Small Size 2.4 GHz PCB antenna

1 KEYWORDS

- *PCB antenna*
- *2.4 GHz*
- *Inverted F Antenna*

2 INTRODUCTION

The PCB anteena used on Button control design no more than 16x5 mm of space and ensures a VSWR ratio of less than 2 across the 2.4 GHz wihen connected to a 50 ohm source.

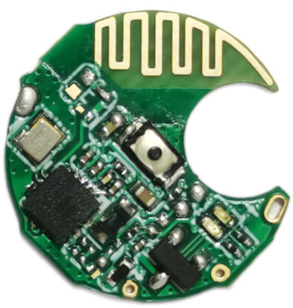


Figure 1: Button control

4 ANTENNA DESIGN

The PCB antenna on the button control 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 button control and to obtain good performance also when the button control 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.

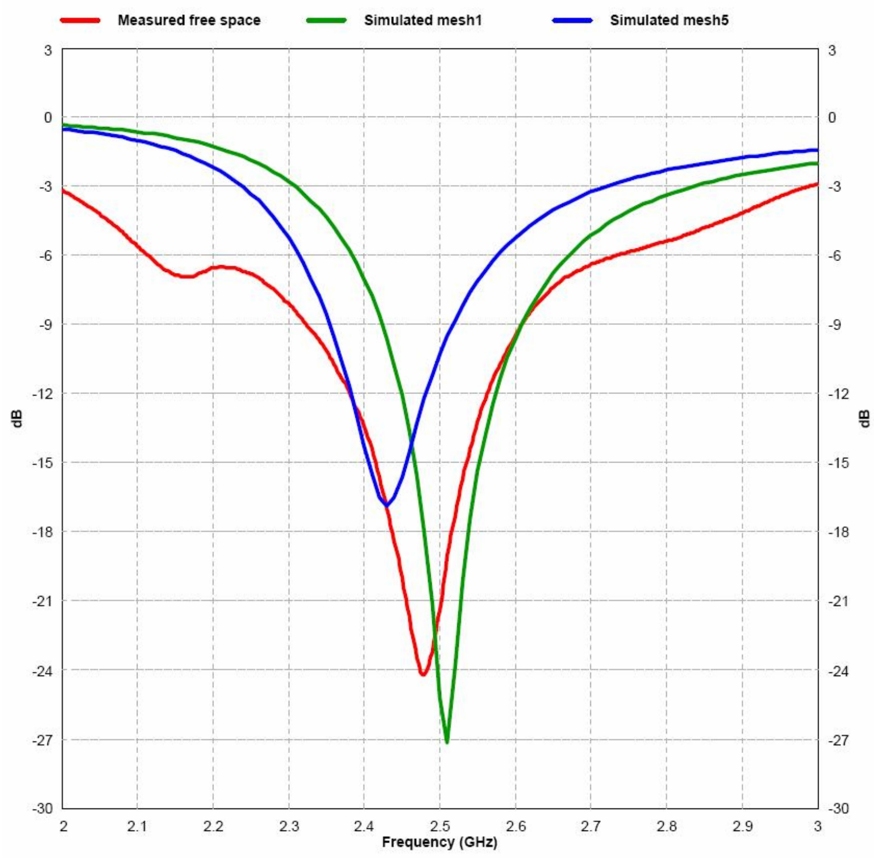


Figure 2: Comparison of Simulation and Measurements Results

4.3 Antenna Information

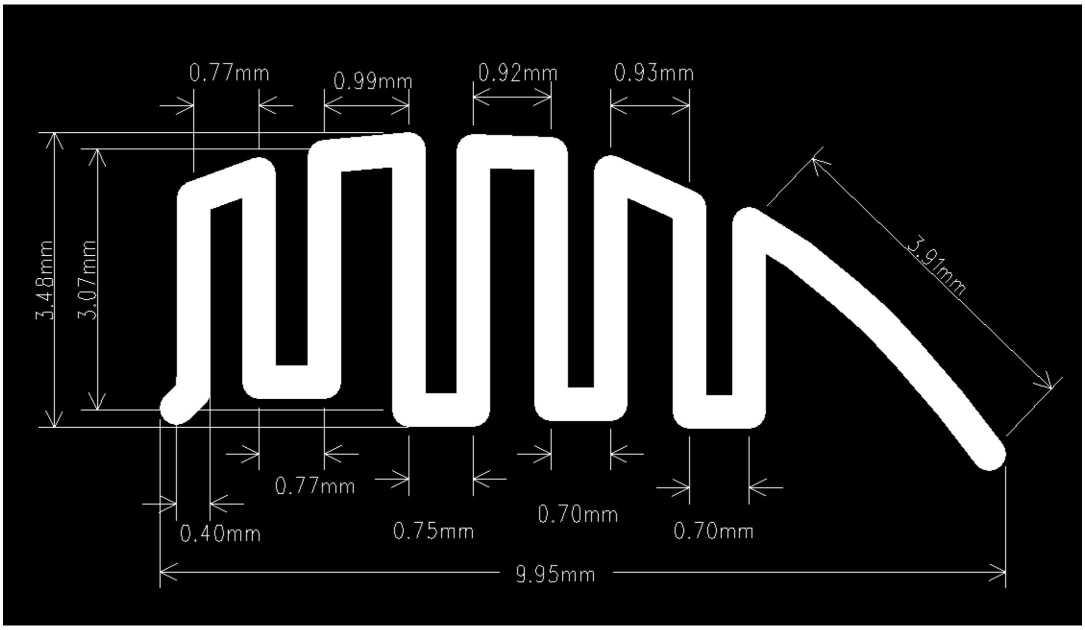
Antenna Model: PCB antenna for Button control

Part number: CH02000607

Manufacturer: Gospell Digital Technology Co., Ltd.

Address: Gospell Industrial Park, Suxian District, Chenzhou City, Hunan Province, China

Antenna demension: 10.0x3.5 mm



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 button control in free space and when connected to a laptop were performed to verify that the antenna is suitable both for button control designs and in a standalone application. Free space is in this document interpreted as a measurement performed without connecting the button control to a computer. In such a measurement the button control 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.

