Microstrip Patch Antenna Design For WLAN , WiMax And UWB Communication System

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AMIT KUMAR(2K11/MOC/01)

Under the supervision of

Prof.P.R.CHADHA
(Associate Professor)
Department Of Electronics and Communication
Delhi Technological University, Delhi
(Formerly Delhi College of Engineering)

Department of Electronics & Communication Engineering

&

Department of Applied Physics

Delhi Technological University, Delhi

(Formerly Delhi College of Engineering)

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List of Publications by Author

Journal Publications International or National

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2.Amit Kumar,P Shrivastava,S Kumar, **"Triangular Microstrip Patch Antenna Design for Wi MAX"** GITM-2013.

3.Amit Kumar,S Patel, **"Quard Band U-Shaped Microstrip Patch Antenna For ISM Band,WiMAX & WLAN"**. GITM-2013 **.**

4. Amit Kumar, Prof.P.R.CHADHA, **"Band Notched U-Shaped Patch Antenna For UWB,GSM800 & WLAN Application",** ICMR 2013 **IEEE,IET** (Communicated)

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Amit Kumar
Master of Technology
Dept.of Electronics and Communication
And,Dept.of Applied Physics
Delhi Technological University
(Formerly Delhi College of Engineering)
Delhi,INDIA
110042

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Abstract

In the recent years the development in communication systems requires the development of low cost, minimal weight, low profile antennas that are capable of maintaining high performance over a wide spectrum of frequencies. This technological trend has focused much effort into the design of a Microstrip patch antenna. In this work, the pattern of multiple designs of a Microstrip patch antenna have been analyzed and studied. In this work multiple numbers of patch antennas has been designed and results are analyzed.

Since the release by the Federal Communications Commission (FCC) of a bandwidth of 7.5GHz (from 3.1GHz to 10.6GHz) for ultra wideband (UWB) wireless communication UWB is rapidly advancing as a high data rate wireless communication technology. WiMAX has three allocated frequency bands from 2.5 to 2.8 GHz, from 3.2 to 3.8 GHz and from 5.2 to 5.8 GHz.

This thesis focuses on ISM band, WLAN, GSM, WiMax, UWB antenna design and analysis. Studies have been undertaken covering the areas of wireless communication band studies, UWB fundamentals and antenna theory. Extensive investigations were also carried out on different types of microstrip patch antennas for applications main toned above. The objective of this thesis is to present a design analysis of microstrip patch antennas, which are applicable to wireless communication systems as WLAN, WiMax, GPS, ISM band communication and UWB ultra wide band communication, in particular.

Microstrip patch antennas have many advantages over conventional antennas which makes them suitable for a wide variety of applications. However, a major drawback of these antennas is the low bandwidth. Various techniques have been proposed by researchers to enhance its bandwidth.

The first part of this thesis outlines what an antenna is and how it radiates. An insight is also given to the fundamental limitations of antennas. As antennas investigated in this thesis are planar-printed designs, an insight into the types of feed lines applicable, such as microstrip, CPW and slotline, is given. To help characterise the antennas investigated, the fundamental antenna analysis parameters, such as impedance bandwidth, S-parameters, radiation pattern, directivity, antenna efficiency, gain and polarisation are discussed. Also discussed is the 3D electromagnetic simulation software, HFSS, which was used to simulate the antennas in this thesis.

In this thesis number of microstrip planer patch antenna design has been proposed and simulated results are presented for discussions. Some of them are single band and most are multi band patch antenna. Substrate used for antenna printing is mostly FR4, Rogerar RT dueroid any more. Most of the antenna dimensions are calculated using basic parametric equations of rectangular microstrip patch antenna.

CONTENTS

LIST OF FIGURES: PAGE NO.

LIST OF TABLES **PAGE NO**

SYMBOLS & ABBREVIATIONS

MICs	Microwave Integrated Circuit
C	Velocity of light in air
f_0	Center frequency
Z_0	Characteristics Impedance
λ	Wavelength
h	Height of substrate
t	Thickness of Patch
L	Length of the Patch
ε_r	Relative permittivity of the substrate
tan δ	Loss tangent of substrate

Chapter 1

Chapter 1

Introduction

Wireless communication systems have advanced significantly from the simple components. Guglielmo Marconi used to transmit radio signals across the Atlantic Ocean at the turn of the 20th century. Today, mobile and satellite communications permeate all aspects of our lives. The number of mobile and cellular phones has skyrocketed in recent years while satellite communication traffics including international telephone calls and DBS-TV (direct broadcast satellite television) has also increased substantially.
Commercial cellular and PCS mobile communications [1] currently occupy the 800 MHz-2 GHz spectral region. Military and commercial satellite communications [2] including voice, data, and DBS-TV operate at higher frequencies ranging from 4-30 GHz, and are moving up higher to 60 GHz and beyond in order to facilitate higher data rates and a wider range of services. While the initial technological achievements in both mobile and satellite communications were geared to provide reliable service with wide functionality, there is a current focus on lowering the cost of service while maintaining superior quality. One of the main approaches to reducing system and operating costs is the conservation of system power resources and minimization of power wasted as heat. Of the approximately 250W of power produced by the solar-cell arrays on a typical satellite, more than 125W is dissipated as heat due to inefficient operation of the transmitter power amplifiers [2].

1.1 A Brief Introduction

Microstrip patch antennas are the most common form of printed antennas. They are popular for their low profile geometry, light weight and low cost. These antennas have many advantages when compared to conventional antennas and hence have been used in a wide variety of applications ranging from mobile communication to satellite, aircraft and other applications [1]. The IEEE 802.16 working group has established a new standard known as WiMAX (Worldwide Interoperability for Microwave Access) which can reach a theoretical up to 30 mile radius coverage. Moreover, in the case of WiMAX, the highest theoretically achievable transmission rates are possible at 70 Mbps. As currently defined through IEEE Standard 802.16, a wireless MAN provides network access to buildings through exterior antennas communicating with central radio base stations (BSs]. Microstrip antennas are widely used in many applications due to their low profile, low cost and ease of fabrication. In some applications it is desired to have a dual band or multiband characteristics. These characteristics can be obtained by coupling multiple radiating elements.Single handset to access several different services such as voice, data, and video, at the same time in any place [5]-[6]. The objective of the new generations of wireless mobile radio systems is to provide flexible data rates and a wide variety of applications to the mobile users while serving as many users as possible [7].The main target for today's communication system is to provide high band width.So for that high band width antenna with small size should be required.

1.2 Simulating Software HFSS

In order to calculate the full three-dimensional electromagnetic field inside a structure and the corresponding S-parameters, HFSS employs the finite element method (FEM) [2]. FEM is a very powerful tool for solving complex engineering problems, the mathematical formulation of which is not only challenging but also tedious. The basic approach of this method is to divide a complex structure into smaller sections of finite dimensions known as *elements*. These elements are connected to each other via joints called *nodes*. Each unique element is then solved independently of the others thereby drastically reducing the solution complexity. The final solution is then computed by reconnecting all the elements and combining their solutions. These processes are named *assembly* and *solution* respectively in the FEM [3]. FEM finds applications not only in electromagnetic but also in other branches of engineering such as plane stress problems in mechanical engineering, vehicle aerodynamics and heat transfer. FEM is the basis of simulation in HFSS. HFSS divides the geometric model into a large number of tetrahedral elements. Each tetrahedron is composed of four equilateral triangles and the collection of tetrahedral forms what is known as the finite element mesh.

At each vertex of the tetrahedron, components of the field tangential to the three edges meeting at that vertex are stored. The other stored component is the vector field at the midpoint of selected edges, which is also tangential to a face and normal to the edge. Using these stored values, the vector field quantity such as the H-field or the E field inside each tetrahedron is estimated. A first-order tangential element basis function is used for performing the interpolation. Maxwell's equations are then formulated from the field quantities and are later transformed into matrix equations that can be solved using traditional numerical techniques.

1.3 Motivation

Today microstrip Patch antennas are playing very important roal in the wireless communication systems such as for WLAN, WiMAX, GPS and many more applications. Compactness of mobile devices are very important in this electronics world. So small sized planer microstrip patch antennas are on more concentration for Antenna designers and communication engineers.In this thesis we are concentrating more on microstrip patch antenna design for WLAN,WiMAX,GPS

and UWB communication systems.Five antennas are designed according to there specifications for being used in mentioned wireless applications.
The UWB technology has experienced many significant developments in recent years. However, there are still challengers in making this technology live up to its full potential. One particular challenge is the UWB antenna. Among the classical broadband antenna configurations that are under consideration for use in UWB systems, a straight wire monopole features a simple structure, but its bandwidth is only around 10%. A vivaldi antenna is a directional antenna [9] and hence unsuitable for indoor systems and portable devices. A biconical antenna has a big size which limits its application [10]. Log periodic and spiral antennas tend to be dispersive and suffer severe ringing effect, apart from big size [11]. There is a growing demand for small and low cost UWB antennas that can provide satisfactory performances in both frequency domain and time domain. In contrast to circular disc monopoles which have relatively large electric near-fields, slot antennas have relatively large magnetic near-fields. This feature makes slot antennas more suitable for applications wherein near-field coupling is not desirable. As such, elliptical/circular slot antennas are proposed and studied for UWB systems in this thesis.

1.4 Organization of the Thesis

This dissertation contains five chapters which are organized as follows:

Chapter-1: An introduction to the work carried out during this research and the organization of the thesis is described in this chapter.

Chapter-2: A brief introduction to basic concepts of antenna theory and concepts are presented in this chapter. Basic definition of antenna parameters like Directivty,Gain,Polarization,Radiation Efficiency and radiation resistance are given in this chapter. Its advantages and applications are also discussed. Besides, current regulation state and standards activities are addressed.

Chapter -3: This chapter is about various Wireless communication systems and its applications. Some communication systems like WLAN,WiMAX and UWB ultra wide band communication systems ,there system requirements and application,antenna required is also discussed in this chapter.

Chapter-4: In this chapter basic concept of microstrip patch antenna is discussed.Basic principle of operation, mathematical description of patch antenna radiation characteristics and factors affecting performance of patch antenna is discussed in this chapter.

Chapter-5: This chapter is main part of this research work carried. In this chapter about 5 types of different microstrip patch antennas for various applications such as for WLAN,WiMAX,GPS,ISM Band and UWB is defined. All these designed patch antenna is simulated my using high frequency simulator HFSS and all the obtained results are discussed and its application with conclusion is presented in this chapter.

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Chapter -2

Chapter -2

Antenna Theory

The main objective of this thesis is to design antennas that are suitable for the future UWB communication systems. Before the design work, it is necessary to get familiar with the fundamental antenna theory in this chapter. Some important parameters that always have to be considered in antenna design are described. At the same time, the primary requirements for a suitable UWB antenna are discussed. Some general approaches to achieve wide operating bandwidth of antenna are presented. Also, some classic UWB antenna configurations are introduced.

2.1 Introduction

2.1.1 Definition of Antenna

The antennas are an essential part of any wireless system. According to *The IEEE Standard Definitions of terms for Antennas*, an antenna is defined as \a means for radiating or receiving radio waves [1]". In other words, a transmit antenna is a device that takes the signals from a transmission line, converts them into electromagnetic waves and then broadcasts them into free space, as shown in Figure 2.1; while operating in receive mode, the antenna collects the incident electromagnetic waves and converts them back into signals.

In an advanced wireless system, an antenna is usually required to optimize or accentuate the radiation energy in some directions and suppress it in others at certain frequencies. Thus the antenna must also serve as a directional in addition to a transition device. In order to meet the particular requirement, it must take various forms. As a result, an antenna may be a piece of conducting wire, an aperture, a patch, a reflector, a lens, an assembly of elements (arrays) and so on. A good design of the antenna can relax system requirements and improve overall system performance.

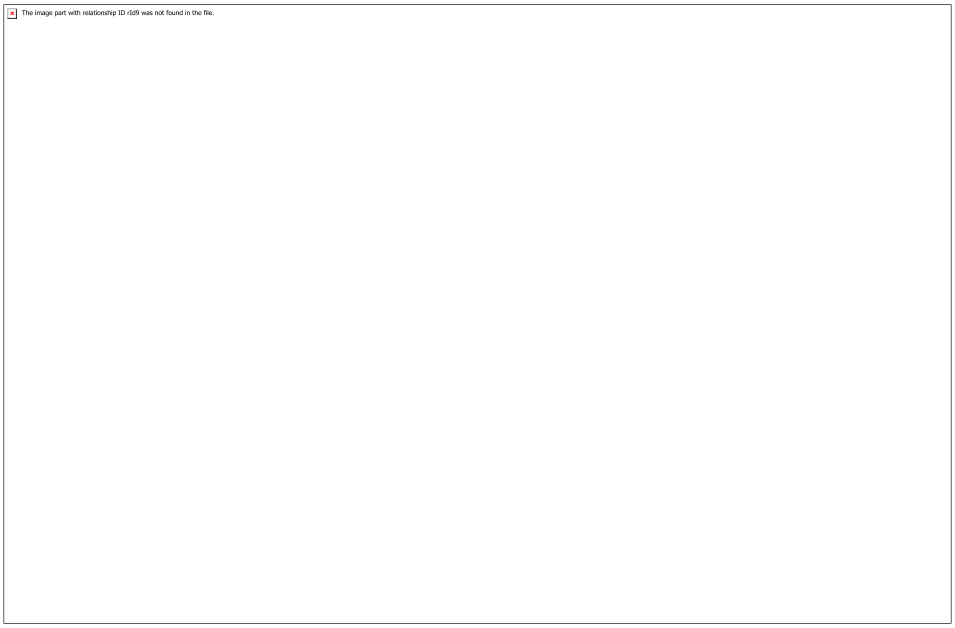


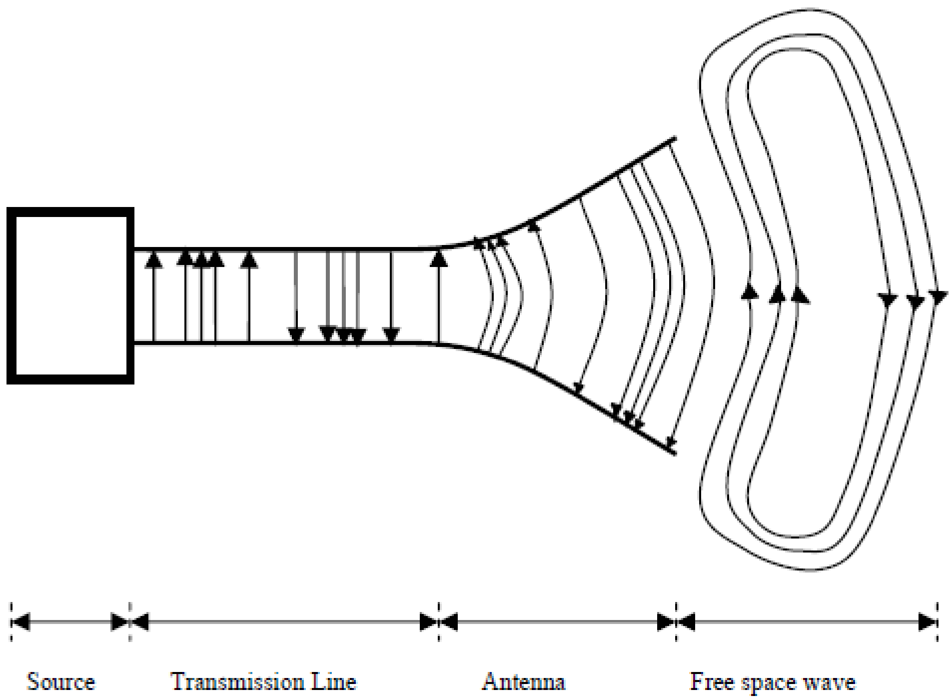
Figure 2.1: Antenna as a transition device

2.1.2 How an Antenna radiates

In order to know how an antenna radiates, let us first consider how radiation occurs. A conducting wire radiates mainly because of time-varying current or an acceleration (or deceleration) of charge. If there is no motion of charges in a wire, no radiation takes place, since no flow of current occurs. Radiation will not occur even if charges are moving with uniform velocity along a straight wire. However, charges moving with uniform velocity along a curved or bent wire will produce radiation. If the charge is oscillating with time, then radiation occurs even along a straight wire as explained by Balanis [5].

The radiation from an antenna can be explained with the help of Figure 2.1 which shows a voltage source connected to a two conductor transmission line. When a sinusoidal voltage is applied across the transmission line, an electric field is created which is sinusoidal in nature and this results in the creation of electric lines of force which are tangential to the electric field. The magnitude of the electric field is indicated by the bunching of the electric lines of force. The free electrons on the conductors are forcibly displaced by the electric lines of force and the movement of these charges causes the flow of current which in turn leads to the creation of a magnetic field.

[5].



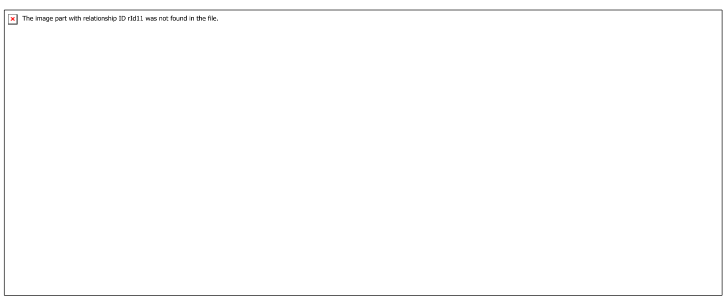


Figure 2.2 Radiation from an antenna

Due to the time varying electric and magnetic fields, electromagnetic waves are created and these travel between the conductors. As these waves approach open space, free space waves are formed by connecting the open ends of the electric lines. Since the sinusoidal source continuously creates the electric disturbance, electromagnetic waves are created continuously and these travel through the transmission line, through the antenna and are radiated into the free space. Inside the transmission line and the antenna, the electromagnetic waves are sustained due to the charges, but as soon as they enter the free space, they form closed loops and are radiated [5].

2.2 Important Parameters of Antenna

To describe the performance of an antenna, definitions of various parameters are necessary. In practice, there are several commonly used antenna parameters, including frequency bandwidth, radiation pattern, directivity, gain, input impedance, and so on.

2.2.1 Frequency Bandwidth

Frequency bandwidth (*BW*) is the range of frequencies within which the performance of the antenna, with respect to some characteristic, conforms to a specified standard. The bandwidth can be considered to be the range of frequencies, on either side of the center frequency, where the antenna characteristics are within an acceptable value of those at the center frequency. Generally, in wireless communications, the antenna is required to provide a return loss less than -10dB over its frequency bandwidth.

The frequency bandwidth of an antenna can be expressed as either absolute band width (*ABW*) or fractional bandwidth (*FBW*). If *fH* and *fL* denote the upper edge and the lower edge of the antenna bandwidth, respectively. The *ABW* is defined as the difference of the two edges and the *FBW* is designated as the percentage of the frequency difference over the center frequency, as given in Equation 3.1 and 3.2, respectively.

$$ABW = f_h - f_l \qquad 2.1$$

$$FBW = 2\frac{f_h - f_l}{f_h + f_l} \qquad 2.2$$

For broadband antennas, the bandwidth can also be expressed as the ratio of the upper to the lower frequencies, where the antenna performance is acceptable, as shown in Equation 3.3.

$$BW = \frac{f_h}{f_l} \qquad 2.3$$

2.2.2 Radiation Pattern

The radiation pattern (or antenna pattern) is the representation of the radiation properties of the antenna as a function of space coordinates. In most cases, it is determined in the far-field region where the spatial (angular) distribution of the radiated power does not depend on the distance. Usually, the pattern describes the normalized field (power) values with respect to the maximum values.

The radiation property of most concern is the two- or three-dimensional (2D or 3D) spatial distribution of radiated energy as a function of the observer's position along a path or surface of constant radius. In practice, the three-dimensional pattern is sometimes required and can be constructed in a series of two-dimensional patterns. For most practical applications, a few plots of the pattern as a function of ′ for some particular values of frequency, plus a few plots as a function of frequency for some particular values of μ will provide most of the useful information needed, where ′ and μ are the two axes in a spherical coordinate.

For a linearly polarised antenna, its performance is often described in terms of its principle *E*-plane and *H*-plane patterns. The *E*-plane is defined as the plane containing the electric-field vector and the direction of maximum radiation whilst the *H*-plane is defined as the plane containing the magnetic-field vector and the direction of maximum radiation [1].

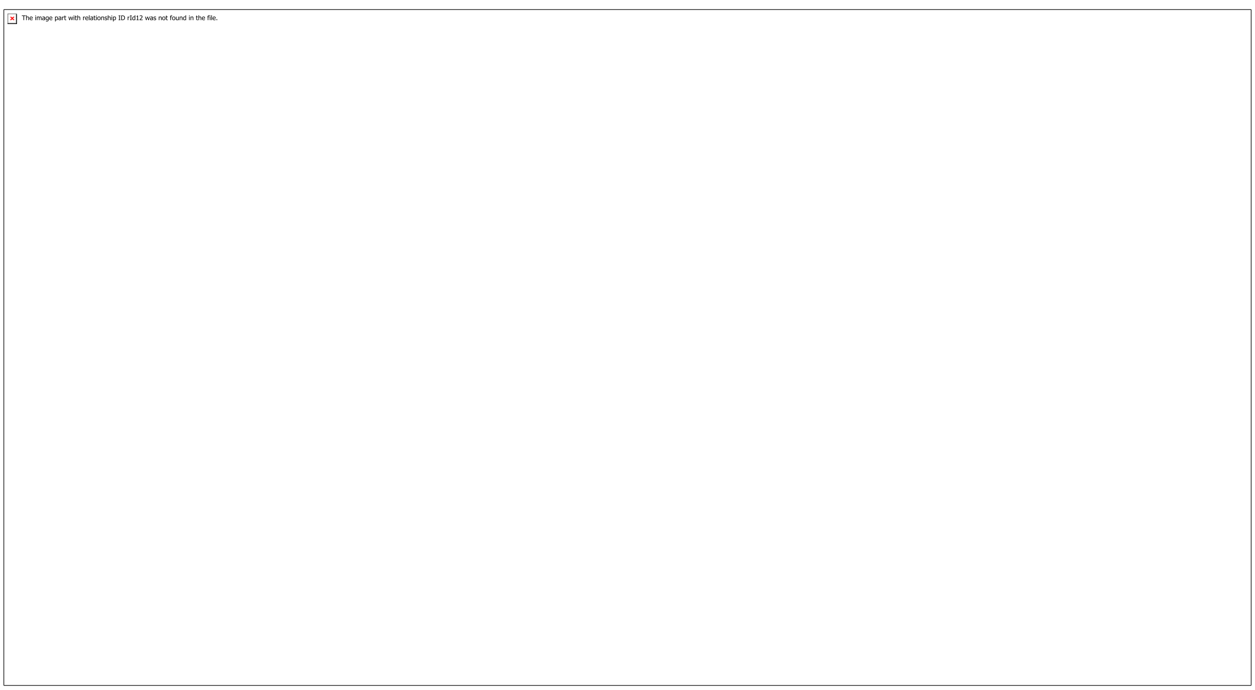


Figure 2.3 Radiation pattern of a generic directional antenna

There are three common radiation patterns that are used to describe an antenna's radiation property:

(a) *Isotropic* - A hypothetical lossless antenna having equal radiation in all directions.

