DESIGN OF BROAD BAND AND HIGH GAIN MICROSTRIP ANTENNA USING METAMATERIALS

DISSERTATION--II

Submitted in partial fulfillment of the requirement for the award of the Degree of

MASTER OF TECHNOLOGY
IN

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By

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MAY 2015

CERTIFICATE

This is to certify that the thesis titled **“Design of Broad Band and High Gain Microstrip Antenna using Metamaterials”** that is being submitted by ***Govinda Pradhan(11003299)*** is in partial fulfillment of the requirements for the award of MASTER OF TECHNOLOGY DEGREE, is a record of bonafide work done under my guidance. The contents of this thesis, in full or in parts, have neither been taken from any other source nor have been submitted to any other Institute or University for award of any degree or diploma and the same is certified.

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The present work is an effort to do the study on **“Design of Broad Band and High Gain Microstrip Antenna using Metamaterials”**. The work would not have been possible to come to the present shape without the able guidance and supervision of my thesis mentor Mr. R Madhusudhan Goud.

I wish to convey my thanks to my family members for their morale during the course of study.

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DECLARATION

I, Govinda Pradhan, student of B.Tech (Hons.) M.Tech (Dual Degree) under Department of Electronics and Communication Engineering of Lovely Professional University, Punjab, hereby declares that all the information furnished in this thesis report is based on my own intensive research and is genuine.

This thesis does not, to the best of my knowledge, contain part of my work which has been submitted for the award of my degree either of this university or any other university without proper citation.

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ABSTRACT

Wireless technology is one of the main areas of research in the world of communication systems and study of communication systems is incomplete without an understanding of the operation of antennas. For wireless communication systems, the antenna is one of the most critical components. A good design of the antenna can relax system requirements and improve overall system performance. A typical example is television for which the overall broadcast reception can be improved by utilizing a high-performance antenna. The performance and advantages of microstrip patch antennas such as low weight, low profile, and low cost made them the perfect choice for communication systems engineers.

In my thesis I learnt about HFSS software which is used for designing and simulation of antennas. As my thesis I choose to work on the design of Broad Band and High gain Microstrip Patch Antenna because of their low fabrication cost and hence can be manufactured in large quantities. In this report I have designed a microstrip patch antenna using meta materials. They can be designed in a variety of shapes in order to obtain enhanced gain and bandwidth. This report provides a detailed study of the design of Microstrip Patch Antennas. I worked on designing, simulation and analysis of a microstrip patch antenna. The software used for designing purpose is Ansoft HFSS 12.

TABLE OF CONTENTS

LIST OF FIGURES

Chapter 1
INTRODUCTION

1.1 HISTORY OF WIRELESS COMMUNICATION SYSTEM

In 1901, M. G. Marconi successfully established a radio link between a land-based station and a tugboat and it was then known as the birth of wireless communications. After that, huge experiments have been made in the field of wireless communication, resulting us to live a better life in today's world of digital surroundings.

In the beginning, wireless communication was only used for the military purposes in order to perform their tactical necessities. Those wireless communication systems was basically designed as per Marconi's model, consisting of a base station which had a powerful transmitter that were designed to serve for a particular geographic area. Each of these base stations was independent and out-of-the-way from each other.

Now-a-days, cellular communication networks have taken the revolutionary step in developing wireless communication across the world. These Cellular systems consist of a group of base stations, which further contains low-power transmitters. These low power transmitters allow base stations to establish connections and communicate with each other, thereby ensuring services to a wider range of customers.

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1.2 WIRELESS COMMUNICATION TECHNOLOGY

In Wireless Communication Technology, we make use of electromagnetic waves to carry the message signal over the part or the entire communication path instead of using some form of wire in telecommunication. Intrusion alarms are the monitoring devices and also sometimes known as wireless because they employ acoustic waves at frequencies above the range of human hearing.

To transmit data between devices low-powered transmission sources are used in wireless method of communication. Broadcasting of high powered radio waves, on a specific wavelength, usually requires government licenses. Many thousands of broadcasts around the world have been carried by this communication system. This also carries voice and other datas and has grown into a huge industry. Unregulated computer users are gradually using these radio waves to transmit information from one system to another.

In order to share experiences and knowledge, communication is done in different forms by the humans. There are generally different forms by which communication between humans is done and they are- sign language, writing, speaking, gestures and broadcasting. Communication can be verbal, nonverbal, interactive or transactive. It can also be intentional or unintentional and intrapersonal or interpersonal.

In the field of communication, we owe much to the Romans that it did not end with communicare, as in case of the Latin root. In order to centralize control of the empire from Rome, Latins devised what might be described as the first real mail, or postal system.

In the early 20th century, by using radiotelegraphy, which is also known as Morse code, the first wireless transmitters went on the air. Afterwards, the medium came to be called as "radio" in which transmission of voices and music via wireless was made possible. With the introduction of television, data communication, fax and the efficient use of a wider portion of the spectrum, the term "wireless" has been resurrected.

Wireless communication is the sharing of information between two or more points that are not connected physically or by any electrical conductor.

Radio waves are used by the most common wireless technologies. By the use of radio waves distances can be short, such as a few meters for television or as far as thousands or even millions of kilometers for deep-space radio communications. Wireless communication provides different types of mobile, fixed, and portable applications. It also includes cellular telephones, two-way radios, personal digital assistants (PDAs), and wireless networking. Another examples of radio wireless communication technology applications are - garage door openers, wireless computer mice, GPS units, keyboards and headsets, headphones, radio receiver, satellite television, broadcast television and cordless telephones.

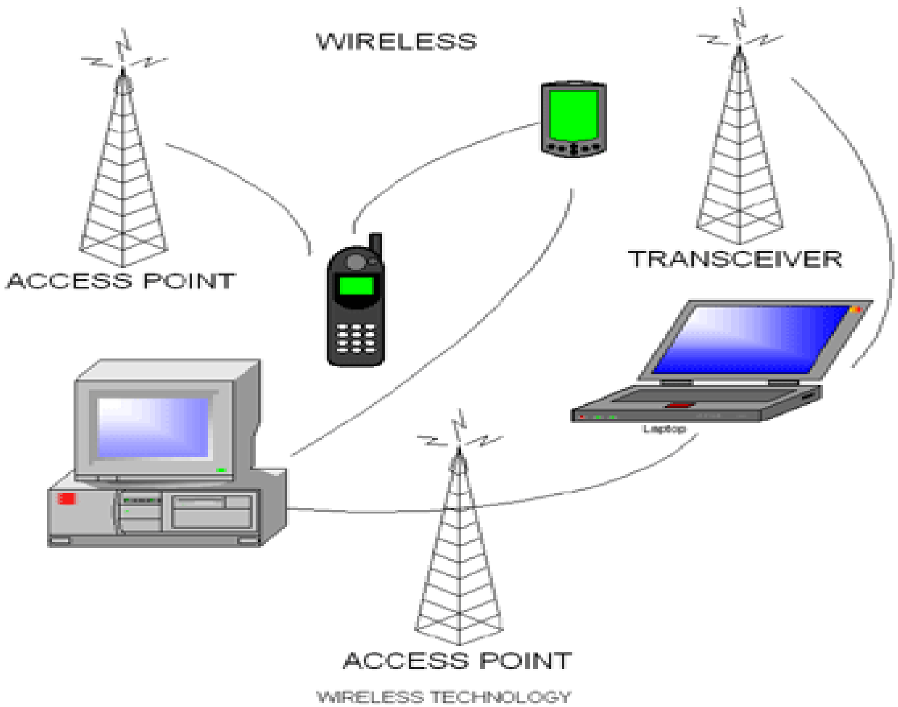


Fig. 1.1 Wireless Communication Technology

1.3 APPLICATIONS OF WIRELESS COMMUNICATION[19]

1.3.1 Television Remote Control – Radio waves are used in order to control television sets via television remote controller. These radio waves are also used to control DVDs modern PCs etc.

1.3.2 Wi-Fi – Wi-Fi (Wireless Fidelity) is used to set up a wireless internet connection between various computers within a fixed range.

1.3.3 Security systems – Wireless technologies are preferred over wired for the security purposes at home, school, office etc.

1.3.4 Cellular Telephone – Cellular Telephone uses Radio waves to set a call from one user to different users in wireless communication system. CDMA, GSM and 3G are the various technologies for the transmission of informations via cellular telephone.

1.3.5 Wireless energy transfer – Wireless energy transfer is a process in which electrical energy is transmitted into electrical load by a power source which does not have built-in power source wirelessly.

1.3.6 Computer Interface Devices – Earlier computer hardware peripherals uses bulky and low quality transceivers for communication purposes but now-a-days manufacturers of computer hardware had realized that by using so many wires can confuse the user thereby using wireless technology we can have a compact and high-quality wireless devices such as Bluetooth, Wi-Fi, infrared receivers.

1.3.7 Wireless Medical Technologies – In medical field to measure heart rate, blood pressure, body temperature, oxygen level and pulses inside brain we use wireless technology. The MBAN works by sending low powered wireless signals to receivers that feed into nursing stations or monitoring sites**.**

1.4 COMMON EXAMPLES OF WIRELESS EQUIPMENT IN USE TODAY

- **Cellular phones and pagers**: provide connectivity for portable and mobile applications, both personal and business
- **Global Positioning System (GPS)**: allows drivers of cars and trucks, captains of boats and ships, and pilots of aircraft to ascertain their location anywhere on earth

- **Cordless computer peripherals**: the cordless mouse is a common example; keyboards and printers can also be linked to a computer via wireless
- **Cordless telephone sets**: these are limited-range devices, not to be confused with cell phones
- **Home-entertainment-system control boxes**: the VCR control and the TV channel control are the most common examples; some hi-fi sound systems and FM broadcast receivers also use this technology
- **Remote garage-door openers**: one of the oldest wireless devices in common use by consumers; usually operates at radio frequencies
- **Two-way radios**: this includes Amateur and Citizens Radio Service, as well as business, marine, and military communications
- **Baby monitors**: these devices are simplified radio transmitter/receiver units with limited range
- **Satellite television**: allows viewers in almost any location to select from hundreds of channels
- **Wireless LANs or local area networks**: provide flexibility and reliability for business computer users

1.5 CATEGORIES OF WIRELESS COMMUNICATION

1.5.1 Fixed wireless: the operation of wireless devices or systems in homes and offices, and in particular, equipment connected to the Internet via specialized modems

1.5.2 Mobile wireless: the use of wireless devices or systems aboard motorized, moving vehicles; examples include the automotive cell phone and PCS (personal communications services)

1.5.3 Portable wireless: the operation of autonomous, battery-powered wireless devices or systems outside the office, home, or vehicle; examples include handheld cell phones and PCS units.

1.6 ADVANTAGES OF WIRELESS COMMMUNICATION

Wireless communication has the following advantages:

- Communication has enhanced to convey the information quickly to the consumers.

- Working professionals can work and access Internet anywhere and anytime without carrying cables or wires wherever they go. This also helps to complete the work anywhere on time and improves the productivity.

iii. Doctors, workers and other professionals working in remote areas can be in touch with medical centers through wireless communication.

iv. Urgent situation can be alerted through wireless communication. The affected regions can be provided help and support with the help of these alerts through wireless communication.

v. Wireless networks are cheaper to install and maintain.

Chapter 2
ANTENNA THEORY

2.1 OVERVIEW

Antennas are the essential components of wireless communication system. The field of antennas is vital and vibrant, and over the last 60 years antenna technology has been a necessary partner of the communications revolution. Many key developments that occurred during this period are in common use today. Many major concerns and challenges are facing us today, mainly since the requirements for system performances are even greater. An antenna is a device that transmits or receives electromagnetic (EM) waves. Mainly antennas are resonant devices, which radiate efficiently over a comparatively narrow frequency band.

An antenna is a device that is used to transform a radio frequency signal, traveling on a conductor, into an electromagnetic wave in free space.

By definition**,** "Antenna is a metallic structure that is designed for radiating and receiving electromagnetic waves."

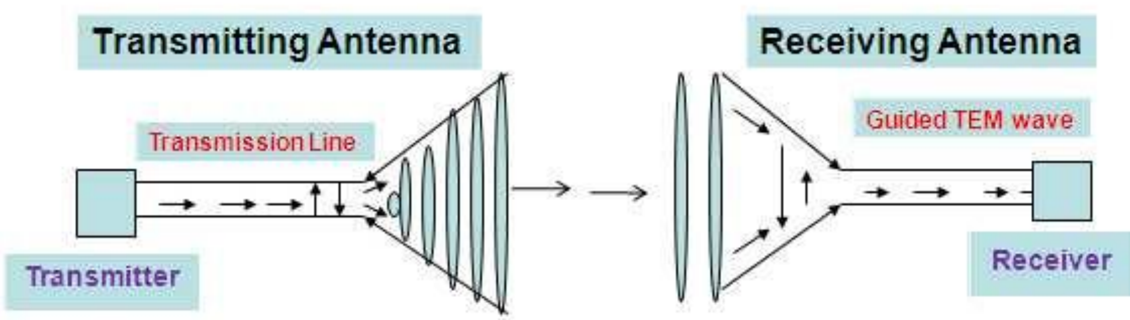


Fig. 2.1 Propagation of TEM wave using transmitting and receiving antenna

- Transmitter - Radiates electromagnetic energy into free space.

