AN421

Antenna Selection Guide for the Si4020 and Si4320 ISM Band FSK Transmitter/Receiver Chipset

Application Note

Version 1.5

Silicon Labs, Inc.
400 West Cesar Chavez
Austin, Texas 78701

Tel: 512.416.8500
Fax: 512.416.9669

Please visit the Silicon Labs Technical Support web page:
https://www.silabs.com/support/pages/contacttechnicalsupport.aspx
and register to submit a technical support request.

ABOUT THIS GUIDE

The antenna selection guide for the Si4020 and Si4320 ISM Band FSK Transmitter/Receiver Chipset is designed to give product designers a quick time-to-market approach for on-board antenna selection. The guide is designed to address geographic regulations covering the standard ISM FSK band frequencies; 315MHz, 434MHz, 868MHz, and 915MHz and to address the approximate range-versus-bandwidth to given antenna pairs.

Designers wishing to develop custom antennas can refer to the **Antenna Development Guide: AN422**.

For further information on the devices used in this publication, see the following datasheets:

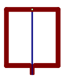
Si4020 Universal ISM Band Transmitter datasheet:	**Si4020-DS**
Si4320 Universal ISM Band Receiver datasheet:	**Si4320-DS**

INTRODUCTION

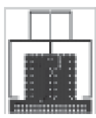
DESCRIPTION

This document is an Antenna Selection Guide for the universal, four-band (315 MHz, 434 MHz, 868 MHz, 915 MHz) Si4020 transmitter and Si4320 receiver.

Within this document two main antenna groups are referenced:



Loop antennas



Modified Inverted (IFA) antennas, the so-called “back IFA” antennas

For further information regarding antenna types and RF link properties, please visit our Web site: **http://www.silabs.com**, and download the ***Antenna Development Guide: AN422.***

1. ANTENNA PAIRS AND RANGES

The range is estimated from the measured EIRP (Equivalent Isotropic Radiated Power) and the sensitivity of the transmitter and the receiver with the different antennas, respectively. The definition of EIRP is given in Appendix A. During the range calculations, ideal free space propagation conditions were assumed. The given range corresponds to a transmitter (TX) with a two-sided FSK deviation of 120 kHz (with data rate of 9600 bps) and 180 kHz (with data rate of 57470 bps). The receiver (RX) baseband filter bandwidth was adjusted to 135 kHz. The EIRP data of the TX with different antennas as well as the measured RX sensitivities at 10^{-2} BER (Bit Error Rate) are given in detail in Appendix A. The free space range calculation method is described in Appendix B. The measurement setup of the TX and RX measurement is detailed in Appendix C.

In some cases, the allowed radiation power (given either in ERP (Equivalent Radiated Power - see Appendix A for definition) or field strength), set by the U.S. FCC or European ETSI guidelines, is lower than the maximum power of the transmitter. In those cases, the range corresponding to the allowed radiation power is given together with the necessary power reduction.

As the impedance of the loop antennas are much higher compared to that of the IFA antennas, the output current of the TX with loop antennas must be reduced so as not to exceed the maximum allowed differential voltage swing (4 Vpp) on the outputs. The given ranges of loop TX antennas correspond to the properly reduced currents.

The receiver sensitivity was measured in the presence of strong interference (GSM, TV etc.) signals with frequencies close to the used bands. The electric field of the interference signals around 900 MHz during the sensitivity measurements were between 60 and 80 mV/m; it is approx. 40-60 dB higher than the useful signal's electric field. As the receiver sensitivity is approx. *6-8 dB better* in an *interference-free environment* (i.e., if a narrow band saw filter is used at the receiver input), the *distance is about 2 times higher* in that circumstance.

The typical range to achieve a BER (Bit Error Rate) of 10^{-2} in the case of various transmitter-receiver antenna pairs is presented for 9600 and 57450 bps data rate at each frequency. The antenna layouts together with the antenna dimensions are also given.

In the case of Back IFA antennas, the frame shows the nearest allowed cutting edge of the PCB. If the cutting is closer to the arms of the antenna, significant de-tuning — and thus reduction of the radiated power — will occur.

U.S. REGULATIONS: 915 MHz, 434 MHz, 315 MHz BAND

Tables 1.1, 1.2, and 1.3 give the typical ranges in meters for different TX and RX antenna pairs for the U.S. 915 MHz, 434 MHz, and 315 MHz band, respectively. The transmitted power is regulated by part 15 of the FCC standards (Note 2). It gives restrictions to the allowed field strength at 3 m distances. The allowed field strengths are 50, 11, and 6 mV/m at 915, 434 and 315 MHz, respectively. In the case of spread spectrum transmission, the maximum allowed TX power is 1 W at 915 MHz, which can be achieved only with an external booster stage.

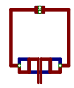
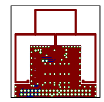
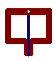
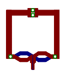
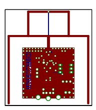
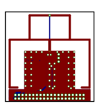
915 MHz U.S. band	RX tapped loop (see Fig 2.5) 		RX back IFA dev (see Fig 2.6) 	
TX loop (see Fig 2.1) (3dB reduced power state) 	*9600 bps*	**127**	*9600 bps*	**502**
	57470 bps	**67**	*57470 bps*	**317**
TX tapped loop (see Fig 2.2) 	*9600 bps*	**246**	*9600 bps*	**980**
	57470 bps	**131**	*57470 bps*	**618**
TX back IFA (see Fig 2.3) (max. power: EIRP ≈ -1 dBm) 	*9600 bps*	**632**	*9600 bps*	**2118**
	57470 bps	**336**	*57470 bps*	**1589**
TX back IFA dev (see Fig 2.4) (max. power: EIRP ≈ 4 dBm, allowed only in case of spread spectrum transmission) 	*9600 bps*	**1164**	*9600 bps*	**4835**
	57470 bps	**618**	*57470 bps*	**2924**

Table 1.1 Range [m] in the 915 MHz U.S. unlicensed band, in the presence of strong interference signals assuming ideal free space propagation conditions (see Appendix D).

Note 1: In an interference-free environment, the estimated ranges are approximately two times higher. In the case of non-ideal propagation, the ranges can dramatically decrease (see Appendix E for details).

Note 2: For further details on FCC part 15, see “Understanding the FCC Regulations for Low-Power, Non-Licensed Transmitters,” by the Federal Communications Commission, available through the FCC Web site, http://www.fcc.gov.

U.S. REGULATIONS: 915 MHz, 434 MHz, 315 MHz BAND (CONTINUED)

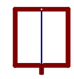
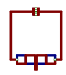
434 MHz U.S. band	RX tapped loop (see Fig. 2.8) 	
TX loop (see Fig. 2.7) (6dB reduced power state) 	*9600 bps*	**44**
	57470 bps	**23**

Table 1.2 Range [m] in the 434 MHz U.S. unlicensed band, in the presence of strong interference signals assuming ideal free space propagation conditions (see Appendix D).

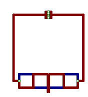
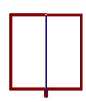
315 MHz U.S. band	RX tapped loop (see Fig. 2.10) 	
TX loop (see Fig. 2.9) (6dB reduced power state) 	*9600 bps*	**56**
	57470 bps	**33**

Table 1.3 Range [m] in the 315 MHz U.S. unlicensed band, in the presence of strong interference signals assuming ideal free space propagation conditions (see Appendix D).

Note 1: In an interference-free environment, the estimated ranges are approximately two times higher. In the case of non-ideal propagation, the ranges can dramatically decrease (see Appendix E for details).

EUROPEAN REGULATIONS: 868 MHz BAND AND 434 MHz BAND

The typical ranges for the 868 MHz and 434 MHz European unlicensed bands are given in Tables 1.4 & 1.5, respectively.

The normal and the cross-tapped loop antenna for 868 MHz are identical to that of the 915 MHz band, as the automatic tuning circuitry allows multi-band operation.

The allowed transmitter ERP is between 7-27dBm (corresponding to 9.14-29.14 dBm EIRP) at 868 MHz depending on the sub-channel frequency. The allowed ERP is 10 dBm (corresponding to 12.14 dBm EIRP) at 434 MHz. (Note 2).

