Multi-fractal Triangular Microstrip Patch Antenna for UWB Application

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Abstract *—A multi-fractal triangular patch antenna for ultra wide band application is presented in this paper. The basic objective of multi-fractal geometry is composed of traditional equilateral triangular patch antenna with microstrip feed. Here we using the Koch and sierpinski fractal concept for structure to achieve the better return loss and bandwidth characteristics with reduced size of antenna. The proposed antenna exhibit resonant frequency at 5.41GHz with better return loss of -42.43dB and bandwidth 2.1219GHz. There is a better matching of feed network and proposed patch antenna which gives VSWR equal to 1.0152. The simulation was performed in Computer Simulation Technology.*

Keywords— *Multi-fractal antenna, Ultra wide band, Koch fractal, Sierpinski fractal, Return loss, Bandwidth, VSWR.*

I. Introduction

The concept of fractal antenna was initially proposed by the French mathematician B.B. Mandelbrot during 1975, research on several naturally occurring irregular and fragment geometry [1].

Later in 1995 Nathan Cohen proposed that fractal are complex geometric design that repeat themselves and space filling properties which leads to wide band operation and therefore suitable for ultra wide band applications. Fractal structures introduce discontinuities in patch which results in better current distribution and hence radiation efficiency increases [2]. FCC and the International Telecommunication UnionRadio Communication Sector (ITU-R) now define UWB as transmission from an antenna, for which the emitted signal bandwidth is more than 20% of the centre frequency or it exceeds 500 MHz[3] . There are so many UWB planar antennas existing so far, but these antennas are having large size. By incorporating fractal structures compact size UWB antennas can be realized

Fractal antenna can meet the need antenna requirements of modern communication thin section, small size, being easy to manufacture and low price. Fractal is produced with the self-similarity of fractal dimension structure through iterative realized the antenna of miniaturization, strengthened the directional antenna and also it is found that the lower cut-off frequency reduces. This effect helps in antenna miniaturization as the multi-fractal antenna covers the frequencies which are lower than its operating frequency range.

Among the various matching technique proposed, the partial ground plane with feed gap optimization technique was found to be yielding the maximum relative bandwidth.

The fractal techniques to be used in this paper are the Koch fractal and the Sierpinski fractal. The Equilateral triangle Sierpinski fractal is one of thesimplest fractal techniques that can be incorporated into a patch. The middle triangle can be removed from the equilateral antenna leaving three equally sized triangles. The process of removing middle triangle is repeated in newly formed triangles. The Koch fractal can be generated from a structure by replacing the segment of starting pattern by generators [4].

In this paper, the proposed multi-fractal antenna covers the UWB range of 4.55 to 6.67GHz achieving return loss of -42.43 dB. The proposed antenna is build and simulated using Computer Simulation Technology (CST v14.0)[5].

II. Antenna design

A. Steps of Development of Proposed Antenna

In order to achieve the better return loss, different types of fractals are introduced in triangular patch structure. Let "C" represents the iterations of Koch, "S" represents iterations of Sierpinski and m, n represents number of iteration. Hence, C[m]S[n] represents the m^{th} iteration of Koch and n^{th} iteration of Sierpinski fractal. Fig.1 (a) represent the 0^{th} iteration of Koch and Sierpinski fractal, Fig. 1 (b) represent 0^{th} iteration of Koch and 1^{st} iteration of Sierpinski, Fig. 1 (c) represent 1^{st} iteration of Koch and 1^{st}Sierpinski fractal on the side of equilateral triangle, Fig. 1(d) represent the 1^{st} iteration of Koch and 2^{nd} iteration of Sierpinski fractal patch.

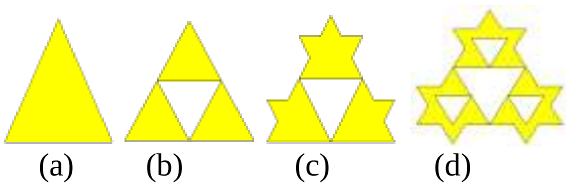

Fig.1 Steps of development (a)C[0]S[0] (b)C[0]S[1] (c)C[1]S[1] (d)C[1]S[2]

B. Proposed Multi-fractal UWB antenna

The proposed fractal antenna is realised on FR4 substrate with relative permittivity of 4.3 and loss tangent of 0.025. The side of equilateral triangular patch a_t for 6 GHz is calculated by using equation (3) Where $f_r$is resonant frequency in GHz and c is velocity of light in m/sec [6].
The resonant frequency corresponding to various modes can be given by

$$f_r = \frac{ck_{mn}}{2\pi\sqrt{\varepsilon_r}} = \frac{2c}{3a_t\sqrt{\varepsilon_r}}\sqrt{m^2+mn+n^2} \quad .... (1)$$

Where $k_{mn}$is wave number and given by

$$k_{mn} = \frac{4\pi}{3a_t}\sqrt{m^2+mn+n^2} .... (2)$$

The expression for lowest order resonance frequency is

$$f_r = \frac{2c}{3a_t\sqrt{\varepsilon_r}} .... (3)$$

Here triangular patch length a_t is calculated in mm.

