Fractal Microstrip Antenna for enhancement of bandwidth and to operate at multi-frequencies

A PROJECT REPORT

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by

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Under the guidance of

Dr. S Jagadeesha
Professor and Dean (Examination)

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Department of Electronics & Communication Engineering
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UJIRE - 574 240

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SDM INSTITUTE OF TECHNOLOGY

(Affiliated to Visvesvaraya Technological University, Belagavi)
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Department of Electronics and Communication Engineering

CERTIFICATE

Certified that the Project Work titled **'Fractal Microstrip Antenna for enhancement of bandwidth to operate at multi-frequencies'** is carried out by **Mr. Anudeep N Rao**, USN: **4SU15EC011, Ms. Anusha K S,** USN**: 4SU14EC013, Mr. Santhosh K,** USN: **4SU15EC078,** the bona-fide students of SDM Institute of Technology, Ujire, in partial fulfillment for the award of the degree of **Bachelor of Engineering** in Electronics and Communication Engineering of Visvesvaraya Technological University, Belagavi during the year 2018-2019. It is certified that all the corrections/ suggestions indicated for Internal Assessment have been incorporated in the report deposited in the departmental library. The report has been approved as it satisfies the academic requirements in respect of project work prescribed for the said Degree.

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Name of the Examiners: **Signature with Date**

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SYNOPSIS

Now a day, due to their several key advantages over conventional wire and metallic antennas, Microstrip antennas have been used for many applications, such as Direct Broadcasting Satellite (DBS) systems, mobile communications, Global Positioning System (GPS) and various radar systems.

Their advantages include low profile, light weight, low cost, ease of fabrication and integration with RF devices etc. They can also be made conformal to mounting structures. However, when they are applied in the frequency range below 2GHz, the sizes of conventional rectangular microstrip patches seem to be too large, which makes it difficult for them to be installed on televisions, notebook computers or other hand-held terminals, etc. Several techniques have thus been proposed to reduce the sizes of conventional half-wavelength microstrip patch antennas. Material of high dielectric constant has been used. However, this will lead to high cost and high loss. Also, poor efficiency due to surface wave excitation is another drawback of this method. In this paper, we propose a compact swastika shaped patch antenna. The objective of the proposed design is to improve the impedance bandwidth. Simulation of the proposed antenna has been carried out using Zeland IE3D 14.0 software and its various characteristics have been investigated. The simulation and implementation of antenna is done and presented in this report.

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List of Acronyms and Abbreviations

CAE	Computer Aided Engineering
EBG	Electromagnetic Band Gap
ECIL	Electronics Corporation of India
EM	Electromagnetic(ism)
FCC	Federal Communications Commission
GPS	Global Positioning System
GSM	Global System for Mobile Communications
ISM	Industrial, Scientific and Medical
MIC	Microwave Integrated Circuits
MIMO	Multiple Input Multiple Output
MMIC	Monolithic Microwave Integrated Circuits
MSA	Microstrip Antenna
PCB	Printed Circuit Board
RADAR	Radio Detection and Ranging
RF	Radio Frequency
RFIC	Radio Frequency Integrated Circuits
RFID	Radio Frequency Identification
SNA	Scalar Network Analyzer
USB	Universal Serial Bus
UWB	Ultra-Wide Band
VNA	Vector Network Analyzer
WIFI	Wireless Fidelity
WIMAX	Worldwide Interoperability for Microwave Access

Chapter 1

Introduction

1.1 Overview of Microstrip Antenna

Microstrip antennas having several advantages such as light weight, low cost, thin profile, conformal to a shaped surface so it can be used in several applications as in aircraft, satellite and wireless communication. One of the most serious problems of microstrip antenna is its narrow bandwidth. Many works have been done and various methods are used to increase the bandwidth of the microstrip antenna. One way to improve bandwidth by the use of parasitic patches either on another layer or on the same layer but if parasitic patches present on different layer then thickness of antenna increases or if these are present on same layer then lateral size of antenna increases. In order to overcome this drawback, we have to develop single layer single patch wideband microstrip antenna.

1.2 Overview of Fractal Antenna

A **fractal antenna** is an antenna that uses a fractal, self-similar design to maximize the effective length, or increase the perimeter (on inside sections or the outer structure), of material that can receive or transmit electromagnetic radiation within a given total surface area or volume. Such fractal antennas are also referred to as multilevel and space filling curves, but the key aspect lies in their repetition of a motif over two or more scale sizes, or "iterations". For this reason, fractal antennas are very compact, multiband or wideband, and have useful applications in cellular telephone and microwave communications. A fractal antenna's response differs markedly from traditional antenna designs, in that it is capable of operating with good-to-excellent performance at many different frequencies simultaneously. Normally standard antennas have to be "cut" for the frequency for which they are to be used—and thus the standard antennas only work well at that frequency. This makes the fractal antenna an excellent choice for wideband and multiband applications. In addition, the fractal nature of the antenna shrinks its size, without the use of any components, such as inductors or capacitors.

1.3 Literature Survey

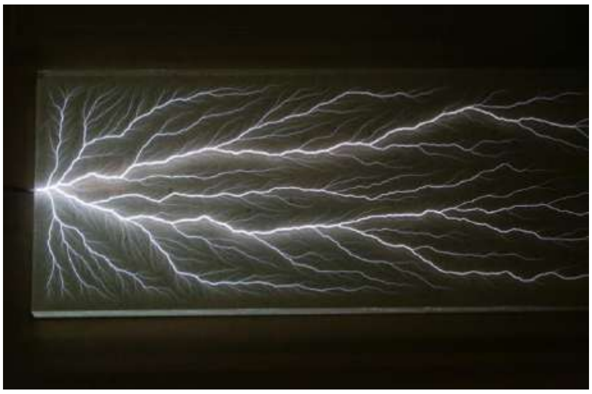
Antennas are mapped according to its physical and electrical size. There are four categories in which antennas are divided that are physically large and electrically large antennas, physically large but electrically small antennas, physically small but electrically large and physically and electrically small antennas. In most of the system physically small and electrically, large antennas are required as because we know that electrically large antenna can work for low frequency but at the same time its physical size must low in order to match with modern wireless devices. The patch antenna comes under the category of physically and electrically large antenna, but it has some issues that its electrical length. Sometime not much large so we have to make some adjustment like the use of shorting pin or making a slot in the given patch to increase its frequency response. But this is not in the case of fractal, fractal antennas are perfect physically and electrically large antennas. Because of space filling properties the electrical size of the antenna we can increase as we increase the number of iterations. Also, the fractal shape has self-similar properties which model antenna which has a similar shape at small size works as itself an antenna at reduced scale for different frequency.

