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Design of Sierpinski Carpet Fractal Antenna with Inset Microstrip Line Feeding

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ABSTRACT: Here in this paper we are designing Sierpinski carpet antenna up to three stages on Roger RT/duroid 5880(tm) with relative permittivity 2.2 and substrate thickness 62 mil using conventional microstrip patch antenna resonating at 2.55GHz frequency with length 38.5mm, width 46.5mm and feed point as (38.855mm,4.852mm) on length and width side respectively. Inset microstrip line feeding is used for excitation of the port of Sierpinski carpet fractal antenna. Measured and calculated results in various tables shows return loss, bandwidth, gain, directivity, and radiation efficiency of each microstrip fractal antenna. From Results it is found that a fractal antenna provides better bandwidth, gain, directivity, and radiation efficiency over conventional patch antenna. Various measured and calculated results with figures are shown in respective tables. The purposed antenna is multiband antenna and small in size. The designs of antenna have been modelled, designed and simulated using high frequency structural simulator (HFSS 15.0) finite element electromagnetic solver software, HFSS Antenna Design Kit and MATLAB.

KEYWORDS: Directivity, Fractal, Gain, HFSS, Inset feeding, Microstrip patch antenna, Radiation efficiency

I.INTRODUCTION

A fractal [1] is object which can be generated recursively. Mandelbort in 1983 gave the term fractal which means broken or irregular fragments, to explain a group of complex geometrical shapes that has inherent self-similarities in their geometrical structures. Fractals [2-6] are used for modelling of the nature complex objects such as galaxies, mountain ranges, coastlines. Many branches of science and engineering use fractals. Fractal antennas are small in size [7, 8] and provide multiband characteristics [8].Sierpinski gasket fractal [9-12], Koch snowflake; Hilbert curve, Sierpinski carpet etc. are some of the important fractals which are used for design of a fractal antenna element. The Sierpinski carpet is a one of the fractal geometrical shape that is generated from the generalization of a cantor set. Waclaw Sierpinski generated Sierpinski carpet first time in this world. Sierpinski carpet fractal is very similar to the Sierpinski gasket fractal. The recursive process of dividing a shape of square or rectangle into small parts of itself generates Sierpinski carpet fractal.

II.GENERAL DESIGN OF SQUARE MICROSTRIP ANTENNA

The step for design of rectangular microstrip antenna is illustrated in the following flow chart.

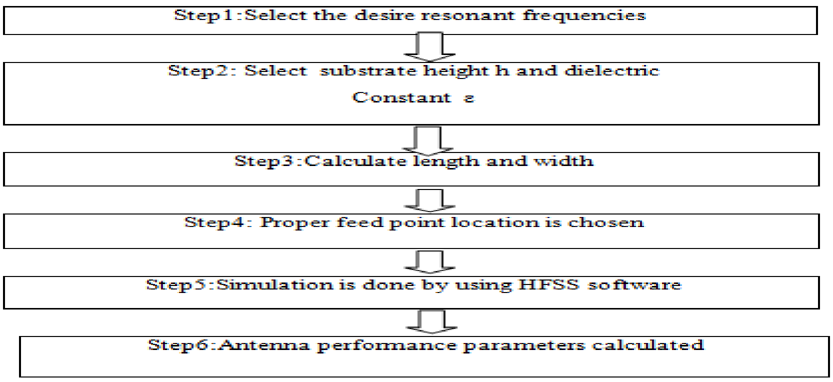

Fig.1: Flow diagram for design steps of a microstrip antenna

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III.FORMULATION OF DESIGN PAPRAMETERS

- Calculation of Width

$$W = \frac{c}{2f}\sqrt{\frac{2}{\epsilon_r + 1}}$$

- Calculate $\in_{reff}$

$$\in_{reff} = \frac{(\in_r + 1)}{2} + \frac{(\in_r - 1)}{2}\left[1 + 12\frac{h}{W}\right]^{-\frac{1}{2}}$$

For W/h>1

- Calculate ΔL i.e normalized length

$$\frac{\Delta L}{h} = 0.412\frac{(\in_{reff} + 0.3)(\frac{W}{h} + 0.264)}{(\in_{reff} - 0.258)(\frac{W}{h} + 0.8)}$$

- Calculate L

$$L = \frac{v_0}{2f_{r\sqrt{\in_{reff}}}} - 2\Delta L$$

- Calculation of input impedance

$$Z_o = R_{in}cos^2(\frac{\pi}{L} - L)$$

With the help of above mentioned procedure, the length, width, input resistance, and feed point location also can be calculated for the microstrip antenna which can be resonant at desired frequencies.

