DESIGN OF MICROSTRIP ANTENNA BASED ON DIFFERENT MATERIAL PROPERTIES

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Microstrip antenna has several advantages compared to conventional microwave antenna. These type of antenna are light weight, low volume and thin profile configurations, which can be made conformal. The cost of fabrication is also low and can be manufactured in a large quantities. This project will discuss about the microstrip antenna. The aim of this project is to design a microstrip antenna by using Flame Retardant 4 (FR4) substrate and Roger 4350 substrate which will be operating in Wireless Local Area Network (WLAN). The frequency chosen for the microstrip antenna is 2.4GHz and it has been chosen from IEEE 802.11 which is for the Wireless Fidelity (WiFi) network. This project is divided into three major parts which are calculation, simulation and hardware design. Computer Simulation Technology (CST) microwave studio software used to analyze the radiation pattern of the antenna before fabricated the antenna. Vector Network Analyzer (VNA) used to measure the fabricated antenna to obtain the measurement result. The simulation and measurement results shows a little bit differences for both of the material substrates. Comparison between simulation and measurement result has been made.
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LIST OF SYMBOL AND ABBREVIATIONS

$\varepsilon_r$ - Dielectric relative constant
$\mu_o$ - Permeability in free space
$\varepsilon_{eff}$ - Effective dielectric constant
$\varepsilon_0$ - Dielectric constant in free space
$\Omega$ - Ohm
$\Gamma$ - Reflection coefficient
$\Delta L$ - Patch length extension
B - Bandwidth
C - Speed of light $3 \times 10^8$
W - Width
L - Length
F - Frequency
dB - decibel
VNA - Vector Network analyzer
MHz - Megahertz
GHz - Gigahertz
VSWR - Voltage standing wave ratio
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CHAPTER 1

INTRODUCTION

1.1 Background of Study

In high-performance like aircraft, spacecraft, satellite and missile application, where sizes, weight, cost, performance, ease of installation, and aerodynamic profile are constraints, low profile antenna may be required. Presently there are many other government and commercial application, such as mobile radio and wireless communications, which have similar specifications. Microstrip patch antenna can be used based on these requirements. This antenna are low profile, conformable to planar and non-planar surface, simple and low cost to manufacture by using a modern printed-circuit technology. Microstrip antennas consist of a patch of metallization on a grounded substrate. These are low-profile, lightweight antennas, most suitable for aerospace and mobile applications. Because of their low-power handling capability, these antenna can be used in low-power transmitting and receiving applications [1].

Wireless technology is a truly revolutionary paradigm shift, enabling multimedia communication between people and devices from any location. Wireless communications is by any measure, the fastest growing segment of the communications industry. As such, it has captured the attention of the media and the imagination of the public [2]. Modern wireless communication systems require low profile, lightweight,
high gain and simple structure antennas to assure reliability, mobility and high efficiency. There are many parameters are important in designing the microstrip antenna. Dielectric substrate is the main parameter in design purpose.

One types of wireless communication at 2.4GHz is Wireless Fidelity (WiFi). It is enable devices such as smartphone, personal computer, video game console or digital audio player can connect to the internet if within range of a wireless network connected to the internet. The microstrip antenna was drawn the maximum attention of the antenna community in recent year. A microstrip antenna is very simple in construction using a conventional microstrip fabrication technique. Microstrip antennas consist of a patch of metallization on a grounded electric substrate. There are low profiles, lightweight antennas, most suitable for aerospace and mobile applications. The conducting patch can be any shape but the most commonly used configurations are circular and rectangular configurations.

Deschamps first proposed the concept of microstrip antennas in 1953 but practical antennas were developed by Munson and Howell in 1970s [3]. Increasing requirements for personal and mobile communications has made the microstrip antennas very important. Microstrip antenna are becoming a popular choice for portable wireless system since they are light weight, low cost and easily manufacturable [4].

It is also can be applied in Wireless Local Area Network (WLAN) application. Wireless Local Area Networks (WLANs) use electromagnetic radio waves to transmit data between computers in a Local Area Network (LAN), without the limitations set by wired network cable or phone wire connection. These 802.11 Wireless Local Area Network (WLAN) systems may operate at 2.4GHz [4].

