

868-/915-MHz Antenna Design

ABSTRACT

Keywords

- CC1000
- CC1020
- CC1021
- CC1070
- CC1100
- CC1101
- CC1101-Q1
- CC1110
- CC1111
- CC1131-Q1
- CC1150
- CC1151-Q1
- Chip Antenna
- 868 MHz
- 915 MHz
- ISM Bands

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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 868- and 915-MHz ISM band. 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.

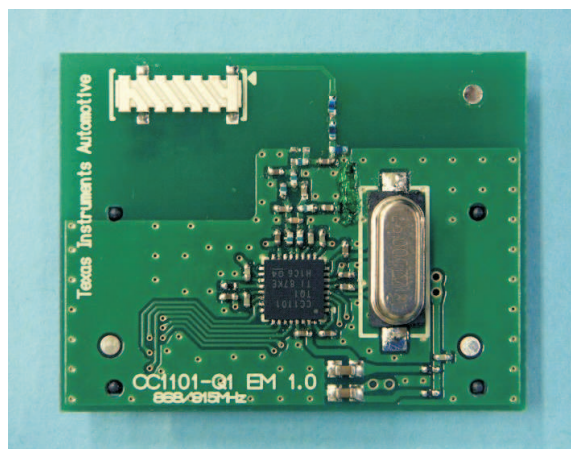


Figure 1. CC1101-Q1 Evaluation Module

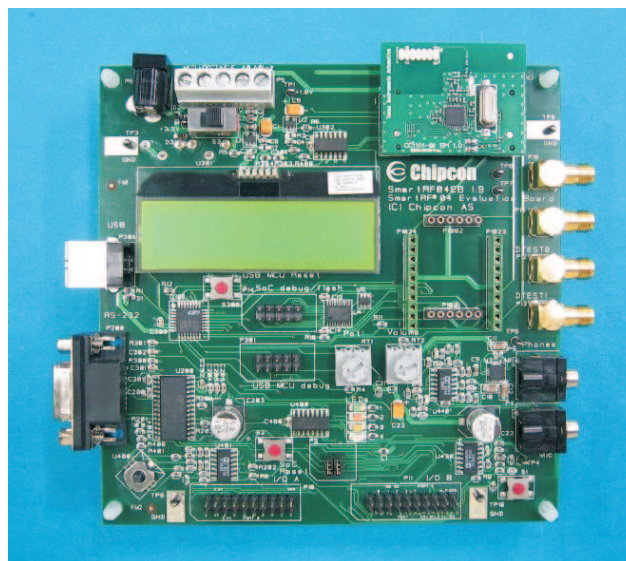


Figure 2. CC1101-Q1 Evaluation Module Attached to SmartRF04 Evaluation Board

2 Abbreviations

ISM — Industrial, scientific, medical
EM — Evaluation module
EB — Evaluation board
PCB — Printed circuit board
VSWR — Voltage standing wave ratio
BW — Bandwidth

3 Description of the Antenna Design

The antenna solution implemented on the CC1101-Q1 EM consists of a chip antenna from Mitsubishi Materials Corporation. See the Appendix at the end of this document for detailed information about this chip antenna.

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 between 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 3 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.

