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CPW fed Rectangular Shape Microstrip Patch Antenna with DGS for WLAN/WiMAX Application

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Abstract: This paper presents CPW fed rectangular shape microstrip patch antenna with Defected Ground Structure that generate wideband bandwidth to cover WLAN/WiMAX bands simultaneously. The antenna was designed on a low-cost, durable FR4 substrate, which is reinforced with a woven fiberglass material. The proposed antenna mainly consists of rectangular shape patch embedded with rectangular slit on substrate and circular shape defect is created to form defected ground structure. Proposed antenna generate impedance bandwidth of 3.78 GHz 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(3.4-3.69 GHz) and 5.5 GHz (5.25-5.85 GHz). The soft nature of the DGS facilitates improvement in the performance of microstrip antennas. The design and optimization of DGS Antenna along with parametric study were carried out using ZELAND IE3D which is based on method of moment

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

INTRODUCTION

Recently, with the rapid development of wireless communication, the demand for the design of an antenna with multiband operation has been increased. Modern communication systems and instruments require lightweight, small size and low cost antennas. The selection of microstrip antenna technology can fulfill these requirements [1] Microstrip patch antenna is a type of antenna that offers a low profile, i.e. thin and easy manufacturability, easy to fabrication by using techniques like etching and photolithography [2], are easy to feed, easy to use in an array and moderate directivity, which provides a great advantage over traditional antennas. 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. In addition some applications of the microstrip antenna in communication systems required smaller antenna size in order to meet the miniaturization requirements. So significant advances in the design of compact microstrip antennas have been presented in [2-9]. Currently, numerous printed multiband monopole antennas have been proposed by employing various promising feed structures such as the microstrip and the coplanar waveguide (CPW). Rectangular Microstrip Patch Antenna is very useful because of its small-size, ease of fabrication.

However still there are challenges in achieving good antenna performance because microstrip antennas suffer from several disadvantages also. The major drawbacks are low bandwidth [5], low efficiency than with other antennas, dielectric and surface losses. So to alleviate these problems EBG and PBG structures were used earlier. However, in implementing EBG, a large area is needed to implement the periodic patterns and it is also difficult to define the unit element of EBG [2-6]. So they are replaced by a new technique called DGS [2]. There are two major advantages associated with using DGS plane. First, such structures provide wider bandwidth with enhanced gain and higher radiation efficiency. Second, 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.

Defected ground structure is realized by etching off a simple shape (defect) from the ground plane. Defected ground structures, either in a single configuration or periodic form that is frequently referred to as a photonic band gap (PBG) show slow-wave effects leading to considerable size realization [7]. Depending on the shape and dimensions of the defect, the shielded current distribution in the ground plane is disturbed, resulting in a controlled excitation and propagation of the electromagnetic waves through the substrate layer [8]. In a word, any defect etched in the ground plane of the microstrip can give rise to increasing effective capacitance and inductance [9].

The currently described antenna design satisfies WLAN/WIMAX standards. In this paper, proposed monopole antenna consists of a rectangular patch. The rectangular slits are loading on the patch, the circular defect etched on the ground plane to form DGS structure. The details of the proposed antenna design, simulated results are presented and discussed in next section.

ANTENNA GEOMETRY

Fig.1 shows the geometry and dimensions of the proposed antenna for multi-band WiMAX/WLAN operations. The antenna is excited by the CPW line and is printed on the FR4 substrate with a thickness of 1.6 mm and relative permittivity of 4.4. FR4 means flame retardant and type 4 indicates woven glass reinforced epoxy resin. The total size of the proposed antenna is 36.2 mm x 18 mm x 1.6 mm. To reduce the size of conventional antenna and widen its bandwidth the ground is loaded with slot. The way that slot are loaded into the ground widen the bandwidth of the antenna due to the disturbance caused to mean current paths of any resonant frequency. The two ground planes are placed symmetrically on each side of the CPW line. The proposed antenna has a single layer metallic structure on one side of FR4 substrate layer whereas the other side is without any metallization.

