RACOM
RADIO DATA NETWORKS

User manual

RAy2 Microwave Link

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version 1.3

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- Due to the nature of wireless communications, transmission and reception of data can never be guaranteed. Data may be delayed, corrupted (i.e., have errors), or be totally lost. Significant delays or losses of data are rare when wireless devices such as the RAy2 are used in an appropriate manner within a well-constructed network. RAy2 should not be used in situations where failure to transmit or receive data could result in damage of any kind to the user or any other party, including but not limited to personal injury, death, or loss of property. RACOM accepts no liability for damages of any kind resulting from delays or errors in data transmitted or received using RAy2, or for the failure of RAy2 to transmit or receive such data.
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Quick Start Guide

- The default addresses of the RAy2 units are:
  - 192.168.169.169/24 - unit labeled **L**
  - 192.168.169.170/24 - unit labeled **U**

- On your PC set up a similar address with the same mask, e.g. 192.168.169.180/24.

  - To configure your PC's address in Windows XP do the following: *Start* – *Settings* – *Network Connections*:
    Change properties of this connection – *Internet Network Protocol (TCP/IP)* – *Properties* – *Use the following IP address* – input 192.168.169.180 and use the mask 255.255.255.0. Click OK twice.

- Connect both RAy2 units to a PoE source and connect to a PC via PoE for configuration, see figure Link Configuration below.

- Input the address of the connected RAy2 unit into the address field of your internet browser (such as Mozilla Firefox), e.g. 198.168.169.169. Login as *admin* with password *admin*.

- *Status* menu provides information on connection.

- *Link settings* – *Radio* menu enables you to change the parameters of the radio and ethernet channel, *Link settings* – *Service access* – *Users* menu lets you change login parameters.

- Continue as suggested by the Step-by-step Guide.

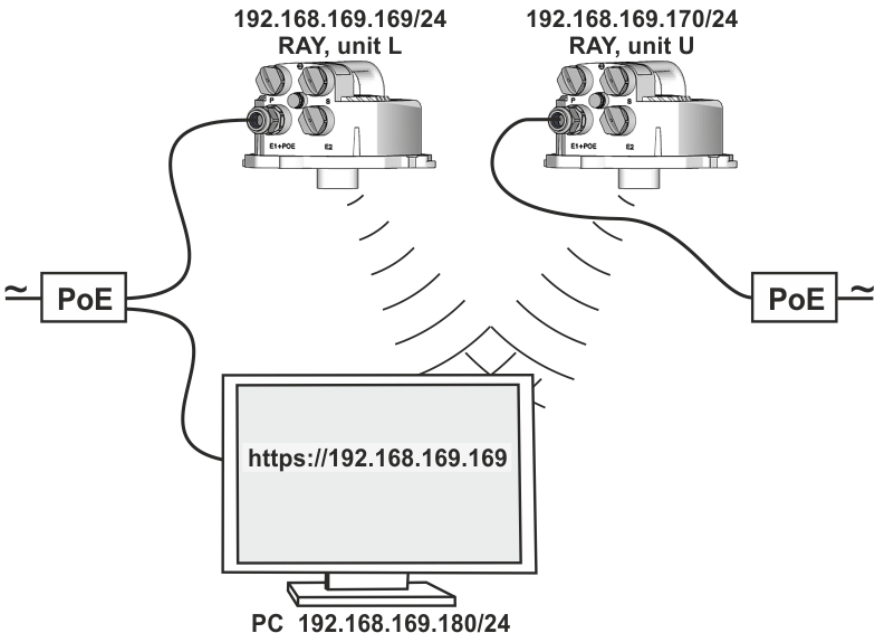


Fig. 1: Link Configuration

List of documentation

User manuals

- **Microwave Link RAy2** - this document
  User manual RAy2-10, RAy2-11, RAy2-17, RAy2-24
- **Microwave Link RAy11, 17, 24**[1]
  User manual RAy11, RAy17, RAy24
- **Microwave Link RAy10**[2]
  User manual RAy10

Datasheets

- **RAy2 - Datasheet**[3]
- **RAy - Datasheet**[4]
- **RAy - SCADA Backbone**[5]

Application notes

- **RAy - Application notes**[6]

Contents of the box

- 2 pc RAy2
- 2 pc Cable bushing set, connectors
- 1 pc Grease marked "SILIKONOVE MAZIVO"

[1] http://www.racom.eu/eng/products/m/ray17/index.html
[2] http://www.racom.eu/eng/products/m/ray/index.html
[3] http://www.racom.eu/download/hw/ray/free/eng/00_letaky/datasheet_RAY2_en.pdf
[4] http://www.racom.eu/download/hw/ray/free/eng/00_letaky/datasheet_RAY_en.pdf
[5] http://www.racom.eu/download/hw/ray/free/eng/00_letaky/leaflet_RAY_scada_en.pdf
[6] http://www.racom.eu/download/hw/ray/free/cz/01_ray/RAy-AppNote-en.pdf

1. RAy2 – Microwave Link

The microwave link RAy2 is designed as a high-speed point-to-point wireless bridge for data transmission under the latest requirements of modern wireless transmission equipment. It is built on a platform with a modern component base.

RAy2 works with an ethernet interface and can be used in backhaul networks as well as a last-mile terminal.The design of microwave link RAy2 reflects effort on meeting the strictest criteria of ETSI standards, particularly for durability against interference, high receiver sensitivity and high output power to achieve maximum link distance. The native gigabit Ethernet interface is able to cope with full speed user data throughput at low latency. High availability of the link (up to 99.999%) is able to be achieved using hitless Adaptive coding and modulation.

The link properties can be summarised as:

- High data throughput
- Spectrum effeciency
- Robustness
- Security - cofiguration via http, https, ssh
- User friendly interface, advanced diagnostics

Key technical features

		Lower band	Upper band
Frequency range	RAy2-10-A	10.30 – 10.42 GHz	10.47 – 10.59 GHz
	RAy2-10-B	10.125 – 10.325 GHz	10.475 – 10.675 GHz
	RAy2-11-A [1)]	10.700 – 10.965 GHz	11.199 – 11.455 GHz
	RAy2-11-B	10.945 – 11.205 GHz	11.435 – 11.700 GHz
	RAy2-11-C	10.5005 – 10.5425 GHz	10.5915 – 10.6335 GHz
	RAy2-11-D	10.5425 – 10.5845 GHz	10.6335 – 10.6755 GHz
	RAy2-17	17.10 – 17.30 GHz	
	RAy2-24	24.00 – 24.25 GHz	
	Modulation	QPSK, 16, 32, 64, 128, 256 QAM fixed or ACM	
Channel spacing		1.75, 3.5, 7, 14, 20, 28, 30, 40, 56 MHz [2)]	
User data rate		user data rate up to 360 Mbps [2)]	
Forward Error Correction		LDPC	
User interface	RJ45	1 Gb Eth. (10/100/1000) (IEEE 802.3ac 1000BASE-T) , MTU 10240 B, recommended cable S/FTP CAT7	
	SFP	1000Base-SX / 1000Base-LX, MTU 10240 B, user exchangable SFP, power consumption max. 1 W	
Power	PoE	40 – 60 VDC, IEEE 802.3at up to 100 m	
	DC	20 – 60 VDC, floating	
Mechanical design		FOD (full outdoor)	
Security		configuration via https, ssh	

[1)] RAy2-11 not available yet
[2)] Detailed Channel spacing and User data rate see Technical parameters.

Standards

Radio parameters	RAy2-10	ETSI EN 302 217-2-2 V1.3.1
	RAy2-17	ETSI EN 300 440-2 V 1.4.1
	RAy2-24	ETSI EN 300 440-2 V 1.4.1
EMC		ETSI EN 301 489-1 V1.8.1 (2008-04), ETSI EN 301 489 -17 V1.3.2 (2008-04)
Electrical safety		EN 60 950-1: 2004

Note

Operation of the RAy2-xx is described in this user manual.
Operation of the RAy11, RAy17 and RAy24 is described in User Manual RAy11,17,24[1].
Operation of the RAy10 is described in the RAy10 User Manual[2].

[1] http://www.racom.eu/eng/products/m/ray17/index.html
[2] http://www.racom.eu/eng/products/m/ray/index.html

2. Implementation Notes

2.1. Link calculation

Before a microwave link can be installed, an analysis and calculation of the microwave link must be made first. The analysis should take place before the site survey itself to get a clear idea about the dimensions of the antennas. The analysis consists of the following steps:

- Free space loss calculation
- Link budget calculation
- Rain attenuation
- Multipath fading
- Fade margin
- Fresnel zones calculation

This chapter explains the individual steps and an example of link design is given at the end.

NOTE - For quick reference you can use the calculator on www.racom.eu[1]

2.1.1. Free space loss calculation

As the electromagnetic waves travel through open space they are attenuated. This attenuation is described as Free-space Loss. The loss depends on the distance travelled by signal and its frequency. Longer distance and higher frequency both mean greater attenuation. Free-space loss can be calculated thus:

$FSL = 32.44 + 20\log f + 20\log D$

Where:

FSL free-space loss (dB)

f frequency of the emitted signal (MHz)

D length of the link (km)

2.1.2. Link budget calculation

The goal is to design a link producing a received signal stronger than the receiver's sensitivity at the required BER (typically 10^{-6}). Since every radio signal in earth atmosphere is subject to fading, some difference between received signal level under normal circumstances and receiver sensitivity is needed to serve as a fade margin. The minimum value of fade margin can be calculated from the requirement for link availability (e.g. 99.999% of the time). The required margin depends on the length of the link as well as other factors such as rain attenuation, diffraction and multipath propagation.

If we ignore the additional loss along the path, the received signal strength can be calculated using the formula for signal propagation in free space as follows:

$P_R = P_T + G_T + G_R - FSL$

Where

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

P_R received power level (dBm)

P_T transmitted power (dBm)

G_T transmitting antenna gain (dBi)

G_R receiving antenna gain (dBi)

FSL free space loss (dB)

P_R must be:

$P_R > P_S$

Where:

P_S receiver sensitivity (dBm)

The receiver's sensitivity defines the minimum level of the received signal at which the receiver is able to process the signal without losses or affecting the transmitted data (for BER better then 10^{-6}).

2.1.3. Fade margin

Determining sufficient fade margin is the most important step in microwave link design. If the margin is too small, the link will be unstable – as a result, sufficient availability of the link or quality of the provided services cannot be guaranteed. On the other hand, unnecessarily large margin makes the link more expensive (higher performance, larger and more expensive antennas) and increases the cost of creating the microwave link.

The following paragraphs describe the two most significant types of signal strength loss – rain and multipath attenuation, which are the most frequent along with free space loss. Mutual relation between rain and multipath attenuation rules out the possibility that the link could be affected by both types of attenuation at the same time – **these types of attenuation do not add up**. To determine the fade margin it is necessary to calculate both rain and multipath attenuation. The larger of the two types of attenuation determines the value of fade margin. In areas with high precipitation, rain attenuation can be expected to be more prominent. By contrast, links located in drier climates and little inclination, will suffer more from multipath attenuation.

2.1.4. Rain attenuation

For frequencies of about 10 GHz rain attenuation starts to become increasingly effective. Precipitation is not identical in all areas which is why ITU released a recommendation Rec. ITU-R PN.837-1 for splitting the world into 15 regions according to precipitation intensity see Fig. 2.1, for more detail Appendix B, *Rain zone map*. In the areas with higher precipitation greater rain attenuation must be expected and a greater signal fade margin must be established; see the calculation of link availability.

The following properties are inherent to rain attenuation:

- It increases exponentially with rain intensity
- It becomes significantly larger as the distance travelled increases (>10 Km)
- Horizontal polarization causes greater rain attenuation than vertical polarization
- Rain outage increases dramatically with frequency and path length

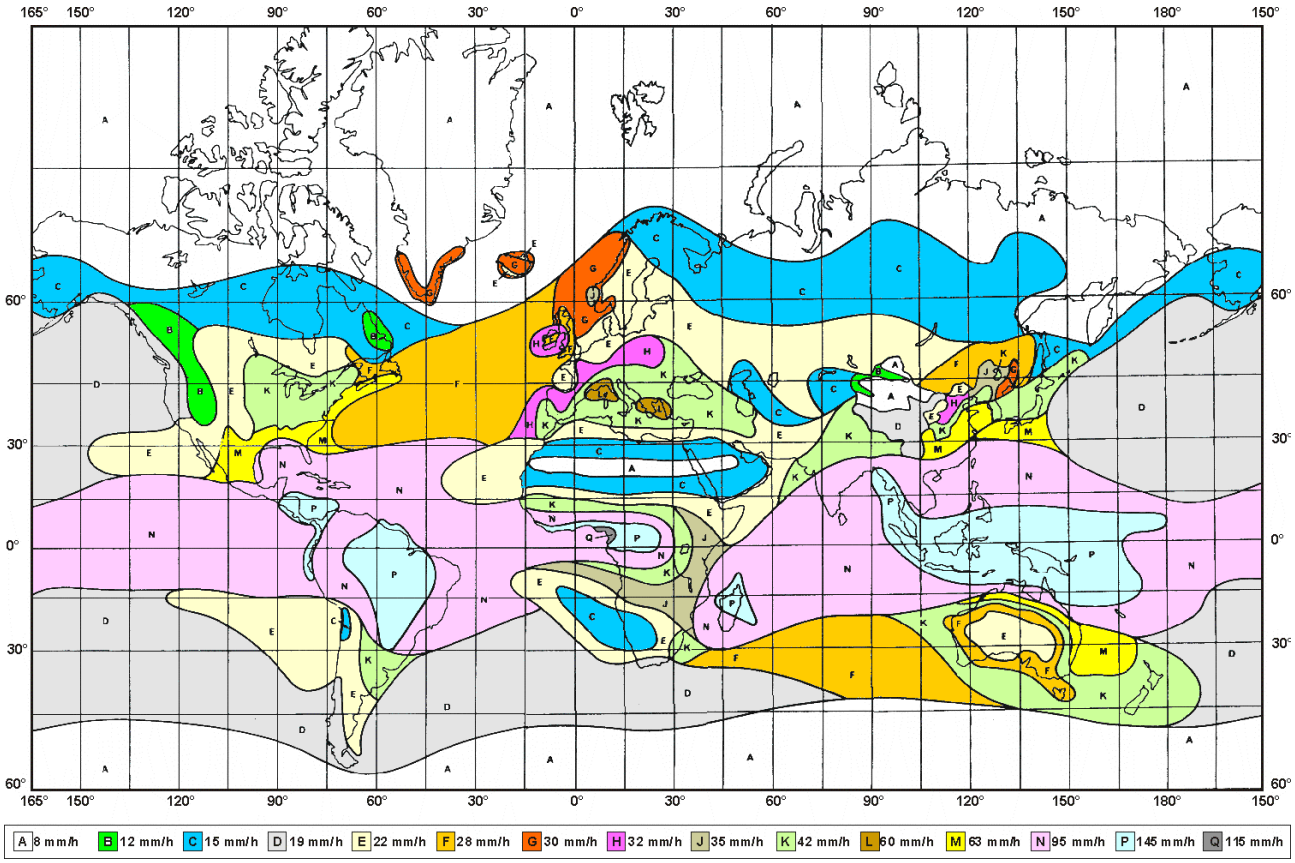


Fig. 2.1: Rain zone map, based on Rec.ITU-R PN.837-1

Rain attenuation can be calculated using ITU-R outage model, which consists of the following:

Obtain the rain rate $R_{0.01}$ exceeded for 0.01 per cent of the time (with an integration time of 1 min). $R_{0.01}$ values are defined for 15 rain zones and different time percentages and they are given in ITU-R Recommendation P.837.

Tab. 2.1: Rain rate R (mm/h) ITU-R P.837

Percentage of time (%)	A	B	C	D	E	F	G	H	J	K	L	M	N	P	Q
1.0	<0.1	0.5	0.7	2.1	0.6	1.7	3	2	8	15	2	4	5	12	14
0.3	0.8	2	2.8	4.5	2.4	4.5	7	4	13	42	7	11	15	34	49
0.1	2	3	5	8	6	8	12	10	20	12	15	22	35	65	72
0.03	5	6	9	13	12	15	20	18	28	23	33	40	65	105	96
0.01	8	12	15	19	22	28	30	32	35	42	60	63	95	145	115
0.003	14	21	26	29	41	54	45	55	45	70	105	95	140	200	142
0.001	22	32	42	42	70	78	65	83	55	100	150	120	180	250	170

Compute specific attenuation γ_R (dB/km) for the frequency, polarization, specific rain rate using ITU-R recommendation P.838. Rain attenuation for rain rate $\gamma_{R_{0.01}}$ can be calculated as follows:

$$\gamma_{R_{0.01}} = k_{h,v} . R_{0.01}^{\alpha^{h,v}}$$

where:

$k_{h,v}$, $\alpha_{h,v}$ constants for horizontal and vertical polarization. Constants are slightly different for each polarization, see next table according to ITU-R P.838

Tab. 2.2: Constants k, α for horizontal and vertical polarization at 10, 11, 17 and 24 GHz

	k_h	α_h	k_v	α_v
10 GHz	0.01	1.26	0.01	1.22
11 GHz	0.02	1.21	0.02	1.16
17 GHz	0.06	1.09	0.07	1.01
24 GHz	0.14	1.01	0.14	0.96

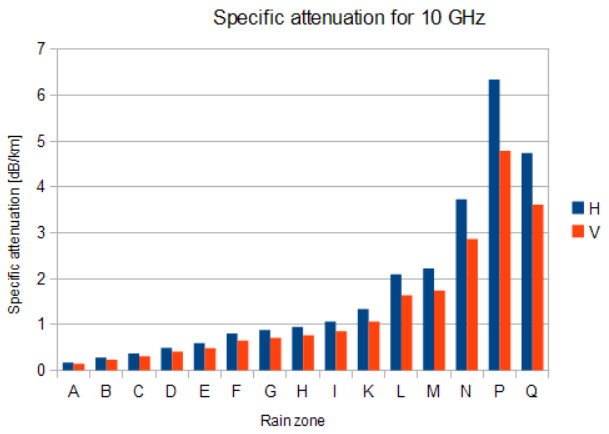


Fig. 2.2: Attenuation for 10 GHz, polarization H, V

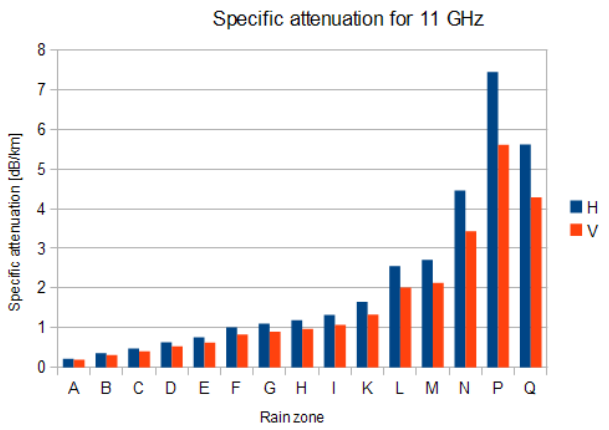


Fig. 2.3: Attenuation for 11 GHz, polarization H, V

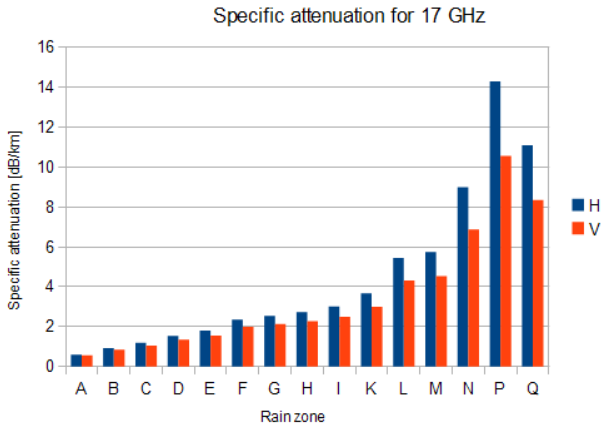


Fig. 2.4: Attenuation for 17 GHz, polarization H, V

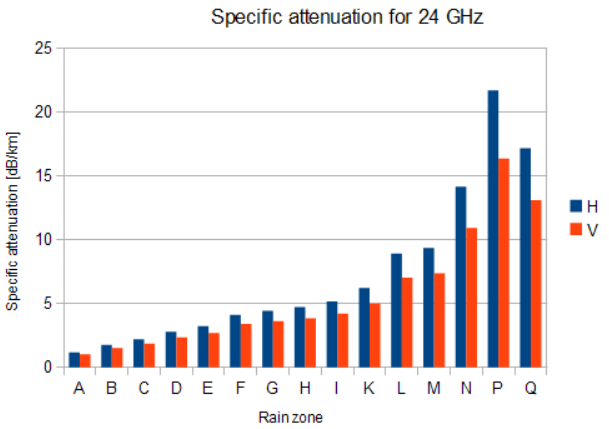


Fig. 2.5: Attenuation for 24 GHz, polarization H, V

Fig. 2.2 shows that rain attenuation is greater for horizontal polarization. In regions with higher precipitation the difference in attenuation is more marked. The microwave links RAy17 and RAy24 use both polarizations, hence the need to consider the worse of the two, i.e. horizontal polarization. When ACM

is active we recommend using horizontal polarization in the direction with lower data traffic (typically up-link).

2.1.5. Multipath fading

Multipath fading is another dominant fading mechanism. A reflected wave causes a phenomenon known as multipath, meaning that the radio signal can travel multiple paths to reach the receiver. Typically, multipath occurs when a reflected wave reaches the receiver at the same time in opposite phase as the direct wave that travels in a straight line from the transmitter.

Multipath propagation gives rise to two kinds of signal degrading effects, i.e., flat fading and frequency selective fading. Flat fading is a reduction in input signal level where all frequencies in the channel of interest are equally affected and is dependent on path length, frequency, and path inclination. In addition, it is strongly dependent on the geoclimatic factor K.

To calculate the probability of outage due to multipath propagation of microwave links the ITU-R probability model can be used which describes a single frequency (or narrowband) fading distribution suitable for large fade depths A in the average worst month in any part of the world (based on ITU-R P.530-14). The calculation for detailed link design is given as follows [1]:

$$P_0 = Kd^{3.4}(1+|\varepsilon_P|)^{-1.03}f^{0.8}\times 10^{0.00067h_L - A/10}$$

where:

d link distance (km)

f frequency (GHz)

h_L altitude of lower antenna (m)

A fade depth (dB)

K is geoclimatic factor and can be obtained from:

$$K = 10^{-4.6-0.0027dN1}$$

The term dN1 is provided on a 1.5° grid in latitude and longitude in ITU-R Recommendation P.453. The data are available in a tabular format and are available from the Radiocommunication Bureau (BR). E.g. in Central Europe the values dN1 range from -242 to -362.

From the antenna heights h_e and h_r (meters above sea level), calculate the magnitude of the path inclination $|\varepsilon_P|$ (mrad) using the following expression:

$$|\varepsilon_P| = \frac{|h_r - h_e|}{d}$$

where:

d link distance (km)

h_r, h_e antenna heights above sea level (m)

2.1.6. Fresnel zones calculation

The position of obstacles between points of the bridge can significantly influence the quality of the microwave link. The radio signal doesn't only radiate along the line of sight, but also in the area around it, i.e. in the so-called 1st Fresnel zone. Within this zone 90 % of the energy is transmitted between the transmitter and receiver antenna. This space has the shape of an ellipsoid. If it is disturbed the link has poorer transmission properties and a higher quality antenna is required. For this reason the position of the antenna can be just as important as its height above ground. 60 % of the 1st Fresnel zone is considered as the most important.

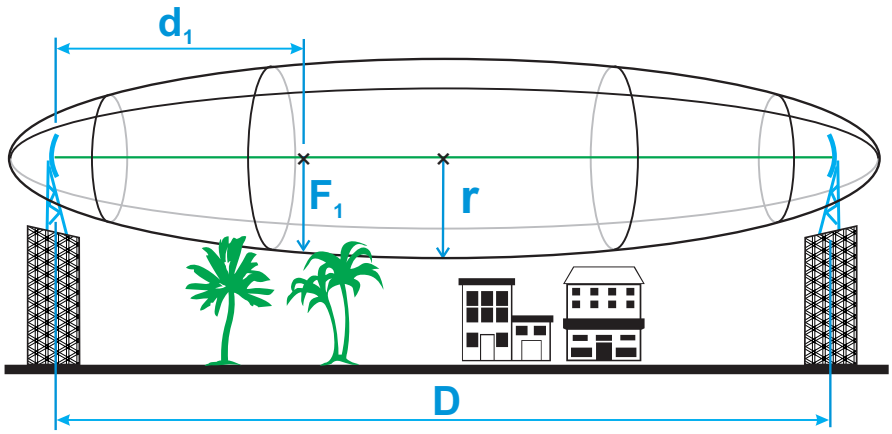


Fig. 2.6: Fresnel zone

The general equation for calculating the first Fresnel zone radius at any point P in between the endpoints of the link is the following:

$$F_1 = \sqrt{\lambda \frac{d_1.d_2}{d_1+d_2}}$$

Where:

F_1 first Fresnel Zone radius in metres

d_1 distance of P from one end in metres

d_2 The distance of P from the other end in metres

λ wavelength of the transmitted signal in metres

The cross sectional radius of each Fresnel zone is the highest in the center of link, shrinking to a point at the antenna on each end. For practical applications, it is often useful to know the maximum radius of the first Fresnel zone. From the above formula, calculation of the first Fresnel zone can be simplified to:

$$r = 8{,}657\sqrt{\frac{D}{f}}$$

where:

r max radius of first Fresnel zone (m)
reducing the radius to 60% get values listed in the following table that define the space particularly sensitive to the presence of obstacles

D total link distance (km)

f frequency (GHz)

Tab. 2.3: 60 % of the 1st Fresnel zone

Length of link D	Radius of zone r for frequency		
	11 GHz	**17 GHz**	**24 GHz**
0,5 km	1.10 m	0.89 m	0.75 m
1 km	1.56 m	1.25 m	1.06 m
2 km	2.21 m	1.77 m	1.50 m
4 km	3.13 m	2.50 m	2.12 m
6 km	3.84 m	3.07 m	2.60 m
8 km	4.43 m	3.54 m	3.00 m
10 km	4.95 m	3.96 m	3.35 m
15 km	6.06 m	4.85 m	4.10 m
20 km	7.00 m	5.60 m	4.74 m
50 km	11.07 m		

2.2. Example of microwave link design

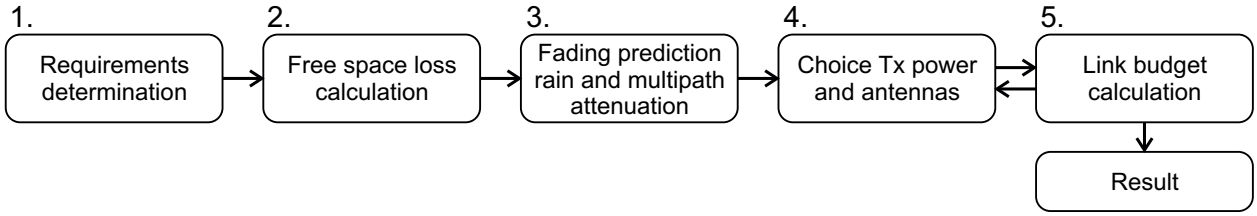


Fig. 2.7: Design flowchart

Step 1 - Requirements Determination

Link parameters:

Link distance: 4 km

First antenna height above sea level: 295 m

Second antenna height above sea level: 320 m

Location: Central Europe (rain zone H, refraction gradient dN1= −300)

Transmission requirements:

Required data rate: >160 Mbps

Required availability: 99.99 %

RAy parameters:

17 GHz

161 Mbps -> Modulation 16QAM; BW=56 MHz; P_S(BER 10^{-6})= −79 dBm

Tx power +5 dBm (max. Tx power)

Antenna gain:

30 cm ... 32.2 dBi

60 cm ... 37.8 dBi

99 cm ... 42 dBi

Step 2 - Free space loss calculation

FSL = 32.44 + 20log f + 20log D = 32.44 + 20log17.2·10^3 + 20log4 = 129.1 dB

Step 3a - Rain attenuation

For 99.99% availability in rain zone B the rain rate is $R_{0.01}$=32 (see Fig. 2.1)

For f=17 GHz k_h=0.06146; α_h=1.0949; k_v=0.06797; α_v=1.0137

Vertical polarization:

$\gamma_{R0.01} = k_v . R^{\alpha_v}_{0.01} = 0.07 \cdot 32^{1.01}$ = 2.32 dB/km => for 4km distance 9.3 dB

Horizontal polarization:

$\gamma_{R0.01} = k_h . R^{\alpha_h}_{0.01} = 0.06 \cdot 32^{1.09}$ = 2.62 dB/km => for 4km distance 10.5 dB

Step 3b - Attenuation due to multipath propagation

We have to find required fade margin for reliability of the link 99.99 percent.

Path inclination:

$$|\varepsilon_P| = \frac{|h_r - h_e|}{d} = \frac{|295 - 320|}{4} = 6{,}25\,mrad$$

The percentage of time that fade depth A (dB) is exceeded in the average worst month is calculated as:

$P_0 = Kd^{3.4}(1+|\varepsilon_P|)^{-1.03} f^{0.8} \times 10^{0.00067 h_L - A/10}$

$P_0 = 10^{-4.6-0.0027\times(-300)} \times 4^{3.4}(1+|6.25|)^{-1.03} 17.2^{0.8} \times 10^{0.032\times 10 - 0.00067\times 295 - A/10}$

$P_0 = 0.022871 \times 10^{-0.19765 - A/10}$

For reliability 99.99% is P_0=0.01 we get exponential function for A:

A = -0.19765 - 10log(0.01/0.022871) = 3.4 dB

The minimum fade margin required to suppress multipath fading on this link would be 4 dB.

Step 4 - Choice of Tx power and antennas

Step 5 - and Link budget calculation

Calculation in steps 3a and 3b determines the minimum fade margin required for stable link operation as 11 dB (rain attenuation is dominant). If you use the maximum performance of antenna with diameter of 30 cm, complete the radio formula as follows:

$P_R = P_T + G_T + G_R - FSL$ = 5 + 32.2 + 32.2 − 129.1 = −59.7 dB

Fade margin:

$A = |P_S| - |P_R|$ = 79 − 59.7 = 19.3 dB

The resulting fade margin is larger than the required 11 dB. Current legislation in the Czech Republic allows maximum EIRP of +20, i.e. the sum of transmit power and antenna gain at the transmitter can be 20 dB at the most. For 99cm antennas, TX power can be up to 20 - 42 = -22 dB, the resultant equation is as follows:

$P_R = P_T + G_T + G_R - FSL$ = -22 + 42 + 42 − 129.1 = −67.1 dB

Fade margin:

$A = |P_S| - |P_R| = 79 - 67.1 = 11.9$ dB

Fade margin is now only 12 dB which corresponds to link availability > 99.99% of the time in a year.

Technical literature often gives the minimum fade margin of 20 dB. For very long links (more than 10 km) fade margin will, indeed, be approximately 20 dB. For shorter links, however, such large margin is not necessary. It is helpful to first conduct the calculation above to receive an idea of the attenuation affecting the link.

The result

To achieve the required transmission capacity and link availability for link distance of 4 km, transmit power -22 dBm and 99 cm antennas were selected for both sides of the link.

Sources for Chapter Chapter 2, *Implementation Notes*:

[1] Lehpamer, H.: Microwave transmission network, Second edition, ISBN: 0071701222, McGraw-Hill Professional, 2010.

ITU-R recommendation used:

- ITU-R P.453-10 – The radio refractive index: its formula and refractivity data
- ITU-R P.530-14 – Propagation data and prediction methods required for the design of terrestrial line-of-sight systems
- ITU-R P.837-1 and 6 – Characteristics of precipitation for propagation modelling
- ITU-R P.838-3 – Specific attenuation model for rain for use in prediction methods
- ITU-R P.310, ITU-R P.526, ITU-R P.676, ITU-R P.834, ITU-R P.835

3. Product

RAy2 microwave links are designed for data transmissions in both licensed and unlicensed ISM bands. They work as a point-to-point link in a full duplex regime with transfer speed of up to 360 Mbps. Bandwidth can be varied from 1.75 up to 56 MHz. Modulation can be fixed or adaptive and can be adjusted from QPSK to 256QAM.

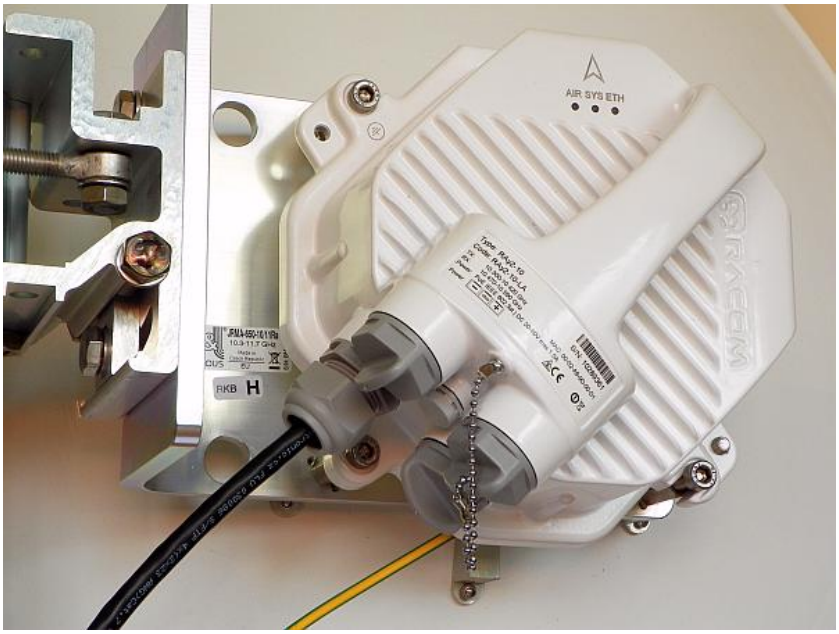


Fig. 3.1: RAy2 – Microwave link

The link is formed by two FOD (Full Outdoor) stations. In the case of links operating in the ISM bands (RAy2-17, RAy2-24), both stations have identical hardware. In the case of links operating in licensed bands, one unit is transmitting in the Lower and receiving in the Upper part of the band. The other unit is operating vice versa.

RAy2 links require the use of external parabolic antennas. Parabolic antennas from different producers are available.

Cross polarization - valid only for links operating in the ISM bands (RAy2-17, RAy2-24):
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°. It therefore transmits and receives using opposite polarizations with respect to the other unit.

3.1. Installation

Fig. 3.2: RAy2 Microwave link – antenna and FOD unit

The antenna is attached to the mast using a holder adjustable in two planes. The RAy2 unit is then mounted on the antenna.
There are two possible mounting positions – for horizontal and vertical polarization. Installation and adjustment of the holder is described in Chapter Antenna mounting.

Note

The RAy2-10 and RAy2-11 units must be mounted with the same polarization while the units RAy2-17 and RAy2-24 must be mounted with reverse polarity, see Cross polarization.

3.2. Connectors

Each unit is equipped with the following interfaces:

- E1+POE – Gigabit metallic Ethernet port. This port is capable of powering the unit with any Power over Ethernet power source working according to IEEE 802.3at standard.
- E2 – Slot for user exchangeable SFP module. A wide range of optical modules is available. Both single or dual mode transceivers can be used. An SFP module with metallic RJ45 interface can also be used.
  The SFP status LED is located just next to the slot.
- P – DC power connector.
  HW button for service purposes.
- S – USB service connector.
  RSS voltage output connectors.

The SFP status LED function: The LED status is controlled directly from the SFP module. It's function is specific for each SFP module. The typical behaviour is an indication of the received signal strength. Should the signal be in the proper power range (not too strong and not too weak), the LED is shining.

IMPORTANT It is strongly recommended to use a high quality SFP module. The SFP modules listed in Accessories are thoroughly tested by RACOM and are guaranteed to function with RAy2 units. It is possible to use any other SFP module, but RACOM cannot guarantee they will be completely compatible with RAy2 units.

Fig. 3.3: Connectors covered

Fig. 3.4: Connectors uncovered

For detailed description see Connectors and Start up.

3.3. Power supply

The microwave unit can be powered either by PoE or a DC power source:

- **Standard PoE plus** (IEEE 802.3at) power source is connected to “E1+POE” connector.
  Supported voltage range is 40-60 V.
- **Any kind of DC power source** connected to “P” 3-pin connector.
  Supported voltage range is 20-60 V.
  The DC power source uses galvanic separation. Any Galvanic separated power source can be used. Should the positive or negative potential be grounded, the middle pin of the 3-port DC connector can be used to make a connection between ground and the respective power wire. If grounding is required it should only be made in one of the following ways: on the DC power source side or using the 3-port DC connector plugged into the unit.

Important

The microwave unit **doesn't support** a combination of both power supplies. Only one power supply can be connected at any one time.

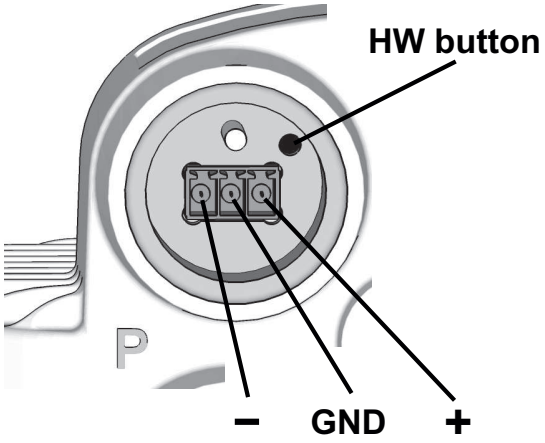


Fig. 3.5: Power supply connector

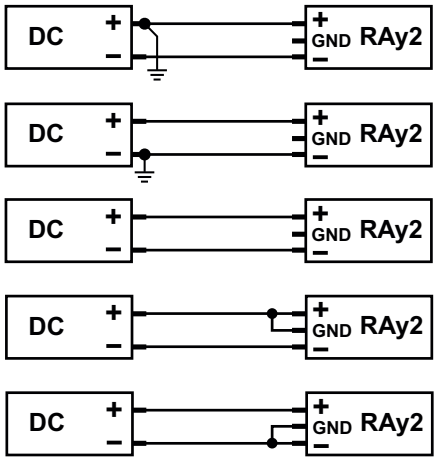


Fig. 3.6: Grounding options

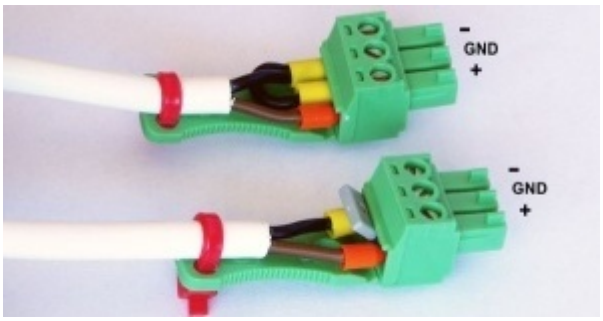


Fig. 3.7: Power supply connector

3.4. Status LEDs

Fig. 3.8: Status LEDs

Tab. 3.1: Meaning of LED status indicators

Diode	Colour	Function
ETH	Green	User port Flashing slowly: Auto Negotiation in progress Flashing rapidly: Link Activity 10/100/1000 Permanently lit: Link 10/100/1000
	Yellow	Management port Flashing: Link Activity 10/100 Permanently lit: Link 10/100
SYS	Green	Permanently lit: System OK Flashing rapidly: Booting Flashing slowly: Operating system in service mode
	Red	Permanently lit: Station is performing defaults. Firmware writing in progress. DO NOT POWER OFF. Flashing slowly: Serious system error.
AIR	Green	Permanently lit: AIR link OK
	Red	Permanently lit: AIR LOSS, loss of connectivity

3.5. Technical parameters

Basic technical parameters are stated in chapter Technical parameters.

3.6. Dimensions

Communication unit ODU

Outer size
- 244 x 244 x 157 mm

Weight
- RAy2-10 — 2.8 kg
- RAy2-11 — 2.8 kg
- RAy2-17 — 2.5 kg
- RAy2-24 — 2.5 kg

Diameters of supplied antennas

RAy2 units are ready for direct mounting to Jirous[1] Class 2 antennas.
Individual datasheets are accessible here[2].

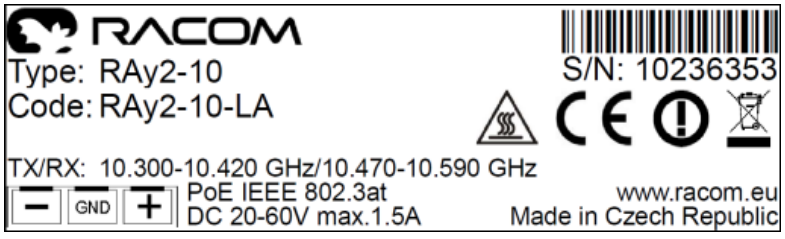
- 10, 11 GHz:
  - 38 cm, 29.0 dBi
  - 65 cm, 35.5 dBi
  - 90 cm, 37.5 dBi
- 17 GHz:
  - 40 cm, 34.8 dBi
  - 68 cm, 38.6 dBi
  - 90 cm, 41.0 dBi
  - 120 cm, 43.7 dBi
- 24 GHz:
  - 40 cm, 36.8 dBi
  - 68 cm, 41.7 dBi

Andrew (Class 2 or 3) or Arkivator antennas can also be used but require an antenna mounting kit. Flexible waveguide is a general-purpose option for any antenna usage.

Name plate

The plate contains name, bar code record, CE label, etc.:

- Type – RAy2 product line identification
- Code – detailed identification of the station type (for details see Section 3.7, “Ordering codes”)
- S/N – serial number, link contains stations with two different numbers
- Power - DC supply connector polarity marks



[1] http://en.jirous.com/
[2] http://www.racom.eu/eng/products/microwave-link.html#accessories_jirous

3.7. Ordering codes

3.7.1. Microwave units

The proper pair (from the same sub-band) of Lower and Upper units should be selected when ordering the microwave link. This is not valid for ISM bands units (RAy2-17, RAy2-24). In such a case the same unit is used for both sides of the link.
User manuals for RAy10[3] and for RAy11, 17, 24[4] are available at www.racom.eu.

Type	Licenced bands		ISM bands	
	10 GHz	11 GHz	17 GHz	24 GHz
Frequency range	A 10.30 - 10.59 GHz	A,B 10.70 – 11.70 GHz	17.10 – 17.30 GHz	24.00 – 24.25 GHz
	B 10.15 - 10.65 GHz	C,D 10.50 – 10.68 GHz		

Sub-bands	Lower [GHz]	Upper [GHz]	Lower [GHz]	Upper [GHz]	no sub-bands	no sub-bands
Sub-band A	10.30-10.42	10.47-10.59	10.700-10.965	11.199-11.455		
ordering code RAy	**RAy10-LA**	**RAy10-UA**	**RAy11-LA**	**RAy11-UA**	**RAy17**	**RAy24**
ordering code RAy2	**RAy2-10-LA**	**RAy2-10-UA**	**RAy2-11-LA** 1)	**RAy2-11-UA** 1)	**RAy2-17**	**RAy2-24**
Sub-band B	10.125-10.325	10.475-10.675	10.945-11.205	11.435-11.700		
ordering code RAy	**RAy10-LB**	**RAy10-UB**	**RAy11-LB**	**RAy11-UB**		
ordering code RAy2	**RAy2-10-LB**	**RAy2-10-UB**	**RAy2-11-LB** 1)	**RAy2-11-UB** 1)		
Sub-band C			10.5005-10.5425	10.5915-10.6335		
ordering code RAy			**RAy11-LC**	**RAy11-UC**		
ordering code RAy2			**RAy2-11-LC** 1)	**RAy2-11-UC** 1)		
Sub-band D			10.5425-10.5845	10.6335-10.6755		
ordering code RAy			**RAy11-LD**	**RAy11-UD**		
ordering code RAy2			**RAy2-11-LD** 1)	**RAy2-11-UD** 1)		

ver. 4.3

1) RAy2-11 not available yet

3.7.2. Feature keys

The Feature keys ordering code consists of three parts:

XXX-YYY-ZZZ

XXX - Product type, e.g. RAy10, RAy11, RAy17, RAy24 or RAy2

YYY - Feature key type.

The "SW" key is available now. This key unlocks the User speed to a given value.
The default user speed without the feature key is the minimum for the respective HW unit.

ZZZ - Feature key value. In case of User speed it states Mbps. Possibilities:

- **RAy10-SW-170** ... RAy10 user data speed max. 170 Mbps
- **RAy11-SW-200**, **RAy11-SW-360** ... RAy11A,B user data speed max. 200 Mbps or 360 Mbps
- **RAy17-SW-200**, **RAy17-SW-360** ... RAy17 user data speed max. 200 Mbps or 360 Mbps
- **RAy24-SW-200**, **RAy24-SW-360** ... RAy24 user data speed max. 200 Mbps or 360 Mbps
- **RAy2-SW-200** ... RAy2 user data speed max. 200 Mbps, valid for RAy2-10, 11AB, 17, 24
- **RAy2-SW-360** ... RAy2 user data speed max. 360 Mbps, valid for RAy2-10, 11, 17, 24

[3] http://www.racom.eu/eng/products/m/ray/index.html
[4] http://www.racom.eu/eng/products/m/ray17/index.html

4. Accessories

4.1. Overview

RACOM-PART-NUMBER	Short description
Antenna Jirous	
ANT-JRMA-380-10/11R	Antenna parabolic 0.38 m 10-11GHz with holder 28.0-29.0 dBi Class 2
ANT-JRMA-650-10/11R	Antenna parabolic 0.65 m 10-11GHz with holder 34.1-35.5 dBi Class 2
ANT-JRMB-900-10/11R	Antenna parabolic 0.9 m 10-11GHz with holder 37.0-37.5 dBi Class 2
ANT-JRMB-400-17R	Antenna parabolic 0.4 m 17GHz with holder 34.8 dBi Class 2
ANT-JRMB-680-17R	Antenna parabolic 0.68 m 17GHz with holder 38.6 dBi Class 2
ANT-JRMB-900-17R	Antenna parabolic 0.9 m 17GHz with holder 41.0 dBi Class 2
ANT-JRMB-1200-17R	Antenna parabolic 1.2 m 17GHz with holder 43.7 dBi Class 2
ANT-JRMB-400-24R	Antenna parabolic 0.4 m 24 GHz with holder 36.8 dBi Class 2
ANT-JRMB-680-24R	Antenna parabolic 0.68 m 24GHz with holder 41.7 dBi Class 2
Antenna mounting kit	
SET-RAY10-ANW	Set mouting RAy10/11 Antenna Andrew 60, 100
SET-RAY10-ARK	Set mouting RAy10/11 Antenna Arkivator 30, 60, 99, 120
SET-RAY17-ANW	Set mouting RAy17 Antenna Andrew 30, 60, 100
SET-RAY17-ARK	Set mouting RAy17 Antenna Arkivator 30, 60, 99
SET-RAY24-ANW	Set mouting RAy24 Antenna Andrew 30, 60, 100
SET-RAY24-ARK	Set mouting RAy24 Antenna Arkivator 30, 60, 99, 120
Flexible waveguide mounting kit	
SET-RAY-FX-R100	Set mouting RAy2 to flange R100
SET-RAY-FX-R120	Set mouting RAy2 to flange R120
Cable bushing	
SET-RAY2-CON-B	Basic set cable bushings and connectors
SET-RAY2-EXT35	Cable bushing lengthening, PG21, 35 mm
Power supply DC	
PWS-AC/DC-AD-55B	Power supply 90-260 VAC / 50 W at 27.6 VDC MeanWell
Power supply PoE	
PWR-POE36U-1AT	Power supply PoE 1xGb Eth 90-264 VAC/ 33.6 W at 56 VDC Phihong
PWR-POE36D-1AT	Power supply PoE 1xGb Eth 36-72 VDC/ 33.6 W at 56 VDC Phihong
Power supply PoE 4x Eth	
PWR-POE125U-4AT-N	Power supply PoE 4xEth 90-264 VAC/ 33.6 W/Port 0/+40°C Phihong
Power supply holder	
HOL-POE-PHI-1A	DIN rail holder for PoE Phihong
HOL-POE-PHI-4A	19" Rack holder for 1xPOE125U-4-AT-N Phihong
Surge protection	
OTH-DL-1GRJ45	Surge protection 1Gb Eth Cat.6 LPZ0B-LPZ1 IP20 -40/+85°C

OTH-DL-CAT.6-60V	Surge protection 1Gb Eth Cat.6 LPZ2-LPZ3 IP20 -40/+85°C
CAT5e cable	
CAB-CAT5E-FTP-TLD	Double shell outdoor FTP Cat5e cable TELDOR
CAT5e, 6 connector	
CON-RJ45-UBNT-CAT6	Connector TC-CON, STP RJ45, Cat5, 8p8c, wire, pleated, AWG24, UBNT
SFP module RJ45	
SFP-RJ45-FIN	SFP module RJ45 interface, -40°C to +85°C, Finisar
SFP module optical	
SFP-DLC-FIN	SFP module, 2-fibres, LC, 10km, -40°C to +85°C, Finisar
SFP-DLC-APAC	SFP module, 2-fibres, LC, 10km, -40°C to +85°C, APAC Opto
Fibre cable patchcord/pigtail	
CAB-FIB-OFA-2F-DLC/DLC-5m	Fibre patch cord, 2-fibres, single mode, 2 LC-connectors, OFA, 5 m
CAB-FIB-OFA-1F-LC/LC-5m	Fibre patch cord, 1-fibre, single mode, 2 LC-connectors, OFA, 5 m
CAB-FIB-OFA-2F-DLC/x-5m	Fibre pigtail, 2-fibres, single mode, LC-connector – loose end, OFA, 5 m
CAB-FIB-OFA-1F-LC/x-5m	Fibre pigtail, 1-fibre, single mode, LC-connector – loose end, OFA, 5 m
DC cable	
CAB-DC-2x1.5	DC power cable 2x1.5 mm, rubber compound
DC surge protection	
OTH-DP-024	Overvoltage protection, DC 24V, LPZ1-LPZ2, IP20, -40/+85°C , Saltek
RAy grounding kit	
KIT-GROUDING-RAY	Grounding kit for RAy units
RAyTool	
SET-RAY-TOOL	Tool set (Knipex, Holex, Wera werk). Heavy duty bag.

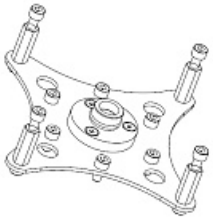
4.2. Details

Antenna

The overview of different Jirous antenna types is listed in Section 3.6, “Dimensions”. The antenna choice determines radio link properties. The radio link calculation should be performed to determine proper antenna size. Rough calculation can be done using a simple on-line calculator.[1]

- see the Overview
- List of datasheets[2]

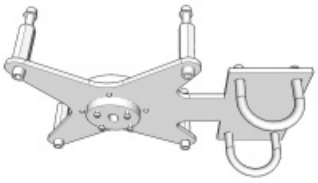
Antenna mounting kit



Other manufacturer's antennas can also be used with RAy2 links. The RAy2 unit can be attached by means of special interconnetions. There are several types of these parts for Andrew and Arkivator antennas. It is also possible to develop interconnetions for other antenna types.

- see the Overview
- The bracket for mounting FOD unit on the antenna.

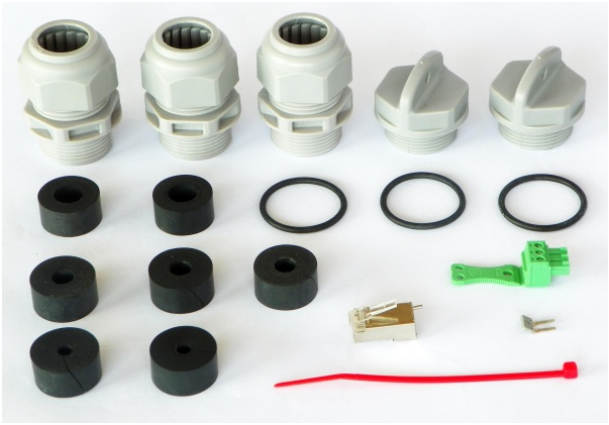
Flexible waveguide mounting kit



The RAy2 unit can be attached to the antenna by flexible waveguide.

- **SET-RAY-FX-R100**
- **SET-RAY-FX-R120**
- The bracket for mounting the flexible waveguide on the FOD unit.

Cable bushing



- **SET-RAY2-CON-B**
- Basic set cable bushings and connectors contains:
  - 3 pc bushing with nut
  - 2 pc blind plug Racom
  - 3 pc O-ring
  - 2 pc rubber sealing small diameter
  - 3 pc rubber sealing medium diameter
  - 2 pc rubber sealing big diameter
  - 1 pc DC connector
  - 1 pc tightening tape
  - 1 pc connector jumper
  - 1 pc RJ-45 ethernet connector

[1] http://www.racom.eu/eng/products/microwave-link.html#calculation
[2] http://www.racom.eu/eng/products/microwave-link.html#accessories

- **SET-RAY2-EXT35**
- Cable bushing lengthening, PG21, 35 mm

Power supply DC

- **PWS-AC/DC-AD-55B**
- orig. part no: AD-55B
- FOD unit power supply 50 W, 24 V, UPS Function, MeanWell
- Datasheet[3]

Power supply PoE

- **PWR-POE36U-1AT**
- orig. part no: POE36U-1AT
- FOD unit power supplies – 30 W PoE adapters, 1x Eth
- Input 100 to 240 VAC, Output 56 V / 33.6 W, Phihong
- Datasheet AC[4]

- **PWR-POE36D-1AT**
- orig. part no: POE36D-1AT
- Input 36 to 72 VDC / 1.2 A, Output 56 V / 33.6 W, Phihong
- Datasheet DC[5]

Power supply PoE 4x Eth

- **PWR-POE125U-4AT-N**
- orig. part no: POE125U-4AT-(x)
- FOD unit power supply 4x 33 W, 4x Eth, Phihong
- Datasheet[6]

Power supply holder

- **HOL-POE-PHI-1A**
- 1x Eth PoE power supply, DIN rail mountable

[3] http://www.racom.eu/download/hw/ray/free/eng/07_prislusenstvi/PWS-AC-DC-AD-55B.pdf
[4] http://www.racom.eu/download/hw/ray/free/eng/07_prislusenstvi/PWR-POE36U-1AT.pdf
[5] http://www.racom.eu/download/hw/ray/free/eng/07_prislusenstvi/PWR-POE36D-1AT.pdf
[6] http://www.racom.eu/download/hw/ray/free/eng/07_prislusenstvi/PWR-POE125U-4AT-N.pdf

- **HOL-POE-PHI-4A**
- 4x Eth PoE power supply, 19" Rack mountable

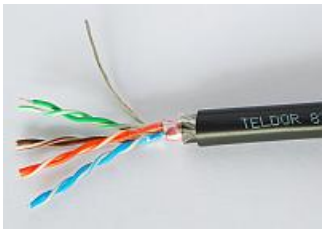
Surge protection

- **OTH-DL-1GRJ45**
- orig. part no: DL-1GRJ45
- Protection from the voltage spikes
- Datasheet[7]

- **OTH-DL-CAT.6-60V**
- orig. part no: DL-Cat. 6-60 V
- Datasheet[8]

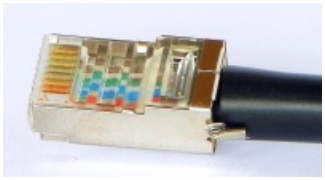
CAT5e cable

- **CAB-CAT5E-FTP-TLD**
- orig. part no: PLU030078
- Cat.5e cable for connecting FOD units to the network, TELDOR
- Datasheet[9]
- Datasheet[10]



CAT5e, 6 connector

- **CON-RJ45-UBNT-CAT6**
- orig. part no: TC-CON connector STP RJ45
  STP RJ45 /Cat6 / 8p8c / wire/ gold plated/ AWG24, UBNT



SFP module RJ45

- **SFP-RJ45-FIN**
- orig. part no: FCLF8521P2BTL
  SFP module, RJ45 interface, -40°C to +85°C , Finisar
- Datasheet[11]

[7] http://www.racom.eu/download/hw/ray/free/eng/07_prislusenstvi/OTH-DL-1GRJ45.pdf
[8] http://www.racom.eu/download/hw/ray/free/eng/07_prislusenstvi/OTH-DL-CAT-6-60V.pdf
[9] http://www.racom.eu/download/hw/ray/free/eng/07_prislusenstvi/CAB-CAT5E-FTP-TLD.pdf
[10] http://www.teldor.com/catalogue.php?actions=show&id=9314
[11] http://www.racom.eu/download/hw/ray/free/eng/07_prislusenstvi/SFP-RJ45-FIN.pdf

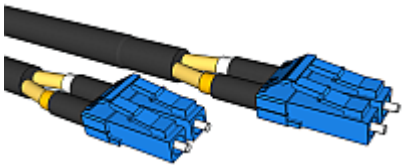
- Datasheet[12]

SFP module optical

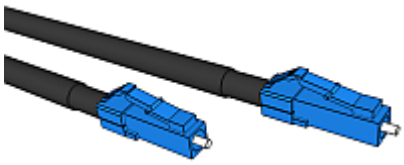
- **SFP-DLC-FIN**
- orig. part no: FTLF1318P3BTL
  SFP module, 2-fibres, LC, 10km, -40°C to +85°C, Finisar
- Datasheet[13]
- Datasheet[14]

- **SFP-DLC-APAC**
- orig. part no: LS38-C3S-TI-N-DD
  SFP module, 2-fibres, LC, 10km, -40°C to +85°C, APAC Opto
- Datasheet[15]
- Datasheet[16]

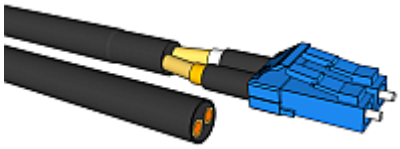
Fibre cable patchcord/pigtail



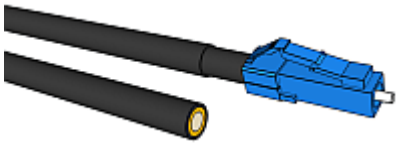
- **CAB-FIB-OFA-2F-DLC/DLC-5m**
- orig. part no: DLCRAC2Fyyy
  patchcord, 2-fibres, single mode, 2 LC-connectors, yyy meters, OFA



- **CAB-FIB-OFA-1F-LC/LC-5m**
- orig. part no: LCRAC1Fyyy
  patchcord, 1-fibres, single mode, 2 LC-connectors, yyy meters, OFA



- **CAB-FIB-OFA-2F-DLC/x-5m**
- orig. part no: DLC0RAC2Fyyy
  pigtail, 2-fibres, single mode, LC-connector – loose end, yyy m, OFA



- **CAB-FIB-OFA-1F-LC/x-5m**
- orig. part no: LC0RAC1Fyyy
  pigtail, 1-fibres, single mode, LC-connector - loose end, yyy m, OFA

- Datasheet[17]

[12] http://www.finisar.com/sites/default/files/pdf/FCLF852xP2BTL_1000BASE-T_Copper_SFP_Transceiver_Spec_RevB2.pdf
[13] http://www.racom.eu/download/hw/ray/free/eng/07_prislusenstvi/SFP-DLC-FIN.pdf
[14] http://www.finisar.com/products/optical-modules/sfp/FTLF1318P3BTL
[15] http://www.racom.eu/download/hw/ray/free/eng/07_prislusenstvi/SFP-DLC-APAC.pdf
[16] http://www.apacoe.com.tw/productlist.do?keyword=ls38-c3s-ti-n-dd
[17] http://www.racom.eu/download/hw/ray/free/eng/07_prislusenstvi/CAB-FIB-OFA.pdf

DC cable

- **CAB-DC-2x1.5**
- orig. part no: H07RN-F ? V05SS-F 2DX1.50
  silicone rubber, 2x1.5 mm², -25 to 60°C, ProPS
- Datasheet[18]
- Datasheet[19]

DC surge protection

- **OTH-DP-024**
- orig. part no: DC 24V
  LPZ1-LPZ2, IP20, -40/+85°C , Saltek
- Datasheet[20]

RAy grounding kit

- **KIT-GROUDING-RAY**
- RAy grounding set for grounding RAy equipment to the mast. Contains a ZSA16 grounding terminal, grounding tape and a cable with grounding lugs.
- Detail see Grounding.
- Datasheet[21]

RAyTool

- **SET-RAY-TOOL**
- Set of tools for installation of the bracket and mounting of connectors. These are branded tools which allow complete installation of the microwave bridge.

