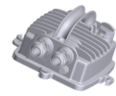# RACOM
www.racom.eu

User manual

RAy3 Microwave Link

fw 2.0.20.0 (for 10-24 GHz) and fw 1.1.8.0 (for 80 GHz)
2025-02-20
version 1.25

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www.racom.eu

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- The radio equipment hardware, firmware and software can't be changed or modified by a user or any other third-party. Only officially distributed firmware from RACOM is allowed to be installed on the equipment.

⚠ **Important**

Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

Quick guide

1. Delivered items

Microwave unit	
Bushings	1x
	6x 2x 2x 2x
Plugs	1x
Connectors	1x
Grease	1x

2. Accessories

Antennas   Antenna brackets

Power supplies PoE or DC   Required tools   Voltmeter or smartphone or laptop with WiFi

MW unit: M8 Allen key
Antennas: M13 and M17 keys

3. Power supply
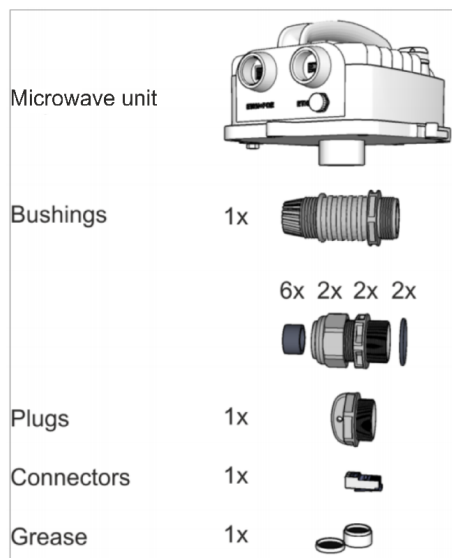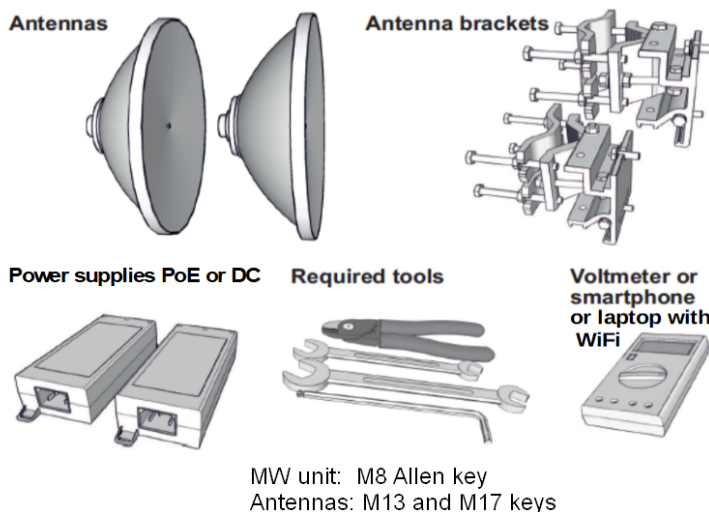
RJ45
ETH1 + PoE
PoE power supply
Adapter DC/RJ45
Unit grounding
DC power supply

4. Configuration

DC 24 – 58 V   PoE + Eth
WiFi
Adapter DC/RJ45
USB/WIFI= std delivery
230 VAC
ETH (PC)   Phone   230 VAC
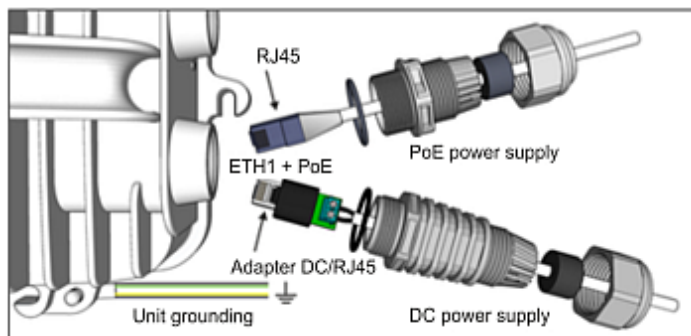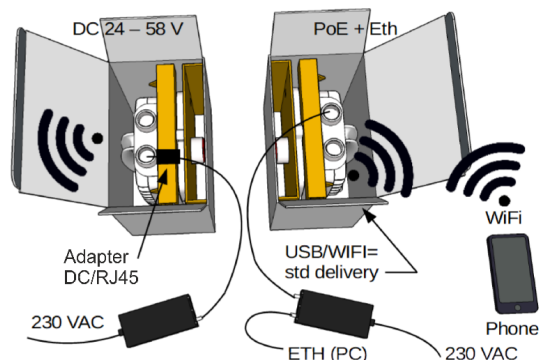
Accessing units

- Default IP addresses for Ethernet access: 192.168.169.169/24 (L unit) and 192.168.169.170/24 (U unit)
- Default IP address for USB/WiFi or USB/Eth access: 172.17.17.17/24 (both units)
Ethernet access - set computer IP address within the range 192.168.169.1-255.   USB/WiFi or USB/Eth access - IP address set automatically by DHCP (enabled by default, can be disabled in unit management). Recommended USB adapter must be plugged in to the unit. Default WiFi setting is without any password (recommended is to set one immediately).

- Web browser access to management: - Antenna Alignment Tool:
   http://172.17.17.17 (both units, USB/WiFi or USB/Eth)   http://172.17.17.17/tk (both units, USB/WiFi or USB/Eth)
   or http://192.168.169.169 (L unit, Ethernet)   or http://192.168.169.169/tk (L unit, Ethernet)
   or http://192.168.169.170 (U unit, Ethernet)   or http://192.168.169.170/tk (U unit, Ethernet)
   Defaults: Username: admin, Password: admin   no Username or Password is required for Tool

Secure HTTPS access can be optionally used instead (use „secured version" below main entry to the management and then accept the https security certificate issued by RACOM).
If the units are linked to each other, the status indicator in management interface states "OK" and status LED lights green. If not, utilize the antenna alignment (see pict. 10 and Antenna Alignment Tool above).

Configuration and backup of basic parameters

- Set bandwidth, channels, modulation, power, **IP addresses** (do not use the default ones), **Access channels** (ssh, https..).
- Change the password, restart both units and check the link status (to verify that the parameters are saved correctly).
- Backup the configuration in the Tools / Maintenance / Backup / Settings menu. Store the backup file to your PC.

5. Bracket and antenna

Mounting
- left sided (pictured below)
- right sided
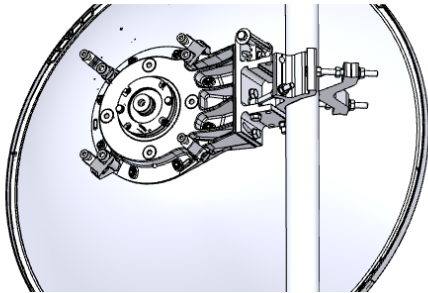
6. Unit lubrication and installation

Grease

Antenna

Thin layer of grease   Check the correct O-ring placement on the antenna
Ensure the antenna and unit are carefully alignet
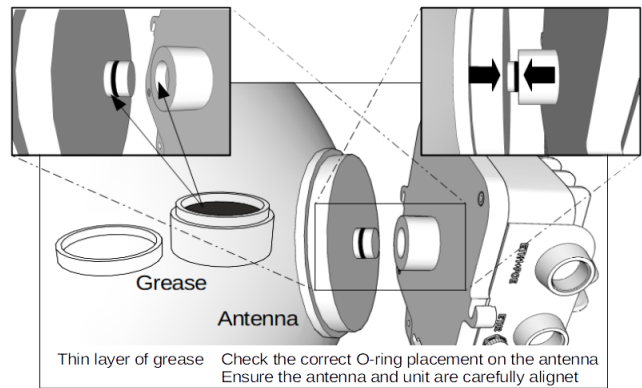
7. Unit polarization
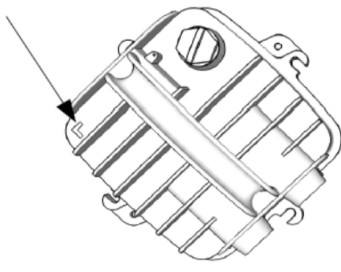
Horizontal

Vertical
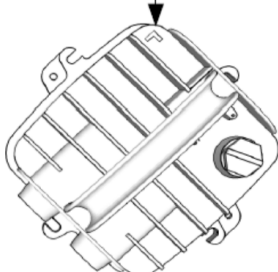
- cross polarization
- one side – horizontal
- the other side - vertical

8. Sealing

Bushings

Plugs

Optical cable

Seal unit interfaces with
bushings and plugs

max. 38 mm
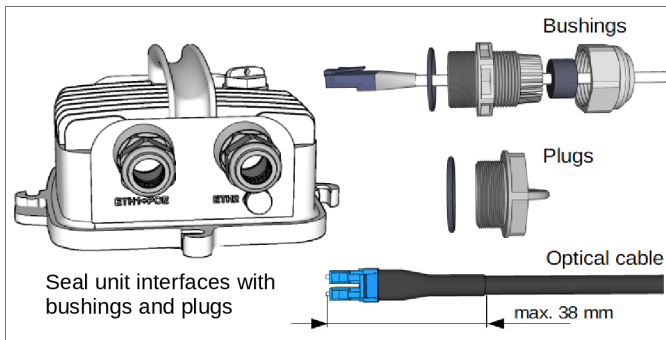
9. Power grounding and connections

PoE+Eth
metallic

DC   Eth fibre
(or metallic)

Adapter
DC/RJ45

Cable
GND kit

Fibre

Unit
GND

Surge
protection

PoE

DC

SWITCH

AC 230 V

AC 230 V

10. Directing antennas

USB-WiFi
module

1
2
3
4

Best RSS
= minimum voltage   OR   smartphone
in range 0-2 V

2 V

11. RSS measurement

Calculation

Alignment

Configuration

-72.8
RSS
MSE
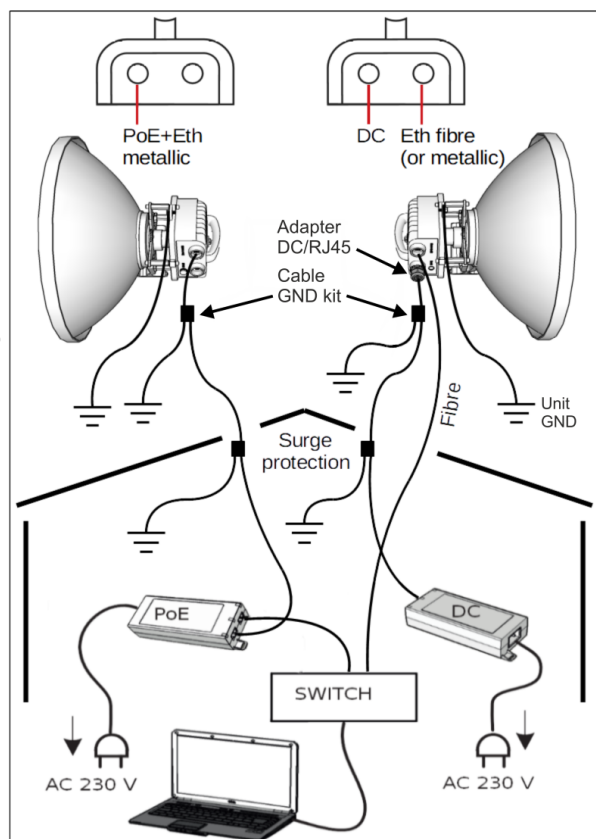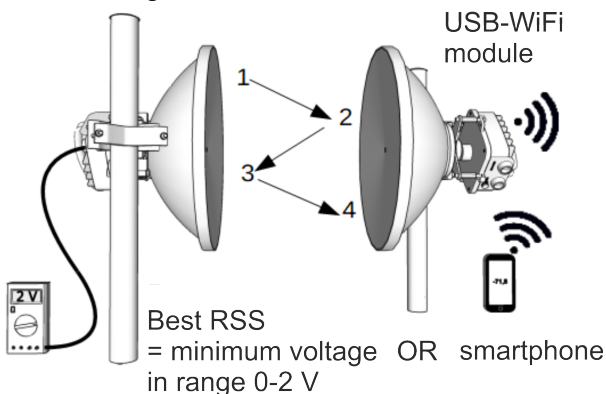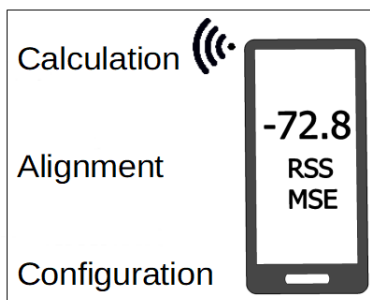
1. Product

RAy3 microwave units work as a wireless Ethernet point-to-point link in a full duplex setting with transfer speeds of up to 2 Gb/s. The link is formed by two RAy units, each equipped by its own parabolic antenna and accessories to be fully operational.

1.1. Main characteristics

Supported are several license-free bands and several licensed bands, all in the identical aluminum box. Bandwidth can be configured from 3.5 up to 2× 112 MHz for standard bands (all models up to 24 GHz) and from 62.5 up to 2000 MHz for E-band (71-86 GHz). Modulation can be fixed or adaptive and for standard bands it can be adjusted from QPSK to 4096QAM. In the case of E-band modulations range from 2PSK up to 128QAM. The lowest modulation on each model could be on the fly (without data loss) strengthened for higher receiver sensitivity by extremely robust FEC – such modulation is marked as QPSK_S or 2PSK_BW/4_S (where 'S' means a strong FEC and 'BW/4' means a narrower channel used in E-band only). RAy3 microwave links operating in 17 and 24 GHz bands can also be operated as a Short Range Device (SRD).

Fig. 1.1: RAy3 – Microwave link

1.1.1. Hardware concept

RAy product line has been designed to have minimum possible number of hardware variants. Functionality of the unit is upgraded according to the "pay-as-you-grow" concept only by activating the relevant software feature keys and does not require any on-site hardware changes. For details see *Section 1.7, "Ordering codes"* and *Section 5.6.1.2, "SW feature keys"*.

HW models are determined only by frequency bands and in the case of licensed bands (i.e. 10, 11 and 18 GHz) also by sub-bands. Additionally in 10, 11, 18 and 80 GHz bands units forming a link differs in HW duplexer which ensures the proper frequency separation of transmitting and receiving channels. This is marked on each unit as Lower (L) or Upper (U) in *Production code* according the position of transmitting channel.

Units for 17 and 24 GHz does not have any HW difference between L and U units, because transmitting and receiving channels are freely defined by software and technically separated from each other by cross polarization.

Cross polarization means that one side of the link uses one polarization for transmission (e.g. horizontal) and the opposite polarization for receiving (e.g. vertical). The other side of the link is turned by 90°. Therefore it transmits and receives using opposite polarization with respect to the second unit. Practical result for users is that units for 17 and 24 GHz must be mounted with reverse polarity on both ends of the link.

ⓘ Note

All units for 17 or 24 GHz band are hardware identical. Default factory settings in the pair use different channels for L and U unit, so the link could be established by using default radio parameters.

1.1.2. Supported bands

Type	Band	Frequency range [GHz]	Sub-bands	Polarization	Note
RAy3-10	10 GHz	10.12–10.68	A (for CZ only), B (global)	Single polarization (Vertical or Horizontal)	Sub-band A is free-band in Czech Republic (CZ); Sub-band B is worldwide licensed band
RAy3-11	11 GHz	10.70–11.70	A (lower part), B (higher part)	Single polarization (Vertical or Horizontal)	Worldwide licensed band
RAy3-17	17 GHz	17.10–17.30	-	*Cross-polarization* (Vertical or Horizontal)	Free-band in several countries
RAy3-18	18 GHz	17.70–19.70	A (ETSI-lower part), B (ETSI-higher part), C (FCC)	Single polarization (Vertical or Horizontal)	Worldwide licensed band
RAy3-24	24 GHz	24.00–24.25	-	*Cross-polarization* (Vertical or Horizontal)	Free-band in EU, US, Canada and several other countries
RAy3-80	80 GHz (E-band)	71–76 & 81–86 GHz	-	Single polarization (Vertical or Horizontal)	Worldwide free-band or light-licensed band

1.1.3. FW concept

RAy is a typical Software Defined Radio product line, where all possible technical features are defined by the internal software. This internal software is distributed to users in a form of unit firmware (FW) developed by RACOM to optimally manage all hardware inside the unit.

The strategy is to have one common code-base to support all RAy3 models for all bands and sub-bands. It ensures that every advance in the FW development (i.e. every new feature or every bug-fix) is available on all relevant RAy3 units within the nearest FW release. Temporary exceptions (like a separate FW version for 10 GHz units) are sometimes necessary, due to the complexity of FW development.

Even the 80 GHz unit requires a different Linux kernel (due to the need of 10 Gb/s peripherals support) and thus the HW specific FW version exists, the code-base is still common across all HW models for all bands. Thus the user interface and most of its functions are identical across all models for all bands and sub-bands as much as technically possible (the only visible differences are due to different band / sub-band rules and band-specific radio HW).

1.1.4. Network concept

RAy links support only the Ethernet type of traffic and they are transparent for IP and UDP packets. Practically all protocols pass through unmodified including MPLS, RSTP (BPDU frames) and many others, except following:

- Management packets targeted for RAy units itself

- Special packets for protocols explicitly mentioned in this manual, which are somehow processed by RAy units (like PTP)

- Packets, which did not went through and were discarded due to capacity limitation and/or policy rules (e.g. PIRL, QoS, EGRES shaping ...)

1.2. Mechanical interfaces

This chapter describes basic properties of each RAy unit, which are important for its mechanical install-ation: antenna waveguide, unit fixing (screws, etc.) and *unit grounding* (screw + cable). Other interfaces (for data, power and service purposes) are described in next chapters *Ethernet + power interfaces* and *Service interfaces*.

1.2.1. Antenna waveguide

Antenna waveguide flange on RAy unit (located across the holder) ensures perfect microwave connection between the unit and the antenna. All RAy units are equipped with identicaly sized round flange (with the outer diameter 50 mm and the inner diameter 28 mm). The only visible mechanical difference between RAy models are the diameters of the round waveguide hole in the middle of the flange. Those diameters differs according frequency ranges and are following:

10-11 GHz	19.00 mm
17-18 GHz	11.00 mm
24 GHz	8.00 mm
70-80 GHz	3.18 mm

RAy3 link requires use of external parabolic antenna for each RAy unit – both for physical mounting as well as for the wireless transmission itself. *Parabolic antennas*[1] from different producers are available.
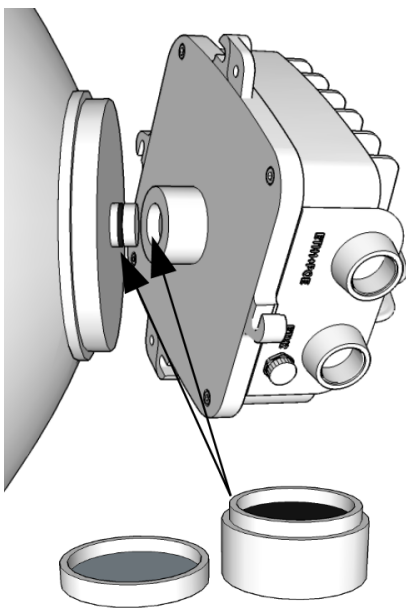
Fig. 1.2: Waveguide pivot and flange

⚠ **Important**

Each antenna has to be equipped by a corresponding RACOM RAy antenna waveguide inter-face - the metallic pivot (28 mm diameter) with a rubber O-ring on it, otherwise the signal to/from the unit can not be transmitted from/to the antenna and such a link would not work.

---

[1] https://www.racom.eu/eng/products/microwave-link.html#accessories_antennas

Before assembling RAy unit with antenna, always *carefully lubricate* both antenna waveguide pivot and RAy waveguide flange with thin layer of silicone grease to prevent the damage of O-ring and surfaces. Pivot fits smoothly in to the flange, if it is properly lubricated. A box with silicone grease is packaged with each delivery of new units - see *Section 1.6.3, "Packaging"*.

(i) Note

If O-ring is injured or damaged, please exchange it immediately for a new one (size 22x2 mm, type 'FPM80'), otherwise moisture + dust can leak into the waveguide and emitter. It may eliminate several dB of signal and cause a corrosion.

Antennas from Jirous, LEAX Arkivator and Shenglu ordered for RAy mounting are automatically equipped by RACOM RAy waveguide interface and are ready for mechanical fixing of RAy unit to the antenna.

Antennas from other vendors has to be equipped by a proper antenna adapter first. The adapter must be mounted on the antenna before the RAy unit can be mounted on it.

All available antennas and adapters are listed on RAy web pages in section *Accessories > Antennas*[2].

---

[2] https://www.racom.eu/eng/products/microwave-link.html#accessories_antennas

1.2.2. Unit mounting

RAy unit is mechanically fixed to the antenna by 4× M8 screws (one per each side of RAy unit).

Installation and basic adjustment of the antenna is described in the *Section 4.2, "Antenna mounting"*. Attaching RAy unit to it by 4× M8×30 (Allen) screws delivered with each antenna or each mount kit is described in the *Section 4.3, "RAy Unit mounting"*. For adjusting the exact antenna direction see *Section 4.7.2, "Directing antennas"* .
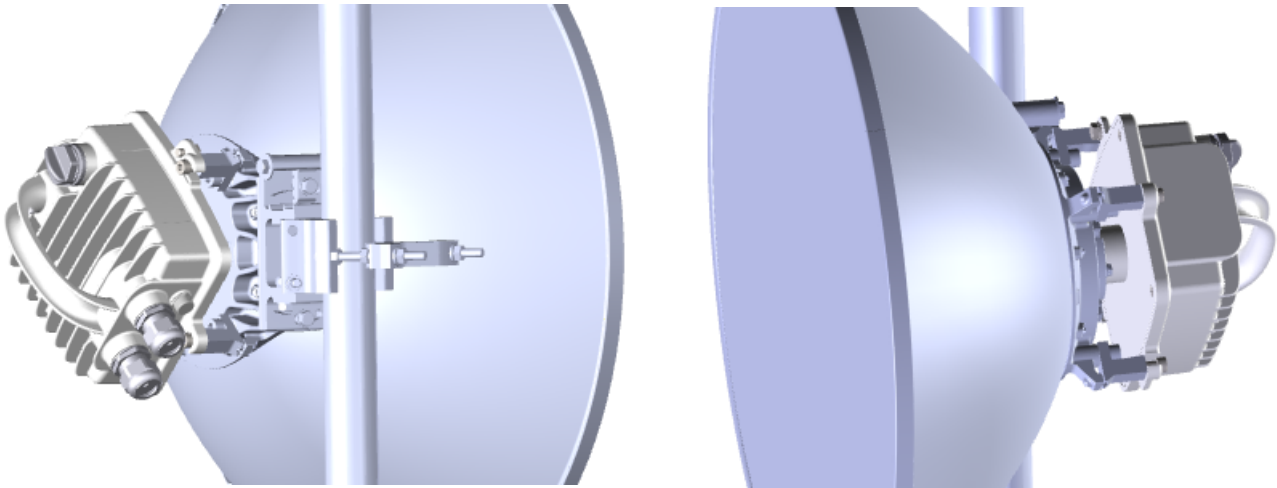
Fig. 1.3: Antenna and RAy3 unit

> **(i)** **Note**
>
> Antennas from Jirous, LEAX Arkivator and Shenglu ordered for RAy mounting are automatically equipped for mechanical fixing of RAy unit (including the delivery of 4× M8×30 Allen screws).
>
> Adapters for antennas from other vendors always contain proper mechanical fixing of RAy unit (including the delivery of 4× M8×30 Allen screws). The adapter has to be mounted to the antenna first, the RAy unit is then mounted on this adapter.
>
> All available antennas and adapters are listed on RAy web pages in section *Accessories > Antennas*[3].

1.2.3. Grounding screw

Grounding screw is used for a proper grounding of the RAy unit, which is necessary for its function (ensured by galvanic connection to the grounded mast through a grounding cable).

One M8 screw (with standard 6-edge head) is delivered with each RAy unit. Grounding screw has two possible positions (two holes) to be mounted in. Those are located near the left and right fixing screws of the RAy unit and both are marked by a yellow grounding symbol ⏚ and both are equivalent (second hole remains unused). For more information about unit grounding see *Section 4.3.3, "RAy unit grounding"*.

Fig. 1.4: Grounding screw

---

[3] https://www.racom.eu/eng/products/microwave-link.html#accessories_antennas

(i) Note

Grounding screw function is to ensure proper grounding of the RAy unit (by a grounding cable), not for mechanical fixing of the unit.

1.2.4. Pressure equalization

Pressure equalization between outside and inside of RAy unit is an important technical requirement. It is realized by a small plastic screw next to ETH2 label. It ensures the pressure equalization without letting moisture or humidity to enter the unit.

⚠ Important

Do not manipulate or remove this small plastic screw. It is part of the cabinet and its manipulation or a deformation can damage the water protection of the unit.

Warranty does not apply for units with this screw missing or deformed.
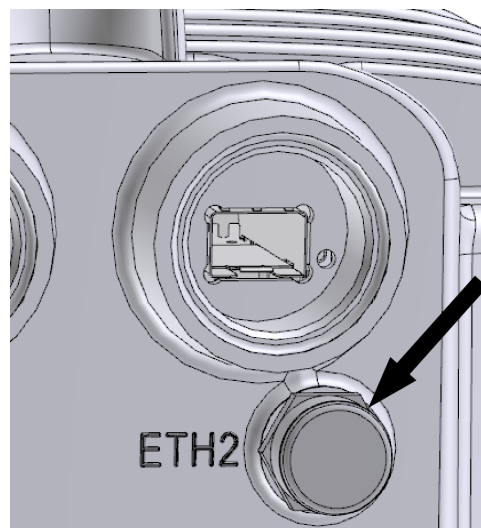
Fig. 1.5: Pressure equalization screw

1.3. Ethernet + power interfaces

This chapter describes interfaces for user data transfer and power sourcing of the unit, as described on the picture and characterized in the table below. Remaining interfaces for service purposes are described in next chapter *Service interfaces*.
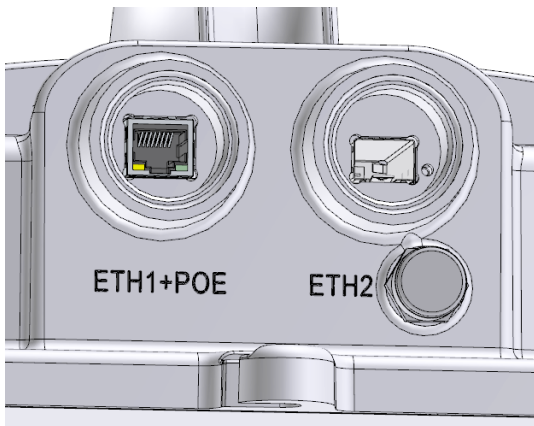
Fig. 1.6: Slots ETH1+POE, ETH2

Slot	Function
ETH1+POE	Gigabit metallic Ethernet + Power over Ethernet (PoE) port This port is capable of powering the unit with active or passive PoE power source or with direct DC.
ETH2	Slot for user exchangeable SFP module A wide range of fibre optics Ethernet modules is available. Both single or dual mode transceivers can be used. SFP module with metallic RJ45 interface can also be used.
	The SFP LED Located on SFP, just next to connectors. It is controlled by SFP module. Its function is specific for each SFP module. The typical behavior is an indication the received signal from the optical or metallic link to be within operational range.

> **(i) Note**
>
> A set of all necessary bushing parts are delivered with each RAy unit - see a description of this standard basic accessory *ACS-RAy3*[4]. Additional bushing options for installation of longer connectors or other equipment are available as well. For bushings installation see *Section 4.4, "Connectors assembly and disassembly"*.

> **⚠ Important**
>
> All bushings and plugs (including the original plugs in the flanges) must be fitted with O-rings and carefully tightened. Otherwise, the unit is not protected against moisture intake through connectors and cannot offer guaranteed functionality.

---

[4] https://www.racom.eu/eng/products/microwave-link.html#accessories_kit

1.3.1. RJ45 connector (ETH1+POE)

RJ45 socket connector marked „ETH1+POE" is a standard 10/100/1000 Mb/s metallic Ethernet port.

This port is also used for power sourcing the unit by PoE (Power over Ethernet) or direct DC power source. Both an active PoE power supply (compliant with IEEE 802.3at respectively IEEE 802.3bt standards known also as PoE+ respectively PoE++) and a passive PoE power supply (with wider voltage range than PoE) are supported.

Supported PoE types of power sourcing are:

- **Active PoE** requires PoE power supply compliant with standards IEEE 802.3bt or IEEE 802.3at (the second one only for RAy3-17 and RAy3-24) and the reasonably quality Ethernet cable, otherwise the proper function of the unit can't be guaranteed. The norm defines supplied voltage in the range 37-57V (for PoE+) respectively 51-57V (for PoE++) and max. current typically 0.55-2.0 A.
- **Passive PoE** can operate in extended voltage ranges which depends on the maximum power consumption of each model:

Fig. 1.7: RJ45 Ethernet connector

  - **20 to 60 V** for 10, 17 and 24 GHz units (for unit boot at least 21 V to prevent booting with discharged 24 V battery)

  - **37 to 60 V** for 11, 18 and 80 GHz units

  - **Any polarity** of DC and PoE inputs are supported.

> **ⓘ Note**
>
> Extended voltage ranges and polarities are identical with direct DC power sourcing described in *Section 1.3.3, "DC power (using ETH1+POE)"*.
>
> Maximum long-term voltage on the unit is recommended to be below 58 V (to ensure over-voltage protection inside the unit stays deactivated).

RJ45 connector pins are wired according standards IEEE 802.3bt (utilizes 4 pairs = 8 wires) and IEEE 802.3at (utilizes 2 pairs = 4 wires). All units support all PoE modes of operation:

- Mode A: pins 1,2 (V+) and 3,6 (V-)
- Mode B: pins 4,5 (V+) and 7,8 (V-)
- Mode A+B: all 8 pins with numbers identical to Mode A and Mode B

> **ⓘ Note**
>
> Additionally to IEEE norm all units can be powered by PoE or DC with opposite +/- polarity.
>
> PoE with 8-wires is strongly recommended for 10, 11, 18 and 80 GHz units due to their power consumption >25 W. PoE with 8-wires is recommended also for other models to minimize the energy lost in the Eth cable (it lowers the resistance of the Eth cable to half compared with 4-wires PoE).
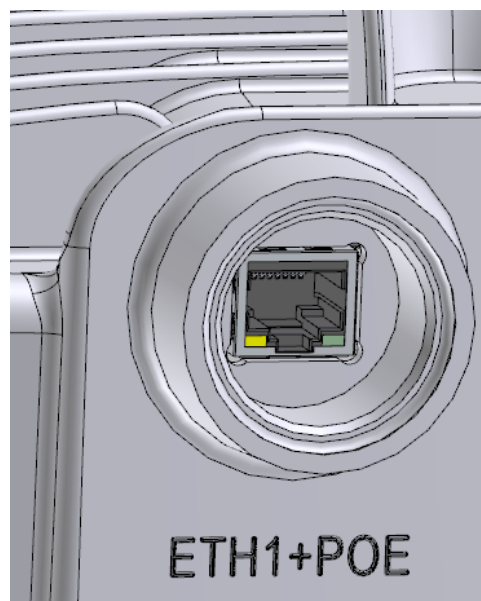
Galvanic separation: All contacts of RJ45 connector are galvanically separated from RAy unit. It ensures galvanic separation for any kind of *PoE power supply* as well as for *DC power sourcing* (made through *OTH-DC/RJ45*[5]).

⚠️ **Important**

The shielding of the Ethernet cable has to be properly grounded near the unit to ensure proper unit connectivity and resistance against over-voltage. Suitable grounding kit (for example items *GND-CAT7 or GND-CAB-UNI*[6] or similar) has to be applied and connected to the mast or to the *Grounding screw* on the well grounded unit chassis (for example by the item *GND-RAy*[7]).

More information about usage and installation of available power options can be found in *Section 4.6, "Power supply"* and *Section 4.5, "Grounding and overvoltage protection"*.

ⓘ **Note**

One plastic RJ45 plug for CAT5e and CAT6 cables is delivered with each unit (within item *ACS-RAy3*[8]), ready to be punched to an Ethernet cable.

Higher quality and CAT7 compatible RJ45 plugs are available to be purchased as well (for example item *CON-RJ45-CAT7*[9]).

1.3.2. SFP/SFP+ slot (ETH2)

„ETH2" is a standard SFP slot for 10/100/1000/2500 Mb/s Ethernet SFP modules, user exchangeable. (Legacy 10-24GHz RAy3 units produced before January 2024 do not support 2500 Mb/s Eth SFP modules, even with FW 2.0.14.0 or later.) In the case of 80 GHz unit the SFP slot supports also SFP+ standard, so 2.5/5/10 Gb/s SFP+ modules can be used as well. It is typically used for second Ethernet data and/or management connection to the unit. In the case of RAy3-80 unit the SFP+ slot is typically a primary data port (and sometime also a primary manage-ment port), because it is the only Ethernet interface on the unit which is able to support higher speeds than 1 Gb/s.

Fig. 1.8: SFP slot

Both fibre optic and metallic Ethernet SFP and SFP+ modules are supported. For optical both single and dual mode fibre optics Ethernet modules (= 2 or 1 fibres) can be used. CSFP/CSFP+ modules are not supported. RA-COM offers just the basic set of mentioned types of SFP and SFP+ modules, as a standard *RAy accessory*[10]. RA-COM has carefully selected and tested all offered SFPs according to high long-term stability in all temperatures, low power consumption and other technical parameters important for users and they are guaranteed to function with RAy units in all situations and temperatures.

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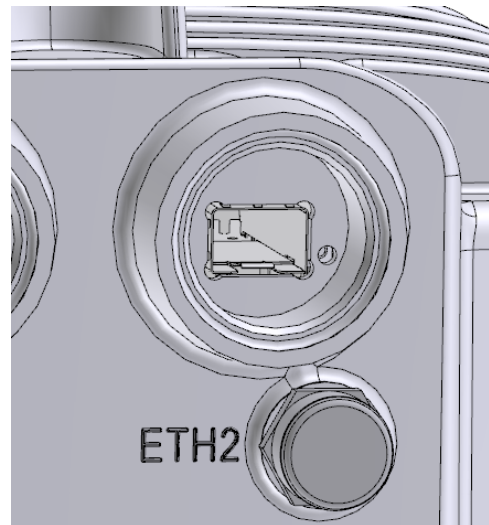
[5] https://www.racom.eu/eng/products/microwave-link.html#accessories_poe

[6] https://www.racom.eu/eng/products/microwave-link.html#accessories_zemneni

[7] https://www.racom.eu/eng/products/microwave-link.html#accessories_zemneni

[8] https://www.racom.eu/eng/products/microwave-link.html#accessories_kit

[9] https://www.racom.eu/eng/products/microwave-link.html#accessories_cable

[10] https://www.racom.eu/eng/products/microwave-link.html#accessories_sfp

The SFP/SFP+ status LED is located just next to the slot. It is controlled by the SFP/SFP+ module and its function is specific for each such a module. The typical behavior is an indication the received signal from the fibre optic or metallic link to be within operational range.

Important

SFP/SFP+ module has to be inserted to out-of-power unit, otherwise its function is unpredictable and the module and/or the unit can be damaged.

Do not remove the smaller plastic screw next to ETH2 label. It is part of the cabinet and assures *pressure equalization* outside and inside.

Note

Other types of standard SFP/SFP+ modules with industry temperature range (at least -30 °C to +85 °C) and with adequate power consumption can be used as well, but RACOM cannot guarantee their complete compatibility with RAy units. RACOM is not responsible for any issues arising from the use of different SFP modules. Following requirements needs to be met by any third-party SFP/SFP+ module inserted into RAy3 unit:

- It is always necessary to use a high quality SFP or SFP+ module with industry temperature range (at least -30 °C to +85 °C), because the temperature inside RAy units ordinary reach over 80 °C in the summer).
- Power consumption of each SFP/SFP+ module has to respect the maximum power load for SFP/SFP+ slot specified for each RAy3 model in its technical parameters. The general limit for SFP module is 1.3 W. Only RAy3-80 can additionally accommodate SFP+ modules, where the power limit is 3.0 W. Modules with higher power consumption would not work in RAy3 units, because the unit would stop power sourcing of the slot to protect its over-heating.
- All RAy3 units support metallic Ethernet SFP modules for 1× 10/100/1000/2500 Mb/s as well as fibre Ethernet SFP modules for 1000/1250 Mb/s, both single and dual mode (= 2 fibres or 1 fibre).
- Additionally RAy3-80 supports SFP+ modules for 1x 1000/2500/5000/10000 Mb/s metallic Ethernet as well as 10 000 Mb/s fibre Ethernet, both single and dual mode (= 2 fibres or 1 fibre).
- Any CSFP or CSFP+ modules for 2× 1000 Mb/s or 2× 10 000 Mb/s are not supported.

1.3.3. DC power (using ETH1+POE)

Direct DC power source can be used to power the RAy3 unit. Instead of standard DC connector the DC cable is mounted to a terminal block on DC/RJ45 adapter (item *OTH-DC/RJ45*[11]). The adapter is then fitted in to the RJ45 connector in slot *ETH1+POE*.

Item *OTH-DC/RJ45*[12] is orderable with the unit (see *Section 1.7.1, "RAy units"*). It is equipped by 2 terminals (each max. 2 A / 1.5 mm^2 / AWG 14) with screws to ensure perfect connection with cooper DC power cable.
Internal RJ45 pins wiring of DC/RJ45 adapter utilizes all 8 contacts on RJ45 and is:

- DC terminal (+) RJ45 pins: 1,2,4,5
- DC terminal (-) RJ45 pins: 3,6,7,8
- RJ45 shield   floating (not connected to any pin)

Both polarities are supported. Supported voltage range depends on the maximum power consumption of each model. Those are:

- **20 to 60 V** for 10, 17 and 24 GHz units (for unit boot at least 21 V to prevent booting with discharged 24 V battery)
- **37 to 60 V** for 11, 18 and 80 GHz units

Maximum long-term voltage on the unit is recommended to be below 58 V (to ensure over-voltage protection inside the unit stays deactivated). Power input is galvanically separated inside the unit.

⚠ **Important**

The optional shielding of the DC cable has to be properly grounded near the unit to ensure proper resistance against over-voltage. Suitable grounding kit (for example item *GND-CAB-UNI*[13] or similar) has to be applied and connected to the mast or to the *Grounding screw* on the well grounded unit chassis (for example by the item *GND-RAy*[14]).

More information about DC power sourcing installation can be found in *Section 4.6, "Power supply"* and *Section 4.5, "Grounding and overvoltage protection"*.
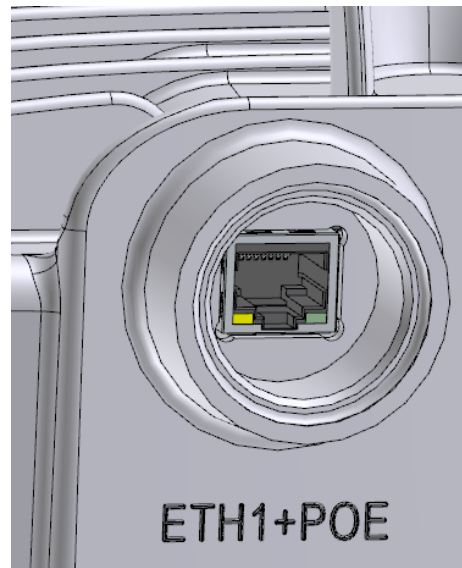
Fig. 1.9: Power supply connector
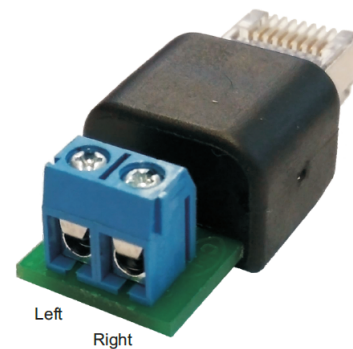
Fig. 1.10: DC-RJ45 adapter

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[11] https://www.racom.eu/download/hw/ray/free/eng/07_prislusenstvi/OTH-DC-RJ45.pdf

[12] https://www.racom.eu/eng/products/microwave-link.html#accessories_poe

[13] https://www.racom.eu/eng/products/microwave-link.html#accessories_zemneni

[14] https://www.racom.eu/eng/products/microwave-link.html#accessories_zemneni
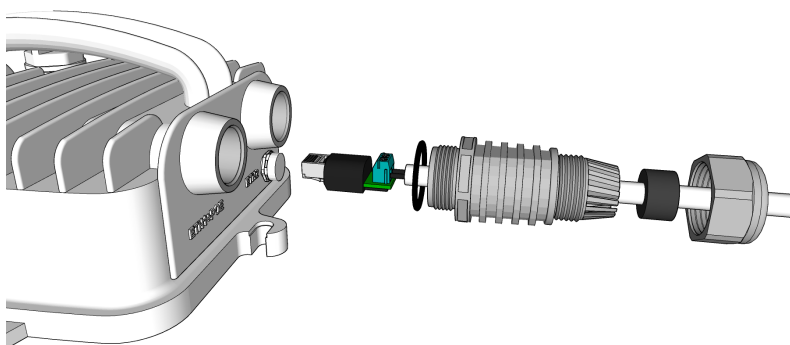
Fig. 1.11: Power via DC-RJ45 adapter

ⓘ Note

DC-RJ45 adapter occupies ETH1+POE port. When used, Ethernet connection to the unit has to be made through SFP module inserted in to ETH2 port. Standard SFP/SFP+ modules for fibre optic Ethernet or for metallic Ethernet (with RJ45 connector) can be used - see *Accessories / SFP modules*[15] for more details.
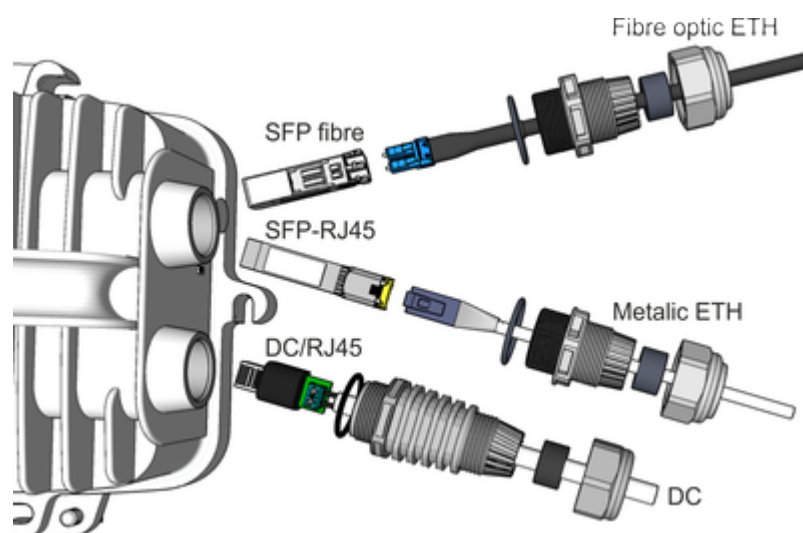
Fig. 1.12: SFP possibilities when direct DC power is used

Other valid possibility how to power the unit using DC power source is to use passive PoE injector or active PoE power supply with DC input and deliver the power to the unit over PoE through Ethernet cable with RJ45 connector plugged in to ETH1+POE slot as described in *Section 1.3.1, "RJ45 connector (ETH1+POE)"*.

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[15] https://www.racom.eu/eng/products/microwave-link.html#accessories_sfp

1.4. Service interfaces

Slot „S" stands for "Service". It contains system connectors – standard USB port and a pair of contacts for RSS voltage output (red + gray ones). Also HW button and Status LED are located there.
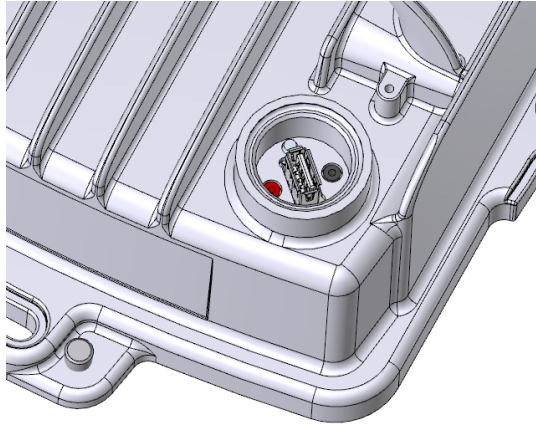
Fig. 1.13: Slot S

Slot	Function
S	**USB service connector** For USB/WiFi or USB/ETH adapters, see *Section 1.4.1, "USB connector (S)"*
	RSS voltage output Red and green connectors (for example 0.547 V means RSS = –54.7 dBm), see *Section 1.4.4, "RSS voltage contacts (S)"*.
	HW button For service purposes: Internal backup or Factory settings, see *Section 1.4.5, "HW button (S)"* and section Default settings in *Section 5.6.1.1, "Backup"*.
	Status LED Visible through semitransparent plug, see *Section 1.5, "Status LED (S)"*

1.4.1. USB connector (S)

USB-A port is designed for access to RAy management through USB/WIFI adapter or USB/ETH adapter plugged in to. More information about installation and configuration of available adapters can be found in *Quick Guide* and in *Section 5.4.3, "Service access"* (part "USB Accessories").

ⓘ **Note**

Only RACOM recommended adapters are supported. See *USB adapters*[16] on RAy Accessories web site.

Fig. 1.14: USB connector

1.4.2. Service WiFi - optional (using USB „S")

Each RAy3 unit is equipped with the service WiFi interface from the factory. It is realized by standalone WiFi module inserted in to the USB connector in slot "S". WiFi can be used solely for unit management (no user traffic can be transmitted by using this WiFi connection).

WiFi module can be disabled in FW (WiFi module is out of power then) or manually unplugged. In both cases the results are identical - no WiFi is possible. Management of the WiFi port is described in *Section 5.4.3, "Service access"* (part "USB Accessories").

Fig. 1.15: USB WiFi adapter

1.4.3. Service Ethernet - optional (using USB „S")

RAy3 unit can be equipped with the service Ethernet interface as an option. It can be used solely for unit management (no user traffic can be transmitted using this Ethernet connection).

Optional Eth adapter (see RAy Accessories *USB adapters web*[17] for available types) can be inserted in to the USB connector in slot "S" (instead of WiFi module). Management of this Ethernet port is described in *Section 5.4.3, "Service access"* (part "USB Accessories").
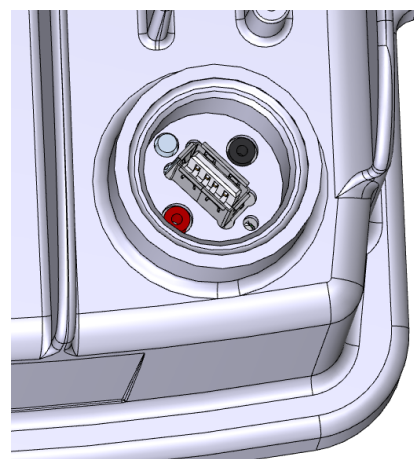
Fig. 1.16: Ethernet adapter

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[16] https://www.racom.eu/eng/products/microwave-link.html#wifi-adapter
[17] https://www.racom.eu/eng/products/microwave-link.html#wifi-adapter

1.4.4. RSS voltage contacts (S)

RSS voltage output connectors are located in slot „S" aside USB connector. This pair of contacts (red + green ones) allows to connect a voltmeter (pin diameter 2 mm) to the RAy unit and measure RSS value transformed to the voltage output.

RSS (Received Signal Strength) is a basic parameter used for directing antennas to the optimal direction. RSS output voltage is calibrated to be proportional to actual RSS dBm (for example 0.547 V means RSS –54.7 dBm). Thus a standard digital voltmeter allows to see RSS value in a digital form interactively during the antenna alignment. More information about RSS voltage output usage is in *Section 4.7.2, "Directing antennas"* (part "Voltmeter") together with several alternative ways to get this value by other methods.

Fig. 1.17: RSS voltage contacts

1.4.5. HW button (S)

It is located in a small hole next to USB connector. It can be pushed by any tiny blunt thing with the diameter up to 2 mm. Its length has to reach about 7 mm in to the hole. (It can be ball pen cartridge – both ends work on the thin one, match, toothpick, etc.).

⚠ **Important**

Usage of very sharp things for pushing the HW button (like needle, edge clip etc.) may **destroy** the contact inside RAy unit! Such a button destruction is not covered by *warranty*.

The button supports multiple functions, which are activated dependent on the state of the unit when the button is pushed and the length of the push:
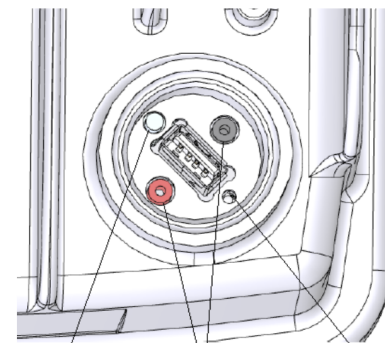
HW button   RSS voltage   Status LED

Fig. 1.18: Service interfaces

Action to be performed	Unit status	Button pushed	SYS LED indication
Restore temporary stored **customer settings** (*backuped previously to FLASH memory of the unit*)	Normal operation	For 5 seconds	Flashes Green
Applying **Factory settings** The entire set of parameters from the Link Settings and Switch settings menu tree is affected including user credentials. Once done, the unit reboots.	Out of power	Pushed before power on, released after SYS LED stops flashing red	Flashes Red (delayed after power on, for a duration of 5 seconds)

ⓘ **Note**
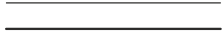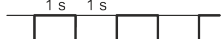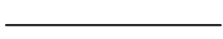
Those actions and their use are described in detail in *Section 5.6.1, "Maintenance"*.

1.5. Status LED (S)

RAy3 unit is equipped with one LED indicator located inside the housing of the FOD unit in slot „S" (during normal operation covered by semi-transparent plug). Meaning of the color combinations of this LED indicator is:

Fig. 1.19: Status LED

Green and Red LEDs	Function
G ▯▯▯▯ R	Unit is starting
G R	Power source voltage is out of allowed range
G R	System is up and working OK
G (1 s 1 s) R	System reports warning or alarm, which can be possibly repaired by user
G R	System reports HW alarm
G R	Unit is out of power or HW button pressed

1.6. Sizes, packaging and labeling

1.6.1. RAy3 unit

• Outer sizes for all RAy3 models are identical:
   245×245×160 mm

• Weight:
   RAy3-10   2.8 kg (6.2 lbs)
   RAy3-11   2.9 kg (6.4 lbs)
   RAy3-17   2.6 kg (5.7 lbs)
   RAy3-18   2.9 kg (6.4 lbs)
   RAy3-24   2.6 kg (5.7 lbs)
   RAy3-80   2.8 kg (6.1 lbs)

Basic technical parameters like identification of the HW model, working frequency, maximum RF Output power, requirements for power supply, most important certifications, etc. are visible on *RAy Product label*. All technical parameters are stated in detail in *Chapter 9, Technical parameters*.

1.6.2. Product label

The label contains identification of the HW model and its serial number, basic technical parameters, most important certifications, QR code to manual, address of the producer, etc. Meaning of the most important information listed on the product label is:

• Type – RAy3 product line identification (for details see *Section 1.7, "Ordering codes"*)
• Code – detailed identification of the unit HW (for details see *Section 1.7.1, "RAy units"*)
• S/N – serial number, MW link consists of two separated units with two different serial numbers
• QR code – www link to the latest version of the User manual
• RF Power – maximum output power
• TX, RX freq – range of working frequency
• PoE – power supply characteristics
• CE, FCC ID, IC or other - available certifications
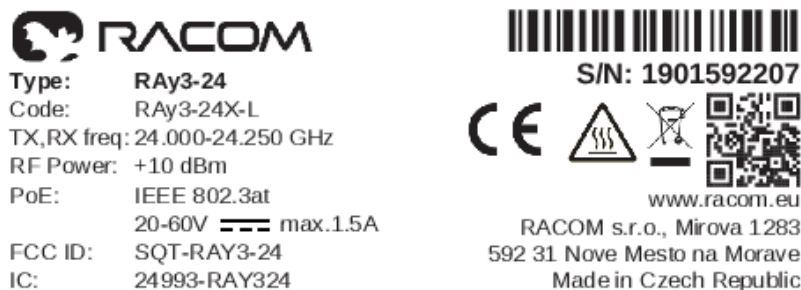
Fig. 1.20: Product label example

⚠ **Important**

The processor included in the unit variant S and X (identified by the item 'Code' on product label and in the *ordering code*) uses an encryption module listed as 5A002.a.1 in the Regulation (EU) 2021/821, setting up a Community regime for the control of exports, transfer, brokering

and transit of dual-use items. Units are subject to export control when exporting outside the European union, according to national, *EU*[18] and US law.

ⓘ Note

A link should consist from a pair of "-L" and "-U" units (L and U are always a last letter in Code printed on product label of each unit), but it is not mandatory for RAy3-17 and RAy3-24 (for those models HW for L and U unit is identical and L/U settings could be assigned by SW). Using L + U pair ensures all default settings of both units match each other (including proper IP addresses as described in this manual). It ensures the link is automatically established when received from the factory or after applying *Default link settings or Factory* settings (to simplify initial setting of the whole link).

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[18] https://policy.trade.ec.europa.eu/help-exporters-and-importers/exporting-dual-use-items_en

1.6.3. Packaging

The RAy3 radio link is supplied in a package containing two separate boxes. Delivery includes:

• 2 pcs RAy3
• 2 pcs Cable bushing set *ACS-RAy3*[19] (bushings and connectors)
• 1 pc *SILICONE GREASE*

If only one unit is delivered, then delivery includes one piece of each item.

The unit is fixed in the box as follows:
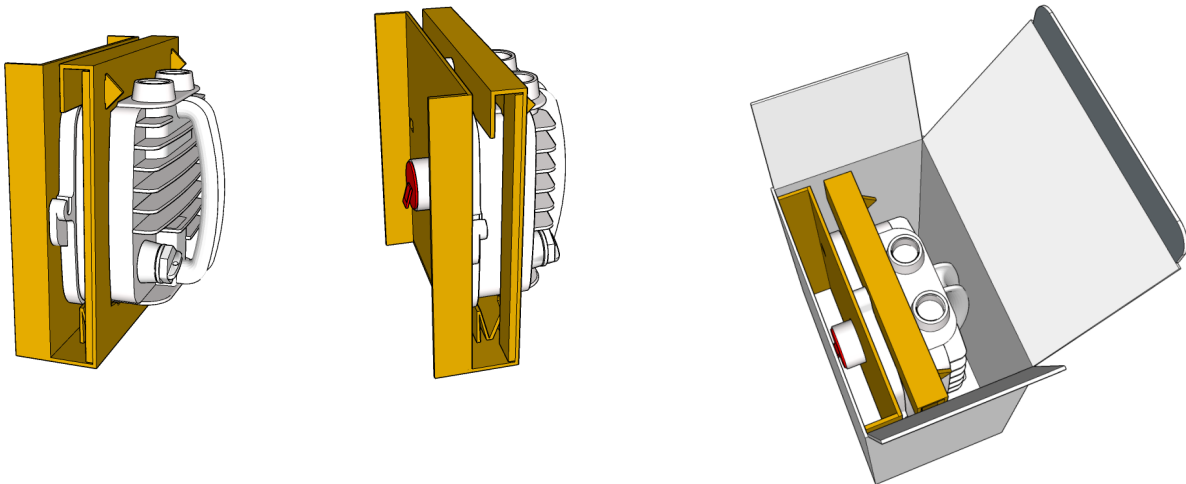
Fig. 1.21: Packaging the RAy3 unit
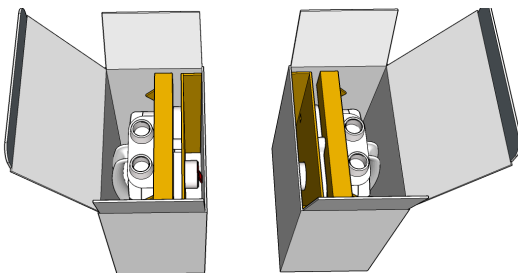
Fig. 1.22: Initial arrangement   Fig. 1.23: SILICONE GREASE capsule Ø45mm × 25mm

ⓘ   **Note**

Two separate boxes in the common package are turned such that both waveguides are heading to each other. It allows to automatically establish a link between delivered RAy3 units without unpacking them from the box. See *Quick Guide, step 4* or *Chapter 3, Step-by-step Guide*.

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[19] https://www.racom.eu/eng/products/microwave-link.html#accessories_kit

Single unit packaging

- Outer sizes for all RAy3 models are identical:
    29×28×18 cm

- Weight:
    RAy3-10   3.4 kg (7.5 lbs)
    RAy3-11   3.5 kg (7.7 lbs)
    RAy3-17   3.2 kg (7.1 lbs)
    RAy3-18   3.5 kg (7.7 lbs)
    RAy3-24   3.2 kg (7.1 lbs)
    RAy3-80   3.4 kg (7.4 lbs)

Double unit packaging

- Outer size:
    38×32×29 cm

- Weight:
    RAy3-10   7.2 kg (15.9 lbs)
    RAy3-11   7.4 kg (16.3 lbs)
    RAy3-17   6.8 kg (15.0 lbs)
    RAy3-18   7.4 kg (16.3 lbs)
    RAy3-24   6.8 kg (15.0 lbs)
    RAy3-80   7.1 kg (15.6 lbs)

1.6.4. Supplied antennas

RAy3 units are ready for direct mounting to:

- *Jirous Class 3*[20] or Class 2 antennas (*Jirous Antennas*[21])
- *LEAX-RAy Class 3*[22] antennas (*LEAX ARKIVATOR TELECOM website*[23])
- *Shenglu-RAy Class 3*[24] antennas

ⓘ **Note**

Jirous Class 3 antennas (type JRMC in Ordering code) smoothly replaced Jirous Class 2 antennas (types JRMA or JRMB in Ordering code) in RACOM portfolio of antennas during Q1/2020.

Individual datasheets with exact sizes and weights are accessible on *RACOM website*[25].

Standard antennas shipment is one antenna in its own box. RACOM is able to arrange more compact shipment for a bigger amount of antennas (on a special request).

Tab. 1.1: Overview of Jirous Class 3 antennas

	Bands		
	10, 11 GHz	**17, 18 GHz**	**24 GHz**
diameter [m]	gain [dBi]	gain [dBi]	gain [dBi]
0.4	29.5-30.5	34.6-35.6	37.4
0.68	34.1-36.0	38.6-40.0	42.0
0.9	37.0-37.5	41.4-42.5	44.0
1.2	40.0-41.0	43.2-44.7	46.0
1.8	43.0-44.0	-	-

Tab. 1.2: Overview of LEAX-RAy antennas

		Bands		
		10, 11 GHz	**17, 18 GHz**	**24 GHz**
nominal diameter [m]	dish diameter [m]	gain [dBi]	gain [dBi]	gain [dBi]
0.3	0.37	29.0-30.1	33.7-34.7	36.9
0.6	0.66	34.1-35.2	39.4-40.5	42.0
0.9	0.98	37.5-38.5	42.4-44.1	45.4
1.2	1.29	40.3-41.7	44.7-45.7	47.9

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[20] https://www.racom.eu/eng/products/microwave-link.html#accessories_antennas
[21] http://en.jirous.com/
[22] https://www.racom.eu/eng/products/microwave-link.html#accessories_antennas
[23] https://www.arkivator-telecom.com/en/products/microwave-antennas.html
[24] https://www.racom.eu/eng/products/microwave-link.html#accessories_antennas
[25] https://www.racom.eu/eng/products/microwave-link.html#accessories_antennas

Tab. 1.3: Overview of Shenglu-RAy antennas

nominal diameter [m]	dish diameter [m]	Bands		
		10, 11 GHz	17, 18 GHz	24 GHz
		gain [dBi]	gain [dBi]	gain [dBi]
0.3	0.38	28.7-30.0	33.3-34.6	36.5
0.6	0.66	33.5-35.0	38.4-39.6	41.5
0.9	1.02	37.8-39.0	42.3-43.5	45.4
1.2	1.30	40.2-41.0	44.0-45.1	46.6
1.8	1.89	-	47.1-48.2	-

Andrew (Class 2 or 3 or 4) or traditional Arkivator antennas or antennas from other suppliers can also be used, but they require an *antenna mounting kit*[26]. *Flexible waveguide*[27] is a general-purpose option for any antenna usage. *Contact us*[28] for available types and details.

1.6.5. Supplied accessories

Antennas and other accessories are necessary for RAy units to allow a proper functionality of the whole microwave link.

RACOM always tries to ship all ordered accessories together with RAy units and antennas. Accessories are mostly small items, so typical RACOM packaging is that all accessories are shipped on the same palette with other material (within one additional RAy box).

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[26] https://www.racom.eu/eng/products/microwave-link.html#accessories_antennas
[27] https://www.racom.eu/eng/products/microwave-link.html#accessories_antennas
[28] https://www.racom.eu/eng/about_us/contact.html

1.7. Ordering codes

All RAy3 models mentioned in this manual have their unique ordering codes. Available are also capacity keys, feature activation keys and accessories necessary to reach expected functionality of the link. All ordering codes are discussed in detail in this chapter and at *RACOM web*[29], and are available for purchase at *RACOM E-shop*[30].

> **Note**
>
> Ask your supplier to ensure completeness of your product delivery for the individual link situation, applicable spectrum regulations, local safety and security requirements, type of power sourcing, grounding, etc.

> **Important**
>
> RACOM does not have any responsibility for improper use of any offered device. It is customers full responsibility to check technical parameters of all ordered items and to use and configure them in accordance with their purpose. It is also customers full responsibility to respect all requirements applicable at the site of installation.

1.7.1. RAy units

RAy ordering codes begin with a string printed on *Product label* (9-11 characters long, lasting by „-L" or „-U"). It defines HW parameters and factory settings, which cannot be changed later on (like working frequency, encryption HW support, factory defaults and limitations built in to units in the factory like limitation of RF Output power or prevention to use any form of encryption). Rest of the ordering code defines functionalities and options which could be added, erased or changed by a user later on (like SW feature key for initial capacity or an optional DC power adapter).

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[29] https://www.racom.eu/eng/products/microwave-link.html#order-codes
[30] https://webservice-new.racom.eu/main/eshop.list

Ordering Code structure:

RAY3-24E-L (360) [DC]

Trade name   Gen.   Band   Var.   FRQ   SW keys   Opt. accessories

Type

Code

Order code

Trade name - trade and marketing name of the product. This name is used for all products within the same product family.
    Possible values: **RAy**

Gen. - generation of the product of specific Trade name. The very first generation does not have any number in this position.

    Possible values: **none, 2, 3**
    Current generation is RAy3. Order codes for legacy products (Gen. 1 or 2) - see *RAy User manual*[31] or *RAy2 User manual*[32].

Band - frequency band in GHz
    Possible values: **10, 11, 17, 18, 24, 80**

Var. - designation of product variant. More variants can be used within one unit, i.e. more letters can be on this position. These variants are fixed in unit HW and cannot be changed later on.
    Possible values:
        E – Data encryption possible.
        N – Data encryption never possible.
        R – reduced RF output power -30 to -15 dBm, for RAy3-24 only (always in combination with encryption letter E, N).
    Legacy values:
        none (position not used) – means same as **X**
        X* – encryption HW support (under production until III/2021; see *export restriction* below)
        S* or **XS*** – encryption HW support, MTU limited to 2048 Bytes (under production until III/2019; see *export restriction* below)

FRQ – frequency
    Possible values:
        L or **U** – unit transmits on Lower (L) or Upper (U) part of the band
            When ordering a link, order one L unit and one U unit - see Note below for more info.
        A or **B** or **C** – sub-band for some frequencies (like RAy3-10, RAy3-11, RAy3-18)
            Two letters (L/U and A/B/C) are used then.

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[31] https://www.racom.eu/eng/products/m/ray17/product.html#obj_kod
[32] https://www.racom.eu/eng/products/m/ray2/product.html#obj-kod

SW keys – if unit is ordered with SW keys, those are specified in this bracket. Every SW key can be ordered independently for specific unit S/N anytime later on. Part No's are different depending on whether the key is ordered with the unit or later.
> Possible values:
> > **360** or **500** or **1000** (except RAy3-80) or **2000** (RAy3-11 only).
> > > Default *Data speed*[33] is 360 Mb/s for all units.
> > > Part No.: RAy3-SW-360; optional 500 Mb/s, Part No.: RAy3-SW-500; optional 1000 Mb/s, Part No.: RAy3-SW-1000
> > **1G** or **2.5G** or **5G** or **10G** (RAy3-80 only).
> > > Default *Data speed*[34] is 1 Gb/s for all units.
> > > Part No.: RAy3-SW-1000; optional 2.5 Gb/s, Part No.: RAy3-SW-2500; optional 5 Gb/s, Part No.: RAy3-SW-5000; optional 10 Gb/s, Part No.: RAy3-SW-10000
> > **Power** (RAy3-11, RAy3-18, RAy3-80 only)
> > > Enables *full RF Output power* of the unit (otherwise max. ˋ*TX power*ˋ is +10 dBm).
> > > Part No.: RAy3-SW-POWER
> > **Encryption** (except RAy3-80)
> > > Enables *AES encryption*.
> > > Part No.: RAy3-SW-ENCRYPTION

Opt. accessories – if unit is ordered with optional accessories, those are specified in this bracket.
> Possible values:
> > **DC** – DC/RJ45 power adapter, Part No.: *OTH-DC/RJ45*[35]

Type – specific product type for which type approvals like CE, FCC etc. are issued
> Possible values:
> > **RAy3-10, RAy3-11, RAy3-17, RAy3-18, RAy3-24, RAy3-80**

Code – detailed HW identification of the unit printed on *Product label* on the housing.
> SW keys and Optional accessories are not HW dependent and can be installed or de-installed later on, so they are not printed on Product label.

Order code – the complete product code, which is used on Quotations, Invoices, Delivery notes etc.

In order to find out the correct Order code, please use *E-shop*[36].

⚠ **Important**

* **Export restrictions:** The processor included in the unit variants 'X' and 'S' uses an encryption module listed as 5A002.a.1 in the Regulation (EU) 2021/821, setting up a Community regime for the control of exports, transfer, brokering and transit of dual-use items. Units are subject to export control when exporting outside the European union, according to national, EU and *US law (ECCN 5A002.a.1)*[37].

In the case of export from the country where the units were originally delivered by RACOM, the exporter must inform RACOM of the new country of delivery.

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[33] https://www.racom.eu/eng/products/microwave-link-detail#scalability

[34] https://www.racom.eu/eng/products/microwave-link-detail#scalability

[35] https://webservice-new.racom.eu/main/eshop.detail?i=1829

[36] https://webservice-new.racom.eu/main/eshop.list?t=10

[37] https://policy.trade.ec.europa.eu/help-exporters-and-importers/exporting-dual-use-items_en

> **ⓘ** **Note**
>
> RAy3-17, RAy3-24 – the same HW for Lower (L) and Upper (U) unit. L/U is used, but indicates only factory defaults for TX/RX frequencies and other parameters which needs to be different for each side of the link. All these parameters can be changed in the management (including changing L to U and vice versa).
>
> All other RAy3 – different HW for Lower (L) and Upper (U) unit.
>
> Selecting the pair of Lower (L) and Upper (U) units for a link allows the link to be established without any initial manual settings – just by powering up both units at factory defaults (see *Quick guide* or *Chapter 3, Step-by-step Guide*).

1.7.2. Capacity SW keys

RAy units allow to pay only for purchased transmission capacity (pay as-you-grow concept). Activation keys could be purchased together with the unit or later at *RACOM E-shop*[38]. Each key is generated for specific S/N of the unit and the purchased capacity. Once installed, it unlocks all combinations of channels and modulations up to the purchased capacity. SW keys could be erased or upgraded. See *Section 5.6.1.2, "SW feature keys"* for more details.

For allowed combinations of channel width and modulation for transmitting channel see *Capacity SW keys table*[39]. The Capacity limit applies for transmitted data on the unit where the key is installed. SW keys for capacity could be different for each side of the link - for example if the link is expected to be configured for asymmetrical capacity.

Several types of SW feature key are available for RAy units:

• Bundled capacity (ordered together with *RAy units* - see previous chapter)
• Separately purchased capacity SW keys (see below)
• Upgrade capacity SW keys (see below)

> **ⓘ** **Note**
>
> RACOM is able to generate customer specific Capacity SW keys on special request.

1.7.2.1. Capacity purchased separately

SW keys purchased separately and installed by user.

Tab. 1.4: Capacity keys code scheme

	RAy3-SW-500
Example:	
Product type RAy	
SW (= all possible feature keys)	
Speed limit in Mbps	

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[38] https://webservice-new.racom.eu/main/eshop.list
[39] https://www.racom.eu/eng/products/microwave-link.html#scalability

For ordering see *RACOM E-shop*[40].

1.7.2.2. Capacity Upgrade

SW keys purchased separately and installed by user.

Tab. 1.5: Upgrade keys code scheme
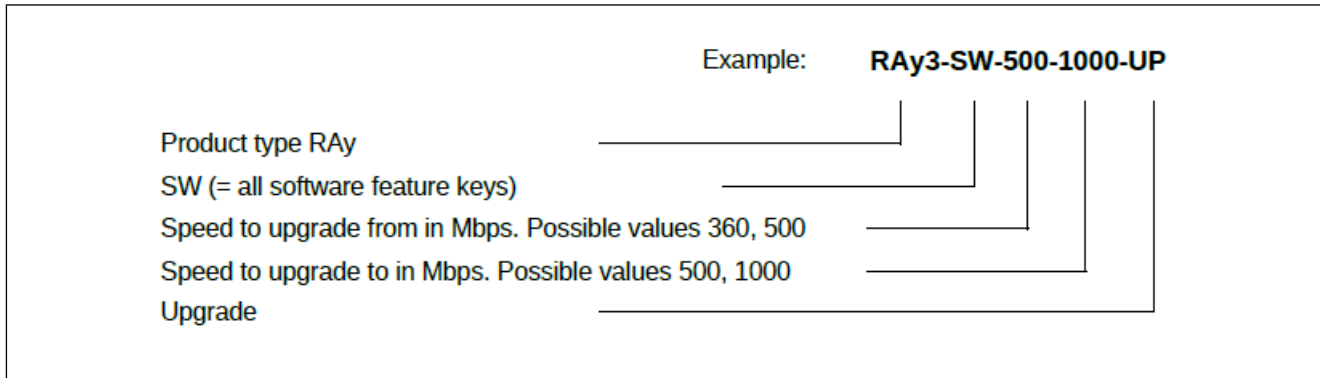
For ordering see *RACOM E-shop*[41].