Microstrip patch antenna can take a variety of forms, but the basic element consists of a single patch of conductor on the upper surface of a grounded dielectric substrate. The patch radiates efficiently when it is resonant, which generally means that
some characteristic dimension of the patch is nearly equal to one-half wavelength in the substrate medium [5].

The shape of the patch can be rather arbitrary, but rectangular and circular patches have several desirable characteristics and more often used in practice [5]. Figure 1.1 shows the side view of simple microstrip patch antenna. The simple microstrip antenna consists of three layers which are substrate, patch layer and ground layer.

![Figure 1.1: Side view of microstrip patch antenna.](image)

1.2 **Problem Statement**

Antenna is develop in order to fulfill the problem occur and upgraded the antenna for the advanced technologies. A conventional antenna is very hard to design compared to microstrip antenna. A conventional antenna is very costly and quite heavy but the microstrip patch antenna has a simple structure and quite easy to fabricated. There are many shape of microstrip patch antenna such as rectangular, circular, triangular and other types of geometries. The most popular configuration is rectangular microstrip patch antenna. In order to produce antenna for Wireless Local Area Network (WLAN) application, based on the factor, a rectangular microstrip patch antenna will be designed. This project will used the Flame Retardant 4 (FR4) and Roger4350 as a dielectric substrate in fabrication of the antenna.
1.3 **Objective**

i. To design a microstrip antenna for Wireless Local Area Network (WLAN) application with frequency of 2.4GHz.

ii. To simulate the antenna design by using Computer Simulation Technology (CST) Microwave Studio.

iii. To fabricate the microstrip antenna by using Flame Retardant 4 (FR4) and Roger4350 substrate.

iv. To investigate the performance of the antennas in term of return loss, operating frequency, bandwidth and Voltage Standing Wave Ratio (VSWR).

1.4 **Scope**

The main scope of this project consist of two parts which is software and hardware design. For the simulation part, a Computer Simulation Technology (CST) Studio will be used in order to design a rectangular microstrip patch antenna. For the hardware part, a rectangular microstrip patch antenna will be fabricated by using the different materials which is Flame Retardant 4 (FR4) and Roger 4350. The Network Analyzer will be used to measure S11, input impedance and Voltage Standing Wave Ratio (VSWR) while for the radiation pattern will be measured in anechoic chamber.
CHAPTER 2

LITERATURE REVIEW

2.1 Overview

This chapter reviews some similar previous work, related journals and researches which include microstrip antenna design that can contribute an ideas for completing this project. This chapters also will discuss about the performance of the antenna and the material that has been used to fabricate the antenna. This chapter is very important to know the performance of the antenna and to get a better performance of the antenna compared to the conventional antenna.

2.2 Basic of Antenna

There are many basic types of antenna element such as the dipoles, horn, slot, spiral, long wire, monopole, and there are also many different types of systems where these element can be arrange in some form of an array, either fixed or electronically controlled. Thus, the antenna can be divided into four types depends on their operating frequency, characteristics and capability. The groups are resonant antenna, broadband antenna, aperture antenna and electrically small antenna.
2.3 Microstrip Antenna

In its simplest configuration, microstrip antenna consist of radiating patch on one side of a dielectric substrate which has a ground plane on the other side. The patch conductors normally is copper or gold. The radiating patch and feeding lines is usually photo etched at the dielectric substrate [6]. Figure 2.1 shows the structure of the microstrip patch antenna.

![Figure 2.1: Microstrip Patch Antenna Structure.](image)

Based on the Figure 2.1, it shows the common microstrip antenna structure where W is the width of the patch, L is the length of the patch, t is the thickness of the patch and h is the height of the substrate. To achieve the great in antenna performance, a thick dielectric which have a low dielectric constant is needed. This will provide higher efficiency, larger bandwidth and greater radiation. But, in order to achieve this, larger antenna size will be produced. In order to reduce the size of the antenna which mean to produce a compact design, a higher dielectric constant which is less efficient and will contribute a narrower bandwidth will be used [6].

Microstrip antenna has several advantages compared to conventional microwave antenna. These types of the antennas are light weight, low volume and thin profile configurations, which can be made conformal. The cost of fabrication is also low. So, it can be manufactured in a large quantities [6]. For the polarization types, it can support
both linear and circular polarization depending on the radiation pattern. Microstrip patch antenna also capable of dual and even triple frequency operations [6]. On the other hand, microstrip patch antennas also have some disadvantages. These type of antenna have a narrow bandwidth, low efficiency and also have a low gain [6].