Extended descriptions

See www.racom.eu, Microwave link, Accessories[22]

E-shop

Accessories easiest to order here:

E-shop RACOM[23]

Use there a search engine Ctrl+S and RACOM-PART-NUMBER of the searched item.

[18] http://www.racom.eu/download/hw/ray/free/eng/07_prislusenstvi/CAB-DC-2x1.pdf
[19] http://www.props-sro.cz/H07RN-F.php?en
[20] http://www.racom.eu/download/hw/ray/free/eng/07_prislusenstvi/OTH-DP-024.pdf
[21] http://www.racom.eu/download/hw/ray/free/eng/07_prislusenstvi/ZSA16-en.pdf
[22] http://www.racom.eu/eng/products/microwave-link.html#accessories
[23] https://webservice-new.racom.eu/main/eshop.list?a=1&t=10

5. Step-by-step Guide

The following chapters will guide you step by step through preparation, installation and activation of the RAy2 link:

- Pre-installation check out
- Installation
- Advanced configuration
- Troubleshooting

Pre-installation Checklist

Familiarise yourself with the controls and prepare your configuration ahead of the installation of the link on the mast tube.

Both units (without antennas) can lie on a desk with flanges running parallel and facing up at an angle; on a non-metal desk they can also face downward. In the case of units operating in the ISM band (RAy2-17, RAy2-24), turn the unit holders so that they are roughly perpendicular to each other. In the case of units operating in licensed bands (RAy2-10, RAy2-11), turn unit holders so that they are roughly parallel to each other. Use an ethernet cable to connect each of the units to a PoE source and connect a PC to one of them for configuration.

Take the following steps to establish a connection between the PC and RAy2 and perform a basic setup.

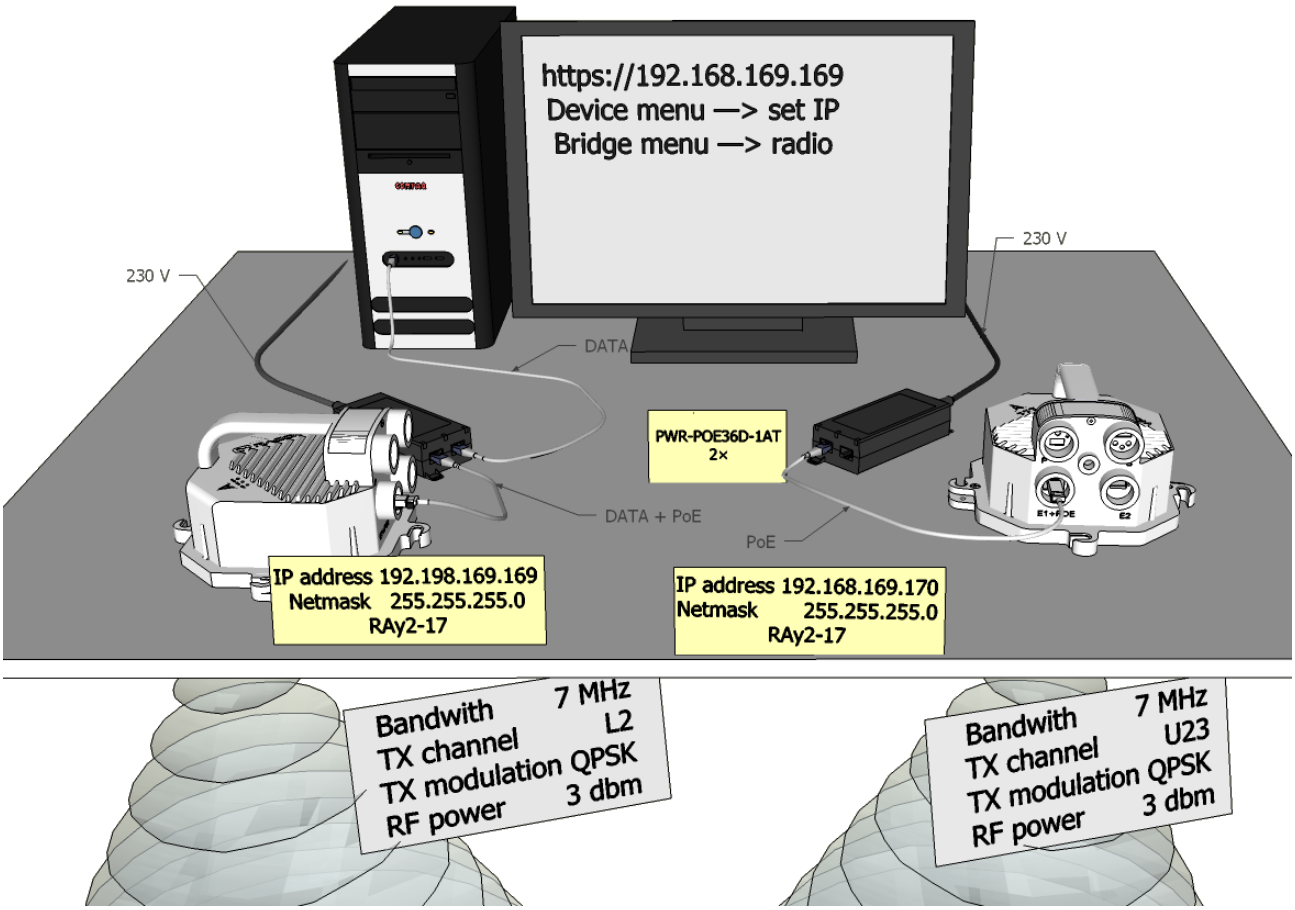


Fig. 5.1: Link Configuration (RAy2-17, perpendicular holders)

Warning

During operation, never bring the waveguides of the stations close to each other. There is a risk of damaging sensitive input circuits.

5.1. Service access

The RAy2 link is supplied with a default configuration of access parameters:

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,
access is allowed over HTTP, HTTPS or SSH,
the username is *admin* and the password is also *admin*.

On your PC setup an IP address that is within the mask, i.e. 192.168.169.180.

Then open the https configuration interface, e.g.
https://192.168.169.169

Other access options are described in the chapter Configuration - Link settings - Service access of this manual.

When connection has been established, use the *Service access* menu to customise access parameters. Default IP addresses should be replaced with well-chosen operating addresses. Leaving default addresses in place 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.

Note

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

Follows the description of basic settings. After entering values on the screen always save the content by clicking on **Apply**.

Note

If there is any problem with https certificate after completing the firmware upgrade, please see the Annex Https certificate for further steps.

5.1.1. Menu Link settings – General

- 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

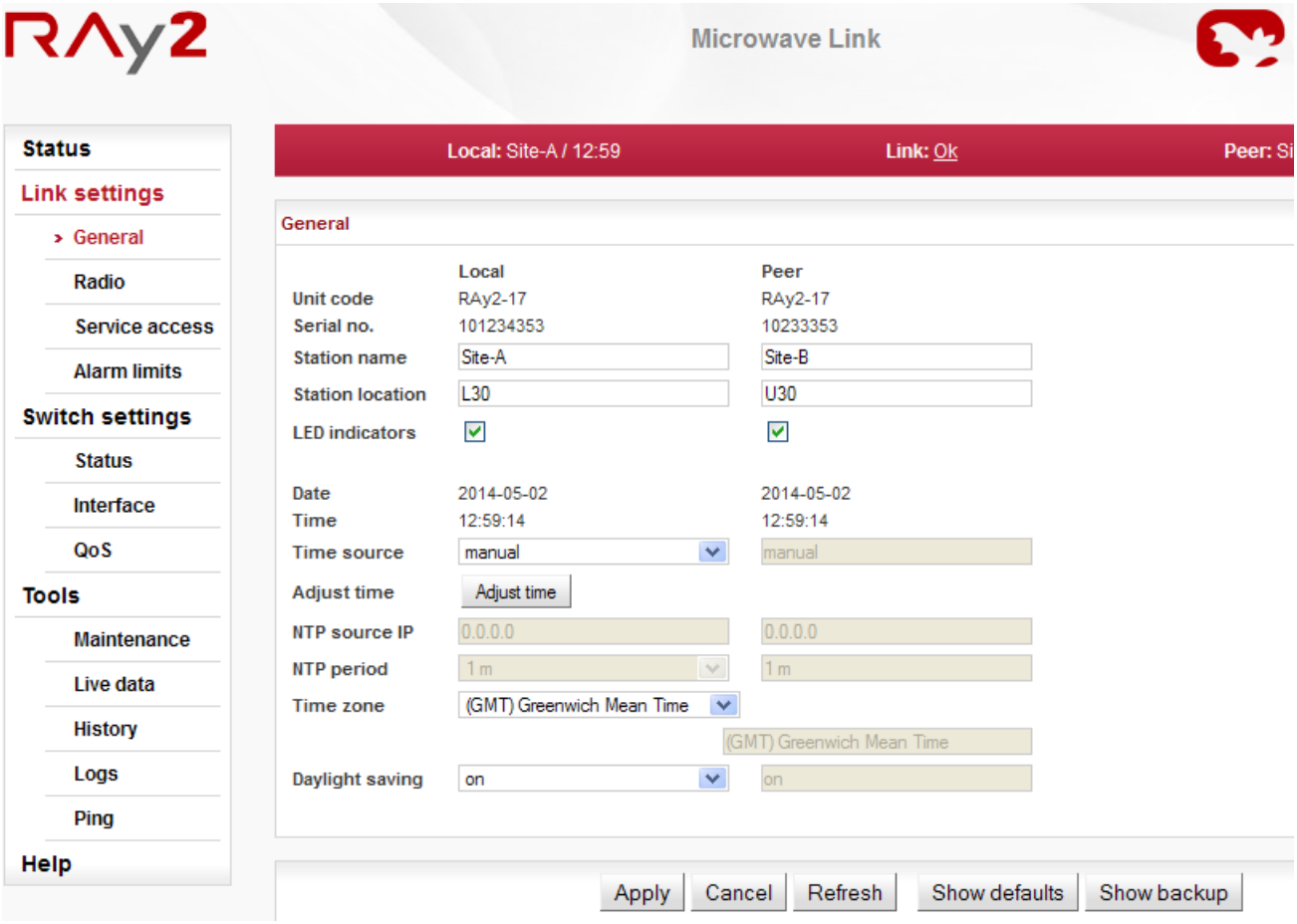


Fig. 5.2: Configuration Menu Link settings - General

5.1.2. Menu Link settings – Service access – Services

- IPv4 address – enter a valid IP address to access the drive. 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 are going to 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.

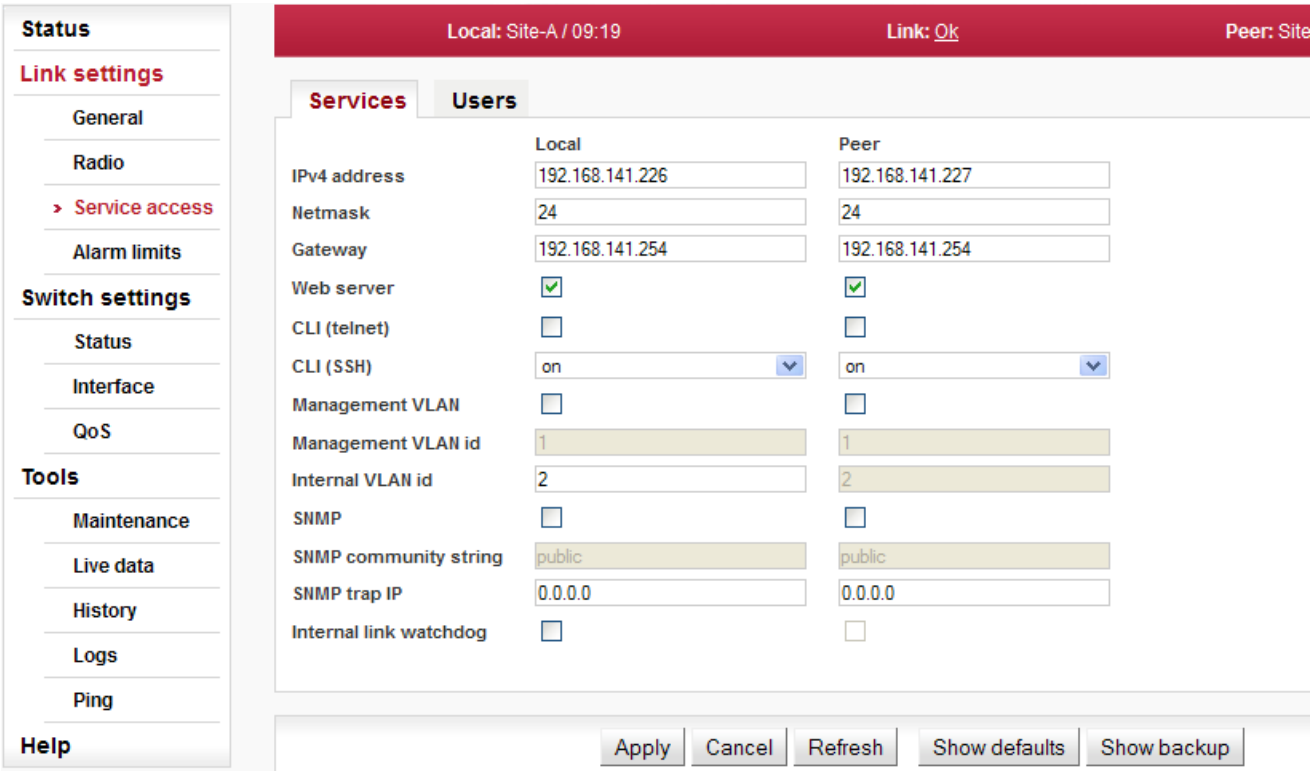


Fig. 5.3: Configuration menu Link settings – Service access – Services

5.1.3. Menu Link settings – Service access – Users

- *Edit* - enter the menu.
- *New password* – choose a password and enter it.
- *Confirm password* – enter the password again to confirm.

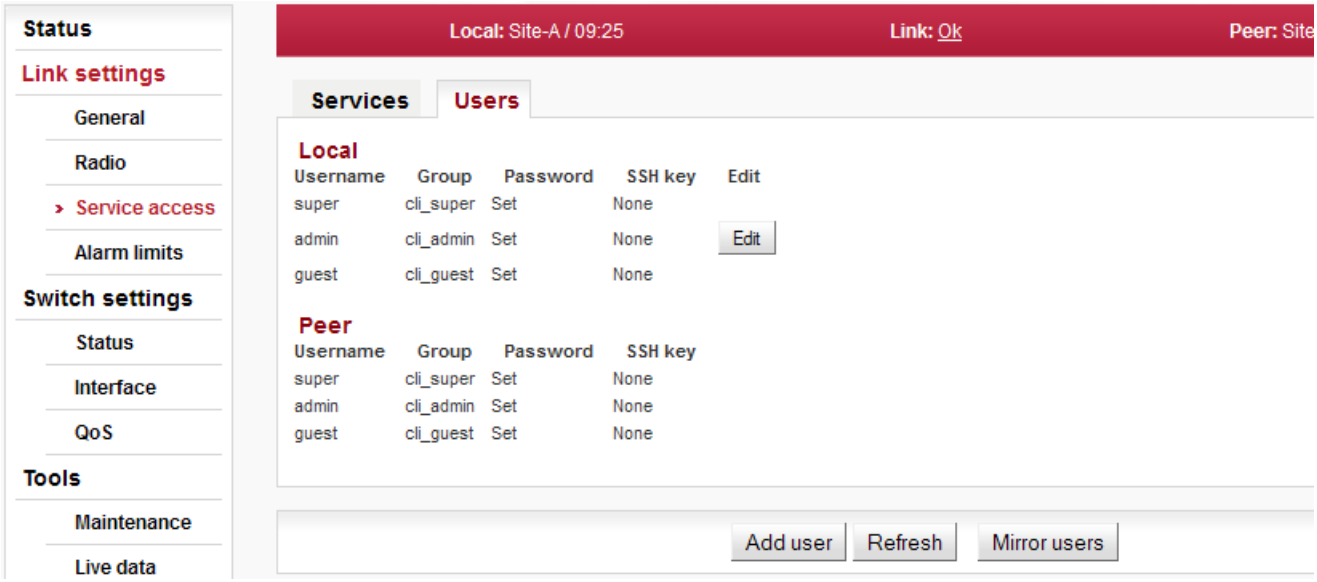


Fig. 5.4: Configuration menu Link settings – Service access – Services

5.1.4. Menu Maintenance – Feature keys

The firmware of the microwave link is capable of controlling the maximum user data speed. The default user speed without the feature key is the minimum for the respective hardware unit. The feature key to assign the maximum user data speed, should be installed prior to physical installation. For further details see the section called “Feature keys”.

5.2. Basic link configuration

Default radio parameters depend on the specific type of link and the specific channel allocation table. Channels are typically set in the lower part of the band, the smallest bandwidth, QPSK modulation, and low power. Both units in the pair should be capable of immediate communication. If it is possible to work with these radio parameters at the installation location, the link can be activated. On an operating link the required operating parameters can then be set up.

If a change in the parameters is necessary, it is done in the menu *Link settings* – *Radio* and saved by clicking Apply. This applies when working on both units simultaneously if they are connected, otherwise each unit is configured individually. When configuring units individually, pay attention to correct settings of duplex pair for channels TX and RX. For example, if one station has TX channel L1, then the second station must also have the channel RX L1.

5.3. 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, this doesn't necessarily mean there is a problem. The message indicates that the limit at 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 SNR values, in case of ACM also the selected modulation and Netbitrate. If the ATPC function is enabled (menu *Link settings – Radio*) it also indicates instantaneous / max. allowed power and for SNR and RSS values it indicates immediate / target value size.
- Menu *Tools – Live data – Bar indicators* displays current size of RSS, SNR and BER.
- Menu *Tools – Ping* allows you to send a ping test to the selected IP address.

Try out the possibility of modulation:

- Modulation ACM. In menu *Link settings – Radio* enable ACM. Set the TX modulation parameter to the required maximum value. In menu *Status – Brief – Radio* you can monitor (Refresh or Start) changes in used modulation based on the instantaneous SNR signal quality. The status and quality of modulation is demonstrated well in menu *Tools – Live data – RX constellation diagram*, hit Refresh.
- To set a fixed modulation go to *Link settings - Radio*, switch off ACM and set the TX modulation to a value from the range of QPSK through 256-QAM based on the results of the previous test. If you choose modulation higher than allowed by SNR, the connection will be lost. *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 the basic modulation QPSK. You can monitor the quality of the received signal under *Tools – Live data – RX constellation diagram*.

Verify the functionality of the entire link:

- If possible, connect user devices to both RAy2 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 RAy2 to the PC connected to the remote RAy2 and test communication between both units over ethernet. This will verify ethernet functionality.

Prepare installation configuration:

- Bandwidth e.g. 3.5 MHz. To get the highest possible receiver sensitivity, set the bandwidth as narrow as possible according to specific frequency band.
- TX channel: Use your allocated channel. If you don't have allocated channel yet, use for example channel L1.
- RX channel will setup automatically when channel lock activates.
- Set TX modulation QPSK to get the highest possible sensitivity.
- Set RF power according to selected antenna and according to individual frequency licence. Set the output power as high as possible.
- Record the access parameters from the Service access menu, especially the IP addresses.
- Restart by interrupting the power supply to verify that the parameters are stored correctly and the link works.

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

6. Installation

6.1. 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 be 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.

6.2. Antenna mounting

6.2.1. Mounting methods

- Mounting on the mast tube can be achieved by:
  - right-side mounting or
  - left-side mounting
- Mounting the FOD unit for antenna polarization can be achieved using:
  - horizontal RX polarization mounting or
  - vertical RX polarization mounting

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

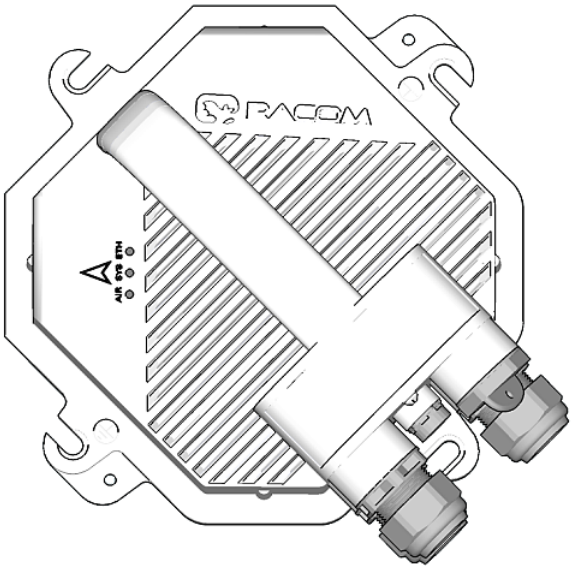


Fig. 6.1: Horizontal RX polarization – see the arrow sign

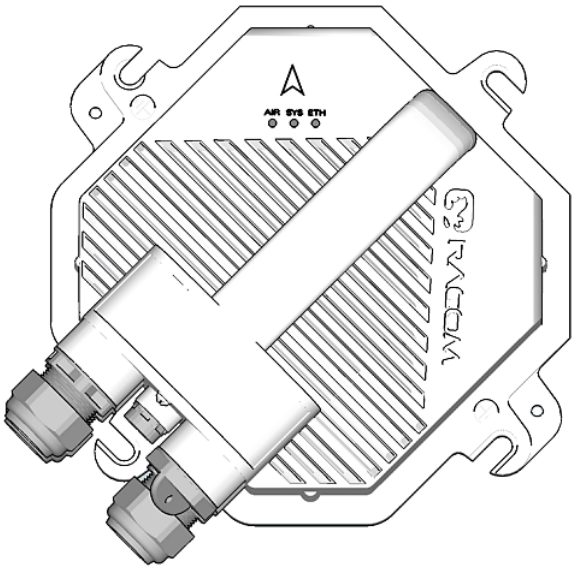


Fig. 6.2: Vertical RX polarization – see the arrow sign

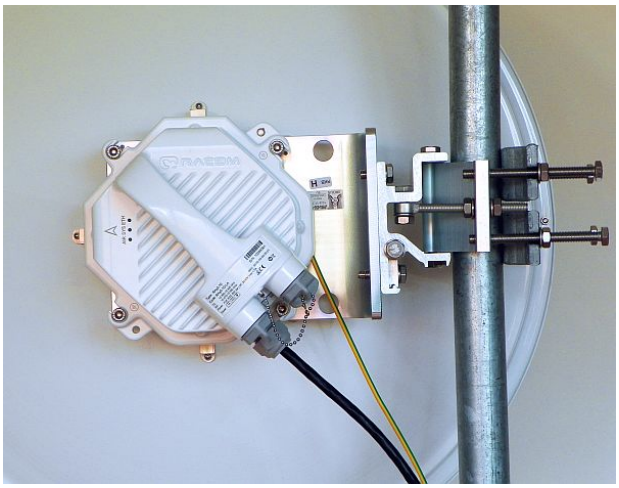


Fig. 6.3: Left-side mounting – horizontal RX polarization

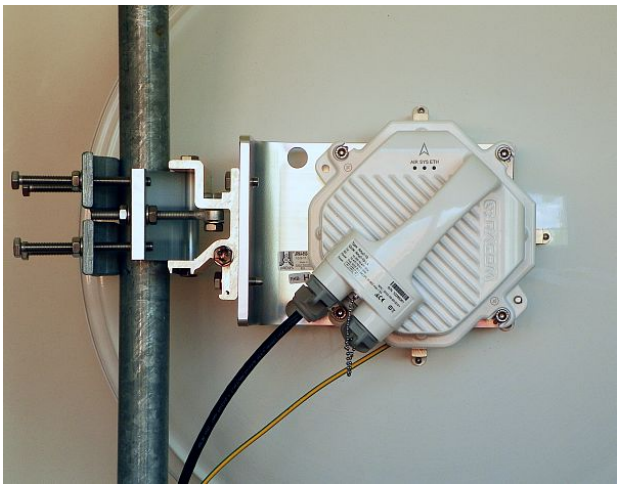


Fig. 6.4: Right-side mounting – vertical RX polarization

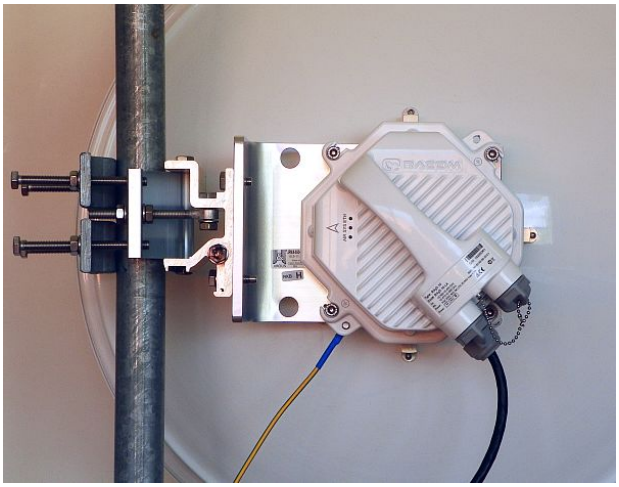


Fig. 6.5: Right-side mounting – horizontal RX polarization

Changing the mounting method

An antenna bracket is supplied as standard partly assembled, and ready for right-side mounting.

On changing the Jirous antenna bracket for left-side mounting the adjustment bolt (part No. 11) and swivel bolt (part No. 6) need to be unscrewed, then shift the bracket body (part No.5) to the other side of clamp plate (part No. 4), (do not turn upside down) and then insert bolt (part No. 6) into the second hole on the mounting plate holder and through the same hole on the clamp plate and secure in place with the nuts. The adjustment bolt (item No. 11) and nuts are switched to the other side of the clamp plate (part No. 4). It is also necessary to switch the hanging bolt (part No. 7) on the antenna mounting plate to the second hole so that after switching sides with the antenna it is on the top again.

In the case of the antenna when changing the method of mounting from right-side to left-side it is only necessary to rotate the plastic cover of the antenna. This is not only important from an aesthetic point of view, so that the RACOM logo is not upside down, but also because there is a discharge channel on the lower edge of the dish (except for ø380 mm dishes).

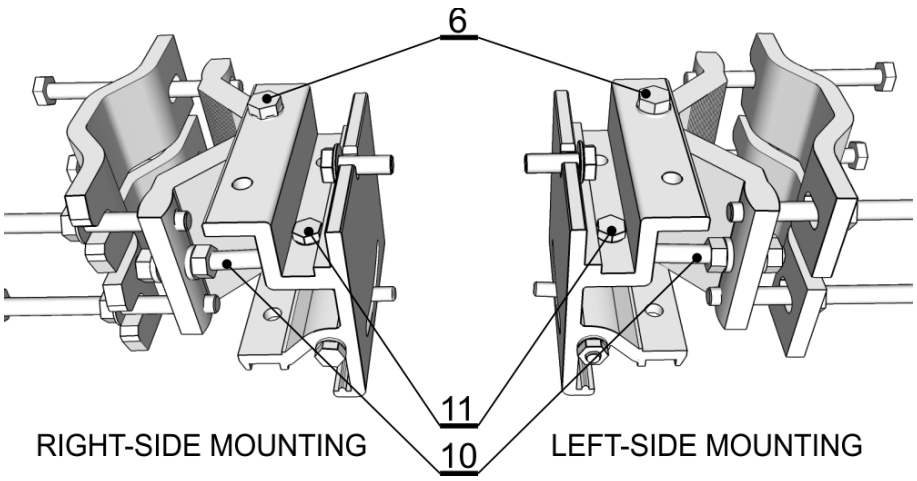


Fig. 6.6: Changing the mounting method

When changing the polarization from horizontal to vertical only the FOD unit needs to be turned through 90° around the central antenna pin by unscrewing the four bolts on the dish using a No. 6 Allen key.

Important

The RAy2-17 and RAy2-24 links are equipped with a polarization duplexer and work in both polarizations simultaneously, see **Cross polarization**. One side of the link must therefore be installed in vertical polarization and the other in the horizontal polarization.

6.2.2. Mounting the FOD unit on the antenna

RAy2 microwave bridge equipment is generally supplied as several component parts packaged separately in a box.

- Two parabolic antennas with assembled mounting plates. There are also 4 screws in a small plastic bag in the box.
- Two brackets for mounting the antenna to the mast.
- Two FOD stations, each separate in a box, in a single package.
- Other accessories based on the order placed (for more detailed information see chapter Chapter 4, *Accessories*)

A No. 17 spanner and a No. 6 Allen key are required for mounting the mechanical parts of the antenna. Spanner No. 17 serves for precisely setting the direction of the antenna. Both spanner and key can be found in the **RAy Tool** set for installing RAy2 microwave bridges.
It is advisable to lightly **lubricate** the retaining screws eg. by the supplied grease.

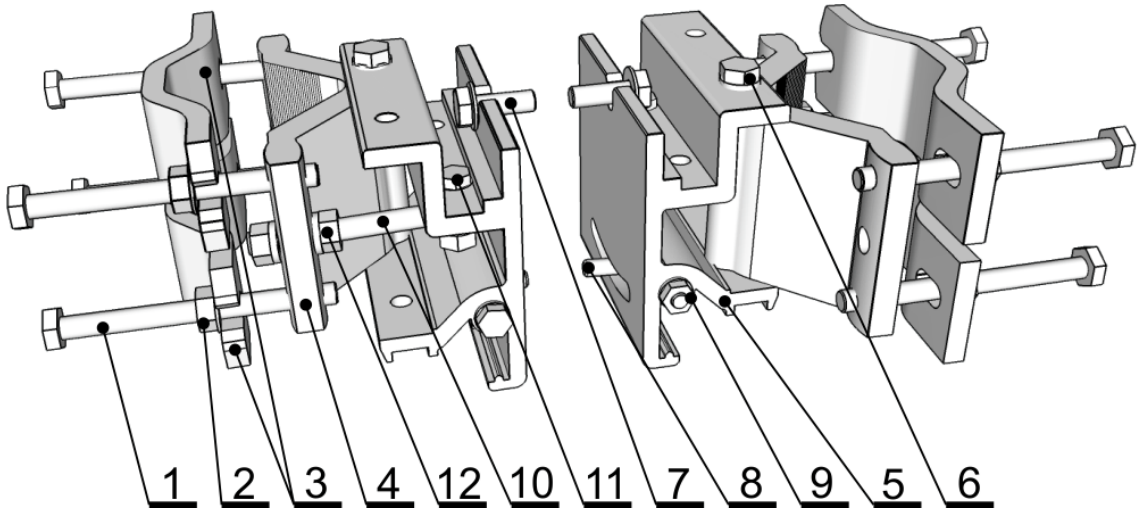


Fig. 6.7: Close up image of the mounted bracket showing numbered parts

a. Prepare the antenna bracket based on the diameter of the mast tube. For smaller diameters face the bent part of the saddle plate (part No. 3) inwards. For larger diameters it should face outwards. Screw the bolts (part No. 1) into the clamp plate (part No. 4) so that they protrude approx. 1 cm through the clamp plate. Clamp the saddle plate to the mast by tightening the nuts (part No. 2) on the bolts.

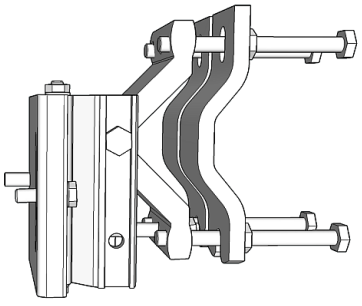


Fig. 6.8: Position of the saddle plate for ø 40–80 mm

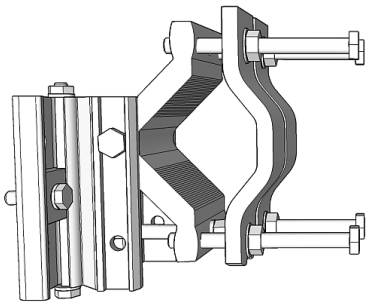


Fig. 6.9: Position of the saddle plate for ø 65–115 mm

b. Slide the antenna bracket onto the mast tube and clamp to the mast by tightening the nuts. Recommendation: Keep the gap between the two saddle plates (part No. 3) as wide as possible, so the horizontal angle adjustement screw can fit in this gap. The range of horizontal adjustement is consequently wider. This has a bigger effect when the mast diameter is smaller.

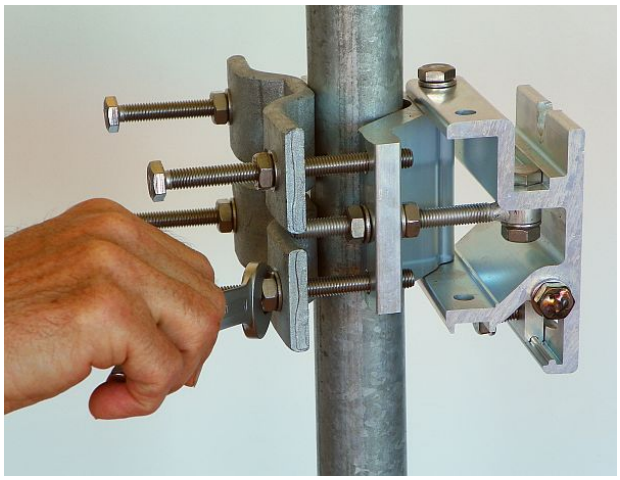


Fig. 6.10: Attaching the bracket to the mast tube

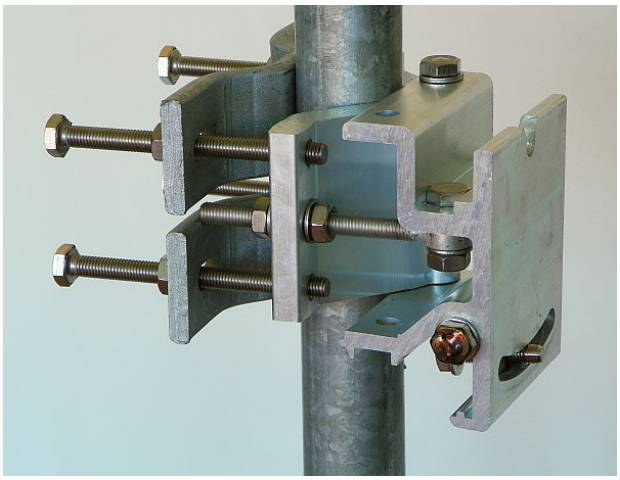


Fig. 6.11: Bracket on the mast tube

c. Screw the hanging bolt (part No. 7) into the upper hole of the mounting plate so that the antenna can be hung on the mounting plate holder. Hang the antenna on it and tighten the lower bolt. (part No. 8)

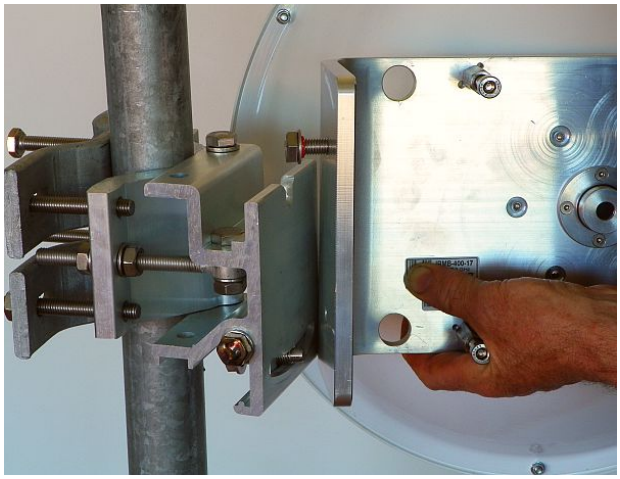


Fig. 6.12: Hanging the bolt on the holder

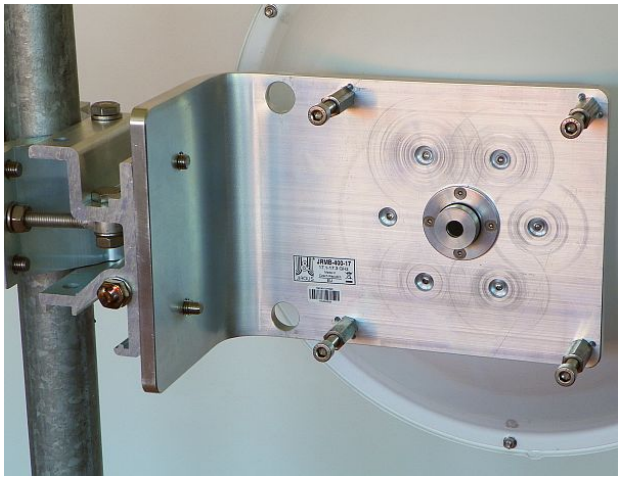


Fig. 6.13: Correct position of the mounting plate

d. Tighten both bolts to the plate before continuing with installation to prevent any unnecessary movements of the equipment. Before precisely adjusting the vertical direction of the antenna upon completing installation it will be necessary to unscrew them again as the lower bolt (part No. 8) passes through the adjustment block and the upper one (part No. 7) serves as the axis of rotation.

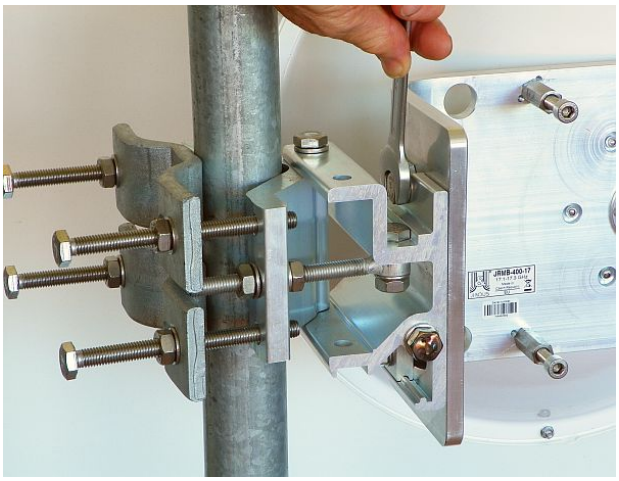


Fig. 6.14: Tightening the upper bolt to the mounting plate

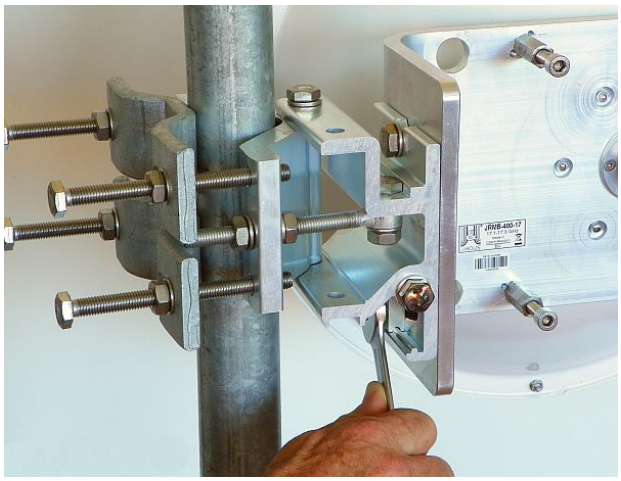


Fig. 6.15: Tightening the lower bolt to the mounting plate

e. Before installing the FOD unit on the antenna first unscrew the 4 bolts on the back of the antenna enough so that the unit can be slid 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 6.2.3, “Lubrication and preservation of the antenna pivot”. Then remove the protective plastic cover from the central pin of the antenna and fit the FOD unit to it carefully so as not to damage the "O" ring. Secure it in place with the four bolts. Carefully ensure the correct polarization of the antenna – see Section 6.2.1, “Mounting methods”. Finally tighten the bolts with a No. 6 Allen key.

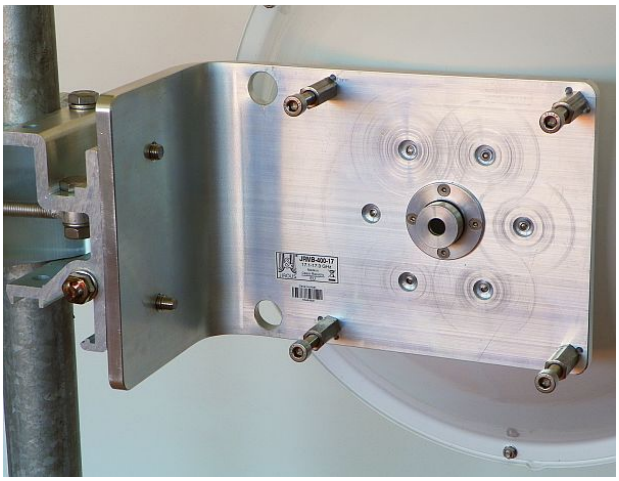


Fig. 6.16: Dish before installing the FOD unit

Fig. 6.17: Tightening bolts on the FOD unit

f. The precise horizontal direction the antenna is pointing in can be adjusted using the bolt with two nuts (part No. 10 and 12). Once the direction has been set the antenna is fixed in place by tightening the nuts against the bracket to prevent further movement of the antenna. The vertical direction the antenna is pointing in can be adjusted by turning the fine adjustment bolt (part No. 9) by the bracket mounting plate. After selecting the correct direction the position is secured by tightening the bolt – see point d. (part No. 7 and 8). The correct position in both directions is found by monitoring RSS voltage, see Section 6.5.2, “Directing antennas”.

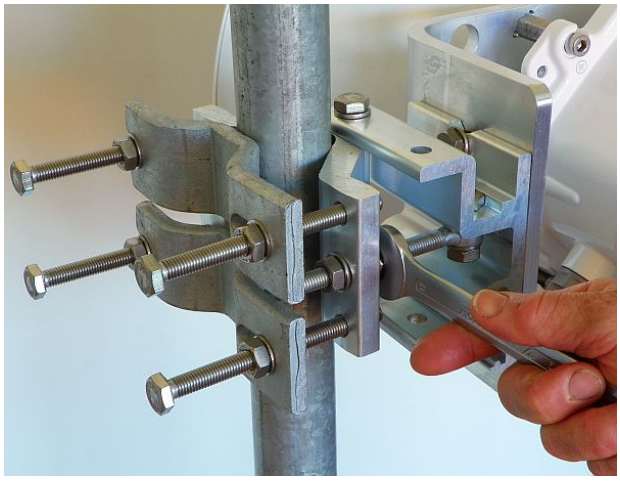


Fig. 6.18: Horizontal adjustment of the antenna direction

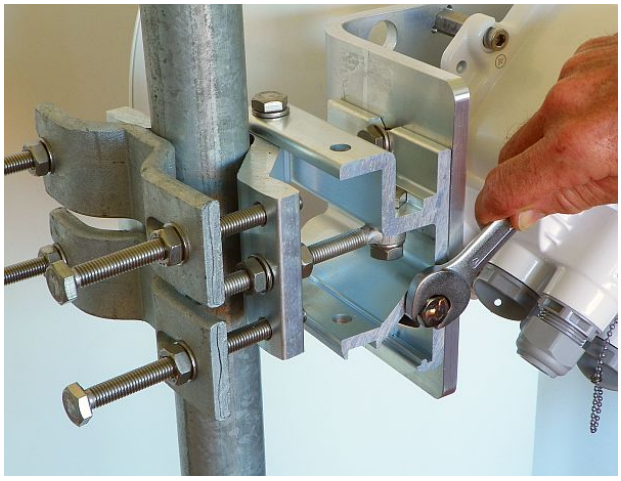


Fig. 6.19: Vertical adjustment of the antenna direction

g. After pointing the antenna in the right direction tighten the bolts on the bracket on the axes of rotation (part No. 6 and 11). Then check again that all other bolts have been sufficiently tightened. We can now proceed to connecting the FOD unit to the user network.

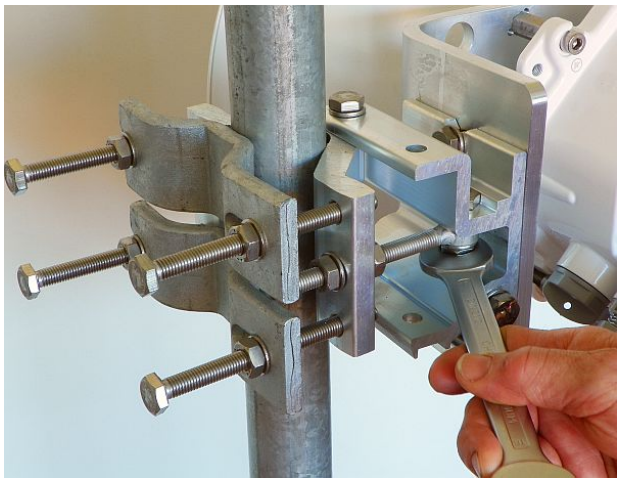


Fig. 6.20: Tightening the axis at the fine adjustment bolt

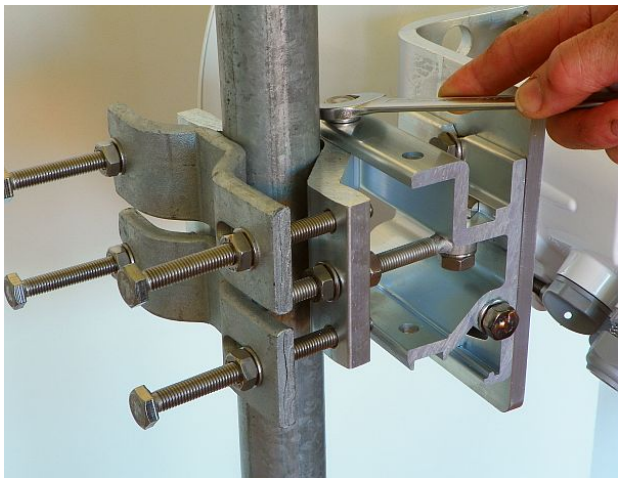


Fig. 6.21: Tightening the axis at the bracket

6.2.3. Lubrication and preservation of the antenna pivot

Before fitting the FOD unit bush onto the antenna pivot ensure that 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 treat these surfaces with the grease which is supplied in the box marked "SILIKONOVE MAZIVO". If you use a different grease for lubrication then it should be a Teflon or a silicon grease.

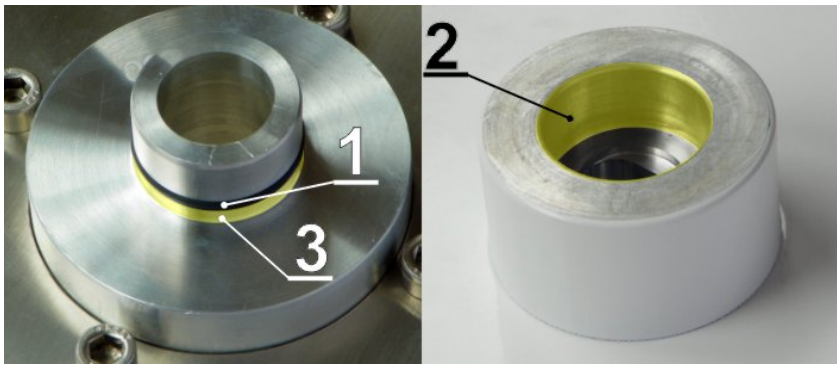


Fig. 6.22: Grease points on the antenna pivot and FOD unit bush

Grease the internal area of the bush on the FOD unit (2) and the "O" ring (1) with a thin even layer that allows the pin to slide easily into the bush without damaging the "O" ring. Grease the area beyond the "O" ring on the antenna pin (3) with a thicker layer so that it fills the gap caused by the play between the pin and the bush (max. 0.1 mm/ø) thus preventing moisture getting in. Installation should be carried out according to the antenna installation description – see point f of this description.

The tub with grease is supplied with the RAy2 units.

6.2.4. Flexible waveguide

Any type of antenna may be connected to the RAy2 unit using a flexible waveguide. Flexible waveguide mounting kit can be ordered as an accessory part.

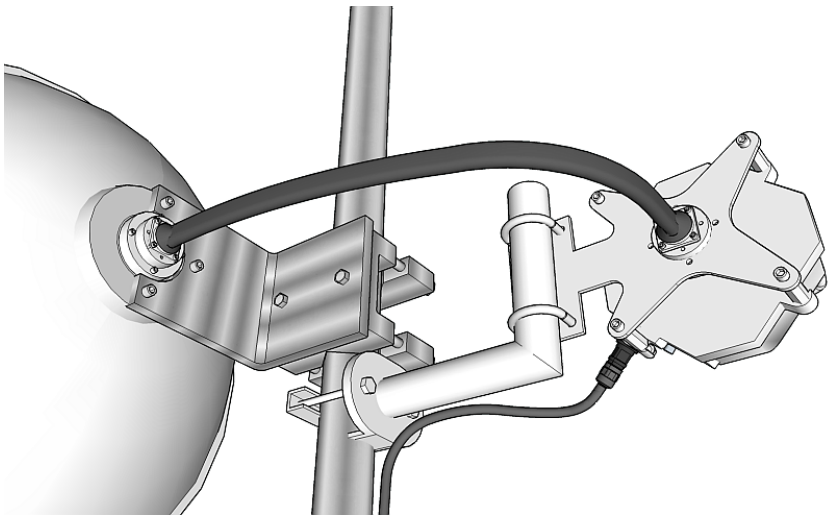


Fig. 6.23: Flexible waveguide assembly

6.3. Connectors

6.3.1. Connecting the FOD communication unit to the user network

The FOD communication unit is connected to the user network by an Ethernet cable via interfaces GbE, IEEE802.3ac 1000BASE-T. As standard, RACOM recommends using an S/FTP CAT 7 cable and two RJ45 connectors for outdoor installations. One set of IE-PS-RJ45-FH-BK connectors and the cable bushing set is delivered as the accessory part.

Based on the PoE standard the station is powered over the Ethernet cable.

The unit is equipped with connectors:

- E1+POE – Gigabit metallic Ethernet port. This port is capable to power unit with any Power over Ethernet power source working according to IEEE 802.3at standard.
- E2 – Slot for user exchangeable SFP module. A wide range of optical modules is available. Both single or dual mode transceivers can be used. The SFP module with metallic RJ45 interface can be used as well. Please see the IMPORTANT NOTICE.
  The SFP status LED is located just next to the slot.
- P – DC power connector.
  HW button for service purposes.
- S – USB service connector.
  RSS voltage output connectors.

Fig. 6.24: FOD communication unit connectors

Important

Before connecting the FOD communication unit to the supply (to the user network) the FOD unit must be grounded according to Section 6.4, “Grounding”.

Assembly procedure:

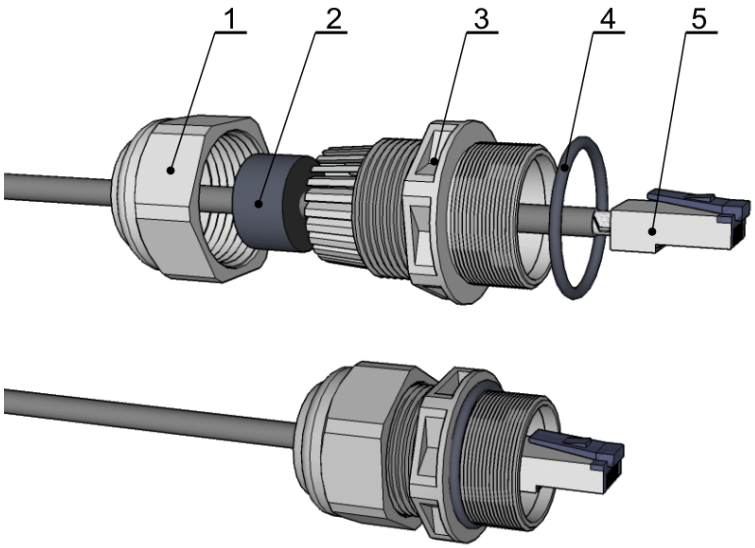


Fig. 6.25: Bushing and connector assembly

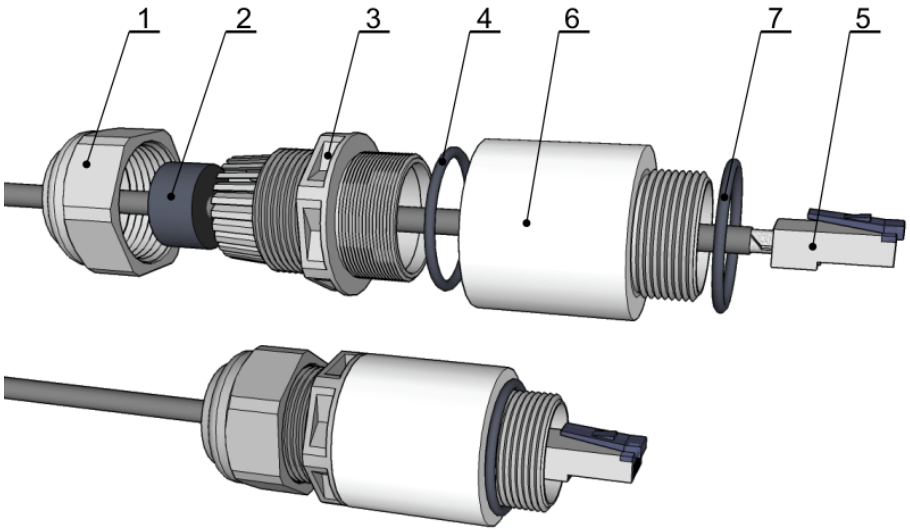


Fig. 6.26: Assembly for a long connector, eg. with SFP-RJ45-FIN

- Put on the cable: the nut No.1, rubber sealing No.2, bushing No.3 and O-ring No.4.
- Attach the appropriate connector No.5 to the cable.
- Plug the connector No.5 into the RAy2 unit.
- Screw the bushing No.3 with the sealing O-ring into the RAy2 unit.
- Move the rubber sealing No.2 along the cable to fit in the bushing. Screw the nut No.1 on bushing No.3.

All necessary parts are delivered as an accessory SET-RAY2-CON-B. For long version use the extension SET-RAY2-EXT35 containing the parts No.6 and No.7.

Warning

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

The rubber sealing is delivered with three different internal diameters to fit different cable diameters. The rubber is diagonally cut to enable sealing of cables with preinstalled connectors.

6.4. Grounding

The lightning and overvoltage protection system example, designed in accordance with regulation CSN EN 62305.

1. Where 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, 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 wiring or grounded internal structures using a CYA 6 mm^2 bonding conductor , see Fig. 6.27, “Grounding installation 1”

3. If it is not possible to set up conditions of electrical insulation in accordance with article 6.3 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. 6.28, “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.

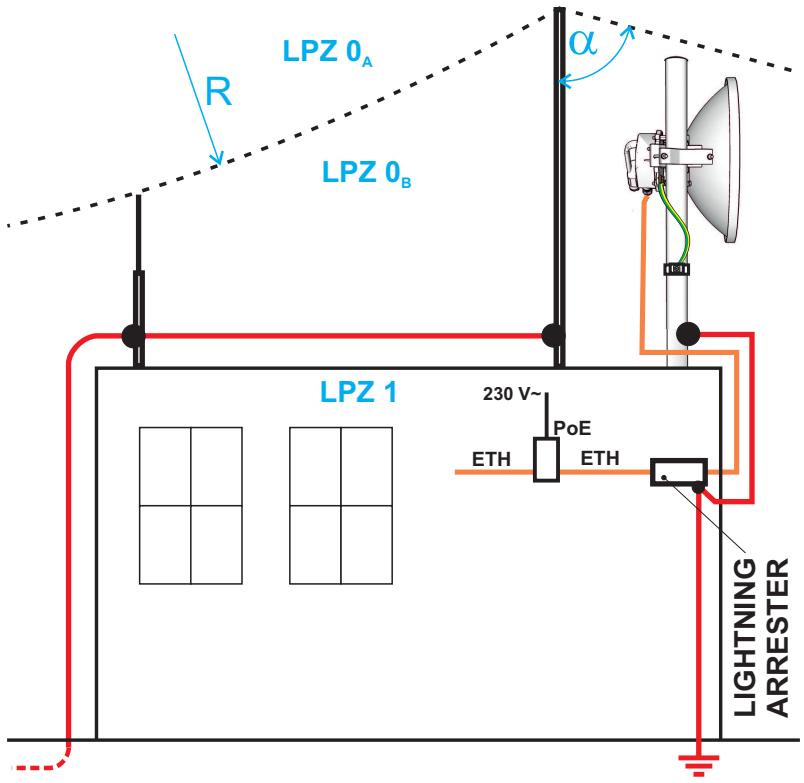


Fig. 6.27: Grounding installation 1

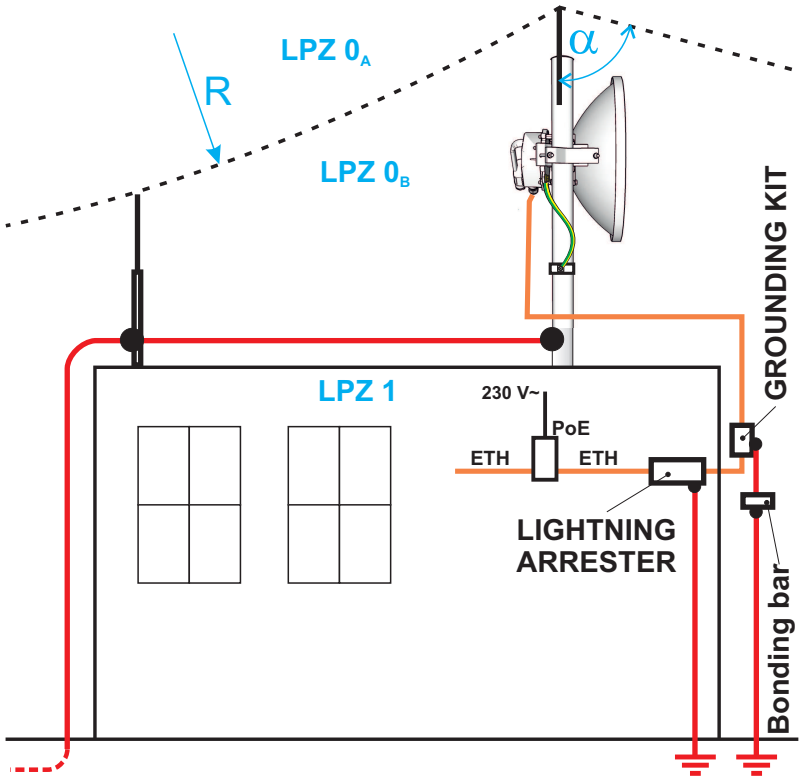


Fig. 6.28: Grounding installation 2

The RAy2 unit is grounded to the flange at the fixing screws using an M8 screw. An insulated copper cable with a minimum cross-section of 6 mm^2 terminated with a terminal lug is used as a protective

conductor. The conductor should have a green/yellow plastic cover along its whole length. For grounding a RAy grounding kit can be ordered as an accessory (see Chapter 4, *Accessories*) containing a grounding terminal ZSA16, 40 cm grounding strip 15 mm wide, and 100 cm of cable with grounding lugs. For instructions on installing terminals see the datasheet RAy grounding kit[1]. A qualified person must install the antenna.

Racom supplies surge protection for installation on Ethernet cables entering buildings. For more details see Surge protection[2].

Additional safety recommendations

- Only qualified personnel with authorisation 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. See Section 6.4, “Grounding”.
- 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.

