

### 1 KEYWORDS

- CC25xx
- CC24xx
- CC2480
- PCB antenna
- USB dongle
- 2.4 GHz
- Inverted F Antenna

### 2 INTRODUCTION

The PCB antenna used on the CC2511 USB dongle reference design is described in this application note. Even if the antenna presented is for a USB dongle design it can be used in all 2.4 GHz designs, especially where small space is required for the antenna.

This application note describes the antenna dimensions, the RF performance

and considerations for complying with regulatory limits when using this design.

The suggested antenna design requires no more than 15.2 x 5.7 mm of space and ensures a VSWR ratio of less than 2 across the 2.4 GHz ISM band when connected to a 50 ohm source.

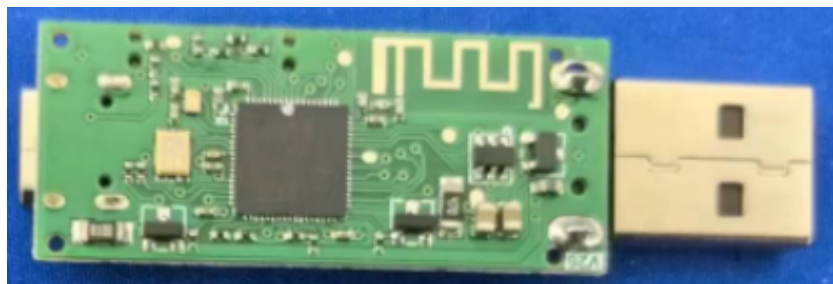


Figure 1: CC2511 USB Dongle

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### 3 ABBREVIATIONS

CAD	Computer Aided Design
CC24xx	CC2400, CC2420, CC2430 and CC2431
CC25xx	CC2500, CC2510, CC2511, CC2550 and CC2520
CC2480	Z-Accel ZigBee Processor
IFA	Inverted F Antenna
ISM	Industrial, Scientific and Medical
LOS	Line Of Sight
PCB	Printed Circuit Board
PER	Packet Error Rate
VSWR	Voltage Standing Wave Ratio

## 4 ANTENNA DESIGN

The PCB antenna on the CC2511 USB dongle reference design is a meandered Inverted F Antenna (IFA). The IFA was designed to match an impedance of 50 ohm at 2.45 GHz. Thus no additional matching components are necessary.

### 4.1 Design Goals

The reflection at the feed point of the antenna determines how much of the applied power is delivered to the antenna. A reflection of less than -10 dB across the 2.4 GHz ISM band, when connected to a 50 ohm source, was a design goal. Reflection of less than -10 dB, or VSWR less than 2, ensures that more than 90% of the available power is delivered to the antenna. Bandwidth is in this document defined as the frequency band where more than 90% of the available power is delivered to the antenna. Another design goal was to fit the size of the PCB antenna on a USB dongle and to obtain good performance also when the dongle is connected to a computer.

### 4.2 Simulation

IE3D from Zeland, which is an electromagnetic simulation tool, was used to design the antenna. The accuracy of the simulation is controlled by the mesh. An increase of the mesh increases the simulation time. Thus, for initial simulations mesh = 1 should be used. When a fairly good result is achieved a higher mesh should be used to obtain more accurate results. Comparison of simulation and measurement results shows that the measured reflection is between the result obtained with mesh = 5 and mesh = 1; see Figure 2 for details.

