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Miniaturized Triple Band Microstrip Patch Antenna with Defected Ground Structure for Wireless Communication Applications

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ABSTRACT
This paper presents a miniaturized triple band multi frequency antenna. The proposed antenna can generate two separate impedance bandwidths to cover all the 2.4/5.2/5.8-GHz WLAN operating bands and the 2.5//5.5-GHz WiMAX bands. The proposed microstrip-fed antenna mainly consists of a circular ring, U-shape-like slots on substrate, and a defected ground structure having L-shape and staircase like slots. The design considerations for achieving broadband operation of the proposed Defected ground structure antenna are discussed, and theoretical results are presented. The antenna operates in two frequency bands, and impedance bandwidth of lower frequency band is 0.92 GHz from 2.37-3.29 GHZ and upper frequency band is 2.57 GHz from 4.22-6.29 GHz covering WLAN/WiMAX bands with a total bandwidth of 3.49 GHz. The overall size of the antenna is 22 mm × 36 mm × 1.6 mm including the finite ground CPW feeding mechanics. The parametric study is performed to understand the characteristics of the proposed antenna. Also, good antenna performances such as radiation patterns, current distribution, and efficiency and antenna gains over the operating bands have been observed. The antenna is simulated using IE3D software.

1. INTRODUCTION
In today's modern mobile, satellite and wireless communication systems, demand for smaller low-cost antennas that can be easily integrated with packaging structures, has been increased to a great extent. There have been growing demands for broadband wireless applications and the wireless access bandwidth has become a bottleneck [1]. In order to support high mobility necessity for a wireless communication device, a compact and light weighted antenna is needed, known as microstrip patch antenna. These antennas have radiating patch on one side of dielectric substrate and ground plane on the other side. Microstrip Patch Antennas (MSAs) received great attention in wireless communication systems due to their selectivity for operating frequency, pattern and polarization [1]. These antennas have various advantages like low profile i.e. can even be conformal, easy to fabrication by using techniques like etching and photolithography, are easy to feed, easy to use in an array and moderate directivity [2]. However still there are challenges in achieving good antenna performance because microstrip antennas suffer from several disadvantages also. The major drawbacks are low bandwidth, low efficiency than with other antennas, and prior to dielectric and surface losses. Out of all these surface losses are the most dangerous one, which occurs due to the excitation of surface waves that occurs in the substrate layer. Surface waves occurs when a portion of total available radiated power get trapped along the surface of antenna substrate. It then extracts the total available power for radiation to space wave [3]. Therefore, surface wave can reduce the antenna efficiency, gain and bandwidth.

So to alleviate these problems EBG and PBG structures were used earlier. EBG are a new type of engineered materials with periodic structures that can control the propagation of electromagnetic waves to an extent that was previously not possible. 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 [4-5]. Moreover, various size reduction and broad banding techniques using shorted pins or shaped slots [7], post-gap [8], or parasitic elements [9] were came in existence, but all these have some disadvantages like poor efficiency, low gains, low bandwidth high XP, so are replaced by a new technique called DGS. Microstrip antenna with DGS can support this purpose with multiband that can operate at different frequencies for one device [2]. DGS is realized by etching the ground plane of microstrip antenna, this disturbs the shield current distribution in the ground plane which influences the input impedance and current flow of the antenna [6]. The geometry of DGS can be one or few etched structure, which is simpler and does not need a large area to implement it.
Antennas with DGS technique are used in various kinds of wireless communication applications like WLAN, WiMAX and Wi-Fi etc. The purpose of this work is to enhance microstrip patch antenna using DGS technique performances operating at various frequency bands for WLAN/WiMAX applications. Depending upon the geometry, design and size of the defects in the ground plane, DGS produces different resonances, cut-off frequencies and -10-dB bandwidths [10]. For this to validate, L-Shaped and staircase like slots are created in left side of ground plane while right side has only staircase defect with chamfered bend. This chamfered band is only responsible for the upper band.

