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DESIGN AND ANALYSIS OF CROWN CIRCULAR MICROSTRIP ANTENNA FOR UWB APPLICATIONS

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Abstract: The work presents the design of crown circular shaped Fractal Microstrip patch antenna for ultra-wideband (UWB) applications. The two iterative Circular fractal antenna have been designed, fabricated on FR4 substrate (ε_r =4.4) and tested using a Vector Network Analyzer with different configurations of ground planes at the bottom of the substrate. The proposed antenna (without ground) offers excellent ultra wideband performance ranging from 3.80 GHz to 12.8 GHz. The antenna exhibits bandwidth of 9 GHz. The experimental radiation pattern of fractal antenna has been observed nearly Omni-directional. Such type of antenna can be used for UWB system.

Keywords: **Ultra-**wide band, Fractal antenna, Omni-directional

I INTRODUCTION

In modern communications, microstrip patch antenna is widely used for mobile, avionics, radar applications as it is low profile antenna and can be integrated easily with other RF front-end circuits. However, low bandwidth is major drawback of microstrip patch antenna. Techniques to overcome this include design of dual band, multi band and ultra wide band (UWB) antennas by changing parameters (shapes) of basic antenna[4].

Apart from microstrip patch antennas with basic geometric shapes, fractal antennas have drawn special interest in microwave engineering since a century. A fractal is a rough or fragmented geometric shape that can be split into parts, each of which is a reduced-size copy of the whole[5]. It is derived from the Latin *fractus* meaning broken, uneven, any of various irregular curves or shapes that repeat themselves at any scale on which they are examined[6].

Fractal antennas are broadly classified as:

- Deterministic Fractal
- Random Fractal

Deterministic Fractals are composed of several scales down and rotate copies of it, such as Koch curves. They are also called geometrical fractals. Their generation requires use of particular mapping or rule which is repeated recursively over and over again. They exhibit the property of strict self similarity. The Random fractals are those which have an additional element of randomness, so they exhibit property of statistical self similarity[7].

Various types of fractal antennas include (1) the von Koch curve, (2) the Sierpinski (gasket and carpet) and (3) the fractal tree.

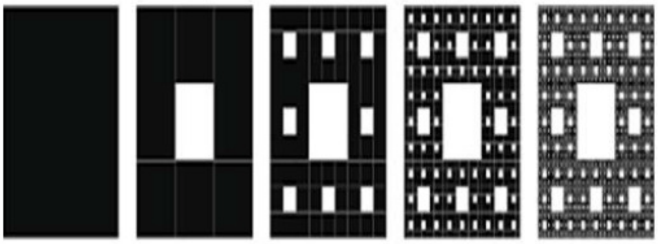

Fig 1: Sierpinski Carpet Fractal Geometry

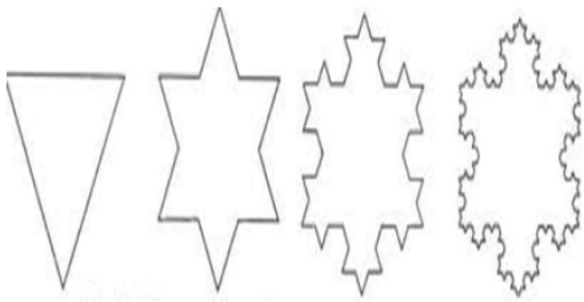

Fig 2: Koch Curve Fractal Geometry

II. ANTENNA DESIGN

The proposed antenna structure falls under Sierpinski Gasket as its structure is repeated again and again [15][16]. As per Federal Communications Commission, bandwidth of ultra-wideband (UWB) radio system is 3-10.8 GHz [17]. It is self similar in a way such that structure of antenna is repeated in definite form so as to produce similar surface current distributions for different frequencies, i.e. to produce multiband response. Due to the space filling property of Fractal Antennas, the electrical length increases and hence the physical size of the whole structure can be reduced.