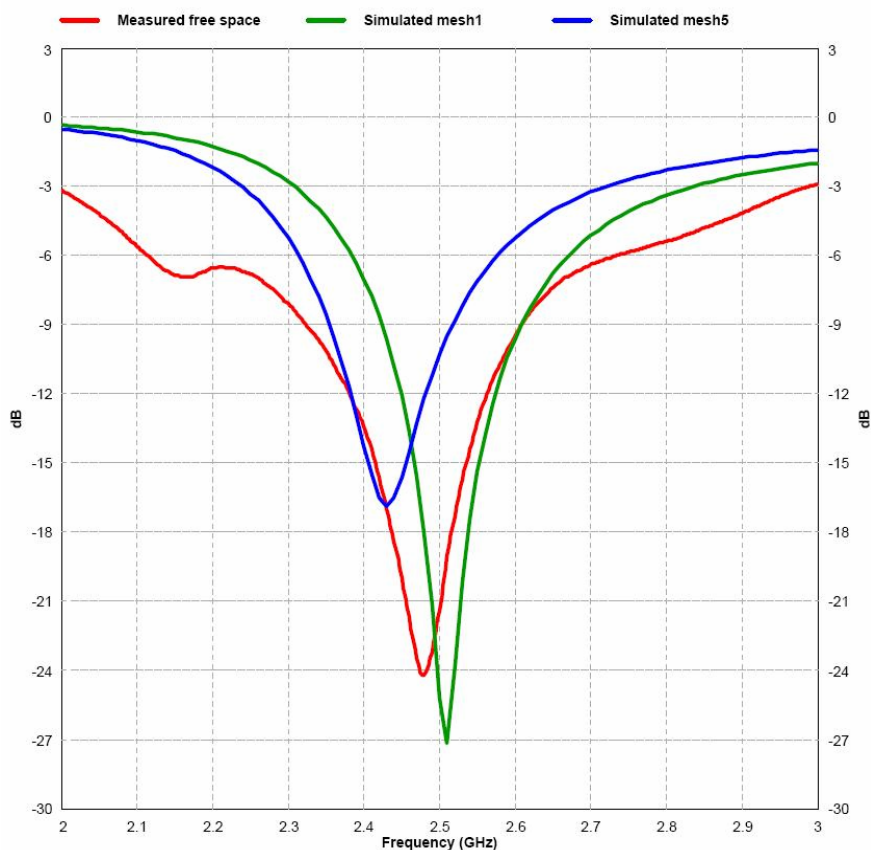
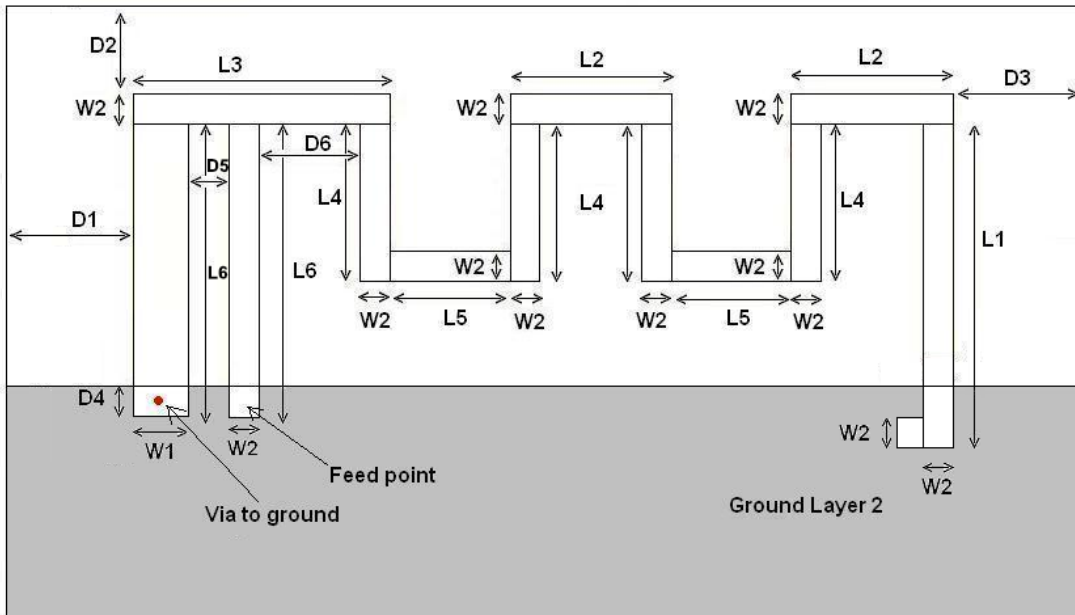


