Appendix A: FCC Part 1.1307, 1.1310, 2.1091, 2.1093; ISED RSS-102: RF Exposure

According to FCC KDB 447498 D01 General RF Exposure Guidance v06 4.3.1. Standalone SAR test exclusion considerations, unless specifically required by the published RF exposure KDB procedures, standalone 1-g head or body and 10-g extremity SAR evaluation for general population exposure conditions, by measurement or numerical simulation, is not required when the corresponding SAR Exclusion Threshold condition, listed below, is satisfied.

Limits

The 1-g and 10-g SAR test exclusion thresholds for 100 MHz to 6 GHz at test separation distances ≤ 50 mm are determined by:

[(max. power of channel, including tune-up tolerance, mW)/(min. test separation distance, mm)] · [√f(GHz)] ≤ 3.0 for 1-g SAR and ≤ 7.5 for 10-g extremity SAR, where:

- f(GHz) is the RF channel transmit frequency in GHz
- Power and distance are rounded to the nearest mW and mm before the calculation
- The result is rounded to one decimal place for comparison

The test exclusions are applicable only when the minimum test separation distance is ≤ 50 mm and for transmission frequencies between 100 MHz and 6 GHz. When the minimum test separation distance is < 5 mm, a distance of 5 mm is applied to determine SAR test exclusion

EUT RF Exposure

Max peak power value: 6 mW (7.8 dBm)

Tune-Up Tolerances: +15%

Minimum Distance: 5 mm

Frequency in GHz: 2.480

Max Power + Tune up: 6.0 mW X 1.15 = 6.9 mW (rounding to the nearest mW = 7 mW)

General RF Exposure = (7 mW / 5 mm) x √2.480 GHz = 2.24 < 3.0

Therefore, SAR evaluation is not required since the result is below the ≤ 3.0 1 g SAR limit.

ISED:

Per RSS-102 Issue 5 Section 2.5.1, this device is exempt from SAR exposure evaluation if the EIRP is equal to or less than the following:

From Table 1, the limit at 2480 MHz with 5 mm separation distance: 3.92 mW

Antenna gain: 3.3 dBi (2.14 numeric)

Duty cycle: 1.5%

EIRP = 6.0 mW X 1.15 X 0.015 X 2.14 = 0.22 mW

Therefore, the device complies with the exemption limits of RSS-102 Issue 5 Section 2.5.1.

2.4-GHz Inverted F Antenna

ABSTRACT

This document describes a printed-circuit board (PCB) design that can be used with all 2.4-GHz transceivers and transmitters from Texas Instruments™. The maximum gain is measured to be +3.3 dBi, and the overall size requirements for this antenna are 25.7 × 7.5 mm. Thus, this antenna is compact, low cost, and high performance.

Contents

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1 Description of Inverted F Antenna Design

Because the impedance of the inverted F Antenna (IFA) is matched directly to 50 Ω, no external matching components are required.

1.1 Implementation of Inverted F Antenna

It is important to make an exact copy of the antenna dimensions to obtain optimum performance. The easiest approach to implement the antenna in a PCB CAD tool is to import the antenna layout from a gerber file or a DXF file. Such files are included in CC2430DB reference design [1]. The gerber file is called Inverted_F_Antenna.spl and the DXF file is called Inverted_F_Antenna.dxf. If the antenna is implemented on a PCB that is wider than the antenna, avoid placing components or having a ground plane close to the end points of the antenna. If the CAD tool being used does not support importing gerber or DXF files, see Figure 1 and Table 1.