2.3.1 Feed Techniques

Microstrip antenna feed techniques can be categorized in two categories which are 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. The microstrip line and the coaxial probe are examples of contacting method.

In the non-contacting, electromagnetic field coupling will be done to transfer the power between the microstrip line and the radiating patch. Techniques that are in these non-contacting methods are aperture coupling and proximity coupling [6]. The feed technique that was used in this project is the microstrip line feed. However, for the coaxial feed, it can be placed at any location to match with its input impedance. It provides narrow bandwidth and it is difficult to model. Figure 2.2 shows the coaxial feed of the antenna [6].

![Coaxial Feed of the Antenna.](image-url)
2.4 Antenna Properties

The performance of the antenna can be determine by this important parameters which is radiation pattern, directivity, gain, half-power beamwidth, bandwidth, input impedance, polarization, reflection coefficient, Voltage Standing Wave Ratio (VSWR) and return loss.

2.4.1 Radiation Pattern

It is defined as a mathematical function or a graphical representation of the radiation properties of the antenna as a function of space coordinates. The radiation property of most concern is the two or three-dimensional spatial distribution of radiated energy as the function of the observer’s position along a path of surface of constant radius [7].

2.4.1.1 Principal Patterns

For a linearly polarized antenna, the performance is usually described in terms of its principal E-plane and H-plane patterns. The E-plane is defined as the plane containing the electric-field vector and the direction of maximum radiation. The H-plane is defined as the plane containing the magnetic-field vector and the direction of maximum [7].

2.4.1.2 Radiation Pattern Lobes

A radiation lobe is a portion of the radiation pattern bounded by regions of relatively weak radiation intensity. A major lobe also called as the main beam is defined as the radiation lobe containing the direction of maximum radiation. A minor lobe is any
lobe except a major lobe. A side lobe is a radiation lobe in any direction other than the intended lobe. Usually a side lobe is adjacent to the main lobe and occupies the hemisphere in the direction of the main beam. A back lobe is a radiation lobe which the axis makes an angle of approximately 180 degrees with respect to the beam of an antenna [7]. Figure 2.3 shows the radiation pattern of a generic directional antenna.

![Radiation Pattern](image)

**Figure 2.3 : Radiation Pattern of a Generic Directional Antenna.**

### 2.4.2 Directivity

Directivity can be defined as the ratio of the radiation intensity in a given direction from the antenna to the radiation intensity averaged of all directions. The average radiation intensity is equal to the total power radiated by the antenna divided by $4\pi$. If the direction is not specified, the direction of maximum radiation intensity is implied [7]. If the direction is not specified, the direction of maximum radiation intensity can be expressed as

\[
D_{max} = D = \frac{U_{max}}{U_0} = \frac{4\pi U_{max}}{P_{rad}}
\]

(2.1)

Where

- $D$ = directivity (dimensionless)
- $D_0$ = maximum directivity (dimensionless)
Reference antennas usually are isotropic radiator where the radiated energy is the same in all direction and have directivity of 1. It can be defined as

\[ D = \frac{F_{\text{max}}}{F_0} \]

(2.2)

Where

\[ F_{\text{max}} = \text{maximum radiated energy} \]
\[ F_0 = \text{isotropic radiator energy} \]

### 2.4.3 Gain

Gain is closely related to directivity but it is measure that takes into account the efficiency of the antenna and also the directional capabilities. Absolute gain of an antenna in a given direction is defined as the ratio of the intensity, in a given direction, to the radiation intensity that would be obtained if the power accepted by the antenna were radiated isotropically. The radiation intensity corresponding to the isotropically radiated power is equal to the power accepted by the antenna divided by \( 4\pi \). It is also can be expressed as

\[ \text{Gain} = 4\pi \frac{\text{Radiation intensity}}{\text{Total input (accepted) power}} = 4\pi \frac{U(\theta, \phi)}{P_{\text{in}}} \]

(2.3)

For a lossless isotropic source, it can be determined by
Half-power Beamwidth

Half-power beamwidth can be 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 of the maximum value of the beam. It is used to describe the 3dB beamwidth. As the beamwidth decreases, the side lobe increases and vice versa [7].

