ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Website: www.ijareeie.com

Vol. 7, Issue 6, June 2018

Bandwidth Optimization using Pi-Shaped Fractal Patch Antenna for Wideband Applications

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ABSTRACT: -In this paper an initially square patch has been analyzed. The dimensions of the patch have been taken as 20mm. The parameters of antenna are analyzed. Now to improve the antenna characteristics further, first iteration is done on the patch and results are studied. Then to get better results, second iteration is also done to make a Pi-π shaped fractal patch antenna and finally the parametric analysis has been done. It uses FR-4 as dielectric substrate. Coaxial feeding technique has been used to provide feed to the antenna. This feeding is done at that point on the patch where the impedance matching takes place. In this thesis work, feed point is taken at (-8.8,-8.8) co-ordinates.. The 2nd iteration produces a bandwidth of 2GHz with a maximum return loss of -28.26dB. In order to gain wideband characteristics a plus shaped DGS is applied to the ground plane of the antenna. By using the DGS improvement is seen in the bandwidth and gain. After applying DGS the proposed antenna produces a bandwidth of 1.9GHz wiith a return loss of -28.26 dB. Hence the proposed antenna is suitable in application with GPS, W-LAN, long distance radio communication and satellite communication.

KEYWORDS: -Microstrip patch antenna, Pi-Shaped, slot antenna, wideband

I. INTRODUCTION

Antenna is one of the largest components of the low profile wireless communication. In order to transmit and receive antenna information; modulation is done in which career wave is superimposed over modulating signal. At the required destination, the modulated signal was then received and the original information signal can be recovered by demodulation. Over the years, techniques have been developed for this process using electromagnetic carrier waves operating at radio frequencies as well as microwave frequencies. In the current scenario small, compatible and affordable microstrip patch antennas are developed in wireless communication industries keep on improving antenna performance. A patch antenna is a narrowband antenna with large beam width. It is fabricated by etching the antenna element pattern in metal trace which is bonded to an insulating dielectric substrate such as a printed circuit board with a continuous metal layer bonded to the opposite side of the substrate known as a ground plane**.** Most of the researchers focused on 2.3 to 6 GHz because it is a mobile communication band and all the people uses mobile phones. So we need a small, compatible and cheapMicrostrip patch antenna. A Microstrip patch antenna is used to process ultra-high frequency signals. Microstrip patch antenna is a wideband, narrow beam, occupy less space. Antenna placed over an insulating material such as FR4, glass, ceramic etc. whose dielectric constant lies between 2.2≤ εr≤12. The microstrip antenna mainly consists of ground,substrate, patch and feed line. The base of the antenna is known as ground plane. Just above the ground with the same dimension a substrate is placed [5].
The patch in the antenna is made of a conducting material Cu (copper) or Au (gold) and this can be in any shape rectangular, circular, triangular and elliptical or some other common shape [2]. Microstrip antennas are used mostly in many applications such as WIMAX (worldwide interoperability microwave access), WI-FI(Wireless fidelity)[11], USB dongle, satellite radio or cell phone receiver or is mounted on an aircraft or spacecraft due to their compact size, less weight, low cost on mass production, ease of installation with multi-frequency bands[1]. The disadvantages of patch

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antenna are narrow bandwidth, lower gain and surface waves. High dielectric constant is the simplest solution but it cause narrow bandwidth and poor efficiency For obtaining multiband, wideband characteristics different techniques such as stub loading, cutting a resonant slot inside the patch, fractal geometry is used. In this paper partial ground plane is used to decrease the back reflections. Hence to increase the bandwidth two parasitic stubs are added on the two sides of patch and the top corner of th e patch as well as the stubs are cut in order to increase the bandwidth[1]. Two slots are also added at the end of the patch to decrease the return loss thus the return loss up to -22 dBi is obtained.

