 MHz	Below 5752.0 MHz	25 dBm
	Above 5822.0 MHz	25 dBm
40 MHz	Below 5765.0 MHz	25 dBm
	Above 5810.0 MHz	25 dBm
45 MHz	Below 5778.0 MHz	23 dBm
	Above 5795.0 MHz	22 dBm

Selection of antennas

For guidance on the selection of dedicated external antennas refer to Choosing external antennas on page 3-29.

For a list of antennas submitted to the FCC for use with the PTP 670 refer to FCC approved antennas on page 2-22.

ISEDC compliance

The PTP 670 complies with the regulations that are in force in Canada.

Caution

If this equipment does cause interference to radio or television reception, refer to Radio and television interference on page 8-14 for corrective actions.

Attention

Si cet équipement cause des interférences à la réception radio ou télévision, reportez-vous a la section Radio and television interference page 8-14 pour déterminer comment remédier au problème.

ISEDC product labels

The ISEDC identifier for the PTP 670 Series is provided in Table 148.

Table 148 ISEDC IDs

Product	ID
PTP 670 (4.9 to 6.05 GHz) Integrated 23 dBi ODU (IC)	109AO-50670
PTP 670 (4.9 to 6.05 GHz) Connectorized ODU (IC)	
PTP 670 (4.9 to 5.9 GHz) ATEX/HAZLOC Integrated 23 dBi ODU (IC)	
PTP 670 (4.9 to 5.9 GHz) ATEX/HAZLOC Connectorized ODU (IC)	

ISEDC identifiers are reproduced on the product labels for the IC regional variant (Figure 116 and Figure 117).

Figure 116 ISEDC certifications on standard ODU product labels

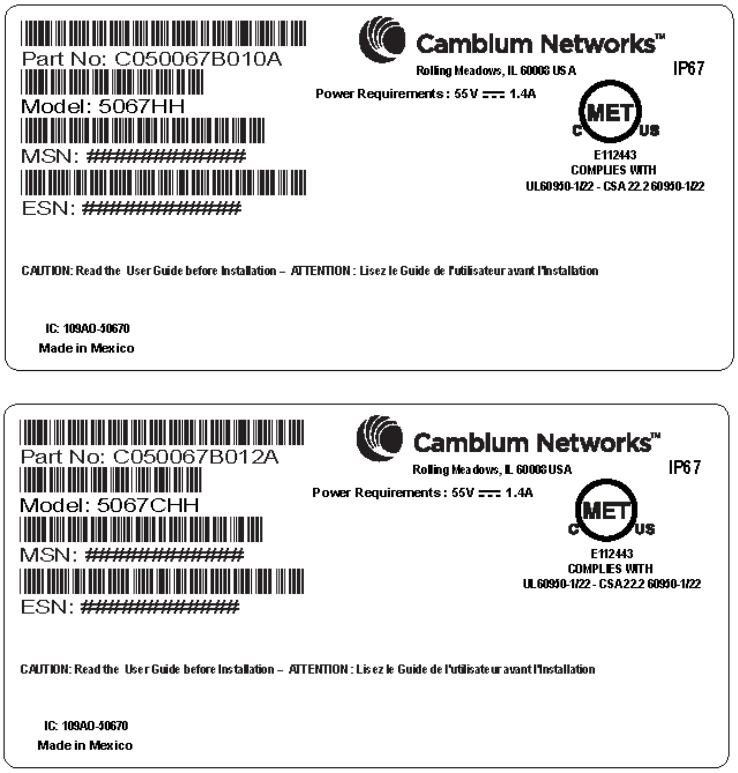
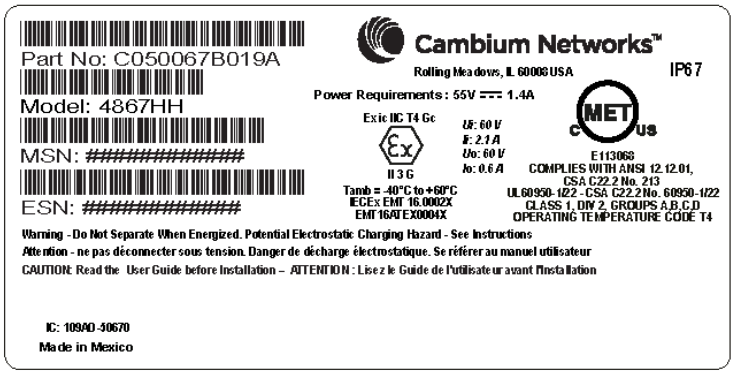
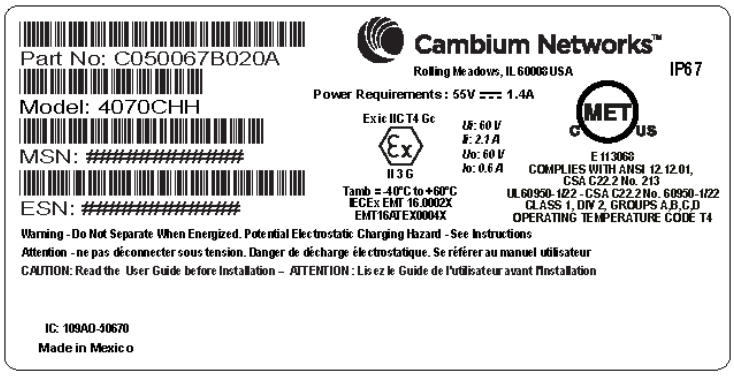


Figure 117 ISEDC certifications on ATEX/HAZLOC ODU product labels





4.9 GHz ISEDC notification

The system has been approved under ISEDC 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 ISDEC

Le système a été approuvé en vertu de ISDEC 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 ISEDC notification

This device complies with ISEDC RSS-247. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) This device must accept any interference received, including interference that may cause undesired operation. Users should be cautioned to take note that high power radars are allocated as primary users (meaning they have priority) of 5250 – 5350 MHz and 5650 – 5850 MHz and these radars could cause interference and/or damage to license-exempt local area networks (LELAN).