1.7.3. Features activation SW keys

RAy units allow to pay only for purchased features (pay as-you-grow concept). Activation SW keys could be purchased together with the unit (as described in *Section 1.7.1, "RAy units"*) or later at *RACOM E-shop*[42] or by a special agreement. Each SW key is generated for specific S/N of the unit and the purchased feature (or a set of features). Once installed, a specific feature or function of the unit is allowed. SW keys could be erased or upgraded. See *Section 5.6.1.2, "SW feature keys"* for more details.

Available SW feature activation keys are listed in following table:

Tab. 1.6: SW keys overview

RAy3	Ordering codes for feature activation keys			
Ordering code	**Meaning**	**Parameters**	**Without key**	**Note**
RAy3-SW-xxx	Limitation of Speed	xxx: value of speed in Mb/s	RAy3-10, 17, 18: < 3 Mb/s RAy3-11: 4 Mb/s RAy3-80: 25 Mb/s	
RAy3-SW-POWER	Unlimited RF Output power	-	RAy3-10: -15 dBm RAy3-11, 18: -1 dBm RAy3-17, 24: -30 dBm RAy3-80: -6 dBm	only RAy3-11, RAy3-18, RAy3-80
RAy3-SW-TX-xyy	Limitation of RF Output power	x: P = positive value N = negative value yy: value of limit in dBm	RAy3-10: -15 dBm RAy3-11, 18: -1 dBm RAy3-17, 24: -30 dBm RAy3-80: -6 dBm	not in E-shop (Special agreement needed)

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[40] https://webservice-new.racom.eu/main/eshop.list
[41] https://webservice-new.racom.eu/main/eshop.list
[42] https://webservice-new.racom.eu/main/eshop.list

RAy3	Ordering codes for feature activation keys			
Ordering code	**Meaning**	**Parameters**	**Without key**	**Note**
RAy3-SW-ENCRYPTION	Allow AES encryption	-	Encryption disabled	not in E-shop (Special agreement needed)

ver 1.0

ⓘ **Note**

Units with variant 'N' in the Code printed on Product label would never allow to use encryption, even if such a SW key is purchased and installed to the unit ('N' prevails).

1.7.4. Tested Accessories

Ordering codes for all accessories offered by RACOM to allow a proper functionality of the whole microwave link are listed on *Accessories section*[43] of RAy web site and they are available for purchase in *RACOM E-shop*[44]. More information about accessories can be also found in *Chapter 2, Accessories*.

ⓘ **Note**

Please consult your supplier to ensure completeness of your product delivery for the individual link situation, spectrum regulations, local security requirements, type of power sourcing, grounding, etc.

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[43] https://www.racom.eu/eng/products/microwave-link.html#accessories
[44] https://webservice-new.racom.eu/main/eshop.list

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2. Accessories

RACOM offers a complete set of accessories to operate RAy microwave units in all relevant use-cases and environments. All accessories are selected and thoroughly tested by RACOM for compatibility and are guaranteed to function with RAy units. There are only a very few accessories which has to be purchased from RACOM to work properly - e.g. WiFi adapters (the reason is limited set of WiFi drivers in RAy FW). Such an information is always part of accessory description. With most types of accessories it is possible to use other components with same or similar functionality and temperature range, but RACOM cannot guarantee they will be completely compatible with RAy units.

All accessories are listed on *Accessories section*[1] of RAy web site and they are available for purchase in *RACOM E-shop*[2].

⚠ **Important**

It is strongly recommended to double-check the main voltage and local installation standards before purchasing accessories to ensure they comply with the accessory specifications and that all safety regulations are complied with.

In particular, we recommend that you consult your local specialists for grounding, voltage spikes, overvoltage protection and other equipment, ensuring a proper installation. For more information see *Section 4.5, "Grounding and overvoltage protection"*.

Units and accessories should be installed by trained professionals (see *Section 10.3, "Professional installation"*).

The warranty does not apply to units damaged by voltage spikes or surges (see *Section 10.6, "Warranty"*).

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[1] https://www.racom.eu/eng/products/microwave-link.html#accessories
[2] https://webservice-new.racom.eu/main/eshop.list

3. Step-by-step Guide

This chapter will guide you step by step through the basic link preparation, installation and configuration. A brief description of all those steps in a picture form can be found in *Quick guide* (the introductory chapter to this manual). Its shortened version is printed on the cardboard holding each delivered unit inside each transport box.

For detailed description of all possible functionality of the unit see other chapters, mainly:

• *Chapter 4, Installation*
• *Chapter 5, Configuration*
• *Chapter 8, Troubleshooting*

3.1. Pre-installation check out

Default settings for *L and U units* are chosen to allow delivered units to automatically establish a link without unpacking RAy3 units from the box. It is enough to open the boxes and power both RAy units up (by PoE or DC power supplies). It allows users to comfortably set up basic parameters necessary for the installation in the lab and thus shorten the time on the tower or roof to a minimum. Following text provides a guide how to optimally arrange the workplace, how to setup the link and which parameters are good to be set up before the installation outside.

Default factory settings define the initial link to be established on the most narrow channel, strongest modulation and lowest available RF Output power (in RAy3-17 and RAy3-24 case those are 3.5 MHz channel, QPSK_S modulation and TX power = -30 dBm). Complete default settings for all models are described in *Chapter 9, Technical parameters*.

(i) **Note**

RAy3 default factory settings allow to install both units on the mast and establish the very short link without prior manual configuration. Typically, TX power has to be increased to a reasonable level (or even to a maximum) before link alignment, because default value of 'Max TX power' is too low for the reasonable distance.
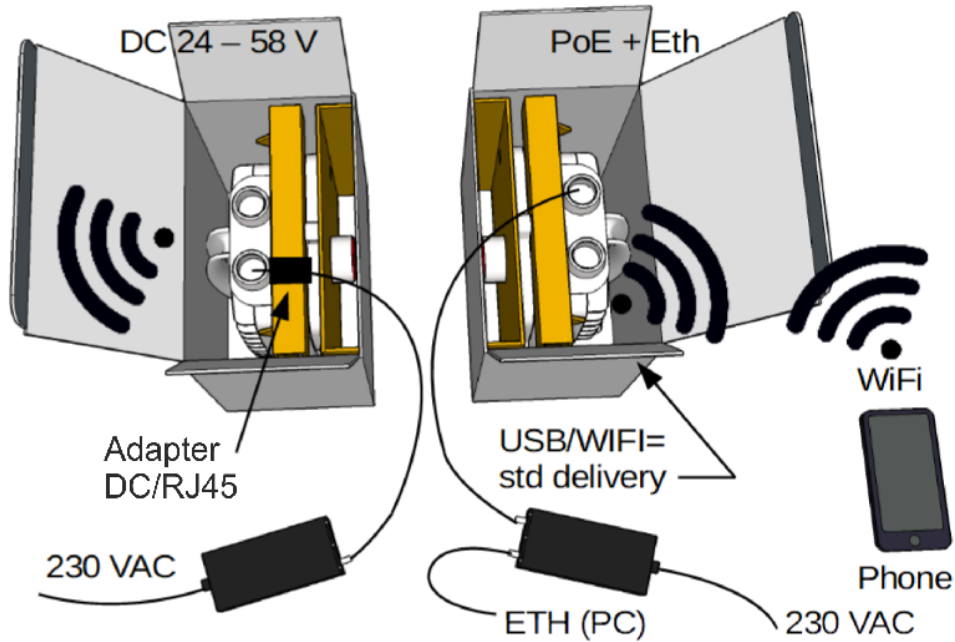
Fig. 3.1: Workplace for link testing and configuration

Take the following steps to link together both delivered RAy3 units and to establish a connection between them and PC or tablet or mobile and perform a basic setup:

■ Open both boxes and double check that both RAy3 units are turned OK, so waveguides are heading to each other.

■ Connect power sources (PoE or DC) to both RAy3 units (using slot ETH1+POE).

■ Wait about 30 seconds until both units boot up and the link is established. The green light should be visible on both units through transparent plug on slot "S". Until a WiFi password is set, red light periodically flashes together with green light - see *Section 1.5, "Status LED (S)"*.

■ Connect by WiFi or by Ethernet cable (plugged in to LAN input on PoE power supply or in to Eth port on USB/ETH adapter) to one of those two units. Units linked together allow effectively set all IP addresses, passwords, security keys, SW feature keys, users, etc. from one side of the link.

○ If WiFi is used, then just select which WiFi to connect to. IP address of your PC or laptop is set automatically by DHCP.

○ If Eth over USB port is used (through USB/ETH adapter OTH-USB/ETH-XA), IP address of your PC or laptop is set automatically by DHCP as well.

○ If Eth connection to one of data ports on RAy3 (ETH1 or ETH2) is used, then the IP address on your PC or laptop has to be set manually to establish a working connection. See Quick Guide for the complete list of IP addresses to use.

○ Enter a web management of the unit and configure everything you like to change to be ready for outside installation. Following parameters are typically set in this phase:
  • IP addresses and VLANs
  • passwords
  • security keys
  • SW feature keys

- users
- WiFi password and behavior
- TX and RX frequencies (if known in advance)
- Higher TX power (to be ready for antenna alignment) – see section "Important" below

Note

- This setup can be used for link configuration, however full radio performance can't be expected (high modulations, full TX power range, etc.) because standard conditions between units (antenna interface, polarization planes, free space attenuation) are not met inside the box.
- High RF Output power does not necessarily lead to better RX signal quality, because the receiver input can be saturated with too strong signal - see *Overexcited receiver*.
- Until a WiFi password is set, red light periodically flashes together with green light - see *Section 1.5, "Status LED (S)"*.

Important

- Maximum secure TX power for RAy units inside the box is 0 dBm. Higher TX power risks the damage of sensitive input circuits!
- If you need to configure higher TX power to be ready for antenna alignment during installation on the mast, first you have to turn units in to position where waveguides are not heading to each other, so reasonable attenuation is ensured. Secure is for example to put RAy units in parallel in to a direction without any metal material in front of the microwave beams (it could reflect waves back to units).
- Maximum time, that units can be powered up inside the box is 10 minutes (standard room temperature expected). Longer time may lead to the unit overheat! If more time is needed for configuration, units have to be unpacked from boxes.

3.2. Service access

The RAy3 link is supplied with a default configuration of access parameters:

For Ethernet access through RJ45 or SFP ports:
- Unit L has the service IP address 192.168.169.169 and mask 255.255.255.0
- Unit U has the service IP address 192.168.169.170 and mask 255.255.255.0

For WiFi or Ethernet access via USB/WiFi or USB/ETH adapter:
- Both units have service IP address 172.17.17.17 and mask 255.255.255.0

For Ethernet access through RJ45 or SFP ports an IP address has to be set on your PC that is within the mask, e.g. 192.168.169.180. For WiFi or USB/ETH access an IP address for laptop or mobile or tablet is set automatically by DHCP (enabled by default).

Then open the HTTP or HTTPS configuration interface, e.g. https://192.168.169.169 or http://172.17.17.17
Access is allowed over HTTP, HTTPS or SSH.
The default username and the password is "admin" (it is strongly recommended to change it).

See *Configuration > Link settings > Service access > USB accessories* chapter for detailed information.

The Antenna Alignment Web Tool can also be used for antenna direction alignment. It can be accessed via a web browser utilizing IP addresses with „/tk" at the end (e.g. http://172.17.17.17/tk for WiFi or USB/ETH adapter or http://192.168.169.169/tk or http://192.168.169.168/tk for ETH1/ETH2 ports).

When connection has been established, use the *Service access* menu to customize access parameters.

Default management IP addresses should be replaced with well-chosen operating addresses. Default can lead to network problems later.

The menu contains parameters for the entire link, both for the Local and remote Peer units. If a connection has been established, both sets of parameters have been set. While working with an isolated unit, only Local parameters are functional for the currently connected unit.

> **(i)** **Note**
>
> If the link is **OK** and there are no parameters shown of the station **Peer**, it is necessary to click on **Refresh**.

Follow the description of basic settings. Pictures in following sections show default factory settings for 24 GHz L unit and RC info "rcinfo24_ISM250_default:XXX". Default settings for unit U (for opposite side of the link) would be adequately exchanged. Names of rcinfo file and values each one represents may be different for other RCinfo (differences typically refer to frequencies and TX power as they are allowed by authorities for the actual band and a region).

After entering values on the screen always save the content by clicking on **Apply**.

3.2.1. Choosing right band according the country of use

Menu Tools > Maintenance > Radio adaptation

First step is to set the right set of rules for the band according the region or country of use, so the unit is compliant with the local regulation. Go to the menu according the picture below and set parameter RCINFO accordingly.

Fig. 3.2: Menu Tools > Maintenance > Radio adaptation

For full explanation of all possibilities of this screen see *Section 5.6.1.4, "Radio adaptation"* in *Chapter 5, Configuration*.

3.2.2. Setting units name and location

Menu Link settings > General

Not necessary settings. Anyhow it is beneficial to name the link and its location for easier identification later on:

- Station name – station can be assigned with a name, e.g. the place of installation.
- Station location – for easier inclusion the network hierarchy, it is possible to enter the station's location
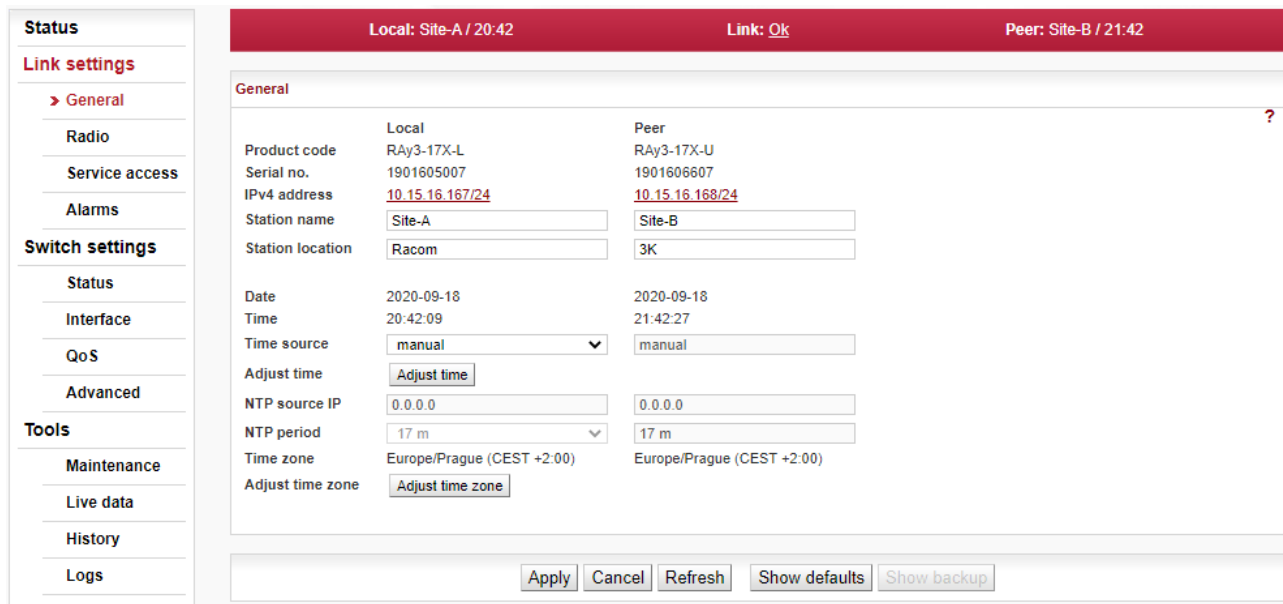
Fig. 3.3: Configuration Menu Link settings > General

For full explanation of all possibilities of this screen see *Section 5.4.1, "General"*.

3.2.3. Setting Ethernet access parameters

Menu Link > Service access > Services

Those settings are necessary to make new units accessible within target Ethernet network. Typically, all following parameters should be set according to both networks IP addressing, routing, planned access methods for data and for management, etc.:

- IPv4 address – enter a valid IP address to access the unit. The default IP address has to be replaced with a valid address. Keeping the default address will probably lead to future problems in the network.
- Netmask – enter the network mask.
- Gateway – if necessary, enter a gateway, otherwise leave blank.
- Enable access protocols that you will need. For security reasons, do not enable more than is necessary.
- HTTP(S) – allow access to the web interface.
- Telnet – enabling access to the CLI interface using telnet protocol.
- SSH – enabling access to the CLI interface using SSH protocol.
- Management VLAN – Enabling 802.1Q VLAN tag for separation of user and service operations.
- Management VLAN ID – Defining 802.1Q VLAN tag for service operations.

Fig. 3.4: Configuration menu Link settings > Service access > Services

For full explanation of all possibilities of this screen see *Section 5.4.3, "Service access"* in *Chapter 5, Configuration*.

3.2.4. Creation of users

Menu Link > Service access > Users

It is recommended to create user accounts managed by the main user already in this phase (for example a user with rights limited to read-only access). Following actions are available:

• Edit - enter the menu.
• New password – choose a password and enter it.
• Confirm password – enter the password again to confirm.
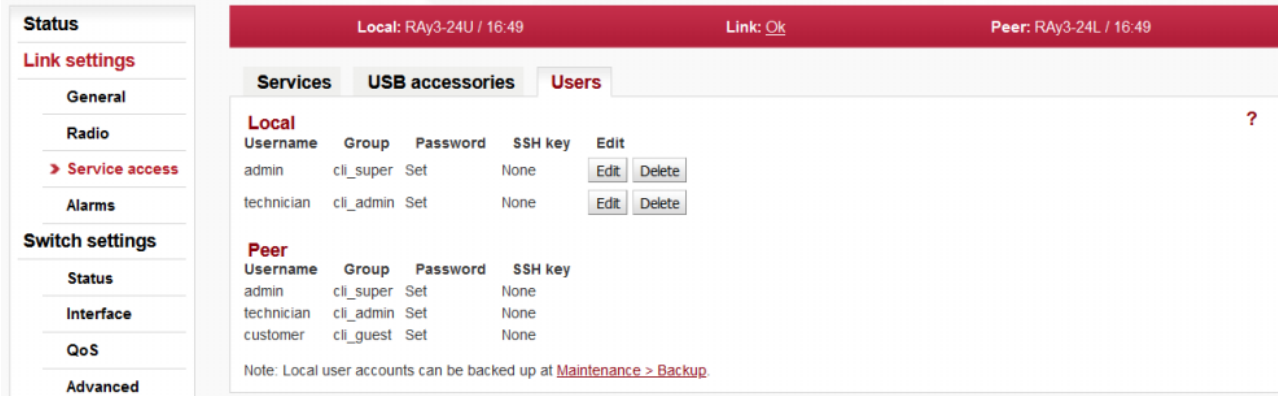
Fig. 3.5: Configuration menu Link settings > Service access > Users

For full explanation of all possibilities of this screen see *Section 5.4.3.3, "Users"* in *Chapter 5, Configuration*.

3.2.5. Applying SW Feature keys

The firmware of the microwave link is capable of controlling several features (for example the maximum user data speed, maximum TX power, etc.). It is recommended to install all separately purchased SW feature keys prior to physical installation to allow all expected functionality of the link to be usable after the installation.

Fig. 3.6: Configuration menu Tools > Maintenance > SW Feature keys

Note

Speed keys purchased with the unit are installed in the factory (and can be double checked within this menu). Key for limited TX power is not installed except specifically ordered. If RCinfo limits the maximum power, it cannot be overruled by SW feature key with the higher TX power.

For full explanation of possibilities of this screen see *Section 5.6.1.2, "SW feature keys"* in *Chapter 5, Configuration*.

3.2.6. WiFi settings

Menu Link > Service access > USB accessories

Go to menu Link Settings > Service Access > USB accessories and enter WiFi password or disable WiFi completely. Standard settings are that Enable on Air link loss is ON (when the link is down, WiFi is activated; when link is OK, WiFi will be deactivated in few minutes) and Force Enable is OFF (activates WiFi permanently). Passphrase has to be set, otherwise the WiFi is unsecured and system warning is active.
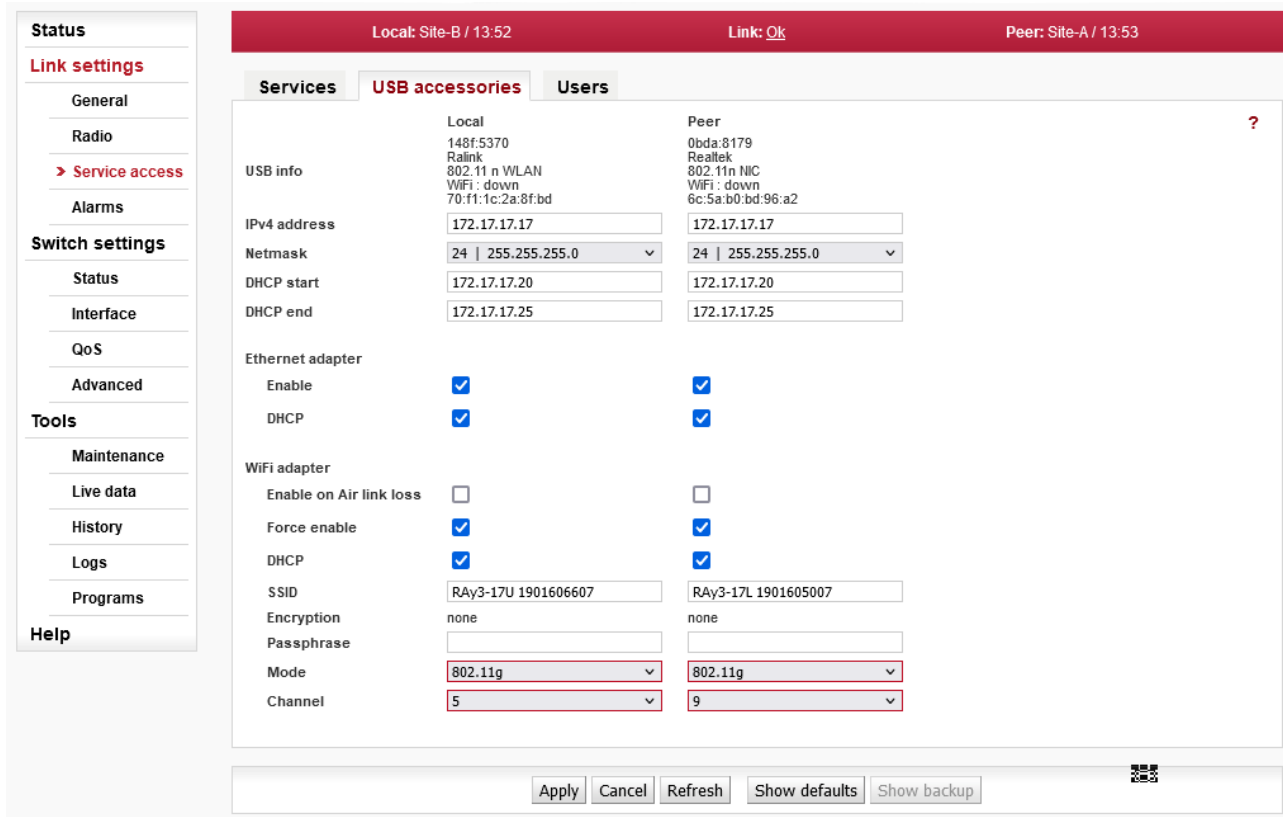
Fig. 3.7: Configuration menu Link settings > Service access > USB accessories

(i) Note

If you access the unit over WiFi, do this step as last action before reboot (as the WiFi connection will be interrupted and new connection with new password would be required to continue the work).

For full explanation of possibilities of this screen see *Section 5.4.3.2, "USB accessories"* in *Chapter 5, Configuration*.

3.3. Basic link configuration

Default radio parameters depend on the specific type of link and the specific channel allocation table. Channels are typically set for smallest possible bandwidth in the lower part of the band. Radio defaults also define QPSK modulation (in the case of RAy3-80 default is 2PSK_BW/4_S modulation), the lowest possible 'Max TX power' parameter and ATPC off, so both units in the pair should connect each other right from the box (or even inside a box). If there is no spectrum conflict with other equipment in the room (or on sites later on) and units can "hear" each other, those parameters can be used as they are and both units can be powered on. After boot (about 30 seconds) the link should be automatically established.

If a change of the parameters is necessary, it can be done in the menu *Link settings > Radio* and saved by clicking Apply button. This applies, when the work is done simultaneously on both units, while they are connected. Otherwise each unit has to be configured individually. When configuring units individually, pay attention to correct settings of duplex pair for channels TX (transmission) and RX (receive). For example, if one station has TX channel L1, then the second station RX channel must be set to the same channel width and to the same channel L1, otherwise units do not hear each other.

3.4. Link test

Verify the functionality of the radio link:

- Switch in screen *Status > Brief.*
- *Status Bar* displays   Link: Ok.
  If the alarm message appears at Local or Peer, it doesn't necessarily mean there is a problem. The message indicates, that WiFi password was not set or the limit of any of the monitored parameters has been exceeded. Essential is the "Link: Ok" message on the status bar.
- The *Status* screen contains values for both Local and Peer units. N/A next to Peer indicates that the data from the Peer unit has not been transferred. If Link is Ok, simply click Refresh at the bottom of the screen and Peer data will be updated.
- Menu *Status > Detailed > Radio* indicates link RSS and MSE values, the selected modulation and Netbitrate. If the ATPC function is enabled (menu Link settings > Radio) it also indicates instantaneous / max. allowed power and for MSE and RSS values it indicates immediate / target value size.
- Menu *Tools > Live data > Bar indicators* displays current RSS and MSE.
- Menu *Tools > Programs > Ping* allows you to send a ping test to the selected IP address.

Try out the possibility of higher modulation:

- Usage of higher modulations require to play with the parameters of ACM (Adaptive Coding and Modulation) or ACMB (Adaptive Coding, Modulation and Bandwidth) in the menu *Link settings > Radio*. To activate ACM/ACMB set the parameter 'ACM/ACMB maximal TX modulation' to a higher value than default QPSK_S (respectively 2PSK_BW/4_S in case of RAy3-80). This value defines the top of ACM/ACMB range the unit modulation can be automatically set based on the instantaneous MSE signal quality. In menu *Status > Brief > Radio* you can monitor (Refresh or Start) changes in used modulation.
- To set a fixed modulation set both parameters 'ACM/ACMB maximal TX modulation' and 'ACM/ACMB minimal TX modulation' to identical values based on the results of the previous test. If you choose modulation higher than allowed by MSE, the connection will be lost and *Status Link* will lose its *Ok* value. Both units will need to be moved closer to resume the link. If this is not possible, use the Ethernet to access each unit individually and set both units to the lower modulation.

Verify the functionality of the entire link:

- If possible, connect user devices to both RAy units over PoE and test mutual communication.
- Another way of testing this is to connect a PC to the other unit and send a ping from one PC to the other.
- The minimum variant of this test is to use an Ethernet cable connection from the PC connected to the local RAy to the PC connected to the remote RAy and test communication between both units over Ethernet. This will verify Ethernet functionality.

Prepare installation configuration:

- Bandwidth: To get the highest possible receiver sensitivity, set the bandwidth as narrow as possible according to specific frequency band (e.g. 3.5 MHz).
- TX channel: Use your allocated channel. If you do not have any allocated channel yet, use for example channel L1.
- RX channel will setup automatically when channel lock activates.
- TX modulation: Set the lowest available modulation to get the highest possible sensitivity (e.g. QPSK_S).
- RF Output power: Set parameter 'Max TX power' as high as possible according to used antenna, to individual frequency license and/or to local legal limitations of maximum EIRP.
- Set a new user *access passwords*.
- Record access parameters from the Service access menu, especially the IP addresses.
- Restart both units by interrupting the power supply to verify that the parameters are stored correctly and the link works.

After this preparation you can continue to install your devices in a working environment.

4. Installation

4.1. Line of sight test

Before you install the device to a mast tube, verify visually that the view in the direction of the remote unit is unobstructed.

Line of sight considerations:

- Free Fresnel zones. Signal needs space wider than the diameter of the antenna.
- Trees at the lower end of the Fresnel zone. They will grow taller in a few years.
- Possible building development.
- Objects in the close proximity of the antenna such as edges of other antennas, their mounting racks, edges of the roof.
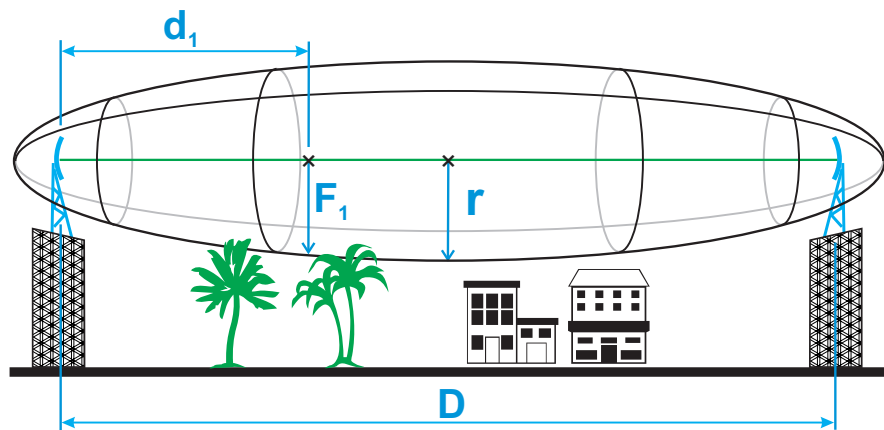
Fig. 4.1: Fresnel zone

4.2. Antenna mounting

Antenna mounting depends on the antenna vendor, antenna type and the size of the chosen antenna. The result of any antenna installation is that it is fixed to the mast, pointing to the right direction and its waveguide and fixing screws are ready for *mounting RAy unit* to it.
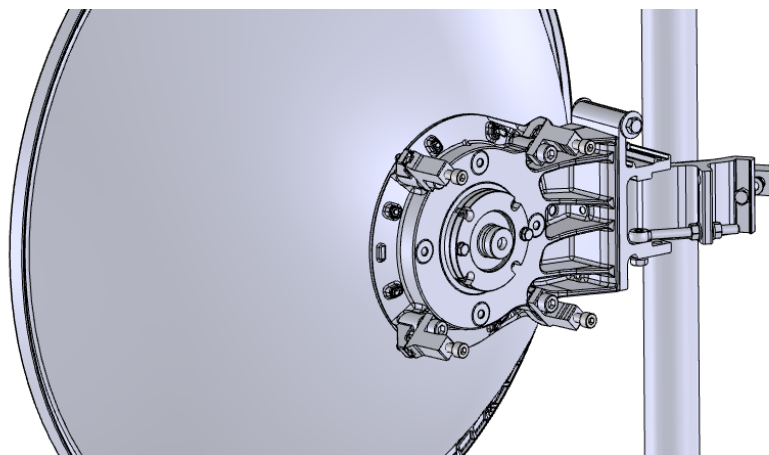
Fig. 4.2: Antenna mounting
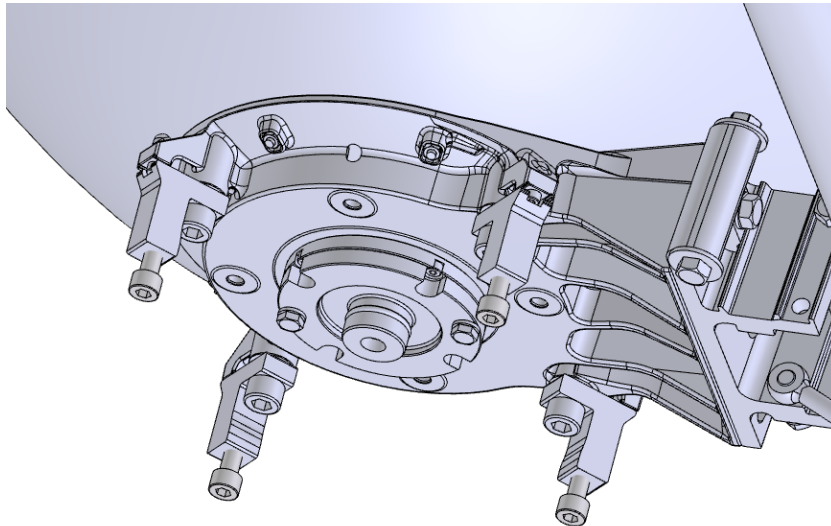
Fig. 4.3: Fixing screws

Common for all antennas is a holder which ensures:

• fixing of the antenna to the mast
• flexibility in two planes (necessary for antenna adjustment to the *proper direction*).

Each holder allows at least 2 methods of mounting antenna on the mast tube:

• right-side mounting
• left-side mounting

Following sections describe in detail installation of antennas, mounting kits and/or flexible waveguides, so the antenna is ready for mounting RAy unit to it. Choose below a chapter relevant for your antenna supplier and installation manual according to antenna type and size.

ⓘ **Note**

Each antenna allows RAy unit to be mounted on it with horizontal or vertical polarization. This is discussed in detail in *Section 4.3, "RAy Unit mounting"*.

4.2.1. Jirous antennas mounting

Mounting instructions for Jirous antennas are available on the manufacturer's website *http://en.jirous.com*. Mounting is also described in detail on RACOM RAy *download*[1] section:

• Installation of Jirous antennas *ANT-JRM-inst.pdf*[2]
    optionally with strut for 120 cm Jirous antenna

4 pcs M8×30 (Allen) screws to mount the RAy unit to the antenna are part of the antenna delivery.

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[1] https://www.racom.eu/eng/products/microwave-link.html#download
[2] https://www.racom.eu/download/hw/ray/free/eng/04_anteny/ANT-JRM-inst.pdf

(i) **Note**

1.2m Jirous antennas on windy sites (max. wind speed above 50 m/s) has to be installed with optional struts *ANT-JRZ-1200-STRUT-F*[3] (fixed) or *ANT-JRZ-1200-STRUT-A*[4] (adjustable). Strut allows to increase operational wind speed (typically up to 65 m/s). Consult *Jirous website*[5] for exact parameters and additional info.
Ensure the *pin lubrication* is completed during assembly.

4.2.2. LEAX-RAy antenna mounting

Mounting instructions for LEAX-RAy antenna are shipped with each antenna. Identical mounting instructions are available within RACOM RAy *download*[6] section, on our website. See list below:

- Installation of 0.3m antennas - *ANT-LEAX-300-inst.pdf*[7]
- Installation of 0.6m antennas - *ANT-LEAX-600-inst.pdf*[8]
- Installation of 0.9m antennas - *ANT-LEAX-900-inst.pdf*[9]
  optionally with standard strut *ANT-LEAX-RAy-900-STRUT*[10] - *ANT-LEAX-strut-std-inst.pdf*[11]
- Installation of 1.2m antennas - *ANT-LEAX-1200-inst.pdf*[12] (includes standard strut)
  optionally with extra strut *ANT-LEAX-RAy-1200-STRUT*[13] - *ANT-LEAX-strut-extra-inst.pdf*[14]
- Installation of **RAy interface** for LEAX-RAy antennas - *ANT-LEAX-RAy-inst.pdf*[15]
  (same for all sizes). The RAy interface is part of each LEAX-RAy delivery (one interface set per antenna). It needs to be mounted to each antenna according to the instruction manual before mounting the RAy unit. Four pcs M8x30 (Allen) screws to mount the RAy unit to the antenna are also part of the antenna delivery.

(i) **Note**

0.9m and 1.2m LEAX-RAy antennas on windy sites (max. wind speed above 50 m/s) has to be installed with *optional struts*[16]. They allow to increase operational wind speed up to 65 m/s (instead of 50 m/s respectively 55 m/s). They also allow to use tower pipe Ø50-120 mm (instead standard Ø90-120 mm). Consult *LEAX ARKIVATOR TELECOM website*[17] for exact parameters and additional info.
Ensure the *pin lubrication* is completed during assembly.

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[3] https://www.racom.eu/eng/products/microwave-link.html#accessories_antennas
[4] https://www.racom.eu/eng/products/microwave-link.html#accessories_antennas
[5] http://en.jirous.com
[6] https://www.racom.eu/eng/products/microwave-link.html#download
[7] https://www.racom.eu/download/hw/ray/free/eng/04_1_anteny/ANT-LEAX-300-inst.pdf
[8] https://www.racom.eu/download/hw/ray/free/eng/04_1_anteny/ANT-LEAX-600-inst.pdf
[9] https://www.racom.eu/download/hw/ray/free/eng/04_1_anteny/ANT-LEAX-900-inst.pdf
[10] https://www.racom.eu/eng/products/microwave-link.html#accessories_antennas
[11] https://www.racom.eu/download/hw/ray/free/eng/04_1_anteny/ANT-LEAX-900-strut-inst.pdf
[12] https://www.racom.eu/download/hw/ray/free/eng/04_1_anteny/ANT-LEAX-1200-inst.pdf
[13] https://www.racom.eu/eng/products/microwave-link.html#accessories_antennas
[14] https://www.racom.eu/download/hw/ray/free/eng/04_1_anteny/ANT-LEAX-1200-strut-inst.pdf
[15] https://www.racom.eu/download/hw/ray/free/eng/04_1_anteny/ANT-LEAX-RAy-inst.pdf
[16] https://www.racom.eu/eng/products/microwave-link.html#accessories_antennas
[17] https://www.arkivator-telecom.com/en/products/microwave-antennas.html

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4.2.3. Other antennas mounting

Antenna which do not have a direct interface to RAy needs also a proper *antenna mounting kit*[18] or a flexible waveguide with a *mounting kit*[19] for it. Such interface has to be installed prior to RAy unit installation to the antenna.

Antenna mounting kit can be ordered as an accessory part (one per antenna). It has to be chosen according to selected band and antenna vendor - contact your local supplier or *RACOM*[20] to check currently available types. Any other antenna can be connected to the RAy by standard flexible waveguide. RACOM offers mounting kits (RAy holders) for different flexible waveguides (see *Accessories*[21] and the picture *Flexible waveguide*).

Standard mechanical tools are enough to install each of those accessories.

4.2.3.1. Antenna mounting kit for standard Arkivator antennas

Items "**ANT-ARK-KIT-xx**" (where xx is the band) fits all traditionally produced Arkivator antennas (from company Arkivator, acquired by LEAX Group) as well as today produced Arkivator antennas from company LEAX Arkivator Telecom sold without RAy interface.

> **(i) Note**
>
> All LEAX-RAy antennas listed in the RACOM portfolio contain specific RAy interface and thus no mounting kit is required.

4.2.3.2. Antenna mounting kit for standard Andrew antennas

Items "**ANT-ANW-KIT-xx**" (where xx is the band) fits most of Andrew antennas manufactured by CommScope with specific vendor's interface unmounted. All generations of RAy units (including those for 17 and 24 GHz ones, which are using *cross polarization*) are OK with Single polarized Andrew VHLP antennas with round waveguide. Dual polarized antennas can be used as well, but are typically more expensive.

- for 17 GHz band use *ANT-ANW-KIT-17/18*[22] and order the following VHLP single-polarized antenna types:

VHLP1-18-BW1	1 ft
VHLP2-18-BW1	2 ft
VHLP3-18-BW1	3 ft
VHLP4-18-BW1	4 ft

  > **(i) Note**
  >
  > All VHLP 18 GHz antennas labelled for 17.700 - 19.700 GHz band are also OK for 17.100 - 17.300 GHz band (confirmed to RACOM by CommScope).

- for 24 GHz band use *ANT-ANW-KIT-24*[23] and order the following VHLP single-polarized antenna types:

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[18] https://www.racom.eu/eng/products/microwave-link.html#accessories_antennas
[19] https://www.racom.eu/eng/products/microwave-link.html#accessories_antennas
[20] https://www.racom.eu/eng/about_us/contact.html
[21] https://www.racom.eu/eng/products/microwave-link.html#accessories_antennas
[22] https://www.racom.eu/eng/products/microwave-link.html#accessories_antennas
[23] https://www.racom.eu/eng/products/microwave-link.html#accessories_antennas

VHLP1-26-BW1   1 ft
VHLP2-26-BW1   2 ft
VHLP3-26-BW1   3 ft
VHLP4-26-BW1   4 ft

(i) **Note**

All VHLP 26 GHz antennas labelled for 24.250 - 26.500 GHz band are OK for 24.000 - 24.250 GHz band (confirmed to RACOM by CommScope).

(i) **Note**

BW1' is a code for 'no flange', which is an optimal choice for VHLP purchase (and typically the cheapest one). Most CommScope distributors do not resell those, because normally each shipped antenna has a unique flange for a concrete MW vendor product (defined by a string of 3 letters+numbers at the end of the ordering code). If any vendor interface is purchased, then it has to be unmounted before installation of RAy antenna mounting kit.

If there is a requirement to connect different type of antenna (for example some newer antenna type), it is possible to modify the existing adapter to meet new requirements.

4.2.3.3. Flexible waveguide

Flexible waveguide mounting kit can be ordered as an *accessory part*[24].
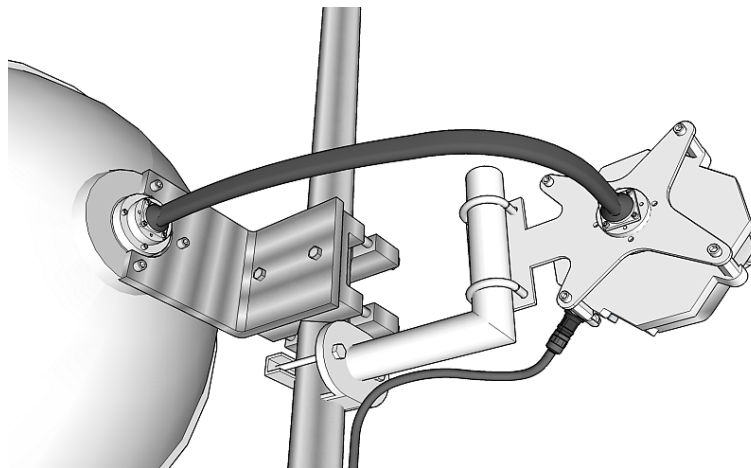
Fig. 4.4: Flexible waveguide assembly

Flexible waveguides themselves are not offered by RACOM - please consult your antenna supplier.

Ensure the *pin lubrication* is completed during assembly.

4.3. RAy Unit mounting

RAy unit can be attached to several different models of antennas from several vendors. Installation of RAy unit on to LEAX-RAy or Jirous antennas or to any other antenna with proper RAy mounting kit (eventually with flexible waveguide) is very simple and it is identical for all antennas and mounting kits.

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[24] https://www.racom.eu/eng/products/microwave-link.html#accessories_antennas

Installation starts with the lubrication of antenna pivot, followed by fixing the RAy unit in a proper position to the antenna and finished by unit grounding to the mast – as described in following sections.

4.3.1. Lubrication of the antenna pivot

Before fitting the RAy flange to the antenna pivot ensure the "O" ring (part No. 1) is in the correct position. It is also essential to prevent moisture getting in between these two parts. This moisture could cause oxidation, which would complicate disassembly of this mechanical coupling in the future. For this reason, we need to lubricate these surfaces with the grease, which is supplied in the capsule marked "SILOCONE GREASE". If you use a different grease for lubrication, then it should be a teflon or a silicone grease.
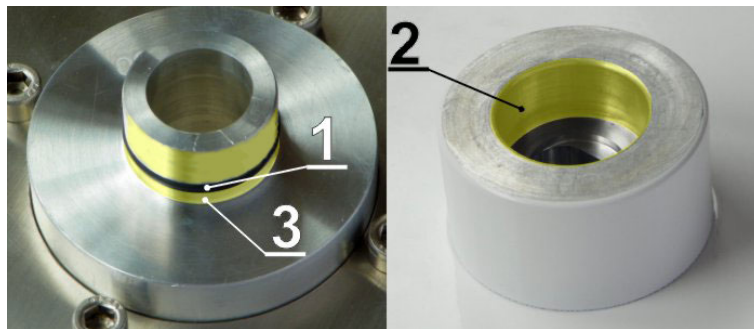
Fig. 4.5: Grease points on the antenna pivot and RAy unit flange

Lubricate internal area of the flange on the RAy unit (2) and the "O" ring (1) with a thin even layer that allows the pin to slide easily into the flange without damaging the "O" ring. The layer has to be really thin and even to ensure no grease is pushed in to the waveguide. A little bit more grease may only be applied in the area (3) beyond the "O" ring on the antenna pin to optimally fill the small gap (max. 0.1 mm) between the pin and the flange to prevent leakage of moisture and water into the unit. Installation should be carried out according to the antenna installation instructions.

A tub of grease is supplied with each RAy unit.

⚠️ **Important**

Lubrication is a very important assembly step for every RAy unit. Failure to lubricate the unit can lead to operational and assembly complications.
The layer of grease has to be really thin (especially on the surface "No 2"), otherwise grease blocks the waveguide after the assembly (and many decibels of the signal are lost).

Fig. 4.6: Silicone grease

4.3.2. RAy unit mounting to the antenna

Each antenna allows RAy unit to be mounted on it with different polarization:

• horizontal TX polarization
• vertical TX polarization
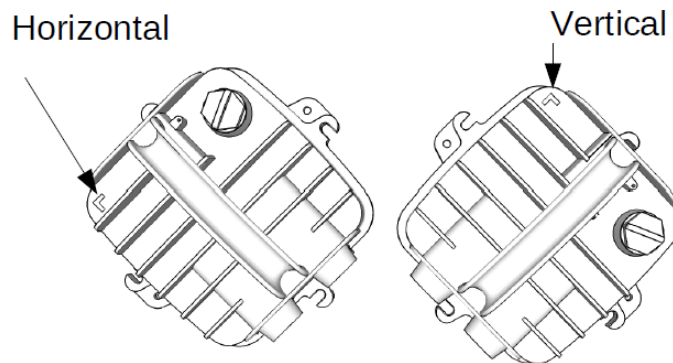
Fig. 4.7: Horizontal and vertical TX polarization – see the arrow sign

In all cases mount the unit with the connectors facing downwards at an angle.

> **ⓘ Note**
>
> RAy3-17 and RAy3-24 links need one unit to be installed with vertical polarization and the other unit with horizontal polarization because these units use *cross polarization*.
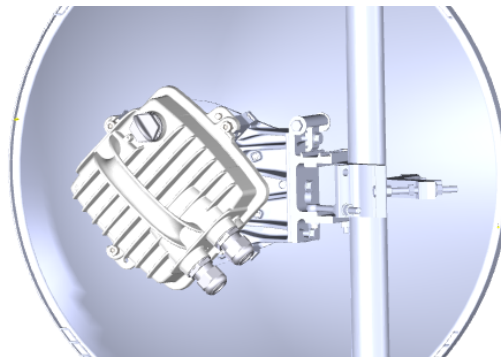
Fig. 4.8: RAy3 unit with antenna (left-side mounting and horizontal polarization)

RAy unit is fixed to the antenna by 4 pcs M8×30 (Allen) screws, which are part of the delivery of each antenna or each mounting kit. Those should be partially unscrewed so that the unit can slide on to them.

Then check whether the "O" ring is correctly fitted on the antenna pin and make sure it is not damaged and has been lubricated with grease – see *Section 4.3.1, "Lubrication of the antenna pivot"* above. If O-ring is injured or damaged, please exchange it immediately for a new one (size 22x2 mm, type 'FPM80'), otherwise moisture and/or dust can leak into the waveguide and emitter. It may eliminate several dB of signal and cause a corrosion.

Then remove the protective plastic cover from the central pin of the antenna and fit the unit flange (located in the center of flat part of RAy unit, across the holder) to it carefully, so there is no possibility to damage the "O" ring. Once the RAy unit is plugged to the antenna pin, turn RAy clockwise so its

screw-holders fit the right position for all 4 screws. Carefully ensure the correct polarization of the unit and secure the RAy unit in place with all four bolts. Finally, gently tighten the bolts with a No. 6 Allen key.

> **Important**
>
> Gently tightening all 4 screws is enough. Do not over-tighten any screw, it may damage the protective color surface of the aluminum unit (enforcing corrosion processes) and in the case of an extreme force also deformations of the RAy aluminum cover may happen. Later de-installation of the unit then becomes difficult.
>
> Please ensure that all 4 screws are tightened equally during tightening and the gap between RAy screw-holders and spacers on all 4 sides of the RAy unit is approximately identical. Too strong tightening of one or 2 screws on one side of RAy unit may lead to the deformation of the sensitive zone of the waveguide between the antenna and the unit, resulting in weaker radio parameters.
>
> Even a small residual gap between RAy unit and the antenna is OK, because important is a good connection of waveguide – it is good enough even with screws gently tightened.

> **Note**
>
> On older LEAX-RAy antennas (shipped during the year 2017) the residual gap under each screw-holder on RAy and antenna body may be up to 1 mm.

4.3.3. RAy unit grounding

RAy unit has to be properly grounded, otherwise its function cannot be guaranteed and the unit can be even damaged. Grounding connection through antenna and its holder is not enough (due to color surface, oxidation etc.), thus a separated grounding is required to ensure the perfect galvanic connection. The RAy grounding kit *GND-RAy*[25] equipped with 85 cm of cable with grounding lugs and grounding terminal ZSA16 with 50 cm grounding strip 15 mm wide is ideally suited for this.

> **Important**
>
> The RAy unit has to be grounded before connecting to the power supply and/or to the user network.

Typically the unit is grounded to the antenna mast, which has to be properly grounded (according to *Fig. 4.19, "Grounding installation 1"* and *Fig. 4.20, "Grounding installation 2"*, where unit grounding to the antenna mast is marked by yellow-green cable).

The RAy unit must be grounded by an insulated copper cable with a minimum cross-section of 6 mm^2 terminated with a terminal lug fixed to the RAy unit by M8 grounding screw. It is marked by yellow ⏚ located on RAy flange nearby fixing ears (place for fixing screws). The conductor should have a green/yellow plastic cover along its whole length and its other end should be ended by an appropriate grounding terminal. For instructions on installing terminals see *the grounding kit datasheet*[26]. The antenna and the unit grounding must be installed by a qualified person.

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[25] https://www.racom.eu/eng/products/microwave-link.html#accessories_zemneni
[26] https://www.racom.eu/download/hw/ray/free/eng/07_prislusenstvi/GND-RAy.pdf

Properly installed unit grounding kit is documented on photos below.

Fig. 4.9: Protective conductor at the RAy unit
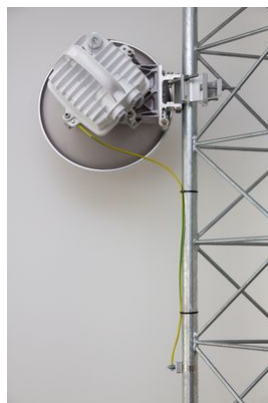
Fig. 4.10: Grounding the RAy unit

Fig. 4.11: RAy grounding kit

Fig. 4.12: Protective conductor at the mast

4.4. Connectors assembly and disassembly

The unit is equipped with 3 connector slots described in detail (including connectors' pin-outs) in *Section 1.3, "Ethernet + power interfaces"* and *Section 1.4, "Service interfaces"*. Use only standard counterparts to these connectors.
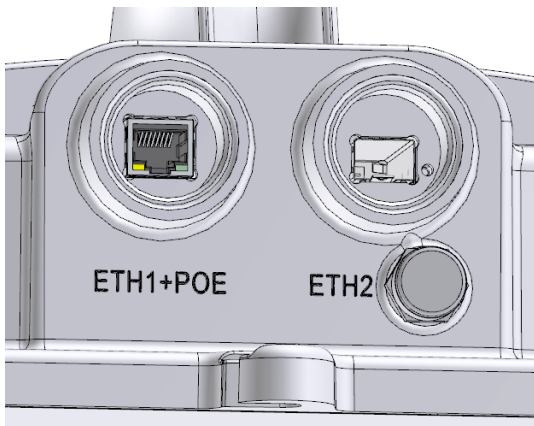
Fig. 4.13: Slots ETH1+POE, ETH2   Fig. 4.14: Slot S
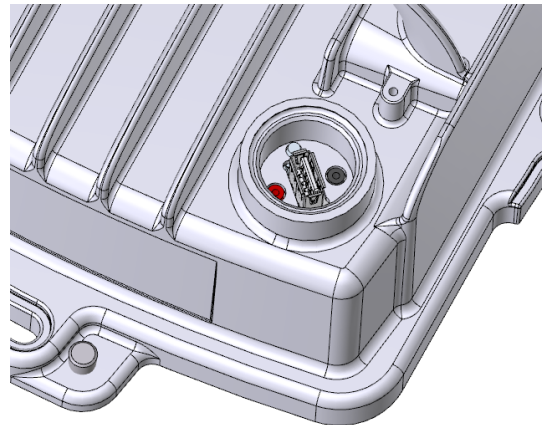
A set of standard bushing and plugs is delivered with each RAy unit as an accessory *ACS-RAy*[27]. The rubber sealing for each bushing is delivered with three different internal diameters to fit different cable diameters. The rubber is diagonally cut to enable sealing of cables with pre-installed connectors.

If the lengthening of the bushing is needed use the long bushing delivered within standard accessory kit *ACS-RAy2*[28] or purchased separately as an option *SET-BUSH65*[29] (providing 65 mm long inner space for connector) or the long extension *OTH-BUSH-EXT500*[30] (adds up to 50 cm).

⚠ **Important**

Before connecting the RAy unit to the power supply and/or to the user network it must be grounded according to *Section 4.3.3, "RAy unit grounding"*.

All cables have to be secured by appropriate bushings which must be fitted with relevant O-rings and carefully tightened in, according the instructions below.

Remaining connector slots on RAy unit has to be secured by plugs (including the original plugs in the flanges). Those must be fitted with O-rings and carefully tightened as well. Otherwise, the unit is not protected against moisture intake through connectors and can not guarantee unit functionality.

[27] https://www.racom.eu/eng/products/microwave-link.html#accessories_kit
[28] https://www.racom.eu/eng/products/microwave-link.html#accessories_kit
[29] https://www.racom.eu/eng/products/microwave-link.html#accessories_cable
[30] https://webservice-new.racom.eu/main/eshop.detail?i=1513

Assembly variants:

Fig. 4.15: Bushing assembly for metallic Ethernet with short *ETH connector*[31]
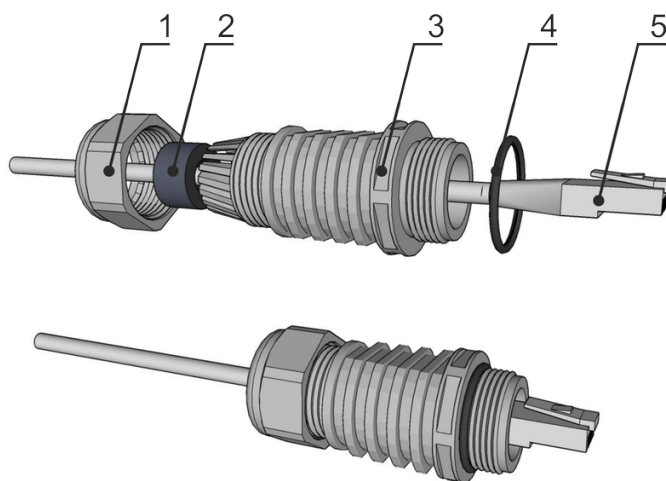
Fig. 4.16: Bushing assembly for metallic Ethernet with long *ETH connector*[32] (for DC-RJ45 adapter or for non-OFA fibre optic cable)
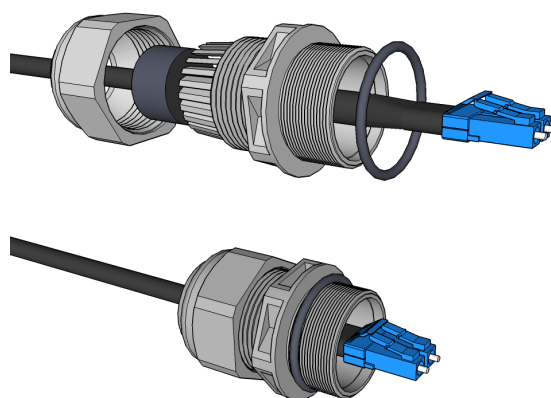
Fig. 4.17: Short bushing assembly for fibre optical Ethernet with *RACOM / OFA fibre*[33] optic cable

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[31] https://www.racom.eu/eng/products/microwave-link.html#accessories_cable

[32] https://www.racom.eu/download/hw/ray/free/eng/07_prislusenstvi/CON-RJ45-CAT7.pdf

[33] https://www.racom.eu/eng/products/microwave-link.html#accessories_cable

Fig. 4.18: Bushing including long lengthening

⚠ **Important**

At the outer end of the long lengthening there is necessary to use a flat ring supplied as part of the *OTH-BUSH-EXT500*[34]. On other places O-rings are used. See Figure above.

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[34] https://www.racom.eu/eng/products/microwave-link.html#accessories_cable

Assembly procedure:

- Put on the cable: the nut No.1, rubber sealing No.2, bushing No.3 and O-ring No.4.
- (If you use extension ring No.6 with O-ring No.7 put those on the cable as well.)
- Attach the appropriate connector No.5 to the cable.
- Plug the connector No.5 into the RAy3 unit.
- (If you use extension ring No.6 with O-ring No.7, lubricate its thread with grease and screw those into the RAy3 unit.)
- Screw the bushing No.3 with the sealing O-ring into the RAy3 unit (or into the extension if used).
- Move the rubber sealing (2) along the cable to fit in the bushing. Screw the nut (1) on bushing (3).

Tip

Practical tip: Screw the ring No.6 and bushing No.3 quote tightly, so they could not rotate when the nut No.1 is screwed (or released later on). Not doing so could damage the cable by twisting it during sealing. It can also create the issue later on when the nut No.1 is released (and ring No.6 or ring No.3 releases first).

Disassembly procedure:

- Release the nut No.1
- Remove the rubber sealing No.2
- Unscrew the bushing No.3 with O-ring No.4 (and extension No.6 with O-ring No.7).
- Remove the connector.

Warning

It is absolutely critical first to completely release and disassemble the nut No.1 and remove the rubber No.2. Failure to do so could cause the damage of Ethernet cable or fibre optic wire by cable rotation. Even connectors inside the RAy unit can be damaged. Should the rubber sealing No.2 become fastened to the cable and/or to the plastic bushings, the rubber sealing must be detached from the cable by a brute force. We suggest you use a flat screw driver to release the rubber sealing No.2.

It is always better to optionally damage the bushing rather than damage a cable or components inside the RAy unit.

Important

When using other bushing or connector than offered by RACOM, there is a danger of bad seal or damaging the connector. Interior space can be small.

4.5. Grounding and overvoltage protection

The proper grounding together with surge protection components should be installed on site to increase the resiliency of the whole installation against natural overvoltage situations (stimulated by storms, lightning and other atmospheric issues). Such a system has to respect local standards for grounding and electromagnetic protection, otherwise the risk of damaging the unit and/or connected IT infrastructure gets much higher. We also recommend to consult each site situation with local experts to ensure the installed grounding is enough for the actual site conditions and that the overvoltage protection of sensitive components or infrastructures is reasonably effective against typical situations on site.

The rule is that every metallic component of wireless infrastructure located outside the building (in LPZ0) should be properly grounded and protected against overvoltage, especially:

- grounded RAy unit itself (as described in *Section 4.3.3, "RAy unit grounding"*)
- grounded all shields from all metallic Ethernet cables
- grounded all DC cables (shields or one wire)
- overvoltage protection is applied on all metallic Ethernet cables at the point of entrance to the building
- overvoltage protection is applied on DC cable at the point of entrance to the building

All types of cables should be grounded and longer cables should be grounded in several places (outside the building every few meters). Overvoltage protective devices are available for all types of cables and usage. Accessories offered by RACOM for those purposes are listed in *Grounding section*[35] of RAy web site.

> ⚠ **Important**
>
> The unit and mast must be properly grounded before the power supply and/or the user network are connected to RAy unit.
>
> Warranty does not apply for units destroyed by surges or over-voltage (see RACOM warranty conditions at *Section 10.6, "Warranty"*).

> ⓘ **Note**
>
> Some PoE power sources, PoE injectors and DC power supplies have overvoltage / surge protection built in. Please consult the datasheets of those versus the local standards and site requirements.
>
> On sensitive sites additional overvoltage protection should / could be applied between different zones (or rooms) even within one building (for example between network center and datacenter).
>
> LPZ acronym means Lightning Protection Zone.

The example and rules below are designed in accordance with regulation EN 62305.

1. Where it is possible, the antenna should be located in an LPZ 0B protection zone with the use of a local or artificial air termination device for protection against direct lightning strikes.

2. When meeting conditions for ensuring electrical insulation (distance from the lightning conductor) in accordance with article 6.3 of this standard, it is not recommended to ground the load-bearing structure and antenna to the external air termination network. Grounding should be attached to the protective system of the internal LV (Low Voltage) wiring or grounded internal structures using a CYA 6 mm^2 bonding conductor , see *Fig. 4.19 Grounding installation 1*.

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[35] https://www.racom.eu/eng/products/microwave-link.html#accessories_zemneni
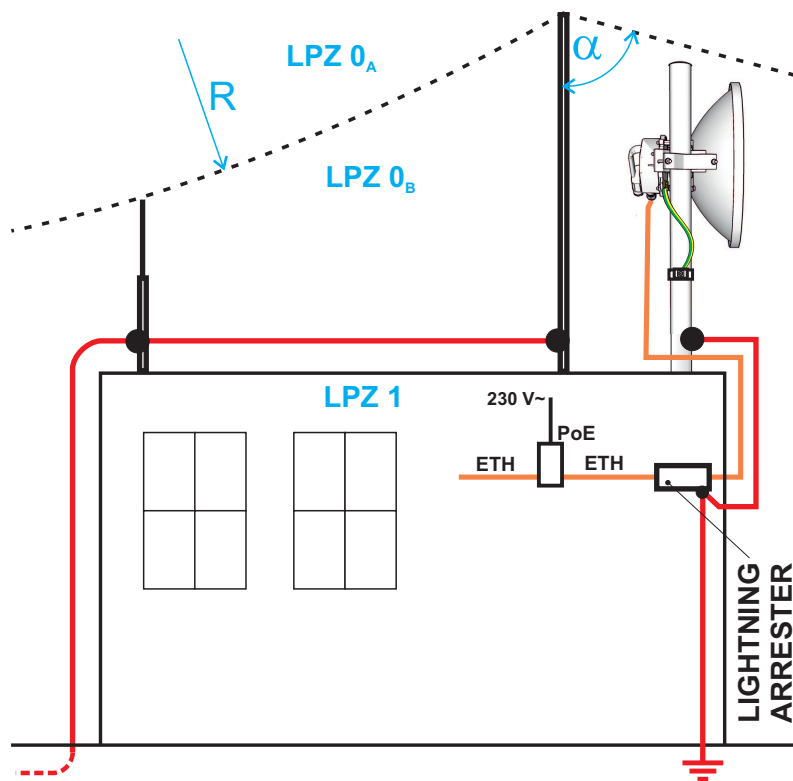
Fig. 4.19: Grounding installation 1
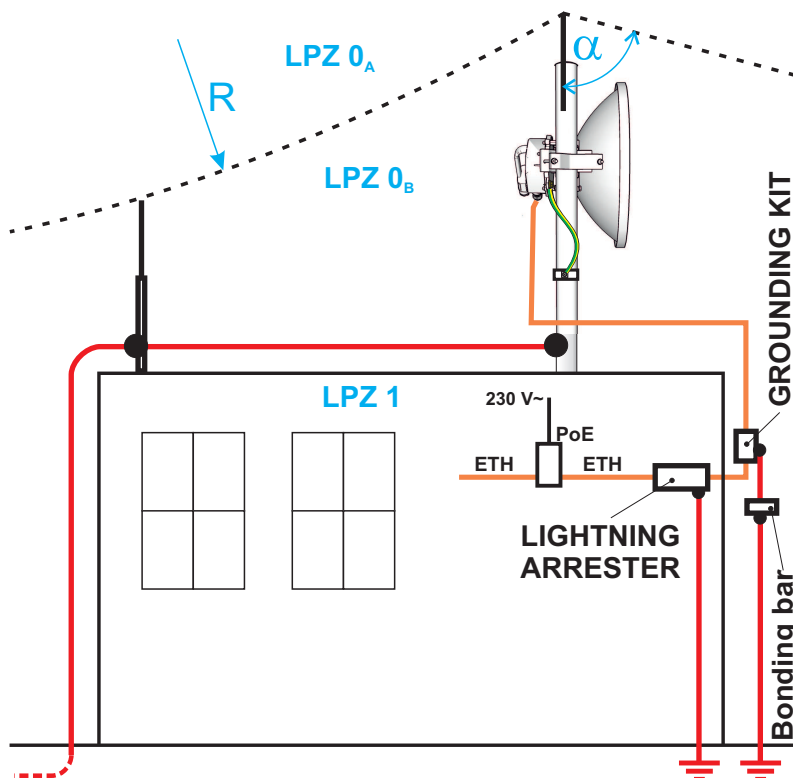
Fig. 4.20: Grounding installation 2

3. If it is not possible to set up conditions of electrical insulation in accordance with article 6.3 of this standard, we recommend connecting the load-bearing structure at roof level to the external air termination network via an 8mm diameter FeZn conductor and shielding the data cable before entry to the building with a grounding kit and CYA 6 mm^2 conductor to the bonding bus, and if not already set up then also to the external air termination network, see *Fig. 4.20 Grounding installation 2*.

4. If there is not an external LPS on the building we recommend routing lightning current through an 8mm FeZn conductor to a common grounding system, or to a separate grounding electrode with a ground resistance up to 10 Ω.

5. For limiting the overvoltage transferred over the data cable and into the building we recommend fitting surge protection at the interface between zones LPZ 0 and LPZ 1 connected via a CYA 4 mm^2 conductor to the same grounding point as the antenna or the antenna mast.

6. We recommend protecting the PoE power supply from overvoltage on the LV side with suitable class D surge protection.

RACOM supplies surge protection for installation on Ethernet cables entering buildings. For more details see *Surge protection*[36].

Additional safety recommendations

- Only qualified personnel with authorization to work at heights are entitled to install antennas on masts, roofs and walls of buildings.

- Do not install the antenna in the vicinity of electrical wiring. The antenna and bracket should not come into contact with electrical wiring at any time.

- The antenna and cables are electrical conductors. During installation electrostatic charges may build up which may lead to injury. During installation or repair work to parts of the antenna lead, bare metal parts must be temporarily grounded.

- The antenna and antenna cable must be grounded at all times.

- Do not mount the antenna in windy or rainy conditions or during a storm, or if the area is covered with snow or ice.

- Do not touch the antenna, antenna brackets or conductors during a storm.

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[36] https://www.racom.eu/eng/products/microwave-link.html#accessories_ochrana

Fig. 4.21: Grounding Kit universal
for 5-11mm cables

Fig. 4.22: Grounding Kit for 5-11mm cables,
assembled

Fig. 4.23: Grounding kit for S/FTP 4+2 cable

Fig. 4.24: Grounding kit detail
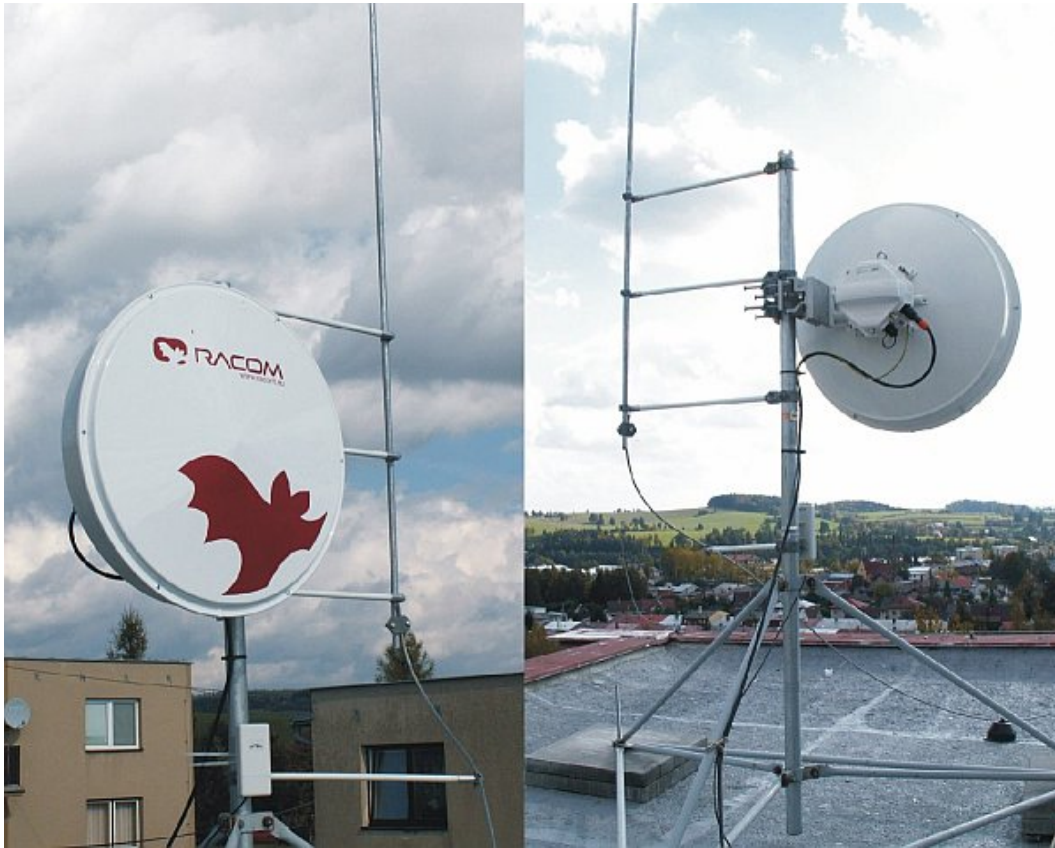
Fig. 4.25: Separated lightning conductor

Note

It is always better not to install the microwave unit directly under the lightning conductor holders. There is lower probability of unit being polluted by birds.