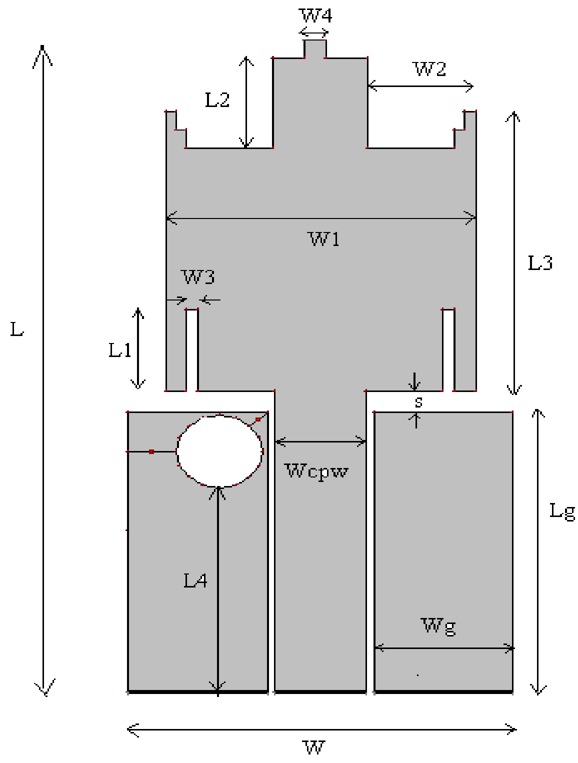

Figure 1: Geometry of proposed Antenna

A rectangular shape patch loaded with two rectangular slits forms the substrate of the planar antenna and a defected ground is formed by inserting circular shaped defect into ground plane. The patch is fed through a coplanar waveguide (CPW) feed.

Table I. Parameters of the Proposed Antenna

Parameter	***Size (mm)***	***Parameter***	***Size (mm)***
L	36.2	W	18
L_g	15.5	W_g	6.5
L_1	4.5	W_1	14.5
L_2	5	W_2	5
L_3	15.5	W_3	0.5
L_4	11.35	W_4	1
W_{cpw}	4.3	S	1.2

The effect of the structure of the ground plane on antenna performance is also investigated by mounting the proposed antenna structure on a defected ground structure (DGS) plane. The DGS plane constitutes of an etched circular shape defect with radius 2mm which are arranged as shown in Fig.1. The geometry of DGS can be one or few etched structure which is simpler and does not need a large area to implement it. Simulation results have been showed that the antenna with DGS can improve the antenna performance. DGS structures provide wider bandwidth with enhanced gain and higher radiation efficiency. 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.

To obtain the optimal parameters of the proposed antenna for WLAN/WiMAX application, IE3D, full-wave commercial EM software that can simulate a finite substrate and a finite ground structure, is used. Thus, the proposed antenna design can provide a wide bandwidth while retaining stable performance via the optimized geometrical parameters. The effects of the key structure parameters on the antenna performances are also analysed and presented in next section.

SIMULATED RESULT AND DISCUSSIONS

Fig.2 shows the simulated return losses (S parameter) of the proposed antenna. It can be clearly seen that the proposed antenna has a multi-band characteristic which covers WiMAX/WLAN spectrum. The antenna impedance bandwidth that is lower than -10dB occupies 3.78 GHz from 3.34GHz to 7.12GHz. It can operate well in WLAN/WiMAX applications. In this design variation of defect ground has a effect on the return loss. The effect of defected ground size has large effect on antenna performance. The microstrip antenna without DGS, the bandwidth is narrow i.e 3.46 GHz and the return loss is high. On the other hand, microstrip antenna with DGS will provide higher operating bandwidth i.e 3.78 GHz and less return loss peak. Therefore, the DGS can be integrated onto the ground plane of such antenna in order to improve its radiation, besides not requiring additional circuits for implementation. 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 (3.4-3.69 GHz) and 5.5 GHz (5.25-5.85 GHz).