For the connectorized version of the product and in order to reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the equivalent isotropically radiated power (EIRP) is not more than that permitted by the regulations. The transmitted power must be reduced to achieve this requirement.

Utilisation de la bande 5.4 GHz ISDEC

Cet appareil est conforme à ISDEC RSS-247. Son fonctionnement est soumis aux deux conditions suivantes: (1) Ce dispositif ne doit pas causer d'interférences nuisibles, et (2) Cet appareil doit tolérer toute interférence reçue, y compris les interférences pouvant entraîner un fonctionnement indésirable. Les utilisateurs doivent prendre garde au fait que les radars à haute puissance sont considères comme les utilisateurs prioritaires de 5250 à 5350 MHz et 5650 à 5850 MHz et ces radars peuvent causer des interférences et / ou interférer avec un réseau local ne nécessitant pas de licence.

Pour la version du produit avec antenne externe et afin de réduire le risque d'interférence avec d'autres utilisateurs, le type d'antenne et son gain doivent être choisis afin que la puissance isotrope rayonnée équivalente (PIRE) ne soit pas supérieure à celle permise par la règlementation. Il peut être nécessaire de réduire la puissance transmise doit être réduite pour satisfaire cette exigence.

5.8 GHz ISEDC notification

RSS-GEN issue 3 (7.1.3) Licence-Exempt Radio Apparatus:

> This device complies with ISEDC 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'Innovation, Sciences et Développement Economique Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes : (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.*

In Canada, high power radars are allocated as primary users (meaning they have priority) of the 5650 – 5850 MHz spectrum. These radars could cause interference or damage to license-exempt local area network (LE-LAN) devices.

Au Canada, les radars à haute puissance sont désignés comme utilisateurs principaux (ils ont la priorité) de la 5650 - spectre 5850 MHz. Ces radars peuvent causer des interférences et / ou interférer avec un réseau local ne nécessitant pas de licence.

5.4 GHz band edge channel power reduction

Equivalent isotropic radiated power (EIRP) is restricted in edge channels when the PTP 670 is operated the 5.4 GHz band with the Canada country license. The amount of EIRP reduction has been determined during regulatory testing and cannot be changed by professional installers or end users. Units intended for the Canada market are locked for use in Canada and cannot be operated under the regulations for other regulatory domains.

The PTP 670 takes into account the antenna gain and cable loss configured by the professional installer in the web-based interface to limit the EIRP to ensure regulatory compliance. No additional action is required by the installer to reduce transmitter power in band edge channels.

The maximum EIRP in band edge channels for the Canada 5.4 GHz band is listed in Table 149.

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 670 est configuré pour utiliser la band 5,4 GHz au Canada. La réduction de la PIRE a été déterminée lors de tests réglementaires et ne peut être changée par des installateurs professionnels ou les utilisateurs. Les PTP 670 destinées au Canada sont verouillés pour opérer exclusivement au Canada et ne peuvent pas être configurés pour adhérer à la réglementation d’autres pays.

Le PTP 670 prend en compte le gain de l'antenne et les pertes des câbles de connexion configurés par l'installateur professionnel via l'interface graphique pour limiter la PIRE pour assurer la conformité à la réglementation en vigueur. Aucune action supplémentaire n'est requise par l'installateur afin de réduire la puissance d'émission dans les canaux aux bords de bande.

La PIRE maximale dans les canaux aux bords de bande 5,4 GHz pour le Canada est listée dans la Table 149.

Table 149 Edge channel power reduction in regulatory bands 12 and 13

Channel Bandwidth	Channel Frequency	Maximum EIRP
5 MHz	Below 5476.0 MHz	24 dBm
	Above 5720.0 MHz	24 dBm
10 MHz	Below 5478.0 MHz	27 dBm
	Above 5715.0 MHz	25 dBm
15 MHz	Below 5480.0 MHz	29 dBm
	Above 5709.0 MHz	26 dBm
20 MHz	Below 5482.0 MHz	30 dBm
	Above 5704.0 MHz	23 dBm
30 MHz	Below 5492.0 MHz	27 dBm
	Above 5694.0 MHz	25 dBm
40 MHz	Below 5500.0 MHz	28 dBm
	Above 5691.0 MHz	24 dBm
45 MHz	Below 5508.0 MHz	24 dBm
	Above 5686.0 MHz	22 dBm

5.8 GHz band edge channel power reduction

Transmitter power is restricted in edge channels when the PTP 670 is operated the 5.8 GHz band with the Canada country license. The amount of transmitter power reduction has been determined during regulatory testing and cannot be changed by professional installers or end users. Units intended for the Canada market are locked for use in Canada and cannot be operated under the regulations for other regulatory domains.

The maximum transmitter power in band edge channels for the Canada 5.8 GHz band is listed in Table 147.

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 670 est configuré pour utiliser la band 5,8 GHz au Canada. La réduction de la PIRE a été déterminée lors de tests réglementaires et ne peut être changée par des installateurs professionnels ou les utilisateurs. Les PTP 670 destinés au Canada sont verouillés pour opérer exclusivement au Canada et ne peuvent pas être configurés pour adhérer à la réglementation d'autres pays.

La PIRE maximale dans les canaux aux bords de bande 5,4 GHz pour le Canada est listée dans la Table 147.

Selection of antennas

For guidance on the selection of dedicated external antennas refer to Choosing external antennas on page 3-29.