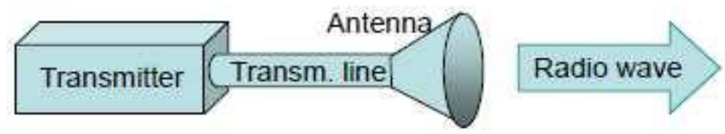


Fig. 2.2 Transmitting Antenna

- Receiver - receives electromagnetic energy from free space.

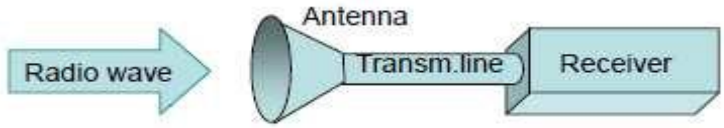


Fig. 2.3 Receiving Antenna

Antennas are crucial components of all equipment that uses radio systems. Antenna are used in radio broadcasting systems, broadcast television systems, satellite communications, two-way radio systems, cell phones, communications receivers, radar and as well as other equipments such as wireless microphones, garage door openers, wireless computer networks, Bluetooth-enabled devices, baby monitors, and RFID tags on merchandise.

In general, an antenna composed of an arrangement of metallic conducting elements, electrically connected (frequently connected throughout a transmission line) to the receiver or transmitter. A transmitter creates an oscillating electric field along the elements by forcing an oscillating current of electrons through the antenna, while the charge of the electrons also creates. A moving transverse electromagnetic field wave is created by the radiation of these time-varying fields, away from the antenna into space. In the receiver, oscillating currents in the antenna is produced by the back and forth movement of the electrons in the antenna elements which is created by the force exerts by oscillating electric and magnetic fields of an incoming radio wave.

2.2 ANTENNA GLOSSARY [14]

There are few common terms that are related to antenna and must be defined and explained:

2.2.1 ANTENNA GAIN

Antenna gain is defined as the intensity of an antenna in a given direction to the intensity that would be produced by an isotropic antenna that radiates equally in all directions and has no losses.

Consider the power density radiated by an isotropic antenna with input power P_0 at a distance R which is given by –

$$S=P_0 / 4\pi\eta R^2$$

An isotropic antenna radiates equally in all directions, and it's radiated power density 'S' is found by dividing the radiated power by the area of the sphere $4\pi R^2$. An isotropic radiator is considered to be 100 percent efficient. The gain of an actual antenna increases the power density in the direction of the peak radiation:

$$S = \frac{P_0}{4\pi R^2} = \frac{|E|^2}{\eta}$$

$$|E|^2 = \frac{1}{R}\sqrt{\frac{P_0 G\eta}{4\pi}} = \sqrt{S\eta}$$

Gain is achieved by directing the radiation away from other parts of the radiation sphere. In general, gain is defined as the gain-based pattern of the antenna.

$$S(\theta,\phi) = \frac{P_0 G(\theta,\phi)}{4\pi R^2}$$

$$U(\theta,\phi) = \frac{P_0 G(\theta,\phi)}{4\pi}$$

Where,

$S(\theta,\phi)$ is Power Density

$U(\theta,\phi)$ is Radiation Intensity

2.2.2 ANTENNA EFFICIENCY

Antenna efficiency is defined as the surface integral of the radiation intensity over the radiation sphere divided by the input power P_0 is a measure of the relative power radiated by the antenna..

$$\frac{P_r}{P_0} = \int_0^{2\pi}\int_0^{\pi} \frac{G(\theta,\phi)}{4\pi} \, \text{Sin}\,\theta d\,\theta d\phi = \eta_e$$

Where,

P_r is the radiated power

η_e is efficiency.

Material losses in the antenna or reflected power due to poor impedance match reduce the radiated power.

2.2.3 RADIATION PATTERN

Radiation pattern is defined as "a mathematical function or a graphical representation of the radiation properties of the antenna as a function of space coordinates."

An antenna radiates in four different patterns:

a) Isotropic Pattern: This pattern is uniformly radiated along all the directions.
b) Directional Pattern: Is a pattern characterized by more efficient radiation in one direction than the other.
c) Omni directional Pattern: A pattern which is uniform in a given plane.

d) Principal Plane Pattern: These are the E-field and H-field of a linearly polarized antenna. Our horn antenna is linearly polarized on both fields.

Radiation patterns are characterized by their lobes. The various lobe definitions are below:

a) Radiation Lobe: Is a peak in the radiation intensity surrounded by the weaker intensity.

b) Main Lobe: Radiation lobe with a maximum radiation.

c) Side lobe: A radiation lobe in any direction except the main lobe.

d) Back Lobe: Is a Lobe opposite to the main lobe.

e) HPBW (half-power beam width): The angular width of the main beam at the half-power point. We were able to achieve a half-power beam width around 11 degrees.

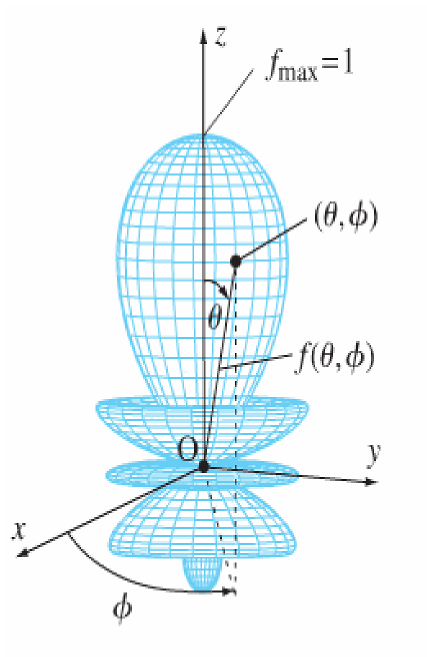


Fig. 2.4 Normalized field pattern of Directional antenna[14]

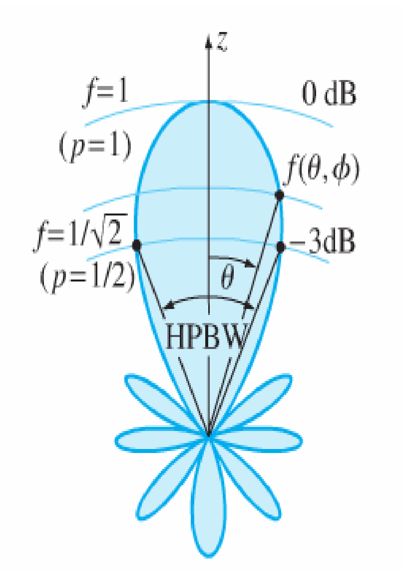


Fig. 2.5 D-cut in phi plane[14]

2.2.4 EFFECTIVE AREA

Antennas capture power from passing waves and deliver some of it to the terminals. Given the power density of the incident wave and the effective area of the antenna, the power delivered to the terminals is the product.

$$P_d = SA_{eff}$$

for an aperture antenna such as a horn, parabolic reflector, or flat-plate array, effective area is physical area multiplied by aperture efficiency. In general, losses due to material, distribution, and mismatch reduce the ratio of the effective area to the physical area.

Typical expected aperture efficiency for a parabolic reflector is 55%. Even antennas with infinitesimal physical areas, such as dipoles, have effective areas because they remove power from passing waves.

2.2.5 DIRECTIVITY

Directivity is a measure of the concentration of radiation in the direction of the maximum.

$$Directivity = \frac{U_{max}}{U_0}$$

Where, U_{max} is maximum radiation intensity.

U_0 is average radiation intensity

Directivity and gain differ only by the efficiency, but directivity is easily estimated from patterns. Gain-directivity times efficiency-must be measured. The average radiation intensity can be found from a surface integral over the radiation sphere of the radiation intensity divided by 4π, the area of the sphere in steradians:

$$Average\ radiation\ intensity = \frac{1}{4\pi}\int_0^{2\pi}\int_0^{\pi} U(\theta,\phi)\ Sin\ \theta d\ \theta d\phi = U_0$$

This is the radiated power divided by the area of a unit sphere. The radiation intensity $U(\theta,\phi)$separates into a sum of co- and cross-polarization components:

$$U_0 = \frac{1}{4\pi}\int_0^{2\pi}\int_0^{\pi}[U_c(\theta,\phi) + U_x(\theta,\phi)\ Sin\ \theta d\ \theta d\phi$$

Both co- and cross-polarization directivities can be defined:

$$Directivity_c = \frac{U_{c,max}}{\mathrm{U}_0}$$

$$Directivity_x = \frac{U_{x,max}}{\mathrm{U}_0}$$

2.2.6 INPUT IMPEDANCE

The input impedance of an antenna is defined as "the impedance presented by an antenna at its terminals or the ratio of the voltage to the current at the pair of terminals or the ratio of the appropriate components of the electric to magnetic fields at a point". Hence the impedance of the antenna can be written as given below.

$$Z_{in} = R_{in} + jX_{in}$$

Where, Z_{in} is the antenna impedance at the terminals.

R_{in} is the antenna resistance at the terminals.

X_{in} is the antenna reactance at the terminals.

The imaginary part, X_{in} of the input impedance represents the power stored in the near field of the antenna. The resistive part, R_{in} of the input impedance consists of two components, theradiation resistance R_r and the loss resistance R_L . The power associated with the radiation resistance is the power actually radiated by the antenna, while the power dissipated in the loss resistance is lost as heat in the antenna itself due to dielectric or conducting losses.

2.2.7 BEAMWIDTH

Beamwidth of an antenna is easily determined from its 2D radiation pattern and is also a very important parameter. Beamwidth is the angular separation of the half-power points of the radiated pattern.

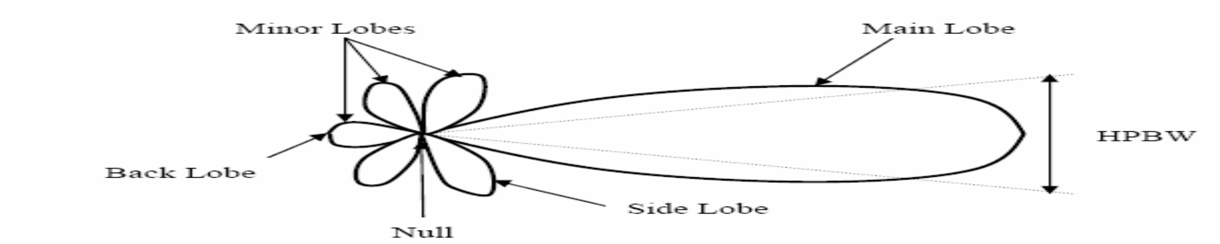


Fig.2.6 Determination of HPBW from radiation pattern[14]

2.3 MOTIVATION

With the intensifying importance of wireless communication systems and personnel IT (information technologies) services (e.g., Bluetooth), growing efforts are committed to the design and implementation of microstrip patch antennas from electrically small electronic circuits to the antenna arrays. One main purpose is the design of microstrip patch antenna which attracts candidates and researchers for adaptive systems in the present and future communication systems. Their main advantages are low cost, light weight, conformal or planar layout, and ease of integration with electronic or signal processing circuitry.

2.4 SCOPE OF THE STUDY

Metamaterial can have an impact in the entire world of technologies in which electromagnetic radiation are used and will give a reliable platform for technological advancement. Negative refractive index metamaterials or left-handed metamaterials have taken special attention in microwaves. Due to the metamaterial properties, the reduction in size as compared to other materials for the multiband operation and reconfigurability of microwave devices and antennas can be possible. The main attractive application of metamaterial is as an absorber and also as sensors for soil moisture measurement, humidity etc. It is also accurate that the developments in fabrication is the only way for the progress in metamaterial research. It has been seen from the early progress and development in research of metamaterials that in the coming future it will lie in the field of optics and medical. Due to this it is clear that it will lead to the advancements in nanotechnology.

There are different ways in which metamaterials can be used in day to day life:-

2. Metamaterials as antenna
3. Metamaterials as absorber
4. Metamaterials as superlens
5. Metamaterials as cloaks
6. Metamaterials as sensor
7. Metamaterials as phase compensator

2.5 OBJECTIVE OF THE STUDY

The main objective of the study is to design a bandwidth enhancement and high gain microstrip patch antenna using metamaterials. Metamaterial as a microstrip patch antenna has been used to improve the radiation and matching properties of miniaturized and magnetic dipole antennas. Metamaterial simply increases the radiated power of the transmitter antenna. The recent and highly optimize Metamaterial antenna radiates 95 percent of the input radio signal at 350 MHz. Experimental metamaterial antenna are as small as one fifth of a wavelength. The directivity of the patch antenna can be increased with the use of metamaterial. To achieve high directivity antennas, Zero-index metamaterials can be used. Because in a zero-index metamaterial the signal propagating will stimulate a spatially static field structure that varies in time. Metamaterial can improve the gain and decrease the return loss of a patch antenna.

2.6 OUTLINE OF THE REPORT

The outline of this Dissertation-II report is as follows

Chapter 3 presents the role of microstrip patch antennas in wireless communication system. It also presents the feeding techniques, advantages and disadvantages of microstrip patch antenna. At last different types of method of analysis of microstrip patch antenna is discussed.

Chapter 4 presents the literature review of different research papers. In this chapter a brief discussion on the various papers has been completed.

Chapter 5 presents the description of software used for the simulation of the antenna design i.e. HFSS 12.0(High Frequency Structural Simulation). With the use of this simulation software I have concluded the result and analysis of the proposed antenna is carried out in chapter 7, 8.

