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Sierpinski Fractal Antenna for SWB Application

Ms.Arumugapriya.E(1) ,Mr.Sathis kumar.N.R(2),Dr.Ramasamy.K(3)
PG Student(1), Assistant professor(2),Principal(3)
Department of ECE(1),(2),(3)
P.S.R.Rengasamy College of Engineering for Women(1),(2),(3)
Sivakasi, India
E-mail:priyaelango.mail@gmail.com(1),sathiskumar@psrr.edu.in(2)

***Abstract*— An antenna is a transducer. It convert electrical energy into radio wave and vice versa. It has reciprocity property. The transmission line of the antenna must maintain 50ohm impedance. A compact octagonal Sierpinski fractal antenna for super wide band application is presented. It consists of an octagonal radiation patch with two iterations of Sierpinski square slots and aperture coupling feeding technique. A resonant frequency of 39GHz is achieved. Desirable antenna characteristics including return loss and omni-directional radiation patterns are obtained for this range.**

Keywords—Octagonal patch; Aperture coupling;Two iteration

I. INTRODUCTION

Wireless communication systems have witnessed tremendous developments in recent years. As the technology is developed, The demands for the coverage of both long-range and short-range frequency spectra is also increased. Though the planar UWB antenna structures having operating band from 3.1 to 10.6 GHz are able to cover the short-range communication. The current users of wireless personal area network are eagerly demanding a super wideband (SWB) to cover both short- and long-range transmission for future UWB communications. The term SWB refers to the ratio bandwidth of 10:1 or more at 10 dB return loss [1]. Owing to its ability of extremely large bandwidth and high data rates, SWB technology is now becoming an essential part of modern wireless communication and finding its application in military and civilian systems. In the literature, few SWB antennas are already reported in the planar domain [2–16]. The challenge faced by antenna researchers is to miniaturise the antenna size without affecting the bandwidth and pattern stability.

In [2], iterations of hexagonal slot loaded circular radiator fed by a microstrip line and asymmetrical with respect to the partial ground plane were used to design a circular–hexagonal fractal SWB antenna. In [3], the asymmetrical ground plane of a microstrip-line-fed monopole was loaded with a triangular notch and a semi-elliptical fractal-complementary slot to achieve SWB characteristics. A tapered CPW-fed elliptical SWB monopole antenna comprising trapeziform ground plane and having dimensions of 120 × 140 mm2 was presented [4] to cover a bandwidth of 0.41–8.86 GHz. A coaxial probe fed asymmetrical circular dipole antenna was designed on two different substrates for SWB applications [5]. The designed antenna configurations cover frequency spectrum from 0.7969 to 17.4663 GHz and 2.6569 to 10.6948 GHz with overall dimensions of 135 × 90 and 39.5 × 36.9 mm2, respectively. Two stepped feedline was used to design a circular disc antenna which covers an impedance bandwidth of 2.7–28.8 GHz. In [7], modified radiator shape, tapered microstrip feedline for impedance conversion and a double corner rounded ground plane for improvement of impedance matching in high-frequency band were used to design an SWB monopole antenna. On the other hand, the methods of using modified radiator, top corner rounded trapezoidal ground plane and tapered feedline were implemented to design an SWB antenna [8]. The circular shape of the radiator was replaced by propeller shape to enhance the impedance bandwidth from 1–11 to 3–35 GHz [9]. A second iterative octagonal SWB fractal antenna having operating range of 10–50 GHz and overall dimensions of 60 × 60 mm2 was presented [10]. In [11], three elliptical radiators were used in a dual polarised antenna pair to achieve polarisation diversity performance along with super wide bandwidth of 0.86–30 and 1.04–27.2 GHz at two ports. The rectangular monopole was loaded with staircase-shaped sections and rectangular stubs are mounted on top of the quarter-circle slot ground to cover frequency spectrum from 3.15 to 32 GHz [12]. In a printed slot antenna [13]