Bandwidth

The term of bandwidth is defines as the range of frequencies within which the performance of the antenna, with respect to some characteristics, conforms to a specified standard. For narrowband antenna, the bandwidth is expressed as a percentage of the frequency difference over the center frequency of bandwidth. The characteristics such as input impedance, gain and polarization of the antenna do not necessarily affect the frequency. So, there is no unique characterization of the bandwidth. There are no distinctions made between pattern and input impedance variations. Pattern bandwidth and impedance bandwidth are used to emphasize this distinction. Gain, side lobe level, beamwidth, polarization and beam direction are associated with pattern bandwidth while input impedance and radiation efficiency are associated with impedance bandwidth [7]. Narrowband by percentage can be expressed by

\[
Bandwidth(BW) = \frac{\text{Higher cut-off frequency} - \text{Lower cut-off frequency}}{\text{Operating frequency}} \times 100\%
\]

(2.5)
2.4.6 Input Impedance

Input impedance can be defined as the impedance presented by the antenna at its terminals or ratio of the voltage to current at a pair of the ratio of the appropriate components of the electric to magnetic field at a point. The input impedance can be determined by the maximum power transfer between transmission line and the antenna. When the input impedance, antenna and transmission line are matched, the maximum power transfer will be achieved. Reflected wave will be generated at the antenna terminal and travel back towards the energy source if it is not matched. It will cause reduction on overall system efficiency [7]. The input impedance can be described as

\[ Z_1 = Z_0 \left| \frac{1+S_{11}}{1-S_{11}} \right| \]

(2.6)

Where

- \( Z_1 \) = n input impedance
- \( Z_0 \) = characteristic impedance
- \( S_{11} \) = return loss

2.4.7 Polarization

Polarization of the antenna in a given direction is defined as the polarization of the wave transmitted (radiated) by the antenna. The polarization of a wave can be defined in terms of a wave radiated or received by the antenna in a given direction. The polarization of a wave radiated by the antenna in a specified direction at a point in the far field is defined as the polarization of the plane wave whose electric field strength is the same as that of the wave and whose direction of propagation is in the radial direction from the antenna [7].
Polarization can be classified as linear, circular and elliptical. The field is said to be linearly polarized if the vector that describes the electric field at a point in space as a function of time is always directed along a line. If the electric field traces an ellipse, the field is elliptically polarized. For circular polarization, 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 [7].

Polarization characteristics of the antenna can be represented by its polarization pattern which is defined as the spatial distribution of the polarizations of a field vector excited by the antenna taken over its radiation sphere [7].

2.4.8 Reflection Coefficient

Determining the value of the input reflection coefficient of the antenna is necessary to determine the location of the resonant bands. The input reflection coefficient $\Gamma_{\text{in}}$, is obtained from expression below

$$\Gamma_{\text{in}} = \frac{Z_{\text{in}} - Z_0}{Z_{\text{in}} + Z_0}$$

(2.7)

Where

$Z_{\text{in}}$ = input impedance of the antenna

$Z_0$ = characteristic impedance used in the transmission line, as a reference

The absolute value of the reflection coefficient can be also expressed as the ratio of the reflected power from the antenna input, $P_{\text{in}}$ and the power delivered to the antenna, $P_{\text{in}}$ as in expression below
\[ |\Gamma_{in}| = \frac{P_{ref}}{P_{in}} \]  
(2.8)

### 2.4.9 Voltage Standing Wave Ratio (VSWR) and Return Loss

When a load is mismatched to a transmission line, not all power from the generator will be delivered to the load. The loss is called return and can be expressed by

\[ \text{Return Loss (RL)} = -20\log|\Gamma| \text{dB} \]  
(2.9)

A matched load, where the reflection coefficient, \( \Gamma=0 \) has returned loss of \( \infty \text{dB} \), whereas a total reflection of all power, where \( \Gamma=1 \), has a return loss of 0dB. In a mismatched line, the presence of reflected wave leads to standing wave, where the magnitude of the voltage oscillates along the line. As the value of reflection coefficient increases, the ratio of the minimum and maximum voltages values (\( V_{max} \) and \( V_{min} \)) also increases. So, the Voltage Standing Wave Ratio (VSWR) measures the ratio of these voltages on a transmission line. It can be expressed by

\[ \text{SWR} = \frac{V_{max}}{V_{min}} = \frac{1+|\Gamma|}{1-|\Gamma|} = \frac{1+S_{11}}{1-S_{11}} \]  
(2.10)

For the antenna to be reasonably functional, a minimum SWR \( 1.5 \leq \) is required.