Fig. 6.29: Grounding kit for S/FTP 4+2 cable

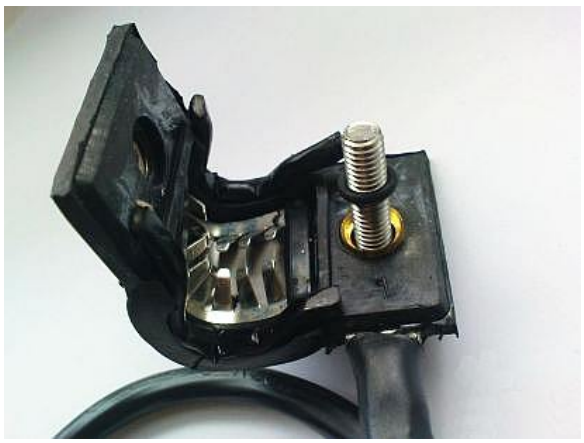


Fig. 6.30: Grounding kit detail

[1] http://www.racom.eu/download/hw/ray/free/eng/07_prislusenstvi/ZSA16-en.pdf
[2] http://www.racom.eu/eng/products/microwave-link.html#accessories

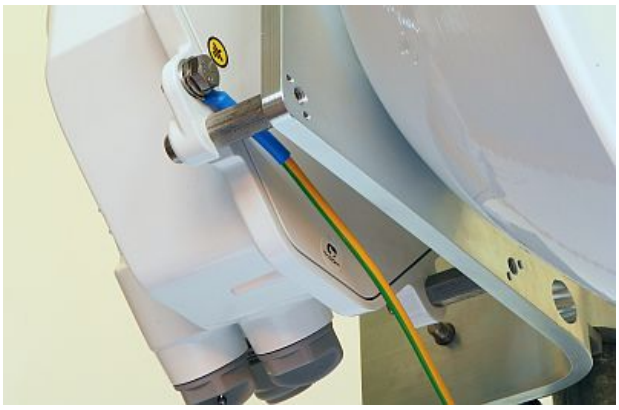


Fig. 6.31: Protective conductor at the FOD unit

Fig. 6.32: Grounding the FOD unit

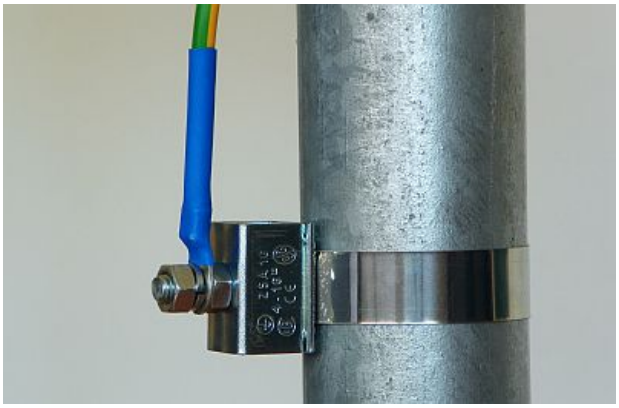


Fig. 6.33: Protective conductor at the mast on a ZSA16 terminal

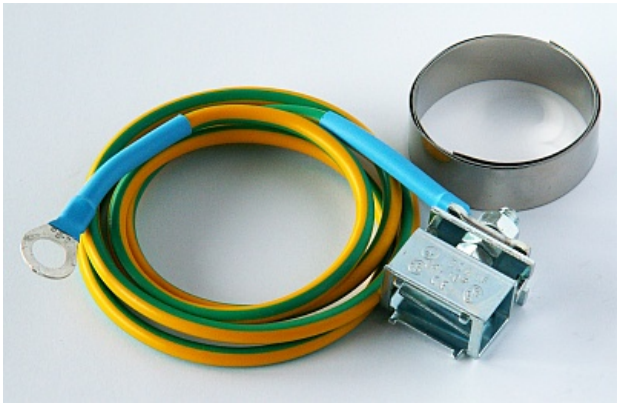


Fig. 6.34: RAy grounding kit

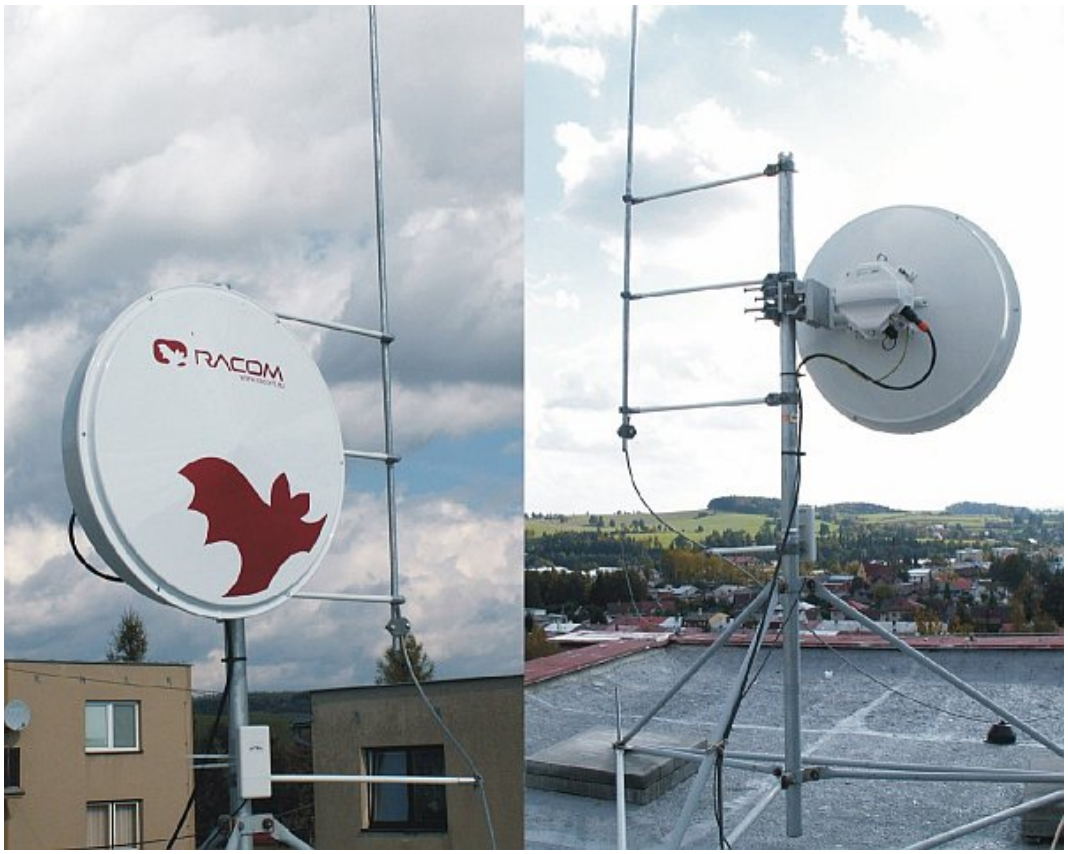


Fig. 6.35: Separated lightning conductor

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:

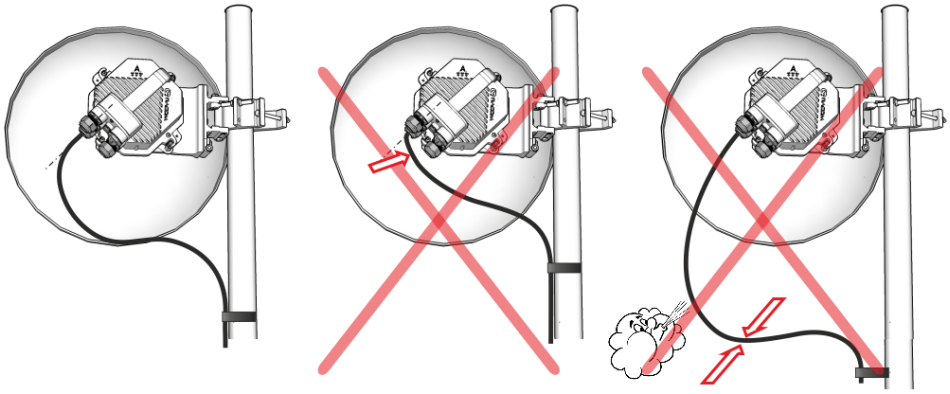


Fig. 6.36: Example of a correct lead installation.

6.5. Start up

Connect a power supply to the installed FOD unit and connect the configuration PC. Use an internet browser (such as Mozilla Firefox) to enter the configuration menu.

6.5.1. Noise on the site

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

Analyse 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 in one location all units emit a signal in the Upper part of the range and receive it in the Lower part of the range, or the other way round. A transmitter must not be installed in the part of the spectrum where other units function as receivers.

6.5.2. Directing antennas

If it is possible, use a narrow channel, low modulation and high power for the first antenna directing alignment. Working on both ends of the link simultaneously is favourable. Connect a voltmeter to the connectors and observe RSS changes in 2 V DC range. A stronger signal corresponds to lower voltage. Alternate units on both sides and slowly adjust the antenna vertically and horizontally to find the position with the strongest reception. At the same time look for the main signal maximums. To differentiate between the main and the side maximums refer to the Main and side lobes paragraph.

RSS measurement

For correctly setting the bridge and positioning it in the right direction it is advisable to connect a PC and use the diagnostic capabilities of the RAy2 station. In uncomplicated cases it is enough to connect a voltmeter via connectors and adjust 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.

Fig. 6.37: RSS connectors

Fig. 6.38: RSS connectors - connecting a voltmeter

Main and side lobes

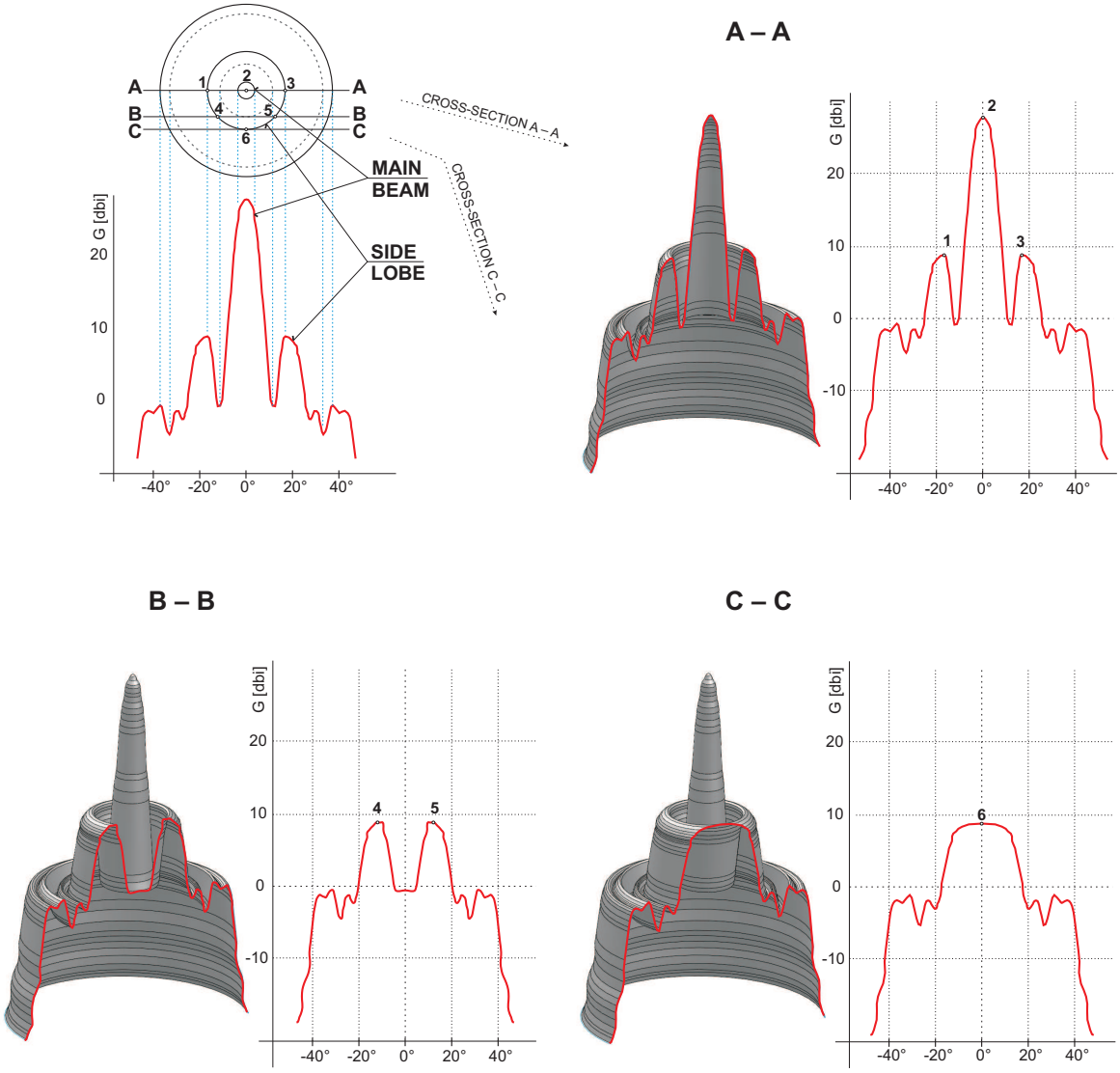


Fig. 6.39: Radiation diagrams

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[3].

[3] http://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 doesn't 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:

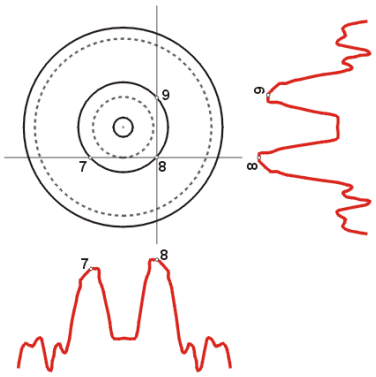


Fig. 6.40: Radiation diagram – incorrect adjustment

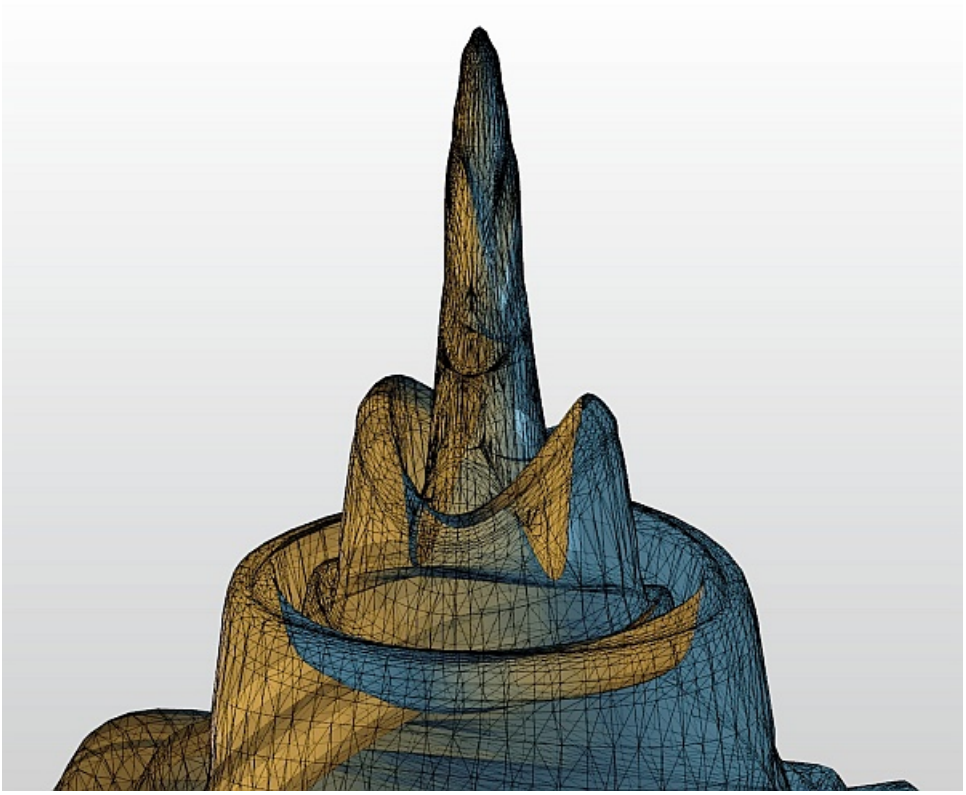


Fig. 6.41: 3D example of more complicated Radiation Pattern

6.5.3. Link test

Basic parameters of the link are shown in the menu *Status* – *Brief*, its quality is characterized by RSS and SNR. Values on Status screens can be refreshed manually by pressing the Refresh button or in real time with a period of several seconds after activating the Start button. Press the Stop button to terminate the periodic refresh of values.

The RSS, SNR and BER values can also be viewed on the screen *Tools* – *Live data* – *Bar indicators*. After pressing the Start button, values will be refreshed with a period of one second.

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

6.5.4. 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 analyser*. 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 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.
- Transmit power (TX power), or ATPC
- Verify and record IP addresses
- Define access channels – https / telnet / ssh / ssh with password

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) - Download* and save the configuration to backup file "cnf_backup.tgz".

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

7. Configuration

7.1. Introduction

Controls

The following configuration buttons are used for configuration:

Apply	Apply and save parameters.
Cancel	Set parameters are overwritten with original values.
Refresh	Reload the current values of the station / both stations.
Show defaults	Show values of individual parameters as they are stored in backup configuration (in the buffer). To use any of these values, you must use the *Apply* button.
Show backup	Show values of individual parameters from backup configuration. To use any of these values, you must use the Apply button. For loading the backup configuration see menu *Tools – Maintenance – Backup*.
Start	Use the *Start* button to start automatic refresh of displayed information. Information subject to this update is highlighted with a refresh icon.
Stop	Use the *Stop* button to stop automatic refresh of displayed information.

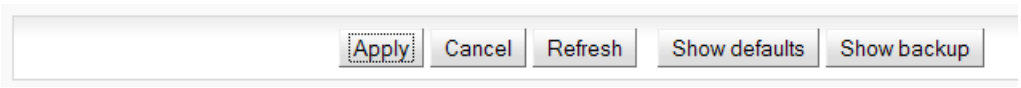


Fig. 7.1: Info Refresh

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. The help text is displayed within the configuration screen after clicking the *Help* menu.

Secure 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.

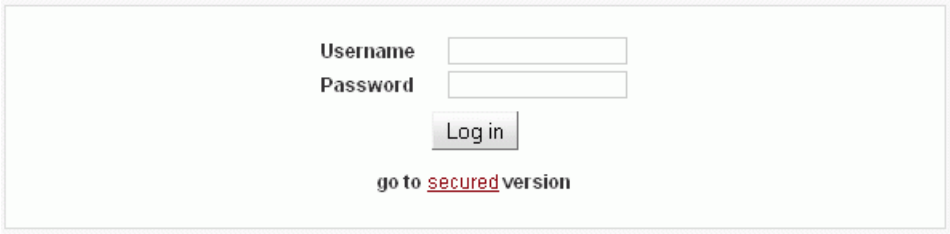


Fig. 7.2: Login

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 is automatically restored.

7.2. Status bar

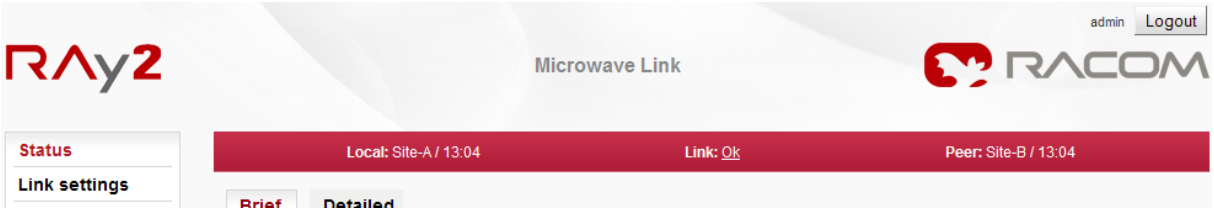


Fig. 7.3: Status bar 1

The Status bar is located on the upper part of the screen below the title bar. It consists of 3 fields:

- **Local** station status (station assigned to the IP address entered in the browser or CLI)
- Local to **Peer** link status.
- **Peer** station status.

Local and Peer field displays:

- Station name according to configuration.
- Actual time valid for respective station.
- Warning or Alarm icon in case of warning or alarm.

Link field display:

- Status of the link between both sides of the station.
- Warning icon when the link is not capable of user data transfer.

The Link status can be one of the following values:

UNKNOWN	Station start up. The initialization is not yet finished.
SETUP	Station initialization according to valid configuration.
SINGLE	Station in operation status. Link to peer station is not established.
CONNECTING	Connection to peer station in progress.
AUTHORIZING	Authorization of the peer station in progress.
OK	Link is connected. Peer station is authorized.

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

All states except for the state of OK are highlighted with a triangle.:

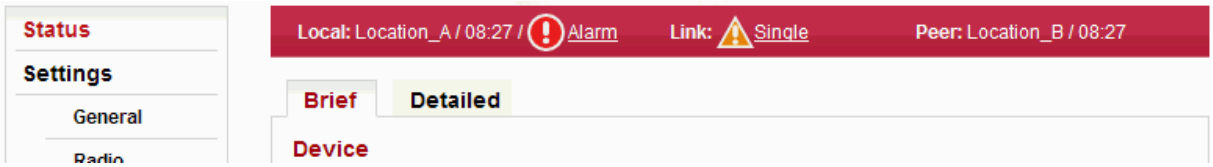


Fig. 7.4: Status bar 2

Example of a complete page - status bar, menu and control buttons:

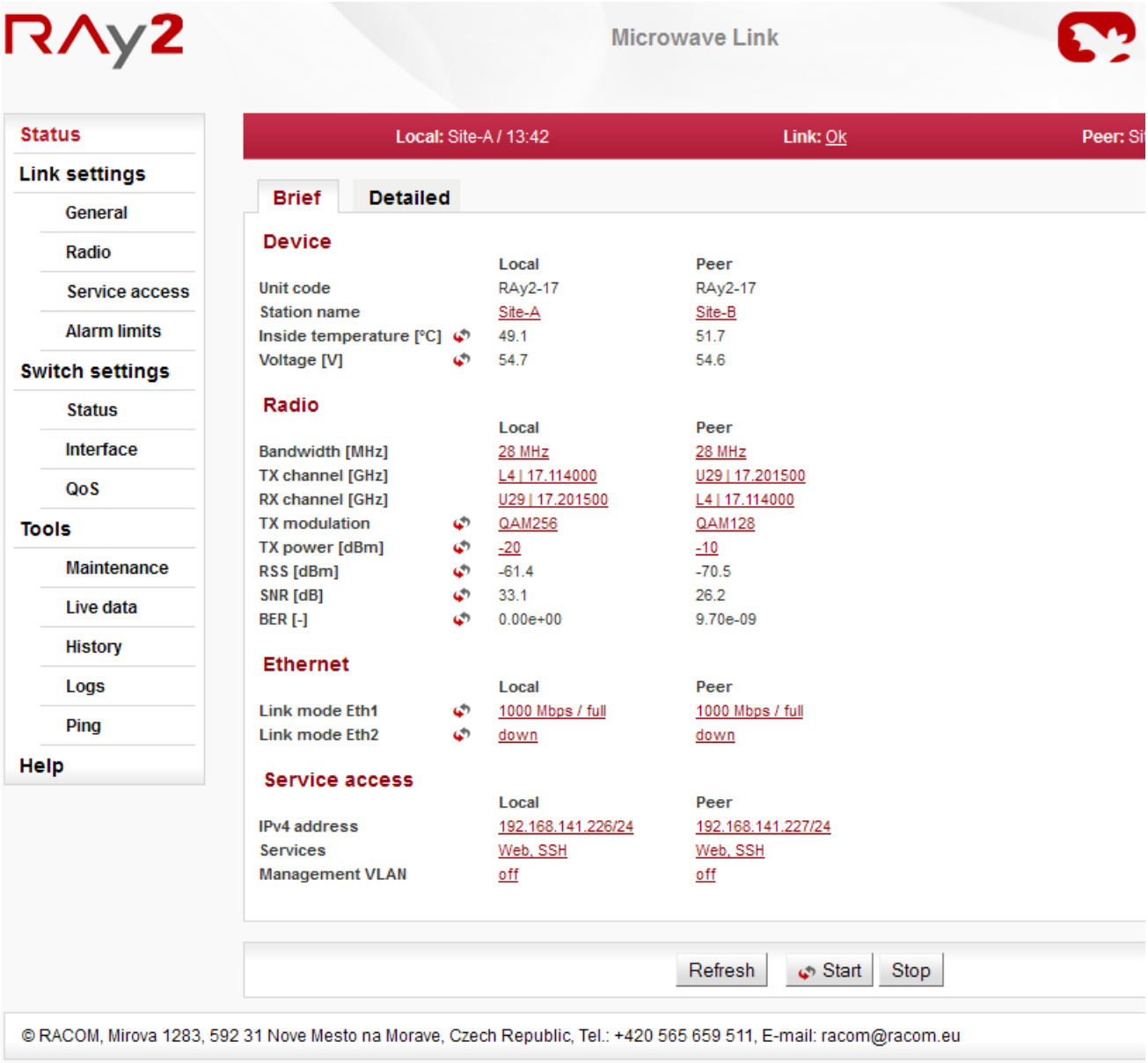


Fig. 7.5: Page example

7.3. Status

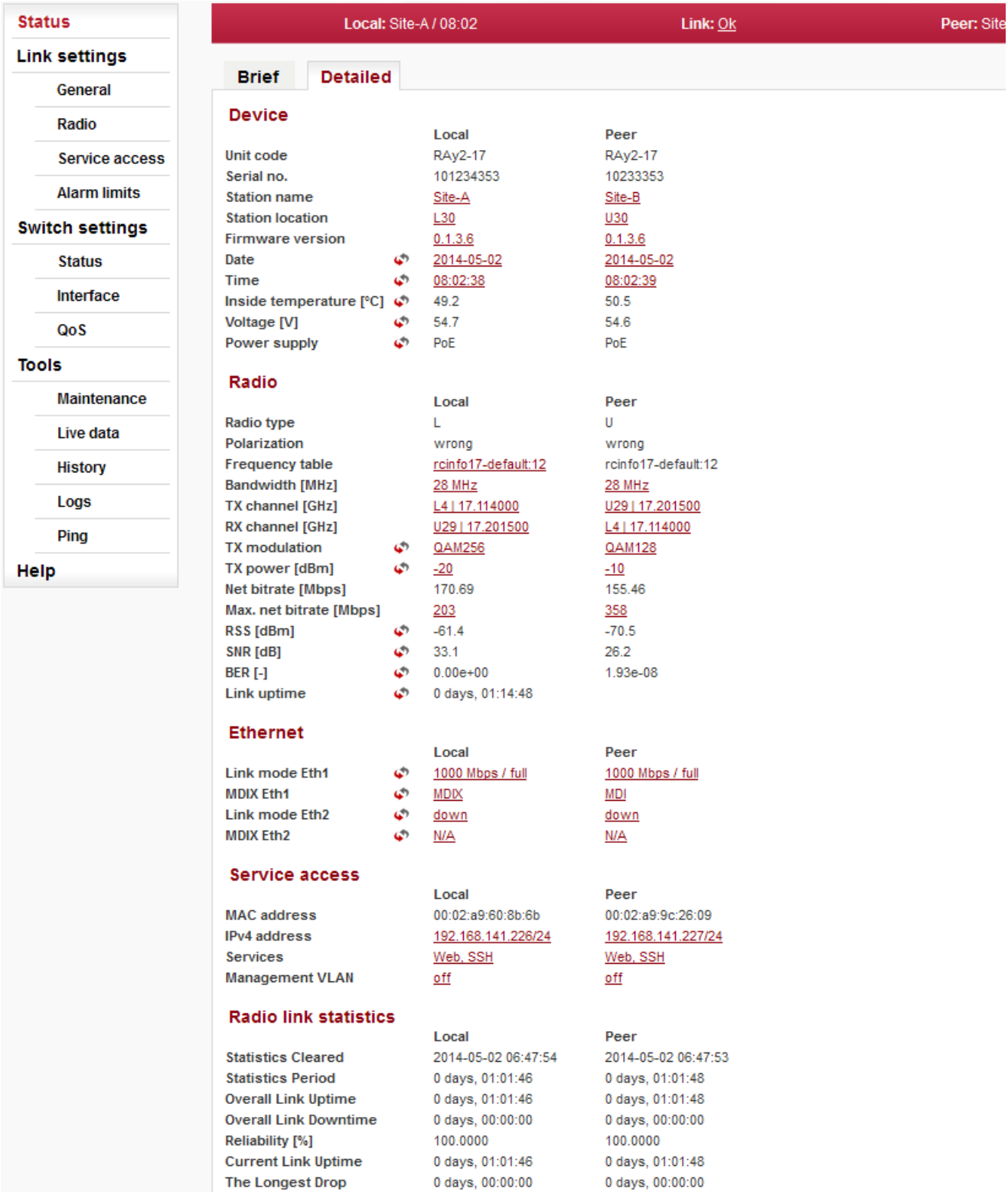


Fig. 7.6: Menu Status

The Device menu provides basic information about local and remote station. Informations are valid at the moment the page is open, or the Refresh button is pushed.

Status – Brief shows only the most important values. *Status – Detailed* provides further details. Below is a list of all values - according to the menu *Status – Detailed*.

7.3.1. Status – Device

Unit code	Station type indicator.
Serial no.	Station serial number.
Station name	Station name selected by user.
Station location	Unit location assigned by user.
Firmware version	Station'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 stations.
Inside temperature [°C]	Temperature inside the station (on the modem board).
Voltage [V]	Station's power supply voltage level.
Power supply	The power supply input, the unit is powered from. PoE - unit is powered via Ethernet cable plugged into port "E1". AUX - unit is powered via DC cable plugged into port "P".

7.3.2. Status – Radio

Radio type	Radio unit type: L (Lower) or U (Upper) part of the frequency band.
Polarization	Horizontal or vertical polarization based on the physical installation. Indicates the polarization of received signal. Local and Peer are indicated separately. The proper position of the cable is sideways down. Notice for ISM connections (RAy2-17, RAy2-24): One side of the link must be installed in vertical polarization and the other in the horizontal polarization.
Frequency table	Displays the currently selected frequency table.
Bandwidth [MHz]	One of standard channel widths can be selected. This parameter must be set identically in local and remote.
Frequency manual input	Enable manual input (if supported). TX and RX frequencies [GHz] are typed directly. It is possible to disconnect the TX-RX lock and select TX and RX channels individually. Corresponding channels at peer station are set automatically.
TX and RX channel [GHz]	Used channels. Both number of the channel and frequency in GHz are listed.
TX modulation	Modulation type currently used for transmitting. When adaptive modulation is enabled, the ACM letters are displayed as well as information about maximum permitted modulation: "current modulation ACM / maximum modulation"
TX power [dBm]	Current output power on the RF channel in dBm. If ATPC is enabled, the ATPC letters are displayed as well as information about maximum permitted power: "current power ATPC / maximum power"
Net bitrate [Mbps]	Current transfer capacity of radio channel for user data.
Max. net bitrate [Mbps]	The maximum RF channel capacity according to installed feature key.

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 / threshold RSS”
SNR [dB]	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 SNR ATPC / threshold SNR”
BER [-]	Bit Error Rate registered at the receiving end. Instantaneous value.
Link uptime	Time elapsed since the current link connection has been established.

7.3.3. Status – Ethernet

Link mode Eth1, 2	Status of ethernet interface. Current bit rate (10 = 10BASE-T, 100 = 100BASE-TX and 1000 = 1000BASE-T) and state of duplex (FD = full duplex, HD = half duplex).
MDIX Eth1, 2	Status of the internal crossover of ethernet cables. (MDIX = internally crossed pairs, MDI = direct connection, N/A means an unknown state).

7.3.4. Status – 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.
Services	Services enabled for station management and monitoring (Web, Telnet, SSH, SNMP, NTP).
Management VLAN	Service access via VLAN management only.

7.3.5. Status – Statistics

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.

7.4. Link settings

7.4.1. General

Setup of general parameters of the link.

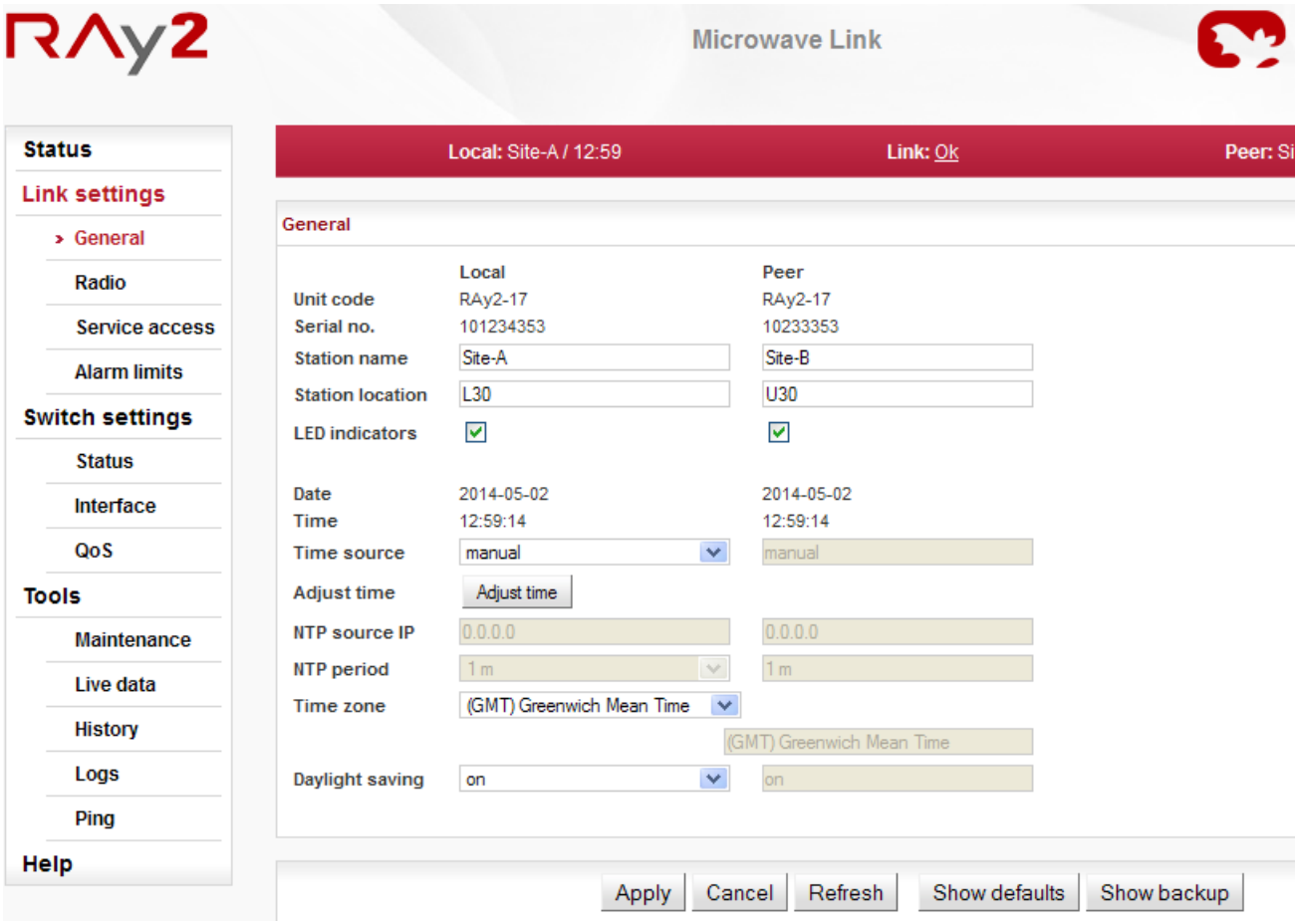
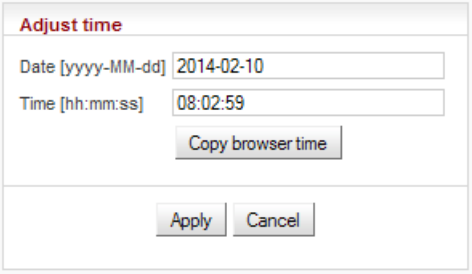


Fig. 7.7: Menu Link settings – General

Unit code	Station type indicator.
Serial no.	Station serial number.
Station name	Station name selected by user.
Station location	Unit location assigned by user.
LED indicators	Enable LED status indicators on the body of the station. You can turn off all LEDs with this option.
Date, Time	The internal real-time clock. The clock is set manually or it is synchronized with NTP server and set for both stations.
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 time from browser (local PC).



NTP source IP IP address of the time synchronization server.

NTP period Time synchronization interval.

Time zone Time zone

Daylight saving Enable daylight saving time

Note

When the time zone and/or daylight saving time is changed, the original values set in the RAy2 unit are kept. The actual change takes place after OS restart in order to prevent unexpected states related with local time change.

7.4.2. Radio

Setup of general parameters of the radio link.

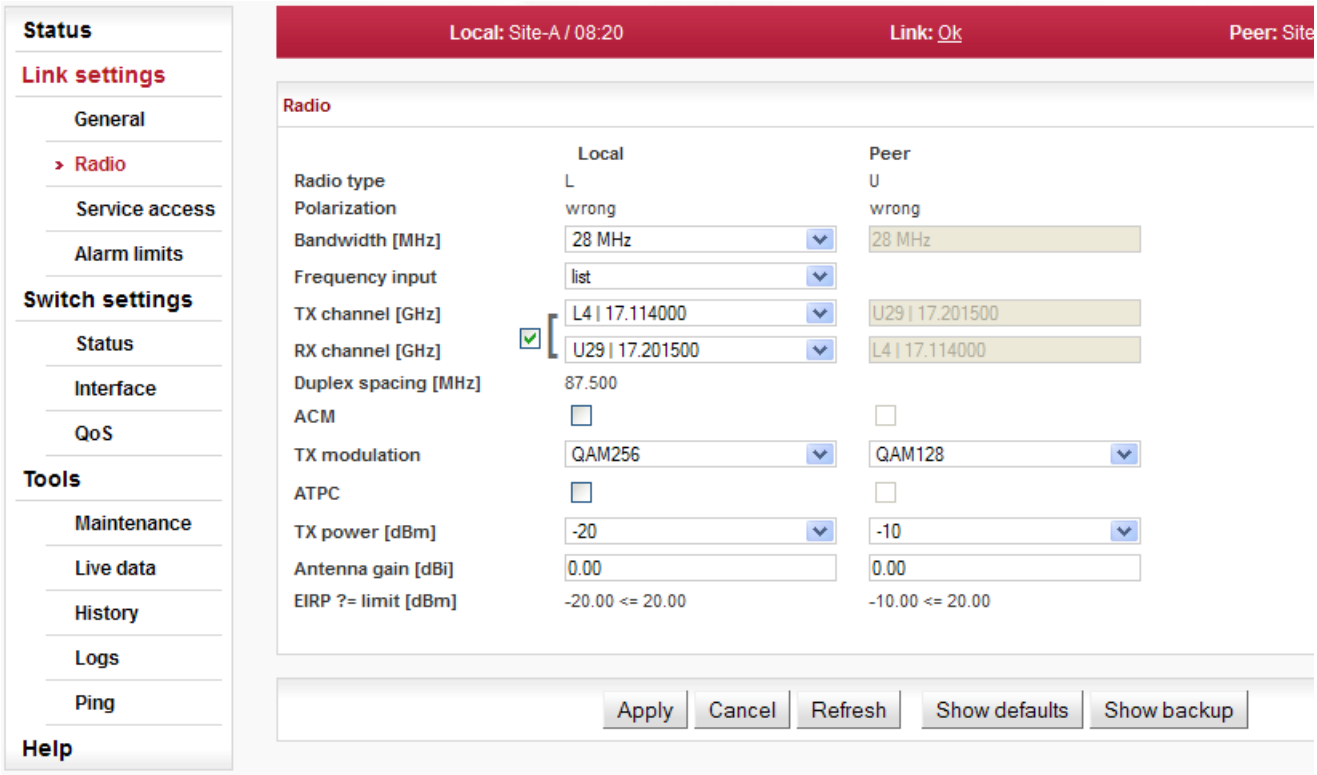


Fig. 7.8: Menu Link settings – Radio

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

Polarization	Horizontal or vertical polarization based on the physical installation. Indicates the polarization of received signal. Local and Peer are indicated separately. The proper position of the cable is sideways down. Notice for ISM connections (RAy2-17, RAy2-24): One side of the link must be installed in vertical polarization and the other in the horizontal polarization.
Bandwidth [MHz]	One of standard channel widths can be selected. This parameter must be set identically in local and remote.
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 stations operating in free bands, it is possible to disconnect the TX-RX lock and select TX and RX channels individually. Corresponding channels at peer station are set automatically. *Notice* – Non-standard duplex setting leads to non-effective use of the spectrum.
Duplex spacing [MHz]	Information about duplex spacing of TX and RX channel.
ACM	Enable automatic control of modulation.
TX modulation	Modulation level for TX channel. You can select in range from QPSK (high sensitivity for difficult conditions) to 256QAM (high speed under appropriate conditions). In case of enabled ACM it has the meaning of the maximum (highest) allowed modulation.
ATPC	Enable automatic control of RF power. Power is regulated towards lower values while maintaining maximum allowed degree of modulation. Maximum output power is limitted by **Tx power** parameter. The power control loop is primarily controlled by RSS. The SNR value is taken into account as well, because the situation of high interference value can lead to high RSS but low SNR.
TX power [dBm]	Desired output RF power. In case of enabled ATPC it has the meaning of the maximum allowed power.
Antenna gain [dBi]	Only for links operating in the ISM band (RAy2-17, RAy2-24). Gain of used antenna. It is used to calculate approximate EIRP.
EIRP ?= limit [dBm]	Only for links operating in the ISM band (RAy2-17, RAy2-24). Approximate calculation of EIRP. Number on the right shows the allowed EIRP limit. Sign between numbers gives information on compliance/non-compliance with allowed EIRP limits.

7.4.3. Service access

Services

Access routes for link configuration.

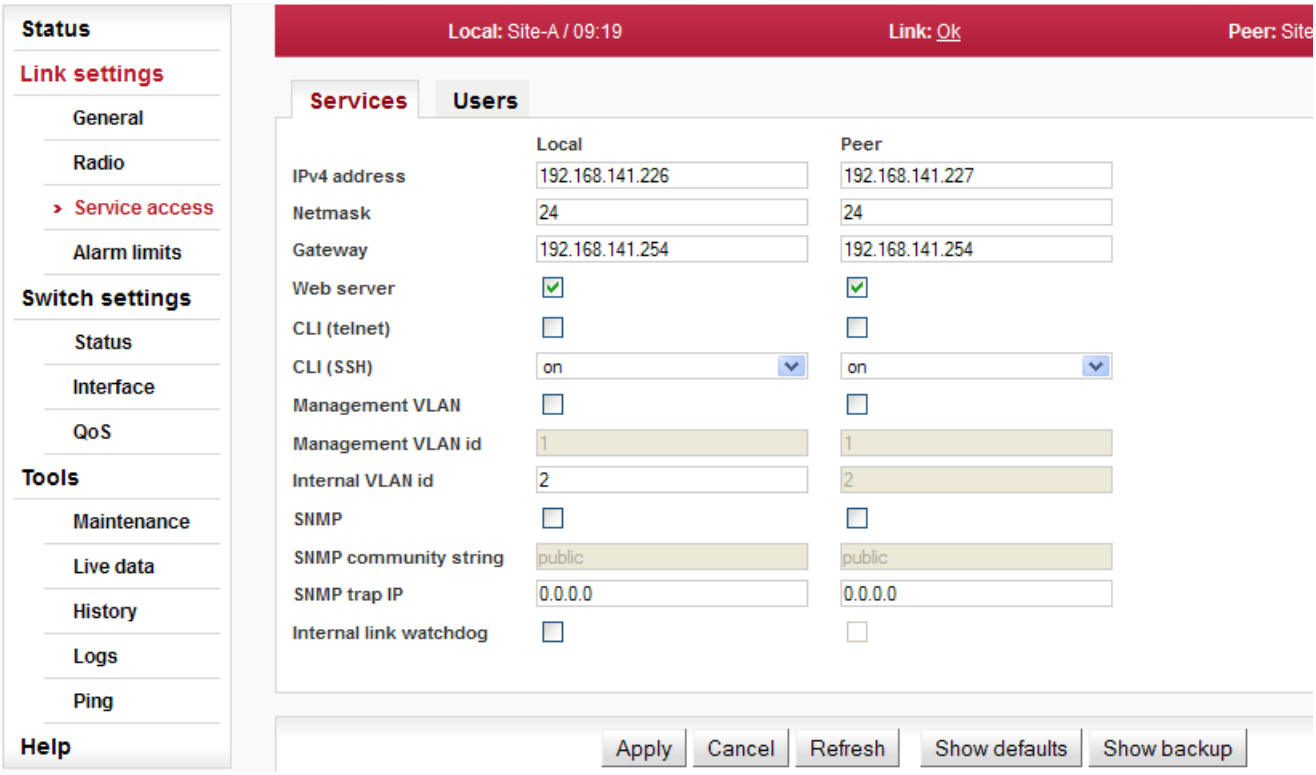


Fig. 7.9: Menu Link settings – Service access – Services

IPv4 address Service IP address, by default 192.168.169.169 for L station and 192.168.169.170 for U station. Four addresses 169.254.173.236/30 are used for internal communication. Must not be used as service IP address.

Unknown IP address For easier identification of service IP address, RAy2 is equipped with LLDP protocol. Protocol sends a broadcast every 60 seconds with the following information:

Management address	IP address
System Description	Serial number
Chassis Subtype	Type (e.g. RAY2-17-L)
IEEE 802.1 - Port and Protocol VLAN ID	
	Port and Protocol VLAN Identifier: (e.g. 300 (0x012C)) only if Management VLAN enabled

Message can be recorded and converted into a readable form using a LLDP client. A suitable tool for this purpose is Wireshark IP traffic analyzing tool, with free licenses available both for 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.

Web server	Allowing access via web server (for HTTP and HTTPS protocol). Attention - after disabling access via web server, you will not be able to access the unit using a web browser!
CLI (telnet)	Enabling access via telnet protocol. Provides access to CLI (Command Line Interface) for simple telnet clients. Disabled by default.
CLI (SSH)	Enabling access via SSH protocol. Provides secure access to CLI. If preventing unauthorized access to the station is number one priority, leave only this server on.
Management VLAN	Enabling access via VLAN management. Blocks access for https, ssh and telnet configuration via untagged packets (without VLAN) making only VLAN access possible. VLAN management is off by default. - ATTENTION- 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.
Management VLAN id	VLAN management id, by default 1. This field has to be filled out even when VLAN management is not active.
Internal VLAN id	The RAy2 uses one VLAN id for internal service communication between both units. It can be changed if there is a conflict with user data. NOTE - The Ethernet frames within this service channel are marked with IEEE 802.1p priority class "7". Default parameters for QoS and Egress queue control are pre-set to prioritize this service communication channel.
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.
Internal link watchdog	Watching over connection of both link units. In case of prolonged failure (10 min) a cold restart is done (the equivalent of turning off the power). Off by default.

Users

List and setup of users. There can be different users on either side of the link.

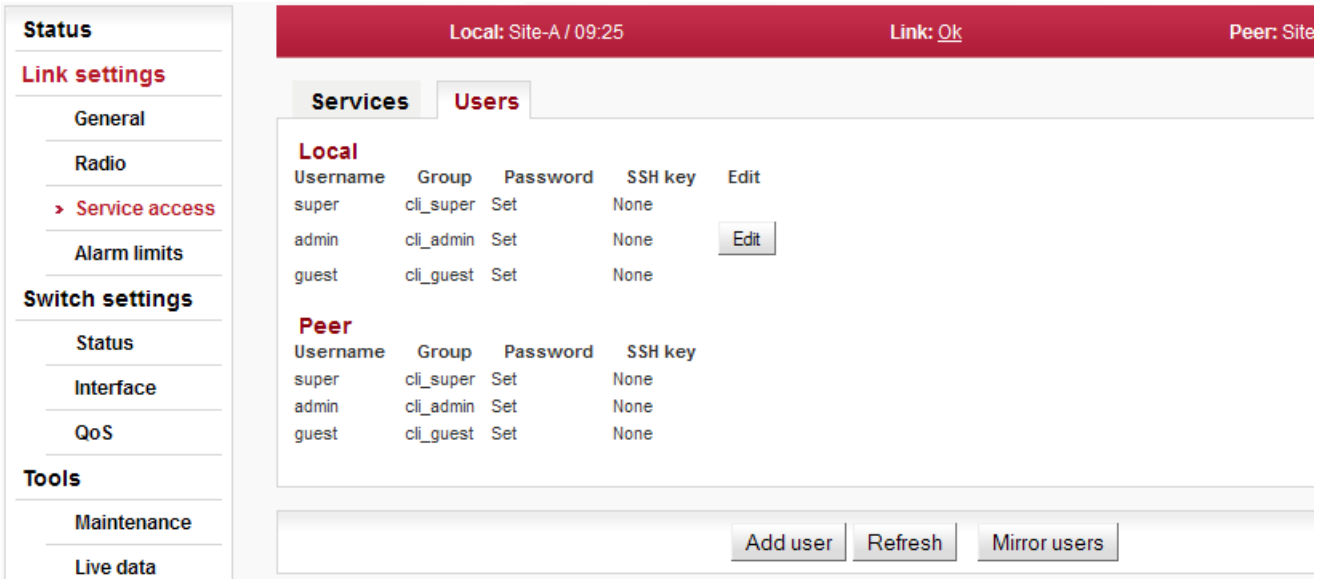


Fig. 7.10: Menu Link settings – Service access – Users

Local, Peer List of users on Local and Peer stations.

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

Group User group to which the user belongs.

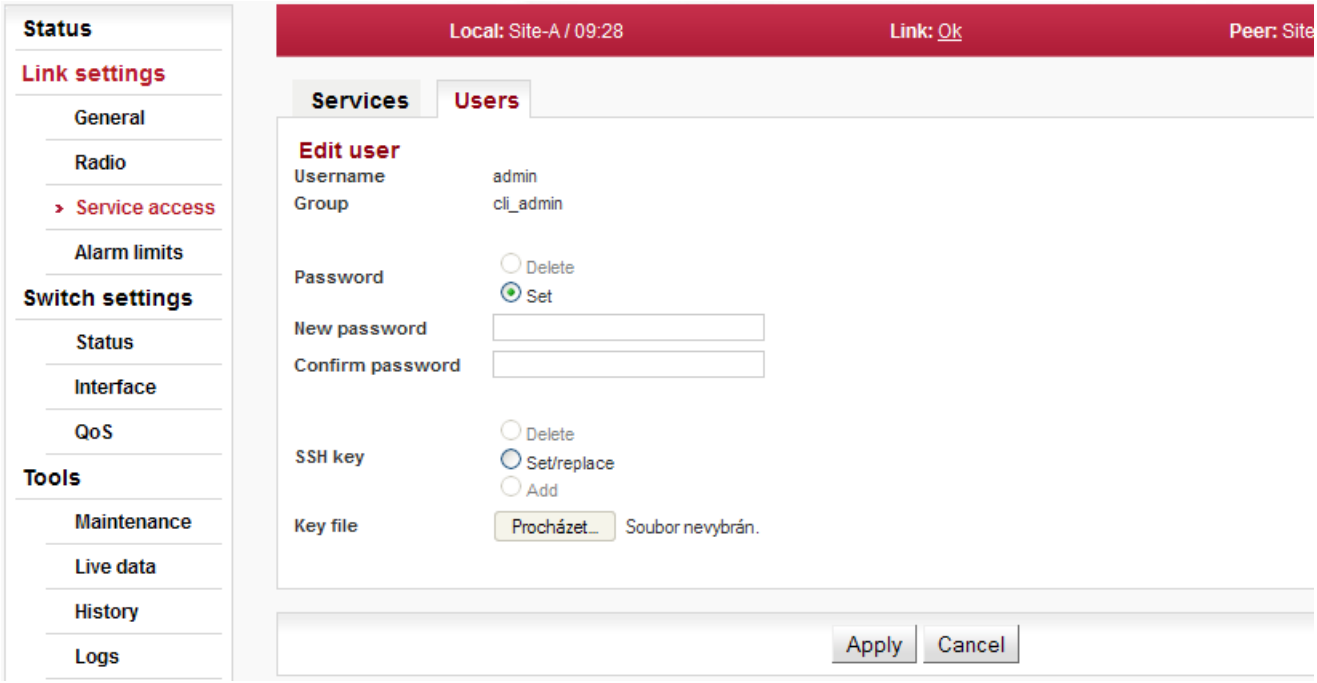
- **cli_guest** This group has the right to only view the setting of the link. Does not have rights to modify the settings. A group can contain a maximum of 10 users.
- **cli_admin** The group has all the rights of group cli_guest plus:
  Right to configure the link. Has the right to view and modify all settings. A group can contain a maximum of 10 users.
- **cli_super** Same rights as cli_admin plus:
  Right to configure user accounts including SSH keys. This group contains the user *super*.

Password Information about whether user has a password

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

Edit user

Clicking *Edit* next to a username opens a screen with configuration of the given account.



Username	User name
Group	The group to which the user belongs.
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 ssh key. **Set** – Password settings.
New password	New password.
Confirm password	Repeat password.
SSH key	Working with ssh key. **Delete** – Clear all ssh keys of the user. **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 this way.
Key file	Insert key file.

Save the menu content by clicking on the button *Apply*.

Delete user

Users from the group cli_super have a *Delete* button next to them. You can delete a user using that button. User is removed without further queries. Users from the group cli_super cannot be deleted.

Add user

The button is located on the bottom bar.

For users from the group cli_super, the *Add user* button is active. You can use it to create a new user from groups *cli_quest* or *cli_admin*.

Username	Name of new user.
Group	The group to which this user will belong.
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 by clicking on the button *Apply*.

Mirror users

The button is located on the bottom bar.

For users from the group cli_super, the *Mirror users* button is active. Selecting this function will copy all user accounts from Local station to Peer station. Existing user accounts on the Peer station are deleted.

7.4.4. Alarm limits

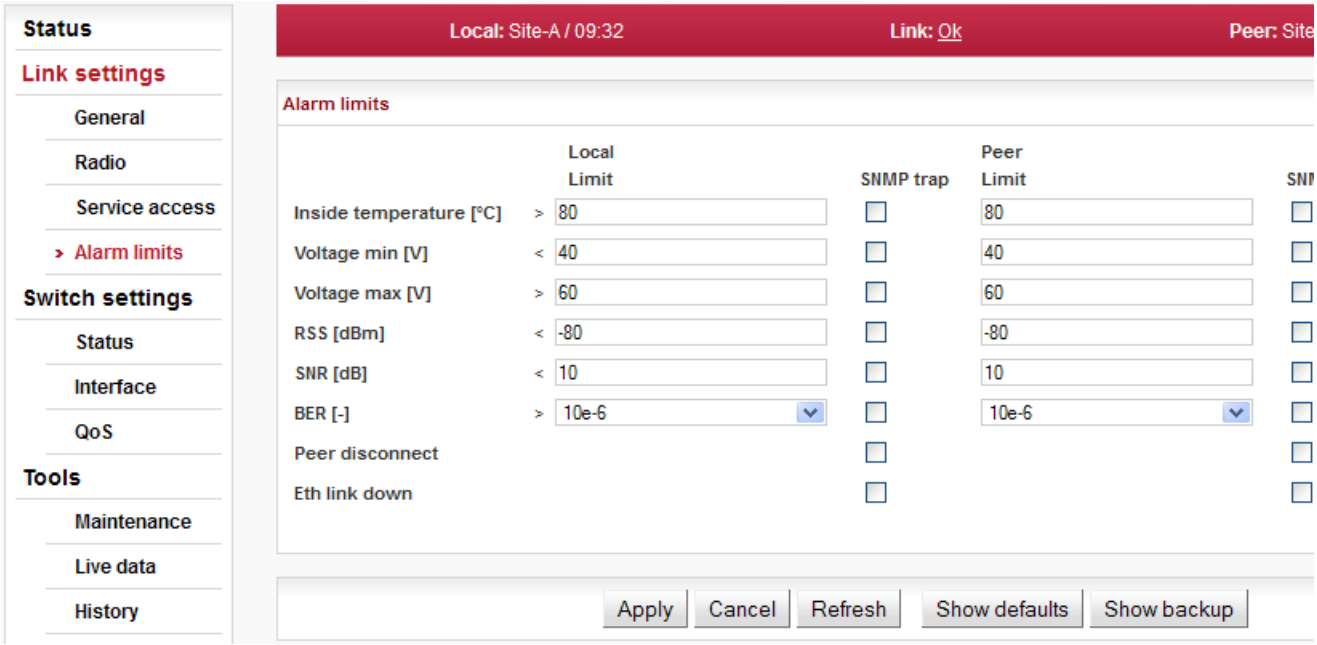


Fig. 7.11: Menu Link settings – Alarm limits

Diagnostic system of the link monitors the operation of the station. It generates various events as output. There are two kinds of events: Warnings and Alarms. The event is always written to the system log and indicated in the status bar. Some events have configurable thresholds. For each event you can choose whether a SNMP trap should be sent if the event occurs.

List of configurable events with default thresholds:

Warning

Inside temperature [°C]	**>80**	Temperature inside the station (on the modem board.)
Voltage min [V]	**<40**	Lower threshold of supply voltage.
Voltage max [V]	**>70**	Upper threshold of supply voltage, SNMP trap on/off is generated same as for Voltage min.
RSS [dBm]	**<−80**	Received Signal Strength.
SNR [dBm]	**<10**	Signal to Noise Ratio.

Alarm

BER	**>10e^{-6}**	Bit Error Rate registered at the receiving end. Instantaneous value.
Peer disconnect		Interruption of radio link.
Eth link down		Both (E1 and E2) user eth link on station interrupted.
RF power fail		Loss of transmit power (not for RAy2-17 neither RAy2-24).

7.5. Switch settings

7.5.1. Status

Port status

The station internal Ethernet switch port status

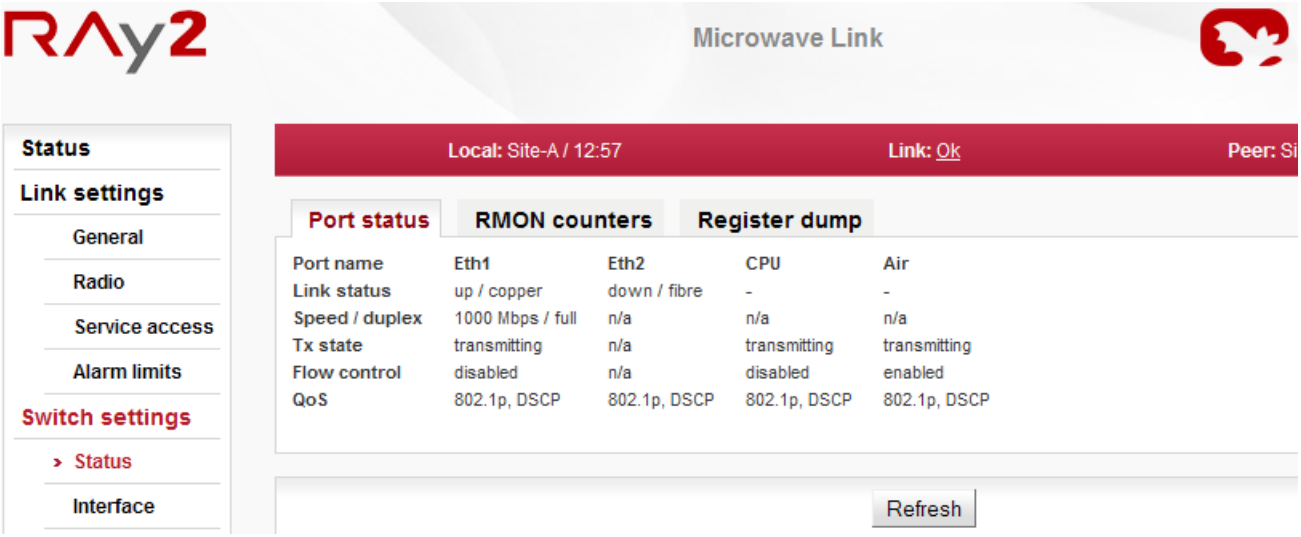


Fig. 7.12: Menu Switch settings - Port status

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	The external port (with RJ45 interface) labeled "E1".
Eth2	The external port (with SFP interface) labeled "E2".
Air	The internal port to radio modem, i.e. link to the peer unit.
CPU	The internal port to management CPU.

Link status Ethernet link status can be

down / type	no link signal detected
up / type	link signal is detected

The type of the physical layer is indicated after the slash

copper	metallic Ethernet interface
fibre	fibre Ethernet interface

Speed / duplex Ethernet link Speed and duplex.

Speed:	10/100/1000 Mbps.
Duplex:	full/half

Tx state Port transmitting status can be

transmitting	Normal port operation
paused	Port transmitter is paused due to Pause frames reception

Flow control Mechanism for temporarily stopping the transmission of data on an Ethernet network. 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. See *Flow control* and *Pause limit* parameters.
Flow control can be one of the following values:

disabled	Flow control is disabled.
enabled	Flow control is enabled.
active	Flow control is enabled and activated. The port has requested the link partner not to send any more data (by sending Pause frames).

QoS

Quality of Service status can be 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.