It is only applicable for an ideal antenna and is often taken as a reference for expressing the directive properties of actual antennas.

(b) *Directional* - An antenna having the property of radiating or receiving electromagnetic waves more effectively in some directions than in others. This is usually applicable to an antenna where its maximum directivity is significantly greater than that of a half wave dipole.

(c) *Omni-directional* - An antenna having an essentially non-directional pattern in a given plane and a directional pattern in any orthogonal plane.

2.2.3 Directivity and Gain

To describe the directional properties of antenna radiation pattern, directivity *D* is introduced and it is defined as the ratio of the radiation intensity *U* in a given direction from the antenna over that of an isotropic source. For an isotropic source, the radiation intensity *U*0 is equal to the total radiated power *Prad* divided by 4. So the directivity can be calculated by:

$$D = \frac{U}{U_O} = \frac{4\pi U}{P_{rad}} \qquad 2.4$$

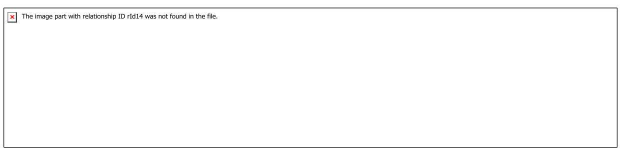
If not specified, antenna directivity implies its maximum value, i.e. *D*0. Antenna gain *G* is closely related to the directivity, but it takes into account the radiation efficiency *erad* of the antenna as well as its directional properties, as given by:

$$G = e_{rad}D \qquad 2.5$$

Figure 3.2 shows the equivalent circuit of the antenna, where *Rr*, *RL*, *L* and *C* represent the radiation resistance, loss resistance, inductor and capacitor, respectively. The radiation efficiency *erad* is defined as the ratio of the power delivered to the radiation resistance *Rr* to the power delivered to *Rr* and *RL*.

Figure 2.4: Equivalent circuit of antenna

So the radiation efficiency e_{rad} can be written as:



2.6

Similarly, the maximum gain $G0$ is related the maximum directivity $D0$ by:

$$G0 = e_{rad} D0 \quad 2.7$$

2.2.4 Input Impedance

The input impedance of an antenna is defined by [5] 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:

$$Z_{in} = R_{in} + jX_{in} \quad 2.8$$

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, the radiation 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.

2.2.5 Voltage Standing Wave Ratio (VSWR)

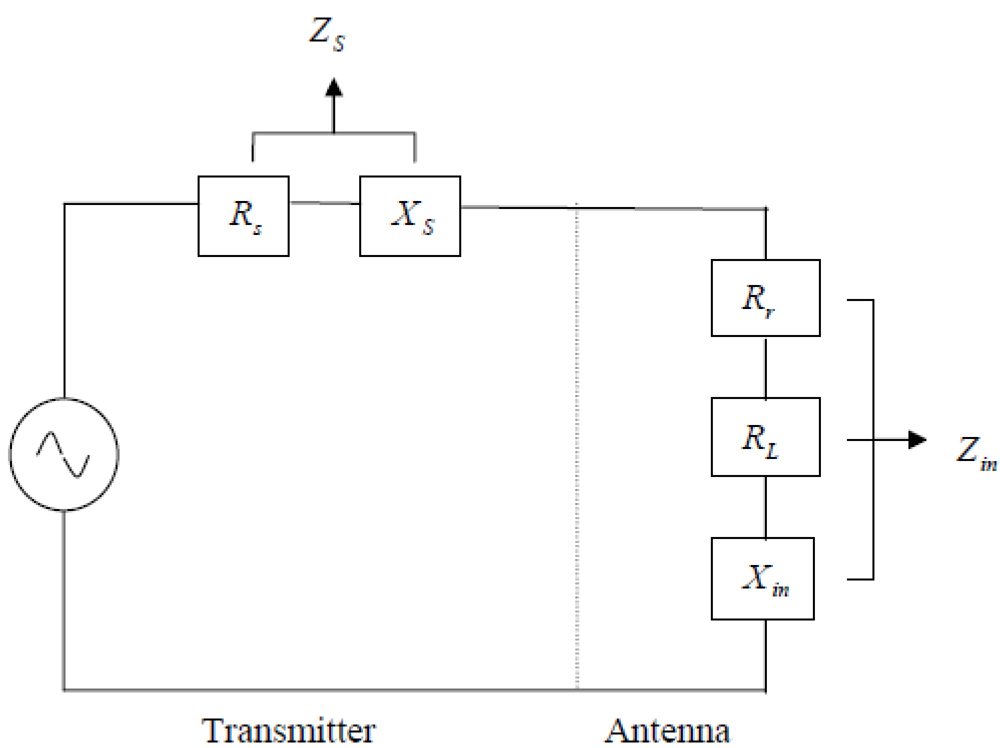


Figure 2.5 Equivalent circuit of transmitting antenna

In order for the antenna to operate efficiently, maximum transfer of power must take place between the transmitter and the antenna. Maximum power transfer can take place only when the impedance of the antenna (Z_{in}) is matched to that of the transmitter (Z_s). According to the maximum power transfer theorem, maximum power can be transferred only if the impedance of the transmitter is a complex conjugate of the impedance of the antenna under consideration and vice-versa. Thus, the condition for matching is:

$$Z_{in} = Z_S^* \qquad 2.9$$

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

$Z_s = R_s + jX_s$ as shown in Figure 2.5

If the condition for matching is not satisfied, then some of the power maybe reflected back and this leads to the creation of standing waves, which can be characterized by a parameter called as the Voltage Standing Wave Ratio (VSWR). The VSWR is given by Makarov [6] as:

$$VSWR = \frac{1+\Gamma}{1-\Gamma} \qquad 2.10$$

$$\Gamma = \frac{V_r}{V_i} = \frac{Z_{in}-Z_s}{Z_{in}+Z_s} \qquad 2.11$$

Where Γ is called the reflection coefficient

V_r is the amplitude of the reflected wave

V_i is the amplitude of the incident wave

The VSWR is basically a measure of the impedance mismatch between the transmitter and the antenna. The higher the VSWR, the greater is the mismatch. The minimum VSWR which corresponds to a perfect match is unity. A practical antenna design should have an input impedance of either 50 Ω or 75 Ω since most radio equipment is built for this impedance.

2.2.6 Return Loss (RL)

The Return Loss (RL) is a parameter which indicates the amount of power that is “lost” to the load and does not return as a reflection. As explained in the preceding section, waves are reflected leading to the formation of standing waves, when the transmitter and antenna impedance do not match. Hence the RL is a parameter similar to the VSWR to indicate how well the matching between the transmitter and antenna has taken place. The RL is given as by [6] as:

$$RL = -20log_{10}\Gamma \qquad \text{(dB)} \qquad 2.12$$

For perfect matching between the transmitter and the antenna, $\Gamma = 0$ and $RL = \infty$ which means no power would be reflected back, whereas a $\Gamma = 1$ has a $RL = 0$ dB, which implies that all incident power is reflected. For practical applications, a VSWR of 2 is acceptable, since this corresponds to a RL of -9.54 dB.

2.2.7 Polarization

Polarization of a radiated wave is defined by [5] as "that property of an electromagnetic wave describing the time varying direction and relative magnitude of the electric field vector".

The polarization of an antenna refers to the polarization of the electric field vector of the radiated wave. In other words, the position and direction of the electric field with reference to the earth's surface or ground determines the wave polarization. The most common types of polarization include the linear (horizontal or vertical) and circular (right hand polarization or the left hand polarization).

Figure 2.6 A linearly (vertically) polarized wave

If the path of the electric field vector is back and forth along a line, it is said to be linearly polarized. Figure 2.6 shows a linearly polarized wave. In a circularly polarized wave, the electric field vector remains constant in length but rotates around in a circular path. A left hand circular polarized wave is one in which the wave rotates counterclockwise whereas right hand circular polarized wave exhibits clockwise motion as shown in Figure 2.7.

Figure 2.7 Commonly used polarization schemes

2.3 Types of Antennas

Antennas come in different shapes and sizes to suit different types of wireless applications. The characteristics of an antenna are very much determined by its shape, size and the type of material that it is made of. Some of the commonly used antennas are briefly described below.

2.3.1 Half Wave Dipole

The length of this antenna is equal to half of its wavelength as the name itself suggests. Dipoles can be shorter or longer than half the wavelength, but a tradeoff exists in the performance and hence the half wavelength dipole is widely used.

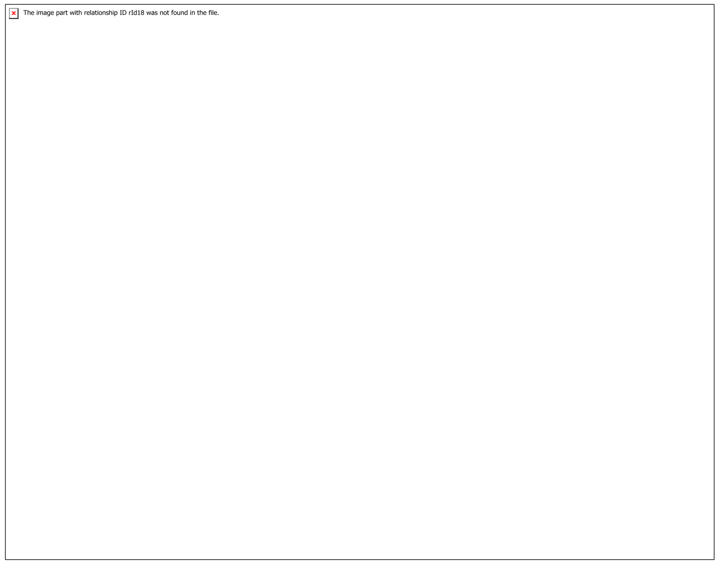


Figure 2.8 Half wave dipole

The dipole antenna is fed by a two wire transmission line, where the two currents in the conductors are of sinusoidal distribution and equal in amplitude, but opposite in direction. Hence, due to canceling effects, no radiation occurs from the transmission line. As shown in Figure 2.9, the currents in the arms of the dipole are in the same direction and they produce radiation in the horizontal direction. Thus, for a vertical orientation, the dipole radiates in the horizontal direction. The typical gain of the dipole is 2dB and it has a bandwidth of about 10%. The half power beam width is about 78 degrees in the E plane and its directivity is 1.64 (2.15dB) with a radiation resistance of 73 Ω [4]. Figure 2.10 shows the radiation pattern for the half wave dipole.

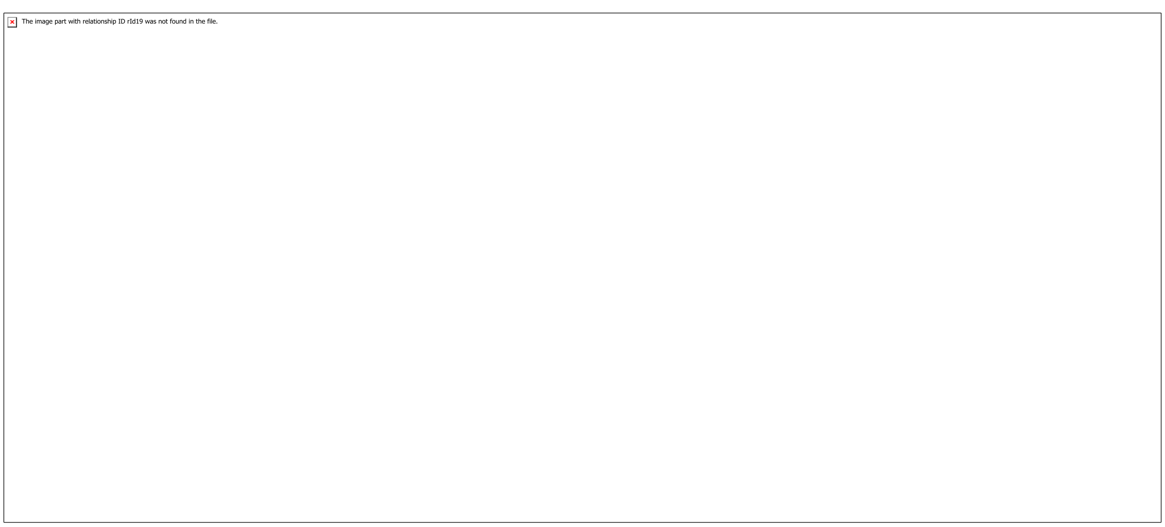


Figure 2.9 Radiation pattern for Half wave dipole

2.3.2 Monopole Antenna

The monopole antenna, shown in Figure 2.11, results from applying the image theory to the dipole. According to this theory, if a conducting plane is placed below a single element of length $L/2$ carrying a current, then the combination of the element and its image acts identically to a dipole of length L except that the radiation occurs only in the space above the plane as discussed by Saunders [8].

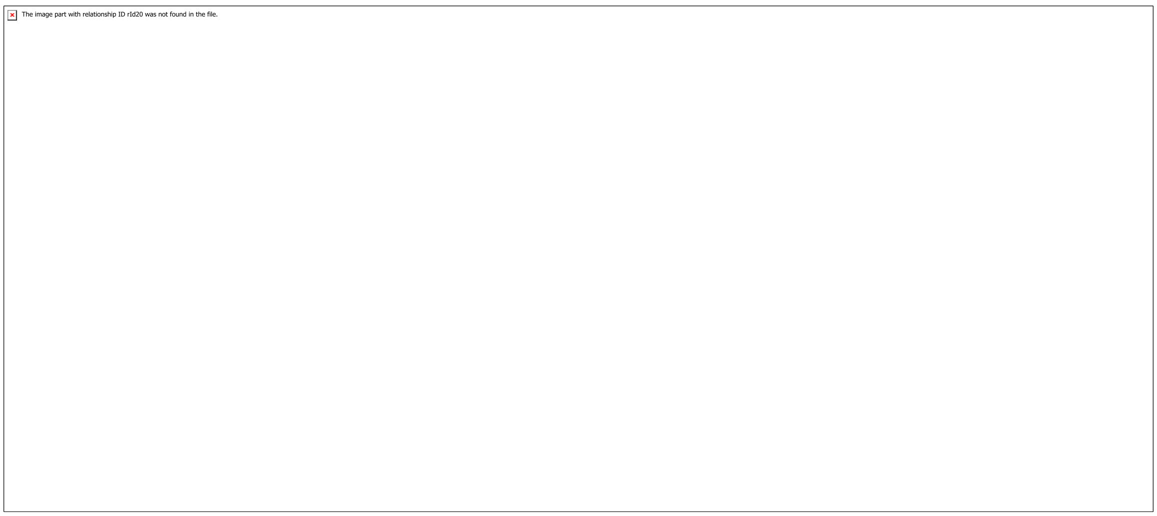


Figure 2.10 Monopole Antenna

For this type of antenna, the directivity is doubled and the radiation resistance is halved when compared to the dipole. Thus, a half wave dipole can be approximated by a quarter wave monopole ($L/2 = \lambda/4$). The monopole is very useful in mobile antennas where the conducting plane can be the car body or the handset case. The typical gain for the quarter wavelength monopole is 2-6dB and it has a bandwidth of about 10%. Its radiation resistance is 36.5 Ω and its directivity is 3.28 (5.16dB) [4]. The radiation pattern for the monopole is shown below in Figure 2.12.

Figure 2.11 Radiation pattern for the Monopole Antenna

2.3.3 Loop Antennas

The loop antenna is a conductor bent into the shape of a closed curve such as a circle or a square with a gap in the conductor to form the terminals as shown in Figure 2.13. There are two types of loop antennas-electrically small loop antennas and electrically large loop antennas. If the total loop circumference is very small as compared to the wavelength ($L \lll \lambda$), then the loop antenna is said to be electrically small. An electrically large loop antenna typically has its circumference close to a wavelength. The far-field radiation patterns of the small loop antenna are insensitive to shape [4].

Figure 2.12 Loop Antenna

As shown in Figure 2.14, the radiation patterns are identical to that of a dipole despite the fact that the dipole is vertically polarized whereas the small circular loop is horizontally polarized.

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Figure 2.13 Radiation Pattern of Small and Large Loop Antenna

The performance of the loop antenna can be increased by filling the core with ferrite. This helps in increasing the radiation resistance. When the perimeter or circumference of the loop antenna is close to a wavelength, then the antenna is said to be a large loop antenna.

The radiation pattern of the large loop antenna is different than that of the small loop antenna. For a one wavelength square loop antenna, radiation is maximum normal to the plane of the loop (along the z axis). In the plane of the loop, there is a null in the direction parallel to the side containing the feed (along the x axis), and there is a lobe in a direction perpendicular to the side containing the feed (along the y axis). Loop antennas generally have a gain from -2dB to 3dB and a bandwidth of around 10%. . The small loop antenna is very popular as a receiving antenna [4]. Single turn loop antennas are used in pagers and multi turn loop antennas are used in AM broadcast receivers.

2.3.4 Helical Antennas

A helical antenna or helix is one in which a conductor connected to a ground plane, is wound into a helical shape. Figure 2.15 illustrates a helix antenna. The antenna can operate in a number of modes, however the two principal modes are the normal mode (broadside radiation) and the axial mode (end fire radiation). When the helix diameter is very small as compared to the wavelength, then the antenna operates in the normal mode. However, when the circumference of the helix is of the order of a wavelength, then the helical antenna is said to be operating in the axial mode.

Figure 2.14 Helix Antenna

In the normal mode of operation, the antenna field is maximum in a plane normal to the helix axis and minimum along its axis. This mode provides low bandwidth and is generally used for hand-portable mobile applications [8].

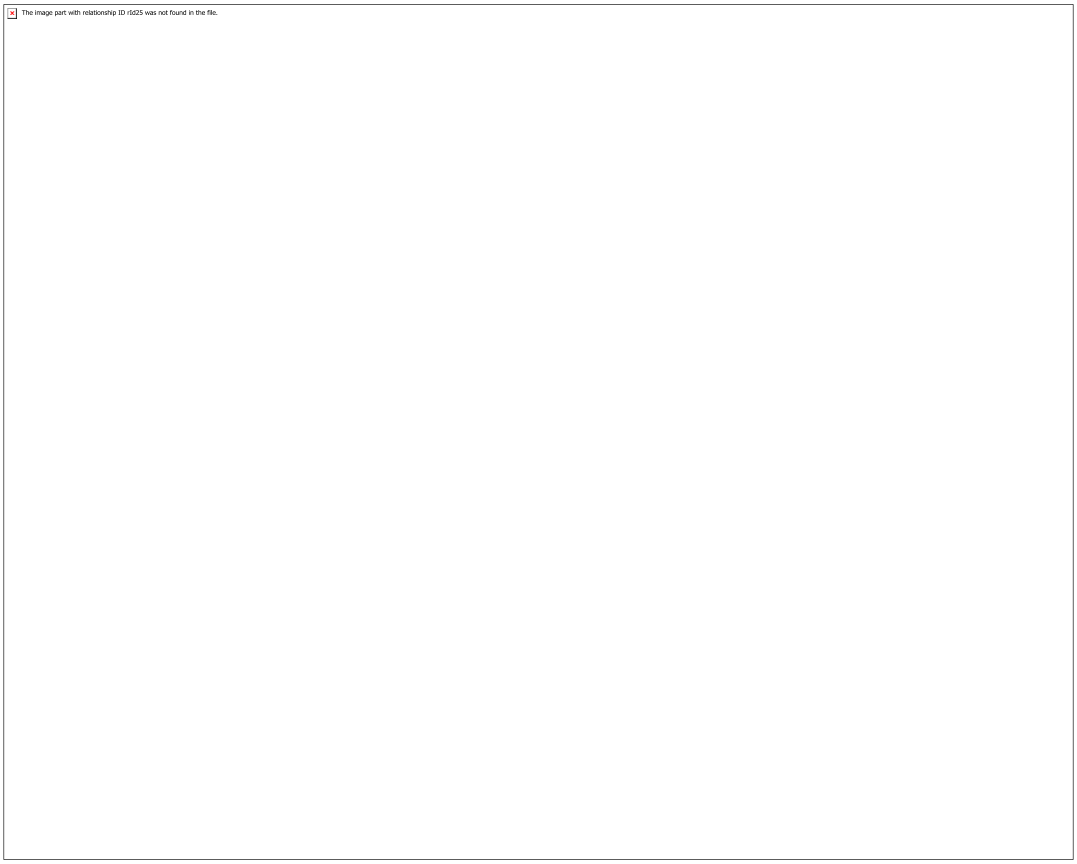

Figure 2.15 Radiation Pattern of Helix Antenna

In the axial mode of operation, the antenna radiates as an end fire radiator with a single beam along the helix axis. This mode provides better gain (up to 15dB) [4] and high bandwidth ratio (1.78:1) as compared to the normal mode of operation. For this mode of operation, the beam becomes narrower as the number of turns on the helix is increased. Due to its broadband nature of operation, the antenna in the axial mode is used mainly for satellite communications. Figure 2.16 above shows the radiation patterns for the normal mode as well as the axial mode of operations.

2.3.5 Horn Antennas

Horn antennas are used typically in the microwave region (gigahertz range) where waveguides are the standard feed method, since horn antennas essentially consist of a waveguide whose end walls are flared outwards to form a megaphone like structure.