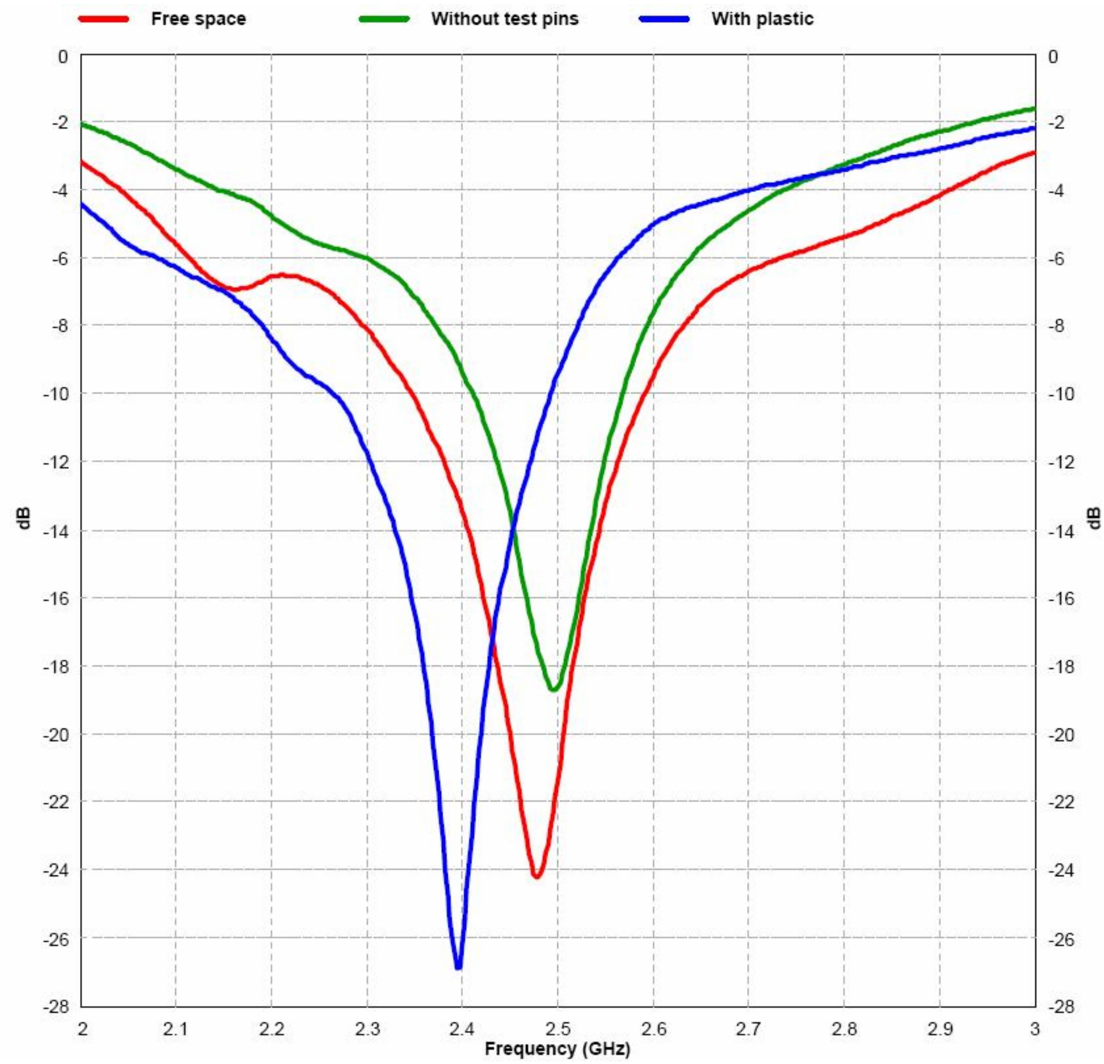


Figure 4: Influence of Plastic Encapsulation and Test Pins

A small part on the button control 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 button control 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 button control 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 button control is connected to a laptop. In free space the antenna has a bandwidth of approximately 250 MHz. When the button control 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.

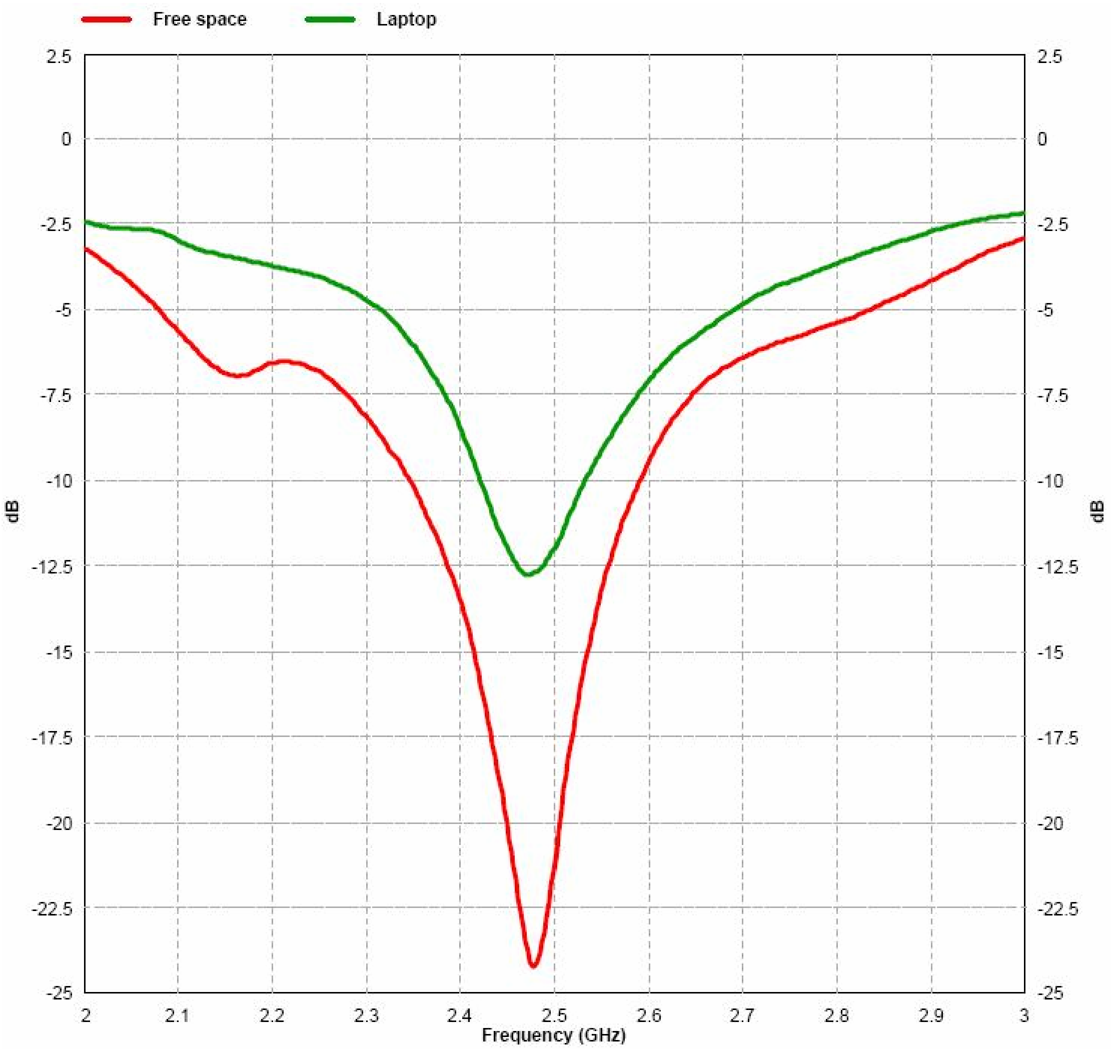


Figure 5: Comparison of Performance

5.2 Radiation Pattern

The radiation pattern for the antenna implemented on the button control reference design has been measured in an anechoic chamber. Figure 7 through Figure 12 shows radiation patterns for three planes, XY, XZ and YZ, measured with vertical and horizontal polarization. All these measurement were performed without connecting the button control to a computer. Figure 13 and Figure 14 shows the radiation pattern when the button control is connected to a laptop. All measurements were performed with 0 dBm output power. Figure 6 shows how the different radiation patters are related to the positioning of the antenna.

