Analysis and Design of Microstrip Patch Antenna with Defected Ground Structure

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Abstract—An analysis of resonant behavior of a microstrip patch antenna with defected ground structure (DGS) has been presented in this paper. It is observed that a size reduction of 56.68% has been achieved by taking out an 'I' shape slot from both the patch and the ground plane. As a result, this new antenna, exhibits multiband behavior and better resonant characteristics than its original structure. The proposed antenna not only has characteristics of good radiation, but also has an advantage of low cost and small size for S-band, C-band and X-band wireless applications.

Keywords—DGS, microstrip antenna, return loss, gain.

I. INTRODUCTION

The astonishing progress in wireless communication system and an increasing demand to integrate different technologies into small user equipment has remarkably increased the fashion of introducing compact antennas [1]. Microstrip patch antenna, because of its small size, low profile, low manufacturing cost and ease of integration with feed networks, is find extensive applications in wireless communication system [2, 3]. Because of extremely thin profile (0.01 to 0.05 wavelength), printed microstrip antennas have found heavy applications in military aircraft, missiles, rockets and satellites [4-7]. Defected Ground Structure (DGS) is either an etched periodic or a non-periodic cascade configuration defect in ground plane of a microstrip antenna. Any defect in the ground plane can give rise to increase in effective capacitance and inductance [8-10]. In this paper a small-sized microstrip antenna, with slot and defected ground structure (DGS) have been designed to examine the relationship between the resonant performances of these antennas.

II. ANTENNA DESIGN & STRUCTURE

Fig.1 shows the basic geometry of the proposed patch antenna with slot and DGS structure.

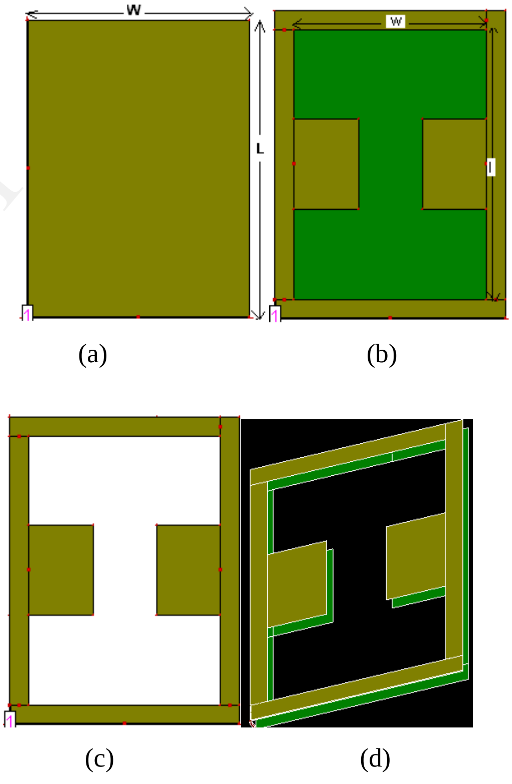

Fig.1 Geometrical Construction of the Proposed Antennas, (a) micro strip antenna (b) micro strip antenna with slot (c) micro strip antenna with slot and DGS (d) 3D view of proposed structure.

The antennas have been designed with FR4 ($\epsilon_{r=}$ 4.4) substrate having height of 1.6 mm. The antenna is a small-size planar patch antenna that has its length, L = 32 mm and width, W = 24 mm on the finite ground plane of similar size. The presented second antenna structure has 'I' shape slot on the patch in its design which accounts for its small size and lower cost. The dimensions of the slots are *l*= 28 mm and *w* = 20 mm. The introduction of slot in the structure increases the electrical length of the antenna. In the third shape a similar 'I' shape slot has been taken out from the ground plane of the proposed antenna that forms defected ground structure. The dimensions of both the slots of patch and ground plane are same. Because the dimensions of the patch are limited along its length

and its width, the EM fields at the patch's edges undergo fringing.

The amount of fringing is function of the dimension of the patch, the thickness of the substrate and its dielectric constant ϵ_r. Because of the fringing effects, the patch of the microstrip antenna looks electrically greater, than its physical size [1]. For better resonance performance parameters, good impedance matching is required and it can be calculated using equation (2) and (3) [1].

