Monopole Triple Band Circular Patch Antenna using Defected Ground Structure for IMT 2000/UMTS/ WLAN/WiMAX Applications

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ABSTRACT
This paper presents a circular patch multiband monopole microstrip antenna using DGS (Defected Ground Structure) technique. In this monopole multiband antenna L-shaped defects are inserted into both sides of ground plane of patch antenna forming a defected ground structure. The antenna exhibits three simulated bands and impedance bandwidth of lower frequency band is 0.73 GHz from 1.91 to 2.64 GHz, the middle frequency band is 1.06 GHz from 2.84-3.92 GHz and upper frequency band is of 0.56 GHz from 5.45-6.01 GHz. The various characteristic parameters like S-parameters, gain, current distribution and radiation pattern are studied. The proposed antenna is suitable for UMTS/WLAN/WiMAX and partial IMT-2000 applications. The compact size antenna using DGS technique is simulated using IE3D software**.**

1. INTRODUCTION
Since the drawn of civilization, communication has been one of foremost importance to mankind. It has been only very recent in human history that the electromagnetic spectrum, outside the visible region, has been employed for communication, through the use of radio. One of mankind's greatest natural resources is the electromagnetic spectrum and the antenna has been instrumental in harnessing this resource [1]. The main function of an antenna is to radiate radio frequency energy developed in the transmitter and to act as an impedance matching device for matching the impedance of transmission line with the impedance of space [2].

Now days, low cost, high performance, light weight, low volume, compatibility with integrated circuits, easy installation and fabrication are the most stringent requirements of an antenna for an antenna designer. All these requirements are fulfilled by using microstrip patch antennas. Microstrip antenna consists of a radiating patch on one side of dielectric substrate and a ground plane on the other side. These are known as half wavelength structures and are operated at fundamental resonance frequency mode [3]. These antennas have the quality that these can be easily designed to operate in dual-band and multi-band applications [4-5].

A dielectric material of low relative permittivity is usually used to separate the two sides, and the radiation is a result of the fringing fields between the patch and the ground plane. For good antenna performance, a thick dielectric substrate having a low dielectric constant is desirable since this provides better efficiency, larger bandwidth and better radiation. However, such a configuration leads to a larger antenna size. In order to design a compact Microstrip patch antenna, substrates with higher dielectric constants must be used which are less efficient and result in narrower bandwidth. Hence a trade-off must be realized between the antenna dimensions and antenna performance [6]. The MSA has proved to be an excellent radiator for many applications like telemetry, radar altimeters, GSM, GPS, satellite communications because of its several advantages, but it also has some disadvantages.

Also we need multi frequency antennas to satisfy the conditions of the wireless local area network (WLAN) standards of 2.4–2.484 GHz/5.15–5.825 GHz, the worldwide interoperability for microwave access (WiMAX) standards of 2.5–2.69 GHz-/3.4–3.69 GHz-/5.25–5.85 GHz ,1.92-2.17 GHz for UMTS and 2.11-2.22GHz/2.3-2.4GHz for IMT[7-9].So other new techniques such as cutting slots on the patch, meandering the lateral edge of patch, using stacked patch and adopting the substrate with high permittivity had been employed to miniaturize the size of antenna[10]. Technologies like Low-temperature co-fire ferrite (LTCF), Low temperature co-fire ceramic technology (LTCC) and some structures like Photonic band gap (PBG), electromagnetic Band Gap (EBG), ground plane aperture (GPA) etc were also developed to enhance the antenna performance [10-12].But these structures have design constraints so these cannot be used for designing microwave wave circuits. So in order to alleviate these problems a new technology DGS (Defected Ground Structures) have been proposed.

DGS means to modify the properties of ground plane of an antenna by inserting various kinds of defects into the ground plane. Due to these defects the electrical properties of antenna get changed and hence with the same physical length one can achieve higher bandwidth and good impedance matching. DGS adds an extra degree of freedom in microwave circuit design and opens the door to a wide range of applications [10]. DGS are made to counter the generation of surface waves so that its conductive properties like current distribution, line inductance and line capacitance get modified and hence the size of antenna for a particular frequency get reduced as compared to antenna design without defect. Defected ground structure is realized by etching a simple shape (defect) from the ground plane. 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 [12-13].For a better performance the shape of the defect may be changed from a simple shape to a complicated one.

