An X-Fractal Patch Antenna with DGS for Multiband Applications

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Abstract- **An X-shaped multiband fractal antenna is presented.FR4 substratehas been used,having thickness of 1.6-mm on which fractal is fabricated.X-fractal has desirable radiation pattern and good reflection coefficient. The proposed antenna can be used for multiple applications such as WLAN, Bluetooth, IMT etc. Effects of different iterations of fractal antenna are separately discussed.By applying of slotted shape defected ground structure (DGS), return loss graph goes to a great extent. Design and simulation has been followed through Computer Simulation Technique (CST).**

Keywords **– Fractal antenna, Patch antenna, DGS, slot antenna, multiband, return loss**

I. INTRODUCTION

Fractals are composed of an endless repetition of a single geometric pattern [1], [2]. Nature is full of fractal as like clouds, trees, rivers, mountains etc. Fractals are come into use to attain multiband, wideband [3]. Characteristics of fractal antenna can be obtained by its geometry [4]. In this study, X shaped fractal is designed to provide multiband antenna [3]-[6]. Slots can also introduce that will enhance the return loss graph. Many researchers investigated about the different fractal shapes as antennas such as Hilbert curve, Sierpinski gasket, and Koch snowflake [7], [8], [9], [10]. Various parameters are come into account after simulation of fractal antenna but most valuable parameter is Reflection coefficient (S11) which determines the multiband features of fractal antenna. Fractal has many other properties like recursive, infinite, space filling and self-symmetry. Due to these properties, fractals have more resonant frequency which leads to lower return loss. Most of fractal element antennas use the fractal structure as a virtual combination of capacitors and inductors. Due to this, an antenna has many different resonances which can be chosen and well-adjusted by choosing the proper fractal design. Slots are also come in contact for better results which can also enhance the gain of antenna that are main factors of desired antenna [10].Loading of slots on ground plane can cause of meandering of excited current paths.Fractal antenna has more number of stages so that complexity of antenna design increases. With this, current in each path also increases, therefore more number of resonances is created and shifting resonant frequencies are down in frequency.

II. ANTENNA DESIGN

Design of X-shaped antenna is shown in Fig.1.Proposed antenna consists of 3 different stages shown in Fig.1. In very first stage (stage1), a horizontal metal strip with length L_1 isdesignedon the substrate of length ($2*L_0+W_g$)and width of L_g and then, rotated by an angle of 45°.A design of antennalooking like a cross is obtained by taking mirror images of the strip, which is the first iteration of desired antenna as shown in Fig. 1.Length of the strips is chosen in such a manner that strips cannot touch to other strips or to the feed line given to the proposed antenna of width 3mm.After first iteration, second iteration is designed with appropriate length so that they cannot interfere with others. In similar way, third iteration is designed by using given lengths. A small strip of length G is introduced above the feed line. The purpose of this small length strip is that, in the third iteration, strips will not interfere with the feed line so that noises will not beintroduced. After the completion of iterations, the ground is designed on the backside of the substrate. The ground is adjusted according to the requirement of frequencies whose dimensions are shown in Fig.5 (a).According to Fig. 7, we can get some frequency bands that we need, but after etching slots from Fig.5(a), we obtained the desired frequencies of antenna which is shown in Fig.8. Now slots are introduced in the ground that will increase the frequency bands of desired antenna. Slots radiate EM wavesin similar way that a dipole does. Slot antennas are also used at UHF and microwave frequencies instead of line antennas when greater control of the radiation pattern is required. Slot antennas are mostly used in radar antennas.Slots are etched from the ground of the antenna that will give the desired frequency bands. In this antenna, slots are cut in such a fashionthat some parts of ground are not connected to each other. The part of ground which is not connected to the input port of antenna or to any other grounded copper are comes in contact with EM waves produced by slots that are having very thin thickness. In this particular antenna, without separating ground from each other doesn't give better results. After we separate ground with the help of slots, bandwidth of frequencies increased. The width of each metal strips is 3mm. The geometry of this fractal is symmetrical about 50 ohm microstrip feed line with width of W_0.

Results of these 3 stages are different to each other. From the simulation results of these three stages, we are looking of three basic parameters like return loss, Voltage Standing Wave Ratio, Gain, Directivity.

Return loss is defined as -20log|r|. Return loss graph of stage 1 is shown below in Fig. 2. In this stage, it covers the frequency range of 3.7-3.85, 4.4-4.9 which is used as international mobile telecommunication, frequency bandwidths of this stage is not too wide. For this reason fractals are introduced in antenna designs. This stage also covers a range of 5.1-5.9, 6.3-6.8.