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(\frac{1}{\sqrt{1 + 12\frac{h}{w}}}\right) \quad (2)$$

$$Z_0 = \frac{120\Pi}{\sqrt{\varepsilon_{eff}}\left[\frac{w}{h} + 1.393 + 0.667\ln\left(\frac{w}{h} + 1.444\right)\right]} \qquad \frac{w}{h} \geq 1 \quad (3)$$

III. RESULTS & DISCUSSSIONS

A. Comparison of Resonant performance of microstrip antenna, with I-shaped slot and DGS.

The simulation tool used for evaluating the performance of all proposed antennas is IE3D software. This software is based on the method of the moments technique. Table. I shows the resonant performance characteristics of the planar patch antenna, antenna with slot and with DGS structure. It has been observed that by taking out 'I' shape slot from the patch and from the ground plane, there is considerable improvement in the return loss, VSWR and input impedance. Moreover, the size of the proposed antenna has been reduced to 56.68% which makes it effectively less expensive comparable to original patch.

Fig. 2 shows the s-parameters of all the proposed small-size planar antennas. From this figure, it is clear that the planar patch antenna and the antenna with slot does not produce any resonant frequency below than -10dB return loss. However, there is a drastic improvement in the resonant properties, especially in terms of return loss of the antenna, when an 'I' shape defect has been introduced in the ground plane of the proposed antenna structure.

Table. I COMPARISON OF RESONANT PERFORMANCE CHARACTERISTICS.

Structure	***Resonant Freq. (GHz)***	***Return Loss (dB)***	***VSWR***	***Input Impedance (Ohms)***
Microstrip Antenna	2.09	-3.42	5.13	19.43
	3.90	-3.37	5.20	10.22
	5.45	-3.90	5.01	11.95
	7.00	-5.27	3.38	15.83
	8.54	-6.10	2.96	17.11
With Slot	1.45	-2.78	6.30	57.91
	5.00	-6.26	2.89	53.06
	6.63	-3.60	4.88	29.06
	8.36	-4.91	3.61	13.91
With Slot and DGS	1.81	-15.50	1.40	46.62
	5.00	-17.88	1.29	53.43
	5.54	-14.34	1.47	37.74
	6.27	-16.56	1.34	51.28
	7.63	-14.46	1.46	39.97
	8.63	-12.9	1.58	31.63

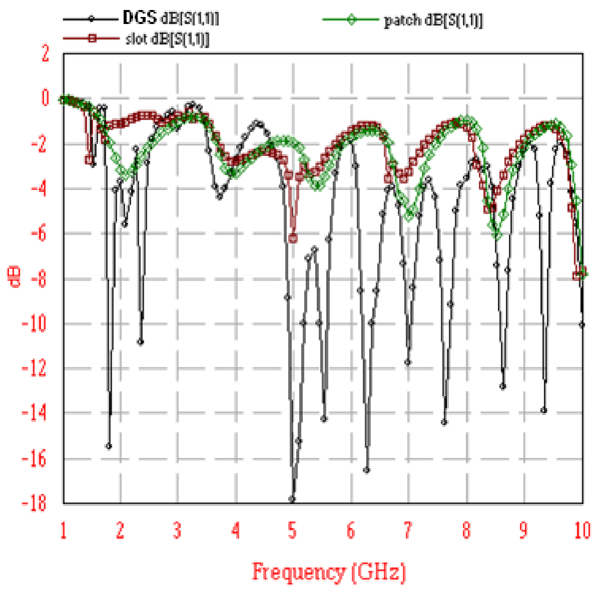

Fig.2 S-parameters of the Proposed Patch, Slot Antenna and DGS

With these resonant properties the proposed antenna can be used for S-band, C-band and X-band wireless applications.

B. Radiation Pattern and Gain.

The radiation patterns of proposed patch antenna with DGS are shown in Fig.4. It has been observed that they are quite similar in nature for all the frequency bands. The radiation pattern is symmetrical to the antenna axis in E-plane, whereas in H-Plane, it is nearly omni-directional.

The Gain for the proposed antennas is shown in Fig.3. The maximum achievable gain for the antenna is 6.1 dBi at 8.636 GHz.

