User Manual for SATELLAR Radio Unit

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Salo, Finland 2010

RESTRICTIONS ON USE

The user of a radio modem must take care that the said device is not operated without the permission of the local authorities on frequencies other than those specifically reserved and intended for use without a specific permit.

PRODUCT CONFORMITY

SATELLAR

SATEL Oy hereby declares that SATELLAR radio modem is in compliance with the essential requirements (radio performance, electromagnetic compatibility and electrical safety) and other relevant provisions of Directive 1999/5/EC. Therefore the equipment is labelled with the following CE-marking. The notification sign informs users that the operating frequency range of the device is not harmonised throughout the market area, and the local spectrum authority should be contacted before the usage of the radio modem is used.

CE1987 ⓘ

DECLARATION of CONFORMITY

In Accordance with

1999/5/EC Directive

of the European Parliament and of the Council of 9 March 1999 on radio equipment and telecommunications terminal equipment and the mutual recognition of their conformity

Doc No: SATEL-DC-RTTE-087

Manufacturer: SATEL Oy

Address: POB 142, (Meriniitynkatu 17), 24101 Salo, Finland

Products :

Type	Model
SATEL-TA12	SATELLAR-RU-XXXX
SATEL-TA14	SATELLAR-CU-XXXX

"XXXX" is used for distinguishing different variants.

As a combined product package the marketing name is either SATELLAR 2DS or SATELLAR 2DSd.

Notified Body Opinion:
according to: Annex IV of R&TTE Directive
Document No: 127761N
Dated on: 23.9.2009
Issued by: Nemko / No: 1987

We, the manufacturer of the above mentioned products, hereby declare that these products conform to the essential requirements of the European Union directive 1999/5/EC. This Declaration of Conformity is based on the following documents:

Doc. No	Type of Product	Test Specification	Laboratory / Date of Issue
127761	SATELLAR RU	EN 300 113-2 V1.4.1	NEMKO / Espoo 8.6.2009
127761A	SATELLAR RU	EN 301 489-1 V.1.8.1 & -5 V.1.3.1	NEMKO / Espoo 5.5.2009
127761D	SATELLAR RU	EN 60950-1 2nd Ed (2005)	NEMKO / Espoo 27.8.2009
127761C	SATELLAR CU	EN 301489-1-5 / IEC 61000-6-2 / 61000-6-4	NEMKO / Espoo 5.5.2009

Salo on the 13th of April, 2010.

SATEL OY

Pekka Aura
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LOCAL AREA WIRELESS DATA COMMUNICATIONS • SATEL OY •

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SATEL WIRELESS WORLD – LOCAL SOLUTION

WARRANTY AND SAFETY INSTRUCTIONS

Read these safety instructions carefully before using the product:

- The warranty will be void if the product is used in any way that is in contradiction with the instructions given in this manual, or if the radio modem housing has been opened or tampered with.

- The radio modem is only to be operated at frequencies allocated by local authorities, and without exceeding the given maximum allowed output power ratings. SATEL and its distributors are not responsible if any products manufactured by it are used in unlawful ways.

- The devices mentioned in this manual are to be used only according to the instructions described in this manual. Faultless and safe operation of the devices can be guaranteed only if the transport, storage, operation and handling of the devices is appropriate. This also applies to the maintenance of the products.

- To prevent damage to both the radio modem and any terminal devices must always be switched OFF before connecting or disconnecting the serial connection cable. It should be ascertained that different devices used have the same ground potential. Before connecting any power cables the output voltage of the power supply should be checked.

- It is possible to connect the device to an outdoor antenna or a cable distribution system. In these cases, in order to conduct the possible over voltages due to lightings to earth, the equipment should be connected to protective earth by using the mounting screws of the device.

- This is a requirement in order to be in compliance with the electrical safety regulations (EN 60950-1).

TABLE OF CONTENTS

1 INTRODUCTION TO SATELLAR PRODUCT FAMILY

SATELLAR is a new generation narrow band radio modem that consists of separate units:

- Central unit
- Radio unit
- expansion units

Using SATELLAR the customer builds his/her own independent radio data communication network.

This document presents the specifications and usage of the Radio unit. The properties of other units are described to the extent that is necessary to understand the operation of the Radio unit.

Data communication

SATELLAR can operate either as a transparent radio link, essentially replacing a wire, for classic RS-232, RS-485 or RS-422 based protocols or as a wireless router in an IP-based network. When the Radio unit is acting in an IP network as a repeater station without any local Ethernet connection it can be used as a standalone device whereas in stations where a local Ethernet connection is needed it must be used together with a Central unit.

Range

With the Radio unit of SATELLAR the communication range of a point to point link is typically longer than 10 km in urban conditions (some obstacles in the line of sight), and longer than 20 km in line of sight conditions. The range can be further extended using high gain antennas, booster modules and radio repeaters.

Security

Data security is often a concern when using radio communication. In SATELLAR a 128 bit encryption on the air-interface ensures privacy in the radio network.

Diagnostics and configuration

Radio modems are often used in applications where reliability and independence are key properties. To support this demand, SATELLAR has built-in diagnostic and remote configuration features. To access these features SATELLAR as a product family offers many different user interfaces. Two of them are available for the Radio unit:

1) LED indicators

The status of the Radio unit can be seen from the LED indicators that are located on the other narrow side of the unit.

2) SATEL NMS PC software

Once deployed status monitoring and configuration can be performed using a Windows based SATEL NMS PC software through the RS-232/485 interface of the Radio unit. This is also possible over the air: the status and configuration data of a distant radio modem can be accessed through a radio connection.

Flexible and expandable

The SATELLAR concept has been designed to be flexible and expandable both in terms of hardware and software functions. This can also be seen when using the Radio unit alone.

Modulation level

Several different modulation methods (2-, 4-, 8-, and 16-FSK) are offered. If the customer requires a long range radio connection he/she selects a low level modulation. On the contrary, if a high data rate is the primary concern a high level modulation must be selected.

Channel width

Two different channel widths are supported and can be selected by changing software settings – without a need to modify the hardware

FEC (Forward error correction) and interleaving

To extend the radio range in a noisy environment (at the expense of the data rate) a forward error correction algorithm (FEC) can be used. The Radio unit offers two different code rates for forward error correction. In packet mode of data transfer the forward error correction is used together with interleaving to minimize the effect of errors occurring in bursts. In the transparent mode the forward error correction is used without interleaving to minimize the latency.

Adjustable output power

RF output power is adjustable with high resolution allowing the customer to select the output power just according to the local conditions of the radio link.

Expansion units

Due to the modular mechanical structure of SATELLAR it is possible to add hardware expansion units, even later as an update. Related to Radio unit the most relevant expansion units are:

- A booster unit for higher output power
- A serial port extender unit: a unit offering two or more serial ports, possibly of different types (RS-232, -422, -485)
- I/O extension (for site monitoring and simple I/O control)

For the availability of different expansion units contact your local distributor.

Mounting

SATELLAR can be mounted directly on a flat surface or to a DIN rail. DIN-rail mounting is possible either on the back-side of the stack of units or on the other narrow side of each unit (the latter case so that the LED indicators remain visible for the user). This is valid also when using the Radio unit alone.

Ruggedized

SATELLAR is constructed of die-cast aluminum to withstand the abuse typical to rough industrial environments. It operates over a wide temperature range and under severe vibration conditions to meet the requirements of vehicular and process industry applications.

