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TIRIS Technology by Texas Instruments™

Radio Frequency module

RI-RFM-104B

Reference Manual

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This is the first edition of this manual, it describes the following equipment:

Radio Frequency module RI-RFM-104B

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FCC / PTT Regulations

The TIRIS RF module generates RF emissions at 134.2 kHz. The radiation of the fundamental and the harmonics will vary with the type of antenna and other devices or functions connected to the RF module.

Prior to operating the RFM together with antenna(s), power supply and a control module or other devices, the required FCC, PTT or relevant government agency approvals must be obtained.

Sale, lease or operation in some countries may be subject to prior approval by the government or other organizations.

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The TIRIS RF module product is considered by the Federal Communications Commission (FCC) to be a "subassembly". As such, no prior approval is required to import, sell or otherwise market the RF module in the United States. In order to form a functioning radio frequency (RF) device, the RF module must be connected to a suitable antenna, power supply, and control circuitry. **A radio frequency device <u>may not</u> be operated unless authorized by the FCC nor may a radio frequency device be marketed (i.e. sold, leased, imported, or advertised for sale or lease) without the prior grant of an FCC equipment authorization.**

FCC authorization to operate an RF device may take one of two forms: first, the FCC may grant the user an experimental license; second, the FCC may issue an equipment authorization permitting use of the RF device on an unlicensed basis. TI can assist the user in obtaining an experimental license that will cover a specific installation of the RF module in a specific site or sites. Experimental authorizations are appropriate to cover operations during the development of an RF device. A grant of equipment authorization (known as "certification") must be obtained from the FCC before RF devices are marketed or operated on a non development basis.

> DEVICES CONSTRUCTED FOR EVALUATION INCORPORATING THIS RF MODULE SHOULD BE OPERATED ONLY UNDER AN EXPERIMENTAL LICENSE ISSUED BY THE FCC AND MAY NOT BE MARKETED. BEFORE ANY DEVICE CONTAINING THIS RF MODULE IS MARKETED, AN EQUIPMENT AUTHORIZATION FOR THE DEVICE MUST BE OBTAINED FROM THE FCC.

Prospective marketers of devices containing this RF module are responsible for obtaining the necessary equipment authorization. Upon request TI can provide assistance in obtaining FCC approval to market devices incorporating this RF module.

WARNING

Care must be taken when handling the RF module. High voltage across the antenna terminals, at the tuning coil and some parts of the printed circuit board (PCB) could be harmful to your health. If the antenna insulation is damaged it should not be connected to the RF module.

CAUTION

This product might be subject to damage by electrostatic discharge (ESD), it should only be handled by ESD protected personnel at ESD secured workplaces.

The transmitter power output stage can only operate with a limited duty cycle. Please pay attention to this fact whilst performing the antenna tuning procedure.

The ground pins GND and GNDP have to be connected externally to avoid damage of the RF module.

1. Introduction

1.1 Purpose

This document describes how to install and use the Series 2000 Reader System Radio Frequency module: RI-RFM-104B.

1.2 Scope

This document is applicable for TI internal and customer use.

1.3 Product Description

The RF module (RFM) is an integral part of TIRIS, together with a control module, and an antenna it is used for wireless identification of TIRIS transponders.

The main task of the RF module is to send an energizing signal via the antenna to initialize the transponder, to demodulate the received identification signal and then send the data together with clock signals to a control module. It is also used to send programming data to Read/Write and Multipage transponders.

The RFM is tuned to resonance with the antenna by adjusting the inductance of the tuning coil at the RFM's RF output stage.

1.4 Product Option Coding

For product and ordering numbers of RF module, antennas, control modules and combinations of these, please contact your regional TIRIS Application Center.

1.5 About this Document

This Document contains the following parts:

Section 1: Introduction. An introduction to this document and general information about the system and the RF module (this part).

Section 2: Electrical Description. A short description of all features of all functional blocks of the RF module (transmitter, antenna, receiver). It also lists all the connector signals and describes all options which can be selected on the RF module by solder jumpers.

Section 3: Specifications. A list of all electrical and mechanical parameters of the RF module.

Section 4: Installing the RF module. A detailed description of the power supply requirements, the antenna characteristics, how to tune the antenna to resonance, how to expand the antenna inductance tuning range and how to adjust the antenna charge-up field strength and the threshold level for wireless synchronization.
In addition it describes the features and usage of the options of this RF module: transmitter carrier phase synchronization and receive multiplexer.

Appendices. Information about the currently available TIRIS standard antennas, showing basic antenna parameters. A summary of all the available options selectable by solder jumpers. Information about the current PTT/FCC regulations. Some "Do's and Don'ts, and a short form of an Installation Guide (independent part to take away).

1.6 Conventions

Certain conventions are used in order to display important information in this specification, 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 RF module.

***Note**: Indicates conditions which must be met, or procedures which must be followed, to ensure proper functioning of the RF module.*

HINT: Indicates information which makes usage of the RF module easier.

2. Product Function

2.1 General

The RF module contains all the analog functions of a TIRIS reading unit that are needed to initialize a TIRIS transponder and to detect its return signal. The RF module delivers DATA and CLOCK signals for identification data processing. The RF module also sends the necessary programming signals to Read/Write transponders and or Multipage transponders.

The data input and output lines, connected to a data processing unit (for example: TIRIS Series 2000 control module, or a customer designed control unit), are Low Power Schottky TTL and HCMOS Logic compatible.

There are five connectors on the RF module, they are:

ST1 which is used to connect the supply voltages and interface signal lines to the controller unit

ST2 which is used for transmitter Carrier Phase Synchronization (CPS)

ST3 this connector is not mounted on the L-tune RF module.

ST4 which is used to connect the (optional) Antenna Tuning Indicator (ATI) which can be used for easy antenna tuning during installation.

ST5, ST6 which are used to connect the receive-only antennas

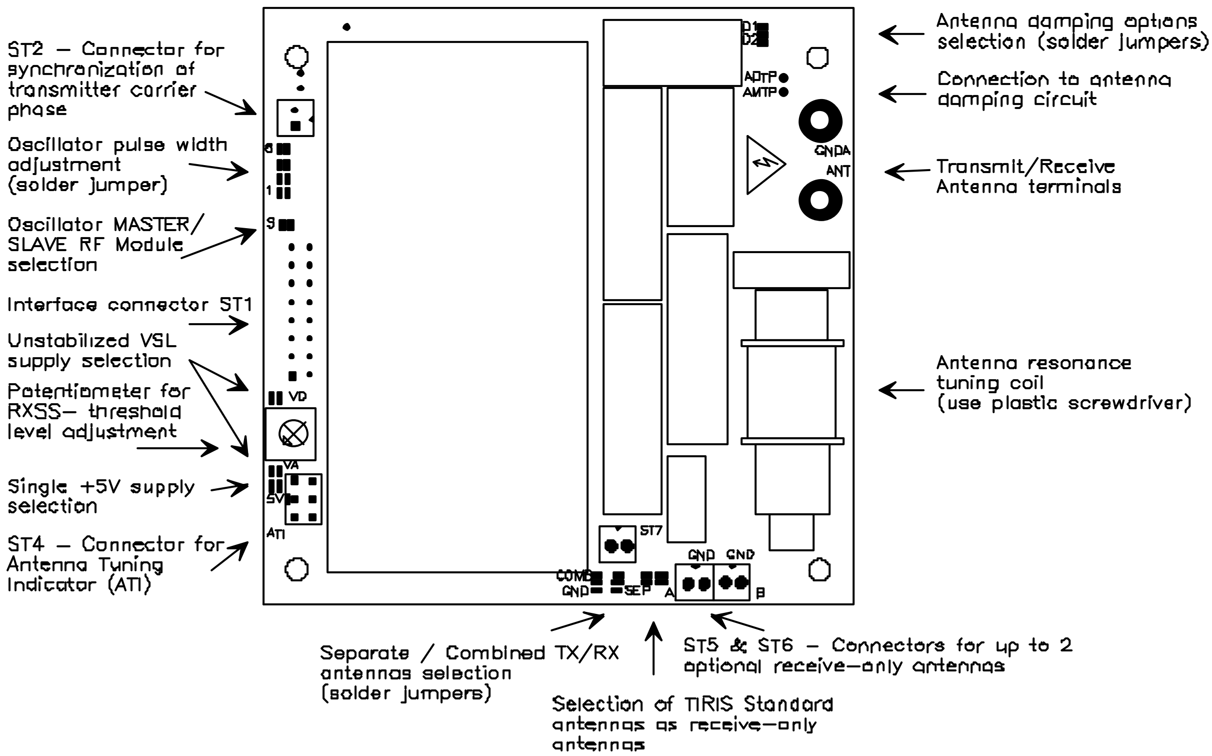


Figure 1: Top View

The transmit/receive antenna is connected to the RF module by the two M3 screw-connectors: ANT and GNDA.

The RF module can be mounted by means of the four M3 mounting bolts on the underside of the RF module.

A layout of the RFM viewed from the top is shown in figure 1. A block schematic of the RF module is shown in figure 2. The RFM is described at block diagram level in the following sections (2.1.1 to 2.1.3).

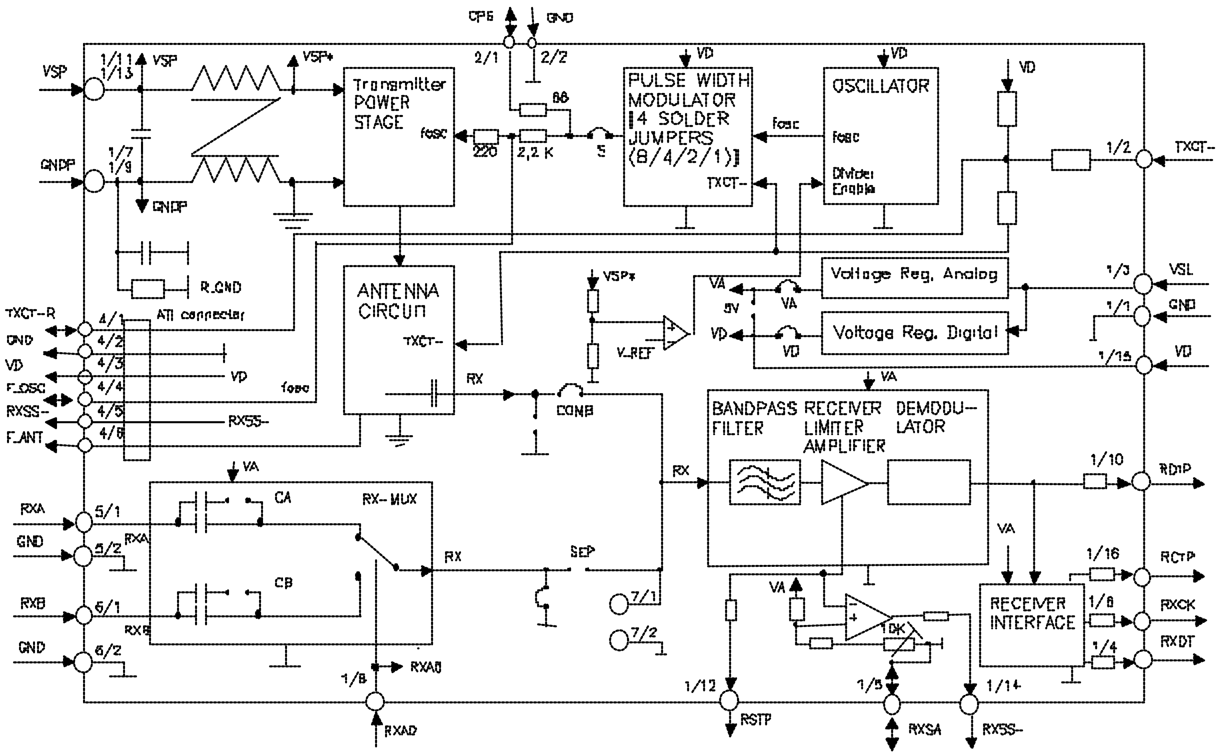


Figure 2: Block Diagram

2.1.1 Transmitter

The RF module has two built-in voltage regulators to separately supply the logic part and receiver part with regulated voltage. The unregulated input supply voltage for these regulators is connected to VSL and GND pins.

Optionally, the logic and receiver parts can both be connected to a external regulated +5 V supply. When this method is used, two solder bridges on the RF module must be opened and one closed. Then the regulated +5 V supply must be connected to pin VD. See also figures 1 and 2.

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

As the transmitter power stage needs a regulated supply voltage in order to meet FCC/PTT regulations and as there is no stabilization on the RF module, the supply voltage for the transmitter power stage must be **externally** regulated.

Note: *The RF module must not be supplied by Switched Mode Power Supplies (SMPS). This is because most SMPS operate at frequencies around 50 kHz. The harmonics of the generated field can interfere with the TIRIS receiver. Therefore only use linear power supplies, or SMPS with* ***a fundamental operating frequency of 200 kHz or higher.***

The ground pins for the logic part and the transmitter are not connected internally, in order to avoid problems with possibly high resistive GNDP pins and in order to have higher flexibility with long supply lines. The pins GND and GNDP must be connected to each other externally. For more details, refer to Section 4: "Installing the RF **module**".

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 (see also figure 2).

The regulated transmitter power stage supply can vary in the range from +5 V to +14 V. This means that the supply lines VSP and VSL can be connected together, when the supply voltage is more than +6 V (for details refer to Section 3: "Specifications").

With the option described above, the complete RF module can be supplied from a single +5 V regulated supply.

The transmitter frequency is generated by a crystal controlled oscillator. The high crystal frequency is divided to get the transmitter frequency of 134.2 kHz.

The oscillator has a protection feature for the transmitter power stage against current overload of the transmitter power stage. When the transmitter power stage supply voltage VSP accidentally exceeds the 'Absolute Maximum Ratings' (see also Section 3: "Specifications"), the oscillator is disabled and thus the transmitter is switched off.

The transmit frequency (134.2 kHz) from the oscillator is fed to the Pulse Width Modulator (PWM). By means of solder jumpers, the PWM can set the pulse width ratio between 3% and 50% in 16 binary steps. For an example of two different oscillator signal pulse widths see figure 3. Decreasing the 134.2 kHz frequency pulse width ratio decreases the generated transmit (charge-up) field strength.

Thus it is possible to adjust the generated field strength by selecting different pulse width ratios. For more information about setting the solder jumpers, see both figure 3 and Section 4: "Installing the RF module".

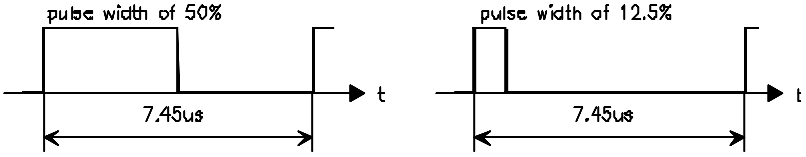


Figure 3: Pulse Width Examples

The PWM and thus the transmitter is activated by connecting the TXCT- signal to ground. The TXCT- input has an internal pull-up resistor. For TXCT- signal input configuration, refer to Section 2.2 "RFM Connectors and Solder Jumpers". The TXCT- signal has to be active for a certain minimum time (for precise value refer to Section 3. "Specifications").

CAUTION: The RF module must not be operated in continuous transmit mode. For details of this and other parameters refer to Section 3: "Specifications".

The pulse width modulated transmit frequency is fed to the transmit power stage via another solder bridge and resistors, which are used for the option of transmitter Carrier Phase Synchronization (CPS). See figures 1 and 2.

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

This effect will not occur when the transmitters feeding these different antennas are all driven by the same oscillator. For this purpose the pulse width modulated transmit frequency is accessible at the connector ST2. All the RF modules to be driven by one oscillator must have their ST2 connectors connected together. An additional solder bridge selects whether the internal oscillator or the external oscillator signal is used. When the solder bridge 'S' is closed, the internal oscillator is used and the RF module is referred to as an oscillator MASTER RF module. When the solder bridge 'S' is open, the external oscillator signal is used and the RF module is referred to as an oscillator SLAVE RF module (see also figure 1 and Sections 2.2.2.2 & 4.7).

Note: *Only one oscillator MASTER RF module (and up to five SLAVE RF modules) is allowed per synchronized system.*

Finally the pulse width modulated oscillator signal is fed to the transmitter power stage. The transmitter power stage amplifies the oscillator signal and feeds this amplified signal to the antenna circuit, to generate the charge-up field.

The antenna circuit is described in Section 2.1.2.

2.1.2 Antenna Circuit

A block diagram of the antenna circuit can be seen in figure 4.

The antenna circuit is a coil and capacitor resonating at the transmit frequency f_TX of 134.2 kHz. The resonator inductance consists of the tuning coil L_TUNE and the antenna coil L_ANT. The antenna coil L_ANT generates the magnetic charge-up field. Figure 5 shows a schematic of the antenna circuit.

The resonator capacitance consists of capacitor C1 parallel to capacitors C2, C3 and C_COUPLE, which are connected in series. Connecting capacitors in parallel and serial is necessary because of the high resonance voltage and the high current flow through the resonator.

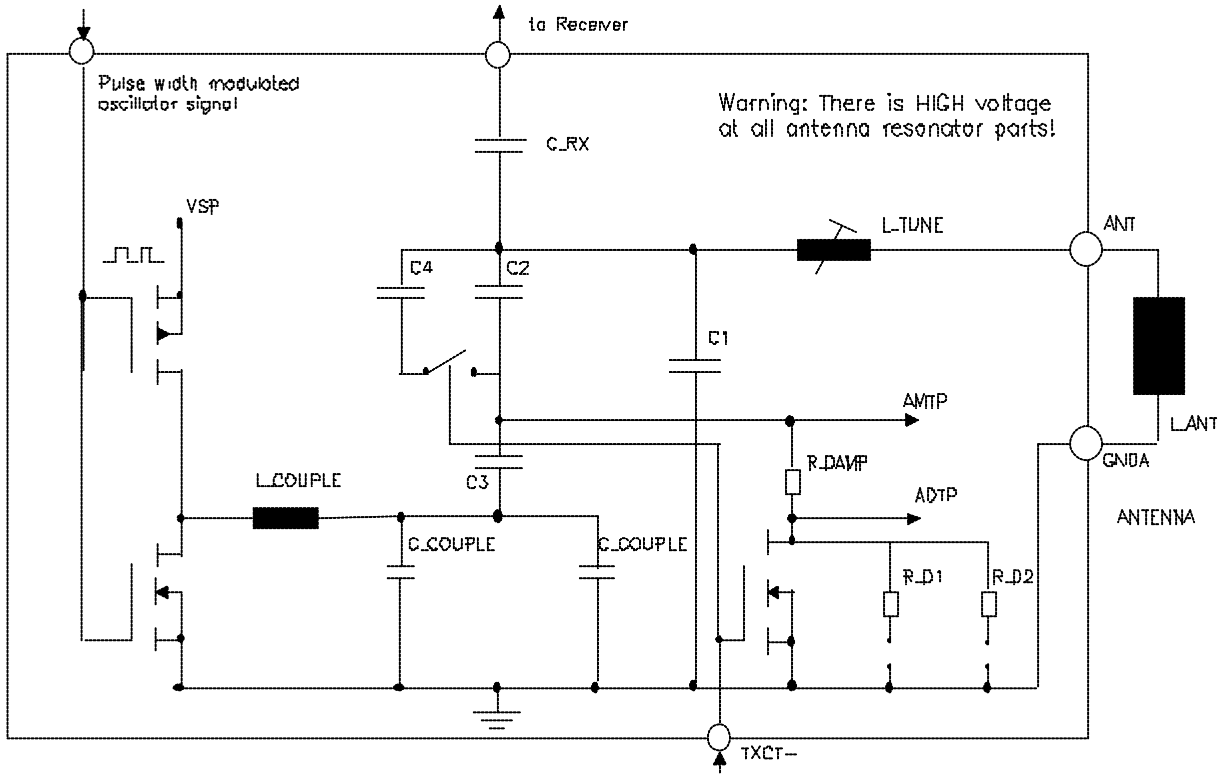


Figure 4: Antenna Circuit Block Diagram

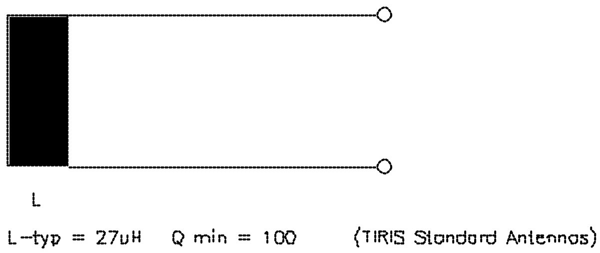


Figure 5: Standard Antenna

In order to get high resonance voltage and thus high charge-up field strength, the antenna circuit has to be tuned to resonance. For this purpose the tuning coil L_TUNE is used. This coil is connected in series with the antenna coil L_ANT and in this way it is possible to change the total inductance of the resonator.

The antenna circuit is tuned to resonance by screwing the ferrite core of the tuning coil L_TUNE in or out (see also figure 1). This must be done with a plastic screwdriver, as a metal screwdriver would affect the inductance of the coil which would lead to incorrect tuning. Therefore please use only the plastic screwdriver which is delivered with the RF module. For information about how to monitor the resonance tuning refer to Section 4: "Installing the RF Module".

HINT: It is strongly recommended to use the TIRIS Antenna Tuning Indicator (ATI), for simple antenna resonance tuning monitoring.

WARNING

Care must be taken when handling the RF module. HIGH VOLTAGE across the antenna terminals and all antenna resonator parts could be harmful to your health. If the antenna insulation is damaged it should not be connected to the RF module.

The antenna resonator is connected to the Power MOS FETs of the transmitter power stage via a coupling coil L_COUPLE.

The antenna resonator has to be damped after the transmit burst, when the RF module is switched to receive mode. A MOS FET is used to do this, the MOS FET connects the damping resistor R_DAMP in parallel to the antenna resonator. In addition, when the damping circuit is active, the capacitor C4 is disconnected in order to adapt the antenna resonance frequency for proper filter bandwidth.

In cases, when low field strength for the larger antennas is necessary, the antenna resonator can additionally be damped by connecting either damping resistor R_D1 or R_D2 to the antenna resonator. This can be done by closing the solder bridges D1 or D2 (see also figure 1).

The antenna circuit is also used for receiving the signal from the transponder. The received signal is coupled via the capacitor C_RX to the receiver circuit, which is described in Section 2.1.3.

Note: *The coupling coil L_COUPLE of the transmitter power stage is operated at high magnetic flux. Because of the high level of magnetic flux change, it is possible that this coil makes a significant audible noise. This can also occur with antennas that have ferrite cores (TIRIS standard stick antennas RI-ANT-S01 and RI-ANT-S02).*

2.1.3 Receiver

The received signal 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 capacitive coupled to the receiver.

