Design and Analysis of Dual-Band swastika Shaped Micro-strip Patch Antenna

A THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE DEGREE OF

M. Tech Degree

In

Microwave and Optical Communication

By

Rakesh Kumar Yadav

2K15/M0C/15

Under the Guidance of Professor

Dr. N. S. Raghava

Department of Electronics and Communication Engineering
Delhi Technological University
Delhi, India

2017

ACKNOWLEDGEMENT

It is my privilege and pleasure to have got the opportunity to appreciate and acknowledge several individuals without whom completion of this project and thesis would not have been possible. First and foremost, sincere gratitude is to be offered to my supervisor, Prof. **Dr N.S. Raghava**, who has been guiding me throughout the entire project. He has been a great source of motivation and has always inspired me to aspire to achieve more. Inconsiderate to be my good fortune to have been associated with him.

I express my thanks tr**od. S. Indus**, Head of Electronics and Communication Department, DTU Delhi for extending his support.

My sincere thanks to **Mr. Akhilesh Verma**, PhD Scholar, Electronics and Communication Department, DTU Delhi, for his consistent guidance to measure various antenna parameter, encouragement and help in learning HFSS Software.

I would also like to thank all PhD scholars and all colleagues in the microwave laboratory for having provided me their regular suggestions and encouragements during the whole work.

At last but not the least I am in debt to my Institution and My family members who have always been there for me.

Rakesh Kumar Yadav

Department of Electronics & Communication
Engineering
Delhi Technological
University

CERTIFICATE

This is to certify that the thesis entitled, "*Design and Analysis of Dual-Band swastika Shaped Micro-strip Patch Antenna for C band and X band Applications*" submitted by **Mr. Rakesh Kumar Yadav** in partial fulfillment of the requirements for the award of Master of Technology Degree in Electronics and Communication Engineering with specialization in "**Microwave and Optical Communication**" during session 2015-17 at the Delhi Technological University, Delhi is an authentic work carried out by him under my supervision and guidance. To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other University/Institute for the award of any degree or diploma.

Supervisor
Dr. N. S. Raghava
Professor
ECE Department
DTU Delhi

Head Of Department
Dr. S. Indu
Professor
ECE Department
DTU Delhi

Abstract

In this paper, a novel single-layer circular swastika shaped antenna with dual-band characteristics is presented. The proposed patch antenna, with design operating frequencies of5.5 GHz and 10.3 GHz, is targeted for applications in C-band and X-band. More importantly, the circular swastika-shaped micro strip patch antenna exhibits a theta polarized radiation pattern with gains of 11.17 dB and 9.05 dB with corresponding reflection Coefficients of (VSWR = 1.419) and (VSWR =1.046) at 5.5 GHz and 10.3 GHz, respectively. The Measurements of the fabricated patch antenna corroborate the simulation results obtained in HFSS. This dual-resonance antenna, with comparatively high gain performance, can be easily integrated into systems for satellite and radar communications.

Table of Contents

List of Figure

Chapter 1

Thesis Overview

1.1 Introduction

Table 1.1

Band	Transmit Frequency (GHz)
Standard C-Band	5.8–6.4
Super Extended C-Band	6.4–6.7
INSAT	6.7–7.0
Russian C-Band	5.9–6.4
LMI C-Band	5.7–6.0

In all, introduction of emblem pure mathematics into antenna style, that doesn't return a lot of, has shown important potential, geared toward bettering antenna characteristics, with varied degrees of success.

The analysis work that's given here is a shot at analyzing and understanding the impact of Swastika geometries on antenna characteristics. In recent years, many reports of such makes an attempt are created [22-25]. Makes an attempt are created at understanding the results of antenna parameters on antenna performances through constant quantity studies and analysis. Finally, with correct effort, associate antenna with Micro-strip fed circular emblem formed C Band and X Band characteristics area unit according.

1.2 Thesis Motivation

Over the previous few years, communication systems have undergone a shift. AWS (Advanced Wireless Services) providing a spread of wire-less services has been authorized. Mobile phones have ceased to be simply phones with the leading players additional bent desegregation applications like TV than ever. As a matter of truth, the scope has transcended the bounds and even analysis has full-grown manifolds for high-scale military applications. Ultrathin, high performance and convenient devices capable to satisfy the multiple specifications became the requirement of the hour. This, in turn, has guaranteed a growing would like for additional efficacies in antenna style and in that lays the origin of subsequent massive issue within the field of antenna engineering. To confront these inevitabilities, investigations into varied novel formed Swastika antennas is administrated.

This is an excellent technique of making tiny volume and low-profile antennas. Antenna efficiencies will be greatly improved by Swastika formed antennas. Besides leading to reduction in antenna dimensions, it's quite fruitful in BW improve techniques. [26] This is often greatly combined by the very fact that Swastikas tend to extend the antenna’s electrical length while not fixing the full space. Antennas will so be miniaturized. While not compromising with the performance and functioning, sizes square measure reducible up to fourfold. As a matter of truth, the performance gets considerably improved in addition.

The aim and motivation of this thesis is, thus, to understand the behavior of Swastika formed antennas.

1.3 Literature Review

The creation of Micro-strip patch antennas (MPA) has been ascribed to variety of creators, notably being Greig and Engleman, Lewin and Deschamps, WHO among themselves distributed the initial works beginning within the Nineteen Sixties. [5] Within the seventies, style equations began to be developed together with the arrival of the many publications administrated by keen researchers and authors like James Hall and David Pozar. Theirs and contribution of others within the initial investigations set the pace for any works. In fields as exacting as those of house analysis, satellite or military applications together with missile and high performance craft producing, wherever each in. counted, the constraints like size, weight, performance, simple integration and most significantly, cost, had created the requirement for a extremely economical nevertheless low profile antenna. The new Micro-strip antennas were simply tailor created for a similar. the prevailing antennas were, as aforementioned, cumbersome and required house to be deployed. With their appealing highlights, like simplicity in incorporation in clusters, compact-ness, extremely cost-efficient nature and light-weight weighted-ness MPAs were arduous to resist and it wasn't long before they began to be thought of as good candidates to be employed in the communication systems of the fashionable era, particularly in WLAN and cellular applications. [5] but, times have modified and even additional economical strategies of radiation and antennas have up over MPAs. toown most popular attributes over the Micro-strip antennas, an inspiration that is being actualised is Swastika. From a quantitative purpose of read, the house filling properties and therefore the self-symmetry property square measure invariably joined to the frequency characteristics of swastikas. The innate property of swastikas to rehash themselves at distinctive scales, i.e., the very fact that they're self-similar repetitive geometrical structures is very important as what it primarily will is enhance the electrical length of the antennas while not fixing the world.

Coined by Benoit B. Mandelbrot [27] these could also be found naturally within the varied patterns discernible within the surroundings and might be generated by mathematical strategies in addition. in turn, ballroom dancing feedback systems were wont to produce the full Swastika thought [28] Ramsey, a person of nice repute, established the fundamental religious doctrine of frequency independence of antennas. He established that associate degree absence of characteristics size that may be scaled by the wave's wavelength would render associate degree antenna frequency-free. In alternative words, associate degree antenna determinable by angles solely, would be freelance of any relation with frequency.

Usage of Swastika pure mathematics within the contradictory patch or ground of associate degree antenna maximizes the effective electrical length. It conjointly ends up in associate degree increment of the perimeter or the boundary on any aspect of the structure of fabric thereby sanctioning the reception and coefficient of EM radiation at intervals a given volume or total expanse. [5] Another fascinating attribute is that the additional one zooms in at finer and finer scales additional do you encounter self-recurring structures, such a lot therefore it becomes just about not possible to understand.

The Microwave region could be a transition region as regards theoretical strategies. Optical issues within the microwave antenna field square measure comparatively complicated and a few square measure of quite novel character; as an example, the optics of a arced 2 dimensional domain finds utilization within the style of speedy scanning antennas.

Antennas for solid Beams:

Solid beam could also be made by associate degree isolated half-wave antenna. This is often a helpful antenna over anoutsized frequency vary, the limit being set by the mechanical issues of supporting the antenna and achieving the desired isolation. The beam so made, however, is just too broad in elevation for several functions. Though this antenna is helpful over anoutsized frequency vary, most directionality for given antenna weight and size is procurable within the microwave region, wherever the biggest quantitative relation of aperture to wavelength will be realised.

Pencil Beam Antenna:

Beams that have directionality each in elevation and AZ could also be made by a combine of dipole components or by a dipole with a reflective plate. The key portion of the energy is contained in a very cone with apex angle somewhat but 180̊. Extremely directive pencil beams square measure made by inserting a partly directive system like the double-dipole unit, dipole-reflector unit, or horn at the main focus of a reflector or a symmetrical lens.

Antenna for flaring Beams:

Simple flaring beams and one-sided flares square measure likewise made by suggests that of reflectors and lenses and by arrays of dipole-reflector units or contrary slots. Such arrays by themselves offer beams that square measure extremely directive in planes containing the array axis however square measure fairly broad within the thwartwise plane. so as to achieve larger directionality within the thwartwise plane the array could also be used as a line supply on the focal line of a parabolic cylindrical reflector; this focuses radiation from a line supply within the same means that a reflector within the type of a two-dimensional figure of revolution focuses radiation from a degree supply.

Except for many kinds of linear array, all small wave antennas use primary sources of radiation along with reflectors and lenses. The EM Wave transmitting part, that extracts power directly from the line, is spoken of because the “primary feed,” the “antenna feed,” or just the “feed”; its pattern as associate degree isolated unit is thought because the “primary pat tern” of the antenna. Together with the optical components of the antenna, the feed produces the over-all pattern of the Antenna, usually named because the “secondary pattern” of the antenna. One amongst our major issues are to determine the relationships among the first pattern of the antenna feed, the properties of the optical components, and therefore the secondary pattern.

1.3.1 Antenna Patterns:

There square measure 2 kindsof patterns-

1. **The antenna as an EM transmitting device: The Gain Function:**

The fields setup by any EM wave transmitting system will be divided into 2 elements the induction field and therefore the field of force. The induction field is very important solely within the immediate section of the EM transmitting system: the energy related to it pulsates back and forth between the radiator and close house. At massive distances the field of force is dominant; it represents a continuous flow of energy directly outward from the radiator.

2. **The antenna as a Receiving Device: The Receiving Cross Section:**

The Performance of associate antenna as a receiving device will be represented in terms of a receiving cross section or receiving pattern. A receiving associate degreetenna can devour energy from anoccurrence plane wave and can feed it into a line that terminates in an engrossing load, the detector. The quantity of energy absorbed within the load can rely on the orientation of antenna, the polarization of the wave, and therefore the electric resistance of the antenna. We tend to shall suppose that the polarization of the wave and therefore the electric resistance characteristics of the detector square measure specified most power is absorbed. The absorbed power will then be expressed because the power incident on an efficient engrossing space, known as the “receiving cross section” or “absorption cross section”.

