SATEL

Mission-Critical Connectivity

SATELLINE-M3-TR9
TRANSCEIVER MODULE

SATELLINE-M3-R9
RECEIVER MODULE

INTEGRATION GUIDE

Version 2.3

IMPORTANT NOTICE

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Salo, FINLAND 2024

RESTRICTIONS ON USE – SATELLINE-M3-TR9

SATELLINE-M3-TR9 radio transceiver module has been designed to operate on 902-928 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-TR9 is allowed to be used in the following countries. More detailed information is available at the local frequency management authority.

Countries: AU, BR, CA, NZ and US.
USA and Canada 902 – 928 MHz. In Australia, New Zeeland and Brazil frequency range is limited to 915 – 928 MHz due to local regulations.

WARNING - RF Exposure
To satisfy FCC and ISED RF exposure requirements for mobile transmitting devices, a separation distance of 25 cm or more should be maintained between antenna of this device and persons during device operation. To ensure compliance, operations at closer than this distance is not recommended. The antenna used for this transmitter must not be co-located in conjunction with any other antenna or transmitter. FCC regulations allow up to 36 dBm equivalent isotropically radiated power (EIRP). Therefore, the sum of the transmitted power (in dBm), the cabling loss and the antenna gain cannot exceed 36 dBm.

This radio transmitter 2422A-SATELTA31 has been approved by Industry Canada to operate with the antenna types listed below with the maximum permissible gain indicated. Antenna types not included in this list, having a gain greater than the maximum gain indicated for that type, are strictly prohibited for use with this device.

Antenna type	Manufacturer	Antenna model	Maximum gain (dBi)
Omnidirectional	Oy CompleTech Ltd	CA915H	5
Directional (yagi)	Oy CompleTech Ltd	CA930Y	6

NOTE!
According to the requirements of the FCC, the integrator should make sure that the SATELLINE-M3-TR9 is compliant to part 15C while integrated in the host device. Output power and spurious emissions should be verified.

PRODUCT CONFORMITY

This device complies with Industry Canada licence-exempt RSS standard(s) and part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device. Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes : (1) l'appareil ne doit pas produire de brouillage, et (2) l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

Modelo: SATELLINE-M3-TR9

04409-19-01451

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

Este equipamento não tem direito à proteção contra interferência prejudicial e não pode causar interferência em sistemas devidamente autorizados.

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.

HOST INTEGRATION

To ensure compliance with all non-transmitter functions the host manufacturer is responsible for ensuring compliance with the module(s) installed and fully operational. For example, if a host was previously authorized as an unintentional radiator under the Declaration of Conformity procedure without a transmitter certified module and a module is added, the host manufacturer is responsible for ensuring that after the module is installed and operational the host continues to be compliant with the Part 15B unintentional radiator requirements. This module is certified for Fixed and Mobile Applications only, for portable applications you will require a new certification.

This device has been modularly approved. Model name, FCC and Industry Canada identifiers of this product must appear on the outside label of the end-user equipment.

Host labelling example:

Model Name:	SATEL-TA31
Contains	FCC ID: MRBSATEL-TA31
	IC: 2422A-SATELTA31

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

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1. INTRODUCTION

SATEL – the world's leading expert and innovator in wireless networking technology. We design, manufacture and offer high quality connectivity solutions that enable secure, mission-critical connections, utilizing the best characteristics of each technology for real-life use-cases.

This document is the integration guide for the SATELLINE-M3-TR9 radio transceiver and -R9 radio receiver modules. It is intended to describe how to use the module and how to integrate it 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
CPU	Central processing unit

1.2 Description of the product

The SATELLINE-M3-TR9 is UHF radio transceiver module, which transmit and receive data from the UHF frequency band. The modules are designed to be as compact and power efficient as possible. The modules have been developed to be especially suitable for integration into battery powered and space constrained host applications benefiting from UHF communications.

The module transmits and receives data via the Air interface, 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 and communicate with the module.

2. TECHNICAL SPECIFICATIONS

2.1 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 V	+6V
Voltage at ENA_MOD	0 V	+6 V
Voltage at VCC_IO	0 V	3.75 V
Voltage at digital inputs (except ENA_MOD)	0 V	3.75 V
Voltage at digital outputs	0 V	3.75 V

Note. All voltages are referenced to GND.

2.2 DC electrical specifications

Recommended operating conditions:

Parameter	Condition	Min	Max	Units
VCC_IN		3.5	5.5	V
ENA_MOD, Vlow		0	0.2	V
ENA_MOD, Vhigh		1.2	VCC_IN	V
VCC_IO		1.8	3.3	V
Logic input, Vlow	1.8 V<VCC_IO<3.3V	0	0.3V	V
Logic input, Vhigh	1.8 V<VCC_IO<3.3V	0.9 VCC_IO	VCCIO	V
Logic output, Vlow	1.8 V<VCC_IO<3.3V	0	0.5	V
Logic output, Vhigh	1.8 V<VCC_IO<3.3V	0.6 VCC_IO	VCCIO	V
Logic output, max current	All logic output except STAT pin.	-	4	mA
Logic output, max current, STAT pin		-	12	mA

2.3 Specifications, SATELLINE-M3-TR9

Receiver part specifications applies to SATELLINE-M3-R9 receiver module.
SATELLINE-M3-TR9 complies with the following international standards:
FCC Parts 15.209 and 15.247 of Title 47
IC RSS-247, ICC RSS-Gen
AS/NZS 4268:2012, AS/NZS 4771:2000

	RECEIVER	TRANSMITTER	Note!
Frequency Range	902-928 MHz		
Spreading Method	Frequency Hopping		
Occupied Bandwidth	230 kHz		
Frequency Stability	<1 kHz		
Maximum Receiver Input Power without Damage	-3 dBm		
Maximum Receiver Input Power without Transmission Errors	-3 dBm		
Sensitivity	typ. -109 dBm for BER 10^{-4}		
Blocking	TBD		
Intermodulation Attenuation	TBD		
Adjacent Channel Selectivity	TBD		
Transmitter Power		10, 20, 50, 100, 200, 500, 1000 mW	
Carrier power stability		< ±1.5 dB	
Data Rate	115.2 kbit/s		
Modulation Method	2-GFSK		
Hopping Bands	7, user selectable		
Hopping Patterns	15 per band, 105 total, user selectable		
Hopping Channels	50-112, user selectable		
Frequency Zones	16 Zones, 7 Channels per Zone		
Temperature Ranges	-40 °C …+70 °C		Functional
	-40 °C …+80 °C		Storage
Operating Voltage	3.5-5.5 VDC		
Power Consumption	300 mW (Receive mode) 3.2 W (Transmit Mode 1 W)		
Vibration	≤ 25g		10 Hz≤$f_{vibration}$≤2,0 kHz
ESD[4]	± 10 kV		Antenna connector. Acc. to EN61000-4-2; 150pF/330Ω