It is necessary to install the Ethernet lead so that there is no excessive mechanical stress applied on the connector bushing:
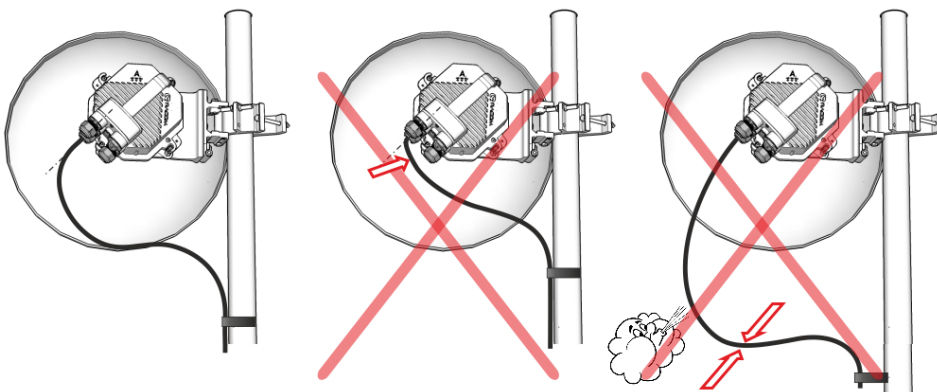
Fig. 4.26: Example of a correct lead installation.

4.6. Power supply

RAy microwave unit can be powered by active PoE, passive PoE or by DC power source. All variants of power are supplied through RJ45 Ethernet connector (in slot ETH1+POE). Detailed description and technical parameters of the connector are described in *Section 1.3.1, "RJ45 connector (ETH1+POE)"*.
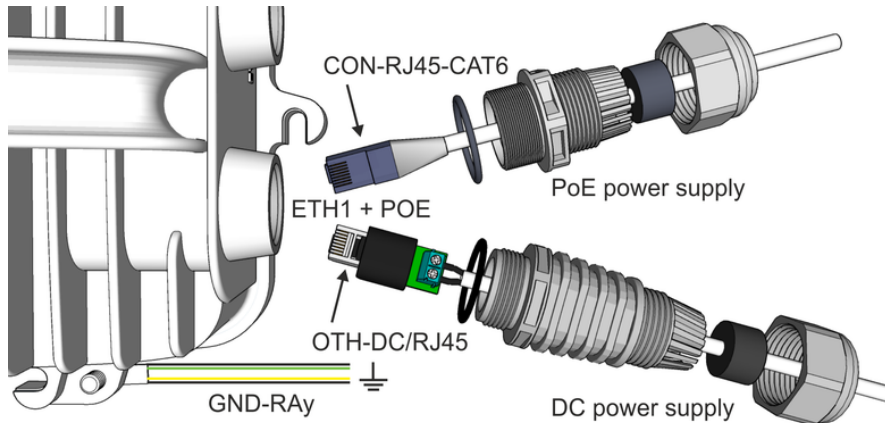
Fig. 4.27: Power supply possibilities

Type of power supply has to be chosen according voltage range and maximum power consumption (Watts) of installed unit. Both those parameters are listed on each unit *Product label* and can be found also in *Chapter 9, Technical parameters*, in RAy datasheets and on *RAy web pages*[37].

If a longer Ethernet or DC cable than few meters is used, then both voltage and Watts of power supply has to be adequately higher to cover the power loss within the Ethernet or DC cable.

RACOM is offering a set of reliable power supplies (sourced by AC or DC power) for all RAy models and all typical use-cases, all guaranteed for compatibility with RAy unit and tested for long-term stability – they are listed in *Powering section*[38] of RAy web site.

4.6.1. PoE power sourcing

PoE (Power over Ethernet) is the most widely used power sourcing for RAy units. It simplifies the unit installation with a single cable both for Ethernet connection and power.

Both active or passive PoE can be used. The key difference between those is that Active PoE power supplies have a special circuits and a detection chip, which classifies power requirements of connected device before powering it, while passive PoE just powers Ethernet wires without any check of the connected device. All RAy units accept the power sourcing from both PoE types because wiring defined by IEEE 802.3at/bt standards for active PoE is used also for passive PoE.

> **(i) Note**
>
> All PoE installations require reasonably quality Ethernet cables and connectors, otherwise the proper PoE function can not be guaranteed.

- **Active PoE power supply** recognize each RAy unit as IEEE 802.3bt (PoE++) or IEEE 802.3at (PoE+) standard-compliant device. The IEEE standards define negotiation method, wires to be used,

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[37] https://www.racom.eu/eng/products/microwave-link-detail#specifications
[38] https://www.racom.eu/eng/products/microwave-link-detail#accessories_poe

operating voltage, maximum supported current, overcurrent protection, effective distance and other parameters. The table below summarizes all key parameters of both IEEE standards relevant for RAy units.

Tab. 4.1: PoE standards according IEEE802.3at/bt and their relevance for RAy units

	PoE+	PoE++
Standard*	IEEE 802.3at	IEEE 802.3bt
PoE Sub-Type	Type 2	Type 3 (Type 4)
PoE Max. Power	30 W	60 W (100 W)
PoE Voltage Range	50 - 57 V	50 (52) - 57 V
Device Max. Power	25.5 W	51 (71) W
Device Voltage Range	42.5 - 57 V	42.5 (41.1) - 57 V
Supported Cables	Cat5 or better	Cat5 or better
Twisted Pairs Used	2-pairs	4-pairs, 2**-pairs
Suitable RAy units	RAy3-17, RAy3-24, all RAy2 and RAy1	RAy3-10, RAy3-11, RAy3-18, RAy3-80

*Most of IEEE 802.3bt power supplies support also IEEE 802.3at standard. Those are marked as 'IEEE 802.3at/bt compatible'.
**2-pairs are not recommended, but allowed for 'PoE Type 3' (for low power devices only)

- **Passive PoE power supply** (called sometime PoE injector) is an equipment pushing input DC power into the pins of Ethernet connector without recognition of RAy unit. It can operate in whole extended voltage ranges *defined for each RAy unit*. Internal RJ45 pins wiring are identical with Active PoE (mentioned above). Typically, the current is sourced from a DC power with adequate parameters. The only additional requirement is that non-grounded wire of DC power circuit to the PoE injector has to be secured by a fuse disconnecting the power circuit in the case of over current (similar like for DC power source connected directly to the RAy unit by a DC connector).

- (i) **Note**

   Pasive PoE power supply has to ensure enough voltage and enough current to the RJ45 connector (ETH1+POE). For RAy3-10, RAy3-17 and RAy3-24 the power voltage has to be at least 20 V, for booting 21 V (to prevent booting with discharged 24 V battery). For other RAy3 models the minimum power voltage has to be at least 37 V. For all models both polarities of DC are supported. More details can be found in *Section 1.3.1, "RJ45 connector (ETH1+POE)"*.

   PoE with 8-wires is strongly recommended for RAy3-10, RAy3-18 and RAy3-80 due to their power consumption bigger than 25 W. PoE with 8-wires is an advantage also for other RAy3 models with low power consumption to minimize the energy lost in the Eth cable (it lowers the resistance of the Eth cable to half compared with 4-wires PoE).

   Quality connectors (like *CON-RJ45-CAT7*[39]) are recommend to be used on both ends of Ethernet cable to ensure long-term reliability of the connection. Such connectors have better resistance against oxidation and also against scorching contacts due to spikes during power-on and power-off the unit by plug / unplug Ethernet cable. Anyhow standard Eth cable with standard Eth connectors should work as well.

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[39] https://www.racom.eu/eng/products/microwave-link.html#accessories_cable

Quality Ethernet cable (i.e. shielded one, like *CAB-CAT7*[40]) with UV protection is recommended for outside use.

Overvoltage protection[41] unit is recommended to be applied between RAy unit and PoE power supply – for details see *Section 4.5, "Grounding and overvoltage protection"* (easily visible on *Fig. 4.19, "Grounding installation 1"*).

4.6.2. DC power sourcing

Direct DC power input for RAy3 unit described in *Section 1.3.3, "DC power (using ETH1+POE)"* requires the use of DC/RJ45 adapter (item *OTH-DC/RJ45*[42]). See this section or *Chapter 9, Technical parameters* if more details (like extended voltage range for each RAy3 model) needs to be understood.

- For RAy3-10, RAy3-17 and RAy3-24 any kind of DC power source with supplied nominal DC voltage in the range 24-60 V and with enough power for the RAy unit plus energy loss on the DC cable can be used. (For RAy3-17 and RAy3-24 the typical minimum is 25 W, for RAy3-10 about 35 W.) It has to ensure a minimum voltage on RJ45 connector of the unit (ETH1+POE) to be at least 20 V, for booting 21 V (to prevent booting with discharged 24 V battery).

- For RAy3-11, RAy3-18 and RAy3-80 any kind of DC power source with nominal DC voltage in the range 40-60 V and with enough Watts for the RAy unit plus energy loss on the DC cable can be used. (For RAy3-11 and RAy3-18 the minimum is typically 40 W, for RAy3-80 about 50 W). It has to ensure a minimum voltage on RJ45 connector of the unit (ETH1+POE) to be at least 37 V.

- RAy3 internal DC power circuits accept both polarities and they ensure galvanic separation of power source line from the RAy unit itself. This simplifies the DC power circuits installation.

- The DC power circuit must be fitted with a fuse to protect against short circuiting (or power supply has to have such a fuse built-in).

(i) Note

- Typically, DC wires have cross-section 1.5 mm^2. DC contacts on *OTH-DC/RJ45*[43] are designed for this cross-section.
- *OTH-DC/RJ45*[44] occupies *ETH1+POE port* on RAy3 unit. When used, Ethernet connection to the unit has to be made through ETH2 port. Possible solutions are described in section **Note** at the end of *Section 1.3.3, "DC power (using ETH1+POE)"*.
- If shielded DC power cable is used, then shield should be grounded by a proper *Grounding kit*[45] to the mast or to the *Grounding screw* on RAy unit.
- If the galvanic separated power source is used and the DC power line needs to be grounded (either positive or negative wire), the connection of one DC line to the ground should be made by a proper *Grounding kit*[46] to the mast. Possible is also to use a small piece of DC cable to connect the line to be grounded to the *Grounding screw* on RAy unit. For more details see *Section 4.5, "Grounding and overvoltage protection"*.

[40] https://www.racom.eu/eng/products/microwave-link.html#accessories_cable
[41] https://www.racom.eu/eng/products/microwave-link.html#accessories_ochrana
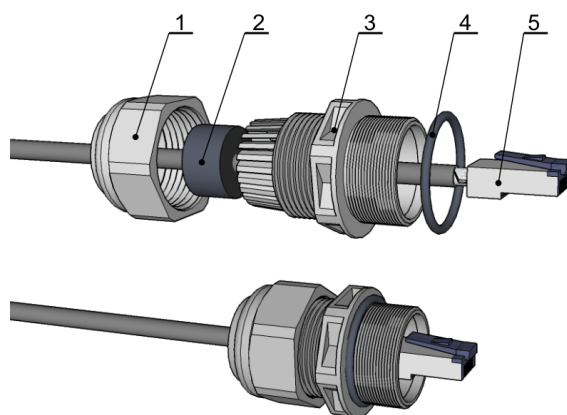[42] https://www.racom.eu/download/hw/ray/free/eng/07_prislusenstvi/OTH-DC-RJ45.pdf
[43] https://www.racom.eu/eng/products/microwave-link.html#accessories_poe
[44] https://www.racom.eu/eng/products/microwave-link.html#accessories_poe
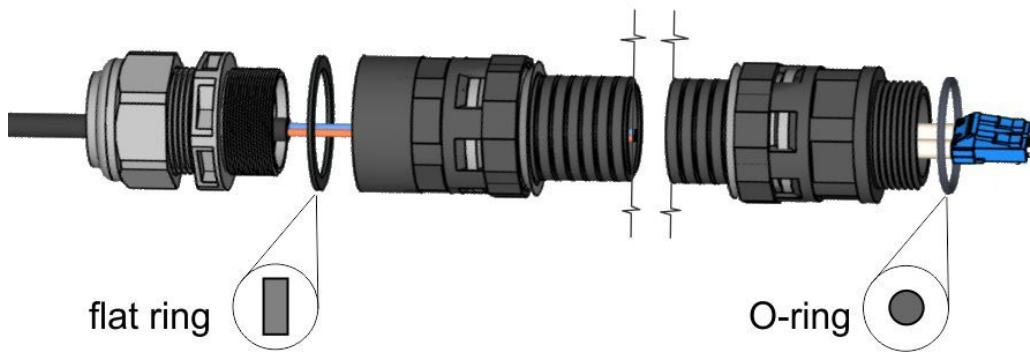[45] https://www.racom.eu/eng/products/microwave-link.html#accessories_zemneni
[46] https://www.racom.eu/eng/products/microwave-link.html#accessories_zemneni

4.7. Start up

Connect a power supply to the installed RAy unit. Connect the device to be used for configuration via WiFi or Ethernet cable. Access the configuration menu using browser or Alignment tool.

4.7.1. Noise on the site

This is particularly true for installation of links working in free bands, where the user has no secured frequency.

Analyze the level of noise in the individual channels using the spectrum analyzer under *Tools > Live data > Frequency spectrum analyzer*. If necessary, adjust the choice of working channel on the basis of the results.

While doing so, respect the rule that all units emit a signal in the Upper part of the range and receive it in the Lower part of the range in one location, or vice versa. A transmitter must not be installed in the part of the spectrum where other units function as receivers.

4.7.2. Directing antennas

Placing the antennas to the correct antenna alignment is very important to ensure the strongest signal is received:
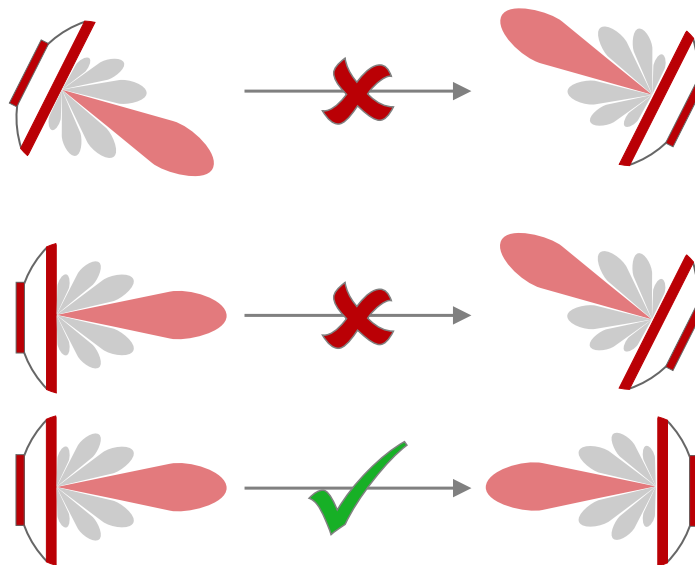
Fig. 4.28: Correct alignment diagram

- For first antenna alignment, use a narrow channel, low modulation and high power where possible.
- ATPC and ACM/ACMB functions should be switched off (prevents RF Output power fluctuations during alignment).
- Where possible adjust both ends of link simultaneously to speed up the process.
- Alternate adjustments at both ends of link in small increments both horizontally and vertically to establish position with strongest signal (highest value of parameter RSS, received signal strength) whilst looking for maximum main signal (see paragraph on main & side lobes).
- Link parameter RSS (received signal strength) is a key parameter for a proper antenna alignment and later on for a proper link functionality. All the adjustment effort is to maximize this parameter on

both sides of the link and to reach pre-calculated RSS value (which is typically calculated before the link is physically established to ensure necessary link transmission parameters could be met).

- Several available methods to measure RSS are built in to the RAy unit. Those are discussed in detail in section *Section 4.7.3, "RSS measurement"*.
- Connect a PC, tablet, mobile or voltmeter according your preferred RSS measurement method and find the best possible antenna alignment for both sides of the link. Following section Main and side lobes would help you.

Main and side lobes

Directional antennas have a specific angle within which radio waves can be transmitted or received (Angle of TX/RX).

The strongest signal is emitted in a forward direction; the main lobe is a graphical representation of its direction of travel and strength. However, signals are also emitted and received from unwanted directions through side lobes. In receiving antennas this is a highly significant factor contributing to the level of interference in a radio network (See *Fig. 4.29 Antenna lobe diagram*).

Fig. 4.30 Signal strength graph provides an indication of comparative signal strength from different beams emitted from a directional antenna.
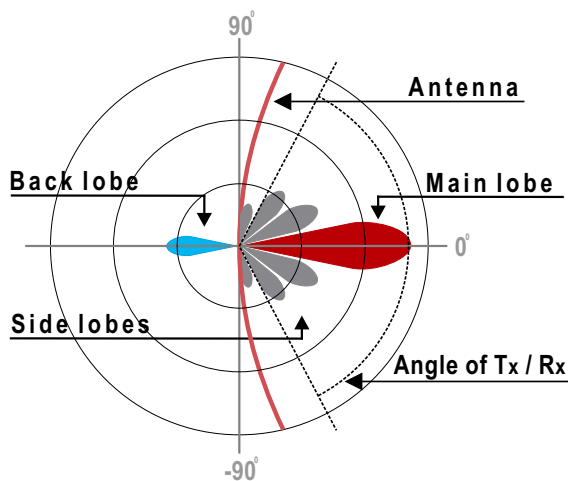
Fig. 4.29: Antenna lobe diagram
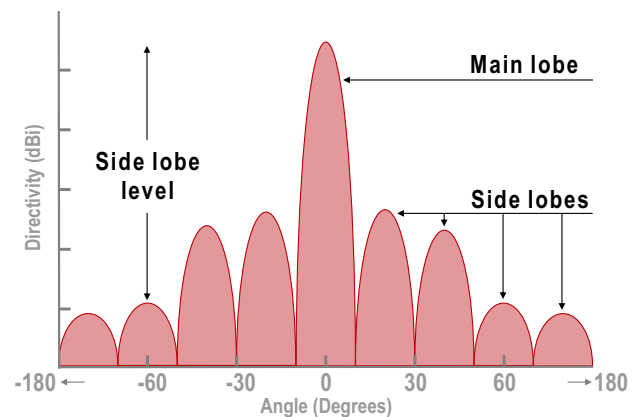
Fig. 4.30: Signal strength graph

Examples
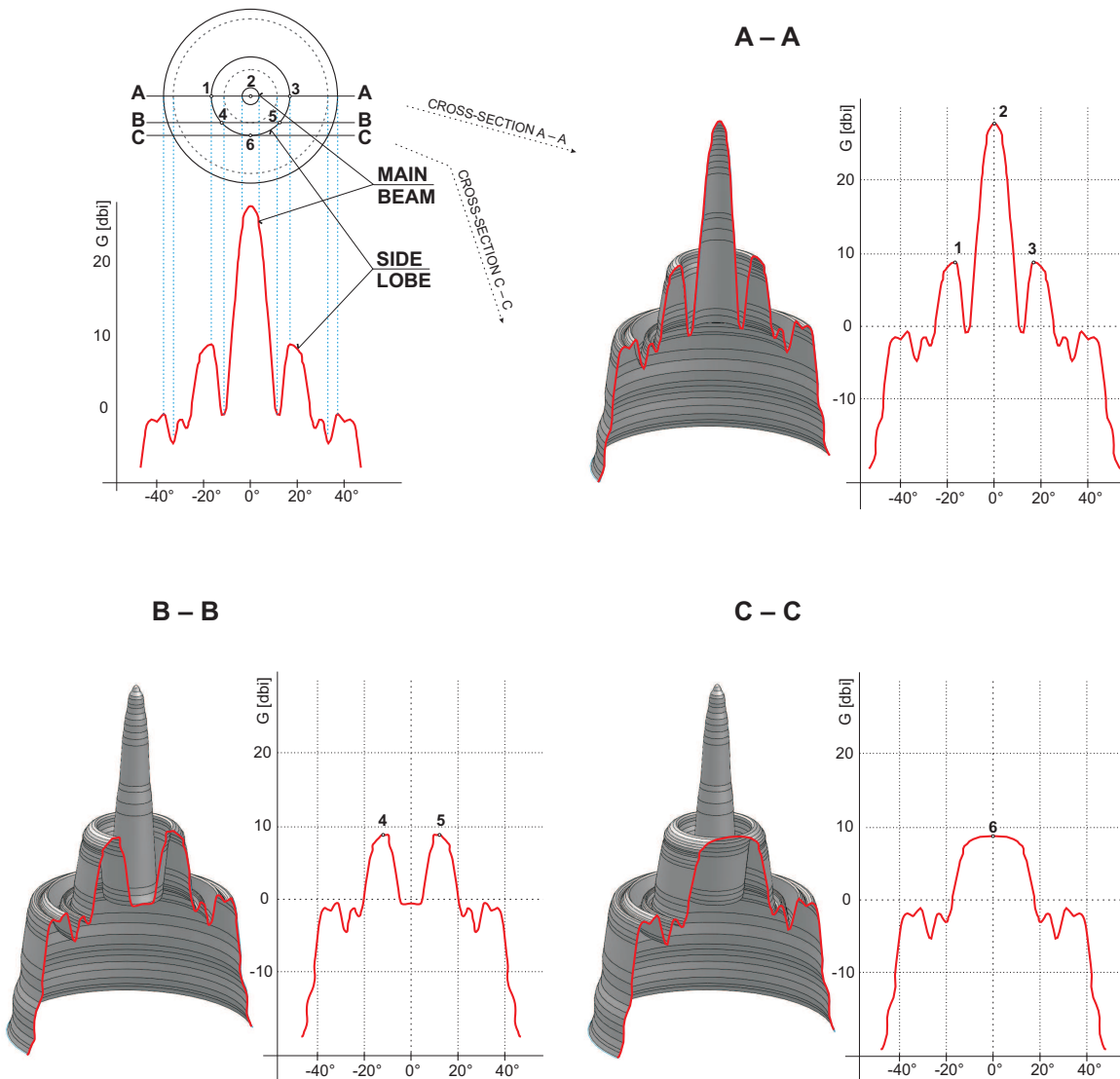
Fig. 4.31: Radiation diagrams

Both antennas should be oriented towards each other using the peaks of the radiation diagram. Adjust the antenna alternately in the horizontal and vertical axes and monitor the resulting signal strength. Use the calculation of the expected RSS with the precision of several dBm as guidance. Side lobes transmit a signal ca 20 dBm weaker, see the *Microwave link Calculation*[47] .

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[47] https://www.racom.eu/eng/products/microwave-link.html#calculation

The resulting RSS helps distinguish between the states A-A and C-C which appear similar. It also helps in situations where simple search for a maximum does not work as shown in the illustration "incorrect adjustment".

Real radiation diagrams are more complex, especially in that they run differently in horizontal and vertical axes. The basic steps for determining the main radiation lobe however stay valid. For example:
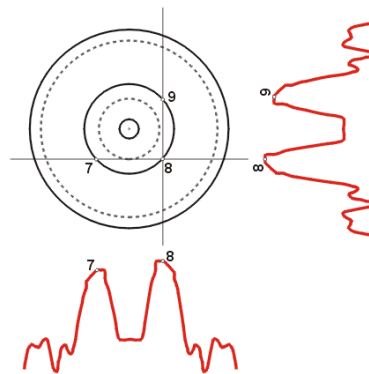
Fig. 4.32: Radiation diagram – incorrect adjustment
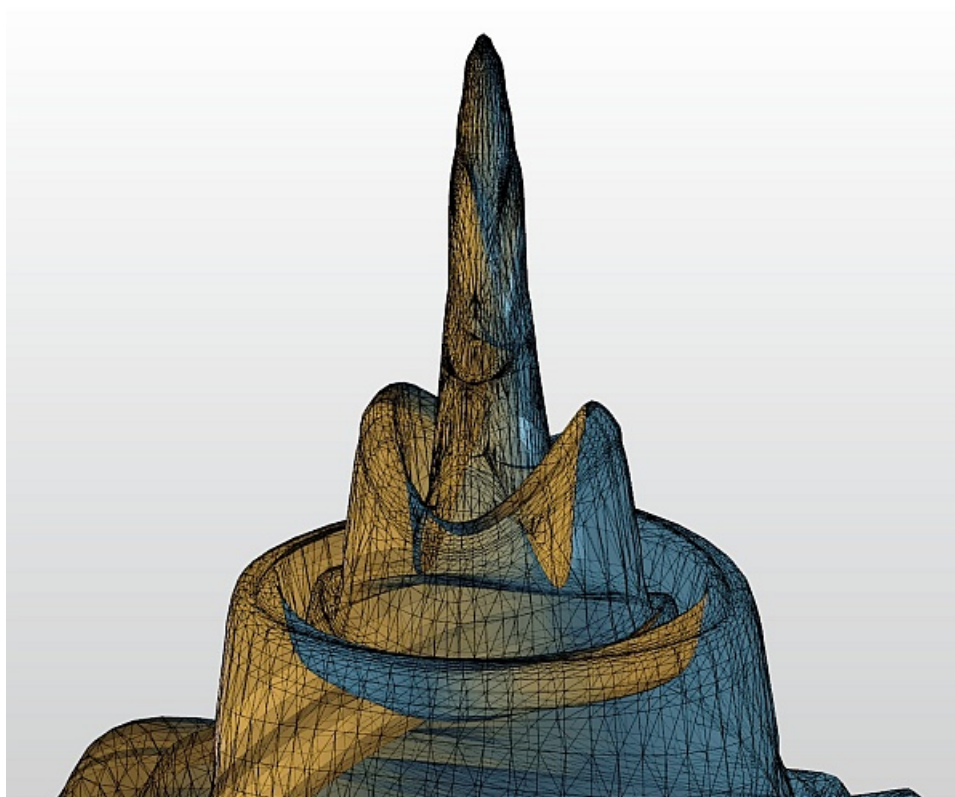
Fig. 4.33: 3D example of more complicated Radiation Pattern

4.7.3. RSS measurement

There are 4 tools available to support measurement of the 2 basic parameters for optimum antenna alignment: RSS (Radio Signal Strength) and MSE (Mean Square Error, the inverse to often used value called SNR - Signal to Noise Ratio):

1. **Voltmeter** – indicates local RSS

2. **RAyTools smartphone** application – indicates RSS, MSE - Local & Peer

3. **Antenna Alignment Tool** web page – indicates RSS, MSE – Local & Peer

4. **Bar graph** on Live Data page inside web management – indicates RSS, MSE, BER – Local & Peer

Before antenna alignment starts, it is recommended to find out RSS and MSE values from the link design for the installed link or calculate these values yourself. There are 4 methods available with increasing levels of accuracy:

• Module Calculation inside RAyTools *smartphone application*
• Link calculation on *RACOM website*[48]
• Use Link calculation chapter in *Application notes*[49]
• Precise link calculation using dedicated tools (e.g. Pathloss)

Voltmeter

RAy units support traditional antenna alignment using a voltmeter measurement representing RSS in dBm (only for a local unit). Connect a voltmeter with the range 2V DC via connectors to the operational unit and adjust antennas to the lowest indicated voltage. Voltage is calibrated according to signal strength. E.g.:
RSS -65 dBm corresponds to voltage 0.65 V,
RSS -80 dBm corresponds to voltage 0.80 V etc.

RAyTools – smartphone application

RAyTools is an application described in detail in Chapter *7. RAyTools app for Mobile devices* . Module *Alignment* displays RSS and MSE for both local and peer RAy unit. All key functionality in this module performs an identical function to Antenna Alignment Tool described in Section *5.6.2 Live data* .

More about RAyTools in Chapter *7. RAyTools app for Mobile devices* .

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[48] https://www.racom.eu/eng/products/microwave-link.html#calculation
[49] https://www.racom.eu/eng/products/m/ray/app/linkcalc/index.html
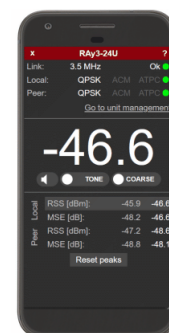
Antenna Alignment Tool – html page within unit management

Antenna Alignment Tool is optimized for devices with smaller displays. All values are refreshed ten times per second to enable smooth operation. The Antenna Alignment Tool is described in Section *5.6.2 Live data* . The Tool is available on *http://<ip>/tk*, (e.g. http://192.168.169.169/tk for standard Ethernet ports, alternatively on http://172.17.17.17/tk in the case of connection through USB/WiFi or USB/Eth).

The Tool is accessible without any username or password.
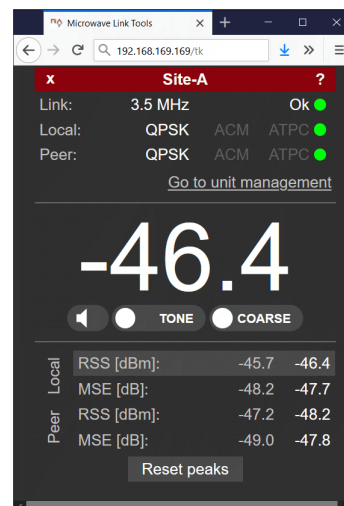
Bar graph in web management

Within user management *Tools > Live data > Bar indicators* shows bar graphs of RSS and MSE values for local and peer units. Values are refreshed every second or manually. See Section *5.6.2 Live data* for detailed information.
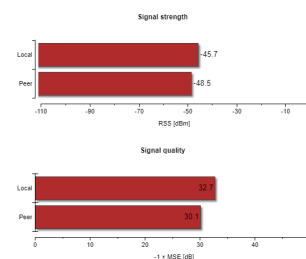
4.7.4. Link test

Basic parameters of the link are RSS and MSE. They can be checked by many different ways:

- in *RAyTools* page Alignment (both sides, refreshed automatically)

- in the menu *Status > Brief* and *Status > Detailed* (both sides, can be refreshed manually by pressing the Refresh button or in real time with a period of several seconds after activating the Start button)

- on the screen *Tools > Live data > Bar indicators* (both sides, refreshed once a second After pressing the Start button)

- on voltmeter (only local RSS value)

Verify the functionality of the radio link similar like in chapter *Link test*.

After installation, it is good to reset the statistics using the *Clear stats* Clear stats button in menu *Status > Detailed* . This allows easier diagnostics of the link's reliability over time.

4.7.5. Parameters setup

After both antennas have been aligned, setup operation parameters for the link. In the case of links operating in the free band, setup the parameters based on survey results from the tool *Tools > Live data > Frequency analyzer*. In the case of links operating on a licensed band, setup the parameters based on the assigned license:

- Bandwidth

- Channel Selection (TX / RX channel)

- Modulation (TX modulation) – ACM/ACMB is recommended. When selecting fixed modulation it is necessary to account for the fade margin. If fixed modulation is setup close to a possible maximum, then a deterioration in RSS could endanger the link both for data transfer as well as service access.

- RF Output power for transmission (parameter 'Max TX power') or ATPC

- Verify and record IP addresses

- Define access channels – HTTPS / telnet / ssh / ssh with password

- Check the *users password settings*

- Check / setup the WiFi password or deactivate WiFi access permanently (in unit management menu *USB accessories* or physically by removing the WiFi module from slot "S")

Restart both units by interrupting their power supply and verify the status of the link. This verifies that all parameters have been stored correctly in the memory.

Select *Tools > Maintenance > Backup > Settings (Local & Peer) > Full* and save the configuration to backup file "cnf_backup.tgz".

This completes the installation. Further configuration can be performed remotely.

5. Configuration

Standard RAy3 unit configuration and management are made through its web-based graphical user interface (GUI). All functions, their parameters, configuration possibilities and options are described within this chapter.

All functions described in this chapter are also available through the unit CLI interface - for its description see *Chapter 6, Command Line Interface*.

5.1. Web interface

RAy can be easily managed from your computer using a web browser. If there is an IP connection between the computer and the respective RAy, you can simply enter its IP address directly in the browser address line and log in.

Port forwarding may also be used to connect to Peer unit (in case the link is established) by entering the IP address of the Local unit and one of the following ports: 8022, 8023, 8080, 8161 and 8443.

5.1.1. Supported web browsers

Supported web browsers for desktops are current versions of:

- Edge
- Chrome
- Firefox
- Safari (for iOS only)

Supported Web browsers for smartphone equipment are current versions of:

- Chrome (for Android only)
- Safari (for iOS only)

> **(i) Note**
>
> For safety reasons, it is recommended to use a web browser without any extensions (especially extensions, which could get access to data).

5.1.2. Login

You can login into the configuration interface using either the **insecure HTTP** protocol (default login screen), or the **secure HTTPS** protocol. You should select the connection method on the login screen. If the HTTPS protocol is used, it is not possible to tap the network communication and acquire the station's login information.

Username [   ]
Password [   ]

Log in

go to secured version

go to antenna alignment screen

Fig. 5.1: Login

ⓘ **Note**

Antenna alignment link below Login window activates smartphone Antenna alignment tool. See its detailed description in chapter *Live data*.

ⓘ **Note**

Web inactivity timeout: The web session is automatically ended after a fixed period of inactivity to ensure security and efficiency. The timeout duration is set to 600 seconds.

5.1.3. User interface buttons

The following configuration buttons are used for configuration:

Apply
Apply and save parameters.

Cancel
Set parameters are overwritten with original values.

Refresh
Reload all current values of the unit / both units.

Show defaults
Clicking the button displays the default values of all individual parameters on the current screen. To use these values, you must click on the "Apply" button.

Show backup
Clicking the button displays the values of individual parameters downloaded from the backup file (*Backup > Settings > Open file upload*). To use any of these values, you must use the "Apply" button. For loading the backup configuration see menu *Tools/Maintenance > Backup*.

Start
Activating automatic refresh fields marked by ↻ icon using the *Start* button with the frequency circa 1 sec.

Stop
Use the "Stop" button to stop automatic refresh of displayed information with 1sec period. Date and time values are refreshed anyway.

| Antenna gain [dBi] | 37.00 | 37.00 |
| EIRP ?= limit [dBm] | 19.00 <= 20.00 | 13.00 <= 20.00 |

Apply | Cancel | Refresh | Show defaults | Show backup

Fig. 5.2: Configuration Controls

5.1.4. Help

The microwave link configuration system is equipped with built in Help - see *Help section*. The Help is accessible in two forms:

- Configuration parameter context help. The help text is displayed in the pop-up window after clicking the parameter name.
- The whole user interface help, activated by clicking the *Help* menu.

5.1.5. Rollback function

If you interrupt the connection on an operating link by entering inappropriate radio link parameters, the original parameters will be restored after 1 minute. The connection should be automatically restored.

(i) Note

The only exception to the Rollback function is during the activation of 'TX mute' setting, which disconnects the link permanently (until this setting is manually de-activated).

5.2. Status bar

Fig. 5.3: Status bar - Everything OK

The Status bar is located on the upper part of the screen below the title bar. It consists of 4 fields:

Local unit status (unit assigned to the IP address entered in the browser or CLI)
Link status (Local to Peer)
LSP status
Peer unit status

In more detail:

■ **Local** and **Peer** status field displays:

Station name
according to configuration

Actual time
valid for respective unit

Warning or Alarm icon
in case of warning or alarm

■ **Link** status field displays:

Ok
if the link is connected, Peer unit is authorized and user data are transmitted

or Warning icon (a triangle)
if the link is not capable of user data transfer,
followed by a **status of the link** (one of the following values):

Unknown
Unit start up. The initialization is not yet finished.

Setup
Unit initialization according to valid configuration.

Single
Unit in operation status. Link to peer unit is not established.

Connecting
Connection to peer unit in progress.

Authorizing
Authorization of the peer unit in progress.

Analyzer
Spectrum analyzer mode active. User data are not transferred.

■ **LSP status** field displays:

nothing displayed
LSP is not enabled

enabled
LSP is enabled but not active

activated
LSP is activated because the activation conditions have been met

The example of a complete Status bar with active Alarm and Link not OK.

Fig. 5.4: Status bar - example of Alarm + Link not OK

5.3. Status

The 'Status' menu provides basic information about local and remote station. Information is valid in the moment, the page is opened, or the Refresh button is clicked. The 'Status/Brief' tab shows only the most important values whereas the 'Status/Detailed' tab provides further details.

Fig. 5.5: Menu Status > Brief (example)

Fig. 5.6: Menu Status > Detailed (example)

Live status data
The ↻ icon marks fields which are automatically updated with 1 sec period when the 'Start' button is active.

LED indicator
System status is also indicated by hardware LED indicator located below the semi-transparent plug on the housing of the FOD unit, see *Section 1.5, "Status LED (S)"*.

Below is a list of all values according both tabs 'Brief' and 'Detailed'.

General

Product code
Unit product code - is the same as the *Ordering code*.

Serial no.
Unit serial number.

Station name
Station name can be modified by user (for example to reflect the unit location in the network topology).

Station location
Station location (for example GPS position or to reflect the network topology hierarchy).

Radio SW version
Software defined radio version.

Firmware version
Unit's firmware version.

Date, Time
The internal real-time clock. The clock is set manually or it is synchronized with NTP server and set for both units.

Inside temperature [°C]
Temperature inside the unit (on the modem board).

Voltage [V]
Unit's power supply voltage level.

Link State Propagation (LSP)

LSP state
The status of the LSP function can take on one of the following values:
• disabled - LSP is not enabled
• enabled - LSP is enabled but not active
• activated - LSP is activated because the activation conditions have been met.

Radio

Dual channel

In the case of *Dual channel operation*, the parameters of both channels are displayed in a separate section.

Radio

		Local	Peer
Band index		U	L
TX polarization		wrong	wrong
Frequency table		11a_490M.rci;8	11a_490M.rci;8
Max. net bitrate [Mbps]		2027.00	2027.00
Net bitrate [Mbps]		1048.09	1048.09
TX, RX bandwidth [MHz]	↺	2x60 MHz	2x60 MHz
Max. TX modulation		4096QAM ACM	4096QAM ACM
TX power [dBm]		18 ATPC	18 ATPC
Calculated RSS [dBm]		-	-
Link uptime	↺	1 days, 06:44:09	

Channel 1

TX channel [GHz]		U1	11.230000	L1	10.740000
RX channel [GHz]		L1	10.740000	U1	11.230000
Current TX modulation	↺	4096QAM	4096QAM
Current TX power [dBm]	↺	14	14
RSS [dBm]	↺	-45.0	ATPC min -45.0	-44.9	ATPC min -45.0
MSE [dB]	↺	-43.1	ATPC max -41.3	-43.0	ATPC max -41.3
BER [-]	↺	0.00e+00	0.00e+00

Channel 2

TX channel [GHz]		U2	11.290000	L2	10.800000
RX channel [GHz]		L2	10.800000	U2	11.290000
Current TX modulation	↺	4096QAM	4096QAM
Current TX power [dBm]	↺	13	14
RSS [dBm]	↺	-45.1	ATPC min -45.0	-45.6	ATPC min -45.0
MSE [dB]	↺	-42.5	ATPC max -41.3	-42.0	ATPC max -41.3
BER [-]	↺	0.00e+00	0.00e+00

Fig. 5.7: Menu Status > Detailed (dual channel)

Band index

Radio unit type: L (Lower) or U (Upper) part of the frequency band.

TX polarization

Horizontal or vertical polarization based on the physical installation. Indicates the polarization of the transmitted signal. Local and Peer are indicated separately. The proper position of the cable is sideways down.

Notice for links in 17 GHz and 24 GHz bands: One side of the link must be installed in vertical polarization and the other in horizontal *polarization*.

Frequency table

Displays the currently used frequency table in format <name:version>.

Net bitrate [Mb/s]

Current transfer capacity of radio channel for user data (Ethernet L1 capacity for packets 1518 bytes long).

Max. net bitrate [Mb/s]
The maximum radio channel capacity according to installed SW key.

TX, RX bandwidth [MHz]
The selected channel bandwidth for transmission and receive. For symmetrical links only one value is listed (i.e. local TX bandwidth = local RX bandwidth). For asymmetrical links both bandwidths are listed in format: 'local TX bandwidth' | 'local RX bandwidth'.

TX and RX channel [GHz]
Used channels. Both number of the channel and frequency in GHz are listed.

Current TX modulation
Modulation currently used for transmitting.

Max. TX modulation
Maximum permitted modulation (user defined upper limit for ACM/ACMB). When adaptive modulation is enabled (i.e. the parameter 'ACM/ACMB min TX modulation' is lower than 'ACM/ACMB max TX modulation'), than the ACM/ACMB indication is displayed as well.

> **(i) Note**
> This parameter is displayed in FW 2.0.9.0 and previous just after the value of the current TX modulation (in the same row, separated by a slash).

TX power [dBm]
Set power/maximum power when ATPC is turned on.

Current TX power [dBm]
Current RF Output power on the TX channel in dBm. If ATPC is enabled, the ATPC letters are displayed as well as information about maximum permitted power: 'current TX power' | ATPC max 'maximum TX power'.

Calculated RSS [dBm]
Optional parameter to store the expected value of RSS.

RSS [dBm]
Received signal strength. If ATPC is enabled, the ATPC letters are displayed as well as information about threshold value for activation of power control loop: 'current RSS' | ATPC min 'threshold RSS'.

MSE [dB]
Mean Square Error (the inverse to often used SNR - Signal to Noise Ratio). If ATPC is enabled, the ATPC letters are displayed as well as information about threshold value for activation of power control loop: 'current MSE' | ATPC max 'threshold MSE'.

BER [-]
Bit Error Rate is registered at the receiving end; instantaneous value.

Link uptime
Time elapsed since the current link connection has been established.

Switch interface

Egress rate limit Air
Status of the Egress rate limiter on the Air interface. The traffic can be limited according to bits per second or frames per second.

Message format for bits per second: "xx.xx Mb/s Ly auto" where:
- xx.xx Mb/s — Egress speed limit.
- Ly — L1/L2/L3 which Ethernet layer is used for speed calculation.
- auto — gives information about active *Speed guard* function.

Message format for frames per second: "xx.xx fps" where:
- xx.xx fps — Egress frames per second limit.

Link mode Eth1, Eth2

Status of Ethernet interface. Current bit rate:
- 10 = 10BASE-T
- 100 = 100BASE-TX
- 1000 = 1000BASE-T; 1000BASE-SX; 1000BASE-LX
- 2500 = 2.5GBASE-T
- 5000 = 5GBASE-T
- 10000 = 10GBASE-T; 10GBASE-SX; 10GBASE-LX

and state of duplex:
- FD = full duplex
- HD = half duplex

Service access

MAC address

HW address of the Ethernet module.

IPv4 address

IP address in the standard dotted decimal notation, including the bit width of netmask after the forward slash.

Management VLAN

Service access via VLAN management only.

Services

Services enabled for unit management and monitoring (Web, Telnet, SSH, SNMP, NTP).

USB accessories

Indicates physical devices inside USB connector in system slot 'S' and its status, for example:
- n/a - info not available (peer has older fw),
- No device - unplugged,
- (Product) - not a network device,
- WiFi: disabled,
- WiFi: 169.254.170.168 / 28,
- Eth: disabled,
- Eth: 169.254.170.168 / 28

Unit 24S compatibility

(formerly 'Unit S mode') This parameter is available only for newly deployed 24 GHz units without the 'S' label in Product code (i.e. '24S'). When "active", the unit behaves like the unit '24S' (it can establish a link only with another '24S' unit). For a link between the units without the 'S' label, this compatibility needs to be disabled ("off").

Radio link statistics

Statistics Cleared

Time of log clearing.

Statistics Period
Period of log refresh.

Overall Link Uptime
Overall time the link has been connected.

Overall Link Downtime
Overall time the link has been disconnected.

Reliability [%]
The ratio of "Uptime" and "Downtime".

Current Link Uptime
Current time the link has been connected.

The Longest Drop
The longest downtime period recorded.

The Last Drop
Length of the last link interruption.

Number of Drops
Number of link interruptions.

5.4. Link settings

5.4.1. General

Setup of general parameters of the link.

Fig. 5.8: Menu Link settings > General

Product code
Unit type indicator.

Serial no.
Unit serial number.

IPv4 address
IP address in the standard dotted decimal notation, including the bit width of netmask after the forward slash.

Station name
Station name can be modified by user (for example to reflect the unit location in the network topology).

Station location
Station location can be modified by user (for example to reflect the network topology hierarchy).
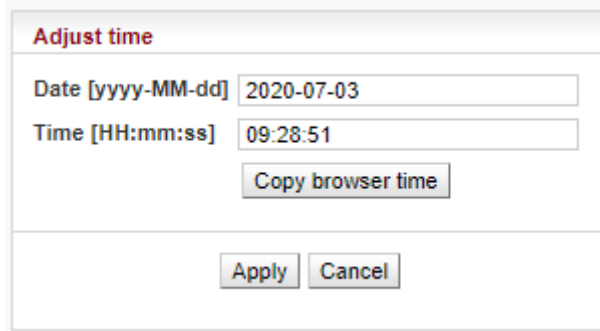
Date, Time
The internal real-time clock. The clock is set manually or it is synchronized with NTP server and set for both units.

Time source
Time synchronization source setup. Manual setup or NTP protocol use. For easier diagnostics of link operation, it is recommended to use the NTP time synchronization.

Adjust time

Manual time setup. Use the dialog box to manually set the current date and time. You can copy

Adjust time

Date [yyyy-MM-dd]   2020-07-03

Time [HH:mm:ss]   09:28:51

Copy browser time

Apply   Cancel

time from browser (local PC).

NTP source IP

IP address of the time synchronization server.

NTP period

Time synchronization interval.

Time zone

Unit Time zone in the format <Configured time zone> (<Used time zone code> <time offset>) ie.: "Europe/Prague (CEST +2:00)".

(i) Note

When the time zone is changed, the original values set in the unit are kept. The actual change takes place after OS restart in order to prevent unexpected states related with local time change.

Adjust time zone

Use the dialog box to set the new time zone. You can copy the time zone from a browser (local PC), select the time zone code from a list or input time zone string.

The string can be either time zone code from IANA time zone database (ie.: "Europe/Prague") or the POSIX format (ie.: "CET-01:00:00CEST-02:00:00,M3.5.0/02:00:00,M10.5.0/03:00:00"). The posix format allows shortened variants usage when default values are used (ie.: "CET", "CET-1CEST", ...).

The unit will reboot to use the new setting.

5.4.2. Radio

5.4.2.1. Radio parameters

Setup of general parameters of the radio link.

Some models of the RAy3 series (RAy3-11) allow to increase the transmission capacity by operating simultaneously in two radio channels. The setting of the second channel must meet the following conditions: both channels have the same bandwidth; both channels are adjacent to each other (Adjacent channels). The second channel is activated by selecting the Dual channel value in the **TX bandwidth [MHz], RX bandwidth [MHz] parameter** - example for two 112 MHz wide channels: "2x 112 MHz" The parameters of the transmission path can be slightly different for both channels, therefore the measurement of RSS, MSE and BER is separate for each channel. Similarly, ACM and ATPC work independently in each channel. In the case of operation in two channels, some radio parameters may differ compared to operation in one channel (lower value of max. available Tx power, lower sensitivity in some cases).

Fig. 5.9: Menu Link settings > Radio

Band index
Radio unit type: L(ower) or U(pper) part of the frequency band.

TX polarization
Horizontal or vertical polarization based on the physical installation. Indicates the polarization of the transmitted signal. Local and Peer are indicated separately. The proper position of the cable is sideways down.
Notice for links in 17 GHz and 24 GHz bands: One side of the link must be installed in vertical polarization and the other in horizontal *polarization*.

Asymmetric bandwidth
Enables asymmetric channel bandwidth (only in models/bands where Asymmetry is supported).

TX bandwidth [MHz], RX bandwidth [MHz]

One of the standard channel widths can be selected. This parameter must be set identically in local and remote (local TX bandwidth = peer RX bandwidth and local RX bandwidth = peer TX bandwidth). When units are connected, this is ensured automatically. If asymmetry is not allowed, then TX bandwidth = RX bandwidth on both units.

Dual channel

If *Dual channel* operation is selected (by setting the TX bandwidth [MHz], RX bandwidth [MHz] parameter to a Dual channel value), the setting of the second channel becomes visible. The setting of the second channel is visible only for checking - the working frequency value is set automatically according to the frequency of the first channel and the selected bandwidth.

TX bandwidth [MHz]	2x60 MHz	2x60 MHz
RX bandwidth [MHz]	2x60 MHz	2x60 MHz
Frequency input	list	
TX channel [GHz]	U1 | 11.230000	L1 | 10.740000
RX channel [GHz]	L1 | 10.740000	U1 | 11.230000
TX channel 2 [GHz]	U2 | 11.290000	L2 | 10.800000
RX channel 2 [GHz]	L2 | 10.800000	U2 | 11.290000

Fig. 5.10: Menu Link settings > Radio (Dual channel)

Frequency input

Allows to choose if TX and RX channel frequencies are selected from the list of predefined channels or if manual input of frequencies would be possible (if supported).

TX channel [GHz], RX channel [GHz]

TX and RX channels are selected from a list of channels. The basic configuration has the TX and RX options interconnected. In this case the basic duplex spacing between channels is preserved and by selecting one channel, the other three are defined as well. For units operating in free bands, it is possible to disconnect the TX-RX lock and select TX and RX channels individually. Corresponding channels at peer unit are set automatically (as long as the link to the other unit is established).

ⓘ **Note**

Non-standard duplex setting may lead to non-effective use of the spectrum. We recommend to use non-standard duplex spacing only in the situations when standard duplex spacing does not allow to establish the link.

Duplex spacing [MHz]

Information about duplex spacing of currently selected TX and RX channel.

ACM/ACMB max TX modulation

Upper limit of the ACM (Adaptive Coding and Modulation) or ACMB (Adaptive Coding, Modulation and Bandwidth) algorithm. Select lower than highest available modulation if the link speed fluctuation needs to be prevented. Select the same value for maximal and for minimal TX modulation if the link speed needs to be constant. The high order modulations may not be available for the narrowest and for the widest channel bandwidths.

ⓘ **Note**

The principle behind ACM and ACMB is to maintain the connection between the two units even when degraded propagation conditions are experienced which make it impossible to maintain the selected modulation level. ACM/ACMB regulates TX modulation across all ranges from 'ACM/ACMB min TX modulation' up to 'ACM/ACMB max TX modulation' (as configured by the user) according to the limits in table 'ACM/ACMB switching according to

MSE state' (tables are specific for each frequency band - i.e. *10 GHz*, *11/18 GHz*, *17/24 GHz*, *80 GHz*).

ACM/ACMB control loop is evaluated with each frame, i.e. roughly after tens of micro-seconds.

Max TX power [dBm]

Maximum allowed level of RF output power. The value is limited by *technical parameters* of the unit. The maximum selectable value differs for various HW options, various modulations and can be affected by a (non)installed *SW feature key* for full TX power.

> **(i) Note**
> Only for 80 GHz units: When ACMB shifts the modulation down (due to the weather or other factors), the TX power limit is automatically increased up to the highest available TX power for the new modulation limited by the configured value of 'Max TX power' (lower value applies). ATPC operates up to this TX power limit.

TX mute

Mutes TX transmission for unlimited time (until this setting is manually de-activated). The link transmission will be interrupted by applying this setting.

> **⚠ Important**
> It would not be possible to de-activate 'TX mute' on Peer unit from the Local one, because the communication between both units will be non-operational due to TX muted on Peer unit. Thus some other network connection to the Peer unit would be required to de-activate this setting. (If such an alternative route does not exist, a site visit will be necessary).

ATPC

Enables automatic control of RF power. Once enabled, the RF Output power is regulated towards lower level while maintaining signal level high enough not to affect current degree of modulation. Its maximum is defined by parameter 'Max TX power' and by the *technical parameters of the unit* for the currently active modulation.

> **(i) Note**
> The principle behind ATPC is to maintain the lowest transmitting power without affecting the throughput of the link. The output is primarily controlled by RSS on the opposite side. ATPC is also used to maintain MSE thus protecting the selected modulation level.
> The ATPC Control loop is evaluated once per second.
> In normal operating conditions, ATPC is applied first (even if it is the slower control loop). When deterioration in propagation conditions gradually increases the attenuation on the route, it is compensated by increasing RF power. ACM/ACMB control will only be applied in conditions when ATPC reaches its ceiling.

ATPC RSS threshold [dBm]

Comparison RSS with this threshold is used for signaling to the peer ATPC algorithm to adjust RF power. The lowest allowed RSS (the threshold) is approx. 10 dBm above declared sensitivity for BER 10^{-6}. If necessary, use this parameter to move the threshold slightly up or down.

Calculated RSS [dBm]

Optional parameter to store the expected value of RSS

Antenna gain [dBi]

Valid only for 17 GHz and 24 GHz links. Gain of used antenna. It is used to calculate approximate EIRP.

EIRP ?= limit [dBm]

Valid only for 17 GHz and 24 GHz links. Approximate calculation of EIRP. Number on the right shows the allowed EIRP limit (in most countries it is 20 dBm). Sign between numbers gives information on compliance / noncompliance with allowed EIRP limits.

Note

If you enter radio link parameters which interrupt the connection on an operating link, the original parameters will be automatically restored after 1 minute (see *Section 5.1.5, "Rollback function"*). The only exception is during activated 'TX mute', which disconnects the link permanently (until 'TX mute' is manually de-activated).

5.4.2.2. Encryption

This functionality requires the *encryption activation SW key* to be installed in both units (available for all bands except 80 GHz). Once installed, part of the user data traffic (one Ethernet port) can be AES encrypted to ensure the security of the over the-air communication.

Fig. 5.11: Menu Link settings > Radio > Encryption

IPsec VPN tunnel by Security Association with symmetrical cryptography is used to encrypt the packets and to ensure keys are safely delivered to the peer and regularly exchanged.

The protocol used for secure key exchange is IKE (Internet Key Exchange) version 2.

Link partner (peer) secure authentication is assured using Pre-Shared Key (PSK) authentication. Both link partners share the same key (password).

The other (non-encrypted) Ethernet port can be used simultaneously with the encrypted port for data transfer and/or for the unit management. The link capacity in the air is shared by both Ethernet ports. The encrypted traffic has a higher priority.

Enable
When user data encryption is enabled, the IPsec tunnel is started.

Port
The Encryption service encrypts all the user data traffic originating from one of two Ethernet ports. Ethernet port Eth1 or Eth2 needs to be selected. It is possible to select different Ethernet ports on each side of the link (e.g. Eth1 on Local and Eth2 on Peer).

DF Ignore
If the communication over the given Ethernet port is encrypted, the longest packet passing through without fragmentation are 2048 Bytes long. The longer packets need to be fragmented:
• in the previous network device, or
• the DF (Do-Not-Fragment) bit in the incoming packets must be cleared, or
• the DF Ignore bit needs to be set
Packets longer than 9000 Bytes are discarded.

IPsec Encryption algorithm
IPsec SA encryption algorithm. The stronger the algorithm, the lower the user data throughput.

IPsec Authentication algorithm

    IPsec SA integrity algorithm. The stronger the algorithm, the lower the user data throughput.

IKE Encryption algorithm

    IKE SA encryption algorithm.

IKE Authentication algorithm

    IKE SA integrity algorithm.

PSK Passphrase

    PSK (Pre-shared key) authentication is used for IKE SA authentication. The key must be the same for both Local and Peer units.

    ⓘ **Note**

    PIRL setup **recommendation**

    In order to prevent Ethernet switch to management CPU connection overload and to keep the unit management connection available it is recommended to set PIRL for the encrypted port (for example) following way (only modified parameters are mentioned).

    This functionality requires the *encryption activation SW key* to be installed in both units.

- Rate [Mb/s] - Green: 150
- Size [kB] - Green: 10.5
- Account discarded frames: Yes (checked)
- Account filtered frames: Yes (checked)
- Flow control de-assertion: CBS limit
- Frame types (checked): Unknown unicast; Unknown multicast; Unknown broadcast; Multicast/Broadcast; Unicast; Network management; ARP; TCP data; TCP control; UDP; "IGMP,ICMP,GRE,IGRP,L2TP"

5.4.2.3. Link State Propagation (LSP)

LSP allows the unit or the entire link to automatically respond to reduced radio channel throughput. Communication between units is maintained even if the LSP function is activated (provided the received signal level is above the most robust modulation sensitivity). Various LSP actions can be triggered when LSP is activated. Access to the remote unit is possible via port forwarding of the local unit (ports allowed are: 8022, 8023, 8080, 8161 and 8443).

Fig. 5.12: Menu Link settings > Radio > LSP

Link State Propagation (LSP)

Enable
Enables LSP on the corresponding unit.

Mode
Master: activates the LSP function depending on the link speed (radio channel throughput) of this unit. See the description of the Threshold parameter.
Slave: If the link is connected, it activates the LSP function synchronously with the activation of this function on the Peer unit.
If the link is disconnected, it activates the LSP function depending on the current link speed, i.e. the same as when selecting Master mode.

Threshold [Mbps]
User speed threshold for activating the LSP function. When the current "Net bitrate" value drops below the set threshold, LSP is activated. "0" means function is disabled.

Actions:

Depending on the network configuration, one of the following actions can be selected when the LSP function is activated:

LSP action: Disable Air

Enable
   Deactivates the connection of the ETH1 and ETH2 ports to the AIR port, which prevents the transmission of user data via the microwave link.

LSP action: Switch to backup link

Enable
   Deactivates the connection of the ETH1 and ETH2 ports to the AIR port and connects the ETH1 and ETH2 ports. Thus, user data will not be transmitted over the air, but sent to the second ETH port, where a backup connection is assumed.

Loop prevention
   Selects a port that is not connected to the AIR port to avoid an Ethernet loop.

LSP action: Port shutdown

Enable
   Switches the ETH port to "link down" when LSP is activated. PoE power remains active. If the port is down, it is not even possible to access the management of the device from this port.

Port
   Selecting a port to "link down" when LSP is activated..

Ongoing Development of LSP (Link State Propagation) Functionality

We are continually refining the functionality of the LSP (Link State Propagation) feature to enhance your overall user experience. As part of this ongoing development process, it is crucial to acknowledge that the LSP function is still in the refinement stage.

Pre-Deployment Testing Recommendations

Examples of functional configurations can be found in the APP note, which can be found in the Application Notes section of the racom.eu website.

Prior to implementing the LSP feature in a live environment, we strongly advise conducting thorough testing in a controlled laboratory setting. This step ensures that the LSP functionality aligns seamlessly with your specific requirements and minimizes the risk of network loops.

Testing Guidelines:

1. Validate that the LSP function operates in accordance with your specified configuration.
2. Verify that the LSP does not induce any unintended network loops or disruptions.
3. Ensure that the LSP performs reliably under diverse network conditions and scenarios.

Your feedback during this testing phase is invaluable in helping us deliver a robust and dependable solution tailored to your needs.

We welcome any feedback or questions you may have during the testing process. Your input is instrumental in our commitment to providing the highest quality of service.

5.4.3. Service access

5.4.3.1. Services

Access routes for link configuration.

Fig. 5.13: Menu Link settings > Service access > Services

Service access

IPv4 address

Service IP address, by default 192.168.169.169 for L unit and 192.168.169.170 for U unit. Management address of the Peer station has to be set up as well.

> (i) **Note**
> **Unknown IP address**
> If you forget the Service IPv4 address, it can be found by reading data broadcast through LLDP protocol. Data is transmitted every 60 seconds and contains the following information:
>   1. Management address: IP address
>   2. System Description: Serial number
>   3. Chassis Subtype: Unit product type
>   4. IEEE 802.1 - Port and Protocol VLAN ID: Port and Protocol VLAN Identifier: (e.g. 300 (0x012C)) but only if Management VLAN is enabled
>
> The message can be recorded and converted into a readable form using an LLDP client. A suitable tool for this purpose is Wireshark IP traffic analyzing tool, with free licenses available for both Windows and Linux. To locate the message easily, use the Capture filter "ether proto 0x88cc" in Wireshark.

Netmask

Mask for service access, 24 by default.

Gateway

Default gateway for service access; empty by default.

Management VLAN, 1st tag, 2nd tag

Enables management access via VLAN. Management VLAN can be single-tagged or dual-tagged. Line for 2nd tag gets active only after 1st tag is activated. Blocks access for HTTPS, ssh and telnet configuration via untagged packets (without VLAN) making only VLAN access possible. VLAN management is off by default.

> ⊗ **Warning**
>
> By enabling VLAN management, ALL accesses are blocked for configuration using normal (untagged) LAN! During tests, you may enable VLAN management on one unit only. Then it is possible to access the link via LAN and VLAN either directly or via radio link.

VID

VLAN management ID, by default 1. This field must have a value entered even when VLAN management is not active.

Protocol

Protocol 802.1q or 802.1ad

Services

Web server

Allows access via web server (for HTTP and HTTPS protocol).

> ⊗ **Warning**
>
> After disabling access via web server, you will not be able to access the unit using a web browser!

CLI (telnet)

Enables access via telnet protocol. Provides access to CLI (Command Line Interface) for simple telnet clients. Disabled by default.

CLI (SSH)

Enables access via SSH protocol. Provides secure access to CLI. If preventing unauthorized access to the unit is the number one priority, leave only this server on.

SNMP

Enabling SNMP server. Off by default.

SNMP community string

SNMP community string. Can contain both lower and uppercase letters, numbers, four characters . : _ - and can be up to 256 characters long.

SNMP trap IP

Address for sending SNMP traps. It is possible to record up to 3 addresses separated by commas.

SNMP MIB

Saving a file with SNMP MIB (Management Information Base) table. The downloaded file is identical to the SNMP MIB table file downloaded from RACOM web (*section Downloads*[1]) for relevant FW version.

LED indicators

Enable LED status indicators on the body of the unit. You can turn off LED indication with this option.

LLDP (Service IP info)

Data transmitted through the LLDP protocol can be accessed in two ways:
- OnTransmissions every 60 seconds
- SingleTransmitted once only when unit is rebooted

See "IPv4 address - Local ... Unknown IP address" for description of the data transmitted through the LLDP protocol.

Link authorization guard

User data flow to the remote unit can be established dependent on remote station authorization. The authorization is secured by using SSH keys. For info about unit authorization see user manual, section *CLI > Configuration with CLI > Remote unit authorization*.
- Disabled — User data flow through the Air channel is enabled even if the remote unit is not authorized.
- Enabled — User data flow through the Air channel is enabled only if the remote unit is authorized. The "Link authorization guard" parameter value of the remote unit is ignored.

Speed guard

The speed guard controls automatically the Egress data rate shaping according to available capacity of the Air channel. The Air channel capacity check and the Egress shaping adjustment takes place approx. once per 50 ms.

SyncE source

The port that will be used as the frequency source for Synchronous Ethernet.

---

[1] https://www.racom.eu/download/hw/ray/free/eng/03b_fw/ray3-mib.mib

5.4.3.2. USB accessories

The USB connector is used for management access (not for user data) to the local unit using Ethernet or WiFi adapter. Only adapters officially recommended by the unit vendor are supported.

Default WiFi IP address of the unit is 172.17.17.17 with DHCP enabled by default allocating IP address automatically to connected device.
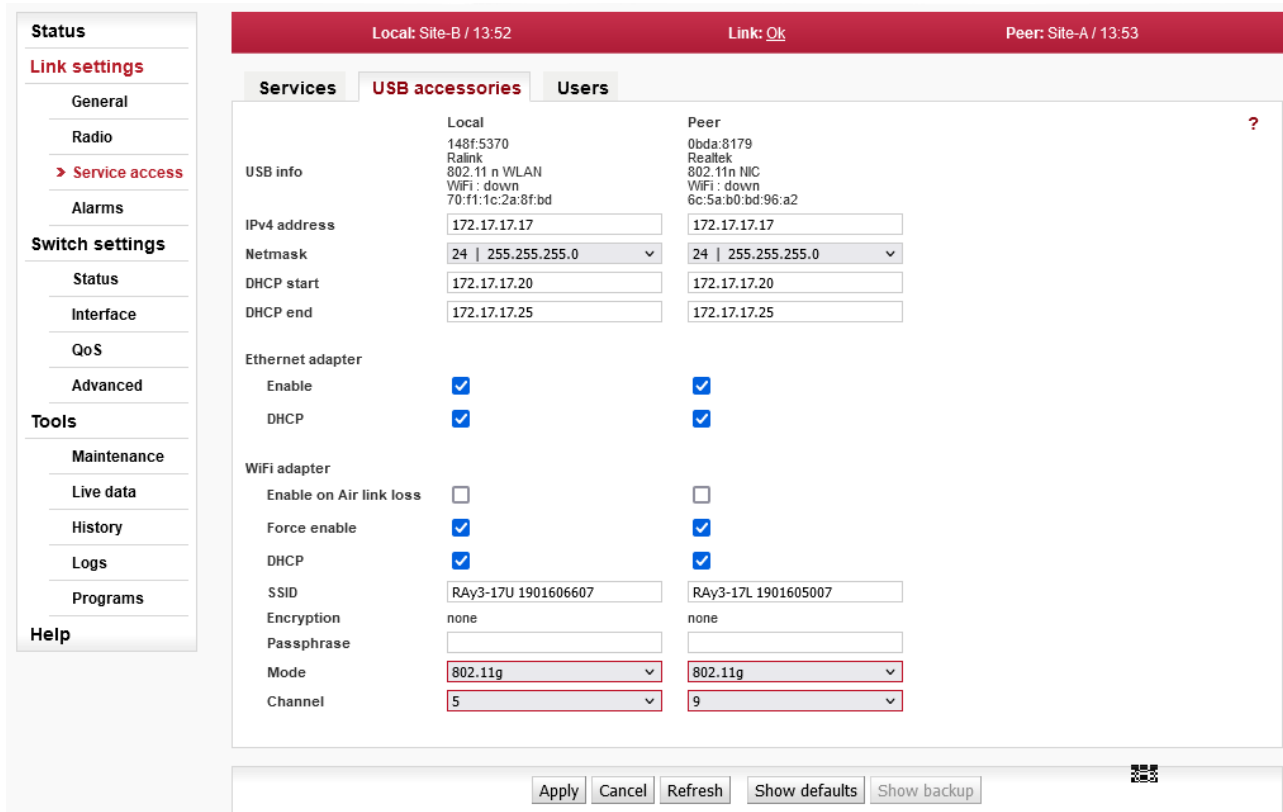
Fig. 5.14: Menu Link settings > Service access > USB accessories

USB info
Status information about device connected via the USB:
- n/a - info not available (HW in USB slot not recognized by FW = probably not officially supplied accessory), or
- No device - no device plugged in the USB port, or
- List of basic USB module credentials:
- Vendor ID: Product ID
- Manufacturer
- Product
- WiFi/Eth: up/down — only for network device
- MAC — only for network device

IPv4 address
Unit service management address when connecting via USB port.

Netmask
Network mask when connecting via USB port.

DHCP start
DHCP range for dynamic address allocation of the management client connected via USB port.

DHCP end
DHCP range for dynamic address allocation of the management client connected via USB port.

Ethernet adapter Enable
Enables operation of USB/Eth adapter.

Ethernet adapter DHCP
Enables DHCP for the client(s) connected via USB Ethernet adapter.

WiFi adapter Enable on Air link loss
WiFi is activated only during Air-Link loss – means WiFi starts to work and transmit SSID. WiFi is activated 60 seconds after Air-Link loss and deactivated 600 seconds after the Air-Link is restored. The WiFi passphrase should be set by admin before using this option (if not *WiFi management* alarm is activated).

WiFi adapter Force enable
WiFi is forced to be permanently active (and to transmit SSID) and *WiFi management* alarm is activated. WiFi passphrase should be set by admin before using this option.
This parameter has a higher priority than "WiFi adapter enable on Air link loss", so if it is set ON then WiFi activity does not depend on Air-Link status.

WiFi adapter DHCP
Enables DHCP on WiFi adapter if present (for automatic setting of client(s) IP address).

WiFi SSID
Name of service WiFi visible by clients (can be max. 32 characters long).

WiFi Encryption
Service WiFi encryption is WPA2 and cannot be changed. Factory default is "none" due to missing passphrase. WPA2 is applied automatically once any passphrase is entered.

WiFi Passphrase
Service WiFi passphrase has to be 8-64 characters long. The WiFi passphrase should be set by admin before any use of WiFi. Until passphrase is set, *WiFi management* alarm is activated.

WiFi Mode
Service WiFi mode can be IEEE 802.11n or IEEE 802.11g

WiFi Channel
WiFi channel can be set 1-11 depending on WiFi mode setting (see parameter above):
IEEE 802.11n — channels 1-7
IEEE 802.11g — channels 1-11
The WiFi adapter does not search for conflicts in the air. If problems occur, changing the channel is the easiest way to resolve the issue.

5.4.3.3. Users

List and setup of users. Example menu of the `cli_super` level user.
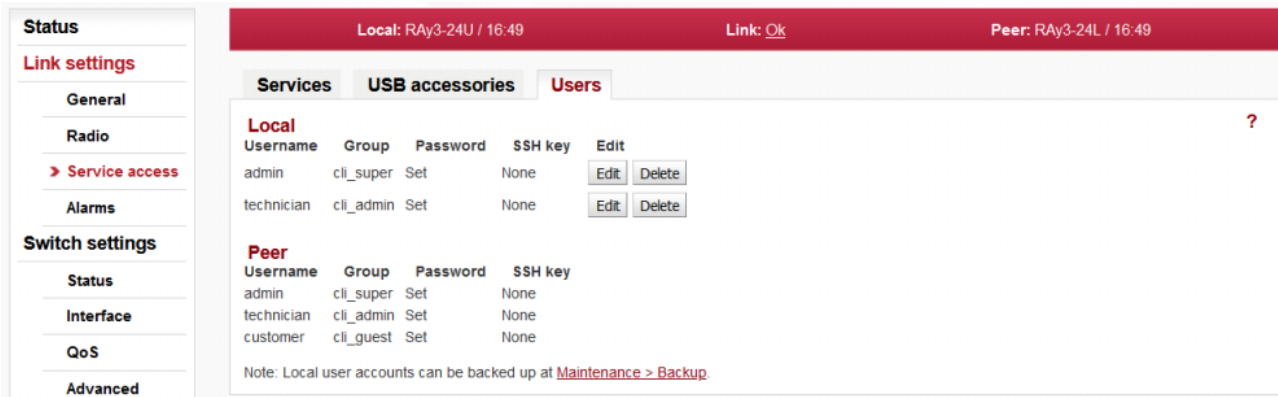
Fig. 5.15: Menu Link settings > Service access > Users

Within the default Factory Settings one user is defined in the system. This user has username **admin** and password **admin** and is assigned the highest level of permissions `cli_super`. This user then assigns other users to the system along with their level of permissions.