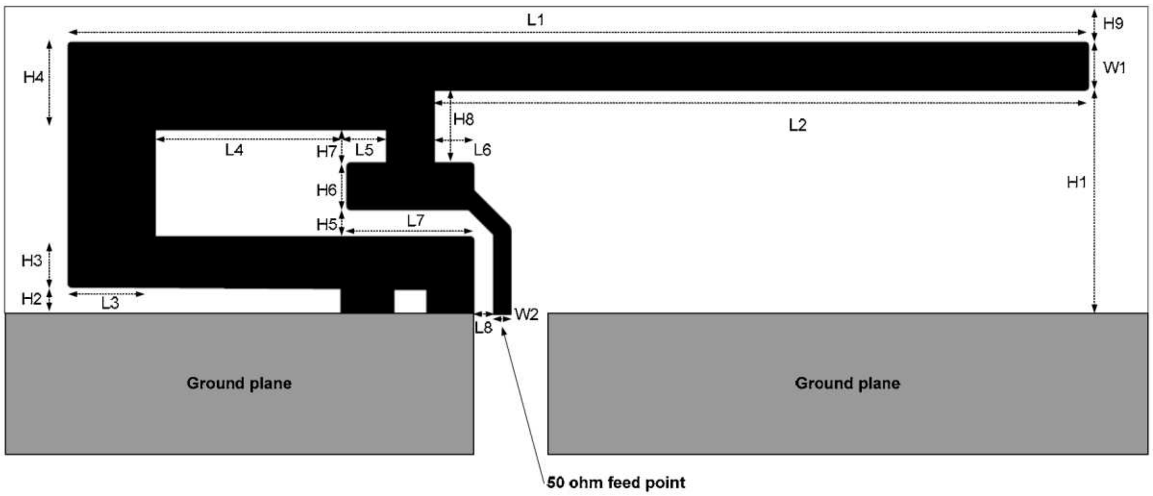

Figure 1. IFA Dimensions

Table 1. IFA Dimensions

H1	5.70 mm	W2	0.46 mm
H2	0.74 mm	L1	25.58 mm
H3	1.29 mm	L2	16.40 mm
H4	2.21 mm	L3	2.18 mm
H5	0.66 mm	L4	4.80 mm
H6	1.21 mm	L5	1.00 mm
H7	0.80 mm	L6	1.00 mm
H8	1.80 mm	L7	3.20 mm
H9	0.61 mm	L8	0.45 mm
W1	1.21 mm		

Because there is no ground plane beneath the antenna, the PCB thickness will have little effect on the performance. The results presented in this document are based on an antenna implemented on a PCB with a 1-mm thickness.

2 Results

All of the results presented in this section are based on measurements performed with CC2430DB [1].

2.1 Radiation Pattern

Figure 2 shows how to relate all of the radiation patterns to the orientation of the antenna. The radiation patterns were measured with the CC2430 device programmed to 0-dBm output power.

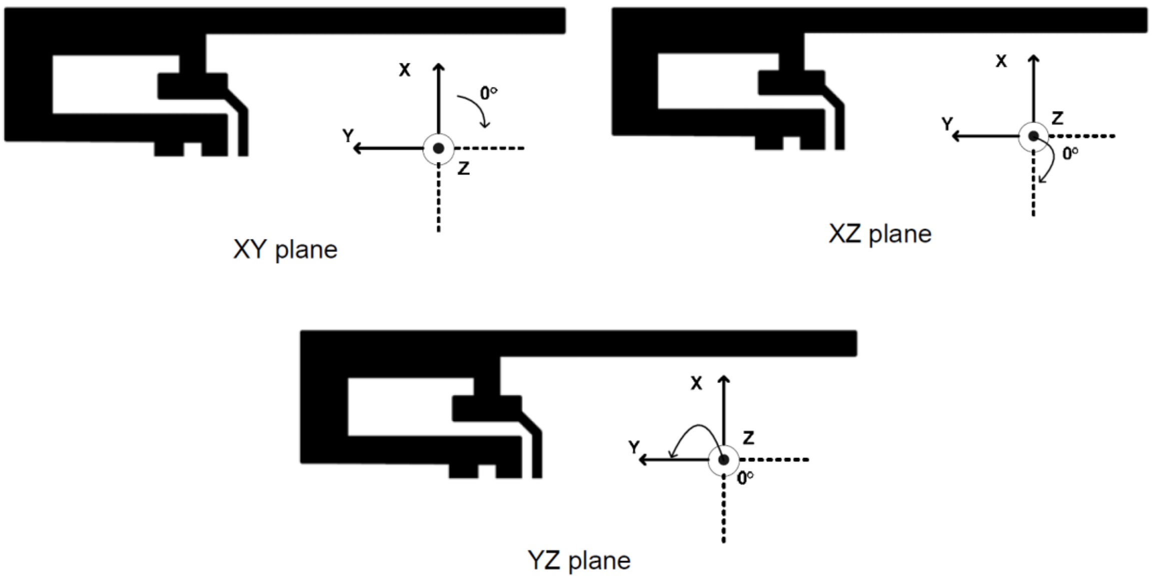

Figure 2. Relating Antenna to Radiation Patterns

Figure 3 shows the XY plane vertical polarization.

