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On the Design of 2×2 MIMO Fractal Antenna Array for C band applications

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Abstract*: A 2×2 MIMO planar fractal antenna array using Sierpinski gasket along with microstrip feed line has been investigated. Different configurations of antenna array has been studied. The optimized unit element used in array is further modified geometrically by corner rounding and cut in feed to improve its performance including gain. Proposed fractal array antenna resonates at 4.19 GHz and 7.86 GHz lies in C band and simulated using High frequency structure simulator. Such an attempt has been rarely reported in the literature. Simulated reflection coefficient shows that Proposed antenna works in C band frequency range for various applications and results are quite promising

***Index Terms*: MIMO, Fractal array, Sierpinski Gasket, C Band**

I. INTRODUCTION

Fractal concept are used in various engineering and science discipline like mathematics, Geology and physiology etc. Fractal shapes with electrodynamics used for development of printed antenna, which is very effective. Fractal antenna has a valuable contribution in today's challenging antenna engineering research [1]. Fractalization of antenna can be achieved through various repetitive structure like Koch curve, sierpinski and other deterministic or non-deterministic fractal shapes. Different type of other modified fractal structure discussed for various applications [2][3]. But sometimes after modification fractal shapes are not properly justified because fractal shapes are the structure which repeat itself and provide multiband or wideband performance [4][5]. Multiband fractal antenna has a compact size because of its increased electrical length and it is easy to fabricate. Fractalization has been achieved through mathematically scaling down the dimension of a structure repetitively. So, it is very useful in achieving multiband/multifunctional characteristics [6][7][8]. Now Multipath fading is a major concern in communication. To mitigate multipath fading multi input and multi output (MIMO) concept is very much used. Channel capacity has been enhanced by MIMO without additional bandwidth and power. High data rate is only possible with MIMO. MIMO Fractal array for 5G applications introduced in[9][10].Printed wide slot array consist of three elements in each array and aligned oppositely. Similarly triangular unit element based 4×4 MIMO array for 5G communication reported in [11]. A 8×8 MIMO antenna array for sub 6 GHz of 5G and 10 element array for 5G communications is introduced in [12] [13]. In this paper MIMO based configurations of fractal antenna array is discussed for C band applications.

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II. II DESIGN AND STRUCTURE

The antenna array is designed on a FR4 substrate of thickness 1.58 mm with dielectric constant 4.4 and loss tangent of 0.017, because FR4 has flame resistant properties and good strength [14]. A microstrip feed is used to achieve the matching with the patch antenna. Firstly, triangular microstrip patch antenna is designed using HFSS Simulator. Then basic triangular shape is simply modified by filleted corner as well as feed and circular cut in feed to improve the performance and same is tuned for desired application. Finally, by utilizing the modified antenna elements 1×2 Sierpinski fractal antenna array and 2×2 Sierpinski antenna array with two configurations is developed with better performance in terms of gain. Following are the design steps:

(a) Conventional Triangular patch antenna (CTPA)

All the dimensions of the patch antenna have been calculated from the mathematical expressions [15] as given by equation (1),(2),(3) and (4). From Equation (1), side length of patch antenna is computed by making use of dielectric constant and given frequency. Effective dielectric constant is calculated by using side length from equation (2). Effective side length as well as resonant frequency by making use of side length and effective side length calculated from (3) and (4). Synthesized antenna performance is examined as per intended application. In Table 1, geometric design parameters triangular patch antenna (Fig. 1.) are given.

(a) Computation of side length

$$a = {}^{2c}\!/_{3f_r\sqrt{\varepsilon_r}} \tag{1}$$

(b) The effective dielectric constant of the Triangular microstrip patch antenna

$$\varepsilon_{eff} = \frac{1}{2}(\varepsilon_r + 1) + \frac{1}{4}\frac{(\varepsilon_r - 1)}{\sqrt{1} + 12\frac{h}{a}} \tag{2}$$

