Small Size 2.4 GHz PCB antenna

1 KEYWORDS

- *CC25xx*
- *CC24xx*
- *CC2480*
- *PCB antenna*
- *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.

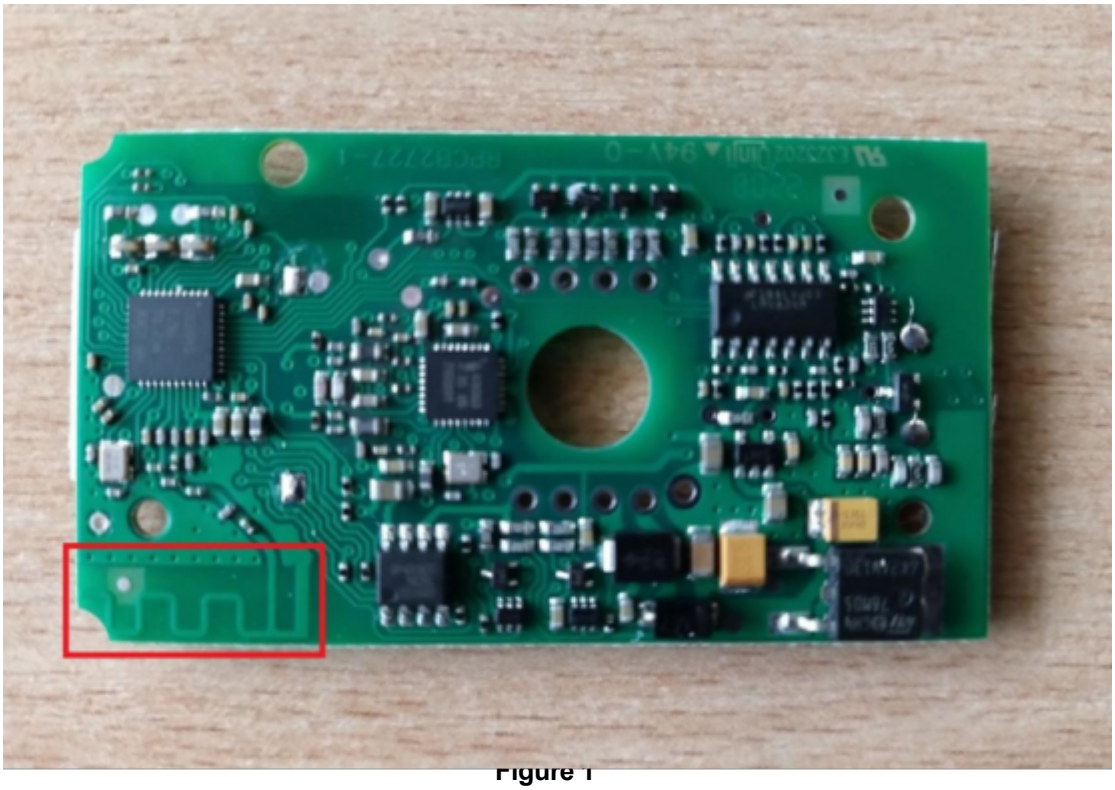
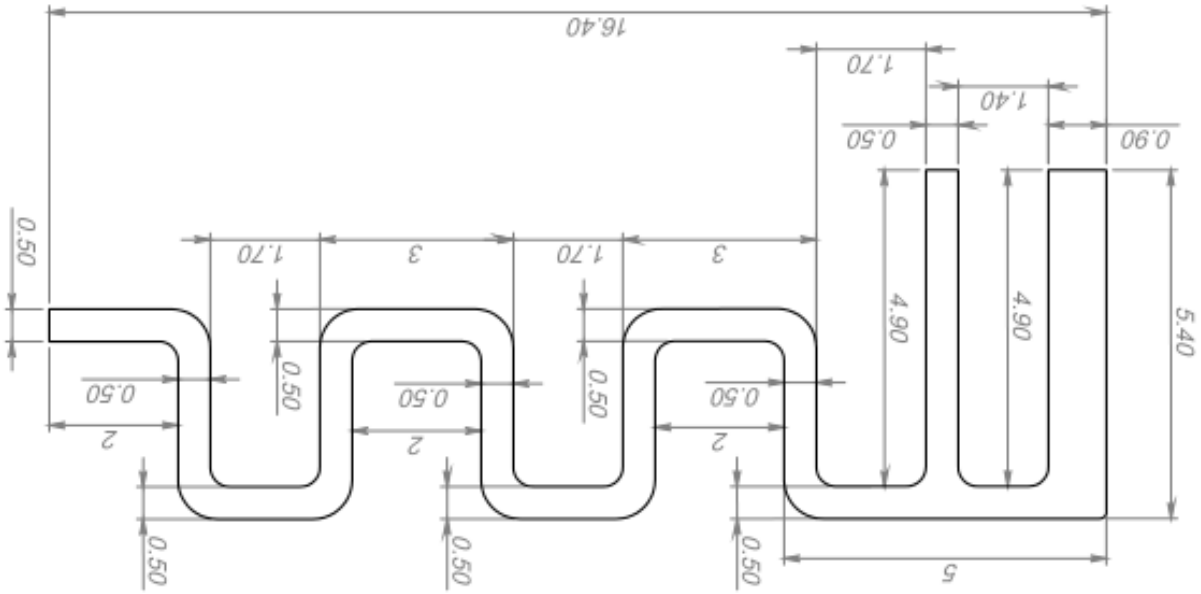


Figure 1

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.



