Compact 868/915 MHz Antenna Design

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Keywords

- *CC1100*
- *CC1101*
- *CC1110*
- *CC1111*
- *CC1150*
- *CC430*
- *Chip Antenna*
- *868 MHz*
- *915 MHz*
- *ISM bands*
- *Johanson Technology*

1 Introduction

This document describes an antenna design that can be used with all transceivers, transmitters, and SoC from Texas Instruments which are capable of operating in the 868 and 915 MHz band. The antenna has been implemented on a USB dongle with CC1111 [1], which is a sub 1 GHz SoC with USB controller. All measurement results presented in this document are based on measurements performed on the CC1111 USB dongle, shown in Figure 1. Maximum gain is measured to be 0.7 dB and the overall size requirement for this antenna is 8.5 mm x 7.8 mm. The antenna solution consists of a chip antenna from Johanson Technology in conjunction with a special PCB trace. The original design is optimized for operation in the 868 MHz band, but it is easy to tune the antenna for operation in the 915 MHz band by reducing the length of the PCB trace. Thus, this is a flexible, compact, medium cost, and high performance antenna solution.

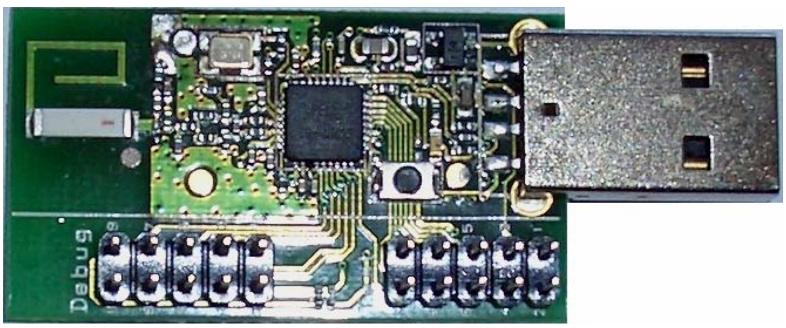

Figure 1. CC1111 USB Dongle

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2 Abbreviations

ETSI	European Telecommunications Standards Institute
HP	Horizontal Polarization
ISM	Industrial, Scientific, Medical
NM	Not Mounted
PCB	Printed Circuit Board
SoC	System on Chip
VP	Vertical Polarization

3 Description of the Antenna Design

The antenna solution implemented on the CC1111 USB dongle consists of a chip antenna [5] from Johanson Technology [6] in conjunction with a special PCB trace. See section 8 for detailed information about this chip antenna. Two matching components are used to ensure optimum performance at the desired frequency. In addition to the matching components, the length of the PCB trace can be used to tune the resonance frequency.

3.1 Implementation of the Antenna

It is important to make an exact copy of the PCB trace to obtain optimum performance. Figure 2 and Table 1 show the recommended dimensions of the PCB trace for a center frequency at 866.5 MHz.

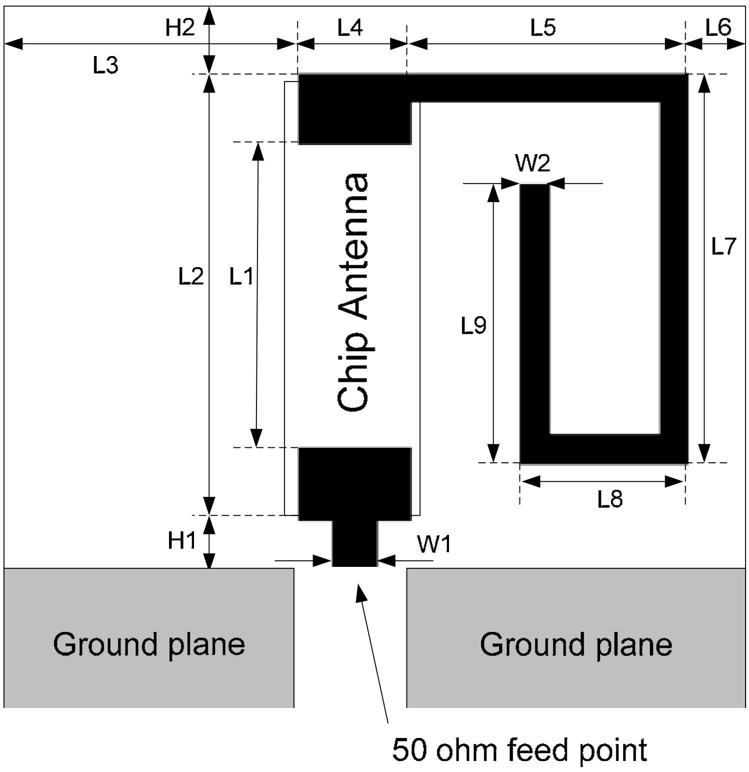


Figure 2. Antenna Dimensions

H1	1.0 mm	L6	2.7 mm
H2	1.3 mm	L7	7.0 mm
L1	5.5 mm	L8	3.0 mm (2.5 mm for 915 MHz)
L2	8.0 mm	L9	5.0 mm (0.0 mm for 915 MHz)
L3	12.8 mm	W1	0.5 mm
L4	2.0 mm	W2	0.8 mm
L5	5.0 mm		

Table 1. Antenna Dimensions

Figure 3 shows how the reflection at the feed point of the antenna is affected by the length of the PCB trace. The blue line shows the measured reflection with the original length. The center frequency can be moved to 915 MHz by adjusting the length of the PCB trace. This is shown by the green line in Figure 3 which is based on a measurement on a board with L9 = 0 mm and L8 = 2.5 mm.

