DESIGN AND SIMULATION OF CIRCULAR PATCH MICROSTRIP ANTENNA USING HFSS SOFTWARE

A

DISSERTATION

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Candidate's Declaration

I, **Rahul Malowa**, Roll No. **2K13/MOC/08**, student of **M. Tech** (**Microwave & Optical Communication**), hereby declare that the dissertation titled **"Design and simulation of circular patch microstrip antenna using HFSS software"**, under the supervision of **Prof.P.R.CHADHA H.O.D** of Electronics and communication Engineering, Delhi Technological University, in partial fulfilment of the requirement for the award of the degree of Master of Technology, has not been submitted elsewhere for the award of any degree.

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

Place: Delhi
Date: 15.07.2015

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Certificate

This is to certify that the dissertation entitled **“Design and simulation of circular patch microstrip antenna using HFSS software ”** submitted by **Rahul Malowa** in completion of major project dissertation for Master of Technology degree in **Microwave and Optical Communication** at Delhi Technological University is an authentic work carried out by him under my supervision and guidance.

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

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Abstract

Communication plays an important role now days and the communication systems are rapidly switching from “wired to wireless”. Wireless communication has developed rapidly in the past decades and it has a dramatic impact on human life. The wireless freedom experienced by consumer electronics, personal computer, handheld devices, and cell phone users are moving into the digital home and office. People want greater freedom and convenience in connecting all types of devices. The answer is Wide band (WB) Technology. This technology will provide the high bandwidth required by the latest and future portable home and office devices for multiple digital video and audio streams.

The future development of the personal communication devices will aim to provide image, speech and data communications at any time, and anywhere around the world. This indicates that the future communication terminal antennas must meet the requirements of multi-band or wideband to sufficiently cover the possible operating bands. However, the difficulty of antenna design increases when the number of operating frequency bands increases. In addition, for miniaturizing the wireless communication system, the antenna must also be small enough to be placed inside the system. However, in order to transmit and receive more information large bandwidths are required, and bandwidth enhancement is currently a popular research area. 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 focuses much effort into the design of a microstrip patch antenna. As is the case in conventional wireless communication systems, an antenna also plays a very crucial role in WB systems. However, there are more challenges in designing a WB antenna than a narrow band one.

This dissertation focuses on WB antenna design. Studies have been undertaken covering the areas of WB fundamentals and antenna theory. Extensive investigations were also carried out on different types of WB antennas.

The antenna discussed in this dissertation is a simple microstrip circular patch antenna which uses a substrate material of FR4 of thickness of 1.59 mm. A partial ground plane is used to get wide impedance bandwidth which results in WB with acceptable return loss and bandwidth over most of the WB frequency band. An unequal E-shaped slot cut out from the radiating patch and a circular arc slot cut out from the ground plane. All the simulations have been carried out using ANSOFT High Frequency Structure Simulator (HFSS).

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LIST OF ABBREVIATIONS

S. No.	**Abbreviation**	**Acronym**
1.	MSA	Microstrip Antenna
2.	MSPA	Microstrip Patch Antenna
3.	ISM	Industrial, Scientific and Medical
4.	FR4 EPOXY	Name of substrate material having dielectric constant 4.4
5.	HFSS	High Frequency Structure Simulator
6.	VSWR	Voltage Standing Wave Ratio
7.	VNA	Vector Network Analyzer
8.	MMIC	Monolithic Microwave Integrated Circuit
9.	FEM	Finite Element Method
10.	1D	One Dimension
11.	3D	Three Dimension

NOTATIONS

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

Chapter – 1

INTRODUCTION

1.1 OVERVIEW

In past decades wireless communication has developed rapidly. In wireless communication systems, antenna is an essential device. Antenna is a transducer which transmits or receives electromagnetic waves. Antenna is a link used between free-space and the energy guiding device which transport electromagnetic energy from the transmitting source to the antenna, or from the antenna to the receiver.

With the advances in telecommunication, the requirement for compact antenna has increased significantly. In mobile communication, the requirement for smaller antennas is quite large, so significant developments are carried out to design compact, minimal weight, low profile antennas for both academic and industrial communities of telecommunication. The technological trend has much focused in the design of microstrip patch antennas because of its simple geometry as well as capabilities of maintaining high performance over a large spectrum of frequency. The variety in design that is possible to microstrip antenna probably exceeds that of any other type of antenna element.

This chapter first provides an introduction to microstrip patch antennas with their advantages and disadvantages, then feeding techniques, analysis method, different parameters of microstrip patch antenna, introduction of circular patch antenna and overview of software used in designing the antenna are presented.

1.2 MICROSTRIP PATCH ANTENNA

The concept of microstrip radiators was first proposed by Deschamps [1] in 1953. However, practical antennas were developed by Munsion and Howell [2], [3] in 1970s. The numerous advantages of MSA, such as its light weight, small volume, and ease of fabrication using printed-circuit technology, led to the design of several configurations for various applications [4]-[6]. With increasing requirements for personal and mobile communications, the demand for smaller and low cost antennas has brought the MSA to the forefront.

A microstrip patch antenna consists of a radiating patch on one side of a dielectric substrate which has a ground plane on the other side as shown in Fig. 1.1.

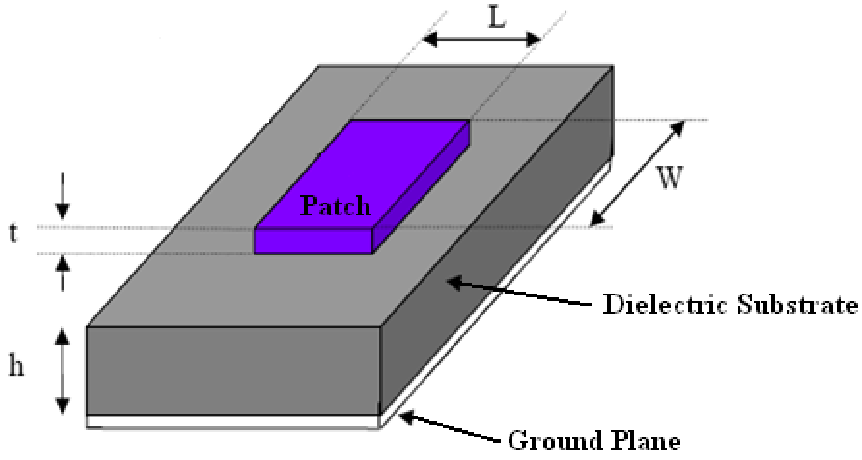


Fig. 1.1 Structure of a microstrip patch antenna [5]

In order to simplify the analysis and performance prediction, the patch is generally square, rectangular, circular, triangular, elliptical or some other common shape as shown in figure 1.2. These are commonly used due to ease of analysis and fabrication. To design 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. Thickness of the patch is selected 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 $2.2 \leq \varepsilon_r \leq 12$ [5].

The radiating patch may be square, rectangular, thin strip (dipole), circular, elliptical, triangular, or any other configuration as shown in Fig. 1.2.

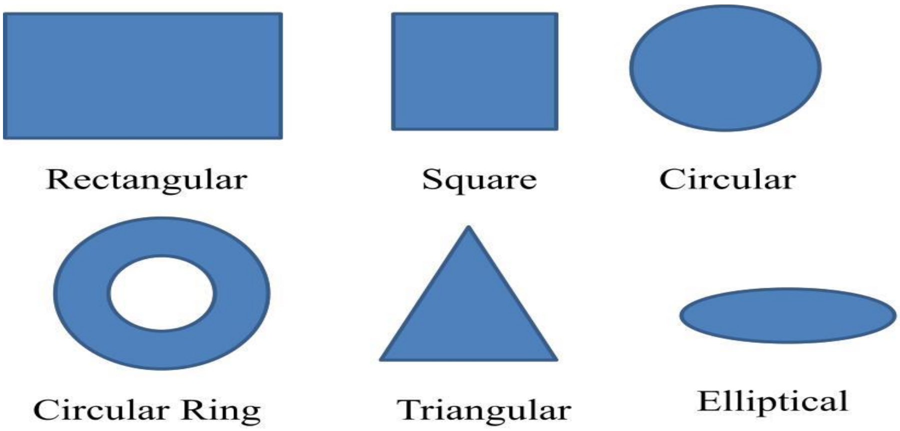


Fig. 1.2 Common patch conductor shapes [6]

Microstrip patch antennas radiate primarily because of the fringing fields between the patch edge and the ground plane. For better antenna performance, a thick dielectric substrate having a low dielectric constant is desirable since this provides better efficiency, larger bandwidth and better radiation. However, such a configuration leads to larger antenna size. In order to design a compact Microstrip patch antenna, substrates with higher dielectric constants must be used which are less efficient and result in narrower bandwidth. Hence a trade-off must be realized between the antenna dimensions and antenna performance [7].

Microstrip patch antennas have a very high antenna quality factor (Q). It represents the losses associated with the antenna where 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. Other problems such as lower gain and lower power handling capacity can be overcome by using an array configuration for the elements.

1.2.1 ADVANTAGES OF MICROSTRIP PATCH ANTENNA

Microstrip patch antennas have several well-known advantages over other antenna structures. Some of their principal advantages are given below:

- Light weight and low volume.
- Low profile planar configuration which can be easily made conformal to host surface.
- Low fabrication cost.
- Feed lines and matching networks can be fabricated simultaneously.
- 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.

1.2.2 DISADVANTAGES OF MICROSTRIP PATCH ANTENNA

As compared to conventional antennas, microstrip patch antennas suffer from many drawbacks. Some of their major disadvantages are given below:

- Low efficiency due to losses in the dielectric substrate.
- Low gain.
- Low power handling capacity.
- Poor radiation pattern due to surface waves which travel within the substrate and scatter at surface discontinuities.
- Require quality substrate and good temperature tolerance.

1.2.3 APPLICATIONS OF MICROSTRIP PATCH ANTENNA

Some typical system applications which employ microstrip technology are given below:

- Satellite communications
- Aircraft antennas
- Missiles and telemetry
- Missiles Guidance Systems
- Environmental instrumentation and remote sensing
- Biomedical Instruments
- Radar systems
- Satellite navigation receiver
- Global positioning system
- Feed elements in complex antennas.

1.3 FEED TECHNIQUES

Microstrip patch antennas can be fed by a variety of methods. These methods can be categorized into two parts- contacting and non-contacting. In the contacting method, the RF power is fed directly to the radiating patch using a connecting element such as a microstrip line. In the non-contacting scheme, electromagnetic field coupling is used to transfer power between the microstrip line and the radiating patch. The four most popular feed techniques used are the microstrip line, coaxial probe (both contacting schemes), aperture coupling and proximity coupling (both non-contacting schemes) [5], [6].

1.3.1 MICROSTRIP LINE FEED

In this type of feed technique, a conducting strip is connected directly to the edge of the microstrip patch as shown in Fig. 1.3.

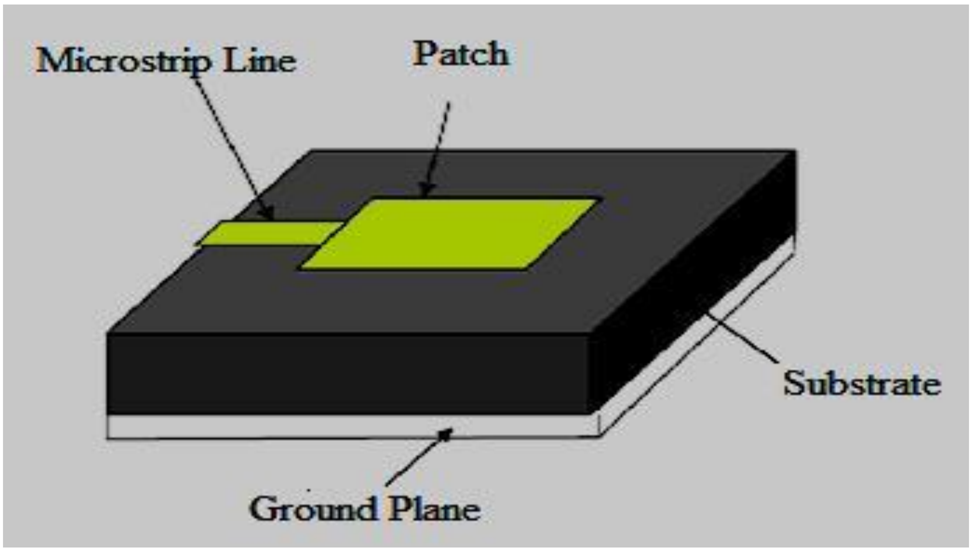


Fig. 1.3 Microstrip Line Feed [7]

The conducting strip is smaller in width as compared to the patch and this kind of feed arrangement has the advantage that the feed can be etched on the same substrate to provide a planar structure [7]. The purpose of the inset cut in the patch is to match the impedance of the feed line to the patch without the need for any additional matching element. This is achieved by properly controlling the inset position. Hence this is an easy feeding scheme, since it provides ease of fabrication and simplicity in modeling as well as impedance matching.

However, as the thickness of the dielectric substrate being used increases, surface waves and spurious feed radiation also increases, which hampers the bandwidth of the antenna. The feed radiation also leads to undesired cross polarized radiation.

1.3.2 COAXIAL FEED

The Coaxial feed or probe feed is a very common technique used for feeding microstrip patch antennas. As seen from Fig. 1.4, 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 [7].

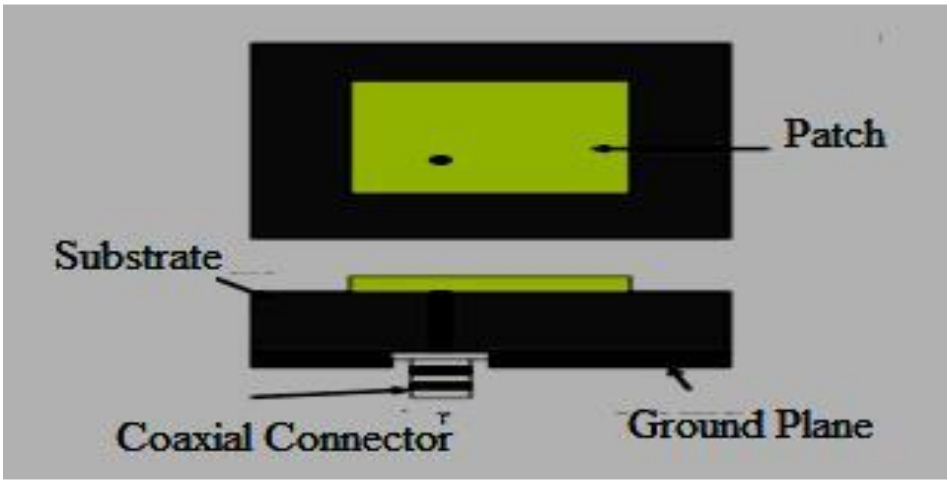


Fig. 1.4 Coaxial Feed [7]

The main advantage of this type of feeding scheme is that the feed can be placed at any desired location inside the patch in order to match with its input impedance. This feed method is easy to fabricate and has low spurious radiation.

