Wi-Fi/Bluetooth PCB Antenna (On/Off Ground) 1001013
2400-2485 MHz

Applications:
- Embedded Design
- Cellular
- Headsets
- Tablets
- Gateway
- Access Point
- Handheld
- Telematics
- Tracking
- Healthcare
- M2M
- Industrial devices
- Smart Grid
- OBD-II
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**Purpose**
This document provides information for incorporating Ethertronics’ standard embedded Wi-Fi/BT PCB antenna into wireless products. Specifications, design recommendations, board layout, packaging and manufacturing recommendations are included.

**Overview**

**Product Selection Guide**

<table>
<thead>
<tr>
<th>Feature</th>
<th>Advantage</th>
<th>Benefits</th>
<th>Typical Deliverable Size</th>
</tr>
</thead>
</table>
| 1001013   | • 2400-2485 MHz                                     | • Capable for Off-Ground and On-Ground (over metal) environments.  
• 2.45GHz  
• Small dimension and High Performance  
• Flexible antenna placement | • SMT mountable antenna assembly  
• 15.0 x 3.2 x 3.3 mm |
| 1001013-02 | • Demo board tuned for Bluetooth/Wifi application  | • Off ground with 5.70mm ground clearance  | • 72 x 50 mm PCB with SMA connector |

**Difference between On Ground and off Ground application**

Across this document, the terms “Off-Ground” and “On-Ground” will be mentioned. The Off-Ground designation is referring to an antenna layout that as all the metal removed from the different PCB layers (or even on the device stack up) under the antenna. Most on board antennas will be designed with this requirement as it is the preferred layout for optimum antenna performances. The On-Ground designation means that the antenna layout maintain ground under the antenna. It might be a ground layers on the PCB, or any other metallic element placed under the antenna area on the PCB.
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**Wi-Fi/Bluetooth PCB Embedded Antenna Features and Benefits Summary**

<table>
<thead>
<tr>
<th>Features</th>
<th>Advantages</th>
</tr>
</thead>
</table>
| PCB Embedded structure with Small Form Factor & Ground clearance Requirements | • Flexibility in antenna placement  
• Robust 3.2mm thickness PCB material  
• Ability to source antenna only for direct placement on customer PCB |
| High Performance Embedded Solution | • Greater than 70% average efficiency cross all bands for off-Ground solution  
• Greater than 45% average efficiency cross all bands for On-Ground solution |
| Off Ground and On Ground solutions | • Enables flexibility in antenna placement within end device  
• Can be used within Tracking, Handhelds, Automotive, and Wearable Devices. |
| Extensive Design Collateral and apps support | • Speeds development time |
| Standard “Off the Shelf” Product | • Speeds development time and reduces costs since reduces NRE and custom development time |
| Cost Effective & Rugged Design | • SMT, Pick and Place, Tape & Reel Packaging, Enable lower manufacturing costs. |

Additional antennas are under development, please see Ethertronics’ Website, or ask your Ethertronics sales person about additional products to meet your needs.

**Design Guidelines**

**Introduction**

The Standard Wi-Fi/BT PCB embedded antennas can be designed into many wireless product types. The following sections explain Ethertronics’ recommended layouts to help the designer integrate the 1001013 antenna element into a product with optimum performances.

**Electrical Specifications**

Typical Characteristics Measurements taken using the standard matching circuit on a 72 x 50 mm ground plane.

<table>
<thead>
<tr>
<th>Frequency (GHz)</th>
<th>2400 – 2485 MHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mounting</td>
<td>Off Ground</td>
</tr>
<tr>
<td>VSWR Match</td>
<td>1.5:1 max</td>
</tr>
<tr>
<td>Average Efficiency</td>
<td>76%</td>
</tr>
<tr>
<td>Peak Gain</td>
<td>2.6 dBi</td>
</tr>
<tr>
<td>Feed Point Impedance</td>
<td>50 ohms unbalanced</td>
</tr>
<tr>
<td>Polarization</td>
<td>Linear</td>
</tr>
<tr>
<td>Power Handling</td>
<td>0.5 Watt CW</td>
</tr>
</tbody>
</table>

**Mechanical Specifications**

<table>
<thead>
<tr>
<th>Ordering Part Number</th>
<th>1001013</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size (mm)</td>
<td>15.0 x 3.2 x 3.3</td>
</tr>
<tr>
<td>Mounting</td>
<td>Surface mounted to the PCB</td>
</tr>
<tr>
<td>Weight (grams)</td>
<td>0.2</td>
</tr>
<tr>
<td>Packaging</td>
<td>Tape &amp; Reel</td>
</tr>
<tr>
<td>Demo Board</td>
<td>1001013-02</td>
</tr>
</tbody>
</table>
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Antenna Dimension and Pad Layout
Figure 1 below shows the Antenna Dimensions and Pad Layout for 1001013

Antenna Dimensions
Typical antenna dimensions (mm)

<table>
<thead>
<tr>
<th>Features</th>
<th>A (mm)</th>
<th>B (mm)</th>
<th>C (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1001013</td>
<td>15.0 ± 0.3</td>
<td>3.2 ± 0.2</td>
<td>3.3 ± 0.3</td>
</tr>
</tbody>
</table>

