DEVELOPMENT OF TRIPLE BAND PLANAR INVERTED-H ANTENNA FOR DCS, WiMAX AND WLAN APPLICATIONS

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ABSTRACT

In this research, a triple band inverted-H planar antenna for DCS1700, WiMAX2600 and WLAN3100 is presented. The antenna consists of square planar radiating patch with dual rectangular slots suspended above the FR4 dielectric substrate. The antenna is fed by using microstrip transmission line feeding, as it is easier to design. The antenna was designed and simulated using CST Microwave Studio. Different parameters such as shorting width, height of antenna, ground plane size and patch slot size that affect the antenna characteristics were also studied. The designed antenna was fabricated and assembled together and tested using network analyzer. The result obtained for the S11 parameter in measurement for the three bands are 1.764 GHz, 2.739 GHz and 3.17 GHz with return loss of -15.14 dB, -15.88 dB and -25.77 dB respectively. Comparison for the measurement and the simulation are carried out in terms of S11 parameter, bandwidth, VSWR, input impedance and radiation pattern.

ABSTRAK

Kajian ini menerangkan antenna H-terbalik tiga jalur untuk DCS1700, WiMAX2600 dan WLAN3100. Antena ini terdiri daripada tampalan terpancar segiempat satah dengan dua slot segiempat tepat yang digantung di atas substratum FR4. Antena disediakan dengan menggunakan jalurmikro penghantaran talian masukan kerana ianya lebih mudah untuk direkabentuk. Antena direka dan disimulasi menggunakan CST Microwave Studio. Parameter yang berbeza seperti lebar pembumian, ketinggian antena, saiz satah bumi dan saiz slot tampal yang memberi kesan kepada ciri-ciri antena juga dikaji. Antena yang direka bentuk adalah dibikin dan dipasang bersama-sama dan diuji menggunakan penganalisa rangkaian. Keputusan yang diperolehi untuk parameter S11 dalam mengukur tiga jalur 1.764 GHz, 2.739 GHz dan 3.17 GHz dengan pembalikan kehilangan -15.14dB, -15.88dB dan -25.77dB masing-masing. Perbandingan bagi mengukur dan simulasi yang dijalankan dari segi parameter S11, jalur lebar, VSWR, galangan masukan dan corak sinaran.

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LIST OF SYMBOLS AND ABBREVIATIONS

PCB	=	Printed circuit board
CST	=	Computer software technology
MWS	=	Microwave studio
EM	=	Electromagnetic
S_{11}	=	Return loss
dB	=	Decibels
BW	=	Bandwidth
VSWR	=	Voltage standing wave ratio
SMA	=	Sub Miniature A
FR4	=	Fire retardant 4
UTHM	=	University Tun Hussien Onn Malaysia
MIC	=	Microwave integrated circuits
RL	=	Return loss
GSM	=	Global system for mobile
Fh	=	Higher frequency
Fl	=	Lower frequency
DCS	=	Digital cellular system
WiMAX	=	Wireless interoperability for microwave access
WLAN	=	Wireless local area network
Γ	=	Reflection Coefficient
fr	=	Center frequency

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CHAPTER 1

INTRODUCTION

1.1 Background

Antenna has been around for a long time, millions of years serving as the organ of touch or feelings in animal, insect and birds. But in the last 100 years they have acquired a new significance as the connection link between a radio system and the outside world [1]. The first radio antenna was built by Heinrich Hertz, a professor at the Technical Institute in Karlsruhe, Germany. The IEEE standard defines an antenna as a part of a transmitting or receiving system that is designed to radiate or receive electromagnetic waves [2].

The emerging high data rate applications and services required in wireless communications make substantial demands on bandwidth and interoperability within the physical layer. Antenna modules for wireless and mobile terminals may be expected to operate over up to three distinct frequency bands which include DCS (1710 MHz), WiMAX (2600 MHz), and WLAN (3100 MHz).

In literature, different ways of generating dual band, multiband and wideband operations in a single antenna have been proposed [3-13].

Wireless operations enable services, such as long-range communications, are impractical or impossible to implement with the use of wires. The term is frequently used in the telecommunications industry to refer to telecommunications systems (e.g. radio transmitters and receivers, remote controls etc.) which use some type of energy (e.g. radio waves, acoustic energy, etc.) to transmit information without the use of wires. Information is passed on in this manner over both short and long distances.

A larger number of microstrip patches to be used in wireless applications have been developed [14-15].

However, to meet these requirements multiband planar antennas are the newest generation of antennas, boasting such attractive features as low profile, light weight, low cost, and ease of integration into arrays. These features make them ideal components of modern communications systems, particularly in cellular and WLAN applications. Consequently, many novel designs of planar antennas for related applications have come into being within the last two to three years. Until now these designs were only accessible to current and prospective antenna designers through journal articles, conference papers, and patent descriptions. Planar antennas for wireless communications organize today's most important planar antenna designs into one easy-to-use reference.

Patch antennas are very attractive because of their low profile, low weight and lower manufacturing cost finding increasing application in the commercial sector of the industry. A large number of microstrip patches to be used for wireless applications have been developed.

A conventional microstrip antennas consist of a pair of parallel conducting layers separating a dielectric medium, referred to as substrate. In this configuration, the upper conducting layer or “patch” is the source of radiation where electromagnetic energy fringes off the edges of the patch and into the substarate. The lower conducting layer acts as a perfectly reflecting ground plane, boucing energy back through the substrate and into the free space [16].

The dimension of the microstrip patch is determined from mathematical equation and using CST Microwave studio [17-18].

In this project, a new multiband modified rectangular-shaped microstrip antenna was designed which covers frequency bands of 1.7 GHz, 2.6 GHz and 3.1 GHz. In order to obtain the triple band operation, two rectangular slots was created on the patch of the antenna. These dual slots will make the antenna to operate at three distinct frequency bands.

1.2 Problem Statement

The study of microstrip patch antenna has made great progress in recent years. Compared with conventional antennas, microstrip patch antennas have more advantages and better prospects. Different researchers have used different dielectric substrates to fabricate microstrip patch antenna which can handle individual frequency operation.

The motivation of this project is to explore and enhance the operational capability of microstrip triple band planar monopole antenna for wireless application which is specifically design and intended to work within digital cellular services, wireless interoperable multiple access and wireless local area network (DCS, WiMAX and WLAN) frequency band range. As such, this can save cost of producing distinct types of antenna for different application purposes.

However, by applying microstrip antenna design and considering the advantages, it is expected to have a better gain with lower cost, light, less mechanical limitation and distraction. The antenna is designed and simulated by using Computer Simulation Tool (CST).