### 2.5 Analysis for Transmission Line Model

The patch and ground-plane are separated by a dielectric. The patch conductor is normally copper. The patches are usually photo-etched on the dielectric substrate. The substrate is usually non-magnetic. The relative permittivity of the substrate is normally
in the region between 1 and 4, which enhances the fringing fields [8]. The rectangular patch is characterized by its length L, width W and thickness h, as shown in figure 2.4 below.

Figure 2.4: A Rectangular Microstrip Patch Antenna Showing Fringing Field that Account for Radiation.

The inner conductor of the coaxial-line is connected to the radiating patch, while the outer conductor is connected to the ground-plane, as shown in figure 2.5.

Figure 2.5: A patch excited using coaxial cable.

An effective dielectric constant ($\varepsilon_{eff}$) must be obtained in order to account for the fringing and the wave propagation in the line. The value of $\varepsilon_{eff}$ is slightly less than
\( \varepsilon_r \) because the fringing fields around the periphery of the patch are not confined in the dielectric substrate but are also spread in the air. It can be expressed by [9].

\[
\varepsilon_{\text{eff}} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2} \left( \sqrt{1 + 12 \frac{h}{W}} \right)
\]  

(2.11)

Where

- \( \varepsilon_{\text{eff}} \) = effective dielectric constant
- \( \varepsilon_r \) = dielectric constant of a substrate
- \( h \) = height of dielectric substrate
- \( W \) = width of a patch

For a given resonance frequency \((f_0)\), the effective length is given by [9]

\[
L_{\text{eff}} = \frac{e}{2f_0 \sqrt{\varepsilon_{\text{eff}}}}
\]  

(2.12)

The fringing fields along the width can be modeled as radiating slots and electrically the patch of the Microstrip antenna looks greater than its physical dimensions. The dimensions of the patch along its length have now been extended on each end by a distance, \( \Delta L \).

The \( \Delta L \) can be expressed by [9]

\[
\Delta L = 0.412h \frac{\left( \varepsilon_{\text{eff}}+3 \right) \left( \frac{W}{\pi} + 0.264 \right)}{\left( \varepsilon_{\text{eff}}-0.258 \right) \left( \frac{W}{\pi} + 0.264 \right)}
\]  

(2.13)

The effective length of the patch \( L_{\text{eff}} \) now becomes

\[
L_{\text{eff}} = L + 2\Delta L
\]  

(2.14)
Where

\[ \Delta L = \text{length due to fringing effects} \]
\[ L = \text{length of patch} \]
\[ L_{eff} = \text{effective length of the patch} \]
\[ h = \text{height of dielectric substrate} \]
\[ W = \text{width of the patch} \]
\[ \varepsilon_{reff} = \text{effective dielectric constant} \]

For efficient radiation, the width, \( W \) is given by [9]

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

(2.15)

Where

\( f_r \) = operating frequency
\( \varepsilon_r \) = dielectric constant of a substrate

2.5.1 Coaxial Probe Feed

![Diagram of Coaxial Probe Feed](image)

Figure 2.6: Choice of Feed Point for a Probe Fed-Patch

Figure 2.6 shows the choice of feed point for a probe fed-patch of the antenna. The advantage of this technique is that it can be placed at any location, and the impedance match will depend on its location on the patch. An improved impedance match will ideally increase the bandwidth, the return loss and improve performance by
reducing the excitation of unwanted modes of radiation. The feed coordinates were calculated using the following equation [10].

\[ Y \text{ (along the width)} = \frac{W}{2} \]

(2.16)

\[ X \text{ (along the length)} = \frac{L}{2\sqrt{\varepsilon_{\text{eff}}(l)}} \]

(2.17)

### 2.6 Wireless Local Area Network (WLAN)

A Wireless Local Area Network (WLAN) is flexible data communication network used as an extension to or an alternative for a wired Local Area Network (LAN) in a building. Increasingly more and more Wireless Local Area Network (WLAN) are being setup in home and or home office situations as the technology is becoming more affordable [11].