Chapter 6 includes the research methodology.

Chapter 7 presents the results and discussion of the Broad band and high gain microstrip patch antenna using metamaterials. Simulation result (S11) is shown in this chapter.

Chapter 8 includes the summary and conclusion.

Chapter 3
ROLE OF MICROSTRIP PATCH ANTENNAS IN WIRELESS COMMUNICATION

3.1 MICROSTRIP PATCH ANTENNA[17]

A Microstrip patch antenna has a dielectric substrate and a radiating patch above this substrate and a ground plane below this substrate as shown in Figure 3.1. The patch can be made by copper, gold or any other conducting material and can have any possible shape. The feed lines and radiating patch are usually placed on the dielectric substrate.

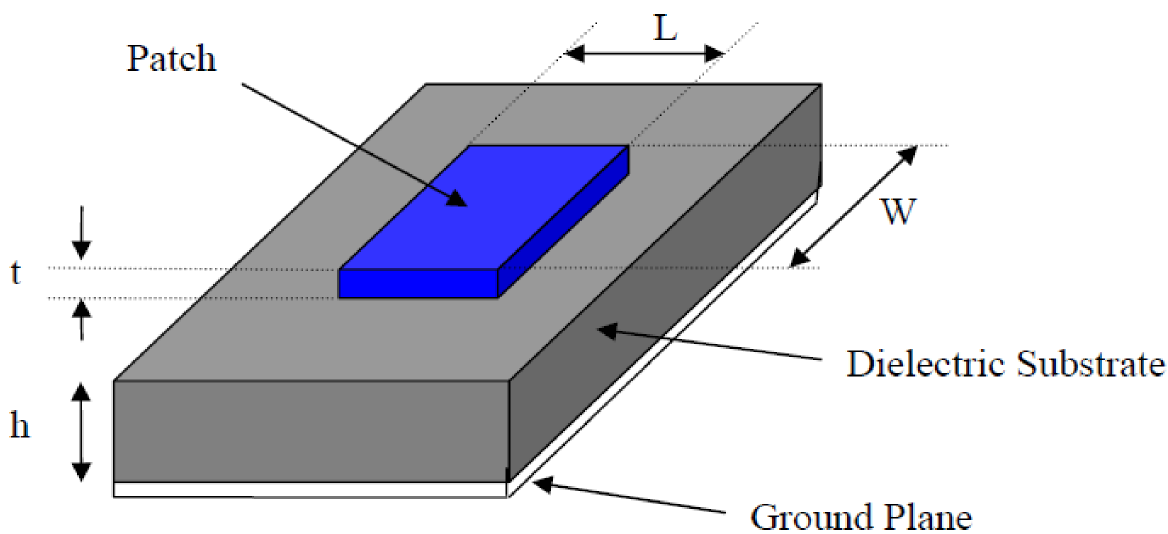


Fig. 3.1 Structure of a Microstrip Patch Antenna[17]

In order to simplify analysis and performance calculation, the patch can be made up of a square, rectangular, circular, triangular, elliptical or some other common shape as shown in Figure 3.2. For a rectangular patch, the length 'L' of the patch is usually $0.3333\lambda_0 < L < 0.5\lambda_0$, where λ_0 is the free-space wavelength. The patch is selected to be very thin such that t

<< λ_0 (where 't' is the patch thickness). The height 'h' of the dielectric substrate is usually $0.003\lambda_0 \leq h \leq 0.05\lambda_0$. The dielectric constant of the substrate (ε_r) is typically in the range $2.2 \leq \varepsilon_r \leq 12$.

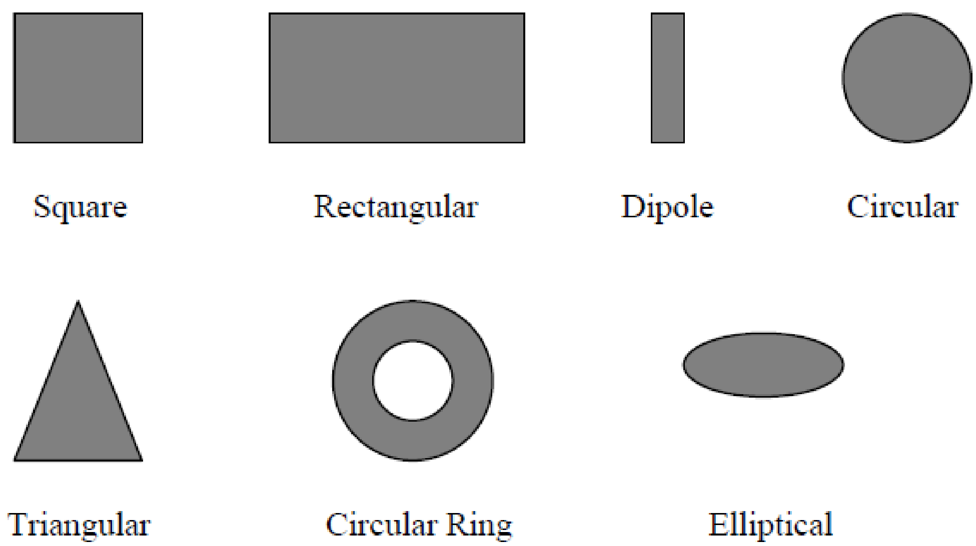


Fig. 3.2 Common Types of microstrip patch elements[17]

3.2 FEEDING TECHNIQUES IN MICROSTRIP PATCH ANTENNA

There are various methods to fed Microstrip patch antennas. These feeding methods can be distinguished into two categories- contacting and non-contacting. In the contacting scheme, we use a microstrip line to fed the RF power directly to the radiating patch. In the non-contacting method, the power is transferred between the microstrip line and the radiating patch with the help of electromagnetic field coupling. The four popular feed techniques used are the microstrip line, coaxial probe (both contacting schemes), aperture coupling and proximity coupling (both non-contacting schemes)[17].

3.2.1 Microstrip Line Feed[17]

In microstrip line feeding technique, a conducting strip is connected directly to the edge of the microstrip patch as shown in Figure 3.3. The width of the conducting strip is smaller as compared to the width of the patch and this type of feeding arrangement has the advantage that the feed can be engraved on the same substrate to provide a planar structure.

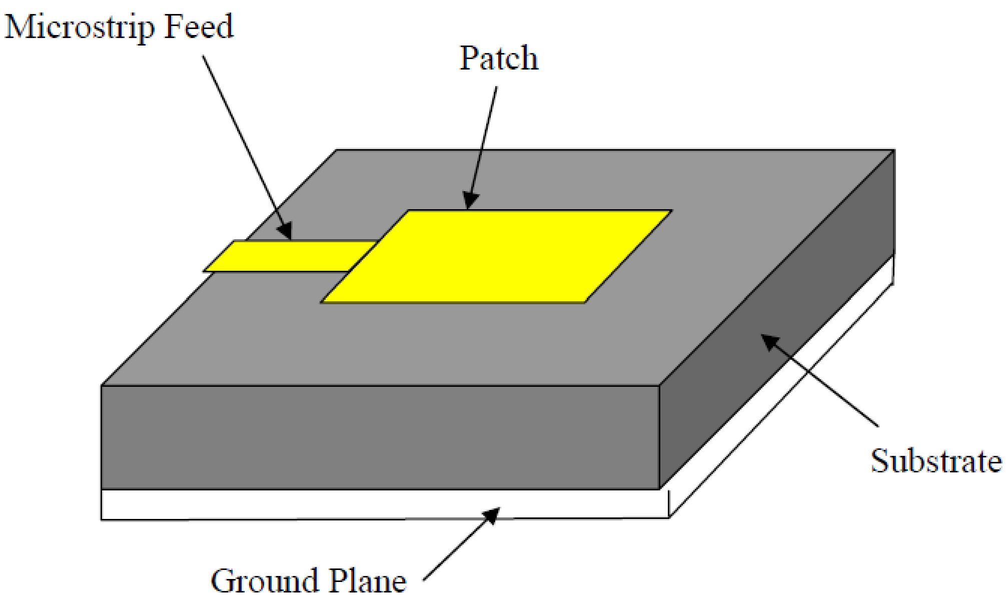


Fig. 3.3 Microstrip Line Feed[17]

To match the impedance of the feed line to the patch the inset cut in the patch is used without the need for any additional matching element. This is attained by properly calculating the inset position. Hence microstrip line is an easy feeding method, because it provides simplicity to fabricated and ease in modeling as well as impedance matching. The bandwidth of the antenna gets effected by the increase in the radiation of surface waves which is occurred by the thickness of the dielectric substrate. The undesired cross polarized radiation is increased by the feed radiation.

3.2.2 Coaxial Feed

It is a very common technique used for feeding Microstrip patch antennas. This type of feeding technique is also known as probe feed. From Figure 3.4 it is clearly visible that the inner conductor of the coaxial connector extends through the dielectric and is soldered to the patch, while the outer conductor is connected to the ground plane.

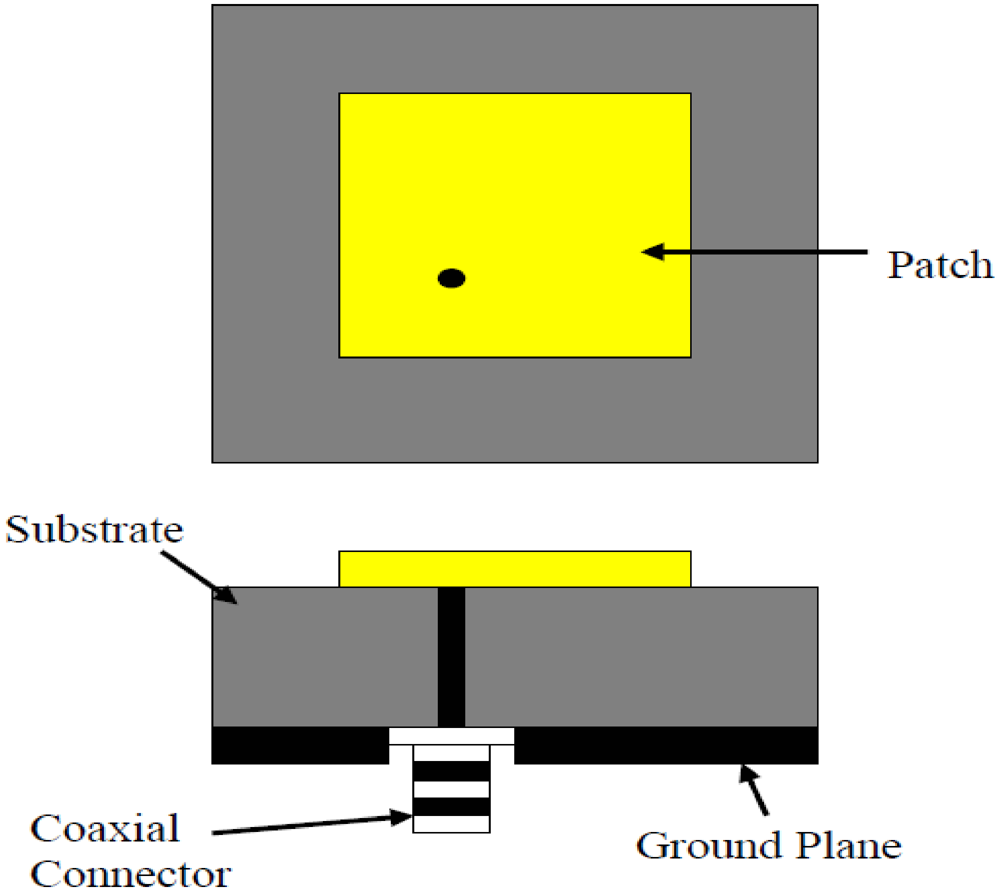


Fig. 3.4 coaxial feed[17]

The major advantage of coaxial feeding scheme is that order to match with the input impedance, the feed can be placed at any preferred position inside the patch. It is easy to fabricate and has low spurious radiation. The main disadvantage of coaxial feed is that it presents narrow bandwidth and it is very difficult to design since a hole has to be drilled into the substrate and the connector obtrudes outside the ground plane, therefore not making it completely planar for thick substrates ($h > 0.02\lambda o$). However, for thicker substrates, the increased probe length makes the input impedance more inductive, leading to matching problems. It can be seen above that for a thick dielectric substrate; the microstrip line feed and the coaxial feed suffer from numerous disadvantages. To overcome this problem the non-contacting feeding techniques have been discussed below.

3.2.3 Aperture Coupled Feed[17]

In aperture coupled feed technique, the patch and the feed line are separated by the ground plane as shown in Figure 3.5. An aperture in the ground plane is made through a slot for coupling between the patch and the feed line.