The expression for calculating the resonant frequency of simple circular microstrip antenna is given as [1][9]

$$f_r = \frac{1.841 v_0}{2\pi r_{eff}\sqrt{\varepsilon_{eff}}}$$

Where v_0 is the velocity of light. The effective radius r_{eff} can be calculated by following expression [2]

$$r_{eff} = r_0\left[1 + \frac{2h}{\pi r_0 \varepsilon_{eff}}\left\{\ln\left(\frac{r_0}{2h}\right) + (1.41\varepsilon_r + 1.77) + \frac{h}{r_0}\left(0.268\varepsilon_{eff} + 1.65\right)\right\}\right]^{1/2}$$

The following Design Equations are used for the antenna[3][8]:

$$\text{Length of Strip } L_s = \frac{0.42 * c}{f_r * \sqrt{\varepsilon_{eff}}}$$

$$\text{Length of Ground Plane } L_g = \frac{0.36 * c}{f_r * \sqrt{\varepsilon_{eff}}}$$

Width of Ground Plane $W_g = \frac{1.38 * c}{f_r * \sqrt{\varepsilon_{eff}}}$

Effective Dielectric Constant $\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2}(1 + 0.3 * h)$

Resonant frequency (GHz) $=3+\frac{2}{\sqrt{\varepsilon_{eff}}}[\frac{21}{L_s}+\frac{65}{W_g}+\frac{18}{L_g}-3]$

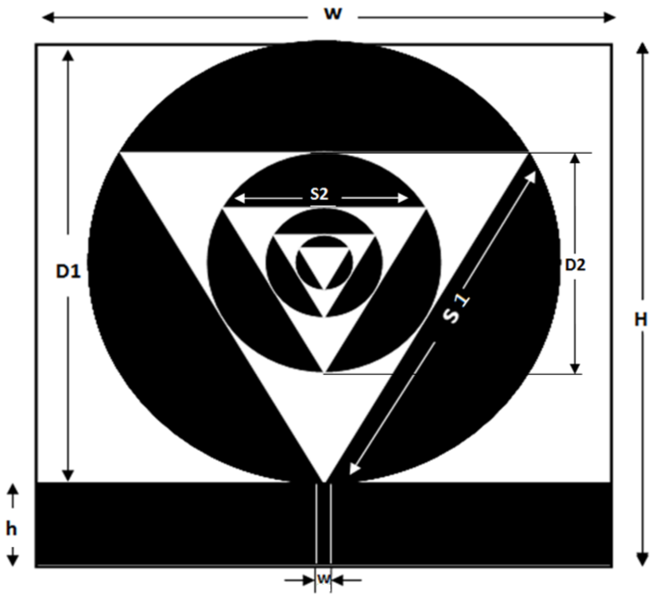

Fig 3: Front view of UWB antenna.

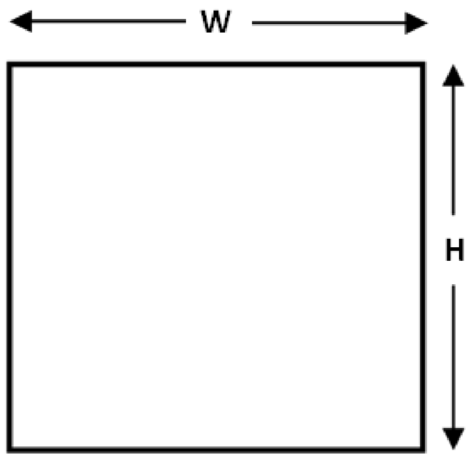

Fig 4: Back view of UWB antenna (no ground)

Design Specifications of the antenna:

- Height of the substrate (h) = 1.6 mm

- Dielectric constant (ε_r) = 4.4
- Substrate used: Double sided copper, FR4 epoxy substrate
- Solution or Resonant Frequency = 3.8 GHz
- Parameters of Interest: S_{11} log magnitude, VSWR, Smith Chart, Polar Plot, 3-D Radiation Pattern

The calculated parameters are as follows:

Sl no.	parameter	Length(mm)
1.	H	106
2.	W	100
3.	h	15
4.	w	2.2
5.	D1	82
6.	D2	41
7.	D3	20.5
8.	D4	10.25
9.	S1	71.016
10.	S2	35.508
11.	S3	17.754
12.	S4	8.877
13.	g	53

Table 1: Dimensions of Fractal Patch

III. SIMULATED AND EXPERIMENTAL RESULTS

The patch with above dimensions is simulated using HFSS 14.0 software. It is then fabricated on a double-sided copper clad with FR-4 substrate and tested on a Vector Network Analyzer E5071C. The simulated and experimental results obtained are compared in this section.