II. ANTENNA DESIGN & EXPERIMENTATION

The geometry corresponding to 0^{th} iteration is shown in figure 4.2. A square patch has been analyzed. This square patch has dimensions of 20mm x 20mm. The ground dimensions are calculated using the defined formulas. This antenna has dimensions of ground as 35mm x 35mm. Feed point is selected by hit and trial method to check where maximum impedance matching takes place. Then the results are analyzed.. Now to improve the results further, 1^{st} iteration of Sierpinski carpet Pi-π shaped fractal is applied on the patch. This first iteration has been done by making a cut of 8mm on the patch. It used Sierpinski carpet Pi-π shaped fractal geometry. This cut is made at the centre of the patch. Then antenna parameters are examined. Now the 1^{st} iteration design

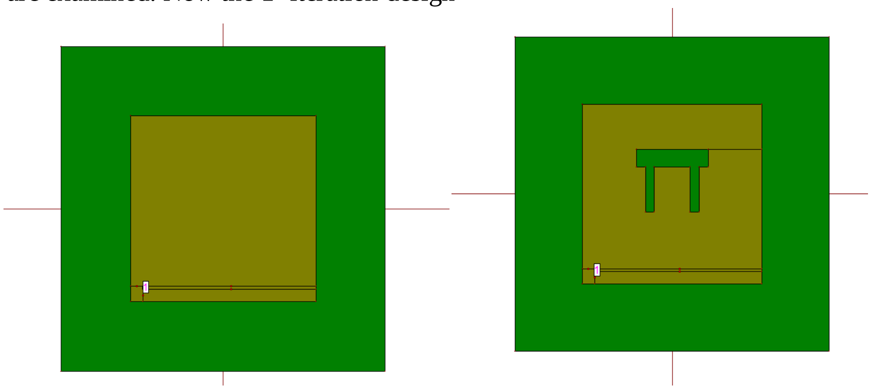

Figure1**:**2D view of simple patch and edge tapered antenna

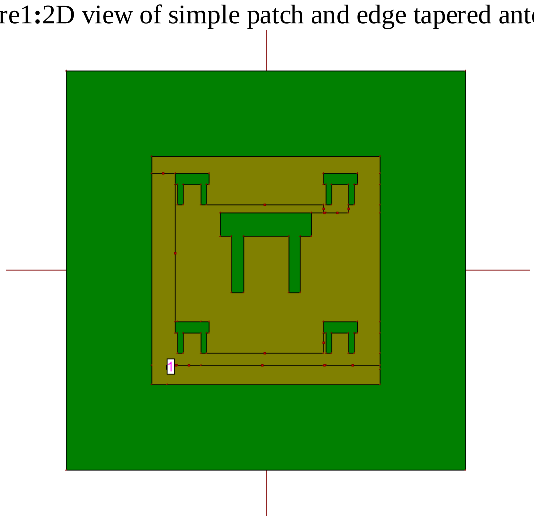

Figure 2: 2D view of proposed antenna

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Table 1: Design parameter and corresponding values

Variable	**Value**
Length of patch	20mm
Width of patch	20mm
Length of ground	35mm
Width of ground	35mm
Thickness of substrate	2.4mm
Feeding technique used	Coaxial Feeding Technique
Substrate used	FR-4
Dielectric constant	4.4
Loss Tangent	0.02
Feed point	X=-8.8, y=-8.8, z=0
First iteration cut	8mm
Second iteration cut	2mm

Initially square patch has been analyzed. The dimensions of the patch have been taken as 20mm. The parameters of antenna are analyzed. Now to improve the antenna characteristics further, first iteration is done on the patch and results are studied. Then to get better results, second iteration is also done to make a Pi-π shaped fractal patch antenna and finally the parametric analysis has been done. It uses FR-4 & RT-Duroid as dielectric substrate. Coaxial feeding technique has been used to provide feed to the antenna. This feeding is done at that point on the patch where the impedance matching takes place. In this thesis work, feed point is taken at (-8.8,-8.8) co-ordinates. The dimensions of the antenna are given in the table 4.1

III. RESULTS & DISCUSSION

a Pi-π shaped fractal antenna has been designed using Sierpinski carpet Pi-π shaped fractal geometry. Initially a square patch has been analyzed. Then 1st iteration is made on it. And to get much better results, one more iteration has been done. As the number of fractal iterations increases, the antenna characteristics are improved and the size of antenna reduces. But this is valid till some limit and beyond that limit the antenna characteristics starts degrading. Now the results of 0th, 1st and 2nd iteration are discussed here and also compare dielectric substrate FR-4. Initially square patch has been analyzed. The dimensions of the patch have been taken as 20mm. The parameters of antenna are analyzed. Now to improve the antenna characteristics further, first iteration is done on the patch and results are studied. Then to get better results, second iteration is also done to make a Pi-π shaped fractal patch antenna and finally the parametric analysis has been done. It uses FR-4 & RT-Duroid as dielectric substrate. Coaxial feeding technique has been used to provide feed to the antenna. This feeding is done at that point on the patch where the impedance matching takes place. In this thesis work, feed point is taken at (-8.8,-8.8) co-ordinates. The dimensions of the antenna are given in the table 4.1

