

SATELLINE-M3-TR3, -TR4 AND -R4 MODULE INTEGRATION GUIDE

Version 2.9

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Salo, FINLAND 2019

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RESTRICTIONS ON USE

SATELLINE-M3-TR3 and -TR4 radio transceiver modules have been designed to operate on 403-473 MHz, the exact use of which differs from one region and/or country to another. The user of a radio transceiver module 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.

SATELLINE-M3-TR3 and -TR4 are allowed to be used in the following countries. More detailed information is available at the local frequency management authority.

Countries: AE, AT, AU, BE, BG, BR, CA, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, HR, IE, IS, IT, JP, KR, LT, LU, LV, MT, NL, NO, PL, PT, RU, RO, SE, SI, SK, TR, US

WARNING! Users of SATELLINE-M3-TR3 and -TR4 radio transceiver modules in North America should be aware, that due to the allocation of the frequency band 406.0 – 406.1 MHz for government use only, the use of radio transceiver module on this frequency band without a proper permit is strictly forbidden.

WARNING - RF Exposure

To comply with FCC and IC RF exposure compliance requirements, maximum antenna gain is 14 dBi and separation distance of at least 1 meter must be maintained between the antenna of this device and all persons. This device must not be co-located or operating in conjunction with any other antenna or transmitter.

Host product labeling requirements

SATELLINE-M3-TR3 and -TR4 is intended to be integrated into a host device. Therefore the SATELLINE-M3-TR3 and -TR4 product related FCC ID and IC ID must be visible in the host device chassis:

FCC ID: MRBSATEL-TA23
IC: 2422A-SATELTA23

PRODUCT CONFORMITY

Under the sole responsibility of manufacturer SATEL Oy declares that SATELLINE-M3-R4 receiver module and SATELLINE-M3-TR3 and -TR4 radio transceiver modules are in compliance with the essential requirements (radio performance, electromagnetic compatibility and electrical safety) and other relevant provisions of Directives 2014/53/EU and 2011/65/EU and Council recommendation 1999/519/EC Therefore the equipment is labeled with the following CE-marking. The operating frequency range of the device is not harmonized throughout the market area, and the local spectrum authority should be contacted before the usage of the radio module.



EU DECLARATION OF CONFORMITY

This declaration of conformity is issued under the sole responsibility of the manufacturer.

Radio equipment:

Model: SATELLINE-M3-TR3, SATELLINE-M3-TR4, SATELLINE-M3-R4
Type: SATEL-TA23

Manufactured by: Satel Oy
Meriniitynkatu 17, P.O.Box 142
FI-24101 Salo
Finland

Products described above are in conformity with the relevant Union harmonisation legislation:

- Directive 2014/53/EU
- Directive 2011/65/EU
- Council recommendation 1999/519/EC

Above described products have been tested and comply with following standards:

- EN 300 113 V2.2.1
- EN 301 489-1 V2.1.1, -5 V2.1.1
- EN 60950-1:2006+A11:2009+A1:2010+A12:2011+A2:2013

The Notified Body SGS Fimko no:0598 performed conformity assessment and issued the EU-type examination certificate: RED-1001 ref:HEL-CERT170400167-02

Signed for and on behalf of Satel Oy
Salo, 6.10.2017


Markus Kantola
CEO

SATEL
MISSION-CRITICAL CONNECTIVITY
Meriniitynkatu 17, P.O. Box 142
24101 Salo, FINLAND
Tel. +358 2 777 7800
info@satel.com www.satel.com


Agência Nacional de Telecomunicações
04411-19-01451

Para maiores informações, consulte o site da ANATEL www.anatel.gov.br

WARRANTY AND SAFETY INSTRUCTIONS

Read these safety instructions carefully before using the product:

-Warranty will be void, if the product is used in any way that is in contradiction with the instructions given in this manual

-The radio transceiver module 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 device are appropriate. This also applies to the maintenance of the products.

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1 INTRODUCTION

SATEL Oy is a Finnish electronics and Telecommunications Company specializing in the design and manufacture of wireless data communication products. SATEL designs, manufactures and sells radio modems intended for use in applications ranging from data transfer to alarm relay systems. End users of SATEL products include both public organizations and private individuals.

SATEL Oy is the leading European manufacturer of radio modems. SATEL radio modems have been certified in most European countries and also in many non-European countries.

This document is the integration guide for the SATELLINE-M3-TR3 and -TR4 radio transceiver modules. It is intended to describe how to use these modules and how to integrate those into a host device.

1.1 Terms and abbreviations

Abbreviation	Description
CTS	Clear To Send, handshaking signal used in asynchronous communication.
DTE	Data Terminal Equipment (typically computer, terminal...)
ESD	Electrostatic discharge
RD	Receive Data
TD	Transmit Data
RTS	Ready To Send, handshaking signal used in asynchronous communication.
RAM	Random Access Memory
LDO	Low dropout regulator
UHF	Ultra High Frequency
RF	Radio Frequency
FPGA	Field-programmable gate array
CPU	Central processing unit

1.2 Description of the products

The SATELLINE-M3-R4 is a UHF radio receiver module, which receives data from UHF transmissions made by SATELLINE-3AS family and similar transmitters. The SATELLINE-M3-TR3 and -TR4 are a UHF radio transceiver modules, that transmits and receives data from UHF transmissions made by SATELLINE-3AS family and similar transmitters.

The modules are designed to be as compact and power efficient as possible. It has been developed to be especially suitable for integration into battery powered and space constrained host applications benefiting from UHF communications.

The transceiver module transmits and receives data via the Air interface (Ant. Connector, RF),

modulates and demodulates, encodes and decodes the data and sends the received data payload to the DTE port. The DTE interface is used to provide power to the module and communicate with the module.

Available product variants can be viewed from SATEL WEB sites.

1.3 DTE connector

The DTE connector is a 20-pin pass-through connector. This connector allows the pin to enter the connector from the bottom side and protrude thru the module PCB to the top side, allowing flexible mounting heights with various pin lengths. Separate models available with top side DTE connector.

Entry from bottom of device, see picture below.

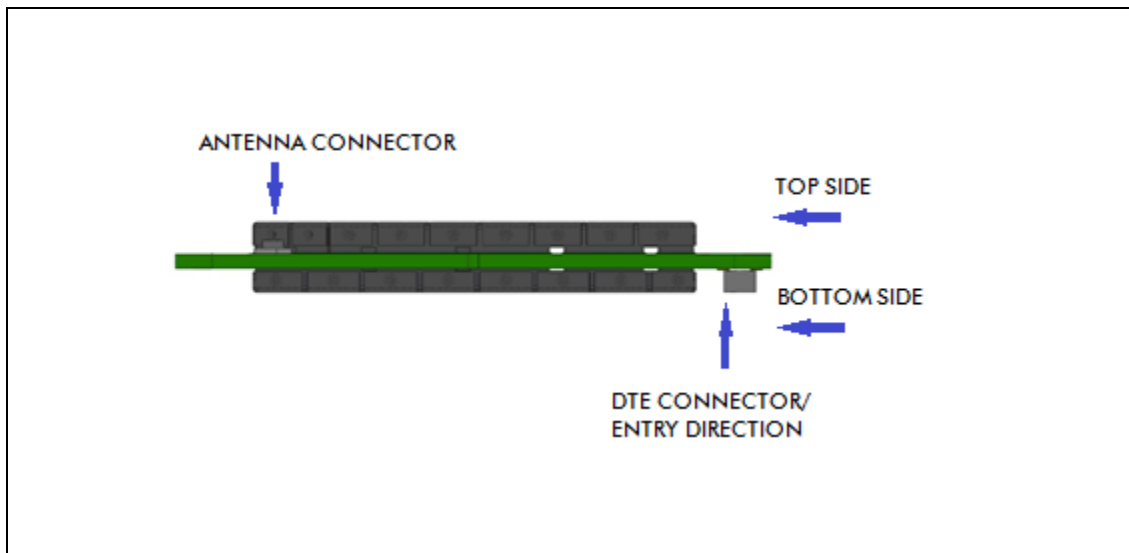


Figure 1. Side view of the module with 1.27mm pitch connector and screw fixing.

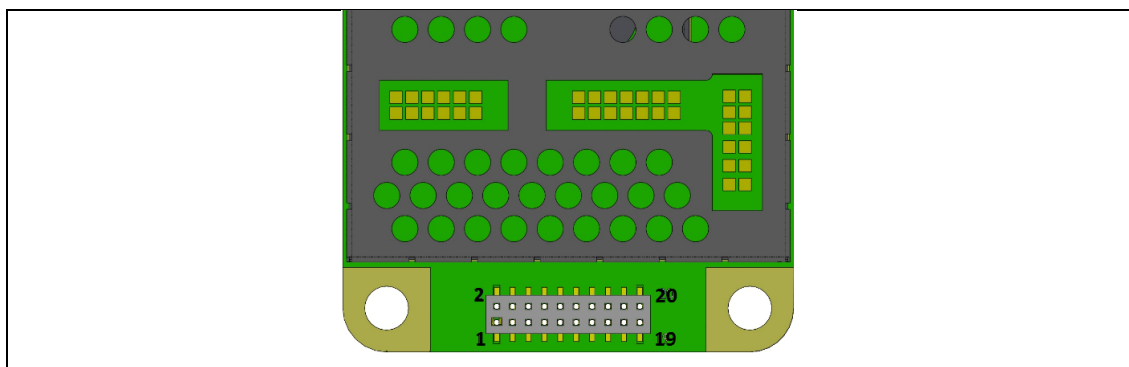


Figure 2. Pin numbering of 1.27 mm pitch DTE connector. View from bottom side of unit.

NOTE! In the bottom side of the actual PCB board the numeric values of 1 and 2 are placed in the wrong order.

1.4 Pin order of the DTE connector

Direction **IN** is data from DTE (Data Terminal Equipment) to the radio transceiver module.
 Direction **OUT** is data from the radio module to the DTE.

Pin No.	Signal name	Type	Direction	Pin State	Description
1,2	VCC IN	POWER	IN	External Voltage	4.0V DC input
3,4	GND	GND	-	External Ground	Ground reference for power and signals
5	VCC_IO	POWER	IN	External Voltage	Device IO driver input DC voltage. Voltage= 1.8 ... 3.3 V
6	ENA_MOD	IO	IN	Internal Pull Down	Enable module by pulling HIGH. > 1.2 V= Module power is ON, <0.2 V= Module power is OFF
7	RD1	CMOS	OUT	Output Driver	Receive data. Data received by module is output on this pin. Driving this pin is prohibited.
8	CTS1	CMOS	OUT	Output Driver	Clear To Send. Module signals when it is ready to receive data. Driving this pin is prohibited.
9	TD1	CMOS	IN	Internal Pull Up	Transmit Data. Data from DTE to module shall be sent on this pin. Pull LOW or drive LOW or HIGH.
10	RTS1	CMOS	IN	Internal Pull Up	Ready to send. DTE can use this pin to signal when it is ready to receive data from module. Pull LOW or drive LOW or HIGH.
11	GPIO1	CMOS	IN	Internal Pull Down	Unconnected.
12	GPIO2	CMOS	IN	Internal Pull Down	
13	GPIO3	CMOS	IN	Internal Pull Down	
14	GPIO4	CMOS	IN	Internal Pull Down	
15	STAT	CMOS	OUT	Output Driver	Status signal. "1" when device is OK and working normally. Various toggle sequences for other state indications. See separate section of manual. Can drive LED directly. 10mA

					output drive capability. Driving this pin is prohibited.
16	GPIO5	CMOS	IN	Internal Pull Down	Unconnected
17	$\overline{\text{SERVICE}}$		IN	Internal Pull Up	Input for service access. Internally pulled high. Pull LOW / drive LOW to set UART1 (RD1, TD1) into known state. See separate section of manual.
18	GPIO6	CMOS	IN	Internal Pull Down	Unconnected.
19	GPIO7	CMOS	IN	Internal Pull Down	Unconnected.
20	GPIO8	CMOS	IN	Internal Pull Down	Unconnected.