However, a major disadvantage is that it provides narrow bandwidth and is difficult to model since a hole has to be drilled in the substrate and the connector protrudes outside the ground plane, thus not making it completely planar for thick substrates ($h > 0.02$). Also, for thicker substrates, the increased probe length makes the input impedance more inductive, leading to matching problems. It is seen above that for a thick dielectric substrate, which provides broad bandwidth, the microstrip line feed and the coaxial feed suffer from numerous disadvantages. The non-contacting feed techniques which have been discussed below, solve these issues.

1.3.3 APERTURE COUPLED FEED

In this type of feed technique, the radiating patch and the microstrip feed line are separated by the ground plane as shown in Fig. 1.5. Coupling between the patch and the feed line is made through a slot or an aperture in the ground plane.

The coupling aperture is usually centered under the patch, leading to lower cross-polarization due to the symmetry of the configuration. The amount of coupling from the feed line to the patch is determined by the shape, size and location of the aperture. Since the ground plane separates the patch and the feed line, spurious radiation is minimized. Generally, a high dielectric material is used for bottom substrate and a thick, low dielectric constant material is used for the top substrate to optimize radiation from the patch.

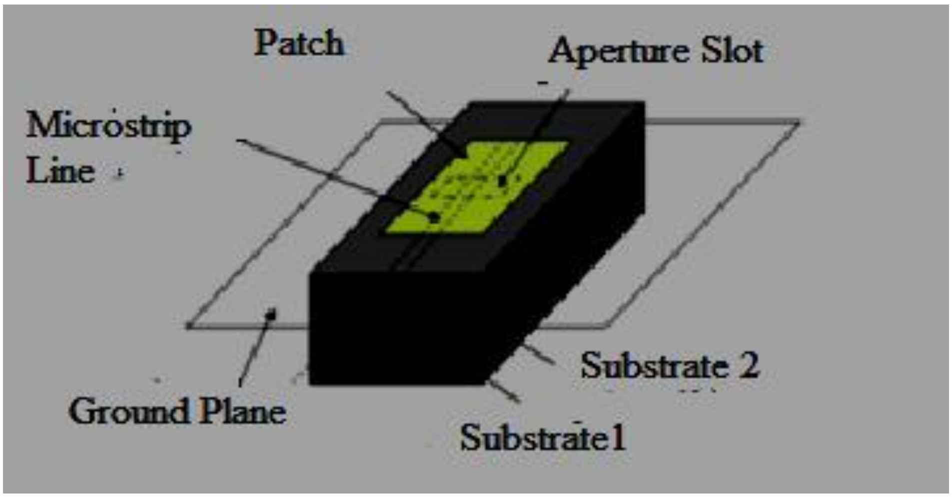


Fig. 1.5 Aperture Coupled Feed [7]

The major disadvantage of this feed technique is that it is difficult to fabricate due to multiple layers, which also increases the antenna thickness. This feeding scheme also provides narrow bandwidth.

1.3.4 PROXIMITY COUPLED FEED

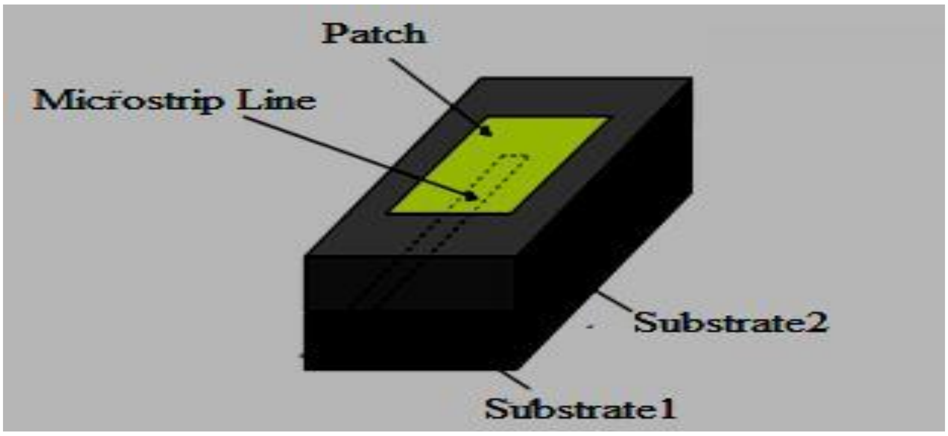


Fig. 1.6 Proximity Coupled Feed [7]

This type of feed technique is also called as the electromagnetic coupling scheme. As shown in Fig. 1.6, two dielectric substrates are used such that the feed line is between the two substrates and the radiating patch is on top of the upper substrate. The main advantage of this feed technique is that it eliminates spurious feed radiation and provides very high bandwidth (as high as 13%), due to an overall increase in the thickness of the microstrip patch antenna. This scheme also provides choices between two different dielectric media, one for the patch and one for the feed line to optimize the individual performances.

Matching can be achieved by controlling the length of the feed line and the width-to-line ratio of the patch. The major disadvantage of this feed scheme is that it is difficult to fabricate because of the two dielectric layers which need proper alignment. Also, there is an increase in the overall thickness of the antenna.

1.4 METHODS OF ANALYSIS

The analysis of rectangular microstrip patch antenna can be done using transmission-line, cavity model and full wave [24]. Here transmission line model and cavity model are briefly described.

1.4.1 TRANSMISSION-LINE MODEL

The transmission-line model is easy, but less accurate than other methods. In this, the microstrip patch antenna consists of a two radiating slot of width W and height h separated by a distance L with a low impedance Z_c. The microstrip line is shown in Fig. 1.7.

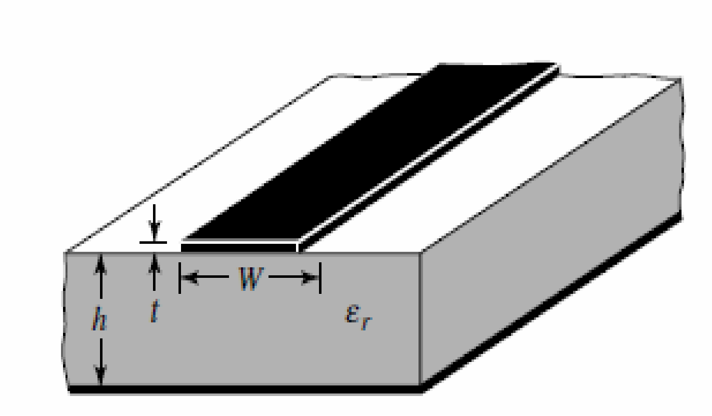


Fig. 1.7 Microstrip line

The fields at the edges of the patch undergo fringing as the dimensions of the patch are finite. The fringing is dependent on the dimensions of the patch and height of the substrate. The electric field lines for a microstrip line feed are shown in Fig. 1.7 [4]. Most of the electric lines stayed within the substrate and some are in the air. As $W/h \gg 1$ and $\varepsilon_r \gg 1$, fringing causes the microstrip line feed to look like wider electrically resemble to its physical dimensions [25].

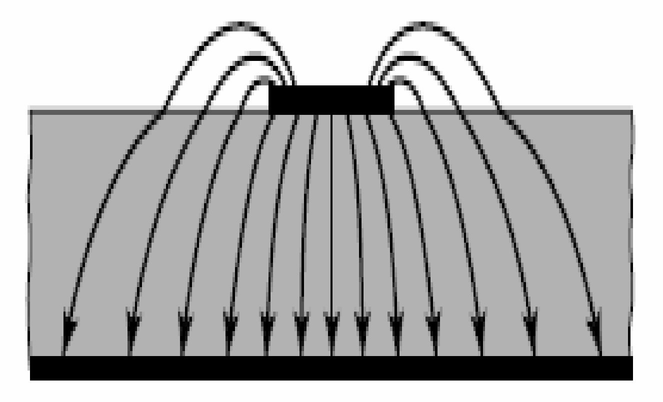


Fig. 1.8 Electric field lines

Due to fringing, an effective dielectric constant ε_{reff} is introduced which is shown in Fig. 1.8. The range of the effective dielectric constant is $1 < \varepsilon_{reff} < \varepsilon_r$. For $\varepsilon_r \gg 1$, the value of ε_{reff} is almost equal to the actual value of the dielectric constant ε_r of the substrate. The value of ε_{reff} very much depends on frequency [26]. For a low frequency, its value is constant and as the frequency increases to higher value, the value of ε_{reff} also increases and nearly closes to the value of dielectric constant ε_r of substrate [27].

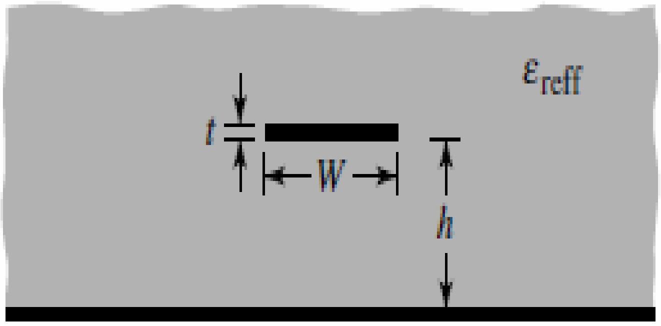


Fig. 1.9 Effective dielectric constant

The expression of the effective dielectric constant can be given as [5], [10], [24]

For $W/h > 1$

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1 + 12\frac{h}{W}\right)^{-½} \tag{1.1}$$

where, ε_{reff} = Effective dielectric constant of substrate

ε_r = Actual dielectric constant of substrate

h = Height of dielectric substrate

W = Width of patch

For some other parameters, different expression is used for effective dielectric constant which is given by

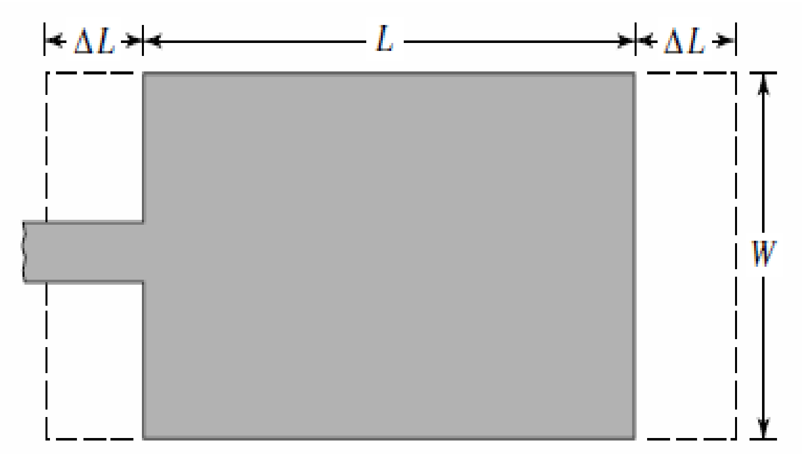
$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1 + 10\frac{h}{W}\right)^{-½} \tag{1.2}$$

The fringing effect also causes to electrically increase the dimensions of the patch as compared to its physical dimensions. The effect is shown in Fig. 1.10, where the length of the patch is increased at both ends by ΔL. The increased length ΔL is a function of effective dielectric constant (ε_{reff}) and width to height ratio (W/h). The Normalized extension in the length Δ L is given by [5], [10]

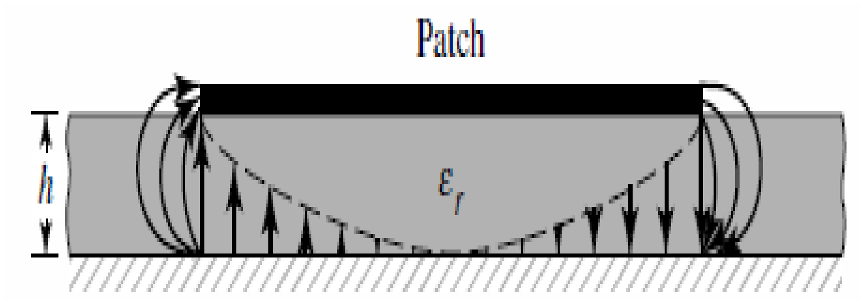
$$\frac{\Delta L}{h} = 0.412\frac{(\varepsilon_{reff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_{reff} - 0.258)\left(\frac{W}{h} + 0.8\right)} \tag{1.3}$$

For some other parameters, different expression is used for Δ L which is given by

$$\Delta L = \frac{h}{\sqrt{\varepsilon_{reff}}} \tag{1.4}$$



(a) Top view



(b) Side view

Fig. 1.10 Physical and effective length of rectangular microstrip patch

The actual length of the patch is given by [24], [28]-[30]

$$\mathrm{L_{eff}} = \mathrm{L} + 2 \vartriangle \mathrm{L} \tag{1.5}$$

where, L_{eff} = Effective length of the patch

L = Actual length of the patch

The effective length of patch is given by

$$\mathrm{L_{eff}} = \frac{\lambda_g}{2} \tag{1.6}$$

Where λ_g is guided wavelength in dielectric medium and is given by

$$\lambda_g = \frac{\lambda_0}{\sqrt{\varepsilon_{reff}}} \tag{1.7}$$

and

$$\lambda_0 = \frac{c}{f_r} \tag{1.8}$$

where, λ_0 = free space wavelength

c = velocity of light in free space, 3×10^8 m/s

The resonance frequency for the mode TM_{mn} of the rectangular microstrip antenna is given by [29]

$$f_0 = \frac{c}{2\sqrt{\varepsilon_{reff}}}\left[\left(\frac{m}{L}\right)^2 + \left(\frac{n}{W}\right)^2\right] \tag{1.9}$$

where m, n are the operating modes of the microstrip patch antenna

The Width of the patch is given by [4]

$$W = \frac{c}{2f}\sqrt{\frac{2}{\varepsilon_r + 1}} \tag{1.10}$$

For some other parameters, different expression is used for width of patch W which is given by [10]

$$W = \frac{\lambda_0}{2\sqrt{\varepsilon_r}} \tag{1.11}$$

The resonant input resistance can be varied with the help of inset feed by recessed a distance y_0 from a slot as shown in Fig. 1.11 [31]. The matching of microstrip line feed with radiating patch can be done by using this technique.

