OPTIMIZATION AND SIMULATION OF MULTIBAND SLOTTED PATCH MICROSTRIP ANTENNA ARRAY USING ADS SOFTWARE

A

DISSERTATION

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD

OF THE DEGREE OF

MASTER OF TECHNOLOGY

IN

MICROWAVE & OPTICAL COMMUNICATION

(2013-2015)

SUBMITTED BY:

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2K13/MOC/03

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Candidate's Declaration

I, **Ankur**, Roll No. **2K13/MOC/03**, student of **M.Tech.** (**Microwave & Optical Communication**), hereby declare that the dissertation titled **"Design and simulation of slotted patch micro-strip antenna array using ADS software"**, under the supervision of **Prof. P.R.CHADHA** of Electronics and communication Engineering Department, Delhi Technological University, in partial fulfillment of the requirement for the award of the degree of Master of Technology, has not been submitted elsewhere for the award of any degree.

I hereby solemnly and sincerely affirm that all the particulars stated above by me are true and correct to the best of my knowledge and belief.

Place: Delhi **ANKUR**

Date: 13.07.2015 **2K13/MOC/03**

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CERTIFICATE

This is to certify that the dissertation entitled **"Optimization and simulation of multiband slotted patch micro-strip antenna array using ADS software "** submitted by **Ankur** in completion of major project dissertation for Master of Technology degree in **Microwave and Optical Communication** at Delhi Technological University is an authentic work carried out by him under my supervision and guidance.

This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

Place: Delhi

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ACKNOWLEGDEMENT

It gives me a great pleasure to express my profound gratitude to my supervisor and project guide **Prof. P.R. CHADHA**, Department of Electronics and Communication Engineering, Delhi Technological University (formerly Delhi College of Engineering), for his invaluable guidance, encouragement and patient reviews throughout the progress of this dissertation. It has been a great experience to get a chance to do research under his rich experience.

I would also like to extend my heartfelt thanks to all faculty members of Department of Electronics and Communication Engineering, Delhi Technological University, for keeping the spirits high and clearing the visions to work on the project.

I am also thankful to my family and friends for their constant support and motivation during this work.

Finally, I am thankful to the Almighty because without his blessings, this work was not possible.

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ABSTRACT

In recent years increase in demand of wireless microwave antenna has increased the research scope in the field of micro-strip technology. To support high mobility necessity for a wireless telecommunication device and for high resolution mapping in RADAR communication a small and light weight concept antenna is most suitable. The development of antenna for wireless communication also required to work on more than one frequency. Therefore antenna having multi frequency operating capability is more in demand. The most effective method for fabrication of micro-strip antenna for multi frequency is that cut slot in proper proportion on patch. This thesis describe about printed micro-strip antennas and array that have limitation in terms of bandwidth and efficiency, all imposed by the very presence of the dielectric substrate. The design antenna generate dual frequency. This frequency band can be used for satellite and radar communication. Due to small size, low weight micro-strip antennas have a vast application. To ensure high directivity and gain of antenna cutting slot dimension must be carefully controlled. A proper dielectric material selection is must. In this design we used epoxy fiber glass as dielectric material with dielectric constant 4.6 and loss tangent of value 0.023.

The proposed antenna is dual frequency which operate at 10.74 GHz and 14.74 GHz. Hence it is a good entrant for application of X band and Ku band in microwave and RADAR communication. The X band belongs to the microwave radio region of the electromagnetic spectrum. It is defined by an IEEE standard for radio waves and RADAR engineering with frequency range from 8GHz to 12GHz. The X band is used for short range tracking, missile guideline, marine, RADAR and airborne intercept. The Ku band belongs to the microwave radio region of EM spectrum. It is defined by the IEEE standard for radar engineering in the of 12 GHz to 18 GHz. It is used for high resolution mapping and satellite altimetry and tracking satellite. This thesis design such antenna which meets the requirement of above stated project All the simulation is done on the ADS momentum 2011.

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LIST OF ABBREVIATIONS

S. No.	Abbreviation	Acronym
1.	MSA	Micro-strip Antenna
2.	MSPA	Micro-strip Patch Antenna
3.	ISM	Industrial, Scientific and Medical
4.	FR4 EPOXY	Name of substrate material having dielectric constant 4.6
5.	ADS	Advance Design System
6.	VSWR	Voltage Standing Wave Ratio
7.	VNA	Vector Network Analyzer
8.	MMIC	Monolithic Microwave Integrated Circuit
9.	FEM	Finite Element Method
10.	1D	One Dimension
11.	3D	Three Dimension

NOTATIONS	
L	Length of the patch
W	Width of the patch
H	Height of dielectric substrate
ε_r	Dielectric constant of substrate
λ_g	Guided wavelength
λ_0	Free space wavelength
C	Velocity of light in free space
ε_{reff}	Effective dielectric constant
ΔL	Extension of patch length due to fringing effect
L_{eff}	Effective length of the patch
f_0	Operating frequency
f_r	Resonance frequency
m, n	Operating modes
Z_c	Characteristic impedance of the micro-strip line
W_0	Width of the micro-strip line

CHAPTER 1

INTRODUCTION:

Wireless communication has developed rapidly in the past decades and has dramatic impact on human life. So there is need to develop low cost minimal weight, low profile antennas. Antenna should be capable of maintaining high performance and high utility over a large spectrum of frequency. This can be achieved using micro-strip patch antenna. With a simple geometry, patch antenna offer low profile, have light weight, inexpensive to fabricate, and use modern day printed circuit technology. These are compatible with microwave and millimeter wave circuit. Once the shape and operating mode of patch are selected design becomes very versatile. A variety in design is possible in micro-strip antenna in term of shape, size, operating frequency, polarization pattern and antenna impedance.

In this thesis a dual band microstrip antenna is designed and simulated using ADS(Advance Design System). ADS is a software tool which compute most of quantites of interest such as antenna radiation pattern, input impedence, and antenna gain. In recsnt wireless communication system dual frequency operation has become a necessity for applications like GPS, GSM services, which operate at two different frequency bands. Also in satellite communication low frequency ratio antenna are very much essential. An inset feed dual frequency patch antenna can produce dual frequency with same polarization sense and low frequency ratio. It is less sensitive to feed position.

CHAPTER 2

BASIC ANTENNA TERMINOLOGY

Antenna is a device which is used to radiate information in form of electromagnetic waves and receive them at receiver end. A guided wave traveling along a transmission line will radiate as free space wave. To be more frank, the region of transition between the free space wave and guided media may be defined as an antenna.

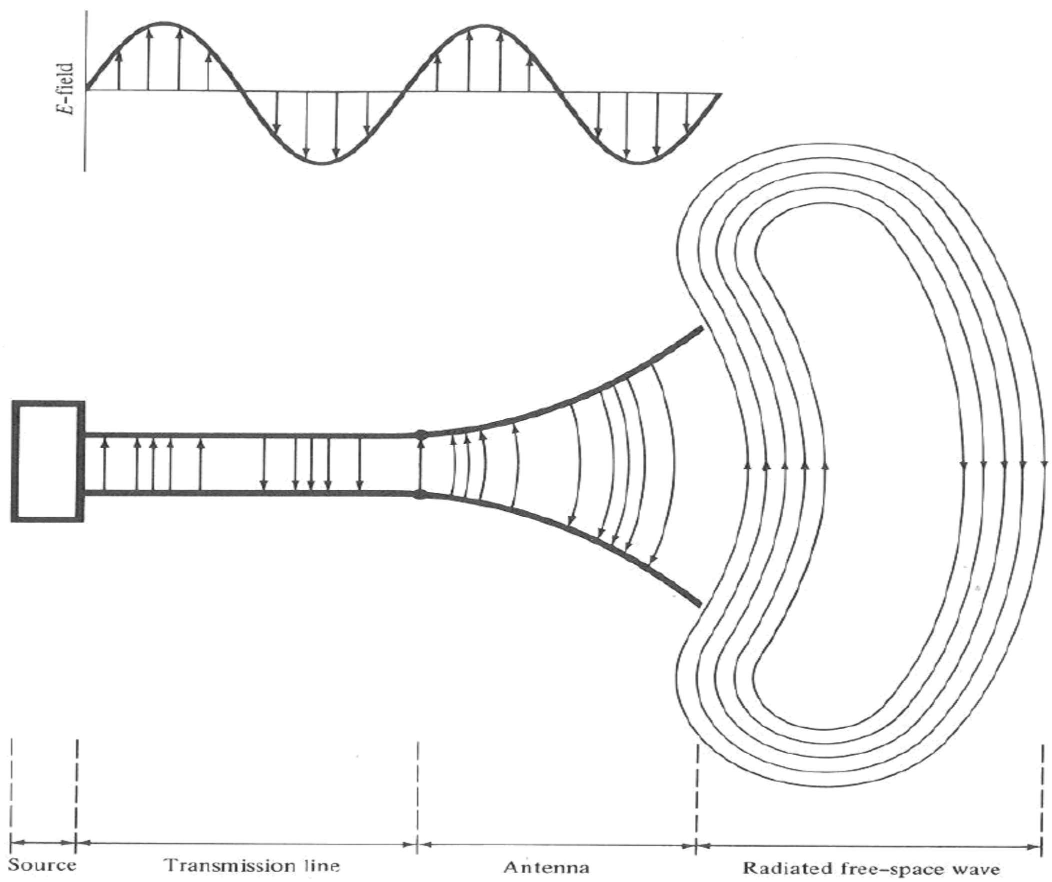


Figure 1. Antenna as a Transition Device[1].

