Bandwith Improvement on Rectangular Monopole Antenna using Dual Bevel Technique for Ultrawideband Technology

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BANDWIDTH IMPROVEMENT ON RECTANGULAR MONOPOLE ANTENNA USING DUAL BEVEL TECHNIQUE FOR ULTRAWIDEBAND TECHNOLOGY

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Abstract

This paper presents the analyzed Monopole Antenna for Ultrawideband with a rectangular patch design using bevel technique at a frequency of 3.1 – 10.6 GHz. The fabricated antennas with dual bevel angles have a very compact width and length of 40 mm x 33 mm respectively and a groundplane width of 13 mm. To get bandwidth improvement on monopole antennas can be applied to the bevel angle on the patch. So, to get the best antenna design, 3 optimizations of antenna size changes were carried out during the simulation, that is optimization of patch length, patch width and bevel angle. Variation of patch length and width is used to change the frequency range and variation of bevel angle to increase bandwidth. From each change, the best result is taken. The experiment obtained the best simulation result of antenna and then fabricate it. From the measurement results on the fabricated antenna, the lowest S11 value is -24.6 dB, gain 2.6 dBi at a frequency of 5 GHz and radiation pattern is omnidirectional. The optimization process using the bevel technique has been proven to be successful in shifting the frequency range by around 600 MHz and increasing the bandwidth by about 4% or 30 MHz.

Keywords: bevel technique, ultrawideband, monopole, antenna, optimization

INTRODUCTION

Ultrawideband radio technology (UWB) is application in high-level wireless data systems, cognitive radio, radar, biomedical imaging, communications and others [1]–[5]. It is well known that the UWB printed monopole antenna offers features such as a simple shape, very wide bandwidth of more than 3 to 10 GHz, ease of manufacture, and small size [6]–[10].

For size reduction, the most useful technique is to cut the different structures in the correct position on a conventional antenna [7]. Reducing the size of the antenna means that the resonant frequency of the cutting structure of the antenna is drastically reduced compared to conventional antennas. Meanwhile, to get a very wide bandwidth on monopole antennas, several techniques have been introduced to increase the bandwidth of planar monopole antennas to get broadband performance such as notch, shorting pin, and beveling techniques [11]–[13]. In [14]–[16] demonstrates the integrated double bevel technique. From this research, there is an increase in bandwidth for variations in the applied bevel angle.

The type of antenna chosen is the Monopole Antenna. Several studies have demonstrated the ability of monopoles to meet wideband frequency requirements. [17]–[20]. UWB antennas must have good mechanical and electrical characteristics. So, monopole antenna design uses bevel technique to increase bandwidth. In this article, there is a research contribution on the effect of variations in bevel angle and patch length and width on antenna performance. The fabricated antenna with a double bevel angle of 5 is very compact in width and length with a size of 40 mm x 33 mm and a groundplane width of 13 mm.

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METHODS

Antenna Monopole

Monopole antenna is a type of antenna made of a conductor attached to a dielectric and at the bottom there is a groundplane and at the top there is a patch which is the part of the antenna that emits radiation.

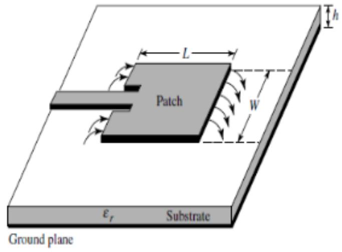


Fig. 1. Monopole antenna structure [21].

The basic structure of a monopole antenna is shown in Fig. **1** consists of a radiating element (radiator) or commonly referred to as a conducting patch, a dielectric substrate, and a ground plane

Flowchart

In the process of designing an antenna, there are several steps that need to be done. It can be shown in Fig. **2**. First determine the desired antenna performance specifications, including frequency range, S11 and radiation pattern. The second step calculates the dimensions of the antenna according to the existing formula. From the calculations, it is designed to be the initial design of the monopole antenna which is then simulated to CST. If the simulation results are in accordance with the performance specifications, the simulation process is complete. Usually, the performance results from the initial design obtained from calculations do not match, so optimization needs to be done until the results are close to the performance specifications.