Service access has three groups of users with different levels of permissions.

Permissions	cli_guest	cli_admin	cli_super
Create new user	No	No	Yes
Change own password	Yes	Yes	Yes
Delete user *	No	No	Yes
Copy (Mirror) permissions local to peer	No	No	Yes
Configure and modify link settings	No	Yes	Yes

Numbers of users that can be defined in the system:

Group	No of users
cli_guest	10
cli_admin	10
cli_super *	2

  * The system prevents the user from deleting both `cli_super` accounts.

The logged-on user is shown in the top right of the screen. There can be different users on either end of the link.

⚠ **Important**

It is strongly recommended that the default password admin is changed. Similarly, all other users should change their password. Using the CLI, it is appropriate to supplement the SSH key.

Local, Peer

List of users on Local and Peer stations.

Username
    This name is entered at Login to log into the link management.

Group
    User group to which the user belongs.
        cli_guest - Read Only
        cli_admin - Configure and modify link settings
        cli_super - Configure and modify user accounts and link settings

Password
    Information about whether user has a password

SSH key
    Information about whether user has at least one ssh key defined.

(i) Note

More users concurrently
If two or more users work concurrently on the unit any change of configuration settings should be applied by all users. This applies to the menu *Link settings* which works with both, Local and Peer parameters.
If one user sends the Apply command, other users will receive a message: "Configuration changed, please go to Link settings and click Refresh". Other users can only use the Apply command after refreshing Link Settings.

Edit user

Clicking "Edit" next to a username opens a screen with configuration of the given account.
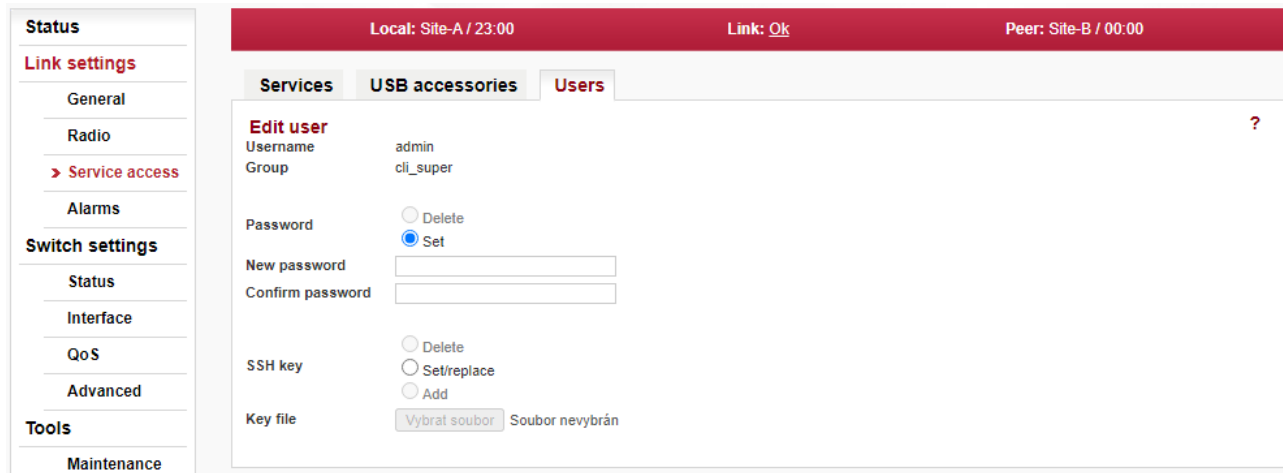
Fig. 5.16: Menu Link settings > Service access > Users > edit

Username
> User name.

Group
> The group to which this user will belong.

Password
> Password can be set or deleted.
> > **Delete** - User will not have a password. The user will only be able to log in with a ssh key. In order to delete the password, you must first upload the ssh key.
> > **Set** - Password settings

New password
> New password.

Confirm password
> Repeat password.

SSH key
> Working with ssh key.
> > **Delete** - Clear all ssh keys from user account.
> > **Set/replace** - Add a new key. If there already was any key(s), it will be overwritten.
> > **Add** - Add a new key. You can enter multiple ssh keys in this way.

Key file
> Insert key file.

Save the menu content by clicking on the button Apply.

> **Note**
>
> The user settings can be backed up, see *Tools > Maintenance > Backup*.

Delete user

Users at level `cli_super` have a Delete button next to each user. Delete a user using this button without being asked to confirm deletion. Users at level `cli_super` cannot both be deleted.

Add user

The button is located on the bottom bar.

For level `cli_super` users, the "Add user" button is active. Use it to create a new user within any group.

Username
　　Name of new user.

Group
　　The group to which this user is assigned.

New password
　　Password for this user.

Confirm password
　　Repeat password.

SSH key
　　If you want the user to have access using ssh protocol and identity verification using ssh key, enter the ssh key here.

Create a new user account by clicking on the button Apply.

Mirror users

The button is located on the bottom bar.

For level `cli_super` users, the "Mirror users" button is active. This function will copy all user accounts from Local unit to Peer unit. All existing user accounts on the Peer unit are deleted.

5.4.4. Alarms

5.4.4.1. Alarms Status
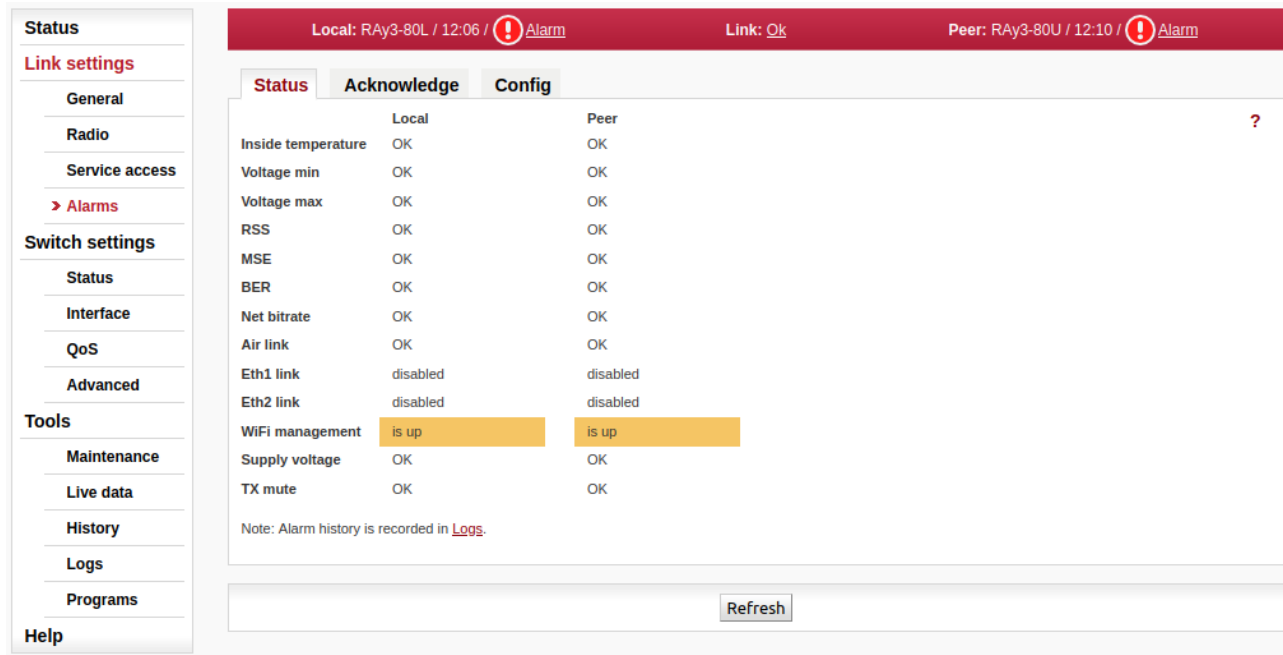
Fig. 5.17: Menu Link settings > Alarms > Status

Overview of alarms

(pink)	alarm
(yellow)	warning
	cleared / OK
✓	confirmed

All system alarms are listed on this screen. Inactive alarms are colored white with an "OK" text label. Active alarms are colored according to the severity of the alarm with a text message describing the measured value status.

For a detailed description of each Alarm see *Section 5.4.4.3, "Alarms Config"*, in unit management just click on the Alarm name.

5.4.4.2. Alarms Acknowledge

Fig. 5.18: Menu Link settings > Alarms > Acknowledge

Alarm acknowledgement allows the operator to confirm the system is set in alarm state. Only an active alarm can be acknowledged. Multiple selections of active alarms (to acknowledge groups of alarms) can be performed using Shift or Ctrl keys.

Name
Alarm identification - The following alarms can appear: Inside temperature, Voltage min, Voltage max, RSS, MSE, BER, Net bitrate, Air link, Eth1 link, Eth2 link, RF power, WiFi management

State
There are three possible alarm states:
OK — No alarm (alarm is inactive) or alarm disabled.
Ack — Alarm is active and acknowledged.
Alarm — Alarm is active and is not acknowledged.

From
Time stamp when the alarm occurred.

To
Time stamp when the alarm expired (returned to normal conditions).

Ack
Time stamp when the alarm was acknowledged. Time stamp format: yyyy-MM-dd hh:mm:ss

User
Name (login) of the user who acknowledged the alarm.

Comment
The comment field can be used to add user defined comments when an 'alarm acknowledge' is performed. Use this comment field to describe important details of the alarm status. The comment can be up to 50 characters long. Special characters are not allowed. The alarm can be acknowledged

multiple times with different comments. Every acknowledgement is written to the internal memory and is visible in the alarm log.

5.4.4.3. Alarms Config
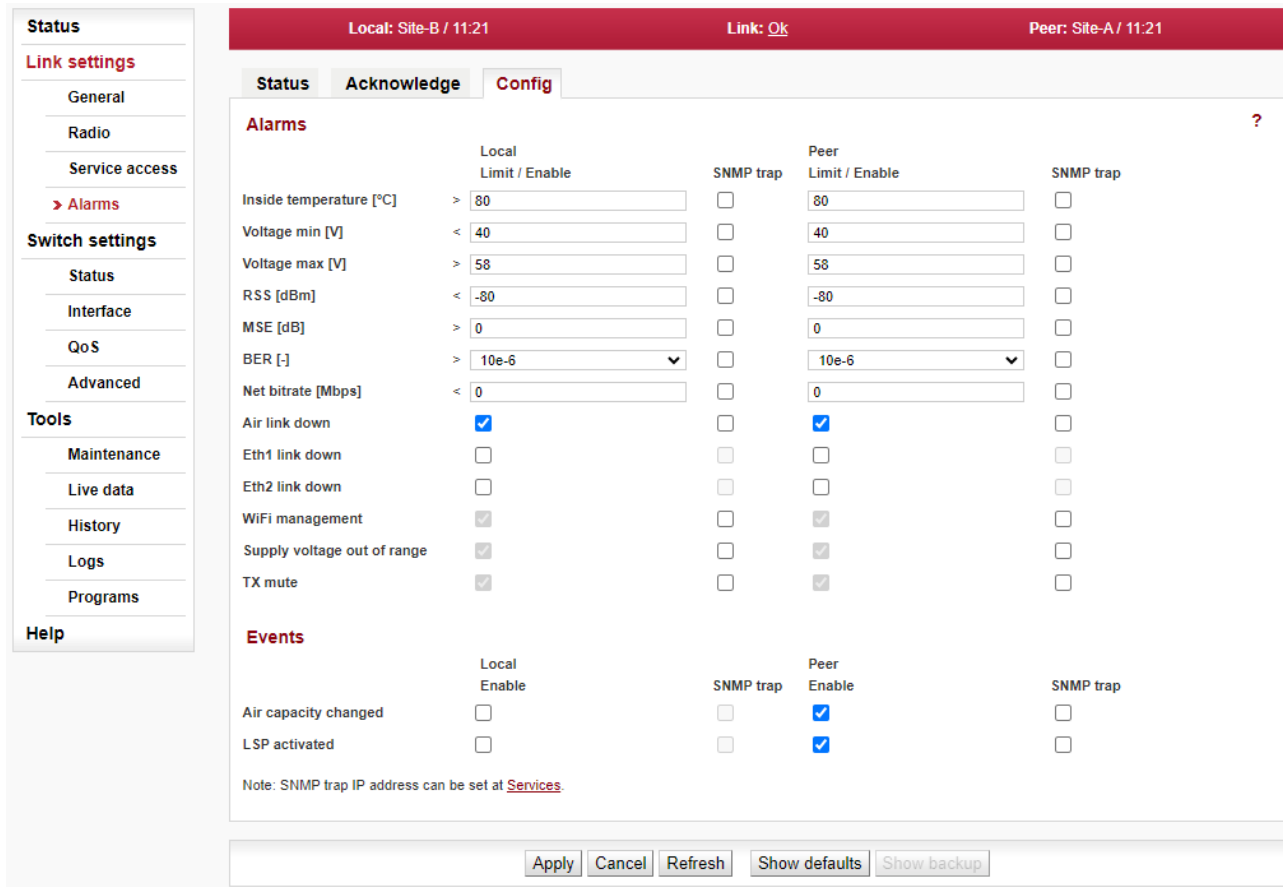
Fig. 5.19: Menu Link settings > Alarms > Config

The diagnostics system of the link monitors the operation of both units.

It generates various event outputs - system warnings and alarms. The event is always written to the system log and indicated in the *Status bar* and *Alarms/Status* screen. Some events have adjustable thresholds. Events with no adjustable thresholds may or may not be Enabled. If they are not Enabled, the system event is not activated even if the system status is changed.

If the event goes above or below the set parameter limits or a link goes down or up, you can choose to send an SNMP trap. All SNMP traps are OFF in defaults.

Alarms

Inside temperature [°C]
 Default >80; severity: alarm
 Temperature inside the unit (on the modem board). Active if temperature exceeds the threshold.

Voltage min [V]
 Default <40; severity: alarm
 Lower threshold of supply voltage. Active if voltage drops below min voltage threshold.

The same SNMP trap (same OID) applies for both Voltage min and max.

Voltage max [V]

Default >58; severity: alarm

Upper threshold of supply voltage. Active if voltage rises above max. voltage threshold.

The same SNMP trap (same OID) applies for both Voltage min and max.

RSS [dBm]

Default <-80; severity: alarm

Received Signal Strength. Active if RSS drops below RSS threshold.

MSE [dB]

Default >0; severity: alarm

Mean Square Error (the inverse to often used SNR - Signal to Noise Ratio). Active if MSE rises above MSE threshold.

BER [-]

Default >$10e^{-6}$; severity: alarm

Bit Error Rate is registered at the receiving end of the link - instantaneous value. Active if BER exceeds the threshold set in this parameter.

Net bitrate [Mb/s]

Default >0; severity: warning

The system warning is generated when the current transfer capacity of radio channel is lower than the threshold set in this parameter.

Air link down

Default on; severity: alarm

Interruption of radio link. Active if radio link is interrupted and units can not communicate by Air.

Eth1/Eth2 link down

Default off; severity: alarm

Corresponding user Eth link (Eth1/Eth2) on station interrupted.

> **Note**
> The "EthX link" system alarm can only be activated if this alarm is Enabled. When the alarm is not Enabled, the "EthX link" alarm on *Status* screen is always "Ok" regardless of the current status of the Ethernet link.

WiFi Management

Default on; severity: warning

Warning is generated when WiFi passphrase is not set or WiFi adapter (and Host Access Point) is permanently enabled (WiFi Force Enable is ON). Parameter can not be changed in web interface (only through CLI).

Supply voltage out of range

(RAy3-18 and RAy3-80 only)

Default on; severity: alarm

Active if voltage before boot is outside of unit voltage range (printed on the unit *Product label*). Indicated also by the system *status LED* (no color).

> **Note**
> The unit does not fully boot. Re-boot the unit by re-powering it with a proper power supply.

TX mute

Default on; severity: warning

Alarms when TX transmission is muted by the operator (i.e. the radio link is out of operation due to the decision of the operator).

Events

Air capacity changed

Default off

If allowed, the Event and/or SNMP Trap is generated when Net bitrate of the air channel changes (e.g. because of ACM/ACMB operation).

LSP activated

Default off

If allowed, the Event and/or SNMP Trap is generated when LSP is activated (Link capacity drops bellow the preset threshold).

5.5. Switch settings

Ethernet switch is a key part of the unit. It is responsible for data transfer inside the unit - see *Appendix B, Unit block diagrams.*

5.5.1. Status

5.5.1.1. Port status

The unit internal Ethernet switch port status

Fig. 5.20: Menu Switch settings > Status > Port status

Port name

Identification of the internal switch port. The switch ports are connected to an external port or to an internal device (radio modem, management CPU).
- Eth1 (port1) — The external port (with RJ45 interface) labeled "ETH1+POE".
- Eth2 (port10) — The external port (with SFP interface) labeled "ETH2".
- CPU (port0) — The internal port to management CPU.
- Air (port9) — The internal port to radio modem, i.e. link to the peer unit.

Link status

Ethernet link status can be
- down — no link signal detected
- up — link signal detected

Speed / duplex

Ethernet link Speed and duplex.
- Speed: — 0/100/1000 Mb/s.
- Duplex: — full/half

SFP info

Information about the (optionally) inserted SFP module - see *Section 1.3.2, "SFP/SFP+ slot (ETH2)"* for info about available SFP modules. Four situations may appear:
- SFP OK — The SFP vendor string read out of SFP module. The vendor, model, connector (RJ45/LC) and wavelength values are shown. Separate window with more detailed information can be opened by clicking the "more..." link.
- No SFP module — SFP module not inserted
- read error — SFP info can not be read
- no SFP option — n/a

MDIX

Status of the internal crossover of Ethernet cables. (MDIX = internally crossed pairs, MDI = direct connection, N/A means an unknown state).

Tx state

Port transmitting status can be
- transmitting — Normal port operation.
- paused — Port transmitter is paused due to Pause frames reception.
- n/a — Info not available.

Stp state

Ethernet switch port forwarding control.
- disabled — The switch port is disabled and it will not receive or transmit any frames.
- forwarding — The switch examines all frames, learning source addresses (SA) from all good frames (except those from MGMT frames) and receives and transmits all frames as a normal switch.
- blocking — Only MGMT frames are allowed to enter (ingress) or leave (egress) a Blocked port. All other frame types are discarded. Learning is disabled on Blocked ports.
- learning — Only MGMT frames are allowed to enter (ingress) of leave (egress) a Learning port. All other frame types are discarded but learning takes place on all good non-MGMT frames that are not discarded owing to being filtered.

QoS

Quality of Service status. It will be available starting from FW version 1.1.1.0. It can present one of the following values:
- disabled — QoS functions are disabled.
- 802.1p — QoS according to 802.1p is enabled.
- DSCP — QoS according to DSCP is enabled.
- 802.1p,DSCP — QoS according to 802.1p and DSCP is enabled. The 802.1 prefer tag is selected.
- DSCP,802.1p — QoS according to 802.1p and DSCP is enabled. The DSCP prefer tag is selected.

5.5.1.2. RMON counters

The unit internal Ethernet switch RMON counters

Status
Link settings
 General
 Radio
 Service access
 Alarms
Switch settings
 › Status
 Interface
 QoS
 Advanced
Tools
 Maintenance
 Live data
 History
 Logs
 Programs
Help

| Local: Site-A / 23:07 | | | Link: Ok | | Peer: Site-B / 00:07 | |

Port status | RMON counters

Port name	Eth1 (p1) data_1		Eth2 (p10) data_2		CPU (p0) cpu		Air (p9) air	
	total	diff	total	diff	total	diff	total	diff
In good octets	3929921	0	0	0	1834992	0	961082	0
In bad octets	0	0	0	0	0	0	0	0
In unicasts	15718	0	0	0	6236	0	8059	0
In multicasts	6432	0	0	0	823	0	407	0
In broadcasts	5354	0	0	0	8	0	2	0
In pause	0	0	0	0	0	0	0	0
In undersize	0	0	0	0	0	0	0	0
In oversize	0	0	0	0	0	0	0	0
In FCS errors	0	0	0	0	0	0	0	0
In fragments	0	0	0	0	0	0	0	0
In jabber	0	0	0	0	0	0	0	0
In RX errors	0	0	0	0	0	0	0	0
In discards	0	0	0	0	0	0	0	0
In filtered	0	0	0	0	0	0	0	0
In accepted	27504	0	0	0	7067	0	8468	0
In bad accepted	0	0	0	0	0	0	0	0
In good AVB A	0	0	0	0	0	0	0	0
In good AVB B	0	0	0	0	0	0	0	0
In bad AVB A	0	0	0	0	0	0	0	0
In bad AVB B	0	0	0	0	0	0	0	0
In TCAM 0	0	0	0	0	0	0	0	0
In TCAM 1	0	0	0	0	0	0	0	0
In TCAM 2	0	0	0	0	0	0	0	0
In TCAM 3	0	0	0	0	0	0	0	0
In dropped AVB A	0	0	0	0	0	0	0	0
In dropped AVB B	0	0	0	0	0	0	0	0
In DA unknown	12181	0	0	0	831	0	424	0
In management	0	0	0	0	7067	0	0	0
Out octets	2743750	0	0	0	2477156	0	2412101	0
Out FCS errors	0	0	0	0	0	0	0	0
Out unicasts	14295	0	0	0	7612	0	8480	0
Out multicasts	814	0	0	0	6839	0	6835	0
Out broadcasts	6	0	0	0	5356	0	5358	0
Out pause	0	0	0	0	0	0	0	0
Out collisions	0	0	0	0	0	0	0	0
Out deferred	0	0	0	0	0	0	0	0
Out single	0	0	0	0	0	0	0	0
Out multiple	0	0	0	0	0	0	0	0
Out late	0	0	0	0	0	0	0	0
Out excessive	0	0	0	0	0	0	0	0
Out queue 0	15108	0	0	0	19799	0	20626	0
Out queue 1	0	0	0	0	1	0	1	0
Out queue 2	0	0	0	0	0	0	0	0
Out queue 3	0	0	0	0	0	0	0	0
Out queue 4	0	0	0	0	0	0	0	0
Out queue 5	0	0	0	0	0	0	43	0
Out queue 6	7	0	0	0	7	0	3	0
Out queue 7	0	0	0	0	0	0	0	0
Out cut throught	0	0	0	0	0	0	0	0
Out octets A	0	0	0	0	0	0	0	0
Out octets B	448	0	0	0	476	0	282	0
Out yellow	0	0	0	0	0	0	0	0
Out dropped yellow	0	0	0	0	0	0	0	0
Size 64 octets	22067	0	0	0	1848	0	16700	0
Size 65-127 octets	14470	0	0	0	21400	0	9788	0
Size 128-255 octets	2186	0	0	0	1051	0	1323	0
Size 256-511 octets	1070	0	0	0	571	0	508	0
Size 512-1023 octets	1128	0	0	0	779	0	305	0
Size 1024-max octets	1698	0	0	0	1225	0	517	0

Histogram counters mode   Received and transmitted
Measure time   00:00:00

Fig. 5.21: Menu Switch settings > Status > RMON counters

The Remote Network MONitoring (RMON) MIB was developed by the IETF to support monitoring and protocol analysis of LANs.

Port name
 Identification of the internal switch port. The switch ports are connected to an external port or to an internal device (radio modem, management CPU).
 • Eth1 (port1) — The external port (with RJ45 interface) labeled "ETH1+POE".
 • Eth2 (port10) — The external port (with SFP interface) labeled "ETH2".
 • CPU (port0) — The internal port to management CPU.
 • Air (port9) — The internal port to radio modem, i.e. link to the peer unit.

The Internal switch port RMON counters

These counters provide a set of Ethernet statistics for frames received on ingress and transmitted on egress.

Ingress statistics counters

In good octets
The sum of lengths of all good Ethernet frames received, that is frames that are not bad frames.

In bad octets
The sum of lengths of all bad Ethernet frames received. Fragments are included.

_____

In unicasts
The number of good frames received that have a Unicast destination MAC address.

In multicasts
The number of good frames received that have a Multicast destination MAC address.

> **(i) Note**
> This does not include frames counted in "In broadcasts" nor does it include frames counted in "In pause".

In broadcasts
The number of good frames received that have a Broadcast destination MAC address.

In pause
The number of good frames received that have a Pause destination MAC address (Flow Control frames). This includes Priority Flow Control Pause frames too.

_____

In undersize
Total frames received with a length of less than 64 octets but with a valid FCS.

In oversize
Total frames received with a length of more than MaxSize octets but with a valid FCS.

In FCS errors
Total frames received with a CRC error not counted in "In fragments", "In jabber" or "In RX" errors.

In fragments
Total frames received with a length of less than 64 octets and an invalid FCS.

In jabber
Total frames received with a length of more than MaxSize octets but with an invalid FCS.

In RX errors
Total frames received with an RxErr signal from the PHY.

_____

In discards

The number of good, non-filtered frames that are received but cannot be forwarded due to a lack of buffer memory.

In filtered

The number of good frames that were not forwarded due to ingress policy filtering rules.

In accepted

The number of good frames that are not policy filtered nor discarded due to an error and made it through the Ingress process and is presented to the Queue Controller.

In bad accepted

The number of good frames that were not forwarded due to ingress policy filtering rules.

In good AVB A, B

The number of good AVB frames received that have a Priority Code Point for Class A (or B) that are not Undersize nor Oversize and are not discarded or filtered.

In bad AVB A, B

The number of bad AVB frames received that have a Priority Code Point for Class A (or B) that are not Undersize nor Oversize.

In TCAM 0 ... 3

The number of good frames received that have a TCAM Hit on a TCAM Entry that has its IncTcamCtr bit set to a one and its FlowID[7:6] = 0 ... 3 and are not discarded or filtered. This allows this counter to be used for any purpose as programmed in the TCAM.

In dropped AVB A, B

The number of good AVB frames received that have a Priority Code Point for Class A (or B) that are not Undersize nor Oversize and are not discarded or filtered but were not kept by the switch due to a lack of AVB buffer.

In DA unknown

The number of good frames received that did not have a Destination Address 'hit' from the ATU (i.e., the frame's DA was not in the address database) and are not discarded or filtered.

In management

The number of good frames received that are considered to be Management frames and are not discarded (i.e., the frame's size is legal and its CRC is good or it was forced good by register. Remote Management frames are counted regardless if the RMU accepted them or not.

Egress statistics counters

Out octets

The sum of lengths of all Ethernet frames sent from this MAC.

Out FCS errors

The number of frames transmitted with an invalid FCS. Whenever a frame is modified during transmission (e.g., to add Out FCS errors or remove a tag) the frame's original FCS is inspected before a new FCS is added to a modified frame. If the original FCS is invalid, the new FCS is made invalid too and this counter is incremented.

Out unicasts
> The number of frames sent that have a Unicast destination MAC address.

Out multicasts
> The number of good frames sent that have a Multicast destination MAC address.

> **ⓘ Note**
> This does not include frames counted in "Out broadcasts" nor does it include frames counted in "Out pause".

Out broadcasts
> The number of good frames sent that have a Broadcast destination MAC address.

Out pause
> The number of Flow Control frames sent. This includes Pause and Priority Flow Control frames.

_____

Out collisions
> The number of collision events seen by the MAC not including those counted in "Out Single", Multiple, Excessive, or Late. This counter is applicable in half-duplex only. See Auto negotiation.

Out deferred
> The total number of successfully transmitted frames that experienced no collisions but are delayed because the medium was Out deferred busy during the first attempt. This counter is applicable in halfduplex only.

Out single
> The total number of successfully transmitted frames that experienced exactly one collision. This counter is applicable in halfduplex only.

Out multiple
> The total number of successfully transmitted frames that experienced more than one collision. This counter is applicable in halfduplex only.

Out late
> The number of times a collision is detected later than 512 bitstimes into the transmission of a frame. This counter is applicable in half-duplex only.

Out excessive
> The number frames dropped in the transmit MAC because the frame experienced 16 consecutive collisions. This counter is applicable in half-duplex only.

_____

Out queue 0 ... 7
> The number of frames that egress this port from Queue 0 ... 7. It does not matter if these frames had a good CRC or not.

Out cut through
> The number of frames that egress this port from the Cut Through path. It does not matter if these frames had a good CRC or not nor what the frame's size was.

Out octets A, B

The sum of lengths of all Ethernet frames sent from the AVB Class A (or B) Queue not including frames that are considered Out octets A, B Management by Ingress. The purpose of this counter is to measure the actual used rate of the shaper for stream data. The actual data rate from any queue, AVB or not, can be measured with this counter, however.

Out yellow

The number of Yellow frames that egressed this port (i.e., the number of Yellow frames that successfully made it through the queue controller).

Out dropped yellow

The number of Yellow frames not counted in "In discards" that are 'head dropped' from an egress port's queues and the number Out dropped yellow of Yellow frame's 'tail dropped' from an egress port's queues due to Queue Controller's queue limits.

Frame size histogram counters

Size 64 octets

Total frames received (and/or transmitted) with a length of exactly 64 octets, including those with errors.

Size 65-127 octets

Total frames received (and/or transmitted) with a length of between 65 and 127 octets inclusive, including those with errors.

Size 128-255 octets

Total frames received (and/or transmitted) with a length of between 128 and 255 octets inclusive, including those with errors.

Size 256-511 octets

Total frames received (and/or transmitted) with a length of between 256 and 511 octets inclusive, including those with errors.

Size 512-1023 octets

Total frames received (and/or transmitted) with a length of between 512 and 1023 octets inclusive, including those with errors.

Size 1024-max octets

Total frames received (and/or transmitted) with a length of between 1024 and MaxSize (see MTU parameter) octets inclusive, including those with errors.

_____

Histogram counters mode

Frame size histogram counters can count received and/or transmitted octets. The mode of histogram counters is indicated here.

Measure time

This is the time interval, the diff column is valid for. The "diff" column shows the difference of the actual value of the counters at the moment of pressing the Difference button and the value of the counters at the moment of pressing the Refresh button.

Refresh, Difference

In another way: The Difference counter reference value can be reset by pressing the Refresh button. The time point at which the Difference counter sample is triggered and the "diff" value is calculated is defined by pressing the Difference button. The "total" column always shows the actual values. It is refreshed either by pressing the Refresh and also the Difference button.

5.5.2. Interface

5.5.2.1. Port setup

Configuration of port settings
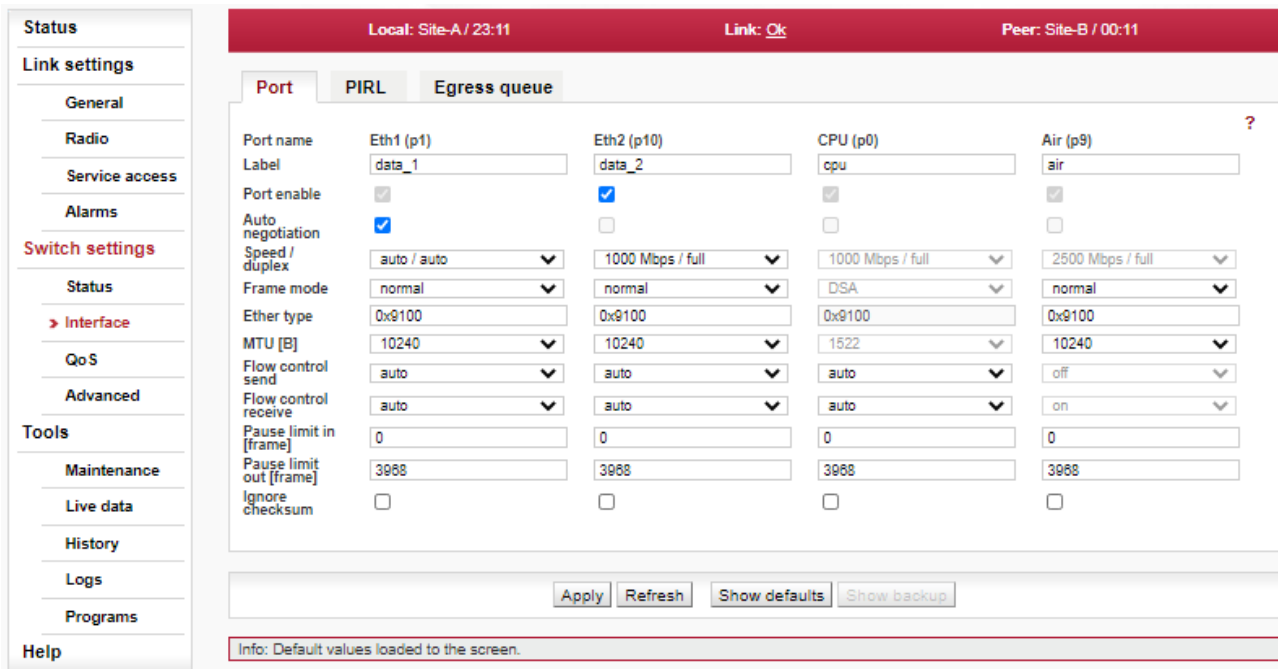
Fig. 5.22: Menu Switch settings > Interface > Port

Port name

Identification of the internal switch port. The switch ports are connected to an external port or to an internal device (radio modem, management CPU).
- Eth1 (port1) — The external port (with RJ45 interface) labeled "ETH1+POE".
- Eth2 (port10) — The external port (with SFP interface) labeled "ETH2".
- CPU (port0) — The internal port to management CPU.
- Air (port9) — The internal port to radio modem, i.e. link to the peer unit.

Label

Name of each port on the switch (up to 15 characters).

Port enable

Enables functionality of individual port on the switch. Each port can be enabled or disabled.

> ⊗ **Warning**
> When the port is disabled, no communication is possible through this port.

Auto negotiation

Enables Auto-Negotiation functionality of individual port. Negotiation is an Ethernet procedure by which two connected devices choose common transmission parameters, such as speed, duplex mode and flow control. In this process, the connected devices first share their capabilities regarding these parameters and then choose the highest performance transmission mode they both support. The device supports three types of Auto-Negotiation:

- 10/100/1000BASE-T Copper Auto-Negotiation. (IEEE 802.3 Clauses 28 and 40)
- 1000BASE-X Fibre Auto-Negotiation (IEEE 802.3 Clause 37)
- SGMII Auto-Negotiation (Cisco specification)

Auto-Negotiation provides a mechanism for transferring information from the local unit to the link partner to establish speed, duplex and Master/Slave preference during a link session.

Auto-Negotiation is initiated upon any of the following conditions:

- Power up reset
- Hardware reset
- Software reset
- Restart Auto-Negotiation
- Transition from power down to power up
- The link goes down

The **10/100/1000BASE-T Auto-Negotiation** is based on Clause 28 and 40 of the IEEE 802.3 specification. It is used to negotiate speed, duplex and flow control over CAT5 (or higher) UTP cable. Once Auto-Negotiation is initiated, the device determines whether or not the remote device has Auto-Negotiation capability. If so, the device and the remote device negotiate the speed and duplex with which to operate.

If the remote device does not have Auto-Negotiation capability, the device uses parallel detect function to determine the speed of the remote device for 100BASE-TX and 10BASE-T modes. If a link is established based on the parallel detect function, it is then required to establish the link at half-duplex mode only. Refer to IEEE 802.3 clauses 28 and 40 for a full description of Auto-Negotiation.

1000BASE-X Auto-Negotiation is defined in Clause 37 of the IEEE 802.3 specification. It is used to auto-negotiate duplex and flow control over fibre cable.

If one side of the link enables 1000BASE-X Auto-Negotiation and the link partner does not, the link cannot linkup. The device implements an Auto-Negotiation bypass mode.

SGMII Auto-Negotiation. SGMII is a de-facto standard designed by Cisco. SGMII uses 1000BASE-X coding to send data as well as Auto-Negotiation information. However, the contents of the SGMII Auto-Negotiation are different than the 1000BASE-X Auto-Negotiation.

> ⊗ **Warning**
> If one device provides Auto-negotiation and the other works with a manual link parameters setting (i.e. without Auto-negotiation) the link operates in half-duplex mode. If the manual setting is set to full-duplex, the "Out collisions" may occur.

Speed / duplex

Ethernet link speed and duplex mode can be selected. Both parameters can be either auto negotiated or set manually. When the Auto negotiation parameter is disabled, only manual setting of the speed and duplex is possible. In most cases it is better to enable the auto negotiation and use "auto / auto" speed and duplex settings.

There are two possibilities to force the link to operate in specific speed and duplex:

- Auto negotiation enabled. Select the desired Speed / duplex. The auto negotiation process advertises only this specified link mode. The link partner is asked to use it.
- Auto negotiation disabled. Select the desired Speed / duplex. The link is set to this specified link mode. The link partner has to be set manually to the same mode.

Frame mode

Ethernet Frame mode control defines the expected Ingress and the generated Egress tagging frame format for this port as follows:

- normal
  Normal Network mode uses industry standard IEEE 802.ac Tagged or Untagged frames. Tagged frames use an Ether Type of 0x8100. Ports that are expected to be connected to standard Ethernet devices should use this mode

- DSA
  Inactive options are not required.

- provider
  Provider mode uses user definable Ether Types per port (see Ether type parameter) to define that a frame is Provider Tagged. Ports that are connected to standard Provider network devices, or devices that use Tagged frames with an Ether Type other than 0x8100 should use this mode. Frames, that ingress this port with an Ether Type that matches the port's "Ether Type" parameter will be considered tagged, will have the tag's VID and PRI bits assigned to the frame (i.e. they will be used for switching and mapping), and will have the Provider Tag removed from the frame. If subsequent Provider Tags are found following the 1st Provider Tag, they too will be removed from the frame with their VID and PRI bits being ignored. Modified frames will be padded if required.
  Frames, that ingress this port with an Ether Type that does not match the "Ether Type" parameter will be considered untagged. The ingressing frames are modified so they are ready to egress out Customer ports (Normal Network Frame Mode ports) unmodified.
  Frames that egress this port will always have a tag added (even if they were already tagged). The added tag will contain this port's "Ether Type" as its Ether Type. The PRI bits will be the Frame Priority assigned to the frame during ingress. The VID bits will be the source port's Default VID bits (if the source port was in Normal Network mode), or the VID assigned to the frame during ingress (if the source port was in Provider mode).

- ether type DSA
  Valid only for the "p5 CPU" port.
  Ether Type DSA mode uses standard Marvell DSA Tagged frame information following a user definable Ether Type (see Ether type parameter). This mode allows the mixture of Normal Network frames with DSA Tagged frames and is useful on ports that connect to a CPU.
  Frames that ingress this port with an Ether Type that matches the port's "Ether Type" will be considered DSA Tagged and processed accordingly. The frame's Ether Type and DSA pad bytes will be removed so the resulting frame will be ready to egress out Marvell DSA Tag Mode ports unmodified. Frames that ingress this port with a different Ether Type will be considered Normal Network Frames and processed accordingly.
  Marvell DSA Tag control frames that egress this port will always get the port's "Ether Type" inserted followed by two pad bytes of 0x00 before the DSA Tag. Marvell DSA Tag Forward frames that egress this port can egress just like the control frames (with the added Ether Type and pad) or they can egress as if the port was configured in Normal Network mode. This selection is controlled by the port's Egress Mode bits above.

Ether type

Ethernet frame type (often called EtherType) is used to indicate which protocol is encapsulated in the payload of an Ethernet Frame. This parameter is important when one protocol is encapsulated to another protocol.
Examples:

Ether type	Standard	Comment
0x8100	IEEE 802.1q	Double-tagged, Q-in-Q or C-tag stacking on C-tag. C-tag in IEEE 802.1ad frames.

0x88a8	IEEE 802.1ad	S-Tag
0x88e7	IEEE 802.1ah	S-Tag (backbone S-Tag)
0x9100	--	It is used very often. For example an old non-standard 802.1QinQ protocol uses this value.

See *http://en.wikipedia.org/wiki/EtherType* for further details.

MTU [B]

Defines maximum transmission unit (MTU) frame size allowed to be received or transmitted from or to a given physical port. This implies that a Jumbo frame may be allowed to be received from a given input port but may or may not be allowed to be transmitted out of a port or ports.
The possible values are 1522, 2048 and 10240 Bytes.

> **(i) Note**
> The definition of frame size is counting the frame bytes from MAC_DA through Layer2 CRC of the frame.

Flow control send/receive (previously TX/RX)

It is the mechanism for temporarily stopping the transmission of data on an Ethernet network, so that the receiving node is not overwhelmed with data from transmitting node. It works according IEEE 802.3x standard. If allowed, speed of data receive in to the switch (from the connected device) is regulated by the switch sending out flow control pause frames (according parameter 'Pause limit out') to the connected device. If allowed, speed of data transmission out from the switch (to the connected device) is regulated by processing received in flow control pause frames (according parameter 'Pause limit in') sent by the connected device.
Enabling flow control allows use of buffers of connected active network elements for leveling uneven flow of user data. For correct operation it is necessary to also enable Flow control on the connected device. Flow control is handled by sending Pause frames to the connected device. Possible values:

• off — Flow control is disabled.
• on — Flow control is enabled (forced to be active).
• auto — Sending pause packets is advertised and depends on result on the auto-negotiation process. Auto-Negotiation has to be supported and enabled on the port to take effect.

> **⚠ Important**
> For optimal utilization of Ethernet switch buffers and maximal operational speed of the link it is recommended to upgrade unit to the latest FW version and apply its defaults to ensure optimal buffers cooperation. Optimal performance may require playing a bit with Pause limit parameters to optimize the communication with the switch or router connected to the MW unit.

> **(i) Note**
> Additional link performance and better utilization of all available buffers in transmitting network could be typically achieved by configuring Flow Control between the MW unit and the nearest switches feeding the link by data. Important for incoming data are parameters 'Flow Control send' on ports 'Eth1(p1)' and/or 'Eth2(p10)', which needs to be set to values 'auto' or 'on' (the value to use depends on the switch).
> FW versions 1.0.16.0 and earlier require RX Flow Control for port 'Air (p9)' on both units to be set to 'on'. The only exception is FW version 1.0.14.0 with activated 'Unit 24S compatibility' (for more info see 'Setting up a link between RAy3-24S and other hardware variant of RAy3-24' in Chapter 8, Troubleshooting).

Pause limit in [frame]

Value limits the number of continuous Pause refresh frames that can be received on this port (if full-duplex) or the number of 16 consecutive collisions (if half-duplex). Pause limit in [frame] When a port has flow control enabled, this parameter can be used to limit how long this port can be Paused or Back Pressured off to prevent a port stall through jamming.
The Flow Control on the port is (temporarily) disabled when the Pause refresh frames count exceeds the value of this parameter.
Setting this parameter to 0 will allow continuous jamming to be received on this port.

Pause limit out [frame]

Value limits the number of continuous Pause refresh frames that can be transmitted from this port – assuming each Pause refresh is for the maximum pause time of 65536 slot times. When full-duplex Flow Control is enabled on this port, this parameter is used to limit the number of Pause refresh frames that can be generated from this port to keep this port's link partner from sending any data. Clearing this parameter to 0 will allow continuous Pause frame refreshes to egress this port as long as this port remains congested.
Setting this parameter to 1 will allow 1 Pause frame to egress from this port for each congestion situation.
Setting this parameter to 2 will allow up to 2 Pause frames to egress from this port for each congestion situation, etc.

Ignore checksum

Enables ignoring Frame checksum (FCS) - or in other words - Force good FCS in the frame. When this parameter is not set (default behavior), frames entering this port must have a good CRC or else they are discarded. When this parameter is set, the last four bytes of frames received on this port are overwritten with a good CRC and the frames are accepted by the switch (assuming that the frame's length is good and it has a destination).

5.5.2.2. PIRL

Page allows to configure PIRL - **Port-based Ingress Rate Limiter**.

It is a useful feature to limit bursts and storms of packets according different services, priorities and other network parameters to optimize the usage of limited capacity of wireless link.

Status							
Link settings	Local: Site-A / 08:49		Link: Ok		Peer: Site-B / 08:49		
General	**Port**	**PIRL**	**Egress queue**				
Radio	**Port Ingress Rate Limiter**						?
Service access	Port name	Id	Rate	Size [kB]	Mode	Edit	Delete
Alarms	Eth1 (p1) data_1	0	10.0 Mbps	3.2	type: pt_multicast_broadcast	Edit	Delete
Switch settings	Eth2 (p10) data_2	0	10.0 Mbps	3.2	type: pt_multicast_broadcast	Edit	Delete
Status							
➤ Interface				Add resource Refresh			

Fig. 5.23: Menu Switch settings > Interface > PIRL

The device supports per port TCP/IP ingress rate limiting along with independent Storm prevention. Port based ingress rate limiting accommodates information rates from 64 kb/s to 1 Mb/s in increments of 64 kb/s, from 1 Mb/s to 100 Mb/s in increments of 1 Mb/s and from 100 Mb/s to 1000 Mb/s in increments of 10 Mb/s.

In addition to this, the device supports Priority based ingress rate limiting. Given ingress rate resource can be configured to track any of the four priority traffic types. The device supports a color- blind leaky bucket scheme, one of the popular schemes for implementing rate limiting. The way a leaky bucket scheme works is that the bucket drains tokens constantly at a rate called Committed Information Rate (CIR) and the bucket gets replenished with tokens whenever a frame is allowed to go through the bucket. All calculations for this bucket are done in tokens. Therefore, both bucket decrementing and incrementing is performed using tokens (i.e. frame bytes are converted into bucket tokens for calculation purposes).

The traffic below Committed Burst Size limit (CBS Limit) is passed without any further actions. If the traffic burst were to continue and the bucket token depth approaches closer to the Excess Burst Size limit (EBS Limit) by less than the CBS Limit, then a set of actions are specified. Note that if the frame gets discarded then the equivalent number of tokens for that frame will not get added to the bucket.

Passed frame size
based token update

EBS Limit

Possible actions:
- Discard the frame
- Pass the frame and
send flow control frame
back to source

All buckets calculations
done in units of tokens

CBS Limit

- Pass the traffic

EBS: Excess Burst Size
CBS: Commited Burst Size
CIR: Commited Information Rate

CIR
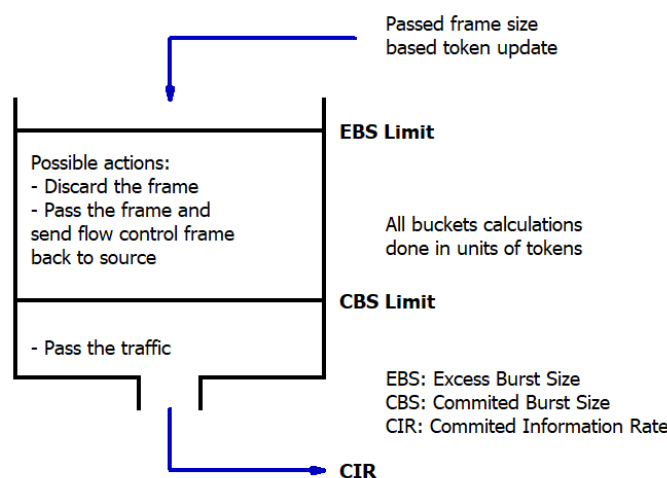
Fig. 5.24: PIRL EBS and CBS limits

There are two default ingress limiting rules already configured in the switch default configuration. They limit the maximum allowed ARP traffic coming to the CPU port to 10 Mb/s from Eth1 and 10 Mb/s from Eth2 ports.

Port name
    Identification of the internal switch port. The switch ports are connected to an external port or to an internal device (radio modem, management CPU).
    • Eth1 (port1) — The external port (with RJ45 interface) labeled "ETH1+POE".
    • Eth2 (port10) — The external port (with SFP interface) labeled "ETH2".
    • CPU (port0) — The internal port to management CPU.
    • Air (port9) — The internal port to radio modem, i.e. link to the peer unit.

ID
    Unique ID of ingress rate resource. Each port can be assigned up to five different ingress rate resources.
    Each resource defines a rule (filter) for the incoming frame. If the rule is met, the frame is affected (as set by the *EBS limit action* parameter). If the incoming frame doesn't meet any rule, it is not affected by PIRL. The frame is accepted and forwarded further to the switch engine.

Rate [Mb/s or fps]
    The Bucket Rate. It is dependent on the *Bucket Rate factor* and the *Bucket increment*.

The calculation is estimated as the real data throughput depends on frame size. The *Accounted bytes* parameter affects this as well.

The formula for the *rate* (in bits or frames per second) is as follows:

rate = α * *BRF* / *BI*.

Where α is constant, which is 62 500 000 for Accounted bytes="frame", and is 500 000 000 for Accounted bytes="layer1". *BRF* is Bucket Rate factor and *BI* is Bucket increment.

Size [kB]

The Burst allocation buffer size depends on the *Bucket increment*, the *Committed Burst Size limit* or the *Excess Burst Size limit*.

The formula for the *BA* is as follows:

BA = *xBS* / *BI*.

Where *xBS* can be either the Committed Burst Size limit *CBS* for the green bucket size or the Excess Burst Size limit *EBS* for the yellow bucket size and *BI* is the Bucket increment.

In order for the rate limiting to be accurate, it is required that bucket size is larger than max. frame size (MTU).

The Burst allocation size should be less than switch internal memory which is 250 kB.

Mode

Rate type or Traffic type of rate limiting. See *Bucket type* parameter.

Edit

The button opens for selected PIRL resource a new window, where all its parameters can be edited (for details see 'PIRL resource configuration').

Delete

The button deletes selected PIRL resource.

Add resource

The button creates a new PIRL resource and opens a new window, where all its parameters can be configured (for details see 'PIRL resource configuration').

PIRL resource configuration

This window opens after pushing button 'Edit resource' or 'Add resource' on page 'PIRL' (for details see above).

Each port can be assigned up to five different ingress rate resources.

Each resource defines a rule (filter) for the incoming frame. If the rule is met, the frame is affected (as set by the *EBS limit action* parameter). If the incoming frame doesn't meet any rule, it is not affected by PIRL. The frame is accepted and forwarded further to the switch engine.

Fig. 5.25: Menu Switch settings > Interface > PIRL > Add resource (or Edit resource)

Resource

Unique identification of added/edited resource. The 🔑 icon indicates which parameter fields are taken as the unique identifier in the database. Those 2 fields ensure each record is unique and must not be duplicated.

Port name, ID
Both parameters are described above (in section 'PIRL Setup').

Settings

All parameters of added/edited PIRL resource which can be configured.

Rate, Size [Mb/s or fps]
Both parameters are described above (in section 'PIRL Setup').

Advanced
(small active text on the right, just below line 'Size')Allows 'Advanced configuration' - more parameters appear.

Accounted bytes
(appears only if 'Advanced configuration' is activated)This parameter determines which frame bytes are to be accounted for in the rate resource's rate limiting calculations. There are four different supported configurations:
• Frame — Frame based configures the rate limiting resource to account for the number of frames from a given port mapped to this rate resource.
• layer 1 — Preamble (8bytes) + Frame's DA to CRC + IFG (inter frame gap, 12 bytes)
• layer 2 — Frame's DA to CRC
• layer 3 — Frame's DA to CRC - 18 - 4 (if the frame is tagged)
A frame is considered tagged if it is either Customer of Provider tagged during ingress.

Bucket increment
(appears only if 'Advanced configuration' is activated)Bucket increment (BI) indicates the amount of tokens that need to be added for each byte of the incoming frame.

Rate factor
(appears only if 'Advanced configuration' is activated)This is a bucket factor (green or yellow) which determines the amount of tokens that need to be decremented for each rate resource decrement (which is done periodically based on the *Committed Information Rate*).

Limit CBS/EBS
(appears only if 'Advanced configuration' is activated)Excess Burst Size limit - used for the yellow bucket. Committed Burst Size limit - used for the green bucket.

Color mode
(appears only if 'Advanced configuration' is activated)Indication of the current color mode. Possible values: Single rate two color, Single rate three color, Dual rate three color.

Account green overflow
false = Green and Yellow buckets are isolated when in Color Aware modetrue = Green and Yellow buckets are connected when in Color Aware mode

Account discarded frames
This parameter decides whether the ingress rate limiting logic accounts for frames that have been discarded by the queue controller due to output port queue congestion reasons. To account for all frames coming into a given port associated with this rate resource, this parameter needs to be set.

Account filtered frames
This parameter decides whether the ingress rate limiting logic accounts for frames that have been discarded because of ingress policy violations. To account for all frames coming into a given port associated with this rate resource, this parameter needs to be set.

Color aware
false = color blind mode
true = color aware mode

EBS limit action
This parameter controls what kind of action is performed when the *EBS limit* has been exceeded. Two types of action can be selected:
• drop — The frame that was received on the port will get discarded.

- flow control — The frame that was received on the port will get discarded.
  In this mode an Ethernet flow control frame gets generated (if the flow control is enabled for that port) and sent to the source port but the incoming frame gets passed through the rate resource. If the port is operating in half-duplex mode then the port gets jammed.

Flow control mode is expected to be programmed on ports that have a trusted flow control mechanism available. The *EBS limit action* is a per-port characteristic. If a port has multiple rate resource buckets then all buckets enabled are expected to be programmed with the same *EBS limit action*.

Flow control de-assertion

This parameter controls the flow control de-assertion when *EBS limit action* is set to generate a flow control message. There are two modes available:

- empty — Flow control gets de-asserted only when the ingress rate resource has become empty.
- CBS limit — Flow control gets de-asserted when the ingress rate resource has enough room to accept at least one frame of size specified by the CBS limit.
  For example, if the CBS limit is programmed to be 2k Bytes, then the flow control will get de-asserted if there is at least 2k Bytes worth of tokens available in the ingress rate resource.

Mask operation

This parameter controls whether an ingress frame must meet both *Priority* and *Frame type* requirements to be counted for ingress rate calculations or if meeting only one requirement is sufficient to be counted for ingress rate calculations for this rate resource.

Priority type

frame - use FPri assigned to the frame
queue - use QPri assigned to the frame

Priority

Any combinations of the eight queue priorities can be selected. Frames with marked priority are accounted for in this ingress rate resource.

If there is no priority selected, priority of the frame does not have any affect on the ingress rate limiting calculations done for this ingress rate resource.

Frame type

Any of the following frame types can be selected to be tracked as part of the rate resource calculations:

Unknown unicasts, Unknown multicasts, Unknown broadcast, Multicasts/Broadcasts, Unicasts, Network management, ARP (Address Resolution Protocol), TCP data, TCP control, UDP, group IGMP, ICMP, GRE, IGRP and L2TP covers Non-TCPUDP, Ingress monitor source, Policy mirror, Policy trap.

More than one frame type can be selected for a given rate resource.

5.5.2.3. Egress queues setup

The Egress queue page allows to set parameters for eight output (egress) queues available in internal Ethernet switch of the unit.

Each queue is used to store frames with given priority (as set in 802.1p and DSCP configuration). The queue depth is controlled dynamically to reach maximum utilization of the switch memory. The queue frame egress is controlled by scheduling algorithms as described further below.
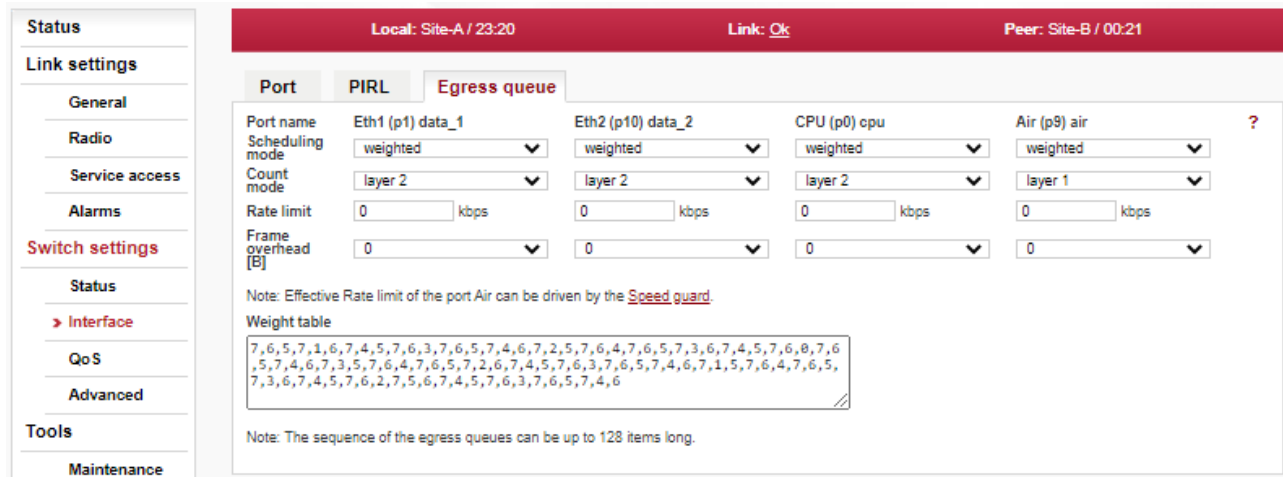
Fig. 5.26: Menu Switch settings > Interface > Egress queue

Port name
> Identification of the internal switch port. The switch ports are connected to an external port or to an internal device (radio modem, management CPU).
> * Eth1 (port1) — The external port (with RJ45 interface) labeled "ETH1+POE".
> * Eth2 (port10) — The external port (with SFP interface) labeled "ETH2".
> * CPU (port0) — The internal port to management CPU.
> * Air (port9) — The internal port to radio modem, i.e. link to the peer unit.

Scheduling mode
> The device supports strict priority, weighted round robin, or a mixture on a per egress port selection basis.
> In the strict priority scheme all top priority frames egress for a port until that priority's queue is empty, then the next lower priority queue's frames egress, etc. This approach can cause the lower priorities to be starved out preventing them from transmitting any frames but also ensures that all high priority frames egress the switch as soon as possible.
> In the weighted scheme an 33, 25, 17, 12, 6, 3, 2, 1 weighting is applied to the eight priorities unless an alternate weighting is programmed into the QoS Weights Table. This approach prevents the lower priority frames from being starved out with only a slight delay to the higher priority frames.
> Some applications may require the top priority queue, or the top 'n' priority queues to be in a fixed priority mode while the lower queues work in the weighted approach. All scheduling modes are selectable on a per port basis.
> The port scheduling mode can be one of the following values:

weighted
> Use weighted round robin for all queues.

weighted 0 - 6
> Use strict priority for queue 7 and weighted round robin for queues 6 to 0

weighted 0 - 5
>   Use strict priority for queues 7 and 6, and weighted round robin for queues 5 to 0

weighted 0 - 4
>   Use strict priority for queues 7 to 5, and weighted round robin for queues 4 to 0

weighted 0 - 3
>   Use strict priority for queues 7 to 4, and weighted round robin for queues 3 to 0

weighted 0 - 2
>   Use strict priority for queues 7 to 3, and weighted round robin for queues 2 to 0

weighted 0 - 1
>   Use strict priority for queues 7 to 2, and weighted round robin for queues 1 to 0

strict
>   Use strict priority for all queues.

Count mode
>   Egress rate limiting count mode. This parameter is used to control which bytes in the transmitted frames are counted for egress rate limiting as follows:
>   - frame — The egress rate limiting is done based on frame count [fps] as opposed to the byte count [kb/s] of the packet.
>   - layer 1 — Preamble (8bytes) + Frame's DA to CRC + IFG (inter frame gap, 12 bytes)
>   - layer 2 — Frame's DA to CRC
>   - layer 3 — Frame's DA to CRC - 18 - 4 (if the frame is tagged)
>
>   Only one tag is counted even if the frame contains more than one tag. A frame is considered tagged if the egress frame going out onto the wire is tagged.

Rate limit
>   Egress data rate shaping. When Rate = 0 egress rate limiting is **disabled**.

>   (i) **Note**
>   The **Count mode** parameter is used to control which bytes in the transmitted frames are counted for egress rate limiting.

If the egress shaping is controlled by **frame rate**, the desired frame rate can vary from 7.6k to 1.488M frames per second. Valid values are between 7632 and 1488000.

If the egress shaping is controlled by **bit rate**, the desired rate can vary from 64 kb/s to 1 Gb/s in the following increments:
- Desired rate between 64 kb/s and 1 Mb/s in increments of 64 kb/s
- Desired rate between 1 Mb/s to 100 Mb/s in increments of 1 Mb/s
- Desired rate between 100 Mb/s to 1 Gb/s in increments of 10 Mb/s
- Desired rate between 1 Gb/s to 10 Gb/s in increments of 100 Mb/s

Therefore, the valid values are:
- 64, 128, 192, 256, 320, 384,..., 960,
- 1000, 2000, 3000, 4000, ..., 100000,
- 110000, 120000, 130000, ..., 1000000,
- 1100000, 1200000, 1300000, ..., 10000000.

>   (i) **Note**
>   The activated "Speed guard" function overwrites the current Rate limit setting.

Frame overhead [B]

This parameter is used to adjust the number of bytes that need to be added to a frame's IFG (inter frame gap) on a per frame basis. This is to compensate for a protocol mismatch between the sending and the receiving stations. For example, if the receiving station were to add more encapsulations to the frame for the nodes further downstream, this per frame adjustment would help reduce the congestion in the receiving station.

This adjustment, if enabled, is added to the Egress Rate Control's calculated transmitted byte count meaning Egress Rate Control must be enabled for this Frame Overhead adjustment to work.

Weight table

The weighted round robin alternate weighting can be defined here. The sequence of the output queue numbers (0,1,2 to 7) defines the sequence of the output queue frame egressing. This sequence can be up to 128 items long.

5.5.3. QoS

Quality of Service (QoS) is the ability to provide different priorities to different applications, users, or data flows, or to guarantee a certain level of performance to a data flow. QoS using 802.1p and DSCP are implemented.

The ingress block has the task of determining the priority of each frame to be used for the internal Queue Controller (QPri) as well as the priority assigned to the frame (FPri) if the frame egresses the switch tagged. The classification as to if the frame is discard eligible (Yellow) is also determined. The Ingress block does not perform the QoS switching policy, which is the task of the Queue Controller. Instead, it has the job of determining the QPri and FPri assigned to each frame for the Queue Controller and Egress block.

5.5.3.1. Port

Port based QoS parameters makes it possible to control QoS based on the ingress port.

Every frame entering the switch gets two priority values assigned to it. One priority value is used inside the switch only to determine which output queue the frame is to be mapped into. This is called QPri for queue priority. The other priority value is used outside the switch only to mark the frame's IEEE PCP bits if the frame egresses a port tagged. This is called FPri for frame priority. A third parameter, called Yellow, is also assigned to the frame. If Yellow=1 the frame is considered eligible for discard if congestion warrants it.

The initial QPri, FPri and Yellow values are assigned differently to various frame types. Some frames are assigned more than one set of QPri, FPri and Yellow values. For example, an IEEE tagged IPv4 frame will get a set of values from the IEEE tag, another set from the IPv4 header and another set from the port. Some applications require that the port's default priority be used regardless of the contents of the frame. The Initial priority parameter selects this default priority.

Fig. 5.27: Menu Switch settings > QoS > Port

Update DSCP
   If the parameter is enabled, the DSCP field in frames that egress this port is updated.

Default frame priority
   All ingressing frames are assigned a default FPri (frame priority) and QPri (queue priority). The default value for Yellow is zero (i.e. the frame is not discarded eligible).

Default queue priority
   All ingressing frames are assigned a default FPri (frame priority) and QPri (queue priority).

5.5.3.2. 802.1p ingress

The IEEE 802.1p QoS technique also known as class of service (CoS), is using a 3-bit field called the Priority Code Point (PCP) within an Ethernet frame header when using VLAN tagged frames as defined by IEEE 802.1Q. It specifies a priority value of between 0 and 7 inclusive that can be used by QoS disciplines to differentiate traffic. The value 0 is generally taken as the lowest priority and 7 as the highest priority.
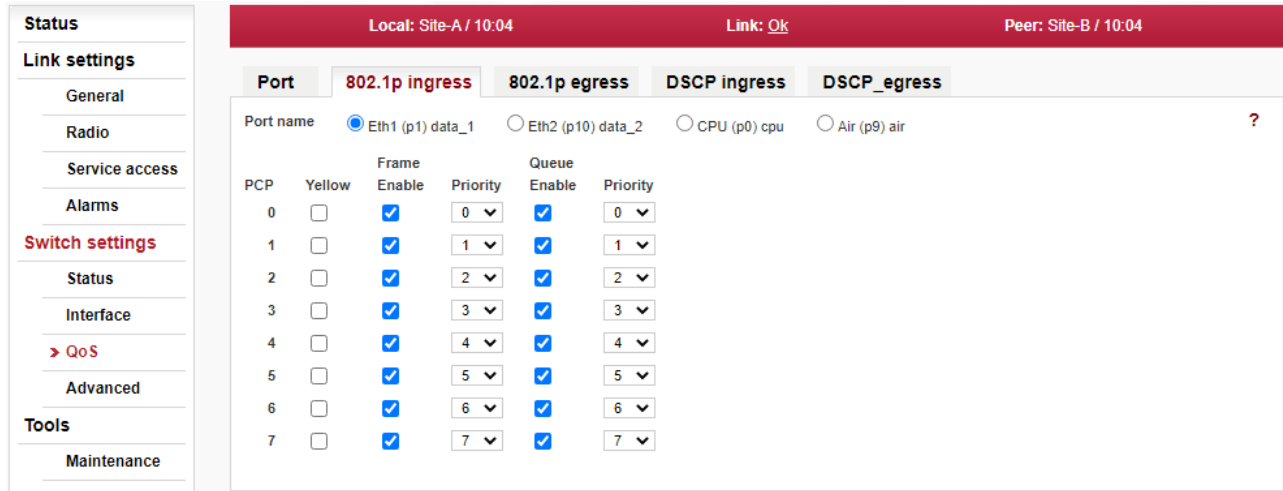
Fig. 5.28: Menu Switch settings > QoS > 802.1p ingress

Priority code point (PCP)
    Priority Code Point (PCP) value to which the following parameters (Yellow, Frame Enable, Frame Priority, Queue Enable and Queue Priority) belong to.

802.1p yellow
    When this parameter is enabled any IEEE tagged frame (having given PCP priority) that accesses this port will be given an initial IEEE color of Yellow. This color will be assigned to the frame using the same rules used to select the frame's initial FPri and QPri values.

Enable 802.1p frame priority
    When the Frame Enable parameter is checked, the Frame Priority (FPri) mapping is enabled.

802.1p frame priority
    The Frame Priority value is taken as the frame's initial IEEE FPri in case the Frame Enable is checked.

Enable 802.1p queue priority
    When the Queue Enable parameter is checked, the Queue Priority (QPri) mapping is enabled.

802.1p queue priority
    The Queue Priority value is taken as the frame's initial IEEE QPri in case the Queue Enable is checked.

5.5.3.3. 802.1p egress

Fig. 5.29: Menu Switch settings > QoS > 802.1p egress

Frame priority for 802.1p mapping

Frame priority value to which the following Green and Yellow parameters (VID marking, PCP marking and PCP) belong to.

VID marking

Enable/disable VID marking for the given Frame priority. When the parameter is disabled frames assigned with this FPri in ingress will not get their VID field updated even if the frame egresses Tagged (normally all egressing Tagged frames get their VID updated to the value assigned in ingress).

PCP marking

Enable/disable PCP marking for the given Frame priority. When the parameter is disabled frames assigned with this FPri in ingress will not get their PCP & CFI fields updated even if the frame egresses Tagged (normally all egressing Tagged frames get their FPri & CFI bits updated to the value assigned in ingress).

802.1p frame PCP

Frame Priority Code Point. This parameter contains the new PCP or FPri value that is assigned to frames that egress this port. The FPri assigned to the frame in ingress is used to access this table.

5.5.3.4. DSCP ingress

The DSCP stands for Differentiated services Code Point which is a 6-bit value stored within the IP header. The QoS techniques using those bits are called DiffServ or Differentiated services.
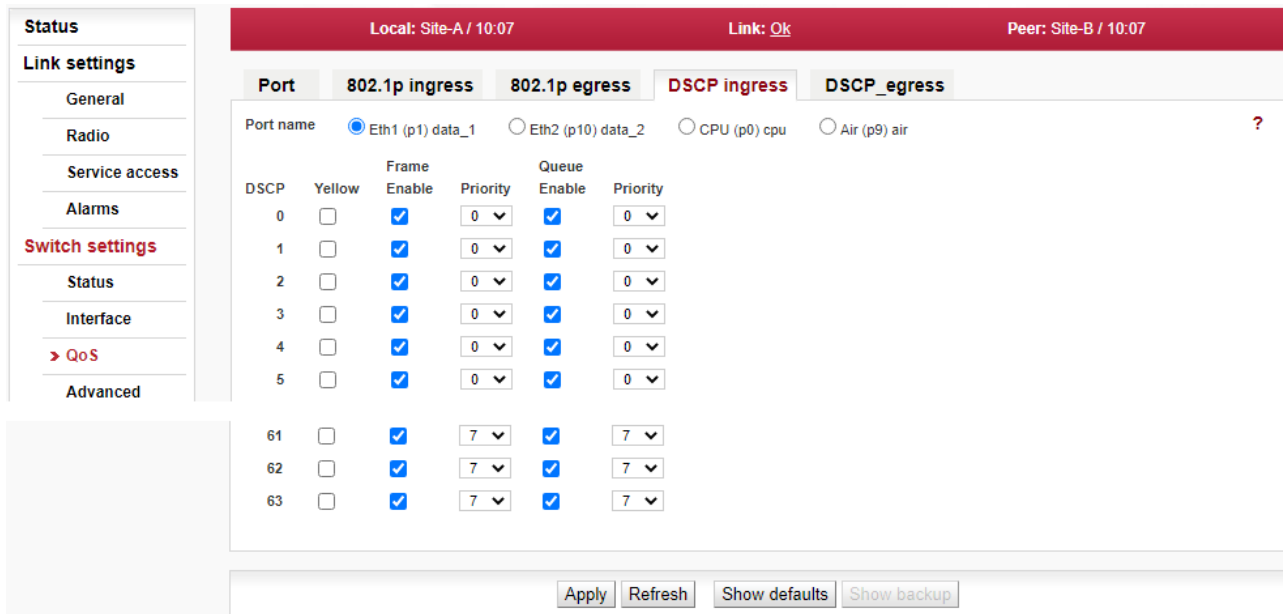
Fig. 5.30: Menu Switch settings > QoS > DSCP ingress

DSCP
> DSCP value to which the following parameters (Yellow, Frame Enable, Frame Priority, Queue Enable and Queue Priority) belong to.