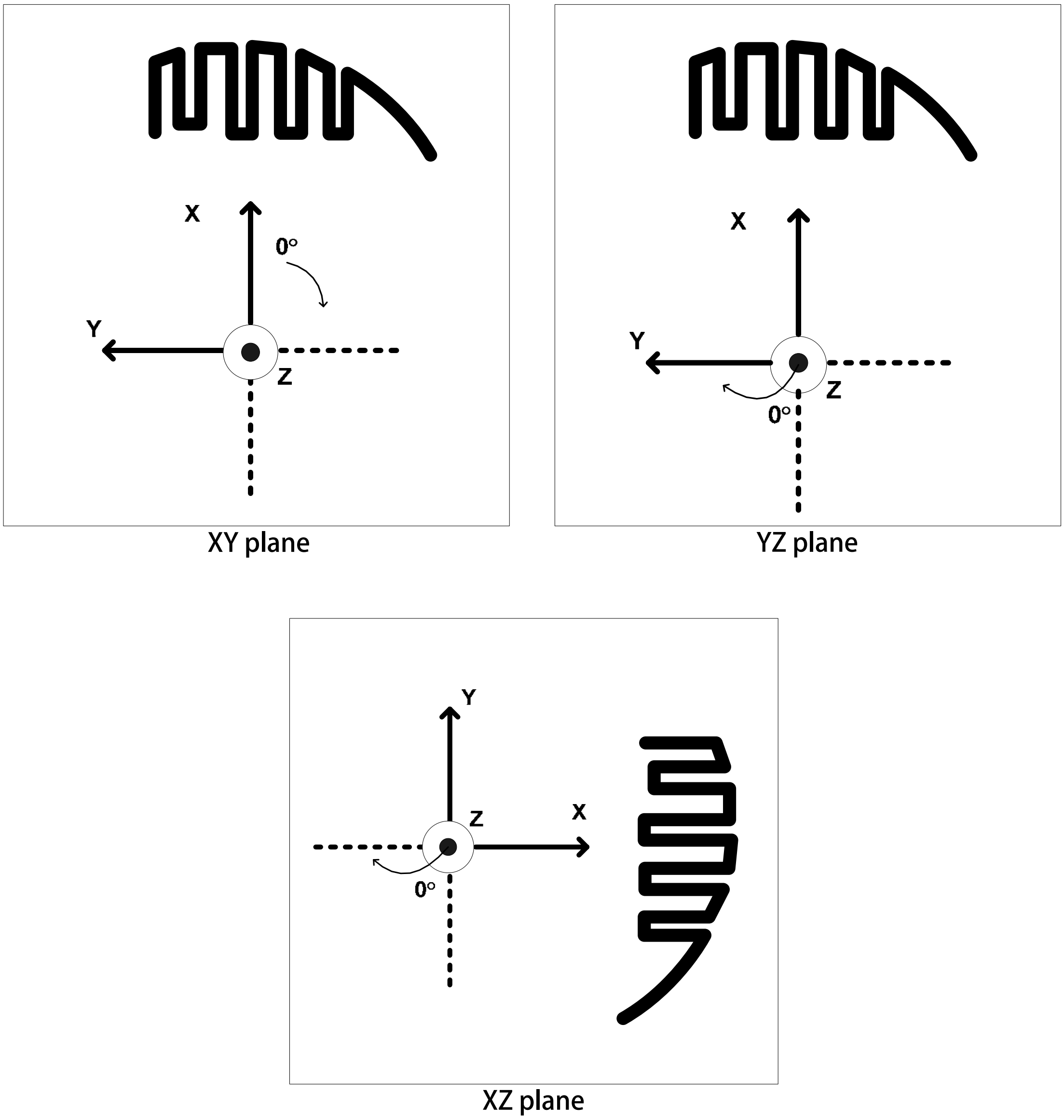
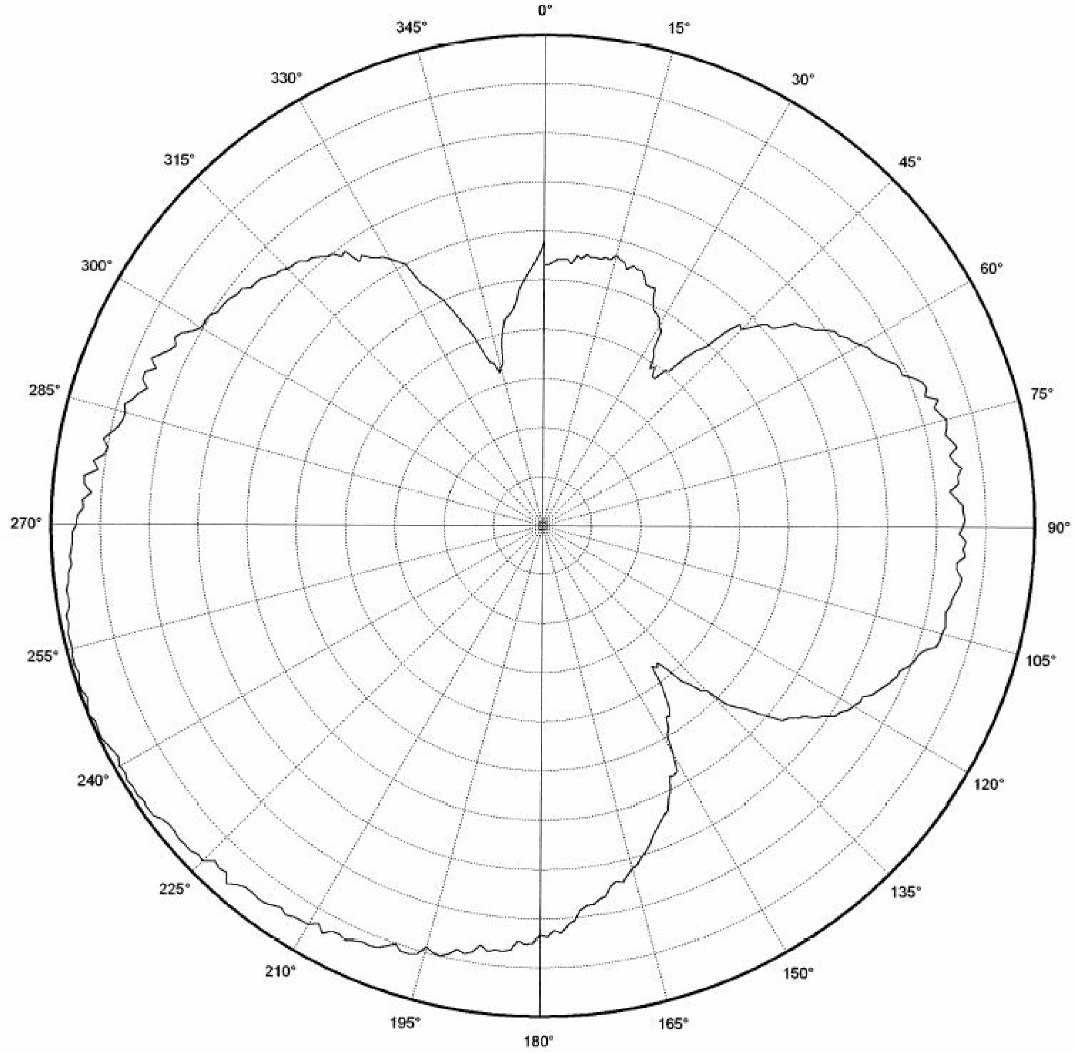