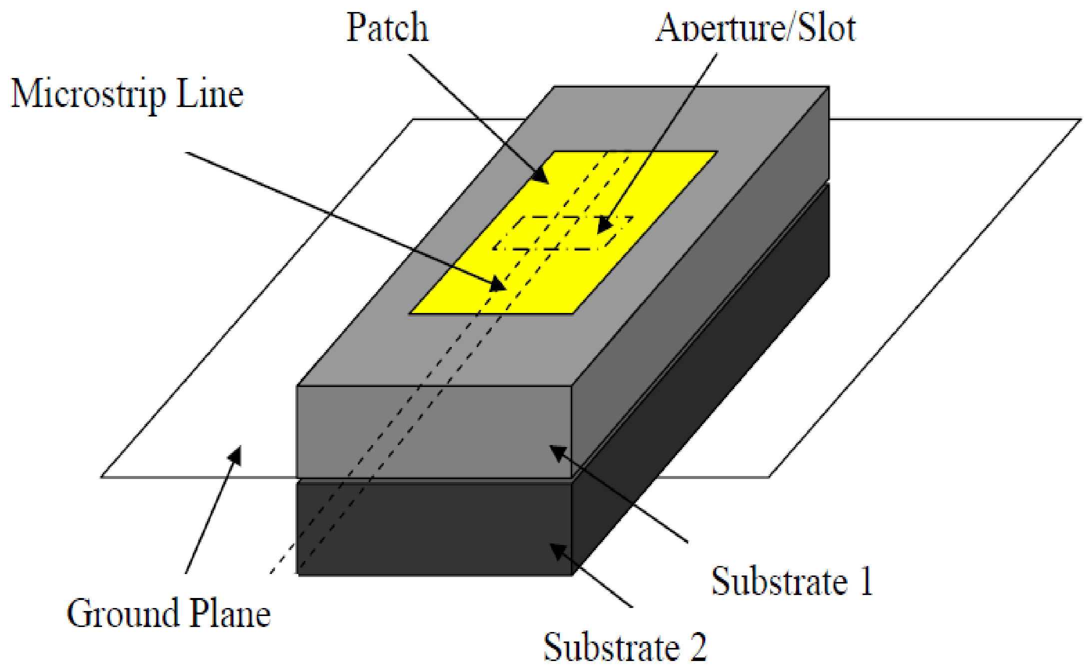


Fig. 3.5 Aperture-coupled feed[17]

Due to symmetry of the configuration the coupling aperture is usually centered under the patch, leading to lower cross polarization. The shape, size and location of the aperture is used to determine the amount of coupling from the feed line to the patch. In this type of feed technique spurious radiation is minimized as the ground plane separates the patch and the feed line. To optimize radiation from the patch, a high dielectric material is used for the bottom substrate and a thick, low dielectric constant material is used for the top substrate. The major disadvantage of aperture coupled feed technique is that it increases the antenna thickness due to multiple layers and it is difficult to fabricate. This type of feeding techniques also provides narrow bandwidth.

3.2.4 Proximity Coupled Feed

Proximity coupled feed technique is also called as the electromagnetic coupling scheme. As shown in Figure 3.6, it is clearly seen that the radiating patch is on top of the upper substrate and the two dielectric substrates are used such that the feed line is between the two substrates. The major advantage of proximity coupled feed technique is that it reduces spurious feed radiation and provides very high bandwidth (as high as 13%), due to overall increase in the thickness of the microstrip patch antenna. This feed technique also offers choices between two different dielectric media, one for the patch and one for the feed line to optimize the individual performances.

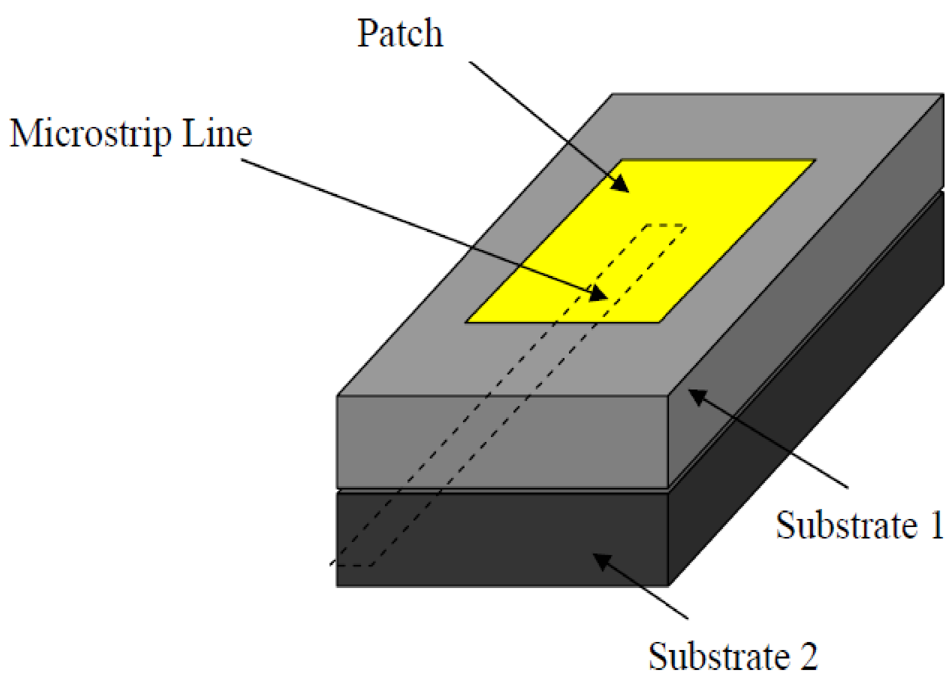


Fig. 3.6 Proximity-coupled Feed[17]

In order to achieve matching the length of the feed line and the width-to-line ratio of the patch is controlled. The main disadvantage of this type of feed technique is that it is very complicated to fabricate because of the two dielectric layers which need proper alignment. And the overall thickness of the antenna is also increased.

3.3 Advantages and Disadvantages of microstrip antenna[17]

Microstrip patch antennas are increasing in popularity for use in wireless applications due to their low-profile structure. Due to which they are highly compatible for embedded antennas in handheld wireless devices such as cellular phones, pagers etc... These microstrip patch antennas are used in telemetry and communication antennas on missiles due to their thin and conformal shape. Satellite communication is the another area where they have been used productively in the present scenario.

The advantages of microstrip patch antenna are given below:

• Light weight.

• Low profile configuration.

• Low fabrication cost, therefore can be made in bulk quantities.

• Linear as well as circular polarization both are supported.

• Ease of integrated with microwave integrated circuits (MICs).

• Capable of dual and triple frequency operations.

• Mechanically robust (when mounted on rigid surfaces).

Microstrip patch antennas undergo a numerous disadvantages as compared to standard antennas. The main disadvantages of the microstrip patch antennas are given below:

• Narrow bandwidth

• Low efficiency

• Low Gain

• Poor end fire radiator

• Capacity to handle power is very low

• Surface wave excitation

Microstrip patch antennas have a very high antenna quality factor ‘Q’. Q shows the losses linked with the antenna. Large value of Q leads to narrow bandwidth and low efficiency. Quality factor can be reduced by increasing the thickness of the dielectric substrate. But there is a tradeoff between the thickness of the dielectric substrate and the total power delivered as the thickness increases, an increasing portion of the total power delivered by the source goes into a surface wave. The generations of this surface wave contributes to the unwanted power loss since it is finally scattered at the dielectric bends and causes degradation of the antenna characteristics. Hence by the use of photonic band gap structures, surface waves can be reduced. By using an array configuration for the elements, other problems such as lower gain and lower power handling capacity can be overcome.

3.4 METAMATERIAL ANTENNAS

Metamaterial antenna is a kind of antennas which uses metamaterials to enhance the performance of miniaturized (electrically small) antenna. The main purpose of the metamaterial antenna is to transmit and receive electromagnetic energy into free space, as same as with any electromagnetic antenna. Since this kind of antenna system uses metamaterials which are used to produce unusual physical properties engineered with novel, often microscopic structures. Metamaterial antennas show the behavior that no other conventional antenna can provide at the same frequency. This class of antennas is used to get the improved radiated power.

A standard antenna reflects most of the signal back to the source and are very small as compared to the wavelength . A metamaterial antenna structure stores and re-radiates energy and acts as if it were much larger than its actual size. To print metamaterial antennas on a PC board a traditional lithography techniques can be used.

The major applications of metamaterial antennas are space communications, satellites, wireless communication, GPS, space vehicle navigation and airplanes.

Antenna designs employing metamaterials can improve the radiated power of an antenna. The experimental metamaterial antennas radiate as much as 95% of the input radio power. The conventional antennas have to be at least half the size of the signal wavelength to work efficiently. At 500 MHz, for example, an antenna would have to be half a meter long. The experimental metamaterial based antennas are as small as one-fiftieth of a wavelength and can be further decreases in size.

Metamaterials are mainly used for the miniaturization of microwave antennas, with acceptable bandwidth and efficient power. To overcome restrictive efficiency-bandwidth limitations for conventionally constructed, miniature antennas, metamaterials are effectively used.

Metamaterials can be used for better utilization of available space for space-constrained cases and make the antenna elements much smaller and to cover a wider frequency range. As the antenna element becomes smaller we can use the radiating elements to make a large antenna arrays to achieve high gain.

Chapter 4
LITERATURE REVIEW

1. In [1] Ying Peng et al proposed a 60GHz ultra thin folded dipole antenna on a metamaterial based surface cavity for 3D FPGA high data transmission. Meta-material resonant cavity was designed in order to increase the radiation efficiency, and to act as a reflector. In this paper the simulation results shows that a 4.6 dB gain and 7 GHz bandwidth were obtained at the center frequency of 60 GHz for the novel antenna. The proposed antenna has 98% reduction in substrate thickness (only 10 mm thick) in comparison with conventional conducting metal cavity antenna having the same gain. The importance of this paper is that such low profile antenna can be integrated with standard silicon CMOS technology to make less cost wireless data transmission possible between FPGA layers or chips. The simulated results of the proposed antenna shows that the antenna has a bandwidth of 7GHz around 60GHz with a gain of 4.6 dB.

2. In [2] Hussein Attia et al proposed that a fast and accurate analytical technique can be developed to calculate the radiation field of an improved directivity of the microstrip antenna covered with artificial magnetic superstrate. The analytical formulation is based on transmission line analogy and the cavity model. In this paper the radiation pattern of a patch antenna covered with superstrate was calculated using the analytical method. To obtain the effective permeability and permittivity the broadside coupled split ring resonator (SRR) inclusions acting as building blocks for the artificial magnetic superstrate were characterized analytically. Measured results were given in this paper to support the analytical solution. A relatively low profile of the whole structure is maintained while the directivity of the patch antenna covered with the artificial magnetic superstrate was improved by about 3.4 dB. Simulation results were shown to express the maximum gain enhancement potential that can be achieved when artificial magnetic superstrates are used.

3. In [3] Ajay kumar et al proposed a antenna design for suppressing the surface waves using mushroom type EBG structures. The EBG structures used in this paper are periodic metallic patches which are connected to the ground plane with vias. The most important characteristic of the EBG structure is their stop band frequency and by the help of this stop band frequencies the surface waves of the proposed antenna are suppressed. The bandwidth of the microstrip antenna is enhanced by the suppression of surface waves. By the use of mushroom type EBG structure the band width of microstrip antenna can be enhanced. In this paper it is observed on the basis of simulation that the proposed antenna can be used in WI-FI, Bluetooth etc. applications.

4. In [4] T. Masri et al proposed that by a spiral fan-shape Electromagnetic Band Gap (EBG) structure between a narrowband patch antenna and its ground plane, the bandwidth of a rectangular patch antenna is enhanced. The simulated result of the proposed antenna design shows the improvement in the bandwidth from about 4 % for a single layered narrow band rectangular microstrip patch, to more than 17 % after the EBG structure was introduced with an excellent return loss and good impedance matching. The methodology, experimental works and simulations carried out in accomplishing the objective above is shown in this paper. For the simulation purpose Microwave Office 2006 software has been used to simulate and to check the optimum design and results.

5. In [5] Filipe Silva et al proposed that the surface currents in the antenna can be reduced by microstrip antennas with the use of EBG structures and effective increase in the gain and reduction in the back radiation level can be achieved leading to less interference in the system as well as to enhanced global efficiency of the antenna. The proposed microstrip antenna with an EBG structure integrated allows an improvement of the location system performance in about 25% to 30% relatively to a conventional microstrip antenna. The main difference is in the return loss but is not significant. This is due to the permittivity value which is not same as that used in the simulation purpose.

6. In [6] Navdeep Singh et al shows the study of different kind of metamaterials such as DNG(Double Negative Structures), Electromagnetic Band Gap (EBG), SNG (Single

Negative Structures), UCPBG (Uniplanar Compact Photonic Band Gap Structures). The proposed antenna design results in miniaturization and enhanced performance of antennas using metamaterials. This paper concludes that Microwave applications antennas and filters without metamaterials, are not more effective as compared to with using metamaterials. It is shown in the paper miniaturized and enhanced microstrip antennas can be developed suing these metamterials under the proper conditions.

7. In [7] Chun-Yih Wu et al designed a high gain patch antenna using meta-material. The proposed antenna is consists of 4 layer of metallic rings and 3 layer of Rogers 5880 substrate. The gain of the antenna can be enhanced upto 2.3 dB in the WiMAX 5.8- GHz band by using thin metamaterial antenna radome (only $0.06\lambda_0$ including the air gap between the antenna radome and the patch antenna) as compared with ordinary FR4 substrate patch antenna. The proposed antenna has a impedance bandwidth of about 350 MHz. The far-field radiation characteristics of both E-plane and H-plane of the proposed antenna are also measured and are discussed in this paper.

8. In [8] Sarawuth Chaimool et al designed a square patch antenna with the center frequency of 1.8 GHz using an artificial magneto-dielectric metasubstrate(AMDM). This proposed antenna design shows that 65% of the size can be reduced by the use of AMDM as compared to the one with a half-wavelength patch antenna designed without the AMDM. The proposed antenna has a radiation efficiency of 72% and directivity of this antenna is 6.24 dBi. This antenna is miniaturized with a factor of 3.08 using AMDM as compared to a conventional air substrate.

