PLUS-SHAPE SLOTTED FRACTAL MICROSTRIP ANTENNA DESIGN FOR WIRELESS APPLICATIONS

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ABSTRACT

In this study, a novel method for designing a Plus Slotted Fractal Antenna is proposed, which combines a fractal antenna with defected extended ground. The Plus Slotted Fractal Antenna has a height of 1.6mm and a permittivity of 4.4 on a FR4 substrate. Up to the second iteration, the Plus Slotted Fractal Antenna is designed. Antennas with Plus Slots are simulated using High-Frequency Structure Simulator (HFSS) software. The proposed antenna produces a 3.68GHz resonance frequency. To increase the antenna bandwidth, a rectangular slit is etched at the proposed antenna's enlarged ground plane. Through the use of a microstrip line feed and a defective and expanded ground plane in the plus slots fractal design proposed antenna, a wide band is accomplished. Analysis is done on the proposed antenna's performance parameters based on VSWR, Efficiency, Gain, Radiation pattern, and Return loss.

Keywords — Gain, Return Loss, Bandwidth, and Fractal Microstrip patch antenna (FMPA).

I. INTRODUCTION

An antenna is a device that is used to both emit and receive electromagnetic waves. Any Microstrip Patch Antenna (MPA) consists of three fundamental layers: substrate, patch, and ground plane. The layer in between the patch and the ground is called the substrate. Permittivity ratings of substrate material vary. Patch antennas are crucial in today's antenna technology [1][2]. Patch antennas are attractive because they are lightweight, low profile, easy to construct, and inexpensive [3–4]. However, conventional patch antennas have certain drawbacks, including low gain, low efficiency, and a narrow bandwidth. Patch antennas can have their gain and bandwidth increased by utilising a variety of feeding mechanisms [5]. Because different antennas are needed for different applications, limited space difficulties arise. Using a multiband antenna, which can function on many frequencies, this issue is resolved. Fractal antennas are employed for multiband applications [6]. The slot antenna is a common choice because to its ability to be sliced into the desired mounting surface and its nearly unidirectional radiation patterns. Similar to a dipole antenna, the slot emits electromagnetic waves. when a driving frequency is applied to the plate, acting as an antenna [7]. It is suggested to use a triangular ring slot antenna with a 5.5GHz operating frequency. Other harmonics are generated in addition to this fundamental mode[8]. UWB is defined by the Federal Communications Commission (FCC) as a transmission with a theoretical bandwidth of 500MHz. The unlicensed use of spectrum from 3.1 to 10.6GHz for UWB wireless communications has made it possible to create ultra-Wideband devices and, consequently, an appropriate antenna [9]. In the modern world, when wireless systems are ubiquitous, UWB systems' main feature—using short pulses to carry data over a wide bandwidth at incredibly low power—makes them more suited for usage with personal devices [10]. It is crucial to preserve the antenna's fundamental qualities, which include low profile, affordability, and ease of fabrication [11]. A family of shapes known as fractals lacks distinctive size. Every fractal is made up of numerous iterations of the same basic shape, which can be repeated indefinitely to generate shapes that are both infinitely long and infinitely wide within finite boundaries. Features of fractal include the following 1) It is simple and recursive 2) It is too irregular to be effectively stated in typical Euclidean geometric terms 3) It is self-similar and 4) It has a finite structure at arbitrarily tiny sizes [12]. Our present effort focuses on creating a wide band, which results in increased bandwidth and smaller antennas. A square patch is used as the basis form, and in the first iteration, the plus shape of the slot is etched onto the patch. Additionally, the plus shape is removed from the center of the ground plane, which is regarded as defective ground. Likewise, additional plus-shaped slots are added to the patch's center plus slot at even smaller scales in the subsequent iterations. It is discovered that the resonance frequencies decrease relative to the zero iteration, which is equivalent to a traditional patch, as the iteration number and iteration factor grow.