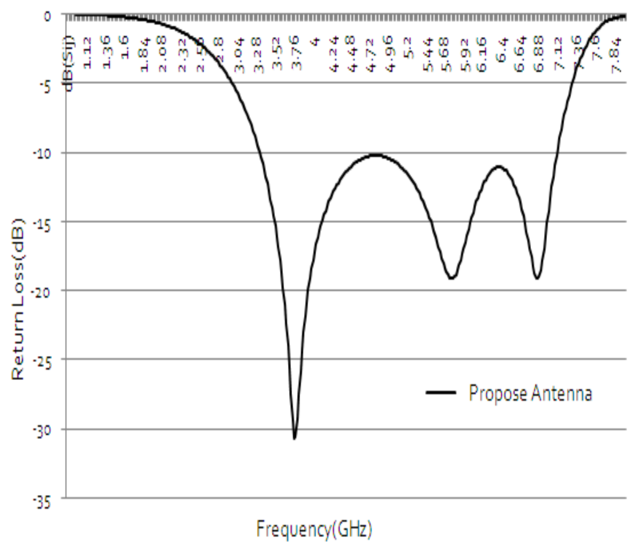

Figure 2: Return loss of proposed multiband antenna

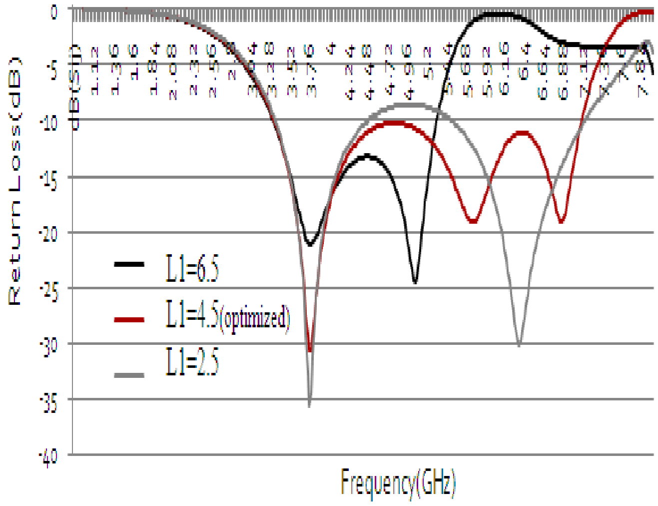

Figure 3: Parametric comparison of return loss of antenna

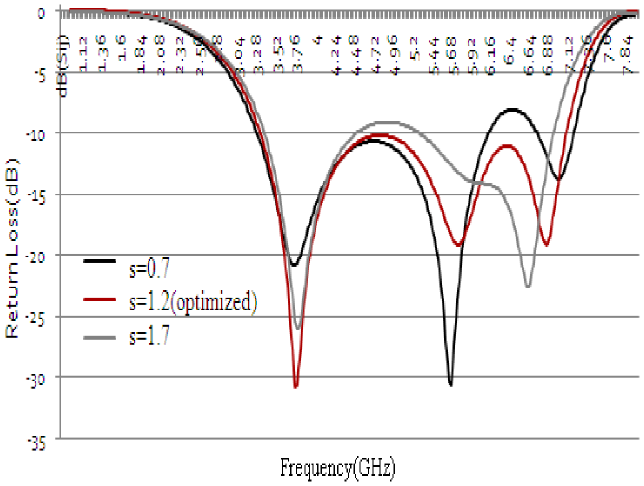

Figure 4. Effect of the variation of distance between the patch and ground(s)

Effects of varying dimensions of key structure parameters on the antenna by varying the length of the rectangular slit L_1 on the frequency response for the proposed antenna is shown in Fig.3. The parametric study on the distance between the patch and the ground of the proposed antenna is shown in Fig.4. Referring to these results, the antenna can satisfy not only the WLAN bands of 5.2/5.8 GHz, but also the WiMAX band of 3.5/5.5 GHz.
This clearly reveals that by using DGS much better bandwidth can be obtained. Hence a multiband antenna is presented in this work using defected ground structure technique, which has higher bandwidth and smaller size of 36.2 mm X 18mm X 1.6 mm. This way it achieves good impedance matching with working bands for WLAN/ WiMAX applications.

3.1 Current Distribution

In order to further study the excitation mechanism of the proposed antenna, the simulated surface current distribution of the whole antenna at the frequency 3.8 GHz are given in Fig.5. Obviously, for the middle band excitation at 3.8GHz, most of the surface current flow along the rectangular slit and feed line. Circular shape defect on ground disturbed the shielded current distribution in the ground plane and on patch, resulting in a controlled excitation and propagation of the electromagnetic waves via the substrate layer.

