Small Size 2.4 GHz PCB antenna

1 INTRODUCTION

The PCB antenna used on the *TPL3135* reference design is described in this application note. Even if the antenna presented is for a TPL3135 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 11 x 2.5 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.

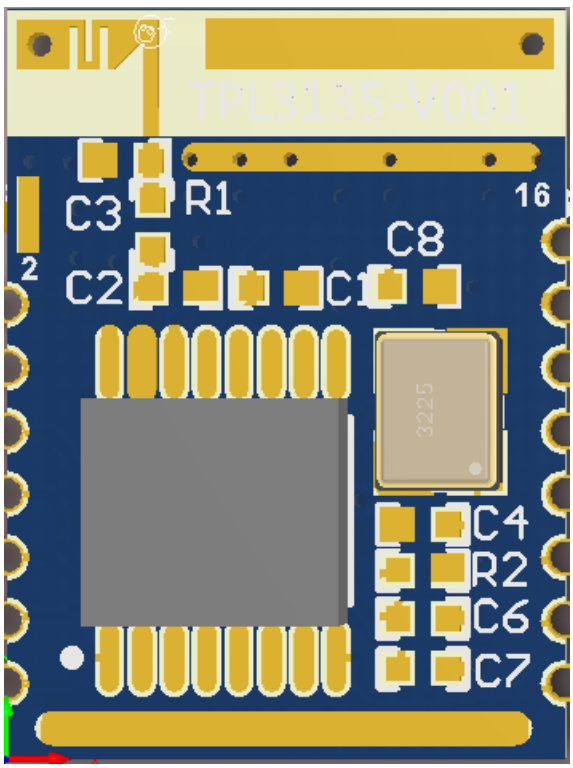


Figure 1 : TPL3135

2 ANTENNA DESIGN

The PCB antenna on the TPL3135 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.

2.1 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 TPL3135 and to obtain good performance also when the dongle is connected to a computer.

2.2 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.

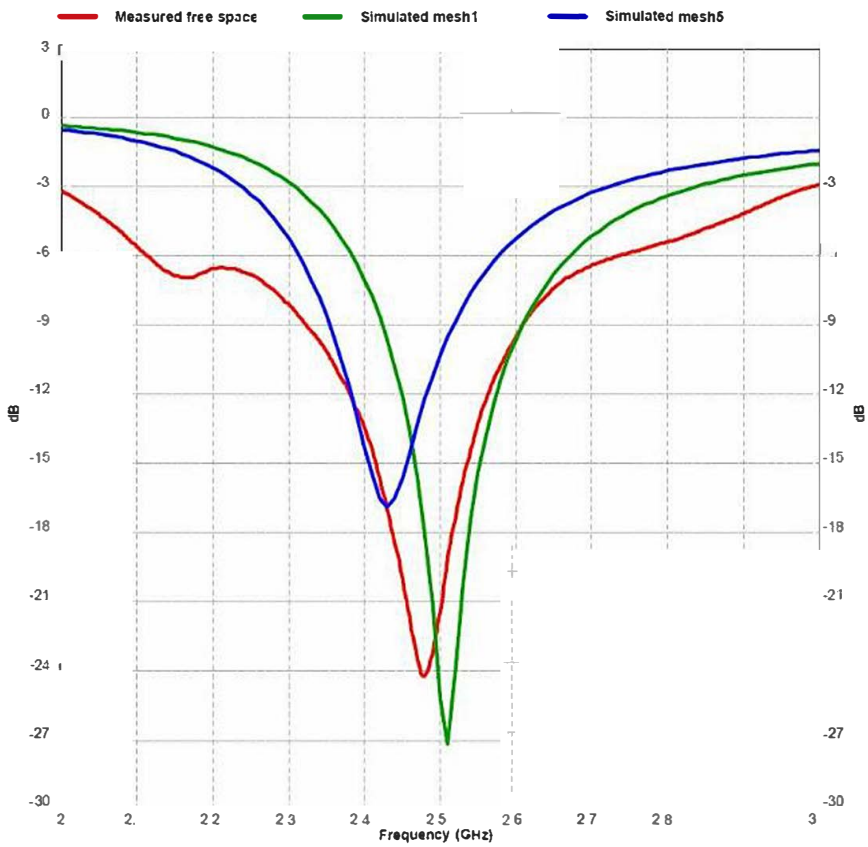


Figure 2: Comparison of Simulation and Measurements Results

2.3 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. 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.

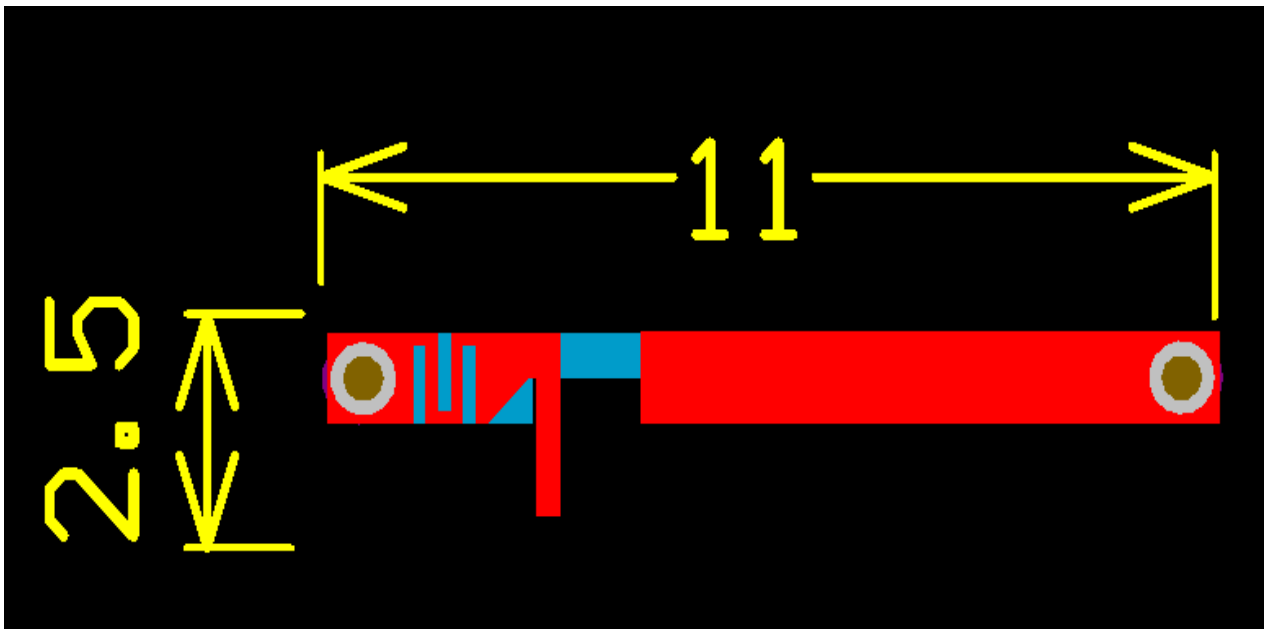


Figure 3: Antenna Dimensions

3 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 TPL3135 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.

