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Implementation of Koch Snowflake Fractal Antenna for Multi-Band Applications

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Abstract

This paper proposes the Koch snowflake fractal patch antenna with coplanar waveguide (CPW) feed. This antenna has been developed as a multiband fractal antenna and is suitable for wireless communication systems in ISM band. Copper has been preferred as a conducting material for patch and ground. FR-4 substrate material has been used which is having a dielectric constant of 4.4. The overall substrate dimension of the antenna is 27 mm (W) x 41.5 mm (L) x1.6 mm (h). The design is carried out by way of High Frequency structure Simulation software (HFSS).

Index Terms ─ *Micro strip patch antenna, multi-bands, Fractal antenna, Koch Snowflake, Reflection co-efficient, VSWR, HFSS.*

1.Introduction

Antenna which is a key element of any communication system makes wireless conversation possible amid 2 locations by propagating the signals amid the stations. A properly designed antenna provides the scope of enhancing the entire system performance. From latest developments in communication techniques there may be growing series of communication provisions and related purposes desiring the design of compacted antennas [1]. For Wi-Fi purposes, there may be immense requirement for wider BW and low profiled antennas. Many antennas be operated at a solitary or double frequency bands, thus a distinctive antenna is required for special functions. In an effort to prevail over this problem there is a need for antenna which can function at wide frequency bands categorized as multiple band antenna [2]. By relating fractal structure to antenna geometry a multiband antenna is constructed [3]. In many specialized functions micro-strip patched antennas are extensively used, as they possess good features viz. slender in heaviness, low profiled, gainful, highly capable, and easy to design. The prefer-ability of generally designed antennas is limited as they carry intrinsically minimum impedance bandwidth. If fractal shape is considered to such antennas by means of some geometrical representation, multi-band antennas can be made. For reducing the dimension for the patch vast available literature is witnessed [4]. To overcome the narrow bandwidth limitation of the micro-strip antennas and to generate more than one resonant frequency numerous techniques sprang up and available till date and still more are on the way e.g. different shaped slots /slits , multiple layer, stack, 2 folded components to the primary radiating patch, utilizing of air gap etc., were proposed and investigated . Koch snowflake fractal geometry is feasible to attain the directional pattern with more than one resonant frequency bands. The objective of this paper is to design antenna which covers ample range of wireless communication applications.

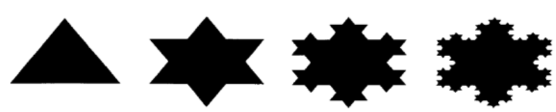

Fig.1. a Koch snowflake antenna with third iteration

As shown in Fig. 1 the process of iteration for Koch snowflake fractal antenna is reported in literature [6]. Here, the iteration process is done till third level. The design consideration of Koch snowflake commence with the basic equilateral triangular patch which is abbreviated as 0^{th} order iteration. The design consideration of triangular patch has 3 factors namely

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frequency of resonance (f_r), relative permittivity (ϵ_r) and side length. Here for convenience the operating frequency is chosen as 4.5 Giga Hertzes. The antenna is intended using a minimum price FR4 substrate with relative permittivity 4.4.

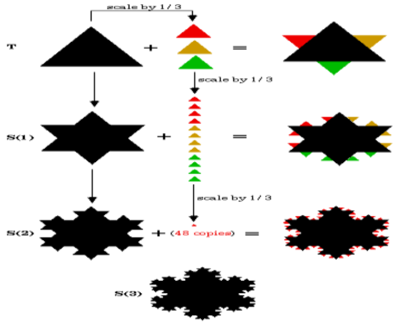

Fig.2. Steps to be considered for Koch snowflake fractal antenna

2. Antenna Design

The fractal has the dimensions of 41.5 mm x 27 mm. By taking scaling factor 1/3. The Koch Snowflake is designed by adding together small triangles. After designing the main triangle, adding 3 smaller triangles, which are scaled by factor of 1/3 are added to the original triangle. The resulting structure is of 1st iteration. Similarly for 2nd iteration 12 triangles were appended and for the 3rd iteration 48 triangles are being attached which is shown in Fig. 2.