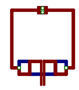
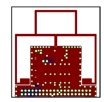
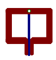
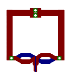
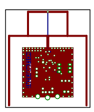
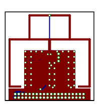
868 MHz E.U. band	RX tapped loop (see Fig 2.13) 		RX back IFA dev (see Fig 2.14) 	
TX loop (see Fig 2.1) (3dB reduced power state) 	*9600 bps*	**107**	*9600 bps*	**372**
	57470 bps	**62**	*57470 bps*	**232**
TX tapped loop (see Fig 2.2) 	*9600 bps*	**302**	*9600 bps*	**1049**
	57470 bps	**174**	*57470 bps*	**645**
TX back IFA (see Fig 2.11) 	*9600 bps*	**893**	*9600 bps*	**3095**
	57470 bps	**514**	*57470 bps*	**1932**
TX back IFA dev (see Fig 2.12) 	*9600 bps*	**1680**	*9600 bps*	**5830**
	57470 bps	**970**	*57470 bps*	**3640**

Table 1.4 Range [m] in the 868 MHz E.U. unlicensed band, in the presence of strong interference signals assuming ideal free space propagation conditions (see Appendix D).

Note 1: In an interference-free environment the estimated ranges are approximately two times higher. In the case of non-ideal propagation, the ranges can dramatically decrease (see Appendix E for details).

Note 2: For further details on ERC/REC devices, see "Relating to the Use of Short Range Devices," available through the European Radio Communications Office website, **http://www.ero.dk**.

EUROPEAN REGULATIONS: 868 MHz BAND AND 434 MHz BAND (CONTINUED)

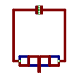
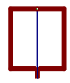
434 MHz E.U. band	**RX tapped loop (see Fig. 2.8)** 	
TX loop (see Fig. 2.7) **(6dB reduced power state)** 	*9600 bps*	**44**
	57470 bps	**23**

Table 1.5 Range [m] in the 434 MHz E.U. unlicensed band, in the presence of strong interference signals assuming ideal free space propagation conditions (see Appendix D).

Note 1: In an interference-free environment, the estimated ranges are approximately two times higher. In the case of non-ideal propagation, the ranges can dramatically decrease (see Appendix E for details).

2. ANTENNA LAYOUTS

All antennas are connected to the Si4020 Transmitter IC output or Si4320 Receiver IC input pins through 0.25 mm wide and 1 mm long leads. They are shown only in the sized figures of the normal loop TX antennas (see Fig. 2.1, Fig. 2.5 and Fig. 2.9) and in the figure of the cross-tapped loop TX antenna (see Fig. 2.2). The large grounding metal plate comprises all the necessary circuitry that would be used in production PCBs, and can be observed in the figures of the back IFA antennas. In case of loop and cross-tapped loop antennas, the boundary of the large metal plate (PCB with components) should be situated at the end of the 0.5 mm wide connection leads (the 0.25 mm-wide connection leads shown for example in Fig. 1 are situated inside the PCB).

All antenna layouts were created on an 0.5 mm-thick FR4 substrate with an epsilon of 4.7.

The impedance of the BIFA antenna is very sensitive to the electrical length of the arms, and therefore sensitive to the variation of the dielectric constant. This effect can be compensated only slightly by the automatic tuning function of the TX. In the case of RX antennas, the sensitivty is lower due to the low RX quality factor (Q). The physical edge of the PCB should be at least 2 mm away from the cut arms of the BIFA antennas. If it is closer, the electrical length of the arms will change and cause significant detuning, especially in the TX, and thus power or RX sensitivity degradation will occur (i.e. in the case of 0.5 mm distance, the power degradation of the TX is approximately 2 dB).

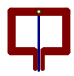
In the case of loop antennas, the epsilon change has negligible effect, thus the PCB cutting close to the antenna metalization is allowed. However, due to the printed capacitor, the tapped antennas have some epsilon dependency, which is usually significant only in the TX due to the higher Q. The automatic tuning function can compensate for the detuning.

The open collector outputs of the transmitter require a DC path to the VCC. Thus, all TX antennas have a narrow bias line situated at the symmetrical axis of the antenna at the bottom layer of the PCB and connected by a ‘via’ hole to the antenna metallization.

The receiver inputs do not require DC path. However, in the case of the cross-tapped loop antennas (for the cross-tapping and for the symmetrical printed capacitance at the main loop) the use of the bottom layer is necessary.

At the end of the arms of several BIFA antennas printed edge tuning capacitors are used to reduce the length of the arms.

915 MHz BAND



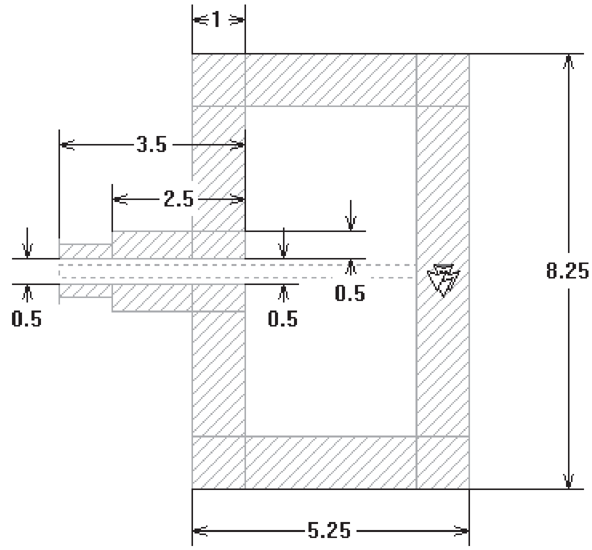
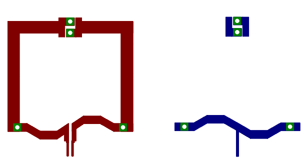


Fig 2.1 915-868 MHz dual band loop TX antenna (dimensions in mm)



Top and bottom view

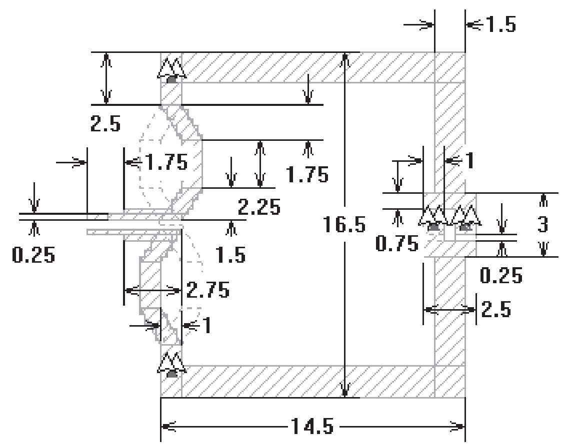


Fig 2.2a 915-868 MHz dual band tapped loop TX antenna (dimensions in mm), this antenna is designed to be a two-layer PCB design, as seen in fig 2.2b below

915 MHz BAND (CONTINUED)

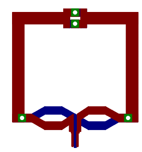
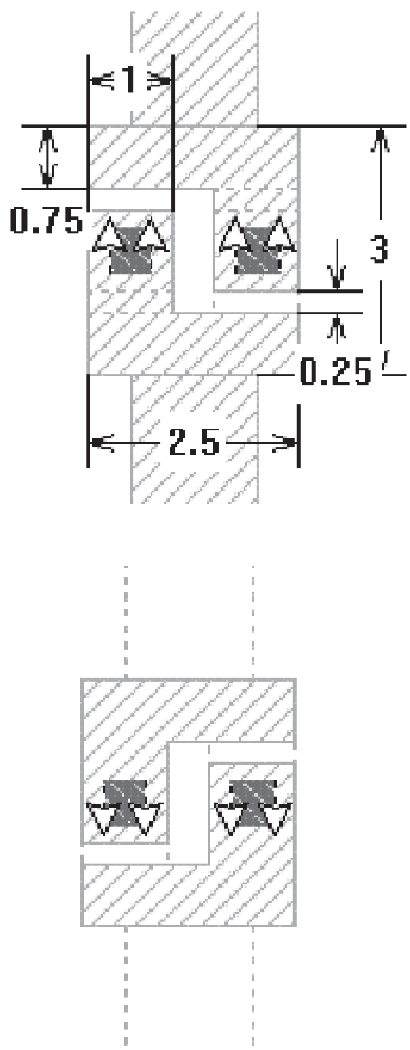


Fig 2.2b

As shown in Fig 2.2a and Fig 2.2b above, the antenna makes use of the capacitance characteristics of the PCB. This capacitor is generated by printing the PCB, as shown below in Fig 2.2c.