Definitions of various parameters are essential to describe the performance of an antenna. Although these parameters may be interrelated, but not a requirement for complete description of the antenna performance. An antenna is must be chosen to perform in a required mode for the particular measurement system. An antenna can be characterized by the following parameters:

1. Radiation pattern of antenna.
2. Radiation resistance of antenna.
3. Beam width and gain of main lobe of antenna.
4. Magnitude and position of side lobes.
5. Magnitude of back lobes.
6. Bandwidth
7. Aperture area
8. Antenna array factor
9. Polarization of the field that it transmits or receives
10. Power that antenna can handle
11. Efficiency.

2.1 RADIATION PATTERN:

A radiation pattern of an antenna defines the variation of the power radiated as a function of the special coordinate away from the antenna. It defines the far field of antenna. Radiation properties include radiation intensity, power flux density, field strength, directivity, phase or polarization. If the radiation pattern is the same in all directions, it is called isotropic radiation pattern. Such Antennas with isotropic patterns don't exist in practice. Thus received electric or magnetic field at a constant radius is called amplitude pattern.

The radiation pattern can be represented in two forms :

- Azimuth Pattern
- Elevation Pattern

If we see the top view of the energy radiated it is called Azimuth Pattern where as the graphical side view is recognized as an Elevation pattern. The basic radiation pattern of an antenna is shown in Fig. 1.

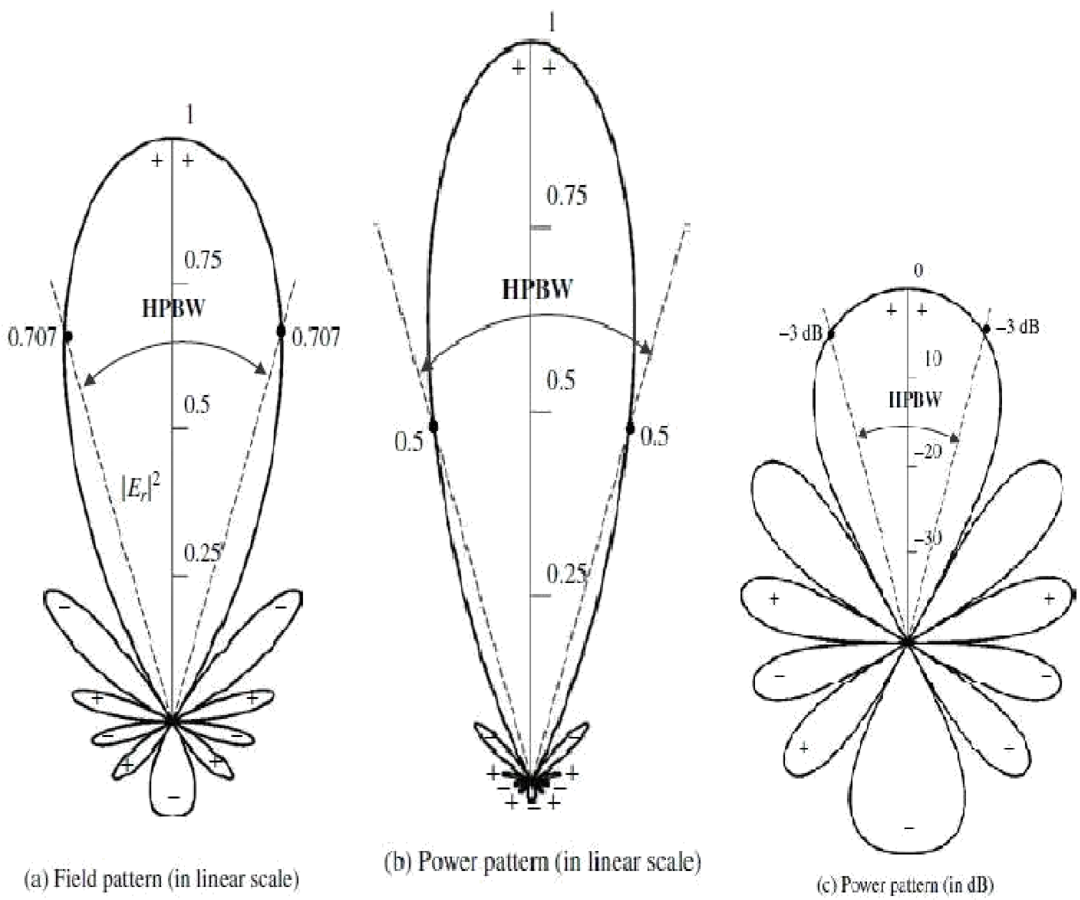


Figure 2: Basic Radiation patterns of an antenna [3].

2.2 DIRECTIVITY:

Directivity of an antenna may be defined as "the ratio of the radiation intensity in a given direction to that of radiation intensity of an isotropic antenna". The directive gain measures the ability of the antenna to direct its power towards a given direction. The maximum directive gain is called directivity. The directivity of a non-isotropic antenna is equal to the ratio of radiation intensity in a particular direction to that of isotropic source averaged in all direction .

$$D = \frac{U}{U0} = 4\pi U/Prad$$

$$D = \frac{1}{\frac{1}{4\pi}\int_0^{2\pi}\int_0^{\pi}|F(\theta,\phi)|^2 \sin\theta d\theta d\phi}$$

For cell phones antenna should have a low directivity because antenna should pick the signal that can come from any direction. While satellite are to receive signals from a fixed direction their dish antennas should have a very high directivity. For example, if you get a direct TV dish, they will tell you to point it in such a way that the antenna will receive the signal.

2.3 GAIN OF ANTENNA:

The term Antenna Gain gives measure of power transmitted in the direction of maximum radiation compared to an isotropic antenna. The gain of an antenna can be defined as the ratio of the radiation intensity in a particular direction, to that of radiation intensity resulted from the power fed to the antenna was radiated isotropically. Antenna gain takes into account the real losses that occurs. A gain of 3 dB depicts the power received will be 3 dB higher than what would be received if a lossless isotropic antenna is used with the same input power.

$$\text{Gain} = 4\pi * \text{Radiation intensity/total input power accepted}$$

2.4 ANTENNA EFFICIENCY:

The efficiency of an antenna tells relationship between the power delivered to the antenna and power dissipated within the antenna or the power radiated by the antenna. The losses associated within an antenna, due to finite conductivity of the antenna, are typically the conduction losses . There are also dielectric losses which may be present within an antenna due to conduction within dielectric. A high efficiency antenna utilizes most of the power at the antenna's input by radiating it away in space. Where as a low efficiency antenna absorbs most of its power within the antenna as losses, or reflected back at input due to impedance mismatch. The antenna efficiency can be written as the ratio of the power radiated to the input power of antenna:

$$\varepsilon_R = \frac{P_{radiated}}{P_{input}}$$

2.5 BEAMWIDTH:

Radiation patterns are also characterized by their beam-widths and side lobe levels. The beam-width of an antenna may be represented as " the angular separation between two identical points which are on opposite sides of the pattern in maximum direction". The beam width of an antenna is a very important figure of merit and it involves a trade-off between main lobe and side lobe, the side lobe level increases as beam-width decreases and vice versa. It is used to describe the capability of an antenna to differentiate between two contingent radiating sources or radar targets.

These are type of beam-widths in the antenna pattern:

- Major lobe
- Back lobe
- Side lobes
- Half power beam width(HPBW)
- Full null beam width(FNBW)

2.5.1. Major lobe:- The major lobe is the region in the direction of maximum radiation, usually within 3 dB of the peak of the main beam.

2.5.2. Side lobes:- The side lobes are usually radiations other than main lobe. These are also in the direction of maximum radiation. Side lobes are undesired directions radiations which can never be completely eliminated.

2.5.3. Half Power Beam-width (HPBW):- Half Power Beam-width (HPBW) is the angular separation in a plane which contains main lobe or the direction of the maximum radiation of a beam. The angle between the two points on beam in the directions in which the radiation intensity dips to 50% (or -3 dB) from the peak of the main beam is called the HPBW.

