COMPACT MONOPOLE ANTENNA FOR WIRELESS USB DONGLE APPLICATIONS

EHAB ALI MOHAMED

This project report presented in partial
fulfillment of the requirements for the award of
the Degree of Master of Electrical Engineering

Faculty of Electrical and Electronic Engineering
Universiti Tun Hussein Onn Malaysia

PTTA UTHM
PERPUSTAKAAN TUNKU TUN AMINAH

JUNE 2013

ABSTRACT

In this project, two designs of printed monopole antenna with multiband operation are presented to cover six bands GSM900 (880-960MHz) and GSM1800/1900/UMTS/LTE2300/2500 (1710-2690 MHz). Both of designs are compact and easy to embed in USB dongle with a length less than a quarter wavelength. Both of antennas were designed with good omnidirectional radiation pattern in the azimuth plane with compact radiator size equal to 20×18 mm^2. The design and simulation process is carried out using CST Studio Suite 2012 software. The proposed antennas are fabricated on FR4 epoxy glass substrate with dielectric constant of 4.3. Measurement of return loss, input impedance, voltage standing wave ratio (VSWR), and bandwidth of the antenna are presented. The simulated and measured results are compared to ensure the antennas have a good performance.

PTTA UTHM PERPUSTAKAAN TUNKU TUN AMINAH

ABSTRAK

Dalam projek ini, dua reka bentuk antena monopol dicetak dengan operasi pelbagai jalur dibentangkan untuk menampung enam jalur GSM900 (880-960 MHz) dan GSM1800/1900/UMTS/LTE2300/2500 (1710-2690 MHz). Kedua-dua rekabentuk yang padat dan mudah untuk dimasukkan ke dalam dongle USB dengan panjang kurang daripada panjang gelombang suku. Kedua-dua antena telah direka dengan corak sinaran omni-terarah baik dalam azimut dengan saiz radiator padat sama dengan 20×18 mm^2. Rekabentuk dan proses simulasi dijalankan dengan menggunakan perisian CST Studio Suite 2012. Antena yang dicadangkan telah direka pada FR4 substratum kaca dengan pemalar dielektrik 4.3. Pengukuran rugi balasan, galangan masukan, nisbah gelombang pegun voltan (VSWR), dan lebar jalur antena dibentangkan di dalam projek ini. Keputusan simulasi dan diukur dibandingkan dengan memastikan antena mempunyai prestasi yang baik.

PTTA UTHM PERPUSTAKAAN TUNKU TUN AMINAH

TABLE OF CONTENTS

	TITLE	**ii**
	DECLARATION	**iii**
	DEDICATION	**iv**
	ACKNOWLEDGEMENT	**v**
	ABSTRACT	**vi**
	LIST OF CONTENTS	**viii**
	LIST OF FIGURES	**xi**
	LIST OF TABLES	**xiii**
	CHAPTER I INTRODUCTION	
1.1	Project Background	1
1.2	Statement of the Problem	2
1.3	Project Objectives	3
1.4	Project Scopes	3
1.5	Thesis Outline	4
1.6	Chapter summary	4
	CHAPTER II LITERATURE REVIEW	
2.1	Multiband antennas for USB dongle	5
2.2	Monopole antenna in USB dongle	6
	2.2.1 Previous work on monopole antenna	6
2.3	Antenna Properties	11
2.4	Monopole antenna as a Printed Antenna	16
	2.4.1 Basic Characteristics of Printed Antenna	17
	2.4.2 Substrate	17
	2.4.3 Feeding method	18

PTTA UTHM PERPUSTAKAAN TUNKU TUN AMINAH

2.4.4 Advantages And Disadvantages Of Monopole Antennas 20
2.5 Chapter Summary 21

CHAPTER III METHODOLOGY

3.1 Flowchart of work progress 23
3.2 Antenna Design 24
3.3 Design Process 24
3.3.1 Mathematical Method 26
3.3.1.1 Effective Dielectric Constant 26
3.3.1.2 Practical width of the transmission line 26
3.3.1.3 Practical length 27
3.3.1.4 Practical Length and width of the radiating plate 27
3.3.2 Design in CST software 28
3.3.2 PCB fabrication process 30
.3.3.1 Feeding Technique 33
3.3.4 Testing and Measurement Process 34
3.3.4.1 Measurement for Return Loss, Input impedance, VSWR and Bandwidth 34
3.4 Antenna design 2 35
3.5 Chapter summary 37

CHAPTER IV RESULT AND ANALYSIS

4.1 Simulation Results 38
4.1.1 Return Loss 38
4.1.2 Bandwidth 39
4.1.3 Voltage Standing Wave Ratio (VSWR) 40
4.1.4 Input Impedance 41
4.1.5 Radiation Pattern 42
4.1.6 Gain 44
4.2 Measurement Result 45

PTTA UTHM PERPUSTAKAAN TUNKU TUN AMINAH

	4.2.1 Return loss	46
	4.2.2 Voltage Standing Wave Ratio (VSWR)	47
	4.2.3 Input Impedance	47
4.3	Simulation and Measurement Result Analysis	48
	4.3.1 Return Loss, S11 (dB)	48
	4.3.2 Voltage Standing Wave Ratio (VSWR)	49
4.4	Simulation results of design 2	50
	4.4.1 Return loss	50
	4.4.2 Bandwidth	50
	4.4.3 Voltage Standing Wave Ratio (VSWR)	52
	4.4.4 Input impedance	52
	4.4.5 Radiation pattern	53
	4.4.6 Gain	56
4.5	Measurement result	57
	4.5.1 Return loss	57
	4.5.2 Voltage Standing Wave Ratio (VSWR)	58
	4.5.3 Input Impedance	59
4.6	Comparison of Simulation and Measurement Result Analysis for the antenna design 2	59
	4.6.1 Return Loss, S11 (dB)	60
	4.6.2 Voltage Standing Wave Ratio (VSWR)	60
4.7	Chapter summary	61
	CHAPTER V CONCLUSION AND RECOMMENDATION	
5.1	Conclusion	62
5.2	Recommendations	63
	REFERENCES	14
	APPENDICES	

