Texas Instruments

Series 2000 Reader System

High Performance Remote Antenna-Reader Frequency Module RI-RFM-008B Antenna Tuning Board RI-ACC-008B

Reference Guide

TI-RFid
A TEXAS INSTRUMENTS TECHNOLOGY

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SCBU023

Series 2000 Reader System

High Performance Remote Antenna-Reader Frequency Module RI-RFM-008B Antenna Tuning Board RI-ACC-008B

Reference Guide



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This manual describes the TI-RFid™ High Performance Remote Antenna-Reader Frequency Module RI-RFM-008B hereafter referred to as the RA-RFM and the Antenna Tuning Board RI-ACC-008B.

Conventions

Certain conventions are used in order to display important information in this manual, these conventions are:

WARNING

A WARNING IS USED WHERE CARE MUST BE TAKEN, OR A CERTAIN PROCEDURE MUST BE FOLLOWED, IN ORDER TO PREVENT INJURY OR HARM TO YOUR HEALTH.

CAUTION

This indicates information on conditions which must be met, or a procedure which must be followed, which if not heeded could cause permanent damage to the RA-RFM.

Note: Indicates conditions which must be met, or procedures which must be followed, to ensure proper functioning of the RA-RFM.

Trademarks

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Product Description

This chapter introduces the RA-RFM component assemblies, showing the transmitter and receiver sections and placement of key user-accessible components.

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1.1 RA-RFM Module - General

WARNING

CARE MUST BE TAKEN WHEN HANDLING THE RA-RFM. HIGH VOLTAGE ACROSS THE ANTENNA TERMINALS AND ALL ANTENNA RESONATOR PARTS CAN BE HARMFUL TO YOUR HEALTH.

CAUTION

This product may be subject to damage by electrostatic discharge (ESD). It should be handled by ESD protected personnel at ESD secured workplaces only. The transmitter power output stage can only operate with a limited duty cycle. Please pay attention to this whilst performing antenna tuning procedures. Ground pins GND and GNDP must be connected externally to avoid damage to the unit.

The RA-RFM, together with the associated Antenna Tuning Board allows the use of up to 120 meters of symmetrically shielded antenna cable (Twin-Ax) between an antenna and the Reader unit. A system diagram is shown in Figure 1-1.

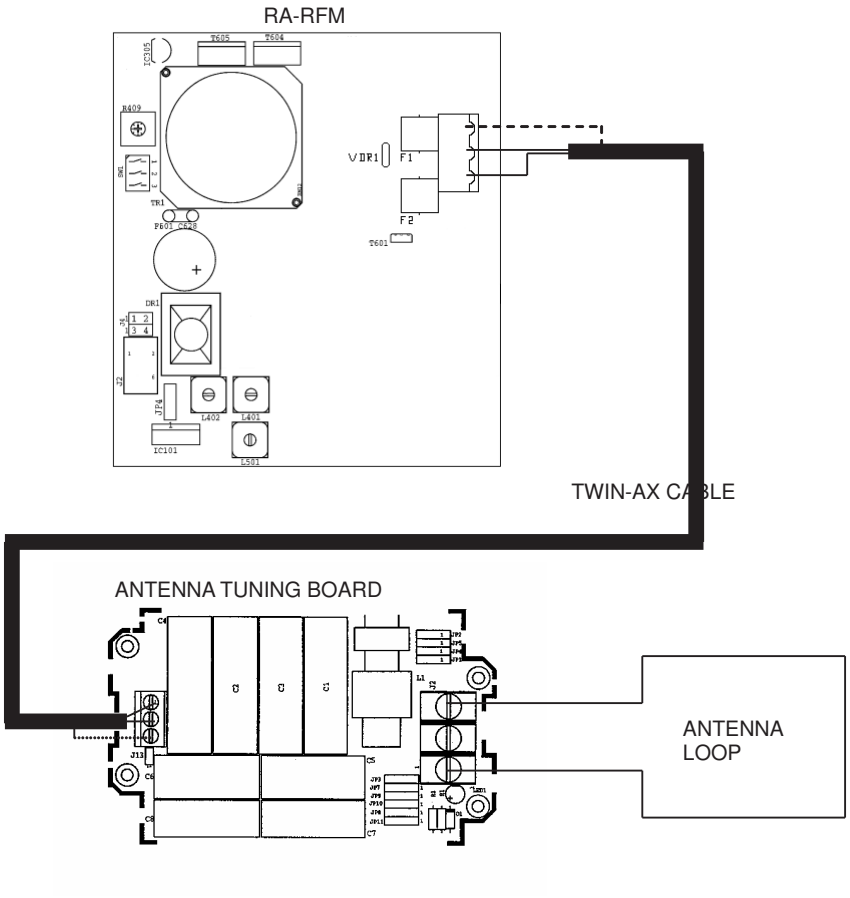


Figure 1-1. RA-RFM System

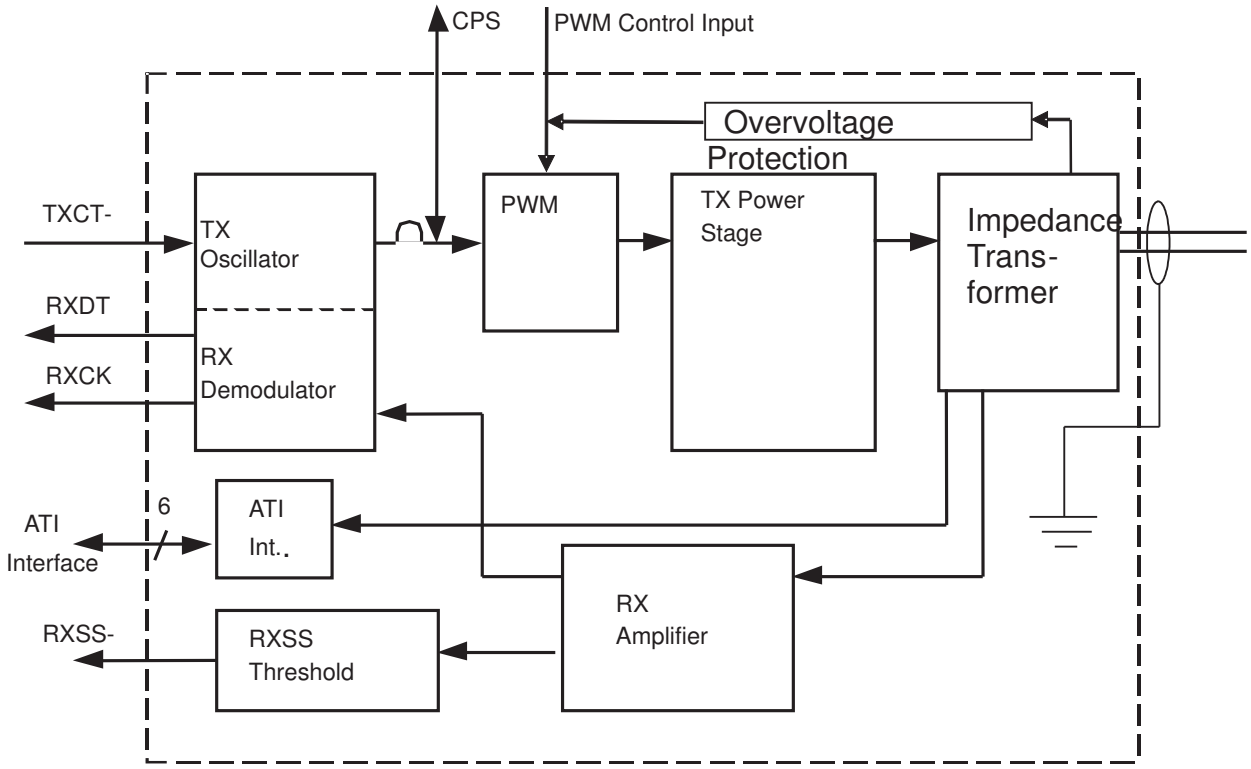


Figure 1-2. RFM Block Schematic

The RA-RFM contains all the analogue functions of a TI-RFid reading unit needed to initialize a TI-RFid transponder, delivering data and clock signals for identification data processing.

The RA-RFM also sends the necessary programming and addressing signals to Read/Write and Multipage transponders.

The data input and output lines, which are connected to a data processing unit, are low-power Schottky TTL and HCMOS logic compatible.

The functions of the RA-RFM are described in Section 1.2.

1.2 Transmitter

The transmitter power stage is supplied with power via two separate supply lines VSP and GNDP. Because of the high current requirements for the transmitter power stage, these supply lines are separated from the logic section supply lines and have two pins per line.

The ground pins for the logic section and the transmitter are not connected internally, in order to avoid possible problems with a high resistivity of GNDP pins and in order to increase flexibility when using long supply lines. Pins GND and GNDP must be connected to each other externally. For more details, refer to Section 3.2, Power Supply Connection.

The transmitter power stage is internally connected to the supply lines GNDP and VSP via a common-mode choke coil in order to reduce electromagnetic interference (EMI) on the supply lines.

The regulated transmitter power stage supply may vary between +7V and +24V. The supply lines VSP and VSL should be connected together when the supply voltage is +7 V or more. For details refer to Chapter 2, Specifications.