Figure 6: How to Relate the Antenna to the Radiation Patterns

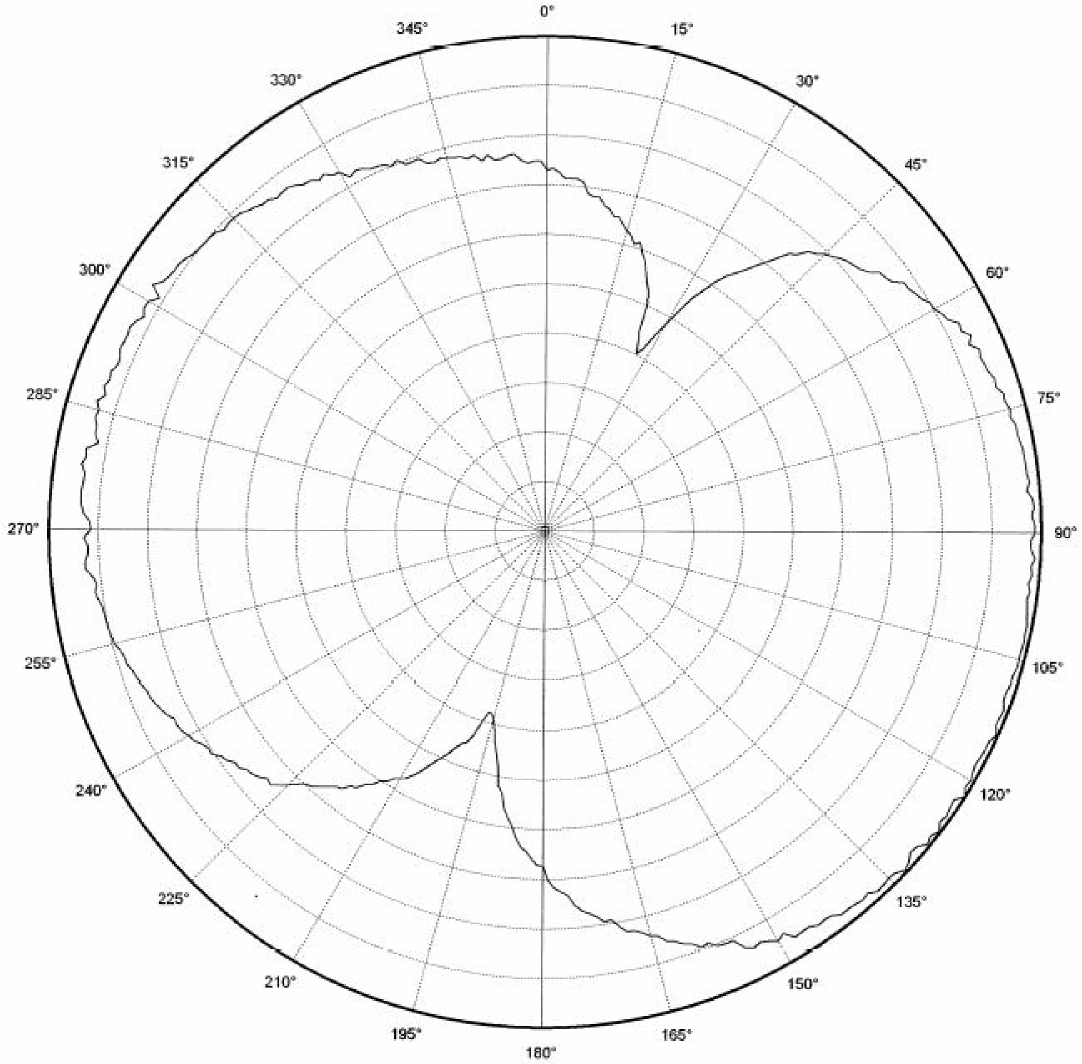


Vertical Polarization

usb XY

CF 2450.000 MHz
4 dB/ div
Ref Lev: -2,5 dBm

Figure 7: Button Control XY Plane



Horisontal Polarization

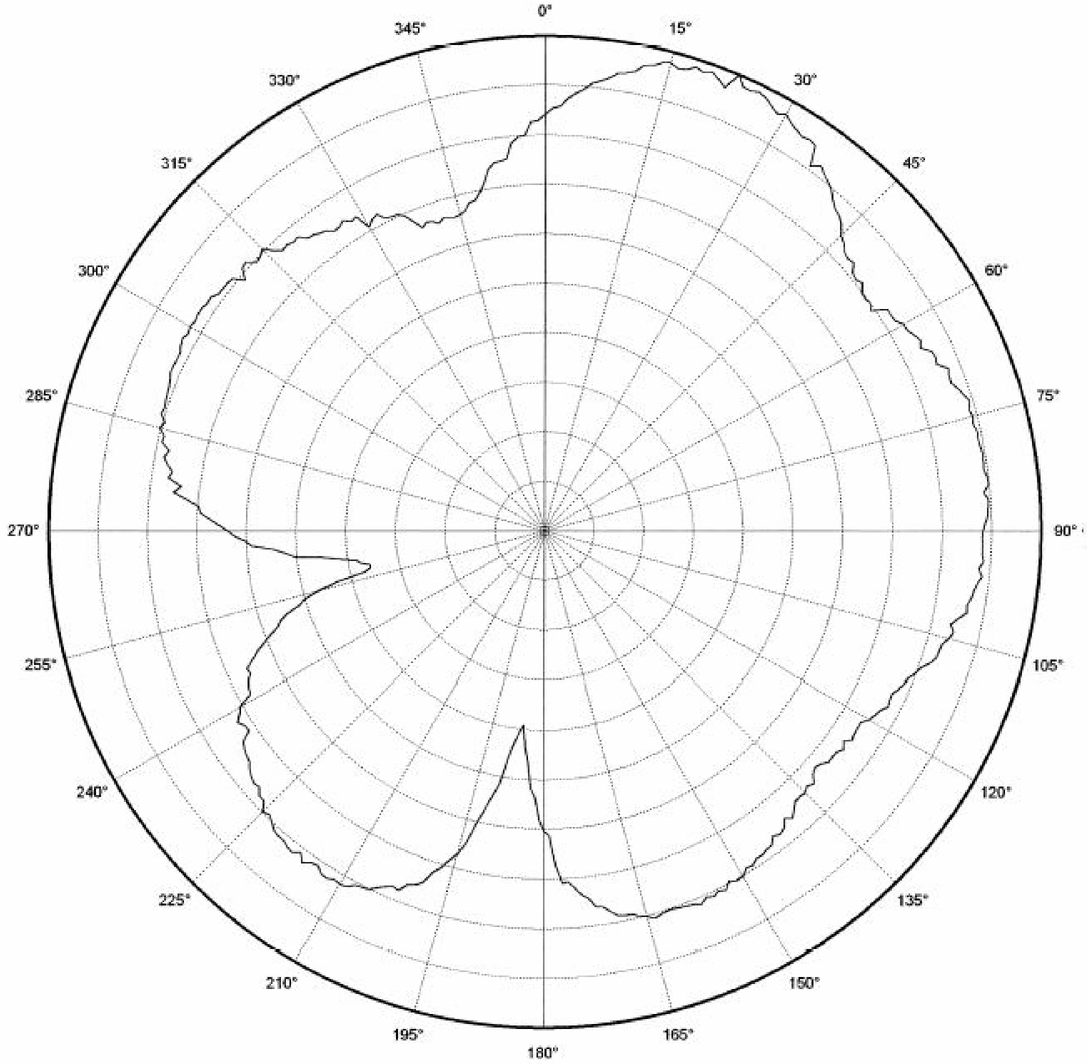
usb XY

CF 2450.000 MHz

5 dB/ div

Ref Lev: 4,5 dBm

Figure 8: Button Control XY Plane