3.1 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.

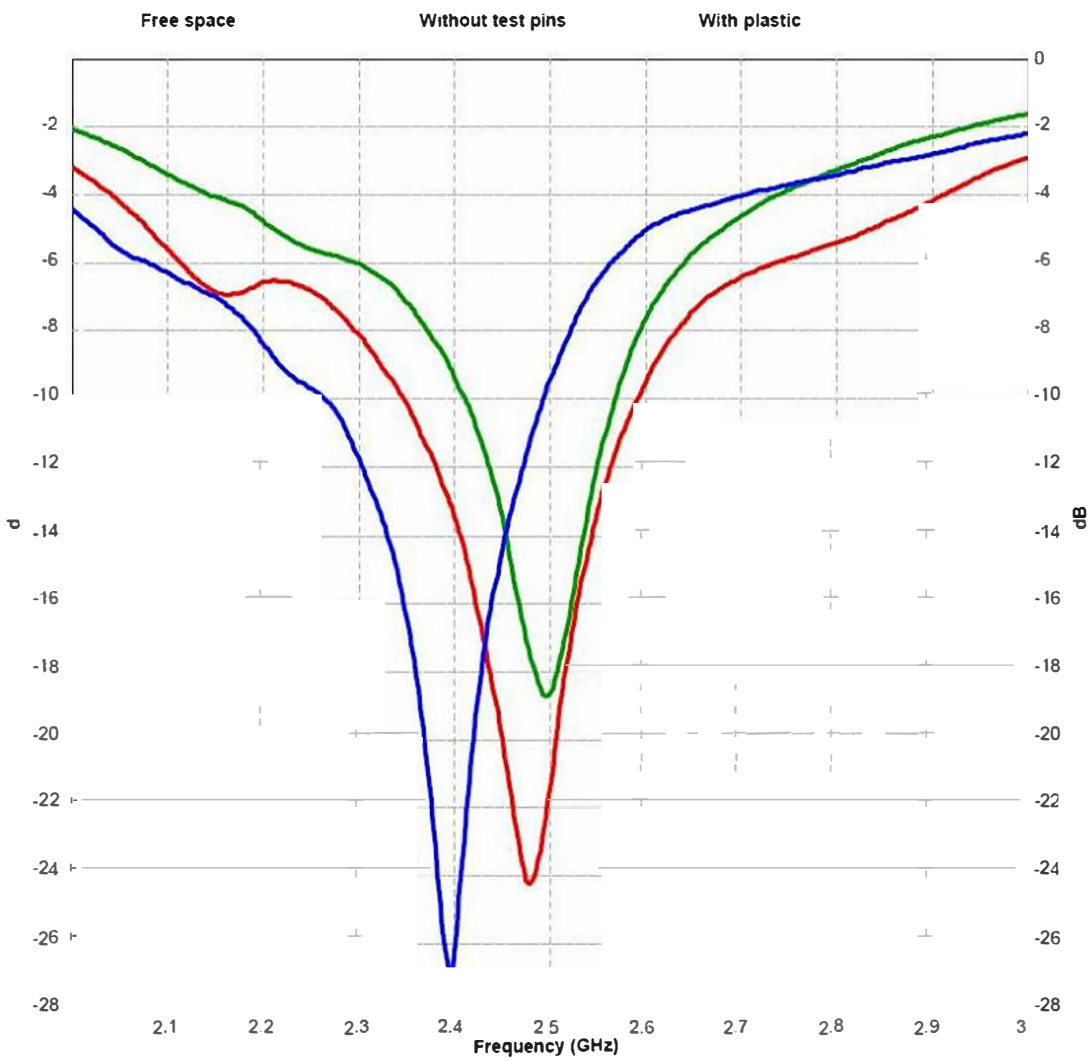


Figure 4: Influence of Plastic Encapsulation and Test Pins

A small part on the TPL3135 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 pe rformance. 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 TPL3135 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 TPL3135 is connected to a laptop. In free space the antenna has a bandwidth of approximately 250 MHz. When the TPL3135 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.