IV. DESIGN STEPS OF SIERPINSKI CARPET FRACTAL ANTENNA

Stage 0: The shape of the 0^{th} iteration is a conventional microstrip patch antenna.
Stage 1: Divide the patch into nine equal parts and remove the centre part of the patch.
Stage 2: Again divide the patch of stage1 into nine equal and remove centre parts as shown in fig. 6
Stage 3: Again divide the patch of stage 2 into nine parts and remove centre parts as shown in fig. 8
Here in this paper, conventional microstrip patch antenna, resonating at 2.55GHz is used whose designing parameters are given above. In this paper we are designing Sierpinski carpet antenna up to three stages on Roger RT/duroid 5880(tm) with relative permittivity 2.2 and substrate thickness 62 mil using conventional microstrip patch antenna. Inset microstrip line feeding is used for excitation of the port of Sierpinski carpet fractal antenna.

V. RESULT AND DISCUSSION

Fig.2 shows the initial step i.e. 0^{th} stage for design of conventional microstrip patch antenna having resonating frequency of 2.55GHz.

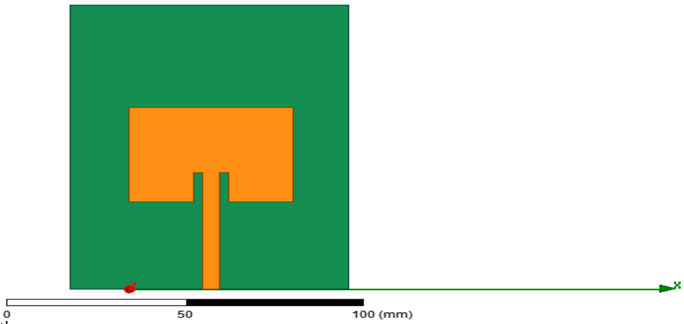

Fig.2: 0^{th} stage 2.55GHz microstrip patch antenna

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Fig.3 shows return loss v/s Frequency plot of 0th stage conventional patch antenna which is resonating at 2.55GHz.

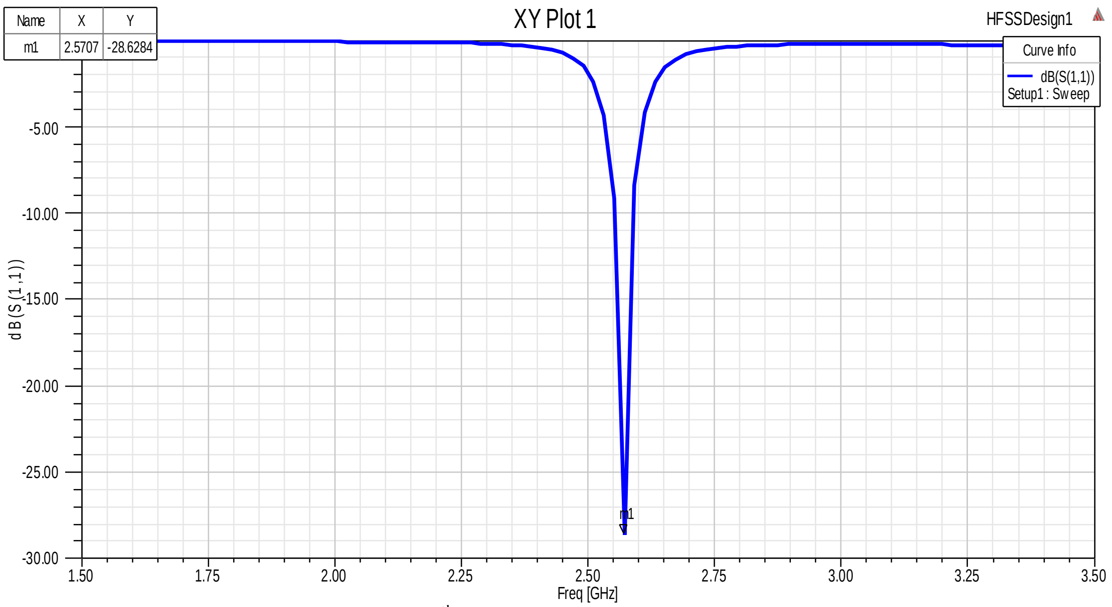

Fig.3: Return loss for 0th stage of 2.55GHz microstrip patch antenna

1st stage of Sierpinski Carpet fractal antenna is shown in Fig.4 feeded with inset microstrip line feeding technique.

