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A Compact UWB Patch Antenna with Semicircular Edge Truncation & Stair Structure

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Abstract: The paper proposes a compact UWB patch antenna that consists of defected ground plane and semicircular edge truncation on radiating patch. The proposed antenna covers almost the entire UWB band (3.1 - 10.6 GHz). The bandwidth achieved is from 3.11 GHz to 10.11 GHz i.e. 7.05 GHz and gain achieved is 2.60 dB. The overall size of the antenna is 30 mm × 30 mm. Simulated and measured results are in good agreement.
Keywords: Compact, UWB, defected ground plane, truncation.

I. INTRODUCTION

There is an upsurge for the requirement of ultra wideband systems that cover maximum frequency bands. In February 2002, the unlicensed band 3.1-10.6 GHz was assigned by Federal Communication Commission (FCC) as Ultra Wide Band (UWB) [1]. The Ultra Wide Band systems have many applications in different fields such as radiolocations, information communication, localization etc [1]. The antennas supporting UWB systems can be used in transmission devices such as DVD, camera, HDTVs etc. Microstrip patch antenna has a low profile structure and can be considered for UWB systems [2]. Some of the popular applications of UWB technology are Wireless personal area network (WPAN), Military application, Imaging systems such as ocean imaging medical diagnostic, Emergency situations such as to detect and rescue survivors in disaster situation

The microstrip patch antenna has a major limitation of narrow bandwidth and hence cannot be used for UWB systems [3]. However different techniques have been proposed in the recent past to increase the bandwidth of the antenna including increasing the height of the antenna, using slots on the patch and ground plane, using parasitic elements etc [4]. A recent technique called metamaterial has been proposed that increases the bandwidth of the antenna and also provides a low system cost [5].

Planar antennas designed for UWB applications have low profile, light weight, and ease of fabrication [6]-[8]. But it is complex to achieve the performance indices such as good gain, large bandwidth and better efficiency in a compact size antenna. It is difficult to achieve a better tradeoff between the bandwidth, efficiency and size. So there is a scope to enhance these parameters in the planar antenna designed for UWB application using different techniques [9]-[10].

this paper, a compact and low profile patch antenna using defected ground structure (DGS) has been proposed. The proposed antenna is composed of a single step stair case structure on lower side of radiating patch and semi circular edge truncation on upper side. The designed antenna provides good gain with wideband coverage. The simulation and measured results shows good agreement between each other. Section II presents the design of the antenna. Various results are discussed in Section III. A comparison table between the simulated and measured results is also presented. The simulations were carried out in Ansoft's High Frequency Structure Simulator (HFSS) software.

II. ANTENNA DESIGN

In order to design a compact and wideband antenna, a defected ground structure has been implemented on the ground plane of the antenna. Figure 1 shows the detailed dimensions of the proposed antenna. The antenna is designed on FR4 substrate. The thickness of the substrate is 1 mm and relative dielectric constant of 4.4. The total dimensions of the substrate are 30 mm × 30 mm. Hence the total volume occupied by the antenna is 30 mm × 30 mm × 1 mm. The antenna consists of a defected ground structure also known as partial ground to help in achieving wider bandwidth. The antenna is fed through microstrip feed line with dimensions 10 mm × 1.9 mm.

As it can be observed from figure 1 that semi circular edge truncation is implemented on upper side of top patch while stair step is implemented on lower side of top patch. Introducing edge truncation and stair step helps in achieving wider bandwidth and improved impedance matching. Microstrip feed line is used to feed the patch which is matched to 50ohm impedance.