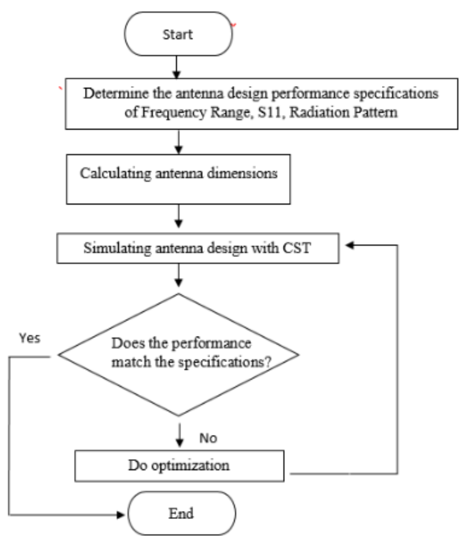


Fig. 2. Flowchart Monopole Antenna Design

Antenna Dimension

The antenna designed is a printed monopole antenna with a working frequency of 3.1 GHz - 10.6 GHz where the resonant frequency or center frequency is 6.85 GHz. In the initial design, patch size calculations were carried out including:

1. Patch Width (Wp):
   To be able to determine the width of the patch from the monopole antenna, it can use equation [21]

$$W = \frac{c}{2f_0\sqrt{\frac{(\varepsilon_r + 1)}{2}}} \tag{1}$$

2. Patch Length (Lp)
   To be able to determine the length of the patch from the monopole antenna, it can use equation [21]

$$L = L_{eff} - 2\Delta L \tag{2}$$

Where L_eff is the effective patch length which can be formulated by equation

$$L_{eff} = \frac{c}{2f_0\sqrt{\varepsilon_{r\,eff}}} \tag{3}$$

Before calculating L_{eff}, look for the permittivity of the effective dielectric material (ε_{reff}) first with the equation

$$\varepsilon_{r\,eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1 + 12\frac{h}{W}\right)^{-1/2} \tag{4}$$

The value of ΔL can be calculated using the equation

$$\Delta L = 0{,}412 \times h\frac{(\varepsilon_{r\,eff} + 0{,}3)\left(\frac{W}{h} + 0{,}264\right)}{(\varepsilon_{r\,eff} - 0{,}258)\left(\frac{W}{h} + 0{,}8\right)} \tag{5}$$

Spesifications and Initial Design

Antenna specifications are an important part of the design process. Antenna design specifications can be seen in Table 1. Antenna design is simulated using CST Microwave Studio. The dielectric material used is FR4 with a dielectric constant of 4.3, the thickness of the dielectric is 1.6 mm, and the thickness of the conductive material (copper) is 0.035 mm. The nominal size of the UWB antenna calculated in the antenna dimension section is tabulated in Table 2. From nominal size can be drawn to the initial design is shown in Fig. **3**. From Fig. **3** the groundplane is a horizontal rectangle, otherwise it was matched and then simulated using CST Microwave to get S11. The S11 results from this initial antenna design are shown in Fig. **4**. Based on the simulation results of the initial design antenna in Fig. **4**, it appears that the antenna has not met the expected frequency, that is 3.1 - 10.6 GHz. So, it is necessary to optimize the antenna to obtain performance according to specifications.

Table 1. Specifications for Monopole Antenna

Parameter	Specification
Frequency range	3.1 – 10.6 GHz
Bandwidth	7.5 GHz
S_{11}	≤ -10 dB
Gain	≥ 2 dBi
Radiation pattern	Omnidirectional

Table 2. Nominal Size of Monopole Antenna

No.	Name	Symbol	*Value (mm)*
1.	Patch Width	Wp	9,812
2.	Patch Length	Lp	13,36
3.	Ground Width	Wg	13
4.	Line Width	Ws	3
5.	Line Length	Ls	13,9
6.	Bevel Angle	α	-
7.	Gap	Lgap	0,9