L1	3.94 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	1.40mm
D6	1.70 mm

Table 1: Antenna Dimensions

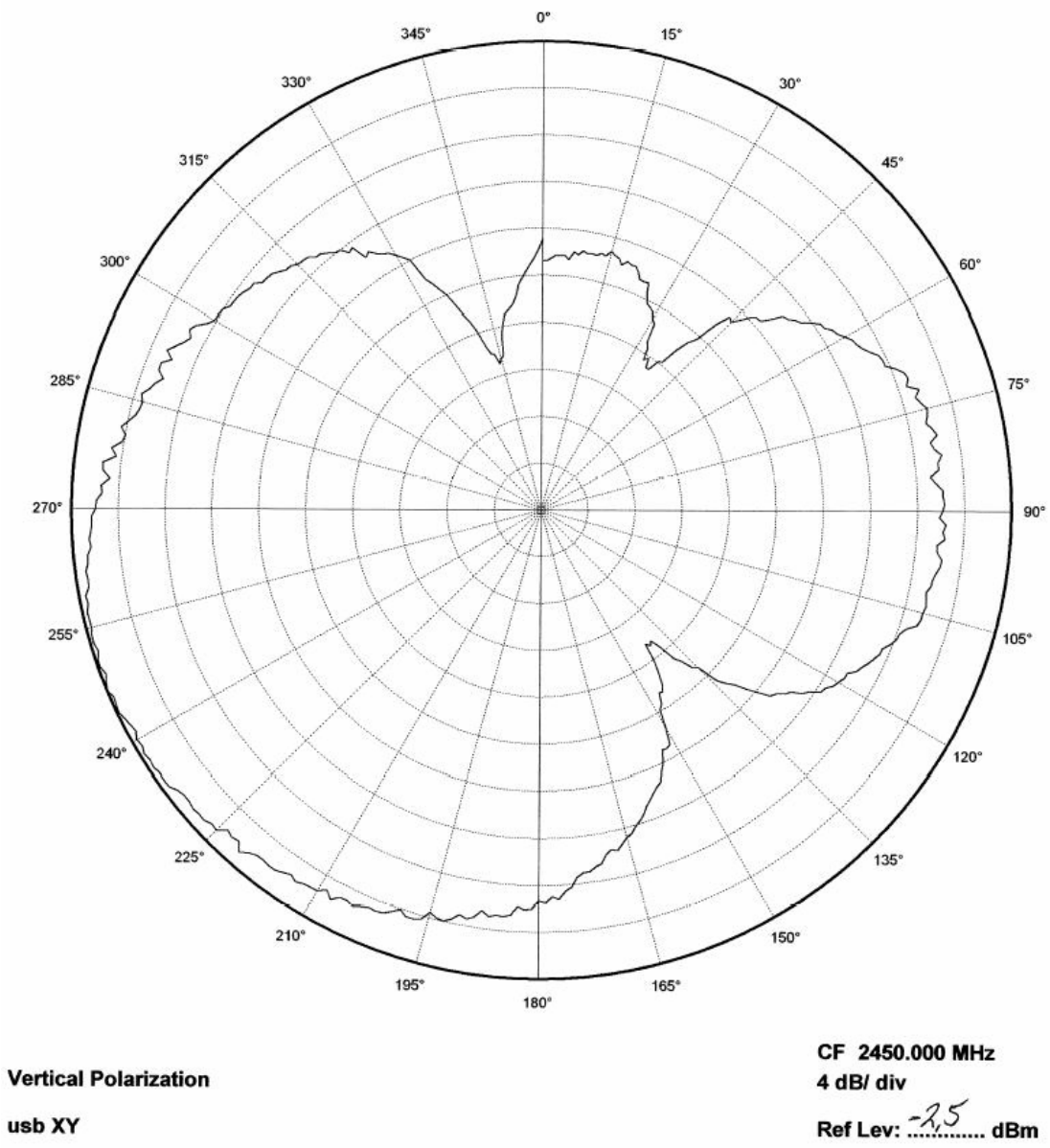


Figure 7: USB Dongle XY Plane

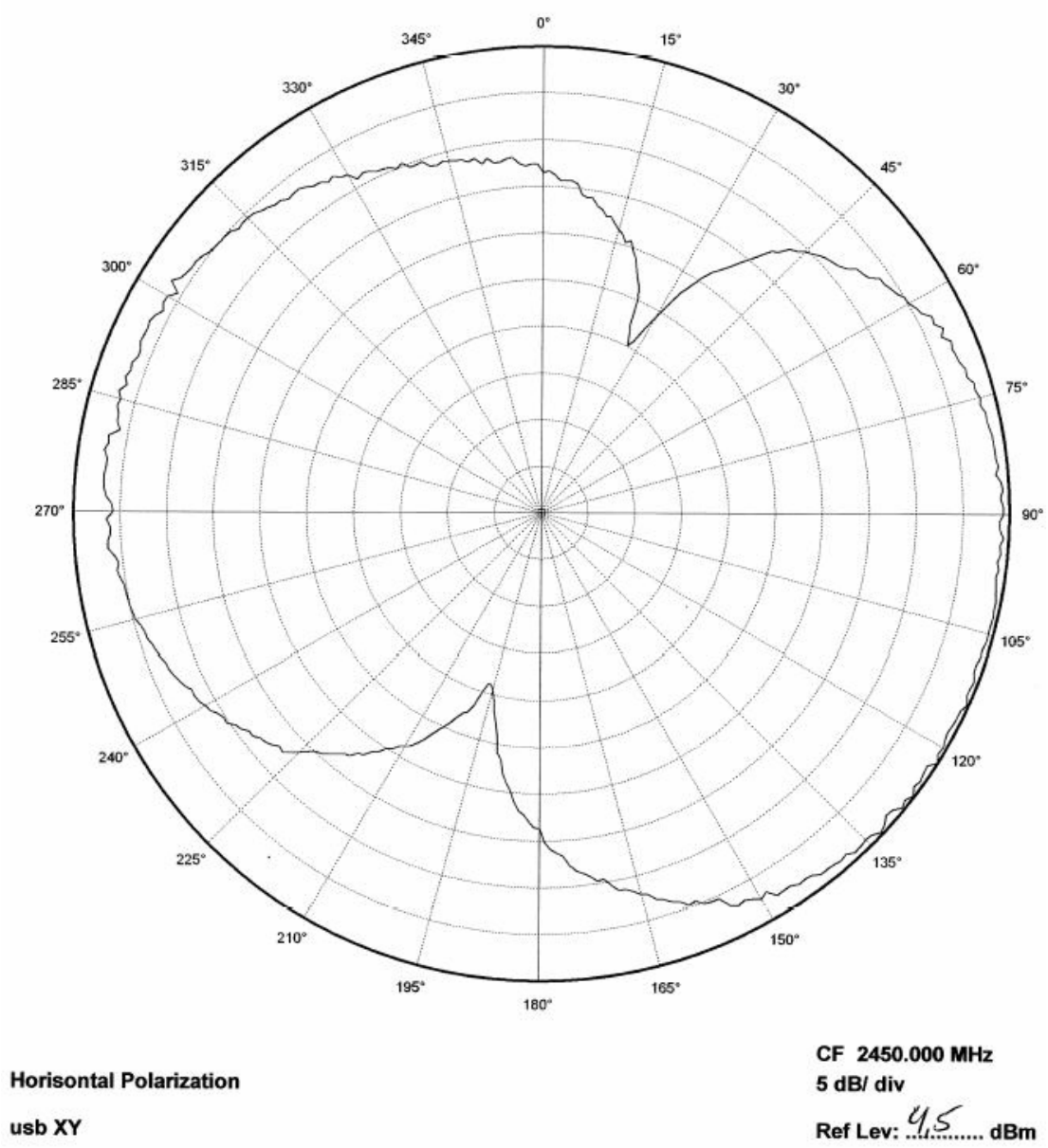


Figure 8: USB Dongle XY Plane

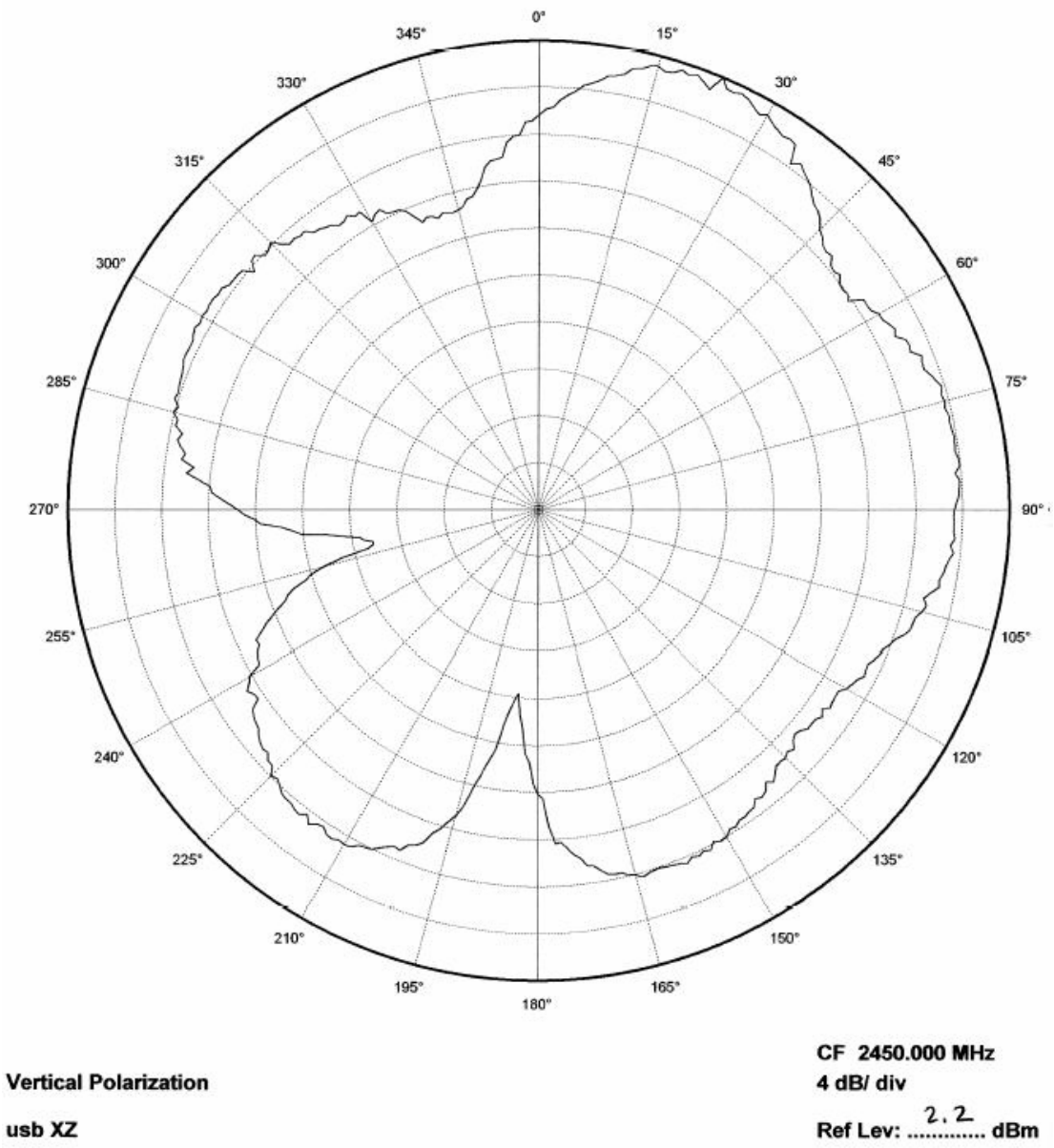


Figure 9: USB Dongle XZ Plane

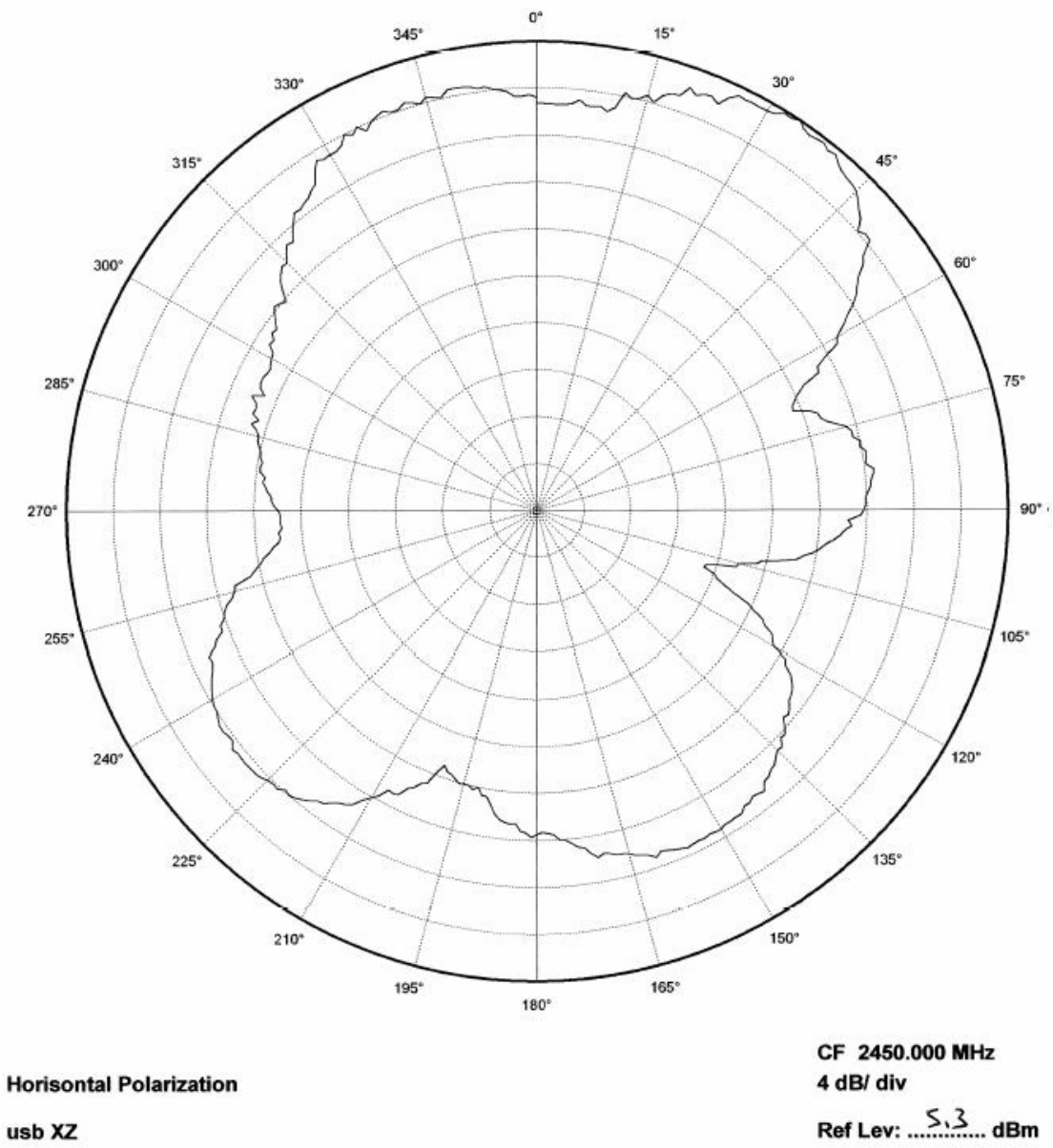


Figure 10: USB Dongle XZ Plane

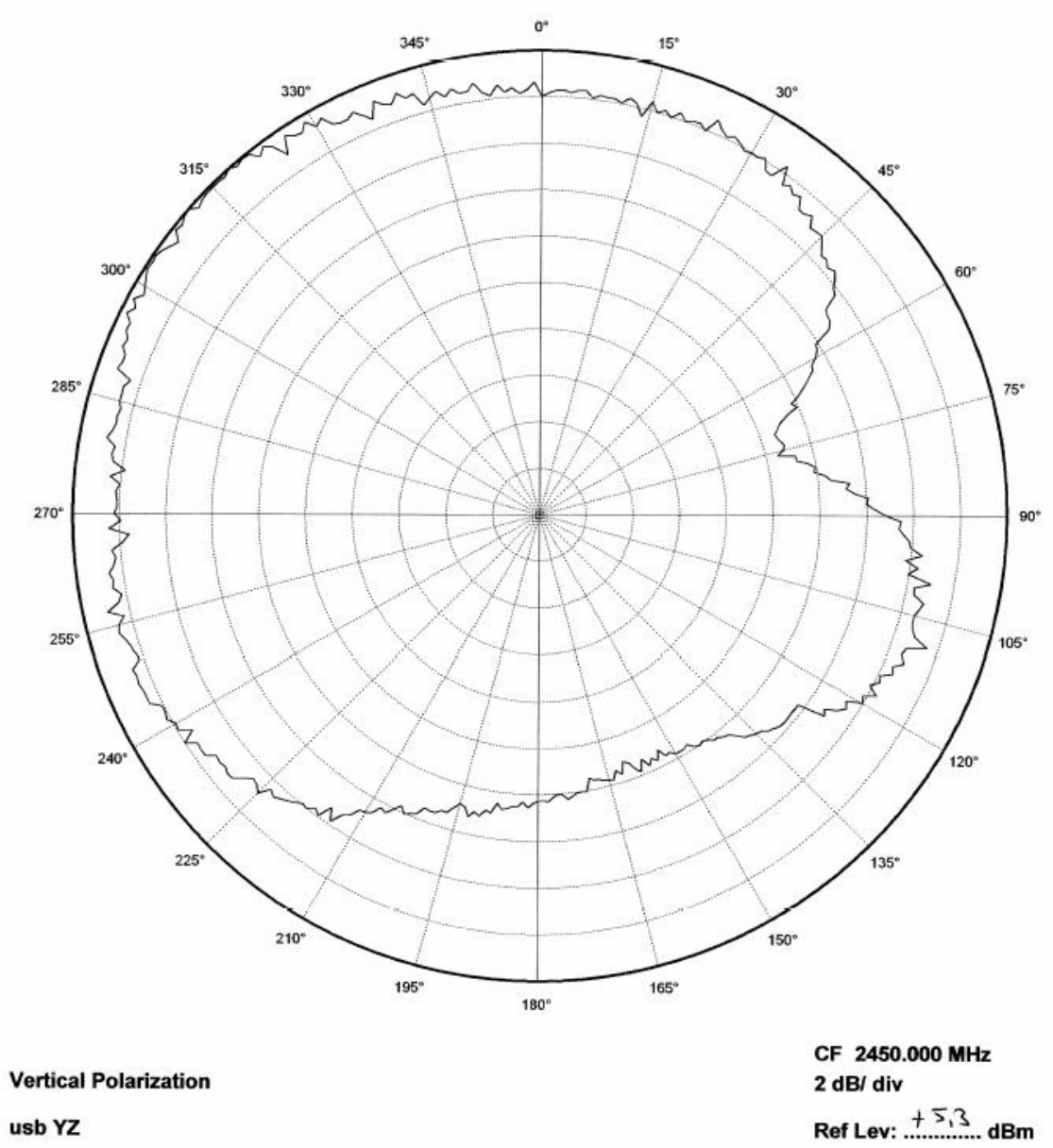


Figure 11: USB Dongle YZ Plane