1.3 Objective

The objectives of this project are:

I. To design a modified rectangular microstrip patch antenna for wireless system operating at 1.7 GHz, 2.6 GHz and 3.1 GHz frequencies.

II. To perform manipulation of multiple resonance frequencies by the modification of the radiators geometry to meet the specifications.

III. To fabricate measure and analyze the antenna performance in terms of return loss, VSWR and radiation pattern using Network Analyzer.

1.4 Project Scope

This project is restricted within the below limitations;

I. A rectangular shape is selected to form the patch of microstrip antenna for wireless application capable to cover DCS 1700, WiMAX 2600 and WLAN 3100.

II. To explore and simulate the parameters of the rectangular patch antenna using CST microwave Studio software.

III. To observe how these parameters affect the antenna performance by comparing the simulated and measured result of the designed antenna.

1.5 Thesis outline

This thesis is organized into five chapters. Chapter I describes the introduction of the proposed project which include the problem statement, objectives, aim and the scope of the work.

Chapter II includes the description of the antenna characteristic, and also the previous literature research regarding the microstrip antenna.

Chapters III include the details and approach used to design the modified rectangular-shaped microstrip monopole antenna. The chapter discusses the design procedure and the simulation process of the designed antenna. It also informs about the simulation software used in designing and simulating the antenna

Chapter IV described the performance result and analysis of overall project. This chapter discusses and analyses the result between the simulation and measurement process.

Chapter V presents the conclusions and future recommendations for the project which include some possible extension ideas and suggestion for future projects.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter reviews several related previous work done by researchers to model different antenna with different frequency applications.

Microstrip antenna was a simple antenna that consists of radiated patch component, dielectric substrate and ground plane. The radiated patch and ground plane is a thin layer of copper or gold which is good conductor. Each dielectric substrate has its own dielectric permittivity value. This permittivity will influence the size of the antenna. Microstrip antenna is a low profile antenna, conformable to planar and non-planar surface, simple and inexpensive to manufacture using modern printed-circuit technology. They have several advantages such as light weight, small dimension, cheap, conformability and easily to integrate with other circuit for many applications [19].

2.2 Basic antenna operation

It is apparent that the size of an antenna is inversely proportional to its operating frequency. A relatively small antenna can efficiently radiate high frequency electromagnetic waves. As for the low frequency waves, it requires relatively large antennas.

The length of the radiating patch is made approximately so that the patch starts to radiate. The patch will be fed with the transmission line that is usually 50Ω impedance. The transmission line is fed at the radiating edge along the width of the patch, as it provides a good polarization with Γ is defined as ratio of the reflected wave (Vo-) to the incident wave (Vo+) at transmission line load [20, 21].

2.3 Microstrip patch antenna

Microstrip patch antennas consist of a very thin layer of metallic strip, patch of any planar or non-planar geometry on a substrate with the value of dielectric constant. The other side of the substrate is a conductive layer, a ground plane. The dimension of patch is usually a fraction of the wavelength and the thickness of the dielectric substrate layer is usually a small fraction of a wavelength.

Microstrip patch antenna becomes very popular because of easy of analysis and fabrication, low profile, small size, low cost and volume, light weight, easy to feed and their attractive radiation characteristics. Although patch antenna has numerous advantages, it has some drawbacks such as narrow bandwidth, lower gain, lower efficiency, poor polarization, lower power handling capability and a potential decrease in radiation pattern. Some application are aircraft and ship antenna, satellite communication, biomedical such as microwave hyperthermia, intruders alarms, mobile such as radio pagers and hand phone, missiles such as radar and telemetry, remote sensing, and GPS.

2.3.1 Patch design of Microstrip

Resonance is determined by the length along the feed axis

Transmission length

Length is approximately $\frac{\lambda}{4} = \frac{\lambda}{4\sqrt{\varepsilon r}}$ (2.1)

Where $\lambda = \frac{c}{f}$ (2.2)

Width is loosely equal to the length, however maximum efficiency is given for width

$$W = \frac{c}{2f\sqrt{\frac{\varepsilon r+1}{2}}} \quad (2.3)$$

$$L = \frac{c}{2f\sqrt{\varepsilon r}} \quad (2.4)$$

$$\text{Effective } \varepsilon r = \frac{\varepsilon r+1}{2} + \frac{\varepsilon r-1}{2}\left[1 + 12\frac{h}{w}\right]^{-\frac{1}{2}} \quad (2.5)$$

The patch usually made from conductor materials like copper and gold. Figures (2.1) illustrate a simple rectangular patch antenna which is characterized by L for length, W for width and thickness, h.

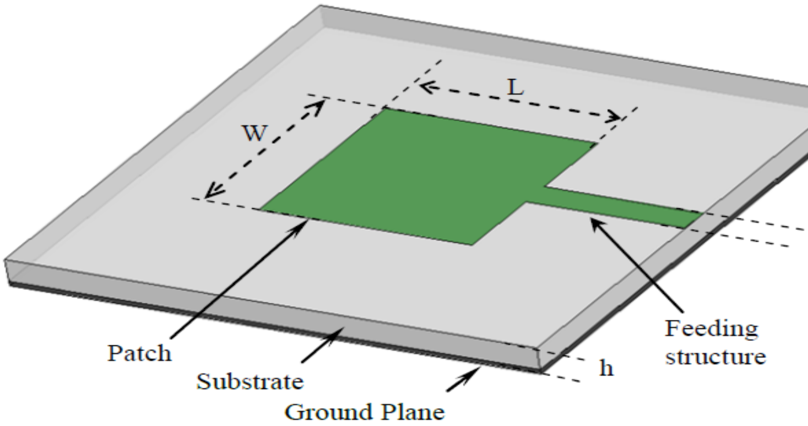

Figure 2.1: Simple microstrip patch antenna

The value of length, L for the microstrip patches influences the resonant frequency of the antenna. The width, W of the patch develops the resonant resistances of the antenna where a large patch giving a lower resistance.

The value of dielectric constant of the substrate is an important value or path to be considered because it enhances the fringing fields which effect the radiation of the patch. Besides that, εr affects the bandwidth and radiation pattern efficiency of the antenna performance. Dielectric constant is the ratio of the amount of electric energy stored in an insulator when a static electric field is imposed across it. The impedance bandwidth is wide with the lower εr and reduce the surface wave excitation and also give better efficiency and loosely bound field for radiation into space. However, lower dielectric constant of substrate is more expensive if compared to high dielectric constant. Therefore, a good performance antenna has to be thicker with lower dielectric constant but affects larger in antenna size. In order to design a compact microstrip antenna, higher dielectric constant must be used results in lower efficiency. Hence, if the permittivity is increased by a factor of 4, the length required decreases by a factor of 2. Using higher values for permittivity is frequently exploited in antenna miniaturization.

