ISSN No. 0976-5697

Volume 5, No. 5, May-June 2014

International Journal of Advanced Research in Computer Science

RESEARCH PAPER

Available Online at www.ijarcs.info

Design and Analysis of CPW Fed Microstrip Patch Antenna with DGS for Wireless Applications

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Abstract: In this paper a design of compact size microstrip antenna is presented that have its applications in WLAN/WiMAX frequency range. The ground element of the proposed antenna is taken in the form of defected ground structure(DGS). The antenna is fed by a Coplanar Waveguide (CPW) feeding technique and printed on a dielectric Fr4 substrate of dimension (36mm X 22 mm X 1.6 mm) permittivity εr =4.4 and height h = 1.6 mm. The optimization on the microstrip antenna has been done to accomplish an -10 dB return loss criterion. . The proposed antenna is composed with regular pentagon shape patch embedded with rectangular slot and the triangular shaped defect in the ground plane. The aim is to use defected ground structure (DGS) CPW fed microstrip antennas for wireless communication that generate bandwidth of 3.02 GHz for upper band to cover IEEE 802.11 WLAN standard in the band at 5.2 GHz (5.15- 5.35 GHz) and 5.8 GHz (5.72-5.82 GHz) and WiMAX standard in the band at 3.5 GHz (3.4-3.69GHz) and 5.5 GHz (5.25-5.85 GHz). The design and optimization of DGS structures along with the parametric study were carried out by using IE3D ZELAND which is based on method of moment

Keywords: Microstrip Antenna, DGS, CPW feed, WLAN, WiMAX

I. INTRODUCTION

The explosive growth in wireless communications systems, with rapid advances in the variety of the data-intensive wireless services being offered, has increased the demands to enhance information accessibility and created a need for more bandwidth-efficient wireless communication techniques. Modern antenna requires not only the function of providing a dual- or multiband operation, but also a simple structure, compact size, and easy integration with the system circuit[2]. For this, many dual- or multiband planar antenna designs such as the microstrip-line-fed antennas, the probe-fed antennas , the planar inverted-F antennas, and the coplanar waveguide (CPW)-fed antennas have been reported. For short- and long range applications, many antenna designs suitable for wireless local area network (WLAN:2.4–2.483, 5.15–5.35, and 5.725–5.85 GHz) and worldwide interoperability for microwave access (WiMAX: 2.5–2.69, 3.3–3.8, and 5.25–5.85 GHz) operation have attracted high attention[3]. Modern communication systems and instruments require lightweight, small size and low cost antennas [4]. The selection of microstrip antenna technology can fulfil these requirements. However, microstrip patch antennas inherently have narrow bandwidth and bandwidth enhancement is usually demanded for practical applications, so for extending the bandwidth many approaches have been utilized. [5]

Recently, a defected ground structure (DGS) technique have been introduced which is used for compact microstrip patch. DGS is realized by engraving off a simple shape defect from the ground plane[6]. The shielded current distribution in the ground plane is disturbed based on the shape and dimensions of the defect, resulting in a controlled excitation and propagation of the electromagnetic waves via the substrate layer. Defected ground structures, either in a single configuration or periodic form show slow-wave effects leading to considerable size realization[4,5]. Different shapes of DGS slot have been studied in compact microstrip antenna designs, which provides better performances- size diminution (lower resonant frequency), improve return losses, impedance bandwidth enhancement (lower quality factor), and gain increasing [5-10]. DGS have received substantial interests, because they can refuse certain frequency bands, and hence it is called electromagnetic band gap (EBG) structures [6]. DGS and the Electromagnetic band gap (EBG) structures, generally called as the photonic band gap structures (PBG), are the two diverse types of generic structures employed for the design of the compact and high performance microwave components. In a word, any defect etched in the ground plane of the microstrip can give rise to increasing effective capacitance and inductance [5].

The currently proposed antenna design satisfies WLAN/WiMAX standards. In this paper, proposed monopole antenna consists of a regular pentagon shape patch. The rectangular slots are loading on to the patch, the triangular defect etched on the ground plane which makes DGS structure. The details of the proposed antenna design and simulated results are presented and discussed in next section.

II. ANTENNA GEOMETRY

The geometry of the proposed monopole antenna is shown in Figure 1. The proposed monopole antenna with DGS is designed on a 1.6 mm thick FR 4 substrate with relative permittivity of 4.4.The antenna was designed on a low-cost, durable FR 4 substrate which is reinforced with a woven fiberglass material. FR4 means flame retardant and type 4 indicates woven glass reinforced epoxy resin. The total size of the proposed antenna is 36 mm x 22 mm x 1.6 mm .To reduce the size of conventional antenna and widen its bandwidth and to enhance the overall performance of the proposed antenna, the ground and patch is loaded with slots.