2 MECHANICAL CONSIDERATIONS

2.1 Fixing device to host

The radio transceiver module can be mounted on to the host by using spacers and screws. Max. screw diameter is 3mm.

2.2 Host board instructions for mounting pegs

In figure below is SATELLINE-M3-R3, -TR3 and TR4 with dimensions as millimeters.

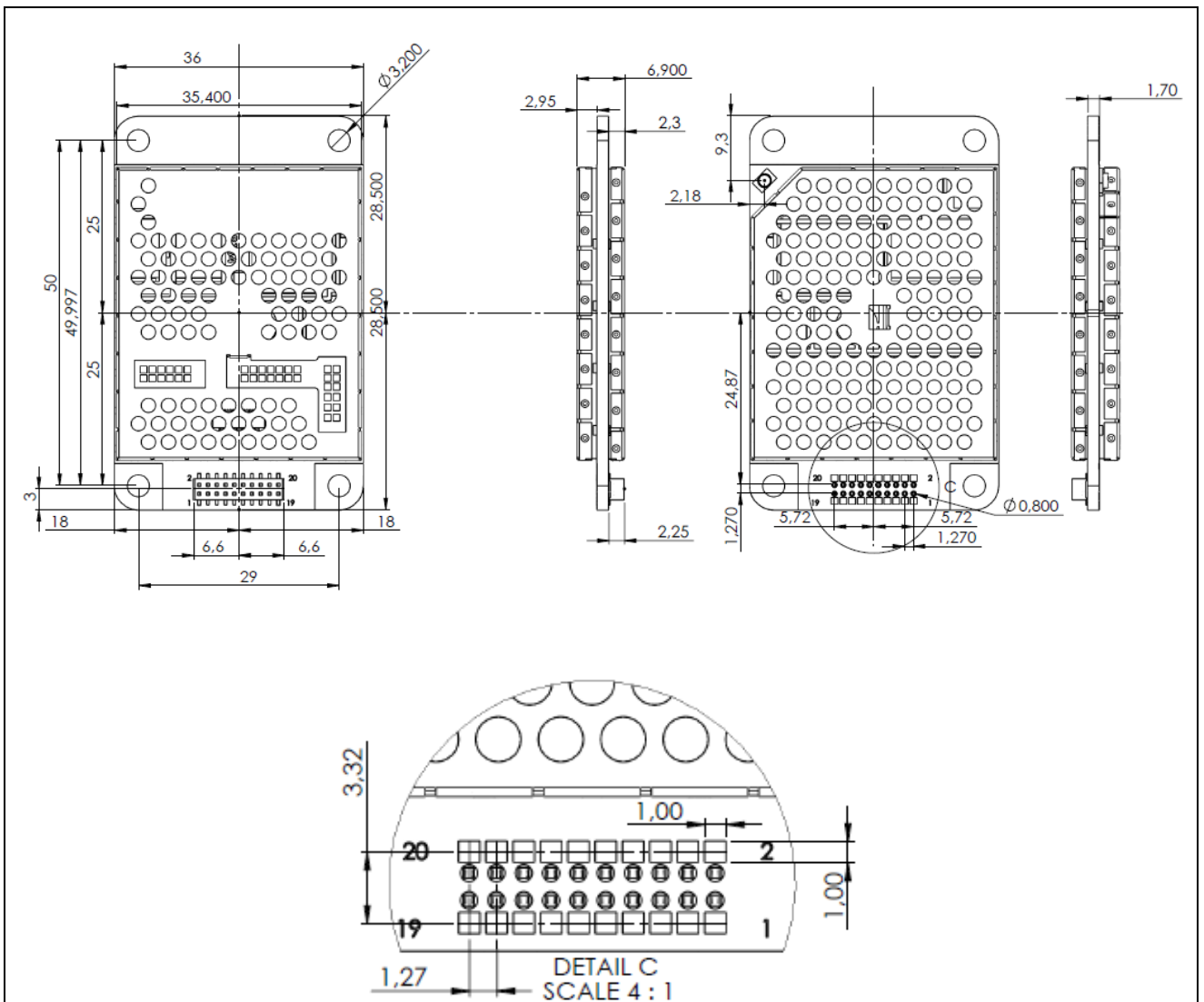
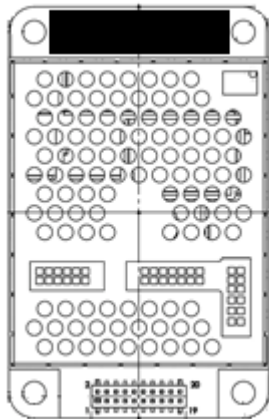


Figure 3. The physical dimensions and the holes in millimeters.

2.3 Heat transfer

While the module is operational especially when transmitter is operating, by the nature causes of electronic circuitry, there is extensive heat production which is suggested to keep on board as minimum as possible. Heat production is focused mainly on the board space where large metal area is exposed. This metal plated area between the mounting holes is the area that can be used to transfer heat away from the board. There are few alternatives to transfer heat. The simple and less effective way is to through the host carrier board by using a heat conductive element between the module. Second method is to conduct heat directly to some mechanical structure which can be a housing or casing of the product or dedicated heat sink if high temperature efficiency is in demand.

Figure 4. Heat transfer area.



3 TECHNICAL SPECIFICATIONS

Receiver part specifications applies to SATELLINE-M3-R4 receiver module.

SATELLINE-M3-TR3 and -TR4 complies with the following international standards:

EN 300 113-2

EN 301 489-1, -5

EN 60950-1

FCC CFR47 PART 90

	RECEIVER	TRANSMITTER	Note!
Frequency Range	403...473 MHz		
Tuning range	70 MHz		
Minimum RF Frequency Step	6.25 kHz (10kHz @20kHz channel spacing)		
Channel Bandwidth	12.5 kHz / 25 kHz		Programmable
Channel Spacing	12.5, 20 (uses 12.5kHz channel width), 25 kHz		
Frequency Stability	<1 kHz		
Maximum Receiver Input Power without Damage	+14 dBm		
Maximum Receiver Input Power without Transmission Errors	-10 dBm		FEC ON
Sensitivity ^{1,2}	-112 dBm @25 kHz -116 dBm@12.5 kHz		FEC ON
Blocking ^{1,2}	> 86 dB @ 25 kHz > 88 dB @ 12.5 kHz		FEC ON
Intermodulation Attenuation ^{1,2}	> 61 dB @ 25 kHz > 61 @ 12.5 kHz		FEC ON
CO-Channel Rejection ^{1,2}	> -11 dB @25 kHz > -10 dB @12.5 kHz		FEC ON
Adjacent Channel Selectivity ^{1,2}	> 56 dB @ 25 kHz > 51 dB @ 12.5 kHz		FEC ON
Spurious Rejection	> 67 dB		FEC ON
Typical Power Consumption	730 mW		RX-mode
	SLEEP1: 215 mW		RX-mode
		4.7 W @ 1 W RF out	TX-mode, Continuous, 50Ω
		3.3 W @ 500 mW RF out	TX-mode, Continuous, 50Ω
		2.8 W @ 100 mW RF out	TX-mode, Continuous, 50Ω
	2.6 W @ 100 mW RF out	TX-mode, Continuous, 50Ω	
Transmitter Power (programmable)		0.01, 0.1, 0.2, 0.5, 1 W	TX-mode, 50Ω load
Communication Mode	Half-Duplex		
Adjacent Channel Power		acc. to EN 300 113-1v.1.7.1	TX-mode
Transient Adjacent Channel Power		acc. to EN 300 113-1v.1.7.1	TX-mode
Carrier power stability		< ±1.5 dB	

	DATA MODULE	
Timing	UART	
Electrical Interface	CMOS Inputs and outputs referred to IO Voltage processed by user (1.8-3.3V) RTS, CTS, RX, TX, +VCC, GND	
Interface Connector	1.27 mm pitch socket	Samtec 20-pin through hole, CLP-110-02-L-D-K-TR
Data speed of Serial interface	1200 – 115200 bps	
Data speed of Radio Air Interface	<u>4FSK FEC OFF / ON (TR3 and TR4):</u> 19200 / 14400 bps (25 kHz) 9600 / 7200 bps (12.5 kHz) <u>8FSK FEC OFF / ON (TR4):</u> 28800 / 19200 bps (25 kHz) 14400 / 9600 bps (12.5 kHz) <u>16FSK FEC ON (TR4):</u> 28800 bps (25 kHz) 14400 bps (12.5 kHz)	
Air Interface Encryption	AES128	Programmable
Data Format	Asynchronous data	
Modulation	4FSK, GMSK (SATELLINE-M3-TR3) 4-, 8-, 16FSK, GMSK (SATELLINE-M3-TR4)	

	GENERAL	
Operating voltage	+4.0 VDC	min. ⁵ 4.0V, max. Nominal +5%
Maximum DC Ripple Voltage ³	max. 9 mVpp	DC ≤ f ≤ 1 kHz
	max. 64 mVpp	1 kHz < f ≤ 10 kHz
	mx. 517 mVpp	10 kHz < f ≤ 100 kHz
	max. 2.035 Vpp	f > 100 kHz
Inrush Current, power turned ON ⁴	< 12A, duration < 50 μs	RX-mode
Inrush Current, from RX to TX ⁴	not detected	TX output power 1W
	< 150 mA, duration < 1 ms	TX output power 500 mW
	< 70 mA, duration < 1 ms	TX output power 200 mW
	< 30 mA, duration < 1 ms	TX output power 100 mW
Temperature Range	-20°C ... +55°C	Type Approval conditions
Temperature Ranges	-30°C ... +70°C	Functional
	-40°C ... +80°C	Storage
Vibration ⁶	≤ 10g	100Hz ≤ f _{vibration} ≤ 1,0 kHz
ESD	±10 kV	Antenna connector. Acc. to EN61000-4-2; 150pF/330Ω
	±8 kV	DTE connector. Acc. to EN61000-4-2; 150pF/330Ω
Antenna Connector	50Ω, HIROSE U.FL compatible	I-PEX 20279-001 -E-01

Construction	PWB with sheet metal EMI shields	
Size L x W x T	57 x 36 x 6.9 mm	
Weight	18g	

Test condition $V_{CC} = 4.0\text{ V}$ and $T_A = 25\text{ °C}$

¹ According to EN 300 113-1 V.1.7.1 measurement setup

² The measured average of a sample of 19 M3-TR3 modules

³ Higher values exceed the -36 dBm spurious limit at the antenna e.g. EN 300 113-1 requirement.

⁴ Measured using Agilent 1147B current probe and TTI TSX1820P DC power supply

⁵ If 1 W output power is wanted then 4.0 V is the minimum DC voltage

⁶ Functional operation is guaranteed in all directions xyz

3.1 Absolute maximum ratings

Absolute maximum ratings for voltages (* on different pins are listed in the following table). Exceeding these values will cause permanent damage to the module.

