CHAPTER 1

INTRODUCTION

1.0 Introduction

Lately, technological developments have stimulated growth of the personal computer and other electronic devices for indoor requirement in offices, manufacturing, shopping areas and warehouses. It is said that about 70% of the demands for high-speed data services occur in indoor environments [1]. In indoor application, the coverage is not as good as outdoor application because the signal has experience losses or attenuation. Therefore, monopole antenna was proposed in this project satisfy with multiple operation application. Multiple operation application very needed in nowadays as the development of the technology. Monopole antenna is the suitable candidate to overcome this problem due to its performance and size. In [2], a compact broadband antenna for indoor distributed antenna system for 2G, 3G, 4G and WiFi was proposed. However, the monopole antenna design[2] have more complex structure.

The demand of wideband and compact antennas are increasing dramatically with the rapid development of wireless communication system and their application[3]. The impedance bandwidth of the antenna measure from 2.45GHz until 5.35GHz is about 74.4%. The reduction in the ground plane size reduces bandwidth and gain[4]. There are several factor control the bandwidth listed in the journal[4] such as inset length, width of patch and height of the air gap. The L-strip electromagnetic coupling feed in antenna design can increase the bandwidth and avoid additional matching circuitry for impedance matching.

1.1 Problem Statement

The use of wireless communication system in Malaysia has developed rapidly causing Malaysia's telecommunication industries to also experience a tremendous growth. Wireless communication covers outdoor and indoor application. This wireless signal coverage is provided by outdoor stations, making outdoor application less problematic. The problem arise for indoor application, as it does not have a good coverage due to high signal losses caused by the building walls[2].Wall function is to provide protection to human and property from climate change or as part of the divider for rooms. The walls are built of brick, but there are other materials that can be used to suit the design. There are effects when using these materials[5].Besides that, wireless communication for indoor application has limitation for certain spectrum and it is inconvenient to receive multi standard operation. Due to the problem mentioned above, a wideband monopole antenna for indoor application with specific band allocation suitable with the frequency that are registered under Malaysian Communication and Multimedia Commission(MCMC) was designed.

As mentioned above, wireless communication system is being used by everybody indoor and outdoor, therefore with the design, people can worry less about having bad coverage while being indoor as it helps to give better line coverage. Rather than only having certain areas indoor where the coverage is good, using the design could cover all areas indoor. Other than that, this design has defined coverage so that user does not have to wonder around looking for places indoor which have a good coverage. This design is cost saving because it is multi operation antenna which can be used for multiple application like WLAN,Wi-MAX and 4G, therefore, user does not need to buy several antennas with different application just so to have a good coverage. Not only it saves cost by reducing the number of antenna, it could also reduce chemical use in fabrication of the antenna.

1.2 Objective

This project was inspired to address the issues noted in this project. Therefore, some of the objectives have been listed after taking account about measurable achievement and realistic at the time planned. The target will be the benchmark for this project. Main objectives of this research are:

i. To design a monopole patch antenna that works at frequency 2.5GHz(WiMAX),2.6GHz(4G-LTE), and 3.5GHz(WLAN) covering the standard frequency that has been registered into SKMM for Malaysian region.

ii. To analyzed the monopole antenna using Computer System Technique(CST) simulation software in term of s-parameter,gain,radiation pattern and other techniques that can be measured based on the capabilities of the system.

iii. To validate the simulated result through experimental setup and evaluation in laboratory.

1.3 Scope of work

There are some scope of work that will focus on material and equipment for the design, analysis and testing. Microstrip patch antenna design will be applied in this project. The proposed prototype antenna has overall size $49\times55\times1.6mm^3$. The microstrip feeding technique used match 50Ω microstrip line by controlling feed position. Monopole antenna design operates at multi-application frequency of 2.5GHz (WLAN),2.6GHz(4G-LTE) and 3.5GHz(WiMAX). It designed using the computer simulation technology(CST 2016) studio suite. The type of antenna that was chosen consist of a circular ring or c-shaped with some modifications ground plane. The antenna design will be optimized until get the best performance. Further procedures can be done after completing the design process to the next process of testing and fabrication process. Vector Network Analyzer(VNA) is an instrument used to measure important parameters and the most essential RF. Anechoic chamber used to test the prototype antenna which completely absorb internal and external electromagnetic wave. Both result will be compared between actual and measure value. The antenna parameters such as s-parameter,gain and radiation pattern will be look at to determine the performance of antenna design.