DESIGN METHODOLOGY

The dimension considerations of the patch are found using the formulae given below: [16-17]

Calculation of Width (W):

Antenna patch width is found by using

$$W = \frac{c}{2f_0\sqrt{(\varepsilon_r + \frac{1}{2})}} \qquad (1)$$

Where $c = 3 * 10^8 m/s$

Computation of Actual Length (L):

The effective length of patch antenna relies on the resonant frequency (f_0).

$$L_{eff} = \frac{c}{2f_0\sqrt{\varepsilon_{reff}}} \qquad (2a)$$

Where $\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1 + 12\frac{h}{W}\right]^{-\frac{1}{2}}$ (2b)

Actual length and effective length of a patch antenna can be combined as

$$L = L_{eff} - 2\Delta L \qquad (3)$$

Where ΔL depends on effective dielectric constant ε_{reff} and the ratio $\left(\frac{W}{h}\right)$

$$\frac{\Delta L}{h} = 0.412\frac{(\varepsilon_{reff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\varepsilon_{reff}-0.258)\left(\frac{W}{h}+0.8\right)} \qquad (4)$$

Number of Iterations is:

$$N_n = 8^n \qquad (5)$$

The ratio of fractal length :

$$L_n = \left(\frac{1}{3}\right)^n \qquad (6)$$

The fractal area ratio after the nth iteration is,

$$A_n = \left(\frac{8}{9}\right)^n \qquad (7)$$

Where n is iteration nth stage number.

Calculation of feed width (W_f):

To get 50Ω characteristic impedance, the necessary feed width to height ratio $\left(\frac{W_f}{h}\right)$ is calculated as

$$\frac{W_f}{h} = \begin{cases} \frac{8e^A}{e^{2A}-2} & \frac{W_0}{h} \leq 2 \\ \frac{2}{\pi}\left\{B - 1 - \ln(2B-1) + \frac{\varepsilon_r - 1}{2\varepsilon_r}\left[\ln(B-1) + 0.39 - \frac{0.61}{\varepsilon_r}\right]\right\} & \frac{W_0}{h} \geq 2 \end{cases} \qquad (8a)$$

$$\text{Where} A = \frac{Z_0}{60}\sqrt{\frac{\varepsilon_r+1}{2}} + \frac{\varepsilon_r+1}{\varepsilon_r-1}\left(0.23 + \frac{0.11}{\varepsilon_r}\right) \qquad (8b)$$

$$B = \frac{377\pi}{2Z_0\sqrt{\varepsilon_r}} \qquad (8c)$$

The antenna matching frequency is

$$f_n \approx 0.26\frac{c}{h}\delta^n \qquad (9)$$

Where δ =3 is the log-period constant,

n is a natural number, c is the velocity of light in vacuum and h is the tallness of the fractal

TABLE 1: Dimensions of Koch snowflake Fractals

Design Parameter	Dimensions (mm)
W	27
L	41.5
a1	24.3
W1	12
d1	2.2
d2	0.74
wg	0.4
lh	13.1
T	1.6
s	0.9

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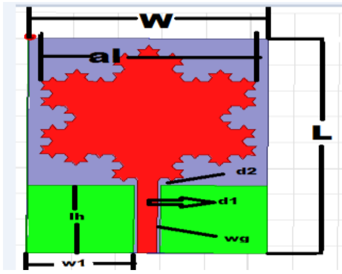

Fig.3. Geometry of Koch snowflake fractal antenna

Fig.4. Fabricated Koch snowflake fractal antenna

The geometry which is selected is being proposed, the same is show in Fig. 3 and 4 which are the fabricated Koch snowflake fractal antennas. These antennas are coplanar waveguide (CPW) feed.

3. Results And Discussion

The Simulations of reflection coefficients for given antenna are shown in Figures 5 & 6. The antenna is resonated at 1.63 GHz, 1.84 GHz ,2.10 GHz, 3.59 GHz, 5.06 GHz and 9.55 GHz. At resonant frequencies the observed reflection coefficients (S_{11}) are -29.40 dB, -19.91 dB, -18.28 dB, -14.87 dB, -15.35 dB, -21.18 dB.