	± 8 kV	DTE connector. Acc. to EN61000-4-2; 150pF/330Ω
Antenna Connector	50 Ω, 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	20 g	
Electrical Interface	CMOS-UART 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	
Data speed of Serial interface	9600 – 115200 bps	

[4] Measured under normal ambient conditions, T_A = 25 °C. When the device is used in different environment, the results may change significantly. It is recommended to use external ESD protection in demanding conditions.

3. TIME PARAMETERS FOR STARTUP AND SHUTDOWN SEQUENCES

The following table shows the recommend times for startup and shutdown sequences.

Parameter	Recom. Time (*	Explanation
$t_{vccin-ena}$	>2 ms	VCC_IN must be high before ENA_MOD is high
$t_{enamod-io}$	>2 ms	ENA_MOD must be high before VCC_IO is high
$t_{enamod-cts}$	100 ms<$t_{enamod-cts}$ < 500 ms	CTS ready settling time
$t_{vccio-cts}$	>2 ms	VCC_IO must be high before CTS is ready
$t_{vccio-gpio}$	>2 ms	VCC_IO must be high before GPIO PINS are active
$t_{gpio-cts}$	>0 ms	GPIOS must be active before CTS is ready
$t_{enamod-gpio}$	>80 ms	Input pins must be low after ENA MOD is low
$t_{gpio-vccio}$	>0 ms	GPIOs must be low before VCC_IO is low
$t_{vccio-vccin}$	>0 ms	VCC_IO must be low before VCC is low

3.1 Startup sequence

The following diagram will describe the startup sequence.

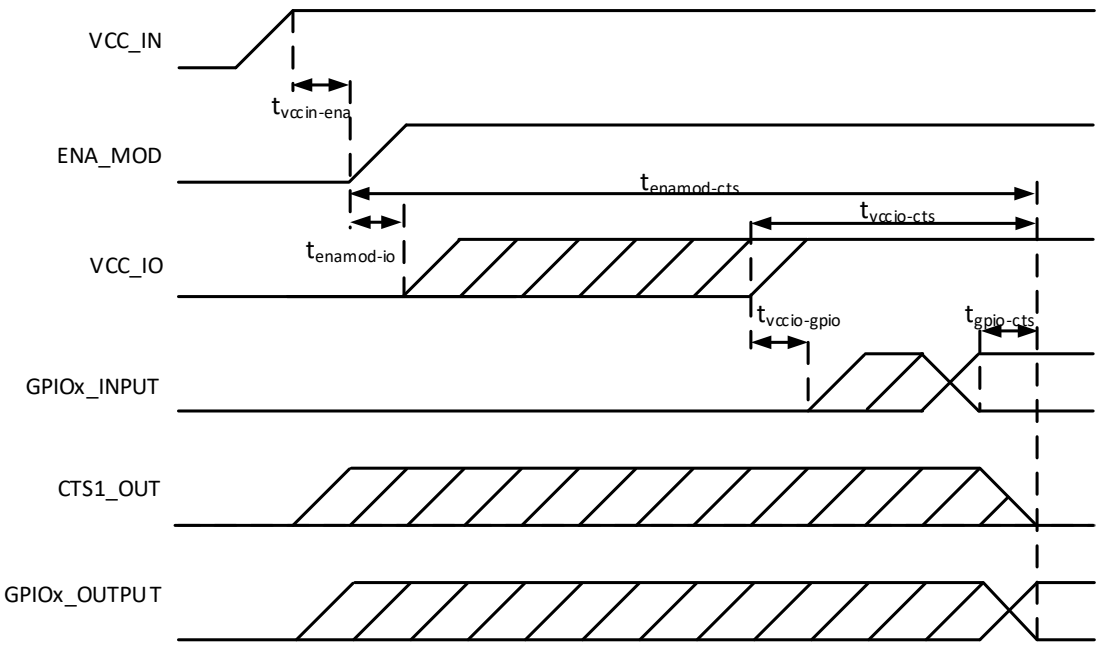

Figure 3.1 Startup sequence.

3.2 Shutdown and ENA sequences

The following diagrams will describe the shutdown and ENA sequences.