1.4 Organization of Work

This thesis consist five main sections, namely the introduction, literature review, methodology, results and conclusion. Chapter 1 describes an identification and significant goals of this project. This chapter consists of an introduction, problem statement, objectives, scope and review of all chapters. Chapter 2 describes the findings of a study by a comparison between journals available. This chapter also describes some general knowledge about the antenna. In Chapter 3, the processes of how the project is generated will be discussed in detail. Tuning methods and optimization process involved in this part is intended to produce the antenna that has the best performance. Chapter 4 will discuss about simulation and measurement result. Simulation result consist of several parameter such as scattering parameter, gain, radiation pattern and directivity. The comparison between simulation and measurement result are shown in this chapter. Lastly, chapter 5 will present about what has learned and discuss the shortcoming outcomes. Suggestion for future improvement also shared in order to facilitate future research.

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CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This is the literature review chapter that present the published antenna design at multi-operation application which is cover WLAN,Wi-MAX and 4G application. The comparison were carried based on selected platform. In addition, this chapter will cover patch antenna theory characteristic parameter.

2.2 Critical literature review

The literature review was performed on a journal to collect related information and facts that can be used in the design process of this project prior to research was carried out by performing a review of the literature in several journals related to research the topic of wide band monopole antenna for indoor application. Table 2.1 summarizes the sample literature of reviewed journals.

Table 2.1 Summary of journals for literature review

Journals	Application	Method	Improvement
[2]	0.66-3.07GHz (2G,3G,4G,Wi-Fi)	Deformed printed monopole on one side of the substrate and a polygon slot in the circular ground plane on the other side	Length of feed line
[6]	698-2690 MHz (LTE)	A tapered profile and a thin slot.Elliptical printed structure directly fed by a microstrip line	Length of feeding layout
[4]	1800MHZ-2370MHZ (3G)	L-strip Electromagnetically coupled rectangular patch antenna	Feed position, Ground plane size,L-Strip horizontal and vertical height
[3]	2.45GHz-5.35GHz (WLAN,WIMAX)	E-shaped patch and parasitic element (square patch)	Introduce additional resonance excitation
[7]	2.4-2.5GHz (WLAN)	E-shaped patch and two RF switches placed at appropriate locations in the slots	Slit position

2.3 Antenna Theory

Antenna are important in radio communication system. Designing an antenna is surrounded by a lot of mathematical derivation. All the way back to 1864, James Maxwell a Scottish physicist derived a set of mathematical equation that predicted existence of these electromagnetic waves. He predicted that it could be reflected, travel at speed of light and presence of loss with distance. Maxwell's four equations describe the electric and magnetic fields arising from varying distributions of electric charges and currents, and how those fields change in time[8]. The equation states that if the magnetic field is made to change very rapidly, it will produce an electric field at all around the magnetic field.

An antenna can be described by anything that can pull electric signal from the air to a wire or from a wire to the air. Generally, it made of metal because metal are good conductor. Antennas are used for anything that receives a signal off the air and that includes satellite dishes. Wi-Fi has antennas,but sometimes there are built into the routers and we cannot see unless it was open. Cellular phone also do the same thing for which the antennas are built into the phone. There are broadcast antennas and receive only antennas. Wi-Fi and cell phones antennas are both broadcast and receive antennas. TV towers and radio towers are broadcast antennas. A special license need in order to broadcast but not to receive. As example, a cell phone or wireless router basically do not have license for that but it actually the equipment is licensed to do it even though an individual personally do not need an individual license.

All antennas start with broadcast, if they do not have anything to receive, there is nothing that they can do. The tower is not just a big piece of metal unless we has put enough electricity through it and it is going to start radiating that power all the way through the air. When there are power put into the tower, it will broadcast and radiates at all directions. Eventually the electric signal is going to hit the antenna that is on our building. If the amount of power received is less than amount of power transmitted, it is mean the antenna has losses or called attenuation.

2.3.1 Types of Antenna

Antennas are design for different application of different materials, structures for better communication.There are several types of antenna popularly used:

