PRINTED ELLIPTICALLY POLARIZED STAR DIPOLE ANTENNA

MUHAMMAD HAZIQ BIN AB MUTALIB

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PRINTED ELLIPTICALLY POLARIZED STAR DIPOLE ANTENNA

by

MUHAMMAD HAZIQ BIN AB MUTALIB

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATION

3D	Three dimensional
5G	fifth generation
CST	Computer Simulation Technology Studio Suite
dB	Decibel
GHz	GigaHertz
GND	Ground
MHz	MegaHertz
MIMO	Multiple-input multiple-output
PCB	Printed circuit board
RFID	Radio Frequency Identification
S-PARAMETER	Scaterring Parameter
SMA	Sub-Miniature version A
UHF	Ultra-high frequency
VNA	Virtual Network Analyzer

LIST OF SYMBOLS

$\boldsymbol{\Gamma}$	reflection coefficient
$\boldsymbol{\gamma}$	transmission coefficient
V	voltage
$\boldsymbol{w}$	width of the dipole arm
$\boldsymbol{l}$	length of the dipole arm
$\boldsymbol{h}$	thickness of substrate
$\boldsymbol{E}$	Electric-field
$\boldsymbol{S_{11}}$	Return loss at Port 1
$\boldsymbol{S_{22}}$	Return loss at Port 2
$\boldsymbol{S_{12}}$	Isolation loss from port 1 to port 2
$\boldsymbol{S_{21}}$	Isolation loss from port 2 to port 1
$\boldsymbol{G}$	Gain
$\boldsymbol{e_t}$	Total efficiency
$\boldsymbol{D}$	Directivity
Φ	Phase shift
$\boldsymbol{t}$	thickness of the copper
$\boldsymbol{t_p}$	thickness of the port

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ABSTRACT

The increases usage of mobile phone has led to a higher demand on capacity and bandwidth of a communication system. The latest development of mobile phones has required a huge amount of data transmission over communication system. By employing dual polarization multiple-in multiple-out (MIMO) method, it able to improve and offer high capacity and bandwidth to meet this huge demand. Crossed dipole antenna or known as STAR dipole antenna which can produce elliptical polarisation was formed where it is able to improve the orthogonality that required for MIMO multiplexing, thus it will improve the multiplexing gain over dual linear polarisation. In previous research, dual elliptically polarised antenna prototype was designed by using copper wire but the prototype is suitable for demonstration purpose as the design was too large and the results was unable to be the same as the first design because of the wire specification. This work therefore aims to design STAR dipole antenna with frequency 2.4GHz in CST software to form elliptical polarisation and print the antenna design onto substrate and make it planar structure as it easy to manufactured and more accurate. As the S-parameter, gain and radiation pattern was characterized, the results concluded that the original STAR dipole antenna had a slightly higher gain than the printed STAR dipole antenna but radiation pattern for both printed and original STAR dipole antenna still quite similar therefore it can be used as substitute to the original antenna.

POLARISASI ELIPS BINTANG DWIKUTUB ANTENNA BERCETAK

ABSTRAK

Peningkatan penggunaan telefon pintar telah menyebabkan permintaan yang besar dalam kapasiti dan jalur lebar sistem komunikasi. Perkembangan telefon pintar terkini memerlukan jumlah besar dalam penghantaran data melalui sistem komunikasi. Dengan menggunakan kaedah dwi-polarisasi kemasukan dan kekeluaran berganda (MIMO), ia dapat meningkatkan dan menawarkan kapasiti dan jalur lebar yang tinggi untuk memenuhi permintaan besar ini. Antena dwikutub bersilang ataupun dikenali sebagai antena bintang dwikutub yang boleh menghasilkan polarisasi elips dibentuk di mana ia dapat meningkatkan ortogonal yang diperlukan untuk pemultipleks MIMO, sehingga akan meningkatkan hasil keuntungan multipleks berbanding polarisasi dua linear. Dalam penyelidikan terdahulu, prototaip antena berpolarisasi dua elips telah direka dengan menggunakan dawai tembaga tetapi prototaip ini sesuai untuk tujuan demonstrasi kerana reka bentuk terlalu besar dan hasilnya tidak akan sama dengan reka bentuk pertama kerana spesifikasi wayar tembaga. Oleh itu, kerja ini bertujuan untuk merekabentuk antena bintang dwikutub dengan frekuensi 2.4GHz dalam perisian CST untuk membentuk polarisasi elips dan mencetak reka bentuk antena ke substrat dan menjadikannya struktur planar kerana ia mudah dibuat dan lebih tepat. Oleh kerana S-parameter, keuntungan dan corak radiasi telah dicirikan, hasilnya menyimpulkan bahawa antena bintang dwikutub asal mempunyai keuntungan yang lebih tinggi daripada antena bintang dwikutub bercetak tetapi corak sinaran untuk antena bintang dwikutub bercetak dan asal masih agak sama, dengan itu boleh digunakan sebagai pengganti antena asal.