Note: The RA-RFM has an in-built temperature protection circuit which sharply limits the transmitter power stage output if an over-current situation or an over-temperature environment causes the temperature to exceed the allowed limits. After the device is switched off and has time to recover (when the temperature drops again or the over-current situation is otherwise rectified) the unit reverts to normal operation when it is switched on again. Such an occurrence is an indication that the RA-RFM is not being operated within specification.

The transmit frequency (134.2 kHz) from the oscillator is fed to the Pulse Width Modulator (PWM). By changing the value of a resistor, the PWM can set the pulse width ratio between 0% and 50%. For an example of two different oscillator signal pulse widths see Figure 1-3. Decreasing the 134.2 kHz frequency pulse width ratio decreases the generated transmit (charge-up) field strength.

It is therefore possible to adjust the generated field strength by selecting different pulse width ratios. For more information about setting the field strength, refer to Appendix 1, Field Strength Adjustment.

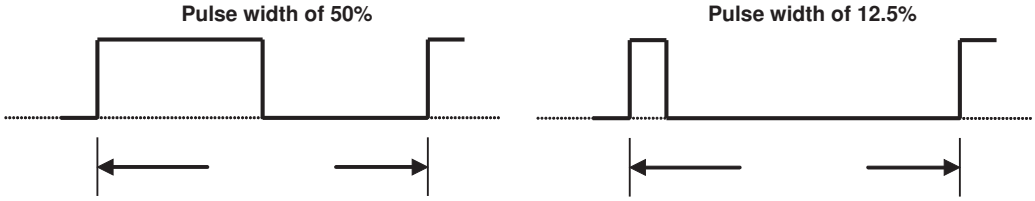


Figure 1-3. Pulse Width Examples

CAUTION

The RA-RFM must not be operated in continuous transmit mode when operated at full power output. When using pulse widths smaller than 50%, the RA-RFM transmitter power stage works in a less efficient way. This leads to an increased power dissipation and thus to higher temperature increase of the transmitter power stage, so ensure that more cooling is provided.

Note: If the RA-RFM is going to be physically located within the antenna field, it may be necessary to shield the module by means of a metal casing.

1.3 Receiver

The signal received from the transponder is a Frequency Shift Keying (FSK) signal with typical low and high bit frequencies of 134.2 kHz and 123.2 kHz respectively. The signal is received from the antenna resonator, which is capacitively coupled to the receiver.

The signal RXCK is the reference clock signal to decode the RXDT data stream. The RXCK signal changes from low to high level during each data bit and the RXDT signal is valid before and after this positive slope for a certain time window. For more details refer to Table 2-3, Timing Characteristics.

The receiver has a built-in RF receive signal detector. The receive signal strength is indicated by the digital output RXSS-. This signal becomes active (= logic LOW level) when the received RF signal strength exceeds a defined level. This threshold level may be adjusted with a potentiometer on the RA-RFM board and is located near connector J1 (see Figure 1-5).

The RXSS- output is used for detection of other transmitting reading units and thus can be used for wireless read cycle synchronization of several reading units.

1.4 RA-RFM Connectors and Jumpers

There are a number of connectors, jumpers and other components on the RA-RFM available for use.

These are:

J1	Connector for supply voltages and interface signal lines to and from the RA-RFM
J2	Connector for the (optional) Antenna Tuning Indicator (ATI), which can be used for easy antenna tuning during installation. Main resonance tuning is carried out with the Antenna Tuning Board near the antenna.
J4	Connector for field strength adjustment resistor and also direct access to receiver input.
JP4	Common-mode noise choke bypass.
R409	RXSS noise level adjustment potentiometer.
SW1	Default all on (Pos. 1 CPS see Appendix 4)

A 3-pin antenna connector connects the RA-RFM via a symmetrically shielded antenna cable (Twin-Ax) to the Antenna Tuning Board.

The RA-RFM is normally mounted from the underside utilizing appropriate spacers and four M3 mounting bolts.

The top view of the RA-RFM (without the normally fitted heatsink) is shown in Figure 1-4. Connectors J2, J4, JP4, R409, switch SW1 and the antenna terminals are accessible from the top.

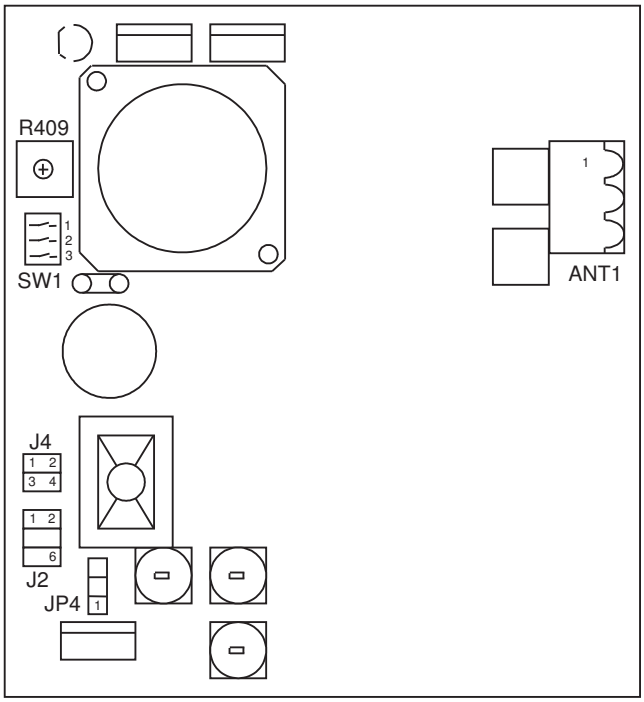


Figure 1-4. RA-RFM Top View

The bottom view of the RA-RFM is shown in Figure 1-5. The connectors J1, J2 and J4 are accessible from the underside. J1 is the 16-pin module connector, this carries the supply voltage lines, the data, and the control lines.

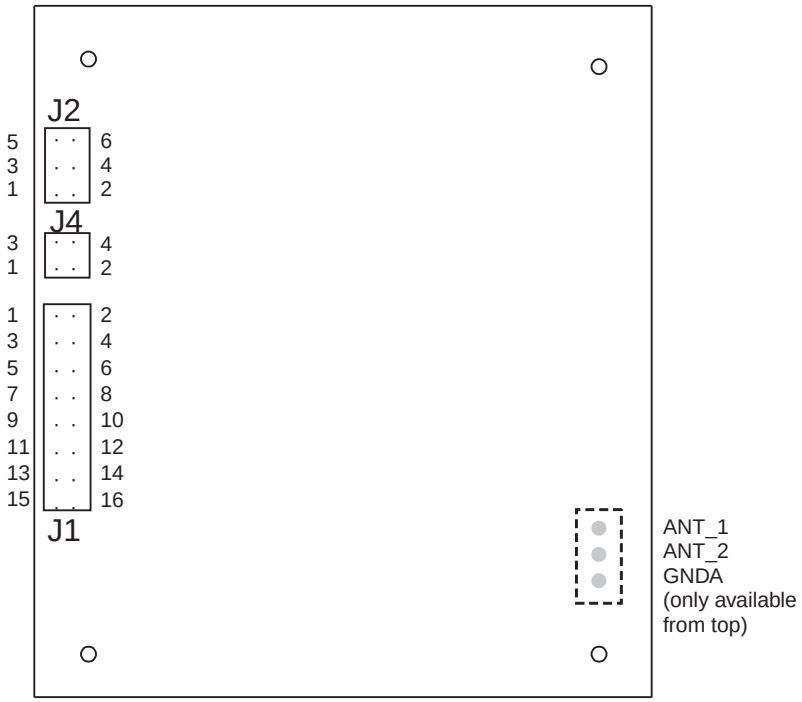


Figure 1-5. RA-RFM Bottom View

Table 1-1 lists the pin functions for connector J1. The connector type is 16 pin, 2 row with 2.54 mm pin spacing.

Table 1-1. J1 Pin Functions

Pin#	Signal	Direction	Description
1	GND	IN	Logic ground
2	TXCT-	IN	Transmitter control input for activation of transmitter (active low, internal pull-up resistor)
3	VSL	IN	Supply voltage for logic and receiver
4	RXDT	OUT	Logic level compatible receiver data signal output
5	RXSA	IN/OUT	Receiver signal strength adjust for RXSS- threshold level
6	RXCK	OUT	Logic level compatible receiver clock output
7	GNDP	IN	Transmitter power stage ground
8			No connection
9	GNDP	IN	Transmitter power stage ground
10	RSTP	OUT	Analog receiver signal strength test pin
11	VSP	IN	Supply voltage for transmitter power stage
12	CPS_OUT	OUT	Carrier Phase Synchronization oscillator signal output
13	VSP	IN	Supply voltage for transmitter power stage
14	RXSS-	OUT	Receiver signal strength output (active low)
15			No connection
16	CPS_IN	IN	Carrier Phase Synchronization oscillator signal input

CAUTION

The transmitter ground pins GNDP and logic ground pin GND must be connected together externally. The RA-RFM may be otherwise permanently damaged.

Table 1-2 lists the pin functions for the ATI connector J2: The connector type is a 6 pin, 2 row connector with 2.54 mm pin spacing.