i. Wire antenna

ii. Aperture antenna - mostly microwave (1-20GHz),high power

iii. Microstrip antenna - printed patch shaped

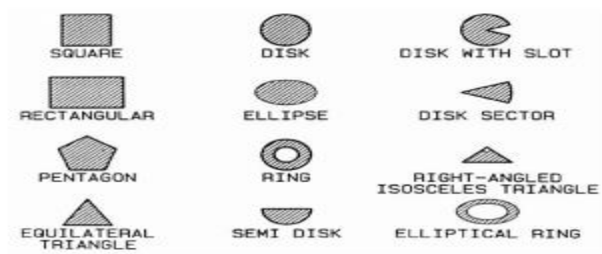


Figure 2.1 different shapes for microstrip antenna

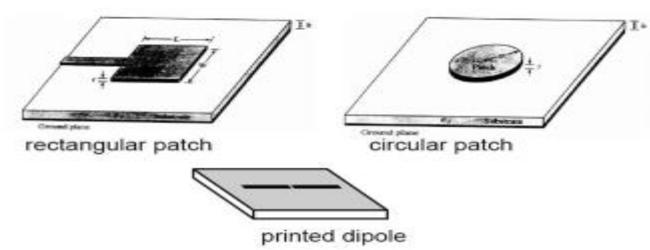


Figure 2.2 single patches

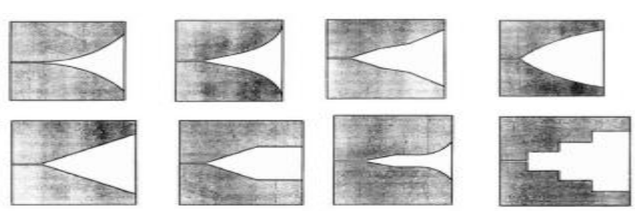


Figure 2.3 vivaldi design for typical range above 10 GHz

iv. Lens antenna - infrared and optical

v. Reflector antenna - high directivity,electrically large

Based on five types of antenna popularly used, microstrip antenna design has been one of the most popular in term of architectures, shapes and feeding method.

2.4 Important Parameter of Antenna

There are many important parameters of antenna to describe an antenna performance such as frequency bandwidth, radiation pattern, directivity, gain, input impedance and a few to name [10].

2.4.1 Frequency Bandwidth

According to Constantine A. Balanis [10], frequency bandwidth (BW) is the range of frequencies which show the performance of the antenna. In communication system, the message signal can be voice, music, picture or computer data. Each of this signal has different range in frequencies. Bandwidth is a frequency range over a signal spans. It is measured in a unit known as hertz(Hz) but also can be defined as the data transmitted per unit time which is measured in bits per second(bps) or megabits per second(Mbps). When bandwidth increases, the speed of connection will be increasing. It also not just directly related to the speed,it also inversely related to the range. As the bandwidth increases, the range will be decreases. An outdoor Wi-Fi with higher bandwidth will get higher speed of connection, but the range of the connection will be low. Bandwidth can be used in two different phases which are baseband and broadband. Baseband is used in Ethernet connection.

An antenna is said to be broadband can transmit a number of signals through the whole band. It allows to send as well as received the signal both at the same time. It also uses very high frequency waves to transmit the information signal and is used in long distance communication devices.

2.4.1.1 Narrowband

It refers to data that utilize a narrower set or band of frequencies which do not exceed coherent bandwidth. This bands is usually considered to cover frequencies less than 200MHz bandwidth.

2.4.1.2 Broadband

In broadcast communication, broadband frequency give a lot of advantage because it can handles many application within the frequency bands. "If the impedance and pattern of an antenna do not change significantly over about an octave (uf / l f =2) or more, it will classified as a broadband antenna"[15].

2.4.1.3 Wideband

A system is consider a wideband when bandwidth of return loss measured less than -10dB significantly exceeds the coherence bandwidth of the channel. This bands is usually considered to cover frequencies more than 200MHz bandwidth.

2.4.1.4 Ultra-wideband

This systems operate in a very large frequency range. interference may occur when the bandwidth of the system share the spectrum with other users as well as with the existing communication systems and consequently. Besides the interference from other users, it will cause disturbances to the network. This bands is usually considered to cover frequencies more than 2GHz bandwidth.

2.4.2 Radiation Pattern

An antenna released its signal in free space. These signals is distributed in free space and that is a region or the surrounding that receive this signal from the antenna. This region classified into two categories which is the near field region and farfield region. In this project, only the farfield region is determined. The signal that released from the antenna is getting distributed in these regions. These distribution of the electromagnetic fields are function of either the special angles like Theta and Phi in spherical coordinate system or function of Theta Phi and the radial distance depending on handling region. Real antenna come in two basic types distinguished by their radiation pattern, omni-directional and directional.

2.4.2.1 Directional Antenna

An antenna generate gain by focusing signal that would radiate in unwanted directions towards the desired direction. As the gain increases, the beam gets stronger and narrower. The gain of antenna measured in decibels(dB). If the signal strength is double, gain in dB will increase by 3. The pattern of the beam can be describe in two ways. First, construct a graph of a signal strength against direction. The common way to provide this data is to wrap the graph into a circle called polar diagram. The diagram below show the radiation pattern on horizontal plane and elevation plane or called side view plane.