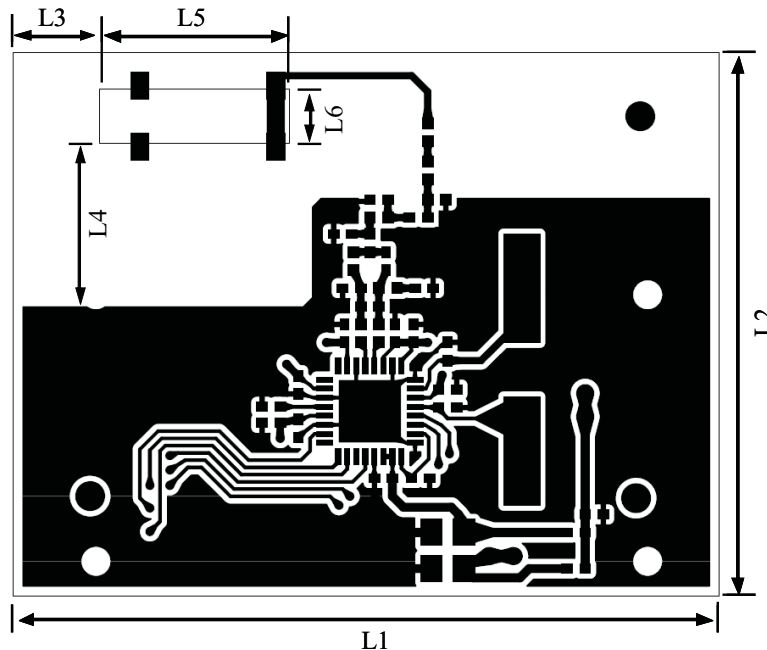


Figure 3. Antenna Dimensions

Table 1. Antenna Dimensions

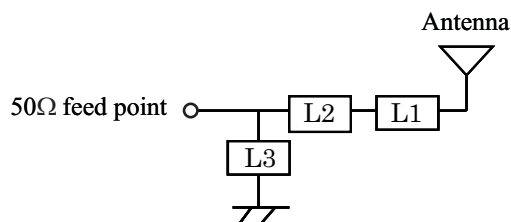
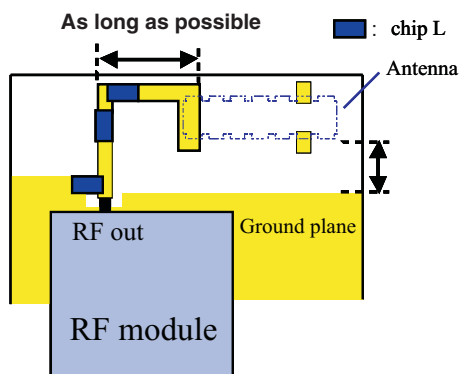
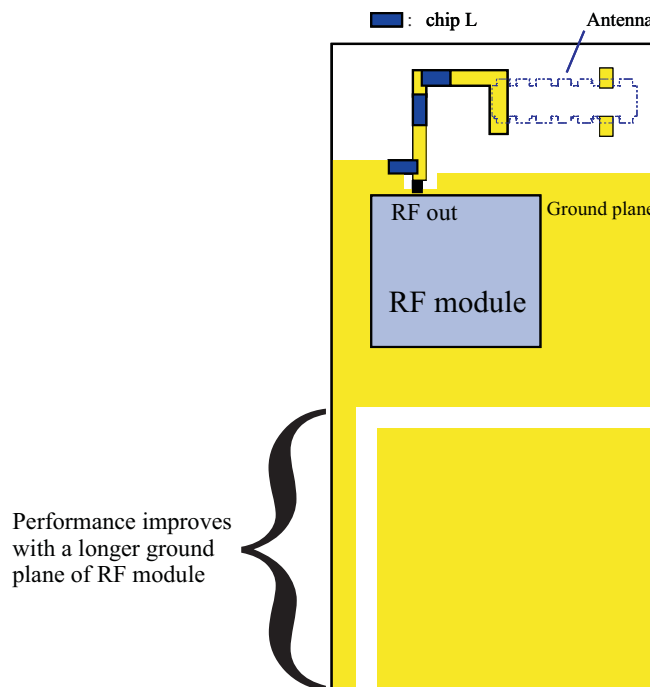
L1	L2	L3	L4	L5	L6
39 mm	30 mm	4.75 mm	9 mm	10.5 mm	3 mm

Figure 4 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 5 and Figure 6 show some points to improve the performance of the antenna. As shown in Figure 5, 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 6, 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.

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 4. Recommended Matching Circuit

Figure 5. Recommended PCB Design

Figure 6. Recommended PCB Design

Other points to be noted in design are now presented.

As mentioned above, 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 implement in the open area around the antenna. Ground planes in the back and inner layers under the antenna should also be removed.

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

3.2 Method of Selecting Antenna Matching Components for Optimized Performance

The method of selecting the inductor value for the matching network is described in this section.

Figure 7 shows the relation between CC1101-Q1 EM and matching network.

