Mitsubishi Ceramic Antenna for 868 MHz, 915 MHz & 955 MHz

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Keywords

- *433 MHz (387 MHz - 510MHz) Antenna*
- *868 MHz (779 MHz - 960MHz) Antenna*
- *915 MHz (779 MHz - 960MHz) Antenna*
- *CC1xxx*
- *Ceramic Chip Antenna*
- *CC-Antenna-DK*
- *Mitsubishi Chip Antenna*

1 Introduction

This document describes an antenna design that can be used with all transceivers and transmitters from Texas Instruments which are capable of operating in the sub 1 GHz bands. The Mitsubishi part number is AMD1103-ST01[1].

The antenna has been implemented on a CC1101-Q1 EM as shown in Figure 1. All measurement results presented in this document are based on measurements performed on the CC1101-Q1 EM attached to a SmartRF04 evaluation board as shown in Figure 2.

The AMD series antennas from Mitsubishi Materials Corporation are surface mountable dielectric chip antennas. They can be used in a wide range of frequency by properly selecting matching inductors. They are compact antenna solutions with high performance.

This antenna is available in the CC-Antenna-DK. CC-Antenna-DK board 3 has been tuned to 868 MHz and CC-Antenna-DK board 12 has been tuned to 433 MHz, as shown in Figure 3.

Figure 1: CC1101-Q1 Evaluation Module

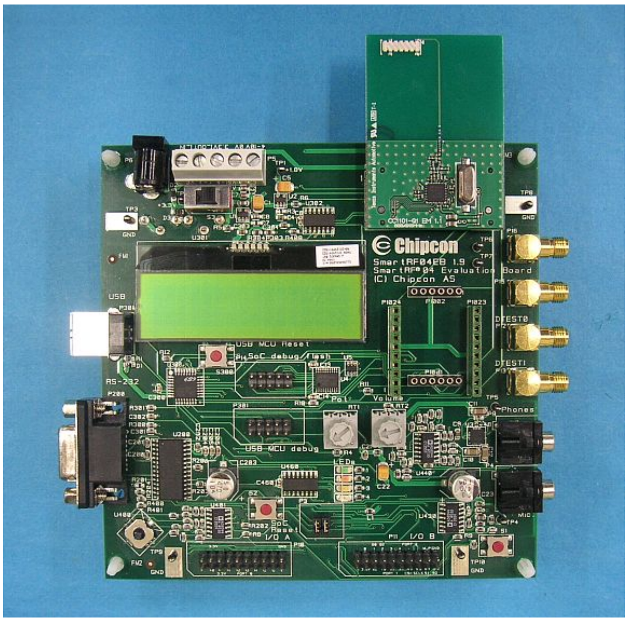

Figure 2: CC1101-Q1 Evaluation Module Attached to SmartRF04 Evaluation Board

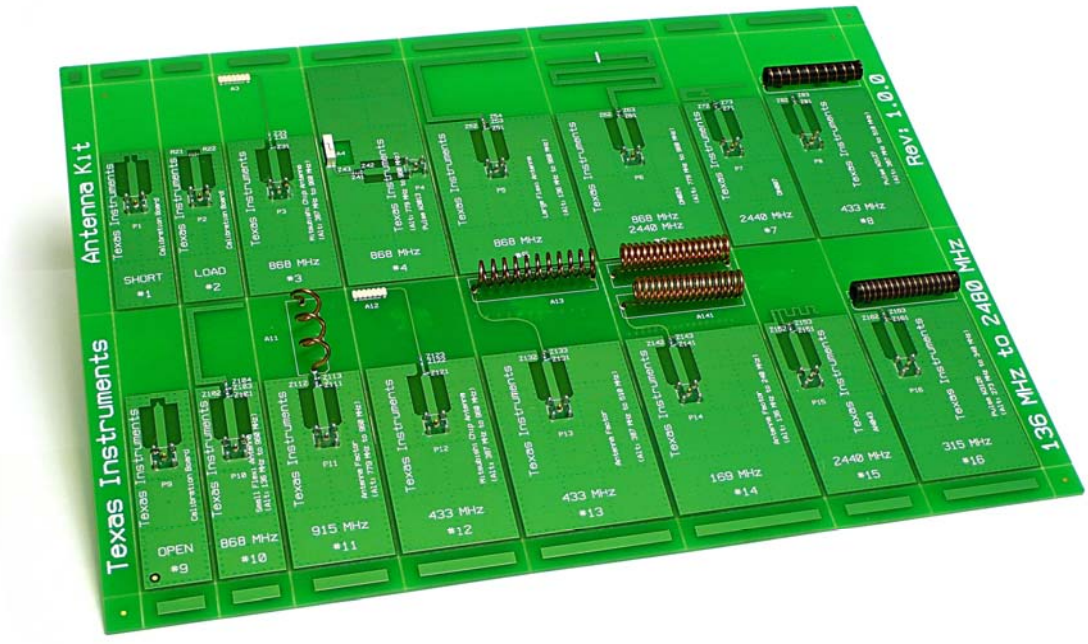

Figure 3: Mitsubishi Antennas on CC-Antenna-DK Board 3 (868 MHz) & Board 12 (433 MHz)