Table 1-2. J2 Pin Functions

Pin#	Signal	Direction	Description
1	TXCT-R	IN	Transmitter control signal via resistor (active low)
2	GND	OUT	Logic ground
3	VD	OUT	Internal regulated logic supply voltage output
4	F_OSC-R	IN/OUT	Pulse width modulated transmitter oscillator signal via resistor
5	RXSS-	OUT	Receiver signal strength output (active low)
6	F_ANT	OUT	Antenna resonance frequency output signal (open collector)

Table 1-3 lists the pin functions for the J4 pulse width adjustment connector. The connector type is 4 pin, 2 row with 2.54 mm pin spacing.

Table 1-3. J4 Pin Functions

Pin#	Signal	Description
1	RX	Analog transponder signal
2	GNDA	Ground antenna circuit
3		Pulse width adjusting resistor connecting pin
4	GND	Logic ground

Table 1-4 lists the functions for the antenna connector used to connect the RA-RFM to the Antenna Tuning Board.

Table 1-4. Connector ANT1

Pin#	Signal	Direction	Description
1	GNDA	OUT	Ground for cable shield
2	ANT_2	IN/OUT	Symmetrical antenna input/output 2
3	ANT_1	IN/OUT	Symmetrical antenna input/output 1

Jumper JP4 allows enabling and disabling of common noise filtering for EMI purposes. The default setting, with common noise filtering active, jumpers pins 2 and 3. A jumper between pins 1 and 2 bypasses common noise filtering.

1.5 Antenna Tuning Board - General

In order to achieve high resonance voltage and thus high charge-up field strength, the antenna circuit must be tuned to resonance. This is the purpose of the tuning coil and capacitor array on this board, shown in Figure 1-6.

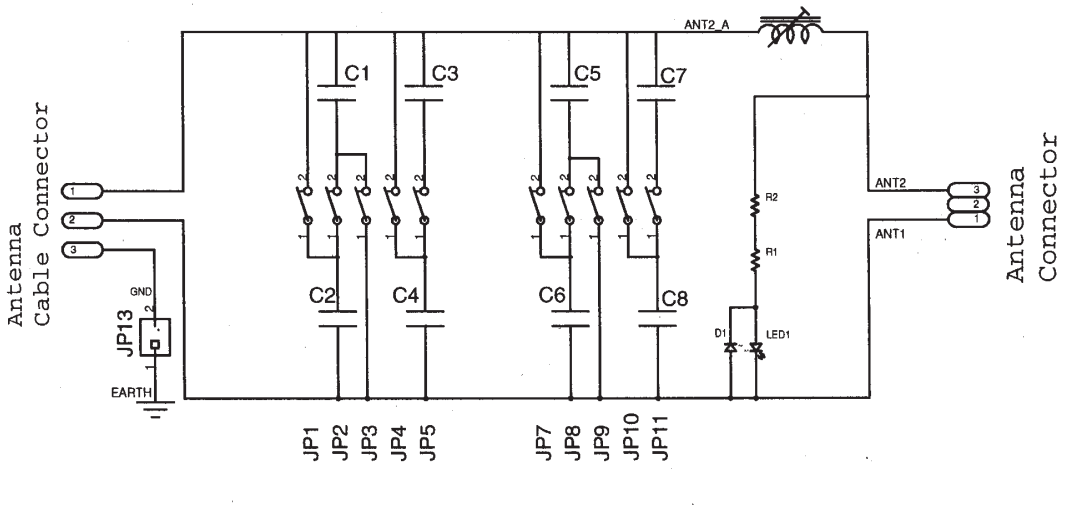


Figure 1-6. Antenna Tuning Board Schematic

The total resonance capacitance is as follows:

Antenna Tuning Board capacitance + cable capacitance (Antenna Tuning Board to RA-RFM)

The main resonance capacitance consists of capacitors C1, C2, C3, C4, C5, C6, C7 and C8 on the Antenna Tuning Board. The high resonance voltage and current flow through the resonator necessitate connecting these capacitors both in serial and parallel. Each resonance capacitor can be switched in and out of circuit by a single jumper in order to tune the RFM to resonance, i.e. match the RFM to different antenna inductances.

CAUTION

If only one capacitor is switched parallel to the resonance circuit, the maximum allowed resonance voltage is 280 Vp (560 Vpp).

WARNING

CARE MUST BE TAKEN WHEN HANDLING THE RA-RFM SYSTEM. HIGH VOLTAGE ACROSS THE ANTENNA TERMINALS AND ALL ANTENNA RESONATOR COMPONENTS MAY BE HARMFUL TO YOUR HEALTH. IF THE ANTENNA INSULATION IS DAMAGED, THE ANTENNA SHOULD NOT BE CONNECTED TO THE RA-RFM SYSTEM.

1.6 Antenna Tuning Board Connectors and Jumpers

A circuit diagram of the Antenna Tuning Board is shown in Figure 1-6. Table 1-5 through Table 1-8 show connector and jumper signals. LED1, visible on the module, indicates the presence of power.

Table 1-5. Antenna Connection

Pin#	Signal	Direction	Description
1	ANT	IN/OUT	Symmetric antenna signal
2			Not connected
3	ANT	IN/OUT	Symmetric antenna signal via series L

Table 1-6. Antenna Cable Connector

Pin#	Signal	Direction	Description
1	ANT	IN/OUT	Symmetric antenna signal from/to RFM
2	ANT	IN/OUT	Symmetric antenna signal from/to RFM
3	GND	IN	Cable shield to housing ground

Table 1-7. Tuning Capacitor Jumpers

	Capacitance (nF)	Max. Resonance Voltage Peak-Peak (VRF_max)	Description
JP1	33	560	Capacitor C2
JP2	16.5	800	Capacitor C1, C2 in series
JP3	33	560	Capacitor C1
JP4	33	560	Capacitor C4
JP5	16.5	800	Capacitor C3, C4 in series
JP7	15	560	Capacitor C6
JP8	7.5	800	Capacitor C5, C6 in series
JP9	15	560	CapacitorC5
JP10	10	560	CapacitorC8
JP11	5	800	Capacitor C7, C8 in series

Note: VRF_max is the maximum allowed resonance voltage for the respective capacitor combination.

Table 1-8. J13 Earth Ground Antenna Tuning Board

Pin#	Signal	Direction	Description
1	Earth	OUT	Housing ground
2	GND	IN	Shield Twin Ax Cable

Note: The pre-drilled mounting holes are connectable to ground.

Specifications

This chapter lists the recommended operating conditions, electrical and mechanical characteristics and dimensions.

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2.1 Recommended Operating Conditions

CAUTION

Exceeding recommended maximum ratings may lead to permanent damage of the RA-RFM.

The RA-RFM must not be operated in continuous transmit mode when operated at full power output.

Install suitable heatsinks when operating the RA-RFM at pulse widths smaller than 50%.

Table 2-1 shows the recommended operating conditions.

Table 2-1. Operating Conditions

Symbol	Parameter	Min	Typ	Max	Unit
V_VSP	Supply voltage of transmitter power stage	7.0	14.0	24.0	V DC
I_VSP	Current consumption of transmitter power stage - refer to the formula below		1.0	2.0	Apeak
P_VSP	Peak pulse power input to transmitter power stage (I_VSP * V_VSP * Duty Cycle)			24	W
V_ANT	Antenna resonance voltage		250	380	Vpeak
V_ANT-25	Antenna resonance voltage (Pulse width setting ≤ 25%)			200	Vpeak
V_ANT- ATI	Minimum antenna resonance voltage for correct operation of ATI	25			Vpeak
V_VSL	Supply voltage input for logic part	7.0		24.0	V DC
I_VD	External current load on internal regulated logic supply voltage output			1.0	mA
T_oper	Operating free-air temperature range	-25		70	°C
T_store	Storage temperature range	-40		85	°C

Note: Free-air temperature is the air temperature immediately surrounding the RA-RFM module. If the module is incorporated into a housing, it must be guaranteed by proper design or cooling that the internal temperature does not exceed the recommended operating conditions.

In order to keep power consumption (P_VSP) below 20 W it is advisable to limit I_VSP. The maximum allowed value, dependent on the configuration, can be determined as follows (in the following examples a supply voltage of 24 V_VSP is used):

$$\text{I_VSP} = \frac{\text{P_VSP}}{\text{V_VSP} \times \text{Duty Cycle}}$$

$$\text{where Duty Cycle} = \frac{\text{Power on time}}{\text{Total Read Cycle Time}}$$

Example 1: Using Standard/Default Settings (≈10 read cycles/second)

$$\text{I_VSP} = \frac{24\ \text{W}}{24\ \text{V} \times 0.5} = 2\ \text{A} \qquad \text{Duty Cycle} = \frac{50\ \text{ms}}{100\ \text{ms}} = 0.5$$

Example 2: Configured to No Sync (≈12 read cycles/second)

$$\text{I_VSP} = \frac{24\ \text{W}}{24\ \text{V} \times 0.625} = 1.6\ \text{A} \qquad \text{Duty Cycle} = \frac{50\ \text{ms}}{80\ \text{ms}} = 0.625$$

The following methods can be used to measure the actual I_VSP value:

1. Use a battery powered oscilloscope to measure the voltage drop across a 0.1 Ω resistor placed in the DCIN+ line, and then calculate the actual current using the formula I = V/R.
2. If a battery powered oscilloscope is not available, measure the potential at both sides of the 0.1 Ω resistor (signal probe) with the GND probe at DCIN- and determine the potential difference.

   Ensure that the measured I_VSP value does not exceed the calculated value.