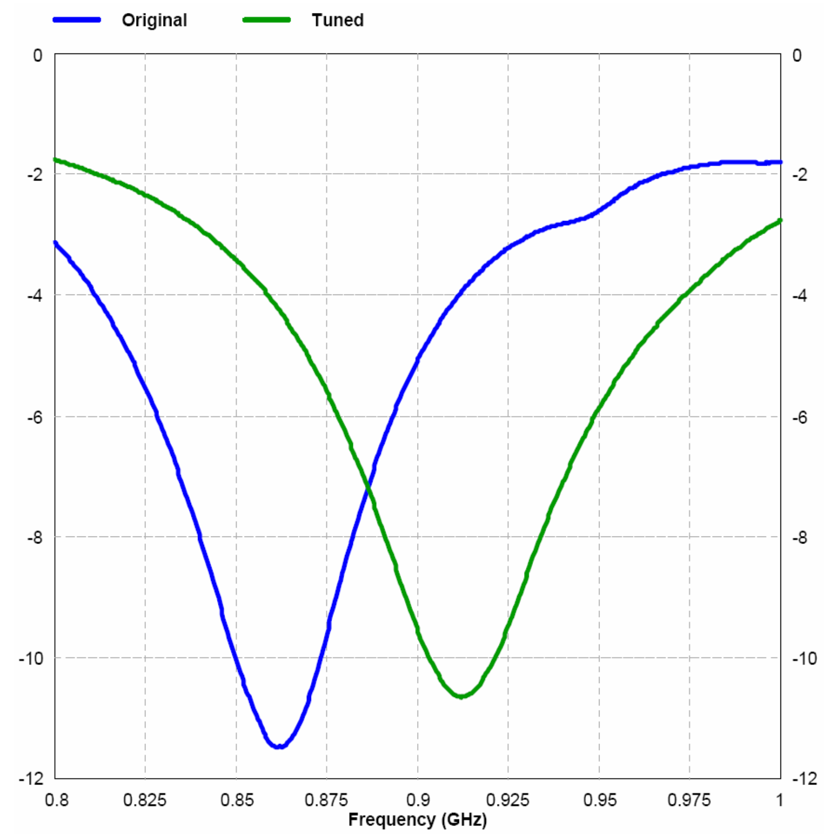


Figure 3. Reflection at the Feed Point of the Antenna

Notice that plastic encapsulation and other objects in the vicinity of the antenna could affect the performance. Thus characterization and tuning should be done with the antenna placed in the environment in which it is going to operate. See Design Note 001 for more information about antenna tuning and reflection measurements [1].

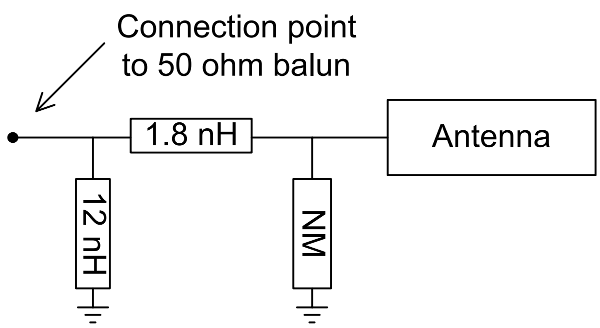


Figure 4. Recommended Matching

Two matching components are being used to obtain a proper impedance match and thus low reflections at the feed point of the antenna. Figure 4 shows the matching network and the recommended values of the two inductors. Inductors from two different vendors have been tested and both gave the same result, see Table 2 for details. Notice that the layout of the CC1111 dongle gives the possibility for another shunt component, marked NM in Figure 4. This can be used if the implementation of the antenna requires additional tuning.

Vendor	Type
Johanson Technology	L-07
Murata	LGQ15H

Table 2. Tested Matching Components

The distance to the board edge, L3 and L6 is not critical. The antenna can be implemented on a PCB with different width than in the reference design, but it is important that no components, ground plane or other metallic objects are implemented close to the antenna. Especially the area under the antenna should not have such objects implemented. Shape and size of the ground plane will affect the radiation pattern. Thus the performance will depend on the layout of the board and what kind of computer the dongle is plugged into.

Since there is no ground plane beneath the antenna, PCB thickness will have little effect on the performance. The results presented in this design note are based on an antenna implemented on a PCB with 1.6 mm thickness.

4 Measurement Results

All results presented in this chapter are based on measurements performed with CC1111 USB Dongle [1]. To reflect the performance during normal operation most of the measurements were done with the dongle placed in a laptop.

4.1 Radiation Pattern

The radiation pattern was measured in three planes, XY, XZ and YZ with the dongle plugged in a laptop. The radiation pattern was also measured in the XY plane without the laptop. This was done to give an indication of the performance for other types of designs using the same antenna. The USB dongle was powered by a battery for this measurement. Table 3 shows the minimum, maximum and average radiation measured when transmitting with 10 dBm output power. Figure 5 shows how to relate all the radiation patterns to the orientation of the antenna. The reference level stated in the bottom right corner of the radiation pattern plots specifies the radiation level at the outer circle. Some of the plots presented in this section do not have proper scaling. Thus the peak gain is higher than the stated reference level on some of the plots.

	With Laptop						Without Laptop	
	XY HP	XY VP	XZ HP	XZ VP	YZ HP	XZ VP	XY HP	XP VP
AVG	+3.5	−0.2	+3.2	−3.7	−0.3	+6.7	−0.5	−16.4
Min	−15.4	−12.3	−16.7	−30.6	−12.6	+2.0	−30.8	−27.2
Max	+9.9	+6.1	+10.7	+5.1	+7.2	+9.0	+6.1	−9.3