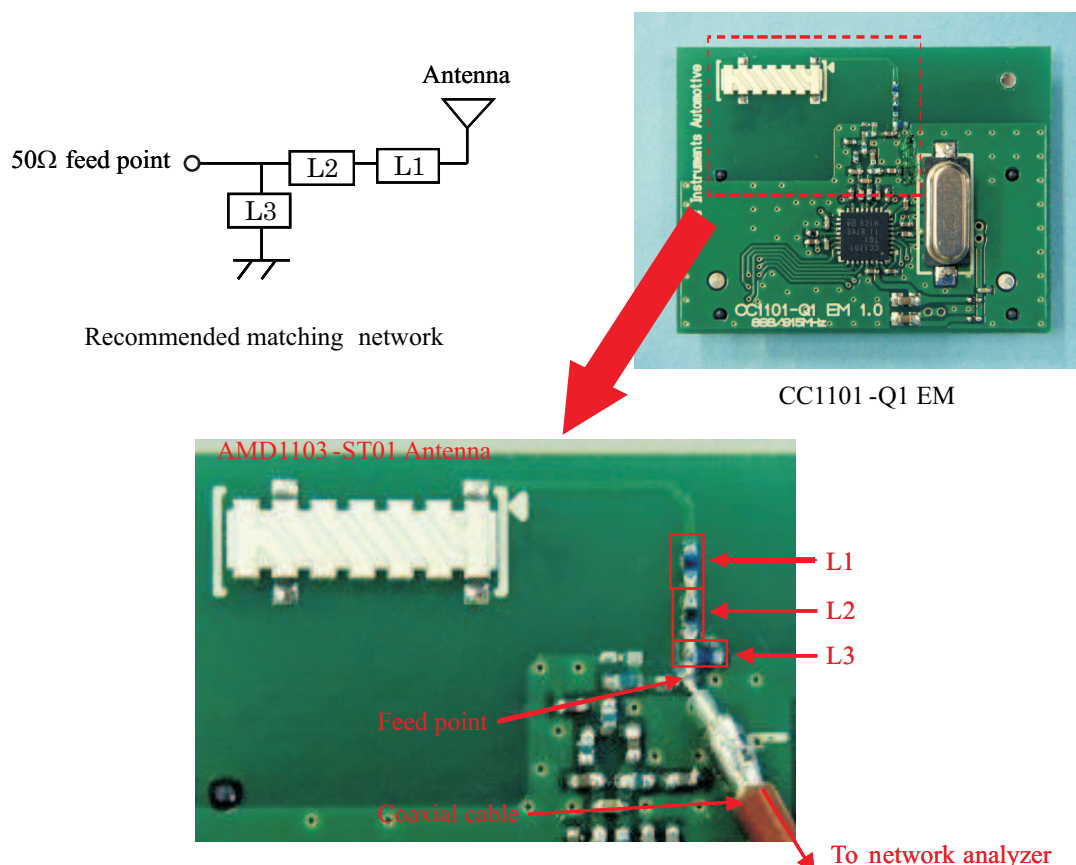


Figure 7. Relation Between CC1101-Q1 EM and Recommended Matching Circuit

The adjustment of the antenna can be conducted with the help of a net work analyzer.

Connect a coaxial cable to the feed point and measure VSWR with a net work analyzer. Perform the adjustment to decrease VSWR at the desired frequency.

The following method should be used to select values for the inductors of the matching network, based on measured VSWR data.

As shown in Figure 8, inductors in the matching network play different roles clearly in the adjustment. In detail, L1, L2 affect resonance frequency as shown in Figure 9, 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.