Table 2-2. Electrical Characteristics

Symbol	Parameter	Min	Typ	Max	Unit
I_VSL	Supply current for logic and receiver part in transmit and receive mode	14	18	22	mA
ViL	Low level input voltage of TXCT-	0	0.4	0.8	V
ViH	High level input voltage of TXCT-	2.4		5.0	V
VoL	Low level output voltage of RXDT and RXCK	0	0.4	0.8	V
VoH	High level output voltage of RXDT and RXCK	4.0		5.25	V
VoL_R	Low level output voltage of RXSS-			0.8	V
VoH_R	High level output voltage of RXSS- (see note below)			5.25	V
Fan-In	Low power Schottky compatible fan-in of signals TXCT- (Iin = -400µA)			1	-
I_IN-TXCT-	Input current for TXCT- signal, when the Accessory Module RI-ACC-ATI2 is connected	2.0	2.5	3.0	mA
Fan-Out	Low power Schottky compatible fan-out of signals RXDT and RXCK			3	-
FanOut_Rl	Low power Schottky compatible fan-out of signal RXSS- (low level only)			1	-
FanOut_Rh	Low power Schottky compatible fan-out of signal RXSS- (high level only) (see note below)				
l_J1	Cable length for connecting J1 of RFM to a Control Module using flat cable	0	0.5	2.0	m
l_CPS	Cable length for connecting the Carrier Phase Synchronization signal between two RFMs	0	1.0	5.0	m
n_CPS	Number of oscillator SLAVE RFMs, which can be driven from one oscillator MASTER RFM	1		5	-
Com_Mode	Common Mode Noise reduction ratio for noise coupled to both antenna terminals ANT1 and ANT2		20		dB
R_GND	Decoupling resistor between GND and GNDP (+/- 5%)	64.6	68	71.4	Ω

Note: RXSS- has an internal pull-up resistor of 10 kΩ. The parameter VoH_R therefore depends on application specific external components.

Table 2-3. Timing Characteristics

Symbol	Parameter	Min	Typ	Max	Unit
t_TX	Transmit burst length for correct operation (see note below)	15	50	100	ms
t_dtck	Delay time from beginning of data bit at RXDT being valid to positive slope of RXCK signal	20			µs
t_dtvd	Time for data bit of RXDT signal being valid after positive slope of RXCK	90			µs
t_ckhi	Time for clock signal RXCK being high	55			µs
t_ri t_fi	Necessary rise and fall times for input signal TXCT- and TXCT-R			1	µs
t_ro t_fo	Rise and fall time of output signals RXDT and RXCK			1	µs
t_ro_R	Rise time of output signal RXSS- (no external connection)			1	µs
t_fo	Fall time of output signal RXSS-			1	µs
tss_01Tl	Propagation delay time from positive slope of TXCT- to positive slope of RXSS- signal (maximum sensitivity)	500	1000	1500	µs
tss_10Tr	Propagation delay time from negative slope of TXCT- to negative slope of RXSS- signal (minimum sensitivity)	50	100	200	µs

Note: Due to transponder parameters a minimum charge-up time of 15 ms is necessary. Decreasing charge-up time decreases read range by sending less energy to the transponder.

Table 2-4. Mechanical Parameters

Parameter	Typical	Unit
Height of complete RA-RFM including mounting bolts	44.0 ± 1.5	mm
Height of Antenna Tuning Board	27.0 ± 3.0	mm
Weight of RA-RFM	160	g
Weight of Antenna Tuning Board	162	g

2.2 Dimensions

All measurements are in millimeters with a tolerance of +/- 0.5 mm unless otherwise noted.

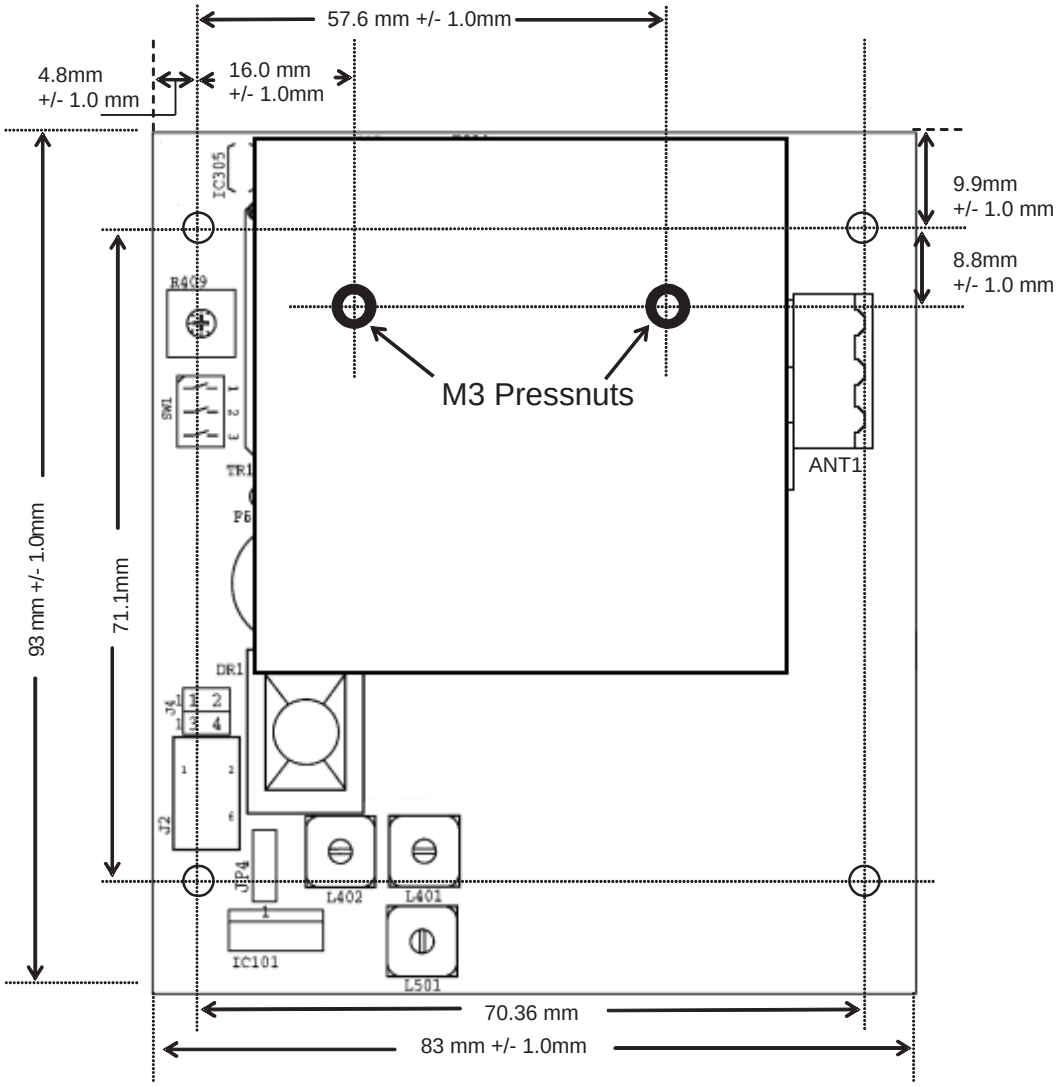


Figure 2-1. Mechanical Dimensions RA-RFM

Note: The heatsink is connected to the antenna resonator ground GNDA. When connecting the heatsink to a housing, the heatsink must be insulated from the housing.