For a list of antennas submitted to the ISEDC for use with the PTP 670 refer to ISEDC approved antennas on page 2-25.

Note

Under ISEDC regulations, this radio transmitter may only operate using an antenna of a type and maximum (or lesser) gain approved for the transmitter by ISEDC. 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'Innovation, Sciences et Développement Economique 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 ISDEC. 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.

Chapter 5: Installation

This chapter describes how to install and test the hardware for a PTP 670 link. It contains the following topics:

- Safety on page 5-2 contains important safety guidelines that must be observed by personnel installing or operating PTP 670 equipment.
- ODU variants and mounting bracket options on page 5-6 provides details of six different bracket options, including the type of ODu and range of pole diameters supported by each option.
- Installing the ODU and top LPU on page 5-7 describes how to mount and ground an Integrated or Connectorized ODU, and how to mount and ground the top LPU.
- Install external antennas for a Connectorized ODU on page 5-11 describes how to mount and connect an external antenna for the Connectorized ODU.
- Installing the copper Cat5e Ethernet interface on page 5-14 describes how to install the copper Cat5e power over Ethernet interface from the ODU (PSU port) to the PSU.
- Installing the PSU on page 5-22 describes how how to install a power supply unit for the PTP 670, either the AC Power Injector 56V, the AC+DC Enhanced Power Injector 56V, or the CMM5.
- Installing a PTP-SYNC unit on page 5-25 describes how to install a PTP-SYNC unit for TDD synchronization.
- Installing the Trimble Accutime GPS receiver on page 5-29 describes how to install a GPS receiver as the timing reference source for PTP-SYNC or CMM5.
- Installing a NIDU on page 5-39 describes how to install a network indoor unit (NIDU) for TDM (T1 or E1) interfaces.
- Installing an SFP Ethernet interface on page 5-25 describes how to install an optical or copper Cat5e Ethernet interface from the ODU (SFP port) to a connected device.
- Installing an Aux Ethernet interface on page 5-54 describes how to install a copper Cat5e Ethernet interface from the ODU (Aux port) to a connected device.
- Supplemental installation information on page 5-55 contains detailed installation procedures that are not included in the above topics, such as how to strip cables, create grounding points and weatherproof connectors.

Note

These instructions assume that LPUs are being installed from the LPU and grounding kit (Cambium part number C000065L007A). If the installation does not require LPUs, adapt these instructions as appropriate.

If LPUs are being installed, only use the five black-capped EMC cable glands supplied in the LPU and grounding kit. The silver-capped cable glands supplied in the ODU kits must only be used in PTP 670 installations which do not require LPUs.

Safety

Warning

To prevent loss of life or physical injury, observe the following safety guidelines. In no event shall Cambium Networks be liable for any injury or damage caused during the installation of the Cambium PTP 670. Ensure that only qualified personnel install a PTP 670 link.

Power lines

Exercise extreme care when working near power lines.

Working at heights

Exercise extreme care when working at heights.

PSU

Always use the AC Power Injector 56V, AC+DC Enhanced Power Injector 56V (PSU) or CMM5 to power the ODU. Failure to use these Cambium supplied PSUs could result in equipment damage and will invalidate the safety certification and may cause a safety hazard.

Grounding and protective earth

The Outdoor Unit (ODU) must be properly grounded to protect against lightning. It is the user's responsibility to install the equipment in accordance with national regulations. In the USA follow the requirements of the National Electrical code NFPA 70-2005 and 780-2004 *Installation of Lightning Protection Systems*. In Canada, follow Section 54 of the *Canadian Electrical Code*. These codes describe correct installation procedures for grounding the outdoor unit, mast, lead-in wire and discharge unit, size of grounding conductors and connection requirements for grounding electrodes. Other regulations may apply in different countries and therefore it is recommended that installation of the outdoor unit be contracted to a professional installer.

AC supply

To power the ODU from an AC supply, use the AC Power Injector 56V (Cambium part number N000065L001C), AC+DC Enhanced Power Injector 56V (Cambium part number C000065L002C) or CMM5.

Always use an appropriately rated and approved AC supply cord-set in accordance with the regulations of the country of use.

DC supply

To power the ODU from a DC supply, use the AC+DC Enhanced Power Injector 56V (Cambium part number C000065L002C) or CMM5. Ensure that the DC power supply meets the requirements specified in PSU DC power supply on page 3-15.

Powering down before servicing

Before servicing PTP 670 equipment, always switch off the power supply and unplug it from the PSU.

Do not disconnect the RJ45 drop cable connectors from the ODU while the PSU is connected to the power supply. Always remove the AC or DC input power from the PSU.

Primary disconnect device

The main power supply is the primary disconnect device. The AC+DC Enhanced Power Injector 56V is fused on the DC input. Some installations will also require an additional circuit breaker or isolation switch to be fitted in the DC supply.

External cables

Safety may be compromised if outdoor rated cables are not used for connections that will be exposed to the outdoor environment. For outdoor copper Cat5e Ethernet interfaces, always use Cat5e cable that is gel-filled and shielded with copper-plated steel. Alternative types of drop cable are not supported by Cambium Networks for the PTP 670..

Drop cable tester

The PSU output voltage may be hazardous in some conditions, for example in wet weather. Do NOT connect a drop cable tester to the PSU, either directly or via LPUs.

Grounding PTP-SYNC

In order to meet the safety requirements for deployment in Australia and New Zealand (AS/NZS 60950-1), the PTP-SYNC unit, if deployed, must be grounded to a Protective Ground in accordance with Local Electrical Regulations.

RF exposure near the antenna

Strong radio frequency (RF) fields will be present close to the antenna when the transmitter is on. Always turn off the power to the ODU before undertaking maintenance activities in front of the antenna.