Table of Contents

2 Abbreviations

BOM	Bill Of Materials
BW	Bandwidth
CITA	Cellular Telecommunications Industry Association
DK	Development Kit
DUT	Device Under Test
EB	Evaluation Board
EIRP	Effective Isotropic Radiated Power
EM	Evaluation Module
ISM	Industrial, Scientific, Medical
NC	Not Connected
NHPRP	Near Horizon Partial Radiated Power
NHPRP45	Near Horizon Partial Radiated Power within 45 degrees angle
OTA	Over The Air
PCB	Printed Circuit Board
RF	Radio Frequency
SWR	Standing Wave Ratio
TRP	Total Radiated Power

3 Description of the Antenna Design

The antenna solution implemented on the CC1101-Q1 EM consists of a chip antenna from Mitsubishi Materials Corporation. For detailed information about this chip antenna, please refer to [1].

A matching network is used to adjust impedance and ensure optimum performance at the desired frequency.

The performance of the antenna is affected by dimensions and layout of the PCB on which it is implemented due to their influence on the impedance of the antenna. Especially the area and dimensions of ground plane and its distance to the antenna affect the performance of the antenna remarkably.

3.1 Implementation of the Antenna

It is important to make an exact copy of the PCB pattern to obtain optimum antenna performance on the CC1101-Q1 EM. Figure 4 and Table 1 show the dimensions of the PCB pattern of the CC1101-Q1 EM. A double-sided FR4 substrate with 1 mm thickness is being used for this module. The thickness of the PCB will have little effect on the performance of the antenna. However, the value of the matching components should be changed with the thickness. The antenna has also been implemented onto the CC-Antenna-DK and this ref design is based upon 1.6mm thick PCB and a larger GND plane [2].

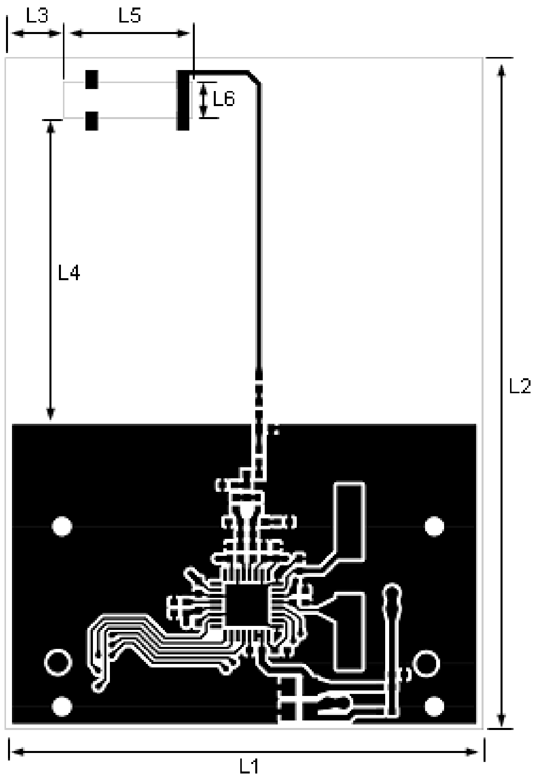

Figure 4: Antenna Dimensions

L1	L2	L3	L4	L5	L6
39 mm	55 mm	4.75	25 mm	10.5	3 mm

Table 1. Antenna Dimensions

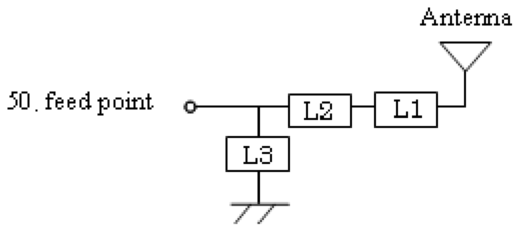

Figure 5: Recommended Matching Circuit

Figure 5 shows a matching network to obtain an optimum performance of the antenna at the desired frequency. Usually, inductors are used for the matching and the method will be described in section 3.2.