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Figure 2.16 Types of Horn Antenna

Horns provide high gain, low VSWR, relatively wide bandwidth, low weight, and are easy to construct [4]. The aperture of the horn can be rectangular, circular or elliptical. However, rectangular horns are widely used. The three basic types of horn antennas that utilize a rectangular geometry are shown in Figure 2.17. These horns are fed by a rectangular waveguide which have a broad horizontal wall as shown in the figure. For dominant waveguide mode excitation, the E-plane is vertical and H-plane horizontal. If the broad wall dimension of the horn is flared with the narrow wall of the waveguide being left as it is, then it is called an H-plane sectoral horn antenna as shown in the figure. If the flaring occurs only in the E-plane dimension, it is called an E-plane sectoral horn antenna. A pyramidal horn antenna is obtained when flaring occurs along both the dimensions. The horn basically acts as a transition from the waveguide mode to the free-space mode and this transition reduces the reflected waves and emphasizes the traveling waves which lead to low VSWR and wide bandwidth [4]. The horn is widely used as a feed element for large radio astronomy, satellite tracking, and communication dishes.

In the above sections, several antennas have been discussed. Another commonly used antenna is the Microstrip patch antenna. The aim of this thesis is to design a compact microstrip patch antenna to be used in wireless communication and this antenna is explained in the next chapter.

2.4 Summary

In this chapter we discussed about antennas and its basic theory, how antenna radiates and all the important parameters of antenna analysis like Antenna gain, Bandwidth of antenna, Input impedance, Radiation pattern, polarization characteristic, Radiation efficiency and many more. Finally we discussed about some basic antennas and its radiation characteristics with applications in wireless communication systems.

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Chapter -3

Chapter -3

Wireless Communication Systems

3.1 Introduction

Wireless communication technology has changed our lives during the past two decades. In countless homes and offices, the cordless phones free us from the short leash of handset cords. Cell phones give us even more freedom such that we can communicate with each other at any time and in any place. Wireless local area network (WLAN) technology provides us access to the internet without suffering from managing yards of unsightly and expensive cable.

The technical improvements have also enabled a large number of new services to emerge. The first-generation (1G) mobile communication technology only allowed analogue voice communication while the second-generation (2G) technology realized digital voice communication. Currently, the third-generation (3G) technology can provide video telephony, internet access, video/music download services as well as digital voice services. In the near future, the fourth-generation (4G) technology will be able to provide on-demand high quality audio and video services, and other advanced services.

In recent years, more interests have been put into wireless personal area network (WPAN) technology worldwide. The future WPAN aims to provide reliable wireless connections between computers, portable devices and consumer electronics within a short range. Furthermore, fast data storage and exchange between these devices will also be accomplished. This requires a data rate which is much higher than what can be achieved through currently existing wireless technologies. The maximum achievable data rate or capacity for the ideal band-limited additive white Gaussian noise (AWGN) channel is related to the bandwidth and signal-to-noise ratio (SNR) by Shannon-Nyquist criterion [1, 2], as shown in Equation 3.1.

$$C = B\, log_2(1 + SNR) \tag{3.1}$$

where C denotes the maximum transmit data rate, B stands for the channel bandwidth. Equation 3.1 indicates that the transmit data rate can be increased by increasing the bandwidth occupation or transmission power. However, the transmission power cannot be readily increased because many portable devices are battery powered and the potential interference should also be avoided. Thus, a large frequency bandwidth will be the solution to achieve high data rate.

On February 14, 2002, the Federal Communications Commission (FCC) of the United States adopted the First Report and Order that permitted the commercial operation of ultra wideband (UWB) technology [3]. Since then, UWB technology has been regarded as one of the most promising wireless technologies that promises to revolutionize high data rate transmission and enables the personal area networking industry leading to new innovations and greater quality of services to the end users.

3.2 Review of the State-of-Art

At present, the global regulations and standards for UWB technology are still under consideration and construction. However, research on UWB has advanced greatly. Freescale Semiconductor was the first company to produce UWB chips in the world and its XS110 solution is the only commercially available UWB chipset to date [4]. It provides full wireless connectivity implementing direct sequence ultra wideband (DS-UWB). The chipset delivers more than 110 Mbps data transfer rate supporting applications such as streaming video, streaming audio, and high-rate data transfer at very low levels of power consumption. At 2005 3GSM World Congress, Samsung and Freescale demonstrated the world's first UWB-enabled cell phone featuring its UWB wireless chipset [5].

The Samsung's UWB-enabled cell phone, as shown in Figure 1.1, can connect wirelessly to a laptop and download files from the Internet. Additionally, pictures, MP3 audio files or data from the phone's address book can be selected and transferred directly to the laptop at very high data rate owing to the UWB technology exploited. These functions underscore the changing role of the cellular phone as new applications, such as cameras and video, require the ability for consumers to wirelessly connect their cell phone to other devices and transfer their data and files very fast.

3.3 Motivation

The UWB technology has experienced many significant developments in recent years. However, there are still challengers in making this technology live up to its full potential. One particular challenge is the UWB antenna. Among the classical broadband antenna configurations that are under consideration for use in UWB systems, a straight wire monopole features a simple structure, but its bandwidth is only around 10%. A vivaldi antenna is a directional antenna [9] and hence unsuitable for indoor systems and portable devices. A biconical antenna has a big size which limits its application [10]. Log periodic and spiral antennas tend to be dispersive and suffer severe ringing effect, apart from big size [11]. There is a growing demand for small and low cost UWB antennas that can provide satisfactory performances in both frequency domain and time domain.

In recent years, the circular disc monopole antenna has attracted considerable research interes due to its simple structure and UWB characteristics with nearly omni-directional radiation patterns [12, 13]. However, it is still not clear why this type of antenna can achieve ultra wide bandwidth and how exactly it operates over the entire bandwidth.

In this thesis, some monopole antenna is investigated in detail in order to understand its operation, find out the mechanism that leads to the UWB characteristic and also obtain some quantitative guidelines for designing of this type of antenna. Based on the understanding of vertical disc monopole, two more compact versions, i.e. coplanar waveguide (CPW) fed and microstrip line fed circular disc monopoles, are proposed.

3.4 APPLICATIONS

3.4.1 WLAN

A **wireless local area network** (**WLAN**) links two or more devices using some wireless distribution method (typically spread-spectrum or OFDM radio), and usually providing a connection through an access point to the wider Internet. This gives users the mobility to move around within a local coverage area and still be connected to the network. Most modern WLANs are based on IEEE 802.11 standards, marketed under the Wi-Fi brand name. WLANs were once called LAWNs (for local area wireless network) by the Department of Defense.

Wireless LANs have become popular in the home due to ease of installation, and in commercial complexes offering wireless access to their customers; often for free. New York City, for instance, has begun a pilot program to provide city workers in all five boroughs of the city with wireless Internet access. Wireless LANs (WLANs) are LANs that use RF instead of cable or optical fiber optical fiber.

Following are mane characteristics associated with WLAN.

• Allows high-speed data transfer without wires or cables

• Supports typical enterprise applications (e-mail, file transfer, audio/video conferencing, etc)

• First introduced in 1999, evolved from legacy RF data technologies such as Hiperlan.

• 120 million ports of WLAN shipped worldwide last year (virtually all laptops have WLAN interfaces now)

IEEE 802.11-1999 is the basic standard governing wireless LANs.

• Standardized by the IEEE 802.11 group, which is a working group in the IEEE

802 LAN/MAN St d d C itt (LMSC) 802 LAN/MAN Standards Committee (LMSC)

• Formed in 1991 to standardize a 1 Mb/s RF-based data network technology.

• Completed its work in 1999 with the first 802.11 wireless LAN standards.

Fig 3.1 WLAN Network.

3.4.2 GPS

GPS is a space-based radionavigation system providing accurate estimates of three dimensional position, velocity, and time. The development was lead by the United States (U.S.) Department of Defense (DOD) in the 1970s primarily for the U.S military, GPS now is fully operational and provides accurate, continuous position, velocity and timing information to both military and civilian users with appropriate GPS receiving equipment world wide [Misra, 2001], [Kaplan, 2006]. There are three main segments that make up GPS: Space Segment (satellites on orbit), Ground Control Segment, and the User Segment [GPS JPO website, 2007]. 24 satellites in six orbital planes make up the GPS baseline constellation. The satellites are circling around the Earth in the period of approximately 12 hours in six medium earth orbits (MEO). Each satellite transmits its own ranging data based on which user position can be calculated at the receiver end and navigation data such as orbital information, satellite status, clock information, etc is available [ICD- GPS-200C, 2000]. The satellites broadcast each set of its signals in a Code Division Multiple Access (CDMA) fashion on the same carrier frequency where each SV is identified by its unique pseudorandom (PRN) code. The Ground Control Segment includes the Monitor Stations which uses high fidelity GPS receivers to track and monitor the satellites status and the Master Control Station which then process the satellite information and commands the ground antennas which serves as an uplink to send control commands to satellites through an S band signal [GPS JPO website, 2007]. The User Segment of GPS includes the various GPS receivers including the receiving antennas for the wide variety of applications throughout the Globe.

Modernization of the Global Positioning System (GPS) has been taking place over the past few years as an important part of adding robustness to satellite navigation. The modernized GPS along with other satellite navigations systems, such as the European-lead Galileo development, the Russian GLONASS, and others, comprise the Global Navigation Satellite System (GNSS), which provides world-wide position, velocity, and timing services for a wide variety of military and civil applications. The currently GPS navigation signals in space operate at two center frequencies designated as GPS L1 (1575.42 MHz) and GPS L2 (1227.6 MHz). The GPS space vehicles (SV) are located in a Medium Earth Orbit (MEO) and broadcast the course acquisition (C/A) code and Precise(Y) (P(Y)) code on the GPS L1 carrier frequency for both military and civilian use, and P(Y) code only for military (i.e., authorized) use on GPS L2 carrier frequency [IS-GPS-200D, 2004]. As part of the modernization of GPS, a new Civil (C) code is being transmitted by the most recent Block IIR-M satellites. At the time of this thesis, there were three GPS Block IIR-M transmitting the C code on the L2 center frequency, which is designated as the L2C signal [USNO website, 2007]. The GNSS signals transmitted from GPS SV uses right hand circular polarization (RHCP) to help minimize the signal fluctuation for mobile and terrestrial users.

3.4.3 Wi MAX

Worldwide Interoperability for Microwave Access (WiMAX) is currently one of the hottest technologies in wireless. The Institute of Electrical and Electronics Engineers (IEEE) 802 committee, which sets networking standards such as Ethernet (802.3) and WiFi (802.11), has published a set of standards that define WiMAX. IEEE 802.16-2004 (also known as Revision D) was published in 2004 for fixed applications; 802.16 Revision E (which adds mobility) is publicated in July 2005. The WiMAX Forum is an industry body formed to promote the IEEE 802.16 standard and perform interoperability testing. The WiMAX Forum has adopted certain profiles based on the 802.16 standards for interoperability testing and “WiMAX certification”. These operate in the 2.5GHz, 3.5GHz and 5.8GHz frequency bands, whic typically are licensed by various government authorities. WiMAX, is based on an RF technology called Orthogonal Frequency Division Multiplexing (OFDM), which is a very effective means of transferring data when carriers of width of 5MHz or greater can be used. Below 5MHz carrier width, current CDMA based 3G systems are comparable to OFDM in terms of performance.

The IEEE 802.16 working group has established a new standard known as WiMAX (Worldwide Interoperability for Microwave Access) which can reach a theoretical up to 30- mile radius coverage. Moreover, in the case of WiMAX, the highest theoretically achievable transmission rates are possible at 70 Mbps. As currently defined through IEEE Standard 802.16, a wireless MAN provides network access to buildings through exterior antennas communicating with central radio base stations (BSs)[1].

WiMAX has three allocated frequency bands called low band, middle band and upper band. The low band has frequency from 2.5 to 2.8 GHz, the middle band has frequency from 3.2 to 3.8 GHz and the upper band has 5.2 to 5.8 GHz.

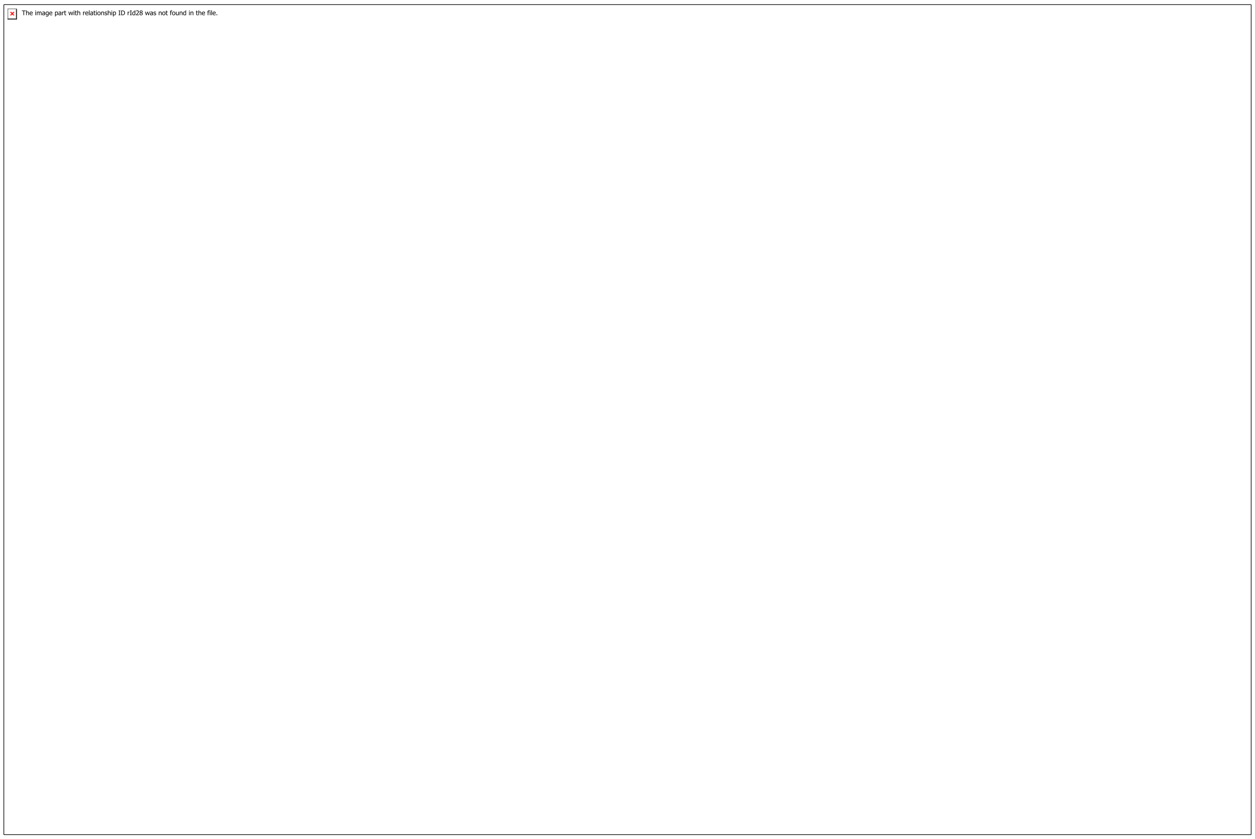

Fig no 3.2 WiMAX band.

3.4.4 WiMax vs. WLAN

Unlike WLAN, WiMAX provides a media access control (MAC) layer that uses a grantrequest mechanism to authorize the exchange of data. This feature allows better exploitation of the radio resources, in particular with smart antennas, and independent management of the traffic of every user.

This simplifies the support of real-time and voice applications. One of the inhibitors to widespread deployment of WLAN was the poor security feature of the first releases. WiMAX proposes the full range of security features to ensure secured data exchange.

- Terminal authentication by exchanging certificates to prevent rogue devices,

- User authentication using the Extensible Authentication Protocol (EAP),

- Data encryption using the Data Encryption Standard (DES) or Advanced Encryption

Standard (AES), both much more robust than the Wireless Equivalent Privacy (WEP) initially

used by WLAN. Furthermore, each service is encrypted with its own security association and private keys.

WiMAX is a standard-based wireless technology that provides high throughput broadband connections over long distance. WiMAX can be used for a number of applications, including “last mile” broadband connections, hotspots and high-speed connectivity for business customers. It provides wireless metropolitan area network (MAN) connectivity at speeds up to 70 Mbps and the WiMAX base station on the average can cover between5 to 10 km. Figure 3.3 below gives WiMAX Overview.

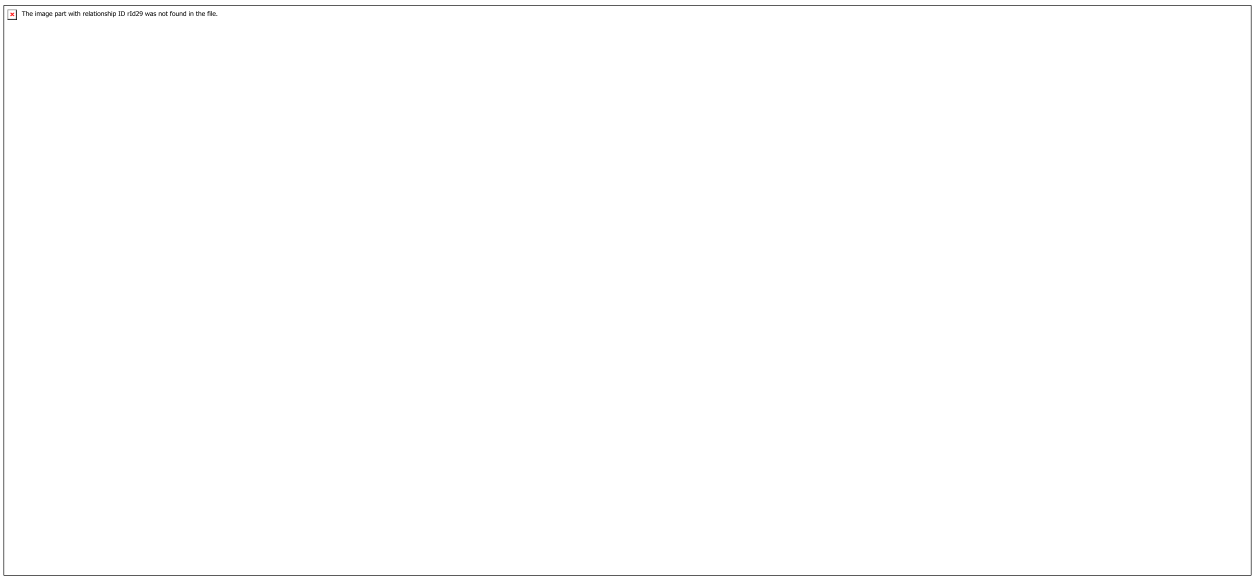

Figure 3.3WiMAX Overview

3.5 UWB Technology

UWB technology has been used in the areas of radar, sensing and military communications during the past 20 years. A substantial surge of research interest has occurred since February 2002, when the FCC issued a ruling that UWB could be used for data communications as well as for radar and safety applications [1]. Since then, UWB technology has been rapidly advancing as a promising high data rate wireless communication technology for various applications.
This chapter presents a brief overview of UWB technology and explores its fundamentals, including UWB definition, advantages, current regulation state and standard activities.

3.5.1 Introduction

UWB systems have been historically based on impulse radio because it transmitted data at very high data rates by sending pulses of energy rather than using a narrowband frequency carrier. Normally, the pulses have very short durations, typically a few nanoseconds (billionths of a second) that results in an ultra wideband frequency spectrum.

The concept of impulse radio initially originated with Marconi, in the 1900s, when spark gap transmitters induced pulsed signals having very wide bandwidths [2]. At that time, there was no way to effectively recover the wideband energy emitted by a spark gap transmitter or discriminate among many such wideband signals in a receiver. As a result, wideband signals caused too much interference with one another. So the communications world abandoned wideband communication in favour of narrowband radio transmitter that were easy to regulate and coordinate.

In 1942-1945, several patents were filed on impulse radio systems to reduce interference and enhance reliability [3]. However, many of them were frozen for a long time because of the concerns about its potential military usage by the U.S. government. It is in the 1960s that impulse radio technologies started being developed for radar and military applications.

In the mid 1980s, the FCC allocated the Industrial Scientific and Medicine (ISM) bands for unlicensed wideband communication use. Owing to this revolutionary spectrum allocation, WLAN and Wireless Fidelity (Wi-Fi) have gone through a tremendous growth. It also leads the communication industry to study the merits and implications of wider bandwidth communication.

Shannon-Nyquist criterion (Equation 3.1) indicates that channel capacity increases linearly with bandwidth and decreases logarithmically as the SNR decreases. This relationship suggests that channel capacity can be enhanced more rapidly by increasing the occupied bandwidth than the SNR. Thus, for WPAN that only transmit over short distances, where signal propagation loss is small and less variable, greater capacity can be achieved through broader bandwidth occupancy.

In February, 2002, the FCC amended the Part 15 rules which govern unlicensed radio devices to include the operation of UWB devices. The FCC also allocated a bandwidth of 7.5GHz, i.e. from 3.1GHz to 10.6GHz to UWB applications [1], by far the largest spectrum allocation for unlicensed use the FCC has ever granted.

According to the FCC's ruling, any signal that occupies at least 500MHz spectrum can be used in UWB systems. That means UWB is not restricted to impulse radio any more, it also applies to any technology that uses 500MHz spectrum and complies with all other requirements for UWB.

3.5.2 UWB Applications

As mentioned earlier in this chapter, UWB offers some unique and distinctive properties that make it attractive for various applications.

Firstly, UWB has the potential for very high data rates using very low power at very limited range, which will lead to the applications well suited for WPAN. The peripheral connectivity through cableless connections to applications like storage, I/O devices and wireless USB will improve the ease and value of using Personal Computers (PCs) and laptops. High data rate transmissions between computers and consumer electronics like digital cameras, video cameras, MP3 players, televisions, personal video recorders, automobiles and DVD players will provide new experience in home and personal entertainment.