There are two options for the receive antenna. Either a combined transmit/receive antenna, or special receive-only antennas are used. The antenna type selection is done by configuring solder bridges (see also figures 1 and 2). For combined transmit/receive antenna, the solder bridge 'COMB' has to be closed. For separate transmit and receive antennas, the solder bridge 'SEP' has to be closed, in order to connect the receive multiplexer to the receiver. For both jumpers the unused input path has to be grounded by solder bridges (for details refer to Section 2.2).

When using the receive multiplexer, the active receive channel is selected by the input signal RXA0 (see figure 2). This select input has an internal pull-up resistor, so that receive channel A is selected as default, when RXA0 is not connected. Connecting RXA0 to ground selects receive channel B.

The combined transmit/receive antenna is a coil as can be seen in figure 5.

The special receive-only antennas are factory tuned resonators with a certain resonance frequency. These antennas can only be used for receive function. They do not work for charge-up function.
A block schematic of a receive-only antenna is shown in figure 6.

There is another alternative for receive-only antennas. Standard TIRIS transmit/receive antennas can also be used as receive-only antennas, if they are built up as tuned and damped resonator. A block schematic of a standard TIRIS antenna for use as a receive-only antenna is shown in figure 7. For using this type of antenna, additional solder jumpers have to be closed on the RF module (see also figures 1 and 2). For more details refer to Section 4: "Installing the RF Module".

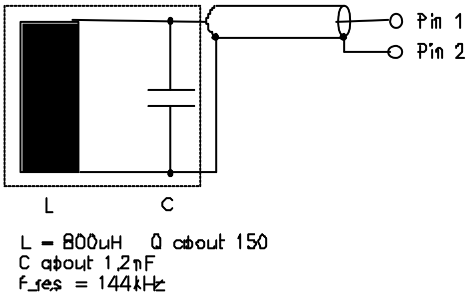


Figure 6: Standard Receive-only Antenna (RI-ANT-S04C)

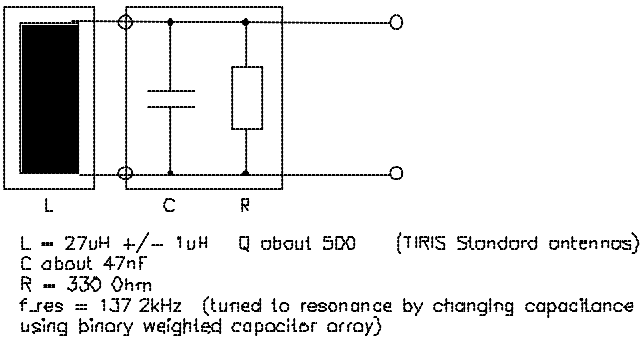


Figure 7: Standard TIRIS Antennas used as Receive-only

The received signal from either antenna is fed to the receiver. The receiver contains a selective bandpass filter with a typical -3 dB bandwidth of 22 kHz. After the bandpass filter, the signal is amplified by the limiter amplifier and then demodulated. The receiver interface converts the demodulated signal to the Low Power Schottky TTL and HCMOS Logic compatible data signals RXCK and RXDT which contain the data received from the transponder.

The signal RXCK is the reference clock signal to decode the RXDT data stream. The RXCK signal changes from 'low' to 'high' level in the middle of each data bit and the RXDT signal is valid before and after this positive slope only for a certain time window (for more details refer to Section 3: "Specifications" and to the RF Module Sequence Control Preliminary User Specification). The output configuration of the RXDT and RXCK signals is shown in figure 8.

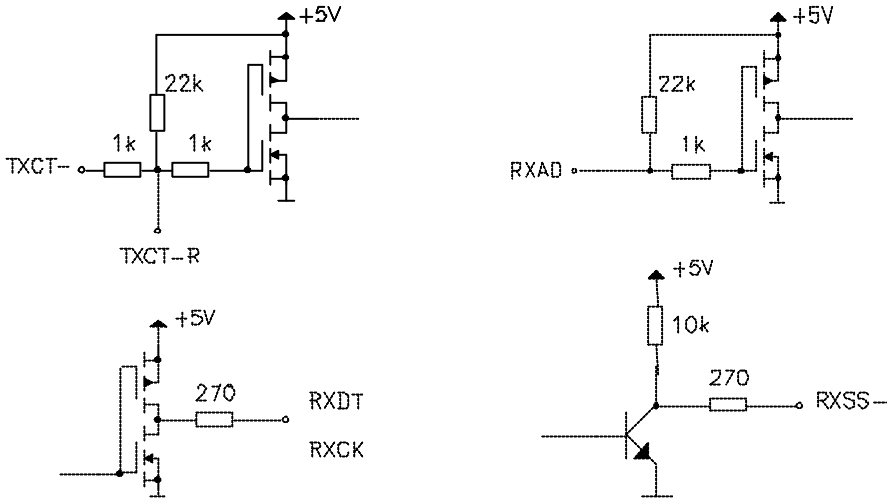


Figure 8: Output Configurations for Data and Clock Signals

All input and output signals have protecting series resistors.

The receiver also has a built-in RF receive signal strength detector. The receive signal strength is indicated by the digital output RXSS-. RXSS- becomes active, when the received RF signal strength exceeds a defined level. This threshold level can be adjusted with a potentiometer on the RF module. The potentiometer is located near connector ST1 (see figures 1 and 2).
The RXSS- output is used for detection of other transmitting reading units and thus can be used for wireless synchronization of several reading units.

2.2 RFM Connectors and Solder Jumpers

2.2.1 Connectors and Signal I/O Configurations

The bottom view of the RF module is shown in figure 9. The connector ST1 is accessible from the underside. ST1 is the 16-pin module connector, this carries the supply voltage lines, the data, and the control lines.

Table 1 lists the pin functions for connector ST1. The connector type is AMP Latch 281273-1, 16p.

The top view of the RF module is shown in figure 10. The connectors ST2, ST4, ST5, ST6, and the antenna terminals are accessible from the top.

Connector ST2 is the 2-pin connector for transmitter Carrier Phase Synchronization, connector ST4 is used to connect the Antenna Tuning Indicator for easy antenna resonance monitoring, ST5 and ST6 are used to connect the receive-only antennas, and GNDA and ANT are the antenna connectors.

Table 2 lists the pin functions for connector ST2. The connector type is AMP-Quick 828548-2, 2p.

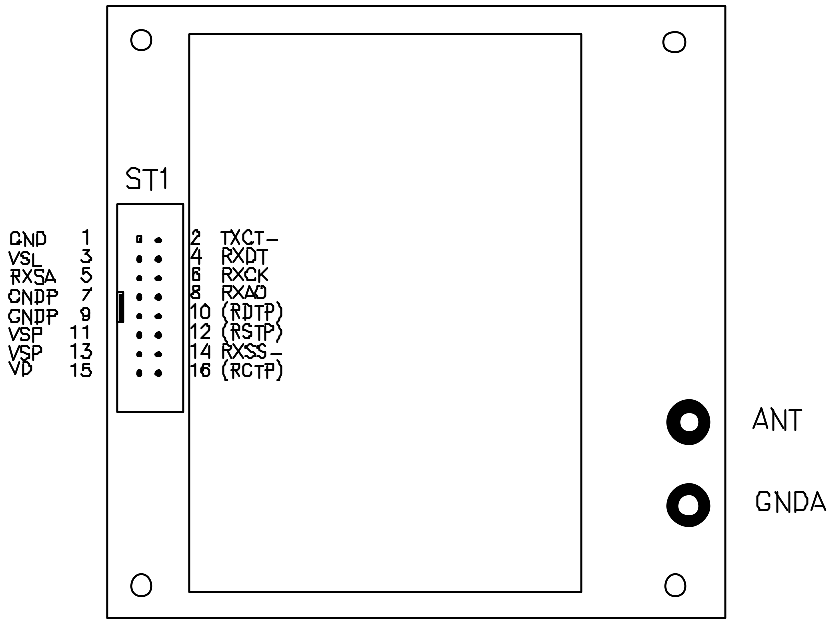


Figure 9: Bottom View

Table 3 lists the pin functions for connector ST4: The connector type is a 6-pole, 2 row pin connector with 2.54 mm pin spacing.

Table 4 lists the pin functions for the antenna connectors: Metric screws M3 must be used.

Table 5 lists the pin functions for the receive-only antenna connectors ST5 and ST6. The connector type is AMP-Quick 828548-2, 2p.

The basic configuration of the input signals TXCT- and RXA0 and output signals RXDT and RXCK is shown in figure 8 .

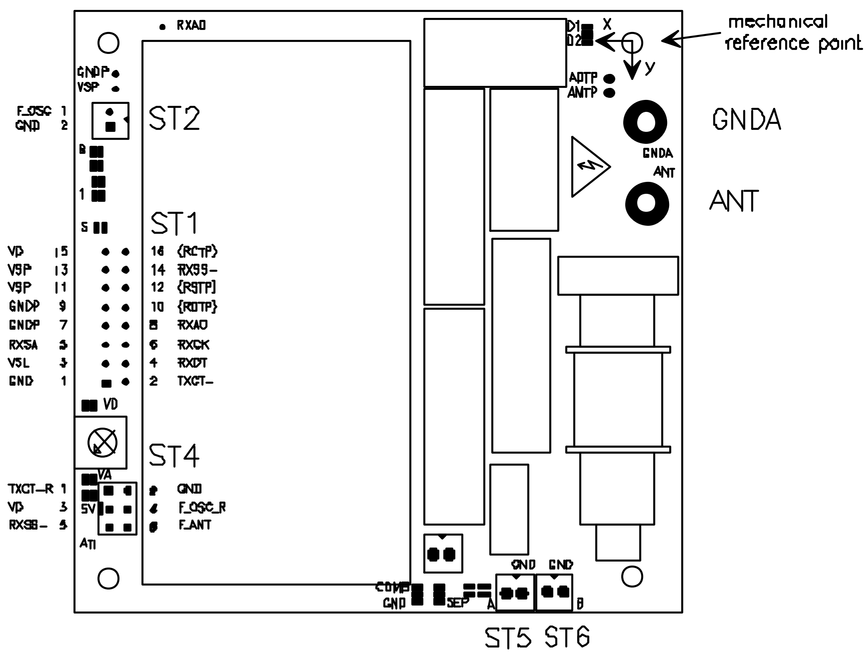


Figure 10: Top View with Connector Signals

Table 1: ST1 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	RXA0	IN	Receive multiplexer channel select signal (internal pull-up resistor selects Channel A as default)
9	GNDP	IN	Transmitter power stage ground
10	(RDTP)		Receiver test pin (no connection allowed)
11	VSP	IN	Supply voltage for transmitter power stage
12	(RSTP)	OUT	Receiver test pin (no connection allowed, exception see Section 4: "Installing the RF Module")
13	VSP	IN	Supply voltage for transmitter power stage
14	RXSS-	OUT	Receiver signal strength output (active low)
15	VD	IN/OUT	Internal regulated logic supply voltage output / externally regulated logic supply voltage input
16	(RCTP)		Receiver test pin (no connection allowed)

CAUTION: The transmitter ground pins GNDP and logic ground pin GND must be connected together externally. Otherwise the RF module may be permanently damaged.

Table 2: ST2 Pin Functions

Pin#	Signal	Direction	Description
1	F_OSC	IN/OUT	Pulse width modulated transmitter oscillator signal: - output for oscillator MASTER RF module - input for oscillator SLAVE RF module
2	GND	IN	Logic ground

Table 3: ST4 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 4: Antenna Connectors

Signal	Description
ANT	Antenna resonator (capacitor side)
GNDA	Antenna resonator ground

Table 5: ST5, ST6 Pin Functions

Pin#	Signal	Direction	Description
1	RXA,RXB	IN	Receive-only antenna resonator
2	GND	IN	Ground

2.2.2 Solder Jumpers

The different options, which can be selected by solder jumpers are described in the following Section.

CAUTION: When closing or opening the solder jumpers, do not use solder temperatures higher than 300 degrees Celsius for longer than 2 seconds. Also, avoid changing the solder jumper settings more than 10 times as there is a risk that the copper lifts off the PCB.

2.2.2.1 Regulated +5 V Logic Supply

The default setting of the jumpers is for an unregulated supply voltage for the logic part to be connected to the RF module. For this configuration, the solder jumpers 'VA' and 'VD' are closed and solder jumper '5V' is open. 'VA', 'VD' and '5V' is printed on the RF module PCB close to these solder jumpers (see figure 11). The unregulated supply voltage for the logic must be connected to pin VSL and GND (pin 3 and 1 of connector ST1).

If the logic part of the RF module is to be supplied by a regulated +5 V supply, the solder jumpers 'VA' and 'VD' have to be opened and solder jumper '5V' has to be closed. See also figure 12. The regulated +5 V supply has to be connected to pin VD and GND (pin 15 and 1 of connector ST1).

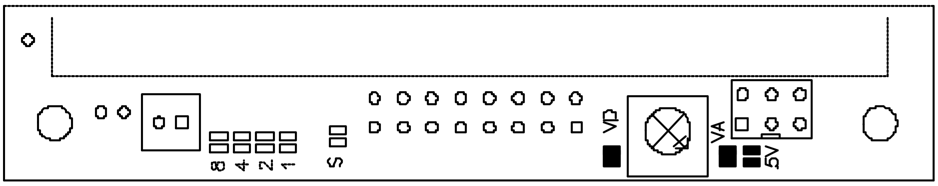


Figure 11: Jumpers VA & VD set for Unregulated Supply (Default)

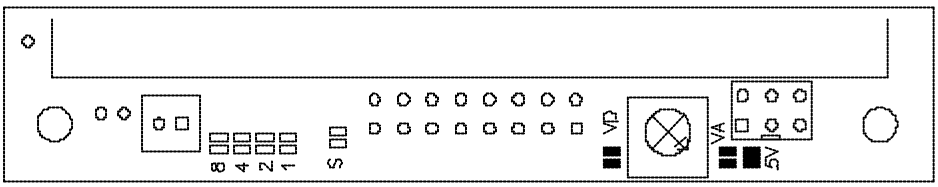


Figure 12: Jumpers VA & VD set for Regulated Supply

2.2.2.2 Carrier Phase Synchronization

As default setting the solder jumper 'S' for transmitter Carrier Phase Synchronization (CPS) is closed, thus configuring the RF module as an oscillator MASTER RF module. 'S' is printed on the RF module PCB close to this solder jumper (see also figure 13). The oscillator output signal is accessible at connector ST2.

To configure as an oscillator SLAVE RF module, the solder jumper 'S' must be opened, see figure 14. The oscillator input signal from the oscillator MASTER RF module has to be supplied to the connector ST2.

Note: *When jumper 'S' is open the RFM is configured as an oscillator SLAVE RF module, and if there is no oscillator signal input at connector ST2 the transmitter does not work.*

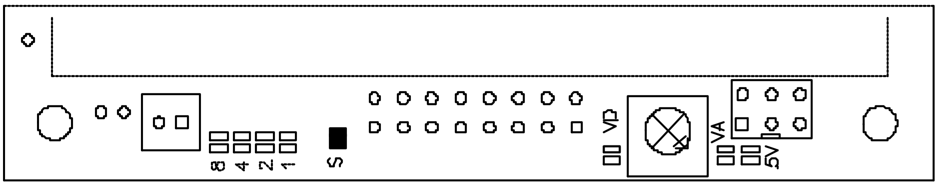


Figure 13: Jumper S set for Oscillator MASTER RF Module (Default)

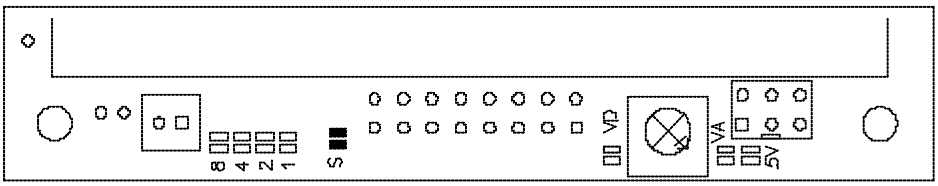


Figure 14: Jumper S set for Oscillator SLAVE RF Module

2.2.2.3 Pulse Width Modulation

The pulse width of the transmitter oscillator signal can be set by the four solder jumpers '8', '4', '2', '1' in 16 binary steps. '8' and '1' is printed on the RF module PCB close to the most significant (8) and least significant (1) solder jumpers. The four solder jumpers are arranged in ascending weight (see also figure 15). The oscillator pulse width determines the amplitude of the generated field strength. For more details refer to Section 4.5.1 "Adjustment of Oscillator Signal Pulse Width" and table 11. Figure 16 shows an example of solder jumper setting for 28% pulse width selection.

As default setting, all four solder jumpers are open, selecting 50% pulse width, which gives maximum field strength.

Note: *The pulse width setting of an oscillator SLAVE RF module does not affect the generated pulse width of this module. The pulse width of this oscillator SLAVE RF module is determined by the pulse width setting of the oscillator MASTER RF module.*

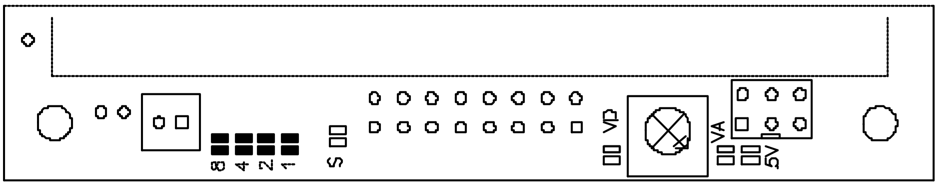


Figure 15: Oscillator Pulse Width Solder Jumpers (Default Configuration)

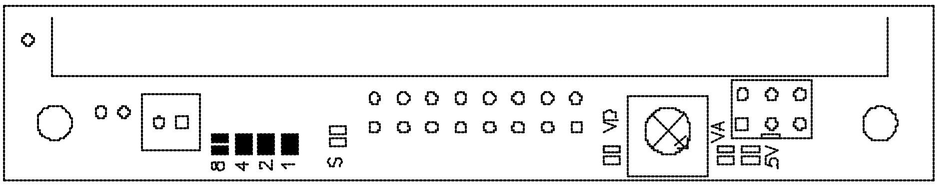


Figure 16: Example - Jumpers set for 28% Oscillator Pulse Width

2.2.2.4 Additional Antenna Damping

When a lower charge-up field strength is necessary for the larger antennas, there is the possibility to additionally damp the transmit antennas. This enables a lower transmit field strength, while the receiver parameters remain unchanged. For this purpose only one of the solder jumpers 'D1' **or** 'D2' can be closed (**never both!**). 'D1' and 'D2' is printed on the RF module PCB close to these solder jumpers. For location of solder jumpers see figure 17.

Solder jumper 'D1' is used in combination with the TIRIS standard gate antenna RI-ANT-G01C to achieve the field strength required by, for example: German PTT (see also figure 18). The optional damping resistor R_D1 gives an additional damping of typical 10 dB.

Solder jumper 'D2' is used in combination with the TIRIS standard gate antenna RI-ANT-G03C to achieve the field strength required by, for example: German PTT (see also figure 19). The optional damping resistor R_D2 gives an additional damping of typical 13 dB.

As default, both solder bridges are open.

CAUTION: These damping options can only be used together with the antennas RI-ANT-G01 and RI-ANT-G03. When using these damping options, the maximum allowed pulse-width is 40.5% (this corresponds to solder jumpers '8' and '4' open and solder jumpers '2' and '1' closed).

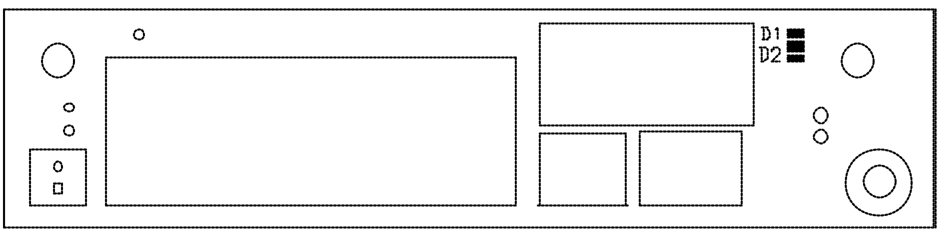


Figure 17: Antenna Damping Solder Jumpers (Default)

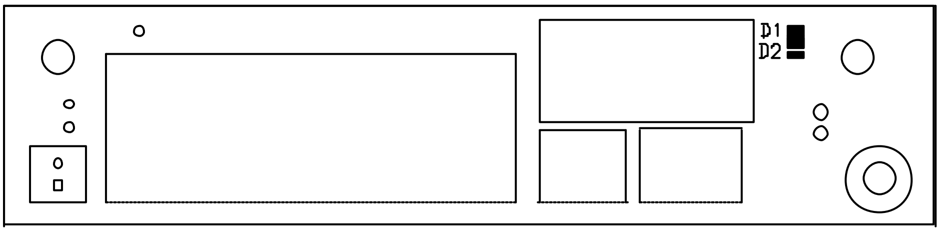


Figure 18: Example - Antenna Jumpers set for G01C (medium) Antenna

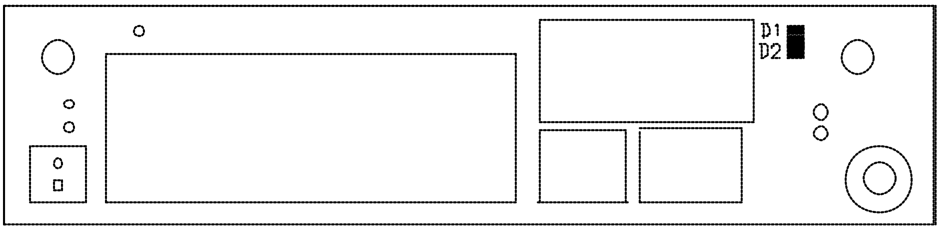


Figure 19: Example - Antenna Jumpers set for G03C (large) Antenna

2.2.2.5 Selection of Combined Transmit/Receive Antenna or Separate Antennas <u>(Receive Multiplexer)</u>

This RF module allows the use of combined transmit/receive antennas, or the option of separate transmit and receive antennas.

The combined transmit/receive antenna is connected to the antenna terminals ANT and GNDA. For the combined antenna the solder jumper 'COMB' must be closed and solder jumper 'SEP' must be grounded. 'COMB' and 'SEP' is printed on the RF module PCB close to these solder jumpers. For location see figure 20.

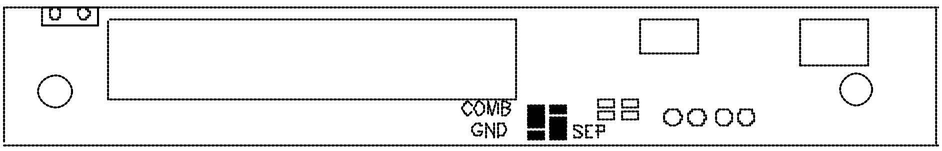


Figure 20: Combined Antenna Jumper Settings (Default)

For separate transmit and receive antennas, the solder jumper 'SEP' must be closed and solder jumper 'COMB' must be grounded. For details and connection of the receive-only antennas see also figure 21.

