CHAPTER-1
INTRODUCTION

1.1 MICROSTRIP ANTENNA

Microstrip antenna technology has developed very rapidly in recent years due to their light weight; small size and their ability to conform on the surface of host vehicle. It has attracted increasing attention of many researchers to investigate this type of antenna or arrays of various configurations to meet various practical applications i.e. mobile-communication, radar, remote sensing, sensors, navigation, surveillance, electronic warfare, radiometers and direct to home systems (DTH) etc.

Microstrip antennas inherently have a narrow bandwidth. However bandwidth enhancement is usually demanded for practical applications. Present day wireless communication systems require smaller antenna size in order to meet the miniaturization requirements for mobile units. Thus, size reduction and bandwidth enhancement are becoming major design considerations for practical applications of microstrip antennas. For this reason, studies to achieve compact and broadband operations of microstrip antennas have greatly increased. In addition to compactness, antennas are also required to provide circular polarization as in satellite links.

Such Microstrip antennas are planned to design, which are compact, broadband with dual frequency operation and can be used for many wireless communication applications like personal mobile communication systems, DTH systems, WIFI systems etc.

Considering above-mentioned facts, studies to achieve compact broadband antennas with dual frequency operations have greatly increased. Several efforts are going on in these directions e.g. making of slots in ground plane or in the radiating patch, incorporation of shorting pin in a microstrip patch and application of high permittivity
substrates. Investigations of microstrip antenna geometries are planned to achieve compact broadband antennas with dual frequency operations.

Microstrip antennas are replacing old and bulky antennas in modern communication system but their low gain and narrow bandwidth sometimes restrict their applications. Present day wireless communication systems require smaller antenna size in order to meet the miniaturization requirements for mobile units. Thus, size reduction and bandwidth enhancement are becoming major design considerations for practical applications of microstrip antennas. Investigations of microstrip antenna geometries are planned to achieve compact broadband antennas with dual frequency operations and can be used for many wireless communication applications.

A microstrip antenna has a radiating patch on one face of a substrate and a ground plane on the other face. A Patch may be Shapes of Square, circular, ring etc.

Microstrip antenna is like a parallel plate capacitor. Like Capacitor it also has two metal layers. Lower conducting layer of microstrip patch antenna is known as ground plane, and the top conducting layer is called a patch. The dimensions of the patch depend on the wavelength ($\lambda$) and therefore the microstrip patch antenna is classified like a resonant antenna. A simple patch antenna is shown in figure 1.1

![Figure 1.1 A Simple Microstrip Patch Antenna](image)
Where

\[ h \] : Height of the substrate
\[ \varepsilon_r \] : Relative permittivity of the patch
\[ W \] : Width of the patch
\[ L \] : Length of the patch.

A patch may be of any shape and dimensions as triangular, circular, rectangular, squares etc. It is shown in figure 1.2. It is generally photo etched on the substrate. The dielectric substrate is generally non–magnetic.

![Figure 1.2 some common shapes of patch elements](image)

Patch radiates between the patch boundary and the ground plane. A good antenna is with thick dielectric substrate should have a low dielectric constant is needed as this gives improved efficiency, larger bandwidth and superior radiations. A configuration leads to a more antenna size. To fabricate a compact patch antenna, high dielectric constants should be used which are low efficient and results in narrow bandwidth. Thus a settlement must be reached in between antenna size and performance.
In the year 1970 quick progress of microstrip antenna technology started. The first aperture coupled microstrip antenna was manufactured and examined by Allen Buck, in 1984, in the University Of Massachusetts Lab Of Antenna.

1.2 UWB TECHNOLOGY

UWB is a Very High-speed alternative to existing wireless technologies such as WLAN, Hiper LAN etc in today’s communication scenario and become essential for a long time due to its economical characteristics and received immense awareness by the researchers belong to industries and academics when FCC (federal communication commission) announced unlicensed RF- band 3.1-10.6 GHz for business use.