When implemented on customer module, the position of the matching network and the antenna can be changed according to the shape of the module. However, the performance of the antenna will change due to the effect of size and geometry of PCB and ground plane. When used in combination with other modules etc., the performance of the antenna will be affected by the objects in vicinity of the antenna. Effects of plastic encapsulation in which the module is placed should also be considered.

Figure 6 and Figure 7 show some points to improve the performance of the antenna. As shown in Figure 6, the PCB trace between the matching network and the antenna should be as long as possible, and the gap between the antenna and the ground plane should be as wide as possible. Moreover, as shown in Figure 7, RF circuit with a longer ground plane tends to show a better performance; even an extended trace of ground plane with 1 mm width is effective. Figure 8 shows the design of the antenna board implemented on the CC-Antenna-DK [2].

Type of inductors will affect the performance of the antenna. Although low-Q type has a cost merit, high-Q type is advantageous for power gain, thus is recommended. The CC1101-Q1 EM is using high-Q type chip inductors for matching.

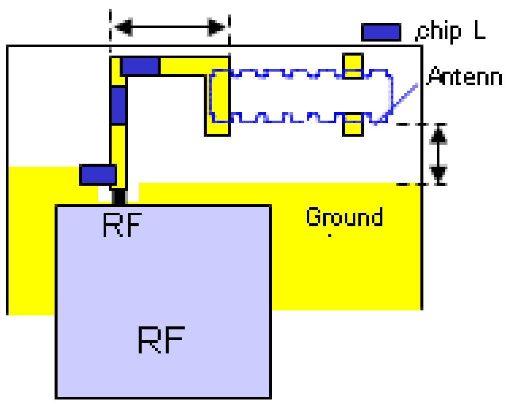

Figure 6: Recommended PCB Design

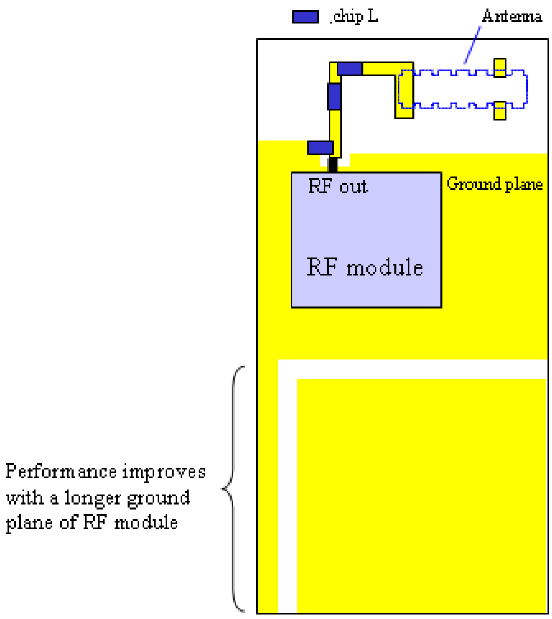

Figure 7: Recommended PCB Design with Larger GND

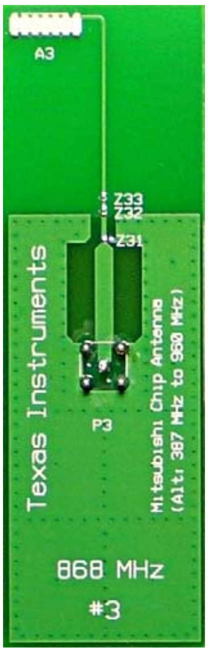

Figure 8. CC-Antenna-DK Board 3 - Mitsubishi Chip Antenna for 868/915/955 MHz

Bandwidth and power gain can be improved by increasing the distance between the ground plane and the antenna. On the other hand, the performance can also be improved by increasing the dimensions of ground plane. Therefore, improved performance can be expected by increasing the distance and the GND plane dimension simultaneously, as long as the layout is allowed.

It is important that no components, ground plane or other metallic objects are positioned in the open area around the antenna. Ground planes on the back and inner layers under the antenna should also be removed.

Since metallic objects in vicinity of the antenna decrease the gain, be sure to keep these objects away from the antenna area.

3.2 Selection of Antenna Matching Components for Optimized Performance

The method of selecting the inductor value for the matching network is described in more detail in this section; refer to Figure 5 and Figure 9.