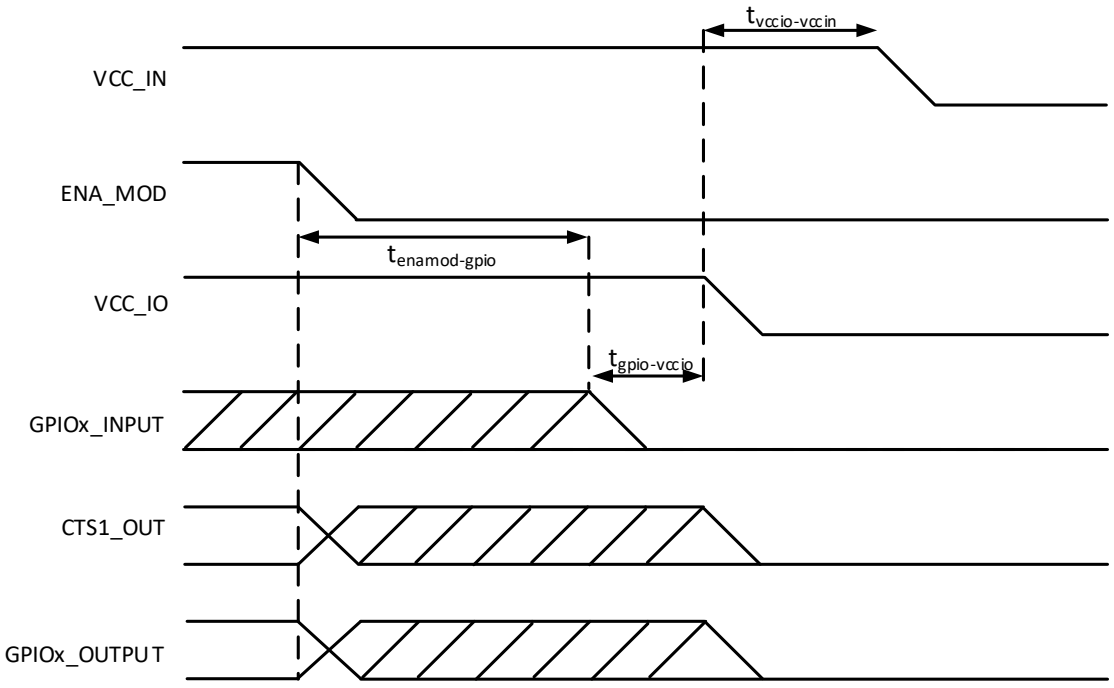

Figure 3.2 Shutdown sequence.

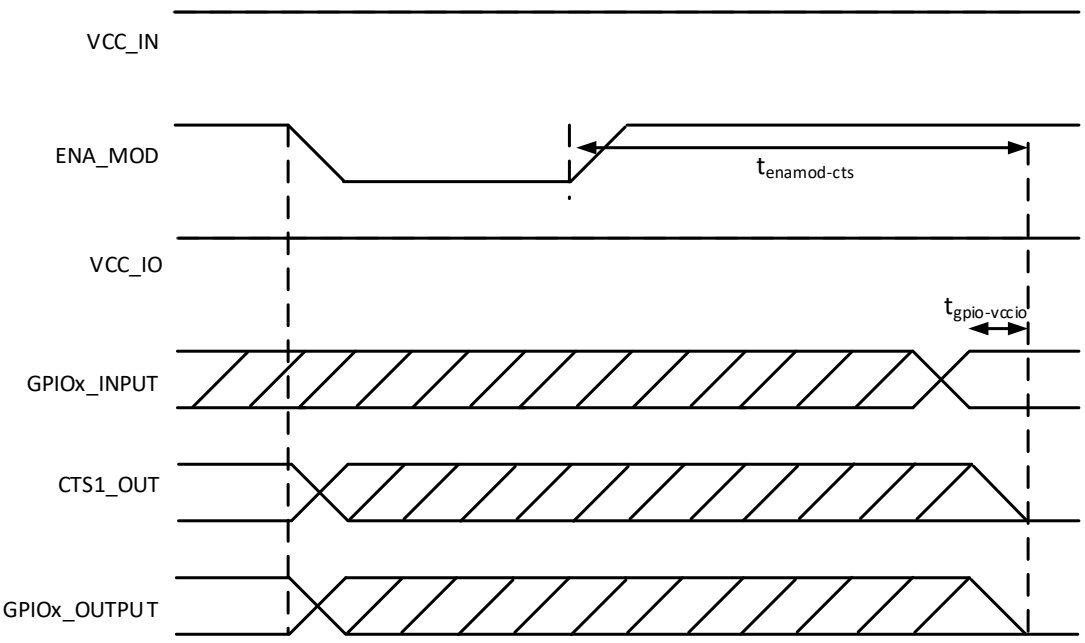

Figure 3.3 ENA sequence.

4. ELECTRICAL INTERCONNECTION

4.1 DTE connector

The DTE connector is a 20-pin pass-through connector which provides electrical connections to the module. Connector is female two row 1.27 mm pitch.

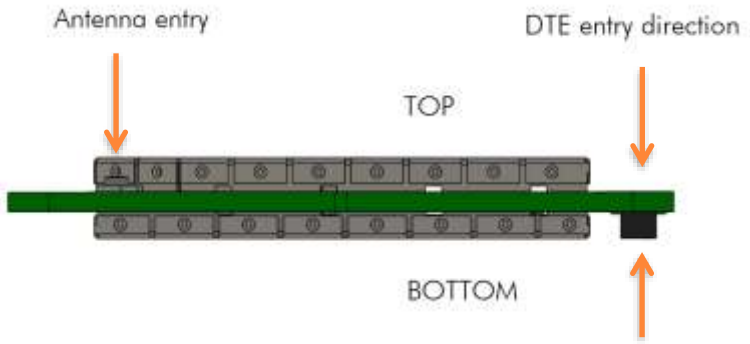

Figure 4.1 The side view of the module with connection directions.

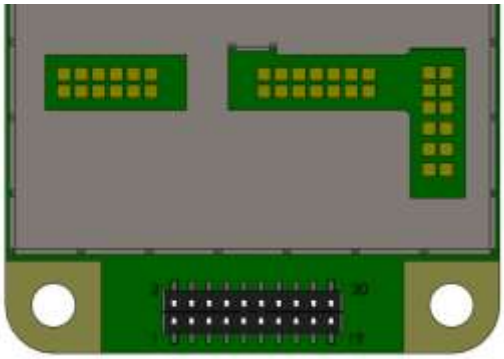

Figure 4.2 Pin numbering of 1.27 mm pitch DTE connector. View from bottom side of unit.

4.2 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.

The equivalent I/O schematic figures are shown in the next chapter.