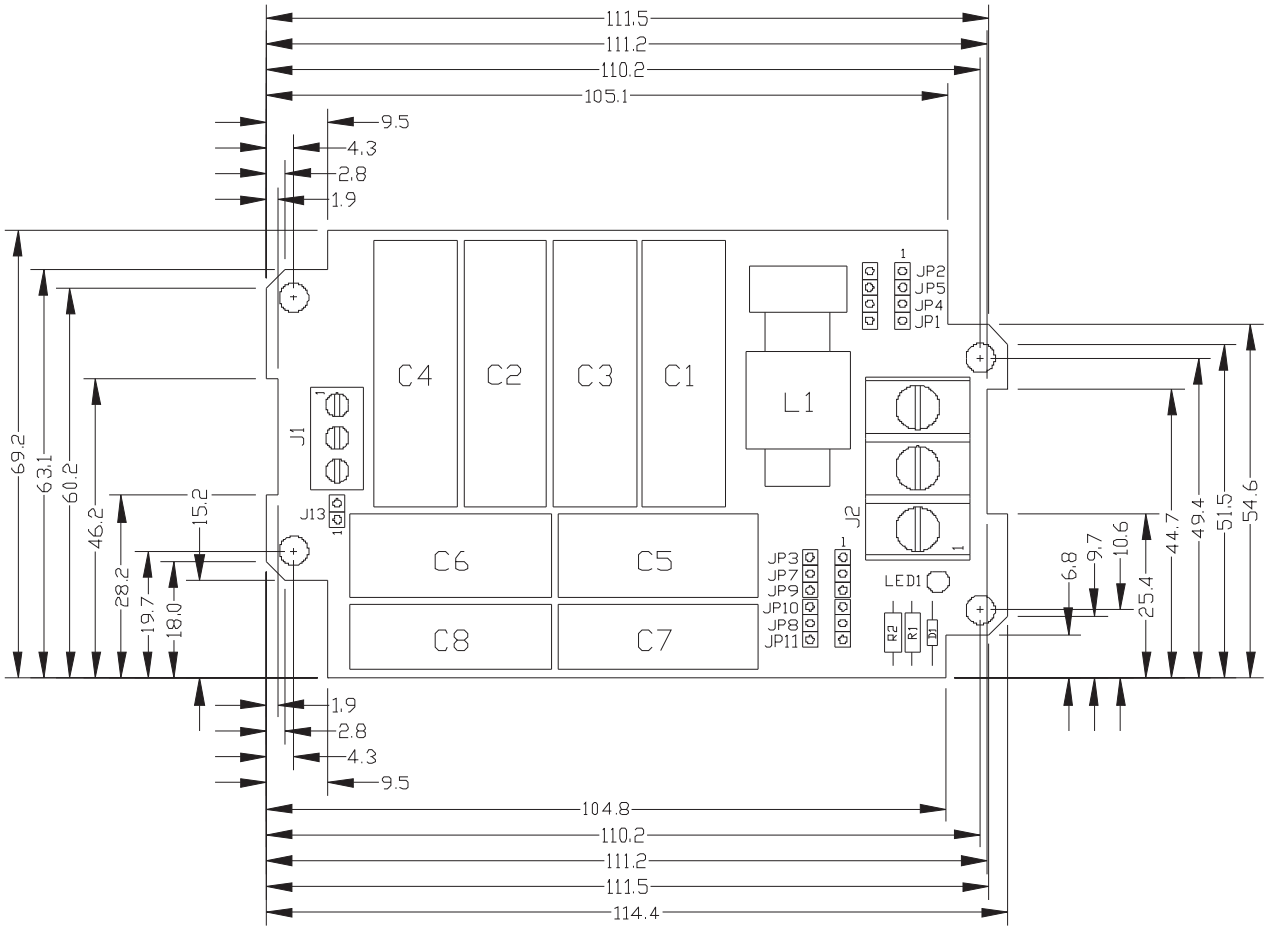


Figure 2-2. Mechanical Dimensions Antenna Tuning Board

Installation

This chapter shows how to install the RA-RFM and specifies power supply requirements and connections.

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3.2 Power Supply Connection 24

3.1 Power Supply Requirements

The logic and receiver sections of the RA-RFM must be supplied via the VSL and GND pins with unregulated voltage.

The transmitter power stage is separately supplied via VSP and GNDP. As there is no stabilization circuitry on the RA-RFM and as the transmitter power stage needs a regulated supply voltage in order to meet FCC/PTT regulations, the supply voltage for the transmitter power stage must be regulated externally. For the voltage supply range please refer to Chapter 2, Specifications.

Note: The RA-RFM should not be supplied by switched mode power supplies (SMPS) as most SMPS operate at frequencies of around 50 kHz. The harmonics of the generated field may interfere with the TI-RFid receiver and therefore only linear power supplies, or SMPS with a fundamental operating frequency of 200 kHz or higher are recommended.

Noise from power supplies or from interface lines may interfere with receiver operation. It is recommended to add additional filters in series to the supply and interface lines if required by the application. For more details refer to Appendix 8, Noise Verification and Appendix 9, Over Voltage Protection.

In order to guarantee full RA-RFM performance, the power supplies should fulfill the specifications for ripple voltage given in Table 3-1.

Table 3-1. Power Supply Ripple Specifications

Supply Type	Maximum Ripple Voltage	Allowable Ripple Frequency
Unregulated VSL supply	30 mV rms	0 to 100 kHz maximum (sinusoidal)
Regulated VSP supply	50 mV rms	0 to 50 kHz maximum (sinusoidal)

3.2 Power Supply Connection

Ground pins for the logic/receiver part and the transmitter power stage are not directly connected internally, the two different grounds having to be connected to each other externally.

The only internal connection is via resistor R_GND, in order to avoid floating grounds if these grounds are accidentally not connected to each other externally.

This is necessary for two reasons:

1. A high resistivity of the GNDP pins could cause a voltage drop across these pins, due to high transmitter power stage current (this does not apply to the supply pins of the logic section). If the grounds were connected to each other internally, this would also lift the internal logic ground and cause logic level compatibility problems with the Control Module (see Figure 3-1).
2. In order to provide greater flexibility when using long supply lines. Long VSP supply lines between the RA-RFM and the Control Module cause a voltage drop across this supply line (again due to high transmitter power stage supply current). This voltage drop would also lift the logic ground and cause logic level compatibility problems with the Control Module. This can be avoided by connecting the grounds externally in any of three different ways (see also Figure 3-1) as described below:
   - For cable lengths of up to 0.5 m between RA-RFM and Control Module, the RFM ground pins GND and GNDP must be connected at the Control Module, as shown in Figure 3-1. The grounds for the VSP, VSL and the Control Module supply are connected together at a common ground. Alternatively, if the voltage drop across the VSP supply line is less than 0.5 V (likely in this case), the ground pins GND and GNDP may be connected together at the RA-RFM. If the system has a TI-RFid Control Module, the RA-RFM ground pins GND and GNDP are already connected together correctly on the Control Module. When using a customer-specific controller, care must be taken to connect the RA-RFM ground pins GND and GNDP to an appropriate ground on the controller.

- For cable lengths of between 0.5 m and 2 m, the RFM ground pins GND and GNDP must be connected together at the Control Module in order to avoid logic level compatibility problems caused by the voltage drop across the VSP supply lines. Connecting the ground pins at the RA-RFM is not permitted since this would lift the logic ground level.
- Cable lengths longer than 2 m are not recommended. If the application demands cabling longer than 2 m, the logic signal connections between the RA-RFM and the Control Module should be done via a differential interface (for example RS422). Due to different ground potentials at different locations it may also be necessary to provide galvanic separation of the interface signals by, for example, opto-couplers. In this case, to avoid problems with difference voltages between GND and GNDP, these pins must always be connected directly at the RA-RFM. As shown in Figure 3-1 a shorting bridge is necessary for this purpose, situated as close as possible to the RA-RFM.

CAUTION

The voltage between GND and GNDP must not exceed ±0.5 V, otherwise the RA-RFM will suffer damage.

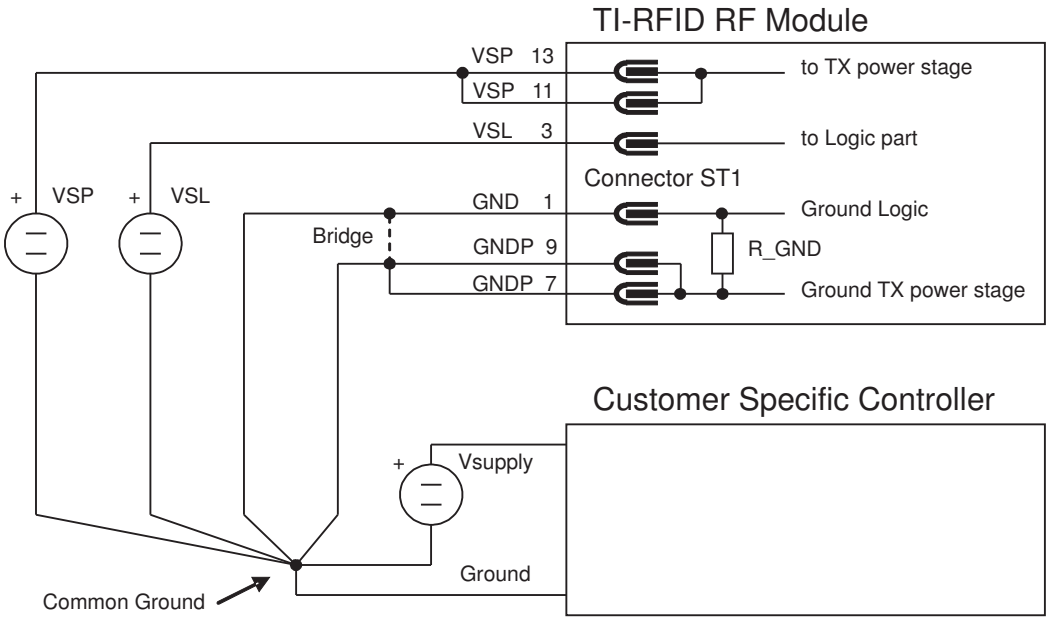


Figure 3-1. External Ground Connection (GND to GNDP)

Associated Antenna Systems

This chapter discusses antenna requirements and antenna tuning procedures.

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4.1 Antenna Requirements 28
4.2 Antenna Resonance Tuning 28
4.3 Tuning Procedure 29

4.1 Antenna Requirements

In order to achieve high voltages at the antenna resonance circuit and thus high field strength at the antenna for the charge-up (transmit) function, the antenna coil must be high Q. The recommended Q factor for proper operation is listed in Table 4-1, Antenna Requirements. The Q factor of the antenna may vary depending on the type, the construction and the size of the antenna. Furthermore, this factor depends on the wire type and wire cross-sectional area used for winding of the antenna.

RF braided wire, consisting of a number of small single insulated wires is recommended for winding of an antenna since it gives the highest Q factor and thus the highest charge-up field strength, for example single wire diameter of 0.1 mm (4 mil) and 120 single insulated wires.

Note: If a high Q is not required (for example for large in-ground antennas), standard braided wire can be used.