Vertical Polarization

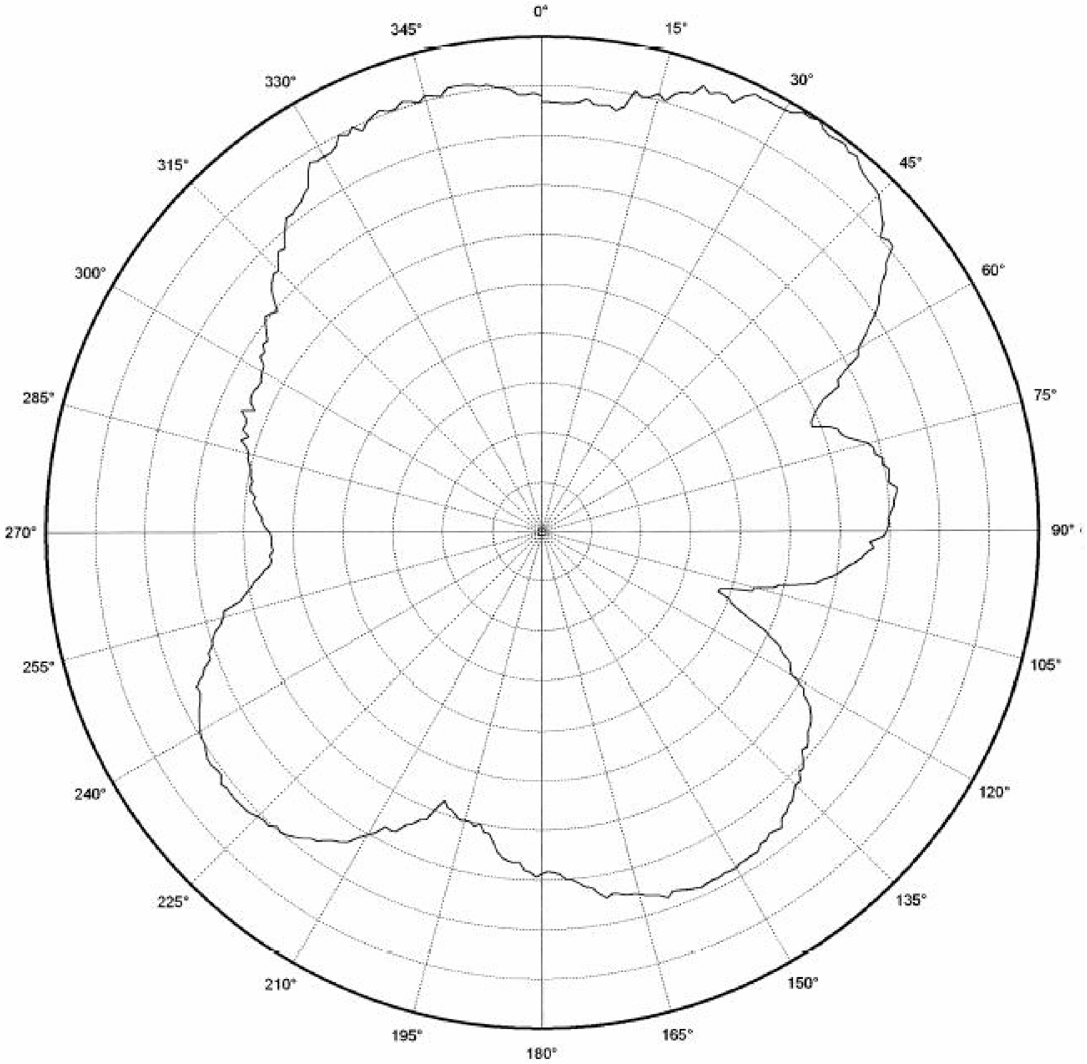
usb XZ

CF 2450.000 MHz

4 dB/ div

Ref Lev: 2.2 dBm

Figure 9: Button Control XZ Plane



Horisontal Polarization

usb XZ

CF 2450.000 MHz

4 dB/ div

Ref Lev: ...5.3... dBm

Figure 10: Button Control XZ Plane

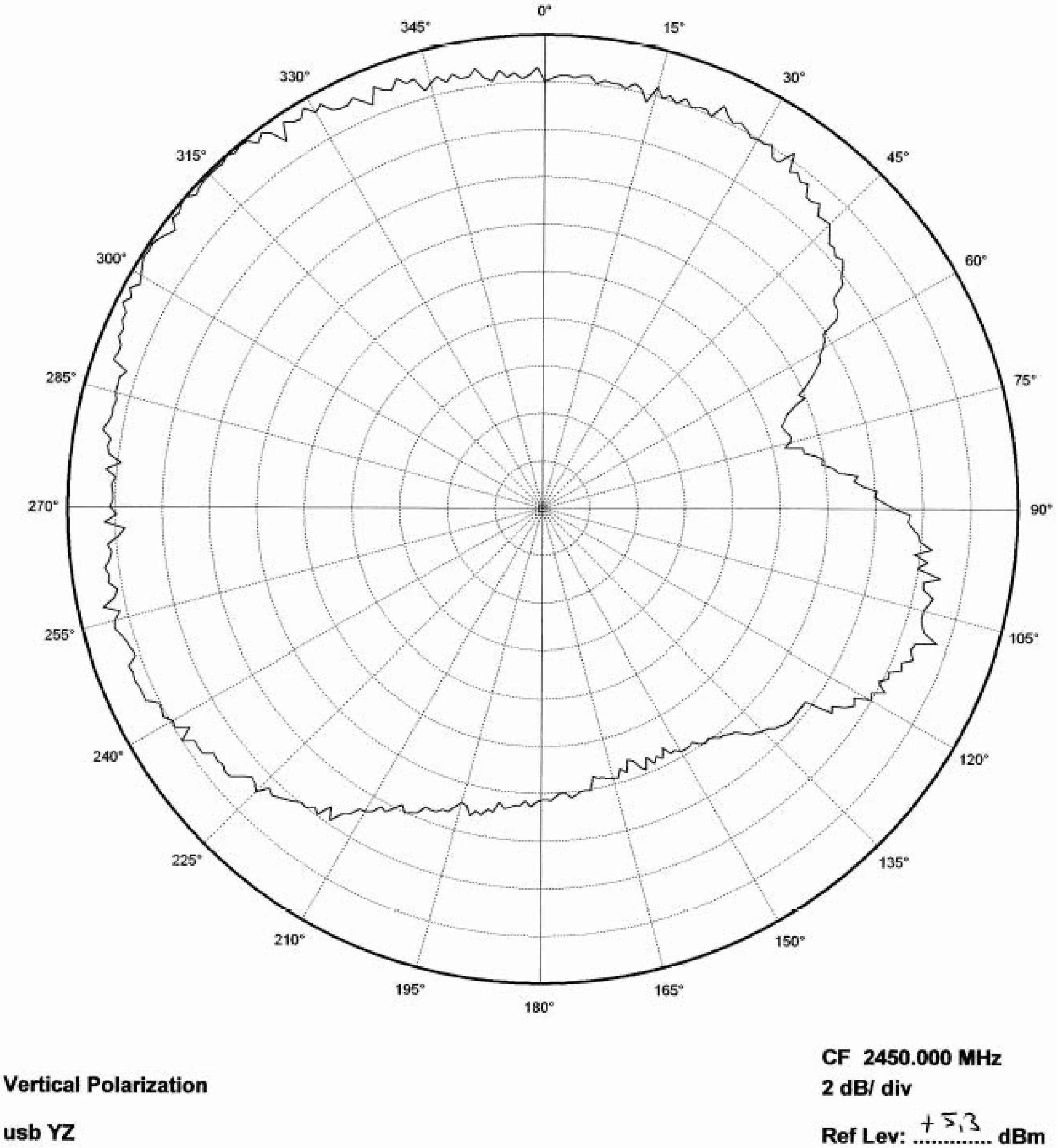
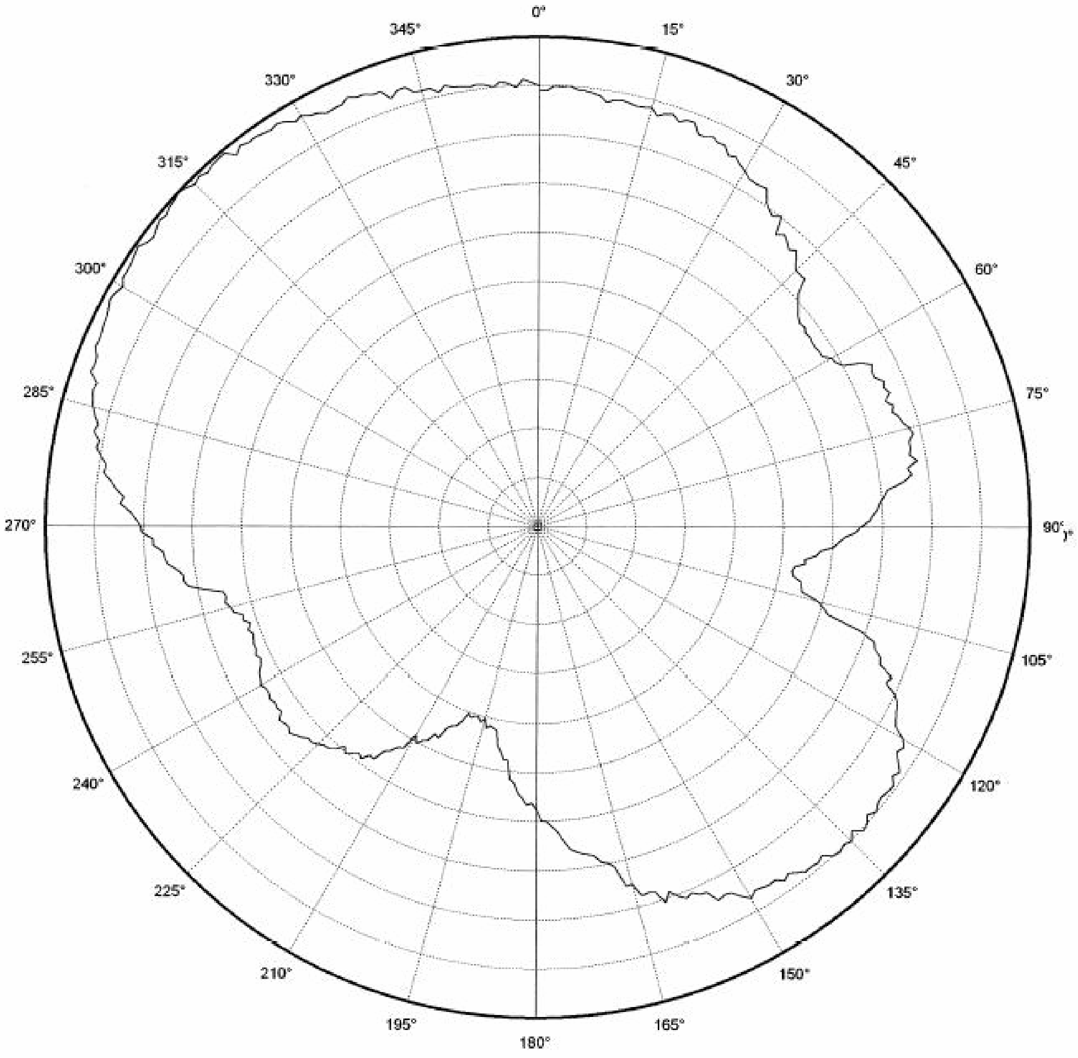