Figure 2: Comparison of Simulation and Measurements Results

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## 4.3 Layout and Implementation

Small changes of the antenna dimensions may have large impact on the performance. Therefore it is strongly recommended to make an exact copy of the reference design to achieve optimum performance. The easiest way to implement the antenna is to import the gerber or DXF file showing the antenna layout. These files are named IFA\_USB.spl and IFA\_USB.dxf respectively and are included in the CC2511 USB dongle reference design available from <http://www.ti.com/lpw>. The imported file can be used as a template when drawing the antenna. By using this procedure it should be possible to make an exact copy. If the PCB CAD tool being used does not support import of DXF or gerber files, Figure 3 and Table 1 should be used to ensure correct implementation. It is recommended to generate a gerber file for comparison with IFA\_USB.spl when making a manual implementation. Most gerber viewers have the possibility to import several gerber files at the same time. Thus by placing the gerber file, showing the manually implemented antenna, on top of IFA\_USB.spl it is easy to verify that the antenna is correctly implemented. It is also recommended to use the same thickness and type of PCB material as used in the reference design. Information about the PCB can be found in a separate readme file included in the reference design. To compensate for a thicker/thinner PCB the antenna could be made slightly shorter/longer.



**Figure 3: Antenna Dimensions**

L1	5.54 mm
L2	2.70 mm
L3	5.00 mm
L4	2.64 mm
L5	2.00 mm
L6	4.90 mm
W1	0.90 mm
W2	0.50 mm
D1	0.50 mm
D2	0.30 mm
D3	0.30 mm
D4	0.50 mm
D5	0.60 mm
D6	1.70 mm

**Table 1: Antenna Dimensions**

## 5 TEST RESULTS

Reflection, radiation pattern and variation of output power across a wide frequency band were measured to verify the performance of the PCB antenna. Measurements of the dongle in free space and when connected to a laptop were performed to verify that the antenna is suitable both for USB dongle designs and in a standalone application. Free space is in this document interpreted as a measurement performed without connecting the dongle to a computer. In such a measurement the dongle is only powered by a battery.

### 5.1 Reflection

All the reflection measurements were performed with a network analyzer connected to a semi-rigid coax cable, which was soldered to the feed point of the antenna. Because of the small size antenna and the small ground plane this kind of measurements is heavily affected by the presence and placement of the coax cable. This influence can result in a small uncertainty in resonance frequency and measured reflection. Typically different placement of the semi-rigid coax cable could change the resonance frequency with 5 -10 MHz and the reflection with 3 - 4 dB.