2.5.4. First Null Beam-width:- It is the angular separation between the first null of the pattern. The resolution criterion states that the resolution capability of an antenna to distinguish between two sources is equal to half the first-null beam-width (FNBW/2), which is usually used to approximate the HPBW.

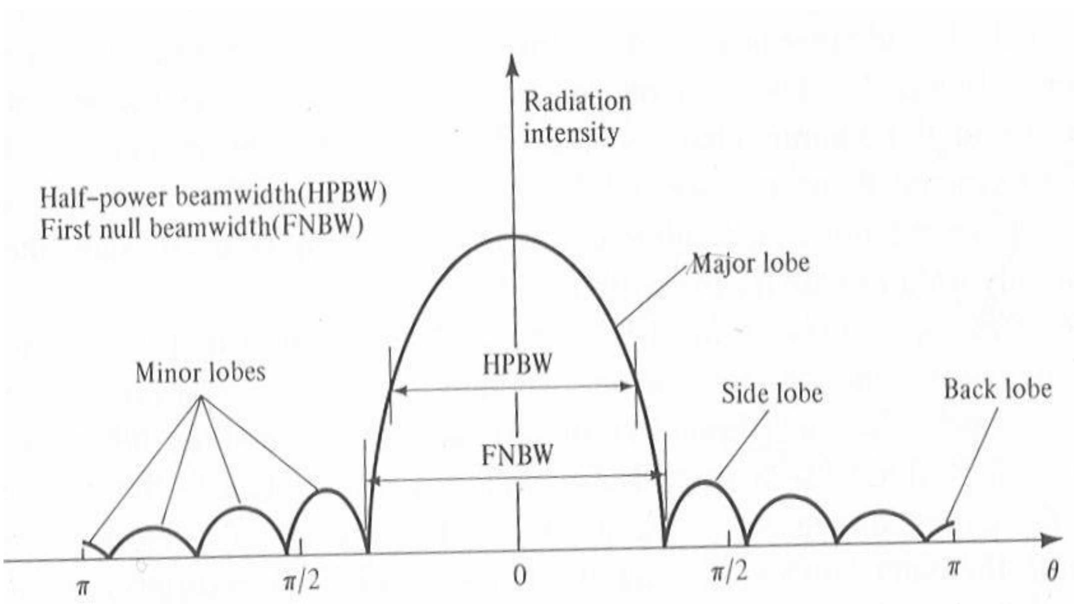


Figure 3: Antenna Beam-width.

2.6 POLAR PATTERN:

Beam-widths are the angular separation of radiation pattern. Now the polar radiation pattern is shown in figure below which depicts the mathematically representation of main lobe, side lobe, HPBW,FNBW of antenna. The main lobe is centered at 90 degrees. The side lobes occur at roughly 45 and 135 degrees. From polar plot in the pattern decreases to -3 dB at 77.7 degrees and 102.3 degrees. Hence the HPBW is 102.3-77.7 = 24.6 degrees. Hence, the First-Null Beam-width is 120-60=60 degrees.

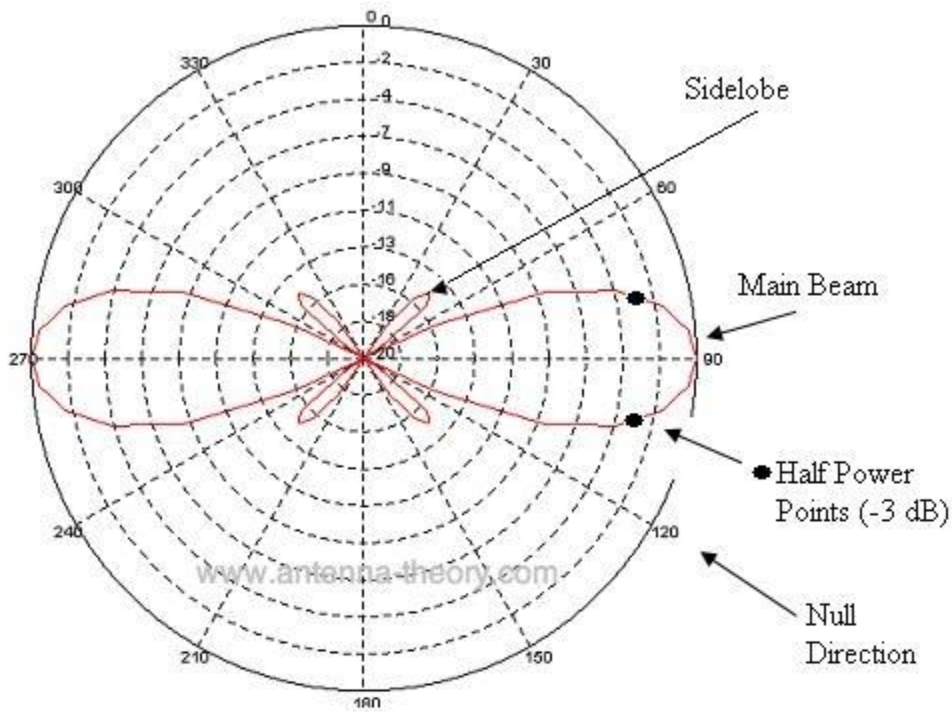
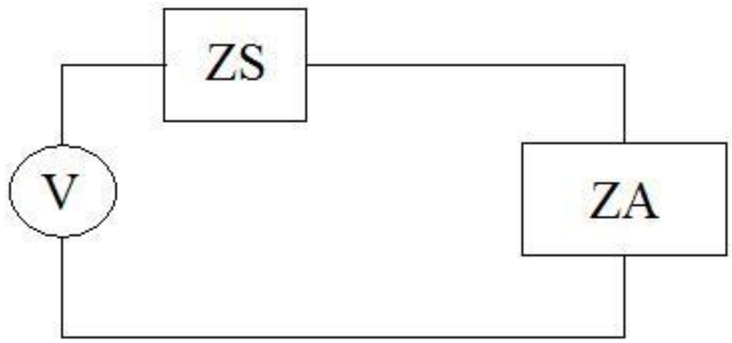


Figure 4: Polar radiation pattern.

2.7 ANTENNA IMPEDANCE:

Antenna impedance is a simple concept. It is the ratio of voltage to the current at a pair of terminal. For any antenna to radiate it should be matched with the impedance of transmission line, which is used to feed the antenna, otherwise antenna will not radiate. Antenna impedance can be represented as a complex quantity, Ra+jX, in which real part represent power which is either radiated away or absorbed as losses within the antenna. Imaginary part represent power stored in near field of the antenna, which is non radiated power. Impedance of antenna vary with frequency. VSWR (voltage standing wave ratio) is used to measure how well matched the antenna is with the feeding source.



$Z_A = R_a + jX_a$

Figure 5: Antenna impedance model.

2.8 POLARIZATION:

The polarization of the wave radiated by the antenna in a given direction is known as the polarization of antenna. If the direction is not given then dirction of maximum gain in taken into account. Polarization of a wave is defined as that property of an electromagnetic wave describing the time varying direction of field and relative magnitude of the electric field vector. Specifically, the extremity of the vector traced as a function of time and the sense in which it is traced at a fixed location in space as observed along the direction of propagation.

Polarization may be classified in linear, circular, or elliptical polarizations. A linear polarized wave is that in which the vector that describes the electric field as a function of time at a point in space is always directed along a line. Similarly if the vector field vary circularly and ellipticaly then the wave is called circularly and ellipticaly polarized wave. The Linear and circular polarizations are particular type of cases which can be obtained when the elliptical wave forms a straight line or circle respectively. Further it can be classified on the basis of rotation of the wave. Clockwise rotation of field vector is known as right hand polarization and anti clockwise as left hand polarization. Hence Polarization may be classified as linear, circular, circular left hand, circular right hand, elliptical, elliptical right and elliptical left hand. For two linealy polarized antenna rotated from each other at some angle then power loss due to polariazation mismatch will be given as:

$$PLF = \cos^2 \phi$$

If both antennas have the same polarization, there is no power loss because the angle between radiated E-fields is zero and hence no polarization mismatch. Circular polarization is a desirable characteristic because two antennas that are circularly polarized do not suffer signal loss because of polarization mismatch. If the angle is 90 degrees that is one antenna is vertically polarized and the other antenna is horizontally polarized, no power will be transferred.

2.9 RETURN LOSS:

The input and output signal can be characterized in the form of return loss. when a load is mismatched means when the input impedance of antenna is not equal to the source impedence all the source power is not delivered to load. This power loss is known as "return loss" and can be represented as:

$$RL = -20l0g(\tau)\ dB$$

Where reflection cofficient , $\tau = (Zl - Zo)/(Zl + Zo)$

$|\Gamma|$= Magnitude of reflection coefficient, V_o = Reflected voltage, V_{in} = Incident voltage, Z_L and Z_o are the load and characteristic impedances.