2 SATELLAR RADIO UNIT TECHNICAL SPECIFICATIONS

Common radio parameters	
Frequency range	Depends on the frequency variant, see chapter 8 for more information
Channel width	12.5 and 25 kHz, selectable by software
Carrier frequency setting	Frequency programmability in 6.25 kHz steps
Carrier frequency accuracy (over temperature):	+/-2.5 ppm
Carrier frequency long term stability	+/-2.0 ppm/3 years
Latency (in transparent mode) (25 kHz, serial port speed 19200 bits/s, over-the-air encryption off, FEC off)	< 11 ms
Modulation methods	2-, 4-, 8-, and 16-FSK
Forward error correction (FEC)	Off, code rate 1/2, code rate 2/3
Interleaving	TBD
Over-the-air encryption	AES 128 bit (CTR-mode)

Transmitter parameters	
Output power	100 mW …1 W, adjustable by software, steps: 10 mW or 0.5 dB
Adjacent channel power:	Typically < -62 dBc (meas. method EN 300 113)

Air speed	bits/s @12.5 kHz	bits/s @ 25 kHz
2-FSK	4800	9600
4-FSK	9600	19200
8-FSK	14400	28800
16-FSK	19200	38400

Receiver parameters

Sensitivity

Channel spacing / modulation	BER / FEC					
	10e-3			10e-6		
	off	67 %	50 %	off	67 %	50 %
25 kHz / 16-FSK	TBD	TBD	TBD	TBD	TBD	TBD
25 kHz / 8-FSK	TBD	TBD	TBD	TBD	TBD	TBD
25 kHz / 4-FSK	TBD	TBD	TBD	TBD	TBD	TBD
25 kHz/ 2-FSK	TBD	TBD	TBD	TBD	TBD	TBD
12.5 kHz / 16-FSK	TBD	TBD	TBD	TBD	TBD	TBD
12.5 kHz / 8-FSK	TBD	TBD	TBD	TBD	TBD	TBD
12.5 kHz / 4-FSK	TBD	TBD	TBD	TBD	TBD	TBD
12.5 kHz / 2-FSK	TBD	TBD	TBD	TBD	TBD	TBD

Co-channel rejection

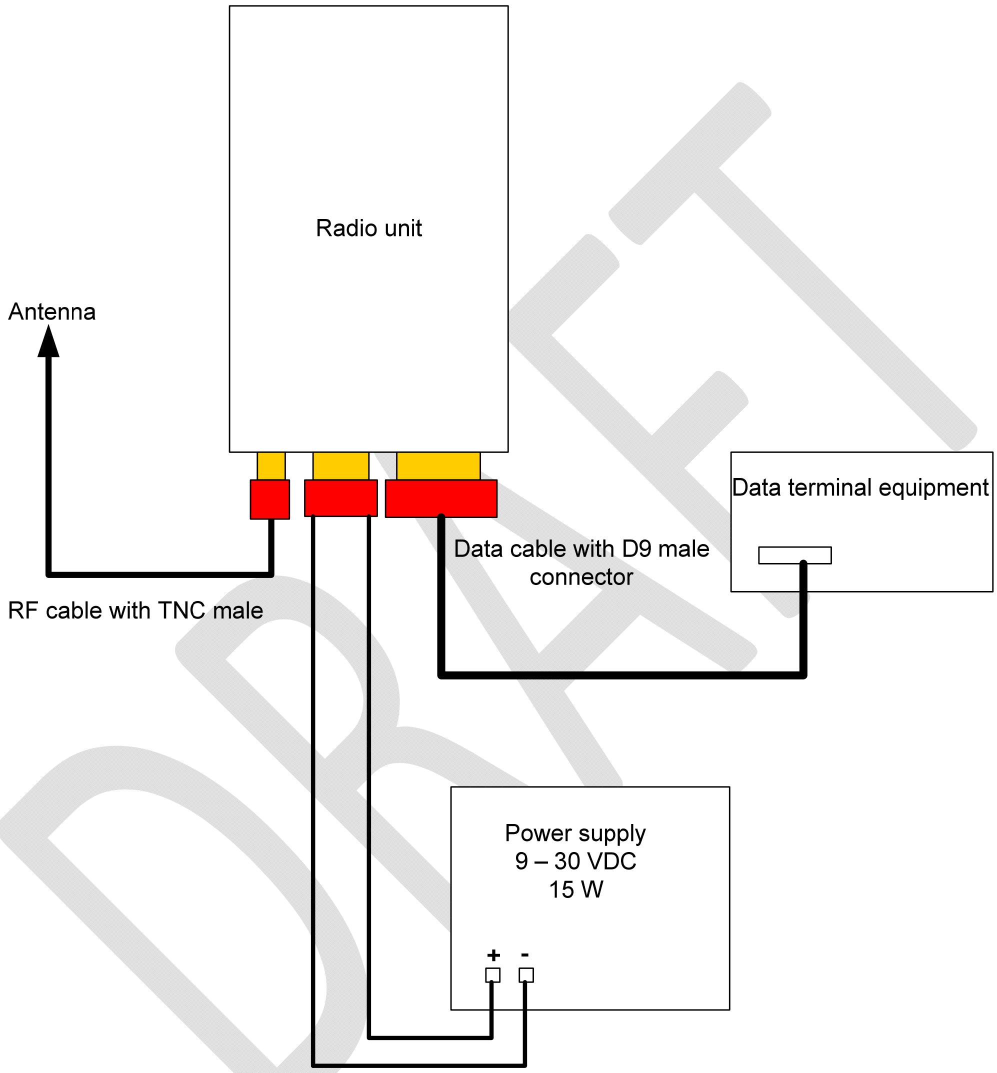
Channel spacing / modulation	BER / FEC					
	10e-3			10e-6		
	off	67 %	50 %	off	67 %	50 %
25 kHz / 16-FSK	TBD	TBD	TBD	TBD	TBD	TBD
25 kHz / 8-FSK	TBD	TBD	TBD	TBD	TBD	TBD
25 kHz / 4-FSK	TBD	TBD	TBD	TBD	TBD	TBD

	25 kHz/ 2-FSK	TBD	TBD	TBD	TBD	TBD	TBD
	12.5 kHz / 16-FSK	TBD	TBD	TBD	TBD	TBD	TBD
	12.5 kHz / 8-FSK	TBD	TBD	TBD	TBD	TBD	TBD
	12.5 kHz / 4-FSK	TBD	TBD	TBD	TBD	TBD	TBD
	12.5 kHz / 2-FSK	TBD	TBD	TBD	TBD	TBD	TBD
Adjacent channel rejection							
	Channel spacing / modulation	BER / FEC					
		10e-3			10e-6		
		off	67 %	50 %	off	67 %	50 %
	25 kHz / 16-FSK	TBD	TBD	TBD	TBD	TBD	TBD
	25 kHz / 8-FSK	TBD	TBD	TBD	TBD	TBD	TBD
	25 kHz / 4-FSK	TBD	TBD	TBD	TBD	TBD	TBD
	25 kHz/ 2-FSK	TBD	TBD	TBD	TBD	TBD	TBD
	12.5 kHz / 16-FSK	TBD	TBD	TBD	TBD	TBD	TBD
	12.5 kHz / 8-FSK	TBD	TBD	TBD	TBD	TBD	TBD
	12.5 kHz / 4-FSK	TBD	TBD	TBD	TBD	TBD	TBD
	12.5 kHz / 2-FSK	TBD	TBD	TBD	TBD	TBD	TBD

Common parameters	
Power consumption	TBD W,1 W transmission TBD W,100 mW transmission TBD W, reception
Start time (from power on)	< 2.5 s
Interfaces – power	2-pin plug with screw flange, pitch 3.5 mm
Interfaces – DTE	RS-232 (TIA-574), D9 female RS-422/485, D9 female
Interfaces – RF	TNC female
Temperature ranges	-25 - +55 deg C, complies with the standards -30 - +75 deg C, functional -40 - +85, storage
Humidity	< 95 % @ 25 deg C, non-condensing
Vibration	at least 10 – 500 Hz/5g without degradation in data transfer capability
Shock resistivity	Dropping height 1 m, all directions
IP rating	IP 52
DC input range	9V....30V
Mechanical dimensions	Radio Unit:130 x 24.3 x 76.5 mm
Mounting	DIN rail (side or back), two-piece mounting clip, or directly on flat surface
Weight	300 g
Standards compliance	
Radio requirements	EN 300 113 MS, FCC Part 90
Emissions, immunity	EN 301 489-1, 301 489-5, FCC Part 15
ESD	IEC 61000-4-2 level 4
RoHS	2002/95/EC

3 TYPICAL SETUP

The figure below shows a typical setup when transferring data through the Radio unit. When using the Radio unit together with the Central unit the recommended minimum distance of the antenna from the Central unit is 2 m in order to avoid degradation of the receiver sensitivity due to interference from the Central unit.