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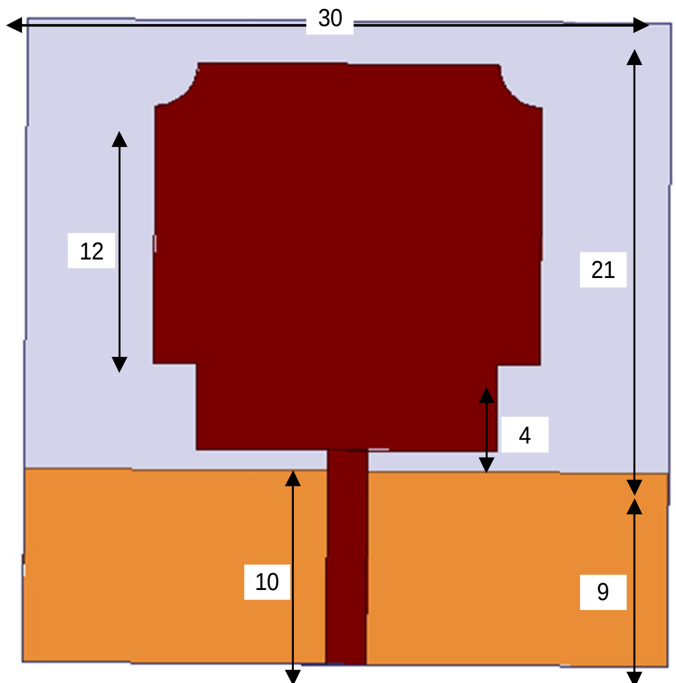

Figure 1 Detailed Dimensions of Proposed Antenna (mm)

III. RESULTS AND DISCUSSIONS

In this section, simulation and experimental results of the proposed antennas are discussed. The antenna is designed and simulated using ANSOFT HFSS. Figure 2 shows the simulated return loss of the proposed patch Antenna. The antenna resonates at antenna resonates at 4.50 GHz and 8.70 GHz having value of -23.65 dB and -20.77 dB respectively. The bandwidth coverage is from 3.11 GHz to 10.16 GHz and hence covering almost the whole Ultra Wideband range (3.1 GHz to 10.6 GHz). The antenna covers frequency bands used in Body Area Network (BAN) systems. Table I show resonant frequencies and their respective return loss values.

