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An Ultra Wideband Small Antenna for 800 Mhz To 10 Ghz

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Abstract: *One of the main concerns in actual antenna design is enhance bandwidth to cover the wide communications standards. Since years ago researchers work in newtechniques looking for better performance in this antenna behavior [1-5]. As others, our group have worked in different techniques to enhance antenna bandwidth as circular or quasi-circular structures, softening sharp corners for both ground and main structures, we also apply slots and cuts, modifying current distribution for field pattern uniformity [6,7].This paper presents application of those techniques over a small ultra-wide band antenna, working from 800 MHz to 10 GHz, covering most of the standards required for actual cellular phones but also for other applications, as satellite communications. Design is applied to a small patch antenna,looking -10 dB for* S_{11} *parameter; good field omnidirectional pattern response and an increasingly frequency linear gain. We use electromagnetic simulation to define the best patch and ground plane geometry, selecting a low cost substrate, with the best performance.*

Westart with a planar circular monopole antenna, moving to an elliptical shapesoftening sharp edges, modifying the ground plane shapeand using vertical slots over the antenna.Each step enhanced the bandwidth, widening it as much as 1 to 10. We obtain good agreement comparing simulation results withmeasured parameters of aconstructed prototype.

Key Notes: *Antenna, ultra-wide band antenna, multiple standard of antenna*

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I. Introduction

Wireless communication systems are in permanent evolution. Systems as PCS, operate in the band of 800 MHz to 6 GHz to include services of data voice and even video; butdemand of other services leadFCC to define an Ultra-Wide Band Antenna as that working from 1.99 to 10.6 GHz [8].

Considering mobility applications, size reduction is also an antenna requirement, our design covers services from 800 MHz to 10 GHz, in one single small size antenna, but taking in account that evolution ofantennas is affected by relationship between size and wavelength.

Miniaturization of antennas is not a new topic; in fact, many efforts in the last decades, attempt to reduce antenna dimensions, looking for better fitting into electronic devices.Size reduction issues techniques have been extensively studied, as those proposed in literature:

- Higher permittivity substrate
- Shorting walls
- Antenna excitation
- Partial cuts
- Slots
- Fractal structures

Using reduction techniques in a planar antenna, we work over S_{11}, gain, and radiation pattern to comply with our goal of an Ultra-Wide Band antenna, covering different standards and FCC definition, as those in Table 1.

Table 1. Communication standards

STANDARDS	CENTRAL FREQUENCY [GHZ]
GSM900	0.920
GSM1800	1.800
PCS	1.900
WCDMA	2.000
Bluetooth	2.400
WLANa	2.440
WiMAX	2.600
WLANg	5.250
WLANb	5.750
FCC	1.99-10.6

II. Parametric antenna design

Our design starts with the simplest way of size reduction of a planar antenna:using a high substrate dielectric constant. Apermittivityof four reduceswavelengthby a factor of two [5], due reduction of propagation velocity as:

$$\lambda = \frac{v}{f} = \frac{c}{f\sqrt{\varepsilon_r}} = \frac{\lambda_0}{\sqrt{\varepsilon_r}}$$

However, increasing dielectric constant with a reduced thickness of substrate material, carries greater losses due surface wave, thenthere is a compromise between bandwidth and radiation efficiency. Lower permittivity produces greater line-widths field and therefore better radiation, thus increasing the efficiency as well as bandwidth. On the other hand, high permittivity generates an increase of antenna impedance and reducing patch radiator due the wavelength reduction. Even more, the increase of permittivity increases substrate cost. Design we present is a compromise between wideband, size reduction, and cost, using commercial FR4 substratewith ε_r=4.3 and 1.6 mm thickness.

After selecting substrate material, we applied some techniques to enhance bandwidthfor a -10 dB down of S_{11} parameter, with special attention in the lower and higher frequencies. Following we present the process.

We start with an elliptical shape;following for feed line design [6],softening straight lines and cornersin patch and ground plane and useof slots, for a better current distribution.

