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Design and Simulation of Rectangular Shape Sierpinski Carpet Fractal Antenna Array for Multi-Band Applications

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Abstract

High data rates and better data quality are demanded features for modern communication. Multiband technology is used to increase the gain, bandwidth to a certain level. This paper describes in detail about on Sierpinski Carpet Fractal antenna array designed upto x-band frequency range by using Mitered Bend feed network up to the second iteration method in order to escalation the gain. A microstrip line which consists of a 45 degrees bent which reduces reflection which is large from the termination of the line. Each iteration is scaled down to 1/3rd of the previous reiteration. The HFSS software is used to design the carpet antenna with thickness of 1.6mm and dielectric constant of 4.4 on FR4 substrate.

Index Terms: *Multiband, sierpinski carpet, fractal antenna, array, mitered bend*

1 Introduction:

In present day communications antenna plays a crucial role due to antenna has a connecting link in the middle of the transmitter and the receiver. High gain, multiband performance, large bandwidth, low cost, ease of fabrication and small size are the important characteristics of an antenna in present day wireless communication systems. Because of these characteristics presented by micro strip patch antennas, they are used in present day's wireless communication devices and systems.

Because of the properties of geometry of fractals like self-affinity and self-similarity the fractal provides the advantages in the utilization of fractal geometry in its applications of the electromagnetic field. By performing the iterations number of times infinitely the geometry of fractals is generated.

The term fractal means irregular or broken fragments. In geometry of fractals the iteration performed on the entire volume or area of the body of the object as its first (initial) structure is taken as the generator which is imitated at various positions, scale and directions. The geometry of fractals leads to decrease in antenna's size and multiband frequency resonance by which the antenna becomes low weight, less cost and compact. The property of multiband resonance is defined due to the characteristics of the self-similarity of sierpinski antenna shown in the figure1. to be an excellence structure[1].

In this paper, the geometry of fractals uses a rectangular structure also called as carpet structure which provides the multiband behavior with enhanced antenna gain and bandwidth . HFSS software is used to simulate the antenna design using method of iterations. The measurement of the antenna are as length (L),width(W), substrate dielectric constant and to determine parameters like bandwidth, reflection coefficient, gain are studied.

The feed method used is microstrip feeding in similar fashion to stimulate the antenna from which corporate feed is formed. The design of sierpinski array is similar to rectangular shape as shown in fig.1

which is utilised in linear structure as an array [2]. The dielectric FR4 is having a thickness of 1.6mm and dielectric constant of 4.4. the feedline used is of microstrip line with width of the main track feed from which an impedance matching of 50 ohm is formed.

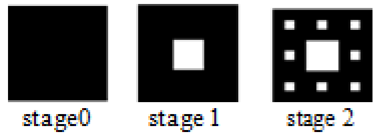

Fig.1. Design of rectangular shape MSCFA.

Therefore, the radiation pattern produced by them, would be the vector sum of the individual ones. In a radio antenna, the feeder or the feed line, is a transmission line or other cables that joins the antenna with the radio receiver or transmitter. The radio frequency current is feeded to the antenna from the transmitter with the help of the transmitting antenna, from which radio waves are transmitted. The minute RF voltage induced in the receiver antenna is transferred from the receiving antenna by means of the radio wave to the receiver. The condition of standing waves is caused on the feeding line, as the impedences are not matched, in which the Radio Frequency energy to the transmitter is redirected back, energy is wasted and perhaps excess heating of the transmitter. In the transmitter by using a device called antenna tuner, fine tuning is done and at times a similar network at the antenna. The tool called an SWR meter (standing wave ratio meter) is used to determine the degree of mismatch between antenna and the feed line, to determine SWR on the line. For high directivity and high gain ,single element antenna is not suitable. By assemblage of antennas (called an array), high gain is achieved. Feed network plan is essential, in the array construction.