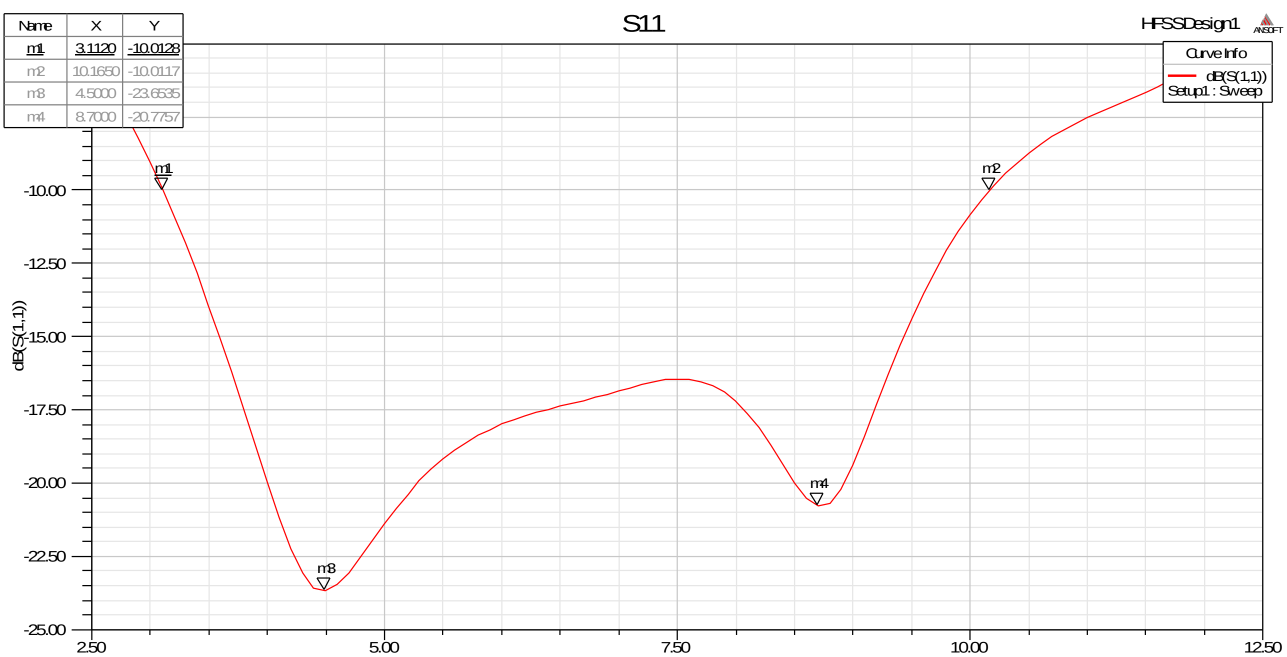

Figure 2. Simulated Return Loss parameter of Proposed Antenna

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Figure 3 shows Voltage Standing Wave Ratio (VSWR) of the proposed Planar Inverted F Antenna (PIFA). The value VSWR should be either 3:1 or less than 3 at the resonating frequencies. VSWR at various frequencies 2.9 GHz and 5.07 GHz is 0.51 and 0.41 respectively. Table II shows the simulated VSWR at different resonant frequencies.

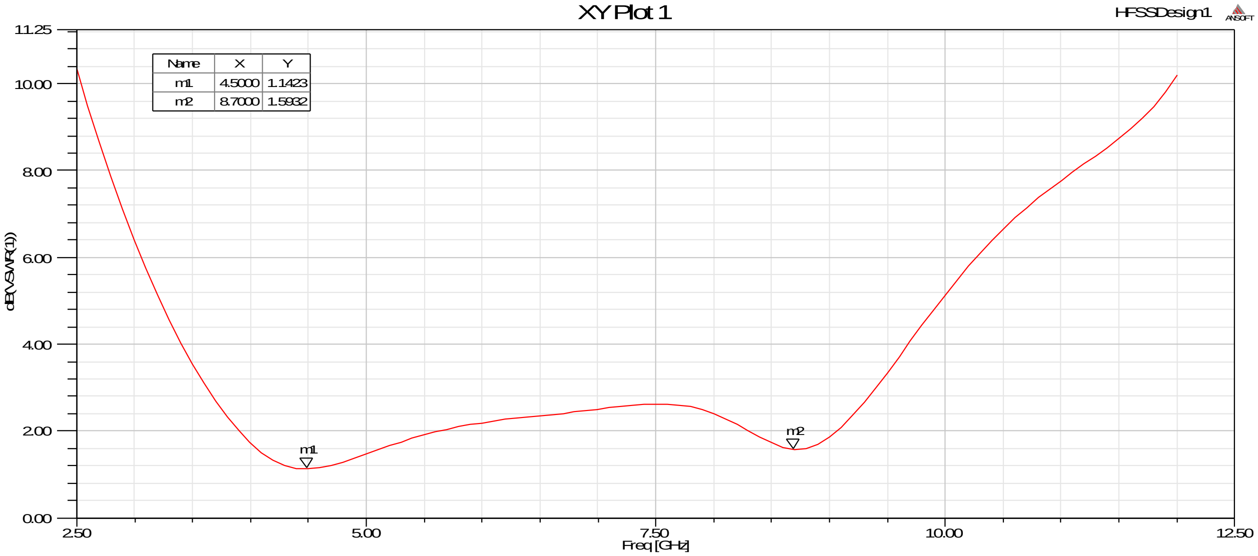

Figure 3. Simulated VSWR of the roposed Antenna

TABLE II. RESONANT FREQUENCY AND VSWR

Resonant Frequency (GHz)	VSWR (dB)
4.50	1.14
8.70	1.59

The simulated peak gain of patch Antenna across the impedance bandwidth of the total field is shown in figure 4. The total peak gain of 2.6 dB can be observed. Hence the proposed antenna shows good gain performance. Gain more than 2 dB is considered good in case of UWB Antennas.