1.3.2 Wavelength Region:

This is the transition region between the standard radio region, within which the wavelength is extremely massive compared to the size of all the elements of the system (except maybe for the massive and cumbersome antennas) and therefore the optical region within which the wavelengths square measure too tiny. Radio emission ideas and techniques still be helpful within the microwave region and at a similar time bound devices employed in the optical region like lenses and micros square measure used. From the purpose of read of the antenna designer the foremost vital characteristic of this frequency region is that the wavelengths square measure of the order of magnitude of the size of convential and simply handled mechanical devices. This results in radial modification of easier antenna techniques and to the looks of recent and hanging potentialities, particularly within the construction and use of complicated antenna structures.

1.4 Chapter Contour

The FIRST chapter of this thesis is devoted to supply a short insight into the historical context of however wireless systems came into existence and also the means demands of our day to day lives and unforgiving experiences with nature galvanized and necessitated invention and innovation and enabled the fashionable communication systems to succeed in the stage they're nowadays. Also, provided is that the motivation behind enterprise such a task and also the literature review. Finally the chapter is summarized and a short summary of the following chapters is given.

The SECOND chapter starts with providing a short introduction concerning antennas through terms and their definitions. Supplementing this, Associate in introduction concerning Micro-strip Patch Antennas (MPAs) is provided. Description concerning their options, feeding ways and their associated blessings and downsides is additionally given. It goes on to supply totally different calculations and formulations for the calculation of feed-line dimension and alternative dimensions of the

MPAs and introduces the allegory pure mathematics and also the risk of its usage in antenna engineering. Allegory antenna engineering could be a booming new field of analysis that basically brings along the attributes of antenna style and allegory pure mathematics. Basic theory providing details of characteristics and categories and dimensions is given. It conjointly provides for a comparison of swastikas used as antennas vis-à-vis typical geometrician ones. Discussing the execs and cons of the allegory antennas, the chapter concludes

The THIRD chapter describes the planning and simulation of Swastika formed MPA.

The FOURTH chapter provides the Results and Measurements.

The FIFTH chapter is that the last one which incorporates conclusion, that is Associate in abstract thought gathered by the compilation of the work and observations and describe concisely concerning the scope of future work.

1.5 Summary

This chapter provides a short account of the brief journey of contemporary communication systems and also the evolution in antenna technology that was a necessary by-product. Besides comprehensively outlining the motivation that provided the impetus for the investigation, and stating the gist of erudite works that are studied and drawn inspiration from, tries area unit created to supply anoutline of the remainder of the thesis during a condensed manner.

Chapter 2

Antenna Theory

2.1 Antenna Fundamentals

Antenna: An antenna is a mean for "receiving and transmitting EM waves"; an intermediate structure between a guiding device as shown in Fig 1.1 and in vacuum. [29]

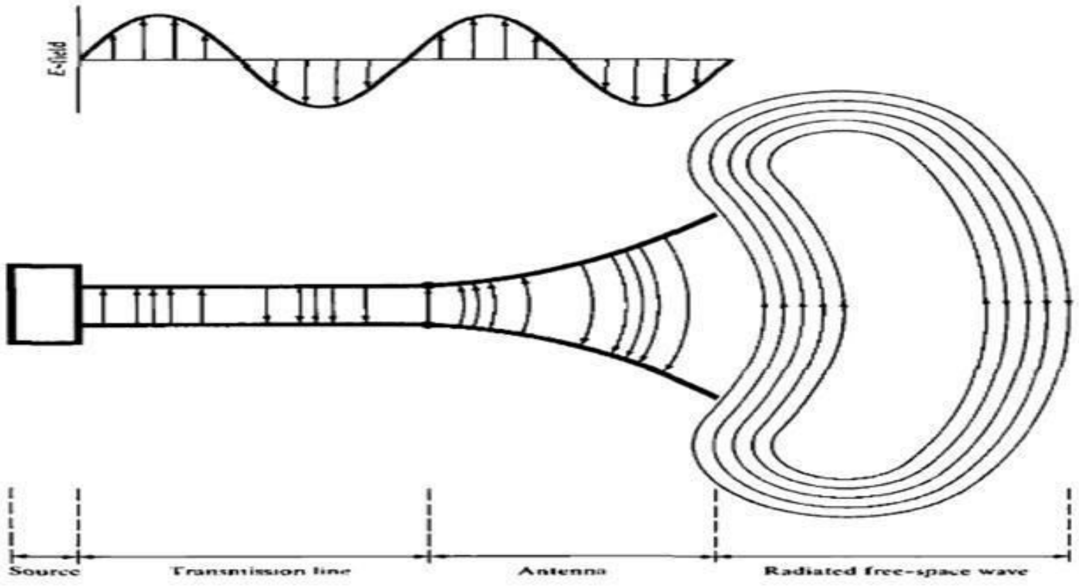


Figure 2.1: Antenna as a transition device

"Besides sending or receiving energy, in a complicated wireless system, Associate in antenna is needed to subdue the radiation energy in some directions and provides prominence thereto in others; so, rendering a vital role of being a directional device to the antenna with the exception of the regular one.” [29] The pathway provides a route for the alternating EM variations that tend to make an entire loop once they detach from the most transition phase thereby freelance of all variations that occur within the antenna once they leave it.

Several parameters ordain the performance of Associate in antenna. A number of those parameters and their properties area unit bestowed below.

Input Impedance:

Calculation of the input electrical phenomenon plays a vital role in determinative and is chargeable for most power transfer between line and also the antenna. Only if the matching of the several input electrical phenomenon of the line and antenna happens, will the transfer happen. Just in case the matching doesn't happen, mirrored waves area unit generated at the antenna terminal. These waves then travel back towards the energy supply thereby leading to the system potency diminution.

2.1.1 Gain:

Effectively measures the potency of Associate in antenna. [29] If gain equals the worth of that of the radial asymmetry it’s aforementioned to be 100% gain and vice-versa. varied dynamics area unit accountable in moving and trimming down the efficaciousness noteworthy of that area unit losses (material, random and network losses) and electrical phenomenon matching. Thus, there area unit plenty of adversities that antennas in impact ought toovercome for acceptable gain. [29] Typically, it may be delineate because the quantitative relation of the Associate in antenna radiated power to it of an isotropic antenna.

Various gains and their several formulations:

Directive Gain:

$$G_D(\vartheta,\phi) = \frac{4\pi U(\theta,\phi)}{P_r} = \frac{4\pi|\bar{E}(\theta,\phi)|^2}{\int_0^{2\pi}\int_0^{\pi}|\bar{E}(\theta,\phi)|^2 \sin\theta \, d\theta \, d\phi}$$

(2.1) [29]

Power Gain:

$$G_P = \frac{4\pi U_{max}}{P_i}$$

[29] wherever Pi=Pr + Pl; Pi being total input power and Pl denoting loss

(2.2) Radiation Efficiency:

$$\eta_r = \frac{G_p}{D} = \frac{P_r}{P_i}$$

(2.3)[29]

2.1.2 Radiation Pattern:

A practical illustration of directional coordinates, it's a method to grasp specifically however antennas direct the energy they emit. 100% potency signifies that the antenna can radiate an equivalent total energy for equal input power regardless of what form the pattern takes. principally evaluated within the far-field region, it provides valuable info concerning intensity level, radial asymmetry, power concentration, polarization and alternative such radiation properties. Relative dB scale is their usual mode of presentation.

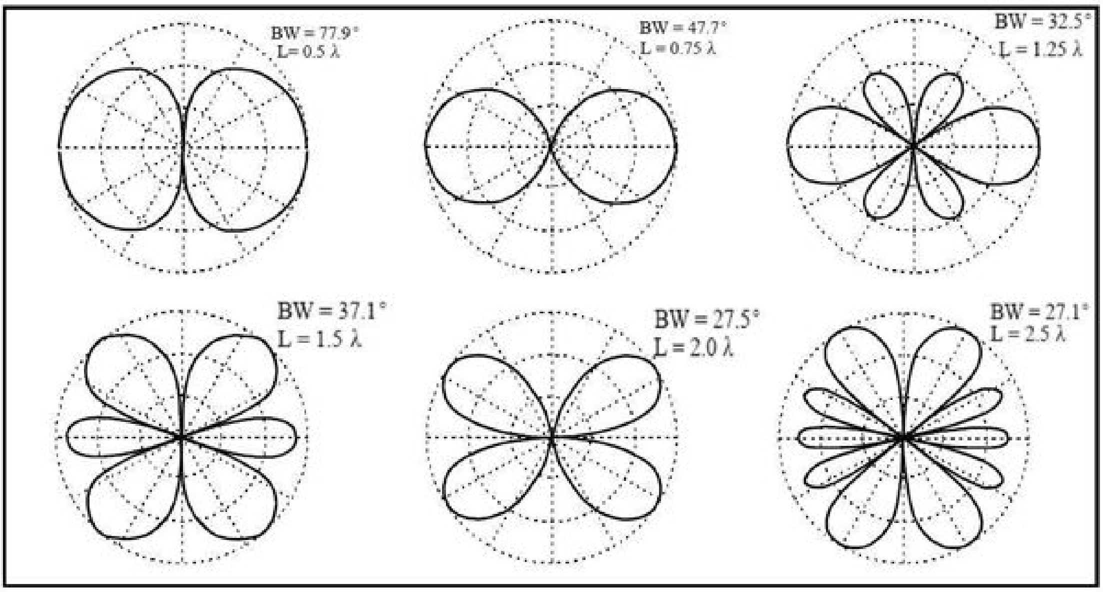


Figure 2.2: graphical record

HPBW (Half-power Beam dimension): Width of the most beam (angular) between the -3dB points that signify the half-power levels.

Side-Lobe Level: (|EMax| in one in all the facet lobes)/(|EMax| in main beam)

Null Positions: There exist bound directions within the far-field territory that have zero radiation.

These area unit referred to as the Null Positions.

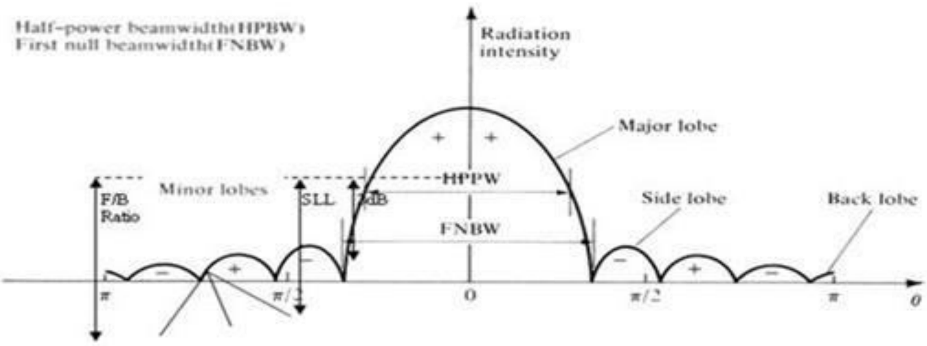


Figure 2.3 Beam width and lɵbes

2.1.3 Directivity (D):

Directivity signifies the gain maxima in any specific orientation or direction. Therefore, it's a vital parameter that measures the antenna's capability of focusing radiated energy. Contoured because the quantitative relation of most radiated power to the common power of a reference isotropic antenna (which, in turn, is a perfect case with spatial relation uniform radiation and unity directivity)

It's represented by the subsequent equation:

$$D = \frac{F_{max}}{F_0}$$

(2.4)

Where Fmax and F0 area unit severally most radiated energy and isotropicantenna's radiated energy.