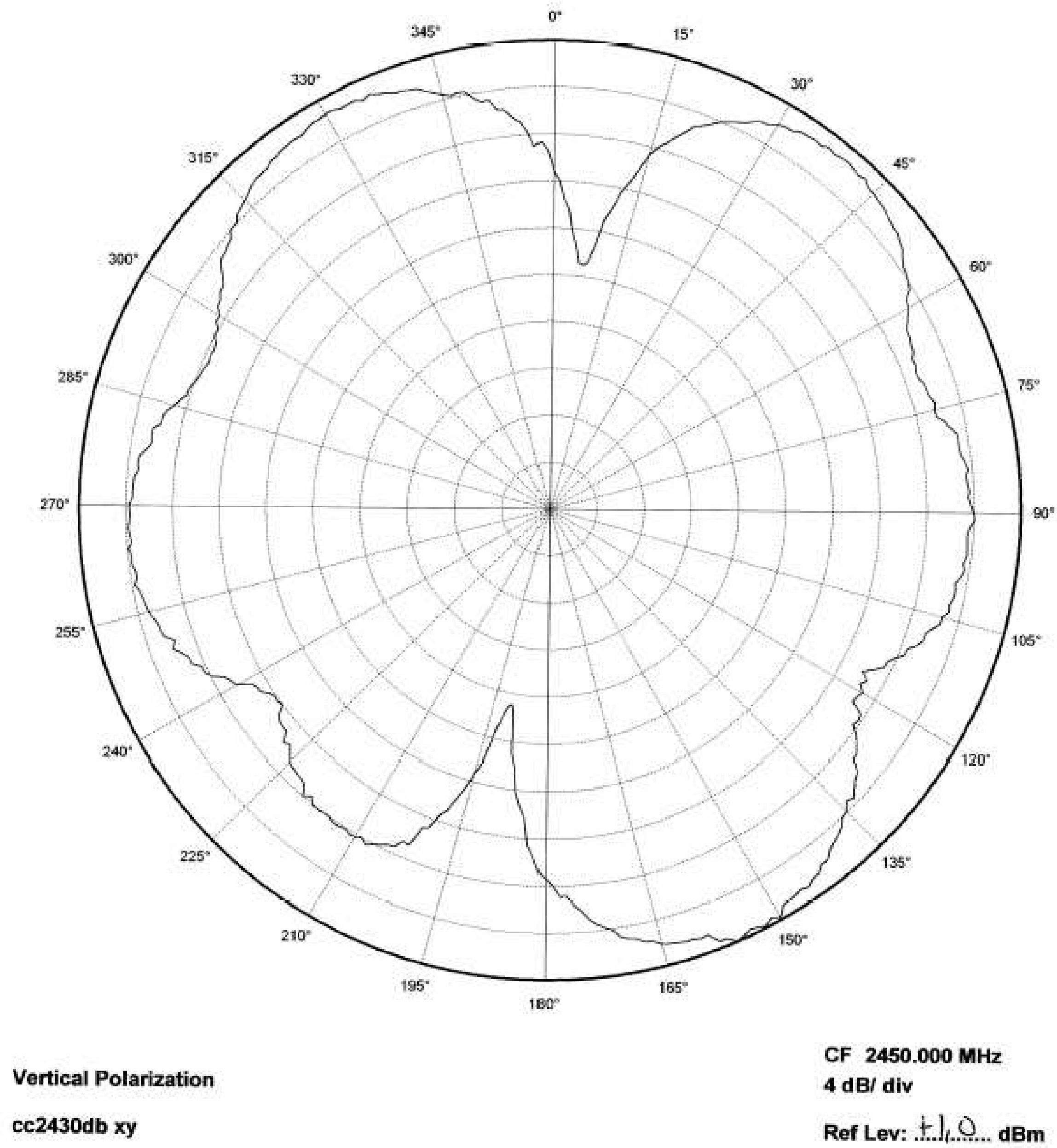

Figure 3. XY Plane–Vertical Polarization

Figure 4 shows the XY plane horizontal polarization.