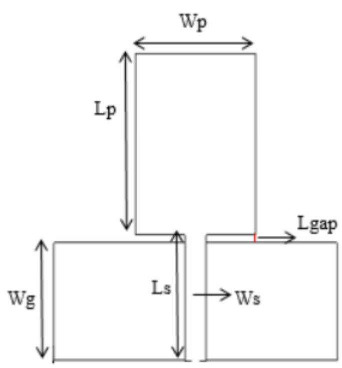


Fig. 3. Initial Monopole Antenna Design

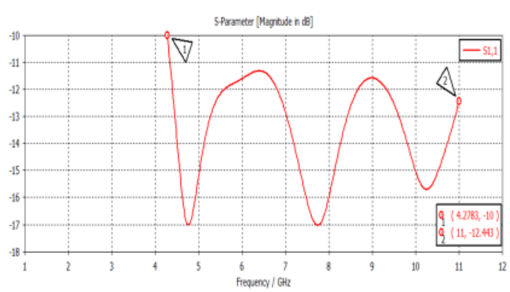


Fig. 4. S11 result of the initial Monopole Antenna design

RESULT AND DISCUSSIONS

To improve impedance matching and get the appropriate frequency range, it is necessary to optimize the dimensions of the patch by varying the length and width and cutting the bottom end of the patch with a certain angle (bevel).

A. Optimization 1

The first optimization step is to make changes to the patch length (Lp) to the performance of S11. Variations in patch length are carried out from 10 - 30 mm with 5 samples, see Fig. **5**. Based on the Fig. **5**, the patch length on the antenna affects the resonance frequency, where the greater the patch length value, the more the resonance frequency will shift to the frequency value. smaller or shifted to the left. In Fig. **5**, S11 is closest to the antenna specifications, namely when the value a = 20 mm.

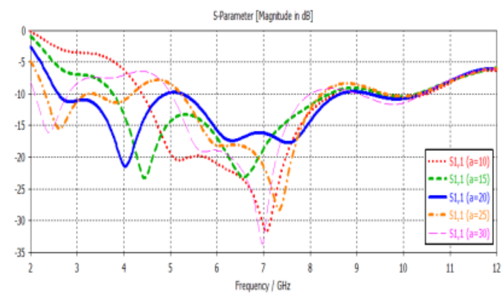


Fig. 5. S11 results on variations in antenna length

B. Optimization 2

The second optimization step is done by changing the size of the patch width (Wp) with size variations from 14 - 18 mm with 5 samples, see the S11 result in Fig. **6**. Based on the graph, the patch width (Wp) on the antenna affects the S11 value along the frequency range. In Figure 6, the value of S11 that is closest to the specification is when the value of b = 17 mm because the value of S11 meets -10 dB along the frequency range.

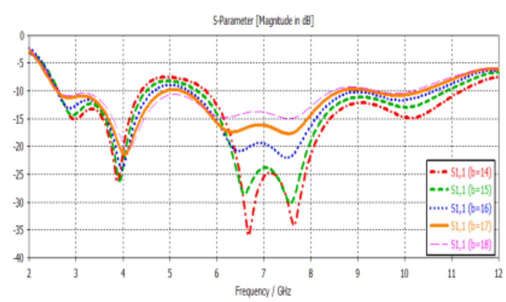


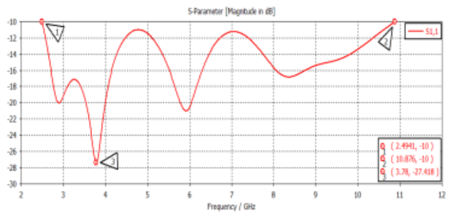
Fig. 6. S11 results on variations in antenna width

C. Optimization 3

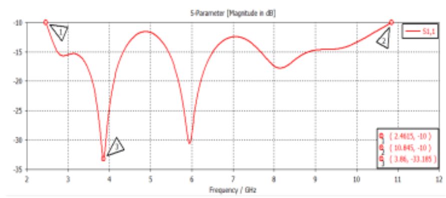
Based on the graph in Figure 6, at size b = 17 the antenna frequency is close to specifications. To get results that are closer to the specifications, a square patch will be cut with a bevel with a bevel angle variation of 5°- 20°. The results of the simulation of bevel angle variations can be seen in the S11 graph shown in Fig. **7**.