Secondly, sensors of all types also offer an opportunity for UWB [3]. Sensor networks are comprised of a large number of nodes within a geographical area. These nodes may be static, when applied for securing home, tracking and monitoring, or mobile, if equipped on soldiers, firemen, automobiles, or robots in military and emergency response situations [19]. The key requirements for sensor networks include low cost, low power and multifunctionality which can be well met by using UWB technology. High data rate UWB systems are capable of gathering and disseminating or exchanging a vast quantity of sensory data in a timely manner. The cost of installation and maintenance can drop significantly by using UWB sensor networks due to being devoid of wires. This merit is especially attractive in medical applications because a UWB sensor network frees the patient from being shackled by wires and cables when extensive medical monitoring is required. In addition, with a wireless solution, the coverage can be expanded more easily and made more reliable.

Thirdly, positioning and tracking is another unique property of UWB. Because of the high data rate characteristic in short range, UWB provides an excellent solution for indoor location with a much higher degree of accuracy than a GPS. Furthermore, with advanced tracking mechanism, the precise determination of the tracking of moving objects within an indoor environment can be achieved with an accuracy of several centimeters [2]. UWB systems can operate in complex situations to yield faster and more effective communication between people. They can also be used to find people or objects in a variety of situations, such as casualties in a collapsed building after an earthquake, children lost in the mall, injured tourists in a remote area, fire fighters in a burning building and so on.

Lastly, UWB can also be applied to radar and imaging applications. It has been used in military applications to locate enemy objects behind walls and around corners in the battlefield. It has also found value in commercial use, such as rescue work where a UWB radar could detect a person's breath beneath rubble, or medical diagnostics where X-ray systems may be less desirable.

UWB short pulses allow for very accurate delay estimates, enabling high definition radar. Based on the high ranging accuracy, intelligent collision-avoidance and cruisecontrol systems can be envisioned [19]. These systems can also improve airbag deployment and adapt suspension/braking systems depending on road conditions. Besides, UWB vehicular radar is also used to detect the location and movement of objects near a vehicle.

3.6 UWB ANTENNAS

In this thesis work a number of UWB microstrip patch antennas are designed, whose shapes are different for different applications. All of these designed antennas are discussed in chapter 5, with there detailed descriptions.

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Chapter -4

Chapter -4

Microstrip Patch Antenna

4.1 Introduction

Microstrip antennas are one of the most widely used types of antennas in the microwave frequency range, and they are often used in the millimetre-wave frequency range as well [1, 2, 3]. (Below approximately 1 GHz, the size of a microstrip antenna is usually too large to be practical, and other types of antennas such as wire antennas dominate). Also called patch antennas, microstrip patch antennas consist of a metallic patch of metal that is on top of a grounded dielectric substrate of thickness *h*, with relative permittivity and permeability εr and μr as shown in Figure 4.1 (usually $\mu r = 1$). The metallic patch may be of various shapes, with rectangular and circular being the most common, as shown in Figure 4.1.

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Figure 4.1 Structure of a Microstrip Patch Antenna

In order to simplify analysis and performance prediction, the patch is generally 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 $t << \lambda_0$ (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 $2.2 \leq \varepsilon_r \leq 12$.

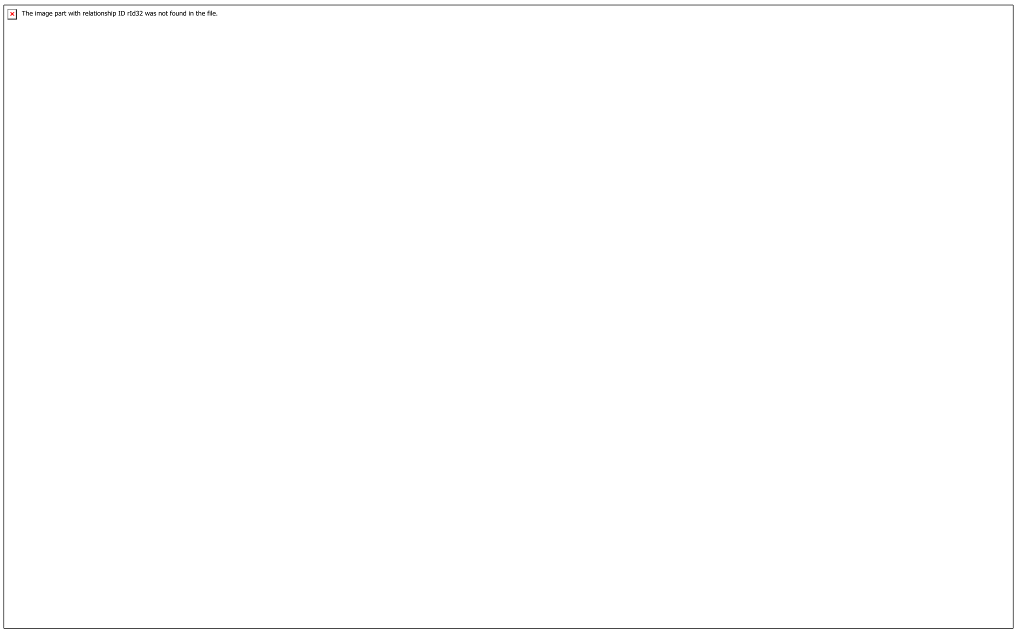


Figure 4.2 Common shapes of microstrip patch elements.

Microstrip patch antennas radiate primarily because of the fringing fields between the patch edge and the ground plane. For good antenna performance, a thick dielectric substrate having a low dielectric constant is desirable since this provides better efficiency, larger bandwidth and better radiation [5]. However, such a configuration leads to a larger antenna size.
In order to design a compact Microstrip patch antenna, higher dielectric constants must be used which are less efficient and result in narrower bandwidth. Hence a compromise must be reached between antenna dimensions and antenna performance.

Most of the discussion in this section will be limited to the rectangular patch, although the basic principles are the same for the circular patch. (Many of the CAD formulas presented will apply approximately for the circular patch if the circular patch is modelled as a square patch of the same area.) Various methods may be used to feed the patch, as discussed below.

4.1.1 Advantages and Disadvantages

Microstrip patch antennas are increasing in popularity for use in wireless applications due to their low-profile structure. Therefore they are extremely compatible for embedded antennas in handheld wireless devices such as cellular phones, pagers etc... The telemetry and communication antennas on missiles need to be thin and conformal and are often Microstrip patch antennas. Another area where they have been used successfully is in Satellite communication. Some of their principal advantages discussed by [5] and Kumar and Ray [9] are given below:

- Light weight and low volume.
- Low profile planar configuration which can be easily made conformal to host surface.
- Low fabrication cost, hence can be manufactured in large quantities.
- Supports both, linear as well as circular polarization.
- Can be easily integrated with microwave integrated circuits (MICs).
- Capable of dual and triple frequency operations.
- Mechanically robust when mounted on rigid surfaces.

Microstrip patch antennas suffer from a number of disadvantages as compared to conventional antennas. Some of their major disadvantages discussed by [9] and Garg et al [10] are given below:

- Narrow bandwidth
- Low efficiency
- Low Gain
- Extraneous radiation from feeds and junctions
- Poor end fire radiator except tapered slot antennas
- Low power handling capacity.
- Surface wave excitation

Microstrip patch antennas have a very high antenna quality factor (Q). Q represents the losses associated with the antenna and a large Q leads to narrow bandwidth and low efficiency.
Q can be reduced by increasing the thickness of the dielectric substrate. But as the thickness increases, an increasing fraction of the total power delivered by the source goes into a surface wave. This surface wave contribution can be counted as an unwanted power loss since it is ultimately scattered at the dielectric bends and causes degradation of the antenna characteristics.
However, surface waves can be minimized by use of photonic bandgap structures as discussed by Qian et al [11]. Other problems such as lower gain and lower power handling capacity can be overcome by using an array configuration for the elements.

4.2 Basic Principles of Operations.

The metallic patch essentially creates a resonant cavity, where the patch is the top of the cavity, the ground plane is the bottom of the cavity, and the edges of the patch form the sides of the cavity. The edges of the patch act approximately as an open-circuit boundary condition. Hence, the patch acts approximately as a cavity with perfect electric conductor on the top and bottom surfaces, and a perfect "magnetic conductor" on the sides. This point of view is very useful in analyzing the patch antenna, as well as in understanding its behavior. Inside the patch cavity the electric field is essentially *z* directed and independent of the z coordinate. Hence, the patch cavity modes are described by a double index (*m*, *n*). For the (*m*, *n*) cavity mode of the rectangular patch in Figure 1b, the electric field has the form

$$E_Z = A_{mn} \cos\left(\frac{m\pi x}{L}\right) \cos\left(\frac{n\pi y}{W}\right) \qquad 4.1$$

Where *L* is the patch length and *W* is the patch width. The patch is usually operated in the (1, 0) mode, so that *L* is the resonant dimension, and the field is essentially constant in the *y* direction. The surface current on the bottom of the metal patch is then *x* directed, and is given by

$$J_{sx} = A_{10} \left(\frac{\pi/L}{j\omega\mu_0\mu_r}\right) \qquad 4.2$$

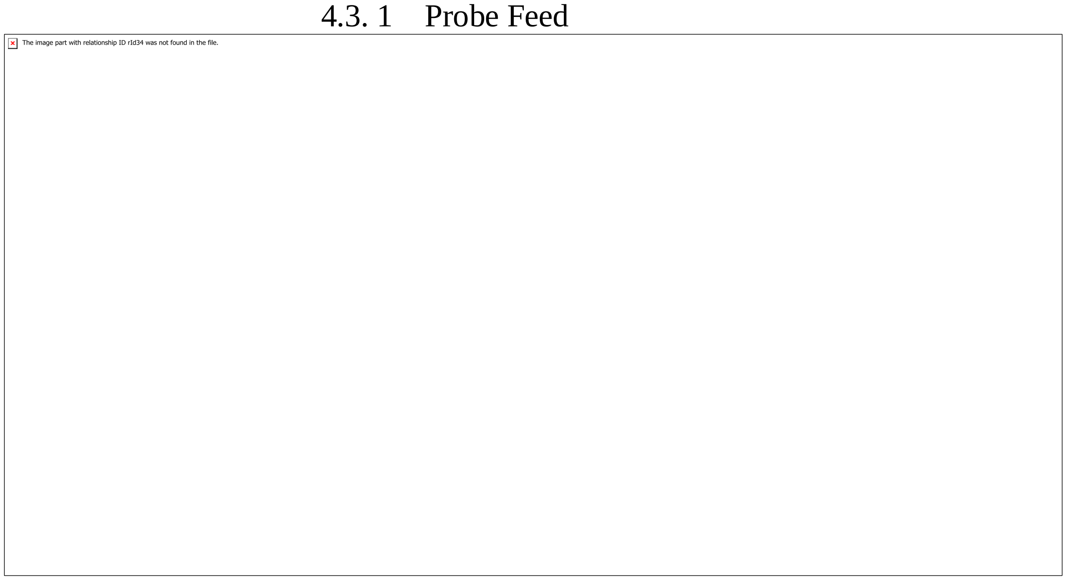
For this mode the patch may be regarded as a wide microstrip line of width *W*, having a resonant length *L* that is approximately one-half wavelength in the dielectric. The current is maximum at the centre of the patch, $x = L/2$, while the electric field is maximum at the two "radiating" edges, $x = 0$ and $x = L$. The width *W* is usually chosen to be larger than the length ($W = 1.5\,L$ is typical) to maximize the bandwidth, since the bandwidth is proportional to the width. (The width should be kept less than twice the length, however, to avoid excitation of the (0,2) mode.)

At first glance, it might appear that the microstrip antenna will not be an effective radiator when the substrate is electrically thin, since the patch current in (2) will be effectively shorted by the close proximity to the ground plane. If the modal amplitude *A*10 were constant, the strength of the radiated field would in fact be proportional to *h*. However, the Q of the cavity increases as *h* decreases (the radiation Q is inversely proportional to *h*). Hence, the amplitude *A*10 of the modal field at resonance is inversely proportional to *h*. Hence, the strength of the radiated field from a resonant patch is essentially independent of *h*, if losses are ignored. The resonant input resistance will likewise be nearly independent of *h*. This explains why a patch antenna can be an effective radiator even for very thin substrates, although the bandwidth will be small.

4.3 Feeding Techniques

The Microstrip antenna may be fed in various ways. Perhaps the most common is the direct probe feed, shown in Figure 2.2a for a rectangular patch, where the centre conductor of a coaxial feed line penetrates the substrate to make direct contact with the patch. For linear polarization, the patch is usually fed along the centre line, $y = W/2$. The feed point location at $x = xf$ controls the resonant input resistance. The input resistance is highest when the patch is fed at the edge, and smallest (essentially zero) when the patch is fed at the centre ($x = L/2$). Another common feeding method, preferred for planar fabrication, is the direct-contact microstrip feed line, shown in Figure 2.2b. An inset notch is used to control the resonant input resistance at the contact point. The input impedance seen by the microstrip line is approximately the same as that seen by a probe at the contact point, provided the notch does not disturb the modal field significantly.

4.3. 1 Probe Feed



4.3.2 Microstrip Feed

4.3.3 Aperture Coupled Feed

Fig.4.3.1, 4.3.2, 4.3.3 Feed Mechanism

An alternative type of feed is the aperture-coupled feed shown in Figure 4.3.3. In this scheme, a microstrip line on a back substrate excites a slot in the ground plane, which then excites the patch cavity. This scheme has the advantage of isolating the feeding network from the radiating patch element. It also overcomes the limitation on substrate thickness imposed by the feed inductance of a coaxial probe, so that thicker substrates and hence higher bandwidths can be obtained. Using this feeding technique together with a foam substrate, it is possible to achieve bandwidths greater than 25% [4]. Another alternative, which has some of the advantages of the aperture coupled feed, is the "electromagnetically-coupled" or "proximity" feed, shown in Figure. In this arrangement the microstrip line is on the same side of the ground plane as the patch, but does not make direct contact. The microstrip line feeds the patch via electromagnetic (largely capacitive) coupling. With this scheme it is possible to keep the feed line closer to the ground plane compared with the direct feed, in order to minimize feed line radiation. However, the fabrication is more difficult, requiring two substrate layers. Another variation of this technique is to have the microstrip line on the same layer as the patch, with a capacitive gap between the line and the patch edge. This allows for an input match to be achieved without the use of a notch.

Table 4.1 below summarizes the characteristics of the different feed techniques.

Table 4.1 comparing the different feed techniques [4].

Characteristics Proximity coupled Feed	**Microstrip Line Feed**	**Coaxial Feed**	**Aperture coupled Feed**	**Proximity coupled Feed**
Spurious feed radiation	More	More	Less	Minimum
Reliability	Better	Poor due to soldering	Good	Good
Ease of fabrication	Easy	Soldering and drilling needed	Alignment required	Alignment required
Impedance	Easy	Easy	Easy	Easy

Matching				
Bandwidth (achieved with impedance matching)	2-5%	2-5%	2-5%	13%

4.4 Resonance Frequency

The resonance frequency for the (1, 0) mode is given by

$$f_0 = \frac{c}{2\, L_e \sqrt{\varepsilon_r}} \qquad 4.3$$

Where *c* is the speed of light in vacuum. To account for the fringing of the cavity fields at the edges of the patch, the length, the effective length *Le* is chosen as

$$L\,e = L + 2\Delta L \qquad 4.4$$

The Hammerstad formula for the fringing extension is [1]

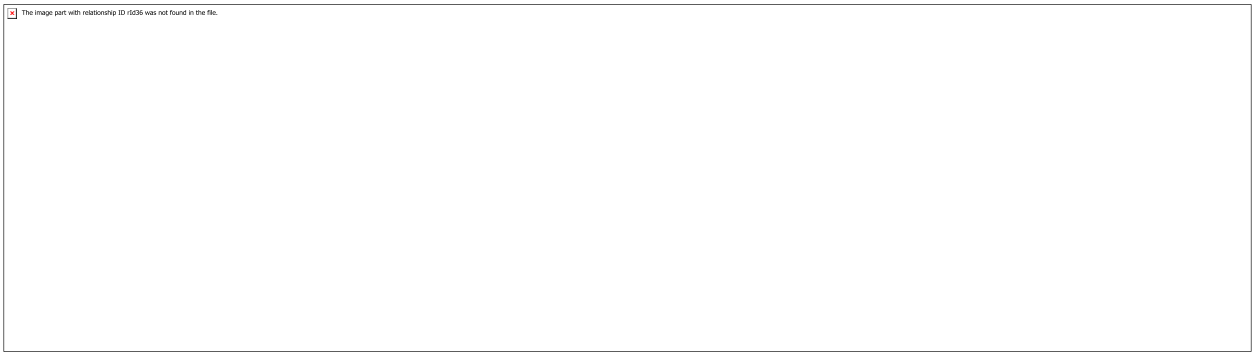
$$\frac{\Delta L}{h} = 0.412\left(\frac{(\varepsilon_{eff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\varepsilon_{eff}-0.258)\left(\frac{W}{h}+0.8\right)}\right) \qquad 4.5$$

Where

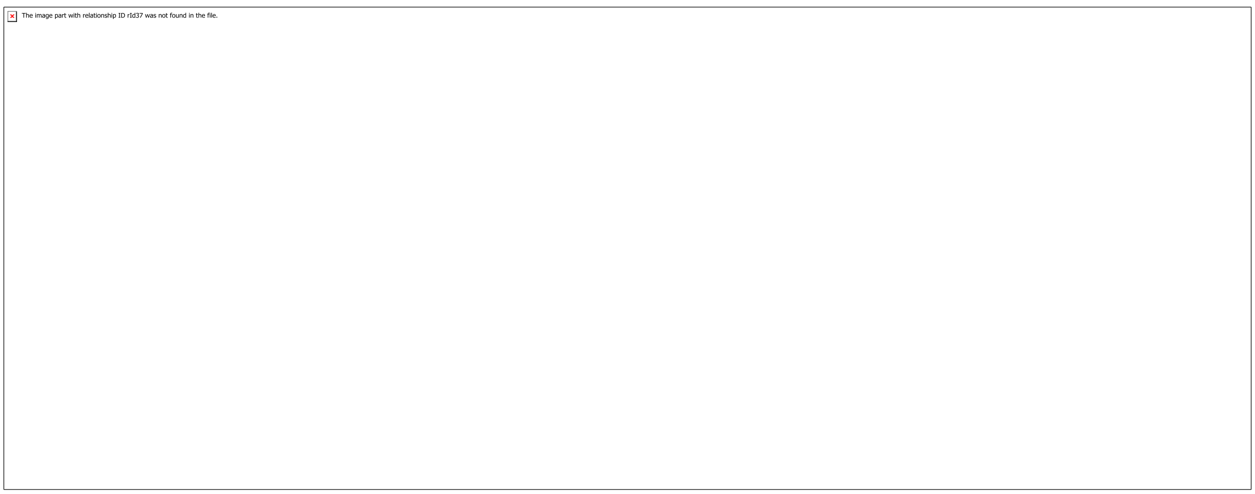
$$\varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left(1+\frac{12h}{w}\right)^{-1/2} \qquad 4.6$$

4.5 Radiation Pattern

The radiation field of the microstrip antenna may be determined using either an “electric current model” or a “magnetic current model”. In the electric current model, the current in (2) is used directly to find the far-field radiation pattern. Figure 4.4a shows the electric current for the (1, 0) patch mode. If the substrate is neglected (replaced by air) for the calculation of the radiation pattern, the pattern may be found directly from image theory. If the substrate is accounted for, and is assumed infinite, the reciprocity method may be used to determine the far-field pattern [5].



(a) Electric Current for (1,0) patch



(b) Magnetic Current for (1, 0) patch

Fig. 4.4 Electric & Magnetic Current Distribution

It can be shown that the electric and magnetic current models yield exactly the same result for the far-field pattern, provided the pattern of each current is calculated in the presence of the substrate at the resonant frequency of the patch cavity mode [5]. If the substrate is neglected, the agreement is only approximate, with the largest difference being near the horizon.
The radiation patterns (E- and H-plane) for a rectangular patch antenna on an infinite substrate of permittivity $\varepsilon_r = 2.2$ and thickness $h/\lambda_0 = 0.02$ are shown in Figure 4.5. The patch is resonant with $W / L = 1.5$. Note that the E-plane pattern is broader than the H-plane pattern. The directivity is approximately 6 dB.

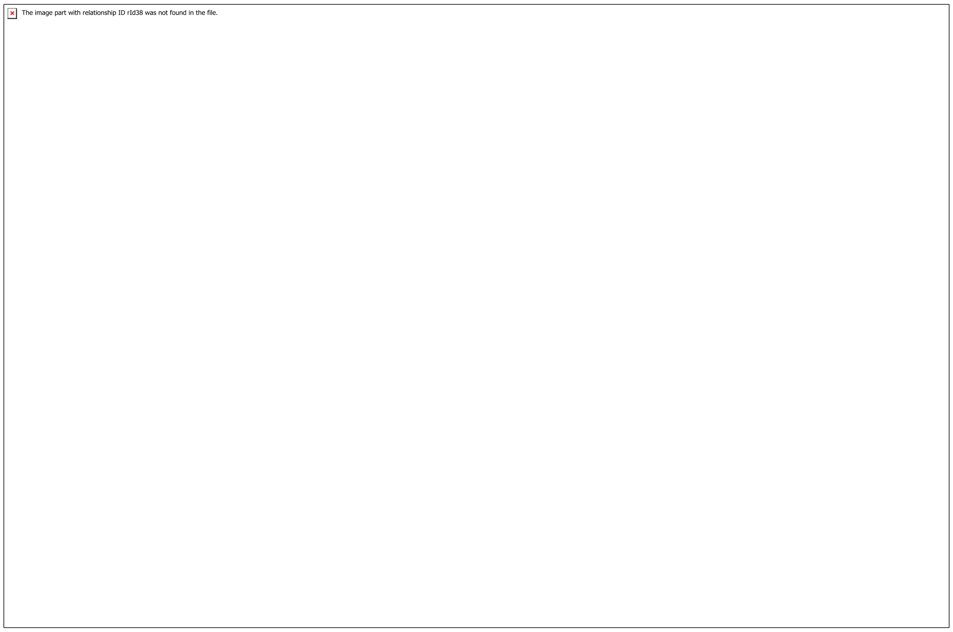


Fig. 4.5 Radiation Pattern (E & H plane)

4.6 Radiation Efficiency

The radiation efficiency of the patch antenna is affected not only by conductor and dielectric losses, but also by surface-wave excitation .since the dominant TM0 mode of the grounded substrate will be excited by the patch. As the substrate thickness decreases, the effect of the conductor and dielectric losses becomes more severe, limiting the efficiency. On the other hand, as the substrate thickness increases, the surface-wave power increases, thus limiting the efficiency. Surface-wave excitation is undesirable for other reasons as well, since surface waves contribute to mutual coupling between elements in an array, and also cause undesirable edge diffraction at the edges of the ground plane or substrate, which often contributes to distortions in the pattern and to back radiation. For an air (or foam) substrate there is no surface-wave excitation. In this case, higher efficiency is obtained by making the substrate thicker, to minimize conductor and dielectric losses (making the substrate too thick may lead to difficulty in matching, however, as discussed above). For a substrate with a moderate relative permittivity such as $\varepsilon r = 2.2$, the efficiency will be maximum when the substrate thickness is approximately $\lambda 0 = 0.02$. The radiation efficiency is defined as

$$e_r = \frac{P_{sp}}{P_{total}} = \frac{P_{sp}}{P_c + P_d + P_{sw} + P_{sp}} \qquad 4.7$$

Where *P sp* is the power radiated into space, and the total input power *P total* is given as the sum of *Pc* - the power dissipated by conductor loss, *Pd* - the power dissipated by dielectric loss, and *P sw* - the surface-wave power.