II. ANTENNA DESIGN CONSIDERATION

The microstrip's base square shape, as depicted in Figure.1. is formed on a dielectric substrate having a relative dielectric constant of ε_r = 4.4 and a thickness of 1.6mm. This is the reference antenna or basic shape. The antenna is excited by the width and length of the microstrip line feed, which are W_f = 2mm and L_f = 7.2mm, respectively, and correspond to an operating frequency of 7.12GHz. The length and width of the conventional antenna are L = 8.8mm, W = 10mm, and the substrate length and width are Ls = 25mm, and Ws = 25mm. The high-frequency modelling program HFSS V-15 is used to develop and optimize this antenna. Vector Network Analyser is used to manufacture and verify the antenna through experimentation. The initial iteration is shown in Figure. 2. Here, the antenna's base shape is further altered by adding plus-shaped slots to the patch's centre. Furthermore, a plus-shaped slot is etched at the ground plane to increase bandwidth. Figure.3(a) depicts the proposed antenna's top view. To reduce the size of the proposed antenna, six plus-shaped slots are etched around the central plus-shaped slot. This fractal approach is used to reduces the size of the antenna, the rectangular slot at the ground plane of the proposed antenna is etched, as shown in Figure.3 (b). A (25 x 25.3)mm^2 ground plane is visible at the top of the proposed antenna in Figure.3.(c), and a 3 mm gap is employed between ground surfaces at the bottom. This configuration was included in the proposed structure to increase bandwidth and gain.

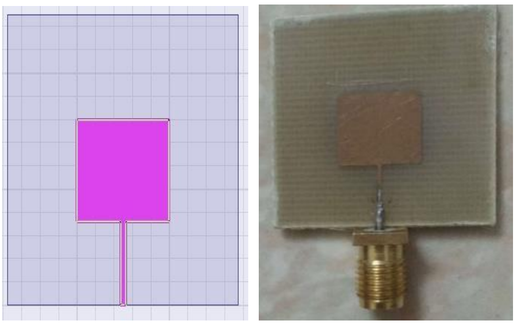


Fig.1. Simulated and Fabricated Conventional Antenna

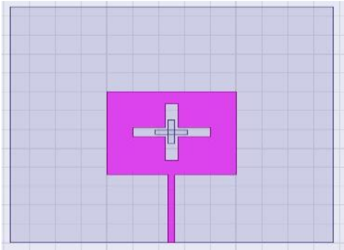
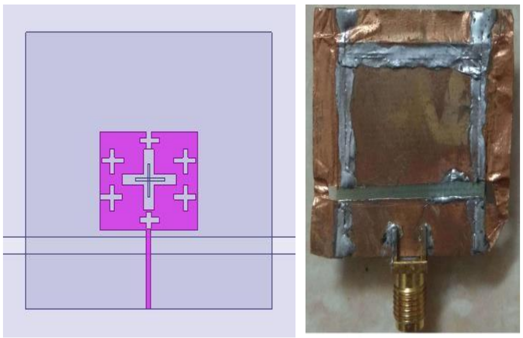
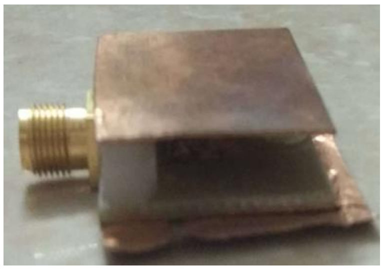


Fig.2. 1st iteration



(a) (b)



(c)

Figure 3.(a): Top view of the constructed and simulated proposed antenna (b) The proposed antenna's bottom view; (c) its side viewpoint.

