International Journal of Enhanced Research in Science Technology & Engineering, ISSN: 2319-7463
Vol. 3 Issue 8, August-2014, pp: (91-96), Impact Factor: 1.252, Available online at: www.erpublications.com

Design of Miniaturized Fractal Antenna on Two Layer Stack

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Abstract: This paper presents rectangular, fractal and proximity coupled patch antennas on a two layer substrate with the air-gap. The antennas have been designed on εr = 2.2, h = 1.5748 mm with initial dimension 49 x 41.01 mm of simple rectangular patch. The simulated resonant frequency of rectangular patch is 2.42 GHz. The fractal antenna and the Fractal antenna with Layered Stack shows the multi band behavior at frequencies ranging from1. 9397 GHZ to 10.06 GHZ and 4.92 GHZ to 9.56 GHZ respectively The bandwidth of fractal patch has been improved with 0.8 mm air gap in two layered fractal patch in stack with better gain than rectangular patch .The radiation pattern of fractal antenna is as similar to rectangular patch antenna but cross polarization is better in fractal patch.

Keywords: Fractal antenna, Multiband antenna, Fractal Geometry, Edge - Feed and UWB System.

INTRODUCTION

With the advancement of wireless communication system and other wireless applications, antenna design has become more useful in the recent years. The Microstrip patch antenna (MPA) has attracted wide interest due to its important characteristics, such as low profile, light weight, , low cost, mechanically robust, simple to manufacture and easy to integrate with other RF devices. Miniaturization of microstrip patch antennas is a recent topic of interest. Numerous methods were introduced to decrease the microstrip patch antenna size such as shorting pins and planes, introducing of a U-slots, using of high permittivity materials [1-2]. Several technical papers have been appeared to improve the bandwidth of the microstrip antenna [2-4]. The bandwidth of microstrip antenna increases with increasing the thickness of the substrate and lowering the dielectric constant. Using the coupling resonant antenna is also the strong technique to increase the bandwidth of microstrip antenna [3]. Although bandwidth of microstrip antenna can be increased by several techniques but the size of microstrip antenna is limited by the half wavelength length for good radiation efficiency.

For reducing the size of antenna,fractal geometries have been introduced in the design of antennas. It has been shown that fractal shaped antennas exhibit characteristics that are associated with the geometric properties of fractals [5]. Fractal geometries have two common properties, space-filling and self-similarity [6-7]. The self-similarity properties of certain fractals result in a multi-band behavior [6]. Using the self similarity properties, a fractal antenna can be designed to receive and transmit over a wide range of frequencies while space-filling properties of fractals make possible to reduce antenna size [7]. The size reduction of antenna using space filling properties of fractal along with incorporation of bandwidth improvement technique is the research aim of this paper. In this paper, the space filling properties of antenna has been applied for the size reduction. The several Fractal patch antennas have been designed, measured and analyzed. This paper also presents the impedance bandwidth improvement of fractal patch antenna in Double layer with air-gap and proximity electromagnetic couple fractal patch also being Simulated. All results are obtained by simulations using HFSS.

GEOMETRY OF ANTENNA

A fractal is a Geometry used in Antennas that typically displays self-Repeating patterns. The dimension of the geometry can be interpreted as a quantification of the space filling ability of the geometry. Fractals geometry is applied in a rectangular microstrip patch antenna as shown in Fig. 1, to miniaturize the size

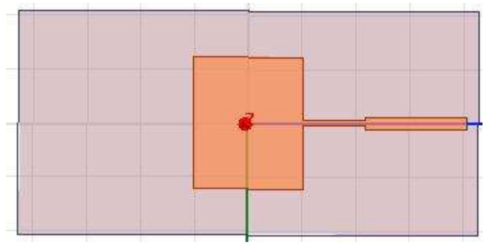

Figure 1. Rectangular Patch Antenna

The combination of fractal geometry and the microstrip configuration can be used to achieve high gain and multiband behaviour in a Planer Antennas. Microstrip fractal patch antenna can be miniaturized by adding Fractal Shapes along the length of the patch. These Fractal forces the currents to meander along a long path length allowing the patch to be miniaturized for a given resonant frequency. The Two fractal antenna Designs are shown in the Fig. 1(a-b). The simple rectangular patch which is the starting structure is generally called initiator. The initiator defines the general shape of the structure which is the 0^{th} iteration of Fractal Design.. Next, add the indentations (Fractal Shapes) along the length of simple rectangular patch in the first iteration for Fractal Design 1 and repeat the process at different scale i.e 0.1 to make Fractal Design 2. The iterative process can be performed an infinite number of times, but we can not use these in antenna design because they can not be fabricated. Therefore, the infinite iterative process should be terminated at a reasonable level. In this paper, Fractal antenna Design 1 and Fractal Antenna Design 2 has been contructed and simulated which is shown in Fig. 2(a-b), for size reduction and bandwidth improvement.