Minimum separation distances

Ensure that personnel are not exposed to unsafe levels of RF energy. The units start to radiate RF energy as soon as they are powered up. Never work in front of the antenna when the ODU is powered. Install the ODUs so as to provide and maintain the minimum separation distances from all persons. For minimum separation distances, see Calculated distances on page 4-22.

Grounding and lightning protection requirements

Ensure that the installation meets the requirements defined in Grounding and lightning protection on page 3-11.

Grounding cable installation methods

To provide effective protection against lightning induced surges, observe these requirements:

- Grounding conductor runs are as short, straight and smooth as possible, with bends and curves kept to a minimum.
- Grounding cables must not be installed with drip loops.
- All bends must have a minimum radius of 200 mm (8 in) and a minimum angle of 90°. A diagonal run is preferable to a bend, even though it does not follow the contour or run parallel to the supporting structure.
- All bends, curves and connections must be routed towards the grounding electrode system, ground rod, or ground bar.
- Grounding conductors must be securely fastened.
- Braided grounding conductors must not be used.
- Approved bonding techniques must be used for the connection of dissimilar metals.

Siting ODUs and antennas

ODUs, external antennas and GPS receivers for PTP-SYNC are not designed to survive direct lightning strikes. For this reason they must be installed in Zone B as defined in Lightning protection zones on page 3-11. Mounting in Zone A may put equipment, structures and life at risk.

Thermal Safety

The ODU enclosure may be hot to the touch when in operation. The ODU must not be operated in ambient temperatures exceeding 40°C unless mounted in a Restricted Access Location. For more information, see ODU ambient temperature limits on page 3-13.

Warning

Do not install the ODU in a location where the ambient temperature could exceed 40°C unless this is a Restricted Access Location as defined by EN 60950-1.

Alerte

L'unité externe ne doit pas être installée dans un endroit où la température ambiante est supérieure à 40C à moins que l'accès soit limité au personnel autorisé.

ODU variants and mounting bracket options

Mounting bracket options

The PTP 670 series supports three mounting bracket options. Select the optimum mounting bracket arrangement based on the pole diameter and the ODU variant:

Table 150 ODU mounting bracket part numbers

Bracket	Pole diameter	ODU variants	Bracket part number
Tilt Bracket Assembly	40 mm to 77 mm (1.6 inches to 3.0 inches)	PTP 670 Integrated PTP 670 Connectorized	N000045L002A
Tilt Bracket Assembly with band clamps	90 mm to 230 mm (3.6 inches to 9.0 inches)	PTP 670 Integrated PTP 670 Connectorized	N000045L002A + third-party band clamps
Mounting Bracket (Integrated)	40 mm to 82 mm (1.6 inches to 3.2 inches)	PTP 670 Integrated	N000065L031A

Note

The Tilt Bracket Assembly is included as part of the PTP 670 Integrated and Connectorized Kits. If required, order the Mounting Bracket (Integrated) separately.

Note

The Tilt Bracket Assembly allows for elevation angle adjustment for the Integrated ODU between –17° and +26°. The Mounting Bracket (Integrated) allows for elevation angle adjustment between –26° and +41°.

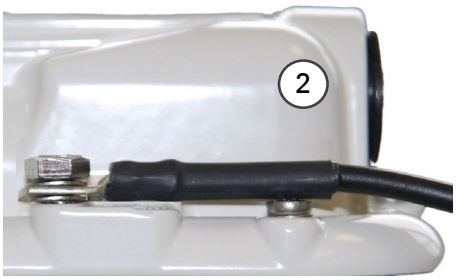
Installing the ODU and top LPU

To install the ODU and top LPU, use the following procedures:

Attach ground cables to the ODU

1 Fasten one ground cable to each ODU grounding point using the M6 (small) lugs: one is for the top LPU (M6 lug at other end) and the other is for the tower or building (M10 lug at other end). It does not matter which cable goes on which ODU grounding point.

2 Tighten both ODU grounding bolts to a torque of 5 Nm (3.7 lb ft).



Mount the ODU on the mast

Select the most appropriate bracket mounting arrangement from the options listed in Mounting bracket options on page 5-6. Refer to individual procedures below for each of the options:

The mounting procedures can be adapted to attach the ODU to a suitable horizontal pole, but the adjustment of azimuth angle is necessarily limited compared with an installation on a vertical pole.