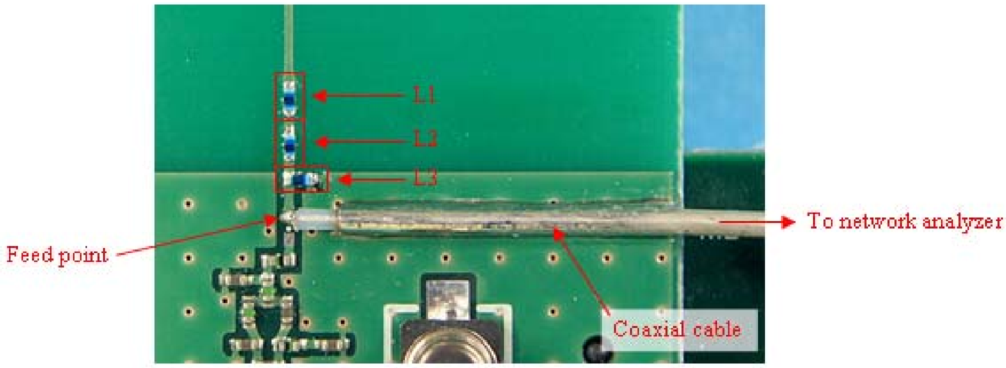

Figure 9: Relation Between CC1101-Q1 EM and Recommended Matching Circuit

The adjustment of the antenna can be conducted with the help of a network analyzer. Connect a coaxial cable to the feed point and measure VSWR with a network analyzer. Perform the adjustment to decrease VSWR at the desired frequency.

Method hereafter should be used to select values for the inductors of the matching network, based on measured VSWR data. As shown in Figure 10, inductors in the matching network play different roles clearly in the adjustment. In detail, L1, L2 affect resonance frequency as shown in Figure 10, while L3 affects impedance. Thus the following steps could be taken for adjustment:

1. Measure VSWR.
2. Select values for L1 and L2 to tune the resonance frequency to the desired frequency.
3. Select value for L3 to decrease VSWR to a minimum value.

First, implement inductors with values for desired frequency as described in Section 4.1 and measure VSWR. If the resonance frequency is higher than desired, select a larger value for L1 or L2. On the contrary, if the resonance frequency is lower than desired, select a smaller value for L1 or L2.
As a result, VSWR shows a minimum at the desired frequency. However, If VSWR at the desired frequency is not sufficiently small (around 1.5), alter the value of L3 to optimize impedance.

