Figure 7. Return Loss

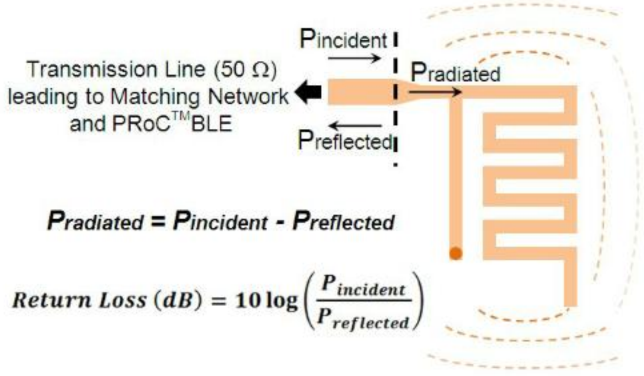
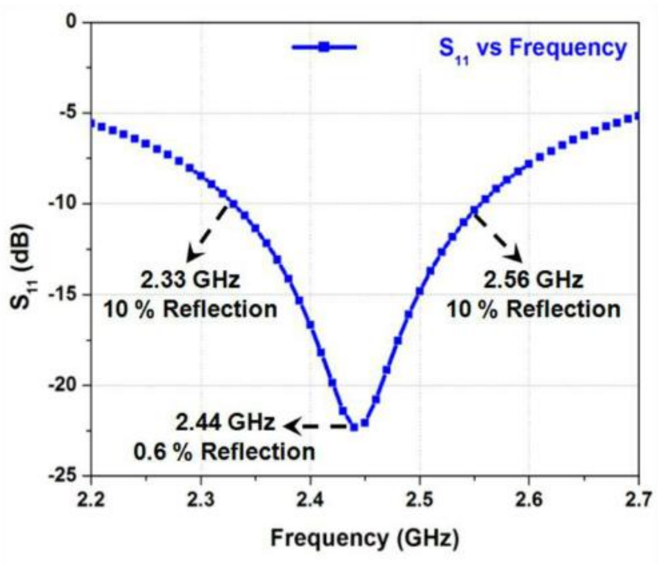


Table 1. Return Loss and Power Reflected from Antenna

S_{11} (dB)	Return Loss (dB)	$P_{reflected}$ / $P_{incident}$ (%)	$P_{radiated}$ / $P_{incident}$ (%)
–20	20	1	99
–10	10	10	90
–3	3	50	50
–1	1	79	21

- **Bandwidth**: Bandwidth indicates the frequency response of an antenna. It signifies how well the antenna is matched to the 50-Ω transmission line over the entire band of interest, that is, between 2.40 GHz and 2.48 GHz for BLE applications.

Figure 8. Bandwidth

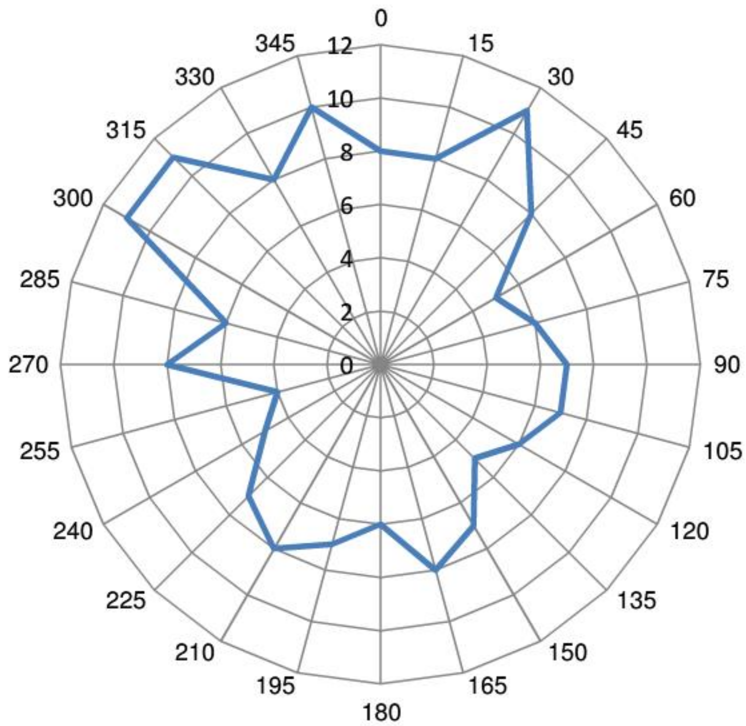


As Figure 8 shows, the return loss is greater than 10 dB from 2.33 GHz to 2.55 GHz. Therefore, the bandwidth of interest is around 200 MHz.