A plot of radiation efficiency for a resonant rectangular patch antenna with W / L
= 1.5 on a substrate of relative permittivity $\varepsilon\ r$ = 2.2 or εr = 10.8 is shown in Figure 4.6. The conductivity of the copper patch and ground plane is assumed to be $\sigma = 3.0\times107$ [S/m] and the dielectric loss tangent is taken as $\tan\delta d = 0.001$. The resonance frequency is 5.0 GHz. (The result is plotted versus normalized (electrical) thickness of the substrate, which does not involve frequency.

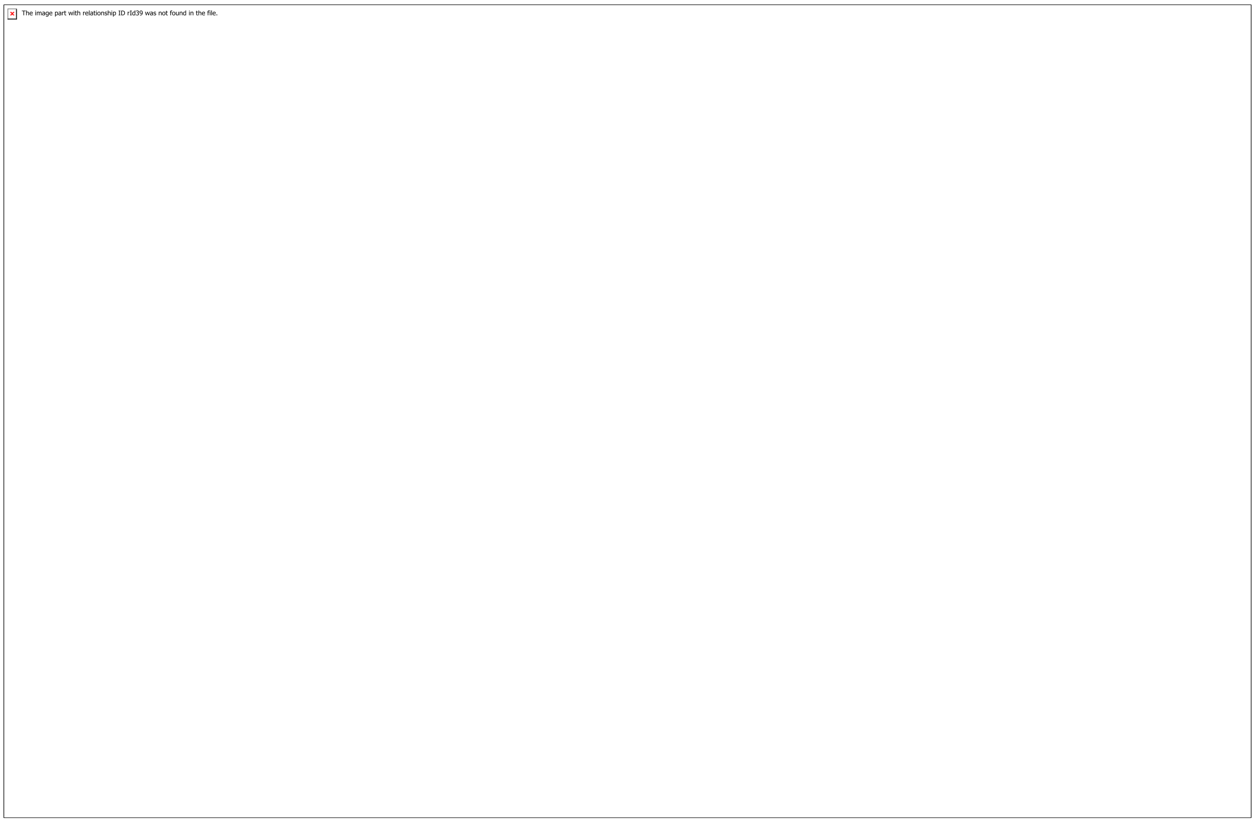


Fig.4.6 Radiation Efficiency for a rectangular patch Antenna

4.7 Band Width

The bandwidth increases as the substrate thickness increases (the bandwidth is directly proportional to h if conductor, dielectric, and surface-wave losses are ignored). However, increasing the substrate thickness lowers the Q of the cavity, which increases spurious radiation from the feed, as well as from higher-order modes in the patch cavity. Also, the patch typically becomes difficult to match as the substrate thickness increases beyond a certain point (typically about 0.05 $\lambda0$). This is especially true when feeding with a coaxial probe, since a thicker substrate results in a larger probe inductance appearing in series with the patch impedance. However, in recent years considerable effort has been spent to improve the bandwidth of the microstrip antenna, in part by using alternative feeding schemes. The aperture-coupled feed of Figure 4.3.3 is one scheme that overcomes the problem of probe inductance, at the cost of increased complexity [7]. Lowering the substrate permittivity also increases the bandwidth of the patch antenna. However, this has the disadvantage of making the patch larger. Also, because the Q of the patch cavity is lowered, there will usually be increased radiation from higher-order modes, degrading the polarization purity of the radiation.

By using a combination of aperture-coupled feeding and a low-permittivity foam substrate, bandwidths exceeding 25% have been obtained. The use of stacked patches (a parasitic patch located above the primary driven patch) can also be used to increase bandwidth even further, by increasing the effective height of the structure and by creating a double-tuned resonance effect [8]. Note that neglecting conductor and dielectric loss yields a bandwidth that is proportional to the substrate thickness h.

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Fig. 4.7 Calculated & Measured Bandwidth

Figure 4.7 shows calculated and measured bandwidth for the same patch. It is seen that bandwidth is improved by using a lower substrate permittivity, and by making the substrate thicker.

4.8 Input Impedance

A variety of approximate models have been proposed for the calculation of input impedance for a probe-fed patch. These include the transmission line method [9], the cavity model [10], and the spectral-domain method [11]. These models usually work well for thin substrates, typically giving reliable results for $h/\lambda 0 < 0.02$. Commercial simulation tools using FDTD, FEM, or MoM can be used to accurately predict the input impedance for any substrate thickness. The cavity model has the advantage of allowing for a simple physical CAD model of the patch to be developed, as shown in Figure 4.7.

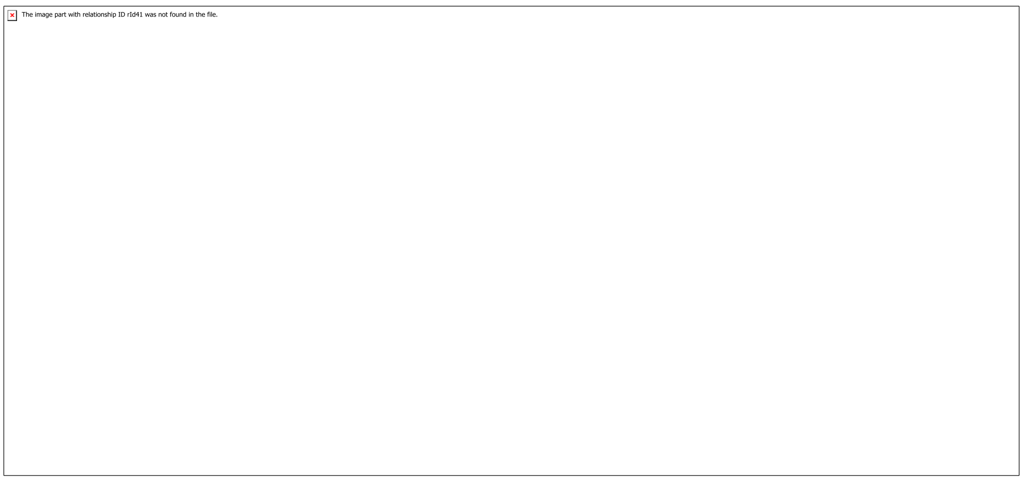


Fig. 4.8 Equivalent Circuit of Patch Antenna

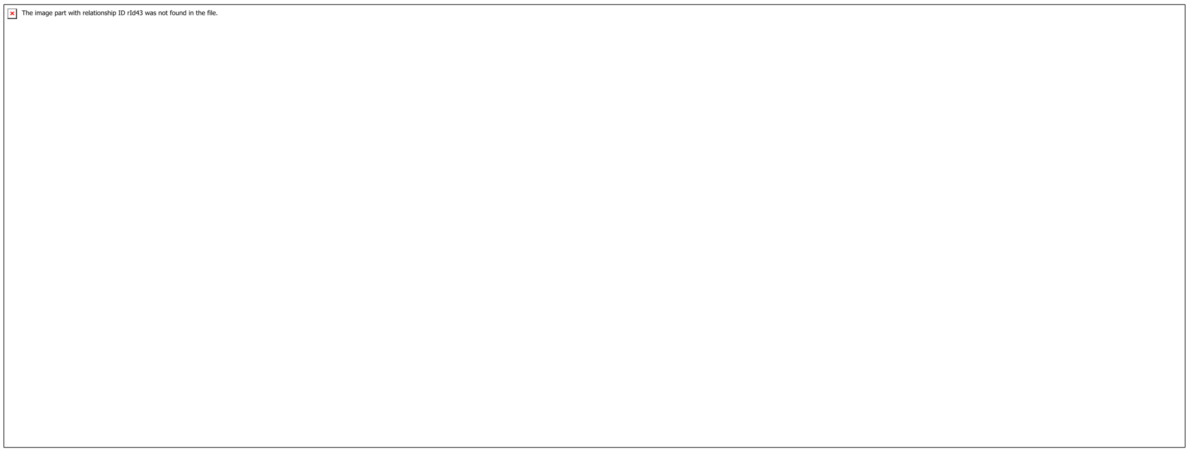
In this model the patch cavity is modeled as a parallel RLC circuit, while the probe inductance is modeled as a series inductor. The input impedance of this circuit is approximately described by

$$Z_{in} \approx jX_f + \frac{R}{1 + j2Q(f/f_0 - 1)} \qquad 4.8$$

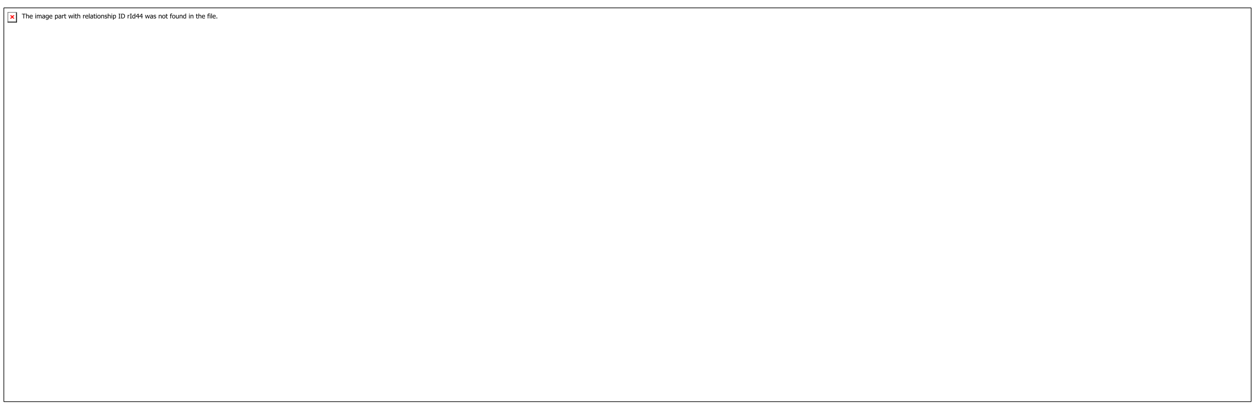
where $f0$ is the resonance frequency, R is the input resistance at the resonance of the RLC circuit (where the input resistance of the patch is maximum), $Q = Q$total is the quality factor of the patch cavity (20), and $Xf = \omega Lp$ is the feed (probe) reactance of the coaxial probe. A CAD formula for the input resistance R is and more.

4.9 Improving Performance

Much research has been devoted to improving the performance characteristics of the microstrip antenna. To improve bandwidth, the use of thick low-permittivity (e.g., foam) substrates can give significant improvement. To overcome the probe inductance associated with thicker substrates, the use of capacitive-coupled feeds such as the top-loaded probe [12] or the L-shaped probe [13] shown in Figure 4.9a and Figure 4.9b may be used. Alternatively, the aperture coupled fed shown in Figure 4.9c may be used, which also has the advantage of eliminating spurious probe radiation. To increase the bandwidth even further, a stacked patch arrangement may be used, in which a parasitic patch is stacked above the driven patch [8]. This may be done using either a probe feed or, to obtain even higher bandwidths, using an aperture-coupled feed (Figure 4.9c).



(a)Top Loading Probe Feeding



(b) L- Probe Feeding

(c) Aperture Coupled Feeding

Fig. 4.9 Feed Types for improving performance.

The bandwidth enhancement is largely due to the existence of a double resonance, and to some extent, to the fact that one of the radiators is further from the ground plane.
Bandwidths as large as one octave (2:1 frequency band) have been obtained with such an arrangement. By using a diplexer feed to split the feeding signal into two separate branches, and feeding two aperture-coupled stacked patches with different centre frequencies, bandwidths of 4:1 have been obtained [14].
Parasitic patches may also be placed on the same substrate as the driven patch, surrounding the driven patch. A pair of parasitic patches may be coupled to the radiating edges, the non-radiating edges, or all four edges [15]. This planar arrangement saves vertical height and allows for easier fabrication, allows the substrate area occupied by the antenna is larger, and there may be more variation of the radiation pattern across the frequency band since the current distribution on the different patches changes with frequency. Broad banding may also be achieved through the use of slots cut into the patch, as in the "U-slot" patch design [16]. This has the advantage of not requiring multiple layers or increasing the size of the patch as with parasitic elements.
Another variation of the microstrip antenna that has been introduced recently is the "reduced surface wave" microstrip antenna shown in Figure 4.10 [17].

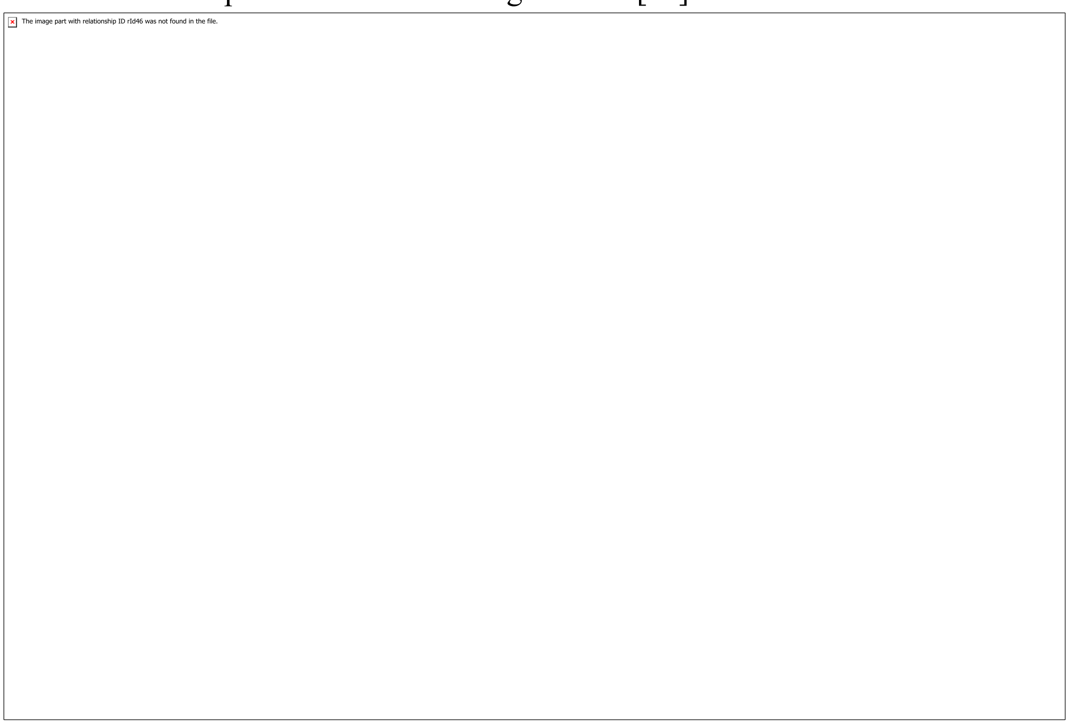


Fig. 4.10 Reduced surface wave microstrip antenna

This design is a variation of a circular patch, with an inner ring of vias that creates a short circuit inner boundary. By properly selecting the outer radius, the patch excites very little surface-wave field, and also only a small amount of lateral (horizontally propagating) radiation. The inner short-circuit boundary is used to adjust the dimensions of the patch cavity (between the inner and outer boundaries) to make the patch resonant. The reduced surface-wave and lateral radiation result in less edge diffraction from the edges of the supporting ground plane, giving smoother patterns in the front-side region and less radiation in the backside region. Also, there is less mutual coupling between pairs of such antennas, especially as the separation increases.

4.10 Multilayer Patch Antenna

Patch antennas can be designed in multi-layer structure with more than one layer of substrate material to support multi-frequency operation over various center frequencies of operation. In some case, a substrate (called super-strate) will be used on top of the patch layer to increase the radiation gain of the antenna. In another case, multi-layer structure is used for increasing bandwidth of the antenna, in which the top patch layer is responsible for radiation and it is fed by coupling through the lower layer. The multilayer patch antenna structure investigated in this thesis is for multi-frequency purpose.

This structure is shown in Figure 4.11, where the top patch element resonates at a lower frequency band and bottom patch element resonates at the upper frequency band.

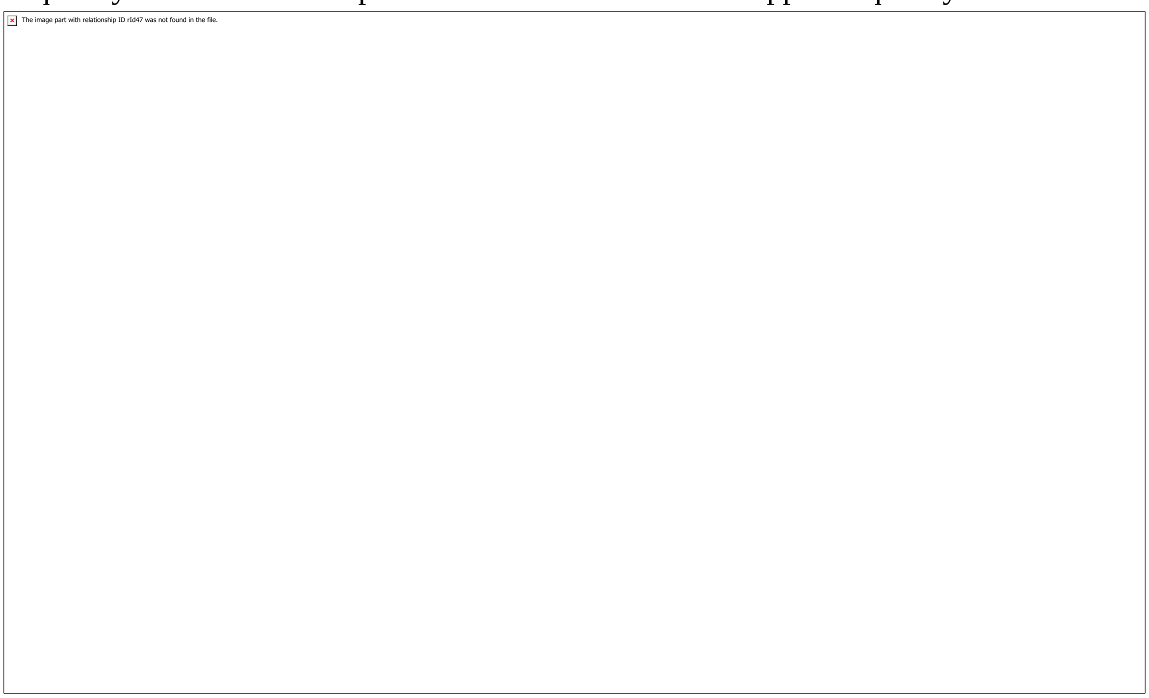


Figure 4.11 3D View of Dual Layer Patch Antenna (without feed)

4.11 Summary

In this chapter we discussed about patch antennas, its advantages and disadvantages, various feeding techniques, Frequency bandwidth, input impedance, equivalent circuit of patch antenna, radiation efficiency and finally improving performance of patch antenna.

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Chapter -5

Chapter -5

Microstrip Patch Antenna Design and Results

The main objective for any wireless communication system is to provide more mobility and flexibility with device under applications. In wireless communications we always more concentrate on the available bandwidth for application and signal to noise ratio at the output end of receiver. To provide all these we will require a medium which will connect users with the device that is antenna.

In this chapter, the designing of a number of planer microstrip patch antenna in various shapes for various applications are explained. Next, a number of compact microstrip patch antenna is designed for use in cellular phones and in various communication devices. Finally, the results obtained from the simulations are demonstrated.

Fig 5.1 Internal View of a simple mobile phone.

5.1 Ractangular Microstrip Patch Antenna Design for WLAN Application Using Probe Feed.

Microstrip patch antennas are the most common form of printed antennas. They are popular for their low profile geometry, light weight and low cost.