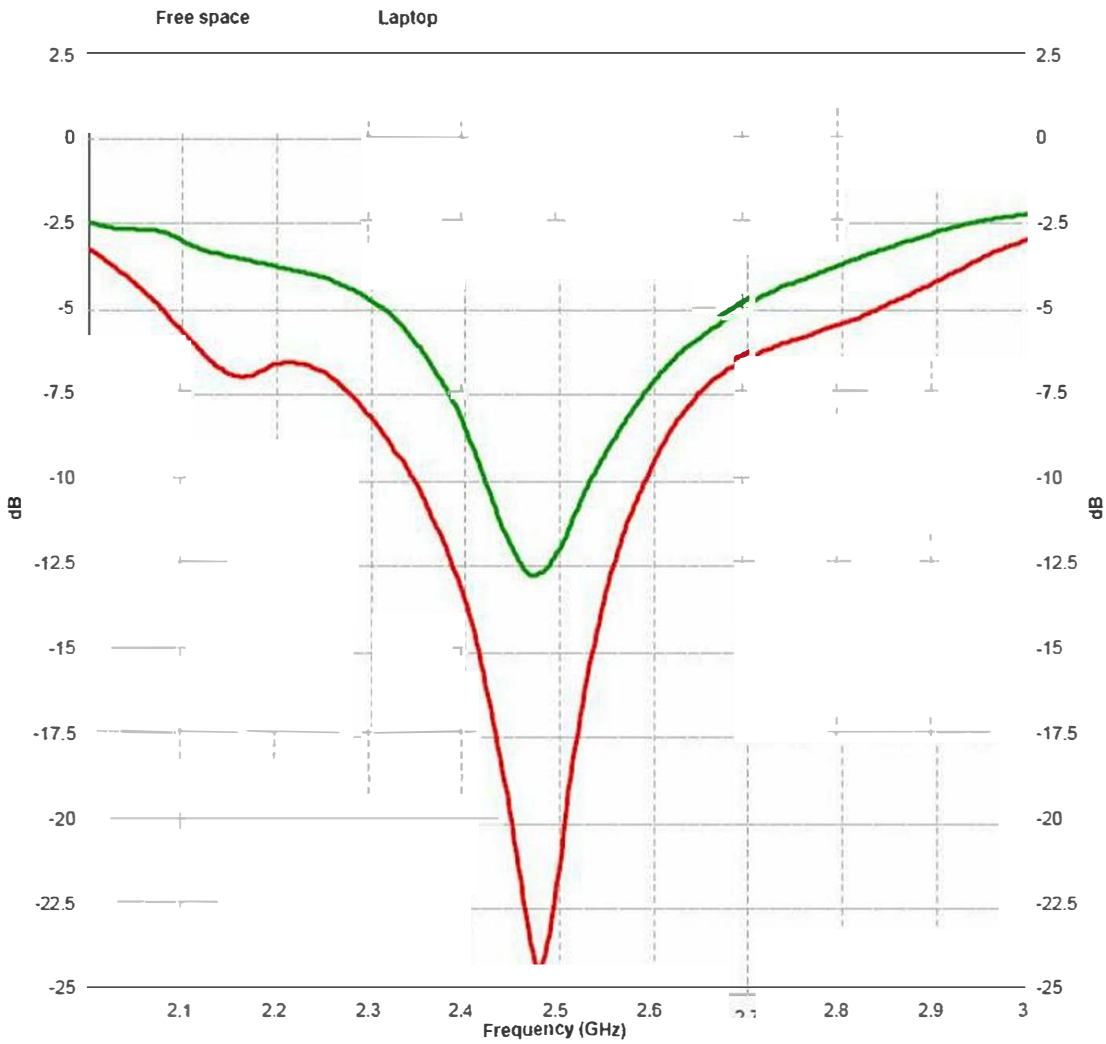


Figure 5: Comparison of Performance

3.2 Radiation Pattern

The radiation pattern for the antenna implemented on the TPL3135 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 dongle to a computer. Figure 13 and Figure 14 shows the radiation pattern when the dongle 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.