Selecting the shape. Most of UWB antennas are printed monopole patches. Even there are many structures, circular or elliptical are the best shapes for wide band applications. Equation 1 defines lower frequency of a wide band antenna, forcircular or elliptical patches[9]:

$$f_l = \frac{7.2}{(L + r + p)}\ GHz \qquad (1)$$

Where:
L= Height of monopole antenna
r= Equivalent radius for a circular antenna
p= Length of strip line
Figure 1 shows elliptical geometry, with *A*and *B*as the major and minor semi-axis, respectively,where:

$$L = 2A, r = \frac{B}{4} \qquad (2)$$

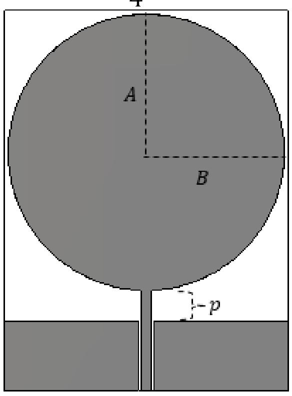


Figure 1. Parameters of an elliptical patch

After analyze different relationships between A and Bwith p=1 mm; the best response for the lower frequencyis shown in Figure 2, withA=40 mm and B= 34 mm. As seen we have 1.117 GHz for S_{11}=-10 dB, although equations 1 and 2 give lower frequency as 0.9114 GHz, for those A and B values.

Transmission line design. We selected a CPW structure for the feed line using W_f =4 mm with a gap of 1 mm, and Z_0 = 50 Ω. Figure 3 shows the transmission line parametersand figure 4 the analysis for different line lengths. The best result is L_f = 40 mm with a lower frequency of 888.9 MHz.

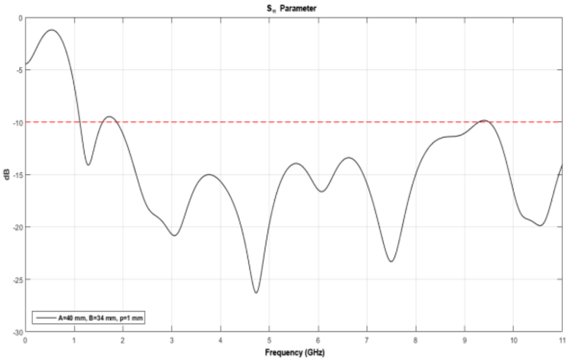


Figure 2. S_{11} parameter for A=40, B=34, p=1, mm.

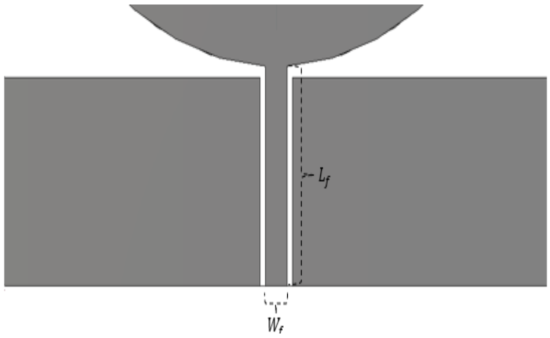


Figure 3. Transmission line parameters

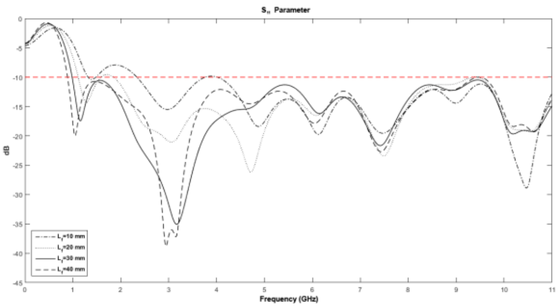


Figure 4. S_{11} vs. transmission line parameters

Ground Plane shape. Next step was modification of ground planeusing an ellipticalshape as shows Figure 5.[10]. Proceeding in the same way we found the best overall band relationship as $L_g=40$ mm and $R_g=50$ mm. Figure 6 shows results for different parameters.

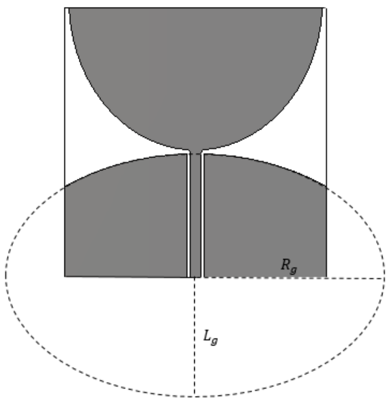


Figure 5. Elliptical ground plane

Softening straight lines. Other technique to enhance bandwidth is to make a soft transition between straight lines and curved shapes as shows Figure 7. Soft transitions make a better current distribution over the structure. Figure 8 depicts the difference introduced by softening straight lines.