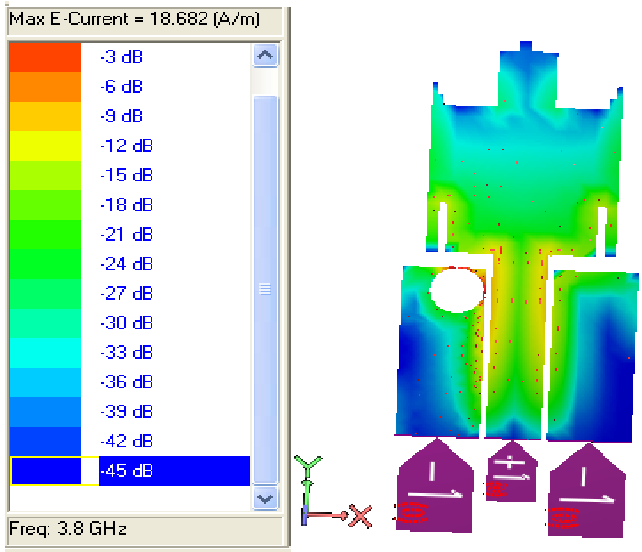

Figure5: Current distribution of proposed antenna with DGS at 3.8 GHz

The formation of the frequency resonances can be explained by observing the surface currents on the conductors of the antenna at 3.8 GHz. Current distributions are changed by changing the length and dimensions of ground plane.

3.2 Voltage Standing Wave Ratio (VSWR)

There should be a maximum power transfer between the transmitter and antenna to perform efficiently. The VSWR plot for CPW feed antenna is shown in Fig.6. Ideally, VSWR must lie in the range of 1-2.

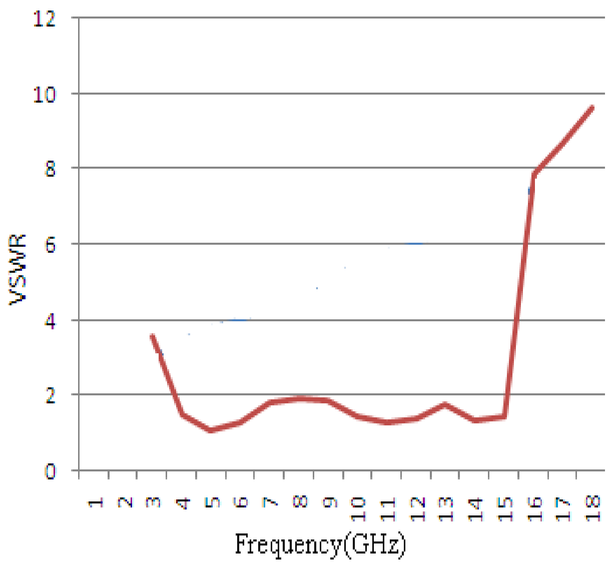

Figure 6: VSWR of proposed antenna

3.3 Radiation pattern

Fig. 7(a) and 7(b) shows simulated 2D radiation pattern for elevation and azimuthal plane respectively. 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, presenting a figure of eight like structure, which satisfies the condition of radiation pattern of a microstrip antenna, which is same as that for a monopole antenna. Similarly H-plane patterns at 90 degree at 3.8GHz frequency are also shown in figure. These patterns are desirable for WLAN/WiMAX applications. Also 3-Dimensional pattern of proposed antenna is shown in Fig 8..