Table 3. Radiation Properties. All Numbers in dBm

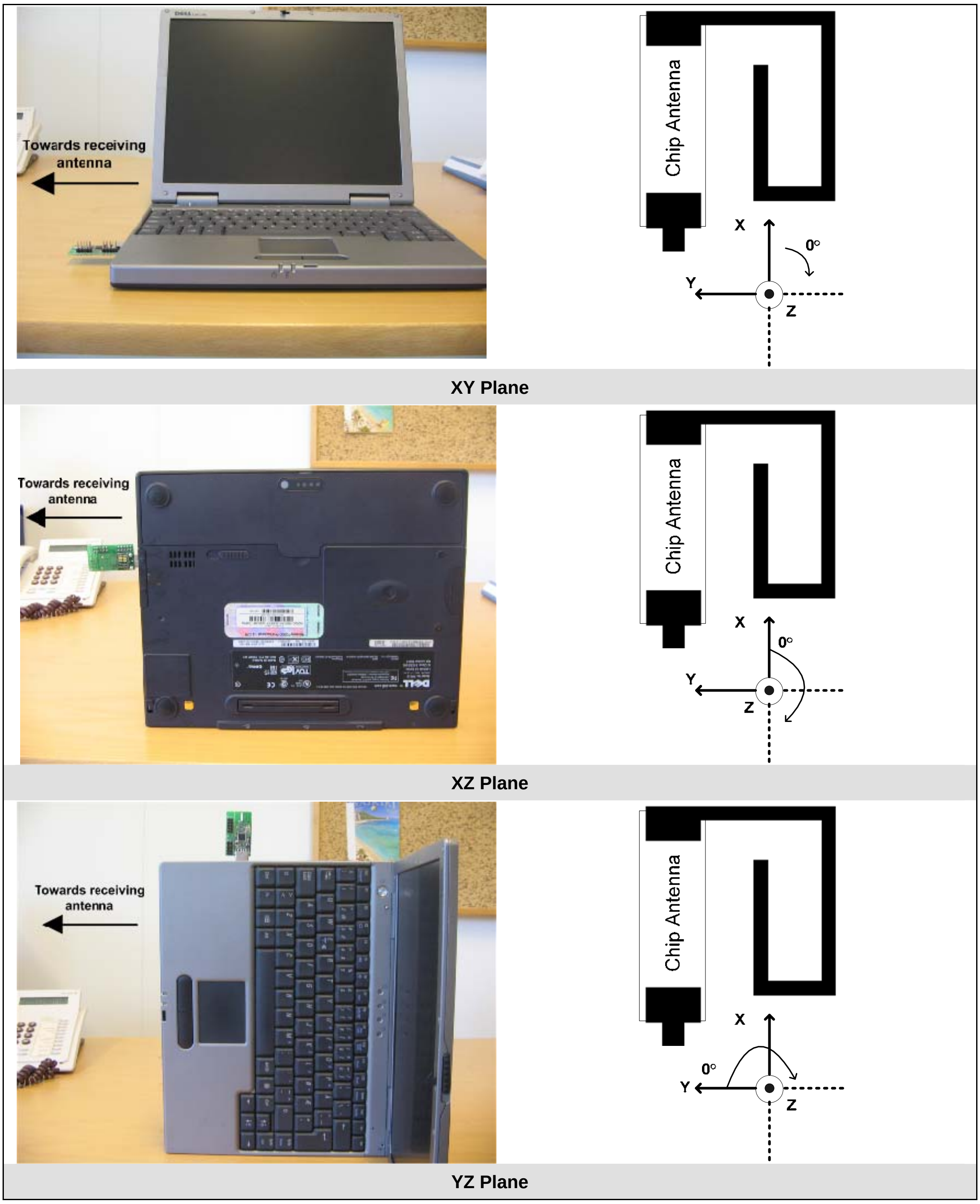


Figure 5. How to Relate the Antenna to the Radiation Patterns

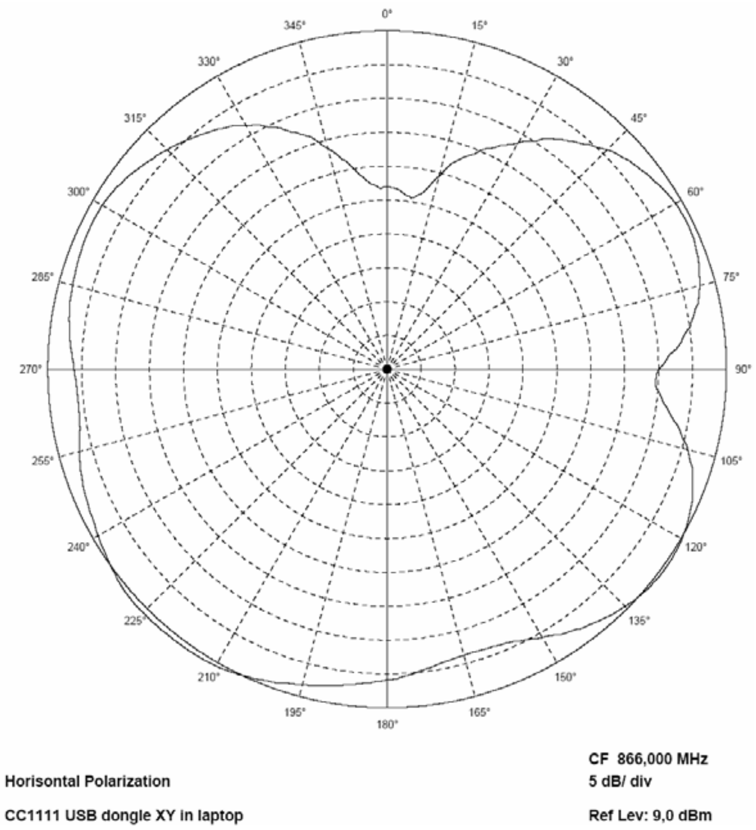


Figure 6. XY HP in Laptop

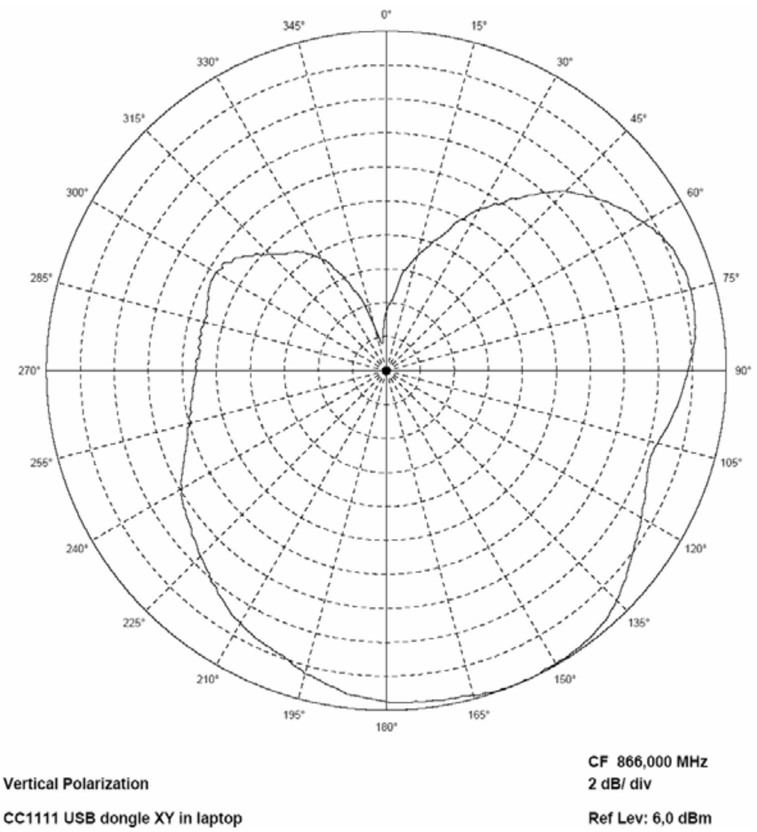


Figure 7. XY VP in Laptop

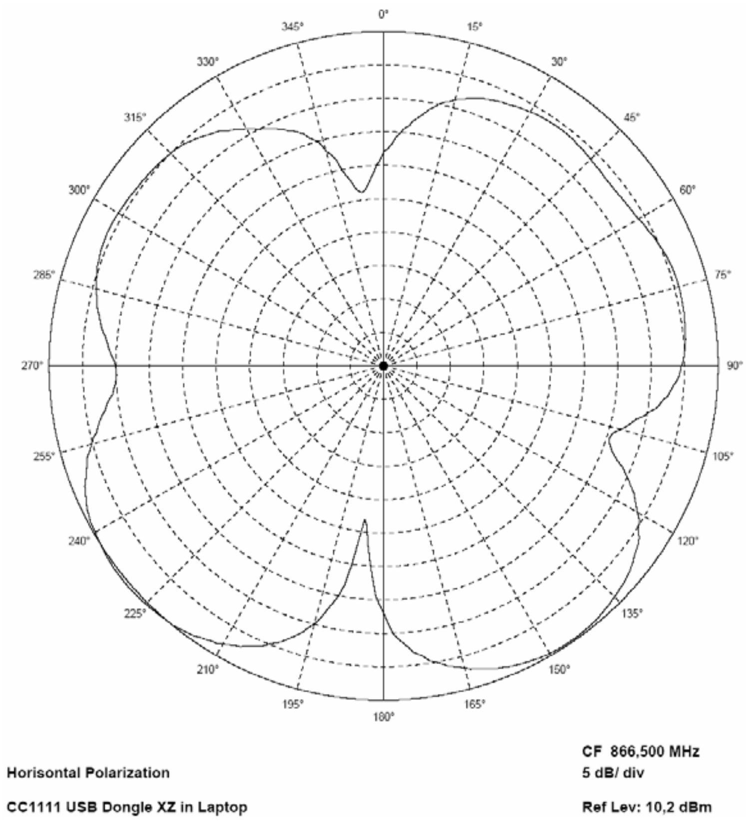


Figure 8. XZ HP in Laptop

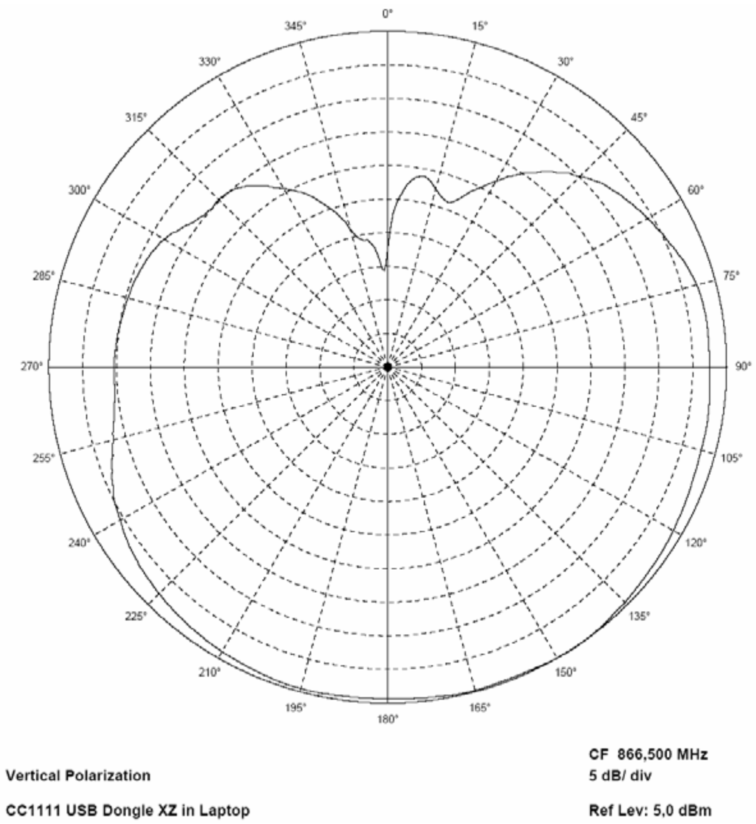


Figure 9. XZ VP in Laptop

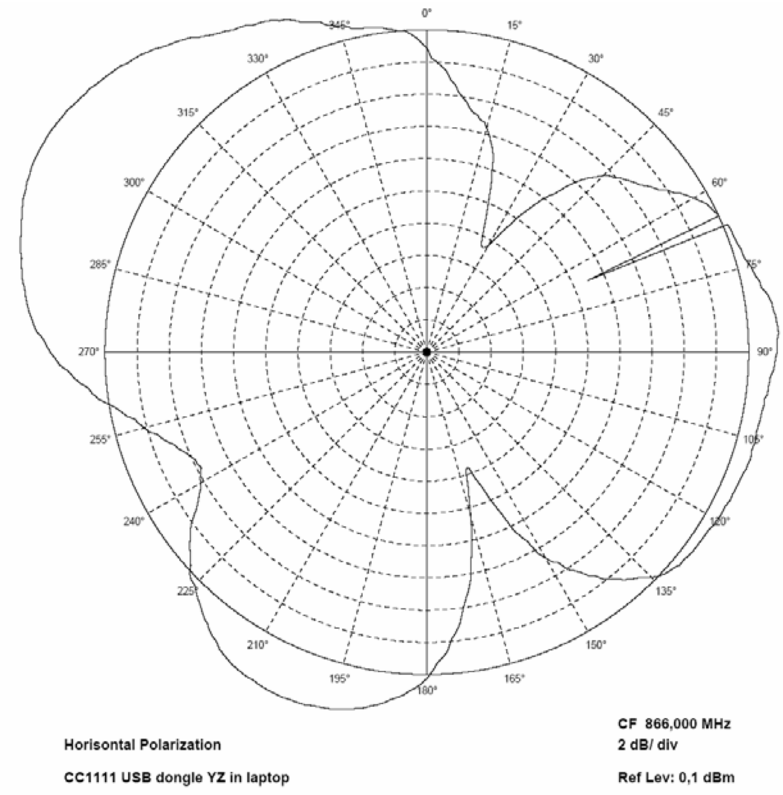


Figure 10. YZ HP in Laptop

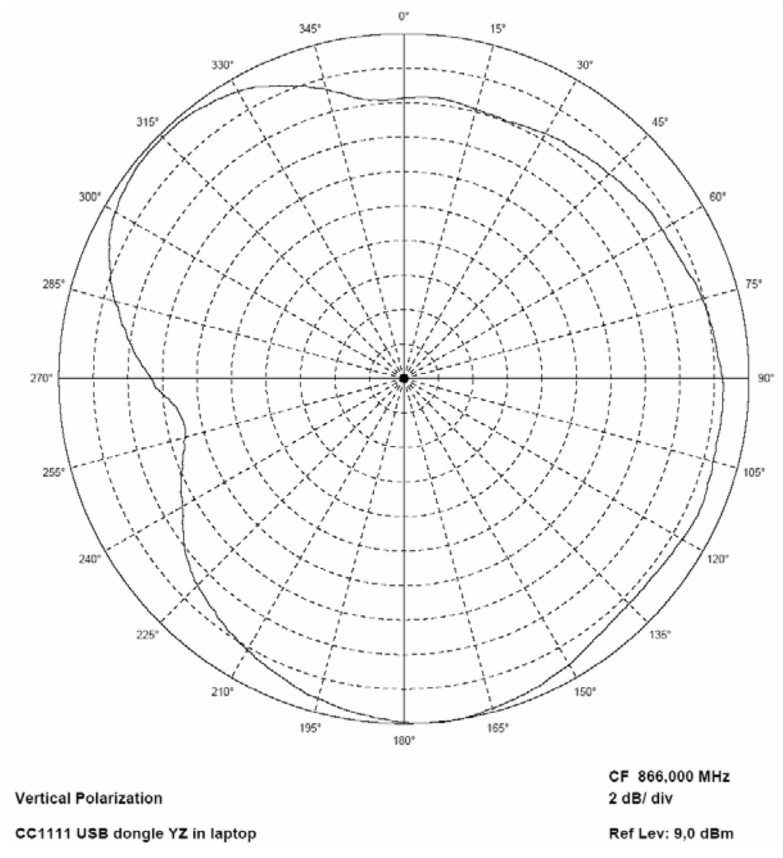


