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Design , Simulation and Fabrication of a U- Shaped Antenna Having Defected Ground For Wide Band Applications

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Abstract— A novel method to develop an Ultra-Wide Band (UWB) antenna is proposed in which a defected ground structure technique is employed. The proposed design is Micro-strip fed slotted patch with an altered ground side. The Operating Band width of antenna is 3.1 GHz to 10.6 GHz. The design parameters of the antenna have been optimized using high frequency finite element based simulation software for the best gain, bandwidth and efficiency performance. Effectively directional radiation patterns and large impedance bandwidth has been observed from simulation results. The design parameters and the simulation results are all reported in this paper including the radiation pattern in different frequencies within the operating band. The proposed antenna is also fabricated and the measurement results are also presented in this paper.
Keywords— UWB, Slot antenna, DGS

I. Introduction

Higher data transmission rates and the increasingly expanding high speed communication with a lot of multimedia data transfer involved, urges the trajectory of the technology advancement to take a detour at the path of the bandwidth enhancement. A huge attention that has been devoted to the design and expansion of the ultra-wide band (UWB) antennas was a response from the scientists in the field of RF and microwave to this demand of the market. These days, UWB antennas have several applications in radar communication, RF identification devices, high-tech sensor networks, positioning and tracking systems, and so many other wireless communication fields.

For accommodating the compact size portable devices the best choice of size for the design of UWB antennas would be a low profile and light weight choice such as printed antennas. This the reason that we see all kind of microstrip designs of UWB antenna reported in publications [1], [2] and [3]. IN 2002, the federal communication commission (FCC) allocated a frequency band from 3.1 GHz to 10.6 GHz for the commercial applications of UWB [1]. After that, several designs for UWB antennas [6], [7] and [8] have been proposed; different kinds of shapes, such as square [1], circular [5], pentagonal [2], hexagonal [6], elliptical [7], ring [8] and trapezoidal can be used to design a UWB antenna [9]. Also there are various configurations and design techniques, which includes monopoles [1], [2] and [7], dipoles and slot antennas [6] and various feeding techniques such as micro-strip [1], [5],[7] and [8], co-planar-waveguide (CPW) [5]. [6] and [9] and also coaxial [11] that were all successfully employed to serve the UWB applications.

Amongst all the mentioned designs and techniques, the printed monopole antennas have received much more attention due to their wideband characteristic, Omni-directional radiation patterns, high radiation efficiency, and compact size[9][10]. Recent technological advances and the size reduction of electronic circuits have changed the wireless communications and sensor network design specifications. In particular, they have exposed the need for electrically small antennas that are efficient and have significant bandwidths. The standard electrically small antenna designs are known to be inefficient due to the large reactance and small resistance, which leads to the poor match to a given source. However, to compensate the impedance mismatch and additional bandwidth the researchers have already been introduced the concept of defected ground structure (DGS), defected micro-strip structure (DMS) and other types of defect either in the feed line or in the body of the antenna itself.

On the other hand, finite element method have been successfully employed to analyze and optimize the design of the UWB antennas because of its accuracy and the merit to handle the unconventional geometries [13][14].

In this paper a simple U-shaped antenna is proposed for UWB applications. The design concept of the antenna and its simulation results are presented in Sections II and III, respectively. In section IV the process of fabrication of the antenna is explained and the results of the measurement are presented which shows an acceptable agreement with the results of the simulation confirming the validity of the design process and the method which is proposed in this paper. Finally, the conclusion is described in Section IV.

II. ANTENNA DESIGN

Fig.1 shows the configuration of the proposed wideband antenna which consists of a two strips on the slotted rectangular ground fed by micro-strip line. The proposed antenna, which has compact dimension of 24×16 mm^2, is constructed on FR4 substrate with thickness of 0.8 mm and relative dielectric constant of 4.4. The width of the Micro-strip Feed line is fixed at 2 mm with ground has dimension of 13 ×16mm^2. Z axis is in the out of page direction.

