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Enhancement of the characteristic of the half E-shaped micro strip patch antenna by effecting cavity structure

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بسم الله الرحمن الرحيم

ولسوف يعطيك ربك فترضى

صدقاللهالعظيم

الضحىالآية 5

Dedication

TO

MY FAMILY *WITHLOVE AND*

RESPECT

AZHAR

&

AREEJ

ACKNOWLEDGEMENTS

"In the name of Allah, the most Gracious, the most Merciful"

Praise be to Allah, for providing me the willingness and strength to a accomplish this work.

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Special thanks are due to my **close friends** for their participation inany way or another in accomplishing this work.

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Without all of you, this experience would never have been the same.

Thank you.

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&

AREEJ

ABSTRACT

The area of microstrip antennas has seen some inventive work in recent years and is one of the most dynamic fields of antenna theory.

The ever increase need for mobile communication and the emergence of newer technologies require an efficient design of antenna of smaller size for wider frequency range applications such as Wi-Max. the main aim of this project is increase the bandwidth of the rectangular patch antenna. A low profile wideband unequal E-shape patch antenna for Wi-Max application is proposed in this project.

This proposed antenna is made by using the microstrip feeding method with operating frequency1.8 GHz. The simulation process has been done through Math Lab software. The properties of antenna such as bandwidth, return loss, VSWR has been investigation and compared between a single element rectangular` and E-shape microstrip antenna.

Its bandwidth is further increased by introducing composed effect of

LIST OF CONTENTS

Titles	Page No
Dedication	I
Acknowledgement	II
Abstract	III
List of Contents	IV
List of Tables	VIII
List of Figures	XI
List of Abbreviations	XV
List of Symbols	XVII

Chapter One: Introduction and Literature Survey

1.1 Introduction	**1**
1.2 Micro strip Antenna	**1**
1.2.1 Advantages and Disadvantages of Micro strip Antennas	**1**
1.3 Problem Statement	**3**
1.4 Aim of the work	**3**
1.5 Project Organization	**3**

Chapter Two: Theory Of Micro strip Patch Antenna

2.1 Introduction	**5**
2.2 Micro strip Antenna Configuration	**5**
2.3 Feeding Methods	**7**
2.3.1 Micro strip Line Feeding	**8**
2.3.2 Coaxial Cable or Probe Feeding	**8**

2.3.3 Aperture Coupling 9

2.3.4 Proximity Coupling 9

2.4 Scattering Parameters 9

2.5 Antenna Parameters 11

2.5.1 Radiation Pattern 12

2.5.2 Return Loss 12

2.5.3 Input Impedance 13

2.5.4 Gain 13

2.5.5Voltage Standing Wave Ratio(VSWR) 14

2.5.6 Half Power Beam width 15

2.5.7 Directivity 15

2.5.8 Bandwidth 16

2.5.9 Polarization 16

2.5.10 Efficiency 17

2.6Methods of Analysis 17

2.6.1 Transmission Lines Model 17

2.6.2 Cavity Model 22

2.6.3 Full Wave Analysis 25

2.6.3.1 Spectral Domain Full –Wave Analysis 26

2.6.3.2 Mixed- Potential Integral Equation Analysis(MPIE) 27

2.6.3.3 Finite-Difference Time-Domain Analysis (FDTD) 27

Chapter Three: Methodology

3.1 Introduction 29

3. 2 Design Procedure 29

3.3 Design Of Rectangular Micro strip Patch Antenna 30

3.4 Design Specifications 30

Chapter Four: Results and discussion

4.1 Introduction 35

4.2 Rectangular Patch Antenna 35

4.2.1 Variable Substrate's Height 35

4.2.2*Rectangular patch antenna Transmission Line feeding (MPTL)* *36*

4.3 E-shape patch antenna 38

Chapter Five: Conclusion and Feature work

5.1 conclusion 41

5.2 Feature work 42

Reference 42

Chapter One

Introduction and Literature Survey

1.1 Introduction

This chapter consists of an introduction of micro strip antenna, its advantages and disadvantages . The literature survey of micro strip antenna with E –shape , and finally the aims of the thesis are also included.

1.2 Micro strip Antenna

Micro strip antennas (often called patch antennas) are widely used in the microwave frequency region because of their simplicity and compatibility with printed-circuit technology, making them easy to manufacture either as stand-alone elements or as elements of arrays. In its simplest form a micro strip antenna consists of a patch of metal, usually rectangular or circular (though other shapes are sometimes used) on top of a grounded substrate [1]. The concept of micro strip antenna dates back to the 1950's,but it was not until the 1970's that greater emphasis was given to develop is technology. Since then, extensive research and development of micro strip antenna and arrays, exploiting the numerous advantages with integrated circuits, have led to diversified applications and to the establishment of the topic as a separate entity within the broad field of microwave antenna [2].In the last 40 years, the micro strip antenna has been developed for many communication systems such as radars, wireless, satellite, broadcasting, ultra-wideband, radio frequency identifications (RFIDs) etc.. [3].

1.2.1 Advantages and Disadvantages of Micro strip Antennas

Micro strip antennas have several advantages compared to conventional microwave antennas and; therefore, many applications over the broad frequency range from ~100 MHz to ~100 GHz. Some of the principle advantages of micro strip antennas compared to conventional microwave antenna are [2]:

- lightweight, low volume, low profile planar configurations which can be made

conformal.

- low fabrication cost using printed circuit (photolithographic) techniques; readily amenable to mass production.
- They can be made thin; hence they don't perturb the aerodynamics of host aerospace vehicles simple array readily created.
- Linear and circular polarization is easy to implement by varying position of

feed.

- Dual frequency use is possible.
- Solid-state devices are easily integrated.
- Feed lines and matching fabricated with antenna.

However, micro strip antennas also have some disadvantages compared to conventional microwave antennas including:

- narrow bandwidth
- low efficiency (lower gain) at higher frequencies
- spurious feed radiation

Several techniques have been applied to overcome this problem such as increasing the substrate thickness, introducing plastic elements i.e. ,co-planar or stack configuration, or modifying the patch shape itself .

Modifying patch s shape includes designing **an E-shaped patch antennas** as shown in Figure (1-1)

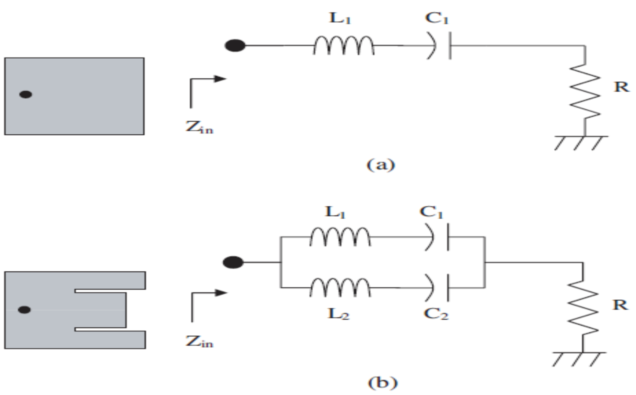


Figure (1-1)Equivalent circuit of (a) rectangular patch and (b) E-shaped micro strip antennas

The ordinary microstrip patch antenna can be modeled as a simple resonant LC circuit as in Figure (1.1 (a)). Currents flow from the feeding point to the top and bottom edges and C values are determined by these currents path length. When two slots are incorporated into the patch, the resonant feature changes, as shown in Figure (1.1 (b)). In the middle part of the patch, the current flows like normal patch. It represents the initial LC circuit and resonates at the initial frequency.However, at the edge part of the patch, the current has to flow around the slots and the length of the current path is increased.This effect can be modeled as an additional series inductance ∆Ls. So the equivalent circuit of the edge part resonates at a lower frequency. Therefore, the antenna changes from a single LC resonant circuit to a dual resonant circuit.

1.3 Literature Survey

M.B.Kadu, R.P.Labade and A.B.Nandgaonkar in 2012; is given design and analysis of E-shaped Micro strip patch antenna that can be used for various MIMO applications. The frequency band selected for design is 2.4GHz ISM Band. E-Shape patch was selected for the application as it is less vulnerable to interference when several antenna elements are placed adjacent to each other to form an array in multiple antenna system. The proposed E-shaped patch antenna is intended to be applied for WLAN operating in 2.4 GHz band in MIMO environment. Index Terms —E-shaped patch, MIMO, Mutual coupling, Return loss[4].

Indu Bala Pauria, Sachin Kumar and Sandhya Sharma in 2012; is presented the design and simulation of E-shape micro strip patch antenna with wideband operating frequency for wireless application. The shape will provide the broad bandwidth which is required in various application like remote sensing, biomedical application, mobile radio, satellite communication etc. The antenna design is an improvement from n Previous research and it is simulated using HFSS(High Frequency Structure Simulator) version 11 software. Coaxial feed or probe feed technique is used in the experiment. Parametric study was included to determine effect of design towards the antenna performance. The performance of the designed antenna was analyzed in term of bandwidth, gain, return loss, VSWR, and radiation pattern. The design was optimized to meet the best possible result. Substrate used was air which has a dielectric constant of 1.0006. The results show the wideband antenna is able to operate from 8.80 GHz to 13.49 GHz frequency band with optimum frequency at 8.73 GHz[5].

Sohag Kumar Saha, Amirul Islam Rony and Ummay Habiba Suma in 2013; is presented the design & simulation of E-shape microstrip patch antenna exhibiting wideband operating frequencies for various wireless applications. This antenna will provide the wide bandwidth which is required in various applications like remote sensing, biomedical application, mobile radio satellite, wireless communication etc. The coaxial feed or probe feed technique is used in the experiment. The performance of the designed antenna was analyzed in terms of bandwidth, gain, return loss,VSWR, and radiation pattern. The design is optimized to meet the best possible result. The proposed antenna is designed by air substrate which has a dielectric constant of 1.0006. The results show the wideband antenna is able to operate from 8.80 to 13.49 GHz frequency band with optimum frequency at 8.73 GHz[6]

R. Divya and M. Priya in 2013; is increased the impedance bandwidth of the micro strip patch antenna. A low profile wideband unequal E-shaped micro strip patch antenna for Wi-Max application is proposed in this paper .This proposed antenna is made by using the micro strip feeding method. Its bandwidth is further increased by introducing composite effect of stacking of patches with partial grounding .The antenna is designed and simulated by three-dimensional electromagnetic field software HFSS'12.The properties of the antenna such as bandwidth, S parameter, VSWR have been investigated.