In recent time people have improved the different challenges of Ultra Wide Band antennas as, radiation patterns, impedance bandwidth, matching characteristics and compact size of the antenna. UWB Spectrum is shown in figure 1.3.

Figure 1.3 UWB Spectrum
1.2.1 MAJOR CHARACTERISTICS OF UWB & UWB ANTENNAS

- UWB antennas have attractive qualities such as small size, cost effective, ease of design, high data rate, wide impedance bandwidth & good Omni-directional radiation.
- Huge data rates (upto 500 Mbps) & high channel capacity.
- Less power (microwatt range) consumption and cost effective.
- Outstanding immunity to multipath interference.
- More secure with the help of PN (pseudo random noise) codes and is hence protected from jamming.
- It suffers from interference with present bands of frequency for communication like C-Band, WiMAX, WLAN and X-Band satellite communication.

1.3 INTRODUCTION AND DEFINING THE PROBLEM OF ELECTROMAGNETIC INTERFERENCE:

1.3.1 Defining the Problem

UWB Systems have a drawback that they are very sensitive to electromagnetic interferences with present Narrowband Wireless communication systems. So it is essential to fabricate antennas with multiband filtering characteristics for avoiding interferences. UWB (3.1 GHz to 10.6 GHz) includes sub narrowband applications like WiMAX operating in 3.3-3.6 GHz band, C band (3.8 - 4.2 GHz), WLAN (5.2-5.8) GHz band and X band satellite communication system operating in 7.25-8.35 GHz band.

1.3.2 Solution / method available

These bands could be rejected with band stop filters in UWB, but this approach will increase the complexity of the system. Therefore it is necessary to design the UWB antenna with band notched characteristic to reduce the complexity and make cost effective systems.

1.3.3 Method to solve this problem
Present work deals with the new methodologies for providing band notched characteristics with the help of slot technology: L and U slot (for C-Band / WLAN notching), CSRR Slot and EBG structure (for WiMAX and WLAN notching), miniaturization in feed line (for WLAN band notching), CPW fed UWB antenna (for X-Band and WLAN notching).

The performances of these designs have been studied using standard simulation tool i.e., Ansoft HFSS and finally measurements are done using VNA.

Here several UWB antennas were fabricated and used to minimize the interference problems due to the narrow band applications.

All designed antennas have been measured and they reflect good agreement between the proposed simulation results and the measured one. The antennas are novel designs specially developed for UWB uses with band filtering characteristics and compact in size.

1.4 FEEDING TECHNIQUES FOR PATCH ANTENNA

- Microstrip Line Feed Technique
- Coaxial Feed Method
- Feeding through Aperture Coupled Feedline
- Proximity Coupled Feed

1.4.1 Microstrip Line Feed Technique

In Microstrip feed technique, a conducting strip is coupled with the edge of the microstrip patch as given in Figure 1.6. The conducting strip is smaller in width as compared to the patch and this type of feed arrangement has the benefit that the feed can be etched on the same substrate to afford a planar structure.
The reason of the cut in the patch is to match the impedance of the feed line to the patch without the requirement for any extra matching element. This may be obtained by accurately controlling the inset location. Thus it is a simple feeding technique, as it provides easiness of fabrication and simplicity in modelling as well as impedance matching. Though the breadth of the dielectric substrate being used, increases, surface waves & it also increases the spurious feed radiation, it hampers the bandwidth of the antenna. It also leads to unwanted cross polarized radiation.