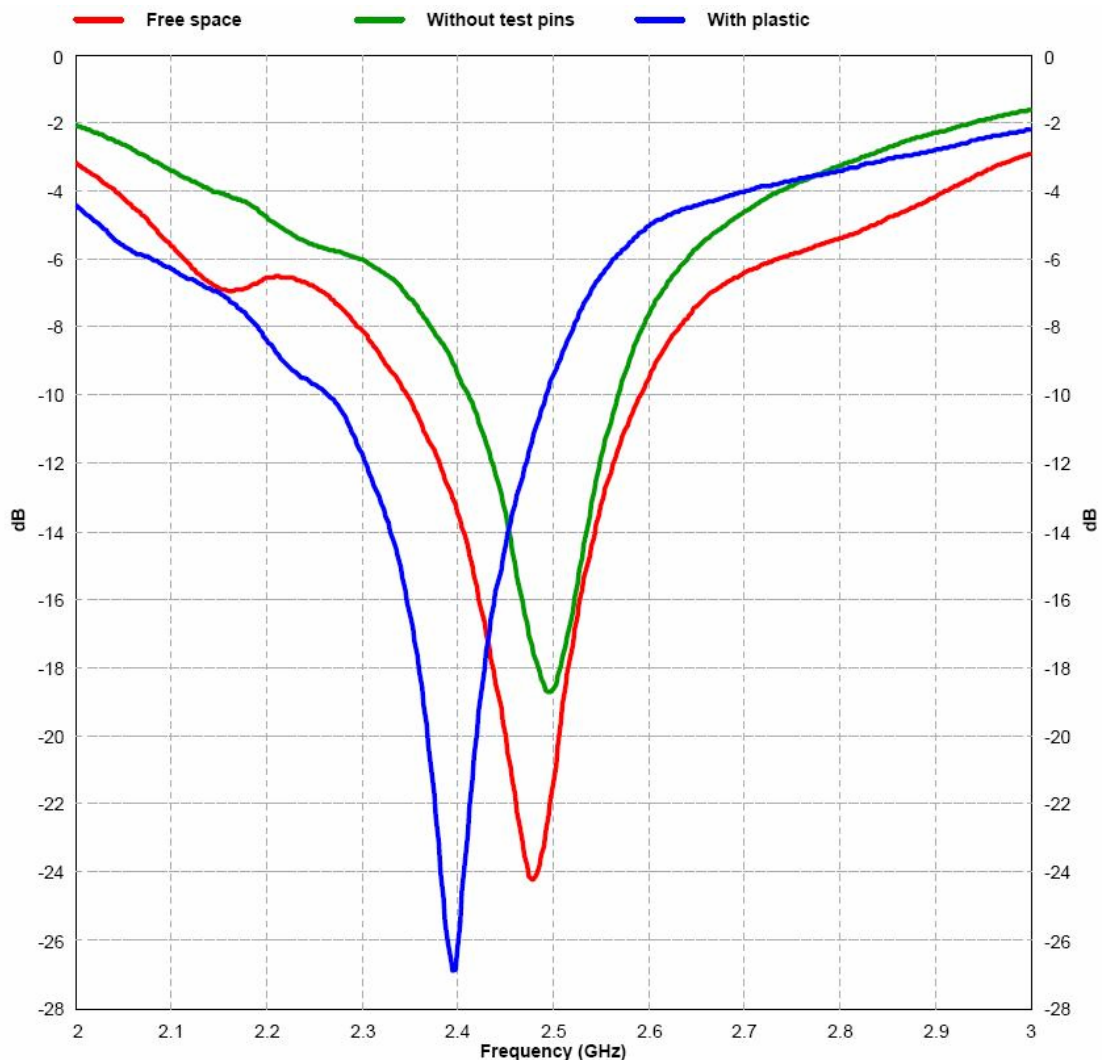


Figure 4: Influence of Plastic Encapsulation and Test Pins

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A small part on the CC2511 USB dongle PCB is equipped with test pins. These are intended for use during development. This part of the PCB will typically be omitted in a final application. The red and green graph on Figure 4 shows that removing this part of the PCB has a small impact on the performance. Figure 4 also shows that plastic encapsulation of the dongle will shift the resonance frequency to a lower frequency. This can be compensated by making the antenna slightly shorter.

The size of the ground plane affects the performance of the PCB antenna. Connecting the USB dongle to a computer increases the size of the ground plane and thus the performance is affected. Figure 5 shows how the performance is affected when the USB dongle is connected to a laptop. In free space the antenna has a bandwidth of approximately 250 MHz. When the USB dongle is connected to the laptop the bandwidth is reduced to around 100 MHz, which still is enough to cover the whole 2.4 GHz ISM band.