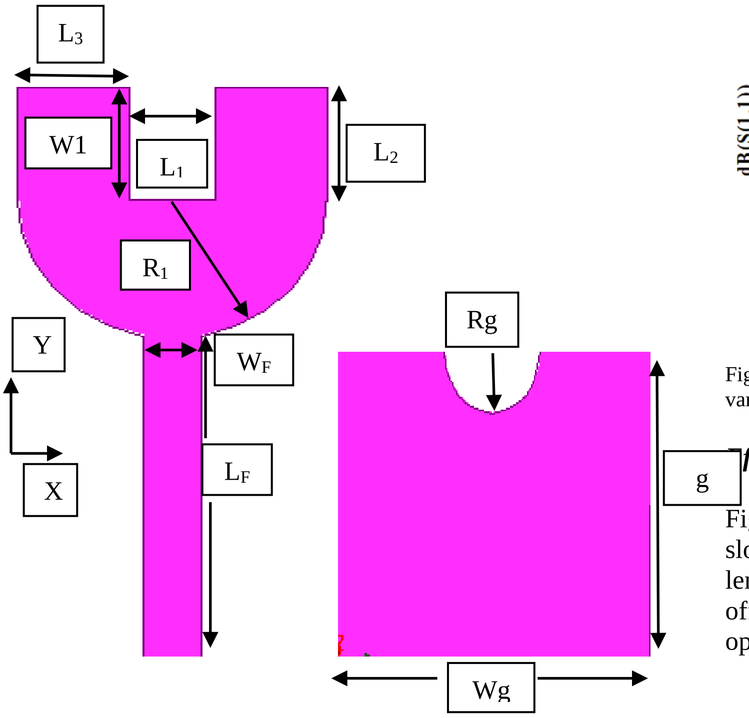

Figure.1 Top view and Bottom view of the proposed Wide Band Antenna

All the proposed antenna design parameters are optimized by HFSS software. The optimal dimensions of the designed antenna are as follows in the table:

L_1=3mm	**L_2=4.5mm**	**L_3=3.9mm**	**L_f=13mm**
W_f=2mm	**W_g=16mm**	**g=12mm**	**R_g=2.4mm**
W_1=4.5mm	**R_1=4.2mm**		

III. RESULTS AND DISCUSSIONS

A parametric study of the proposed antenna was carried out in order to wide band operation These geometry parameters were all optimized and then obtained for achieving good impedance matching over wide bandwidths .To reduce the complexity of the design, some antenna parameters are selected to be fixed as shown in Figure.1 In this section the effects of the feed line width (W_f), feed line length (Lg), ground length (g), ground cut radius (R_g), on the antenna performance is studied in details.

Effects of variation of the feed line width (W_f):

Figure.2 illustrates the return loss (S_{11}) plot of the proposed slotted wide band antenna for different values of feed line width *Wf*. It can be observed that the lower cut off frequency and operating band width depends on this parameter. The optimized value of *Wf* is found to be 2 mm.

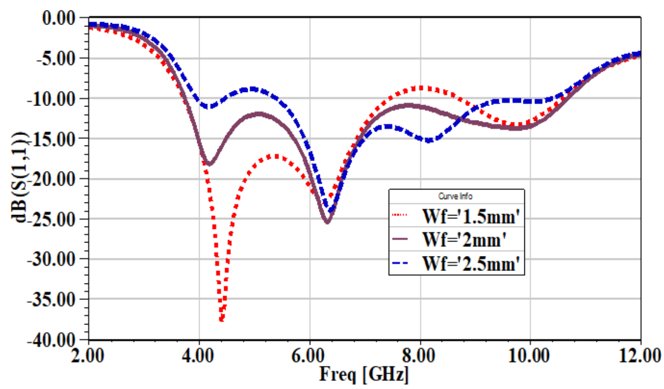

Figure.2 Simulated return loss against frequency for proposed antenna with varying feed line width *Wf.*

Effects of variation of the feed line length (Lf):

Figure.3 illustrates the return loss (S_{11}) plot of the proposed slotted wide band antenna for different values of feed line length L*f*. It can be observed that the lower cut off, upper cut off frequency and band width depends on this parameter. The optimized value of L*f* is found to be 13mm.

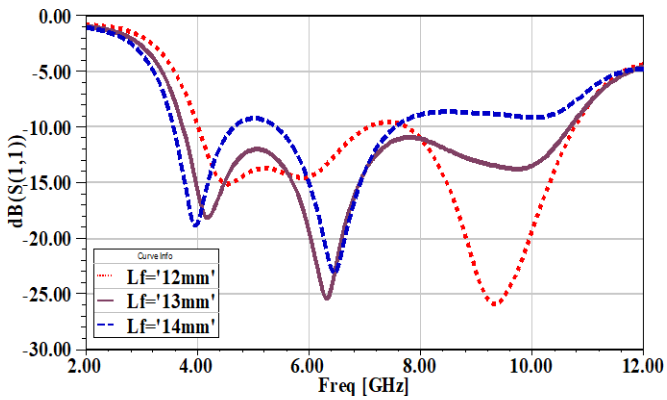

Figure.3 Simulated return loss against frequency for proposed antenna with varying feed line length L*f.*

Effects of variation of the ground length (g):

Figure.4 illustrates the return loss (S_{11}) plot of the proposed slotted wide band antenna for different values of ground length g. It can be observed that the lower cut off and

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operating band width on this parameter. The optimized value of *g* is found to be 12mm.