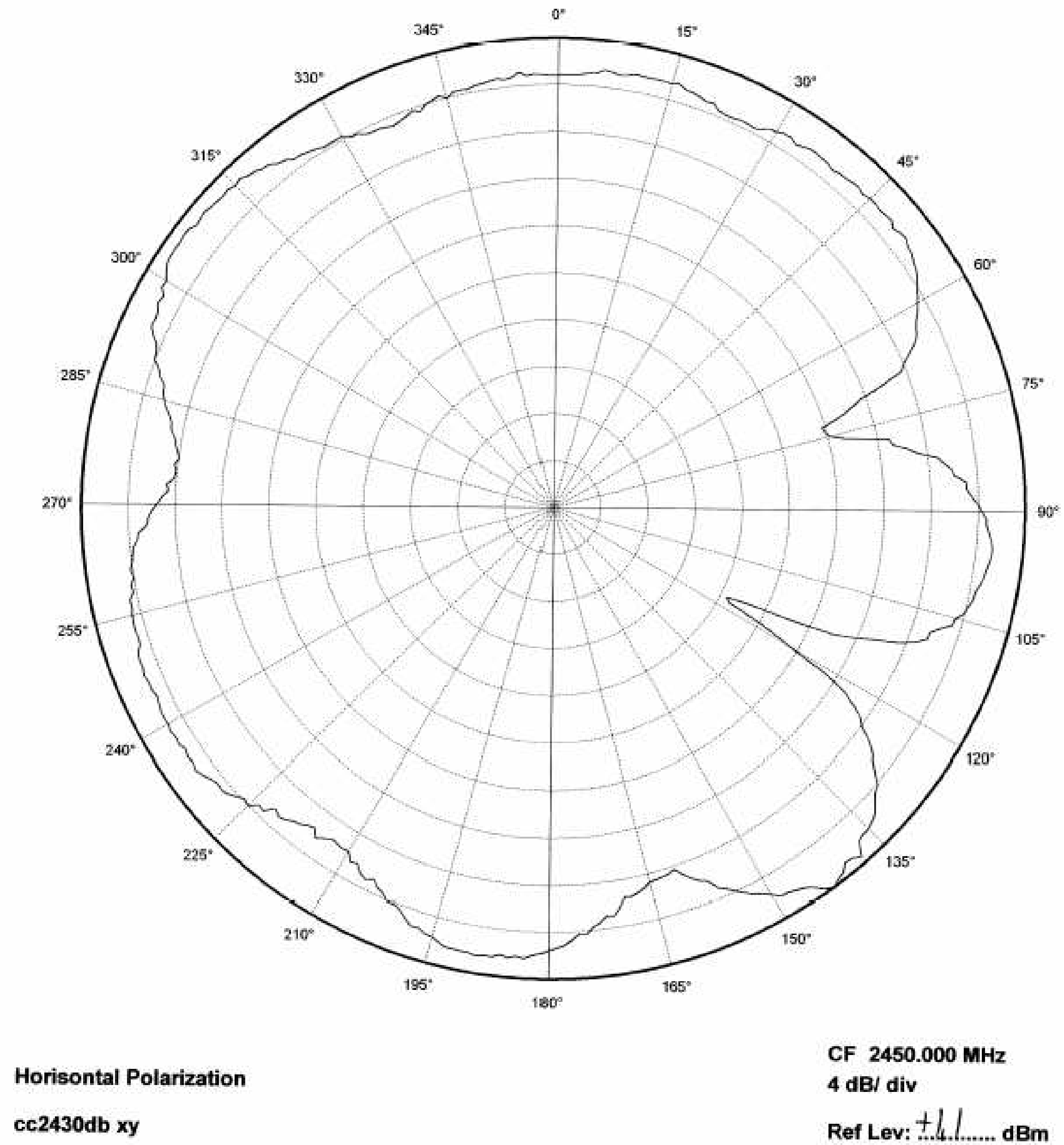

Figure 4. XY Plane–Horizontal Polarization

Figure 5 shows the XZ plane vertical polarization.