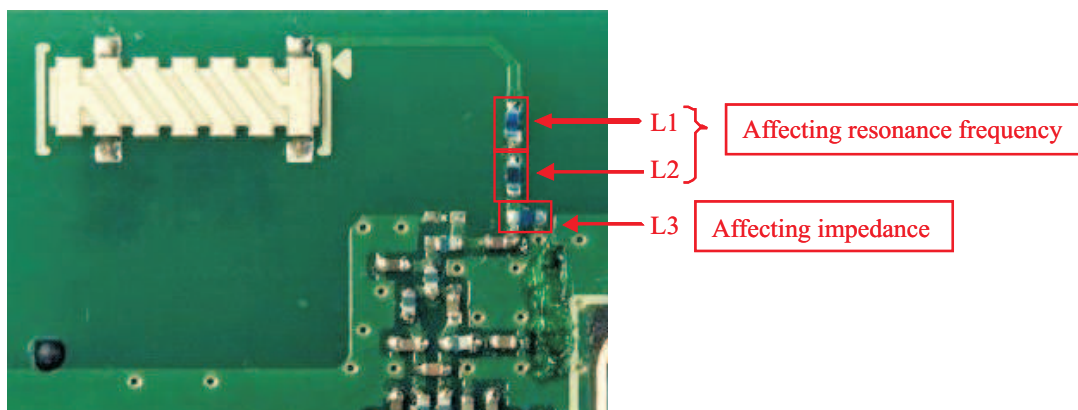


Figure 8. Functions of Inductors

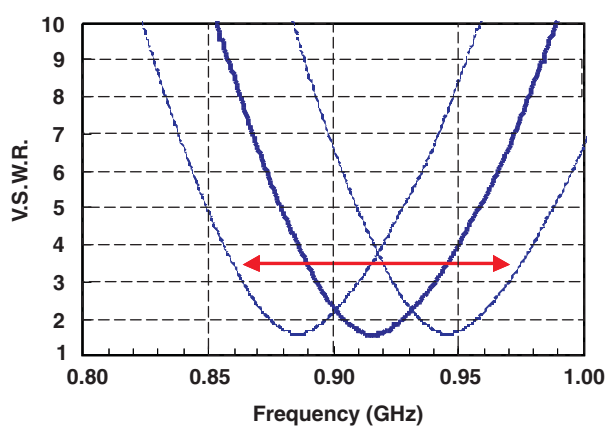


Figure 9. Resonance Frequency is Changed to L1 and L2

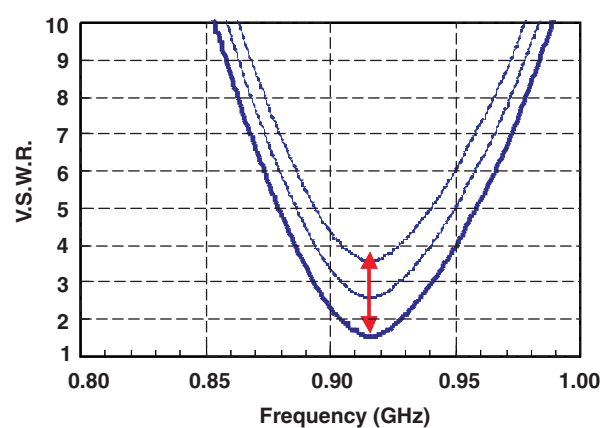


Figure 10. Impedance is Changed by L3

4 Measurement Results

All results presented in this document are based on measurements performed with the CC1101-Q1 EM attached to the SmartRF04 EB. The CC1101-Q1 EM has been adjusted in the method show 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 11 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.