The height of the substrate h also controls the bandwidth; increasing the height increases the bandwidth. The fact that increasing the height of a patch antenna increases its bandwidth can be understood by recalling the general rule that "an antenna occupying more space in a spherical volume will have a wider bandwidth [22]. This is the same principle that applies when noting that increasing the thickness of a dipole antenna increases its bandwidth. Increasing the height also increases the efficiency of the antenna. Increasing the height does induce surface waves that travel within the substrate (which is undesired radiation and may couple to other components).

2.3.2 Microstrip transmission line design

The transmission line model is the simplest of all and gives good physical insight but it is less accurate. The transmission line model has been utilized to determine the input performance of rectangular-shaped patch antenna.

Microstrip or patch antennas are becoming increasingly useful because they can be printed directly onto a circuit board. Microstrip antennas are becoming very widespread within the mobile phone market. Patch antennas are low cost, have a low profile and are easily fabricated.

Consider the microstrip antenna shown in Figure 2.2, fed by a microstrip transmission line. The patch antenna, microstrip transmission line and ground plane are made of high conductivity metal (typically copper). The patch is of length L, width W, and sitting on top of a substrate (some dielectric circuit board) of thickness h with permittivity ε_r. The thickness of the ground plane or of the microstrip is not critically important. Typically the height h is much smaller than the wavelength of operation, but not much smaller than 0.05 of a wavelength.

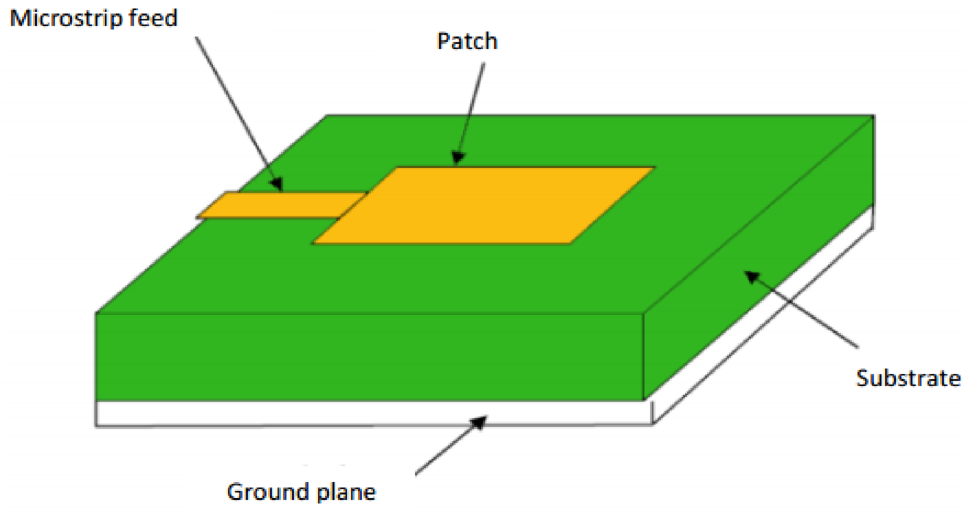

Figure 2.2: Microstrip transmission line orientation

2.3.3 Rectangular microstrip antenna

Microstrip antenna works as one type of transducer that converts the electrical energy into the electromagnetic energy in the form of electromagnetic waves. It is required by any radio receiver or transmitter to couple its electrical connection to the electromagnetic field.

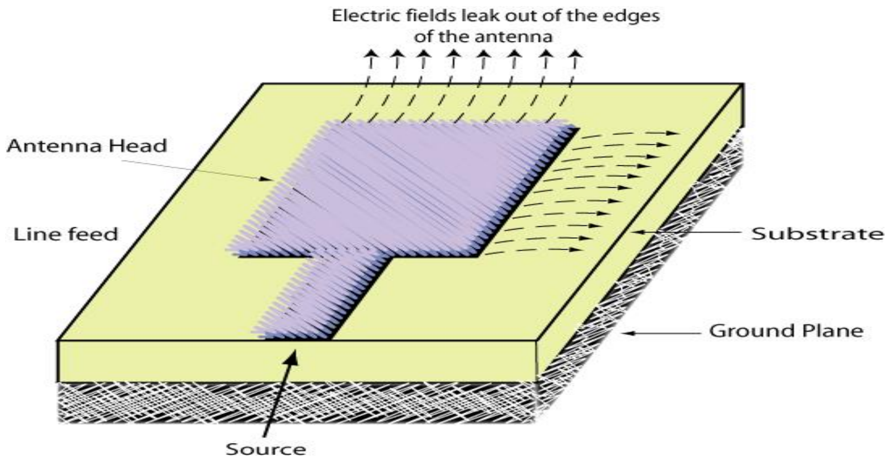

Figure 2.3: Radiation of EM wave for microstrip

The rectangular patch is the most widely used configuration because it is very easy to analyze using transmission line and cavity models [23]. Microstrip patch antenna radiate primarily because of the fringing fields between the patch edge and the ground plane. The EM wave fringe off the top patch into the substrate, reflecting off the ground plane and radiates out into the air.

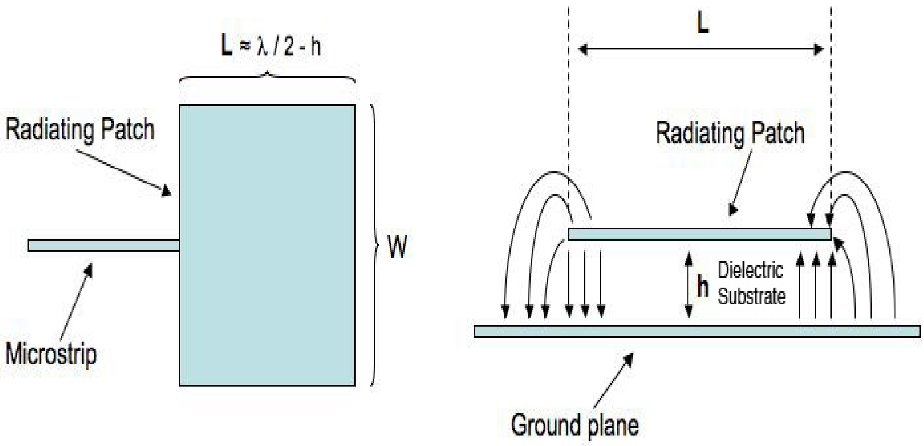

Figure 2.4: Radiation of EM wave for microstrip

2.4 Overview of monopole antenna

The monopole antenna was invented in 1895 by radio pioneer Guglielmo Marconi [24], who discovered if he attached one terminal of his transmitter to a long wire suspended in the air and the other to the earth, he could transmit for longer distances. For this reason it is sometimes called a Marconi antenna, although Alexander Popov [25] independently invented it at about the same time. Common types of monopole antenna are the whip, rubber ducky, helical, random wire, umbrella, inverted-L and T-antenna, mast radiator, and ground plane antennas.