Figure 1: Antenna Dimensions and Pad Layout for 1001013

Antenna Footprint Layout
Figure 2 below shows the GPS PCB Antenna Layout for 1001013-02 Off-Ground
Figure 3 below shows the GPS PCB Antenna Layout for 1001013-01 On-Ground
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Figure 2 below shows the GPS PCB Antenna Layout for 1001013-02 (Off-Ground)

Pin Descriptions

<table>
<thead>
<tr>
<th>Pin#</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Feed</td>
</tr>
<tr>
<td>2</td>
<td>Dummy Pad</td>
</tr>
<tr>
<td>3</td>
<td>Dummy Pad</td>
</tr>
<tr>
<td>4</td>
<td>Dummy Pad</td>
</tr>
</tbody>
</table>

Pin Descriptions

<table>
<thead>
<tr>
<th>Component</th>
<th>Value</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>DNI</td>
<td>N/A</td>
</tr>
<tr>
<td>S1</td>
<td>0Ω</td>
<td>N/A</td>
</tr>
<tr>
<td>P2</td>
<td>0.4pF</td>
<td>±0.25pF</td>
</tr>
<tr>
<td>P3</td>
<td>0Ω</td>
<td>N/A</td>
</tr>
</tbody>
</table>

*Actual matching values depend on customer design

* VIAS: Diam. 0.2mm, (no vias on transmission lines).
Via holes must be covered by solder mask

Figure 2: Antenna Layout for 1001013-02 (Off-Ground)
Figure 3 below shows the GNSS PCB Antenna Layout for 1001013-01 (On-Ground)

<table>
<thead>
<tr>
<th>Pin#</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Feed</td>
</tr>
<tr>
<td>2</td>
<td>Dummy Pad</td>
</tr>
<tr>
<td>3</td>
<td>Dummy Pad</td>
</tr>
<tr>
<td>4</td>
<td>Dummy Pad</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Component</th>
<th>Value</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>2.4pF</td>
<td>±0.1pF</td>
</tr>
<tr>
<td>S1</td>
<td>0Ω</td>
<td>N/A</td>
</tr>
<tr>
<td>P2</td>
<td>DNI</td>
<td>N/A</td>
</tr>
<tr>
<td>P3</td>
<td>0Ω</td>
<td>N/A</td>
</tr>
</tbody>
</table>

*Actual matching values depend on customer design*

Figure 3: Antenna Layout for 1001013-01 (On-Ground)
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**Typical Measured Data**

**VSWR, Efficiency and Radiation Pattern**

Below are the typical performances using Ethertronics standard 50x70mm PCB board and tuning specified above.

Figure 4 below shows the 2.4GHz PCB Antenna Typical Performance for 1001013-02 (Off-Ground)

Figure 5 below shows the 2.4GHz PCB Antenna Typical Performance for 1001013-01 (On-Ground)
Antenna Placement Guidelines on PCB
The 1001013 antenna can be mounted onto any PCB using Ethertronics’ recommended footprint layout and ground layout with proper PCB size. For the purposes of the Design Guidelines section, the standard Ethertronics demo board 1001013-02 has been used. It reflects the standard sized PCB in most common end device.

Figure 6 shows below the optimal placement of the antenna on a PCB following the guidelines below:

- The antenna should always be placed along the edge of the board unless there are special conditions preventing it.
- The recommended antenna location is at the right side of the long edge with a certain distance “B” (recommend 5mm ≤ B ≤ 15mm) from the feed point to the edge of PCB. Ethertronics demo board default location is X=72mm, Y=50mm, B=15mm. The edge where the antenna is located should be greater than 50mm, and more locations will be available based on the conditions below:
  - X ≥ 50mm, Y < 50mm
    - only one location available (Location1). It can be increased to two if the reverse antenna is placed on the opposite edge.
  - X ≥ 50mm, Y ≥ 50mm
    - Four locations available (Location1/Location2/Location3/Location4). It can be increased to eight if the reverse antennas are placed on the two other edges.
Antenna Placement Guidelines on PCB (continued)

Antenna Tuning Guidelines

In real application environment, variation of the antenna resonating frequency may be caused by a the following effects: different antenna locations, PCB board variations, components and shield cans located close to the antenna, and outside cover…

To solve the above effects, there are four methods can be applied:

- Tuning through the matching network
- Tuning the antenna ground clearance
- Changing the antenna location

Tuning through the matching network

Performance can be improved by tuning the matching circuit. In general, adjusting the value of the matching components allow to control resonance shifting slightly and optimize the impedance within the required bands. Optimum matching values may vary with different boards transmission line design and antenna working environments. The following pages show the return loss and efficiency variation when using different matching value.

All the tests below are Based on 72 x 50 mm demo board. Antenna performance is detuned when changing the antenna ground clearance, the study below shows how to using matching tuning to optimize antenna performance.