A Rectangular Microstrip Patch Antenna with probe feed by using a substrate of Rogers RT/ duroid 5880 (tm) the relative permittivity of which is 2.2 and electric loss angle is 0.0004, with a simple rectangular microstrip with Probe Feed has been designed and simulated on high frequency structure simulator (HFSS) .All the Required Property of this microsrip Antenna such as bandwidth, S parameter ,Reflection loss and VSWR has been found and plotted .

5.1.1 Introduction

A microstrip or patch antenna is a low profile antenna that has a number of advantages over other antennas it is lightweight, inexpensive, and easy to integrate with accompanying electronics. Microstrip antennas are one of the most widely used types of antennas in the microwave frequency range, and they are often used in the milli metre-wave frequency range Also called patch antennas, microstrip patch antennas consist of a metallic patch of metal that is on top of a grounded dielectric substrate of thickness *h*, with relative permittivity and permeability εr and μr as shown in Figure 2.1 (usually $\mu r = 1$). The metallic patch may be of various shapes, with rectangular and circular being the most common[1]-[7].

Coaxial Probe Feed-

The coaxial feed or probe feed is a very common contacting scheme of feeding patch antennas. The configuration of a coaxial feed is shown in Fig.5.2. The inner conductor of the coaxial connector extends through the dielectric and is soldered to the radiating patch, while the outer conductor is connected to the ground plane.

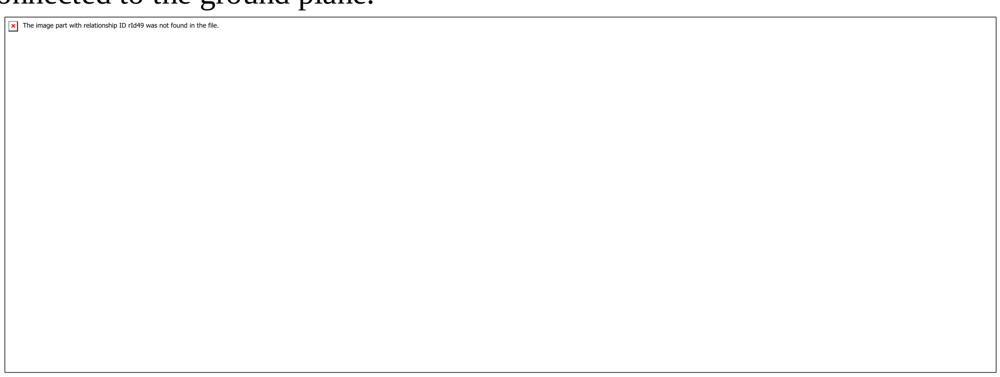


Fig 5.2 coaxial probe feed.

5.1.2 Antenna Geometry for Probe Feed

The detailed Design of Microstrip Patch Antenna in Shawn in Figure 5.3 and 5.4. in this design we are having following parameters. Choosing a substrate is as crucial as the design itself. Many different factors as dielectric constant, thickness, stiffness as well as loss tangent are considered. In Patch Antenna using a thick substrate would incur a loss in accuracy.

The resonant frequency of the patch is determined by the patch length. The length of the patch should be slightly less than half the dielectric wavelength. The resonant length determines the resonant frequency and is about l/2 for a rectangular patch excited in its fundamental mode. The patch is, in fact, electrically a bit larger than its physical dimensions due to the fringing fields. The deviation between electrical and physical size is mainly dependent on the PC board thickness and dielectric constant[2]-[4].

The Detailed Dimension description is given in the TABLE 1, various parameters are considered while doing the simulation. For our designing purpose we are using substrate material as Rogers RT/ duroid 5880 (tm) the relative permittivity of which is 2.2 and electric loss angle is 0.0004.

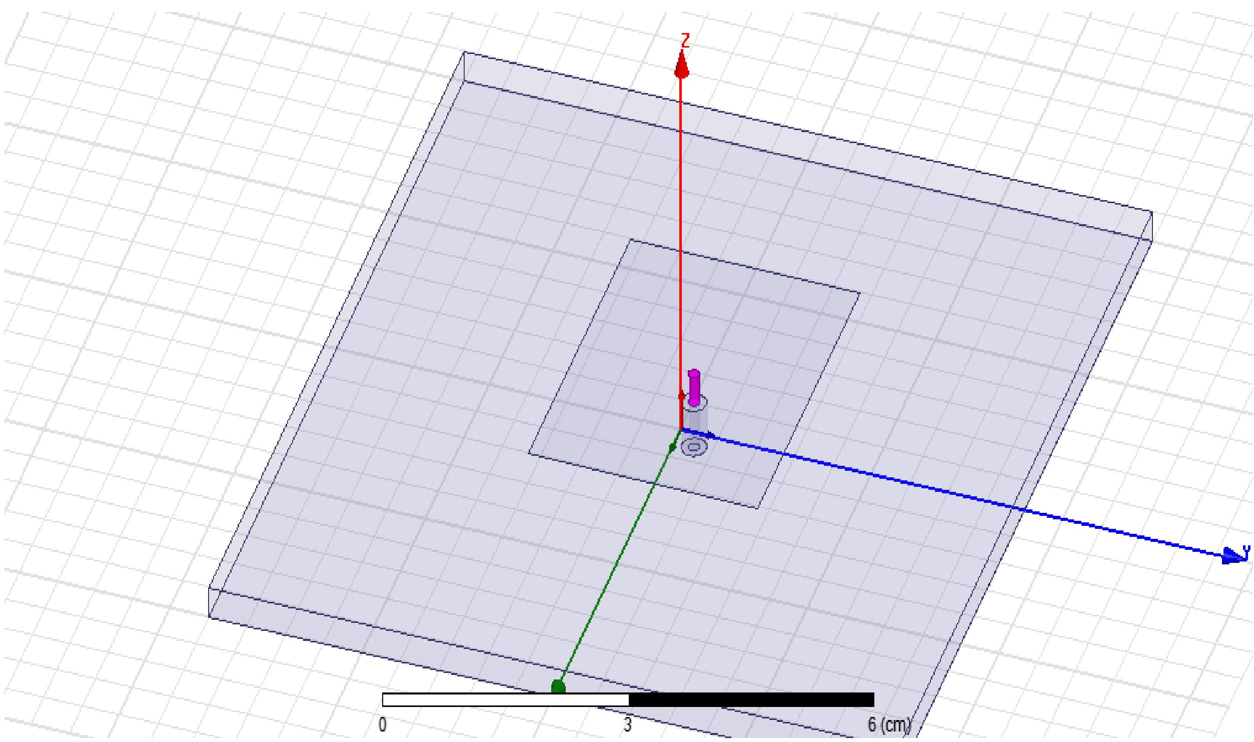


Fig 5.3 Detailed design of rectangular microstrip Patch antenna.

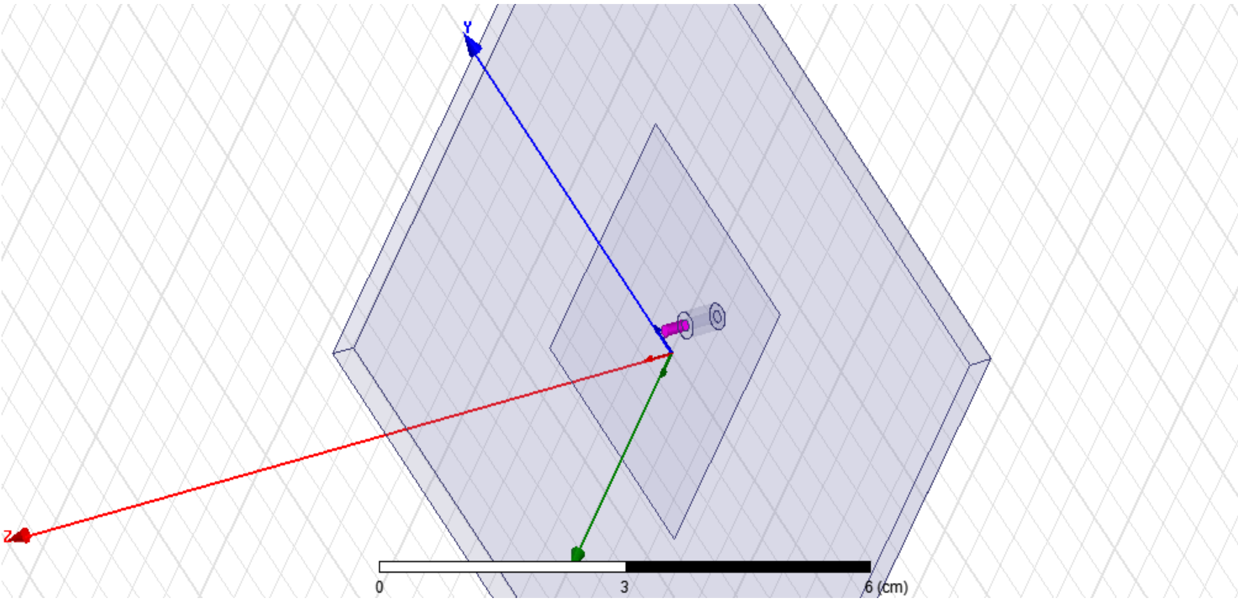


Fig 5.4 side view of rectangular patch antenna.

TABLE 5.1 THE DIMENSION OF RECTANGULAR PATCH AND SUBSTRATE IN CM

	Length (L)	Width(W)	Hight(H)	ε_r
Patch	6.0	4.5	0.32	2.2
Substarte	15.0	13.5	0.32	2.2

After designing substrate and the patch next we will provide some excitation .For providing execution we will use Probe Feed Technique. For that we are using coaxial cable of material Pic with dielectric constant 1.The detailed description of coax and probe is given in TABLE 2.

TABLE 5.2 THE DIMENSON OF COAXIAL PROBE CABLE IN CM

	Radius	Hight	ε_r
Coax cable	0.66	0.5	1
Coax Pin	0.57	0.5	1
Probe	0.57	0.32	1

5.1.3 Design Results

The simulation is done in HFSS (High Frequency Structural Simulator).The simulated result of S11 scattering parameter (return loss) of single element rectangular microstrip antenna is presented in figure 5.5.

On the basis of different techniques a Rectangular Probe Feed Patch antena has been designed and this prototype is improved by applying those techniques.

The return loss of Rectangular patch antenna is shown in fig.5.5 which shows that it resonates at 2.365 GHz frequency. These resonant frequencies give the measure of the impedance bandwidth characteristic of the patch antenna[3]-[5].

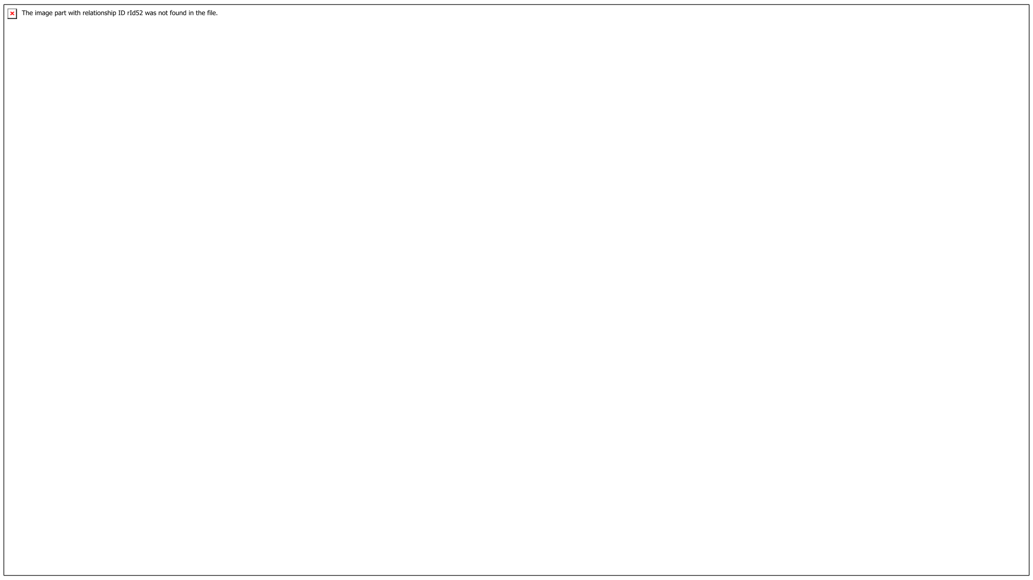


Fig 5.5 Scattering parameter at different frequencies of operation.

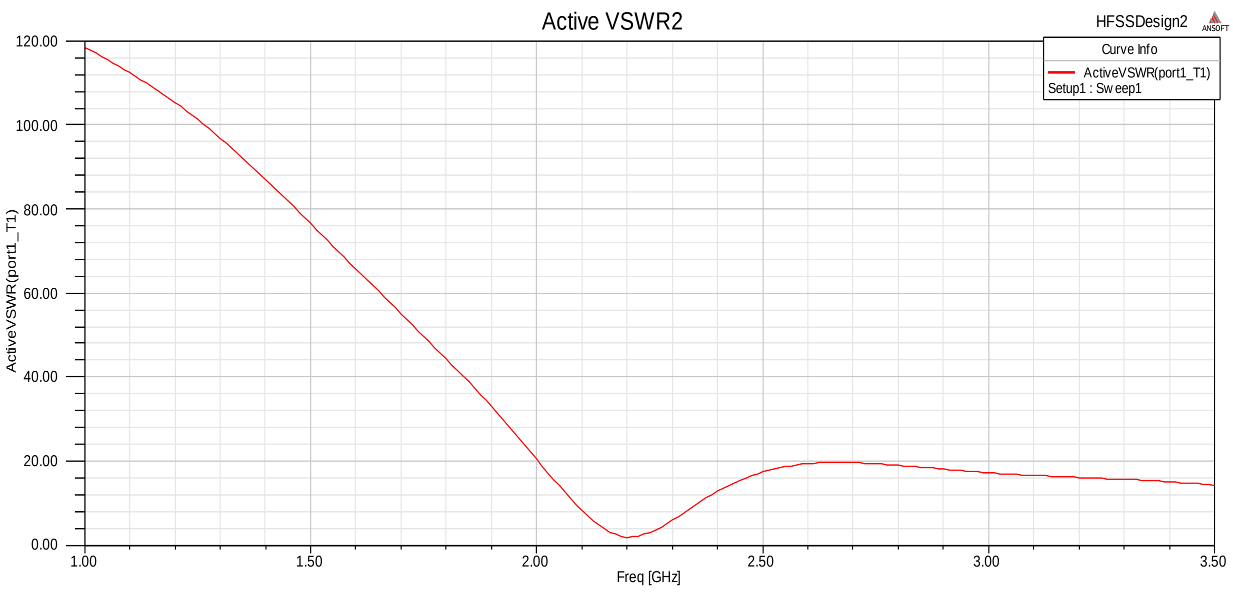


Fig 5.6 VSWR plot for the antenna.

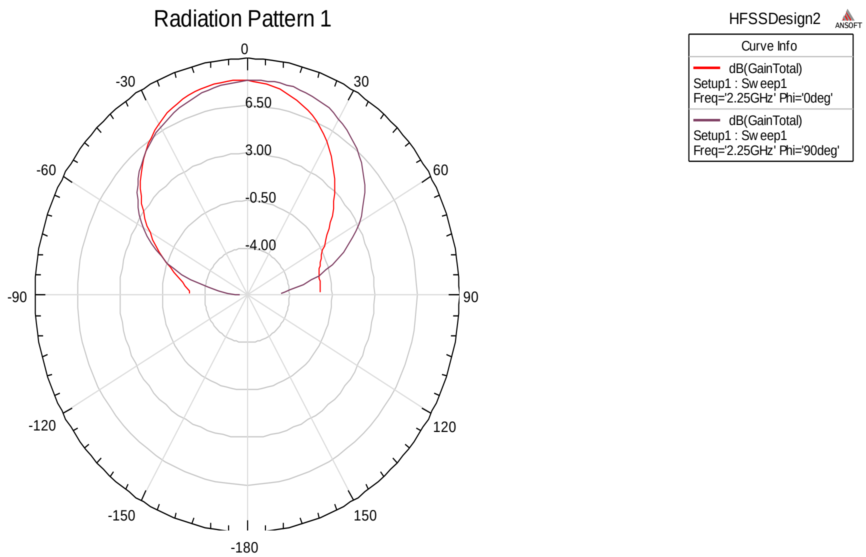


Fig 5.7 Radiation Pattern of Ractangular patch antenna.

5.1.4 Conclusion

Small-size Microstrip antenna for WLAN Application using probe feed is proposed and successfully implemented. In summary, the antenna presented in this paper possessed the most suitable far-field patterns for WLAN application. From the results (figure 4.1to figure 4.4) it is found that for antenna operating at the resonant frequencies, the resulting far-field patterns in the horizontal plane were as expected from a typical microstrip antenna and is most suitable for WLAN application.

This proposed microstrip antenna enhanced the impedance bandwidth and provides good matching. This antenna is simulated by HFSS.

5.2 E shaped Microstrip Patch antenna WLAN Application Using Probe Feed.

In this design a microstrip patch antenna with very high gain and compact size with high directivity is introduced. All the geometrical calculations are done by using basic parametric equation of patch antenna discussed in chapter 4.

5.2.1 E shaped Antenna Geometry for Probe Feed

In this paper, the well known technique of an E shaped patch used for a wide band width. An E-shaped patch antenna is easily formed by cutting two slots from a rectangular patch [4]. By cutting the slots from a patch, gain and bandwidth of microstrip antenna can be enhanced. For this proposed antenna, size of ground plane is (L X W) 76 X 88 mm and thickness of dielectric substrate is 6.7 mm with r = 2.2.The geometry of E shaped patch antenna is shown in table 1. 1

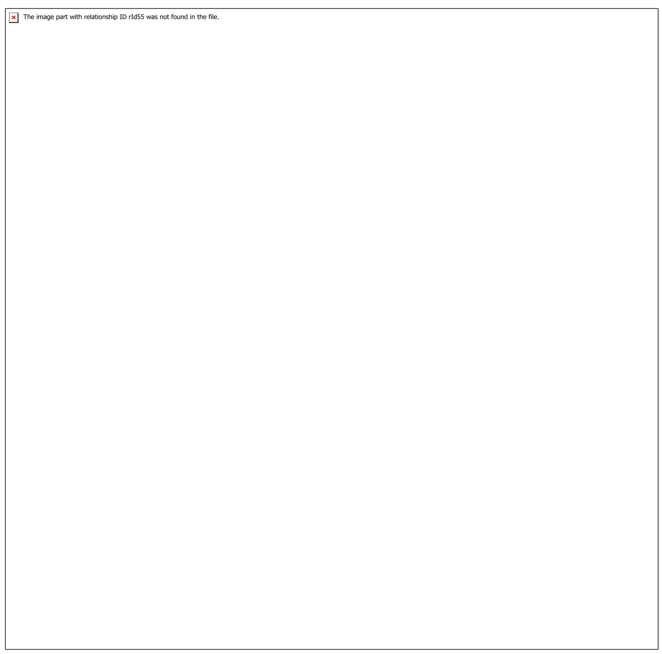


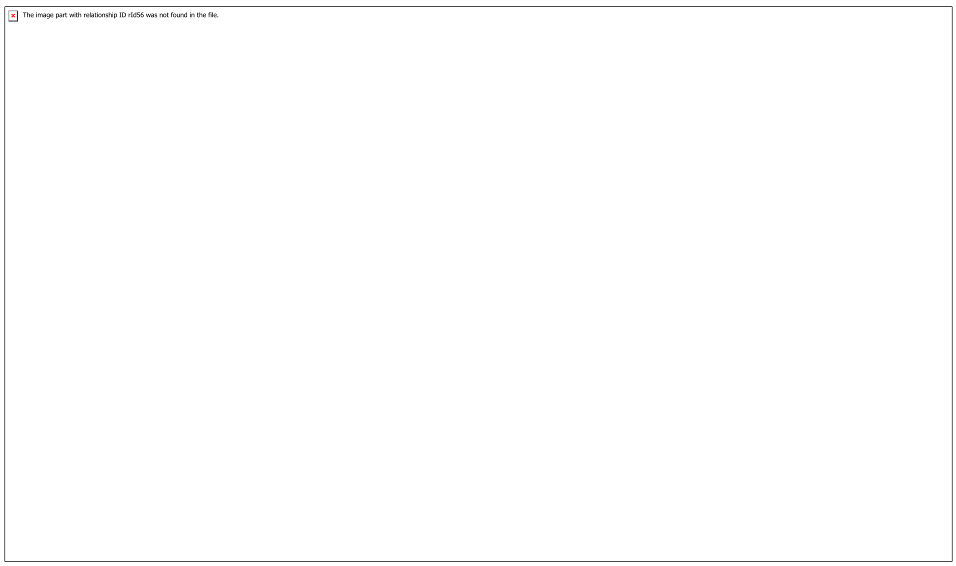
Fig 5.8 Geometry of E shaped patch Antenna.

Table 5.3 Dimensions of patch in MM.