A monopole antenna is a class of radio antenna consisting of a straight rod-shaped conductor, often mounted perpendicularly over some type of conductive surface, called a ground plane. The driving signal from the transmitter is applied, or for receiving antennas the output signal to the receiver is taken, between the lower end of the monopole and the ground plane. One side of the antenna feedline is attached to the lower end of the monopole, and the other side is attached to the ground plane, which is often the earth. This contrasts with a dipole antenna which consists of two identical rod conductors, with the signal from the transmitter applied between the two halves of the antenna.

2.4.1 Types of monopole antenna

There are two basic types of monopole antennas: solid and planar. The solid type, although more expensive to manufacture is known for having good bandwidth and being completely omni-directional. The more commonly used and less expensive planar-type also has good bandwidth, but experiences distortion at higher frequencies, thereby making it non omni-directional. A cross-shaped, planar-type monopole antenna [23] has been designed and implemented in recent years that overcome this frequency distortion while continuing to retain good bandwidth. A dual-frequency cross-shaped monopole [24] has also been fabricated and tested in an attempt to reduce frequency distortion even further.

2.5 Feeding Techniques

Feeding techniques [25] are important in designing the antenna to make sure antenna structure can operate at full power of transmission. Designing the feeding techniques for the high frequency, need more difficult process. It is because of input loss on feeding increase depending on frequency, and finally given huge effect on the overall design. There are a few techniques that can be used. The technique is used in this project is microstrip feed. It is easy to fabricate, simple to match and model. However, as the substrate thickness increase surface wave and spurious feed radiation increase, which for practical designs limit the bandwidth.

A feedline is used to excite and radiate by direct or indirect contact. There are many different techniques of feeding and four most popular are coaxial probe feed, microstrip line, aperture coupling and proximity coupling [26].

2.5.1 Microstrip transmission line

Microstrip line is easy to fabricate, simple to model and match by controlling the inset cut position in the patch. For this project, the line fed is used as the feeding technique because it allows the user to control the impedance match between feed and antenna.

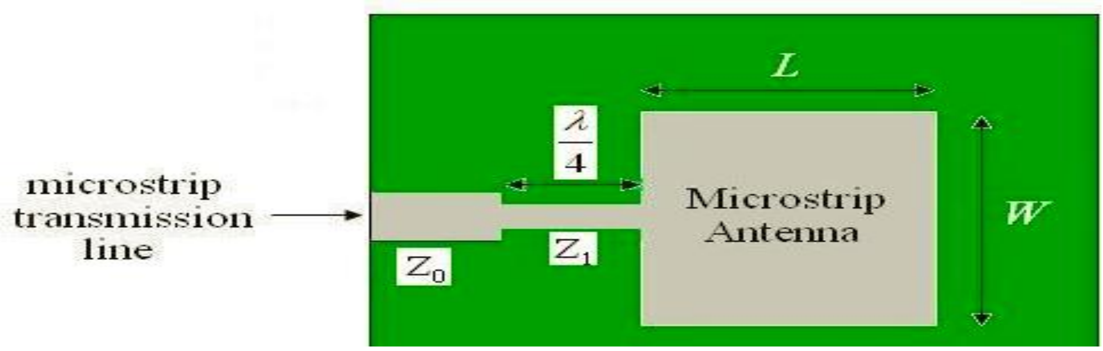

Figure 2.5: Microstrip line feed patch monopole antenna

2.5.2 Coaxial probe feed

This method is widely used because of its simplicity in fabrication and matching with low radiation. The inner conductor of the coaxial is attached to the radiation patch while the outer conductor is connected to the ground plane.

Advantages of coaxial feeding is easy of fabrication, easy to match, low spurious radiation and its disadvantages is narrow bandwidth, and difficult to model specially for thick substrate [27].

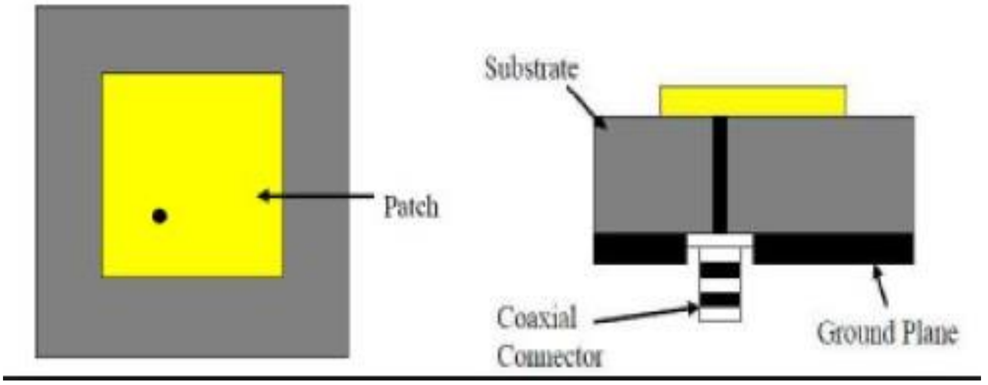

Figure 2.6: Coaxial probe feed patch monopole antenna

2.6 Description of Previous Methods

This section, describes several researches and projects that related to the rectangular-shaped microstrip antenna design.

2.6.1 Dual-Wideband G- shaped Slotted Printed Monopole Antenna for WLAN and WiMAX Applications

In this work, a new dual-wideband printed monopole antenna was presented for satisfying the wireless local area network (WLAN) and the Worldwide Interoperability for Microwave Access (WiMAX) applications simultaneously. A G-shaped slotted printed rectangular monopole antenna with a defected ground plane for band broadening was presented. The antenna was deployed on FR4-Epoxy dielectric substrate with the overall dimensions of the proposed antenna can reach 30 x 48 x 1.6mm^3. Theoretical and experimental characteristic were illustrated for this antenna, which achieved impedance bandwidth of 60.26% (over 2.4-4.47 GHz) and 28.04% (over 4.6-6.1GHz), with a reflection coefficient ≤ -10 dBs the obtained characteristic demonstrates that the proposed antenna was able to operate at dual wideband frequency covering all the WLAN bands and WiMAX bands. [28]