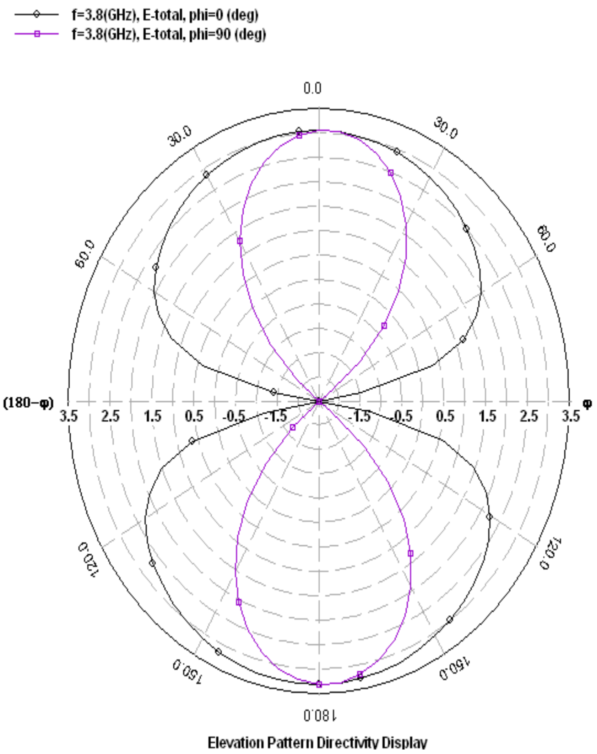

Figure 7(a): Elevation radiation pattern at 90 degree at 3.8 GHz

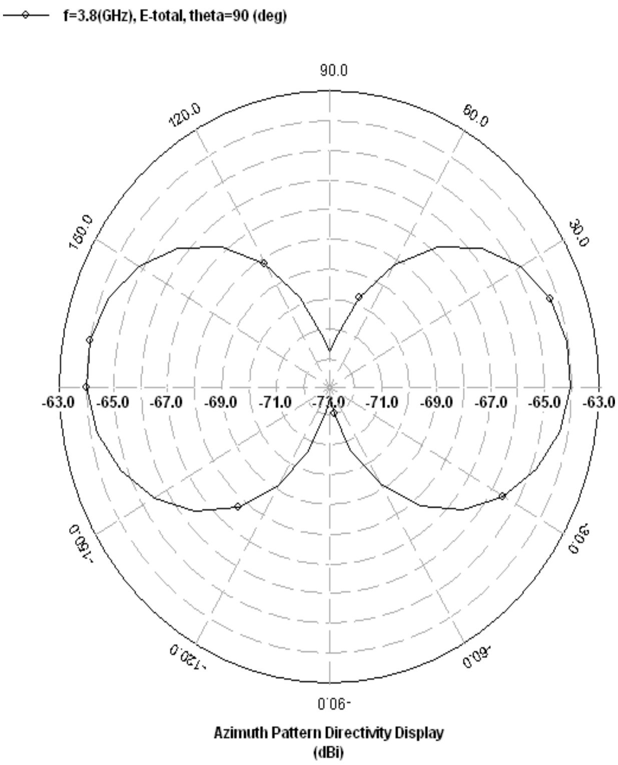

Figure 7(b): Azimuthal radiation pattern at 90 degree at 3.8 GHz

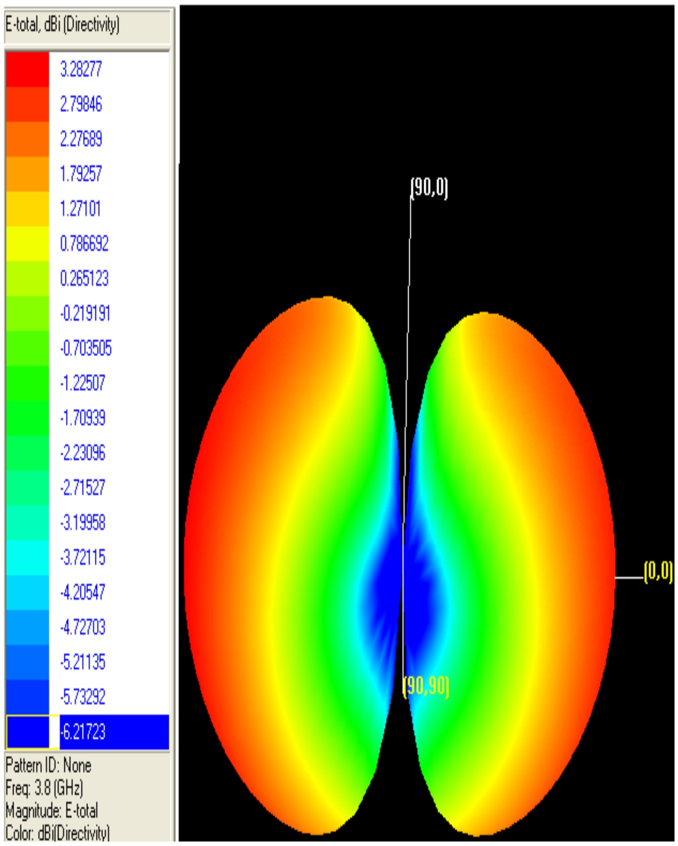

Figure 8: 3-Dimensional Pattern of Proposed Antenna

CONCLUSIONS

A CPW-fed rectangular patch antenna with Defected ground structure suitable for WLAN/WiMAX applications is presented. The proposed antenna consists of rectangular shape patch embedded with rectangular slit and circular shaped defect on the ground plane antenna exhibits single wide band which creates an impedance bandwidth of 3.78 GHz for the working band of 3.34GHz-7.12GHz. The 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. Radiation pattern performance of the antenna is acceptable at all the frequency bands. Moreover, the proposed antenna has several advantages, such as small size, excellent radiation patterns, good efficiency. These characteristics are very attractive for wireless communication systems.

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