Tri-Band Fractal Patch Antenna for GSM and Satellite Communication Systems

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***Abstract*—Due to their smaller size and light weighted structures patch antennas are accustomed in modern communication Technology. With additional size in reduction, micro strip antennas are commonly used in handsets, GPS receivers etc. This paper presents a novel design of fractal shape patch antenna using U-slot on patch and defected ground structure. Due to slots on patch and ground, tri-band resonating response is attained with maximum gain and directivity of 4.22dB and 6.51dBi showing high impedance bandwidth and radiation efficiency. The antenna showed good VSWR of 1.63 to 1.02 thus, showing high efficiency. As evident in the simulation results, the proposed antenna has been found useful for W-LAN, GSM, Radio Satellite, Fixed Satellite Services (RSS) & (FSS) and satellite communication systems.**

Keywords*—miniaturization; directivity; gain; slots; Bandwidth; VSWR

I. Introduction

The increasing demand of wireless communication and multimedia services has resulted in growing efforts of designing and accomplishment of micro strip patch structures due their cost efficiency and small size. Applications of such antennas comprise but not restricted to personal communication systems, military applications, jets aircrafts and much more. One of the most necessarily antenna application is in wireless communication. In contrast with classical antennas, patch antennas offer several advantages such as ease in fabrication, low cost light weighted structures. Several techniques have been proposed to reduce the patch antenna size but at the cost of lower gain, lower directivity and reduced bandwidth. Some of the techniques are mentioned below.

With use of split ring resonators, size reduction was only up to 10 to 15% [1-2]. In [3], the dimensions of an antenna are miniaturaized to a significant level but gain and the bandwidth is also decreased. By increasing electric permittivity of a substrate, antenna size can be reduced significantly but increase of surface waves in substrate can result in declination of radiation pattern hence worsening antenna bandwidth [4]. Meta materials reduced antenna size when inserted in ground plane structure but the cost surges a bit higher [5-6]. Use of synthetic magnetic conductors resulted with lowered gain at desired resonant frequencies [7]. Hence in simple words patch size reduction has been a very common interesting topic among researchers [8-11].

Therefore, in this paper we have proposed a miniaturized fractal shape patch antenna with u-slots on patch and defected ground structure with good impedance bandwidth, gain and directivity. The proposed antenna is showing multi frequency response which can be used for various applications systems.

II. Antenna Design

The basic patch antenna consists of patch, substrate and ground plane. The basic patch antenna with coaxial probe feed (contacting) is given in fig 1.

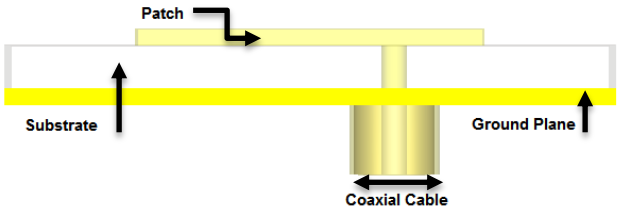

Fig. 1. Normal patch antenna

A. Substrate

The first important task while designing an antenna is selection of a proper substrate with proper dielectric constant.

In proposed antenna design, due its cost effectiveness, moisture withstanding capabilities, FR4 (lossy) is chosen as substrate with dielectric constant of 4.3.

B. Width

In order to derive Patch width, following equation is used. (1).

$$W = \frac{c}{2 f_0 \sqrt{\frac{(\varepsilon r+1)}{2}}} \quad (1)$$

Whereas c is the speed of light in free space and f_0 is the resounding frequency and **εr** is the relative permittivity.

C. Length

In order to derive Patch length, following equation is used. (2).

$$L = L(eff) - 2\Delta L \quad (2)$$

Where

$$L(eff) = \frac{c}{2f_0\sqrt{\varepsilon_{(reff)}}} \quad (3)$$

And

$$\varepsilon_{(reff)} = \frac{\varepsilon r + 1}{2} + \frac{\varepsilon r - 1}{4}\left(1 + \frac{12h}{W}\right)^{-1/2} \quad (4)$$

Where h is the height and W as mention above is the patch width. Antenna with resonating frequency of 4.5GHz is designed by calculating patch dimensions.

Various dimensions of the proposed antenna technique are provided in table 1.