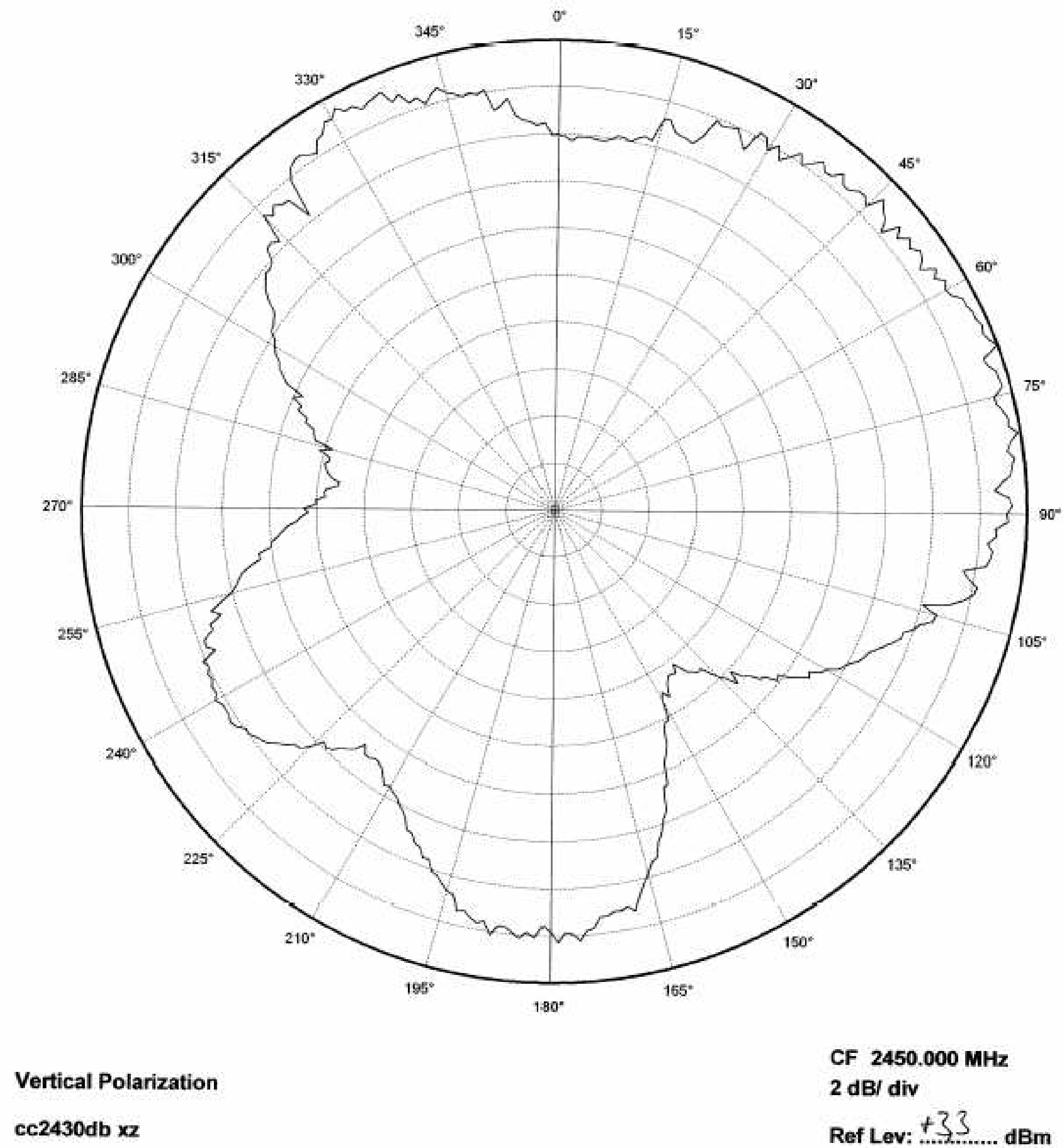

Figure 5. XZ Plane–Vertical Polarization

Figure 6 shows the XZ plane horizontal polarization.

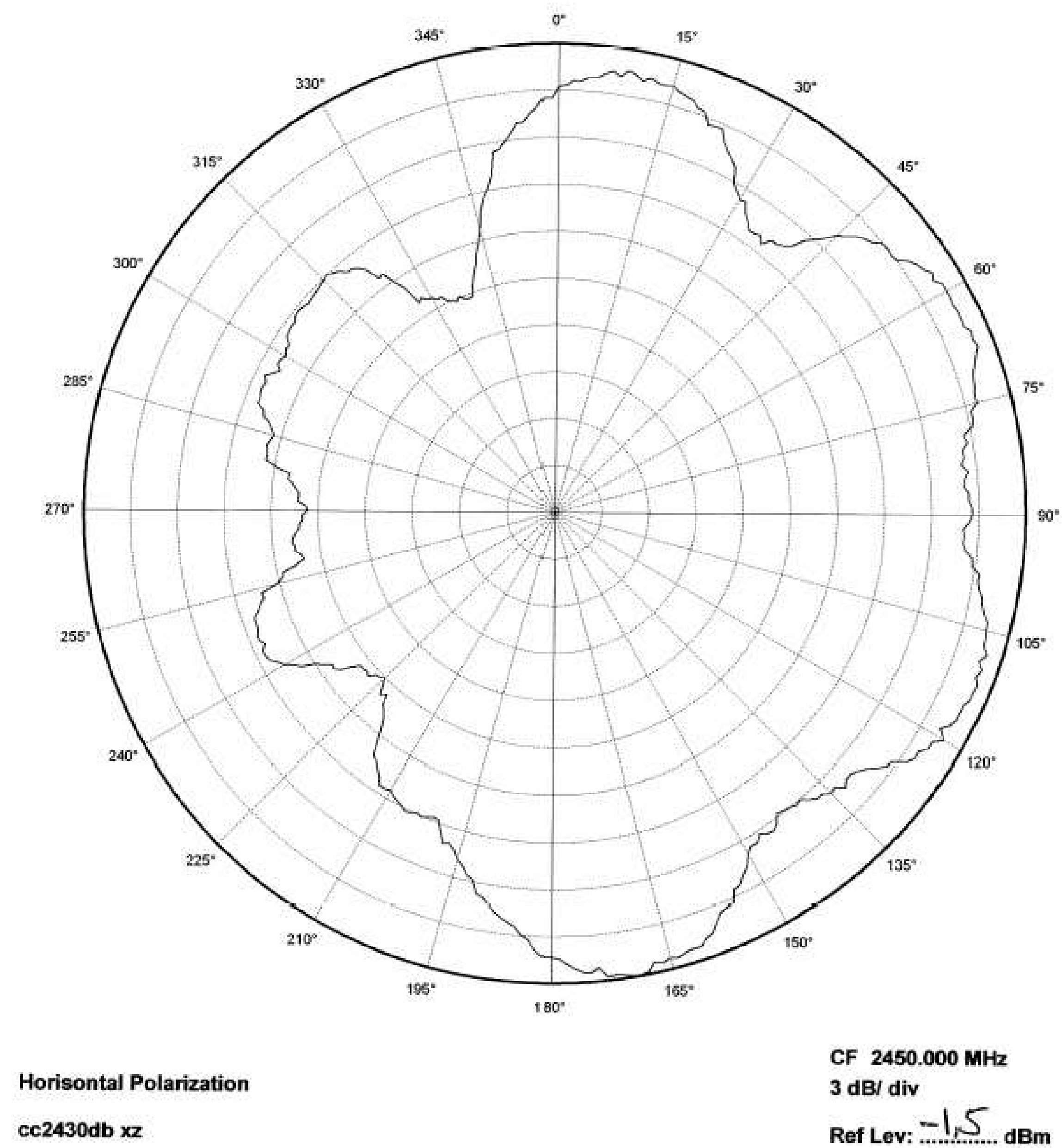

Figure 6. XZ Plane–Horizontal Polarization

Figure 7 shows the YZ plane vertical polarization.

