Compact Multiband Patch Antenna with Fractal Defective Ground Structure for Wireless Applications

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Abstract — Compact microstrip patch antenna with L – shaped spur lines using Hilbert shaped fractal defective ground structure (DGS) is proposed and investigated for multiband applications. The objective of the paper is to obtain average size reduction of about 72% using resonant frequency shift method with the help of DGS. The impedance bandwidth, gain and efficiency are observed and compared for the proposed antenna with and without DGS. Excellent agreement is found between simulated and measured results.

Index Terms — Defective ground structure, spur lines, patch antenna, gain, impedance bandwidth.

I. Introduction

Radio frequency (RF) electronics technology for wireless devices continues in size miniaturization; there is a corresponding demand for similar decrease in size for antenna element. Compact antenna covering more than one wireless communication band is considered a multiband [1-4]. Challenge is to design the antenna to operate over multiple frequency bands with reduced size. Metallic ground plane may be considered a dominant portion of the radiating structure [5-6]. Several techniques have been demonstrated using fractal elements and elevation of patches are discussed in the available literature. Concentric ring shaped DGS [7] discusses about suppressing the harmonics in microstrip based active antenna designs. Efficient size reduction of LP filters and broad bandwidth with patches is discussed in [8-9] using sierpinski fractal DGS. Liu *et al* presented a monopole antenna exciting tri-bands with DGS playing a major role [10]. Probe fed broad band antenna with V- slot DGS [11] and Z-type DGS [12] for bandwidth enhancement are few latest models developed in current literature.

In the present design, it is observed that the L-shaped spur lines on the patch metal layer create additional multi-resonant frequencies. Fractal DGS on the metallic ground would give the size reduction with lowering the frequencies. The size reduction property of the proposed antenna may be suitable for miniaturized planar and conformal antenna arrays that are suitable for personal communication devices.

In this paper, Hilbert shaped fractal geometrical element is adopted as optimum choice that allow both miniaturization and multi-band behavior. The optimal feed positions of iterative shapes of proposed antenna are same, which indicated that the feed postion is insensitive to the variation in the spur-line length. Due to the spur-line perturbation, the radiation pattern of the lower operating frequency has a relatively larger cross-polarization component than that of the higher resonant frequencies [13]. The embedded spur lines are normally placed at non radiating edges of the patch and the design resonates at three bands. When the spur line length is greater than about one-half of the patch side length ($L_6 > L_1/2$), the antenna can have a new resonant mode at a frequency less than the fundamental frequency. Furthermore, this new resonant mode and TM_{10} mode can both be excited with good impedance matching using single probe feed located with (-8, 8) at point P.

II. Antenna Design and Simulations

The proposed dual L-shaped spur lines with Hilbert shaped defective element on the metallic ground plane is as shown in the Fig. 1. It is printed on a dielectric substrate of 3.175mm thick with a relative permittivity of 2.33 and loss tangent of 0.0012. The radiating patch is completely covered by $36x36x3.175mm^3$ dimensions on top.

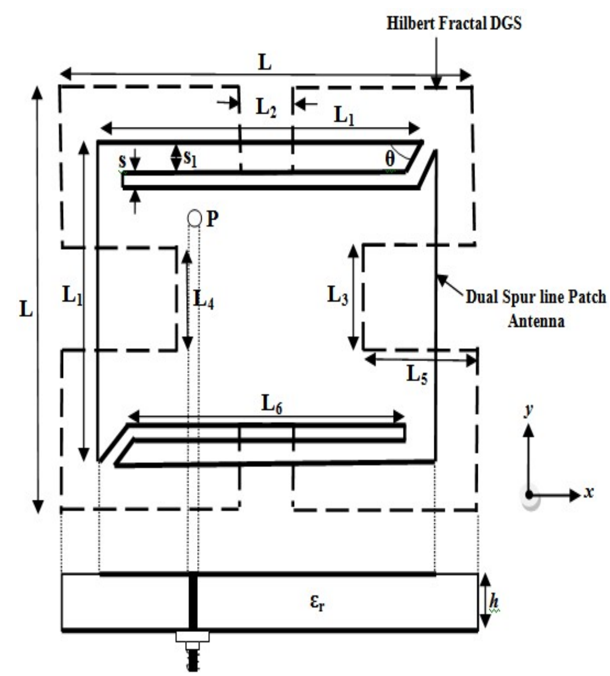

Fig. 1. Geometry of the Proposed Antenna (*All dimensions in mm*)

