# Solid Sharp-Edged Wire Diamond Dipole Microstrip Antenna

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*Abstract* – **This paper presents a solid sharp-edge wire diamond dipole microstrip antenna for UWB applications, operating within the range of 3.1-10.6GHz. A 3D electromagnetic simulator was used for designing and simulation of the antenna, with the following parameters; radiation efficiency of 88.14%, VSWR of 1.239, return loss of -19.440dB and gain of 7.694dBi. The antenna was fabricated using RT Duroid 5870 substrate with a 2.33 relative permittivity and was fed by coaxial feed. An analysis of a prototype was carried out by using Vector Network Analyzer (VNA). It was observed that the simulated and the measured parameters agree with each other.**

***Index terms*** **– UWB antenna, solid sharp-edge wire diamond dipole microstrip antenna, coaxial feed**

## I. INTRODUCTION

The antenna is defined as "a means for radiating or receiving radio waves" by the *IEEE Standard Definitions of Terms for Antennas*. It is also defined as a transitional structure between free-space and a guiding device, transporting electromagnetic energy from the transmitting source to the antenna, or from the antenna to the receiver [1]. One of the most recently used antennas are the microstrip antennas. These antennas consist of a metallic patch on a grounded substrate. Microstrip antennas have several advantages, such as light weight, low profile, low cost and ease of fabrication. The metallic patch can be modeled for different varieties of configurations, such as the diamond shape. The diamond dipole antenna configuration is selected based on the theory that thickening a dipole increases its impedance bandwidth and spreads the energy throughout the dipole. Apart from that, adding sharp corners to a thick dipole antenna adds current nulls at anti-resonant frequencies, with the tendency of currents to concentrate on edges become more pronounced [2]. The proposed antenna was designed for the use in Ultra-wideband (UWB). This enables transmission over a wide frequency, where a low power spectral density can be received. UWB has promised to offer high data rates at short distances with low power, primarily due to wide resolution bandwidth. Compact and cheap ultra wideband antennas are needed for numerous UWB applications like wireless communications. Ultra-wideband allocation is set to be in 3.1-10.6GHz spectrum by the Federal Communications Commission [3], requires an antenna with VSWR ≤ 2 for proper impedance matching throughout the entire band. The focus of this work is to model, simulate and test a solid sharp-edge wire diamond dipole microstrip antenna for the UWB 3.1-10.6GHz band that achieves a radiation efficiency >70%, a near omni-directional radiation pattern, a nearly linear phase and sufficient impedance bandwidth, with a small and compact physical profile.

## II. METHODOLOGY

Fig.1 depicts the process involved in realizing the antenna.

### *A. Antenna Design*

The proposed antenna structure is as shown in Fig. 2. The microstrip antenna was composed of two isosceles triangles with a coaxial feed connected to both patches. The two triangles were designed to have an almost equal height and base. The triangle height was chosen in such a way that the antenna frequency was centered in the range of a dipole antenna [4,5], where the height and base were scaled to be $\lambda/4$ *at the center frequency of interest.*