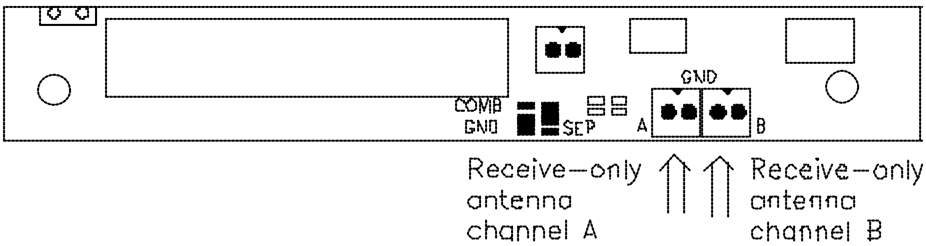


Figure 21: Separate Antenna Jumper Settings & Connecting Points

For more information on the receive multiplexer option refer to Section 4: "Installing the RF Module".

As default, combined transmit/receive antenna configuration is selected (solder jumper 'COMB' closed, solder jumper 'SEP' grounded as shown in figure 20).

2.2.2.6 Selection of Receive-Only Antenna Type

If the receive multiplexer option has been selected ('SEP' closed, 'COMB' grounded) there is an additional option of selecting one of two different types of receive-only antennas, which are used together with the receive multiplexer. The solder jumpers 'CA' and 'CB' are used for this purpose. See figure 22 for location of solder jumpers.

When the solder jumpers 'CA' and 'CB' are open, the TIRIS standard receive-only antenna RI-ANT-S04 must be connected to the receive multiplexer. This receive-only antenna is a factory tuned resonator (the antenna circuit is shown in figure 6). In order to connect the TIRIS standard antennas to the receive multiplexer, the solder jumpers 'CA' and 'CB' must be closed. Please note that these standard antennas must be connected in parallel to a resistor and capacitor in order to form the correct resonator (see also figure 7).

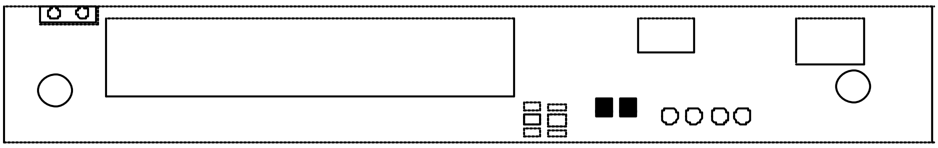


Figure 22: Antenna Jumpers set for TIRIS Standard Antennas as Receive-Only Antennas

As default, the TIRIS standard receive-only antenna RI-ANT-S04 is selected. This means that solder jumpers 'CA' and 'CB' are open.

3. Specifications

3.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)

Logic supply voltage	V_VSL	+26	V
Transmitter power stage supply voltage	V_VSP	+15	V
Supply current for transmitter power stage	I_VSP	1.5	A
Power input to transmitter power stage	P_VSP	20	W
Antenna resonance voltage	V_ANT	250	Vpeak
Output current of internal regulated logic supply voltage VD	I_VD	2.0	mA
Maximum voltage difference between pins GND and GNDP	delta-V	±0.5	V
Operating free-air temperature range for RI-RFM-104B	T_oper	-25 to +70	°C
Storage temperature range	T_store	-40 to +85	°C

Notes: *The maximum power input to the transmitter power stage is 20 W for a burst length of 50 ms followed by a pause of 20 ms.*

Free-air temperature: air temperature immediately surrounding the RF 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 absolute maximum ratings.

CAUTIONS:

Exceeding absolute maximum ratings may lead to permanent damage to the RF module. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

The RF module must not be operated in continuous transmit mode.

If the ambient temperature is less than +50 °C and power “ON” times other than the recommended 50 ms are used, the power “OFF” time must always be as long as or longer than the power “ON” time. However, the power “ON” time must be at least 15 ms and the power “OFF” time at least 20 ms.

To operate the RF module at ambient temperatures higher than +50°C, the maximum current consumption of the transmitter power stage has to be reduced according to the curve shown in figure 23

or

the number of transmit bursts per second must be reduced (for unchanged current consumption). Each transmit burst has to be followed by an "OFF" period, which is at least 3 times the transmit burst length (for example:
50 ms "ON" followed by 150 ms "OFF").

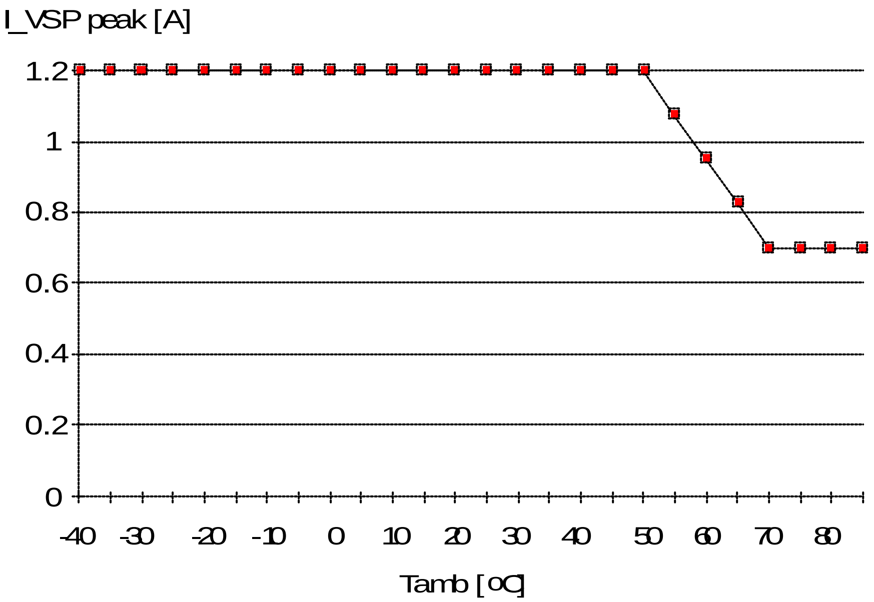


Figure 23: Maximum Current Consumption I_VSP
@ 50 ms power "ON" and 50 ms power "OFF"

3.2 Recommended Operating Conditions

at a free-air temperature of 25 °C

Symbol	Parameter	min.	typ.	max.	Unit
V_VSP	Supply voltage of transmitter power stage	5.0		14.0	V
I_VSP	Supply current of transmitter power stage			1.2	A
P_VSP	Power input to transmitter power stage (I_VSP * V_VSP)			16.8	W
V_ANT	Antenna resonance voltage			240	Vpeak
V_ANT-ATI	Minimum antenna resonance voltage for correct operation of ATI accessory	25			Vpeak
V_VSL	Supply voltage input for logic part	6.0		25.0	V
I_VD	External current load on internal regulated logic supply voltage output			1.0	mA

3.3 Electrical Characteristics

Symbol	Parameter	min.	typ.	max.	Unit
V_VD	Internal regulated logic supply voltage output	4.75	5.0	5.25	V
I_VSL	Supply current for logic and receiver part in - receive mode - transmit mode		 9.0 11.0		 mA mA
V_TX_off	Switch off threshold level for VSP transmitter power stage supply voltage	16.13	18.0	20.0	V
ViL	Low level input voltage of TXCT- and RXA0	0		0.8	V
ViH	High level input voltage of TXCT- and RXA0	2.4		5.0	V
VoL	Low level output voltage of RXDT and RXCK	0		0.8	V
VoH	High level output voltage of RXDT and RXCK	4.0			V
VoL_R	Low level output voltage of RXSS-			0.8	V
VoH_R	High level output voltage of RXSS- (see note below)				
Fan-In	Low Power Schottky compatible fan-in of signals TXCT- and RXA0 (Iin = -400 µA)			1	-
I_IN-TXCT-	Input current for TXCT- signal, when the accessory RI-ACC-ATI1 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_ST1	Cable length for connecting ST1 of the RF module to a controller unit using flat cable		0.5	2.0	m
l_RXSA	Cable length for connecting external resistors to RXSA using twisted pair line (for details refer to Section 4)		0.5	5.0	m

Note: *RXSS- has an internal pull-up resistor of 10 kOhm. Therefore the parameters VoH_R, FanOut_Rh and t_ro_R depend on application specific external components.*

3.3 Electrical Characteristics (continued)

Symbol	Parameter	min.	typ.	max.	Unit
l_CPS	Cable length for connecting the Carrier Phase Synchronization signal between two RF modules		1.0	5.0	m
n_CPS	Number of oscillator SLAVE RF modules, which can be driven from one oscillator MASTER RF module		1	5	-
R_D1	Additional antenna damping resistor R_D1 (+/- 5%)	760	800	840	Ohm
R_D2	Additional antenna damping resistor R_D2 (+/- 5%)	288	303	318	Ohm
d_R_D1	Additional field strength damping, when using solder jumper D1 (R_D1) in combination with RI_ANT-G01C		10		dB
d_R_D2	Additional field strength damping, when using solder jumper D2 (R_D2) in combination with RI_ANT-G03C		13		dB
R_DAMP	Antenna damping resistor (+/-2.5%)	78	80	82	Ohm
L_TUNE	Inductance of antenna tuning coil	1.3	3.0	4.7	µH
C_ANT	Total antenna resonator capacity (+/- 2.5%)	45.8	47.0	48.2	nF
R_GND	Decoupling resistor between GND and GNDP (+/- 5%)	31.3	33	34.7	Ohm

3.4 Timing Characteristics

Symbol	Parameter	min.	typ.	max.	Unit
t_TX	Transmit burst length for correct operation (see note 1)	5	50	100	ms
f_OSZ	Internal oscillator frequency	4.2937	4.2944	4.2951	kHz
f_TX	Transmitter output frequency	134.18	134.20	134.22	kHz
f_mRX	Receiver center frequency		128.2		kHz
b_RX	-3 dB bandwidth of receiver		22.0		kHz
t_valid_b	Time of data signal RXDT valid before positive slope of RXCK signal	15	60	120	µs
t_valid_a	Time of data signal RXDT valid after positive slope of RXCK signal	15	60	120	µs
t_ri t_fi	Rise and fall time of input signal TXCT- and RXA0			1 1	µs µs
t_ro t_fo	Rise and fall time of output signals RXDT and RXCK			1 1	µs µs
t_ro_R	Rise time of output signal RXSS-	(see note 2)			
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
t_short	Maximum time of short circuit between antenna terminals GNDA and ANT			10	s

Note 1: *Because of the transponder parameters, it is necessary to have a minimum charge-up time of 15 ms.*

Note 2: *RXSS- has an internal pull-up resistor of 10 kOhm. Therefore the parameters VoH_R, FanOut_Rh and t_ro_R depend on application specific external components.*

CAUTION: The parameter t_short refers to static short circuit of the antenna terminals. Shorting the antenna terminals during operation may cause permanent damage to the RF Module.

3.5 Mechanical data

The mechanical size of the RFM is shown in figure 24 with the height and weight in the table below figure 24, the dimensions are given in millimeters and all have a tolerance of ± 1 mm.

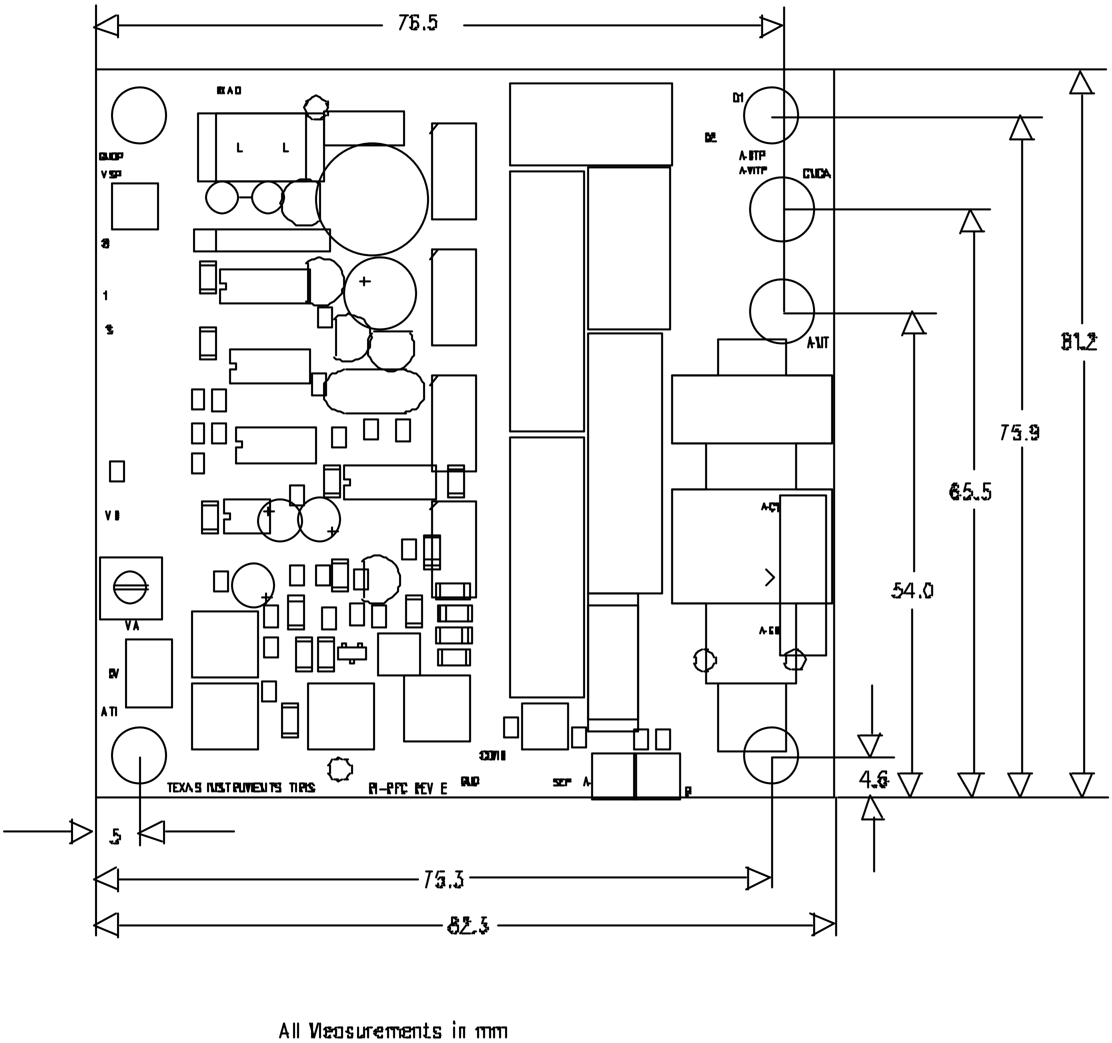


Figure 24: Module Dimensions

Parameter	typical	Unit
Height of complete RF module (including mounting bolts)	36.0 +/- 1.5	mm

Weight of complete RF module	170	Grams

4. Installing the RF Module

4.1 Power Supply

4.1.1 Supply Requirements

The logic and receiver part of the RF module have to be supplied via the VSL and GND pins with unregulated voltage (voltage regulators for the logic and receiver part are built in).

As an option, the logic and receiver part can also be connected to an external regulated +5V supply. For this purpose the solder bridge setting has to be changed (for details refer to Section 2.2). Then the regulated +5 V supply must be connected to pin VD.

The transmitter power stage is supplied via different supply lines VSP and GNDP. As there is no stabilization on the RF module 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 in the range from +5 V to +14 V.

Note: *The RF module must not be supplied by Switched Mode Power Supplies (SMPS). This is because most SMPS operate at frequencies around 50 kHz. The harmonics of the generated field can interfere with the TIRIS receiver. Therefore only use linear power supplies, or SMPS with* ***a fundamental operating frequency of 200 kHz or higher.***

Also, noise from power supplies or noise on the interface lines can interfere with the receiver. Therefore it is recommended to add additional filters in series to the supply and interface lines if the application requires this. For more details refer to Section 4.9: "Noise Verification" and Section 4.10: "Over Voltage Protection".

In order to guarantee full RF module performance, the power supplies should fulfill the specifications for ripple voltage given in Table 6.

Table 6: Power Supply Ripple Specifications

Supply type	**Maximum allowed Ripple Voltage**	**Allowed Ripple Frequency**
Unregulated VSL supply	30 mVrms	0 to 100 kHz maximum(sinusoidal)
Regulated +5V VSL supply	300 µVrms	0 to 100 kHz maximum(sinusoidal)
Regulated VSP supply	50 mVrms	0 to 50 kHz maximum(sinusoidal)

Table 7 lists the typical current consumption of the transmitter power stage for the TIRIS standard antennas, when the RF module transmitter power stage is supplied with VSP = 14V.

Table 7: Current Consumption for TIRIS Standard Antennas

Antenna type	**Typical Transmitter Supply Current (for VSP = 14V and 50%)**
RI-ANT-S01	1.2 Amperes DC
RI-ANT-S02	1.2 Amperes DC
RI-ANT-G01	1.0 Amperes DC

RI-ANT-G02	1.2 Amperes DC
RI-ANT-G03	0.9 Amperes DC

4.1.2 Connection of the Supplies

The ground pins for the logic/receiver part and the transmitter power stage are not directly connected internally. The two different grounds must be connected to each other externally. Internally they are just connected via the resistor R_GND, in order to avoid floating grounds in case accidentally the grounds were not connected to each other externally.

The grounds must be connected together externally for two reasons:

1. Possibly high resistive GNDP pins would cause a voltage drop across these connector pins, because of the high transmitter power stage current (this does not apply to the supply pins of the Logic part). 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 controller unit (see also figure 25). This is avoided, by connecting the grounds GND and GNDP externally.

2. In order to provide higher flexibility with long supply lines. Long VSP supply lines between the RF module and the controller unit cause a voltage drop across this supply line (again because of the high transmitter power stage supply current). This voltage drop would also lift the logic ground and cause logic level compatibility problems with the controller unit. This can again be avoided by connecting the grounds externally in any of three different ways (see also figure 25):

    a. For cable lengths of up to 0.5 m between the RF module and controller unit, the RFM ground pins GND and GNDP must be connected at the controller unit, as shown in figure 25. Here the grounds for the VSP, VSL and the controller unit supply are all connected together at the common ground.

       If the voltage drop across the VSP supply line is less than 0.5 V (very likely in this case), the ground pins GND and GNDP can alternatively be connected together at the RF module.

       If your system has a TIRIS control module, the RF module ground pins GND and GNDP are already connected together in the correct way on that control module.

    b. For cable length between 0.5 m and 2 m, the RFM ground pins GND and GNDP must be connected together at the controller unit in order to avoid logic level compatibility problems caused by the voltage drop across the VSP supply lines (see also figure 25).
       In this case, connecting the ground pins at the RF module is not allowed, because this would lift the logic ground level.

    c. Cable lengths longer than 2 m are not recommended. If, for your application you HAVE to use a cable longer than 2 m, the logic signal connections between the RF module and the controller unit must be done via a differential interface (for example: RS422). Because of different ground potentials at different locations it may also be necessary in this case to provide galvanic separation of the interface signals by, for example: optocouplers.

       In this case, to avoid problems with difference voltages between GND and GNDP, these pins must always be connected directly at the RF module. A shorting bridge is necessary as close as possible to the RF module for this purpose, as shown in figure 25.

CAUTION: In all cases, the voltage between GND and GNDP must not exceed ±0.5 V. Otherwise the RF module will be damaged.

The oscillator has a protection feature for the transmitter power stage against current overload of the transmitter power stage. When the transmitter power stage supply voltage VSP exceeds accidentally the 'Absolute Maximum Ratings' (see also Section 3: "Specifications"), the oscillator is disabled and thus the transmitter is switched off.

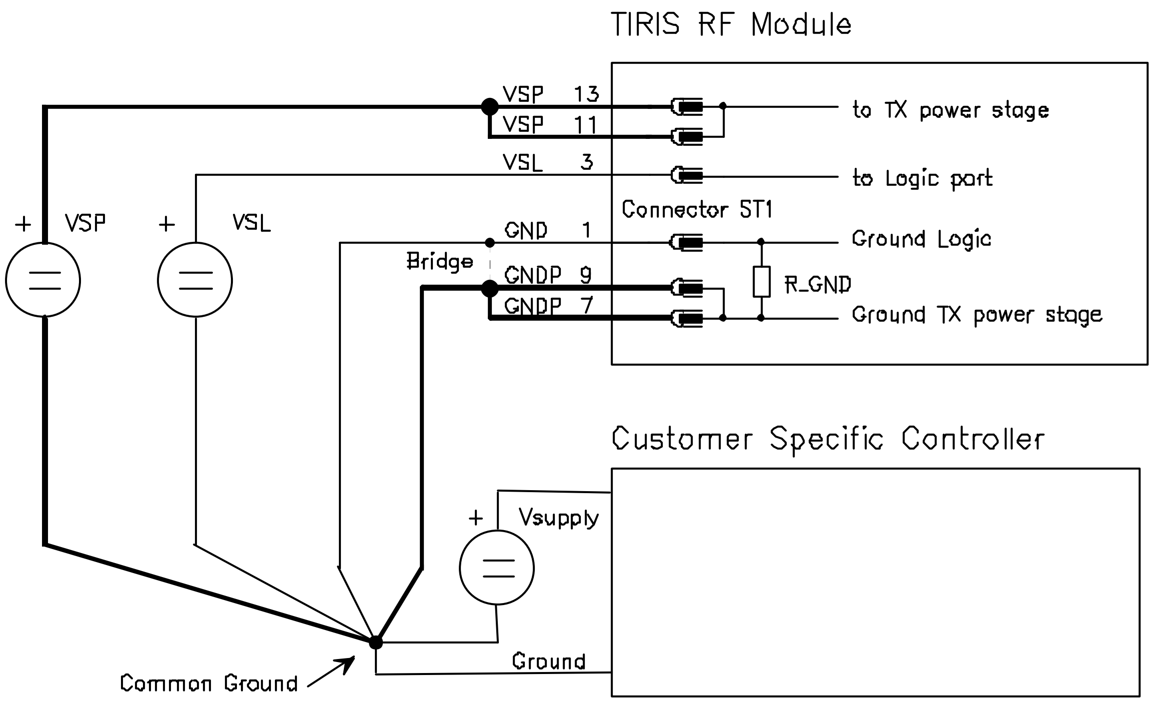


Figure 25: External Ground Connection (GND to GNDP)

4.2 Antenna Requirements

The transmit antenna for the RF module (which is used to charge up the transponder) is a coil (see figure 5), this coil is part of the antenna resonant circuit (see figure 2).

In order to achieve the high voltages at the antenna resonant circuit and thus high field strength at the antenna for charge-up (transmit) function, the antenna coil must have a high quality factor. The recommended quality factor for proper operation is listed in table 8. The quality factor of the antenna may vary, depending on the type, the construction and the size of the antenna. Furthermore, the quality factor depends on the wire type and wire cross-section area used for winding the antenna.