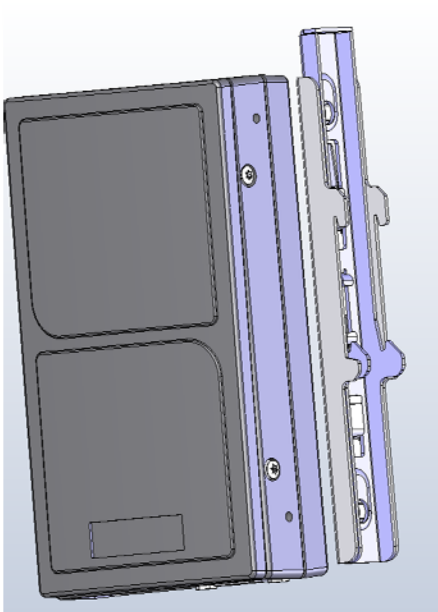
If the user wants to change/view settings the Data terminal equipment needs to be replaced by a PC. The role of the port must then be changed to accept NMS messages. This can be done by pressing the function button that is located below the LED indicators at the other edge of the unit. The functionality of the button is described in chapter 5.6. The port can also be configured so that it is possible to use the Data terminal equipment and PC simultaneously (see chapter 7.3 for details).

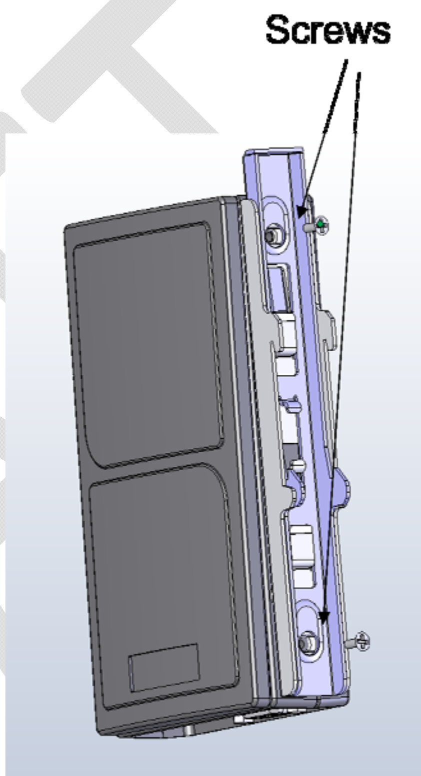
4 MOUNTING

The Radio unit can be mounted in two different ways

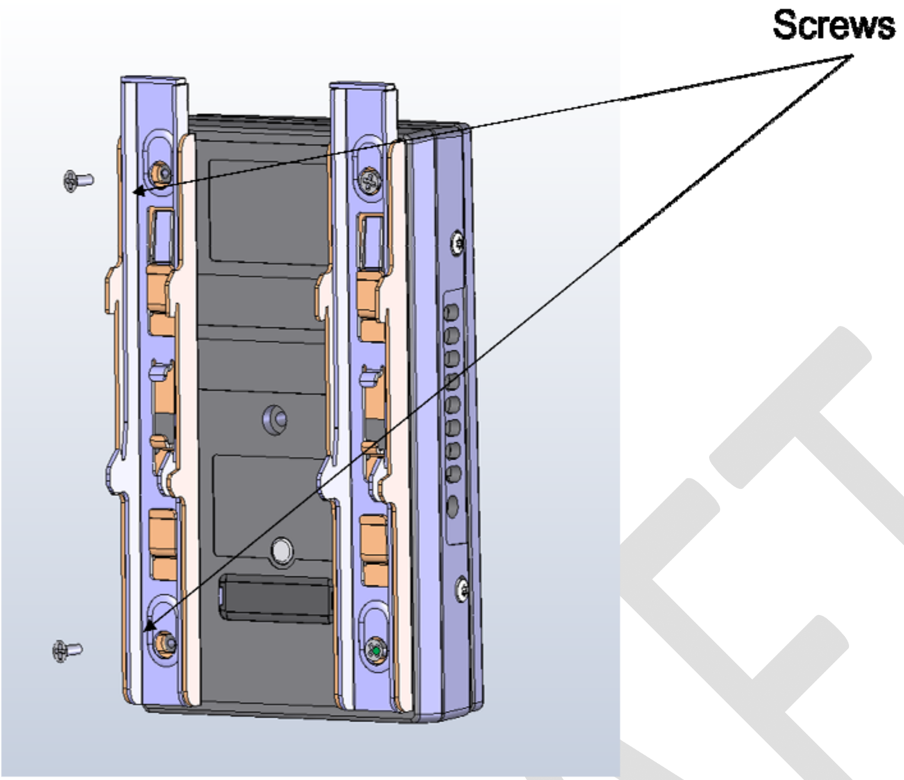
- using SATELLAR specific DIN rail adapter connected at the other edge of the unit
- using two DIN rail adapters connected at the bottom
- using a special two piece mounting clip connected at the bottom

The mountings are further clarified in the figures below.

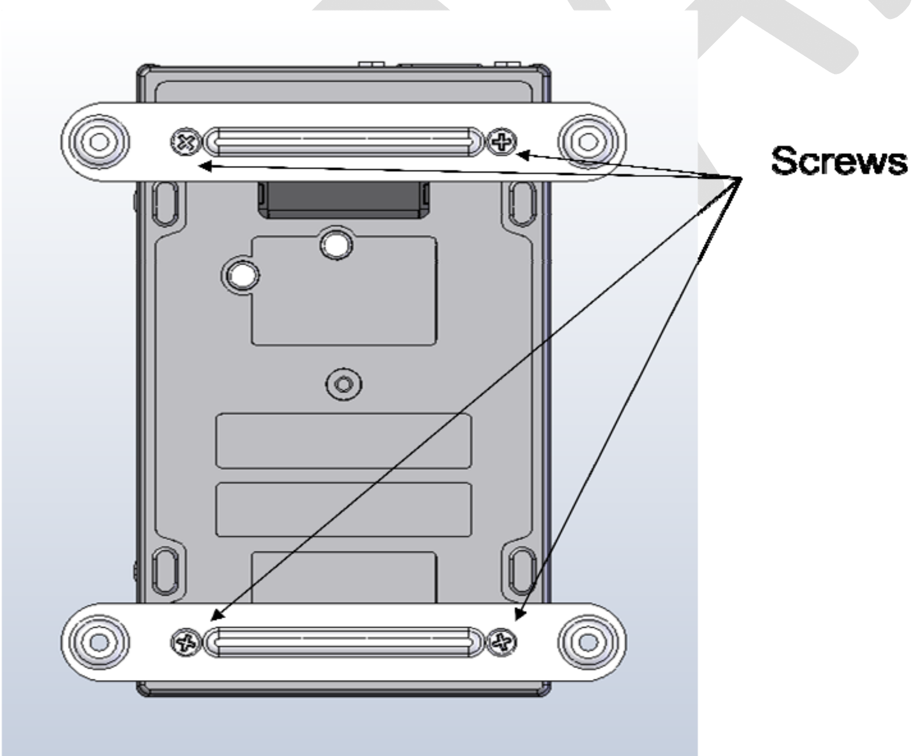




DIN rail adapter at the other edge.