Directivity:

$$D = \frac{4\pi U_{max}}{P_r} = \frac{4\pi|\bar{E}_{\max}|^2}{\int_0^{2\pi}\int_0^{\pi}|\bar{E}(\theta,\phi)|^2 \sin\theta \, d\theta d\phi}$$

Where$U = R^2 P_{av} \propto R^2 |\bar{E}|^2$

(2.5)

Where

$$P_{rad} = \oint P_{av}\, dS = \oint U d\Omega \propto R^2 \int_0^{2\pi} \int_0^{\pi} |\bar{E}|^2 \sin\theta d\theta d\phi$$

(2.6) is that the radiated power (time-averaged).

2.1.4 Polarization:

Polarization of any given EM Wave transmitting system is given by that of the wave it radiates. [29] during a sense it offers a crisp description regarding the sense and orientation of the wave's field vector. [30] 3 basic classesof identical ar Linear, Elliptical and Circular. [29] generally, most of the radiated waves ar either linearly or circularly polarized, therefore creating it the same old polarization of the radiators.

2.1.5 Bandwidth:

Bandwidth alludes to defined range of frequencies over that the antenna gives certain needed or pre-fixed properties. In different words, the vary over wherever sure sets of conditions are matched. [30] The trade-offs in varied performance parameters is what's the matter of concern whereas crucial a selected measure. 2 strategies by that interpretation measure calculated are:

Narrowband by %:

$$BW_p = \frac{f_h - f_l}{f_c} * 100\%$$

(2.7) Broadband by Ratio:

$$BW_b = {f_h}/{f_l}$$

(2.8)

Wherever fc: Center Frequency

fh: Higher Cut-off frequency

fl: Lower Cut-off Frequency

The UWB (Ultra-Wide Band) band was named intrinsically by the Federal Communications Commission (Federal Communication Commission) in 2002, once the information measure of three.l-10.6 gigacycle was allotted for industrial use. The –10dB information measure of the UWB emission forms the idea of the band of operation. UWB technology was allowable by existing wireless communications' framework tooverlap and pose within the three.1 to 10.6GHz range, with the already to be had services like the IEEE 802.11 WLANs & Wi-MAX. As per Federal Communications Commission Rule, any signal with uncomplete information measure, bigger than zero.25 or occupying a minimum of 500MHz spectrum will be utilized in UWB systems. UWB is applicable to any or all the technologies that use 500MHz spectrum likewise as suits all different needs for UWB, is what it basically means that. [31]

2.2 Micro-strip Antennas

One of the foremost booming topics in recent years within the field of antenna design style and theory is that the Micro-strip placoid Antenna and is progressively being a vicinity of diverse trendy microwave systems. The terribly plan of MPAs traces back to 1953 [32] and 1955 dated patent [33]. However it came into focus beginning principally within the Nineteen Sixties and 70s once microwave devices began to be manufactured; fictional on low volume semiconductor chips and affixedon ably planned packages.

As additional stress was given on the assembly of low price and compact antennas, due to the ever increasing demands for moveable and private devices for mobile communications,

Micro-strip or just, as they're typically stated, „patch' antennas came into the limelight. In its most elementary configuration, a patch antenna may be aEM Wave transmittingpatch connected with a bimetallic path, known as a „feed line', written on the front aspect of a di-electric substrate, that is grounded on the opposite aspect. The same radiating patch will assume varied shapes, starting from circle to triangular, from rectangular to annulate rings as shown within the following page in Fig. 2.4. These feed lines and radiating patches ar written mistreatment lithography or computer circuit technique, on the stuff substrate.The aspect and high read of anoblong patch antenna is additionally shown within the future Fig. 2.5 [5]

The basic properties of the patch antennas are evaluated within the denotive literature [34, 35].

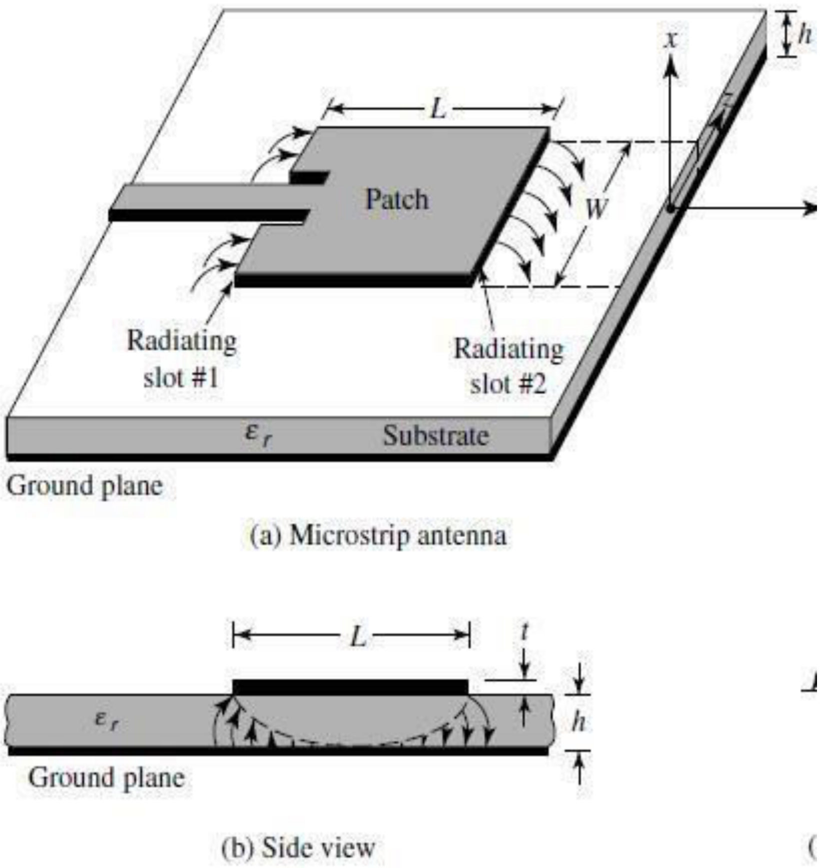


Figure 2.4: Rectangular Micro-strip Patch Antenna

Essentially,of the 2 varieties of EM wave radiation, one is that the broadside radiation and end-fire radiation being the opposite. If most of the pattern is perpendicular to the axis of the antenna or the patch, then the radiation is spoken as Broad-side radiation. However, for those radiations within which the most is within the direction of the antenna axis, the term used is End-fire radiation.

The micro-strip patch antennas area unit devised in such the way that the direction of the pattern most is perpendicular to the direction of the antenna axis or patch. In alternative words, its behavior is analogous theretoof a broadside radiator. the belief of constant is allotted by correct mode selection; mode being the configuration of the sector of the excitation that lays to a lower place the patch. correct mode choice also can render the likelihood of end-fire radiation.As shown within the Fig a pair of2.4, the patch and also the ground plane area unit separated by the nonconductor sheet.

A voltage between ground plane and feed probe drives the antenna, in transmission mode of operation. From there on, current exits on to the bottom plane and patch. Electrically speaking the nonconductor substance is sometimes skinny. So, the nonconductor elements that area unit in parallel to the bottom plane area unit basically terribly tiny through the substrate. If the length of the patch component is [*fr1], massive current and field amplitudes result at resonance. The magnetic current and surface current density that is evoked on the patch leads to the radiation.

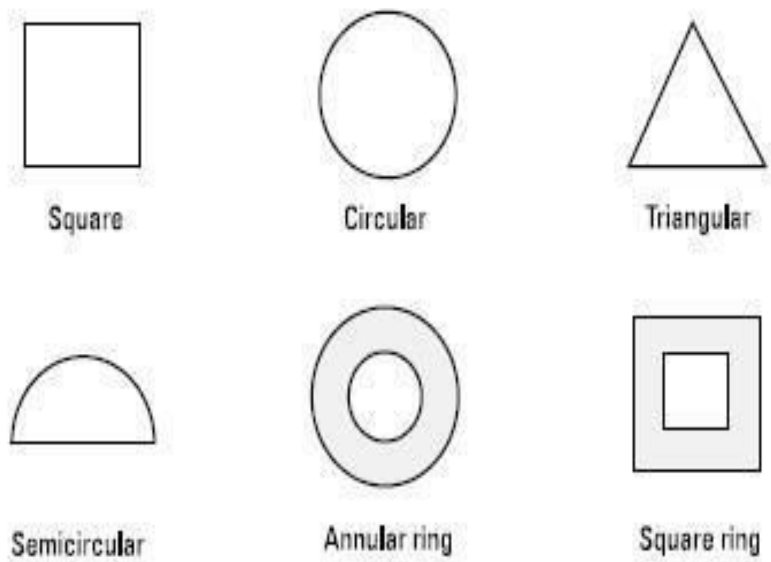


Figure 2.5 Various patch shapes

For the crafting of patch antennas many substrates are and area unit used. The vary of the ϵ_r is some times a pair of 2.2 ≤ 12 looking on the practicality, substrates may be chosen. Substrates with low $\epsilon_r$with goodly thickness area unit chosen for higher performance of the antenna in terms of the potency that is bettered, higher radiation into house as fields become loosely delimited and information measure that is enlarged. However, the component size will increase still that is its principal trade-off. Substrates whose nonconductor constants area unit high and have lower thickness basically keep company with tightly sure fields. Thus, they realize use for microwave electronic equipment because the said property renders coupling and lowest unwanted radiation. This, in turn, leads to smaller sizes of the weather. However, thanks to their bigger loss tendency, their bandwidths area unit comparatively smaller and their potency is low. [36]

In view of the very fact that patch antennas got to be integrated sometimes with alternative microwave electronic equipment, a middle ground is found between circuit style and antenna performance in terms of parameters like potency, information measure etc. [29]

2.2.1 Feeding ways

To modify the antenna operate at the transmission's full power, feed-lines area unit vital. making feeding techniques for antennas to control at high frequencies may be a tasking task. The proportion of feeding's input loss on the frequency may be a major concern, albeit and should leave vast repercussions on the general style of the antenna.