RMON counters

The station internal Ethernet switch RMON counters

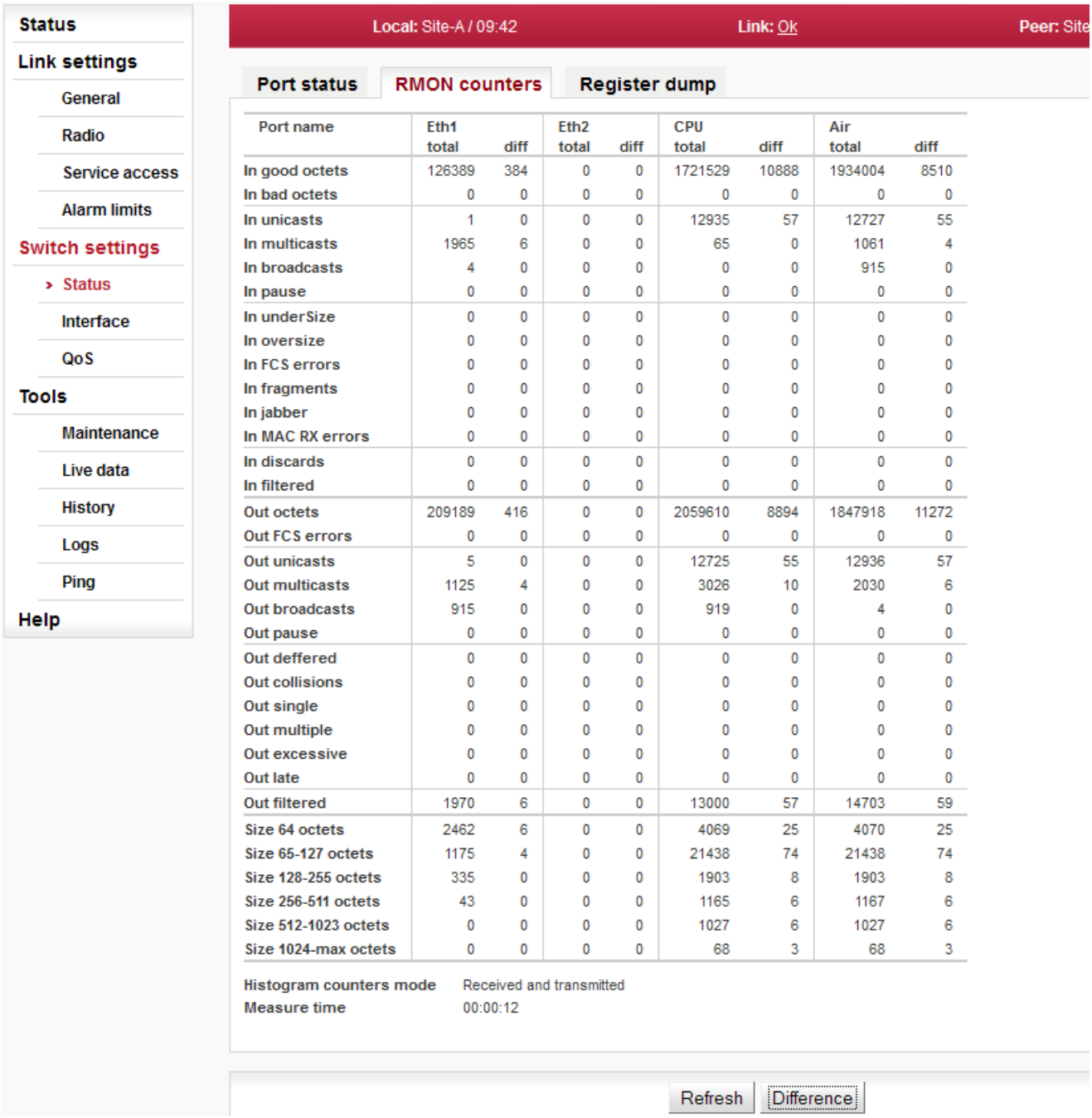


Fig. 7.13: Menu Switch settings - RMON counters

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	The external port (with RJ45 interface) labeled "E1".
Eth2	The external port (with SFP interface) labeled "E2".
CPU	Description.
Air	The internal radio modem - 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.
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. 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.
In undersize	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 MAC 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 MAC RX errors	Total frames received with an RxErr signal from the PHY.
In discards	Total number of frames that normally would have been forwarded, but could not be due to a lack of buffer space.
In filtered	Total number of good frames that were filtered due to ingress switch policy rules.

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 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.
Out deffered	The total number of successfully transmitted frames that experienced no collisions but are delayed because the medium was busy during the first attempt. This counter is applicable in half-duplex only.
Out collisions	The number of collision events seen by the MAC not including those counted in Single, Multiple, Excessive, or Late. This counter is applicable in half-duplex only.
Out single	The total number of successfully transmitted frames that experienced exactly one collision. This counter is applicable in half-duplex only.
Out multiple	The total number of successfully transmitted frames that experienced more than one collision. 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 late	The number of times a collision is detected later than 512 bits-times into the transmission of a frame. This counter is applicable in half-duplex only.
Out filtered	Total number of good frames that were filtered due to egress switch policy rules.

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	It other words: The Difference counter reference value can be reset by pressing the Refresh button. The time point, 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.

Register dump

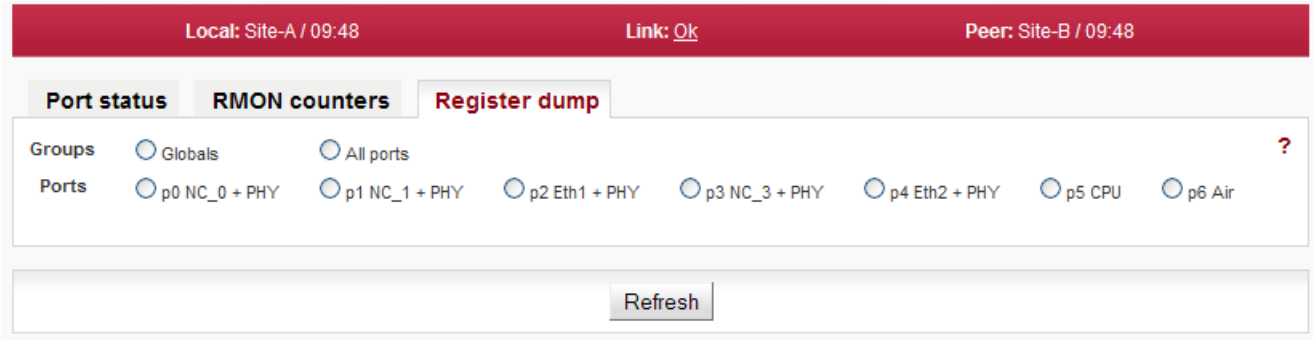


Fig. 7.14: Menu Switch settings - Register dump

The exact contents of the internal switch configuration and diagnostic registers can be listed for diagnostic purposes. All registers are separated into several groups.

Groups	Globals	Global switch parameters.
	All ports	Global port related parameters.
Ports	Port specific parameters.	
Registers	Registers contents is listed in hexadecimal notation.	

7.5.2. Interface

Port

Port settings

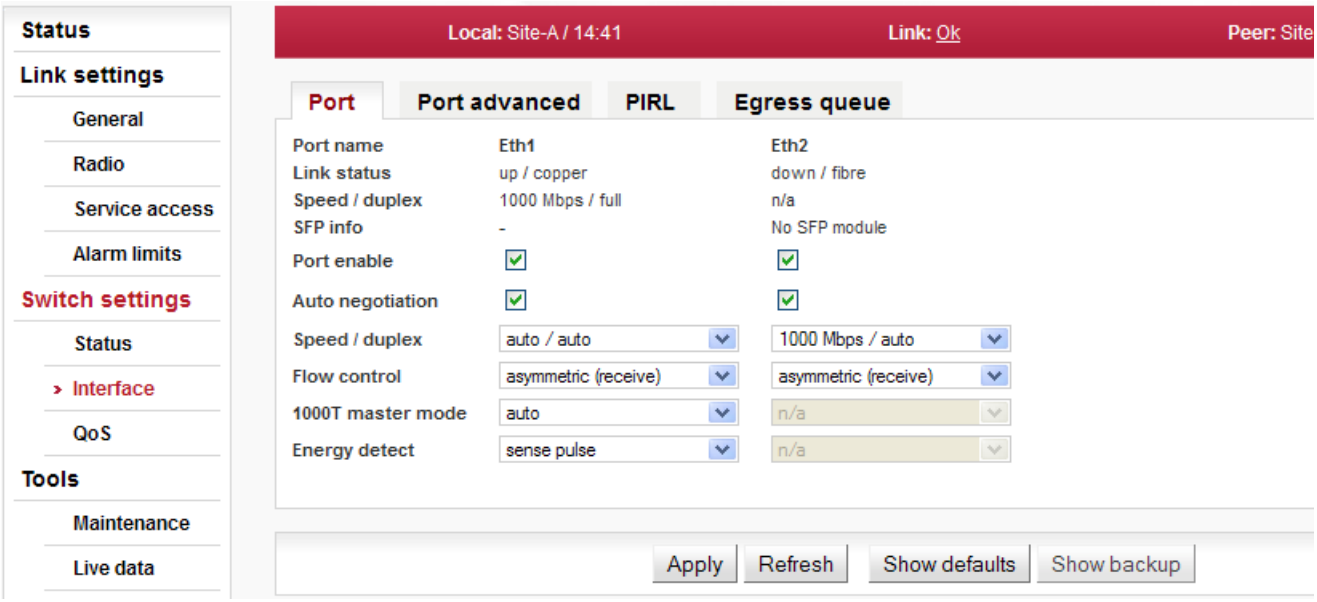


Fig. 7.15: Menu Switch settings - Port

Phyter is responsible for Ethernet signal conversion between wire (e.g. Cat7 cable) and internal switch bus.

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 The external port (with RJ45 interface) labeled "E1".
- Eth2 The external port (with SFP interface) labeled "E2".

Link status Ethernet link status can be

- down / type no link signal detected
- up / type link signal is detected

The type of the physical layer is indicated after the slash

- copper metallic Ethernet interface
- fibre fibre Ethernet interface

Speed / duplex Ethernet link Speed and duplex.

- Speed 10/100/1000 Mbps
- Duplex full/half

SPF info Information about the (optionally) inserted SFP module. The three different types of SFP modules can be used:

- Fibre dual mode with LC connector
- Fibre single mode with LC connector
- Copper with RJ45 connector

There can be one of the following scenarios:

scenario	message
SPF OK	The SFP vendor string read out of SFP module. The vendor, model, connector (RJ45/LC) and wavelength values are shown.
No SPF	No SFP module
read error	n/a
no SPF option	–

Port enable

The port can be enabled or disabled.

WARNING: When the port is disabled, no communication is possible through this port.

Auto negotiation

Auto-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 Fiber Auto-Negotiation (IEEE 802.3 Clause 37)

SGMII Auto-Negotiation (Cisco specification)

Auto-Negotiation provides a mechanism for transferring information from the local station 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 the parallel detect function to determine the speed of the remote device for 100BASE-TX and 10BASE-T modes. If link is established based on the parallel detect function, then it is required to establish 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 fiber cable.

If the PHY 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 between the PHY and the MAC. However, the contents of the SGMII Auto-Negotiation are different than the 1000BASE-X Auto-Negotiation.

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 how to force link to operate in specific speed and duplex:

Auto negotiation enabled. Select the desired Speed / duplex. The auto negotiation process advertise 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.

Flow control

Flow control mechanism is handled by sending Pause frames to the connected device. There are several modes of Pause frames generation:

no pause	Pause frames disabled.
symmetric	Pause frames transmission and reception enabled.
asymmetric (send)	Pause frames transmission enabled, reception disabled.
asymmetric (receive)	Pause frames reception enabled, transmission disabled.

Auto-Negotiation has to be enabled to enable Pause frames sending and receiving.

1000T master mode

The 1000BASE-T master/slave mode can be manually configured.

auto	Automatic MASTER/SLAVE configuration.
master	Manual configure as MASTER.
slave	Manual configure as SLAVE.

Energy detect

The device can be placed in energy detect power down modes by selecting either of the two energy detect modes. Both modes enable the PHY to wake up on its own by detecting activity on the Ethernet cable. The energy detect modes only apply to the copper media.

In first “sense” mode, if the PHY detects energy on the line, it starts to Auto-Negotiate sending FLPs (Fast Link Pulse) for 5 seconds. If at the end of 5 seconds the Auto-Negotiation is not completed, then the PHY stops sending FLPs and goes back to monitoring receive energy. If Auto-Negotiation is completed, then the PHY goes into normal 10/100/1000 Mbps operation. If during normal operation the link is lost, the PHY will re-start Auto-Negotiation. If no energy is detected after 5 seconds, the PHY goes back to monitoring receive energy.

In “sense pulse” mode, the PHY sends out a single 10 Mbps NLP (Normal Link Pulse) every one second. Except for this difference, this is identical to previous mode (“sense”) operation. If the device is in “sense” mode, it cannot wake up a

connected device; therefore, the connected device must be transmitting NLPs. If the device is in “sense pulse” mode, then it can wake a connected device.

off	Off
sense pulse	Sense and periodically transmit NLP (Energy Detect+TM).
sense	Sense only on Receive (Energy Detect).

Port advanced

The station internal Ethernet switch Port settings

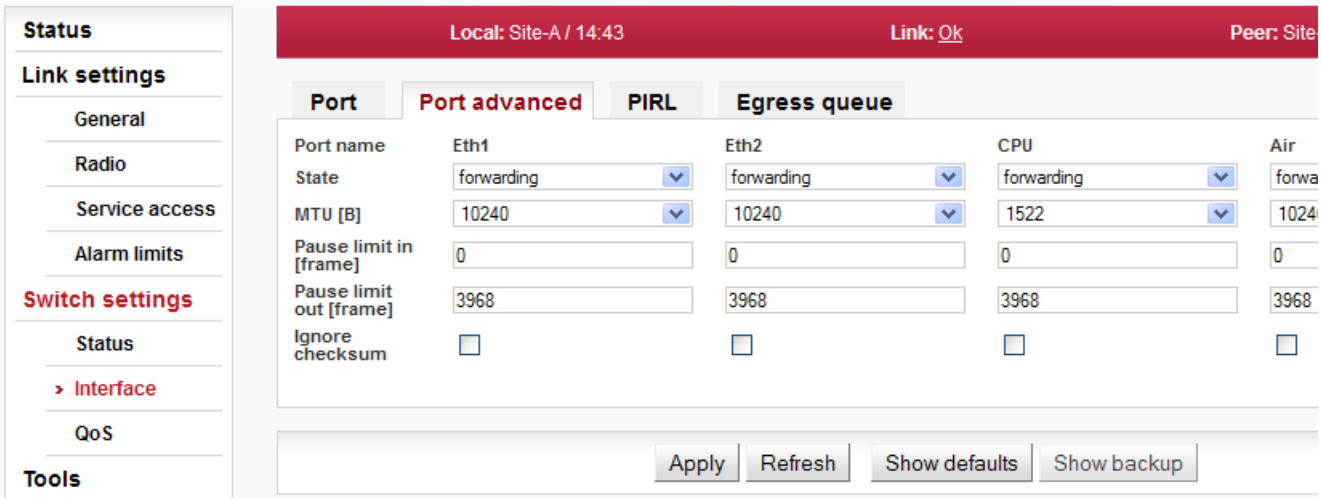


Fig. 7.16: Menu Switch settings - Port advanced

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	The external port (with RJ45 interface) labeled "E1".
Eth2	The external port (with SFP interface) labeled "E2".
Air	The internal radio modem - link to the peer unit.

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.

MTU [B] MTU determine the maximum 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.

NOTE: The definition of frame size is counting the frame bytes from MAC_DA through Layer2 CRC of the frame.

Pause limit in [frame]

Limit 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). 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 Pause refresh frames count exceeds value of this parameter.

Setting this parameter to 0 will allow continuous jamming to be received on this port.

Pause limit out [frame]

Limit 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 Frame checksum

Ignore Frame checksum (FCS) - or in other words - Force good FCS in the frame. When this parameter is not set (default behaviour), 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).

PIRL

Port based ingress rate limiting, see also the Functional diagram

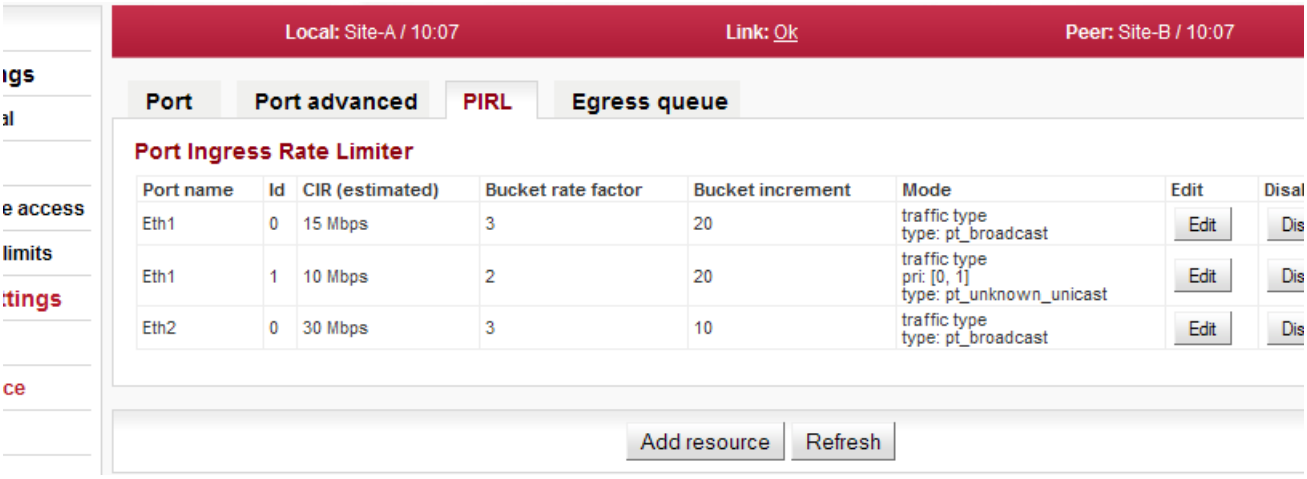


Fig. 7.17: Menu Switch settings - PIRL

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 Kbps to 1 Mbps in increments of 64 Kbps, from 1 Mbps to 100 Mbps in increments of 1 Mbps and from 100 Mbps to 1000 Mbps in increments of 10 Mbps.

In addition to this, the device supports Priority based ingress rate limiting. A given ingress rate resource can be configured to track any of the four priority traffic types. One of the popular schemes for implementing rate limiting is a leaky bucket. 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).

These device supports a color blind leaky bucket scheme.

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.

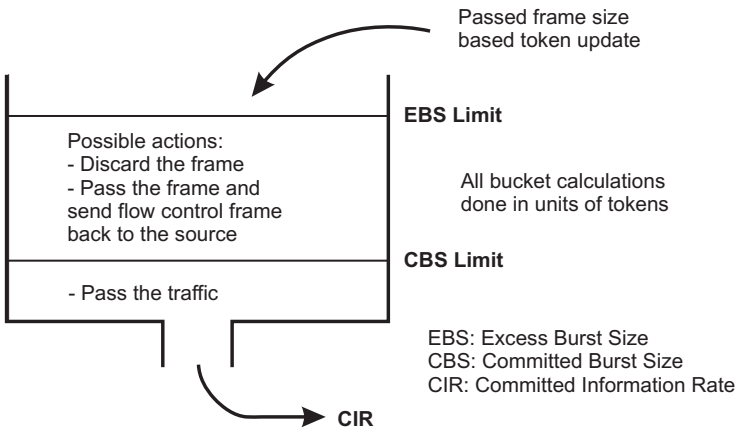


Fig. 7.18: Leaky bucket

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	The external port (with RJ45 interface) labeled "E1".
Eth2	The external port (with SFP interface) labeled "E2".
Air	The internal radio modem - link to the peer unit.

Id 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.

CIR (estimated) The Committed Information Rate (CIR) is dependent on the Bucket Rate factor and the Bucket increment.

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

The formula for the CIR (in bits per second) is as follows: CIR = a * BRF / BI.

Where "a" is constant, which is 12 500 000 for Accounted bytes="frame", and is 100 000 000 for Accounted bytes="layer1". BRF is Bucket Rate factor and BI is Bucket increment.

Bucket rate factor This is a factor 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).

Bucket increment Bucket increment (BI) indicates the amount of tokens that need to be added for each byte of incomming frame.

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

Edit Press Edit to edit selected or add another PIRL resource.

Disable Press Disable to delete selected PIRL resource.

Add resource Press Add resource button to add another PIRL resource.

PIRL - resource configuration

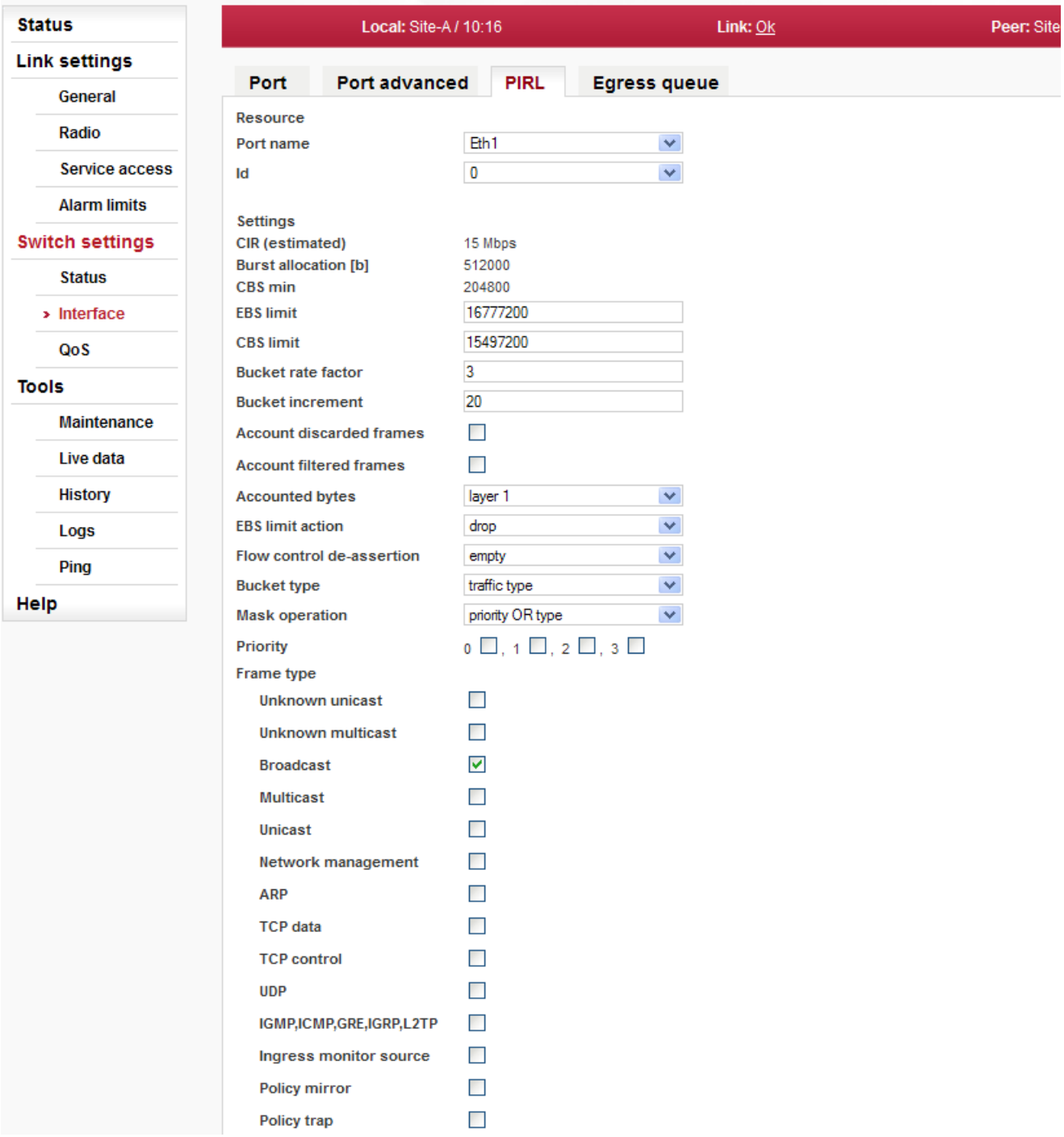


Fig. 7.19: Menu Switch settings - PIRL Resource

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.

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	The external port (with RJ45 interface) labeled "E1".
Eth2	The external port (with SFP interface) labeled "E2".
Air	The internal radio modem - link to the peer unit.

Id 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.

CIR (estimated) The Committed Information Rate (CIR) is dependent on the Bucket Rate factor and the Bucket increment.

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

The formula for the CIR (in bits per second) is as follows: CIR = a * BRF / BI.

Where "a" is constant, which is 12 500 000 for Accounted bytes="frame", and is 100 000 000 for Accounted bytes="layer1". BRF is Bucket Rate factor and BI is Bucket increment.

Burst allocation [b] The Burst allocation (BA) is dependent of the Bucket increment, the Committed Burst Size limit and the Excess Burst Size limit.

The formula for the BA is as follows: BA = 8 * (EBS-CBS) / BI.

Where EBS is the Excess Burst Size limit, CBS is the Committed Burst Size limit and BI is the Bucket increment.

CBS min The minimum value for CBS limit is related to the maximum frame size and Bucket increment.

The CBS limit should always be bigger than CBS min.

The calculation for CBS min is as follows:

CBS min = BI * MaxFrameSize [bytes].

Where BI is the Bucket increment.

If the CBS limit is lower than this value (i.e. to allow a large burst), then an ingress stream composed of maximum sized frames may exceed the Committed Information Rate. It is for this reason that we recommend the CBS limit value always stays above the CBS min value. Also, the CBS limit should never exceed the EBS limit.

EBS limit Excess Burst Size limit.

The EBS limit should always be bigger than CBS limit. It is recommended that the EBS limit be set to 16777200.

CBS limit Committed Burst Size limit. This indicates the committed information burst amount.

Rate factor Bucket Rate factor

This is a factor 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).

Bucket increment Bucket increment (BI) indicates the amount of tokens that need to be added for each byte of incomming frame.

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.

Accounted bytes

This parameter determines which frame bytes to be accounted for in the rate resource's rate limiting calculations.

There are for different supported configurations:

frame	The egress rate limiting is done based on frame count [fps] as opposed to the byte count [kbps] 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)

A frame is considered tagged if it is either Customer of Provider tagged during ingress.

EBS limit action

This parameter controls what kind of action is performed when the EBS limit has been exceeded. Three types of action can be selected:

drop	The frame that was received on the port will get discarded.
flow control	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.
accept	The frame that was received on the port is accepted even though there is not enough tokens to accept the entire incoming frame. This mode is expected to be selected for TCP based applications. It is not recommended for media streaming applications where data timing is critical.

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 those 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.

Bucket type Any given bucket can be programmed to be aggregate rate based or traffic type based.

Rate based ingress rate limit: Limits all types of traffic on the ingress port.

Traffic type based ingress rate limit: Limits a specific type of traffic on the ingress port.

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 Any combinations of the four 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 doesn't 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:

Management (MGMT), Multicasts, Broadcasts, Unicasts, Address Resolution Protocol (ARP), TCP Data, TCP Ctrl, UDP, Non-TCPUDP (covers IGMP, ICMP, GRE, IGRP and L2TP), IMS, PolicyMirror, PolicyTrap, Unknown Unicasts or Unknown Multicasts.

More than one frame type can be selected for a given rate resource.

Egress queue control

See also Output queue diagram.

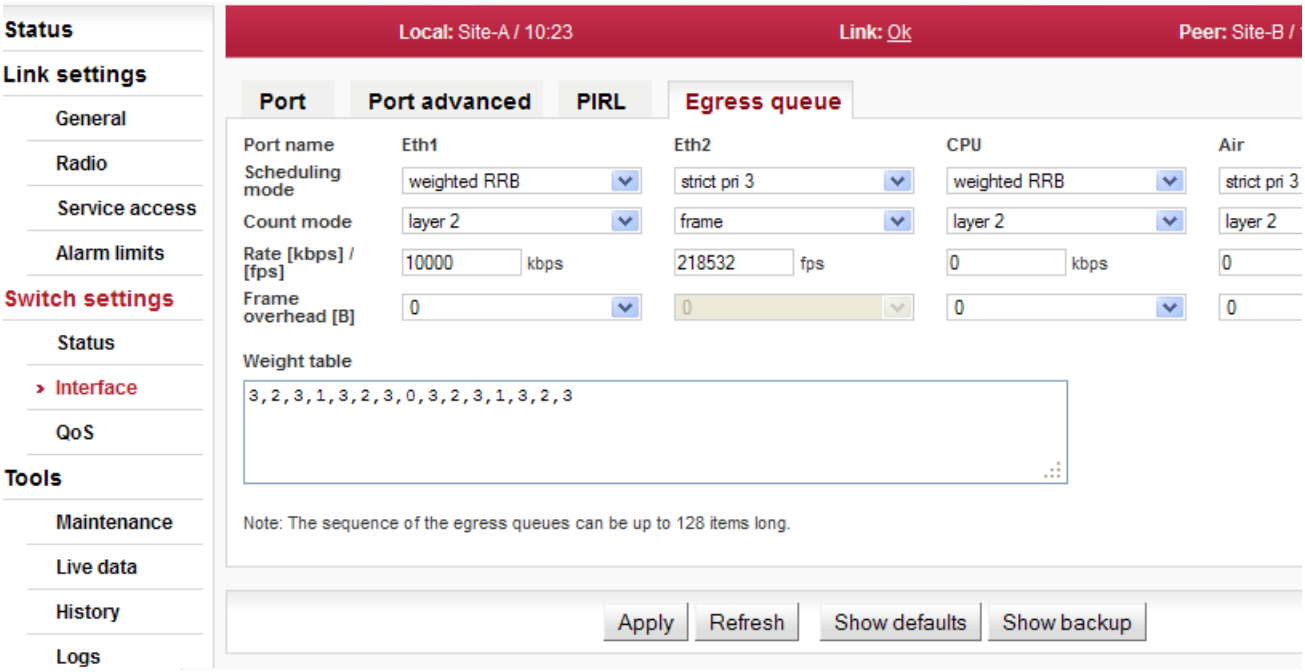


Fig. 7.20: Menu Switch settings - Egress queue

Scheduling mode

Port's 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 8, 4, 2, 1 weighting is applied to the four 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 two 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 RRB	Use an weighted round robin queuing scheme.
strict pri 3	Use Strict for priority 3 and use weighted round robin for priorities 2,1 and 0
strict pri 3, 2	Use Strict for priorities 3 and 2 and use weighted round robin for priorities 1 and 0
strict	Use a Strict priority scheme for all priorities

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 [kbps] 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 [kbps] / [fps]

Egress data rate shaping. When Rate = 0 egress rate limiting is disabled.

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 7600 and 1488000.

If the egress shaping is controlled by bit rate, the desired rate can vary from 64 kbps to 1 Gbps in the following increments:

Desired rate between 64 kbps and 1 Mbps in increments of 64 kbps

Desired rate between 1 Mbps to 100 Mbps in increments of 1 Mbps

Desired rate between 100 Mbps to 1 Gbps in increments of 10 Mbps

Therefore, the valid values are:

64, 128, 192, 256, 320, 384,..., 960,

1000, 2000, 3000, 4000, ..., 100000,

110000, 120000, 130000, ..., 1000000

Frame overhead [B]

Egress Rate Frame Overhead adjustment.

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 down stream, 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 or 3) defines the sequence of the output queue frame egressing. This sequence can be up to 128 items long.

7.5.3. QoS

The QoS classification is handled in the switch Ingress block. The Ingress block does not perform the QoS switching policy, which is the task of the Queue Controller.

See the Functional diagram.

802.1p

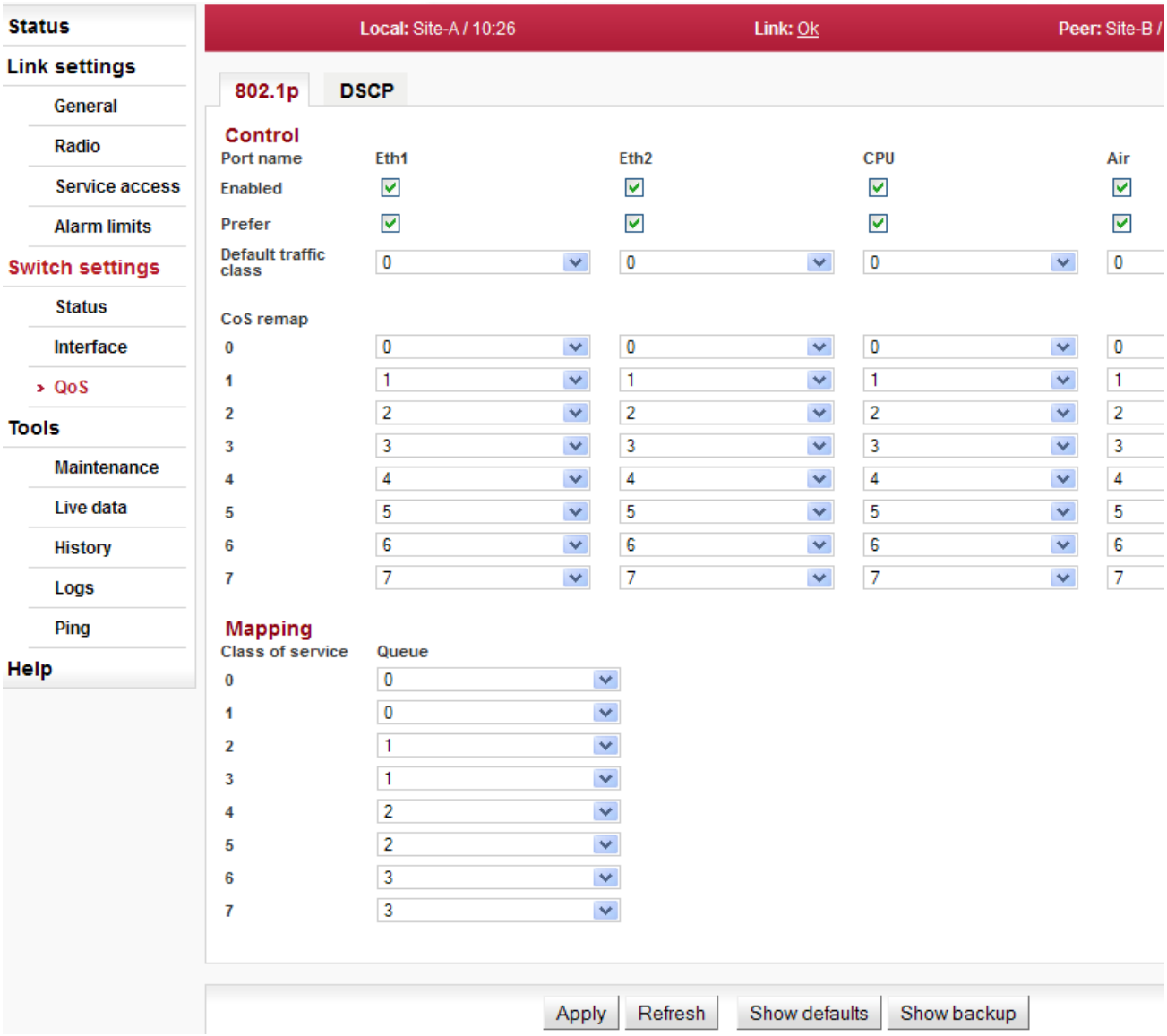


Fig. 7.21: Menu Switch settings - 802.1p

This QoS technique also known as class of service (CoS), is 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.

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	The external port (with RJ45 interface) labeled "E1".
Eth2	The external port (with SFP interface) labeled "E2".
CPU	The internal port to management CPU.
Air	The internal port to radio modem, i.e. link to the peer unit.

Enabled The QoS classification according to IEEE 802.1p priority bits is enabled/disabled.

Prefer Enable this parameter to force 802.p priority over DSCP.

When enabled, the DSCP Prefer parameter is automatically disabled.

Default traffic class The IEEE 802.1q untagged frames (thus having no IEEE 802.1p priority) are treated with this priority.

CoS remap The frame's IEEE 802.1p priority can be changed to other value.

Class of service Arranging individual priorities (coded in priority bits according to IEEE 802.1p) into selected output queue (0..3).

DSCP

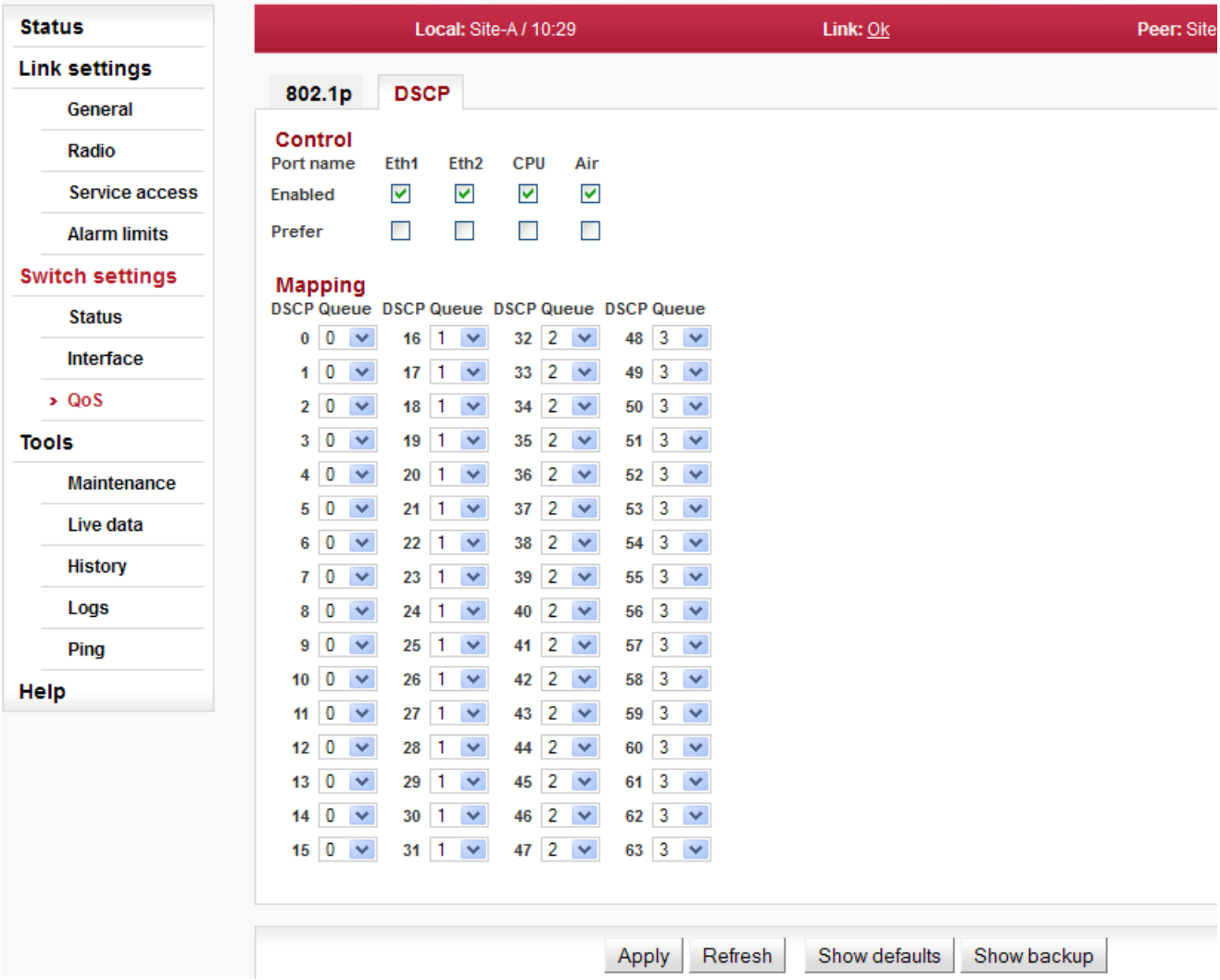


Fig. 7.22: Menu Switch settings - DSCP

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.

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	The external port (with RJ45 interface) labeled "E1".
Eth2	The external port (with SFP interface) labeled "E2".
CPU	The internal port to management CPU.
Air	The internal port to radio modem, i.e. link to the peer unit.

Enabled The QoS classification according to DSCP priority bits is enabled/disabled.

Prefer Enable this parameter to force DSCP priority over 802.p.

When enabled, the IEEE 802.1p Prefer parameter is automatically disabled.

DSCP 0..63 Arranging individual priorities (coded in DS field of IP header) into selected output queue (0..3).

7.6. Tools

7.6.1. Maintenance

Restart

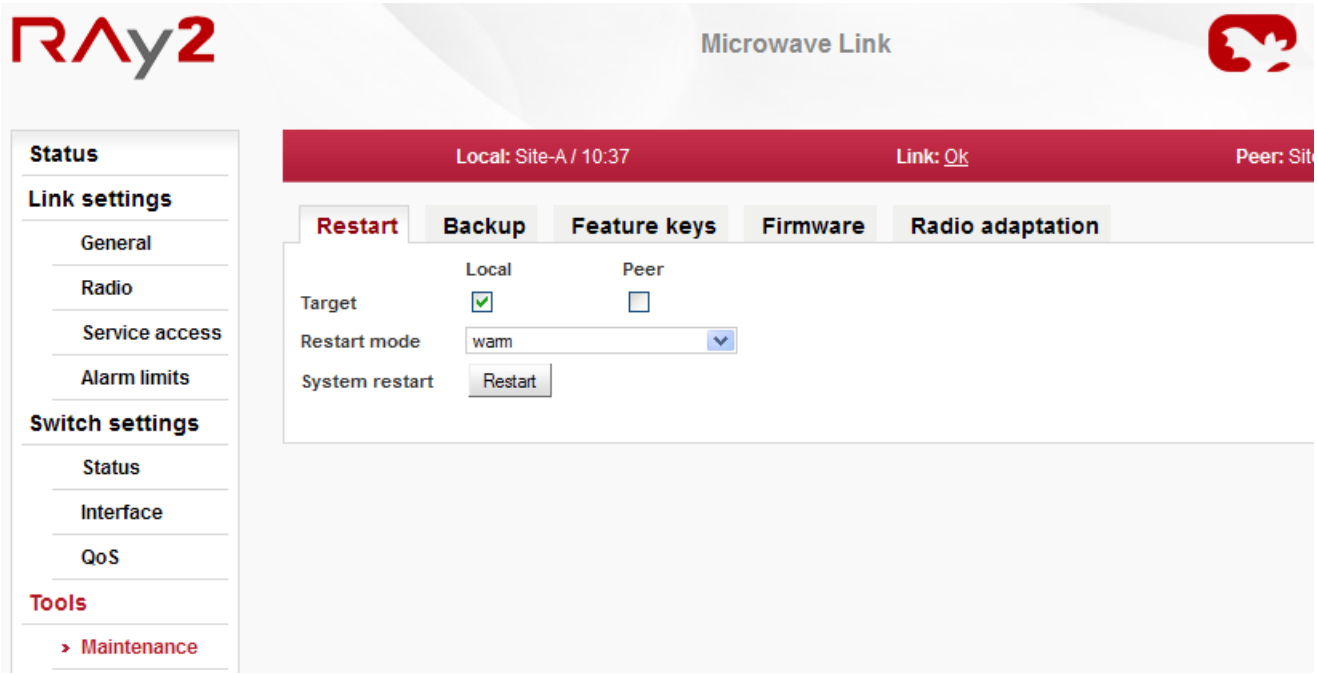


Fig. 7.23: Menu Tools - Restart

Target Restart of selected unit, Local or Peer.

Restart mode
- Warm — Reboot management system.
- Cold — Restart the whole station as if power was removed.

System restart Performs the selected restart.

Backup

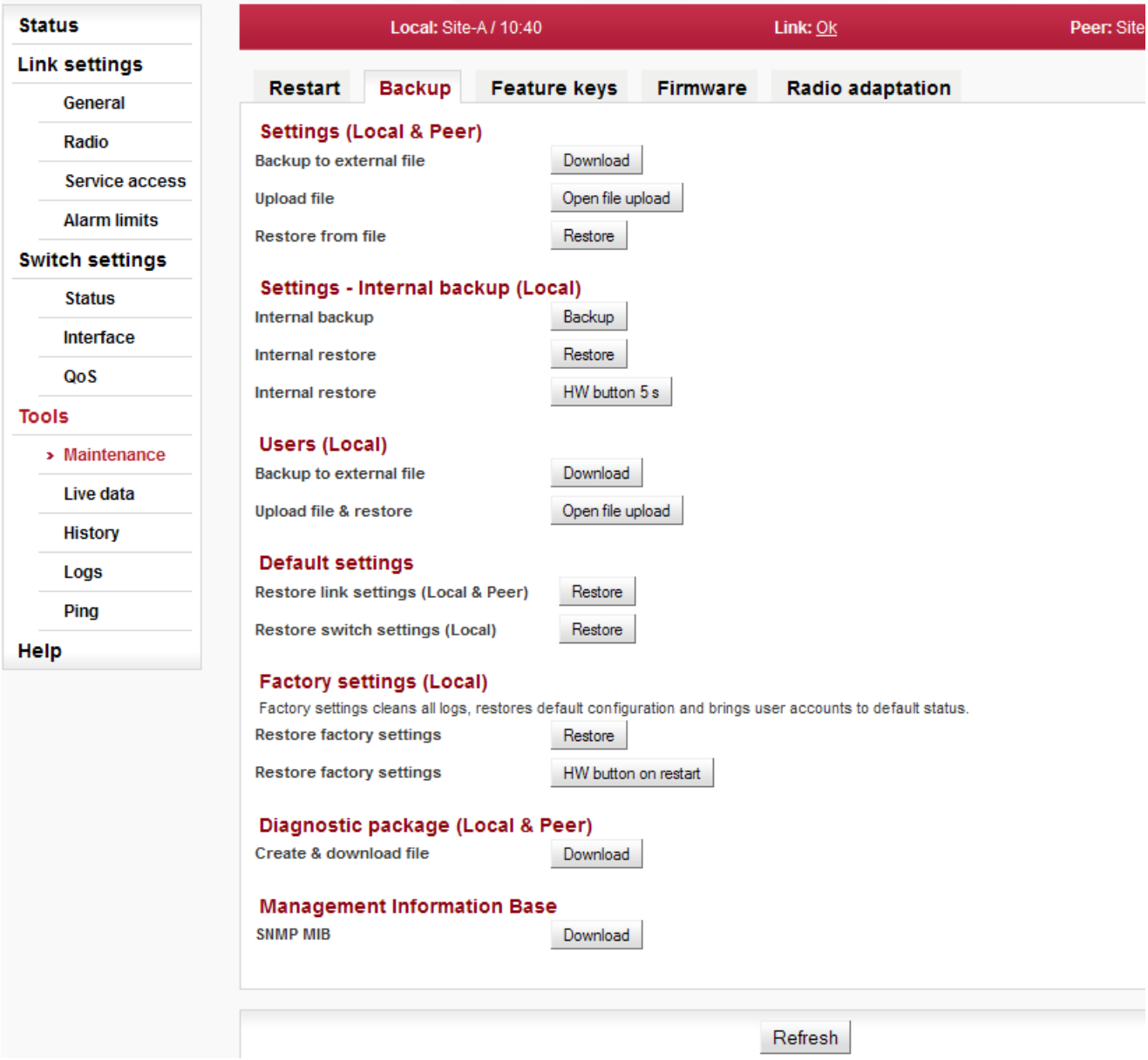


Fig. 7.24: Menu Tools - Backup

Settings (Local & Peer)

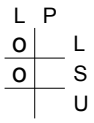
Saving and restoring unit configuration. User accounts are not affected by those functions.

Local	Peer	
o	o	Link
o	o	Switch
		Users

Backup to external file	Configuration is saved to backup file which is downloaded to management PC.
Upload file	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 from file	After the configuration backup file has been loaded into the unit buffer (using Download button above), the whole unit configuration can be restored using "Restore" button.

Settings - Internal backup (Local)

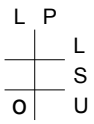


It is possible to make a temporary backup of the unit configuration. The backup is stored directly in the unit FLASH memory.

NOTE: The internal backup is deleted if factory settings or firmware upgrade are performed.

Internal backup	Make a temporary backup of the unit configuration locally in the unit FLASH memory.
Internal 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 restored using the hardware button. The HW button is located next to the DC connector within the port marked "P". The rollback and reboot functions are suppressed while restoring from internal backup. All changes are applied immediately. Should the time zone be changed, the station has to be restarted for changes to take effect. Press the HW button for the required time interval 5 seconds. The button being pressed is confirmed by the Status LED flashing green. After the 5 seconds guard time, the station restores to customer settings.

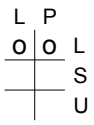
Users (Local)



Saving and restoring user accounts.

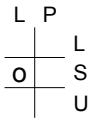
Backup to external file	Backup local unit user accounts to an external file. The file is downloaded to management PC. **NOTE:** The "super" user privileges are necessary to be able to perform this action.
Upload file & restore	Restoring user accounts from an external backup file.

Default settings



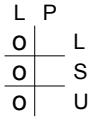
Applying default values to configuration parameters.

Restore link settings (Local & Peer)	Whole set of parameters from the "Link settings" menu tree is affected.



Restore switch settings (Local)	Whole set of parameters from the "Switch settings" menu tree is affected.

Factory setting (Local)



WARNING: Using the factory settings function will revert the unit to its original state. All configuration items, user accounts, measured values and system messages (logs) will be irreversibly deleted.
WARNING: This task takes a few minutes to complete. Do not interrupt the power supply during the operation.

Restore factory settings	Applying Factory settings to Local station. The station reboots itself after applying all changes.

	Restore factory settings - HW button	It is possible to bring the station to Factory settings by holding the hardware button depressed during station boot. The HW button is located next to the DC connector within the port marked "P". Disconnect the power supply from the station. Keep the HW button depressed while reconnecting the power. The status LED starts to flash red after a few seconds. Keep the HW button pressed another 5 seconds until the red status LED stops flashing. The station boot up sequence continues and Factory settings are applied. Should the HW button be released when the status LED is in the red flashing phase (but before the 5 s guard time), the station stays in Service mode. Please, leave this mode by rebooting the station.
Diagnostic package (Local & Peer)	To facilitate communication with the technical support you can create an archive file with detailed information about the station. If connection with Peer station is active the diagnostic information from both stations are saved.	
	Create & download file	Saving a file with information about the station (Local and Peer). **NOTE:** This task takes a few minutes to complete.
Management Information Base	SNMP MIB	Provides Management Information Base table.

Feature keys

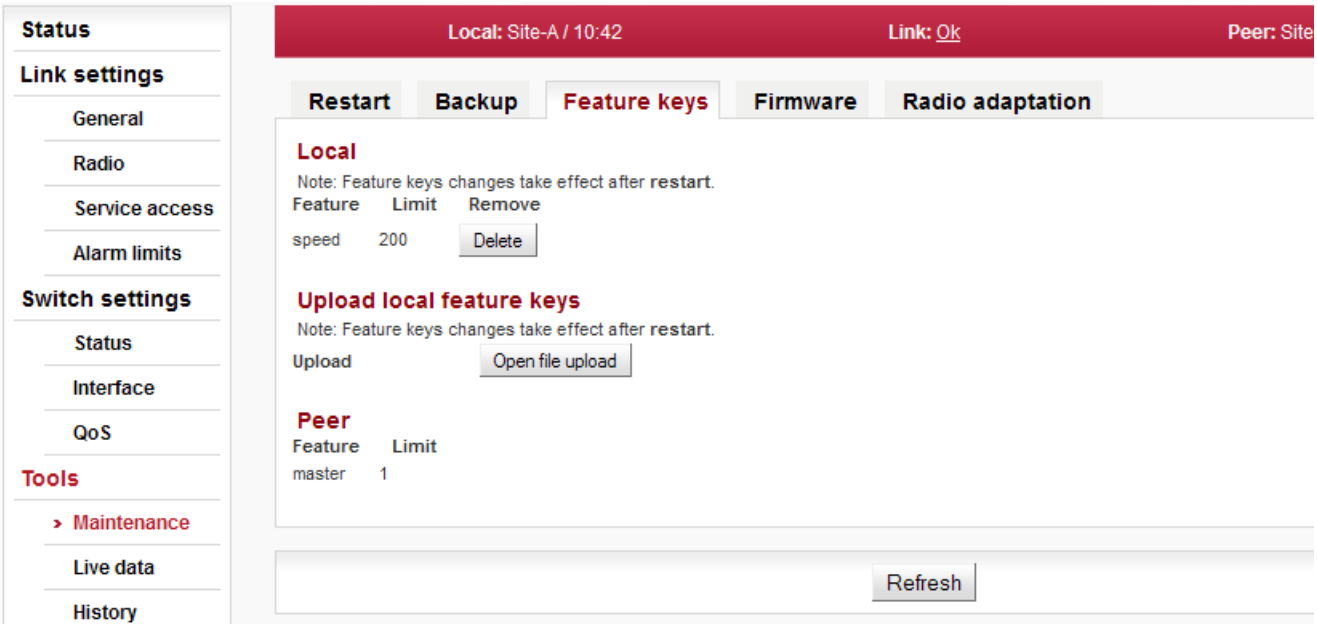


Fig. 7.25: Menu Tools - Feature keys

The sub-set of RAy2 parameters is affected by use of Feature keys.

The feature keys limiting data transfer speed [Mbps] are now available. Speed of the transferred data is determined by a combination of the radio channel bandwidth (parameter Bandwidth [MHz]) and modulation order (parameter TX modulation). The Feature key limiting the data transfer speed enables only certain combinations of the channel bandwidth and modulation order to get the data transfer speed according to the Feature key. The data transfer speed is typically slightly higher than declared.

When installed, the Feature key is activated after the station restart. The station can be restarted using the Tools - Maintenance - Restart. Choose the Restart mode – warm.

Feature Name of the function controlled by the Feature key.

Feature keys of the Peer station are only displayed. They can be neither added, nor deleted. To be able to manipulate the Feature keys, it is necessary access directly management system of the relevant station - use the IP address of the relevant station.

Limit The numeric value set by the key.

Remove The specific Feature key can be deleted using the Delete button. The parameters controlled by this Feature key are reset to their default values after the station restart. Note: The link radio parameters can be changed subsequently (e.g. to a different operating frequency)!

Upload Feature keys are installed into the station from the binary files.

Open file upload - Dialog for the Feature key binary file selection is open.

The Feature key is activated after the station restart.

Firmware

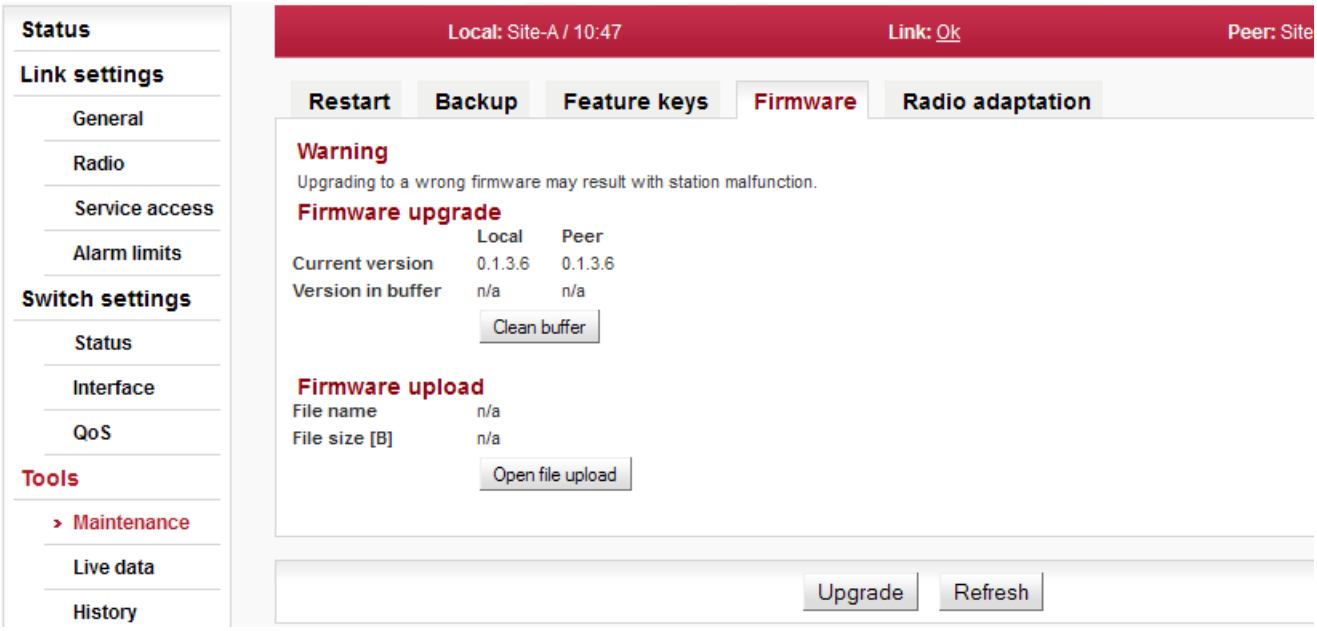


Fig. 7.26: Menu Tools - Firmware

If a new firmware version is released for the given microwave link type, you can upload it to your RAy2 units.

Current version Information about the current firmware version on Local and Peer station.

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 below).

Clean buffer You can use the Clean buffer button to delete prepared firmware package in the buffer.

File name Name of the firmware file.

File size [B] Size of the firmware file.

Open file upload Opens a dialog for uploading firmware package to the unit buffer. Only after firmware has been prepared in the buffer, you can perform the actual upgrade.

Upgrade Use the Upgrade button on the bottom bar to perform the firmware installation.

Warning

Installing the firmware takes several minutes (about 10 minutes). During this time, transmission of user data is interrupted (for about 8 minutes). Do not interrupt the power supply during firmware installation!

Radio adaptation

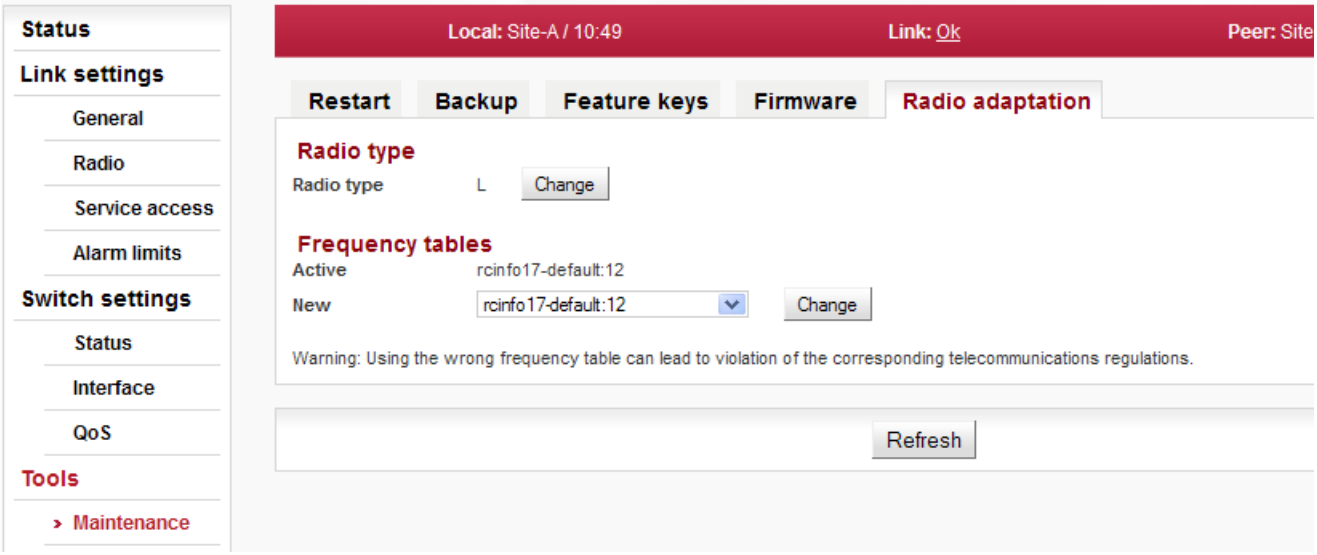


Fig. 7.27: Menu Tools - Radio adaptation

Radio type

IMPORTANT - Applies only to links operating in the ISM band (RAy2-17, RAy2-24).

Hardware of these links is universal for the entire frequency band. To facilitate the configuration of radio parameters, units are coded for L (Lower) and U (Upper) part of the band. L or U band assignment can be modified.

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 Settings-Radio).

Default values of radio parameters.

A set of radio parameters, needed for the ATPC operation.

WARNING - Using the wrong frequency table can lead to violation of the corresponding telecommunications regulations.

Radio type	Radio unit type: L (Lower) or U (Upper) part of the frequency band. Use the Change button to change the radio type.
Active	Name of the currently used frequency table.
New	Select a new frequency table. Use the Change button to change the table.