1 Sierpinski carpet Pi-π shaped fractal patch antenna (0th iteration)

In this, the results for 0th iteration are discussed. The antenna characteristics are explained in terms of return loss, bandwidth, resonant frequency, gain and directivity. Return loss should have more negative value. Ideally it is defined

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having more value than -10dB because this is the return loss for isotropic antenna. The return loss versus frequency graph for 0th iteration is shown in figure 5.1

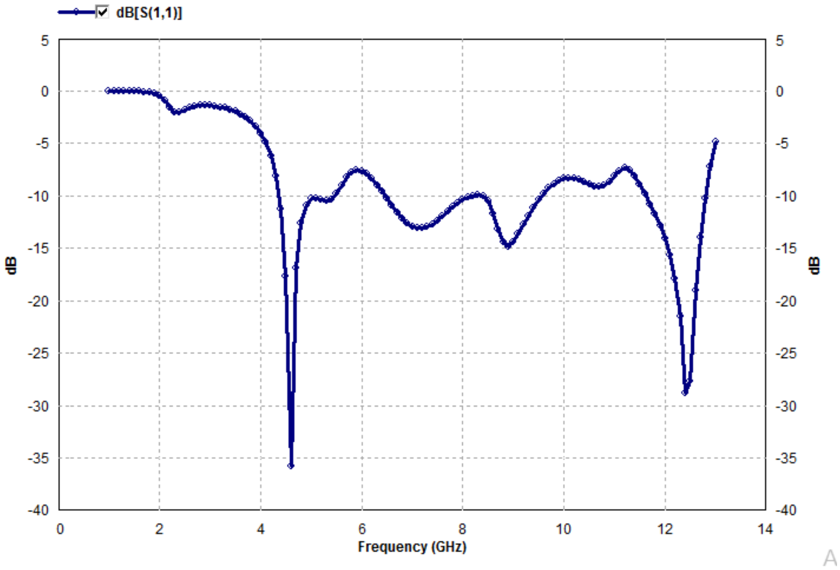

Figure 1Return loss versus frequency

This antenna resonates at 4.4GHZ, 8.8GHZ and 12.4GHZ with return loss -36dB, -12dB and -29dB respectively. It produces a maximum band of 450MHz. This antenna covers the bandwidth from 4GHz to 14GHz frequency. The 3D radiation pattern for 0th iteration at different resonant frequencies is shown in figure 5.2(a) & 5.2(b).

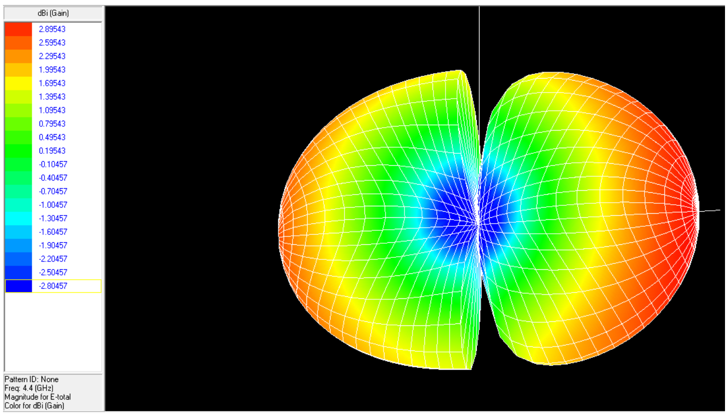

Figure 2(a) Radiation pattern at 4.4GHz

Figure 5.2 shows the 3D radiation patterns at different frequencies. Radiation pattern basically shows the maximum gain produced by the antenna. Gain takes into account the efficiency of an antenna and its directivity. This antenna's radiation pattern shows that maximum gain at 4.4GHz is 2.9dBi, at 12.4GHz is 6dBi. Now the characteristics for 0th iteration were not so good. So in order to get improved characteristics, 1st iteration is done.