In this paper, a triple-band monopole antenna, for IMT/UMTS/WLAN/WiMAX applications, is presented. It uses coplanar waveguide feeding. In both sides of the ground plane of this circular patch antenna, L-shaped defects are slotted which provides a different current distribution path than when there were no defects. Hence due to these slots the electrical length of the microstrip patch antenna get increased while the physical length is same i.e. same as when there were no defects in the ground plane. By virtue of new current path older current distribution get disturbed and its inductive properties get changed and due to which different resonances are obtained in the input impedance of antenna. Hence a multiband, compact size antenna design is proposed. The simulation results of different characteristic parameters are presented.

2. ANTENNA GEOMETRY

The geometry of the defected-ground-structure microstrip antenna for multiband application is shown in fig. 1 together with its geometrical dimensions. A circular concentric ring forms the substrate of the monopole antenna. The antenna was designed on a low-cost, durable FR4 substrate with $\epsilon_r = 4.4$, and height= 1.6 mm .A circular disc was chosen as the radiating element because it has high input impedance.

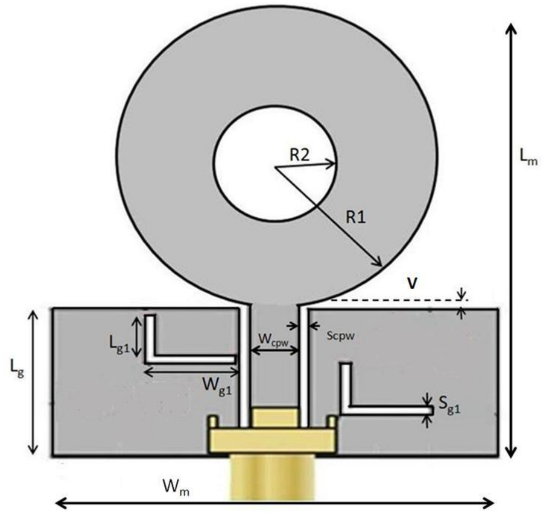

Fig 1: Geometry of proposed Multiband Antenna

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
R1	24mm	S_{g1}	1mm
R2	8mm	S_{g2}	1mm
L_g	19.6mm	V	0.5mm
L_{g1}	7mm	W_{cpw}	5mm
W_g	18.6mm	W_m	43.2mm
W_{g1}	9mm	S_{cpw}	1mm
L_m	44		

The main radiating elements of the antenna, which are etched on both sides of the ground plane, are L-Shape defects, which make the antenna to achieve better impedance. The outer radius and inner radius of the circular ring are R1and R2 respectively.

These defects in the ground plane of monopole antenna provides different resonances and better impedance matching which creates three impedance bandwidths of 0.73, 1.06, and 0.56 GHz for the working bands of 1.91–2.64 GHz centred at 2.2 GHz, 2.84-3.92 GHz centred at 3.38 GHz, 5.45–6.01 GHz centred at 5.7 GHz, respectively. In addition, the proposed antenna is compact in size 44 X 43.2mm i.e. this antenna is smaller than the antenna which was 46 X 47.2 mm when there were no defects and simple in configuration. So by using this defected ground structure technique size of antenna get reduced. The concentric circular rings 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 design evolution of the proposed multi-band antenna and its corresponding simulated return losses are presented in Fig. 2. This figure clearly shows that it has three working bands and impedance bandwidth of lower frequency band is 0.73 GHz from 1.91 to 2.64 GHz, the middle frequency band is 1.06 GHz from 2.84-3.92 GHz and upper frequency band is of 0.56 GHz from 5.45-6.01 GHz. This implies that it covers all four wireless bands i.e. IMT band from 2.11-2.22GHz/2.3-2.4GHz, UMTS band from 1.92-2.17 GHz, WLAN band 2.4/5.8 GHz and WiMAX band from 2.3/2.5/5.5 GHz. Fig 3 shows the return loss comparison of antenna when no defects were inserted in the ground plane, only L shape defect was inserted in the one side of ground plane and with L- shape defects on both sides of the ground plane respectively.