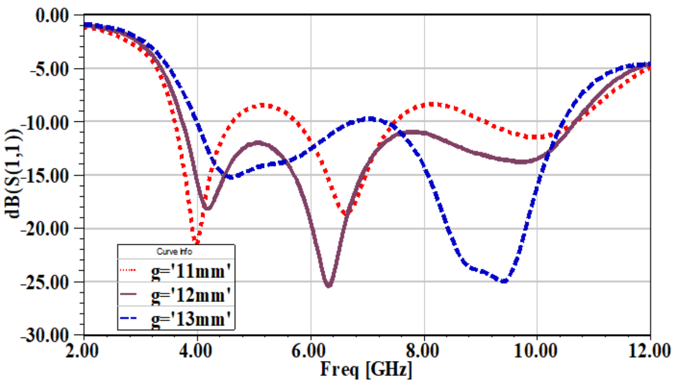

Figure.4 Simulated return loss against frequency for proposed antenna with varying ground length g.

Effects of variation of the ground cut radius parameter (Rg):

Figure.5 illustrates the return loss (S_{11}) plot of the proposed slotted wide band antenna for different values of ground defect parameter R*g*. It can be observed that the lower cut off frequency, upper cut off frequency and band width depends on this parameter. The optimized value of *Rg* is found to be 2.4mm.

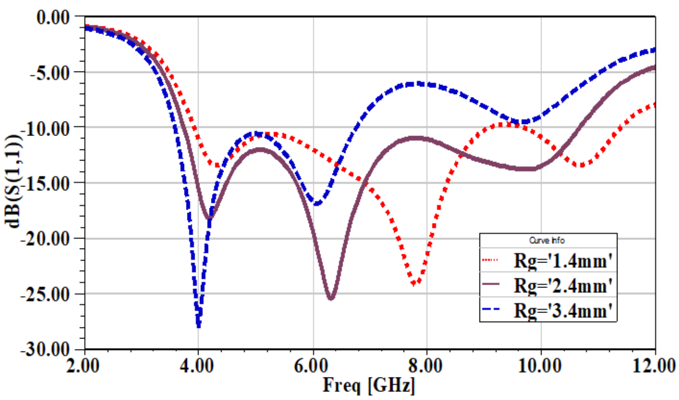

Figure.5 Simulated return loss against frequency for proposed antenna with varying ground cut radius *Rg.*

The optimized Structure Results:

Figure.6 illustrates the return loss plot of simulated optimized structure of the proposed slotted wide band antenna which

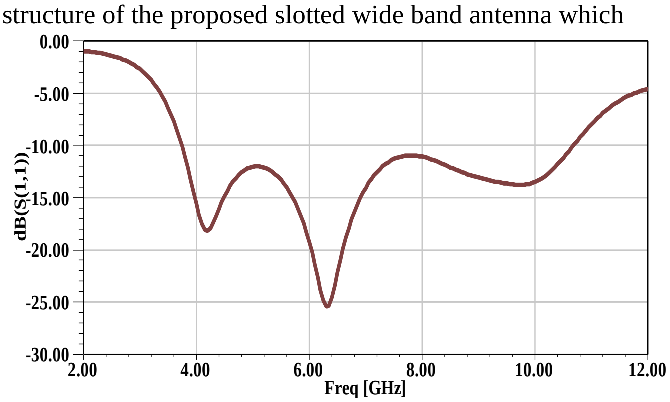

Figure.6 Simulated return loss against frequency for optimized proposed antenna

covers 3.8GHz to 10.5GHz. The radiation characteristics are also investigated. Figure.7, Figure.8 and figure.9 presents the far field 10dB normalized radiation patterns of E plane and H plane for the designed antenna at 5GHz, 7GHz and 9GHz. E-plane has non-directional radiation pattern while H-plane has directive radiation pattern.