Fig.4 Conventional & Proposed antenna measurement

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The upper plate is also a ground plane with an actual size of (25×25.3) mm^2, which has length and breadth Lg = 27mm, Wg = 27mm as shown in Figure.3. The real size of the bottom ground plane is (27×27) mm^2, but the ground plane is increased 2mm on both sides and is called the extended ground plane. The proposed antenna uses a microstrip line feed to improve the performance parameters. Both the conventional antenna and the proposed antenna have a feeding length of 7.2 mm and a breadth of 2 mm. The proposed antenna's defective ground plane is utilized to represent the performance metrics. Improved are gain, VSWR, and return losses. A (22 x 4) mm^2 rectangular slit is carved from the ground plane. For impedance matching between feed and patches, the feed network has been built with 50Ω. The proposed antenna's parameters have all been enhanced through the use of fractal methods. The amount of impedance matching between the transmitter and antenna is measured by the VSWR factor. Figure.4. displays the experimental setup used to measure the antenna's parameters.

Proposed Antenna is designed by using following steps:

Step 1: Calculation of the Width of the Patch (W).

$$W = \frac{c}{2f_o\sqrt{\frac{\varepsilon_r+1}{2}}} \qquad (1)$$

Step 2: Calculation of the Effective Dielectric Constant.

$$\varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left(1+12\frac{h}{w}\right)\wedge {}^{1}/_{2} \qquad (2)$$

Step 3: Calculation of the length extension ΔL of the Patch

$$\Delta L = 0.412h\frac{(\varepsilon_{reff}+0.3)\left(\frac{w}{h}+0.264\right)}{(\varepsilon_{reff}-0.258)\left(\frac{w}{h}+0.8\right)} \qquad (3)$$

Step 4: Calculation of actual length of patch

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

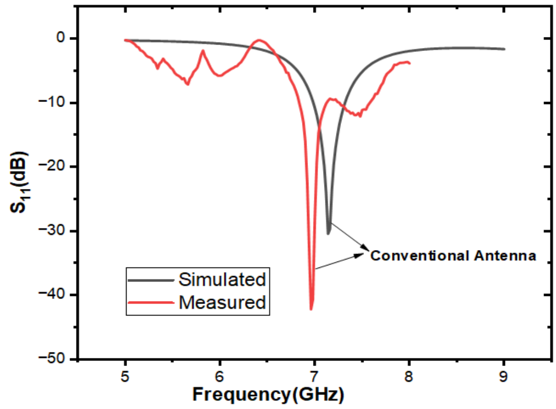
Step 5: Calculation of width and length of substrate

$$L_s = L + 2*6h \qquad (5)$$

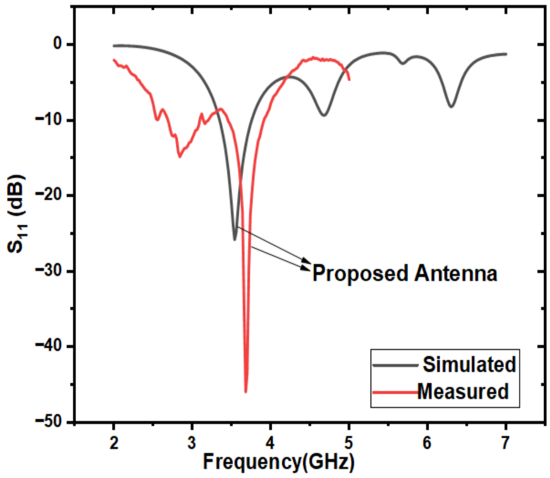
$$W_s = w + 2*6h \qquad (6)$$

III. RESULTS AND DISCUSSION

This section discusses outcomes from simulations and experiments. The power that is reflected to the input due to an impedance mismatch is referred to as return loss. The proposed antenna and conventional antenna's Return Losses (RL) v/s frequency (GHz) graphs are shown in Figure.5. Conventional antenna operating at 7.12GHz return loss −25.04dB is used in the simulation. The identical antenna is illustrated in Figure 5(a) resonating at 6.9GHz with a return loss of −42.17dB during the measurement