PTTA UTHM PERPUSTAKAAN TUNKU TUN AMINAH

LIST OF FIGURES

2.1	The configuration of the proposed antenna (a) Top view. (b) Detailed dimensions of strip.	7
2.2	Geometry of the proposed antenna.	8
2.3	Geometry of proposed monopole antenna for WLAN-band USB dongle application (units: mm).	8
2.4	Geometry of the proposed antenna for wireless USB dongle applications.	9
2.5	Generic directional antenna	12
2.6	HPBW and FNBW	13
2.7	Geometry of a printed antenna feeding methods	17
2.8	The substrate	18
3.1	Flowchart of work progress	23
3.2	The proposed antenna	24
3.3	Flow chart for antenna design	25
3.5	CST Microwave Studio workspace	29
3.6	3-dimension position of the antenna in CST Microwave Studio	30
3.6	Output result in Navigation tree	30
3.7	Fabrication process	32
3.8	SMA connector- Socket SMA Panel	33
3.9	the fabricated antenna	34
3.10	Network Analyzer	35
3.11	(a) the proposed antenna 2 in CST	36
3.11	(b) the proposed antenna 2	36
4.1	return loss for planar monopole antenna	39
4.2(a)	the bandwidth for the frequency 0.912 GHz	39
4.2(b)	the bandwidth for the frequency 1.872 GHz	40
4.3	Simulated Voltage Standing Wave Ratio (VSWR)	41
4.4	Simulated input impedance for the dual band patch antenna	41

PTTA UTHM PERPUSTAKAAN TUNKU TUN AMINAH

4.5(a)	2D view X-Z plane for the operating frequency of 0.92 GHz	42
4.5(b)	3D view X-Z plane for the operating frequency of 0.92 GHz	42
4.6(a)	2D view X-Z plane for the operating frequency of 1.9 GHz	43
4.6(b)	3D view X-Z plane for the operating frequency of 1.9 GHz	43
4.7(a)	2D view X-Z plane for the operating frequency of 0.92 GHz	44
4.7(b)	3D view X-Z plane for the operating frequency of 0.92 GHz	44
4.8(a)	2D view X-Z plane for the operating frequency of 1.9 GHz	45
4.8(b)	3D view X-Z plane for the operating frequency of 1.9 GHz	45
4.9	Measured return loss, S11 (dB)	46
4.10	Measured voltage standing wave ratio (VSWR)	47
4.11	Input impedance of the measured antenna	48
4.12	Return loss comparison	49
4.13	VSWR comparison	49
4.14	Return loss for antenna design 2	50
4.15 (a)	Bandwidth for the lower band	51
4.15 (b)	Bandwidth for the higher band	51
4.16	VSWR for antenna design2	52
4.17	The input impedance for the antenna design 2	53
4.18(a)	2D view X-Z plane for the operating frequency of 0.92 GHz	53
4.18 (b)	3D view X-Z plane for the operating frequency of 0.92 GHz	54
4.19(a)	2D view X-Z plane for the operating frequency of 1.9 GHz	54
4.19 (b)	3D view X-Z plane for the operating frequency of 1.9 GHz	55
4.20(a)	2D view X-Z plane for the operating frequency of 2.4 GHz	55
4.20 (b)	3D view X-Z plane for the operating frequency of 2.4 GHz	56
4.21	The gain of the antenna	56
4.22(a)	Measurement of return loss for the antenna design 2	57
4.22(b)	Measurement of return loss for the antenna design 2	58
4.23	Measurement of VSWR for the antenna design 2	58
4.24	Measurement of input impedance for the antenna design 2	59
4.25	Return loss comparison for the antenna design	60
4.26	VSWR comparison for the antenna design 2	61

PTTA UTHM PERPUSTAKAAN TUNKU TUN AMINAH

LIST OF TABLES

2.1	Cellular and network band standards	6
2.2	Summarizes some of the prior work on monopole antennas	10
2.3	Feeding methods	19
3.1	Basic parameters of the proposed antenna	26
3.2	Calculated parameters of printed monopole antenna	28
3.3	Calculated parameters of design 2	36
4.1	Operating frequency, return loss and bandwidth of the monopole antenna	40
4.2:	Operating frequency, return loss and bandwidth of the design 2	51

PTTA UTHM PERPUSTAKAAN TUNKU TUN AMINAH

CHAPTER I

INTRODUCTION

1.1. Project Background

In the last few years, USB dongle have evolved immensely both in design and function. Due to the progress in integrated circuit technology, handheld communication devices are not only getting lighter in weight but are also shrinking in size. USB dongles are now required to operate at several frequency bands for enhanced functionality and performance. Due to the preference for smaller and multifunction devices, it is necessary for an internal antenna to be multiband as well as physically small. But a known challenge in antenna design is the balance between antenna size and its performance [1].

Due to the rapidly growing demand for multiple services on a mobile terminal, various multiband antennas for USB dongle application have been introduced [2].

An antenna in the communication products is an element mainly used for radiating or receiving signals, and the antennas used in the current wireless products have to own the features of small size, excellent performance and low cost, so as to be broadly accepted and confirmed by the market. Generally, the features of antenna can be known by the parameters of operation frequency, radiation pattern, return loss, and antenna gain [3].

PTTA UTHM PERPUSTAKAAN TUNKU TUN AMINAH

Recently, interest in application of the universal serial bus (USB) dongle embedded with antennas for achieving wireless network access has rapidly increased. Small size, good radiation efficiency and impedance matching are gotten more attention on the antenna design for mobile communication.

For this, an antenna of the terminal equipment for the wireless USB is required. Usually, such a kind of antenna is required to be of compact size, have a simple structure, and a potential function on dual or multiband operation for easy integration with the USB circuit and sufficiently covering the possible operating bands. So far, many prototypes of the WLAN-band USB antenna have been reported. These proposed antennas include monopole antennas, the meander-line antenna, the spiral antenna, and the inverted-F antenna.

However, most of these designs are generally complex and have a large size in the radiator or the ground structure which detracts from practical use in a wireless USB dongle device [4].

In this work, an internal antenna model with small space requirement and good performance at varying broadband is proposed.

1.2. Problem Statements

Reduction of the monopole antenna's physical size reduces the operating radiation bandwidth of the antenna. In order to overcome this problem caused from size reduction, several conventional monopole antennas having such as helical radiating elements and a sleeve surrounding the monopole radiating element have been provided. However, it has been difficult to manufacture these conventional antennas within strict tolerance requirements. Moreover, even though these conventional antennas may reduce the antenna's physical length, they still have the adverse effect of inherently increasing the diameters thereof, thus actually increasing the antenna’s overall size.

Moreover, it is quite difficult for the conventional monopole antennas to simultaneously have the feature of low cost, small size, high antenna gain, broad operation bandwidth and good radiation patterns, so that the applications of the conventional monopole antennas are greatly limited.

PTTA UTHM PERPUSTAKAAN TUNKU TUN AMINAH

Hence, there is an urgent need to develop a monopole antenna for satisfactorily meeting the antenna requirements of low cost, small size, high antenna gain, broad operation bandwidth and good radiation patterns.