Two DIN rail adapters at the bottom

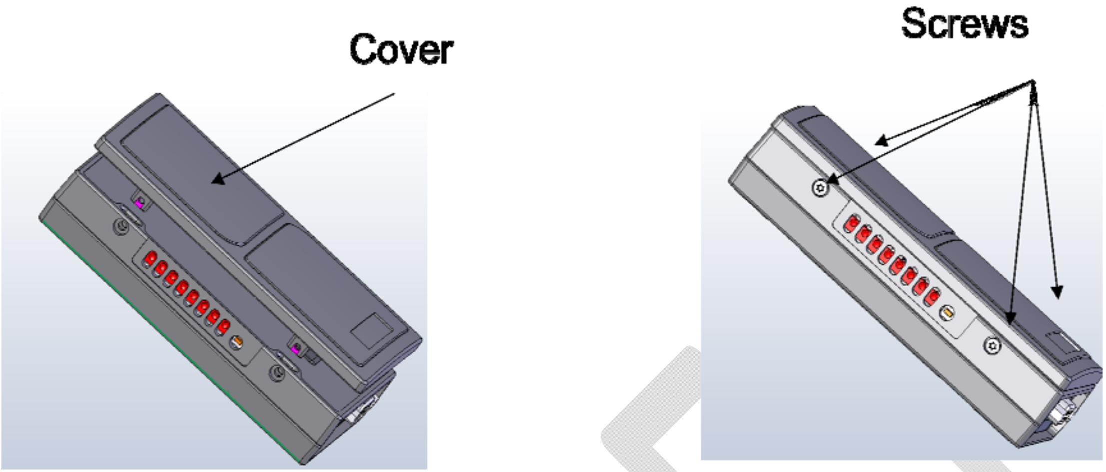


A two piece mounting clip at the bottom

The two piece mounting clip with the necessary screws is delivered in the sales package and the DIN rail adapter can be ordered as an accessory.

4.1 Front cover

When the Radio unit is used alone without the Central unit or any expansion unit it is possible to attach a special front cover on the unit. How this can be done is described in the figure below.



Attachment of the front cover to the Radio unit

5 INTERFACES

This chapter describes the external interfaces of the Radio unit, how its status can be monitored, and how the settings can be checked and modified. If you are using the Radio unit attached with a Central unit with a display it is possible to see and change settings by the graphical user interface of the Central unit. How this can be done is explained in the user manual of the Central unit. The meanings of Radio unit related parameters are, however, described in chapter 7 of this manual.

5.1 Serial data

The Radio unit offers two alternatives for serial data interfaces: RS-232 and RS-422/485. These are two different HW variants of the Radio unit as also indicated in type designation (see chapter 8). Both interfaces use D9 female connector.

For RS-232 the pin-out follows standard TIA-574 as shown in the table below.

Pin nr	Pin name	Pin description
1	CD	Explained in chapter 6.3.3
2	RD	Receive Data: data traffic from the Radio unit to the DTE
3	TD	Transmit Data: data traffic from the DTE to the Radio unit
4	DTR	DTR function is not in use in the Radio unit
5	SGND	Signal Ground: the common voltage reference between the DTE and the Radio unit
6	DSR	Data Set Ready: an indication from the Radio unit to the DTE that the Radio unit is powered on
7	RTS	Explained in chapter 6.3.3
8	CTS	Explained in chapter 6.3.3
9	NC	Not Connected

The serial interface uses asynchronous data format. No external synchronizing signal is needed, since necessary timing information is acquired from the start and stop bits transmitted before and after each data byte. The data transfer speed of the serial interface can be set to 1200, 2400, 4800, 9600, 19200, 38400, or 57600 bits per second. The length of the data field must be 7 or 8 bits. A parity bit may also be used. The number of stop bits can be selected (1 or 2 bits).

RS-422/485 pin-out has been selected to follow the standard for RS-485 Profibus. The selection between RS-422/485 can be done by modifying the user settings. The RS-422/485 interface features a galvanic isolation between the interface signals and the other electronics of the Radio unit.

RS422/485 interface can additionally be configured to RS-232 by modifying the user settings. The pin-out, however, does not follow the standard TIA-574: only RD and TD lines are in use in this case (pins 2 and 3, respectively).

The pin-out of the D9 connector is the following:

	RS-422/485		RS-232	
Pin nr	Pin name	Pin description	Pin name	Pin description
1	NC	Not Connected	NC	Not Connected
2	NC	Not Connected	RD	Receive Data: data traffic from the Radio unit to the DTE
3	B	Receive/transmit data, non-inverting	TD	Transmit Data: data traffic from the DTE to the Radio unit
4	Y	Receive data, non-inverting	NC	Not Connected
5	GND	Data ground	NC	Not Connected
6	5V_TERM	5 V for bus termination	NC	Not Connected
7	NC	Not Connected	NC	Not Connected
8	A	Receive/transmit data, inverting	NC	Not Connected
9	Z	Receive data, inverting	NC	Not Connected

5.2 Radio

The Radio unit has s TNC female RF connector with impedance of 50 ohms. The frequency range of the Radio unit is coded in the type designation that can be seen on the other narrow side of the unit (where also the LED indicators are located). The details of this are explained in chapter 8.
The RF frequency can be set in 6.25 kHz steps. The Radio unit supports two different channel spacing, 12.5 and 25 kHz that can be selected by software – without any need to modify the hardware, like channel selection filters – and four different modulation methods, namely 2-, 4-, 8-, and 16-FSK. The output power can be adjusted with a high resolution between the specified minimum and maximum values as can be seen in the technical specification in chapter 2.
Channel spacing together with the modulation method determines the air speed as clarified in the technical specification in chapter 2. Air speed can be set independently of the data rate of the serial port.
The modulation method also affects the receiver sensitivity. The best sensitivity can be obtained by the lowest level modulation, i.e. 2-FSK in our case. For typical sensitivities in different conditions see the technical specification in chapter 2. In the same table are also presented values for co-channel and adjacent channel rejections.

Another method to improve the sensitivity of the receiver is to use a forward error correction, FEC. The improvement happens at the expense of the user data rate: the air speed remains the same but the fraction of bits available for the user is as indicated by the code rate of the FEC. The Radio unit offers two different code rates, 67 % and 50%. For example, if 4-FSK is used in 25 kHz channel and the FEC is switched on with the code rate of 50 % the user bit rate goes

down to 9600 bits/s. The effect of the FEC on the sensitivity depends on the code rate and the level of BER at which the radio link is operating. At the BER level of 10e-6 the 50 % code rate improves the sensitivity 5 – 6 dB and at 10e-3 level the improvement is 2 – 3 dB as can be seen in the technical specification in chapter 2.
Changing of the modulation method or use of the FEC helps in receiver sensitivity improvement first of all in noisy connections, i.e. the bit errors are mostly evenly distributed over the whole transmission period. If the errors happen in bursts these methods are not very efficient. For this reason the FEC is used together with the method of interleaving. This means that before transmitting the data from the DTE, the Radio unit collects a certain amount of data to a buffer and rearranges it according to a certain rule. The receiver knows the rule and recovers the original order of data bits. After this the receiver sees the errors scattered so that the FEC can better correct for the errors. It should, however, be noted that FEC and interleaving increase the latency and must be avoided in the cases where a low latency is a primary requirement.