DSCP Yellow
> When this parameter is enabled any IP frame that accesses this entry will be given an initial IP color of Yellow. This color will be assigned to the frame using the same rules to select the frame's initial FPri and QPri values.

Enable DSCP frame priority
> When this parameter is enabled, the Frame Priority Mapping will be used.

DSCP frame priority
> The value set in this parameter is used as the frame's initial IP Frame priority as long as Enable is checked.

Enable DSCP queue priority
> When this parameter is enabled, the queue Priority mapping will be used.

DSCP queue priority
> The value set in this parameter is used as the frame's initial IP Queue priority as long as Enable is checked.

5.5.3.5. DSCP egress

Fig. 5.31: Menu Switch settings > QoS > DSCP egress

Port name
    Selects the port on Eth switch for which settings below are shown/updated.

Frame priority
    Frame priority value for DSCP mapping to which the following Green and Yellow parameters (DSCP marking and DSCP) belong to.

DSCP marking
    When this parameter is enabled for some Frame priority, the Frame Priority Mapping will be used, i.e. IP frames assigned with this FPRi in ingress will get their DSCP fields updated.

DSCP
    This parameter defines the new DSCP value that is assigned to frames that egress this port. The FPri assigned to the frame in ingress is used to access this table.

5.5.4. Advanced

5.5.4.1. VLAN setup

The VLAN (Virtual LAN) page allows to set VLAN related and global parameters needed for VLAN functionality of the unit.

⚠️ **Important**

Parameters in VLAN page are tightly related to the settings configured in pages STU and VTU. For a proper functionality all parameters inside pages VLAN, STU and VTU have to correspond to each other.

Fig. 5.32: Menu Switch settings > Advanced > VLAN

Global

Remove one provider tag

When this parameter is enabled and a port is configured as a Provider Port, recursive Provider Tag stripping will NOT be performed. Only the first Provider Tag found on the frame will be extracted and removed. Its extracted data will be used for switching.

When this parameter is disabled and a port is configured as a Provider Port, recursive Provider Tag stripping will be performed. The first Provider Tag's data will be extracted and used for switching, and then all subsequent Provider Tags found in the frame will also be removed. This will only occur if the port's "Ether type" is not 0x8100 (recursive Provider Tag removal cannot be performed when the Provider's Ether Type is equal to 0x8100).

VTU page mode

> The VTU page mode supports alternate VID look up results based on if a frame is a Multicast (including Broadcasts) or not, or based on what source port the frame came in on, or if the frame was properly Provider tagged or not.

Ports settings

Port name

> Identification of the internal switch port. The switch ports are connected to an external port or to an internal device (radio modem, management CPU).
> - Eth1 (port1) — The external port (with RJ45 interface) labeled "ETH1+POE".
> - Eth2 (port10) — The external port (with SFP interface) labeled "ETH2".
> - CPU (port0) — The internal port to management CPU.
> - Air (port9) — The internal port to radio modem, i.e. link to the peer unit.

Egress mode

> This parameter determines the makeup of frames when they egress this port. The Egress mode behavior is affected by the Frame mode (menu Interface/Port advanced/Frame mode) parameter.
> **Frame mode ... normal:**
> - unmodify — Frames are transmitted unmodified.
> - untag — Remove the tag from any tagged frame.
> - tag — Add a tag (e.g. according to "Default VID") to any untagged frame. Ethernet frame type is set to 0x8100.
> **Frame mode ... provider:**
> - unmodify — Use this mode when "Frame mode" is set to "provider".
> - untag — not used
> - tag — not used
> **Frame mode ... ether type DSA:**
> - unmodify — not used
> - untag — not used
> - tag — not used
> - ether type tag — Add a tag (e.g. according to "Default VID") to any untagged frame. Ethernet frame type is set according to "Ether type" parameter (menu Switch settings/Interface/Port advanced).

802.1q mode

> This parameter determines if 802.1q base VLANs are used along with port based VLANs for this Ingress port. It also determines the action to be taken if an 802.1q VLAN Violation is detected. VLAN barriers (both port based and 802.1q based) can be bypassed by VLAN Tunnel.
> - **disabled** — Use Port Based VLANs only. The VID assigned to the frame is the port's Default VID which is used as the VID in the Provider Tag if the frame egresses a Provider port.
> - **fallback** — Enable 802.1q for this Ingress port. Do not discard Ingress Membership violations and use the VLAN Table bits if the frames' VID is not contained in the VTU.
>   The ingressing frames are not discarded and it doesn't matter if the frames' VID is a member of the VTU.
> - **check** — Enable 802.1q for this Ingress port. Do not discard Ingress Membership violation but discard the frame if its VID is not contained in the VTU.
>   The ingressing frames' VID must be configured in the VTU to enable it to ingress. The VTU "Member tag" parameter doesn't have any effect.
> - **secure** — Enable 802.1q for this Ingress port. Discard Ingress Membership violations and discard frames whose VID is not contained in the VTU.

The ingressing frame is checked fully against the record in the VTU table. The "VID" and the "Member tag" parameters are validated to allow the frame to ingress.

Discard tagged

When this parameter is enabled all non-MGMT frames that are processed as tagged are discarded as they enter this switch port. Priority only tagged frames (with a VID of 0x000) are considered untagged. This feature works whether 802.1q is enabled on the port or not.

If the port is configured in Provide Mode and this parameter is enabled, frames that contain an Ether Type that matches the port's PortEType ("Ether type" parameter) that have a non-zero VID will be discarded.

Discard untagged

When this parameter is enabled all non-MGMT frames that are processed as untagged are discarded as they enter this switch port. Priority only tagged frames (with a VID of 0x000) are considered untagged. This feature works if 802.1q is enabled on the port or not.

If the port is configured in Provide Mode and this parameter is enabled, frames that don't contain an Ether Type that matches the port's PortEType ("Ether type" parameter) that have a non-zero VID will be discarded.

VTU priority override

When this parameter is set to anything other than "none", VTU priority overrides can occur on this port. A VTU priority override occurs when the determined VID of a frame results in a VID whose "Use VID priority" parameter is enabled. When this occurs three (other than "none") forms of priority overrides are possible:

* **none** — Normal frame priority processing occurs.
* **frame** — The "VID priority" value assigned to the frame's VID (in the VLAN database) is used to overwrite the frame's previously determined FPri (frame priority). If the frame egresses tagged the priority in the frame will be this new "VID priority" value - the frame is permanently modified.
* **queue** — The "VID priority" value assigned to the frame's VID (in the VLAN database) is used to overwrite the frame's previously determined QPri (queue priority). The QPri is used internally to map the frame to one of the egress queues inside the switch. QPri override will not affect the contents of the frame in any way.
* **frame + queue** — Both the above overrides take place on the frame.

The VTU Priority override has higher priority than the port's Default Priority and the frame's IEEE and/or IP priorities. The priority determined by the frames' VID can however be overridden by the frames' SA and/or DA Priority Overrides.

VTU page

When "VTU page mode" is set to value "port" this setting is used to determine which VTU page is used for frames ingressing this port. This supports different VTU lookup results for the same VID based on the value of this bit and allows Core ports to use one set of VTU values while Edge ports use a different set.

Force default VID

Force to use Default VID. When 802.1q is enabled on this port and this parameter is enabled, all Ingress frame's VID are ignored and the "Default VID" is assigned and replaced into the frame (if the frame egresses tagged). When this parameter is disabled all IEEE802.3ac Tagged frames with a non-zero VID use the frame's VID unmodified. When 802.1q is disabled on this port, this bit has no effect.

VID 0 enable

When this bit is cleared to a zero normal network switching occurs (i.e., a frame received with a VID of 0x000 will get an initial VID assignment from the Port's Default VID from Port offset 0x07).

When this bit is set to a one frames received with a VID of 0x000 will NOT get an initial VID assignment from the port's Default VID – it will get an initial VID assignment value of 0x000 instead.

Default VID

Default VLAN Identifier. When 802.1q is enabled on this port the Default VID parameter is used as the IEEE Tagged VID added to untagged or priority tagged frames during egress that ingressed from this port. It is also used as a tagged frame's VID if the frame's VID was 0x000 (i.e., it is a priority tagged frame) or if the port's "Force Default VID" is enabled.

When 802.1q is disabled on this port, the Default VID field is assigned to all frames entering the port (whether tagged or untagged). This assignment is used internal to the switch.

FID

Port's Default Filtering Information Database (FID). This parameter can be used with non-overlapping VLANs to keep each VLAN's MAC address mapping database separate from the other VLANs. This allows the same MAC address to appear multiple times in the address database (at most one-time per VLAN) with a different port mapping per entry. This field is overridden by the FID returned from a VTU hit and it should be zero if not used. It must be a unique number for each independent, non-overlapping, address database if used.

VLAN tunnel

When this parameter is disabled, the port based VLANs defined in the VLAN Table, 802.1q VLANs defined in the VTU and Trunk Masking are enforced for ALL frames.

When this parameter is enabled, the port based VLAN Table masking, 802.1q VLAN membership masking and the Trunk Masking are bypassed for any frame entering this port with a DA that is currently 'static' in the ATU. This applies to unicast as well as multicast frames.

While enabled, the Unicast frames with the management CPU DA can go from the Eth1 and Eth2 ports in to the CPU port. The static record with the CPU DA in the ATU table has to be configured (it is pre-configured by default).

Member (VLAN Table)

The In Chip Port based VLAN Table contains parameters used to restrict the output ports to which an input port can send frames. These parameters (VLAN Table bits) are used for all frames, except for MGMT frames, even if 802.1q is enabled on this port. These parameters restrict where a port can send frames to (unless a VLANTunnel frame is being received). If ForceMap (Learning) is enabled, these parameters indicate which port or ports all frames that ingress this port are sent to overriding the mapping from the address database. The default setting prevents sending frames from Eth1 to Eth2 and vice versa. This is very important for separating different networks (e.g. different customers) connected to separate user ports.

> **Note**
>
> The parameter Link authorization guard (from menu *Link Settings > Service access > Services*) affects the user data flow through the Air channel. When the Link authorization guard is enabled, the user Ethernet ports to Air port connection control is disabled. Parameter status of user Ethernet to Air port connection changes dynamically according to Link authorization status.

5.5.4.2. STU setup

The STU (Spanning Tree Unit) is related to VLAN functionality (pages STU, VTU and VLAN has to correspond to each other). The per VLAN STU in the device supports user commands to access and modify the contents of the Port State database.
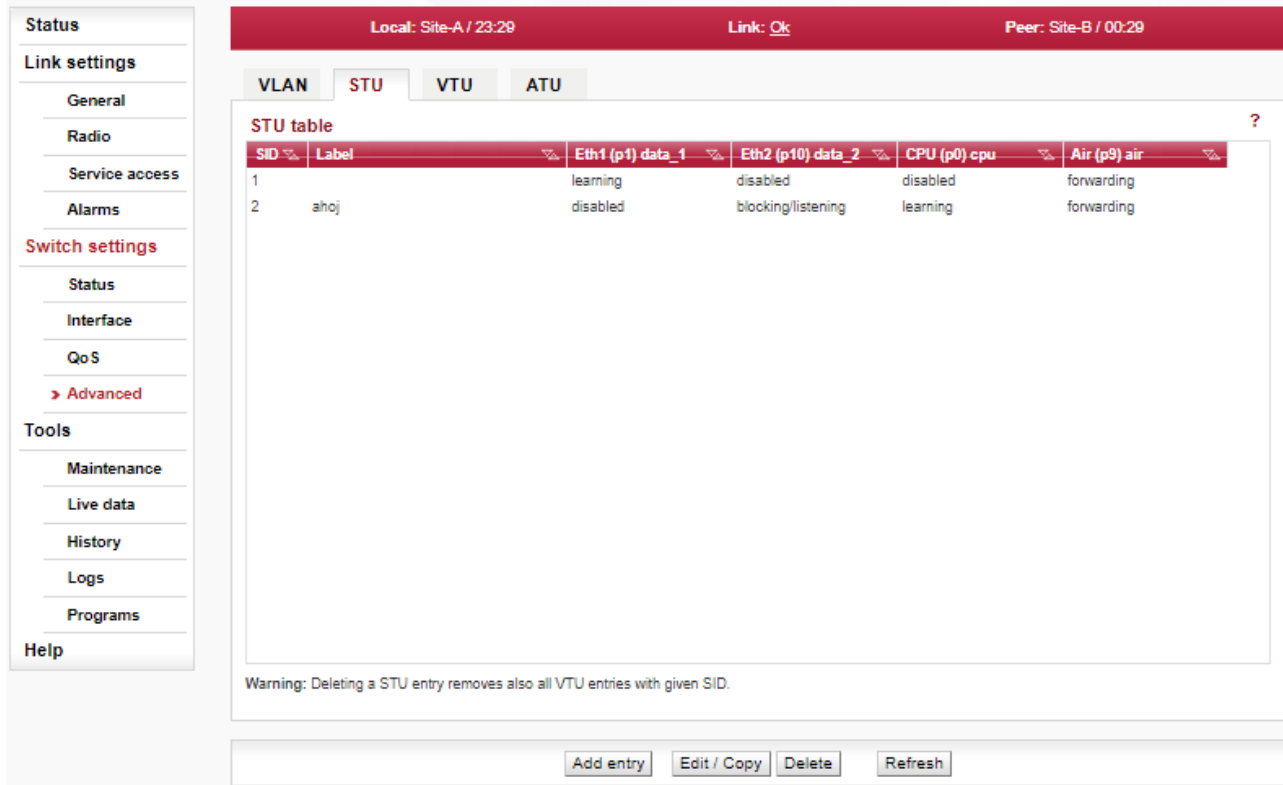
Fig. 5.33: Menu Switch settings > Advanced > STU

SID

VTU 802.1s (MSTP) Port State Information Database number. This parameter indicates the SID number that is associated with the 802.1s "Port state" parameter. It is essential to define the SID to be able to create records in the VTU (VLAN Table).

Label

A custom string label for a STU entry.

Port state (for ports Eth1, Eth2, CPU and Air)

This parameter is used to support 802.1s per VLAN spanning tree. Port states are valid for frames with a VID that is associated to this SID:
- disabled — Use non-VLAN Port States (i.e., the port's default Port State) for this port.
- blocking/listening
- learning
- forwarding

This "Eth port state" takes precedence over the port's Port State bits unless the port's Port State (driven by STP) is Disabled (which prevents all frames from flowing).

Add entry

Creates a new STU database entry. New window is opened to allow to enter values to each field (see their meanings above). The 'Primary key icon' 🔑 indicates which parameter field is taken as

the unique identifier in the database. This field entry ensures each record is unique and must not be duplicated.

Fig. 5.34: Menu Switch settings > Advanced > STU > Add Entry (or Edit Entry or Copy Entry)

Edit/Copy

Opens the configuration dialog for the selected STU database record. New window is opened to allow to modify values of each field (for layout and values see the explanation for 'Add entry' button).

> **Note**
> Should the Primary key value be modified, the "other" record - identified by the entered Primary key - is added (if it does not exist yet) or modified (if it exists already).

Delete

Deletes the selected STU database record.

5.5.4.3. VTU setup

The VTU (VLAN Table Unit) is related to VLAN functionality (pages STU, VTU and VLAN has to correspond to each other). Its records form the VLAN Table.
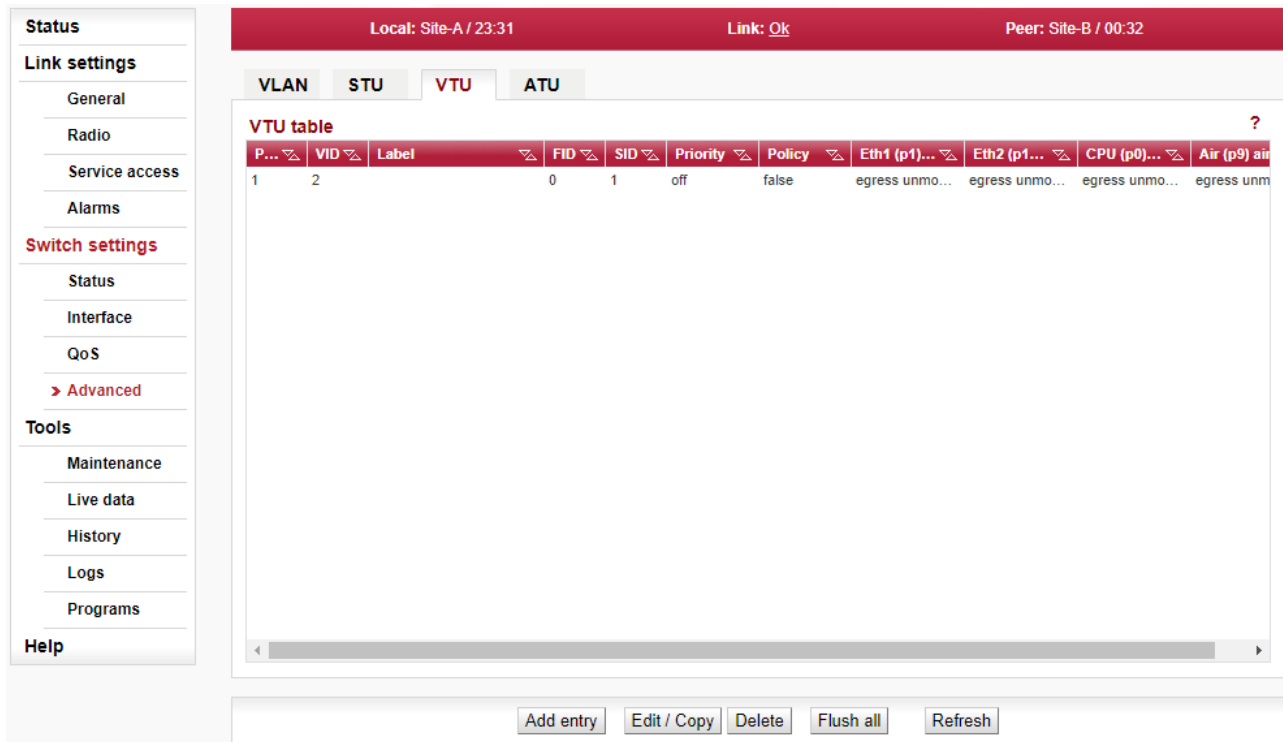
Fig. 5.35: Menu Switch settings > Advanced > VTU

Page
To be implemented yet.

VID
VLAN ID. This parameter indicates the VID number that is associated with the Member tag, VTU Priority, VTU policy and the FID (Forwarding Information Database number).

Label
A custom string label for a VTU entry.

FID
Forwarding Information Database number. If separate address databases are used, this parameter indicates the address database number to use for all frames assigned with this VID. All MAC DA look-ups and SA learning will refer to the address database number defined by the FID associated with the frame's VID. Multiple VID's can use the same FID. If separate address databases are not used, the FID must be zero. The ATU database records are joined with the VTU database records via this number.

SID
802.1s Information Database Number. If 802.1s per VLAN spanning tree is being used, this parameter indicate the spanning tree instance number to use for all frames assigned with this VID. Multiple VID's can use the same SID. The STU database records are joined with the VTU database records via this number.

Priority

Indicates status of parameters 'VID Frame Priority' and 'VID Queue Priority' (see their explanation below).

VID frame priority

(appears only in windows 'Add/Edit/Copy VTU entry')VID Frame Priority Use. This parameter is used to indicate that frames assigned with this VID can have their priority overridden with the "VID priority" value (see below) if the port's "VTU priority override" parameters is enabled to do so. See "VTU priority override" for more details. VID Priority override value when enabled by the "Use VID priority" parameter (see above). Used for priority override on ingressing frames. Enabling a priority on a VID will override the frame's priority only if the port's "VTU priority override" parameter is enabled to do so.

VID queue priority

(appears only in windows 'Add/Edit/Copy VTU entry')VID Queue Priority Use. This parameter is used to indicate that frames assigned with this VID can have their priority overridden with the "VID priority" value (see below) if the port's "VTU priority override" parameters is enabled to do so. See "VTU priority override" for more details. VID Priority override value when enabled by the "Use VID priority" parameter (see above). Used for priority override on ingressing frames. Enabling a priority on a VID will override the frame's priority only if the port's "VTU priority override" parameter is enabled to do so.

Policy or VID policy

('VID policy' appears in windows 'Add/Edit/Copy VTU entry')This parameter is used to indicate that frames assigned with this VID can have Layer 2 Policy actions applied to it if the port's "Policy VTU" (menu Advanced/Monitoring, Policy/Policy) is enabled to do so.

Don't learn

(appears only in windows 'Add/Edit/Copy VTU entry')To be implemented yet.

Filter UC/BC/MC

(appears only in windows 'Add/Edit/Copy VTU entry')To be implemented yet

Member tag

(For ports Eth1, Eth2, CPU and Air). This parameter is used to indicate which ports are members of the VLAN (i.e., with the given VID) and if these VLANs frames should be tagged or untagged, or unmodified when exiting the port as follows:
* egress unmodified — Port is a member of this VLAN and frames are to egress unmodified.
* egress untagged — Port is a member of this VLAN and frames are to egress Untagged.
* egress tagged — Port is a member of this VLAN and frames are to egress Tagged.
* not member — Port is not a member of this VLAN. The result is that frames assigned with this VID cannot egress this port.
This parameter takes effect only if the "802.1q mode" parameter (see menu Advanced/VLAN) is set to "secure" mode.

Add entry

Creates a new VTU database entry. New window is opened to allow to enter values to each field (see their meanings above). The 'Primary key icon' 🔑 indicates which parameter field is taken as the unique identifier in the database. This field entry ensures each record is unique and must not be duplicated.
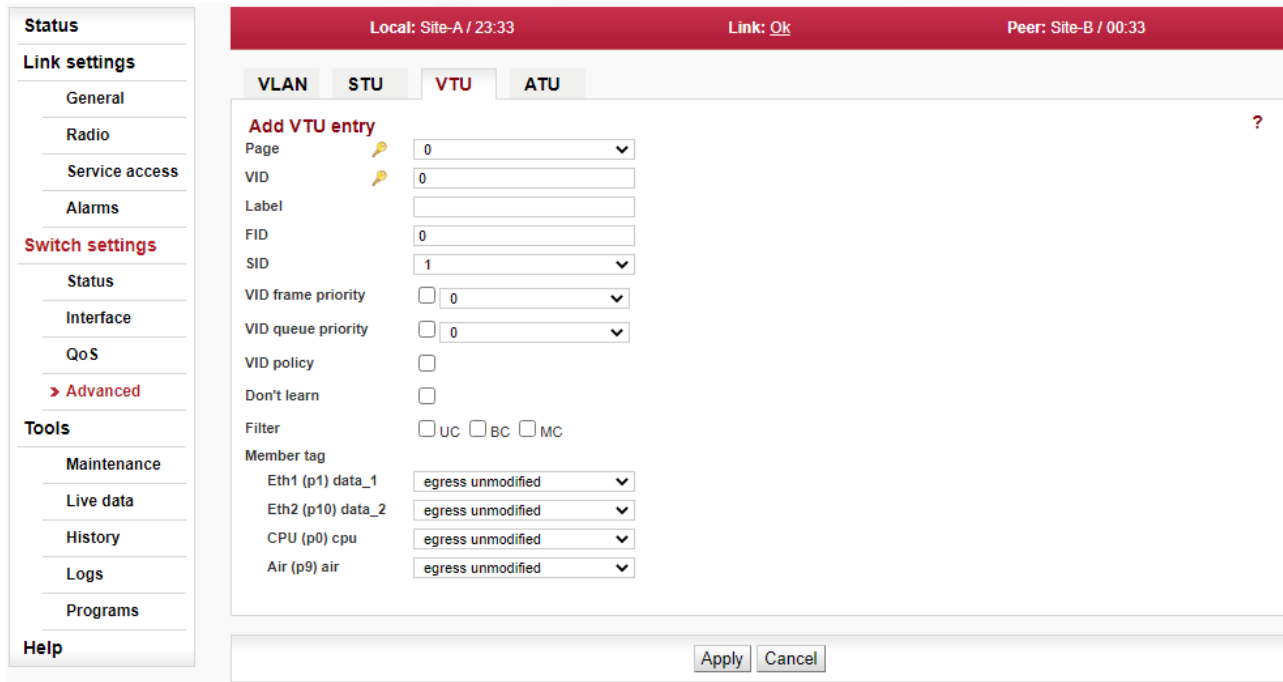
Fig. 5.36: Menu Switch settings > Advanced > VTU > Add Entry (or Edit Entry or Copy Entry)

Edit/Copy

Opens the configuration dialog for the selected VTU database record. New window is opened to allow to modify values of each field (for layout and values see the explanation for 'Add entry' button).

ⓘ **Note**
Should the Primary key value be modified, the "other" record - identified by the entered Primary key - is added (if it does not exist yet) or modified (if it exists already).

Delete

Deletes the selected VTU database record.

Flush all

Deletes the whole VTU database.

5.5.4.4. ATU setup

The Address Translation Unit (ATU) in the device supports user commands to access the contents of the MAC address database.

There is one static record which cannot be deleted. This is the management CPU record. The unicast frames directed to management are allowed to access the CPU port. The "VLAN tunnel" parameter is also used to enable the AP frames to access the CPU port.

Fig. 5.37: Menu Switch settings > Advanced > ATU

FID
   Forwarding Information Database number. If multiple address databases are not being used, this parameter must remain zero. If multiple address databases are being used, this parameter is used to set the desired address database number that is to be associated with this ATU Entry's MAC Address. When frames ingress the switch, the VID assigned to the frame is used to access the VTU. The VTU returns the FID associated with that VID for MAC address lookups in to the ATU.

MAC
   MAC address associated with this ATU entry in the database number defined by the FID.

Label
   A custom string label for a ATU entry.

Entry state
   The Entry state parameter is used to determine the entry's age or its type as follows:
   • static — Use for ordinary static entry.
   • static policy — Use for "Policy DA" and/or "Policy SA" (menu Advanced/Monitoring/Policy).
   • static non rate limiting — Use for "SA non rate limit" and/or "DA non rate limit" (menu Interface/PIRL).

- static management — This value is used for the mapping of the DA even if the "DA mapping" parameter is disabled (menu Advanced/ATU settings).
- dynamic — ordinary dynamic entry.

Priority

Shows the actual MAC priority settings (for explanation see items 'Use MAC priority', 'MAC frame priority' and 'MAC queue priority' below).

Use MAC priority

(appears only in windows 'Add/Edit/Copy ATU entry')Use this parameter to enable the "MAC priority" (see "MAC priority" description).

MAC frame priority

(appears only in windows 'Add/Edit/Copy ATU entry')The MAC's Frame Priority override value when enabled by the "Use MAC priority" parameter. Used for priority override on ingressing frames. Enabling a priority on a MGMT MAC address will override all priorities for these MGMT frames. Enabling a priority on a static, non-MGMT MAC address, will only override the frame's priority if the port's "DA priority override" or "SA priority override" parameters are enabled.

MAC queue priority

(spears only in windows 'Add/Edit/Copy ATU entry')The MAC's Queue Priority override value when enabled by the "Use MAC priority" parameter. Used for priority override on ingressing frames. Enabling a priority on a MGMT MAC address will override all priorities for these MGMT frames. Enabling a priority on a static, non-MGMT MAC address, will only override the frame's priority if the port's "DA priority override" or "SA priority override" parameters are enabled.

Destination type

Shows the actual settings of port association, trunks, etc.

Trunk member

(spears only in windows 'Add/Edit/Copy ATU entry')When this parameter is enabled, the MAC address is a member of a trunk - according to the "Trunk ID" parameter. When this parameter is disabled, the MAC address is associated with port(s) - according to the "Port association" parameter.

Trunk ID

The Trunk ID associated with this MAC address. The port or ports that this DA MAC address is associated with is determined by the "Port association" parameter below. Use this parameter to ensure the proper unit management CPU is accessed when two units are connected in trunk.

Port association

(For ports ETH1, ETH2, CPU and Air). Mask of ports associated with this MAC address.

Add entry

Creates a new ATU database entry. New window is opened to allow to enter values to each field (see their meanings above). The 'Primary key icon' 🔑 indicates which parameter field is taken as the unique identifier in the database. This field entry ensures each record is unique and must not be duplicated.

Fig. 5.38: Menu Switch settings > Advanced > ATU > Add Entry (or Edit Entry or Copy Entry)

Edit/Copy

Opens the configuration dialog for the selected VTU database record. New window is opened to allow to modify values of each field (for layout and values see *Fig. 5.38, "Menu Switch settings > Advanced > ATU > Add Entry (or Edit Entry or Copy Entry)"* above and for the description the explanation for Add entry button).

> **(i)** **Note**
> Should the Primary key value be modified, the "other" record - identified by the entered Primary key - is added (if it does not exist yet) or modified (if it exists already).

Delete

Deletes the selected ATU database record.

Flush all and use default

Deletes the whole ATU database and create default record(s).

Flush non-static

Delete all but static ATU database records.

5.6. Tools

5.6.1. Maintenance

5.6.1.1. Backup
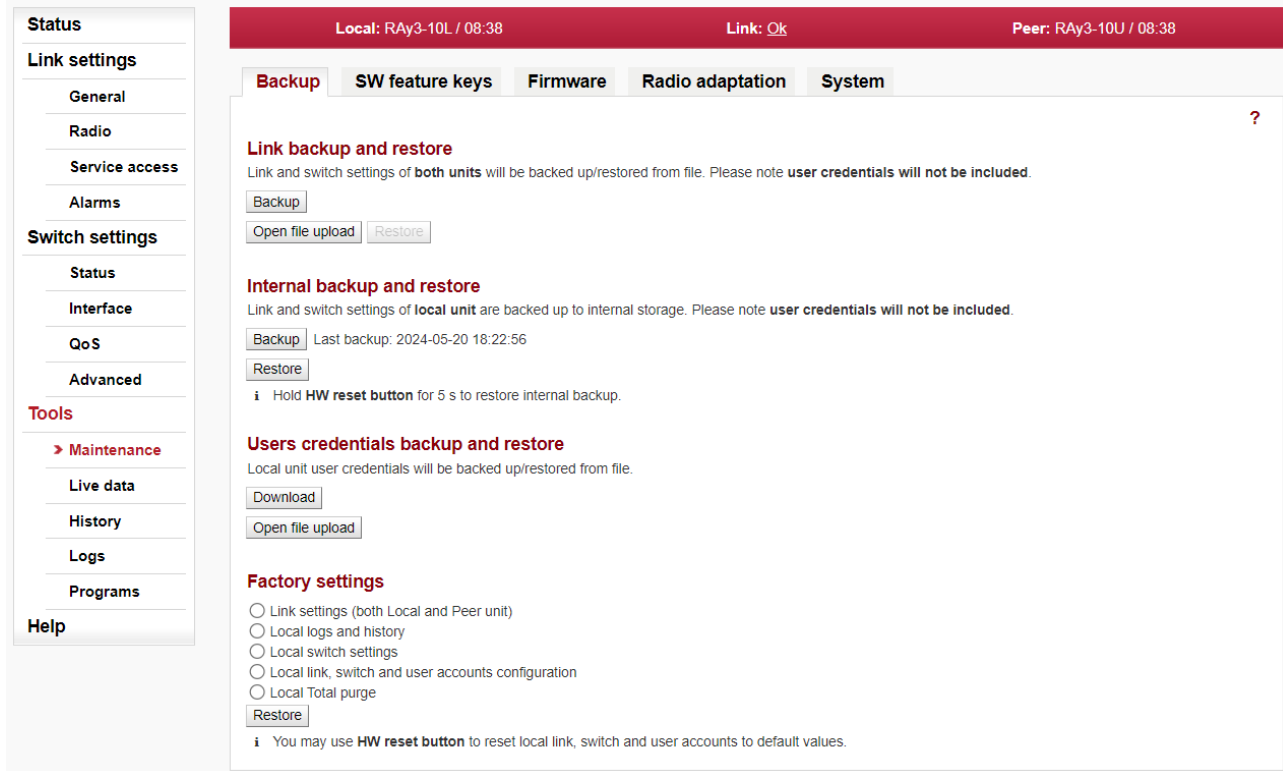
Fig. 5.39: Menu Tools > Maintenance > Backup

Link backup and restore

Link and switch settings of both units are backed up/restored to/from file. User accounts and SW keys are not backuped/restored by those functions.

Scope

Local	Peer	
O	O	Link
O	O	Switch
		User

Backup
Configuration is saved to backup file which is downloaded to management PC. The backup file name contains the date, time and unit serial number as follows:
`yyyyMMddhhmm_SN_cnf_backup.tgz`.

Open file upload
Upload configuration from a backup file into buffer. The current unit configuration is not affected. The uploaded configuration can be displayed using 'Show backup' button on particular configuration

screens. The configuration of the entire unit can be restored (from this buffer) using 'Restore' button below.

Restore
    After the configuration backup file has been loaded into the unit buffer (using Open file upload button above), the whole unit configuration can be restored using 'Restore' button.

Internal backup and restore

It is possible to make a temporary backup of the local unit configuration. The backup is stored directly in the unit FLASH memory. User accounts and SW keys are not backuped/restored by those functions.

> **(i) Note**
>
> Such fast backup is strongly recommended before any manipulation of unit parameters or before antenna alignment, because it allows fast restore to the surely working configuration.
>
> This backup is totally independent from the backup to external file and its values are not displayed using 'Show backup' button.

Scope

```
Loc   Peer
 O    |     Link
 O    |     Switch
      |     User
```

Backup
    Make a temporary backup of the unit configuration locally in to the unit FLASH memory.

Restore
    Restore (from the unit FLASH memory) the temporary backup of the unit configuration.

Internal restore - HW button
    The local temporary backup of the unit configuration can be also restored using *the hardware button*. The HW button is located next to the USB connector within the *slot marked "S"*. Press the HW button for the required time interval of 5 seconds. The button being pressed is confirmed by the Status LED flashing green. After the 5 seconds guard time, the unit restores to the settings stored previously in to the unit FLASH memory.

> **(✖) Warning**
>
> The internal backup FLASH is deleted if factory settings or firmware upgrade are performed.
>
> The rollback and reboot functions are suppressed while restoring from internal backup. All changes are applied immediately. Should the time zone be changed, the unit has to be restarted for changes to take effect.

Users credentials backup and restore

Saving and restoring of the local unit user credentials.

> ⓘ **Note**
>
> The 'super' user privileges are necessary to be able to perform those actions.

```
Loc   Peer
              Link
              Switch
  O           User
```

Download
Backup local unit user accounts to an external file. The file is downloaded to management PC.

Open file upload
Restoring user accounts from an external backup file.

Factory settings

The unit offers several factory reset options. Select the desired action and press the Reset button to perform the action.

Link settings (both Local and Peer unit)
The entire set of parameters from the Link Settings menu tree is affected (except user credentials).

Local logs and history
Local logs and history (graphs) will be cleaned. Unit will reboot.

Local switch settings
The entire set of parameters from the Switch menu tree is affected (except user credentials).

Local link, switch and user accounts configuration
The entire set of parameters from the Link Settings and Switch settings menu tree is affected including user credentials. The execution of this level of Factory settings can also be invoked by pressing the HW button before turning on the unit power. For details, see the *Section 1.4.5, "HW button (S)"*.

Local Total purge
Reverts the unit to its original state - as it was shipped from the factory. SW feature keys are also deleted.

> ⊗ **Warning**
> All configuration items, user accounts, SW keys, measured values and system messages (logs) will be irreversibly deleted. This task takes a few minutes to complete. Do not interrupt the power supply during the operation.

Restore
Performs the action selected by the radio button above. The unit reboots itself after applying all changes.

5.6.1.2. SW feature keys
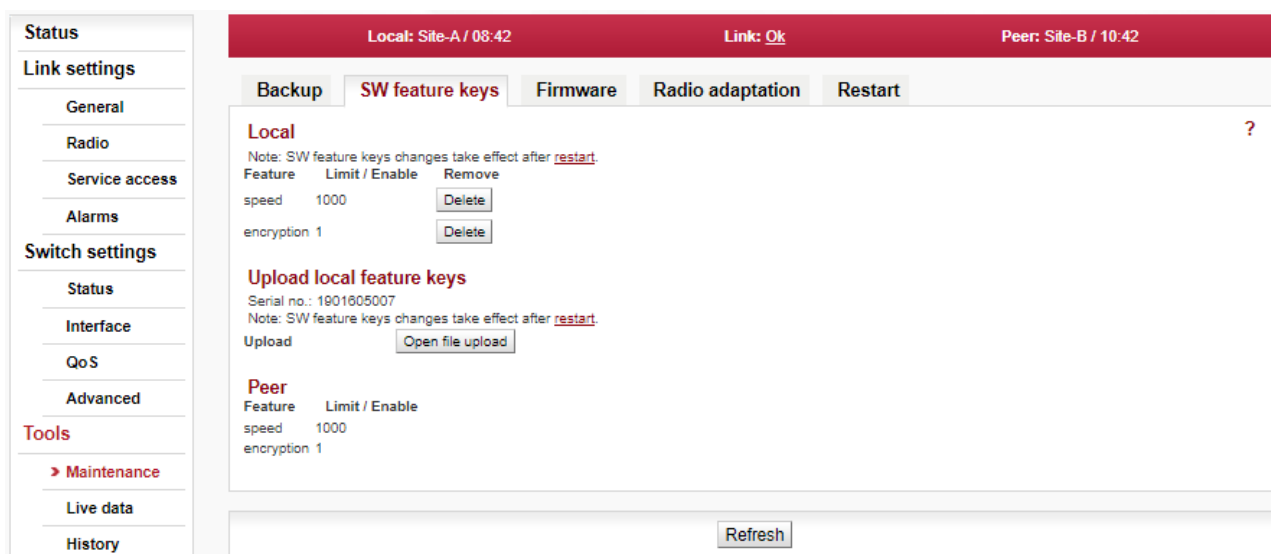
Fig. 5.40: Menu Tools > Maintenance > SW feature keys

The sub-set of unit parameters is affected by use of SW feature keys. Those can be purchased together with the unit or later at *RACOM E-shop*[2] or by a special agreement - see *Section 1.7, "Ordering codes"* for more details

Several SW feature keys limit data transfer speed [Mb/s] and/or other functionality of the unit. Each SW key is generated for specific S/N of the unit and the purchased feature. Once installed, a specific feature or function of the unit is allowed. Feature keys could be erased or upgraded anytime. To be able to manipulate SW keys, it is necessary to access directly the management system of the relevant unit - use the IP address of the relevant unit.

Speed of the transferred data is determined by a combination of the radio channel bandwidth (parameter Bandwidth [MHz]) and modulation order (parameter TX modulation). SW key limiting the data transfer speed enables only certain combinations of the channel bandwidth and modulation. The maximum data transfer speed is typically slightly higher than declared by the SW key speed value. SW keys for capacity could be different for each side of the link - for example if the link is expected to be configured for asymmetrical capacity.

When installed, the SW key is activated after the unit restart. The unit can be restarted using the Tools > Maintenance > Restart. Choose the Restart mode – warm.

Local

Shows current status of installed SW feature keys on Local unit.

Feature
The functionality controlled by the SW keys:
• Speed
• TX power
• Sync Eth
• Encryption etc.

---

[2] https://webservice-new.racom.eu/main/eshop.list

Limit / Enable

The numeric value set by the SW feature key or the indication of key activity (value '1' means the key is active).

Remove

The specific SW feature key can be deleted using the Delete button. The parameters controlled by this key are reset to their default values after the unit restart. Only local keys could be deleted.

> **(i)** **Note**
> Before deleting the SW feature key it is recommended to configure the link such a way that it does not require this key.

Upload local feature keys

SW feature keys are installed into the unit from binary files. Installed keys are activated after the unit restart.

Button 'Open file upload'

Opens a dialog for the SW feature key binary file selection.

> **(i)** **Note**
> Use the file as it is (do not unpack).

Peer

Shows current status of installed SW feature keys on Peer unit.

Items 'Feature' and 'Limit / Enable' have identical meaning as for the local unit.

5.6.1.3. Firmware
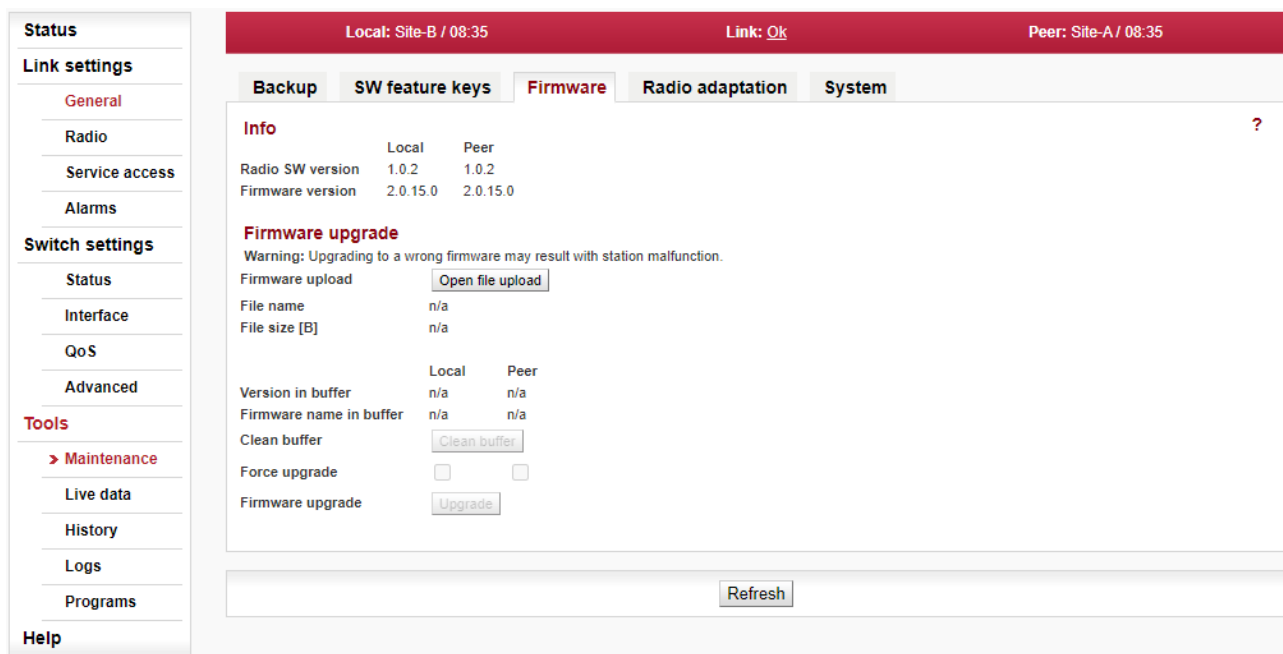
Fig. 5.41: Menu Tools > Maintenance > Firmware

If a new firmware version is released for the given microwave link type, you can upload it to your units.

Info

Radio SW version
Information about the Software Defined Radio (SDR) version on the Local and Peer units.

Firmware version
Information about the current firmware package version on the Local and Peer units.

Firmware upgrade

Firmware upload
Open file upload - opens a dialog for uploading firmware package to the unit buffer. Only after firmware has been prepared in the buffer, can you perform the actual upgrade.

> **(i) Note**
> Use the file as it is (do not unpack).

File name
Name of the uploaded firmware file.

File size [B]
Size of the uploaded firmware file (in bytes).

Version in buffer
Information about firmware version prepared in the buffer for installation into the unit (Local, Peer). This firmware must first be prepared in the Firmware upload section (see above).

Clean buffer
You can use the Clean buffer button to delete prepared firmware package in the buffer.

Force upgrade
Force mode blocks all safety and compatibility checks and may result in breaking your unit.

> **⚠ Important**
> You should not use force mode until instructed to do so by the technical support.

Firmware upgrade
Use the Upgrade button to perform the firmware installation.

> **⊗ Warning**
> Installing the firmware takes about 45 seconds (including reboot). During this time, transmission of user data is interrupted. Do not interrupt the power supply during firmware installation!

5.6.1.4. Radio adaptation

Fig. 5.42: Menu Tools > Maintenance > Radio adaptation

Band index

Band index

Band index displays radio channel assignment of local unit transmitter (TX) for **L (Lower)** or **U (Upper)** part of the frequency band.

Change button

Applies only for 17 GHz and 24 GHz links (where hardware of each unit is universal for the entire frequency band). Change button changes the band index (L -> U and U-> L). If units are linked together both Local and Peer units are changed in the same time.

ⓘ Note

Changing band index is allowed only in symmetric mode (i.e. TX bandwidth is the same as RX bandwidth).

After restoring *factory settings* Band index is set to its pre-defined state L or U as typed on *Product Label*.

⊗ Warning

When the radio band index is changed, the "Link settings" menu parameters of each unit are **reset to default** values except login / password details.

Frequency tables

The microwave link contains one or more frequency tables (called rcinfo). These tables contain the following information:

- List of available bandwidths and modulations.

- Assignment of frequencies to the channels and the names of these channels. These channels are used to configure radio parameters of the link (see screen *Link settings > Radio*).

- Default values of radio parameters.

- A set of radio parameters, needed for the ATPC operation.

Just one frequency table can be active in a given time. Tables can not be modified by a user or combined together. If a different radio parameters or channel names has to be used (for example due to new telecommunication regulation), please contact your supplier and ask for a proper FW with the frequency table for your situation.

Active
Name of the currently used frequency table in format <name:version>.

New
Select a new frequency table. Available tables are displayed in format <name:version>. Use the Change button to change the table.

Warning
Using the wrong frequency table can lead to violation of the corresponding telecommunications regulations.

Note
Later versions of the same frequency table allow a wider functionality of the unit. Thus it is recommended to keep active the latest version of chosen frequency table.

Compatibility

Unit '24S' compatibility (formerly 'Unit S mode')
This parameter is available only for newly deployed 24 GHz units without the 'S' label in Product code (i.e. '24S') - as visible on *Product label* and in *Ordering codes*. When "active", the unit behaves like the unit '24S' (it can establish a link only with another '24S' unit). For a link between the units without the 'S' label, this compatibility needs to be disabled ("off"). The unit reboots after changing this parameter.

Note
Used only if a combination of different hardware variants of units have to be used to set up the link together. Wrong setting of compatibility causes the link is not established (both units remain in status 'Connecting'). For more info see chapter Troubleshooting in the product manual, the topic *'Setting up a link between RAy3-24S and other hardware variant of RAy3-24'*.

5.6.1.5. System
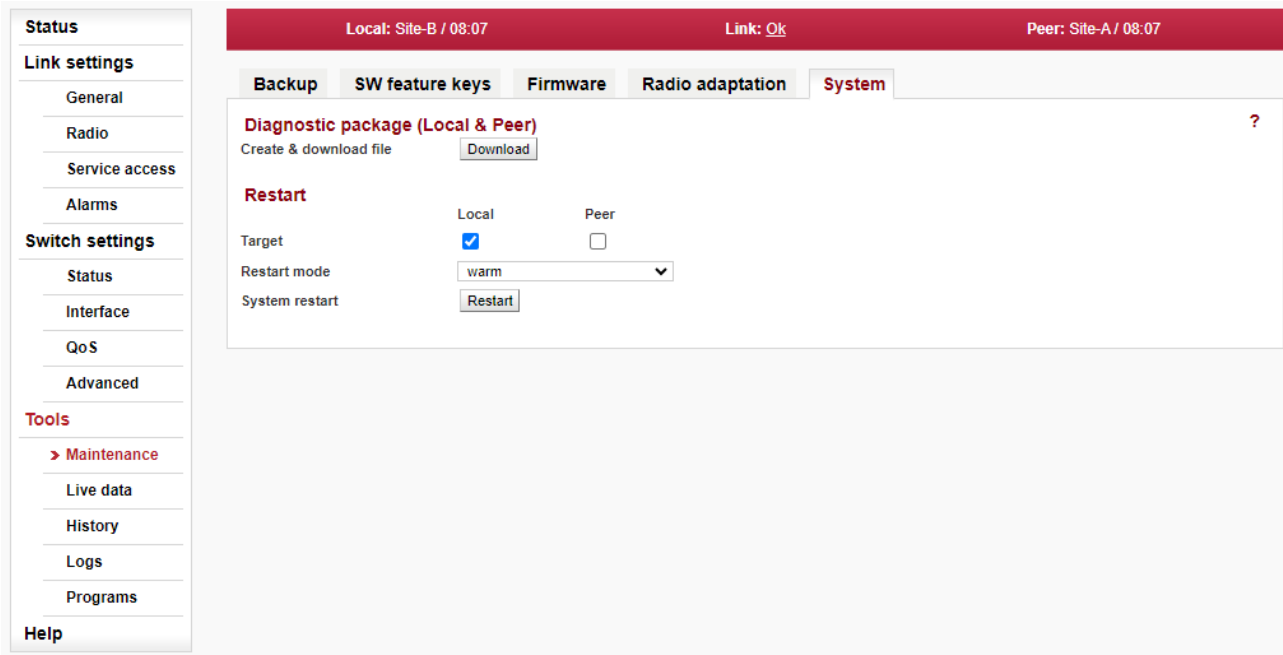
Fig. 5.43: Menu Tools > Maintenance > Restart

Diagnostic package (Local & Peer)

To facilitate communication with the technical support you can create an archive file with detailed information about the unit. If connection with Peer unit is active the diagnostic information from both units are saved.

Create & download file
Saving a file with information about the unit (Local and Peer).

> **Note**
> This task takes a few minutes to complete.

Restart

Target
Chose the unit(s) to be restarted: Local or Peer or both.

Restart mode
Chose the type of the restart:
• Warm — Reboot only management system and web interface.
• Cold — Restart the whole unit as if power was removed.

System restart
Pushing the "Restart" button performs the selected restart.

5.6.2. Live data

5.6.2.1. Bar indicators

Fig. 5.44: Menu Tools > Live Data > Bar indicators

Graphical indication of RSS and MSE.

Refresh
One-time update of displayed values.

Start, Stop
Start button starts automatic update of displayed values with a period of 1 second. Stop button stops refreshing of both graphs.

Antenna alignment
Link "go to antenna alignment screen" activates Antenna Alignment Tool (black page).

5.6.2.2. Antenna Alignment Tool

The Antenna Alignment Tool supports interactive antenna alignment. RSS and MSE are displayed for both local and peer unit. A selected value can be indicated in large font and acoustically. Values are refreshed 10× per second.

When performing antenna alignment, both ATPC and ACM/ACMB functions should be disabled; their automatic behavior interferes with the alignment process which is based on finding the maximum signal strength.

The tool is accessed via management IP address e.g. http://192.168.169.169/tk for standard Ethernet ports, and via http://172.17.17.17/tk for connections using USB/WiFi or USB/Eth. The Antenna Alignment Tool does not require user authentication.
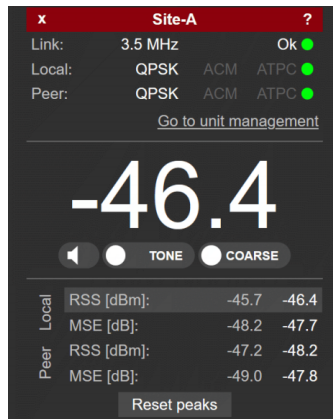
Fig. 5.45: Antenna Alignment Tool

Red strip
    (top of the page)
- \+ — Increases the number of displayed parameters
- x — Decreases the number of displayed parameters
- text — Local Station name (e.g. Site-A)

Link
- 3.5 MHz Ok — Channel width
Link connected (green icon).
The Peer values (see below) are visible when the connection between Local and Peer unit has been established.

Local, Peer
- from QPSK_S to 4096QAM or from 2PSK_BW/4_S to 128QAM — Current modulation of the TX signal.
- ACM/ACMB, ATPC — Status of ACM/ACMB + ATPC (red color warns at least one of those is enabled).

Go to unit management
    Link to the full configuration interface of the microwave unit; user authentication is required.

-46.4
    Actual RSS [dBm] or MSE value. The selected value is chosen by clicking/tapping on the respective value below the main display.

Exclamation icon !
    An exclamation icon is displayed when either Local or Peer unit has ACM/ACMB or ATPC enabled. Those should be both disabled; they can affect signal strength.

Icon of speaker
    Acoustic indication for local RSS value ON/OFF. The TONE or BEEP signal is supplemented with voice output every 10 seconds, notifying signal strength.

TONE / BEEP

Select the sound generated. The better the signal, the higher the frequency. The acoustic indication is linked to the value on the main display. If a WiFi connection is used to access Antenna Alignment, the 'noise' audio signal is used to notify low quality or low stability of the WiFi signal.

COARSE / FINE

Choose the scale of acoustic indication.

- COARSE — for approximate alignment. Range of tones (or frequency of beeps) is equal to -100 to -30 dBm.
- FINE — for a more precise alignment. Range of tones (or frequency of beeps) is equal to ±10 dBm from the value sampled at the moment when the FINE button was pressed).

RSS, MSE

Values RSS and MSE for local and peer unit (4 values in total):

- First column — Best values recorded
- Second column — Current values.

The value to be displayed on the main display is selected by a tapping/clicking on the respective value.

Reset peaks

Best values history is cleared.

5.6.2.3. Frequency spectrum analyzer
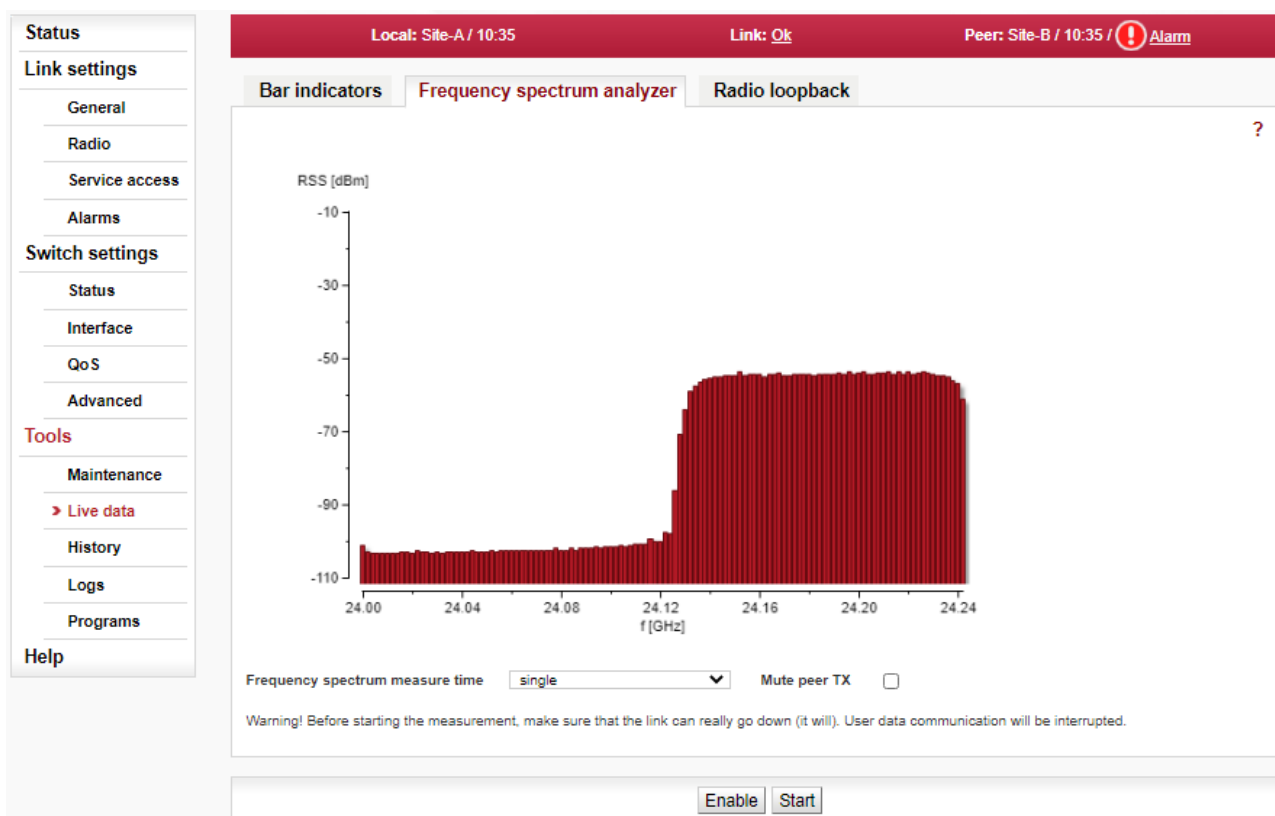
Fig. 5.46: Menu Tools > Live Data > Frequency spectrum analyzer

A very useful tool for identifying in-band interference and locating a free channel. It is not a full-blown spectrum analyzer as it scans the spectrum with 2 MHz channel resolution. The accuracy of measured results is given by the accuracy of measuring RSS.

Enable

Opening analyzer functions.

Start

Interrupts communication on the link and starts scanning frequencies in the band.

Spectrum measure time

Selection of measurement length in range:

Mute peer TX

The deactivation of Peer station transmission during measurement. single sweep … up to 15 min

> **Note**
>
> Single sweep takes about 2 seconds for the whole band scan in 17 or 24 GHz (only 200-250 MHz wide). For licensed bands and for RAy3-80 it takes adequately longer - according the width of RX and TX parts of the band.
>
> The link is automatically re-established after it is finished.

> **Warning**
>
> Running spectrum measurement causes interruption of user data flow between stations!

Interruption of the scan before selected measure time can be achieved anytime by visiting any of the *Link menu* settings and select Refresh. This restores the configuration connection (message Peer: n/a).

5.6.2.4. Radio loopback
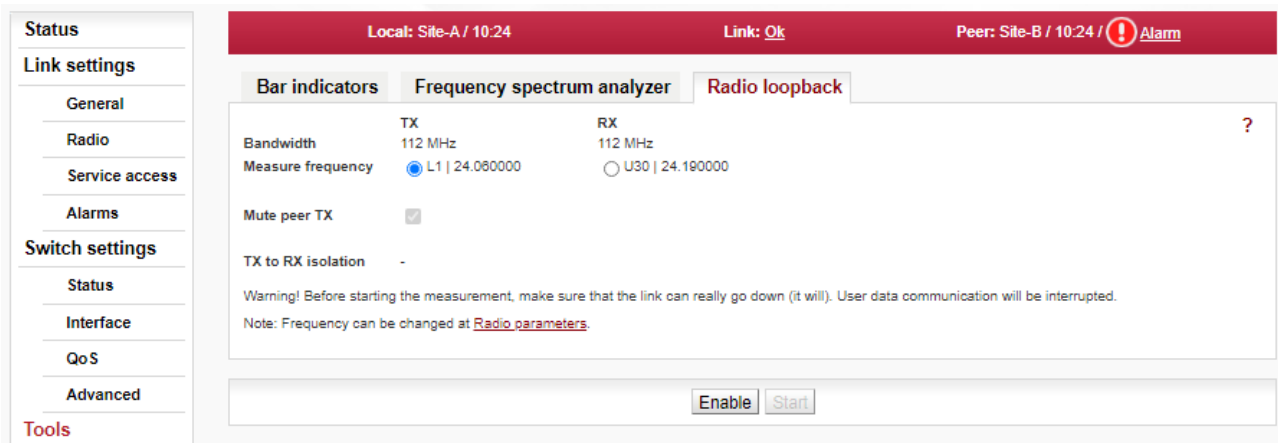
Fig. 5.47: Menu Tools > Live Data > Radio loopback

Radio loopback measurement serves as a check of quality of the antenna connection to the microwave unit and the quality of the antenna itself. Only available for the 17 GHz and 24 GHz units. The function provides indicative measurement of an antenna parameter CPI (Cross-Port Isolation). It is done by evaluation of strength of the signal in other (RX) polarization received from its own transmitter (trans-

mitting in TX polarization, 90 degrees from RX polarization). The lower the strength of unwanted signal returned by the antenna received, the better the antenna quality for *Cross-polarization* data transmission used by 17 and 24 GHz units.

Warning

User traffic is interrupted during command execution!

Bandwidth

Channel widths used for transmitting.

Measure frequency

By default, the Radio loopback is measured with the current frequency of the transmitter. Measurement can be performed with the frequency of the receiver. Both results may differ slightly because the antenna parameters are frequency dependent.

Mute peer TX

The deactivation of Peer station transmission during measurement (not to interfere with the measurement).

TX to RX isolation

The result of the Radio loopback measurement is given as the ratio between the levels of the transmitted and received signal. The ratio is given as a logarithmic value in [dB]. The higher the number, the better the antenna quality. Here are the thresholds for evaluating the results:
- less than 40 dB - insufficient
- from 40 dB to 45 dB - reasonable
- more than 45 dB - good

ⓘ Note

Possible reasons for isolation ratio lower than 45 dB are listed below. They are ordered according the probability of occurrence. Typical methods of repair are described as well:
- Silicon grease in the waveguide => clean the antenna waveguide and the neck of the unit
- Antenna for another frequency band => check the type of antenna and replace it with a suitable one
- Frozen (dewy) antenna => after climatic conditions improvement everything returns to original values (antenna heating would eliminate that - quite useful in mountainous areas)
- Reflective (metal) surface near the antenna (even outside of the Fresnel zone) => change of antenna position
- Mechanically damaged antenna dish or radome => inspection of the antenna, cleaning or replacement of the radome
- Lost mirror at the end of a waveguide inside the antenna => inspection of the antenna interior, its repair or replacement
- Damaged polarization transducer inside the unit => repair of the unit at the manufacturer (this never occurred, yet)
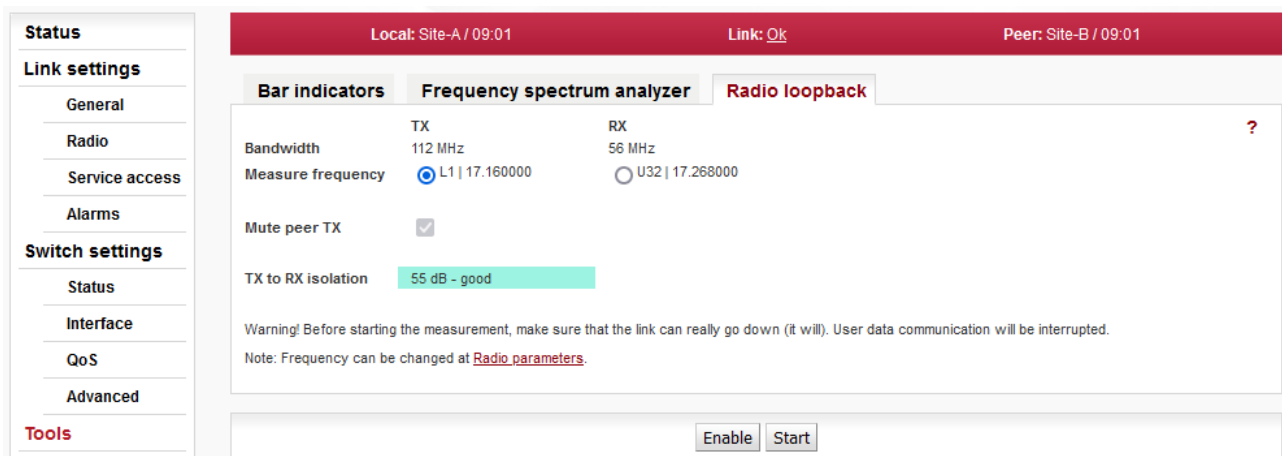
Fig. 5.48: Menu Tools > Live data > Radio loopback result

5.6.3. History

The unit continuously stores information about the values of important variables. Stored values can be viewed using three methods - Thumbnails, Viewer and Data.

5.6.3.1. Thumbnails

Preview all values for the last 24 hours. Click on a thumbnail to open the viewer with a chart.

Fig. 5.49: Menu Tools > History > Thumbnails

Temperature
Instantaneous value of temperature inside the unit. Measured on the modem board.

Voltage
Instantaneous value of unit supply voltage.

TX power
Instantaneous value of transmission RF Output power.

RSS

Received signal strength.

Signal quality

Signal quality of the received signal. It is negative value of Mean Square Error (MSE, the inverse to often used SNR - Signal to Noise Ratio).

BER

Instantaneous bit error rate on link.

Net bitrate

Instantaneous transmission capacity.

Eth1, Eth2 in throughput

Instantaneous speed (20s average) of incoming user data on the user Ethernet port.

Eth1, Eth2 out throughput

Instantaneous speed (20s average) of outgoing user data on the user Ethernet port.

Dual channel

In the case of *Dual channel* operation, the parameters of both channels are displayed. The parameters of the second channel are marked with index 2 (TX power 2, RSS 2, Signal quality 2, BER 2).
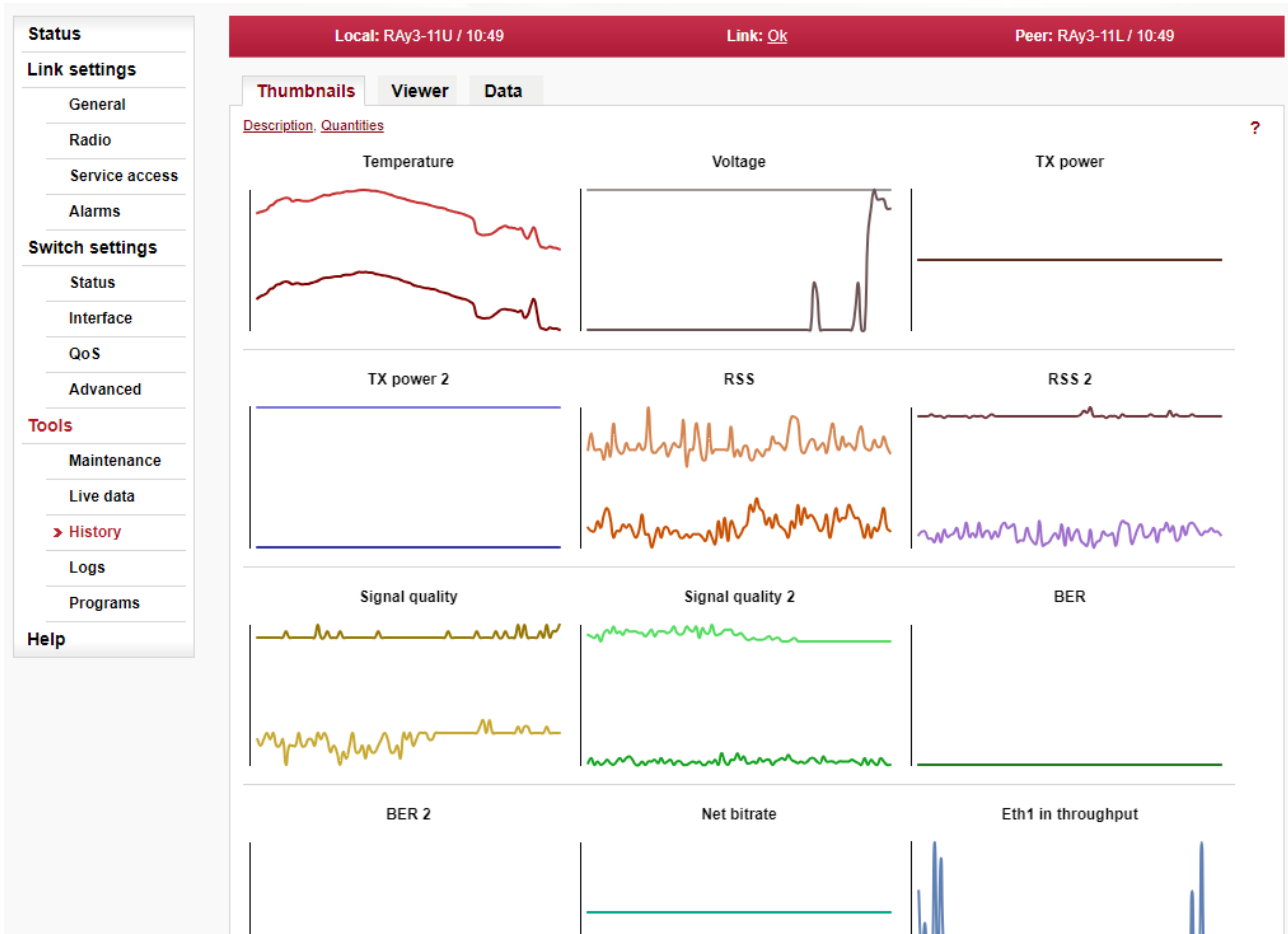
Fig. 5.50: Menu Tools > History > Thumbnails

5.6.3.2. Viewer

Detailed graphical view of one or two selected values for the given interval. You can choose to view data from Local or Peer or both.
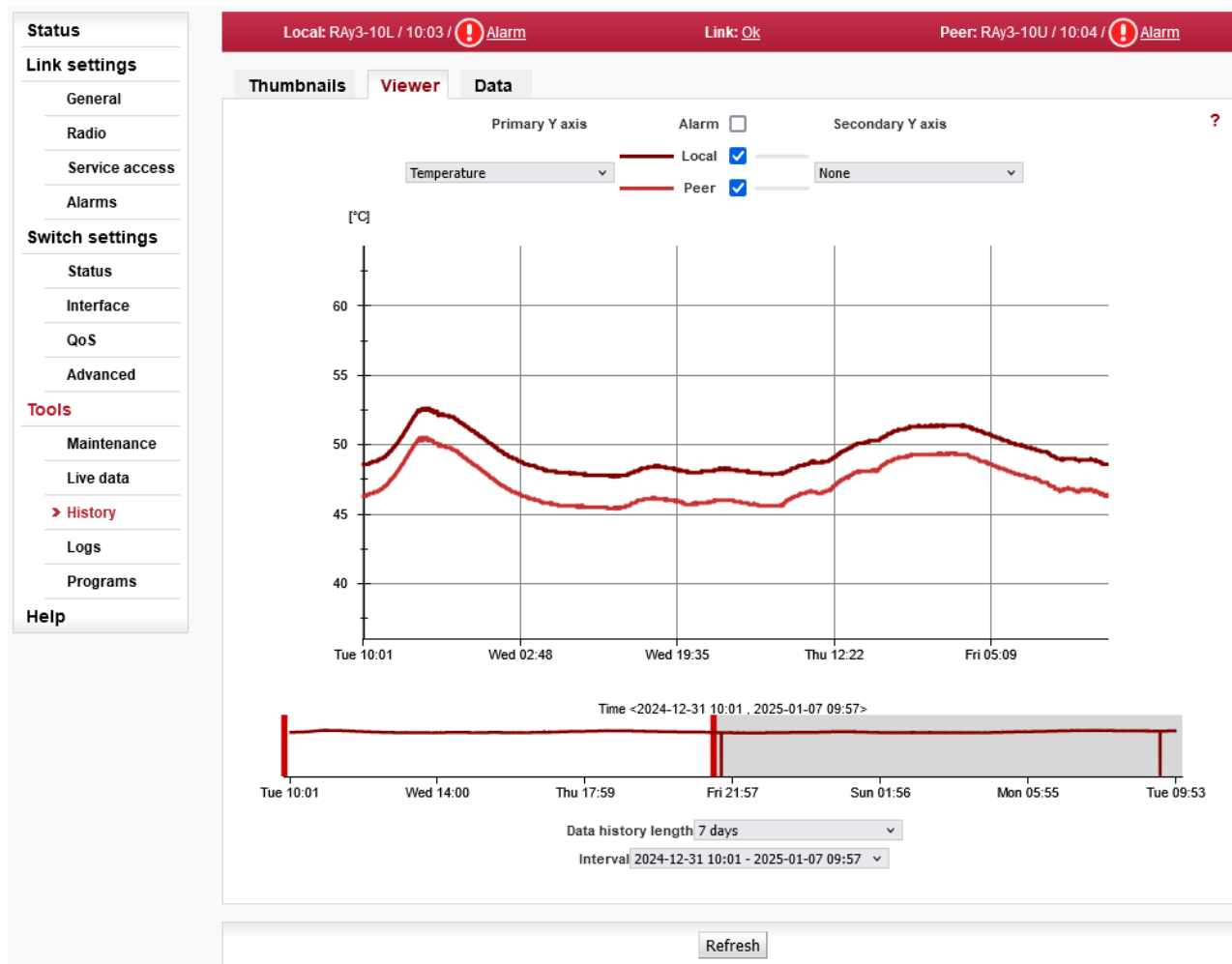
Fig. 5.51: Menu Tools > History > Viewer

Data history length
    The values are saved in the following resolutions and history lengths:
    7 days, Resolution 1 minute, length of history 7 days
    30 days, Resolution 15 minutes, length of history 30 days
    180 days, Resolution 1 day, length of history about 180 days

Interval
    Selecting time interval to be displayed from the currently selected history length. Each history length can have multiple time intervals to choose from. Time interval represents data history in a continuous time. In other words, new time interval appears when backward time jump is detected. On the other hand, when forward time jump is detected, it is represented as a blank spot in the graph and as a slope in the slider (slope does not appear when data values of the current series are close to their minimum).