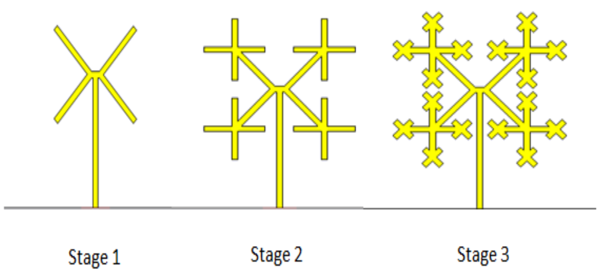


Fig.1 Different stages of X-shaped fractal antenna having that are used in proposed fractal antenna

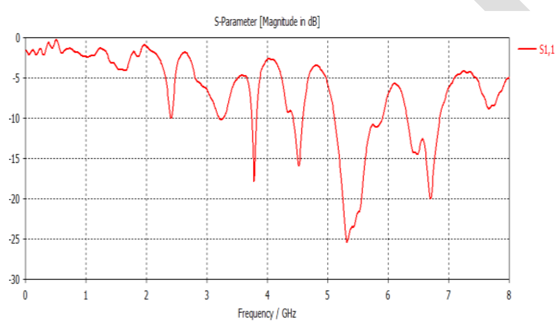


Fig.2 S_{11} (Db) simulated for the stage 1

Now,Results in the next iteration improves further in gain and also we found new frequency bands. Reflection coefficient graph of stage 2 is shown below. As in stage 2 frequency band of 2.20 -2.39are not upper to -10 dB but after second iteration this band increases reflection coefficient parameter and become in use for IMT band.

Table 2.1

Dimensions of optimized X-shaped fractal antenna

Parameter	L_1	L_2	L_3	W_0	H	L_g
Size(mm)	60	30	9	3	1.6	120
Parameter	G	K	L_f	W_g	L_0	
Size(mm)	3	12	63.71	20	43.71	

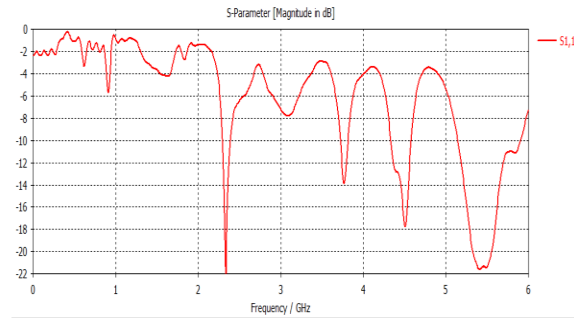


Fig.3 S_{11} (Db) simulated for the stage 2

A. Geometry of final proposed antenna

Front view of fractal antenna is as shown below in Fig. 4(a) with proper defined dimensions. To avoid overlapping between feed line and strips of last stages, we can introduce a strip with length G. By taking appropriate length of this factor, overlapping is restricted. This typical design is applied on the substrate of material FR4 having length (L_f+L_0) and width of 1.6mm.Length of the strips in this proposed antenna is centre to centre. Ground which is a conducting material of copper serves as a return path for current to different components on the design also shows a major role in the reflection coefficient graph. According to this ground plane, return loss graph varies. Ground does not necessarily have to be connected with the port from where input is transmitted. Ground plane is adjusted according the fractal design. Plane of ground which is so adjusted to get desired antenna frequencies is as shown in Fig. 5(a).