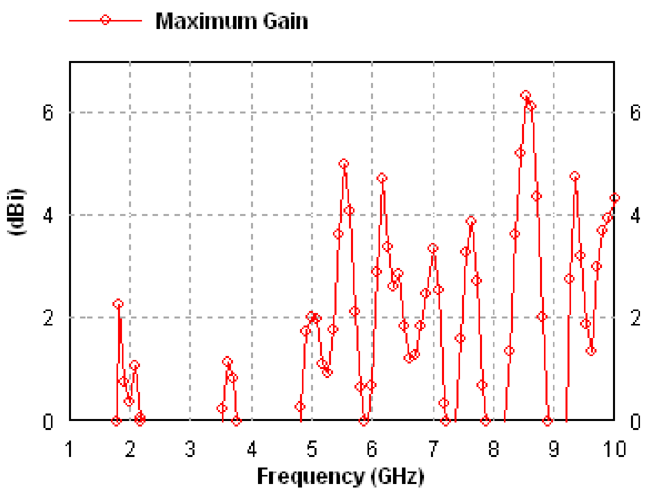

Fig.3 Simulated Gain of Proposed Antenna with DGS

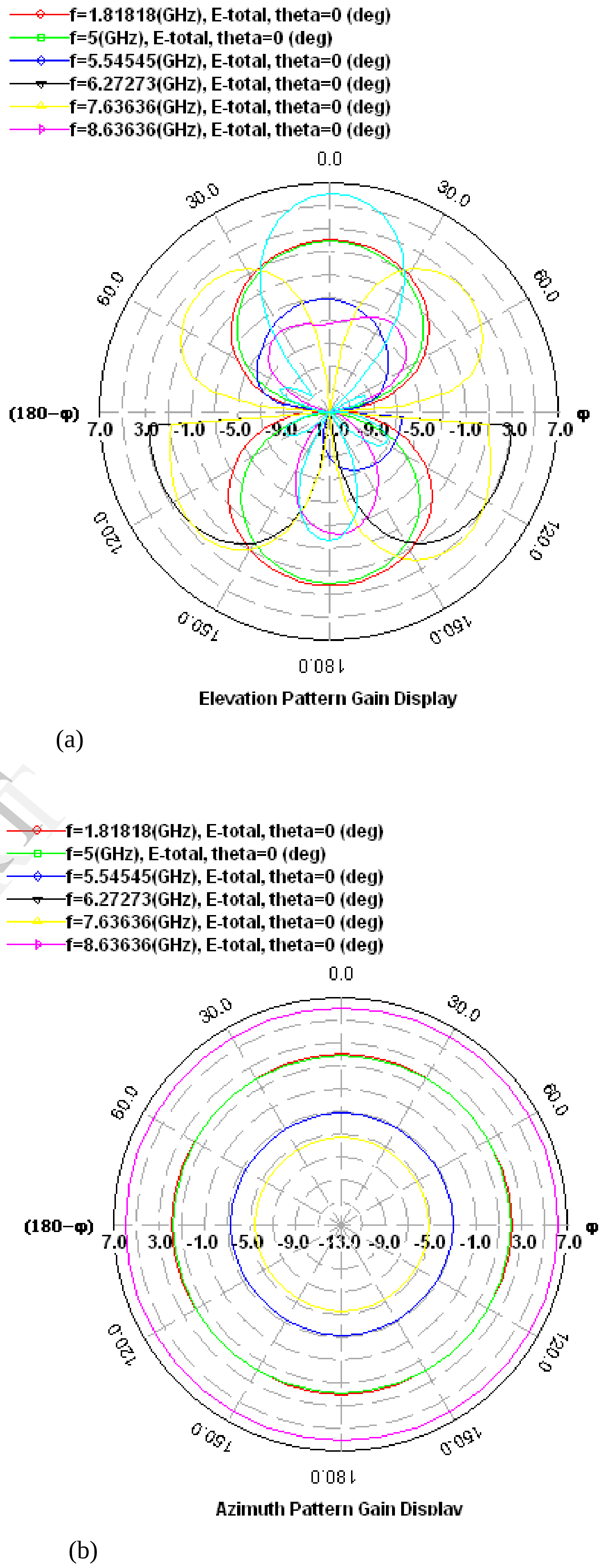

Fig.4 Simulated Radiation patterns of proposed antenna with DGS (a) E-plane (b) H-plane

IV. CONCLUSION

In this paper, the microstrip patch antenna with DGS and miniature sizes are employed. The results are compared with original patch antenna and further with the slot antenna. These results has been revealed that in addition to the reduction of the size of the antenna by 56.68%, there is considerable improvement in return loss, input impedance and VSWR with the introduction of 'I' shape defect in ground plane. The simulated results illustrated that the proposed antenna is suitable for S-band, C-band and X-band wireless applications.

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