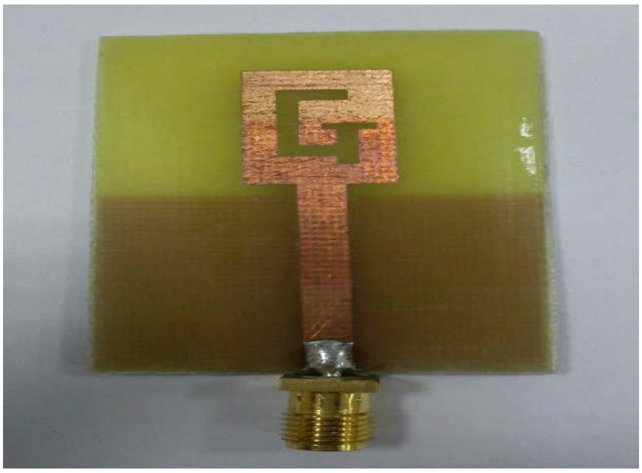

Figure 2.7 : Dual-Wideband G- shaped Slotted Printed Monopole Antenna for WLAN and WiMAX Applications

2.6.2 Design of double l-slot microstrip patch antenna array for WiMAX and WLAN application using ceramic substrate

In this work, a double L-slot microstrip patch antenna array using coplanar waveguide feed for Wireless Local Area Network (WLAN) and Worldwide Interoperability for Microwave Access (WiMAX) frequency bands was presented. The proposed antenna was fabricated on Aluminium Nitride Ceramic substrate with dielectric constant 8.8 and thickness of 1.5mm. The key feature of this substrate was that it can withstand in high temperature. The return loss was about -31dB at the operating frequency of 3.6GHz with 50Ω input impedance. The basic parameters of the proposed antenna such as return loss, VSWR, and radiation pattern are simulated using Ansoft HFSS. Simulation results of antenna parameters of single patch and double patch antenna array are analyzed and presented. [29].

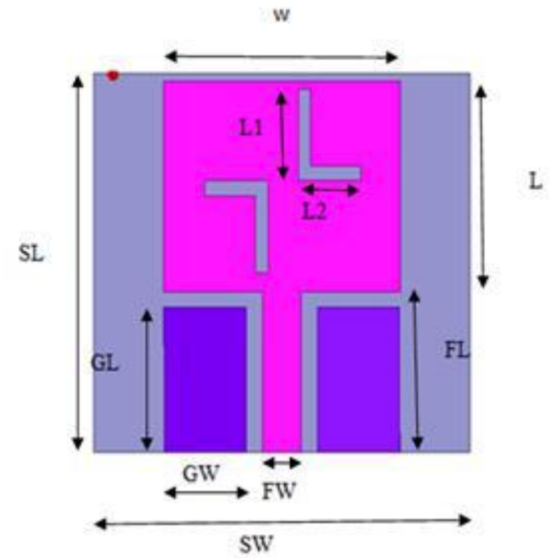

Figure 2.8: Design of double l-slot microstrip patch antenna array for wimax and wlan application using ceramic substrate

2.6.3 Design Studies of Stacked U-Slot Microstrip Patch Antenna for Dual Band operation

In this work, an extensive design study of a stacked u-slot microstrip patch antenna for dual band operation was presented. This antenna consists of two stacked microstrip patches, both having u-slots embedded in them. Two feeding techniques namely probe-feeding and co-planar waveguide feeding were used and the results compared. Particle swarm optimization had been used to optimize the antenna parameters. The simulated results indicated that using co-planar waveguide feeding results in a tremendous increase in bandwidth when compared with probe feeding, however a degradation in gain was observed. [30].

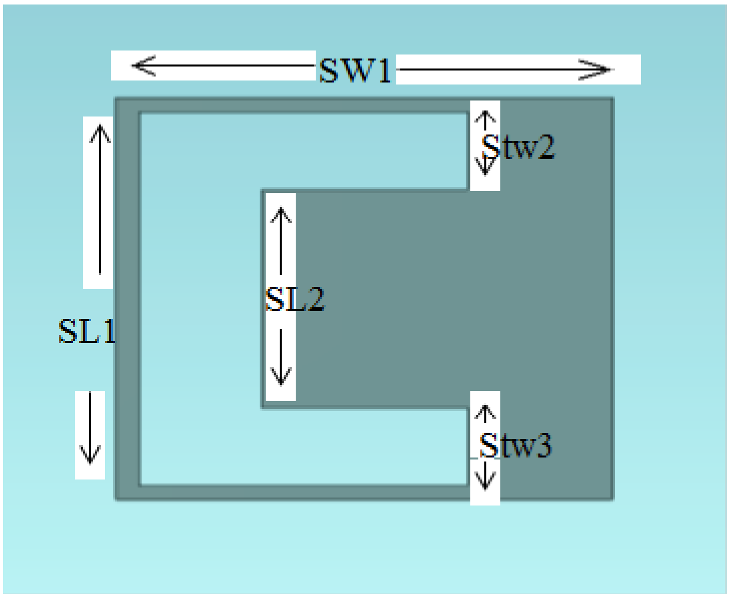

Figure 2.9: Design Studies of Stacked U-Slot Microstrip Patch Antenna for Dual Band operation

2.6.4 Multiband and Wideband Monopole Antenna for GSM900 and Other Wireless Applications

In this work, the design of a compact monopole antenna for multiband and wideband operations was proposed. The antenna had three distinct frequency bands, centred at 0.94, 2.7, and 4.75 GHz. The antenna has a compact size of only 30×40×1.57 mm^3 including the ground plane. The multiband and wideband operations were achieved by using an E-shaped slot on the ground plane. The design procedure was also discussed. The frequency bands can be independently controlled by using the parameters of the E-slot. The impedance bandwidth, current distributions, radiation patterns, gain, and efficiency of the antenna were studied by computer simulation and measurements [31].

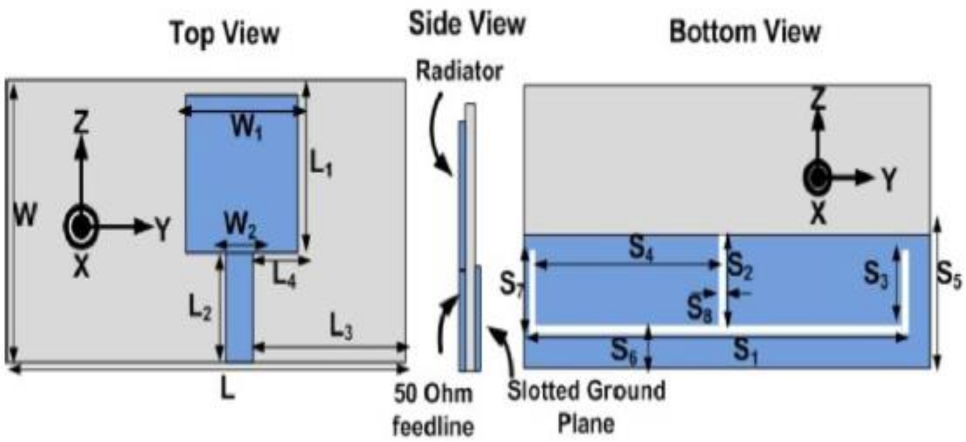

Figure 2.10: Multiband and wideband monopole antenna for GSM900 and other wireless applications