Fig 5(a): Fabricated Patch

Fig 5(b): Fabricated Patch being tested

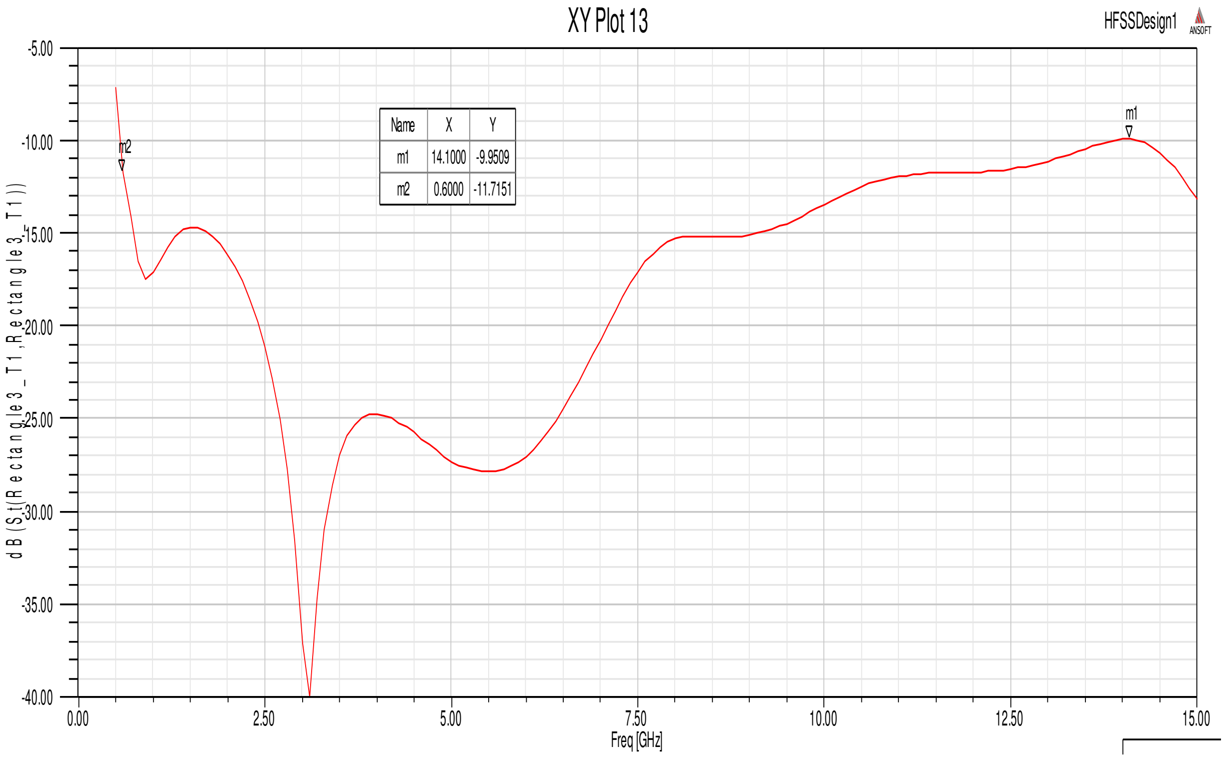

Fig 6: Simulated Return Loss

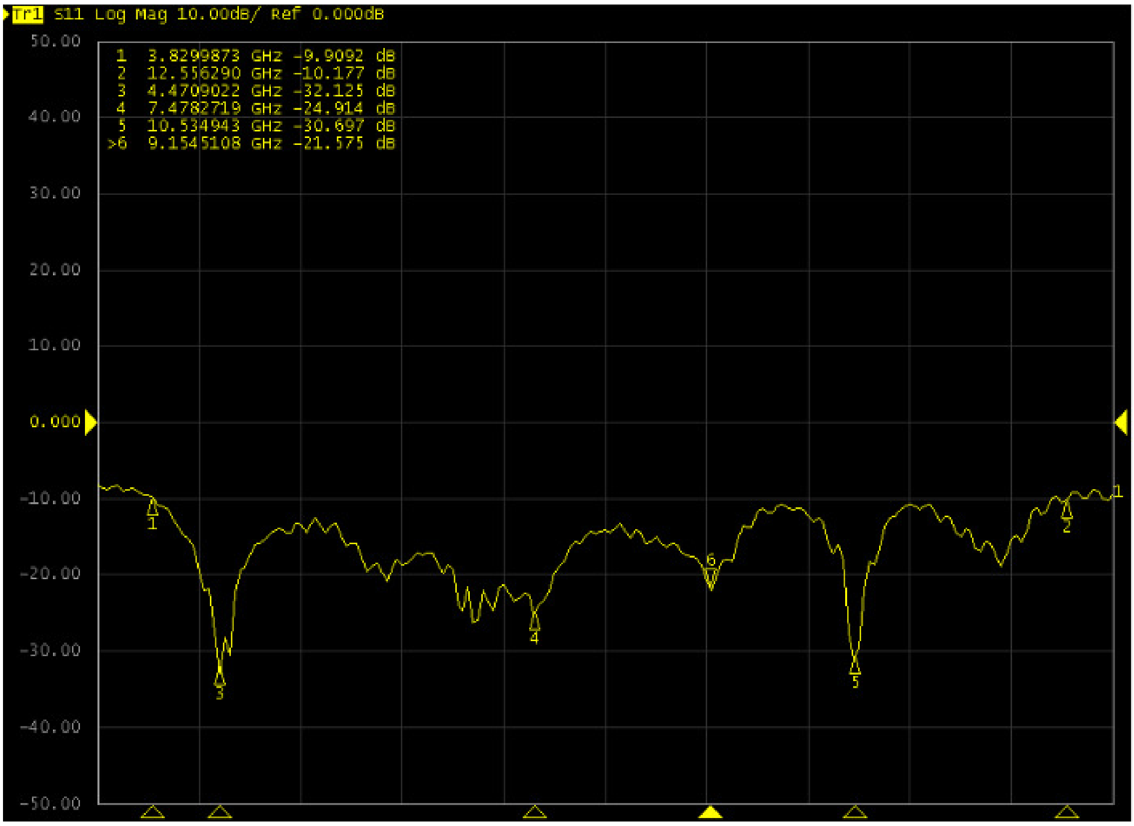

Fig 7: Measured Return Loss

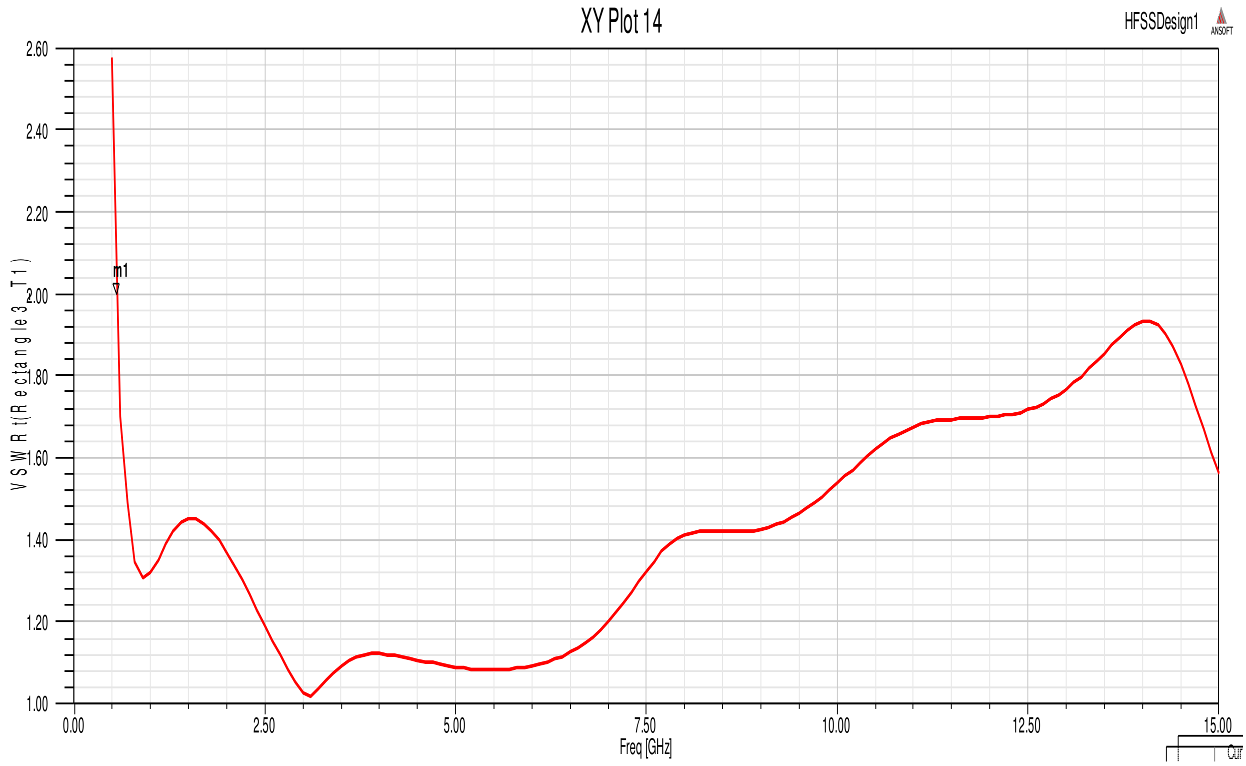

Fig 8: Simulated VSWR

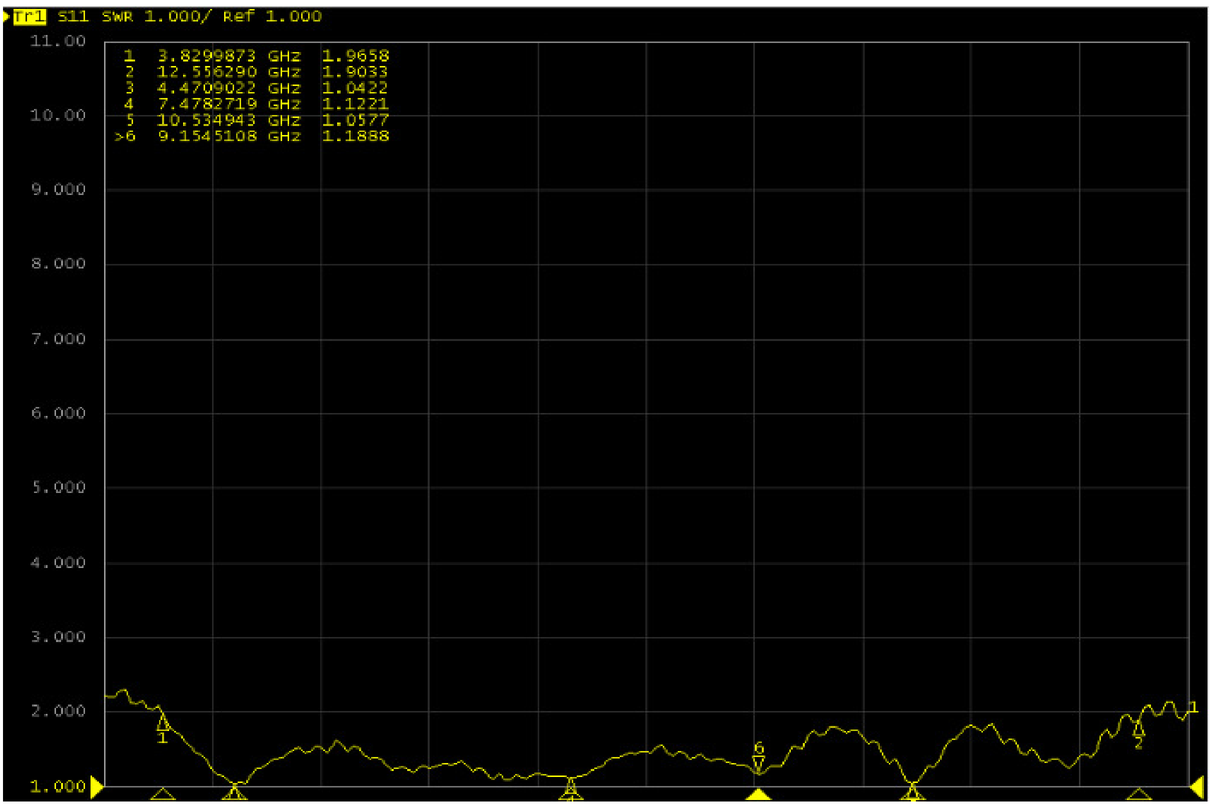

Fig 9: Measured VSWR

IV CONCLUSIONS

The simulated ultra wide band extends from 0.57 GHz to 13.7 GHz while practically the band extends from 3.82 GHz to 12.55 GHz. There is deviation between the simulated and practical values, but this deviation is within the acceptable limit. The antenna is said to resonate at that frequency where the return loss crosses -10 dB. From the results observed from the antenna, the simulated and practical return loss values are in agreement. The antenna resonates for wide range of frequencies and thus used for numerous applications.

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