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Octagon and Decagon Shaped Fractal Patch Antennas for S, C and X Band Applications

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Abstract: This paper explores design of fractal micro strip patch antennas. Fractals are not restricted to geometric shapes and designs, but can depict processes in time involving bio and nature-inspired problems. Self-similarity property of fractal is used for multiband and miniaturization. CST microwave studio software is used for simulation of reflection coefficient, voltage standing wave ratio (VSWR), gain and surface current. The simulation output results where the reflection coefficient is less than -10dB, VSWR is less than 2, gain is positive and surface current is symmetrically distributed determine the resonating frequencies for these particular antenna designs. These antennas are designed to have applications in S band,C band and as well as X band with good bandwidth and gain. These frequencies in S band (2-4 GHz) are useful in applications such as Wi-Fi, Bluetooth, ZigBee, IEEE 802.15 etc. C band (4-6GHz) frequencies are used in downlink of communication satellite, weather radar system. The frequencies in X band (8-12 GHz) have applications in radar, space communication, fixed satellite, mobile satellite and radio location services.

***Index Terms*: Decagon, fractal, micro strip patch, and nature inspired, octagon.**

I. INTRODUCTION

Now a day, demand of low profile high gain antenna is increased due to wireless service/ communication. This can be achieved by introducing fractal concept in antenna geometry. In fractal, same shape is repeated at different scale. Fractals are found in nature in broccoli, river channels, fern leaf, snowflake etc. Different shapes of fractal like Sierpinski carpet, Koch snowflake and many more [1-3]. Self-similarity and space filling are basic properties of fractal. An octagonal shape MIMO (multiple input multiple output) antenna for WLAN and WiMAX services is presented.

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Here Fr-4 substrate of dimension 50mm* 50 mm and four antenna elements orthogonal to each other is used. Antenna resonates in 4.13GHz to 6.09 GHz at 5.5GHz provides gain of 3.69 dB. By introducing DGS antenna resonated at 2.4 GHz. For Wimax band 3.5GHz, resonators are added. Total gain of 3.15dB is achieved [3]. Minkowski fractal antenna of octagon shape patch is given for UWB. Antenna resonates at 4.2GHz and 9.4GHz. Notches are added into ground plane [4]. Another antenna using both Minkowski and Koch fractal is presented. FR-4 substrate of 120mm*120mm is used, antenna resonates in 700 MHz to 4.71 GHz with gain of 3.93dB used for UHF detection [5]. Another octagon patch antenna with annular ring is given. The antenna works in 5.24-8.02 GHz range with maximum gain of 4dB and bandwidth 234MHz. Octagonal shape complimented antenna for low frequency operations is presented in [6]. Antenna substrate of 50mm *50mm is used in square patch with octagon slot. Antenna resonates in 1.22GHz, 2.67 GHz and 3.03GHz with gain of 1.96 dB [7]. Another octagonal shape fractal patch antennas are presented in [8-9].

Fractal antenna using different shape of patch also presented like a decagon shape carpet fractal antenna for wireless application is presented for 7GHz-13GHz in [10]. Another decagon fractal MIMO antenna of size 60mm*50mm using Fr-4 is presented for WLAN application with gain of 2.32dB [11].

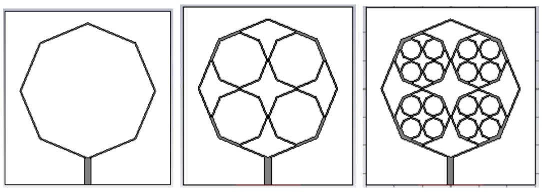
Fractals are not restricted to geometric shapes and designs, but can depict processes in time involving bio and nature-inspired problems. There have been recent works on biological, natural antennas and cavity resonators also [12-18].

In this paper two antennas of octagon and decagon fractal patch are presented. Design is simulated using CST microwave studio.

II. ANTENNA DESIGN

A. Octagon Fractal

Fr-4 substrate of size 60 mm by 63mm is considered. Outer circle of radius 24.75 is taken then inner circle of radius 24.25 is subtracted from outer one. Circle is divided into 8 segments. So octagon of thickness 0.50mm is achieved. Micro strip feed of width 2.3mm and length 9.6mm is considered. Ground of size 60 by 9.5mm is considered.