- **Radiation efficiency**: A portion of the non-reflected power (see Figure 7) gets dissipated as heat or as thermal loss in the antenna. Thermal loss is due to the dielectric loss in the FR4 substrate and the conductor loss in the copper trace. This information is characterized as radiation efficiency. A radiation efficiency of 100 percent indicates that all non-reflected power is radiated to free space. For a small-form-factor PCB, the heat loss is minimal.
- **Radiation pattern**: Radiation pattern indicates the directional property of radiation, that is, which directions have more radiation and which have less. This information helps to orient the antenna properly in an application.

An isotropic dipole antenna radiates equally in all directions in the plane perpendicular to the antenna axis. However, most antennas deviate from this ideal behavior. See the radiation pattern of a PCB antenna shown in Figure 9 as an illustration. Each data point represents RF field strength, measured by the received signal strength indicator (RSSI) in the receiver. As expected, the contours are not exactly circle, as the antenna is not isotropic.

Figure 9. Radiation Pattern



- **Gain**: Gain indicates the radiation in the direction of interest compared to the isotropic antenna, which radiates uniformly in all directions. This is expressed in terms of dBi—how strong the radiation field is compared to an ideal isotropic antenna.

6 Antennas for Cypress PRoC/PSoC BLE

One of the product objective for Cypress BLE is to have an antenna design within the tight area that requires no more than two external components for tuning. Tuning is the process that ensures that near-maximum power is sent to the antenna while transmitting over the working band of frequencies. This is ensured by making the return loss in the band of interest greater than 10 dB. When the impedance seen looking into the antenna and the chip output impedance are the same, maximum power is transferred to the antenna; the same rule holds true for receiving too. Antenna tuning ensures that the antenna impedance is matched to 50 Ω looking towards the antenna. Radio tuning ensures that the impedance looks 50 Ω, looking towards the chip, when the chip is in the receive mode.

The integrated balun inside PRoC/PSoC BLE is not exactly 50-Ω impedance and may require two components for tuning. For a low-data-rate and low-RF-range application, the PCB antenna Cypress recommends does not require any component for antenna tuning.

For high-data-rate applications like voice recognition over remote control, at least four components for the matching network are recommended. Two of these will be used for radio tuning and two will be used for antenna tuning. It may be possible to do the tuning with two components if the resulting bandwidth is acceptable. Having an [6]extra component footprint is a wise design choice for future mitigation of [7]EMI radiation in a new product. Filters can be implemented for out-of-band operation using those components.

Cypress PRoC/PSoC devices can also be employed in applications such as indoor positioning, smart home, smart appliances, and sensor hub. Because these applications may not have space constraints, you can employ an antenna with a better RF range and radiation pattern. The wire antenna can be a perfect fit for such an application where the ID (Industrial Design) can have some height to fit a wire.

In some application like wearable ultra small form factor is required. The chip antenna usually takes less space compared to a PCB antenna, The chip antenna is more popular in this application category. Cypress recommends a few guideline for using the ultracompact chip antennas.

There are many applications that directly embed a Cypress module in the host PCB for wireless connectivity. For such applications, a very-low-cost, FCC-passed, tiny module is desired. Cypress has come up with EZ-BLE module for such application. The Cypress EZ-BLE module uses Johansson chip antenna 2450AT18B100E.

Though there are multiple antennas for the 2.4-GHz band, most BLE applications are catered by two Cypress-Proprietary PCB Antennas. Cypress recommends using two proprietary PCB antennas, meandered inverted-F antenna (MIFA) and inverted-F antenna (IFA), which are characterized and simulated extensively for BLE applications. MIFA in particular is useful to most of the applications.