1.4.2 Coaxial Feed Method / Probe Feed Method

The Coaxial feed method is a very simple technique used to feed the Microstrip patch antennas. It can be seen in Figure 1.5, the inner conductor of the coaxial connector extends by the dielectric and it is soldered to the radiating patch, whereas the outer conductor is joined to the ground plane.
Figure 1.5: Coaxial Feed Method / Probe Feed Method

- The major benefit of this feeding technique is that the supply can be placed at any wanted location inside the patch for matching with its I/ P impedance. This type of feed technique is simple to manufacture and has less spurious radiation. Though, major drawback of this method is that it gives narrow bandwidth and is complicated to model as a hole has to be drilled in the dielectric substrate and the connector protrudes outer surface of the ground plane, therefore not making it fully planar for broad substrates ($h > 0.02\lambda_0$). For thicker dielectric substrates, input impedance become more inductive if the probe length increases, which creates matching problems. It can be observed that for a thick substrate, which gives broad bandwidth, the micro strip line feed and the coaxial feed face from many drawbacks. The non-contacting feed methods which have been explained given below, resolve these types of problems.

1.4.3 Feeding through Aperture Coupled Feed line

Here, the patch and the microstrip feed line are separated by the ground plane it is given in Figure 1.6. Coupling among the patch and the feed line is made through a slot or an aperture in the ground plane.
The coupling aperture is generally cantered below the patch, leading to poorer cross polarization due to symmetry of the organization. Coupling amount from the feed line to the patch is calculated by the size, shape and location of the aperture. As the ground plane separates the patch and the feed line, spurious radiation is minimized. Normally, a high dielectric constant material is used to the bottom substrate and a thick, low dielectric constant material is used for the top substrate to make the optimization radiation from the patch. The drawback of this feeding method is that it is complicated to construct due to many layers, this also raises the thickness of the antenna. This feeding method also gives narrow bandwidth.

1.4.4 Proximity coupled Feed line

This feed technique is also known as the electromagnetic coupling scheme. As given in Figure 1.9, two substrates are used such that the feed line is between the two dielectric substrates and the radiating patch is placed on top of the upper dielectric substrate. The major benefit of this technique is that it removes spurious feed radiation and gives high bandwidth, due to overall raise in the breadth of the patch. This technique also gives choices between two unlike dielectric media, one for the patch and another one for the feed line to optimize the performances.
Proximity-coupled Feed Matching can be attained by varying the length of the feed line and the width-to-line ratio of the patch. The main drawback of this feed technique is that it is not easy to construct because of the two dielectric layers which require correct alignment.

Work on microstrip antennas has no limits. It requires only dedication, motivation and patience. Extensive research work on microstrip antennas is going on in different parts of the world due to their extensive applications in wireless communication systems.

Size reduction and bandwidth enhancement are becoming major design considerations for practical applications of microstrip antennas. For this reason, studies to achieve compact and broadband operations of microstrip antennas have greatly increased. I will design microstrip antennas to achieve compact broadband with dual or multiband operation, which can fulfill requirement of present days wireless communication systems.

In this way one may feel that there is vast scope to carry out work in this field. If one has desired to work hard, there are no limits.

There has been an ever-growing demand in military as well as in commercial sectors for these microstrip antennas which possesses the following highly desirable attributes: Compact size, Low profile, Conformal in nature, Multiband or broadband.

It is now an established type of antenna that is confidently prescribed by designers worldwide, particularly when low-profile radiators are demanded. The microstrip antenna
has now reached an age of maturity where many well-tried techniques can be relied upon and there are few mysteries about its behaviour. Rigorous efforts are going on and now these antennas are finding applications in satellite & mobile communication, radars, remote sensing, sensors, navigation, surveillance, electronic warfare, radiometers, imaging, signal processing and so on.

Several countries are now having their satellites in outer space and they are providing those facilities to mankind, which were beyond imagination forty years back. India has recently become sixth nation in the world by designing and developing its own space vehicles for outer space and the first Indian spacecraft named Chandrayan-1 is expected to land on the surface of moon with the help of PSLV rocket in 2008. Developments in the field of telecommunication are not hidden to anyone. Mobile handsets are now becoming an imperative need for human beings. Satellite based global positioning systems (GPS) are expected to be used in near future for land vehicle, aircraft and maritime vessels to determine their position accurately. The direct broadcast satellite (DBS) systems are providing television services to general public in many countries. The essential and common component in all these systems is an antenna structure.