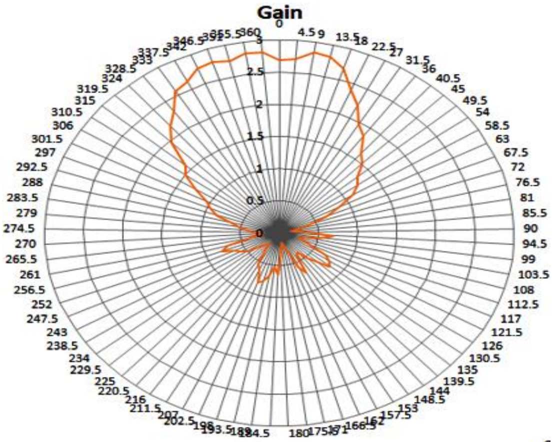
(a)



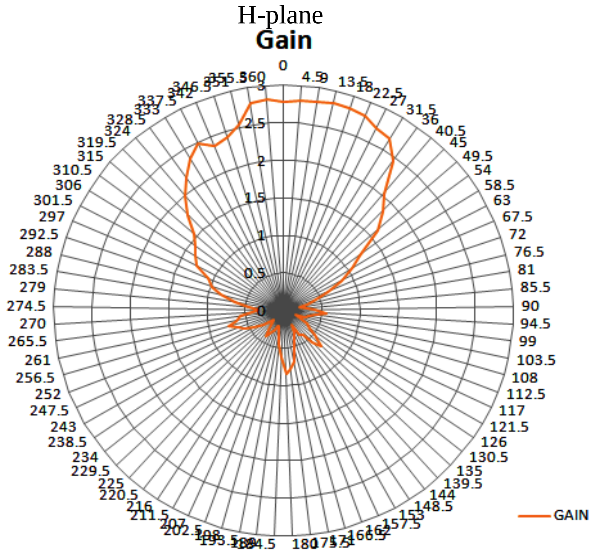
(b)

Figure 5.(a) and (b): Experimental and Simulated S11 Graph

In the simulation, the proposed antenna has a return loss of -27.06dB operating at 3.54GHz. The same antenna resonates at 3.68GHz during the measurement, as shown in Figure.5(b), with a return loss of -45.09dB. Using a vector network analyser, measured results are obtained (MS46322A). A comparison is presented between the experimental and simulation results for the second iteration of the proposed antenna. The difference between the simulated and measured values is due to losses in the dielectric material and conductor. Although the size reduction of the proposed antenna is enhanced by up to 50% in modeling, the measurement produces just 47.12%. The fractal concept is used to improve size reduction. Similar to the increase in bandwidth from 400 to 500MHz, Table.1 illustrates an improvement in gain from (4.17 to 4.58)dB. Radiation patterns are the antenna's radiations graphically represented as a function of spatial coordinates. Another name for it is a 2D polar plan. Figure.6. shows the polar plots of each iteration in the conventional antenna's E and H planes at the resonant frequency of 2.5 GHz.



H-plane



E-plane

Fig.6 Gain graph E-H plane of Conventional Antenna

IV.TABLE

COMPARISION OF PROPOSED ANTENNA PERFORMANCE

Parameters	Simulated	Measured
Resonance freq GHz)	3.54	3.68
Return loss(S_{11})	-27.06	-45.9
Bandwidth(MHz)	400MHz	500MHz
Size reduction (%)	50%	47.12%
Gain (dB)	4.17	4.58

IV.CONCLUSION

The proposed structure's incorporation of a gap maintained between the top ground plane and the extended ground plane has been shown to significantly improve the antenna's bandwidth and gain. An antenna for a microstrip patch is built and simulated. Using an iterative process, the design is divided into two stages for the conventional antenna. At every stage, the proposed antenna is altered to improve the S_{11}, gain, and bandwidth characteristics. An initial 7.12GHz frequency is intended for use by a conventional antenna. Using the extended ground concept and creating faulty ground as the final phase in the process allows the plus-shaped slotted fractal microstrip antenna to achieve the highest gain, bandwidth, and size reduction. The bandwidth region and gain were enhanced, reaching a maximum of 4.58dB at 3.68GHz. The maximum bandwidth of the suggested antenna is 500MHz. This antenna simultaneously covers the S and C bands.

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