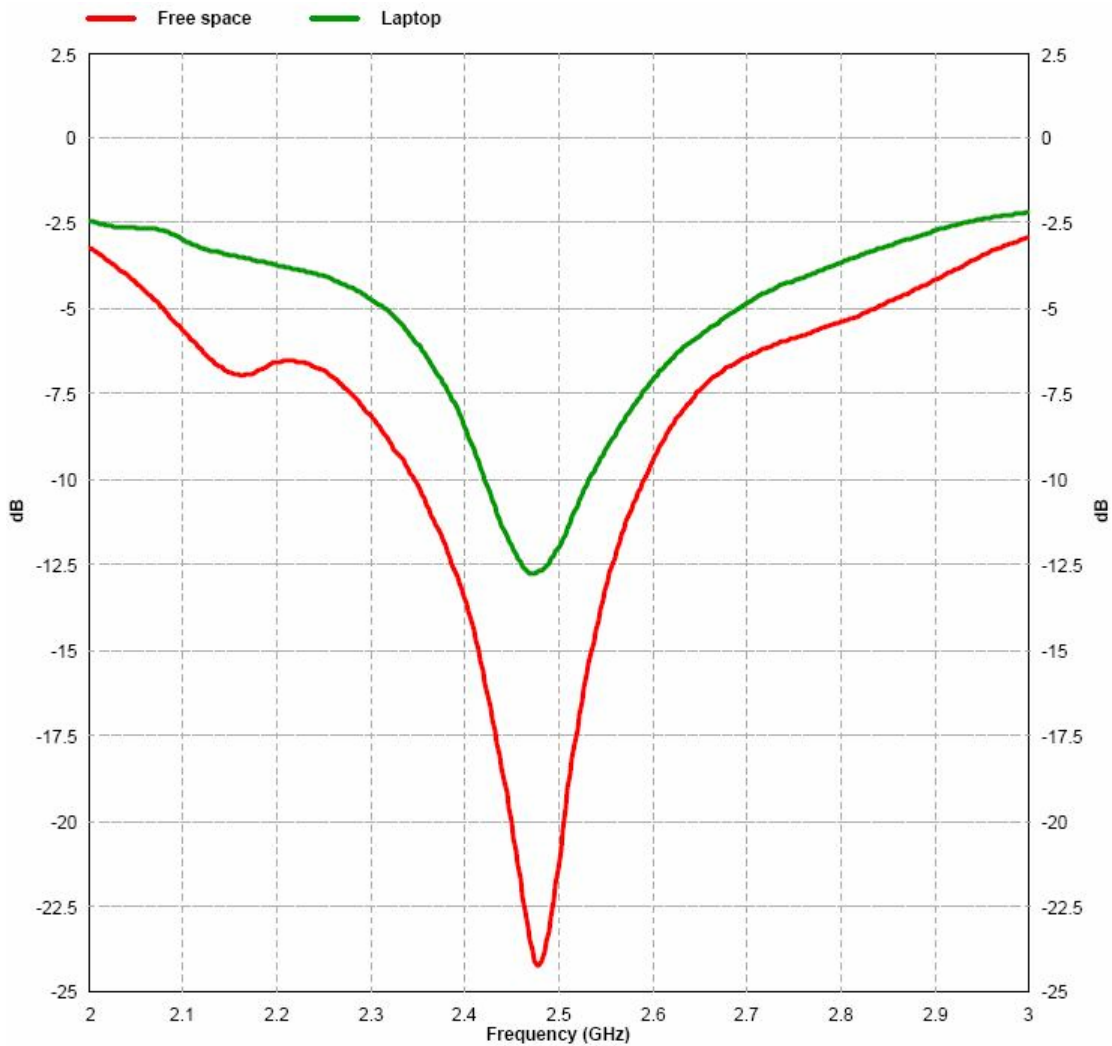