As we know any arbitrary metallic device can receive electromagnetic shape, and if we control the dimensions such as width and length of the antenna consequently we can control the radiation pattern, gain, bandwidth and other parameter of the antenna. The fractal antenna has the property that we can control the dimensions of the antenna at too any scales because of space filling property. Various fractal shapes have its own advantage because of its geometrical size and shape. In wireless communication system antenna with multiband and broadband is necessary for mobile phone and other applications so that more user could integrate in one channel and can use the same antenna for more than one application such as Bluetooth, data communication, and WIFI etc. It is not convenient to use one antenna for one application instead it is better to use one antenna for more application to co-operate with space in mobile phone and other portable handheld devices. The conventional antenna has one or sometime two frequency band of operation means different antennas are needed for different frequency bands. To overcome this issue, fractal antenna is a good candidate, recent progress in the study of fractal antennas suggests some attractive solutions for using a single small antenna operating in several frequency bands. Fractal is not only used for multiband applications but also it has size reduction property which makes it a good candidature for small system applications. Size reduction is possible due to make use of space-filling property [4]. The fractal antenna has basically two properties on which it works, first is self-similar and other is space filling. First, one should expect a self-similar antenna, which contains many different scales copies of itself to operate in a similar way at several wavelengths. That is, the antenna should maintain similar radiation parameters through several bands. Second, the space-filling properties of some fractal shapes might allow fractal shaped small antennas to take better advantage of confined space [5]. Fractals are geometrical shapes, which are self-similar, repeating themselves at different scales.

(a)

(b)

(c)



(d)

Figure 1.1 (a) Pine leaf. (b) Aloe Vera. (c) Pine cone. (d) Electric discharge.

The fractal term is first coined by French mathematician Benoit B. Mandelbrot in 1970. Fractal is roughly defined as a broken or fragmented geometric shape that can be reduced a size copy of the original shape. Fractal is a compact multiband antenna, and also known as infinitely complex because of its similarity at all level of magnification.

Two types of fractal shapes are existed -

(a) Natural

(b) Mathematical [6]

Natural fractal shapes can be found all around us such as coastline, clouds, lighting, plants or trees, vegetable, rivers, cosmos etc. are shown in Figure 1.1 (a to d).
A fractal antenna is an alternative solution for multi-frequency devices, where more than one antenna could be used for multichannel requirement instead fractal antenna itself works as multi-frequency and multiband antenna [9, 10]. After B. B. Mandelbrot many researchers worked on the fractal antenna for different applications such antennas are named as Hilbert Curve, Sierpinski, Koch Curve, Cantor Curve, [11, 12, 13 and 14]. Fractal antennas are used almost all over wireless applications such as GPS (L1: 1.2, L2; 1.2 GHz), WIFI, Bluetooth, mobile, WI-Max [15].

Fractal antennas have been proved significant improvement in the military frequency applications. The Industrial, Scientific and Medical (ISM) band is released for 2.4 and 5.8 GHz frequency, which is free for every user, so most of the low-cost devices make use of this frequency band. Bluetooth, WIFI, GPS also comes under this frequency band. Fractal antennas have a wideband and broadband property which perhaps need to be in large scale MIMO channel requirement. Particularly applications where large spectral bandwidth is necessary the fractal antenna are used because of its space filling and self-similarity properties [16]. Fractal antenna for USB- multiband and wideband antenna are desired in recent communication systems, wideband antennas are used in applications such as RADAR, unmanned aerial vehicle for ground moving target indication, for cooperate with increasing data rate demand antenna with smaller in diameter and wideband width characteristics are required. The UWB frequency comes in the range of 3.1 GHZ to 10. GHZ according to FCC Federal Communications commission’s. As in conventional UWB antenna the size of the antenna is used to be large in order to cover the maximum bandwidth. To overcome this issue, the fractal antenna uses its space filling property to avoid large dimension antenna.

In most of the leading antenna technology, UWB antenna is very much famous because of its qualities which overcome on the tradition antenna technology. Also, advantage of using the UWB antenna is that it has low power consumption and high data rate.

A fractal often has the following features:

- It is too irregular to be easily described in traditional Euclidean geometric language.
- It has a fine structure at arbitrarily small scales.
- It is self-similar (at least approximately or stochastically) It has a Hausdorff dimension which is greater than its topological dimension.
- It has a simple and recursive definition.

Chapter 2

Microstrip Antenna

2.1 Introduction

Decamps G.A. first proposed the concept of microstrip antenna in 1953.However, practical microstrip antennas were developed by Munsoon and Howell in 1970. The numerous advantage of microstrip antenna, such as its low weight, small volume and ease of fabrication using printed-circuit technology led to the design of several configurations for various applications. With increasing requirements for personal and mobile communication, the demand for the smaller and low profile antenna have brought the microstrip antenna (MSA) to the forefront.

As shown in Figure 2.1, conventional Microstrip antenna consists of a pair of parallel conducting layers separating a dielectric medium, referred as substrate. In this configuration, the upper conducting layer or “patch” is the source of radiation where electromagnetic energy fringes off the edges of the patch and into the substrate. The lower conducting layer acts as a perfectly reflecting ground plane, bouncing energy back through the substrate and into the free space. Physically the patch is a thin conductor that is an appreciable fraction of a wavelength in extent. The patch which has resonant behavior is responsible to achieve adequate bandwidth. Conventional patch design yields few percent bandwidths. In most practical applications, patch antenna is rectangular or circular in shape; however, in general any geometry is possible.

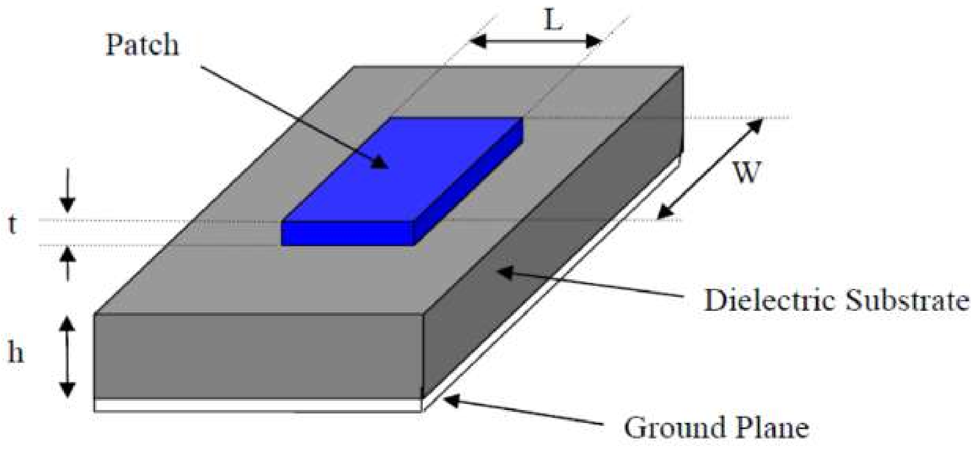


Figure 2.1 Microstrip antenna

Microstrip antenna should be designed so that its maximum wave pattern is normal to the patch. This is accomplished by proper choice of mode of excitation beneath the patch. Generally, patch of microstrip antenna thickness is very thin in the range of $t<<\lambda_0$ (λ_0 is free space wave length) and the height h of dielectric material is between $0.003\lambda_0<h<0.05\lambda_0$. For a rectangular patch, the length L of the element is usually $\lambda_0/3<L<\lambda_0/2$.

There are numerous substrates that can be used for the design of microstrip antenna, and their dielectric constant are usually in the range of $4.4<\varepsilon_r<10$, where ε_r is relative dielectric constant. The substrate whose size is thick and dielectric constant is in the range of lower end provides better efficiency and bandwidth, but it expenses large element size.