P.Ramya, S.Gopalakrishnan and R.Pradeep, in 2014; is proposed for wimax(World Wide Interoperability For Microwave Access)application. The patch antenna works at the frequency of 3.5 GHz with the satisfying antenna parameters like directivity, gain and radiated powerwithFR4(Flame Resistance-4)[7].

Prof. Jaikaran Singh, Mukesh Tiwari and M.Neha Patel in 2014; is covered two aspects of microstrip antenna designs. The first is the analysis of single element narrowband rectangular microstrip antenna which operates at the central frequency of 6.5GHz. The second aspect is the analysis and design of slot cut E-shaped microstrip antenna. The simulation process has been done through high frequency structure simulator (HFSS). The properties of antenna such as bandwidth, return loss, VSWR has been investigated and compared between a single element rectangular and E-shaped microstrip antenna[8].

1.4 Problem Statement

The main drawback of the microstrip antenna that we have addressed in this work is its inherent narrow bandwidth. Many methods have been proposed in the literature to improve its bandwidth and these include the addition of parasitic patches either laterally or vertically, the use of a thick substrate and the cutting of slots. This work, presents E-shape patch antenna to enhancement the characteristic of rectangular patch antenna**.**

1.5 Aim of the work

Design and performance evaluation of rectangular microstrip patch antenna and E-shap patch antenna using Mat lab software.

1.6 Project Organization

This project is organized, as follows:

Chapter 1:

Presents an introduction for microstrip patch antenna, aim of the work and outline of the project and literature survey .

Chapter 2:

The theory of microstrip patch antenna is presented and, includes the construction, parameters, feeding types, analysis and mechanism of the patch antenna.

Chapter 3:

Implementation the design of the rectangular patch antenna and E-shape patch antenna. The Matlab software is used to obtain the parameters of the design of antenna (Return losses, Gain, Directivity, Input impedance, VSWR and the area of antenna) and, results discussion.

Chapter 4

The Math Lab software is used to obtain the simulation of the rectangular patch antenna and E-shape patch antenna , then the results discussion.

Chapter 5:

Provides the conclusion remarks and presents some ideas for the future works.

Chapter Two

Theory of Microstrip patch Antenna

2.1 Introduction

This chapter is divided into four main sections. The 1st section illustrates the construction of microstrip patch antenna. The 2nd section explains the types of feeding. Next, the 3rd section presents the antenna parameters. Finally, the analysis, theory and working mechanism of microstrip patch antenna are discussed in 4th section.

2.2 Microstrip Antenna Configuration

Microstrip antenna is also referred to as a patch antenna. It consists of a very thin metallic strip ($t << \lambda_o$ where λ_o is the free – space wavelength) and substrate patch placed a small fraction of a wavelength ($h << \lambda_o$,usually$0.003\lambda_o \leq h \leq 0.05\lambda_o$) above a ground plane, as shown in Figure (2.1).

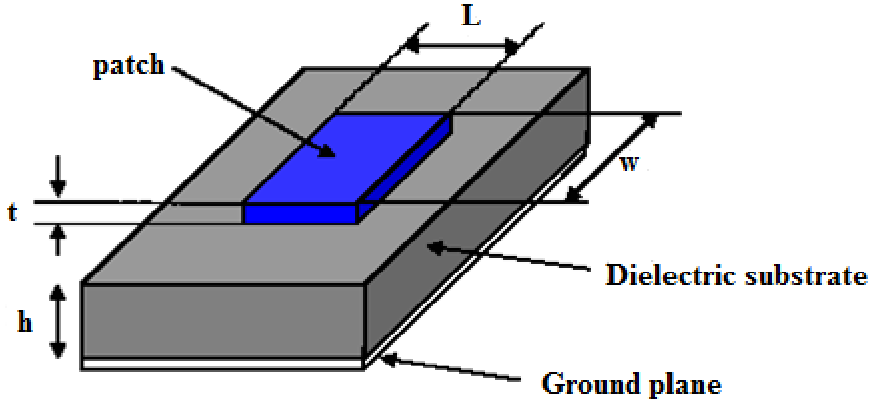


Figure 2.1:Microstrip antenna [9]

The microstrip patch is designed so that its pattern maximum is normal to the patch (broadside radiator). This is accomplished by properly choosing the mode (field configuration) of excitation beneath the patch. In designing microstrip antennas, a number of substrates can be used[18].

There are many substrates that can be used for the design of microstrip antennas, and their dielectric constants (ε_r) are usually in the range of $2.2 \leq \varepsilon_r \leq 12$. Thick substrates are most desirable for antenna performance as their dielectric constants are in the lower end, which provides better efficiency, larger bandwidth, loosely bound fields for radiation into space (better radiation power). However, these are achieved at the expense of larger element size, increase in weight, dielectric loss, surface wave loss and extraneous radiations. Thin substrates with higher dielectric constants, on the other hand, are desirable for microwave circuitry because they require tightly bound fields to minimize undesired radiation and coupling, thus leading to smaller sizes. However, because of their greater losses, they are less efficient and have relatively smaller bandwidth .The radiating elements and the feed lines are usually photo etched on the dielectric substrate[1].

Patch shapes are versatile in terms of resonant frequency, polarization, pattern and impedance. The radiating patch may be square, rectangular, thin strip (dipole), circular, elliptical, triangular or any other configuration. These and other are illustrated in Figure(2.2).

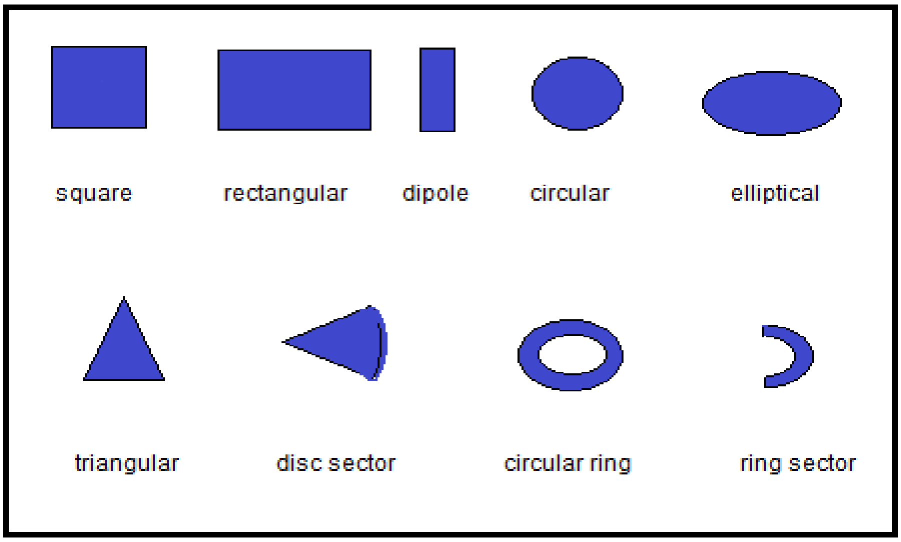


Figure 2.2: Common shapes of microstrip patch elements [20]

Square, rectangular, dipole (strip), and circular are the most common because of ease of analysis and fabrication, and their attractive radiation characteristics, especially low cross – polarization radiation [23].

2.3 Feeding Methods

There are several techniques available to feed or transmit electromagnetic energy to a microstrip patch antenna . The role of feeding is very important in case of efficient operation of antenna to improve the antenna input impedance matching [24]. The four most popular are the microstrip line feed, coaxial feed, aperture coupling and proximity coupling [25], as shown in Figure (2.3)

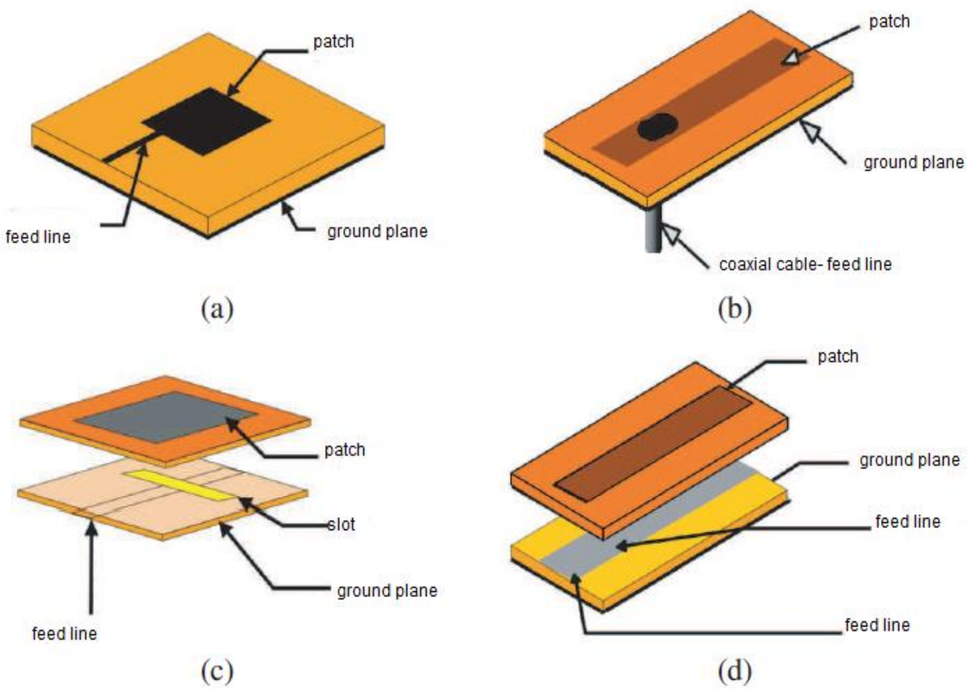


Figure 2.3: Methods of microstrip antennas feeding: (a) microstrip line, (b) coaxial line, (c) aperture coupling, (d) by proximity coupling [25]

2.3.1 Microstrip Line Feeding

In this type of feeding technique, a conducting strip is connected directly to the edge of the microstrip patch, as shown in Figure(2.3a) The width of conducting strip is small as compared to the patch and this kind of feed arrangement has the advantage that the feed can be etched on the same substrate to provide a planar structure. The purpose of the inset cut in the patch is to match the impedance of the feed line to the patch input impedance without the need for any additional matching element. This can be achieved by properly adjusting the inset cut position and dimensions. Hence this is an easy feeding scheme because it provides ease of fabrication and simplicity in modeling as well as impedance matching. However, as the thickness of the dielectric substrate being increased, surface waves and spurious feed radiations also increase which hamper the bandwidth of the antenna. The feed radiation also leads to undesired cross polarized radiation [24].