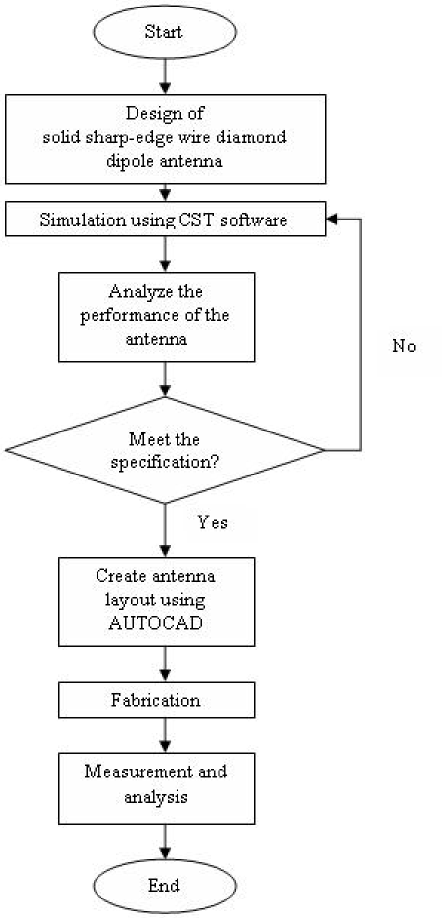


Fig.1. Flow chart of realizing the antenna

The diamond dipole microstrip antenna prototype is printed on a 2.33 relative permittivity substrate of 0.5mm thickness. The relative permittivity is chosen based on the theory that a low εr is needed for microstrip antennas. The thickness of the metallization layer printed on the substrate is 0.0356mm. The antenna is supported by a ground plane of 6mm thickness and dimensions of *W*=73mm and *L*=96mm. Fig.2 and Fig.3 illustrates the thickness and dimensions of the antenna respectively.

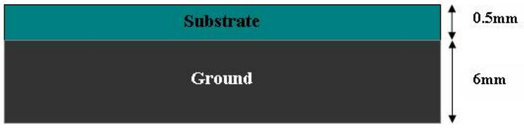


Fig.2. Thickness of the antenna

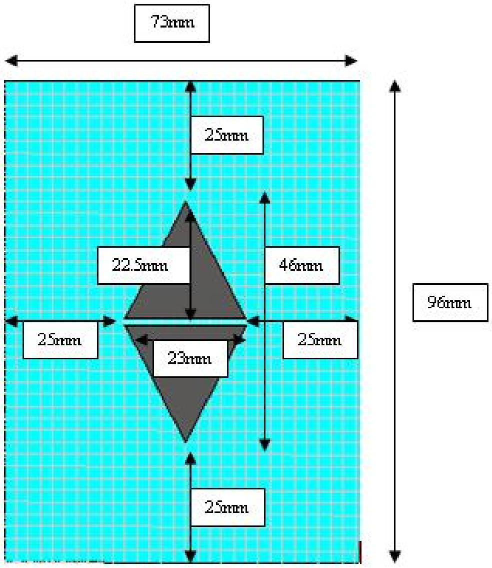


Fig.3. Dimensions of the antenna

### *B. Feeding Technique*

Feeding technique plays a significant role in determining the input impedance and polarization characteristics of an antenna [6]. The feeding technique adopted for this antenna is coaxial feed as in Fig.4. With coaxial probe feed, the antenna was fed from underneath via a probe. The outer conductor of the cable is connected to the ground plane, while the center conductor is extended up, soldered to the patch. The position of the feed was altered to control the input impedance, as indicated by Fig.5. Coaxial feed was commonly used for dipole antennas because it is very easy to fabricate and have low spurious narrow bandwidth. The disadvantage is that it will be more difficult to model for thick substrates, and the probe may also radiate, which lead to radiation in undesirable directions.

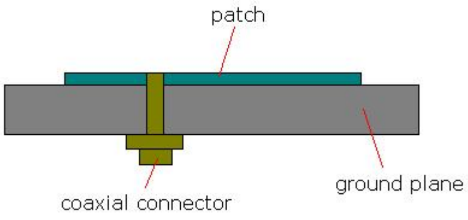


Fig.4. Coaxial feed

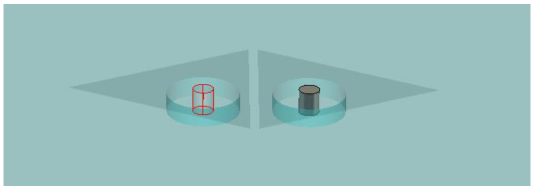


Fig.5. The antenna with coaxial feed (3D)

### *C. Simulation and Measurement*

The antenna was designed by using a 3D electromagnetic simulator. First, the antenna on planar substrate was chosen and the working plane properties were set. Next, the substrate and the ground were modeled. The dimensions of the antenna were then entered. Fig.6. illustrates the patch antenna after the dimensions were entered.