1.3. Project Objectives

Objectives of this project are as follows:

- To design and fabricate a compact monopole antenna which should be able to generate two operating bands to cover the GSM900 (880-960 MHz) and GSM1800/1900/UMTS/ LTE2300/2500 (1710-2690 MHz).
- To develop and improve a monopole antenna to satisfy the antenna requirements of low cost, small size, high antenna gain, broad operation bandwidth and good radiation patterns, thereby overcoming the disadvantages of the conventional monopole antenna.

1.4. Project Scope

- There are various types of antennas available in current situation. But in this project, only monopole antenna will be considered. The designed antenna should be performing in desired frequency.
- If the single antenna can be tuned to more than one frequency, it is considered as multiband antenna.
- With a small size and easy fabrication by printing on an FR4 substrate, the proposed antenna can be applied in today's major wireless mobile and USB dongle terminals.
- The CST software will be used in this project to develop and improve the proposed antenna.

PTTA UTHM PERPUSTAKAAN TUNKU TUN AMINAH

1.5. Thesis Outline

The thesis outline has been arranged as follows:

Chapter II describes some projects that have been done associated to the planar monopole antenna, antenna properties and planar antenna characteristics. Chapter III of this thesis explains about the methodology that has been used in order to complete this project. Calculation, details about the software and equipments that have been used also are described. Chapter IV describes the simulation and measurement that have been obtained. Analyses for both of the results are also explained. Lastly, Chapter V suggests several recommendations to upgrade this project. Overall conclusion for this project has been stated as well.

1.6. Chapter summary

This first chapter contains all the important parts needed in order to complete this project. It consists of background of study for this project, the problem statement, the objective and scopes. The background study explains briefly about the application of the planar monopole antenna that will be used in this project. As for the problem statement, it explains about the advantages of using the planar monopole antenna compared to other conventional antennas. The objective explains the project objectives and the scope explains about software that will be used in the project.

PTTA UTHM PERPUSTAKAAN TUNKU TUN AMINAH

CHAPTER II

LITERATURE REVIEW

2.1. Multiband antennas for USB dongle

Nowadays users of technology not only expect smaller, slimmer, lighter, and stylish devices but also want their handheld devices to be more efficient in supporting different technologies such as LTE, Global System for Mobile Communications (GSM), Global Positioning Systems (GPS), Personal Communications Service (PCS), Digital Cellular System (DCS), WLAN and WiMAX [1].

Table 2.1: Cellular & network band standards.

Technology	Standard	Frequency Band
LTE	4G	746-806 MHz
GSM 850, GSM900	2G	824-894 MHz, 880-960 MHz
PCS, DCS	2G	1880-1990 MHz,1710-1880 MHz
UMTS	3G	1885-2025 MHz for uplink, 2110-2200 MHz for downlink
WLAN	3G	2400-2484 MHz, 5150-5350 MHz, 5.725-5.85 GHz
WiMAX	4G	2.5-2.69 GHz, 3.3-3.8 GHz, 5.25-5.85 GHz

PTTA UTHM PERPUSTAKAAN TUNKU TUN AMINAH

Available space for internal antennas inside USB dongle has made the job of antenna designer more challenging. Antenna has little available space for its integration inside the device than before so a small simple multi-band antenna with high efficiency is desirable. Many researchers and designers have attempted to design both broadband and multiband compact antennas for USB devices. Researchers have used different techniques to enhance the bandwidth and miniaturize multiband antenna for compact dongles and other devices. At lower frequencies designers worked hard to come up with a compact design of multiband antenna [1].

2.2. Monopole Antenna in USB Dongle

This chapter introduces some of monopole antennas that have been designed by previous researchers. The basic information of the antenna design and the characteristics of the antenna are presented in this chapter.

2.2.1. Previous work on monopole antenna

Dongho Kim, Uisheon Kim , Iaehoon Choi (2010)

The authors designed a novel internal monopole antenna for wireless USB dongle application. The proposed antenna covers the WiBro, WLAN, Bluetooth, S-DMB, and WiMAX bands with a small size (15 mm × 5 mm × 1 mm). The overall dimension of the proposed antenna including the system ground is 45 mm × 15 mm × 1 mm. The proposed antenna consists of two strips and one stub. Two strips are connected via a hole (Φ = 0.4 mm). By adding a stub and stick-shaped strip, the wide dual resonant frequency characteristic can be achieved [2].

PTTA UTHM PERPUSTAKAAN TUNKU TUN AMINAH

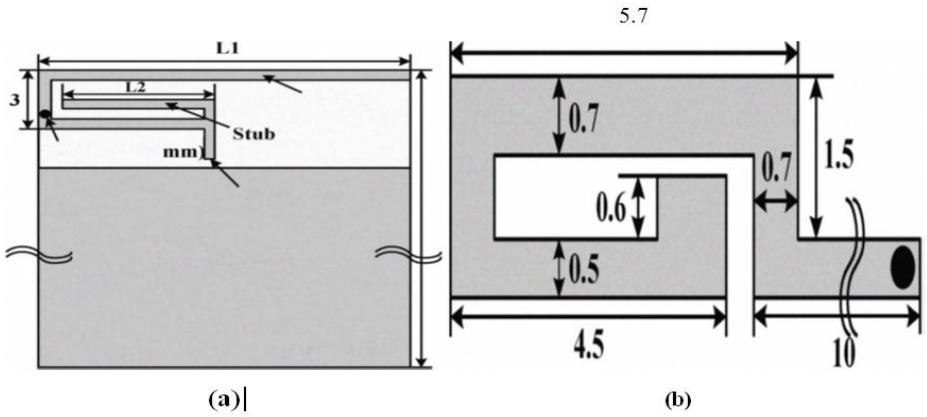


Figure 2.1: The configuration of the proposed antenna (a) Top view. (b) Detailed dimensions of strip.

Jyoti Ranjan Panda, Aditya Sri Ram Saladi, Rakhesh Singh Kshetrimayum (2010)

They proposed a simple and compact microstrip-fed printed monopole antenna (PMA) for applications in wireless local area network (WLAN) and radio frequency identification (RFID). The dual-band operation is achieved from the 9-shaped folded antenna which is printed on a non-conductor backed dielectric. Consistent omnidirectional radiation patterns have been observed in both the frequency bands from the experimental results. The proposed antenna is simple in design and compact in size. It exhibits broadband impedance matching, consistent omnidirectional radiation patterns and appropriate gain characteristics (>2.5 dBi) in the RFID and WLAN frequency regions [3].