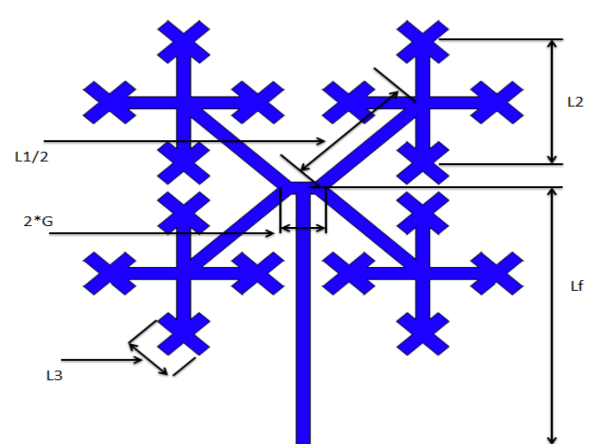


Fig.4(a) Final designed fractal patch antenna

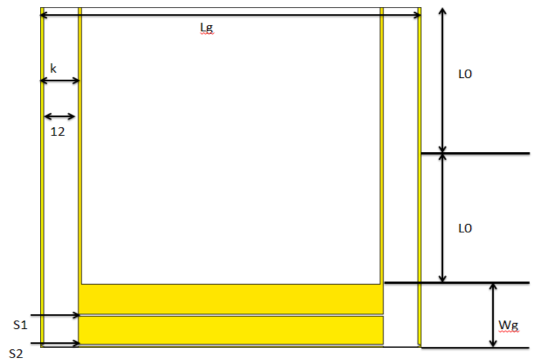


Fig.5(a) Ground of the designed antenna

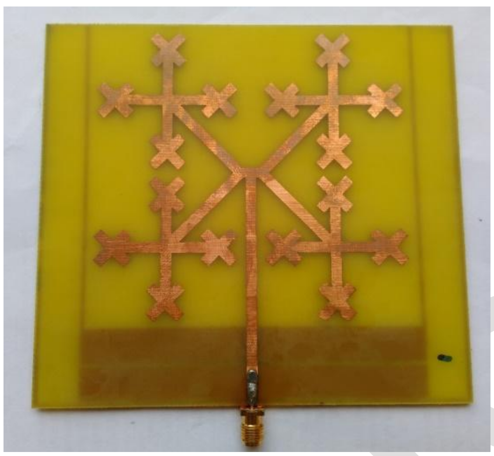


Fig.4(b)Front patch of fabricated antenna

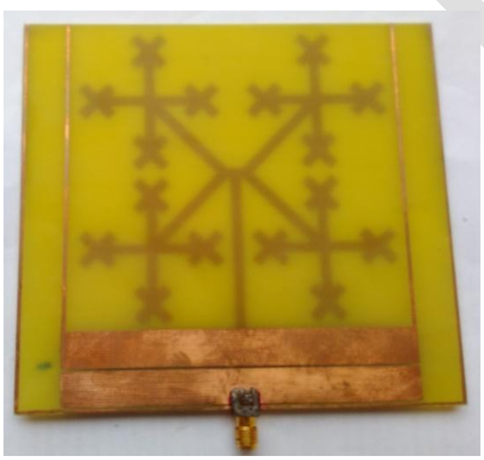


Fig.5(b) Ground of the fabricated antenna

Slots S1and S2 that is etched from the ground has width of 0.5 each. Lower dimension of slot s1 from where it is etched is (L_f-0.5) and S2 has lower dimension is (L_f-10). Slots with width of 12 and length of(L_f+L_0-0.3) also cut from the ground having length of (L_f+L_0) and width of k from both side. Results of antenna are mainly depends on slots of antenna.Main advantage of slot is that, it increases the electrical length of antenna due to which more EM wave are come in contact and thus enhance the various parameters of antenna.

Fig.6 given below is without etching slot S1 from the ground. This clearly shows that there is a lot of difference between the etching slot and without slots. Many of the frequency bands are decreases their gain, bandwidth and also effect on side lobes.Fabricated antenna is shown in fig. 4(b) and 5(b)