2.2 Radiation mechanism of microstrip antenna

Radiation from Microstrip can be understood by considering the simple case of a rectangular microstrip patch spaced a small fraction of wavelength above ground plane as shown in the figure. Field vary along the patch length which is about half wavelength ($\lambda/2$). Radiation from Microstrip antenna occurs from the fringing fields between the open circuited edge of Microstrip antenna conductor and the ground plane. The fields at the end can be resolved into normal and tangential components with respect to ground plane. The normal components are out of phase because of the patch length is λ long, therefore the far field produced by them cancelled in the broadside direction. The tangential components (those parallel to ground plane) are in phase and resulting fields combine to give maximum radiated field normal to the surface of the structure: i.e. broadside director.

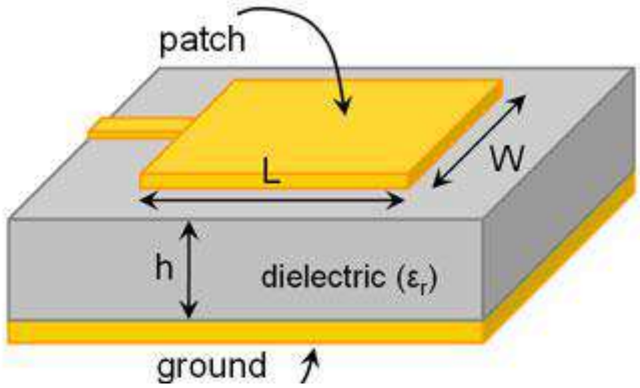


Figure 2.2 Microstrip patch antenna

The radiation from discontinuities in Microstrip antenna was first examined by Lewin, whose analysis is based on the current flowing in the conductors. This can also be described as the surface current distribution on the patch. A patch, which is connected to the microwave source, has a charge distribution on the upper and lower surface of the patch as well as ground plane. The patch is half wavelength ($\lambda/2$) long, at the dominant mode which creates the positive and negative distribution as shown in the Figure 2.3.

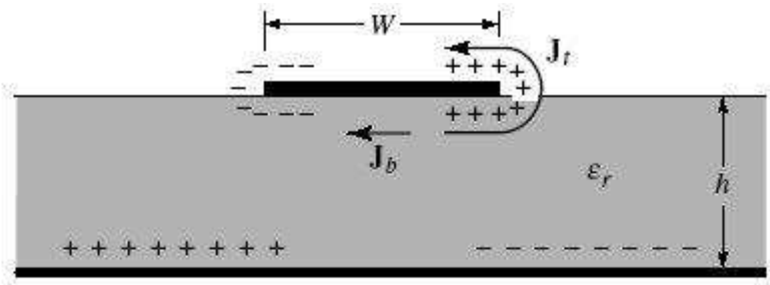


Figure 2.3 Microstrip antenna charge distribution

2.3 Advantages and Disadvantages

Microstrip antenna have several advantages compared to the conventional microwave antennas. Some of the advantages of microstrip antennas discussed are listed as follows -

- They are light weight and have a small volume and a low-profile planar configuration.
- They can be made conformal to the host surface.
- They ease of mass production using printed –circuit technology leads to a low fabrication cost.
- They are ease to integrate with MICs on the same substrate.
- The antenna has low scattering cross sections.

However, MSAs suffer disadvantages as compared to conventional microwave antennas. Some of them are as follows:

- Quite large size for lower microwave frequencies.
- Narrow impedance bandwidth.
- Low efficiency.
- Low gain.
- Low power handling capability.

2.4 Applications of microstrip antennas:

- The telemetry and communication antennas on missiles need microstrip antenna.
- Radar altimeters use small arrays of microstrip radiators.
- Satellite imaging systems.
- Global system for mobile communication (GSM) and global positioning system (GPS) are major uses of microstrip.

Chapter 3

Microstrip Antenna Feeding Techniques

3.1 General

Microstrip patch antennas can be fed by a variety of methods. These methods can be classified into two categories- contacting and non-contacting. In the contacting method, the RF power is fed directly to the radiating patch using a connecting element such as a microstrip line. In the non-contacting scheme, electromagnetic field coupling is done to transfer power between the microstrip line and the radiating patch. The four most popular feed techniques used are the microstrip line, coaxial probe (both contacting schemes), aperture coupling and proximity coupling (both non-contacting schemes).

3.2 Microstrip Line Feed

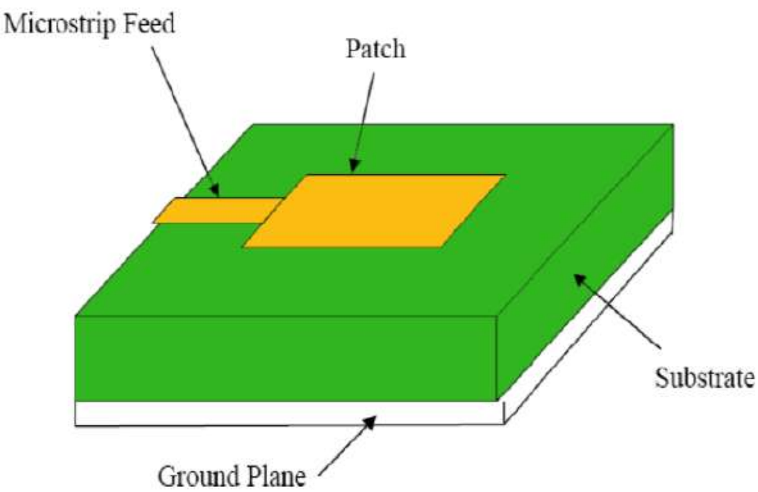


Figure 3.1 Microstrip line feed

In this type of feed technique, a conducting strip is connected directly to the edge of the Microstrip patch. The conducting strip is smaller in width as compared to the patch and this kind of feed arrangement has the advantage that the feed can be etched on the same substrate to provide a planar structure.

However, as the thickness of the dielectric substrate being used, increases, surface waves and spurious feed radiation also increases, which hampers the bandwidth of the antenna.

The feed radiation also leads to undesired cross polarized radiation. This method is advantageous due to its simple planar structure.

3.3 Coaxial Probe Feed

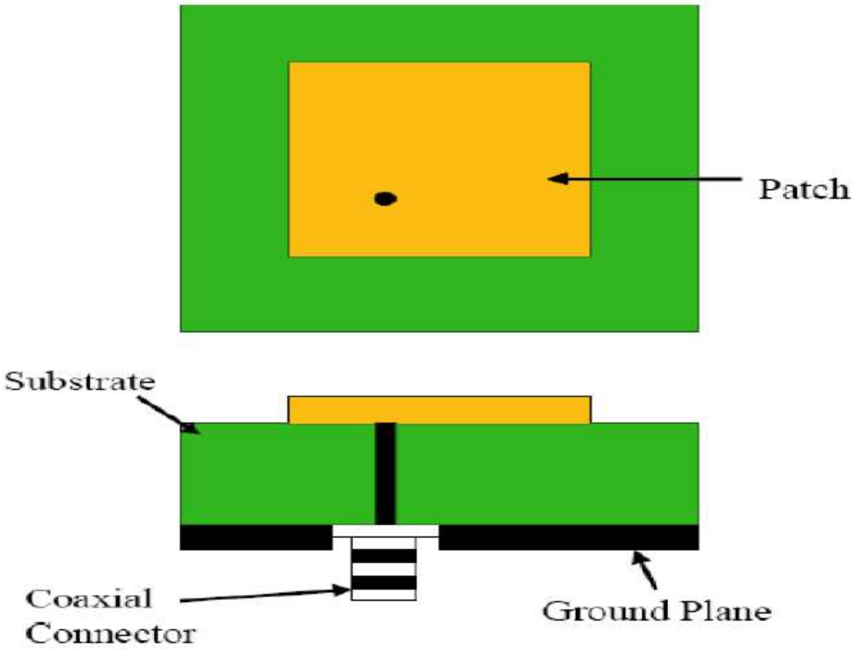


Figure 3.2 Coaxial probe feed

The Coaxial feed or probe feed is a very common technique used for feeding Microstrip patch antennas. The inner conductor of the coaxial connector extends through the dielectric and is soldered to the radiating patch, while the outer conductor is connected to the ground plane. The main advantage of this type of feeding scheme is that the feed can be placed at any desired location inside the patch in order to match with its input impedance.

