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DESIGN OF FRACTAL ANTENNA FOR UWB APPLICATIONS

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ABSTRACT

The aim of this paper is to design an antenna suitable for wireless applications. A small, low cost fractal antenna is designed, fabricated on a FR-4 substrate of size 28 mm x 28 mm and tested for this purpose in the laboratory using the N5230 A Agilent network analyzer. The simulation results show that the bandwidth achieved is 7.1 GHz. The experimental result of the fabricated antenna is also presented.
Keywords: *Ultra Wide Band (UWB), Fractal Antenna), Microstrip Antenna*

1. INTRODUCTION

Wireless communication technology is an advancing field of study and its importance is in great demand in commercial and military applications. Multiband antenna and wide band antennas are desired in all communication systems. Wideband antennas also find applications particularly in Unmanned Aerial Vehicles (UAVs), Synthetic Aperture Radar (SAR), and Ground Moving Target Indicators (GMTI). Some of these applications also require that an antenna be embedded into the airframe structure.

The development of high data rate wireless communication systems has further increased the demand for antenna with smaller dimension and wide bandwidth characteristics compared to conventional antennas. In 2002, when Federal Communications Commission (FCC) allowed the use of frequency band from 3.1GHz to 10.6 GHz [1] for commercial uses, there has been lot of research on developing antenna for this band. This band is generally used for short distance communication with effective isotropic radiation pattern (EIRP) of -41.3 dB / MHz, to avoid interference with other system operating in same band [1]. This is called the ultra-wide band and is defined relative to the bandwidth as $2(f_H - f_L) / (f_H + f_L) > 0.2$, where f_H and f_L are the upper and lower band limits respectively.

In recent years several printed monopole antennas are developed for UWB range for their low profile, ease of fabrication and large bandwidth. Various matching techniques are proposed for achieving wide band characteristics. In [3] a UWB antenna is designed with the help of rectangular patch consisting of two steps and half arc ground plane. Feed gap optimization [4], shaping of ground plane [5], multiple feed technique [6], can also be used to achieve wide band characteristics.

Fractal geometry is a good solution to this problem. The self-similarity of fractals causes multiband and hence wide-band properties. The concept of fractal was first defined by a French mathematician B. B. Mandelbrot [7]. Antenna designers and researchers have been always putting forth various ideas about miniaturization of antenna size and arriving at wider bandwidth and improved antenna gain. Of the many methods proposed for this purpose, fractal antenna method leads to shrinking the size and also does not lead to complex structural design.

Fractals are those shapes which are the same and repeated. They are constructed by using a sort of iterative mathematical rule that the geometry of the antenna is generated from a single object step by step. Fractal antenna technology is a geometry based technology and not material based. It uses standard materials and substrates. The benefits of fractals are reduced antenna size, multiband functionality and improved antenna performance.

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Fractals have self-similarity properties which are helpful in achieving multi band characteristics and hence can be optimized for size and UWB applications. Also fractal curves introduce discontinuity in terms of bends and cuts to the radiating patch which increases radiation efficiency of antenna. Various UWB fractal antennas [6, 7] have been reported till date.

In the literature, variety of fractal antenna have been developed and investigated. Several self-similar antenna geometries are proposed: Some examples are, Seirpinski monopole, Koch curve, Hilbert curve and Minkowski curve as in [13-16]

In this paper a square fractal antenna is developed which covers the UWB range of 3.1 GHz to 10.2 GHz achieving bandwidth of 7.1GHz. The micro strip patch antenna which has a low profile can be fabricated by the photolithographic techniques and meets the requirements of the wireless communication system except its bandwidth requirement. The bandwidth enhancement is to be taken care by the proposed fractal structure of the antenna.

2. ANTENNA DESIGN

2.1. Fractal Antenna Design

The design started with the square patch antenna in the first stage. This is called as the zero order. The patch is assumed to be made up of nine small and equal size square structures. As a first iteration, two such small squares are indented in the center. This produces the first order. Next iteration gives the second order which is shown in Figure 1. By doing so, it is observed that the length of the perimeter of the patch is increased and the metal area of the structure has reduced than the original. The second iteration is performed by considering each small square patch as made up of nine smaller square patches and repeating the same procedure as done in the first iteration leading to the second iteration. Similar concepts are discussed and experimented in [4-6] and [8]. Antenna is designed assuming to be fabricated on FR4 substrate with relative permittivity of 4.4.