Pin no.	Equivalent I/O schematic	Signal name	Type	Direction	Pin state	Description
1,2	Figure 1	VCC_IN	POWER	IN	External Voltage	DC input
3,4	-	GND	GND	-	External Ground	Ground reference for power and signals
5	Figure 2	VCC_IO	POWER	IN	External Voltage	Device IO driver input
6	Figure 7	ENA_MOD	IO	IN	Internal Pull Down	Module ENA pin
7	Figure 3	RD1	CMOS	OUT	Output Driver	Receive data, active low.
8	Figure 3	CTS1	CMOS	OUT	Output Driver	Clear To Send, active low.
9	Figure 6	TD1	CMOS	IN	Internal Pull Up	Transmit Data, active low.
10	Figure 6	RTS1	CMOS	IN	Internal Pull Up	Ready to send, active low.
11	Figure 4	GPIO1	CMOS	OUT	Internal Pull Down	*)
12	Figure 4	GPIO2	CMOS	OUT	Internal Pull Down	*)
13	Figure 6	GPIO3	CMOS	IN	Internal Pull Up	*)
14	Figure 6	GPIO4	CMOS	IN	Internal Pull Up	*)
15	Figure 5	STAT	CMOS	OUT	Output Driver	Various sequences (section 4.6).
16	Figure 6	GPIO5	CMOS	IN	Internal Pull Up	*)
17	Figure 6	$\overline{\text{SERVICE}}$	CMOS	IN	Internal Pull Up	Input for service access, active low. See separate section of the manual (section 4.5).
18	Figure 4	GPIO6	CMOS	OUT	Internal Pull Down	*)
19	Figure 4	GPIO7	CMOS	OUT	Internal Pull Down	*)
20	Figure 4	GPIO8	CMOS	OUT	Internal Pull Down	Reserved for future use.
*) See separate document: TIL-0026_SATEL-Radio-Modules_GPIO-Interface.pdf						

4.3 Equivalent I/O Schematics

The module input-output equivalent circuits are shown in the figure and the component values in the table below.

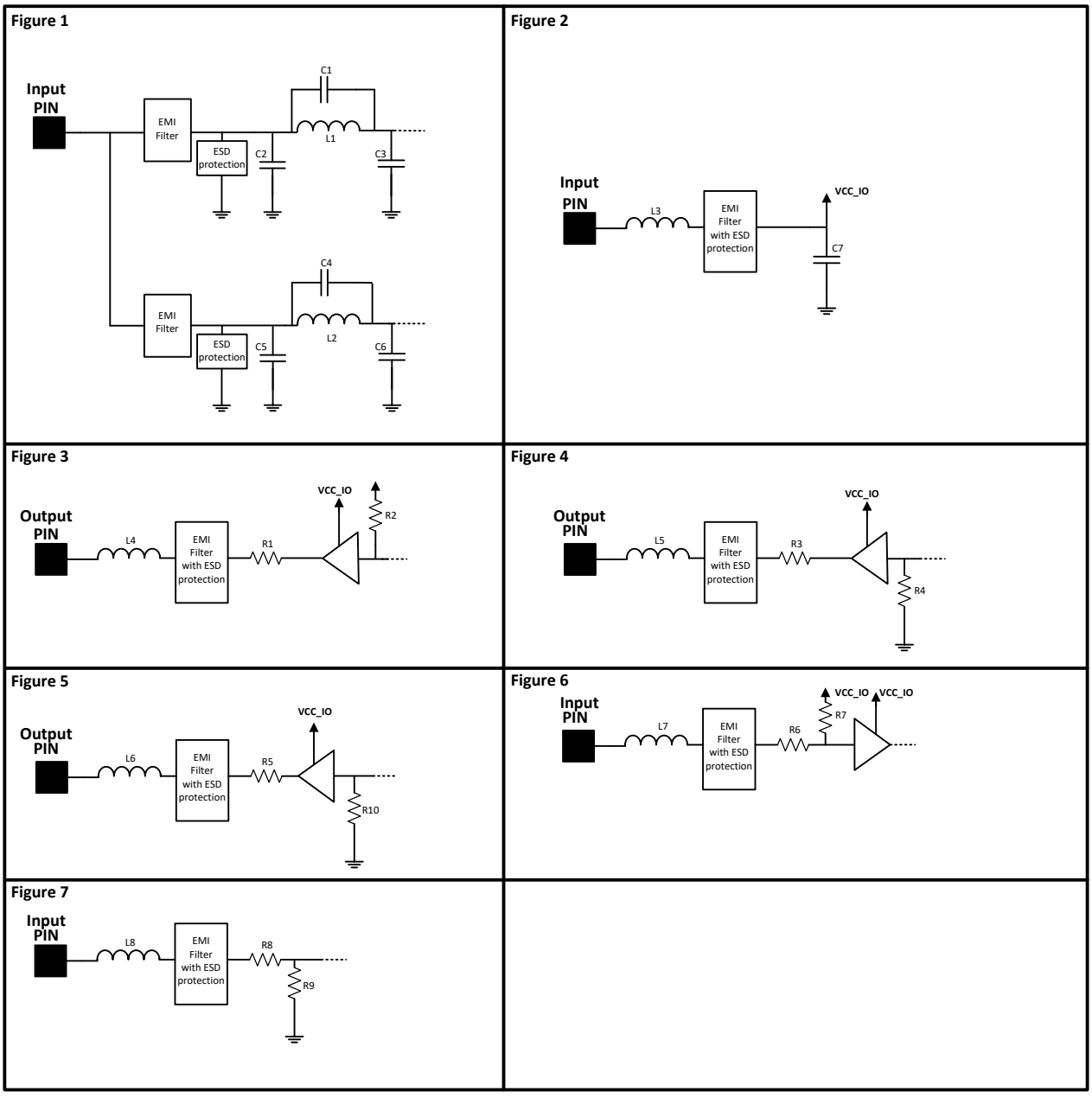

Figure 4.3 The module input-output equivalent circuits.

Component values of the equivalent schematics:

Component	Value	Note
C1	10 nF	
C2	1 nF	
C3	30 uF	
L1	2.2 uH	
C4	10 nF	
C5	1 nF	
C6	44 uF	
L2	15 uH	
L3	1000 Ω +- 25%	Measured Impedance at 100 MHz
C7	100 nF	
L4	1000 Ω +- 25%	Measured Impedance at 100 MHz
R1	330 Ω	
R2	100 kΩ	
L5	1000 Ω +- 25%	Measured Impedance at 100 MHz
R3	330 Ω	
R4	100 kΩ	
L6	1000 Ω +- 25%	Measured Impedance at 100 MHz
R5	330 Ω	
L7	1000 Ω +- 25%	Measured Impedance at 100 MHz
R6	330 Ω	
R7	100 kΩ	
L8	1000 Ω +- 25%	Measured Impedance at 100 MHz
R8	1 kΩ	
R9	>1 MΩ	
R10	100 kΩ	

4.4 VCC_IO pin

VCC_IO pin determines the voltage level of UART signals and the voltage level of GPIO output signals. VCC_IO level also determines GPIO LOW/HIGH levels on each GPIO and UART input pins.