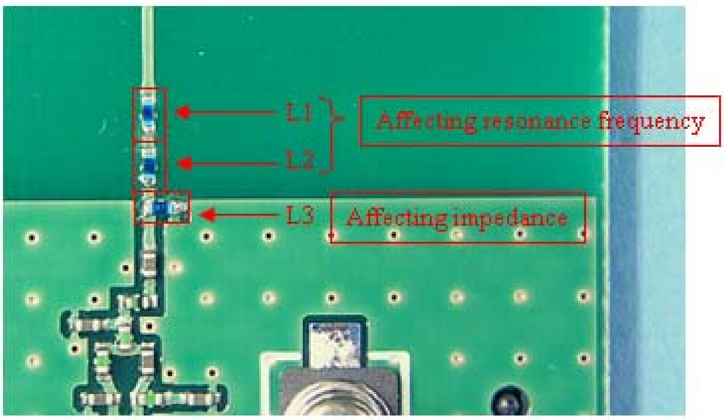

Figure 10: Functions of Inductors

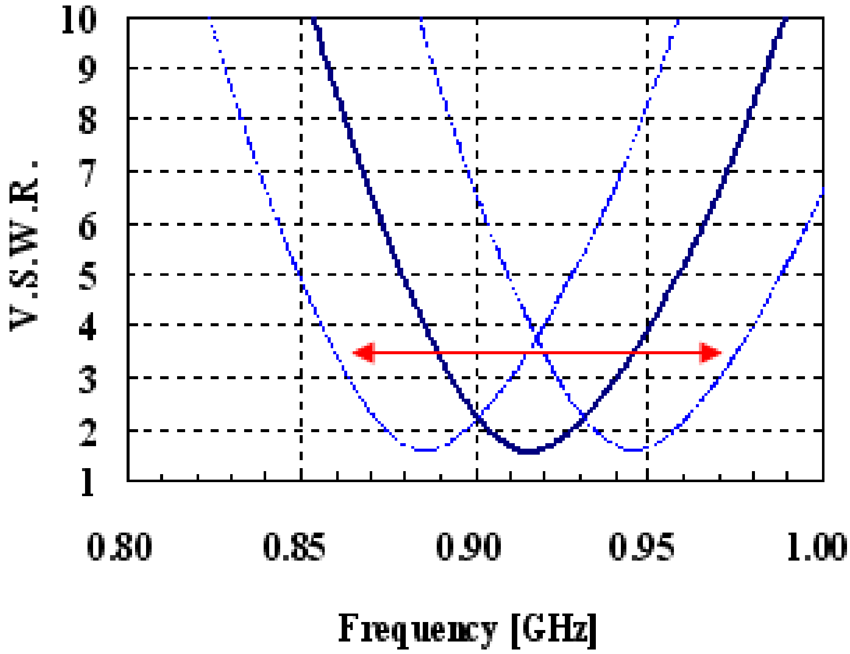

Figure 11: Resonance Frequency is Changed to L1 and L2

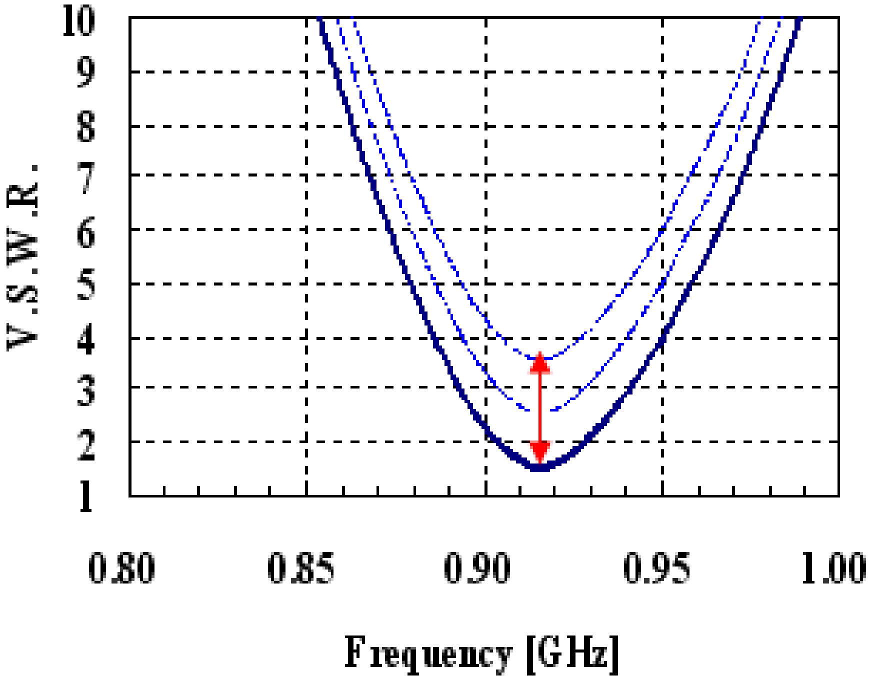

Figure 12: Impedance is Changed by L3

4 Measurement Results

All results presented in this document are based on measurements performed with the CC1101-Q1 EM attached to the SmartRF04EB. The CC1101-Q1 EM has been adjusted in the method shown in Section 3.2 at variant frequency in the state of being attached to the SmartRF04 EB,

The bandwidth was evaluated from VSWR property. The radiation pattern measured in an anechoic chamber will be described. Figure 13 shows how to relate radiation pattern to the orientation of the antenna. The antenna gain was obtained by averaging the power gain in vertical and horizontal polarization measured in the YZ, ZX and XY planes.