9. In [9] Anand Kumar et al shows the comparison of two different designs of microstrip patch antenna using metamaterial substrate at 86 GHz. The simulation software used is CST Microwave Studio. First design shows the improvement of the gain by suppressing the surface wave using partial substrate method. Second design shows the purpose of using mushroom type EBG structure as antenna substrate to suppress the surface wave. A double fishnet metamaterial has been designed and used as base for both the cases. By the

use of metamaterials, gain and directionality of the antenna is effectively enhanced which have been compared for the two cases. The antenna designed with EBG substrate has slightly more beamwidth of main beam and side lobes are less as compared to the antenna designed with partial substrate. The proposed antenna is the first design of microstrip patch antenna using both EBG and fishnet metamaterial for enhanced performance.

10. In [10] Ruchika Gupta et al proposed a microstrip patch antenna placed over a high impedance electromagnetic bandgap (EBG) substrate. The simulation of the proposed antenna design is carried out on electromagnetic (EM) simulation software using FR-4 substrate with dielectric constant of 4.54 and thickness of 1.60mm. The proposed antenna has a dimension of 60x60mm^2. By the adjustment of gaps between the adjacent patches in X-direction and the Y-direction respectively and the radii of the related vias, the bandwidth of microstrip patch antenna is enhanced. For the surface wave reduction, the EBG cells are placed in E-plane. A novel design of this microstrip patch antenna using mushroom-like EBG structure is carried out with these effective methods which show enhanced bandwidth than the conventional one. The simulation result presents the bandwidth enhancement of the microstrip patch antenna.

11. In [11] Neeraj Rao et al designed a novel antenna to achieve enhanced bandwidth with high gain of a microstrip patch antenna. This antenna configuration is used to suppress the surface wave by making holes in the substrate and multiple layer dielectrics is used to improve the bandwidth of the microstrip patch antenna. In the end, this paper provides the improved gain by creating electromagnetic band gap(EBG) structures and increased bandwidth is achieved by using a multiple layer dielectric substrate.

12. In [12] Yasser M. Madany proposed a compact Ultra wideband antenna structure. This antenna is been analyzed, fabricated using a commercial software. The radiation characteristics, such as return loss and the surface current densities have been introduced, which provides excellent performance and lower S11 up to -31.4 dB with the increase in bandwidth to 22.34 %.

13. In [13] Mahmoud Niroo-Jazi et al proposed a single layer conventional mushroom-like EBG structure to enhance the gain of a coaxial fed patch antenna. To investigate the effect of the antenna radiation pattern this EBG configuration is used in both E- and H-plane directions. The simulation result displays that more than two times of the gain can be enhanced if we convert the suppressed surface waves into the radiated ones, and this can be achieved without losing the matching bandwidth.

Chapter 5
SOFTWARE USED: HIGH FREQUENCY STRUCTURAL SIMULATOR (HFSS 12.0)

5.1 WHAT IS HFSS?

HFSS stands for High Frequency Structural Simulator. HFSS is simulation software based on FEM (finite element method). HFSS is an interactive software package for calculating the electromagnetic behavior of a structure. The software includes post-processing commands for analyzing this behavior in detail.

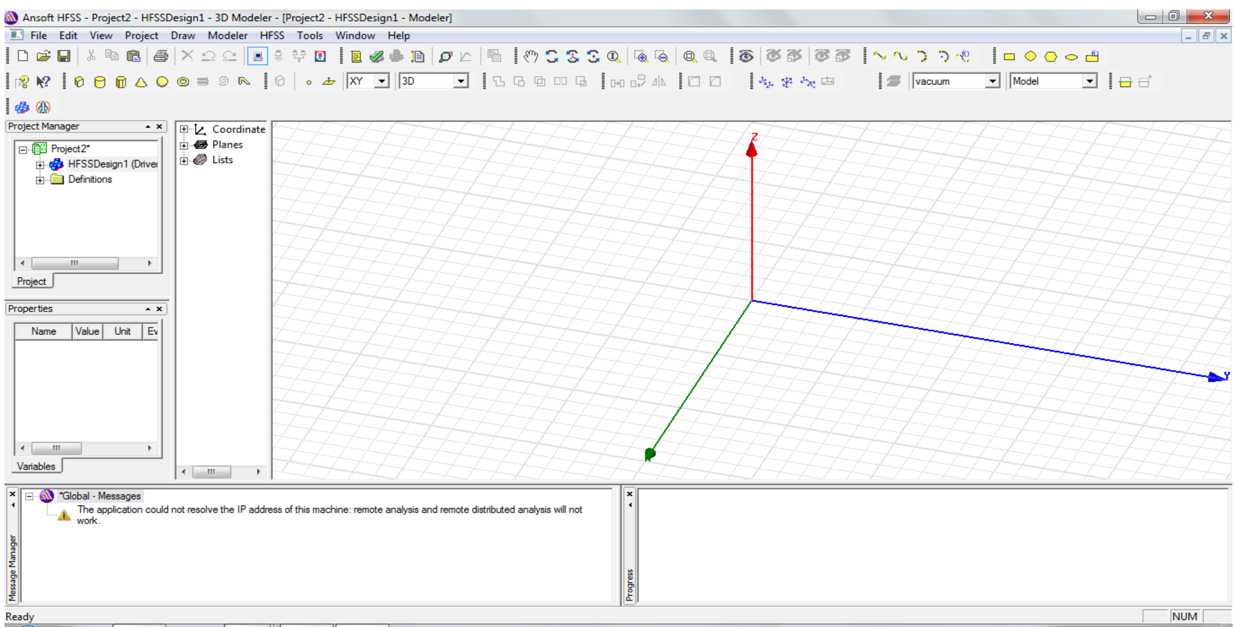


Fig 5.1 Snapshot of the HFSS environment

HFSS is an interactive simulation system whose basic mesh element is a tetrahedron. This permits you to analyze any arbitrary 3D geometry, particularly those with complex design, shapes and structures. In a fraction of the time it would take using other techniques. Ansoft HFSS has progressed recently from the inputs and feedbacks from many users. In industries, Ansoft HFSS is used to produce high-productivity research, development, and virtual prototyping.

HFSS is used to compute the following:

- Basic electromagnetic field quantities
- For open boundary problems
- Radiated near and far fields
- Characteristic port impedances and propagation constants
- Generalized S-parameters
- The eigenmodes or resonances of a structure

5.2 STARTING ANSOFT HFSS

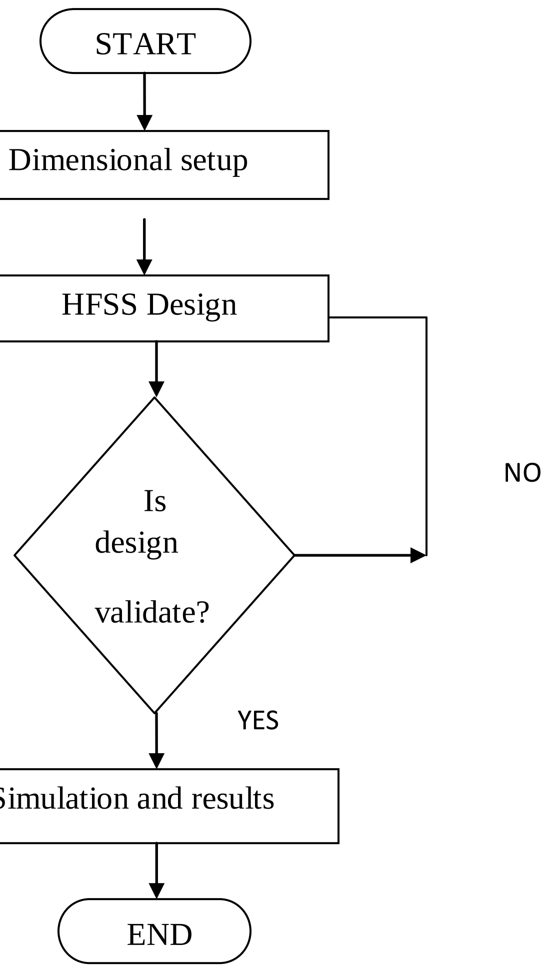


Fig. 5.2 Flowchart for procedure

1. Click on the Microsoft Start button, select Programs, and select the Ansoft HFSS 12.0.

2. Another way is by double click on the HFSS 12.0 icon on the Windows Desktop.

5.3 ANSOFT TERMS

There are several optional panels in the Ansoft HFSS window which are following:

1. **Project Manager-** It contains a design tree which further consists the structure of the project.

2. **Message Manager-** It permits you to check any errors or warnings which occur before the beginning of a simulation.

   a) **Property Window-** It shows and allows you to change model if you want.

   b) Parameters or attributes.

   c) **Progress Window-** It displays solution progress of the design.

   d) **3D Modeler Window-** It includes the model and model tree for the Active design.

