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Design and Analysis of Compact Planar Antenna with Defective Ground for UWB Application

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ABSTRACT

This paper proposes a new patch antenna design using defected ground structure (DGS) for ultra wideband frequencies from 3 GHz 9.4 GHz. The proposed antenna has been designed using rectangular patch with FR-4 glass epoxy substrate having relative permittivity of 4.3 while the height of substrate being kept at 1.6mm. Various parameters like return loss, voltage standing wave ratio (VSWR), directivity, radiation pattern and bandwidth are analyzed. It has been observed that a good impedance match (return loss ⩽ -10 dB) for the entire band is achieved. This antenna can be used for wireless applications which include WiMAX, Wi- Fi, satellite applications and some applications in X band.

I. INTRODUCTION

WIRELESS communication has been employed in most of the applications. For many devices, antenna plays an important role at its end terminal. Recently antennas with large bandwidth are required to support number of applications in a single device. Ultra wideband antennas are suitable for these requirements due to their advantages such as wide band, good radiation properties, low-power consumption, high data rate, robustness to the multipath environment and relatively low complexity. In 2002, Federal Communication Commission (FCC) approved to use the ultra-wideband (UWB) technology (3.1-10.6 GHz) for commercial wireless communication which leads researchers to design compact antennas for UWB applications. In recent years, these compact antennas with multiband operating capabilities are essential in commercial systems to cope with single system having multi functionality. Industries are in need of low profile compact antennas with multiband operating capabilities to meet the requirements [1]. It leads to research on low-profile-antennas for multiband applications and some of the researches on this are reported in [2]-[4]. There are many conventional techniques to achieve wideband characteristics defined as slots of various shapes with large dimension in ground layer, direct change in shape of the radiating elements and introduction of defects in ground layer with coplanar waveguide/strip line feeding techniques. The examples include modified patch and ground plane [5],[9],[12], modified strip line feed [6], U-shaped patch [7], multiple slots[8],[15], semicircular patch[10], U-shaped slot[11], slotted circular patch[13], and hexagonal wide slot[14]

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structures were discussed. Applications like Wi-Fi, Wi-Max with high gain antennas are presented in [16],[17]. Fractal shapes also designed for UWB applications [18].

In this paper, UWB patch antenna is proposed with stub introduced at the top of the patch and defected ground. The inset feed is connected with the patch to match 50Ω impedance of SMA connector. The feed is shifted to right side of the patch to achieve improved bandwidth impedance performance. The overall dimension of the antenna is 25x17x1.6mm3. To validate the proposed antenna return loss, VSWR, far-field radiation pattern, gain and directivity parameters are calculated.

II. ANTENNA CONFIGURATION

Microstrip antennas received considerable attention since 1970s, even though it was patented in 1955. But the idea of designing microstrip antenna originated in 1953. Microstrip antennas has a very thin (t<<λ, where λ is the free-space wavelength) metallic strip (patch) placed over a substrate usually having a height in the range of 0.003λ≤ h ≤ 0.05λ which is a small fraction of a wavelength (h<<λ) over a ground plane. Microstrip patch antennas are usually designed to operate in a broadside mode of radiation in which its maximum radiation is normal to the patch. Proper selection of excitation mode (configuration of EM fields) in the antenna system will serve this feature.

A. Basic Characteristics

Design of rectangular microstrip patch antennas involves selection of appropriate length and width of patch. The length LS of the patch layer is usually lies in the range of λ/3 < LS < λ/2. A substrate element having relative permittivity of εr and permeability of μr is used to separate the patch layer from ground layer. Variety of substrate materials can be used for microstrip antenna design, and typical range of their relative permittivity values are 2.2 ≤ εr≤ 12. Usually lower range values are preferred for substrate selection due to its good efficiency, wider bandwidth and ease of detachment of fields from antenna. But the antenna size becomes little larger.

B. Design Specifications

The design of the patch is developed by using rectangular patch antenna. The basic rectangular patch antenna consists of a top layer patch element, a feeding line that excites the resonating top patch, a ground layer, and a DC-shorting port that is connecting the ground and the top plate at one end of the resonating patch. Practical design of rectangular microstrip patch antennas starts simplified formulation that already been analyzed. From which we can derive the design of rectangular microstrip patch antennas. With assumption of resonance frequency of fr, substrate dielectric constant i.e., relative permittivity εr, and the height of the substrate h, the design has been carried out.

