TEST Engineering & Management

March - April 2020
ISSN: 0193-4120 Page No. 9399 - 9403

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

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Article Info
Volume 83
Page Number: 9399 - 9403
Publication Issue:
March - April 2020

Article History
Article Received*: 24 July 2019*
Revised*: 12 September 2019*
Accepted*: 15 February 2020*
Publication*: 09 April 2020*

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 45°-meter bend in a micro strip line reduces a large reflection from the end of the line. Each iteration is scaled down to 1/3rd of the previous iteration. This carpet antenna is designed using High frequency structure simulator software on FR4 substrate with a dielectric constant of 4.4, and having thickness of 1.6mm.

Keywords; *Multiband, sierpinski carpet, fractal antenna, array, mitered bend.*

I. INTRODUCTION

In Modern communications antenna plays a vital role because antenna has a connecting link between the transmitter and the receiver. Modern wireless communication systems involve that antennas which has high gain, large bandwidth, multiband performance, small size, low cost and ease of fabrication. Due to such these advantages offered by micro strip patch antennas, preferred for wireless communication systems now a day's Due to properties of fractal geometry such as self-similarity and self-affinity the fractal gives the advantages behavior for the application of electromagnetic field. The fractal geometry is generated by applying the iterations infinitely number of times.

The term fractal means irregular or broken fragments. In fractal the iteration applied to the whole volume of the object as its initial structure is considered as the generator which is replicated at different positions, directions and scale. The fractal geometry leads to either multiband frequency resonance or miniaturization of size of antenna which makes the antenna compact, low weight and less cost. The multiband resonance occurs due to the self-similarity characteristics of sierpinski antenna as shown in the figure1. to be an excellence structure[1].

The fractal geometry recycled in this paper is rectangular or also called carpet structure which gives the multiband behavior with improved bandwidth and gain of antenna. The design of this antenna is simulated using HFSS software, using iteration method. The antenna dimension as width (W), length (L), substrate dielectric constant and parameter such as reflection coefficient, bandwidth, gain are studied.

Microstrip feeding is used in parallel fashion to excite the antenna which forms the corporate feed. The sierpinski array design resembles rectangular shape as shown in fig.1 which is used as an array in linear structure [2]. The thickness of dielectric FR4 is 1.6mm having 4.4 dielectric constant. Microstrip

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is used as feedline with thickness of the main track feed forming 50-ohm impedance matching.

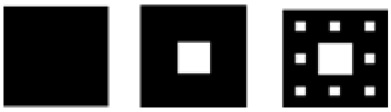

Fig.1. Design of rectangular shape MSCFA.

Therefore, the radiation pattern produced by them, would be the vector sum of the individual ones. In a radio antenna, the feed line or feeder, is the cable or other transmission line that connects the antenna with the radio transmitter or receiver. In a transmitting antenna, it feeds the radio frequency (RF) current from the transmitter to the antenna, where it is radiated as radiowaves. In a receiving antenna it transfers the tiny RF voltage induced in the antenna by the radio wave to the receiver. If these impedances are not matched it can cause a condition called standing waves on the feed line, in which the RF energy is redirected back toward the transmitter, wasting energy and possibly overheating the transmitter. This fine-tuning is done with a device called an antennatuner in the transmitter, and sometimes a matchingnetwork at the antenna. The degree of mismatch between the feedline and the antenna is measured by an instrument called an SWR meter (standing wave ratio meter), which measures the standing wave ratio (SWR) on the line. Single element antenna is not suitable for high gain or high directivity. High gain can be achieved by an assemblage of antennas, called an array. In the construction of an array, feed network design is essential.