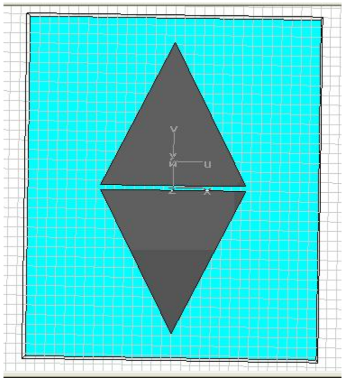


Fig.6. Patch antenna

Now, the coaxial feed was constructed as the excitation source for the patch antenna. The working coordinate system (WCS) was chosen to define the new center point for the coaxial feed. The coaxial feed was constructed to both patches. Fig.7. depicts the antenna with coaxial feed.

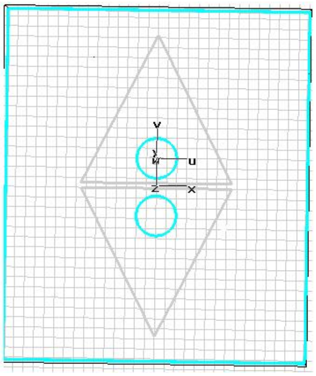


Fig.7. Antenna with coaxial feed

An excitation port to the patch antenna device was then added, where the reflection parameter was then calculated. The model was rotated to the bottom side, followed by 'pick face' at the coaxial feed. The coaxial feed was then defined with the waveguide ports. Fig.8. shows the antenna with waveguide ports.

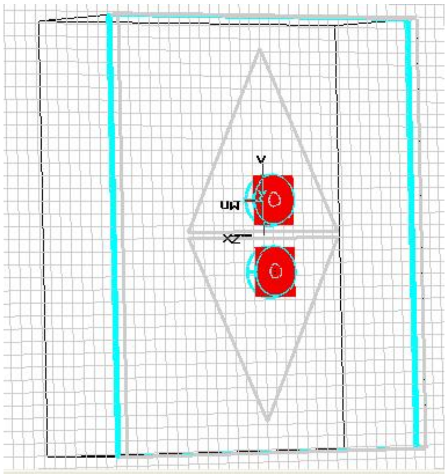


Fig.8. Antenna with defined waveguide ports

The frequency range and the farfield monitor were then set. Fig.9. illustrates the antenna after the frequency has been assigned.

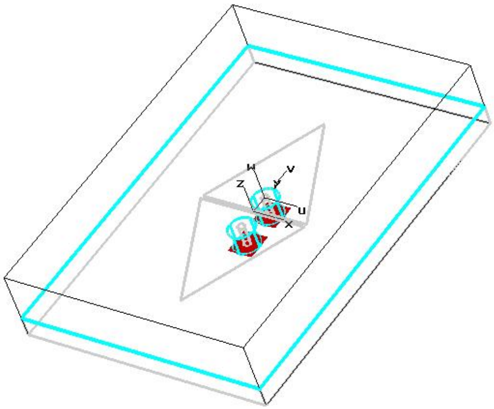
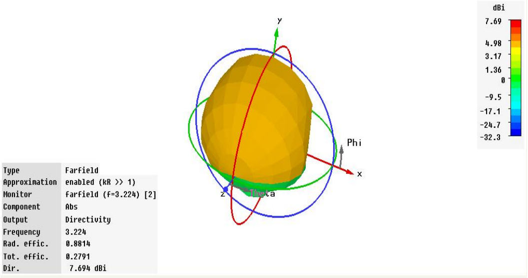


Fig.9. Antenna with defined frequency

The solver's parameters were specified in the "Solver Parameters" dialog box. Finally the 'Start Solver' button was pressed to start the calculation. A progress window appears showing some information about the calculation's status. This progress window disappears when the solver has successfully finished. Otherwise, the 'Details field' will be shown to display error messages or warnings.

The antenna was simulated by using the transient solver in the CAD software. In 1D result, which involves the port signals and S-parameters, an operating frequency of 3.224GHz was achieved. The farfield at the operating frequency of 3.224GHz achieve a radiation efficiency of 88.14% and a directivity of 7.694dBi. Fig.10 shows the farfield of the antenna.



| | |
|---|---|
| Type | Farfield |
| Approximation | enabled (kR >> 1) |
| Monitor | farfield (f=3.224) [2] |
| Component | Abs |
| Output | Directivity |
| Frequency | 3.224 |
| Rad. effic. | 0.8814 |
| Tot. effic. | 0.2791 |
| Dir. | 7.694 dBi |

Fig.10. Farfield

The fabrication of the antenna was then carried out. The antenna was tested by using vector network analyzer (VNA) to obtain the measurement result. The simulated result and the measured result were being compared and analyzed.