1.5 ADVANTAGES OF MICROSTRIP PATCH ANTENNAS:

Microstrip patch antennas are growing in popularity for utilize in wireless communication devices due to having low-profile configuration. Consequently these are enormously compatible for embedded systems in hand held wireless instruments like pagers, cellular phones, etc. The communication antennas and telemetry on missiles require to be thin and compact and are generally Microstrip patch antennas. One more area where they are used successfully is in Satellite communication. Some of their main advantages are discussed as given below:

- Occupy less volume and Light weight
- Low profile planar organization which can be simply made compact to host surface.
- Economical, so can be manufactured in bulky quantities.
- It is applicable to linear as well as circular polarization.
• Can be integrated without any difficulty with MICs (microwave integrated circuits)
• Capable for dual as well as triple frequency operations.
• Mechanically strong when mounted on rigid surfaces.

1.6 DRAWBACKS OF MICROSTRIP PATCH ANTENNAS

These antennas have a number of drawbacks as compared to usual antennas. Major drawbacks are given below:

• Narrow bandwidth
• Less efficient
• Poor Gain
• Superfluous radiation from feeding point and junctions
• Bad end fire radiator
• Handling power capacity is very low

Thus, advantages of microstrip antennas far outweigh their disadvantages for many applications. In early stage of their development, microstrip antennas found application mainly in military appliances such as missiles, rockets, aircrafts and satellites. Now these antennas are widely used in commercial sectors due to reduced cost of substrate materials and improved fabrication technology.

1.7 APPLICATIONS OF PATCH ANTENNA

During the past ten years, microstrip antenna experienced a great gain in popularity and is inviting wide interest in various modern communications.

The following subsections discuss some of the applications of microstrip antennas in the military, space and commercial sectors. The number of applications in these sectors is overwhelmingly and only a few examples are given below.

(a) Military Applications:—

In the military sector, high-velocity aircraft, missiles rockets and spacecrafts need low-profile and light weight antennas for conformal mounting outside their surfaces. The microstrip antenna is best suited for this requirement, As these antenna would neither
disturb the aerodynamic flow nor protrude inward to disrupt other already crowded space. The uses of microstrip antennas in the military sector have been numerous. These include functions such as altimeters, beacons, guidance fusing, telemetry command, communication radar, ECM, ECCM, GPS and so on.

(b) Space Applications:-

In the space sector, numerous applications of microstrip antennas have been implemented. To name a few, the following space programs have used microstrip antennas as arrays. Earth Limb Measurement Satellite (ELMS), International Sun Earth Explorer (ISEE), SEASET, Shuttle Imaging Radar (SIR), GEOSTAR, Solar Mesospheric Explorer (SME) and Mars Pathfinder.

(c) Mobile System and Base System Applications:-

Microstrip antennas are finding use for land-mobile base stations, maritime and aeronautical mobile systems in present scenario. In a cellular mobile phone, a service region enclosed by a base station antenna is separated into mini sectors to raise the utilization of RF channels. These antennas are fabricated to have a zone or multi-beam model to form three to six zones in 360° coverage. These patterns can be synthesized using an antenna array and microstrip antennas can be used as the most appropriate antenna elements. Antenna like a dipole and a parabolical or corner reflector, beam shaping cannot easily be realized. The array can be designed in flat structures and the antenna tower production is easier and economical from installing the microstrip antenna array on the tower than by using conventional weighty metallic antennas. Hori and Nakajima [1983] offered the configuration of base station antennas, which contain sector beam that shows a 60° – 120° sector beam array. It made of two or four sub arrays and every sub array made of 2 × 4 elements. The patch element is a broadband microstrip antenna having a parasitic element.