The radiating patch is fed by coplanar waveguide (CPW) transmission line with a width of 4.45 mm and a length of 16mm.

Proposed antenna shown in Figure 1 consist of regular pentagon patch which is embedded with rectangular slot. The effects of the defected ground plane on proposed antenna performance are also investigated. In this design, variation of defected ground plane has a large effect on the return loss. The triangular shape defect with angle of 60 degree etched on ground plane as shown in Figure 1. The overall dimensions of proposed antenna are shown in Table 1. There are two major advantages associated with using DGS plane. First, such structures provide better return losses for good radiation efficiency. Secondly, these structures forbid the propagation of electromagnetic waves in a certain frequency band. Therefore, they can be used to block surface waves that usually corrupt antenna performance at a certain frequency band.

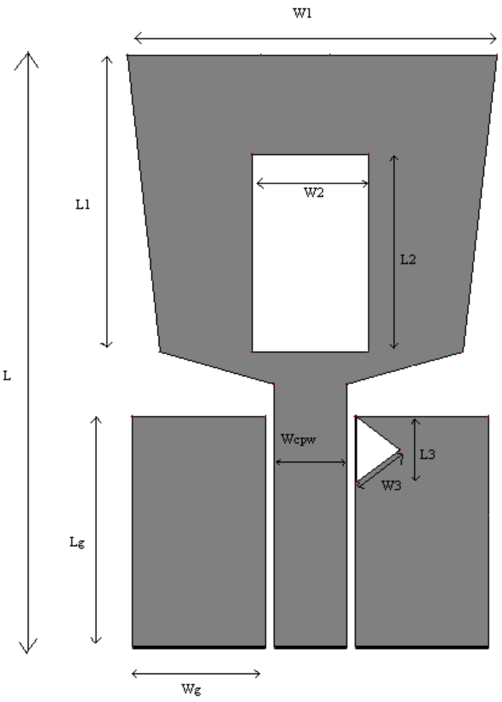


Figure 1 Geometry of proposed Antenna

Table I. Parameters of the Proposed Multiband Antenna

Parameter	Size(mm)	Parameter	Size(mm)
L	36	W_1	22
L_g	14	W_g	8
L_1	18	W_2	6.975
L_2	12	W_3	2.75
L_3	5	W_{cpw}	4.45

To obtain the optimal parameters of the proposed antenna for WLAN/WiMAX application, IE3D, full-wave commercial EM software is used that can simulate a finite substrate and a finite ground structure. Thus, the proposed antenna design can provide a wide bandwidth while retaining stable performance via the optimized geometrical parameters.

III. SIMULATED RESULTS AND DISCUSSION

The proposed antenna is simulated using combinations of the slots i.e rectangular shape slot on patch and triangular shape defect onto the ground. Simulated return loss of the optimized proposed antenna is shown in Figure 2. The simulated result has a -10 dB impedance bandwidth of 3.02 GHz which covers frequency bands of WLAN/WiMAX standard. The proposed monopole antenna has a broader bandwidth covering the required bandwidths of the IEEE 802.11 WLAN standard in the band at 5.2 GHz (5.15- 5.35 GHz) and 5.8 GHz (5.72-5.82 GHz) and WiMAX standard in the band at 3.5 GHz (3.4-3.69GHz) and 5.5 GHz (5.25-5.85 GHz).

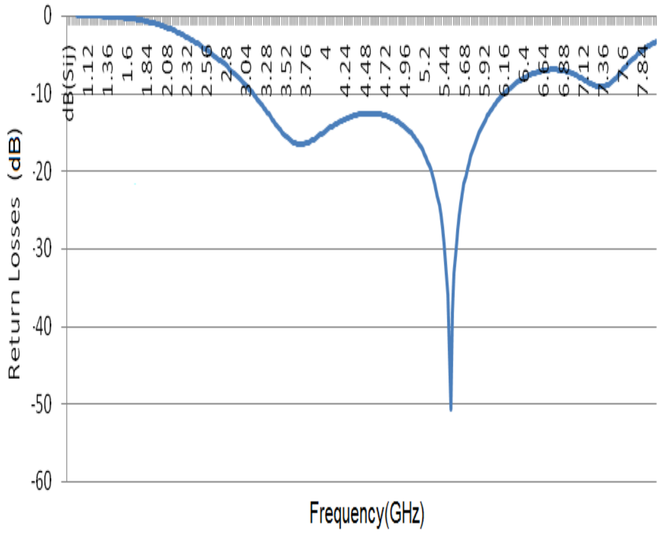
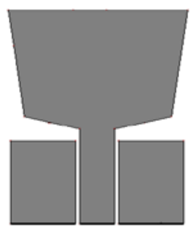
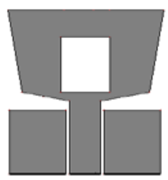