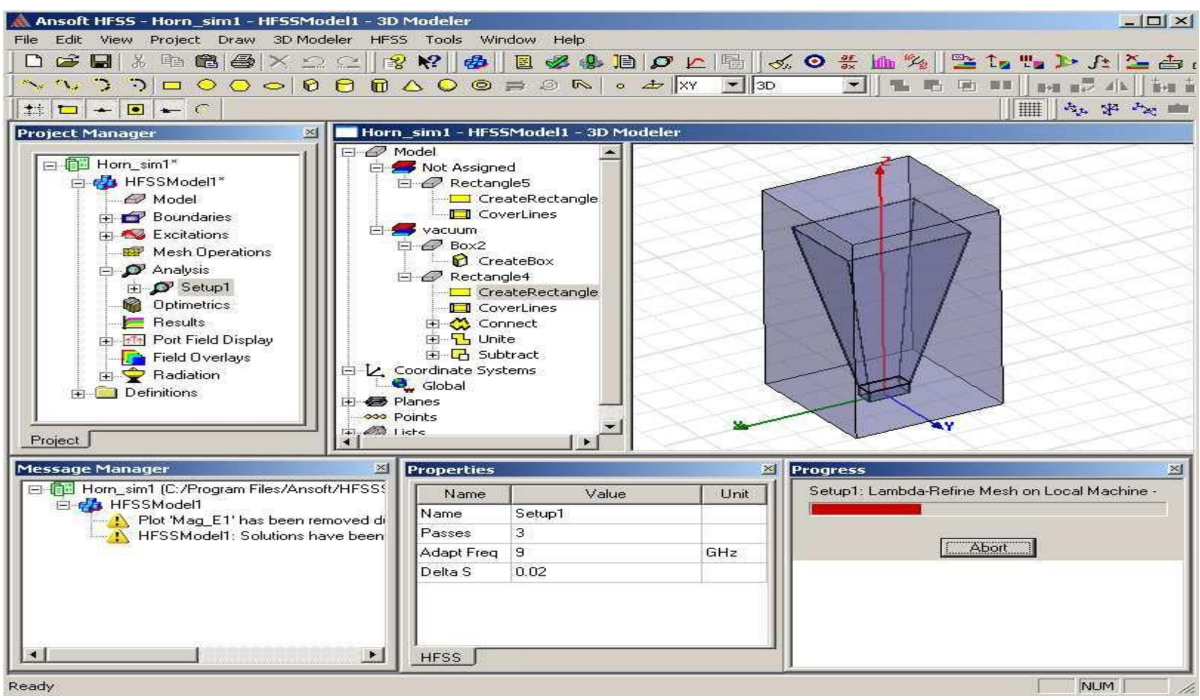


Fig. 5.3 Different terms of Ansoft

5.3.1 Project Manager

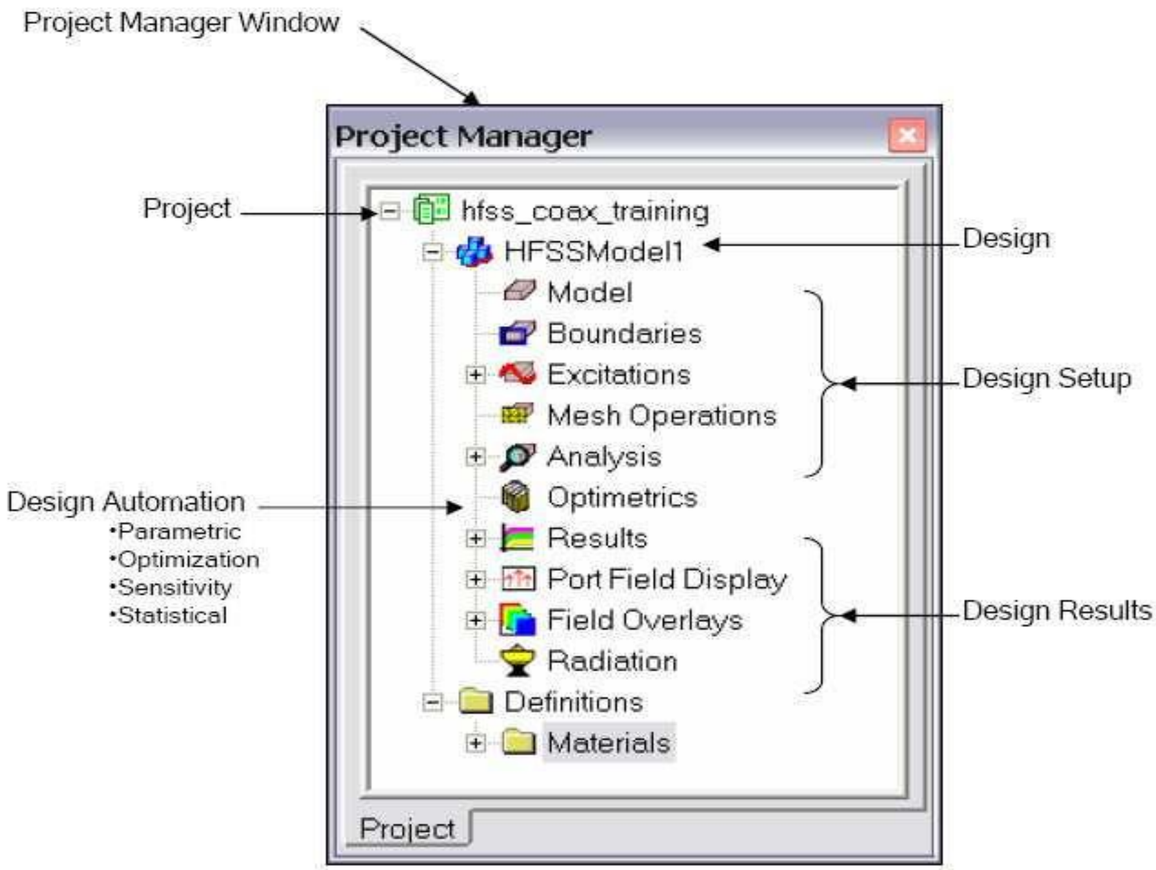


Fig. 5.4 Different terms of Project window

5.3.2 Property Window

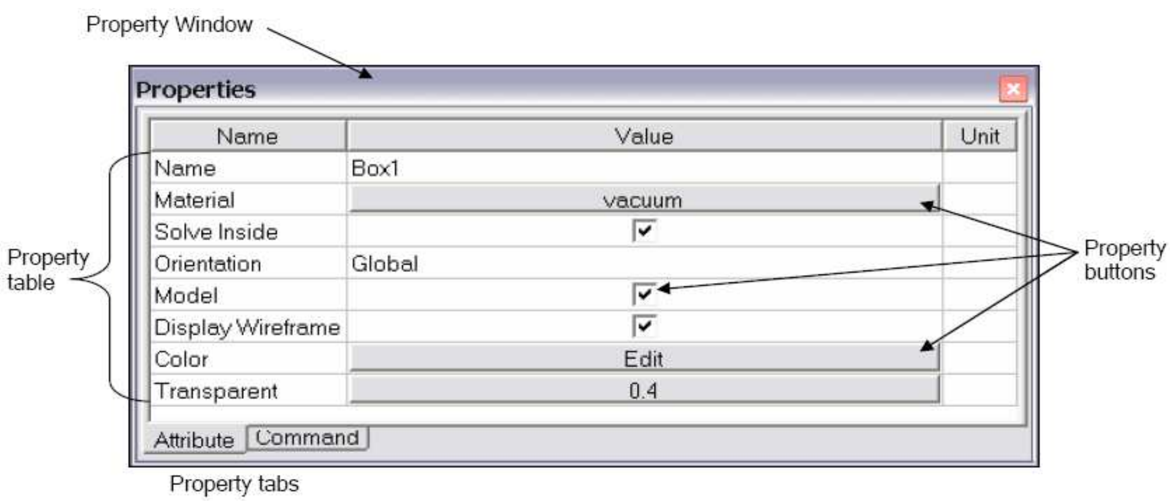


Fig. 5.5 Different terms of Property window

5.3.3 Ansoft 3D Modeller

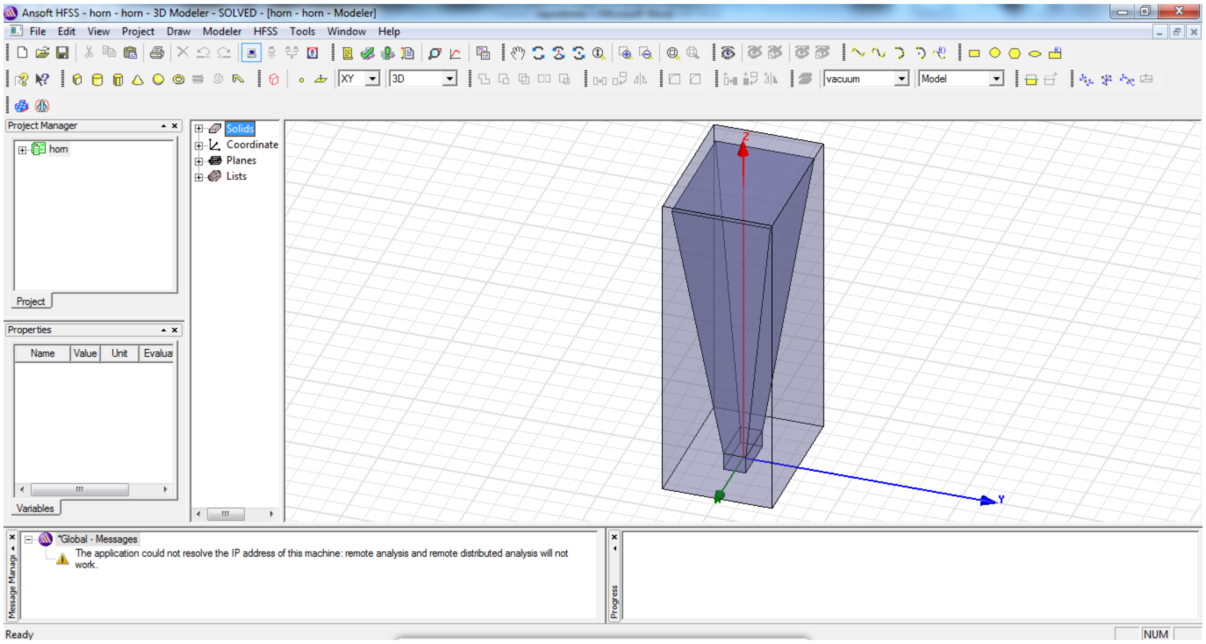
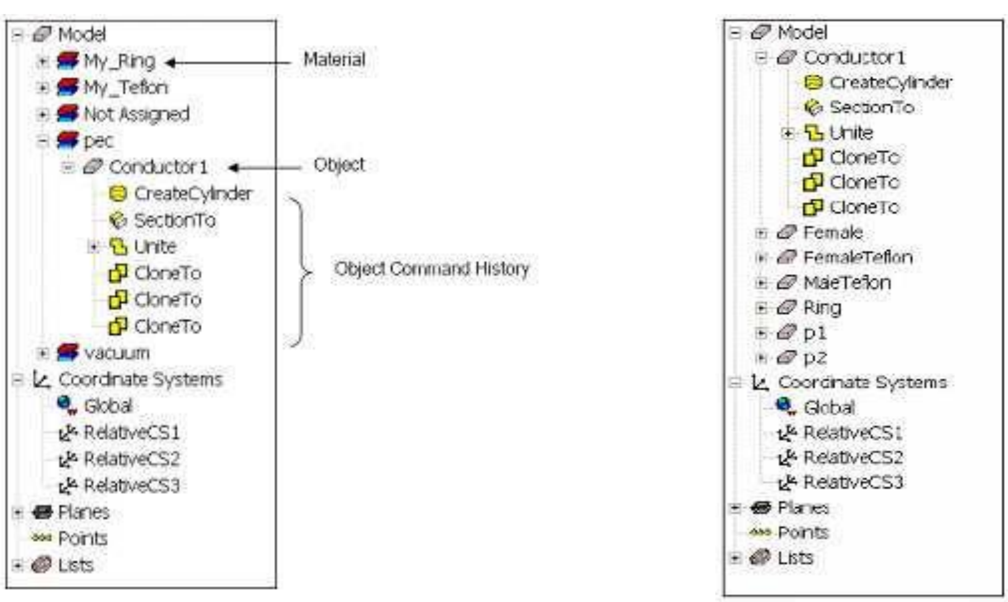


Fig. 5.6 3D Modeller window

5.3.4 3D Modeler Design Tree



(a) Grouped by materials (b) Object view

Fig. 5.7 Modeller design tree

5.4 TOOLBARS

1. The toolbar buttons provide the shortcut keys for commonly used commands. Most of the available toolbars are displayed in the figure 5.8 of the Ansoft HFSS initial screen.

2. Toolbars can be customized as per your requirement and in a way that is convenient for you. Some toolbars are always displayed. Some toolbars are displayed automatically when anyone select a document of the related type. For example, if you select a 2D report from the project tree, the 2D report toolbar is displayed.

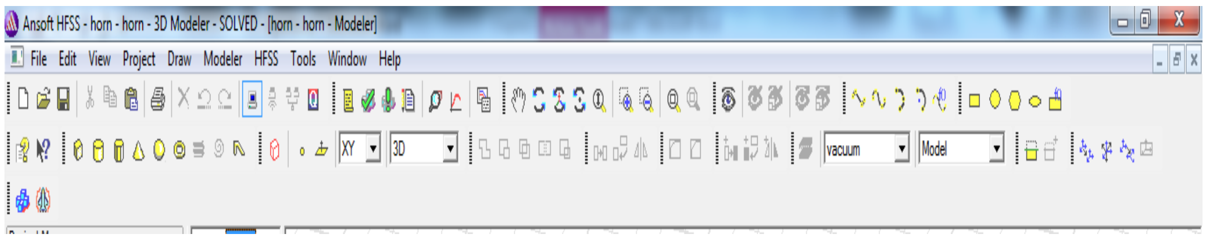


Fig. 5.8 Toolbars of Ansoft HFSS

5.5 SOLUTION TYPE

This section describes how to set the Solution Type. The Solution Type defines how the excitations are defined, the type of results, and the convergence. The following Solution Types are available in HFSS:

1. **Driven Modal** – Driven Modal is set to calculate the modal-based S-parameters. The S-matrix solutions are represented in terms of the incident and reflected powers of waveguide modes.

2. **Driven Terminal** – Driven Terminal is set to calculate the terminal-based S-parameters of the transmission line ports. The S-matrix solutions are represented in terms of terminal currents and voltages.

3. **Eigen mode** – Eigen mode is set to calculate the resonances of a structure. The Eigen mode is used to find the resonant frequencies of the structure and the fields at those resonant frequencies.

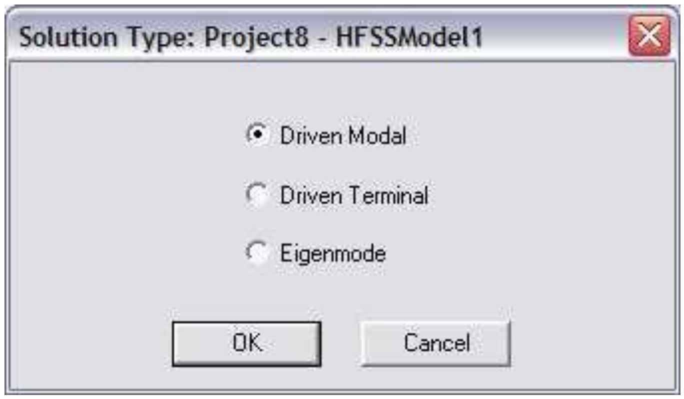


Fig. 5.9 Solution Type window

Chapter 6
RESEARCH METHODOLOGY

The idea of the designing a microstrip patch antenna using metamaterials came from the successive research on these antennas in today's scenario. The use of metamaterials for the designing of microstrip patch makes it very effective to use it in the field of high frequency microwave application.

There are numerous research that have been completed or many more are ongoing till date in the entire communication world of technologies.

I have studied about the principle of metamaterials in the antenna applications from [15]. After that I have collected the research papers based on the designing of microstrip patch antenna using metamaterials from internet (IEEE explore). Then detailed reading of these research papers has been done.

Different designs are provided in the research papers, among them I choose to design a enhanced bandwidth and high gain microstrip patch antenna using metamaterials. To carry out the design I have used a simulation software i.e. HFSS (high frequency structural simulator). With the help of HFSS I have designed an antenna and simulation of the antenna is performed.

I have use SRR structures to obtain the artificial behavior of the microstrip patch antenna using metamaterials. These SRR structures are integrated just above the ground plane and in between the substrate of the antenna. By doing this we can have a very good results and high gain is achieved.