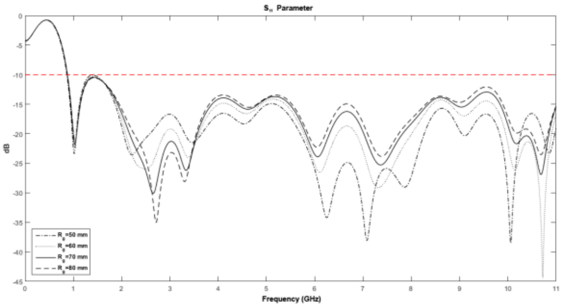


Figure 6. Parameters for elliptical ground plane

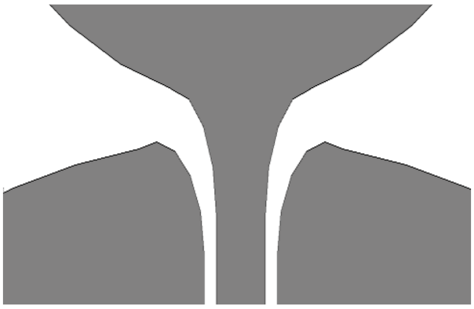


Figure 7. Softening straight lines

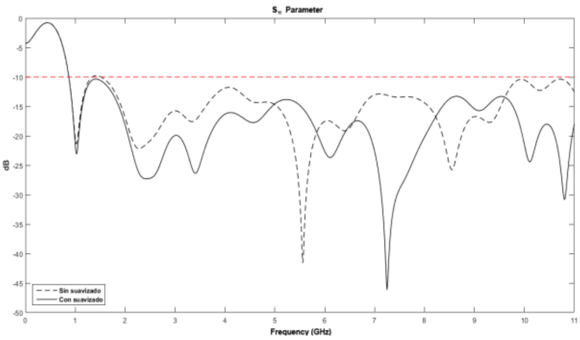


Figure 8. S_{11} after softening straight lines

Modifying ground plane structure. To have a better response, we introduce "legs" on ground plane as seen in Figure 9. We analyse the effect in current distributions. Figure 10shows response,without modification, for three frequencies on the patch, (red is maximum and blue minimum) as seen current is almost concentrated in patch perimeter of ground plane. Modifying plane shape, current distribution changes for better as shows Figure 11. As seen, there are only small blue holes in antenna at higher frequencies.We selected W_c=12.5 mm and R_c=32 mm for the best results. Even S_{11} parameter had very small changes, main effect was over radiatedfield patterns, as seen in figures 12a and 12b,for with and without modification respectively.

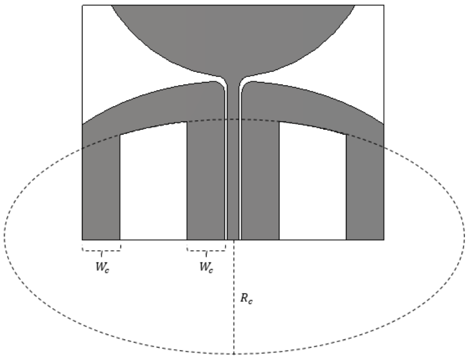
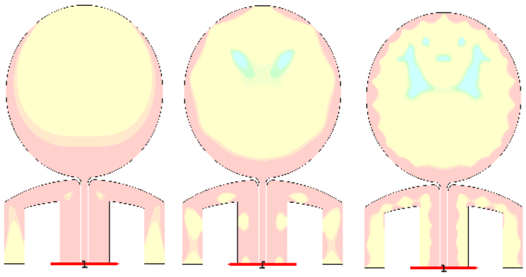
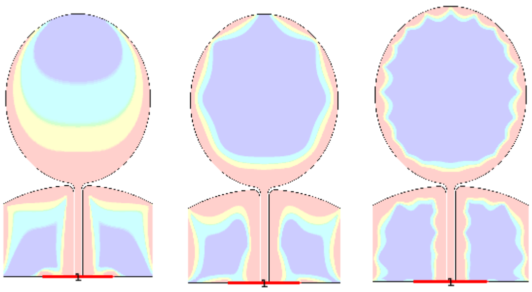