However, its major drawback is that it provides narrow bandwidth and is difficult to model since a hole has to be drilled in the substrate and the connector protrudes outside the ground plane, thus not making it completely planar for thick substrates.

Also, for thicker substrates, the increased probe length makes the input impedance more inductive, leading to matching problems. It is seen above that for a thick dielectric substrate, which provides broad bandwidth, the microstrip line feed and the coaxial feed suffer from numerous disadvantages. So to reduce these types of disadvantages, we will study non-contacting schemes.

3.4 Proximity Coupled Feed

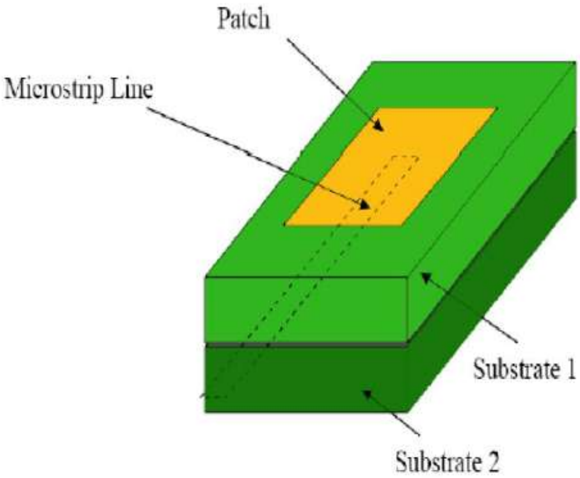


Figure 3.3 Proximity coupled feed

This type of feed technique is also called as the electromagnetic coupling scheme. Two dielectric substrates are used such that the feed line is between the two substrates and the radiating patch is on top of the upper substrate. The main advantage of this feed technique is that it eliminates spurious feed radiation and provides very high bandwidth (as high as 13%) due to overall increase in the thickness of the microstrip patch antenna. This scheme also provides choices between two different dielectric media, one for the patch and one for the feed line to optimize the individual performances.

This method is advantageous to reduce harmonic radiation of microstrip patch antenna implemented in a multilayer substrate.

The goal of the design is the suppression of the resonances at the 2nd and 3rd harmonic frequencies to reduce spurious radiation due to the corresponding patch modes to avoid the radiation of harmonic signals generated by non-linear devices at the amplifying stage. The study shows the possibility of controlling the second harmonic resonance matching by varying the length of the feeding line. On the other hand, the suppression of the third harmonic is achieved by using a compact resonator.

3.5 Aperture Coupled Feed

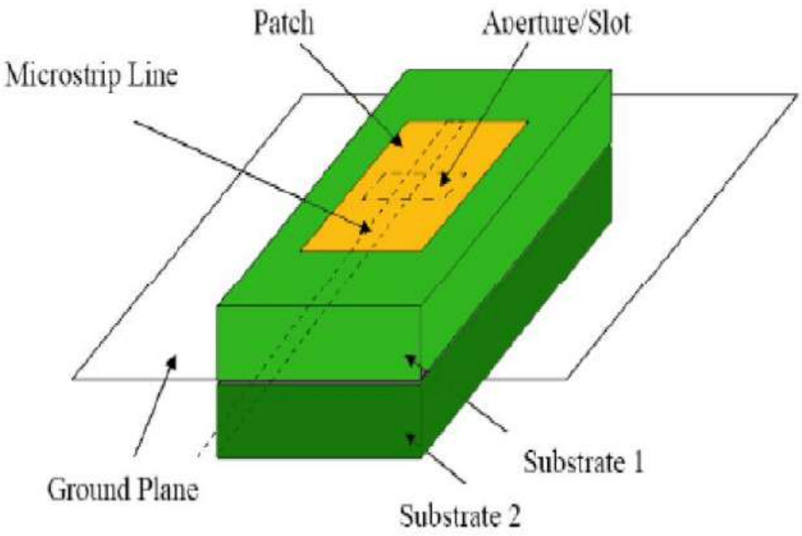


Figure 3.4 Aperture coupled feed

In this type of feed technique, the radiating patch and the microstrip feed line are separated by the ground plane. Coupling between the patch and the feed line is made through a slot or an aperture in the ground plane and variations in the coupling will depend upon the size i.e. length and width of the aperture to optimize the result for wider bandwidths and better return losses. The coupling aperture is usually centered under the patch, leading to lower cross-polarization due to symmetry of the configuration.

Since the ground plane separates the patch and the feed line, spurious radiation is minimized. Aperture coupled feeding is attractive because of advantages such as no physical contact between the feed and radiator, wider bandwidths, and better isolation between antennas and the feed network. Furthermore, aperture-coupled feeding allows independent optimization of antennas and feed networks by using substrates of different thickness or permittivity.

Chapter 4

Fractal Antenna

4.1 General

As we know any arbitrary metallic device can receive electromagnetic shape, and if we control the dimensions such as width and length of the antenna consequently we can control the radiation pattern, gain, bandwidth and other parameter of the antenna. The fractal antenna has the property that we can control the dimensions of the antenna at too any scales because of space filling property. Various fractal shapes have its own advantage because of its geometrical size and shape. In wireless communication system antenna with multiband and broadband is necessary for mobile phone and other applications so that more user could integrate in one channel and can use the same antenna for more than one application such as Bluetooth, data communication, and WIFI etc. It is not convenient to use one antenna for one application instead it is better to use one antenna for more application to co-operate with space in mobile phone and other portable handheld devices. The conventional antenna has one or sometime two frequency band of operation means different antennas are needed for different frequency bands. To overcome this issue, fractal antenna is a good candidate, recent progress in the study of fractal antennas suggests some attractive solutions for using a single small antenna operating in several frequency bands. Fractal is not only used for multiband applications but also it has size reduction property which makes it a good candidature for small system applications. Size reduction is possible due to make use of space-filling property [4]. The fractal antenna has basically two properties on which it works, first is self-similar and other is space filling. First, one should expect a self-similar antenna, which contains many different scales copies of itself to operate in a similar way at several wavelengths. That is, the antenna should maintain similar radiation parameters through several bands. Second, the space-filling properties of some fractal shapes might allow fractal shaped small antennas to take better advantage of confined space [5]. Fractals are geometrical shapes, which are self-similar, repeating themselves at different scales.