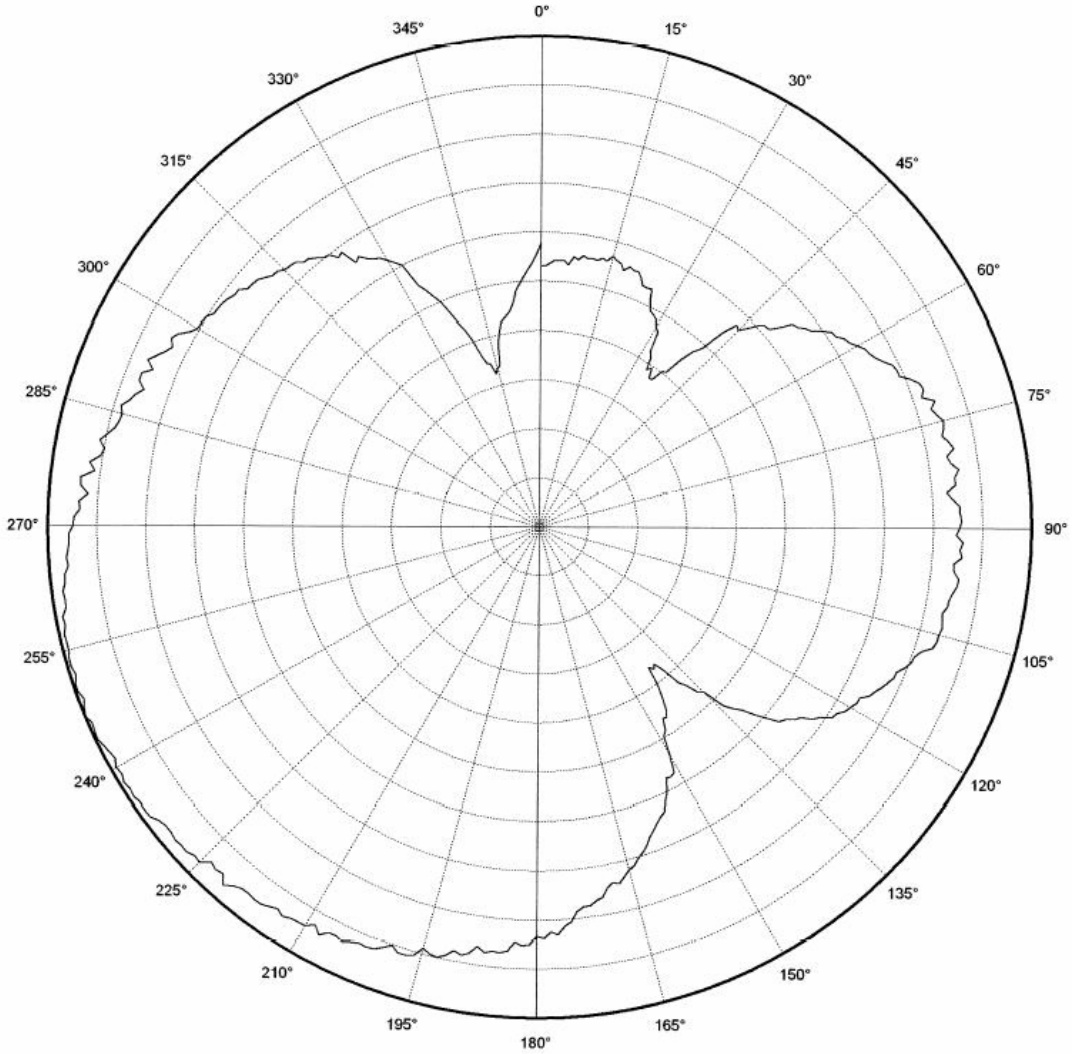