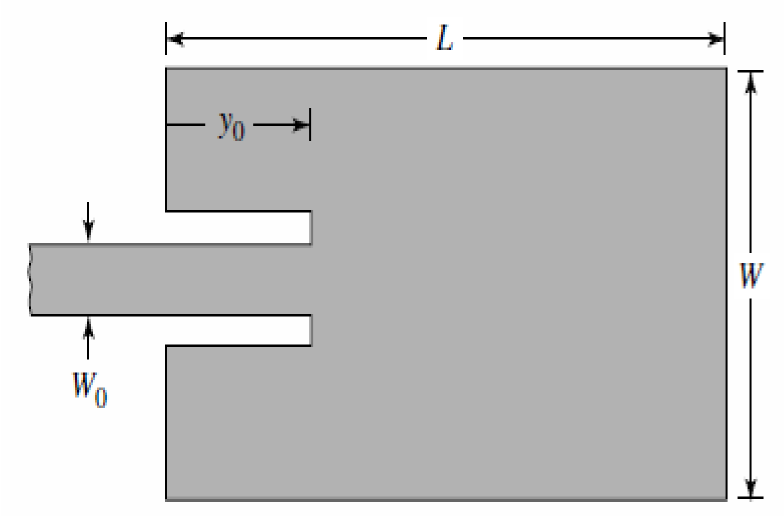


Fig. 1.11 Recessed microstrip line feed

The distance y_0 can be determined by the following equation [10]

$$R_{in}(y = y_0) = R_{in}(y = 0)\cos^2\left(\frac{\pi}{L}y_0\right) \quad (1.12)$$

where, R_{in} $(y = y_0)$ = Input resistance at a distance y_0

R_{in} $(y = 0)$ = Input resistance at the edge of the patch

The graph in Fig. 1.12 is calculated by equation (1.12). The graph shows that as the inset feed reaches to the center of the patch from the edge, the input impedance changes very rapidly and closes to zero [24]. At the center of the patch, input resistance also changes very rapidly.

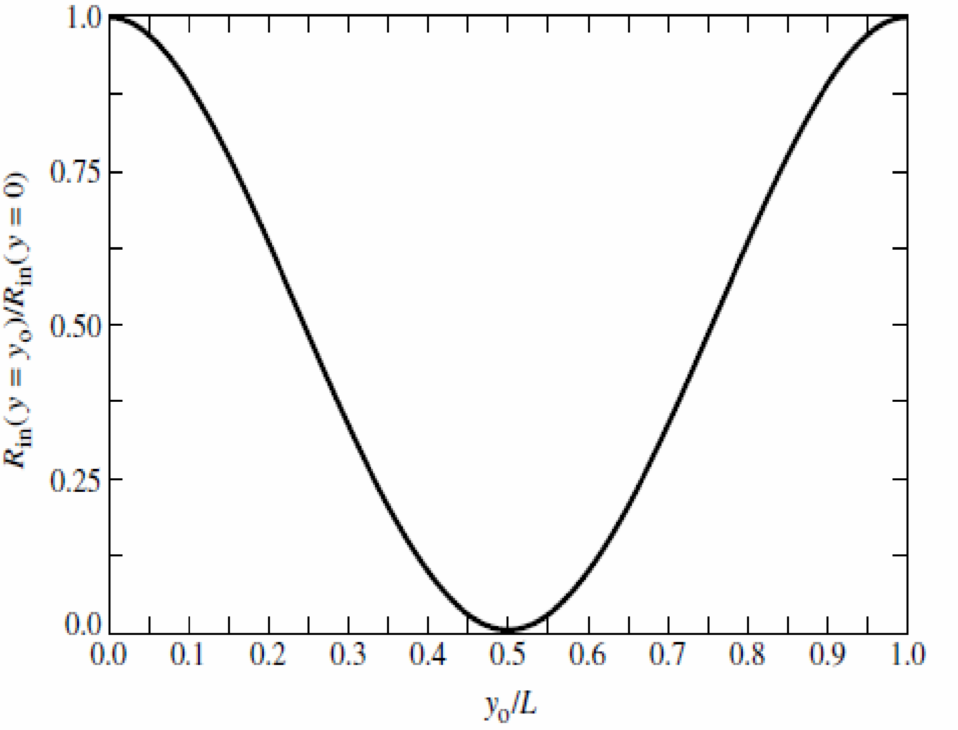


Fig. 1.12 Variation of normalized input resistance

The characteristic impedance Z_c of a Microstrip line is given by [10]

For $\frac{W_0}{h} \leq 1$

$$Z_C = \frac{60}{\sqrt{\varepsilon_{reff}}}\left[\ln\left(\frac{8h}{Wo} + \frac{Wo}{4h}\right)\right] \tag{1.13}$$

For $\frac{W_0}{h} > 1$

$$Z_C = \frac{120\pi}{\sqrt{\varepsilon_{reff}}\left[\frac{W_0}{h} + 1.393 + 0.667\ln\left(\frac{W_0}{h} + 1.444\right)\right]} \tag{1.14}$$

where, W_0 = Width of the microstrip line

1.4.2 CAVITY MODEL

In the cavity model, the patch (cavity) is enclosed by electric walls on the top and bottom and magnetic walls around the edges [5]. Four magnetic side walls represent four narrow apertures/slots from which radiation takes place. The calculation of the radiation field is done by the equivalence principle. The following observations are concluded from the above assumption.

- As the substrate is very thin, the fields in the inner region do not vary with z ($\partial/\partial z \equiv 0$)
- The electric field is in the z-direction and magnetic field components are in the region that is enclosed by the patch metallization & the ground plane.
- There is no component of electric current in the patch normal to the patch metallization which suggest that the magnetic field tangential component is negligible and magnetic wall can be settled along the periphery i.e. $\partial E_Z/\partial n = 0$.

When energy is given in the patch, charge distribution is generated across the top and bottom of the patch and the surface of the ground plane as shown in Fig. 1.13. Two mechanisms are used to handle the charge distribution. These are (a) Attractive mechanism and (b) Repulsive mechanism [5]. In attractive mechanism, charge concentration is maintained at the bottom of the patch by the attraction of opposite charges at the bottom of the patch and the ground plane. In repulsive mechanism is due to the bottom charges of the patch which moves to its edges and then to top surface.

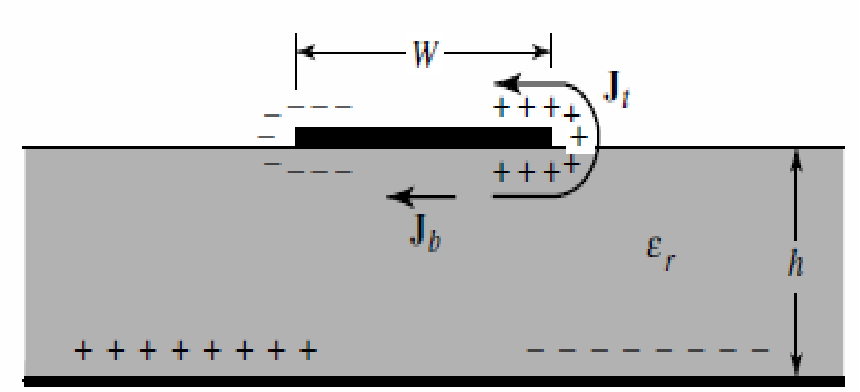


Fig. 1.13 Charge distribution and current density creation on microstrip patch [5]

1.5 ANTENNA PARAMETERS

Before we talk about specific antennas, there are a few common terms that must be defined and explained:

1.5.1 GAIN AND DIRECTIVITY

"The gain of an antenna is the radiation intensity in a given direction divided by the radiation intensity that would be obtained if the antenna radiated all of the power equally in all directions." The definition of gain requires the concept of an isotropic radiator; that is, one that radiates same power in all directions. The isotropic antenna is very important as a reference to other antennas. It has a unity gain in all directions, i.e. "all of the power delivered to it is radiated equally well in all directions". Although the isotropic antenna is a fundamental reference for antenna gain, another commonly used reference is the dipole. In this case the gain of an ideal (lossless) half wavelength dipole is used. Its gain is 1.64 relative to an isotropic radiator.

"The radiation intensity corresponding to the isotropically radiated power is equal to the power accepted (input) by the antenna divided by 4п. When the direction is not stated, the power gain is usually taken in the direction of maximum radiation".

$$\mathrm{Gain} = \frac{4\pi \text{ radiation intensity}}{\text{total input (transmitted)power}} \tag{1.15}$$

The directivity of the antenna is closely related to the gain. The gain is a measure that takes into account the efficiency of the antenna as well as its directional capabilities. While directivity is a measure that describes only the directional properties of the antenna, and it is therefore determined by the pattern. "Directivity of an antenna is defined as the radiation intensity in a given direction from the antenna divided by the radiation intensity averaged over all directions. The average radiation intensity is equal to the total power radiated by the antenna divided by 4π". In mathematical form, it can be written as

$$\mathrm{D} = \frac{4\pi\mathrm{U}}{\mathrm{P_{ead}}} \tag{1.16}$$

Where, U is the radiation intensity in (W/unit solid angle) and P_{rad} is total radiated power in (W). If the direction is not specified, it implies the direction of maximum radiation intensity (maximum directivity) expressed as

$$D = \frac{4\pi U_{max}}{P_{rad}} \tag{1.17}$$

1.5.2 RETURN LOSS (S_{11})

Return loss is a measure of the effectiveness of an antenna to deliver power from the source to the antenna. It is also a measure of the loss of signal power resulting from the reflection caused at a discontinuity in a transmission line. This discontinuity can be a mismatch with the terminating load or with a device inserted in the line. "The return loss is defined by the ratio of the incident power of the antenna to the power reflected back from the antenna source. It is usually expressed as a ratio in decibels (dB)". The S_{11} is given by as:

$$S_{11}(dB) = 10\log_{10}\frac{P_i}{P_r} \tag{1.18}$$

Where S_{11} (dB) is the return loss in dB, P_i is the incident power and P_r is the reflected power. Return loss is a measure of how well devices or lines are matched. When return loss is high matching is good. A high return loss is desirable and results in a lower insertion loss.

1.5.3 ANTENNA POLARIZATION

"The term polarization means the orientation of the electric field vector E at some point in space. If the E-field vector retains its original orientation at each point in space, then the polarization is linear; if it rotates as the wave travels in space, then the polarization is circular or elliptical". In most cases, the radiated-wave polarization is linear and either vertical or horizontal. At sufficiently large distances from an antenna, (beyond 10 wavelengths) the radiated far-field wave is a plane wave.

1.5.4 VOLTAGE STANDING WAVE RATIO

The standing wave ratio (SWR), also known as the voltage standing wave ratio (VSWR), is an antenna characteristic, used to describe the performance of an antenna when attached to a transmission line. It is a measure of how well the antenna terminal impedance is matched to the characteristic impedance of the transmission line. Specifically," the VSWR is the ratio of the maximum to the minimum RF voltage along the transmission line". The maxima and minima along the lines are caused by partial reinforcement and cancellation of a forward moving RF signal on the transmission line and its reflection from the antenna terminals. The VSWR can be expressed as

$$\mathrm{VSWR} = \frac{\mathrm{V_{max}}}{\mathrm{V_{min}}} = \frac{1+|\Gamma|}{1-|\Gamma|} \tag{1.19}$$

Where Γ is magnitude of reflection coefficient. If the antenna terminal impedance exhibits no reactive (imaginary) part and the resistive (real) part is equal to the characteristic impedance of the transmission line, then the antenna and transmission line are said to be matched. It indicates that none of the RF signal sent to the antenna will be reflected at its terminals. There is no standing wave on the transmission line and the VSWR has a value of one. If the antenna and transmission line are not matched, then some fraction of the RF signal sent to the antenna is reflected back along the transmission line. This causes a standing wave, characterized by maxima and minima, to exist on the line. In this case, the VSWR has a value greater than one. The VSWR of 1.5 is considered excellent, while values of 1.5 to 2.0 are considered good, and values higher than 2.0 may be unacceptable.

1.5.5 BANDWIDTH

"The bandwidth of an antenna is defined as the range of frequency within the performance of the antenna or characteristics of the antenna (gain, radiation pattern, terminal impedance) have acceptable values". For most antennas, gain and radiation pattern do not change as rapidly with frequency as the terminal impedance does. Since the transmission line characteristic impedance hardly changes with frequency. The impedance bandwidth of the microstrip antenna is also defined as the frequency range over which it is matched with the feed line within specified limits.

The frequency bandwidth of an antenna can be expressed as either absolute bandwidth (ABW) or fractional bandwidth (FBW). f_H and f_L, denote the upper edge and the lower edge of 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 1.20 and 1.21 respectively.

$$\mathrm{ABW} = \mathrm{f_H} - \mathrm{f_L} \tag{1.20}$$

$$\mathrm{FBW} = 2\frac{\mathrm{f_H} - \mathrm{f_L}}{\mathrm{f_H} + \mathrm{f_L}} \tag{1.21}$$

1.5.6 INPUT IMPEDENCE

For an efficient transfer of energy, the impedance of the radio, of the antenna and of the transmission cable connecting them must be the same. Transceivers and their transmission lines are typically designed for 50 Ohm impedance. If the antenna has impedance different from 50 Ohm, then there is a mismatch and an impedance matching circuit is required.

1.5.7 RELECTION COEFFICIENT

"A reflection coefficient Γ is defined to give a measure of the reflection. It is derived by normalizing the amplitude of the reflected voltage V_o^- to the amplitude of the incident voltage V_O^{+}" and is given

$$\Gamma = \frac{V_0^-}{V_0^+} = \frac{Z_L - Z_0}{Z_L + Z_0} \tag{1.22}$$

1.5.8 BANDWIDTH

The bandwidth of an antenna refers to the range of frequencies over which the antenna can operate correctly. The antenna's bandwidth is the number of Hz for which the antenna will exhibit an SWR less than 2:1.