The increasing popularity of indoor Wireless Local Area Network (WLAN) capable of high-speed transfer rate is prompting the development of efficient broadband antennas. Due to increased usage in residential and office areas, these systems are required to be low profile, low cost as well as highly effective and efficient [11]. Microstrip patch antennas are well suited for Wireless Local Area Network (WLAN) application systems due to their versatility, conformability, low cost and low sensitivity to manufacturing tolerances. Conventionally patch antennas have showed a narrowband response, implicating low bit rate transfer.

The most commonly used Wireless Local Area Network (WLAN) system is the IEEE 802.11b system, with a maximum throughput of 11Mbps using a narrowband system. Broadband refers to transmission of information using a system that uses a comparatively larger frequency band, resulting in increases data transfer rate or
throughput. The broadband 802.11a system requires them to have a good coverage without failing signal strength. The range of coverage is dependent directly on the antenna performance hence the significance of the broadband antenna. A key requirement of a Wireless Local Area Network (WLAN) system is that it should be low profile, where it is almost invisible to the user. For this reason the microstrip patch antennas are the antennas of choice for Wireless Local Area Network (WLAN) use [11].

2.7 Previous Work Study

This review is made focusing on the current project based on the previous student’s work. This section describes the several of researches and projects that related to microstrip patch antenna design. An extensive literature search in the area of microstrip antenna for different substrate was conducted. It has been done to get some idea for the project. The databases such as IEEE and Google scholar, which are a leading source literature for antenna and engineering research, were used to complete the study. Mostly the literature reviews that have been found are based on a previous researcher’s technical papers from IEEE. The literature search is basically related on recent performance of different substrate, simulation and experiment testing and model updating on the antenna design. In this section, there are 6 papers that related to this studied will be discussed.

Kiran Jain [12] have carried out a research for different substrate used in microstrip patch antenna to enhance overall efficiency of antenna. Various substrates like Foam, Duroid, Benzocyclobutane, Roger4350, Epoxy, Flame Retardant 4 (FR4) and Duroid6010 are in use to achieve better gain and bandwidth. Another factor that impact directly is loss tangent it shows inverse relation with efficiency the dilemma is here is that substrate with lower loss tangent is costlier.

Substrates use in microstrip patch antenna varies from $2.2 \leq \varepsilon \leq 12$. Lower the permittivity of dielectric material larger the size of the antenna but it achieves better
efficiency and larger bandwidth. Table 2.1 shows the comparison between different substrate.

<table>
<thead>
<tr>
<th>Substrate</th>
<th>$\varepsilon_r$</th>
<th>Loss tangent</th>
<th>Resonance frequency</th>
<th>Return Loss</th>
<th>Gain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benzocyclobutane</td>
<td>2.6</td>
<td>0</td>
<td>2.04GHz</td>
<td>-18.124</td>
<td>5.5</td>
</tr>
<tr>
<td>Duroid 6010</td>
<td>10.7</td>
<td>0.00060</td>
<td>2.455GHz</td>
<td>-9.449</td>
<td>4.02</td>
</tr>
<tr>
<td>Nylon fabric</td>
<td>3.6</td>
<td>0.0083</td>
<td>989MHz</td>
<td>-35.42</td>
<td>6.11</td>
</tr>
<tr>
<td>Roger 4350</td>
<td>3.48</td>
<td>0.004</td>
<td>2.586GHz</td>
<td>-25.29</td>
<td>4.62</td>
</tr>
<tr>
<td>RT-Duroid</td>
<td>2.2</td>
<td>0.0009</td>
<td>10GHz</td>
<td>-12.03</td>
<td></td>
</tr>
<tr>
<td>Foam</td>
<td>1.05</td>
<td>0</td>
<td>454MHz</td>
<td>-16.732</td>
<td>2.73</td>
</tr>
<tr>
<td>FR4</td>
<td>4.4</td>
<td>0.018</td>
<td>5.8GHz</td>
<td>-14.73</td>
<td>9.8</td>
</tr>
</tbody>
</table>

The criterion for selection of right substrate is its price, efficiency and size. Minimum size is achieved by using foam substrate but it is costlier and losses are higher in it even the efficiency is much less than others. Maximum efficiency is achieved in Roger4350 but the size and price are the issues in it. Than an optimal solution is FR4 substrate but it sometimes requirement dependent.