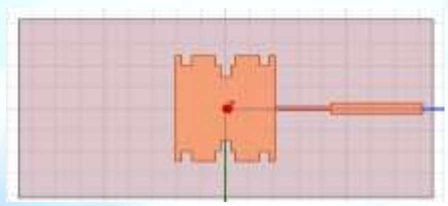

Figure 2a. Fractal Design 1

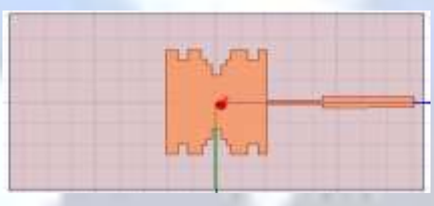

Figure 2b. Fractal Design 2

III. RESONANT FREQUENCY

The resonant frequency of rectangular patch can be calculated by using the following equation (1).

$$f_r = \frac{c}{2L\sqrt{(\varepsilon_{reff})}} \qquad (1)$$

The resonant length of patch is not exactly equal to the physical length due to the fringing fields on the sides of patch. Effective length of patch is longer than the physical length of patches.which is due to fringing field in the Patch Antennas.

IV. SIMULATED AND EXPERIMENTAL RESULTS

The proposed fractal antenna has been designed on the substrate of permittivity εr = 2.2 and thickness 1.57 mm. The substrate size of the antenna has been taken as 171.1 mm x 83 mm. The antenna was designed and Simulated with optimized dimension. The simulation of the antenna was carried out by using HFSS software based on the Finite Element Method. The rectangular patch antenna as shown in Fig. 1a has been simulated by considering the infinite ground plane. The simulated center frequency is 2.42 GHz. The fractal antenna of Design 2 iteration with edge feed from the bottom of the substrate is shown in Fig. 2b .The simulated center frequency of the fractal patch of Design 1and Design 2 has been observed 1.9 GHZ and 5.02 GHZ respectively. This shows the size reduction of the patch antenna. The simulated results are shown in Fig. 5(a-b-c-d). The two fractal Design with stack on the same thickness substrate with air gap of 0.8 mm are shown in Fig. 4(a-b) These stacked Fractal Design also been simulated with the same feed position as fractal patch. The simulated resonant frequency of fractal antenna design 1 with the layered stack is observed 4.9 GHz and 8.1 GHz as shown in Fig. 5c.. . The simulated resonant frequency of fractal antenna design 2 with the layered stack is observed 5.05 GHz and 5.7 GHz as shown in Fig. 5d. The fractal patches on multilayer in stack with air-gap of 0.8mm have been design to improve the impedance bandwidth shown in Fig. 5(a-b). The air-gap improves the bandwidth shown in table-2 with the same feed position as fractal patch with Double layer. The bandwidth can further be improved by optimizing the feed position along with air-gap.. In this bandwidth improves but the size of total antenna is large because feed length of 38 mm which reaches to the center of fractal patch. In table I, the simulated results of Fractal Designs are tabulated with each Design. Table II, compare all the simulated results of Stacked fractal Designs .with air-gap. It can be seen in the tables that simulated and experimental results are in good agreements. The side view of the Stacked Fractal Design is shown in the Fig 3. In which two layers of the substrate over which which the patch are loaded is shown.