Tilt Bracket Assembly

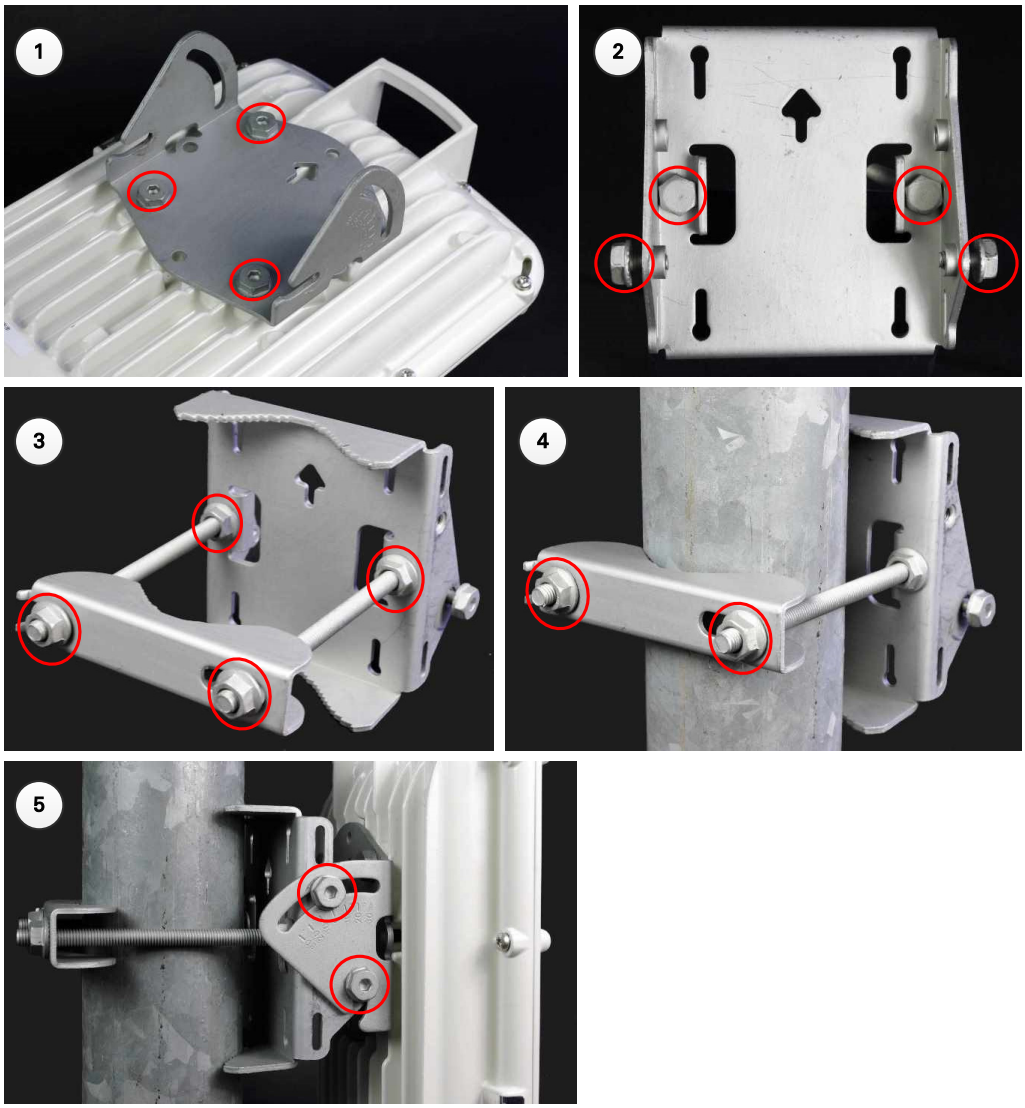
1 Fix the mounting plate of the Tilt Bracket to the back of the ODU using four of the short bolts, ensuring that the arrow in the plate points towards the top of the ODU. Tighten the four bolts to a torque setting of 5.0 Nm (3.7 lb ft) using a 13 mm spanner or socket.

2 Fit the two long bolts through the bracket body so that the bolt heads engage in the slots as shown. Fit two of the short bolts into the side of the bracket body but do not tighten.

3 Thread two of the nuts to the long bolts and tighten against the bracket body using a 13 mm spanner. Fit the bracket strap and thread the remaining nuts onto the long bolts.

4 Fix the assembled bracket body to the pole, adjust the azimuth angle, and tighten the nuts to a torque setting of 10.0 Nm (7.4 lb ft) using a 13 mm spanner, ensuring that the arrow in the body is pointing upwards.

5 Hoist the ODU to the mounting position. Fit the mounting plate to the bracket body by positioning the open-ended slots over the short bolts. Insert the remaining short bolts through the longer curved slots into the threaded holes in the bracket body. Adjust the elevation angle, and tighten the bolts to a torque setting of 5.0 Nm (3.7 lb ft) using a 13 mm spanner or socket.

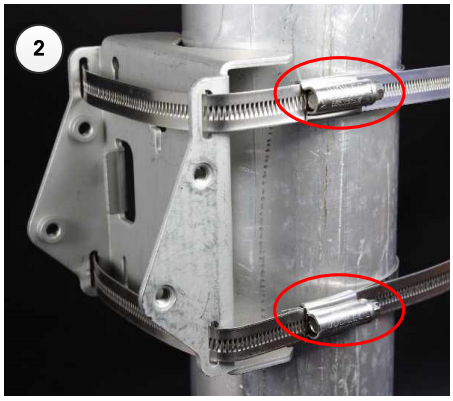


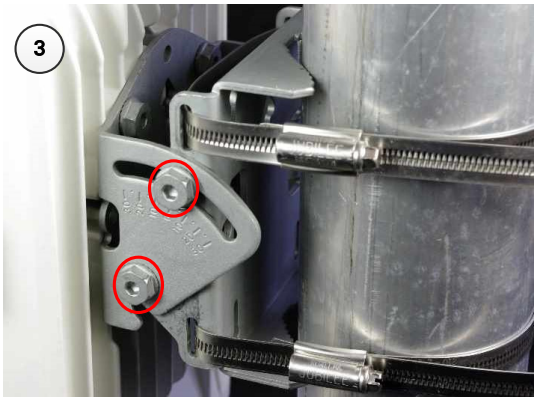
Tilt Bracket Assembly with band clamps

1 Follow Step 1 for the Tilt Bracket Assembly procedure above.

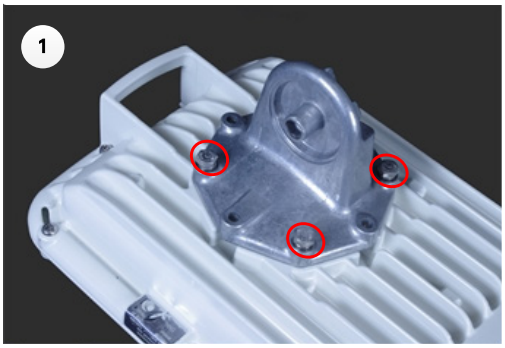
2 Feed the band clamps through the slots in the bracket body. Secure the bracket body to the pole using band clamps (not supplied by Cambium), ensuring that the arrow in the body is pointing upwards. Adjust the azimuth angle, and tighten the band clamps to a torque setting of 6.0 Nm (4.5 lb ft).