Based on Fig. **7**, all bevel values indicate the appropriate bandwidth. However, there was a difference in graded S11 and the resonant frequency. When the bevel angle value is 20°, the lowest S11 is -27.318 dB and has 4 resonant frequencies around 3 GHz, 4 GHz, 6 GHz, and 8 GHz. When the bevel angle value is 15°, the lowest S11 is -33.185. When the bevel angle value is 10°, the lowest S11 is -59.167 dB. From the bevel angles 10° and 15° have 3 resonant frequencies around 4 GHz, 6 GHz, and 8 GHz. When the bevel angle value is 5, the lowest S11 is -27.874 dB and has 4 resonant frequencies around 4 GHz, 6 GHz, 8 GHz, and 10 GHz. When viewed at frequencies around 7-8 GHz at bevel angle values of 20°, 15° and 10°, it has a high S11 value approaching -10 dB compared to S11 when the bevel 5° value which has an S11 value smaller than -15 dB.

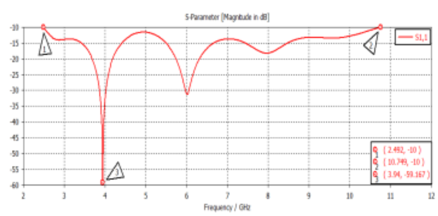
This shows that the matching impedance around the 7-8 frequency at the 5° bevel angle value is better than the others. It can be concluded the bevel angle with a value of 5° has the best results where the S11 value is less than -10dB throughout the frequency range compared to other angles.



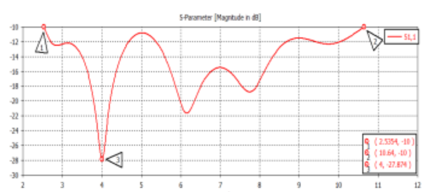
a. S11 result at 20° bevel angle



b. S11 result at 15° bevel angle



c. S11 result at 10° bevel angle



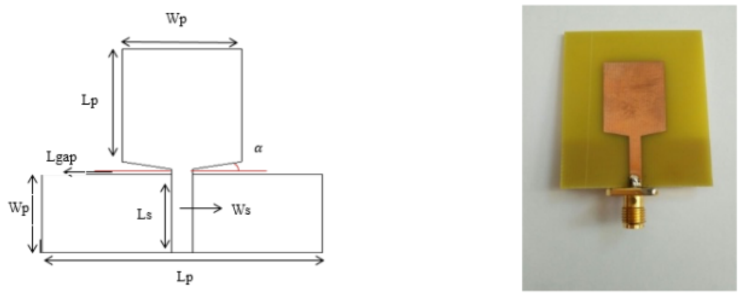
d. S11 result at 5° bevel angle

Fig. 7. S11 result with variation bevel angle

The final design of the monopole antenna for UWB communication has been simulated and the best simulation results have been obtained with reference to the specifications, see Table 3 and the fabricated antenna shown in Fig. **8**. Furthermore, the antenna is fabricated, and measurements are taken in the laboratory.

Table 3. Monopole antenna final design size

No.	Name	Symbol	Value(mm)
1.	Patch Width	Wp	17
2.	Patch Length	Lp	20
3.	Ground Width	Wg	13
4.	Ground Length	Lg	40
5.	Line Width	Ws	3
6.	Line Length	Ls	13.9
7.	Bevel Angle	α	5°



a. Monopol antenna final design **b.** Fabricated monopole antenna

Fig. 8. Monopole antenna final design and fabricated

S11 Measurement

Measurement of S11 on the antenna using Advantest R3770 Network Analyzer. The Vector Network Analyzer tool can analyze S11. The results of the S11 measurements are then compared with the results of the S11 simulations in order to see the difference. Fig. **9** shows the comparison of S11 simulation results and measurement result from printed monopole antennas based on the resonant frequency. It can be seen that the measurement results are better than the simulation results because all S11 values along the frequency 3.1 – 10.6 have S11 values that are low or far from -10 dB. However, there is a shift in the frequency range between simulation and measurement. That is from 2.5 - 10.6 GHz shifted to 3.1 - 10.9 GHz. Even if the measurement results are shifted according to the specified specifications.