2.3.2 Coaxial Cable or Probe Feeding

The Coaxial cable or probe feeding is a very common technique used for feeding Microstrip patch antennas. As seen from Figure (2.3 b), the inner conductor of the coaxial cable extends through the dielectric and is soldered to the radiating metal patch, while the outer conductor is connected to the ground plane. The main advantage of this feeding scheme is that, the feed can be placed at any desired location on the patch in order to match cable impedance with the antenna input impedance. This feeding method is easy to fabricate and has low spurious radiation. However, its major disadvantage is that it provides narrow bandwidth and is difficult to model since a hole has to be drilled in the substrate and the connector protrudes outside the ground plane, thus not making it completely planar for thick substrates ($h > 0.02\,\lambda_o$). Also, for thicker substrates, the increased probe length makes the input impedance more inductive, leads to impedance matching problems. The main aim to use probe feeding is enhancing the gain, narrow bandwidth and impedance matching [24].

2.3.3 Aperture Coupling

The aperture coupling, as shown in Figure(2.3c) is the most difficult of all four to fabricate and it also has narrow bandwidth. However, it is easier to model and has moderate spurious radiation. The aperture coupling consists of two substrates separated by a ground plane. On the bottom side of the lower substrate, there is a micro strip feed line whose energy is coupled to the patch through a slot on the ground plane separating the two substrates. The ground plane between the substrates also isolates the feed from the radiating element and minimizes interference of spurious radiation for pattern formation and polarization purity[1].

2.3.4 Proximity Coupling.

The proximity coupling, as shown in Figure(2.2d) has the largest bandwidth, and is easy to model and has low radiation, but the fabrication is more difficult [1].

Both aperture and proximity coupling provide good polarization purity and no cross-polarized radiation in the principal planes, which can be found in micro strip and coaxial feeds [1].

2.4Scattering Parameters

When designing Radio Frequency (RF) or Microwave systems ,the scattering S-parameters representations play a main role. System characterization can no longer be accomplished through simple open or short circuit measurement for high frequencies. This is because of the wire itself possess an inductance that can be of substantial magnitude at high frequency when they short circuit it. While open circuit leads to capacitive loading at the terminal [22].

S-parameter are power wave descriptors that define input–output relations of a network in terms of incident and reflected power waves.

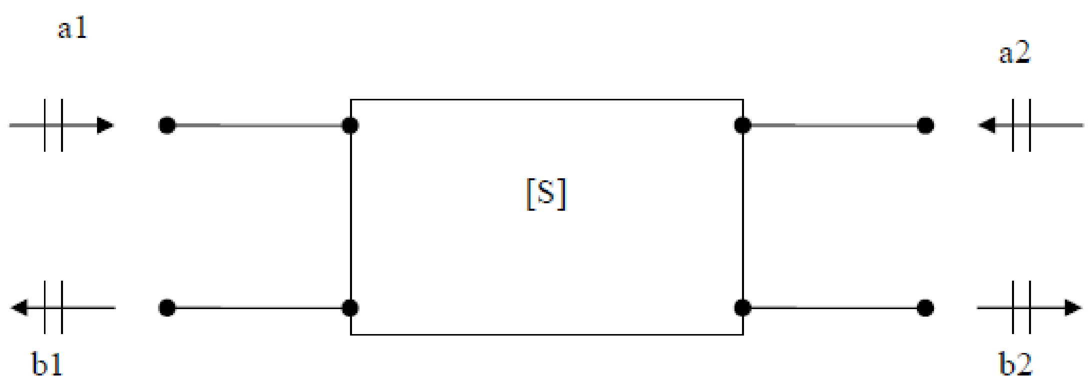


Figure 2. 4: Convention used to define S-parameters for a two- port network

Based on the directional convention shown in Figure (2.4), the position to define the S- parameters :

$$\begin{Bmatrix} b_1 \\ b_2 \end{Bmatrix} = \begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix} \begin{Bmatrix} a_1 \\ a_2 \end{Bmatrix} \qquad \textbf{(2.1)}$$

Where the terms are : S_{11} is the electric field leaving the input divided by the electric field entering the input , under the condition that no signal enters the output . Since b_1 and a_1 are the electric fields, their ratio is a reflection coefficient.

$S_{11}= \frac{b_1}{a_1}$ when a_2 =0 reflected power wave at port 1 / incident power wave at port 1 .

S_{21} term is related to the transmission coefficient which is the electric field leaving the output divided by the electric field entering the input , when no signal enters the output .

$S_{21} = \frac{b_2}{a_1}$ when a_2=0 transmission power wave at port 2 / incident power wave at port 1.

S_{12} is a transmission coefficient related to the isolation of the component and specifies how much power leaks back through the component in the wrong direction .

$S_{12} = \frac{b_1}{a_2}$ when a_1 = 0 transmitted power wave at port 1/ incident power wave at port 2.

S_{22} is similar to S_{11}, but looks to the other direction into the component .

$S_{22} = \frac{b_2}{a_2}$ when a1 =0 reflected power wave at port 2 / incident power wave at port 2 .

2.5 Antenna Parameters

There are some important parameters need to be considered that characterize all antenna designs. These are the radiation pattern, return loss, input impedance, gain, VSWR, half – power beamwidth, directivity, bandwidth, polarization and antenna efficiency.

2.5.1 Radiation Pattern

The radiation pattern of an antenna provides the information that describes how the antenna directs the energy it radiates. All antennas, 100% efficient , will radiate the same total energy for equal input power regardless of pattern shape . Radiation patterns are generally presented on a relative power dB scale. It can be shown in polar plot 360 degree. Example of radiation pattern is shown in Figure (2.5).In many cases, the convention of an E- plane pattern is used in the presentation of antenna pattern data . The E-plane is the plane that contains the antenna's radiated electric field potential while the H-plane is the plane that contains the antenna's radiated magnetic field potential. These planes are always orthogonal [42].

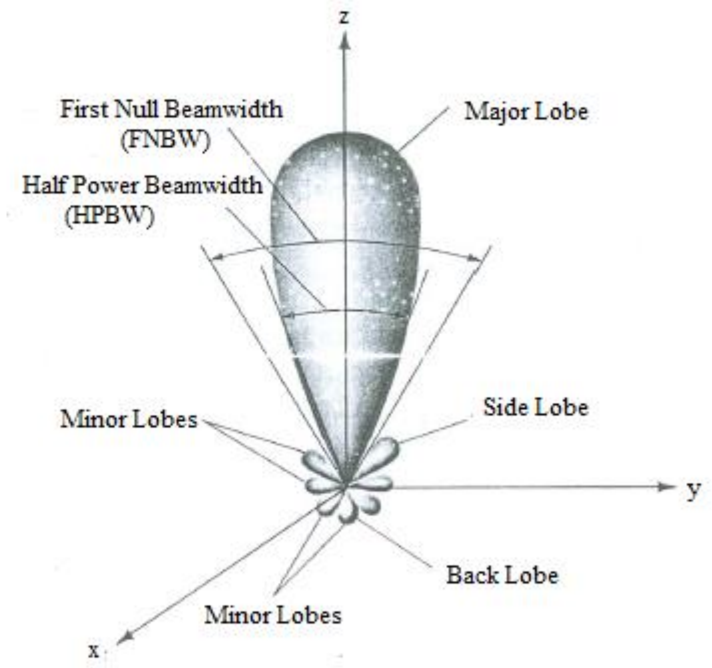


Figure 2.5:Radiation pattern [42]

2.5.2 Return Loss

Return loss is a convenient way to characterize the input and output signal sources. Return loss can be defined in dB, as follows[23]:

$RL = -20log\,|\Gamma|\,(dB)$ **(2.2)**

Where, $|\Gamma| = \frac{V_o^-}{V_o^+} = \left|\frac{Z_l - Z_o}{Z_l + Z_o}\right|$ **(2.3)**

$|\Gamma|$ = reflection coefficient

V_o^-= the reflected voltage

V_o^+ = the incident voltage

Zl= load impedance

Z_o= characteristic impedance of the antenna

2.5.3 Input Impedance

Generally, input impedance is important to determine maximum power transfer between transmission line and the antenna. This transfer only happens when input impedance of antenna and the impedance of the transmission line are matched. If not matched, reflected wave will be generated at the antenna terminal and travel back towards the energy source. The reflection of energy causes a reduction in the overall system efficiency[22]. If the return losses is known ,the input impedance is given by:

$$z_{in} = Z_O\left(\frac{1+S_{11}}{1-S_{11}}\right) \quad \textbf{(2.4a)}$$

$$z_{in} = \mathbf{R} + \mathbf{j}\frac{(wl_1 - 1/wc_1)(wl_2 - 1/wc_2)}{w(l_1+l_2) - (1/wc_1 + 1/wc_2)} \quad \textbf{(2.4b)}$$

2.5.4 Gain

The antenna gain describes the antenna's ability to radiate power in acertain direction when connected to a power source. Gain is usually calculated in the direction of maximum radiation. Gain is given by referencing the antenna under test against a standard antenna. This is technically known as the gain transfer technique. The two most common reference antennas are the isotropic antenna and the resonant half-wave dipole antenna. The isotropic antenna radiates equally well in "all" directions. Real isotropic antennas do not exist, but they provide useful and simple theoretical antenna patterns with which to compare real antennas. An antenna gain of 2 (3 dB) compared to an isotropic antenna would be written as 3 dBi. Here dBi means that the directivity

D is measured compared to an isotropic antenna .The resonant half-wave dipole can be a useful standard for comparing with other antennas at one frequency or over a very narrow band of frequencies. To compare the dipole to an antenna over a range of frequencies requires an adjustable dipole or a number of dipoles of different lengths. An antenna gain of 1(0 dB) compared to a dipole antenna would be written as 0 dBd. dBd is used when the directivity refers to the directivity of a dipole antenna[23]. Gain can be obtained by using Equation (2.5):

$$G = \eta x D \quad (2.5)$$

Where,

G = gain

η= efficiency

D = directivity

2.5.5Voltage Standing Wave Ratio(VSWR)

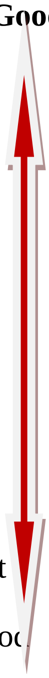
It is the ratio between the maximum voltage and the minimum voltage along transmission line connected to the antenna . The VSWR, which can be derived from the level of reflected and incident waves, is also an indication of how closely or defiantly an antenna terminal input impedance is matched to the characteristic impedance of the transmission line. Increasing VSWR indicates an increase in the mismatch between the antenna and the transmission line. A decrease in VSWR means good matching with minimum VSWR which is one [22]. The VSWR is given by :

$$VSWR = \frac{1+S_{11}}{1-S_{11}} \quad (2.6)$$

Most wireless systems operate at 50 Ohm impedance . Hence, the antenna must be designed with an impedance as close to 50 ohm as possible . AVSWR of 1 indicates an antenna impedance of exactly 50 ohm. Mostly, the ratio of VSWR ≥1.5 is needed for antenna functional. Table(2.1)shows several VSWR values compared to reflection coefficient [s_{11}] value. Value of VSWR 2 ([s_{11}] = -9.5 dB), shows 90% of power is reflected, while for VSWR 3 ([s_{11}] = -6 dB), shows 75% power is reflected .A good antenna to operate is within 1≤VSWR≤2[22].