Figure 5 shows the simulated 2D radiation pattern of proposed antenna. As depicted from the results the antenna shows good radiation pattern i.e., omni-directional in nature.

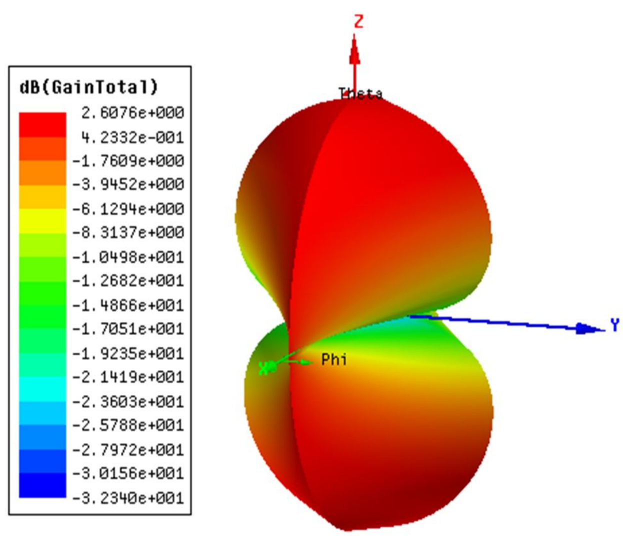

Figure 4. Simulated 3D Gain of the proposed antenna

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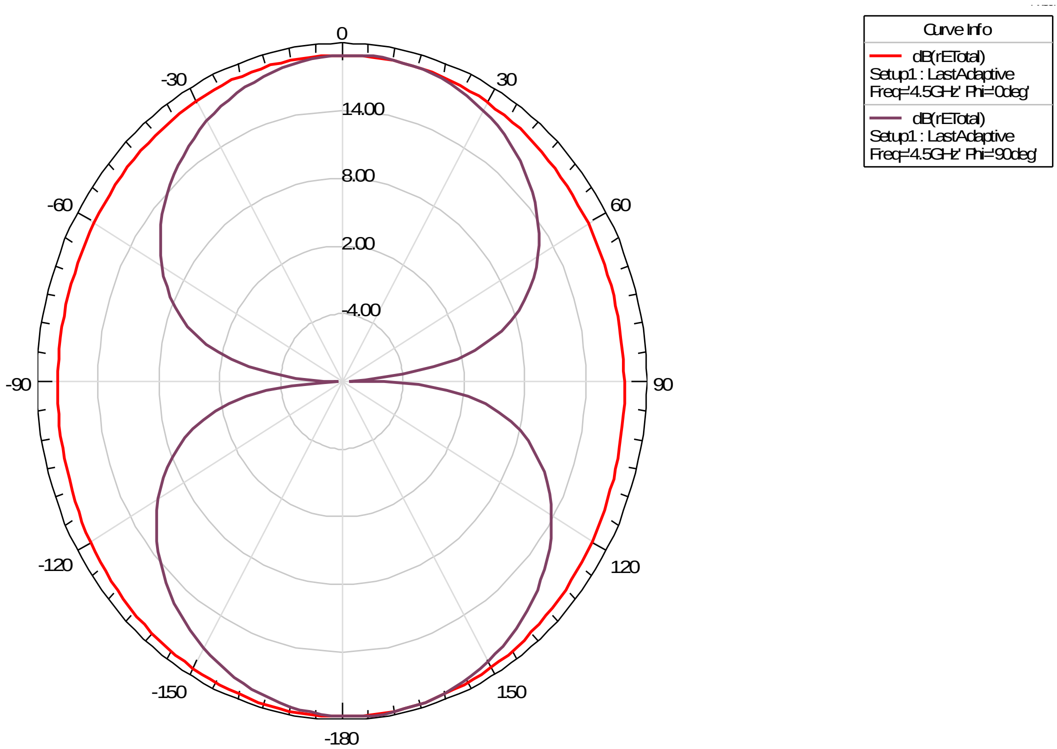
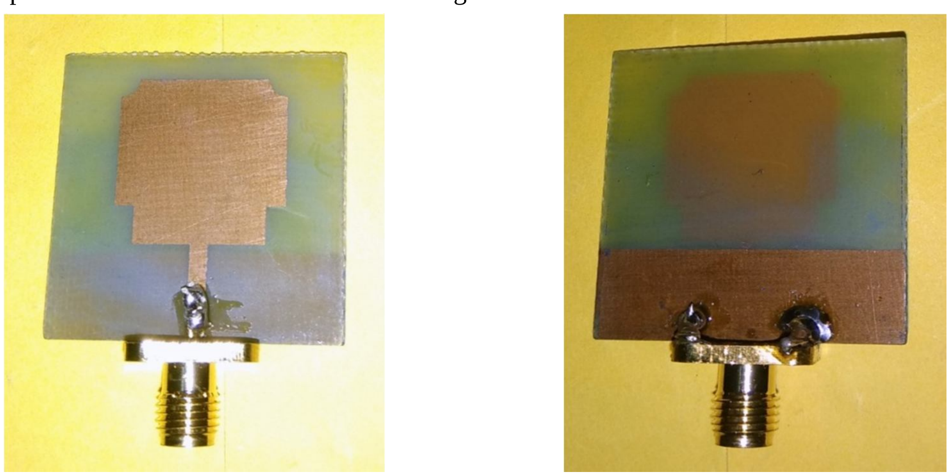