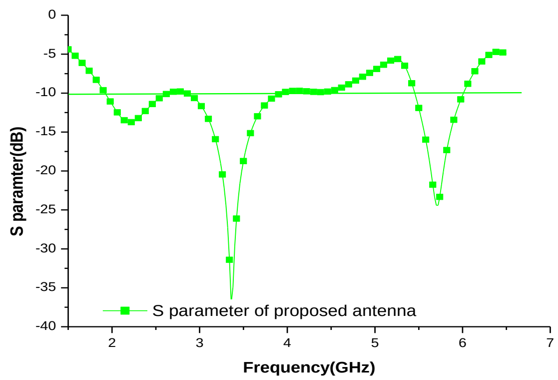

Fig 2: Return loss of proposed multiband antenna

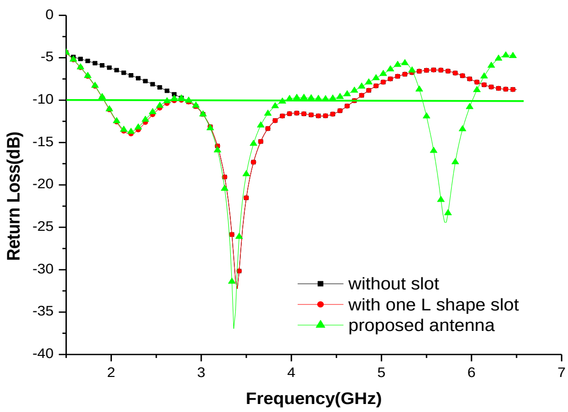

Fig 3: Comparison of return Loss of (a) Proposed Antenna (b) Antenna having Slot on One Side of Ground Plane (c) Antenna having No Slots

As shown in Fig. 3, it is clear that the graph, when no slot is cut on any of the ground plane, provides only single impedance bandwidth of 1.88 GHz for the working band of 2.82-4.7 GHz centred at 3.4 GHz and also the size of antenna is 46 X 45.2 mm. But with the addition of L-shape defect on one side of ground, excite the antenna to another resonant mode having good value of return loss i.e. -13.8 db and band of 1.91–2.64 GHz centred at 2.2 GHz. Then addition of same L shape-defect on another side excite the ground to another resonating band with return loss of 33.6 db and band of 5.45-6.01 GHz centred at 5.66 GHz . Hence a multiband antenna is presented using defected ground structure technique, which has higher bandwidth and smaller size of 44 X 43.2 mm. This way it achieves good impedance matching with three separate working bands for the IMT/UMTSWLAN/ WiMAX applications.

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

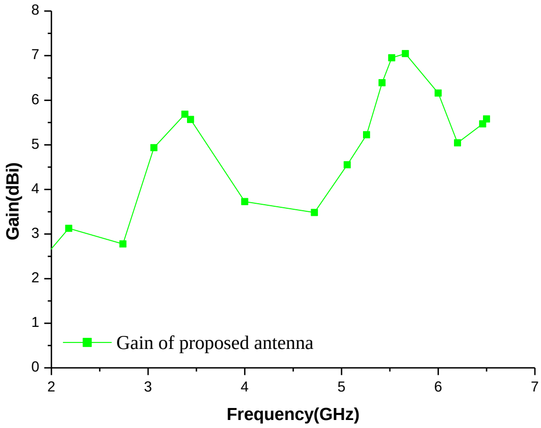

Fig 4: Gain curve of proposed antenna

curve shows that it has maximum gain at the desired resonant frequencies. The gain of antenna tells about the figure of merit of an antenna. For the 1.91–2.64 GHz working band, the peak gain is about 3.12 dBi. For the medium band i.e. 2.82-3.89 GHz, the antenna is with relatively small gain variation, the peak gain and gain variation are 5.66dBi and 0.26 dBi, respectively. The peak gain and gain variation within the highest operating band are both increased, the peak gain reaches about 6.99dBi, and the gain variation is about 0.33 dBi. As a result, the gain of the proposed antenna within the operating bands satisfies the requirement of IMT, UMTS, WLAN and WiMAX applications.