(a) iteration-0 (b) iteration-2 (c) iteration-3

Fig.1 Octagon fractal iterations

Iteration-0 consists of single octagon. Then this octagon is divided into small four octagons, so iteraton-1 is achieved. This pattern is again followed to obtain iteration-2. Iteration-1 octagons again divided into four small octagons and iteration-2 is achieved. The fractal octagon antenna is symmetric also. Octagon fractal iterations are shown in above fig 1.

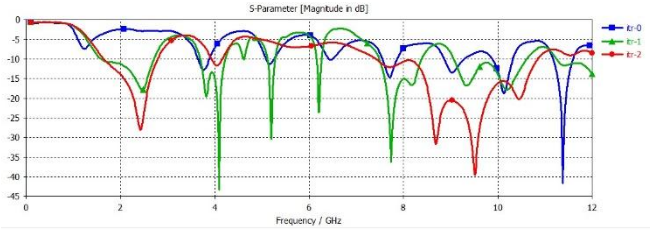
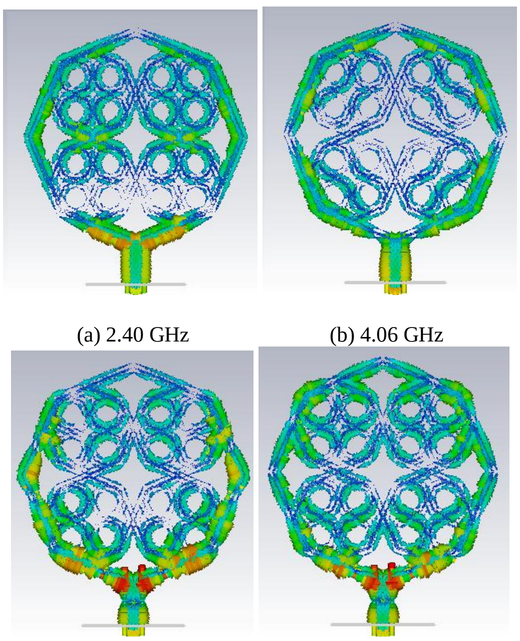


Fig. 2 Reflection coefficient of octagon fractal iterations

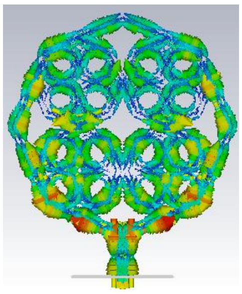
Table I- Resonating frequency and gain of octagon fractal iterations

Iteration	Resonating frequency (GHz)	Gain (dB)
0 th	3.78 GHz, 5.17, 7.73, 9.08, 10.20, 11.4 GHz	3.6 dB, 3.7, 3.6, 2.0, 3.8 dB
1st	4.08, 5.2, 6.23, 7.75, 9.34, 10.20 GHz	3.9, 1.8, 5.6, 3.1, 2.9 dB
2^{nd}	2.40GHz, 4.06, 8.39, 9.52, 10.45 GHz	3.3, 5.0, 5.6, 5.5, 4.5 dB



(a) 2.40 GHz (b) 4.06 GHz

(c) 8.39 GHz (d) 9.52 GHz

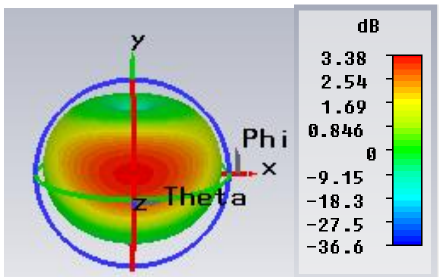


(e) 10.52 GHz

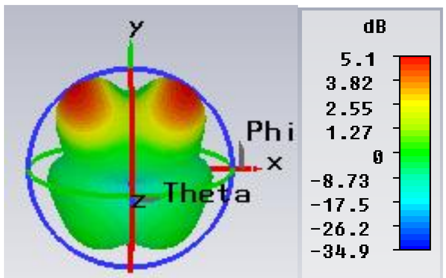
Fig. 3 Surface current distribution of octagon fractal iteration-2

Reflection coefficient (S11) compared result is shown in fig 2. At each iteration multiple operating frequency is obtained. In Iteration-2 bandwidth is improved. 2.40GHz frequency antenna band is 1.65 GHz to 2.78 GHz so 47.08 % bandwidth is achieved. 2^{nd} frequency 4.06 GHz in band 3.93GHz-4.15 GHz of bandwidth 5.4% and 3^{rd} band from 7.40 GHz -10.84 GHz with three resonating frequencies 8.39 GHz, 9.52 GHz and 10.52 GHz with bandwidth 36.32%.