TABLE I. DIMENSIONS OF PROPOSED ANTENNA

Parameters	**Values in MM**
Patch Length, PL	16.11
Patch Width, PW	21.43
Ground Length, GL	28.11
Ground Width, GW	33.43
Vertical Fractal Slot Length, VFSL	10.0
Vertical Fractal Slot Width, VFSW	4.0
Horizontal Fractal Slot Length ,HFSL	8.0
Horizontal Fractal Slot Width, HFSW	4.0
U Slot Length, UL	6.0
U Slot Width, UW	1.0
Patch Height, PH	0.0035
Height of Ground, HG	0.08
Height of Substrate, HS	2.0
Horizontal U and H Slot Width, HUW&HHW	1.0
Horizontal U Slot Length, HUL	8.0
Horizontal H Slot Length, HHL	7.0
Vertical U and H Slot Length, VUL&VHL	6.0
Vertical U and H Slot Width, VUW &VHW	1.0

After designing patch antenna for 4.5 GHz, fractal shape is implemented as following.

Patch is slotted by 8mm length and 10mm width horizontally and 10mm length and 4mm width vertically. U shape slot on fractal patch is designed with the following dimensions as shown in Fig 2.

Length of slot is 6mm and width of the slot is 1mm.Now to further reduce size and for efficient frequency response defected ground structure technique is used by adding U and H slot on a ground plane as shown in fig 2 and figure 3.

Fig. 2. Frontal View of Patch

Fig. 3. Frontal View of Ground

The antenna is fed by Co-axial cable a contacting scheme in which inner conductor is mounded to patch through hole from ground through substrate while outer conductor connected with ground plane.

III. RESULTS AND DISSCUSSIONS

After simulation, we got the following results in Return loss graph.

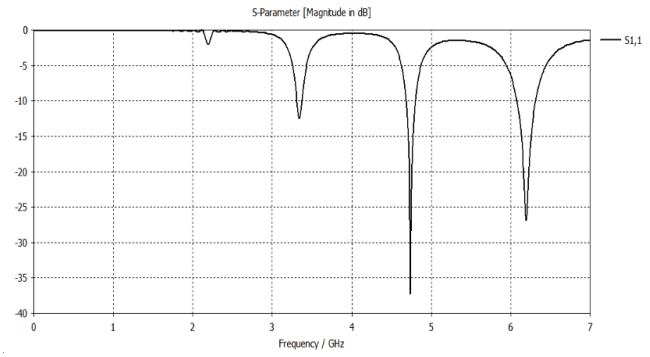

Fig. 4. Return loss graph of antenna

From taking a look at return loss graph shown in Fig 4, we clearly see that we have got a multi frequency response with very good return loss. For frequency 3.349 we have got -12.05dB return loss, 2.92dB of gain 5.64dBi directivity and 60 MHZ of bandwidth.

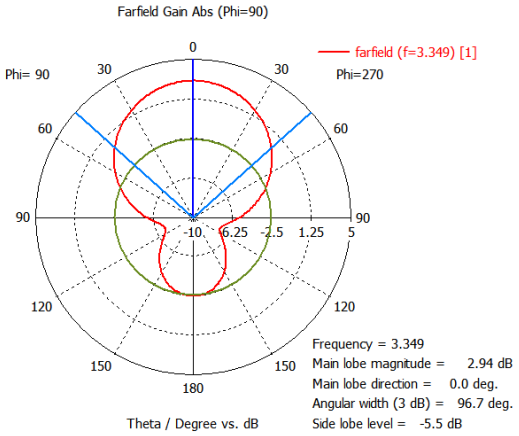

Fig. 5. 1D plot of Gain at 3.349 GHz frequency

In 3.349GHz gain plot, the main front lobe scale is 2.91dB, main front lobe direction is 0 degrees and angular width is 96.8 degrees while back lobe scale is -5.5dB.

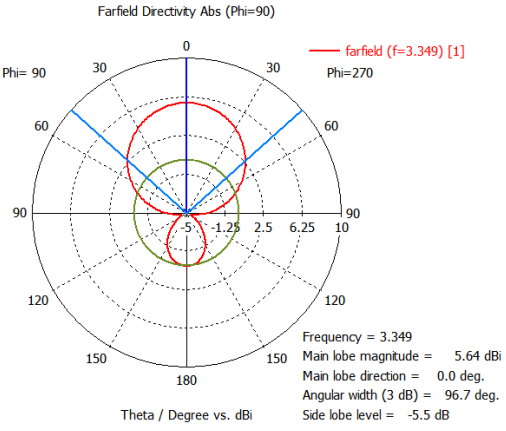

Fig. 6. 1D plot of Directivity at 3.349 GHz frequency

In 3.349GHz directivity plot, the main front lobe scale is 5.64dBi, main lobe direction is 0.0 degrees and angular width is 96.8 degrees while back lobe scale is -5.5dB.