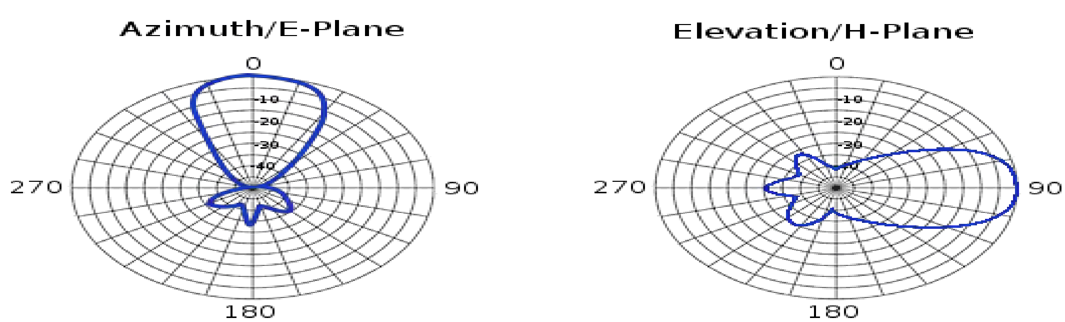


Figure 2.4 H-plane and E-plane of a microstrip antenna

Second ways to describe the radiation pattern of an antenna is to use beam-width. The angle of coverage can be describe based on the shape of the pattern in polar diagram in figure 2.5.

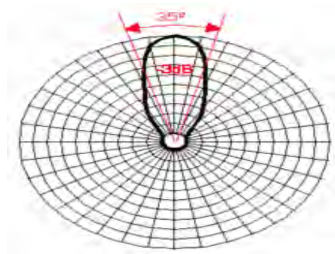


Figure 2.5 Beam-width of the antenna

2.4.2.2 Omnidirectional Antenna

Omnidirectional antenna implies that antenna radiates signal in all directions. The gain is generated by taking signal that would radiate into the sky or the ground and send it equally into a disk in the horizontal plane only. The thinner the disk, the higher the gain. Polar patter can be used to describe the antenna radiation pattern where H-plane pattern should be close to a circle at the radius corresponding to its gain and the E-plane pattern should be 2 bulbs along the horizontal touching the radius.

2.4.3 Polarization

Antenna polarization is relative to the E-field(electric vector) of antenna. If the E-field is horizontal, then the antenna horizontally polarized. When the E-field is vertical, the antenna is vertically polarized. All antennas in the same network must be polarized identically regardless of antenna type. Polarization may deliberately be used to increase isolation from unwanted signal sources, reduce interference and help define a specific coverage area. Low frequency antenna use vertically polarized because of ground effect while high frequency use horizontally polarized.

2.4.3.1 Types of Polarization

i) Circular polarization

Circular polarized antenna broadcast radio wave like a corkscrew. At a given point, two orthogonal wave are in phase. The waves are superposed. The resultant wave in a plane is nearly polarized. The amplitudes may differ but the waves must be in phase. The phase is shifted by a quarter cycle. The Ey displacement is greatest when the Ez displacement is zero. The resultant wave is circularly polarized.

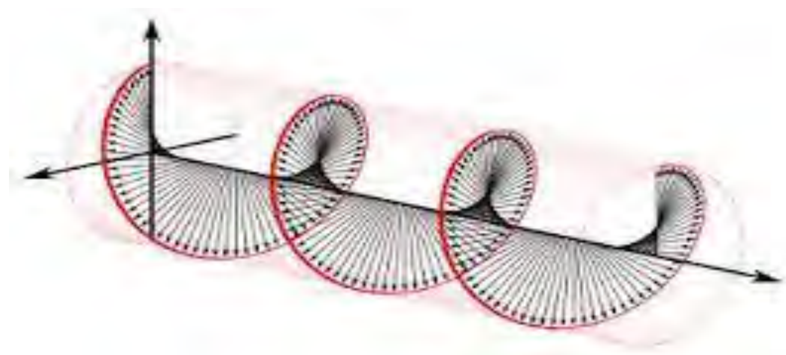


Figure 2.6 circular polarization

ii) Linear polarization

Linear polarized antennas broadcast radio waves on a single plane. It can be vertical or horizontal. Linear polarization antenna are great applications. It characteristic that concentrating radio waves on a single plane make it ranges typically twice as much as a circular polarized antenna with comparable gain.

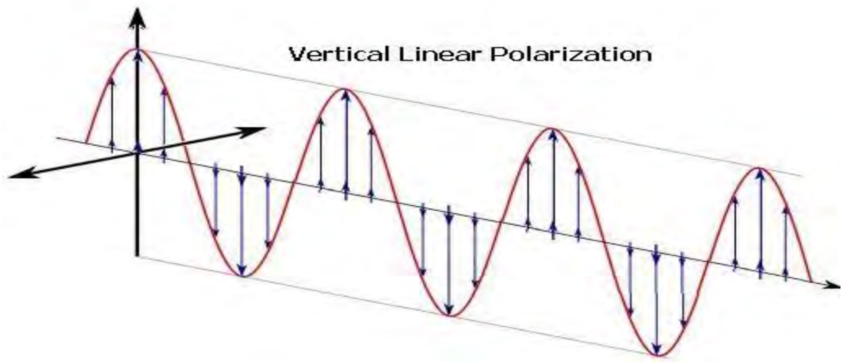


Figure 2.7 vertical linear polarization

iii) Elliptical polarization

Elliptically polarized light comprises two opposite waves unequal adequacy which vary in stage by 90 degree. The representation demonstrate ellipse polarization light.