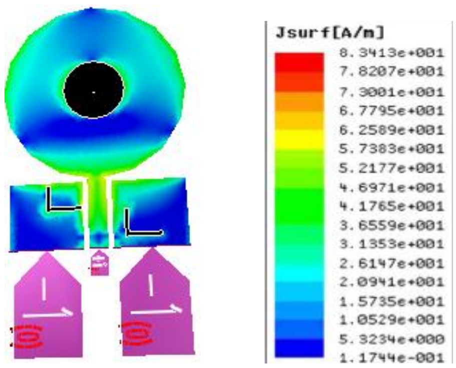

Fig 5: Current distribution of proposed multiband antenna at 3.38 GHz

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. Due to the addition of slots in the ground plane it can be seen that there is a strong concentration of currents on the lower edge of the disc, around the L-shaped slot, along the top edge of the ground plane and along the feed length. Thus, once the current reaches the top of the balanced CPW feed, the L-shaped slots force the current to wrap around the slots and thus create an alternate path for the current. Thus, this current distribution removes cross polarization and hence different operating bands are obtained.

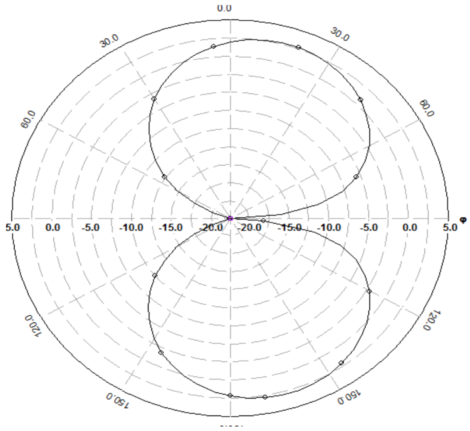

Fig 6: Elevation radiation pattern at 2.74 GHz

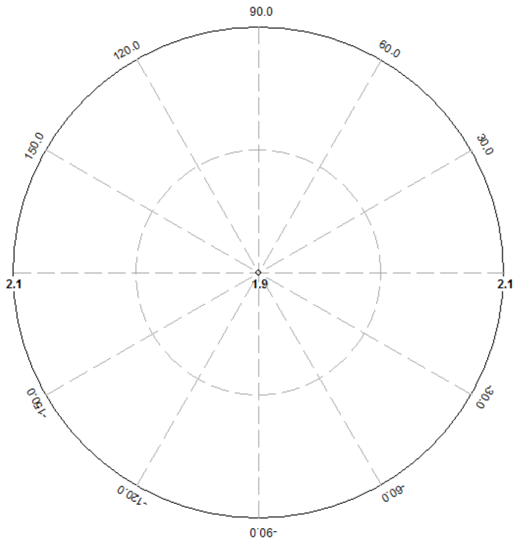

Fig 7 Azimuthal radiation pattern at 2.74 GHz

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 in figure 3.4, 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 omnidirectional pattern as shown in figure 7. These patterns are desirable for IMT/UMTS/WLAN/WiMAX applications.

This antenna has maximum efficiency of 99.93% at 5.5 GHz. Figure 8 shows the efficiency curve of propose monopole multiband antenna.

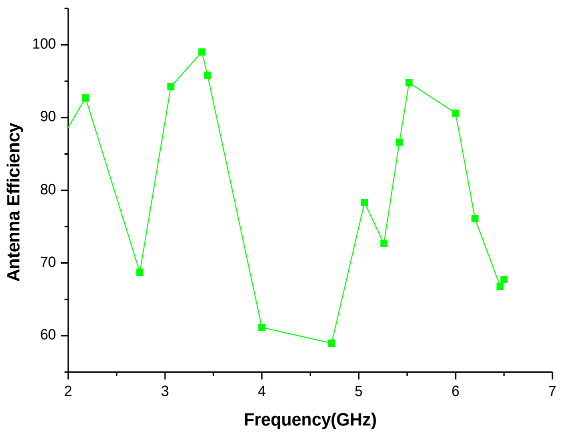

Fig 8 Efficiency of proposed multiband antenna

4. CONCLUSION

A triple-band monopole antenna suitable for IMT/UMTS/WLAN/ WiMAX applications is proposed. Using L-shaped slots in both sides of ground plane antenna, three 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. 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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