Good

Table 2.1: VSWR vs. return loss



VSWR	**Return Loss[s_{11}]**
1.01	-46.1
1.05	-32.3
1.10	-26.4
1.20	-20.8
1.30	-17.7
1.40	-15.6
1.50	-14.0
1.75	-11.3
2.00	-9.5
2.50	-7.4

Not

Good

2.5.6 Half Power Beamwidth

In plane containing the direction of the maximum of a beam, this is the angle between the directions in which the radiation intensity is one half the maximum value of the beam [23].

2.5.7 Directivity

Directivity (D) is important parameter that shows the ability of the antenna to focus radiated energy. Directivity is the ratio of maximum radiated energy to radiate reference antenna. Reference antenna usually is isotropic radiator where the radiated energy is the same in all directions and has directivity of 1. Directivity can be defined as [22]:

$$D = \frac{E_{max}}{E_0} \quad \textbf{(2.7)}$$

where, E_{max} = maximum radiated energy

E_o = isotropic radiator radiated energy

2.5.8 Bandwidth

The bandwidth of the patch is defined as the frequency range over which it is matched with that of the feed line within specified limits. In other words, the frequency range over which the antenna will perform satisfactorily. The bandwidth of the antenna is usually defined by the acceptable standing wave ratio (SWR) value over the concerned frequency range. To calculate bandwidth, 1.5ratio will be used [23].Bandwidth can be defined as:

$$\boldsymbol{Bandwidth = \frac{SWR-1}{Q\sqrt{SWR}}} \qquad \textbf{(2.8)}$$

where , Q is the quality factor

$$\boldsymbol{SWR = \frac{1+|\Gamma|}{1-|\Gamma|}} \qquad \textbf{(2.9)}$$

There are two methods for computing an antenna bandwidth . An antenna

is considered as broadband if $f_H/f_L \geq 2$[22] .

Narrowband ratio by percentage :-

$$\boldsymbol{Bwp = \frac{f_H-f_L}{f_r}} \textbf{ x 100 \%} \qquad \textbf{(2.10)}$$

Broadband ratio

$$\boldsymbol{Bwb = \frac{f_H}{f_L}} \textbf{(2.11)}$$

where,$f_r$is the operating frequency

f_H is theHigher cut-off frequency

f_L is theLower cut-off frequency

Bwp is the Narrowband ratio

Bwb is the Broadband ratio

2.5.9 Polarization

The polarization of an antenna describes the orientation and sense of the radiated waves electric field vector . There are three basic polarizations:-

- Linear polarization (linear)
- Elliptical polarization
- Circular polarization

Generally, most antennas radiate with linear or circular polarization .Antennas with linear polarization radiate at the same plane with the direction of the wave propagation . For circular polarization , the antenna radiates in circular form [22].

2.5.10 Efficiency

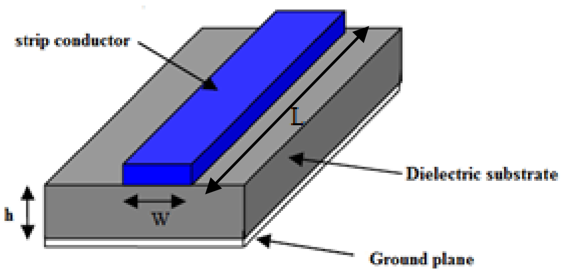
Efficiency is used to express the ratio of the total power radiated by an antenna (and the power dissipated in the antenna structure as heat) to the net power accepted by the antenna from the connected transmitter [23].

2.6Methods of Analysis

There are many methods of analysis for micro strip antennas. The most popular models are the transmission-line, cavity and full-wave models. The transmission-line model is the easiest of all, it gives good insight and it is adequate for most engineering purposes and requires less computation. However, it is less accurate and it is more difficult to model coupling. Comparing with the transmission-line model, the cavity model is more accurate, but at the same time more complex. However, it also gives good physical insight, and is rather difficult to model coupling, although it has been used successfully. In general, when applied properly, the full wave models are very accurate, very versatile, and can treat single elements, finite and infinite arrays, stacked elements, arbitrary shaped elements, and coupling. However, they are the most complex models and usually give less physical insight[1].

2.6.1 Transmission Lines Model

This model represents the microstrip antenna by two slots of width ***W*** and height ***h***, separated by a transmission line of length **L**, as shown in Figure (2.6). The microstrip is essentially a nonhomogeneous line of two dielectrics , typically the substrate and air.



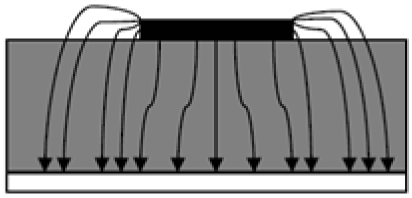


Figure 2.6: Microstrip line [22] Figure 2.7: Electric field lines[22]

Hence, as seen from Figure (2.7), most of the electric field lines reside in the substrate and parts of some lines in air. As a result, this transmission line cannot support pure Transverse Electric- Magnetic (TEM) mode of transmission, since the phase velocities would be different in the air and the substrate. Instead, the dominant mode of propagation would be the quasi-TEM mode. Hence, an effective dielectric constant ($\mathcal{E}_{reff}$)must be obtained in order to account for the fringing and the wave propagation in the line. The value of $\mathcal{E}_{reff}$ is slightly less than $\mathcal{E}_r$ because the fringing fields around the periphery of the patch are not confined in the dielectric substrate, but they also spread in the air, as shown in Figure (2.6). The expression for $\mathcal{E}_{\mathrm{reff}}$ is given by[26] :

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2}+\frac{\varepsilon_r-1}{2}\left[1+12\frac{h}{w}\right]^{\frac{-1}{2}} \quad (2.12)$$

where, $\boldsymbol{\varepsilon_{reff}}$ =Effective dielectric constant

Ɛr=Dielectric constant of substrate

h = Height of dielectric substrate

W= Width of the patch

Consider Figure (2.8), which shows a rectangular microstrip patch antenna of length (*L*), width (*W*)resting on a substrate of height (*h*).The coordinate axes are selected such that the length is along the *x* direction, width is along the *y* direction and the height is along the *z* direction[26].

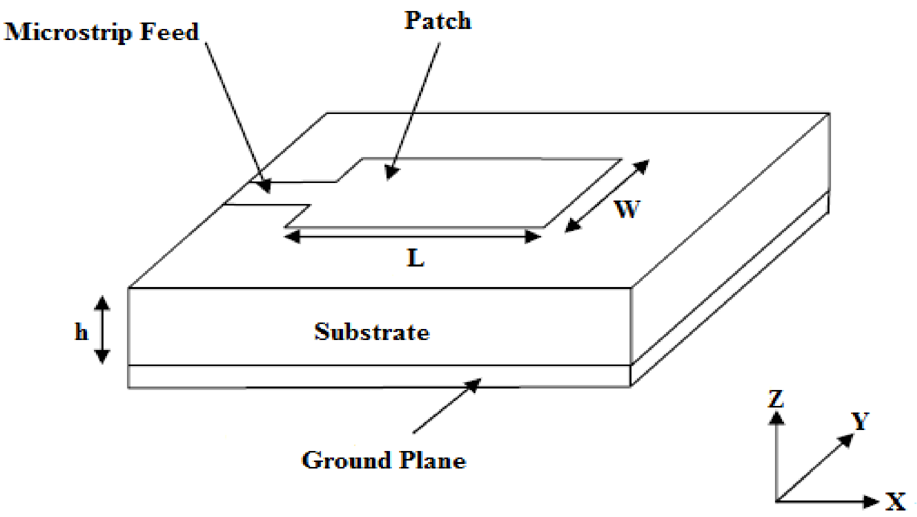


Figure 2.8: Microstrip patch antenna [26]

In Figure (2.9), the microstrip patch antenna is represented by two slots, separated by a transmission line of length (*L*) and open circuited at both ends. Along the width of the patch, the voltage is maximum and the current is minimum due to the open ends. The fields at the edges can be resolved into normal and tangential components with respect to the ground plane[42].