In other words, the bandwidth of an antenna is defined as the frequency range over which it is Directivity is the ability of an antenna to focus energy in a particular direction when transmitting, or to receive energy better from a particular direction when receiving. In a static situation, it is possible to use the antenna directivity to concentrate the radiation beam in the desired direction. However, in a dynamic system where the transceiver is not fixed, the antenna should radiate equally in all directions, and this is known as a Omni-directional antenna. The gain is not a quantity which can be defined in terms of a physical quantity such as the Watt or the Ohm, but it is a dimensionless ratio. The gain is given in reference to a standard antenna. The two most common reference antennas are the isotropic antenna and the resonant half-wave dipole antenna [9].The isotropic antenna radiates equally in all directions.

Real isotropic antennas do not exist, but they provide useful and simple theoretical antenna patterns with which to compare real antennas. Any real antenna will radiate more matched with that of the feed line within specified limits. The bandwidth or Impedance bandwidth of an antenna can be defined as the percentage of the frequency difference (f_H-f_L) over the center frequency f_C

$$\mathrm{BW} = 2\frac{f_H - f_L}{f_H + f_L} \times 100 \tag{1.23}$$

Where $f_c = (f_H + f_L)/2$ and f_H is the high frequency and f_L is the low frequency.

1.5.8 RADIATION PATTERN [10]

An antenna radiation pattern or antenna pattern is defined as "a mathematical function or a graphical representation of the antenna as a function of space coordinates. In most cases, the radiation pattern is determined in the far field region and is represented as a function of the directional coordinates. Radiation properties include power flux density, radiation intensity, field strength, directivity, phase or polarization,". The radiation property of most concern is the two- or three dimensional spatial distributed of radiated energy as a function of the observer's position along a path or surface of constant radius.

A trace of the received electric (magnetic) field at a constant radius is called the amplitude pattern. On the other end, a graph of the spatial variation of the power density along a constant radius is called an amplitude power pattern of an antenna, the

- Field Pattern (in linear scale) typically represents a plot of the magnitude of the electric or magnetic field as a function of the angular space.
- Power pattern (in linear scale) typically represents a plot of the square of the magnitude of the electric or magnetic field as a function of the angular space.
- Power pattern (in dB) represents the magnitude of the electric or magnetic field, in decibels, as a function of the angular space.

A. RECTANGULAR /CARTESIAN PLOTS

Rectangular /Cartesian plots are standard x-y plots where the x and y axes are plotted at right angle to each other. In a radiation plot, the angle with respect to bore sight is varied and the magnitude of the power radiated is measured; thus the angle is the independent variable and the power radiated is the dependent variable. A typical rectangular plot of an antenna radiation pattern is shown in Fig. 1.14.

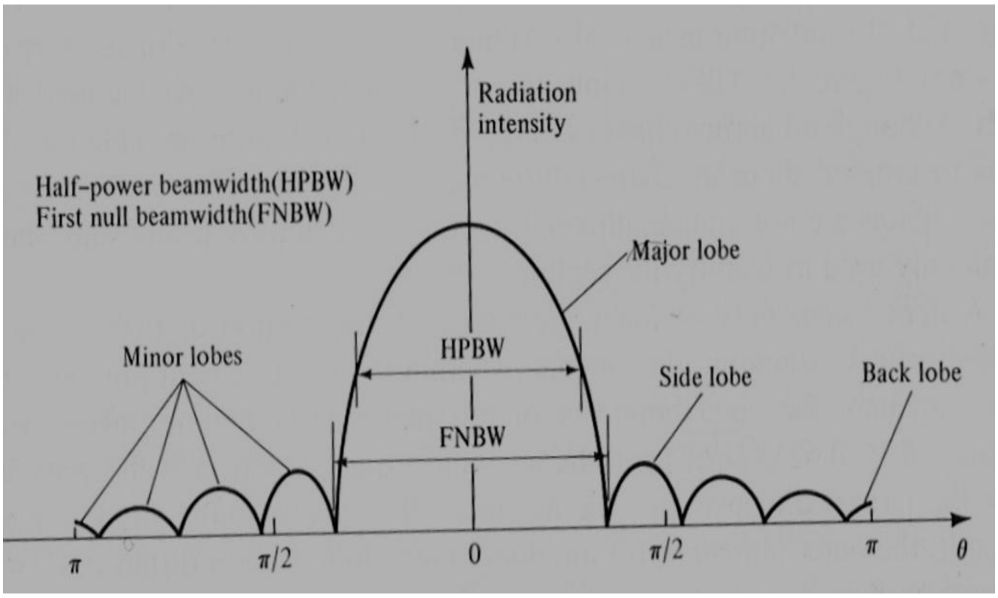


Fig. 1.14 Rectangular Plot of an Antenna [10]

- **Major** lobe is the radiation lobe that is directed in the direction of maximum radiation.
- **Minor** lobe is any lobe except a major lobe. These represent radiation in the undesired direction.
- **Side** lobe is a radiation lobe in any direction other than the intended lobe. It is adjacent to the major lobe.
- **Back** lobe is a radiation lobe whose axis makes an angle of approximately 180^0 with respect to the beam of an antenna.
- **First Null Beam width** is the angular separation between the first nulls of the pattern.
- **Half Power Beam** Width is defined in a plane containing the direction of the maximum of a beam, the angle between the two directions in which the radiation intensity is one half of the maximum value of the beam.

B. POLAR PLOT

In polar plot, the angles are plotted from bore sight and the power or intensity is plotted along the radius as shown in Fig. 1.15. This gives a pictorial representation of radiation pattern of the antenna and is easier to visualize than the rectangular/Cartesian plots. Although the accuracy cannot be increased as in the case of the rectangular plot as the scale of the angular positions can only be plotted from 0^0 to 360^0. However, the scale of the intensity of power can be varied. Each circle on the polar plot represents a contour plot where the power has the same magnitude and is shown relative to the power at bore sight. These levels will always be less than the power at sight and values should be shown as negative because the power in general is maximum at bore sight. However, they are normally written without a sign and should be assumed to be negative, contrary to standard arithmetic convention.

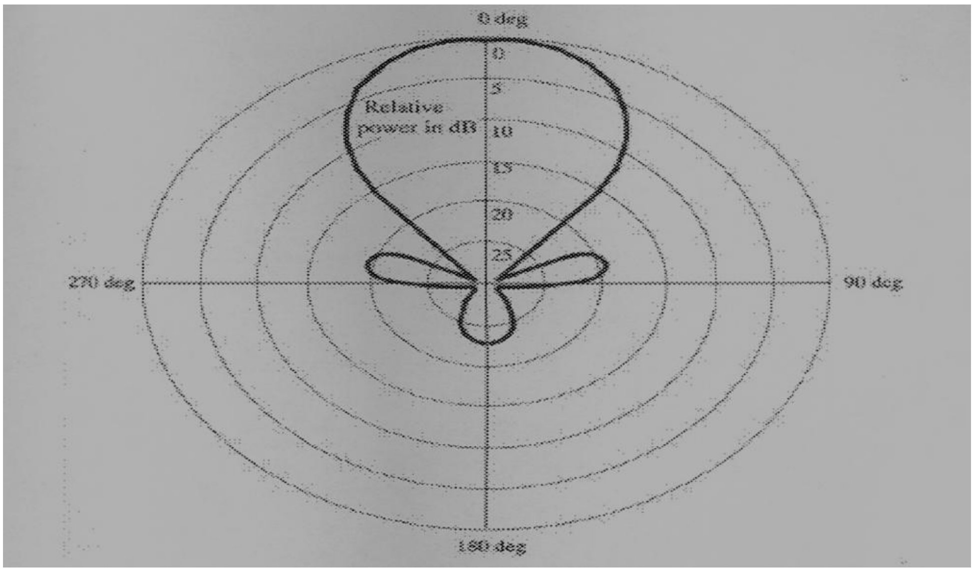


Fig. 1.15 Typical Polar Plot of an Antenna [10]

C. HALF POWER BEAM WIDTH

The beam width of a pattern is defined as "the angular separation between two identical points on the opposite side of the pattern maximum". The half-power beam width is defined as “In a plane containing the direction of the maximum of a beam, the angle between the two directions in which the radiation intensity is one-half the maximum value of the beam.”Often the term beam width is used to describe the angle between any two points on the pattern such as the angle between the 10-dB points. The beam width of the antenna is a very important figure of merit, and it is often used as a tradeoff between the bandwidth and the side lobe level;that is,as the bandwidth decreases the side lobe increases and via versa [10].

1.5.9 POLARIZATION

The polarization of an antenna is "the orientation of the electric field (E-plane) of the radio wave with respect to the earth’s surface and is determined by the physical structure and orientation of the antenna". It is defined as “the property of an electromagnetic wave describing the time varying direction and relative magnitude of the electric field vector".

The direction or position of the electric field with respect to the ground gives the wave polarization. The common types of the polarization are linear, circular or elliptical. Linear and circular polarizations are special cases of elliptical, and they can be obtained when the ellipse becomes a straight line or a circle, respectively.

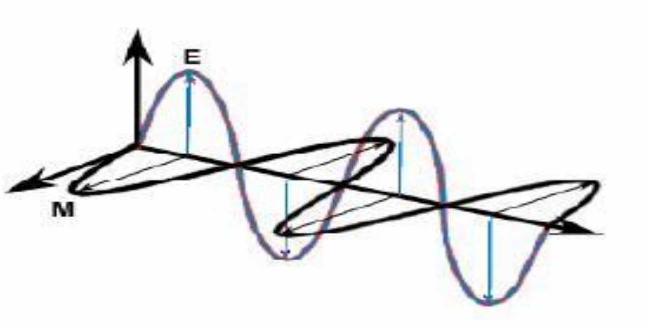


Fig. 1.16 A linearly polarized wave

A time-harmonic wave is linearly polarized at a given point in space if the electric-field (or magnetic field) vector at that point is always oriented along the same straight line at every instant of time as shown in Fig. 1.16. Linear polarization includes vertical linear polarization (in time phase) and horizontal linear polarization (180^o or out-of-phase) as shown in Fig. 1.17.

A time-harmonic wave is circularly polarized at a given point in space if the electric-field (or magnetic field) vector at that point traces a circle as a function of time. The commonly used polarized schemes are as shown in Fig. 1.17. The clockwise rotation of the electric field vector is designated as right hand polarization and counterclockwise as left hand polarization (in circular) the former includes horizontal and vertical.

It can be noted that the circular polarization has the electric field vector’s length constant, but rotates in a circular path.

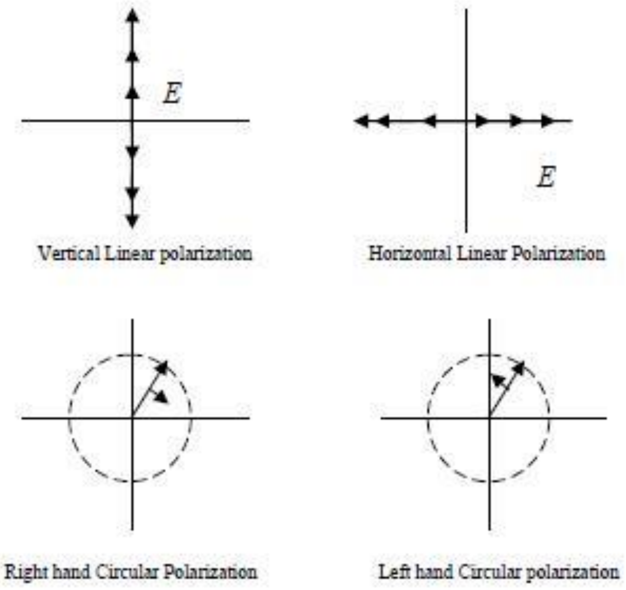


Fig. 1.17 The commonly used polarized schemes

1.6 HIGH FREQUENCY STRUCTURE SIMULATOR (HFSS)

HFSS is a full wave 3D electromagnetic field simulator. It uses the Finite Element Method (FEM) for solving the structure, i.e. a structure is subdivided into many smaller segments called finite elements. The tetrahedra are used as finite elements by HFSS and the entire group of tetrahedra is called a mesh. A field solution for the entire structure can be found by obtaining a solution for the fields within the finite elements and these fields are interrelated which satisfy the Maxwell's equations across inter-element boundaries. With the help of field solution, the generalized scattering matrix solution is determined. The Fig. 1.18 shows the flow chart of the working of HFSS.