An elliptical-slot antenna augmented with a parasitic oval patch and a specially engineered microstrip-line-fed elliptical tuning fork element were used to achieve an operating bandwidth of 2.26–22.18 GHz. In [14], circular sectors matched directly to 50 Ω and full structure instead of half structure were used to improve the bandwidth performance of an SWB antenna. In [15], the hexagonal radiator loaded with two iterations of the triangular slots and

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semi-circular ground planes were utilised to achieve SWB characteristics. All these structures have used Fire Resin-4 (FR-4) epoxy as the antenna substrate due to its low cost [2–16]. In parallel to this, some researchers have avoided FR-4 substrate due to its lossy performance at very high or millimetre range frequencies [17, 18]. Unfortunately, all these SWB structures have large dimensions.

II. ANTENNA

A. Microstrip antenna

The Microstrip Patch Antennas (MPA) is widely being used because of its low volume and thin profile characteristics. The size of MPA is basically determined by its resonance length and width. The reduction of the patch size can be achieved by using patch substrate material with very high permittivity and small substrate height . But, in this case, the low radiation efficiency will reduce the antenna gain.

A microstrip antenna in its simplest form consists of a radiating patch on one side of a dielectric substrate and a ground plane on the other side

Patch: is a radiant conductive element and which can take several forms.

Substrate: allows to isolate both conductive planes, characterized by the permittivity.

Ground plane: is a conductor situated below the circuit on which is placed the substrate.

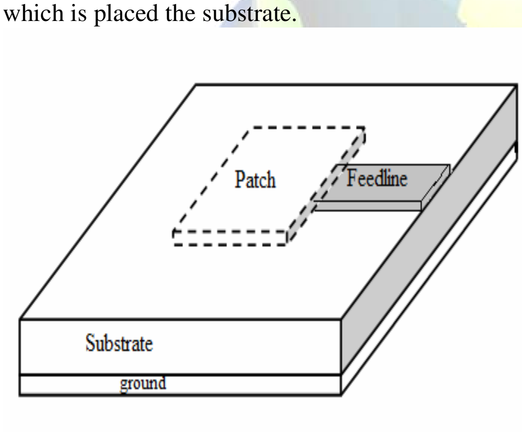

Fig.1a Structure of microstirp patch antenna

B. Fractal antenna

Fractal geometry is emerged as a very good solution to achieve broadband characteristics without increasing the antenna size. The self-similarity property of fractal geometries causes multiband or broadband behaviour. The space filling property leads to size reduction.

In this paper, an octagonal Sierpinski fractal antenna is designed. The conventional octagoanal radiating patch is loaded with two iterations of square Sierpinski fractal slots to achieve SWB bandwidth. Impedance matching over a wide frequency spectrum is achieved by feeding the radiating patch by an aperture coupling feeding. The simulation of the antenna structure is carried out by using Ansoft's finite element method-based high-frequency structure simulator (HFSS)

C. Aperture coupling

An aperture coupled antenna eliminates direct electrical connections between the feed conductor and radiating patch, and the ground plane electrically isolates the two structures. The two dielectric substrates can be selected independently to optimize both microstrip guided waves and patch radiating waves. Aperture coupled antennas are advantageous in arrays because they electrically isolate the feed and phase shifting circuitry from the patch antennas. It automatically reduce the cross polarization