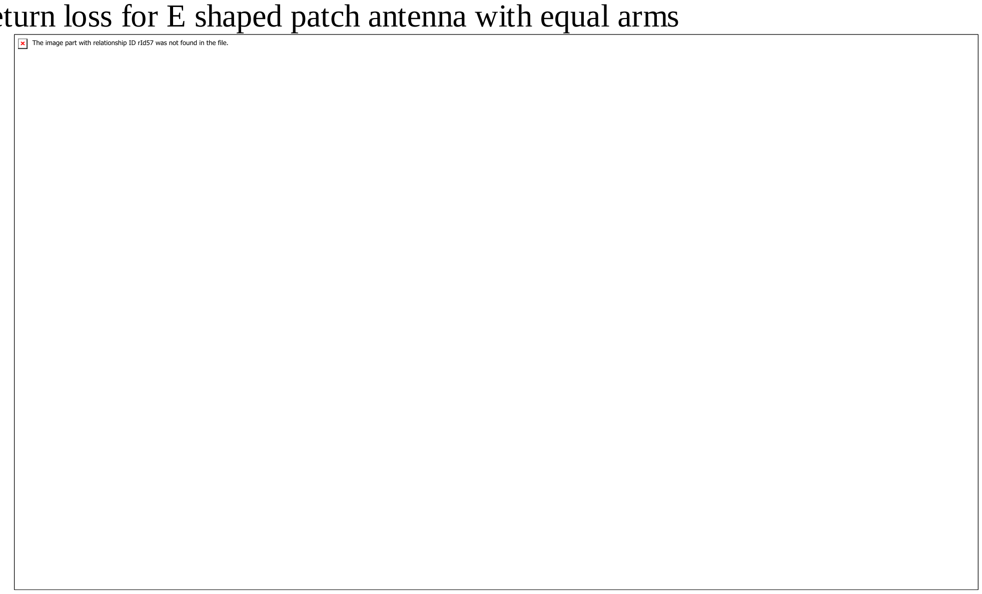
W	L	Ws	SL1	SL2	P	F	H	ε_r
48	36	6.3	30	30	11.4	9	6.7	2.2

5.2.2 Design Results

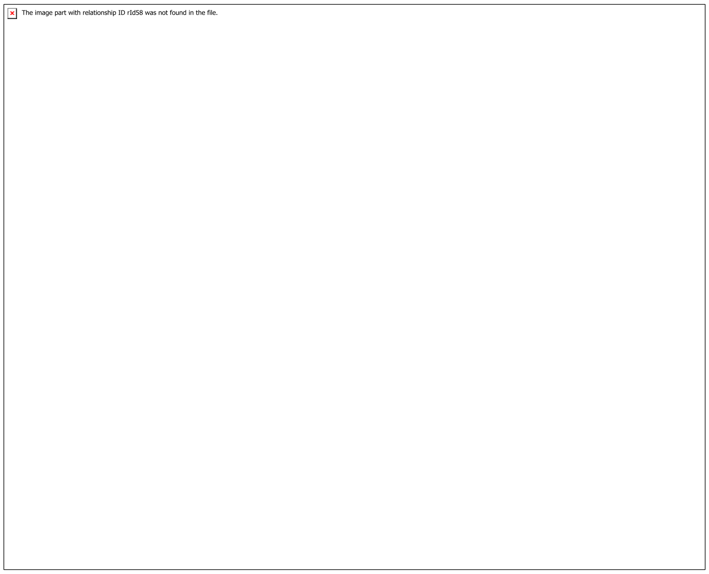
This E shaped patch antenna provides a 7.8 % (2.34 - 2.53 GHz) impedance bandwidth with 5.8 dB gain. The figure 5.9 is showing the return loss in dB and smith chat for equal size of slots in patch. The E shaped patch antenna is designed here, has -33 dB return loss. The gain curve is shown in figure 5.9. This antenna provides good VSWR (~1.02). When the slot SL1 gets shorter, it forms the unequal slots E shaped patch antenna as shown in fig 5.9 [15]. This unequal E shapedpatch antenna provides circular polarization. This antenna provides 16.4 % (2.15 GHz-2.53 GHz) impedance bandwidth at -10 dB return loss and 6dB gain[5]-[8].
The figures are showing the return loss in dB and smith chat for unequal length of slots in patch. The E shaped patch antenna designed here has near about (-32) dB return loss. The gain curve is shown in figure 5.9, this antenna provides good VSWR (~1.5) . Table 2 shows simulated results.

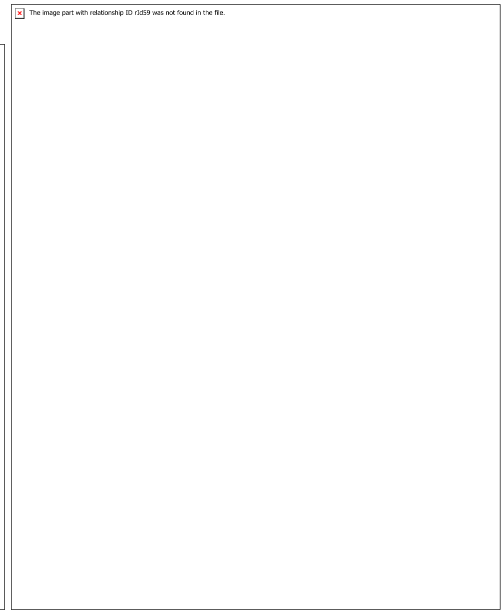


(a) Return loss for E shaped patch antenna with equal arms

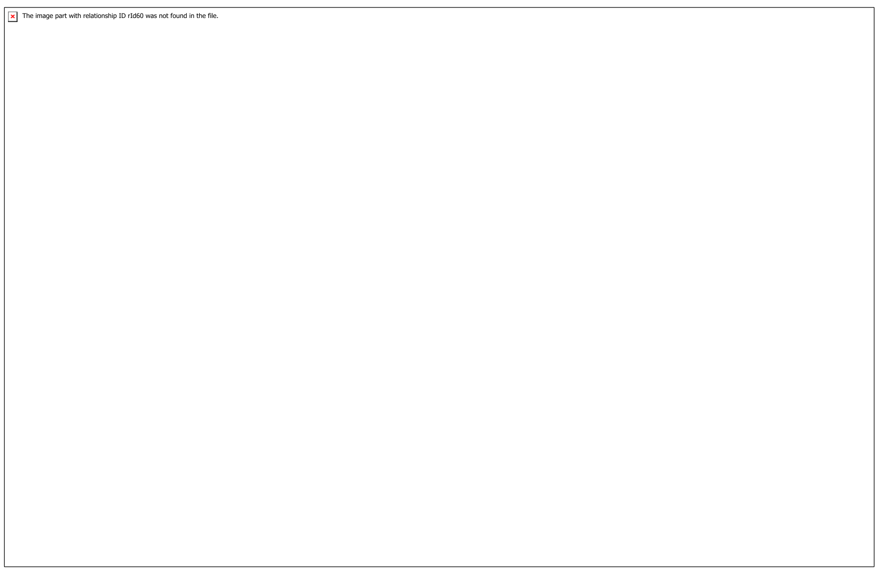


(b) Return Loss for E shaped patch with Unequal arms.





(c) Smith chart and Gain plot for E shaped patch antenna.



(d) Gain plot for Unequal arms E shaped patch.

Fig 5.9,(a),(b),(c),(d),Return loss and gain Plot of E shaped patch antenna.

TABLE 5.4. Simulated Results for E shaped Probe Feed Patch Antenna

Patch shape	Frequency	Gain	Return Loss	Band Width
E shaped patch	2.45GHz	5.6dB	-33dB	7.8%
Eshaped patch with unequal arms	2.43GHz	6dB	-31.2dB	16.4%

5.2.3 Conclusion

An E shaped microstrip patch antenna is designed and by observing the simulated results we can say that antenna is resonating at 2.45 GHz .which is most suited for WLAN application .From the above obtained results we can say antenna is resonating at 2.45GHz ,and antenna will be used in WLAN application. The design is simulated in HFSS.

A small-size Microstrip antenna for WLAN Application using probe feed and aperture feed is proposed and successfully implemented. From the comparative study of different configurations of feeding techniques, it is concluded that unequal slot in patch provides a bandwidth of 16.4 % with 6 dB gain and near about 1.06 VSWR and an aperture coupled feed microstrip antenna provides a bandwidth of around 24% with 1.04 VSWR.

This proposed microstrip antenna enhanced the impedance bandwidth and provides good matching. This antenna is simulated by HFSS’11.

5.3 Design of a Dual-Band Microstrip Patch Antenna for GPS,WiMAX and WLAN.

5.3.1 Introduction

A multi band microstrip patch antenna has been designed for GPS,WiMAX and WLAN applications. The proposed antenna is designed by using substrate of RT duroid having permittivity of about 2.2 and loss tangent of 1.The substrate is having thickness of 6mm at which a trapezoidal patch antenna with V slot has been introduced in this paper. The designing results like S11 parameter return loss, VSWR and field pattern is plotted successfully. The obtained result is having a two band resonance with S11 less then -10dB and VSWR less than 2. So a dual band trapezoidal microstrip patch antenna has been designed and all results are plotted. Simulating software used is IE3D.

Wireless local area networks (WLAN) are widely used worldwide. The 802.11a standard uses the 5-GHz band which is cleaner to support high-speed WLAN. However, the segment of frequency band used varies from one region of the world to another[16][17]. Dual frequency microstrip antennas with a single feed are required in various radar and communication systems, such as global positioning system (GPS), WiMAX,WLAN etc[11].

These communication system applications include fixed broadband local multipoint communication services, small mobile units, laptops and remote-sensing devices [12]. Also, bandwidth should be further enhanced in order to increase the information transfer rate, without sacrificing the performance[14]. There are lots of communication schemes that make use of the large operational bandwidth[18][19]. For example, the Orthogonal frequency-division multiplexing (OFDM) scheme transmit and receive signals with a number of frequency components [13]-[15]. Another example is the transmission of broadband pulse radiating edge.

In this paper, we design a trapezoidal patch with V-shaped antenna which works as a dual frequency. First resonance frequency f1 centered at 3.5 GHz frequency is due to its patch itself. Second resonant frequency f2 is due to V-shape slot, which is centered at 5.0 GHz.

5.3.2 Antenna Structure

The configuration of proposed antenna is shown in figure 1. The antenna consist of a trapezoidal microstrip patch with V-shaped slot, support on a grounded dielectric sheet of thickness h and dielectric constant ε r. The trapezoidal patch has an upper side of length L1, base of trapezoidal patch of length L2 and height of trapezoidal patch of length W1, W2. V-shape slot has a length of L3, L4 and a width of W3, W4 which is loaded on trapezoidal patch. The feed point is located at the central line of the patch, with a distance of d f (x.y) from the bottom edge of trapezoidal patch.The dimension of trapezoidal patch with V-shape slot are tabulated in table 1.

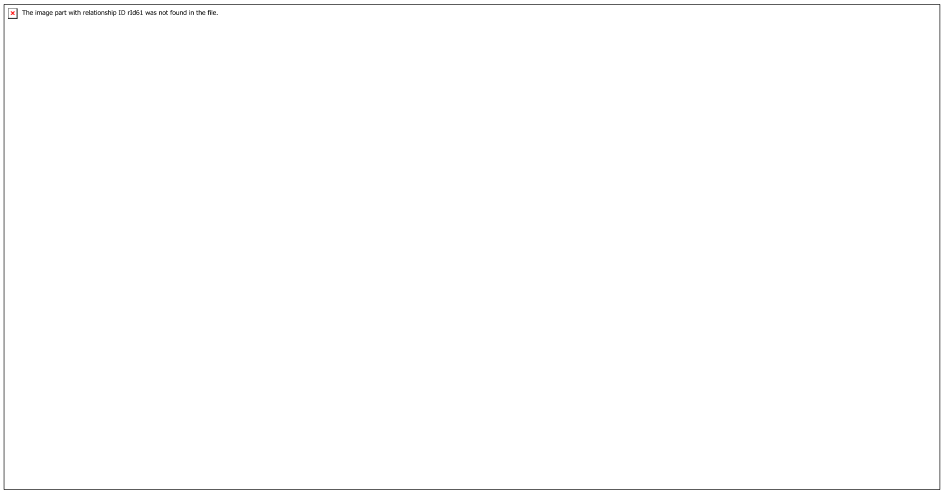


Fig.5.10: Geometry of proposed antenna

Table 5.5. Dimension of proposed antenna

S.no	**Parameter**	**Value(mm)**
1	L1	30
2	L2	26
3	W1,W2	21.04
4	L3,L4	0.5
5	W3,W4	1.5
6	ε r	2.2
7	h	6

The proposed antenna is designed and simulated by using IE3D software. All the proposed design parameters are calculated by using conventional formula for patch antenna design process.

5.3.3 Design Results

In this section, the simulated results of various parameters like VSWR, Return loss, input impedance and radiation characteristics of proposed antenna are presented and discussed. The simulated results are obtained using IE3D Simulator.

5.3.3.1 Return Loss or S11 Parameter

The simulated result for the return loss less than -10dB is shown in figure 2. From simulated result we get dual band. Based on a -10 dB return loss, 4% impedance bandwidth is obtained at first resonant frequencies f1 in the frequency range (3.41-3.57) GHz and 15.6 % impedance bandwidth is obtained at second resonance frequencies in the frequency range of 4.75-5.53 GHz.

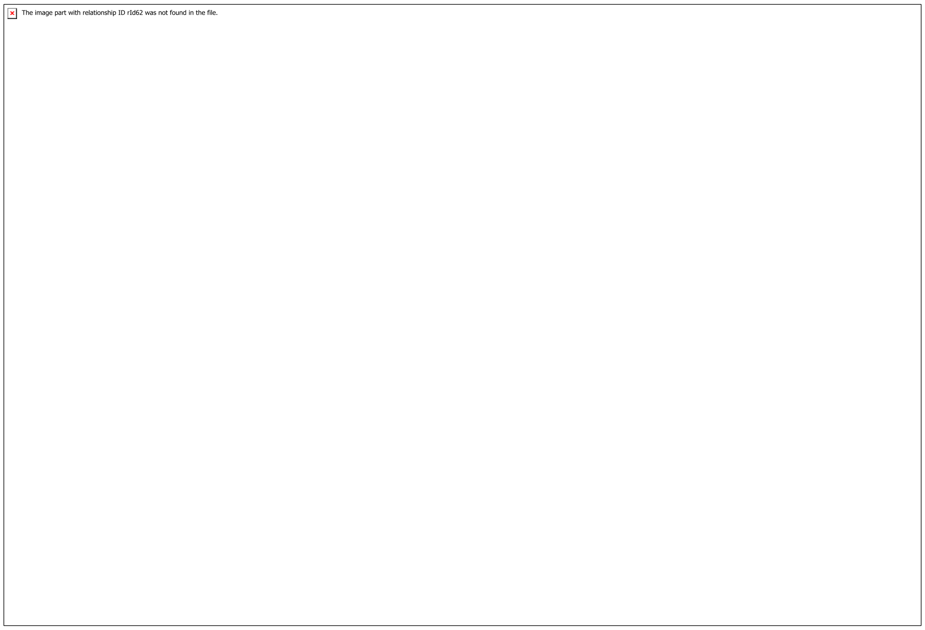


Fig. 5.11: Return loss

VSWR plot shows that the VSWR occur at first resonant frequency is 1.66 and second resonant frequency is 1.07. This depict that there is good impedance matching between probe-fed microstrip transmission line and the trapezoidal radiating element.

5.3.3.2 Input Impedance

The simulated result for the antenna input impedance is plotted in figure 4. It is shown that the real part of the input impedance at first resonant frequency f1 oscillates around 74.83Ω with frequency while the imaginary part of the input impedance at resonant frequency oscillates around 0Ω with frequency.

At second resonant frequency f2, the real part of the input impedance at resonant frequency oscillates around 50Ω with frequency while the imaginary part of the input impedance at resonant frequency oscillates around 0Ω with frequency. Hence, from the graph it is clear that there is proper matching occur at both resonant frequencies.

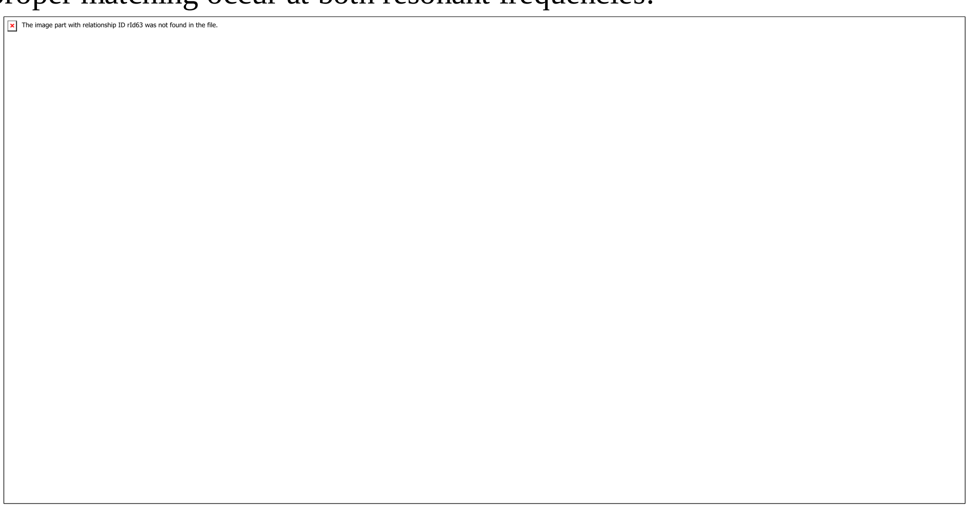


Fig. 5.12: Real part and imaginery part of input impedance

5.3.3.3 Radiation Pattern

From figure below Shows the measured radiation pattern at first resonant frequency 3.5 GHz. it can be observed that in the ϕ=0 plane, the cross polarization is -13 db below the co polarization above the ground plane. In the ϕ=90 plane, the cross polarization is -19.3 dB below the co polarization level.

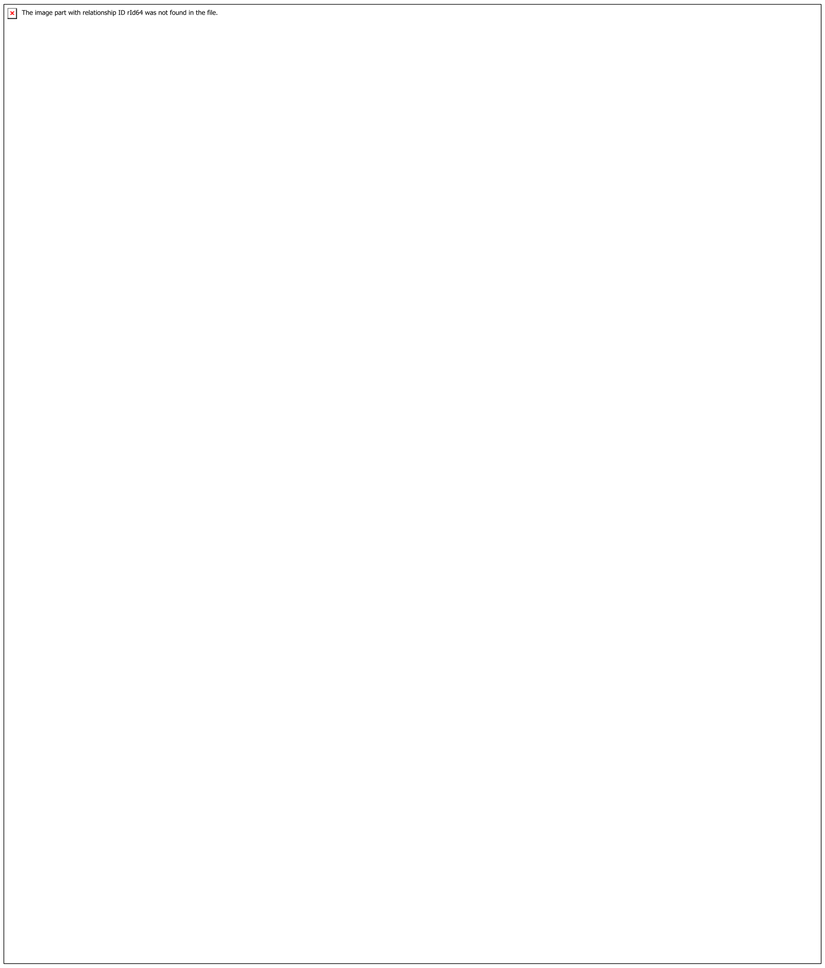


Fig. 5.13: Radiation pattern at 3.5 GHz

Table 5.6. Simulated data

Resonant frequency	F1	F2
Centre frequency	3.5 GHz	5 GHz
bandwidth	4.95	15.6%
Frequency range	(3.41-3.57)GHz	(4.75-5.53)GHz
Return loss	-12.8 dB	-29.37 dB
VSWR	1.66	1.07

5.3.3.4 Conclusion

The dual frequency and wide-band operation of a trapezoidal patch with V-shaped slot have been studies and simulated. The proposed antenna is compact, occupies small volume and has simple structure compared to other antenna design. The antenna offer a 2:1 VSWR bandwidth of 4% from frequency range (3.41-3.57)GHz at first resonant frequency which cover 3.5 GHz band WiMAX applications. second resonant frequency cover the WLAN(5.15-5.35) band application with impedance bandwidth 0f 15.6%.the simulated return loss, VSWR, radiation pattern and gain showed well performance.

5.4 Multiband Microstrip Patch Antenna for Wireless Communication Systems.

5.4.1 Introduction

In this design a multiband microstrip patch antenna Design has been introduced which is a simple planer asymmetric C shaped microstrip patch.This patch antenna is designed on Sustrate of RT duroid having permitivty of 2.2.The thickness used for substrate is 0.25mm.The antenna is designed and all the results are ploted by using simulating software HFSS.Return loss,VSWR and field pattern of the designed one is ploted and found three band of operation having S11 less than -10dB and VSWR less than 2.The antenna designed antenna is having compact size and operation in WLAN,WiMAX and in ISM Band communication.Antenna is having very good polarization ratio and gain bandwidth.Operating band width is found around 300MHz[18]-[24].

5.4.2 Proposed Antenna Geometry

A modified c shaped microstrip patch antenna has been proposed here which is a multi band and multi operational antenna with very good impedance band width. The proposed antenna is designed with a substrate of Rogers RT/ duroid 5880(tm) having thickness of h=0.25mm.THE substrate used is having dimension of W=40mm and L=35mm.Proposed antenna is having following new geometry.

1st The detailed dimensions are given in the table below all of which are calculated by using conventational relationship bitbeen W and L and all the material constants.

The Detailed dimensions are given in the below table, where all the dimensions are in mm.

Table 5.7: *the detailed Dimensions of the modified C shaped patch*.