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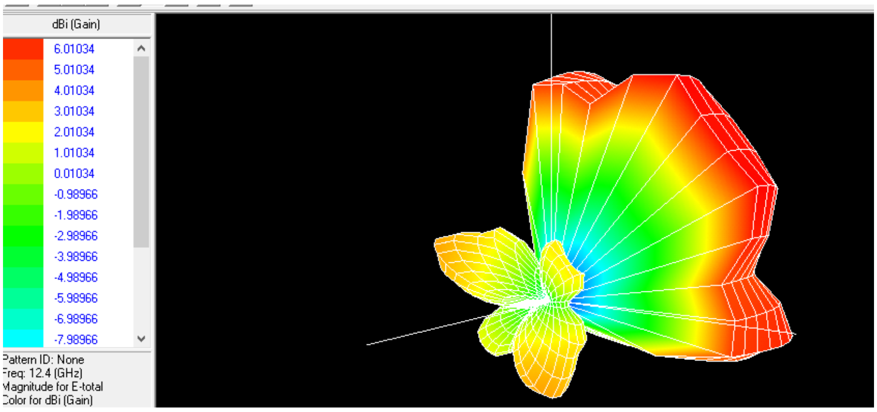

Figure 2(b) Radiation pattern at 12.4GHz

5.2 Sierpinski carpet Pi-π shaped fractal patch antenna (1st iteration)

The return loss versus frequency graph for 1st iteration is shown in figure 5.3 (a)

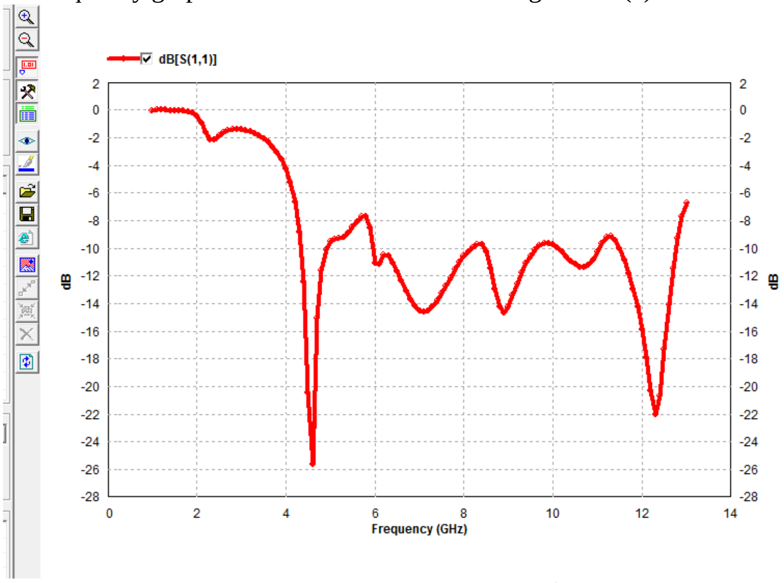

Figure 3(a) Return loss versus frequency

This graph shows that the antenna with 1st iteration resonates at 4.6GHz, 7GHz and 12.1 GHz frequencies with return loss of -27dB, -15.1dB and -22.1dB respectively. Resonant frequency 4.3GHz produces bandwidth of 900MHz while the other resonant frequency of 12.3GHz produces 700MHz bandwidth and the third resonant frequency of 9.7GHz produces a bandwidth of 1200MHz. The bandwidth produced is much increased than the 0th iteration design. Now the 3D radiation pattern for 1st iteration at different frequencies is drawn in figure 4. This pattern shows the gain obtained at different frequencies.