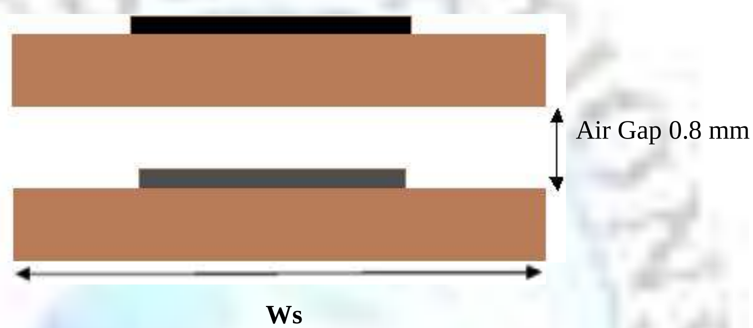

Figure 3. Side view of the Stacked Fractal Design

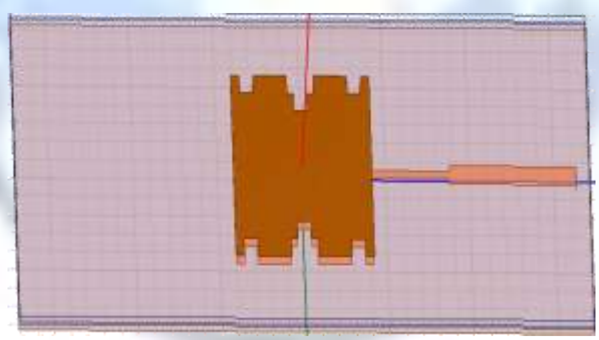

Figure 4a. Stacked Fractal Design 1

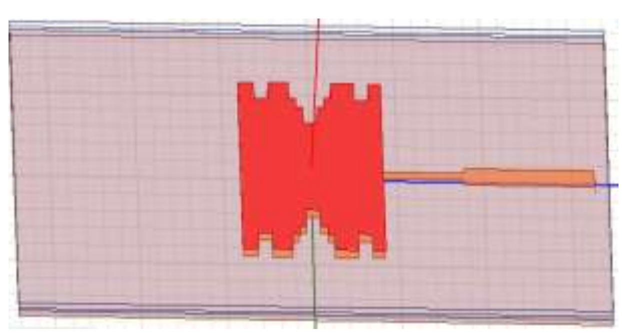

Figure 4a. Stacked Fractal Design 2

In the Fig 3, the sideview of the Stacked Fractal Antenna design shows Ws which is the width of the substrate taken to Design and simulate the antenna. The substrate loaded with Fracal Patch is mounted or separated by an air gap with another substrate loaded with Fractal Patch .The bottom Substrate is feed through the Edge of the microstrip transmission line. The upper section of the Stacked Fractal antenna is fed through the coupled electromagnetic energy from the bottom antenna section. This pheonomenon is called Proximity coupling.

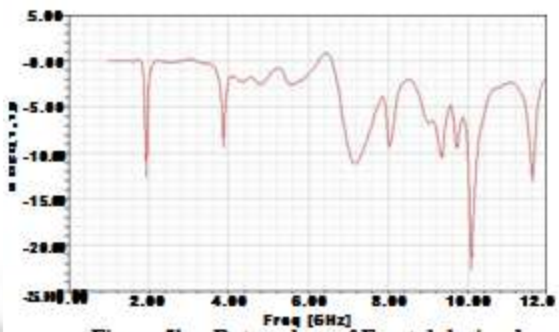

Figure 5ha. Return loss of Fractal design 1

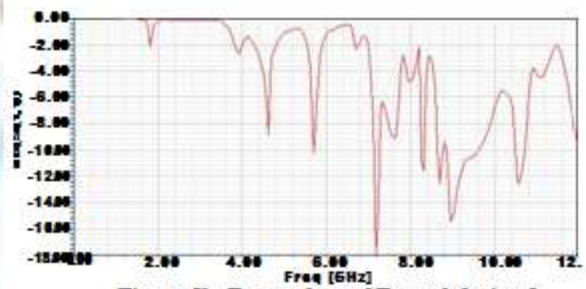

Figure 5b. Return loss of Fractal design 1

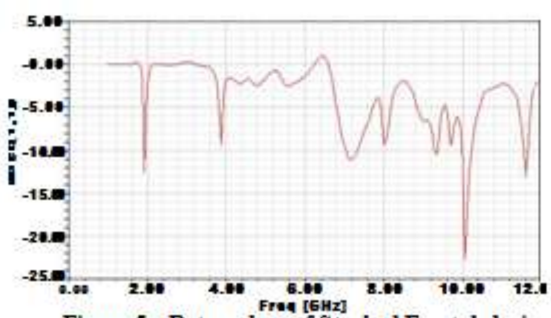

Figure 5c. Return loss of Stacked Fractal design 1

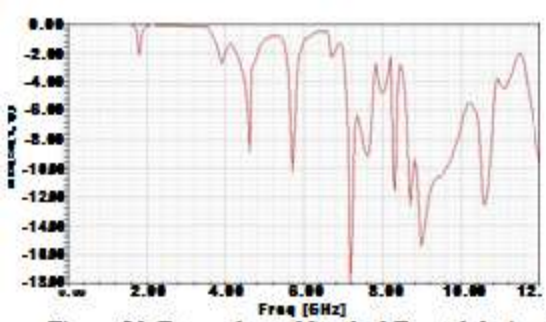

Figure 5d. Return loss of Stacked Fractal design 2

Radiation pattern of rectangular and fractal patch antenna is shown in Fig. 6(a –b-c). It is calculated at the center frequencies of the antennas. The radiation pattern of both Fractal and rectangular patch antennas is found similar. The cross polarization level in H plane of fractal antenna is better in comparison to the simple rectangular patch. This cross polarization increases with the air-gap in the Double layered fractal patch antenna shown in Fig. 5b and Fig 5c. and may be unwanted for certain applications. However, by adjusting the height of the air-gap, the cross-polarization level could be achieve according to the applications. Thus, the fractal patch antenna can be used to replace a normal rectangular patch with its similar characteristic of radiation and smaller patch size compared to that of a rectangular patch, for better gain and also for the multiband behavior corresponding to All designs.