Figure 11. YZ VP in Laptop

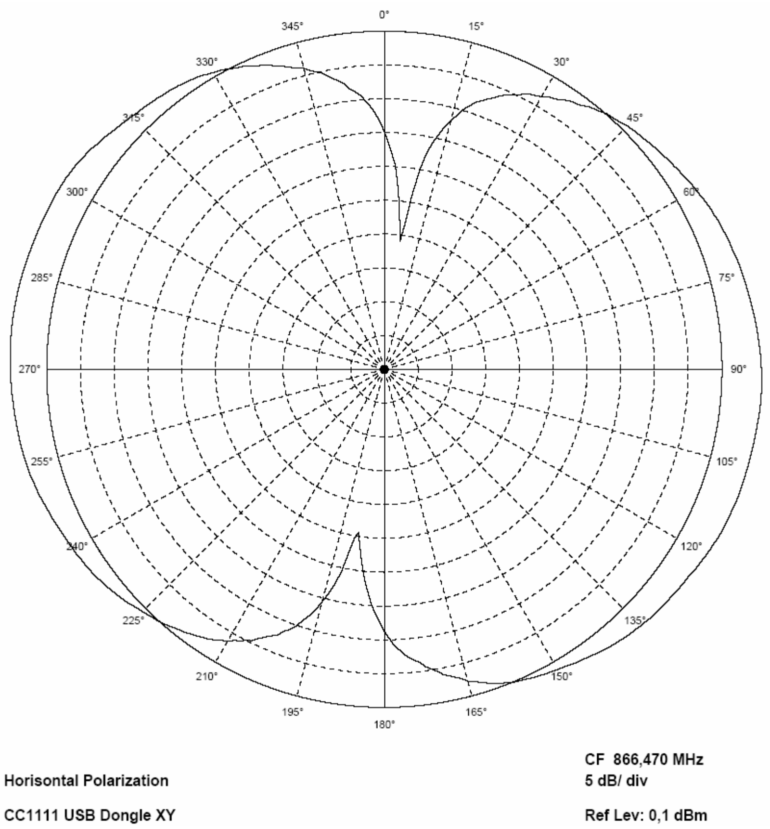


Figure 12. XY HP. Only CC1111 USB Dongle and Battery

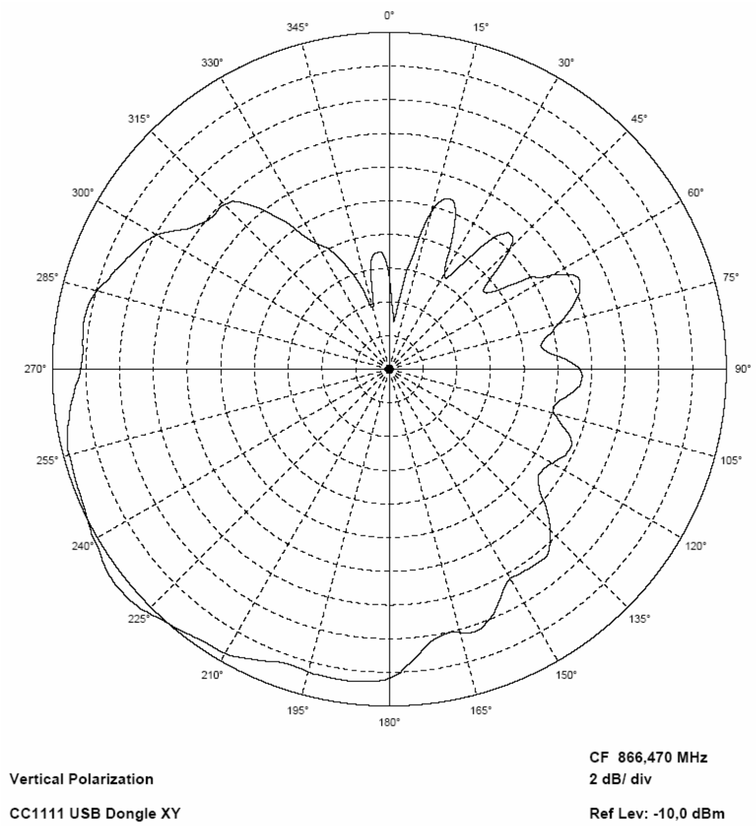


Figure 13. XY VP. Only CC1111 USB Dongle and Battery

4.2 Bandwidth

A 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. By using the “Max hold” function on a spectrum analyzer the variation in output power across the frequency band can easily be measured. Figure 14 shows how the USB dongle output power varies when the PCB is horizontally oriented and pointing