## III. RESULT

Fig.11 and Fig.12 show the return loss, $S_{11}$ of the proposed antenna for simulated and measured results. An operating frequency of 3.224GHz and 3.125GHz has been achieved for simulation and measurement respectively. Theoretically, the best radiation will be achieved when the return loss approaches zero. A dip of 0.1067 has been observed at the simulated operating frequency, which is nearing zero, indicating a good response with almost zero reflections.

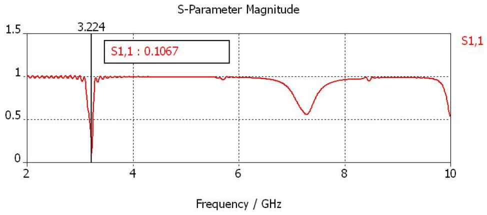


Fig.11. Simulated Return Loss

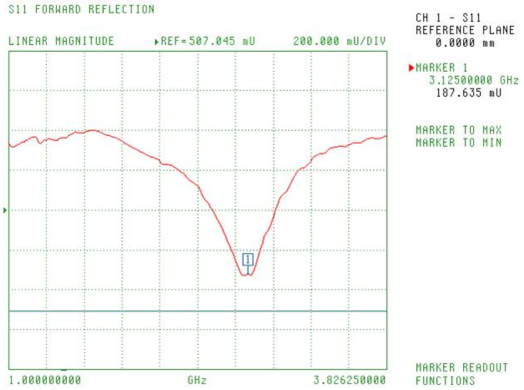


Fig.12. Measured Return Loss

Fig.13 and Fig.14 show the gain in dB of the proposed antenna for simulated and measured results. A dip of -19.44dB was observed at the operating frequency of the simulated result and -18.408dB for the measured result. It can also be observed that the result has fulfilled the characteristic of a good antenna by having multiple resonances.

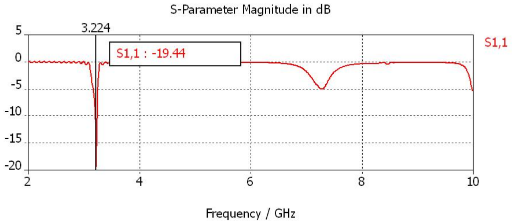


Fig.13. Simulated Return Loss in dB

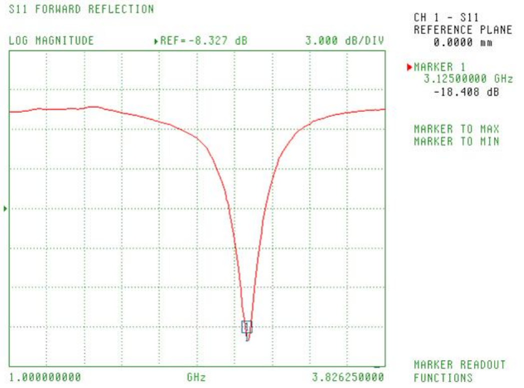


Fig.14. Measured Return Loss in dB

Fig.15 and Fig.16 represents the simulated and measured polar plot. The simulated polar plot indicates the theoretical diamond dipole radiation pattern, giving a near omni-directional radiation pattern as expected.