7.6.2. Live data

Bar indicators

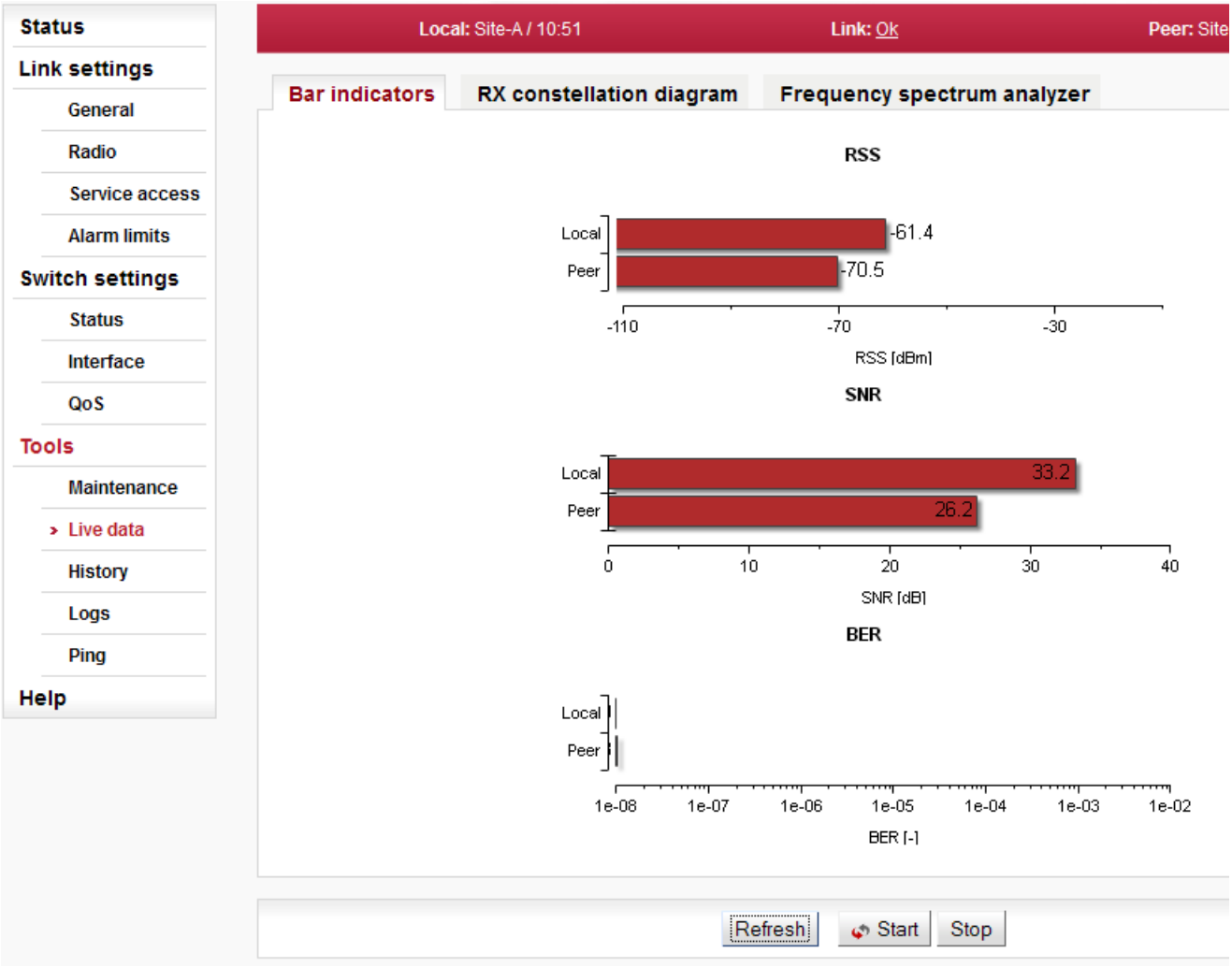


Fig. 7.28: Menu Tools - Bar indicators

Graphical indication of BER, SNR and RSS.

Refresh	One-time update of displayed values.
Start, Stop	Use the Start button to start automatic update of displayed values with a period of 1 second. Use the Stop button to stop it.

RX constellation diagram

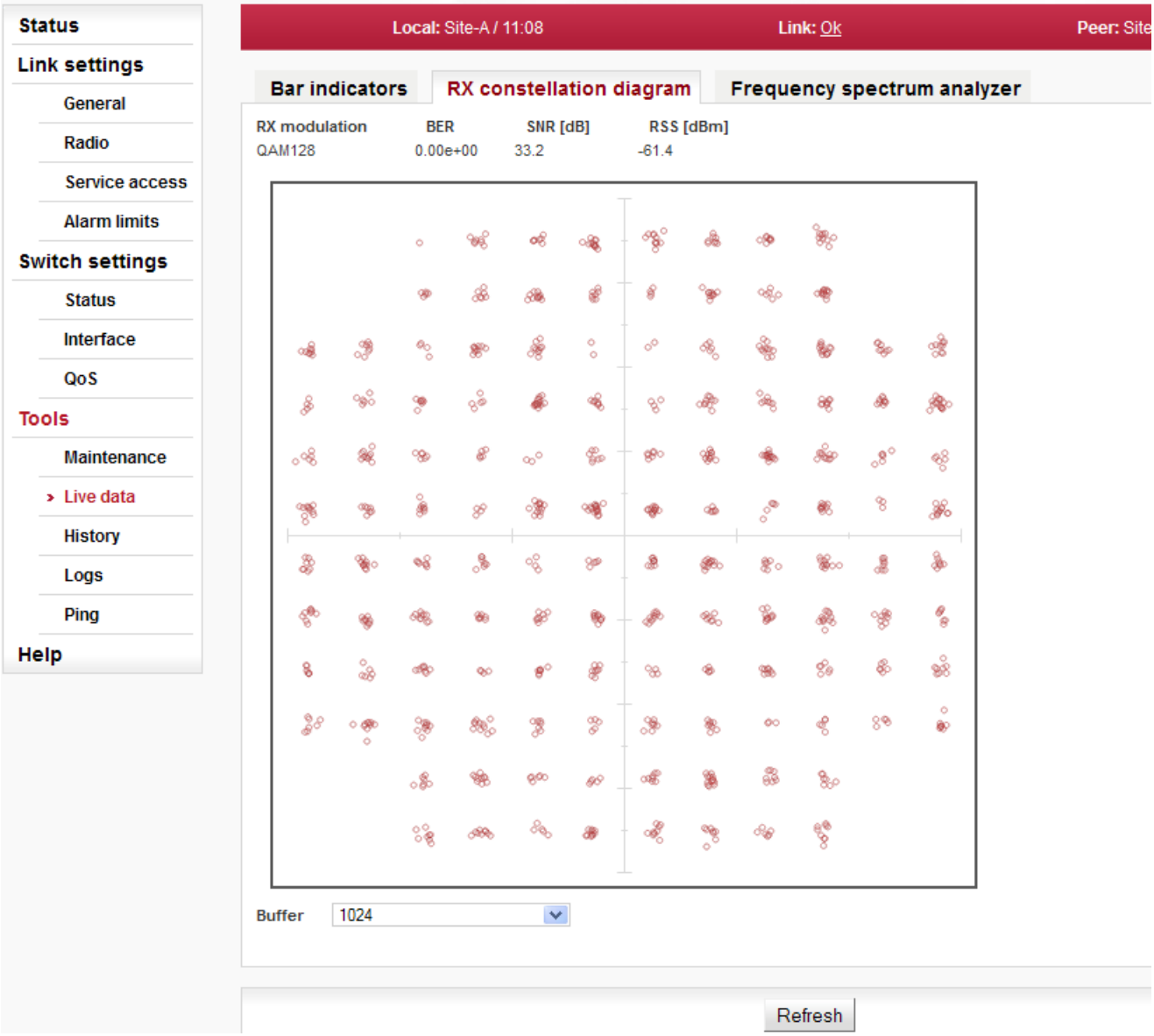


Fig. 7.29: Menu Tools - RX constellation

Constellation diagram shows the quality of received signal.

RX modulation	Modulation level of RX channel.
Buffer	Number of plotted points.
Refresh	One-time update of diagram.

Frequency spectrum analyzer

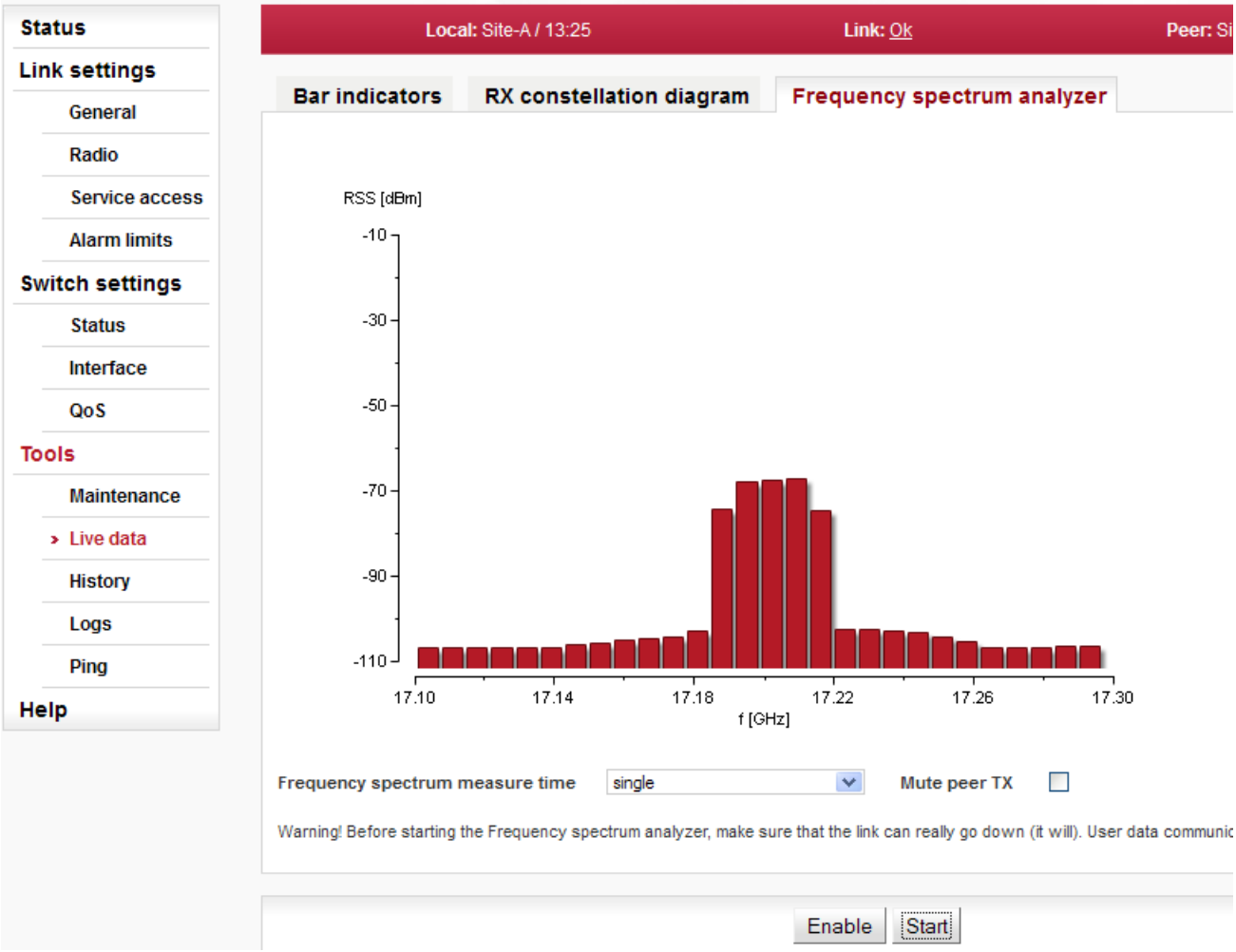


Fig. 7.30: Menu Tools - Frequency analyzer

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 7MHz channel resolution. The accuracy of measured results is given by the accuracy of measuring RSS.

Warning

Running spectrum measurement causes interruption of user data flow between stations!

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: single sweep … up to 15 min
Mute peer TX	The deactivation of Peer station transmission during measurement.

7.6.3. History

Station continuously stores information about the values of important variables. Stored values can be viewed using three methods - Thumbnails, Viewer and Data

Thumbnails

Preview all values for the last 24 hours. Click on a thumbnail to open the viewer with a chart.

Fig. 7.31: Menu Tools - History - Thumbnails

Temperature inside the station	Instantaneous value of temperature inside the station. Measured on the modem board. Temperature of radio board is available via SNMP.

Supply voltage	Instantaneous value of station supply voltage.
RSS	Received signal strength.
SNR	Signal-to-noise ratio of the received signal.
BER	Instantaneous bit error rate on link.
Net bitrate	Instantaneous transmission capacity.
Ethernet in throughput	Instantaneous speed (20s average) of incoming user data on the user Ethernet port.
Ethernet out throughput	Instantaneous speed (20s average) of outgoing user data on the user Ethernet port.
TX power	Instantaneous value of transmission power.

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.

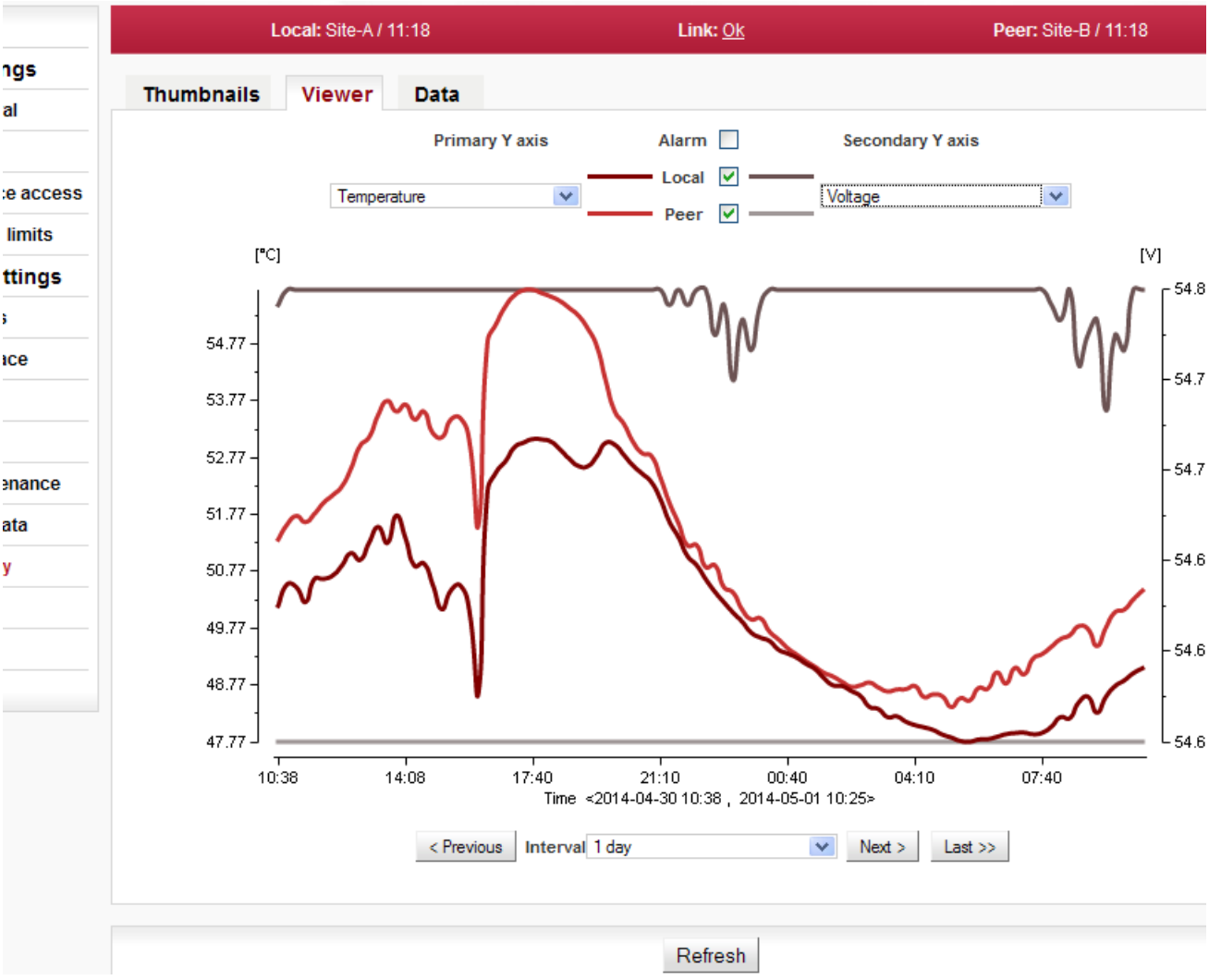


Fig. 7.32: Menu Tools - History - Viewer

Interval

Selecting width of interval to be displayed. Based on the interval width, data are displayed in a suitable grid: Up to 3 hours in at one minute. Up to 4 days at 15 minutes. For longer intervals at one day. More options:

Previous	Move by one width of selected interval towards older values.
Next	Move by one width of selected interval towards newer values.
Last	Move to the newest values.

The values are saved in the following resolutions and history lengths:

Resolution 1 minute, length of history 1 week

Resolution 15 minutes, length of history 30 days

Resolution 1 day, length of history about 180 days

Primary Y axis

Selecting one of the observed values:

Temperature, Voltage, RSS, SNR, BER, Net bitrate, Ethernet in throughput, Ethernet out throughput, TX power

Secondary Y axis

Selecting a second value:

None

Temperature, Voltage, RSS, SNR, BER, Net bitrate, Ethernet in throughput, Ethernet out throughput, TX power

Alarm

Enables the display of alarms, if there were any.

Data

Numerical view of all values

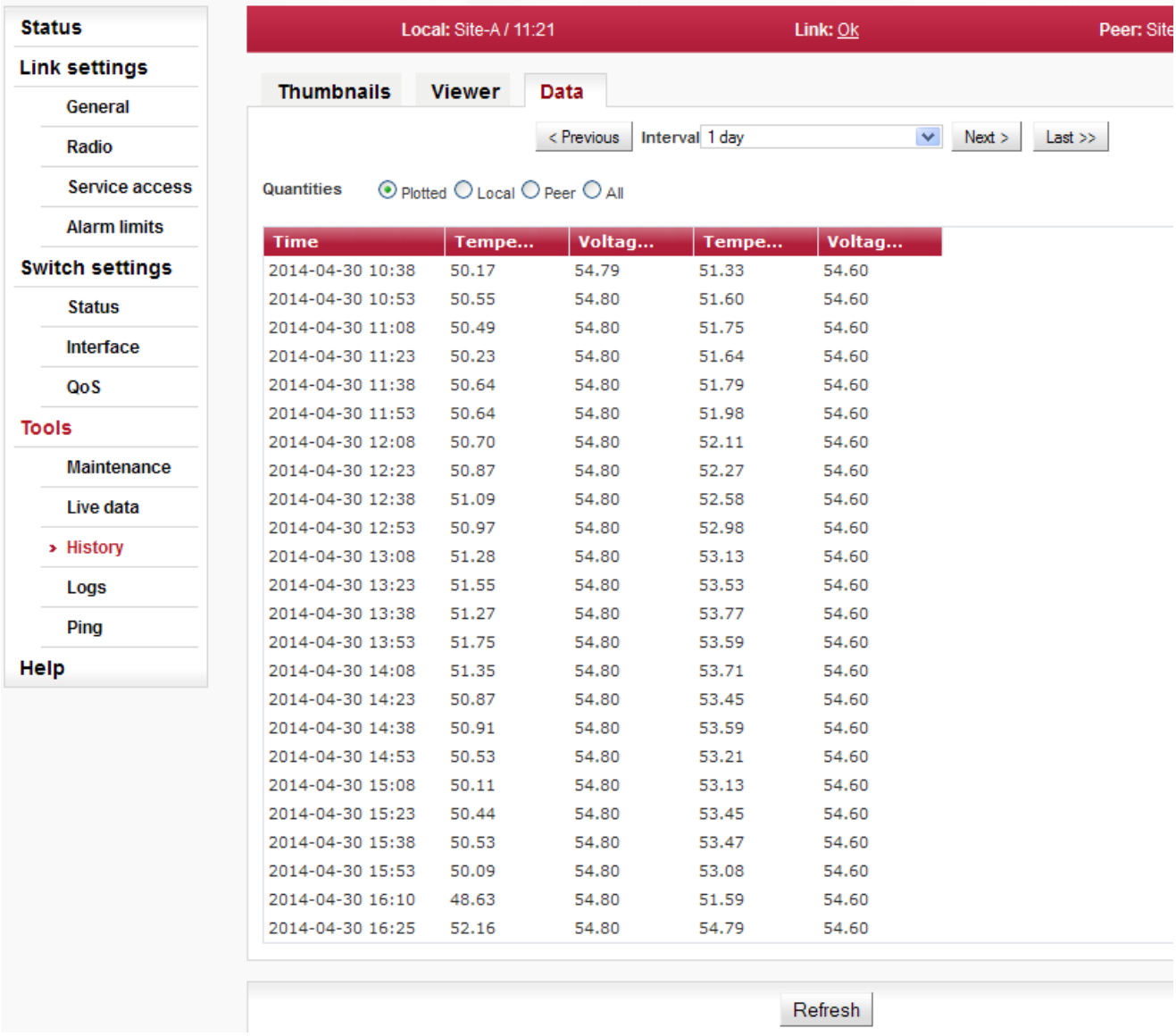


Fig. 7.33: Menu Tools - History - Data

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.

7.6.4. Logs

Shows internal station logs. Individual tabs allow total or filtered view.

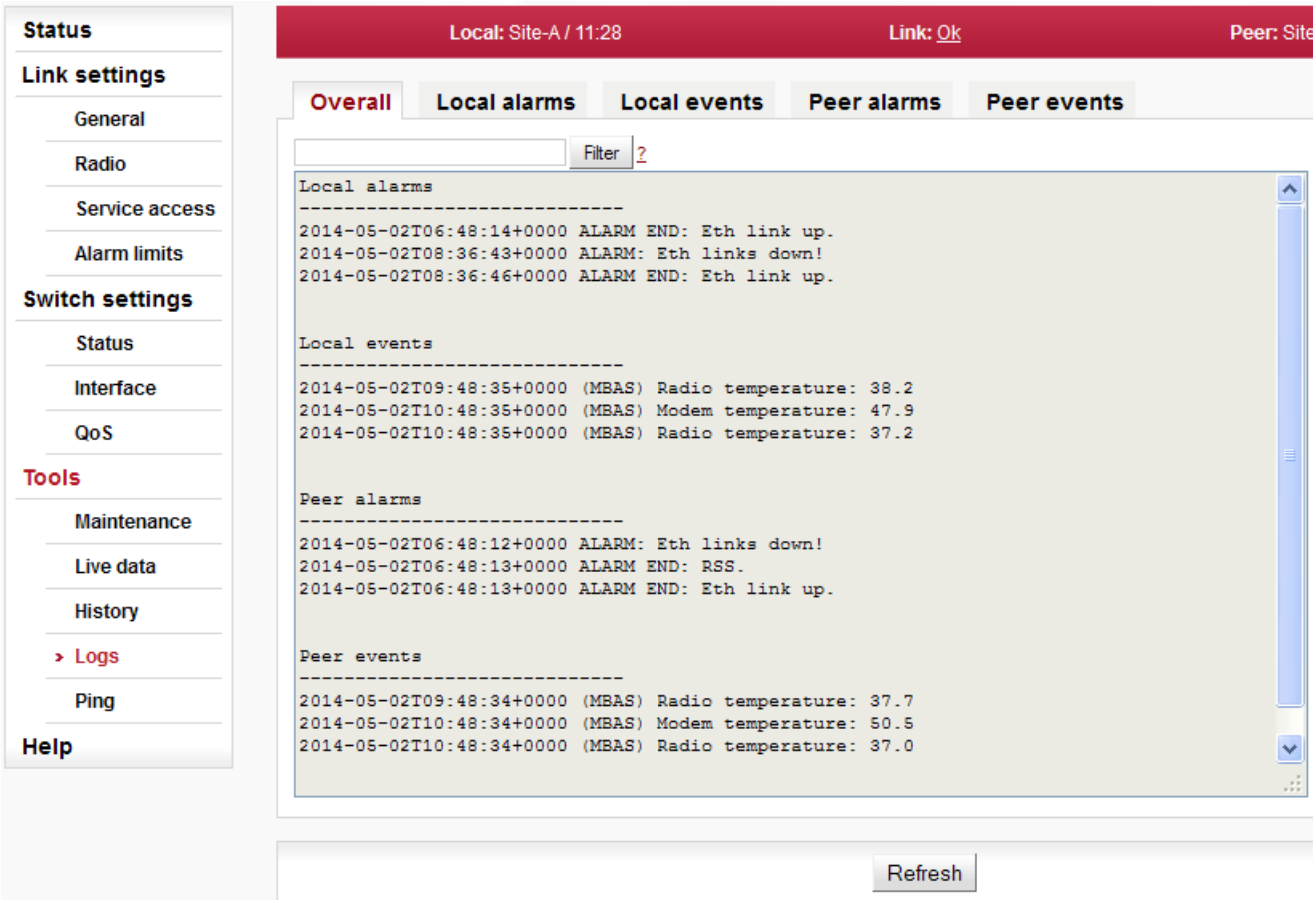


Fig. 7.34: Menu Tools - Logs

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 of CLI interface is needed.

Overall	Displays the last 3 records from all types of logs.
Local alarms, Peer alarms	Alarms from Local or Peer station.
Local events, Peer events	Events from Local or Peer station.
Local ACM, Peer ACM	History of modulation switching if ACM is enabled. Local and Peer station.
Filter	Listings of all logs can be filtered. You can enter text in the upper left corner window for filtering listings. For example, you want to know when was the configuration of the station modified: On the Local events screen, enter “Configuration” and hit Enter. You can use plain text or regular expressions for filtering (JavaScript format).

7.6.5. Ping

The Ping tool allows sending ICMP pings to a selected address

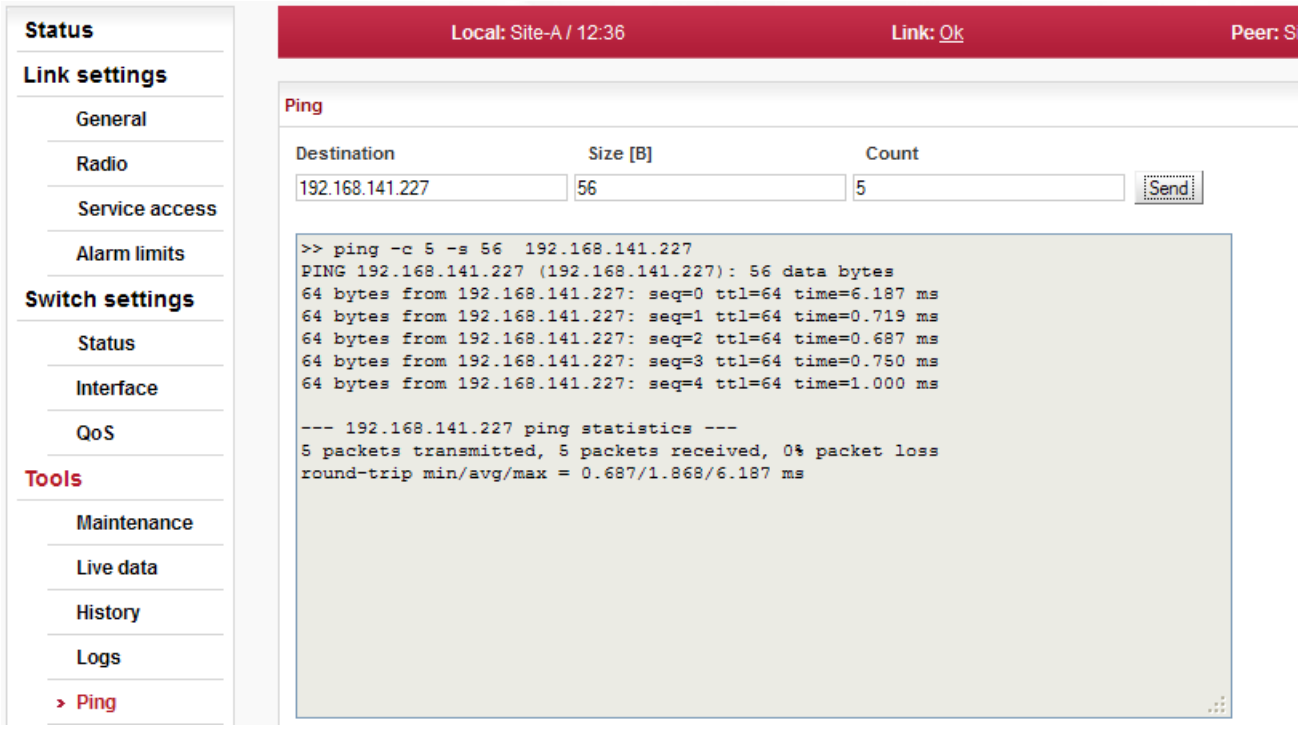


Fig. 7.35: Menu Tools - Ping

Start the test by clicking on Send. The result is displayed in the text window.

Destination	Destination address in dotted decimal notation. The default address 127.0.0.1 is the localhost address - i.e. the station itself.
Size [B]	Length of sent data 7 to 1500 bytes, 8 bytes of the header will be added.
Count	Number of sent pings. The period for sending pings is constant: 1000 ms.

7.7. Help

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.

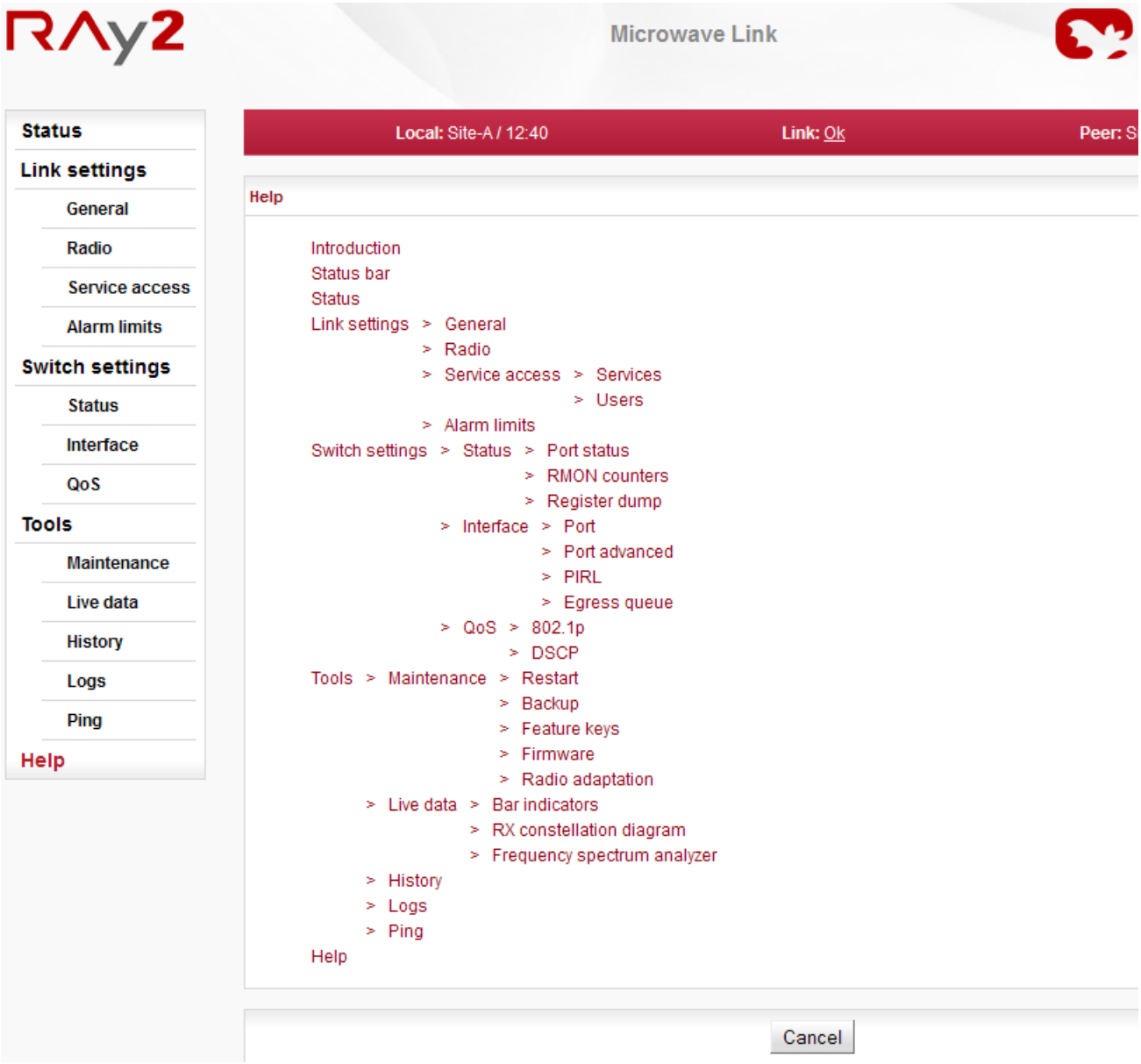


Fig. 7.36: Help menu

Every item of this Help opens the specific menu help.

Help from configuration menu

Clicking the **name of the specific parameter** in the configuration menu brings the help belonging to this parameter. The help text is displayed in the pop up window:

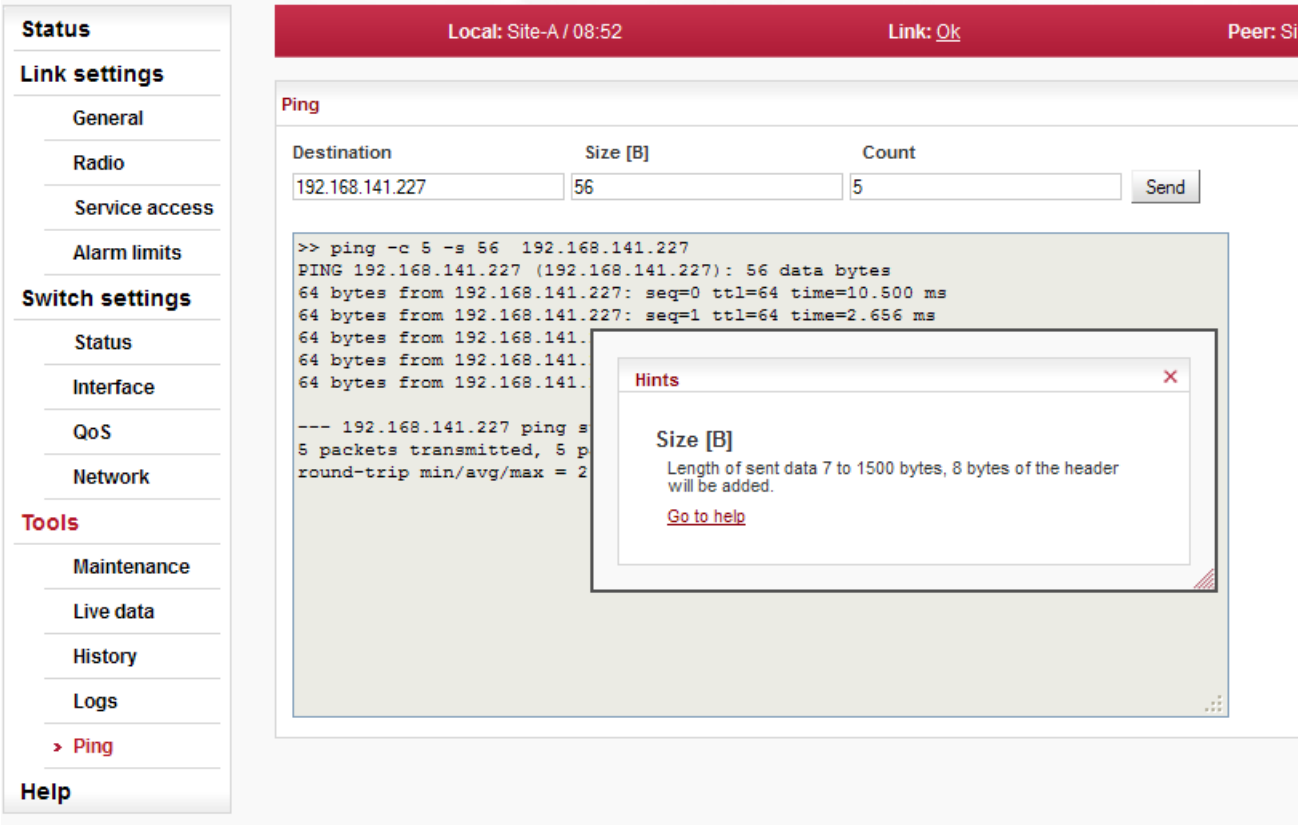


Fig. 7.37: Parameter help

There is a **Go to help** link within the help text. It displays the whole configuration menu help:

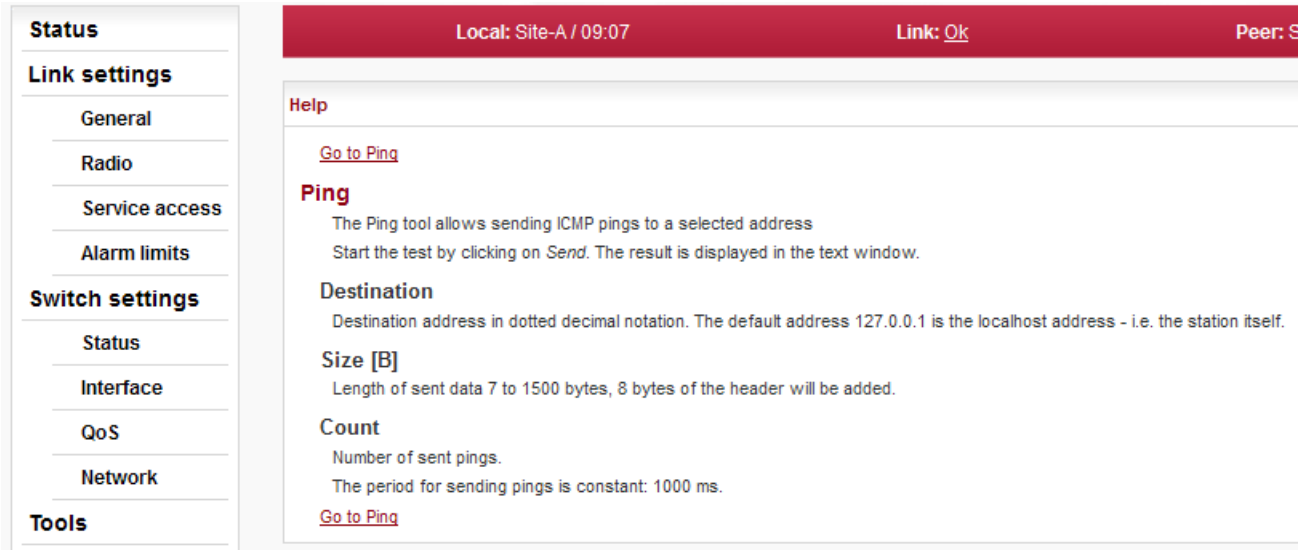


Fig. 7.38: Configuration menu help

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:

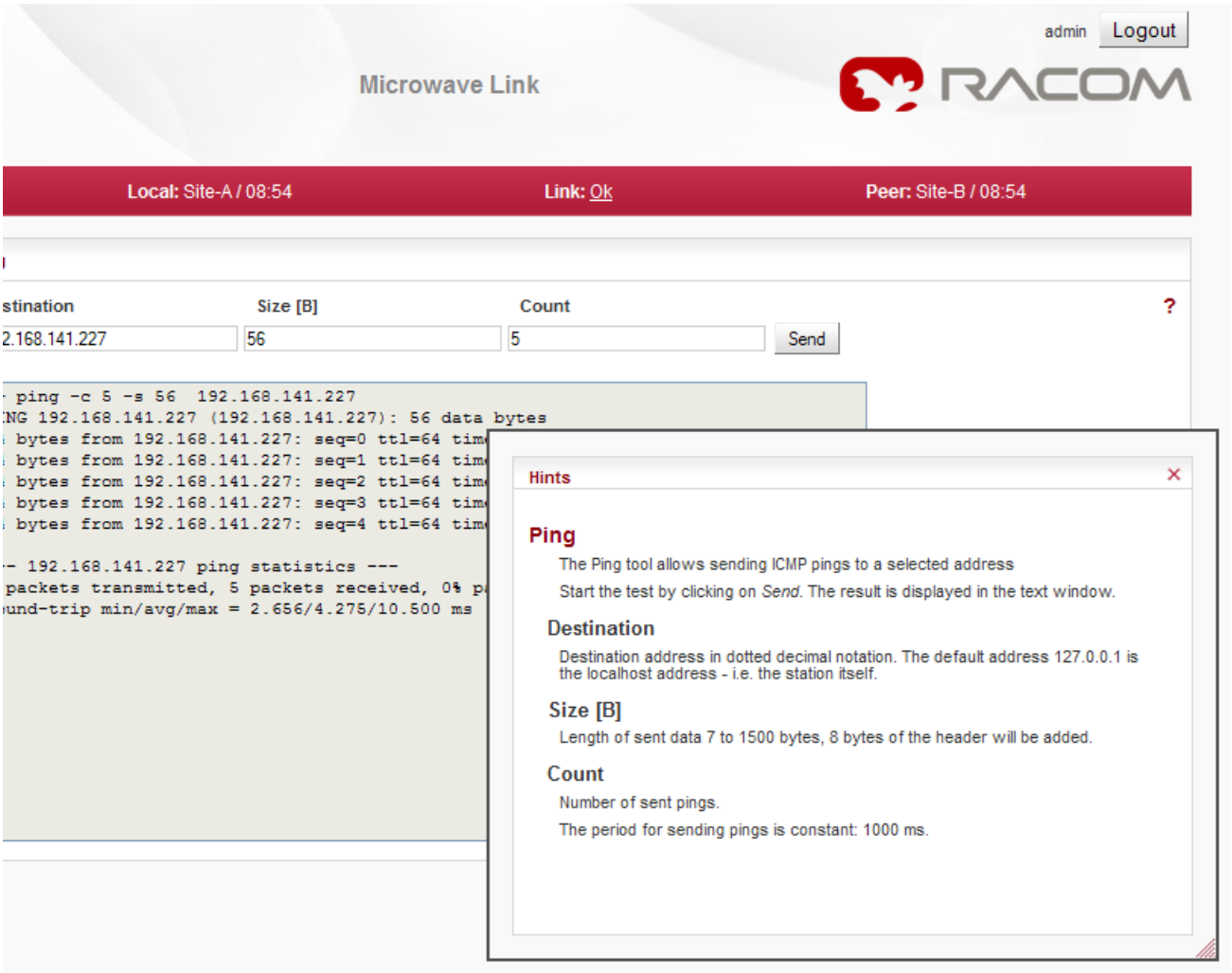


Fig. 7.39: Summary help

The Help window can be moved by dragging the *Hints* bar. Resize it by dragging the bottom corner.

8. Command Line Interface

Command Line Interface (CLI) provides an alternative to HTTPS access. CLI allows you to work in text regime using a ssh (putty) or telnet client.

8.1. Connection via CLI

Using the **telnet** client to connect to 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`). Works if `Service access/Services/Telnet` is checked in https access.

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.

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.

8.2. Working with CLI

- Overview of CLI options

  ```
  cli_help
  ```

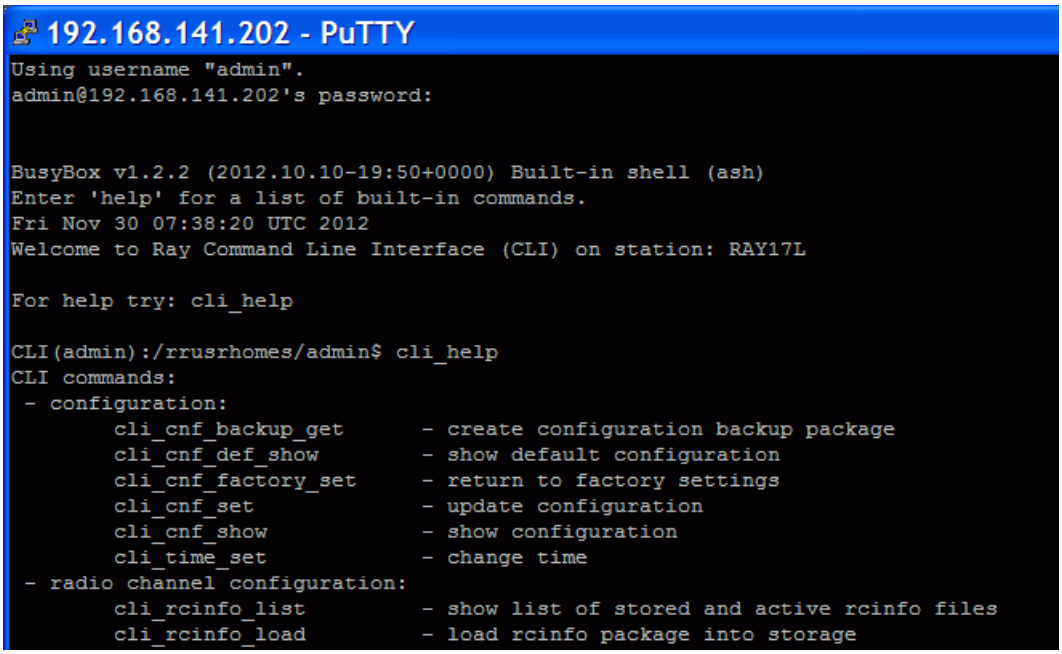


  Fig. 8.1: CLI menu

- 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, adding with tabulator can help
- Incorrect command is rejected (e.g. inserting forbidden frequency)
- 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 space in quotation marks:
  `cli_time_set -t b -T '2012-11-27 10:55:00'`
  Set time in both units

8.2.1. 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 RAy2 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 RAy2 unit
  `CLI(admin):/rrusrhomes/admin$ cli_user_authkey -c a -k /tmp/usr_ssh_key.pub`
- Test of access to RAy2 unit using SSH key
  `[user@laptop ~]$ ssh -i usr_ssh_key admin@192.168.141.202`

8.2.2. 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

8.3. Configuration with CLI

8.3.1. 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`
  Attention, the command
  `cli_cnf_factory_set`
  is not a default setting - it uses factory settings, deletes all logs and saved data. It is very likely that the connection to peer station will be interrupted!

8.3.2. Firmware upgrade

- Current version of fw
  `cli_info_station`

- Preparation of files
  fw package, for example `bm4-RACOM-0.1.12.0.cpio` copy using ssh or putty into folder `/tmp` in RAy17
  Command
  `cli_fw_clear_buffer`
  Clears the RAy2 buffer
  `cli_fw_buffer_status`
  Checks buffer status

- Saving into buffers
  `cli_fw_load_package -f /tmp/bm4-RACOM-0.1.12.0.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 3 minutes, this message appears:
  `Firmware upgrade started. Estimated time to finish is 370 s.`
  Connection is terminated. After a few minutes, log in to RAy2 again

8.3.3. Remote unit authorization

The RAy2 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 so called Secured mode of remote unit authorization. This mode is based on locking the two specific units into one communication pair. The 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 affected units. The authorization keys can be backed up to an external medium to be able to make a service unit exchange, if necessary.

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 has to 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 selected file in the internal unit file system. It can be transferred to an external medium for example using the scp client.
- Authorization key restoration from the external medium.
  The key has to be transferred to the unit internal file system first. 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`

9. Troubleshooting

- **Polarization incorrect**

  Install the unit with the correct *horizontal* or *vertical* polarization: The arrow mark (placed just next to the Status LED) indicates the unit RX polarization. When the arrow is perpendicular to the earth, unit receives signal in vertical polarization. When the arrow is parallel to the earth, unit receives signal in horizontal polarization. The connectors must point downward at an angle.

- **The link cannot be established**

  Start with the most “resilient” configuration. This configuration depends on the type of unit. We recommend to use the narrowest available bandwidth (e.g. 3.5 MHz), the lowest modulation level (QPSK) and maximum available output power. 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, continue to operation parameters.

  The units operating in licensed bands (RAy2-10, RAy2-11) are mounted with the same RX polarization (the polarization indication arrows show the same polarization on both units).

  The units working in ISM band (RAy2-17, RAy2-24) must be mounted one with RX horizontal polarisation (horizontal arrow) and the second with RX vertical polarisation (vertical arrow).

- **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. Attention, the Remote unit will report as Local.

- **Distinguishing Local-Remote**

  The unit accessed via service access always reports as Local. If you connect through another (peer) unit and radio channel, certain amount of caution is necessary. For example, not to reduce the transmission power so that the link interrupts accidentally. Errors of this type should be fixed by 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 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.

- **RSS**

  To configure the link and monitor its state, several menus display the RSS signal strength. Please keep in mind, that Ray2 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.

- **Problem with https certificate**

  See the Appendix E, *Https certificate*

10. Technical parameters

10.1. General parameters

10.1.1. Technical parameters overview

Type	Licensed bands		ISM bands	
	RAy2-10	RAy2-11 [1)]	RAy2-17	RAy2-24
Band [GHz] sub-bands A,B..	A: 10.30 – 10.59	A,B: 10.70 – 11.70	17.1 – 17.3	24.0 – 24.25
	B: 10.125 – 10.675	C,D: 10.50 – 10.68		
ODU inits	Unit L and U		One universal unit	
Duplex spacing [MHz]	any combination L and U units	A,B: 490, 530	optional min 60	optional min 60
		C,D: 91		
Channel spacing CS [MHz]	1.75, 3.5, 7, 14, 20, 28, 56	A,B: 1.75, 3.5, 7, 14, 28, 30, 40, 56	3.5, 7, 14, 28, 40, 56	3.5, 7, 14, 28, 40, 56
		C,D: 1.75, 3.5, 7, 14, 28		
Channel freq.	detail	detail	detail	detail
User speed [Mbps]	2.5 – 360	A,B: 2.5 – 360	4.9 – 360	4.9 – 360
		C,D: 2.5 - 170		
	detail	detail	detail	detail
Latency [µs]	81 (64B/359Mbps), 234 (1518B/359Mbps)			
Sensitivity, BER 10^{-6} [dBm]	-100 (2.5 Mbps) -67 (340 Mbps)	-99 (2.5 Mbps) -67 (340 Mbps)	-96 (4.9 Mbps) -66 (340 Mbps)	-96 (4.9 Mbps) -65 (340 Mbps)
	detail	detail	detail	detail
Output Power [dBm]	-15 – +10	-5 – +23 (QPSK) -5 – +17 (256QAM)	-25 – +5	-30 – +10
ATPC	yes	yes	yes	yes
Consumption [W]	21	TBD	21	23
Weight [kg]	2.8	2.8	2.5	2.5
Radio param.	EN 302 217-2-2 V 1.3.1		EN 300 440-2 V 1.4.1	

ver. 2.3

[1)] RAy2-11 not available yet

Modulation	fixed QPSK, 16, 32, 64, 128, 256 QAM or ACM
FEC	LDPC
User interface RJ45	1 Gb Eth. (10/100/1000) (IEEE 802.3ac 1000BASE-T) , MTU 10240 B, recommended cable S/FTP CAT7
User interface SFP	1000Base-SX / 1000Base-LX, MTU 10240 B, user exchangable SFP
Service	USB-A
Power	PoE, 40 - 60 VDC , IEEE 802.3at up to 100m
	DC, 20 - 60 V, floating
Operating temperature range	-30 – +55°C (ETSI EN 300019-1-4, class 4.1.)
Mechanical design	FOD (Full Outdoor)
Dimensions	244 × 244 × 157 mm
EMC	ETSI EN 301 489-1 V 1.8.1 (2008-04), ETSI EN 301 489-17 V1.3.2 (2008-04)
Electrical safety	EN 60 950-1:2004

ver. 1.1

10.1.2. Link speed

Nominal link speed

RAy2 - xx	**User data rate [Mbps]**								
Modulation / CS	**1.75 MHz**	**3.5 MHz**	**7 MHz**	**14 MHz**	**28 / 30 MHz**		**40 MHz**	**56 MHz**	**56 MHz TO**
	ACCP	**ACCP**	**ACCP**	**ACCP**	**ACCP**	**ACAP**	**ACCP**	**ACCP**	**ACCP**
QPSK	2.5	4.9	8.5	19.9	36.8	38.3	50.1	72.9	85.8
16-QAM	4.9	9.6	17.2	38.8	80.9	84.1	110.0	160.2	169.9
32-QAM	6.3	12.1	22.1	49.1	102.4	106.4	139.2	202.7	206.2
64-QAM	7.4	14.3	29.7	62.3	129.8	135.0	176.5	256.9	268.1
128-QAM	8.9	17.2	34.7	73.6	155.5	161.7	211.4	303.7	309.0
256-QAM		19.7	40.7	81.2	170.7	185.2	232.1	337.7	358.9

ver. 2.5

Link speed according to RFC 2544

RAy2 - xx	**Link speed [Mbps] for frames 64 - 1518 B**							minimum maximum values	
Modulation / CS	**1.75 MHz**	**3.5 MHz**	**7 MHz**	**14 MHz**	**28 / 30 MHz**		**40 MHz**	**56 MHz**	**56 MHz TO**
	ACCP	**ACCP**	**ACCP**	**ACCP**	**ACCP**	**ACAP**	**ACCP**	**ACCP**	**ACCP**
QPSK	2.1 2.3	4.2 4.6	7.5 8.3	17.6 19.6	32.6 36.5	33.8 37.9	44.3 49.6	64.7 72.3	76.1 85.2
16-QAM	4.3 4.8	8.4 9.3	15.1 17.0	34.3 38.5	71.7 80.2	74.6 83.4	97.5 109.2	142.1 159.0	150.7 168.6
32-QAM	5.4 6.0	10.6 11.9	19.6 21.8	43.4 48.6	90.7 101.5	94.3 105.6	123.4 138.2	179.9 201.3	182.9 204.8
64-QAM	6.5 7.2	12.6 14.1	26.1 29.3	55.2 61.7	115.1 128.8	119.7 133.9	156.6 175.3	228.0 255.1	238.1 266.4
128-QAM	7.8 8.7	15.1 17.0	30.7 34.3	65.2 73.0	138.0 154.5	143.5 160.5	187.7 209.9	269.7 301.6	274.5 307.1
256-QAM		17.4 19.4	36.1 40.3	71.9 80.5	151.5 169.5	164.4 184.0	206.1 230.7	300.2 335.8	318.8 356.5

ver. 1.1

ACM switching according to SNR state

RAy2 - xx	**SNR degrade / improve [dB]**								
Modulation / CS	**1.75 MHz**	**3.5 MHz**	**7 MHz**	**14 MHz**	**20 MHz**	**28 MHz**	**40 MHz**	**56 MHz**	**56 MHz TO**
	ACCP	**ACCP**	**ACCP**	**ACCP**	**ACCP**	**ACCP**	**ACCP**	**ACCP**	**ACCP**
QPSK	- 19.0	- 19.0	- 19.0	- 19.0	- 19.0	- 19.0	- 19.0	- 19.0	- 19.0
16-QAM	17.0 23.0	17.0 23.0	17.0 23.0	17.0 23.0	17.0 23.0	17.0 23.0	17.0 23.0	17.0 23.0	17.0 23.0
32-QAM	20.0 26.0	20.0 26.0	20.0 26.0	20.0 26.0	20.0 26.0	20.0 26.0	20.0 26.0	20.0 26.0	20.5 26.0
64-QAM	23.0 28.5	23.0 28.5	23.0 28.5	23.0 28.5	23.0 28.5	23.0 28.5	23.0 28.5	23.0 28.5	24.5 28.5
128-QAM	25.0 -	25.0 31.5	25.0 30.5	25.0 30.5	25.0 30.5	25.0 30.5	25.0 30.5	25.0 30.5	27.0 31.0
256-QAM	- -	28.5 -	28.0 -	28.0 -	28.0 -	28.0 -	28.0 -	28.0 -	29.0 -

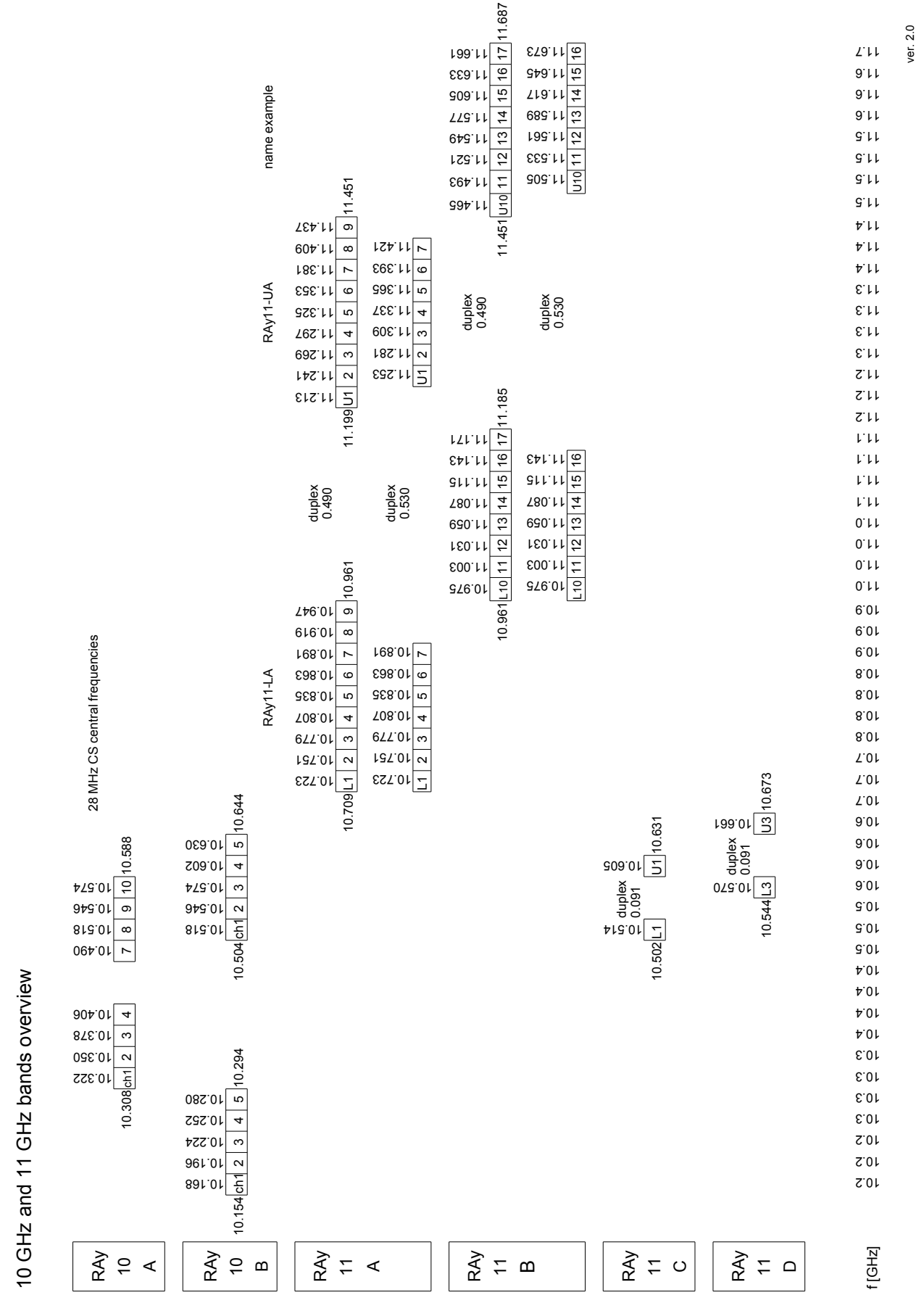
ver. 1.1

10.1.3. Duplex spacing

Duplex spacing L and U channels		
RAy2-10		
Sub-bands		
A	All combinations of channels	
B	All combinations of channels	
RAy2-11		
Sub-bands	Duplex spacing [MHz]	
A, B	490, 530	
C, D	91	
RAy2-17		
	Optional duplex spacing	
Channel width	minimum	default
[MHz]	[MHz]	[MHz]
3.5	60	73.5
7	60	73.5
14	65	87.5
28	70	84
40	70	70
56	85	85
RAy2-24		
	Optional duplex spacing	
Channel width	minimum	default
[MHz]	[MHz]	[MHz]
3.5	60	73.5
7	60	73.5
14	65	87.5
28	70	84
40	70	70
56	85	85

ver. 2.3

10.1.4. Frequency overview 10 GHz and 11 GHz, for CS 28 MHz



10.2. Nominal frequency tables description

RAy11 – xA , **RAy11 – x**B [1]			TX channel nominal frequencies Band 10.7 – 11.7 GHz, [3] duplex frequency 490 MHz [4]		
Bandwidth: **56 MHz (CS 80)** [2]			CEPT 12-06 Annex C [5]		
A sub-band [6] (Freq.table: rcinfo11_A_490, rcinfo11_A_490_n) [7]			**B** sub-band (Freq.table: rcinfo11_B_490, rcinfo11_B_490_n)		
Ch.No.	Lower [MHz]	Upper [MHz]	Ch.No.	Lower [MHz]	Upper [MHz]
1 [8]	10755 [9]	11245 [10]	7	10995	11485
2	10795	11285	8	11035	11525
3	10835	11325	9	11075	11565
4	10875	11365	10	11115	11605
5	10915	11405	11	11155	11645
				ver. 1.0	[11]

1) The respective RAy unit name. The letter “x” stands for “L” or “U” (Lower or Upper band unit).