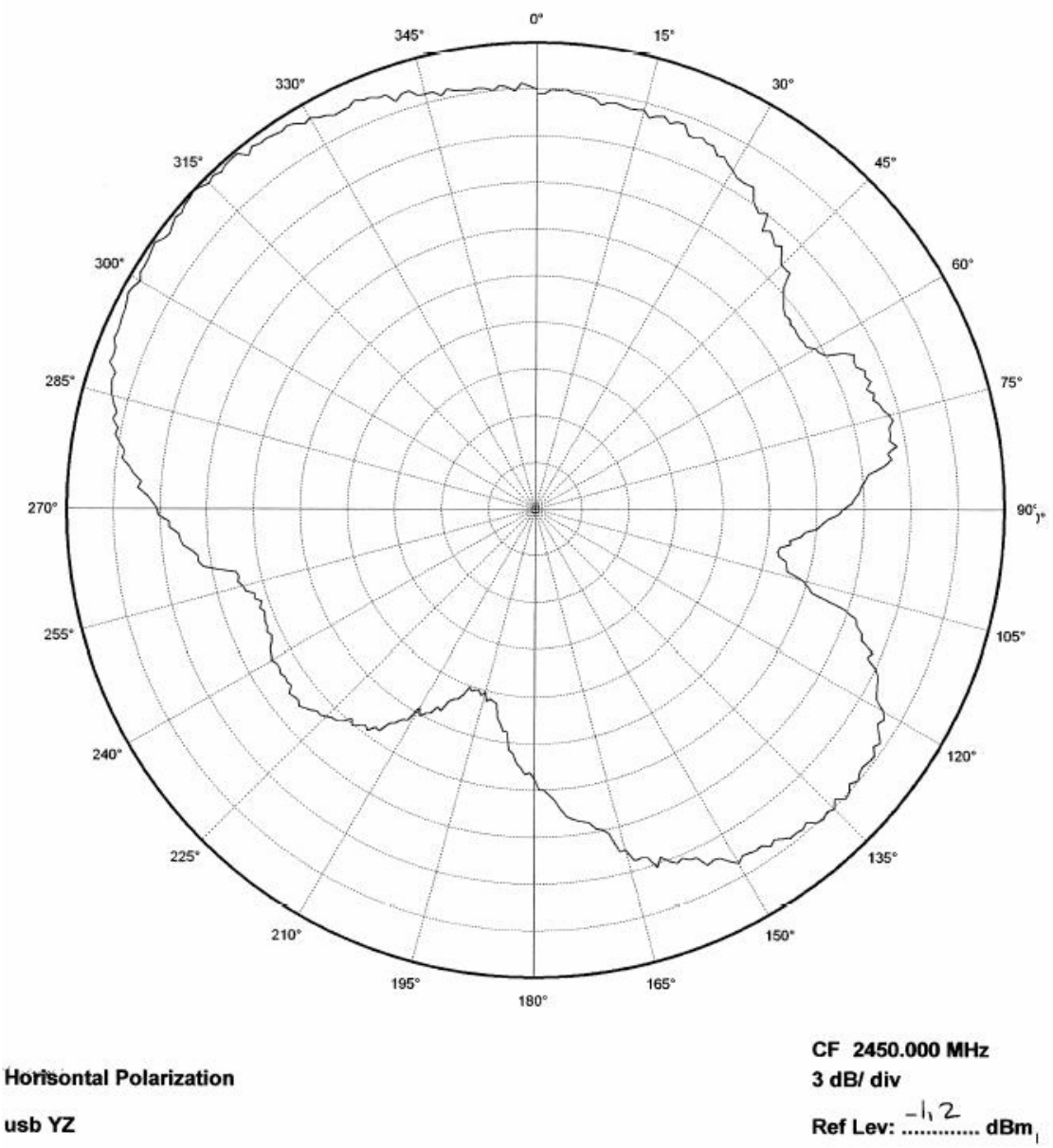


Figure 12: USB Dongle YZ Plane

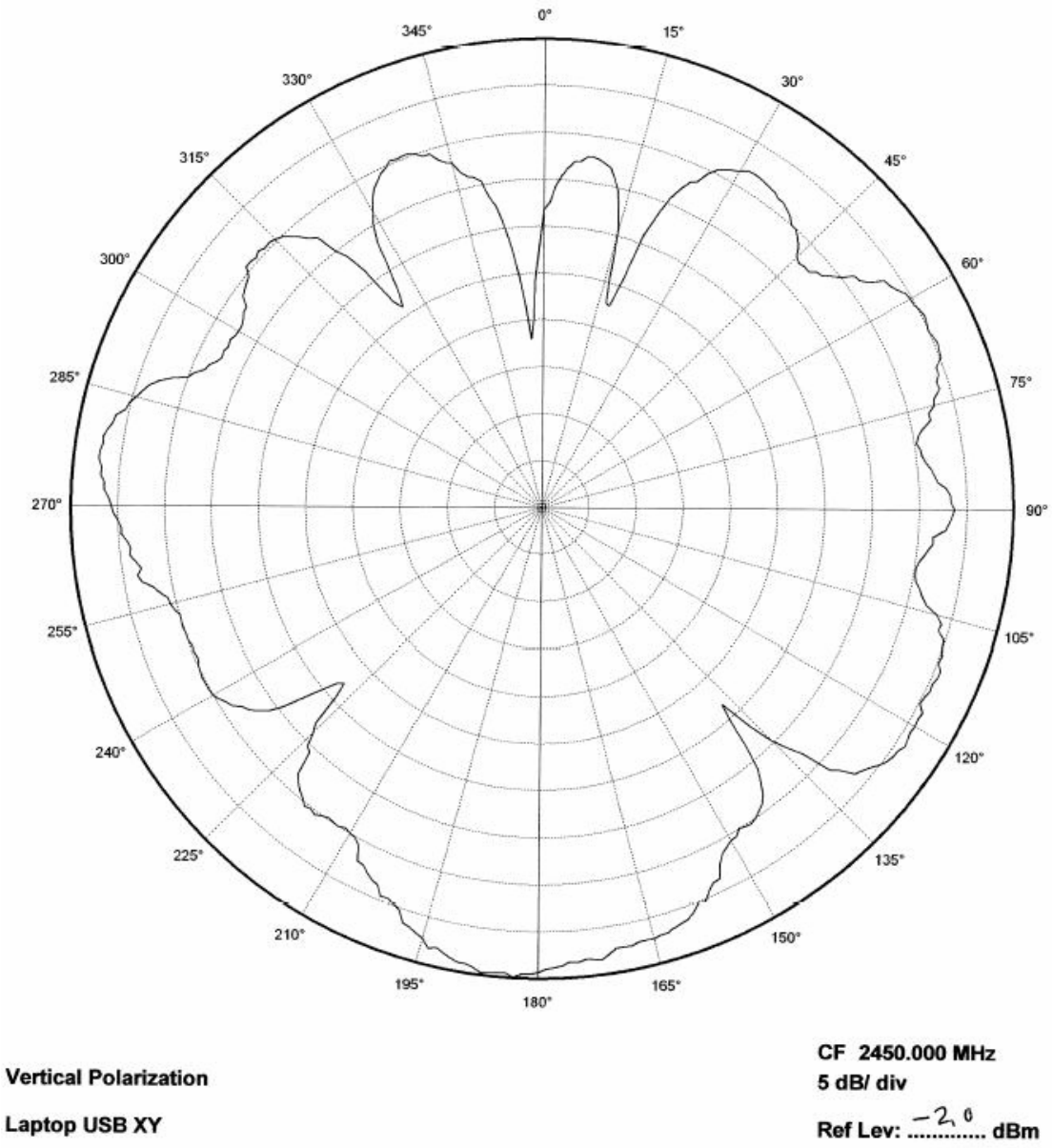


Figure 13: USB Dongle in Laptop XY Plane

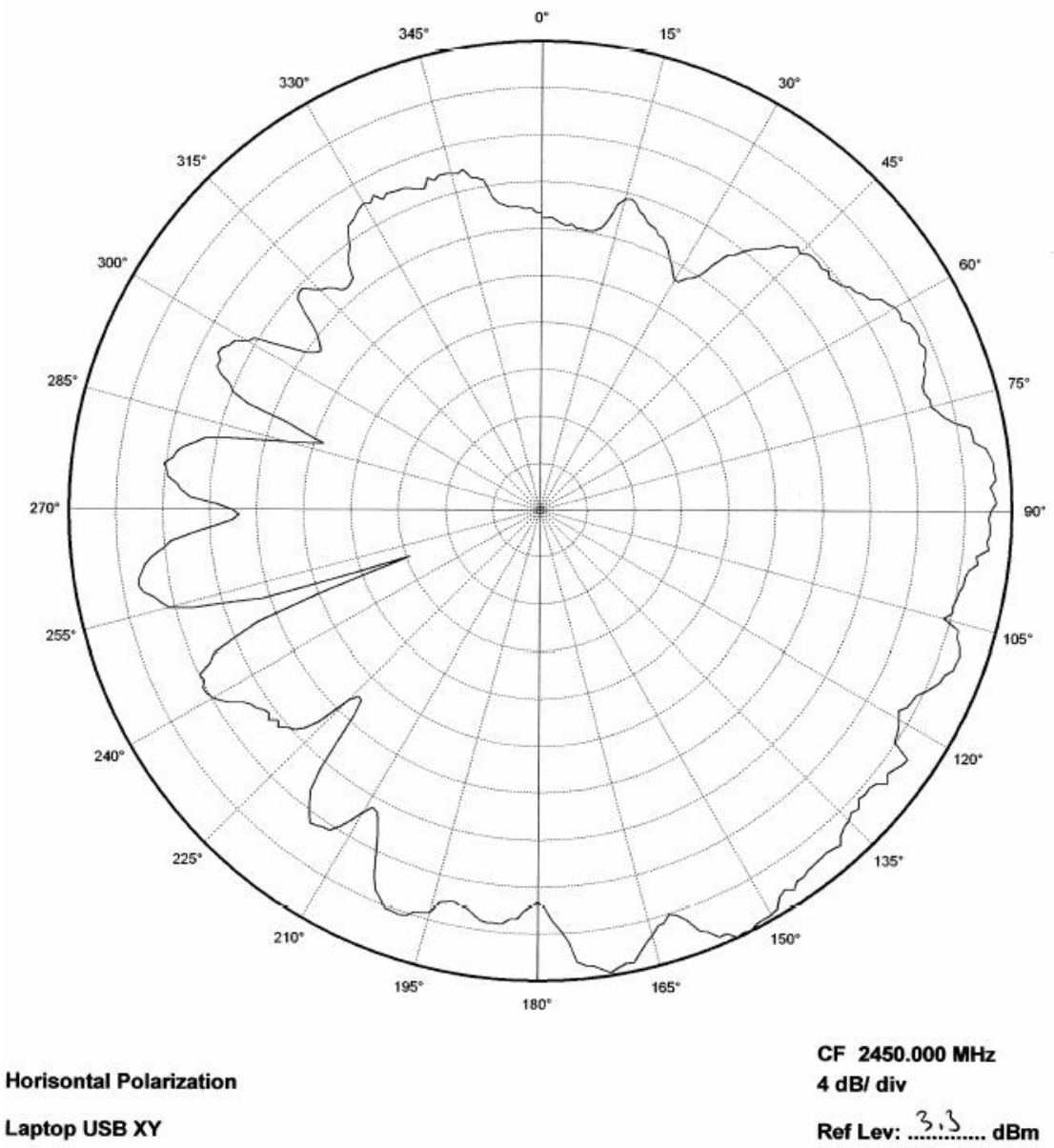


Figure 14: USB Dongle in Laptop XY Plane

5.3 Output Power

To make a realistic bandwidth measurement of the antenna a small test program was used. The test program stepped the center frequency of a carrier from 2.3 to 2.8 GHz. This bandwidth measurement was also done to verify the result from the