Figure 11: Button Control YZ Plane



Horisontal Polarization

usb YZ

CF 2450.000 MHz

3 dB/ div

Ref Lev: -1,2 dBm

Figure 12: Button Control YZ Plane

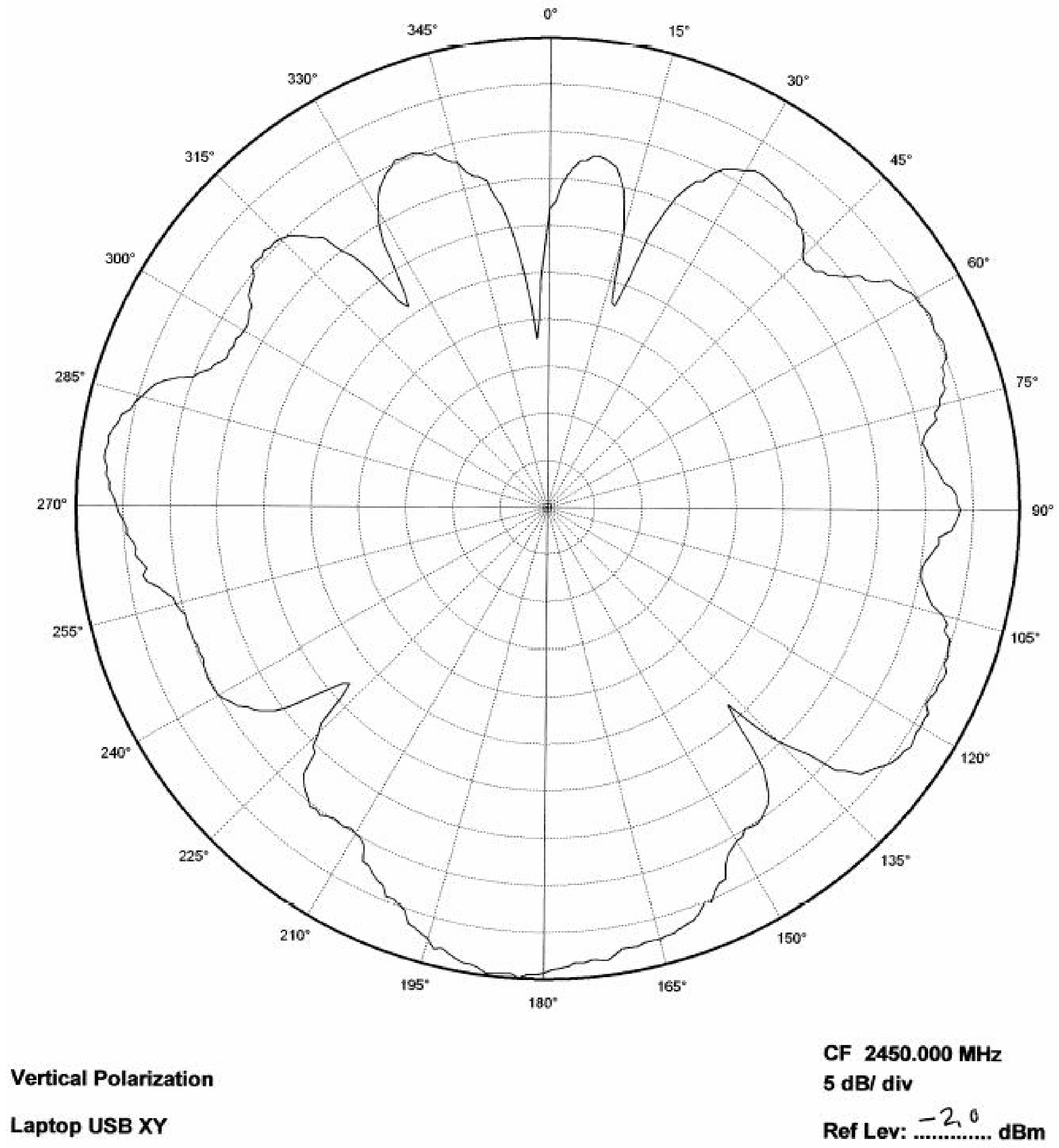


Figure 13: Button Control in Laptop XY Plane

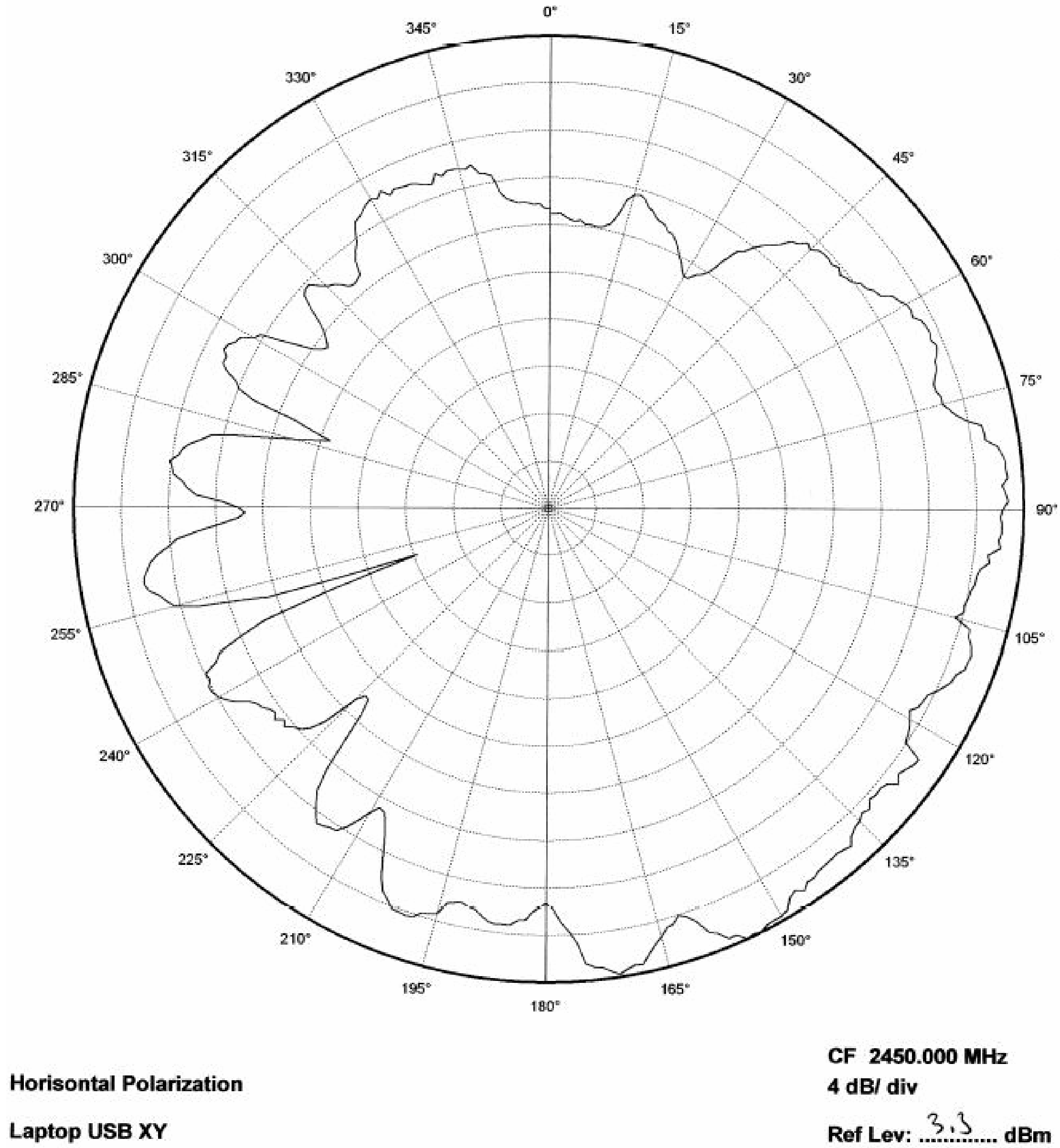


Figure 14: Button Control in Laptop XY Plane

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 button control 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.