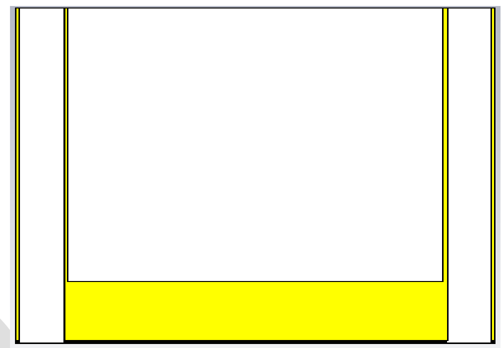


Fig.6 Ground without slot S1

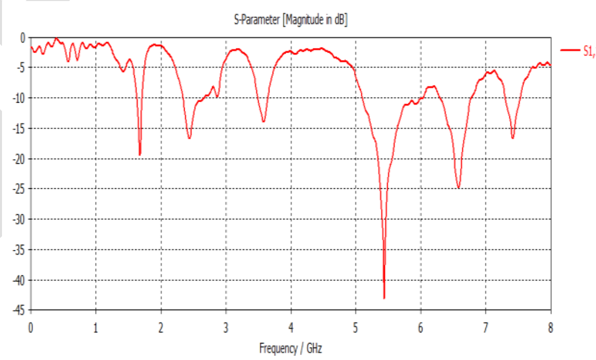


Fig.7 S_{11} (dB) simulated without the slot S1

III. Results and Discussion

Reflection coefficient graph of the desired antenna is as shown below in Fig.8.This is the final results of third iteration, which shows that by increasing the number of paths of current, there will be increasing number of frequency bands occurs with good gain i.e. there are low radiation losses and dispersion. Resonant frequency increases as the iteration increases. The impedance bandwidths at the lower and upper bands (dB) are 6.9% (2.39–2.56 GHz) and 14.5% (5.10–5.90 GHz), respectively.This proposed antenna works for international mobile telecommunication having band of 2.3-2.59 GHz. This frequency range also covers the Bluetooth band that is used in mobile communication, having frequency range from 2400-2500 MHz

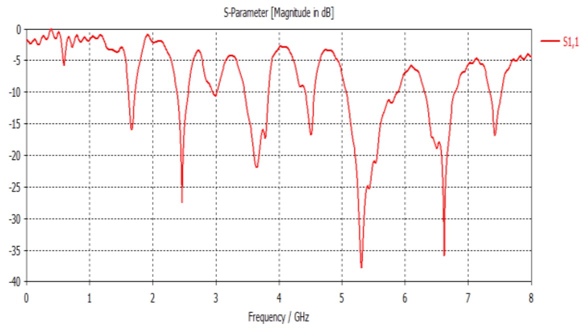


Fig.8 S_{11} (dB) simulated for the proposed antenna

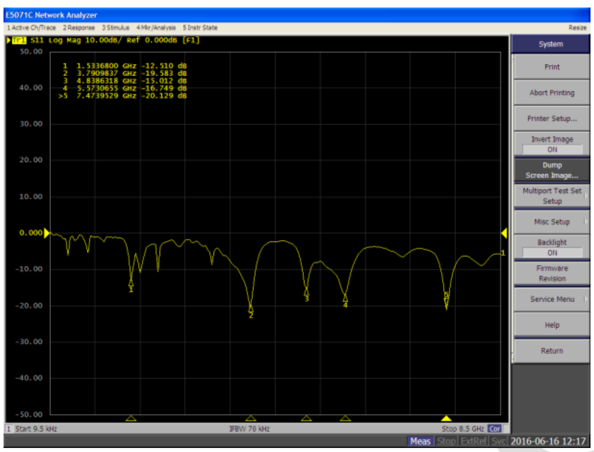
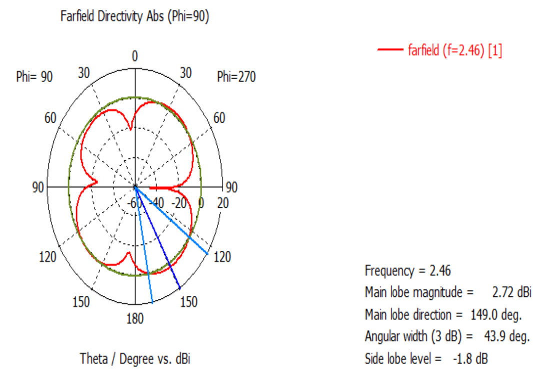


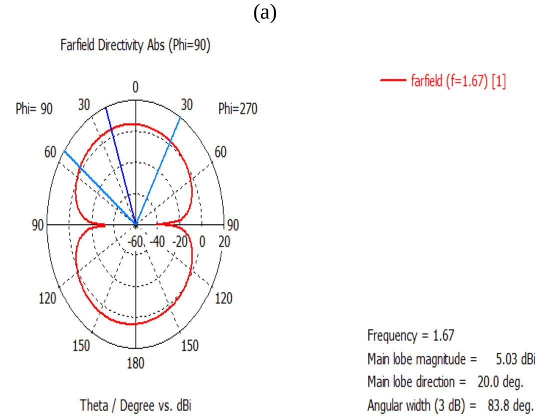
Fig. 9 S_{11} (dB) measured for the proposed antenna

The main aim of using this X- shaped antenna is to work on WLAN having range 5.1-5.9GHz and 2.4GHz. This designed antenna covers almost complete 5-6 GHz frequency i.e. having huge bandwidth range. This antenna has application in next 5th generation technique which will work in frequency range between 6-7GHz.