The best wire for winding an antenna is RF litze-wire. This is a wire with a number of small single insulated wires. RF litze-wire gives the highest quality factor and thus the highest charge-up field strength. Therefore we recommend the use of RF litze-wire with maximum single wire diameter of 0.1 mm (4 mil) for winding an antenna. In addition we recommend to use RF litze-wire with at least 120 single insulated wires.

For proper operation of the transmitter and receive function, the antenna has to be tuned to the resonance frequency f_TX. For a detailed description of the antenna resonance tuning procedure, see Section 4.3: "Antenna resonance tuning".

To ensure that the antenna can be tuned to resonance with the tuning coil on the RF module, the antenna inductance can only vary within the limits given in table 8.

Table 8: Antenna Characteristics

Parameter	Conditions	min.	typ.	max.	Unit
L_ANT	Antenna inductance range, within which the antenna can be tuned to resonance using the tuning coil on the RF module	26.0	27.0	27.9	µH
Q_ANT	Recommended quality factor of antenna coil for proper operation	100			-

Basically there are two different kind of antennas: Gate antennas and Ferrite core antennas. Gate antennas have no material inside the coil loop, whereas Ferrite core antennas use ferrite material inside the coil loop to increase the quality factor.

However, it must be considered that although a ferrite core antenna may have a very high quality factor under test conditions with low magnetic field strength, this quality factor drops, when a high magnetic field strength is applied to the ferrite core.

HINT: For more details and characteristics refer to the 'Antenna Reference Guide' (Manual number: 22-21-007).

4.3 Antenna Resonance Tuning

In order to achieve the high charge-up field strength, the antenna resonator frequency must be tuned to the transmitter frequency f_TX (tuning to resonance). This is done by changing the inductance of the antenna resonator coil. To do this, there is a tuning coil on the RF module (see also figure 1). This tuning coil is in series to the antenna coil. Thus by screwing the ferrite core of the tuning coil in or out, the inductance of the antenna resonator is increased or decreased.

Note: *Adjusting the ferrite core of the tuning coil must be done with a plastic screwdriver, as a metal screwdriver would affect the inductance of the coil which would lead to incorrect tuning. Therefore use only the plastic screwdriver which is delivered with the RF module.*

For applications, where the RF module is exposed to vibration, the ferrite core of the tuning coil must be fixed with silicon rubber when tuned!

When you tune the antenna, the resonance condition must be monitored. This can be done using either method A or method B as described following:

A) Monitoring Generated Field Strength

Monitor the field strength generated by the RF module and the antenna. Measure the induced RF voltage of a pick-up coil placed at a fixed distance to the antenna. The antenna is tuned to resonance when the voltage at the pick-up coil has reached its maximum value.

For this method, the RF module must be switched into repetitive transmit mode, by operating it from a controller unit. Therefore this method can only be used together with a controller unit.

To measure the output you can use any of these three methods:

- An additional pick-up coil and an oscilloscope
- An additional pick-up coil and a standard voltmeter
- The TIRIS Field Strength Meter RI-ACC-FSM1.

For connection of the RF module and the location of the sensor unit see figure 26. For sensor unit alternatives see figure 27.

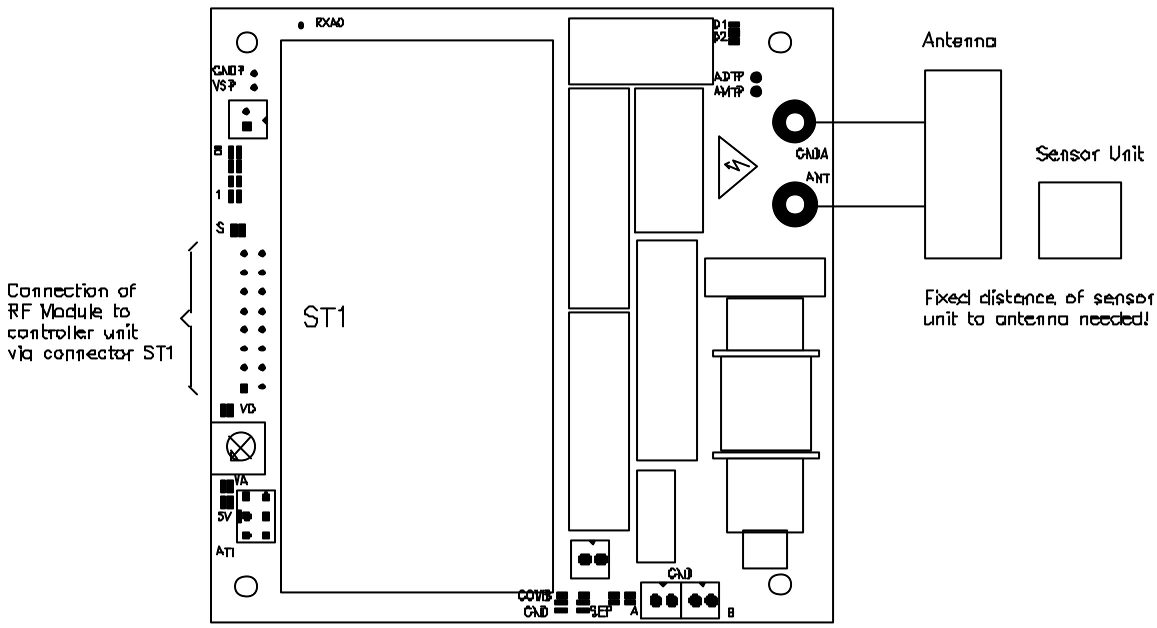


Figure 26: Monitoring the Generated Field Strength

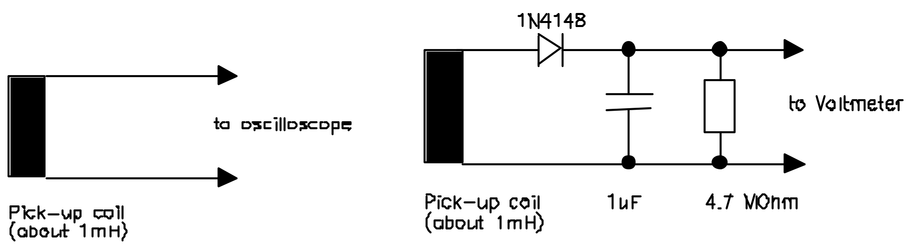


Figure 27: Antenna Tuning Pick-up Coils

HINT: As the RF module just has to be tuned to the maximum voltage at the pick-up coil, all types of coil can be used as pick-up tool. The inductance of the pick-up coil is of little importance. However, if a pick-up coil with high inductance (a high number of windings and large size) is used, higher voltage is induced at the pick-up coil. Which means that the pick-up coil can be placed further away from the antenna.

B) Antenna Tuning Indicator Tool

Monitoring of the correct antenna resonance tuning can be dramatically simplified by using the 'Antenna Tuning Indicator' (ATI) tool RI-ACC-ATI1-00.

This tool offers the feature of operating the transmitter in pulsed mode, independently to the controller unit. Additionally it indicates by LEDs, in which direction the ferrite core must be turned and when the antenna is tuned to resonance. Furthermore, this tool is supplied via the RF module, by just plugging it onto the RF module during the tuning procedure.

Notes: *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. This is because metal changes the inductance of the antenna. In addition, the quality factor of the antenna decreases, so that the field strength decreases. The extent of the inductance and quality factor reduction depends on the kind of metal, the distance of the antenna to the metal and the size of the metal.*

When the oscillator signal pulse width, or the supply voltage VSP of a RF module with an already tuned ferrite core antenna (for example: RI-ANT-S01C) is changed more than 50%, the ferrite core antenna has to be retuned to the new conditions. This is necessary, because the inductance of a ferrite core antenna changes slightly at different field strengths.

Each antenna is tuned individually to the RF module and this results in the special tuning coil setting for this combination of antenna and RF module only. If a different antenna is connected to the RF module, the new combination has to be tuned to resonance again!

The tuning procedure flow is as follows:

* Switch RF module power supply off
* Connect the antenna to the RF module by means of the two M3 screw connectors
* Install antenna tuning monitoring unit:

  Connect antenna tuning indicator unit to the RF module
  or
  Put field strength sensor unit at fixed distance to antenna and switch RF module into repetitive transmit mode

* Switch RF module power supply on
* Tune antenna to resonance by screwing the ferrite core of the tuning coil in or out until a maximum is achieved
* Switch RF module power supply off
* Disconnect monitoring unit

* Switch RF module power supply on again

==> Antenna resonance tuning is complete!

4.4 Expanding Antenna Tuning Inductance Range

It is possible to expand the tuning range of the antenna inductance. This may be necessary:

- when TIRIS standard antennas are used close to metal
- when antenna extension cables are used
- when customer specific antennas which might not be within the necessary antenna tuning inductance range are used.

Expanding the antenna tuning inductance range to lower or higher values can be done by connecting additional capacitors in parallel and in series to the antenna resonator. In addition the damping function has to be modified by connecting additional resistors to the antenna damping circuit.

The capacitors and resistors have to be connected in parallel and in series in order to withstand the high voltages and high currents occurring at the antenna resonant circuit.

WARNING

There is HIGH VOLTAGE at all antenna resonator components, which could be harmful to your health! Therefore at any time that you are working on the RF module, switch it OFF. The external components must be mounted in a way that they cannot be touched by accident.

To ensure that the RF module functions properly when the antenna tuning inductance range is expanded, special capacitors and resistors, as listed below, must be used:

Capacitor type: - Polypropylene film capacitor
- Minimum 1250V DC operating voltage
- Capacitance tolerance: max. ±5%
- Type: SIEMENS "KP"
or WIMA "FKP1"

Resistor type: - Metal film resistor
- Minimum 200V DC operating voltage
- Minimum load rating: 0.25 Watts
- Resistance tolerance: max. ±2%
- Temperature coefficient: max. ±50ppm
- Type: e.g. Minimelf resistors

The antenna tuning inductance range can be decreased to 13.7 µH in six ranges, as shown in figure 28 and table 9.

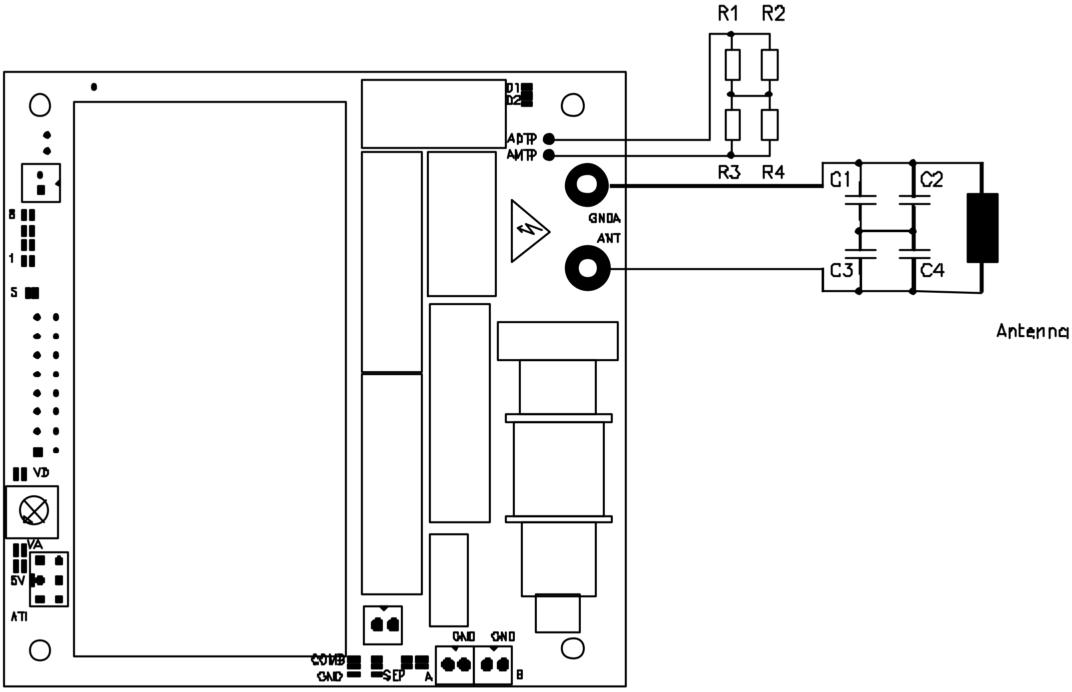


Figure 28: Circuit for Expanding Antenna Tuning Range to Lower Values

Table 9: Capacitor and Resistor Values for Expanding Antenna Tuning Inductance Range to Lower Values

Antenna inductance range	**Capacitor value**	**Resistor value**
24.1 µH to 25.9 µH	C1, C2, C3, C4 = 3.3 nF	R1, R2, R3, R4 = 1200 Ohm
22.3 µH to 24.0 µH	C1, C2, C3, C4 = 6.8 nF	R1, R2, R3, R4 = 560 Ohm
20.4 µH to 22.2 µH	C1, C2, C3, C4 = 11 nF (10 nF and 1 nF in parallel)	R1, R2, R3, R4 = 330 Ohm
18.4 µH to 20.3 µH	C1, C2, C3, C4 = 16 nF	R1, R2, R3, R4 = 220 Ohm
16.5 µH to 18.3 µH	C1, C2, C3, C4 = 22 nF	R1, R2, R3, R4 = 180 Ohm
13.7 µH to 16.4 µH	C1, C2, C3, C4 = 32 nF	R1, R2, R3, R4 = 120 Ohm

The antenna tuning inductance range can be increased to 37.6 µH in 7 ranges, as shown in figure 29 and table 10.

As shown in figure 29, three capacitors (C1, C2, C3) are connected in series to the antenna coil. The specification for these capacitors is listed below:

Capacitor type: - Polypropylene film capacitor
- Minimum 1250V DC operating voltage
- Capacitance: 47 nF ±2.5%
- Type: SIEMENS "KP" or WIMA "FKP1"

In addition to C1, C2 and C3, the capacitor C4 must be connected in parallel to the RF module antenna terminals. Different capacitor values have to be used for each range, these values are given in table 10. Also, the damping function has to be modified by connecting additional resistors to the antenna damping circuit.

HINT: The adaptation of the antenna inductance can be simplified by using the TIRIS Accessory Module RI-MOD-LEX1.

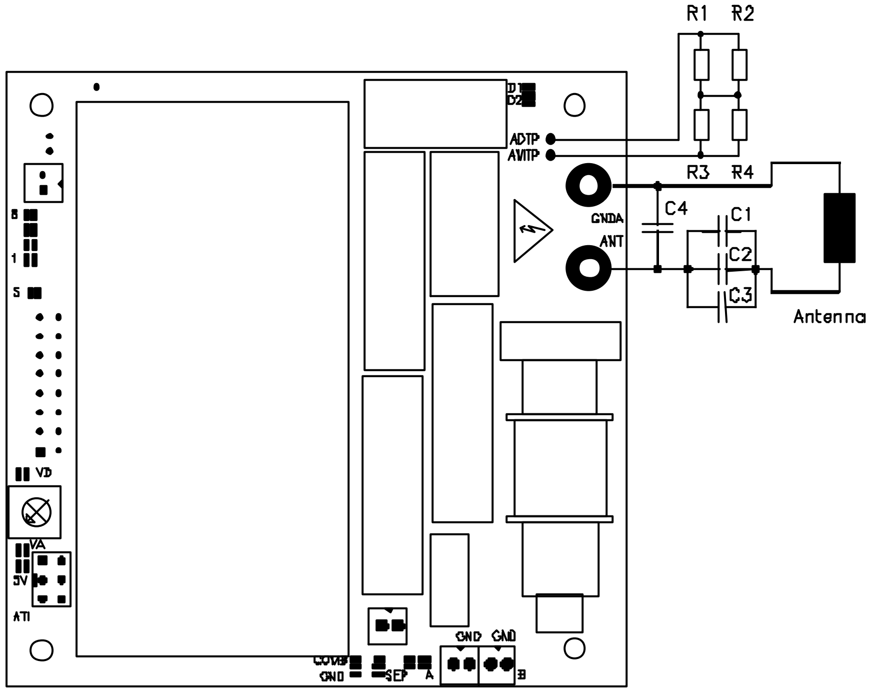


Figure 29: Circuit for Expanding Antenna Tuning Range to Higher Values

Table 10: Capacitor Values for Expanding Antenna Tuning Inductance Range to Higher Values

C1, C2 & C3 = 47 nF

Antenna inductance range	Capacitor value	Resistor value
28.0 µH to 29.3 µH	C4 = 18.3 nF (parallel 6.8 nF, 6.8 nF, 4.7 nF)	R1, R2, R3, R4 = 120 Ohm
29.4 µH to 31.0 µH	C4 = 13.6 nF (parallel 6.8 nF, 6.8 nF)	R1, R2, R3, R4 = 120 Ohm
31.1 µH to 32.4 µH	C4 = 10 nF	R1, R2, R3, R4 = 120 Ohm
32.5 µH to 33.8 µH	C4 = 6.8 nF	R1, R2, R3, R4 = 180 Ohm
33.9 µH to 35.0 µH	C4 = 3.98 nF (parallel 3.3 nF, 0.68 nF)	R1, R2, R3, R4 = 180 Ohm
35.1 µH to 36.2 µH	C4 = 2.2 nF	R1, R2, R3, R4 = 220 Ohm
36.3 µH to 37.6 µH	C4 not needed	R1, R2, R3, R4 = 220 Ohm
Two serial connected TIRIS standard antennas	C4 = 3.3 nF C2 and C3 not needed	R1, R2, R3, R4 = 120 Ohm

Notes: *It is not recommended to use antennas with quality factors lower than 50. If you do have to use such an antenna, no additional damping resistors are necessary.*
We recommend that you ***do not use*** *antennas with inductances lower than 13.7 µH or more than 37.8 µH (except when connecting two antennas in series), because the additional capacitor values become very large.*
Antennas with fewer turns (==> smaller inductance) generate less charge-up field strength at same operating conditions and in addition also have less receive sensitivity.
Using capacitors parallel to the antenna resonator changes the coupling of the RF module's TX Power Stage and this reduces the generated field strength.

In order to avoid adaptation problems, we strongly recommend that you only use standard TIRIS antennas

4.5 Field Strength Adjustment

The generated magnetic field strength determines the charge-up distance of the transponder. The higher the magnetic field strength, the longer the transponder charge-up distance. However, the charge-up distance does not increase linearly with the field strength. The transponder charge-up distance can be verified using the TIRIS Charge Level Meter RI-ACC-CLM1.

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

The field strength generated by the RF module depends on the four factors listed below:

1. Quality factor of the antenna.

   The quality factor is a measure of the efficiency of the antenna and therefore the higher the quality factor of the antenna coil, the higher the field strength which is generated by the RF module (assuming that all other parameters remain unchanged).

   The quality factor of the antenna itself depends on the cross-section area of the wire, the wire type, the size of the antenna and the type of antenna (Gate or Ferrite antenna). The bigger the cross-section area of the RF litze-wire, the bigger the quality factor of the antenna. RF litze-wire gives a higher quality 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 RF module, because the antenna covers a bigger area and thus generates a higher flux (assuming that all other parameters remain unchanged).

HINT: Large antennas have less immunity to noise for receive function than small antennas.

3. Supply voltage of the RF module power stage.

   The higher the supply voltage of the RF module transmitter power stage (VSP voltage), the higher the field strength which is generated by the RF module (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 (here saturation means 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 RF module, because more power is 'fed' into the antenna resonator by the transmitter power stage (assuming that all other parameters remain unchanged).

   For an example of two different oscillator pulse width settings, see figure 3.

The generated field strength can be measured in several ways. You can measure it using a calibrated field strength meter, or by using either of the following ways:

1. Use the TIRIS 'Field Strength Meter' accessory (part number RI-ACC-FSM1).
2. Measure the antenna resonance voltage using an oscilloscope and then calculating the field strength. For details see 'Antenna Reference Guide' (Manual number 22-21-007).

In summary: the generated field strength of an antenna can be adjusted with the supply voltage VSP of the RF module transmitter power stage **and** by selecting the corresponding oscillator signal pulse width. Figures 30 to 33 show **typical** field strength values for all TIRIS standard antennas for different oscillator signal pulse widths and different transmitter power stage supply voltages.

In cases, when low field strengths should be generated with larger antennas (RI-ANT-G01 or RI-ANT-G03), the antenna resonator can additionally be damped by connecting either damping resistor R_D1 or R_D2 to the antenna resonator. This can be done by closing the solder bridges D1 or D2 (see also figure 1). Using these optional damping functions give the advantage that the field strength can again be fine tuned (for example: to meet the German PTT regulations) with selection of the oscillator signal pulse width in a wide range (to both larger and smaller values).

CAUTION: These damping options can only be used together with the antennas RI-ANT-G01 and RI-ANT-G03. When using these damping options, the maximum allowed pulse-width is 40.5% (this corresponds to solder jumpers '8' and '4' open and solder jumpers '2' and '1' closed).