Figure 2 Return loss of proposed multiband antenna

Table 2. Geometry of Antenna1, Antenna 2 and Antenna 3

	Antenna 1	>Bandwidth= 3.2 GHz >Resonance peak=-45.7dB
	Antenna 2	>Bandwidth= 3.4 GHz >Resonance peak= -35.1dB
	Antenna 3	>Bandwidth= 3.02 GHz >Resonance peak =-50.44 dB

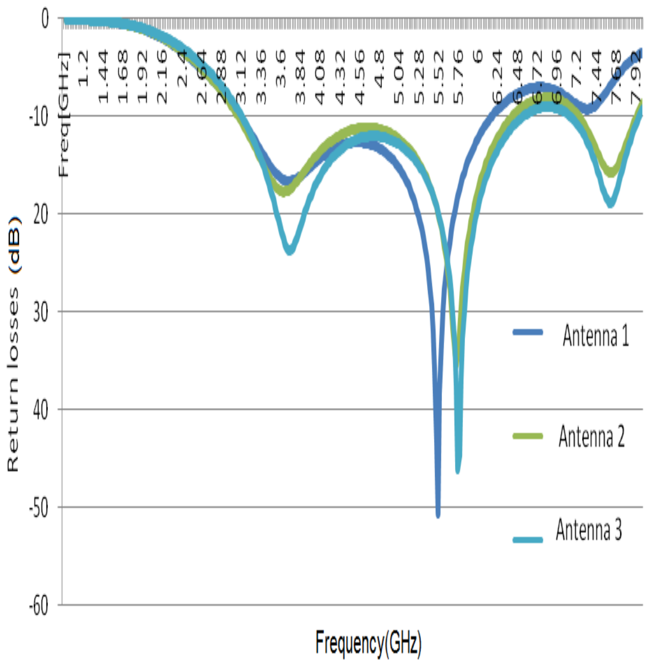


Figure 3 Return losses of antenna 1, antenna 2, antenna 3

Figure 3 compares the simulated return loss versus frequency of the proposed antenna as shown in Table 2. From the above graph it has been concluded that the effect of defected ground has large effect on antenna performance. The microstrip antenna without DGS will provide higher operating bandwidth and less return losses . On the other hand, microstrip antenna with DGS , bandwidth is narrow and return losses is high. Therefore, the DGS can be integrated onto the ground plane of such antenna in order to improve its radiation, besides not requiring additional circuits are for implementation. Also, the Figure shows that most of the constructed shapes with slots loading gives reasonable bandwidth i.e antenna 2 has 3.4 GHz bandwidth and antenna 1 has 3.2 GHz bandwidth. Hence, the bandwidth is improved with loading of slots into the patch. These configurations give the antenna the capability to be used for different applications. For a specific application one can decide the required resonant frequencies applicable for that application. From the simulation result shown in Figure3. It can be seen that, by adding a triangular shape defect etched in the ground plane, considerably the bandwidth is not improved but the return losses is improved from -35.1dB to 50.44dB.

IV. A. CURRENT DISTRIBUTION

We also simulate the surface current distributions for the resonant frequency at 5.7 GHz or 5.5 GHz respectively. The resonant current shown in below figures, flows along lower corners of the square slot of the at frequency 5.7 GHz. The triangular shape defect on ground disturbs the current distribution, resulting in a controlled excitation and propagation of the electromagnetic waves via the substrate layer and gives maximum value of return losses.