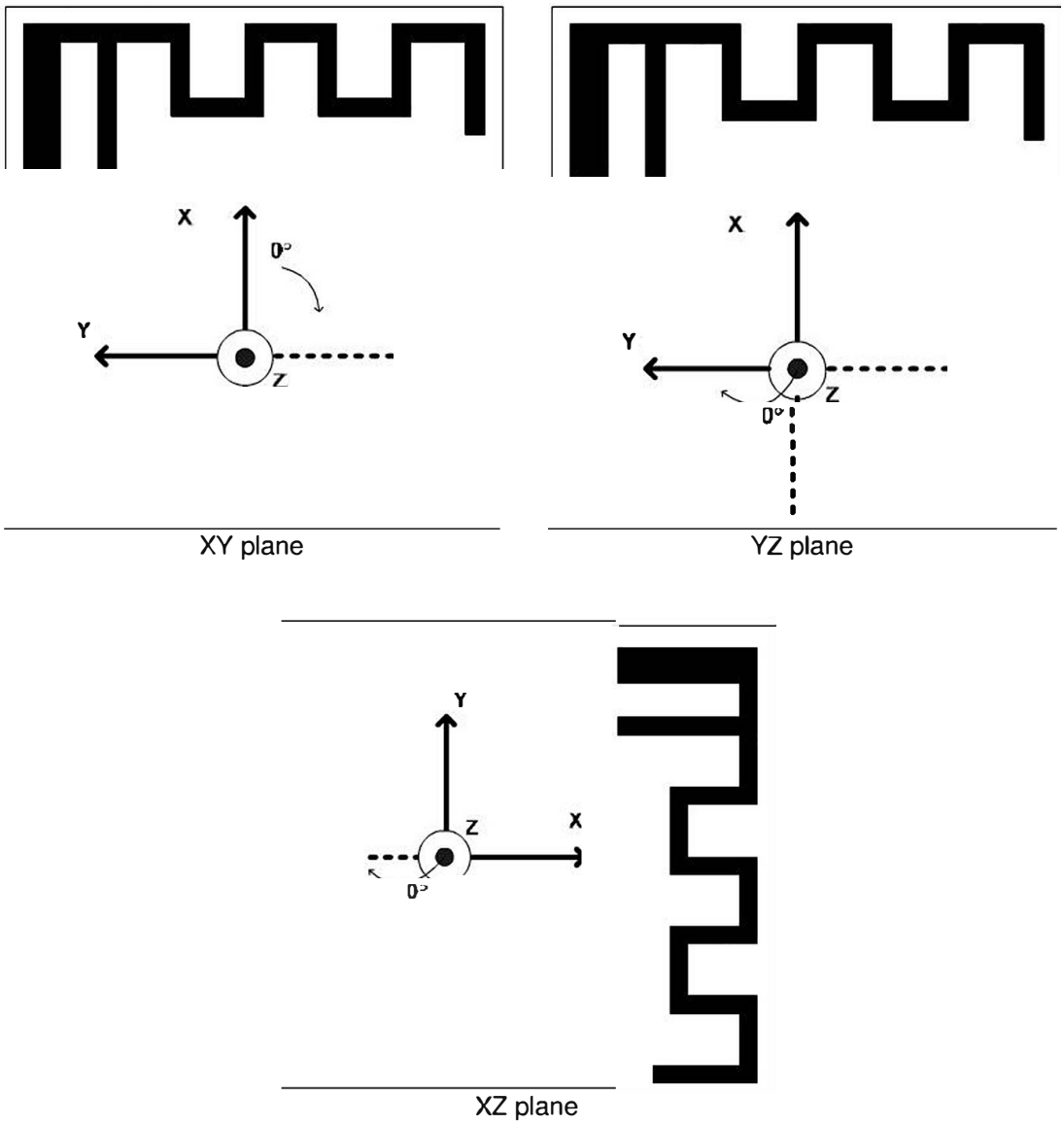
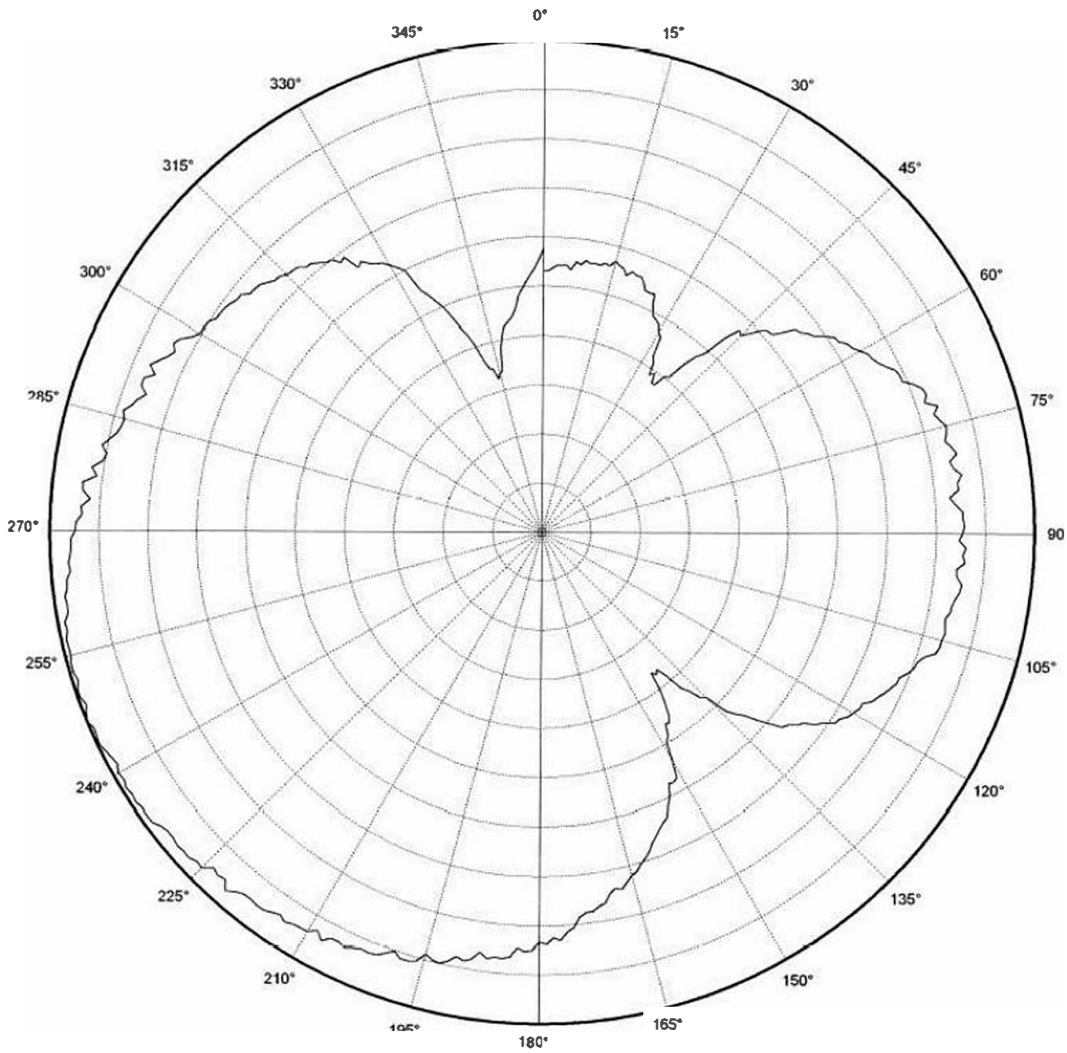