Figure 9. Ground plane modification



a) b) c)

Figure 10. Current distribution without modification for a) Low; b) Medium; and c) High frequencies



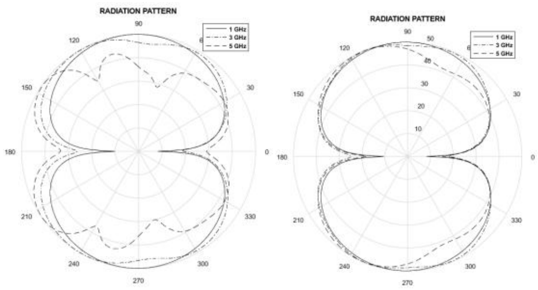
a) b) c)

Figure 11. Current distribution with modification for a) Low; b) Medium; and c) High frequencies

For even better current distribution we introduced slots on the patch [10], getting good results on field patterns, show at the end. With Figure 13 as reference, Table 2 shows the final antenna dimensions.

III. Construction and comparison.

Figure 14 shows the constructed prototype using FR4 substrate with 1.6 mm thickness and 0.035 mm copper clad. For prototype measuring, we use an Anritsu MS4624B Vector Network Measurement System inside an anechoic chamber, as seen in Figure 15. Next figures presentmeasurements compared with simulation results.



a) b)

Figure 12.Field pattern a) without modification b) with modification

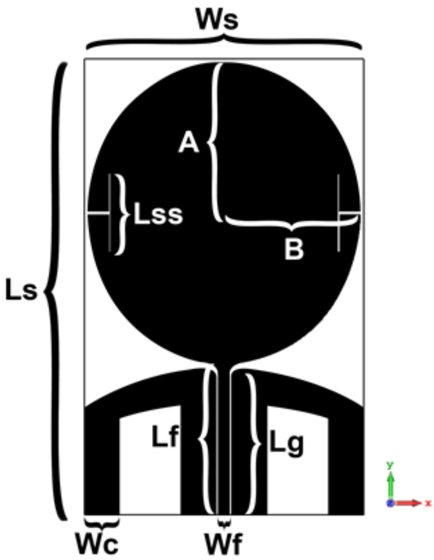


Figure 13. Final dimensions

Table 2. Final dimensions

Parameter	*Dimension (mm)*
A	43
B	39
L_s	130
W_s	80
L_f	43
W_f	3
L_g	42
R_g	58
W_c	10
L_{ss}	22.5

Figure 16 shows the S_{11}parameter of measured and simulation results. As notice,from 700 MHz to 10 GHz, response is down of the -10 dB.As well, Figure 17 presentsVSWR. As seen, there are good similitudes for simulations and measurements.

Figure 14The constructed prototype

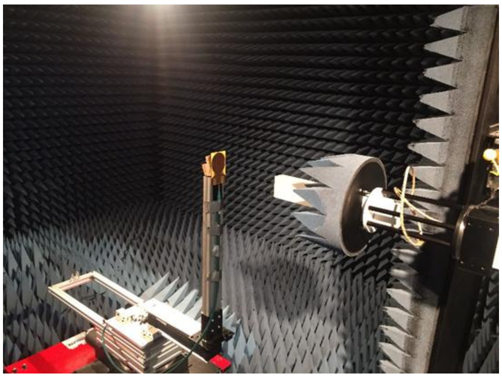


Figure 15.Measurement System inside an anechoic chamber

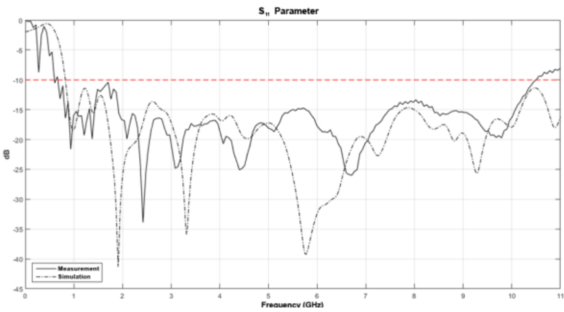


Figure 16.S_{11} Comparison

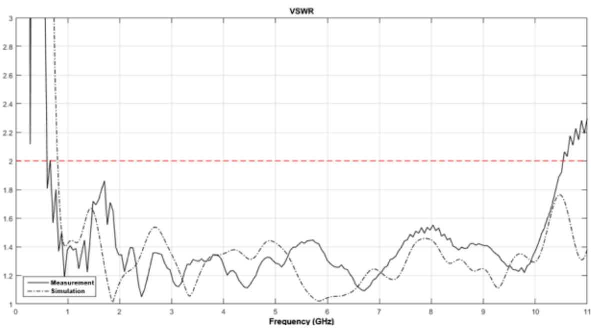


Figure 17VSWR

Figure 18 shows the gain response, as seen there is a maximum difference of 2 dB between simulation and measured results.