However, you can choose any antenna described in this document to suit your application requirements.

7 Cypress-Proprietary PCB Antennas

Cypress recommends IFA and MIFA types of PCB antennas. The low data rate and typical range requirement in a BLE application make these antennas extremely useful. These antennas are inexpensive and easy to design, because they are a part of the PCB, and provide good performance in the 150-250 MHz bandwidth range.

MIFA is recommended for applications that require a minimum PCB area such as a wireless mouse and presenter. IFA is recommended for applications where one of the antenna dimensions is required to be much shorter than the other such as a heart-rate monitor. Most BLE applications are catered by MIFA antennas.

7.1 Meandered Inverted-F Antenna (MIFA)

The MIFA is a popular antenna widely used in human interface devices (HIDs) because it occupies a small PCB area. Cypress has designed a robust MIFA that offers an excellent performance with a small form factor. The antenna size is 7.2 mm × 11.1 mm (284 mils × 437 mils), making it suitable for HID applications such as a wireless mouse, keyboard, or presenter. Figure 10 shows the layout details of the recommended MIFA, both top layer and bottom layer in a two-layer PCB. The antenna trace-width is 20 mils throughout. The main parameter that would change, depending on the PCB stack spacing, is the value of "W," the RF trace (transmission line) width.

[6] Extra components before the antenna is a recommended practice that helps in implementing filters for EMI reduction in future.

[7] EMI is electro-magnetic interference regulation that sets limit for radiated power for public health.

Meandered Inverted-F Antenna (MIFA)

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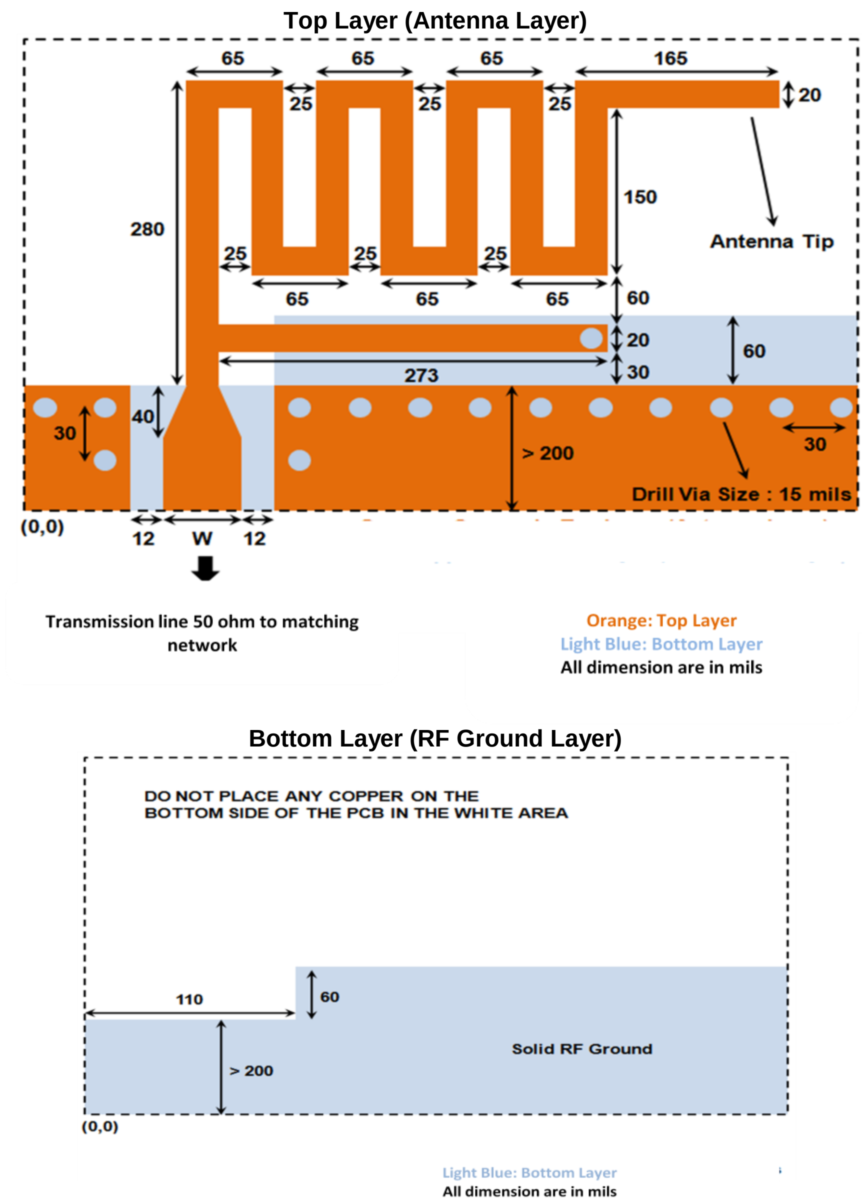
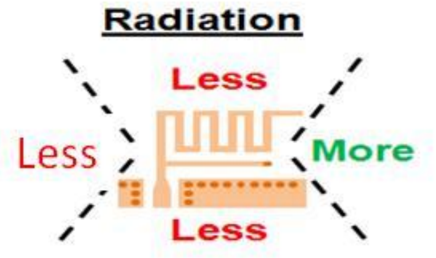
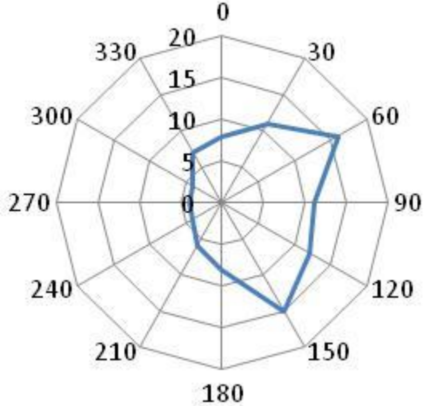
Figure 10. MIFA Layout