5.3 DC supply

The DC connector of the Radio unit is a detachable / lockable screw terminal. The DC voltage range is from 9 to 30 V and the used power supply should be able to deliver at least 15 W of DC power. Please note that the Radio unit delivers DC power for the whole stack of SATELLAR units (Central unit and expansion units). So when using the Radio unit together with other units the power consumption of the whole stack must be taken into account when selecting the DC power supply. There is one exception in this: when the extension unit is an RF booster unit the DC power is fed into that unit, not to the Radio unit.

5.4 Diagnostics, monitoring, changing settings

The settings of the Radio unit can be viewed and changed by Satel NMS PC SW. The computer is then connected to the serial connector of the Radio unit and the connector must be configured to accept NMS messages as described in chapter 5.6. It is also possible to establish a remote connection to another Radio unit and change and view the settings of that modem over-the-air.

When the Radio unit operates together with the version of the Central unit that includes a display and a keypad the device settings can be viewed and changed via the graphical user interface of the Central unit. Alternatively, the Web interface or any other method provided by the Central unit can be used. These are explained in more detail in Central unit user manual.
Settings are described in chapter 7 and the use of PC software is described in its own documentation.

5.5 LED indicators

The Radio unit provides eight LED indicators that are located on the other narrow side of the unit. They are listed and described in the table below.

Name	Description
RX	ON: Radio is receiving OFF: Radio is not receiving
TX	ON: Radio is transmitting OFF: Radio is not transmitting
RTS	Request To Send; more details in chapter 6.3.3
CTS	Clear To Send; more details in chapter 6.3.3
TD	Transmit Data
RD	Receive Data
STAT	Blinking: Both MCU and DSP in operation ON: MCU operating, DSP not operating OFF: MCU and DSP not operating
PWR	Steady blinking: SATBUS device detected, feeding power to SATBUS Long-short blinking: SATBUS device detected, sinking power from SATBUS ON: No SATBUS device detected

If the Radio unit goes to an error state an error message is displayed for the user as a four digit binary number. In the error state the LEDs are blinking slowly, about once in a second. LSB is in PWR and MSB in TD. The error codes are presented in the table below.

Name	Code	Description
ERROR_PA_WARM	1	TBD
ERROR_SVR	2	TBD
ERROR_PWR	3	TBD
ERROR_VOLT	4	TBD
ERROR_RAM	5	TBD
ERROR_L_NVM	6	TBD
ERROR_SW_GENERAL	7	TBD
ERROR_WATCHDOG	8	TBD
ERROR_WRONG_USER_SETTING	9	TBD
ERROR_MEM	10	TBD
ERROR_DSP_COMM	11	TBD
ERROR_SATEL_FFS	12	TBD
ERROR_SWUPM	13	TBD
ERROR_DSP	14	TBD
ERROR_UNKNOWN	15	TBD

5.6 Function button

The function button is located below the LED indicators. It is used to control the operation of the D9 serial data connector as described in the table below.

Duration of the press	Indication	Effect
Less than 2 s	All the LEDs are switched on	The serial data connector is reset to the state defined by the user (see chapter 7.27.3)
More than 2 s	The uppermost LED is switched off	The serial data connector is deactivated and all the data traffic flows internally between the Radio and Central units
More than 4 s	The two uppermost LEDs are switched off	The serial data connector is configured to receive NMS messages in RD and TD lines
More than 6 s	The three uppermost LEDs are switched off	The radio unit is restarted and the serial data connector is reset to the state defined by the user

When the button is released the LEDs return to the normal state as described in chapter 5.5.

6 DATA TRANSMISSION

The Radio unit can operate in two different modes of data transmission: transparent and packet. The transparent mode is the traditional mode where the communication is based on RS-232/422/485 based protocols, like MODBUS and PROFIBUS. The Radio unit is then effectively replacing a wire between two Data Terminal Equipments. The packet data transfer has become widely used in modern communication systems, e.g. in systems based on IP protocol. In the Radio unit the packet data transfer requires different functionality compared to the transparent one as explained later in this chapter.

6.1 Transparent data transmission

When the Radio unit operates in transparent mode of data transmission the Data Terminal Equipment (DTE) is connected to the serial data connector (D9) of the unit. Data transfer starts immediately when the first bit of data comes from the DTE and stops when the data ends. The Radio unit does not store the data anywhere and does not rearrange it by any means. It just outputs all the data that it gets as its input. The radio link between the two DTE is realized without any routers or repeaters in between. This mode is a simple point-to-point connection where the connecting wire is replaced by a radio link. All the data that comes from the DTE is transmitted and all the data that is received through the radio link is passed forward to the DTE. The DTE is fully responsible of the traffic control: it decides when to transmit, interprets the incoming data for correctness and makes decisions of retransmissions if needed.

This transparent mode of data transfer in a simple point-to-point connection between the two DTE offers the shortest possible latency – the time needed for a receiving DTE to receive the first bit of data from the instant the sending DTE has initiated the transmission. The factors affecting the latency in the Radio unit are

- Receive-transmit turn-around time: The Radio unit is normally in reception mode, i.e. listens the radio channel. When it recognizes that the DTE wants to send data it switches to transmission mode which requires a certain time to happen in the radio hardware.
- Delays in filters: Channel filtering both in the transmitter and the receiver required first of all by the radio standards (like EN 300 113) generates delay in the radio link.
- RF power ramp-up time: The RF power cannot be switched on extremely fast because of the transient spectrum requirements of the radio standards.
- Synchronization: After the RF power ramp-up there must be a certain synchronization sequence during which the receiver adjusts to the frequency of the sending radio and decides whether the received signal is a valid transmission instead of an external interferer. The length of the synchronization sequence is a parameter that can be modified: shortening the sequence gives lower latency, making it longer gives a more reliable synchronization in noisy environments.

In addition the factors affecting the latency are

- Forward error correction: The principle of forward error correction is to read a few bits to a data register and generate a codeword based on a certain mathematical formula and the stored data bits. This at first generates some delay in the transmitter but especially in the receiver where a longer bit sequence must be stored before being able to decode the incoming codeword.

- Encryption in the radio path: The principle of encryption is to collect a certain amount of data to a shift register and manipulate it according to a certain rule. The process of encryption adds delay in the data flow and must be avoided in the cases where low latency is the most important requirement.

Strictly speaking the last two factors violate the principle of transparent data transmission (no modifications to the content of the data). However, this is more or less a matter of definition. More important is to understand that switching these on affects the latency and must not be done in applications where low latency is a critical requirement.

To use the Radio unit in transparent mode:

- Configure the data port settings as required by the used data transmission protocol (data rate, number of data bits, number of stop bits, parity).

- Set the network protocol mode to basic (see chapter 6.5 for explanation)

- If required modify the pause length parameter (see chapter 6.3.5. for explanation)

- Modify the synchronization interval parameter: Data stream in transparent data transmission can be in principle of infinite length. If the receiver looses the synchronization it will not be able to continue reception until it gets a new synchronization sequence. If the data stream is very long a lot of data disappears. To minimize this effect the transmitter adds a new synchronization sequence after a period called sync interval. The receiver then detects the new synchronization sequence and is able to continue the reception. Repeated synchronization sequences cause some extra delay in the system and the interval must be defined experimentally in the application.

- Set all the radio parameters as required (unless already set in the factory): radio frequency, channel spacing, RF output power, modulation method, forward error correction, encryption, and the length of the synchronization sequence.

6.2 Packet data transmission

Modern communication systems are nowadays very often based on packet data transfer. In that the length of the transmission is known beforehand and the maximum allowed size of the packet is normally limited. Unlike in transparent data transfer there is normally no guaranteed latency in the system which means that the delay of the data from the sender to the receiver varies depending on the amount of traffic in the network.

To support packet data transfer two new features have been added to the Radio unit, namely medium access control (MAC) and packet routing. These are explained later in this chapter.