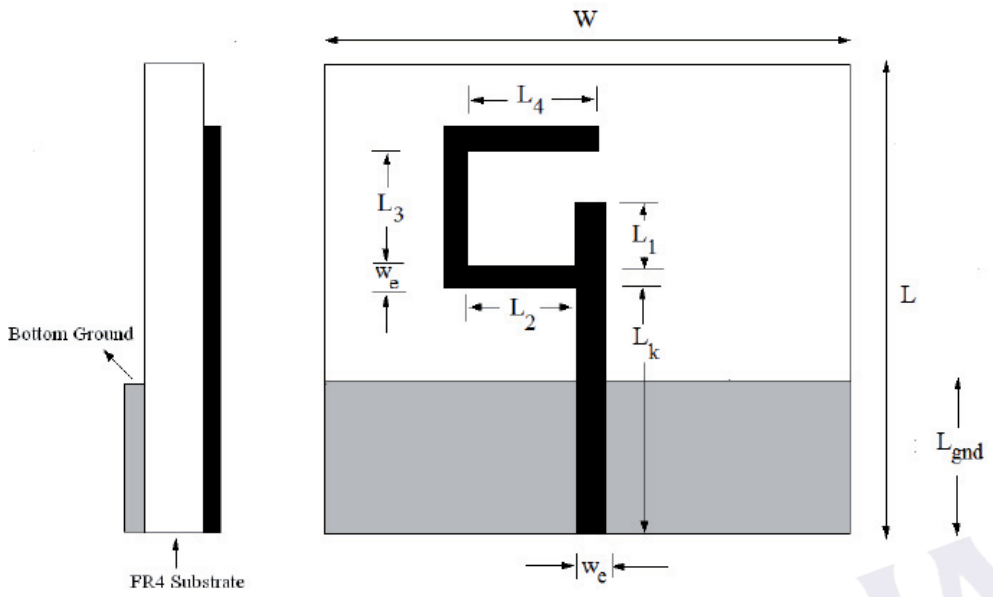


Fig. 2.2: Geometry of the proposed antenna.

W. -C. Liu and Y. -L. Chen (2011)

The researches proposed a simple printed strip-monopole antenna suitable for wireless universal serial bus (USB) dongle application. The proposed antenna, comprising a folded-strip radiator and a rectangle ground, has a compact size of only 10 × 37 mm^2 and is capable of generating two resonances of 270 MHz (2.25–2.52 GHz) and 840 MHz (5.02–5.86 GHz) simultaneously covering the 2.4/5.2/5.8 GHz WLAN operating bands with good impedance matching conditions [4].

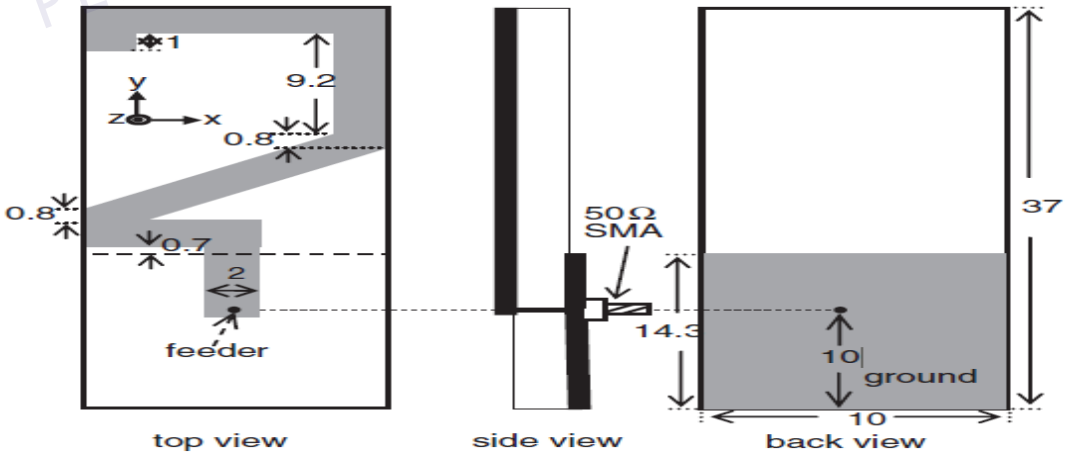


Figure 2.3: Geometry of proposed monopole antenna for WLAN-band USB dongle application (units: mm).

Yong-Ling Ban, Jin-Hua Chen, Si-Cheng Sun, Joshua Le-Wei Li and Jin-Hong Guo (2012)

In this work, a new planar printed ultra wideband antenna for wireless USB dongle eight-band 698–960 MHz and 1710–2690 MHz has been proposed to cover the bands LTE/GSM/UMTS based on the simulation and experimental studies. The presented antenna, occupying a compact size of 19 mm × 20 mm, embodies a rectangular patch and a long parasitic strip, which are directly printed on the top of the employed FR4 substrate. Over 54% radiation efficiency with 1.8 dBi antenna gain is obtained from the measured results [5].

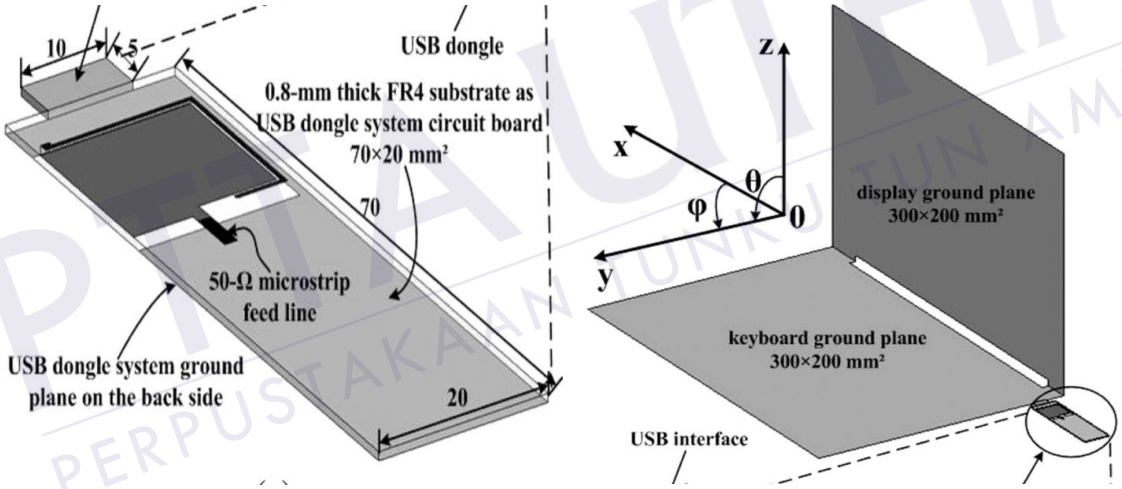


Figure 2.4: Geometry of the proposed antenna for wireless USB dongle applications.

Table 2.2 summarizes some of the prior work on monopole antennas for USB dongle in many frequency bands such as WLAN, WiMAX and cellular bands (GSM, PCS, DCS, and UMTS).