Parameter	Min	Max
Voltage at VCC_IN	-0.3 V	+5 V
Voltage at ENA_MOD	-0.3 V	+6 V
Voltage at VCC_IO	-0.5 V	3.75 V
Voltage at digital inputs (except ENA_MOD)	-0.5 V	3.75 V
Voltage at digital outputs (when no power is applied to unit)	-0.5 V	3.75 V
Antenna port power	n.a.	+14 dBm
Antenna port DC voltage	-10V	+10V

Table. Absolute maximum ratings of module. (* All voltages are referenced to GND)

3.2 DC electrical specifications

Over recommended operating conditions

Parameter	Condition	Min	Max	Units
VCC_IN	4.0V is considered nominal	4.0V ¹	Nominal +5%	V
ENA_modem, Vlow		0	0.4	V
ENA_modem, Vhigh		0.9	VCC_IN	V
Logic input, Vlow	1.8V < VCC_IO < 3.3V	-0.3	< 0.35 * VCC_IO	V
Logic input, Vhigh	1.8V < VCC_IO < 3.3V	0.65 * VCC_IO	3.6	V
Logic output, Vlow	1.8V < VCC_IO < 3.3V	-	0.4	V
Logic output, Vhigh	1.8V < VCC_IO < 3.3V	VCC_IO - 0.4	3.6	V
Logic output, max current	All logic output except STAT pin.	-	4	mA
Logic output, max current, STAT pin		-	12	mA

¹ Minimum voltage if the maximum TX output power (1W/50 Ω load) is wanted. Meets the ETSI requirements on given operating voltage range.

4 DEFAULT DELIVERY VALUES

DEFAULT VALUES OF THE ADJUSTABLE SETTINGS		
Setting	Default value	Range
Radio frequency		
Operating TX and RX frequency	438.000 MHz	403 - 473 MHz
Channel Spacing (equals channel width)	12.5 kHz	12.5 kHz, 20 kHz (uses 12.5kHz channel width), 25 kHz
Transmitter Output Power	1 W	100 mW, 200 mW, 500 mW and 1 W
Radio settings		
Radio Compatibility	SATEL 3AS	SATEL 3AS PacCrest-4FSK PacCrest-GMSK PacCrest-FST TrimTalk450s(P) TrimTalk450s(T) SATELLINE-2ASxE SATEL-8FSK-1 (FEC OFF) SATEL-8FSK-2 (FEC ON) SATEL-16FSK-1 (FEC ON)
Addressing		
RX Address	OFF	ON/OFF
TX Address	OFF	ON/OFF
Serial port		
Data speed	115200 bps	1200 -115200 bps
Data bits	8	8
Parity bits	None	None, Even, Odd
Stop bits	1	1
Handshaking		Handshaking lines apply to the DATA-port
CTS	TX Buffer State	Clear to send, TX Buffer State
RTS	Ignored	Ignored, Flow Control
Additional setup		
Error Correction, FEC	OFF	ON/OFF
Error check	OFF	OFF, CRC8Partial, CRC8Full, CRC16Full
SL Command Mode	ON	ON/OFF
Repeater Mode	OFF	ON/OFF
TX Delay	0	0 65535 ms
Over-the-Air-Encryption	OFF	ON/OFF
Use Channel List	OFF	ON/OFF
Power Save Mode	OFF	ON/OFF
Add RSSI to Data	OFF	ON/OFF
Radio state	Tx/Rx	Tx/Rx / Rx (transceiver modules)

5 TIME PARAMETERS FOR STARTUP AND SHUTDOWN SEQUENCES

Parameter		Recom. Time *	Explanation
T_{vic}	Input capacitor charge time	$> 50\mu s$	When voltage is applied to VCC_IN the filter capacitors inside the module are charged, creating a small current surge. If the feeding power supply is not very strong it is recommended to wait this time before rising ENA_MOD to minimize current surge.
T_{ioen}	IO module start time	$< 18ms$	ENA_MOD enables the LDOs feeding the FPGA and CPU inside the module. It is recommended to apply VCC_IO voltage within 18ms after ENA_MOD is applied.
T_{iovs}	IO voltage startup time	$< 1ms$	It is considered good design practice to KEEP all IO signals (except ENA_MOD) low or floating until the internal parts of the module have power and the IO voltage is stable.
T_{ior}	IO drive fall time	$< 300\mu s$	It is considered good design practice to set all IO signals (except ENA_MOD) low or floating before starting to shut down the transceiver module. This way any latch up/brownout problems can be avoided. IO-pins are not internally driven after Tior.
T_{ldof}	LDO discharge time	$> 300\mu s$	To avoid any possibility of reverse biasing of regulators inside the module, it is considered good design practice to use ENA_MOD to shut down the regulators before deactivating VCC_IN.

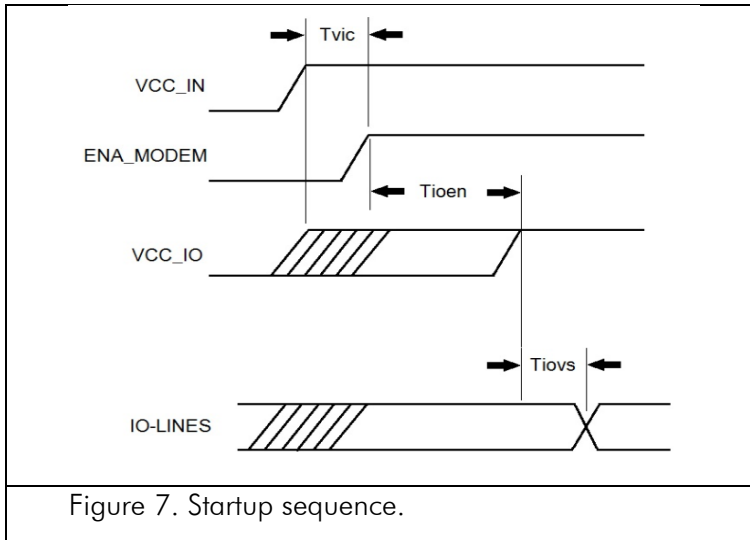
Table. Startup and shutdown sequence parameters.

*) Recommendations:

The radio module is designed and tested for the minimum times mentioned in the table. The recommendations are there for those who want to do the very best possible startup and shutdown sequences.

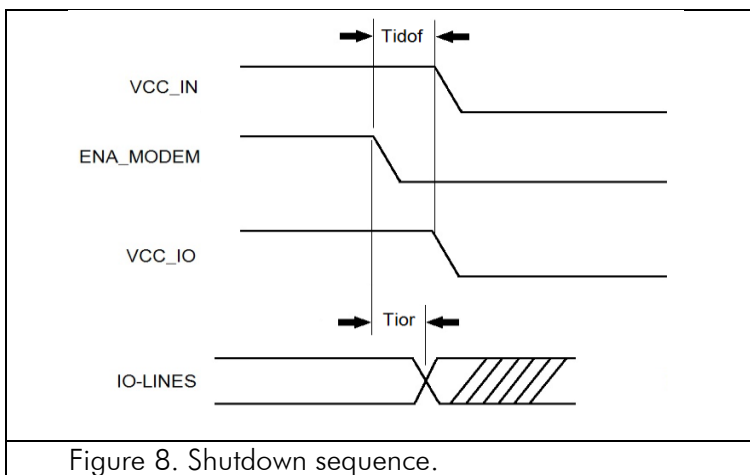
5.1 Startup sequence

The following diagram will describe the startup sequence.



5.2 Shutdown sequence

The following diagram will describe the shutdown sequence.



5.3 Stat pin

The STAT pin indicates the status of the device. It can be used to drive a LED using a series resistor. STAT pin drive capability is 10mA (loads the VCC_IO).
 The STAT pin has the following behavior.

Blink cycle	Mode
"1" - statically	module is operational "searching for a new frame"
"0" for the endurance of the received frame.	"0" when module is receiving data from air interface. In practical cases will toggle at the frequency of the data packets on the air interface.
"0" statically	Module is in sleep1 mode
The pin is toggled in transmission interval	Module is sending data Over the Air
Pin is toggled in 1s interval	Module has the connection to Configuration Manager program.
Pin is toggled in 500ms interval	SL Command mode.
Pin is toggled in 250ms interval	Module has detected a fault, fault codes can be read via Configuration Manager program.

Table. Modes of STAT pin.

5.4 Service pin

The SERVICE pin is used to set the UART1 into a known state. Pulling this pin low will activate the service mode and set the UART1 into 38400, n, 8, 1. This is intended for service access of the module, to have a known serial port setting in order to access the module settings.
 The pin does not affect any permanent settings, nor does it change the mode of the module. Releasing/ driving the pin high will return serial port 1 into the configured state.
 When service pin is used the SL Commands are forced to be ON although they are OFF in settings.

6 OPERATING MODES

The radio transceiver module has the following modes of operation:

Mode	Function	Description
Ready to receive from RF	Search for sync	Module is searching for the start of a radio transmission from the RF signal.
	Receive data	The module has found a valid radio transmission and is receiving data.
TX	Transmit	The module transmits
Safe mode		Mode is entered when a fault has been detected and the device has been Rebooted. In safe mode fault codes can be read from the module.
Sleep mode	Sleep1	Will turn the module into a state where it will hold parts of the radio on, wakeup will take approx. 30 ms
Power Save mode	Power save	Automatic sleep/wake-up procedure where module sleeping time is dynamically adjusted to received data packets. Decreases the power consumption of complete receiving cycle approx. 30%.

6.1 Safe mode

When a fault has been detected by the Firmware, the module is set to Safe mode. In this mode the module toggle's the Stat Pin in 250ms interval indicating an Error and reboots the device after 5s. Transmitting/Receiving is prohibited during malfunction. When connecting to the device with SATEL Configuration Manager the Error code is shown in pop up box. If the device does not recover after multiple reboots, please contact SATEL Oy.

SATEL Configuration Manager can be downloaded from website www.satel.com/support-and-services/downloads/.

The version 1.3.15 or newer is compatible with SATELLINE-M3-TR3 and -TR4 radio transceiver modules.

6.2 Power up / power down scenarios

The transceiver module can be set in four (4) states, "ON", "OFF", "sleep1" and "Power Save". When power is applied to the module, the module switches to ON state when voltage in ENA_MOD pin is >1.2V.

The module can be shut down by driving ENA_MOD line to <0.2V.

In the "OFF" state current consumption is only that of leakage current from an LDO (0.34 mA). In this state all non-essential parts off the module are powered down and all settings / state information that are not stored in NVM are reset.

6.3 Sleep Mode

When being in sleep mode, the radio part of the module is switched off while the serial interface communication related parts remain powered on. The module will be automatically woken up after the CPU senses a state change in the TD1 pin. *Example:* The module is in Sleep1- mode. The module is woken up by sending a character or characters into the TD1 pin after which the module responses "OK". After "OK" the module is ready for normal communication.

To turn the module ON from sleep1 mode:

- 1) Issue a state change to TD1 (toggle pin (minimum pulse duration time 10 μ s) or issue a byte on the UART (for example 0x00))
- 2) Wait for "OK" -response from the module. The wake-up time is approx. 30 ms.
- 3) Start communicating normally

Module will remain powered ON until a new sleep command is issued.