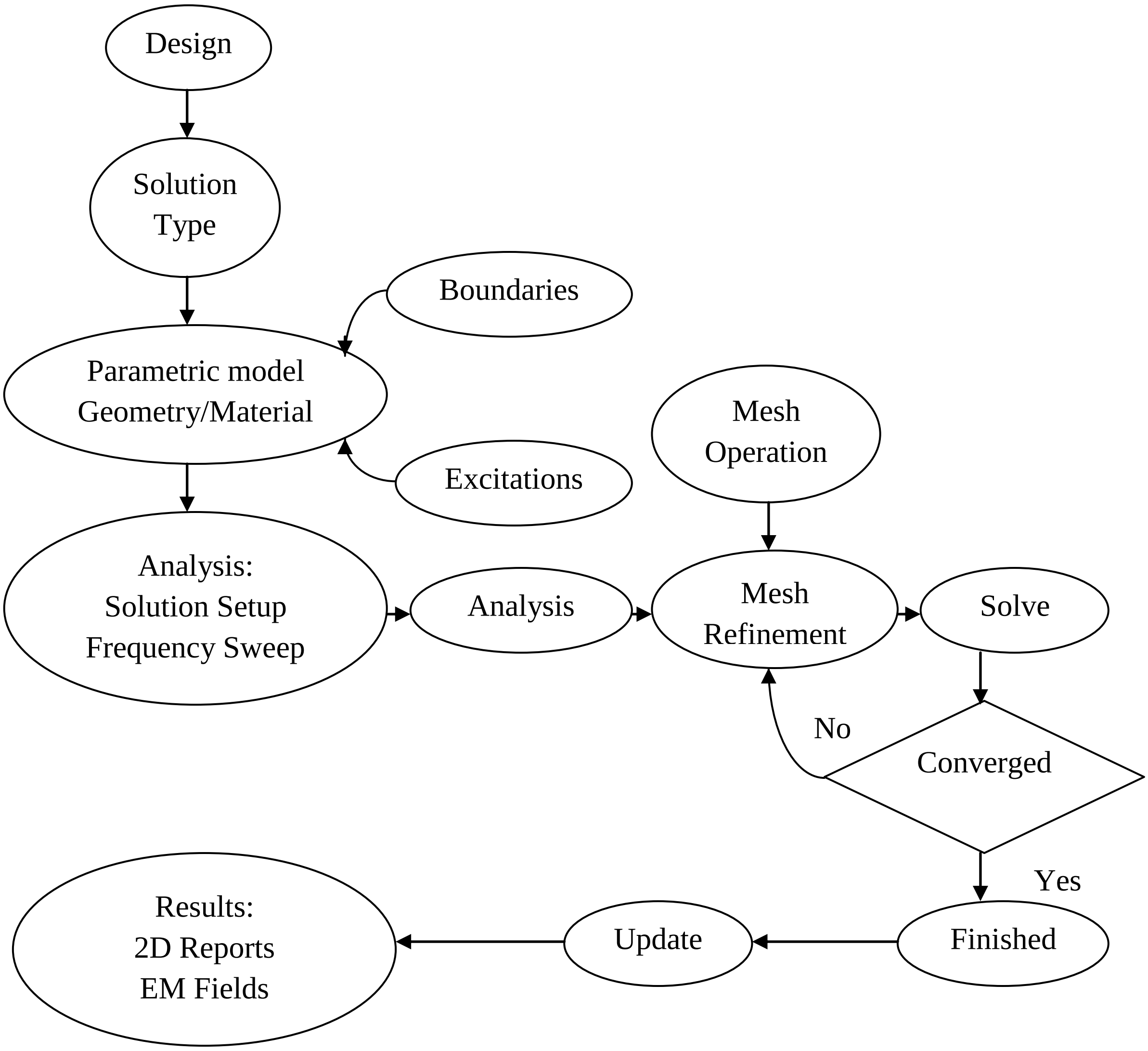


Fig. 1.18 Flow Chart for operations and working in HFSS

1.7 CIRCULAR PATCH ANTENNA

Other than the rectangular patch, the next most popular configuration is the circular patch or disk, as shown in Figure 1.19. It also has received a lot of attention not only as a single element but also in arrays. The modes supported by the circular patch antenna can be found by treating the patch, ground plane, and the material between the two as a circular cavity. As with the rectangular patch, the modes that are supported primarily by a circular microstrip antenna whose substrate height is small $(h<<\lambda)$ are TM^z where z is taken perpendicular to the patch. As far as the dimensions of the patch, there are two degrees of freedom to control (length and width) for the rectangular microstrip antenna. Therefore the order of the modes can be changed by changing the relative dimensions of the width and length of the patch (width-to-length ratio). However, for the circular patch there is only one degree of freedom to control (radius of the patch). Doing this does not change the order of the modes; however, it does change the absolute value of the resonant frequency of each.

Other than using full-wave analysis the circular patch antenna can only be analyzed conveniently using the cavity model. This can be accomplished using a procedure similar to that for the rectangular patch, but now using cylindrical coordinates. The cavity is composed of two perfect electric conductors at the top and bottom to represent the patch and the ground plane, and by a cylindrical perfect magnetic conductor around the circular periphery of the cavity. The dielectric material of the substrate is assumed to be truncated beyond the extent of the patch.

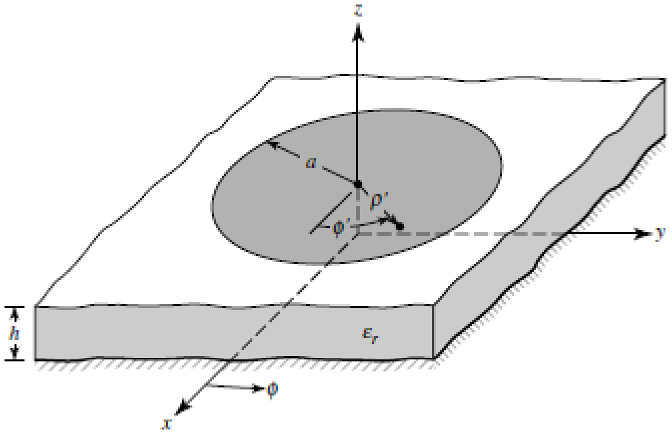


Fig. 1.19 Circular patch microstrip antenna

1.7.1 DESIGN OF CIRCULAR PATCH ANTENNA

Based on the cavity model formulation, a design procedure is outlined which leads to practical designs of circular microstrip antennas for the dominant TM^z_{110} mode. The procedure assumes that the specified information includes the dielectric constant of the substrate (ε_r), the resonant frequency (f_r) and the height of the substrate *h*. The procedure is as follows:

Specify ε_r, f_r (in Hz) and h (in cm)

Determine The actual radius "a" of the patch.

$$a = \frac{F}{\left\{1 + \frac{2h}{\pi \epsilon r F}\left[ln\left(\frac{\pi F}{2h}\right) + 1.1726\right]\right\}^{\frac{1}{2}}} \tag{1.24}$$

where,

$$F = \frac{8.79 \times 10^9}{f\sqrt{\varepsilon}} \tag{1.25}$$

1.8 OBJECTIVE OF THE WORK

Wideband (WB) technology is rapidly developing at a high speed, and high data rate wireless communication mode. WB technology has been used in the areas of radar, sensing and military communications. My objective is to design a WB antenna that will provide wide bandwidth by considering different bandwidth enhancement techniques. During the design process, HFSS simulation software has been used to analysis different antenna parameters such as return loss, VSWR, radiation pattern. The expected antenna has compact size and simple structure that can provide large bandwidth which covers complete WB (Wideband) range.

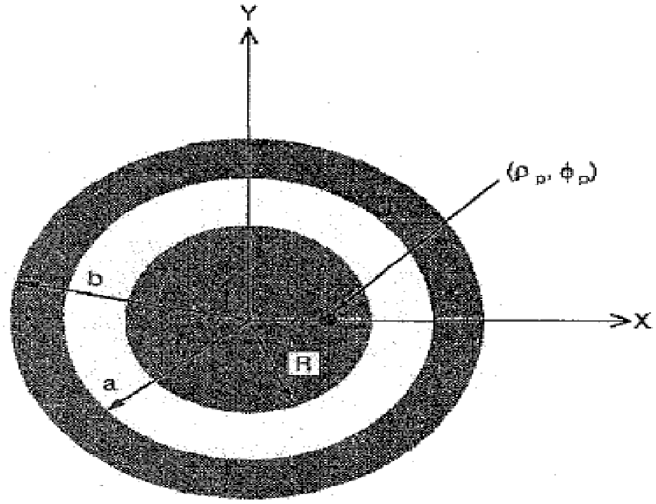
LITERATURE SURVEY

Prior to starting research or design new antenna, it is important to have a deep understanding of the existing pages of microstrip antenna. The main sources of information for the dissertation are books, journal, thesis, dissertations and the internet. There are three major areas in the literature review, which are antenna design, methods for improving performance of microstrip patch antenna and related simulation software.

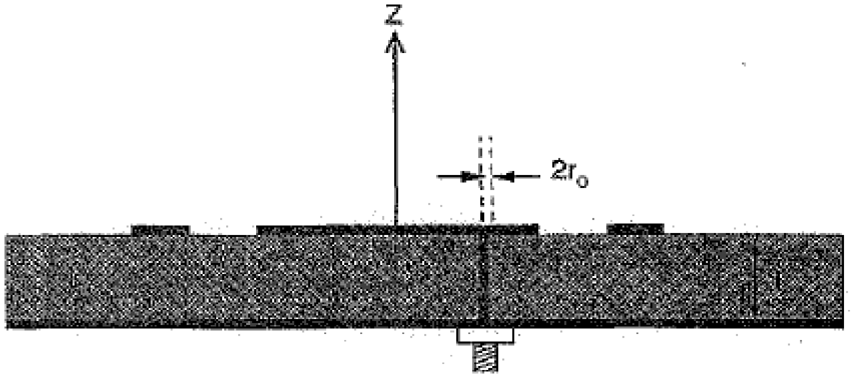
In order to start the project, the first step is to study the research papers that have been published by other researchers. This chapter provides a brief review of the past work in the field of antenna either theoretical or experimental.

D. M. Kokotoff et. al [28] presented an annular ring loaded circular patch antenna, which provides higher impedance bandwidth, higher gain, higher efficiency and easy to fabricate as compared to a conventional circular patch.

Circular microstrip patch antenna with probe feed and an annular ring is designed on a substrate having thickness d and dielectric constant ε_r , a patch is mounted having radius R. Coaxial probe is used having radius r_0 located at (ρ_p, φ_p) from the center of the patch. The annular ring of outer radius “b” and inner radius “a” are placed concentrically about the circular patch shown in Fig. 2.1.



(a) Top view



(b) Side view

Fig. 2.1 Schematic diagram of probe fed circular microstrip patch antenna with concentric annular ring

K. M. Luk et. al [29] studied the experimental result for circular patch with different slots. In this paper, two configurations are studied which are as follows

a) An arc shaped slot.

b) Rectangular U-shaped slot.

a) An arc shaped slot-

An arc shaped slot is cut on the circular patch as shown in Fig. 2.2. In this paper two feed point location is tested, one with a coaxial feed at the center (r = 0) and the other with an offset feed (r > 0). In the first case the bandwidth is about 14% and in the second case a dual frequency response is obtained rather than a broadband characteristic.

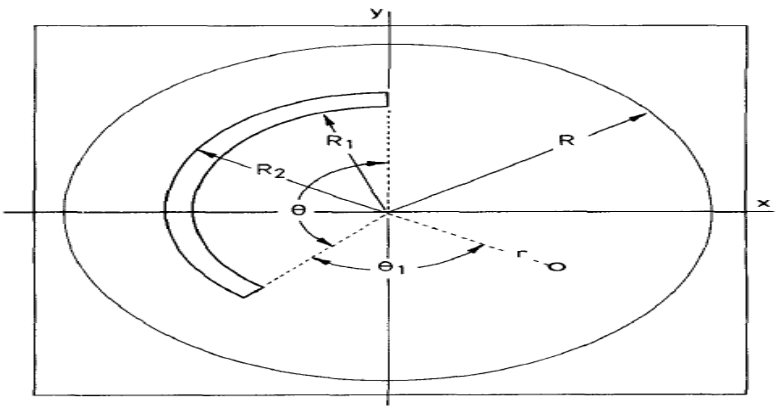


Fig. 2.2 Geometry of a circular patch microstrip antenna with an arc shaped slot

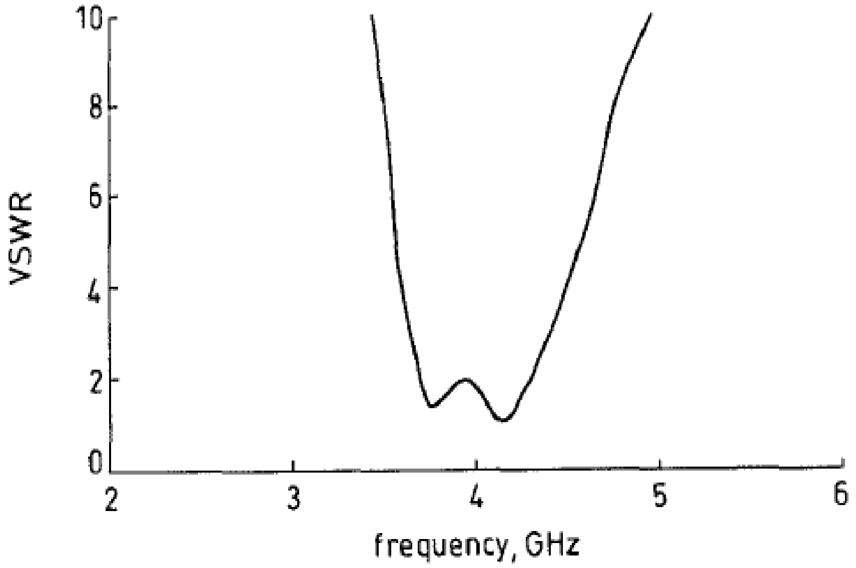


Fig. 2.3 Input SWR against frequency of circular patch microstrip antenna with an arc shaped slot

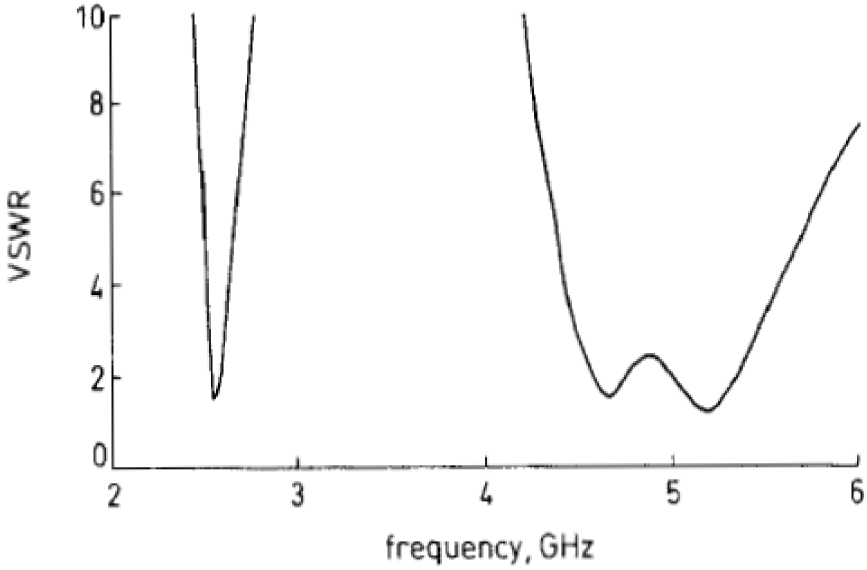


Fig. 2.4 Input SWR against frequency of circular patch microstrip antenna with an arc shaped slot center feed

b) Rectangular U-shaped slot-

In this configuration, a U-shaped slot was cut on the circular patch. Coaxial feed is used at the center as shown in Fig. 2.5. In this case the bandwidth is about 23%.