2.6.5 A new dual-frequency broadband L-slot mixed E-shaped patch antenna

In this work, a new dual-frequency broadband L-slot mixed E-shaped patch antenna was presented. It was based on E-shaped patch antenna. Two L-shaped slots were cut on E-shaped patch, and two short-pins were inserted between top patch and ground. Besides, the meandered feed patch was also used for good match. As simulated by HFSS10.0 software dual-frequency broadband was obtained. One was between 800MHz and 980MHz. The other was between 1500MHz and 3000MHz. The peak of gain was 3.2dbi in 900MHz and 5dbi in 2000MHz. It may apply for AMPS, GSM, DCS, PCS, UMTS and WLAN. [32].

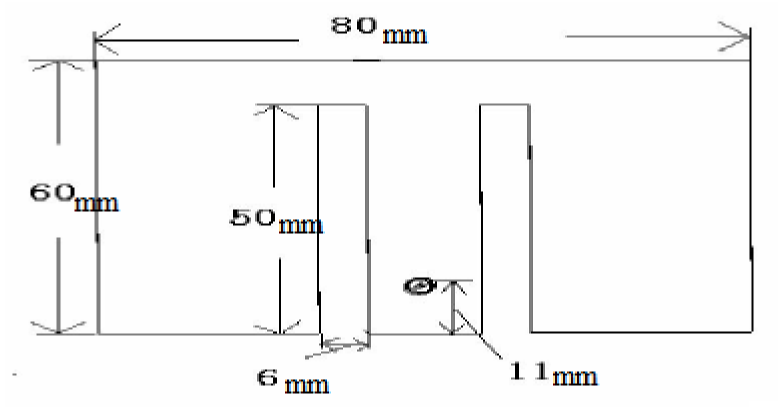

Figure 2.11: A new dual-frequency broadband L-slot mixed E-shaped patch antenna

2.6.6 Modified Design of Microstrip Patch Antenna for WiMAX Communication System

In this work, a new design for U-shaped microstrip patch antenna was proposed, which can be used in WiMAX communication systems. The aim of this work was to optimize the performance of microstrip patch antenna. Nowadays, WiMAX communication applications are widely using U-shaped microstrip patch antenna and it has become very popular. The proposed antenna design used 4.0-4.5 GHz frequency band. RT/DUROID 5880 material was used for creating the substrate of the microstrip antenna. This modified design of the microstrip patch antenna gave high performance in terms of gain and return loss [33].

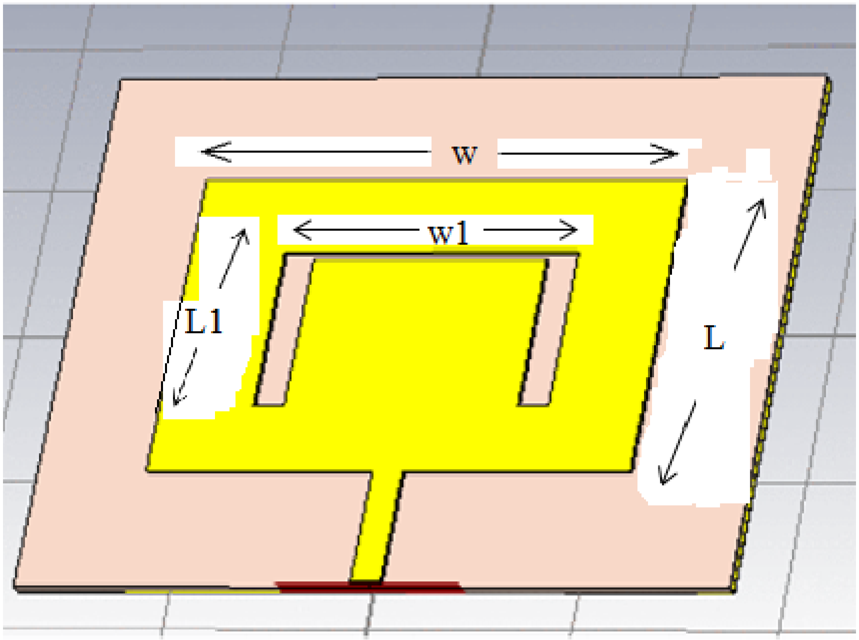

Figure 2.12: Modified design of microstrip patch antenna for WiMAX application

2.6.7 Miniaturized Multiband Planar Antenna for GSM, UMTS, WLAN, and WiMAX bands

This paper presented a compact multiband planar monopole microstrip antenna for modern mobile phone applications. The proposed antenna covered the following wireless communication bands: GSM (824–894 MHz), PCS (1850–1990MHz), WLAN (2.4-2.484 GHz), WiMAX (2.5-2.69 GHz and 5.1-5.8 GHz). A new technique of using a combination of slots and slits in the radiating patch and the ground plane had been employed to achieve the multiband performance of the antenna. The proposed antenna exhibited good radiation performance in terms of gain, return loss, and compactness. The proposed antenna was suitable for many wireless handheld devices. A good agreement between the simulated and the experimental results was achieved [34].

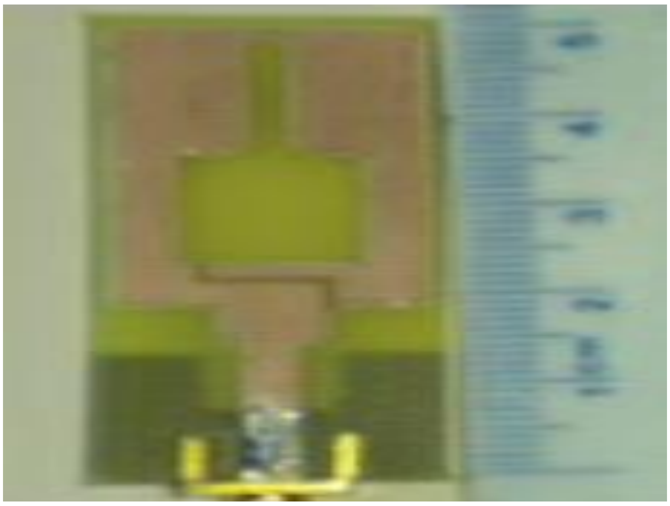

Figure 2.13: Miniaturized Multiband Planar Antenna for GSM, UMTS, WLAN, and WiMAX bands

2.7 Overview of antenna systems application for Wireless Application

Microstrip patch antennas are well known for their performance and their robust design, fabrication and their extent usage. These usages of the microstrip antennas are spreading widely in all fields and areas and now they are booming in the commercial aspects due to their low cost of the substrate material and the fabrication. Due to the increasing usage of the patch in the wide range, would take over the usage of the conventional antennas for maximum applications. Microstrip patch antenna has several applications. In this project we use wireless communication because it requires small, low-cost, and low profile antennas [35-37].