Table 2.2: summarizes some of the prior work on monopole antennas

Prior Work	Antenna Volume	Bands Supported	Peak Gain (dBi)
Wideband Internal Monopole Antenna for Wireless USB Dongle Application [2]	45 mm × 15 mm × 1 mm	WiBro, 2.3-2.4 GHz WLAN, 2.4-2.485 GHz and 5.15-5.825 GHz WiMAX, 2.5-2.7 GHz S-DMB, 2.605-2.655 GHz	5.63 dBi and 5.89 dBi
A Compact Printed Monopole Antenna for Dual-band RFID and WLAN Applications [3]	30 mm × 38 mm	2.45/5.2 GHz WLAN and RFID bands	2.76 dBi and 3.29 dBi for the lower and upper bands, respectively.
Compact strip-monopole antenna for WLAN-band USB dongle application [4]	10 mm × 37 mm	2.4/5.2/ 5.8 GHz WLAN bands	3.1 dBi and 5.0 dBi for the lower and upper bands, respectively.
Printed Monopole Antenna With a Long Parasitic Strip for Wireless USB Dongle LTE/GSM/UMTS Operation [5]	19 mm × 20 mm	LTE/GSM/UMTS 698–960 and 1710–2690 MHz	1.8–3.5 dBi, for the lower bands LTE700/GSM850/900 and 3.0–7.8 dBi for the upper bands DCS1800/PCS1900/UMTS2100/LTE2300/2500

PTTA UTHM PERPUSTAKAAN TUNKU TUN AMINAH

2.3 Antenna Properties

The performance of the antenna is determined by the several properties as follows:

a. Radiation Pattern

An antenna's radiation pattern is the characteristics that affect the system coverage and the performance of antenna. Radiation patterns of an antenna usually measured in the far field regions from the antenna. It is presented in 3D-polar diagram or graph for a 360° angular pattern in one of two sweep planes and presented on a relative power dB scale [6]. The graph plotting gives a result for field strength of power densities at various angular positions relative to the antenna. It also shows the intensity of radiation from a transmitting antenna or the response of a receiving antenna. The radiation pattern also describes the direction of the energy that radiates or receives. Normally, all antennas do not radiate totally its energy than is delivered to their input connector.

A radiation pattern plot for a generic directional antenna is shown in figure 2.5. This figure illustrate the main lobe, which includes the direction of maximum radiation, a back lobe of radiation opposite the main lobe, and sides lobes separated by nulls where no radiation occurs. For omnidirectional antenna, the radiation pattern is constant in the horizontal plane but may vary vertically. It is seen that this pattern is nondirectional in the azimuth plane [f (ϕ), $\Theta=\pi/2$] and directional in the elevation plane [g (Θ), ϕ = constant]. An omnidirectional antenna is a special type of a directional pattern [7].

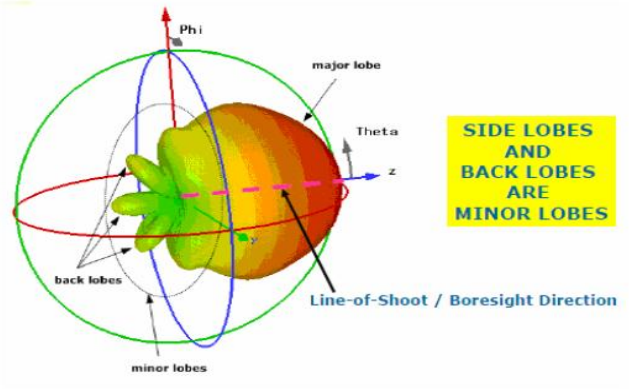


Figure 2.5: Generic directional antenna

b. Bandwidth

The bandwidth of an antenna expresses its ability to operate over a wide frequency range [8]. Bandwidth also defines the range over which the power gain is maintained within 3 dB of its maximum value or VSWR is not greater than 2:1. The bandwidth is also presented in the form of percentage of the nominal operating or center frequency. To ensure the antenna is in a good performance, the VSWR should be less or equal 2 (VSWR≤ 2) with return loss more or equal than -10dB (RL≥-10dB). The designed antenna must satisfy the bandwidth requirements for the wireless system. There are two fundamental bandwidth criteria the antenna must typically meet the impedance bandwidth (return loss bandwidth) and the gain bandwidth. There are no universal definitions of these bandwidths that apply to every wireless system, but typically the return loss bandwidth is the frequency range in which the return loss is better than −10dB, which means that less than 10% of the power is reflected into the RF circuitry.

c. Beamwidth

Beamwidth is defined as the angular separation between two identical points on opposite side of the pattern maximum [9]. In antenna pattern, there are some beamwidth

which are half power or 3 dB beamwidth (HPBW) and full null Beamwidth (FNBW). Both the HPBW and FNBW are shown in figure 2.2 [10]. The most widely used is HPBW which is defined by IEEE as. In a plane containing the direction of the maximum of a beam, the angle between the two directions in which the radiation intensity is one-half value of the beam. The HPBW is simply a measure of the angular width of the -3 dB point on the antenna pattern relative to the pattern maximum. At -3 dB point, the power level is half (1/2) of the value at the pattern maximum.

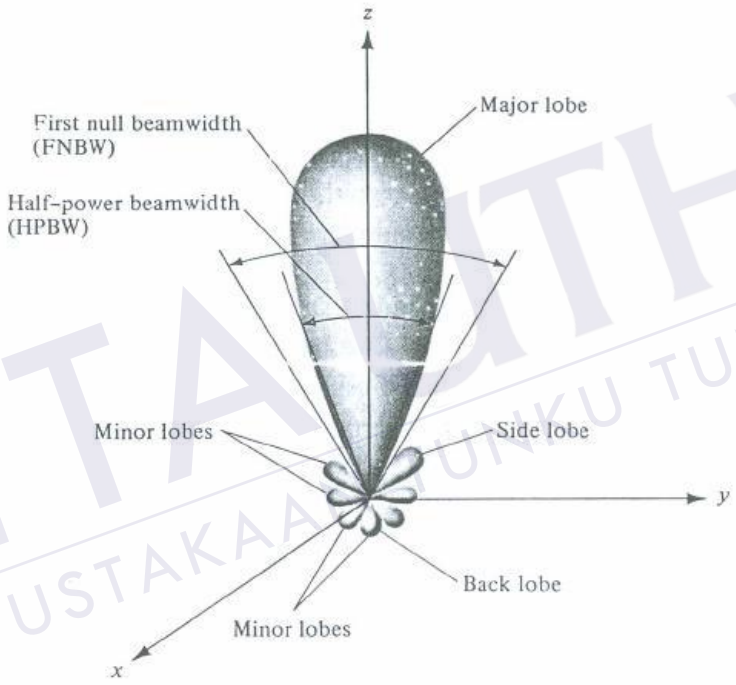


Figure 2.6: HPBW and FNBW

d. Directivity

The directivity, D of an antenna functioned as direction of an antenna. It is defined by [8] as the ratio of the radiation intensity in a given direction from the antenna to the radiation intensity averaged over all directions.