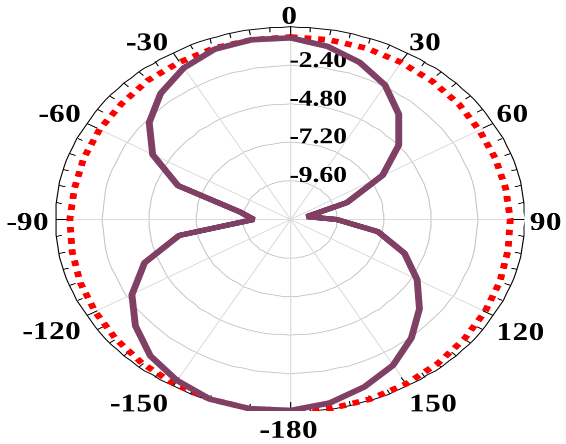

Figure.7 dash line show E plane (ϕ=0°) and Solid line show H plane (ϕ=90°) at 5GHz frequency.

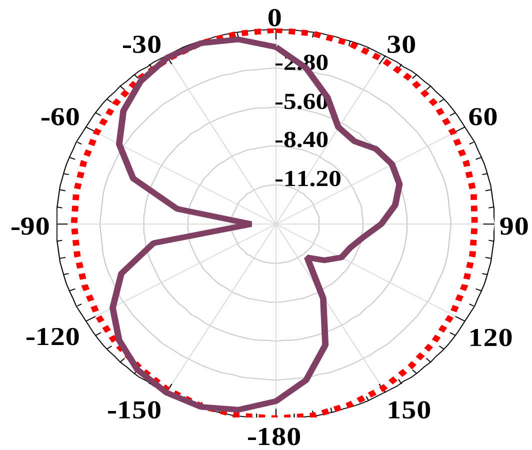

Figure.8 dash line show E plane (ϕ=0°) and Solid line show H plane (ϕ=90°) at 7GHz frequency.

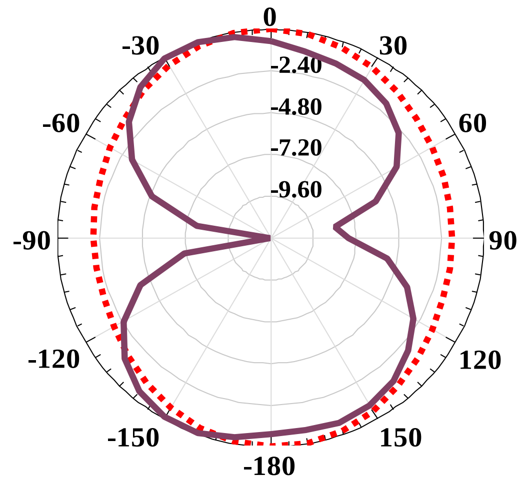

Figure.9 dash line show E plane (ϕ=0°) and Solid line show H plane (ϕ=90°) at 9GHz frequency.

Figure.10 and Figure.11 shows the current density on proposed antenna which is mainly on the fed-line for 4GHz, 6GHz and 10GHz.