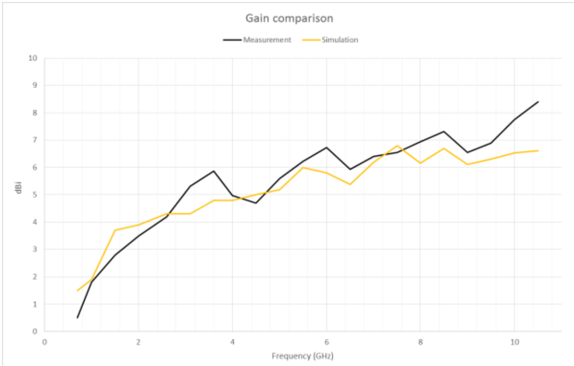


Figure 18. Gain response

Finally, Figures 19 to 22 present field patterns comparison for different frequencies along the bandwidth; we notice the coincidence between measurement and simulation, but specially the similitude between field distributions at different frequencies forwide-band response, due the uniform current distribution.

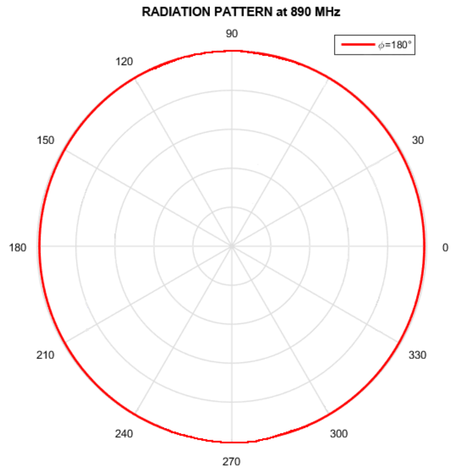


Figure 19a. Simulated radiation pattern at 890MHz

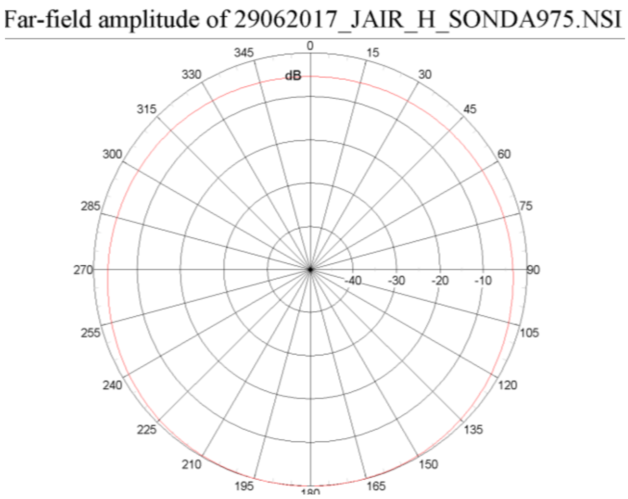


Figure 19b. Measured radiation pattern at 890 MHz

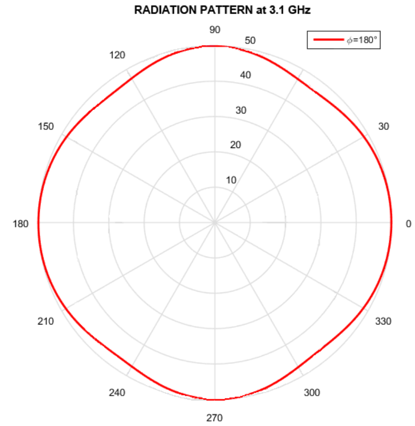


Figure 20a. Simulated radiation pattern at 3100MHz

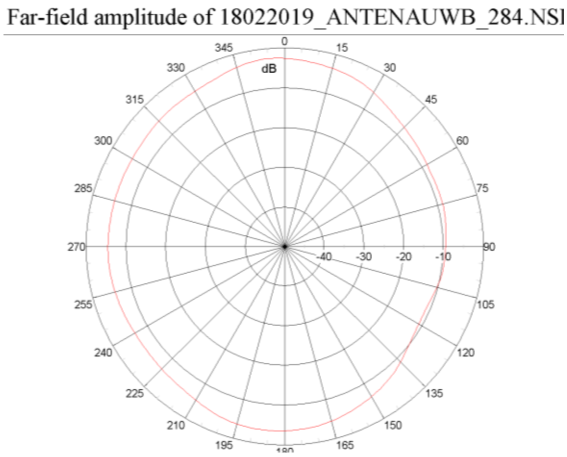


Figure 20b. Measured radiation pattern at 3100 MHz