   Example: “RAy11-xA” means both “RAy11-LA” and “RAy11-UA” units. See overview table for details.

   Note: The optional last figure in the unit name (e.g. RAy11-LA-2) denotes number of Ethernet ports and it is not relevant for the Nominal frequency tables.

2) The respective channel set (nominal frequencies) name in the Ray unit configuration interface (see Configuration, item “Bandwith [MHz]”. In addition to the bandwith definition, the name may contain additional text which defines the respective alternative of channel plan.

   Examples: “Bandwith: 40 MHz (ITU)” means that the nominal frequencies in the table follow the recommendation ITU-R F.387 rec.1.2. for 40 MHz bandwith, see also the note 5) below.

   “Bandwith: 40 MHz (ACMA)” means that the table describes the 40 MHz channel plan defined by ITU-R F.387 rec. 1.1. (b), applied e.g. in Australia.

3) The whole frequency range.

4) Duplex spacing – the frequency difference between the Upper and Lower channels in a duplex pair.

5) The name of standard or recommendation defining the respective channel plan.

6) Name of the sub-band defined by channels in the table.

7) Name of the “Frequency table” containing the channel set described (see Configuration, item "Frequency tables").

8) The channel number according to RAy unit configuration interface (see Configuration, item “TX channel [GHz]”).

9) The nominal TX frequency of the Lower-band channel

10) The nominal TX frequency of the Upper-band channel.

11) Table version.

10.3. RAy2-10 parameters

10.3.1. Output power

RAy2-10-xA, **RAy2-10-xB**	**TX power**	
Modulation	**Max**	**Min**
	[dBm]	**[dBm]**
QPSK	10	-15
16-QAM	10	-15
32-QAM	10	-15
64-QAM	10	-15
128-QAM	10	-15
256-QAM	10	-15

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10.3.2. Radio parameters

RAy2-10					Channel spacing 1.75 MHz; ACCP operation			
Modulation	Raw Bit Rate	User Bit Rate	RSS / SNR for BER 10^{-6}		Co-channel rejection		Adjacent channel Selectivity	
					1 dB	3 dB	1 dB	3 dB
			RSS	SNR	declared / limit	declared / limit	declared / limit	declared / limit
[-]	*[Mbps]*		*[dBm]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*
QPSK	3.1	2.5	-100	9.5	15 / 23	12 / 19	-12 / 0	-14 / -4
16-QAM	6.3	5.0	-93	15.0	22 / 30	20 / 26.5	-11 / -3	-13 / -7
32-QAM	7.8	6.3	-89	19.0	24 / 30	22 / 26.5	-10 / -3	-12 / -7
64-QAM	9.4	7.4	-88	20.5	29 / 30	26 / 26.5	-9 / -3	-10 / -7
128-QAM	11.0	8.9	-85	23.5	30 / 30	28 / 26.5	-8 / -3	-7 / -7

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RAy2-10					Channel spacing 3.5 MHz; ACCP operation			
Modulation	Raw Bit Rate	User Bit Rate	RSS / SNR for BER 10^{-6}		Co-channel rejection		Adjacent channel Selectivity	
					1 dB	3 dB	1 dB	3 dB
			RSS	SNR	declared / limit	declared / limit	declared / limit	declared / limit
[-]	*[Mbps]*		*[dBm]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*
QPSK	6	4.9	-97	9.5	15 / 23	12 / 19	-14 / 0	-16 / -4
16-QAM	12	9.6	-90	15.0	22 / 30	20 / 26.5	-13 / -3	-15 / -7
32-QAM	15	12.1	-87	18.5	24 / 30	22 / 26.5	-12 / -3	-14 / -7
64-QAM	18	14.3	-84	20.5	29 / 30	26 / 26.5	-11 / -3	-12 / -7
128-QAM	21	17.2	-83	23.5	30 / 30	28 / 26.5	-9 / -3	-8 / -7
256-QAM	24	19.7	-81	26.0	33 / 30	31 / 26.5	-5 / -3	-7 / -7

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RAy2-10					Channel spacing 7 MHz; ACCP operation			
Modulation	Raw Bit Rate	User Bit Rate	RSS / SNR for BER 10^{-6}		Co-channel rejection		Adjacent channel Selectivity	
					1 dB	3 dB	1 dB	3 dB
			RSS	SNR	declared / limit	declared / limit	declared / limit	declared / limit
[-]	*[Mbps]*		*[dBm]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*
QPSK	12	8.5	-95	8.5	15 / 23	12 / 19	-20 / 0	-22 / -4
16-QAM	24	17.2	-88	15.0	22 / 30	20 / 26.5	-18 / -3	-19 / -7
32-QAM	30	22.1	-85	18.5	24 / 37	22 / 33	-16 / -2	-18 / -6
64-QAM	36	29.7	-81	21.5	29 / 37	26 / 33	-14 / -2	-16 / -6
128-QAM	42	34.7	-79	25.0	32 / 37	30 / 33	-12 / -2	-14 / -6
256-QAM	49	39.7	-77	26.0	33 / 37	31 / 33	-10 / -2	-12 / -6

ver. 2.2

RAy2-10					Channel spacing 14 MHz; ACCP operation			
Modula-tion	Raw Bit Rate	User Bit Rate	RSS / SNR for BER 10^{-6}		Co-channel rejection		Adjacent channel Selectivity	
					1 dB	3 dB	1 dB	3 dB
			RSS	SNR	declared / limit	declared / limit	declared / limit	declared / limit
[-]	*[Mbps]*		*[dBm]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*
QPSK	24	19.9	-93	8.5	14 / 23	12 / 19	-21 / 0	-23 / -4
16-QAM	48	38.8	-86	15.0	20 / 30	18 / 26.5	-19 / -3	-21 / -7
32-QAM	60	49.1	-82	18.5	26 / 33	23 / 29	-17 / -5	-19 / -9
64-QAM	72	62.3	-79	21.5	28 / 37	26 / 33	-14 / -2	-17 / -6
128-QAM	84	73.6	-76	25.0	30 / 37	28 / 33	-12 / -2	-14 / -6
256-QAM	96	81.2	-74	28.0	33 / 37	31 / 33	-10 / -2	-12 / -6

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RAy2-10					Channel spacing 20 MHz; ACCP operation			
Modula-tion	Raw Bit Rate	User Bit Rate	RSS / SNR for BER 10^{-6}		Co-channel rejection		Adjacent channel Selectivity	
					1 dB	3 dB	1 dB	3 dB
			RSS	SNR	declared / limit	declared / limit	declared / limit	declared / limit
[-]	*[Mbps]*		*[dBm]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*
QPSK	31	22.8	-92	8.5	14 / 23	12 / 19	-21 / 0	-23 / -4
16-QAM	62	50.2	-85	15.0	20 / 30	18 / 26.5	-19 / -3	-21 / -7
32-QAM	77.5	63.5	-81	18.5	26 / 33	23 / 29	-17 / -5	-19 / -9
64-QAM	93	80.5	-78	21.5	28 / 37	26 / 33	-14 / -2	-17 / -6
128QAM	108.5	96.4	-74	25.0	30 / 37	28 / 33	-12 / -2	-14 / -6
256-QAM	124	110.4	-72	28.0	33 / 37	31 / 33	-10 / -2	-12 / -6

ver. 2.2

RAy2-10					Channel spacing 28 / 30 MHz; ACCP operation			
Modula-tion	Raw Bit Rate	User Bit Rate	RSS / SNR for BER 10^{-6}		Co-channel rejection		Adjacent channel Selectivity	
					1 dB	3 dB	1 dB	3 dB
			RSS	SNR	declared / limit	declared / limit	declared / limit	declared / limit
[-]	*[Mbps]*		*[dBm]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*
QPSK	50	36.8	-91	7.5	12 / 23	10 / 19	-21 / 0	-23 / -4
16-QAM	100	80.9	-83	15.0	20 / 30	18 / 26.5	-18 / -3	-20 / -7
32-QAM	125	102.4	-79	18.5	24 / 33	22 / 29	-16 / -5	-19 / -9
64-QAM	150	129.8	-76	21.5	28 / 35	26 / 32	-12 / -5	-15 / -8
128QAM	175	155.5	-72	25.0	30 / 35	28 / 32	-9 / -5	-12 / -8
256-QAM	200	170.7	-70	26.5	33 / 35	31 / 32	-6 / -5	-9 / -8

ver. 2.2

RAy2-10					Channel spacing 28 / 30 MHz; ACAP operation			
Modulation	Raw Bit Rate	User Bit Rate	RSS / SNR for BER 10^{-6}		Co-channel rejection		Adjacent channel Selectivity	
					1 dB	3 dB	1 dB	3 dB
			RSS	SNR	declared / limit	declared / limit	declared / limit	declared / limit
[-]	*[Mbps]*		*[dBm]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*
QPSK	52	38.3	-89.5	7.5	12 / 23	10 / 19	-15 / 0	-17 / -4
16-QAM	104	84.1	-82.5	15.0	20 / 30	18 / 26.5	-12 / -3	-14 / -7
32-QAM	130	106.4	-78.5	18.5	24 / 37	22 / 33	-10 / 3	-13 / -1
64-QAM	156	135.0	-75.5	21.5	28 / 37	26 / 33	-6 / 3	-9 / -1
128QAM	182	161.7	-71.5	25.0	30 / 37	28 / 33	-3 / 3	-6 / -1
256-QAM	208	185.2	-68.5	26.5	33 / 41	31 / 38	0 / 10	-3 / 7

ver. 2.2

RAy2-10					Channel spacing 40 MHz; ACCP operation			
Modulation	Raw Bit Rate	User Bit Rate	RSS / SNR for BER 10^{-6}		Co-channel rejection		Adjacent channel Selectivity	
					1 dB	3 dB	1 dB	3 dB
			RSS	SNR	declared / limit	declared / limit	declared / limit	declared / limit
[-]	*[Mbps]*		*[dBm]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*
QPSK.	68	50.1	-88	7.5	12 / 33	10 / 29	-22 / -4	-24 / -8
16-QAM	136	110.0	-81	15.0	19 / 33	17 / 29	-18 / -4	-21 / -8
32-QAM	170	139.2	-77	18.5	24 / 33	21 / 29	-16 / -4	-19 / -8
64-QAM	204	176.5	-74	21.5	27 / 33	25 / 29	-14 / -4	-16 / -8
128QAM	238	211.4	-70	25.0	30 / 37	28 / 33	-10 / -4	-12 / -8
256-QAM	272	232.1	-68	26.5	33 / 37	30 / 33	-8 / -4	-10 / -8

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RAy2-10					Channel spacing 56 MHz; ACCP operation			
Modulation	Raw Bit Rate	User Bit Rate	RSS / SNR for BER 10^{-6}		Co-channel rejection		Adjacent channel Selectivity	
					1 dB	3 dB	1 dB	3 dB
			RSS	SNR	declared / limit	declared / limit	declared / limit	declared / limit
[-]	*[Mbps]*		*[dBm]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*
QPSK	99	72.9	-87	7.5	12 / 23	10 / 19	-26 / 0	-28 / -4
16-QAM	198	160.2	-80	15.0	19 / 30	17 / 26.5	-19 / -3	-21 / -7
32-QAM	247.5	202.7	-76	18.5	24 / 33	22 / 29	-15 / -5	-17 / -9
64-QAM	297	256.9	-73	21.5	27 / 35	25 / 32	-14 / -5	-16 / -8
128QAM	346.5	303.7	-69	25.0	30 / 35	28 / 32	-10 / -5	-12 / -8
256-QAM	396	337.7	-67	26.5	33 / 35	30 / 32	-8 / -5	-10 / -8

ver. 2.2

RAy2-10					**Channel spacing 56 MHz TO; ACCP operation**			
Modula-tion	**Raw Bit Rate**	**User Bit Rate**	RSS / SNR for BER 10^{-6}		**Co-channel rejection**		**Adjacent channel Selectivity**	
					1 dB	3 dB	1 dB	3 dB
			RSS	**SNR**	declared / limit	declared / limit	declared / limit	declared / limit
[-]	*[Mbps]*		*[dBm]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*
QPSK	99	85.8	-85	10.0	13 / 23	11 / 19	-24 / 0	-26 / -4
16-QAM	198	169.9	-78	16.0	20 / 30	18 / 26.5	-18 / -3	-20 / -7
32-QAM	247.5	206.2	-74	19.0	25 / 33	23 / 29	-14 / -5	-15 / -9
64-QAM	297	268.1	-70	22.5	29 / 35	26 / 32	-9 / -5	-11 / -8
128QAM	346.5	309.0	-67	25.5	32 / 35	29 / 32	-8 / -5	-10 / -8
256-QAM	396	358.9	-64	27.5	35 / 35	32 / 32	-7 / -5	-8 / -8

ver. 2.2

10.3.3. Nominal frequencies, band 10.30 – 10.59 GHz

RAy2-10 - x**A**

Bandwidth: **1.75 MHz**

TX channel nominal frequencies
Band 10.30 – 10.59 GHz — default duplex 168 MHz
Based on 7 MHz channels — duplex range 57.75 – 285.25 MHz

A sub-band (Freq.table: rcinfo10_A_default:3)

Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]	Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]
L1	10301.875			L35	10361.375	U35	10529.375
L2	10303.625			L36	10363.125	U36	10531.125
L3	10305.375			L37	10364.875	U37	10532.875
L4	10307.125			L38	10366.625	U38	10534.625
L5	10308.875	U5	10476.875	L39	10368.375	U39	10536.375
L6	10310.625	U6	10478.625	L40	10370.125	U40	10538.125
L7	10312.375	U7	10480.375	L41	10371.875	U41	10539.875
L8	10314.125	U8	10482.125	L42	10373.625	U42	10541.625
L9	10315.875	U9	10483.875	L43	10375.375	U43	10543.375
L10	10317.625	U10	10485.625	L44	10377.125	U44	10545.125
L11	10319.375	U11	10487.375	L45	10378.875	U45	10546.875
L12	10321.125	U12	10489.125	L46	10380.625	U46	10548.625
L13	10322.875	U13	10490.875	L47	10382.375	U47	10550.375
L14	10324.625	U14	10492.625	L48	10384.125	U48	10552.125
L15	10326.375	U15	10494.375	L49	10385.875	U49	10553.875
L16	10328.125	U16	10496.125	L50	10387.625	U50	10555.625
L17	10329.875	U17	10497.875	L51	10389.375	U51	10557.375
L18	10331.625	U18	10499.625	L52	10391.125	U52	10559.125
L19	10333.375	U19	10501.375	L53	10392.875	U53	10560.875
L20	10335.125	U20	10503.125	L54	10394.625	U54	10562.625
L21	10336.875	U21	10504.875	L55	10396.375	U55	10564.375
L22	10338.625	U22	10506.625	L56	10398.125	U56	10566.125
L23	10340.375	U23	10508.375	L57	10399.875	U57	10567.875
L24	10342.125	U24	10510.125	L58	10401.625	U58	10569.625
L25	10343.875	U25	10511.875	L59	10403.375	U59	10571.375
L26	10345.625	U26	10513.625	L60	10405.125	U60	10573.125
L27	10347.375	U27	10515.375	L61	10406.875	U61	10574.875
L28	10349.125	U28	10517.125	L62	10408.625	U62	10576.625
L29	10350.875	U29	10518.875	L63	10410.375	U63	10578.375
L30	10352.625	U30	10520.625	L64	10412.125	U64	10580.125
L31	10354.375	U31	10522.375	L65	10413.875	U65	10581.875
L32	10356.125	U32	10524.125	L66	10415.625	U66	10583.625
L33	10357.875	U33	10525.875	L67	10417.375	U67	10585.375
L34	10359.625	U34	10527.625	L68	10419.125	U68	10587.125

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RAy2-10 - x**A**

Bandwidth: **3.5 MHz**

TX channel nominal frequencies
Band 10.30 – 10.59 GHz default duplex 168 MHz
Based on 7 MHz channels duplex range 59.5 – 283.5 MHz

A sub-band (Freq.table: rcinfo10_A_default:3)

Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]	Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]
L1	10302.75			L18	10362.25	U18	10530.25
L2	10306.25			L19	10365.75	U19	10533.75
L3	10309.75	U3	10477.75	L20	10369.25	U20	10537.25
L4	10313.25	U4	10481.25	L21	10372.75	U21	10540.75
L5	10316.75	U5	10484.75	L22	10376.25	U22	10544.25
L6	10320.25	U6	10488.25	L23	10379.75	U23	10547.75
L7	10323.75	U7	10491.75	L24	10383.25	U24	10551.25
L8	10327.25	U8	10495.25	L25	10386.75	U25	10554.75
L9	10330.75	U9	10498.75	L26	10390.25	U26	10558.25
L10	10334.25	U10	10502.25	L27	10393.75	U27	10561.75
L11	10337.75	U11	10505.75	L28	10397.25	U28	10565.25
L12	10341.25	U12	10509.25	L29	10400.75	U29	10568.75
L13	10344.75	U13	10512.75	L30	10404.25	U30	10572.25
L14	10348.25	U14	10516.25	L31	10407.75	U31	10575.75
L15	10351.75	U15	10519.75	L32	10411.25	U32	10579.25
L16	10355.25	U16	10523.25	L33	10414.75	U33	10582.75
L17	10358.75	U17	10526.75	L34	10418.25	U34	10586.25

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RAy2-10 - x**A**

Bandwidth: **7 MHz**

TX channel nominal frequencies
Band 10.30 – 10.59 GHz default duplex 168 MHz
VO-R/14/12.2012-17 duplex range 63 – 280 MHz

A sub-band (Freq.table: rcinfo10_A_default:3)

Ch.No.	Ch.No. old	Lower [MHz]	Ch.No.	Ch.No. old	Upper [MHz]	Ch.No.	Ch.No. old	Lower [MHz]	Ch.No.	Ch.No. old	Upper [MHz]
L1	x	10304.5				L10	CH2BB	10360.5	U10	CH8BB	10528.5
L2	CH0AA	10308.0				L11	CH3AA	10367.5	U11	CH9AA	10535.5
L3	CH1AA	10311.5	U3	CH7AA	10479.5	L12	CH3AB	10374.5	U12	CH9AB	10542.5
L4	CH1AB	10318.5	U4	CH7AB	10486.5	L13	CH3BA	10381.5	U13	CH9BA	10549.5
L5	CH1BA	10325.5	U5	CH7BA	10493.5	L14	CH3BB	10388.5	U14	CH9BB	10556.5
L6	CH1BB	10332.5	U6	CH7BB	10500.5	L15	CH4AA	10395.5	U15	CH10AA	10563.5
L7	CH2AA	10339.5	U7	CH8AA	10507.5	L16	CH4AB	10402.5	U16	CH10AB	10570.5
L8	CH2AB	10346.5	U8	CH8AB	10514.5	L17	CH4BA	10409.5	U17	CH10BA	10577.5
L9	CH2BA	10353.5	U9	CH8BA	10521.5	L18	CH4BB	10416.5	U18	CH10BB	10584.5

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RAy2-10 - x**A**

Bandwidth: **14 MHz**

TX channel nominal frequencies
Band 10.30 – 10.59 GHz default duplex 168 MHz
VO-R/14/12.2012-17 duplex range 70 – 273 MHz

A sub-band (Freq.table: rcinfo10_A_default:3)

Ch.No.	Ch.No. old	Lower [MHz]	Ch.No.	Ch.No. old	Upper [MHz]	Ch.No.	Ch.No. old	Lower [MHz]	Ch.No.	Ch.No. old	Upper [MHz]
L1	CH0A	10308.0									
L2	CH1A	10315.0	U2	CH7A	10483.0	L6	CH3A	10371.0	U6	CH9A	10539.0
L3	CH1B	10329.0	U3	CH7B	10497.0	L7	CH3B	10385.0	U7	CH9B	10553.0
L4	CH2A	10343.0	U4	CH8A	10511.0	L8	CH4A	10399.0	U8	CH10A	10567.0
L5	CH2B	10357.0	U5	CH8B	10525.0	L9	CH4B	10413.0	U9	CH10B	10581.0

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RAy2-10 – x**A**

Bandwidth: **28 MHz**

TX channel nominal frequencies
Band 10.30 – 10.59 GHz default duplex 168 MHz
VO-R/14/12.2012-17 duplex range 84 – 252 MHz

A sub-band (Freq.table: rcinfo10_A_default:3)

Ch.No.	Ch.No. old	Lower [MHz]	Ch.No.	Ch.No. old	Upper [MHz]	Ch.No.	Ch.No. old	Lower [MHz]	Ch.No.	Ch.No. old	Upper [MHz]
L1	CH1	10322	U1	CH7	10490	L3	CH3	10378	U3	CH9	10546
L2	CH2	10350	U2	CH8	10518	L4	CH4	10406	U4	CH10	10574

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RAy2-10 - x**A**

Bandwidth: **56 MHz**

TX channel nominal frequencies
Band 10.30 – 10.59 GHz default duplex 168 MHz
Based on 28 MHz channels duplex range 112 – 224 MHz

A sub-band (Freq.table: rcinfo10_A_default:3)

Ch.No.	Ch.No. old	Lower [MHz]	Ch.No.	Ch.No. old	Upper [MHz]	Ch.No.	Ch.No. old	Lower [MHz]	Ch.No.	Ch.No. old	Upper [MHz]
L1	CH1	10336	U1	CH7	10504	L2	CH3	10392	U2	CH9	10560

ver. 2.0

10.3.4. Nominal frequencies, band 10.15 – 10.65 GHz

RAy2-10 – x**B**	TX channel nominal frequencies Band 10.15 – 10.65 GHz duplex spacing 350 MHz
Bandwidth: **1.75 MHz**	Based on 3.5 MHz channels
B sub-band	(Freq.table: rcinfo10_B_default:3)

Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]	Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]
L1	10151.375	U1	10501.375	L43	10224.875	U43	10574.875
L2	10153.125	U2	10503.125	L44	10226.625	U44	10576.625
L3	10154.875	U3	10504.875	L45	10228.375	U45	10578.375
L4	10156.625	U4	10506.625	L46	10230.125	U46	10580.125
L5	10158.375	U5	10508.375	L47	10231.875	U47	10581.875
L6	10160.125	U6	10510.125	L48	10233.625	U48	10583.625
L7	10161.875	U7	10511.875	L49	10235.375	U49	10585.375
L8	10163.625	U8	10513.625	L50	10237.125	U50	10587.125
L9	10165.375	U9	10515.375	L51	10238.875	U51	10588.875
L10	10167.125	U10	10517.125	L52	10240.625	U52	10590.625
L11	10168.875	U11	10518.875	L53	10242.375	U53	10592.375
L12	10170.625	U12	10520.625	L54	10244.125	U54	10594.125
L13	10172.375	U13	10522.375	L55	10245.875	U55	10595.875
L14	10174.125	U14	10524.125	L56	10247.625	U56	10597.625
L15	10175.875	U15	10525.875	L57	10249.375	U57	10599.375
L16	10177.625	U16	10527.625	L58	10251.125	U58	10601.125
L17	10179.375	U17	10529.375	L59	10252.875	U59	10602.875
L18	10181.125	U18	10531.125	L60	10254.625	U60	10604.625
L19	10182.875	U19	10532.875	L61	10256.375	U61	10606.375
L20	10184.625	U20	10534.625	L62	10258.125	U62	10608.125
L21	10186.375	U21	10536.375	L63	10259.875	U63	10609.875
L22	10188.125	U22	10538.125	L64	10261.625	U64	10611.625
L23	10189.875	U23	10539.875	L65	10263.375	U65	10613.375
L24	10191.625	U24	10541.625	L66	10265.125	U66	10615.125
L25	10193.375	U25	10543.375	L67	10266.875	U67	10616.875
L26	10195.125	U26	10545.125	L68	10268.625	U68	10618.625
L27	10196.875	U27	10546.875	L69	10270.375	U69	10620.375
L28	10198.625	U28	10548.625	L70	10272.125	U70	10622.125
L29	10200.375	U29	10550.375	L71	10273.875	U71	10623.875
L30	10202.125	U30	10552.125	L72	10275.625	U72	10625.625
L31	10203.875	U31	10553.875	L73	10277.375	U73	10627.375
L32	10205.625	U32	10555.625	L74	10279.125	U74	10629.125
L33	10207.375	U33	10557.375	L75	10280.875	U75	10630.875
L34	10209.125	U34	10559.125	L76	10282.625	U76	10632.625
L35	10210.875	U35	10560.875	L77	10284.375	U77	10634.375
L36	10212.625	U36	10562.625	L78	10286.125	U78	10636.125
L37	10214.375	U37	10564.375	L79	10287.875	U79	10637.875
L38	10216.125	U38	10566.125	L80	10289.625	U80	10639.625
L39	10217.875	U39	10567.875	L81	10291.375	U81	10641.375
L40	10219.625	U40	10569.625	L82	10293.125	U82	10643.125
L41	10221.375	U41	10571.375	L83	10294.875	U83	10644.875
L42	10223.125	U42	10573.125	L84	10296.625	U84	10646.625

ver. 2.0

RAy2-10 – x**B**

Bandwidth: **3.5 MHz**

TX channel nominal frequencies
Band 10.15 – 10.65 GHz duplex spacing 350 MHz
CEPT/ERC/REC 12-05 E

B sub-band (Freq.table: rcinfo10_B_default:3)

Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]	Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]
L1	10152.25	U1	10502.25	L22	10225.75	U22	10575.75
L2	10155.75	U2	10505.75	L23	10229.25	U23	10579.25
L3	10159.25	U3	10509.25	L24	10232.75	U24	10582.75
L4	10162.75	U4	10512.75	L25	10236.25	U25	10586.25
L5	10166.25	U5	10516.25	L26	10239.75	U26	10589.75
L6	10169.75	U6	10519.75	L27	10243.25	U27	10593.25
L7	10173.25	U7	10523.25	L28	10246.75	U28	10596.75
L8	10176.75	U8	10526.75	L29	10250.25	U29	10600.25
L9	10180.25	U9	10530.25	L30	10253.75	U30	10603.75
L10	10183.75	U10	10533.75	L31	10257.25	U31	10607.25
L11	10187.25	U11	10537.25	L32	10260.75	U32	10610.75
L12	10190.75	U12	10540.75	L33	10264.25	U33	10614.25
L13	10194.25	U13	10544.25	L34	10267.75	U34	10617.75
L14	10197.75	U14	10547.75	L35	10271.25	U35	10621.25
L15	10201.25	U15	10551.25	L36	10274.75	U36	10624.75
L16	10204.75	U16	10554.75	L37	10278.25	U37	10628.25
L17	10208.25	U17	10558.25	L38	10281.75	U38	10631.75
L18	10211.75	U18	10561.75	L39	10285.25	U39	10635.25
L19	10215.25	U19	10565.25	L40	10288.75	U40	10638.75
L20	10218.75	U20	10568.75	L41	10292.25	U41	10642.25
L21	10222.25	U21	10572.25	L42	10295.75	U42	10645.75

ver. 2.0

RAy2-10 – x**B**

Bandwidth: **7 MHz**

TX channel nominal frequencies
Band 10.15 – 10.65 GHz duplex spacing 350 MHz
CEPT/ERC/REC 12-05 E

B sub-band (Freq.table: rcinfo10_B_default:3)

Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]	Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]
L1	10157.5	U1	10507.5	L11	10227.50	U11	10577.50
L2	10164.5	U2	10514.5	L12	10234.50	U12	10584.50
L3	10171.5	U3	10521.5	L13	10241.50	U13	10591.50
L4	10178.5	U4	10528.5	L14	10248.50	U14	10598.50
L5	10185.5	U5	10535.5	L15	10255.50	U15	10605.50
L6	10192.5	U6	10542.5	L16	10262.50	U16	10612.50
L7	10199.5	U7	10549.5	L17	10269.50	U17	10619.50
L8	10206.5	U8	10556.5	L18	10276.50	U18	10626.50
L9	10213.5	U9	10563.5	L19	10283.50	U19	10633.50
L10	10220.5	U10	10570.5	L20	10290.50	U20	10640.50

ver. 2.0

RAy2-10 – x**B**

TX channel nominal frequencies
Band 10.15 – 10.65 GHz duplex spacing 350 MHz

Bandwidth: **14 MHz**

CEPT/ERC/REC 12-05 E + 7 MHz based channels

B sub-band

(Freq.table: rcinfo10_B_default:3)

Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]	Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]
L1	**10161**	**U1**	**10511**	**L6**	**10231**	**U6**	**10581**
L1c	10168	U1c	10518	L6c	10238	U6c	10588
L2	**10175**	**U2**	**10525**	**L7**	**10245**	**U7**	**10595**
L2c	10182	U2c	10532	L7c	10252	U7c	10602
L3	**10189**	**U3**	**10539**	**L8**	**10259**	**U8**	**10609**
L3c	10196	U3c	10546	L8c	10266	U8c	10616
L4	**10203**	**U4**	**10553**	**L9**	**10273**	**U9**	**10623**
L4c	10210	U4c	10560	L9c	10280	U9c	10630
L5	**10217**	**U5**	**10567**	**L10**	**10287**	**U10**	**10637**
L5c	10224	U5c	10574				

ver. 2.0

RAy2-10 – x**B**

TX channel nominal frequencies
Band 10.15 – 10.65 GHz duplex spacing 350 MHz

Bandwidth: **20 MHz**

B sub-band

(Freq.table: rcinfo10_B_default:3)

Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]	Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]
L1	10175	U1	10525	L4	10235	U4	10585
L2	10195	U2	10545	L5	10255	U5	10605
L3	10215	U3	10565	L6	10275	U6	10625

ver. 1.0

RAy2-10 – x**B**

TX channel nominal frequencies
Band 10.15 – 10.65 GHz duplex spacing 350 MHz

Bandwidth: **28 MHz**

CEPT/ERC/REC 12-05 E

B sub-band

(Freq.table: rcinfo10_B_default:3)

Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]	Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]
L1	10168	U1	10518	L4	10252	U4	10602
L2	10196	U2	10546	L5	10280	U5	10630
L3	10224	U3	10574				

ver. 2.0

RAy2-10 – x**B**

TX channel nominal frequencies
Band 10.15 – 10.65 GHz duplex spacing 350 MHz

Bandwidth: **56 MHz**

CEPT/ERC/REC 12-05 E

B sub-band

(Freq.table: rcinfo10_B_default:3)

Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]	Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]
L1	10182	U1	10532	L3	10238	U3	10588
L2	10210	U2	10560	L4	10266	U4	10616

ver. 2.0

10.4. RAy2-11 A,B parameters

Note

The RAy2-11 units are not available yet

10.4.1. Output power

RAy2-11-xA, RAy2-11-xB	**TX power**	
Modulation	**Max**	**Min**
	[dBm]	**[dBm]**
QPSK	23	-5
16-QAM	20	-5
32-QAM	19	-5
64-QAM	18	-5
128-QAM	18	-5
256-QAM	17	-5

ver. 2.0

10.4.2. Radio parameters

RAy2-11-xA, RAy2-11-xB					Channel spacing 1.75 MHz; ACCP operation			
Modulation	**Raw Bit Rate**	**User Bit Rate**	RSS / SNR for BER 10^{-6}		**Co-channel rejection**		**Adjacent channel Selectivity**	
					1 dB	3 dB	1 dB	3 dB
			RSS	**SNR**	declared / limit	declared / limit	declared / limit	declared / limit
[-]	*[Mbps]*		*[dBm]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*
QPSK	3.1	3.1	-99	9.5	15 / 23	12 / 19	-12 / 0	-14 / -4
16-QAM	6.3	6.3	-93	15.0	22 / 30	20 / 26.5	-11 / -3	-13 / -7
32-QAM	7.8	7.8	-89	19.0	24 / 30	22 / 26.5	-10 / -3	-12 / -7
64-QAM	9.4	9.4	-88	20.5	29 / 30	26 / 26.5	-9 / -3	-10 / -7
128-QAM	11.0	11.0	-84	23.5	30 / 30	28 / 26.5	-8 / -3	-7 / -7

ver. 2.2

RAy2-11-xA, RAy2-11-xB					Channel spacing 3.5 MHz; ACCP operation			
Modulation	**Raw Bit Rate**	**User Bit Rate**	RSS / SNR for BER 10^{-6}		**Co-channel rejection**		**Adjacent channel Selectivity**	
					1 dB	3 dB	1 dB	3 dB
			RSS	**SNR**	declared / limit	declared / limit	declared / limit	declared / limit
[-]	*[Mbps]*		*[dBm]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*
QPSK	6	4.9	-97	9.5	15 / 23	12 / 19	-14 / 0	-16 / -4
16-QAM	12	9.6	-90	15.0	22 / 30	20 / 26.5	-13 / -3	-15 / -7
32-QAM	15	12.1	-87	18.5	24 / 30	22 / 26.5	-12 / -3	-14 / -7
64-QAM	18	14.3	-84	20.5	29 / 30	26 / 26.5	-11 / -3	-12 / -7
128-QAM	21	17.2	-81	23.5	30 / 30	28 / 26.5	-9 / -3	-8 / -7
256-QAM	24	19.7	-79	26.0	33 / 30	31 / 26.5	-5 / -3	-7 / -7

ver. 2.2

RAy2-11-xA, RAy2-11-xB					Channel spacing 7 MHz; ACCP operation			
Modulation	**Raw Bit Rate**	**User Bit Rate**	RSS / SNR for BER 10^{-6}		**Co-channel rejection**		**Adjacent channel Selectivity**	
					1 dB	3 dB	1 dB	3 dB
			RSS	**SNR**	declared / limit	declared / limit	declared / limit	declared / limit
[-]	*[Mbps]*		*[dBm]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*
QPSK	12	8.5	-95	8.5	15 / 23	12 / 19	-20 / 0	-22 / -4
16-QAM	24	17.2	-88	15.0	22 / 30	20 / 26.5	-18 / -3	-19 / -7
32-QAM	30	22.1	-85	18.5	24 / 37	22 / 33	-16 / -2	-18 / -6
64-QAM	36	29.7	-81	21.5	29 / 37	26 / 33	-14 / -2	-16 / -6
128-QAM	42	34.7	-79	25.0	32 / 37	30 / 33	-12 / -2	-14 / -6
256-QAM	49	40.7	-76	26.0	33 / 37	31 / 33	-10 / -2	-12 / -6

ver. 2.3

RAy2-11-xA, RAy2-11-xB			Channel spacing 14 MHz; ACCP operation					
Modulation	Raw Bit Rate	User Bit Rate	RSS / SNR for BER 10^{-6}		Co-channel rejection		Adjacent channel Selectivity	
					1 dB	3 dB	1 dB	3 dB
			RSS	SNR	declared / limit	declared / limit	declared / limit	declared / limit
[-]	*[Mbps]*		*[dBm]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*
QPSK	24	19.9	-93	8.5	14 / 23	12 / 19	-21 / 0	-23 / -4
16-QAM	48	38.8	-86	15.0	20 / 30	18 / 26.5	-19 / -3	-21 / -7
32-QAM	60	49.1	-82	18.5	26 / 33	23 / 29	-17 / -5	-19 / -9
64-QAM	72	62.3	-79	21.5	28 / 37	26 / 33	-14 / -2	-17 / -6
128-QAM	84	73.6	-75	25.0	30 / 37	28 / 33	-12 / -2	-14 / -6
256-QAM	96	81.2	-73	28.0	33 / 37	31 / 33	-10 / -2	-12 / -6

ver. 2.1

RAy2-11-xA, RAy2-11-xB			Channel spacing 28 / 30 MHz; ACCP operation					
Modulation	Raw Bit Rate	User Bit Rate	RSS / SNR for BER 10^{-6}		Co-channel rejection		Adjacent channel Selectivity	
					1 dB	3 dB	1 dB	3 dB
			RSS	SNR	declared / limit	declared / limit	declared / limit	declared / limit
[-]	*[Mbps]*		*[dBm]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*
QPSK	50	36.8	-91	7.5	12 / 23	10 / 19	-21 / 0	-23 / -4
16-QAM	100	80.9	-83	15.0	20 / 30	18 / 26.5	-18 / -3	-20 / -7
32-QAM	125	102.4	-79	18.5	24 / 33	22 / 29	-16 / -5	-19 / -9
64-QAM	150	129.8	-76	21.5	28 / 35	26 / 32	-12 / -5	-15 / -8
128QAM	175	155.5	-72	25.0	30 / 35	28 / 32	-9 / -5	-12 / -8
256-QAM	200	170.7	-70	26.5	33 / 35	31 / 32	-6 / -5	-9 / -8

ver. 2.0

RAy2-11-xA, RAy2-11-xB			Channel spacing 28 / 30 MHz; ACAP operation					
Modulation	Raw Bit Rate	User Bit Rate	RSS / SNR for BER 10^{-6}		Co-channel rejection		Adjacent channel Selectivity	
					1 dB	3 dB	1 dB	3 dB
			RSS	SNR	declared / limit	declared / limit	declared / limit	declared / limit
[-]	*[Mbps]*		*[dBm]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*
QPSK	52	38.3	-89.5	7.5	12 / 23	10 / 19	-15 / 0	-17 / -4
16-QAM	104	84.1	-82.5	15.0	20 / 30	18 / 26.5	-12 / -3	-14 / -7
32-QAM	130	106.4	-78.5	18.5	24 / 37	22 / 33	-10 / 3	-13 / -1
64-QAM	156	135.0	-75.5	21.5	28 / 37	26 / 33	-6 / 3	-9 / -1
128QAM	182	161.7	-71.5	25.0	30 / 37	28 / 33	-3 / 3	-6 / -1
256-QAM	208	185.2	-68.5	26.5	33 / 41	31 / 38	0 / 10	-3 / 7

ver. 2.1

RAy2-11-xA, RAy2-11-xB			Channel spacing 40 MHz; ACCP operation					
Modula-tion	Raw Bit Rate	User Bit Rate	RSS / SNR for BER 10^{-6}		Co-channel rejection		Adjacent channel Selectivity	
					1 dB	3 dB	1 dB	3 dB
			RSS	SNR	declared / limit	declared / limit	declared / limit	declared / limit
[-]	*[Mbps]*		*[dBm]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*
QPSK.	68	50.1	-88	7.5	12 / 33	10 / 29	-22 / -4	-24 / -8
16-QAM	136	110.0	-81	15.0	19 / 33	17 / 29	-18 / -4	-21 / -8
32-QAM	170	139.2	-77	18.5	24 / 33	21 / 29	-16 / -4	-19 / -8
64-QAM	204	176.5	-74	21.5	27 / 33	25 / 29	-14 / -4	-16 / -8
128QAM	238	211.4	-70	25.0	30 / 37	28 / 33	-10 / -4	-12 / -8
256-QAM	272	232.1	-68	26.5	33 / 37	30 / 33	-8 / -4	-10 / -8

ver. 2.0

RAy2-11-xA, RAy2-11-xB			Channel spacing 56 MHz; ACCP operation					
Modula-tion	Raw Bit Rate	User Bit Rate	RSS / SNR for BER 10^{-6}		Co-channel rejection		Adjacent channel Selectivity	
					1 dB	3 dB	1 dB	3 dB
			RSS	SNR	declared / limit	declared / limit	declared / limit	declared / limit
[-]	*[Mbps]*		*[dBm]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*
QPSK	99	72.9	-87	7.5	12 / 23	10 / 19	-26 / 0	-28 / -4
16-QAM	198	160.2	-80	15.0	19 / 30	17 / 26.5	-19 / -3	-21 / -7
32-QAM	247.5	202.7	-76	18.5	24 / 33	22 / 29	-15 / -5	-17 / -9
64-QAM	297	256.9	-73	21.5	27 / 35	25 / 32	-14 / -5	-16 / -8
128QAM	346.5	303.7	-69	25.0	30 / 35	28 / 32	-10 / -5	-12 / -8
256-QAM	396	337.7	-67	26.5	33 / 35	30 / 32	-8 / -5	-10 / -8

ver. 2.0

RAy2-11-xA, RAy2-11-xB			Channel spacing 56 MHz TO; ACCP operation					
Modula-tion	Raw Bit Rate	User Bit Rate	RSS / SNR for BER 10^{-6}		Co-channel rejection		Adjacent channel Selectivity	
					1 dB	3 dB	1 dB	3 dB
			RSS	SNR	declared / limit	declared / limit	declared / limit	declared / limit
[-]	*[Mbps]*		*[dBm]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*
QPSK	99	85.8	-85	10.0	13 / 23	11 / 19	-24 / 0	-26 / -4
16-QAM	198	169.9	-78	16.0	20 / 30	18 / 26.5	-18 / -3	-20 / -7
32-QAM	247.5	206.2	-74	19.0	25 / 33	23 / 29	-14 / -5	-15 / -9
64-QAM	297	268.1	-70	22.5	29 / 35	26 / 32	-9 / -5	-11 / -8
128QAM	346.5	309.0	-67	25.5	32 / 35	29 / 32	-8 / -5	-10 / -8
256-QAM	396	358.9	-64	27.5	35 / 35	32 / 32	-7 / -5	-8 / -8

ver. 2.1

10.4.3. Nominal frequencies, duplex 490 MHz

RAy2-11 - xA**, RAy2-11 - x**B

TX channel nominal frequencies
Band 10.7 – 11.7 GHz, duplex spacing 490 MHz

Bandwidth: **1.75 MHz**

Channel arrangements based on 28 MHz channels

A sub-band (Freq.table: rcinfo11_A_490_default:11)

Ch.No.	Lower [MHz]	Upper [MHz]	Ch.No.	Lower [MHz]	Upper [MHz]
1	10709.875	11199.875	74	10837.625	11327.625
2	10711.625	11201.625	75	10839.375	11329.375
3	10713.375	11203.375	76	10841.125	11331.125
4	10715.125	11205.125	77	10842.875	11332.875
5	10716.875	11206.875	78	10844.625	11334.625
6	10718.625	11208.625	79	10846.375	11336.375
7	10720.375	11210.375	80	10848.125	11338.125
8	10722.125	11212.125	81	10849.875	11339.875
9	10723.875	11213.875	82	10851.625	11341.625
10	10725.625	11215.625	83	10853.375	11343.375
11	10727.375	11217.375	84	10855.125	11345.125
12	10729.125	11219.125	85	10856.875	11346.875
13	10730.875	11220.875	86	10858.625	11348.625
14	10732.625	11222.625	87	10860.375	11350.375
15	10734.375	11224.375	88	10862.125	11352.125
16	10736.125	11226.125	89	10863.875	11353.875
17	10737.875	11227.875	90	10865.625	11355.625
18	10739.625	11229.625	91	10867.375	11357.375
19	10741.375	11231.375	92	10869.125	11359.125
20	10743.125	11233.125	93	10870.875	11360.875
21	10744.875	11234.875	94	10872.625	11362.625
22	10746.625	11236.625	95	10874.375	11364.375
23	10748.375	11238.375	96	10876.125	11366.125
24	10750.125	11240.125	97	10877.875	11367.875
25	10751.875	11241.875	98	10879.625	11369.625
26	10753.625	11243.625	99	10881.375	11371.375
27	10755.375	11245.375	100	10883.125	11373.125
28	10757.125	11247.125	101	10884.875	11374.875
29	10758.875	11248.875	102	10886.625	11376.625
30	10760.625	11250.625	103	10888.375	11378.375
31	10762.375	11252.375	104	10890.125	11380.125
32	10764.125	11254.125	105	10891.875	11381.875
33	10765.875	11255.875	106	10893.625	11383.625
34	10767.625	11257.625	107	10895.375	11385.375
35	10769.375	11259.375	108	10897.125	11387.125
36	10771.125	11261.125	109	10898.875	11388.875
37	10772.875	11262.875	110	10900.625	11390.625
38	10774.625	11264.625	111	10902.375	11392.375
39	10776.375	11266.375	112	10904.125	11394.125
40	10778.125	11268.125	113	10905.875	11395.875
41	10779.875	11269.875	114	10907.625	11397.625
42	10781.625	11271.625	115	10909.375	11399.375
43	10783.375	11273.375	116	10911.125	11401.125
44	10785.125	11275.125	117	10912.875	11402.875
45	10786.875	11276.875	118	10914.625	11404.625
46	10788.625	11278.625	119	10916.375	11406.375
47	10790.375	11280.375	120	10918.125	11408.125
48	10792.125	11282.125	121	10919.875	11409.875
49	10793.875	11283.875	122	10921.625	11411.625
50	10795.625	11285.625	123	10923.375	11413.375
51	10797.375	11287.375	124	10925.125	11415.125
52	10799.125	11289.125	125	10926.875	11416.875
53	10800.875	11290.875	126	10928.625	11418.625
54	10802.625	11292.625	127	10930.375	11420.375
55	10804.375	11294.375	128	10932.125	11422.125
56	10806.125	11296.125	129	10933.875	11423.875
57	10807.875	11297.875	130	10935.625	11425.625
58	10809.625	11299.625	131	10937.375	11427.375
59	10811.375	11301.375	132	10939.125	11429.125
60	10813.125	11303.125	133	10940.875	11430.875
61	10814.875	11304.875	134	10942.625	11432.625
62	10816.625	11306.625	135	10944.375	11434.375
63	10818.375	11308.375	136	10946.125	11436.125
64	10820.125	11310.125	137	10947.875	11437.875
65	10821.875	11311.875	138	10949.625	11439.625
66	10823.625	11313.625	139	10951.375	11441.375
67	10825.375	11315.375	140	10953.125	11443.125
68	10827.125	11317.125	141	10954.875	11444.875
69	10828.875	11318.875	142	10956.625	11446.625
70	10830.625	11320.625	143	10958.375	11448.375
71	10832.375	11322.375	144	10960.125	11450.125
72	10834.125	11324.125	145	10961.875	11451.875
73	10835.875	11325.875	146	10963.625	11453.625

B sub-band (Freq.table: rcinfo11_B_490_default:11)

Ch.No.	Lower [MHz]	Upper [MHz]	Ch.No.	Lower [MHz]	Upper [MHz]
136	10946.125	11436.125	209	11073.875	11563.875
137	10947.875	11437.875	210	11075.625	11565.625
138	10949.625	11439.625	211	11077.375	11567.375
139	10951.375	11441.375	212	11079.125	11569.125
140	10953.125	11443.125	213	11080.875	11570.875
141	10954.875	11444.875	214	11082.625	11572.625
142	10956.625	11446.625	215	11084.375	11574.375
143	10958.375	11448.375	216	11086.125	11576.125
144	10960.125	11450.125	217	11087.875	11577.875
145	10961.875	11451.875	218	11089.625	11579.625
146	10963.625	11453.625	219	11091.375	11581.375
147	10965.375	11455.375	220	11093.125	11583.125
148	10967.125	11457.125	221	11094.875	11584.875
149	10968.875	11458.875	222	11096.625	11586.625
150	10970.625	11460.625	223	11098.375	11588.375
151	10972.375	11462.375	224	11100.125	11590.125
152	10974.125	11464.125	225	11101.875	11591.875
153	10975.875	11465.875	226	11103.625	11593.625
154	10977.625	11467.625	227	11105.375	11595.375
155	10979.375	11469.375	228	11107.125	11597.125
156	10981.125	11471.125	229	11108.875	11598.875
157	10982.875	11472.875	230	11110.625	11600.625
158	10984.625	11474.625	231	11112.375	11602.375
159	10986.375	11476.375	232	11114.125	11604.125
160	10988.125	11478.125	233	11115.875	11605.875
161	10989.875	11479.875	234	11117.625	11607.625
162	10991.625	11481.625	235	11119.375	11609.375
163	10993.375	11483.375	236	11121.125	11611.125
164	10995.125	11485.125	237	11122.875	11612.875
165	10996.875	11486.875	238	11124.625	11614.625
166	10998.625	11488.625	239	11126.375	11616.375
167	11000.375	11490.375	240	11128.125	11618.125
168	11002.125	11492.125	241	11129.875	11619.875
169	11003.875	11493.875	242	11131.625	11621.625
170	11005.625	11495.625	243	11133.375	11623.375
171	11007.375	11497.375	244	11135.125	11625.125
172	11009.125	11499.125	245	11136.875	11626.875
173	11010.875	11500.875	246	11138.625	11628.625
174	11012.625	11502.625	247	11140.375	11630.375
175	11014.375	11504.375	248	11142.125	11632.125
176	11016.125	11506.125	249	11143.875	11633.875
177	11017.875	11507.875	250	11145.625	11635.625
178	11019.625	11509.625	251	11147.375	11637.375
179	11021.375	11511.375	252	11149.125	11639.125
180	11023.125	11513.125	253	11150.875	11640.875
181	11024.875	11514.875	254	11152.625	11642.625
182	11026.625	11516.625	255	11154.375	11644.375
183	11028.375	11518.375	256	11156.125	11646.125
184	11030.125	11520.125	257	11157.875	11647.875
185	11031.875	11521.875	258	11159.625	11649.625
186	11033.625	11523.625	259	11161.375	11651.375
187	11035.375	11525.375	260	11163.125	11653.125
188	11037.125	11527.125	261	11164.875	11654.875
189	11038.875	11528.875	262	11166.625	11656.625
190	11040.625	11530.625	263	11168.375	11658.375
191	11042.375	11532.375	264	11170.125	11660.125
192	11044.125	11534.125	265	11171.875	11661.875
193	11045.875	11535.875	266	11173.625	11663.625
194	11047.625	11537.625	267	11175.375	11665.375
195	11049.375	11539.375	268	11177.125	11667.125
196	11051.125	11541.125	269	11178.875	11668.875
197	11052.875	11542.875	270	11180.625	11670.625
198	11054.625	11544.625	271	11182.375	11672.375
199	11056.375	11546.375	272	11184.125	11674.125
200	11058.125	11548.125			
201	11059.875	11549.875			
202	11061.625	11551.625			
203	11063.375	11553.375			
204	11065.125	11555.125			
205	11066.875	11556.875			
206	11068.625	11558.625			
207	11070.375	11560.375			
208	11072.125	11562.125			

ver. 2.1

RAy2-11 - xA**, RAy2-11 - x**B

TX channel nominal frequencies
Band 10.7 – 11.7 GHz, duplex spacing 490 MHz

Bandwidth: **3.5 MHz**

Channel arrangements based on 28 MHz channels

A sub-band (Freq.table: rcinfo11_A_490_default:11)

Ch.No.	Lower [MHz]	Upper [MHz]	Ch.No.	Lower [MHz]	Upper [MHz]
1	10710.75	11200.75	38	10840.25	11330.25
2	10714.25	11204.25	39	10843.75	11333.75
3	10717.75	11207.75	40	10847.25	11337.25
4	10721.25	11211.25	41	10850.75	11340.75
5	10724.75	11214.75	42	10854.25	11344.25
6	10728.25	11218.25	43	10857.75	11347.75
7	10731.75	11221.75	44	10861.25	11351.25
8	10735.25	11225.25	45	10864.75	11354.75
9	10738.75	11228.75	46	10868.25	11358.25
10	10742.25	11232.25	47	10871.75	11361.75
11	10745.75	11235.75	48	10875.25	11365.25
12	10749.25	11239.25	49	10878.75	11368.75
13	10752.75	11242.75	50	10882.25	11372.25
14	10756.25	11246.25	51	10885.75	11375.75
15	10759.75	11249.75	52	10889.25	11379.25
16	10763.25	11253.25	53	10892.75	11382.75
17	10766.75	11256.75	54	10896.25	11386.25
18	10770.25	11260.25	55	10899.75	11389.75
19	10773.75	11263.75	56	10903.25	11393.25
20	10777.25	11267.25	57	10906.75	11396.75
21	10780.75	11270.75	58	10910.25	11400.25
22	10784.25	11274.25	59	10913.75	11403.75
23	10787.75	11277.75	60	10917.25	11407.25
24	10791.25	11281.25	61	10920.75	11410.75
25	10794.75	11284.75	62	10924.25	11414.25
26	10798.25	11288.25	63	10927.75	11417.75
27	10801.75	11291.75	64	10931.25	11421.25
28	10805.25	11295.25	65	10934.75	11424.75
29	10808.75	11298.75	66	10938.25	11428.25
30	10812.25	11302.25	67	10941.75	11431.75
31	10815.75	11305.75	68	10945.25	11435.25
32	10819.25	11309.25	69	10948.75	11438.75
33	10822.75	11312.75	70	10952.25	11442.25
34	10826.25	11316.25	71	10955.75	11445.75
35	10829.75	11319.75	72	10959.25	11449.25
36	10833.25	11323.25	73	10962.75	11452.75
37	10836.75	11326.75			

B sub-band (Freq.table: rcinfo11_B_490_default:11)

Ch.No.	Lower [MHz]	Upper [MHz]	Ch.No.	Lower [MHz]	Upper [MHz]
69	10948.75	11438.75	106	11078.25	11568.25
70	10952.25	11442.25	107	11081.75	11571.75
71	10955.75	11445.75	108	11085.25	11575.25
72	10959.25	11449.25	109	11088.75	11578.75
73	10962.75	11452.75	110	11092.25	11582.25
74	10966.25	11456.25	111	11095.75	11585.75
75	10969.75	11459.75	112	11099.25	11589.25
76	10973.25	11463.25	113	11102.75	11592.75
77	10976.75	11466.75	114	11106.25	11596.25
78	10980.25	11470.25	115	11109.75	11599.75
79	10983.75	11473.75	116	11113.25	11603.25
80	10987.25	11477.25	117	11116.75	11606.75
81	10990.75	11480.75	118	11120.25	11610.25
82	10994.25	11484.25	119	11123.75	11613.75
83	10997.75	11487.75	120	11127.25	11617.25
84	11001.25	11491.25	121	11130.75	11620.75
85	11004.75	11494.75	122	11134.25	11624.25
86	11008.25	11498.25	123	11137.75	11627.75
87	11011.75	11501.75	124	11141.25	11631.25
88	11015.25	11505.25	125	11144.75	11634.75
89	11018.75	11508.75	126	11148.25	11638.25
90	11022.25	11512.25	127	11151.75	11641.75
91	11025.75	11515.75	128	11155.25	11645.25
92	11029.25	11519.25	129	11158.75	11648.75
93	11032.75	11522.75	130	11162.25	11652.25
94	11036.25	11526.25	131	11165.75	11655.75
95	11039.75	11529.75	132	11169.25	11659.25
96	11043.25	11533.25	133	11172.75	11662.75
97	11046.75	11536.75	134	11176.25	11666.25
98	11050.25	11540.25	135	11179.75	11669.75
99	11053.75	11543.75	136	11183.25	11673.25
100	11057.25	11547.25			
101	11060.75	11550.75			
102	11064.25	11554.25			
103	11067.75	11557.75			
104	11071.25	11561.25			
105	11074.75	11564.75			

ver. 2.1

RAy2-11 - xA, **RAy2-11 - x**B

TX channel nominal frequencies
Band 10.7 – 11.7 GHz, duplex spacing 490 MHz

Bandwidth: **7 MHz**

Channel arrangements based on 28 MHz channels

A sub-band (Freq.table: rcinfo11_A_490_default:11)			**B** sub-band (Freq.table: rcinfo11_B_490_default:11)		
Ch.No.	Lower [MHz]	Upper [MHz]	Ch.No.	Lower [MHz]	Upper [MHz]
1	10712.5	11202.5	35	10950.5	11440.5
2	10719.5	11209.5	36	10957.5	11447.5
3	10726.5	11216.5	37	10964.5	11454.5
4	10733.5	11223.5	38	10971.5	11461.5
5	10740.5	11230.5	39	10978.5	11468.5
6	10747.5	11237.5	40	10985.5	11475.5
7	10754.5	11244.5	41	10992.5	11482.5
8	10761.5	11251.5	42	10999.5	11489.5
9	10768.5	11258.5	43	11006.5	11496.5
10	10775.5	11265.5	44	11013.5	11503.5
11	10782.5	11272.5	45	11020.5	11510.5
12	10789.5	11279.5	46	11027.5	11517.5
13	10796.5	11286.5	47	11034.5	11524.5
14	10803.5	11293.5	48	11041.5	11531.5
15	10810.5	11300.5	49	11048.5	11538.5
16	10817.5	11307.5	50	11055.5	11545.5
17	10824.5	11314.5	51	11062.5	11552.5
18	10831.5	11321.5	52	11069.5	11559.5
19	10838.5	11328.5	53	11076.5	11566.5
20	10845.5	11335.5	54	11083.5	11573.5
21	10852.5	11342.5	55	11090.5	11580.5
22	10859.5	11349.5	56	11097.5	11587.5
23	10866.5	11356.5	57	11104.5	11594.5
24	10873.5	11363.5	58	11111.5	11601.5
25	10880.5	11370.5	59	11118.5	11608.5
26	10887.5	11377.5	60	11125.5	11615.5
27	10894.5	11384.5	61	11132.5	11622.5
28	10901.5	11391.5	62	11139.5	11629.5
29	10908.5	11398.5	63	11146.5	11636.5
30	10915.5	11405.5	64	11153.5	11643.5
31	10922.5	11412.5	65	11160.5	11650.5
32	10929.5	11419.5	66	11167.5	11657.5
33	10936.5	11426.5	67	11174.5	11664.5
34	10943.5	11433.5	68	11181.5	11671.5
35	10950.5	11440.5			
36	10957.5	11447.5			

ver. 2.1

RAy2-11 - xA**, RAy2-11 –** x**B**

TX channel nominal frequencies
Band 10.7 – 11.7 GHz, duplex spacing 490 MHz

Bandwidth: **14 MHz**

Channel arrangements based on 28 MHz channels

A sub-band (Freq.table: rcinfo11_A_490_default:11)			**B** sub-band (Freq.table: rcinfo11_B_490_default:11)		
Ch.No.	Lower [MHz]	Upper [MHz]	Ch.No.	Lower [MHz]	Upper [MHz]
1	10716	11206	18	10954	11444
2	10730	11220	19	10968	11458
3	10744	11234	20	10982	11472
4	10758	11248	21	10996	11486
5	10772	11262	22	11010	11500
6	10786	11276	23	11024	11514
7	10800	11290	24	11038	11528
8	10814	11304	25	11052	11542
9	10828	11318	26	11066	11556
10	10842	11332	27	11080	11570
11	10856	11346	28	11094	11584
12	10870	11360	29	11108	11598
13	10884	11374	30	11122	11612
14	10898	11388	31	11136	11626
15	10912	11402	32	11150	11640
16	10926	11416	33	11164	11654
17	10940	11430	34	11178	11668
18	10954	11444			

ver. 2.1

RAy2-11 - xA**, RAy2-11 –** x**B**

TX channel nominal frequencies
Band 10.7 – 11.7 GHz, duplex spacing 490 MHz

Bandwidth: **28 MHz**

CEPT Rec. 12-06, Annex B.2

A sub-band (Freq.table: rcinfo11_A_490_default:11)			**B** sub-band (Freq.table: rcinfo11_B_490_default:11)		
Ch.No.	Lower [MHz]	Upper [MHz]	Ch.No.	Lower [MHz]	Upper [MHz]
1	10723	11213	10	10975	11465
2	10751	11241	11	11003	11493
3	10779	11269	12	11031	11521
4	10807	11297	13	11059	11549
5	10835	11325	14	11087	11577
6	10863	11353	15	11115	11605
7	10891	11381	16	11143	11633
8	10919	11409	17	11171	11661
9	10947	11437			

ver. 2.1

RAy2-11 - xA, **RAy2-11 – x**B

TX channel nominal frequencies
Band 10.7 – 11.7 GHz, duplex spacing 490 MHz

Bandwidth: **30 MHz** IC

A sub-band (Freq.table: rcinfo11_A_490_default:11)			**B** sub-band (Freq.table: rcinfo11_B_490_default:11)		
Ch.No.	Lower [MHz]	Upper [MHz]	Ch.No.	Lower [MHz]	Upper [MHz]
1	10725	11215	9	10965	11455
2	10755	11245	10	10995	11485
3	10785	11275	11	11025	11515
4	10815	11305	12	11055	11545
5	10845	11335	13	11085	11575
6	10875	11365	14	11115	11605
7	10905	11395	15	11145	11635
8	10935	11425	16	11175	11665

ver. 1.0

RAy2-11 - xA, **RAy2-11 – x**B

TX channel nominal frequencies
Band 10.7 – 11.7 GHz, duplex spacing 490 MHz

Bandwidth: **40 MHz (ITU)** ITU-R F.387 rec.1.2, CEPT 12-06 Annex B.1

A sub-band (Freq.table: rcinfo11_A_490_default:11)			**B** sub-band (Freq.table: rcinfo11_B_490_default:11)		
Ch.No.	Lower [MHz]	Upper [MHz]	Ch.No.	Lower [MHz]	Upper [MHz]
1	10735	11225	7	10975	11465
2	10775	11265	8	11015	11505
3	10815	11305	9	11055	11545
4	10855	11345	10	11095	11585
5	10895	11385	11	11135	11625
6	10935	11425	12	11175	11665

ver. 1.1

RAy2-11 - xA, **RAy2-11 – x**B

TX channel nominal frequencies
Band 10.7 – 11.7 GHz, duplex spacing 490 MHz

Bandwidth: **40 MHz (ACMA)** ACMA

A sub-band (Freq.table: rcinfo11_A_490_default:11)			**B** sub-band (Freq.table: rcinfo11_B_490_default:11)		
Ch.No.	Lower [MHz]	Upper [MHz]	Ch.No.	Lower [MHz]	Upper [MHz]
2	10755	11245	8	10995	11485
3	10795	11285	9	11035	11525
4	10835	11325	10	11075	11565
5	10875	11365	11	11115	11605
6	10915	11405	12	11155	11645

ver. 1.1

RAy2-11 - x**A, RAy2-11 –** x**B**	TX channel nominal frequencies Band 10.7 – 11.7 GHz, duplex spacing 490 MHz
Bandwidth: **56 MHz**	CEPT 12-06, Annex C