6.4 Power Save Mode

The Power save mode performs an automatic, self-adjusting receiver wake-up/sleep cycle. It is designed for applications which base on one-way communication with relatively constant TX interval and, in which the data packet separation is > 200 ms.

When enabled, the unit makes the *transmission interval study* basing on four (4) successfully received data packets. The shortest time between transmitted packets is measured (t_{min}). Measured value is updated after each successfully received data packet, so that possible changes in the message length becomes noted.

Ensuring that the complete messages will be received even if there occur little variation in transmission interval, some safety margin (t_{marg}) is left into Ready to receive from RF mode time.

Safety margin is calculated by dividing the shortest time between transmitted packets (t_{min} , in ms) with 8 and by adding 60 ms to this result:

$$t_{marg} = \frac{t_{min}}{8} + 60 \text{ ms}$$

The length of the whole sleeping period (t_{sleep}) is calculated by decreasing the shortest time between transmitted packets (t_{min}) with safety margin (t_{marg}) and transmission time of the original message (t_{TX}):

$$t_{sleep} = t_{min} - t_{marg} - t_{TX}$$

Transmission interval study is started over always after 100 successful sleep/wake-up cycles and, if the expected receiving slot ($t_{RX\ slot}$) with enhanced overlap margin ($t_{overlap}$) has been missed. In latter case the package is considered to be lost.

$$t_{overlap} = t_{marg} + 100\ ms$$

$$t_{RX\ slot,\ min} = t_{min} - t_{marg}$$

$$t_{RX\ slot,\ max} = t_{min} + t_{overlap}$$

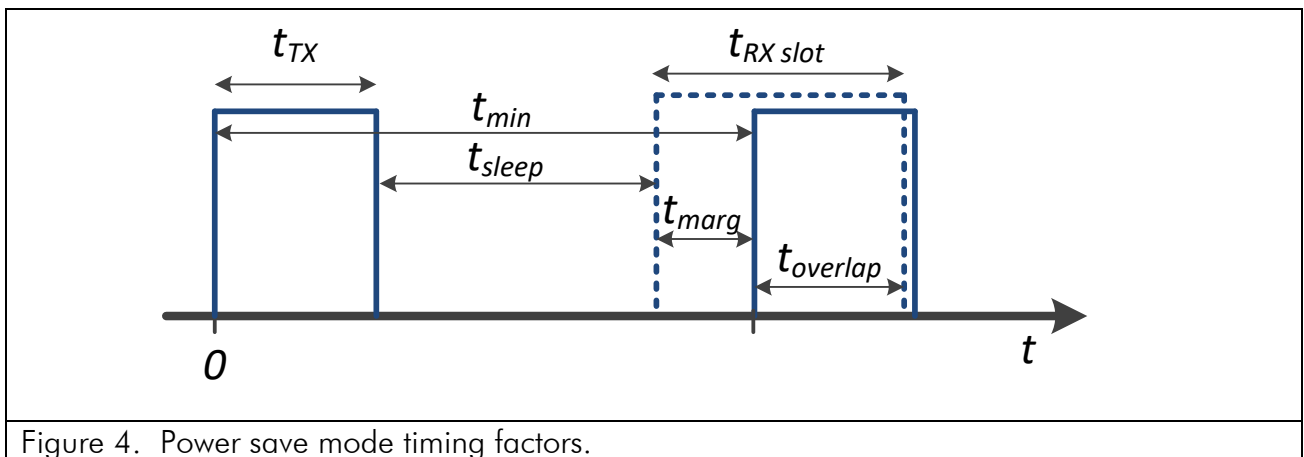


Figure 4. Power save mode timing factors.

E.g. In system with TX interval of 1 s, and with 300 ms (approx. 300B @ 9600 bps) transmission time:

$$t_{min} = 1000\ ms$$

$$t_{TX} = 300\ ms$$

$$t_{marg} = 125\ ms + 60\ ms = 185\ ms$$

$$t_{sleep} = 1000\ ms - (125\ ms + 60\ ms) - 300\ ms = 515\ ms$$

$$t_{RX\ slot,\ min} = 1000\ ms - 185\ ms = 815\ ms$$

$$t_{RX\ slot,\ max} = 1000\ ms + 185\ ms = 1185\ ms$$

6.5 Restart

After startup the module can be restarted by issuing a SL command, upon which the module will shut down all circuitry, and Reboot the CPU (see SL-list).

7 RF interface

7.1 RF interface

The antenna interface is a 50 Ω coaxial connector. Matching networks are not included on the module and should be placed in the host application if the antenna is not 50 Ω . The HIROSE U.FL compatible connector is located on the TOP side of the board.

NOTE! The used connector has gold plated contacts - whereas a standard HIROSE U-FL has silver plated contacts.

If silver - gold joints are not allowed in your product, use gold plated cable-connector to mate to this device.

NOTE!

Setting the transmitter output power to such a level that exceeds the regulations set forth by local authorities is strictly forbidden. The setting and/or using of non-approved power levels may lead to prosecution. SATEL and its distributors are not responsible for any illegal use of its radio equipment, and are not responsible in any way of any claims or penalties arising from the operation of its radio equipment in ways contradictory to local regulations and/or requirements and/or laws.

7.1.1 Encryption

Data security is often a concern when using radio communication. In the SATELLINE-M3-TR3, -TR4 and -R4 product family an AES128-bit encryption (CTR-mode) on the air-interface ensures privacy in the radio network. The principle of encryption in the radio path is to collect a certain amount of data to a shift register and manipulate it according to a certain rule. Every data packet is encrypted individually. The process of encryption adds 10 ms delay in the data flow to each sent data packet (<5 characters) and must be avoided in the cases where low latency is the most important requirement.

AES is open source software from public domain. Author: Brian Gladman (U.K). The CTR-mode is SATEL's in-house implementation.

Separate product models from the SATELLINE-M3-TR3, -TR4 and -R4 radio modem family supports the encryption for the RF interface. The models supporting this feature and encryption level can be viewed in SATEL WEB sites at www.satel.com/products/. The radio models that does not support the encryption feature are compatible with the radio models with the encryption when the feature is disabled. It is not possible to update/change the models NOT supporting the encryption to support this feature in the field. This task can be executed is SATEL factory premises and will be charged according to the service price list. The factory default value for the encryption feature is OFF state. The setting state with the static, distributed encryption keys have to be set equally to the radios in the same radio network.

Please contact SATEL for more detailed information regarding the radio network compatibility settings in radio network between different models (channel width, radio frequency etc.).

The encryption password key is generated by using Main and Aux –keys + in the beginning of the data packet transferred changing 32-bit string. It is mandatory to insert both information keys with the mentioned length keys. Options for generating the encryption keys are:

- Manually via terminal connection:
 - o SL commands
- Automatically with password via Configuration Manager software (generates automatically the Main and Aux keys)

It is recommended to set up a radio network with encryption enabled by using only one selected configuration way. The equivalency of the encryption keys between radio modems can be verified from the Key Hash –information field. Last 4 marks indicates the equivalency [0-9, A-F].

NOTE! The encryption works ONLY in SATELLINE-3AS –radio compatibility mode.

7.1.2 Radio state

This setting allows users to disable/enable the transmitter. Unless overridden by the factory configuration, users can select state of the radio by using Configuration Manager software (starting from version 1.8.0) and selecting the value of Misc settings → Enabled Radio States:

- Tx/Rx (both transmitter and receiver are enabled)
- Rx Only (transmitter disabled, receiver enabled)

In case the factory configuration defines the modem as Rx-only device, the value can't be changed by the users.

NOTE! Rx Only device replies "0mW" to SL@P? (Get transmitter power) command

7.1.3 Priority RX/TX

Priority setting selects the priority between reception and transmission. The setting can be changed either with Configuration Manager SW or via SL commands. By default, transmission has higher priority than reception i.e. the default value is Priority TX.

Priority TX means that the device attached to a radio modem decides the timing of the transmission. The transmitter is immediately switched on when the terminal device starts to output data. Should reception be in progress, the radio modem will stop it and change to a transmit state. There is no need to use any handshaking for the control of timing.

Priority RX means, that a radio tries to receive all data currently in the air. If a terminal device outputs data to be transmitted (or an SL command) it will be buffered. The radio modem will wait until the reception has stopped before transmitting the buffered data. This will result in timing slacks to the system, but decreases the number of collisions on the air; this is particularly useful in systems based on multiple random accesses.

7.1.4 Forward Error Correction (FEC)

FEC improves the reliability of data transfer over the radio by adding additional correction information to the radio messages. Based on that information, the receiving radio modem will be able to correct erroneous bits provided the ratio of erroneous and correct bits is reasonable. However, the use of FEC decreases the data throughput, because the amount of transmitted data increases about 30 % (see Appendix 11.2). FEC should be used on long distance links and/or if the radio channel is "noisy" in other words suffering from interfering signals.

NOTE! All radio modems, which are to communicate with each other, must have the same setting for FEC (ON or OFF). If the transmitting radio modem and the receiving radio modem has different settings, data will not be received.

7.1.5 Error checking

When the error checking is switched on, the radio will add a checksum to the transmitted data. When the data is received, the checksum is verified before data is forwarded to the serial port. Options for error checking can be accessed either via SL commands or Configuration Manager SW. Setting must be set equally for all radio modems in the same network. Error Check modes:

OFF (default setting). Received data is not verified at all. In practice, this is the fastest way to operate, because the data is given out from serial port immediately after it has been received. This is recommended method, if the application protocol already includes error checking functions.

CRC8 Partial verifies the data in small blocks and they are delivered to DTE as sub messages after validating. Once an error is detected, the rest of the message is ignored. In practice, if the error appears in the middle of the message, the first part is forwarded to DTE and the data in erroneous sub-message and after that will be lost.

CRC16 Full and CRC 8 Full check adds checksum characters accordingly at the end of the user data message. At the reception end the receiver receives first the whole package and if the checksum matches the data message is forwarded to the serial port.

7.1.6 Separate TX/RX frequencies

Modem can transmit (TX-frequency) and receive (RX-frequency) on separate frequencies. The switch between the frequencies introduces an extra 40 ms delay in the data transfer that must be taken account when designing the system.

A list of predefined radio channels can be stored in the memory in order to change the radio settings simply by switching between the channels. Each channel carries the following info:

- Channel number (any number -32767...32767)
- Transmitter/Receiver frequency
- Channel width (12.5, 20 or 25 kHz)
- Transmitter power level (optional)

Additionally, the default channel that the radio modem uses after a reset is defined.

7.1.7 Channel list

Channel lists can be created and utilized by using either SATEL Configuration Manager Software or SL commands.

SATEL Configuration Manager software provide a channel list editor (snapshot below) for creating and saving a channel list in the radio modem, or in a file for later usage.

Channel Selector									
Default Channel Set									
Clear	Load	Save	Add	Edit	Up	Down	Set default	Delete	Close
#	User Channel	Frequency	Channel Width	Tx Power					
1	0	430000000	12500	1000					
2	-5	438000000	12500	100					
3	123	468200000	25000	500					
4	12345	430000000	12500	200					

SL commands provide an interface for a host device to command the radio modem directly. An example of the procedure for creating or replacing a channel list:

1. Clear existing channel list (SL\$C=0)
2. Set channel info for each of the channels to be created starting from index 0 (SL\$L=)
3. Set number of channels in channel list (SL\$C=)
4. Set the default channel (SL\$D=)
5. Verify the new configuration:
 - Get number of channels in channel list (SL\$C?)
 - Get channel info for each of the channels (SL\$L?)
 - Get the default channel (SL\$C?)
7. Enable Channel list (SL\$M=1) in order to activate the Channel list
8. Save the settings (SL**>)

7.1.8 Repeater -mode

Repeaters and addressing may be used to extend the coverage area of a radio modem network, and to direct messages to selected radio modems in the network. In large systems, with several repeaters and formed repeater chains, it is often practical to use routing instead of plain addresses.