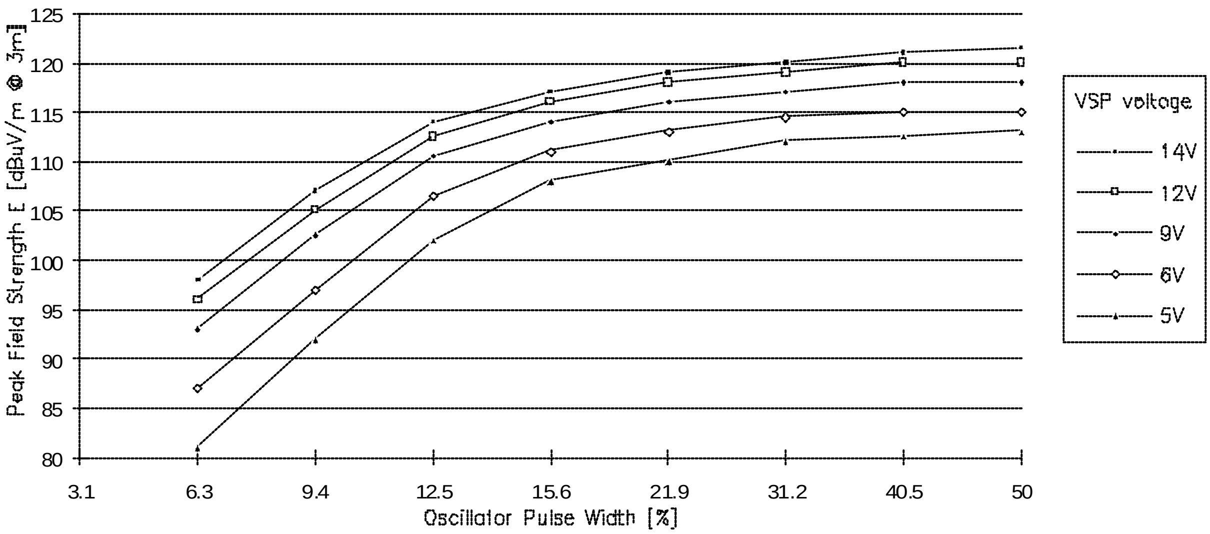


Figure 30: Field Strength Compared to Pulse Width for Antennas RI-ANT-S01C & S02C (Typical Values)

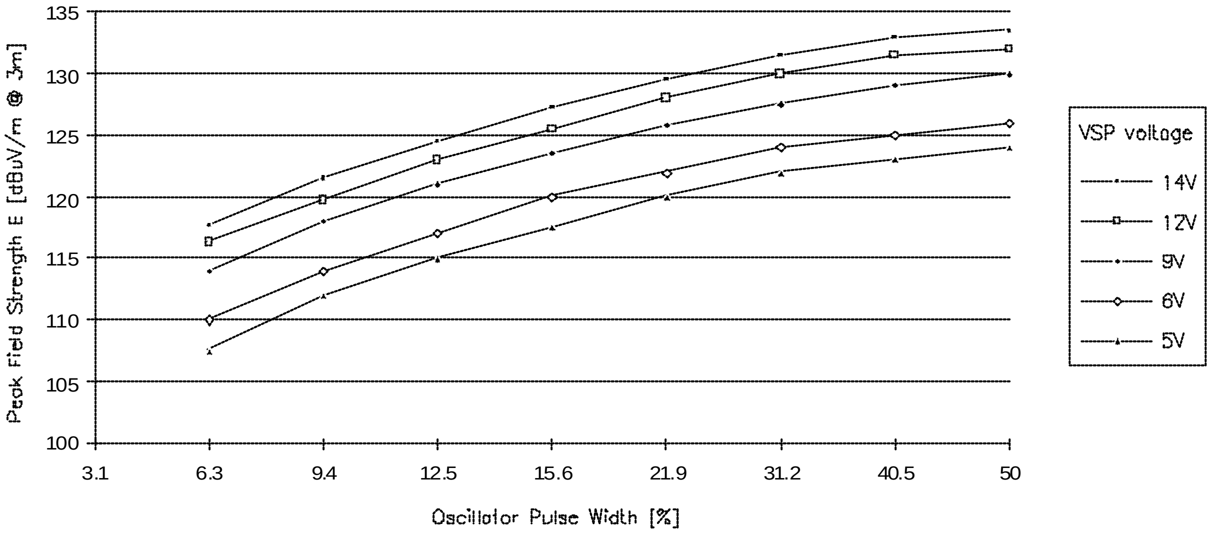


Figure 31: Field Strength Compared to Pulse Width for Antenna RI-ANT-G01C (Typical Values)

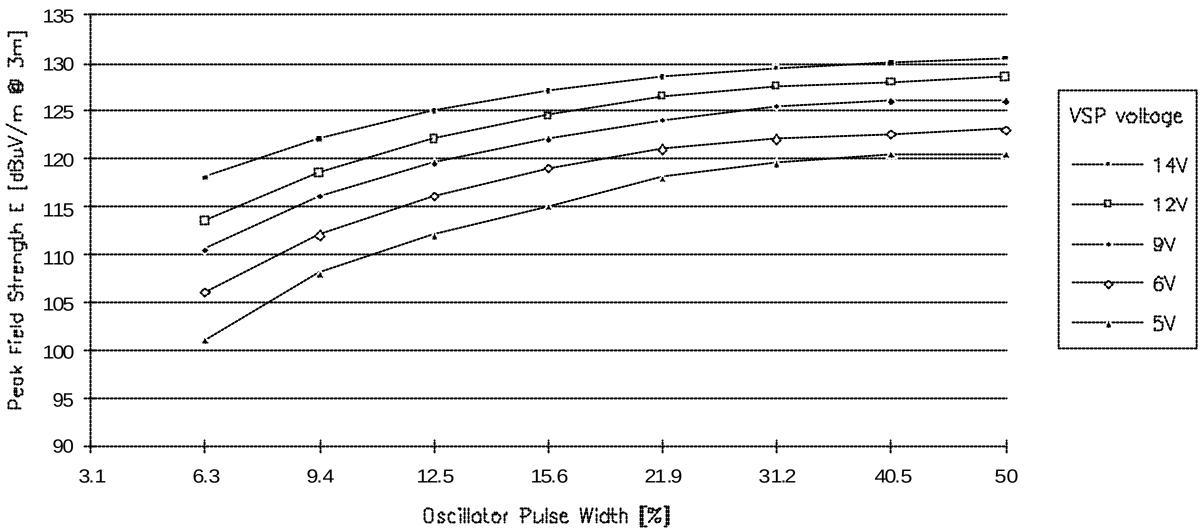


Figure 32: Field Strength Compared to Pulse Width for Antenna RI-ANT-G02C (Typical Values)

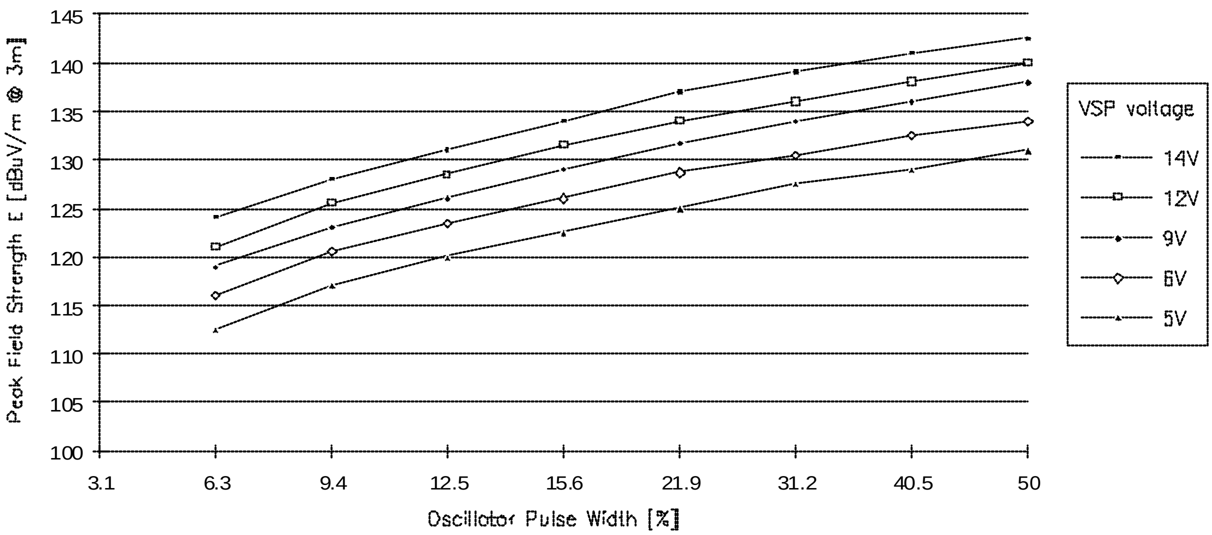


Figure 33: Field Strength Compared to Pulse Width for Antenna

RI-ANT-G03C (Typical Values)

4.5.1 Adjustment of Oscillator Signal Pulse Width

The RF module has a built-in feature to set the pulse width of the transmitter signal coming from the oscillator. This enables the generated field strength to be reduced from 100% down to about 10%.

To do this there are 4 solder jumpers on the upper side of the RF module PCB (close to the connector ST1). These 4 solder jumpers are binary weighted which means that the pulse width can be set to 16 different values. The solder jumper with the least significant value (1 = LSB) is located next to the connector ST1. The other solder jumpers are in ascending order. Thus the solder jumper with the most significant value (8 = MSB) is the most distant one from the connector ST1.

As default setting, these solder jumpers are all open and thus generate a pulse width of 50%. A pulse width of 50% corresponds to maximum possible field strength. By closing the solder jumpers with solder, the field strength is decreased. The relationship between the jumper settings and the pulse width is shown in table 11.

Table 11: Selected Oscillator Signal Pulse Width Versus Solder Jumper Setting

Solder jumpers setting				**Oscillator signal pulse width [%]**
MSB '8'			**LSB '1'**	
-	-	-	-	50
-	-	-	X	46.9
-	-	X	-	43.7
-	-	X	X	40.6
-	X	-	-	37.5
-	X	-	X	34.4
-	X	X	-	31.2
-	X	X	X	28.1
X	-	-	-	25
X	-	-	X	21.9
X	-	X	-	18.8
X	-	X	X	15.6
X	X	-	-	12.5
X	X	-	X	9.4
X	X	X	-	6.3
X	X	X	X	3.1

- means: solder jumper open X means: solder jumper closed

Note: *The pulse width for the oscillator signal pulse width setting of 3.1% is very short (only 230 ns). The pulse response of the RF module transmitter power stage to this short pulse is different for each RF module. Therefore in order to have reproducible field strength values for different RF modules, it is recommended to* ***not use*** *the pulse width setting of 3.1%.*

In the following paragraphs you will find a flow description for adjusting the field strength according to FCC/PTT values in combination with TIRIS standard antennas. This method can only roughly determine the generated field strength, therefore the actual generated field strength should be verified with a calibrated field strength meter, especially for customized antennas. For more details see 'Antenna Reference Guide' (Manual number 22-21-007).

* Find out corresponding field strength regulation for the country. As guideline see Appendix C.
* Select antenna type (determined by the application, see also 'Antenna Reference Guide' Manual number 22-21-007).
* Select transmitter power stage supply voltage.
* Find out the oscillator signal pulse width needed for this antenna type, this transmitter power stage supply voltage and the corresponding FCC/PTT value in figures 30 to 33. Select corresponding pulse width on the RF module.
* If necessary, use optional antenna damping function, when low field strength (for example: to meet the German PTT requirements) is needed for big antennas.

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

Example of adjusting the field strength of the antenna RI-ANT-G03 according to German PTT regulations:

German PTT regulations allow a peak field strength value of 123 dBµVm at 3 meter for CISPR detector and 50 ms burst length followed by a 20 ms pause (refer also to Appendix C about FCC/PTT regulations). This specification should be fulfilled for the antenna RI-ANT-G03C for a supply voltage VSP of 12V.

Looking at figure 33 shows us that for this field strength a pulse width of about 7% is necessary. As this pulse width is already quite small and thus does not allow accurate field strength adjustment using the oscillator pulse width setting, the optional antenna damping solder jumper 'D2' should be closed (solder jumper 'D2' is used in combination with antenna RI-ANT-G03C). In addition this allows to even further decrease the field strength.

This damping option gives an additional damping of typical 13 dB. So the pulse width for 136 dBµV/m can be selected, which is gives a oscillator pulse width setting of about 31%.

31% oscillator pulse width corresponds to solder jumpers '8' and '1' open and solder jumpers '4' and '2' closed. So the antenna RI_ANT_G03C should be installed with solder jumper 'D2' closed and with above listed oscillator pulse width solder jumper setting for a VSP voltage of 12V, in order to correspond to German PTT regulations.

CAUTION: The RF module must not be operated in continuous transmit mode. For details of parameters see Section 3: "Specifications".

4.6 RXSS- Threshold Level Adjustment

The RF module has a built-in receive signal field strength detector with the output signal RXSS- and an on-board potentiometer 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 you have more than one reading unit in an area that they do not interfere with each other. The controller unit software watches the RXSS- signal to detect whether other reading units are transmitting. This means that the controller unit can operate the transmitter of the RF module so 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 with the potentiometer on the RF module. This must be done, after the antenna has been tuned to resonance.

It is recommended to use the small screwdriver delivered together with the RF module to adjust the RXSS- threshold level. The RXSS- threshold level adjustment potentiometer is located on the upper side of the RF module PCB near connector ST1 (see figure 1).

Turning the potentiometer all the way counter-clockwise (left-hand stop), results in maximum threshold sensitivity, this means that the RXSS- signal will be activated at low receive field strength. This is the default position and can be used for standard ferrite core antennas. The sensitivity must be reduced when you are using air coil antennas. If there is high noise level in the area, it may also be necessary to adjust the RXSS- threshold level even for ferrite core antennas.

Adjust the RXSS- threshold level as follows:

* Turn the RXSS- threshold level potentiometer fully counter-clockwise (left-hand stop).

* Deactivate the transmitter by connecting pin 1 to pin 3 of connector ST4, as shown in figure 34.

* Ensure that no other reading units are transmitting, by connecting pin 1 to pin 3 of connector ST4 of all other RF modules in the area, as shown in figure 34.

* Eliminate noise sources as much as possible.

* Monitor the voltage at RXSS- output pin with a voltmeter or an oscilloscope as shown in figure 34.

* Turn the RXSS- threshold level adjustment potentiometer on the RF module clockwise, until the RXSS- output is just statically inactive.

  "Statically" means without voltage spikes 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).

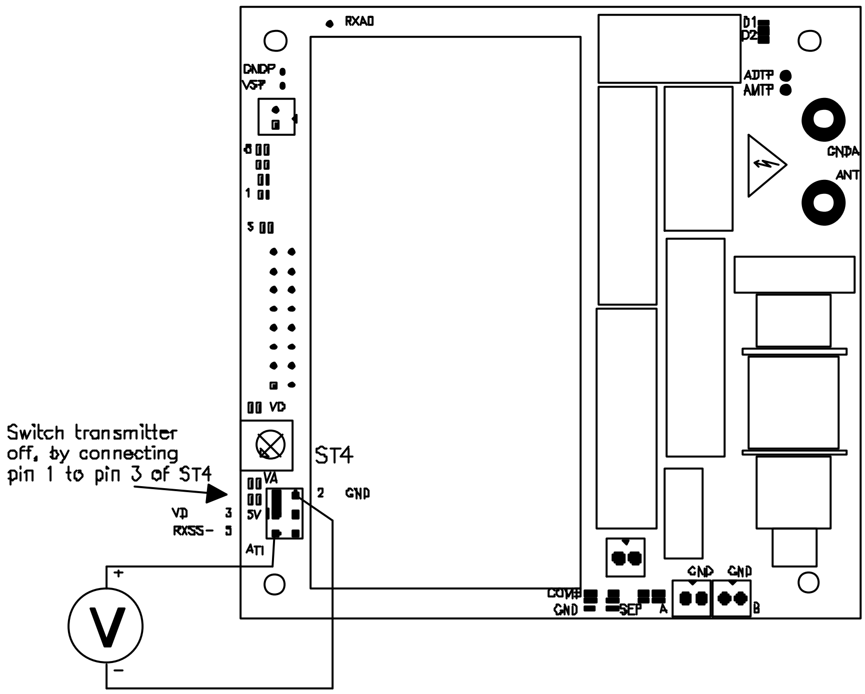


Figure 34: Monitor Connection and Transmitter Disabling for RXSS Adjustment

Notes: *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. This leads 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-S01) 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 (==> low RXSS- output level). Therefore a controller unit would all the time assume that another reading unit is transmitting and would all the time try to synchronize to this other reading unit. Therefore the reading repetition rate would decrease (from approximately 10 to approximately 5 readings per second for TIRIS control modules). In addition, this reading unit can no longer synchronize to other reading units. Therefore this reading unit interferes with other reading units and reading at all reading units becomes impossible.

The RXSS- threshold level must be adjusted individually for every RF module and antenna (reading system). 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 of course to have a long reading distance).

The RXSS- threshold level must be adjusted in such a way that no spikes occur on the RXSS- signal output, because this leads to incorrect synchronization function. Therefore an oscilloscope should be preferred for adjusting the threshold level.

HINT: It is strongly recommended to use the 'Antenna Tuning Indicator' (ATI) accessory for adjusting the RXSS- threshold level. This is because the ATI automatically switches the transmitter off and has an internal spike extension circuit, so that the RXSS- threshold level is adjusted in such a way that no spikes occur on the RXSS- output.

There is an additional possibility to adjust the RXSS- threshold level, when the internal potentiometer (10 kOhm) is turned fully clockwise. In this position, the threshold level can be decreased by connecting external resistors from the pin RXSA to ground GND. When a larger distance (more than 0.5 meter) between the external resistors and the RF module is necessary, it is recommended to use twisted pair lines and to connect a ceramic capacitor of 100 nF as close as possible to the pins RXSA and GND of the RF module (see also figure 35).

Note: *Maximum cable length between external resistors and RXSA pin of RF module depends on the cable used and the electromagnetic noise level in the area. Therefore it is recommended to use only twisted pair lines, or even better, coaxial cable and not to exceed the cable length which is specified in Section 3: "Specifications".*

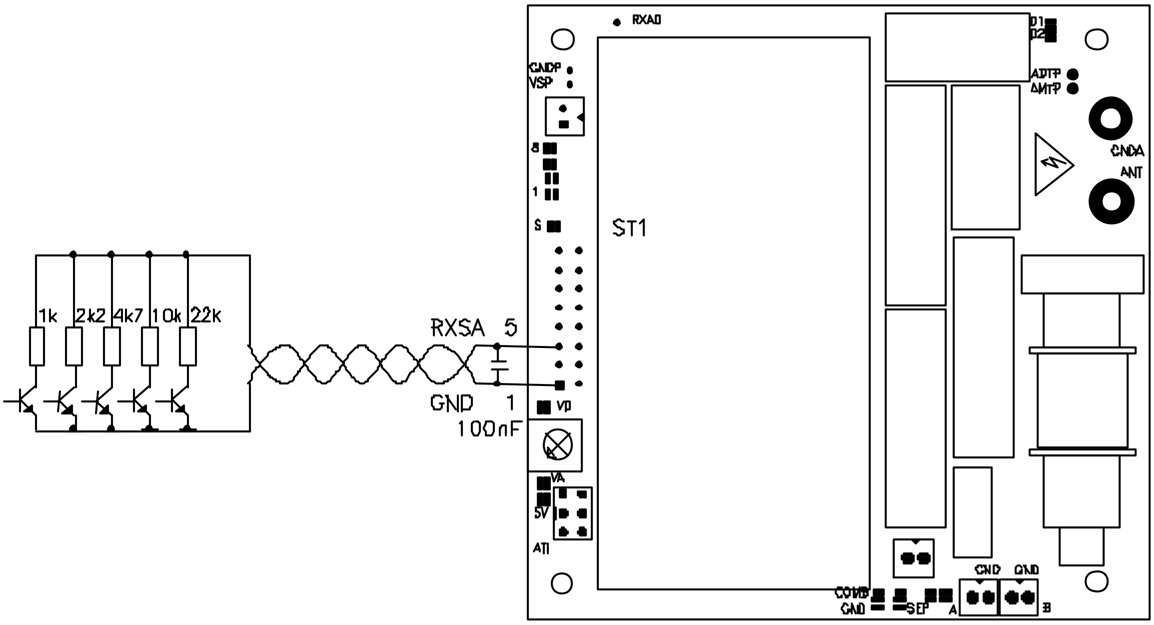


Figure 35: Adjusting RXSS with External Resistors

4.7 Transmitter Carrier Phase Synchronization (CPS)

In some applications it is necessary to use several charge-up antennas close to each other. In this circumstance, 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 RF modules.

The impact of this effect depends on three factors:

1. The size of the antenna:

   The larger the size of the antennas, the further the distance between the antennas must be, so that this effect does not occur.

2. The magnetic field strength:

   The stronger the generated magnetic field strength, the further the distance between the antennas must be, so that this effect does not occur.

3. The orientation and distance between antennas:

   Increasing the distance between antennas, decreases the impact of this effect.

Note: *Remember that putting two antennas close together also changes antenna inductance, so that the antennas may no longer be tunable to resonance. For details see 'Antenna Reference Manual' (Manual number 22-21-007).*

This effect will not occur when the transmitters of different RF modules are operated from the same oscillator signal. This is the reason that the pulse width modulated oscillator signal is accessible at the connector ST2. All RF modules to be driven by one oscillator must have their ST2 connectors connected together as shown in figure 36.

An additional solder bridge selects whether the internal oscillator or the external oscillator signal is used. When the solder bridge 'S' is closed, the internal oscillator is used and the RF module is referred to as an oscillator MASTER RF module. When the solder bridge 'S' is open, the external oscillator signal is used and the RF module is referred to as an oscillator SLAVE RF module (see also figure 1).

Note: *Only one oscillator MASTER RF module is allowed per synchronized system.*

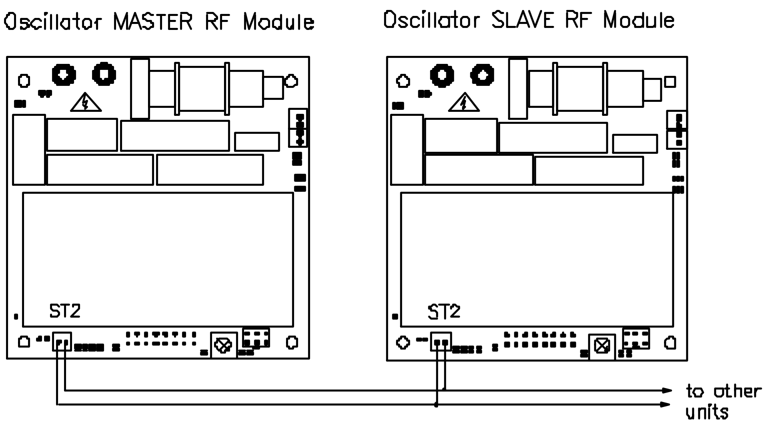


Figure 36: Connecting RFMs together for "MASTER/SLAVE" Oscillator Configuration

If you are using several antennas close to each other, you should always check whether the charge-up field strength changes regularly (= beat effect). You can check this by verifying the antenna resonance voltage with an oscilloscope. If the antenna resonator voltage changes periodically more than about 5% of the full amplitude we recommend that you use wired transmitter carrier phase synchronization as shown in figure 36.

In addition, the distances given in table 12 can be used as a guideline on determining when it is necessary to cross-check for beat effect. If the distances between antennas is less than the value given in table 12, you should check for beat effect. The values given in table 12 refer to the distances shown in figure 37 and are valid for maximum charge-up field strength.

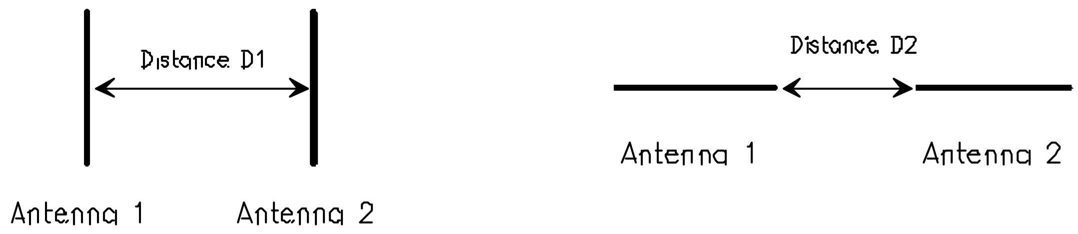


Figure 37: Distance between Antennas (top view)

Table 12: Maximum Distances Between Antennas

Antenna type	**Distance D1 [m]**	**Distance D2 [m]**
RI_ANT_S01 <=> RI_ANT_S01	1.0	0.8
RI_ANT_S02 <=> RI_ANT_S02	1.0	0.8
RI_ANT_G01 <=> RI_ANT_G01	1.7	1.5
RI_ANT_G02 <=> RI_ANT_G02	1.3	1.0
RI_ANT_G03 <=> RI_ANT_G03	2.0	1.7

If an application requires more than one RF module to be used, or a longer Carrier Phase Synchronization line than that specified in Section 3: "Specifications", it is necessary to drive the pulse width modulated oscillator signal via a differential interface (for example: RS422 interface).