Chapter 5

Design and Implementation

5.1 Introduction

The accelerating progress of wireless communication and ever increase number of communication and navigation services such as cellular phones, global positioning system (GPS), wibro and ISM in the last 5 years as credited an ever growing demand for multi system application. To cover many or all of these services by one antenna which is multiband compact antenna with adequate performance is required. Applying fractal to elements allows for smaller, resonant antenna which is multiband or broadband and may be optimized for the gain. They do not used additional loading components and are simple and cost effective to fabricate.

Fractal geometry involves a recursive generating methodology that results in contours with infinitely fine structures. By using deferent properties of fractal varies geometries have been designed to achieve size reduction size reduction, enhance bandwidth and multiband operation. In this work three different approaches have been considered. They are.

- ❖ Design of micro strip geometry by using self-similar property.
- ❖ Design of micro strip geometry by using self-affinity property.

Micro strip geometries of varies patches used in this work were designed and simulated using well known IE3D Electromagnetic Simulation and Optimization software. For better confirmation of these simulated values, the whole experimental work of various micro strip antenna geometries is carried out and its results are compared using vector network analyzer available in department of Electronics and Communication. The progress of photolithographic etching and PCB fabrication process were done by Atlantic Circuits, ECIL (Cherlapalli), Hyderabad.

Formulae

Step 1: Calculation of the width (W):

The width of the micro strip patch antenna is given by

$$w = \frac{c}{2f\sqrt{\frac{\epsilon_r + 1}{2}}}$$

Step 2: Calculation of effective dielectric constant:

Where ε_{reff} is the effective dielectric constant which may be obtained by

$$\epsilon_{reff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2}\left(\frac{1}{\sqrt{1 + \frac{12h}{w}}}\right)$$

Step 3: Calculation of effective length:

Effective length L_{eff} may be calculation as

$$L_{eff} = \frac{C}{2f\sqrt{\epsilon_{reff}}}$$

Step 4: Calculation of the length extension:

The length extension ΔL may be calculated by the following expression

$$\Delta L = 0.412\frac{(\epsilon_{reff} + 0.3)(\frac{W}{h} + 0.264)}{(\epsilon_{reff} - 0.258)(\frac{W}{h} + 0.8)}$$

Step 5: Calculation of actual length of patch (L):

Patch length can be obtained using

$$L_{eff} = L + 2\Delta L$$

Step 6: calculation of the ground plane dimension (L and W)

The transmission line model is applicable to infinite ground plane only. For partial consideration, it is essential to have a finite ground plane. The size of the ground plane is greater than the patch dimensions by approximately six times the substrate thickness all ground the periphery. Hence for this design, the ground plane dimension would be given as:

$$L_g = 6h + L$$

$$W_g = 6h + W$$

Where h is the height of the substrate.

5.2 Vector Network Analyzer (VNA)

Network analyzer is an instrument that measure the network parameters of electrical networks. Network analyzer commonly measure the S-parameter because reflection and transmission in electrical network are easy to measure at high frequencies. Network analyzer are often used for two-port networks such as amplifiers and filters. But they can be used on a network with arbitrary number of ports. Network analyzer is used for stability analysis of open loop or for the measurement of audio and ultrasonic components. The two main types of network analyzer are

- Scalar Network analyzer (SNA) – measurement amplitude properties only.
- Vector Network analyzer (VNA) – measurement of both amplitude and phase properties.

A Vector Network Analyzer is a test system that enables the RF performance of radio frequency (RF) and microwave devices to be characterized in terms of network scattering parameters or S-parameters. The key element is that it can measure both amplitude and phase. Only with knowledge of phase and magnitude from a VNA, circuit models can be developed that will enable complete situation to be undertaken. Hence, the information provided by this is used to ensure that the RF design of the circuit is optimized to provide the best performance.

Importance of VNA Measurements

Measuring both magnitude and phase of components is important for several reasons. First, both measurements are required to fully characterize a linear network and ensure distortion-free transmission. To design efficient matching networks, complex impedance must be measured. Engineers developing models for computer-aided engineering (CAE) circuit simulation programs require magnitude and phase data for accurate models.

In addition, time-domain characterization requires magnitude and phase information in order to perform an Inverse-Fourier transform. Vector error correction, which improve measurement accuracy by removing the effects of inherent measurement system errors, requires both magnitude and phase data to build an effective error model. Phase-measurement capability is very important even for scale measurements such as return loss, in order to achieve high level of accuracy.

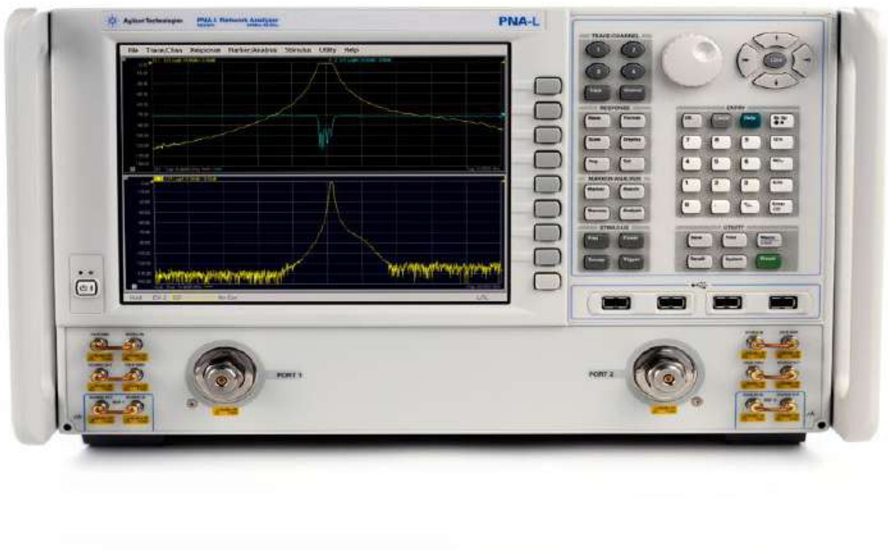


Figure 5.1 Vector network analyzer

Basic theory and implementation

IE3D is a full-wave EM solver. It solves the Maxwell equation, which govern the macro electromagnetic phenomenon. Not much assumption involved except the numerical nature the method.

The original Maxwell's equation having differential form and the solution of the equation are the electric (E) field and magnetic (H) field in the whole space. To solve the EM problem, we need to solve the E-field and H-field numerically. Numerical solution of the original Maxwell equations E-field and H-field involves many unknowns. Instead, the IE3D solves the Maxwell's equation in an integral form through the use of Green's functions. We try to represent the E-field and H-field as some weighted integrals of electric current and metallic structures and magnetic current derived from the electric distribution on a metallic domain is limited and solution domain of the IE3D is very limited. A typical example is micro strip circuit. The solution domain is just a surface of printed strip only. Its solution domain significantly smaller than that of the original Maxwell's equation.

5.3 Zeland IE3D software

Introduction

Electromagnetic simulation is an advanced technology to yield high accuracy analysis and design of complicated microwave and RF printed circuit, antennas, high-speed digital circuit and other electronic components. IE3D is integrated full-wave electromagnetic simulation and optimization package for the analysis and the design of 3D and planar microwave circuit, MMIC, RFIC, RFID, antennas, digital circuit and high speed printed circuit board (PCB). Since its formal introduction in 1993 IE3D has been adopted as an industrial standard in planar and 3D electromagnetic simulation and much improvement has been achieved in the IE3D since then. It has become the most versatile, easy to use, efficient and accurate electromagnetic simulation tool.