In circumstances where it is necessary to extend the coverage area of a radio modem network, modem can be used as repeater stations.

The maximum size of a repeated data packet is 1 kB (kilobyte). The Repeater Function is switched on in the radio settings. In the repeater mode the radio modem will function as a totally independent unit. Other devices are not necessary.

A radio modem acting as a repeater can also be used to receive and transmit data. In repeater mode the radio modem will transmit the received data to the serial interface in a normal fashion. The difference being that the received data will be buffered into the buffer memory. After reception the radio modem will re-transmit the buffered data using the same radio channel as in reception. Data received through the serial interface a radio modem in repeater mode will transmit normally.

The same network may include several repeaters, which operate under the same base station. Repeaters may also be chained; in which case a message is transmitted through several repeaters. In systems with more than one serially or parallelly chained repeater, addressing or routing protocol must be used to prevent a message ending up in a loop formed by repeaters, and to ensure that the message finally reaches only the intended radio modem.

Please contact SATEL for more information of Repeater-, and Addressing –features.

7.2 Data buffering

Whenever the radio modem is in Data Transfer Mode it monitors both the radio channel and the serial interface. When the terminal device starts data transmission the radio modem switches to transmission mode. At the beginning of each transmission a synchronisation signal is transmitted and this signal is detected by another radio modem, which then switches into receive mode. During the transmission of the synchronisation signal the radio modem buffers data into its memory. Transmission ends when a pause is detected in the data sent by the terminal device, and after all buffered data has been transmitted. When the serial interface speed is the same or slower than the speed of the radio interface, the internal transmit buffer memory cannot overflow. However, when the serial interface speed exceeds the speed of the radio interface, data will eventually fill transmit buffer memory. In this instance, it will take a moment after the terminal device has stopped transmission of data for the radio modem to empty the buffer and before the transmitter switches off. The maximum size of transmit buffer memory is one kilobyte (1 kB). If the terminal device does not follow the status of the CTS-line and transmits too much data to the radio modem, the buffer will be emptied and the transmission is restarted.

In the receive mode, the buffer works principally in the above described way thus evening out differences in data transfer speeds. If the terminal device transmits data to a radio modem in receive mode, the data will go into transmit buffer memory. Transmission will start immediately when the radio channel is available.

7.3 Pacific Crest and TRIMTALK compatibility

SATELLINE-M3-TR3, -TR4 and -R4 supports additional to the original SATELLINE-3AS data transfer also:

- Pacific Crest FST compatible data transfer over the air, if the opponent Pacific Crest modems operate in the transparent mode/FEC ON/Scrambling ON that is the most common setup among RTK applications. The other modes are currently not supported.

- TRIMTALK® 450s compatible data transfer over the air.

SATELLINE-M3-TR3, -TR4 and -R4 provides the following radio compatibility options:

- SATELLINE-3AS Original SATELLINE-3AS data transfer mode (Default)
- PacCrest-4FSK Transparent mode/FEC ON/Scrambling ON (Option 1)
- PacCrest-GMSK Transparent mode/FEC ON/Scrambling ON (Option 2)
- TrimTalk450s(P) Trimtalk450s GMSK Rx fitted to PacCrest transmitters (Option 3)
- TrimTalk450s(T) Trimtalk450s GMSK Rx fitted to Trimble transmitters (Option 4)
- PacCrest-FST (Option 5)

Notes:

Supported compatibility options may vary depending on the model and factory configuration.

All radio modems of a system must have identical FEC setting (ON or OFF) in SATELLINE-3AS mode.

The implementation of Radio compatibility options is based on the reference measurements and the available public data of the following radio modems manufactured by Pacific Crest Corporation: ADL, RFM96W, PDL HPB, PDL LPB. TRIMTALK is a trademark of Trimble Navigation Ltd.

7.3.1 Settings in compatibility modes

In order to use the Pacific Crest/TRIMTALK modes implemented in SATELLINE radios:

PACIFIC CREST modems must have:

- Protocol Mode
- Transparent w/EOT Timeout (when using Pacific Crest modulations)
- TrimTalk 450s (when using TRIMTALK GMSK modulation)
- Modulation Type depends on the system
- GMSK (default, always selected when using TRIMTALK 450s mode)
- 4-Level-FSK
- FEC = ON
- Scrambling = ON
- Data Security Code set to = 0 (=not used)
- Local Address= 0...254 (0 by default)

Pacific Crest modems receive messages from SATELLINE modems that have their TX1 address matching the Local Address.

Remote address=0...255 (255 by default, that is the broadcast address to be received by all). SATELLINE modems receive the message from a Pacific Crest radio, provided their RX1 address matches the Remote Address of a Pacific Crest transmitter (or if the message has the broadcast address 255).

SATELLINE modems must have the following key settings:

- FEC OFF (because the FEC here means SATEL 3AS FEC, not Pacific Crest/TRIMTALK FEC)
- Error check OFF
- Error Check mode OFF
- Radio Compatibility Option 1 in case of Pacific Crest 4FSK
- Radio Compatibility Option 2 in case of Pacific Crest GMSK
- Radio Compatibility Option 3 in case of TRIMTALK GMSK

When TX address is selected ON, then TX1 address is used like PDL Remote address that is the destination address for the transmitted messages. Default value is 0x00FF (=255) (note the hexadecimal format of the setting).

When RX Address is selected ON, then RX1 address is used like PDL Local address. Default value is 0x0000 (=0) (note the hexadecimal format of the setting).

Addresses are NOT applicable in TRIMTALK 450s mode so SATELLINE modems must have their RX/TX addresses OFF with Option3.

The configuration tools and settings are different between SATELLINE and Pacific Crest modems: Pacific Crest modems are configured via the serial port using PDLCONF Windows™ program that sends binary control messages to the serial port of the modem.

SATELLINE-EASy radio modems are configured via the serial port using SL commands or SATEL Configuration Manager PC-program.

The table below shows the analogy of settings between Pacific Crest and SATELLINE radio modems.

Pacific Crest setting	Corresponding SATELLINE setting
Identification: Owner	not implemented
Identification: Channel Bandwidth	Channel spacing
Identification: RF Power	TX power
Radio Link: Channel Selection Type (Manual)	Radio frequency
Radio Link: Current Channel	Radio frequency
Radio Link: Link Rate	Radio compatibility mode and channel spacing determine the link rate
Radio Link: Modulation Mode	Radio compatibility
Radio Link: Scrambling	ON by default
Radio Link: Transmit Retries	not implemented
Radio Link: TX ACK Timeout	not implemented
Radio Link: Csma Monitoring	Priority (RX=ON, TX=OFF) Default: RX
Radio Link: AutoBase/AutoRover	not implemented
Radio Link: Digisquelch	Signal threshold
Radio Link: Forward Error Correction	ON by default Note: SATELLINE-EASy FEC must be OFF!
Radio Link: Local Address (0 by default)	Primary RX address (RX1) (OFF by default)
Radio Link: Remote Address (255 by default)	Primary TX address (TX1) (OFF by default)
Serial Interface: Protocol Mode	Radio compatibility
Serial Interface: BREAK to Command	not implemented
Serial Interface: Modem Enable: Yes	not applicable
Serial Interface: Soft Break Enable	not implemented
Serial Interface: EOT value (in 0.01s units)	Pause length (in serial port byte intervals)
Serial Interface: Digipeater Delay	not implemented
Serial Interface: Local Node Repeater	not implemented
Frequency Table	Radio frequency
Data Security Code (must be 0=not used)	not implemented
Potential conflicts: FEC setting applies only to the SATELLINE-3AS mode, the other radio compatibility modes have their own FEC bindings (although some previous or special firmware versions differ in the way FEC setting is handled - in case of doubt please contact technical support) Error check and Full CRC16 check must be OFF in SATELLINE modem FCS (Free Channel Scanning) feature is not supported by Pacific Crest radios SATELLINE RX/TX addressing does not use ARQ scheme like Pacific Crest radios.	

7.3.2 Repeater function

The implemented Pacific Crest/TRIMTALK modes support also the repeater function. The repeater function is configured either by using the SL commands:

- "SL@M=R" (Repeater ON)
- "SL@M=O" (Repeater OFF)

or by selecting Repeater OFF/ON in the Radio Settings –tab in the Configuration Manager SW.

Note 1. If error correction is ON (FEC ON) and TRIMTALK mode is activated by using "SL@S=3" command, the firmware automatically switches SATEL FEC OFF temporarily, and turns it back at the mode return.

7.3.3 Support for Local / Remote addresses

If the modem has TX address ON then primary TX address is handled in the same way as Remote address in Pacific Crest PDL modems. The default value is 0x00FF (255 in decimal format) i.e. the broadcast address.

If the modem has RX address ON then primary RX address is handled in the same way as PDL Local address in Pacific Crest PDL modems. The default value is 0x0000 (0 in decimal format). SATELLINE modem needs to have TX Delay 50ms or more in order to avoid messages from colliding in case it is to be placed in a Pacific Crest system that uses addressing and acknowledging scheme.

In case only broadcast messages are used (like in RTK applications) there is usually no need for TX Delay, except if the transfer delays identical to Pacific Crest modems are preferred – in such cases an appropriate value of TX Delay is 34 ms.

Note 1. SATELLINE-modems do not support Pacific Crest retransmit/acknowledge scheme. However, that has no effect in RTK applications because they utilize only broadcast messages.

8 SETTINGS

The configuration of settings can be changed easily - the next chapters describe the details:

SATEL Configuration Manager PC software

This clear to use software suits in most cases. Additional to other tools, it includes the channel list editor for creating the channel lists.