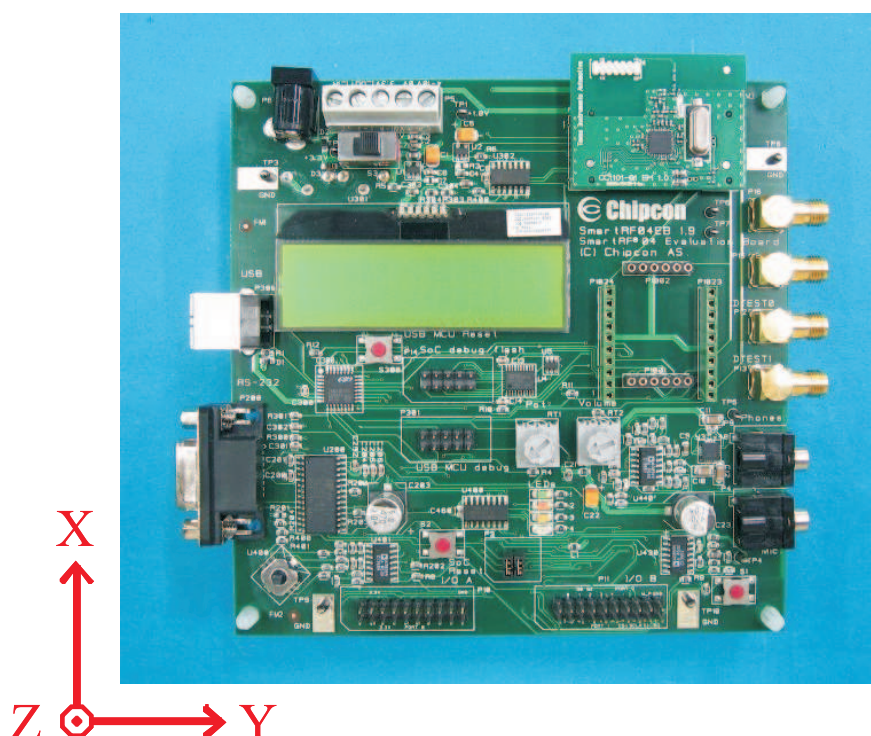


Figure 11. How to Relate the Antenna to the Radiation Patterns

4.1 Bandwidth

4.1.1 868-MHz Bandwidth

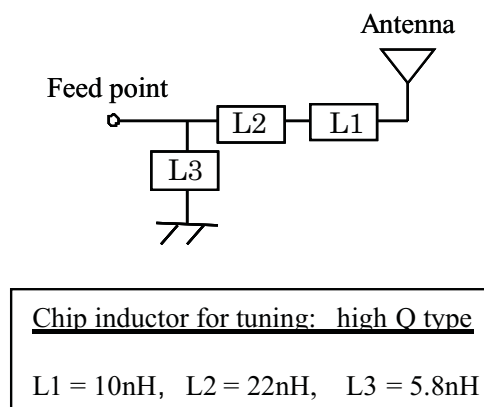
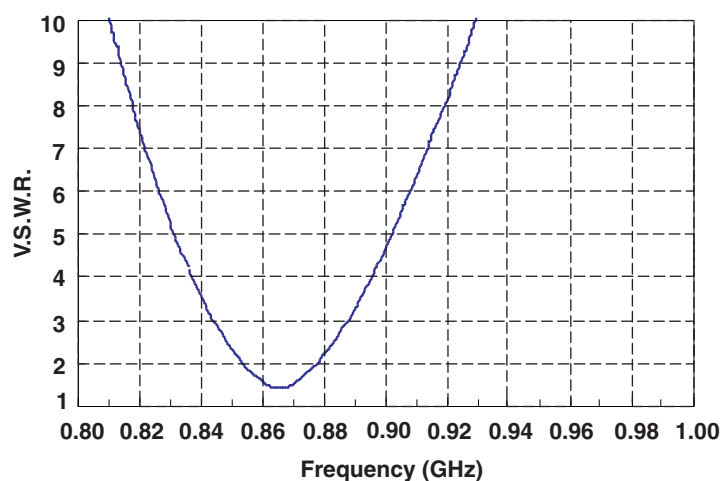


Figure 12. 868-MHz VSWR Characteristics

Table 2. 868-MHz VSWR Characteristics

f_0	VSWR	BW (VSWR ≤ 2)	BW (VSWR ≤ 3)
868 MHz	1.44	25 MHz (853 ~ 878 MHz)	44 MHz (844 ~ 888 MHz)

4.1.2 915-MHz Bandwidth

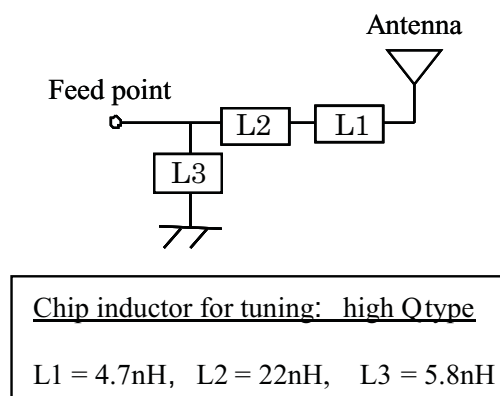
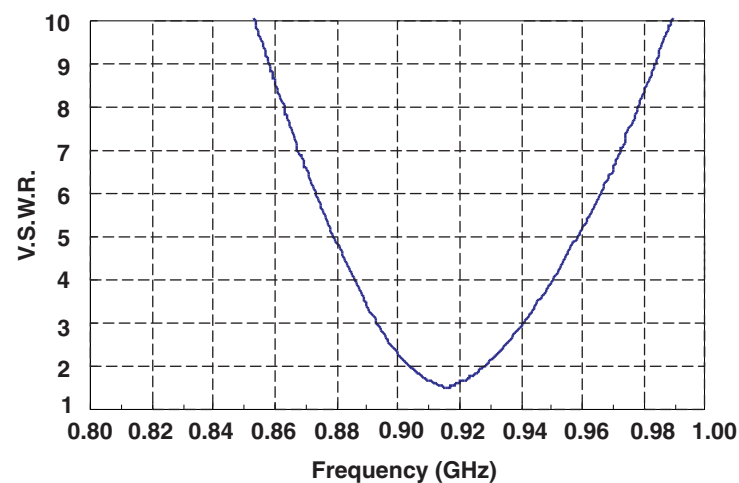


Figure 13. 915-MHz VSWR Characteristics

Table 3. 915-MHz VSWR Characteristics

f_0	VSWR	BW (VSWR ≤ 2)	BW (VSWR ≤ 3)
915 MHz	1.55	24 MHz (904 ~ 928 MHz)	48 MHz (893 ~ 941 MHz)