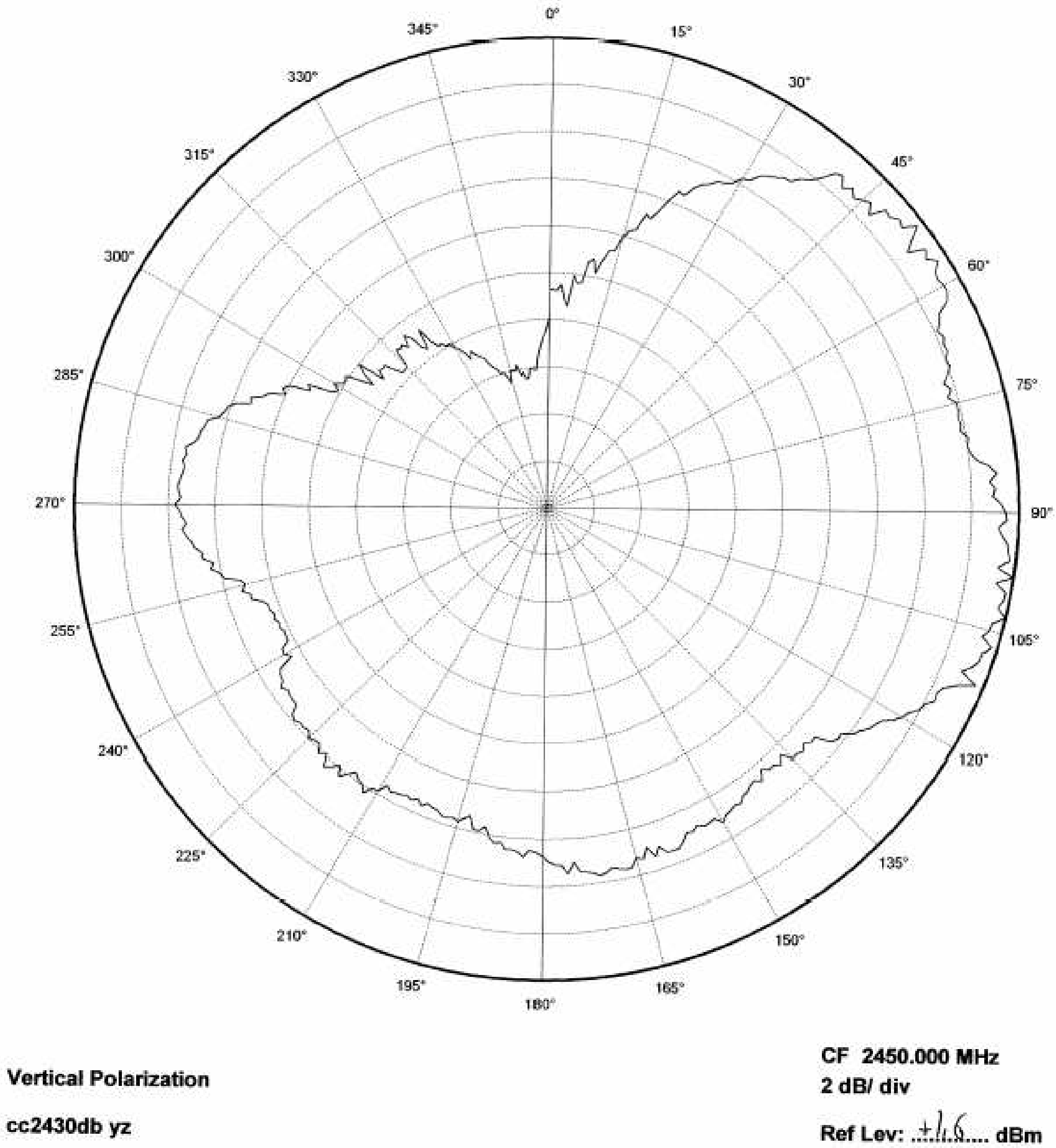

Figure 7. YZ Plane–Vertical Polarization

Figure 8 shows the YZ plane horizontal polarization.