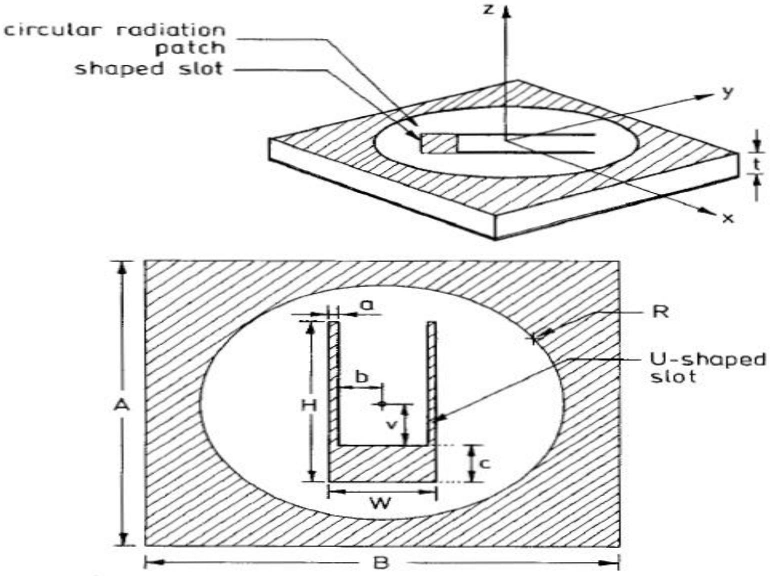


Fig. 2.5 Geometry of a U-slot circular patch antenna

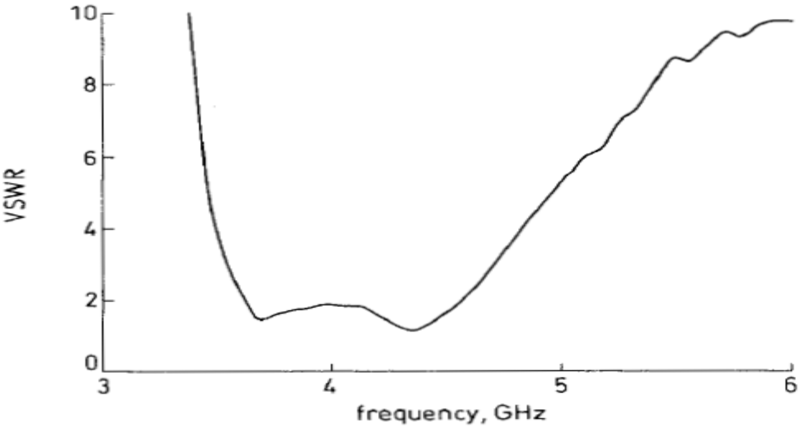


Fig. 2.6 Input SWR against frequency of a U-slot circular antenna

R. Bhalla and L. Shafai [30] presented a microstrip antenna having a circular arc slot on a rectangular patch. This antenna is designed for a wide bandwidth of about 30%.

Rectangular patch having dimension L = 55.5mm and W = 29 mm and substrate height h = 5.5 mm is used. A circular arc slot is cut in the center of the patch. This antenna is fed by a 50Ω coaxial probe having an inner diameter of 1.27 mm as shown in Fig. 2.7.

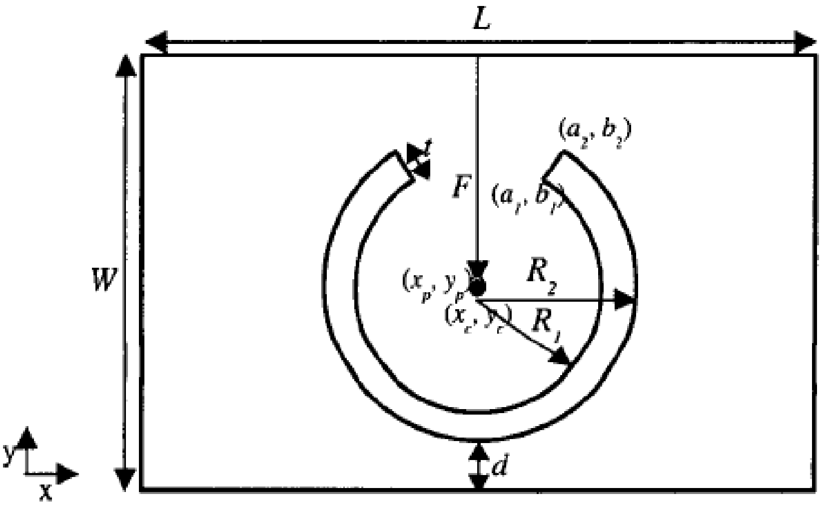


Fig. 2.7 Geometry of the microstrip patch antenna with a circular arc slot

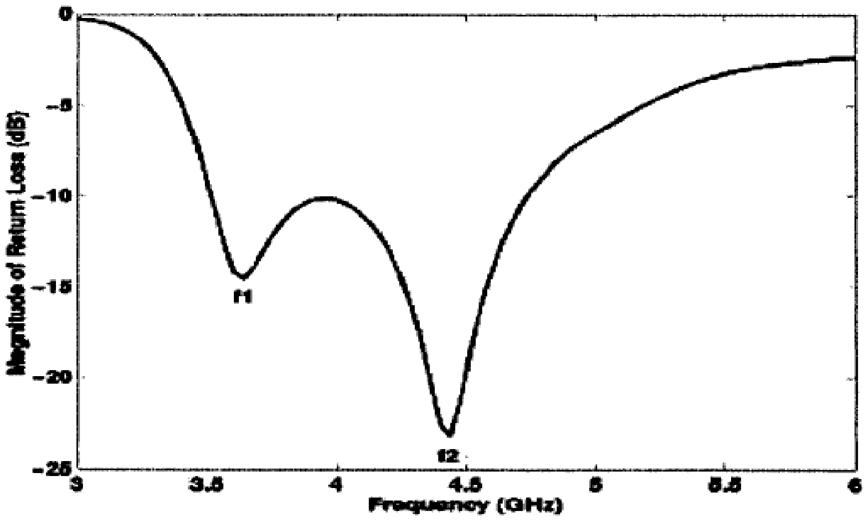


Fig. 2.8 Return loss of the microstrip patch antenna with a circular arc slot

Garima et. al [31] has proposed a diamond shape slot on a circular patch microstrip antenna. Glass epoxy FR-4 substrate is used having radius 16.2 mm, dielectric constant $\varepsilon_r = 4.37$ and $\tan \delta = 0.0025$, thickness of substrate $h = 0.158$ cm. A diamond shape slot is cut at the center as shown in Fig. 2.9. The proposed design is compared with the conventional microstrip patch antenna. This antenna efficiently resonates at a single frequency and offers 1.12 GHz bandwidth that is 16.93% w.r.t its central frequency, which is in the range of broadband performance. The gain and directivity are marginally improved compared to that of the circular patch antenna.

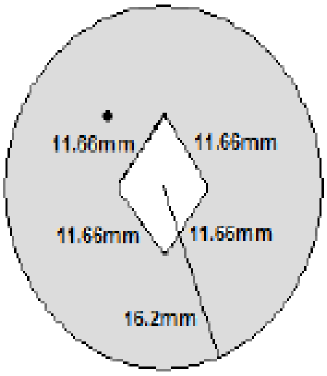


Fig. 2.9 Geometry of the microstrip patch antenna with a diamond shape slot

Mamta Devi Sharma et. al [32] proposed a microstrip patch antenna having unequal parallel slots, which is modified structure of E-slot patch antenna and U-slot patch antenna. This antenna provides a bandwidth of 16.4% with 1.5 VSWR.

HFSS software is used for simulation purpose. Coaxial probe feed & aperture couple feed is used and compared in this paper. An E-shaped slot is cut on a rectangular patch having dimensions 76×88 mm. Dielectric substrate having dielectric constant $\varepsilon_r = 2.2$ and thickness 6.7 mm is used. The geometry is shown in Fig. 2.10. These antennas provide 7.8% bandwidth.

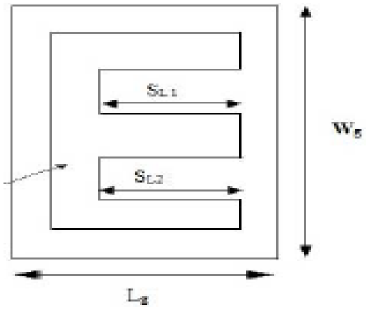


Fig. 2.10 Geometry of the microstrip patch antenna with an E-shape slot

An unequal parallel slot is cut on a patch called unequal E-shaped patch antenna which provides 16.4% bandwidth. The geometry is shown in Fig. 2.11.

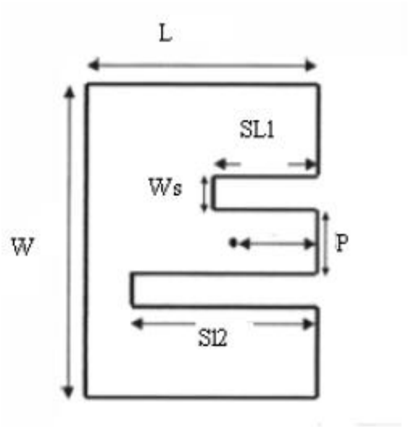


Fig. 2.11 Geometry of the microstrip patch antenna with unequal E-shape slot

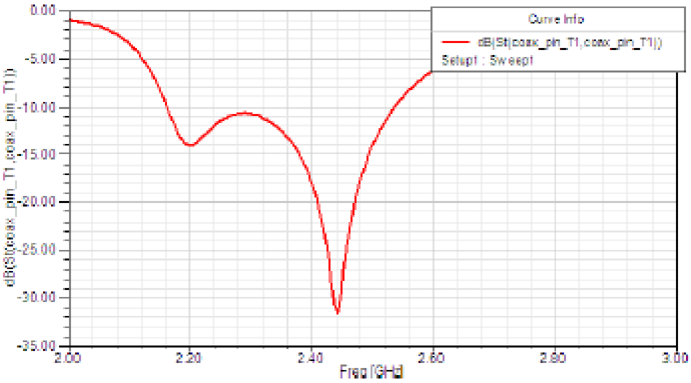


Fig. 2.12 Return loss of the microstrip patch antenna with unequal E-shape slot

A U-slot is cut on patch, which also enhance the bandwidth of the antenna. The propose U-slot geometry is shown in Fig. 2.13. The coaxial probe field is used. This antenna provides 11.74% bandwidth.

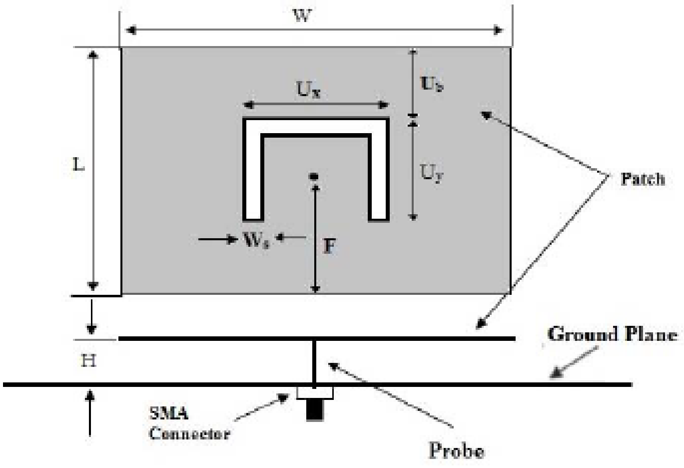


Fig. 2.13 Geometry of the microstrip patch antenna with U-shape slot

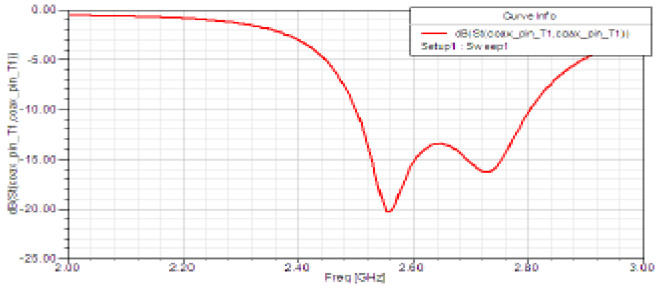


Fig. 2.14 Return loss of the microstrip patch antenna with U-shape slot

Chapter - 3

ANTENNA DESIGN, SIMULATION AND RESULTS

3.1 INTRODUCTION

The technical improvements in communication technology from the first-generation (1G) to second-generation (2G) to third-generation (3G) have enabled a large number of new services like 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 us on-demand high quality audio and video services, and other advanced services with very high data rate.

In recent years, more interests have been put into wireless personal area network (WPAN) technology. The future WPAN aims to offer reliable wireless connections between computers, portable devices and consumer electronics within a short range with fast data storage and exchange between these devices. This requires a data rate, which is much higher than the 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 [25], as shown in equation (3.1).

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

Where C is the maximum transmitting data rate, B is the channel bandwidth. Equation (3.1) indicates that the transmit data rate can be increased by increasing the channel bandwidth. The transmission power cannot be increased because many portable or mobile devices are battery powered and the potential interference should also be avoided. Thus, to achieve high data rate, a large frequency bandwidth will be the solution.

On February 14, 2002, the Federal Communications Commission (FCC) of the United States adopted the First Report and Order that the permitted commercial operation of ultra wideband (UWB) technology [26]. The Federal Communications Commission (FCC) provided a band of 3.1 GHz to 10.6 GHz, i.e. bandwidth of 7.5 GHz for UWB applications. UWB characterizes transmission systems with spectral occupancy in excess of 500 MHz or a fractional bandwidth of more than 20% [27]. Since then, UWB technology has been regarded as one of the most promising wireless technologies that promises high data rate transmission and enables the personal area networking industry leading to new innovations.

In this chapter, requirements to design a WB antenna are discussed. Then the performance and characteristics of the proposed microstrip patch antenna with band dispensation characteristics are presented. Parametric study of designing a circular microstrip patch antenna has been carried out by HFSS simulation software. The simulation software HFSS uses the finite element method for solving the electromagnetic fields associated with the structure. It also uses adaptive mesh technique each time refining its mesh and hence produces accurate results.

3.2 REQUIREMENTS FOR UWB ANTENNAS

1. A huge impedance bandwidth of an ultra wideband antenna makes it distinguishable from other antennas. According to the FCC's rules and regulations, a suitable UWB antenna should be able to occupy an absolute bandwidth, no less than 500 MHz or a fractional bandwidth of at least 0.2.

2. The performance of a UWB antenna is required to be uniform over the entire operational band. Ideally, antenna radiation pattern and gain should be stable across the whole working band. Sometimes, it is also demanded that the UWB antenna provides the band-rejection characteristic to coexist with other narrow- band devices to reduce interference in the same operational band.

