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.

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.

![Antenna Dimensions Diagram]

**Figure 3. Antenna Dimensions**

<table>
<thead>
<tr>
<th>L1</th>
<th>L2</th>
<th>L3</th>
<th>L4</th>
<th>L5</th>
<th>L6</th>
</tr>
</thead>
<tbody>
<tr>
<td>39 mm</td>
<td>30 mm</td>
<td>4.75 mm</td>
<td>9 mm</td>
<td>10.5 mm</td>
<td>3 mm</td>
</tr>
</tbody>
</table>

*Table 1. Antenna Dimensions*

*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.
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.

![Recommended matching network](image)

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.

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 7. Relation Between CC1101-Q1 EM and Recommended Matching Circuit
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 mcartRF04 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

![Graph showing VSWR characteristics for 868 MHz.]

Table 2. 868-MHz VSWR Characteristics

<table>
<thead>
<tr>
<th>$f_0$</th>
<th>VSWR</th>
<th>BW (VSWR ≤ 2)</th>
<th>BW (VSWR ≤ 3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>868 MHz</td>
<td>1.44</td>
<td>25 MHz (853 ~ 878 MHz)</td>
<td>44 MHz (844 ~ 888 MHz)</td>
</tr>
</tbody>
</table>

Figure 12. 868-MHz VSWR Characteristics

Chip inductor for tuning: high Q type

L1 = 10nH, L2 = 22nH, L3 = 5.8nH

4.1.2 915-MHz Bandwidth

![Graph showing VSWR characteristics for 915 MHz.]

Table 3. 915-MHz VSWR Characteristics

<table>
<thead>
<tr>
<th>$f_0$</th>
<th>VSWR</th>
<th>BW (VSWR ≤ 2)</th>
<th>BW (VSWR ≤ 3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>915 MHz</td>
<td>1.55</td>
<td>24 MHz (904 ~ 928 MHz)</td>
<td>48 MHz (893 ~ 941 MHz)</td>
</tr>
</tbody>
</table>

Figure 13. 915-MHz VSWR Characteristics

Chip inductor for tuning: high Q type

L1 = 4.7nH, L2 = 22nH, L3 = 5.8nH
4.2 Radiation Pattern

4.2.1 868-MHz Radiation Pattern

![Antenna and Radiation Patterns](image)

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

![Graphs of Radiation Patterns](image)

**Figure 15. 868-MHz Radiation Pattern**

### Table 4. 868-MHz Gain in Each Measurement Plane

<table>
<thead>
<tr>
<th>POLARIZATION</th>
<th>YZ PLANE</th>
<th></th>
<th>ZX PLANE</th>
<th></th>
<th>XY PLANE</th>
<th></th>
<th>3 PLANE TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AVE</td>
<td>MAX</td>
<td>AVE</td>
<td>MAX</td>
<td>AVE</td>
<td>MAX</td>
<td></td>
</tr>
<tr>
<td>Vertical pol. (dBd)</td>
<td>-5.1</td>
<td>-2.3</td>
<td>-8.9</td>
<td>-6.7</td>
<td>-16.4</td>
<td>-13.8</td>
<td></td>
</tr>
<tr>
<td>Horizontal pol. (dBd)</td>
<td>-10.2</td>
<td>-6.6</td>
<td>-8.3</td>
<td>-4.6</td>
<td>-7.5</td>
<td>-3.1</td>
<td></td>
</tr>
<tr>
<td>Power gain (dBd)</td>
<td>-4</td>
<td>-2.1</td>
<td>-5.6</td>
<td>-2.6</td>
<td>-6.9</td>
<td>-3</td>
<td>-5.3</td>
</tr>
</tbody>
</table>
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

<table>
<thead>
<tr>
<th>POLARIZATION</th>
<th>YZ PLANE</th>
<th>ZX PLANE</th>
<th>XY PLANE</th>
<th>3 PLANE TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AVE</td>
<td>MAX</td>
<td>AVE</td>
<td>MAX</td>
</tr>
<tr>
<td>Vertical pol.</td>
<td>–5.6</td>
<td>–2.4</td>
<td>–9.2</td>
<td>–6.7</td>
</tr>
<tr>
<td>Horizontal pol.</td>
<td>–9.9</td>
<td>–6.2</td>
<td>–8.3</td>
<td>–4.4</td>
</tr>
<tr>
<td>Power gain</td>
<td>–4.2</td>
<td>–2.3</td>
<td>–5.7</td>
<td>–2.4</td>
</tr>
</tbody>
</table>
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 dBi and the formula converting it to dBi is shown in Equation 1.

Table 6. Summary of the Antenna Properties

<table>
<thead>
<tr>
<th></th>
<th>868-MHz BW (VSWR ≤ 3)</th>
<th>915-MHz BW (VSWR ≤ 3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>868-MHz 3 plane total average power gain</td>
<td>44 MHz</td>
<td>48 MHz</td>
</tr>
<tr>
<td>915-MHz 3 plane total average power gain</td>
<td>-5.3 dBi</td>
<td>-5.4 dBi</td>
</tr>
<tr>
<td>Antenna size</td>
<td>10.5 mm x 3 mm x 0.8 mm</td>
<td></td>
</tr>
</tbody>
</table>

Conversion to dBi:

\[ dBi = dBd + 2.14 \] (1)

6 Reference

1. CC1101-Q1 Data Manual (SWRS076)
2. CC1101 Development Kit 868 - 915 MHz (SWRU040)
4. Contact information: http://www.mmea.com/
   • Japan: www.mmc.co.jp/adv/dev/ devsales@mmc.co.jp
   • U.S.A. and Europe: www.mmea.com sales@mmea.com
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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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