- IE3D is power full-wave EM design package for all aspects of high frequency application.
- It is based upon 3D integral equation, method of movement for high accuracy and high efficiency full-wave EM simulation.,
- It is not just for planar structures; it can also handle full-3d structure elegantly.
- It is not limited by uniform grids and shape of the structure.
- It is much more capable, accurate, efficient and flexible than other EM simulator.

Chapter 6

Testing and Results

6.1 Test Setup

Figure 6.1 Testing for return loss

The testing of fabricated antennas were conducted at National Institute of Technology (NITK), Surathkal, Karnataka. The tests for return loss and field gain were performed with Agilent Vector Network Analyzer (VNA) having the sweep range of 10 MHz to 40 GHz, 1W Horn antenna and radiation test-bench. The return loss (S11) was measured for each antenna as shown in figure 6.1. The gain (S21) was measured for each antenna on the radiation test-bench using the horn antenna setup as shown in Figure 6.2. The horn antenna was used as unity power source for determining gain. The gain was calculated using Friss transmission formula and given conversion factor for radiation test-bench.

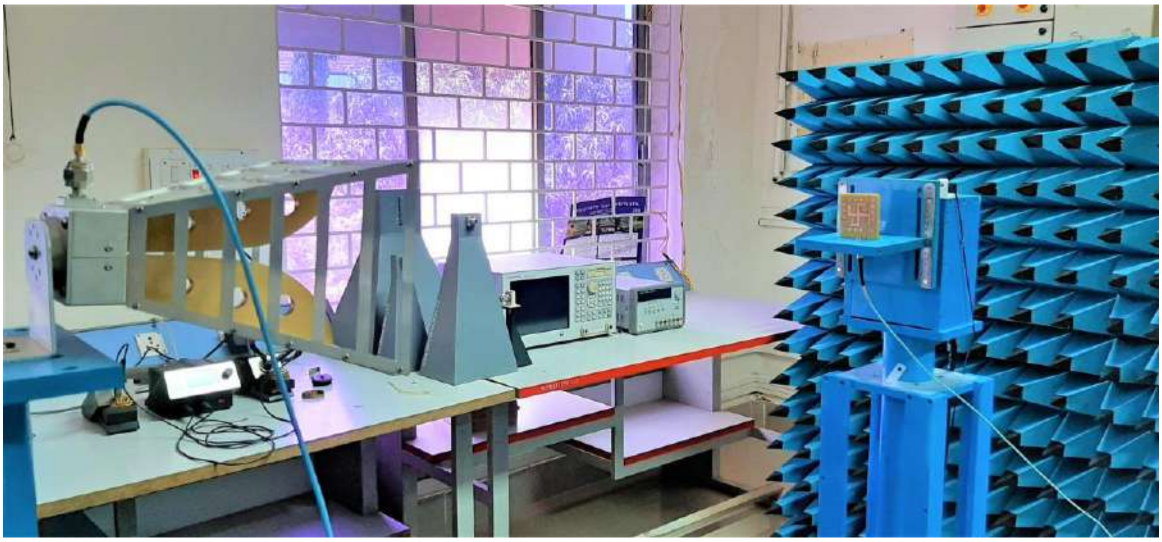


Figure 6.2 Testing for gain

6.2 Procedure

6.2.1 For Return loss

1) Calibrate the VNA to the required sweep range by connecting calibration unit between port1 and port2.
2) Select start frequency and stop frequency of the sweep.
3) Once the VNA has been calibrated, replace calibration unit with test antenna at port1.
4) Start the sweep for S11.
5) After completion of sweep, save the sweep data.

6.2.2 For Field Gain

1) Calibrate the VNA to the required sweep range by connecting calibration unit between port1 and port2.
2) Select start frequency and stop frequency of the sweep.
3) Once the VNA has been calibrated, replace calibration unit with test antenna at port2 and horn antenna at port1.
4) Start the sweep for S21.
5) After completion of sweep, save the sweep data.