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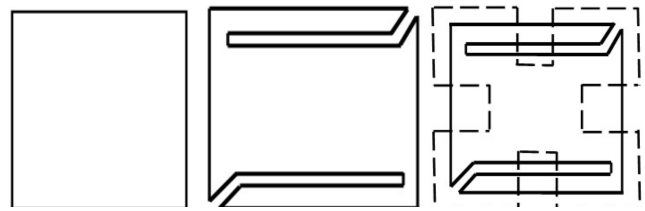
The optimized dimensions of the top layer and bottom layer of antenna are displayed in Table I. The purpose of metallization with fractal DGS on bottom layer is to shift the S_{11} response to a lower frequency without increasing the size of the radiating patch. Further, the impedance matching at obtained frequencies also needs to be maintained.

TABLE I
GEOMETRICAL DIMENSIONS OF THE PROPOSED STRUCTURE

Parameter	mm	Parameter	mm
L	40	s_1	2
L_1	36	s	1
L_2	6	L_6	29
L_3	12		30^0
L_4	12	P	(-8, 8)
L_5	13		

The design iterations of the model are as shown in Fig. 2. The simulated return loss curve shown in Fig. 3 denotes the performance in terms of 10-dB impedance bandwidth and gain of the patch antenna. Fig. 4 gives the gain versus frequency response. The antenna efficiency of 82, 78, 58 and 31% for the case of without DGS resonating at 2.56, 3.02, 3.715 and 5.01GHz respectively. It is found that fractal DGS shows high antenna efficiency at low frequency as shown in Fig. 5.



(a) (b) (c)

Fig. 2. Design iterations-(a) basic patch (b) L-shaped spur lines without DGS (c) Spur lines with Hilbert fractal DGS

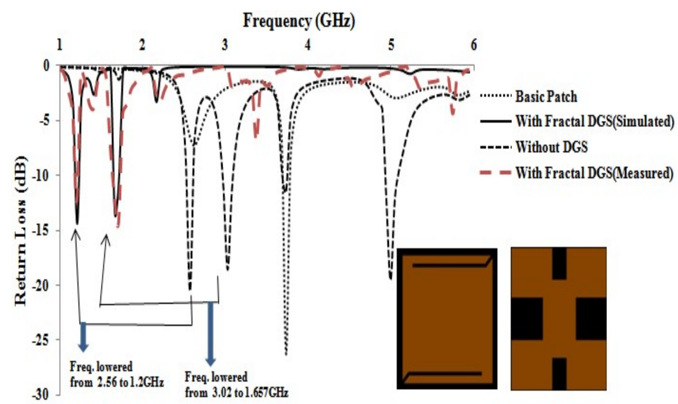


Fig. 3. Simulated and Measured Return loss of propose

TABLE II
COMPARISON OF PARAMETERS FOR PROPOSED ANTENNA WITH EXISTING MODELS

Antenna/ Year	Description	Frequencies (GHz)	Size reduction (based on low resonant freq.)	10-dB Return Loss bandwidth (%)	Gain (dBi)	Volume (mm^3)	Applications
[8], 2003	Fractal DGS for Planar Circuits	3.76 5.75	20%	-	-	13x13x0.762	RF Low pass filters
[9], 2007	Modified Sierpinski Fractal	0.9 1.8 2.4	-	22 54.3	0.34 4.11 2.75	100x53.7x0.8	GSM/PCS/DCS
[11],2010	Broadband antenna with V-slot DGS	5.8	-	45		-	Array Applications for low XP
[12], 2013	Z-type DGS for BW enhancement	10 With DGS		2.8 12.1	- 8.7	32x32x1.59	X band operations
[Proposed]	**Spur lines antenna with Fractal DGS**	**1.202**	**80%**	**6.3**	**3.9**	40x40x3.175	1-2GHz Wireless receivers
		1.657	**64%**	**4.6**	**-0.5**		
	Spur lines antenna without DGS	**2.56**	**19%**	5.8	**6.4**	36x36x3.175	WLAN/WiMAX
		3.02	**-**	4.2	**6.2**		
		3.725	**-**	3.04	**4.9**		
		5.01	**-**	2.15	**3**		

Table II presents the performance of proposed antenna when compared with current existing models. Plot of radiation patterns in E-plane (y-z plane) at different resonant frequencies without DGS is shown in Fig. 6. From the observed results, the improved -10dB impedance bandwidth and 72% of average size reduction of antenna are obtained. However, the gain reduced to 21% of the original gain with the placing of DGS on the ground plane. Size reduction in turn makes the patch antenna suitable for wireless transceivers with the advantage of antenna resonating at low resonance.