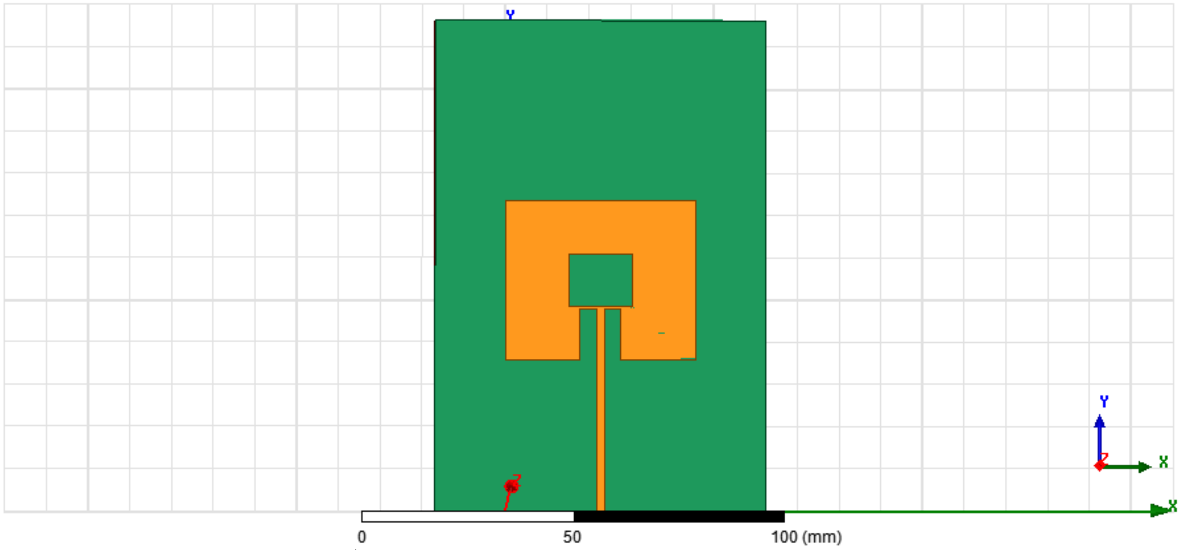

Fig.4: 1st stage 2.55 GHz Sierpinski carpet fractal antenna

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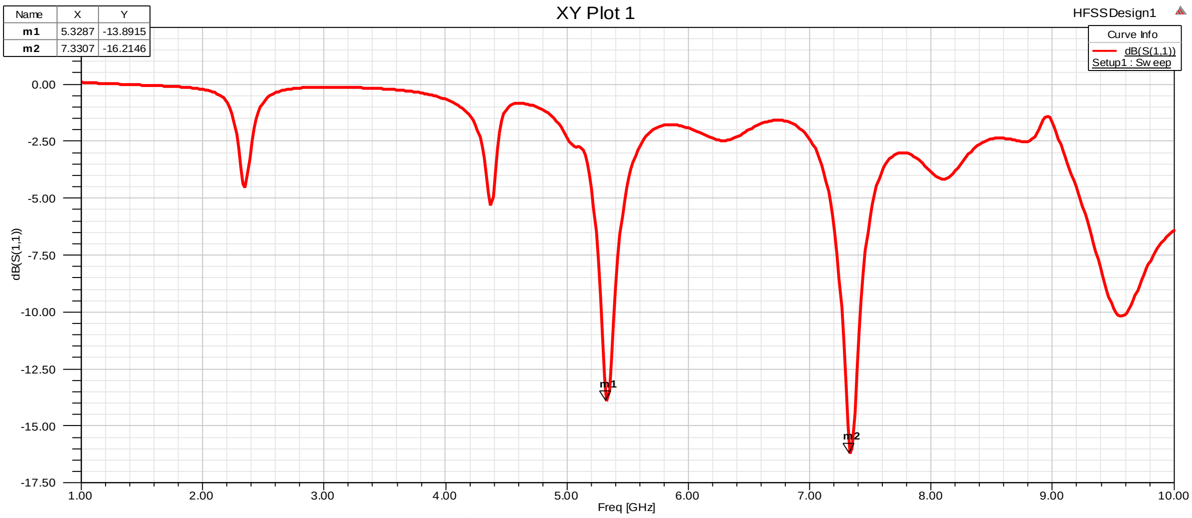

Fig.5: Return loss for 1st stage 2.55GHz Sierpinski carpet fractal antenna

Return loss v/s Frequency graph for 1st stage Sierpinski carpet fractal antenna is shown in fig.5 which shows the multiband characteristics of fractal antenna. Whereas Table 1 is showing measured and calculated values of various parameters i.e. return loss, bandwidth, gain, directivity and radiation efficiency.