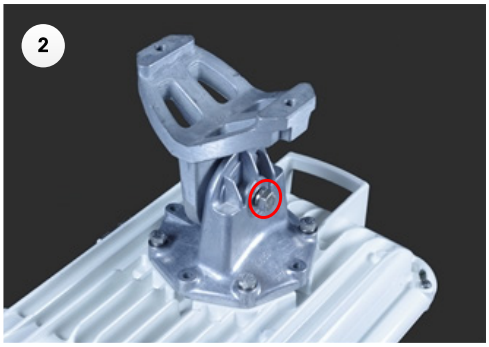
3 Hoist the ODU to the mounting position. Fix the mounting plate to the bracket body with four of the short bolts, using a 13 mm spanner or socket. Adjust the elevation angle, and tighten the bolts to a torque setting of 5.0 Nm (3.7 lb ft).

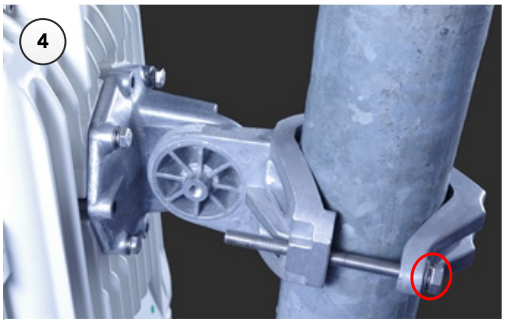


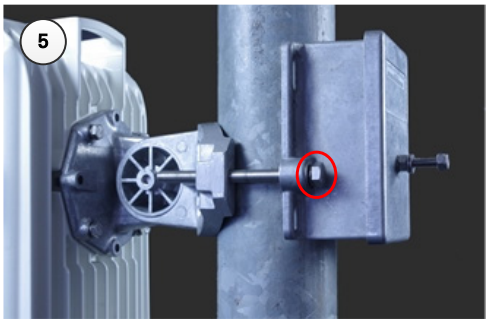


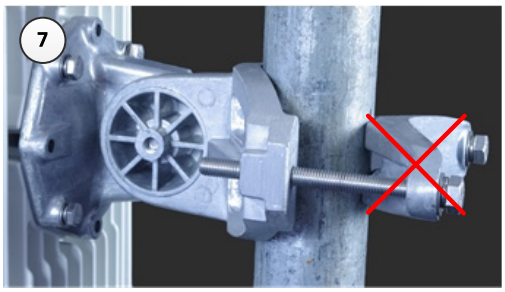
Mounting bracket (Integrated)











1 Fix the mounting plate to the back of the ODU using the four bolts, and spring and plain washers provided. Ensure that the spring washer is between the bolt head and the plain washer Tighten the bolts to a torque setting of 5.0 Nm (3.7 lb ft).

2 Attach the bracket body to the mounting plate using the M8 bolt, spring and plain washers. Ensure that the spring washer is between the bolt head and the plain washer.

3 Hoist the ODU to the mounting position.

4 Attach the bracket body to the pole using the bracket clamp, M8 bolts, and spring and plain washers. Ensure that the spring washer is between the bolt head and the plain washer. For back-to-back mounting, use the LPU in place of the clamp.

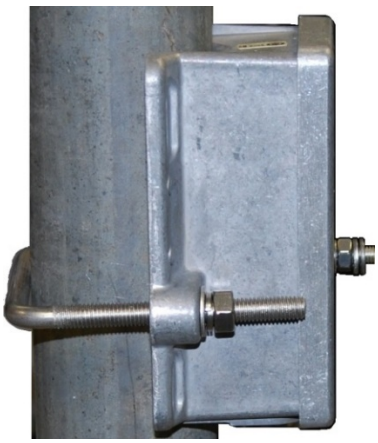
5 Adjust the elevation and azimuth to achieve visual alignment. Tighten all three bracket bolts to a torque of 8.0 Nm (6.0 lb ft).

Caution

Do not reverse the bracket clamp, as this arrangement may lead to failure of the assembly. Do not over-tighten the bolts as this may lead to failure of the assembly.

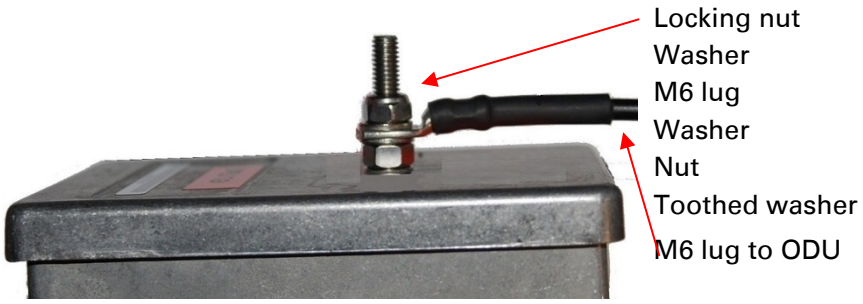
Mount the top LPU

1 For separate LPU mounting, use the U-bolt bracket from the LPU kit to mount the top LPU on the pole below the ODU. Tighten to a torque setting of 7.0 Nm (5.2 lb ft):



