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A Tree-Shaped Sierpinski Carpet Fractal Antenna for 5G Applications

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Abstract

A Tree-shaped Sierpinski Carpet fractal antenna is discussed here. The proposed antenna intended for triple-band and 5G applications. A tree-shaped antenna is constructed by using iteration 3 to a square patch antenna with a Sierpinski carpet fractal in it and that patch is connected through rectangular connectors. The designed antenna structure is fed by microstrip feed and simulated using ANSYS HFSS software. The substrate material used in the designing process is FR-4 glass epoxy of height 1.60 mm and a relative permittivity of 4.4 and a dimension of the substrate is 110 x 90 mm2. The proposed antenna works for several services like Wi-Fi, Wi-Max, Ku, K, and Ka bands. It is suitable for UWB and 5G applications. The proposed tree-shaped structure provides a peak gain of 6.8 dBi and the simulated result covers triple-band.

1. Introduction

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Nowadays, as wireless communication technology and its applications develop rapidly. Subsequently, it is important to construct antennas with lightweight, low cost, multiband frequency operation, and minimal effort. There are now numerous sorts of antennas that have been proposed to accomplish multiband capacities. To get multiband improvement, different design techniques have been examined including Slot-loaded advancements, coupling feed advances, loading the matching network, and fractal innovations [1]. Mostly for multiband operation, wide bandwidths and high gain requirement microstrip patch antenna is designed using fractal design techniques. [2].The relationship between fractal and nature is first described by Benoit Mandelbrot in 1970. The word "fractal" roughly defined as broken lines or fragmented geometric shapes that can be reduced to a size copy of the original shape [3]. Fractal antennas have a very basic level arrangement with two properties: self-likeness and space filling which is utilized to build the antennas electrical length and radiation efficiency[4]. Particularly applications where large spectral bandwidth is necessary the fractal antenna are used because of its space-filling and self-similarity properties [5]. In recent communication systems, for USB multiband and wideband fractal antenna are desired. Wideband antennas are used in applications such as RADAR, Unmanned aerial vehicle for ground moving target indication, to cooperate with increasing data rate demand antenna with smaller in size, and wideband width characteristics are required. According to FCC Federal Communications commission's, the UWB frequency ranges start from 3.1 GHz to 10 GHz. As in conventional for covering maximum bandwidth, the UWB antenna is generally large in size. To overcome this issue, the fractal antenna uses its space-filling property to avoid large dimension antenna. UWB fractal antenna is designed and tested which shows UWB characteristics and small size antenna in [6]. There are some conventional structures, for example, Koch, Box, Sierpinski, Cantor, and Mandelbrot fractal. In fractal shape antennas, the tree-shaped fractal antenna is very much useful in designing of the UWB antenna [7]. In 1916, The Sierpinski Carpet was presented by a clean mathematician Waclaw Sierpinski, it is a significant piece of the fractal set[8]. The Sierpinski Carpet development is begun with a rectangle and the 9 simultaneous sub-rectangle is cut from that rectangle in 3-by-3 lattice then the inside sub-rectangle is removed from the fundamental rectangle [9]. T. Shanmuganantham etal, discussed the different shapes of fractal antennas are given in [11]-[14].

2. Antenna Design and Specifications

The proposed Sierpinski Carpet fractal tree-like structure antenna is designed on FR-4 glass epoxy material with relative permittivity 4.4, loss tangent is around 0.02, and the height of the substrate is 1.60 mm. For designing the primary antenna structure, initially, a basic square fix is planned with the Sierpinski cover plan in it are associated with a rectangular connector as appeared in figure 2.

The designed structure uses microstrip fed utilized to broaden the transmission capacity, and the general dimension is 110 × 90 × 1.6 mm3. The overall area of the antenna, as substrate length 90 mm and width 110 mm respectively. The ground plane dimension is equal to the measurement of the substrate and square patch side measurement as 32mm. The designed antenna structure has appeared in figure 2 with the designing parameter given in Table 1.

Table 2: Designing parameter of 2nd order antenna

Parameter	L	W	LT	L1	Lw	R1	C1	Lw1
Spec	90	110	16	32	5	16	8	2

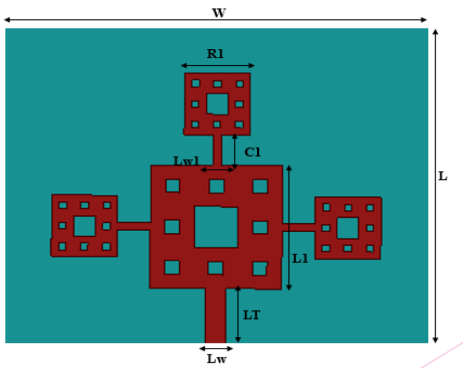

Fig.3 Second order antenna design

Table 3: Designing parameter of 3rd order antenna

Parameter	L	W	LT	L1	Lw	R1	C1	Lw1	R2	C2	Lw2
Spec	90	110	16	32	5	16	8	2	8	4	1

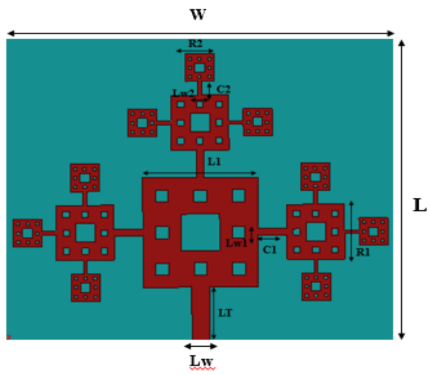

Fig.4. Third order antenna design

3. Results and Discussion

The designed tree-shaped Sierpinski carpet fractal antenna all parameter computation and evaluation are done in the HFSS software package as a simulation tool and final measurements are recorded in Table 3. Return Loss is demonstrated by S11 Parameter. The characteristics of iterated Sierpinski carpet fractal tree-shaped antenna show various results in terms of reflection coefficient, voltage standing wave ratio, and field gain. A structured design recreated and shows the distinctive frequency which covers the UWB and triple-band application. Simulated antenna design return loss has appeared in figures 5(a), 5(b), and 5(c).