Figure 6: How to Relate the Antenna to the Radiation Patterns

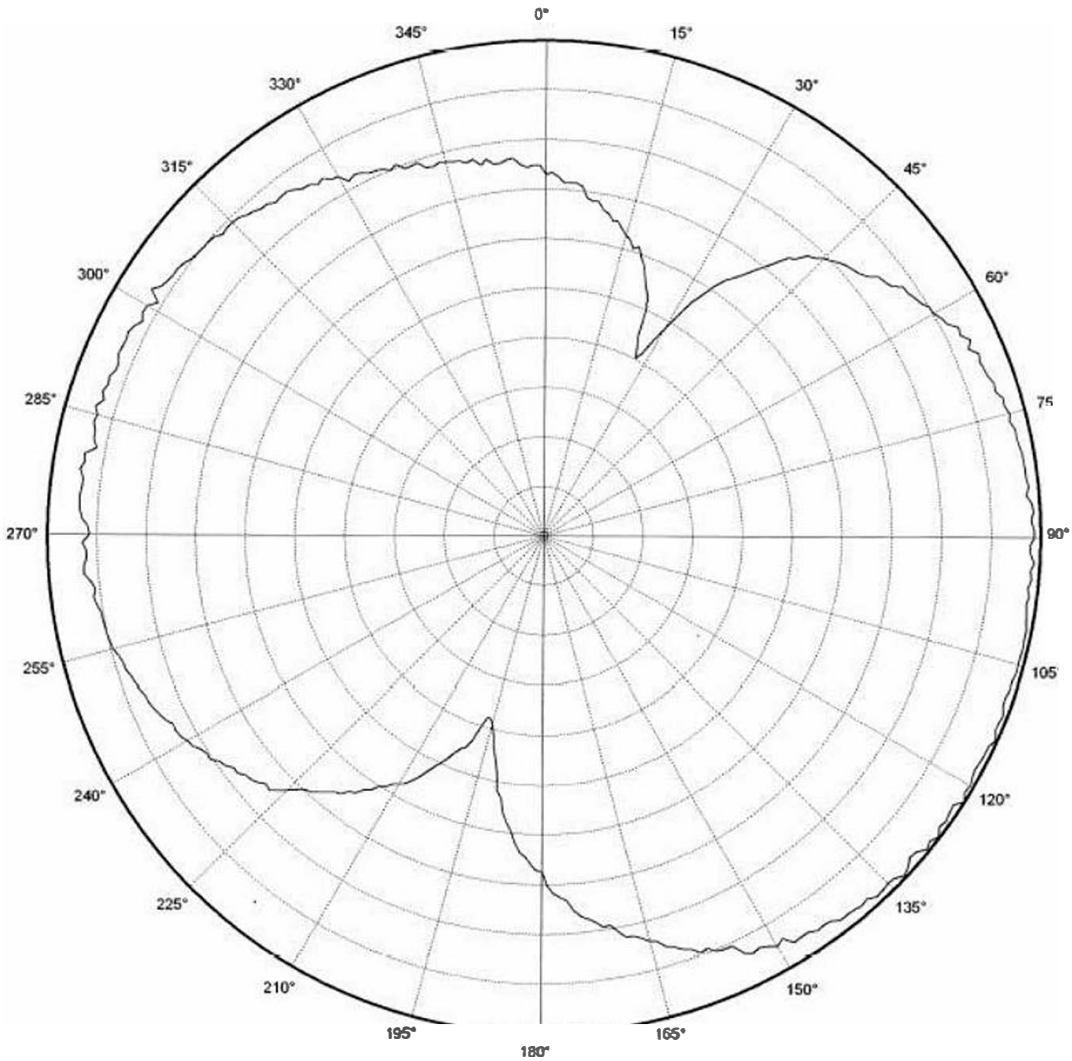


Vertical Polarization

usb XY

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

Figure 7: TPL3135 XV Plane

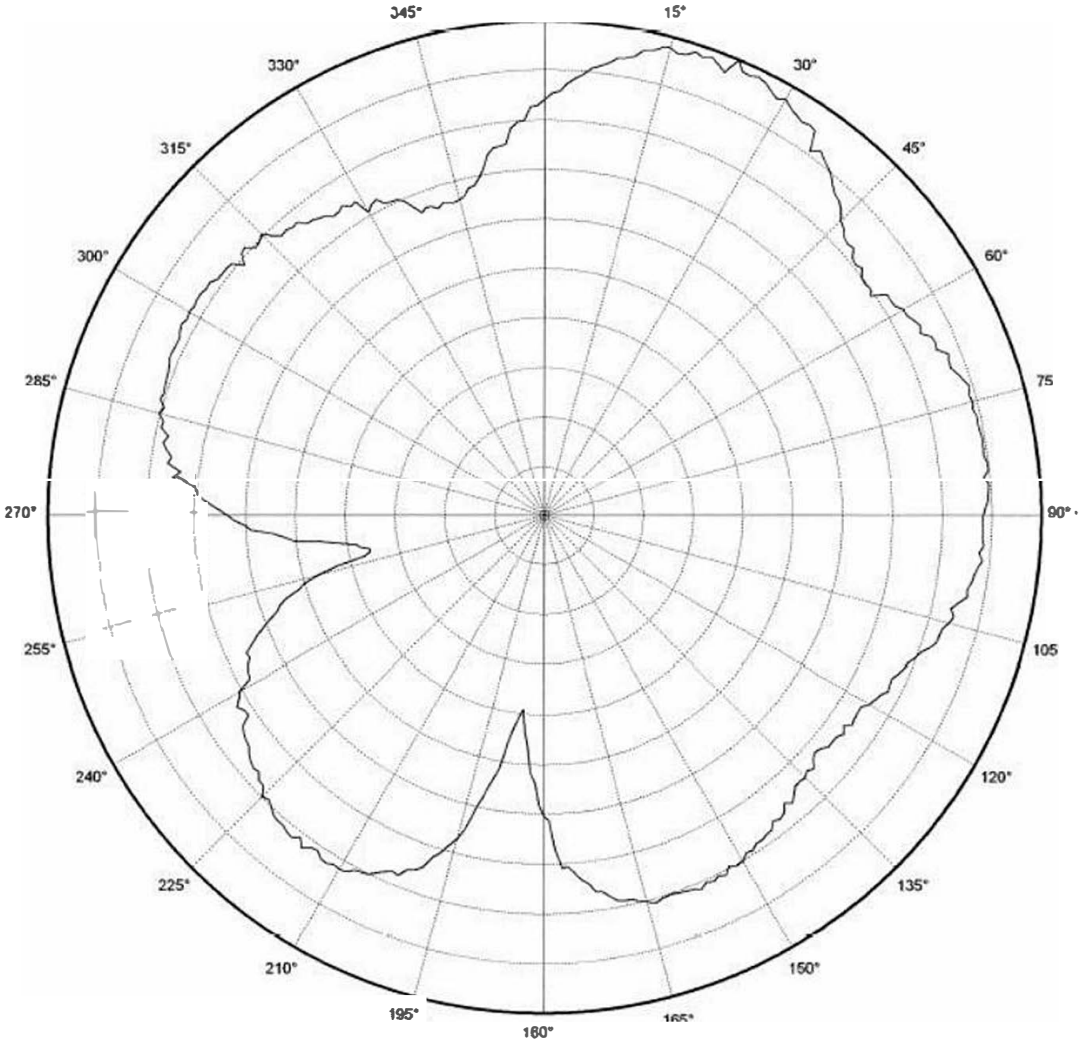


Horisontal Polarization

usb XY

CF 2450.000 MHz
5 dB/ div
Ref Lev: 4.5 dB

