Novel Design of Star-Shaped Fractal Slot Antenna for UWB Applications

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Abstract : In this work, a star- shaped microstrip fractal antenna with partial ground has been designed with different iterations using High Frequency Structure Simulator (HFSS'13). The star shaped microstrip antenna is mounted on FR4 substrate and undergoes 5 levels of iterations. The antenna performance has compared for gain, bandwidth, Voltage Standing Wave Ratio (VSWR), Radiation Pattern for five iterations. The antenna covers ultra wide band from 3 GHz – 9.1 GHz exhibiting good radiation characteristics in this band. The maximum gain of antenna is 5.13 dBi for fifth iteration of star-shaped patch is achieved.

Keywords: Microstrip antenna, fractal antenna, Return loss, VSWR, partial ground, HFSS

1 INTRODUCTION

Microstrip antenna offer an advantage of thin profile, light weight, low cost, conformability with integrated circuitry (MMICs) [1]. They are extremely compatible for embedded antenna in hand held devices such as cellular phones, pagers, etc. [2]. There are many approaches to reduce the size of antenna without much affecting antenna's performance. The application of fractal geometry is one such technique. Fractal geometries are used for multiband and broadband behaviours [3]. Fractals show very high similarity and symmetry nature.

Fractal is a rough or fragmented geometric shape that can be subdivided into parts each of which is the reduced copy of the whole. Fractal antenna is an antenna that uses a fractal, self-similar design to maximize the length or increase the parameter on inside sections or the outer structure of material that can receive or transmit electromagnetic radiation within a given total surface area or volume. [4] Fractal antennas have performance parameters that repeat periodically with an arbitrary fineness dependent on the iteration depth. Iteration depth refers to the number of iterations that should be carried out to get the higher order structure [5]. The self-similarity properties of certain fractals result in a multiband behaviour. Various fractal geometries have been found to be useful in developing new and innovative designs for antenna. These include Sierpenski gasket, Koch curves and Minskowski curves.

Recently, partial ground has been gaining interest for their planar form and ease of fabrication. Partial ground is realized by etching the half of ground plane of microstrip antenna. The introduction of partial ground reduces the back-lobe radiation of the microstrip antenna by suppressing the surface wave diffraction from the edges of the antenna ground plane. The partial ground also improves the front-to-back ratio of the antenna.

2 ANTENNA CONFIGURATION

The antenna is fabricated on FR4 substrate. The material is so chosen because of its cheap and easily available in market. The thickness of substrate of star-shaped fractal antenna is 1.6 mm. Two FR4 substrates of 0.8 mm each are mounted on one another to make the total height of antenna as 1.6 mm. The substrate has dimensions 35 x 20 mm. The antenna is fed by transmission line of length 17 mm and width 1.5 mm. The antenna patch and ground are excited by a 50Ω SMA connector. The antenna star-shaped patch is made using an eclipse and etching out a hexagonal from its inner part. This geometry is iterated five times to give the patch the shape of star. The radius of major axis of eclipse is 9mm and that of minor axis is 8.06 mm and the ratio between the two axes is 0.9. This is the outer border of the patch. The dimensions of hexagon are adjusted to be fitted in the eclipse. Both the eclipse and hexagon are centred at the origin so that the structure so produced has equal distance from all sides of the antenna. A feed line of width 1.5 mm is attached to the elliptical patch and extended up to the edges of substrate. Table 1 lists the parameters of the antenna with optimised values. The whole structure gives a "star" look. The concept of partial ground is used in this geometry.

Ground plane plays an important role in the antenna performance. The requirement of compact antenna is associated with ground position and dimensions. To achieve bandwidth enhancement, the star-shaped antenna proposed here has been made using partial ground. The dimensions of ground plane play an important role in antenna performance. The partial ground plane diverts or change the direction of return current flowing through the ground plane. This makes ground plane highly inductive and thus the voltage across ground lane drops. Therefore an optimum compromise must be made between the dimensions of ground plane so that the overall performance of the antenna improves.