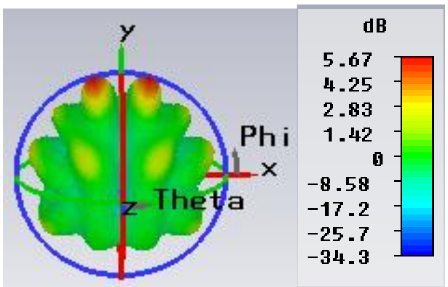
At 2.40 GHz frequency current flows in outer octagon and middle eight octagons. At 4.06 GHz surface current distribution is outer ring and four outer ring connected octagons. At both 2.40 GHz and 4.06 GHz surface current distribution is symmetric about y-axis. At 8.39 GHz current flows in outer ring and in middle four octagons also the octagons connected with outer rings. At 9.52 GHz and 10.45 GHz current is in both inner and outer octagons. From above fig 3 current distribution is symmetric.



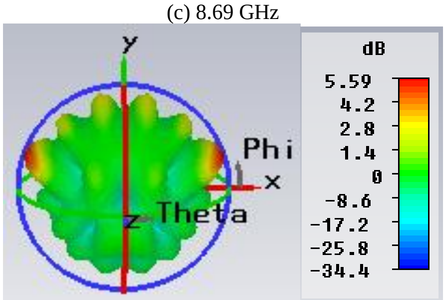
(a) 2.40 GHz



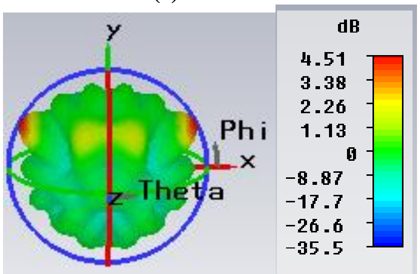
(b) 4.06 GHz



(c) 8.69 GHz



(d) 9.52 GHz

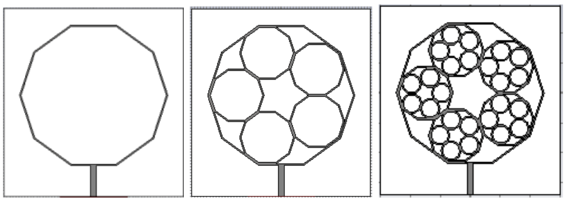


(e) 10.45 GHz

Fig. 4 Gain of octagon fractal iteration-2

Gain is shown in table-I. Gain is improved in 2nd iteration. Maximum gain obtained is 5.67dB at 8.69 GHz and minimum is 3.38 dB at 2.40 GHz is shown in fig 4.

B. Decagon Fractal



(a) Iteration-0 (b) Iteration-1 (c) Iteration-2

Fig. 5 Decagon fractal itrerations

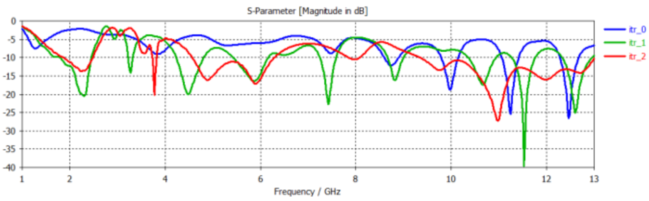
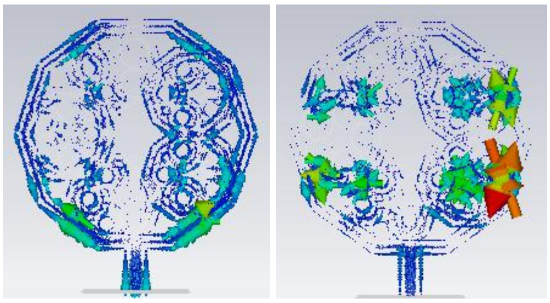