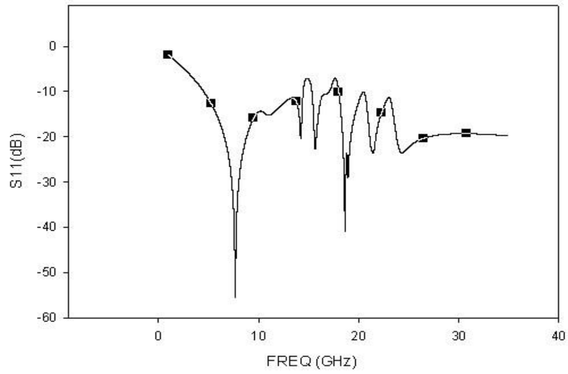

Fig.5(a) - S Parameter characteristic of first iteration

In the above figure 5(a), it shows the band secured by the first iteration of the proposed antenna from 4 GHz to 17.1 GHz, 18 GHz to 23 GHz, lastly from 23.3 GHz to 35 GHz.

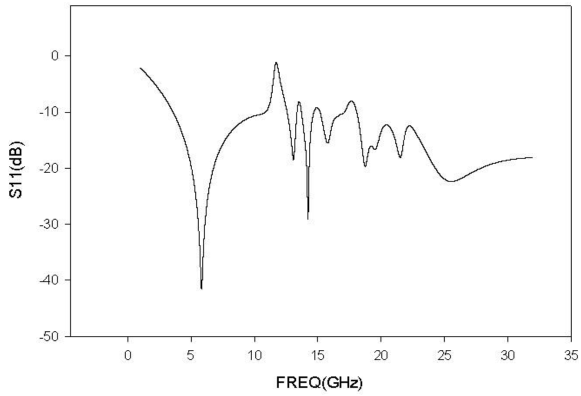

Fig.5(b) - S Parameter characteristic of second iteration

In Figure 5(b), it shows the band secured by the second iteration of the proposed antenna from 5 GHz to 14.6 GHz, 15.2 GHz to 17 GHz lastly from 18 GHz to 35 GHz.

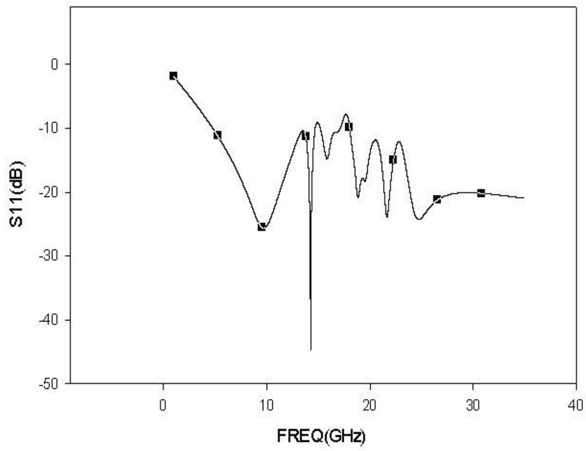

Fig.5(c) - S Parameter characteristic of third iteration

In the above figure 5(c), it shows the band secured by the tree-shaped fractal antenna is from 5 GHz to 14.6 GHz, 15.2 GHz to 17 GHz lastly 18 GHz to 35 GHz. From the above figure 6, the simulated result obtained from the designed structure has great VSWR execution which is under 2 for the distinctive operational band which is required for UWB and 5G applications.

Table 4 – Comparison table

Frequency band	1ST Order Iteration	2nd Order Iteration	3rd Order Iteration
	Bandwidth (GHz)	Bandwidth (GHz)	Bandwidth (GHz)
1	4-17.1	5-14.6	3.1-14.6
2	18-23	15.2-17	15.1-17.1
3	23.3-35	18-35	18-35

Simulated results for 1st order iteration, 2nd order iteration, and 3rd order iteration appeared in figure 5(a), 5(b), and 5(c). Furthermore, the comparison of triple-band secured by the proposed antenna for first order, 2nd order, and third-order iteration appeared in above Table 4.

4. Conclusion

This paper presents another fractal tree-like structure on a square patch with Sierpinski carpet fractal in it. The simulation result of the tree-shaped fractal design secured triple-band ranges (3.1–14.6 GHz), (15.1–17.1 GHz), and (18–35 GHz) for return loss less than -10dB with maximum gain 6.8 dB at the various resonances frequencies. These outcomes make the introduced antenna appropriate for the triple-band, UWB, and fifth-generation applications. The reproduced outcome reveals the proposed design results give great s11 characteristics and it has a better return loss of - 47.47 dB at 14.3 GHz and this fractal antenna is most appropriate for a triple band and 5G applications.

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