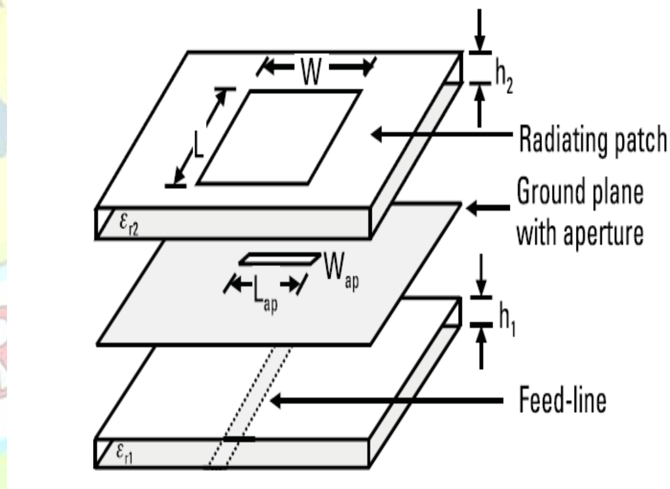

Fig.1b Aperture coupling

III. ANTENNA DESIGN

A. Antenna designing parameter

Antenna designing parameter helps to design the radiation patch. The length and width of the patch is calculated using specified formulas. In square patch length and width oh the patch is calculated. In circular patch radius of the patch is calculated

$$a = \frac{F}{\left\{1+\frac{2h}{\pi\epsilon_r F}\left[\ln\left(\frac{\pi F}{2h}\right)+1.7726\right]\right\}^{1/2}}$$

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Where,

$$F = \frac{8.791 \times 10^9}{f_r \sqrt{\epsilon_r}}$$

$€_r$ -Substrate dielectric constant

h - Height of substrate

f_r - Resonant frequency

a - Patch radius

B. Octagonal shaped fractal antenna design

The configuration of the designed antenna structure is illustrated in Fig. 2a and optimised values of various dimensions are listed in Table 1. It is designed on Roger R04232 substrate having dielectric constant of 3.2, loss tangent of 0.002 and a thickness of 1.27 mm. This antenna structure consists of an octagonal radiator loaded with two iterations of square slot to form the octagonal Sierpinski radiator, aperture coupled feedline and rectangular ground. [6] proposed a novel method for secure transportation of railway systems has been proposed in this project. In existing methods, most of the methods are manual resulting in a lot of human errors. This project proposes a system which can be controlled automatically without any outside help. This project has a model concerning two train sections and a gate section. The railway sections are used to show the movement of trains and a gate section is used to show the happenings in the railway crossings. The scope of this project is to monitor the train sections to prevent collisions between two trains or between humans and trains and to avoid accidents in the railway crossings. Also an additional approach towards effective power utilization has been discussed. Five topics are discussed in this project : 1) Detection of obstacles in front of the train;2) Detection of cracks and movements in the tracks;3) Detection of human presence inside the train and controlling the electrical devices accordingly 4) Updating the location of train and sharing it with other trains automatically 5) Controlling the gate section during railway crossing. This project can be used to avoid accidents in the railway tracks.

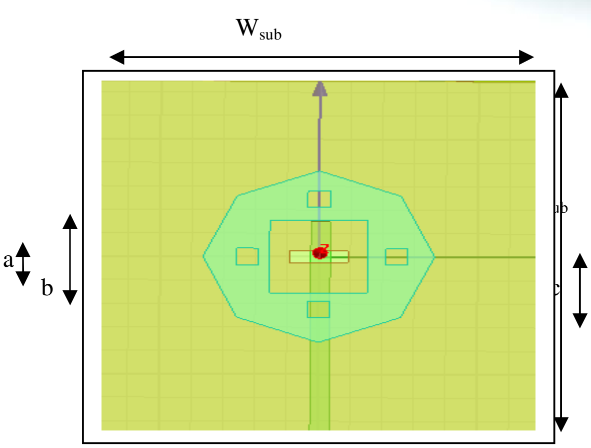

Fig.3 Geometry of the designed antenna

planes. The reason behind using the octagonal radiator is that the bandwidth performance of a circular patch antenna is better in comparison with any other geometry and octagonal geometry is approximately equal to that of circular patch. The dimensions of the microstrip feedline are calculated by using the standard equations . The rectangular ground plane neutralized the inductive effect of the radiator by producing capacitive effect resulting into purely resistive impedance of the antenna structure. Aperture coupling feeding technique is utilised due to its several advantages , avoid cross polarization, less losses etc. All the antenna dimensions are optimised by using HFSS. All the antenna parameters are optimised stepwise. During the stepwise optimisation, one parameter is varied at a time while keeping all other parameters constant. In each optimisation that value of parameter is chosen for which impedance bandwidth performance is better than other values.