Resonating frequencies (GHz)	Return loss (dB)	Bandwidth (MHz)	Gain (dB)	Directivity (dB)	Radiation Efficiency
5.32	-13.8916	104	4.9708	4.9412	0.9945
7.33	-16.2146	158.8	9.008	9.5971	0.9981

Table 1: Measured and calculated results at different resonating frequencies of 1st stage 2.55GHz Sierpinski carpet fractal Antenna with various parameters

Design of 2nd stage Sierpinski carpet fractal antenna using HFSS is illustrated in fig.6.

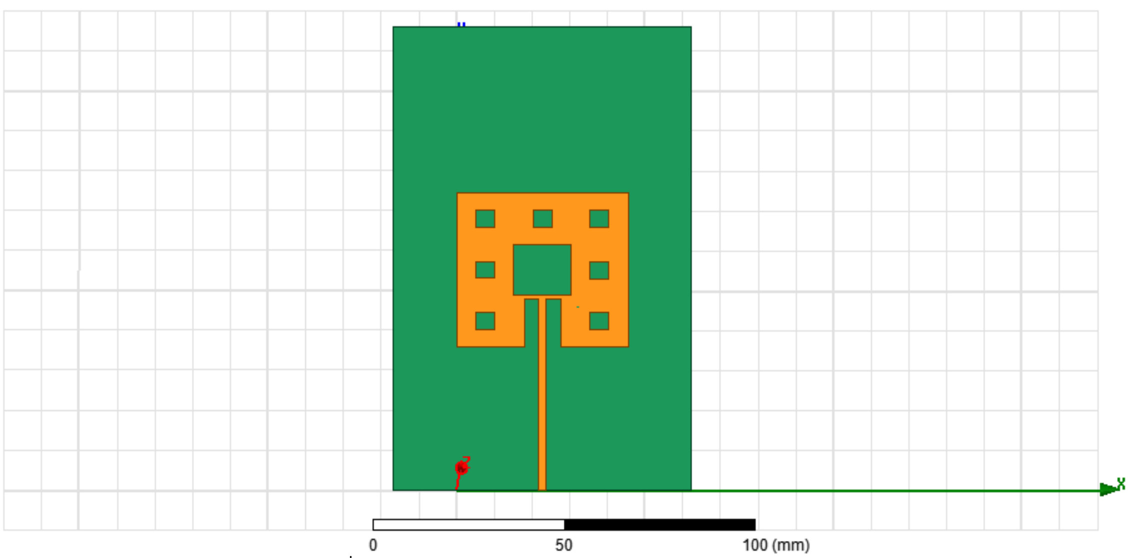

Fig.6: 2nd stage 2.55 GHz Sierpinski carpet fractal antenna

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Return loss v/s frequency graph for 2nd stage Sierpinski carpet fractal antenna is shown in fig.7, which shows that it is resonating at three frequencies below -10dB.