$$D(\Theta,\phi) = \frac{\text{Radiation intensity of antenna in direction } (\Theta,\phi)}{\text{Mean radiation intensity in all directions}} \quad (2.1)$$

e. Gain or Power Gain

The power gain G, or simply the gain of an antenna is defined as a ratio of its radiation intensity to that of an isotropic antenna radiating the same total power as accepted by the real antenna [8].

f. Input Impedance

Antenna impedance is a ratio of voltage over current at any point in the antenna. The ability of accept power from a source for an antenna is determined by the input impedance the antenna presents. If the input impedance of the antenna is not match with the characteristic impedance of the transmission line, a reflected wave will be generated at the antenna terminal and travel back towards the energy source. This reflection of energy results in a reduction in the overall system efficiency. This loss in efficiency will occur if the antenna is used to transmit or receive energy. If the return loss is known, the input impedance is given by

$$\text{Zin} = \text{Z}_0 \left(\frac{1+\text{S11}}{1-\text{S11}}\right) \quad (2.2)$$

g. Voltage Standing Wave Ratio (VSWR)

Voltage Standing Wave Ratio (VSWR) is defined as the ratio of the maximum voltage to the minimum voltage of a standing wave on a transmission line. Standing wave is the resultant wave or the algebraic sum of the incident wave and reflected wave at any point along the line. It is measured to see the performance of the antenna relative

PTTA UTHM PERPUSTAKAAN TUNKU TUN AMINAH

to the transmission line. Increasing in VSWR means the greater of the mismatch occur between antenna and transmission line. VSWR can be presented by:

$$\text{VSWR} = \frac{1+|\Gamma|}{1-|\Gamma|} \tag{2.3}$$

Where Γ is a reflection coefficient.

Normally, an antenna is required to operate with a VSWR better than 1.5:1 with 50 Ω impedance. Therefore an antenna VSWR should be closely to the 50 Ω of the antenna impedance. The system is perfectly matched if the VSWR equals to 1:1 where there is no power reflected and all the energy are absorbed at their input terminal.

h. Polarization

Polarization refers to the direction in space of the E-Field (electric vector) portion of the electromagnetic wave being radiated by the transmission system. Low frequency antenna is usually vertically polarized because of ground effect (reflected waves) and physical construction methods while high frequency antennas are generally horizontally polarized. Polarization may be classified as linear, circular or elliptical. If the vector that describes the electric field at a point in space as a function of time is always directed along a line, the field is said to be linear polarized. In general, when the electric field traces is an ellipse, the field is said to be elliptically polarized. Linear and circular polarizations are special cases of elliptical because they can be obtained when the ellipse becomes a straight line or a circle [6].

i. Scattering Parameter

S-parameters are a set of parameters describing the scattering and reflection of traveling waves when a network is inserted into transmission line. S-parameters are normally used to characterize high frequency network, where simple models valid at

PTTA UTHM PERPUSTAKAAN TUNKU TUN AMINAH

lower frequencies cannot be applied. For a two port network (assume the load is matched), the S parameters can be concluding as below:

S11 is the reflection coefficient of the input

S22 is the reflection coefficient of the output

S21 is the forward transmission gain

S12 is the reverse transmission gain (from output to input)

The reflection coefficient may also be established using other field or circuit quantities. The reflection coefficient is given by equation 2.4.

$$RC = \left| \frac{Z1-Z2}{Z1+Z2} \right| = \frac{SWR-1}{SWR+1} \quad (2.4)$$

Where Z1 is the impedance toward the source, Z2 is the impedance toward the load, the vertical bars designate absolute magnitude, and SWR is the standing wave ratio.

2.4 Monopole antenna as a Printed Antenna

There are two types of antenna which are active and passive. Passive antenna is a reciprocal device, meaning that it can be either transmitter or receiver. Active antenna is non-reciprocal device. Printed antenna is one of the passive antennas. This type of antenna has patch and printed slot antenna. Printed antenna also known as microstrip antenna. This type of antenna has a variety of beneficial properties including mechanical durability, conformability, compactness and cheap manufacturing costs. Printed antenna is a simpler antenna. Since it is printed on a substrate and it is easy to integrate it with microstrip circuits which are printed on the same substrate.

PTTA UTHM PERPUSTAKAAN TUNKU TUN AMINAH

2.4.1 Basic Characteristics of Printed Antenna

From figure 2.7, the printed antenna consists of a pair of parallel conducting layers separating with a dielectric medium. The dielectric medium refers to a substrate used in the design. As shown in figure 2.3, the upper conducting layer or patch functioned as a source of radiation where electromagnetic energy fringes off the edges of the patch and into the substrate. The lower conducting layer functions as a perfectly reflecting ground plane, bouncing energy back through the substrate and into free space.

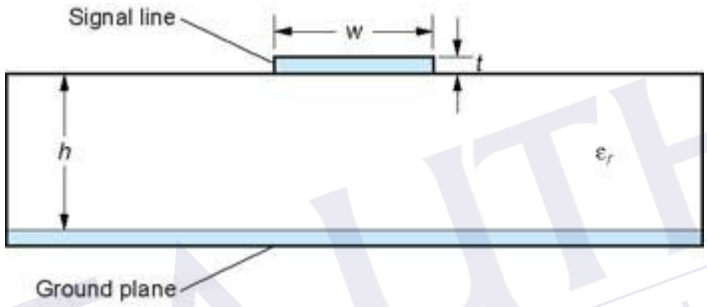


Figure 2.7: Geometry of a printed antenna feeding methods

2.4.2 Substrate

Substrate used in fabricating process in designing the antenna must consist of dielectric. Normally, the dielectric constant is considered when choosing the best material of substrate. In the normal course of fabricating dielectric substrate for microwave integrated circuits (MICs), a dielectric filled resonator cavity is automatically constructed. For a rectangular substrate with its top and bottom surface metallization but its side is not metallized becomes a parallel plate dielectric loaded waveguide resonator. As shown in figure 2.4, h is referring to the thickness of the substrate, W is the width and L is the length of the substrate [10].