(c) The effective side length of patch (L)

$$a_{eff} = a + \frac{h}{\sqrt{\varepsilon_r}} \tag{3}$$

$$f_r = {}^{2c}\Big/_{3a_{eff}\sqrt{\varepsilon_{eff}}} \qquad (4)$$

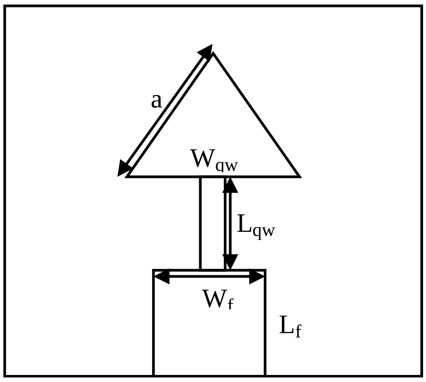

Fig. 1: Conventional triangular patch antenna

Table I : Design parameters of patch antenna

S. No.	Parameters	Value (mm)
1	Side Length (a)	19.5
2	Feed width (W_f)	2.8
3	Feed length(L_f)	4
4	Quarter wave Transformer length (Lqw)	7.7
5	Quarter wave Transformer width(Wqw)	0.7
6	Ground plane (L×W)	30×30

After designing the triangular patch antenna, it gets modified along its corner and its feed is also modified to enhance S11 and gain of antenna.

(b) Synthesis of triangular fractal patch antenna array

Four different designs of antenna are simulated (1) modified triangular fractal patch antenna (MTFPA) (2) 2×2 modified fractal patch antenna array (3) 2×2 MIMO fractal array with simple configuration (4) 2×2 MIMO fractal array with orthogonal configuration. Sharp bends at corner causes parasitic reactance which change in performnce of antenna. Parasitic reactance is overcome by chamfering and filleting [16]. Then basic patch antenna is modified in the form of filleted corner to reduce parasitic reactance. Reflection coefficient has been improved by cutting slot of circular shape in the feed line. A circular cut is also to get the novelty in shape. These novelties helped to improved performance of basic patch antenna. Modified triangular fractal patch antenna with rounded corner and cut in feed is shown in the Fig. 2. This antenna is transformed into 2×2 fractal array shown in Fig. 3. In order to enhance the perfornance further 2×2 MIMO antenna array is designed, shown in Fig. 4(a) and 4(b). Outer edge vertices of power divider network for array design also filleted for improved performance. 2×2 antenna array with all dimensions (in mm) shown in Fig. 3.

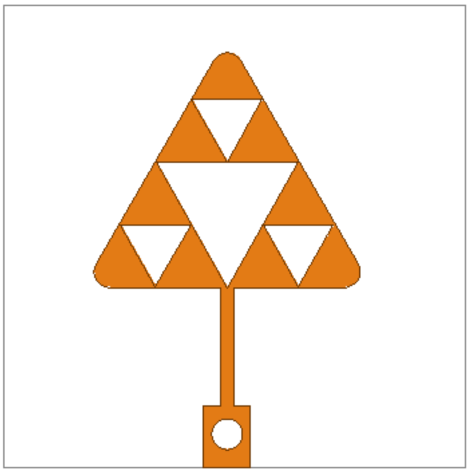

Fig. 2 Modified triangular Fractal patch

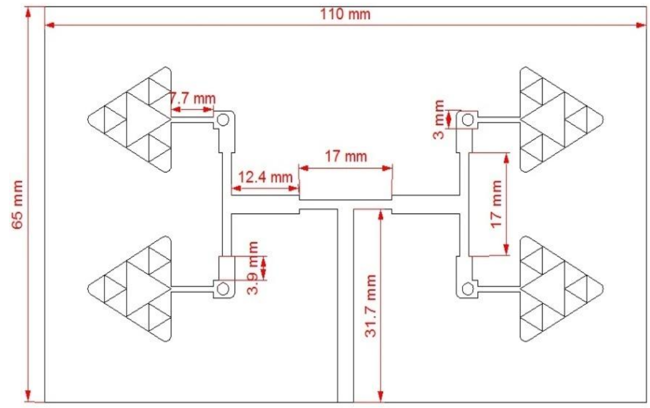

Fig. 3: 2×2 Modified Triangular fractal antenna array(All dimensions are in mm|)