Table1: Optimised dimensions of the octagonal antenna

Dimension	Value,mm
L_{sub}	30
W_{sub}	28
a	1.4
b	6.19
c	7.3

The basic or zeroth iteration of the designed antenna structure consists of an octagonal radiator, aperture coupling feeding and rectangular ground planes symmetrical to the feedline. This octagonal radiator is loaded with a rectangular slot due to the fact that the current density is concentrated along the periphery of the radiator and zero or negligible current is present at the central portion. So removal of this zero current density portion does not affect the antenna performance. This slot loading resulted into first iteration of the antenna structure. Thereafter, this central square slot is scaled down by a ratio of 0.33 and the resulting squares are etched out in the surrounding of central slot from the first iteration structure to derive the second iterative structure.

IV. RESULTS AND DISCUSSION

The two iterations of designed antenna structure are shown in Fig.4. The reflection coefficient versus frequency plots of second iteration demonstrated in Fig. 4d and listed the three iteration comparison in Table 2.

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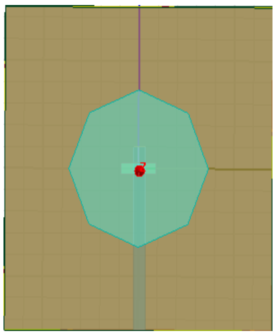
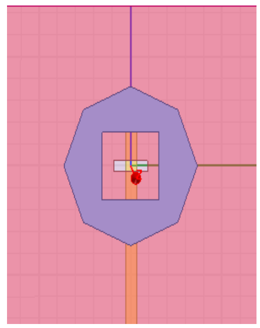
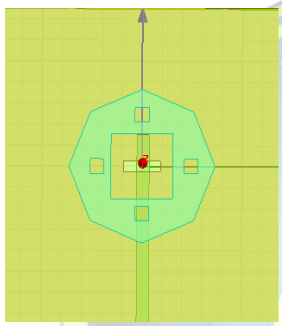


a



b



c

Fig.4 Iteration structures of the octagonal sierpinski antenna
a.Zeroth
b.First
c.Second

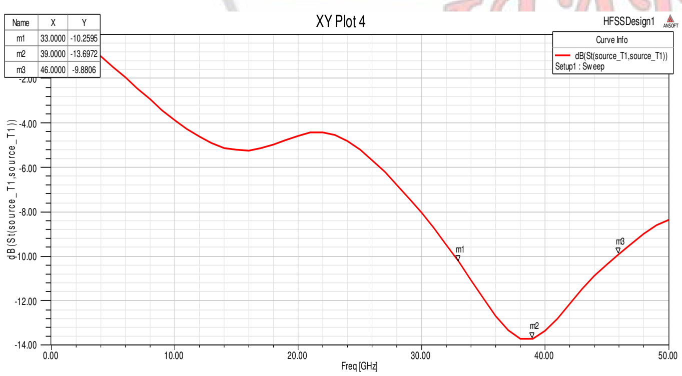


Fig.4d Returnloss

It is observed that for octagonal radiator, dual operating bands, i.e. 39-42 GHz and 33-46 GHz are achieved. In case of first iteration, i.e. octagonal radiator loaded with a square shaped slot, the lower and higher band edge frequencies of both operating bands got shifted toward lower frequency. For second iterative structure, two operating bands got merged resulting into a wide operating band from 33 to 46 GHz. This signifies that the impedance bandwidth has got enhanced on increasing the number of iterations. Owing to practical limitations, third iterative structure is not designed or analysed.

Table 2: Bandwidth comparison of iterative structures

Iteration	f_L(GHz)	f_H(GHz)	BW(dB)
Zeroth	39	42	3
First	39	42	3
Second	33	46	13

The antenna characteristics are analysis using HFSS. In HFSS the analysis is carried out by dividing the frequency spectrum in to multiple parts. It is observed the simulation and experimental results are in good agreement.