CHAPTER 1

INTRODUCTION

1.1 Research Background

The increased usage of mobile phones for the past decade has led to a higher demand on the capacity and bandwidth of a communication system. Online video streaming, online gaming and 4K video transmission are examples of the latest trend that requires a huge amount of data transmission over a communication system. Researchers have been studying on how to improve and significantly offer higher capacity and bandwidth to meet this huge demand. One of the method used is to employ dual polarization MIMO multiplexing method in order to achieve high capacity data transmission and bandwidth.

There are three main types of polarisation: elliptical, linear and circular polarisation. For any electromagnetic wave, the locus of its electric-field is an ellipse and therefore, it is an elliptically polarised wave. The ellipse can theoretically form either a straight line or circular locus. In these conditions, the polarisation state is linear or circular, respectively. A wave then inherently exhibits elliptical polarisation if it is not modified to become linear or circular polarisation and hence has an elliptical locus.

Most of the previous literatures focused on the linear or circular polarization issue. Little attention has been given to the elliptically polarized waves as they have always been deemed as unwanted polarisation, although in practice, any antenna is elliptically polarised as it can never be perfectly circularly or linearly polarised. However, one study was carried out previously to investigate the advantage of using elliptical polarisation and thus improving orthogonality required for MIMO multiplexing [1]. Results concluded that at short distances with low scattering in the MIMO channel and directional antennas, elliptically polarized antennas provide improved multiplexing gain over dual linear polarizations.

1.2 Problem Statements

The increasing usage of smart phones and mobile devices have demand for high bandwidth and capacity in wireless links in recent years. In 2015, global mobile devices and connections grew to 7.9 billion, up from 7.3 billion in 2014 and it have exceeded the world population [2]. As a result, these demands have led to the massive growth of mobile data traffic. Dual polarization MIMO multiplexing method can be employed in order to achieve high capacity data transmission and bandwidth. One of the previous study in the literature has investigated the feasibility of utilizing dual elliptical polarization as an alternative MIMO polarization multiplexing method. Results concluded that elliptically polarized antennas are able to provide improved multiplexing gain over dual linear polarizations. The generated dual elliptical polarization improved the orthogonality of the MIMO channels and reduce the interference between the channels, thus increasing the much demand higher capacity and bandwidth in the 5G communication.

In previous research, an elliptically polarized STAR dipole was fabricated by using a copper wire which was suitable for demonstration purposes in showing the ability of elliptical polarisation to form polarization multiplexing as show in Figure 1.1 [1]. The design antenna was too large to put inside the portable device thus it will disturb the other device inside the portable device. Moreover, the height of the wire was too long which it will disturb the device performance and the copper wire was not having a specific value to make another antenna with the same size and this cause the result would not having the same as the first antenna.

In this project, the STAR dipole is re-designed such that it can be printed on a substrate, making it a planar form which would then be more accurate and easier to be manufactured and re-produced. Plus, the size of the printed STAR dipole is smaller than the original STAR dipole so that it can be put inside the portable device without bothering the other device. Moreover, the printed STAR dipole can be produce a lot as it has design specification to follow. A printed dual elliptically polarized STAR dipole antenna prototype was designed and fabricated in this work with an operating frequency at 2.4 GHz.

(a) original STAR dipole arm

(b) Side view of original STAR dipole

Figure 1. 1 : The fabricated wire of the STAR dipole antenna *[1]*

1.3 Objective of Research

The objectives of the project are listed as follow:

- To design, simulate and optimize printed elliptically polarized STAR dipole antenna at frequency 2.4GHz using CST design software
- To fabricate planar STAR dipole antenna
- To characterize the S-parameter, gain and radiation pattern result of the printed STAR dipole antenna

1.4 Scope of Research

In this project, the STAR dipole antenna will be printed onto a substrate and make it planar structure. The design of the antenna will be optimised using CST simulation software. Then, the s-parameters of the STAR dipole antenna is measured. The design then will be fabricated after the simulation is completed whereby the antenna will be printed onto a substrate upon design optimization to achieve a compact design. After completed the fabrication process, the S-parameter, gain and radiation pattern result of the printed STAR dipole antenna will be characterized.

1.5 Thesis Outline

This project is discussed in details in this thesis. It describes and explained in five main chapters. The introduction is the first chapter that covers the overview of the project, problem statements, objective, scope of research and outline of the report.

