An Ultra Wideband Small Antenna for 800 Mhz To 10 Ghz

Jorge Sosa-Pedroza¹; Fabiola Martínez-Zúñiga²; Jair de Jesús Sebastian Villa³
Escuela Superior de Ingeniería Mecánica y Eléctrica
Instituto Politécnico Nacional MÉXICO

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 new techniques 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.

West start with a planar circular monopole antenna, moving to an elliptical shape softening sharp edges, modifying the ground plane shape and 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 with measured parameters of a constructed 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; but demand of other services lead FCC 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 of antennas 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>
<thead>
<tr>
<th>Table 1. Communication standards</th>
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<tbody>
<tr>
<td><strong>STANDARDS</strong></td>
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<tr>
<td>GSM900</td>
</tr>
<tr>
<td>GSM1800</td>
</tr>
<tr>
<td>PCS</td>
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<td>WCDMA</td>
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<td>WLANb</td>
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<tr>
<td>FCC</td>
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II. Parametric antenna design

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

\[ \lambda = \frac{c}{f} = \frac{\lambda_0}{\sqrt{\varepsilon_r}} \]

However, increasing dielectric constant with a reduced thickness of substrate material, carries greater losses due surface wave, therefore there 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 substrate with \( \varepsilon_r = 4.3 \) and 1.6 mm thickness.

After selecting substrate material, we applied some techniques to enhance bandwidth for 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 corners in patch and ground plane and use of 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, for circular or elliptical patches[9]:

\[ f_l = \frac{7.2}{(L + r + p)} \text{ GHz} \]  

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:

\[ L = 2A, r = \frac{B}{4} \]  

Transmission line design. We selected a CPW structure for the feed line using \( W_f = 4 \text{ mm} \) with a gap of 1 mm, and \( Z_0 = 50 \Omega \). Figure 3 shows the transmission line parameters and figure 4 the analysis for different line lengths. The best result is \( L_f = 40 \text{ mm} \) with a lower frequency of 888.9 MHz.
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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 plane using an elliptical shape 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](image1)

![Figure 7. Softening straight lines](image2)

![Figure 8. S11 after softening straight lines](image3)

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 10 shows 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 radiated field patterns, as seen in figures 12a and 12b, for with and without modification respectively.
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 present measurements compared with simulation results.
Figure 12. Field pattern a) without modification  
   b) with modification

![Figure 12. Field pattern a) without modification  
   b) with modification](image)

Figure 13. Final dimensions

Table 2. Final dimensions

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Dimension (mm)</th>
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<tbody>
<tr>
<td>A</td>
<td>43</td>
</tr>
<tr>
<td>B</td>
<td>39</td>
</tr>
<tr>
<td>L_s</td>
<td>130</td>
</tr>
<tr>
<td>W_r</td>
<td>80</td>
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<tr>
<td>L_f</td>
<td>43</td>
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<tr>
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<tr>
<td>L_g</td>
<td>42</td>
</tr>
<tr>
<td>R_g</td>
<td>58</td>
</tr>
<tr>
<td>W_c</td>
<td>10</td>
</tr>
<tr>
<td>L_m</td>
<td>22.5</td>
</tr>
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</table>

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 presents VSWR. As seen, there are good similitudes for simulations and measurements.
Figure 14: The constructed prototype

Figure 15: Measurement System inside an anechoic chamber

Figure 16: $S_{11}$ Comparison

Figure 17: VSWR

Figure 18 shows the gain response, as seen there is a maximum difference of 2 dB between simulation and measured results.
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 for wide-band response, due the uniform current distribution.

![Figure 18. Gain response](image)

![Figure 19a. Simulated radiation pattern at 890MHz](image)

![Figure 19b. Measured radiation pattern at 890 MHz](image)
Figure 20a. Simulated radiation pattern at 3100MHz

Figure 20b. Measured radiation pattern at 3100 MHz

Figure 21a. Simulated radiation pattern at 7000MHz
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.

Acknowledgments

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