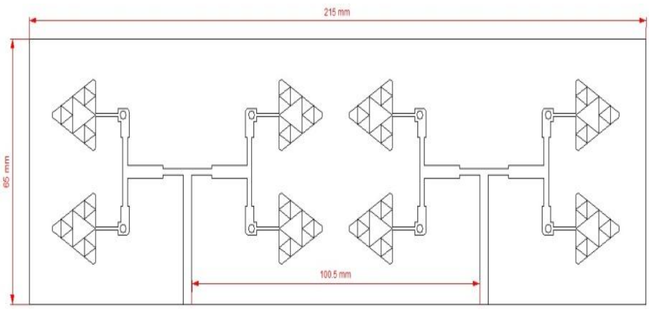

Fig. 4(a) 2×2 MIMO fractal array with simple configuration

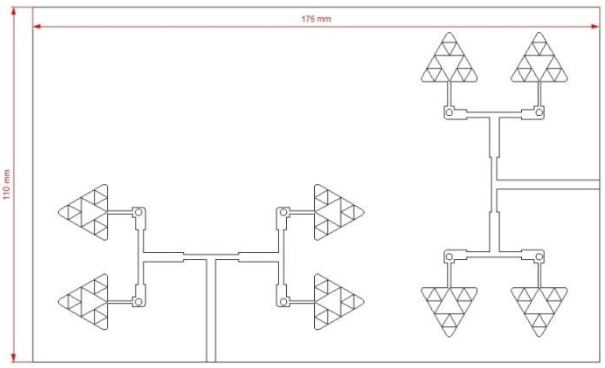

Fig.4(b) 2×2 MIMO fractal array with orthogonal configuration

III. RESULTS AND DISSCUSSION

To check the antenna design performance, it is simulated using finite element based method high frequency structure simulator. Antenna performance is measured in terms of S11, S12, S22, gain and bandwidth. S11 of simple fractal patch shows that antenna resonate at 4.2 GHz covers a bandwidth from 4.19 to 4.25 GHz, whereas conventional antenna resonate at 4.9 GHz shown in Fig. 5. Fractal structure shifts resonance at lower frequency. In second design 2×2 array resonates at 4.19 GHz and 7.87 GHz. 2×2 MIMO antenna array with simple configuration resonates at 4.15 GHz and 7.84 GHz. Similarly 2×2 MIMO antenna array with orthogonal configuration resonates at 4.19 and 7.86 GHz shown in Fig. 6,7,8 respectively. Performance parameters S11, S12, S22, gain and bandwidth discussed in table II.