Packet data transfer is typically in use in the Radio unit in cases when it is working together with the Central unit that interfaces with the DTE using the IP protocol. The Central unit acts as an IP router and it packs the IP data so that the Radio unit is seen as a virtual serial port. Therefore the Radio unit does not need to be especially configured for the IP traffic. However, settings related to medium access control and routing must be done. As explained earlier, as a repeater station the Radio unit can act without a Central unit also in cases where IP data is transferred. Only when a local Ethernet connection is needed the Central unit must be used.

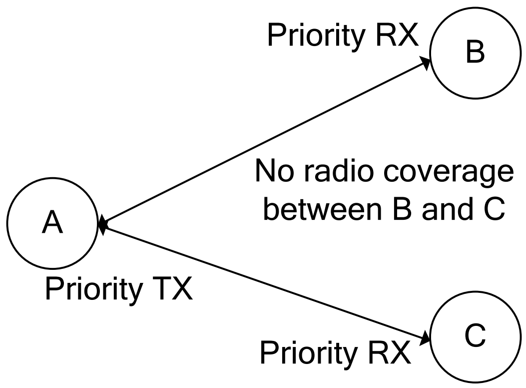
6.3 Data flow control in transparent data transmission

As explained in chapter 6.1 transparent mode of data transmission is used in its simplest form only when there is a point-to-point connection between two stations and the traffic control is implemented in the DTE side. In this chapter is described how the Radio unit should be configured if the working environment is different.

6.3.1 Priority

It may happen that the Radio unit is receiving data over the air and simultaneously the DTE wants to send. The Radio unit then needs to know how to prioritize. For that purpose there are two priority settings available, RX and TX. If priority is set to RX the ongoing reception is allowed to continue and the data from the DTE is buffered until the reception ends. On the contrary, if the priority is set to TX the reception is stopped and the Radio unit starts to send the data immediately. RX priority is used when it is important to avoid collisions in the radio link. TX priority causes collisions but helps in getting the most important data fast through.

An example of how to use priority settings in a simple network is shown in the figure below.



Station A has a radio link to stations B and C and sends control commands to those. Stations B and C respond by sending either status information or acknowledgement messages to control commands from A and they cannot hear each others' radio transmissions. Control commands from station A are of high priority, so station A needs to start sending despite it has a reception going on from either of the stations B or C. Therefore station A is set to priority TX while the others are set to priority RX.

Priority settings only help if the radio coverage is as described in the figure above, i.e. if stations B and C cannot hear each others' transmissions. Consider a situation where station B is sending to A and A then needs to send a high priority message to station C while it still has reception ongoing from B. Due to priority setting to TX it is possible but if stations B and C are within each others' radio coverage the two simultaneous messages from A and B collide at C and therefore the message from A is probably not received correctly there. This kind of situation cannot be solved with priority settings but needs a more complicated handshaking procedure that is explained in chapter 6.3.3. Priority settings help in getting the important messages fast through but must be used carefully keeping in mind that the stations set to priority RX may not be within each others' radio coverage.

6.3.2 TX delay

TX delay can be used in a situation where a certain master station sends queries as broadcast messages to many sub-stations. To prevent replies from the sub-stations to collide at the master station different TX delay values can be set to each of the sub-stations. This means that a sub-station does not reply to the query until the TX delay period has been expired. TX delay is fixed, i.e. the maximum length of the reply message must be approximately known at the network configuration phase in order to really avoid collisions at the master station. TX delay can be considered as a primitive time-slot mechanism.

6.3.3 Handshaking

The handshaking lines of the serial data interface can be used to control the data flow from/to the Radio unit. There are three different control lines for this purpose, namely CTS, RTS, and CD lines.

6.3.3.1 CTS (Clear To Send)

The CTS line is normally in the active state (signal level low/high?) which means that the Radio unit is ready to accept data from the DTE. When the Radio unit sets the line to the inactive state the data transfer from the DTE to the Radio unit is not possible.

There are five alternative criteria for the user to select when the CTS line goes to the inactive state. These are explained in the table below:

Selection	Description
Data on channel	Inactive when there is a data reception ongoing
RSSI Threshold	Inactive when the received signal is stronger than the pre-defined threshold value
TX buffer	Inactive when the transmission buffer is in danger of overflowing. This happens typically in cases where the data rate of the serial interface is higher than the air speed
Pause detection	Inactive when a pause is detected in the transmitted data and there is still data in the transmission buffer. After the buffer has been emptied the line returns to the active state
Off	Line is not monitored at all

6.3.3.2 RTS (Request To Send)

The RTS line is normally in the active state (signal level low/high?) which means that the DTE is ready to accept data from the Radio unit. When the DTE sets the line to the inactive state the data transfer from the Radio unit to the DTE is not possible.

There are three alternatives for the user to select how the Radio unit reacts when the RTS line goes to the inactive state. These are explained in the table below.

Selection	Description
Flow control	The radio unit continues the reception but buffers the received data until the RTS line goes back to the active state. This is typically used in situations where the DTE is too slow to receive all the data. The size of the receiver buffer is about 1.6 kBytes but must be checked for each particular HW and SW version if seen critical in the application.
Reception control	The radio unit stops the whole reception.
Ignore	The status of the RTS line is not followed at all

6.3.3.3 CD (Carrier Detect)

The CD line is an indicator from the Radio unit to the DTE that a signal has been detected on the radio channel. There are four alternative criteria for the user to select when the line goes to the active state (signal level low/high?). These are explained in the table below.

Selection	Description
Data on channel	Active when there is a data reception ongoing
RSSI Threshold	Active when the received signal is stronger than the pre-defined threshold value
Always on	The line is always in the active state
Always off	The line is always in the inactive state

It depends on the application how the DTE reacts to the information provided by the CD line.

6.3.4 Error control

For error checking purposes there are two mechanisms in the Radio unit: cyclic redundancy check (CRC) and error detection.

Cyclic redundancy check is possible for the user to switch on and off. If it is on the transmitter calculates the checksum based on the whole data stream that has been sent. Before ending the transmission it adds the checksum to the end of the data. The receiver then buffers the data and sends it forward after it has been able to verify that the checksum corresponds to the received data. A drawback in this is that the latency increases. If the checksum calculation is switched off the data is continuously sent forward but then there must be some kind of error control in the DTE.

Error detection operates at the byte level. The user can select the strength of the error detection out of the three alternatives: strong, medium, and weak. 'Strong' means that the data is rejected immediately after a single erroneous byte has been detected while 'Medium' allows up to N errors and 'Weak' up to M.

It depends on the particular requirements of the application environment what level of error control is needed. The strongest protection against errors is obtained if error detection is set to "Strong", checksum calculation switched on, and FEC to the lowest code rate. If it is not possible e.g. for latency reasons to use the checksum calculation the user can play with the strength of the byte level error detection and FEC code rate. The weakest protection against errors is obtained when checksum calculation and FEC are switched off and byte level error detection is set to 'Weak'. In this situation the latency is the lowest possible and the user data rate the highest.

6.3.5 Pause length

Pauses are used to separate two messages from each other. A typical pause length that is interpreted as the end of the message is three characters. However, non-real time operating systems used in many DTE easily add some random pauses in the data stream and those pauses are then seen as message breaking points in the Radio unit. To overcome this situation pause length parameter has been introduced and must be set higher than the highest operating system initiated random pause. The data stream from the DTE must then take this setting into account: the Radio unit does not recognize the pauses that are shorter than the value of the pause length parameter.