2. ANTENNA GEOMETRY
Figure 1 shows the geometry of the defected-ground-structure microstrip antenna for multiband applications, together with its geometrical dimensions. The basis of the proposed antenna structure is a circular patch monopole, which has a radius R, and connected at the end of the CPW feed-line. A circular patch has three U-shaped slots. The antenna was designed on a low-cost, durable FR4 substrate with €r = 4.4, which is reinforced with a woven fiberglass material. FR4 means flame retardant and type 4 indicates woven glass reinforced epoxy resin. The proposed antenna has a single layer metallic structure on one side of FR4 substrate layer whereas the other side is without any metallization. A circular disc was chosen as the radiating element because it has high input impedance.

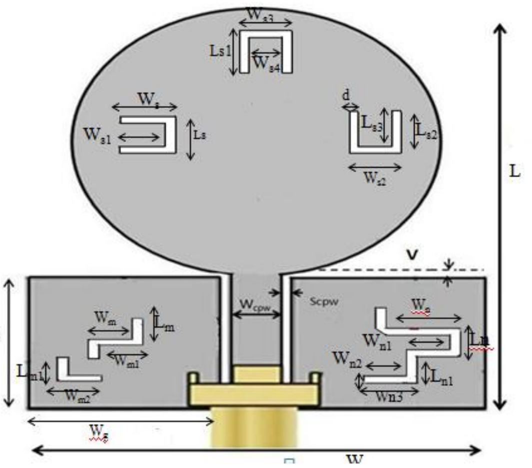

Fig 1: Geometry of proposed Multiband Antenna

The circular disc monopole was fed through a coplanar waveguide (CPW) feed, which was in turn connected through a standard 50 SMA connector. The parametric specifications are shown in table 1.

Table 1: Parameters of the proposed multiband antenna

Parameter	Size	Parameter	Size
R	16mm	S_{cpw}	.75mm
L	22mm	W	36mm
L_g	20.5mm	W_g	14.5mm
L_s	4mm	W_s	5mm
L_{s1}	5mm	W_{s1}	4mm
L_{s2}	5mm	W_{s2}	4mm
L_{s3}	4mm	W_{s3}	5mm
d	1mm	W_{s4}	4mm
L_m	5mm	W_m	4mm
L_{m1}	4mm	W_{m1}	4mm
L_n	5mm	W_{m2}	5mm
L_{n1}	4mm	Wn	5mm
W_{n1}	4mm	W_{n2}	5mm
		Wn_3	4mm

The main radiating elements of the antenna, which are etched on the ground plane, are L-Shape and stair case defects, which make the antenna to achieve better impedance.

These defects in the ground plane of monopole antenna provides different resonances and better impedance matching which creates two impedance bandwidths of 0.92 and 2.57 GHz, for the working bands of 2.37-3.29 GHZ and 4.22-6.29 GHz respectively. In addition, the proposed antenna is compact in size 22mm X 36mm X 1.6mm i.e. this antenna is smaller than the antenna which was 25mm X 38mm X 1.6 mm when there were no defects and simple in configuration. So by using this defected ground structure technique size of radiating antenna get reduced. The U-Shaped slots also affect the impedance performance and the resonant frequencies of the antenna to some extent. The antenna is simulated using IE3D simulator. The effects of the key structure parameters on the antenna performances are also analyzed and presented.

3. RESULTS AND DISCUSSIONS

The simulated return loss and parametric study results for the proposed monopole antenna are also obtained. Simulated return loss of the optimized proposed antenna is shown in Figure 2. The simulated result has a -10 dB impedance bandwidth of lower frequency band is 0.92 GHz from 2.37-3.29 GHZ and upper frequency band is 2.57 GHz from 4.22-6.29 GHz. The proposed antenna has a broader bandwidth covering the required bandwidths of the IEEE 802.11 WLAN standards in the bands at 5.2 GHz (5150–5350 MHz) and 5.8 GHz (5725–5825 MHz) but about WLAN lower band.