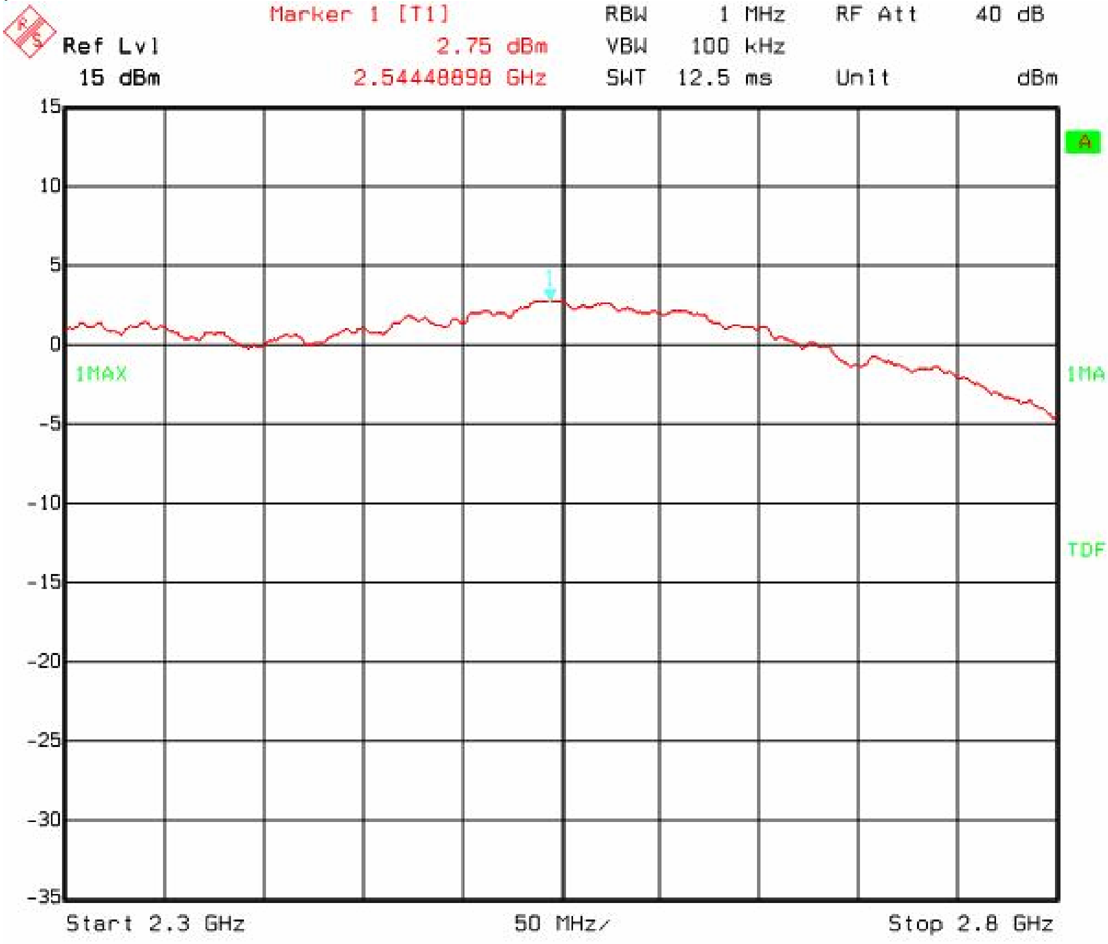


Figure 15: Output Power, Button Control

The reflection results in Figure 5 indicate that the output power will be slightly reduced when the button control 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 button control is connected to a laptop. This agrees with the results in Figure 5.

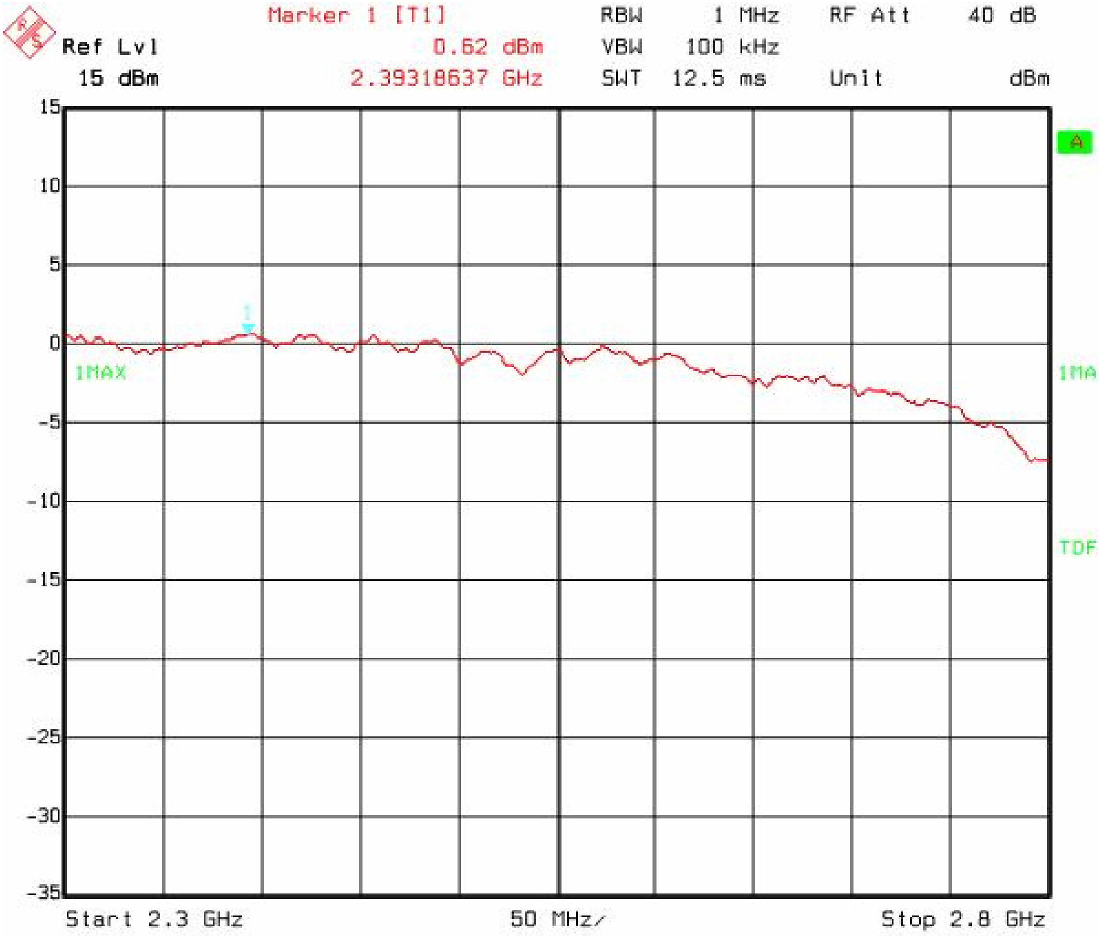


Figure 16: Output Power, Button Control in Laptop

5.4 Spurious Emission and Harmonics

Table 2 shows measured output power and emi ssion at the second har monic. Above the second harmonic no peaks were detected when m easuring 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 spur ious emission are shown in Table 3. FCC allows for up to 20 dB higher emission if duty cyc ling 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