A multi beam base station antenna for land mobile communication made of 8 × 8 microstrip patch elements. The antenna works in vertical horizontal polarization and has eight beams within 120° area. When conventional patch elements have been used for base station antennas for miniature internal communication systems, sometimes indoor
communication interrupts when receiving antenna is to be positioned near the standing wave distribution minima. Ito & Saskai [1988] projected a easy printed antenna made of a $\lambda/2$ slot, a thick strip with a signal combiner. The antenna gets transmitted signal from both electric and magnetic fields as a result there will be almost no disturbance from standing waves. This type of antenna is known as an E-H antenna.

(d) Application in modern wireless systems:-

In modern scenario, microstrip antennas are finding wide-ranging applications in today’s wireless systems. A normal patch may not be applied for this reason due to its single resonance frequency, poor bandwidth and gain properties. These patch antennas were modified in various ways to improve their performance so that these antenna geometries are now becoming suitable candidate for application in Wi-Fi, Wi-Max, WLAN and Bluetooth applications. Vermeeren et al. [2001] projected a simple economical planar antenna for interior communication under blue tooth protocol. Ju et al. [2004] designed a several U-shaped slot microstrip patch antenna at 5.5GHz band WLAN applications. Jeong et al. [2006] designed a corner truncated square spiral microstrip patch antenna 5GHz band WLAN applications. Chen and Chang [2007] proposed a original design of printed monopole antenna for WLAN / Wi Max uses.

(e) Integration with electronic circuitry for different applications:-

Looking their compact size and improved properties, microstrip antennas are now becoming an integral part of electronic equipments. In recent times, several workers have reported integration of these antennas with electronic circuitry. Radisic et al. [1997] integrated circular sector microstrip antenna in class F power amplifier and in [1998] same group reported novel architectures having microstrip antennas of better efficiency amplifiers for wireless uses. Hang et al. [2000] demonstrated a push-pull amplifier integrated for power combining & harmonic tuning.

1.8 META-MATERIALS

Meta- materials are artificially loaded media which provide negative permittivity and permeability in fixed ranges. Implementation of these structures is arrays of split ring
resonators (SRR) and wires. They are complex 3D systems that are complex to use for radio frequency & microwave devices.

1.8.1 Features of metamaterials

- Improvement in the performance of a small monopole antenna, realized via the use of an ENG envelope that compensates for its high capacitive reactance.
- Lens effect produced by DNG slabs that are useful for enhancing the directivities of small antennas, e.g. dipoles and microstrip patches, by collimating the cylindrical waves emanating from these antennas and focusing them at infinity.

1.8.2 Applications of metamaterials

2. Waveguide discontinuity problem involving metamaterials.
3. Electronic control of leaky wave antenna.
4. Planar negative Refractive lens.
5. Zero order Resonator.
7. Electronic control of leaky wave antenna.

1.9 MODERN WIRELESS COMMUNICATION TECHNOLOGIES

The growth of the Internet over the last decade has led to an growing demand for high speed.Broadband Wireless technologies are rapidly getting popularity by the thriving global use of the Wireless individual Area Networks (Bluetooth- IEEE 802.15.1), WLAN (WiFi- IEEE 802.11n) and Wi-MAX(IEEE 802.16).

1.9.1 Bluetooth Technology

The Bluetooth technology began in 1994. Bluetooth is a poorer powered and shorter scope (30 feet) networking ability which transmits at an attractive speed around 800 kbps. The idea of Bluetooth is to restore a lot of the aggravating cables which we have to attach our instruments. The thought is to reinstate the cables which are essential to convoy transportable devices carried by various mobile voyagers with a low-cost, protected,
vigorose RF link. Initially Bluetooth marketed to minute handheld instruments such as cell phones & laptops. Bluetooth decreases the time and cables we need to achieve our tasks. Bluetooth makes it simple to reassign files between our Bluetooth instrument and a Bluetooth facilitated instrument of our friends and business associates. The Bluetooth standard came forward effectively into society, the humankind demanded more. It is described in an editorial Let’s Go Digital printed by Ilse Jurrien in 2006 that 3 fresh Bluetooth stuffs are practised each day and ten million Bluetooth components are transported per week. Bluetooth is so resourceful, successful and protected that even the IEEE permitted the 802.15.1 Standard for Wireless Person Area Networks based on the Bluetooth requirement as reported by Gifford in 2004.