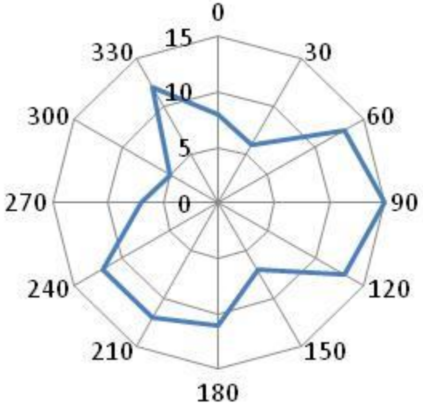




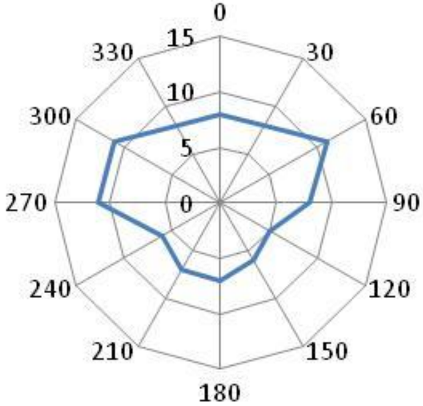
About Z axis



About X axis



About Y axis



The radiation pattern is tested with a 30-degree angular resolution on a Pioneer Board carrying a module with a MIFA antenna. The connecting headers are metals. In a bare board, the radiation pattern is different than what is shown; this is for illustration only to show how to position the antenna in a PCB. You are encouraged to measure similar pattern in your final product assembly to determine the best place for the antenna.

Gain 1.6dBi , PCB antenna , Model No.: 2.4G ANT

Properties at 2.44 GHz	MIFA
Appearance	
Recommended Applications	Less Area (Mouse, Keyboard, Presenter)
Dimensions (mm)	7.2 × 11.1
Dimensions (mils)	284 × 437
Gerber File	Web
Cost (US$)	Minimal
Bandwidth (MHz) ($S_{11} \leq -10$ dB)	230
Gain (dBi)	1.6