reflection measurements, described in section 5.1. The output power was measured using max hold on a spectrum analyzer. CC2511 was programmed for 0 dBm output power and the antenna was horizontally oriented and directed towards the receiving antenna. This corresponds to 0° in the XY plane on Figure 6. The bandwidth measurements were not performed with a correction factor on the spectrum analyzer. Thus, the results in Figure 15 and Figure 16 only show the relative changes in output power and not the actual level.

Figure 15 shows the bandwidth of the antenna when the dongle is not connected to a computer. The result shows that the antenna has a variation in output power of less than 3 dB across a frequency band of more than 350 MHz. This demonstrates that the antenna has a

broadband characteristic. Maximum output power is measured to be at 2.54 GHz. Thus if the same antenna is implemented on a PCB with similar size and if the application is only intended for stand alone usage the antenna could be made slightly longer to obtain best performance at 2.42 GHz.

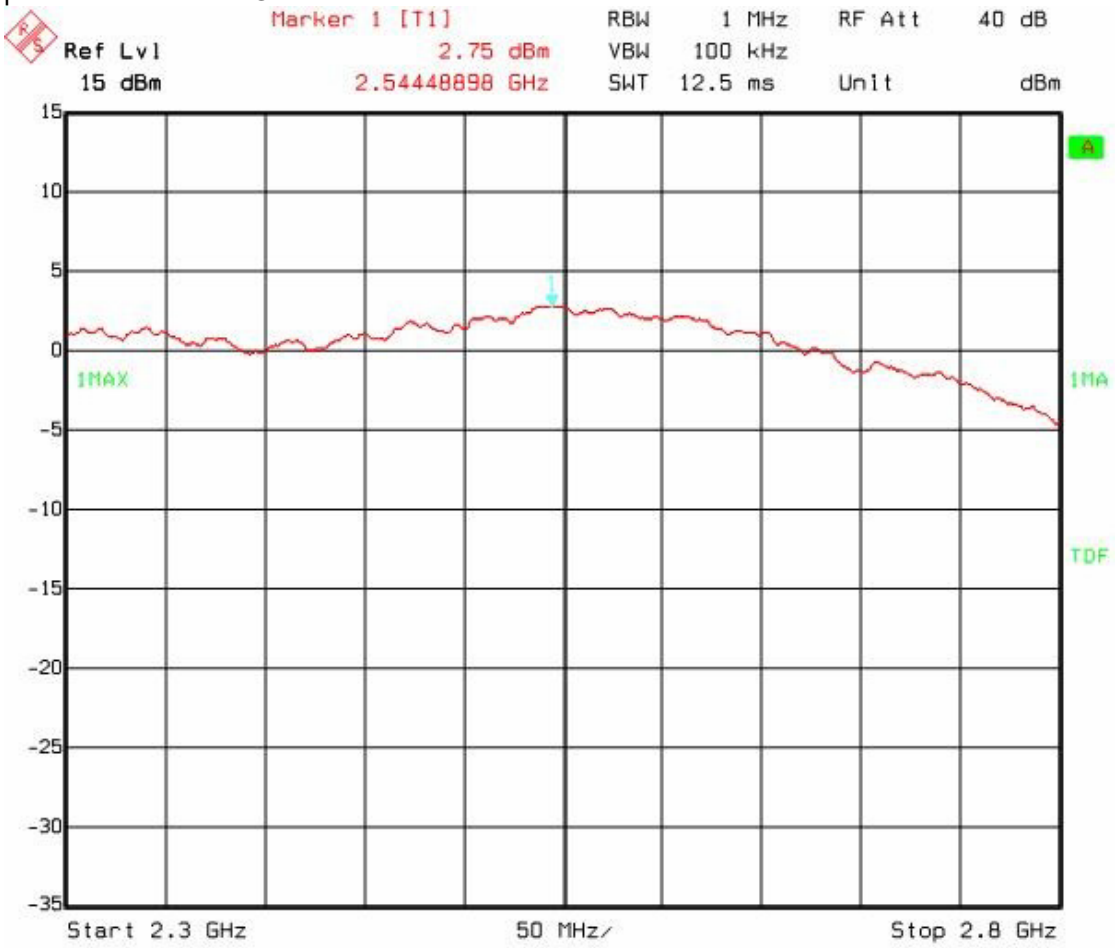


Figure 15: Output Power, USB Dongle

The reflection results in Figure 5 indicate that the output power will be slightly reduced when the dongle is connected to a laptop. Comparison of the results in Figure 15 and Figure 16 shows that the output power is reduced by approximately 2 dB when the dongle is connected to a laptop. This agrees with the results in Figure 5.