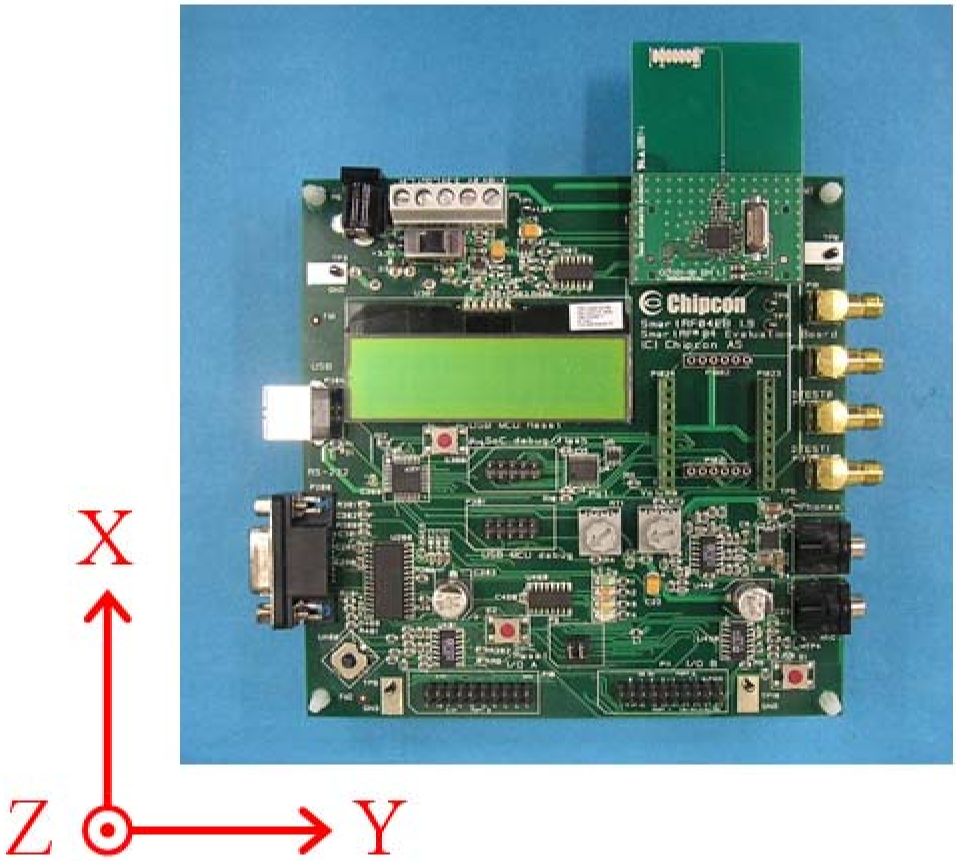

Figure 13: How to Relate the Antenna to the Radiation Patterns

4.1 Bandwidth

4.1.1 868 MHz

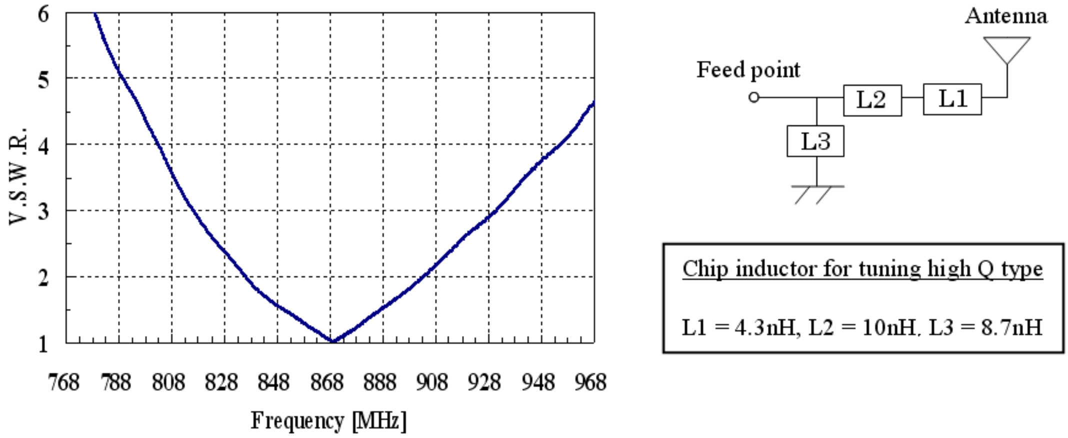

Figure 14: 868 MHz VSWR Characteristics

f_0 [MHz]	VSWR	BW (VSWR ≦ 2)	BW (VSWR ≦ 3)
868	1.04	68 MHz	115 MHz

Table 2. 868 MHz VSWR Characteristics

4.1.2 915 MHz

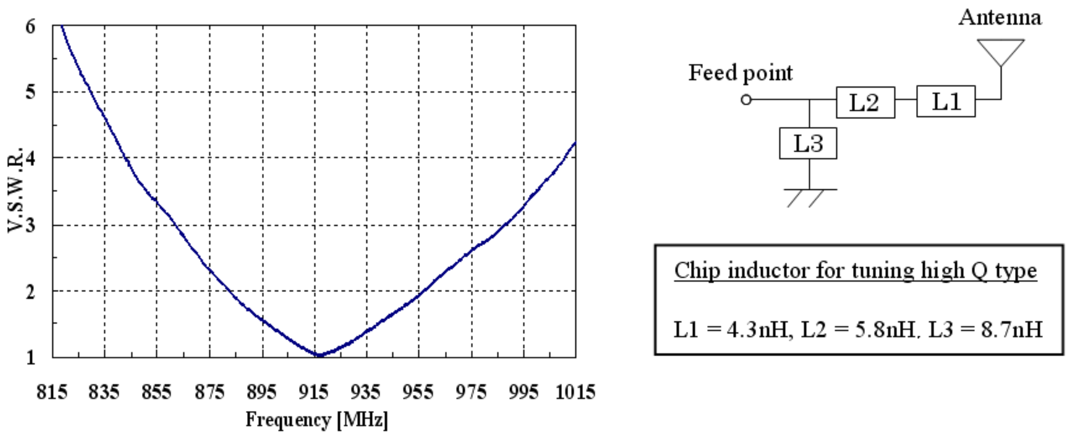

Figure 15: 915 MHz VSWR Characteristics

f_0 [MHz]	VSWR	BW (VSWR ≦ 2)	BW (VSWR ≦ 3)
915	1.04	80 MHz	136 MHz

Table 3. 915 MHz VSWR Characteristics