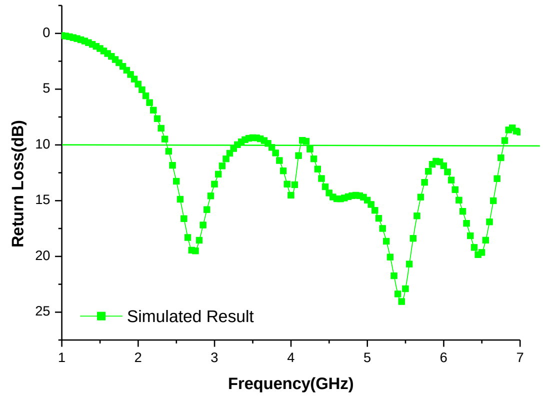

Fig 2: Return loss of proposed multiband antenna

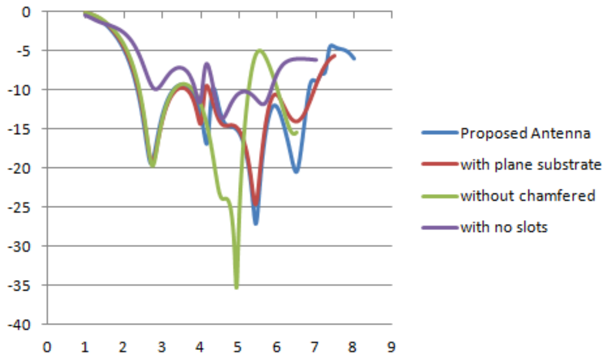

Fig 3: Comparison of return Loss of (a) Proposed Antenna (b) with plane substrate (d) Antenna having Slot on only Right Side of Ground Plane (d) Antenna having No Slots

As shown in Fig. 3, it is clear that the graph, when no slot is cut on the substrate, then very minute changes is noticed. So U-shaped slots in the substrate help in improving the performance of antenna. But when no slots are cut on the substrate and as well on any of the ground, then very low valued return losses are obtained. Also the size of antenna in this case is large i.e. 25mm X 38 mm X 1.6mm.This clearly reveals that by using DGS much better return loss can be obtained. It is also shown that when chamfered bend is removed from the right side then upper band gets disappeared. So with the addition of L-shape and staircase defects on left side and staircase defect with chamfered defect on right side of ground, excite the antenna to various resonating modes having good value of return loss i.e. -19.3 dB, 24.8dB and 19.8dB for the working bands of 2.37-3.29 GHZ and 4.22-6.29 GHz respectively. Hence a multiband antenna is presented using defected ground structure technique, which has higher bandwidth and smaller size of 22mm X 36mm X 1.6mm. This way it achieves good impedance matching with two separate working bands for WLAN/ WiMAX applications.

Figure 4 presents the gain versus frequency curve of the proposed multiband antenna. The gain versus frequency

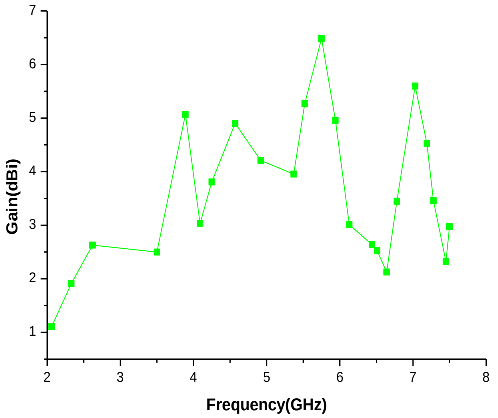

Fig 4: Gain curve of proposed antenna

curve shows that it has maximum gain at the desired resonant frequencies. It has maximum gain of 6.4 dBi at 5.64 GHz with a maximum gain variation of 1.6 dBi.

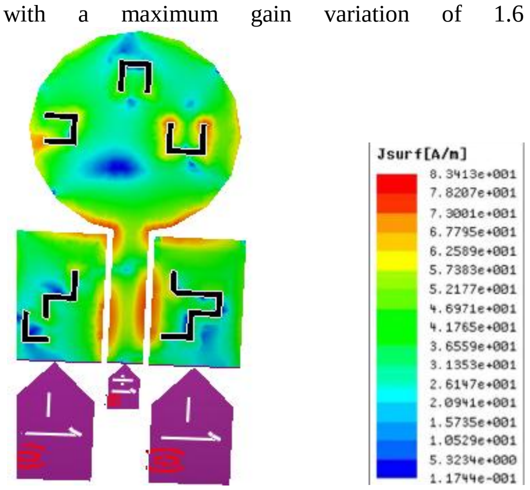

Fig 5: Current distribution of proposed multiband antenna at 3.38 GHz

The formation of the lower and upper frequency resonances can be explained by observing the surface currents on the conductors of the antenna at 3.38 GHz, as shown in Fig.-5.Current distribution is changed by changing the length and dimensions of ground plane.