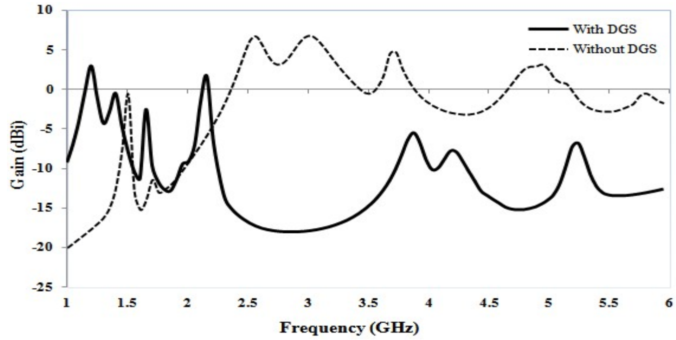


Fig. 4. Gain versus frequency response for proposed antenna with and without fractal DGS

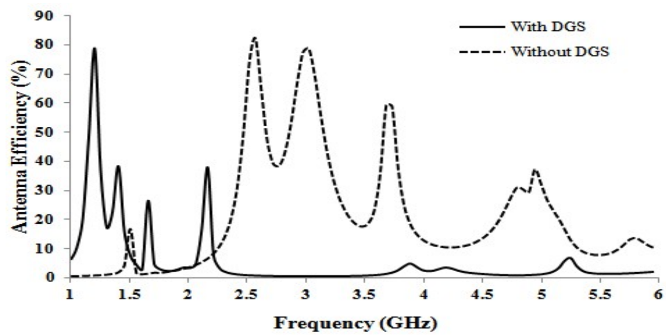


Fig. 5. Measured Antenna efficiency for proposed antenna with and without fractal DGS

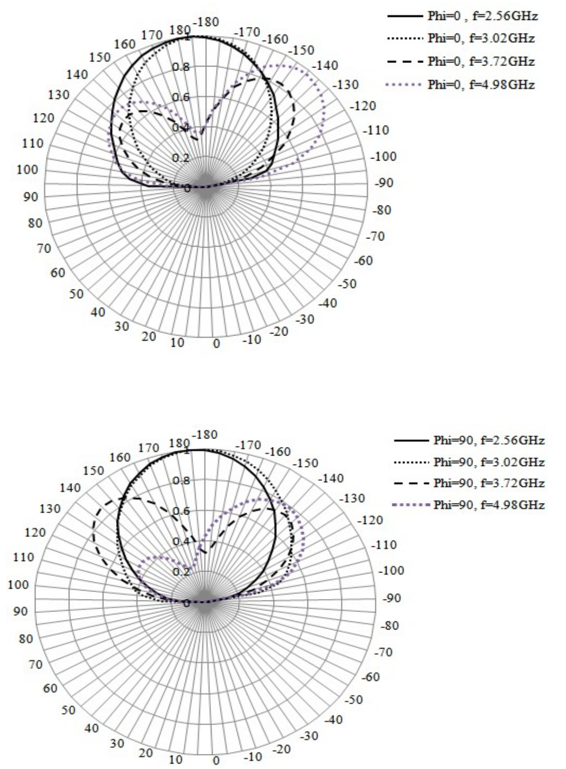


Fig. 6. E-plane Radiation patterns for phi=0^0 and phi=90^0 at resonant frequencies of 2.56, 3.02, 3.72 and 4.98 GHz (*y-z plane*). (Without DGS)

III. CONCLUSION

A novel fractal DGS based microstrip patch antenna is presented and discussed. A significant impedance bandwidth comparison is also shown for antenna structures with and without DGS. Frequency is lowered to 1.202GHz from 2.56GHz and 1.657GHz from 3.72GHz respectively with the applied DGS. The characteristic properties are improved with the introduction of DGS. Bandwidth of the antenna is increase with 72% and size reduction is also obtained. The results show better gain value, besides minor disagreement observed at high frequency E-plane pattern (y-z plane) due to inaccuracies in the simulation. The proposed antenna is applicable for various wireless applications such as WiMAX/ WLAN receivers.

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