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Design and Analysis of Sierpinski Fractal Antenna Array for Wireless Applications

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Abstract

The growing demand of customers requires reduced size, low profile, multiband and conformal antenna for wireless communication. In this paper, I have presented the Sierpinski fractal antenna array techniques at a different level of iteration. The proposed antenna resonates at multiple operating frequencies, to give broader bandwidth. The simulation of the antenna was done using CAD FEKO software and tested using VNA. The presentation of different level of iterations of antenna shape has been studied in terms of parameters like Bandwidth, Return Loss, VSWR and Radiation Pattern. Compared simulated and the experimental results which are good in agreement. The proposed antenna is suitable for the bandwidth enhancement like 100MHz, 1220MHz, and 2450MHz respectively at resonant frequencies 2.05GHz, 3.68GHz, and 7.85GHz. Designed antenna is suitable for FM radio broadcasting, GPS system, RFID, and fixed microware applications.

Keywords: *Bandwidth Sierpinski structure , VNA, fractal antenna array, GPS, RFID*

1. Introduction

Now a day's wireless communication system (GSM, UMTS, ZigBee) requires a compact antenna which is capable of operating at different bands. Fractal geometry antennas have been studied to answer those requirements [1]. The goal of this work is to research, analyze, and to implement the design of an antenna with the properties of fractal geometry which results in an antenna that resonates at multiple frequencies.

The fractal concept is used as a size reduction technique for different types of antennas such as dipoles, loops, patches, and so on leading to the development of fractal antenna [2]. Studies in this area establish that using fractal structure radiation pattern is much better as compared to the conventional antennas. Usually, a single antenna could work at a single frequency only means multi-band operation could be achieved by using multiple antennas only. Nowadays, to achieve multiband performance a fractal antenna structure is used because of its self-similar structure at different scales [3,4].

The proposed work aims to design a Sierpinski fractal antenna array to give the wide-band and frequency independent behaviour. Physical size of the antenna decides the radiation pattern, which is related to the wavelength of operating frequency. The geometry used in this proposed work is carpet structure or rectangular, which provides the multiband behaviour with improved bandwidth of the antenna. The dimensions of the antenna like, width (W), length (L), substrate dielectric constant are calculated and parameters such as reflection coefficient,VSWR and bandwidth have been studied by simulating the proposed

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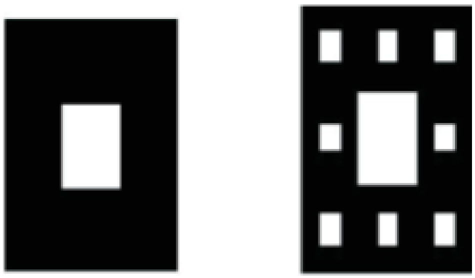
antenna with CADFEKO software. In this work micro strip feeding is used in a parallel fashion to excite the antenna which forms the corporate feed. The design of this antenna is simulated , fabricated and tested with VNA and compared simulated and experimental results.

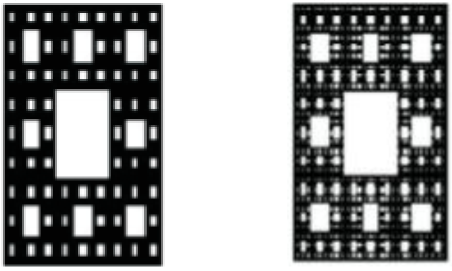
2. Sierpinski Fractal Antenna Array And Its Design

A. Introduction

Figure (1) shows the generalization of the Cantor set to two dimensions. It is created according to the IFS method. A rectangular elementary shape is iteratively shaped, rotated and translated, then removed from the original form to create a fractal [4].



a)Iteration-1 b) Iteration-2



c) Iteration-3 d)Iteration-4

Figure (1) Sierpinski antenna with IFS method

Amongst emerging standards, one of the most promising is the IEEE 802.16 Wireless Metropolitan Area network Air Interface (generally called WiMAX) [5].