Micro-strip patch antennas area unit fed by varied feeding techniques, well-liked among whom area unit as under: [29]

- Micro-strip line
- Coaxial Probe

- Proximity Coupling
- Aperture Coupling
- Coplanar Wave Guide (CPW) feeding

Micro-strip Feedline:

Also referred to as the conducting strip, its dimension is far smaller than that of the patch. Characteristically it's related to thicker substrate that is proportionate to the surface waves. [30] This feed-line is related to simple modelling and fabrication because the feed will merely be incised together with the patch on the substrate successively leading to a planate structure. The inset feed position may be manipulated and therefore matching is easy.

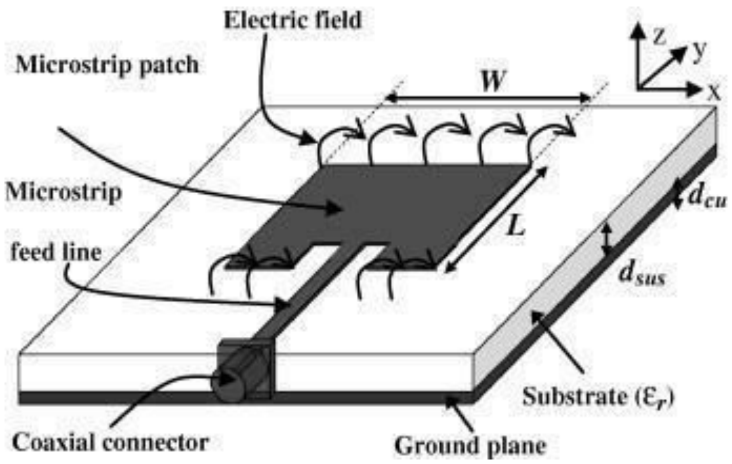


Figure 2.6: Micro-strip Line Feeding

However one major con of this methodology of feeding is that because the surface waves area unit proportional to surface thickness, a rise within the thickness of the surface leads to spurious radiation that successively leads to the information measure obtaining limited; the limit of radiation information measure being a pair of to five.

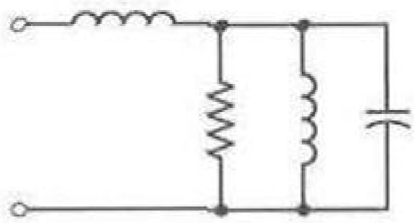


Figure 2.7: Equivalent Circuit of Micro-strip Feed Line

- **CoaxialProbe Feed:**

In this technique of feeding, the concentric inner conductor is connected to the patch that is answerable for radiation whereas contact is created with the bottom plane via the outer conductor. they're wide used and one in all the first reasons is its inherent benefits just like the simple matching and fabrication. increase that the very fact that, the spurious radiation related to it's additionally pretty low.
However, it's its own characteristic shortcomings. it'scharacterized by slender information measure and is extremely troublesome to model particularly for substrates with higher thickness.

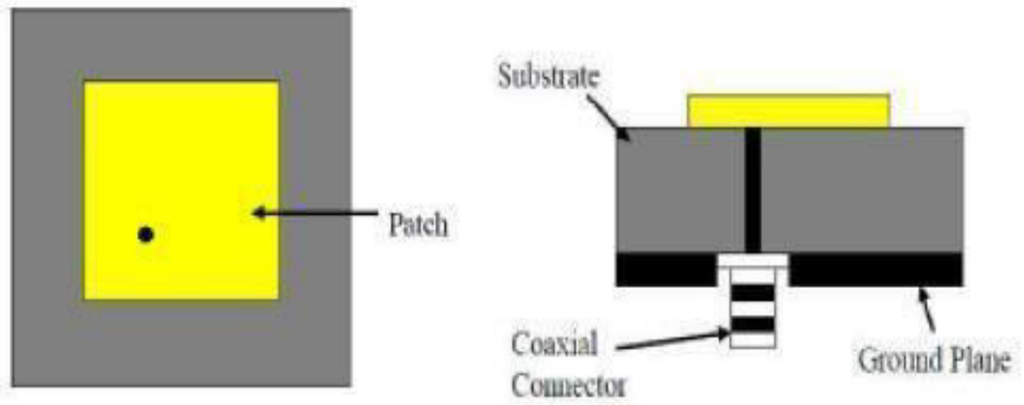


Figure 2.8: concentricFeeding

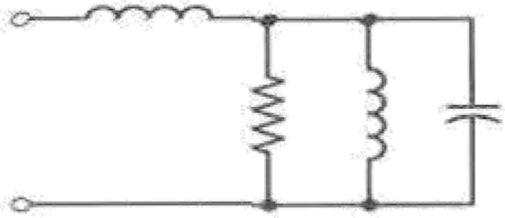


Figure 2.9: Equivalent circuit of concentric Probe Feed

Both the concentric probe and also the Micro-strip printing operation generate higher order modes as a result of their associated asymmetries. This successively ends up in cross-polarized radiation. to beat this, introduction of non-contacting aperture coupling has been done.

- **Aperture Coupling:**

In this technique, a ground plane separates 2 substrates. There's a Micro-strip feed line beneath the lower substrate. Its energy, via a extract the bottom plane between the 2 substrates is coupled to the diverging patch. The diverging component and also the feed mechanism area unit therefore severally optimized through this procedure. The nonconductor permittivity of the lower substrate is often high whereas for the substrate on top of the bottom, low nonconductor with sensible thickness is desirable. additionally polarization purity is achieved because the separation of the 2 substrates by the bottom plane isolates the diverging component and also the feed, thereby minimizing spurious radiations interferences for formation of patterns. [5]

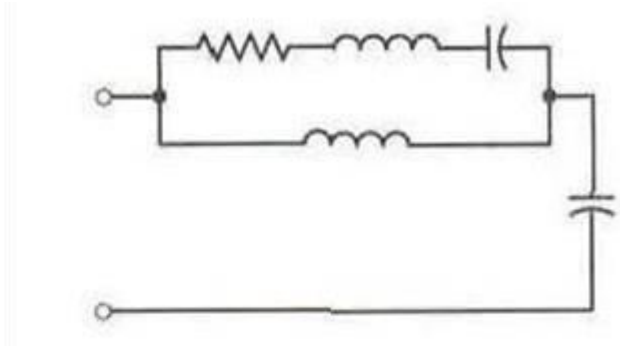


Figure 2.10: Equivalent circuit of Aperture Coupled Feed

The design may be optimized by mistreatment the dimension of the feedline, size and position of the slot and alternative electrical parameters of the substrate. By dominant the slot’s length and also the feed’s dimension, matching may be achieved.

Magnetic coupling can dominate if the slot’s position is true below the patch at the middle, wherever ideally for the dominant mode, H-field is goop and E-field is null.

Small information measure happens to be the worst potential demerit of micro-strip antennas that basically necessitates the rise its information measure. Proximity coupling is one such methodology.

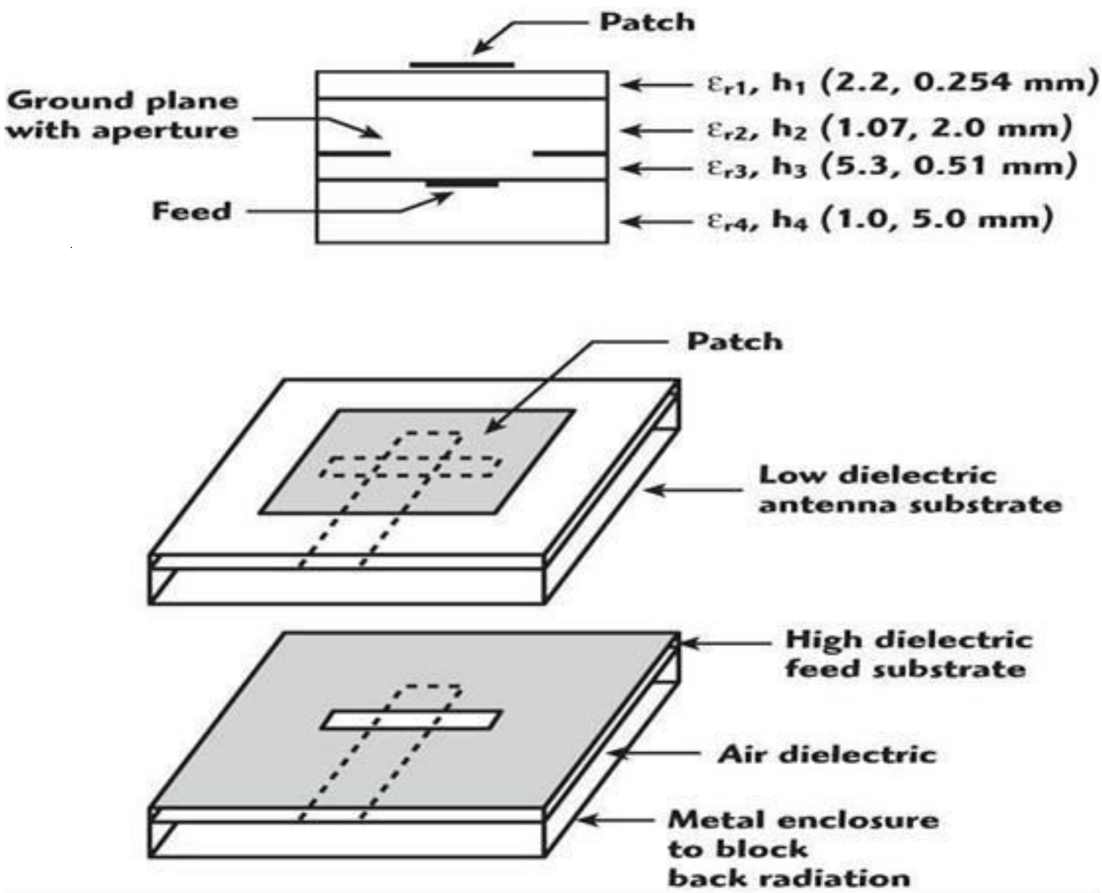


Figure 2.11:Aperture Coupled

- **ProximityCoupling:**

In this technique there's a ground plane that lies toa lower place with 2 substrates on top of. Between the 2 substrates, at the boundary, employing a proximity-coupled micro-strip feed line to a patch antenna, information measure is increased. The same patch antenna is written simply on top of the feed-line on a substrate.

The two varieties of information measure specifically, resistivity information measure (the vary of frequencies over that antenna and also the feed-line stay matched up to some predefined level) and also the pattern information measure (the vary of frequencies over wherever the pattern maintains its fidelity) area unit glad by the perfect broadband diverging component. Thus, it characteristically possesses massive information measure, in fact, the biggest of all the feeding schemes. It’s additionally related to low spurious radiation. Albeit it’s easier to model, there's basically lots of issue related to the fabrication.