away from the receiving antenna. This corresponds to 180° in Figure 6 . Notice that the bandwidth will vary with polarization and orientation of the antenna.

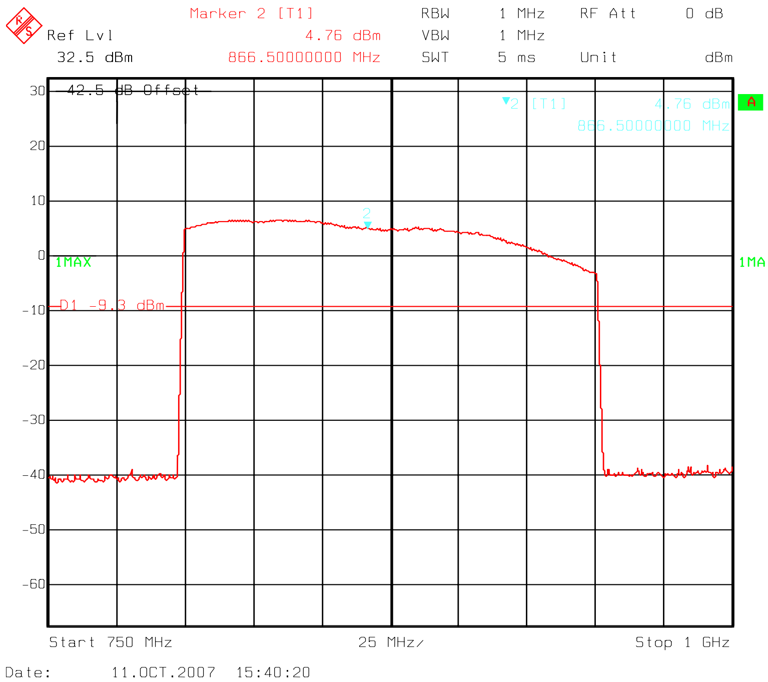


Figure 14. Bandwidth

4.3 Harmonic Emission

Harmonic emission was measured with the CC1111 transmitting at 868 MHz with 10 dBm output power and the USB dongle plugged into the laptop. The measured harmonic emission is shown in Table 4.

Frequency	Emission
2. harm 1732 MHz	-55.5 dBm
3. harm 2599 MHz	-55.6 dBm
4. harm 3465 MHz	-56.9 dBm
5. harm 4332 MHz	-57.6 dBm
6. harm 5198 MHz	-46.2 dBm
7. harm 6065 MHz	-39.0 dBm
8. harm 6931 MHz	-50.2 dBm
9. harm 7798 MHz	-56.9 dBm
10. harm 8664 MHz	-48.9 dBm

Table 4. Harmonic Emission

4.4 TX Spurious Emission 30 - 1 GHz

A sweep from 30 MHz to 1 GHz was done to measure spurious emission. All results in section 4.4 are without correction factor, but shows that no spurs were measured to be above the noise floor. The test was performed with CC1111 transmitting at 868 MHz with 10 dBm output power and the dongle plugged into the laptop.