SL commands

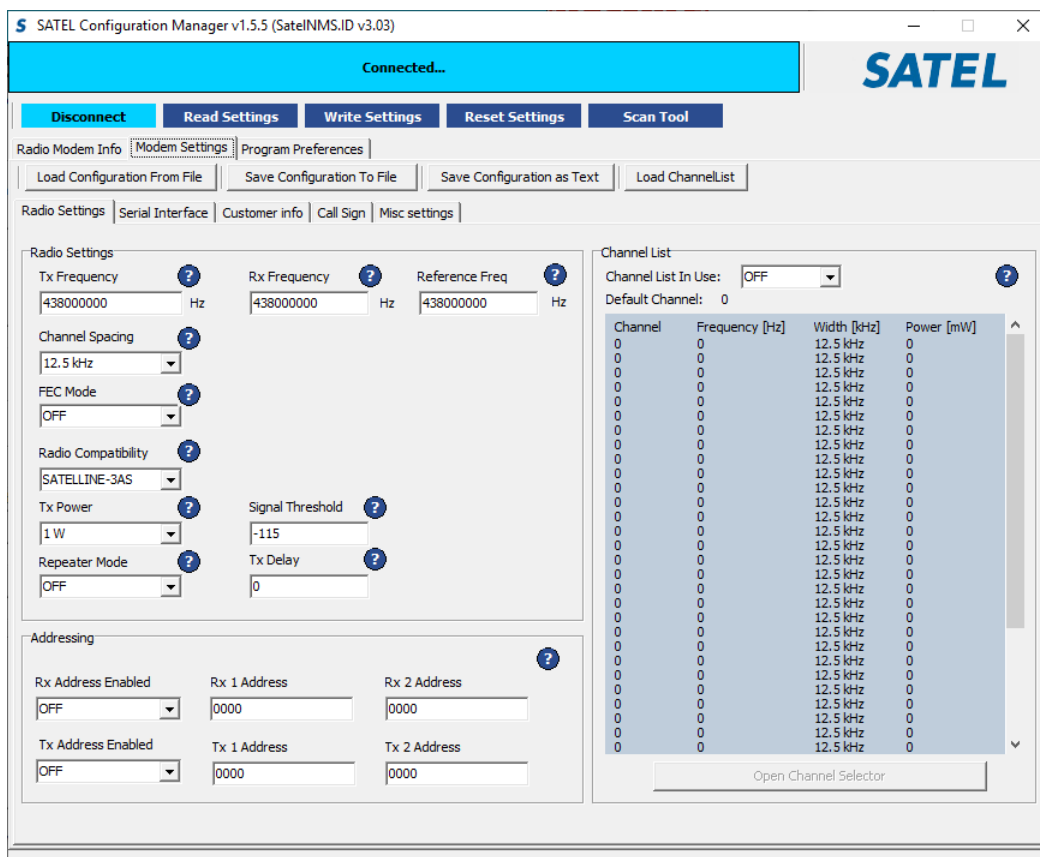
A terminal device can command or configure the radio modem by using special commands. SL commands are applied especially in cases where radio modems are to be integrated seamlessly inside a system behind the integrator's own user interface.

8.1 SATEL Configuration Manager software

SATEL Configuration Manager is the PC software for the configuration of SATELLINE-M3-R/TR, SATEL-R/TR –module based radio models, covering most of the SATEL radio products.

Minimum requirements: PC (Windows 95, 98, 2000, XP, Vista and Win7) equipped with a COM port (USB-RS adapters available) and the radio modem, powered up, to be configured.

The software is available from the dealers or at <https://www.satel.com/support-and-services/downloads/>.



8.2 Changing parameters using SL commands

The controlling terminal device can change the configuration settings of the module. This is accomplished with the help of SL commands. SL commands can be used to change e.g. the frequency or addresses. It is also possible to ask the radio transceiver module to show current settings which are in use.

8.2.1 SL Commands

The controlling terminal device can change the configuration settings of a radio. This is accomplished with the help of SL commands, which can be used during data transfer. SL commands can be used to change e.g. the frequency or addresses. It is also possible to interrogate a radio modem in order to gain information concerning current settings that are in use. SL command -setting must be enabled before they can be used.

An SL command is a continuous string of characters, which is separated from other data by pauses which are equal or greater than time defined by Pause length parameter (default=3 characters) in the set-up. No extra characters are allowed at the end of an SL command.

Serial interface settings are the same as in data transfer. SL command is properly recognised also in the case when the command string is terminated by <CR> (=ASCII character no. 13, Carriage Return, 0x0d) or <CR><LF> (<LF> = ASCII char. no. 10, Line Feed, 0x0a). If multiple SL commands are sent to the module, the next command can be given after receiving the response ("Ok" or "Error") of the proceeding command. In addition, it is recommended to implement a timeout to the terminal software for recovering the case when no response is received from the radio module.

The transceiver module will acknowledge all commands by returning an "OK" (command carried out or accepted) or the requested value, or an "ERROR" (command not carried out or interpreted as erroneous) message.

it is possible to use SL commands in Port 2 (TD2 signal in GPIO3 (Pin13) and RD2 signal in GPIO1 (Pin11)) when Port2 Function has been configured as Diagnostics. SL commands can be used even in parallel with Port1 – in that case the response appears in the same port where the SL command came from.

Port2 is configured on Serial Interface sheet of Configuration Manager software (starting from version 1.8.0) by selecting the Port2 Function:

- OFF (=Port 2 not in use)
- Diagnostics (=SL commands ON in this case)

CR/LF characters are added to end the response messages (unless they are already present) in order to make parsing easier. Settings can be toggled, SL Commands ON/OFF, CR/LF ON/OFF.

The SL commands are listed in appendix 11. In order to get information of the latest and/or special SL commands please contact SATEL.

8.2.2 SL Command Mode

The SL commands have always been enabled in the previous products like M3-R3. When the SL commands are enabled there are possibilities that the user data may start with the characters "SL" which is handled as the SL command. This has caused the firmware to go to the continuous SL command search mode and any data has not been sent or even an "ERROR" acknowledgment has been received. To avoid this kind behavior the user can disable the SL commands. The SL commands can be disabled or enabled by using SL commands or toggling the "SL Command mode" parameter via the *SATEL Configuration Manager*, version v1.3.15 or newer.

By default the *SL Command mode* is set to **ON**. If the *SL Command mode* is set to **OFF** then the SL commands can be enabled or disabled by using the below described procedure. Regardless of original SL command –setting state, changing the setting state with this procedure will effect to the reception process of the radio module. SL command –setting state can be changed only via *SATEL Configuration Manager* in maintenance access level.

NOTE!

To enable the SL Commands* (disables interface transmission and reception):

- Send three "+" characters via serial port so that there is at least three bytes delay between each character. The response is "OK", when successfully set.
<+> <at least three bytes pause> <+> <at least three bytes pause> <+>

To disable the SL Commands* (enables radio interface transmission and reception):

- Send three "-" characters via serial port so that there is at least three bytes delay between each character. The response is "OK", when successfully set.
<-> <at least three bytes pause> <-> <at least three bytes pause> <->

*) Regardless of the set state for the SL command mode.

Note2!

The "+ + +" and "- - -" procedures are not allowed to be used, when radio is transmitting or receiving data (i.e. the application data occupies the TD or RD lines of the radio).

9 CONSIDERATIONS

9.1 EMI Interferers

The module is designed to be mounted inside a host device. The module is designed to withstand EMI even beyond type approval requirements. However, a small module which is integrated closely to modern high speed electronics is bound to receive some interference.

To make a working integration, consider the following: EMI can enter the module in four ways:

- 1) Via the antenna (radiation from enclosure enters the antenna)
- 2) Radiated disturbances to the coaxial cable
- 3) Radiation from other electronics / cabling directly to the module
- 4) Conducting through the DTE interface (power, control and data lines).

Because the module is shielded and the DTE interface is filtered, the usually worst method of disturbance is via the antenna port, which is easily overlooked in design. Keep in mind that the radio module has a sensitivity of approx. -115 dBm (depends on mode of operation and speed etc.). While the module has an approx. 10 dB S/N requirement, this constitutes, that any signal entering the radio antenna on receive frequency on a level of < -125 dBm $(-115\text{dBm}-10\text{dB})$, causes desensitization of the radio on that particular channel.

Example:

An interferer has a level of -100dBm on the frequency 421 MHz. The radio will show an approximate sensitivity of -90dB $(-100\text{dBm} + \text{S/N requirement } 10 \text{ dB})$ on 421 MHz.

Now consider that generic EMC requirements usually have pass/fail criteria of -57dBm (if normalized to the surface of the device). **So there is almost a 70dB gap between generic EMC requirements and co-existence requirements between a high sensitivity narrowband radios.**

To avoid problems of co-existence a good design should apply:

- 1) EMI shielding in enclosure – ambient air interface
- 2) careful layout
- 3) shielding of all digital high speed parts and cables
- 4) Have a clocking plan to avoid clock frequencies causing harmonics on the UHF band of interest.

Number one is to recognize this challenge and act upon it.

SATEL R&D can help in this by participating in design review of the host device, aiming to catch problems early in the design phase.

9.2 Electrostatic discharge

As the module is intended to be embedded in a host application, in a typical use case, the antenna port is the only port of the module directly interface with a surface or contact area subjected to Electrostatic Discharge (ESD).

Thus, the antenna port is the only interface with high level ESD protection. The DTE port also features ESD protection diodes, but is not designed to withstand similar performance as expected from standalone units with enclosures.

Consequently, the module should be subject to ESD handling precautions that typically apply to ESD sensitive components. Proper ESD handling and packaging procedures must be applied throughout the processing, handling and operation of any application that incorporates this module.

The module fulfills the ESD values listed in the following table.

Specification / Requirement	Contact discharge	Air discharge
EN 61000-4-2		
Antenna interface	±10kV	<±15kV
DTE interface	±8kV	-
JEDEC JESD22-A114D (Human Body Model, Test conditions: 1.5 kΩ, 100 pF)		
Module surface	±1kV	n.a.

Table. ESD ratings. Measured Acc. to EN 61000-4-2 specification.

9.3 Using the device in unmanned high reliability applications

The module features software and hardware watchdogs which are incorporated inside the CPU. While we believe that this is a reliable method of keeping the module in operational condition, there are parts of the module that can't be monitored for proper operation to 100%. For example the module chip has a firmware that resides in the chips RAM. The firmware can't be read back or reloaded, without interrupting reception. Hence the module can't reload this automatically by itself without causing breaks in communication.

To avoid the module from ending up in a state where for example the module chip firmware is corrupted for example by ionizing radiation, it is recommended that the controlling system implements some form of watchdog function for the module.

This can be done for example if the system knows that data should be received every second, and no data has been received for a minute – then do a module restart using the ENA_MOD pin or by issuing a restart command, or a cold boot by toggling VCC_IN low and high again.

10 PROPOSALS FOR MORE RELIABLE RADIO LINK

In case where the environment is challenging the following methods can be used for improving the transmission reliability:

- Forward Error Correction, FEC, is recommend to use in challenging environment like urban areas.
- Directional antennas.
- Before building the radio link(s) it is highly recommended that the radio environment is measured to find out whether the radio environment is clean enough by using a spectrum analyzer or radio module's RSSI, Received Signal Strength Indication, value.
- Co-operation with the local authority to find out the optimum free radio channel.
- If the channel is disturbed an external band-pass filter can be used for improving the filtering.
- If at the adjacent channel is TDMA, Time Domain Multiple Access, it is recommended to use time slot for receiving which is not in synchronization with the TDMA radio transmission.
- In Europe it is not recommended to use channels which are located near by the TETRA or television frequencies.