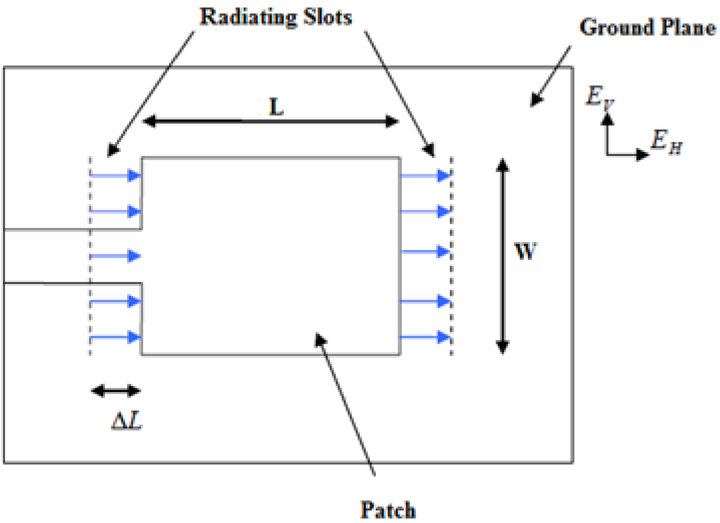


Figure 2.9:Top view of antenna [22]

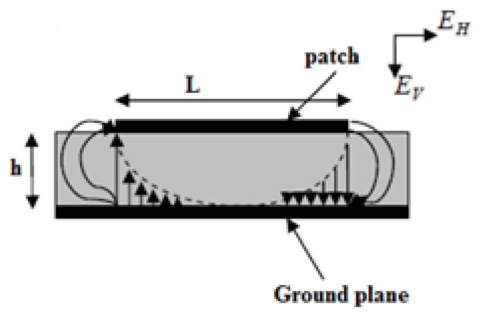


Figure 2.10:Side view of antenna [22]

It is seen from Figure (2.10)that, the normal components of the electric field at the two edges along the width are in opposite directions and thus out of phase if the patch is *λ/ 2* long and hence they cancel each other in the broadside direction. The tangential components (seen in Figure (2.10)), which are in phase, mean that the resulting fields combine to give maximum radiated field normal to the surface of the structure. Hence, the edges along the width can be represented as two radiating slots, which are λ/ 2 apart and excited in phase and radiating in the half space above the ground plane. 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 [27]. The dimensions of the patch along its length have now been extended on each end by a distance, which is given by[26]:

$$\Delta L = 0.412h\frac{(\varepsilon_{reff}+0.3)\left[\frac{w}{h}+0.264\right]}{(\varepsilon_{reff}-0.258)\left[\frac{w}{h}+0.8\right]} \quad (2.13)$$

The effective length of the patch L_{eff}now becomes:

$$L_{eff}=L+2\Delta L \quad (2.14)$$

For a given resonance frequencyf_r, the effective length is given by [26] as:

$$L_{eff}=\frac{c}{2f_r\sqrt{\varepsilon_{reff}}} \quad (2.15)$$

For a rectangular microstrip patch antenna, the resonance frequency for anyTM_{mn}mode is given by[27]:

$$f_r=\frac{c}{2\sqrt{\varepsilon_{reff}}}\left[\left(\frac{m}{L}\right)^2+\left(\frac{n}{W}\right)^2\right]^{-\frac{1}{2}} \quad (2.16)$$

where $\boldsymbol{m}$ and $\boldsymbol{n}$ are modes along $\boldsymbol{L}$and $\boldsymbol{W}$ respectively. For efficient radiation, the width $\boldsymbol{W}$ is given by[27] as:

$$\boldsymbol{W}=\frac{\boldsymbol{c}}{\boldsymbol{2f_r}\sqrt{\frac{(\boldsymbol{\varepsilon_r+1})}{\boldsymbol{2}}}} \qquad \textbf{(2.17)}$$

The characteristic impedance of a microstrip line, feed to the patch antenna, is given by [1]**:**

$$Z_c = \begin{cases} \frac{60}{\sqrt{\varepsilon_{reff}}}\, ln\left[\frac{8h}{W_0}+\frac{W_0}{4h}\right],\ \frac{W_0}{h} \leq 1 & \textbf{(2.18 a)} \\ \frac{120\pi}{\sqrt{\varepsilon_{reff}}\left[\frac{W_0}{h}+1.393+0.667\, ln\left(\frac{W_0}{h}+1.444\right)\right]},\ \frac{W_0}{h} > 1 & \textbf{(2.18 b)} \end{cases}$$

where , W_o is the width of the microstrip line, and

Z_c is the characteristic impedance of microstrip line feed

The notch width for microstrip line feed is calculated, as follows [28]:

$$\boldsymbol{g} = \frac{\boldsymbol{c}}{\sqrt{\boldsymbol{2x\varepsilon_{reff}}}}\frac{\boldsymbol{4.65x10^{-12}}}{\boldsymbol{f_r}} \qquad \textbf{\textit{(2.19)}}$$

And also , $\boldsymbol{Z_c} = \boldsymbol{R_{in}}\ \mathbf{cos^2}\left(\frac{\boldsymbol{\pi}}{\boldsymbol{L}}\ \boldsymbol{d}\right)$ **(2.20)**

where , g is the notch width

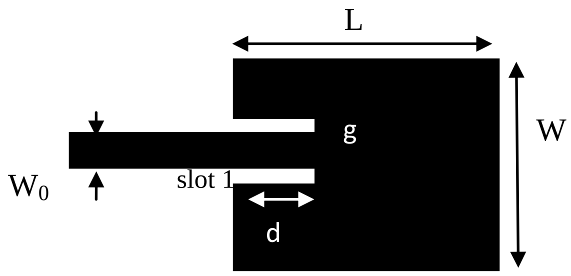
d is the inset distance from the radiating edge, and

R_{in} is the resonant input resistance when the patch is feed at a radiating edge.

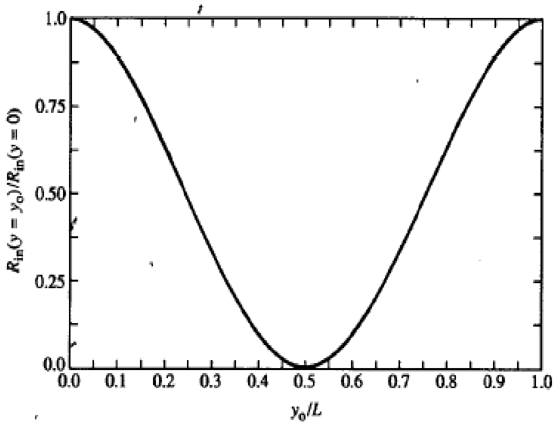
The inset distance (d) is selected such that Z_c is equivalent to the feed line impedance. The notch width ‘ g ’ is located symmetrically along the width of the patch[28].

The resonant input resistance can be changed by using an inset feed, recessed a distance d from slot 1, as shown in Figure (2.11a) [1]. The inset feed point can be found using Equation (2.21)

$$\boldsymbol{R_{in}}(\boldsymbol{y}=\boldsymbol{d}) = \boldsymbol{R_{in}}\,(\boldsymbol{y}=\mathbf{0})\,\mathbf{cos^2}\left(\frac{\boldsymbol{\pi}}{\boldsymbol{L}}\ \boldsymbol{d}\right) \qquad \textbf{(2.21)}$$



(a)Recessed micro strip line feed



(b) Normalized input resistance

Figure 2.11:Microstrip inset feed and variation of normalized input resistance [1]

From Equation (2.21) and Figure (2.11b), the maximum value occurs at the edge of the slot (d = 0) where the voltage is maximum and the current is minimum. The minimum value occurs at the center of the patch ($d = L/2$) where the voltage is zero and the current is maximum. Therefore, the input resistance changes with the position of the feed point [1].

2.6.2 Cavity Model

Although the transmission line model, discussed in the section 2.5.1,is easy to use, it has some inherent disadvantages. Specifically, it is useful for patches of rectangular design and it ignores field variations along the radiating edges. These disadvantages can be overcome by using the cavity model [26].

In this model, the interior region of the patch is modeled as a cavity bounded by electric wall all along the periphery. This assumption is only for thin substrates ($h<<\lambda_o$)[22]:

- The field in the interior region does not vary with z direction (that is δ/δ_z≡0, where , δ loss tangent) because the substrate is very thin $h \ll \lambda_o$.
- The electric field is in z directed only , and the magnetic field has only the transverse components in the region bounded by the patch metallization and the ground plane . This observation provides for the electric walls at the top and bottom .
- The electric current in the patch has no component normal to the edge of the patch metallization, which implies that the tangential component of H along the edge is negligible, and a magnetic wall can be placed along the periphery. Mathematically, $\delta E_z/\delta_n$=0[22].

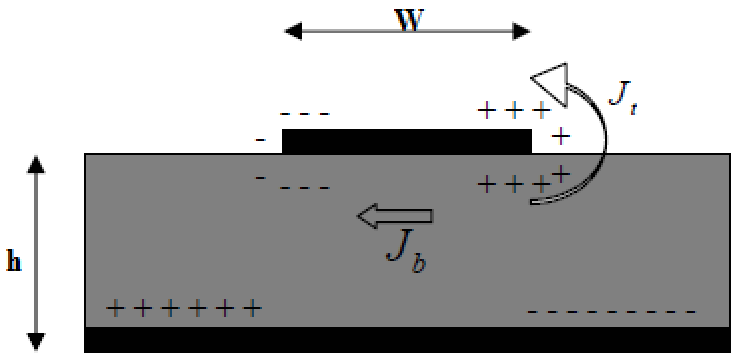


Figure 2.12:Charge distribution and current density creation on the microstrip patch[26]

Consider Figure (2.12) shown, when the microstrip patch is provided with power, a charge distribution is seen on the upper and lower surfaces of the patch and at the bottom of the ground plane. This charge distribution is controlled by attractive and repulsive mechanisms. The attractive mechanism is between the opposite charges on the bottom side of the patch and the ground plane, which helps in keeping the charge concentration intact at the bottom of the patch. The repulsive mechanism is between the like charges on the bottom surface of the patch, which causes pushing of some charges from the bottom, to the top of the patch. As a result of this charge movement, currents flow at the top and bottom surface of the patch. The cavity model assumes that, the height to width ratio (i.e. height of substrate and width of the patch) is very small and as a result, the attractive mechanism dominates and causes most of the charge concentration and the current to be below the patch surface. Much less current would flow on the top surface of the patch and as the height to width ratio further decreases, the current on the top surface of the patch would be almost equal to zero, which would not allow the creation of any tangential magnetic field components to the patch edges. Hence, the four sidewalls could be modeled as perfectly magnetic conducting surfaces. This implies that, the magnetic fields and the electric field distribution beneath the patch would not be disturbed. However, in practice, a finite width to height ratio would be there and this would not make the tangential magnetic fields to be completely zero, but they become very small, and the side walls could be approximated to be perfectly magnetic conducting [26].