Bluetooth technology works in (ISM) band at 2.4 - 2.485 GHz frequency range. Bluetooth is altered using AFH (adaptive frequency hopping). This technique has the ability to decrease interference among wireless technologies contribution the ISM band. The signal hops itself among 79 frequencies at 1 MHz intervals to reduce interference.

Bluetooth technology has engaged the world by eliminating the bulky wires which convoy most instruments. The Bluetooth standard is acknowledged on a worldwide scale building communication among instruments everywhere in the world a flawless attempt aiding in the increase of innovation to additional not only the society but economy as a whole.

1.9.2 WLAN (Wireless Local Area Network)

Wireless LANs are categorized as per their configurations which are dependent on the type of application they are used for. The four general applications of wireless LANs are LAN extensions, building interconnections, adhoc networks and nomadic access. Wireless LANs are distinguished from their wired counterparts through their lower layer technologies in the OSI model representation. The differentiating layers are the data link layer and the physical layer.

1.9.3 Wi-Fi Technology

Wi-Fi intended for Wireless Fidelity. Wi-Fi is a smaller range arrangement, normally
hundreds of meters, characteristically used by an end client to use their own system. Wi-Fi is little cost and is normally used to offer Internet admittance within a solitary room or house. For instance, many hotels, coffee shops, bus stations and railway stations include Wi-Fi access points giving access to the Internet for clients.

Wireless Routers that include a cable-modem or DSL-modem or & a Wi-Fi access point, frequently set up in houses to offer inter-networking and Internet-access to all instruments linked (using cable or wirelessly) to them. One can also attach Wi-Fi instruments in ad-hoc manner for client-to-client associations without any router. Wi-Fi permits LANs to be installed without cabling for consumer instruments, normally reducing the expenditure of network installation and development. Wireless system adapters are built into mainly modern laptops. Wi-Fi and Bluetooth have their resemblance but the main reason of Wi-Fi is to attach us to the internet to surf the web at broadband speed. Wi-Fi and Bluetooth are dissimilar but complimenting methods that can be extremely effective when employed jointly. Bluetooth provides us the capability to easily and rapidly transfer information to another Bluetooth client or instruments like printers, laptops, etc. and Wi-Fi provides us the capability to attach to the Internet wirelessly when we are contained by the range of a Wi-Fi hotspot.

1.9.4 Wi-Max Technology

Wi-Max means Worldwide Interoperability for Microwave Access. It is a telecommunications method of transferring wireless data above extensive distances many ways, using point-to-point links to occupied mobile cellular kind access. Wi-MAX is an extremely scalable, long-range scheme, covering a lot of kilometres by means of licensed spectrum to transport a point-to-point link to the Internet beginning from an ISP to an end client. Wi-Max can be employed to offer a wireless substitute to DSL and cable for broadband access, also to offer high-speed data and telecommunications facilities. Wi-Max can be employed to attach many Wi-Fi hotspots with all and also to other parts of Internet. Wi-Max could attach remote villages to the Internet by means of broadband. This would keep away from hassles in cabling throughout the forests and difficult terrain only to attain a few people in distant places. Maintaining such scheme would also be
trouble-free. Wi-Max could offer voice, Internet access, and IPTV to those areas.

The Wi-MAX specifications offer symmetrical bandwidth over long distance and range with powerful encryption and normally less interference. Wi-MAX is determined on licensed spectrum. Ease of use changes by country; most offered spectrum is in 2.3 GHz-2.7 GHz range and 3.4-3.7 GHz range. Total offered spectrum changes from 40 MHz to over 200 MHz depending on rules, Wi-Fi hotspots are normally backhauled over ADSL in mainly coffee shops so Wi-Fi access is normally extremely contended and has deprived upload speeds among the router and the internet. It offers connectivity among network endpoints without the requirement for straight line of sight in constructive circumstances, and the 802.16 specifications relate across a broad range of the RF spectrum. The mainly bands used will be approximately 3.5GHz, 2.3-2.5GHz or 5GHz. The real radio bandwidth of spectrum allotments is also likely to change.