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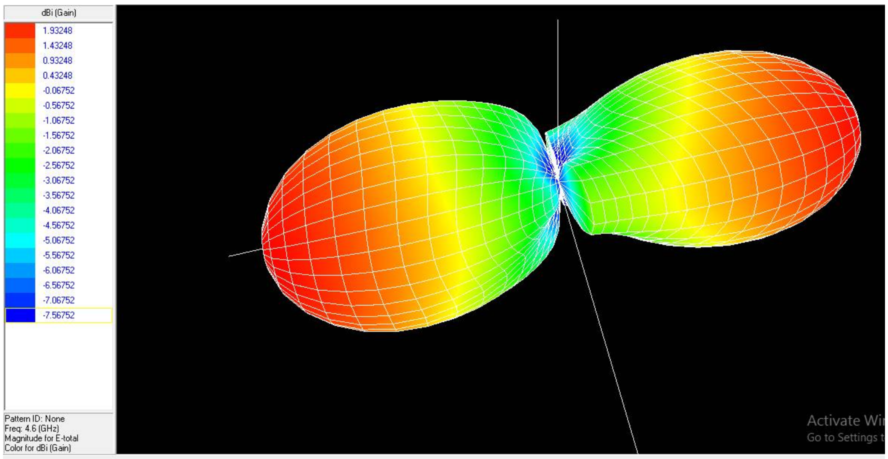

Figure 4 (a) Radiation pattern at 4.6GHz

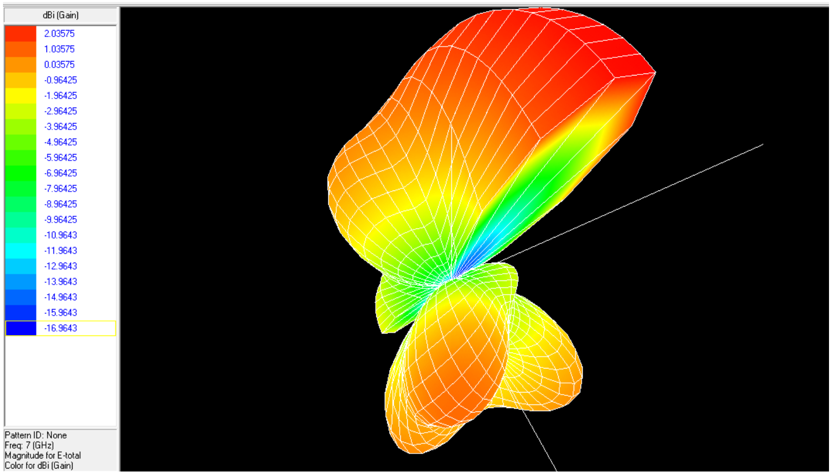

Figure 4 (b) Radiation patterns at 7GHz

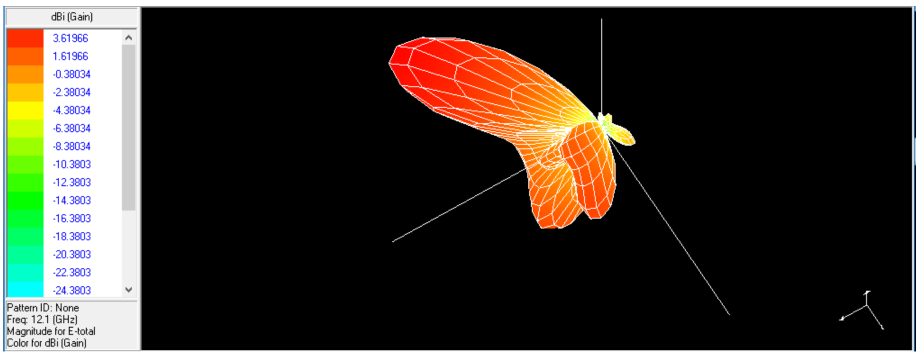

Figure 4(c) Radiation patterns at 12.1GHz

4Sierpinski carpet Pi-π shaped fractal patch antenna (2^{nd} iteration)

The return loss versus frequency graph for 2^{nd}iteration is shown in figure (a)

This graph shows that the antenna with 2^{nd} iteration resonates at multiple frequencies 5.6GHz, 8.2GHz,9.6GHz and 12.1 GHz frequencies with return loss of -13dB, -16.1dB, 21.1 dB and -13.1dB respectively. Resonant frequency

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8.2GHz to 10.1GHz produces bandwidth of 1900MHz while the other resonant frequency of 12.1GHz produces 700MHz bandwidth. The bandwidth produced is much increased than the 0th iteration design. Now the 3D radiation pattern for 2nd iteration at different frequencies is drawn in figure 5.6. This pattern shows the gain obtained at different frequencies.