For an efficient radiator, a practical width [12] that leads to good radiation efficiencies is

$$W = \frac{c}{2 f_r}\sqrt{\frac{2}{\varepsilon_{eff}+1}} \tag{1}$$

where, c is the free-space velocity of light and the effective dielectric constant of the microstrip patch antenna is given by,

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

Then the extension of length ΔL is calculated using

$$\frac{\Delta L}{h} = 0.412\frac{(\varepsilon_{eff}+0.3)(\frac{W}{h}+0.264)}{(\varepsilon_{eff}-0.258)(\frac{W}{h}+0.8)} \tag{3}$$

The actual length of the patch can now be determined by using

$$L = \frac{c}{2 f_r\sqrt{\varepsilon_{eff}}} - 2\Delta L \tag{4}$$

The length and width of the patch can be determined by using equations (1) to (4). The cuts and slots are made in the patch and the dimensions optimized for best results. The proposed antenna structure is illustrated in Fig. 1.

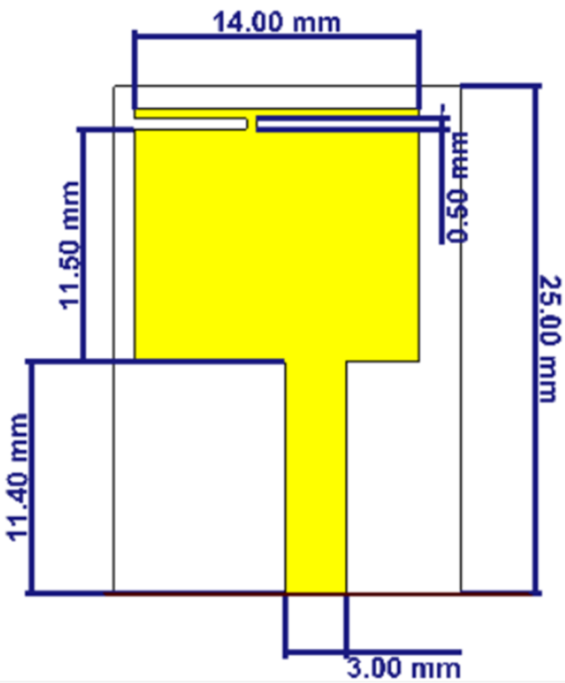


Fig.1 Top view geometry of the proposed antenna

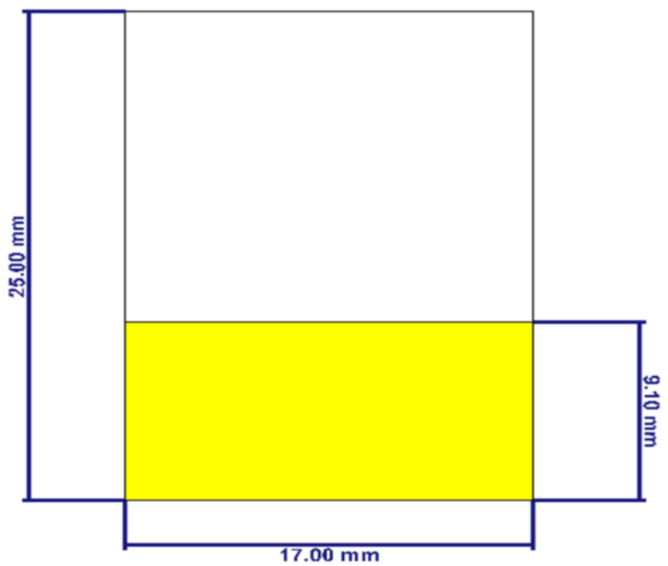


Fig.1 a) Bottom view geometry of the proposed antenna

The stub introduction in the patch causes additional resonance at 5.4 GHz. Defected ground structure causes resonances at 3.4 GHz and 8.5 GHz. The optimized design parameters are listed in Table 1.