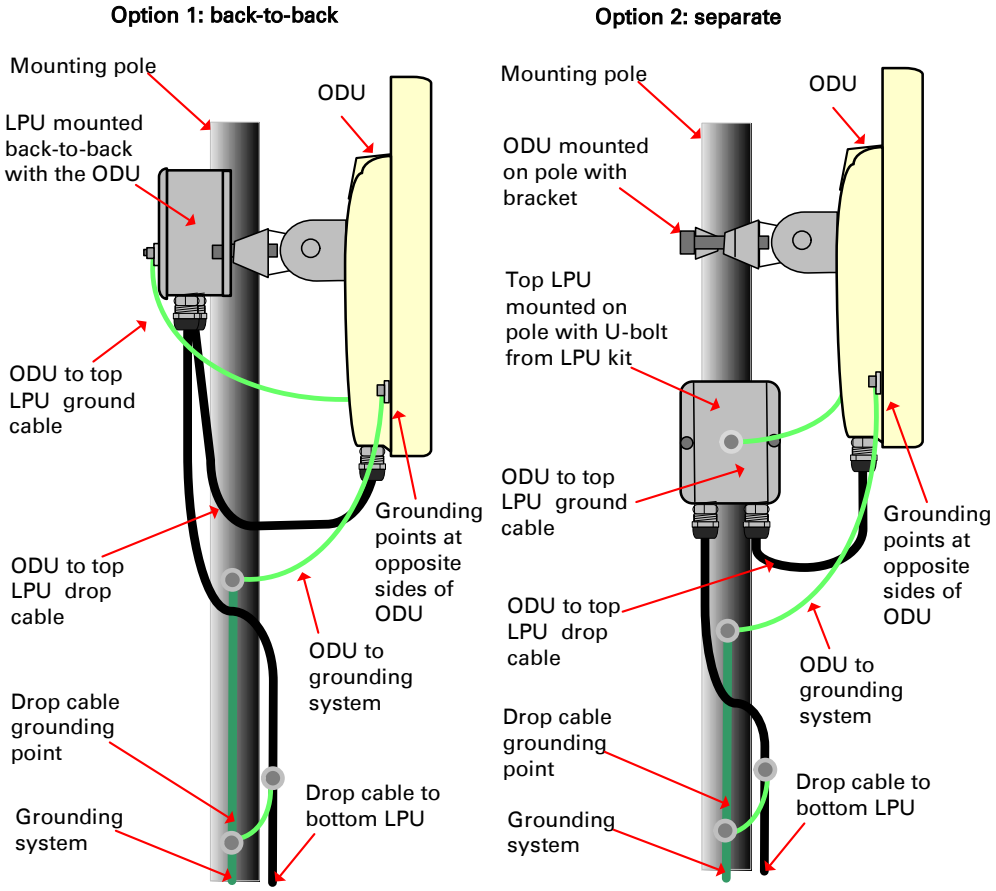
Interconnect and ground the ODU and top LPU

1 Fasten the ODU grounding cable to the top LPU using the M6 (small) lug. Tighten both nuts to a torque of 5 Nm (3.7 lb ft):



2 Select a tower or building grounding point within 0.3 meters (1 ft) of the ODU bracket. Remove paint from the surface and apply anti-oxidant compound. Fasten the ODU grounding cable to this point using the M10 (large) lug.

3 If local regulations mandate the independent grounding of all devices, add a third ground cable to connect the top LPU directly to the grounding system.