Primary Y axis
    Selecting one of the observed values:

Temperature, Voltage, TX power, RSS, Signal quality, BER, Net bitrate, Ethernet in throughput, Ethernet out throughput

Secondary Y axis

Selecting a second value:

None, Temperature, Voltage, TX power, RSS, Signal quality, BER, Net bitrate, Ethernet in throughput, Ethernet out throughput

Alarm

Enables the display of alarms, if there were any.

5.6.3.3. Data

Numerical view of all values.

Fig. 5.52: Menu Tools > History > Data

Quantities
Detailed graphical view of values for selected interval.

- Plotted — Shows only the values that are selected for the graph.

- Local, Peer, All — Shows all logged values. Filtering of values from local, remote or both.

Data history length, Interval
See explanation of those in Viewer section above.

5.6.4. Logs

Shows internal unit logs. Individual tabs allow total or filtered view.

Fig. 5.53: Menu Tools > Logs

When you first open the screen, it is necessary to start browsing logs by pressing the Refresh button.

Maximum length of displayed logs is 250 entries. If you need to display longer history, use CLI interface instead.

Overall
Displays the last 3 records from all types of logs.

Local alarms, Peer alarms
Alarms from Local or Peer unit.

Local events, Peer events
Events from Local or Peer unit.

Local system, Peer system
System events from Local or Peer unit.

Filter
Listings of all logs can be filtered. Filtering string is entered in to the upper left corner window and Filter button is pushed. For example, you want to know when the configuration of the unit was modified: On the Local events screen, enter `Configuration` and hit Enter. Plain text or regular expressions can be used for filtering (JavaScript format).

5.6.5. Programs

5.6.5.1. Ping

The Ping tool allows sending ICMP pings to a selected address
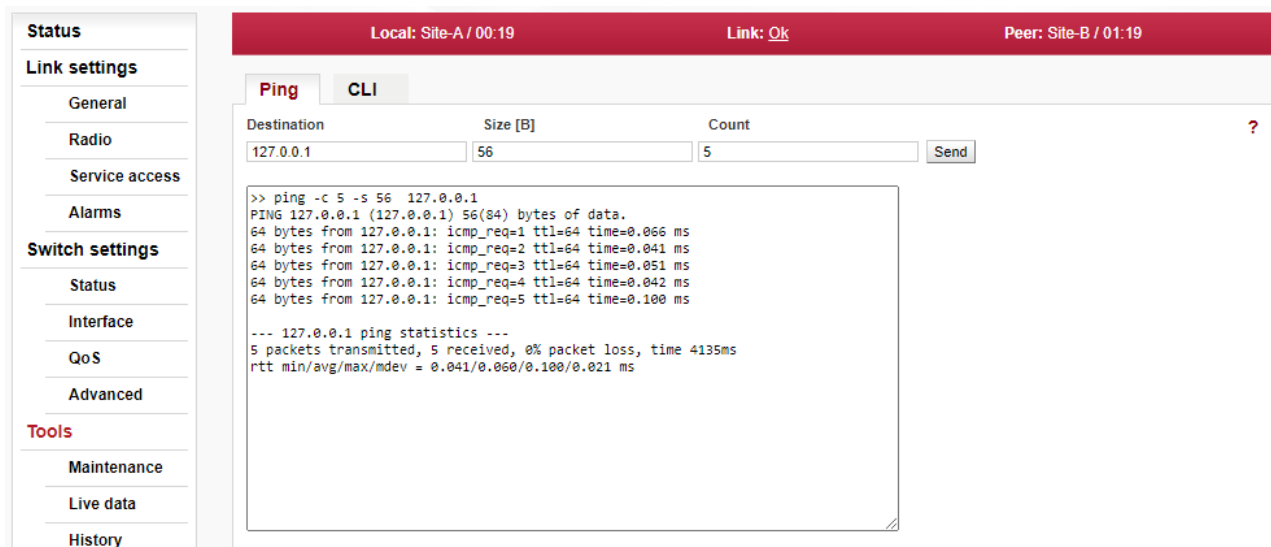
Fig. 5.54: Menu Tools > Programs > Ping

Destination
    Destination address in dotted decimal notation. The default address 127.0.0.1 is the localhost address - i.e. the unit itself.

Size [B]
    Length of sent data 7 to 1500 bytes, 8 bytes of the header will be added.

Count
    Number of sent pings.

Start the test by clicking on *Send*. The period for sending pings is constant: 1000 ms. The result is displayed in the text window.

5.6.5.2. CLI

Web interface for executing non-interactive scripts and programs.
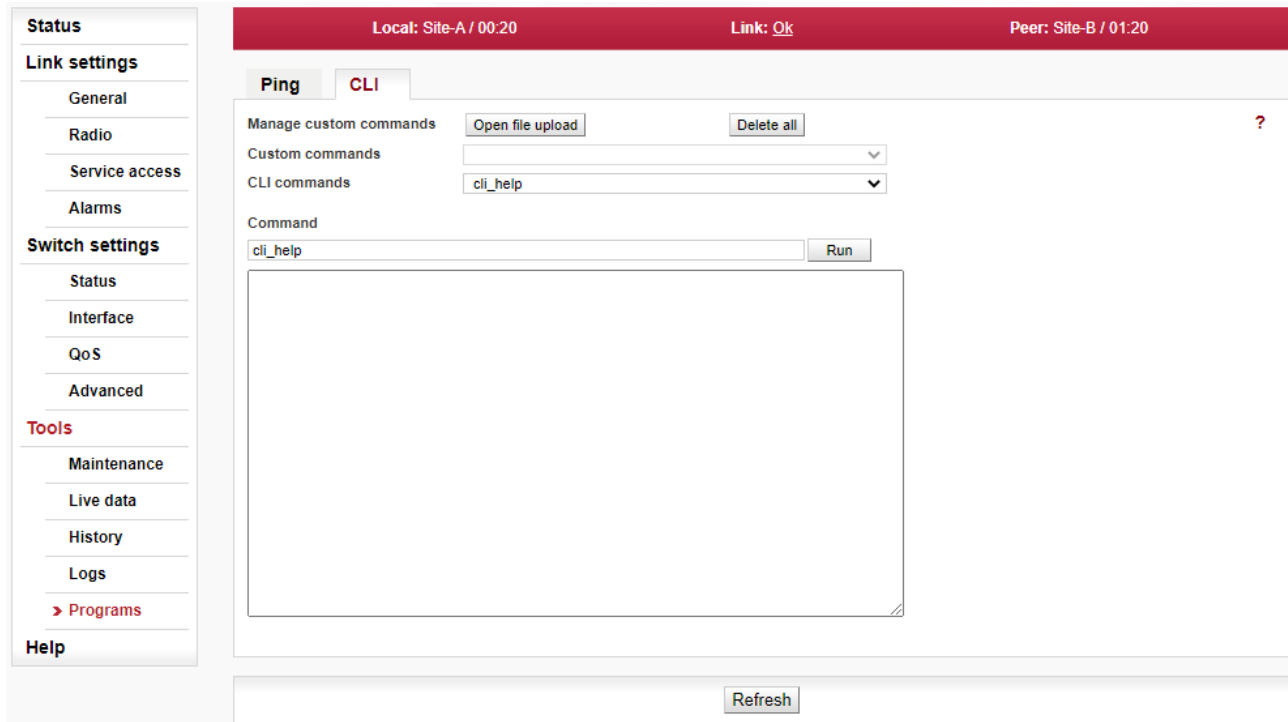
Fig. 5.55: Menu Tools > Programs > CLI

Manage custom commands
Using "Open file upload"/"upload" the user can upload scripts to the unit. The uploaded file can be either a single shell script with extension .sh (e.g. my_script.sh) or package with multiple scripts with extension .tar.gz or .tgz created using tar.
"Delete all" removes all custom scripts from the unit.
Custom scripts are located in /home/shared/bin.

Custom commands
A custom script can be selected here and initial comments/help is shown.

CLI commands
A CLI command can be selected here. You can use cli_help for listing all CLI commands or <command> --help to obtain detailed help on a selected command.

Command
Command line for writing commands with parameters. You can use any non-interactive program/script according to your permissions. Command is executed by pushing the "Run" button.

Format of custom scripts
Custom scripts must be a shell script with preamble #!/bin/sh and extension sh.
Blocks of lines beginning with the comment sign (#) after preamble are considered to be help and are listed when the script is selected in the web interface.
Scripts should not be interactive as there is no possibility to send a response from the web interface.
All script options should be implemented as parameters.
Syntax should be valid for interpret shell ash from BusyBox v1.20.1.

Example of custom script

```
#!/bin/sh
#script checks if service with the same name or vid already exists
#if not creates a new entry in VTU with given VID
#
#   input parameters:
#       service_name - name of the new service
#       VID - vid of the new service
#
#   return values:
#       0 - ok
#       3 - bad parameter
#       5 - service already exists
#       6 - there already exists an entry with given VID
#      42 - other error

D42_NAME="$1"
D42_VID="$2"

D42N="service_data42"

error()
{
        echo "$D42N: Error: $*" >&2
}

info()
{
        echo "$D42N: $*" >&2
}

die()
{
        error "$*"
        exit 42 #error
}

# basic check if not empty
if [ -z "$D42_NAME" ]; then
        error "Bad service name"
        exit 3
fi
if [ -z "$D42_VID" ]; then
        error "Bad service VID"
        exit 3
fi

D42_FOUND=$(cli_nw_get --vtu all | grep "$D42_NAME")
if [ -n "$D42_FOUND" ]; then
        error "Service(s) with name $D42_NAME found"
        echo $D42_FOUND
        exit 5
```

```
fi

D42_VALID=$(cli_nw_get --vtu "$D42_VID" | sed -n 's/^valid=\(.\+\)$/\1/p')
if [ "pre_$D42_VALID" = "pre_true" ]; then
        error "VID $D42_VID is used"
        cli_nw_get --vtu "$D42_VID"
        exit 6
fi

D42_VALID=$(cli_nw_get --stu 1 | sed -n 's/^valid=\(.\+\)$/\1/p')
if [ "pre_$D42_VALID" = "pre_false" ]; then
        info "Creating STU entry with SID=1"
        cli_nw_set --stu 1 'label="D42_auto", port_state=["disabled", "disabled", ▶
"forwarding", "disabled", "disabled", "forwarding", "forwarding"]'
        if [ $? -ne 0 ]; then
                die "Failed to create STU entry"
        fi
fi

info "Creating service \"$D42_NAME\" with VID=$D42_VID"
cli_nw_set --vtu "$D42_VID" label="$D42_NAME" 'fid=0, sid=1, pri_override=true, priority=5, ▶
policy=false, member_tag=["unmodify", "unmodify", "tag", "unmodify", "not_member", ▶
"not_member", "unmodify"]'
if [ $? -ne 0 ]; then
        die "Failed to create service \"$D42_NAME\" with VID=$D42_VID"
fi
```

5.7. Help
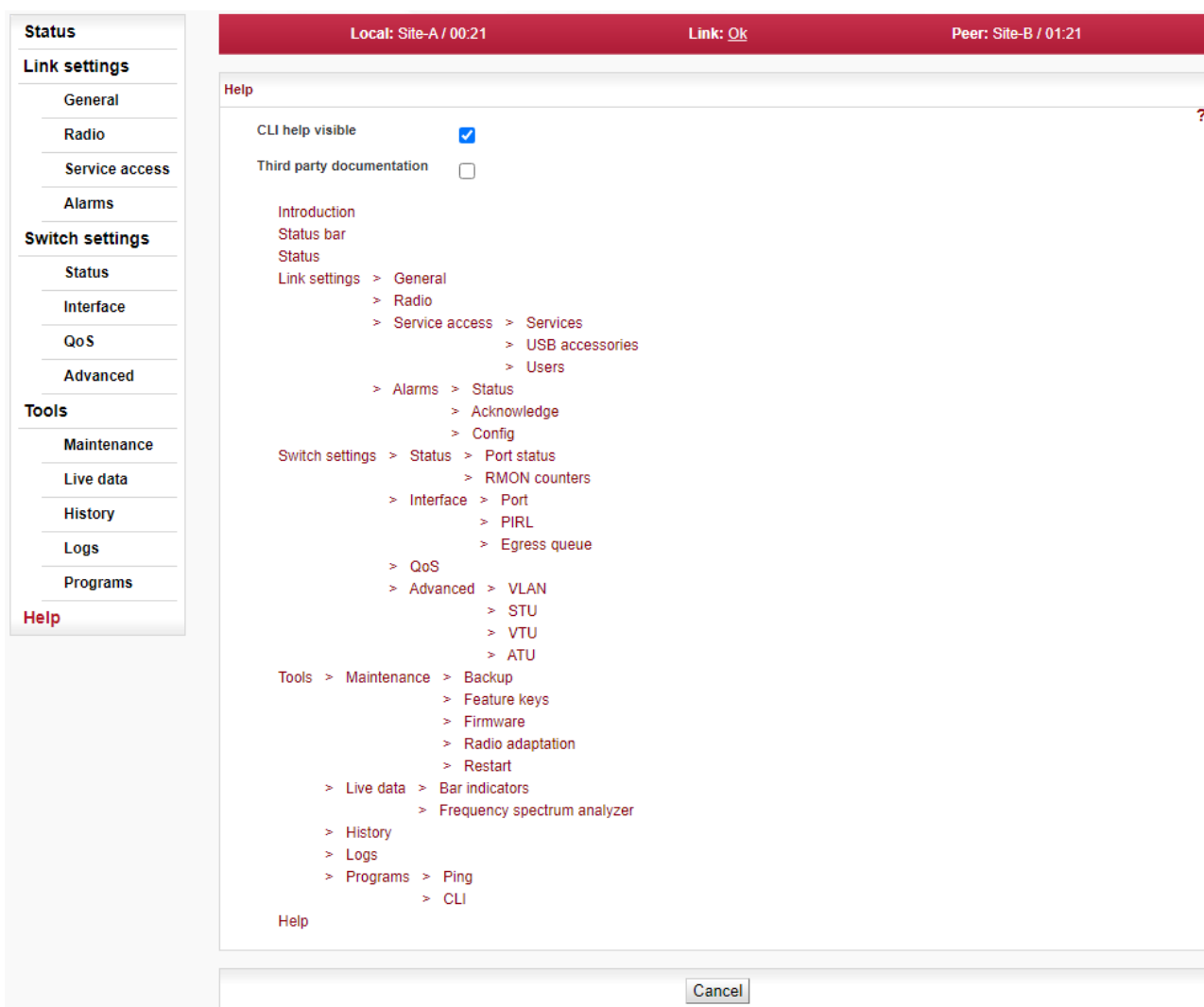
Fig. 5.56: Help menu

Help from Help menu

The Help screen displays contents of the embedded help. The help text is displayed in the whole configuration window. The text structure corresponds to individual configuration screens. Every item of this Help opens the specific help menu.

CLI help visible
 Allows displaying of the CLI help with examples.

Help from configuration menu

Clicking the **name of the specific parameter** in the configuration menu brings up the help belonging to this parameter. The help text is displayed in the pop-up window:
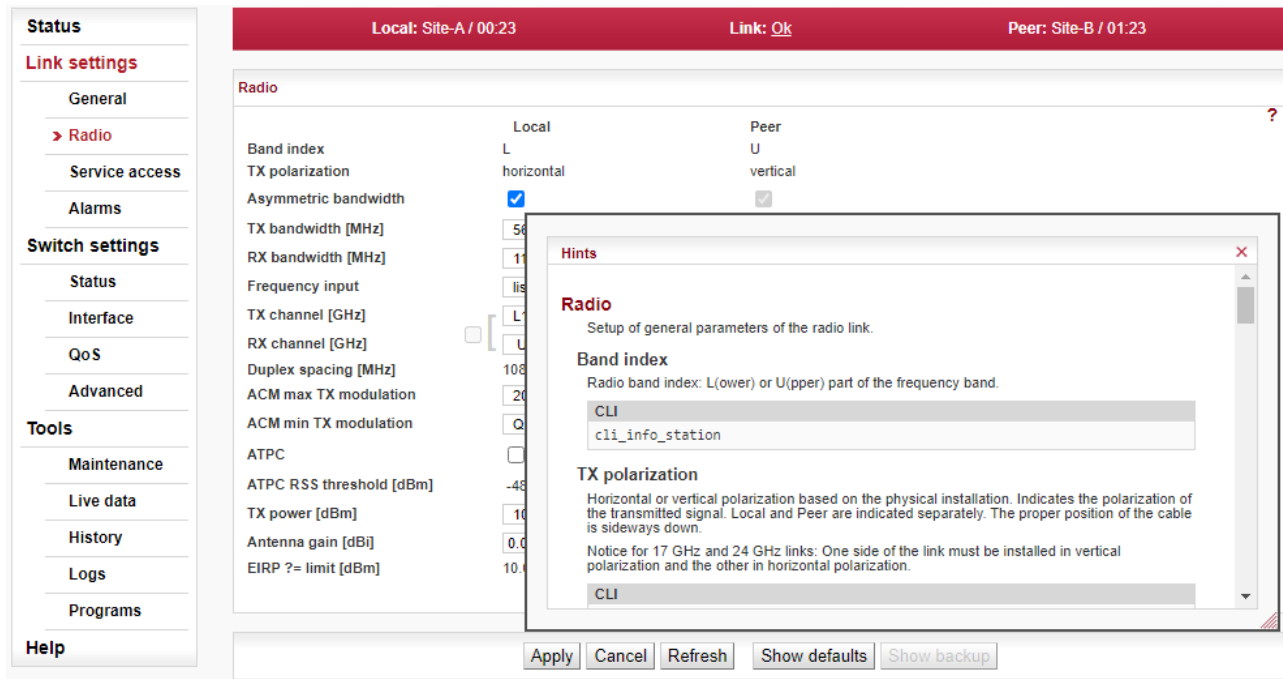
Fig. 5.57: Parameter help

There is a **Go to help** link within the help text. It displays the whole configuration menu help:
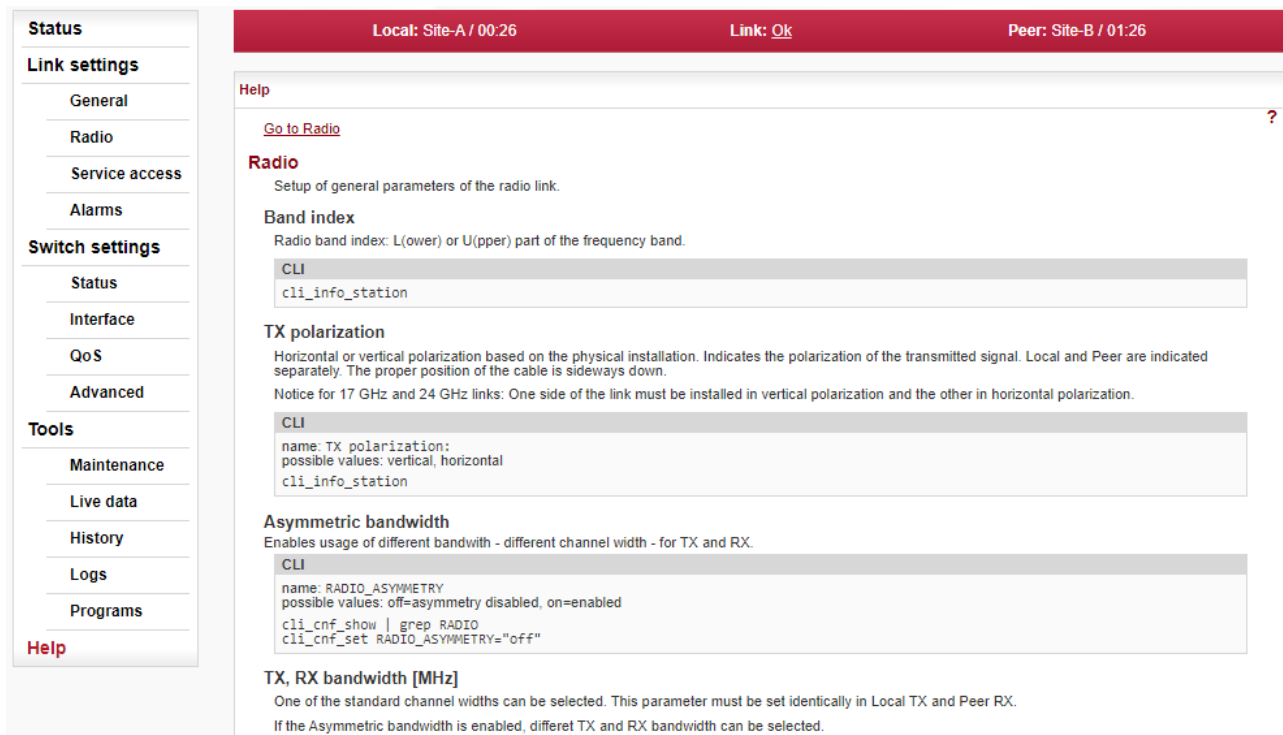
Fig. 5.58: Configuration menu help

There is a link on each help screen which points to the respective configuration screen.

Clicking the **question mark** icon in the upper right corner of the configuration screen brings a summary help for the configuration screen in the pop-up window:

Fig. 5.59: Summary help

The Help window can be moved by dragging the *Hints* bar. Resize it by dragging the bottom corner.

6. Command Line Interface

The Command Line Interface (CLI) provides an alternative to GUI management (HTTP or HTTPS access). CLI allows you to work in a text regime interface using a SSH (PuTTY) or telnet client. For a more detailed description of functions and parameters managed through CLI please consult relevant sections of *Chapter 5, Configuration*.

6.1. Connection via CLI

6.1.1. Telnet

Use the **telnet** client to connect to the unit with service IP address 192.168.169.169. Type this in the command prompt:

```
telnet 192.168.169.169
```

Then use the username and password from the menu `Service access > Users` for HTTPS access (by default `admin, admin`). This works if `Service access > Services > Telnet` is checked in HTTPS access.

6.1.2. PuTTY

Connection using **putty client**. Type this into the Host Name (or IP address) field:

```
admin@192.168.169.169
```

Click Open. Then enter the password `admin`. This procedure (without key) is subject to selection `Service access > Services > SSH` **on** in HTTPS access.

If you own the private key part, then you do not need a password. In PuTTY, continue by selecting `Connection/SSH/Auth` and selecting path to file with key e.g. `key.ppk`. Use `Session > Logging` to save the PuTTY configuration. To access the unit via CLI simply select the connection in PuTTY and click Open.

6.1.3. SSH

Connection using client **ssh** in Linux.
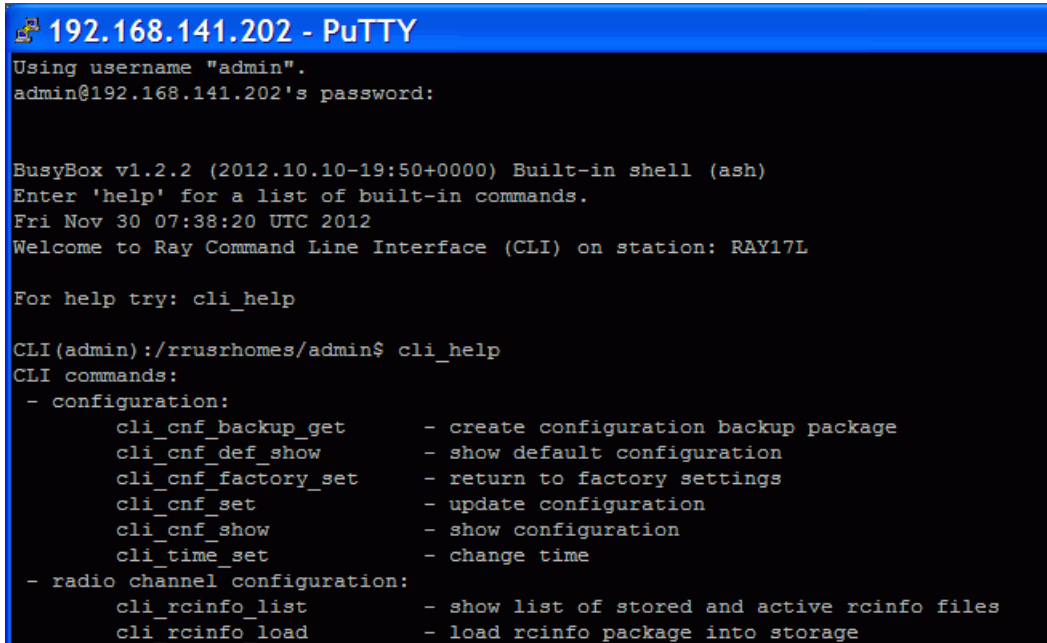
```
ssh admin@192.168.169.169 -i key
```

If you know the password and it is enabled in `Service access > Services > SSH` **onlykey** in HTTPS access, you can skip the key and use password in the next query.

6.2. Working with CLI

- Overview of CLI options

  `cli_help`

Fig. 6.1: CLI menu

- Parameters of CLI commands are listed in the help. For example:

`-h`	help listing
`-t`	target unit
`-t l`	local, default option
`-t b`	both, both units, command item for remote unit has PEER_ prefix
`-t p`	peer, opposite unit, when reading using the show command

- When inserting commands, using the tabulator can help

- An incorrect command is rejected (e.g. inserting forbidden frequency)

- A parameter that caused the loss of the connection is restored after 1 minute (Rollback)

- Reading parameters of local unit
  `cli_cnf_show`

- Reading radio parameters of peer unit
  `cli_cnf_show -t p | grep RADIO`

- Entering parameters (TX power of local unit)
  `cli_cnf_set RADIO_TX_PWR=-3`
  Items of command (RADIO_TX_PWR=) are taken from the list cli_cnf_show

- Entering more parameters in both units
  ```
  cli_cnf_set -t b RADIO_TX_CHAN=17128000 PEER_RADIO_RX_CHAN=17128000
  ```

- Put parameters containing spaces in quotation marks:
  ```
  cli_time_set -t b -T '2012-11-27 10:55:00'
  ```
  Set time in both units

6.2.1. SSH keys

- Generation using ssh-keygen
  ```
  [user@laptop ~]$ ssh-keygen -t dsa -f usr_ssh_key
  ```
  Uses working directory to save private `usr_ssh_key` and public part of the key `usr_ssh_key.pub`

- Copying the key into the RAy unit
  ```
  [user@laptop ~]$ scp usr_ssh_key.pub admin@192.168.141.202:/tmp
  ```
  The public part of the key is written to the folder `/tmp`

- Installation of key in RAy unit
  ```
  CLI(admin):/rrusrhomes/admin$ cli_user_authkey -c a -k /tmp/usr_ssh_key.pub
  ```

- Testing access to RAy unit using SSH key
  ```
  [user@laptop ~]$ ssh -i usr_ssh_key admin@192.168.141.202
  ```

6.2.2. Scripts

- Script example with access using key

```
[user@laptop ~]$ ssh -i usr_ssh_key admin@192.168.141.202
"source /etc/profile;cli_info_link;echo \$?;cli_cnf_show | grep TX_PWR;echo $?"
Warning: Permanently added '192.168.141.202' (DSA) to the list of known hosts.
cli_info_link: Link status: up
0
RADIO_TX_PWR=4
0
[user@laptop ~]$
```

- The script contains:

`source /etc/profile;`	environment settings
`cli_info_link;`	query for link status
`echo \$?;`	reading return value
`cli_cnf_show	grep TX_PWR;`	query for radio power
`echo \$?`	reading return value
`cli_info_link: Link status:up`	return value
`0`	OK command
`RADIO_TX_PWR=4`	power +4 dBm
`0`	OK command

6.3. Configuration with CLI

6.3.1. Configuration file

- Configuration backup
    `cli_cnf_backup_get`
  Saves the configuration of both units to file `cnf_backup.tgz` into the working directory.

- Configuration restore
    `cli_cnf_set -t b -b cnf_backup.tgz`
  Restores configuration of both units from file `cnf_backup.tgz`

- Default configuration list
    `cli_cnf_def_show`
  Warning, the command
    `cli_cnf_factory_set`
  is not a default setting - it uses factory settings, deleting all logs and saved data. It is very likely that the connection to peer unit will be interrupted!

6.3.2. Firmware upgrade

- Current version of fw
    `cli_info_station`

- Preparation of files
  fw package, a file with cpio extension, for example `xxxxxx.cpio` copy using SSH or PuTTY into folder `/tmp` in RAy3-17
  Command
    `cli_fw_clear_buffer`
  Clears the RAy buffer
    `cli_fw_buffer_status`
  Checks buffer status

- Saving into buffers
    `cli_fw_load_package -f /tmp/xxxxxx.cpio`
  A new fw package is loaded into the buffer (20 sec)
    `cli_fw_upload2peer`
  The fw package is also loaded into the peer unit (20 sec)

- Upgrade
    `cli_fw_upgrade -t b`
  Firmware in both units will be replaced with new version from the buffer. After few seconds, this message appears:
    `Firmware upgrade started. Estimated time to finish is 45 s.`
  Connection is terminated. After a minute, log in to RAy again

6.3.3. Remote unit authorization

The RAy unit in default configuration, establishes a connection with any remote unit and both units act as a communication pair. Should the higher protection from the unauthorized communication take-over be required, it is possible to use the so called Secured mode of remote unit authorization. This mode is based on locking the two specific units into one communication pair. Units with Secured mode activated

refuse to make a connection with any other communication unit. The units are locked using the unique authorization keys. The keys are exchanged between the units concerned. The authorization keys can be backed up to an external medium to be able to make a service unit exchange, if necessary. Should the *Link authorization quard* be disabled, the user data occurs even the remote unit is not authorized.

The Secured mode set up process consists of a few steps:

- Unique authorization keys generation:
  ```
  cli_link_key_gen -t b
  ```

- Authorization keys exchange between the two communication units:
  ```
  cli_link_key_swap
  ```

- Authorization keys activation:
  ```
  cli_link_key_apply -t b
  ```
  Parameter `-t` determines whether we configure the whole link (`-t b`) or only one unit (`-t l`).

- Secured mode activation. Both sides of the link must have identically secured mode set On or Off:
  ```
  cli_cnf_set -t b SVC_SECURE_PEER_MODE=on PEER_SVC_SECURE_PEER_MODE=on
  ```

- Secured mode de-activation:
  ```
  cli_cnf_set -t b SVC_SECURE_PEER_MODE=off PEER_SVC_SECURE_PEER_MODE=off
  ```

- Backup of the keys to an external medium. The backup has to be performed to be able to make service exchange of the corrupted unit, if necessary. The new exchanged unit is not able to make an active connection with the other unit if it is not loaded with the proper authorization key.
  ```
  cli_link_key_save -s s -f <file>
  ```
  The key is backed up to a selected file in the internal unit file system. It can be transferred to an external medium using for example the scp client.

- Authorization key restoration from the external medium.
  The key has to be transferred to the unit internal file system first. The scp client can be used. The CLI commands can be applied subsequently:
  ```
  cli_link_key_load -t b -f <file>
  cli_link_key_apply -t b
  ```

6.3.4. Radio loopback

"Radio loopback" function provides indicative measurement of antenna parameter CPI (Cross-Port Isolation). CPI is the ratio between transmitted signals on TX polarization and unwanted signal returned by the antenna on opposite polarization.

- Command
  ```
  cli_rloop
  ```

The Radio loopback command takes 15 seconds. The result is suppression [dB] of the unwanted signal (transmitter to receiver penetration). Radio loopback can only be used with units operating in 17 GHz or 24 GHz band.

Warning

User traffic is interrupted during command execution!

7. RAyTools app for Mobile devices

RAyTools is a stand-alone mobile and tablet application designed to perform all steps of establishing a new link and operate it, especially with link design, antenna alignment, and operation of a link (initially or later during its servicing). Additionally it can be used instead of traditional voltmeter for precise antenna alignment. It is optimised for use on mobile devices with smaller displays and especially in challenging conditions.

RAyTools offers these features:

○ Link Calculation – to calculate RAy link or verify the link budget
○ Antenna Alignment – to align antennas using interactive screen and chart, optionally with acoustic indication, for convenient antenna alignment
○ Link Management – standard web-based unit management

ⓘ **Note**

   If gloves are used it is strongly recommended to activate smartphone option for "work in gloves", which increase the sensitivity of touch screen display (quite common option for modern smartphones).

7.1. App versions & availability

Currently 2 versions of RAyTools app are available:

- **RAyTools ver.2** (available 2017-2023) - supports all RAy2 and RAy3 units. The link calculator knows all antennas offered or supported by RACOM until year 2021. The app is available for old versions of Android and iOS and it is not maintained by RACOM anymore. So it is expected that it will be phased out from GooglePlay and AppStore during year 2023 or soon after.
- **RAyTools ver.3** (available since 6/2023) - supports RAy3 units only. The link calculator knows all antennas offered or supported by RACOM until today. The app is available for Android (version 10 and higher), iOS (version 15 and higher), iPadOS (version 15 and higher) and MacOS Ventura or later using Apple Silicon.
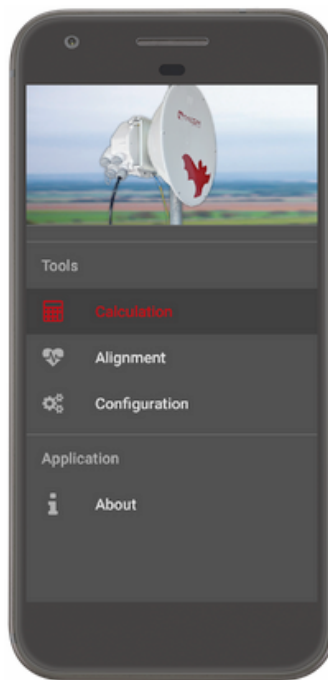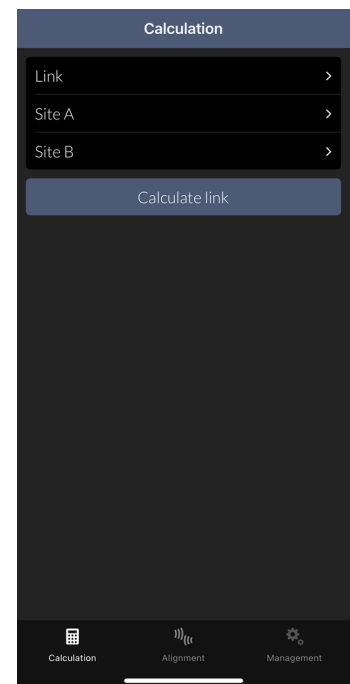
RAyTools ver.2   RAyTools ver.3

ⓘ **Note**

   Users with RAyTools ver.2 installed on their devices may continue using it and the app remains fully functional. It can be installed in parallel with RAyTools ver.3 and both will be fully functional with any RAy unit which meets all HW+FW requirements specified in following section. New version just provides better experience and ensures compatibility with future RAy products.

7.2. RAy FW requirements

Each version of RAyTools app has a different FW requirements:

- **RAyTools ver.2** supports both RAy2 and RAy3 units. In the case of RAy2 the firmware version 2.1.28.0 or later is required for antenna alignment, while on RAy3 any FW version is OK.
- **RAyTools ver.3** supports RAy3 units only. In the case of RAy3-80 unit the minimum firmware version for antenna alignment is 1.1.2.0, for all other bands the minimum firmware version is 2.0.11.0.

(i) Note

For units with firmware version lower than defined above a legacy tool at *http://172.17.17.17/tk* can be used. This legacy tool is provided on the RAy WiFi interface by any RAy3 unit and all RAy2 units with FW 2.1.28.0 or later. For its description see *Section 5.6.2.2, "Antenna Alignment Tool"*. We recommend updating FW soon and to use RAyTools ver.3.

7.3. WiFi requirements

Antenna Alignment and Link Management functions require a WiFi connection to the RAy unit. It needs to be established by the user before those 2 features can be used.

RAy WiFi network name is "RAy Code + RAy Serial Number" (for example "RAy3-24-1234567890"). RAy unit does not provide Internet Access to the smartphone or tablet, so the user has to accept "No Internet access" message once a WiFi connection to RAy is established. See *Chapter 8, Troubleshooting* if problem with WiFi connection occurs.

(i) Note

WiFi on the RAy unit is active only if RAy WiFi module is present and its functionality is allowed in RAy management (permanently or only during air link loss). For WiFi module see *Section 1.4.2, "Service WiFi - optional (using USB „S")"*, for WiFi setup see *Section 5.4.3.2, "USB accessories"*.

Every RAy3 shipped from the factory is equipped by a WiFi module and the WiFi is allowed with no password (one should be set immediately by the user, otherwise the WiFi alarm is activated - see instructions in *Section 5.4.3.2, "USB accessories"*).

RAy2 units were shipped from the factory without any WiFi module, so it has to be purchased from RACOM and activated before any connection between RAy2 unit and RAyTools application may be established.

7.4. Functions RAyTools ver.2

7.4.1. Calculation

Can be used in conjunction with all RA-COM microwave products and compatible antennas. Available parameters to input that affect link budget are:
- Modulation
- Throughput
- TX Power
- Link distance
- Antenna specifications

RAyTools calculation outputs are:
- Free Space Loss (FSL)
- 1st Fresnel Zone radius
- RSS
- Sensitivity
- Fade margin (shown to be acceptable/marginal/inadequate)
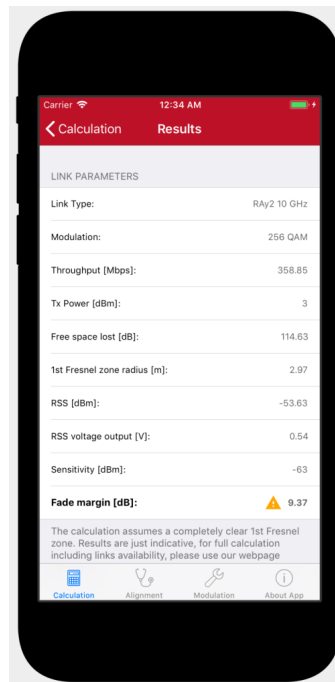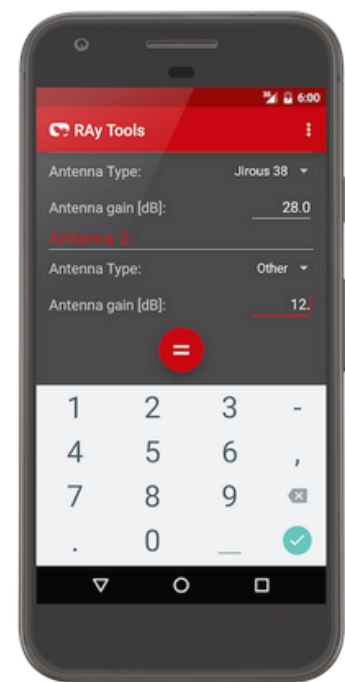
iOS version   Android version

The calculation assumes a clear line of sight and makes no allowance for precipitation. A more accurate calculation can be performed using the tool available on RACOM web pages (see *https://www.racom.eu/eng/products/microwave-link.html#calculation*). Precise link calculation should be performed using dedicated tools (e.g. Pathloss).

7.4.2. Alignment

This function behaves like a digital voltmeter with values in dBm (instead of Volts). When activated, the biggest number on the display (the main value) is RSS dBm value (with 0.1 dBm precision), refreshed 10x per second.

Smaller 4 lines in lower part of the display show 4 key metrics (local RSS and MSE and once the link is established also remote RSS and remote MSE) and their best values (in right column). Any of those can be chosen to become the main one (the biggest number on the display), just by taping on it by a finger.

Additionally the sound can be switched on. Then tones or pulses related to the main value are produced, with coarse or fine sensitivity (coarse at the beginning, fine for fine tuning). Additionally every 5 seconds the current value is told in English, so the absolute value of main parameter could be heard even without looking to the display. The sound can be used with a big advantage in situations, when both hands are needed and the mobile has to be in the pocket (in such a case Bluetooth ears are the best choice).
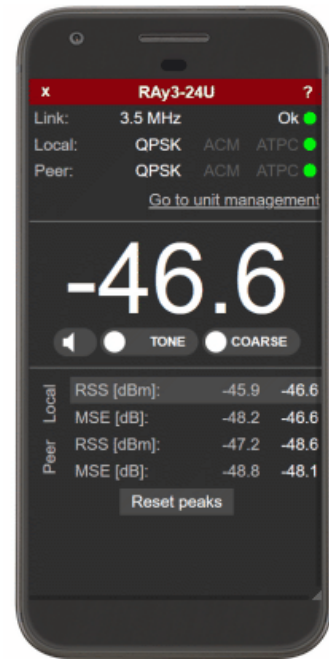
Antenna Alignment Tool is accessed using this menu. See Section *5.6.2 Live data* for detailed description.

ⓘ **Note**

This function works only if WiFi connection with RAy unit is established.

7.4.3. Configuration

Links to web management of RAy unit as described in *Chapter 5, Configuration*. User authentication is required.
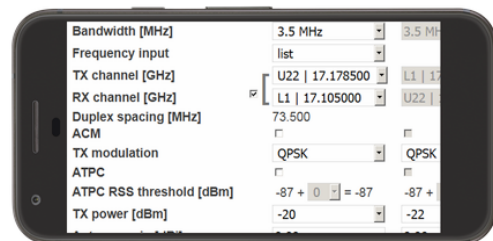
ⓘ **Note**

This function works only if WiFi connection with RAy unit is established.

7.4.4. About

This item shows the application version and its Release notes.

7.5. Functions RAyTools ver.3

In this RAyTools version all functions, user screens and their interaction with the user are identical for both mobile operating systems supported (Android and iOS).

7.5.1. Calculation

The app link calculation feature offers similar detail and a calculator precision as our web-based *Calculation tool*[1]. It supports all RAy links and RACOM-provided antennas. User can choose either precise calculation using two sites including height profile or general calculation which only requires general location of the link to assess weather impact.

For precise calculation, user inputs following parameters:
• Band
• Channel spacing
• Modulation
• Tx power

And following Site A and B parameters:
• Antenna type
• Antenna gain
• Antenna height
• Location (Latitude, Longitude, Altitude)

General calculation only requires antenna type and gain, link distance and general link location.

It is possible to use the device GNSS to locate the place. Please note, that it may require the user to allow RAyTools app to use of GNSS (GPS).

After tapping on 'Calculate link' the app displays a window with terrain overview, link parameters and total availability with and without ACM and details about calculation parameters.

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[1] https://www.racom.eu/eng/products/microwave-link.html#calculation
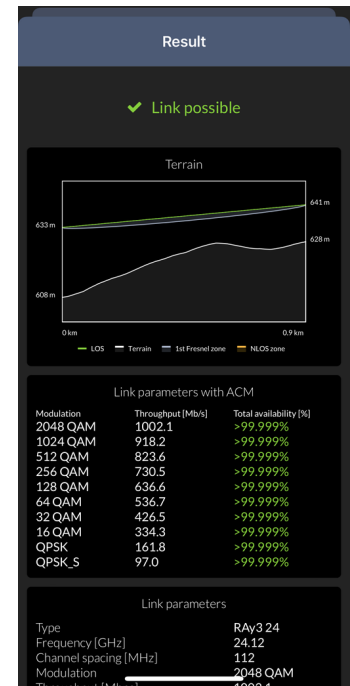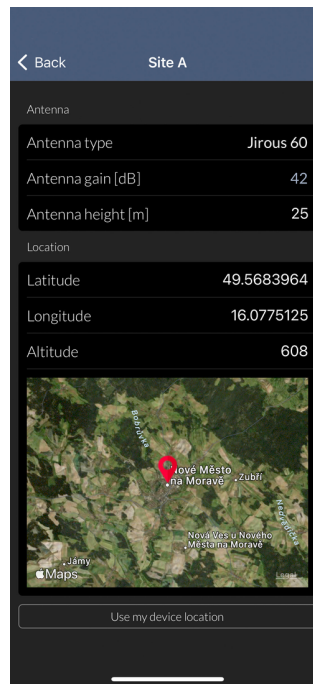
7.5.2. Alignment

This function allows voltmeter-free antenna alignment. It behaves like a digital voltmeter with values in dBm (instead of Volts). When activated, the biggest number on the display (the main value) is Local RSS dBm value (with 0,1 dBm precision), refreshed 10x per second.

The app provides additional real-time valuable information which speeds up antenna alignment and ensures the best possible result:
- The real-time RSS chart is plotted (simplifying differentiation between main and side lobes).
- Local RSS and MSE peak and live values
- Pear RSS and MSE peak and live values (once the link is established)
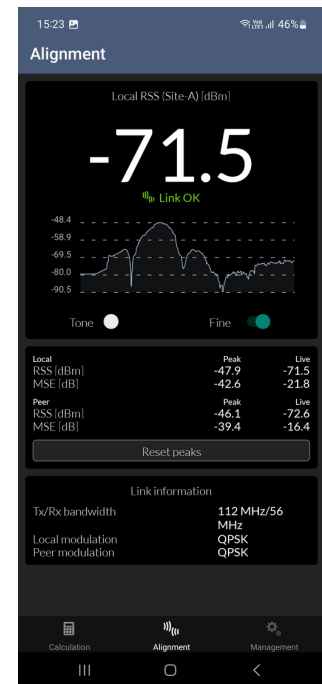
User can also activate "Tone" feature to align without looking at the display just by hearing app audio feedback. The sound can be used with a big advantage in situations, when both hands are needed and the mobile has to be in the pocket (in such case Bluetooth ears are the best choice).

"Fine" feature switches chart to more detailed one for fine alignment.

The app notifies user in case unit settings are not suitable for alignment.

(i) Note

This function works only if WiFi connection with RAy unit is established.

7.5.3. Management

Allows access to standard web admin interface of the RAy unit directly connected to the tablet or smartphone by WiFi. User authentication is required. Management of RAy unit is described in *Chapter 5, Configuration*.

ⓘ **Note**

This function works only if WiFi connection with RAy unit is established.
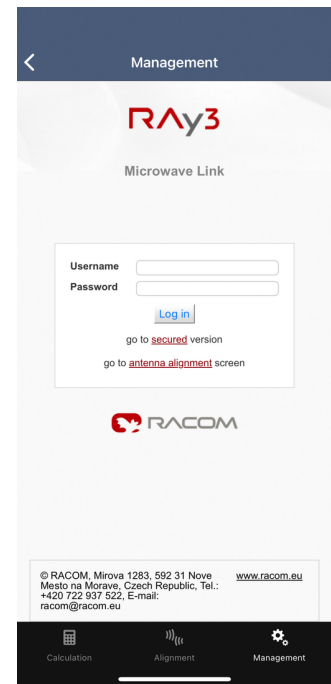
7.6. Application availability

Both versions of RAyTools application are available for mobile operating systems Android (Google compatible devices) and iOS (Apple devices). All display sizes are supported on both operating systems.

Android version can be downloaded from Google Play (*https://play.google.com/store*), iOS version is available for download on AppStore (*https://www.apple.com/ios/app-store*) or their local versions.

Fig. 7.1: RAyTools v.2 icon   Fig. 7.2: RAyTools v.3 icon

ⓘ **Note**

RAyTools ver.2 application was designed for older versions of Android and iOS operating systems. So it may be phased out from GooglePlay and AppStore anytime.

RAyTools ver.2 application contains an automatic crash report feature; Firebase tool is used to report the crash. Any data transmitted is for the exclusive use of RACOM developers to analyze the problem. It will not be used in any other way by Apple, Google, Firebase or RACOM. For more info see *RACOM Privacy policy*[2] on our web.

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[2] https://www.racom.eu/eng/about_us/privacy-policy

7.7. Feedback to RACOM

Any feedback for this application is welcome. Please contact RACOM *standard technical support*[3] both for feedback submission and/or reporting of any issues.

We would also like to hear from any who would like to become a beta tester of upcoming versions of RAyTools.

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[3] https://www.racom.eu/eng/support/request.html

8. Troubleshooting

• **LED on powered unit does not shine**

Please check the power supply voltage and Watts and please count with losses on the wires (long wires or low quality Eth cable can consume significant power).
Each unit has to be powered by adequate power supply with voltage in the proper range (as stated in datasheet or in *Chapter 9, Technical parameters* or on *Product label* on each unit housing). Power supply has to be able to deliver enough power (Ampers and Watts) for the unit.
The voltage level is checked before system boot. If the voltage is below 21 V, the unit LED does not shine at all and no boot is performed.
For units with minimum input voltage 37 V (like RAy3-18 or RAy3-80) may happen that unit shines red for first 15 seconds after powering and then LED gets dark. It means input voltage is in the range 21-37 V. (Note: management interface indicates that as well.)

• **LED on powered unit shines other colors than just green**

The unit operating the wireless link OK should shine just green. The only exception is during the unit boot (when LED is red) and during establishing the wireless link with the unit on the other end (when LED blinks green).
For a resolution of the system status and the reason of the different LED colors (including any kind of red blinking) see *Section 1.5, "Status LED (S)"*.

• **Polarization incorrect**

Units RAy3-17 and RAy3-24 must be mounted with opposite polarization; one with TX horizontal polarization (horizontal arrow) and the second with TX vertical polarization (vertical arrow). See *Cross polarization* for more info.
Install the unit with the correct *horizontal* or *vertical* polarization: The arrow mark indicates the unit TX polarization. When the arrows heading perpendicular to the earth, the unit transmits a signal in vertical polarization. When the arrow is heading parallel to the earth, the unit transmits a signal in horizontal polarization. The connectors must point downward at an angle.

• **The link cannot be established**

Double check the correct polarization (see above) of both units on the link.
Double check the correct compatibility settings for both units on the link. For more info see *Section 5.6.1.4, "Radio adaptation"* and Troubleshooting topic *Setting up a link between RAy3-24S and other hardware variant of RAy3-24* (see below in this chapter).
Start with the most "resilient" configuration. This configuration depends on the variant of unit. We recommend using the maximum available output power, the narrowest available bandwidth (e.g. 3.5 or 5 MHz, respectively 250 MHz in the case of 80 GHz unit), the lowest modulation level (QPSK_S respectively 2PSK_BW/4_S in the case of 80 GHz unit ensured by setting both parameters *'ACM/ACMB max TX modulation"* and *'ACM/ACMB min TX modulation'* to such value on both units). TX and RX channels must be the same as the RX and TX channels in the remote unit. When the connection has been established and the antennas have been directed, proceed with operation parameters.

• **RSS and Antenna alignment**

To configure the link and monitor its state, several menus display the RSS signal strength (most interactive are pages *Live Data > Bar indicators* or *Antenna Alignment Tool*). Additionally RSS can be monitored by a voltmeter connected to *RSS voltage contacts* or by RACOM smartphone application *RAyTools* on a mobile phone connected to *RAy WiFi*.

(i) **Note**

Please keep in mind, that RAy is not a measuring instrument, hence the precision of the RSS reading is limited. Though, in most situations the RSS reading accuracy is better than ± 2dB, the absolute RSS value should not be used for accurate comparisons e.g. between two links.

- **Ethernet Buffers are small**

To optimize the total buffer size of RAy radio (by optimizing a cooperation between Ethernet switch buffer and a buffer inside modem chip) it is required to set 'Flow Control receive' for port 'Air (p9)' (in menu *Switch settings > Interface > Port*) on both units to be 'on'. With latest FW versions this parameter cannot be edited in web interface (CLI still allows that), so the change to the proper state can be achieved in web interface only by applying unit defaults (followed by manual settings of other parameters in this page, if needed). See *Chapter 6, Command Line Interface*.

(i) **Note**

Correct Flow Control setting typically increases operational speed of the link for mixed traffic, where bigger capacity of buffers helps to optimize the link performance.

Additional link performance and better utilization of all available buffers in transmitting network could be typically achieved by configuring Flow Control also between each MW unit and the nearest switch feeding the link by data. For more info see Port setup in *Section 5.5.2, "Interface"*.

- **Ethernet throughput far below published RFC2544 numbers**

In the case when Ethernet throughput of the link is far below expectations based on *published Ethernet speeds* measured according RFC2544, one of the reasons may be wrong settings for a cooperation between Ethernet buffers insideRAy unit and between RAy unit (Ethernet switch inside the unit) and outside network (Ethernet switches and routers RAy is connected to).
To ensure buffers inside RAy unit are cooperating optimally please double-check 'Flow Control Receive' parameter for port 'Air (p9)' (in menu *Switch settings > Interface > Port*) - it should be 'on' for both units. (Units produced with initial FW 1.0.16.0 and later solve that automatically, so there is no need to manually set the parameter).

- **Access to the Local unit is blocked**

Access to the Local unit may be accidentally blocked, for instance by disabling HTTPS access. If you can access the Remote unit over HTTPS, type its address in your web browser's address field. The link will transfer the packet over the Local unit with blocked service access all the way to the Remote unit, which will give you access to the control menus of both units. Warning, the Remote unit will report as Local.

- **Distinguishing Local-Remote**

A unit accessed via service access always reports as Local. If you connect through another (peer) unit and radio channel, a certain amount of caution is necessary. For example, do not reduce the transmission power so that the link interrupts accidentally. Errors of this type should be fixed by the rollback function within approx. 1 minute.

Resolution can be done by comparing the length of ping on Local and Remote. Pinging the unit behind the radio channel is slower. The difference is more pronounced in the case of a long packet and the low speed of the radio channel.

- **Access security**

  For better protection against unauthorised access to configuration you should only allow as few kinds of access as possible. The most secure type is SSH with key – leave only SSH active with "only key" choice.

- **Problem with HTTPS certificate**

  First login into the unit management typically requires to accept web browser warning about self-signed HTTPS certificate. The issue may occur if a list of trusted HTTPS certificates stored by your web browser already contains a record for a network element with identical IP address or network name as the current unit management interface. In this case, the trusted HTTPS certificates for the particular network element in your web browser needs to be manually erased. After that self-signed certificate of the unit can be accepted.
  Fast workaround: Try to use a different web browser or use HTTP connection instead (should be no issue in private network).

- **Overexcited receiver**

  A natural property of each radio receiver is to compress the signal in one of the functional blocks, when the signal level gets out of the AGC (automatic gain control) dynamic range. The result of this effect is non-linear distortion of the received signal which is observed as decrease in the signal to noise ratio, i.e. in case of digital modulations increase of the Mean Square Error (MSE).
  Limit for guaranteed functionality of RAy3 radio receiver is -15 dBm (measured on the waveguide input). This limit applies for all channel bandwidths and all modulations.
  Beyond this limit the distortion of linearity appears and signal quality is depreciated. In extreme cases, this can lead to the disintegration of the radio link due to reduced signal to noise ratio (as a result of signal distortion).

- **ACM or ACMB does not respect parameter 'ACM/ACMB min TX modulation'**

  This parameter requires an identical value on both sides of the link. On the established link this is ensured by FW, but for not linked (standalone) units such an equation has to be set manually before linking, otherwise the link may be not established or if established, the value set at parameters 'ACM/ACMB min TX modulation' is not respected.
  The solution is to manually reconfigure parameter 'ACM/ACMB min TX modulation' at least on one end of a link to the value identical with the other end.

- **Setting up a link between RAy3-24S and other hardware variant of RAy3-24**

  Sometime it is necessary to set up a link from a legacy unit RAy3-24S and some newly deployed hardware variant of RAy3-24 unit (like RAy3-24X) - for example after exchange of failed unit on one end of the link (for an explanation of hardware variants '24S', '24X', '24E' and other see *Section 1.7, "Ordering codes"*).
  Then it is necessary to configure newly deployed unit to behave like unit variant 'S' (legacy model). To achieve that the parameter 'Unit 24S compatibility' (in menu *Tools > Maintenance > Radio adaptation*) has to be set to 'active'.

(i) Note

Wrong setting of compatibility causes the link is not established (both units remain in status 'Connecting').

Unit with FW version 1.0.14.0 with activated 'Unit S mode' (identical with 'Unit 24S compatibility' in later FW versions) requires to manually set RX FlowControl for port 'Air (p9)' (in menu Switch settings / Interface / Port) to the value 'auto'. On FW version 1.0.16.0 it is recommended to set this parameter to 'on'. In later FW versions it is enough to manually apply default values of FlowControl parameters.

• **RAyTools smartphone disconnects from RAy unit**

Most smartphones and tablets (on both platforms, i.e. Android + iOS) require by default WiFi with Internet access. If it is not avilable (like at WiFi on RAy unit), they automatically disconects from such WiFi and start to search for alternative WiFi network with Internet (even if user accepts the WiFi network mesage "No Internet access" during connecting to RAy). This automatic behavior has to be switched off in smartphone or tablet management (typically this feature is "ON" as a default).

9. Technical parameters

Tab. 9.1: Parameters 10 GHz

RAy3-10	General parameters			ver. 3.4
Type	**RAy3-10**			
Radio				
Frequency range	10.125 – 10.675 GHz			
	Lower	Upper	Lower	Upper
Sub-band A	10.301 – 10.420	10.476 – 10.588	-	-
Sub-band B	-	-	10.125 – 10.325	10.475 – 10.675
Sub-band notes	Free-band in CZ		Global licensed band	
Type of duplex traffic	FDD (Frequency division duplex)			
Speed (each direction)	2.8 – 1014 Mb/s, *see details*			
Channel bandwidth	3.5, 7, 14, 28, 56, 84, 112 MHz		3.5, 7, 10, 14, 20, 28, 56, 112 MHz	
Duplex spacing	flexible, min. 58 MHz, typ. 168 MHz, max. 285 MHz		350 MHz	
Modulations	QPSK, 16QAM, 32QAM, 64QAM, 128QAM, 256QAM, 512QAM, 1024QAM, 2048QAM, 4096QAM			
ACM	Hitless - through all modulations including stronger FEC [1]			
Asymmetry of TX/RX speeds	Yes (all combinations of available Bandwidths & Modulations supported)			
FEC	LDPC			
Sensitivity, BER 10^{-6}	-100.5 dBm (4.1 Mb/s); -50.5 dBm (1014 Mb/s), *see details*			
Receiver dynamics (RSS range)	-100 to -30 dBm			
Precision of RSS measurement	±2 dB			
RF Output Power	-15 to +13 dBm (QPSK) -15 to +10 dBm (QAM modulations)		-15 to +15 dBm (preliminary)	
Precision of RF Output power setting	±1 dB			
ATPC	Yes (range up to 30 dB)			
Noise figure	3 dB (typ.)			
Ethernet (user data & management)				
RJ45	1 Gb Eth. 10/100/1000BASE-T Auto MDI/MDIX			
SFP (user exchangeable)	2.5 Gb Eth. SFP slot 10/100/1000/2500BASE-T; 1000BASE-SX; 1000BASE-LX (power max. 1.3 W)			
Throughput L2 (RFC 2544)	Up to 1001 Mb/s @ 2.5 Gb Eth. interface, *see details*			
Latency L2 (RFC 2544, one way)	150 µs (66 B / 352 Mb/s); <200 µs (1518 B / 352 Mb/s); <100 µs (66 B / 1010 Mb/s); <150 µs (1518 B / 1010 Mb/s)			

RAy3-10	General parameters	ver. 3.4
Type	**RAy3-10**	
MTU (max. packet length)	10240 Bytes	
Synchronization	Synchronous Ethernet; PTP (transparent for IEEE-1588v2)	
Electrical		
Primary power	PoE active IEEE 802.3bt (POE++) PoE passive 20 – 60 VDC DC 20 – 60 VDC floating	
Power consumption (typ.)	26.5 W max. 28 W (with SFP)	
System interfaces		
USB	USB 2.0, Host A; USB / WiFi; USB / ETH	
WiFi	Mini WiFi 2.4 GHz b/g/n in USB slot (only for Alignment, Management & Diagnostics) - included in basic configuration	
Ethernet	USB/Eth adapter in USB slot (only for Alignment, Management & Diagnostics) - optional	
RSS voltage	Two contact sockets	
Indication LED	System status (multicolor)	
System button	Default settings, Configuration restore from internal backup	
Environmental		
Ingress Protection	IP66	
MTBF (Mean Time Between Failure)	> 1.000.000 hours (> 114 years)	
Operating temperature	-30 to +55 °C (ETSI EN 300019-1-4, class 4.1.)	
Operating humidity	15 – 100 %	
Storage humidity	5 – 95 % non-condensing	
Surge immunity	4 kV (EN 61000-4-5)	
ESD resistance	8 kV (EN 61000-4-2)	
Mechanical		
Design & Mounting	FOD (Full Outdoor), direct mounting to antenna	
Unit types	Specific units for each Sub-band and for Lower (L) and Upper (U) part of the band	
Casing	Rugged die-cast aluminum, compatible with RAy1 and RAy2	
Size	H×W×D: 160×245×245 mm (6.3×9.6×9.6 in)	
Weight	2.8 kg (6.2 lbs)	
Antenna	Class 3, 0.3 – 1.8 m, direct mounting (Jirous or LEAX/Arkivator or Shenglu or others)	
Diagnostics & Monitoring		
Real time monitoring	RSS, MSE, BER	
Diagnostic tools	Spectrum analyzer, Pinger	

RAy3-10	General parameters	ver. 3.4
Type	**RAy3-10**	
History charts	Temperature, Power voltage, RSS, MSE, BER, Data rate, RF Output power	
Statistics	RMON counters for all interfaces	
Antenna alignment	RSS voltage, Smartphone app (RAyTools), Web	
SNMP	SNMP v2c including configurable TRAPs	
Security		
Management	Web (HTTP, HTTPS), CLI (SSH, Telnet), Smartphone app (RAyTools)	
Access accounts	3 levels (Guest, Admin, Super)	
WiFi	passphrase; HW/SW enable/disable; active only during air-link loss	
Encryption	AES 128, 192, 256 [2]	
Standards		
Approvals	CE (RED), RoHS	CE (RED), RoHS
Spectrum	EN 302 2017 V3.1.1	
EMC	EN 301 489-1 V2.2.3 EN 301 489-3 V2.1.1 EN 301 489-4 V3.3.1	
Safety	EN 62368-1:2020 + A11:2020	
FCC	-	
IC	-	

[1] Stability optimized (stronger) FEC

[2] Encryption is prohibited in Variant 'N'

Tab. 9.2: Parameters 11/18 GHz

RAy3-11/18	General parameters			ver. 3.3
Type	**RAy3-11**		**RAy3-18**	
Radio				
Frequency range	10.7 – 11.7 GHz		17.700 – 19.700 GHz	
	Lower	Upper	Lower	Upper
Sub-band A	10.695 - 10.989	11.199 - 11.491	17.700 – 18.209	18.710 – 19.219
Sub-band B	10.905 - 11.195	11.395 - 11.699	18.167 – 18.690	19.177 – 19.700
Sub-band C	-	-	17.700 – 18.300	19.300 – 19.700
Type of duplex traffic	FDD (Frequency division duplex)			
Speed (each direction)	4.1 – 2026 Mb/s, *see details*		2.8 – 1014 Mb/s, *see details*; 2.8 – 2026 [3] Mb/s,	
Channel bandwidth	5, 7, 10, 14, 20, 28, 30, 40, 56, 60, 80, 100, 112 MHz		Sub-bands A, B (ETSI): 5, 7, 7.5, 13.75, 27.5, 55, 110 MHz; Sub-band C (FCC): 5, 10, 20, 30, 40, 50, 60, 80, 100, 110 MHz	
Dual Channel	2× 60; 2× 80; 2× 112 MHz		up to 2× 110 MHz [3]	
Duplex spacing	typ. 490 MHz (ETSI) or 530 MHz (rest of the world)		Sub-bands A, B (ETSI): 1008, 1010 MHz; Sub-band C (FCC): 1560 MHz	
Modulations	QPSK, 16QAM, 32QAM, 64QAM, 128QAM, 256QAM, 512QAM, 1024QAM, 2048QAM, 4096QAM			
ACM	Hitless - through all modulations including stronger FEC [1]			
Asymmetry of TX/RX speeds	Yes (all combinations of available Bandwidths [3] & Modulations supported)			
FEC	LDPC			
Sensitivity, BER 10^{-6}	-100.5 dBm (4.1 Mb/s) -51 dBm (2026 Mb/s) *see details*		-101.5 dBm (2.8 Mb/s) -49.5 dBm (1014 Mb/s) *see details*	
Receiver dynamics (RSS range)	-100 to -30 dBm			
Precision of RSS measurement	±2 dB			
RF Output Power (all modulations)	-1 to +24 dBm (7 - 112 MHz channels) -1 to +23 dBm (5 MHz channel) -1 to +18 dBm (Dual channels)		-1 to +23 dBm (all channels)	
Precision of RF Output power setting	±1 dB			
ATPC	Yes (range 24 dB)			
Noise figure	3 dB (typ.)			
Ethernet (user data & management)				
RJ45	1 Gb Eth. 10/100/1000BASE-T Auto MDI/MDIX			

RAy3-11/18	General parameters	ver. 3.3
Type	**RAy3-11**	**RAy3-18**
SFP (user exchangeable)	2.5 Gb Eth. SFP slot 10/100/1000/2500BASE-T; 1000BASE-SX; 1000BASE-LX (power max. 1.3 W)	
Throughput L2 (RFC 2544)	Up to 1001 Mb/s @ 2.5 Gb Eth. interface; with Dual Channel up to 2 Gb/s @ 2.5 Gb Eth, *see details*	Up to 1001 Mb/s @ 2.5 Gb Eth. interface, *see details*
Latency L2 (RFC 2544, one way)	150 µs (66 B / 352 Mb/s); <200 µs (1518 B / 352 Mb/s); <100 µs (66 B / 1014 Mb/s); <150 µs (1518 B / 1014 Mb/s)	
MTU (max. packet length)	10240 Bytes	
Synchronization	Synchronous Ethernet; PTP (transparent for IEEE-1588v2)	
Electrical		
Primary power	PoE active IEEE 802.3bt (POE++) PoE passive 37 – 60 VDC DC 37 – 60 VDC floating	
Power consumption (typ.)	30 W for TX ≤ +17 dBm up to 33 W for TX = +23 dBm max. 35 W (with SFP)	
System interfaces		
USB	USB 2.0, Host A; USB / WiFi; USB / ETH	
WiFi	Mini WiFi 2.4 GHz b/g/n in USB slot (only for Alignment, Management & Diagnostics) - included in basic configuration	
Ethernet	USB/Eth adapter in USB slot (only for Alignment, Management & Diagnostics) - optional	
RSS voltage	Two contact sockets	
Indication LED	System status (multicolor)	
System button	Default settings, Configuration restore from internal backup	
Environmental		
Ingress Protection	IP66	
MTBF (Mean Time Between Failure)	> 1.000.000 hours (> 114 years)	
Operating temperature	-30 to +55 °C (ETSI EN 300019-1-4, class 4.1.)	
Operating humidity	15 – 100 %	
Storage humidity	5 – 95 % non-condensing	
Surge immunity	4 kV (EN 61000-4-5)	
ESD resistance	8 kV (EN 61000-4-2)	
Mechanical		
Design & Mounting	FOD (Full Outdoor), direct mounting to antenna	
Unit types	Specific units for each Sub-band and for Lower (L) and Upper (U) part of the band	
Casing	Rugged die-cast aluminum, compatible with RAy1 and RAy2	

RAy3-11/18	General parameters		ver. 3.3
Type	**RAy3-11**		**RAy3-18**
Size	H×W×D: 160×245×245 mm (6.3×9.6×9.6 in)		
Weight	2.9 kg (6.4 lbs)		
Antenna	Class 3, 0.3 – 1.8 m, direct mounting (Jirous or LEAX/Arkivator or Shenglu or others)		
Diagnostics & Monitoring			
Real time monitoring	RSS, MSE, BER		
Diagnostic tools	Spectrum analyzer, Pinger		
History charts	Temperature, Power voltage, RSS, MSE, BER, Data rate, RF Output power		
Statistics	RMON counters for all interfaces		
Antenna alignment	RSS voltage, Smartphone app (RAyTools), Web		
SNMP	SNMP v2c including configurable TRAPs		
Security			
Management	Web (HTTP, HTTPS), CLI (SSH, Telnet), Smartphone app (RAyTools)		
Access accounts	3 levels (Guest, Admin, Super)		
WiFi	passphrase; HW/SW enable/disable; active only during air-link loss		
Encryption	AES 128, 192, 256 [2]		
Standards			
Approvals	CE (RED), RoHS, FCC , IC		CE (RED), RoHS, FCC, IC
Spectrum	EN 302 2017 V3.1.1		
EMC	EN 301 489-1 V2.2.3 EN 301 489-3 V2.1.1 EN 301 489-4 V3.3.1		
Safety	EN 62368-1:2020 + A11:2020		
FCC	FCC part 101		FCC part 101
IC			compliant

[1] Stability optimized (stronger) FEC

[2] Encryption is prohibited in Variant 'N'

[3] Pending

Tab. 9.3: Parameters 17/24 GHz

RAy3-17/24	General parameters		ver. 2.3
Type	**RAy3-17**		**RAy3-24**
Radio			
Frequency range	17.10 – 17.30 GHz		24.00 – 24.25 GHz
Type of duplex traffic	FDD (Frequency division duplex)		
Speed (each direction)	2.6 – 1012 Mb/s, *see details*		
Channel bandwidth	3.5, 5, 7, 10, 14, 20, 28, 40, 56, 80, 100, 112 MHz		
Duplex spacing	Flexible, min. 24 MHz between channel edges or 18 MHz in case of 2× 112 MHz Channel		
Modulations	QPSK, 16QAM, 32QAM, 64QAM, 128QAM, 256QAM, 512QAM, 1024QAM, 2048QAM, 4096QAM		
ACM	Hitless - through all modulations including stronger FEC [1]		
Asymmetry of TX/RX speeds	Yes (all combinations of Bandwidths & Modulations supported)		
FEC	LDPC, RS		
Sensitivity, BER 10^{-6}	-100.5 dBm (2.6 Mb/s) -54.0 dBm (1012 Mb/s) *see details*		
Receiver dynamics (RSS range)	-100 to -30 dBm		
Precision of RSS measurement	±2 dB		
RF Output Power	-30 to +10 dBm		-30 to +10 dBm (-30 to -15 dBm) [2]
Precision of RF Output power setting	±1 dB		
ATPC	Yes (range 40 dB)		
Noise figure	3 dB (typ.)		
Ethernet (user data & management)			
RJ45	1 Gb Eth. 10/100/1000BASE-T Auto MDI/MDIX		
SFP (user exchangeable)	2.5 Gb Eth. SFP slot 10/100/1000/2500BASE-T; 1000BASE-SX; 1000BASE-LX (power max. 1.3 W)		
Throughput L2 (RFC 2544)	Up to 999 Mb/s @ 2.5 Gb Eth. interface, *see details*		
Latency L2 (RFC 2544, one way)	268 µs (64 B, 366 Mb/s); 313 µs (1518 B, 366 Mb/s); 173 µs (64 B, 1002 Mb/s); 198 µs (1518 B, 1002 Mb/s)		
MTU (max. packet length)	10240 Bytes [3]		
Synchronization	Synchronous Ethernet; PTP (transparent for IEEE-1588v2)		
Electrical			

RAy3-17/24	General parameters	ver. 2.3
Type	**RAy3-17**	**RAy3-24**
Primary power	PoE active IEEE 802.3at (POE+) PoE passive 20 – 60 VDC DC 20 – 60 VDC floating	
Power consumption (typ.)	22.5 W max. 25 W (with SFP)	
System interfaces		
USB	USB 2.0, Host A; USB / WiFi; USB / ETH	
WiFi	Mini WiFi 2.4 GHz b/g/n in USB slot (only for Alignment, Management & Diagnostics) - included in basic configuration	
Ethernet	USB/Eth adapter in USB slot (only for Alignment, Management & Diagnostics) - optional	
RSS voltage	Two contact sockets	
Indication LED	System status (multicolor)	
System button	Default settings, Configuration restore from internal backup	
Environmental		
Ingress Protection	IP66	
MTBF (Mean Time Between Failure)	> 1.000.000 hours (> 114 years)	
Operating temperature	-30 to +55 °C (ETSI EN 300019-1-4, class 4.1.)	
Operating humidity	15 – 100 %	
Storage humidity	5 – 95 % non-condensing	
Surge immunity	4 kV (EN 61000-4-5)	
ESD resistance	8 kV (EN 61000-4-2)	
Mechanical		
Design & Mounting	FOD (Full Outdoor), direct mounting to antenna	
Unit types	One universal unit for Lower (L) and Upper (U) part of the band	
Casing	Rugged die-cast aluminum, compatible with RAy1 and RAy2	
Size	H×W×D: 160×245×245 mm (6.3×9.6×9.6 in)	
Weight	2.6 kg (5.7 lbs)	
Antenna	Class 3, 0.3 – 1.8 m, direct mounting (Jirous or LEAX/Arkivator or Shenglu or others)	
Diagnostics & Monitoring		
Real time monitoring	RSS, MSE, BER	
Diagnostic tools	Spectrum analyzer, Pinger, Radio loopback	
History charts	Temperature, Power voltage, RSS, MSE, BER, Data rate, RF Output power	
Statistics	RMON counters for all interfaces	
Antenna alignment	RSS voltage, Smartphone app (RAyTools), Web	
SNMP	SNMP v2c including configurable TRAPs	

RAy3-17/24	General parameters		ver. 2.3
Type	**RAy3-17**	**RAy3-24**	
Security			
Management	Web (HTTP, HTTPS), CLI (SSH, Telnet), Smartphone app (RAyTools)		
Access accounts	3 levels (Guest, Admin, Super)		
WiFi	passphrase; HW/SW enable/disable; active only during air-link loss		
Encryption	AES 128, 192, 256 [4)]		
Standards			
Approvals	CE (RED), RoHS	CE (RED), FCC, IC, RoHS	
Spectrum	EN 300 440 V2.2.1		
EMC	EN 301 489-1 V2.1.1 EN 301 489-3 V1.6.1 EN 301 489-4 V3.1.1		
Safety	EN 62368-1:2014 + A1:2017		
FCC	-	CFR 47 part 15 (SQT-RAY3-24)	
IC	-	24993-RAY324	

[1)] Stability optimized (stronger) FEC

[2)] RF Output power -30 to -15 dBm for all models with variant "R" (e.g. RAy3-24R or RAy3-24NR)

[3)] Model RAy3-24S (produced December 2018 till April 2019) has MTU 2048 bytes. All other models have MTU 10240 bytes.