Figure 8: TPL3135 XV Plane

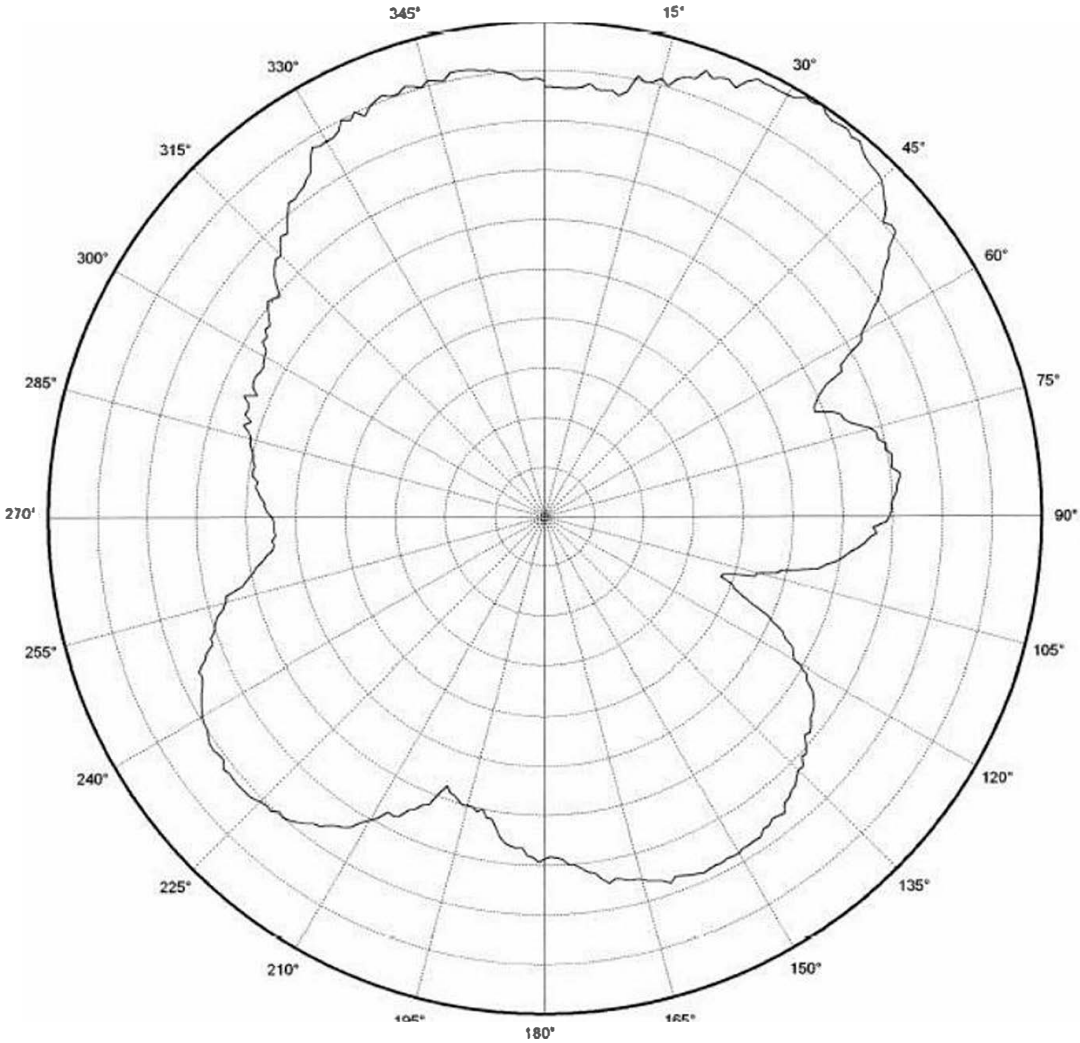


Vertical Polarization

usb XZ

CF 2450.000 MHz
4 dB/ div
Ref Lev: 2.2 dBm

Figure 9: TPL3135 XZ Plane

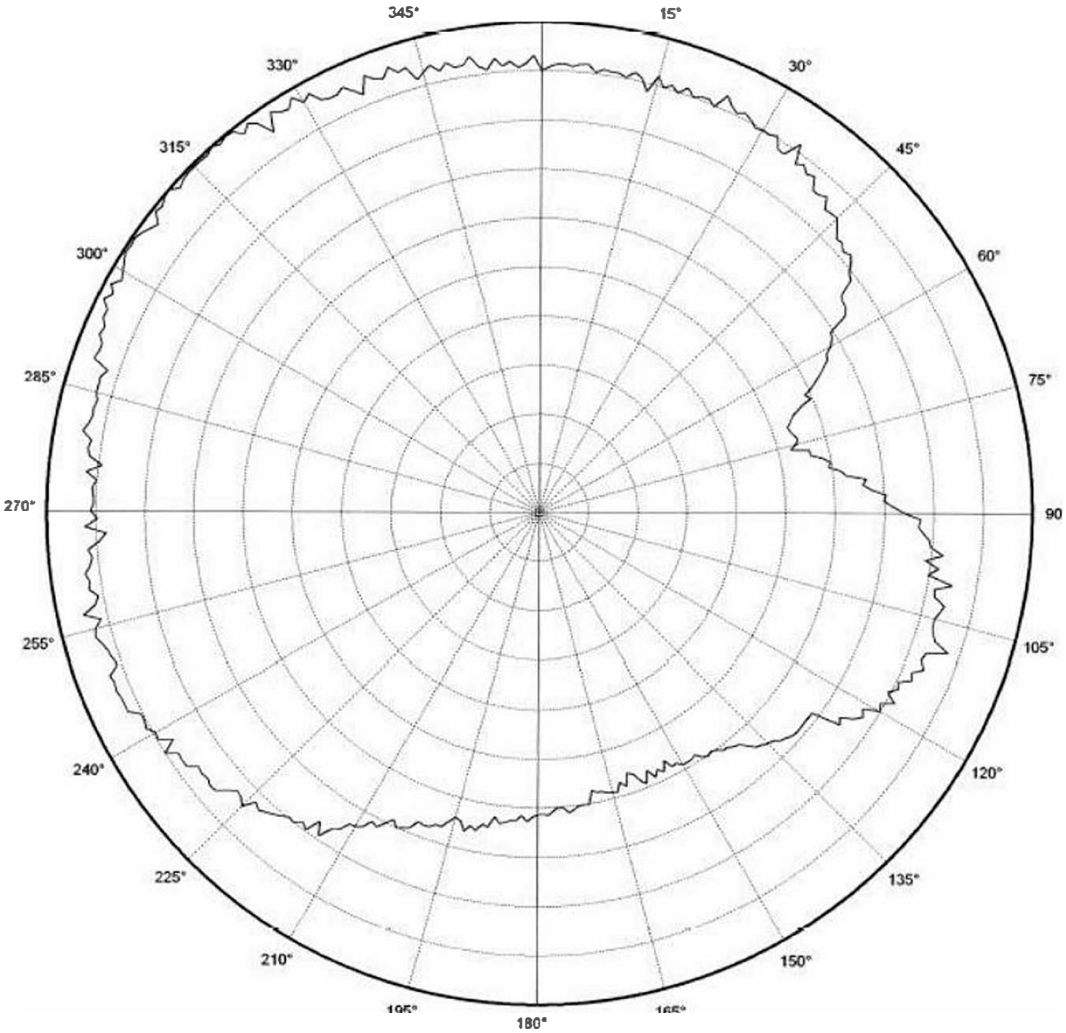


CF 2450.000 MHz
4 dB/ div
Ref Lev: 5.3 dBm

Horisontal Polarization

XZ

Figure 10: TPL3135 XZ Plane

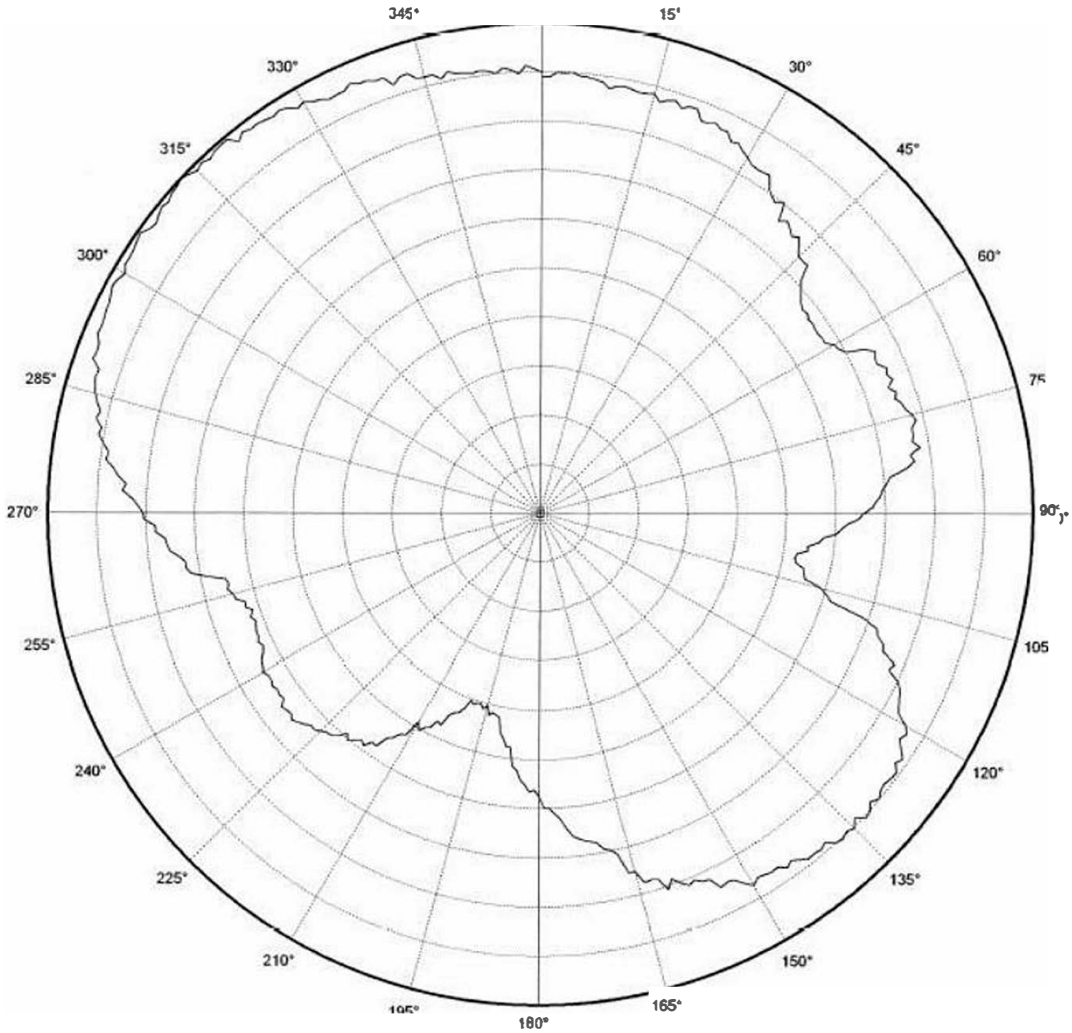