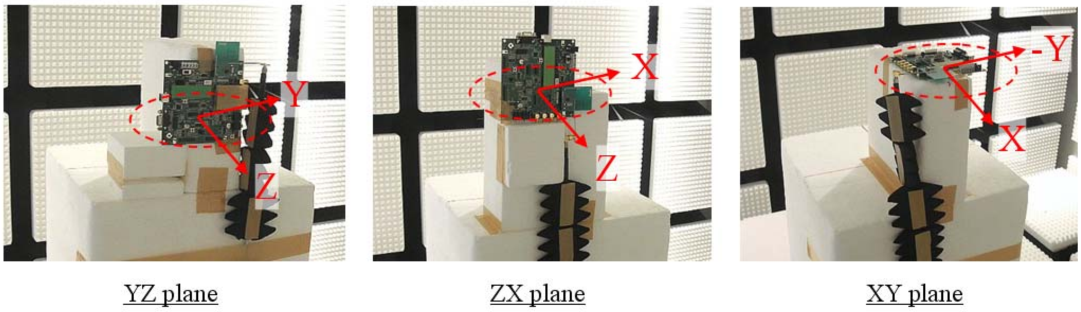

Figure 16: How to Relate the Antenna to the Radiation Patterns

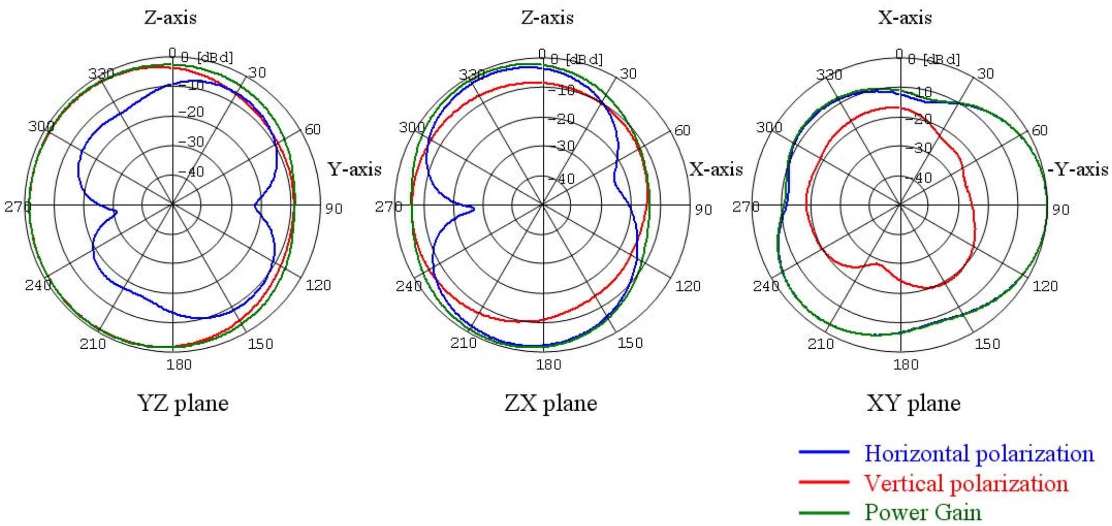

Figure 17: 868 MHz Radiation Patterns

Polarization	YZ Plane		ZX Plane		XY Plane		3 Plane total
	AVE.	MAX.	AVE.	MAX.	AVE.	MAX.	
Vertical pol. [dBd]	**-3.3**	**-0.9**	**-8.5**	**-5.3**	**-20.2**	**-16.6**	
Horizontal pol.	**-11.6**	**-6.6**	**-5.8**	**-1.5**	**-5.0**	**-0.4**	
Power gain [dBd]	**-2.7**	**-0.8**	**-3.9**	**-0.7**	**-4.8**	**-0.4**	**-3.7**