[4)] Encryption is possible only with model variants 'X, 'S' and 'E'. Variants 'S' and 'X' means the unit is equipped with HW encryption support. Variants 'E', 'S' and 'X' allow SW encryption, while encryption is prohibited in Variant 'N'.

Tab. 9.4: Parameters 80 GHz

RAy3-80	General parameters	ver. 1.3
Type	**RAy3-80**	
Radio		
Frequency range	71 – 86 GHz (E-band)	
	Lower (unit L)	Upper (unit U)
	71.000 – 76.000 GHz	81.000 – 86.000 GHz
Type of duplex traffic	FDD (Frequency division duplex)	
Speed (each direction)	up to 10 Gb/s, *see details*	
Channel bandwidth	62.5 [2)], 125 [2)], 250, 500, 750, 1000, 1250, 1500, 1750, 2000 MHz	
Duplex spacing	flexible; typ. 10 GHz, min. 5 GHz, max. 15 GHz	
Modulations	2PSK, 4PSK, 8PSK, 16QAM, 32QAM, 64QAM, 128QAM, 256QAM	
ACMB	Hitless - including bandwidth reduction to 1/2 or 1/4 and stronger FEC [1)] (together with RF Output power regulation increases the system gain by up to 35.5 dB)	
Asymmetry of TX/RX speeds	Yes, only due to different Modulations (Channel bandwidths are always symmetrical)	
FEC	LDPC	
Sensitivity, BER 10^{-6}	-85 dBm (25 Mb/s) -59 dBm (4 Gb/s) -76 dBm (0.2 Gb/s) -53 dBm (7 Gb/s) *see details* -68 dBm (1 Gb/s) -46.5 dBm (10 Gb/s)	
Receiver dynamics (RSS range)	-100 to -30 dBm	
Precision of RSS measurement	±2 dB	
RF Output Power	-6 to +20 dBm (+17 dBm @ 32QAM; +16 dBm @ 64QAM; +14 dBm @ 128QAM, +13 dBm @ 256QAM)	
Precision of RF Output power setting	±1 dB	
ATPC	Yes (range 26 dB)	
Noise figure	3 dB (typ.)	
Ethernet (user data & management)		
RJ45	1 Gb Eth. 10/100/1000BASE-T Auto MDI/MDIX	
SFP (user exchangeable)	10 Gb Eth. SFP+ slot for 1000/10000 BASE-SX; 1000/10000 BASE-LX; 1000/2500/5000/10000 BASE-T (power max. 3 W)	
Throughput L1 (RFC 2544)	10000 Mb/s (64-128 B frames); 9512 Mb/s (1518 B frames), *see details*	
Latency L1 @ 10 Gb/s (RFC 2544, one way)	12.9 µs (64 B frames); 23.5 µs (1518 B frames)	
Latency L2 @ 10 Gb/s (RFC 2544, one way)		
MTU (max. packet length)	10240 Bytes	

RAy3-80	General parameters	ver. 1.3
Type	**RAy3-80**	
Synchronization	Synchronous Ethernet; PTP (transparent for IEEE-1588v2)	
Electrical		
Primary power	PoE active IEEE 802.3bt (POE++) PoE passive 37 – 60 VDC DC 37 – 60 VDC floating	
Power consumption (typ.)	35 W @ channel ≤ 500 MHz 37 W @ channel 1000 MHz 42 W @ for channel 2000 MHz max. 45 W (with SFP+)	
System interfaces		
USB	USB 2.0, Host A; USB / WiFi; USB / ETH	
WiFi	Mini WiFi 2.4 GHz b/g/n in USB slot, (only for Alignment, Management & Diagnostics) - included in basic configuration	
Ethernet	USB/Eth adapter in USB slot (only for Alignment, Management & Diagnostics) - optional	
RSS voltage	Two contact sockets	
Indication LED	System status (multicolor)	
System button	Default settings, Configuration restore from internal backup	
Environmental		
Ingress Protection	IP66	
MTBF (Mean Time Between Failure)	> 1.000.000 hours (> 114 years) projected	
Operating temperature	-30 to +55 °C (ETSI EN 300019-1-4, class 4.1.)	
Operating humidity	15 – 100 %	
Storage humidity	5 – 95 % non-condensing	
Surge immunity	4 kV (EN 61000-4-5)	
ESD resistance	8 kV (EN 61000-4-2)	
Mechanical		
Design & Mounting	FOD (Full Outdoor), direct mounting to antenna	
Unit types	Specific units for Lower (L) and Upper (U) part of the band	
Casing	Rugged die-cast aluminum	
Size	H×W×D: 160×245×245 mm (6.3×9.6×9.6 in)	
Weight	2.8 kg (6.1 lbs)	
Antennas	Class 3; 0.20 – 0.68 m; direct mounting (MTI 20cm/41dBi or Jirous 1ft/47 dBi, 2ft/51dBi or LEAX/Arkivator 1ft/47 dBi, 2ft/50dBi or Shenglu 2ft/48dBi or others)	
Diagnostics & Monitoring		
Real time monitoring	RSS, MSE, BER	
Diagnostic tools	Spectrum analyzer, Pinger	
History charts	Temperature, Power voltage, RSS, MSE, BER, Data rate, RF Output power	

RAy3-80	General parameters	ver. 1.3
Type	**RAy3-80**	
Statistics	RMON counters for all interfaces	
Antenna alignment	RSS voltage, Smartphone app (RAyTools), Web	
SNMP	SNMP v2c including configurable TRAPs	
Security		
Management	Web (HTTP, HTTPS), CLI (SSH, Telnet), Smartphone app (RAyTools)	
Access accounts	3 levels (Guest, Admin, Super)	
WiFi	passphrase; HW/SW enable/disable; active only during air-link loss	
Standards		
Approvals	CE (RED), RoHS, FCC , IC	
Spectrum	EN 302 2017 V3.3.1	
EMC	EN 301 489-1 V2.2.3 EN 301 489-3 V2.1.1 EN 301 489-4 V3.3.1	
Safety	EN 62368-1:2020 + A11:2020	
FCC	FCC part 101	
IC	compliant	

[1] Stability optimized (stronger) FEC

[2] Quarter or Half Bandwidth (Channel reduced to 1/4 or 1/2)

9.1. RAy3-10 details

9.1.1. RAy3-10 Link speed

Tab. 9.5: Raw link speed 10 GHz (displayed in user interface)

RAy3-10	Raw link speed – Bit Rate [Mb/s]										ver. 2.2
Channel [MHz]	Modulation										
	QPSK_S[1]	QPSK	16 QAM	32 QAM	64 QAM	128 QAM	256 QAM	512 QAM	1024 QAM	2048 QAM	4096 QAM
3.5	2.8	4.8	8.5	12	15	18	21	24	27	29	
5	4.1	7.0	9	17	22	26	31	35	38	42	
7	5.8	10	18	25	32	38	44	50	56	61	65
10	8.2	14	25	35	44	52	60	68	76	83	89
14	12	21	36	50	65	76	88	100	111	122	130
20	17	29	50	70	90	106	122	138	154	169	180
28	24	42	73	102	130	154	178	201	224	245	262
40	34	59	102	142	182	214	247	280	312	342	365
50	42	73	126	175	224	265	306	346	385	422	451
56	49	84	146	204	261	308	356	403	448	491	525
84	68	117	203	283	362	427	494	559	623	676	711
100	85	147	254	354	454	535	619	701	780	848	892
112	97	167	289	403	517	609	704	797	888	964	1014

[1] Stability optimized (stronger) FEC

(i) Note

Values are equal to Eth L1 throughput @ 2.5 GE SFP port for 1518 B frames according RFC 2544 test (starting with FW 2.0.14.0).

Tab. 9.6: Ethernet L1 Link speed 10 GHz (according to RFC 2544)

RAy3-10	Link speed [Mb/s] for Eth L1 frames 64 B / 1518 B / 9018 B										ver. 2.1
Channel MHz	**Modulation**										
	QPSK _S[1)]	**QPSK**	**16 QAM**	**32 QAM**	**64 QAM**	**128 QAM**	**256 QAM**	**512 QAM**	**1024 QAM**	**2048 QAM**	**4096 QAM**
3.5	3.3	5.9	10.6	15	19	22	26	29	33	36	
	2.8	4.8	8.5	12	15	18	21	24	27	29	
	2.8	4.8	8.6	12	15	18	21	24	26	29	
5	5.0	8.6	11	21	27	32	37	42	47	52	
	4.1	7.0	8.5	17	22	26	31	35	38	42	
	3.8	7.1	8.5	17	22	26	30	34	38	42	
7	7.3	13	22	31	39	47	54	61	68	74	79
	5.8	10	18	25	32	38	44	50	56	61	65
	5.9	10	18	25	32	38	44	49	55	60	64
10	10	17	30	42	54	64	74	83	93	102	109
	8.2	14	25	35	44	52	60	68	76	83	89
	8.0	14	25	34	44	52	60	68	75	83	88
14	15	26	44	62	79	93	108	122	136	149	159
	12	21	36	50	65	76	88	100	111	122	130
	12	21	36	50	64	75	87	99	110	121	129
20	20	35	61	85	110	129	149	169	188	206	221
	17	29	50	70	90	106	122	138	154	169	180
	17	29	50	69	89	105	121	137	153	167	179
28	30	51	89	124	160	188	217	246	274	300	321
	24	42	73	102	130	154	178	201	224	245	262
	24	42	72	101	129	152	176	199	222	243	260
40	42	72	124	173	222	262	302	342	381	418	446
	34	59	102	142	182	214	247	280	312	342	365
	34	58	101	141	180	212	245	278	309	339	362
50	51	89	154	214	274	323	374	423	471	516	552
	42	73	126	175	224	265	306	346	385	422	451
	42	72	125	174	223	262	303	343	382	418	447
56	60	103	179	249	319	376	435	492	548	600	642
	49	84	146	204	261	308	356	403	448	491	525
	48	84	145	202	259	305	353	399	444	487	520
84	83	143	248	345	443	522	603	683	761	826	869
	68	117	203	283	362	427	494	559	623	676	711
	67	116	201	280	359	423	489	554	617	670	705

RAy3-10	Link speed [Mb/s] for Eth L1 frames 64 B / 1518 B / 9018 B										ver. 2.1
Channel MHz	**Modulation**										
	QPSK _S[1]	QPSK	16 QAM	32 QAM	64 QAM	128 QAM	256 QAM	512 QAM	1024 QAM	2048 QAM	4096 QAM
100	104	180	311	433	555	655	756	856	954	1036	1090
	85	147	254	354	454	535	619	701	780	848	892
	84	146	252	351	450	531	613	694	774	840	884
112	118	205	354	493	632	745	861	974	1086	1179	1240
	97	167	289	403	517	609	704	797	888	964	1014
	96	166	287	400	512	604	698	790	880	956	1005

Tab. 9.7: Ethernet L2 Link speed 10 GHz (according to RFC 2544)

RAy3-10	Link speed [Mb/s] for Eth L2 frames 64 B / 1518 B / 9600 B										ver. 2.1
Channel MHz	Modulation										
	QPSK _S[1)	QPSK	16 QAM	32 QAM	64 QAM	128 QAM	256 QAM	512 QAM	1024 QAM	2048 QAM	4096 QAM
3.5	2.5	4.5	8.1	11	14	17	20	22	25	27	
	2.8	4.7	8.4	12	15	18	21	24	26	29	
	2.8	4.8	8.6	12	15	18	21	24	26	29	
5	3.8	6.6	8.1	16	21	24	28	32	36	39	
	4.0	6.9	8.4	17	22	26	30	34	38	42	
	3.8	7.1	8.5	17	22	26	30	34	38	41	
7	5.6	10	17	23	30	35	41	46	52	57	60
	5.7	10	18	25	32	37	43	49	55	60	64
	5.9	10	18	25	32	38	44	49	55	60	64
10	7.5	13	23	32	41	49	56	64	71	78	83
	8.1	14	24	34	44	52	59	67	75	82	88
	8.0	14	24	34	44	52	60	68	75	82	88
14	11	19	34	47	60	71	82	93	103	113	121
	12	20	36	50	64	75	87	98	109	120	128
	12	21	36	50	64	75	87	99	110	120	129
20	15	27	47	65	83	99	114	129	143	157	168
	16	28	50	69	89	104	121	137	152	167	178
	17	28	50	69	89	105	121	137	152	167	178
28	23	39	68	95	122	143	166	187	209	229	244
	24	41	72	100	129	152	175	199	221	242	259
	24	42	72	100	129	152	176	199	222	243	259
40	32	55	95	132	169	199	230	261	290	318	340
	33	58	100	140	179	211	244	276	308	337	360
	34	58	101	140	180	212	245	277	309	338	361
50	39	68	117	163	209	246	285	322	359	393	420
	41	72	124	173	222	261	302	342	380	417	445
	41	72	124	173	222	262	303	343	381	417	446
56	45	79	136	190	243	287	331	375	417	457	489
	48	83	144	201	258	304	351	397	442	485	518
	48	83	145	201	258	305	352	398	443	486	519
84	63	109	189	263	337	398	460	520	580	630	662
	67	116	200	279	358	422	487	552	615	667	702
	67	116	201	280	358	422	488	553	616	669	703

RAy3-10	Link speed [Mb/s] for Eth L2 frames 64 B / 1518 B / 9600 B										ver. 2.1
Channel MHz	Modulation										
	QPSK _S[1]	QPSK	16 QAM	32 QAM	64 QAM	128 QAM	256 QAM	512 QAM	1024 QAM	2048 QAM	4096 QAM
100	79	137	237	330	423	499	576	652	727	789	830
	84	145	251	350	448	529	611	691	770	836	880
	84	145	251	351	449	530	612	693	772	838	882
112	90	156	269	376	481	568	656	742	827	898	945
	96	165	286	398	510	601	695	787	877	952	1001
	96	165	286	399	511	603	696	789	879	954	1003

9.1.2. RAy3-10 Radio parameters

Tab. 9.8: Radio parameters 10 GHz, BER = 10^{-6}

RAy3-10	Bit Rate [Mb/s] / RSS [dBm] / MSE [dB][2]										ver. 2.3
Channel [MHz]	Modulation										
	QPSK _S[1]	QPSK	16 QAM	32 QAM	64 QAM	128 QAM	256 QAM	512 QAM	1024 QAM	2048 QAM	4096 QAM
3.5	2.8	4.8	8.5	12.1	15.4	18.2	21.1	23.9	26.8	29.2	
	-99.5	-95.5	-91.5	-88.0	-85.0	-82.0	-79.0	-75.5	-72.5	-68.5	
	-6.0	-8.1	-13.2	-17.4	-20.2	-23.1	-26.1	-29.1	-32.4	-35.2	
5	4.1	7.0	8.5	17.4	22.2	26.2	30.5	34.5	38.3	42.1	
	-100.5	-96.5	-92.0	-87.0	-84.0	-81.5	-78.5	-75.5	-72.0	-68.5	
	-5.8	-8.2	-13.3	-17.5	-20.2	-23.0	-26.1	-29.0	-32.3	-35.1	
7	5.8	10.4	18.0	25.0	32.1	37.9	44.0	49.8	55.5	60.8	65.0
	-97.0	-93.5	-89.0	-85.0	-82.0	-79.0	-76.0	-73.0	-70.0	-67.0	-62.5
	-6.0	-8.2	-13.3	-17.5	-20.2	-23.1	-26.1	-29.1	-32.3	-35.0	-38.3
10	8.2	14.1	24.6	34.5	44.3	52.2	60.2	68.2	76.1	83.2	89.1
	-97.0	-93.0	-88.0	-83.5	-80.5	-78.0	-75.0	-72.0	-69.0	-65.5	-61.5
	-5.9	-8.2	-13.3	-17.5	-20.3	-23.1	-26.1	-29.1	-32.3	-35.0	-38.3
14	11.9	20.7	36.0	50.4	64.5	76.2	88.1	99.6	110.9	121.5	129.9
	-94.5	-90.5	-86.5	-82.0	-79.0	-76.0	-73.0	-70.0	-67.0	-64.0	-60.0
	-6.0	-8.2	-13.3	-17.5	-20.2	-23.0	-26.1	-29.0	-32.3	-35.0	-38.2
20	16.7	28.8	50.2	70.0	89.7	105.8	122.2	138.4	154.1	168.8	180.4
	-94.0	-90.0	-85.0	-80.5	-77.5	-75.0	-72.0	-69.0	-66.0	-62.5	-59.0
	-6.0	-8.2	-13.3	-17.6	-20.3	-23.0	-26.1	-29.0	-32.3	-35.0	-38.2
28	24.2	42.0	73.0	101.7	130.3	153.8	177.7	201.2	224.0	245.4	262.3
	-91.5	-87.5	-83.5	-79.0	-76.0	-73.0	-70.0	-67.0	-64.0	-61.0	-57.5
	-6.0	-8.2	-13.3	-17.5	-20.3	-23.1	-26.1	-29.0	-32.3	-35.0	-38.3
40	33.8	58.7	101.6	141.7	181.6	214.1	247.4	280.1	311.7	341.6	365.1
	-91.0	-87.0	-82.0	-77.5	-74.5	-72.0	-69.0	-66.0	-63.0	-60.0	-56.0
	-5.9	-8.2	-13.3	-17.5	-20.3	-23.0	-26.1	-29.0	-32.2	-35.0	-38.2
50	42.0	72.6	125.7	175.1	224.5	264.7	305.8	346.2	385.4	422.2	451.3
	-90.0	-86.0	-81.0	-76.5	-73.5	-71.0	-68.0	-65.0	-62.0	-59.0	-55.0
	-5.9	-8.2	-13.3	-17.6	-20.3	-23.1	-26.2	-29.1	-32.2	-35.0	-38.3
56	48.7	84.4	146.1	203.6	261.0	307.7	355.6	402.6	448.2	490.9	524.7
	-89.0	-85.0	-80.0	-76.0	-73.0	-70.0	-67.0	-64.0	-61.0	-58.0	-54.0
	-6.0	-8.2	-13.3	-17.6	-20.3	-23.1	-26.2	-29.1	-32.2	-35.0	-38.3
84	67.8	117.2	202.8	282.7	362.3	427.2	493.6	558.8	622.6	676.0	711.1
	-87.5	-83.5	-78.5	-73.5	-71.0	-68.5	-65.5	-62.5	-59.5	-56.5	-52.5
	-6.0	-8.3	-13.4	-17.7	-20.4	-23.2	-26.3	-29.1	-32.2	-34.8	-38.0

RAy3-10	Bit Rate [Mb/s] / RSS [dBm] / MSE [dB][2]										ver. 2.3
Channel [MHz]	Modulation										
	QPSK _S[1]	QPSK	16 QAM	32 QAM	64 QAM	128 QAM	256 QAM	512 QAM	1024 QAM	2048 QAM	4096 QAM
100	85.1	147.0	254.3	354.4	454.2	535.5	618.7	700.5	780.5	847.5	891.5
	-87.0	-83.0	-78.0	-73.0	-70.5	-67.5	-64.5	-61.5	-58.5	-55.0	-51.0
	-6.0	-8.3	-13.4	-17.8	-20.5	-23.3	-26.3	-29.1	-32.2	-34.8	-37.9
112	96.8	167.3	289.4	403.2	516.9	609.4	704.1	797.1	888.2	964.3	1014.4
	-86.0	-82.0	-77.0	-72.0	-69.5	-66.5	-63.5	-60.5	-57.5	-54.5	-50.5
	-6.0	-8.3	-13.4	-17.8	-20.5	-23.3	-26.3	-29.2	-32.3	-34.8	-37.9

RSS values in the table are typical. Actual values may differ by up to ± 2 dB.

[1] Stability optimized (stronger) FEC

[2] Table cells contain values:

User Bit Rate [Mb/s]	Bit Rate for the selected modulation and bandwidth
RSS (Received Signal Strength) [dBm]	Minimum required RSS (RX Sensitivity threshold)
MSE (Mean Square Error) [dB]	Maximum required MSE (the inverse of SNR)

Tab. 9.9: ACM switching 10 GHz according to MSE state

RAy3-10			MSE degrade [dB] / MSE improve [dB]									ver. 2.1
Channel MHz	**Modulation**											
	QPSK_S[1]	**QPSK**	**16 QAM**	**32 QAM**	**64 QAM**	**128 QAM**	**256 QAM**	**512 QAM**	**1024 QAM**	**2048 QAM**	**4096 QAM**	
3.5	--	-9.6	-14.7	-18.9	-21.7	-24.6	-27.6	-30.6	-33.9	-36.7		
	-10.6	-15.7	-19.9	-22.7	-25.6	-28.6	-31.6	-34.9	-37.7	--		
5	--	-9.7	-14.8	-19.0	-21.7	-24.5	-27.6	-30.5	-33.8	-36.6		
	-10.7	-15.8	-20.0	-22.7	-25.5	-28.6	-31.5	-34.8	-37.6	--		
7	--	-9.7	-14.8	-19.0	-21.7	-24.6	-27.6	-30.6	-33.8	-36.5	-39.8	
	-10.7	-15.8	-20.0	-22.7	-25.6	-28.6	-31.6	-34.8	-37.5	-40.8	--	
10	--	-9.7	-14.8	-19.0	-21.8	-24.6	-27.6	-30.6	-33.8	-36.5	-39.8	
	-10.7	-15.8	-20.0	-22.8	-25.6	-28.6	-31.6	-34.8	-37.5	-40.8	--	
14	--	-9.7	-14.8	-19.0	-21.7	-24.5	-27.6	-30.5	-33.8	-36.5	-39.7	
	-10.7	-15.8	-20.0	-22.7	-25.5	-28.6	-31.5	-34.8	-37.5	-40.7	--	
20	--	-9.7	-14.8	-19.1	-21.8	-24.5	-27.6	-30.5	-33.8	-36.5	-39.7	
	-10.7	-15.8	-20.1	-22.8	-25.5	-28.6	-31.5	-34.8	-37.5	-40.7	--	
28	--	-9.7	-14.8	-19.0	-21.8	-24.6	-27.6	-30.5	-33.8	-36.5	-39.8	
	-10.7	-15.8	-20.0	-22.8	-25.6	-28.6	-31.5	-34.8	-37.5	-40.8	--	
40	--	-9.7	-14.8	-19.0	-21.8	-24.5	-27.6	-30.5	-33.7	-36.5	-39.7	
	-10.7	-15.8	-20.0	-22.8	-25.5	-28.6	-31.5	-34.7	-37.5	-40.7	--	
50	--	-9.7	-14.8	-19.1	-21.8	-24.6	-27.7	-30.6	-33.8	-36.5	-39.8	
	-10.7	-15.8	-20.1	-22.8	-25.6	-28.7	-31.6	-34.8	-37.5	-40.8	--	
56	--	-9.7	-14.8	-19.1	-21.8	-24.6	-27.7	-30.6	-33.8	-36.5	-39.8	
	-10.7	-15.8	-20.1	-22.8	-25.6	-28.7	-31.6	-34.8	-37.5	-40.8	--	
84	--	-9.8	-14.9	-19.2	-21.9	-24.7	-27.8	-30.6	-33.7	-36.4	-39.7	
	-10.8	-15.9	-20.2	-22.9	-25.7	-28.8	-31.6	-34.7	-37.4	-40.7	--	
100	--	-9.8	-14.9	-19.3	-22.0	-24.8	-27.8	-30.6	-33.7	-36.4	-39.7	
	-10.8	-15.9	-20.3	-23.0	-25.8	-28.8	-31.6	-34.7	-37.4	-40.7	--	
112	--	-9.8	-14.9	-19.3	-22.0	-24.8	-27.8	-30.7	-33.8	-36.4	-39.7	
	-10.8	-15.9	-20.3	-23.0	-25.8	-28.8	-31.7	-34.8	-37.4	-40.7	--	

[1] Stability optimized (stronger) FEC

9.1.3. RAy3-10 Sub-bands

Tab. 9.10: Sub-band Upper/Lower limits, Duplex spacing 10 GHz

RAy3-10		Sub-bands		
Sub-band		**Sub-band TX Range [GHz]**		**Duplex spacing [MHz]**
		Unit L	**Unit U**	
A	min.	10.301	10.476	Flexible; typ. 168 MHz, min. 58 MHz, max. 284 MHz
	max.	10.420	10.588	
B	min.	10.125	10.475	350
	max.	10.325	10.675	

9.1.4. RAy3-10 Frequency tables

Tab. 9.11: Frequency tables 10 GHz

RAy3-10	Frequency tables		
Name	**Description**		**Note**
rcinfo10_A_default	10.30 - 10.59 GHz	default duplex 168, default table	VO-R/14/05.2020-7 (CZ only)
rcinfo10_B_default	10.12 - 10.68 GHz	duplex 350, default table	CEPT/ERC/REC 12-05 E, Rec. ITU-R F.747-1 (03/12), Rec. ITU-R F.1568-1 (01/05)

9.1.5. RAy3-10/11/18 Emission designation

Tab. 9.12: Emission designation 10/11/18 GHz (ETSI)

for QPSK	3M22G7WEN, 6M68G7WEN, 13M3G7WEN, 26M9G7WEN, 53M7G7WEN, 74M7G7WEN, 106MG7WEN
for QAM	3M22D7WEN, 6M68D7WEN, 13M3D7WEN, 26M9D7WEN, 53M7D7WEN, 74M7D7WEN, 106MD7WEN

Tab. 9.13: Emission designation 10/11/18 GHz (FCC)

for QPSK	37M5G7W, 74M7G7W
for QAM	37M5D7W, 74M7D7W

9.2. RAy3-11 details

9.2.1. RAy3-11 Link speed

Tab. 9.14: Raw link speed 11 GHz (displayed in user interface)

RAy3-11	Raw link speed – Bit Rate [Mb/s]										ver. 2.0
	Modulation										
Channel [MHz]	QPSK_S[1]	QPSK	16 QAM	32 QAM	64 QAM	128 QAM	256 QAM	512 QAM	1024 QAM	2048 QAM	4096 QAM
5	4.1	7.0	9	17	22	26	31	35	38	42	
7 & 7.5	5.8	10	18	25	32	38	44	50	56	61	65
10	8.2	14	25	35	44	52	60	68	76	83	89
14	12	21	36	50	65	76	88	100	111	122	130
20	17	29	50	70	90	106	122	138	154	169	180
27.5 & 30	24	42	73	102	130	154	178	201	224	245	262
40	34	59	102	142	182	214	247	280	312	342	365
50	42	73	126	175	224	265	306	346	385	422	451
55 & 60	49	84	146	204	261	308	356	403	448	491	525
80	68	117	203	283	362	427	494	559	623	676	711
100	85	147	254	354	454	535	619	701	780	848	892
112	97	167	289	403	517	609	704	797	888	964	1014
2× 60	98	169	292	407	521	615	710	804	895	981	1048
2× 80	135	234	405	565	724	853	986	1116	1244	1350	1420
2× 112	193	334	578	805	1032	1217	1406	1592	1774	1926	2026

[1] Stability optimized (stronger) FEC

(i) Note

Values are equal to Eth L1 throughput @ 2.5 GE SFP port for 1518 B frames according RFC 2544 test (starting with FW 2.0.14.0).

Tab. 9.15: Ethernet L1 Link speed 11 GHz (according to RFC 2544)

RAy3-11	Link speed [Mb/s] for Eth L1 frames 64 B / 1518 B / 9600 B										ver. 2.0
Channel MHz	**Modulation**										
	QPSK _S[1]	**QPSK**	**16 QAM**	**32 QAM**	**64 QAM**	**128 QAM**	**256 QAM**	**512 QAM**	**1024 QAM**	**2048 QAM**	**4096 QAM**
5	5.0	8.6	11	21	27	32	37	42	47	52	
	4.1	7.0	8.5	17	22	26	31	35	38	42	
	3.8	7.1	8.5	17	22	26	30	34	38	42	
7 & 7.5	7.3	13	22	31	39	47	54	61	68	74	79
	5.8	10.4	18	25	32	38	44	50	56	61	65
	5.9	10	18	25	32	38	44	49	55	60	64
10	10	17	30	42	54	64	74	83	93	102	109
	8.2	14	25	35	44	52	60	68	76	83	89
	8.0	14	25	34	44	52	60	68	75	83	88
14	15	26	44	62	79	93	108	122	136	149	159
	12	21	36	50	65	76	88	100	111	122	130
	12	21	36	50	64	75	87	99	110	121	129
20	20	35	61	85	110	129	149	169	188	206	221
	17	29	50	70	90	106	122	138	154	169	180
	17	29	50	69	89	105	121	137	153	167	179
27.5 & 30	30	51	89	124	160	188	217	246	274	300	321
	24	42	73	102	130	154	178	201	224	245	262
	24	42	72	101	129	152	176	199	222	243	260
40	42	72	124	173	222	262	302	342	381	418	446
	34	59	102	142	182	214	247	280	312	342	365
	34	58	101	141	180	212	245	278	309	339	362
50	51	89	154	214	274	323	374	423	471	516	552
	42	73	126	175	224	265	306	346	385	422	451
	42	72	125	174	223	262	303	343	382	418	447
55 & 60	60	103	179	249	319	376	435	492	548	600	642
	49	84	146	204	261	308	356	403	448	491	525
	48	84	145	202	259	305	353	399	444	487	520
80	83	143	248	345	443	522	603	683	761	826	869
	68	117	203	283	362	427	494	559	623	676	711
	67	116	201	280	359	423	489	554	617	670	705
100	104	180	311	433	555	655	756	856	954	1036	1090
	85	147	254	354	454	535	619	701	780	848	892
	84	146	252	351	450	531	613	694	774	840	884

RAy3-11	Link speed [Mb/s] for Eth L1 frames 64 B / 1518 B / 9600 B										ver. 2.0
Channel MHz	Modulation										
	QPSK _S[1]	QPSK	16 QAM	32 QAM	64 QAM	128 QAM	256 QAM	512 QAM	1024 QAM	2048 QAM	4096 QAM
112	118	205	354	493	632	745	861	974	1086	1179	1240
	97	167	289	403	517	609	704	797	888	964	1014
	96	166	287	400	512	604	698	790	880	956	1005
2× 60	116	201	347	484	620	731	845	956	1000	1166	1246
	98	169	292	407	521	615	710	804	895	981	1048
	97	167	290	404	517	610	705	798	888	973	1040
2× 80	161	278	482	671	861	1015	1172	1327	1479	1606	1689
	135	234	405	565	724	853	986	1116	1244	1350	1420
	134	232	402	560	718	847	978	1108	1234	1340	1410
2× 112	230	397	687	958	1228	1447	1672	1893	2109	2290	2409
	193	334	578	805	1032	1217	1406	1592	1774	1926	2026
	192	331	574	799	1024	1208	1395	1580	1760	1911	2011

Tab. 9.16: Ethernet L2 Link speed 11 GHz (according to RFC 2544)

RAy3-11	Link speed [Mb/s] for Eth L2 frames 64 B / 1518 B / 9600 B										ver. 2.0
Channel MHz	Modulation										
	QPSK _S[1]	QPSK	16 QAM	32 QAM	64 QAM	128 QAM	256 QAM	512 QAM	1024 QAM	2048 QAM	4096 QAM
5	3.8	6.6	8	16	21	24	28	32	36	39	
	2.8	4.7	8	12	15	18	21	24	26	29	
	2.8	4.8	9	12	15	18	21	24	26	29	
7 & 7.5	5.6	10	17	23	30	35	41	46	52	57	60
	2.8	5	8	12	15	18	21	24	26	29	0
	2.8	5	9	12	15	18	21	24	26	29	0
10	7.5	13	23	32	41	49	56	64	71	78	83
	2.8	5	8	12	15	18	21	24	26	29	0
	2.8	5	9	12	15	18	21	24	26	29	0
14	11	19	34	47	60	71	82	93	103	113	121
	3	5	8	12	15	18	21	24	26	29	0
	3	5	9	12	15	18	21	24	26	29	0
20	15	27	47	65	83	99	114	129	143	157	168
	3	5	8	12	15	18	21	24	26	29	0
	3	5	9	12	15	18	21	24	26	29	0
27.5 & 30	23	39	68	95	122	143	166	187	209	229	244
	3	5	8	12	15	18	21	24	26	29	0
	3	5	9	12	15	18	21	24	26	29	0
40	32	55	95	132	169	199	230	261	290	318	340
	3	5	8	12	15	18	21	24	26	29	0
	3	5	9	12	15	18	21	24	26	29	0
50	39	68	117	163	209	246	285	322	359	393	420
	41	72	124	173	222	261	302	342	380	417	445
	41	72	124	173	222	262	303	343	381	417	446
55 & 60	45	79	136	190	243	287	331	375	417	457	489
	48	83	144	201	258	304	351	397	442	485	518
	48	83	145	201	258	305	352	398	443	486	519
80	63	109	189	263	337	398	460	520	580	630	662
	67	116	200	279	358	422	487	552	615	667	702
	67	116	201	280	358	422	488	553	616	669	703
100	79	137	237	330	423	499	576	652	727	789	830
	84	145	251	350	448	529	611	691	770	836	880
	84	145	251	351	449	530	612	693	772	838	882

RAy3-11	Link speed [Mb/s] for Eth L2 frames 64 B / 1518 B / 9600 B										ver. 2.0
Channel MHz	**Modulation**										
	QPSK _S[1]	QPSK	16 QAM	32 QAM	64 QAM	128 QAM	256 QAM	512 QAM	1024 QAM	2048 QAM	4096 QAM
112	90	156	269	376	481	568	656	742	827	898	945
	96	165	286	398	510	601	695	787	877	952	1001
	96	165	286	399	511	603	696	789	879	954	1003
2× 60	88	153	264	369	472	557	643	729	762	888	950
	96	166	288	402	515	607	701	794	884	968	1034
	97	167	289	403	516	609	703	796	887	971	1038
2× 80	123	212	367	512	656	773	893	1011	1127	1223	1287
	134	231	400	557	714	842	973	1102	1227	1333	1402
	134	232	401	559	717	845	976	1105	1232	1337	1407
2× 112	175	303	524	730	935	1103	1274	1442	1607	1745	1836
	191	330	570	795	1019	1201	1388	1571	1751	1901	2000
	192	331	572	798	1022	1205	1393	1577	1757	1907	2006

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9.2.2. RAy3-11 Radio parameters

Tab. 9.17: Radio parameters - 11 GHz, BER = 10^{-6}

RAy3-11	Bit Rate [Mb/s] / RSS [dBm] / MSE [dB][2]										ver. 2.0
Channel [MHz]	**Modulation**										
	QPSK _S[1]	**QPSK**	**16 QAM**	**32 QAM**	**64 QAM**	**128 QAM**	**256 QAM**	**512 QAM**	**1024 QAM**	**2048 QAM**	**4096 QAM**
5	4.1	7.0	9	17	22	26	31	35	38	42	
	-100.5	-97.0	-92	-87	-85	-82	-79	-76	-72	-69	
	-5.9	-8.3	-13	-18	-20	-23	-26	-29	-32	-35	
7 & 7.5	5.8	10	18	25	32	38	44	50	56	61	65
	-99.0	-95	-90	-85	-83	-80	-77	-74	-71	-68	-64
	-5.9	-8	-13	-18	-20	-23	-26	-29	-32	-35	-39
10	8.2	14	25	35	44	52	60	68	76	83	89
	-97.5	-94	-89	-84	-82	-79	-76	-73	-69	-66	-62
	-5.9	-8	-13	-18	-20	-23	-26	-29	-32	-35	-39
14	12	21	36	50	65	76	88	100	111	122	130
	-96	-92	-87	-82	-80	-77	-74	-71	-68	-65	-61
	-6	-8	-13	-18	-20	-23	-26	-29	-32	-35	-38
20	17	29	50	70	90	106	122	138	154	169	180
	-95	-91	-86	-81	-79	-76	-73	-70	-66	-63	-59
	-6	-8	-13	-18	-20	-23	-26	-29	-32	-35	-38
27.5 & 30	24	42	73	102	130	154	178	201	224	245	262
	-93	-89	-84	-79	-77	-74	-71	-68	-65	-62	-58
	-6	-8	-13	-18	-20	-23	-26	-29	-32	-35	-38
40	34	59	102	142	182	214	247	280	312	342	365
	-92	-88	-83	-78	-75	-73	-70	-67	-63	-60	-56
	-6	-8	-13	-18	-20	-23	-26	-29	-32	-35	-38
50	42	73	126	175	224	265	306	346	385	422	451
	-91	-87	-82	-77	-74	-71	-68	-65	-62	-59	-55
	-6	-8	-13	-18	-20	-23	-26	-29	-32	-35	-38
55 & 60	49	84	146	204	261	308	356	403	448	491	525
	-90	-86	-81	-76	-74	-71	-68	-65	-62	-59	-55
	-6	-8	-13	-18	-20	-23	-26	-29	-32	-35	-38
80	68	117	203	283	362	427	494	559	623	676	711
	-89	-85	-80	-75	-72	-70	-66	-63	-60	-57	-53
	-6	-8	-13	-18	-21	-23	-26	-29	-32	-35	-38
100	85	147	254	354	454	535	619	701	780	848	892
	-88	-84	-79	-74	-71	-68	-65	-62	-59	-56	-52
	-6	-8	-14	-18	-21	-23	-26	-29	-32	-35	-38

RAy3-11	Bit Rate [Mb/s] / RSS [dBm] / MSE [dB][2]										ver. 2.0
Channel [MHz]	**Modulation**										
	QPSK_S[1]	QPSK	16 QAM	32 QAM	64 QAM	128 QAM	256 QAM	512 QAM	1024 QAM	2048 QAM	4096 QAM
112	97	167	289	403	517	609	704	797	888	964	1014
	-87	-83	-78	-73	-71	-68	-65	-62	-59	-55	-51
	-6	-8	-14	-18	-21	-23	-26	-29	-32	-35	-38
2× 60	98	169	292	407	521	615	710	804	895	981	1048
	-90	-86	-81	-76	-74	-71	-68	-65	-62	-59	-55
	-6	-8	-13	-18	-20	-23	-26	-29	-32	-35	-38
2× 80	135	234	405	565	724	853	986	1116	1244	1350	1420
	-89	-85	-80	-75	-72	-70	-66	-63	-60	-57	-53
	-6	-8	-13	-18	-21	-23	-26	-29	-32	-35	-38
2× 112	193	334	578	805	1032	1217	1406	1592	1774	1926	2026
	-87	-83	-78	-73	-71	-68	-65	-62	-59	-55	-51
	-6	-8	-14	-18	-21	-23	-26	-29	-32	-35	-38

RSS values in the table are typical. Actual values may differ by up to ± 2 dB.

[1] Stability optimized (stronger) FEC

[2] Table cells contain values:

User Bit Rate [Mb/s]	Bit Rate for the selected modulation and bandwidth
RSS (Received Signal Strength) [dBm]	Minimum required RSS (RX Sensitivity threshold)
MSE (Mean Square Error) [dB]	Maximum required MSE (the inverse of SNR)

Tab. 9.18: ACM switching - 11 GHz according to MSE state

RAy3-11		MSE degrade [dB] / MSE improve [dB]										ver. 2.0
Channel MHz		**Modulation**										
	QPSK _S[1]	QPSK	16 QAM	32 QAM	64 QAM	128 QAM	256 QAM	512 QAM	1024 QAM	2048 QAM	4096 QAM
5	--	-9.7	-14.8	-19.0	-21.7	-24.5	-27.6	-30.5	-33.8		
	-10.7	-15.8	-20.0	-22.7	-25.5	-28.6	-31.5	-34.8	--		
7 & 7.5	--	-9.7	-14.8	-19.0	-21.7	-24.6	-27.6	-30.6	-33.8	-36.5	
	-10.7	-15.8	-20.0	-22.7	-25.6	-28.6	-31.6	-34.8	-37.5	--	
10	--	-9.7	-14.8	-19.0	-21.8	-24.6	-27.6	-30.6	-33.8	-36.5	
	-10.7	-15.8	-20.0	-22.8	-25.6	-28.6	-31.6	-34.8	-37.5	--	
14	--	-9.7	-14.8	-19.0	-21.7	-24.5	-27.6	-30.5	-33.8	-36.5	-39.7
	-10.7	-15.8	-20.0	-22.7	-25.5	-28.6	-31.5	-34.8	-37.5	-40.7	--
20	--	-9.7	-14.8	-19.1	-21.8	-24.5	-27.6	-30.5	-33.8	-36.5	-39.7
	-10.7	-15.8	-20.1	-22.8	-25.5	-28.6	-31.5	-34.8	-37.5	-40.7	--
27.5 & 30	--	-9.7	-14.8	-19.0	-21.8	-24.6	-27.6	-30.5	-33.8	-36.5	-39.8
	-10.7	-15.8	-20.0	-22.8	-25.6	-28.6	-31.5	-34.8	-37.5	-40.8	--
40	--	-9.7	-14.8	-19.0	-21.8	-24.5	-27.6	-30.5	-33.7	-36.5	-39.7
	-10.7	-15.8	-20.0	-22.8	-25.5	-28.6	-31.5	-34.7	-37.5	-40.7	--
50	--	-9.7	-14.8	-19.1	-21.8	-24.6	-27.7	-30.6	-33.8	-36.5	-39.8
	-10.7	-15.8	-20.1	-22.8	-25.6	-28.7	-31.6	-34.8	-37.5	-40.8	--
55 & 60	--	-9.7	-14.8	-19.1	-21.8	-24.6	-27.7	-30.6	-33.8	-36.5	-39.8
	-10.7	-15.8	-20.1	-22.8	-25.6	-28.7	-31.6	-34.8	-37.5	-40.8	--
80	--	-9.8	-14.9	-19.2	-21.9	-24.7	-27.8	-30.6	-33.7	-36.4	-39.7
	-10.8	-15.9	-20.2	-22.9	-25.7	-28.8	-31.6	-34.7	-37.4	-40.7	--
100	--	-9.8	-14.9	-19.3	-22.0	-24.8	-27.8	-30.6	-33.7	-36.4	-39.7
	-10.8	-15.9	-20.3	-23.0	-25.8	-28.8	-31.6	-34.7	-37.4	-40.7	--
112	--	-9.8	-14.9	-19.3	-22.0	-24.8	-27.8	-30.7	-33.8	-36.4	-39.7
	-10.8	-15.9	-20.3	-23.0	-25.8	-28.8	-31.7	-34.8	-37.4	-40.7	--
2× 60	--	-9.7	-14.8	-19.1	-21.8	-24.6	-27.7	-30.6	-33.8	-36.5	-39.8
	-10.7	-15.8	-20.1	-22.8	-25.6	-28.7	-31.6	-34.8	-37.5	-40.8	--
2× 80	--	-9.8	-14.9	-19.2	-21.9	-24.7	-27.8	-30.6	-33.7	-36.4	-39.7
	-10.8	-15.9	-20.2	-22.9	-25.7	-28.8	-31.6	-34.7	-37.4	-40.7	--
2× 112	--	-9.8	-14.9	-19.3	-22.0	-24.8	-27.8	-30.7	-33.8	-36.4	-39.7
	-10.8	-15.9	-20.3	-23.0	-25.8	-28.8	-31.7	-34.8	-37.4	-40.7	--

[1] Stability optimized (stronger) FEC

9.2.3. RAy3-11 Sub-bands

Tab. 9.19: RAy3-11 Sub-band Upper/Lower limits, Duplex spacing

RAy3-11		Sub-bands		
Sub-band		**Sub-band TX Range [GHz]**		**Duplex spacing [MHz]**
		Unit L	**Unit U**	
A	min.	10.695	11.199	typ. 490 MHz (ETSI) or 530 MHz (rest of the world)
	max.	10.989	11.491	
B	min.	10.905	11.395	
	max.	11.195	11.699	

9.2.4. RAy3-11 Frequency tables

Tab. 9.20: Frequency tables 11 GHz

RAy3-11		Frequency tables	
Name	**Description**		**Note**
rcinfo11_A_490_default	10.7 – 11.5 GHz	duplex 490, default table	CEPT/ERC 12-06 VO-R/14/05.2020-7 (CZ only)
rcinfo11_B_490_default	10.9 – 11.7 GHz	duplex 490, default table	
rcinfo11_A_530	10.7 – 11.5 GHz	duplex 530	ITU F.387-13 (11/2019)
rcinfo11_B_530	10.9 – 11.7 GHz	duplex 530	
rcinfo11_A_FCC	10.7 – 11.5 GHz	duplex 490, FCC compliant	FCC 47 CFR 101.147
rcinfo11_B_FCC	10.9 – 11.7 GHz	duplex 490, FCC compliant	

9.2.5. RAy3-11 Emission designation 11 GHz

For Emission designation codes see table in *Section 9.1.5, "RAy3-10/11/18 Emission designation"*.

9.3. RAy3-17 details

9.3.1. RAy3-17/24 Link speed

Tab. 9.21: Raw link speed 17/24 GHz (displayed in user interface)

RAy3-17/24	Raw link speed – Bit Rate [Mb/s]										ver. 2.2
Channel [MHz]	Modulation										
	QPSK_S[1]	QPSK	16 QAM	32 QAM	64 QAM	128 QAM	256 QAM	512 QAM	1024 QAM	2048 QAM	4096 QAM
3.5	2.6	4.9	9.5	11	14	17	20	22	23		
5	3.6	6.9	14	16	21	25	28	31	33		
7	5.7	10	20	24	31	37	42	47	52	57	
10	7.7	14	28	33	43	51	58	64	72	79	
14	12	22	41	50	65	78	89	99	110	120	129
20	17	32	60	73	94	112	128	143	159	173	187
28	24	39	82	106	133	159	182	204	229	251	272
40	34	54	114	149	186	222	255	286	321	352	380
56	49	82	170	215	270	322	370	418	464	506	545
80	70	116	242	306	385	459	526	595	660	720	
100	87	146	301	385	484	574	659	743	829	904	
112	98	163	338	431	542	643	738	832	928	1012	

[1] Stability optimized (stronger) FEC

(i) **Note**

Values are equal to Eth L1 throughput @ 2.5 GE SFP port for 1518 B frames according RFC 2544 test (starting with FW 2.0.14.0).

Tab. 9.22: Ethernet L1 Link speed 17/24 GHz (according to RFC 2544)

RAy3-17/24	**Link speed [Mb/s] for Eth L1 frames 64 B / 1518 B / 9018 B**										ver. 2.0
Channel [MHz]	**Modulation**										
	QPSK _S[1)	**QPSK**	**16 QAM**	**32 QAM**	**64 QAM**	**128 QAM**	**256 QAM**	**512 QAM**	**1024 QAM**	**2048 QAM**	**4096 QAM**
3.5	3.2	5.9	11.6	14.0	17.8	21.1	23.7	26.4	28.2		
	2.6	4.9	9.5	11	14	17	20	22	23		
	2.6	4.8	9.2	11	14	17	19	21	23		
5	4.6	8.5	17	20	26	30	34	38	41		
	3.6	6.9	13.6	16	21	25	28	31	33		
	3.6	7.0	13.5	16	21	24	28	30	33		
7	6.8	13	25	30	38	45	51	57	64	70	
	5.7	10.3	20	24	31	37	42	47	52	57	
	5.5	10	20	24	31	37	42	46	52	57	
10	10	18	34	41	52	62	71	79	88	97	
	7.7	14	28	33	43	51	58	64	72	79	
	7.8	14	27	33	42	50	57	64	71	78	
14	14	27	51	61	80	95	108	121	135	146	158
	12	22	41	50	65	78	89	99	110	120	129
	12	22	41	50	65	77	88	98	109	119	128
20	21	39	73	89	115	137	156	175	195	211	228
	17	32	60	73	94	112	128	143	159	173	187
	17	32	59	72	94	111	127	142	158	171	185
28	30	47	100	130	163	194	223	250	280	307	332
	24	39	82	106	133	159	182	204	229	251	272
	24	38	81	105	132	157	181	203	227	249	269
40	42	66	140	182	228	272	312	350	392	430	465
	34	54	114	149	186	222	255	286	321	352	380
	34	54	113	148	185	220	253	284	318	349	377
56	60	100	208	263	330	394	452	511	567	619	667
	49	82	170	215	270	322	370	418	464	506	545
	48	81	168	213	268	319	367	414	460	502	541
80	85	142	296	374	470	561	643	727	807	880	
	70	116	242	306	385	459	526	595	660	720	
	69	115	240	303	381	455	522	590	654	714	
100	107	178	369	470	592	702	806	909	1013	1105	
	87	146	301	385	484	574	659	743	829	904	
	86	144	299	381	480	569	653	737	821	896	

RAy3-17/24	Link speed [Mb/s] for Eth L1 frames 64 B / 1518 B / 9018 B										ver. 2.0
Channel [MHz]	**Modulation**										
	QPSK _S[1]	**QPSK**	**16 QAM**	**32 QAM**	**64 QAM**	**128 QAM**	**256 QAM**	**512 QAM**	**1024 QAM**	**2048 QAM**	**4096 QAM**
112	120	200	413	526	663	786	902	1017	1134	1238	
	98	163	338	431	542	643	738	832	928	1012	
	97	162	335	427	537	638	732	825	920	1004	

Tab. 9.23: Ethernet L2 Link speed 17/24 GHz (according to RFC 2544)

RAy3-17/24		Link speed [Mb/s] for Eth L2 frames 64 B / 1518 B / 9018 B									ver. 2.1
Channel [MHz]	**Modulation**										
	QPSK _S[1)]	**QPSK**	**16 QAM**	**32 QAM**	**64 QAM**	**128 QAM**	**256 QAM**	**512 QAM**	**1024 QAM**	**2048 QAM**	**4096 QAM**
3.5	2.4	4.5	8.8	11	14	16	18	20	21		
	2.6	4.8	9.4	11	14	17	19	21	23		
	2.6	4.8	9.2	11	14	17	19	21	23		
5	3.5	6.5	13	15	20	23	26	29	31		
	3.6	6.8	13	16	21	24	27	30	33		
	3.6	7.0	13	16	21	24	27	30	33		
7	5.2	10	19	23	29	34	39	44	48	53	
	5.6	10	20	24	31	36	42	46	51	57	
	5.5	10	20	24	31	37	42	46	52	57	
10	7.3	13	26	31	40	47	54	60	67	74	
	7.6	14	27	33	42	50	57	64	71	78	
	7.8	14	27	33	42	50	57	64	71	78	
14	11	21	39	47	61	72	82	92	103	111	121
	12	22	41	50	65	77	87	98	109	118	128
	12	22	41	50	65	77	87	98	109	118	128
20	16	30	56	68	88	104	119	133	148	161	174
	17	32	59	72	93	111	126	141	157	171	184
	17	32	59	72	93	111	126	141	158	171	185
28	23	36	76	99	124	148	170	190	213	234	253
	24	38	81	105	131	157	180	202	226	248	268
	24	38	81	105	132	157	180	202	227	249	269
40	32	50	107	139	174	207	238	267	299	328	354
	34	53	113	147	184	220	252	282	317	347	375
	34	54	113	147	184	220	252	283	317	348	376
56	46	76	158	200	252	300	344	389	432	471	508
	48	81	168	212	267	318	365	413	458	500	538
	48	81	168	213	267	319	366	413	459	501	540
80	65	108	226	285	358	427	490	554	615	671	
	69	115	239	302	380	453	519	587	651	711	
	69	115	240	303	380	454	521	589	653	712	
100	81	136	281	358	451	535	614	692	772	842	
	86	144	297	380	478	567	651	734	818	893	
	86	144	298	381	479	568	652	735	820	894	

RAy3-17/24		Link speed [Mb/s] for Eth L2 frames 64 B / 1518 B / 9018 B										ver. 2.1
Channel [MHz]	Modulation											
	QPSK_S[1]	QPSK	16 QAM	32 QAM	64 QAM	128 QAM	256 QAM	512 QAM	1024 QAM	2048 QAM	4096 QAM
112	91	152	314	401	505	599	687	775	864	943	
	96	161	333	425	535	635	728	821	916	999	
	97	161	334	426	536	636	730	823	918	1002	

9.3.2. RAy3-17/24 Radio parameters

Tab. 9.24: Radio parameters 17/24 GHz, BER = 10^{-6}

RAy3-17/24	Bit Rate [Mb/s] / RSS [dBm] / MSE [dB][2)										ver. 2.3
Channel [MHz]	**Modulation**										
	QPSK _S[1)	**QPSK**	**16 QAM**	**32 QAM**	**64 QAM**	**128 QAM**	**256 QAM**	**512 QAM**	**1024 QAM**	**2048 QAM**	**4096 QAM**
3.5	2.6	4.9	9.5	11.3	14.5	17.3	19.5	21.6	23.2		
	-100.5	-96.0	-90.0	-86.5	-83.5	-80.5	-77.5	-74.5	-71.0		
	-6.1	-9.0	-15.2	-18.4	-21.6	-24.9	-28.0	-31.0	-34.6		
5	3.6	6.9	13.6	16.2	20.8	24.7	27.7	30.8	33.0		
	-99.0	-94.5	-89.0	-85.5	-82.5	-79.5	-76.5	-73.5	-70.5		
	-6.5	-9.0	-15.1	-18.0	-21.3	-24.6	-27.6	-30.7	-34.3		
7	5.7	10.3	19.9	24.2	31.0	36.8	42.1	46.7	52.0	57.4	
	-97.0	-93.5	-88.0	-84.5	-81.5	-78.5	-75.5	-72.5	-68.5	-64.5	
	-6.2	-8.5	-14.4	-17.7	-20.9	-24.2	-27.5	-30.3	-34.6	-38.2	
10	7.7	14.4	27.6	33.2	42.7	50.7	57.9	64.5	71.6	78.9	
	-95.0	-92.0	-86.5	-83.0	-80.0	-77.0	-74.0	-71.0	-67.5	-64.0	
	-7.0	-8.5	-14.4	-17.4	-20.5	-23.8	-26.9	-29.7	-33.6	-37.0	
14	11.9	22.1	41.4	50.2	65.4	77.7	88.5	99.1	110.2	119.8	129.4
	-93.5	-90.5	-85.0	-81.5	-78.5	-75.5	-72.5	-69.5	-66.5	-63.0	-59.0
	-6.6	-8.7	-14.3	-17.4	-20.6	-23.6	-26.7	-29.6	-33.3	-36.5	-40.2
20	17.2	32.0	59.8	72.5	94.3	112.1	127.9	143.2	159.2	172.8	186.5
	-93.0	-89.0	-83.5	-80.0	-77.0	-74.0	-71.0	-68.0	-65.0	-62.0	-58.5
	-6.1	-8.7	-14.2	-17.3	-20.2	-23.5	-26.5	-29.3	-32.6	-35.4	-39.1
28	24.4	38.7	81.6	106.3	133.2	158.7	182.2	204.4	229.1	251.3	271.6
	-92.5	-89.5	-83.0	-78.5	-75.5	-72.5	-69.5	-66.5	-63.5	-60.5	-57.5
	-5.8	-7.2	-13.5	-17.2	-20.1	-23.3	-26.2	-29.2	-32.7	-35.5	-38.7
40	34.2	54.1	114.3	148.9	186.3	222.4	255.0	286.2	320.9	351.8	380.3
	-90.5	-87.5	-81.0	-77.0	-74.0	-71.0	-68.0	-65.0	-62.0	-59.0	-56.0
	-5.8	-7.3	-13.6	-17.3	-20.1	-23.3	-26.1	-29.0	-32.4	-35.2	-38.1
56	49.0	81.6	170.1	215.1	270.1	322.3	369.8	418.1	463.8	506.1	545.5
	-89.5	-86.0	-79.0	-75.0	-72.0	-69.0	-66.0	-63.0	-60.0	-57.0	-54.0
	-5.5	-7.3	-13.9	-17.4	-20.2	-23.4	-26.5	-29.3	-32.3	-35.0	-38.2
80	69.6	116.3	242.1	306.1	384.6	458.9	526.3	595.0	660.0	720.2	
	-88.0	-84.5	-77.5	-73.5	-70.5	-67.5	-64.5	-61.5	-58.5	-55.5	
	-5.5	-7.3	-13.8	-17.5	-20.2	-23.5	-26.5	-29.4	-32.4	-35.0	
100	87.3	145.8	301.4	384.7	484.2	574.4	659.2	743.2	828.6	904.3	
	-87.0	-83.5	-76.5	-72.5	-69.5	-66.5	-63.5	-60.5	-57.5	-54.5	
	-5.6	-7.4	-13.7	-17.2	-20.3	-23.3	-26.3	-29.0	-32.2	-34.9	

RAy3-17/24	Bit Rate [Mb/s] / RSS [dBm] / MSE [dB][2]										ver. 2.3
Channel [MHz]	**Modulation**										
	QPSK _S[1]	QPSK	16 QAM	32 QAM	64 QAM	128 QAM	256 QAM	512 QAM	1024 QAM	2048 QAM	4096 QAM
112	97.6	163.3	337.6	430.7	542.1	643.1	738.0	832.1	927.7	1012.4	
	-86.5	-83.0	-76.0	-72.0	-69.0	-66.0	-63.0	-60.0	-57.0	-54.0	
	-5.5	-7.3	-13.7	-17.2	-20.3	-23.2	-26.5	-29.1	-32.2	-35.0	

RSS values in the table are typical. Actual values may differ by up to ± 2 dB.

[1] Stability optimized (stronger) FEC

[2] Table cells contain values:

User Bit Rate [Mb/s]	Bit Rate for the selected modulation and bandwidth
RSS (Received Signal Strength) [dBm]	Minimum required RSS (RX Sensitivity threshold)
MSE (Mean Square Error) [dB]	Maximum required MSE (the inverse of SNR)

Tab. 9.25: ACM switching 17/24 GHz according to MSE state

RAy3-17/24					MSE degrade [dB] / MSE improve [dB]							ver. 2.1
Channel MHz	**Modulation**											
	QPSK _S[1]	**QPSK**	**16 QAM**	**32 QAM**	**64 QAM**	**128 QAM**	**256 QAM**	**512 QAM**	**1024 QAM**	**2048 QAM**	**4096 QAM**	
3.5	--	-10.5	-16.7	-19.9	-23.1	-26.4	-29.5	-32.5	-36.1			
	-11.5	-17.7	-20.9	-24.1	-27.4	-30.5	-33.5	-37.1	--			
5	--	-10.5	-16.6	-19.5	-22.8	-26.1	-29.1	-32.2	-35.8			
	-11.5	-17.6	-20.5	-23.8	-27.1	-30.1	-33.2	-36.8	--			
7	--	-10.0	-15.9	-19.2	-22.4	-25.7	-29.0	-31.8	-36.1	-39.7		
	-11.0	-16.9	-20.2	-23.4	-26.7	-30.0	-32.8	-37.1	-40.7	--		
10	--	-10.0	-15.9	-18.9	-22.0	-25.3	-28.4	-31.2	-35.1	-38.5		
	-11.0	-16.9	-19.9	-23.0	-26.3	-29.4	-32.2	-36.1	-39.5	--		
14	--	-10.2	-15.8	-18.9	-22.1	-25.1	-28.2	-31.1	-34.8	-38.0	-41.7	
	-11.2	-16.8	-19.9	-23.1	-26.1	-29.2	-32.1	-35.8	-39.0	-42.7	--	
20	--	-10.2	-15.7	-18.8	-21.7	-25.0	-28.0	-30.8	-34.1	-36.9	-40.6	
	-11.2	-16.7	-19.8	-22.7	-26.0	-29.0	-31.8	-35.1	-37.9	-41.6	--	
28	--	-8.7	-15.0	-18.8	-21.6	-24.8	-27.7	-30.6	-34.2	-37.0	-40.2	
	-9.7	-16.0	-19.8	-22.6	-25.8	-28.7	-31.6	-35.2	-38.2	-41.2	--	
40	--	-8.8	-15.1	-18.8	-21.6	-24.8	-27.6	-30.5	-33.9	-36.7	-39.6	
	-9.8	-16.1	-19.8	-22.6	-25.8	-28.6	-31.5	-34.9	-37.7	-40.6	--	
56	--	-8.8	-15.4	-18.9	-21.7	-24.9	-28.0	-30.8	-33.8	-36.5	-39.7	
	-9.8	-16.4	-19.9	-22.7	-25.9	-29.0	-31.8	-34.8	-37.5	-40.7	--	
80	--	-8.8	-15.3	-19.0	-21.7	-25.0	-28.0	-30.9	-33.9	-36.5		
	-9.8	-16.3	-20.0	-22.7	-26.0	-29.0	-31.9	-34.9	-37.5	--		
100	--	-8.8	-15.2	-18.7	-21.8	-24.7	-28.0	-30.6	-33.7	-36.5		
	-9.8	-16.2	-19.7	-22.8	-25.7	-29.0	-31.6	-34.7	-37.5	--		
112	--	-8.8	-15.2	-18.7	-21.8	-24.7	-28.0	-30.6	-33.7	-36.5		
	-9.8	-16.2	-19.7	-22.8	-25.7	-29.0	-31.6	-34.7	-37.5	--		

[1] Stability optimized (stronger) FEC

9.3.3. RAy3-17 Frequency Limits

Tab. 9.26: RAy3-17 Upper/Lower frequency limits

RAy3-17	Frequency limits		
	TX Range [GHz]		Duplex spacing [GHz]
	Unit L	Unit U	
min.	17.104	17.104	Flexible, min. 24 MHz between channel edges
max.	17.296	17.296	

9.3.4. RAy3-17 Frequency tables

Tab. 9.27: Frequency tables 17 GHz

RAy3-17	Frequency tables		
Name	Description		Note
rcinfo17_ISM200_default	17.1 – 17.3 GHz	default table	VO-R/12/11.2021-11 (CZ only), channels placement optimized for the band 200 MHz wide

The microwave link contains one or more frequency tables (called rcinfo), see menu *Radio adaptation*. Tables are labeled in format <name:version>, e.g.: rcinfo17_ISM200_default:15

9.3.5. RAy3-17/24 Emission Designation

Tab. 9.28: Emission Designation 17/24 GHz (ETSI)

for QPSK	107MG7WEN, 95M5G7WEN, 76M6G7WEN, 53M9G7WEN, 37M6G7WEN, 27M0G7WEN, 19M2G7WEN, 13M5G7WEN, 9M03G7WEN, 6M70G7WEN, 4M50G7WEN, 3M20G7WEN
for QAM	107MD7WEN, 95M5D7WEN, 76M6D7WEN, 53M9D7WEN, 37M6D7WEN, 27M0D7WEN, 19M2D7WEN, 13M5D7WEN, 9M03D7WEN, 6M70D7WEN, 4M50D7WEN, 3M20D7WEN

9.4. RAy3-18 details

9.4.1. RAy3-18 Link speed

Tab. 9.29: Raw link speed 18 GHz (displayed in user interface)

RAy3-18	Raw link speed – Bit Rate [Mb/s]										ver. 2.2
Channel [MHz]	**Modulation**										
	QPSK_S[1]	**QPSK**	**16 QAM**	**32 QAM**	**64 QAM**	**128 QAM**	**256 QAM**	**512 QAM**	**1024 QAM**	**2048 QAM**	**4096 QAM**
3.5	2.8	4.8	8.5	12	15	18	21	24	27	29	
5	4.1	7.0	9	17	22	26	31	35	38	42	
7 & 7.5	5.8	10	18	25	32	38	44	50	56	61	65
10	8.2	14	25	35	44	52	60	68	76	83	89
13.75	12	21	36	50	65	76	88	100	111	122	130
20	17	29	50	70	90	106	122	138	154	169	180
27.5 & 30	24	42	73	102	130	154	178	201	224	245	262
40	34	59	102	142	182	214	247	280	312	342	365
50	42	73	126	175	224	265	306	346	385	422	451
55 & 60	49	84	146	204	261	308	356	403	448	491	525
80	68	117	203	283	362	427	494	559	623	676	711
100	85	147	254	354	454	535	619	701	780	848	892
110	97	167	289	403	517	609	704	797	888	964	1014

[1] Stability optimized (stronger) FEC

ⓘ   Note

Values are equal to Eth L1 throughput @ 2.5 GE SFP port for 1518 B frames according RFC 2544 test (starting with FW 2.0.14.0).