4.5 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, 8, N, 1. This is intended for service access of the module, to have a known serial port setting in order to provide easy access to module settings.

The pin does not affect any permanent settings, nor does it change the mode of the module. It is recommended to pull high or pull up by resistor to VCC_IO to return serial port 1 into the configured state. When service pin is LOW the SL Commands are temporary forced to be ON

4.6 Stat pin

The STAT-pin indicates the status of the device. It can be used to drive or sink a LED current using a proper series resistor. STAT-pin drive or sink capability is +/-10mA at 3.3 V. It is recommended to use VCC_IO for LED current.

Notice that if STAT-pin is used to sink LED current, LED behavior is opposite to driving scheme. The behavior of the STAT pin is described down below.

Modes of STAT pin:

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 1 s interval	Module has the connection to Configuration Manager program.
Pin is toggled in 500 ms interval	SL command mode set to **OFF** and SL commands enabled using "+ + +" sequence, section 7.2.
Pin is toggled in 250 ms interval	Module has detected a fault, fault codes can be read via Configuration Manager program.

4.7 VCC pins

VCC pins are to feed operating voltage to the module. Limit for this voltage is mentioned in chapter 2.2 DC electrical specifications. User must take into consideration surge current and current consumption issues before using these pins. Also, the user must be aware for any voltage drop on the feeding path.

4.8 UART pins

Pins 7, 8, 9, 10 are used for UART serial transmission between the module and the terminal. The UART signal level corresponds to the level in VCC_IO pin. VCC_IO pin must be fed with a correct voltage level to match the terminal device.

4.9 GPIO pins

See separate document: TIL-0026_SATEL-Radio-Modules_GPIO-Interface.pdf
Unused pins should be left unconnected.

4.10 Antenna 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.

5. MECHANICAL CONSIDERATIONS

5.1 Fixing device to host

The radio module can be mounted on to the host application by using spacers and screws. It is highly recommended to use conducting metal spacers and screws to create proper electrical conductivity between the module and the host application. Recommended materials for spacers include brass or aluminum and steel screws. User must take care that there is no excessive mechanical stress created to the DTE connector while inserting and attaching the module. Recommended maximum screw size is M3 for the PCB, minimum spacer height between the module and the host application is 3 mm. Please contact SATEL or local SATEL distributor for heat sink piece models availability.

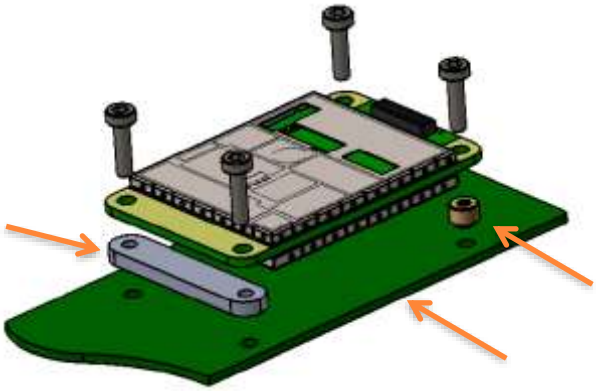

Figure 5.1 Example of module attachment to application PCB.

Since the module creates heat while operating, it must take into consideration to maximize the heat transfer from the module to an external heat sink. Proper heat sinking methods could be copper plated PCB, metal housing or a heat sink piece. The most recommended solution is to use a metal conductor to transfer heat from the module to an external heat sink which dimensions and location is adequate for a proper performance. To source the heat from the module is the plain area next to the antenna connector shown in a figure 5.2. Heat can be conducted from either side. To further improve the heat conductivity and reducing the heat transfer barriers, proper heat conducting paste or heat conducting tape should be used. For any additional information please contact SATEL or local SATEL distributor.

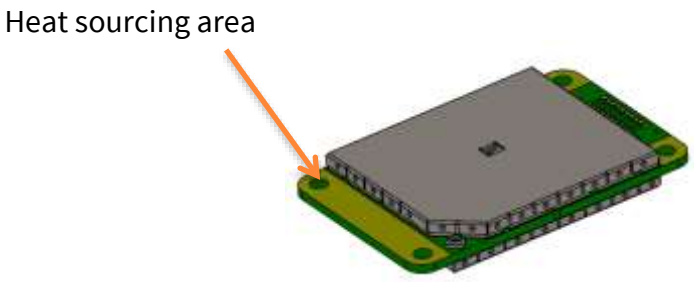

Figure 5.2 Heat sourcing area, both sides.

5.2 Module dimensions

In figure below is a module with dimensions as millimeters.