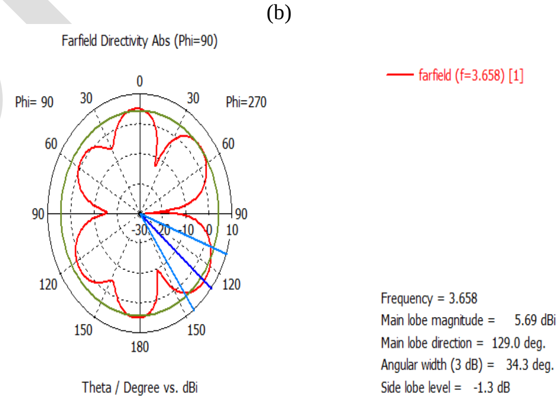
Radiation pattern ofX-shaped antenna is as shown in Fig. 10. By giving the proper feed to the antenna, radiation pattern will improve also. Displacement of feed may give improper results of radiation pattern. Therefore, Position of feed for a fractal antenna is exactly placed at the centre of the fractal width direction (y axis) and somewhere along the fractal resonant length direction (x axis). The exact position of feed along the resonant length is determined by the electromagnetic field distribution in the fractal. Looking at the current (magnetic field) and voltage (electric field) variation along the fractal, the current has a maximum at the centre and a minimum near the left and right edges, while the E-field is zero in the centre and maximum near the left and minimum near the right edges. Radiation pattern obtained shows the directivity of antenna in following figures. Measured results are shown in Fig. 9 and they are in agreement with the simulated results. Some of the minor deviations are due to fabrication errors.



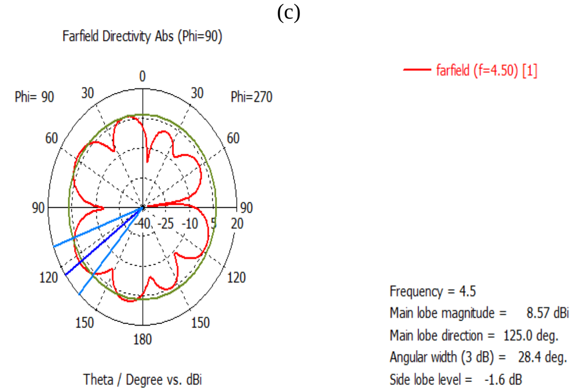
(a)



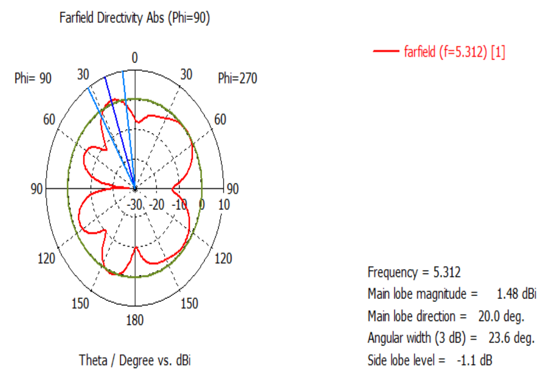
(b)



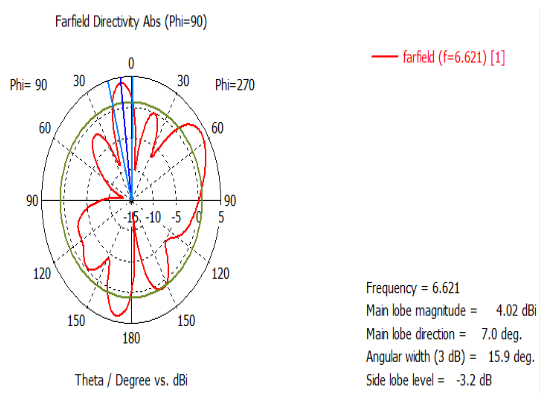
(c)



(d)



(e)



(f)

Fig.10 Radiation patterns at different frequency (a) 2.46 GHz (b)1.67 GHz (c)3.658 GHz (d)4.5 GHz (e)5.312 GHz (f)6.621 GHz

IV. Conclusion

A novel planar antenna design that is based on an X-shaped fractal structure has been proposed. This X-shaped type of antenna is easy to implement because of its simple design. The design procedure and rules for avoiding overlapping between strips have been given in this paper. Results show that the proposed antenna can work for multiple resonances with reasonable antenna directivity which is shown on radiation patterns. The PSO method has been applied to optimize the proposed X-fractal for 2.45/5.5GHz WLAN application and 5th generation technique. Concluded result shows that the optimized antenna successfully achieves the design goal that we need. The proposed X-shaped fractal has great capability for designing antennas with multiband or wideband features.

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