Figure 1.8: The frequency locations of (a) WiMAX and (b) WLAN
Our visualization of the upcoming scenario is that Wi-Max will facilitate mobile broadband at a reasonable price. It will be attained by the acceptance of Wi-Max by a cellular supplier seeking to create a jump to the disturbing technology. Wi-Max is not expected to totally abolish the Wi-Fi technology in the near future, but will be harmonize to Wi-Fi as its main backhaul service of choice. Wi-Max assures to help corporations develop business, make down costs, raise overall profitability, raise the quality of service and raise the number of clients which attach to the Internet. Furthermore, the mobile Wi-Max method is considered to offer high-quality mobile broadband multimedia services; however, it provides challenges that operators need to believe prior to setting up their networks.

1.10 ANTENNA PARAMETERS

1.10.1 S-Parameters

S-parameters explain the input-output association between ports in an electrical scheme. For example, if we have two ports (Port 1 and Port 2), then $S_{12}$ stand for the power transmitted from Port 1 to Port 2. $S_{21}$ represents the power transmitted from Port 2 to Port 1.

$S_{21}$ stand for the power arriving at antenna 2 relative to the power input to antenna 1. For instance, $S_{21}=0$ dB means that all the power transported to antenna 1 ends up at the terminals of antenna 2 , that isn't actually possible. If $S_{21}=-10$ dB, means that 1 Watt transported to antenna 1, ends up as -10 dB at antenna 2, or 0.1 Watts.

$S_{11}$ stand for the power which is reflected from the antenna. If $S_{11}=0$ dB, then the entire power is transported from the antenna and nothing is radiated back. If $S_{11}=-10$ dB, means if 3 dB of power is fed to the antenna, -7 dB is reflected power. The remaining was "transported" by the antenna. This accepted power is either absorbed or radiated as losses inside the antenna. As antennas are characteristically premeditated to be small loss, the majority of the power fed to the antenna is emitted.

1.10.2 Voltage Standing Wave Ratio (VSWR)

VSWR stands for voltage standing wave ratio of electromagnetic waves (RF Waves) in
waveguide. VSWR gives an idea about Reflection Coefficient, Transmission and Impedance. Value of VSWR varies from 1 to ∞. Physical Meaning of VSWR is shown in figure 1.9. It is calculated through the voltage along a transmission line of an antenna. It is defined as the ratio of the maximum amplitude of a standing wave to the lowest amplitude of a standing wave.

![Figure 1.9 Physical Meaning of VSWR](image)

VSWR is an evaluation of how efficiently RF power is transmitted from a power source, by transmission line, for the antenna.

If designed antenna is 100% ideal, 100% of the power is transmitted. This needs an exact matching of the source impedance with the characteristic impedance of the transmission line and all of its connectors, and the load's impedance. The signal AC voltage will be the equal from end to end as it runs by without interference. Practically in the systems, mismatched impedances source some power to be reflected back in the direction of the source. Reflections create destructive interference, which leads to peaks and valleys in the voltage at different times and distances along with line.
VSWR measures these voltage differences. VSWR is the ratio of the maximum voltage anywhere in the transmission line to the minimum. In an ideal system the voltage doesn't change, its VSWR is 1.0 (or, as generally represented, 1:1). And if reflections occur, the voltages change and VSWR become higher -1.2 (or 1.2:1), for example.

1.10.3 Radiation Pattern

A radiation pattern explains the change of the power radiated using an antenna as a function of the path away from the antenna. The variation in power like a function of the angle of arrival is experimented in the far field.