Top and bottom view

Fig 2.2c Printed capacitor of the 915MHz TX cross-tapped loop antenna

915 MHz BAND (CONTINUED)

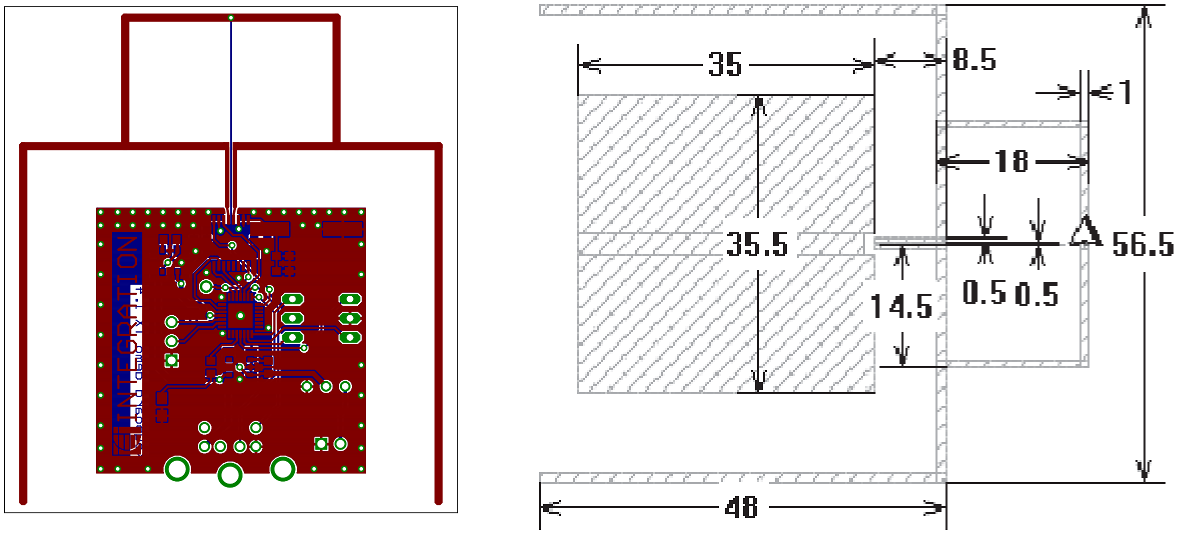


Fig 2.3 915 MHz TX back IFA antenna (dimensions in mm)

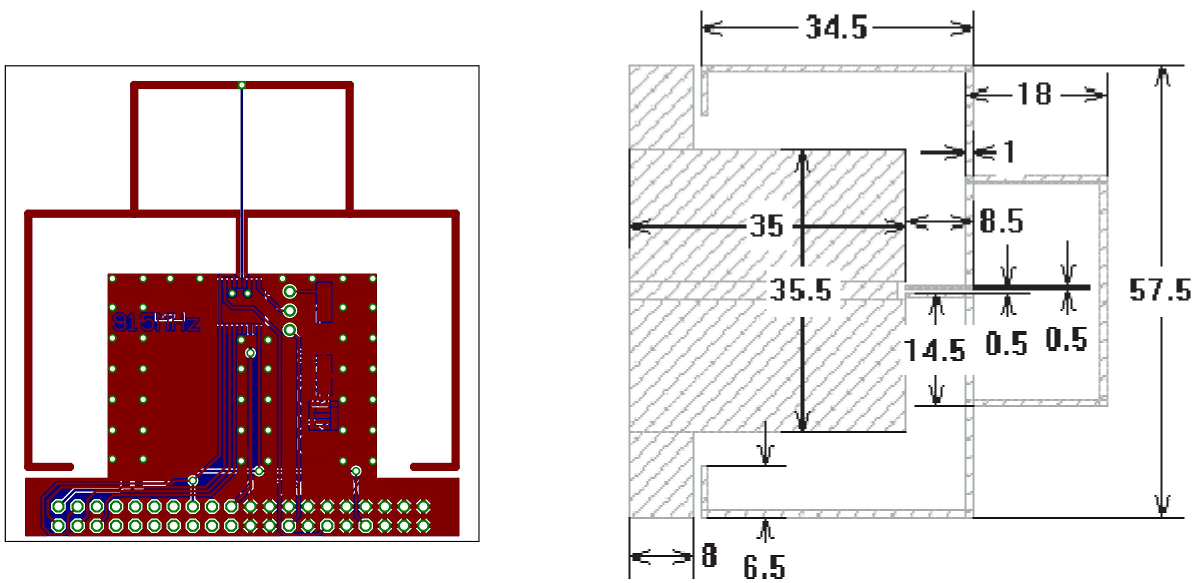
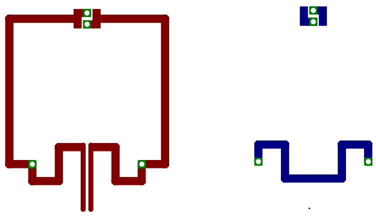


Fig 2.4 915 MHz TX back IFA antenna 2 (dimensions in mm)

915 MHz BAND (CONTINUED)



Top and bottom view

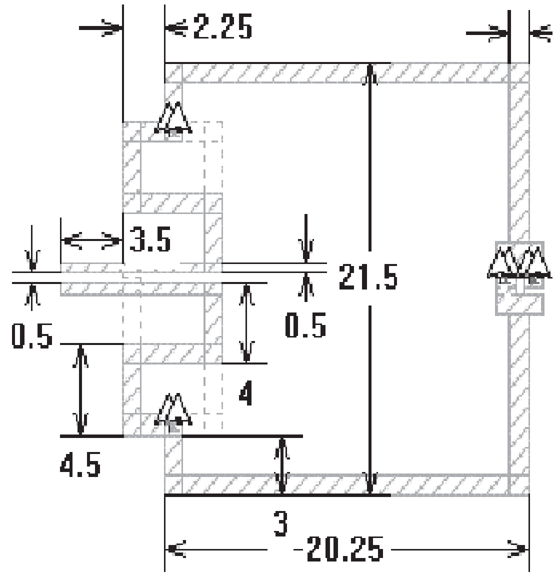


Fig 2.5a 915 MHz RX cross-tapped loop antenna (dimensions in mm)

This antenna is designed to be a two layer PCB design, as such the overall look of the antenna can be seen in the diagram below in Fig 2.5b

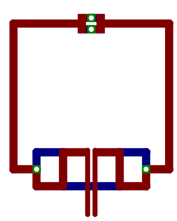
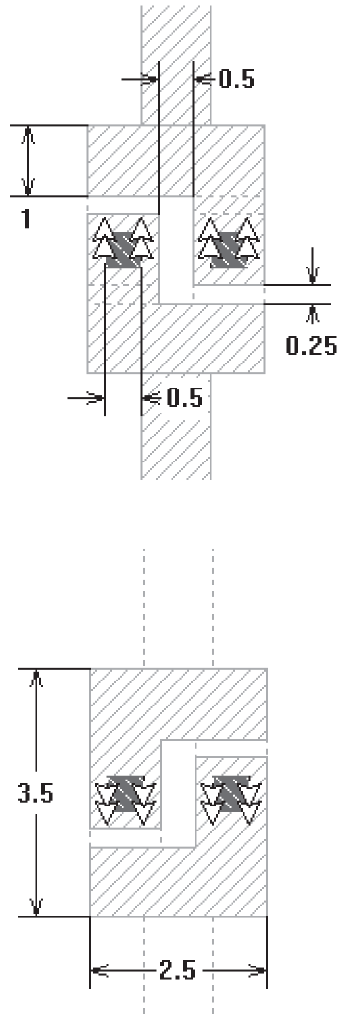


Fig 2.5b

915 MHz BAND (CONTINUED)

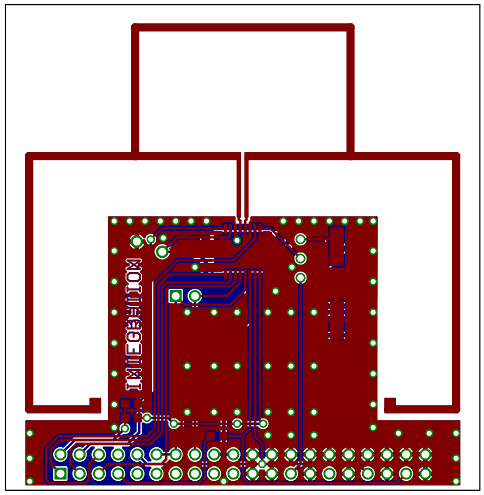
As shown in Fig 2.5a and Fig 2.5b above, the antenna makes use of the capacitance characteristics of the PCB. This capacitor is generated by printing the PCB, as shown below in Fig 2.5c.