Figure 5. Simulated 2D radiation pattern of proposed antenna

Figure 6 shows the proposed UWB band antenna fabricated using FR4 substrate material.



(a) (b)

Figure 6 Single Element Fabricated Antenna (a) Front view (b) Back view

The measured return loss plot is shown in fig. 4.7. From the plot it can be observed that the bandwidth coverage is in the entire UWB band. The two resonant frequencies are at 4 GHz and 9.95 GHz with return loss of -26.3 dB and -46.8 dB respectively. The bandwidth covered is from 3.35 GHz to beyond 10.6 GHz. Fig. 4.8 shows measured VSWR plot of proposed antenna which is less than 2 dB in the entire range of operation.

The fabrication and the testing of the UWB antenna is done and it is observed that there occur some shifts in the results of simulated and fabricated antennas due to manual fabrication process, cable and connector losses.

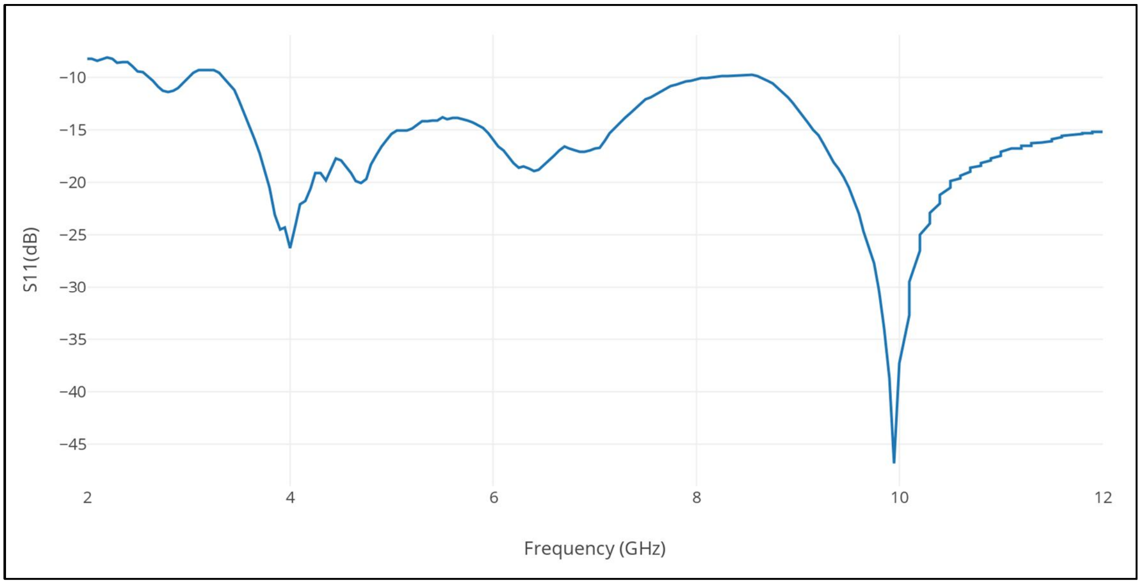