II. MITERED BEND FEED NETWORK

In order to guide the signals to/from the elements meter bends are introduced. A 90° bend in a micro strip line produces a large reflection from the end of the line. Some signal bounces around the corner, but a large portion reflects back the way the signal travelled down the line. If the bend is an arc of radius at least three times the strip width, then reflections are minimal. This large bend takes up a lot of real estate compared to the 90° bend. A sharp 90° bend behaves as a shunt capacitance between the ground plane and the bend. In order to create a better match, the bend is mitered to reduce the area of metallization and remove the excess capacitance. The signal is no longer normally incident to micro strip edge, so it reflects from the end down the other arm.

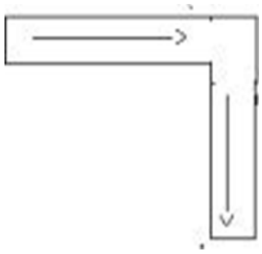

Fig.2. 90° bend.

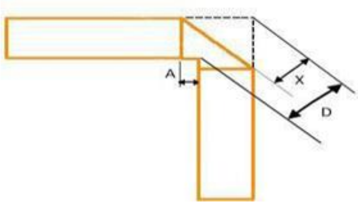

Fig.3. 45° Miter bend

Thefeedlineismiteredbasedonthefollowingequations

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

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

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

WhereWisthewidthofthepatchantenna and histhicknessofthesubstrate(1.6mm).Design requires T junction and miter bending (MBEND) modification to generate low insertion loss at the input port. Mitered T-junction and micro strip bends were applied in order to have low reflection and insertion losses. The mitered T- junction of 3dB power divider is shown in Fig-4.

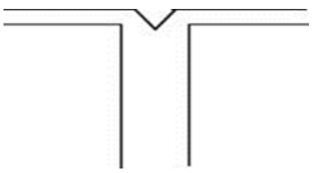

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Fig.4. Mitered 'T' bend.

III. ANTENNA DESIGN

The design starts with Sierpinski Carpet Planar Monopole Antenna. The first basic rectangular patch is designed. In the first iteration, the basic square patch is segmented by removing the middle square from it, by taking scale factor of 1/3rd. For second iteration, scaling is done on remaining eight squares with scaling factor of 1/3rd. The dimensions of the patch are calculated using the formulas given in below

Lengthofthepatchisgivenby

L=Leff-2ΔL (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)

Ratio of fractal length $L_{n} =$ $(1/3)^n$ -----(10)

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

Where n is iteration n^{th} stage number.

IV. IV.DIMENSIONS OF SIERPINSKI CARPET FRACTAL ANTENNA

The patch has the dimensions of 27 mm x 9 mm. For the first iteration, the basic square patch is segmented by removing the middle square from it, by taking scale factor 1/3, so a Rectangular slot of dimensions 9 mm x 5mm is made in the patch. Keeping the first iteration constant. For second iteration segments are done on remaining eight squares following the scale factor of 1/3rd. The second iteration is made with the dimensions of 4 mm x 2 mm.

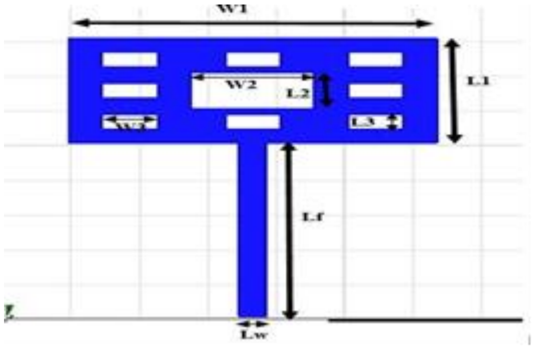

Fig.5. Structure of single element Sierpinski carpet

Dimensions Parameters for proposed MSCFA.

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

Two element Sierpinski carpet antenna array with mitered bend feed network is designed and fabricated.