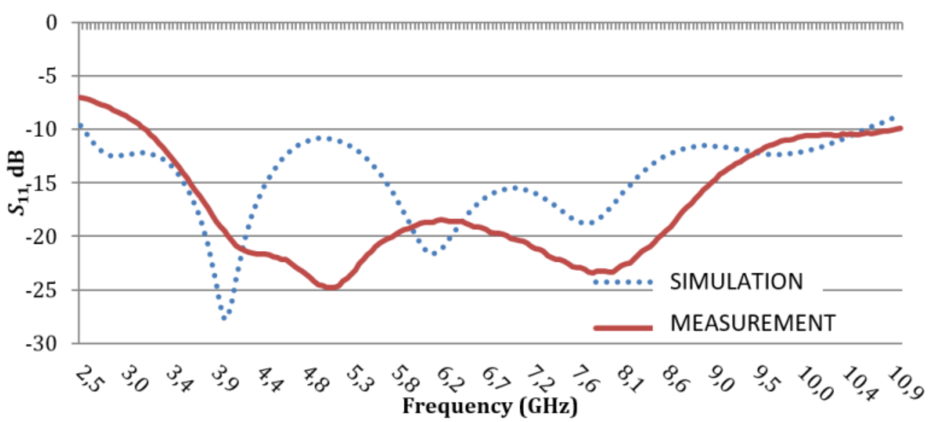


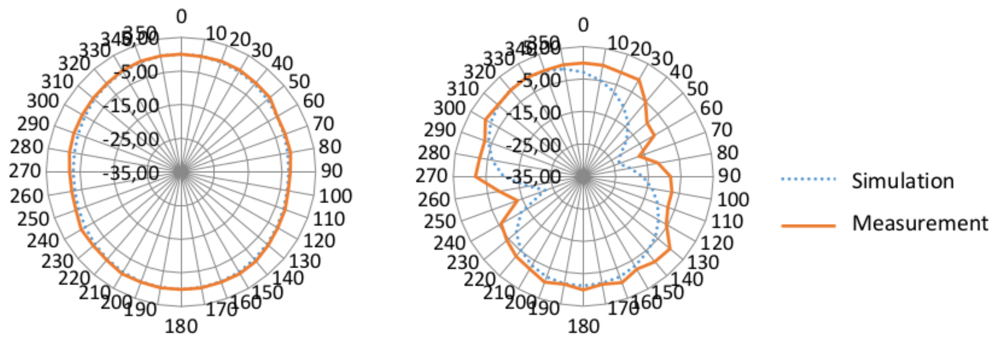
Fig. 9. Comparison between S11 simulation and measurement

Gain and Radiation Pattern Measurement

Gain measurements are carried out in a room without an echo or what is called an anechoic chamber. Anechoic chamber is a room designed to dampen reflected sound or electromagnetic waves. From Table 4, it can be seen that the printed monopole antenna in the measurement has a gain of more than 2 dBi, so it is in accordance with the specifications. While the radiation pattern is shown from the elevation radiation pattern in Fig. ***10*** and the azimuth radiation pattern in Figure 10. From the measurement and simulation results, the results are almost the same. In both radiation patterns, the direction of the radiation pattern can be seen in all directions. Therefore, it can be said that the antenna radiation pattern is omnidirectional.

Table 4. Result gain measurement

Frequency	**Gain (dBi)**
3,1 GHz	3,1
5 GHz	2,6
10,6 GHz	3,7



a. Azimuth Radiation Pattern **b.** Elevation Radiation Pattern

Fig. 10. Comparison radiation pattern

CONCLUSIONS

Monopol Antenna for UltraWideband Communication (UWB) was designed, fabricated and the performance measure is verified by measurements in the laboratory using a VNA (Vector Network Analyzer). The optimization process using the bevel technique has been proven to be successful in shifting the frequency range by around 600 MHz and increasing the bandwidth by about 4% or 30 MHz. Applying a bevel on the right and on the left (dual bevel) around the patch has an influence on the results of S11. Applying 5° to the bevel angle can increase the matching impedance across the entire frequency range with S11 values lower than -10dB. The fabricated antenna has the lowest S11 value of -24.6 dB at a frequency of 5 GHz, a bandwidth of 7.8 GHz and a gain of 2.6 dBi. The final result shows that the performance of the fabricated antenna meets the specifications.

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