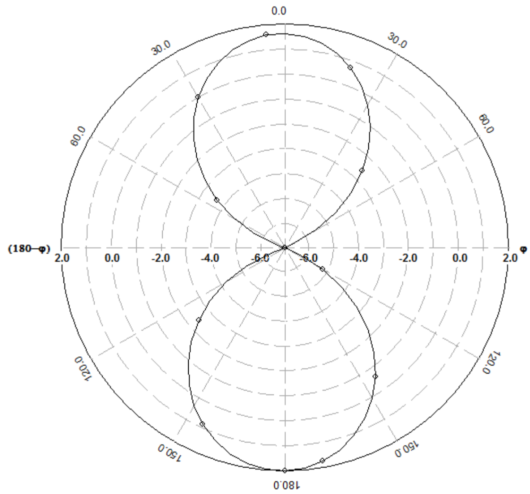

Fig 6: Elevation radiation pattern at 90 degree at 4.57 GHz

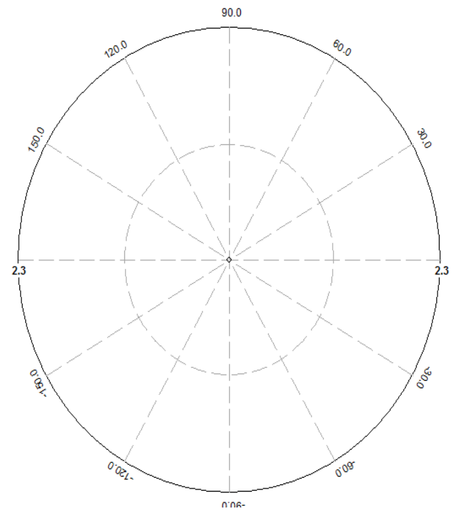

Fig 7: Azimuthal radiation pattern at 0degree 4.57 GHz

In figure 6 and 7 simulated 2D radiation pattern for elevation and azimuthal plane respectively is shown. 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 for 0 degree forms an omni-directional pattern as shown in figure 7.These patterns are desirable for WLAN/WiMAX applications. Simulation studies indicate that the maximum antenna radiation efficiency is approximately 95.93% at 5.7 GHz. Figure 8 shows the efficiency curve of propose monopole multiband antenna.

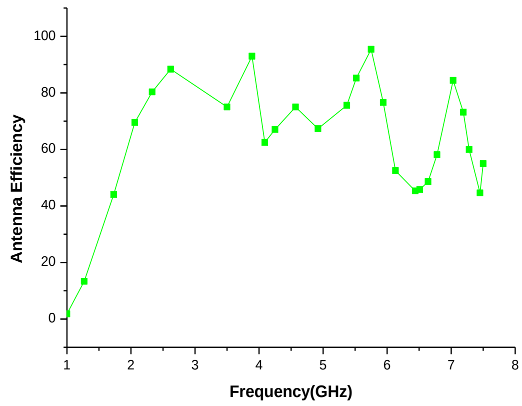

Fig 8 Efficiency of proposed multiband antenna

4. CONCLUSION

A triple-band monopole antenna suitable for WLAN/ WiMAX applications is proposed. Using L-shaped and staircase defect on left side and staircase defect with chamfered bend on right side ground plane antenna, two resonant modes with excellent impedance performance are achieved. Effects of varying dimensions of key structure parameters on the antenna and various parameters like gain, 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 and gain 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, and higher gains and good efficiency. These characteristics are very attractive for some wireless communication systems.

5. REFERENCES

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