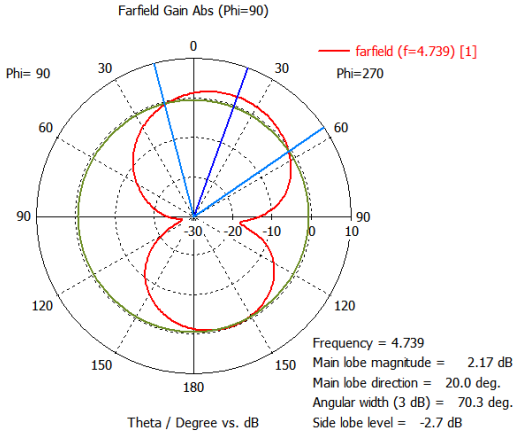

Fig. 7. 1D plot of Gain at 4.739 GHz frequency

In 4.739GHz gain plot, the main front lobe scale is 2.17dB, main lobe direction is 20.0 degrees and angular width is 70.4 degrees while back lobe scale is -2.7dB.

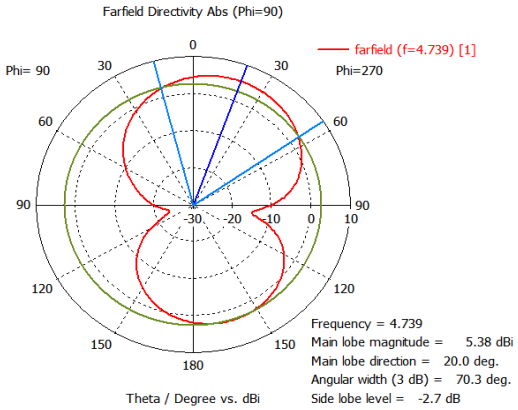

Fig. 8. 1D plot of Directivity at 4.739 GHz frequency

In 4.739GHz directivity plot, the main front lobe scale is 5.38dBi, main front lobe direction is 20.0 degrees and angular width is 70.4 degrees while back lobe scale is -2.7dB.

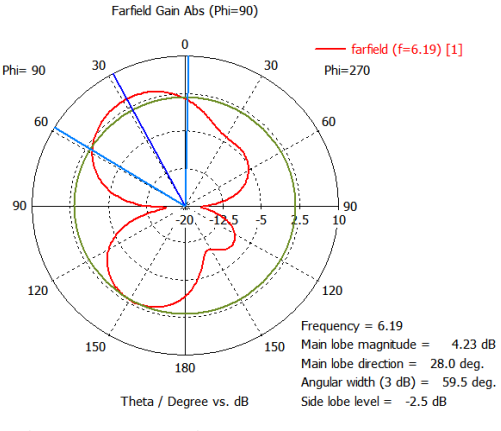

Fig. 9. 1D plot of Gain at 6.19 GHz frequency

In 6.19GHz gain plot, the main front lobe scale is 4.22dB, main front lobe direction is 28.0 degrees and angular width is 59.2 degrees while back lobe scale is -2.5dB.

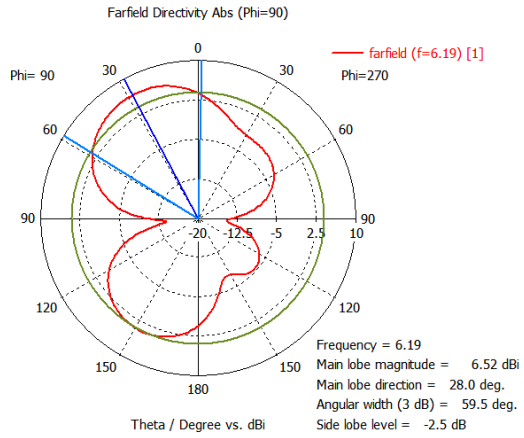

Fig. 10. 1D plot of directivity at 6.19GHz frequency

In 6.19GHz directivity plot, the main front lobe magnitude is 6.51dBi, main front lobe direction is 28.0 degrees and angular width is 59.2 degrees while back lobe scale is -2.5dB.