Fig. 6 Reflection coefficient of decagon fractal itreration

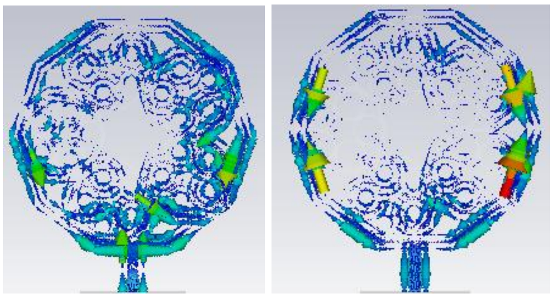
Decagon iterations are obtained in the similar fashion of decagon fractal iterations. Iteration-0 decagon, outer radius is 24.75mm and inner radius is 24.25mm so difference is 0.5mm. Here in iteration-1, decagon is divided into five small octagons. Each small decagon of iteartion-1 is again divided into five smaller decagons and iteration-2 is achieved as shown in above fig 5. Same thickness of 0.5mm is retained in iteration-1 and iteration-2. Fig 6 gives the compared simulated reflection coefficient for different iterations. In iteration-2 antenna resonates at 2.25 GHz in frequency (2.25GHz-3.2GHz with bandwidth 27.1%), 3.73 GHz, 4.85 & 5.91 GHz in (4.58GHz-6.29GHz with bandwidth 26.76%) and at 9.77 GHz, 10.96GHz and 12.0GHz in frequency band (9.35GHz-13.01GHz with bandwidth 33.4%) as shown in Table-II.

Table II- Resonating Frequency and gain of Decagon Fractal Iteration

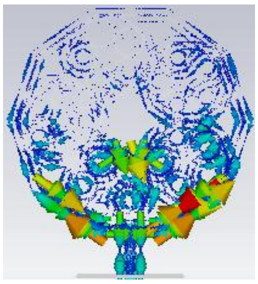
Iteration	Resonance Frequency (GHz)s	Lower frequency (GHz)	Upper frequency (GHz)	Bw%	Gain (dB)
2	2.32	1.87	2.48	27.1%	3.24
	3.73	3.72	3.81	2.6	0.08
	4.85	4.58	6.29	26.76%	5.42
	5.91				4.14
	10.96	9.35	13.01	33.4%	3.73



(a) 2.25 GHz (b) 3.73 GHz



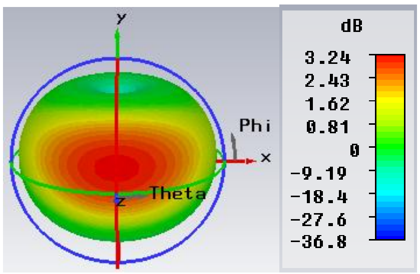
(c) 4.85 GHz (d) 5.91 GHz



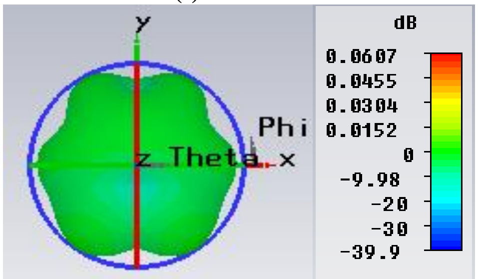
(e) 10.96 GHz

Fig. 7 Surface current of decagon fractal iteration-2

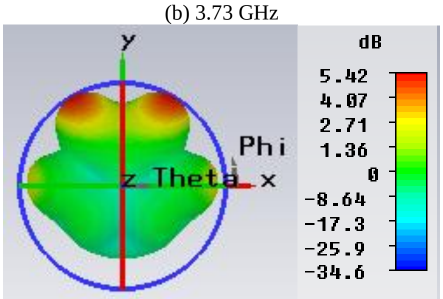
Surface current distribution at frequency 2.25 GHz is in outer lower ring of decagon and some current in inner small decagons. At 3.73 GHz, 4.85 GHz, 5.91 GHz and 10.96 GHz frequency current distribution is symmetrical about y-axis as shwon in fig 7.