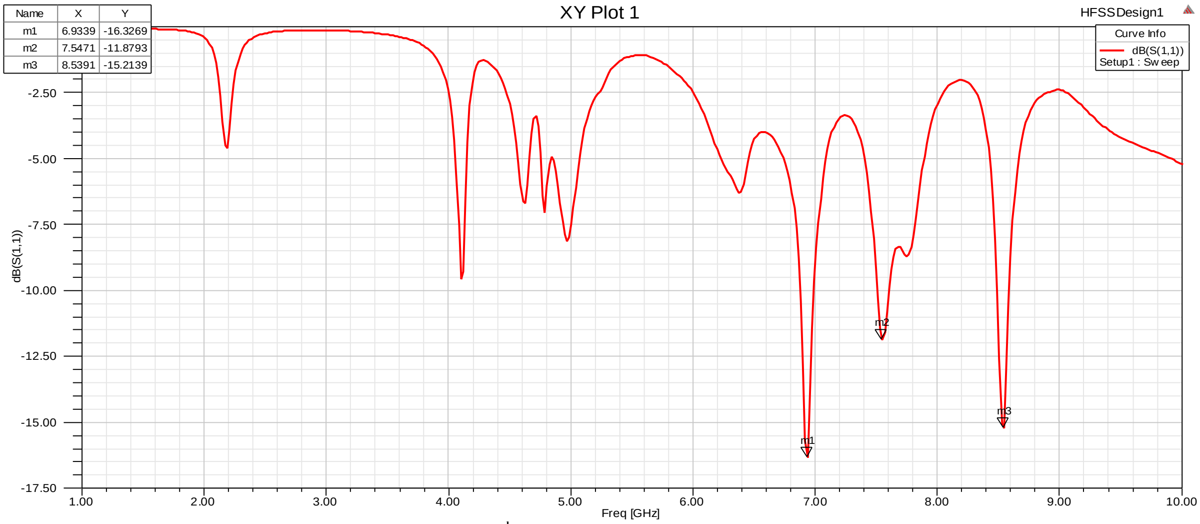

Fig.7: Return loss for 2nd stage 2.55 GHz Sierpinski carpet fractal antenna

The various measured and calculated parameters i.e. return loss, bandwidth, gain, directivity and radiation efficiency for 2nd stage resonating frequencies are shown in the Table 2.

Resonating frequencies (GHz)	Return loss (dB)	Bandwidth (MHz)	Gain (dB)	Directivity (dB)	Radiation Efficiency
6.9339	-16.3269	106.1	9.5808	9.1964	0.9979
7.5471	-11.8793	90.2	6.2015	6.1572	0.9927
8.5391	-15.2139	102.3	4.8116	4.6868	0.9963

Table 2: Measured and calculated results at different resonating frequencies of 2nd stage 2.55GHz Sierpinski carpet fractal Antenna with various parameters i.e. return loss, bandwidth, gain, directivity and radiation efficiency.

Using above stages of fractal antenna 3rd stage Sierpinski carpet fractal antenna is designed using HFSS, which is shown in fig.8

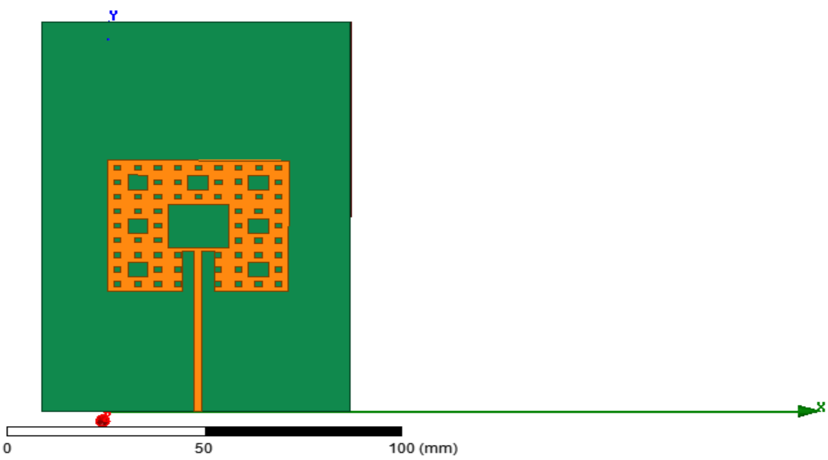

Fig.8: 3rd stage 2.55 GHz Sierpinski carpet fractal antenna

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3rd stage Sierpinski carpet fractal antenna return loss v/s frequency plot is shown in fig.9.it is showing various frequencies which are resonating below -10dB.