Figure 7 Measured Return Loss of Proposed Single Element Patch antenna

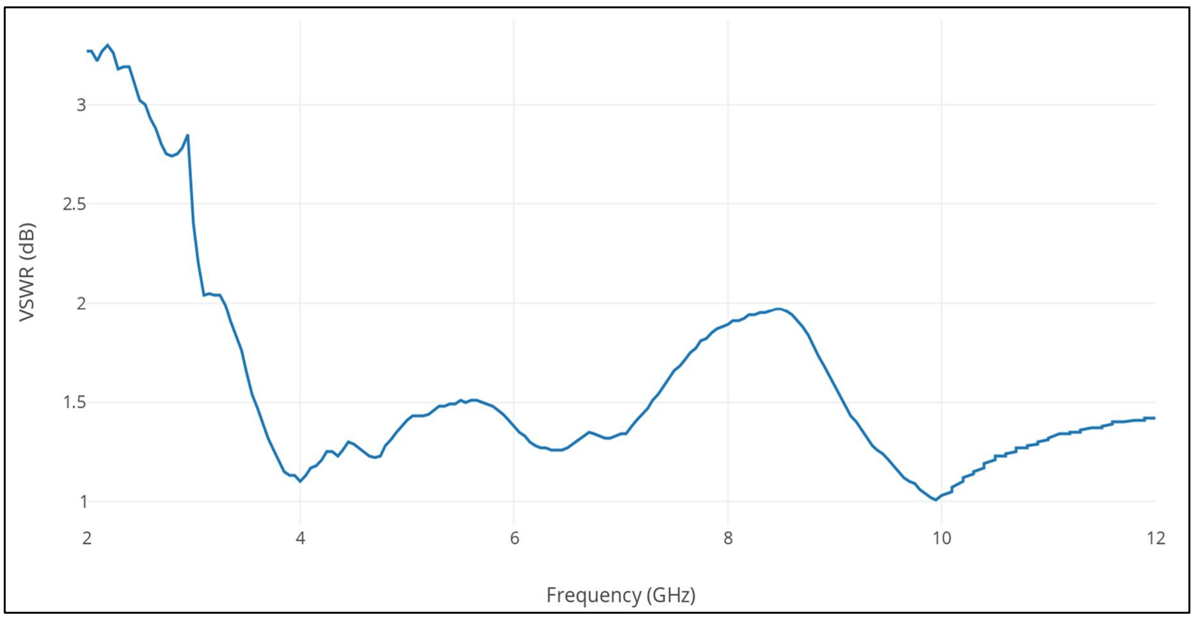


Figure 8 Measured VSWR Plot of Proposed Single Element Patch antenna

Table 4.1 Comparison between Simulated results and Measured results of Single Element Antenna

Parameters	Simulated Results	Measured Results
Resonant Frequencies	4.50 GHz & 8.70 GHz	4 GHz & 9.95 GHz
Return Loss	-23.65 dB & -20.77 dB	-26.3 dB & -46.80 dB
Overall Bandwidth	7.05 GHz (3.11 to 10.16 GHz)	8.65 GHz (3.35 to 12 GHz)

IV. CONCLUSION

In this paper a compact UWB patch antenna with DGS is proposed. From the results it is concluded that with low profile structure i.e., 30 mm × 30mm × 1 mm the proposed antenna shows better performance in terms of gain and bandwidth. The bandwidth coverage is 7.05 GHz and peak gain of 2.60 dB. The proposed antenna can be used in compact devices for wearable applications.

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