11 APPENDIX

11.1 SL COMMANDS

Category	Command	Description	Response
Addressing	SL#A?	Show all addresses (RX1, RX2, TX1, TX2)	"xxxx,yyyy,zzzz,vvvv"
Addressing	SL#A=xxxx, yyyy, zzzz,vvvv	Set RX/TX addresses (RX1, RX2, TX1, TX2)	"OK" or "ERROR"
Addressing	SL#I?	Get primary addresses (TX1, RX1)	"xxxx;yyyy"
Addressing	SL#I=xxxx	Set all addresses (RX1, RX2, TX1, TX2) to value xxxx [0000....ffff]	"OK" or "ERROR"
Addressing	SL#P?	Get primary transmit address (TX1) and primary receive address (RX1)	"xxxx;yyyy"
Addressing	SL#P=xxxx;yyyy	Set primary transmit address (TX1) to value xxx and primary receive address (RX1) to value yyyy [0000....ffff]	"OK" or "ERROR"
Addressing	SL#Q?	Get TX address mode	"0" = TX address OFF "1" = TX address ON
Addressing	SL#Q=x	Set TX address ON/OFF. Values of x are: "0" = TX address OFF "1" = TX address ON	"OK" or "ERROR"
Addressing	SL#R?	Get primary receive address (RX1)	"yyyy"
Addressing	SL#R=xxxx	Set receive addresses (RX1, RX2) to value xxxx [0000....ffff]	"OK" or "ERROR"
Addressing	SL#S?	Get secondary transmit address (TX2) and secondary receive address (RX2)	"xxxx;yyyy"
Addressing	SL#S=xxxx;yyyy	Set secondary transmit address (TX2) to value xxx and secondary receive address (RX2) to value yyyy [0000....ffff]	"OK" or "ERROR"
Addressing	SL#T?	Get primary transmit address (TX1)	"xxxx"
Addressing	SL#T=xxxx	Set transmit addresses (TX1, TX2) to value xxxx [0000....ffff]	"OK" or "ERROR"
Addressing	SL#W?	Get RX address mode	"0" = RX address OFF "1" = RX address ON
Addressing	SL#W=x	Set RX address ON/OFF. Values of x are: "0" = RX address OFF "1" = RX address ON	"OK" or "ERROR"
ChannelList	SL\$A=1	Go to channel list default channel	"OK" or "ERROR"
ChannelList	SL\$C?	Get number of channels in channel list	decimal number

ChannelList	SL\$C=nn	Set number of channels in channel list. nn = 0...40, 0 clears the whole list	"OK" or "ERROR"
ChannelList	SL\$D?	Get channel list default channel number	decimal number
ChannelList	SL\$D=n	Set channel list default channel, n is channel number	"OK" or "ERROR"
ChannelList	SL\$E=1	Search free channel Modem searches for next traffic-free channel. Listening time of traffic is about 2 seconds Modem shows next free channel by activating command again	"OK" followed by "channel n is free" Value of n is channel number of next free channel on channel list
ChannelList	SL\$F?	Get active channel number	decimal number
ChannelList	SL\$F=n	Set modem to channel number n in channel list	"OK" or "ERROR"
ChannelList	SL\$L?nn	Get channel info. Index nn=[0...(number of channels-1)]	Channel number, Frequency, Channel width, Tx Power For example: "CH 1, 430.150000 MHz, 25.0 kHz, 100 mW\0D"
ChannelList	SL\$L=laa,Nbbb bbb,Fccc.cccccc ,Wdd.ddd,Peee ee<CR>	I = Index field aa = 0...39 //Future reservation 0...255 N = Channel number field bbbbbb = -32767...32767 F = Tx/Rx Frequency field ccc.cccccc = Tx/Rx Frequency in MHz (only numbers or "." allowed, "," is not allowed) W = Channel spacing/width field dddd = 12.5, 20 or 25 (unit is kHz, trailing decimals are tolerated e.g. "25", "25.0", "25.00" and "25.000" are all valid) P = Transmitter power field eeeee = 0...35000 (modem rounds the value to the closest applicable) Note: 0 means "don't care" value for power. <CR> = Carriage return character	"OK" or "ERROR"
ChannelList	SL\$M?	Get status of channel list. 0 = Not in use, 1 = Channel list in use	"0" or "1"
ChannelList	SL\$M=n	Set status of channel list. 0 = Not in use, 1 = Channel list in use	"OK"
ChannelList	SL\$R?	Get listening time (seconds) of Search free channel function	decimal number
ChannelList	SL\$R=n	Set listening time (seconds) of Search free channel function	"OK" or "ERROR"

ChannelList	SL\$\$=1	Set channel scanning mode When activated, modem scans channels one by one and saves RSSI readings to memory	"OK" followed by channel/RSSI info For example: "OKCH 6 - 122 dBm, CH 22 -121 dBm, CH 10003 -122 dBm, "
DataPort	SL%B?	Get serial data parameters	baud rate, character length, parity, number of stop bits (for example "38400, 8, N, 1")
DataPort	SL%B=a,b,c,d	Set serial data port parameters. a= "115200", "57600", "38400", "19200", "9600", "4800", "2400" or "1200" (defines baud rate) b="8" (defines character length) c= "N", "O" or "E" (defines parity) d= "1" (defines number_of_stop bits)	"OK" or "ERROR"
DataPort	SL%L?	Get pause length	Decimal number
DataPort	SL%L=n	Set pause length	"OK" or "ERROR"
Memory	SL**>	Save current settings as permanent settings	"OK" or "ERROR"
Memory	SL*R>	Restore settings to their factory set values	"OK" or "ERROR"
ModemInfo	SL!H?	Get radio HW info	"HW:nnnnn"
ModemInfo	SL!V?	Get modem "type"	Depending on variant, for example "M3-TR3"
ModemInfo	SL%1?	Get arbitrary data stored in memory location 1	If empty data is stored, response = "Undefined", otherwise data and carriage return
ModemInfo	SL%1="data"	Set arbitrary data (max 25 characters) in memory location 1	"OK" or "ERROR"
ModemInfo	SL%2?	Get arbitrary data stored in memory location 2	If empty data is stored, response = "Undefined", otherwise data and carriage return
ModemInfo	SL%2="data"	Set arbitrary data (max 25 characters) in memory location 2	"OK" or "ERROR"
ModemInfo	SL%3?	Get arbitrary data stored in memory location 3	If empty data is stored, response = "Undefined", otherwise data and carriage return
ModemInfo	SL%3="data"	Set arbitrary data (max 25 characters) in memory location 3	"OK" or "ERROR"
ModemInfo	SL%4?	Get arbitrary data stored in memory location 4	If empty data is stored, response = "Undefined", otherwise data and carriage return

ModemInfo	SL%4="data"	Set arbitrary data (max 25 characters) in memory location 4	"OK" or "ERROR"
ModemInfo	SL%D?	Get Modem Type	Depends on model, for example "M3-TR3"
ModemInfo	SL%H?	Get logic hardware version	Hardware info
ModemInfo	SL%S?	Get Serial Number	Serial number of radio modem
ModemInfo	SL%V?	Get firmware revision information	For example "V07.22.2.3.0.2"
RadioFreq	SL!D?	Get lower limit of frequency band 1	"nnn.nnnnn MHz"
RadioFreq	SL!U?	Get upper limit of frequency band 1	"nnn.nnnnn MHz"
RadioFreq	SL!W?	Get lower limit of frequency band 2	"nnn.nnnnn MHz"
RadioFreq	SL!Y?	Get upper limit of frequency band 2	"nnn.nnnnn MHz"
RadioFreq	SL&F?	Get active frequency	"nnn.nnnnn MHz"
RadioFreq	SL&F=nnn.nnnn n	Set active frequency to nnn.nnnnn MHz	"OK" or "ERROR"
RadioFreq	SL&FR?	Get Rx frequency	"nnn.nnnnn MHz"
RadioFreq	SL&FR=nnn.nnn nn	Set Rx frequency to nnn.nnnnn MHz	"OK" or "ERROR"
RadioFreq	SL&FT?	Get Tx frequency	"nnn.nnnnn MHz"
RadioFreq	SL&FT=nnn.nnn nn	Set Tx frequency to nnn.nnnnn MHz	"OK" or "ERROR"
RadioFreq	SL&W?	Get channel spacing/channel width	"25.0 kHz", "20kHz", "12.5 kHz"
RadioFreq	SL&W=xxxx	Set channel spacing. Value of xxxx is: "1250" for 12,5 kHz "2000" for 20 kHz "2500" for 25 kHz Before using this command, make sure that active frequency matches new channel spacing	"OK" or "ERROR"
RadioProperty	SL%F?	Get status of Error correction (FEC)	"0" = FEC OFF , "1" = FEC ON
RadioProperty	SL%F=x	Set Error correction (FEC). Value of x is: "1" Set FEC ON "0" Set FEC OFF	"OK" or "ERROR"
RadioProperty	SL%E?	Get status of Error check and Full CRC16 check modes	"0" Error check off "1" CRC8 Partial "2" CRC8 Full "3" CRC16 Full

RadioProperty	SL%E=x	Set Error check and Full CRC16 check modes. Value of x is: "0" Error check off "1" CRC8 Partial "2" CRC8 Full "3" CRC16 Full	"OK" or "ERROR"
RadioProperty	SL%R?	Get region code setting/status	0,0 = Default, 1,1 = US, 1,2 = US & Illegal radio setting combination (TX is disabled)
RadioProperty	SL@C?	Get Call sign settings	a, b, c followed by Carriage Return character, where: a=CallSignState (0=OFF, 1=ON) b=CallSignInterval (0...255) in minutes c=CallSignId (max 16 alphanumeric characters) For example: "1,5,MYMESSAGE" followed by Carriage Return character
RadioProperty	SL@C=a,b,c	Set Call Sign settings a=CallSignState (0=OFF, 1=ON) b=CallSignInterval (0...255) in minutes c=CallSignId (max 16 alphanumeric characters)	"OK" or "ERROR"
RadioProperty	SL@D?	Get Tx delay (ms)	For example "0 ms" or "50 ms"
RadioProperty	SL@D=n	Set Tx delay (ms), n is [0...65535]	"OK" or "ERROR"
RadioProperty	SL%E?	Get supported radio compatibility modes.	List of numbers, separated by commas, showing the supported modes: 0=Satel3AS, 1=PacCrest 4FSK, 2=PacCrest GMSK, 3=TrimTalk, 4=TrimTalk Trimble, 5=PCC FST For example: "0,1" indicates that the modem supports Satel3AS and PacCrest 4FSK protocols.
RadioProperty	SL@F?	Get noise level of radio channel	"-xxx dBm"
RadioProperty	SL@M?	Get repeater function	"O" = Repeater OFF(character O) "R" = Repeater ON
RadioProperty	SL@M=x	Set repeater function. Values of x are: "O" = Repeater function	"OK" or "ERROR"

		OFF(character O) "R" = Repeater function ON	
RadioProperty	SL@P?	Get transmitter output power	One of these values "100mW", "200mW", "500mW", "1000 mW". Rx-only modems reply with "0 mW"
RadioProperty	SL@P=nnnnn	Set RF output power (mW) For example "SL@P=100" sets 100 mW transmitter output power. "100" sets 100 mW transmitter output power. "200" sets 200 mW transmitter output power. "500" sets 500 mW transmitter output power. "1000" sets 1000 mW transmitter output power.	"OK" / "ERROR"
RadioProperty	SL@R?	Get RSSI (Received Signal Strength Indication) of last received message (dBm)	"-nnn dBm", nnn is a decimal value of field strength between -80 dBm and -118 dBm. Value is available 7 s after reception, after that the response is "<-118 dBm". SATELLINE-3AS Epic returns the stronger value of two transceivers.
Radio Property	SL@S?	Get radio compatibility mode	decimal number. See list on lower left
RadioProperty	SL@S=x	Set radio compatibility mode. Value of x is: 0 = SATELLINE-3AS 1 = PacCrest-4FSK (Option1) 2 = PacCrest-GMSK (Option2) 3 = Trimtalk450s(P) (Option 3, RX fits PacCrest modems) 4 = Trimtalk450s(T) (Option 4, RX fits Trimble modems) 5 = PacCrest-FST (Option5) 6 = SATELLINE-2ASxE 20 = 8FSK FEC OFF (TR4 only) 21 = 8FSK FEC ON (TR4 only) 22 = 16FSK FEC ON (TR4 only) 23 = PacCrest-4FSK FEC Off (Scrambler On)	decimal number