A sub-band (Freq.table: rcinfo11_A_490_default:11)			**B** sub-band (Freq.table: rcinfo11_B_490_default:11)		
Ch.No.	Lower [MHz]	Upper [MHz]	Ch.No.	Lower [MHz]	Upper [MHz]
1	10737	11227	10	10989	11479
2	10765	11255	11	11017	11507
3	10793	11283	12	11045	11535
4	10821	11311	13	11073	11563
5	10849	11339	14	11101	11591
6	10877	11367	15	11129	11619
7	10905	11395	16	11157	11647
8	10933	11423			

ver. 2.1

RAy2-11 - x**A, RAy2-11 –** x**B**	TX channel nominal frequencies Band 10.7 – 11.7 GHz, duplex spacing 490 MHz
Bandwidth: **56 MHz (CS 80)**	CEPT 12-06, Annex C

A sub-band (Freq.table: rcinfo11_A_490_default:11)			**B** sub-band (Freq.table: rcinfo11_B_490_default:11)		
Ch.No.	Lower [MHz]	Upper [MHz]	Ch.No.	Lower [MHz]	Upper [MHz]
1	10755	11245	7	10995	11485
2	10795	11285	8	11035	11525
3	10835	11325	9	11075	11565
4	10875	11365	10	11115	11605
5	10915	11405	11	11155	11645

ver. 1.0

10.4.4. Nominal frequencies, duplex 530 MHz

RAy2-11 - xA**, RAy2-11 - x**B

TX channel nominal frequencies
Band 10.7 – 11.7 GHz, duplex spacing 530 MHz
Channel arrangements based on 28 MHz channels

Bandwidth: **1.75 MHz**

A sub-band (Freq.table: rcinfo11_A_530:11)						**B** sub-band (Freq.table: rcinfo11_B_530:11)					
Ch.No.	Lower [MHz]	Upper [MHz]	Ch.No.	Lower [MHz]	Upper [MHz]	Ch.No.	Lower [MHz]	Upper [MHz]	Ch.No.	Lower [MHz]	Upper [MHz]
1	10709.875	11239.875	63	10818.375	11348.375	136	10946.125	11476.125	198	11054.625	11584.625
2	10711.625	11241.625	64	10820.125	11350.125	137	10947.875	11477.875	199	11056.375	11586.375
3	10713.375	11243.375	65	10821.875	11351.875	138	10949.625	11479.625	200	11058.125	11588.125
4	10715.125	11245.125	66	10823.625	11353.625	139	10951.375	11481.375	201	11059.875	11589.875
5	10716.875	11246.875	67	10825.375	11355.375	140	10953.125	11483.125	202	11061.625	11591.625
6	10718.625	11248.625	68	10827.125	11357.125	141	10954.875	11484.875	203	11063.375	11593.375
7	10720.375	11250.375	69	10828.875	11358.875	142	10956.625	11486.625	204	11065.125	11595.125
8	10722.125	11252.125	70	10830.625	11360.625	143	10958.375	11488.375	205	11066.875	11596.875
9	10723.875	11253.875	71	10832.375	11362.375	144	10960.125	11490.125	206	11068.625	11598.625
10	10725.625	11255.625	72	10834.125	11364.125	145	10961.875	11491.875	207	11070.375	11600.375
11	10727.375	11257.375	73	10835.875	11365.875	146	10963.625	11493.625	208	11072.125	11602.125
12	10729.125	11259.125	74	10837.625	11367.625	147	10965.375	11495.375	209	11073.875	11603.875
13	10730.875	11260.875	75	10839.375	11369.375	148	10967.125	11497.125	210	11075.625	11605.625
14	10732.625	11262.625	76	10841.125	11371.125	149	10968.875	11498.875	211	11077.375	11607.375
15	10734.375	11264.375	77	10842.875	11372.875	150	10970.625	11500.625	212	11079.125	11609.125
16	10736.125	11266.125	78	10844.625	11374.625	151	10972.375	11502.375	213	11080.875	11610.875
17	10737.875	11267.875	79	10846.375	11376.375	152	10974.125	11504.125	214	11082.625	11612.625
18	10739.625	11269.625	80	10848.125	11378.125	153	10975.875	11505.875	215	11084.375	11614.375
19	10741.375	11271.375	81	10849.875	11379.875	154	10977.625	11507.625	216	11086.125	11616.125
20	10743.125	11273.125	82	10851.625	11381.625	155	10979.375	11509.375	217	11087.875	11617.875
21	10744.875	11274.875	83	10853.375	11383.375	156	10981.125	11511.125	218	11089.625	11619.625
22	10746.625	11276.625	84	10855.125	11385.125	157	10982.875	11512.875	219	11091.375	11621.375
23	10748.375	11278.375	85	10856.875	11386.875	158	10984.625	11514.625	220	11093.125	11623.125
24	10750.125	11280.125	86	10858.625	11388.625	159	10986.375	11516.375	221	11094.875	11624.875
25	10751.875	11281.875	87	10860.375	11390.375	160	10988.125	11518.125	222	11096.625	11626.625
26	10753.625	11283.625	88	10862.125	11392.125	161	10989.875	11519.875	223	11098.375	11628.375
27	10755.375	11285.375	89	10863.875	11393.875	162	10991.625	11521.625	224	11100.125	11630.125
28	10757.125	11287.125	90	10865.625	11395.625	163	10993.375	11523.375	225	11101.875	11631.875
29	10758.875	11288.875	91	10867.375	11397.375	164	10995.125	11525.125	226	11103.625	11633.625
30	10760.625	11290.625	92	10869.125	11399.125	165	10996.875	11526.875	227	11105.375	11635.375
31	10762.375	11292.375	93	10870.875	11400.875	166	10998.625	11528.625	228	11107.125	11637.125
32	10764.125	11294.125	94	10872.625	11402.625	167	11000.375	11530.375	229	11108.875	11638.875
33	10765.875	11295.875	95	10874.375	11404.375	168	11002.125	11532.125	230	11110.625	11640.625
34	10767.625	11297.625	96	10876.125	11406.125	169	11003.875	11533.875	231	11112.375	11642.375
35	10769.375	11299.375	97	10877.875	11407.875	170	11005.625	11535.625	232	11114.125	11644.125
36	10771.125	11301.125	98	10879.625	11409.625	171	11007.375	11537.375	233	11115.875	11645.875
37	10772.875	11302.875	99	10881.375	11411.375	172	11009.125	11539.125	234	11117.625	11647.625
38	10774.625	11304.625	100	10883.125	11413.125	173	11010.875	11540.875	235	11119.375	11649.375
39	10776.375	11306.375	101	10884.875	11414.875	174	11012.625	11542.625	236	11121.125	11651.125
40	10778.125	11308.125	102	10886.625	11416.625	175	11014.375	11544.375	237	11122.875	11652.875
41	10779.875	11309.875	103	10888.375	11418.375	176	11016.125	11546.125	238	11124.625	11654.625
42	10781.625	11311.625	104	10890.125	11420.125	177	11017.875	11547.875	239	11126.375	11656.375
43	10783.375	11313.375	105	10891.875	11421.875	178	11019.625	11549.625	240	11128.125	11658.125
44	10785.125	11315.125	106	10893.625	11423.625	179	11021.375	11551.375	241	11129.875	11659.875
45	10786.875	11316.875	107	10895.375	11425.375	180	11023.125	11553.125	242	11131.625	11661.625
46	10788.625	11318.625	108	10897.125	11427.125	181	11024.875	11554.875	243	11133.375	11663.375
47	10790.375	11320.375	109	10898.875	11428.875	182	11026.625	11556.625	244	11135.125	11665.125
48	10792.125	11322.125	110	10900.625	11430.625	183	11028.375	11558.375	245	11136.875	11666.875
49	10793.875	11323.875	111	10902.375	11432.375	184	11030.125	11560.125	246	11138.625	11668.625
50	10795.625	11325.625	112	10904.125	11434.125	185	11031.875	11561.875	247	11140.375	11670.375
51	10797.375	11327.375	113	10905.875	11435.875	186	11033.625	11563.625	248	11142.125	11672.125
52	10799.125	11329.125	114	10907.625	11437.625	187	11035.375	11565.375	249	11143.875	11673.875
53	10800.875	11330.875	115	10909.375	11439.375	188	11037.125	11567.125	250	11145.625	11675.625
54	10802.625	11332.625	116	10911.125	11441.125	189	11038.875	11568.875	251	11147.375	11677.375
55	10804.375	11334.375	117	10912.875	11442.875	190	11040.625	11570.625	252	11149.125	11679.125
56	10806.125	11336.125	118	10914.625	11444.625	191	11042.375	11572.375	253	11150.875	11680.875
57	10807.875	11337.875	119	10916.375	11446.375	192	11044.125	11574.125	254	11152.625	11682.625
58	10809.625	11339.625	120	10918.125	11448.125	193	11045.875	11575.875	255	11154.375	11684.375
59	10811.375	11341.375	121	10919.875	11449.875	194	11047.625	11577.625	256	11156.125	11686.125
60	10813.125	11343.125	122	10921.625	11451.625	195	11049.375	11579.375			
61	10814.875	11344.875	123	10923.375	11453.375	196	11051.125	11581.125			
62	10816.625	11346.625				197	11052.875	11582.875			

ver. 2.1

RAy2-11 - xA**, RAy2-11 - x**B

TX channel nominal frequencies
Band 10.7 – 11.7 GHz, duplex spacing 530 MHz

Bandwidth: **3.5 MHz**

Channel arrangements based on 28 MHz channels

A sub-band (Freq.table: rcinfo11_A_530:11)						**B** sub-band (Freq.table: rcinfo11_B_530:11)					
Ch.No.	Lower [MHz]	Upper [MHz]	Ch.No.	Lower [MHz]	Upper [MHz]	Ch.No.	Lower [MHz]	Upper [MHz]	Ch.No.	Lower [MHz]	Upper [MHz]
1	10710.75	11240.75	32	10819.25	11349.25	69	10948.75	11478.75	101	11060.75	11590.75
2	10714.25	11244.25	33	10822.75	11352.75	70	10952.25	11482.25	102	11064.25	11594.25
3	10717.75	11247.75	34	10826.25	11356.25	71	10955.75	11485.75	103	11067.75	11597.75
4	10721.25	11251.25	35	10829.75	11359.75	72	10959.25	11489.25	104	11071.25	11601.25
5	10724.75	11254.75	36	10833.25	11363.25	73	10962.75	11492.75	105	11074.75	11604.75
6	10728.25	11258.25	37	10836.75	11366.75	74	10966.25	11496.25	106	11078.25	11608.25
7	10731.75	11261.75	38	10840.25	11370.25	75	10969.75	11499.75	107	11081.75	11611.75
8	10735.25	11265.25	39	10843.75	11373.75	76	10973.25	11503.25	108	11085.25	11615.25
9	10738.75	11268.75	40	10847.25	11377.25	77	10976.75	11506.75	109	11088.75	11618.75
10	10742.25	11272.25	41	10850.75	11380.75	78	10980.25	11510.25	110	11092.25	11622.25
11	10745.75	11275.75	42	10854.25	11384.25	79	10983.75	11513.75	111	11095.75	11625.75
12	10749.25	11279.25	43	10857.75	11387.75	80	10987.25	11517.25	112	11099.25	11629.25
13	10752.75	11282.75	44	10861.25	11391.25	81	10990.75	11520.75	113	11102.75	11632.75
14	10756.25	11286.25	45	10864.75	11394.75	82	10994.25	11524.25	114	11106.25	11636.25
15	10759.75	11289.75	46	10868.25	11398.25	83	10997.75	11527.75	115	11109.75	11639.75
16	10763.25	11293.25	47	10871.75	11401.75	84	11001.25	11531.25	116	11113.25	11643.25
17	10766.75	11296.75	48	10875.25	11405.25	85	11004.75	11534.75	117	11116.75	11646.75
18	10770.25	11300.25	49	10878.75	11408.75	86	11008.25	11538.25	118	11120.25	11650.25
19	10773.75	11303.75	50	10882.25	11412.25	87	11011.75	11541.75	119	11123.75	11653.75
20	10777.25	11307.25	51	10885.75	11415.75	88	11015.25	11545.25	120	11127.25	11657.25
21	10780.75	11310.75	52	10889.25	11419.25	89	11018.75	11548.75	121	11130.75	11660.75
22	10784.25	11314.25	53	10892.75	11422.75	90	11022.25	11552.25	122	11134.25	11664.25
23	10787.75	11317.75	54	10896.25	11426.25	91	11025.75	11555.75	123	11137.75	11667.75
24	10791.25	11321.25	55	10899.75	11429.75	92	11029.25	11559.25	124	11141.25	11671.25
25	10794.75	11324.75	56	10903.25	11433.25	93	11032.75	11562.75	125	11144.75	11674.75
26	10798.25	11328.25	57	10906.75	11436.75	94	11036.25	11566.25	126	11148.25	11678.25
27	10801.75	11331.75	58	10910.25	11440.25	95	11039.75	11569.75	127	11151.75	11681.75
28	10805.25	11335.25	59	10913.75	11443.75	96	11043.25	11573.25	128	11155.25	11685.25
29	10808.75	11338.75	60	10917.25	11447.25	97	11046.75	11576.75			
30	10812.25	11342.25	61	10920.75	11450.75	98	11050.25	11580.25			
31	10815.75	11345.75				99	11053.75	11583.75			
						100	11057.25	11587.25			

ver. 2.1

RAy2-11 - xA, **RAy2-11 - x**B

TX channel nominal frequencies
Band 10.7 – 11.7 GHz, duplex spacing 530 MHz

Bandwidth: **7 MHz**

ITU-R F.387 , Annex 5

A sub-band (Freq.table: rcinfo11_A_530:11)			**B** sub-band (Freq.table: rcinfo11_B_530:11)		
Ch.No.	Lower [MHz]	Upper [MHz]	Ch.No.	Lower [MHz]	Upper [MHz]
1	10712.5	11242.5	35	10950.5	11480.5
2	10719.5	11249.5	36	10957.5	11487.5
3	10726.5	11256.5	37	10964.5	11494.5
4	10733.5	11263.5	38	10971.5	11501.5
5	10740.5	11270.5	39	10978.5	11508.5
6	10747.5	11277.5	40	10985.5	11515.5
7	10754.5	11284.5	41	10992.5	11522.5
8	10761.5	11291.5	42	10999.5	11529.5
9	10768.5	11298.5	43	11006.5	11536.5
10	10775.5	11305.5	44	11013.5	11543.5
11	10782.5	11312.5	45	11020.5	11550.5
12	10789.5	11319.5	46	11027.5	11557.5
13	10796.5	11326.5	47	11034.5	11564.5
14	10803.5	11333.5	48	11041.5	11571.5
15	10810.5	11340.5	49	11048.5	11578.5
16	10817.5	11347.5	50	11055.5	11585.5
17	10824.5	11354.5	51	11062.5	11592.5
18	10831.5	11361.5	52	11069.5	11599.5
19	10838.5	11368.5	53	11076.5	11606.5
20	10845.5	11375.5	54	11083.5	11613.5
21	10852.5	11382.5	55	11090.5	11620.5
22	10859.5	11389.5	56	11097.5	11627.5
23	10866.5	11396.5	57	11104.5	11634.5
24	10873.5	11403.5	58	11111.5	11641.5
25	10880.5	11410.5	59	11118.5	11648.5
26	10887.5	11417.5	60	11125.5	11655.5
27	10894.5	11424.5	61	11132.5	11662.5
28	10901.5	11431.5	62	11139.5	11669.5
29	10908.5	11438.5	63	11146.5	11676.5
30	10915.5	11445.5	64	11153.5	11683.5

ver. 2.1

RAy2-11 - xA**, RAy2-11 –** x**B**

TX channel nominal frequencies
Band 10.7 – 11.7 GHz, duplex spacing 530 MHz

Bandwidth: **14 MHz**

ITU-R F.387 , Annex 5

A sub-band (Freq.table: rcinfo11_A_530:11)			**B** sub-band (Freq.table: rcinfo11_B_530:11)		
Ch.No.	Lower [MHz]	Upper [MHz]	Ch.No.	Lower [MHz]	Upper [MHz]
1	10716	11246	18	10954	11484
2	10730	11260	19	10968	11498
3	10744	11274	20	10982	11512
4	10758	11288	21	10996	11526
5	10772	11302	22	11010	11540
6	10786	11316	23	11024	11554
7	10800	11330	24	11038	11568
8	10814	11344	25	11052	11582
9	10828	11358	26	11066	11596
10	10842	11372	27	11080	11610
11	10856	11386	28	11094	11624
12	10870	11400	29	11108	11638
13	10884	11414	30	11122	11652
14	10898	11428	31	11136	11666
15	10912	11442	32	11150	11680

ver. 2.1

RAy2-11 - xA**, RAy2-11 –** x**B**

TX channel nominal frequencies
Band 10.7 – 11.7 GHz, duplex spacing 530 MHz

Bandwidth: **28 MHz**

ITU-R F.387 , Annex 5

A sub-band (Freq.table: rcinfo11_A_530:11)			**B** sub-band (Freq.table: rcinfo11_B_530:11)		
Ch.No.	Lower [MHz]	Upper [MHz]	Ch.No.	Lower [MHz]	Upper [MHz]
1	10723	11253	10	10975	11505
2	10751	11281	11	11003	11533
3	10779	11309	12	11031	11561
4	10807	11337	13	11059	11589
5	10835	11365	14	11087	11617
6	10863	11393	15	11115	11645
7	10891	11421	16	11143	11673

ver. 2.1

RAy2-11 - xA, **RAy2-11 – x**B

TX channel nominal frequencies
Band 10.7 – 11.7 GHz, duplex spacing 530 MHz

Bandwidth: **40 MHz (ITU)**

ITU-R F.387 rec.1.1

A sub-band (Freq.table: rcinfo11_A_530:11)			**B** sub-band (Freq.table: rcinfo11_B_530:11)		
Ch.No.	Lower [MHz]	Upper [MHz]	Ch.No.	Lower [MHz]	Upper [MHz]
2	10755	11285	8	10995	11525
3	10795	11325	9	11035	11565
4	10835	11365	10	11075	11605
5	10875	11405	11	11115	11645

ver. 1.0

RAy2-11 - xA, **RAy2-11 – x**B

TX channel nominal frequencies
Band 10.7 – 11.7 GHz, duplex spacing 530 MHz

Bandwidth: **40 MHz (CEPT)**

CEPT 12-06 Annex A.1

A sub-band (Freq.table: rcinfo11_A_530:11)			**B** sub-band (Freq.table: rcinfo11_B_530:11)		
Ch.No.	Lower [MHz]	Upper [MHz]	Ch.No.	Lower [MHz]	Upper [MHz]
1	10735	11265	7	10975	11505
2	10775	11305	8	11015	11545
3	10815	11345	9	11055	11585
4	10855	11385	10	11095	11625
5	10895	11425	11	11135	11665

ver. 1.1

RAy2-11 - xA, **RAy2-11 – x**B

TX channel nominal frequencies
Band 10.7 – 11.7 GHz, duplex spacing 530 MHz

Bandwidth: **56 MHz**

CEPT 12-06, Annex C

A sub-band (Freq.table: rcinfo11_A_530:11)			**B** sub-band (Freq.table: rcinfo11_B_530:11)		
Ch.No.	Lower [MHz]	Upper [MHz]	Ch.No.	Lower [MHz]	Upper [MHz]
1	10737	11267	10	10989	11519
2	10765	11295	11	11017	11547
3	10793	11323	12	11045	11575
4	10821	11351	13	11073	11603
5	10849	11379	14	11101	11631
6	10877	11407	15	11129	11659

ver. 2.1

RAy2-11 - x**A, RAy2-11 –** x**B**			TX channel nominal frequencies Band 10.7 – 11.7 GHz, duplex spacing 530 MHz		
Bandwidth: **56 MHz (CS 80)**			CEPT 12-06, Annex C		
A sub-band (Freq.table: rcinfo11_A_530:11)			**B** sub-band (Freq.table: rcinfo11_B_530:11)		
Ch.No.	Lower [MHz]	Upper [MHz]	Ch.No.	Lower [MHz]	Upper [MHz]
1	10755	11285	7	10995	11525
2	10795	11325	8	11035	11565
3	10835	11365	9	11075	11605
4	10875	11405	10	11115	11645

ver. 1.0

10.5. RAy2-11 C,D parameters

Note

The RAy2-11 units are not available yet

10.5.1. Output power

RAy2-11-xC, RAy2-11-xD	TX power	
Modulation	Max	Min
	[dBm]	[dBm]
QPSK	20	-5
16-QAM	18	-5
32-QAM	17	-5
64-QAM	16	-5
128-QAM	16	-5
256-QAM	15	-5

ver. 2.0

10.5.2. Radio parameters

RAy2-11-xC, RAy2-11-xD					Channel spacing 1.75 MHz; ACCP operation			
Modulation	Raw Bit Rate	User Bit Rate	RSS / SNR for BER 10^{-6}		Co-channel rejection		Adjacent channel Selectivity	
					1 dB	3 dB	1 dB	3 dB
			RSS	SNR	declared / limit	declared / limit	declared / limit	declared / limit
[-]	*[Mbps]*		*[dBm]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*
QPSK	3.1	2.5	-98	9.5	15 / 23	12 / 19	-12 / 0	-14 / -4
16-QAM	6.3	5.0	-92	15.0	22 / 30	20 / 26.5	-11 / -3	-13 / -7
32-QAM	7.8	6.3	-88	19.0	24 / 30	22 / 26.5	-10 / -3	-12 / -7
64-QAM	9.4	7.4	-87	20.5	29 / 30	26 / 26.5	-9 / -3	-10 / -7
128-QAM	11.0	8.9	-83	23.5	30 / 30	28 / 26.5	-8 / -3	-7 / -7

ver. 2.1

RAy2-11-xC, RAy2-11-xD					Channel spacing 3.5 MHz; ACCP operation			
Modulation	Raw Bit Rate	User Bit Rate	RSS / SNR for BER 10^{-6}		Co-channel rejection		Adjacent channel Selectivity	
					1 dB	3 dB	1 dB	3 dB
			RSS	SNR	declared / limit	declared / limit	declared / limit	declared / limit
[-]	*[Mbps]*		*[dBm]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*
QPSK	6	4.9	-96	9.5	15 / 23	12 / 19	-14 / 0	-16 / -4
16-QAM	12	9.6	-89	15.0	22 / 30	20 / 26.5	-13 / -3	-15 / -7
32-QAM	15	12.1	-86	18.5	24 / 30	22 / 26.5	-12 / -3	-14 / -7
64-QAM	18	14.3	-83	20.5	29 / 30	26 / 26.5	-11 / -3	-12 / -7
128-QAM	21	17.2	-80	23.5	30 / 30	28 / 26.5	-9 / -3	-8 / -7
256-QAM	24	19.7	-78	26.0	33 / 30	31 / 26.5	-5 / -3	-7 / -7

ver. 2.1

RAy2-11-xC, RAy2-11-xD					Channel spacing 7 MHz; ACCP operation			
Modulation	Raw Bit Rate	User Bit Rate	RSS / SNR for BER 10^{-6}		Co-channel rejection		Adjacent channel Selectivity	
					1 dB	3 dB	1 dB	3 dB
			RSS	SNR	declared / limit	declared / limit	declared / limit	declared / limit
[-]	*[Mbps]*		*[dBm]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*
QPSK	12	8.5	-94	8.5	15 / 23	12 / 19	-20 / 0	-22 / -4
16-QAM	24	17.2	-87	15.0	22 / 30	20 / 26.5	-18 / -3	-19 / -7
32-QAM	30	22.1	-84	18.5	24 / 37	22 / 33	-16 / -2	-18 / -6
64-QAM	36	29.7	-80	21.5	29 / 37	26 / 33	-14 / -2	-16 / -6
128-QAM	42	34.7	-78	25.0	32 / 37	30 / 33	-12 / -2	-14 / -6
256-QAM	49	40.7	-75	26.0	33 / 37	31 / 33	-10 / -2	-12 / -6

ver. 2.1

RAy2-11-xC, RAy2-11-xD			Channel spacing 14 MHz; ACCP operation					
Modulation	Raw Bit Rate	User Bit Rate	RSS / SNR for BER 10^{-6}		Co-channel rejection		Adjacent channel Selectivity	
					1 dB	3 dB	1 dB	3 dB
			RSS	SNR	declared / limit	declared / limit	declared / limit	declared / limit
[-]	*[Mbps]*		*[dBm]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*
QPSK	24	19.9	-92	8.5	14 / 23	12 / 19	-21 / 0	-23 / -4
16-QAM	48	38.8	-85	15.0	20 / 30	18 / 26.5	-19 / -3	-21 / -7
32-QAM	60	49.1	-81	18.5	26 / 33	23 / 29	-17 / -5	-19 / -9
64-QAM	72	62.3	-78	21.5	28 / 37	26 / 33	-14 / -2	-17 / -6
128-QAM	84	73.6	-74	25.0	30 / 37	28 / 33	-12 / -2	-14 / -6
256-QAM	96	81.2	-72	28.0	33 / 37	31 / 33	-10 / -2	-12 / -6

ver. 2.1

RAy2-11-xC, RAy2-11-xD			Channel spacing 28 / 30 MHz; ACCP operation					
Modulation	Raw Bit Rate	User Bit Rate	RSS / SNR for BER 10^{-6}		Co-channel rejection		Adjacent channel Selectivity	
					1 dB	3 dB	1 dB	3 dB
			RSS	SNR	declared / limit	declared / limit	declared / limit	declared / limit
[-]	*[Mbps]*		*[dBm]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*
QPSK	50	36.8	-90	7.5	12 / 23	10 / 19	-21 / 0	-23 / -4
16-QAM	100	80.9	-82	15.0	20 / 30	18 / 26.5	-18 / -3	-20 / -7
32-QAM	125	102.4	-78	18.5	24 / 33	22 / 29	-16 / -5	-19 / -9
64-QAM	150	129.8	-75	21.5	28 / 35	26 / 32	-12 / -5	-15 / -8
128QAM	175	155.5	-71	25.0	30 / 35	28 / 32	-9 / -5	-12 / -8
256-QAM	200	170.7	-69	26.5	33 / 35	31 / 32	-6 / -5	-9 / -8

ver. 2.0

RAy2-11-xC, RAy2-11-xD			Channel spacing 28 / 30 MHz; ACAP operation					
Modulation	Raw Bit Rate	User Bit Rate	RSS / SNR for BER 10^{-6}		Co-channel rejection		Adjacent channel Selectivity	
					1 dB	3 dB	1 dB	3 dB
			RSS	SNR	declared / limit	declared / limit	declared / limit	declared / limit
[-]	*[Mbps]*		*[dBm]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*
QPSK	52	38.3	-88.5	7.5	12 / 23	10 / 19	-15 / 0	-17 / -4
16-QAM	104	84.1	-81.5	15.0	20 / 30	18 / 26.5	-12 / -3	-14 / -7
32-QAM	130	106.4	-77.5	18.5	24 / 37	22 / 33	-10 / 3	-13 / -1
64-QAM	156	135.0	-74.5	21.5	28 / 37	26 / 33	-6 / 3	-9 / -1
128QAM	182	161.7	-70.5	25.0	30 / 37	28 / 33	-3 / 3	-6 / -1
256-QAM	208	185.2	-67.5	26.5	33 / 41	31 / 38	0 / 10	-3 / 7

ver. 2.1

10.5.3. Nominal frequencies

RAy2-11 - x**C**, **RAy2-11 -** x**D**	TX channel nominal frequencies Band 10.5 – 10.68 GHz, duplex spacing 91 MHz
Bandwidth: **1.75 MHz**	Channel arrangements based on 7 MHz channels

C sub-band (Freq.table: rcinfo11_C_default:12)			**D** sub-band (Freq.table: rcinfo11_D_default:12)		
Ch.No.	Lower [MHz]	Upper [MHz]	Ch.No.	Lower [MHz]	Upper [MHz]
1	10501.375	10592.375	25	10543.375	10634.375
2	10503.125	10594.125	26	10545.125	10636.125
3	10504.875	10595.875	27	10546.875	10637.875
4	10506.625	10597.625	28	10548.625	10639.625
5	10508.375	10599.375	29	10550.375	10641.375
6	10510.125	10601.125	30	10552.125	10643.125
7	10511.875	10602.875	31	10553.875	10644.875
8	10513.625	10604.625	32	10555.625	10646.625
9	10515.375	10606.375	33	10557.375	10648.375
10	10517.125	10608.125	34	10559.125	10650.125
11	10518.875	10609.875	35	10560.875	10651.875
12	10520.625	10611.625	36	10562.625	10653.625
13	10522.375	10613.375	37	10564.375	10655.375
14	10524.125	10615.125	38	10566.125	10657.125
15	10525.875	10616.875	39	10567.875	10658.875
16	10527.625	10618.625	40	10569.625	10660.625
17	10529.375	10620.375	41	10571.375	10662.375
18	10531.125	10622.125	42	10573.125	10664.125
19	10532.875	10623.875	43	10574.875	10665.875
20	10534.625	10625.625	44	10576.625	10667.625
21	10536.375	10627.375	45	10578.375	10669.375
22	10538.125	10629.125	46	10580.125	10671.125
23	10539.875	10630.875	47	10581.875	10672.875
24	10541.625	10632.625	48	10583.625	10674.625

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RAy2-11 - x**C, RAy2-11 -** x**D**

TX channel nominal frequencies
Band 10.5 – 10.68 GHz, duplex spacing 91 MHz

Bandwidth: **3.5 MHz**

based on 7 MHz

C sub-band (Freq.table: rcinfo11_C_default:12)			**D** sub-band (Freq.table: rcinfo11_D_default:12)		
Ch.No.	Lower [MHz]	Upper [MHz]	Ch.No.	Lower [MHz]	Upper [MHz]
1	10502.25	10593.25	13	10544.25	10635.25
2	10505.75	10596.75	14	10547.75	10638.75
3	10509.25	10600.25	15	10551.25	10642.25
4	10512.75	10603.75	16	10554.75	10645.75
5	10516.25	10607.25	17	10558.25	10649.25
6	10519.75	10610.75	18	10561.75	10652.75
7	10523.25	10614.25	19	10565.25	10656.25
8	10526.75	10617.75	20	10568.75	10659.75
9	10530.25	10621.25	21	10572.25	10663.25
10	10533.75	10624.75	22	10575.75	10666.75
11	10537.25	10628.25	23	10579.25	10670.25
12	10540.75	10631.75	24	10582.75	10673.75

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RAy2-11 - x**C, RAy2-11 -** x**D**

TX channel nominal frequencies
Band 10.5 – 10.68 GHz, duplex spacing 91 MHz

Bandwidth: **3.5 MHz**

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C sub-band (Freq.table: rcinfo11_C_default:12)			**D** sub-band (Freq.table: rcinfo11_D_default:12)		
Ch.No.	Lower [MHz]	Upper [MHz]	Ch.No.	Lower [MHz]	Upper [MHz]
1	10504.0	10595.0	13	10546.0	10637.0
2	10507.5	10598.5	14	10549.5	10640.5
3	10511.0	10602.0	15	10553.0	10644.0
4	10514.5	10605.5	16	10556.5	10647.5
5	10518.0	10609.0	17	10560.0	10651.0
6	10521.5	10612.5	18	10563.5	10654.5
7	10525.0	10616.0	19	10567.0	10658.0
8	10528.5	10619.5	20	10570.5	10661.5
9	10532.0	10623.0	21	10574.0	10665.0
10	10535.5	10626.5	22	10577.5	10668.5
11	10539.0	10630.0	23	10581.0	10672.0

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RAy2-11 - x**C, RAy2-11 -** x**D**

TX channel nominal frequencies
Band 10.5 – 10.68 GHz, duplex spacing 91 MHz

Bandwidth: **7 MHz**

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C sub-band (Freq.table: rcinfo11_C_default:12)			**D** sub-band (Freq.table: rcinfo11_D_default:12)		
Ch.No.	Lower [MHz]	Upper [MHz]	Ch.No.	Lower [MHz]	Upper [MHz]
1	10504	10595	7	10546	10637
2	10511	10602	8	10553	10644
3	10518	10609	9	10560	10651
4	10525	10616	10	10567	10658
5	10532	10623	11	10574	10665
6	10539	10630	12	10581	10672

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RAy2-11 - x**C, RAy2-11 -** x**D**

TX channel nominal frequencies
Band 10.5 – 10.68 GHz, duplex spacing 91 MHz

Bandwidth: **14 MHz**

based on 7 MHz

C sub-band (Freq.table: rcinfo11_C_default:12)			**D** sub-band (Freq.table: rcinfo11_D_default:12)		
Ch.No.	Lower [MHz]	Upper [MHz]	Ch.No.	Lower [MHz]	Upper [MHz]
1	10507.5	10598.5	4	10549.5	10640.5
2	10521.5	10612.5	5	10563.5	10654.5
3	10535.5	10626.5	6	10577.5	10668.5

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RAy2-11 - x**C, RAy2-11 -** x**D**

TX channel nominal frequencies
Band 10.5 – 10.68 GHz, duplex spacing 91 MHz

Bandwidth: **28 MHz**

based on 7 MHz

C sub-band (Freq.table: rcinfo11_C_default:12)			**D** sub-band (Freq.table: rcinfo11_D_default:12)		
Ch.No.	Lower [MHz]	Upper [MHz]	Ch.No.	Lower [MHz]	Upper [MHz]
1	10514.5	10605.5	3	10570.5	10661.5

ver. 2.0

10.6. RAy2-17 parameters

10.6.1. Output power

RAy2-17	TX power	
Modulation	Max	Min
	[dBm]	[dBm]
QPSK	5	-25
16-QAM	5	-25
32-QAM	5	-25
64-QAM	5	-25
128-QAM	5	-25
256-QAM	5	-25

ver. 2.0

10.6.2. Radio parameters

RAy2-17			Channel spacing 3.5 MHz; ACCP operation					
Modulation	Raw Bit Rate	User Bit Rate	RSS / SNR for BER 10^{-6}		Co-channel rejection		Adjacent channel Selectivity	
					1 dB	3 dB	1 dB	3 dB
			RSS	SNR	declared / limit	declared / limit	declared / limit	declared / limit
[-]	*[Mbps]*		*[dBm]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*
QPSK	6	4.9	-97	9.5	15 / 23	12 / 19	-14 / 0	-16 / -4
16-QAM	12	9.6	-90	15.0	22 / 30	20 / 26.5	-13 / -3	-15 / -7
32-QAM	15	12.1	-87	18.5	24 / 30	22 / 26.5	-12 / -3	-14 / -7
64-QAM	18	14.3	-84	20.5	29 / 30	26 / 26.5	-11 / -3	-12 / -7
128-QAM	21	17.2	-83	23.5	30 / 30	28 / 26.5	-9 / -3	-8 / -7
256-QAM	24	19.7	-81	26.0	33 / 30	31 / 26.5	-5 / -3	-7 / -7

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RAy2-17			Channel spacing 7 MHz; ACCP operation					
Modulation	Raw Bit Rate	User Bit Rate	RSS / SNR for BER 10^{-6}		Co-channel rejection		Adjacent channel Selectivity	
					1 dB	3 dB	1 dB	3 dB
			RSS	SNR	declared / limit	declared / limit	declared / limit	declared / limit
[-]	*[Mbps]*		*[dBm]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*
QPSK	12	8.5	-95	8.5	15 / 23	12 / 19	-20 / 0	-22 / -4
16-QAM	24	17.2	-88	15.0	22 / 30	20 / 26.5	-18 / -3	-19 / -7
32-QAM	30	22.1	-85	18.5	24 / 37	22 / 33	-16 / -2	-18 / -6
64-QAM	36	29.7	-81	21.5	29 / 37	26 / 33	-14 / -2	-16 / -6
128-QAM	42	34.7	-79	25.0	32 / 37	30 / 33	-12 / -2	-14 / -6
256-QAM	49	39.7	-77	26.0	33 / 37	31 / 33	-10 / -2	-12 / -6

ver. 2.1

RAy2-17	Channel spacing 14 MHz; ACCP operation							
Modulation	Raw Bit Rate	User Bit Rate	RSS / SNR for BER 10^{-6}		Co-channel rejection		Adjacent channel Selectivity	
					1 dB	3 dB	1 dB	3 dB
			RSS	SNR	declared / limit	declared / limit	declared / limit	declared / limit
[-]	*[Mbps]*		*[dBm]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*
QPSK	24	19.9	-92	8.5	14 / 23	12 / 19	-21 / 0	-23 / -4
16-QAM	48	38.8	-85	15.0	20 / 30	18 / 26.5	-19 / -3	-21 / -7
32-QAM	60	49.1	-81	18.5	26 / 33	23 / 29	-17 / -5	-19 / -9
64-QAM	72	62.3	-78	21.5	28 / 37	26 / 33	-14 / -2	-17 / -6
128-QAM	84	73.6	-75	25.0	30 / 37	28 / 33	-12 / -2	-14 / -6
256-QAM	96	81.2	-73	28.0	33 / 37	31 / 33	-10 / -2	-12 / -6

ver. 2.1

RAy2-17	Channel spacing 28 MHz; ACCP operation							
Modulation	Raw Bit Rate	User Bit Rate	RSS / SNR for BER 10^{-6}		Co-channel rejection		Adjacent channel Selectivity	
					1 dB	3 dB	1 dB	3 dB
			RSS	SNR	declared / limit	declared / limit	declared / limit	declared / limit
[-]	*[Mbps]*		*[dBm]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*
QPSK	50	36.8	-90	7.5	12 / 23	10 / 19	-21 / 0	-23 / -4
16-QAM	100	80.9	-83	15.0	20 / 30	18 / 26.5	-18 / -3	-20 / -7
32-QAM	125	102.4	-79	18.5	24 / 33	22 / 29	-16 / -5	-19 / -9
64-QAM	150	129.8	-76	21.5	28 / 35	26 / 32	-12 / -5	-15 / -8
128QAM	175	155.5	-72	25.0	30 / 35	28 / 32	-9 / -5	-12 / -8
256-QAM	200	170.7	-69	26.5	33 / 35	31 / 32	-6 / -5	-9 / -8

ver. 2.0

RAy2-17	Channel spacing 40 MHz; ACCP operation							
Modulation	Raw Bit Rate	User Bit Rate	RSS / SNR for BER 10^{-6}		Co-channel rejection		Adjacent channel Selectivity	
					1 dB	3 dB	1 dB	3 dB
			RSS	SNR	declared / limit	declared / limit	declared / limit	declared / limit
[-]	*[Mbps]*		*[dBm]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*
QPSK	68	50.1	-88	7.5	12 / 33	10 / 29	-22 / -4	-24 / -8
16-QAM	136	110.0	-81	15.0	19 / 33	17 / 29	-18 / -4	-21 / -8
32-QAM	170	139.2	-77	18.5	24 / 33	21 / 29	-16 / -4	-19 / -8
64-QAM	204	176.5	-74	21.5	27 / 33	25 / 29	-14 / -4	-16 / -8
128QAM	238	211.4	-70	25.0	30 / 37	28 / 33	-10 / -4	-12 / -8
256-QAM	272	232.1	-68	26.5	33 / 37	30 / 33	-8 / -4	-10 / -8

ver. 2.0

RAy2-17	Channel spacing 50 MHz; ACCP operation							
Modulation	Raw Bit Rate	User Bit Rate	RSS / SNR for BER 10^{-6}		Co-channel rejection		Adjacent channel Selectivity	
					1 dB	3 dB	1 dB	3 dB
			RSS	SNR	declared / limit	declared / limit	declared / limit	declared / limit
[-]	*[Mbps]*		*[dBm]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*
QPSK	90	66.3	-87.5	7.5	12 / 23	10 / 19	-24 / 0	-26 / -4
16-QAM	180	145.6	-80.5	15.0	19 / 30	17 / 26.5	-18 / -3	-21 / -7
32-QAM	225	184.2	-76.5	18.5	24 / 33	22 / 29	-16 / -5	-19 / -9
64-QAM	270	233.6	-73.5	21.5	27 / 35	25 / 32	-14 / -5	-16 / -8
128QAM	315	276.1	-69.5	25.0	30 / 35	28 / 32	-10 / -5	-12 / -8
256-QAM	360	320.6	-66.5	26.5	33 / 35	30 / 32	-8 / -5	-10 / -8

ver. 1.0

RAy2-17	Channel spacing 56 MHz; ACCP operation							
Modulation	Raw Bit Rate	User Bit Rate	RSS / SNR for BER 10^{-6}		Co-channel rejection		Adjacent channel Selectivity	
					1 dB	3 dB	1 dB	3 dB
			RSS	SNR	declared / limit	declared / limit	declared / limit	declared / limit
[-]	*[Mbps]*		*[dBm]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*
QPSK	99	72.9	-87	7.5	12 / 23	10 / 19	-24 / 0	-26 / -4
16-QAM	198	160.2	-80	15.0	19 / 30	17 / 26.5	-18 / -3	-21 / -7
32-QAM	247.5	202.7	-76	18.5	24 / 33	22 / 29	-16 / -5	-19 / -9
64-QAM	297	256.9	-73	21.5	27 / 35	25 / 32	-14 / -5	-16 / -8
128QAM	346.5	303.7	-69	25.0	30 / 35	28 / 32	-10 / -5	-12 / -8
256-QAM	396	337.7	-66	26.5	33 / 35	30 / 32	-8 / -5	-10 / -8

ver. 2.0

RAy2-17	Channel spacing 56 MHz TO; ACCP operation							
Modulation	Raw Bit Rate	User Bit Rate	RSS / SNR for BER 10^{-6}		Co-channel rejection		Adjacent channel Selectivity	
					1 dB	3 dB	1 dB	3 dB
			RSS	SNR	declared / limit	declared / limit	declared / limit	declared / limit
[-]	*[Mbps]*		*[dBm]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*
QPSK	99	85.8	-85	10.0	13 / 23	11 / 19	-24 / 0	-26 / -4
16-QAM	198	169.9	-78	16.0	20 / 30	18 / 26.5	-18 / -3	-20 / -7
32-QAM	247.5	206.2	-74	19.0	25 / 33	23 / 29	-14 / -5	-15 / -9
64-QAM	297	268.1	-70	22.5	29 / 35	26 / 32	-9 / -5	-11 / -8
128-QAM	346.5	309.0	-67	25.5	32 / 35	29 / 32	-8 / -5	-10 / -8
256-QAM	396	358.9	-64	27.5	35 / 35	32 / 32	-7 / -5	-8 / -8

ver. 2.1

10.6.3. Nominal frequencies

RAy2-17	TX channel nominal frequencies Band 17.1 – 17.3 GHz, default duplex sp. **73.5** MHz		
Bandwidth: **3.5 MHz**		duplex spacing range 63 – 189 MHz	
(Freq.table: rcinfo17_default:13)			
basic channels (default duplex)		optional channels	
Ch.No. Lower [MHz]	Ch.No. Upper [MHz]	Ch.No. Lower [MHz]	Ch.No. Upper [MHz]
	U19 17168.0	no more channels	
	U20 17171.5		
	U21 17175.0		
L1 17105.0	**U22** 17178.5		
L2 17108.5	**U23** 17182.0		
L3 17112.0	**U24** 17185.5		
L4 17115.5	**U25** 17189.0		
L5 17119.0	**U26** 17192.5		
L6 17122.5	**U27** 17196.0		
L7 17126.0	**U28** 17199.5		
L8 17129.5	**U29** 17203.0		
L9 17133.0	**U30** 17206.5		
L10 17136.5	**U31** 17210.0		
L11 17140.0	**U32** 17213.5		
L12 17143.5	**U33** 17217.0		
L13 17147.0	**U34** 17220.5		
L14 17150.5	**U35** 17224.0		
L15 17154.0	**U36** 17227.5		
L16 17157.5	**U37** 17231.0		
L17 17161.0	**U38** 17234.5		
L18 17164.5	**U39** 17238.0		
L19 17168.0	**U40** 17241.5		
L20 17171.5	**U41** 17245.0		
L21 17175.0	**U42** 17248.5		
L22 17178.5	**U43** 17252.0		
L23 17182.0	**U44** 17255.5		
L24 17185.5	**U45** 17259.0		
L25 17189.0	**U46** 17262.5		
L26 17192.5	**U47** 17266.0		
L27 17196.0	**U48** 17269.5		
L28 17199.5	**U49** 17273.0		
L29 17203.0	**U50** 17276.5		
L30 17206.5	**U51** 17280.0		
L31 17210.0	**U52** 17283.5		
L32 17213.5	**U53** 17287.0		
L33 17217.0	**U54** 17290.5		
L34 17220.5	**U55** 17294.0		
L35 17224.0			
L36 17227.5			
L37 17231.0			

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RAy2-17

TX channel nominal frequencies

Band 17.1 – 17.3 GHz, default duplex sp. **73.5** MHz

Bandwidth: **7 MHz**

duplex spacing range 63 – 189 MHz

(Freq.table: rcinfo17_default:13)

basic channels (default duplex)				optional channels			
Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]	Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]
		U19	17168.0				
						U20	17171.5
		U21	17175.0				
				L1	17105.0	U22	17178.5
L2	17108.5	**U23**	17182.0				
				L3	17112.0	U24	17185.5
L4	17115.5	**U25**	17189.0				
				L5	17119.0	U26	17192.5
L6	17122.5	**U27**	17196.0				
				L7	17126.0	U28	17199.5
L8	17129.5	**U29**	17203.0				
				L9	17133.0	U30	17206.5
L10	17136.5	**U31**	17210.0				
				L11	17140.0	U32	17213.5
L12	17143.5	**U33**	17217.0				
				L13	17147.0	U34	17220.5
L14	17150.5	**U35**	17224.0				
				L15	17154.0	U36	17227.5
L16	17157.5	**U37**	17231.0				
				L17	17161.0	U38	17234.5
L18	17164.5	**U39**	17238.0				
				L19	17168.0	U40	17241.5
L20	17171.5	**U41**	17245.0				
				L21	17175.0	U42	17248.5
L22	17178.5	**U43**	17252.0				
				L23	17182.0	U44	17255.5
L24	17185.5	**U45**	17259.0				
				L25	17189.0	U46	17262.5
L26	17192.5	**U47**	17266.0				
				L27	17196.0	U48	17269.5
L28	17199.5	**U49**	17273.0				
				L29	17203.0	U50	17276.5
L30	17206.5	**U51**	17280.0				
				L31	17210.0	U52	17283.5
L32	17213.5	**U53**	17287.0				
				L33	17217.0	U54	17290.5
L34	17220.5	**U55**	17294.0				
				L35	17224.0		
L36	17227.5						
				L37	17231.0		

ver. 2.0

RAy2-17 TX channel nominal frequencies

Band 17.1 – 17.3 GHz, default duplex sp. **87.5** MHz

Bandwidth: **14 MHz** duplex spacing range 66.5 – 182 MHz

(Freq.table: rcinfo17_default:13)

basic channels (default duplex)				optional channels			
Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]	Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]
						U17	17175.0
		U18	17178.5				
						U19	17182.0
						U20	17185.5
						U21	17189.0
		U22	17192.5				
				L2	17108.5	U23	17196.0
				L3	17112.0	U24	17199.5
				L4	17115.5	U25	17203.0
L5	17119.0	**U26**	17206.5				
				L6	17122.5	U27	17210.0
				L7	17126.0	U28	17213.5
				L8	17129.5	U29	17217.0
L9	17133.0	**U30**	17220.5				
				L10	17136.5	U31	17224.0
				L11	17140.0	U32	17227.5
				L12	17143.5	U33	17231.0
L13	17147.0	**U34**	17234.5				
				L14	17150.5	U35	17238.0
				L15	17154.0	U36	17241.5
				L16	17157.5	U37	17245.0
L17	17161.0	**U38**	17248.5				
				L18	17164.5	U39	17252.0
				L19	17168.0	U40	17255.5
				L20	17171.5	U41	17259.0
L21	17175.0	**U42**	17262.5				
				L22	17178.5	U43	17266.0
				L23	17182.0	U44	17269.5
				L24	17185.5	U45	17273.0
L25	17189.0	**U46**	17276.5				
				L26	17192.5	U47	17280.0
				L27	17196.0	U48	17283.5
				L28	17199.5	U49	17287.0
L29	17203.0	**U50**	17290.5				
				L30	17206.5		
				L31	17210.0		
				L32	17213.5		
L33	17217.0						
				L34	17220.5		
				L35	17224.0		

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RAy2-17

TX channel nominal frequencies

Band 17.1 – 17.3 GHz, default duplex sp. **84** MHz

Bandwidth: **28 MHz**

duplex spacing range 70 – 168 MHz

(Freq.table: rcinfo17_default:13)

basic channels (default duplex)				optional channels			
Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]	Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]
						U21	17185.5
						U22	17189.0
						U23	17192.5
						U24	17196.0
L4	17115.5	**U25**	17199.5				
				L5	17119.0	U26	17203.0
				L6	17122.5	U27	17206.5
				L7	17126.0	U28	17210.0
				L8	17129.5	U29	17213.5
				L9	17133.0	U30	17217.0
				L10	17136.5	U31	17220.5
				L11	17140.0	U32	17224.0
L12	17143.5	**U33**	17227.5				
				L13	17147.0	U34	17231.0
				L14	17150.5	U35	17234.5
				L15	17154.0	U36	17238.0
				L16	17157.5	U37	17241.5
				L17	17161.0	U38	17245.0
				L18	17164.5	U39	17248.5
				L19	17168.0	U40	17252.0
L20	17171.5	**U41**	17255.5				
				L21	17175.0	U42	17259.0
				L22	17178.5	U43	17262.5
				L23	17182.0	U44	17266.0
				L24	17185.5	U45	17269.5
				L25	17189.0	U46	17273.0
				L26	17192.5	U47	17276.5
				L27	17196.0	U48	17280.0
L28	17199.5	**U49**	17283.5				
				L29	17203.0		
				L30	17206.5		
				L31	17210.0		
				L32	17213.5		

ver. 2.0

RAy2-17 TX channel nominal frequencies

Band 17.1 – 17.3 GHz, default duplex sp. **70** MHz

Bandwidth: **40 MHz** duplex spacing range 70 – 154 MHz

(Freq.table: rcinfo17_default:13)

basic channels (default duplex)				optional channels			
Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]	Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]
L6	17122.5	**U27**	17192.5				
				L7	17126.0	U28	17196.0
				L8	17129.5	U29	17199.5
				L9	17133.0	U30	17203.0
				L10	17136.5	U31	17206.5
				L11	17140.0	U32	17210.0
				L12	17143.5	U33	17213.5
				L13	17147.0	U34	17217.0
				L14	17150.5	U35	17220.5
				L15	17154.0	U36	17224.0
				L16	17157.5	U37	17227.5
				L17	17161.0	U38	17231.0
L18	17164.5	**U39**	17234.5				
				L19	17168.0	U40	17238.0
				L20	17171.5	U41	17241.5
				L21	17175.0	U42	17245.0
				L22	17178.5	U43	17248.5
				L23	17182.0	U44	17252.0
				L24	17185.5	U45	17255.5
				L25	17189.0	U46	17259.0
				L26	17192.5	U47	17262.5
				L27	17196.0	U48	17266.0
				L28	17199.5	U49	17269.5
				L29	17203.0	U50	17273.0
L30	17206.5	**U51**	17276.5				

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RAy2-17

TX channel nominal frequencies

Band 17.1 – 17.3 GHz, default duplex sp. **85** MHz

Bandwidth: **56 MHz**

duplex spacing range 85 – 141 MHz

(Freq.table: rcinfo17_default:13)

basic channels (default duplex)				optional channels			
Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]	Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]
L8	17129.5	**U29**	17214.5				
				L9	17133.0	U30	17218.0
				L10	17136.5	U31	17221.5
				L11	17140.0	U32	17225.0
				L12	17143.5	U33	17228.5
				L13	17147.0	U34	17232.0
				L14	17150.5	U35	17235.5
				L15	17154.0	U36	17239.0
				L16	17157.5	U37	17242.5
				L17	17161.0	U38	17246.0
				L18	17164.5	U39	17249.5
				L19	17168.0	U40	17253.0
				L20	17171.5	U41	17256.5
				L21	17175.0	U42	17260.0
				L22	17178.5	U43	17263.5
				L23	17182.0	U44	17267.0
L24	17185.5	**U45**	17270.5				

ver. 2.0

10.7. RAy2-24 parameters

10.7.1. Output power

RAy2-24	TX power	
Modulation	Max	Min
	[dBm]	[dBm]
QPSK	10	-30
16-QAM	10	-30
32-QAM	10	-30
64-QAM	10	-30
128-QAM	10	-30
256-QAM	10	-30

ver. 1.0

10.7.2. Radio parameters

RAy2-24	Channel spacing 3.5 MHz; ACCP operation							
Modula-tion	**Raw Bit Rate**	**User Bit Rate**	RSS / SNR for BER 10^{-6}		**Co-channel rejection**		**Adjacent channel Selectivity**	
					1 dB	3 dB	1 dB	3 dB
			RSS	**SNR**	declared / limit	declared / limit	declared / limit	declared / limit
[-]	*[Mbps]*		*[dBm]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*
QPSK	6	4.9	-96	9.5	15 / 23	12 / 19	-14 / 0	-16 / -4
16-QAM	12	9.6	-89	15.0	22 / 30	20 / 26.5	-13 / -3	-15 / -7
32-QAM	15	12.1	-86	18.5	24 / 30	22 / 26.5	-12 / -3	-14 / -7
64-QAM	18	14.3	-83	20.5	29 / 30	26 / 26.5	-11 / -3	-12 / -7
128-QAM	21	17.2	-79	23.5	30 / 30	28 / 26.5	-9 / -3	-8 / -7
256-QAM	24	19.7	-77	26.0	33 / 30	31 / 26.5	-5 / -3	-7 / -7

ver. 1.0

RAy2-24	Channel spacing 7 MHz; ACCP operation							
Modula-tion	**Raw Bit Rate**	**User Bit Rate**	RSS / SNR for BER 10^{-6}		**Co-channel rejection**		**Adjacent channel Selectivity**	
					1 dB	3 dB	1 dB	3 dB
			RSS	**SNR**	declared / limit	declared / limit	declared / limit	declared / limit
[-]	*[Mbps]*		*[dBm]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*
QPSK	12	8.5	-93	8.5	15 / 23	12 / 19	-20 / 0	-22 / -4
16-QAM	24	17.2	-86	15.0	22 / 30	20 / 26.5	-18 / -3	-19 / -7
32-QAM	30	22.1	-83	18.5	24 / 37	22 / 33	-16 / -2	-18 / -6
64-QAM	36	29.7	-79	21.5	29 / 37	26 / 33	-14 / -2	-16 / -6
128-QAM	42	34.7	-76	25.0	32 / 37	30 / 33	-12 / -2	-14 / -6
256-QAM	49	40.7	-74	26.0	33 / 37	31 / 33	-10 / -2	-12 / -6

ver. 1.0

RAy2-24	Channel spacing 14 MHz; ACCP operation							
Modulation	Raw Bit Rate	User Bit Rate	RSS / SNR for BER 10^{-6}		Co-channel rejection		Adjacent channel Selectivity	
					1 dB	3 dB	1 dB	3 dB
			RSS	SNR	declared / limit	declared / limit	declared / limit	declared / limit
[-]	*[Mbps]*		*[dBm]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*
QPSK	24	19.9	-91	8.5	14 / 23	12 / 19	-21 / 0	-23 / -4
16-QAM	48	38.8	-84	15.0	20 / 30	18 / 26.5	-19 / -3	-21 / -7
32-QAM	60	49.1	-80	18.5	26 / 33	23 / 29	-17 / -5	-19 / -9
64-QAM	72	62.3	-77	21.5	28 / 37	26 / 33	-14 / -2	-17 / -6
128-QAM	84	73.6	-73	25.0	30 / 37	28 / 33	-12 / -2	-14 / -6
256-QAM	96	81.2	-71	28.0	33 / 37	31 / 33	-10 / -2	-12 / -6

ver. 1.0

RAy2-24	Channel spacing 28 MHz; ACCP operation							
Modulation	Raw Bit Rate	User Bit Rate	RSS / SNR for BER 10^{-6}		Co-channel rejection		Adjacent channel Selectivity	
					1 dB	3 dB	1 dB	3 dB
			RSS	SNR	declared / limit	declared / limit	declared / limit	declared / limit
[-]	*[Mbps]*		*[dBm]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*
QPSK	50	36.8	-89	7.5	12 / 23	10 / 19	-21 / 0	-23 / -4
16-QAM	100	80.9	-82	15.0	20 / 30	18 / 26.5	-18 / -3	-20 / -7
32-QAM	125	102.4	-78	18.5	24 / 33	22 / 29	-16 / -5	-19 / -9
64-QAM	150	129.8	-75	21.5	28 / 35	26 / 32	-12 / -5	-15 / -8
128-QAM	175	155.5	-71	25.0	30 / 35	28 / 32	-9 / -5	-12 / -8
256-QAM	200	170.7	-68	26.5	33 / 35	31 / 32	-6 / -5	-9 / -8

ver. 1.0

RAy2-24	Channel spacing 40 MHz; ACCP operation							
Modulation	Raw Bit Rate	User Bit Rate	RSS / SNR for BER 10^{-6}		Co-channel rejection		Adjacent channel Selectivity	
					1 dB	3 dB	1 dB	3 dB
			RSS	SNR	declared / limit	declared / limit	declared / limit	declared / limit
[-]	*[Mbps]*		*[dBm]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*
QPSK	68	50.1	-87	7.5	12 / 33	10 / 29	-22 / -4	-24 / -8
16-QAM	136	110.0	-80	15.0	19 / 33	17 / 29	-18 / -4	-21 / -8
32-QAM	170	139.2	-76	18.5	24 / 33	21 / 29	-16 / -4	-19 / -8
64-QAM	204	176.5	-73	21.5	27 / 33	25 / 29	-14 / -4	-16 / -8
128-QAM	238	211.4	-69	25.0	30 / 37	28 / 33	-10 / -4	-12 / -8
256-QAM	272	232.1	-67	26.5	33 / 37	30 / 33	-8 / -4	-10 / -8

ver. 1.1

RAy2-24	Channel spacing 50 MHz; ACCP operation							
Modulation	Raw Bit Rate	User Bit Rate	RSS / SNR for BER 10^{-6}		Co-channel rejection		Adjacent channel Selectivity	
					1 dB	3 dB	1 dB	3 dB
			RSS	SNR	declared / limit	declared / limit	declared / limit	declared / limit
[-]	*[Mbps]*		*[dBm]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*
QPSK	90	66.3	-86.5	7.5	12 / 23	10 / 19	-24 / 0	-26 / -4
16-QAM	180	145.6	-79.5	15.0	19 / 30	17 / 26.5	-18 / -3	-21 / -7
32-QAM	225	184.2	-75.5	18.5	24 / 33	22 / 29	-16 / -5	-19 / -9
64-QAM	270	233.6	-72.5	21.5	27 / 35	25 / 32	-14 / -5	-16 / -8
128-QAM	315	276.1	-68.5	25.0	30 / 35	28 / 32	-10 / -5	-12 / -8
256-QAM	360	320.6	-65.5	26.5	33 / 35	30 / 32	-8 / -5	-10 / -8

ver. 1.0

RAy2-24	Channel spacing 56 MHz; ACCP operation							
Modulation	Raw Bit Rate	User Bit Rate	RSS / SNR for BER 10^{-6}		Co-channel rejection		Adjacent channel Selectivity	
					1 dB	3 dB	1 dB	3 dB
			RSS	SNR	declared / limit	declared / limit	declared / limit	declared / limit
[-]	*[Mbps]*		*[dBm]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*
QPSK	99	72.9	-86	7.5	12 / 23	10 / 19	-26 / 0	-28 / -4
16-QAM	198	160.2	-79	15.0	19 / 30	17 / 26.5	-19 / -3	-21 / -7
32-QAM	247.5	202.7	-75	18.5	24 / 33	22 / 29	-15 / -5	-17 / -9
64-QAM	297	256.9	-72	21.5	27 / 35	25 / 32	-14 / -5	-16 / -8
128-QAM	346.5	303.7	-68	25.0	30 / 35	28 / 32	-10 / -5	-12 / -8
256-QAM	396	337.7	-65	26.5	33 / 35	30 / 32	-8 / -5	-10 / -8

ver. 1.0

RAy2-24	Channel spacing 56 MHz TO; ACCP operation							
Modulation	Raw Bit Rate	User Bit Rate	RSS / SNR for BER 10^{-6}		Co-channel rejection		Adjacent channel Selectivity	
					1 dB	3 dB	1 dB	3 dB
			RSS	SNR	declared / limit	declared / limit	declared / limit	declared / limit
[-]	*[Mbps]*		*[dBm]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*
QPSK	99	85.8	-84	10.0	13 / 23	11 / 19	-24 / 0	-26 / -4
16-QAM	198	169.9	-77	16.0	20 / 30	18 / 26.5	-18 / -3	-20 / -7
32-QAM	247.5	206.2	-73	19.0	25 / 33	23 / 29	-14 / -5	-15 / -9
64-QAM	297	268.1	-69	22.5	29 / 35	26 / 32	-9 / -5	-11 / -8
128-QAM	346.5	309.0	-66	25.5	32 / 35	29 / 32	-8 / -5	-10 / -8
256-QAM	396	358.9	-63	27.5	35 / 35	32 / 32	-7 / -5	-8 / -8

ver. 1.1

10.7.3. Nominal frequencies - ISM

RAy2-24

TX channel nominal frequencies
Band 24.00 – 24.25 GHz, default duplex sp. **73.5** MHz
Bandwidth: **3.5 MHz** duplex spacing range 63 – 241.5 MHz