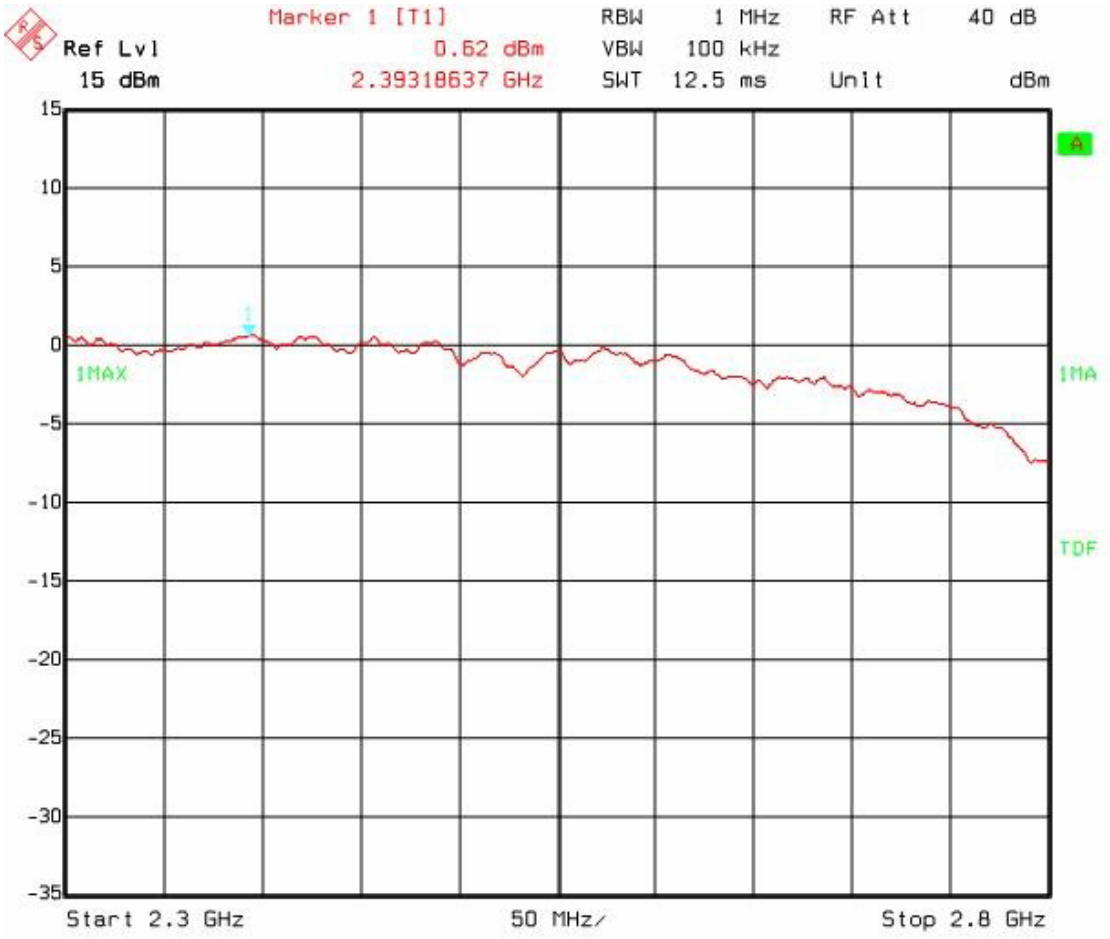


Figure 16: Output Power, USB Dongle in Laptop

5.4 Spurious Emission and Harmonics

Table 2 shows measured output power and emission at the second harmonic. Above the second harmonic no peaks were detected when measuring TX emission. This can be seen from Figure 17 and Figure 18. These measurements were performed according to FCC requirements. An approximate conversion to dBm can be done by subtracting 95 from the measured value in dBµV/m. Since the measurement setup for ETSI and FCC is different this conversion will not give an exact result, but typically it will give a result that is within 1-2 dB of the result from a correct ETSI measurement.

Output power	2.44 GHz	4.88 GHz
1 dBm	96.9 dBµV/m	56.1 dBµV/m
0 dBm	96.1 dBµV/m	54.3 dBµV/m
-2 dBm	93.1 dBµV/m	52.5 dBµV/m

Table 2: Measured Level of Output Power and Harmonics

ETSI and FCC limits for output power and TX spurious emission are shown in Table 3. FCC allows for up to 20 dB higher emission if duty cycling is used. Thus, it is possible to use the antenna described in this document and be compliant with both ETSI and FCC regulation.

	EN 300 328	EN 300 440	FCC 15.247	FCC 15.249
2.4 – 2.483 GHz	20 dBm	10 dBm*	125 dBµV/m 116 dBµV/m**	94 dBµV/m
2. harm	-30 dBm	-30 dBm	54 dBµV/m	54 dBµV/m

*Depends on the power class.
** Depends on the number of channels being used.