2.10 ANTENNA APERTURE:

The received power of an antenna is measured in terms of effective area or effective aperture. Effective aperture parameter defines how much power is captured from a given plane wave. Suppose p is the power density of the plane wave at the antennas terminals available to the antenna's receiver measured in W/m^2, then:

$$P_t = p\, A_e$$

Hence, the effective area is a function of wavelength and gain of the antenna and represents how much power is being captured by antenna from the plane wave delivered by another antenna. Thus area factor also advocate the losses in the antenna. A general relationship for the effective aperture to the wavelength and peak antenna gain (G) of any antenna can be given by:

$$A_e = \frac{\lambda^2}{4\pi} G$$

Effective aperture is measured on actual antennas also by comparison with a known antenna of known effective aperture or by using the measured gain by the above equation.

CHAPTER 3
MICROSTRIP PATCH ANTENNA

3.1 INTRODUCTION

Microstrip patcn antenna can be printed directly onto a circuit board. Conventionaly microstrip antennas consist of a pair of parallel conducting layers separating a dielectric medium, generally called a substrate, the upper conducting layer known as "patch" is the source of radiation. Electromagnetic energy fringes off the edges of the patch. The lower conducting layer acts as a perfectly reflecting ground plane which bounces energy back through the substrate and into free space. The patch is a thin conductor that is compareable with the appreciable fraction of a wavelength in extent. The patch is responsible to achieve adequate bandwidth. Microstrip antennas are becoming very widespread because these have a position of safety and are effectively manufactured. These recieving wires are low profile, suited to planar and non planar surfaces. The rectangular patch is the most generally utilized design. These are of low cost, have a low profile and are easily fabricated. Major operational disadvantages of microstrip antennas are their low proficiency, low power, high Q, poor polarization virtue and restricted recurrence data transmission. The micro-strip patch can have diverse shapes like roundabout, rectangular or square as demonstrated:

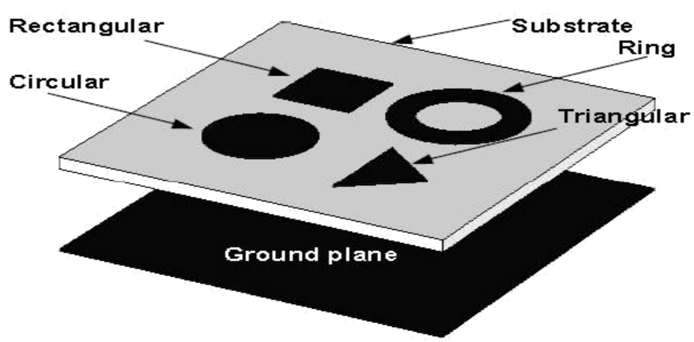


Figure 6: Different shapes of micro-strip patch.

3.2 RECTANGULAR PATCH:

The rectangular patch is the most widely used configuration. A basic form of rectangular patch consist of two parallel plates one of which is conducting ground plane and other is dielectric layer of certain thickness and permitivity. A patch of conducting material is fabricated on substrate layer.

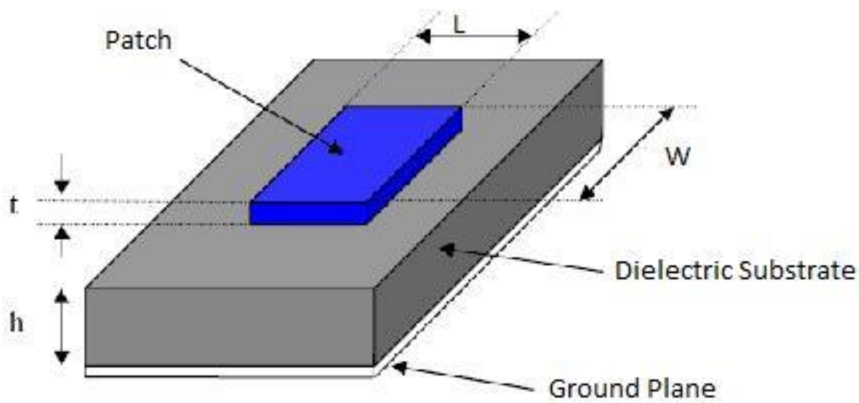


Figure 7: Rectangular micro-strip patch antenna.

This patch of a micro-strip antenna is made of a conducting material. The thickness of patch effects the radiation property of the antenna. Also the dielectric constant of material used and thickness of substrate effects the performance of antenna. In the typical design procedure of rectangular Micro-strip patch antenna, three essential parameters are:

1. Resonance frequency $f_{r.}$
2. Dielectric constant of the substrate, $\varepsilon_{r.}$
3. Thickness of substrate, h.

These parameters must be choosen carefully while fabricating the patch because these parameters effects the radiation property of the antenna. After the proper selection of above three parameters, the next step is to calculate the radiating patch width and length.

The designing procedure can be divided into following steps:

Step 1: Calculation of width of patch (W_p):

For an efficient radiator, practical width for good radiation efficiencies is:

$$W_p = \frac{c}{2f_r}\sqrt{\frac{2}{\varepsilon_r + 1}}$$

Where, c= velocity of light=3×10^8m/s

f_r= resonance frequency

ε_r=dielectric constant

Step 2: Calculation of effective dielectric constant of the patch material:

Effective dielectric constant of material can be calculated using formula:

$$\varepsilon_r^{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[\frac{1}{\sqrt{1 + \frac{12h}{W_p}}}\right]$$

Step 3: Calculation of effective length of the patch:

It is the effective length of the patch which depends on the effective dielectric contant.

$$L_{eff} = \frac{c}{2f_r\sqrt{\varepsilon_r^{eff}}}$$

Step 4: Calculation of length extension:

Length extension due to effective length is:

$$\Delta L = 0.412h\,\frac{(\varepsilon_r^{eff} + 0.3)(\frac{W_p}{h} + 0.264)}{(\varepsilon_r^{eff} - 0.258)(\frac{W_p}{h} + 0.8)}$$

Step 5: Calculation of actual length of patch:

Hence actual length of patch can be calculated as:

$$L_p = L_{eff} - 2\Delta L$$

Step 6: calculation of inset depth in patch:

Inset depth decide the impedance of path used for feeding.

$$Z_o = Z_{in} cos^2(\frac{\pi d}{L_p})$$

Where,

Z_o = Characteristics impedance

Z_{in} = input impedance

d = inset depth/notch depth/gap depth

3.3 FRINGING FIELD OF MICROSTRIP PATCH:

For the principal E-plane fringing is a function of the ratio of the length of the patch L to that of height H of the substrate (L/H), and also the dielectric constant ϵ_r of the substrate. The dimensions of the patch are finite which results the fields at the edges of the patch to undergo fringing effect. Due to fringing some of the electric field confines inside the substrate while some extends outwards. Most of the electric field lines confines in the substrate and some line exist in air. The electric field lines reside to the substrate because W/H >> 1 and ε_r >> 1. Hence the micro-strip line appears electrically wider compared to its physical dimensions.

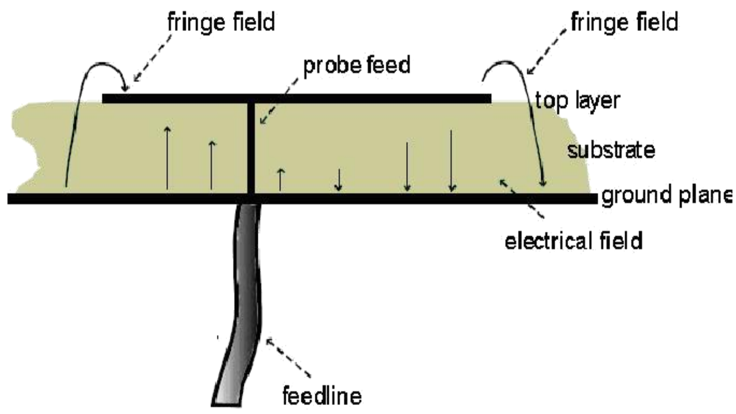


Figure 8:- Fringing in the micro-strip patch [4].

It is the fringing between edge of patch and that of ground plane which causes the patch to radiate. This E-fields on the edge of the micro-strip antenna combine in phase and produce the radiation. To make antennas efficient, dielectric substrates with high thickness and low dielectric constant are suitable. This results in larger bandwidth efficiency and desirable radiation. But the antenna size will increase, which is not desireable. To overcome this problem, a thin dielectric material substrate with high dielectric constant must be used. But a trade-off needs to be made to reduce the size.