Table.1. Dimensions of the Proposed antenna

Parameters	Dimension (mm)
Length of Substrate	25
Width of Substrate	17
Substrate thickness	1.6
Length of Patch	11.5
Width of Patch	14
Feed width	2.8
Feed Length	11.4
Ground length	9.1
Ground width	17
Stub Length	14
Spacing between Stub & Patch	6.875

III. PARAMETRIC STUDY OF THE PROPOSED ANTENNA

The proposed antenna is fabricated on a commercially available low-cost (FR-4) substrate with (relative permittivity) of 4.3, permeability of 1 and the loss tangent of 0.025. The dimensions of the substrate are 25 mm × 17 mm × 1.6 mm and the antenna is fabricated by standard photolithography process. The parameters included in the analysis are return loss, VSWR, far-field radiation pattern, gain and directivity. The simulation is carried out using CST Microwave Studio.

Return loss is the loss of power in the signal returned/reflected by a discontinuity in a transmission line or optical fiber this discontinuity can be mismatched with the terminating load in the line. It is usually expressed in dB. Return loss is related to both standing wave ratio (SWR) and reflection coefficient (Γ). Increasing return loss corresponds to lower SWR. Return loss is a measure of how well devices or lines are matched. A match is good if the return loss is high. A high return loss is desirable and results in low insertion loss for the proposed antenna. The patch antenna gives the resonant peaks at -40 dB, -25 dB and -31 dB at a frequency of 3.4 GHz, 5.4 GHz and 8.5 GHz respectively. Fig.2 shows the return loss (S11) characteristics of the proposed antenna and this shows that almost a perfect feed configuration is achieved i.e. patch and feed line are in perfect impedance matching state.

Voltage standing wave ratio (VSWR) is an indication of amount of mismatch between an antenna and the feed line connecting to it. The parameter VSWR is a measure that numerical describes how well the antenna is impedance matched to transmission line. VSWR is defined as the ratio of maximum voltage to the minimum voltage of standing wave along the transmission line. The closer VSWR is to one, greater the efficiency of electrical power transfer. Fig.3. illustrates the VSWR response of the antenna and it is found that VSWR is closer to 1 for the entire band of operation.

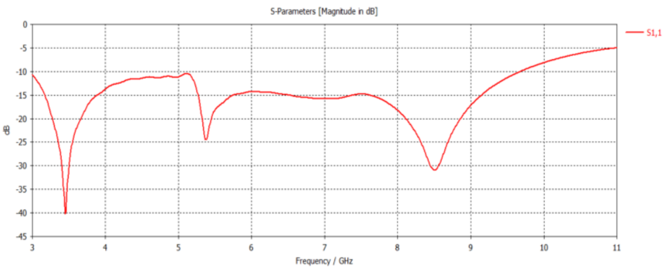


Fig.2. Return loss (S11) characteristics

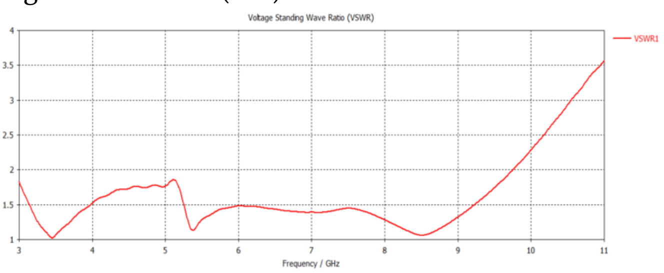


Fig.3. VSWR characteristics

The antennas radiation pattern is observed at the frequencies 3.4 GHz, 5.4 GHz, 8.5 GHz. The designed antenna is radiating all its power in one direction and therefore the optimized antenna has result with the effective radiation pattern and therefore the side lobes are nulls in the pattern has been minimized and the better directivity is achieved. The measured directivity is 2.75 dB, 2.77 dB and 2.77 dB at 3.59 GHz, 5.9 GHz and 8.4 GHz respectively. Their corresponding far field also presented here which shows radiation in desired direction by suppressing the side lobes in the undesired directions. The far field directivity pattern and absolute gain patterns are illustrated in Fig.4.