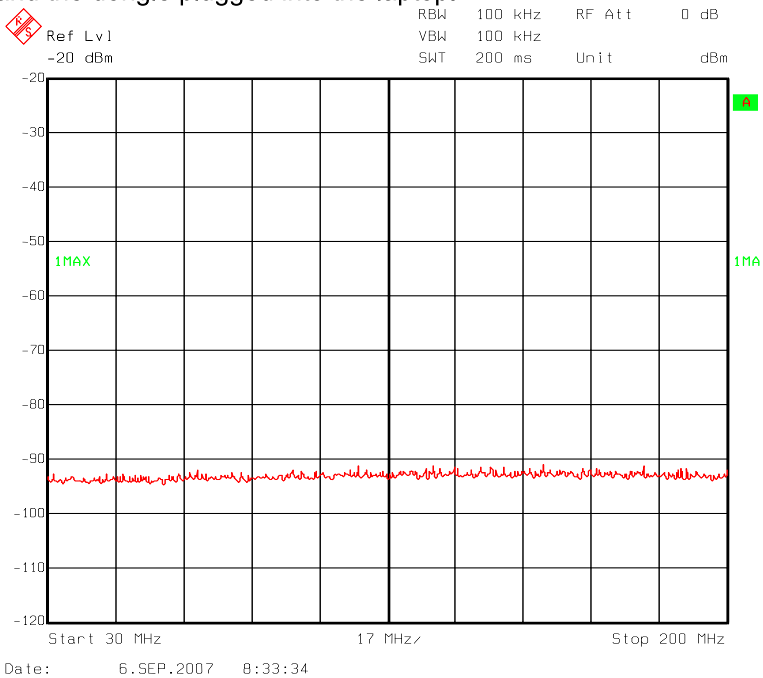


Figure 15. 30 - 200 MHz. Vertical Polarization

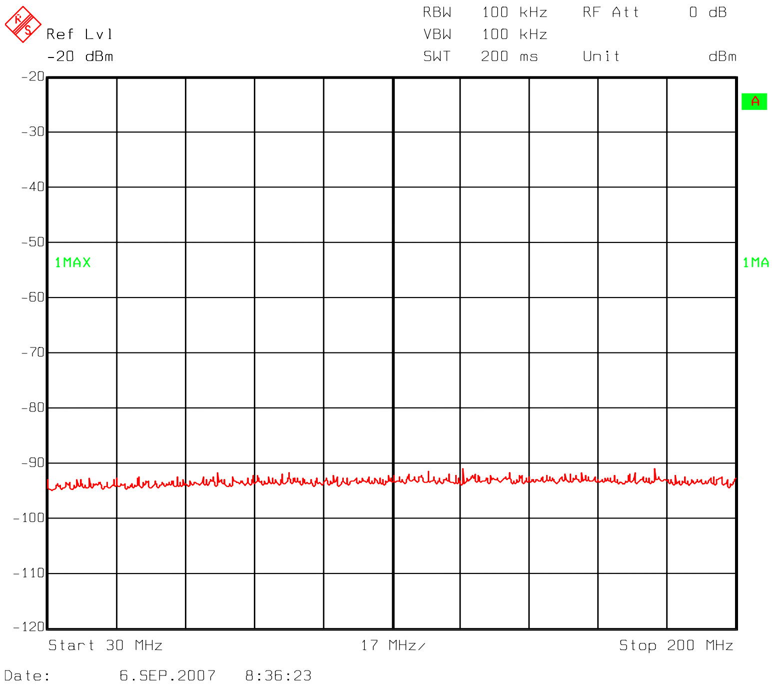


Figure 16. 30 - 200 MHz. Horizontal Polarization

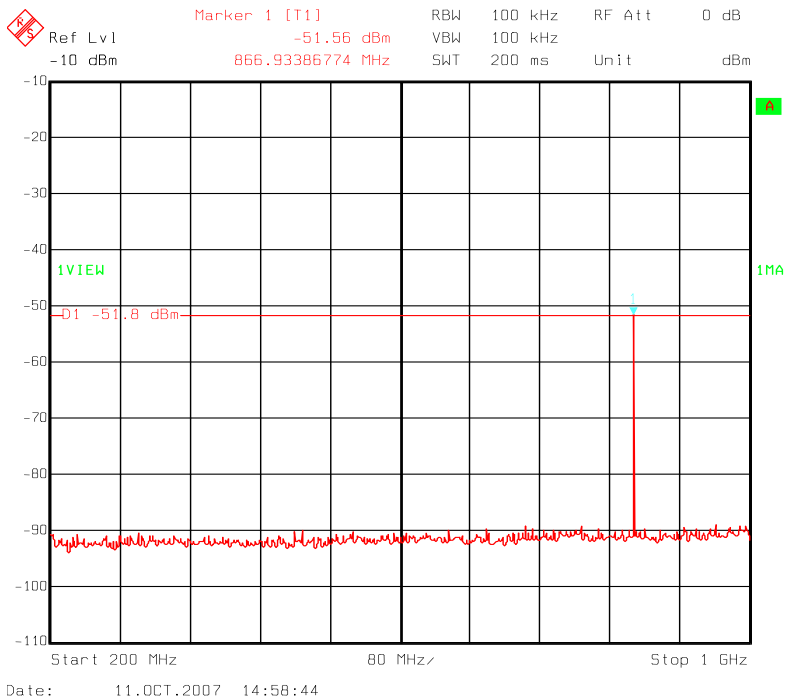


Figure 17. 200 MHz - 1 GHz. Vertical Polarization

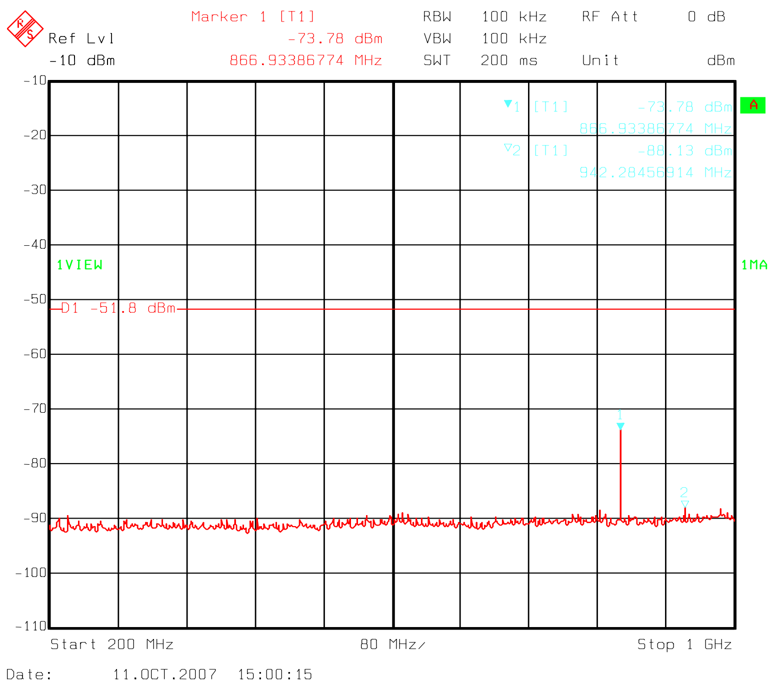


Figure 18. 200 MHz - 1 GHz. Horizontal Polarization

4.5 VCO Leakage

Figure 19 shows the measured CC1111 VCO leakage RX. The measured level is below ETSI limit of -47 dBm. This measurement was done with the USB dongle plugged into the laptop.