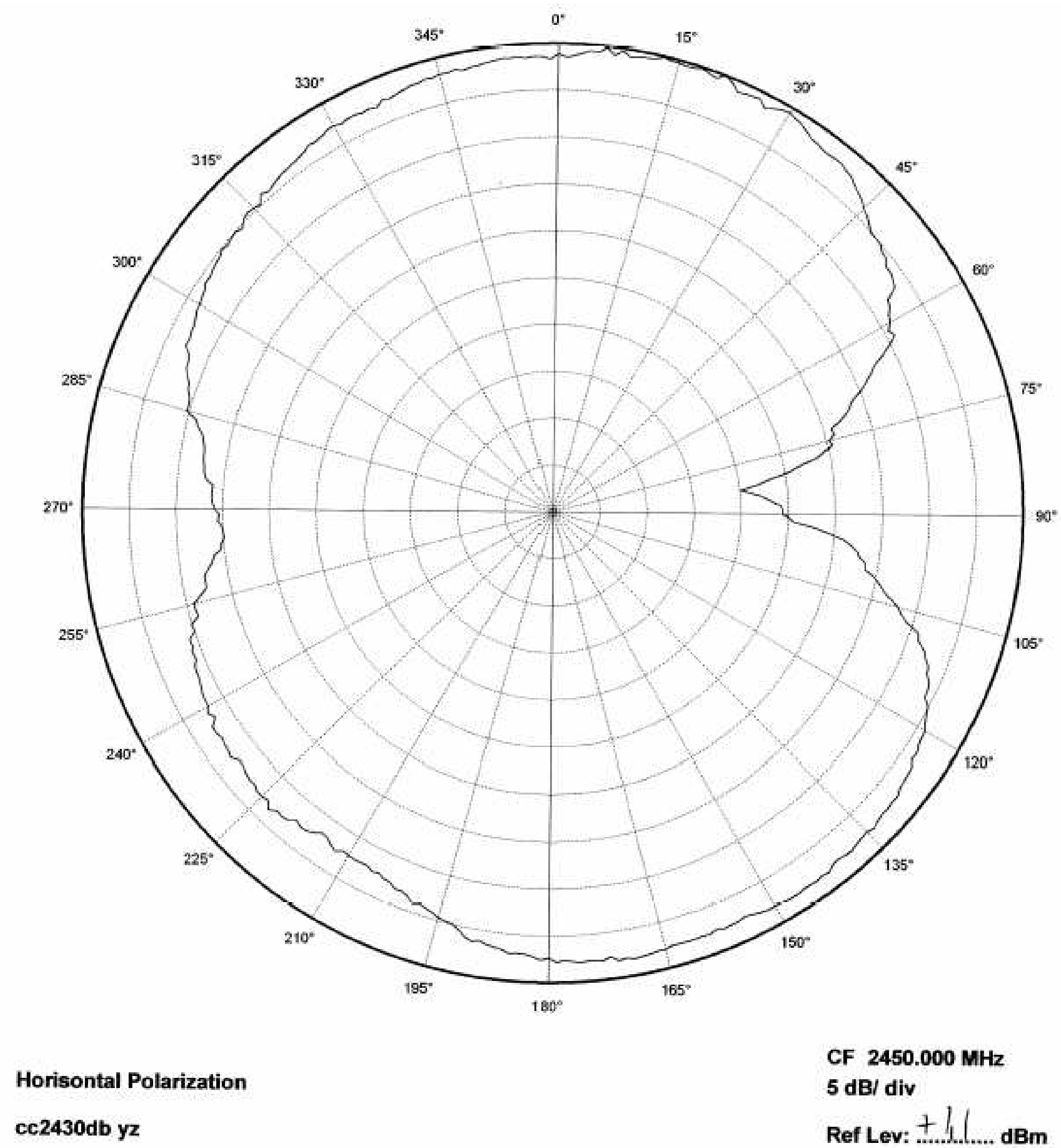

Figure 8. YZ Plane–Horizontal Polarization

2.2 Reflection

Figure 9 shows that the IFA ensures less than 10% reflection of the available power for a bandwidth of more than 300 MHz. A large bandwidth makes the antenna less sensitive to detuning because of plastic encapsulation or other objects in the vicinity of the antenna.