		24 = PacCrest-GMSK FEC Off (Scrambler On) 26 = PacCrest-4FSK FEC Off Scrambler Off 27 = PacCrest-GMSK FEC Off Scrambler Off 28 = PacCrest-4FSK FEC On Scrambler Off 29 = PacCrest-GMSK FEC On Scrambler Off	
Radio Property	SL&P?	Get TX/RX priority.	1 = TX priority 2 = RX priority
Radio Property	SL&P=n	Set TX/RX priority. Value of n: 1 = TX priority 2 = RX priority	OK or ERROR
Reset	SL@X=n	Reset command. Values of n are: "9" Reset modem	"OK" or "ERROR", then modem resets required blocks.
Test	SL+P=xxx	Get measured signal strength from remote modem i.e. SL "ping" Value of xxx [0000...ffff] defines address of remote modem	"OK" followed by RSSI info from remote modem
Operational mode	SL++?	Get status of transmission control	"0" = Transmission enabled or "1" = Transmission disabled
Operational mode	SL+++	Disable radio transmission / reception	"OK" or "ERROR"
Operational mode	SL++O	Enable radio transmission / reception	"OK" or "ERROR"
Operational mode	SL%N=1	Set enabled radio states Tx/Rx	"OK" or "ERROR"
Operational mode	SL%N=0	Set enabled radio states Rx only	"OK" or "ERROR"
Operational mode	SL%N?	Get enabled radio states	0 (=Tx/Rx) or 1 (=Rx only)
Operation mode	SL+S=x	Activate sleep mode "1" turn the modem into a state where it will hold serial interface parts of the module on, wakeup will take approx. 30ms "5" Turns ON Power save mode. "6" Turns OFF Power save mode.	"OK" or "ERROR"
Operation mode	SL%Z=0	SL commands are OFF (working then only in the command mode) and CR/LF feature OFF	"OK" or "ERROR"
Operation mode	SL%Z=1	SL commands are always ON and CR/LF feature OFF	"OK" or "ERROR"

Operation mode	SL%Z=3	SL commands are always ON and CR/LF feature ON	"OK" or "ERROR"
Operation mode	SL%Z=4	SL commands are OFF (working then only in the command mode and CR/LF feature ON	"OK" or "ERROR"
Operation mode	SL%Z?	Get SL command mode	Responds with a number accordingly

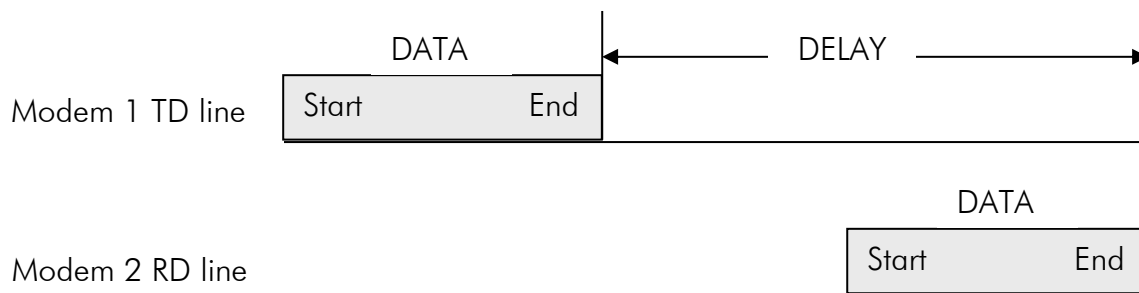
11.1.1 Encryption commands

Command	Effect and description of command
SL%Y=n	Set Encryption mode. Value of n: 0=OFF, 1=ON
SL%Y?	Get Encryption mode. Response: 0=OFF, 1=ON
SL%K?	Get Key hash. Response is to be used for the key match check
SL%A?	Get Key hash. Response is the same for SL%K? and SL%A?
SL%A?=<Main key>	Set Main key. 32 characters [1..9, A..F, a..f]
SL%A=<AUX key>	Set AUX key. 32 characters [1..9, A..F, a..f]

11.2 Transmission delays

The tables on the next page present the transmission delays vs. the size of the message to be transmitted. The values are in 10% margin.

The delays are measured from the end of transmission to the end of reception on the serial interface as shown below.



SATELLINE-3AS mode (FEC OFF) on 12.5 kHz channel - Transfer delays				
Bps	1 byte	10 bytes	100 bytes	500 bytes
1200	40 ms	40 ms	29 ms	22 ms
4800	34 ms	34 ms	31 ms	22 ms
9600	32 ms	32 ms	32 ms	27 ms
19200	32 ms	35 ms	64 ms	193 ms
38400	32 ms	36 ms	91 ms	352 ms

SATELLINE-3AS mode (FEC ON) on 12.5 kHz channel - Transfer delays				
Bps	1 byte	10 bytes	100 bytes	500 bytes
1200	52 ms	49 ms	48 ms	50 ms
4800	45 ms	45 ms	44 ms	44 ms
9600	44 ms	44 ms	68 ms	121 ms
19200	44 ms	44 ms	104 ms	360 ms
38400	48 ms	48 ms	132 ms	496 ms

SATELLINE-3AS mode (FEC OFF) on 25 kHz channel - Transfer delays				
Bps	1 byte	10 bytes	100 bytes	500 bytes
1200	30 ms	30 ms	18 ms	16 ms
4800	23 ms	23 ms	21 ms	12 ms
9600	23 ms	23 ms	21 ms	17 ms
19200	22 ms	22 ms	22 ms	19 ms
38400	22 ms	22 ms	38 ms	102 ms

SATELLINE-3AS mode (FEC ON) on 25 kHz channel - Transfer delays				
Bps	1 byte	10 bytes	100 bytes	500 bytes
1200	35 ms	34 ms	29 ms	30 ms
4800	28 ms	28ms	27 ms	23 ms
9600	28 ms	28 ms	28 ms	23 ms
19200	28 ms	28 ms	36 ms	64 ms
38400	27 ms	27 ms	58 ms	185 ms

In the PacCrest-4FSK, PacCrest-GMSK and Trimtalk450s modes the whole message is first read from the serial port. The end of the message is detected when there is a pause in data. After that data is framed and transmitted over the radio. Likewise the reception is done fully before outputting the message to the serial port.

Symbol rates of the compatibility modes		
The actual raw data rate is appr. 2/3 of the symbol rate.		
Compatibility mode	Symbol rate on 12.5 kHz channel	Symbol rate on 25 kHz channel
PacCrest 4FSK	9600 bps	19200 bps
PacCrest GMSK	4800 bps	9600 bps
Trimtalk450s	4800 bps	9600 bps
PacCrest FST	9600 bps	19200 bps

The typical latency vs. the size of a message is shown in the tables below for each radio compatibility mode. The delays are measured from the end of transmitted data to the end of received data on the serial interface.

Pacific Crest 4FSK mode on 12.5 kHz channel - Transfer delays				
Bps	1 byte	10 bytes	100 bytes	500 bytes
9600	74 ms	82 ms	302 ms	1293 ms
19200	73 ms	77 ms	249 ms	1031 ms
38400	72 ms	74 ms	222 ms	900 ms

Pacific Crest 4FSK mode on 25 kHz channel - Transfer delays				
Bps	1 byte	10 bytes	100 bytes	500 bytes
9600	43 ms	51 ms	208 ms	911 ms
19200	41 ms	46 ms	155 ms	650 ms
38400	39 ms	43 ms	127 ms	519 ms

Pacific Crest GMSK mode on 12.5 kHz channel - Transfer delays				
Bps	1 byte	10 bytes	100 bytes	500 bytes
9600	93 ms	101 ms	445 ms	2011 ms
19200	91 ms	97 ms	393 ms	1750 ms
38400	91 ms	92 ms	366 ms	1619 ms

Pacific Crest GMSK mode on 25 kHz channel - Transfer delays				
Bps	1 byte	10 bytes	100 bytes	500 bytes
9600	52 ms	62 ms	281 ms	1272 ms
19200	50 ms	55 ms	226 ms	1009 ms
38400	48 ms	51 ms	198 ms	878 ms

Trimtalk450s modes on 12.5 kHz channel - Transfer delays				
Bps	1 byte	10 bytes	100 bytes	500 bytes
9600	153 ms	177 ms	421 ms	1505 ms
19200	151 ms	172 ms	368 ms	1244 ms
38400	151 ms	168 ms	341 ms	1113 ms

Trimtalk450s modes on 25 kHz channel - Transfer delays				
Bps	1 byte	10 bytes	100 bytes	500 bytes
9600	82 ms	98 ms	267 ms	1017 ms
19200	80 ms	93 ms	215 ms	756 ms
38400	79 ms	89 ms	187 ms	625 ms

Radio compatibility Option 5 - Pacific Crest FST on 12.5 kHz channel				
Bps	1 byte	10 bytes	100 bytes	500 bytes
9600	47 ms	71 ms	261 ms	1145 ms
19200	45 ms	64 ms	207 ms	883 ms
38400	48 ms	65 ms	184 ms	756 ms

Radio compatibility Option 5 - Pacific Crest FST on 25 kHz channel				
Bps	1 byte	10 bytes	100 bytes	500 bytes
9600	31 ms	48 ms	190 ms	840 ms
19200	29 ms	41 ms	136 ms	578 ms
38400	28 ms	38 ms	109 ms	447 ms

12 VERSION HISTORY

Version history:

Version:	Date:	Remarks:
0.1	15.05.2013	First Draft.
0.2	27.5.2013	Modified by ML
0.2	30.5.2013	Reviewed by R&D
0.3	3.6.2013	Modified by ML
0.3	11.6.2013	Reviewed by JPu
0.4	12.6.2013	New draft version 0.4 by ML
0.4	17.06.2013	Reviewed by R&D
0.4	17.06.2013	Modified by ML
0.4	18.06.2013	Reviewed by R&D
0.5	18.06.2013	Modified by KSu
0.6	19.06.2013	Modified by ML
0.7	23.08.2013	Updated information in the table in paragraph 1.4 and specification tables, updated SL command response for SL!H? command.
1.0	03.10.2013	Added Power save mode description, updated Timing parameters table (in chapter 5). General modifications.
1.1	01.11.2013	Added RF Exposure warning and host device labeling requirements.
1.2	09.01.2014	Modified RF Exposure warning
1.3	14.05.2014	Measurement image updated
1.5	07.05.2015	Output power corrected, DoC added
1.6	22.05.2015	Added TR4 information
1.7	29.10.2015	Chapter 6.2 table corrected
1.9	13.07.2016	Added DoC and SL-commands
2.0	13.04.2017	Added Chapter 9 PROPOSALS FOR MORE RELIABLE RADIO LINK
2.1	20.04.2017	Chapter 3.2 modified
2.2	12.07.2017	Chapter 3.2 modified
2.3	19.04.2018	Restrictions on use (page 2), Product conformity (page 3) and chapter 6 Data Speed of Radio Interface modified
2.4	25.04.2019	Added information regarding 20 kHz channel spacing
2.5	08.05.2019	Corrected the download link to SATEL Configuration Manager
2.6	18.06.2019	Added Anatel, BR certification number
2.9	1.11.2019	Multiple major modifications