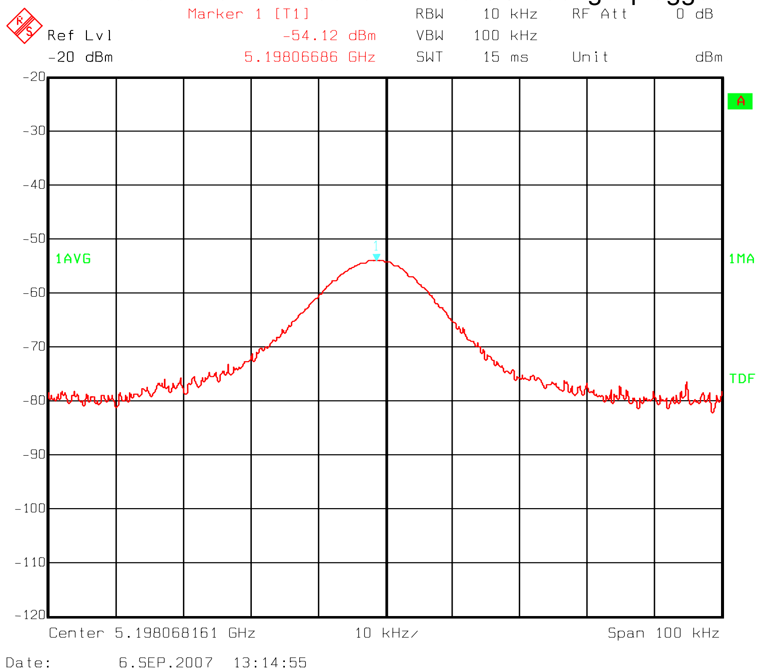


Figure 19. VCO leakage. Horizontal Polarization

5 Compliance with Regulatory Standards

Measurements on the CC1111 USB dongle show that spurious and harmonic emissions are below ETSI and FCC limits. For compliance with ETSI is it not recommended to use CC1111 for operation between 863 and 865.5 MHz, due to a spur close to carrier which will violate the -36 dBm ETSI limit. For more information and recommendations on how to comply with the different ETSI sub bands please see Application Note 050 [4].

6 Conclusion

The antenna solution presented in this document performs well for all frequencies in the 868 MHz and 915 MHz ISM band. Table 5 lists the most important properties for the presented antenna. Note that the gain numbers are related to an isotropic antenna and thus given in dBi.

Peak gain XY Plane with laptop	-0.1 dBi
Peak gain XZ Plane with laptop	+0.7 dBi
Peak gain YZ Plane with laptop	-1.0 dBi
Peak gain XY Plane without laptop	-3.9 dBi
Reflection 863 – 870 MHz	< -10 dB
Reflection 902 – 928 MHz (L9 = 0 mm, L8 = 2.5 mm)	< -9.0 dB
Antenna Size	8.5 mm x 7.8 mm

Table 5. Summary of the Antenna Properties

7 References

[1] CC1111 Data Sheet (cc1111f16.pdf)

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

[3] CC1111 USB Dongle Reference Design (swrr049.zip)

[4] AN050 Using the CC1101 in the European 868MHz SRD band (swra146.pdf)

[5] Full Detail Specification of 0868AT43A0020
http://www.johansontechnology.com/products/rfc/ant/

[6] Contact information: http://www.johansontechnology.com/sales/

8 Appendix A

High Frequency Ceramic Solutions

Subset of Detail Specification

868MHz Antenna **P/N 0868AT43A0020**

Summary Specification: 06/06/07

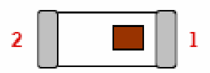
General Specifications

Part Number	0868AT43A0020
Frequency Range	858 - 878 Mhz
Peak Gain	-1.0 dBi typ. (XZ-total)
Average Gain	-4.0 dBi typ. (XZ-total)
Return Loss	9.5 dB min.

Input Power	3W max.
Impedance	50 Ω
Operating Temperature	-40 to +85°C
Reel Quanity	1,000
MSL	2

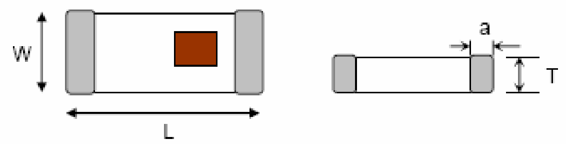
No.	Function
1	Feeding Point
2	NC

Terminal Configuration



Mechanical Dimensions

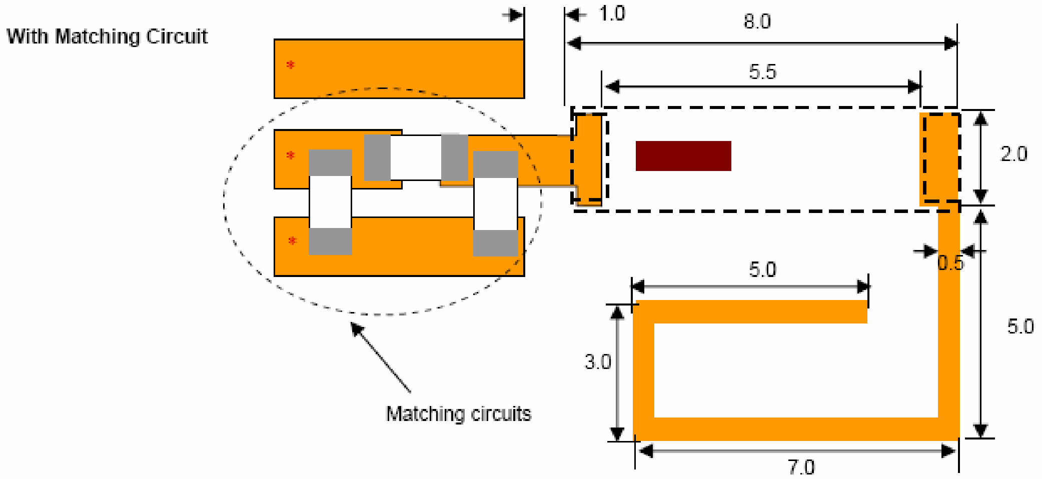
	In	mm
L	0.276 ± 0.008	7.00 ± 0.20
W	0.079 ± 0.008	2.00 ± 0.20
T	0.031 +.004/-.008	0.80 +0.1/-0.2
a	0.020 ± 0.012	0.50 ± 0.30



Mounting Considerations

Mount these devices with brown mark facing up. Units: mm

* Line width should be designed to provide 50 Ω impedance matching characteristics.



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9 General Information

9.1 Document History

Revision	Date	Description/Changes
SWRA160B	2009.08.20	Added CC430 to list of devices
SWRA160A	2008.04.08	Added information about matching components.
SWRA160	2007.10.25	Initial release.