6.4 Collision avoidance in packet data transmission

The purpose of collision avoidance is (as the name tells) to prevent the data packets to collide with each other on the radio channel. This is particularly important in IP data transmission where the data packets are sent forward whenever there are any to be sent. In Ethernet there is a collision avoidance algorithm in use. However, it is strongly related to the fact that the network is built by using cables, i.e. all the stations can detect whether there is traffic on the line or not. Particular to the radio transmission is the presence of the so called hidden terminals: the terminals that are transmitting without every other terminal in the network to be able to detect that. The main purpose of the algorithm implemented in the Radio unit is to provide a collision free operation also in the presence of hidden terminals. The algorithm is called CSMA/CA (Carrier Sense Multiple Access/Collision Avoidance) and is based on sending handshaking signals (RTS, CTS, ACK) between the stations. A pre-requisite for the algorithm to work is that each station in the network has an address and that there is a kind of routing table in use. Routing table tells each individual station which neighboring station to listen to and to which station to send data.

There are a few settings in the Radio unit that control the operation of the collision avoidance algorithm. Those are set in the factory so that the algorithm should perform well at the field as such. However, to reach the optimum performance for a particular use case the following properties of the network should be considered

- Network topology: are there only point-to-point connections in the network or are there one or more repeaters in use. If there are repeaters in the network all the stations must remain silent for a while after each transmission to give a possible repeating station a privilege to forward the message. By telling each of the Radio units that there are only point-to-point connections in the network helps in saving this additional waiting time and thus increases the data throughput.

- Retransmissions at the radio protocol level: There might be retransmissions at the higher protocol layers (e.g. TCP) irrespective of this setting. Normally, retransmissions at the radio protocol level should be on if the data goes through one or more repeaters or if the higher protocol layers do not include retransmissions.

- Back-off counter: this defines the time how long a station must wait before starting a transmission in the case the radio channel is reserved. If the network is small the back-off counter can be low because the probability of collisions is low. As the size of the network increases the back-off counter should be higher. The correct value should be found experimentally based on the number of stations and the amount of traffic.

6.5 Network protocol modes

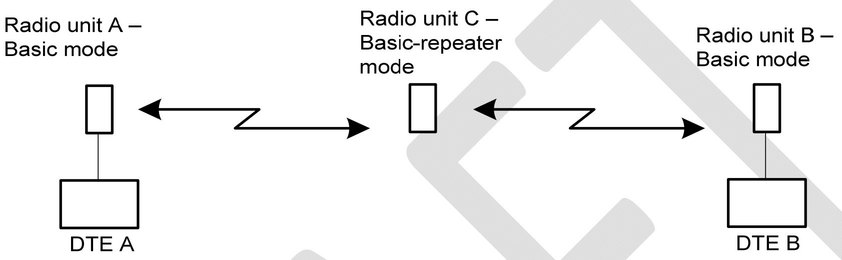
Related to different network topologies the Radio unit can be configured in the following network protocol modes:

- Basic mode
- Basic-repeater mode
- Source routing-master mode
- Source routing-slave mode
- Packet routing mode

6.5.1 Basic and basic-repeater mode

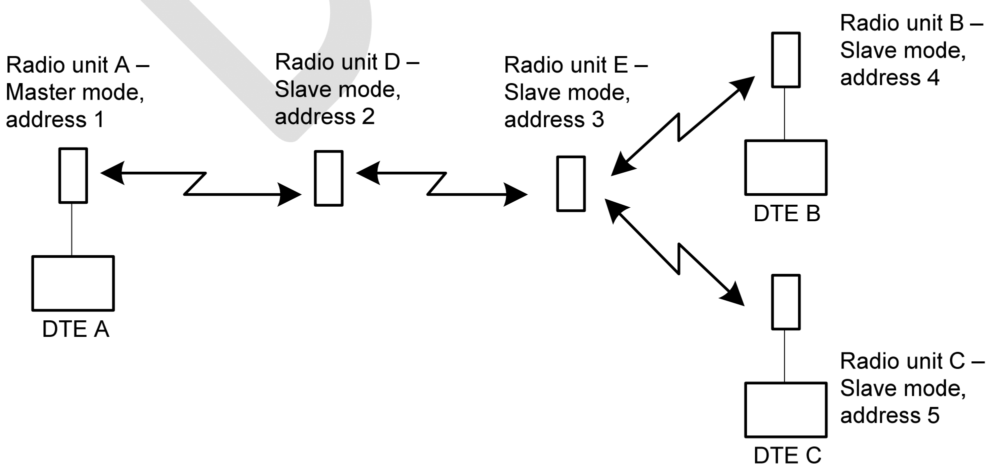
Basic mode is a simple point-to-point connection between two Radio units operating in transparent mode of data transmission. Point-to-multipoint connection is also possible using the methods described in chapters 6.3.1, 6.3.2, and 6.3.3 to minimize the probability of collisions. The main feature in this mode is that the Radio unit is forwarding all the received data to the serial interface and the DTE must decide whether the data is relevant or not.

Basic-repeater mode is used to extend the radio coverage by adding one Radio unit operating in this mode between two basic mode Radio units as described in the figure below.



6.5.2 Source routing

When two or more repeaters are used it is necessary to use addresses to route the data. This is because otherwise the repeaters would send the same messages to each other again and again in the network. When using addresses the repeaters are forwarding only the data that belongs to them, not all the data they hear in the network. This mode is called source routing. The name comes from the fact that only one station in the network can be used as an entry point, the source, for the routing data. This station is called a master and the other stations are slaves. Network topology is created by Satel NMS PC software and sent to the master station which then includes the routing data in the messages to the slave stations. The following picture clarifies the situation.



Radio unit A acts as a master station in this network and has the following routing table in the memory:

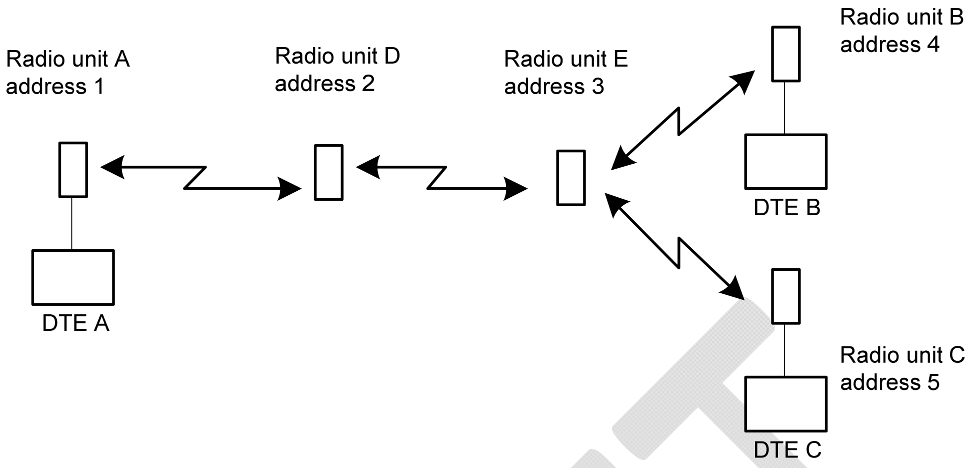
DTE	Route
B	2, 3, 4
C	2, 3, 5

When DTE A sends data e.g. to DTE B the radio unit A picks the address from the message and then determines which route to use. In this example the route is the upper one, i.e. 2, 3, 4. Before sending the message the Radio unit A adds the route to the start of the message and in addition tells that the next receiver is station D with address 2. All the other stations (not in the figure) except for D that possibly hear the message ignore it. Station D picks the message, copies the routing data, and modifies the next receiver indicator to point to station E with address 3. The same procedure is repeated through the whole chain until the message reaches the destination DTE, B in this example.
When DTE B replies to A the message goes through the repeater chain in an opposite direction. For example, when the reply message reaches station E, that remembers the route and forwards the message indicating that the next receiver is station D. The route remains valid as long as the reply message has reached the original sender. For the next message the routing information must be sent again.
How the DTE includes the address data in the message depends on the used protocol. The software module in the Radio unit that picks the address information out of the data is called a protocol filter. The supported protocols are dependent on the version of the Radio unit software and can be seen by Satel NMS PC software when the connection between the computer and the Radio unit has been established.