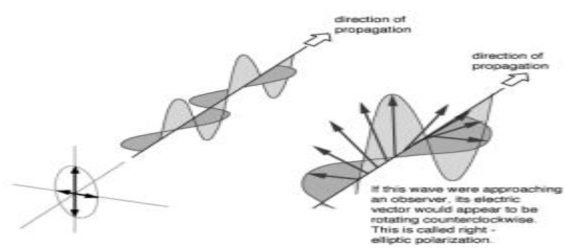


Figure 2.8 ellipse polarization

In the event that the thumb of right hand were indicating toward spread of the light,the electric vector would rotating toward the fingers.

2.4.4 Circularly Polarized Microstrip Patch Antenna

Microstrip receiving wires consistently created to end up distinctly a standout among the most appealing radio wire choices in an extensive variety of cutting edge microwave frameworks. In the majority of correspondence system,increasing the pick up of receiving wires utilized for transmission and gathering assume a noteworthy part in upgrading the framework execution. coordinating the polarization of the transmitting and getting radio wire is one of the principle calculates expanding pick up. Polarization portrays the introduction of motions in the plane oppositely to a transverse wave's heading of level. These wave planes could straightly sway in a similar bearing or their heading and sufficiency could change such to take after a circular form.

Polarization coordinating diminishes the transmission misfortune by adjusting the introduction of these wave proliferation's in both the transmitting and accepting radio wires. In accomplish this, coordinating the transmitter and beneficiary ought to have the same hub ratio,spatial introduction and a similar feeling of polarization. Coordinating is trying in remote advances that require versatility and compactness, for example, WLAN,GPS and so forth the utilization of circularly energized reception apparatuses presents an appealing answer for accomplish this polarization coordinate. While getting a circularly spellbound wave, the radio wire introduction is not imperative to be in the course opposite to the proliferation heading, consequently taking into account more portability.

A standout among the most mainstream reception apparatuses utilized for the generation of circular polarization is microstrip radio wire. Microstrip antenna alone do not create circular polarization. Circular polarization is accomplish in microstrip receiving wire by either acquainting a bother section with an essential single bolstered microstrip reception apparatus, or by sustaining the radio wire with double nourish in greatness however having 90 degree physical stage move.

2.4.5 Directivity and Gain

Antenna gains means antenna directional that expressed in terms of “dBi”. The word of “i” mean it relative to an isotropic radiation pattern. Basically every antenna is relative to perfect gain of 1. Isotropic radiation pattern is the same amount of energy in every direction. It is impossible to make or create an antenna isotropic. The gain of antenna works for both transmitter and receiver. Higher gain antenna will act as telescopes. The lower of an antenna make it less directional.

Nowadays, many researchers have managed to design an antenna that able transmitting or receiving signal with high directivity and gain. The directivity and gain are closely related. There area design and technique can enhance gain and directivity by reduce antenna size, using different materials and design. In theory, directivity is the ratio of the radiation intensity of an antenna energy in particular direction. The gain of an antenna describes as the ration of radiation power in a specific direction to its power in pattern direction. The main lobe always related with gain and shows specified direction of maximum radiation.

2.4.6 Voltage Standing Wave Ration (VSWR)

VSWR also known as Standing Wave Ratio(SWR) is a measurement of the power that sent from transmitting equipment to the antenna and how much power is reflected back. It is as the alternating current from transmitter goes out through an aerial. These standing waves are alternating point of high or low voltage and current. VSWR can be measured at any point along a current and voltage distribution. A low SWR are indicated by a high current and the highest SWR are indicated by low current. When an amplifier or transceiver has not very tolerant or poor SWR, they need a 50Ω match. If the antenna is a good match, it radiates off the antenna into free space. The reflected power back can cause damage to the transmitter in communication equipment. Ideal value of VSWR is 1, where it is indicates that antenna is perfectly matched to the transmission line.

2.4.7 Return Loss

In telecommunication, return loss is a measure of how much power is reflected back at the antenna port due to mismatch from the transmission line. The return loss is another way of expressing mismatch. It is a logarithmic ratio measured in dB that compares the power reflected by the antenna to the power that is fed into the antenna from the transmission line. Return loss is related to both standing wave ratio (SWR) and reflection coefficient (Γ). Increasing return loss corresponds to lower SWR. Generally, in wireless communications, the antenna is required to provide a return loss at least less than -10dB over its frequency bandwidth [6].

$$RL(\text{dB}) = -20 \log_{10} |\Gamma| \qquad (2.1)$$

Where,

RL = return loss

Γ = reflection coefficient

2.4.8 Input Impedance

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. Antenna and their transmission lines are typically designed for 50 Ω impedance. If the antenna has impedance different from 50Ω, then, there is a mismatch and an impedance matching circuit is required.