As goes for VSWR it showed satisfactory results clearly evident from figure 11 as all the resonant frequencies showed response less than 2dB which shows the antenna is efficient as 96 to 98%.

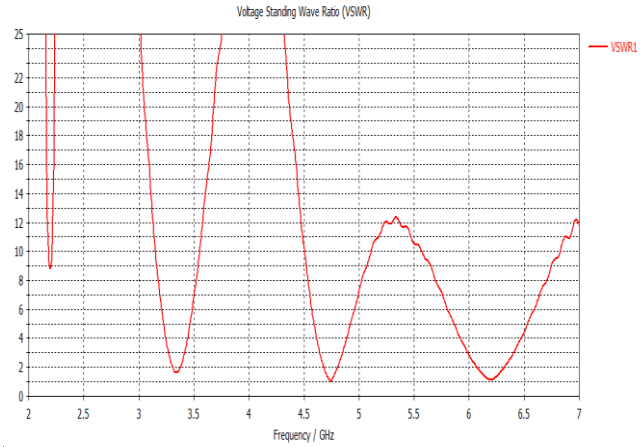

Fig. 11. Voltage Standing Wave Ratio Graph of Antenna

The approximate values of VSWR of the proposed antenna are shown in the following table.

TABLE II. VSWR VALUES OF RESONANT FREQUENCIES

Resonant Frequency	VSWR	Reflection Coefficient	Reflected Power (%)	Reflected Power (dB)	Mismatch Loss (dB)
3.3GHz	1.63	0.24	5.7	-12.41	0.26
4.7GHz	1.02	0.01	0.0	-40.09	0.00
6.1GHz	1.10	0.05	0.2	-26.44	0.01

From results shown in table 2 all the resonant frequencies prove that antenna impedance is matched. For 3.3GHz antenna power delivered is up to 94.3%. For 4.7GHz nearly all the power is delivered from transmitter side. And at last for 6.1GHz power radiated is nearly 99.98%.

The results attained from resonating frequencies both gain and directivity are better than [12-13]. For resonant frequency of 3.3GHz there are no side lob radiations and with the gain exceeding 2dB, makes it suitable for GSM and LTE applications. For 4.7GHz frequency although with slight increase in back radiation, with the higher gain and return loss of resonant frequency it becomes suitable for vehicular and S-band communication applications. At last for 6.1GHz the radiation pattern achieved was very interesting as it was in The form of butterfly. But with the side lob level of 2.5dB this antenna proves significant response of it making it suitable for Fixed Satellite Services (Earth to Space) applications.

The following table shows all the parameters results of the resonant frequencies of proposed antenna.

TABLE III. PARAMETER RESULTS

Resonant Frequency	Return Loss	Gain	Bandwidth	Directivity
3.3GHz	-12.36dB	2.91dB	60 MHz	5.64dBi
4.7GHz	-37.43dB	2.17dB	110 MHz	5.38dBi
6.1GHz	-26.10dB	4.22dB	300 MHz	6.51dBi

The dimensions of conventional patch antenna with the central resounding frequency of 3.346GHz would require dimensions of 27.94×21.00=585 mm² while as for proposed design, only by dimensions of 16x21= 361mm² it is achieved, resulting in shrinking the size up to 61.70%, which is more significant than formerly published methodologies. Also the antenna is showing triple band frequency response with good gain, directivity and good bandwidth for resonant frequencies [12-13].

IV. CONCLUSION

In this paper, a new methodology with tri band resonating frequency is presented. Antenna with size reduction of 61.70% is obtained using defected ground structure and U-Shaped slot on the fractal shape patch. As a result antenna produced responded with a high gain, directivity and good impedance bandwidth for each resonant frequency. The proposed antenna is highly efficient as for all resonating frequencies, the VSWR is seen to be less than 2. The proposed antenna is very useful and can be used for W-LAN, GSM, Radio Satellite, Fixed Satellite Services (RSS) & (FSS) and Satellite communication system applications.

V. FUTURE SCOPE

The proposed tri band antenna can be implemented via MIMO technique and also as in terms of stack configuration. Using stack configuration, further miniaturization can be expected.

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