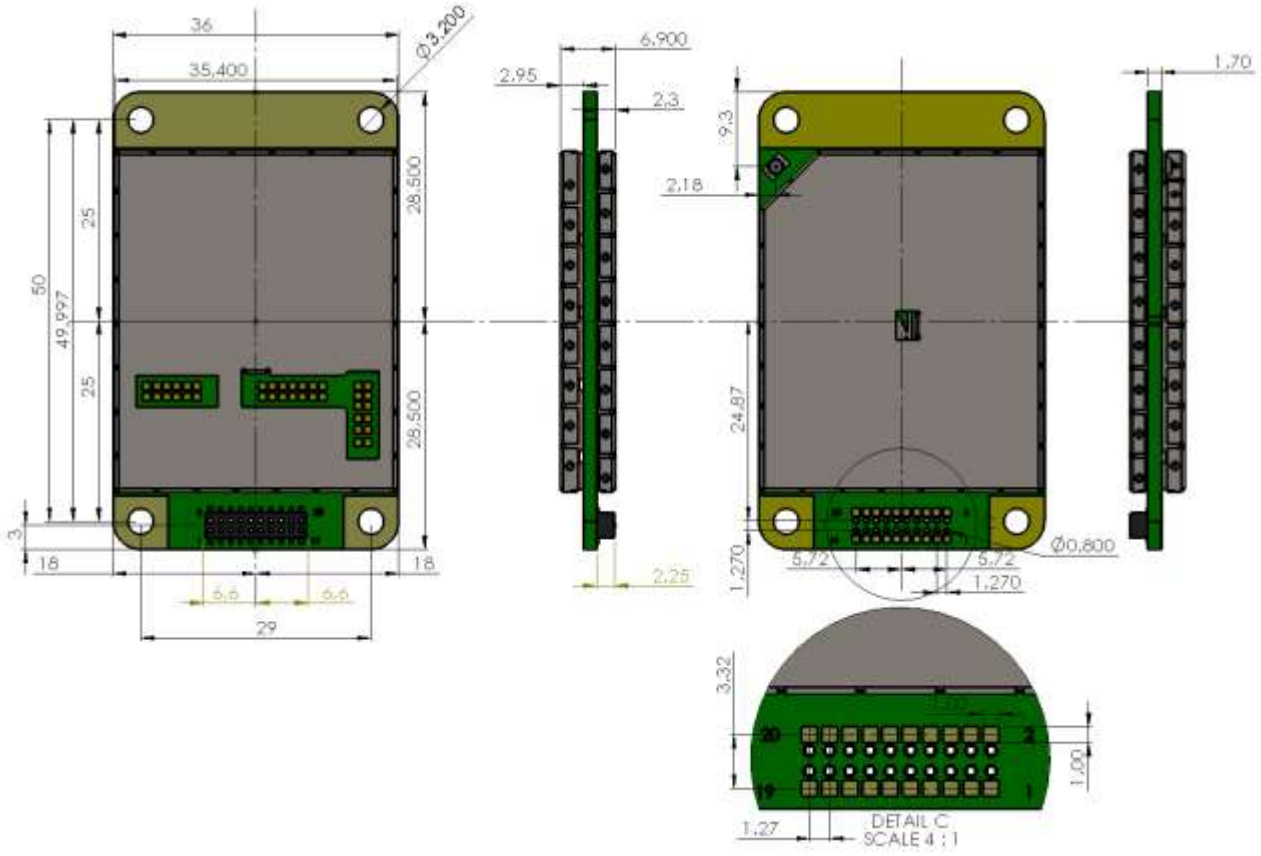

Figure 5.3 The module physical dimensions and the holes in millimeters**.**

6. CONFIGURATION

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

SATEL SW tools
Easy-to-use SATEL software tools suit most cases. Please see additional information in next chapters.

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.

6.1 SATEL NETCO DEVICE

SATEL NETCO DEVICE is a software for configuring and reprogramming a SATEL device. The configuration parameters can be read and written from/to the locally connected, powered device. The device configuration can be also created/saved/explored from/to a file without device connection.

The most common use case for which the SATEL NETCO DEVICE is optimized for is editing existing parameters in a SATEL radio product using local connection, such as serial interface.

Please see additional information from SATEL WEB pages at:
https://www.satel.com/products/software/
The software is available from SATEL WEB pages at: https://www.satel.com/support-and-services/downloads/

6.2 SATEL Configuration Manager software

SATEL Configuration Manager is a software for configuring and reprogramming a SATEL device. The parameters can be read and written from/to the connected, powered device. The program file can be saved into a separate file to be used to other devices.

The most common use case for which the SATEL Configuration Manager is optimized for is editing existing parameters in a SATEL radio product using locally connected product over a serial interface. Minimum requirements: COM port with baud rate min. 9600 bps (alternatively with industrial level USB-RS-232 converter).

Please see additional information from SATEL WEB pages at:
https://www.satel.com/products/software/

The software is available from SATEL WEB pages at: https://www.satel.com/support-and-services/downloads/

6.3 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.

6.3.1 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). Pause according to set Pause Length -parameter is required also in this case. 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. SL command response time depends of the used command. Typical response time is ~100ms and upwards. Recommended safe timeout for SL command response is 500ms.

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.

See Appendix C for SL commands. To get information of the latest and/or special SL commands please contact SATEL or local SATEL distributor: https://www.satel.com/where-to-buy/.

6.3.2 SL Command Mode

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 of 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 SATEL SW tools, SATEL NETCO DEVICE or SATEL Configuration Manager (maintenance access level required).

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 the original SL command –setting state, changing the setting state with this procedure will affect the reception process of the radio module.

Radio can be set to *Command Mode* separately with "+++" command, regardless of the set SL command mode (ON/OFF). *Command mode* enables forcibly the SL command mode and disables the radio interface functions (Tx/Rx). By exiting from the Command Mode, user defined SL command parameter mode is restored, as well as radio interface functions.

To enable the *Command mode*:

- Send three "**+**" characters via serial port so that there is at least three bytes delay (according to Pause Length -setting) between each character. The response is **"OK"**, when successfully set.
  <**+**><*at least three bytes pause**><**+**><*at least three bytes pause**><**+**>

To disable the *Command mode*:

- Send three "**-**" characters via serial port so that there is at least three bytes delay (according to Pause Length -setting) between each character. The response is **"OK"**, when successfully set.
  <**-**><*at least three bytes pause**><**-**><*at least three bytes pause**><**-**>

**Pause Length -setting*

Note!
The "+ + +" and "- - -" procedures are not recommended to be used when radio is transmitting or receiving data (i.e., the application data occupies the TD or RD lines of the radio).
Note2!
900MHz frequency band (TR9/R9) parameters set via SL commands require device restart for the new parameters to be taken into use. The device reset is performed during exiting the command mode (---).

7. 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 (section 6.1).
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%.

Receiver parts applies to SATELLINE-M3-R9 receiver module.

7.1 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 250 ms interval indicating an Error and reboots the device after 5 s. 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 https://www.satel.com/support-and-services/downloads/.

7.2 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 is set to HIGH.

The module can be shut down by driving ENA_MOD line to LOW state. In the "OFF" state current consumption is only that of leakage current from an LDO, section 2.3. In this state all non-essential parts off the module are powered down and all settings/state information that are not stored in nonvolatile memory are reset.

7.3 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 µs) 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.

7.4 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.