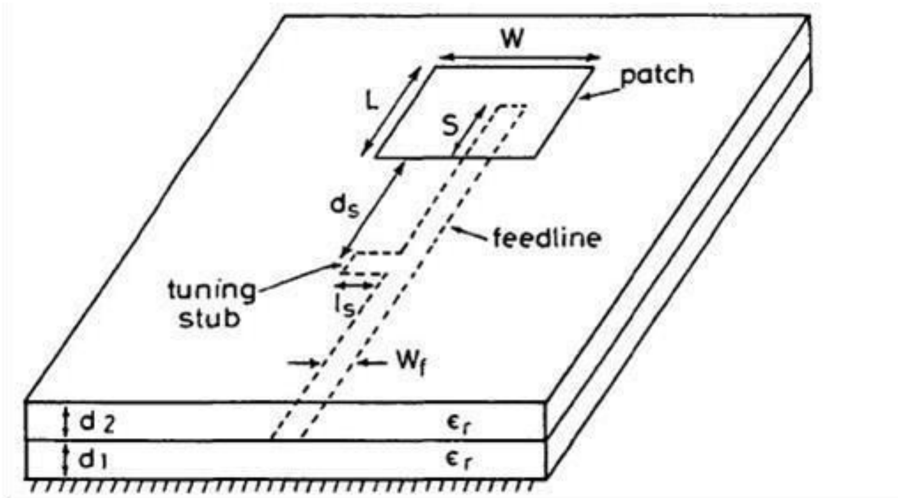


Figure 2.12: Proximity Coupled Feeding

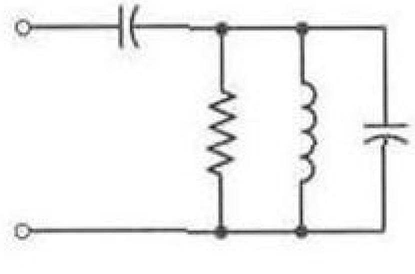


Figure 2.13: Equivalent circuit diagram

 Co-Planar wave guide (CPW):

In this technique, a separate ground plane ceases to exist. Rather it’s higher than the substrate on either side of the feed line as shown within the figure that follows. band techniques like proximity coupled and aperture coupled feeding expertise alignment drawback between the feed line and also the slot.

however having graven each of them on identical facet of the substrate, the CPW technique suffers from no such disadvantage.
It has an easy configuration having fully no would like for coupling via holes and may match resistance higher as long as it's on one metallike layer. simply integrated with circuits, this methodology among alternative benefits has less dispersion and low radiation loss. The associated information measure is fairly giant further.

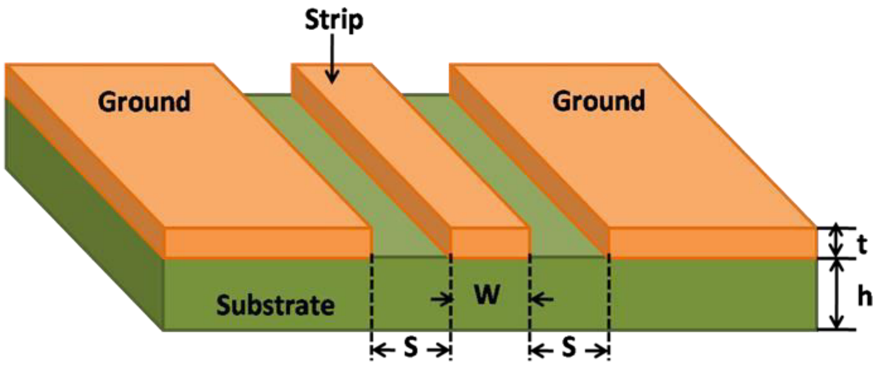


Figure 2.14 Co-Planar Waveguide feeding

2.2.1 Structural Analysis of MPA

There ar many widespread models for the analysis of MPAs major of that ar particularly, conductor model, Full wave model and Cavity model. whereas cavity model is related to a lot of accuracy however in that lays the inherent rise in quality and issue to model coupling. Full wave model is that the most advanced of the ton capable of treating single components further as stacked ones, infinite arrays and coupling with skillfulness and accuracy.

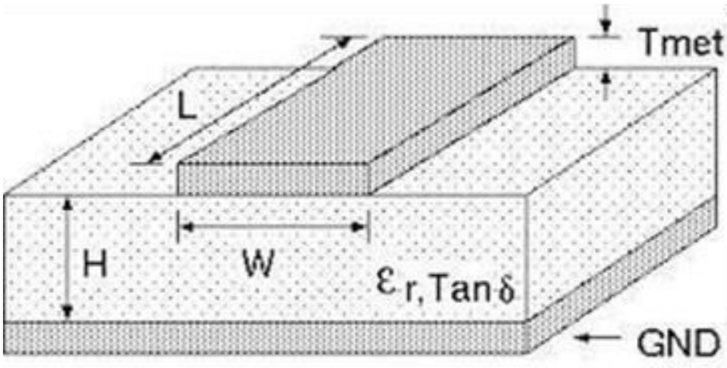


Figure 2.15: Micro-strip Line

Although conductor model is neither correct nor versatile, it’s the only of all. It represents the micro-strip antenna simply by a low-impedance conductor of length L, dimension W and height H separating 2 slots as shown within the previous page.

- **Fringing Fields**

The patch’s dimensions will solely be finite whether or not it’s on the dimension or the length. in that lays the basis supply of the fringing fields that endure fringing at the patch’s edges. Illustrated below is that the fringing of fields for a micro-strip antenna with 2 EM Wave transmittingslots.

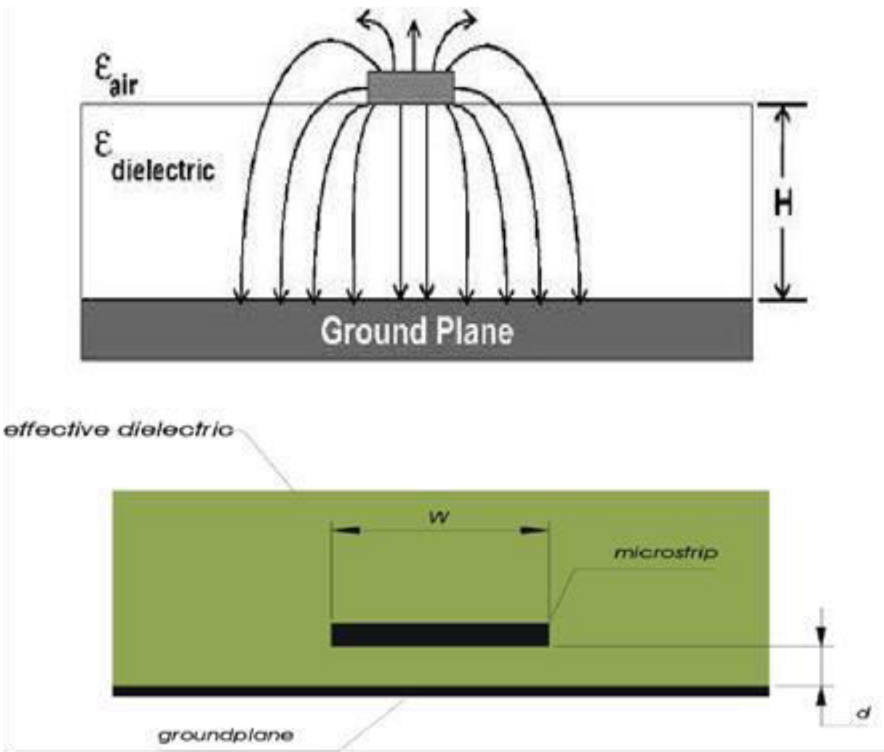


Figure 2.16: Effective insulator Constant and E-field Lines

The height of the substrate and also the patch dimensions ar the foremost deciding parameters of the number of fringing. Typical E-field lines of a micro-strip antenna ar as shown higher than. As W/H >>1 and and as illustrated within the figure most of the said lines be the substrate itself. There exists solely a region of it within the conterminous air medium. therefore creating it the 2 dielectrics', particularly substrate and air, line a non- solid one. The electrical dimensions of the Micro-strip look wider than they're physically owing to fringing. whereas some waves travel through the substrate, thereforeme do so through air. therefore to require into thought each the same sort of wave propagation and also the fringing there's the introduction of an efficient insulator constant (EDC), denoted by [29]

$$\epsilon_{reff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2}\left(\frac{1}{\sqrt[2]{\frac{12H}{W} + 1}}\right)$$

(2.9)

Valid for W/H >one for low frequency of operation wherever H is that the substrate's height and W is that the dimension of the feed line. is that the substrate's insulator constant.

Thus, it will be finished with conviction that for ifof the substrate a lot of|is far|is way} bigger than unity the worth of EDC would be much nearer to the substrate's insulator constant in

Actuality. 1<€reff<€r, if air is that the medium higher than the substrate. Frequency of operation, however, conjointly affects the EDC. With a rise in frequency, there's AN associated increase within the E-field lines concentration within the substrate. [29] EDC remains constant for low frequency of operation.€reff→€r at intermediate frequencies.

The height of the substrate H and also the W, the feedline's dimension conjointly have an effect on the characteristic resistance Z0.

$$Z_o = \frac{60}{\epsilon_{reff}} \ln\left(\frac{8H}{W} + \frac{W}{4H}\right); \ \frac{W}{H} \leq 1$$

(2.10)

$$= \frac{120\pi}{\epsilon_{reff}} \ln\left(\frac{8H}{W} + \frac{W}{4H}\right); \ \frac{W}{H} > 1$$

(2.11)

H and W ar set by parameters A and B, that successively rely on insulator constant of the substrate and also the characteristic resistance given by the subsequent 2 equations.

$$\frac{W}{H} = \frac{8e^A}{e^{2A} - 2}; \frac{W}{H} < 2$$

$$\frac{W}{H} = \frac{2}{\pi}\left[B - 1 - \ln(2B - 1) + \frac{\epsilon_r - 1}{2\epsilon_r}\left\{\ln(B - 1) + 0.39 - \frac{0.61}{\epsilon_r}\right\}\right]; \frac{W}{H} > 2$$

(2.12)

The values of A and B ar severally given by the subsequent equations:

$$A = \frac{Z_0}{60}\sqrt{\frac{\epsilon_r + 1}{2}} + \frac{\epsilon_r - 1}{\epsilon_r + 1}\left(.23 + \frac{.11}{\epsilon_r}\right)$$

$$B = \frac{377\pi}{2Z_0\sqrt{\epsilon_r}}$$

Now since fringing has a bearing on the antenna's resonant frequency it ought to be looked into and reduced.