PTTA UTHM PERPUSTAKAAN TUNKU TUN AMINAH

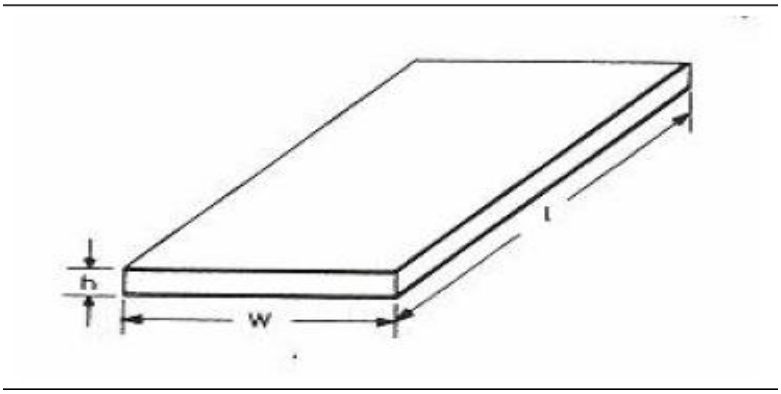
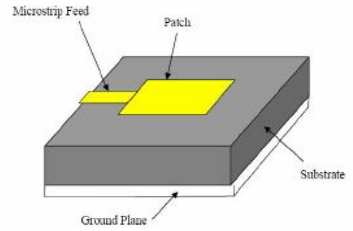
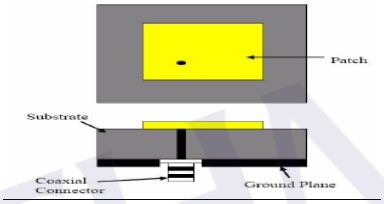
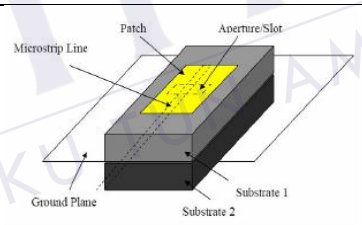
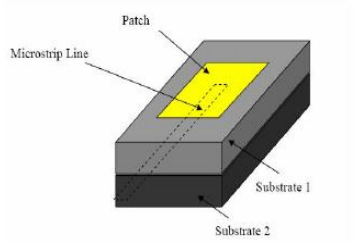


Figure 2.8: The substrate

2.4.3 Feeding Methods

Feeding methods are important in designing the antenna. It is to make sure the antenna structure can operate at full power of transmission. Printed antennas can be fed by a variety of methods as shown in table 2.3 [6]. There are two categories classified the feeding technique which are contacting and non-contacting. In the contacting method, the RF power is fed directly to the radiating element using a connecting element such as a microstrip line. In the non-contacting scheme, electromagnetic field coupling is done to transfer power between the microstrip line and the radiating element. The most popular feed techniques used are the microstrip transmission line, coaxial probe, aperture coupling and proximity coupling. The simplest feeding methods are microstrip transmission line and coaxial probe. Both approaches utilize direct contact with the radiator.

Table 2.3: Feeding methods

Feeding techniques	Types	Figuer
Contacting	Microstrip transmission line	
	Coaxial probe	
Non-contacting	Aperture coupling	
	Proximity coupling	

PTTA UTHM PERPUSTAKAAN TUNKU TUN AMINAH

2.4.4 Advantages and Disadvantages Of Monopole Antennas

Monopole is a special case of a wire antenna. All the other types of wire antennas can be considered as a general structure of wire antennas in this paragraph. Monopole antennas are used in several applications that general structure of wire antennas can be used also. Monopoles have several advantages and disadvantages compared to general wire antennas. The fundamental advantages and disadvantages of using monopole antennas compared to wire antennas are displayed below.

- **Advantages**

1. Compact size.
2. Low fabrication cost and simple to manufacture.
3. Omni-directional radiation pattern, which allows it to transmit and receive in 360 degrees.
4. Circular polarization.
5. Desired impedance level.
6. Great bandwidth (using optimum values of loads).
7. Resonant antenna.

- **Disadvantages**

1. Narrow operational bandwidth.
2. Significant losses in power gain, at high frequencies [11].

PTTA UTHM PERPUSTAKAAN TUNKU TUN AMINAH

2.5 Chapter Summary

Planar monopole antenna is very useful in wireless communication systems. The advantages of the monopole antenna make it reliable to be use in the communication systems. This chapter described about the antenna properties and also previous related works to this project.

PTTA UTHM
PERPUSTAKAAN TUNKU TUN AMINAH

CHAPTER3

METHODOLOGY

In this design, printed monopole antenna has been chosen. Upon frequency selection, mathematical computation and understating of formulation needed to design a monopole simulation.

In this design, CST simulator will be used to perform the simulation and to get the best return loss. After that, the performance of the antenna will be determined based on the gain obtained by the radiation pattern to evaluate the performance. Finally, the antenna will be fabricated and tested using a network analyzer.

PTTA UTHM PERPUSTAKAAN TUNKU TUN AMINAH

3.1 Project Flow Chart

The project flow chart is shown in figure 3.1.