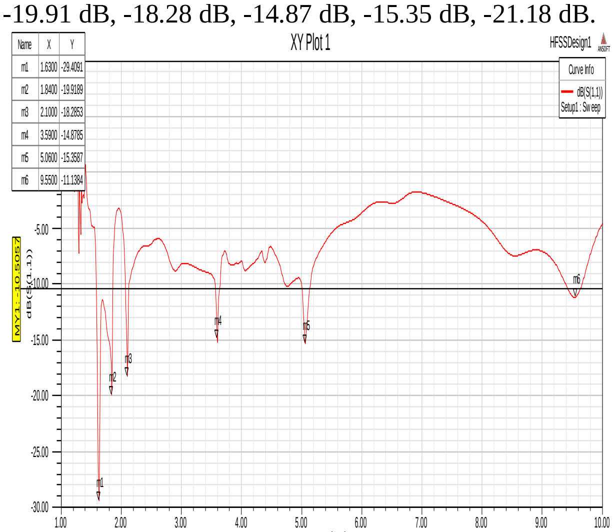

Fig.5. Simulated Reflection of Koch snowflake fractal antenna

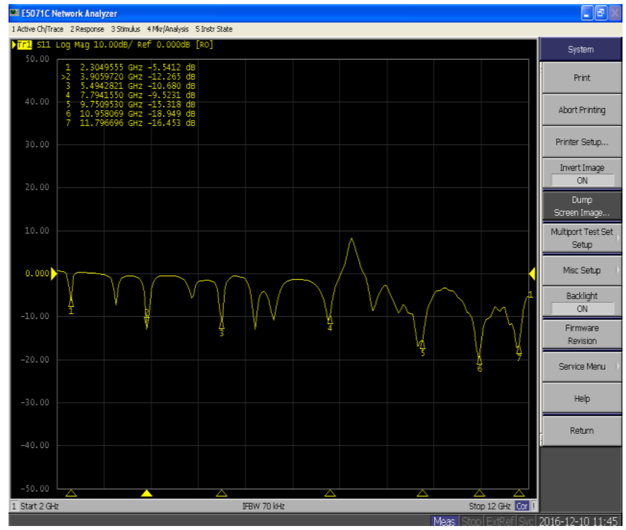

Fig.6. Measured Reflection of Koch snowflake fractal antenna

The simulated and measured plots of VSWR of this antenna are shown in Figures 7 & 8. The observed VSWR at different resonant frequencies are 1.05, 1.22,1.27,1.44,1.42 and 1.77.

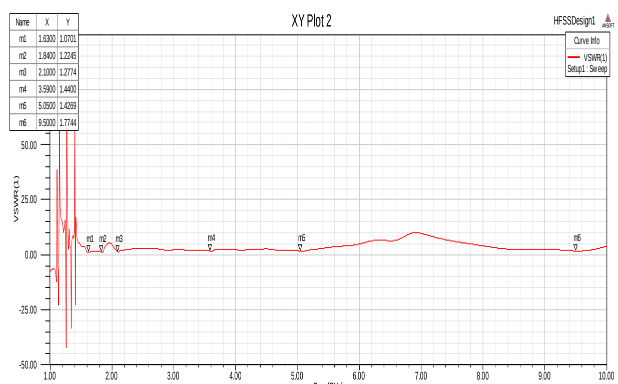

Fig.7. Simulated VSWR of Koch snowflake fractal

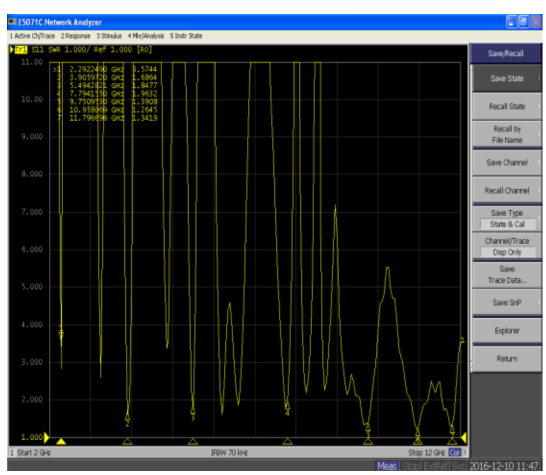

Fig.8. Measured VSWR of Koch snowflake fractal

TABLE 2: Results of Results of Koch snowflake fractal antenna

Resonant frequency in GHz		Reflection coefficient (s_{11}) in dB		VSWR		Gain in dB
Simulated	Measured	Simulated	Measured	Simulated	Measured	Simulated
1.63	2.30	-29.40	-9.00	1.07	2.00	2.386
1.84	3.49	-19.91	-15.03	1.22	1.68	
2.10	5.40	-18.28	-9.0	1.27	1.89	
3.59	7.79	-14.87	-14.93	1.44	1.96	
5.06	9.75	-15.35	-30.27	1.42	1.39	
9.55	10.95	-21.18	-12.71	1.77	1.26	

4. Conclusions

It can be concluded that Koch snowflake fractal antenna designed and experimentally verified. From the results, it is observed that the controlling parameter has different dimensions like number of iterations and feeding network. The obtained results are tabulated in Table 2. By using this feed network better impedance matching is achieved. The developed multibands are valuable in many wireless communication standards like GPS, DCS, PCS, ISM and WIMAX.

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