4.2 Radiation Pattern

4.2.1 868-MHz Radiation Pattern

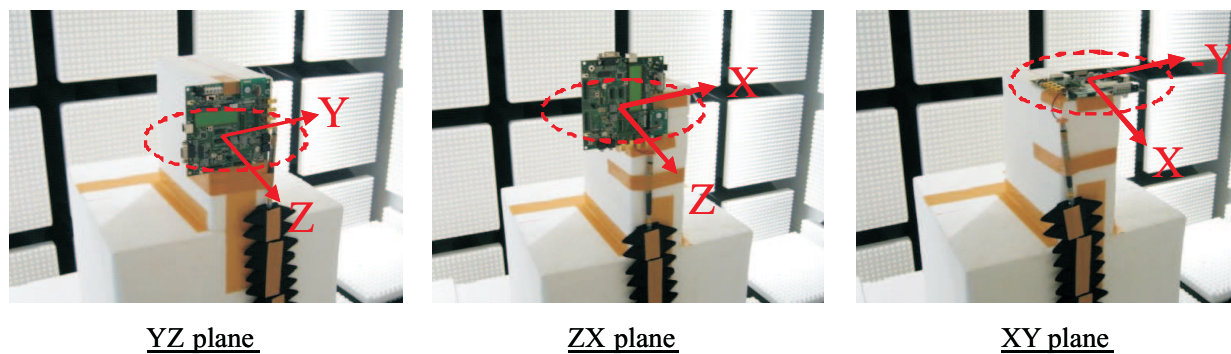


Figure 14. How to Relate the Antenna to the Radiation Patterns

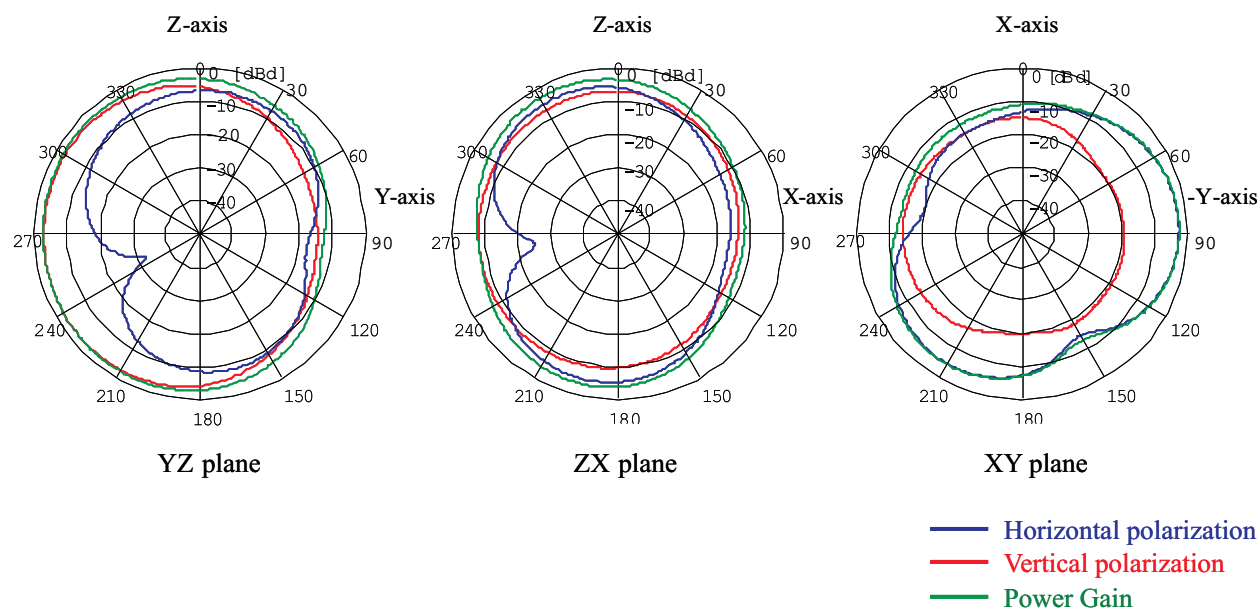


Figure 15. 868-MHz Radiation Pattern

Table 4. 868-MHz Gain in Each Measurement Plane

POLORIZATION	YZ PLANE		ZX PLANE		XY PLANE		3 PLANE TOTAL
	AVE	MAX	AVE	MAX	AVE	MAX	
Vertical pol. (dBd)	-5.1	-2.3	-8.9	-6.7	-16.4	-13.8	-
Horizontal pol. (dBd)	-10.2	-6.6	-8.3	-4.6	-7.5	-3.1	-
Power gain (dBd)	-4	-2.1	-5.6	-2.6	-6.9	-3	-5.3