2.2. Dimensions Of The Antenna

The dimensions of the antenna are calculated using the standard equations.

$$L=W=0.5\lambda_d \qquad (1)$$

$$\lambda_d = \frac{\lambda}{\sqrt{\varepsilon}} \qquad (2)$$

Dimension of feed line is calculated using transmission line model equation [10] for characteristic impedance of 50 Ω and is found to be ($W_{feed} \times L_{feed}$) 2.9 × 12mm^2. Dimension of partial ground is 28.08 X 11.3mm^2. Dimension of the substrate is ($W_{sub} \times Lsub \times H_{sub}$) 28.08 × 28.08 × 1.6mm^3. The antenna is fed by a micro strip feed line whose length is 12.48 mm and width is2.86 mm. The proposed structure is simulated using CST Microwave Studio 2010. The fabricated and measured result is also reported in the paper.

3. SIMULATION

The antenna characteristics can be known from its return loss, resonant frequency, bandwidth radiation pattern, gain and efficiency. The antenna is designed and simulated using the CST Microwave studio with the dimensions mentioned for the full ground plane and for partial ground planes. The return loss characteristics are as shown in Figure 2. The first order structure and the second order structure is simulated only with the partial ground based on the result obtained from the zero order structure as shown in Figure 3 and Figure 4.

4. EXPERIMENTAL VALIDATION

The second order fractal antenna with partial half arc ground plane is fabricated on FR-4 substrate using PCB techniques with the dimensions based on the calculations done and mentioned earlier. The fabricated antenna is tested using the Agilent network analyser N5230A. The fabricated antenna and its measured return loss is shown in Figure 5.

5. RESULT AND DISCUSSION

From the simulation results shown in Figure 2, it is noticed that the zero order structure does not have a significant bandwidth which can be utilised. But if the ground plane is altered to be partial rectangular ground, the bandwidth extends from 3.2 GHz to 8.2 GHz. If the ground plane is altered to be partial half arc plane, the bandwidth extends from 3.2 GHz to 8.6 GHz. there is an appreciable change in its bandwidth. In the first order antenna structure, the bandwidth for the partial rectangular groung plane is from 3.6 GHz to 6.8 GHz and again from 8.3 GHz to 12 GHz. This structure seems to have two resonant frequencies. The first order antenna structure with half arc ground plane has a bandwidth from 3.5 GHz to 7.3 GHz. The second order stucture with the rectangular partial ground plane also has multiple resonant frequencies and

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with partial half arc ground plane has a bandwidth of 7.1 GHz.

6. CONCLUSION

It can be seen from the return loss curves that the second order fractal antenna with half arc ground has the bandwidth characteristics of an UWB antenna. In consenses with the theory, number of resonant frequencies increases with the increase in the order of the fractal antenna. It is also noticed that the partial ground plane alters the bandwidth of the antenna. These two theories are incorporated in the effort to achieve the UWB characteristics.
The experimentally achieved bandwidth is less than the simulated bandwidth and may be due to the variations in the fabrication method and also due to the SMA connector used. Metal area of the fabricated second order fractal antenna is decreased by 39.5% when compared with the initial square patch antenna. The UWB characteristic and size reduction are achieved by designing a fractal structure on half arc ground plane.

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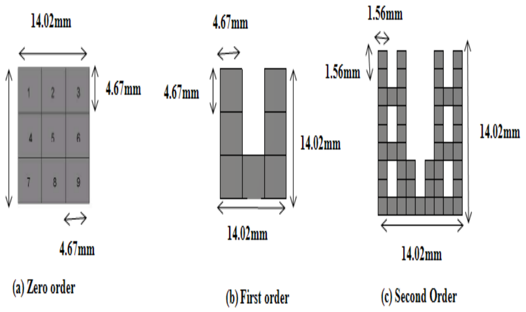
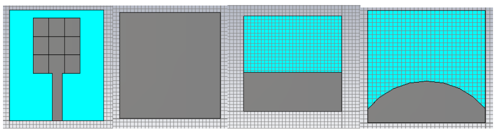
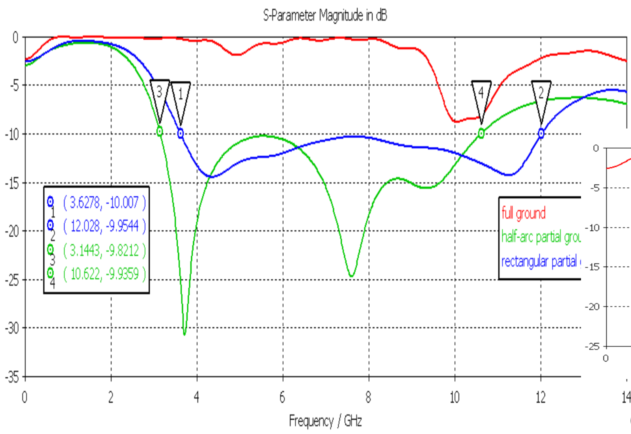