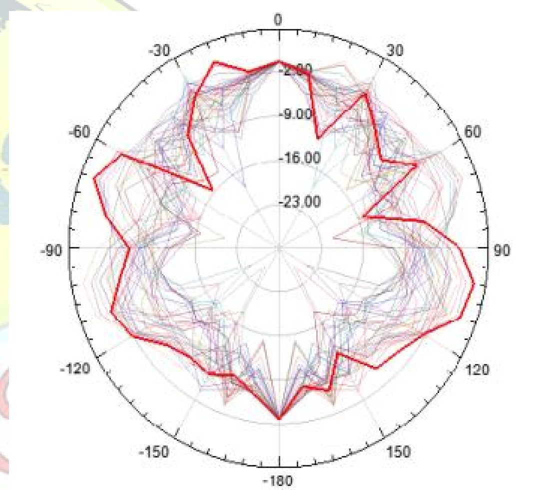


Fig.4e Radiation pattern

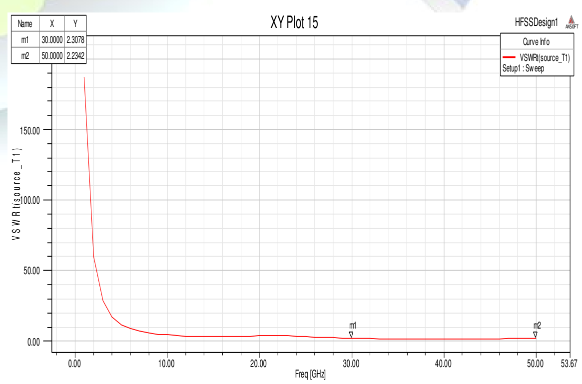


Fig.4f VSWR

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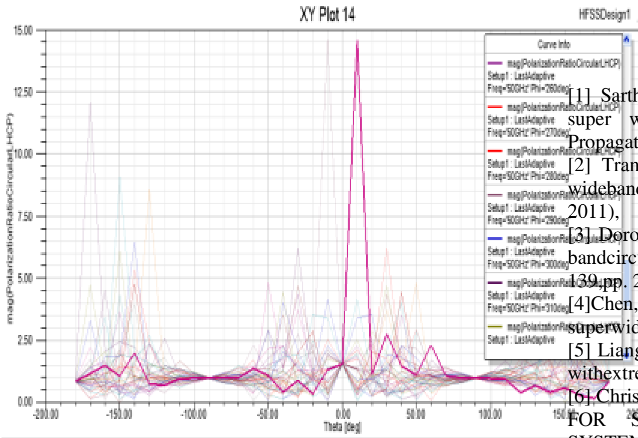

Fig. 4g Polarization ratio

v.Conclusion

A compact octagonal Sierpinski fractal antenna for SWB applications is investigated for SWB applications. The designed antenna structure is derived from a conventional octagonal shaped aperture coupling fed antenna by loading the radiator with two iterations of square slots to achieve the Sierpinski structure. The experimental results have validated the simulated results and thus justified the suitability of this antenna structure for SWB applications. The comparison of the designed antenna structure with other antenna structures available in the literature is done in terms of a well-defined termof antenna characteristics. The comparison in terms of BW verified the advantages of miniaturised size and wide bandwidth provided by this antenna structure over other antenna structures.

Owing to the advantages of miniaturised size and wide bandwidth over other antenna structures, this antenna structure will be useful for UWB applications, mobile applications, wireless access systems (WAS)/radio local area networks (RLANS) (17.1–17.3 GHz), satellite applications, defence systems, broadband disaster relief applications (BBDR) (4.94–4.99 GHz), radio determination applications (4.5–7 GHz, 13.4–14 GHz), Doppler navigation aids, radio astronomy (22.5 GHz, 24.05–27 GHz, 36.43–36.50 GHz), short-range radar (SRR) (21.4–27 GHz), industrial, scientific and medical (ISM) (24.25 GHz), wideband high definition television, aeronautical radio navigation, very-small-aperture terminal (VSAT)/Satellite News Gathering (SNG)

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