6.5.3 Packet routing

An important feature in source routing is that there is no medium access control behind, i.e. all the traffic must be originated by the master station: DTE A sends a query message to DTE B that then replies using the same radio route in the inverse order. Thereafter A can send the same query to C that also replies. In this way there occur no collisions on the radio channel. This amount of functionality is enough for the so called polling protocols. A drawback, however, is that slave stations cannot generate any messages independently, e.g. automatic status reports from the slave stations are not possible. Another drawback is that the slave stations cannot communicate with each other.

The mentioned drawbacks can be overcome by using packet mode routing. Packet mode routing assumes a proper medium access control behind (see chapter 6.4) which is also the reason way the mode is called in this name: medium access control requires that the data is sent in packets the length of which are always known before starting a transmission. Packet mode routing allows each station to be in connection with every other station and there is no master station that initiates all the traffic in the network. Each unit has one or more neighbor (next hop) stations, i.e. stations to which all the traffic is going to be routed. For every neighbor station are listed the addresses of the stations that are found behind each of them. Each station just needs to select the correct neighbor station according to the final destination address and thereafter the data proceeds hop by hop towards the destination. As an example is presented how the routing table looks like for the network topology seen in the figure below:



The routing table is the following:

Radio unit	Next hop	Addresses behind
A	2	3, 4, 5
B	3	1, 2, 5
C	3	1, 2, 4
D	1	-
	3	4, 5
E	2	1
	4	-
	5	-

In this example the routing is very simple for Radio units A, B, and C because they have only one possible next hop regardless of the final destination. Units D and E, on the contrary, must select between two alternatives.

Primarily, packet mode routing is used when transferring data over IP. This requires a Central unit to be connected together with the Radio unit except for the repeater stations where the Radio unit can operate alone. How the IP addresses are configured for IP transmission is explained in Central unit user manual.

7 SETTINGS

As mentioned in chapter 5.4 settings can be viewed and changed by Satel NMS PC software or by the user interfaces of the Central unit. Settings have been described in earlier chapters in conjunction with the overall descriptions of the different functionalities. Here below is presented a summary of all the user related parameters and how they are organized in groups.

7.1 Radio settings

RX frequency	RF frequency of the receiver in MHz, e.g. 451.106250 MHz: can be adjusted by a numeric editor or selected from a predefined list in the case the Radio unit has been configured to show the particular allowed frequencies
TX frequency	RF frequency of the transmitter in MHz, e.g. 451.106250 MHz: can be adjusted by a numeric editor or selected from a predefined list in the case the Radio unit has been configured to show the particular allowed frequencies
RF output power	RF output power in mW or dBm, e.g. 900 mW or 29.5 dBm: can be adjusted by a numeric editor. RF output power is continuously adjustable between 100 – 1000 mW and 20 – 30 dBm in 10 mW or 0.5 dB steps, respectively.
Channel spacing	Can be either 12.5 or 25 kHz
Air speed	Can be selected from a predefined list that depends on the selected channel spacing and available modulation methods as explained in chapter 5.2.
Forward error correction	Can be selected from a predefined list of OFF, rate 67 %, and rate 50 %. Forward error correction is used together with interleaving. See chapter 5.2 for more information
Interleaving	

Length of the synchronization sequence	Can be either 32 or 64 symbol intervals. See chapter 6.1 for more information.
Synchronization interval	Can be adjusted by a numeric editor in the range of 0 – 65535 bytes. See chapter 6.1 for more information.
Over-the-air encryption	Can be either OFF or ON

7.2 Serial connector configuration

As indicated in chapter 5.6 the setting selected here comes to use when the function button is pressed less than two seconds.

- In models RU-xxxx00 (RS-232 interface)
  - Can be selected from a predefined list of
    - Data + handshake: pin-out as described in chapter 5.1
    - Data + handshake + NMS: NMS port to DTR/DSR, otherwise the pin-out as Data + handshake
    - Data + NMS: NMS port to RTS/CTS, otherwise the pin-out as Data + handshake
- In models RU-xxxx01 (how about NMS in this case?)
  - Can be selected from a predefined list of
    - RS-422
    - RS-485
    - RS-232 (RD & TD only)

7.3 Data port settings

Number of data bits	7 or 8 bits
Data rate	1200, 2400, 4800, 9600, 38400, and 57600 bits/s
Number of stop bits	1 or 2 bits
Parity	No parity check, Even, and Odd

7.4 Serial data flow control

Priority	Selectable: RX and TX. See chapter 6.3.1 for more details.
TX delay	0 – 65535 ms. See chapter 6.3.2 for more details.
Handshaking lines	CTS: Can be selected from a predefined list of Data on channel, RSSI threshold, TX buffer state, pause detection, and OFF. See chapter 6.3.3 for more details. RTS: Can be selected from a predefined list of Flow control, Reception control, and Ignore. See chapter 6.3.3 for more details CD: Can be selected from a predefined list of Data on channel, RSSI threshold, Always on, and OFF. See chapter 6.3.3 for more details. RSSI Threshold: The RSSI threshold value in dBm that is used if RSSI threshold has been selected as a criterion either for CTS or CD as explained in chapter 6.3.3.
Error control	CRC: ON or OFF. See chapter 6.3.4 for more details. Error detection: Strong, Medium, and Weak. See chapter 6.3.4 for more details.
Pause length	3 – 255 bytes. See chapter 6.3.5 for more details.

7.5 Collision avoidance

Network topology (chapter 6.4)
- Point-to-point
- Repeater

Retransmissions (chapter 6.4)
- Off
- On

Back off counter (chapter 6.4)
- Can be selected between 1 and 64

Maximum number of RTS retransmissions

- This value tells how many times a station can try to initiate the same transmission. After the maximum number has been reached the station gives up. For new data the RTS retransmission counter is reset.

RSSI threshold

- The value above which the received signal is strong enough to be able to conclude that the radio channel is occupied.

7.6 Network protocol modes

As explained in chapter 6.5 the Radio unit can be configured to operate in the following network protocol modes

- Basic mode
- Basic-repeater mode
- Source route-master mode
- Source route-slave mode
- Packet route mode

7.6.1 Station addresses and network ID

If the Radio unit is configured to operate either in source or packet route mode is must be given an address. The user can select between 8 or 12 bit addresses. The address is then freely selectable between 1 and 254 or 1 and 4094, respectively. The network ID is a four bit number, thus selectable between 0 and 15.

8 TYPE DESIGNATION

The type designation label of the Radio unit is located on the side sticker, below the LED indicators. The fields of the label are the following

XX – a b c d e f

Field	Description
XX	Type designator of the unit, in this case RU
a	RF feature designator 1: 1 W TX, 12.5/25 kHz channel bandwidth
bcd	RF variant designator 360: 360 – 405 MHz frequency range 400: 400 – 445 MHz frequency range 440: 440 – 485 MHz frequency range 450: 450 – 470 MHz frequency range 460: 460 – 520 MHz frequency range
ef	Interface board designator 00: RS-232 interface, TNC RF connector 01: RS-485 interface, TNC RF connector

9 ACCESSORIES

The Radio unit is delivered with the following accessories

- A two piece mounting clip with the necessary screws
- A DC connector
- A quick start guide

A SATELLAR specific DIN rail adapter can be ordered separately. If the Radio unit is used as a standalone device it can be delivered with a plastic front cover.

PC SW

APPENDICES