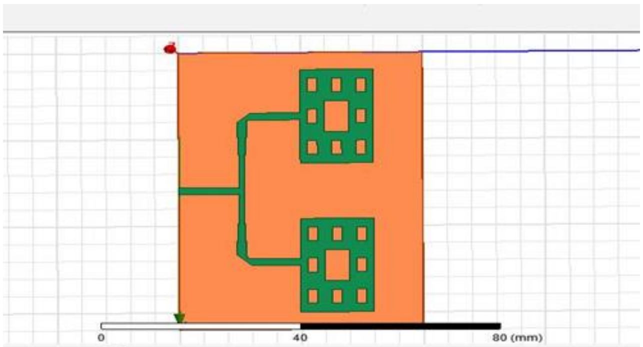

Fig.6. Photograph for MSCFA

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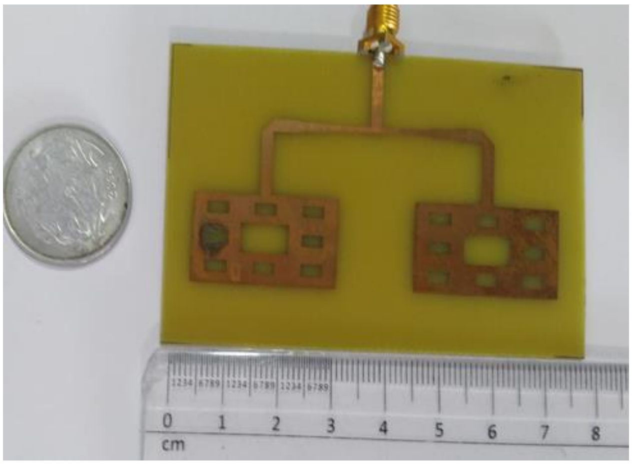

Fig.7. Fabricated MSCFA

Thefabricatedantennashowninabovefigurehavingmicrostriplinefeeding,thetransmissionlineconsistsofmiteredbend.ThesubstrateusedisFR4havingthickness1.6mmwithdielectricconstant4.4.

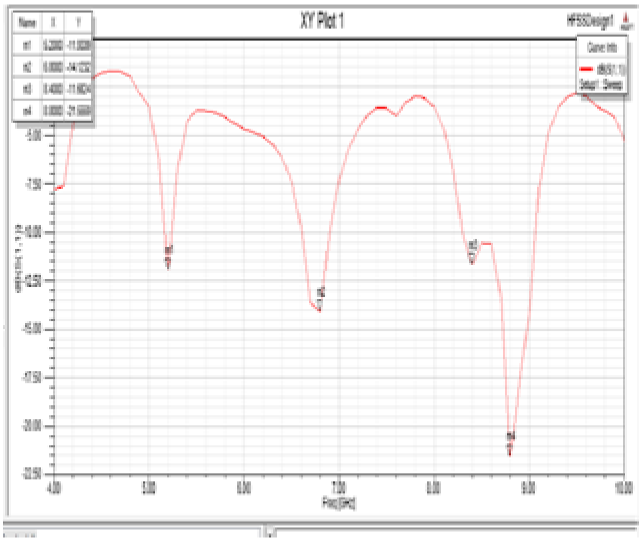

Fig.8. S-Parameter curve for 2 element antenna array

Sparameter(returnloss)showsthattheantennahasresonantfrequencyat4.8GHz S_{11}-12db, 6.8 GHzwith S_{11}=-14db,7.2GHz,S_{11}=-13db, 9.5GHzwithS_{11}=-15dbwhichislessthan-10dB

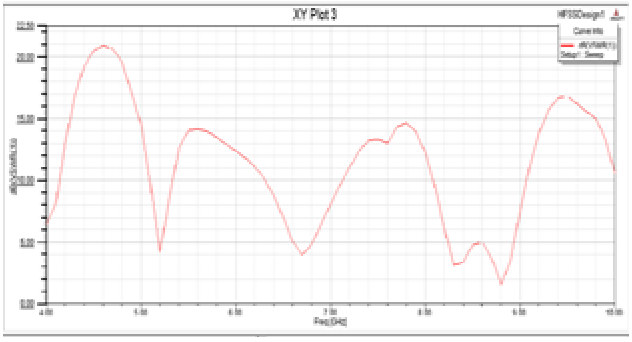

Fig.9. VSWR Curve for 2 element antenna array

Thevoltagewavestandingwaveratioofarrayantennaatresonantfrequency5.2GHzis1.45,6.8GHzis2.02,8.4GHzis1.76,8.8GHzis1.23