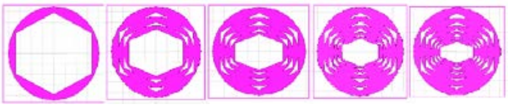

Figure 1: Five iterations performed on patch

Table 1: Optimized parameters of antenna

Parameters	**Values (mm)**
Length of substrate	35
Width of substrate	20
Height of substrate	1.6
Length of ground	20
Width of ground	20
Length of feed	17
Width of feed	1.5
Major axis of eclipse	9
Minor axis of eclipse	8.06

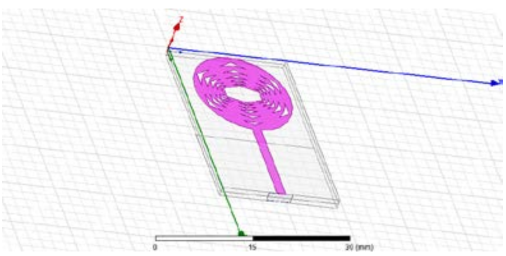

Figure 2: Five iterations of hexagonal patch

3 RESULTS AND DISCSSION

This antenna has been simulated using HFSS'13 version for the Ultra Wideband application. Results of proposed antenna have been compared based on the iteration depth. The antenna has been simulated using High Frequency Structure Simulator version 13. Figure 3(a) shows the return loss versus frequency plot for star-shaped antenna with final iteration. . Figure 3(b) shows the VSWR versus frequency plot for star-shaped antenna with final iteration. . Figure 3(c) shows the Gain versus frequency plot for star-shaped antenna with final iteration of antenna. Table 2 shows the comparison of results between zero, one, two, three, four and fifth iteration of antenna.

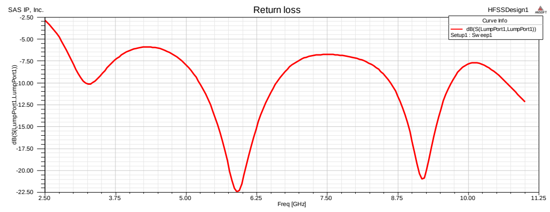

Figure 3(a): Return loss of final iteration

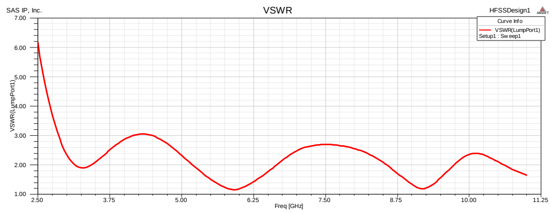

Figure 3(b): VSWR of final iteration

Figure 3(c): Gain of final iteration

Table 2: Comparison of results for five iterations.

Iterations	Frequency (GHz)	Return loss (dB)	VSWR	Bandwidth (MHz)	Gain
0th	3.13	-15.0533	1.43	510	4.09
1st	3.18 5.94 9.13	-14.0897 -12.4865 -18.3127	1.48 1.62 1.27	510 770 1020	4.46
2nd	3.26 5.94	-11.0806 -16.9196	1.77 1.33	340 1190	4.77

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	9.17	-17.8862	1.29	1020	
3rd	3.30 5.94 9.21	-10.5438 -20.7206 -19.3164	1.84 1.20 1.24	240 1060 1270	4.56
4th	5.98 9.13	-19.5195 -18.9613	1.23 1.25	1150 1360	5.96
5th	5.94 9.17	-22.2463 -20.9669	1.16 1.19	1360 1150	5.13

Thus we see that when the antenna is iterated the fifth time, more frequencies are added up and they show multiband behaviour, which demonstrates the behaviour of fractals. This happens because as the iteration increases, the resonance coupling between feed and patch become more complicated and leads to more at different frequencies. The space filling property of fractal fill the area of antenna as iteration depth increases.

4 CONCLUSION

In this paper, a star-shaped fractal antenna is proposed for Ultra Wideband applications. The antenna is simulated using High Frequency Structure Simulator version 13. The proposed antenna is given a unique shape of a star using the concept of fractals. The simulation results show that the antenna shows multiband and broadband nature at non-harmonic frequencies. This is the property of fractal that they make the antenna multiband because they offer larger distances to current to flow and hence the larger loops of current are formed that radiate even at non-harmonics of frequencies. Fractals also are space-filling curves that fill the area occupied by the antenna. Also the results shown here show that the partial ground plane antenna offers a gain of 5.13 dB and a omni-directional radiation pattern. The greatest advantage of the proposed antenna is that it is compact. The antenna covers the range from 3.1 GHz to 9.17 GHz and is well suited for ultra wideband applications. The antenna finds application in communication technology where high data rates have to be sent using low power [6]-[7]. Also the antenna is suited for wireless personal area networks, which sends higher data rates to short distances for example in DVD players, televisions, cameras etc. the antenna also can be used in sensors that require large amount of data to be sent from time to time and at low powers [8]. Employing the antenna in sensor networks also lower the cost and ease of installation as it is wireless. The antenna can also be used for accurate GPS (General Positioning System) that requires exchange of high data rates at shorter distances. Thus it is an excellent example of fractal antenna with wideband characteristics.

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