Top and bottom view

Fig 2.5c Printed capacitor of the 915MHz RX cross-tapped loop antenna

915 MHz BAND (CONTINUED)



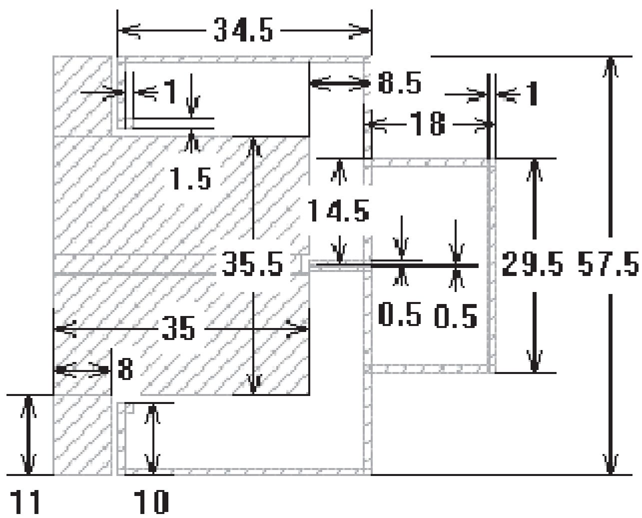


Fig 2.6 915 MHz RX BIFA antenna (dimensions in mm)

434 MHz BAND

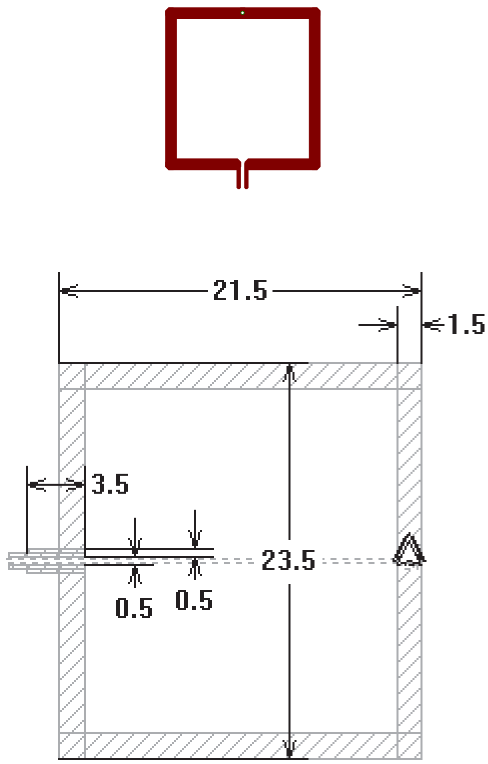


Fig 2.7   434 MHz TX loop antenna (dimensions in mm)

434 MHz BAND (CONTINUED)

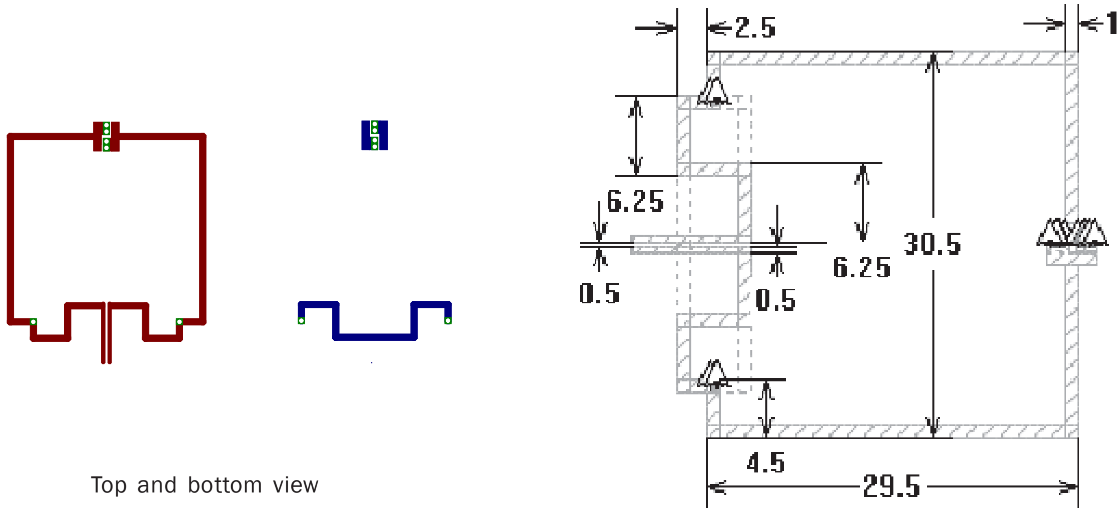


Fig 2.8a   434 MHz RX cross-tapped loop antenna (dimensions in mm)

This antenna is designed to be a two layer PCB design. The overall look of the antenna can be seen in the diagram below, Fig 2.8b

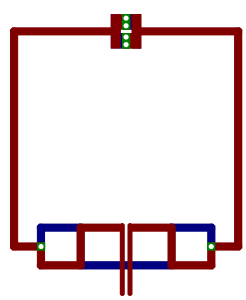
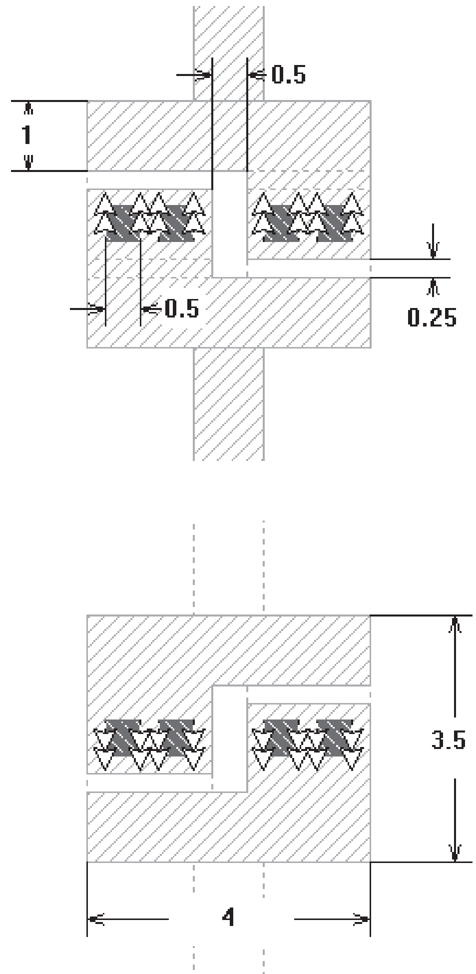


Fig 2.8b

434 MHz BAND (CONTINUED)

As shown in Fig 2.8a and Fig 2.8b, the antenna makes use of the capacitance characteristics of the PCB. This capacitor is generated by printing the PCB, as shown below in Fig 2.8c.



Top and bottom view

***Fig 2.8c** Printed capacitor of the 434 MHz RX cross-tapped loop antenna*

315 MHz BAND

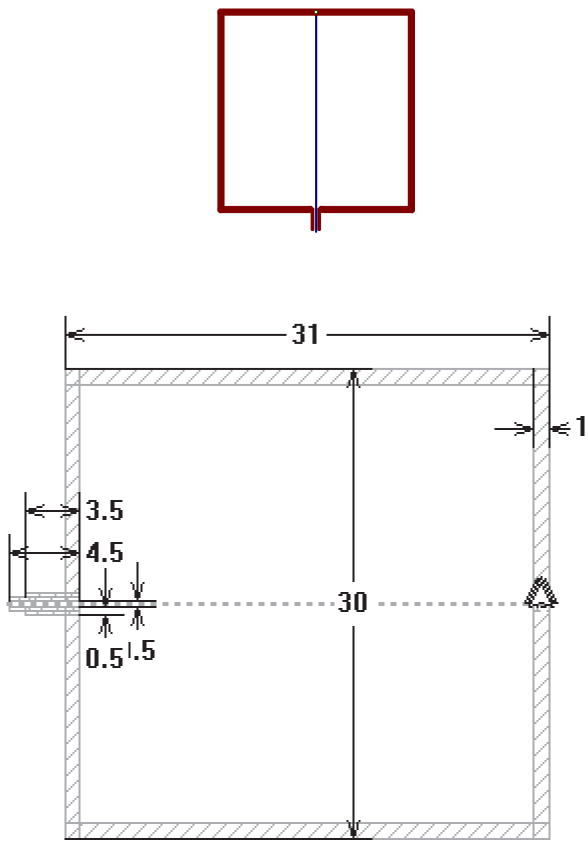
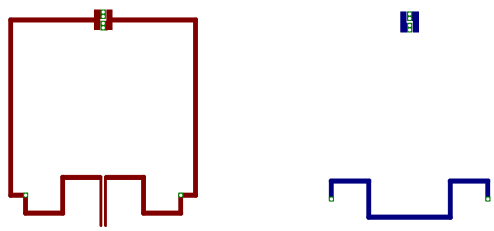


Fig 2.9 *315 MHz TX loop antenna (dimensions in mm)*

315 MHz BAND (CONTINUED)



Top and bottom view

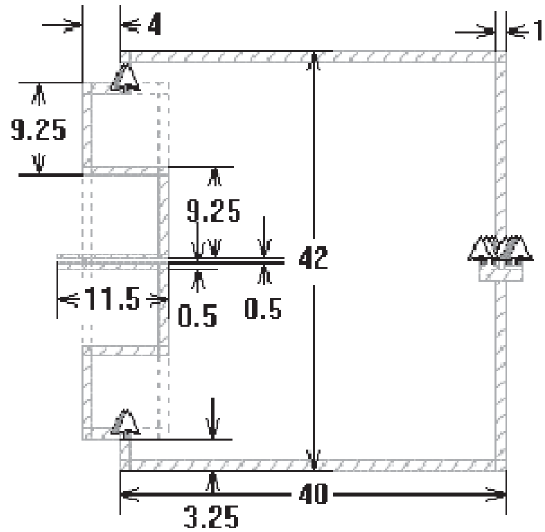


Fig 2.10a 315 MHz RX cross-tapped loop antenna (dimensions in mm)

This antenna is designed to be a two-layer PCB design. The overall look of the antenna can be seen in the diagram below, Fig 2.10b.

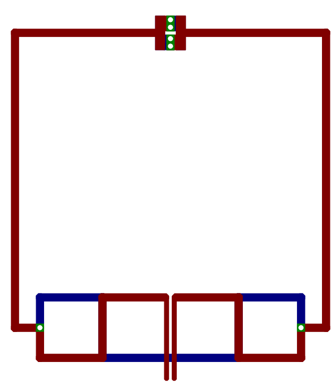
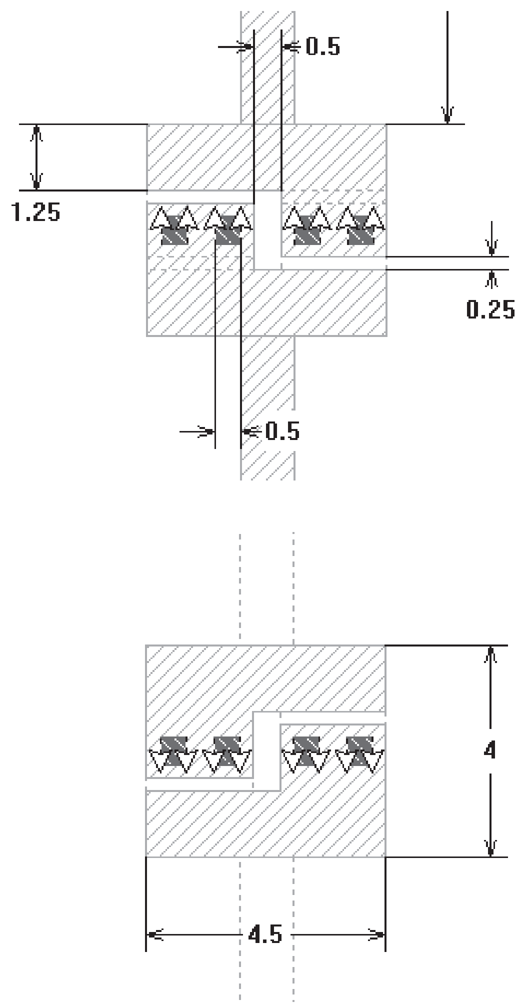


Fig 2.10b

315 MHz BAND (CONTINUED)

As shown in Fig 2.10a and Fig 2.10b above, the antenna makes use of the capacitance characteristics of the PCB. This capacitor is generated by printing the PCB, as shown below in Fig 2.10c.



Top and bottom view

Fig 2.10c Printed capacitor of the 315 MHz RX cross-tapped loop antenna

868 MHz BAND

The 915-868 MHz multiband normal loop and cross-tapped loop antenna is given above by Fig. 2.1 and Fig 2.2, respectively.

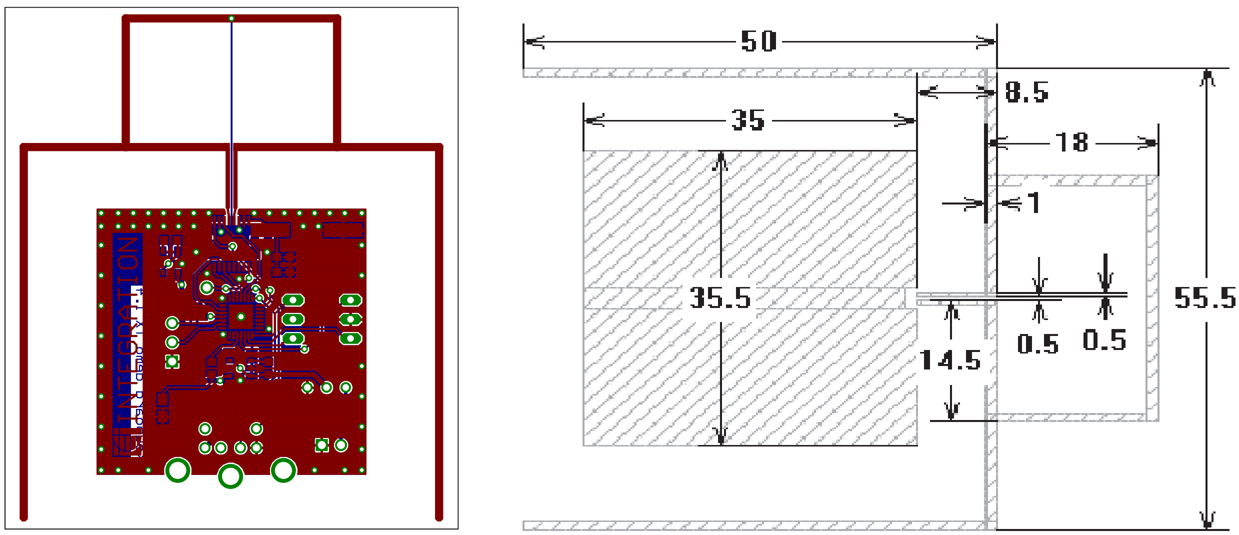


Fig 2.11 868 MHz TX back IFA antenna (dimensions in mm)

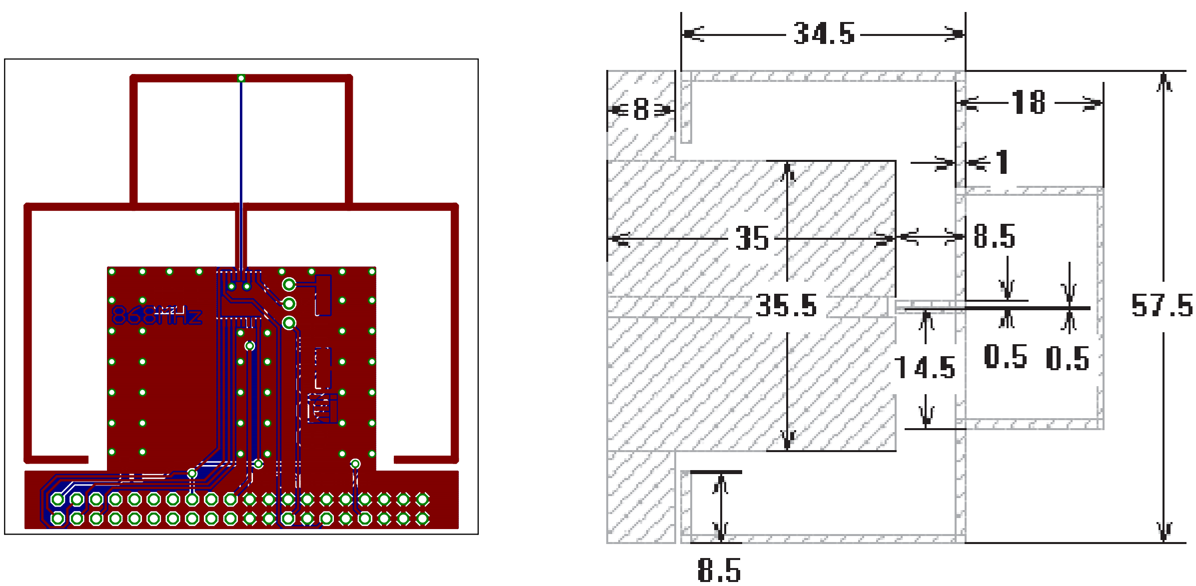
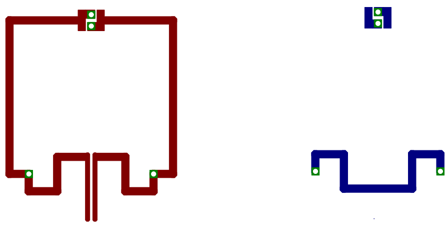


Fig 2.12 868 MHz TX back IFA antenna (dimensions in mm)

868 MHz BAND (CONTINUED)



Top and bottom view

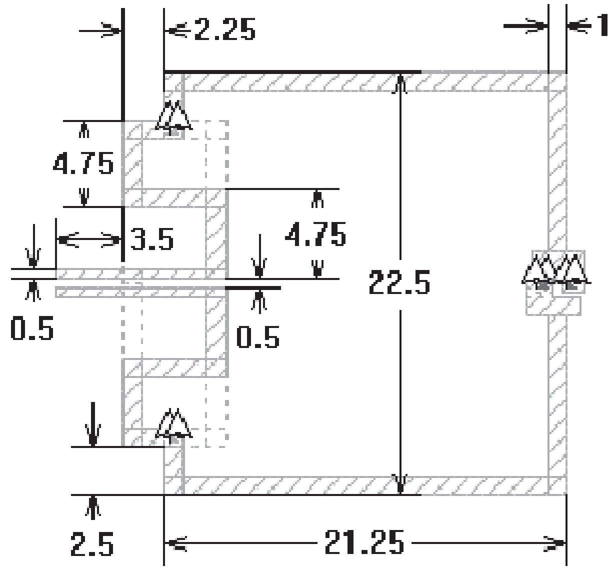


***Fig 2.13a** 868 MHz RX cross-tapped loop antenna (dimensions in mm)*

This antenna is designed to be a two layer PCB design, as such the overall look of the antenna can be seen in the diagram below, Fig 2.13b

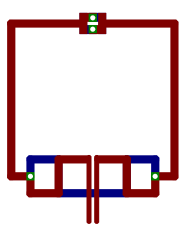
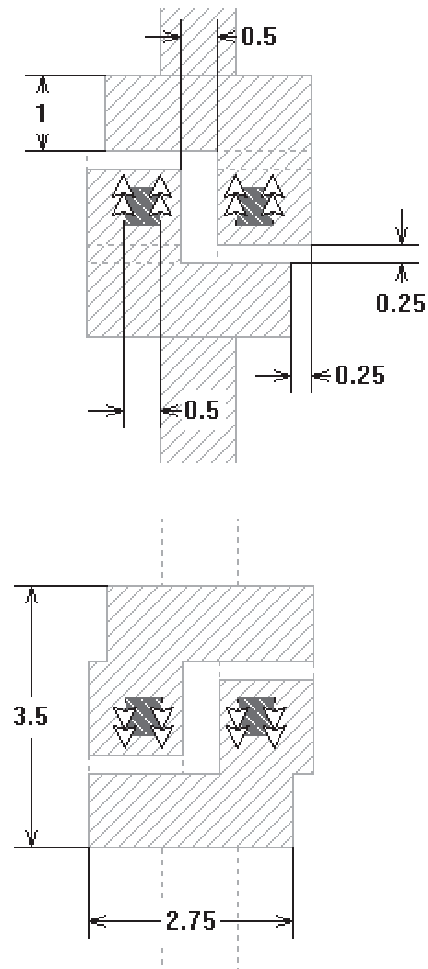


Fig 2.13b

868 MHz BAND (CONTINUED)

As shown in Fig 2.13a and Fig 2.13b above, the antenna makes use of the capacitance characteristics of the PCB. This capacitor is generated by printing the PCB, as shown below in Fig 2.13c.



Top and bottom view

***Fig 2.13c** Printed capacitor of the 868 MHz RX cross-tapped loop antenna*

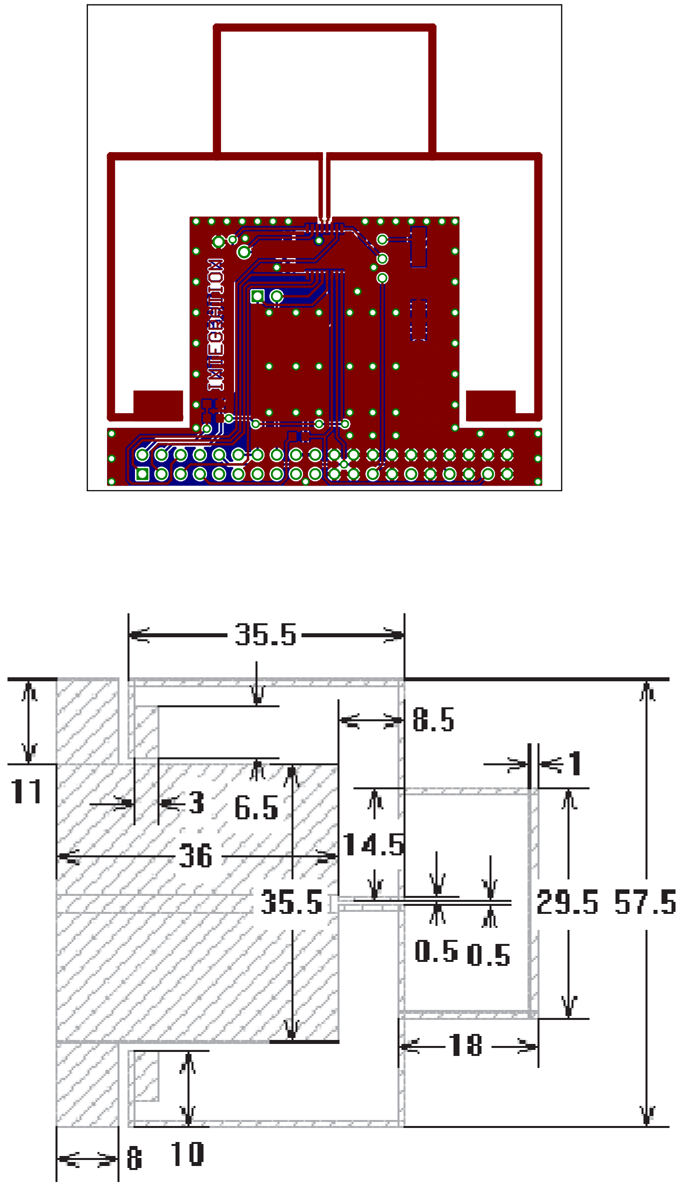


***Fig 2.14** 868 MHz RX back IFA antenna (dimensions in mm)*

APPENDIX

APPENDIX A

The radiated power can be described either by ERP (Equivalent Radiated Power) or EIRP (Equivalent Isotropic Radiated Power).

The EIRP is the power that would be radiated by a hypothetical isotropic antenna with a radiation intensity equal to the maximum radiation intensity of the characterized antenna-TX configuration.

In the case of ERP, instead of the isotropic antenna, a perfectly matched half wavelength dipol is used as a reference. The gain (relative to isotropic antenna) of the dipol is 2.14 dB, i.e. ERP[dBm]=EIRP[dBm]-2.14

$EIRP_{max}$ [dBm]	Antenna type			
	Loop	**Tapped loop**	**Back IFA**	**Back IFA dev. board**
915 MHz	-15.3 (-3dB state)	-9,5	-1.2	4.4
868 MHz	-20 (-3dB state)	-11	-1.6	3.9
434 MHz	-18.3 (-6dB state)	N/A	N/A	N/A
315 MHz	-20.4 (-6dB state)	N/A	N/A	N/A

Table A.1 Maximum EIRP in dBm of the Si4020 transmitter IC with the previously given TX antennas

For high impedance loop antennas, the current must be reduced due to the allowed maximum voltage swing on the outputs. At low bands (315, 434MHz) a 6 dB reduction is necessary, whereas at high bands, a 3 dB reduction is enough due to the lower Q of the TX chip.

E_{min} r.m.s. [mV/m]	Antenna type			
	Tapped loop		**Back IFA dev.**	
	9600 bit/s	**57470 bit/s**	**9600 bit/s**	**57470 bit/s**
915 MHz	0.24	0.44	0.06	0.09
868 MHz	0.16	0.28	0.05	0.07
434 MHz	0.48	0.9	N/A	N/A
315 MHz	0.29	0.5	N/A	N/A

Table A.2 Required r.m.s. electric field strength at the antenna of the Si4320 receiver IC in mV/m to achieve a BER of 10^{-2} in case of strong interference

In an interference-free environment, half of the values are enough (6 dB better sensitivity). The applied two sided deviation is 120 kHz and 180 kHz at 9600 and 57470 bps rates, respectively.

APPENDIX B

Range calculations:

From the EIRP (in watts) the power density (denoted by S) at a given d distance (in meters) can be calculated by Equation 1:

$$S = \frac{EIRP}{4\pi d^2} \quad \left[\frac{W}{m^2}\right]$$

The r.m.s. electric field strength can be calculated from the S by Equation 2:

$$E = \sqrt{120\pi S} \quad \left[\frac{V}{m}\right]$$

From Equation 1 and Equation 2, the range can be derived if the EIRP of the TX and the required r.m.s. electric field strength at the RX antenna is known:

$$d = \frac{\sqrt{30EIRP}}{E} \quad [m]$$

APPENDIX C

TX EIRP Measurement Setup

The TX measurement setup is shown in Fig C.1. The wideband dipole is used as a reference RX antenna and is connected to a spectrum analyzer. The transmitting testboard is controlled by the Silicon Labs Wireless Development Software (WDS). The distance and the height of the testboard is slightly changed to find the maximum and minimum of the received power. Knowing the gain of the reference antenna, the power spectral density and thus the EIRP or the field strength at 3m can be calculated from the product mean (average in dB) of the received maximum and minimum power.

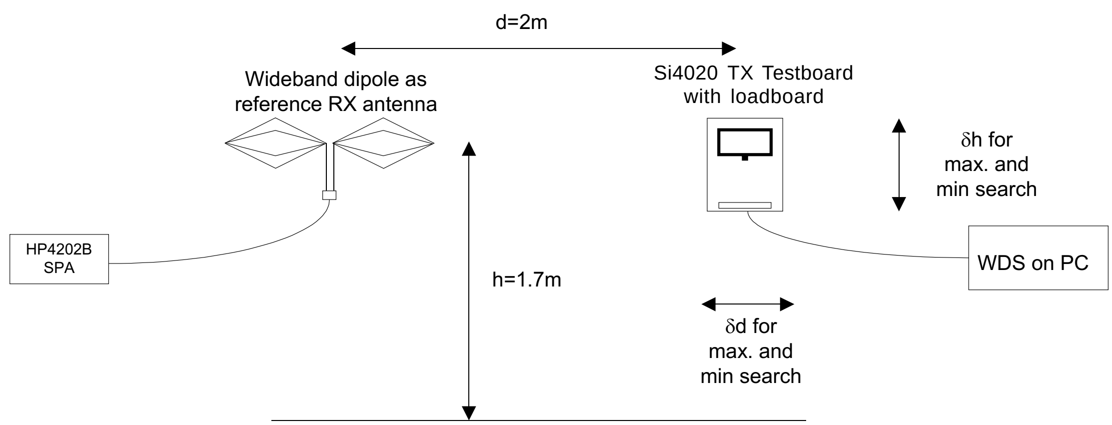


Fig C.1. TX EIRP measurement setup

APPENDIX C (CONTINUED)

RX Sensitivity Measurement Setup

The RX measurement setup is shown in Fig C.2. The wideband dipole is used as a reference TX antenna and is connected to a signal generator. The receiving testboard is controlled by the Silicon Labs Wireless Development Software (WDS). The HP 4432B signal generator generates the FSK modulated signal. The clock and data recovered by the Si4320 RX chip is fed back to the generator for the BER measurements and monitored by an oscilloscope. The distance and the height of the testboard is slightly changed to find the maximum and minimum of the measured BER. Knowing the gain of the reference TX antenna, the power spectral density and thus the required field strength by the measured RX antenna to achieve the desired BER value can be calculated. As a final value the product mean (average in dB) of the reqired maximum and minimum electric field is given.

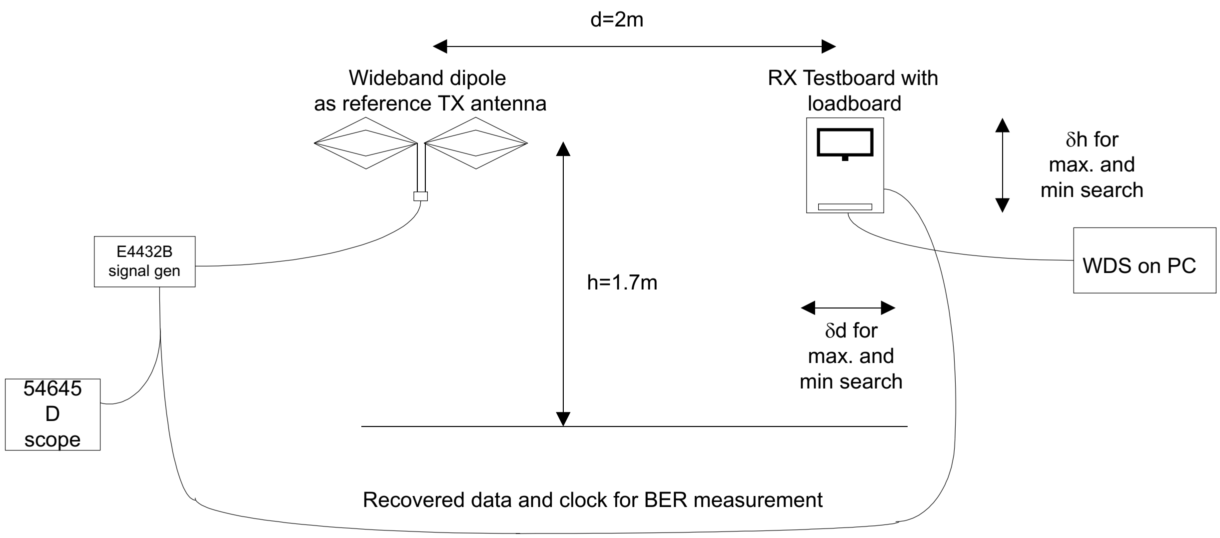


Fig C.2. RX sensitivity measurement setup

APPENDIX

APPENDIX D

Jamming Signal Levels During Receiver Sensitivity Measurements

The receiver sensitivity is measured in the presence of strong interferences.
Fig. D. shows the measured spectra when applying a wideband dipole (G=-1.5..-0.5 dB with cable) as a receiver antenna at the place of the sensitivity measurement.

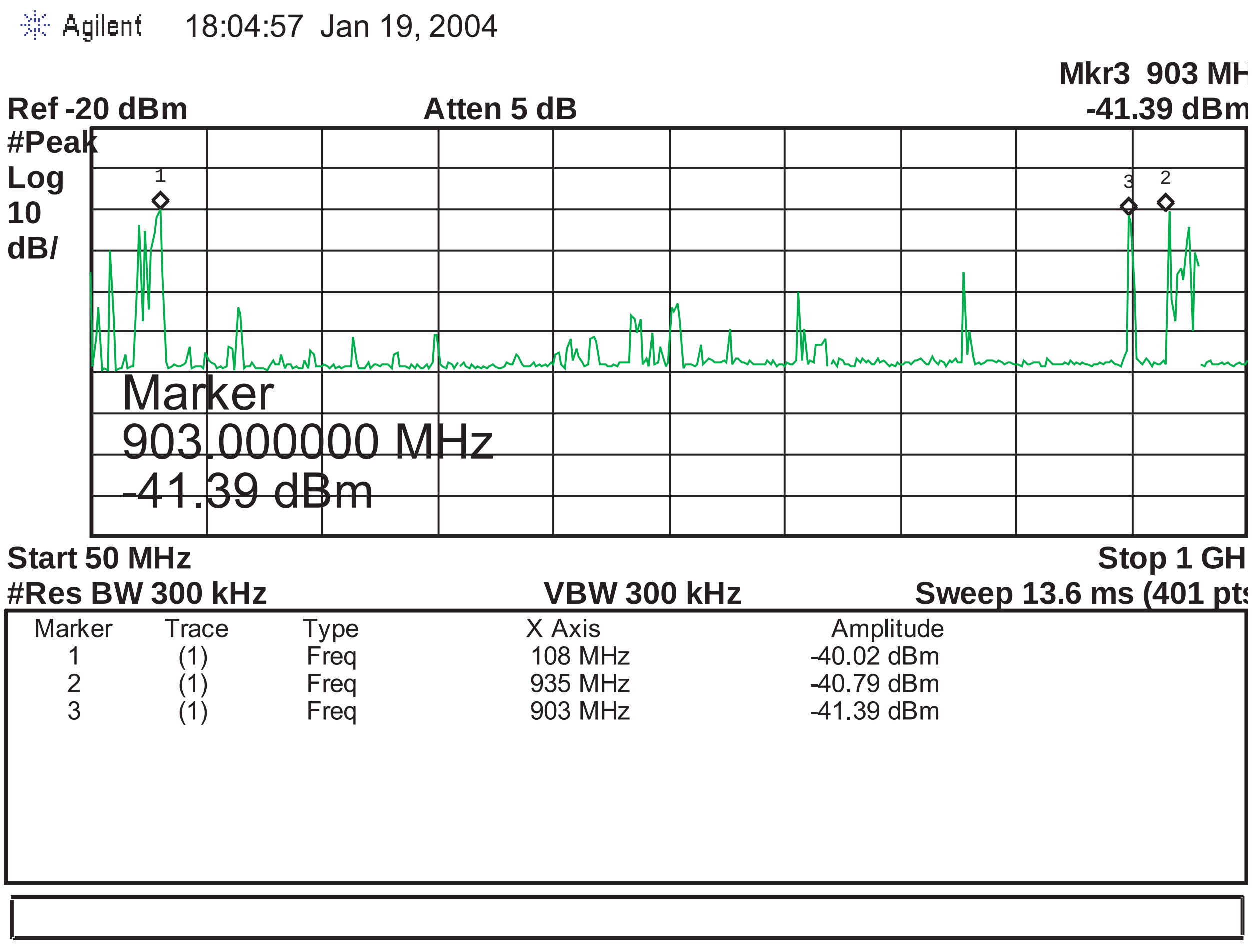


Fig. D.

As one can observe, the highest jamming signals are around 900 MHz and 100 MHz. At 900 MHz, the level of the jamming signals are between -40 and -50 dBm (which corresponds to approximately 70 to 20 [mV/m] r.m.s. electric field strength). It is approximately 30-50 dB higher than the useful signal's electric field during the sensitivity measurements. The interference is also very high, around 100 MHz (radio) and 1.8 GHz (GSM, not shown). The signal level of the other jamming signals is approximately –60 to -70 dBm, corresponding to several mV/m electric field strength.

APPENDIX E

Range Calculations in the Case of Non-Ideal Propagation Conditions

In the case of real propagation conditions (urban area, indoors, etc.), the practical range can be significantly different from the calculated free space range. According to the literature (Note 1), the average path loss for an arbitrary *d* TX-RX distance can be described by power function either for an indoor or an outdoor environment:

$$\overline{a}(d) \approx \left(\frac{d}{d_0}\right)^n \qquad \text{e.1.a}$$

or

$$\overline{a}^{dB}(d) = \overline{a}^{dB}(d_0) + 10n\log\left(\frac{d}{d_0}\right) \qquad \text{e.1.b}$$

where d_0 is a reference close in distance (but already in the far field of the TX antenna) with a known path loss, and *n* is the propagation exponent that strongly depends on the channel properties. Table 2.1 gives the *n* for several typical environments. Typical value of d_0 is 2-3 m. A calculation example is given below.

It should be emphasized that the actual path loss can strongly deviate from the given average above due to variation of the clutter and obstacle positions in the environment. Hence, the path loss behaves as a random statistical variable with log-normal (normal in dB) distribution around the mean value given above (for more details please refer to Note 1).

Environment	Propagation Exponent, *n*
Free space	2
Urban area cellular radio	2.7 .. 3.5
In building line-of-sight (in case of duct effect)	1.6 .. 1.8
Obstructed in building	4 .. 6
Obstructed in factories	2 .. 3

Note 1: T.S. Rappaport, Wireless Communications, Principles and Practice.

APPENDIX E (CONTINUED)

Method of Range Calculation Using the Free Space Range Data as a Starting Point

Taking the applied 2 m distance of the measurements as a reference distance (d_0), the power margin at d_0 can be calculated by Equation e.2. from the previously given free space range data.

$$\overline{m}^{dB}\left(d_{id}\right) = 20\log\left(\frac{d_{id}}{d_0}\right) \tag{e.2}$$

During the increase of the distance this margin is used in the link, i.e.:

$$n10\log\left(\frac{d_{nreal}}{d_0}\right) = 20\log\left(\frac{d_{id}}{d_0}\right) \tag{e.3}$$

By rearranging equation e.3 the resulting distance (d_{nreal}) in nonideal environment can be derived:

$$d_{nreal} = \sqrt[n]{d_{id}^2\, d_0^{n-2}} \tag{e.4}$$

Calculation Example

Using the BIFA antennas of Fig 2.12 and 2.14 as a TX and RX antenna in a 868 MHz communication link at 9600 bps bit rate, the resulted ideal free space range in the presence of strong interferences is around 5830 m (Table 1.4). In an obstructed indoor environment (n=4), the resulted average range is:

$$d_{nreal} = \sqrt[4]{5830^2\, 2^2} = 108m \tag{e.5}$$

Silicon Labs, Inc.
400 West Cesar Chavez
Austin, Texas 78701
Tel: 512.416.8500
Fax: 512.416.9669
Toll Free: 877.444.3032
www.silabs.com
wireless@silabs.com

SILICON LABS