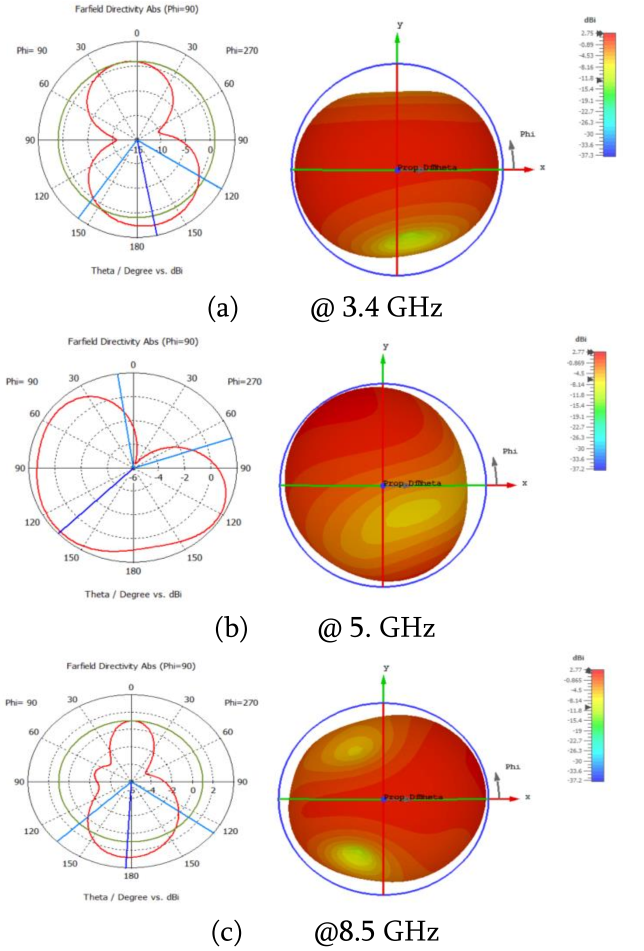
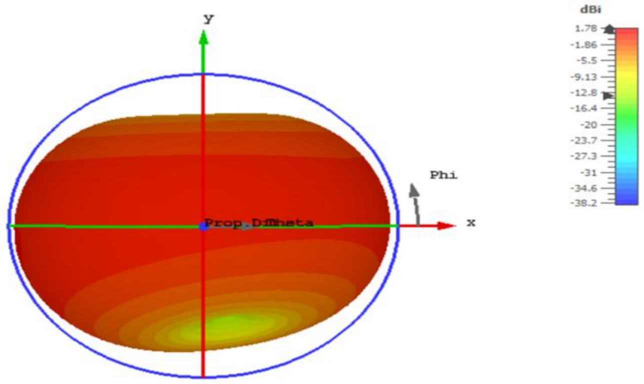
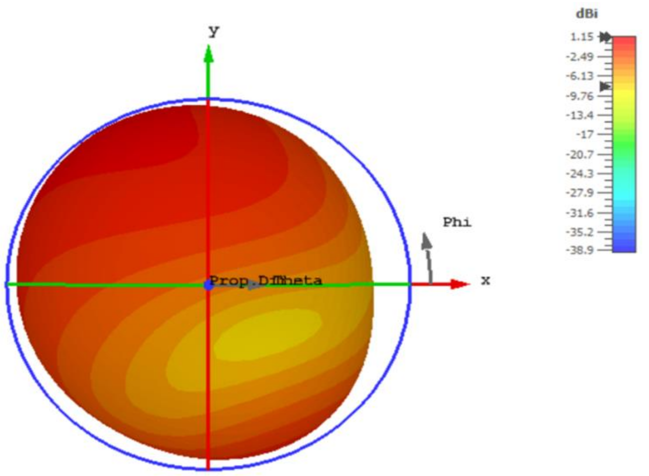