In order to ensure that the transmitter and receiver function correctly, the antenna must be tuned to the resonance frequency of 134.2 kHz. For a detailed description of the antenna resonance tuning procedure, refer to Section 4.2, Antenna Resonance Tuning.To ensure that the antenna can be tuned to resonance with the Antenna Tuning Board, the antenna inductance can only vary within the limits given in Table 4-1.

Table 4-1. Antenna Requirements

Parameter	Conditions	Min	Typ	Max	Unit
L_ANT	Antenna inductance range within which the antenna can be tuned to resonance	8	27	80	µH
Q_ANT	Recommended Q factor of antenna coil for correct operation	40		450	-

Note: Although a ferrite core antenna may have a high Q factor under test conditions with low magnetic field strengths, the Q factor decreases when a high magnetic field strength is applied to the ferrite core.

WARNING

CARE MUST BE TAKEN WHEN HANDLING THE RA-RFM. HIGH VOLTAGE ACROSS THE ANTENNA TERMINALS AND ALL ANTENNA RESONATOR PARTS COULD BE HARMFUL TO YOUR HEALTH. IF THE ANTENNA INSULATION IS DAMAGED THE ANTENNA SHOULD NOT BE CONNECTED TO THE RA-RFM.

4.2 Antenna Resonance Tuning

In order to achieve a high charge-up field strength, the antenna resonator frequency must be tuned to the transmitter frequency of 134.2 kHz. This is done by adjusting the capacitance of the Antenna Tuning Board. Fine tuning may be performed by adjusting the setting of the tuning coil on the Antenna Tuning Board.

When tuning the antenna using the tuning capacitors on the Antenna Tuning Board, the resonance condition must be monitored. This can be done by monitoring the field strength generated by the antenna, and can be performed by measuring the induced RF voltage of a pick-up coil placed at a fixed distance from the antenna. The antenna is tuned to resonance when the voltage at the pick-up coil has reached its maximum value. To utilize this method, the RA-RFM must be switched into repetitive transmit mode by operating it from a controller unit. Measurement may be done by using an oscilloscope or a voltmeter, Figure 4-1 showing the necessary configurations.

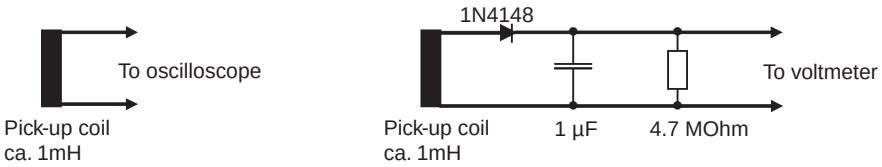


Figure 4-1. Antenna Tuning Pick-up Coil Configuration

As the RA-RFM has only to be tuned to the maximum voltage obtainable at the pick-up coil, any type of coil may be used, the inductance being of little importance. However, if a pick-up coil with a high inductance (high number of windings and large size) is used, it may be positioned further from the antenna.

Monitoring of the correct antenna resonance tuning can also be performed using the Antenna Tuning Indicator (ATI) tool RI-ACC-ATI2.

This device allows the transmitter to be operated in pulsed mode, independently of the Control Module. It indicates by LEDs whether the tuning capacity should be increased or decreased (marked on the ATI as IN for increase and OUT for decrease) and when the antenna is tuned to resonance, in which case the green LED is on or flashing together with the IN or OUT LED. The device is plugged into the RA-RFM connector J2 during the tuning procedure, power being supplied from this module.

The following notes refer to antenna resonance tuning in general:

Note: If an antenna has to be installed in an environment where metal is present, the tuning of the antenna must be done in this environment, since the presence of metal changes the inductance of the antenna. In addition, the Q factor of the antenna decreases, thereby decreasing the field strength. The extent of the inductance and quality factor reduction depends on the kind of metal, the distance of the antenna from it and its size.

When the oscillator signal pulse width, or the supply voltage VSP of an RA-RFM with a pre-tuned ferrite core antenna (for example: RI ANT S02) is changed by a factor of more than 50%, the ferrite core antenna has to be re-tuned to the new conditions due to the inductance changing slightly at different field strengths.

Each antenna is tuned individually to the RA-RFM and this results in a unique tuning jumper arrangement for this combination of antenna and RA-RFM.

If a different antenna or RA-RFM is connected, the new combination must be tuned to resonance again.

4.3 Tuning Procedure

1. Switch RA-RFM power supply off.
2. Calculate the required resonance capacitance (see calculation method below).
3. Set the tuning range jumper on the Antenna Tuning Board which is closest to the calculated value according to Table 4-2.
4. Connect the Antenna Tuning Board via twin-ax cable to the RA-RFM via the ANT1 connector.
5. Connect antenna tuning monitor (oscilloscope or voltmeter).
6. Switch RA-RFM power supply on.
7. Tune the antenna to maximum by adjusting the series coil on the Antenna Tuning Board.
8. If this is not successful, retune the antenna to maximum by changing the tuning capacity one level up or down and then repeating step 7.
9. If this is still unsuccessful, check the calculations and repeat the process from step 1.

The antenna resonance tuning is now complete.

Table 4-2. Tuning Range Settings

Jumper Setting	C_tunb (nF)	C_deviation (nF)	Tuning Range (µH)	Cable Length (meter)	V-RF_max (V)
JP2	16.5	±0.5			800 Vpp
JP2, JP11	21.5	±0.7			800 Vpp
JP2, JP8	23.5	±1			800 Vpp
JP2, JP5	33	±1.5			800 Vpp
JP2, JP5, JP11	38	±2.3			800 Vpp
JP2, JP5, JP8, JP11	45.5	±3	27	5 to 40	800 Vpp
JP3, JP4	66	±7			560 Vpp
JP2, JP4, JP7, JP10	74.5	±7	16	5 to 40	560 Vpp
JP1, JP3, JP5	82.5	±10			560 Vpp
JP1, JP3, JP5, JP10	92.5	±12			560 Vpp
JP1, JP3, JP4, JP7, JP10	124	±20	8	5 to 40	560 Vpp

The column 'C_tunb' is the capacity which is adjusted on the Antenna Tuning Board. 'C_deviation' is the allowed tolerance within which the corresponding jumper setting is valid.

The columns 'Tuning Range' and 'Cable Length' show some examples of jumper settings for a particular antenna inductance and length. The cable length can be between 5 and 120 meters. The column 'V-RF_max' shows the maximum allowable resonance voltage at the antenna terminals.

In order to calculate C_tunb, use the following formula:

C_res. = 1406.45/(L_ant. + 3) (µH/nF)

C_tunb. = C_res. – C_cable – 2.2 (nF)

(Default setting is 45.5 nF for 27µH and cable length up to 40 meters.)

Recommended Cable: Twinax

- Characteristic impedance: 100 to 105 Ω
- Capacitance: 50.9 pF/meter
- Diameter: 8.4 mm

Regulatory, Safety & Warranty Notices

Topic Page

5.1 Regulatory Notes 32

5.1 Regulatory Notes

Prior to operating the RFM together with antenna(s), power supply and a control module or other devices, the required FCC or relevant government agency (CE) approvals must be obtained. Sale, lease or operation in some countries may be subject to prior approval by government or other organizations.

5.1.1 FCC Notices (U.S.A)

A typical system configuration containing the RFM has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC rules. It is the responsibility of the system integrators to get their complete system tested and to obtain approvals from the appropriate local authorities before operating or selling this system.

5.1.2 CE Conformity (Europe)

A CE Declaration of Conformity is available for the RFM at TI-RFid Sales Offices.

The equipment complies with the essential requirements of the Telecommunication Terminal Equipment Act (FTEG) and the R&TTE Directive 99/5/EC when used for its intended purpose.



Any device or system incorporating this module in any other than the originally tested configuration needs to be verified against the requirements of the Telecommunication Terminal Equipment Act (FTEG) and the R&TTE Directive 99/5/EC. A separate Declaration of Conformity must be issued by the system integrator or user of such a system prior to marketing it and operating it in the European Community.

It is the responsibility of the system integrators to get their complete system tested and obtain approvals from the appropriate local authorities before operating or selling the system.

Field Strength Adjustment

The magnetic field strength generated determines the charge-up distance of the transponder. The higher the magnetic field strength, the further the transponder charge-up distance. The charge-up distance does not, however, increase linearly with the field strength.

The reading distance of a transponder is determined, amongst other factors, by the charge-up distance and the local noise level. Increasing the charge-up field strength does not necessarily increase the reading distance.

The field strength generated by the RA-RFM depends on the four factors listed below:

1. Q factor of the antenna.

   The Q factor is a measure of the efficiency of the antenna and therefore the higher the Q factor of the antenna coil, the higher the field strength generated by the RA-RFM, assuming that all other parameters remain unchanged. The Q factor of the antenna itself depends on the cross-sectional area of the wire, the wire type, the size of the antenna and the type of antenna (gate or ferrite). The larger the cross-sectional area of the RF braided wire, the higher the Q factor of the antenna. RF braided wire gives a higher Q factor than solid wire assuming that all other parameters remain unchanged.
2. Size of the antenna.

   The larger the antenna, the higher the field strength which is generated by the RA-RFM, since the antenna covers a larger area and thus generates a higher flux assuming that all other parameters remain unchanged. Large antennas have less immunity to noise for receive functions than small antennas.
3. Supply voltage of the RA-RFM power stage.