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter explains the methods used in order to obtain the optimum result of the project, starting from the designing process until the testing process. The design and simulation processes are done by using CST Microwave Studio. The simulation result is optimized to achieve the best performance of antenna.

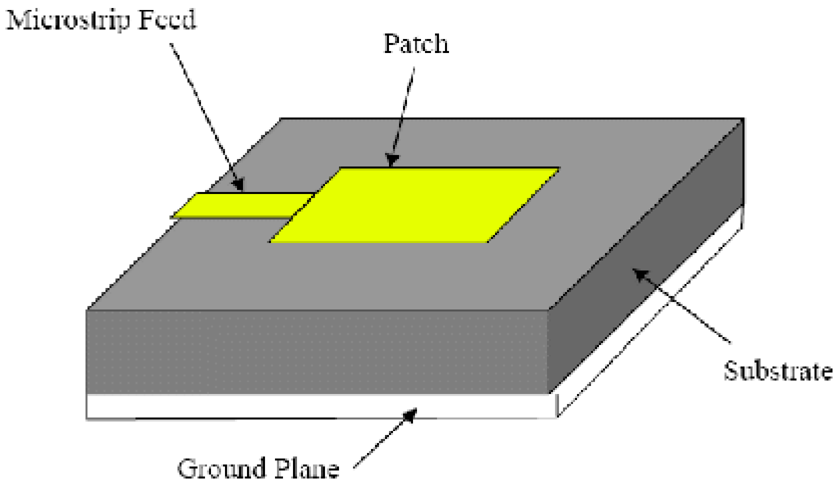

Figure 3.1: Microstrip Patch Antenna

3.2 Flow chart

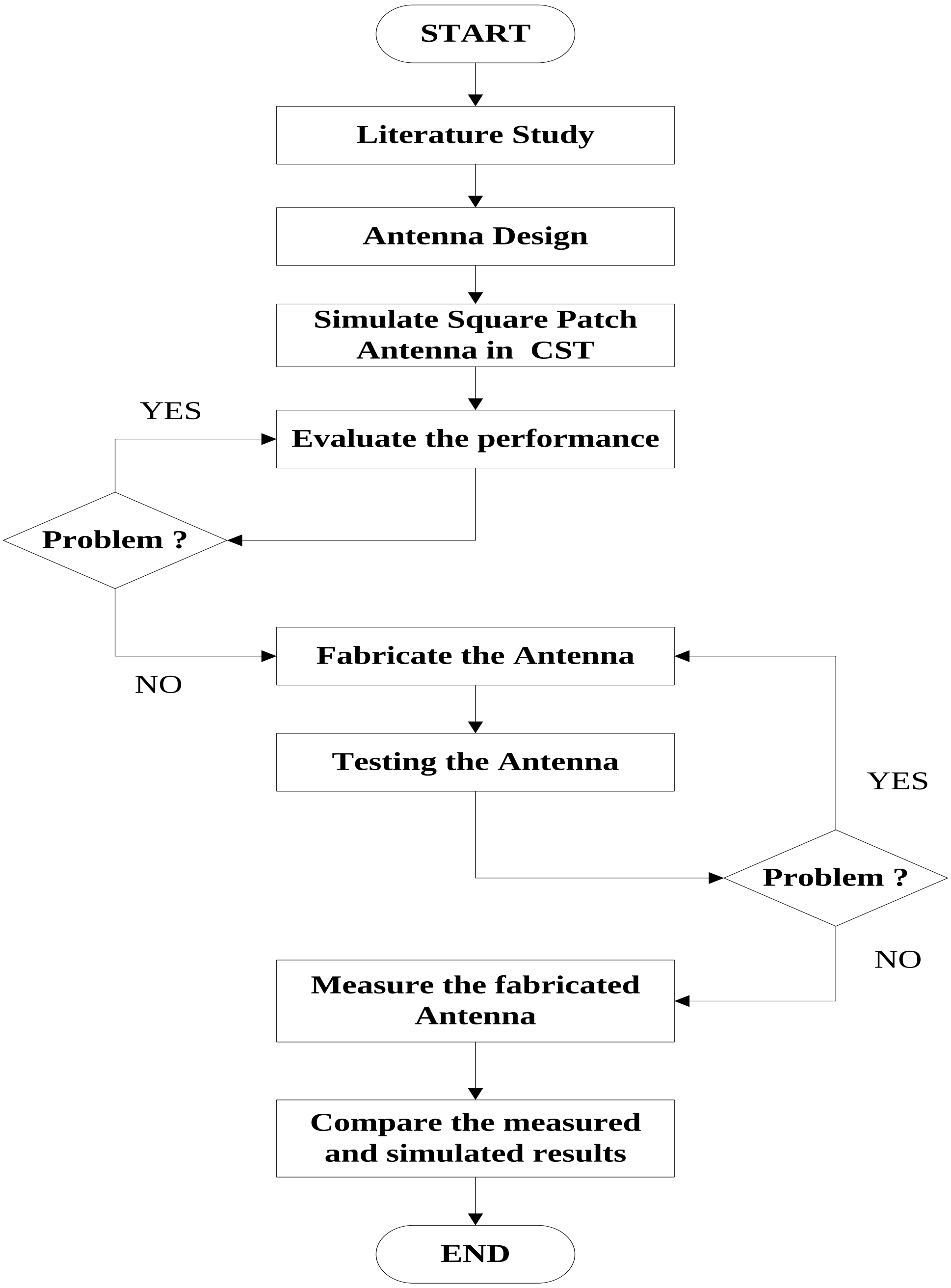

Figure 3.2: Flow chart of the project

3.3 Design procedures

The design of the inverted-H shaped antenna is done at resonant frequency, fr = 1.7 GHz, 2.6 GHz and 3.1 GHz, substrate height h = 1.6mm, ground plane size is chosen to be 60×60mm and dielectric constant εr = 4.3 (FR4 substrate). The antenna has been designed using the transmission line model from equation (3.1). The dimensions is calculated and found using equation (3.2) for the width, and the length using equation (3.5). The geometry and dimensions of the initial proposed inverted-H antenna for DCS, WiMAX and WLAN operation can be seen in figure 3.3. The proposed antenna is exited using 50 Ω microstrip feed line.