Fig.4. Far field pattern and directivity pattern at different frequencies

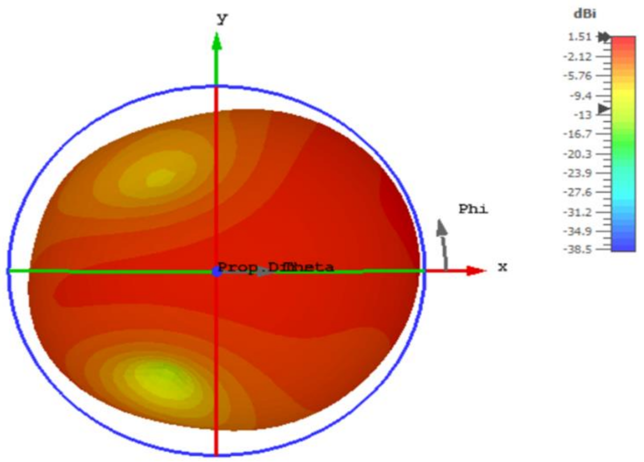
The gain of the proposed patch antenna is calculated at the frequency of 3.4 GHz, 5.4 GHz and 8.5 GHz and is given by 1.78 dB, 1.15 dB and 1.51 dB. The observed gain patterns are illustrated in Fig. 5.



(a) @ 3.4 GHz



(b) @ 5.4 GHz



(c) @8.5 GHz

Fig.5. Far field gain pattern at different frequencies

IV. CONCLUSION

The proposed antenna shows very good Ultra Wide Band characteristics which has simulation results from 3 GHz to 9.4 GHz with a Bandwidth of 6.4 GHz. The gain and VSWR parameters are achieved as per the requirement to deploy in UWB applications. The dimension of the antenna also very small (25x17x1.6 mm3). The proposed antenna covers wide range of wireless applications from Wi-MAX (3.2-3.8 GHz), Wi-Fi (Upper WLAN) (5.5 GHz), satellite applications (5.6-6.8 GHz) and some applications in X band (8-12 GHz). Furthermore this paper emphasizes on exploring a new range of high frequency applications using MIMO structures.

V. REFERENCES

[1]. Sudeep Baudha and Manish V.Yadav, A novel design of a planar antenna with modified patch and defective ground plane for ultra-wideband applications, Microw Opt Technol Lett. 2019; 18. DOI: 10.1002/mop.31716.

[2]. Rakesh N.Tiwari, Prabhakar Singh and Binod Kumar Kanaujia, A modified microstrip line fed compact UWB antenna for WiMAX/ISM/WLAN and wireless communications, Int. J. Electron. Commun. (AEÜ) 104 (2019) 5865. https://doi.org/10.1016/j.aeue.2019.03.008.

[3]. Tiwari R.N., Singh P. and Kanaujia B.K., Asymmetric U-shaped printed monopole antenna embedded with T-shaped strip for Bluetooth, WLAN/WiMAX applications, Wireless Networks; 2018. https://doi.org/10.1007/s11276-0181781-5.

[4]. Awad NM and Abdelazeez MK, Multi-slot microstrip antenna for ultra-wide band applications, J King Saud Univ Eng Sci. 2018;30:38-45

[5]. Gautam AK, Bisht A and Kanaujia BK, A wideband antenna with defected ground plane for WLAN/WiMAX applications, AEU-Int J Electron Commun 2016;70 (3):3548

[6]. Telsang TM and Kakade AB, Ultra-wideband slotted semi-circular patch antenna, Microw Opt Technol Lett. 2014;56:362-369.

[7]. Khidre A, Lee KF, Elsherbeni AZ and Yang F, Wide band dual-beam U-slot microstrip

antenna", IEEE Trans Antennas Propag. 2013;61:1415-1418.

[8]. Chakraborty M, Rana B, Sarkar PP and Das A, "Design and analysis of a compact rectangular microstrip antenna with slots using defective ground structure", Procedia Technol. 2012;4:411-416.

[9]. Gupta HK, Singhal PK, Sharma PK andJadon VK, "Slotted circular microstrip patch antenna designs for multiband application in wireless communication", Int J Eng Technol. 2012;3:158-167.

[10]. Haderi MR and Mohajeri F, "A compact hexagonal wide-slot antenna with microstrip-fed monopole for UWB application. IEEE Antennas Wirel Propag Lett 2011;10:682–5.

[11]. Sim CYD, Chung WT and Lee CH, "Compact slot antenna for UWB applications", IEEE Antennas Wirel Propag Lett 2010;9:63–6.

[12]. C.A.Balanis, "Antenna Theory-Analysis and Design", John Wiley & Sons Inc.