L1	2mm
L2	7mm
L3	12mm
W1	6mm
W2	7mm
W3	1.5mm

The proposed geometry is given in below figure

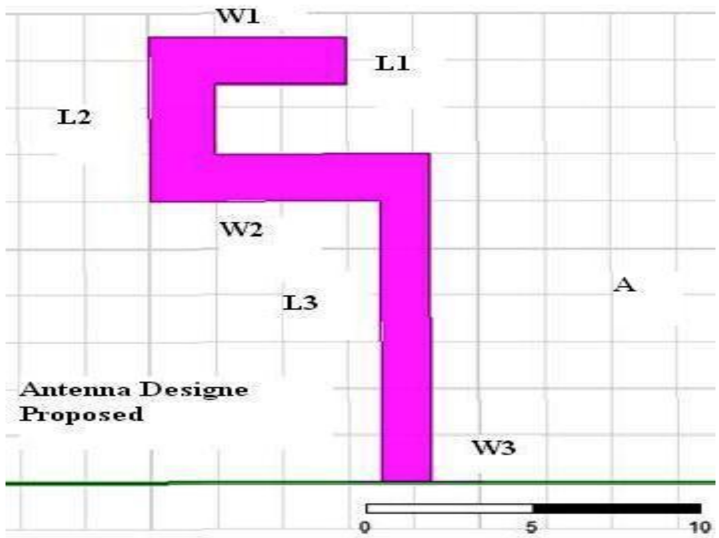


Fig no 5.14 Design of Proposed C shaped Patch.

The proposed shape is designed by using HFSS modular and the final result is obtained by simulating the same by using HFSS simulator.

5.4.3 Design Results

When designed antenna is simulated in HFSS then following results were observed.Plote of returnloss and VSWR is given below. BY seaing the overall response of antenna for s11 parameter and VSWR.A multiband antenna has been designed.

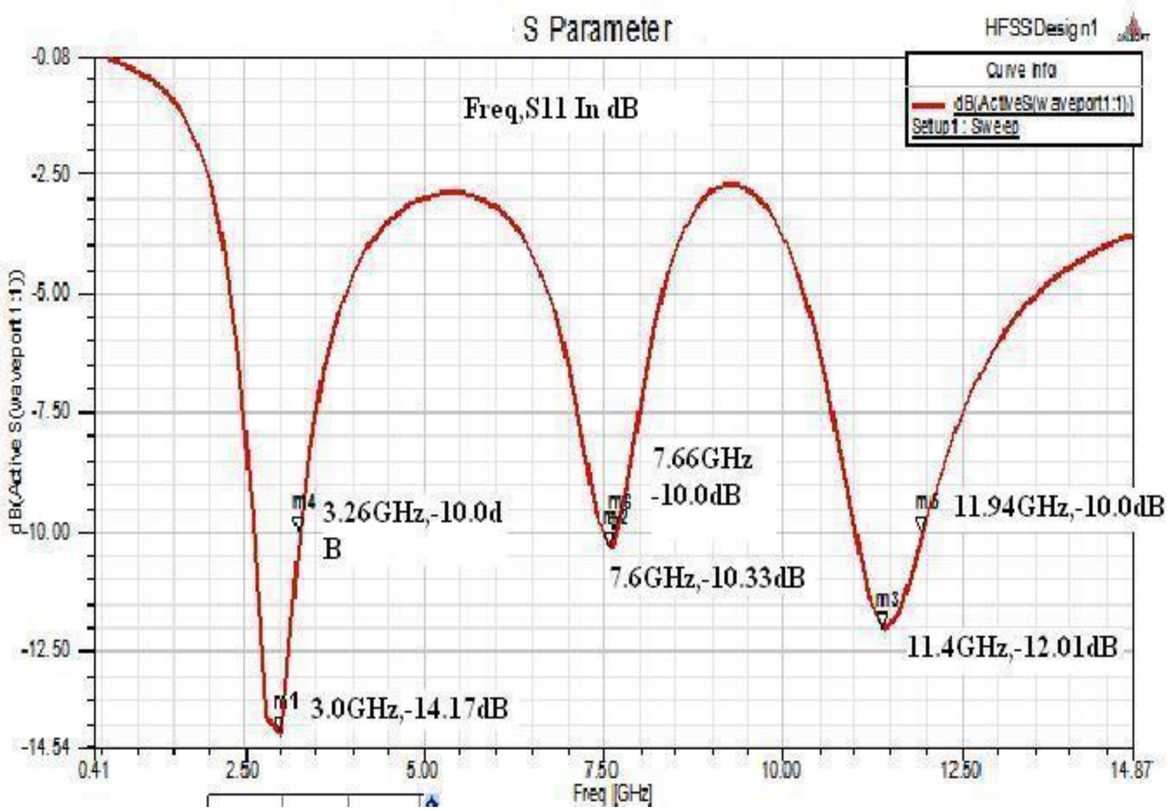


Fig 5.15 *S11 parameter*

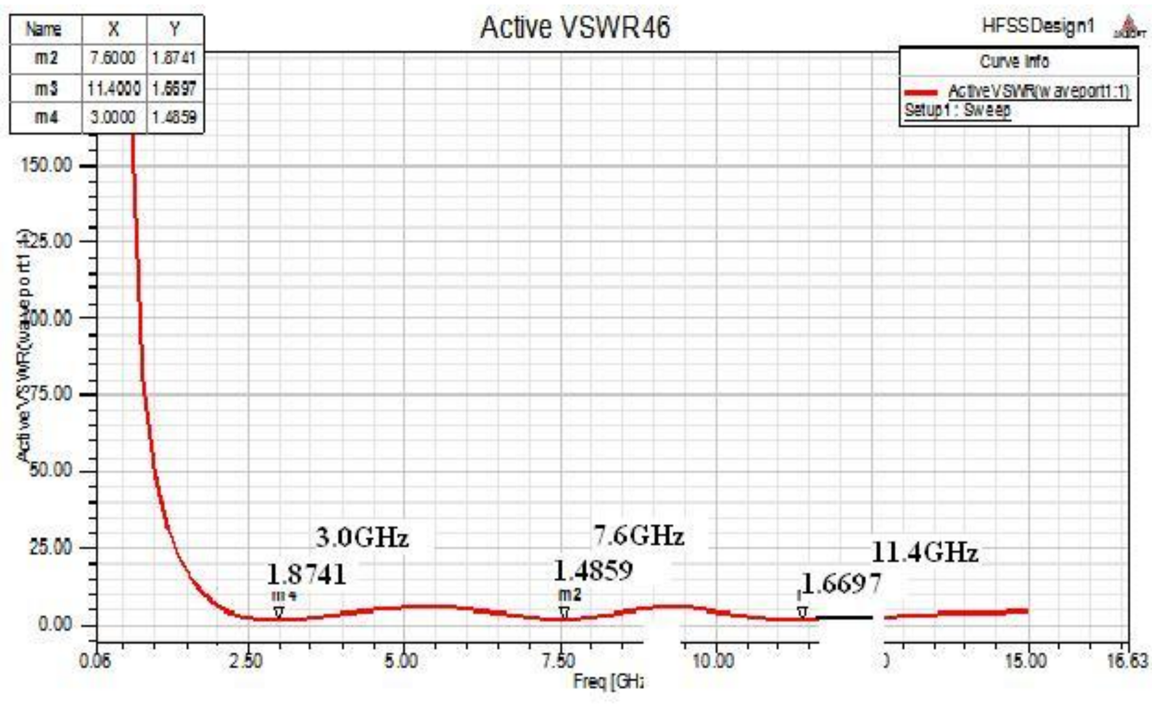


Fig 5.16 VSWR (Frq, VSWR)

From the above obtained results we can say that The designed antenna is having three band of operations which is having three band of operation. Obtained S11 parameter at all these frequencies is having values less then -10dB.Value of VSWR at all these three resonating frequency band is also less than 2 and greater then 1.So we can say that designed antenna is resonating at 3 different resonating frequencies. All these Frequencies have its own operation. The obtained result is also listed in the table below.

Table 5.8: detailed designed simulation results.

Frequency	S11	VSWR
3.0GHz	-14.17 dB	1.485
7.6GHz	-10.33 dB	1.8741
11.4GHz	-12.01 dB	1.669

5.4.4 Conclusion

1st it is resonating at 3GHz which is near to ISM band and also the same band is applicable for lower WiMAX band application. The antenna is having return loss of -14.1772dB at 3GHz with impedance band width of approximately 300MHz .similarly at 7.6GHz having S11 of -10.3361dB with band width of 300MHz and at 11.40 GHz s11 is -12.0183dB with band width of 300 MHz

This designed antenna is the new one proposed and simulated on HFSS also results are checked mathematically, both results are approximately same.

This antenna can be used in various ISM band communication, can be used as a fixed antenna service and as a satellite antenna at the same time. More number of operations like WLAN,WiMAX,ISM band communication can be done by using same antenna system.

5.5 Microstrip Patch Antenna for Ultra Wide Band Application and Smart Grid.

The Federal Communication Commission (FCC) releases ultra-wide band (UWB) from 3.1-10.6 GHz in 2002 for the use of indoor and hand-held systems [13].

UWB ultra wide band is quite important for much mobile application, other than that a band for smart grid application is also introduced for high data rate communication, being used in smart grid technology. The band for smart grid technology is 11GHz – 18GHz.

5.5.1 Introduction

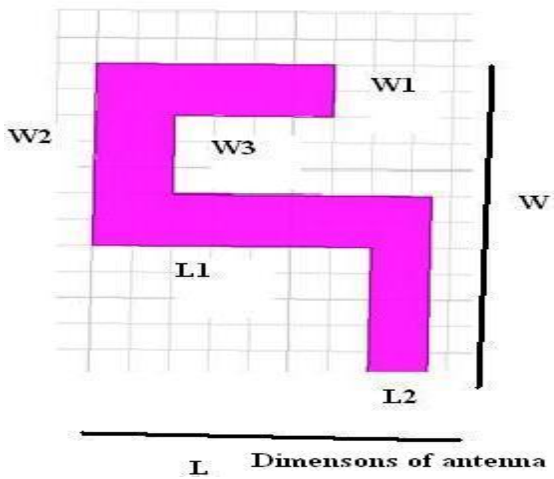
As wireless communications applications continue to require more and more bandwidth, there has been continued increase in demand for ultra-wide bandwidth antennas. Planar monopole antennas are generally suitable for mobile applications and hence we researched avenues to improve the bandwidth of this antenna structure. In this paper a dual band microstrip patch antenna has been designed. The designed antenna is having a very large impedance bandwidth in UWB region (>100%).The 2nd band is mainly designed for smart grid operation which is from 11-18GHz.The antenna is a simple planer asymmetric C shaped microstrip patch antenna printed on substrate of FR4 having permittivity of 4.4.The return loss of both the resonating frequency band is very less(<-10dB).Antenna is designed by using high frequency structure simulator HFSS. All the desired results are plotted and discussed[22]-[26].

The antenna presented in this design is designed for two specific operations, one is for UWB application and another is for application in smart grid technology.1st band of antenna is 3.2GHz to 8.6GHz having band width of 5.4GHz, all this band is in UWB band region.2nd band is from 13.6GHz to 18GHz which is in smart grid band application. The return loss of up to -16dB in 1st band and up to 29dB in 2nd band is obtained with very wide band width. All the geometrical details and results are discussed in the section below. The antenna presented here is having radiation total efficiency of 0.9207 or 92.07% which is very good one.

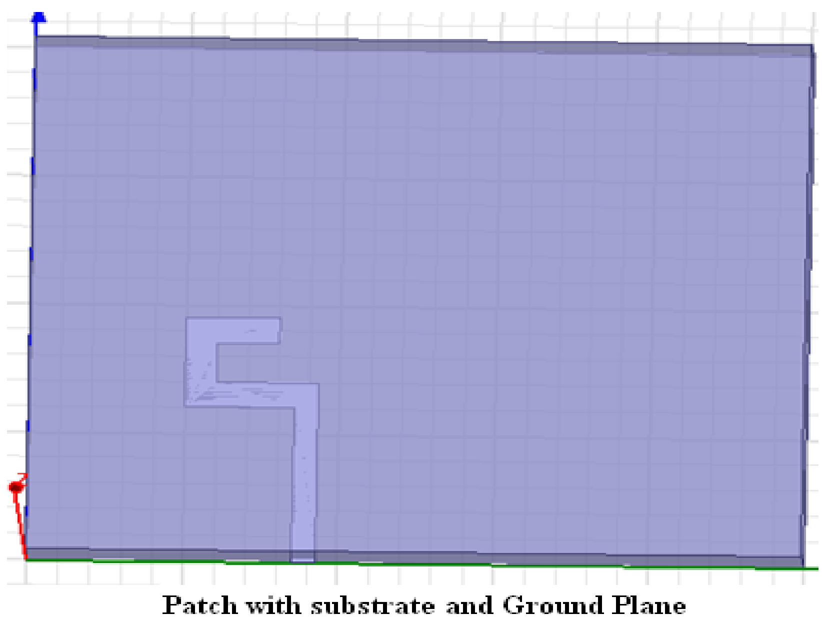
The aim of this research was to design a novel UWB planar Antenna that fulfills the criteria of UWB while keeping the Physical characteristics into consideration.

5.5.2 Antenna Geometry

Proposed antenna which an ultra wide band antenna is a planer structure of asymmetric C shaped printed on a substrate of FR4 having permittivity of 4.4 and thickness of 6mm.The geometrical diagram is given in figure 1 below. All the dimensions indicated are in mm. All these dimensions are calculated using basic patch antenna parameter and designing equations. The governing parameter for impedance band width is mainly thickness of substrate and its permittivity.



(a)



(b)

Fig.5.17.(a),(b)Geometry of proposed patch antenna with dimensions.

In general planar slot antennas two parameters affect the impedance bandwidth of the antenna, the slot width and feed structure. The wider slot gives more bandwidth and the feed structure gives the good impedance matching. Basically unequal arms in patch antenna is given for producing unequal current distribution which results in multiple number of tuned resonating frequency bands[26]-[32]. The enhanced band width is mainly due to substrate used with more thickness. Compact size of antenna with very less head radiation is more suitable for today's mobile communication with UWB capability.

5.5.3 Design Results

Return Loss and VSWR

The simulated result for the return loss less than -10dB is shown in figure 2. From simulated result we get dual band. Based on a -10 dB return loss,1st band is having impedance band width of 5.4GHz which is 84.37%,and 2nd band is having impedance band width of 4.4GHz which is 28.57% of resonant band

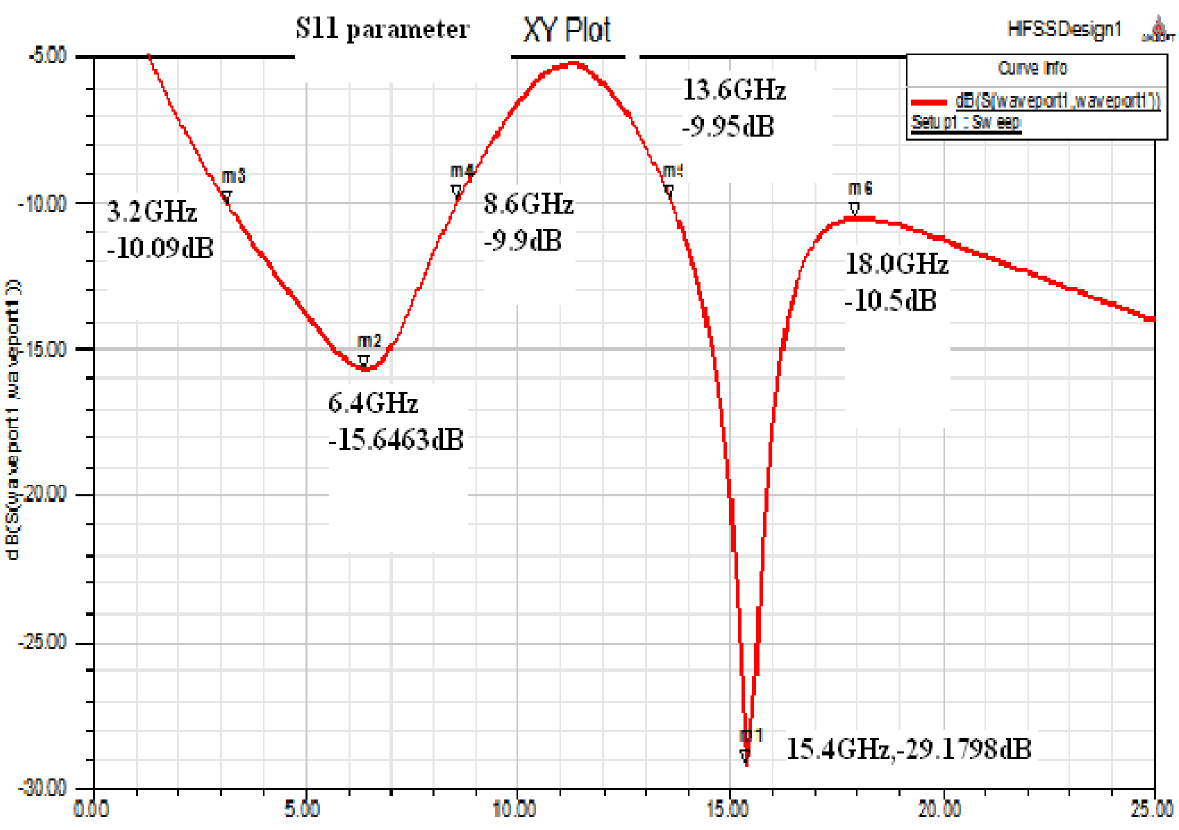
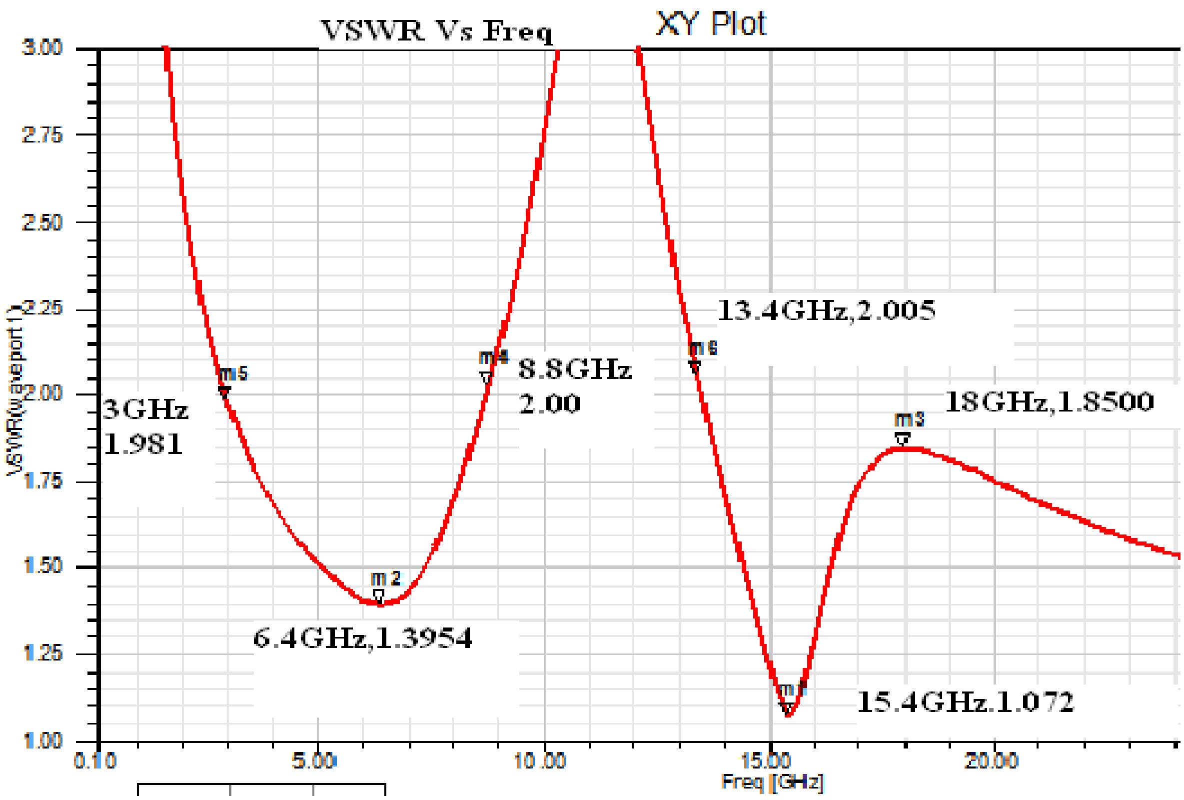


Fig.5.18 (a)S11 parameter Return Loss Of proposed antenna.

Return loss at 1st resonant frequency is -15.6463dB and for 2nd band is -29.1798dB.2nd band gives better matching between load and the antenna.

VSWR plot for the same antenna is presented here in figure 2 (b).Which is obtained by HFSS simulator.



5.18 (b) VSWR parameter.

Fig.5.18 (a),(b) S11 parameter and VSWR parameter.

Proposed antenna is having VSWR at 1st resonating frequency is 1.3954 and same at 2nd resonating frequency is 1.072 .From 3GHz to 8.8 GHz in 1st band and from 13.4 GHz to 18 GHz in 2nd band is having VSWR between 1 and 2.This depict that there is good impedance matching between feed and microstrip transmission line and the proposed C shaped radiating element. The entire band width discussed for s11 parameter is also having VSWR less than 2 and more than 1 it mins the proposed antenna will provide better matching between radiating element and load[30]-[33].

Very good return loss and VSWR is obtained at the frequency band defined in 1st band as well as in 2nd band.1st band can be used for ultra wide band communication system which is from 3.1GHz to 10.6 GHz as defined in [31]-[35],the proposed antenna is providing 72% of total available UWB for application. The 2nd band obtained can be used for smart grid technology band which if from 11 GHz to 18GHz.Out of total 7GHz band in smart grid band 4.4GHz band is provided by the proposed antenna which is 62.85% of total available smart band.

5.5.4 Conclusion

The proposed antenna is having very good resonating band in UWB from 3.2GHz to 8.6GHz and in Smart grid band allotted from 13.6GHz to 18GHz.In smart grid applications the antenna is having very good gain and return loss. Smart grid is an advance technology for power transmission. A smart grid, an updated electrical grid that includes wireless technology and smart meters, is needed for energy efficiency and security. In addition to reducing pollution and power outages, smart grids utilize real-time communication to optimize the delivery and storage of energy and prevent loss. To accomplish these goals, the electrical industry must modernize by using current technology that facilitates communication on the electrical grid.

Proposed antenna is best suited for the applications mentioned above.Gain, directivty, return loss and VSWR all are in mentioned limit for radiation. Proposed antenna is having gain of about 6dB.

The antenna design and simulation was carried out using ANSYS' HFSS software which is the industry-standard simulation tool for 3-D full-wave electromagnetic field simulation.

5.6 References

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