2.4.9 Microstrip Patch Antenna

Based on IEEE paper [7], microstrip patch antenna have more advantages compared than conventional microwave in wireless communication system application. Microstrip antenna was first developed in year 1950s, due to development of printed circuit (PCB) technology. After passing years, many studies about microstrip patch antenna and used in practical applications such on missiles and aircraft which has giving new era in antenna industry. It is popular because it is integrated with both passive and active microwave devices

According to paper [8], microstrip patch antenna consists of radiated patch component, dielectric substrate and ground plane. The patch and ground plane are separated by dielectric sheet or substrate. The ground plane and patch usually is a thin layer of copper or gold which is good conductor. The dielectric substrate is an electrical insulators and act as base for other materials usually in range of 2.2 to 12. From other research, it is shown that if low dielectric substrate used, then a thick substrate will be required and vice versa. Thick substrate will produce large bandwidth and good efficiency while thin substrate with high dielectric constant lead to smaller size but less efficient due to various losses. Figure 2.9 shows the structure of antenna basic parts.

There are four basic parts in the antenna design:

i. The patch

ii. Dielectric Substrate

iii. Ground Plane

iv. Feed Line

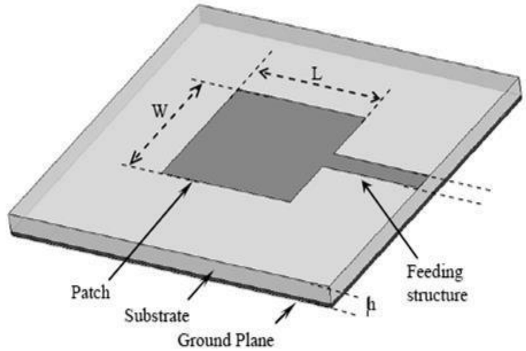


Figure 2.9 Basic Structure of Microstrip Patch Antenna

2.4.10 Feeding Techniques

There are many methods of feed techniques but some of the common techniques are microstrip line, coaxial probe, aperture coupling and proximity coupling [9]

i. Microstrip Line

Feeding methods by using conducting strip connected to the patch and can be consider as extension of patch. This technique is easy to fabricate and to control the inset position. The disadvantages of using this method is that if substrate thickness increases, feed ration increase also which limit the bandwidth as shown in Figure 2.10 respectively.

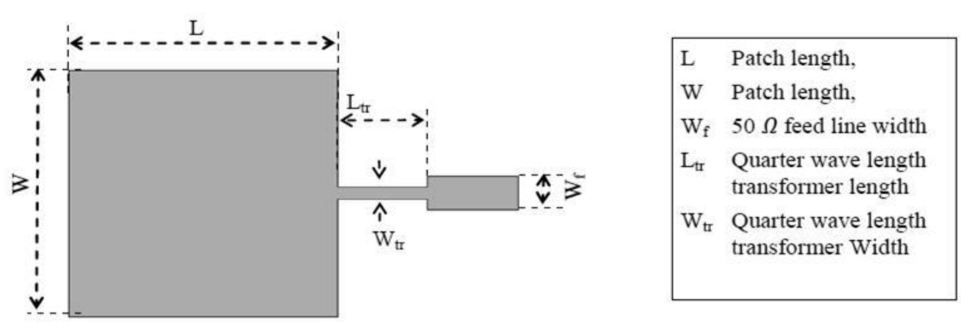


Figure 2.10 Microstrip line feed patch antenna

ii. Coaxial Probe

This type of feeding method is in which that the inner conductor of the coaxial is attached to the patch of antenna while the outer conductor is connected to the ground plane. Coaxial feeding is easy of fabrication, easy to match, low radiation but produce narrow bandwidth and difficult to model specially for thick substrate because need to drill as shown in Figure 2.11.