Figure 38 shows how such a system must be connected:

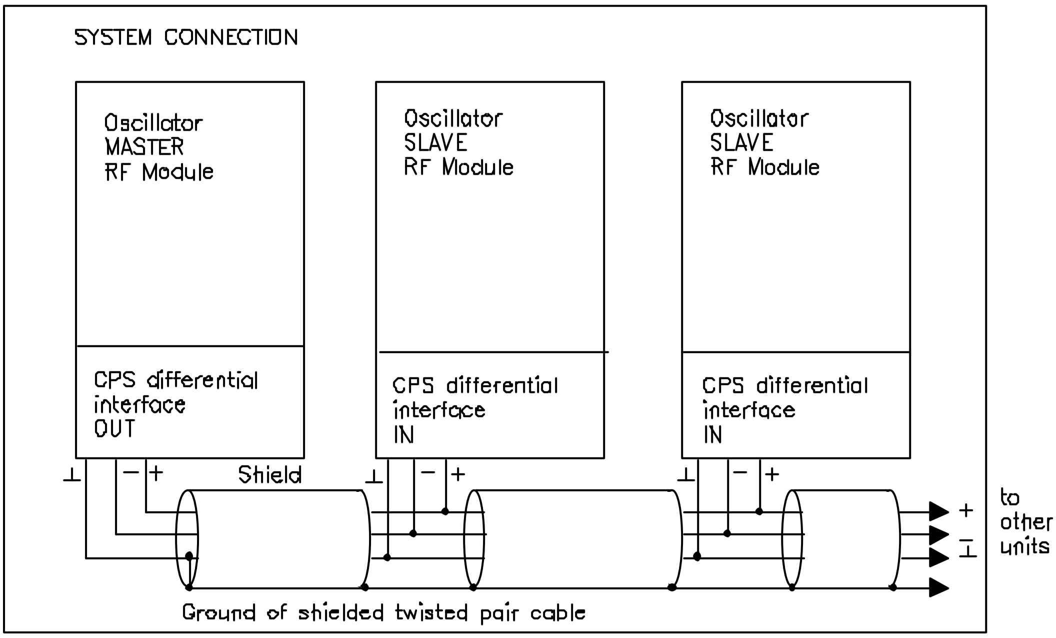


Figure 38: Connecting Multiple RFMs together

A proposal for such an external circuit is shown in figure 39. It shows a differential interface, which can be configured as transmitter (for oscillator MASTER RF module) and as receiver (for oscillator SLAVE RF modules). This selection can be done with jumper JP1.

The diodes D1 to D5 are used for protection against over voltage spikes on the supply and interface lines. The jumper JP2 connects the RS422 interface line termination resistor. This termination resistor must be installed at the last receiver at the end of the RS422 interface line. Only one termination resistor is allowed per interface line.

Resistor R5 is necessary to limit the current flow on the ground line, which could be caused by different ground potentials at the different locations of the RF module.

Note: *The circuit shown in figure 39 allows up to 32 RF modules to be connected together over a total maximum wire length of 100 meters.*

When you are using a Carrier Phase Synchronization interface, be careful not to exceed the maximum number of RF modules or the maximum cable length as specified in Section 3: "Specifications".

The pulse width setting of an oscillator SLAVE RF module does not affect the generated pulse width of this module. The pulse width of this oscillator SLAVE RF module is determined by the pulse width setting of the oscillator MASTER RF module.

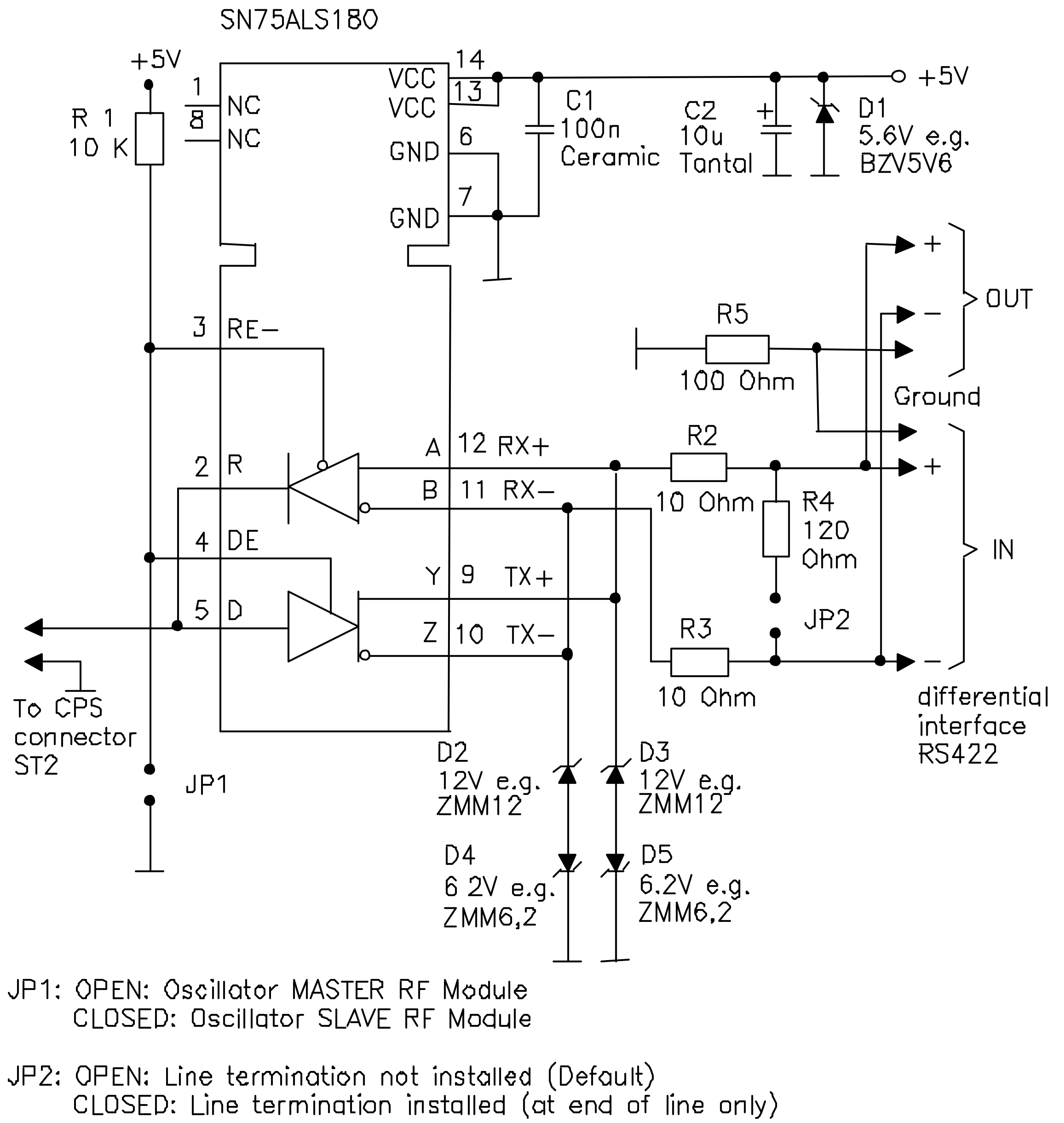


Figure 39: Circuit and Jumper Settings for RS422 Interface

CAUTION: Use over voltage protection components at the CPS connector for CPS lines between 0.5 and 5m, when the circuit shown in figure 39 is not used. See also Section 4.9: "Over Voltage Protection".

Notes: *Keep in mind that when using the transmitter Carrier Phase Synchronization feature, it is absolutely necessary that the read cycles of each different controller are synchronized. When the transmitter of the oscillator MASTER RF module is not activated by its controller, the oscillator signal output of the oscillator MASTER RF module is disabled. This means that all the oscillator SLAVE RF modules have no transmitter oscillator input signal and thus none of the oscillator SLAVE RF modules are able to transmit.*

*Therefore the read cycles of all RF modules connected to this CPS interface must be synchronized and all read cycles must occur **simultaneously**!*

4.8 Receive Multiplexer

This RF module has the option to use special receive-only antennas in combination with the built-in receive multiplexer.

The use of one combined transmit/receive antenna or up to two special receive-only antennas can be selected by solder jumpers (see also figure 20 and 21).

The receive multiplexer offers the following possibilities:

* The charge-up and receive functions of the antenna are separated allowing more freedom to separately place the charge-up and receive-only antennas to optimize identification area.

* The receive multiplexer allows to charge-up a transponder with one transmit antenna and to read it at either of two different locations, by activating one receive-only antenna out of the two receive-only antennas.

When using the receive multiplexer, the active receive channel is selected by the input signal RXA0. Receive channel A is selected when RXA0 is connected to +5 V or when RXA0 is open. Channel A is selected as default. Connecting RXA0 to ground selects receive channel B.

The special receive only antenna RI-ANT-S04 is a factory tuned resonator with a defined resonance frequency. These antennas can only be used for receive function. They do not work for charge-up function. For a block schematic of a receive only antenna see figure 6.

Note: *A minimum distance between receive-only antennas (and between receive-only antennas and charge-up antenna) must be maintained to ensure that the system functions properly. A* ***distance of at least 20 cm*** *must be between the antennas, so that the parameters of the antennas are not changed and thus proper function is guaranteed.*

In addition, a minimum distance of 5 cm from antenna to metal must also be kept.

Figure 40 shows a system configuration for the receive multiplexer.

TIRIS standard antennas can be used for the charge-up function. However, when using this receive only antenna option there is more freedom in configuring the charge-up antenna, this is because it only needs to be optimized for the charge-up function. This means that the antenna can be quite big without the usual disadvantage of high noise sensitivity of a big antenna.

The receive path can be either receive channel A or receive channel B via the special receive-only antennas. Again, as these antennas are only used for receive function, they can be optimized for this purpose.

Figure 41 shows a very basic application example for the receive multiplexer: Access control for a doorway, where also the direction of the people passing by is recognized.

The charge-up antenna could be made as a simple single loop round the door.

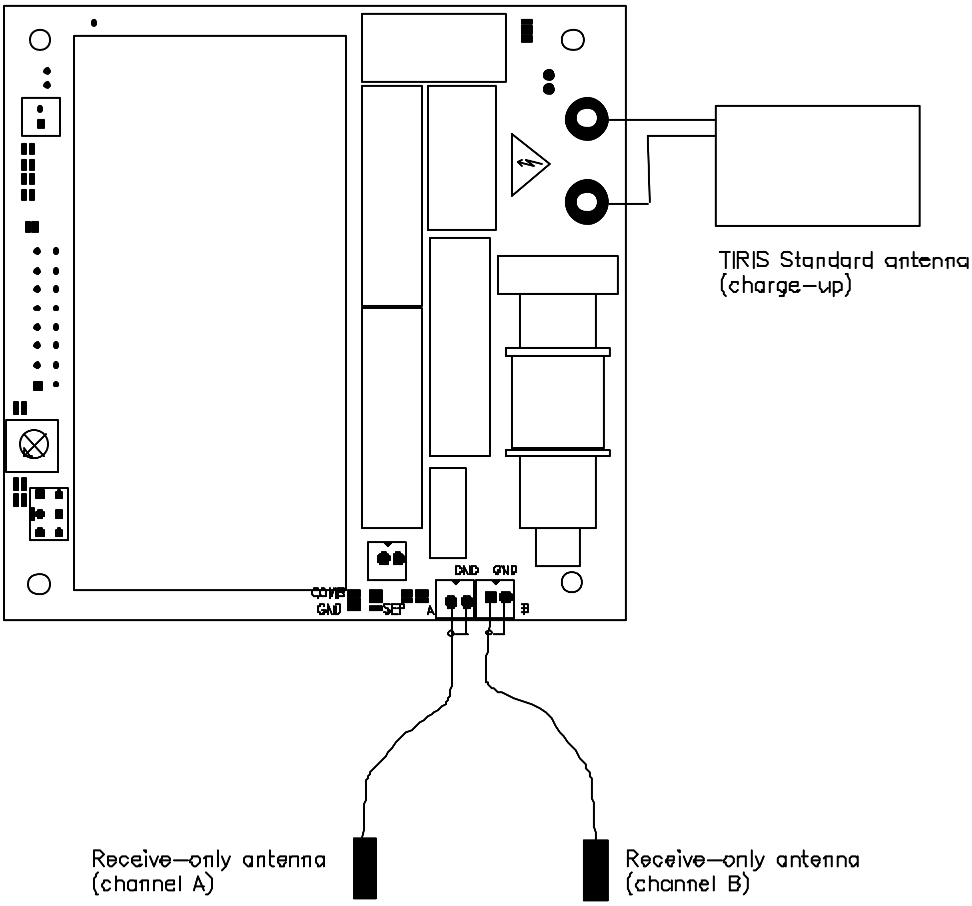


Figure 40: Receive Multiplexing - Connecting the Antennas

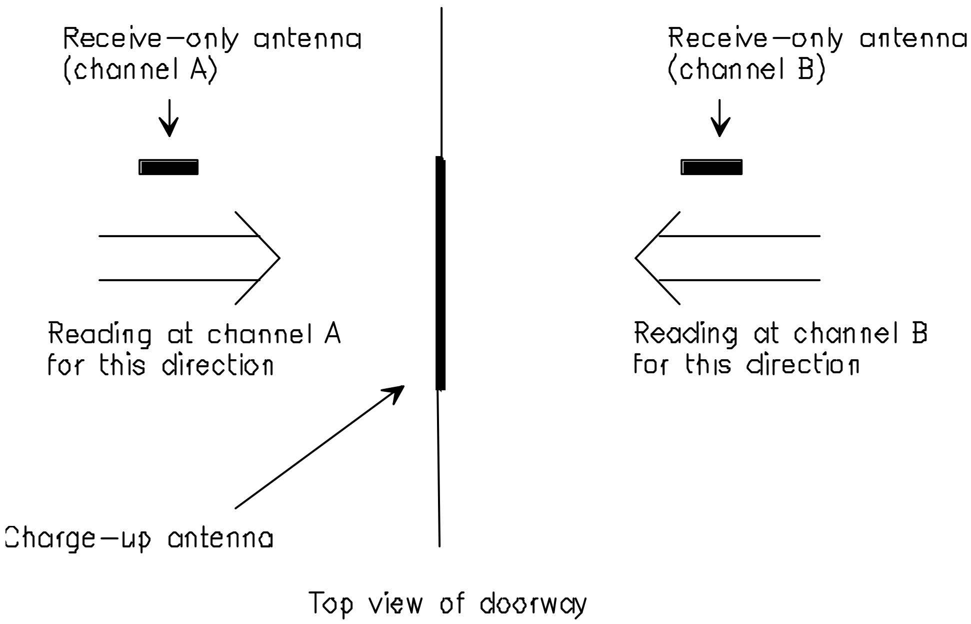


Figure 41: Example of Receive Multiplexing

The transponder signal is received via one of the two receive-only antennas. One receive-only antenna is put on each side of the doorway. So it is possible to detect with the channel select function of the receive multiplexer on which side of the doorway the transponder is located.

There is another alternative for receive-only antennas. TIRIS standard transmit/receive antennas can also be used as receive-only antennas, when they are built up as a tuned and damped resonator. For a schematic of this circuit see figure 7.

When using this type of antenna, additional solder jumpers have to be closed on the RF module, as shown in figure 22.

To tune this type of receive-only antenna resonance, it is recommended to use a capacitor array as shown in figure 42.

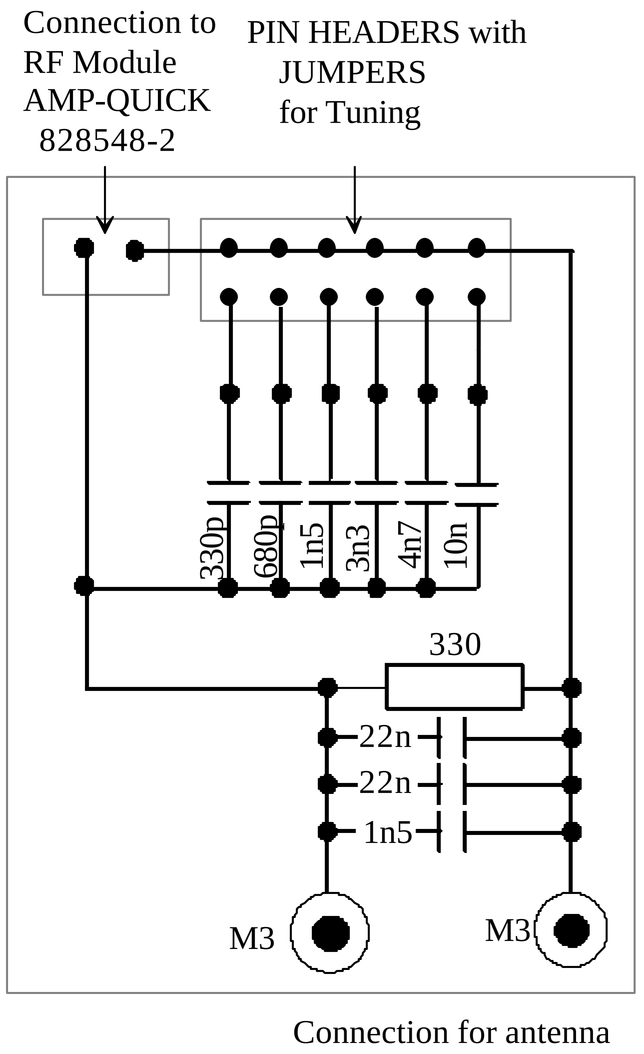


Figure 42: Converter Board for using Standard Antennas as Receive-only

Note: *Although the voltage value of the capacitors can be as low as 50 V for RX, it is recommended that high value (430V) capacitors are used.*

If the receive antenna is ever in the charge-up field and is not connected to the reader, high voltages could be induced that damage the capacitors. When the antenna is connected to the reader RX Multiplexer, built-in protection circuits safeguard the board.

The tuning to resonance can be done either by coupling the 137.2 kHz (the slightly higher frequency is necessary in order to match the bandpass parameters) resonance sine wave signal to the antenna using a sine wave function generator in combination with a coupling coil (==> **Method A**, which should be preferred),

or

the transmitter of the RF module is used to couple a 134.2 kHz sine wave signal to the receive-only antenna (==> **Method B**). This can be done by operating the transmitter of the RF module in pulsed mode via the controller unit.

The correct set-up for method B can be seen in figure 43. This set-up also applies to method A with the exception that a function generator operating at 137.2 kHz is used instead of the RF module transmitter.

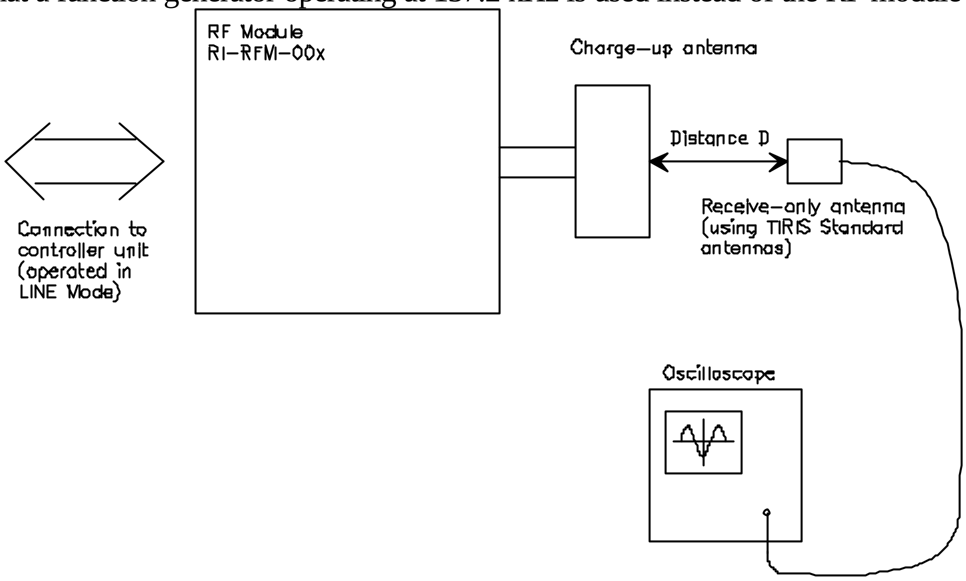


Figure 43: Tuning Receive Only Antennas (Method B)

Tuning procedure:

When using method A, the total capacitance of the receive-only antenna resonator has to be changed until the induced voltage at the receive-only antenna has reached its maximum. We recommend that you use a binary weighted capacitor array as shown in figure 42 for adjusting the resonance frequency.

When using method B, the total capacitance of the receive-only antenna resonator also has to be changed until the induced voltage at the receive-only antenna has reached its maximum. However in this case, the antenna is tuned to 134.2 kHz and not to 137.2 kHz. Therefore the total capacity has to be reduced by 2.2 nF after the tuning procedure. In this way, the antenna is again tuned to about 137.2 kHz.

* Put the TIRIS standard antenna plus the converter board at a fixed distance to the charge-up antenna (about 1 meter) and measure the induced voltage at the antenna using an oscilloscope. Ensure that the induced voltage does not exceed the specified voltage for the capacitor and resistor which are used on the converter board (a safe way is to not exceed 40 Vpeak), by changing the distance to the charge-up antenna.

* Tune the receive-only antenna to resonance by changing the capacity on the converter board, until the induced voltage has reached its maximum!

HINT: The 'Resonance Meter' accessory RI-ACC-REM1 can also be used to tune receive-only antennas to 137.2 kHz resonance.

CAUTION: Be careful with receive-only antennas near charge-up antennas, if the receive-only antennas are not connected to the receive multiplexer. The induced voltage may exceed the rated voltage specified for the capacitor and resistor used for the receive-only antenna. Therefore it is recommended to short circuit receive-only antennas when they are not connected to the RF module. The RF module has on-board clamping diodes and thus protecting the antenna.

Note: *It may happen that these receive-only antennas still can receive a transponder over a short distance (some centimetres), even when this receive channel is disabled.*

4.9 Noise Verification

Noise can have a negative effect on the receive performance of the RF module. There are two different kind of noise: radiated and conducted noise. Their characteristics are shown in table 13.

Table 13: Characteristics of Radiated and Conducted Noise

	Radiated Noise	**Conducted Noise**
Source	This is radiated from inductive parts for example: deflection coils, motor coils, ...	This is generated from power units, for example: motors, switched mode power supplies. It can be seen as voltage spikes or ripple voltage.
Path	It is radiated via magnetic fields.	It is galvanically conducted via all cables (supply and interface) connected to the RF module.
Effect	Disturbs receive function by magnetic interference with signal from transponder at the antenna.	Leads to malfunction and reduced sensitivity of receiver circuit, because of for example: interfered supply voltage. But conducted noise can also cause in addition radiated noise!

