Introduction
This application note describes an example of the design of a pattern antenna and its characteristics when connected with the RL78/G1D.

Target Device
RL78/G1D (R5F11A)

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1. **Overview**

This application note describes an example of the design of a pattern antenna.

1.1 **Related Documents**

- RL78/G1D Guidelines for RF Board Design (R01AN2465E)
- RL78/G1D User’s Manual: Hardware (R01UH0515E)
2. Configuration of a Reference Antenna

The antenna is a pattern antenna formed on the RL78/G1D evaluation board. Figure 1 consists of photographs of the evaluation board on which the antenna is formed. The antenna is formed as a meandering land pattern on the board, and is connected to a feeder with an impedance of 50 Ω. The land pattern connects the feeder of the antenna with the adjacent GND on the evaluation board. Mounting a 1005 (1-mm long) component in series between the feeder and the GND on the land allows adjustment of the resonance frequency and impedance of the antenna and gives the antenna a wide adjustable range.

Caution To mount the adjusting component, cut the part of the feeder between the land for the ground and for the antenna beforehand.

Figure 1 Appearance of the Evaluation Board on which the Reference Antenna is Formed

2.1 Antenna Layout

Figure 2 shows layouts of the patterns formed for the antenna in each layer of the evaluation board. The evaluation board has four layers: L1, L2, L3, and L4. The 33 mm × 7 mm area in which the pattern antenna is formed in each layer includes no other pattern. The body of the antenna is formed in layers L1 and L4. The pattern in L1 is connected to the pin for antenna connection (50 Ω). Multiple via holes connect the pattern in L4 to that in L1.

Figure 2 Pattern Layouts in Each Layer of the Evaluation Board
Figure 3 shows dimensions of the antenna.

(a) Dimensions of the Pattern Antenna (in L1)

(b) Dimensions of the Pattern Antenna (in L4)

(c) Locations of Via Holes

* Dimensions are design values.
The resonance frequency and impedance of the antenna differ with elements of its surrounding environment, including the size and shape of the board to which the antenna is connected, the wiring patterns on the board, and the housing of the board. Changes to any of these factors require adjustment of the antenna. To start with, adjusting the length of the antenna is more effective than using an adjusting component such as a capacitor or inductor.

To attain the target frequency for the product you are developing, we recommend the following procedure.

1. Lower the resonance frequency of the antenna by lengthening it relative to the dimensions shown in figure 3.
   
   **Caution** In lengthening the antenna, repeat the meandering section of the pattern in L1 and L4 so that the wiring in each has the same length.

2. Shorten the antenna while confirming that the resonance frequency is still approaching the target value.
   
   **Caution** Shorten the patterns for the antenna in L1 and L4 from the end of the meandering pattern so that the wiring in each layer has the same length.

### 2.2 Layer Configuration of the Printed Circuit Board

The layer configuration of the printed circuit board including the antenna and chip-evaluation sections is given below.

- **Board configuration**
  - Four wiring layers

<table>
<thead>
<tr>
<th>Configuration</th>
<th>Thickness (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resist</td>
<td>0.030</td>
</tr>
<tr>
<td>Cu (L1)</td>
<td>0.030</td>
</tr>
<tr>
<td>PP</td>
<td>0.030</td>
</tr>
<tr>
<td>Cu (L2)</td>
<td>0.035</td>
</tr>
<tr>
<td>Core material</td>
<td>0.043</td>
</tr>
<tr>
<td>Cu (L3)</td>
<td>0.035</td>
</tr>
<tr>
<td>PP</td>
<td>0.043</td>
</tr>
<tr>
<td>Cu (L4)</td>
<td>0.035</td>
</tr>
<tr>
<td>Resist</td>
<td>0.043</td>
</tr>
</tbody>
</table>

* Dimensions are design values.

Figure 4 shows the layer configuration and thicknesses of each layer.
3. **Antenna Characteristics**

This section describes the voltage standing wave ratio (VSWR) and emission characteristics of the antenna.

In the measurements, a 1.8-pF capacitor (1005-sized package) is mounted as the adjusting component (A in the figure below) on the evaluation board, and is semi-rigidly attached to the feeder.

![Top View](image)

* The figure is of the board with no components mounted.
* The antenna has the same dimension as that in figure 3.

**Figure 5 Position for Mounting the Adjusting Component**
3.1 VSWR

The results for measurement of the VSWR are given in figure 6. The measurements were made by using a network analyzer in a shield room.

The antenna satisfies $VSWR \leq 2$ over a bandwidth of 115 MHz, including the band from 2400 MHz to 2484 MHz stipulated in the Bluetooth v. 4.1 specification (the section on low-energy single mode).

![Figure 6 VSWR of the Reference Antenna](image-url)
### 3.2 Emission Characteristics

Figure 7 shows the coordinate axes, the positions where rotation starts (0°), and the directions of rotation. The coordinate axes are defined on the basis of the top view of the evaluation board as shown in figure 7(a). The positions where rotation starts (0°) and its directions in obtaining the emission patterns in each plane are defined as shown in figure 7(b).

![Top View](image)

**Figure 7** Coordinate Axes and Directions of Rotation for Obtaining the Emission Patterns

Table 1 shows the emission patterns and average gains measured with the antennas separated by 3 m from each other in a six-surface radio-wave-dark room. The measurements were made in three planes: XY, XZ, and YZ.

#### Table 1 Emission Patterns of the Reference Antenna and Average Gains

<table>
<thead>
<tr>
<th>Item</th>
<th>XY Plane (Horizontally Polarized Wave)</th>
<th>XZ Plane (Vertically Polarized Wave)</th>
<th>YZ Plane (Horizontally Polarized Wave)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emission patterns of the reference antenna</td>
<td><img src="image" alt="XY_2440 MHz" /></td>
<td><img src="image" alt="XZ_2440 MHz" /></td>
<td><img src="image" alt="YZ_2440 MHz" /></td>
</tr>
<tr>
<td>Average gain</td>
<td>-2.30 dBi</td>
<td>-1.79 dBi</td>
<td>-2.30 dBi</td>
</tr>
</tbody>
</table>

**Caution** The values of the adjusting component and for the antenna characteristics in this application note are for reference. They are not guaranteed values. Since the characteristics will differ with the conditions of mounting and the surrounding environment, make the required adjustments for the needs of your actual application.
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## Revision Record

**RL78/G1D Application Note**

<table>
<thead>
<tr>
<th>Rev.</th>
<th>Date</th>
<th>Description</th>
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<tr>
<td>0.90</td>
<td>Mar 19, 2015</td>
<td>— First edition issued</td>
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