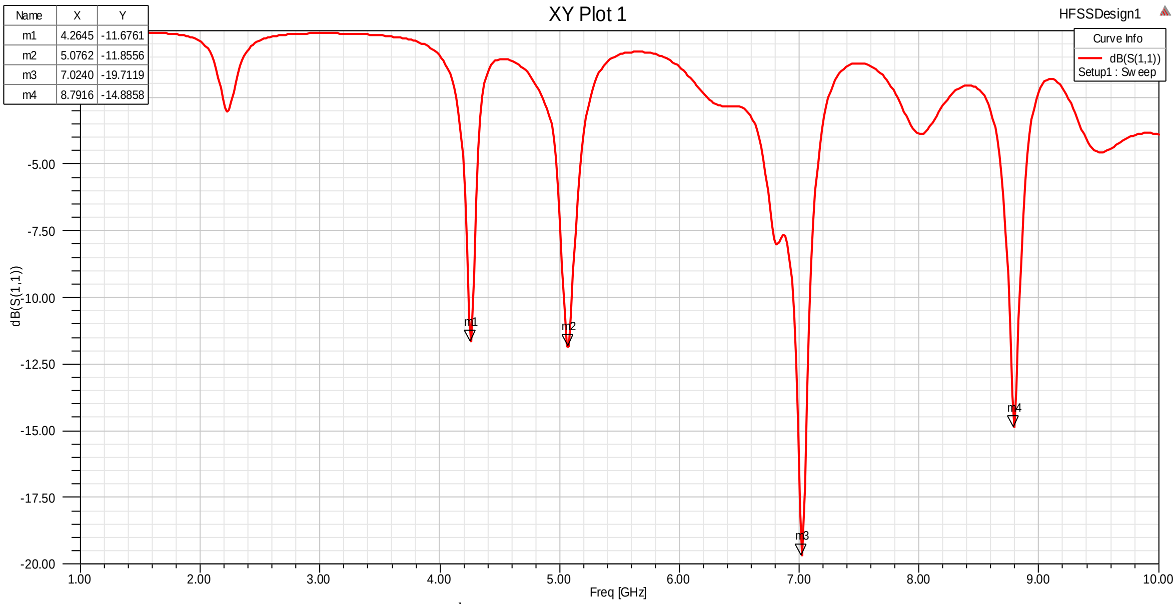

Fig.9: Return loss for 3rd stage 2.55GHz Sierpinski carpet fractal antenna

The various parameters i.e. return loss, bandwidth, gain, directivity and radiation efficiency which are calculated for 3rd stage Sierpinski carpet fractal antenna resonating frequencies are shown in table 3.

Resonating frequencies (GHz)	Return loss (dB)	Bandwidth (MHz)	Gain (dB)	Directivity (dB)	Radiation Efficiency
4.2645	-11.6761	38.6	7.2374	7.2961	0.99195
5.0762	-11.8556	71.2	3.2443	3.229	0.9923
7.2766	-19.7119	135.6	4.7288	4.6778	0.9947
8.7735	-14.8858	97.1	3.0024	3.0024	0.9915

Table 3: Measured and calculated results at different resonating frequencies of 3rd stage 2.55GHz Sierpinski carpet fractal Antenna with various parameters i.e. return loss, bandwidth, gain, directivity and radiation efficiency.

VI. CONCLUSION

In this paper 2.55GHz microstrip patch antenna dimensions are used to design Sierpinski carpet fractal antenna up to three iterations using inset feeding techniques to calculate return loss, bandwidth, gain, and directivity and radiation efficiency for different resonating frequencies of fractal antenna. Calculated and measured results are shown in the respective tables.

2.55GHz patch dimension Sierpinski fractal antenna is designed up to three iterations where 1st iteration Sierpinski fractal antenna resonates at two frequencies and provides a highest bandwidth of 158.8MHz at 7.33GHz frequency with gain of 9.00dB and 0.998 radiation efficiency.

2nd iteration resonates at three frequencies among which at 6.93GHz provides a highest bandwidth of 106.1MHz with 9.58dB gain and radiation efficiency of 0.997.

3rd iteration Sierpinski carpet fractal antenna resonates at four frequencies with highest bandwidth of 135.6MHZ at 7.27GHz frequency with 4.72dB gain and 0.994 radiation efficiency. So it is found from measured and calculated tables that Sierpinski carpet fractal antenna provides multiband and broadband characteristics with better return loss, bandwidth, gain, and directivity and radiation efficiency at different resonating frequencies in comparison of conventional microstrip patch antennas.

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Designed fractal antennas can be used for commercial and military applications. It can work effectively in S, C and X bands.

VII. SCOPE OF FUTURE WORK

Though, this paper presented the study of multiband fractal antenna design. But still there is an enough scope of improvement and further research. In future, researchers can concentrate on following area of fractal for further research.

- Design of multiband and wide broadband fractal antenna using other fractal geometric shapes.
- Optimization for miniaturization of fractal antenna size using different types of optimization techniques using MATLAB or HFSS.
- Study the effective behavior on fractal antenna parameters due to change in substrate relative permittivity ε and substrate thickness *h*.
- Use of different types of feeding techniques for ultra wide band fractal antenna design.

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