3.4 FEED METHODS:

A feedline is used to excite the antenna or transfer electromagnetic energy so that antenna can radiate. The selection of feeding technique is an important entity because it directly affects the bandwidth, return loss, VSWR, patch size and smith chart. Microstrip patch antennas can be fed by a variety of methods and are classified into two groups- contacting and non-contacting. There are several configurations that can be used to feed micro-strip antennas. The four most known feed models are:

- Micro-strip line feed or inset feed
- Coaxial probe feed
- Aperture coupled feed
- Proximity coupled feed

3.4.1 Microstrip Line Feed or Inset feed:

In this antenna feed technique, a conducting strip of smaller width than patch, is connected directly to the edge of the Micro-strip patch as shown. This kind of feed arrangement conducting strip can be etched on the same substrate to provide a planar structure, which is advantageous. An inset cut is made in patch by properly controlling the inset position. The purpose of the inset cut is to match the impedance of the feed line to the patch. And also there is no need for any additional matching element. Since it provides ease of fabrication, simplicity in modeling and impedance matching, it is easy method of feeding. However if the thickness of the dielectric substrate is increased, surface waves also increases, which in practical use hampers the bandwidth of antenna. The feed radiation also leads to undesired cross polarized radiation.

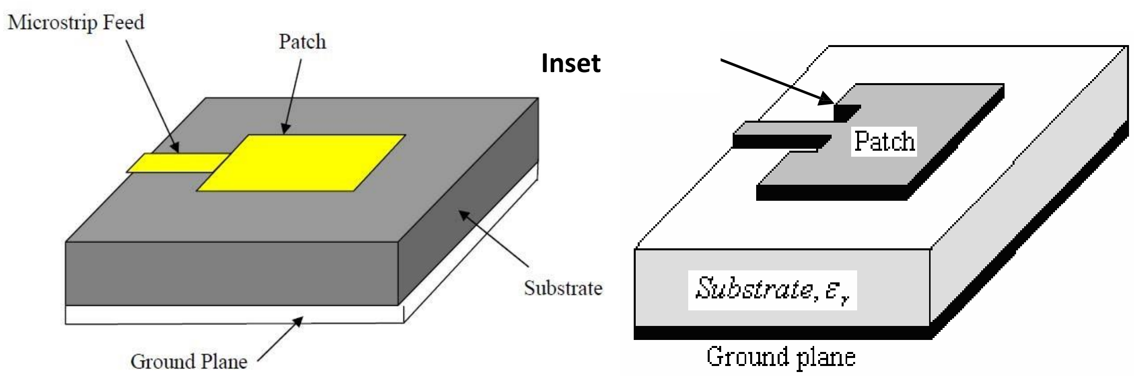


Figure 9: Micro-strip feed and Inset feed model.

3.4.2 Coaxial Probe Feed

The Coaxial feed is a very common technique for feeding Micro-strip patch antennas. In this technique the inner conductor of the coaxial connector is soldered to the radiating patch which extends through the dielectric. While the outer conductor is soldered to the ground plane. In order to match its input impedance the feed can be given at any desired point inside the patch.

This feed method is advantageous because of low spurious radiation. However, its major disadvantage is that it is difficult to model and provides narrow bandwidth. The connector extends outside the ground plane, because of a hole which has to be drilled in the substrate thus not making it completely planar for thick substrates where $h > 0.02\lambda o$. The increased probe length makes the input impedance more inductive and hence leads to matching problem. It is seen that for a thick dielectric substrate the Micro-strip line feeds and the coaxial feeds suffer from several disadvantages.

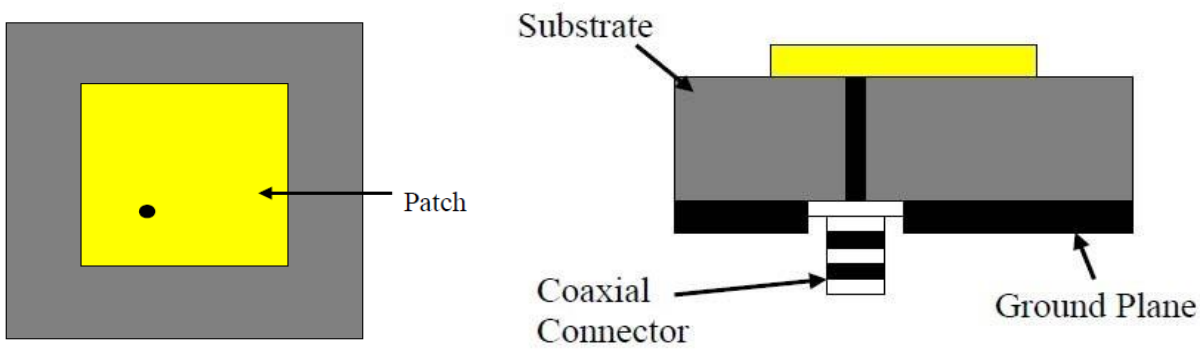


Figure 10: Coaxial feed model.

3.4.3 Aperture coupled feed:

In this feed, radiating patch and micro-strip line are isolated by the ground plane. This is done by coupling the patch with the feed line through a slot or an aperture in the ground plane. This leads to lower cross polarization owing to symmetry of the configuration. Spurious radiation is minimized because ground plane isolate the patch and the feed line. The amount of coupling to the patch is determined by size, shape and location of the aperture. Generally material used for the bottom substrate is of high dielectric constant and for surface a thick, low dielectric constant material which optimizes the radiation from the patch.

The major disadvantage of this technique is that due to multiple layers it is difficult to fabricate, and also increases the antenna thickness. This scheme also provides narrow bandwidth generally up to 21%.

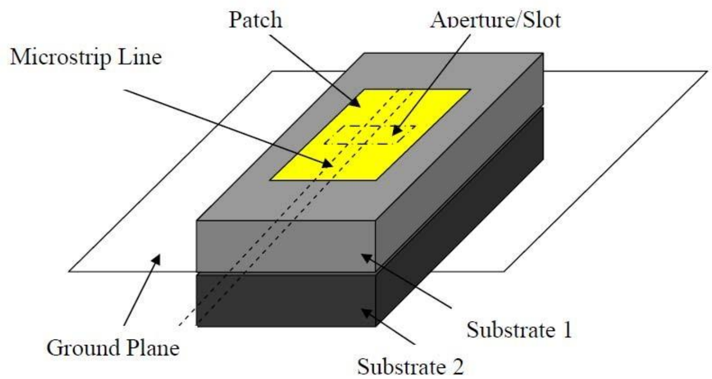


Figure 11: Aperture coupled feed model [1].

3.4.4 Proximity coupled feed:

This technique is also called electromagnetic coupling scheme. In this type of feed two dielectric substrates are used in such a way so that the feed line is between the two substrates where as the radiating patch lies on top of the upper substrate. It eliminates spurious feed radiation and also due to overall increase in the thickness of the patch, provides high bandwidth (as high as 13%). Matching can be done by controlling the width-to-line ratio of the patch and the length of the feed line.

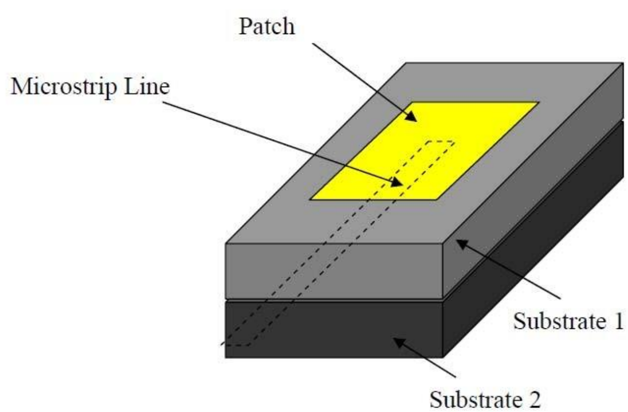


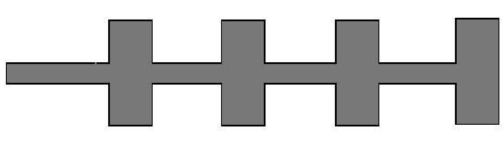
Figure 12: Proximity coupled feed model [1].

The major disadvantage of this technique is that there is an overall increase in the thickness because of the two dielectric layers. It also difficult to fabricate because dielectric layer requires proper alignment.