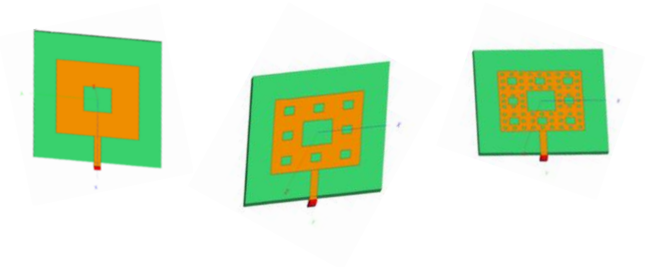
To overcome the disadvantages of Micros trip patch antenna is to construct a multiband antenna by applying fractal shape into antenna geometry [6, 7].The Sierpinski carpet structure is same as the Seirpinski gasket, but it contains squares shapes instead of triangles, as shown in fig 1 for four iterations [8]. Initially, it provides a square in the plane and then divides the square into 9 smaller squares were the open central square is removed. Also, the next 8 squares are divided into nine smaller similar squares for the second iteration and so on for four iterations shown in figure (1). It has efficient radiation-pattern computations and adaptive beamforming, especially for an array with multiple stages of devolopment which contain a relatively large number of elements. The proposed antenna is designed for enhancement of bandwidth by forming the array of antenna with different iterations.

B. Design Values

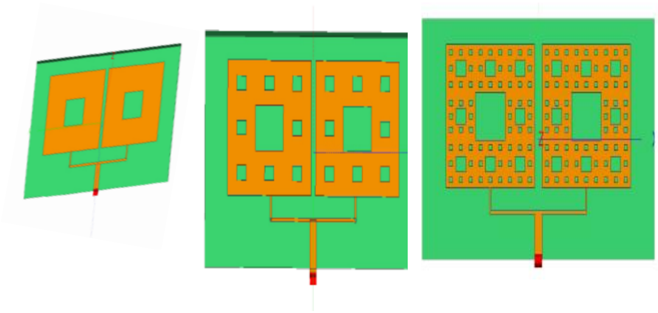
Table (1) describes the design values of the Sierpinski fractal antenna and its array. Figure.3 shows the model of the fabricated Sierpinski fractal antenna array for the third iteration.

TABLE(1) (Dimensions)

Shape of the Patch	Rectangular
Frequency	2.5 GHz
Length of the patch (L)	28.72mm
Width of the patch	37mm
The dielectric constant of the materialSubstrate	4.4
Effective dielectric constant	4.791
Height of substrate material	1.6mm
Substrate length (Ls)	48mm
Substrate width (Ls)	96mm
Feeding Method	Corporate fed/parallel feed



a)1st iteration b)2nd iteration C) 3rd iteration
Figure 2: Seirpinski fractal antenna (1x1)



a)1st iteration b)2nd iteration C) 3rd iteration
Figure 3. Seirpinski fractal antenna (1x2)

The sierpinski array design is in figure (2). which is a linear structure in array pattern. The thickness of dielectric substrate FR4 is 0.003mm and dielectric constants of 4.4. Microstrip is used as feed line with the main track feed forming 50Ω impedance matching with an SMA connector to the source and sub-track of 100Ω which connects two edges of a patch of the antenna in parallel fashion forming a linear array. For the rectangular patch, the length of the element is $\lambda 0 / 3 < L < \lambda 0 / 2$, where λ0 is the free space wavelength.

Figure 2(a-c) represents the iteration wise structure of a single element. But the purpose of the antenna design here is to enhance the bandwidth, but due to single element it is not possible. So array(2x2 element) of seirpinski antenna is designed and achieved the required bandwidth which is shown
Below figure 3.

3. Simulation and Fabrication Results and Discussion

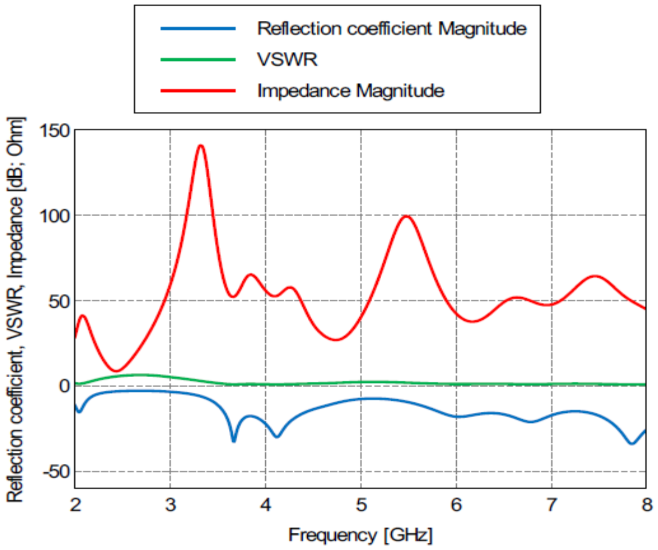


Figure 4: Simulation results with measured values.