In this paper the partial ground plane with feed gap optimization technique is suitable apt for Ultra wide band operation as it accounted for the compensation of both real and imaginary part of characteristic impedance of the antenna because the stub matching and quarter-wave transformer matching resulted in narrow impedance bandwidth and was not found suitable for the UWB antenna, also the binomial transformer matching gave more impedance bandwidth but resulted in poor return loss as the matching technique did not account for imaginary part of characteristic impedance of the antenna. For further improvement in antenna parameter can be realized by modifying the ground plane by introducing a rectangular slit in ground plane[7-9].

Fig.2 shows the proposed multi-fractal patch antenna in which dimension of feed line L_f and $W_f$is calculated using transmission line model equation [10] and its length $L_f$is $8.6mm$ and width W_f is 1.9mm.

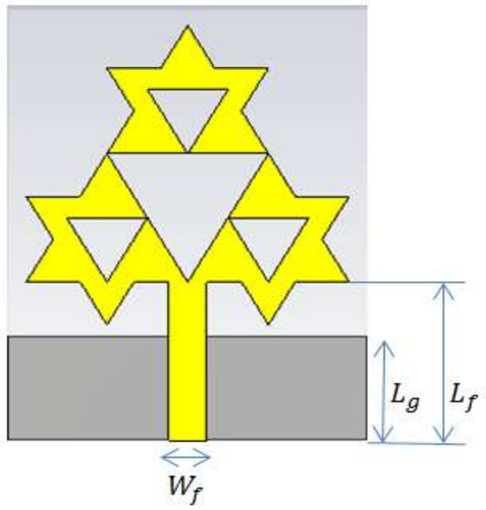

Fig.2

Proposed Antenna (C1S2)

Here the partial ground plane width is kept constant which is equal to the width of the dielectric material and the lengthL_g of the partial ground plane is varied for best impedance matching between characteristic impedance of feed line and impedance of the proposed microstrip multi fractal antenna.

III. RESULTS AND DISCUSSIONS

A. Return loss

Designed antenna gives the return loss of -42.43dB at resonant frequency of 5.41GHz and Bandwidth of 2.1219 GHz which covers the frequency range of 4.55 to 6.67 GHz.

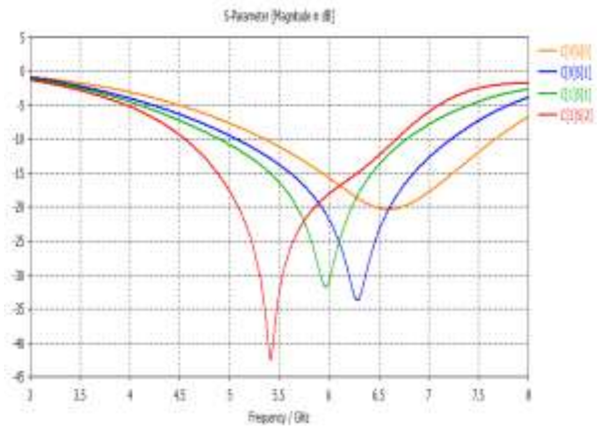

Fig.3 Return loss(dB) characteristics of C[0]S[0], C[0]S[1], C[1]S[1] and C[1]S[2]

A comparison between the different antenna structures C[0]S[0], C[0]S[1], C[1]S[1] and proposed multi-fractal antenna C[1]S[2] is shown in the table I.

TABLE I
COMPARISON BETWEEN DIFFERENT TRIANGULAR AND PROPOSED MULTI-FRACTAL ANTENNA

Shape of Antenna	Return loss (dB)	Relative Bandwidth (%)	VSWR	Maximum Gain (dB)
C[0]S[0]	-20.376	35.2	1.212	2.610
C[0]S[1]	-33.721	34.34	1.042	2.593
C[1]S[1]	-31.76	31.55	1.053	2.550
C[1]S[2]	-42.43	39.2	1.015	2.486

The proposed Koch-Sierpinski multi-fractal antenna C[1]S[2] show an improvement of 25.82% from C[0]S[1] shaped antenna and 33.6% from C[1]S[1] shaped antenna return loss.

B. Antenna Impedance

Here input port impedance is set as the characteristics impedance of 50Ω then the proposed antenna structure impedance is matched with the port characteristics impedance by varying the length of partial ground plane L_g. At resonance frequency 5.41GHz the proposed antenna impedance is equal to 50.72Ω which is close to the characteristics impedance of 50Ω and it is shown in fig.4.