Since the walls of the cavity, as well as the material within it are lossless, the cavity would not radiate and its input impedance would be purely reactive. Hence, in order to account for radiation and a loss mechanism, one must introduce a radiation resistance R_r and a loss resistance R_{loss}. A loss cavity would now represent an antenna and the loss is taken into account by the effective loss tangent δ_{eff} which is given as:

$$\boldsymbol{\delta_{eff} = 1/Q_T} \quad \textbf{(2.22)}$$

Q_T is the total antenna quality factor and has been expressed by:

$$\frac{1}{Q_T} = \frac{1}{Q_d} + \frac{1}{Q_c} + \frac{1}{Q_r} \quad \textbf{(2.23)}$$

- Q_d represents the quality factor of the dielectric and is given as :

$$Q_d = \frac{\omega_r E_T}{P_d} = \frac{1}{\tan\delta} \quad \textbf{(2.24)}$$

where

ω_r is the angular resonant frequency

E_T is the total energy stored in the patch at resonance

P_d is the dielectric loss

$\tan\delta$ is the loss tangent of the dielectric

- Q_c represents the quality factor of the conductor and is given as:

$$Q_c = \frac{\omega_r E_T}{P_c} = \frac{h}{\Delta} \quad \textbf{(2.25)}$$

where

P_c is the conductor loss

Δ is the skin depth of the conductor
*h*is the height of the substrate

- Q_r represents the quality factor for radiation and is given as:

$$Q_r = \frac{\omega_r E_T}{P_r} \quad (2.26)$$

where,

P_r is the power radiated from the patch

Substituting Equations (2.23), (2.24), (2.25) and (2.26) into Equation (2.22), the following is obtained**:**

$$\delta_{\text{eff}} = \tan\delta + \frac{\Delta}{h} + \frac{P_r}{\omega_r E_T} \quad (2.27)$$

Thus, Equation (2.27) describes the total effective loss tangent for the micro strip patch antenna[26].

2.6.3 Full Wave Analysis

There are three popular techniques for full-wave analysis. These are called the ***spectral domain full -wave solution, the mixed- potential electric field integral equation approach****,* and ***finite-difference time-domain*** technique.

Some of the features of the full-wave techniques include[22]:

- Accuracy- This technique provides the most accurate solution.
- Versatility- It can be used for arbitrarily shaped microstrip elements including multilayer geometries, and various types of feeding techniques.
- Completeness- The solutions include the effects of dielectric and conductor loss, space wave radiation, surfaces wave and coupling effects.
- Computation cost- Numerical method is used in full-wave techniques, therefore require carful programming to reduce computation cost.

2.6.3.1 Spectral Domain Full –Wave Analysis

The spectral –domain full-wave uses the exact Green's function for the mixed dielectric nature of the micro strip antenna, (***Green's function includes the effects of dielectric loss, conductor loss, surface wave modes, and space wave radiation***).The Green's function is employed in the electric field integral equation formulation to satisfy the pound ray conditions at the patch metallization . The resulting integral equations are discredited into a set of linear equations by means of the moment method to yield a matrix equation . The solution of the matrix equation provides the current distribution on the patch metallization . The near- field and the far- field characteristics of the antenna are then obtained from the current distribution and the Green's function. Figure (2.13) lists the major steps in the analysis[19].

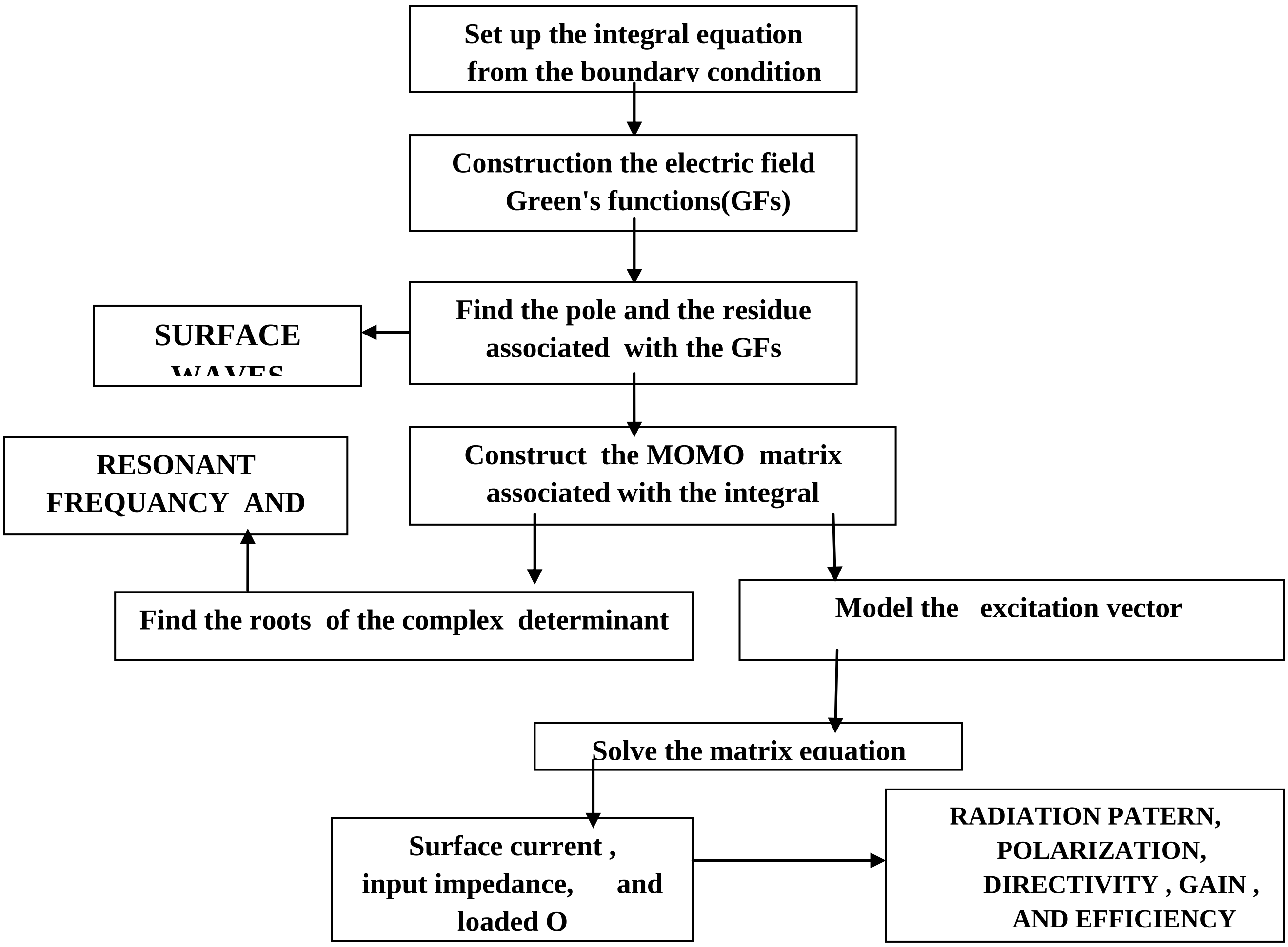


Figure 2.13:Spectral Domain Full –Wave Analysis steps[19]

2.6.3.2 Mixed- Potential Integral Equation Analysis(MPIE)

The MPIE (Mixed –Potential Integral Equation) approach is computationally more efficient than the integral equation analysis described in the spectral domain. An integral equation solution based on MPIE has been used to analyze various types of microstrip antenna configurations . These include various types of patch shapes, feed types, stacked geometries , anisotropic substrates , and array geometries . Some of the prominent studies utilizing this technique for the basic technique and the analysis are[19]:

- A rectangular patch
- The circular patch
- The triangular patch
- A printed slot antenna
- An arbitrary shaped geometry
- The patch on anisotropic substrate
- A proximity –coupled microstrip feed antenna
- An aperture –coupled microstrip antenna
- A stacked antenna configuration
- A multilayered printed antenna
- Computation of radar cross section

2.6.3.3 Finite-Difference Time-Domain Analysis (FDTD)

In addition to the integral equation approach described earlier , the Finite- Difference Time – Domain (FDTD) technique is used extensively in the analysis and design of micro strip antennas. The major difference between FDTD and other numerical techniques is that analytical preprocessing and modeling are almost absent in FDTD. Therefore, complex antenna can also be analyzed using FDTD. This analysis approach can be used to include the effect of finite size of the substrate and ground plane, which is very important in the design of many micro strip antennas like micro strip antennas for handheld receivers. Interaction between the device and circuits at the field level can be incorporated using FDTD. This is necessary for accurate analysis of microwave active circuits and antennas. Active microstrip antennas can be analyzed using FDTD . The FDTD was first proposed by Yee in 1966 and has been used by many investigations , because it has the following advantages over other techniques[19]:

1. From a mathematical point of view, it is direct implementation of Maxwell's curl equations. Therefore, analytical processing of Maxwell's equation is almost negligible.

2. It is capable of predicting broadband frequency response because the analysis is carried out in the time domain.
3. It is capable of analyzing complex systems, including wave interaction with human body, or satellite, nonlinear device simulations, complex antennas , and so on.
4. It is capable of analyzing structures using different types of materials, for example, loss dielectrics, magnetized ferrites, and anisotropic plasmas.
5. Finally, it provides a real – time animation display, which is a powerful tool for both a student and an electromagnetic designer.

To this list can be added the advantage of computational efficiency for large problems in comparison with the other techniques such as the method of moment or finite – element method, especially when predicting broadband response .

Chapter Three

Methodology

3.1 Introduction

This chapter presents the methodology will explain the steps of work operation, the requirement to design rectangular patch antenna and E-shape patch antenna.

3. 2 Design Procedure

In order to clarify the processes of designing the (rectangular microstrip antenna ,E-shape patch antenna) the project will be divided into two tasks to achieve term goals.

1- Design rectangular micro strip patch antenna

2- Design E- shape patch antenna

The flow chart as in Figure (3.1), explains the process.

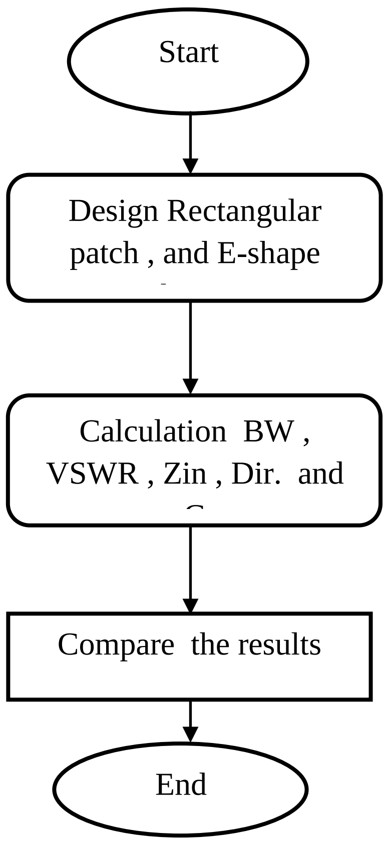


Figure 3.1: Flowchart for the design

3.3 Design Of Rectangular Micro strip Patch Antenna

The flow chart, as in Figure (3.2), explains the process.