Figure 5: Comparison of Performance

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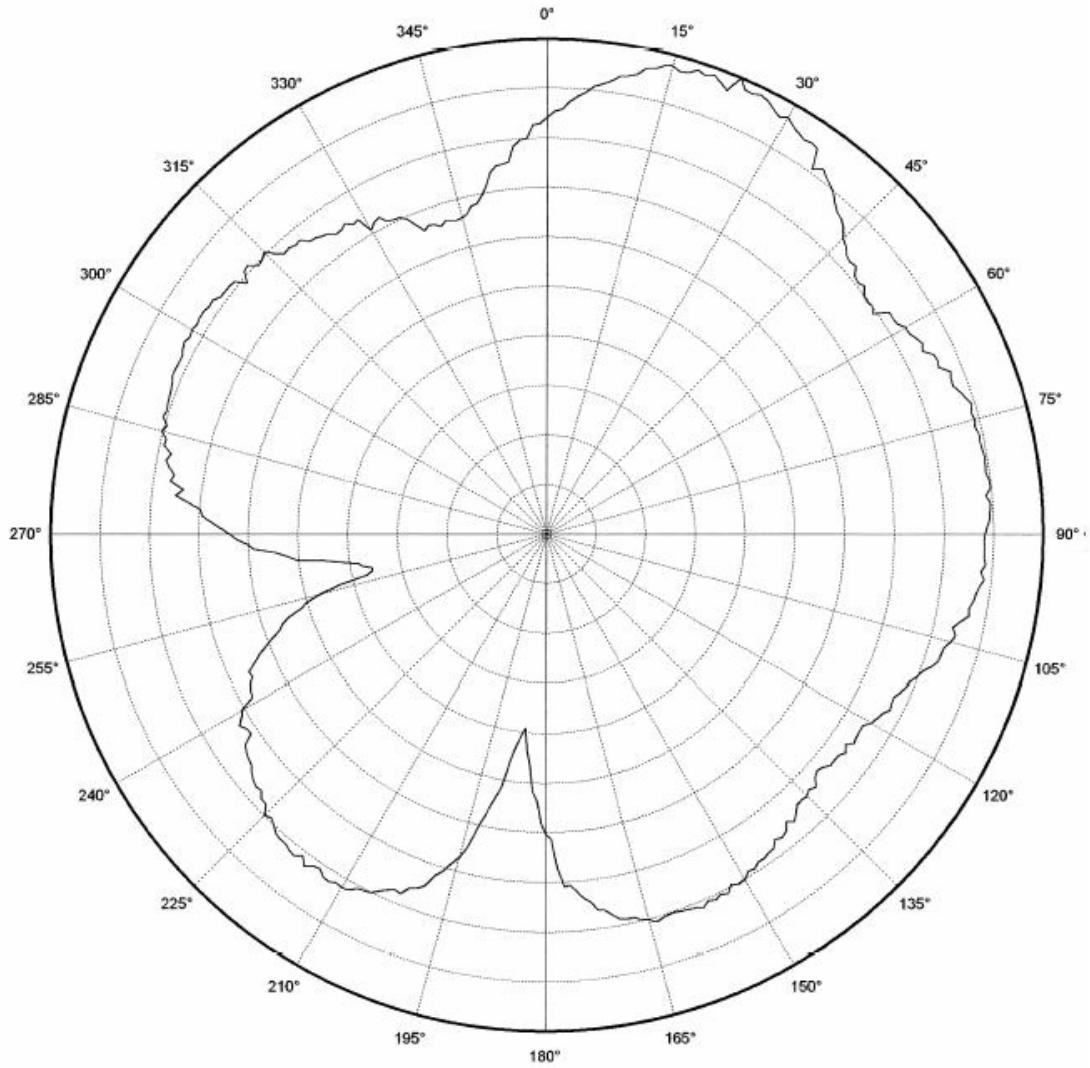
Vertical Polarization  
usb XY