(Freq.table: rcinfo24_ISM250_default:11)

basic channels (default duplex)				optional channels			
Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]	Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]
		U19	24069.0	no more channels			
		U20	24072.5				
		U21	24076.0				
L1	24006.0	**U22**	24079.5				
L2	24009.5	**U23**	24083.0				
L3	24013.0	**U24**	24086.5				
L4	24016.5	**U25**	24090.0				
L5	24020.0	**U26**	24093.5				
L6	24023.5	**U27**	24097.0				
L7	24027.0	**U28**	24100.5				
L8	24030.5	**U29**	24104.0				
L9	24034.0	**U30**	24107.5				
L10	24037.5	**U31**	24111.0				
L11	24041.0	**U32**	24114.5				
L12	24044.5	**U33**	24118.0				
L13	24048.0	**U34**	24121.5				
L14	24051.5	**U35**	24125.0				
L15	24055.0	**U36**	24128.5				
L16	24058.5	**U37**	24132.0				
L17	24062.0	**U38**	24135.5				
L18	24065.5	**U39**	24139.0				
L19	24069.0	**U40**	24142.5				
L20	24072.5	**U41**	24146.0				
L21	24076.0	**U42**	24149.5				
L22	24079.5	**U43**	24153.0				
L23	24083.0	**U44**	24156.5				
L24	24086.5	**U45**	24160.0				
L25	24090.0	**U46**	24163.5				
L26	24093.5	**U47**	24167.0				
L27	24097.0	**U48**	24170.5				
L28	24100.5	**U49**	24174.0				
L29	24104.0	**U50**	24177.5				
L30	24107.5	**U51**	24181.0				
L31	24111.0	**U52**	24184.5				
L32	24114.5	**U53**	24188.0				
L33	24118.0	**U54**	24191.5				
L34	24121.5	**U55**	24195.0				
L35	24125.0	**U56**	24198.5				
L36	24128.5	**U57**	24202.0				
L37	24132.0	**U58**	24205.5				
L38	24135.5	**U59**	24209.0				
L39	24139.0	**U60**	24212.5				
L40	24142.5	**U61**	24216.0				
L41	24146.0	**U62**	24219.5				
L42	24149.5	**U63**	24223.0				
L43	24153.0	**U64**	24226.5				
L44	24156.5	**U65**	24230.0				
L45	24160.0	**U66**	24233.5				
L46	24163.5	**U67**	24237.0				
L47	24167.0	**U68**	24240.5				
L48	24170.5	**U69**	24244.0				
L49	24174.0	**U70**	24247.5				
L50	24177.5						
L51	24181.0						
L52	24184.5						

ver. 2.0

RAy2-24

TX channel nominal frequencies
Band 24.00 – 24.25 GHz, default duplex sp. **73.5** MHz

Bandwidth: **7 MHz**

duplex spacing range 63 – 238 MHz

(Freq.table: rcinfo24_ISM250_default:11)

basic channels (default duplex)				optional channels			
Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]	Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]
		U19	24069.0				
		U21	24076.0			U20	24072.5
L2	24009.5	**U23**	24083.0	L1	24006.0	U22	24079.5
L4	24016.5	**U25**	24090.0	L3	24013.0	U24	24086.5
L6	24023.5	**U27**	24097.0	L5	24020.0	U26	24093.5
L8	24030.5	**U29**	24104.0	L7	24027.0	U28	24100.5
L10	24037.5	**U31**	24111.0	L9	24034.0	U30	24107.5
L12	24044.5	**U33**	24118.0	L11	24041.0	U32	24114.5
L14	24051.5	**U35**	24125.0	L13	24048.0	U34	24121.5
L16	24058.5	**U37**	24132.0	L15	24055.0	U36	24128.5
L18	24065.5	**U39**	24139.0	L17	24062.0	U38	24135.5
L20	24072.5	**U41**	24146.0	L19	24069.0	U40	24142.5
L22	24079.5	**U43**	24153.0	L21	24076.0	U42	24149.5
L24	24086.5	**U45**	24160.0	L23	24083.0	U44	24156.5
L26	24093.5	**U47**	24167.0	L25	24090.0	U46	24163.5
L28	24100.5	**U49**	24174.0	L27	24097.0	U48	24170.5
L30	24107.5	**U51**	24181.0	L29	24104.0	U50	24177.5
L32	24114.5	**U53**	24188.0	L31	24111.0	U52	24184.5
L34	24121.5	**U55**	24195.0	L33	24118.0	U54	24191.5
L36	24128.5	**U57**	24202.0	L35	24125.0	U56	24198.5
L38	24135.5	**U59**	24209.0	L37	24132.0	U58	24205.5
L40	24142.5	**U61**	24216.0	L39	24139.0	U60	24212.5
L42	24149.5	**U63**	24223.0	L41	24146.0	U62	24219.5
L44	24156.5	**U65**	24230.0	L43	24153.0	U64	24226.5
L46	24163.5	**U67**	24237.0	L45	24160.0	U66	24233.5
L48	24170.5	**U69**	24244.0	L47	24167.0	U68	24240.5
L50	24177.5			L49	24174.0		
				L51	24181.0		

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RAy2-24

TX channel nominal frequencies
Band 24.00 – 24.25 GHz, default duplex sp. **87.5** MHz

Bandwidth: **14 MHz**

duplex spacing range 66.5 – 231 MHz

(Freq.table: rcinfo24_ISM250_default:11)

basic channels (default duplex)				optional channels			
Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]	Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]
						U17	24076.0
						U18	24079.5
						U19	24083.0
		U20	24086.5				
						U21	24090.0
						U22	24093.5
				L2	24009.5	U23	24097.0
L3	24013.0	**U24**	24100.5				
				L4	24016.5	U25	24104.0
				L5	24020.0	U26	24107.5
				L6	24023.5	U27	24111.0
L7	24027.0	**U28**	24114.5				
				L8	24030.5	U29	24118.0
				L9	24034.0	U30	24121.5
				L10	24037.5	U31	24125.0
L11	24041.0	**U32**	24128.5				
				L12	24044.5	U33	24132.0
				L13	24048.0	U34	24135.5
				L14	24051.5	U35	24139.0
L15	24055.0	**U36**	24142.5				
				L16	24058.5	U37	24146.0
				L17	24062.0	U38	24149.5
				L18	24065.5	U39	24153.0
L19	24069.0	**U40**	24156.5				
				L20	24072.5	U41	24160.0
				L21	24076.0	U42	24163.5
				L22	24079.5	U43	24167.0
L23	24083.0	**U44**	24170.5				
				L24	24086.5	U45	24174.0
				L25	24090.0	U46	24177.5
				L26	24093.5	U47	24181.0
L27	24097.0	**U48**	24184.5				
				L28	24100.5	U49	24188.0
				L29	24104.0	U50	24191.5
				L30	24107.5	U51	24195.0
L31	24111.0	**U52**	24198.5				
				L32	24114.5	U53	24202.0
				L33	24118.0	U54	24205.5
				L34	24121.5	U55	24209.0
L35	24125.0	**U56**	24212.5				
				L36	24128.5	U57	24216.0
				L37	24132.0	U58	24219.5
				L38	24135.5	U59	24223.0
L39	24139.0	**U60**	24226.5				
				L40	24142.5	U61	24230.0
				L41	24146.0	U62	24233.5
				L42	24149.5	U63	24237.0
L43	24153.0	**U64**	24240.5				
				L44	24156.5		
				L45	24160.0		
				L46	24163.5		
L47	24167.0						
				L48	24170.5		
				L49	24174.0		

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RAy2-24 TX channel nominal frequencies

Band 24.00 – 24.25 GHz, default duplex sp. **84** MHz

Bandwidth: **28 MHz** duplex spacing range 70 – 217 MHz

(Freq.table: rcinfo24_ISM250_default:11)

basic channels (default duplex)				optional channels			
Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]	Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]
						U21	24086.5
						U22	24090.0
		U23	24093.5				
						U24	24097.0
				L4	24016.5	U25	24100.5
				L5	24020.0	U26	24104.0
				L6	24023.5	U27	24107.5
				L7	24027.0	U28	24111.0
				L8	24030.5	U29	24114.5
				L9	24034.0	U30	24118.0
L10	24037.5	**U31**	24121.5				
				L11	24041.0	U32	24125.0
				L12	24044.5	U33	24128.5
				L13	24048.0	U34	24132.0
				L14	24051.5	U35	24135.5
				L15	24055.0	U36	24139.0
				L16	24058.5	U37	24142.5
				L17	24062.0	U38	24146.0
L18	24065.5	**U39**	24149.5				
				L19	24069.0	U40	24153.0
				L20	24072.5	U41	24156.5
				L21	24076.0	U42	24160.0
				L22	24079.5	U43	24163.5
				L23	24083.0	U44	24167.0
				L24	24086.5	U45	24170.5
				L25	24090.0	U46	24174.0
L26	24093.5	**U47**	24177.5				
				L27	24097.0	U48	24181.0
				L28	24100.5	U49	24184.5
				L29	24104.0	U50	24188.0
				L30	24107.5	U51	24191.5
				L31	24111.0	U52	24195.0
				L32	24114.5	U53	24198.5
				L33	24118.0	U54	24202.0
L34	24121.5	**U55**	24205.5				
				L35	24125.0	U56	24209.0
				L36	24128.5	U57	24212.5
				L37	24132.0	U58	24216.0
				L38	24135.5	U59	24219.5
				L39	24139.0	U60	24223.0
				L40	24142.5	U61	24226.5
				L41	24146.0	U62	24230.0
L42	24149.5	**U63**	24233.5				
				L43	24153.0		
				L44	24156.5		
				L45	24160.0		
				L46	24163.5		

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RAy2-24 TX channel nominal frequencies

Band 24.00 – 24.25 GHz, default duplex sp. **70** MHz

Bandwidth: **40 MHz** duplex spacing range 70 – 203 MHz

(Freq.table: rcinfo24_ISM250_default:11)

basic channels (default duplex)				optional channels			
Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]	Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]
				L6	24023.5	U27	24093.5
				L7	24027.0	U28	24097.0
L8	24030.5	**U29**	24100.5				
				L9	24034.0	U30	24104.0
				L10	24037.5	U31	24107.5
				L11	24041.0	U32	24111.0
				L12	24044.5	U33	24114.5
				L13	24048.0	U34	24118.0
				L14	24051.5	U35	24121.5
				L15	24055.0	U36	24125.0
				L16	24058.5	U37	24128.5
				L17	24062.0	U38	24132.0
				L18	24065.5	U39	24135.5
				L19	24069.0	U40	24139.0
L20	24072.5	**U41**	24142.5				
				L21	24076.0	U42	24146.0
				L22	24079.5	U43	24149.5
				L23	24083.0	U44	24153.0
				L24	24086.5	U45	24156.5
				L25	24090.0	U46	24160.0
				L26	24093.5	U47	24163.5
				L27	24097.0	U48	24167.0
				L28	24100.5	U49	24170.5
				L29	24104.0	U50	24174.0
				L30	24107.5	U51	24177.5
				L31	24111.0	U52	24181.0
L32	24114.5	**U53**	24184.5				
				L33	24118.0	U54	24188.0
				L34	24121.5	U55	24191.5
				L35	24125.0	U56	24195.0
				L36	24128.5	U57	24198.5
				L37	24132.0	U58	24202.0
				L38	24135.5	U59	24205.5
				L39	24139.0	U60	24209.0
				L40	24142.5	U61	24212.5
				L41	24146.0	U62	24216.0
				L42	24149.5	U63	24219.5
				L43	24153.0	U64	24223.0
L44	24156.5	**U65**	24226.5				

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RAy2-24

TX channel nominal frequencies

Band 24.00 – 24.25 GHz, default duplex sp. **85** MHz

Bandwidth: **56 MHz**

duplex spacing range 85 – 190 MHz

(Freq.table: rcinfo24_ISM250_default:11)

basic channels (default duplex)				optional channels			
Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]	Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]
				L8	24030.5	U29	24115.5
				L9	24034.0	U30	24119.0
				L10	24037.5	U31	24122.5
				L11	24041.0	U32	24126.0
				L12	24044.5	U33	24129.5
				L13	24048.0	U34	24133.0
				L14	24051.5	U35	24136.5
				L15	24055.0	U36	24140.0
				L16	24058.5	U37	24143.5
				L17	24062.0	U38	24147.0
				L18	24065.5	U39	24150.5
				L19	24069.0	U40	24154.0
				L20	24072.5	U41	24157.5
				L21	24076.0	U42	24161.0
L22	24079.5	**U43**	24164.5				
				L23	24083.0	U44	24168.0
				L24	24086.5	U45	24171.5
				L25	24090.0	U46	24175.0
				L26	24093.5	U47	24178.5
				L27	24097.0	U48	24182.0
				L28	24100.5	U49	24185.5
				L29	24104.0	U50	24189.0
				L30	24107.5	U51	24192.5
				L31	24111.0	U52	24196.0
				L32	24114.5	U53	24199.5
				L33	24118.0	U54	24203.0
				L34	24121.5	U55	24206.5
				L35	24125.0	U56	24210.0
				L36	24128.5	U57	24213.5
				L37	24132.0	U58	24217.0
L38	24135.5	**U59**	24220.5				

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10.7.4. Nominal frequencies - FCC ETSI

RAy2-24 TX channel nominal frequencies

Band 24.05 – 24.25 GHz, default duplex sp. **73.5** MHz

Bandwidth: **3.5 MHz** duplex spacing range 63 – 192.5 MHz

(Freq.table: rcinfo24_ISM200:10)

basic channels (default duplex)				optional channels			
Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]	Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]
		U33	24118.0	no more channels			
		U34	24121.5				
		U35	24125.0				
L15	24055.0	**U36**	24128.5				
L16	24058.5	**U37**	24132.0				
L17	24062.0	**U38**	24135.5				
L18	24065.5	**U39**	24139.0				
L19	24069.0	**U40**	24142.5				
L20	24072.5	**U41**	24146.0				
L21	24076.0	**U42**	24149.5				
L22	24079.5	**U43**	24153.0				
L23	24083.0	**U44**	24156.5				
L24	24086.5	**U45**	24160.0				
L25	24090.0	**U46**	24163.5				
L26	24093.5	**U47**	24167.0				
L27	24097.0	**U48**	24170.5				
L28	24100.5	**U49**	24174.0				
L29	24104.0	**U50**	24177.5				
L30	24107.5	**U51**	24181.0				
L31	24111.0	**U52**	24184.5				
L32	24114.5	**U53**	24188.0				
L33	24118.0	**U54**	24191.5				
L34	24121.5	**U55**	24195.0				
L35	24125.0	**U56**	24198.5				
L36	24128.5	**U57**	24202.0				
L37	24132.0	**U58**	24205.5				
L38	24135.5	**U59**	24209.0				
L39	24139.0	**U60**	24212.5				
L40	24142.5	**U61**	24216.0				
L41	24146.0	**U62**	24219.5				
L42	24149.5	**U63**	24223.0				
L43	24153.0	**U64**	24226.5				
L44	24156.5	**U65**	24230.0				
L45	24160.0	**U66**	24233.5				
L46	24163.5	**U67**	24237.0				
L47	24167.0	**U68**	24240.5				
L48	24170.5	**U69**	24244.0				
L49	24174.0	**U70**	24247.5				
L50	24177.5						
L51	24181.0						
L52	24184.5						

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RAy2-24 TX channel nominal frequencies

Band 24.05 – 24.25 GHz, default duplex sp. **73.5** MHz

Bandwidth: **7 MHz** duplex spacing range 63 – 189 MHz

(Freq.table: rcinfo24_ISM200:10)

basic channels (default duplex)				optional channels			
Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]	Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]
		U33	24118.0				
		U35	24125.0			U34	24121.5
L16	24058.5	**U37**	24132.0	L15	24055.0	U36	24128.5
L18	24065.5	**U39**	24139.0	L17	24062.0	U38	24135.5
L20	24072.5	**U41**	24146.0	L19	24069.0	U40	24142.5
L22	24079.5	**U43**	24153.0	L21	24076.0	U42	24149.5
L24	24086.5	**U45**	24160.0	L23	24083.0	U44	24156.5
L26	24093.5	**U47**	24167.0	L25	24090.0	U46	24163.5
L28	24100.5	**U49**	24174.0	L27	24097.0	U48	24170.5
L30	24107.5	**U51**	24181.0	L29	24104.0	U50	24177.5
L32	24114.5	**U53**	24188.0	L31	24111.0	U52	24184.5
L34	24121.5	**U55**	24195.0	L33	24118.0	U54	24191.5
L36	24128.5	**U57**	24202.0	L35	24125.0	U56	24198.5
L38	24135.5	**U59**	24209.0	L37	24132.0	U58	24205.5
L40	24142.5	**U61**	24216.0	L39	24139.0	U60	24212.5
L42	24149.5	**U63**	24223.0	L41	24146.0	U62	24219.5
L44	24156.5	**U65**	24230.0	L43	24153.0	U64	24226.5
L46	24163.5	**U67**	24237.0	L45	24160.0	U66	24233.5
L48	24170.5	**U69**	24244.0	L47	24167.0	U68	24240.5
L50	24177.5			L49	24174.0		
				L51	24181.0		

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RAy2-24

TX channel nominal frequencies

Band 24.05 – 24.25 GHz, default duplex sp. **87.5** MHz

Bandwidth: **14 MHz**

duplex spacing range 66.5 – 182 MHz

(Freq.table: rcinfo24_ISM200:10)

basic channels (default duplex)				optional channels			
Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]	Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]
						U31	24125.0
		U32	24128.5				
						U33	24132.0
						U34	24135.5
						U35	24139.0
		U36	24142.5				
				L16	24058.5	U37	24146.0
				L17	24062.0	U38	24149.5
				L18	24065.5	U39	24153.0
L19	24069.0	**U40**	24156.5				
				L20	24072.5	U41	24160.0
				L21	24076.0	U42	24163.5
				L22	24079.5	U43	24167.0
L23	24083.0	**U44**	24170.5				
				L24	24086.5	U45	24174.0
				L25	24090.0	U46	24177.5
				L26	24093.5	U47	24181.0
L27	24097.0	**U48**	24184.5				
				L28	24100.5	U49	24188.0
				L29	24104.0	U50	24191.5
				L30	24107.5	U51	24195.0
L31	24111.0	**U52**	24198.5				
				L32	24114.5	U53	24202.0
				L33	24118.0	U54	24205.5
				L34	24121.5	U55	24209.0
L35	24125.0	**U56**	24212.5				
				L36	24128.5	U57	24216.0
				L37	24132.0	U58	24219.5
				L38	24135.5	U59	24223.0
L39	24139.0	**U60**	24226.5				
				L40	24142.5	U61	24230.0
				L41	24146.0	U62	24233.5
				L42	24149.5	U63	24237.0
L43	24153.0	**U64**	24240.5				
				L44	24156.5		
				L45	24160.0		
				L46	24163.5		
L47	24167.0						
				L48	24170.5		
				L49	24174.0		

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RAy2-24

TX channel nominal frequencies

Band 24.05 – 24.25 GHz, default duplex sp. **84** MHz

Bandwidth: **28 MHz**

duplex spacing range 70 – 168 MHz

(Freq.table: rcinfo24_ISM200:10)

basic channels (default duplex)				optional channels			
Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]	Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]
						U35	24135.5
						U36	24139.0
						U37	24142.5
						U38	24146.0
L18	24065.5	**U39**	24149.5				
				L19	24069.0	U40	24153.0
				L20	24072.5	U41	24156.5
				L21	24076.0	U42	24160.0
				L22	24079.5	U43	24163.5
				L23	24083.0	U44	24167.0
				L24	24086.5	U45	24170.5
				L25	24090.0	U46	24174.0
L26	24093.5	**U47**	24177.5				
				L27	24097.0	U48	24181.0
				L28	24100.5	U49	24184.5
				L29	24104.0	U50	24188.0
				L30	24107.5	U51	24191.5
				L31	24111.0	U52	24195.0
				L32	24114.5	U53	24198.5
				L33	24118.0	U54	24202.0
L34	24121.5	**U55**	24205.5				
				L35	24125.0	U56	24209.0
				L36	24128.5	U57	24212.5
				L37	24132.0	U58	24216.0
				L38	24135.5	U59	24219.5
				L39	24139.0	U60	24223.0
				L40	24142.5	U61	24226.5
				L41	24146.0	U62	24230.0
L42	24149.5	**U63**	24233.5				
				L43	24153.0		
				L44	24156.5		
				L45	24160.0		
				L46	24163.5		

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RAy2-24 TX channel nominal frequencies

Band 24.05 – 24.25 GHz, default duplex sp. **70** MHz

Bandwidth: **40 MHz** duplex spacing range 70 – 154 MHz

(Freq.table: rcinfo24_ISM200:10)

basic channels (default duplex)				optional channels			
Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]	Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]
L20	24072.5	**U41**	24142.5				
				L21	24076.0	U42	24146.0
				L22	24079.5	U43	24149.5
				L23	24083.0	U44	24153.0
				L24	24086.5	U45	24156.5
				L25	24090.0	U46	24160.0
				L26	24093.5	U47	24163.5
				L27	24097.0	U48	24167.0
				L28	24100.5	U49	24170.5
				L29	24104.0	U50	24174.0
				L30	24107.5	U51	24177.5
				L31	24111.0	U52	24181.0
L32	24114.5	**U53**	24184.5				
				L33	24118.0	U54	24188.0
				L34	24121.5	U55	24191.5
				L35	24125.0	U56	24195.0
				L36	24128.5	U57	24198.5
				L37	24132.0	U58	24202.0
				L38	24135.5	U59	24205.5
				L39	24139.0	U60	24209.0
				L40	24142.5	U61	24212.5
				L41	24146.0	U62	24216.0
				L42	24149.5	U63	24219.5
				L43	24153.0	U64	24223.0
L44	24156.5	**U65**	24226.5				

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RAy2-24

TX channel nominal frequencies

Band 24.05 – 24.25 GHz, default duplex sp. **85** MHz

Bandwidth: **56 MHz**

duplex spacing range 85 – 141 MHz

(Freq.table: rcinfo24_ISM200:10)

basic channels (default duplex)				optional channels			
Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]	Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]
L22	24079.5	**U43**	24164.5				
				L23	24083.0	U44	24168.0
				L24	24086.5	U45	24171.5
				L25	24090.0	U46	24175.0
				L26	24093.5	U47	24178.5
				L27	24097.0	U48	24182.0
				L28	24100.5	U49	24185.5
				L29	24104.0	U50	24189.0
				L30	24107.5	U51	24192.5
				L31	24111.0	U52	24196.0
				L32	24114.5	U53	24199.5
				L33	24118.0	U54	24203.0
				L34	24121.5	U55	24206.5
				L35	24125.0	U56	24210.0
				L36	24128.5	U57	24213.5
				L37	24132.0	U58	24217.0
L38	24135.5	**U59**	24220.5				

ver. 2.0

11. Safety, environment, licensing

11.1. Frequency

RAy2 microwave links designed for operation in licensed bands must be used in accordance with license issued by the Telecommunications Authority for the area the device is operating in.

RAy2 microwave links designed for operation in ISM bands must comply with the maximum permitted radiated power (EIRP) in accordance with conditions of the given country.

11.2. RoHS and WEEE compliance

The RAy2 is fully compliant with the European Commission"s RoHS (Restriction of Certain Hazardous Substances in Electrical and Electronic Equipment) and WEEE (Waste Electrical and Electronic Equipment) environmental directives.

RoHS Restriction of hazardous substances (RoHS)

The RoHS Directive prohibits the sale in the European Union of electronic equipment containing these hazardous substances: lead, cadmium, mercury, hexavalent chromium, polybrominated biphenyls (PBBs), and polybrominated diphenyl ethers (PBDEs).

End-of-life recycling programme (WEEE)

The WEEE Directive concerns the recovery, reuse, and recycling of electronic and electrical equipment. Under the Directive, used equipment must be marked, collected separately, and disposed of properly. Racom has instigated a programme to manage the reuse, recycling, and recovery of waste in an environmentally safe manner using processes that comply with the WEEE Directive (EU Waste Electrical and Electronic Equipment 2002/96/EC).

Battery Disposal —This product may contain a battery. Batteries must be disposed of properly, and may not be disposed of as unsorted municipal waste in the European Union. See the product documentation for specific battery information. Batteries are marked with a symbol, which may include lettering to indicate cadmium (Cd), lead (Pb), or mercury (Hg). For proper recycling return the battery to your supplier or to a designated collection point.

11.3. Conditions of Liability for Defects and Instructions for Safe Operation of Equipment

Please read these safety instructions carefully before using the product:

- Liability for defects does not apply to any product that has been used in a manner which conflicts with the instructions contained in this operator manual, or if the case in which the radio modem is located has been opened, or if the equipment has been tampered with.
- The radio equipment can only be operated on frequencies stipulated by the body authorised by the radio operation administration in the respective country and cannot exceed the maximum permitted output power. RACOM is not responsible for products used in an unauthorised way.

- Equipment mentioned in this operator manual may only be used in accordance with instructions contained in this manual. Error-free and safe operation of this equipment is only guaranteed if this equipment is transported, stored, operated and controlled in the proper manner. The same applies to equipment maintenance.
- In order to prevent damage to the radio modem and other terminal equipment the supply must always be disconnected upon connecting or disconnecting the cable to the radio modem data interface. It is necessary to ensure that connected equipment has been grounded to the same potential.
- Only undermentioned manufacturer is entitled to repair any devices.
- Should the RAy2 unit be used with accessories other than those recommended, Racom takes no responsibility for any malfunction caused by the use of such accessories. Using unsuitable accessories (e.g.cable connectors) can result in a mechanical damage to RAy2 internal connectors, allow the penetration of water inside the unit, or reduce the efficiency of internal surge protection circuits.

11.4. Important Notifications

RACOM reserves the right to make changes in the technical specification or in this product function or to terminate production of this product or to terminate its service support without previous written notification of customers.

Conditions of use of this product software abide by the license mentioned below. The program distributed by this license has been freed with the purpose to be useful, but without any specific guarantee. Under any circumstances the author or another company or person is not responsible for secondary, accidental or related damages resulting from application of this product.

The producer does not provide the user of any kind of guarantee containing assurance of suitability and usability for his application. Products are not developed, designed nor tested for utilization in devices directly affecting health and life functions of persons and animals, nor as a part of another important device, and does not provide of guarantees if the company product has been used in these aforementioned devices.

RACOM Open Software License

Version 1.0, November 2009

The program (binary version) is available for free on the contacts listed on http://www.racom.eu. This product contains open source or another 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 is mentioned in 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 li-

cences on contacts listed on http://www.racom.eu. This product also includes software developed by the University of California, Berkeley and its contributors.

11.5. Warranty

RACOM-supplied parts or equipment ("equipment") is covered by 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.

11.6. Declaration of Conformity

RACOM
RADIO DATA NETWORKS

Declaration of Conformity RAy2-10

In accordance with **1999/5/EC** Directive of the European Parliament and of the Council of 9th of March 1999 on radio equipment and telecommunications terminal equipment and the mutual recognition of their conformity.

Manufacturer:	**RACOM**	
Address:	**Mirova 1283, 592 31 Nove Mesto na Morave, Czech Republic**	
VAT:	**CZ46343423**	
Product:	**RAy2-10**	CE
Purpose of use:	**Microvave IP Bridge**	**10.125 – 10.675 GHz RAy2-10-LA, RAy2-10-UA** **10.300 – 10.590 GHz RAy2-10-LB, RAy2-10-UB**

We, the manufacturer of the above mentioned product, hereby declare that:
all essential radio test suites have been carried out and that the above named product is in conformity to all the essential requirements of the European Union directive **1999/5/EC** – ANNEX III (the technical documentation relevant to the abovementioned equipment can be made available for inspection on application to manufacturer);

The Declaration of Conformity is based on the following documents:

Spectrum	EN 302 217-2-2 V2.1.1
EMC	EN 301 489-1 V1.9.2
	EN 301 489-4 V2.1.1
Safety	EN 60950-1: 2006

Nove Mesto na Morave, 14th of May 2014
Jiri Hruska, CEO

RACOM s.r.o. • Mirova 1283 • 592 31 Nove Mesto na Morave • Czech Republic
Tel.: +420 565 659 511 • Fax: +420 565 659 512 • E-mail: racom@racom.eu

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Fig. 11.1: Declaration of Conformity for RAy2-10

RACOM
RADIO DATA NETWORKS

Declaration of Conformity RAy2-17

In accordance with **1999/5/EC** Directive of the European Parliament and of the Council of 9th of March 1999 on radio equipment and telecommunications terminal equipment and the mutual recognition of their conformity.

Manufacturer:	**RACOM**
Address:	**Mirova 1283, 592 31 Nove Mesto na Morave, Czech Republic**
VAT:	**CZ46343423**
Product:	**RAy2-17**
Purpose of use:	**Microvave IP Bridge 17.10 – 17.30 GHz**

CE

We, the manufacturer of the above mentioned product, hereby declare that:
all essential radio test suites have been carried out and that the above named product is in conformity to all the essential requirements of the European Union directive **1999/5/EC** – ANNEX III (the technical documentation relevant to the abovementioned equipment can be made available for inspection on application to manufacturer);

The Declaration of Conformity is based on the following documents:

Spectrum	EN 300 440-2 V1.4.1
EMC	EN 301 489-1 V1.9.2
	EN 301 489-4 V2.1.1
Safety	EN 60950-1: 2006

Nove Mesto na Morave, 14th of May 2014
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Fig. 11.2: Declaration of Conformity for RAy2-17

RACOM
RADIO DATA NETWORKS

Declaration of Conformity RAy2-24

In accordance with **1999/5/EC** Directive of the European Parliament and of the Council of 9th of March 1999 on radio equipment and telecommunications terminal equipment and the mutual recognition of their conformity.

Manufacturer:	**RACOM**
Address:	**Mirova 1283, 592 31 Nove Mesto na Morave, Czech Republic**
VAT:	**CZ46343423**
Product:	**RAy2-24**
Purpose of use:	**Microvave IP Bridge 24.00 – 24.25 GHz**

CE

We, the manufacturer of the above mentioned product, hereby declare that:
all essential radio test suites have been carried out and that the above named product is in conformity to all the essential requirements of the European Union directive **1999/5/EC** – ANNEX III (the technical documentation relevant to the abovementioned equipment can be made available for inspection on application to manufacturer);

The Declaration of Conformity is based on the following documents:

Spectrum	EN 300 440-2 V1.4.1
EMC	EN 301 489-1 V1.9.2
	EN 301 489-4 V2.1.1
Safety	EN 60950-1: 2006

Nove Mesto na Morave, 14th of May 2014
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Fig. 11.3: Declaration of Conformity for RAy2-24

11.7. Country of Origin Declaration

RACOM
RADIO DATA NETWORKS

Country of Origin Declaration

Producer:	**RACOM s.r.o.**
Address:	**Mirova 1283, 592 31 Nove Mesto na Morave, Czech Republic**
VAT No:	**CZ46343423**

We, the manufacturer, hereby declare that Country of Origin of the RAy microwave links and its accessories is the Czech Republic, EU.

Part Number	Description
RAy2-10	Unit RAy2-10, 2× Gb Eth
RAy2-17	Unit RAy2-17, 2× Gb Eth
RAy2-24	Unit RAy2-24, 2× Gb Eth

Nove Mesto na Morave, 14 of May 2014
Jiri Hruska, CEO

RACOM s.r.o. • Mirova 1283 • 592 31 Nove Mesto na Morave • Czech Republic
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Fig. 11.4: Country of Origin Declaration

Appendix A. Antenna dimensions

Example antennas diameter of 68 and 90 cm. More on www.racom.eu[1].

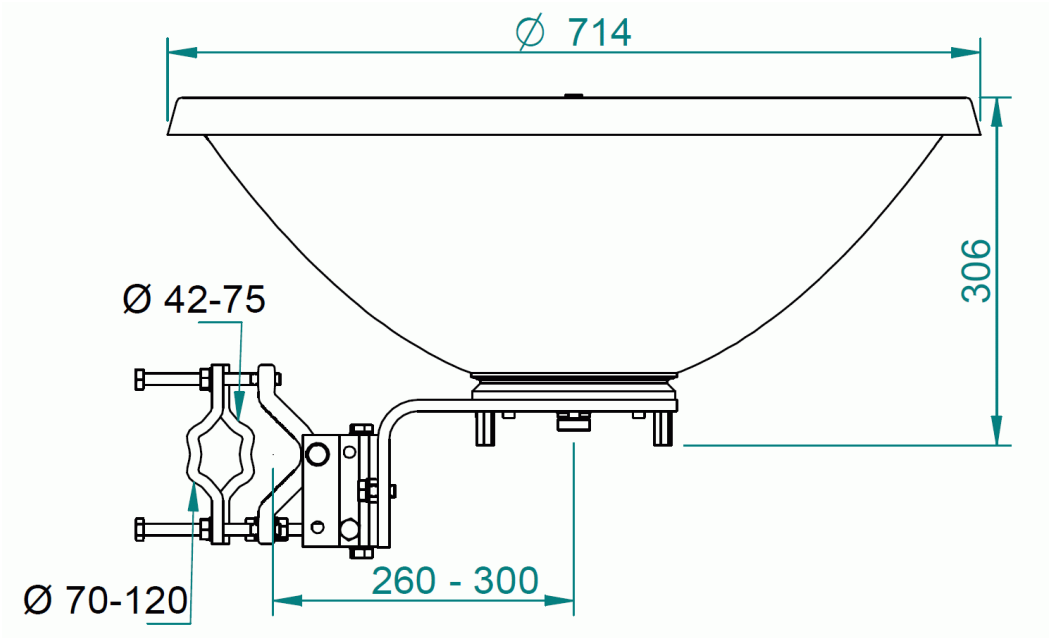


Fig. A.1: Jirous antenna 68

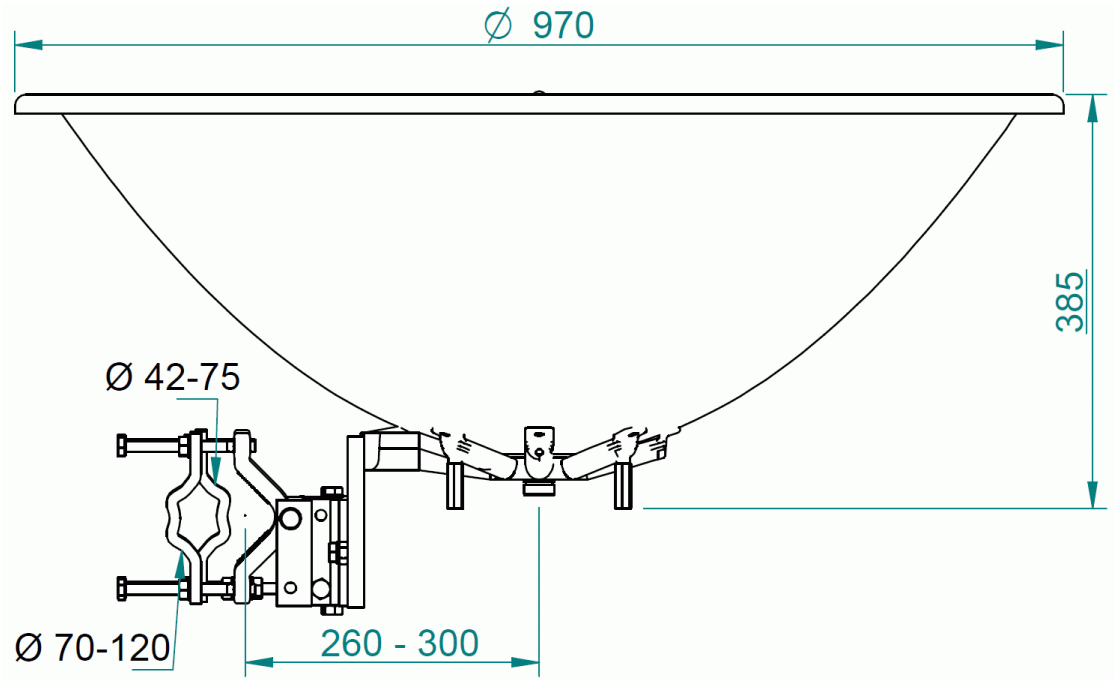
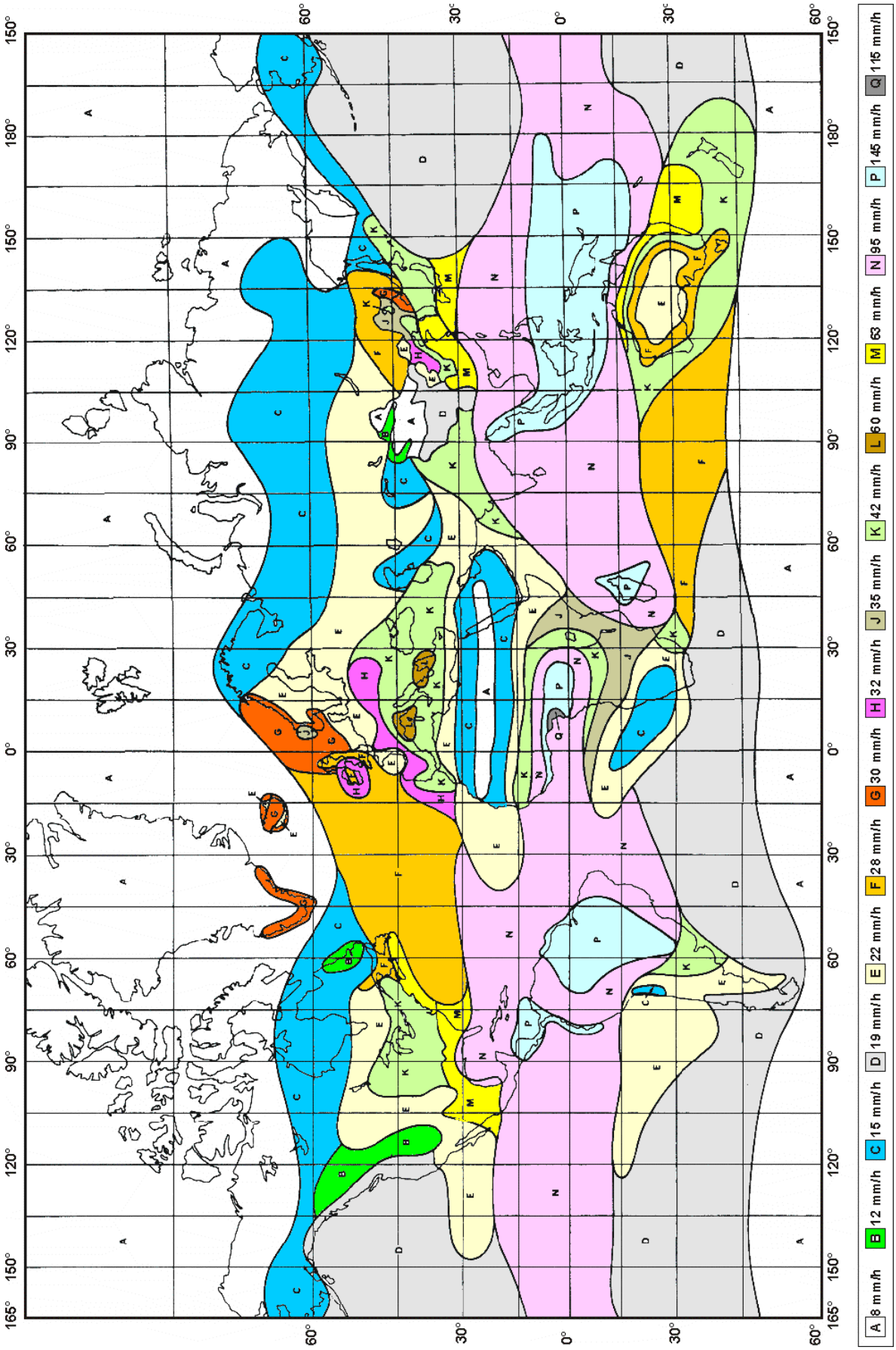


Fig. A.2: Jirous antenna 90

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

Appendix B. Rain zone map

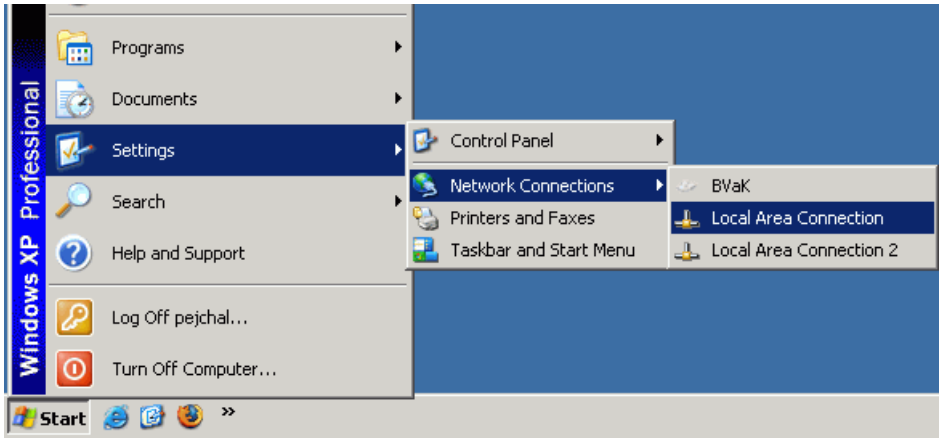


Appendix C. IP address in the PC

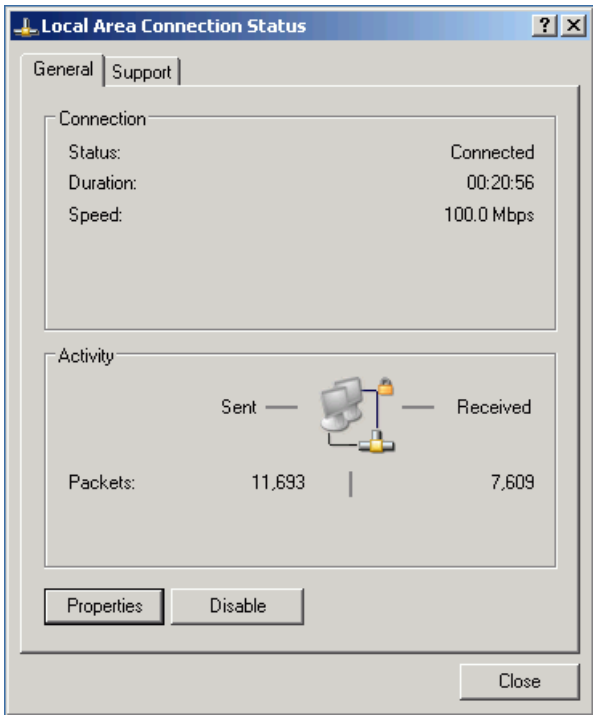
Setting up the IP address in the PC

For configuration of the link a suitable IP address has to be set up in the PC, for example 192.168.1.233. In the next example for Windows XP we presume that the PC uses DHCP as the primary configuration.

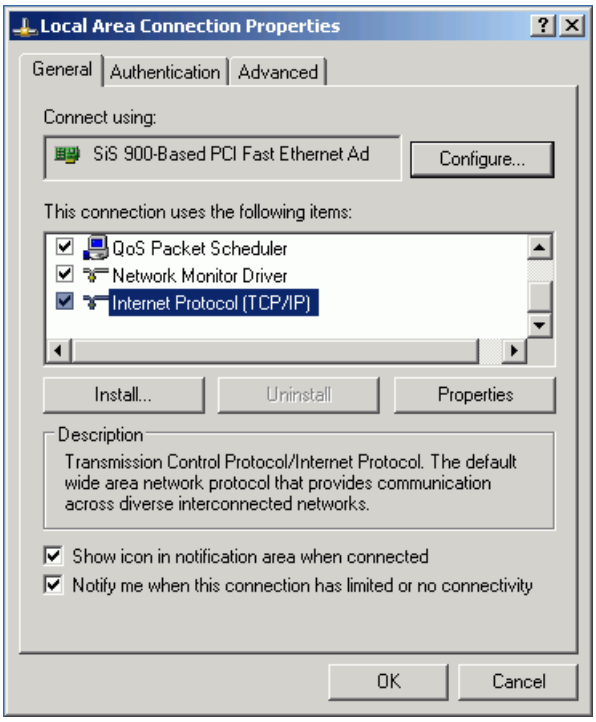
- Open the Start menu, **Settings**, **Network Connections**, **Local Area Connection**



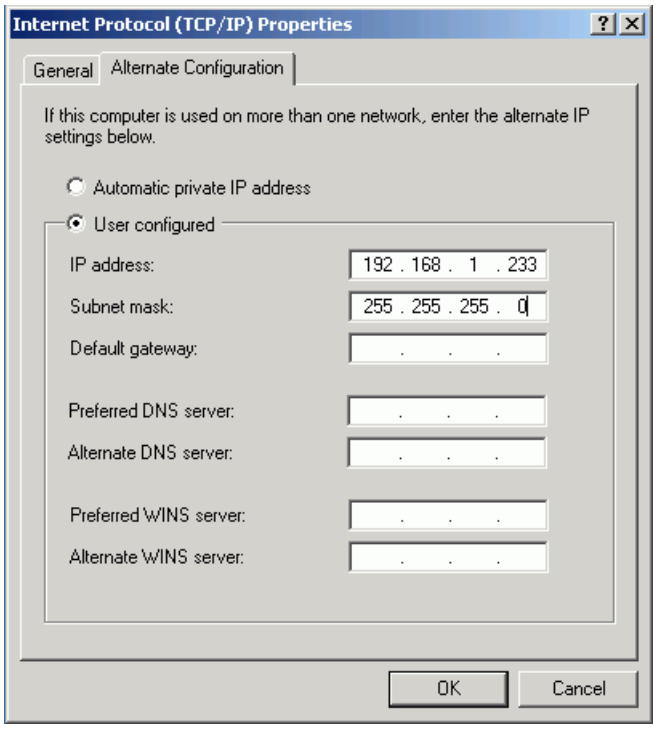
- In the window **Local Area Connection** select **Properties**



- Another window opens. Select **Internet Protocol (TCP/IP)** and click **Properties**



- Another window opens
- On the **General** tab select **Use the following IP address**
- Enter IP Address 192.168.1.233
- Set Subnet mask to 255.255.255.0
- Click **OK** to acknowledge this window and acknowledge the previous window in the same manner
-
- The second option is to use automatic switching. In this case on the *General* tab select, for example O*btain an IP address from the DHCP server automatically* and address 192.168.1.233 will be seen on the Alternate configuration tab. However, this detection and subsequent switching works slower and isn't entirely reliable.
- Select tab **Alternate configuration**
- Select **User defined configuration**
- Enter IP Address 192.168.1.233
- Set Subnet mask to 255.255.255.0



- Click **OK** to acknowledge this window and acknowledge the previous window in the same manner

If you don't use Windows XP then proceed according to the manual when setting up the IP address.

Checking the IP address in the PC

In Windows proceed in the following manner:

1. Open the Start menu and click **Run...**
2. Enter command **cmd**
3. Enter command **ipconfig** and read the PC IP address and mask:

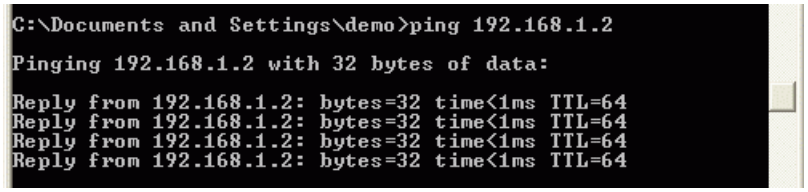
Checking the PC - radio modem connection using Ping

In Windows send a ping as follows:

1. Check the connection between the PC and the radio modem via the Ethernet cable.
2. In the Start menu click **Run...**
3. Enter command **cmd**

4. Write **ping 192.168.1.2** and press OK

5. A message appears in a window:



   If no communication takes place a message appears with the text "Request timed out".

If communication between the web browser and radio modem doesn't take place check the browser settings. The *Work offline* item in the *File* menu cannot be crossed out.

Appendix D. 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 a key. The key can be in Linux format and it begins:

```
-----BEGIN DSA PRIVATE KEY-----
.....
```

or in PuTTY format which begins:

```
PuTTY-User-Key-File-2: ssh-dss
.....
```

To convert the Linux format to PuTTY do the following:

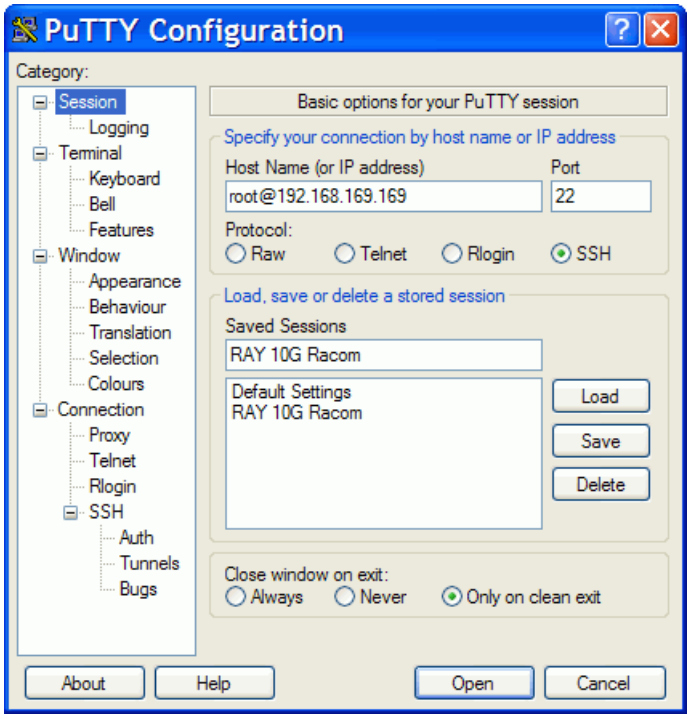
In c:\Program Files\putty\ directory run PUTTYGEN.EXE

Click on “Load” and choose the Linux private key.

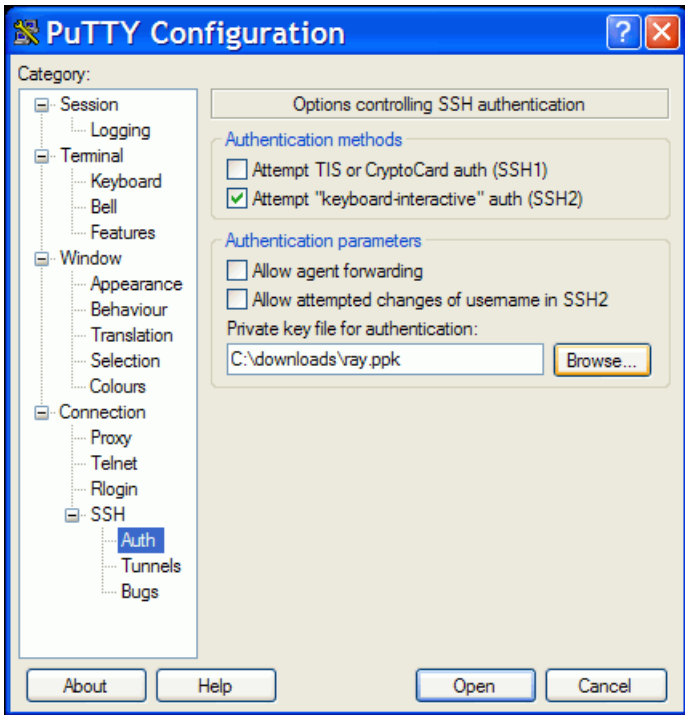
In the next window type your password into the *Key passphrase* and *Confirm passphrase* fields. After that click *Save private key*. Choose location and save the key.

PuTTY access with key

In PuTTY menu fill in the address, e.g. *root@192.168.169.169* and the name of the link, e.g. *RAy 17 Racom*.



Go to *Connection / SSH / Auth* in the left column and locate the key *C:\downloads\ray.ppk*



Go back to *Session* and *Save* the configuration.

To connect select the name of the connection and click *Open*. PuTTY asks for password created during key conversion.

Appendix E. Https certificate

When switching from older versions of the firmware the access certificate for https was changed. The web browser configuration has to take place in order to remove link between microwave link management IP address and previous https certificate.

Mozilla Firefox how-to:

1. https certificate
   Remove management IP address from the list: `Tools - Options - Advanced - Encryption - View Certificates – Servers`
   Another possibility: remove certificate Racom “RAy” or Racom “RACOM's product” from the list: `Tools - Options - Advanced - Encryption - View Certificates – Authorities`

2. Upon the new RAy unit connection following message appear: “*This Connection is Untrusted*”.

3. If you are sure that there is no security risk, choose: “*I Understand the Risks*”.

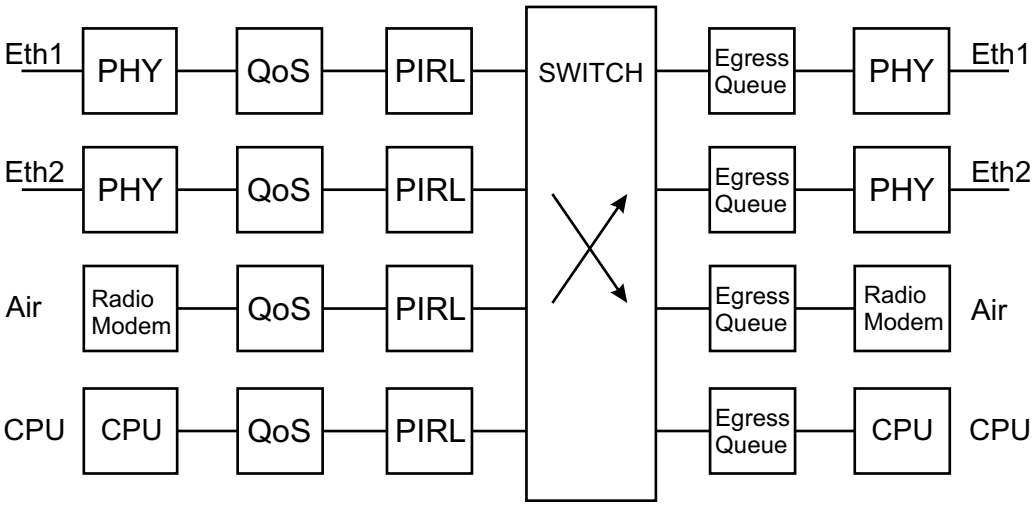
4. The next step is “*Add Exception...*”

5. Finally, you have to “*Confirm Security Exception*”. If the Apply button is not active, it is necessary to perform step No. 1/ and restart web browser.

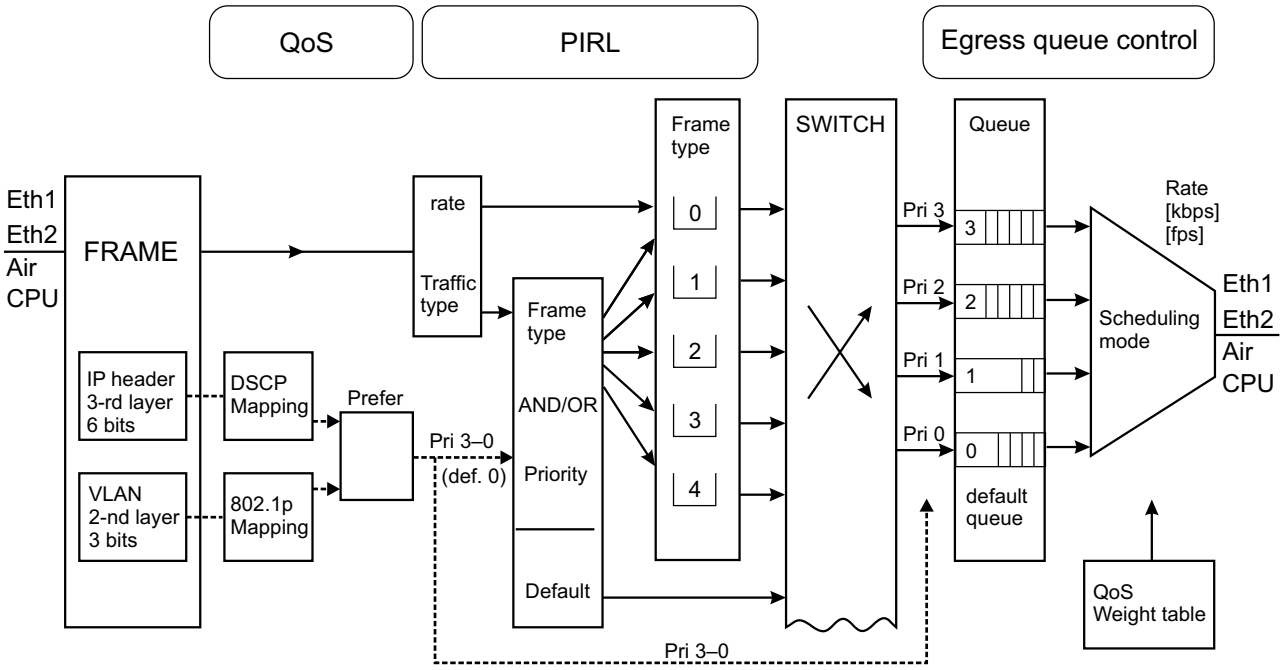
Internet Explorer may give following message “*There is a problem with this website's security certificate*”. Choose “*Continue to this website (not recommended)*”. The address line gives you status information “*Certificate Error*”. This inconvenience is caused by impossibility to create security certificate valid for list of user selected IP addresses.

Appendix F. Ethernet switch functional diagram

The overall diagram of the unit, see also the description:



Frame processing detail:



Index

Appendix G. Revision History

Revision 1.0 2014-05-28
First issue

Revision 1.1 2014-06-04
Name plate changes

Revision 1.2 2014-07-15
RAy2-11C,D user speed and CS correction

Revision 1.3 2014-07-25
Accessory supplemented