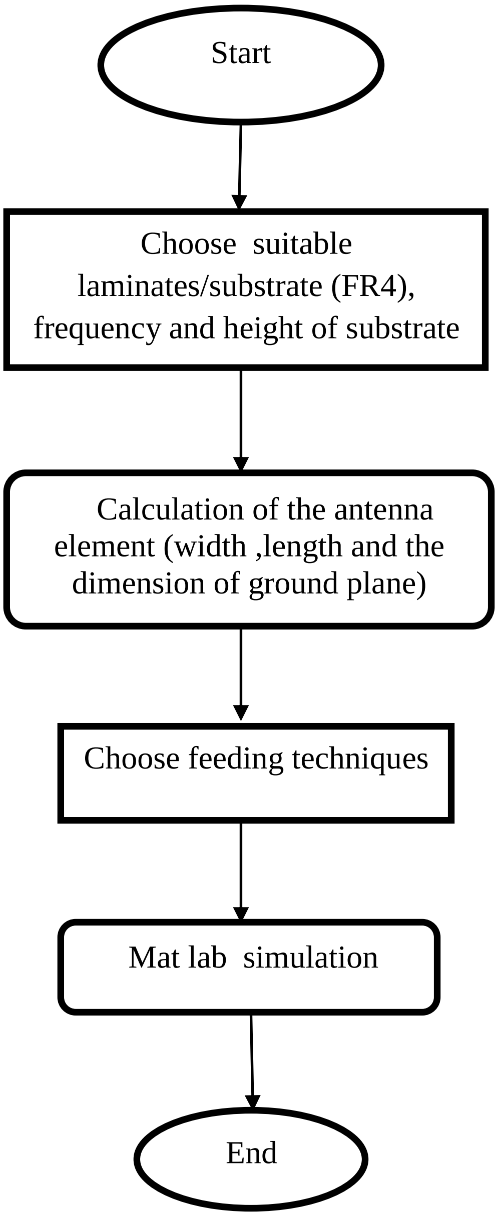


Figure 3.2: Flowchart for the design of rectangular patch antenna

3.4 Design Specifications

There are three essential parameters for the designs of a rectangular Micro strip Patch Antenna :

- ***Operating frequency (f_r):*** The resonant frequency of the antenna must be selected appropriately. The resonant frequency selected for this design is 1.8 GHz for mobile communication.

The propagation of the electromagnetic field is usually considered in free space, where it travels at the speed of light $c = 3\text{x}10^8$ m/s. Hence , the wavelength of the antenna when operating at1800MHz is 0.167m.

- ***Dielectric constant of the substrate (ε_r):*** The dielectric material selected for this design is FR4 (ε_r = 4.3). This type is chosen because it is cheaper, it operates until 10 GHz frequency, loss tangent 0.025 and the dielectric substrate FR4 are acceptable for the purpose of proof –of –concept design.

- ***Height of dielectric substrate (h):***For the micro strip patch antenna to be used in this design, it is essential that, the height of the substrate and permittivity should satisfy the equation below as a lower limit on the height, below which the broad band operation is unlikely[1] .

$$h \leq 0.06 \frac{\lambda}{\sqrt{\varepsilon_r}} \quad (3.1)$$

Hence, the height of the dielectric substrate is selected as ≤ 0.0046 m or 4.6 mm. Therefore, the height of the substrate selected for this design is 3.5mm. Table (3.1) shows the specifications of FR4 laminates.

Table 3.1: Laminates specifications of FR4

Relative dielectric constant	≅ 4.3
Loss tangent δ	0.025
Substrate height	3.5mm
Acceptable frequency range	<10 GHz

- ***Calculation of the Width (W):*** The width of the micro strip patch antenna is given by Equation (2.17) as:

$$W = \frac{c}{2f_r\sqrt{\frac{(\varepsilon_r+1)}{2}}}$$

Substituting c =3x10^{8}m/s , ε_r=4.3 and f_0=1800 MHz,

W=0.052 m or 52 mm

- ***Calculation of Effective dielectric constant (ε_{reff}):***Equation (2.12) gives the effective dielectric constant as:

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

  Substituting ε_r=4.3, W= 52 mm and h= 3.5 mm,

  ε_{reff} = 3.873

- ***Calculation of the Effective length (L_{eff}):*** Equation (2.15) gives the effective length as:

  $$L_{eff} = \frac{c}{2f_r\sqrt{\varepsilon_{reff}}}$$

  Substituting c=3x10^{8}m/s, ε_{reff}=3.873and f_0=1800 MHz

  L_{eff}= 0.0423 m or 42.3 mm

- ***Calculation of the length extension (ΔL):*** Equation (2.13) gives the length extension as:

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

  Substituting ε_{reff} =3.873, W= 52 mm and h= 3.5 mm,

  ΔL =0.0016 m = 1.6 mm

- ***Calculation of actual length of patch (L):*** The actual length is obtained by re-writing Equation (2.14) as:

  $L_{eff}=L+2\Delta L$

  Substituting L_{eff}=42.3 mm, and ΔL = 1.6 mm,

  L = 39.13 mm or 0.03913 m

- ***Calculation of the ground plane dimensions (L*g* and W*g*):***The transmission line model is applicable to infinite ground planes only. However, for practical considerations, it is essential to have a finite ground plane. The finite ground can be obtained if the size of the ground plane is greater than the patch dimensions by approximately six times the substrate thickness all around the periphery. Hence, for this design, the ground plane dimensions would be given as [16]:

$$L_g = 6h + L \qquad (3.2)$$

$$W_g = 6h + w \qquad (3.3)$$

where L_g = Length of ground plane ,

W_g = Width of ground plane

Hence, the calculated L_g and W_g are 60mm and 73 mm respectively

- ***Micro strip Patch Antenna Dimensions***

Based on the calculation above, the L and W derived are 39 mm and 52mm.

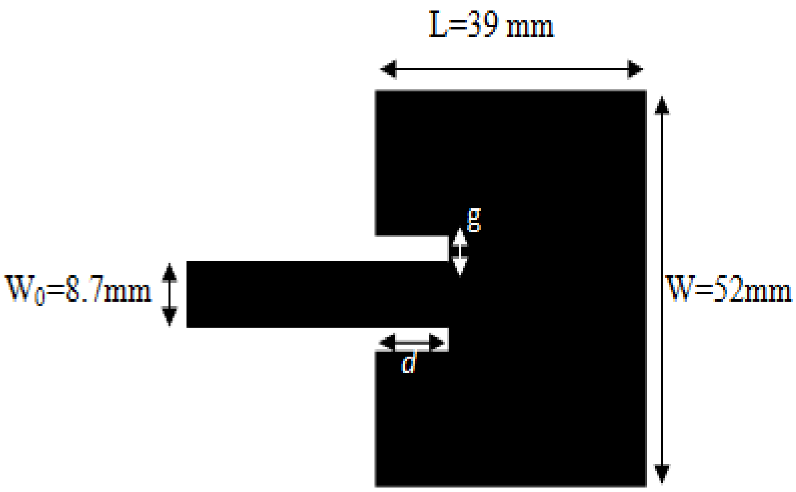


Figure 3.3 Rectangular patch antenna

The micro strip antenna is fed using micro strip inset feed line, the design specification is, as follows:

Frequency f_r= 1.8 GHz

Dielectric constant $\mathcal{E}_r$= 4.3

Substrate height h = 3.5 mm

Metallic strip thickness t = 0.1 mm

Conductivity of ground plane (Copper) σ_g= 5.8 x 10^7 S/m

Effective dielectric constant ε_{reff}= 3.873

The dimensions of the 50Ω micro strip feed line are calculated by using (2.18), (2.19) and (2.20):

W_0= 8.7mm

g=1 mm

d= 12.5mm

The E- shape is fed using micro strip inset feed line, the design specification is, as follows:

Frequency f_r= 1.8 GHz

Dielectric constant ε_r= 4.3

Substrate height h = 3.5 mm

Metallic strip thickness t = 0.1 mm

Conductivity of ground plane (Copper) σ_g= 5.8 x 10^7 S/m

Effective dielectric constant ε_{reff}= 3.873

The dimensions of the 50Ω micro strip feed line are calculated by using (2.18), (2.19) and (2.20):

W_0= 8.7mm

g=1 mm

d= 12.5mm

L_1=26 mm

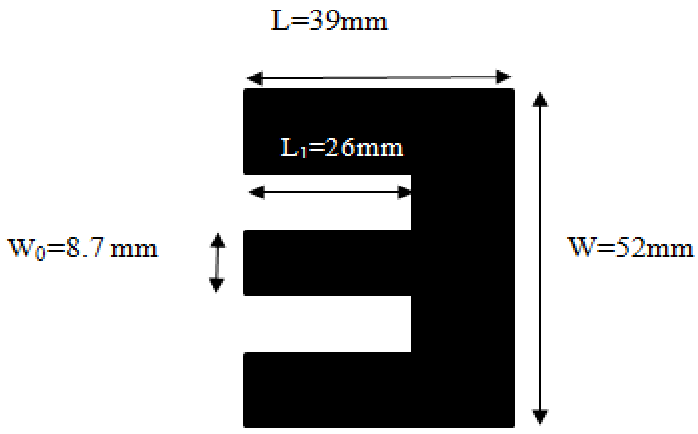


Figure 3.4E-shape patch antenna

Chapter Four
Results and discussion

4.1 Introduction

This chapter consists of the simulation of the designed antenna using Math Lab software performed on the rectangular micro strip antenna and E-shape patch antenna with Transmission Line feeding.

4.2 Rectangular Patch Antenna

4.2.1 Variable Substrate's Height

When dielectric constant(εr) is 4.3, resonant frequency($f\ r$) at 1.8 GHz and the height of dielectric substrate (h) between ($1 - 4.5$) mm is taken, and the simulated dimensions are shown in Table (4.1).