Chapter 7
RESULTS AND DISCUSSION

7.1 MICROSTRIP PATCH ANTENNA

A microstrip patch antenna is designed by using metamaterials. Metamaterial properties are achieved by adding joined SRR structure. These SRRs are inserted over the ground plane and between (in the middle) the substrate. To create artificial DNG metamaterial a rectangular EC-SRR (edge-coupled) has been used with a wire-strip. The base of the proposed microstrip antenna is in x-y plane and height of the antenna is in z plane. The essential parameters for the design of a rectangular Microstrip Patch Antenna are:

1. Calculation of width (W) of patch:

$$W = \frac{c}{2fo\sqrt{\frac{(\varepsilon r+1)}{2}}}$$

Substituting c = 3x10^8 m/s, ε_r =4.4 and f_o = 6.3 GHz,
We get: W = 38.04 mm

2. Calculation of effective Dielectric constant (ε_{reff})

$$\varepsilon_{reff} = \frac{\varepsilon r+1}{2} + \frac{\varepsilon r-1}{2}\left[\sqrt{\left(1+12\,\frac{h}{w}\right)}\right]$$

Substituting ε_r = 4.4, W =38.04 mm and h = 1.6 mm
We get: ε_{reff} = 4.08

3. Calculation extension Length: It is used for calculating resonant frequency of Micostrip antenna.

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

Substituting $\mathcal{E}_{reff} = 4.08$, W = 38.04 mm and h = 1.6 mm
We get: $\Delta L = 0.73$mm

4. Calculation of Length (L) of patch:
Effective Length (Leff):

$$L_{eff} = \frac{c}{2fo\sqrt{\mathcal{E}reff}} \quad \text{and} \quad L = L_{eff} - 2\Delta L$$

Substituting $L_{eff} = 30.86$ mm and $\Delta L = 0.73$ mm
We get: L = 29.4 mm

5. Calculation of inset feed point:
Conductance (G):

$$G = \frac{1}{90}\left(\frac{W}{\lambda o}\right) = 0.001$$

Calculation of resonant input resistance (R_{in}):

$$R_{in} = \frac{1}{2G} = 500\Omega$$

$$R_{in}(y=y_o) = R_{in}(y=0)\cos^2\left(\frac{\lambda o}{L}yo\right)$$

$$y_o = 11.6881\text{mm}$$

The parameters for the patch in HFSS simulation tool are the following:

- Dielectric constant = 4.4
- Frequency (fr) = 6.3 GHz.
- Height (h) of substrate = 1.6 mm.
- Velocity of light (c) = 3×10^8 ms^{-1}.
- Practical width (W) of patch = 38.04mm.
- Loss Tangent (tan δ) = 0.019
- Practical Length (L) of patch = 29.4mm.
- Practical width (W) of substrate = 38.04mm.
- Practical Length (L) of substrate = 40.562mm.
- Width of SRRs = 1mm.

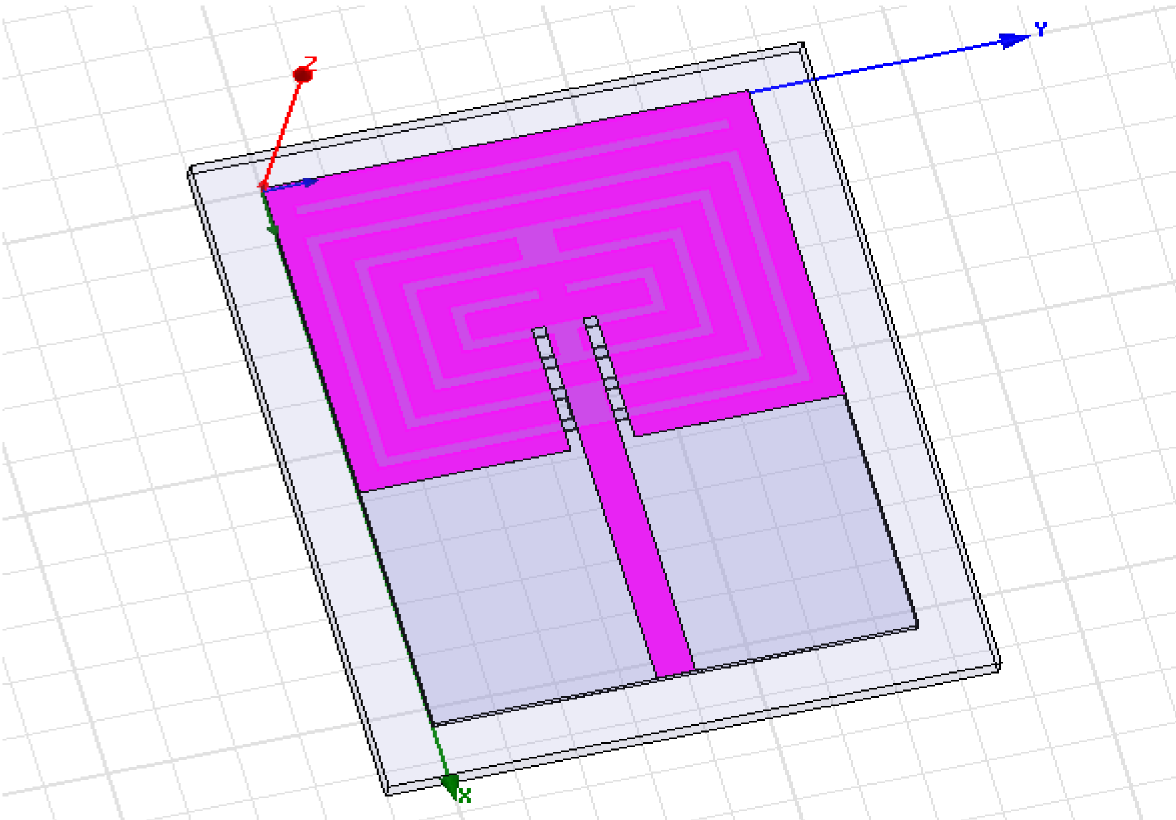


Fig. 7.1 Snapshot of the Structural View of Patch

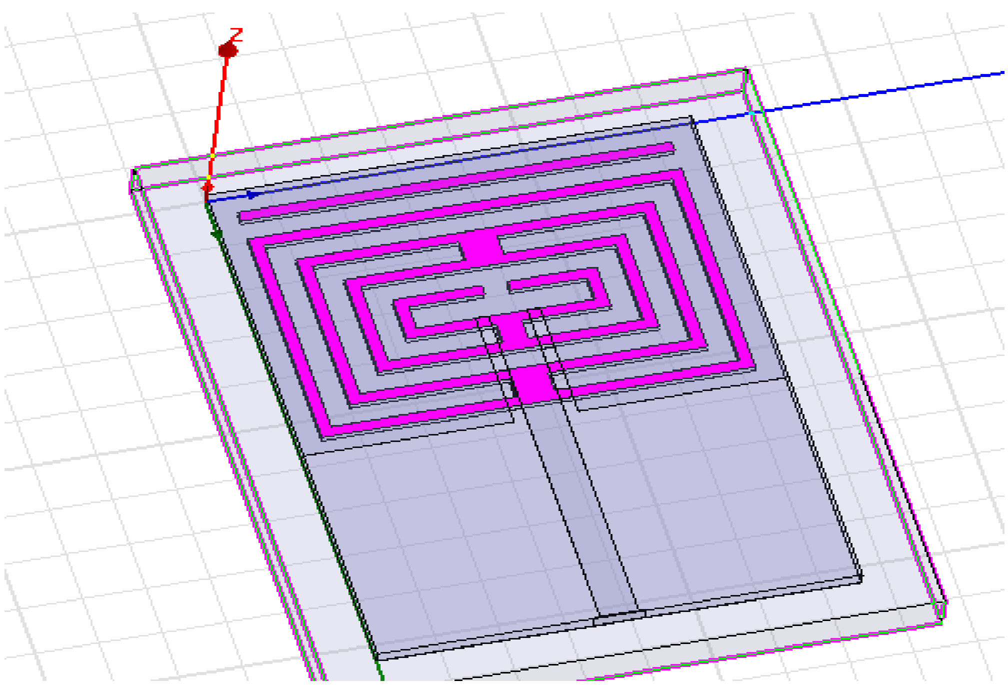


Fig. 7.2 Structural view of SRRs (above the ground and between the substrate)

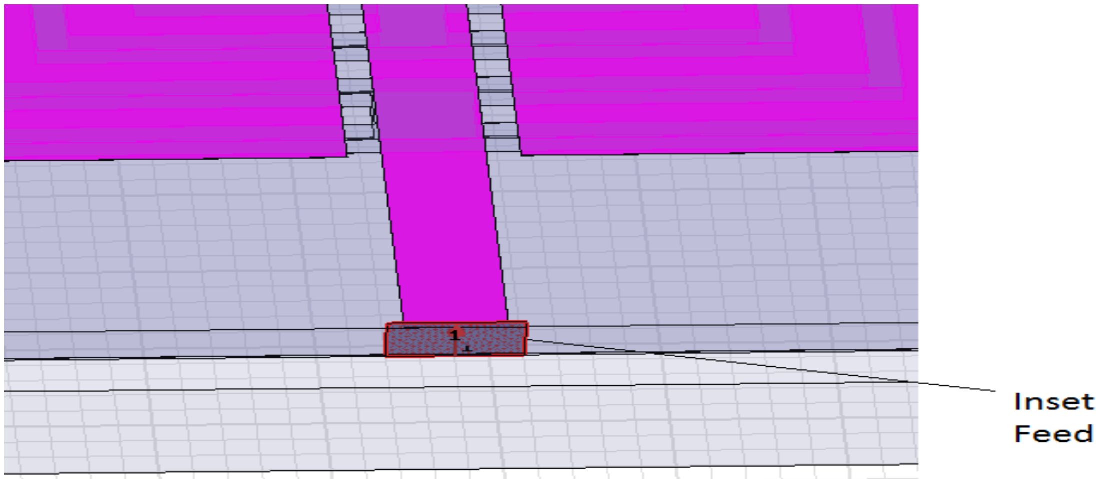


Fig. 7.3 Inset Feed

7.2 SIMULATION OF THE MICROSTRIP PATCH ANTENNA

7.2.1 Steps of simulation

After designing the IFL microstrip antenna in HFSS 3D modeler window, validation of the design has been checked. It checks design settings, 3D model, boundaries and Excitations, mesh operations, analysis setup, optimetrics and radiation. If all of these parameters are valid then the analysis of the design is done. Analysis of the design is carried out by a shortcut key ‘analyze all’ in the toolbar window.