CF 2450.000 MHz  
4 dB/ div  
Ref Lev: *-2.5* dBm

Figure 7: USB Dongle XY Plane



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Vertical Polarization

usb XZ

CF 2450.000 MHz

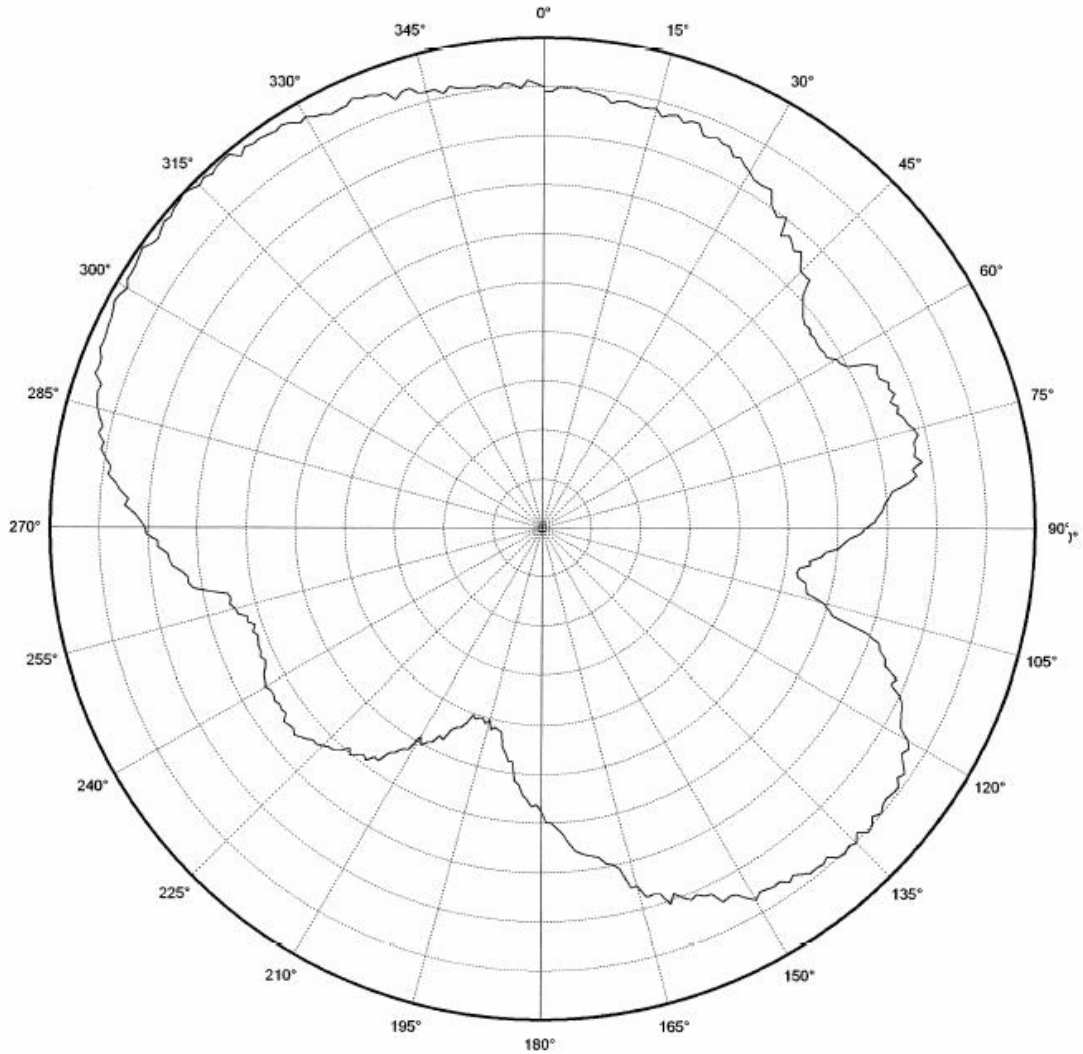
4 dB/ div

Ref Lev: ..... 2.2 dBm

Figure 8: USB Dongle XZ Plane



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Horizontal Polarization

usb YZ

CF 2450.000 MHz

3 dB/ div

Ref Lev: <sup>-1,2</sup> ..... dBm

Figure 9: USB Dongle YZ Plane