Figure 1: Design of Fractal Antenna

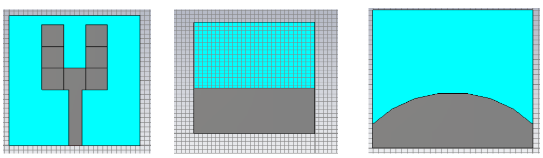


(a) Zero Order Fractal Antenna With Different Ground Planes

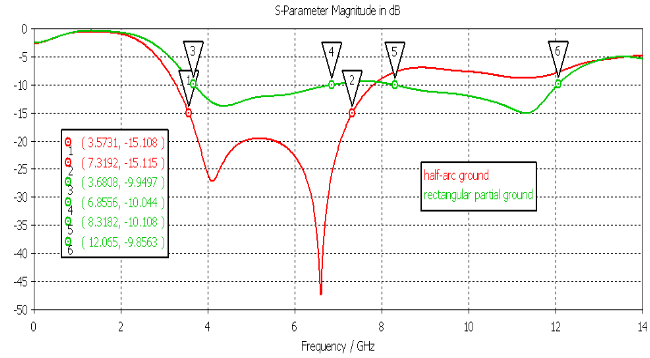


(b) Return Loss With Different Ground Planes

Figure 2: Zero Order Fractal Antenna

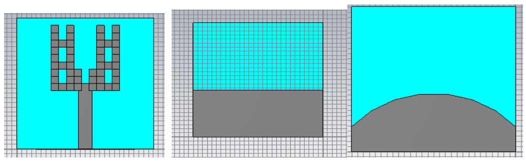


(a) First order fractal antenna with different ground planes

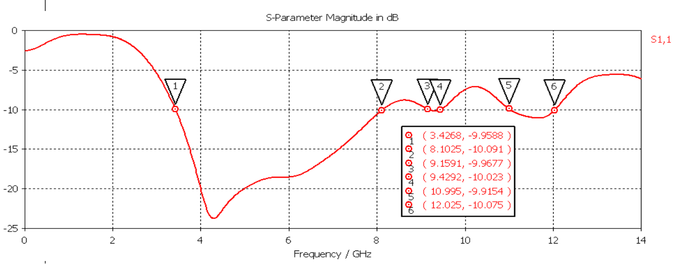


(b) Return Loss With Different Ground Planes

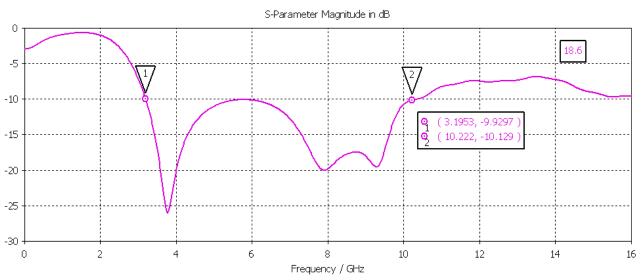
Figure 3: First Order Fractal Antenna



(a) Second OrderFractal Antenna With Partial Ground Plane



(b) Return Loss With Partial (rectangular) Ground Plane



(c) Return loss with partial (half arc) ground plane

Figure 4: Second Order Fractal Antenna

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Figure 5: Fabricated Second Order Fractal Antenna With Half Arc Ground Plane

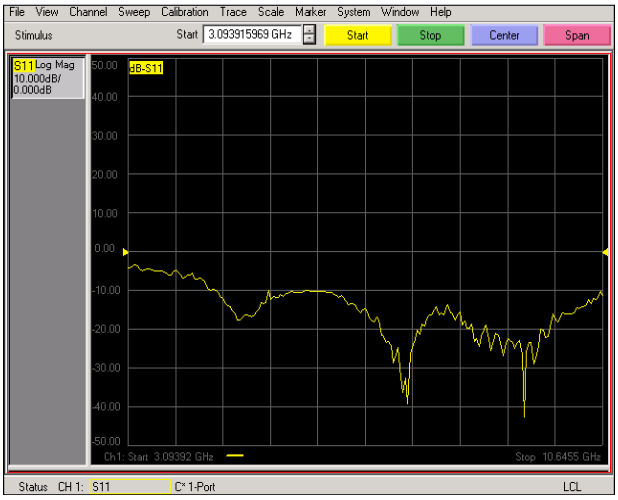

Figure 6: Measured Return Loss Of The Fabricated Antenna