Typically, 50Ω is taken because the feed line's characteristic resistance for the subsequent reasons:

50Ω is that the internal resistance all obtainable supply ports. most Power

Theorem dictates that for transferring most power 50Ω must be chosen because the patch antenna's feed line's characteristic resistance.[5]

Theoretically, for minimum attenuation 76Ω is needed within the line and for optimum power transfer 37Ω is that the calculated ideal resistance. Compromising, the typical of the 2 values is chosen. [5]

2.2.3 Benefits and downsides

Modern communication systems wide use the MPAs. Starting from satellite communications to usage in missile systems for military functions to GPS, patch antennas have varied utilities. Attributable to their characteristic options, discussion regarding their varied benefits is completed below:

Benefits

- Lightweight and tiny Volume.
- Low Profile flattened configuration
- Conform to any surface
- Using PCB technology, will be made in mass resulting in lower value or more cost-effective suggests that of fabrication
- Given identical substrate it's significantly easier for desegregation with alternative MICs each circular further as linear polarization is allowed for.
- Low volume renders them compact; will be used for private mobile commas
- Are operable at multiple frequencies
- Cavity backing is evitable
- Scattering cross section is low
- Ease of attaching to missiles and alternative such house important devices

Disadvantages:

- Gain is pretty low
- Bandwidth is slim and is related to tolerance problems
- Difficulty in achieving purity in terms of polarization
- High performance arrays need complicated feed structures
- At high frequencies, unacceptable levels of mutual coupling and cross-polarization

Some strategies to attenuate limitations:

Limitations related to excitation of surface waves like pattern degradation, increasedmutual coupling, lesser gain and lesser potency will be prohibited mistreatment photonic band-gap structures [29]

Low power handling ANd lower gain will be overcome mistreatment an array configuration

With a rise within the substrate height H, there's AN associated increase in bandwith and thus potency. The trade-off related to this can be the generation of surface waves that lead to losses.

2.3 Swastika Circular Antenna

Antenna theory has become one among the most recent fields wherever tetraskelion pure mathematics use has created a big impact. As a matter of truth, a number of the antennas commercially employed in the medium sector have already been replaced by that mistreatment tetraskelion pure mathematics. many enhancements have already been ascertained within the case of antennas that create use of the said pure mathematics. What's in reality missing could be a direct affiliation between the usage of the properties of the underlying tetraskelion pure mathematics and also the antenna options. [30]

Some of the numerous enhancements attributed to swastikas ar size reduction of antennas and introduction of multi-band nature. They still stay the prime motivation, albeit a lot of utilities have inherit the scene. for example, reports of the many dipole and monopole antennas are created. as long as these qualitative links aren't continually full-proof, style improvement necessitates the existence of a quantitative affiliation. It's a section of continuous analysis to link to try and do identical, i.e. to ascertain a relation between the tetraskelion dimensions and antenna behavior.

2.4 Summary

A discussion regarding varied terms related to antennas was wiped out this chapter. conjointly a quick introduction was given regarding the fundamentals of MPAs. varied feeding mechanisms with relevancy compact and low volume antennas, for wireless applications were mentioned further. the explanation behind mistreatment the 50Ω conductor was in short thrown come upon.

Besides deduction of the patch antenna theory, the execs and cons {and the|and therefore the|and conjointly the} strategies helpful tocut back such limitations were also in short prohibited. Discussions on tetraskelion pure mathematics were conjointly done. Besides comparison the standard euclidian with the tetraskelion pure mathematics, the latter's execs and cons were conjointly mentioned.

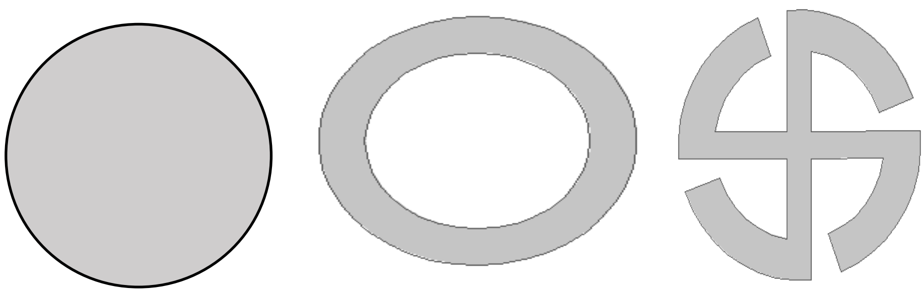
Chapter 3

Antenna design and Simulation

3.1 Introduction

This chapter presents the planning and analysis of a swastika formed Micro-strip Patch Antenna and its two different frequency Band behavior. the planning consists of a C band and X band that constitutes the bottom on that another allegory pure mathematics. The patch as a full is on high of the Rogers RT/duroid 5880 (tm) substrate of material constant two.2. the selection of Rogers RT/duroid 5880 (tm) is predicated totally on laminates have rock bottom electrical loss of any bolstered PTFE material, low wetness absorption, area unit isotropous, and have uniform electrical properties over frequency. below the substrate lies a ground that itself could be a circular phase. The antenna exhibits narrowband characteristic. For associate antenna to be selected as a narrow-band one, the resistivity information measure should be but five hundredth, i.e.

$$[BW]_p=\frac{f_h-f_l}{f_c}\times 100\%$$



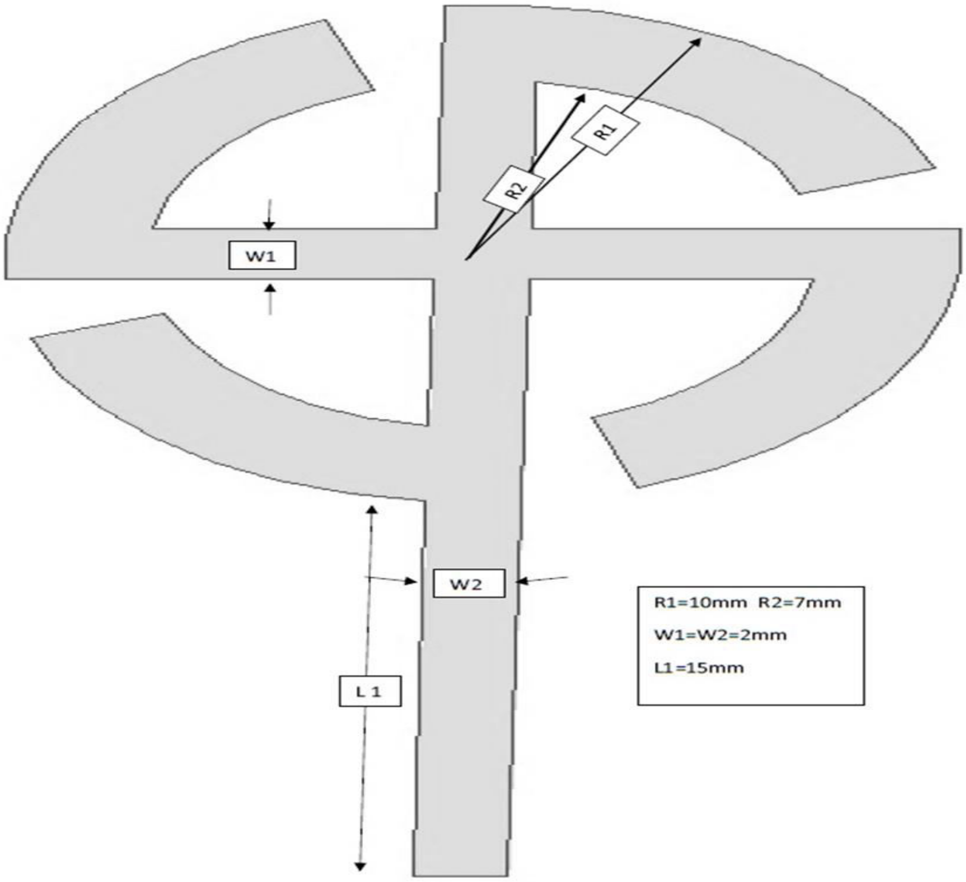


Figure 3.1: Structure of front patch

Table 3.1: Dimensions of the Front patch

Length of the patch	35mm
Width of the patch	20mm
Width of the strip line feed	2mm
Length of the strip line feed	15mm
Width of outer circular ring	2mm
slots in ring	10˚

N.B: Taking the center of the substrate as the origin, rest of the coordinates are determined.

The entire patch is fed with a 50-ohm micro-strip feed line with dimensions 15mm X 2mm.