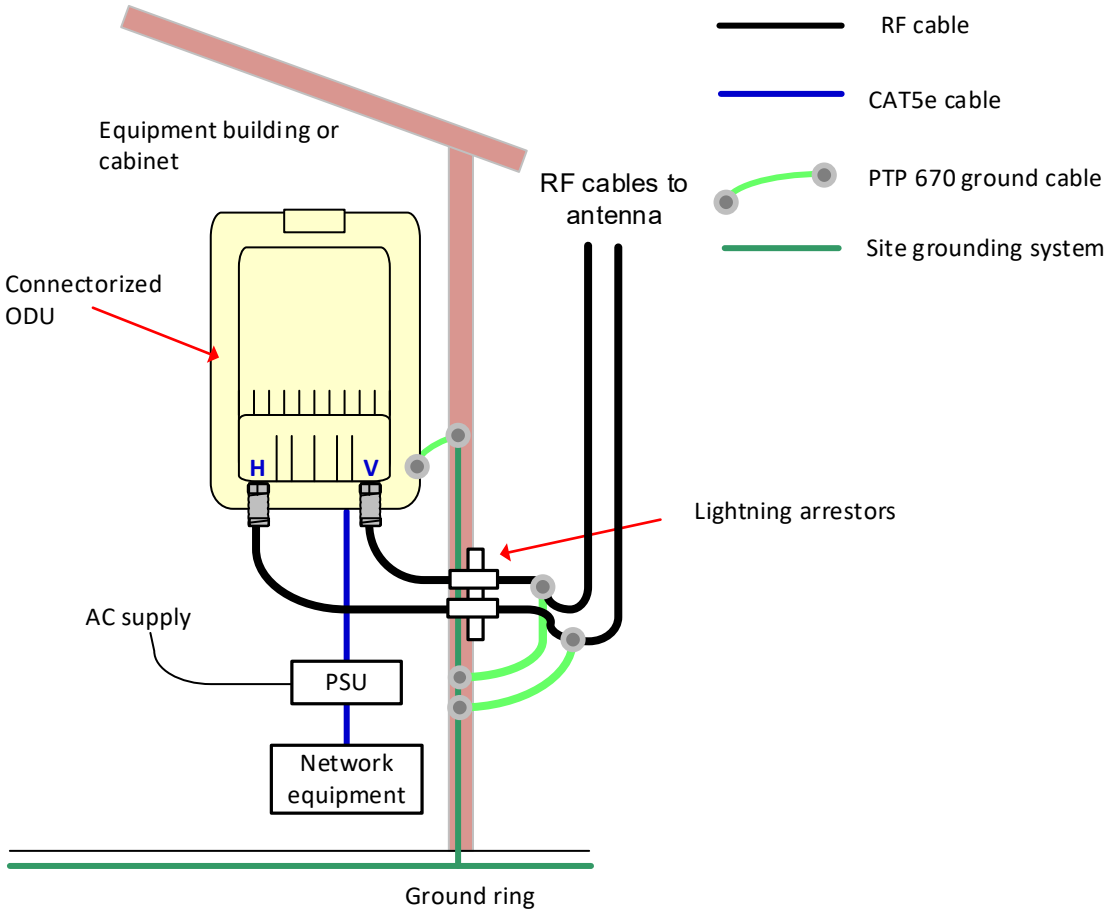
Caution

Do not attach grounding cables to the ODU mounting bracket bolts, as this arrangement will not provide full protection.

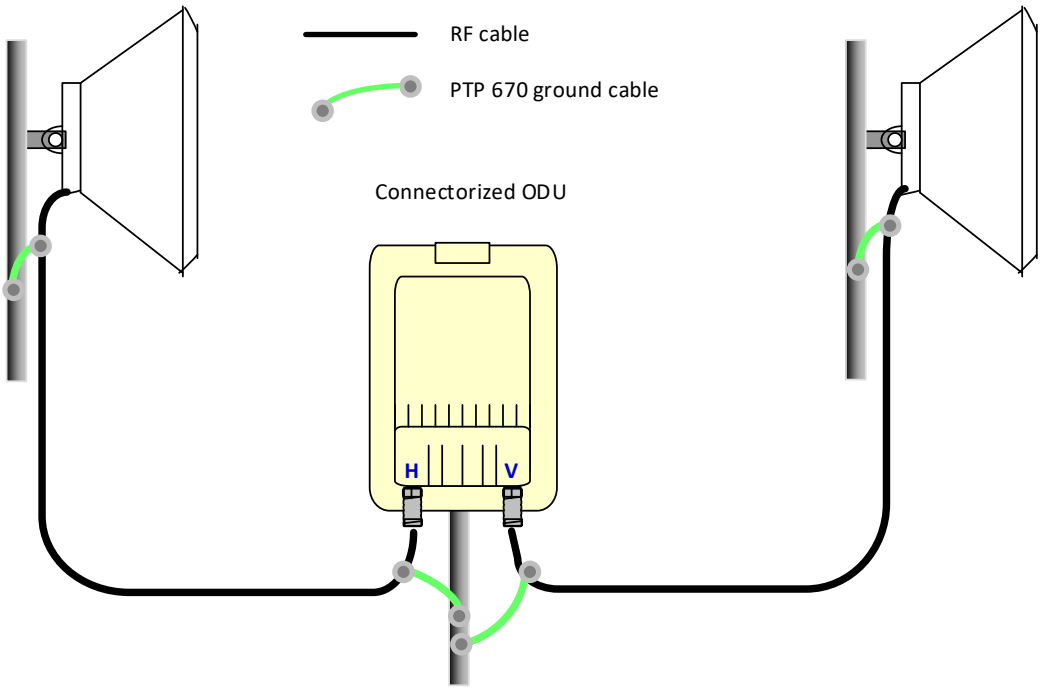
Install external antennas for a Connectorized ODU

To mount and connect an external antenna, proceed as follows:

1. Mount the antenna(s) according to manufacturer's instructions. When using separate antennas to achieve spatial diversity, mount one with Horizontal polarization and the other with Vertical polarization.
2. Connect the ODU V and H interfaces to the antenna(s) with RF cable of type LMR-400 (Cambium part numbers 30010194001 and 30010195001) and N type connectors (Cambium part number 09010091001). Tighten the N type connectors to a torque setting of 1.7 Nm (1.3 lb ft).
3. If the ODU is mounted indoors, install lightning arrestors at the building entry point:
4. Form drip loops near the lower ends of the antenna cables. These ensure that water is not channeled towards the connectors.
5. If the ODU is mounted outdoors, weatherproof the N type connectors (when antenna alignment is complete) using PVC tape and self-amalgamating rubber tape.
6. Weatherproof the antenna connectors in the same way (unless the antenna manufacturer specifies a different method).



7 Ground the antenna cables to the supporting structure within 0.3 meters (1 foot) of the ODU and antennas using the Cambium grounding kit (part number 01010419001):



8 Fix the antenna cables to the supporting structure using site approved methods. Ensure that no undue strain is placed on the ODU or antenna connectors. Ensure that the cables do not flap in the wind, as flapping cables are prone to damage and induce unwanted vibrations in the supporting structure.

Installing the copper Cat5e Ethernet interface

To install the copper Cat5e Ethernet interface, use the following procedures:

Caution

To avoid damage to the installation, do not connect or disconnect the drop cable when power is applied to the PSU or network terminating equipment.

Caution

Do not connect the SFP or Aux drop cables to the PSU, as this may damage equipment.

Caution

Always use Cat5e cable that is gel-filled and shielded with copper-plated steel. Alternative types of Cat5e cable are not supported by Cambium Networks. Cambium Networks supply this cable (Cambium part numbers WB3175 and WB3176), RJ45 connectors (Cambium part number WB3177) and a crimp tool (Cambium part number WB3211). The LPU and grounding kit contains a 600 mm length of this cable.

Install the ODU to top LPU drop cable

Fit glands to the ODU to top LPU drop cable

Fit EMC strain relief cable glands (with black caps) to both ends of the 600 mm length of pre-terminated cable. These parts are supplied in the LPU and grounding kit.

1 Disassemble the gland and thread each part onto the cable (the rubber bung is split). Assemble the spring clip and the rubber bung: