868 MHz, 915 MHz, and 955 MHz Monopole PCB Antenna

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Keywords

- *CC1000*
- *CC1010*
- *CC1020*
- *CC1021*
- *CC1050*
- *CC1070*
- *CC1100*
- *CC1100E*
- *CC1101*
- *CC1110*
- *CC1111*
- *CC1150*
- *CC430*
- *PCB Antenna*
- *868 MHz*
- *915 MHz*
- *955 MHz*
- *Monopole*

1 Introduction

This document describes a PCB antenna designed for operation in the 868 MHz, 915 MHz and 955 MHz ISM bands. This antenna can be used with all transceivers and transmitters from Texas Instruments which operates in these frequency bands. Maximum gain is measured to be -3.2 dB, when implemented on the smallest possible ground plane. Overall size requirements for this antenna are 38 x 24 mm. Thus this is a medium size, low cost antenna solution. Figure 1 shows a picture the board being used to develop and characterize this antenna. The board is pin compatible with CC1110 EM and can be plugged into SmartRF®04EB for test and characterization purpose.

Figure 1. Prototype Board for 868 MHz, 915 MHz, and 955 MHz PCB Monopole Antenna

Table of Contents

2 Abbreviations

CF	Correction Factor
EB	Evaluation Board
EM	Evaluation Module
ISM	Industrial, Scientific, Medical
PCB	Printed Circuit Board
RF	Radio Frequency

3 Description of the PCB Antenna

The antenna described in this document is a meandering monopole. Since the impedance of this antenna is approximately matched to 50 ohm no external matching components are needed. The geometry of the ground plane affects the impedance of the antenna. Thus the length of the antenna should be tuned according to the size and shape of the ground plane. This PCB antenna reference design has included the option for one series and two shunt components at the feed point of the antenna. These can be used to compensate for detuning caused by plastic encapsulation and other object in the vicinity of the antenna. For further information on impedance matching and impedance measurements, see DN001 Antenna Measurement with Network Analyzer [1] and ISM-Band and Short Range Device Antennas [2].

3.1 Implementation of the Meandering Monopole Antenna

To obtain optimum performance it is important to make an exact copy of the antenna dimensions. The antenna was implemented on a 0.8 mm thick FR4 substrate. Since there is no ground plane beneath the antenna the PCB thickness is not critical, but if a different thickness is being used it will be necessary to tune the length of the antenna to obtain optimum performance.

One approach to implement the antenna in a PCB CAD tool is to import the antenna layout from a Gerber file. Such a file is included in the CC1110EM Meander Antenna Reference Design [3], and is a called “antenna.spl”. If the antenna is implemented on a PCB that is wider than the antenna it is important to avoid placing components or having a ground plane close to each side of the antenna. If the CAD tool being used does not support import of Gerber files, Figure 2 and Table 1 can be used.

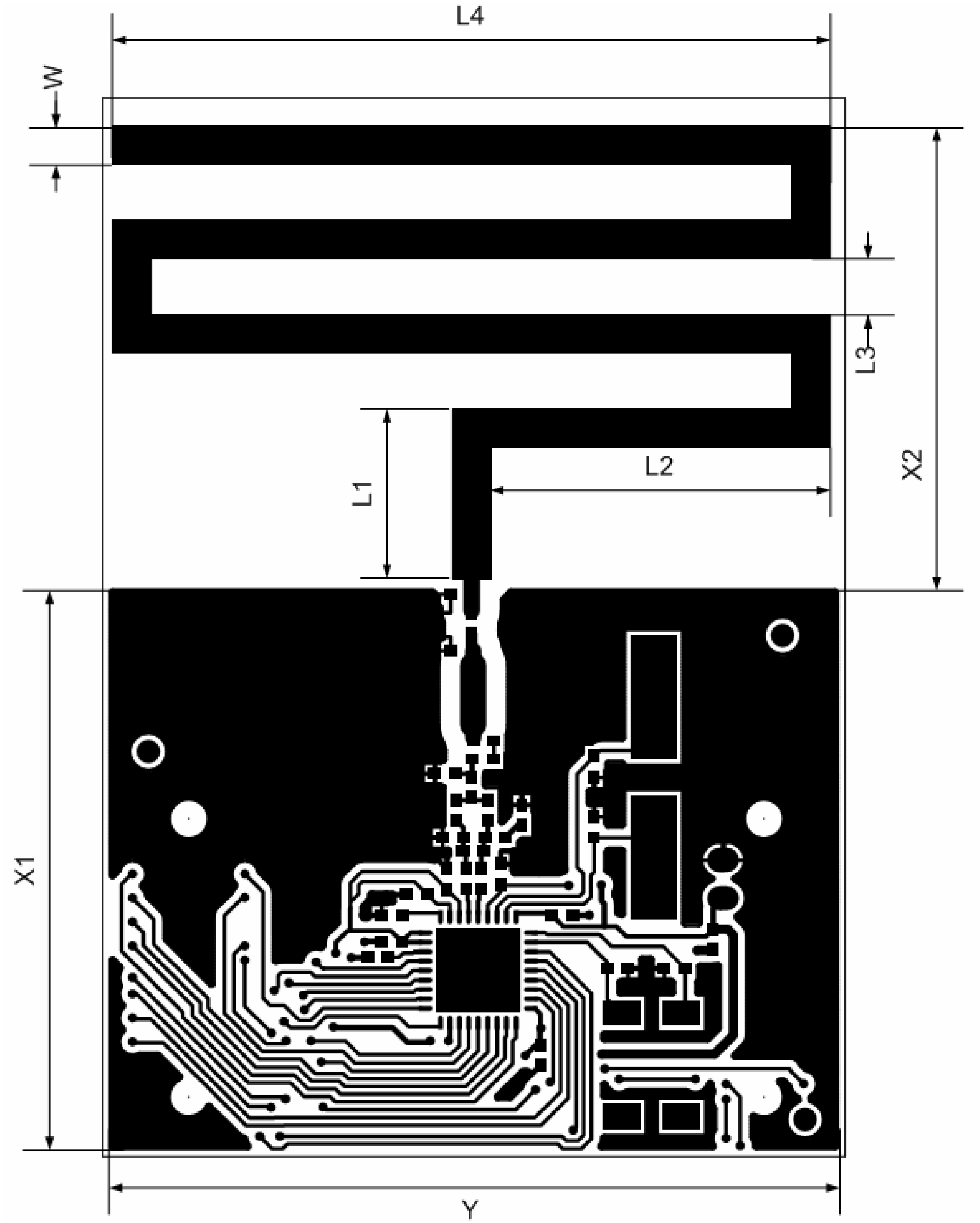

Figure 2. Antenna Dimensions

L1	9.0 mm	**Y**	39.0 mm
L2	18.0 mm	**X1**	30.0 mm
L3	3.0 mm	**X2**	24.0 mm
L4	38.0 mm	**W**	2.0 mm

Table 1. Antenna Dimensions

Optimum length for the last antenna segment is dependent on the geometry of the ground plane. With this ground plane (30 x 39 mm), L4 (for the last segment) should be approx. 32 mm for 868 MHz and 22 mm for 915 MHz. The antenna can also be used for 955 MHz but then the total length of the antenna has to be reduced more than the length specified for 915 MHz. For bigger ground planes L4 would have to be further reduced.

4 Results

Measurement results are presented in this section. Notice that the performance will be affected by the size and shape of the ground plane.

4.1 Radiation Pattern

Figure 3 shows how to relate the radiation patterns in this section to the orientation of the antenna. The pictures in Figure 3 shows how the board was placed when measuring the different planes. For all measurements the board was turned around a vertical axis and 0° corresponds to the direction out of the picture. The radiation patterns were measured with 10 dBm output power.

Notice that the size of the ground plane will affect the radiation pattern. Thus implementing this antenna on a board with a different size and shape of the ground plane will most likely affect the radiation pattern.

To be able to run the radio the module was connected to the battery-board SoC_BB. To adjust for the added ground plane the antenna length was trimmed 40 mm, as according to Figure 11

The values in the plots of the antenna patterns are in dBm and represents gain relative to 10 dBm. Thus 5 dBm in the plot equals a gain of –5 dB, etc.

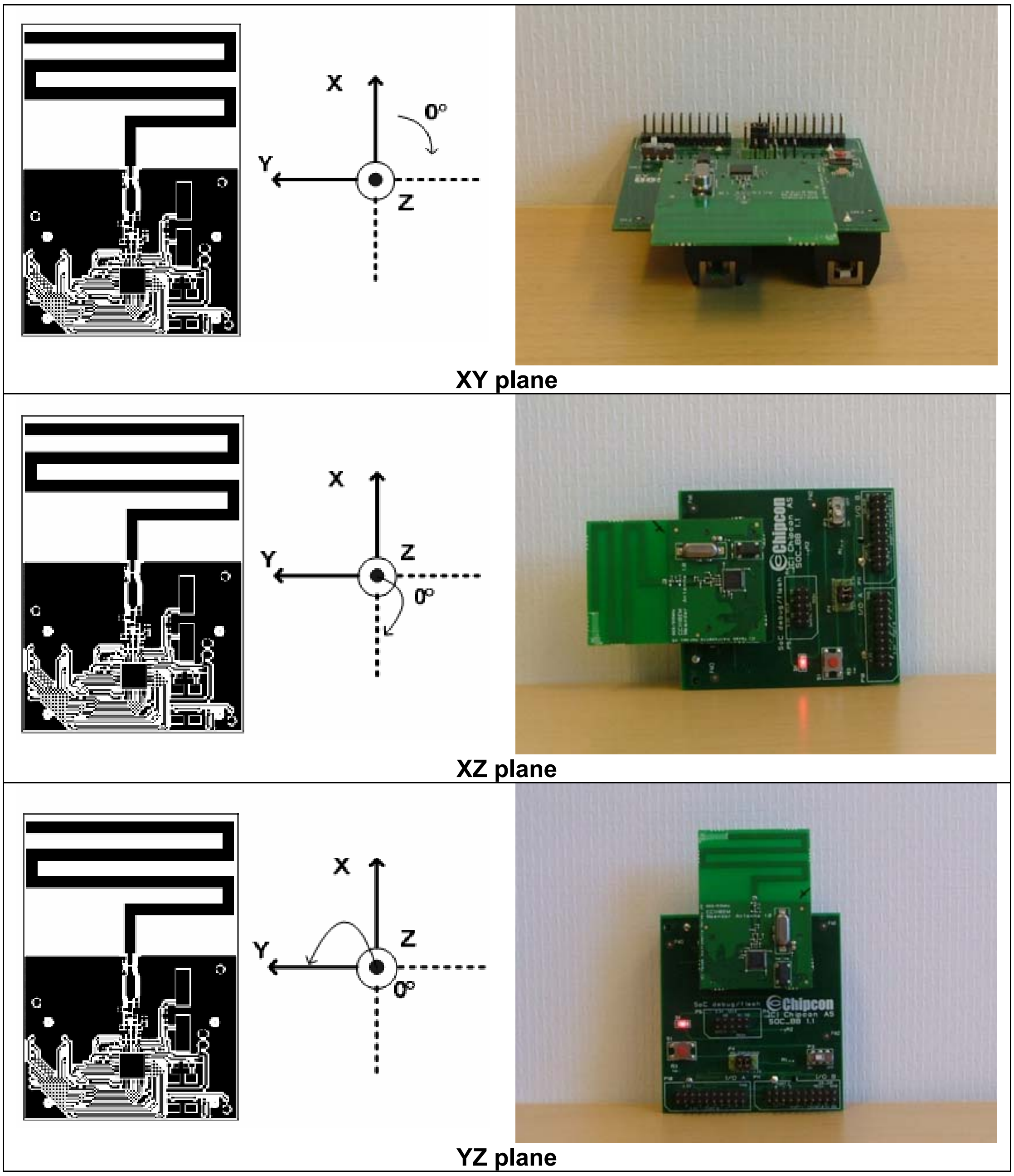

Figure 3. How to Relate the Antenna to the Radiation Patterns

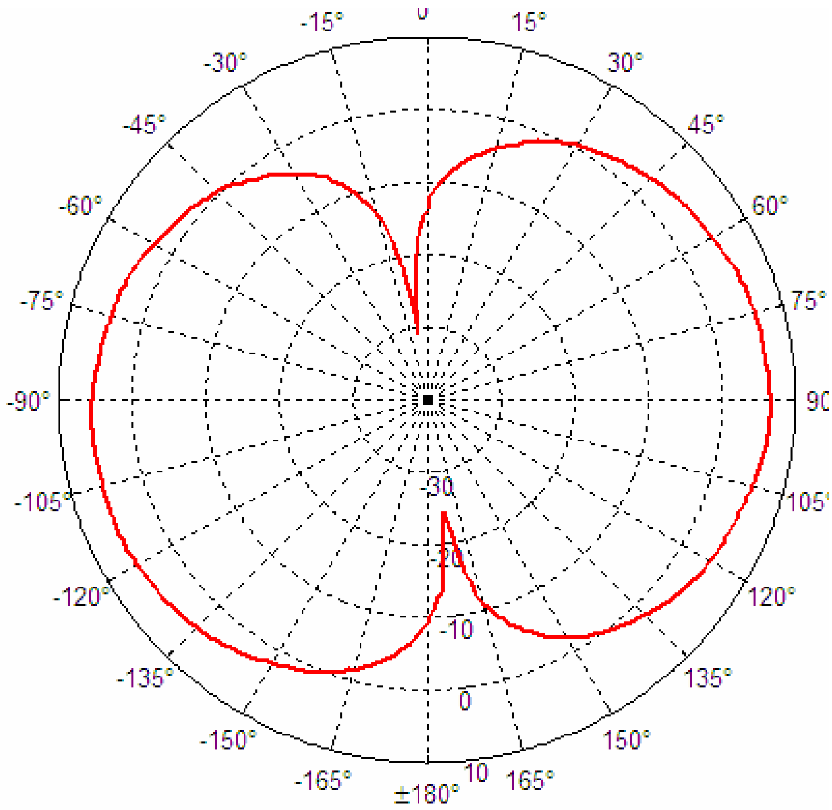

Figure 4. XY Plane, Horizontal Polarization

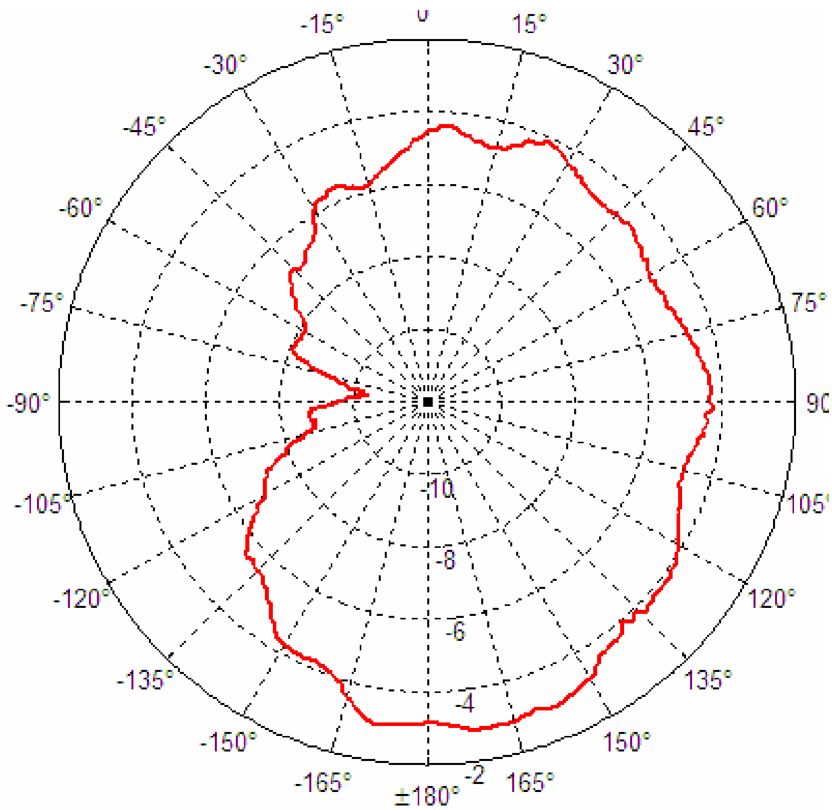

Figure 5. XY Plane, Vertical Polarization

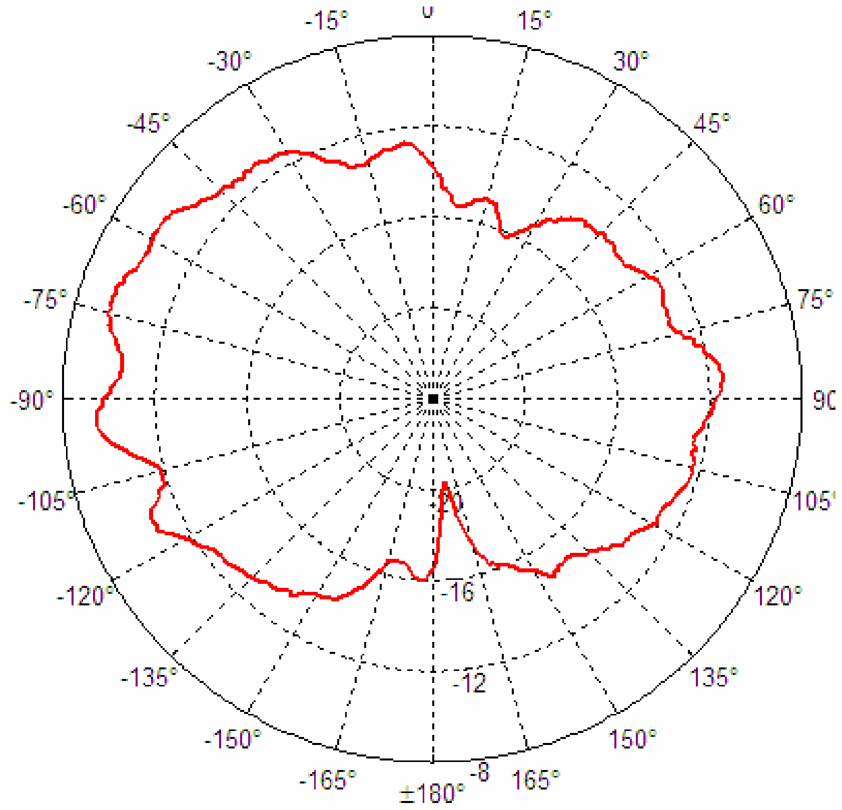

Figure 6. YZ Plane, Horizontal Polarization

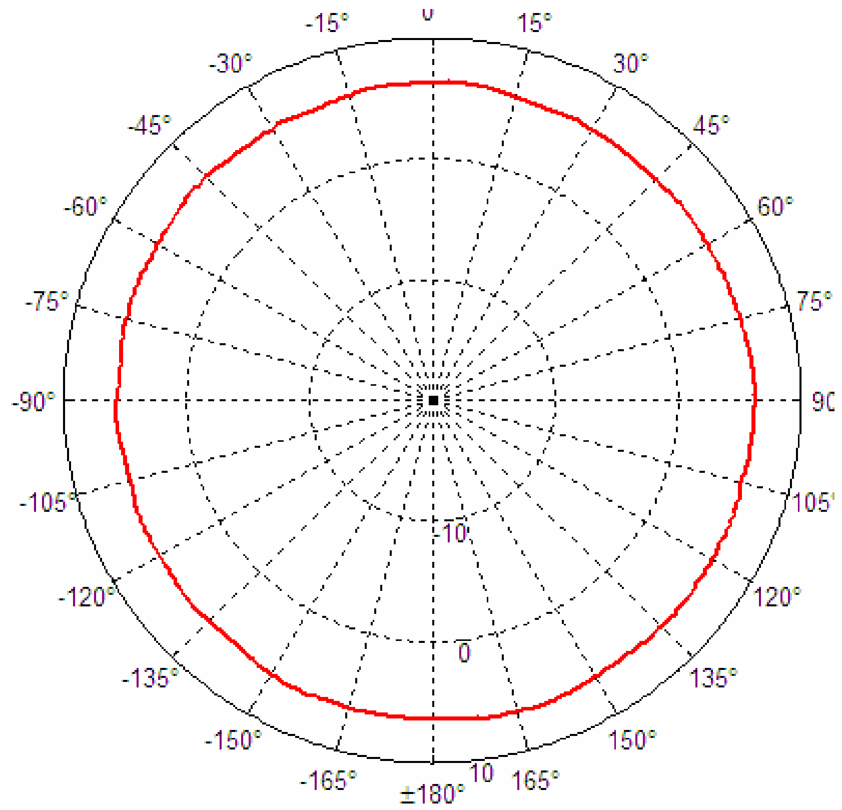

Figure 7. YZ Plane, Vertical Polarization

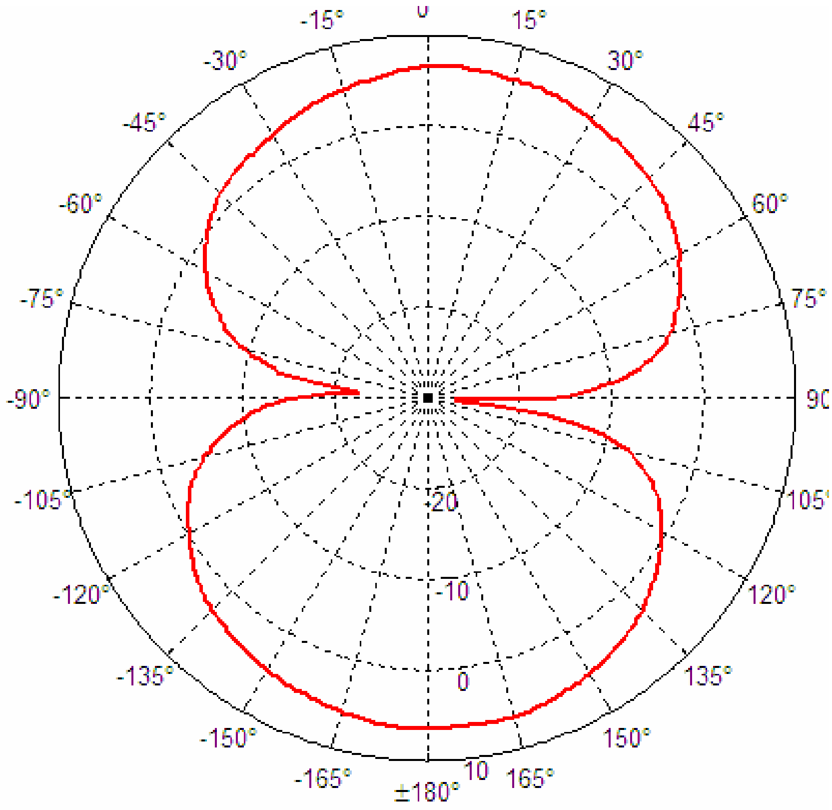

Figure 8. XZ Plane, Horizontal Polarization

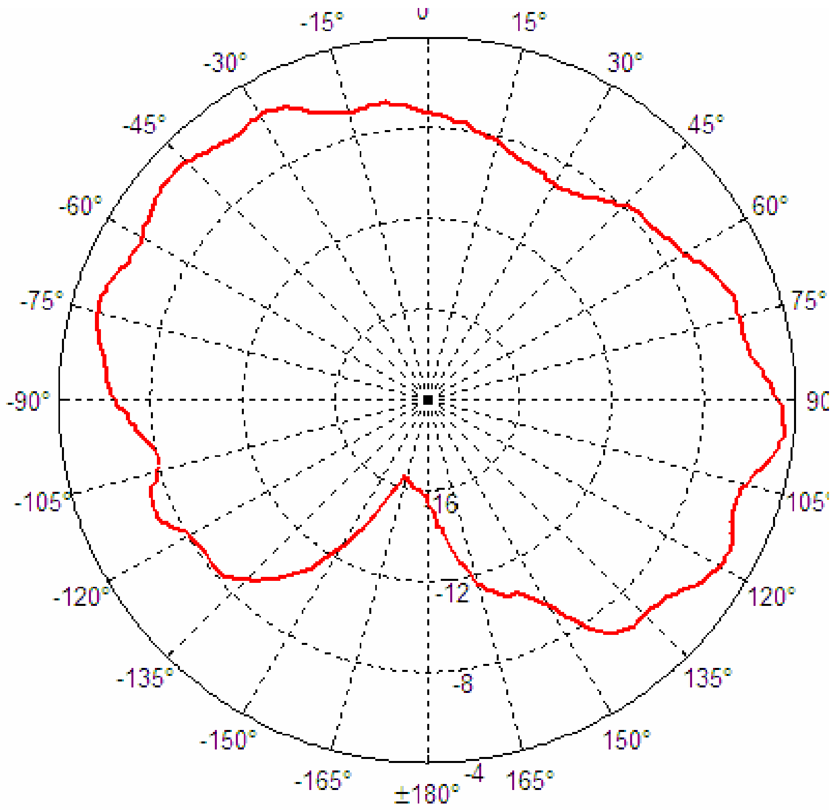

Figure 9. XZ Plane, Vertical Polarization

4.2 Reflection

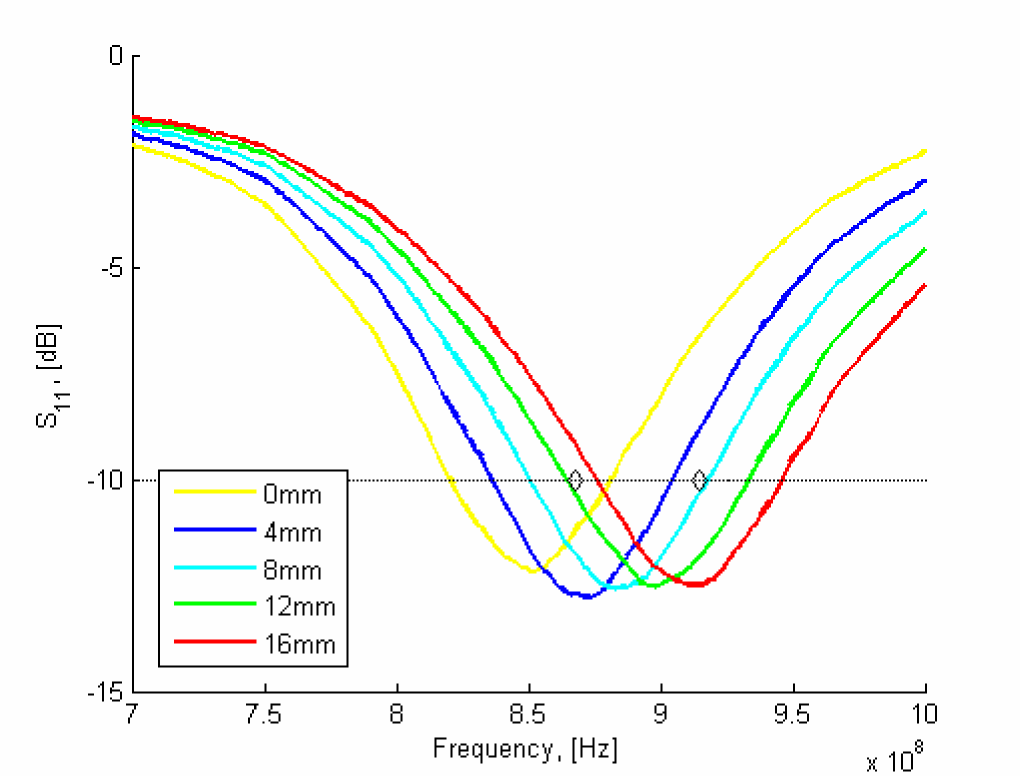

Figure 10. Measured Reflection at the End of a 15 mm Long 50 Ω Line Feeding the Antenna

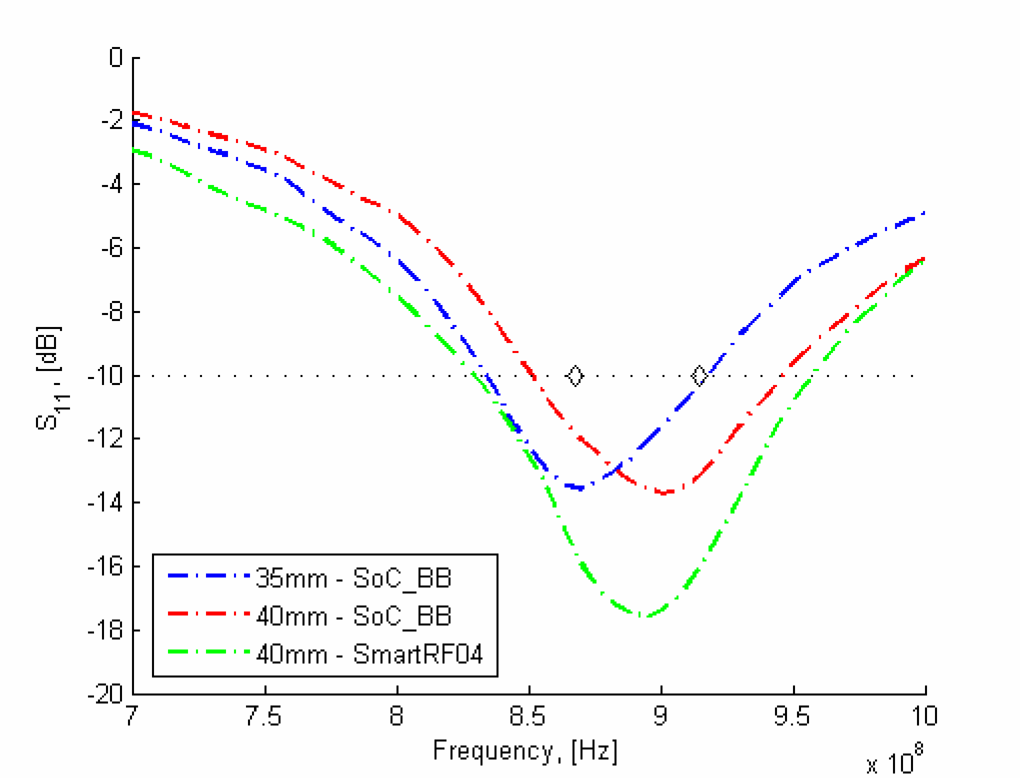

Figure 11. Measured Reflection at the Feed Point of the Antenna with the Module Connected to the SoC_BB and SmartRF®04EB

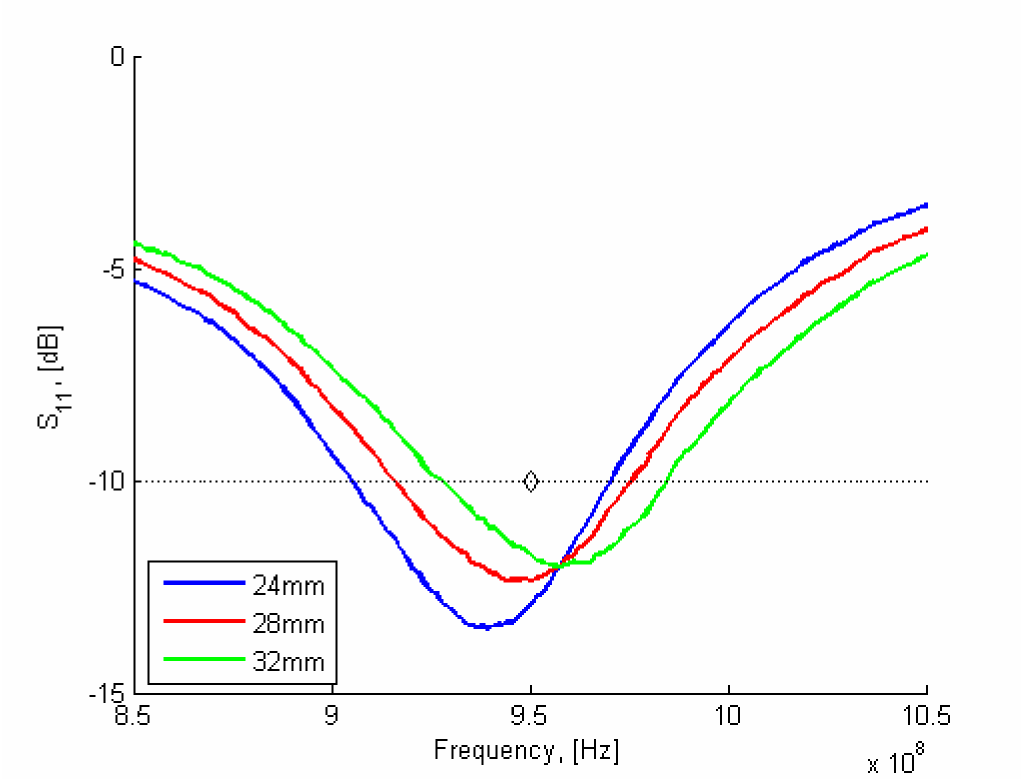

Figure 12, Measured Reflection at the Feed Point of the Antenna

The values in the figures represent length subtracted from L4 for the last (top most) antenna segment.

Figure 10 and Figure 11 shows that the antenna reflects less than 10% of the available power for a bandwidth of approximately 50 MHz. It is also clear from Figure 10 that the antenna is easily tuned to the desired center frequency simply by adjusting the length of the antenna. When connected to SoC_BB and SmartRF®04EB further adjustments are needed, as shown in Figure 11, to adapt the antenna to the larger ground planes. Larger ground planes also results in less reflection and greater bandwidth.

As shown in Figure 12, this antenna can also be used in the frequency band around 950 MHz.

4.3 Bandwidth

Another way of measuring the bandwidth after the antenna is implemented on a PCB and connected to a transmitter is to write test software that steps a carrier across the frequency band of interest. For this antenna a 10 dBm carrier from 782 MHz to 950 MHz was used. By using the “Max Hold” option on the spectrum analyzer it is possible to see how the output power varies across frequency when using this test program. Notice that the bandwidth characteristic is dependent on direction and polarization. The result shown in Figure 13 is based on a measurement performed with the PCB horizontally oriented (XY-plane, $\varphi = -90°$) and a horizontally polarized receiving antenna. The measurement was not performed in an anechoic chamber, thus the graph shows only the relative variations of the output power.

The antenna can also be used for 955 MHz but then the total length of the antenna has to be reduced more than the length specified for 915 MHz

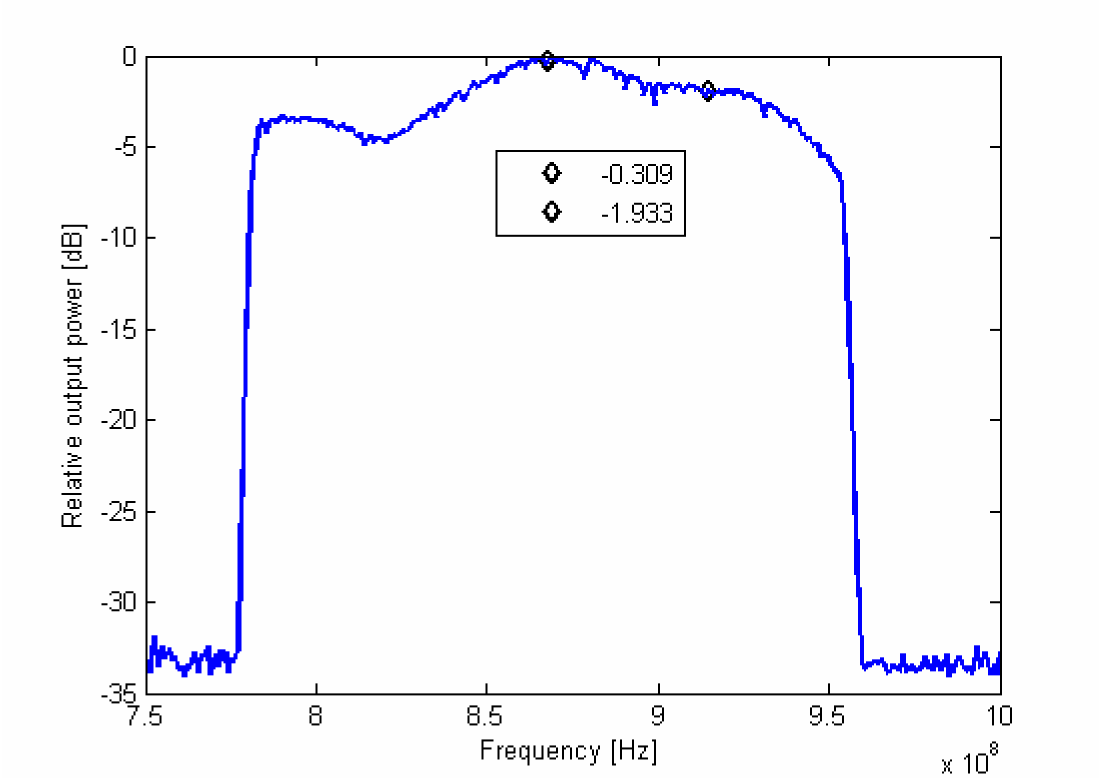

Figure 13, Bandwidth of Antenna when Tuned for 868 MHz According to Figure 11

4.4 Harmonic Emission

Measurement of harmonic emission has not been done for this antenna. Harmonic emission will be dependent on ground plane geometry, encapsulation etc. Thus this measurement should be performed on a complete prototype. Table 2 shows the FCC- and ETSI limits. Above 1 GHz, FCC allows the radiation to be up to 20 dB above the limits given in Table 2, if duty cycling is being used. The second harmonic would only be an issue when qualifying under FCC part 15.249 since 15.247 only requires 20 dBc. Notice that programmed output power and size of the ground plane will affect the level of the harmonics and thus determine the necessary duty cycling.

	2. harm	3. harm	4. harm	5. harm	6. harm	7. harm	8. harm	9. harm
Limit: FCC 249	54 dBµV/m	54 dBµV/m	54 dBµV/m	54 dBµV/m	54 dBµV/m	54 dBµV/m	54 dBµV/m	54 dBµV/m
Limit: FCC 247	20 dBc	54 dBµV/m	54 dBµV/m	54 dBµV/m	20 dBc	20 dBc	54 dBµV/m	54 dBµV/m
Limit ETSI	−30 dBm	−30 dBm	−30 dBm	−30 dBm	−30 dBm	−30 dBm	−30 dBm	−30 dBm

Table 2, ETSI and FCC Limits for Harmonic Radiation.

The allowed additional emission, or correction factor, is calculated based on maximum transmission time during 100 ms. Equation 1 can be used to calculate the correction factor, where t is equal to maximum transmission time during 100 ms. Using Equation 1 it can be calculated that a maximum transmission time of 50 ms, during 100 ms, will permit all radiation above 1 GHz to be 6 dB above the given limits.

$$CF = -20 \bullet \log\left(\frac{t}{100ms}\right)$$

Equation 1. FCC Correction Factor

4.5 Range

Measurements of the antenna range have been performed outdoors, in line of sight with two equal antennas as sender and receiver. The evaluation models were connected to one SmartRF®04EB each. The measurements were done with both antennas aligned with the YZ-plane horizontally (φ = 0°). At a data rate of 38.4 kBaud a range of over 1800 meters was achieved (PER = 1 %).

5 Conclusion

The antenna proposed in this design note can be used for 868 MHz, 915 MHz and 955 MHz operation. Required board size for this antenna is 38 x 24 mm and maximum gain is approximately -3.3 dB dependent on direction. Measurements of reflection show that the center frequency is dependent on the size of the ground plane, but this is easily compensated for by adjusting the antenna length. The radiation patterns show wide distribution of the radiated power, but also some major dips. Especially noteworthy is the dip in the XY-plane, horizontal polarization, although this is somewhat compensated for by the vertical polarization.

Antenna Size	38 x 24 mm
Range	~1800 m (line-of-sight)
Max Gain in XY Plane	−3.28 dB
Max Gain in XZ Plane	−3.38 dB
Max Gain in YZ Plane	−3.22 dB
Reflection	< −12 dB

Table 3. Key Parameters

6 References

[1] DN001 Antenna Measurement with Network Analyzer (swra096.pdf)

[2] ISM-Band and Short Range Device Antennas (swra046.pdf)

[3] CC1110EM Meander Antenna Reference Design (swrr059.zip)

7 Document History

Revision	Date	Description/Changes
SWRA227D	2009.08.20	Added CC430 to list of devices
SWRA227C	2009.07.15	Corrected link to CC1110EM Meander Antenna Reference Design
SWRA227B	2009.04.14	Added EB to Abbreviations. Cosmetic changes
SWRA227A	2009.03.17	Updated with 955 MHz. Removed logo from header
SWRA227	2007.04.16	Initial release.