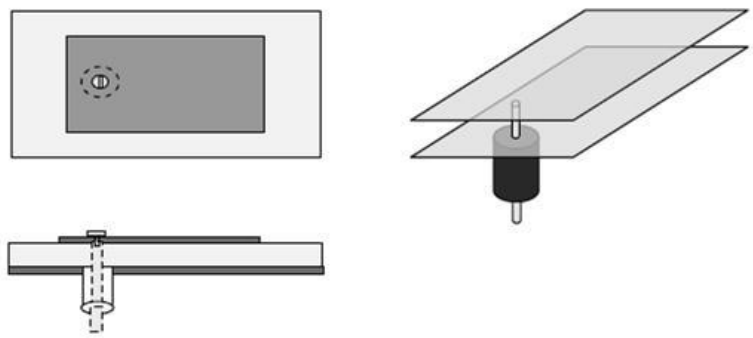


Figure 2.11 Coaxial probe feed

iii. Aperture Coupling

Consists of two different substrate separated by a ground plane. On the bottom side of lower substrate there is a microstrip feed line coupled to the patch and in the middle, a slot of ground plane separating two substrates. The two substrates parameters can be chosen different than each other to enhance antenna performance [14].In most design usually top substrates uses a thick low dielectric constant substrate and for the bottom substrate is the high dielectric substrate. Figure 2.9 show that this feed line allows independent optimization of the feed mechanism and radiating element. The ground plane in the middle helps to reduce interference of radiation for pattern formation and polarization.

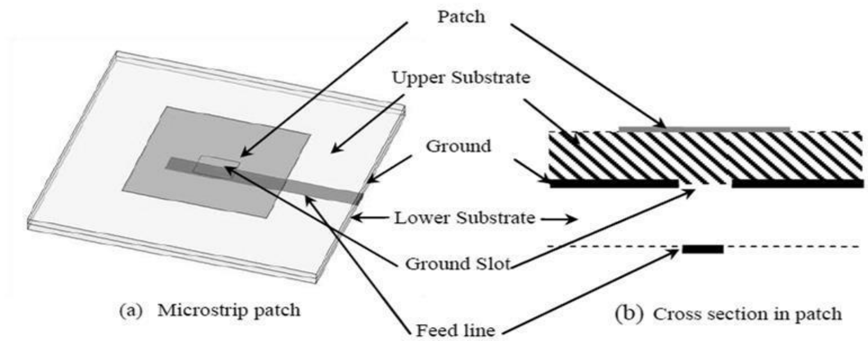


Figure 2.12 Aperture Coupled feed patch antenna

iv. Proximity Coupling

This method uses the length of feeding stub and width of patch to control match. The coupling mechanism is capacitive in nature. Advantages using this type method will produce largest bandwidth and low spurious radiation. Disadvantages are fabrication is difficult because the two dielectric layers need proper alignment also increase the thickness of the antenna as shown in figure 2.13. The comparison of four different techniques in feeding techniques is shown from table 2.2 respectively.

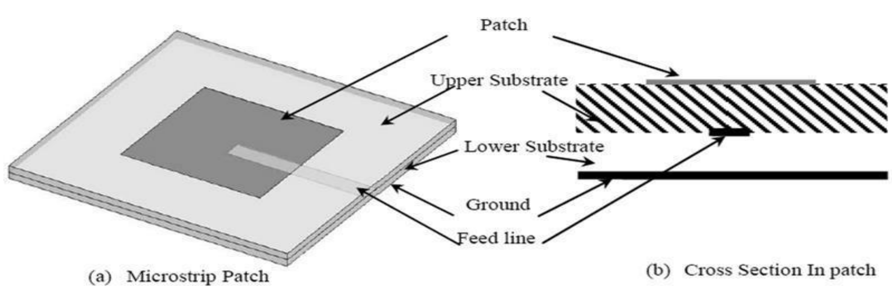


Figure 2.13 Proximity coupled microstrip patch antenna

Table 2.2 Comparing the different feed techniques [9]

Feed type property	Microstrip line feed	Coaxial feed	Aperture coupled feed	Proximity coupled feed
Spurious feed radiation	More	More	Less	Minimum

Reliability	Better	Poor due to soldering	Good	Good
Ease of fabrication	Easy	Soldering and drilling needed	Alignment required	Alignment required
Impedance matching(IM)	Easy	Easy	Easy	Easy
Bandwidth (after IM)	2-5%	2-5%	2-5%	13%

2.4.11 Patch Types

Microstrip patch antenna can be design in numerous shapes and size because of simple dimensional. The design of patch that generally used like square, rectangular, dipole, circular, triangular, circular ring and elliptical. Figure 2.8 shows the basic shapes of microstrip patch antenna.