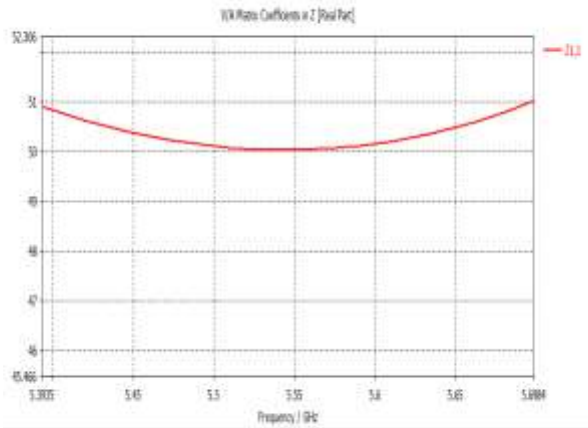

Fig. 4 Antenna impedance at resonanting frequency

C. VSWR

The VSWR of the proposed antenna is 1.015 at resonating frequency 5.41GHz which shows the good impedance matching between characteristic impedance and proposed antenna impedance and also it is always lies between 1 to 2 for the all operating frequency range of 4.55 GHz to 6.67 GHz and it is shown in fig.5.

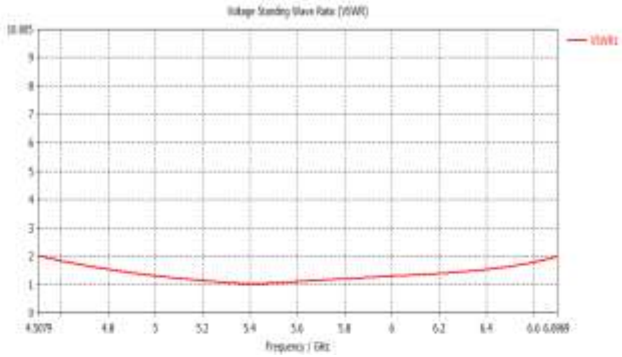

Fig. 5 VSWR

D. Radiation Efficiency

Radiation efficiency for proposed multi-fractal patch antenna C[1]S[2] ranges from 82.6% to 95.9% in the range of operating frequency 4.55 to 6.67GHz.It is shown in the fig. 6.

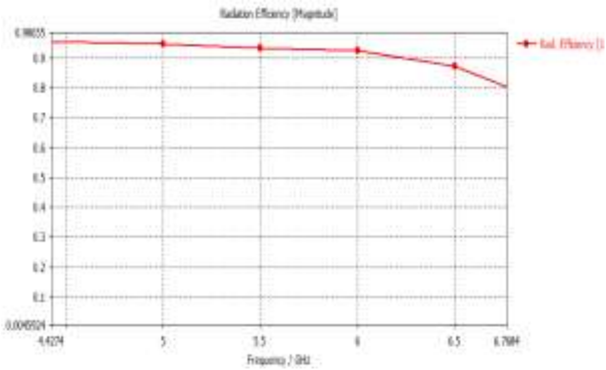

Fig. 6 Radiation efficiency of c[1]S[2] antenna

E. Surface Current Distribution

By the introduction of multi-fractal geometry, more current flows through discontinuities of patch and hence enhancing the radiation efficiency of the proposed multi-fractal antenna C[1]S[2] and it is shown in the fig. 7.

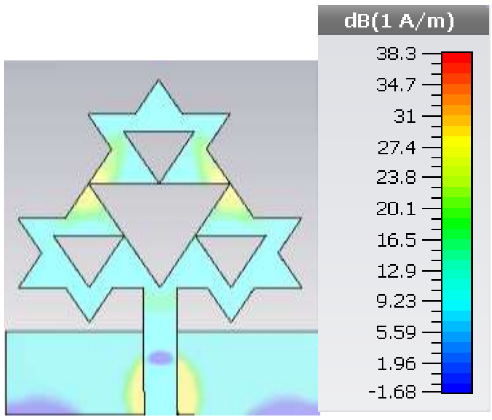

Fig. 7 Surface current distribution (A/m) at 5.41GHz

IV. CONCLUSION

The Koch-like sided Sierpinski multi-fractal antenna has better impedance bandwidth and return loss characteristics than the conventional antenna. The proposed fractal antenna C[1]S[2] has27.08 % less metal parts as compared to conventional antenna, thus making the proposed fractal antenna lighter in weight.Therefore multi-fractal concept can be adopted in designing smaller antennas with better antennacharacteristics. Better return loss and impedance bandwidth characteristics can be achieved by feed gap optimization and modification of ground plane and antenna exhibits an improvement of return loss of 33.6% compared to C[1]S[1] antenna.The proposed antenna satisfies the band specifications for wireless LAN applications IEEE802.11a (5.15-5.35GHz, 5.725-5.875) and WiMAX application at 5GHz (5.25-5.85 GHz) with a stable radiation pattern of bandwidth 2.1219 GHz throughout the frequency range of 4.55-6.67GHz.

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