3. Directional or omnidirectional radiation property is needed depending on the practical application. For indoor wireless communication, omnidirectional property in radiation pattern is demanded for UWB antennas with low directivity in an entire frequency band. For radar systems and other directional systems where high gain is desired, directional antennas are preferred.

4. Another important requirement to design an UWB antenna is the radiation efficiency. The power transmitted into space is very low so the radiation efficiency is required to be quite high.

5. UWB technology is mainly employed for indoor and portable devices, so a suitable antenna needs to be small enough. It is also highly desirable that the antenna features low profile planar configuration and compatibility for integration with printed circuit board (PCB).

6. A UWB antenna is required to achieve good time domain characteristics. For the narrow band systems an antenna has a uniform performance with some variation in gain, return loss over the entire working band. So good time domain performance (minimum pulse distortion in the received waveform) becomes an important requirement to design a suitable UWB antenna. Therefore, it is indispensable and important to study the antenna's characteristics in time domain.

3.3 ANTENNA DESIGN AND SIMULATION RESULTS

As mentioned earlier (in chapter-1), microstrip patch antennas are inexpensive, low weight, easy to manufacture, and versatile. They are most suitable for portable devices. The circular patch antenna is one of the most widely used configuration. In this chapter, the circular patch antenna is analyzed and designed using the transmission line model, and then its design is optimized using the software HFSS.

3.3.1 CIRCULAR PATCH ANTENNA

The antenna is designed using FR4 epoxy material as a dielectric substrate with dielectric constant $\varepsilon_r = 4.4$, loss tangent $\tan \delta = 0.02$ and thickness $h = 1.59$ mm. The antenna is designed to operate at a frequency of 6 GHz. The substrate has radius $R = 16.2$ mm as shown in Fig. 3.1. A coaxial probe feed is used with outer radius $R_w = 1.6$ mm.

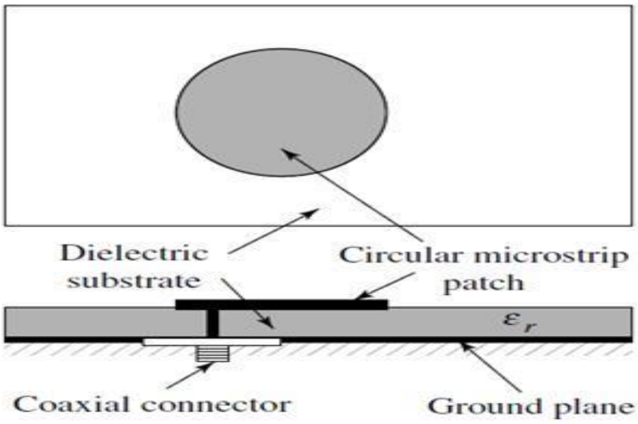


Fig. 3.1 Geometry of circular microstrip patch antenna

3.3.2 CIRCULAR PATCH ANTENNA WITH DIAMOND SHAPE SLOT

A diamond shape slot is cut on the circular patch to enhance the bandwidth of the antenna. The modified geometry of circular patch antenna is shown in Fig. 3.2. The outer circle radius of the patch is 16.2 mm, considered on glass epoxy FR-4 substrate. A concentric diamond slot is embedded in its center. The dimensions of the diamond slot is 4-8mm and coaxial probe feed arrangement is used with SMA connectors associated with 50 Ω feed line. The available bandwidth value is more than eight times higher than that of the conventional circular patch antenna with the same radius. Further higher bandwidth up to 30% with slight alterations in patch dimensions may also be achieved, but other antenna characteristics reduces to an extent.

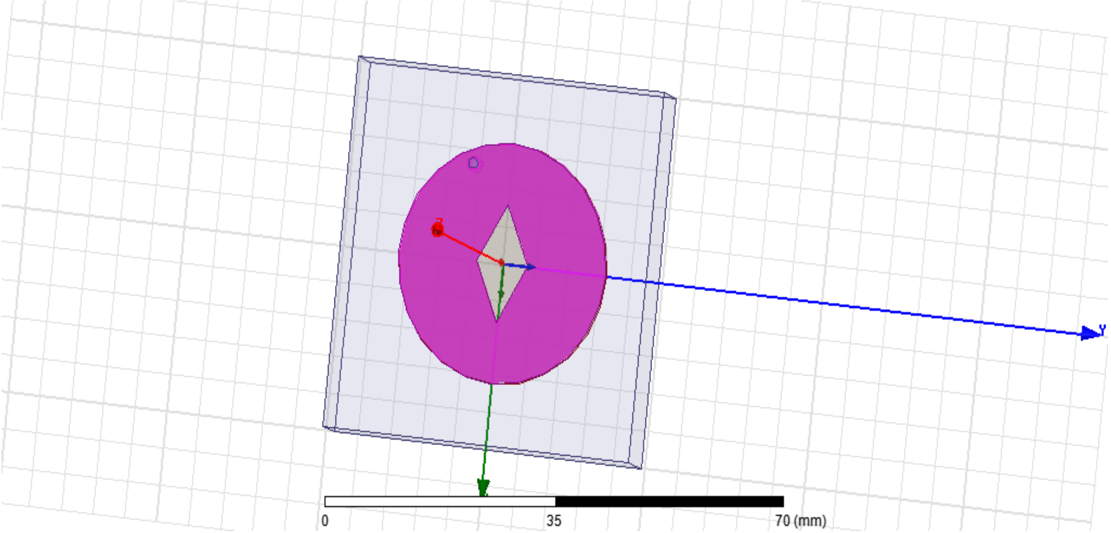


Fig. 3.2 Geometry of circular microstrip patch antenna with diamond shape slot

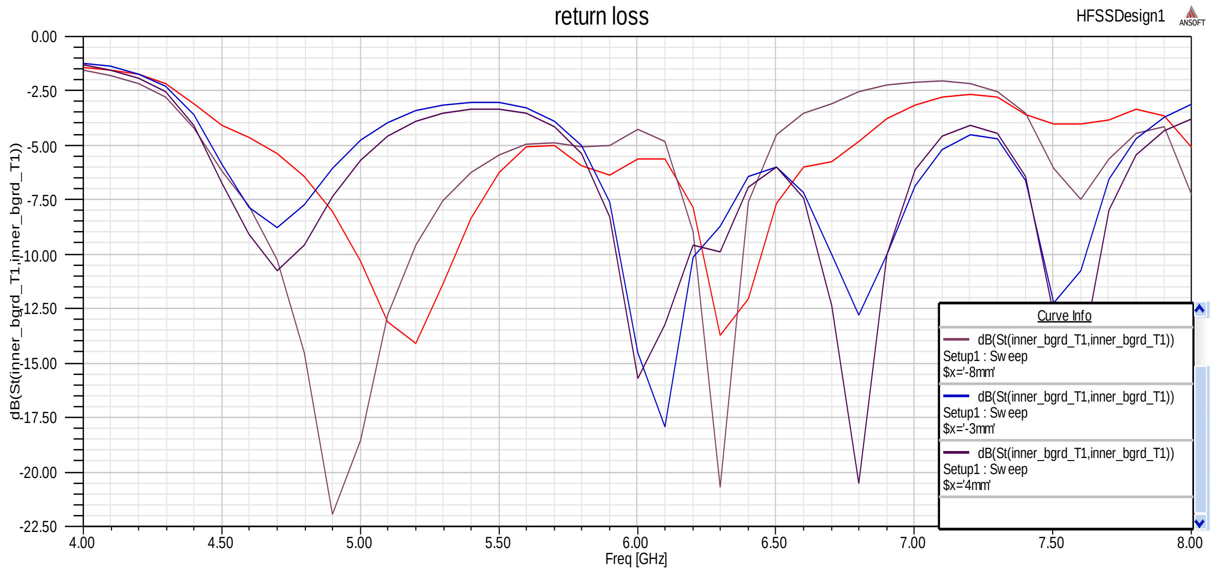


Fig. 3.3 Effect on return loss of Diamond-shaped slot on different feed location

3.3.3 CIRCULAR PATCH ANTENNA WITH DIAMOND SHAPE SLOT AND UNEQUAL E-SHAPE SLOT

The result obtained from the above antenna model is not satisfactory. Some modification must be done to improve the antenna bandwidth, so an unequal E-shape slot is cut on the patch. The dimensions of the unequal parallel slot are 10×2 mm, 2.5×2 mm and 8×2 mm.

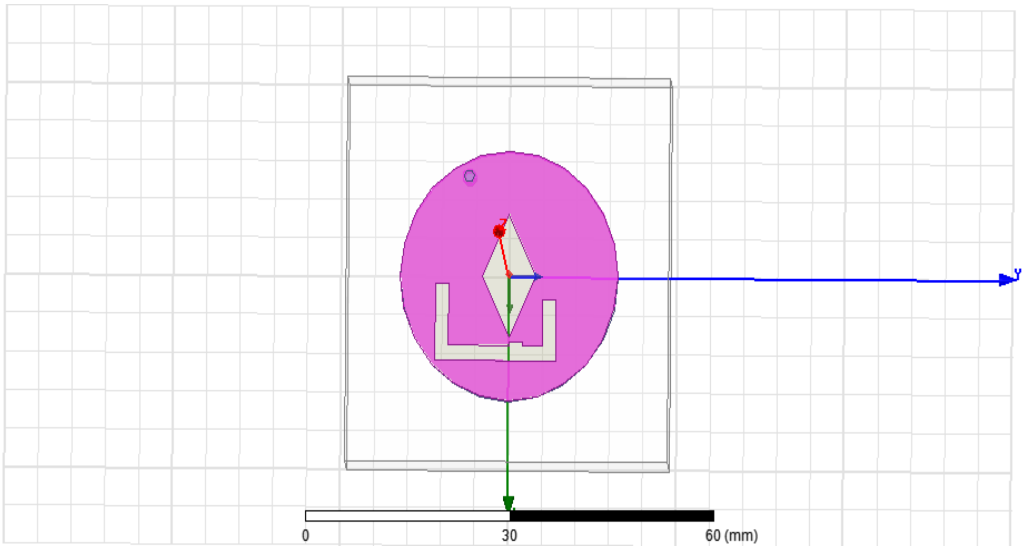


Fig. 3.4 Geometry of circular microstrip patch antenna with diamond shape slot and unequal E-shape slot

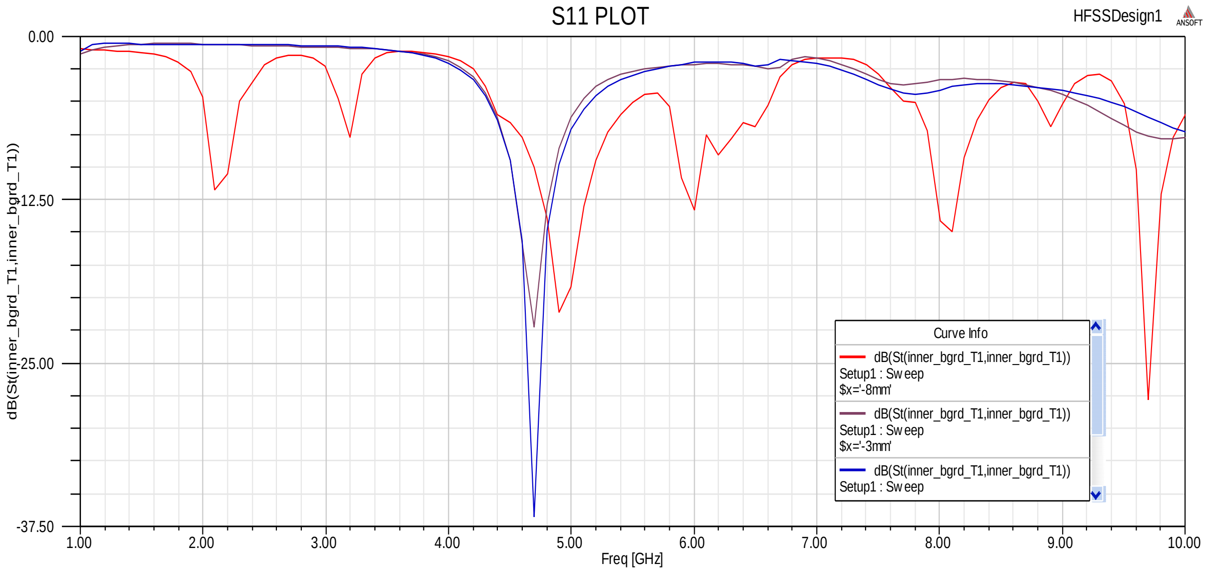


Fig. 3.5 Effect on return loss of Diamond-shaped slot and E-shape slot on different feed location

On cutting E-shape slot on circular patch already having diamond shape slot, the bandwidth has degrade marginally but the gain of the antenna improved by large amount. The dimensions of parallel slot are different and therefore many combinations are possible.

3.3.4 WB ANTENNA DESIGN

We start with the Conventional circular patch and through modifying the patch by cutting different structure slots; we reach a model having a diamond shape slot and unequal E- shape slot on patch. But the above antenna model is good in terms of single frequency or a multiband response. We don't get the result which satisfies wide band characteristic.

On cutting slot on the ground, we get some good result. On cutting a slot proposed by R.Bhalla and L. Shafai [30], a microstrip antenna having a circular arc slot on a circular ground is designed. We get an antenna model which provides wide bandwidth.