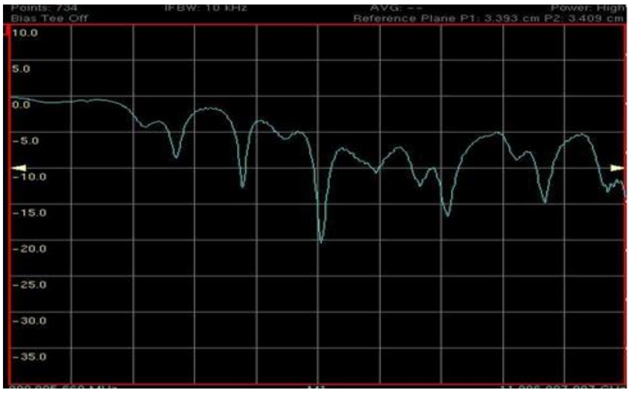

Fig.10. S-Parameter for fabricated 2-element antenna

Sparameter(returnloss)showsthattheantennahasresonantfrequencyat4.8GHz S_{11}-13db, 6.1GHzwith S_{11}=-21db,7.2GHz,S_{11}=-17db, 9.6GHzwithS_{11}=-15dbwhichislessthan-10dB

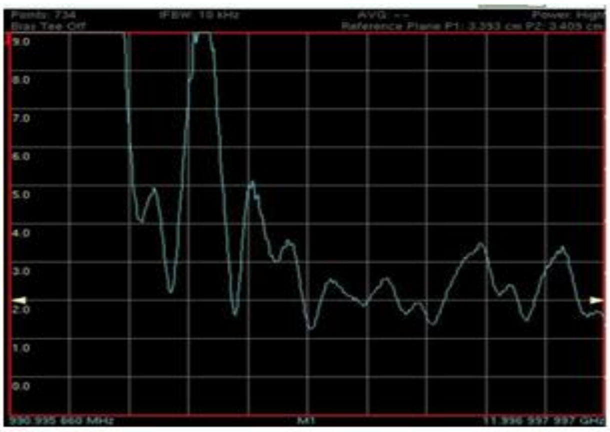

Fig.11.VSWR for fabricated 2-element antenna array

Thevoltagewavestandingwaveratioofarrayantennaatresonantfrequency4.8GHzis1.7,6.1GHzis1.25,7.2GHzis1.45,9.6GHzis1.6

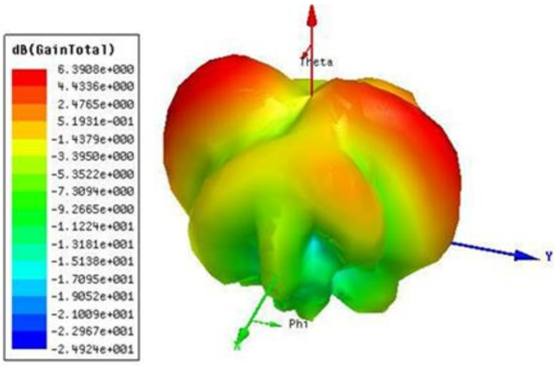

Fig.12.Gain plot for 2-element antenna array

The aboveplot representsthat thearrayantennahasgainof6.39dBbyusingmiteredbend.

V. PERFORMANCE PARAMMETERS FOR THE PROPOSED ANTENNA

VSWR:

Resonant frequencies	Simulatedresults	Fabricatedresults
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:

Resonantfrequencies	Simulatedresults	Fabricatedresults
4.8GHz	-12	-13
6.1GHz	-15.25	-21
7.2GHz	-13.42	-17
9.6GHz	-17.85	-15

VI. 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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