A. Voltage Standing Wave Ratio (VSWR):

The Figure 7 indicates that antenna shows good impedance matching with feed network. There should be a maximum power transfer between the transmitter and the antenna to perform efficiently. Ideally, VSWR must lie in the range of 1-2 near the operating frequency value

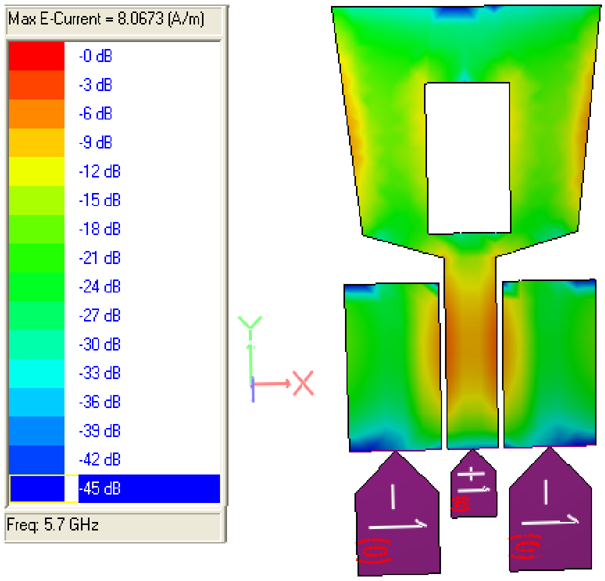


Figure 5 Current Distribution Pattern of Proposed Antenna at 5.7 GHz (without DGS)

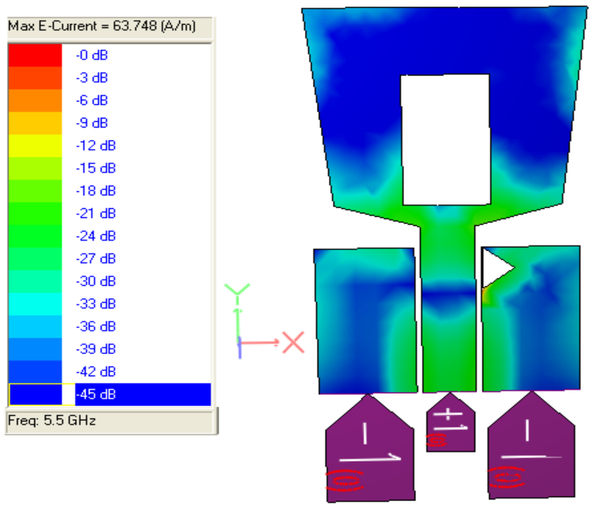


Figure 6 Current distribution of proposed antenna at 5.5 GHz (with DGS)

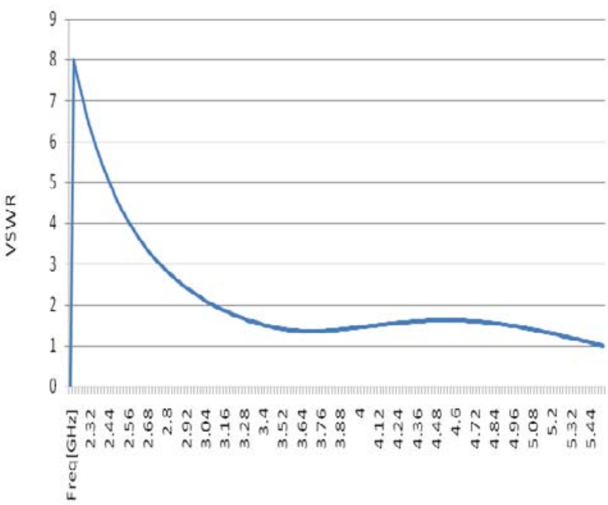


Figure 7 VSWR of proposed antenna.

B. Radiation pattern:

This work is to design a small antenna suitable to be used for wireless communication, where a three-dimensional (3D) omni-directional radiation and high radiation efficiency are desirable where the red colour indicates the stronger radiated E-fields and the blue colour the weaker ones. Simulated 2D radiation pattern for elevation and azimuthal plane respectively is shown in Figure 8-10. Radiation pattern presents the graphical representation of radiation properties of antenna as a function of space co-ordinates. E-plane patterns at 90 degree are shown, which satisfies the condition of radiation pattern of a microstrip antenna, which is same as that for a monopole antenna. Similarly H-plane patterns for 90 degree forms an omni-directional pattern. These patterns are desirable for WLAN/WiMAX applications.