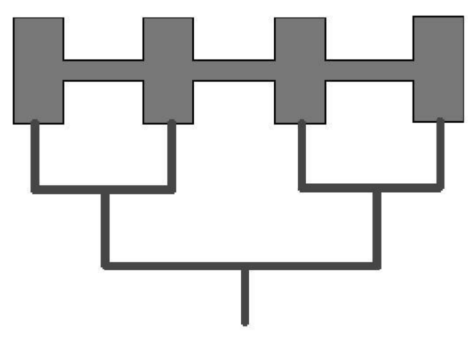
3.5 ANTENNA ARRAY:

An antenna array is a set of two or more antenna elements which results in increase in gain and directivity. The signals from the antennas are united or processed to achieve improved performance in terms of gain and directivity over that of a single antenna. The antenna array is used:

- To increase the overall gain.
- To provide diversity reception.
- Minimize interference from another antenna.
- Recognize the direction of arrival of the incoming signals.
- To maximize the Signal Noise Ratio (SINR).
- To "Steer" the array to make it more sensitive in a particular direction.



(a) Series feed array



(b) Corporate feed array

Figure : Antenna array with different feed .

In some application, it is necessary to design antennas with high gain to meet demands of long distance communication. High gain can only be obtained by increasing the size of the antenna electrically. This can be achieved by increasing the size of the antenna element. But this is not practically feasible. Another way to make dimensions large, without increasing the size of individual antenna element, is to form an arrangement of radiating elements in some electrical and geometrical configuration. This new geometrically formed antenna structure is referred to as an antenna array.

The ultimate radiation pattern of the array is shaped by an important parameter called array factor. The array factor is the function of the total number of elements, the phase difference between each element and their spacing. For a uniform antenna array factor can be formulated as:

$$AF = \frac{\sin\frac{N\psi}{2}}{\sin\frac{\psi}{2}}$$

After normalizing the array factor to make the maximum value to unity can be written as:

$$(AF)n = \frac{1}{N\sin\frac{\psi}{2}}\sin\frac{N\psi}{2}$$

CHAPTER 4

INTRODUCTION TO ADS MOMENTUM

Momentum is a complete tool for estimating the performance of microwave or high frequency printed circuit boards, antennas and integrated circuits. It is a part of Advance Design System which provides the simulation tools required for evaluating and designing products of modern communication systems. Momentum computes the S-parameters, gain, return loss and efficiency for general planar circuits. It is an electromagnetic solver. The planer circuits include micro-strip, coplanar waveguides, slot-line, strip-lin and many other topologies. ADS also provide utility in solving multilayer communication circuits and printed circuit boards with accurate results [7]. The ADS Momentum enhancement instrument stretches out Momentum capacity to a genuine configuration computerization device. The Momentum Optimization process differs geometry parameters naturally to help in accomplishing the ideal structure. Energy enhancements should be possible by utilizing format segments from the schematic page. One of the considerable focal points that Momentum has is the 3-dimensional interface that it accommodates the client amid reenactments and results. While figuring the reception apparatus parameters, Momentum gives both 2D and 3D diagrams of the directivity and the far-field radiation of the radio wave. Block Diagram of ADS Momentum Simulation gives the pictorial idea of working of momentum. The Block diagram in Fig. 17 is a pictorial representation shows how ADS Momentum simulates its designs in precise manner step by step and generares the outputs.

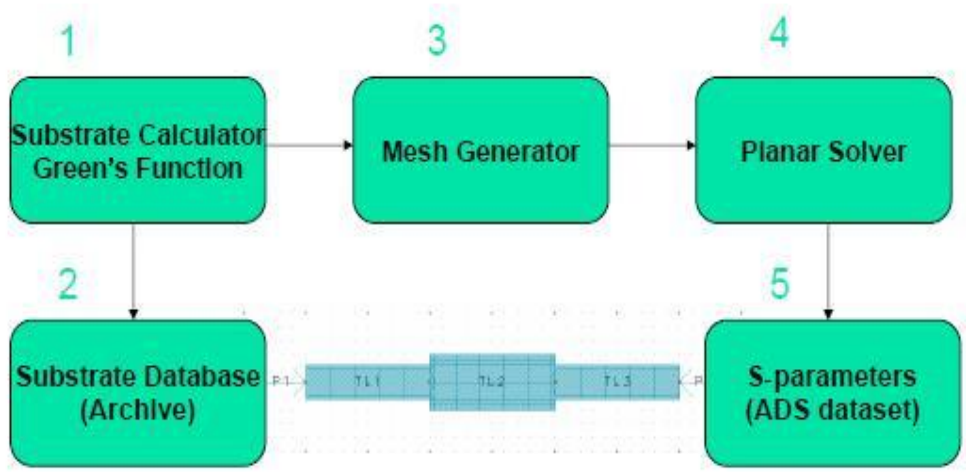


Figure 14: Block diagram ADS momentum simulation [7].

CHAPTER 5

DESIGNING, SIMULATION AND RESULT:

INTRODUCTION:

Basic single element of patch antenna, as shown in Figure can be designed for the dual frequency model using transmission line model.

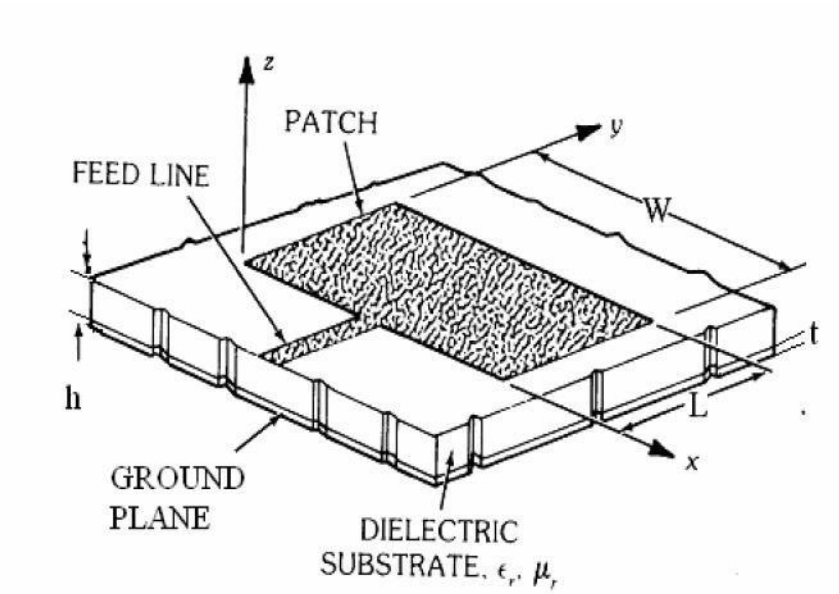


Figure 15: Typical Rectangular Patch Antenna

In the typical design procedure of the Micro-strip antenna, the operating resonant frequency, thickness of substrate and dielectric constant of the substrate material are known or selected initially. In this design of Micro-strip antenna, a Epoxy fiber glass dielectric material with dielectric loss tangent of 0.023 is selected as the substrate with 1.58 mm height. A patch antenna that operates at the specified operating frequency f0 = 10.74 GHz can be designed by the following steps using transmission line model equations. The antenna is existed by the INSET feed away from the center of the patch.

5.1 LAYOUT FORMATION:

For designing rectangular patch antenna first open the new workshop. Set the scale to millimeter so that all the measurement are in millimeter only. Then open the new cell by clicking on cell icon. Then open the layout window select the rectangular patch and define the length of the patch. The width of the patch=8.4mm and the length of patch =5.1mm. A U-slot is being cut in the patch of dimension 1.7*1.2mm to get the dual band of frequency. The U- slot used is inverted. Another T- slot is used to hone up the frequency. Antenna impedance is measured using line calculator in the schematic window. Figure shows the screen shot of the layout window. The essential parameter specifications for the design of the rectangular microstrip patch antenna are as in Table 5.1.

Shape	Single Band Rectangular
Frequency of operation	10.74 GHz and 14.74GHz
Dielectric constant of substrate	4.6 (Epoxy fiber glass)
Height of the dielectric substrate	1.58 mm
Feeding method	INSET feeding
VSWR	1.5:1
Gain	25 dB - 30dB
Polarization	Linear

Table 5.1: Design parameter specifications of micro-strip antenna

By using the parameter given in the table we design the antenna patch. The 3D layout design is shown in the figure which gives the overall antenna array design. While choosing the dielectric material special care should be taken. The thickness and dielectric constant should be chossen to optimize the antenna performance. As dielectric constant of the material increases dimension of the antenna decrease but there ia trade off between thickness and resonant frequency.