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

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

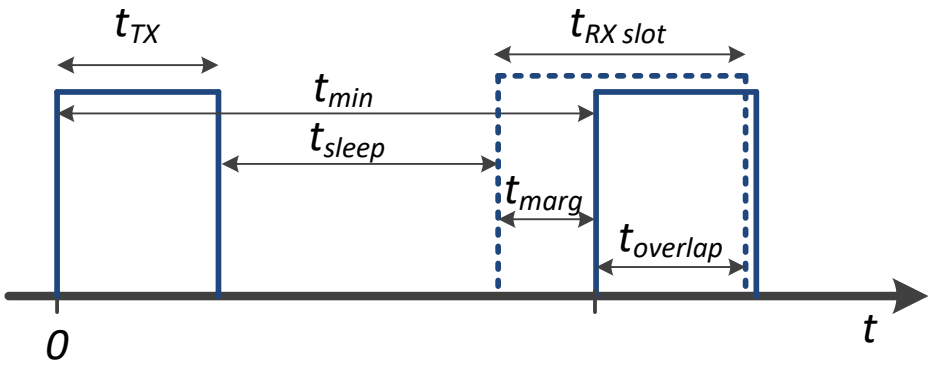

Figure 7.1 Power save mode timing factors.

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

$t_{min} = 1000\ ms$
$t_{TX} = 300\ ms$
$t_{marg} = 125\ ms + 60\ ms = 185\ ms$

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

$t_{RX\ slot,\ min} = 1000\ ms - 185\ ms = 815\ ms$
$t_{RX\ slot,\ max} = 1000\ ms + 285\ ms = 1285\ ms$

7.5 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 command list).

8. DEFAULT DELIVERY VALUES – SATELLINE-M3-TR9

Receiver parts applies to SATELLINE-M3-R9 receiver module, forced permanently to Point to Multipoint Slave (RX Only) mode (cannot be changed).

Operation Mode	**Default value**
Point-to-Multipoint Slave	3
Set Baud Rate	
Baud Rate	115200
Data Parity	0
Modbus RTU	0
RS232/485	0
Setup Port	3
TurnOffDelay/OnDelay	0/0
FlowControl	0
Radio Parameters	
FreqKey	5
Hop Table Version	0
Hop Table Size	112
Hop Freq Offset	0
Frequency Zone	All 1s (Enabled)
Max Packet Size	8
Min Packet Size	9
Xmit Rate	1
RF Date Rate	3
RF Xmit Power	1000
Slave Security	0
RTS to CTS	0
Retry Timeout	255
Low Power Mode	0
High Noise	0
MCU Speed	0
Remote LED	0
Multipoint Parameters	
Number of Repeaters	1
Master Packet Repeat	3
Max Slave Retry	9
Retry Odds	9
DTR Connect	0
Repeater Frequency	0
Network ID	255
Multimaster Sync	0
Slave/Repeater	0
Subnet ID	“Disabled”

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. -107 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 higher than -117 dBm (-107 dBm-10 dB), causes desensitization of the radio on that particular channel.

Example:
An interferer has a level of -100 dBm at the frequency 902 MHz. The radio will show an approximate sensitivity of -90 dB (-100 dBm + S/N requirement 10 dB) at 902 MHz.

Now consider that generic EMC requirements usually have pass/fail criteria of -57 dBm (if normalized to the surface of the device). **So there is almost a 60 dB 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.

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.

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 cannot be read back or reloaded, without interrupting reception. Hence the module cannot 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. APPENDIX C

10.1 SL COMMANDS – SATELLINE-M3-TR9/R9, Freewave

Receiver parts applies to SATELLINE-M3-R9 receiver module, forced permanently to Point to Multipoint Slave (RX Only) mode (can't be changed).

				General format of the Freewave related SL commands is: Set Emulation mode settings: SL~E=M1,I<index>,A<Attribute1>,B<Attribute2>,C<Attribute3>,... prefix M indicates the emulation mode (M1 means Freewave, M2 means something else...) prefix I is the index indicating the specific setting under the emulation mode prefixes A, B, C, ... indicate the corresponding attributes Get Emulation setting: SL~E?M1,I<index> Format of response is M1,I<index>,A<Attribute1>,B<Attribute2>,C<Attribute3>,... Get Emulation settings summary: SL~E? Response is reserved for the summary of the emulation settings (to be defined later)
Setting name	**Type**	**Values (Range)**	**Value descriptions**	**SL Command**
Modem Mode	Uint8	0 -7 , A-B	0: Point to Point Master 1: Point to Point Slave 2: Point to MultiPoint Master 3: Point to MultiPoint Slave 4: Point to Point Slave/Repeater 5: Point to Point Repeater 6: Point to Point Slave/Master Switchable 7: Point to Multipoint Repeater A: Mirrored Bit Master B: Mirrored Bit Slave	SL~E=M1,I1,A<Mode> <Mode> = [0-7,A-B] as presented on the left

Call Book Entry To Call	Uint8	0 - A	0 - 9: Call Book Entry Index A: All	SL~E=M1,I2,A<index> <index> = [0-9,A] as presented on the left
Call Book	Uint8, Uint8[3], Uint8[3], Uint8[3]	0 - 9, 0x000000 - 0xFFFFFF, 0x000000 - 0xFFFFFF, 0x000000 - 0xFFFFFF	0 - 9: Call Book Entry Index 0x000000 - 0xFFFFFF: Address 0x000000 - 0xFFFFFF: Repeater1 Address 0x000000 - 0xFFFFFF: Repeater2 Address	SL~E=M1,I3,A<index>,B<Address>,C<Address>,D<Address> A indicates Call Book Entry Index field <index> = [0-9] as presented on the left B indicates Address field C indicates Repeater1 Address field D indicates Repeater2 Address field <Address> = [000000-FFFFFF]
Frequency Key	Uint8	0 - E	0 - E: Key for frequency hop table	SL~E=M1,I4,A<Frequency Key> <Frequency Key> = [0-9,A-E]
Frequency Zone	Uint16	0x0000 - 0xFFFF	Used to enable/disable frequency bands Bit 0: 902.2464 - 903.8592 MHz Bit 1: 904.0896 - 905.4720 MHz Bit 2: 905.7024 - 907.0848 MHz Bit 3: 907.3152 - 908.6976 MHz Bit 4: 908.9280 - 910.3104 MHz Bit 5: 910.5408 - 911.9232 MHz Bit 6: 912.1536 - 913.5360 MHz Bit 7: 913.7664 - 915.1488 MHz Bit 8: 915.3792 - 916.7616 MHz Bit 9: 916.9920 - 918.6048 MHz Bit 10: 918.8352 - 920.2176 MHz Bit 11: 920.4480 - 921.8304 MHz Bit 12: 922.0608 - 923.4432 MHz Bit 13: 923.6736 - 925.0560 MHz Bit 14: 925.2864 - 926.6688 MHz Bit 15: 926.8992 - 927.8208 MHz	SL~E=M1,I5,A<Frequency Zone> <Frequency Zone> = [0000...FFFF], each bit enables (1) or disables (0) the corresponding frequency band as defined on the left