Figure 7 below is matching tuning demonstrations for 1001013
Tuning the antenna ground clearance

Ground clearance is one of the most critical factors for antenna performance. Up to 2dB difference can be observed from antenna off ground to on ground condition. Increasing the ground clearance will result in wider antenna frequency bandwidth and higher efficiency data.

Figure 8 below illustrates the ground clearance changes options for 1001013.
Changing the antenna location

The antenna performances will be impacted by the antenna location even same. Based on a 70mm x 50mm PCB, we considered 5 different locations:

- Location 1: right side of the long edge - which performs the best
- Location 2: center of the long edge
- Location 3: center of the short edge
- Location 4: left side of the long edge

Figure 9 below is 1001013 antenna on different board locations

![Antenna Tuning Guidelines (continued)](image)
More Examples

1001013 tested performance with vary PCB sizes and vary antenna locations

<table>
<thead>
<tr>
<th>PCB Size (mm)</th>
<th>1001013 Antenna Location</th>
<th>Average Efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50x50</td>
<td>center of edge</td>
<td>73</td>
</tr>
<tr>
<td>100x50</td>
<td>center of long edge</td>
<td>73</td>
</tr>
<tr>
<td>100x50</td>
<td>center of short edge</td>
<td>65</td>
</tr>
<tr>
<td>100x100</td>
<td>right side of edge</td>
<td>60</td>
</tr>
<tr>
<td>100x200</td>
<td>right side of long edge</td>
<td>65</td>
</tr>
<tr>
<td>100x200</td>
<td>right side of short edge</td>
<td>63</td>
</tr>
</tbody>
</table>

MIMO Application Examples

Figure 11 below shows typical MIMO configurations where two 1001013 antennas located:

Material Specifications

<table>
<thead>
<tr>
<th>Item</th>
<th>Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antenna Substrate</td>
<td>FR4</td>
</tr>
<tr>
<td>Contact Finish</td>
<td>Hot Air Solder Level (HASL) or Au</td>
</tr>
</tbody>
</table>
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Manufacturing and Assembly Guidelines
Ethertronics' antennas are designed for high volume board assembly. Because different product designs use different numbers and types of devices, solder paste, and circuit boards, no single manufacturing process is best for all PCBs. The following recommendations have been determined by Ethertronics, based on successful manufacturing processes.

These antennas are designed for automated pick and place surface mounting. However, as with any SMT device, Ethertronics antennas can be damaged by the use of excessive force during the handling or mounting operation.

Component Handling Recommendations
The following are some recommendations for component handling and automated mounting:

- Ethertronics Standard 1001013 antennas ship in tape and reel.

Ethertronics’ antennas are not moisture sensitive and the ceramic antennas meet the requirements for a Level 1 classification of J-STD-020A (moisture/reflow sensitivity classification for non-hermetic solid state surface mount devices from the Institute for Interconnecting and Packaging Electronic Circuits). Nevertheless, as a precaution to maintain the highest level of solderability, Ethertronics antennas are dry-packed.

Paste Stencil Recommendation
Ethertronics recommends application of paste stencil to a thickness of 0.1mm, applied to within 0.125 mm of the solder mask surrounding each exposed metal pad on the PCB. PCB layouts for each antenna are provided in earlier section of this document.

Soldering Recommendations
The recommended method for soldering the antenna to the board is forced convection reflow soldering. The following suggestions provide information on how to optimize the reflow process for the antenna:

- Adjust the reflow duration to create good solder joints without raising the antenna temperature beyond the allowed maximum of 260°C

Additional Manufacturing Recommendations
Care should be taken during certain customer-specific manufacturing processes including PCB separation and Ultrasonic Welding to ensure these processes don’t create damage to the components.

Cleaning Recommendations
After the soldering process, a simple wash with de-ionized water sufficiently removes most residues from the PCB. Most board assembly manufacturers use either water-soluble fluxes with water wash, or “no clean” fluxes that do not require cleaning after reflow.

Acceptable cleaning solvents are CFC alternatives, Isotropy Alcohol (IPA), and water. If the application uses other types of solvents, please consult with Ethertronics.

Cleaning processes that should be avoided are ultrasonic cleaning and any abrasive techniques, such as scrubbing with a cotton swab or with an abrasive material.
Rework & Removal Recommendations

There may be a need to rework or remove the antenna from the PCB. Although Ethertronics’ antennas are designed for ease-of-use, use care when separating them from the PCBs. Careless heating or removal of the antenna can cause thermal, mechanical or lead damage. These degradations may render the antenna useless, impeding any failure analysis and preventing the reuse of the device. Therefore it is recommended to observe the following precautions:

- The component can be reworked and soldered by hand using a soldering iron. However care should be used so the temperature does not exceed 260°. The soldering iron should not touch the composite material while soldering the leads of the antenna.
- The component can be reworked and soldered using a hot air rework station. However, care should be taken to ensure that the temperature does not exceed 260° C.
- Once the solder on the PCB is sufficiently heated, use a vacuum pen to lift the antenna straight up off the PCB. Avoid twisting or rotating the device while removing it.

Tape & Reel Specifications

Product will be shipped in Tape and Reel packaging