![Figure 1.10: Example of Radiation Pattern in the H & E-plane](image)

1.11 SYSTAMATIC METHOD TO DESIGN AND FABRICATION OF MICROSTRIP PATCH ANTENNA

Object is to design a Microstrip patch antenna and make analysis by Vector Network Analyzer instrument with calculating essential parameters. The design and analysis methodology can be subdivided into three phases.
(1) Designing the Microstrip patch  (2) Fabrication  (3) Analysis of designed Patch

1.11.1 Designing the patch: -

To draw the image of patch on HFSS / I-CAD Software, we need length and width of the patch. To calculate these parameters we may use following standard formulas.

(i) Calculation of the Width (W): The width of the Microstrip patch antenna is given by equation as:

\[ W = \frac{c}{2f_0\sqrt{\frac{\varepsilon_r + 1}{2}}} \]  

............... (1.1)

(ii) Calculation of Effective dielectric constant (\(\varepsilon_{reff}\)): the effective dielectric constant is given as:

\[ \varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2} \left[ 1 + 12 \frac{h}{w} \right]^\frac{1}{2} \]  

............... (1.2)

(iii)Calculation of the Effective length (L eff): The effective length is given as:

\[ L_{eff} = \frac{C}{2f_0\sqrt{\varepsilon_{reff}}} \]  

............... (1.3)

(iv) Calculation of the length extension (\(\Delta L\)): the length extension is given as:

\[ \Delta L = 0.412h \frac{(\varepsilon_{reff}+0.3)(\frac{w}{h}+0.264)}{(\varepsilon_{reff}-0.258)(\frac{w}{h}+0.8)} \]  

............... (1.4)

(v) Calculation of actual length of patch (L): The actual length is obtained by re-writing equation as:
\[ L = L_{\text{eff}} - 2\Delta L \] ........................ (1.5)

(vi) Calculation of the ground plane dimensions \((L_g \text{ and } W_g)\): The model of transmission line is applicable to infinite ground planes only. Though, for practical assumptions, it is necessary to contain a finite ground plane. It is given that same results for finite and infinite ground plane are obtained if the dimension of the ground plane is higher than the patch dimensions by approximately six times the substrate breadth all around the periphery. Thus, for this fabrication, the ground plane dimensions are given as

\[
\begin{align*}
L_g &= 6h + L \\
W_g &= 6h + W
\end{align*}
\] ........................ (1.6)

1.11.2 Fabrication: -

It is fabricated in following steps.

Steps 1: Drawing and masking: First we have to draw length and width of the patch using I-CAD software. This designed image is shown in figure 1.10. This design will be submitted to Masking Machine Operator to design the mask. He will prepare the mask of patch by using masking machine.
Step 2: Photo resist on substrate: Taking substrate and then cleaned by acetone to remove dust & other waste particles. Then keep it in oven for one minute to dry the acetone. Then on one side of substrate apply the photo resist material in dark room. Now keep this in oven at 100 °C for 20 minutes.

Steps 3: Now keep the mask on the substrate (on surface where photo resist material is applied). Then keep this in ultra machine for 2 minutes & 30 seconds.

Step 4: Now keep this in developer for a one minute and then put this in acetone tank for 2 seconds. Now we can see patch film on substrate in proper light.

Step 5: Apply the DIE on the developed patch film carefully. Now we keep it in oven at 100 °C to dry the die on developed patch film.

Step 6: Then keep this in FeCl3 tank to remove copper on the substrate for patch. Then clean the die using acetone.

Step 7: Finding of feed point location (X f, Y f): A coaxial probe type feed may be used in this design. As given in Figure 5.2, the centre of the patch is taken as the origin and the feed point location is shown by the co-ordinates (X f, Y f,) from the origin. Location of the feed point should be at that point on the patch, where the input impedance is 50 ohms for the resonant frequency. Thus, a trial and error method is used to locate the feed point. For another location of the feed point, the return loss is compared and feed point is chosen where the return loss is maximum negative. These in the design, f Y will be zero and only f X will be varied to find the optimum feed point.
Step 8: - Finally we soldered the 3db connector. Now patch antenna is ready