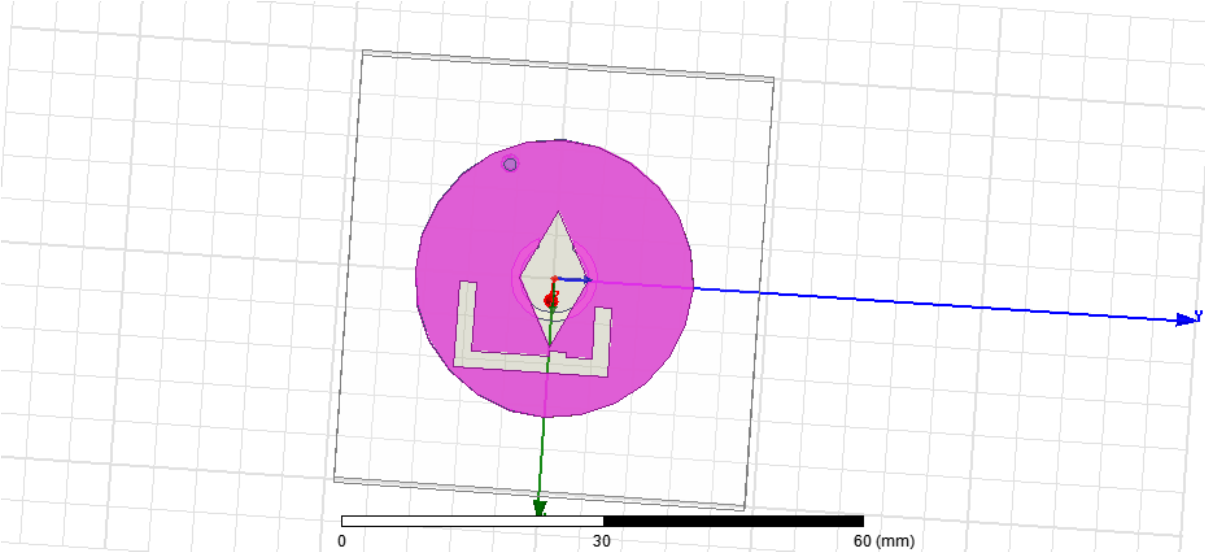


Fig. 3.6 Top view of diamond shape slot and unequal E-shape slot

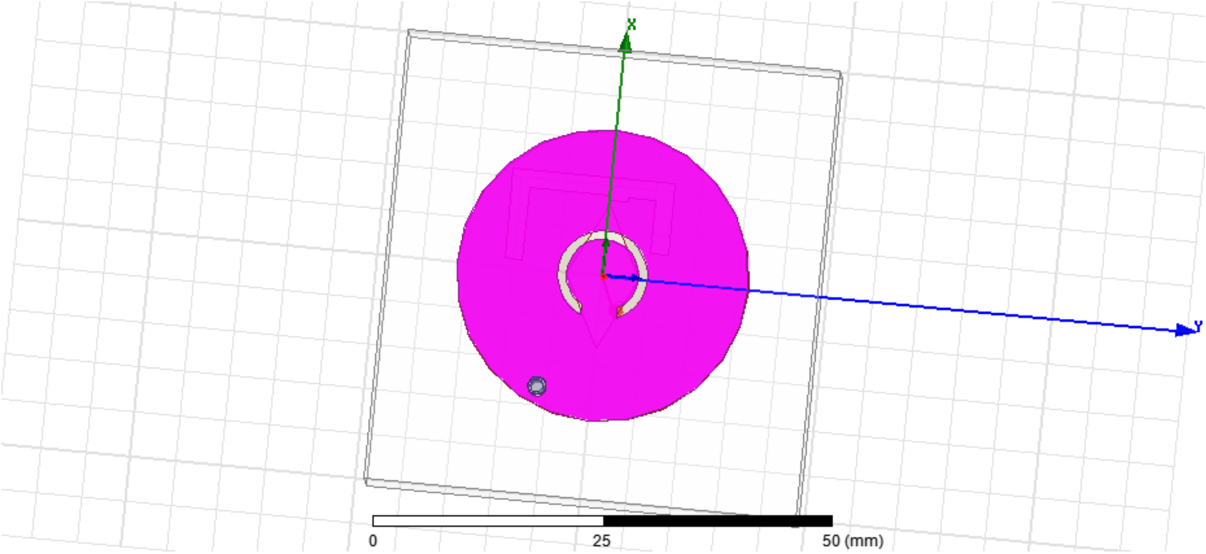


Fig. 3.7 Bottom view circular arc slot

Fig. 3.6 and Fig. 3.7 shows the whole geometry with detailed design parameters of the proposed WB antenna, which consists of 1.59 mm thick FR4 substrate of radius R = 16.2 mm with dielectric constant ε_r = 4.4. A circular patch of radius 16.2mm is mounted on the substrate. This antenna is fed by coaxial probe feed. A circular arc slot is cut at ground having inner radius r_a = 4 mm and outer radius r_b = 5 mm.

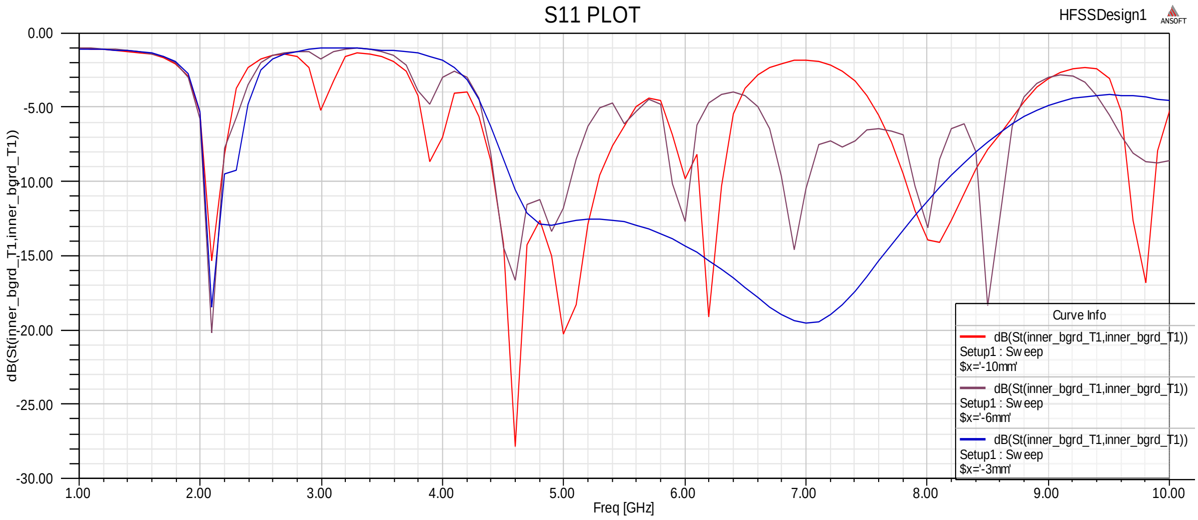


Fig. 3.8 Effect on return loss of WB antenna on different feed location

Fig. 3.8 shows the S_{11} plot on different feed location. The feed location (-3, -6, 0) gives an approx bandwidth of 4 GHz starting 4.4 GHz to 8.2 GHz.

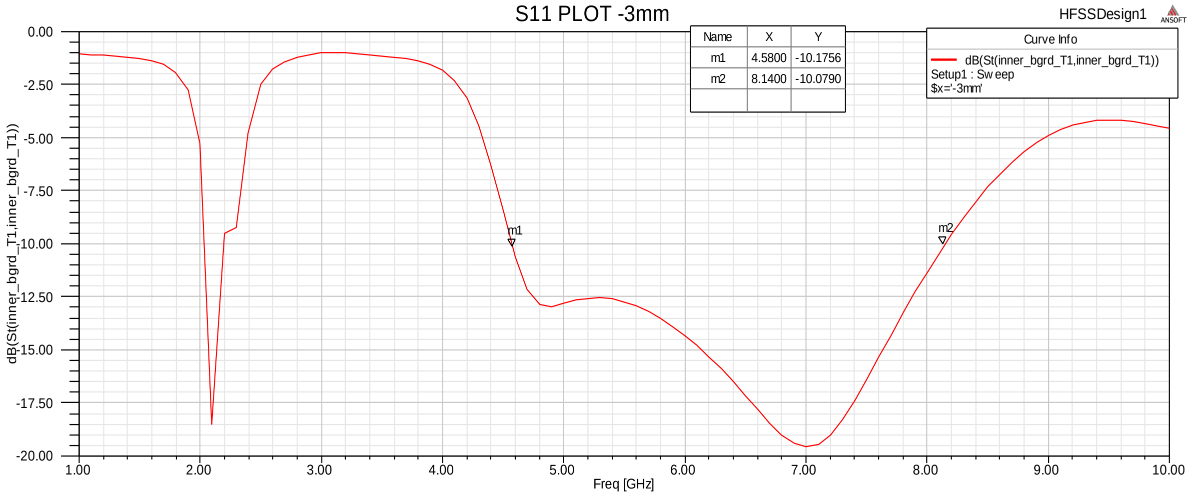
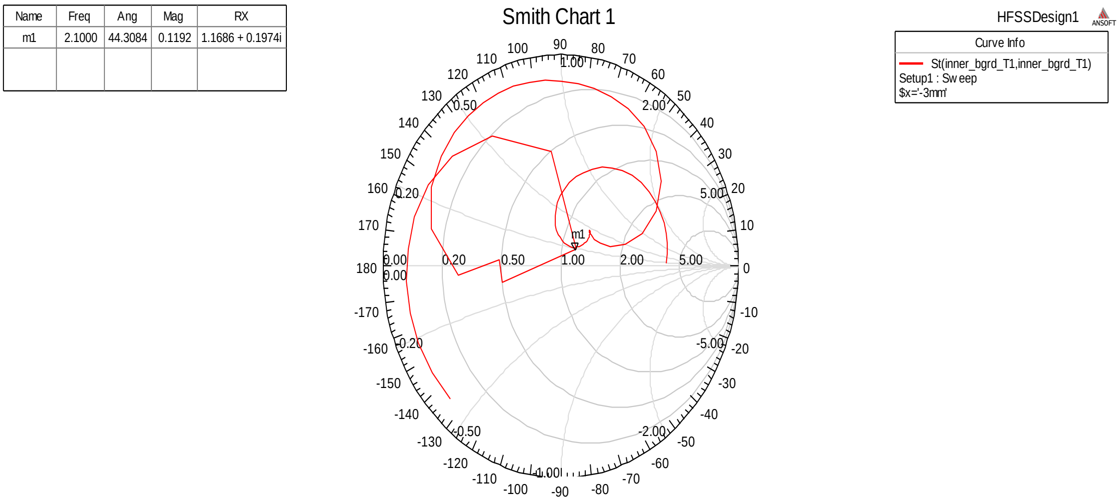


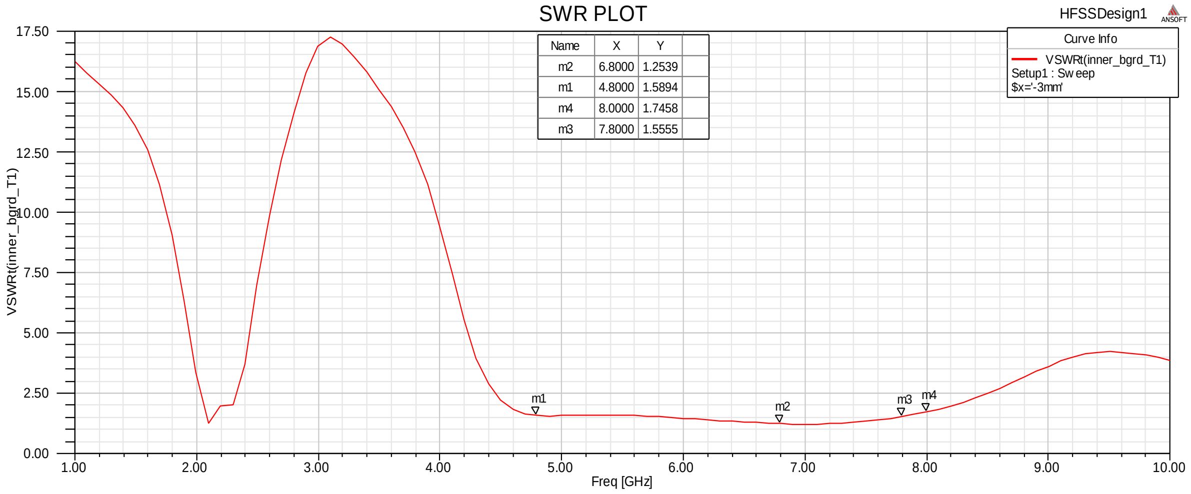
Fig. 3.9 Effect on return loss of WB antenna at feed location (-3,-6, 0)

Fig. 3.9 shows the S_{11} plot at feed location (-3, -6, 0). At this feed location the antenna gives 3.8 GHz bandwidth with good gain. The SWR, Smith chart and polar plot are given below for this particular feed location.



Name	Freq	Ang	Mag	RX
m1	2.1000	44.3084	0.1192	1.1686 + 0.1974i

Fig. 3.10 Smith chart of WB antenna at feed location (-3, -6, 0)



Name	X	Y
m2	6.8000	1.2539
m1	4.8000	1.5894
m4	8.0000	1.7458
m3	7.8000	1.5555

Fig. 3.11 SWR of WB antenna at feed location (-3, -6, 0)

Fig. 3.12 3D polar plot of the WB antenna at feed location (-3, -6, 0)

Chapter - 4

CONCLUSION AND FUTURE WORK

UWB technology will become the key solution for the future applications that require very high data rate, which results from the availability of large frequency spectrum. Therefore, the antenna redesign and analysis of those applications were carried out in this dissertation. The main aim of this dissertation was to develop a wideband antenna. The objective of this dissertation is achieved whereby the wideband antennas in circular shape were successfully developed by using Ansoft HFSS software. The performances of the antennas have been analyzed and investigated by simulation of different types of antennas with new shapes in patch such as the use of cutting slots in the patch. The results analyzed in the terms of return loss, VSWR, and radiation pattern.

Studies indicate that the UWB characteristic is obtained by making the proper selection for size of the ground, and the distance between the bottoms of the patch to the ground plane that means feed gap D_H. In a broad sense, the ground plane serves as an impedance matching circuit (helps in matching the impedance of the patch which is altered due to modification in the shape of the patch) and it tunes the input impedance and hence changes the operating bandwidth. Patch and ground plane shapes as well as feeding structure can be optimized to achieve a wide impedance bandwidth performance.

Based on the conclusions drawn and the limitations of the work presented, future work can be carried out in the following areas:

- UWB can promise enough speed to stream HDTV. However, at high frequencies there is more absorption, so the effective range and the throughput at a given range are reduced.
- UWB systems operate at extremely low power level which limits its transmission range. In order to enhance the quality of the communication link and improve channel capacity and range, directional systems with high gain are required for some applications. Therefore, research on UWB directional antenna could be carried out.
- It can also be used to determine the position of transmitters in indoor. UWB provides a location-finding feature, much like a local version of GPS. UWB capabilities are therefore crucial to rescue and law-enforcement missions.

- One drawback of UWB is that it is susceptible to interference from other transmitters. The ability of a UWB receiver to overcome this problem is sometimes called jamming resistance. This is a key characteristic of good receiver design. Multipath interference is also an issue, and one that also needs to be addressed in the receiver design.

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