2 Mitered bend feed network:

From the elements, signals are guided, therefore meter bends are introduced. A large reflection is produced due to 90 degrees bend in the microstrip line at the line end. A number of rebounds of the signal about the corner, Huge portion is reflected backwards in the path the signal moved down the line. The reflections are minimal when the curve is an arc of the radius which is 3 times of the width of the strip. This huge curve takes uses a large space compared to the 90° bend. Between the bend and the ground plane, a 90 degrees sharp bent acts as a shunt capacitance. To make a good match, to lessen the metallized area to eliminate the extra capacitance, the bent is mitered. The signal is reflected from the end down of the other arm so that it is no longer incident normally to microstrip edge

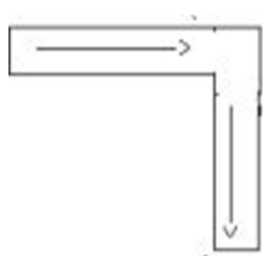

Fig.2. 90° bend.

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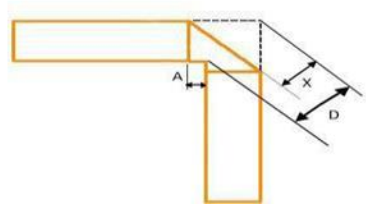

Fig.3. 45° Miter bend

The feed line is mitered based on the following equations

$D = W\sqrt{2}$ ---(1)

$X = W\sqrt{2} * (0.52+0.65 * e^{(-1.35 * w/h)})$------(2)

$A = X\sqrt{2} - W$--------------------------(3)

Where the patch antenna width is W and h is thickness of the substrate (1.6mm).In the design to produce a less insertion loss near the port of the input, it requires a mitered bending modification and a T-junction. To have insertion losses and low reflection losses, micro strip bends and mitered T-junction are applied. Fig.4 shows the 3dB power divider with mitered T- junction.

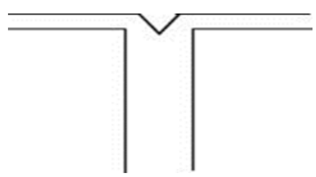

Fig.4. Mitered 'T' bend.

3 Antenna design:

The 1st elementary rectangular patch is designed and antenna design begins with Sierpinski Carpet Planar Monopole Antenna, elementary patch in square type is made into segments by eliminating the central square from it, by assuming scaling factor of 1/3rd, in the 1st iteration. Scaling is performed on left over 8 squares with scaling factor of 1/3rd in the second iteration. By using the below given formulas the patch dimensions are calculated.

the patch length is given by

$L = L_{eff} - 2\Delta L$ ----------(4)

$\boldsymbol{Bandwidth = \Delta W = W2 - W1 = Wo/Q}$ ----(5)

$D = GDmax = \frac{Umax}{Uavg} = 4\Pi Umax/Prad$-----(6)

$^{\varepsilon}ap = Ae/Ap$ -----(7)

$Ae = Preceived/Pavg$ -----(8)

Iteration factor $N = 8^n$ -----(9)

fractal length ratio $L_n = (1/3)^n$ -----(10)

area of fractal after the n^{th} iteration $A_n=(8/9)^n$ -----(11)

Where n is nth iteration stage number.

4 Sierpinski carpet fractal antenna Dimensions:

The dimensions of the antenna patch are 27 mm x 9 mm. By eliminating the middle square from the elementary patch of the sqaure in the first iteration, by using a scale factor of 1/3, and the Rectangular type slot with measurements of 9 mm x 5mm is completed in the patch by maintaining consistency of the 1st iteration. For 2nd iteration sections are made on other 8 squares with the scaling factor of 1/3rd.. The dimensions of the second iterations are 4 mm x 2 mm.

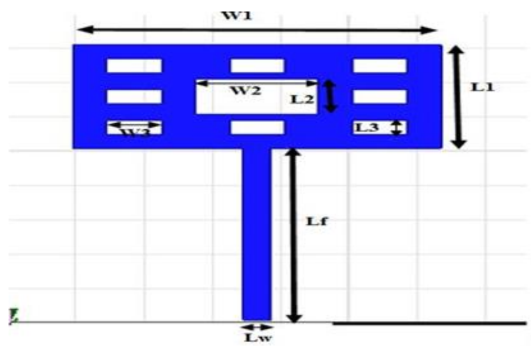

Fig.5. Structure of single element Sierpinski carpet

Dimensions Parameters for proposed MSCFA.

Parameters	**Value** (mm)
Width1	27
Width2	9
Width3	4
Length1	15
Length2	5
Length3	2
Length of the feeder	13
Width of the substrate	2

With mitered bend feed network two element Sierpinski carpet antenna array is designed and fabricated.