Hop Table Version	Uint8	0 - 6	0: 902 - 928 MHz 1: 915 - 928 MHz 2: 902 - 928 MHz, 16 fewer freqs 3: 916 - 920 MHz 4: 921 - 928 MHz 5: 902 - 911 & 919 - 928 MHz 6: 902 - 915 MHz	SL~E=M1,I6,A<Hop Table Version> <Hop Table Version> = [0-6] as presented on the left
Hop Table Size	Uint8	50 - 112	50 - 112: Number of different frequencies in hop table	SL~E=M1,I7,A<Number of different frequencies in hop table> <Number of different frequencies in hop table> = [50-112]
Max Packet Size	Uint8	0 - 9	0 - 9: Defines maximum packet size in transmit	SL~E=M1,I8,A<Max Packet Size> <Max Packet Size> = [0-9]
Min Packet Size	Uint8	0 - 9	0 - 9: Defines minimum packet size in transmit	SL~E=M1,I9,A<Max Packet Size> <Max Packet Size> = [0-9]
Transmit Rate	Boolean	0 - 1	0: Diagnostics 1: Normal	SL~E=M1,I10,A<Transmit Rate> <Transmit Rate> = 0 (=Diagnostics) or 1 (=Normal)
RF Data Rate	Uint8	2 - 3	2: High 3: Normal	SL~E=M1,I11,A<RF Data Rate> <RF Data Rate> = 2 (=High) or 3(=Normal)
Transmit Power	Uint8	10-1000	10 mW 20 mW 50 mW 100 mW 200 mW 500 mW 1000 mW	GET: SL@P? SET: SL@P=
Slave Security	Boolean	0 - 1	0: On 1: Off	SL~E=M1,I12,A<Slave Security> <RF Data Rate> = 2 (=High) or 3(=Normal)
RTS To CTS	Uint8	0 - 2	0: Disabled 1: Enabled 2: ???	SL~E=M1,I13,A<RTS To CTS> <RTS To CTS> = 0 (=Disabled), 1 (=Enabled) or 2 (don't care?)
Retry Timeout	Uint8	8 - 255	8 - 255: Counter value when connection is dropped off if data is not received.	SL~E=M1,I14,A<Retry Timeout> <Retry Timeout> = [8-255]
Repeaters	Boolean		0: Disabled 1: Enabled	SL~E=M1,I15,A<Repeaters> <Repeaters> = 0 (=Disabled), 1 (=Enabled) or 2 (don't care?)
Master Packet Repeat	Uint8	0 - 9	0 - 9: Defines how many times master will send packets	SL~E=M1,I16,A<Master Packet Repeat> <Master Packet Repeat> = [0-9]
Max Slave Retry	Uint8	0 - 9	0 - 9: Defines how many times slave try to transmit data if ack is not received	SL~E=M1,I17,A<Max Slave Retry> <Max Slave Retry> = [0-9]

Retry Odds	Uint8	0 - 9	0 - 9: Defines a random base when slave is trying to resend data to master if Max Slave Retry count is reached. Value 0 means that the slave's data buffer is purged after Max Slave Retry count is reached	SL~E=M1,I18,A<Retry Odds> <Retry Odds> = [0-9]
Repeater Frequency	Boolean	0 - 1	0: Disabled 1: Enabled	SL~E=M1,I19,A<Repeater Frequency> <Repeater Frequency> = 0 (=Disabled) or 1 (=Enabled)
Network ID	Uint16	0 - 4095	0 - 4095: Network ID for multipoint networks. Network ID 255 = Call Book Mode	SL~E=M1,I20,A<Network ID> <Network ID> = [0-4095] Note: Network ID 255 = Call Book Mode
Slave/Repeater	Boolean		0: Disabled 1: Enabled	SL~E=M1,I21,A<Slave/Repeater> <Slave/Repeater> = 0 (=Disabled) or 1 (=Enabled)
TX Subnet	Uint8	0 - 9, A - F	0: Roaming 1 - E: Subnet ID F: Disabled	SL~E=M1,I22,A<TX Subnet> <TX Subnet> = [0-9, A-F] as presented on the left
RX Subnet	Uint8	0 - 9, A - F	0: Roaming 1 - E: Subnet ID F: Disabled	SL~E=M1,I23,A<RX Subnet> <RX Subnet> = [0-9, A-F] as presented on the left
Serial port settings				GET: SL%B? SET: SL%B=

11. VERSION HISTORY

Version history:

Version:	Date:	Remarks:
0.1	31.03.2015	First Draft.
0.2	20.05.2015	Updated 5.1 and 5.2 startup and shutdown sequences and 1.4 pin order of the DTE connector.
0.3	11.06.2015	Minor corrections and new performance values added.
0.4	11.10.2015	The document has been reorganized and a number of corrections have also been made.
1.0	15.01.2016	First official version.
1.1	11.02.2016	Updated 4.2 Pin order references to correct sections.
1.2	05.01.2017	Added Indian frequency variant infos.
1.3	09.02.2017	Added SATELLINE-M3-TR9
1.4	15.6.2017	Added usage restrictions for SATELLINE-M3-TR9
1.5	2.8.2017	Added permissible antenna types for Industry Canada. Updated RF exposure warning. Added host integration instructions.
1.6	13.09.2017	Added a note to SATELLINE-M3-TR9 integrators, page 3.
1.7	21.09.2017	Inserted chapters 13.2 and 2.5
1.8	07.02.2018	Corrections for settings chapters
1.9	09.05.2019	Corrected the Configuration Manager download link
2.0	04.06.2019	Added frequency limits AU, NZ and BR
2.1	13.06.2019	Added Anatel, BR certification number
2.2	30.4.2021	SATELLINE-M3-R9 additions, multiple changes
2.3	28.6.2024	SATELLINE-M3-TR8 removed (info available in IG v2.2). Multiple changes