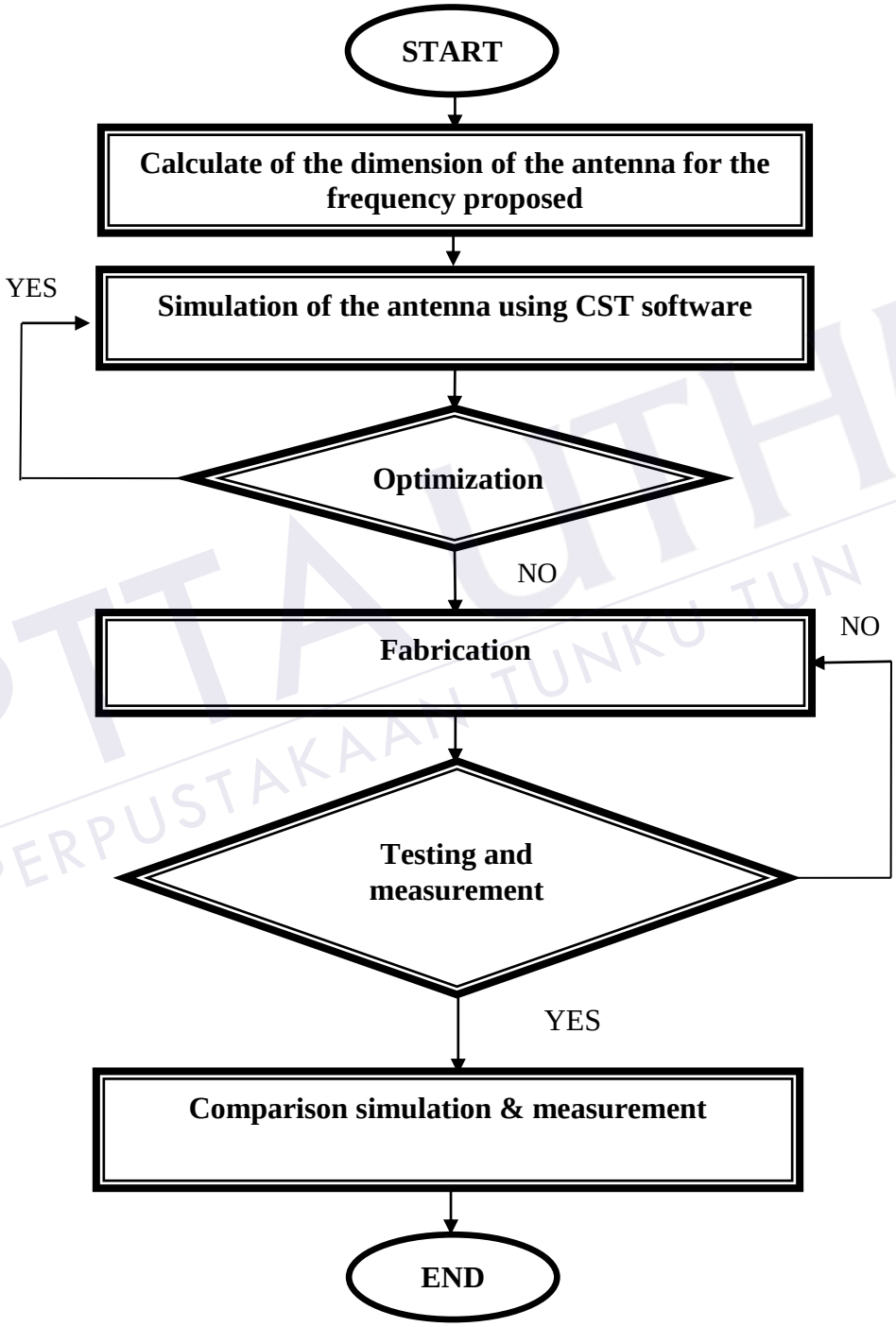


Figure 3.1: Flowchart of work progress

PTTA UTHM PERPUSTAKAAN TUNKU TUN AMINAH

3.2 Antenna Design

The design of the antenna is shown in Figure 3.2. The figure shows a specific designed for a multiband printed monopole antenna including a structure of the substrate, radiating element and the ground. The antenna is etched on the grounded FR4 substrate of dielectric constant, ε_r = 4.3 and substrate thickness h = 1.6 mm. A 50 Ω transmission line is used as a feeder to the antenna. The multiband operation (0.92 GHz, 1.9 GHz) of the antenna is obtained from the resonant structure. The dimension of radiating plate is $20 \times 19.3\ mm^2$. This dimension is obtained close to a quarter wavelengths at 0.92 GHz. The ground of the antenna is chosen to be two plates coplanar with a dimension $23\times 10.65\ mm^2$ for each plate. The dimensions of the antenna are optimized using the simulation software of CST Microwave Studio and prototype of the printed antenna is fabricated and tested.

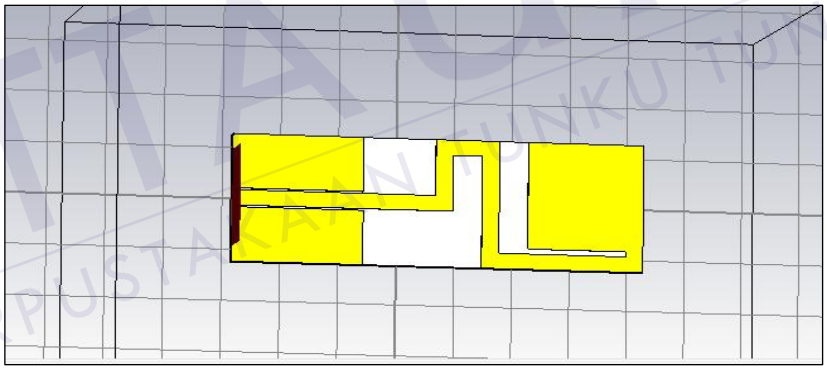


Figure 3.2: The proposed antenna

3.3 Design Process

The project begins with the understanding of the printed multiband monopole antenna. The characteristics of the antenna have been studied to understand the performance of an antenna. The studies related to the impedance, Voltage Standing Wave Ratio (VSWR), gain, radiation pattern, beamwidth, bandwidth and directivity of the antenna.

The development of the antenna can be summarized in four steps as follows:

PTTA UTHM PERPUSTAKAAN TUNKU TUN AMINAH

REFERENCES

1. M. Khan, “Some multiband compact and cost effective antennas for mobile communication applications”, Southern Illinois University Carbondale, 2006.

2. D. Kim, U. Kim, L. Choi, “Design of a wideband internal monopole antenna for wireless USB dongle application”, Microwave Conference Proceedings (APMC), Asia-Pacific, pp. 231-234, 2010.

3. W. -C. Liu and Y. -L. Chen, “Compact strip-monopole antenna for WLAN-band USB dongle application”, Electronics Letters, vol. 47, no. 8, pp. 479-480, 2011.

4. P. Li, Z. Nie, X. Zong, J. Ouyang and Y. O. Ban, “A compact internal folded monopole for GSM/UMTS/LTE in the USB Dongle”, Cross Strait Quad-Regional Radio Science and Wireless Technology Conference (CSQRWC), vol. 2, pp. 926-928, 2011.

5. Y. -L. Ban, J. -H. Chen, S. -C. Sun, J. -W. Li and J. -H. Guo, “Printed monopole antenna with a long parasitic strip for wireless USB dongle LTE/GSM/UMTS operation”, IEEE Antennas and Wireless Propagation Letters, vol. 11, pp. 767-770, 2012.

6. C. A. Balanis, “Antenna theory: Analysis and design”, 2nd. ed, JohnWiley & Sons Inc., New York, 1997.

7. S. R. Saunders, “Antennas and propagation for wireless communication systems”, John Wiley & Sons Ltd., 1999.

PTTA UTHM PERPUSTAKAAN TUNKU TUN AMINAH

8. C. A. Balanis, “Antenna theory: Analysis and design”, 3rd. ed., John Wiley & Sons Inc., 2005.

9. A. Jaafar, “Sierpinski gasket patch and monopole fractal antenna”, Master Thesis, Universiti Teknologi Malaysia, 2005.

10. N. Abdullah, “Microstrip sierpinski carpet antenna design”, Master Thesis, Universiti Teknologi Malaysia, 2005.

11. Bynikolaos, H. Vardalahos, “Investigation of loaded monopole antenna”, University of Leeds, 2000.

PTTA UTHM
PERPUSTAKAAN TUNKU TUN AMINAH