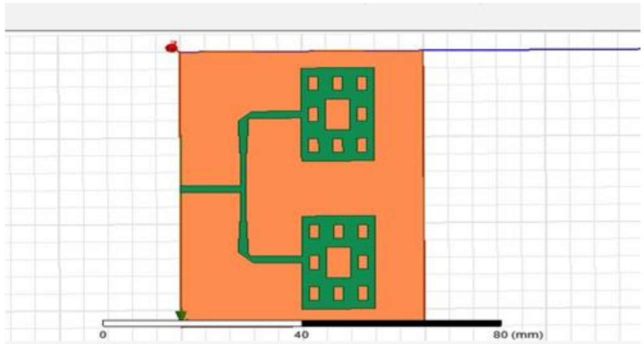

Fig.6. Photograph for MSCFA

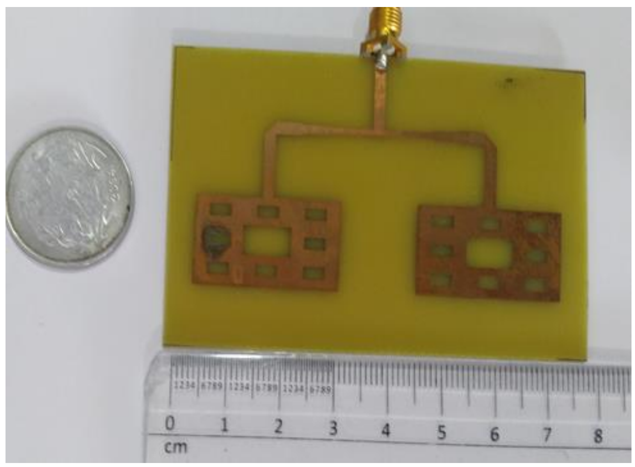

Fig.7. Fabricated MSCFA

The fabricated antenna shown in above figure having microstrip line feeding,the transmission line consists of mitered bend. The substrate used is FR4 having thickness 1.6mm with dielectric constant 4.4.

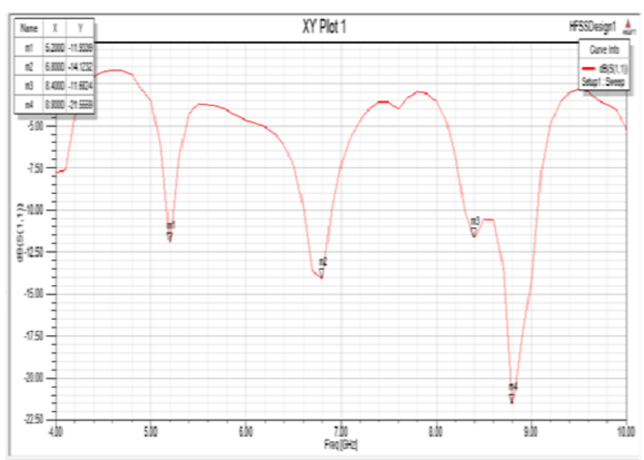

Fig.8.. S-Parameter curve for 2 element antenna array

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S parameter (return loss) shows that the antenna has resonant frequency at 4.8GHz S_{11} -12db, 6.8 GHz with $S_{11=}$ -14db,7.2GHz, S_{11} = - 13db, 9.5GHz with S_{11}=-15db which is less than -10dB

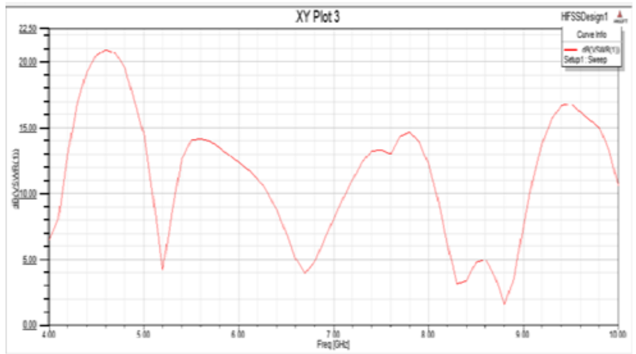

Fig.9. VSWR Curve for 2 element antenna array

The voltage wave standing wave ratio of array antenna at resonant frequency 5.2GHz is 1.45,6.8GHz is 2.02,8.4GHz is 1.76,8.8GHz is 1.23