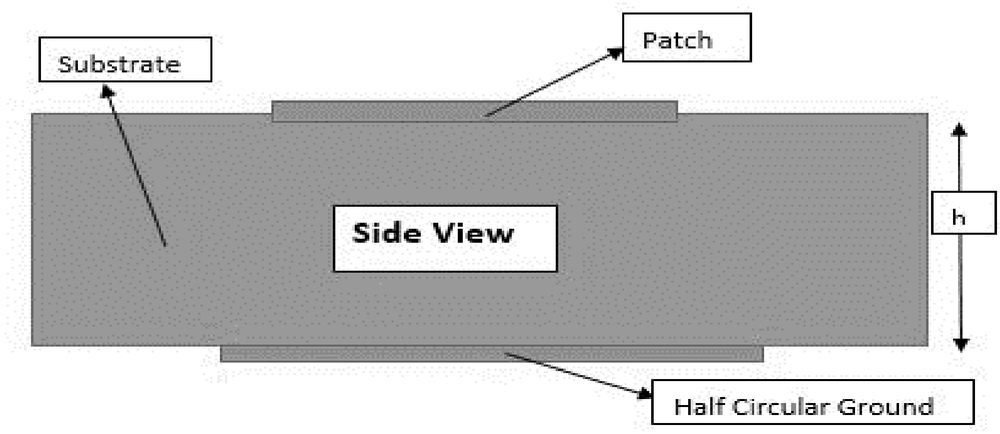


Figure 3.2: Side view of the design with substrate height 1.6mm

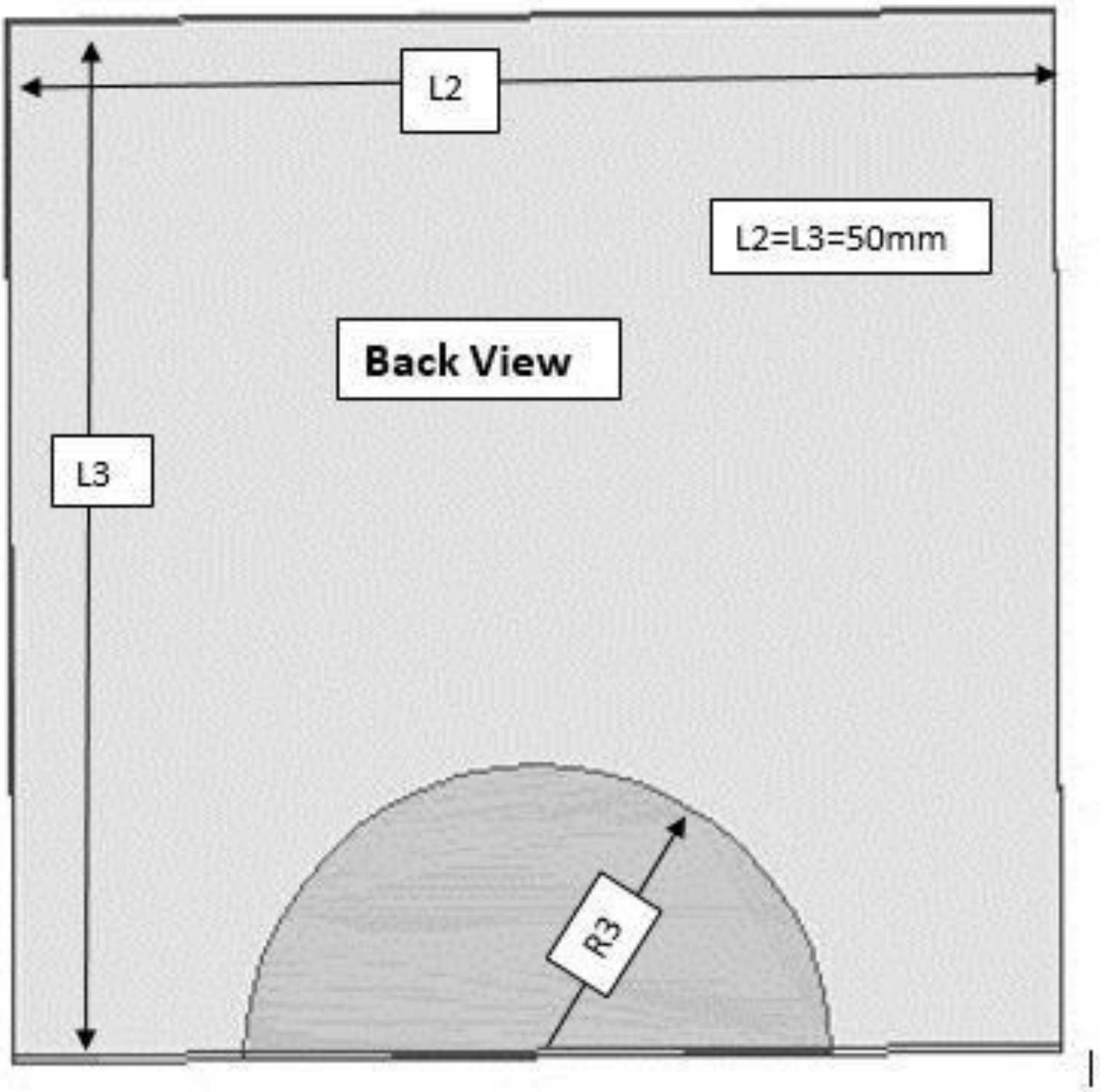


Figure 3.3: Shape of bottom ground

Table 3.2: Dimensions of the Ground

Length of substrate	50mm
Width of substrate	50mm
Radius of half circular ground	14mm

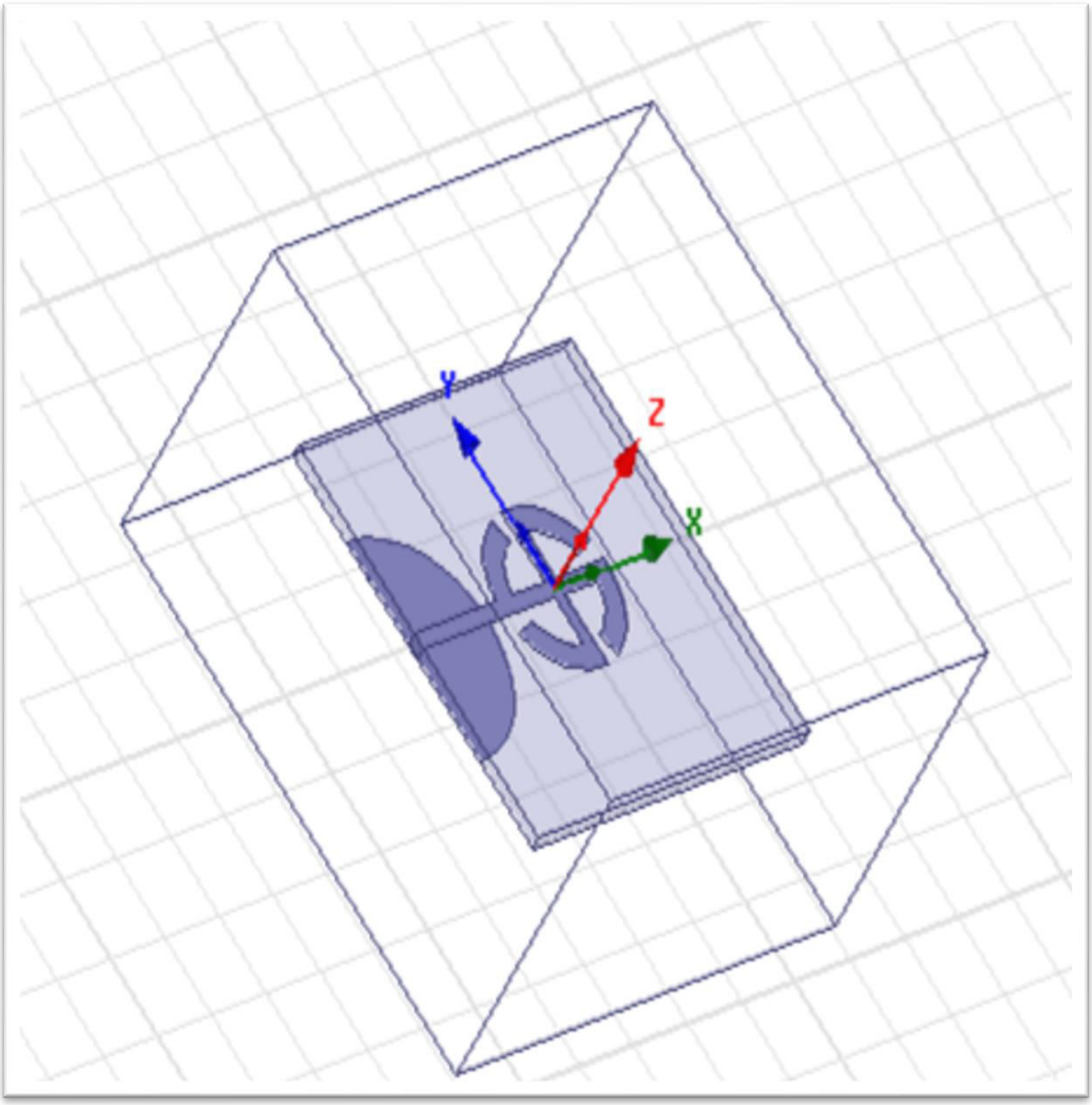


Figure 3.4 : Antenna Design in HFSS

3.3 Antenna Design View after Fabrication

Figure 3.5: Antenna Design after Fabrication(a) Patch View(b)Ground View

In case of the projected style, a circular patch of radius 10mm is subjected to the circular Swastika style over the length and therefore the breadth taking the notch length to be one fifth of the overall radius of the circle to be two millimeter ring. Cut four slots in ring size of ten° from the middle of the ring.

The patch that continues to be is once more subjected to the planning is then simulated through the HFSS over a frequency vary of four gigahertz to fifteen gigahertz. The come loss plot, S11 parameter graph is shown as below.

Chapter 4

Antenna Results and Measurements

4.1 Simulated Results:

As is visible from the graph and calculated thenceforth the distinction between the high bring to an end frequency and also the low bring toan end frequency seems to be 1.3614 gigahertz that once divided by
3.368 gigahertz offers the electrical phenomenon information measure proportion.

$$BW_p = \frac{f_h - f_l}{f_c} \times 100\% < 50\%$$

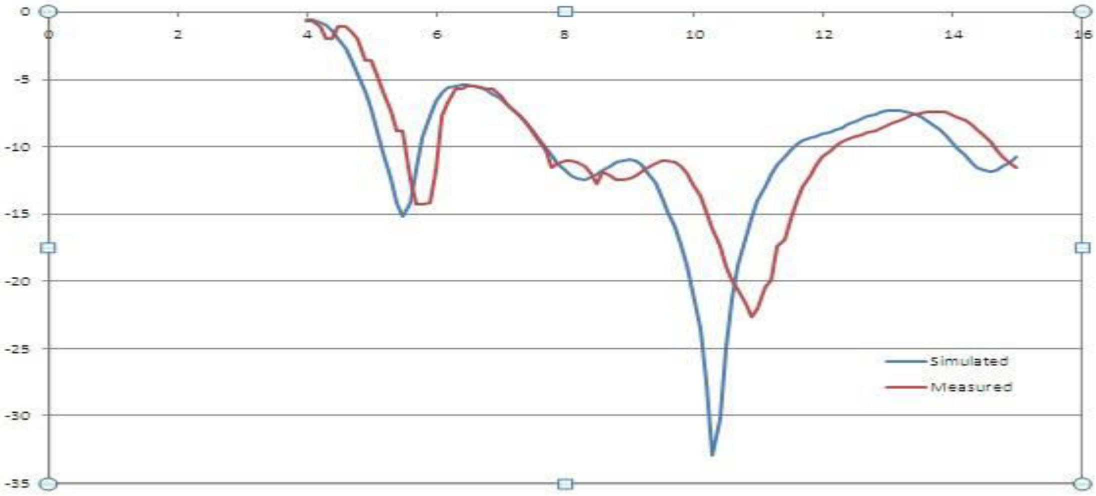
Where

f_hIsthe higher cut off frequency

$f_l$is the lower cut off frequency

$f_c$is the central resonance frequency

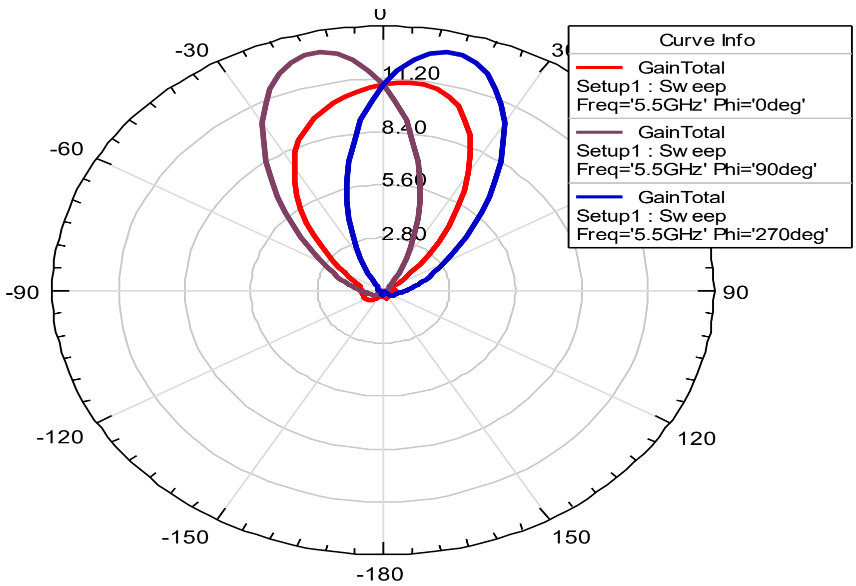
(11.570-7.700)/10.300)*100% = 37.558% < 50%