Table 4.1: The relation between the parameters of rectangular patch antenna and the height of substrate

Parameters \ height (mm)	1	1.6	2	2.5	3	3.5	4	4.5
Width (mm)	51.2	51.2	51.2	51.2	51.2	51.2	51.2	51.2
Effective dielectric constant	4.135	4.057	4.011	3.96	3.914	3.873	3.835	3.801
Effective length (mm)	40.98	41.37	41.61	41.87	42.12	42.34	42.55	42.74
Length extension (mm)	0.466	0.743	0.927	1.155	1.38	1.6	1.83	2.05
Actual length (mm)	40.045	39.88	39.75	39.56	39.35	39.13	38.89	38.64
Return loss Db	-21.57	-23.9	-21.7	-21.85	-23.95	-25	-17.37	-18.18
Bandwidth MHz	42	47.2	53.9	64.1	74.8	83	84.1	93
Gain dB	-2.6	0.808	1.9	2.7	3.1	3.3	3.5	3.7
Directivity dBi	5.2	5.49	5.6	5.8	5.9	6	6.1	6.1
VSWR	1.182	1.136	1.179	1.176	1.135	1.113	1.263	1.277

From Table (4.1), it is observed that, the best results (return losses RL = -25 dB, BW= 83MHz, Gain= 3.3 dBi and a good VSWR = 1.113) appear when the height of the substrate is 3.5 mm. So, the substrate height is selected depending upon these results.

4.2.2*Rectangular patch antenna Transmission Line feeding (MPTL)*

According to calculation of dimensions in the section (3.14), Figure(4.1) shows these obtained:

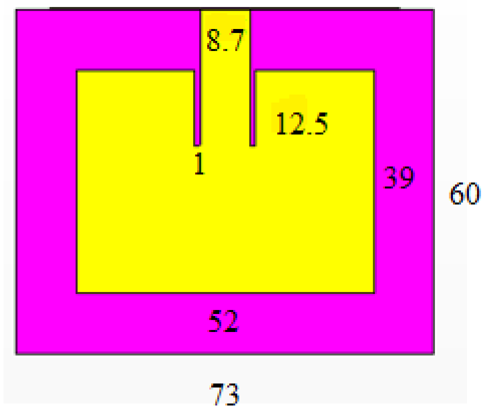


Figure 4.1: Rectangular Patch Antenna with (MPTL)

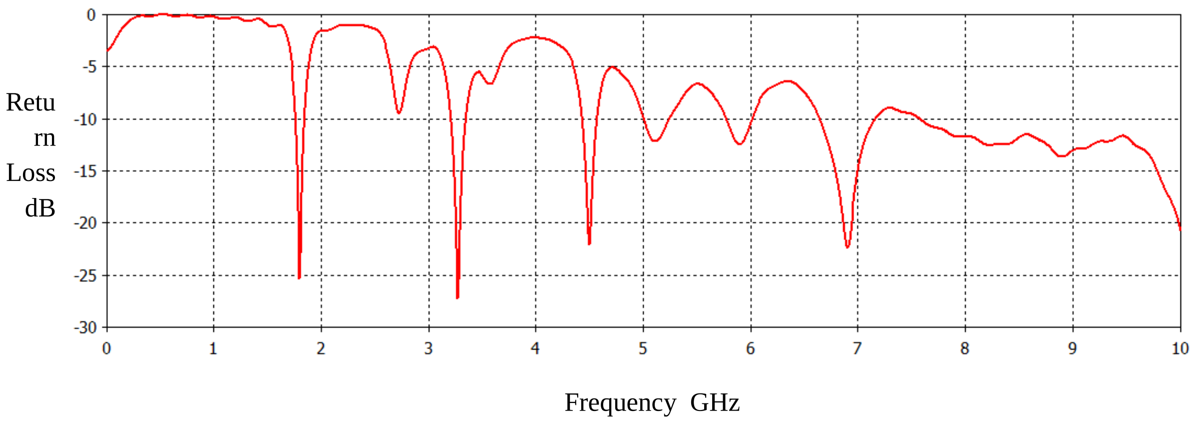


Figure 4.2: Return Loss for rectangular Patch Antenna with (MPTL)

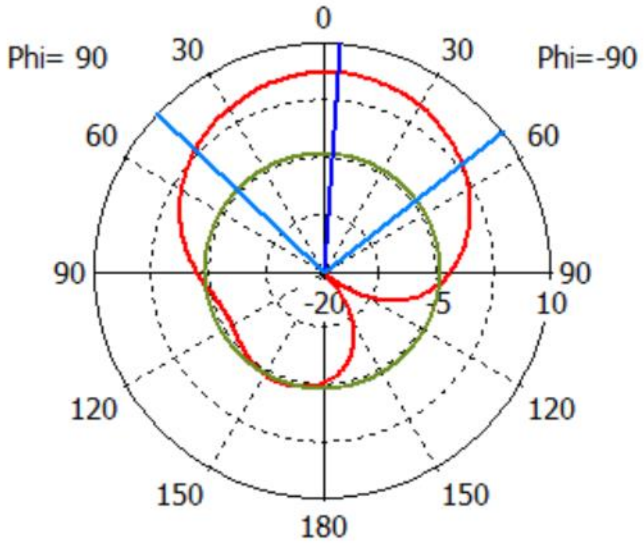


Fig. (4.3) Rectangular Patch Antenna with (MPTL) radiation pattern E-plane

From Figure (4.2), it is seen that, at the antenna resonant frequency *fr*=1.8 GHz, the corresponding bandwidth 83MHz with return loss is -25dB.From Figure (4.3), the E-field pattern is Omnidirectional ,with angular width 98.4^{o}, gain 3.3 dB and directivity 6dBi.

4.3 E-shape patch antenna

According to calculation of dimensions in the section (3.14), Figure(4.4) shows these obtained:

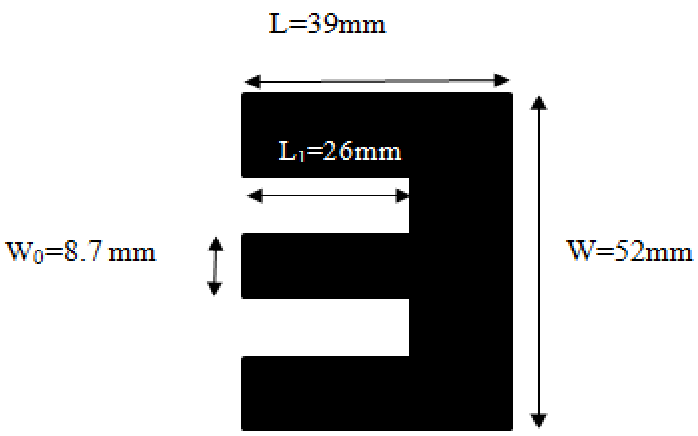


Figure 4.4: E-shape Patch Antenna

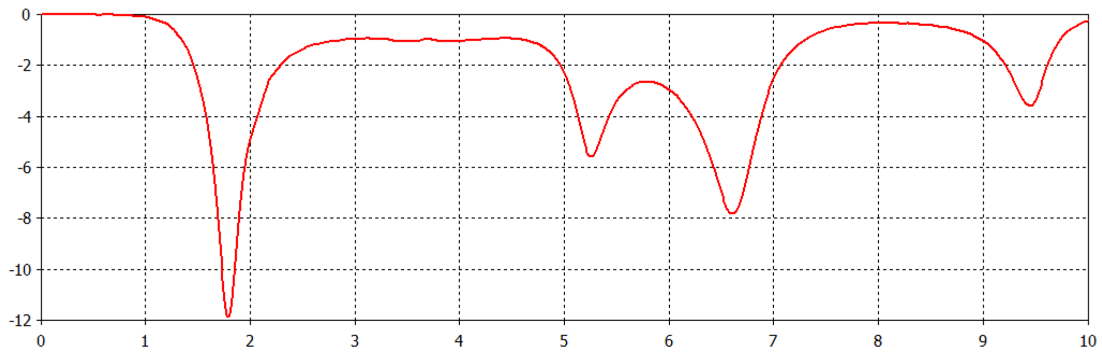


Figure 4.5: Return Loss forE-shape Patch Antenna

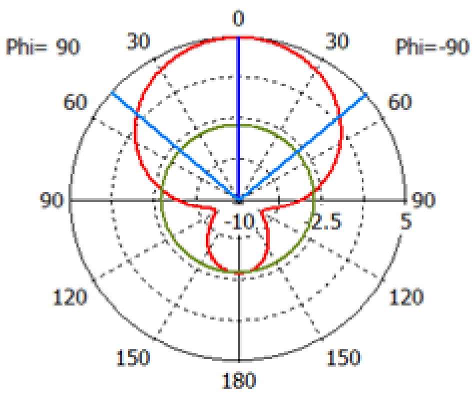


Fig. (4.6) E- shape Patch Antenna radiation pattern E-plane

The return loss decreases to -12 dB at 1.8 GHz reference frequency, as shown in Figure (4.5), while the bandwidth increases to 123.9 MHz .From Figure (4.6), the radiation pattern shows good performance at 1.8GHz with main lobe magnitude in gain 4.9 dB and the beam width is equal to 98.1° higher compares to the previous results.

Table 4.2: Comparison between the types of feeding and the obtained parameters of designed rectangular patch antenna

Antenna parameters / Types of design antenna	BW MHz ($f_L - f_H$)	Gain dB	Dir. dBi	VSWR	Return Loss dB	Input impedance Z Ω	Beam width (-3dB) deg. w.r.t E-plane	Area mm^2
Rectangular patch antenna	83 (1762-1845)	3.3	6	1.113	-25	45-j3.4	98.4	1894.25
E- shape patch antenna	123.9 (1730.8-1854.7)	4.9	6.1	1.23	-26	60.7-j4.4	98.1	1446.6

Chapter Five

Conclusion and Feature work

5.1 conclusion

This project was aiming to study the design rectangular patch antenna and compare with E-shape and E-shape path antenna .The work includes also ,simulation and measurement of the return loss ,radiation pattern ,coin ,directivity and bandwidth of the proposed antenna.From this project ,the following points can be concluded:

1-The rectangular path antenna covers the required frequency band 1.8GHz .In addition ,to the frequencies (1.8 ,3.3 ,4.5 ,5.1 ,5.9 ,6.6 and 8.9GHz bands ,so it can be used ultra-band.

2- The E-shape patch antenna covers.

3- The E-shape patch antenna enhancement the bandwidth 20% ,gain 19%and decrease the area compare with rectangular patch antenna.

5.2 Feature work

This thesis can be expanded to useother types of :

1-Shape patch antenna as circular shape patch antenna to get Ulta- wideband frequency operation**.**

2-Feeding to appliance on all these designs.