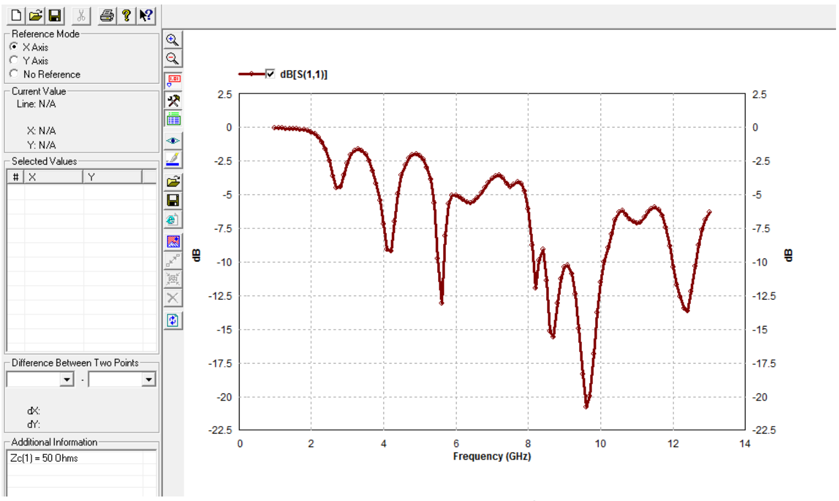

Figure 5(a) Return loss versus frequency

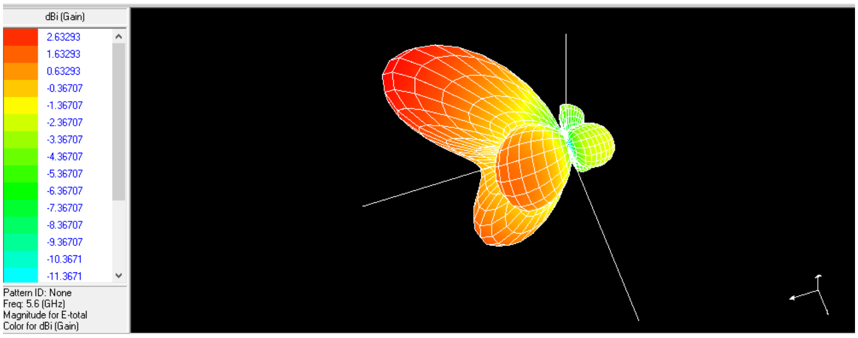

Figure 6(a) Radiation pattern at 5.6GHz

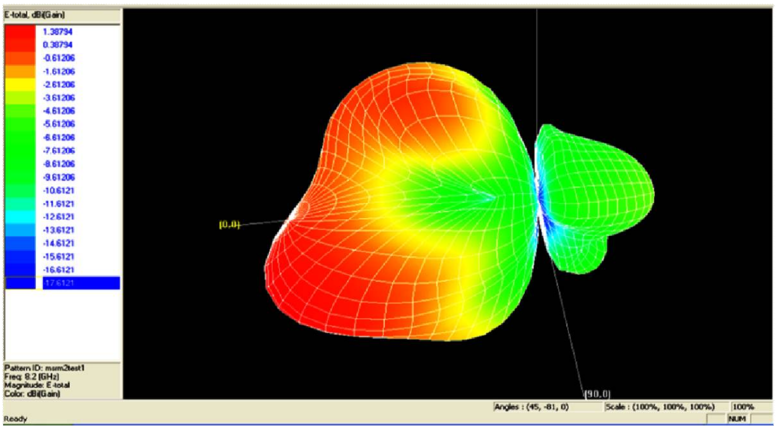

Figure 6(b)Radiation pattern at 8.2GHz

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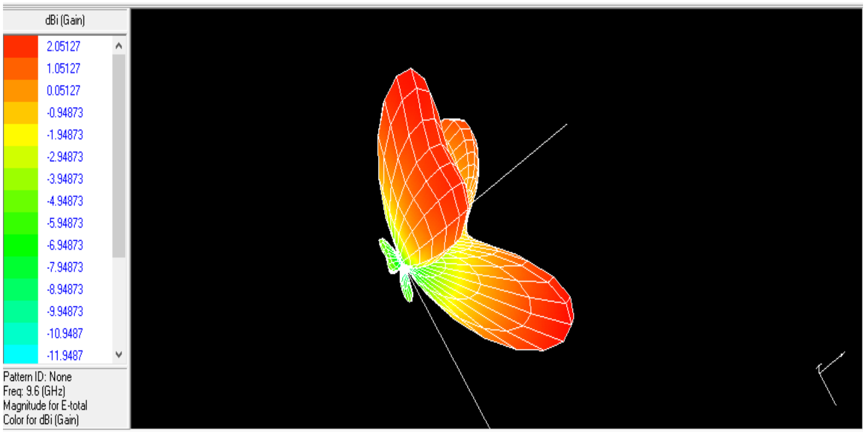

Figure 6(c)Radiation pattern at 9.6GHz

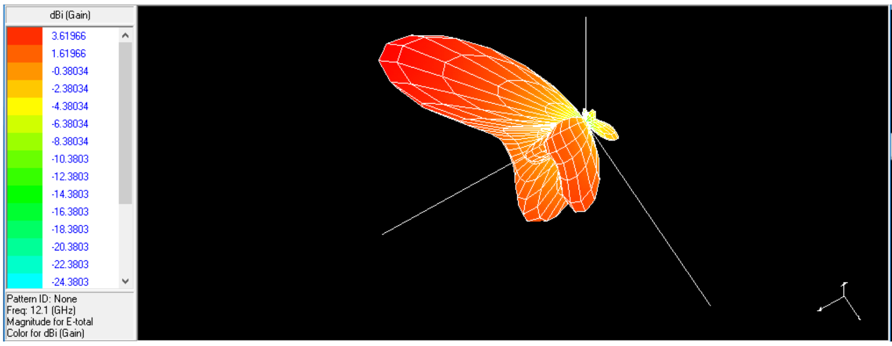

Figure 6(d) Radiation pattern at 12.1GHz

Table1:- Comparative analysis of three iterations

Iteration Number	Resonance Frequency (GHz)	Return Loss (dB)	Gain (dBi)	Directivity (dBi)	Bandwidth (MHz)
0^{th} Iteration	4.4	-36	2.9	4.348	450MHz
	12.4	-29	6.1	9.136	900MHz
1^{st} iteration	4.4	-17	2.324	8.4	600MHz
	7	-15.1	2.0	4.6	2.2GHz
	9.6	-15	2.05	4.34	800MHz
	12.1	-20	3.61	7.6	1.2GHz
2^{nd} Iteration	5.6	-13	2.29	5.82	200MHz
	8.2		1.38	7.62	
	9.4	-28.26	2.68	8	2GHz
	9.7		1.92	6.8	
	12.1	-13	3.61	7.6	900MHz

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IV. CONCLUSION

In this paper effect of using different substrate on the designed antenna has been discussed. In this work, Pi-π shaped fractal microstrip patch antenna has been designed using Sierpinski carpet Pi-π shaped fractal geometry. This antenna has been applicable for C and X microwave frequency bands. Initially a square patch of side 20mm has been analysed. Then two iterations has been applied on the patch using Sierpinski carpet Pi-π shaped fractal geometry. The 2nd iteration design resonates at 5.6GHz, 8.2GHz, 9.4GHz, 9.7GHz and 12.1GHz frequencies. It produces a band of 1900MHz having maximum return loss of -28.26dB. The feedpoint is taken at (-8.8,-8.8) coordinates using coaxial feed. For proposed antenna it has average efficiency of 110.2% with average gain of 6.08dB having bandwidth of 89.6%.By using substrate material as simple patch antenna has average gain of 9.12 dB with 105.9% average efficiency having 18.5% bandwidth. For edge tapered antenna it has average efficiency of 102.4 with average gain of 8.51 dB having 94.7% bandwidth. For proposed antenna it has average efficiency of 96.8% with average gain of 5.7dB having bandwidth of 88%. For future work, this antenna can be deisgned using non contacting feeds and poximity feeds and the antenna paramters like gain and bandwidth can be improved. This study will provide guidelines to the researchers working in this area.

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