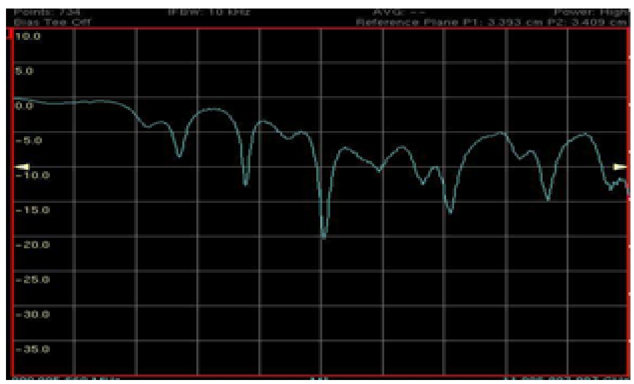

Fig.10. S-Parameter for fabricated 2-element antenna

S parameter (return loss) shows that the antenna has resonant frequency at 4.8GHz S_{11} -13db, 6.1GHz with $S_{11=}$ -21db,7.2GHz, S_{11} = - 17db, 9.6GHz with S_{11}=-15db which is less than -10dB

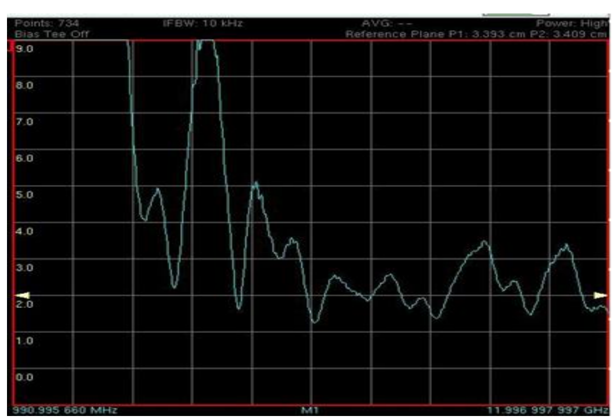

Fig.11.VSWR for fabricated 2-element antenna array

The voltage wave standing wave ratio of array antenna at resonant frequency 4.8GHz is 1.7,6.1GHz is 1.25,7.2GHz is 1.45,9.6GHz is 1.6

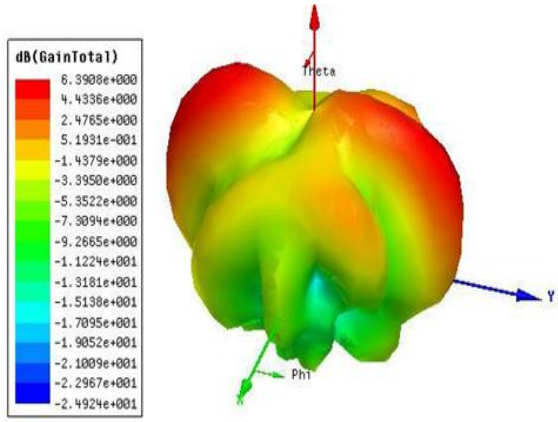

Fig.12. Gain plot for 2-element antenna array

The above plot represents that the array antenna has gain of 6.39dB by using mitered bend.

5 Performance parammeters for the proposed antenna

VSWR:

Resonant frequencies	**Simulated results**	**Fabricated results**
4.8GHz	1.85	1.7
6.1GHz	1.7	1.45
7.2GHz	1.45	1.25
9.6GHz	1.2	1.6

RETURN LOSS:

Resonant frequencies	**Simulated results**	**Fabricated results**
4.8GHz	-12	-13
6.1GHz	-15.25	-21
7.2GHz	-13.42	-17
9.6GHz	-17.85	-15

6 Conclusion

The design of rectangular Shape MSCFA is done by coaxial feeding technique. The proposed sierpenski carpet Fractal Array Antenna with mitered bend is designed and simulated upto third iteration. The proposed antenna operates with different resonant frequencies at 4.8GHz, 6.1GHz, 7.2GHz, 9.6GHz. The designed antenna provides high gain and good return loss. From the results the gain is improved for array compared to single element and from fabricated results it is shown that return loss is also improved at 4.8GHz,6.1GHz,7.2GHz frequencies. MSCFA can used in X-Band applications. The various parameters are measured and compared with fabricated results

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