   The higher the supply voltage of the RA-RFM transmitter power stage (VSP voltage), the higher the field strength which is generated by the RA-RFM assuming that all other parameters remain unchanged. However, the generated field strength does not increase linearly with VSP supply voltage. In addition, ferrite core antennas show saturation effects (saturation means here that the ferrite core cannot generate more magnetic field strength, even with a higher input current).
4. The oscillator signal pulse width.

   The bigger the selected transmitter oscillator signal pulse width, the higher the magnetic field strength which is generated by the RA-RFM, since more power is fed into the antenna resonator by the transmitter power stage assuming that all other parameters remain unchanged.

The generated field strength can be measured in several ways. It may be measured using a calibrated field strength meter or by measuring the antenna resonance voltage using an oscilloscope and then calculating the field strength.

In summary: the generated field strength of an antenna can be adjusted with the supply voltage VSP of the RA-RFM transmitter power stage and by selecting the corresponding oscillator signal pulse width.

Note: For correct adjustment of field strength according to FCC/PTT values, especially for customized antennas, a calibrated field strength meter must be used. Field strength measurements must be taken on a free field test site according to VDE 0871 or equivalent regulation.

Adjustment of Oscillator Signal Pulse Width

The RA-RFM has an built-in feature to allow setting of the pulse width of the transmitter signal coming from the oscillator. This enables the generated field strength to be reduced from 50% down to 0%.

For this purpose a pulse width setting resistor may be inserted between J4 pins 3 and 4 on the RA-RFM. Inserting a smaller resistance value decreases the pulse width and thus also the field strength. As default, no resistor is connected, thus selecting the maximum pulse width of 50% and the maximum field strength. By connecting a shorting bridge, the smallest pulse width of approximately 0% is selected.

Table B-1 provides an overview of oscillator signal pulse width and corresponding field strength reduction when different oscillator signal pulse widths are selected by connecting different resistor values.

Table B-1. Oscillator Signal Pulse Width vs Resistor Value (Estimated Values)

Resistor Value [kΩ]	Oscillator Signal Pulse Width [%]	Field Strength Reduction [dB]
open	50	0
151	37	-3
59	25	-6
17	12	-12
10	6	-18
shorted	0	∞

CAUTION

When using pulse widths smaller than 50%, the RA-RFM transmitter power stage works less efficiently. This leads to an increased power dissipation and thus to a higher temperature of the transmitter power stage. Ensure that the antenna resonance voltage does not exceed 200 Vp when the selected oscillator signal pulse width setting is smaller than 25%.

Note: The pulse width for an oscillator signal pulse width setting of 5% and smaller is extremely short. The pulse response of the RA-RFM transmitter power stage to this short pulse is different for each unit. In order to have reproducible field strength values for different RA-RFMs, it is not recommended to use the smallest pulse width setting.

Threshold Level Adjustment

The RA-RFM has a built-in receive signal field strength detector with the output signal RXSS- and an on-board potentiometer (R409) to adjust the threshold level of field strength detection. The digital output RXSS- is used for wireless synchronization of two or more reading units. This is necessary to ensure that if more than one reading unit is in an area, they do not interfere with each other. The Control Module software monitors the RXSS- signal to detect whether other reading units are transmitting. The Control Module can operate the transmitter of the RA-RFM such that the reading units either transmit simultaneously or alternately. In this way the read cycles of each of the reading units occur at the same time or at secure different times. Depending on the antenna type used and the local noise level, the RXSS- threshold level has to be adjusted. This needs to be done after the antenna has been tuned to resonance. It is recommended to use a small screwdriver to adjust the RXSS- threshold level. The R409 potentiometer is located on the upper side of the RA-RFM board near connector switch SW1. Turning the potentiometer all the way clockwise (right-hand stop), results in minimum threshold sensitivity, i.e. the RXSS- signal will be activated at high receive field strength. This is the default position and can be used for standard gate antennas. It may be necessary to increase the sensitivity when using ferrite core antennas. If there is high noise level in the area, it is necessary to adjust the RXSS- threshold level.

Adjust the RXSS- threshold level as follows:

1. Turn the RXSS- threshold level potentiometer fully counter-clockwise (left-hand stop).
2. Deactivate the transmitter by connecting pin 1 to pin 3 of connector J2 (using a jumper).
3. Ensure that no other reading units are transmitting, by connecting pin 1 to pin 3 of connector J2 (jumper) of all other RA-RFMs in the area.
4. Monitor the voltage at RXSS- output pin with a voltmeter or an oscilloscope.
5. Turn the RXSS- threshold level adjustment potentiometer on the RA-RFM clockwise, until the RXSS- output is just statically inactive. "Statically" means no voltage spikes present on the RXSS- signal. 'Inactive' means that the receive signal strength is below the RXSS- threshold level and not triggering RXSS- (the RXSS- output voltage remains > 4 V).
6. Remove all jumpers connected to J2.

Note: Reducing the RXSS- threshold level sensitivity (turning the potentiometer clockwise), reduces the sensitivity of the built-in receive signal strength detector. This has the effect that the distance for wireless detection of other transmitting reading units is decreased, leading to reduction of wireless synchronization distance. The wireless synchronization distance between two reading units is normally about 15 meters for two aligned stick antennas (RI-ANT S02) with maximum receive field strength detection sensitivity.

When the RXSS- threshold level is adjusted such that it is too sensitive, then the RXSS- output is constantly active (i.e. low RXSS- output level). Therefore a Control Module assumes that another reading unit is transmitting and continually tries to synchronise to this other reading unit. As a result, the reading repetition rate decreases from approximately 10 down to 5 readings per second. This reading unit can additionally no longer synchronize to other reading units, causing interference with other reading units and reading at all reading units becomes impossible.

The RXSS- threshold level must be adjusted individually for every RA-RFM and reading system antenna. In addition, the RXSS- threshold level must be individually adjusted to the local noise level in the application area where the antenna is used.

As high noise levels mean that the RXSS- threshold level must be adjusted to a less sensitive value, it is recommended to reduce the local noise level in order to have high synchronization sensitivity and a long reading distance.

The RXSS- threshold level must be adjusted so that no spikes occur on the RXSS- signal output since these lead to an incorrect synchronization function. An oscilloscope should therefore be used when adjusting the threshold level.

The Antenna Tuning Indicator (RI-ACC-ATI2) accessory can be used to adjust the RXSS- threshold level, since this device automatically switches the transmitter off and has an internal spike extension circuit, causing the RXSS- threshold level to be adjusted such that no spikes occur on the RXSS- output.

Transmitter Carrier Phase Synchronization (CPS)

In some applications it is necessary to use several charge-up antennas close to each other. Under these circumstances, the magnetic charge-up fields generated by different antennas superimpose on each other and may cause a beat effect on the magnetic charge-up field, due to the slightly different transmit frequencies of different RA-RFMs.

The impact of this effect depends on three factors:

1. Antenna size:
   The larger the size of the antennas, the further the distance between the antennas must be, so that this effect does not occur.
2. Magnetic field strength:
   The stronger the generated magnetic field strength, the further the distance between the antennas must be such that the effect does not occur.
3. Orientation and distance between antennas:
   Increasing the distance between antennas decreases the impact of this effect.

Note: Putting two antennas close together also changes antenna inductance, so that the antennas may no longer be tuneable to resonance.

If several antennas are used close to each other, a check should be made to determine if the charge-up field strength changes regularly (i.e., beat effect). This may be checked by verifying the antenna resonance voltage with an oscilloscope. If the antenna resonator voltage changes periodically by more than approximately 5% of the full amplitude, it is appropriate to use wired transmitter carrier phase synchronization.

In addition, the distances given in Table D-1 can be used as a guideline to determine when it is necessary to cross-check for beat effect. If these distances are less than the value given in Table D-1, a check for beat effect should be made. The values given refer to the distances shown in Figure D-1 and are valid for maximum charge-up field strength.



Figure D-1. Distance Between Antennas (Top View)

Table D-1. Maximum Distances Between Antennas

Antenna type	Distance D1 [m]	Distance D2 [m]
RI_ANT_S02 <=> RI_ANT_S02	0.8	1.0
RI_ANT_G01 <=> RI_ANT_G01	1.7	1.5
RI_ANT_G02 <=> RI_ANT_G02	1.3	1.0
RI_ANT_G04 <=> RI_ANT_G04	2.0	1.7

This effect will not occur if the transmitters of different RA-RFMs are operated from the same oscillator signal. This is the reason why the pulse width modulated oscillator signal is accessible at the connector J1.

Configuration

Master or Slave setting of a RA-RFM is determined by switch 1 position 1 (SW1/1). If this is in the ON position, the RA-RFM is a MASTER, if in the OFF position, it is a SLAVE. When a RA-RFM has been configured as a master, then J1 pin 12 of this unit should be connected to J1 pin 16 of the slave units to allow the master oscillator output (CPS_OUT) to drive the slave oscillator inputs (CPS_IN). The logic ground (e.g., J1 pin 1) of both master and slave units should be connected together.

CAUTION

Use overvoltage protection components at the CPS connector for CPS lines between 0.5m and 5m.