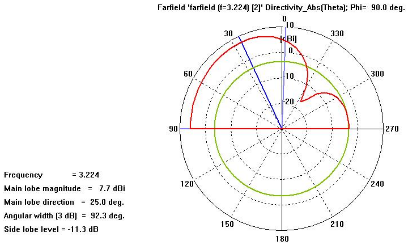


Fig.15. Simulated Polar plot

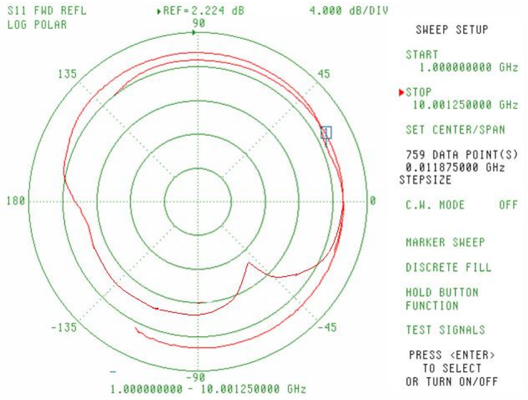


Fig.16. Measured Polar plot

The value of VSWR was 1.239 and 1.557 for simulated and measured values respectively as indicated by Fig.17. and Fig.18. Both values meet the requirements of a good antenna design whereby VSWR should be less than two for proper impedance matching throughout the entire band with sufficient bandwidth.

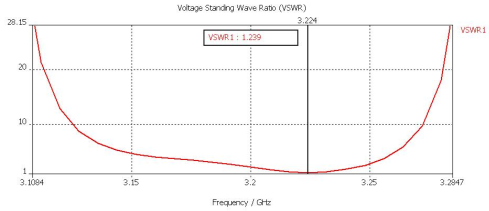


Fig.17. Simulated VSWR

Fig.18. Measured VSWR

Fig.19 and Fig.20 depict the simulated and measured input impedance. The input impedance is complex and includes both resonant and nonresonant part which is usually reactive. Both the resistance and reactance is equal to the average sum of its maximum value (positive) and its minimum value (negative).

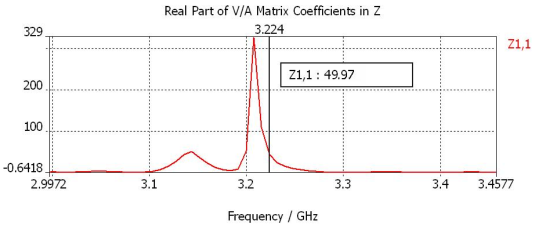


Fig.19. Simulated Input Impedance

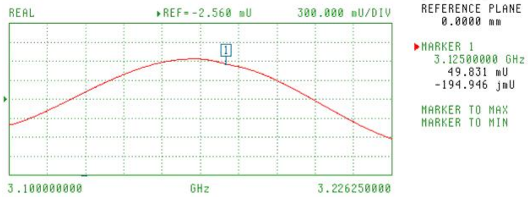


Fig.20. Measured Input Impedance

| Parameters | Simulated result | Measurement result |
|---|---|---|
| Operating frequency | 3.224GHz | 3.125GHz |
| Return loss | -19.440dB | -18.408dB |
| VSWR | 1.239 | 1.557 |
| Input impedance | 49.97Ω | 49.831Ω |
| Radiation efficiency | ±88% | ±80% |
| Gain | 7.694dBi | 7.1dBi |

Table 1. Comparison between simulated and measured result

## IV. DISCUSSION

The simulated and measured results differ slightly due to several factors. One of the reason was due to the fringing effects arises from the screws used to attach the substrate and the ground plane. In this case, the distance between the patch and the screws was not $\lambda/4$, while the best distance between the patch and the screws should be $\lambda/4$.

The discrepancy between the measured and simulated was also due to the improper attachment between the substrate and the ground plane as it was utmost important that no air gap was introduced between the two planes. It was observed that it is very hard to achieve, where both the substrate and the ground were closely attached.

As coaxial feed was used, skin effect affect the antenna's performance due to the solder lead that was used to attach the inner conductor of coaxial feed to the patch. The skin effect will cause other unwanted signals to radiate.

## V. CONCLUSION

A solid sharp edge wire diamond dipole microstrip antenna was successfully designed, simulated, fabricated and measured for the ultra-wideband (UWB) communications in the 3.1-10.6GHz. Parametric studies of the antenna characteristics were presented and the radiation properties of an antenna prototype were discussed and compared.

## VI. FUTURE DEVELOPMENT

The performance of the antenna could be further improved by having a proper attachment between the substrate and the ground plane and addressing the problem of skin effect.

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