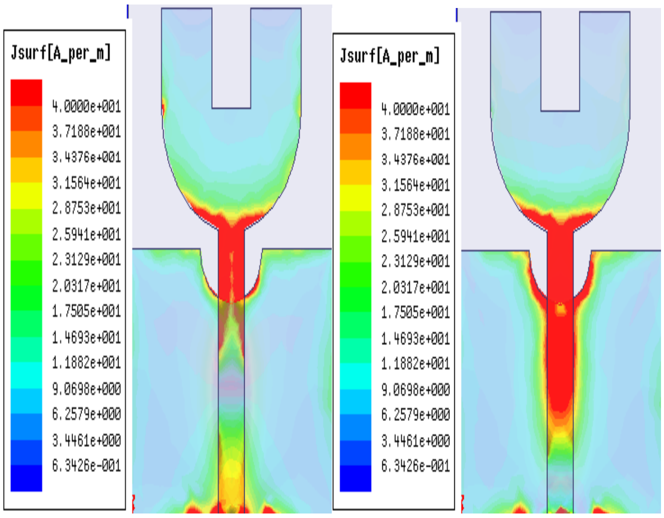

Figure.10 Current density of proposed wide band antenna at 4GHz and 6GHz

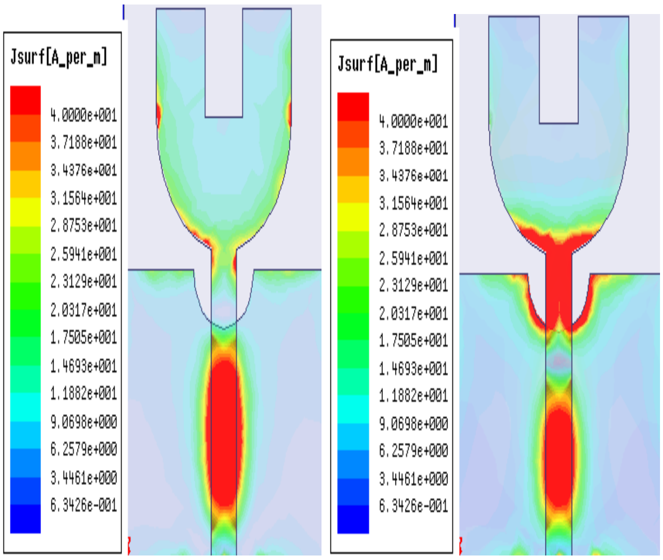

Figure.11 Current density of proposed wide band antenna at 8GHz and 10GHz

IV. FABRICATION

The antenna described in the previous sections was fabricated on a Rogers' FR4 substrate with thickness of 0.8 mm and relative dielectric constant of 4.4. Fig. 12 shows the fabricated structure as an SMA connector is used to feed the antenna via a coaxial feed line. Fabricating an ultra-wide band antenna is always challenging as details in etching process can have an effect in the performance of the antenna in terms of the impedance matching. A small compromise in the matching will lead to shrinkage of the bandwidth. Since the definition of ultra-wide band lies in meeting the FCC requirement of 3.1 GHz to 10.6 GHz.

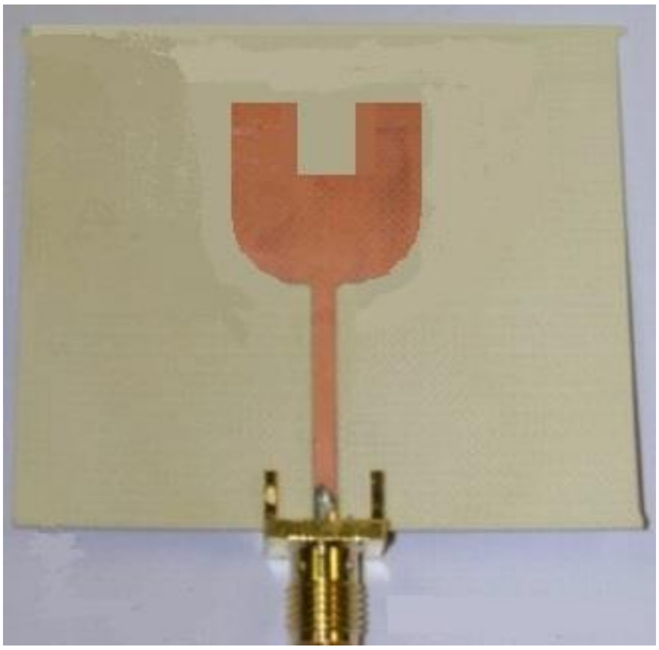

Figure. 12 The fabricated antenna on Rogers' FR4 substrate with thickness of 0.8 mm and relative dielectric constant of 4.4

The fabricated structure was tested for the return loss by the Agilent vector network analyzer. Fig. 13 shows the reflection coefficient achieved by the measurement.

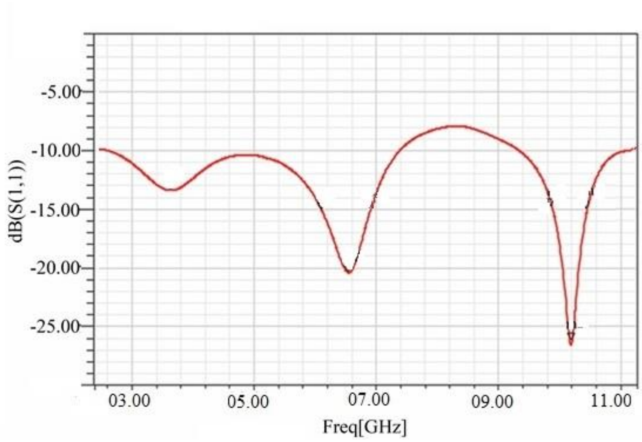

Figure 13 Te measured return loss of the UWB U-shaped antenna conducted by the Agilent Network Analyzer

The measurement results show an acceptable agreement with the simulation results. The only discrepancy is between 7 GHz and 9 GHz; however it still meets the -7 dB return loss which is still acceptable for the impedance matching.

V. CONCLUSIONS

A new Ultra-wide band antenna was proposed and demonstrated in this work. According to simulation results proposed antenna is having 3.1GHz to 10.6GHz operating frequency range with the return loss below -10 dB. The antenna was fabricated and the measurement results were in a good agreement with the simulation results. The FCC UWB requirement was met for the return bel9ow -7 dB for the fabricated prototype.

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