Note: When using the transmitter Carrier Phase Synchronization feature, it is absolutely necessary that the read cycles of each of the different Control Modules are synchronized. When the transmitter of the oscillator MASTER RFM is not activated by its Control Module, the oscillator signal output of the oscillator MASTER RFM is disabled. This means that all the oscillator SLAVE RFMs have no transmitter oscillator input signal and thus none of the oscillator SLAVE RFMs are able to transmit.

Refer to the Hardware and Software Manuals for the TI-RFid Control Modules for more information about the necessary wiring and settings for synchronization of the RA-RFM when using transmitter Carrier Phase Synchronization (CPS).

If an application requires more than one RA-RFM to be used, or a longer Carrier Phase Synchronization line than that specified in Chapter 2 must be used, it is necessary to drive the pulse width modulated oscillator signal via a differential interface such as an RS422 interface.

Noise Considerations

Noise can have a negative effect on the receive performance of the RA-RFM. There are two different kinds of noise: radiated and conducted. Their characteristics are shown in Table E-1.

Table E-1. Characteristics of Radiated and Conducted Noise

	Radiated Noise	Conducted Noise
Source	Inductive parts for example: deflection coils, motor coils.	Power units, for example: motors, switched mode power supplies. Can be seen as voltage spikes or ripple voltage.
Path	Via magnetic fields.	Galvanically conducted via all cables (supply and interface) connected to the RA-RFM.
Effect	Disturbs receive function by magnetic interference with signal from transponder at the antenna.	Leads to malfunction and reduced sensitivity of receiver circuitry due to, for example, interfered supply voltage. Conducted noise can also cause radiated noise.

Note: The RA-RFM has a built-in function for suppression of common mode noise coupled to the antenna.

Method for detecting and distinguishing between noise types:

The principle of this procedure is to eliminate any conducted noise from the supply and all interface lines. In order to do this test the RA-RFM must be powered from a battery (for example: 9 V, 20 mA) in order to eliminate any conducted noise from a power supply. Conducted noise via the interface lines is eliminated for this test by simply disconnecting all interface lines to the RA-RFM. The measurement criteria for low noise is the amplitude of the receive signal strength detector of the RA-RFM.

The test pin RSTP at connector J1 pin 10 carries an analog output voltage indicating the receive signal strength. This voltage should be measured in combination with the antenna RI-ANT-G02. The necessary set-up for this test is shown in Figure E-1. This configuration operates the RA-RFM from a battery and has no interface line connected.

As the transmitter is switched off in this configuration, a normal battery may be used. A low noise level is indicated by an RSTP voltage of less than 1.0 VDC when using antenna RI-ANT-G02.

Note: Both noise types can be either differential or common mode noise. Use common mode noise filters (for example: a BALUN transformer) to reduce common mode noise and use selective filters to reduce differential noise.

The following procedure for testing for noise impact should be implemented when the normal set-up for the RA-RFM and antenna gives bad reading distances, even though the antenna is correctly tuned for sufficient transponder charge-up.

Try the configuration shown in Figure E-1. If this configuration shows bad noise conditions (RSTP voltage more than approximately 1.0 VDC) then the problem is radiated noise.

Eliminate noise sources or try special antennas (e.g., noise-balanced antennas).

1. When the configuration of Figure E-1 shows good noise conditions (RSTP voltage less than 1.0 VDC) then the problem is conducted noise.
2. Change the configuration so that the interface lines are again connected to the RA-RFM with the transmitter still switched off. If the RSTP voltage now indicates bad noise conditions, the conducted noise is coming via the interface lines.
3. Try to eliminate the noise on the interface lines. See Appendix F, Over Voltage Protection.
4. When the configuration above (interface lines connected) shows good noise conditions (RSTP voltage less than 1.0 VDC), then the problem is conducted noise via the supply lines.
5. Try to eliminate the noise on the supply lines. See Appendix F, Over Voltage Protection.

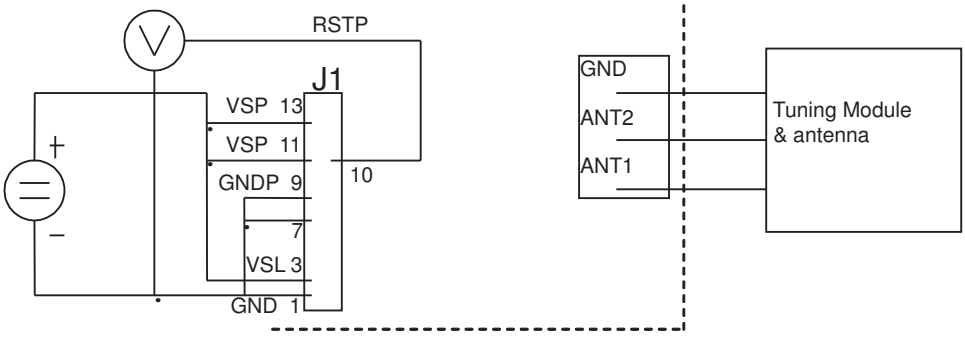


Figure E-1. Noise Testing Configuration

Over Voltage Protection

For applications where there is a risk that voltage spikes and noise are on the lines to the RA-RFM, additional protection circuitry and filters must be added. A proposal on how this may be achieved is shown in Figure F-1, and this circuit may be used as a guideline for protection circuitry. This may not be sufficient for all applications, however, and must be checked individually when necessary.

1. The supply input has to be protected against voltage spikes. R1 and D1 fulfil this purpose. Zener diode D1 clamps the voltage spikes to 18 volts so that the maximum allowed transmitter power stage supply voltage is not appreciably exceeded. For diode D1, type ZY18 is recommended, this type having a 2 W power dissipation. If a higher current is needed, dump type ZX18 may be used, this diode having a 12.5 W power dissipation.
2. The Common Mode Choke Coil and the capacitors C1 and C2 are used to reduce the conducted noise coming to the RA-RFM via the supply lines.
3. All input and output signals should be protected with 5.6 V zener diodes. The specified type can dump 1.3 W.
4. The coils L1 to L6 are ferrite beads and should put in series to the line when conducted noise is observed entering via the interface lines.
5. The varistor V1 protects the antenna circuit against high voltage induced at the antenna coil, for example by lightning. The type of varistor given is commonly available but may not be sufficient for protection in all cases.

Note: The zener diodes types given in Figure F-1 are commonly used types, not special suppresser diodes for fast voltage spike suppression. If the application requires it, special suppresser diodes should be used.

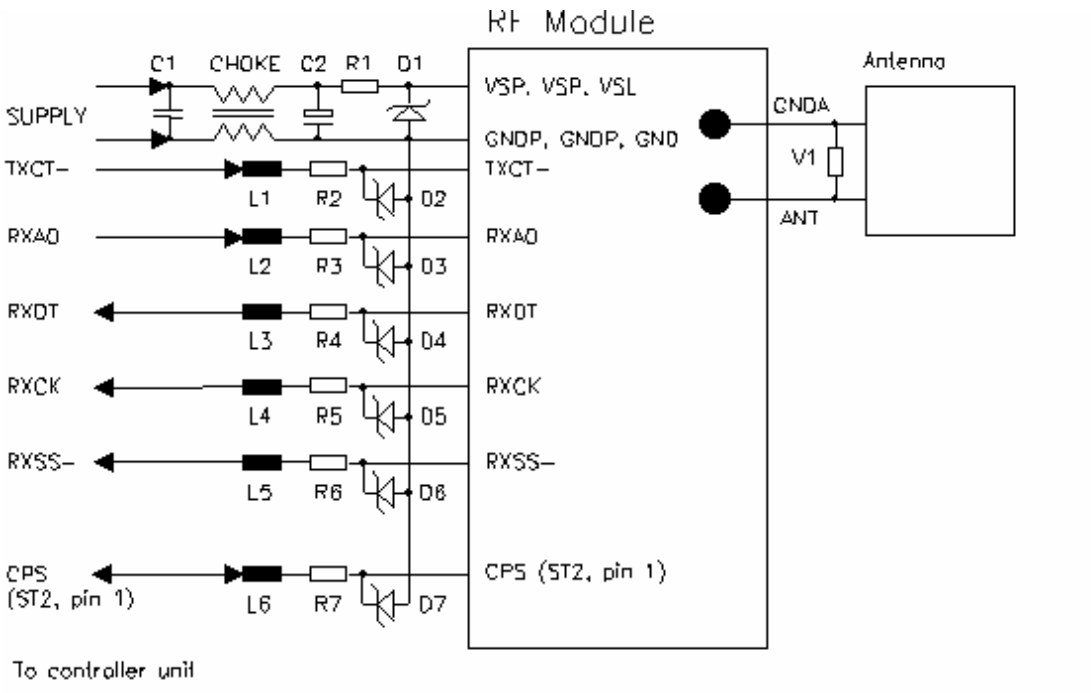


Figure F-1. Circuit for Overvoltage Protection

All components must be mounted close to the RA-RFM with the shortest possible wiring		
C1: 100 nF Ceramic	R1: 1 Ω / 2 W	V1: Varistor 420V; e.g, Siemens S10V-520K420
C2: 100 µF low ESR	R2, R3, R4, R5, R6, R7: 22 Ω / 0.25 W	
CHOKE: Common Mode Choke Coil L1, L2, L3, L4, L5, L6: Ferrite beads	D1: ZY18 resp. ZX18 D2,D3, D4, D5, D6, D7: BZX85C5V6	

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