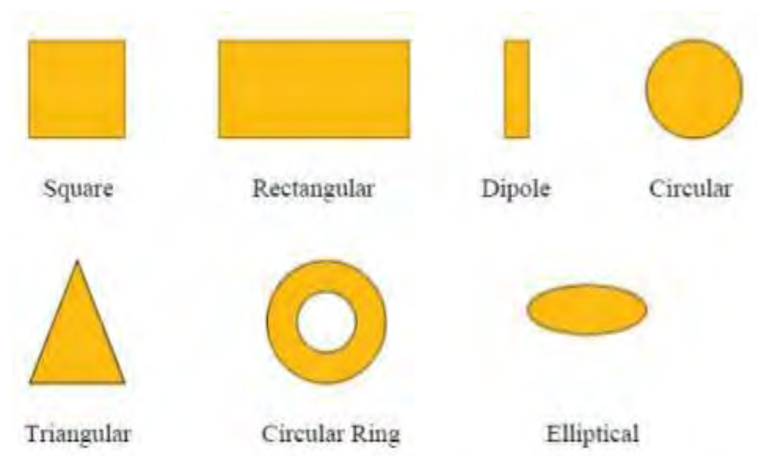


Figure 2.14Common Shape of Microstrip Patch Antenna

The various advantage and disadvantage of microstrip patch antenna are given in table 2.23[1]

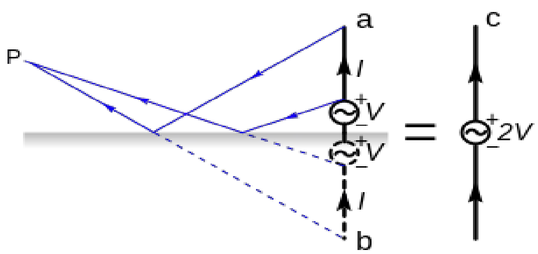
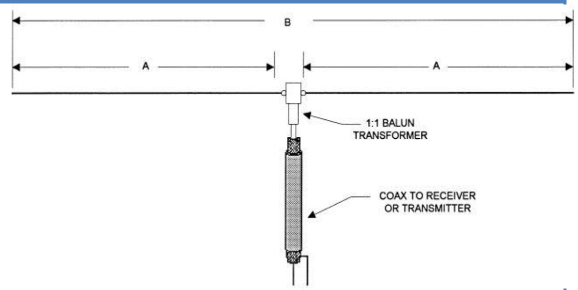
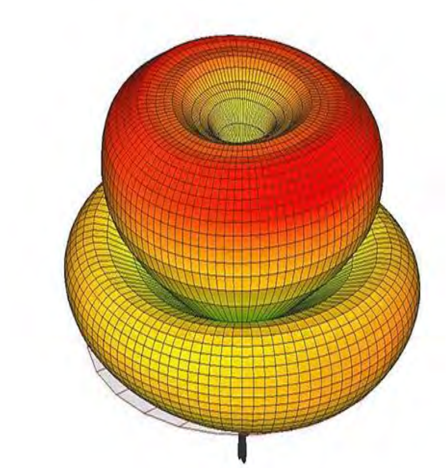
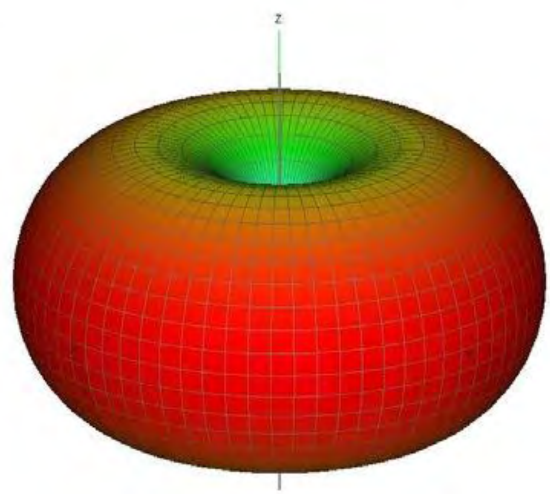
Table 2.3 Advantages and disadvantages of microstrip antenna

Advantages	Disadvantages
Low weight	Low efficiency
Low profile	Low gain
Thin profile	Large ohmic loss in the feed structure of arrays
Required no cavity backing	Low power handling capacity
Linear and circulation polarization	Excitation of surface waves
Capable of dual and triple frequency operation	Polarization purity is difficult to achieve
Feed lines and matching network can be fabricated simultaneously	Complex feed structures require high performance arrays

2.4.12 Monopole and dipole

Basically, monopole and dipole antenna are very similar. The main different can be seen between them is the size. Monopole ground element serves as an image ground to radiating element. Thus the name is"mono"-pole. Dipole has combination of two different element which is connected together perform as a radiating element and the other is ground. Monopole antenna are the best choice for size comparison because it has smaller size than dipole antenna. The directivity of the monopole antenna is twice the directivity of the dipole antenna despite the monopole antenna size is half the size of dipole antenna. The dipole antenna is known for its radiation pattern shaped like a donuts.

Table 2.4: monopole and dipole antenna

monopole	dipole
 Figure 2.15 monopole half wavelength	 Figure 2.16 dipole half wave
 Figure 2.17 monopole radiation pattern	 Figure 2.18 dipole radiation pattern