Table 3: ETSI and FCC Limits

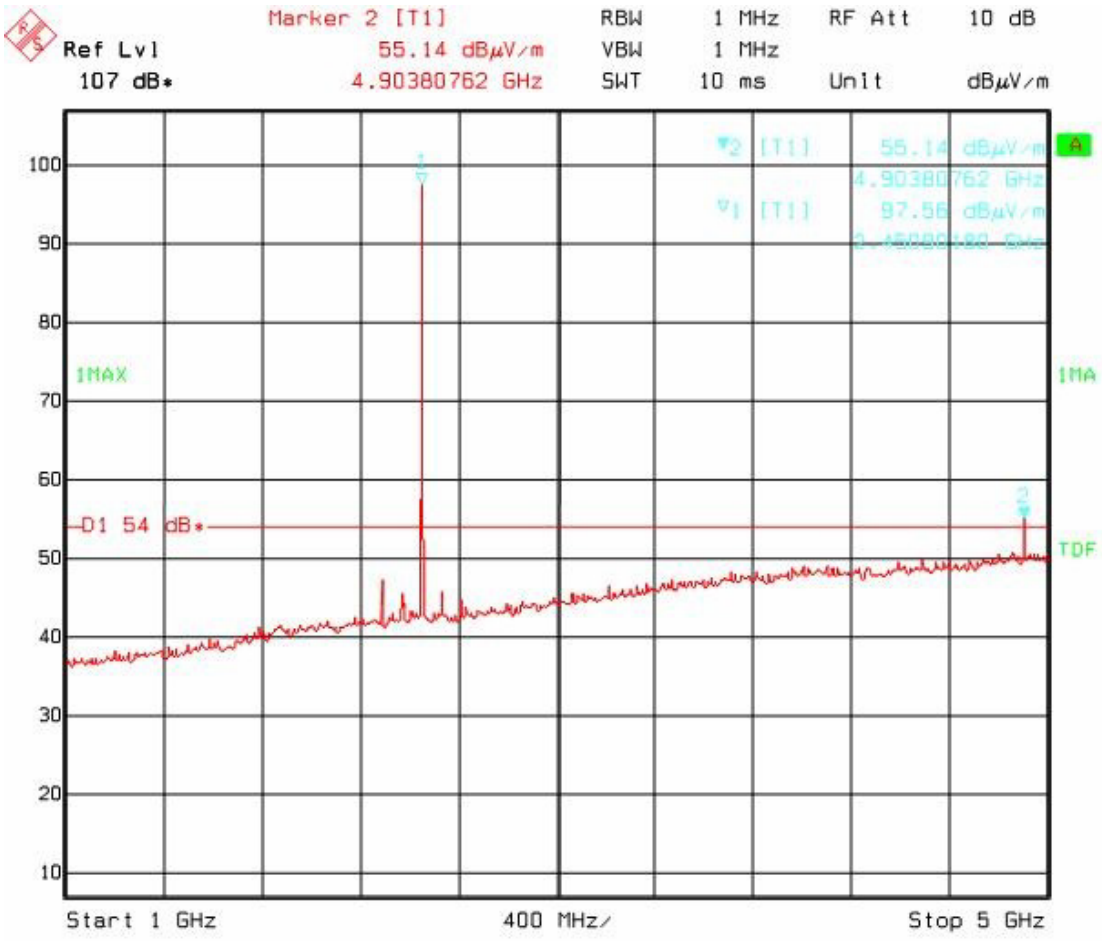


Figure 17: TX Spurious Emission 1 – 5 GHz

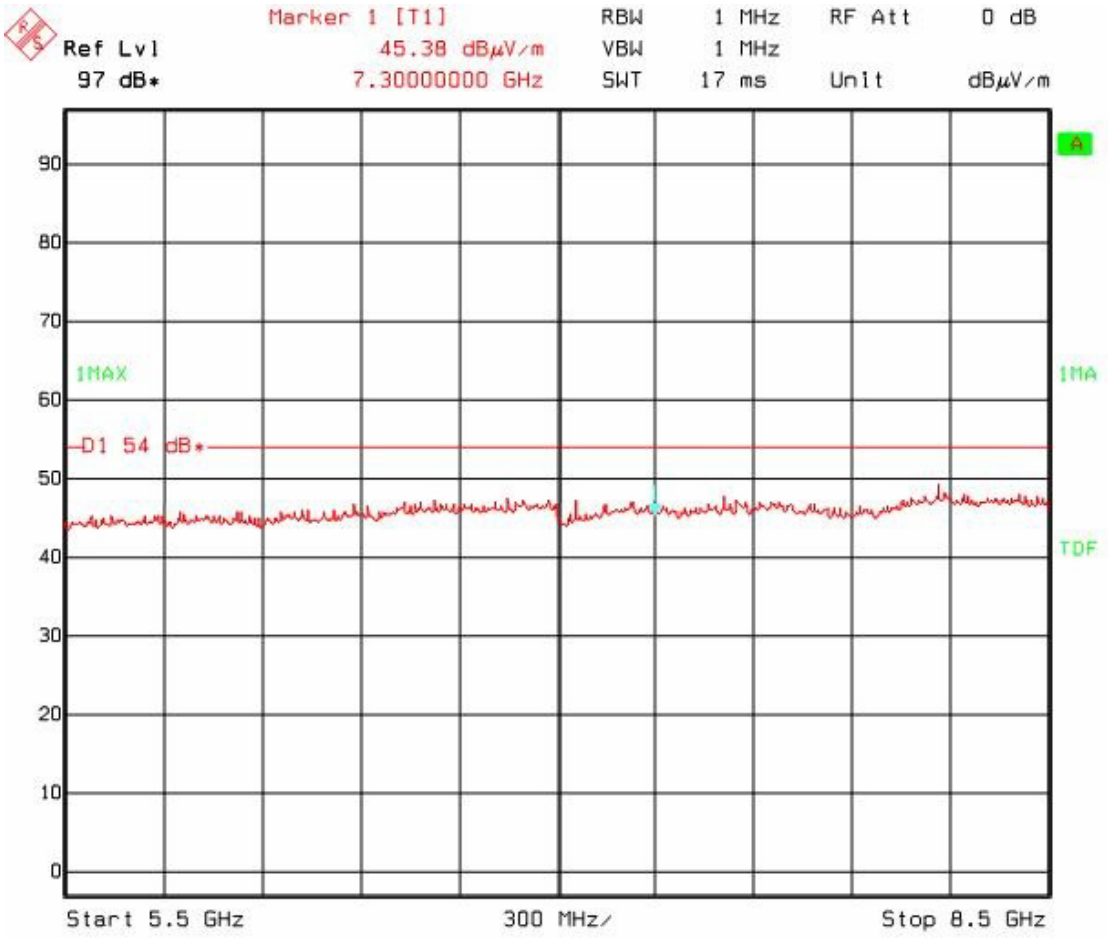


Figure 18: TX Spurious Emission 5.5 – 8.5 GHz

As opposed to FCC, ETSI has specific RX emission requirements. Table 4 and Table 5 list the ETSI RX spurious requirements.

	Narrowband spurious emission	Wideband spurious emission
30 MHz to 1 GHz	-57 dBm	-107 dBm/Hz
1 GHz to 12.75 GHz	-47 dBm	-97 dBm/Hz

Table 4: EN 300 328 RX Spurious Requirements

25 MHz to 1 GHz	-57 dBm
1 GHz to 10 times the carrier frequency*	-47 dBm

*Applies for equipment operating between 1 GHz and 20 GHz.

Table 5: EN 300 440 RX Spurious Requirements

The only signal detected above the noise floor when measuring RX spurious emission was the VCO leakage at 4.89 GHz. Figure 19 shows that the measured VCO leakage is below ETSI limits.

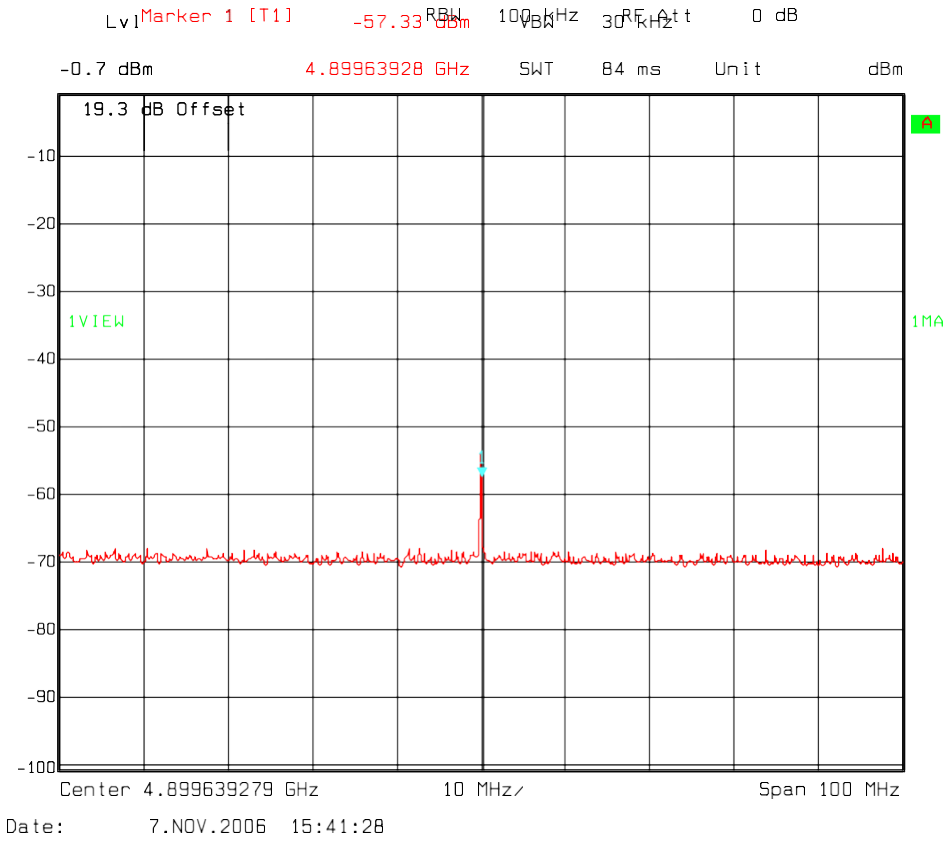


Figure 19: RX Spurious Emission

6 CONCLUSION

This application note shows that it is possible to implement a 2.4 GHz antenna on a small area and still achieve good performance. Table 6 lists the most important properties of the Inverted F Antenna, described in this document. The free line of sight (LOS) range was measured with 250 kbps and 1 % PER.

Gain in XY plane	4.0dB
Gain in XZ plane	3.3 dB
Gain in YZ plane	3.3 dB
Gain in XY plane, connected to laptop	3.3 dB
LOS range	240 m
Antenna size	15.2 x 5.7 mm

Table 6: IFA Properties (Measured on CC2511 Dongle Reference Design)

The results provided in section 5 shows that it is possible to comply with both ETSI and FCC regulations when implementing the suggested antenna together with CC2511 on a USB dongle.

7 GENERAL INFORMATION

7.1 Document History

Revision	Date	Description/Changes
SWRA117D	2008-04-04	Changed CCZACC06 to CC2480
SWRA117C	2008-02-27	Added reference to CCZACC06 and CC2520
SWRA117B	2007-06-01	Changed name of document
SWRA117A	2007-01-08	Added more dimensions in Figure 3 and Table 1
SWRA117	2006-11-28	Initial release.