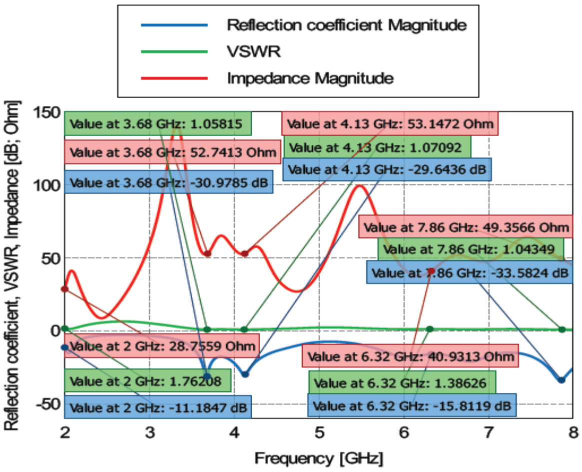


Figure 4 Simulation results

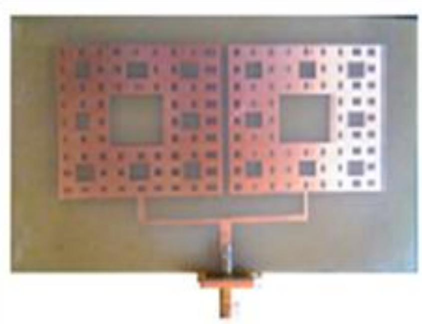


Figure 5 Fabricated antenna

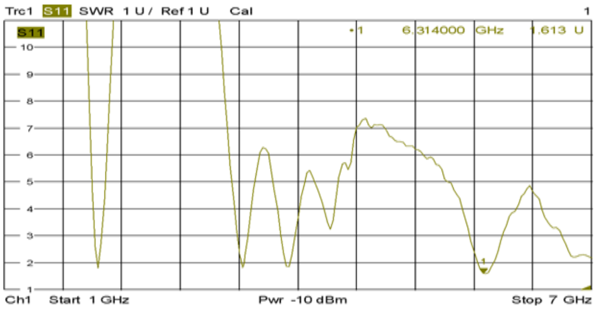


Figure 6 VSWR of fabricated antenna.

Figure (4) dicipates the simulation results of Sierpinski fractal antenna array, how reflection coefficient, Bandwith and VSWR is varying with frequency. Figure 5 repersents the model of fabricated antenna and figure (6-8) describes about how the variation of reflection co efficient , VSWR and a bandwidth for different operating freuency are achived , that indicates the proposed antenna is satisfying the condition of multiband frequency operation.