O.Bayarmaa [13] proposed to design mobile handset antenna for make mobile handset more compact and thin. This antenna has an advantage of performing different frequency bands by one antenna design. Design and simulations are done using CST microwave Studio program. A Reconfigurable Antenna is designed by using the FR4 (lossy) substrate with the dielectric constant of $\varepsilon_r=4.3$ and dielectric loss tangent 0.025. The substrate thickness of h=1.6mm. This paper aim frequency between 0.9 GHz to 3.6GHz.

Antenna designers are always looking for creative ways to improve performance. This antenna resembles an Inverted-F, which explains the Planar Inverted-F Antenna.
(PIFA) name. The Planar Inverted-F Antenna is popular because it has a low profile and an omnidirectional pattern. The antenna design shown in Figure 2.7.

Figure 2.7: Antenna Design.

Figure 2.8 shows the simulated return loss of the proposed antenna. From the obtained results, it is clearly seen the return losses of the proposed antenna can cover the required bandwidth of the $S_{11} < -17.05\,\text{dB}$ at 0.9GHz, $S_{11} < -21.86\,\text{dB}$ at 2.4GHz and $S_{11} < -38.78\,\text{dB}$ at 3.6GHz band.

Figure 2.8: S-Parameter Magnitude in dB (Return loss).
Haruichi Kanaya [14], in this paper describe the design of one-sided directional slot antenna with quarter wavelength ($\lambda/4$) top metal layer, which is connected on the bottom metal layer, for 2.4GHz-band application. By using the two resonances appeared from the slot and $\lambda/4$ top metal, we can realize the one-sided directional radiation. We designed and simulated the proposed antenna by using the commercial electro-magnetic (EM) field simulator. This antenna is fabricated on FR4 printed circuit board and also carried out experiments on this antenna. Figure 2.9 shows the layout of the one-sided directional slot antenna with floating bottom metal layer. Cross sectional view of the substrate is also shown, namely, conductor-baked configuration.

![Figure 2.9](image.png)

Figure 2.9: Layout of the one-sided directional slot antenna with $\lambda/2$ floating bottom metal layer.

Figure 2.10 shows the simulated and measured return loss of this antenna. Center frequency and bandwidth is almost the same values. We can obtain that the $(S_{11})$ is approximately more than 10dB, which is almost the same as that of simulated value.
Figure 2.10: Comparison of the measured and simulated return loss of this antenna.

T. Jayachitra, V.K Pandey, Anshuman Singh [15], in this paper describe design of microstrip patch antenna used FR4 substrate for WLAN application. Simulation is done by ADS software. The implemented antenna is having FR4 substrate with dielectric constant 4.6 and input impedance 50 Ohm. Thickness of the substrate is taken as 1.6 mm. Operating frequency has chosen as 2.4GHz. Figure 2.11 show proposed antenna layout and photograph of a patch antenna on FR4 PCB.

Figure 2.11: Proposed Antenna Layout design and Photograph of a Patch Antenna on FR4 PCB.

The simulation of circular microstrip antenna is done on ADS software and get simulation results of return loss, Gain, 3D E- fields. Figure 2.11 depicts the resonating frequency of proposed patch antenna is 2.4 GHz and the return loss is -31.905dB. This low value of return loss yields higher efficiency in WLAN applications. Figure 2.12 and 2.13 shows the return loss characteristic of simulated and fabricated antenna, both are in a good agreement. The antenna is having best impedance matching at 2.45 GHz.
Maximum gain of antenna is approximately 6.368 dB and directivity is 9.016 dB which meets the requirements of wireless communication. The simulated and measured results satisfy the requirements of wireless communication. Table 2.2 shows the overall results for circular polarized microstrip patch antenna.

![Simulated result of return loss characteristic.](image1)

Figure 2.12: Simulated result of return loss characteristic.

![Measured results of return loss.](image2)

Figure 2.13: Measured results of return loss.

Table 2.2: Circular polarized microstrip patch antenna results

<table>
<thead>
<tr>
<th>Specifications</th>
<th>Observation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency(GHz)</td>
<td>2.404</td>
</tr>
</tbody>
</table>
REFERENCES