Method to detect and distinguish 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 RF module 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 RF module.

The measurement criteria for low noise is the amplitude of the receive signal strength detector of the RF module. The test pin RSTP at connector ST1 carries an analog output voltage indicating the receive signal strength. This voltage should be measured in combination with the antenna RI-ANT-G02. The set-up for this can be seen in figure 44. This configuration operates the RF module from a battery and has no interface line connected. As the transmitter is switched off for this configuration, a normal battery can be used for this test.

A low noise level is indicated by an RSTP voltage less than about 1.0 VDC when using antenna RI-ANT-G02.

***Note**: Remember that 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 procedure for testing of noise impact is as follows:

* The normal set-up for the RF module and antenna gives bad reading distance, even though the antenna is correctly tuned for sufficient transponder charge-up.

* Try the configuration shown in figure 44. If this configuration shows bad noise conditions (RSTP voltage more than about 1.0 VDC), then the problem is radiated noise.

==> Eliminate noise sources or try special antennas (e.g. Noise Balanced antennas). For more details refer to the 'Antenna Reference Guide' (Manual number 22-21-007)

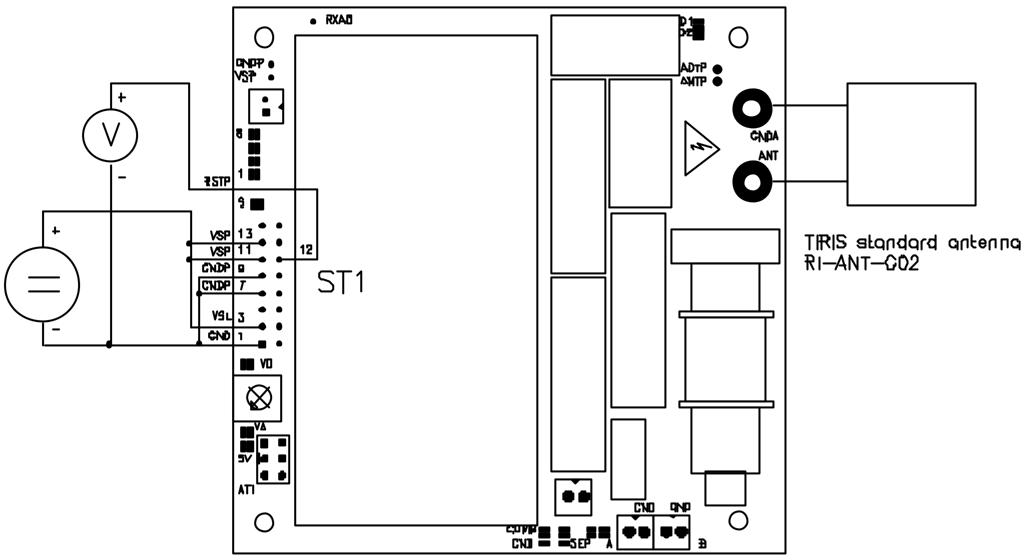


Figure 44: Noise Testing Configuration (Testing RSTP)

* When the configuration of figure 44 shows good noise conditions (RSTP voltage less than 1.0 Vdc), then the problem is conducted noise.

Now change the configuration so that the interface lines are again connected to the RF module (but the transmitter still switched off). If the RSTP voltage now indicates bad noise conditions, the conducted noise is coming via the interface lines.

==> Try to eliminate the noise on the interface lines. Some proposals are given in Section 4.10: "Over Voltage Protection".

* When the above configuration (interface lines connected) shows good noise conditions (RSTP voltage less than 1.0 Vdc), then the problem is conducted noise via the supply lines.

==> Try to eliminate the noise on the supply lines. Some proposals are given in Section 4.10: "Over Voltage Protection".

4.10 Over Voltage Protection

For applications, where there is the risk that voltage spikes and noise are on the lines to the RF module, additional protection circuitry and filters must be added. A useful proposal for this is shown in figure 45. This circuit can be used as a guideline for protection circuitry. However it may be that this is not sufficient for all applications. This has to be checked individually when necessary.

* The supply input has to be protected against voltage spikes. R1 and D1 are used for this purpose. Zener diode D1 clamps the voltage spikes to 18 volts so that the maximum allowed transmitter power stage supply voltage is not exceeded by too much. For diode D1 the type ZY18 is recommended, this type has 2W power dissipation. If you need a higher current dump type ZX18 can be used, this diode has 12.5W power dissipation.

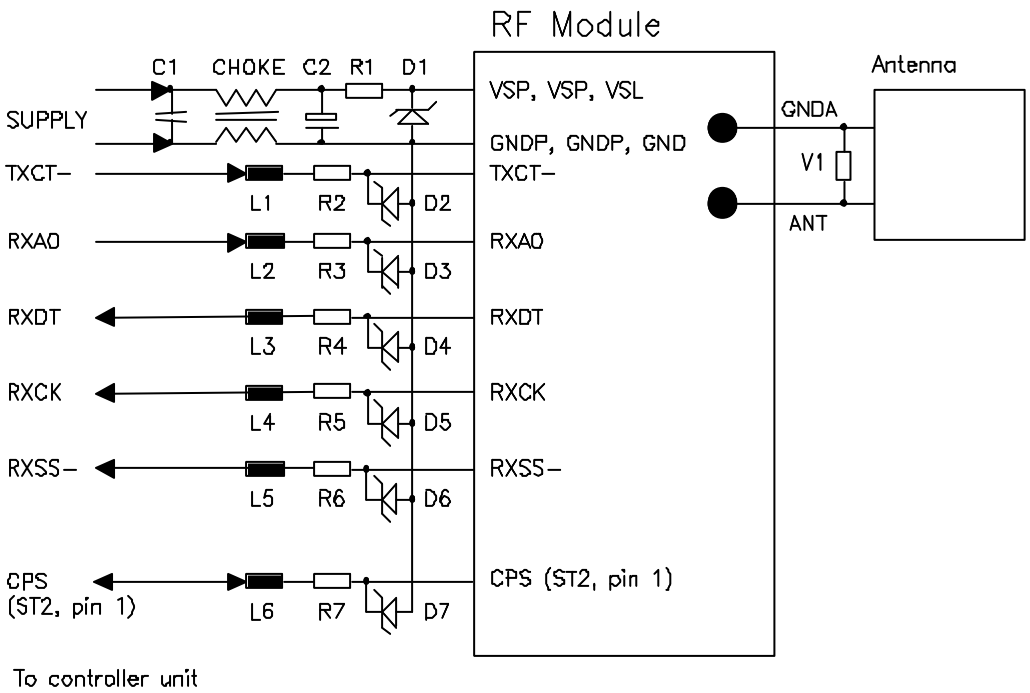
  The Common Mode Choke Coil and the capacitors C1 and C2 are used to reduce the conducted noise coming to the RF module, via the supply lines.

* All input and output signals should be protected with 5.6 V zener diodes. The specified type can dump 1.3W.

  The coils L1 to L6 are ferrite beads and should put in series to the line, when conducted noise is coming via the interface lines.

  The varistor V1 protects the antenna circuit against high voltage induced at the antenna coil, for example: by lightning. The given type of varistor is a common one and may not always be sufficient for protection in all cases.

Note: *The zener diodes types given in figure 47 are* ***not special suppresser diodes*** *for fast suppressing of voltage spikes, they are commonly used diodes. If the application requires it, special suppresser diodes should be used.*



All components must be mounted close to the RF Module with shortest possible wires!

C1: 100nF Ceramic
C2: 100uF low ESR

CHOKE: Common Mode Choke Coil
L1, L2, L3, L4, L5, L6: Ferrite beads

R1: 1 Ohm / 2W
R2, R3, R4, R5, R6, R7. 22 Ohm / 0.25W

D1: ZY18 respectively ZX18
D2, D3, D4, D5, D6, D7· BZX85C5V6

V1 = Varistor 420V
e.g. SIEMENS
SIOV-S20K420

Figure 45: Circuit for Overvoltage Protection

4.11 Interface Line Extension

As already described in Section 4.1: "Power Supply", if the interface lines exceed 2 meters it is necessary to drive the signals at connector ST1 via a differential interface. The RS422 differential interface is well suited to drive these interface signals over lines longer than 2 meters.

Two interface converters are necessary, one on the RF module side and one on the controller unit side.

The converter on the controller unit side has to convert the signals TXCT- and RXA0 from HCMOS logic level to RS422 level and the signals RXDT, RXCK and RXSS- from RS422 to HCMOS logic level.

The converter at the RF module side must work the other way round.

A circuit proposal for this is shown in figure 46 (it shows only the conversion of the signals TXCT-, RXDT, RXCK and RXSS-).

The circuit shows the interface converter at the controller unit on the left side of the drawing.
The interface drivers SN75157 and SN75ALS180 are used. Also the recommended interface line protection circuitry is shown. The interface cable consists of 4 twisted pairs plus shield.
The shield of the interface cable is connected to ground only at the controller unit.

The interface converter at the RF module is shown on the right-hand side of the drawing. Here the interface drivers SN75158 and SN75ALS180 are used. Again the recommended interface line protection circuitry is shown. The converter at the RF module side and the RF module itself are supplied from the controller unit via two power supply cables. Using such long supply cables, causes voltage drop across the cables. This in turn means that the RF module supply voltage is lower which results in a smaller field strength being generated.

In order to avoid this voltage drop across the power supply cables for the RF module, it is recommended to supply the RF module from a local supply at the RF module installation site. In this case, however, there needs to be an additional ground line between the controller unit and the RF module interface circuit, in order to have a defined ground path for the return current of the RS422 interface.

The 100 Ohm series resistor in this ground line is necessary to reduce the current in this ground line, which might be caused by different ground potentials of the controller unit and the RF module. The 100 Ohm series resistor does not affect the RS422 interface function. A circuit proposal is shown in figure 47.

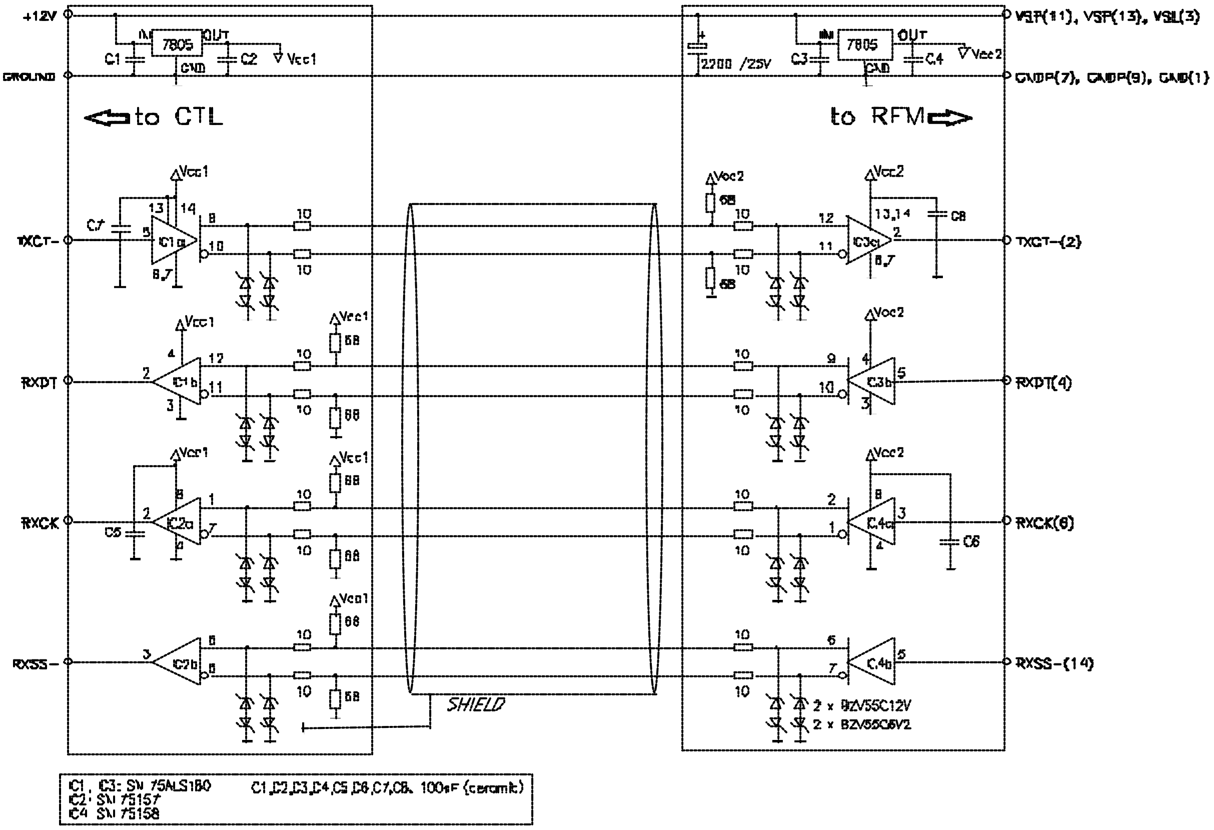


Figure 46: Conversion Circuit without Own Supply

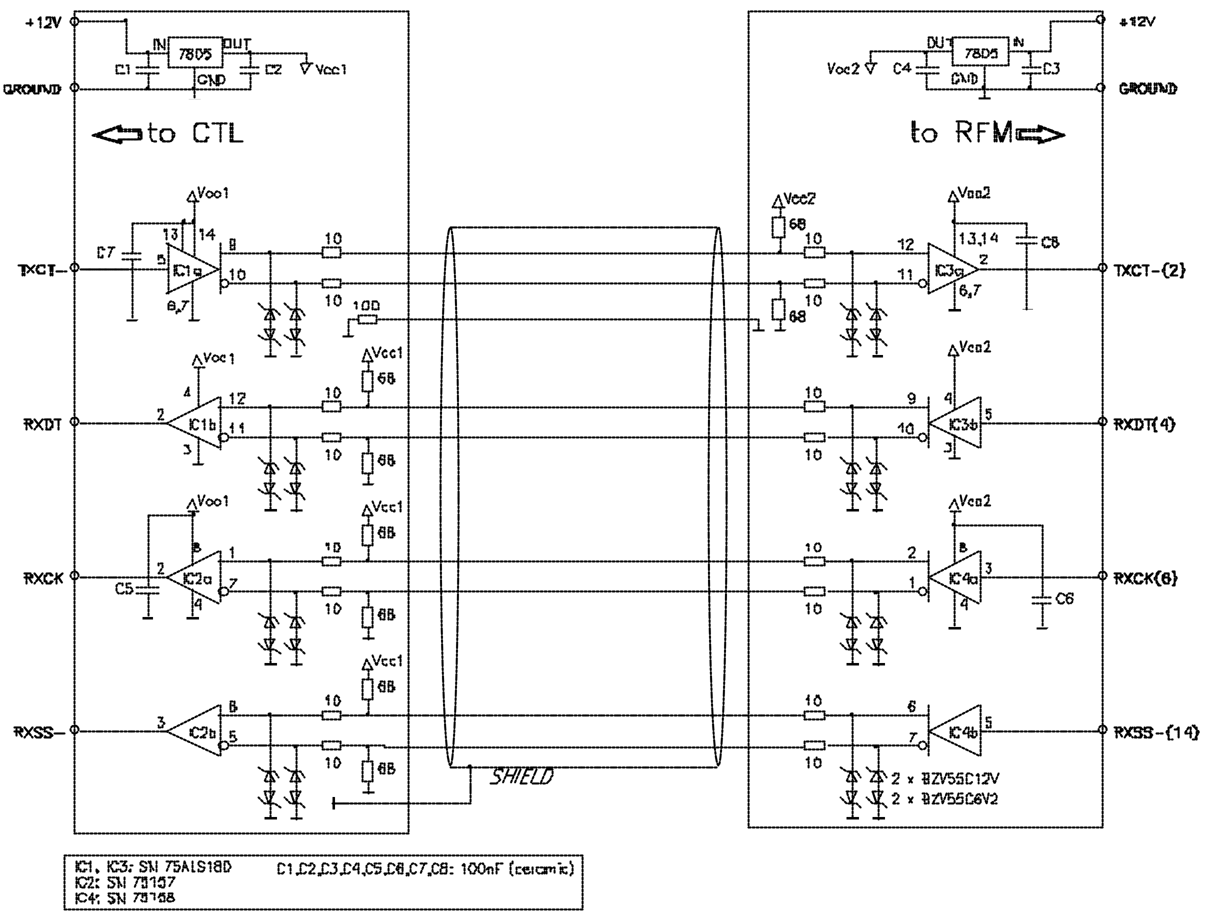


Figure 47: Conversion Circuit

If the ground potential differences between the controller unit and the RF module are too big, there will be a very high current flow through this ground line series resistor. Therefore we recommend that you use additional optical isolators (optocouplers), in order to overcome the problems with different ground potentials. A circuit proposal for this is shown in figure 48.

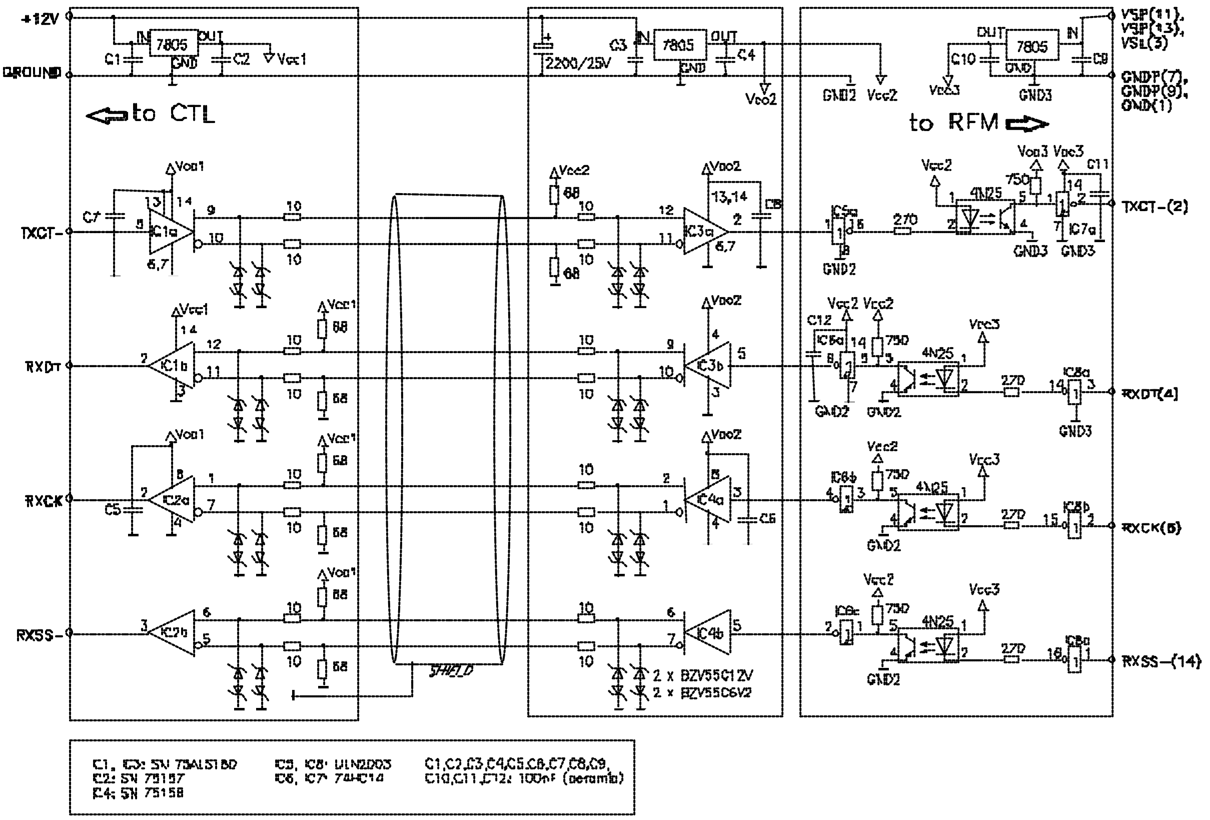


Figure 48: Conversion Circuit with Optocouplers

The interface converter at the controller unit side is the same as that already shown in figures 45 and 46. The circuit at the RF module side is different. Optocouplers are used here to galvanically separate the interface signals. Schmitt trigger circuits are used to shape the output signals from the optocouplers back to a correct square wave. Darlington transistors are used to drive the high current for the optocoupler LEDs.

The circuitry to the left of the optocouplers is supplied by the controller unit. The circuitry to the right of the optocouplers and the RF module itself are supplied from the local supply at the RF module.

In this way the problems with different ground potentials and supply voltage drop, caused by long cables are avoided and the interface lines can be extended without problems.

Note: *The circuits shown in figure 46, 47 and 48 are only a proposal for extending the interface line length. It cannot be guaranteed that these circuits will be correct for all applications!*

Appendix A. Short Description of Antennas

In the following list you will find the basic characteristics of the currently available standard TIRIS antennas. For more details refer to the "Antenna Reference Guide" (Manual number 22-21-007).

Gate antenna RI-ANT-G01

Parameter	**Condition**	**min.**	**typ.**	**max.**	**Unit**
L_G01	Antenna inductance range	26.0	27.0	28.0	µH
Q_G01	Quality factor at f = 134.2 kHz	110	130	150	-
l_G01	Length of antenna		715		mm
h_G01	Height of antenna		270		mm
w_G01	Width of antenna		16		mm
l_cable	Length of antenna feeder cable		1		m

Gate antenna RI-ANT-G02

Parameter	**Condition**	**min.**	**typ.**	**max.**	**Unit**
L_G02	Antenna inductance range	26.0	27.0	28.0	µH
Q_G02	Quality factor at f = 134.2 kHz	130	150	170	-
l_G02	Length of antenna		200		mm
h_G02	Height of antenna		200		mm
w_G02	Width of antenna		16		mm
l_cable	Length of antenna feeder cable		1		m

Gate antenna RI-ANT-G03

Parameter	**Condition**	**min.**	**typ.**	**max.**	**Unit**
L_G03	Antenna inductance range	26.0	27.0	28.0	µH
Q_G03	Quality factor at f = 134.2 kHz	100	120	140	-
l_G03	Length of antenna		940		mm
h_G03	Height of antenna		520		mm
w_G03	Width of antenna		16		mm
l_cable	Length of antenna feeder cable		1		m

Stick antenna RI-ANT-S01

Parameter	**Condition**	**min.**	**typ.**	**max.**	**Unit**
L_S01	Antenna inductance range	26.0	27.0	28.0	µH
Q_S01	Quality factor at f = 134.2 kHz - unloaded - during operation with high magnetic field	 400 100	 420 120	 450 140	-
l_S01	Length of antenna		140		mm
d_S01	Diameter of antenna		21		mm
l_cable	Length of antenna feeder cable		1		m

Stick antenna RI-ANT-S02

Parameter	**Condition**	**min.**	**typ.**	**max.**	**Unit**
L_S02	Antenna inductance range	26.0	27.0	28.0	µH
Q_S02	Quality factor at f = 134.2 kHz - unloaded - during operation with high magnetic field	 350 100	 370 120	 400 140	-
l_S02	Length of antenna		140		mm
d_S02	Diameter of antenna		21		mm
l_cable	Length of antenna feeder cable		3		m

Receive-only antenna RI-ANT-S04

Parameter	**Condition**	**min.**	**typ.**	**max.**	**Unit**
L_S04	Antenna inductance		800		µH
f_res_S04	Resonance frequency of receive-only antenna resonator		144		kHz
l_S04	Length of antenna		175		mm
d_S04	Diameter of antenna		21		mm
l_cable	Length of antenna coax cable		3		m

Appendix B. Summary of Solder Jumper Settings

All of the jumpers on the RF module are listed in this Appendix together with their use. They are listed twice: first in table B-1 in alphabetical order, and then in tables B-2 to B-6 in "function groups".