4.2.2 915-MHz Radiation Pattern

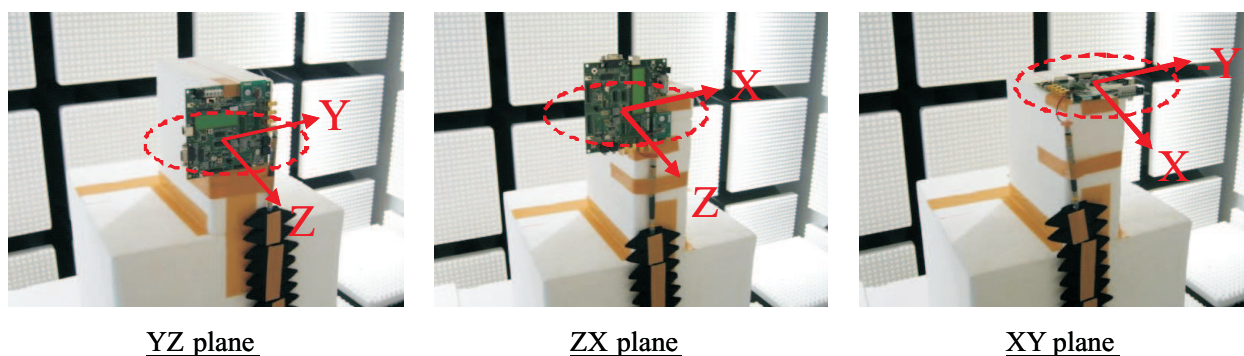


Figure 16. How to Relate the Antenna to the Radiation Patterns

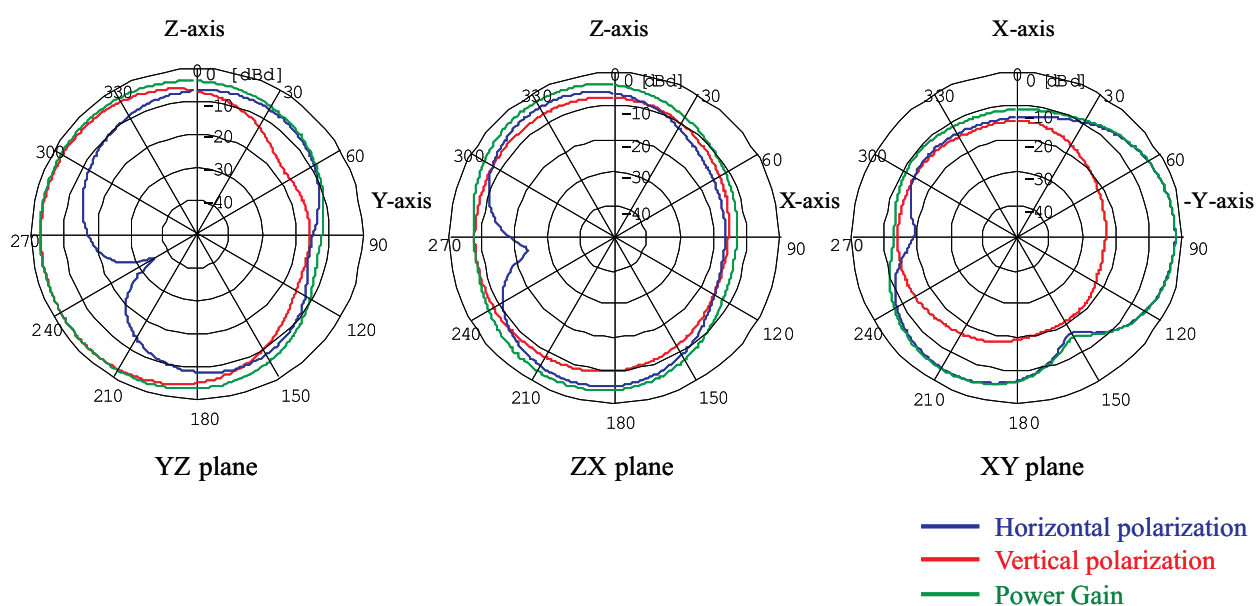


Figure 17. 915-MHz Radiation Pattern

Table 5. 915-MHz Gain in Each Measurement Plane

POLORIZATION	YZ PLANE		ZX PLANE		XY PLANE		3 PLANE TOTAL
	AVE	MAX	AVE	MAX	AVE	MAX	
Vertical pol. (dBd)	-5.6	-2.4	-9.2	-6.7	-16.5	-13.6	-
Horizontal pol. (dBd)	-9.9	-6.2	-8.3	-4.4	-7.3	-2.6	-
Power gain (dBd)	-4.2	-2.3	-5.7	-2.4	-6.8	-2.5	-5.4

5 Conclusion

AMD1103-ST01 antenna presented in this document performs well in the 868-MHz and 915-MHz ISM band. [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](#).