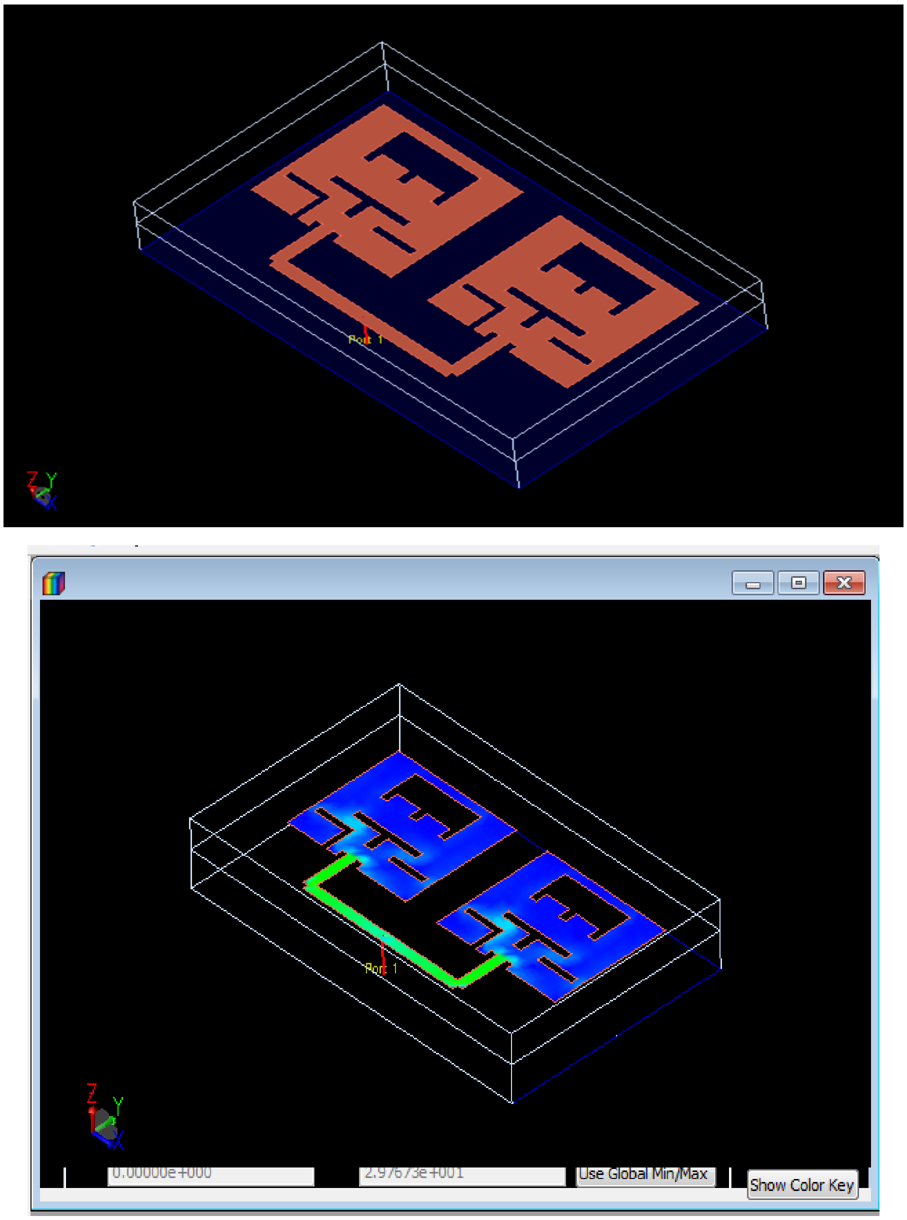


Figure 16: 3D view of antenna patch in ADS Momentum.

5.2 DEFINING THE SUBSTRATE:

By opening the layout window in Momentum we can define the substrate thickness, dielectric material type, thickness of conductor. These are the important parameter in substrate defining because resonance frequency and gain of patch antenna depends on the patch width and dielectric material used. The thickness of metal patch defines the gain of the patch antenna. As the antenna is loaded with the dielectric as its substrate, the length of antenna decrease as the relative dielectric constant of the substrate increases. In this model we use Epoxy fiber glass material as substrate with dielectric constant 4.6 and loss tangent 0.023. the thickness substrate is kept 1.5 mm.

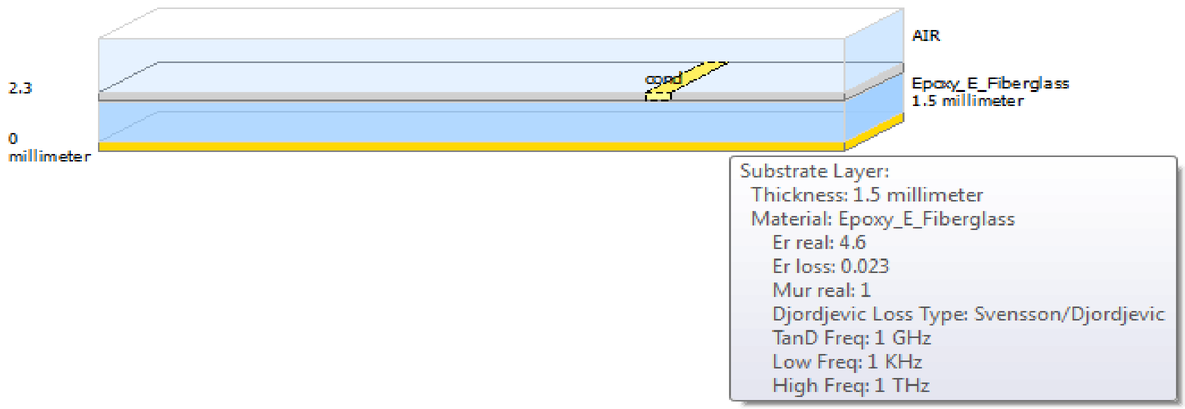


Figure 17: Defining Substrate parameter in momentum

5.3 SIMULATION AND RESULT:

5.3.1 RETURN LOSS:

The design is simulated using ADS momentum at dual frequency. Figure shows the antenna array plot for 2*1 array. The reflection coefficient measures the fraction of feed power absorption over the total power. And the peak return loss is found to be -32 dB at 10.74GHz frequency and bandwidth found to be 2 GHz. This shows that the return loss decrease at this frequency and bandwidth improves. Figure shows the S11 parameter plot against frequency. The S11 parameter measures the amount of power reflected back from input terminal to the feed source.

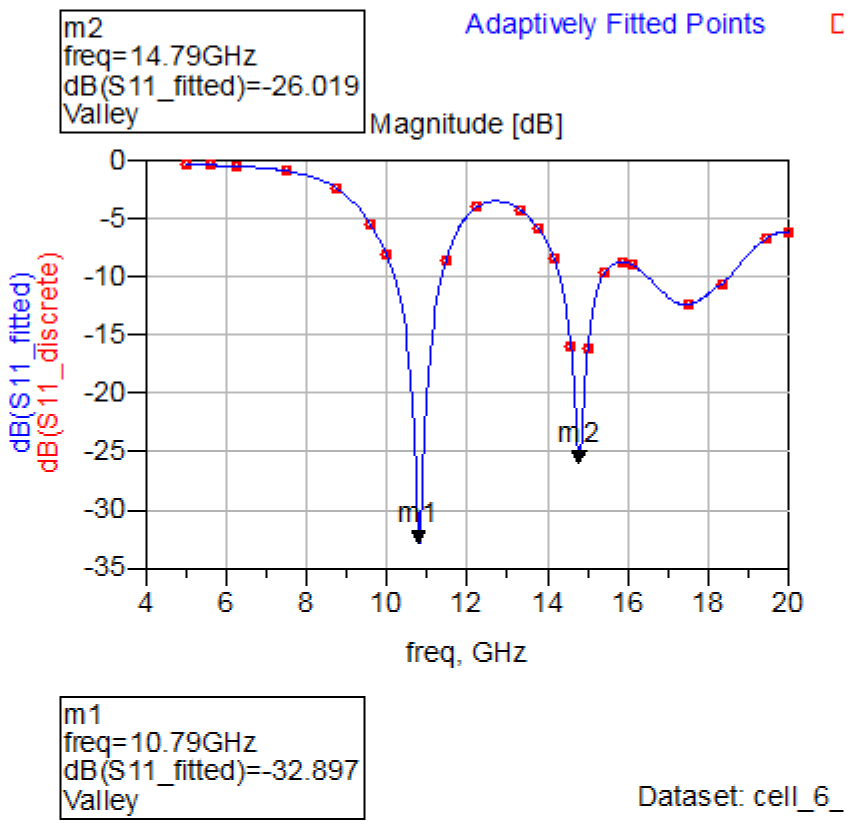


Figure 18: Simulated S-parameter and return loss.

5.3.2 SMITH CHART EVALUATION:

Smith chart gives the graphical approach to understand the impedance matching. For impedance to be matched impedance point is moved along the r circle or x- circle such that it cut the unity circle at desired frequency. In figure the point m3 gives the impedance and frequency. Smith chart is also used to evaluate reflection parameter and hence VWSR.