Vertical Polarization

YZ

CF 2450 000 MHz
2 dB/ div
Ref Lev: +5.3 **Bm**

Figure 11: TPL3135 VZ Plane



Horizontal Polarization

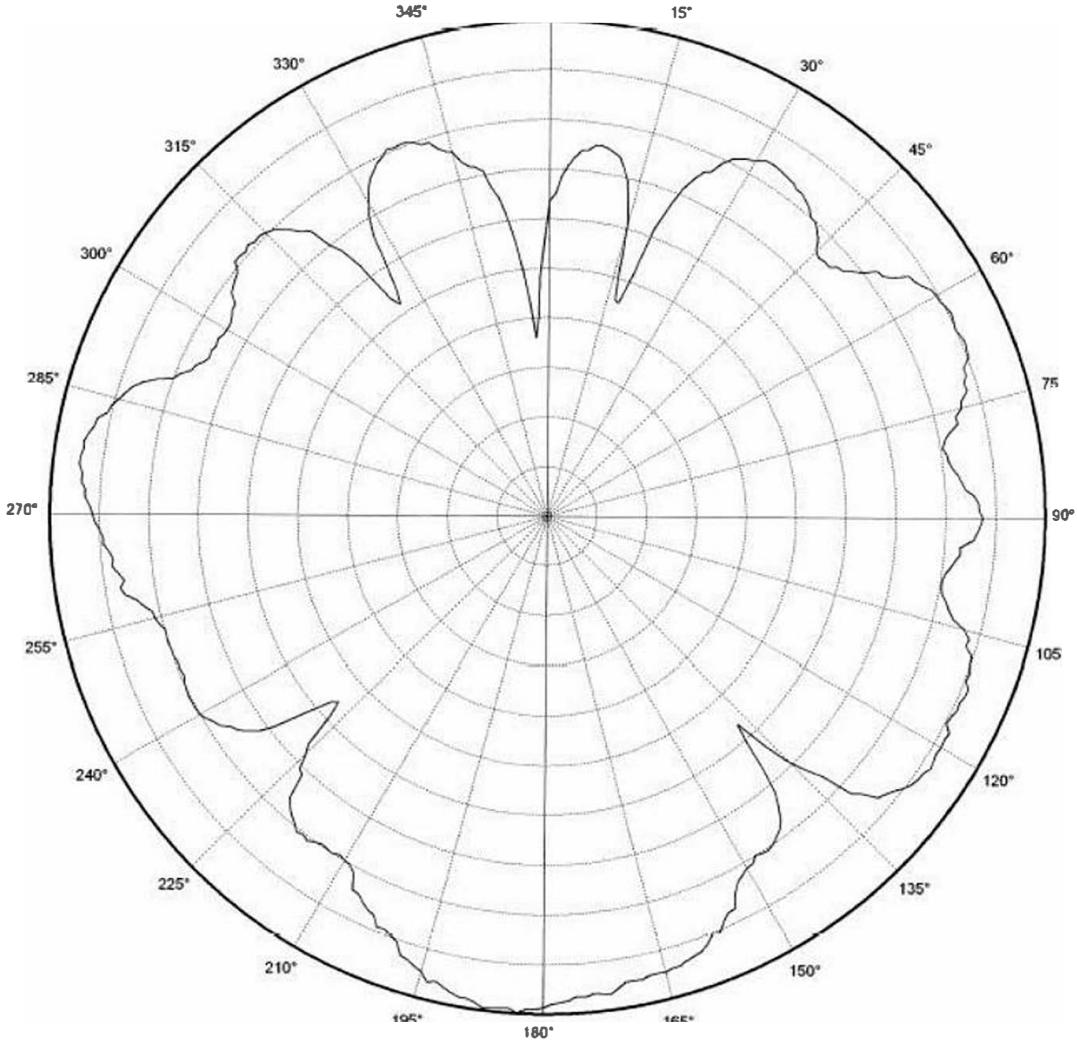
YZ

CF 2450.000 MHz

3 dB/ div

Ref Lev: -1.2 dBm

Figure 12:TPL3135 VZ Plane

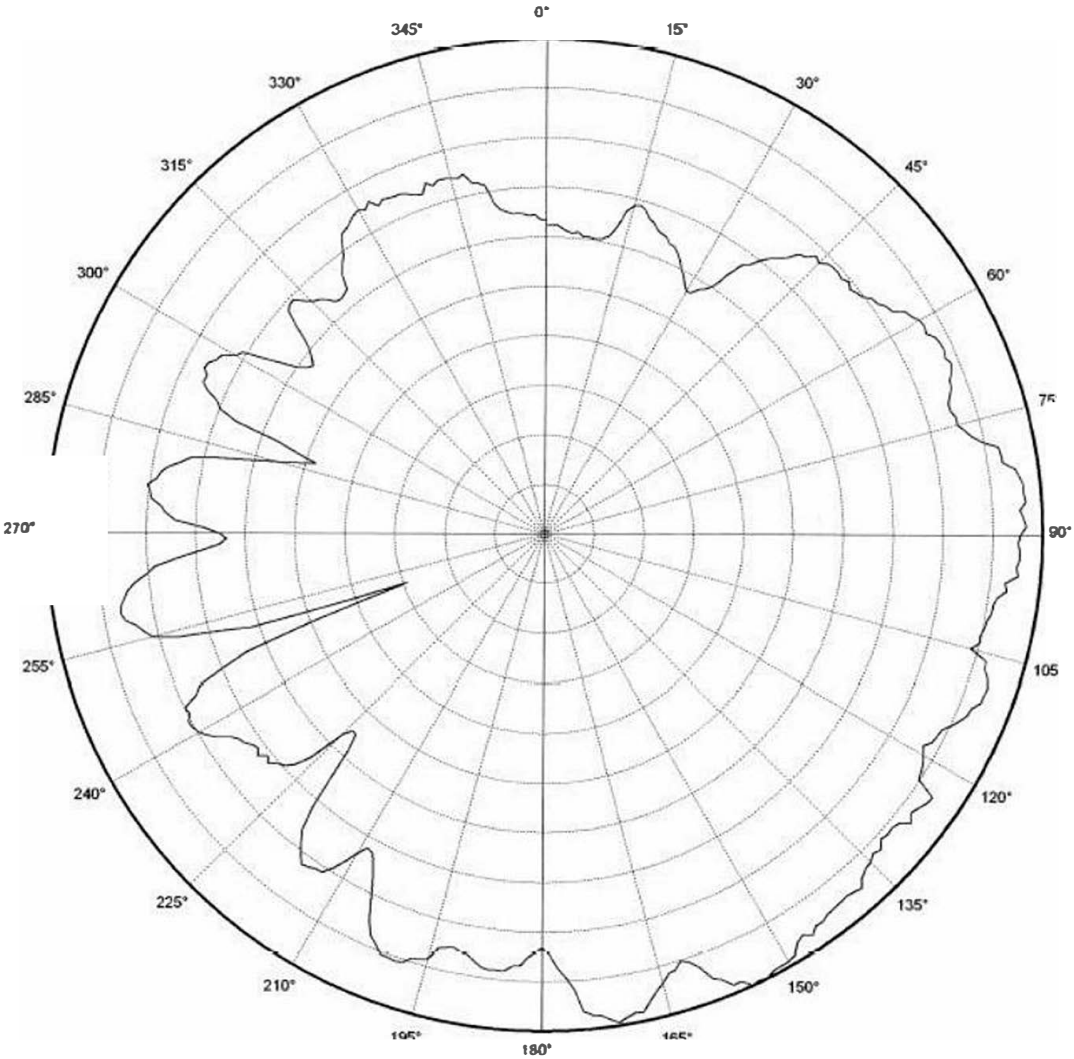


Vertical Polarization

Laptop XY

CF 245 000 MHz
5 dB/ d
Ref Lev -2.0 **dBm**

Figure 13: TPL3135 XV Plane



Horisontal Polarization

Laptop XY

CF 2450.000 MHz
4 dB/ div
Ref Lev: 3.3 dBm

Figure 14: TPL3135 XV Plane

4 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	4.5 dBi
Gain in XZ plane	4.8 dBi
Gain in YZ plane Gain in XY plane, connected to laptop	5.3 dBi 3.3 dBi
LOS range	240 m
Antenna size	11x 2.5mm