Table 4. 868 MHz Gain in Each Measurement Plane

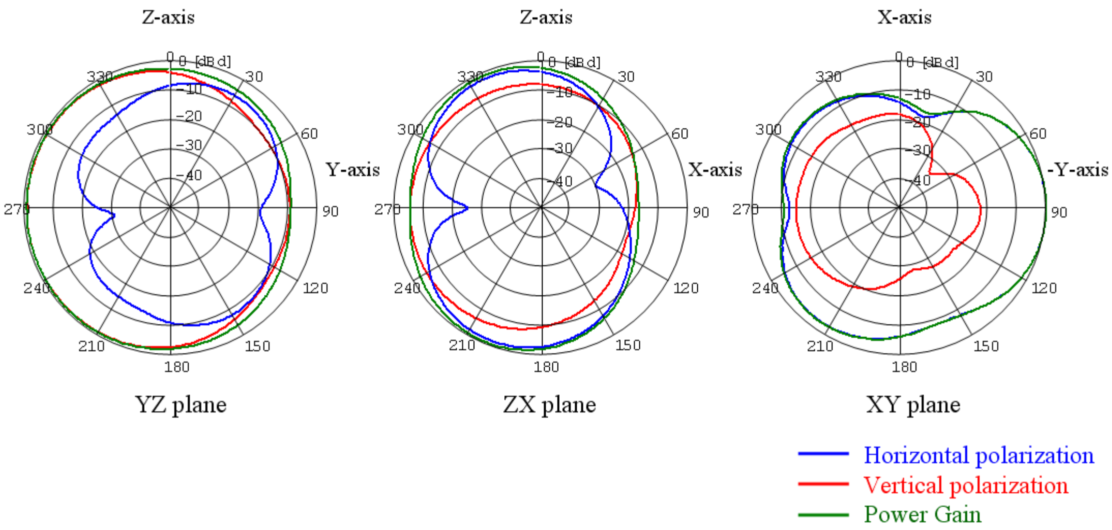

Figure 18: 915 MHz Radiation Patterns

Polarization	YZ Plane		ZX Plane		XY Plane		3 Plane total
	AVE.	MAX.	AVE.	MAX.	AVE.	MAX.	
Vertical pol.	**-3.3**	**-0.7**	**-8.3**	**-4.9**	**-18.9**	**-14.7**	
Horizontal pol.	**-10.8**	**-6.1**	**-5.9**	**-1.4**	**-4.9**	**-0.1**	
Power gain	**-2.6**	**-0.6**	**-3.9**	**-0.3**	**-4.7**	**-0.1**	**-3.6**

Table 5. 915 MHz Gain in Each Measurement Plane

Measurements from the CC-Antenna-Kit boards with the Mitsubishi Antenna are documented in [2], [3] & [4].

5 Conclusion

AMD1103-ST01 antenna presented in this document performs well in the 868 MHz and 915 MHz ISM band; 955 MHz frequency band is also recommended for this antenna. Table 6 lists main results measured on the presented antenna. Note that the gain numbers are given in dBd and the formula converting it to dBi is shown in Equation 1.

The antenna can also be used at lower frequencies such as 433 MHz but then the efficiency of the antenna will be lower [4] compared to operation at 868 MHz [3]. The measurements performed on the CC-Antenna-DK with the Mitsubishi antenna are similar to the measurements performed on the CC1101-Q1 Evaluation Module.

868MHz BW (VSWR ≦ 2)	68 MHz
915MHz BW (VSWR ≦ 2)	80 MHz
868MHz 3 plane total average power	-3.7 dBd
915MHz 3 plane total average power	-3.6 dBd
Antenna Size	10.5mm×3.0mm×0.8m

Table 6. 915 MHz Summary of Antenna Properties

$$dBi = dBd + 2.14$$

Equation 1. Conversion to dBi

6 References

[1] **Product Information:** http://www.mmc.co.jp/adv/dev/english/index_e.html

[2] **DN031** (SWRA328.PDF) **– CC-Antenna-DK Documentation and Antenna Measurements Summary**

[3] **DN600** (SWRA329.PDF) **– Full CTIA Measurement Report for CC-Antenna-DK Board 3**

[4] **DN608** (SWRA337.PDF) **– Full CTIA Measurement Report for CC-Antenna-DK Board 12**

[5] **AN058** (SWRA161.PDF) **– Antenna Selection Guide**

[6] **CC-Antenna-DK Rev 1.0.0. Reference Design** (SWRR070.ZIP)

7 General Information

7.1 Document History

Revision	Date	Description/Changes
SWRA307	2009.11.23	Initial release.
SWRA307A	2010.10.14	Updated with new EM board, DN assigned & CC-Antenna-DK links.

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