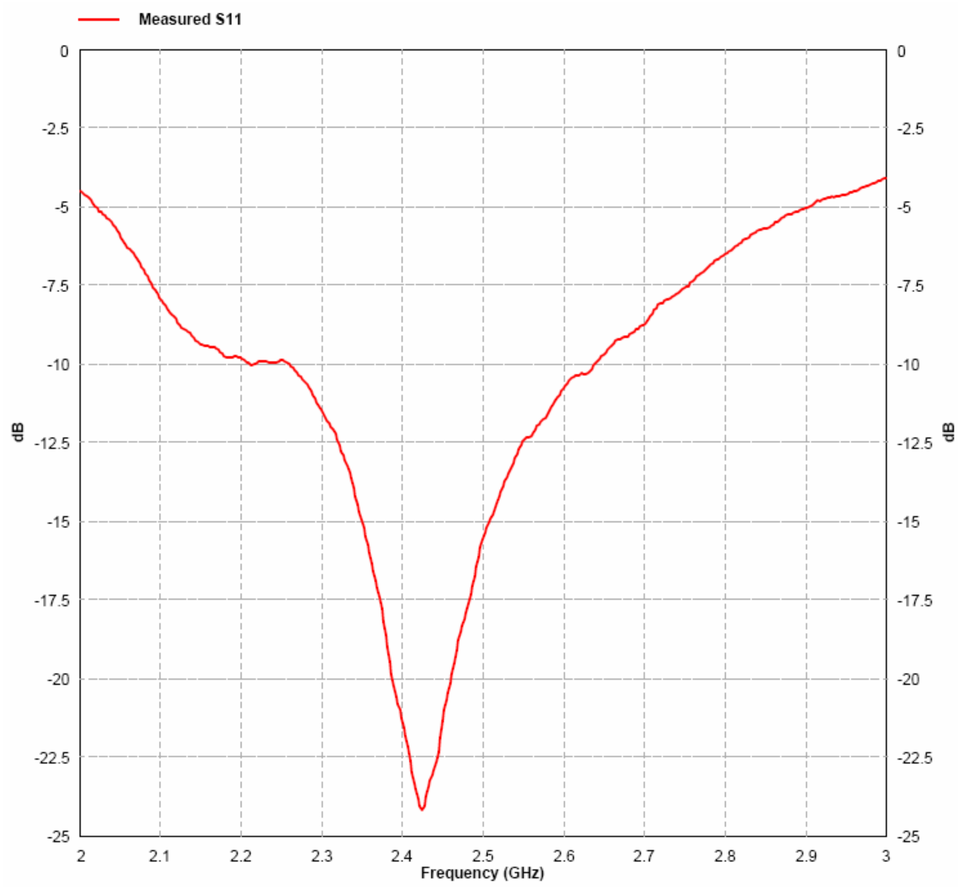

Figure 9. Measured Reflection at Feed Point of Antenna

2.3 Bandwidth

Another way of measuring the bandwidth after the antenna is implemented on a PCB and connected to a transmitter is to write test software that steps a carrier across the frequency band of interest. By using the maximum hold function on a spectrum analyzer, the variation in output power across frequency can easily be measured.

Figure 10 shows how the output power varies on the IFA when the PCB is horizontally oriented and the receiving antenna has horizontal polarization. This measurement was not performed in an anechoic chamber, thus the graph shows only the relative variation for the given frequency band.

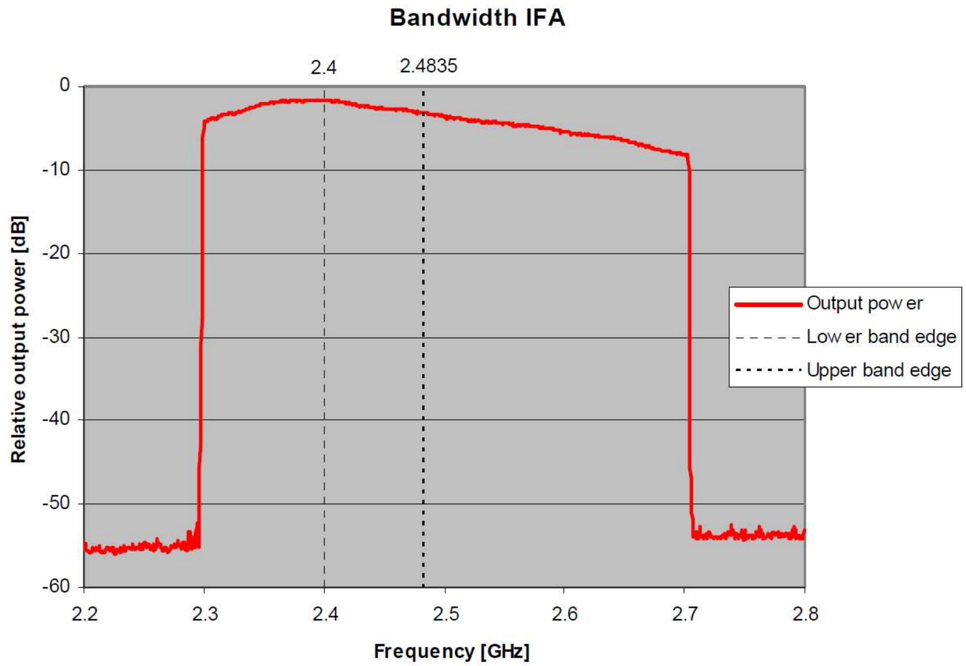

Figure 10. Bandwidth of IFA

3 Conclusion

The PCB antenna presented in this document performs well for all frequencies in the 2.4-GHz ISM band. Except for two narrow dips, the antenna has an omni directional radiation pattern in the plane of the PCB. These properties will ensure stable performance regardless of operating frequency and positioning of the antenna. Table 2 lists the most important properties for the IFA.

Table 2. Summary of IFA Properties

Gain in XY plane	1.1 dBi
Gain in XZ plane	3.3 dBi
Gain in YZ plane	1.6 dBi
Reflection	< –15 dB
Antenna size	25.7 × 7.5 mm

4 References

1. *CC2430DB Reference Design*

Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from B Revision (April 2008) to C Revision	Page
• Changed +3.3 dB to be +3.3 dBi	1
• Changed dB in Table 2 to dBi	11

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