Table B-1: Jumpers (Alphabetic Listing)

Jumper	*Function*	*Setting*
1	Pulse Width Setting (LSB)	See Table 11
2	Pulse Width Setting	See Table 11
4	Pulse Width Setting	See Table 11
8	Pulse Width Setting (LSB)	See Table 11
5V	Power Supply Selection	Closed = Regulated Supply Open = Unregulated Supply
CA	Antenna Selection	Closed = TIRIS "standard" antenna Open = TIRIS **Receive Only** antenna
CB	Antenna Selection	Closed = TIRIS "standard" antenna Open = TIRIS **Receive Only** antenna
COMB	Antenna Selection	Closed = Combined TX/RX antenna Open (and grounded) = Separate antennas for TX and RX
D1	Transmit Antenna Damping	Closed = G01C
D2	Transmit Antenna Damping	Closed = G03C
S	Carrier Phase Synchronization	Closed = MASTER oscillator (or single RF module) Open = SLAVE oscillator
SEP	Antenna Selection	Closed = Separate antennas for TX and RX Open (and grounded) = Combined TX/RX antenna
VA	Power Supply Selection	Closed = Unregulated Supply Open = Regulated Supply
VD	Power Supply Selection	Closed = Unregulated Supply Open = Regulated Supply

Table B-2: Pulse Width Setting Jumpers

Jumper	*Function*	*Setting*
1	Pulse Width Setting (LSB)	See Table 11
2	Pulse Width Setting	See Table 11
4	Pulse Width Setting	See Table 11

8	Pulse Width Setting (LSB)	See Table 11

Table B-3: Power Supply Jumpers

Jumper	*Function*	*Setting*
5V	Power Supply Selection	Closed = Regulated Supply Open = Unregulated Supply
VA	Power Supply Selection	Closed = Unregulated Supply Open = Regulated Supply
VD	Power Supply Selection	Closed = Unregulated Supply Open = Regulated Supply

Table B-4: Antenna Selection Jumpers

Jumper	*Function*	*Setting*
COMB	Antenna Selection	Closed = Combined TX/RX antenna Open (and grounded) = Separate antennas for TX and RX
SEP	Antenna Selection	Closed = Separate antennas for TX and RX Open (and grounded) = Combined TX/RX antenna

If jumpers COMB and SEP are set for separate transmit and receive antennas you can then select whether you are going to use the TIRIS Receive only antenna (RI_ANT_S04C) or one of the "standard" TIRIS antennas:

CA	Antenna Selection receive-only	Closed = TIRIS "standard" antenna as Open = TIRIS **Receive Only** antenna
CB	Antenna Selection receive-only	Closed = TIRIS "standard" antenna as Open = TIRIS **Receive Only** antenna

Table B-5: Antenna Damping Jumpers

If you are using one of the larger TIRIS antennas and you need to damp the power output (for example, to meet PTT requirements) you can achieve 10 dB damping by using jumper D1 or 13 dB damping by using jumper D2 depending on the antenna.

Jumper	*Function*	*Setting*
D1	Transmit Antenna Damping	Closed = G01C
D2	Transmit Antenna Damping	Closed = G03C

Table B-6: Master/Slave (Synchronization) Jumpers

Jumper	*Function*	*Setting*

S	Carrier Phase Synchronization	Closed = MASTER oscillator (or single RF module) Open = SLAVE oscillator

Appendix C. PTT/FCC regulations

The field strength limits for the fundamental radiation for various countries are listed in table C-1. (Status: May 1996, this information is subject to change and may not be complete.)

Note: *The figures given here are to the best of our knowledge correct as of May 1996. For the current status please contact the relevant authority in your country.*

Table C-1: Field strength limits for various countries

Country	*Agency*	*Specification*		*Calculated @ D = 3 meter*	*Detection Method*
	Limit	*Unit*	*Distance*	*(exp=3.0)*	
ETSI (note 2)	65	dBµA/m	10 meter	148	Peak
DENMARK	see ETSI				
FINLAND	see ETSI				
NORWAY	see ETSI				
SWEDEN	see ETSI				
SWITZERLAND	see ETSI				
AUSTRALIA	30	µV/m	350 meter	154	Peak
BELGIUM	25	mA/m	3 meter	140	Peak
FRANCE	15	µV/m	353 meter	148	Peak
GERMANY	65	dBµV/m	30 meter	122**	CISPR
ITALY	30W RF output to antenna				Peak
JAPAN	15	µV/m	356 meter	148	Peak
NETHERLANDS	126	mA/m	1 meter	125	CISPR
NEW ZEALAND	83	dBµV/m	30 meter	143	Peak
UNITED KINGDOM	removable Antenna 10W RF output to antenna				Peak
UNITED STATES	18	µV/m	300 meter	139**	Average

* exp = 2.85)

***Note 1**: For proper adjustments of the indicated PTT values, a calibrated field strength meter must be used. Field strength measurement have to be taken on a free field test site according to VDE 0871 or an equivalent regulation.*

TIRIS operates with intermittent power. TIRIS peak radiation may exceed nominal values depending on the signal measurement method (CISPR or average). For applications of the correction factors, see figures 47 and 48. These correction factors have to be added to the values given in the above table. (See also ETSI Final Draft Sept. 1994 I-ETS 300 330 item 6.7 "Pulse modulated signal below 135 kHz").

***Note 2:** The regulation I-ETS 300 330 (Sept. 1994) is applied. The regulation can be subject to change.*

In some countries PTT approvals have been given based on test reports according to the I-ETS 300 330.

Note 3: *Field strength conversion between different distances is done according to the formula :*

*D E = 20 * exponent * log (d1/d2) [dBmV/m]*

D E : field strength difference which has to be added to or subtracted from the known field strength value in dBmV/m

d1 : distance of the known field strength value

d2 : distance of the desired field strength value

Field strength conversion between H and E is :

H [A/m] = E [V/m] / 377 W

or:

H [dBmA/m] = E [dBmV/m] - 51.5 dB

This is a nominal calculation, not valid for near-field conditions, but applicable in this case, because all field strength measurement equipment is calibrated according to this formula.

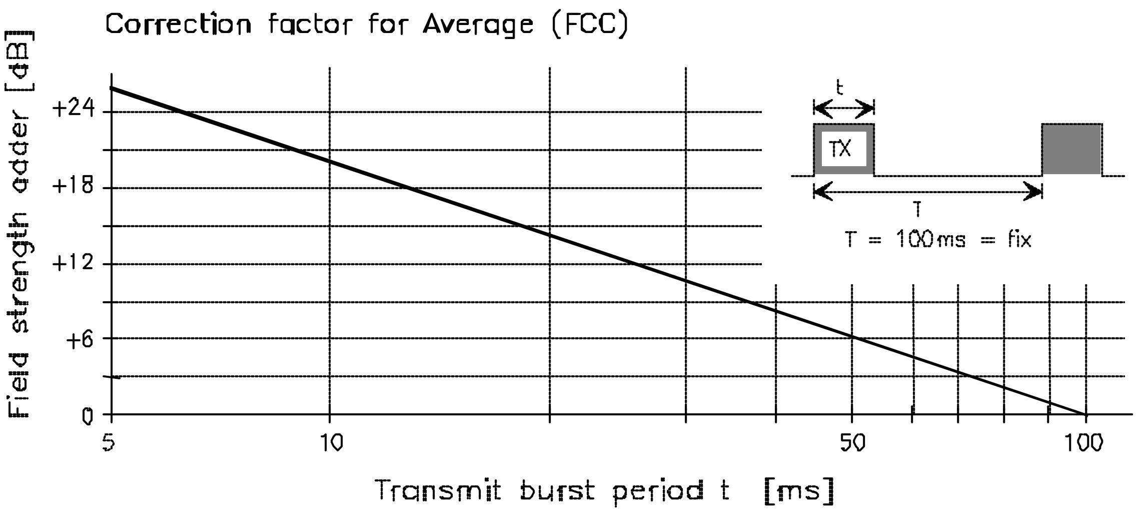


Figure 49: Field Strength Level Correction Factor Using Average Detector

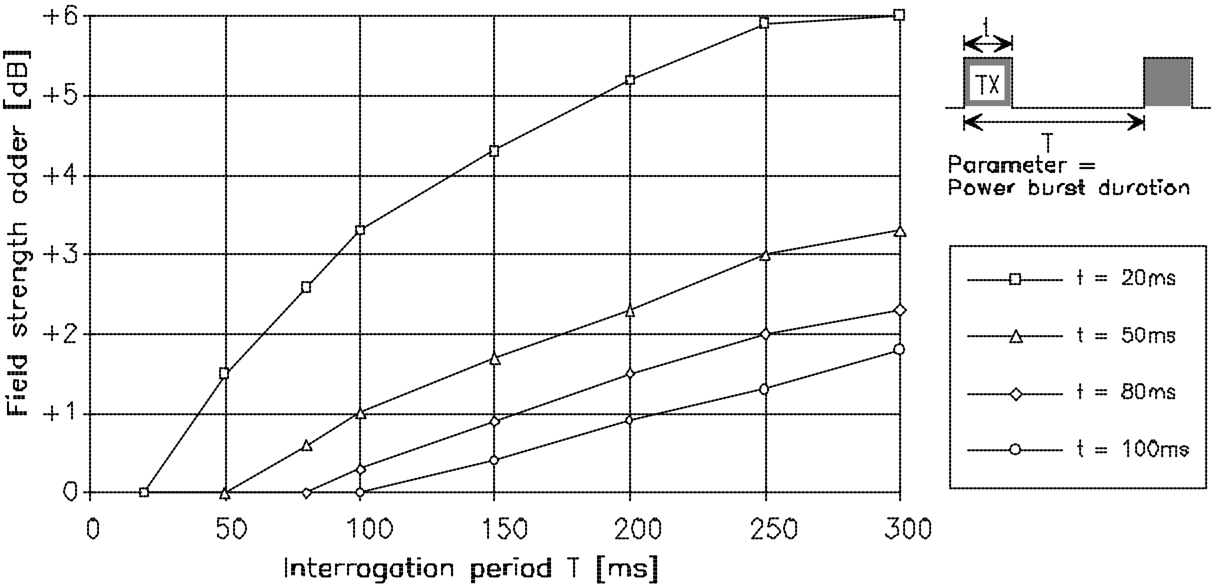


Figure 50: Field Strength Level Correction Factor Using CISPR Detector

Appendix D. Do's and Don'ts

DOs

* Remember, and Apply ESD handling.

* Connect the RF module correctly to the power supplies. Especially remember to connect the ground pins GND and GNDP to each other externally.

* Only operate the RF module with linear regulated power supplies.

* Always tune the antenna correctly to resonance (if possible by using the Antenna Tuning Indicator). Use a plastic screwdriver for adjusting the tuning coil.

* Use only the correct capacitors and resistors, which can withstand the high voltages and current, when expanding the antenna tuning range.

* Always retune to resonance, when the installation has changed, for example: when metal was added, when the antenna was exchanged and so on.

* Adjust the generated field strength to the local FCC/PTT requirements. For this either adjust the VSP supply voltage or select the correct oscillator signal pulse width.

* Obtain the relevant FCC/PTT approval for the system.

* Always adjust the RXSS- threshold level correctly (if possible by using the Antenna Tuning Indicator). Adjust the level so that no spikes occur at RXSS-.

* Use transmitter carrier phase synchronization, when using several antennas close to each other. Use RS422 interface extension for long cables and more RF modules.

* If the application needs it, install over voltage protection circuit at all inputs and outputs.

* Eliminate noise sources, or increase the distance from noise sources as much as possible.

* Pay attention to the WARNINGs, CAUTIONs, Notes and Hints in this specification.

DON'Ts

* Do not touch the antenna resonator parts. HIGH VOLTAGE at any part of the antenna resonator during the transmit burst can be harmful to your health. Switch the RF module power off at whenever you are working on the RF module.

* Do not handle the parts at non ESD secured workplaces. Do not allow unsecured personnel to handle the RF module.

* Do not use Switched Mode Power Supplies (SMPS) for supplying the RF module (unless the SMPS works with a fundamental frequency of at least 200 kHz).

* Do not operate the RF module above recommended operating conditions.

* Do not exceed the maximum allowed difference voltage between GND and GNDP, which is ±0.5 V.

* Do not operate the RF module in continuous transmit mode. Use the Antenna Tuning Indicator or operate the RF module in LINE Mode via the controller unit for tuning procedure.

* Do not put the tuning coil of the RF module close to noise sources and metal, because of coupling of interfering noise and detuning.

* Do not short circuit the antenna terminals during operation.

* Do not use the additional antenna damping option for other antennas than specified and do not exceed the maximum allowed oscillator pulse width.

* Do not connect the receiver test pins of connector ST1 under any circumstance.

Appendix F. Installation Guide (short form)

First Step: Connect RF module and control module to the power supplies.

In order to install the RF module, it has to be connected to the control module (customer specific) and to the power supplies as shown in figure 51.

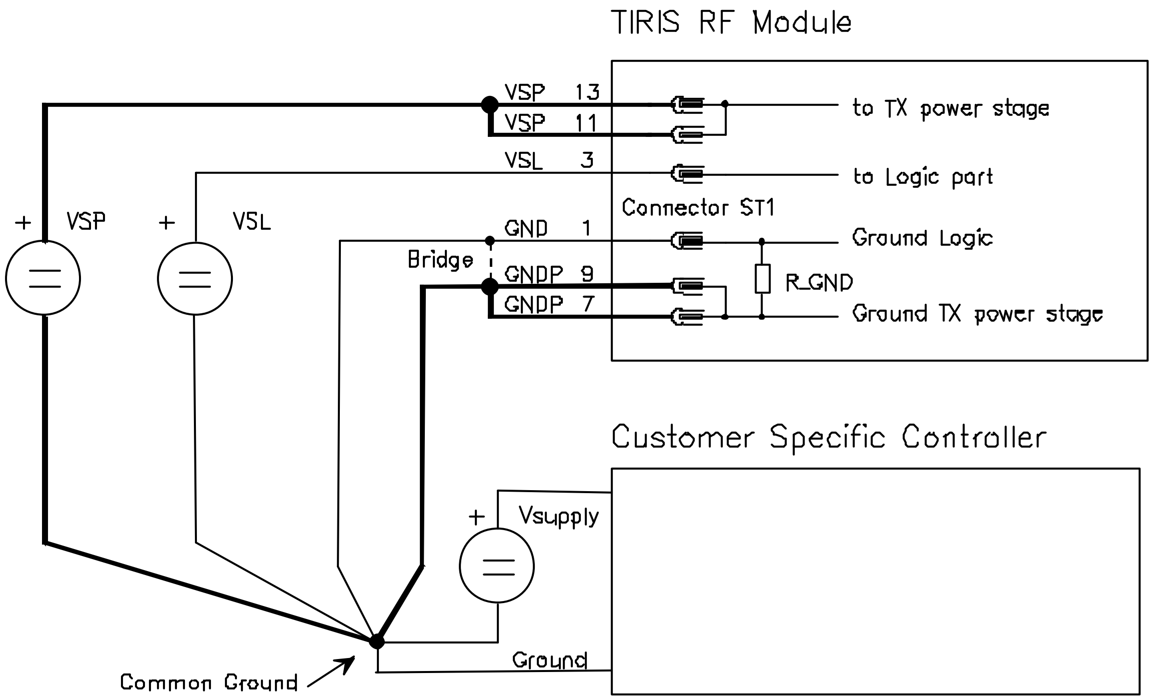


Figure 51: Connecting the RF module and Control Module to the Power Supplies

CAUTION: In order to avoid permanent damage to the RF module, logic ground pin GND and both power ground pins GNDP of the RF module have to be connected to each other externally.

Second step: Connecting the antenna and tuning it to resonance.

Connect the antenna to the RF module using the screws delivered with the RF module.

Then each charge-up antenna has to be tuned individually to resonance with the RF module by adjusting the tuning coil.

It is possible to measure and check resonance condition as shown in figure 52. For this the RF module has to be operated intermittently via the controller unit.

However it is strongly recommended to use the Antenna Tuning Indicator accessory for resonance tuning.

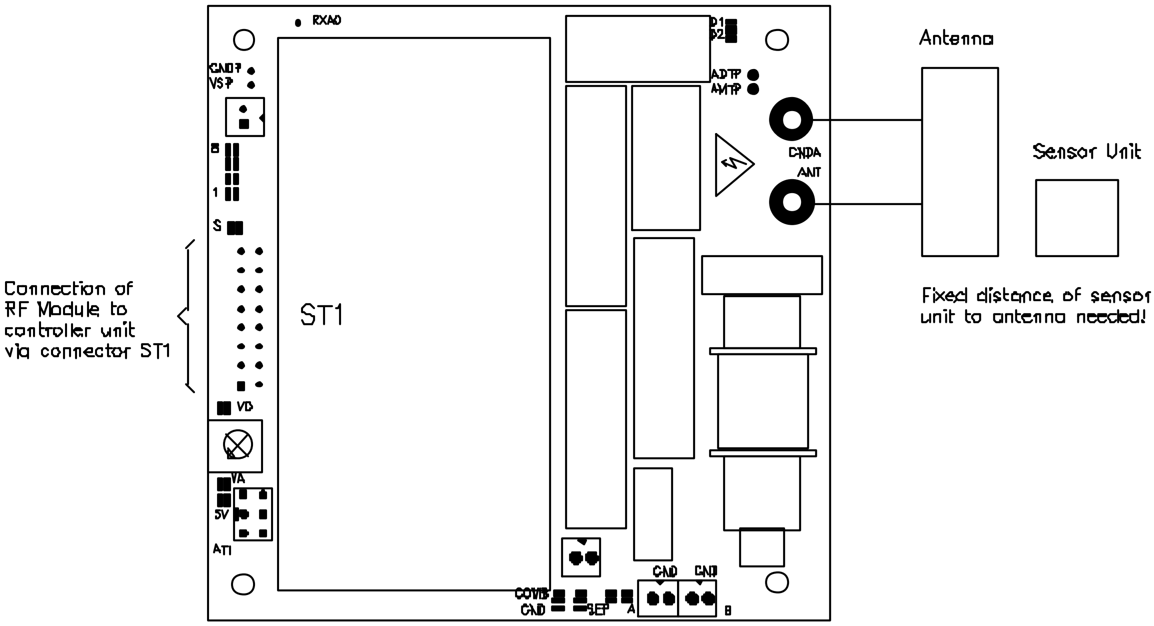


Figure 52: Measuring and Checking Resonance Condition for Tuning the Antenna to Resonance

After tuning the antenna to resonance, the generated field strength has to be adjusted to the local PTT/FCC regulations, either by adjusting the supply voltage VSP of the transmitter power stage or by adjusting the oscillator signal pulse width. For detailed information, please refer to section 4.

Third step: The RXSS- threshold level has to be adjusted.

For correct wireless synchronization, the RXSS- threshold level has to be adjusted using the built-in potentiometer. This has to be done individually for each antenna and RF module.

To do this the voltage at the RXSS- pin has to be measured with a standard voltmeter or an oscilloscope, as shown in figure 53. The threshold level is adjusted according to the following procedure:

* Turn the RXSS- threshold level potentiometer fully counter-clockwise (left- hand stop).

* Deactivate the transmitter by connecting together pin 1 and pin 3 of connector ST4, as shown in figure 53.

* Ensure that no other reading units are transmitting, by connecting pin 1 to pin 3 of connector ST4 of all other RF modules in the area, as shown in figure 53.

* Eliminate noise sources as much as possible.

* Monitor the voltage at RXSS- output pin with a voltmeter or an oscilloscope as shown in figure 53.

* Turn the RXSS- threshold level adjustment potentiometer on the RF module clockwise, until the RXSS- output is just statically inactive.

  "Statically" means without voltage spikes 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).

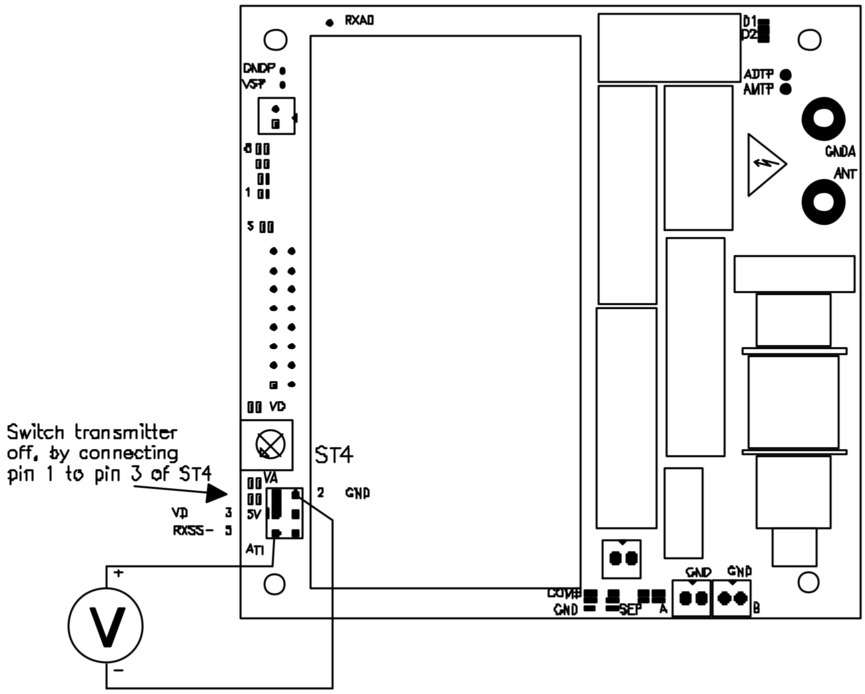


Figure 53: Measuring the RXSS- Signal for Adjusting the RXSS- Threshold Level

===> Installation/Tuning of the RF module is complete!