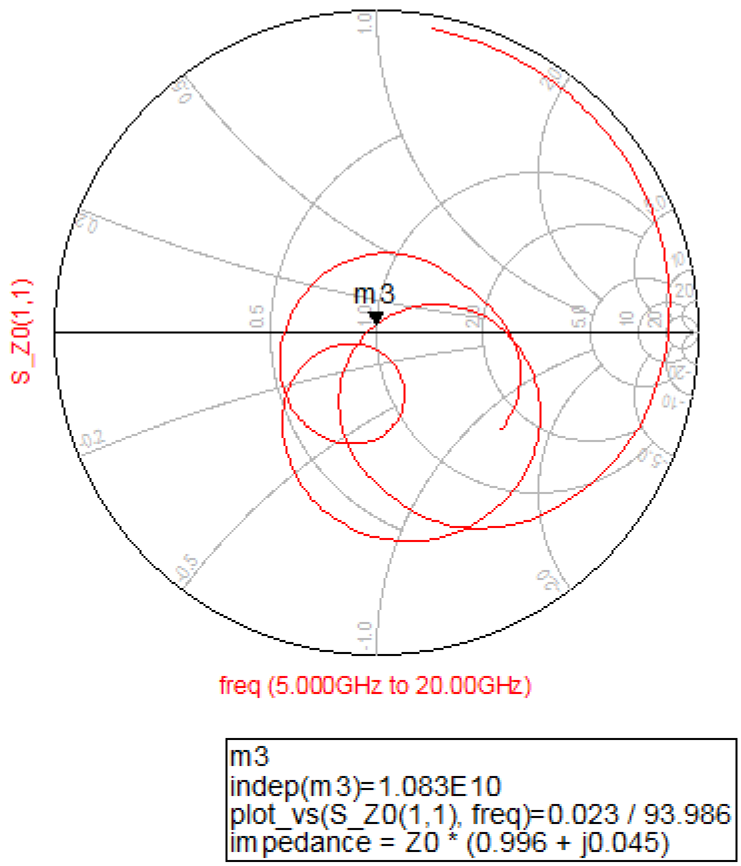


Figure 19: Smith chart evaluation of simulated result.

5.3.3 THREE-D RADIATION PATTERN:

After simulation a 3D radiation pattern can be generated using ADS Momentum. Radiation pattern determine how efficiently antenna radiate. Figure below shows the precise directional 3D pattern. The radiation pattern defines the major lobe, HPBW, FNBW and directional properties of the antenna. Figure shows the bottom view and side view of pattern.

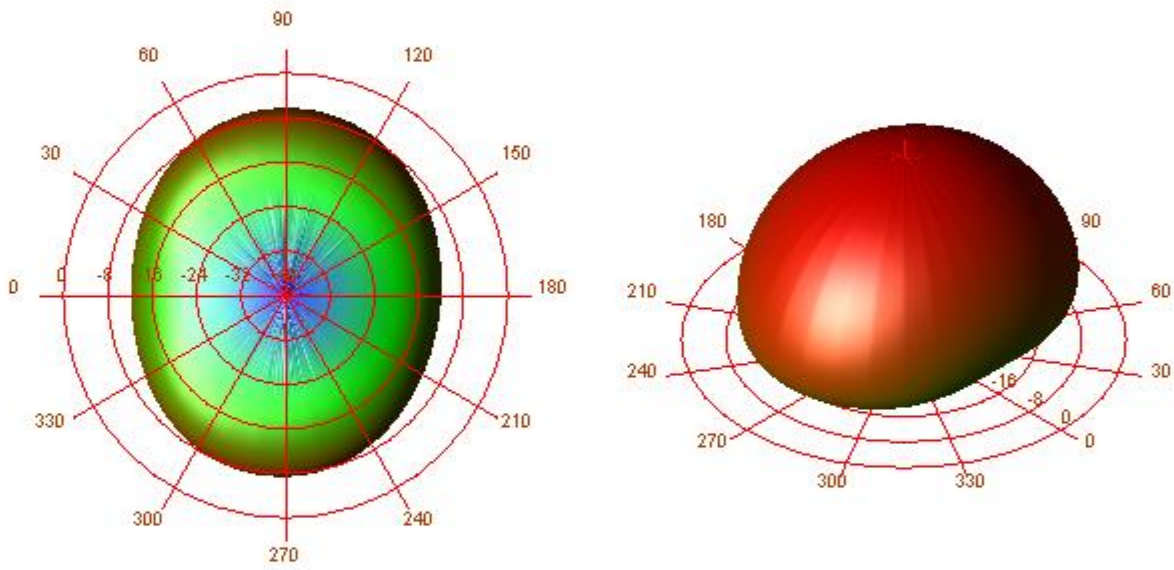


Figure 20: 3D radiation pattern for proposed antenna.

CHAPTER 6
CONCLUSION

6.1 Conclusion Summary:

All the simulation results show that the micro-strip phase array antenna performs better then the single rectangular patch antenna. Detailed simulation result of dual band micro-strip array has been obtained and analysed carefully. The proposed antenna resonate at dual frequency band of 10.74 GHz and 14.74 GHz which is proposed frequency of operation. The return loss of -32 dB at 10.74 GHz and -25dB at 14.74 GHz has achieved which is good. This antenna uses inset feed technique. The main beam is in the broadside direction between 90° and 270° with nulls at 0° and 180°. Similarly the efficiency, directivity and gain of the array patch antenna is better than the single patch. All these simulations lead to the conclusion that the number of patches in an array is directly proportional to the efficiency, directivity and gain of the antenna. If we increase the number of elements in the array, the radiation pattern will improve further. Another important conclusion that was deduced from all the experiments that were made during the design of this antenna was that impedance matching is very important. Efficient results were only obtained when the impedance of the system was perfectly matched to 50 Ω.

6.2 Future work

Antenna technology is a vast field. Every day new research is published. A few design parameters were taken into consideration while designing this antenna. Further improvements can be made in the following areas:

- The gain, directivity, radiation pattern and efficiency can be improved by using 2^n array elements in the micro-strip phase array antenna. We have used only two circular patches.
- The beam of the circular patch phase array antenna can be steered using phase shifters in the design.
- Recent research involves the use of photonic band gap crystals in the substrate to improve the band width of the antenna.
- Instead of the ADS Momentum, the HFSS simulator can be used for design and simulation.

REFERENCES:

[1] C. A. Balanis, *Antenna Theory*, 3rd edition, John Wiley, New York, 2005.N. J. Kolias.

[2] C. Compton, J. P. Fitch and D. M. Pozar, *Antenna*, CRC Press, 2000.

[3] M. K. A. Rahim, A. Asrokin, M. H. Jamaluddin, M. R. Ahmad, T. Masril and M. Z. A.

[4] Abdul Aziz, “Microstrip Patch Antenna Array at 5.8 GHz for Point to Point Communication,” International RF and Microwave Conference Proceedings, pp. 216-219, Malaysia, September 2006.

[5] J. J. Carr, *Practical Antenna Handbook*, fourth edition, McGraw-Hill, New York, 2001.

[6] S. N. Makarov, *Antenna and EM Modeling with MATLAB*, John Wiley, New York, 2002.

[7] R. Iwata and S. Chen**,** “Mutual Coupling Effects in Microstrip Patch Phased Array Antenna,” IEEE Antennas and Propagation Society International Symposium, pp. 1028-1031, New York, August 2002.

[8] L. Allen and L. Diamond, “A Simple Model for Mutual Coupling Effects on Patterns of Unequally Spaced Arrays,” IEEE AP-15, pp. 530-533, 1967.

[9] N. Misran and M. T. Islam, “Broadband E-H Shaped Microstrip Patch Antenna for Wireless Systems”, PIER, pp. 163-173, Malaysia, 2009.

[10] N. C. Karmakar, “Investigations into a Cavity-Backed Circular Patch Antenna,” IEEE AP-50, pp. 1706-1714, 2002.

[11] Y. Qian, R. Cocciolo, D. Sievebpiper, V. Radisic, E. Yablonovitch, “A microstrip patch antenna using novel photonic band-gap structures,” Microwave Journal, Vol-4, pp. 1-4, 1999.

[12] G.P. Gauthier, A. Courtay and G.M. Rebeiz, “Micro-strip Antennas on Synthesized LowDielectric-constant Substrates,” IEEE AP- 45, p. 1310, August 1997.

[13] Agi and Malloy, “Integration of a Microstrip Patch Antenna with a Two-Dimensional Photonic Crystal Substrate,” Electromagnetics, Vol. 19, 1999

[14] ADS built in manuals and online help.

[15] R. F. Harrington, *Field computation by Moment Methods*, Maxillan, New York, 1968.

[16] T. F. Lai, W. N. Mahadi and N. Soin, "Circular Patch Microstrip Array Antenna for KU-band," World Academy of Science, Engineering and Technology. Vol. 48, pp. 298-302,2008.