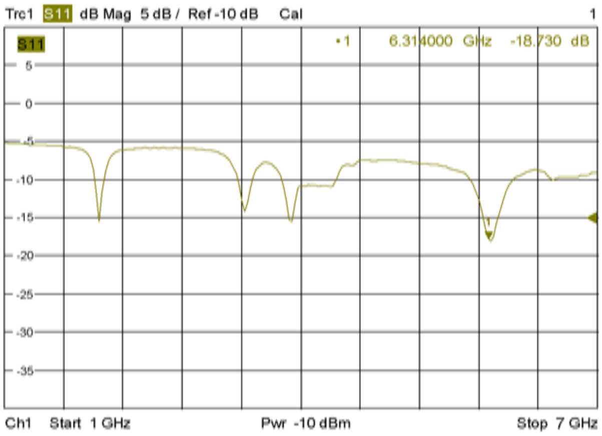


Figure 7 Reflection coefficient of fabricated antenna

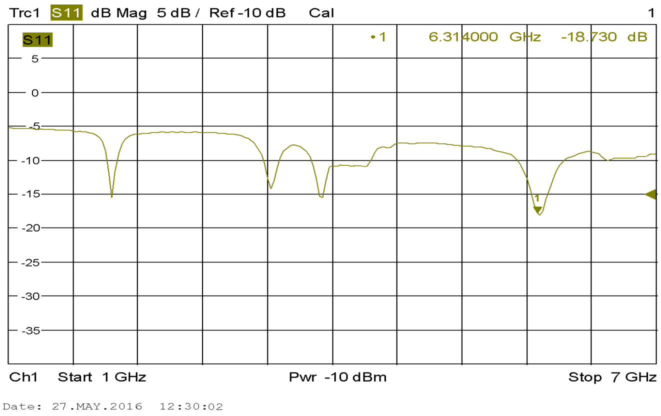


Figure 8 Reflection coefficient and Bandwidth

Table 2. Comparision of Simulated and experiment results

In Table 2, simulated and experimental parameters are illustrated. A reflection coefficient is defined as the amplitude or the intensity of a reflected wave relative to an incident wave. The ideal value of reflection coefficient is less than -10dB which corresponds to VSWR of less than 2. The reflection coefficient of the fabricated antenna is -15.006dB, -14.07dB, -15.976dB, -18.776dB at respective resonant frequency 2.12GHz, 3.905 GHz, 4.30 GHz, 6.320 GHz achieved the bandwidth at -10dB as 289 MHz, 315 MHz, 730 MHz, 805 MHz. And simulated reflection coefficient of fabricated antenna is -17.63dB, -29.31dB, -28.05dB at respective resonant frequency 2.1GHz, 4.52GHz, 6.31GHz achieved the bandwidth at -10dB as 149.8MHz, 1.1262 GHz, 848 MHz. VSWR is a measure of how well antenna is matched to the cable impedance. A perfectly matched antenna would have a VSWR of 1:1. This ratio indicates how much power is reflected or transferred into a cable. The ideal value of VSWR is lying in between 1 to 2.It have been observed that VSWR for Simulated and Fabricated SFAA is 2.531, 0.524, 0.687 and 1.850, 1.901, 1.890, 1.601

Sr No.	**Iteration wise Result**	**Frequency GHz**	**Reflection Co efficient**	**VSWR**	**Bandwidth**
1	1st (1×1)	2.12, 3.77, 4.27	-29.42 -27.9 -28.4	0.58 0.83 0.69	140 MHz 1.51 GHz
2	2nd (1×1)	4	-0.92	2.44	-
3	3rd (1×1)	2.09, 3.71, 4.23	-46.06 -25.8 -34.4	0.08 0.9 0.45	140 MHz, 1.501GHz
4	1st (1×2)	3.95, 5.67	-0.1115 0.19	-4 3	-
5	2nd (1×2)	4.048	-20.29	1.21	1.0482 GHz
6	3rd (1×2)	2.1, 4.52, 6.31	-17.63 -29.31 -37.66	1.340, 1.084, 1.082	149.8MHz, 1.1262 GHz 848 MHz
7	Experimental results	2.12 3.905 4.30 6.320	-15.006 -14.07 -15.976 -18.776	1.850, 1.901, 1.890, 1.601	289 MHz, 315 MHz, 730 MHz, 805 MHz

The antenna bandwidth is defined as the range of usable frequencies on either side of the centre frequency. The bandwidth is measured at less than equal to -10dB over which the frequency is useful for the application. The bandwidth of SFAA is also improved. The overall gain of SFAA improved up to 7dB.

4. Conclusion

In this paper, it is described, briefly about all antenna parameters. The parameter such as Reflection Co-efficient, Bandwidth, VSWR, and Radiation pattern is concentrated more. The simulation is carried for different iterations of Sierpinski fractal antenna (1×1) and Sierpinski fractal antenna array (1×2). It is observed that the SFAA (1×2) with 3rd iteration shows improved performance over at Sierpinski fractal antenna (1×1) at 3rd iteration. The micro-strip, fed Sierpinski fractal antenna array has been designed and simulated using CAD-FEKO software. Experimental and simulation results are compared and SFAA implemented shows multiple resonances. The size of the patch is decreases by 33.9% of the traditional micro strip antenna array. Sierpinski fractal antenna array (1×2) shows multiple resonances at 4 bands with an increase in bandwidth compared to Microstrip antenna bandwidth which is inherently narrow band.

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