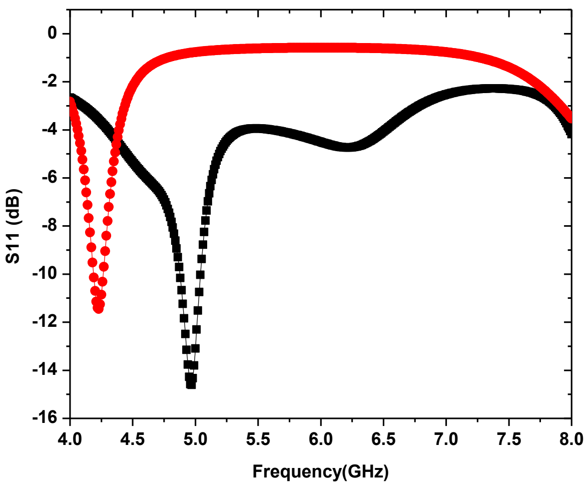

Fig. 5. S11 Comparison of MTFPA and Modified triangular patch antenna

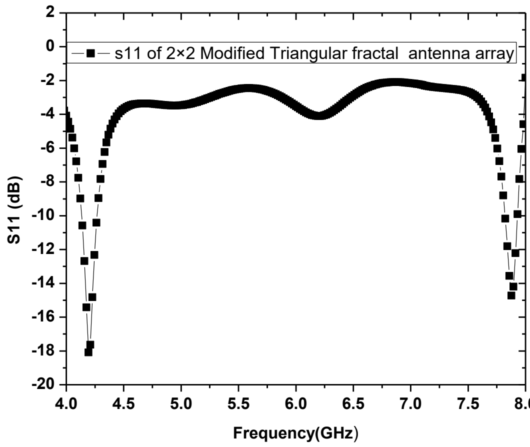

Fig. 6. S11 of 2×2 Modified Triangular fractal antenna array

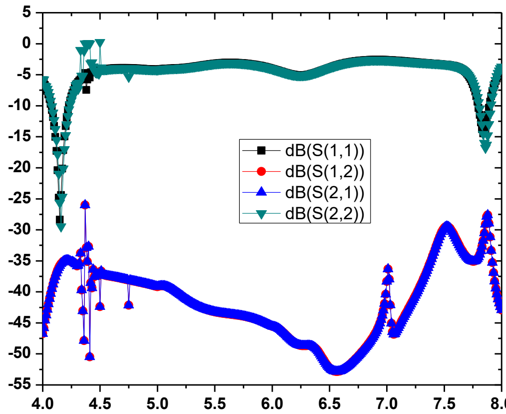

Fig. 7. S parameters of 2×2 MIMO fractal array with simple configuration

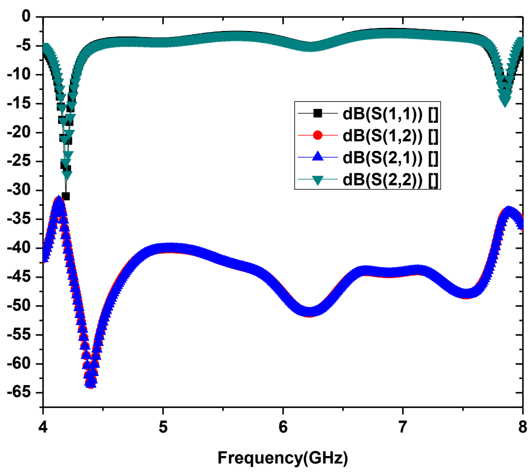

Fig. 8. S parameters of 2×2 MIMO fractal array with orthogonal configuration

Table II Results of Different Configurations of Antenna Array

Design	Freq. GHz	S11 (dB)	S12 or S21 (dB)	S22 (dB)	Bandwidth (MHz)	Gain (dB)
2×2Fractal Array	4.19 7.82	-18.08 -14.72	-----	------	120 90	4.16 11
2×2MIMO Fractal Array with Simple Configuration	4.15 7.84	-28.36 -14.45	-35.76 -31.72	-28.36 -14.45	140 90	2.56 8.19
2×2MIMO Fractal Array with orthogonal Configuration	4.19 7.86	-31.03 -12.52	-37.86 -33.82	-31.03 -12.52	160 80	3.73 7.42

(a) Radiation Pattern

Radiation pattern at $\phi = 0^{\circ}$ and $\phi = 90^{\circ}$ for 4.15 GHz, 7.84 GHz are shown in Fig. 9(a) and 9(b) for first configuration which shows that radiation pattern is distorted at high frequency due to higher order modes. Similarly radiation pattern for orthogonal configuration at 4.19 GHz and 7.86 GHz also shown in Fig. 9(c) and 9(d) respectively.

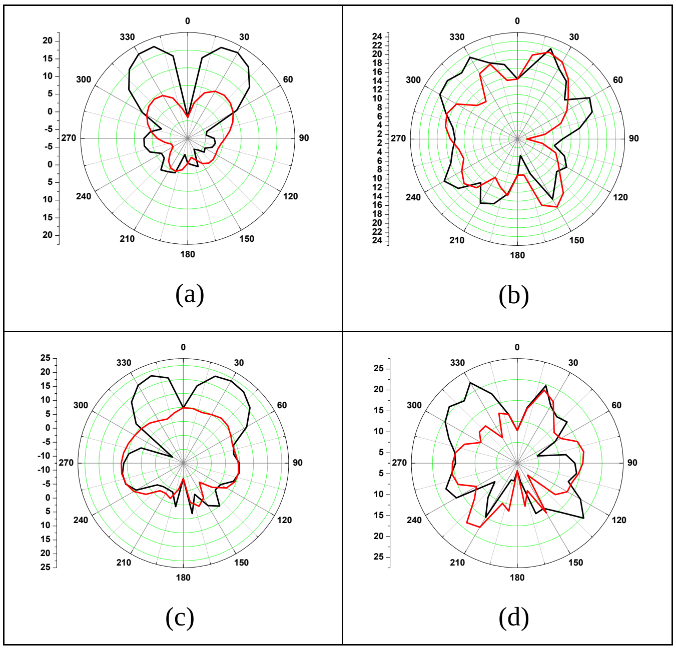

Fig. 9. Radiation pattern (a) 4.15 GHz (b) 7.84 GHz (c) 4.19 GHz (d) 7.86 GHz

V. HELPFUL HINTS

IV CONCLUSIONS

MIMO Fractal antenna array based on Sierpinski geometry is designed with microstrip feed for wireless C band applications. Proposed antenna array shows dual band behavior at 4.1 GHz and 7.8 GHz with enough bandwidth. MIMO Antenna array with orthogonal configurations introduces novelty and enhancement in gain than fractal array with simple configuration at lower frequency. Good isolation is achieved in both configurations which proves effectiveness of design.

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