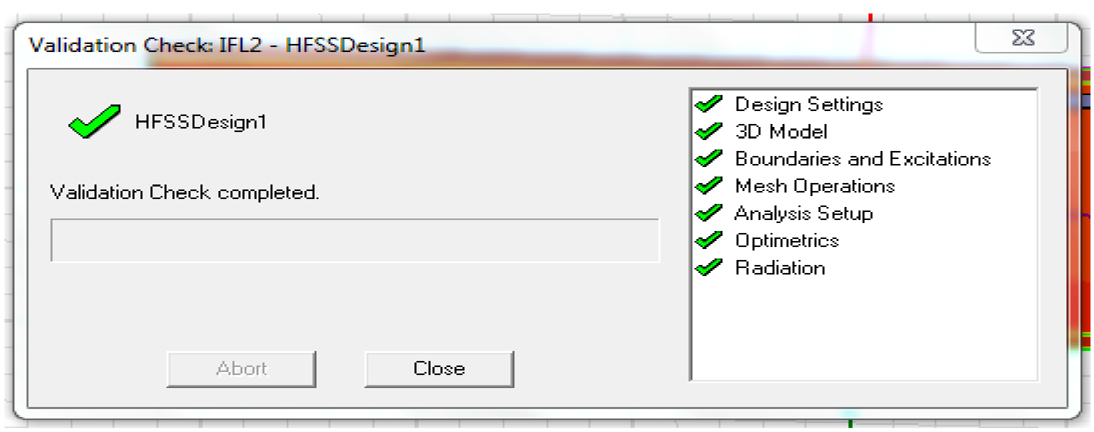


Fig. 7.4 Snapshot of the validation check

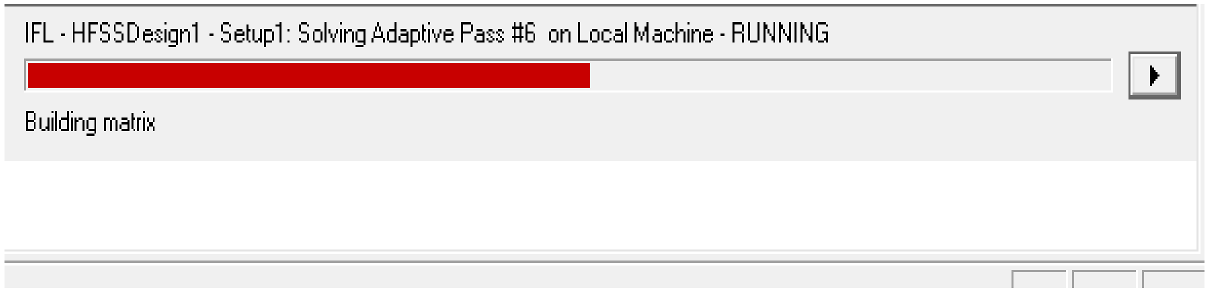


Fig. 7.5 Snapshot of the design analysis process

7.3 RESULTS OF SIMULATION

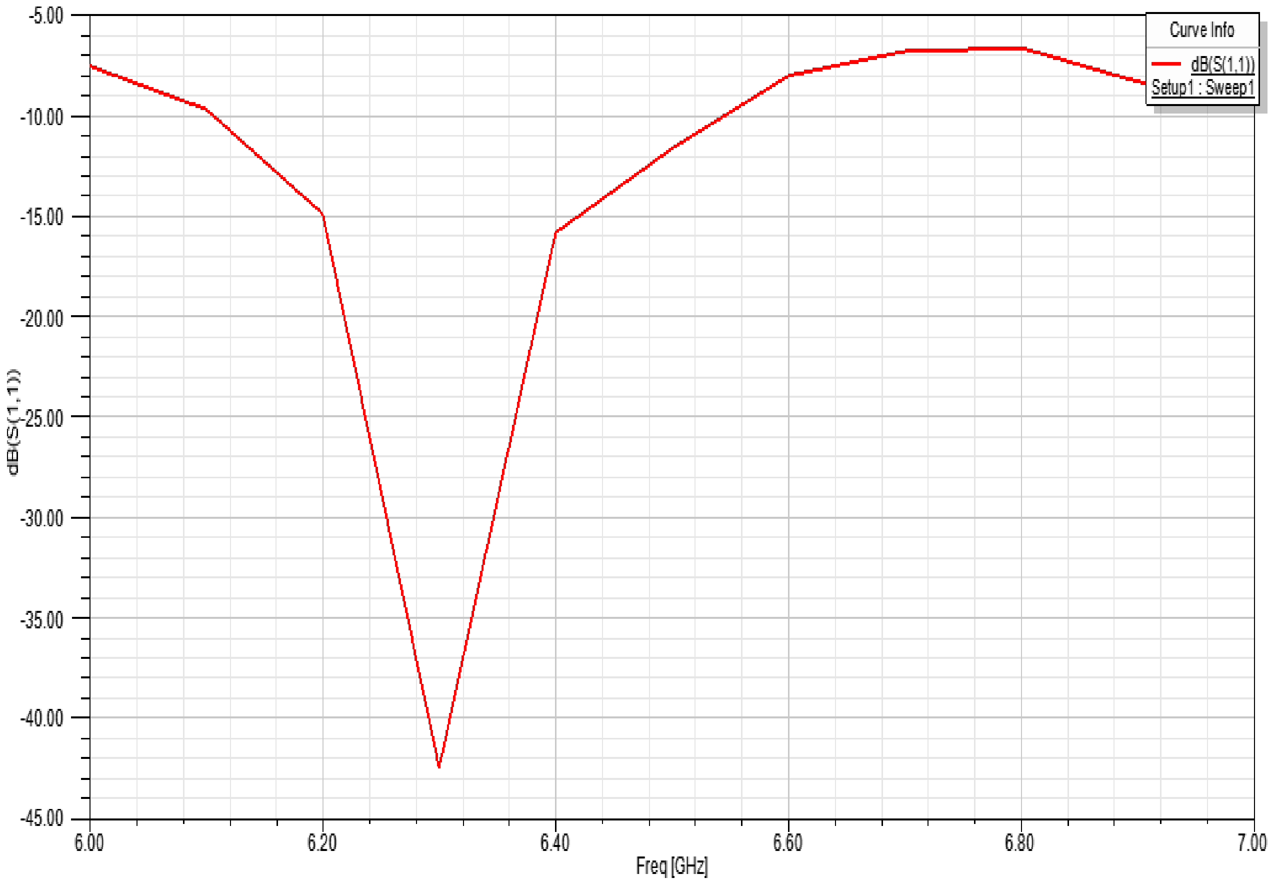


Fig. 7.6 Simulation result(S11) of the microstrip patch antenna

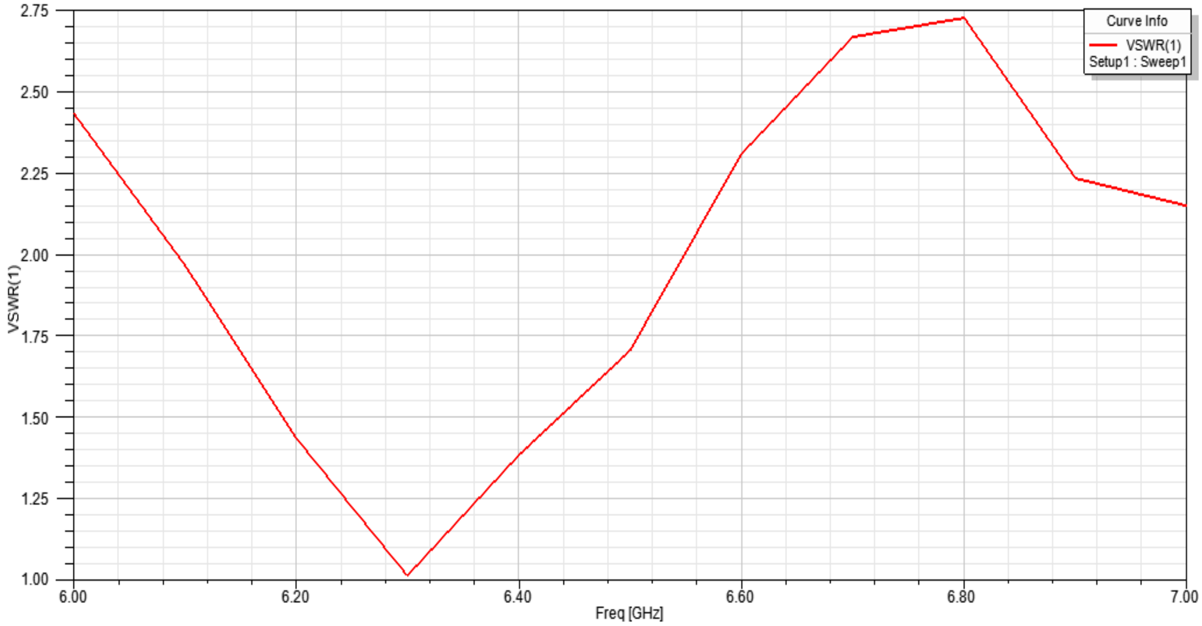


Fig 7.7 VSWR

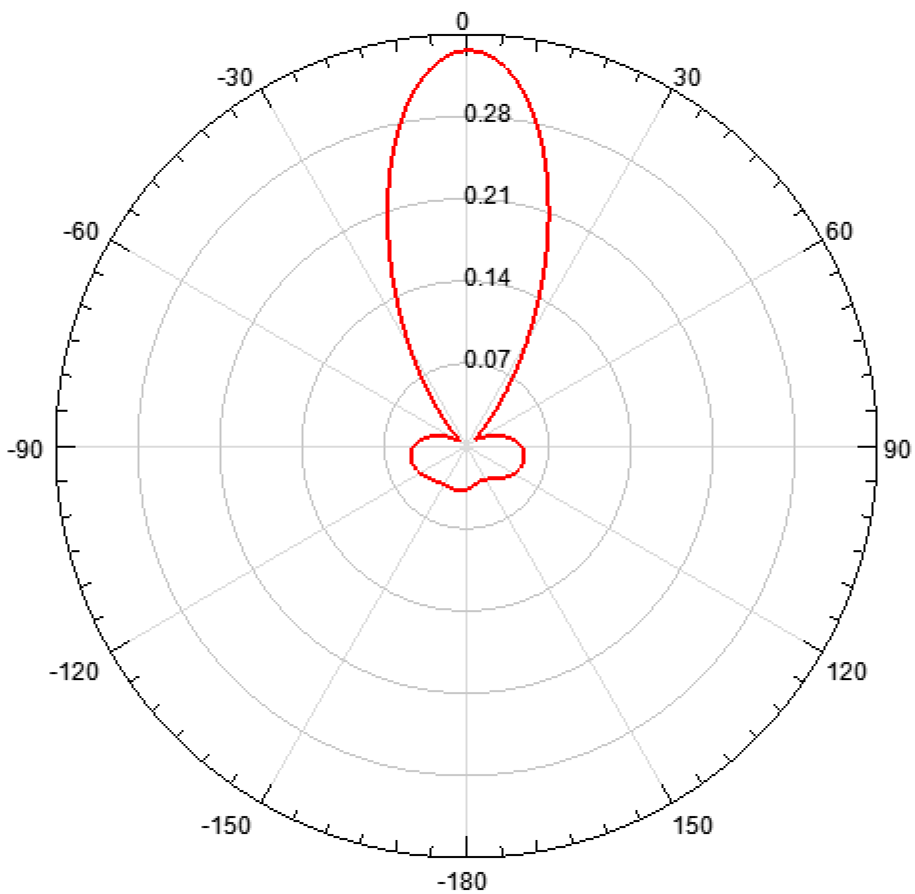


Fig. 7.8 Radiation Pattern for proposed patch antenna.

Chapter 8
SUMMARY AND CONCLUSIONS

In this Dissertation-II report it is clearly shown in depth about the fundamentals of the wireless communication technology in the present scenario. Since wireless technologies are incomplete without the study of antennas. The importance of the antenna in today's wireless communication system is briefly discussed in this report. The basic theory of antenna and the antenna parameters such as directivity, gain, radiation pattern, beamwidth, input impedence, effective area etc are discussed in the earlier chapters of the report.

Further in this report, the use of microstrip patch antennas, their feeding techniques, advantages and disadvantages and method of analysis has been provided.

After that a Broad band and high gain microstrip patch antenna is designed using metamaterials and their simulation and results has been shown in chapter 7. This design is carried out using HFSS (high frequency structural simulation) about which is shown in chapter 5.

In the chapter 7 an inset fed microstrip patch antenna was designed and simulated. It can be seen that by using SRRs structure we can have broadband operating antenna with high gain. The proposed design has a simple structure and can easily be constructed at low cost. It can also be concluded that the result of the broadband and high gain microstrip patch antenna providing the optimum results. These are have been carried out by using SRR structures over the ground plane and between the substrate of the patch antenna.

REFERENCES

1. Ying Peng and Zhirun Hu, "60 GHz meta-material wideband antenna for FPGA Giga bit data transmission", 978-1-4244-5309-2/10, ©2010 IEEE.

2. Hussein Attia, Omar Siddiqui, Leila Yousefi and Omar M. Ramahi, "Metamaterial for Gain Enhancement of Printed Antennas: Theory, Measurements and Optimization", 978-1-4577-0069-9/11, ©2011 IEEE.

3. Ajay kumar, Dwejendra Arya, D.K Srivastava, "Band Width of Microstrip Antenna Improved by using Mushroom type EBG Structure", 978-1-4799-1205-6/13, ©2013 IEEE.

4. T. Masri, M. K. A. Rahim, M. H. Jamaluddin and A. Asrokin, "Bandwidth Enhancement of a Narrowband Rectangular Microstrip Antenna on a Spiral Fan-Shape Electromagnetic Band-Gap (EBG) Patch Structure", 0-7803-9745-2/06, (©)2006 IEEE.

5. Filipe Silva and Pedro Pinho, "Performance of microstrip antennas in the presence of EBG in an indoor localization system", 978-1-4244-9561-0/11, ©2011 IEEE.

6. Navdeep Singh, Harish Kumar, Sarabjeet Singh, "A study on Applications of Meta-Material based Antennas", 978-1-4244-8679-3/11, ©2011 IEEE.

7. Chun-Yih Wu, Shih-Huang Yeh and Tzu-Hao Lu, "Planar High Gain Antenna for 5.8-GHz WiMAX Operation", 1-4244-1272-2/07, ©2007 IEEE.

8. Sarawuth Chaimool, Atcharaporn Pinsakul, Prayoot Akkaraekthalin, "Patch Antenna Miniaturization Using Artificial Magneto-Dielectric Metasubstrate", Proceedings of ISAP2012, Nagoya, Japan.

9. Anand Kumar, Dinesh Kumar V, Mahesh P. Abegaonkar, Siban K . Koul, “A Microstrip Patch Antenn a with Metamaterial and EBG Structures”, 97B-1-4799-1607-B/13, ©2013 IEEE.

10. Ruchika Gupta, Mithilesh Kumar, “Bandwidth Enhancement of Microstrip Patch Antennas by Implementing Electromagnetic Bandgap (EBG) Structures”, 978-0-7695-4850-0/12, © 2012 IEEE.

11. Neeraj Rao, Dinesh Kumar V, “Performance Enhancement of a Microstrip Antenna by Suppression of surface waves using EBG Structure in Multiple Layer Substrate”, 978-1-4577-0048-4/11, ©2011 IEEE.

12. Yasser M. Madany, “Bandwidth Enhancement of Compact UWB Microstrip Patch Antenna Using EBG Structures”, 978-1-4673-5317-5/13, ©2013 IEEE.

13. Mahmoud Niroo-Jazi, E. Erfani, and Tayeb A. Denidni, “On the Antenna Gain Enhancement Using Artificial Materials”, 978-1-4673-5317-5/13, ©2013 IEEE.

14. Constantine A. Balanis , “Antenna Theory” (Third Edition), JohnWiley &Sons, 2005 Skolnik, M. (1980). “*Introduction to Radar Systems*”, 2nd ed.. McGraw-Hill.

15. Nader Engheta, Richard W. Ziolkowski, “METAMATERIALS Physics and Engineering Explorations”, A john wiley & sons, inc., Publication, IEEE PRESS.

16. Kaushal Gangwar, Dr. Paras and Dr. R.P.S. Gangwar, “Metamaterials: Characteristics, Process and Applications”, Advance in Electronic and Electric Engineering. ISSN 2231-1297, Volume 4, Number 1 (2014), pp. 97-106 © Research India Publications http://www.ripublication.com/aeee.htm.

17. http://irianto.staff.gunadarma.ac.id/Downloads/files/2878/Chapter3.pdf.

18. Nabila Hossain, Md Imran Wahiduzzaman Khan and Najia Hossain, “Design and Analysis of DNG Metamaterial based Microstrip Patch Antenna with Tetra Band

Resonance," ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 3, Issue 9, September 2013.

19. http://en.wikipedia.org/wiki/Wireless.