3.3.1 Design parameter of Antenna

The three essential parameters for the design of an inverted-H microstrip patch antenna are:

Table 3.1: The essential parameters for rectangular patch

Parameter	Unit
Cental frequency, fr	1.7 GHz
Dielectric constant, ε_r	4.3
Substrate thickness, h	1.6mm

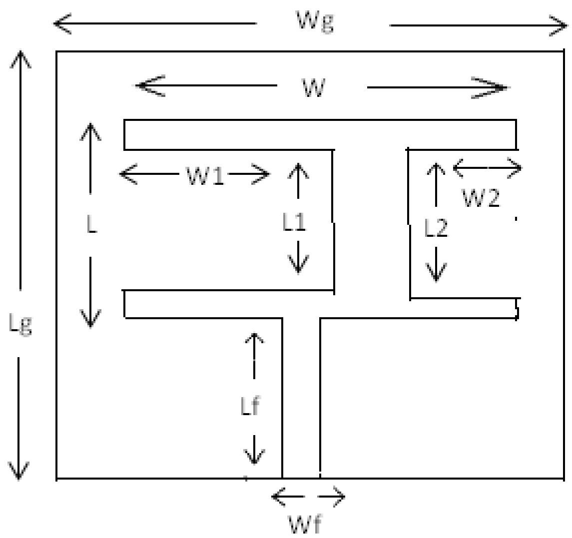

Figure 3.3: Layout of inverted-H antenna with micro-strip feed

3.3.1.1 Design of inverted-H Microstrip Antenna Using Theory Calculation FR4

The propagation of electromagnetic field is usually considered in free space, where it is travels at the speed of light C is $3x10^8$m/s. $\lambda,$ lambda is the wavelength, expressed in meters.

Wavelength of the bands

The following expression is used

$$\lambda = \frac{c}{fr(GHz)} \qquad (3.1)$$

Hence, the wavelength of the antenna when operating at 1.7 GHz, 2.6 GHz and 3.1 GHz are 0.1764 m, 0.1154m and 0.0968m respectively.

From the above, the essential parameters for the design we can calculate that

a) Calculation of the width

$$W = \frac{c}{2f_r\sqrt{\frac{(\varepsilon_r+1)}{2}}} \qquad (3.2)$$

Substitution C = $3x10^8$m/s, ε_r =4.3, fr = 1.7 GHz

W = 54.20mm

b) Calculation of effective dielectric constant

$$\varepsilon_{reff} = \frac{\varepsilon r+1}{2} + \frac{\varepsilon r-1}{2}\left[\frac{1}{\sqrt{1+12(\frac{h}{W})}}\right] \qquad (3.3)$$

Substitution ε_r =4.3, W=54.20mm, h =1.6mm

ε_{reff} = 4.06

c) Calculation of length extension

$$\Delta L = 0.412h\,\frac{(\varepsilon_{reff}+0.3)\left(W/_h+0.264\right)}{(\varepsilon_{reff}-0.258)\left(W/_h+0.8\right)} \qquad (3.4)$$

Substitution W =54.20mmh =1.6mm, ε_{reff} = 4.06

ΔL =0.744 mm

d) Calculation of the actual length of the patch

$$L = \frac{c}{2f_r\sqrt{\varepsilon_{reff}}} - 2\Delta L \qquad (3.5)$$

Substitution C = $3x10^8$m/s, ε_{reff} = 4.06, fr = 1.7 GHz

L = 42.30 mm

Table 3.2: Calculated parameters for the patch with microstrip feed line

Center frequency, fr	1.7 GHz
Dielectric constant, ε_r	4.3
Substrate thickness, h	1.6mm
Metallic strip thickness, t	0.1 mm
Conductivity of ground plane (Copper), g	5.8 x 10^7 S/m
Effective dielectric constant, ε_{reff}	4.06
Resonant input impedance, Zo	50 Ω
The length extension, ΔL	0.744 mm
The actual length of patch, L	42.30mm
The actual width of the patch, W	54.20mm

Based on the results obtained from the previous phases, the analysis of this project has been done. All the formulas available in this design are based on rectangular microstrip patch antennas.

3.3.1.2 Design of inverted-H Microstrip Antenna Using Theory Calculation FR4

The propagation of electromagnetic field is usually considered in free space, where it is travels at the speed of light C is $3x10^8$m/s. $\lambda,$ lambda is the wavelength, expressed in meters.

Table 3.3: The essential parameters for rectangular patch

Cental frequency, fr	2.6 GHz
Dielectric constant, ε_r	4.3
Substrate thickness, h	1.6mm

Wavelength of the band

The following expression is used

$$\lambda = \frac{c}{fr(GHz)} \quad (3.10)$$

Hence, the wavelength of the antenna when operating at 2.6 GHz is 0.11538 m.

From the above, the essential parameters for the design we can calculate that

a) Calculation of the width

$$W = \frac{c}{2f_r\sqrt{\frac{(\varepsilon_r+1)}{2}}} \tag{3.11}$$

Substitution C = $3x10^8$m/s, ε_r = 4.3, fr = 2.6 GHz

W = 35.44 mm

b) Calculation of effective dielectric constant

$$\varepsilon_{reff} = \frac{\varepsilon r+1}{2} + \frac{\varepsilon r-1}{2}\left[\frac{1}{\sqrt{1+12(\frac{h}{w})}}\right] \tag{3.12}$$

Substitution ε_r = 4.3, W = 35.44 mm, h =1.6mm

ε_{reff} = 3.98

c) Calculation of length extension

$$\Delta L = 0.412h\,\frac{(\varepsilon_{reff}+0.3)\left(W/_h+0.264\right)}{(\varepsilon_{reff}-0.258)\left(W/_h+0.8\right)} \tag{3.13}$$

Substitution W = 35.44 mm, h =1.6mm, ε_{reff} = 3.98

ΔL = 0.741 mm

d) Calculation of the actual length of the patch

$$L = \frac{c}{2f_r\sqrt{\varepsilon_{reff}}} - 2\Delta L \tag{3.14}$$

Substitution C = $3x10^8$m/s, ε_{reff} = 3.98, fr = 2.6 GHz

L = 27.44mm

Table 3.4: Calculated parameters for the patch with microstrip feed line

Center frequency, fr	2.6 GHz
Dielectric constant, ε_r	4.3
Substrate thickness, h	1.6mm
Metallic strip thickness, t	0.1 mm
Conductivity of ground plane (Copper), g	5.8 x 10^7 S/m
Effective dielectric constant, ε_{reff}	3.98

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