6.3 Antenna Geometry and Comparative Results

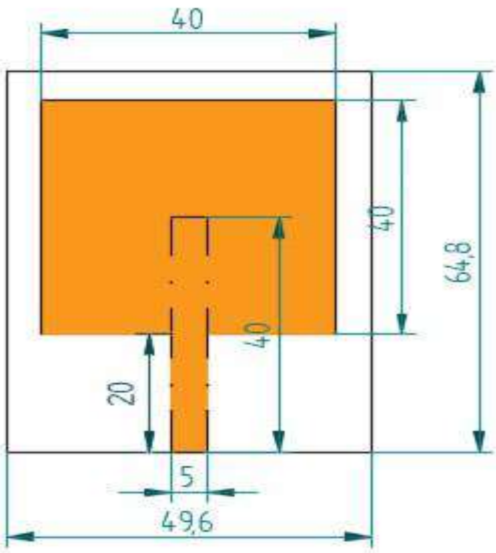


Figure 6.3 Geometry of reference antenna

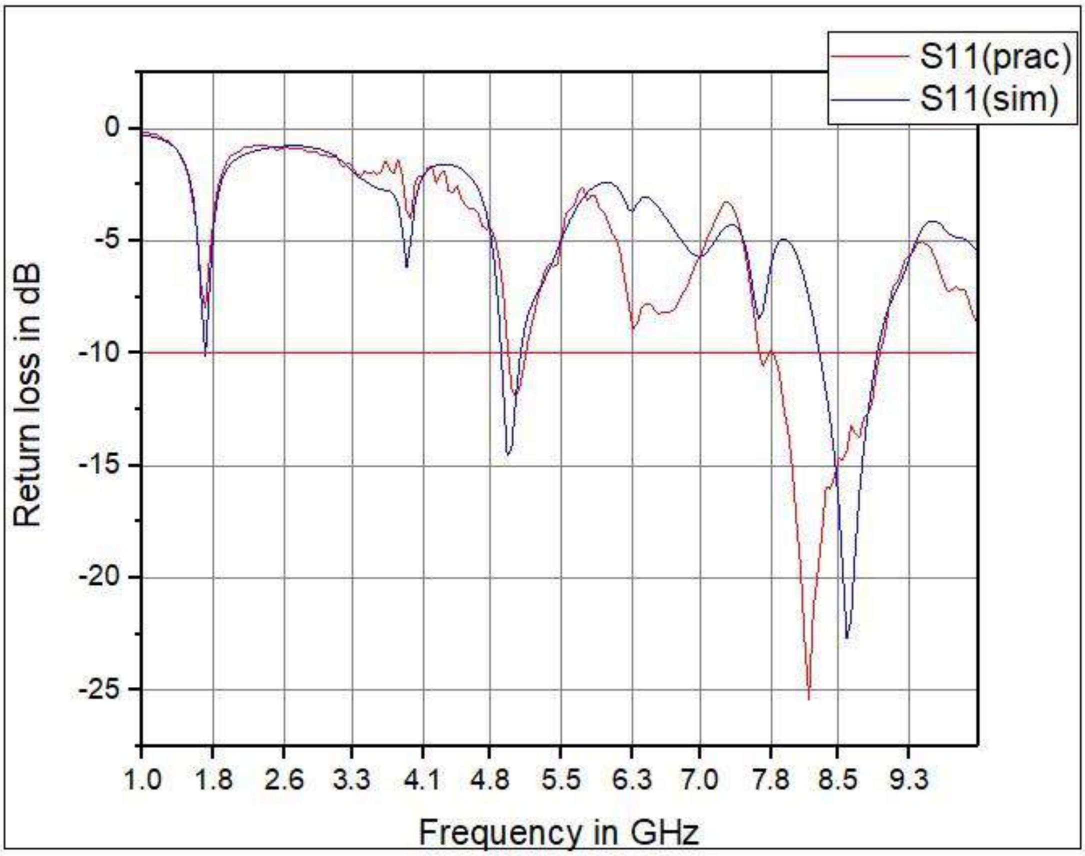


Figure 6.4 Return loss characteristics of reference antenna

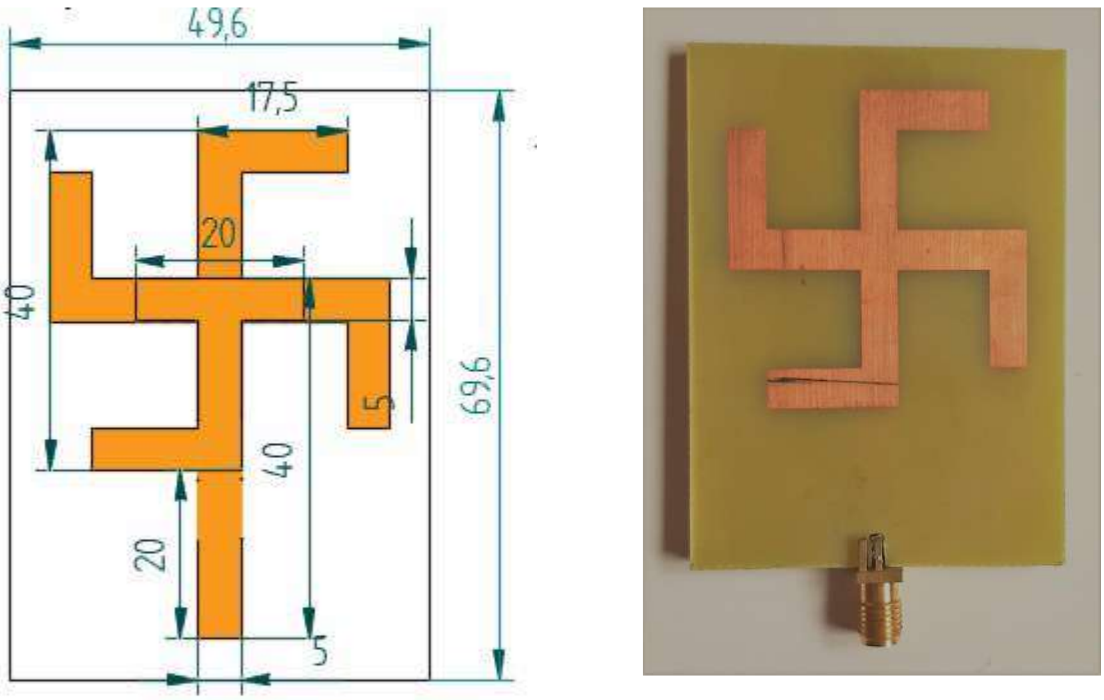


Figure 6.5 Geometry of swatik patch antenna

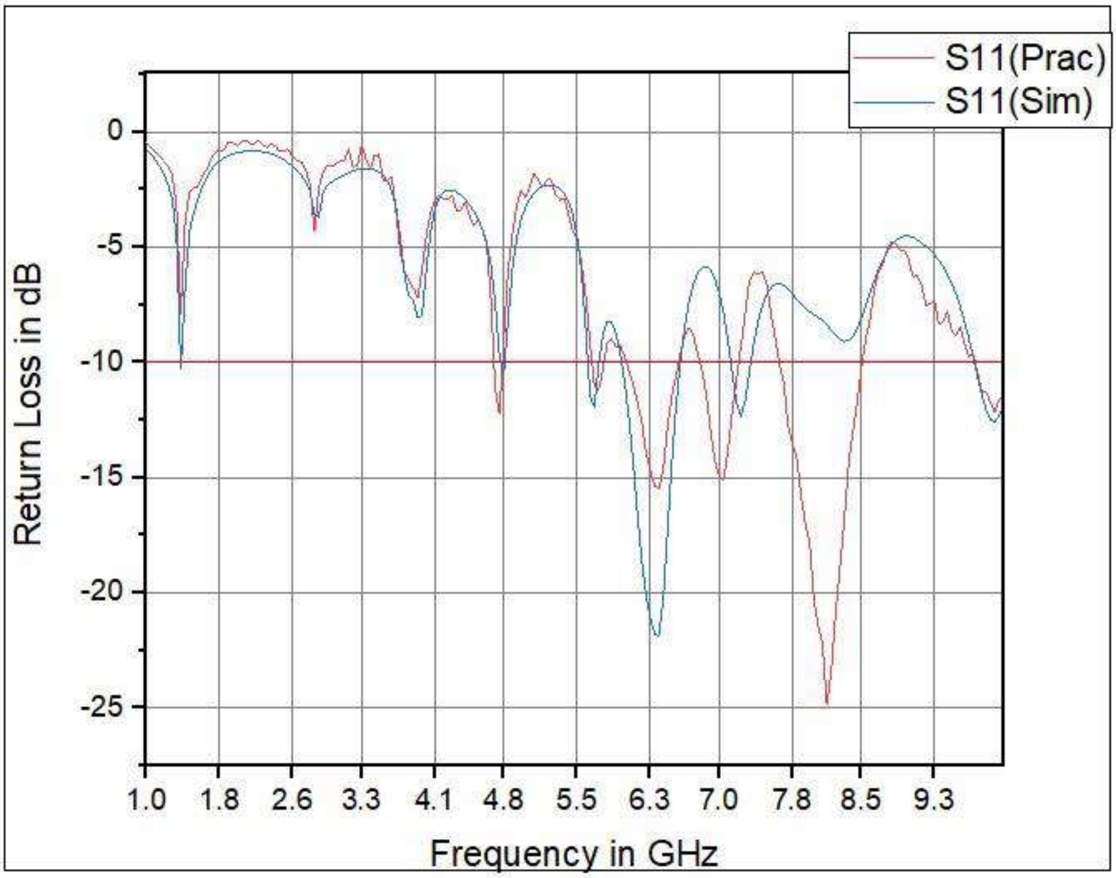


Figure 6.6 Return loss characteristics of swastik patch antenna

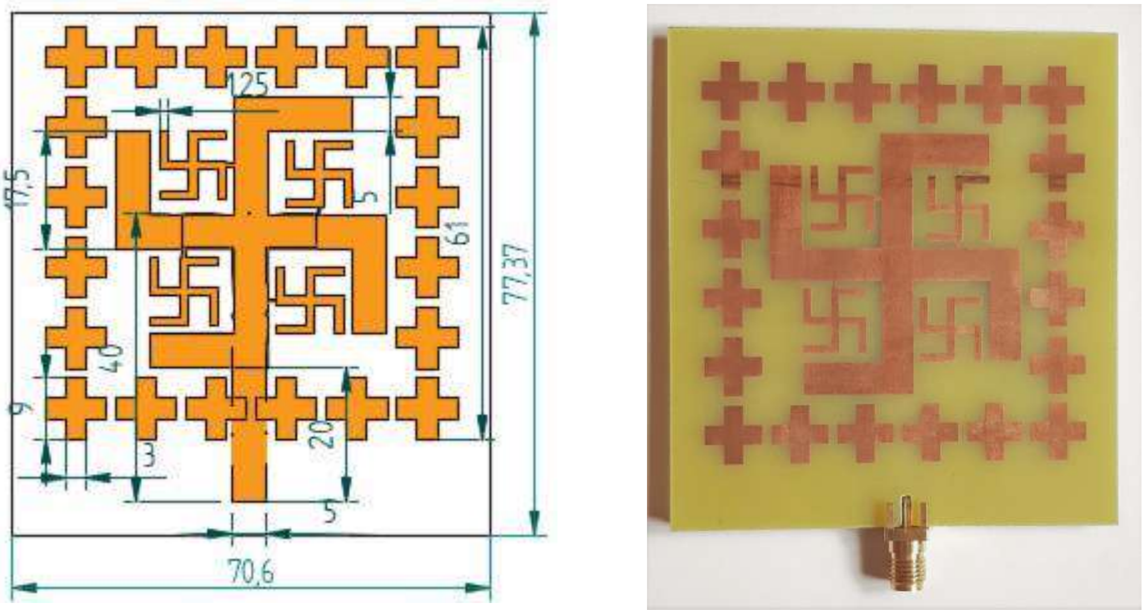


Figure 6.7 Geometry of fractal antenna with EBG

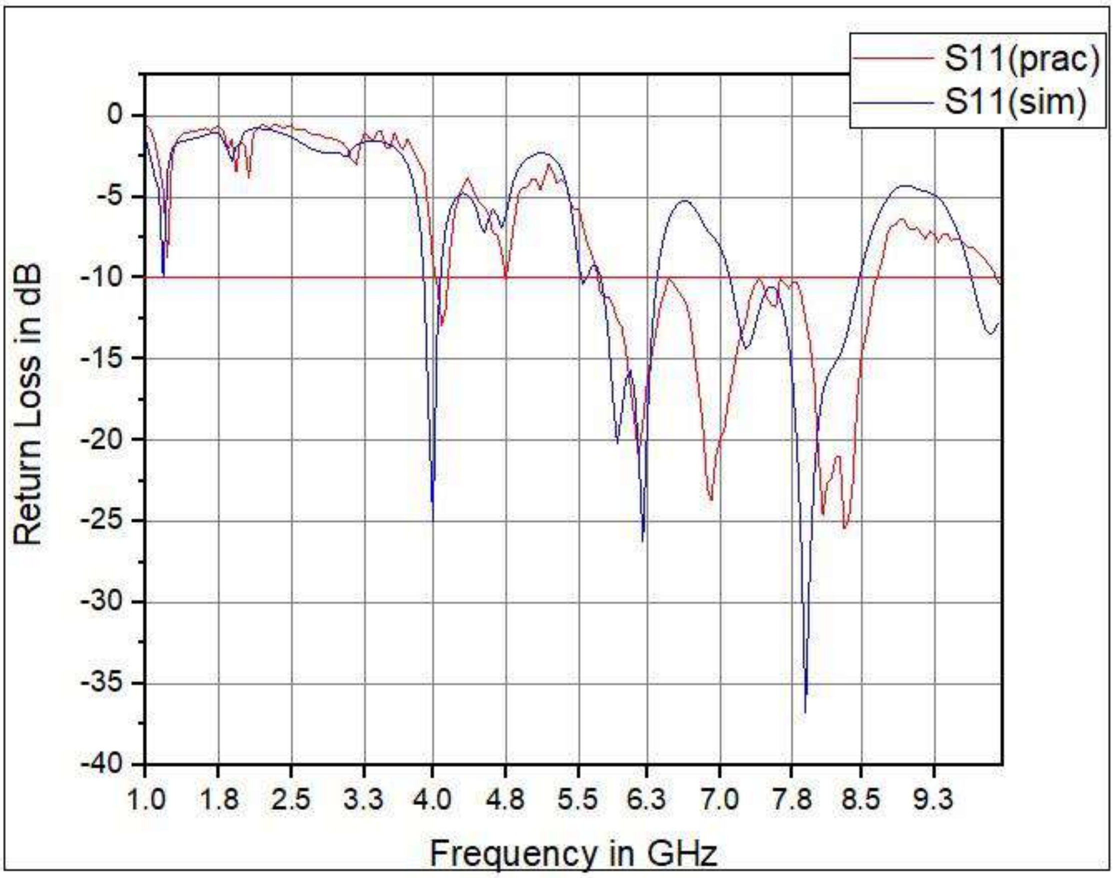


Figure 6.8 Return loss characteristics of fractal antenna with EBG

Sl.No.	Prototype Antenna	Resonant Frequency (GHz)		Return Loss (dB)		Impedance (Ω)		Gain (dB)	
		Sim.	Prac.	Sim.	Prac.	Sim.	Prac.	Sim.	Prac.
1	Reference Antenna	4.99	5	-14.42	-11.95	50.22	50.1	2.5	1.6
		8.63	8.2	-22.53	-25.44	52.83	52	7	1.78
2	Swastik Fractal Antenna	5.72	4.73	-11.84	-12.25	51.51	50.83	2.09	0.97
		6.36	6.4	-21.85	-15.50	52.29	51.43	2.86	1.37
		7.27	8.15	-12.53	-24.85	48.8	48.1	-1.62	2.76
		9.91	9.91	-12.53	-12.18	47.93	46.52	6.01	2.49
3	Swastik Fractal First Iteration	4	4.105	-15.3	-12.91	51.29	50.26	0.02	0.26
		6.27		-25.4		55.33	54.95	1.65	
		8	8.33	-31.5	-25.44	47.81	47.23	1.96	2.783
		9.9	9.91	-13.4	-10.64	47.15	47.03	6.01	3.6

Table 6.1 Comparison between simulated and practical results

Chapter 7

Conclusions and Scope for future work

7.1 Conclusions

Swastik microstrip fractal antenna was designed and simulated hierarchically with swastik and reference (square) patch antenna for improvement in bandwidth and to operate at multiple frequencies with reduction in resonant frequency for a given area of metallic (copper) patch. The electromagnetic simulations and analysis were carried out using Zeland IE3D 14.0 software.

The proximity coupled feeding technique was employed to obtain better bandwidth while swastik patch helped in multi-frequency operation. Swastik fractal was deployed to induce the reduction in resonant frequencies and electromagnetic band gap (EBG) structures were included in order to reduce imminent harmonic noise therefore increasing the gain at resonant frequencies.

The antennas were fabricated using photolithographic etching and were tested for credibility with Agilent E8363C PNA Network Analyzer. The practical results were correlated with simulation results.

4.2 Future Scope

Control of Beam Forming, reducing losses (or) increasing efficiency and improvement of directivity may be achieved through the implementation of the following techniques –

- **Aperture Coupled Feeding**
- **Various Co-planar EBG structures**
- **Ground Plane Alliterations**
- **Increasing Thickness of Substrate**
- **Use of Low Loss RF Materials**
- **Use of Metallic conductors other than Copper**

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