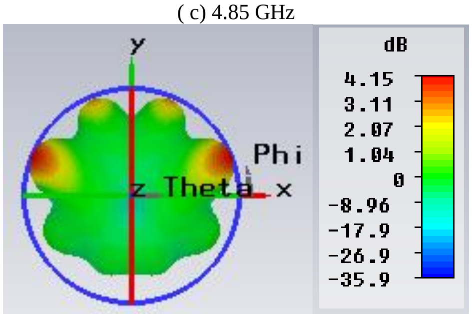
(a) 2.25 GHz



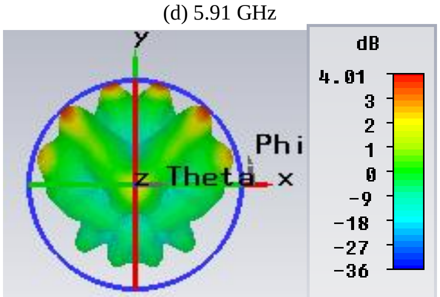
(b) 3.73 GHz



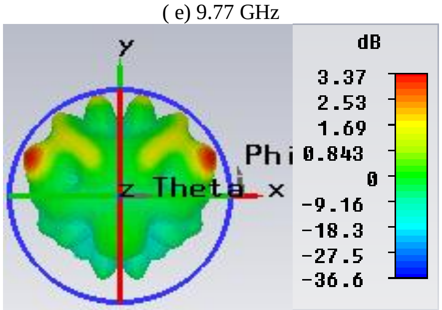
(c) 4.85 GHz



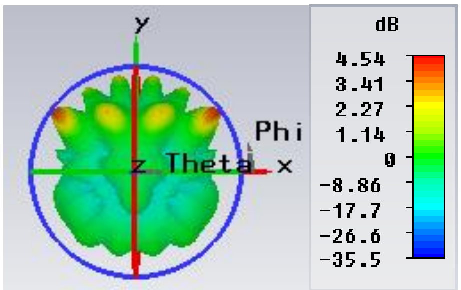
(d) 5.91 GHz



(e) 9.77 GHz



(f) 10.96 GHz



(g) 12.01 GHz

Fig. 8 Gain of decagon fractal iteration-2

Gain at different frequencies for iteration-2 is given in fig 8. Maximum gain of 5.42dB at 4.85 GHz and minimum is 0.06 dB at 3.73 GHz is achieved.

Table III- Proposed antennas maximum bandwidth and gain

Antenna	Type of patch	Resonating Frequencies (GHz)	Maximum Bandwidth (%)	Maximum Gain (dB)	Applica-tions
1.	Octagon fractal patch	2.4, 4.06, 8.39,9.52, 10.45 GHz	47.08%	5.6dB	S,C and X band
2.	Decagon fractal patch	2.32, 3.73, 4.85,5.91, 10.96 GHz	33.4%	5.42 dB	S,C and X band

The Proposed octagon antenna is having application at 2.4GHz in Wi-Fi, Bluetooth, ZigBee IEEE 802.15, 7.40GHz-10.84GHz in X band application like radar, space communication, fixed satellite, mobile satellite (7.9-8.4GHz), radio location services (8.5-10.5 GHz). Decagon antenna also having application in S, C and X band. Proposed antennas maximum bandwidth and maximum gain is summarized in Table-III.

The designed octagon antenna having better in size and gain with [5], better gain [3, 6, 7 and 8] and decagon antenna is better in comparison to [11].

III. CONCLUSION

Octagon and decagon shaped micro strip fractal patch antennas were presented. The octagon fractal patch antenna has maximum bandwidth of 47% at 2.40GHz, a S band frequency, used in IEEE 802.11b/g standard WLAN. The maximum gain of 5.6dB was achieved at 8.39GHz, an X band frequency.

In case of decagon fractal patch antenna bandwidth of 33.4 % is achieved for X band frequencies in the range of 9.35GHz to 13.0 GHz. The maximum gain of 5.42 dB was at C band frequency 4.5 GHz.

In conclusion these antenna designs potentially have applications in WLAN, weather radar, amateur radio as well as fixed and mobile satellite communications.

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