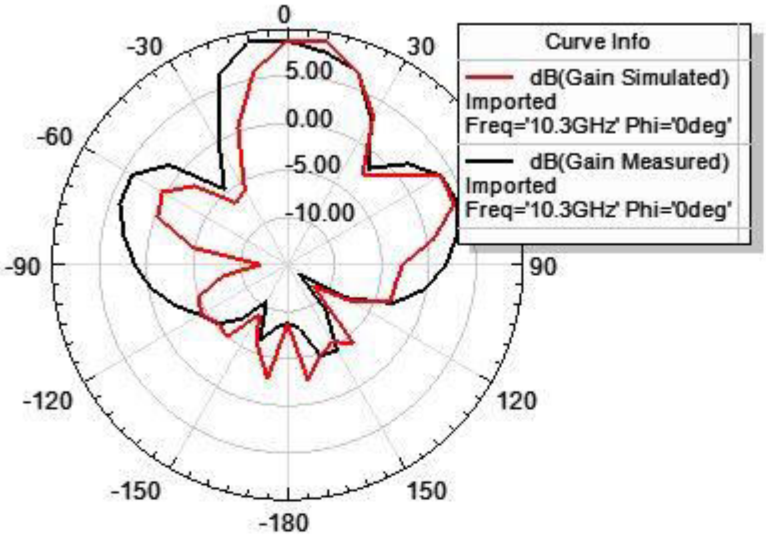
4.1 Figure:-Return loss (S11) Vs frequency plot

The Gain Vs Frequency plots only those points where the resonant frequencies are Fall upon

The radiation pattern of one of the resonant frequencies is shown hereby:
At fc= 5.5 GHz

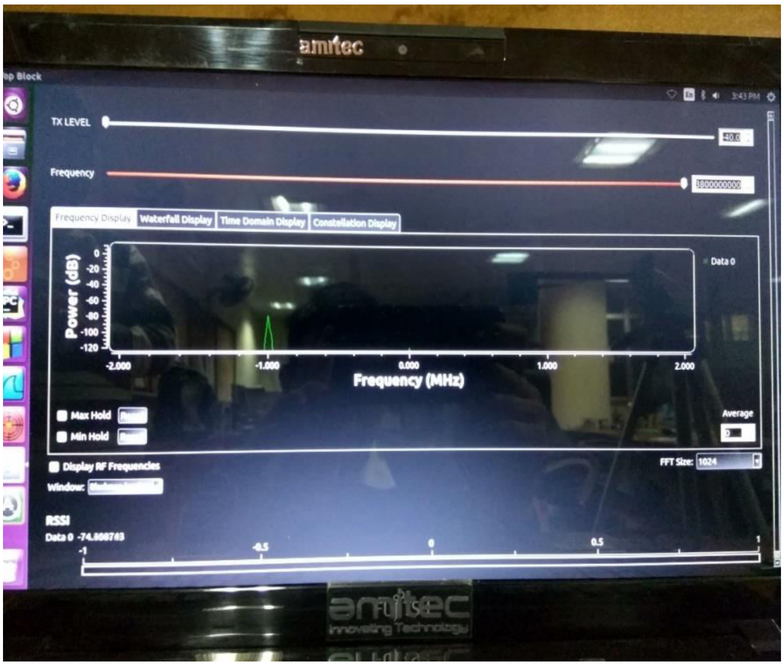


4.3Figure: -Realized gain at freq =5.5 Phi=0deg, 90deg, 270deg



4.4Figure: -Realized gain at freq =10.3 Ghz Phi=0deg, simulated and measured

4.2 Measured Results:



4.11 Figure:-Measured Tx(-40dB) and Rx(-85dB) power level

Figure 4.11shows comparison of power level between transmitted by antenna and received by the proposed antenna

4.3 Summary

Thus, the antenna is so evidenced to be narrow-band operational. The Narrow- Band Antenna operational at the $c = 5.4125$ GHz, that falls within the C-band of SHF, are often used for amateur radio and satellite operators. This band also can notice use in radars, for weather detection, combat ship and for house communication as this can be employed by National Aeronautics and Space Administration for communication with ISS and shuttles.

Chapter 5

Conclusion and Future Work

5.1 Conclusion

This thesis has been an endeavor within the a part of the author to grasp and contribute within the method towards the antenna theory's combination with emblem pure mathematics. It contains SIX chapters together with this, the last one.

It presents the planning methodology and theory of Micro-strip and emblem antennas. 3 styles are projected, one Narrow-band, one multi-band and one ultra-wide band of that the last one has been fictitious. The radiation patterns and gain patterns of every has been analyzed completely. The effectivity of incorporating emblem into antenna theory has been conferred, additionally.

The THIRD Chapter conferred the planning and analysis of a emblem hybrid showcasing narrowband behavior. the planning consisted of a Circular emblem pure mathematics. The information measure proportion of this antenna clothed to be thirty seven.581% that successively qualified it to be a narrowband antenna operative at a resonant frequency of five.5 GHz.

The FOURTH Chapter showed a emblem antenna with the scope for utilization of the said properties. With resonant frequencies occurring at multiple positions over the SHF, it will be fictitious to utilize the properties of the several bands. it absolutely was CPW fed emblem that was generated by iteratively carving out circles at intervals squares specified electrical property perpetually remains, over a stuff substrate of stuff constant of four.4 with none ground plane. The resultant antenna radiated at multiple frequencies (5.5 Ghz, and 10.3 GHz) over the SHF vary thereby rendering it multi-band practicality.

5.2 Future Work

- Measurement of the said projected antennas and comparison of the results therefore obtained and therefore the simulated results will be place to publication.

- Study of the result on emblem antenna performance of fabric properties, will be done the last style has been done on lossy substrate. LTCC (low temperature co-fired ceramic) substrates will be used instead. Direct integration with MICs will be thereby done.

References

1. NS Raghava K Viswanadha, *Design of a Compact, High Gain, Efficient and Low Cross Polarization Meander Line Cornered Microstrip Patch Antenna with EBG Structure for VSAT Applications, 2017*
2. Ns raghava, k viswanadha indian j. Sci. Res 16 (2), 123-127*Review on implementation of silicon-on-insulator technology for slot antennas, 2017*
3. NS Raghava,P Dawar, A De Cogent Physics 3 (1), 1236510 *High gain, directive and miniaturized metamaterial C-band antenna,2016*
4. NS Raghava, P Dawar, A De, *Materials Research Innovations 20 (3), 240-246 UWB and directive E-shaped metamaterial patch antenna, 2016*
5. P Dawar, NS Raghava, A De Cogent Physics 2 (1), 1123595 *A novel metamaterial for miniaturization and multi-resonance in antenna.*
6. Zhi Ning Chen and Michael Y. W. Chia, "Broadband Planar Antennas, Design and Applications," John Wiley & Sons, Ltd.
7. K. L. Wong, Planar Antennas for Wireless Communications. Wiley-Interscience, 2000
   a. F. Peterson, S. L. Ray, and R. Mittra, Computational Methods for Electromagnetics. IEEE Press Series on Electromagnetic Wave Theory, 1997.
8. E. K. Miller, L. Medgyesi Mitschang, and E. H. Newman, Computational Electromagnetics: Frequency-Domain Method of Moments. IEEE Press, 1992

9. IE3D User Manual. Zeland Sofware Inc, 2003.
10. FEKO User's Manual, Suite 5.1. EM Software & Systems, South Africa
11. User Manual for the CST. IMST GmbH, Germany, 2004.
12. User Manual for HFSS. Ansoft Corporation Pittsburg, PA, USA., 2000
13. J. Robinson and Y. Rahmat-Samii, "Particle Swarm Optimization In
14. Electromagnetics," IEEE Transactions on Antennas and Propagation, vol. 52, no. 2, pp. 397–407, 2004.
15. C. G. Christodoulou, M. Georgioipoulos, and A. H. E. Zooghby, Applications of Neural Networks in Smart Antennas for Mobile Communications. Applied Computational Intelligence, CRC Press, LLC, 2000.
16. C. Christodoulou, M. Georgiopoulos, and C. Christopoulos, Applications of Neural Networks in Electromagnetics. Artech House, 2001.
17. Y. Rahmat-Samii and E. Michielssen, Electromagnetic Optimization by Genetic Algorithms. New York: John Wiley & Sons, 1999.
18. D. S. Linden, Automated Design and Optimization of Wire Antennas Using Genetic Algorithms. PhD thesis, Massachusetts Institute of Technology, Department of Electrical Engineering and Computer Science, 1997.
19. D. T. Pham, A. Ghanbarzadeh, E. Ko¸ c, S. Otri, S. Rahim, and M. Zaidi, "The Bees
20. Algorithm: A Novel Tool for Complex Optimization Problems," in Proc. 2nd Int.

21. Virtual Conf. on Intelligent Production Machines and Systems (IPROMS 2006), 2006
22. E. K. P. Chong and S. H. Zak, An Introduction toOptimization. Wiley-Interscience Series in Discrete Mathematics and Optimization, 2001.
23. C. Puente, J. Romeu, R. Bartoleme, and R. Pous, "Swastika multiband antenna based on Sierpinski gasket," Electron. Lett., vol. 32, pp. 1-2, 1996.
24. C. Puente-Baliarda, J. Romeu, R. Pous, and A. Cardama, "On the behavior of the Sierpinski multiband swastika antenna," IEEE Trans. Ant. Propagat., vol. 46, pp. 517524,1998.
25. N. Cohen, "Swastika antenna applicationsin wireless telecommunications,"in Professional Program Proc. of Electronics Industries Forum of New England, 1997, IEEE, pp. 43-49, 1997.
26. C. Puente-Baliarda, J. Romeu, R. Pous, J. Ramis, and A. Hijazo, "Small but long Koch swastika monopole," Electron. Lett., vol. 34, pp. 9-10, 1998.
27. E. E. C. de Oliveira, P. H. da F. Silva, A. L. P. S. Campos, S. Gonc, A.D.Silva, "Overall Size Antenna Reduction using Swastika Geometry", Microwave and Optical Technology Letters, vol. 51, no. 3, March 2009, pp. 671 -674.
28. B. B. Mandlebrot, The Swastika Geometry of Nature. W.H.Freeman and Company, 1983.
29. http://www.sciencedirect.com/science/article/pii/S1007570411003297
30. C. A. Balanis, "*Antenna Theory - Analysis and Design*," 2nd edition, John Wiley.

31.Kennedy, Ombeni Kanze (2014) Design and Analysis of Swastika Antennas for wideband Apllications. BTech thesis

32.FCC 802 Standards Notes, “FCC first report and order on ultra-wideband technology,” 2002.

33.G. A. Deschamps, “Micro-strip Microwave Antennas,” 3 rd USAF Symposium on Antennas, 1953.