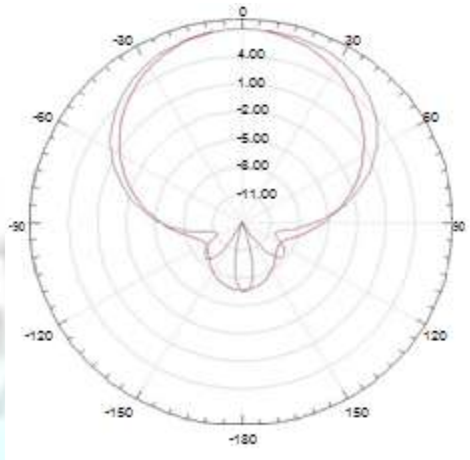

Figure 6a. Radiation Pattern of Rectangular Patch

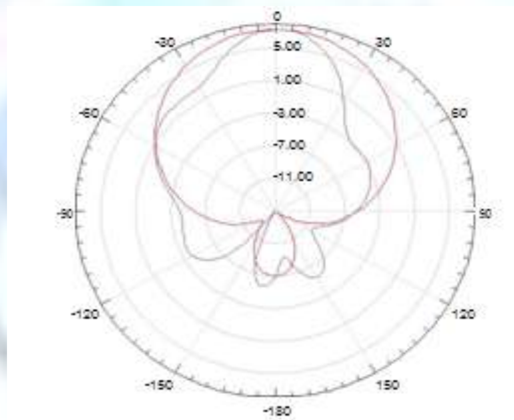

Figure 6b. Radiation Pattern of Stacked Fractal Design 1

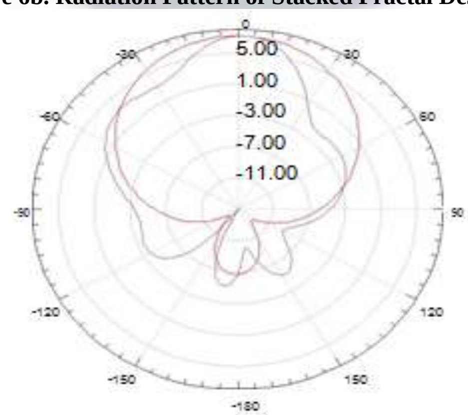

Figure 6c. Radiation Pattern of Stacked Fractal Design 2

Table 1: Simulated Results of Fractal Design

Design	Freaquency	Return Loss (db)
Fractal design 1	1.9397	-12.60
	7.1910	-11.06
	9.34	-10.53
	10.06	-22.60
Fractal Design2	5.7	-10.80
	7.17	-17.92
	8.3	-11.53
	9.01	-15.00

Table II: Simulated Results Of Fractal Design With Stack

Two layer stack	frequency	Return	gain
Stacked fractal desgn 1	4.92	-15.17	7.32
	5.75	-14.94	
	8.18	-36.32	
	9.18	-16.96	
Stacked fractal design 2	5.00	-19.30	7.15
	5.71	-15.04	
	8.36	-13.05	
	9.56	-11.88	

CONCLUSION

The fractal geometry on the normal rectangular patch has been simulated and studied. It has been found that this structure with proper indentation (Fractal Shapes) along the length gives a good miniaturization compared with a Normal rectangular patch antenna . Such properties of the patches make it possible to apply fractal antennas to those applications. needing reduced size antennas. The simulated Fractal Designs shows multiband behavior with return loss Obtained at frequencies ranging from 1.9397 GHZ to 10.06 GHZ.. The simulated Fractal Designs with the stacked layers also shows multiband behavior with return loss Obtained at frequencies ranging from 4.92 GHZ to 9.56 GHZ, and also considerably increasing the gain of the antenna. From 6.3 db of the fractal design to 7.32 db. The radiation pattern of fractal patch antenna is similar to normal patch. The cross polarization level is better for fractal patch antenna. Bandwidth of these antennas can be further improved by selecting the proper feed position and air-gap.

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