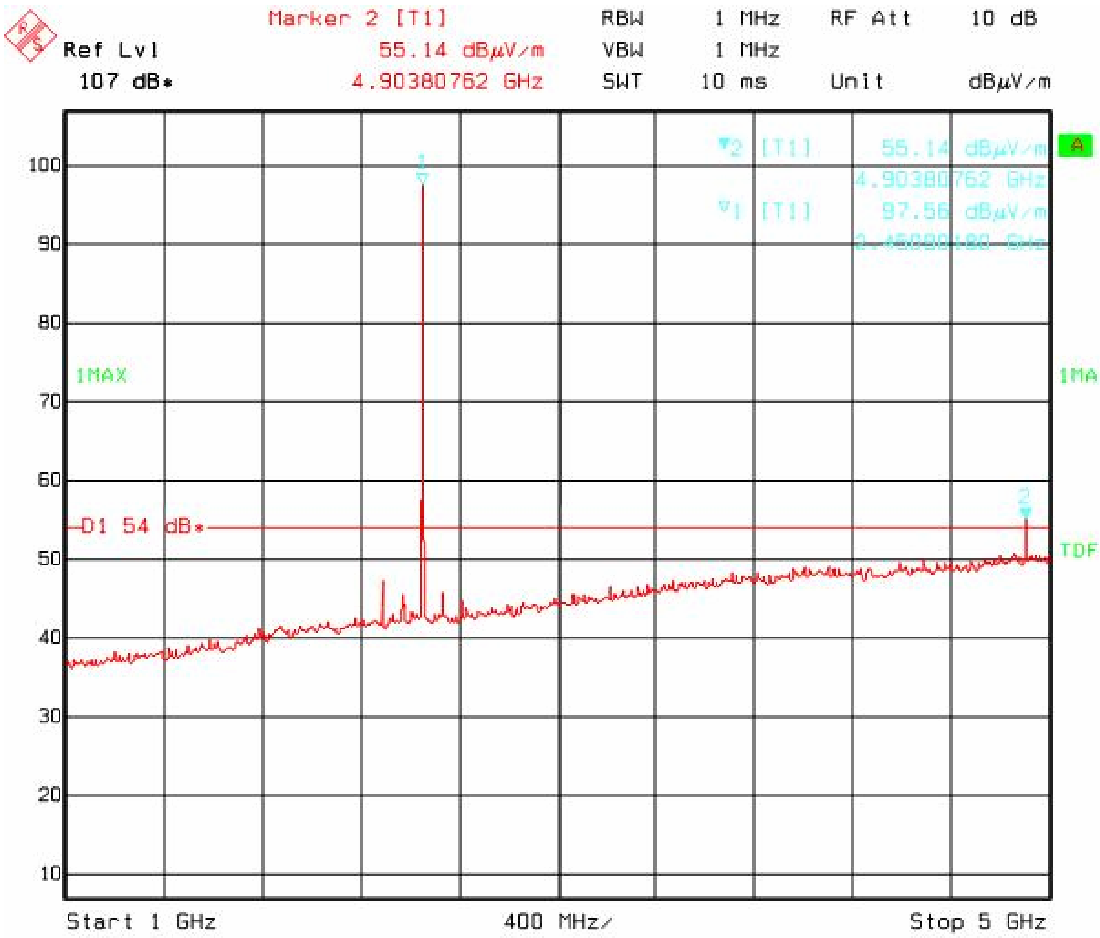


Figure 17: TX Spurious Emission 1 – 5 GHz

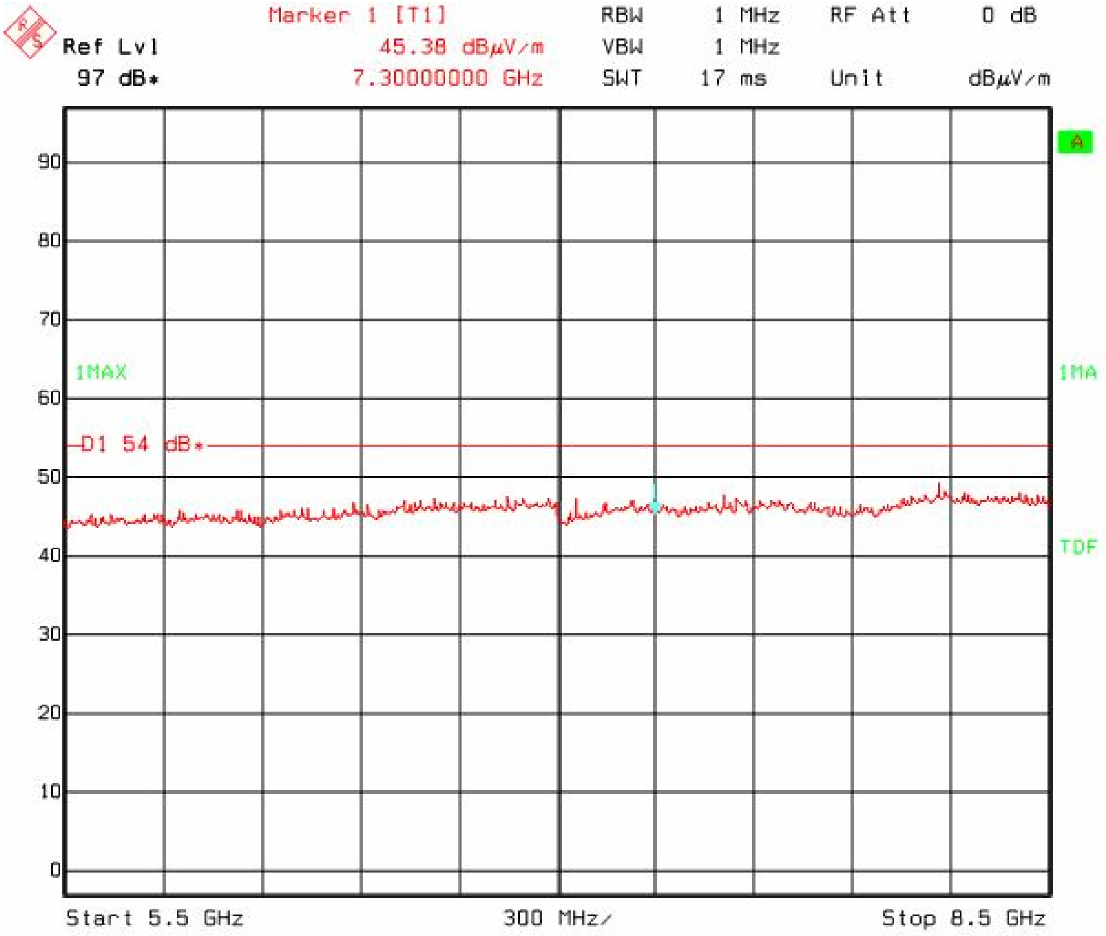


Figure 18: TX Spurious Emission 5.5 – 8.5 GHz

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.

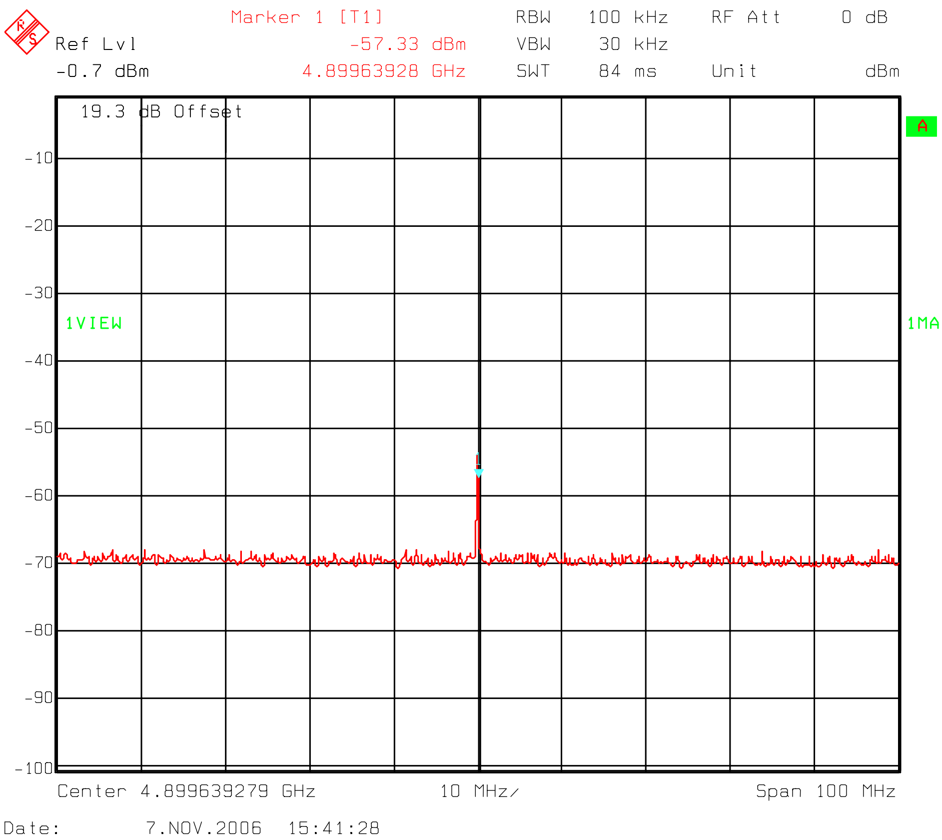


Figure 19: RX Spurious Emission

6 Efficiency and Gain

Freq (MHz)	Effi (%)	Gain (dBi)
2400	58.08	3.26
2410	61.8	3.74
2420	60.67	3.33
2430	57.81	3.27
2440	55.21	2.76
2450	52	2.32
2460	51.52	2.05
2470	50.93	2.11
2480	54.33	2.3
2490	52.72	1.94
2500	55.59	2.21