Table 6. Summary of the Antenna Properties

868-MHz BW (VSWR \leq 3)	44 MHz
915-MHz BW (VSWR \leq 3)	48 MHz
868-MHz 3 plane total average power gain	-5.3 dBd
915-MHz 3 plane total average power gain	-5.4 dBd
Antenna size	10.5 mm x 3 mm x 0.8 mm

Conversion to dBi:

$$dBi = dBd + 2.14$$

(1)

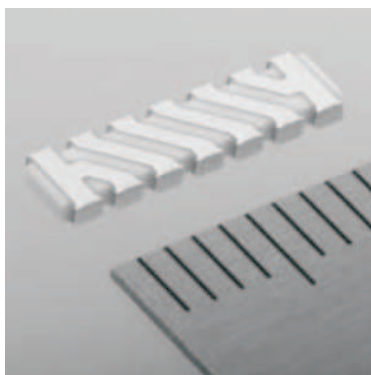
6 Reference

1. CC1101-Q1 Data Manual ([SWRS076](#))
2. CC1101 Development Kit 868 - 915 MHz ([SWRU040](#))
3. Product information: http://www.mmc.co.jp/adv/dev/english/index_e.html
4. Contact information: <http://www.mmea.com/>
 - Japan: www.mmc.co.jp/adv/dev/ devsales@mmc.co.jp
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7 Appendix



SURFACE MOUNTABLE DIELECTRIC CHIP ANTENNAS AMD SERIES



AMD1103-ST01

Surface mountable dielectric chip antennas AMD series are result of harmonizing our long experience in ceramic material and process technologies for high frequency applications together with cutting-edge RF design technologies. It is very small with low profile, but has a wide range of frequency band. It is suitable for compact mobile equipment and communication modules.

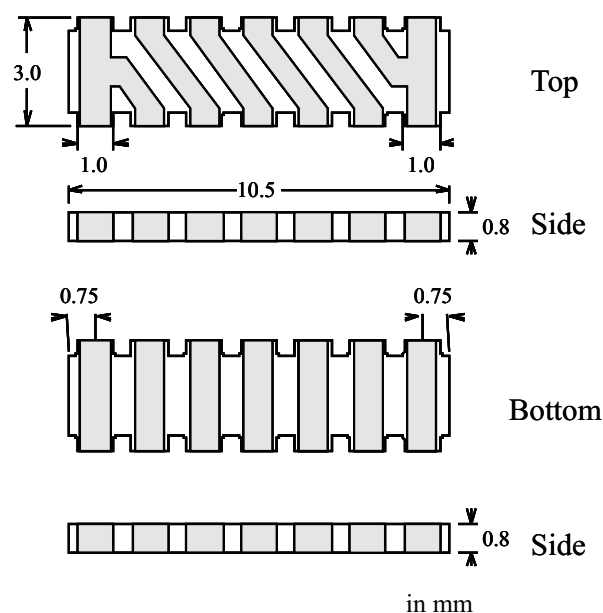
7.1 Features

- Very Small
- High Gain
- Omni-Directional
- With an External Tuning Circuit, the Adjustment to an Application Frequency Range is Possible
- AMD1103-ST01: 400 MHz ~ 1000 MHz

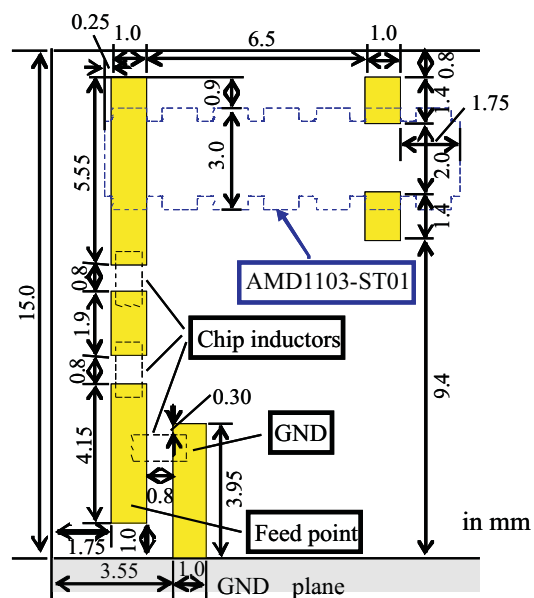
7.2 Applications

- Telemeter (Industrial and Medical Use)
- Telemetry
- Telecontroller
- Data Communication
- Keyless Entry System
- Immobilizer System
- Car security System
- Voice Communication Terminal

7.3 Dimensions



7.4 Recommended Land Pattern (Reference)



Chip inductor with 1608 size

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