Tab. 9.30: Ethernet L1 Link speed 18 GHz (according to RFC 2544)

RAy3-18	Link speed [Mb/s] for Eth L1 frames 64 B / 1518 B										ver. 2.1
Channel MHz	**Modulation**										
	QPSK _S[1]	**QPSK**	**16 QAM**	**32 QAM**	**64 QAM**	**128 QAM**	**256 QAM**	**512 QAM**	**1024 QAM**	**2048 QAM**	**4096 QAM**
3.5	3.3	5.9	11	15	19	22	26	29	33	36	
	2.8	4.8	8.5	12	15	18	21	24	27	29	
5	5.0	8.6	11	21	27	32	37	42	47	52	
	4.1	7.0	9	17	22	26	31	35	38	42	
7 & 7.5	7.3	13	22	31	39	47	54	61	68	74	79
	5.8	10	18	25	32	38	44	50	56	61	65
10	9.9	17	30	42	54	64	74	83	93	102	109
	8.2	14	25	35	44	52	60	68	76	83	89
13.75	15	26	44	62	79	93	108	122	136	149	159
	12	21	36	50	65	76	88	100	111	122	130
20	20	35	61	85	110	129	149	169	188	206	221
	17	29	50	70	90	106	122	138	154	169	180
27.5 & 30	30	51	89	124	160	188	217	246	274	300	321
	24	42	73	102	130	154	178	201	224	245	262
40	42	72	124	173	222	262	302	342	381	418	446
	34	59	102	142	182	214	247	280	312	342	365
50	51	89	154	214	274	323	374	423	471	516	552
	42	73	126	175	224	265	306	346	385	422	451
55 & 60	60	103	179	249	319	376	435	492	548	600	642
	49	84	146	204	261	308	356	403	448	491	525
80	83	143	248	345	443	522	603	683	761	826	869
	68	117	203	283	362	427	494	559	623	676	711
100	104	180	311	433	555	655	756	856	954	1036	1090
	85	147	254	354	454	535	619	701	780	848	892
110	118	205	354	493	632	745	861	974	1086	1179	1240
	97	167	289	403	517	609	704	797	888	964	1014

Tab. 9.31: Ethernet L2 Link speed 18 GHz (according to RFC 2544)

RAy3-18	Link speed [Mb/s] for Eth L2 frames 64 B / 1518 B										ver. 2.1
Channel MHz	Modulation										
	QPSK _S[1]	QPSK	16 QAM	32 QAM	64 QAM	128 QAM	256 QAM	512 QAM	1024 QAM	2048 QAM	4096 QAM
3.5	2.5	4.5	8.1	11	14	17	20	22	25	27	
	2.8	4.7	8.4	12	15	18	21	24	26	29	
5	3.8	6.6	8.1	16	21	24	28	32	36	39	
	4.0	6.9	8.4	17	22	26	30	34	38	42	
7 & 7.5	5.6	10	17	23	30	35	41	46	52	57	60
	5.7	10	18	25	32	37	43	49	55	60	64
10	7.5	13	23	32	41	49	56	64	71	78	83
	8.1	14	24	34	44	52	59	67	75	82	88
13.75	11	19	34	47	60	71	82	93	103	113	121
	12	20	36	50	64	75	87	98	109	120	128
20	15	27	47	65	83	99	114	129	143	157	168
	16	28	50	69	89	104	121	137	152	167	178
27.5 & 30	23	39	68	95	122	143	166	187	209	229	244
	24	41	72	100	129	152	175	199	221	242	259
40	32	55	95	132	169	199	230	261	290	318	340
	33	58	100	140	179	211	244	276	308	337	360
50	39	68	117	163	209	246	285	322	359	393	420
	41	72	124	173	222	261	302	342	380	417	445
55 & 60	45	79	136	190	243	287	331	375	417	457	489
	48	83	144	201	258	304	351	397	442	485	518
80	63	109	189	263	337	398	460	520	580	630	662
	67	116	200	279	358	422	487	552	615	667	702
100	79	137	237	330	423	499	576	652	727	789	830
	84	145	251	350	448	529	611	691	770	836	880
110	90	156	269	376	481	568	656	742	827	898	945
	96	165	286	398	510	601	695	787	877	952	1001

9.4.2. RAy3-18 Radio parameters

Tab. 9.32: Radio parameters - 18 GHz, BER = 10^{-6}

RAy3-18	Bit Rate [Mb/s] / RSS [dBm] / MSE [dB][2]										ver. 2.3
Channel [MHz]	**Modulation**										
	QPSK _S[1]	**QPSK**	**16 QAM**	**32 QAM**	**64 QAM**	**128 QAM**	**256 QAM**	**512 QAM**	**1024 QAM**	**2048 QAM**	**4096 QAM**
3.5	2.8	4.8	8.5	12.1	15.4	18.2	21.1	23.9	26.8	29.2	
	-101.5	-98.0	-93.5	-88.5	-85.5	-83.0	-80.0	-77.0	-73.5	-70.0	
	-5.8	-8.1	-13.2	-17.4	-20.2	-23.1	-26.1	-29.1	-32.4	-35.2	
5	4.1	7.0	8.5	17.4	22.2	26.2	30.5	34.5	38.3	42.1	
	-100.5	-96.5	-92.0	-87.0	-84.0	-81.5	-78.5	-75.5	-72.0	-68.5	
	-5.8	-8.2	-13.3	-17.5	-20.2	-23.0	-26.1	-29.0	-32.3	-35.1	
7	5.8	10.4	18.0	25.0	32.1	37.9	44.0	49.8	55.5	60.8	65.0
	-98.5	-94.5	-89.5	-85.0	-82.0	-79.5	-76.5	-73.5	-70.5	-67.0	-63.0
	-5.9	-8.2	-13.3	-17.5	-20.2	-23.1	-26.1	-29.1	-32.3	-35.0	-38.3
10	8.2	14.1	24.6	34.5	44.3	52.2	60.2	68.2	76.1	83.2	89.1
	-97.0	-93.0	-88.0	-83.5	-80.5	-78.0	-75.0	-72.0	-69.0	-65.5	-61.5
	-5.9	-8.2	-13.3	-17.5	-20.3	-23.1	-26.1	-29.1	-32.3	-35.0	-38.3
14	11.9	20.7	36.0	50.4	64.5	76.2	88.1	99.6	110.9	121.5	129.9
	-95.5	-91.5	-86.5	-82.0	-79.0	-76.5	-73.5	-70.5	-67.5	-64.0	-60.0
	-5.9	-8.2	-13.3	-17.5	-20.2	-23.0	-26.1	-29.0	-32.3	-35.0	-38.2
20	16.7	28.8	50.2	70.0	89.7	105.8	122.2	138.4	154.1	168.8	180.4
	-94.0	-90.0	-85.0	-80.5	-77.5	-75.0	-72.0	-69.0	-66.0	-62.5	-59.0
	-5.9	-8.2	-13.3	-17.6	-20.3	-23.0	-26.1	-29.0	-32.3	-35.0	-38.2
28	24.2	42.0	73.0	101.7	130.3	153.8	177.7	201.2	224.0	245.4	262.3
	-92.5	-88.5	-83.5	-79.0	-76.0	-73.5	-70.5	-67.5	-64.5	-61.0	-57.5
	-6.0	-8.2	-13.3	-17.5	-20.3	-23.1	-26.1	-29.0	-32.3	-35.0	-38.3
40	33.8	58.7	101.6	141.7	181.6	214.1	247.4	280.1	311.7	341.6	365.1
	-91.0	-87.0	-82.0	-77.5	-74.5	-72.0	-69.0	-66.0	-63.0	-60.0	-56.0
	-5.9	-8.2	-13.3	-17.5	-20.3	-23.0	-26.1	-29.0	-32.2	-35.0	-38.2
50	42.0	72.6	125.7	175.1	224.5	264.7	305.8	346.2	385.4	422.2	451.3
	-90.0	-86.0	-81.0	-76.5	-73.5	-71.0	-68.0	-65.0	-62.0	-59.0	-55.0
	-5.9	-8.2	-13.3	-17.6	-20.3	-23.1	-26.2	-29.1	-32.2	-35.0	-38.3
55	48.7	84.4	146.1	203.6	261.0	307.7	355.6	402.6	448.2	490.9	524.7
	-89.0	-85.0	-80.0	-75.5	-72.5	-70.0	-67.0	-64.0	-61.0	-58.0	-54.0
	-5.9	-8.2	-13.3	-17.6	-20.3	-23.1	-26.2	-29.1	-32.2	-35.0	-38.3
80	67.8	117.2	202.8	282.7	362.3	427.2	493.6	558.8	622.6	676.0	711.1
	-88.0	-84.0	-79.0	-74.0	-71.5	-68.5	-65.5	-62.5	-59.5	-56.5	-52.5
	-6.0	-8.3	-13.4	-17.7	-20.4	-23.2	-26.3	-29.1	-32.2	-34.8	-38.0

RAy3-18	Bit Rate [Mb/s] / RSS [dBm] / MSE [dB][2]										ver. 2.3
Channel [MHz]	**Modulation**										
	QPSK _S[1]	QPSK	16 QAM	32 QAM	64 QAM	128 QAM	256 QAM	512 QAM	1024 QAM	2048 QAM	4096 QAM
100	85.1	147.0	254.3	354.4	454.2	535.5	618.7	700.5	780.5	847.5	891.5
	-87.0	-83.0	-78.0	-73.0	-70.5	-67.5	-64.5	-61.5	-58.5	-55.0	-51.0
	-6.0	-8.3	-13.4	-17.8	-20.5	-23.3	-26.3	-29.1	-32.2	-34.8	-37.9
110	96.8	167.3	289.4	403.2	516.9	609.4	704.1	797.1	888.2	964.3	1014.4
	-86.5	-82.5	-77.5	-72.5	-70.0	-67.0	-64.0	-61.0	-57.5	-53.5	-49.5
	-6.0	-8.3	-13.4	-17.8	-20.5	-23.3	-26.3	-29.2	-32.3	-34.8	-37.9

RSS values in the table are typical. Actual values may differ by up to ± 2 dB.

[1] Stability optimized (stronger) FEC

[2] Table cells contain values:

User Bit Rate [Mb/s]	Bit Rate for the selected modulation and bandwidth
RSS (Received Signal Strength) [dBm]	Minimum required RSS (RX Sensitivity threshold)
MSE (Mean Square Error) [dB]	Maximum required MSE (the inverse of SNR)

Tab. 9.33: ACM switching - 18 GHz according to MSE state

RAy3-18		MSE degrade [dB] / MSE improve [dB]										ver. 2.1
Channel MHz		**Modulation**										
	QPSK _S[1]	QPSK	16 QAM	32 QAM	64 QAM	128 QAM	256 QAM	512 QAM	1024 QAM	2048 QAM	4096 QAM	
3.5	--	-9.6	-14.7	-18.9	-21.7	-24.6	-27.6	-30.6	-33.9	-36.7		
	-10.6	-15.7	-19.9	-22.7	-25.6	-28.6	-31.6	-34.9	-37.7	--		
5	--	-9.7	-14.8	-19.0	-21.7	-24.5	-27.6	-30.5	-33.8	-36.6		
	-10.7	-15.8	-20.0	-22.7	-25.5	-28.6	-31.5	-34.8	-37.6	--		
7 & 7.5	--	-9.7	-14.8	-19.0	-21.7	-24.6	-27.6	-30.6	-33.8	-36.5	-39.8	
	-10.7	-15.8	-20.0	-22.7	-25.6	-28.6	-31.6	-34.8	-37.5	-40.8	--	
10	--	-9.7	-14.8	-19.0	-21.8	-24.6	-27.6	-30.6	-33.8	-36.5	-39.8	
	-10.7	-15.8	-20.0	-22.8	-25.6	-28.6	-31.6	-34.8	-37.5	-40.8	--	
13.75	--	-9.7	-14.8	-19.0	-21.7	-24.5	-27.6	-30.5	-33.8	-36.5	-39.7	
	-10.7	-15.8	-20.0	-22.7	-25.5	-28.6	-31.5	-34.8	-37.5	-40.7	--	
20	--	-9.7	-14.8	-19.1	-21.8	-24.5	-27.6	-30.5	-33.8	-36.5	-39.7	
	-10.7	-15.8	-20.1	-22.8	-25.5	-28.6	-31.5	-34.8	-37.5	-40.7	--	
27.5 & 30	--	-9.7	-14.8	-19.0	-21.8	-24.6	-27.6	-30.5	-33.8	-36.5	-39.8	
	-10.7	-15.8	-20.0	-22.8	-25.6	-28.6	-31.5	-34.8	-37.5	-40.8	--	
40	--	-9.7	-14.8	-19.0	-21.8	-24.5	-27.6	-30.5	-33.7	-36.5	-39.7	
	-10.7	-15.8	-20.0	-22.8	-25.5	-28.6	-31.5	-34.7	-37.5	-40.7	--	
50	--	-9.7	-14.8	-19.1	-21.8	-24.6	-27.7	-30.6	-33.8	-36.5	-39.8	
	-10.7	-15.8	-20.1	-22.8	-25.6	-28.7	-31.6	-34.8	-37.5	-40.8	--	
55 & 60	--	-9.7	-14.8	-19.1	-21.8	-24.6	-27.7	-30.6	-33.8	-36.5	-39.8	
	-10.7	-15.8	-20.1	-22.8	-25.6	-28.7	-31.6	-34.8	-37.5	-40.8	--	
80	--	-9.8	-14.9	-19.2	-21.9	-24.7	-27.8	-30.6	-33.7	-36.4	-39.7	
	-10.8	-15.9	-20.2	-22.9	-25.7	-28.8	-31.6	-34.7	-37.4	-40.7	--	
100	--	-9.8	-14.9	-19.3	-22.0	-24.8	-27.8	-30.6	-33.7	-36.4	-39.7	
	-10.8	-15.9	-20.3	-23.0	-25.8	-28.8	-31.6	-34.7	-37.4	-40.7	--	
110	--	-9.8	-14.9	-19.3	-22.0	-24.8	-27.8	-30.7	-33.8	-36.4	-39.7	
	-10.8	-15.9	-20.3	-23.0	-25.8	-28.8	-31.7	-34.8	-37.4	-40.7	--	

[1] Stability optimized (stronger) FEC

9.4.3. RAy3-18 Sub-bands

Tab. 9.34: RAy3-18 Sub-band Upper/Lower limits, Duplex spacing

RAy3-18		Sub-bands		
Sub-band		**Sub-band TX Range [GHz]**		**Duplex spacing [MHz]**
		Unit L	**Unit U**	
A	min.	17.700	18.710	1008, 1010
	max.	18.209	19.219	
B	min.	18.167	19.177	1008, 1010
	max.	18.690	19.700	
C	min.	17.700	19.300	1560
	max.	18.300	19.700	

9.4.4. RAy3-18 Frequency tables

Tab. 9.35: Frequency tables 18 GHz

RAy3-18	Frequency tables		
Name	**Description**		**Note**
rcinfo18_A_default	17.7 – 19.3 GHz	default table	CEPT/ERC/REC 12-03 E, Rec. ITU-R F.595-11, (02/22)
rcinfo18_B_default	18.1 – 19.7 GHz	default table	
rcinfo18_C_default	17.7 – 19.7 GHz	default table, FCC compliant	47 CFR Part 101 (FCC)

9.4.5. RAy3-18 Emission designation

For Emission designation codes see table in *Section 9.1.5, "RAy3-10/11/18 Emission designation"*.

9.5. RAy3-24 details

9.5.1. RAy3-24 Link speed

For **Raw link speed 24 GHz** see table *Raw link speed 17/24 GHz*.

For **Ethernet L2 Link speed 24 GHz (according to RFC 2544)** see table *Ethernet L2 Link speed 17/24 GHz*.

Tables are located in *Section 9.3.1, "RAy3-17/24 Link speed"* (parameters of both models are identical).

9.5.2. RAy3-24 Radio parameters

For **Radio parameters 24 GHz** see table *Radio parameters 17/24 GHz*.

For **ACM switching according to MSE state** see table *ACM switching 17/24 GHz*.

9.5.3. RAy3-24 Frequency Limits

Tab. 9.36: RAy3-24 Upper/Lower frequency limits

RAy3-24	Frequency limits		
	TX Range [GHz]		Duplex spacing [GHz]
	Unit L	Unit U	
min.	24.004	24.004	Flexible, min. 24 MHz between channel edges or 18 MHz in case of 2× 112 MHz channel
max.	24.246	24.246	

9.5.4. RAy3-24 Frequency tables

Tab. 9.37: Frequency tables 24 GHz

RAy3-24	Frequency tables	
Name	Description	Note
rcinfo24_ISM250_default	24.000 – 24.250 GHz	default table	VO-R/10/07.2021-8 (CZ only), CEPT/ERC/REC 70-03, channels placement optimized for the band 250 MHz wide
rcinfo24_ISM250_-9dBm	24.000 – 24.250 GHz	limited RF power	
rcinfo24_ISM250_-15dBm	24.000 – 24.250 GHz	limited RF power	
rcinfo24_ISM200	24.050 – 24.250 GHz		CFR 47 part 15 (FCC), channels placement optimized for the band 200 MHz wide
rcinfo24_ISM150	24.000 – 24.150 GHz		channels placement optimized for the band 150 MHz wide

RAy3-24	Frequency tables		
Name	**Description**		**Note**
rcinfo24_FCC200	24.050 – 24.250 GHz		CFR 47 part 15 (FCC), channels placement optimized for the band 200 MHz wide

The microwave link contains one or more frequency tables (called rcinfo), see menu *Radio adaptation*. Tables are labeled in format <name:version>, e.g.: rcinfo24_ISM250_default:15

9.5.5. RAy3-24 Emission designation 24 GHz

For Emission designation codes see table in *Section 9.3.5, "RAy3-17/24 Emission Designation"* (designations of both models are identical).

9.6. RAy3-80 details

9.6.1. RAy3-80 Link speed

Tab. 9.38: Raw link speed 80 GHz (displayed in user interface)

RAy3-80	Raw link speed – Bit Rate [Mb/s]										ver. 2.1
Channel [MHz]	Modulation										
	2 PSK[1]	2 PSK[2]	2 PSK[3]	2 PSK	4 PSK	8 PSK	16 QAM	32 QAM	64 QAM	128 QAM	256 QAM
250	25.3	43.4	86.8	174	348	523	756	931	1105	1222 [4]	1338 [4]
500	51.7	88.1	176	352	707	1061	1533	1888	2242	2478	2715 [4]
750	77.5	132	264	528	1059	1590	2298	2829	3360	3715	4069
1000	103	175	351	702	1407	2113	3053	3759	4464	4935	5405
1250	129	220	440	880	1765	2650	3831	4716	5601	6191	6781 [4]
1500	155	264	528	1056	2118	3181	4597	5659	6721	7429	
1750	181	308	616	1232	2472	3711	5363	6602	7841	8667	
2000	199	338	676	1353	2713	4073	5886	7246	8606	9512	

[1] **2PSK_BW/4_S**   Stability optimized (stronger) FEC & Quarter Bandwidth

[2] **2PSK_BW/4**   Quarter Bandwidth (Channel reduced to 1/4)

[3] **2PSK_BW/2**   Half Bandwidth (Channel reduced to 1/2)

[4] Available on units manufactured after July 1, 2024

ⓘ **Note**

Values are equal to Eth L1 throughput @ 10GE port for 1518 B frames (RFC 2544 test).

Tab. 9.39: Ethernet L1 Link speed 80 GHz (according to RFC 2544)

RAy3-80	Link speed [Mb/s] for Eth L1 frames 64 B / 1518 B / 9600 B										ver. 2.1
Channel [MHz]	**Modulation**										
	2 PSK[1]	**2 PSK[2]**	**2 PSK[3]**	**2 PSK**	**4 PSK**	**8 PSK**	**16 QAM**	**32 QAM**	**64 QAM**	**128 QAM**	**256 QAM**
250	31	53	106	212	426	639	924	1138	1351	1494[4]	1636[4]
	25	43	87	174	348	523	756	931	1105	1222[4]	1338[4]
	25	43	86	172	345	518	749	922	1096	1211[4]	1327[4]
500	63	108	215	431	864	1297	1875	2308	2741	3030	3318[4]
	52	88	176	352	707	1061	1533	1888	2242	2478	2715[4]
	51	87	174	349	700	1052	1520	1871	2222	2457	2691[4]
750	95	161	323	646	1295	1944	2810	3459	4108	4541	4973
	78	132	264	528	1059	1590	2298	2829	3360	3715	4069
	77	131	262	523	1050	1576	2278	2805	3331	3682	4033
1000	126	214	429	858	1720	2583	3733	4595	5457	6033	6607
	103	175	351	702	1407	2113	3053	3759	4464	4935	5405
	102	174	348	695	1395	2094	3027	3726	4425	4892	5358
1250	158	269	538	1076	2158	3240	4683	5765	6847	7568	8289[4]
	129	220	440	880	1765	2650	3831	4716	5601	6191	6781[4]
	128	218	436	873	1750	2627	3797	4674	5552	6137	6722[4]
1500	189	323	646	1291	2590	3888	5619	6917	8216	9081	
	155	264	528	1056	2118	3181	4597	5659	6721	7429	
	154	262	524	1047	2100	3153	4556	5609	6662	7364	
1750	221	377	753	1507	3021	4536	6556	8071	9585	10000	
	181	308	616	1232	2472	3711	5363	6602	7841	8667	
	179	305	611	1222	2450	3678	5316	6544	7772	8591	
2000	243	413	827	1653	3316	4978	7195	8857	10000	10000	
	199	338	676	1353	2713	4073	5886	7246	8606	9512	
	197	335	670	1341	2689	4037	5834	7182	8530	9397	

[1] **2PSK_BW/4_S**   Stability optimized (stronger) FEC & Quarter Bandwidth

[2] **2PSK_BW/4**   Quarter Bandwidth (Channel reduced to 1/4)

[3] **2PSK_BW/2**   Half Bandwidth (Channel reduced to 1/2)

[4] Available on units manufactured after July 1, 2024

Tab. 9.40: Ethernet L2 Link speed 80 GHz (according to RFC 2544)

RAy3-80				Link speed [Mb/s] for Eth L2 frames 64 B / 1518 B / 9600 B							ver. 2.1
Channel [MHz]	**Modulation**										
	2 PSK[1]	**2 PSK[2]**	**2 PSK[3]**	**2 PSK**	**4 PSK**	**8 PSK**	**16 QAM**	**32 QAM**	**64 QAM**	**128 QAM**	**256 QAM**
250	23.6	40.3	80.8	162	324	487	704	867	1029	1138[4]	1246[4]
	25.0	42.8	85.7	171	344	516	746	918	1091	1206[4]	1321[4]
	25.0	42.9	85.9	172	345	517	748	921	1093	1209[4]	1324[4]
500	48.2	82.1	164	328	658	988	1428	1758	2088	2308	2528[4]
	51.0	87.0	174	348	698	1047	1514	1863	2213	2446	2679[4]
	51.1	87.1	174	349	699	1049	1517	1867	2218	2452	2685[4]
750	72.2	123	246	492	987	1481	2141	2635	3130	3460	3789
	76.5	130	260	521	1045	1570	2268	2793	3317	3666	4016
	76.6	130	261	522	1048	1573	2273	2799	3324	3674	4024
1000	95.8	163	327	653	1311	1968	2844	3501	4158	4596	5034
	101.5	173	346	693	1389	2085	3014	3710	4406	4871	5335
	101.8	173	347	694	1392	2090	3020	3718	4416	4881	5347
1250	120	205	410	820	1644	2469	3568	4392	5216	5766	6316[4]
	128	217	434	869	1742	2616	3781	4654	5528	6110	6693[4]
	128	218	435	871	1746	2622	3789	4665	5540	6124	6708[4]
1500	144	246	492	984	1973	2962	4281	5270	6260	6919	
	153	260	521	1043	2091	3139	4537	5585	6634	7332	
	153	261	522	1045	2095	3146	4547	5597	6648	7349	
1750	168	287	574	1148	2302	3456	4995	6149	7303	7619	
	178	304	608	1216	2439	3662	5293	6516	7739	8554	
	179	305	609	1219	2445	3670	5305	6530	7756	8573	
2000	185	315	630	1260	2526	3793	5482	6749	7619	7619	
	196	334	668	1335	2677	4020	5809	7152	8494	9389	
	196	335	669	1338	2683	4028	5822	7168	8513	9378	

[1] **2PSK_BW/4_S** Stability optimized (stronger) FEC & Quarter Bandwidth

[2] **2PSK_BW/4** Quarter Bandwidth (Channel reduced to 1/4)

[3] **2PSK_BW/2** Half Bandwidth (Channel reduced to 1/2)

[4] Available on units manufactured after July 1, 2024

9.6.2. RAy3-80 Radio parameters

Tab. 9.41: Radio parameters 80 GHz, BER = 10^{-6}

RAy3-80	Bit Rate [Mb/s] / RSS [dBm] / MSE [dB] [4]										ver. 2.1
Channel [MHz]	**Modulation**										
	2 PSK[1]	**2 PSK**[2]	**2 PSK**[3]	**2 PSK**	**4 PSK**	**8 PSK**	**16 QAM**	**32 QAM**	**64 QAM**	**128 QAM**	**256 QAM**
250	25.3	43.4	86.8	174	348	523	756	931	1105	1222 [5]	1338 [5]
	-85.0	-82.0	-79.0	-76.0	-73.0	-68.0	-65.0	-62.0	-59.0	-57.0 [5]	-55.0 [5]
	-4.1	-6.1	-6.1	-6.1	-8.1	-13.0	-16.2	-18.6	-21.1	-23.1 [5]	-26.0 [5]
500	51.7	88.1	176	352	707	1061	1533	1888	2242	2478	2715 [5]
	-82.0	-79.0	-76.0	-73.0	-70.0	-65.0	-61.0	-59.0	-56.0	-53.0	-51.0 [5]
	-4.1	-6.1	-6.1	-6.1	-8.2	-13.1	-16.2	-18.6	-21.0	-23.4	-26.0 [5]
750	77.5	132	264	528	1059	1590	2298	2829	3360	3715	4069
	-80.0	-77.0	-74.0	-71.0	-68.0	-63.0	-59.0	-57.0	-54.0	-51.0	-49.0
	-4.1	-6.1	-6.1	-6.1	-8.4	-13.3	-16.2	-18.7	-21.1	-23.6	-26.4
1000	103	175	351	702	1407	2113	3053	3759	4464	4935	5405
	-79.0	-76.0	-73.0	-70.0	-67.0	-62.0	-58.0	-56.0	-53.0	-50.0	-48.0
	-4.1	-6.1	-6.1	-6.1	-8.4	-13.3	-16.2	-18.4	-21.1	-23.6	-26.4
1250	129	220	440	880	1765	2650	3831	4716	5601	6191	6781 [5]
	-78.0	-75.0	-72.0	-69.0	-66.0	-61.0	-57.0	-55.0	-52.0	-49.0	-47.0 [5]
	-4.1	-6.1	-6.1	-6.1	-8.4	-13.3	-16.2	-18.7	-21.1	-23.6	-26.4 [5]
1500	155	264	528	1056	2118	3181	4597	5659	6721	7429	
	-77.0	-74.0	-71.0	-68.0	-65.0	-60.0	-56.0	-54.0	-51.0	-47.5	
	-4.1	-6.1	-6.1	-6.1	-8.5	-13.5	-16.2	-18.8	-21.2	-23.6	
1750	181	308	616	1232	2472	3711	5363	6602	7841	8667	
	-76.5	-73.5	-70.5	-67.5	-64.5	-59.5	-55.5	-53.5	-50.5	-47.0	
	-4.1	-6.1	-6.1	-6.1	-8.5	-13.5	-16.2	-18.8	-21.2	-23.6	
2000	199	338	676	1353	2713	4073	5886	7246	8606	9512	
	-76.0	-73.0	-70.0	-67.0	-64.0	-59.0	-55.0	-53.0	-50.0	-46.5	
	-4.1	-6.1	-6.1	-6.1	-8.5	-13.5	-16.2	-18.8	-21.2	-23.6	

[1] **2PSK_BW/4_S**   Stability optimized (stronger) FEC & Quarter Bandwidth

[2] **2PSK_BW/4**   Quarter Bandwidth (Channel reduced to 1/4)

[3] **2PSK_BW/2**   Half Bandwidth (Channel reduced to 1/2)

[4] Table cells contain values:

    Bit Rate [Mb/s]   User Raw link speed = Eth L1 Bit Rate

    RSS (Received Signal Strength) [dBm] Minimum required RSS (RX Sensitivity threshold)

    MSE (Mean Square Error) [dB]   Maximum required MSE (the inverse of SNR)

[5] Available on units manufactured after July 1, 2024

Tab. 9.42: TX power range 80 GHz

RAy3-80	TX power range [dBm]	ver. 1.1
Modulation	**Minimum TX power [dBm]**	**Maximum TX power [dBm]**
2PSK_BW/4_S [1] up to 16QAM	-6	+20
32QAM	-6	+17
64QAM	-6	+16
128QAM	-6	+14
256QAM	-6	+13

[1] Stability optimized (stronger) FEC & Quarter Bandwidth (Channel reduced to 1/4)

Tab. 9.43: ACM switching 80 GHz according to MSE state

RAy3-80	MSE degrade [dB] / MSE improve [dB]										ver. 2.1
Channel [MHz]	**Modulation**										
	2 PSK[1]	**2 PSK[2]**	**2 PSK[3]**	**2 PSK**	**4 PSK**	**8 PSK**	**16 QAM**	**32 QAM**	**64 QAM**	**128 QAM**	**256 QAM**
250	--	-8.1	-8.1	-8.1	-10.1	-16.0	-19.2	-21.6	-24.1	-26.1 [4]	-29.0 [4]
	-8.1	-11.6	-11.6	-12.1	-17.0	-20.2	-22.6	-25.0	-27.1	-30.0	--
500	--	-8.1	-8.1	-8.1	-10.2	-16.1	-19.2	-21.6	-24.0	-26.4	-29.0 [4]
	-8.1	-11.6	-11.6	-12.2	-17.1	-20.2	-22.6	-25.0	-27.4	-30.0	--
750	--	-8.1	-8.1	-8.1	-10.4	-16.3	-19.2	-21.7	-24.1	-26.6	-29.4
	-8.1	-11.6	-11.6	-12.4	-17.3	-20.2	-22.7	-25.1	-27.6	-30.1	--
1000	--	-8.1	-8.1	-8.1	-10.4	-16.3	-19.2	-21.7	-24.1	-26.6	-29.4
	-8.1	-11.6	-11.6	-12.4	-17.3	-20.2	-22.7	-25.1	-27.6	-30.1	--
1250	--	-8.1	-8.1	-8.1	-10.4	-16.3	-19.2	-21.7	-24.1	-26.6	-29.4 [4]
	-75.0	-11.6	-11.6	-12.4	-17.3	-20.2	-22.7	-25.1	-27.6	-30.1	--
1500	--	-8.1	-8.1	-8.1	-10.5	-16.5	-19.2	-21.8	-24.2	-26.4	
	-74.0	-11.6	-11.6	-12.5	-17.5	-20.2	-22.8	-25.2	-26.9	--	
1750	--	-8.1	-8.1	-8.1	-10.5	-16.5	-19.2	-21.8	-24.2	-26.4	
	-73.5	-11.6	-11.6	-12.5	-17.5	-20.2	-22.8	-25.2	-26.9	--	
2000	--	-8.1	-8.1	-8.1	-10.5	-16.5	-19.2	-21.8	-24.2	-26.4	
	-73.0	-11.6	-11.6	-12.5	-17.5	-20.2	-22.8	-25.2	-26.9	--	

[1] **2PSK_BW/4_S** Stability optimized (stronger) FEC & Quarter Bandwidth

[2] **2PSK_BW/4** Quarter Bandwidth (Channel reduced to 1/4)

[3] **2PSK_BW/2** Half Bandwidth (Channel reduced to 1/2)

[4] Available on units manufactured after July 1, 2024

9.6.3. RAy3-80 Frequency Limits

Tab. 9.44: RAy3-80 Upper/Lower frequency limits, Duplex spacing

RAy3-80	Frequency limits		
	TX Range [GHz]		Duplex spacing [GHz]
	Unit L	Unit U	
min.	71.000	81.000	Flexible; typ. 10 GHz, min. 5 GHz, max. 15 GHz
max.	76.000	86.000	

9.6.4. RAy3-80 Frequency tables

Tab. 9.45: Frequency tables 80 GHz

RAy3-10	Frequency tables		
Name	Description		Note
rcinfo80_default	71-76 and 81-86 GHz	default table	ITU-R F.2006 (03/2012) ECC REC (05)07 (revised 2009 and 2013) FCC 47 CFR, part 15 VO-R/23/09.2013-5 (CZ only)

10. Safety, regulations, warranty

10.1. Regulations

RAy3 microwave links must be used in accordance with rules issued by the Telecommunications Authority for the area the device is operating in.

RAy3 microwave links must comply with the maximum permitted radiated power (EIRP) in accordance with conditions of the given country.

Important

For US:

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

1. This device may not cause harmful interference.
2. This device must accept any interference received, including interference that may cause undesired operation of the device.

Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

For Canada:

This device contains licence-exempt transmitter(s)/receiver(s) that comply with Innovation, Science and Economic Development Canada's licence-exempt RSS(s). Operation is subject to the following two conditions:

1. This device may not cause harmful interference.
2. This device must accept any interference, including interference that may cause undesired operation of the device.

L'émetteur/récepteur exempt de licence contenu dans le présent appareil est conforme aux CNR d'Innovation, Sciences et Développement économique 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;
2. L'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

10.2. Safety distance

10.2.1. EU requirements

Safety distance evaluation based on Standard EN 62311:2020 which refers to Council Recommendation 1999/519/EC of 12 July 1999.

Tab. 10.1: Table of basic radio and antennas parameters

Product	Frequency	Max. Tx power	Antenna gain [dBi]				Operation time
	[GHz]	[dBm]	30 cm	60 cm	90 cm	120 cm	[h]
RAy3 10	10.1 - 10.7	13	29	34.1	37.5	40.3	24
RAy3 11	10.5 - 11.7	24	30.1	35.2	38.5	41.0	24
RAy3 17	17.1 - 17.3	10	33.7	39.4	42.4	44.7	24
RAy3 18	17.7 - 19.7	24	34.7	39.7	43.5	45.2	24
RAy3 24	24.1 - 24.25	10	36.9	42.0	45.4	47.9	24
RAy3 80	71 - 86	20	47.3	52.2	n/a	n/a	24

The limits for power density (S) depend on the frequency of the electromagnetic fields. For Frequency Range from 2 GHz to 300 GHz:

- For general public exposure, the limit for power density (S) is 10 W/m^2.
- For occupational exposure, the limit for power density (S) is 50 W/m^2.

Tab. 10.2: Calculation of equivalent plane wave power density S for RAy3-10

Antenna diameter	Tx power	Tx power	Effective area	Sawg	Smax/Savg	**Smax**
[m]	[dBm]	[W]	$[m^2]$	$[W/m^2]$	-	**$[W/m^2]$**
0,37	13	0,02	0,108	0,186	3,0	**0,558**
0,66	13	0,02	0,342	0,058	4,0	**0,234**
0,99	13	0,02	0,770	0,026	4,5	**0,117**
1,29	13	0,02	1,307	0,015	5,0	**0,077**

Tab. 10.3: Calculation of equivalent plane wave power density S for RAy3-11

Antenna diameter	Tx power	Tx power	Effective area	Sawg	Smax/Savg	**Smax**
[m]	[dBm]	[W]	$[m^2]$	$[W/m^2]$	-	**$[W/m^2]$**
0,37	24	0,25	0,108	2,325	3,0	**6,975**
0,66	24	0,25	0,342	0,731	4,0	**2,923**
0,99	24	0,25	0,770	0,325	4,5	**1,461**
1,29	24	0,25	1,307	0,191	5,0	**0,956**

Tab. 10.4: Calculation of equivalent plane wave power density S for RAy3-17

Antenna diameter	Tx power	Tx power	Effective area	Sawg	Smax/Savg	Smax
[m]	[dBm]	[W]	[m^2]	[W/m^2]	-	[W/m^2]
0,37	10	0,0100	0,108	0,093	3,0	0,279
0,66	10	0,0100	0,342	0,029	4,0	0,117
0,99	10	0,0100	0,770	0,013	4,5	0,058
1,29	10	0,0100	1,307	0,008	5,0	0,038

Tab. 10.5: Calculation of equivalent plane wave power density S for RAy3-18

Antenna diameter	Tx power	Tx power	Effective area	Sawg	Smax/Savg	Smax
[m]	[dBm]	[W]	[m^2]	[W/m^2]	-	[W/m^2]
0,37	24	0,25	0,108	2,325	3,0	6,975
0,66	24	0,25	0,342	0,731	4,0	2,923
0,99	24	0,25	0,770	0,325	4,5	1,461
1,29	24	0,25	1,307	0,191	5,0	0,956

Tab. 10.6: Calculation of equivalent plane wave power density S for RAy3-24

Antenna diameter	Tx power	Tx power	Effective area	Sawg	Smax/Savg	Smax
[m]	[dBm]	[W]	[m^2]	[W/m^2]	-	[W/m^2]
0,37	10	0,0100	0,108	0,093	3,0	0,279
0,66	10	0,0100	0,342	0,029	4,0	0,117
0,99	10	0,0100	0,770	0,013	4,5	0,058
1,29	10	0,0100	1,307	0,008	5,0	0,038

Tab. 10.7: Calculation of equivalent plane wave power density S for RAy3-80

Antenna diameter	Tx power	Tx power	Effective area	Sawg	Smax/Savg	Smax
[m]	[dBm]	[W]	[m^2]	[W/m^2]	-	[W/m^2]
0,37	10	0,0100	0,108	0,093	3,0	0,279
0,66	10	0,0100	0,342	0,029	4,0	0,117

Evaluated equipment is in line with requirements for all above mentioned antennas. Antenna radome is always used with those antennas and it excludes access to antenna irradiator.

In all the above mentioned cases and all possible distances limits are met.

10.2.2. FCC requirements

Safety distances with respect to the US health limits of the electromagnetic field intensity are in the Minimum Safety Distance tables below, calculated for different antennas and RAy power levels.

Tab. 10.8: Minimum Safety Distance 24 GHz

RAy3-24	24.000 – 24.250 GHz		+10 dBm RF power	
Antenna code	Parabolic antenna diameter [m]	Gain [dBi]	Distance where the FCC limits is met for	
			General Population / Uncontrolled Exposure [cm]	Occupational / Controlled Exposure [cm]
ANT-LEAX-RAy-300-24	ø 0.3	37.0	70	30
ANT-JRMB-400-24R	ø 0.4	36.8		
ANT-LEAX-RAy-600-24	ø 0.6	42.4	120	60
ANT-JRMB-680-24R	ø 0.7	41.7		
ANT-LEAX-RAy-900-24	ø 0.9	45.7	180	80
ANT-JRMB-900-24R	ø 0.9	44.0		
ANT-LEAX-RAy-1200-24	ø 1.2	48.4	240	110
ANT-JRMB-1200-24R	ø 1.2	46.6		

ver. 1.0

10.3. Professional installation

RAy units are only intended for installation by professionally trained people and in locations not accessible to the public. Installation and servicing must be carried out by personnel with appropriate technical training and knowledge of potential hazards.

RAy units shall be installed according to local Electrical Safety Codes. Each person participating on the installation has to respect all local standards and regulations for personal security and electromagnetic protection for everybody on the site. We also recommend to consult each site situation with local experts to ensure both the people and installed equipment are safe, the grounding and other protection are chosen reasonably for the actual site conditions. Trained staff must check that all parts recommended by experts regarding grounding and overvoltage protection of sensitive components or infrastructures are perfectly installed, so they effectively protect the equipment against typical situations.

It is the responsibility of the installer to ensure that all building and safety codes are met and that the installation is fully completed and equipment properly secured.

10.4. RoHS and WEEE compliance

RoHS
compliant

WEEE
compliant

This product is fully compliant with the European Parliament's 2011/65/EU RoHS (Restriction of Certain Hazardous Substances in Electrical and Electronic Equipment), as amended by Directive (EU) 2015/863, and Directive 2012/19/EU WEEE (Waste Electrical and Electronic Equipment) environmental directives.

Disposed equipment must be collected separately, and disposed of properly. In any case it may not be put aside as unsorted municipal waste. Equipment has to be returned to supplier or producer (RACOM) or placed to a designated collection point ensuring proper recycling and recovery of waste in an environmentally safe manner using processes that comply with the WEEE Directive.

Battery Disposal   RACOM products and accessories may contain a battery. Batteries must be disposed of properly, and may not be put aside as unsorted municipal waste. For proper recycling, return the product or its battery to your supplier or place it to a designated collection point.

10.4.1. RoHS and WEEE Declaration of Conformity

EU DECLARATION OF CONFORMITY

Equipment	**RipEX, RipEX2** **RAy2, RAy3** **M!DGE2, M!DGE3** **RipEX-HS, RipEX2-HS**
Manufacturer	**RACOM s.r.o.** **Mirova 1283, 592 31 Nove Mesto na Morave, Czech Republic**

This declaration of conformity is issued under the sole responsibility of the manufacturer.

The equipment described above is in conformity with the Directive 2011/65/EU of the European Parliament and of the Council on the restriction of the use of certain hazardous substances in electrical and electronic equipment (RoHS), as amended by Directive (EU) 2015/863, Directive 2012/19/EU of the European Parliament and of the Council on waste electrical and electronic equipment (WEEE) and Regulation (EC) No 1907/2006 of the European Parliament and of the Council concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH).

REACH: Equipment mentioned above do not contain any substances from the "Candidate List of Substances of Very High Concern" with more than 0.1% of the global weight of the delivered item (without packaging of the item)

Compliance has been verified via internal design controls, supplier declarations and/or analytical test data.

Signed for and on behalf of the manufacturer:

Nove Mesto na Morave, 3rd May 2024
Marek Bobula, Technical director

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www.racom.eu

ver. 1.4

Fig. 10.1: RoHS and WEEE Declaration of Conformity

10.5. RACOM Open Software License

Version 1.0, November 2009
Copyright (c) 2025, RACOM s.r.o., Mírová 1283, Nové Město na Moravě, 592 31

Everyone can copy and spread word-for-word copies of this license, but no changes are permitted.

The program (binary version) is freely available on https://www.racom.eu. This product contains open source or other software originating from third parties subject to GNU General Public License (GPL), GNU Library / Lesser General Public License (LGPL) and / or further author licences, declarations of responsibility, exclusion and notifications. Exact terms of GPL, LGPL and some further licences are mentioned in the source code packets (typically the files COPYING or LICENSE). You can obtain applicable machine-readable copies of source code of this software under GPL or LGPL licences on https://www.racom.eu. This product also includes software developed by the University of California, Berkeley and its contributors.

10.6. Warranty

RACOM supplied parts or equipment ("equipment") are covered under warranty for inherently faulty parts and workmanship for a warranty period as stated in the delivery documentation from the date of dispatch to the customer. The warranty does not cover custom modifications to software. During the warranty period RACOM shall, on its option, fit, repair or replace ("service") faulty equipment, always provided that malfunction has occurred during normal use, not due to improper use, whether deliberate or accidental, such as attempted repair or modification by any unauthorised person; nor due to the action of abnormal or extreme environmental conditions such as overvoltage, liquid immersion or lightning strike.

Any equipment subject to repair under warranty must be returned by prepaid freight to RACOM direct. The serviced equipment shall be returned by RACOM to the customer by prepaid freight. If circumstances do not permit the equipment to be returned to RACOM, then the customer is liable and agrees to reimburse RACOM for expenses incurred by RACOM during servicing the equipment on site. When equipment does not qualify for servicing under warranty, RACOM shall charge the customer and be reimbursed for costs incurred for parts and labour at prevailing rates.

This warranty agreement represents the full extent of the warranty cover provided by RACOM to the customer, as an agreement freely entered into by both parties.

RACOM warrants the equipment to function as described, without guaranteeing it as befitting customer intent or purpose. Under no circumstances shall RACOM's liability extend beyond the above, nor shall RACOM, its principals, servants or agents be liable for any consequential loss or damage caused directly or indirectly through the use, misuse, function or malfunction of the equipment, always subject to such statutory protection as may explicitly and unavoidably apply hereto.

Liability for defects does not apply to any product that has been used in a manner that conflicts with the instructions contained in this operator manual, if the case in which the radio modem is packed has been opened, or if the equipment has been tampered with.

10.7. Declarations of Conformity

10.7.1. RED Declarations of Conformity

RACOM
www.racom.eu

EU DECLARATION OF CONFORMITY

Radio equipment type	RAy3-10	Radio SW version
	RAy3-18	1.0.2
Manufacturer	RACOM s.r.o.	
	Mirova 1283, 592 31 Nove Mesto na Morave, Czech Republic	

This declaration of conformity is issued under the sole responsibility of the manufacturer.

The radio equipment described above is in conformity with the Directive 2014/53/EU of the European Parliament and of the Council on the harmonisation of the laws of the Member States relating to the making available on the market of radio equipment and repealing Directive 1999/5/EC.

Harmonised standards used for demonstration of conformity:

Spectrum	EN 302 217-2 V3.1.1
EMC	EN 301 489-1 V2.2.3
	EN 301 489-3 V2.1.1
	EN 301 489-4 V3.3.1
Safety	EN 62368-1:2020+A11:2020

Signed for and on behalf of the manufacturer:

Nove Mesto na Morave, 14th of June 2022
Jiri Hruska, CEO

RACOM s.r.o. | Mirova 1283 | 592 31 Nove Mesto na Morave | Czech Republic
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ver. 2.0

Fig. 10.2: RED Declaration of Conformity for RAy3-10 and RAy3-18

RACOM

EU DECLARATION OF CONFORMITY

Radio equipment type	**RAy3-11**	**Radio SW version**
		1.0.2
Manufacturer	**RACOM s.r.o.**	
	Mirova 1283, 592 31 Nove Mesto na Morave, Czech Republic	

This declaration of conformity is issued under the sole responsibility of the manufacturer.

The radio equipment described above is in conformity with the Directive 2014/53/EU of the European Parliament and of the Council on the harmonisation of the laws of the Member States relating to the making available on the market of radio equipment and repealing Directive 1999/5/EC.

Harmonised standards used for demonstration of conformity:

Spectrum	EN 302 217-2 V3.1.1
EMC	EN 301 489-1 V2.2.3
	EN 301 489-3 V2.3.2
	EN 301 489-4 V3.3.1
Safety	EN 62368-1:2020+A11:2020

Signed for and on behalf of the manufacturer:

Nove Mesto na Morave, 3rd of June 2024
Marek Bobula, Technical director

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ver. 1.0

Fig. 10.3: RED Declaration of Conformity for RAy3-11

RACOM
www.racom.eu

EU DECLARATION OF CONFORMITY

Radio equipment type	RAy3-17	**Radio SW version**	
		1.0.2	
Manufacturer	RACOM s.r.o.		
	Mirova 1283, 592 31 Nove Mesto na Morave, Czech Republic		

This declaration of conformity is issued under the sole responsibility of the manufacturer.

The radio equipment described above is in conformity with the Directive 2014/53/EU of the European Parliament and of the Council on the harmonisation of the laws of the Member States relating to the making available on the market of radio equipment and repealing Directive 1999/5/EC.

Harmonised standards used for demonstration of conformity:

Spectrum	EN 300 440 V2.2.1
EMC	EN 301 489-1 V2.1.1
	EN 301 489-3 V1.6.1
	EN 301 489-4 V3.1.1
Safety	EN 62368-1:2014+A1:2017

Signed for and on behalf of the manufacturer:

Nove Mesto na Morave, 15th of August 2019
Jiri Hruska, CEO

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Fig. 10.4: RED Declaration of Conformity for RAy3-17

EU DECLARATION OF CONFORMITY

Radio equipment type	RAy3-24	Radio SW version
		1.0.2

Manufacturer   **RACOM s.r.o.**
Mirova 1283, 592 31 Nove Mesto na Morave, Czech Republic

This declaration of conformity is issued under the sole responsibility of the manufacturer.

The radio equipment described above is in conformity with the Directive 2014/53/EU of the European Parliament and of the Council on the harmonisation of the laws of the Member States relating to the making available on the market of radio equipment and repealing Directive 1999/5/EC.

Harmonised standards used for demonstration of conformity:

Spectrum	EN 300 440 V2.2.1
EMC	EN 301 489-1 V2.1.1
	EN 301 489-3 V1.6.1
	EN 301 489-4 V3.1.1
Safety	EN 62368-1:2014+A1:2017

Signed for and on behalf of the manufacturer:

Nove Mesto na Morave, 26th of October 2018
Jiri Hruska, CEO

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Fig. 10.5: RED Declaration of Conformity for RAy3-24

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EU DECLARATION OF CONFORMITY

Radio equipment type	RAy3-80	Radio SW version
		1.0.2
Manufacturer	RACOM s.r.o.	
	Mirova 1283, 592 31 Nove Mesto na Morave, Czech Republic	

This declaration of conformity is issued under the sole responsibility of the manufacturer.

The radio equipment described above is in conformity with the Directive 2014/53/EU of the European Parliament and of the Council on the harmonisation of the laws of the Member States relating to the making available on the market of radio equipment and repealing Directive 1999/5/EC.

Harmonised standards used for demonstration of conformity:

Spectrum	EN 302 217-2 V3.3.1
EMC	EN 301 489-1 V2.2.3
	EN 301 489-3 V2.1.1
	EN 301 489-4 V3.3.1
Safety	EN 62368-1:2020+A11:2020

Signed for and on behalf of the manufacturer:

Nove Mesto na Morave, 28th of April 2023
Jiri Hruska, CEO

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Fig. 10.6: RED Declaration of Conformity for RAy3-80

10.7.2. Simplified declaration

10.7.2.1. Simplified EU declaration of conformity

BG
С настоящото RACOM s.r.o. декларира, че този тип радиосъоръжение RAy3 е в съответствие с Директива 2014/53/EC.

ES
Por la presente, RACOM s.r.o. declara que el tipo de equipo radioeléctrico RAy3 es conforme con la Directiva 2014/53/UE.

CS
Tímto RACOM s.r.o. prohlašuje, že typ rádiového zařízení RAy3 je v souladu se směrnicí 2014/53/EU.

DA
Hermed erklærer RACOM s.r.o., at radioudstyrstypen RAy3 er i overensstemmelse med direktiv 2014/53/EU.

DE
Hiermit erklärt RACOM s.r.o., dass der Funkanlagentyp RAy3 der Richtlinie 2014/53/EU entspricht.

ET
Käesolevaga deklareerib RACOM s.r.o., et käesolev raadioseadme tüüp RAy3 vastab direktiivi 2014/53/EL nõuetele.

EL
Με την παρούσα ο/η RACOM s.r.o., δηλώνει ότι ο ραδιοεξοπλισμός RAy3 πληροί την οδηγία 2014/53/EE.

EN
Hereby, RACOM s.r.o. declares that the radio equipment type RAy3 is in compliance with Directive 2014/53/EU.

FR
Le soussigné, RACOM s.r.o., déclare que l'équipement radioélectrique du type RAy3 est conforme à la directive 2014/53/UE.

HR
RACOM s.r.o. ovime izjavljuje da je radijska oprema tipa RAy3 u skladu s Direktivom 2014/53/EU.

IT
Il fabbricante, RACOM s.r.o., dichiara che il tipo di apparecchiatura radio RAy3 è conforme alla direttiva 2014/53/UE.

LV
Ar šo RACOM s.r.o. deklarē, ka radioiekārta RAy3 atbilst Direktīvai 2014/53/ES.

LT
Aš, RACOM s.r.o., patvirtinu, kad radijo įrenginių tipas RAy3 atitinka Direktyvą 2014/53/ES.

HU
RACOM s.r.o. igazolja, hogy a RAy3 típusú rádióberendezés megfelel a 2014/53/EU irányelvnek.

MT

B'dan, RACOM s.r.o., niddikjara li dan it-tip ta' tagħmir tar-radju RAy3 huwa konformi mad-Direttiva 2014/53/UE.

NL
Hierbij verklaar ik, RACOM s.r.o., dat het type radioapparatuur RAy3 conform is met Richtlijn 2014/53/EU.

PL
RACOM s.r.o. niniejszym oświadcza, że typ urządzenia radiowego RAy3 jest zgodny z dyrektywą 2014/53/UE.

PT
O(a) abaixo assinado(a) RACOM s.r.o. declara que o presente tipo de equipamento de rádio RAy3 está em conformidade com a Diretiva 2014/53/UE.

RO
Prin prezenta, RACOM s.r.o. declară că tipul de echipamente radio RAy3 este în conformitate cu Directiva 2014/53/UE.

SK
RACOM s.r.o. týmto vyhlasuje, že rádiové zariadenie typu RAy3 je v súlade so smernicou 2014/53/EÚ.

SL
RACOM s.r.o. potrjuje, da je tip radijske opreme RAy3 skladen z Direktivo 2014/53/EU.

FI
RACOM s.r.o. vakuuttaa, että radiolaitetyyppi RAy3 on direktiivin 2014/53/EU mukainen.

SV
Härmed försäkrar RACOM s.r.o. att denna typ av radioutrustning RAy3 överensstämmer med direktiv 2014/53/EU.

10.8. FCC and IC authorization

RAy3 complies with following FCC and IC standards:

Code	FCC part	FCC ID	IC specification	IC Certif. No.
RAy3-24	15	SQT-RAY3-24	RSS-210 Issue 9	24993-RAY324

Code	FCC part	IC specification
RAy3-11	pending	pending
RAy3-18	15, 101	SRSP-317.8, ICES-003
RAy3-80	15, 101	SRSP-317.0, ICES-003

FCC and IC comment - the following modulations are not allowed in RAy3-80:

Bandwidth	Modulation
250 MHz	64QAM, 128QAM, 256QAM
500 MHz	128QAM, 256QAM
750 MHz	256QAM
1000 MHz	256QAM
1250 MHz	256QAM

Appendix A. SSH key generation

Linux

Use "ssh-keygen" command.

Windows

Use "PUTTYGEN.EXE" software, which is typically located in the c:\Program Files\putty\ directory and apply the "Generate" button.

To use CLI (Command Line Interface) access the unit with a PuTTY client. Access is protected by an SSH key.

Appendix B. Unit block diagrams

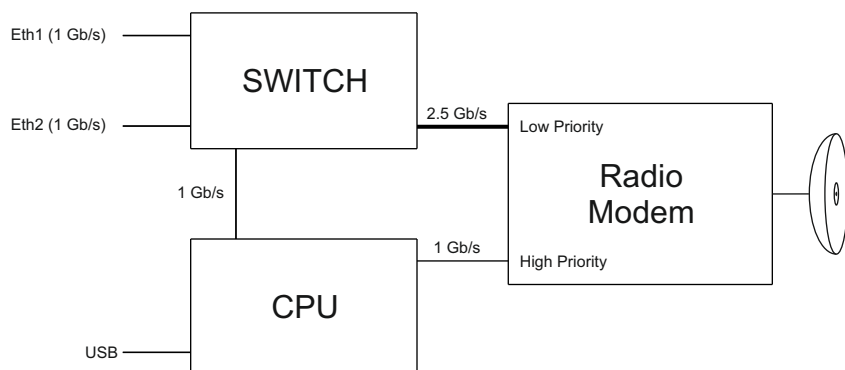## Units with 2× 1 Gb/s Ethernet inputs (10/11/13/17/18/24 GHz)

Fig. B.1: Block diagram of the unit with 2× 1 Gb/s Eth inputs

Unit with 1× 1 Gb/s Ethernet + 1× 1/2.5/5/10 Gb/s Ethernet inputs (80 GHz)
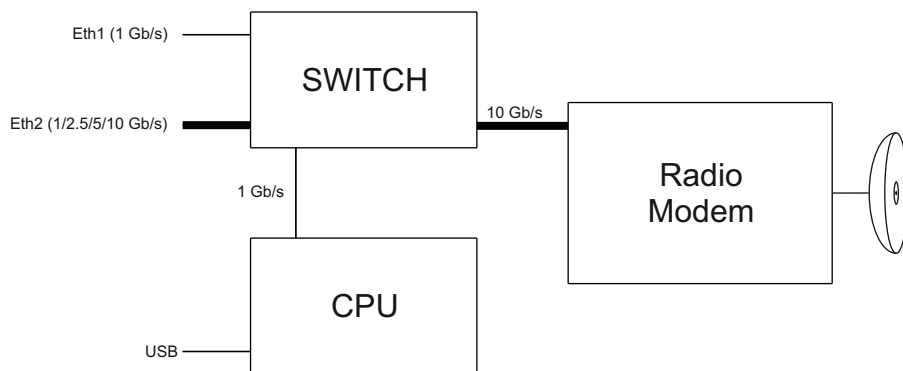
Fig. B.2: Block diagram of the unit with 1 + 10 Gb/s Eth inputs

Revision History

Revision 1.0   2018-10-04
First issue

Revision 1.1   2019-04-15
RAy3-17 data - preliminary
RAy3 HW variants introduced

Revision 1.2   2019-05-20
Extended *Chapter 5, Configuration* (to reflex FW development)

Revision 1.3   2019-07-23
Updated *Legal Notice*, *Section 1.6, "Sizes, packaging and labeling"*, *Section 1.7, "Ordering codes"* and *Section 10.8, "FCC and IC authorization"* (RAY3-24 FCC for US and IC for Canada compliance)
Extended *Chapter 5, Configuration* (to reflex FW development)

Revision 1.4   2019-09-06
Updated *Chapter 2, Accessories*
Extended *Chapter 5, Configuration* (to reflex FW development)
Extended *Section 10.7.1, "RED Declarations of Conformity"* - DoC RAy3-17

Revision 1.5   2019-11-11
New items in *Chapter 2, Accessories* (marked by '*')
Improved description of some items (*accepted polarities of PoE and power supply*, *FlowControl parameters in Eth switch*, *Chapter 8, Troubleshooting*).
Final parameters for RAy3-17

Revision 1.6   2020-02-10
Extended sections:
PIRL setup, *Egress queue setup* and *VLAN setup* (to reflex FW development).
Improved description of some items (new *Pressure equalization*).

Revision 1.7   2020-04-09
In *Chapter 2, Accessories* removed sections 2.1. Overview and 2.2 Details (from now all Accessories are available in *section Accessories*[1] on RAy web site).
Improved description of some items:
Section 1.3.3, "DC power (using ETH1+POE)"
Table 1.1, "Overview of Jirous Class 3 antennas"
Section 1.7, "Ordering codes"
Section 4.2.3.2, "Antenna mounting kit for standard Andrew antennas"
Section 5.5.2.1, "Port setup", description of parameter Flow Control
Section 5.6.1.4, "Radio adaptation"
Extended sections:
Section 5.5, "Switch settings" - RSTP status, *RSTP setup* (to reflex FW development)

Revision 1.8   2020-06-22

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[1] https://www.racom.eu/eng/products/microwave-link.html#accessories

Improved description of some items:
Section 1.7, "Ordering codes"
Section 3.3, "Basic link configuration"
Section 4.3.2, "RAy unit mounting to the antenna"
Section 5.5.1, "Status" - RMON counters
Chapter 7, RAyTools app for Mobile devices
Removed Appendix B. - Change of HTTPS certificate (not relevant for RAy3 yet)

Revision 1.9   2020-09-29

Completely new *Section 5.5.3, "QoS"* (to reflex FW development)
Improved description of *Section 1.3.3, "DC power (using ETH1+POE)"*

Revision 1.10   2021-03-10

Two completely new sections: "*Encryption*" in *Section 5.4.2, "Radio"* and "*Radio loopback*" in *Section 5.6.2, "Live data"* (to reflex FW development)
Improved *Section 1.6, "Sizes, packaging and labeling"* - added sizes and weights of boxes.
Change of HTML and PDF typography of the manual to improve text flow and text scaling possibilities on all types of displays (including small mobiles).

Revision 1.11   2021-08-18

Improved description of *Section 1.2.1, "Antenna waveguide"* and *Section 1.2.2, "Unit mounting"*
Updated *Section 1.3, "Ethernet + power interfaces"* (added RAy3-18).
Updated *Section 1.6, "Sizes, packaging and labeling"* (added RAy3-18)
Updated *Section 1.7, "Ordering codes"* (added RAy3-18 and encryption SW key).
Updated *Section 5.3, "Status"* and *Section 5.4.2.1, "Radio parameters"* (added parameter 'Power to be received [dBm]')
Improved description of *Section 5.6.1.1, "Backup"* and *Section 5.6.1.2, "SW feature keys"*
New sections in *Chapter 9, Technical parameters* (added preliminary RAy3-18 parameters)

Revision 1.12   2022-01-13

Updated *Section 1.1, "Main characteristics"* (mentioned RAy3-10 and RAy3-18)
Updated *Section 1.5, "Status LED (S)"* (new indication for power supply voltage out of range)
Updated *Section 1.6, "Sizes, packaging and labeling"* (mentioned RAy3-10, RAy3-18)
Updated *Section 1.7, "Ordering codes"* (mentioned RAy3-10, RAy3-18 and new SW feature key "Power")
Updated section *Section 5.4.4.1, "Alarms Status"* (new names of alarm severities)
Improved sections *Section 5.6.2.4, "Radio loopback"* and *Section 6.3.4, "Radio loopback"* (corrected explanation of measured antenna parameter CPI - Cross-Port Isolation)
Updated several sections in *Chapter 9, Technical parameters* (improved MTBF for RAy3-17 and RAy3-24, added final RAy3-18 and preliminary RAy3-10 parameters)
Updated section *Section 10.7.1, "RED Declarations of Conformity"* (added RAy3-18B)

Revision 1.13   2022-02-11

Updated *Section 4.6, "Power supply"* (mentioned stronger power supplies, IEEE 802.3at/bt standards, etc. needed for RAy3-10 and RAy3-18)
Updated *Chapter 8, Troubleshooting* (added item "RAyTools smartphone disconnects from RAy unit").
Updated *Table 9.1, "Parameters 10 GHz"* (added Sub-band B in to preliminary RAy3-10 parameters)
Updated *Section 10.7.1, "RED Declarations of Conformity"* (added DoC for RAy3-18)

Revision 1.14   2022-04-20
Updated *Section 1.7.1, "RAy units"* (added RAy3-10 order codes)
Updated *Section 5.6.1.1, "Backup"* (improved specification of the backup and settings functionality)
Updated *Section 5.6.2.4, "Radio loopback"* (limit for good TX to RX isolation lowered to 45 dB)
Updated *Chapter 9, Technical parameters* (completed RAy3-18 parameters, added RAy3-10 parameters)

Revision 1.15   2022-06-15
Updated *Chapter 9, Technical parameters* (simplification of structure, moving some tables into 'details' sections, added column 'Note' into all 'Frequency tables', tuning of RAy3-10 parameters)
Section 9.1, "RAy3-10 details" (final technical parameters)
Section 10.7, "Declarations of Conformity" (added DoC for RAy3-10)

Revision 1.16   2023-03-23
Updated *Chapter 1, Product* (added RAy3-11 and RAy3-80 to most sections, added *Section 1.1.3, "FW concept"*
Updated *Chapter 3, Step-by-step Guide* (FW development related changes, modified for RAy3-80)
Added *Section 5.1.1, "Supported web browsers"*
Updated *Section 5.3, "Status"* (parameter 'TX modulation' modified into 2 parameters 'Current TX modulation' and 'Max TX modulation')
Updated *Section 5.4.2.1, "Radio parameters"* (modified for RAy3-80, modified parameter 'TX power' to 'Max TX power')
Updated *Section 5.6.1.4, "Radio adaptation"* (added info about new more powerful frequency tables)
Updated *Section 5.6.2.2, "Antenna Alignment Tool"* (modified for RAy3-80)
Updated *Chapter 9, Technical parameters* (added RAy3-11 and RAy3-80, added Emission Designation sections for most bands)

Revision 1.17   2023-05-02
Updated *Section 1.1.3, "FW concept"* (added info about specific FW clone for RAy3-80)
Updated *Chapter 9, Technical parameters* (removed "preliminary" for RAy3-80 parameters)
Updated *Section 10.7.1, "RED Declarations of Conformity"* (added RAy3-80 DoC)

Revision 1.18   2023-06-07
Updated *Section 1.3.2, "SFP/SFP+ slot (ETH2)"* (added SFP+)
Extended *Chapter 7, RAyTools app for Mobile devices* (added RAyTools ver.3, changed the structure of the chapter)

Revision 1.19   2023-08-08

Added new function 'TX mute'. Updated sections are:
- *Section 5.4.2.1, "Radio parameters"*
- *Section 5.4.4.1, "Alarms Status"*
- *Section 5.4.4.2, "Alarms Acknowledge"*
- *Section 5.4.4.3, "Alarms Config"*

Chapter 9, Technical parameters - values in row 'Sensitivity, BER 10-6' in tables 9.1 - 9.4 (to reflect the changes listed below).

Changed all RSS sensitivity values of all RAy3 models for all bands and sub-bands from 'guaranteed' to 'typical' values (those are better by 1.5 dB for 10-24 GHz bands and by 3 dB for 80 GHz band). Updated sections are:
- *Section 9.1.2, "RAy3-10 Radio parameters"*
- *Section 9.3.2, "RAy3-17/24 Radio parameters"*
- *Section 9.4.2, "RAy3-18 Radio parameters"*
- *Section 9.6.2, "RAy3-80 Radio parameters"*

Revision 1.20   2023-12-20

Section 1.3.2, "SFP/SFP+ slot (ETH2)" - added support for 2.5 Gb/s SFP moduls
New *Section 5.4.2.3, " Link State Propagation (LSP)"* providing description of new function 'Link State Propagation'
Chapter 9, Technical parameters - tables 9.1 - 9.3, values in rows:
- 'Speed (each direction)' to reflect the link speed changes listed below
- 'SFP (user exchangeable)' to reflect HW and FW development (newly supported also 2500 Mb/s SFP modules for RAy3-10/11/17/18/24)
- new row 'Dual Channel' for RAy3-11/18 to reflect expected future HW and FW development

Slightly improved most of link capacity values in Mb/s for all combinations of available channel and modulation for all bands and sub-bands (i.e. for all RAy3 models for 10-24 GHz bands). The reason is the decision to use link capacities achievable on L1 Ethernet traffic with 1518 Bytes frames measured by RFC2544 test (instead of capacities calculated from modem baud rates till FW 2.0.14.0). Updated sections are:
- *Section 9.1.1, "RAy3-10 Link speed"*
- *Section 9.1.2, "RAy3-10 Radio parameters"*
- *Section 9.3.1, "RAy3-17/24 Link speed"*
- *Section 9.3.2, "RAy3-17/24 Radio parameters"*
- *Section 9.4.1, "RAy3-18 Link speed"*
- *Section 9.4.2, "RAy3-18 Radio parameters"*

Revision 1.21   2024-02-09

Updated *Section 5.4.2.3, " Link State Propagation (LSP)"*

Revision 1.22   2024-05-22

Updated *Section 5.4.2.3, " Link State Propagation (LSP)"* - Loop prevention parameter was added

Updated *Section 5.4.4.3, "Alarms Config"* - information about individual Alarm severity is now provided

Updated *Section 5.6.1.1, "Backup"* - redesigned "Tools > Maintenance > Backup" screen

Updated *Chapter 9, Technical parameters* - values in "Ethernet L2 Link speed …" tables of the individual RAy3 models

Updated *Table 9.37, "Frequency tables 24 GHz"* - rcinfo24_FCC200 was added

Updated *Section 10.8, "FCC and IC authorization"* - the FCC and IC certification overview

Revision 1.23   2024-06-10

Updated *Table 9.2, "Parameters 11/18 GHz"*

Added *Section 9.2, "RAy3-11 details"*

Added Dual channel choice in *Section 5.4.2.1, "Radio parameters"*

Revision 1.24   2024-07-09

After upgrading the microwave link to FW 1.1.7.0 (or newer), the following combinations of channel widths and modulations can be newly set. The RAy3-80 technical parameter tables have been supplemented with these configurations

• 250 MHz / 64QAM
• 500 MHz / 128QAM
• 750 MHz / 256QAM
• 1000 MHz / 256QAM

The following combinations of channel widths and modulations can be set on units manufactured after July 1, 2024 (and loaded with FW 1.1.7.0 or newer). The RAy3-80 technical parameter tables have been supplemented with these configurations

• 250 MHz / 128QAM
• 250 MHz / 256QAM
• 500 MHz / 256QAM
• 1250 MHz / 256QAM

Added *Safety distance calculation for EU*

Revision 1.25   2025-01-24

Described *Factory settings HW button option*

Added description *LSP Action: Port shutdown*

Added information about *limited use of some modulations* in countries requiring FCC or IC certification