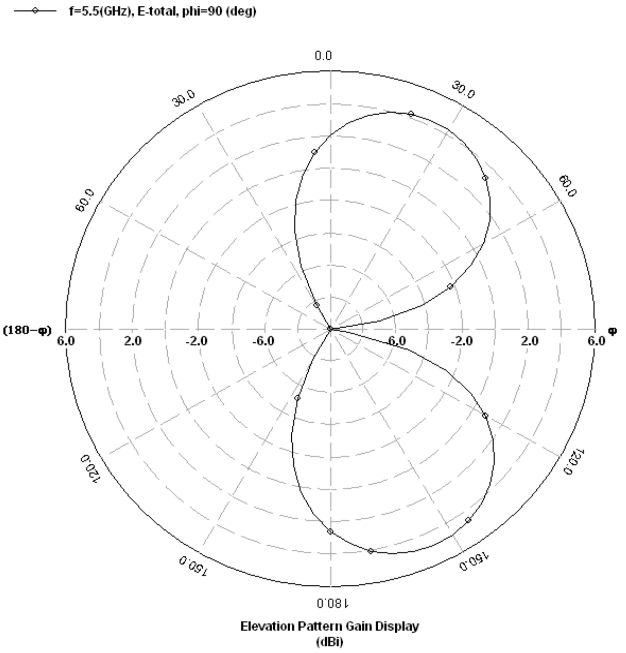


Figure 8 Elevation radiation pattern at 90 degree at 5.5 GHz

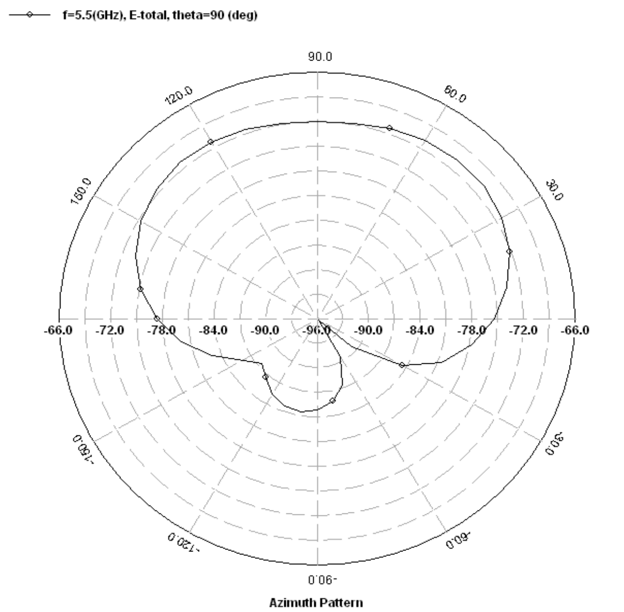


Figure 9 Azimuthal radiation pattern at 90 degree at 5.5GHz

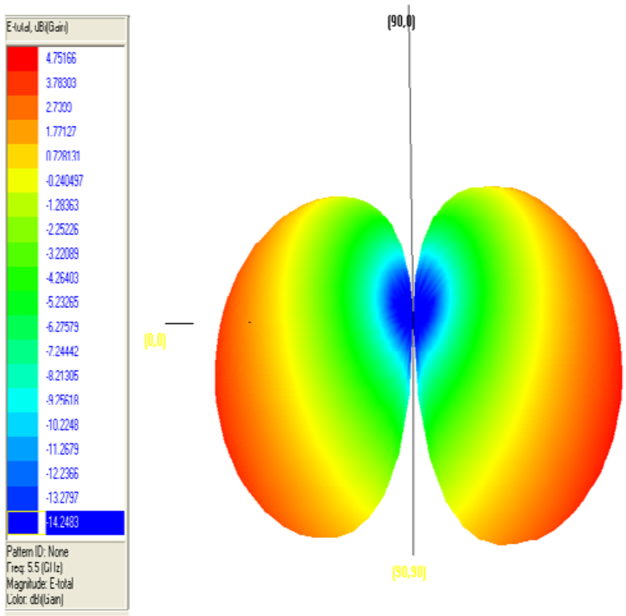


Figure 10 3-Dimensional Pattern of Proposed Antenna

V. `CONCLUSIONS

A CPW fed defected ground structure antenna suitable for WLAN/WiMAX applications is presented. To reduce the size of conventional antenna and widen its bandwidth the patch is loaded with rectangular slot. The rectangular slots are loading on the patch, the tringular shape defect etched on the ground plane as DGS. The simulated result has a -10 dB impedance bandwidth of 3.02 GHz which covers upper bands of WLAN/WiMAX. Effects of varying dimensions of key structure parameters on the antenna and various parameters like VSWR, current distribution, radiation pattern and their performance are also studied. The parametric studies show significant effects on the impedance bandwidth of the proposed antenna. Moreover, the proposed antenna has several advantages, such as small size, excellent radiation patterns, good efficiency. These characteristics are very attractive for some wireless communication systems.

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