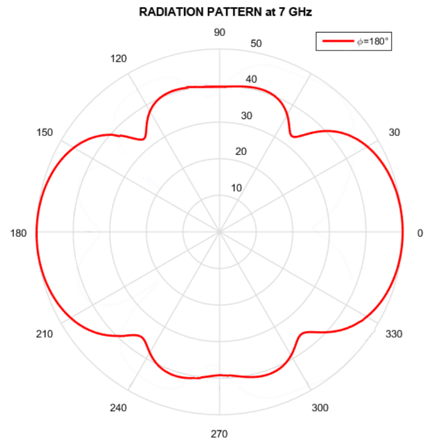


Figure 21a. Simulated radiation pattern at 7000MHz

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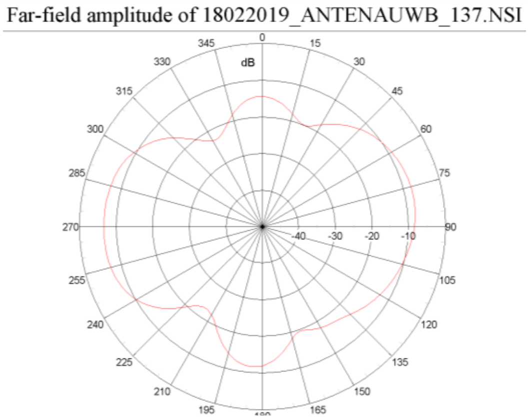

Figure 21b. Measured radiation pattern at 7000MHz

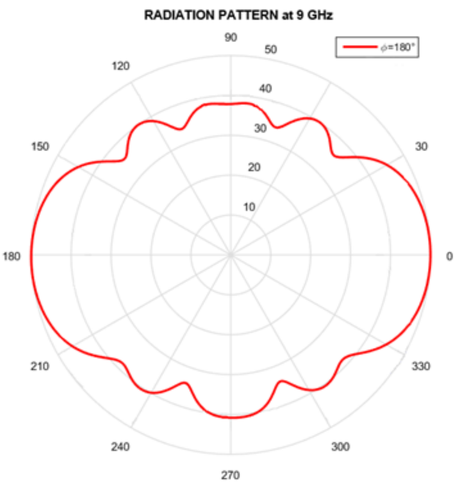

Figure 22a. Simulated radiation pattern at 9000MHz

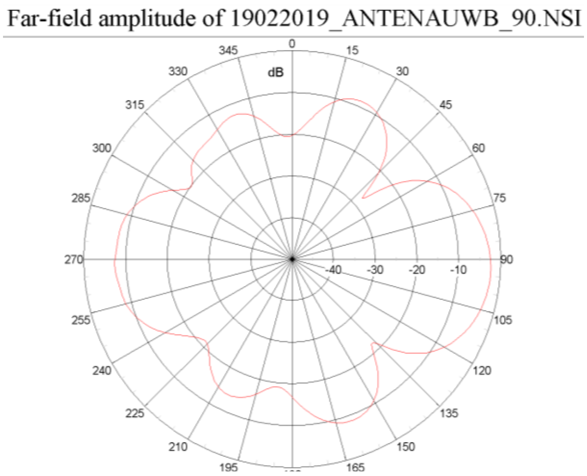

Figure 22b. Measured radiation pattern at 9000 MHz

IV. Conclusions

We presented design and construction of an Ultra Wide Band Antenna. Process uses many techniques for widening bandwidth appearing in literature.Measurements and simulations are similar, showing the expected wideband response, for all designing parameters as coupling, gain and field patterns

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