In chapter 2, literature review is deliberated in details. Firstly, the basic background of the elliptical polarisation which is how the elliptical polarisation are happen will be discussed. Moreover, s-parameter is discussed more in details with the some explained about the port inside the s-parameter that includes about return loss and insertion loss.

Methodology lies on chapter 3 as it will reveal the method implemented to carry out the project. The overall design flow is unfolded. The development of the design in term of software used in this project is shown as well.

In chapter 4, the simulation results of the S-parameter obtained from CST software and measured results from visual network analyser (VNA) have been showed with further explanation about simulated and measured S-parameter. Results obtained are measured by referring on magnitudes of S-parameter and reflection coefficient. The results obtained are then been discussed and analysed thoroughly.

Lastly, chapter 5 show the conclusion of the study of the project. Some recommendations were proposed for future works in order to improvise the performance of the proposed design.

CHAPTER 2

LITERATURE REVIEW

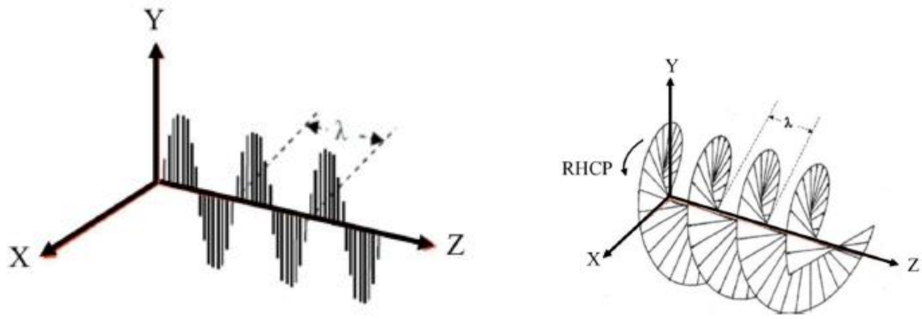
2.1 Introduction

This chapter will discuss more about the previous research that related to the crossed dipole antenna which could be found in many journals and books. The chapter begins with a basic of dipole antenna, forming crossed dipole antenna and from crossed dipole to the STAR dipole antenna.

This chapter also discuss about the background on how the elliptical polarisation happen, details on S-parameter which include return loss and insertion loss, and further details about radiation pattern.

2.2 Background to elliptical polarisation

Wave polarisation is defined as the shaped and locus of the tip of the Electrical field, *E* vector at a given point in space as a function of time [3]. The time dependent electric field plane is orthogonal to the direction of propagation. The locus of *E* is an ellipse and the wave are elliptically polarised in any practical situation. However, the ellipse, may form a circular locus or simply a single straight line in a theoretically ideal case. In these conditions, the polarisation state is linear or circular, respectively, where the two cases are illustrated in Figure 2.3. In the linear case, the polarisation is vertical and so the locus is parallel with the x axis while in circular case, a circular locus is made normal to the direction of propagation. The electric field components, E_x and E_y are 90^o phase difference with equal in magnitude in circular polarisation, while in linear polarisation, only one of the electric field components has a certain value and the other is equal to zero [1].



(a) **(b)**

Figure 2. 1:an example illustration of Linear and Circular Polarisation (a) Vertical polarisation (b) Right circular polarisation *[4]*

The history of elliptically polarized antennas studies began in the 1950s [5]. In [6], to calculate the power received when an elliptically polarized antenna intercepts an elliptically polarized wave of different polarization, the theorem of reciprocity was presented. In terms of the distant field, the calculations were made that would be produced by the antenna when radiating a known power. Another publication discussed the concept of equivalent length of an antenna, which is when used for reception, the length of a vector whose scalar product with the electric vector of an incident plane wave gives the open-circuit voltage at the terminals of the antenna. This concept become complex but is able to be adapted to antennas radiating and receiving elliptically polarised waves when used appropriately [7].

To propagate an elliptically polarized electromagnetic wave it is necessary to launch an electromagnetic wave which is plane polarized in one direction simultaneously with a wave, plane polarized in a direction normal to the polarization of the first wave. Various devices exist for launching such waves with the proper direction such, for example, as the dipole for propagating electromagnetic waves with polarization parallel to the axis of an antenna and the slot for propagating electromagnetic waves of polarization normal to the axis of an antenna. If the two waves are launched from two different points in space, there is a good probability that the ellipticity of the resultant wave will not be uniform throughout the propagation pattern, in other words the axial ratio of ellipticity (the ratio of the major to the minor axis of the ellipse) may be of an acceptably low value only within certain Small solid angles subtended from the antenna [8].

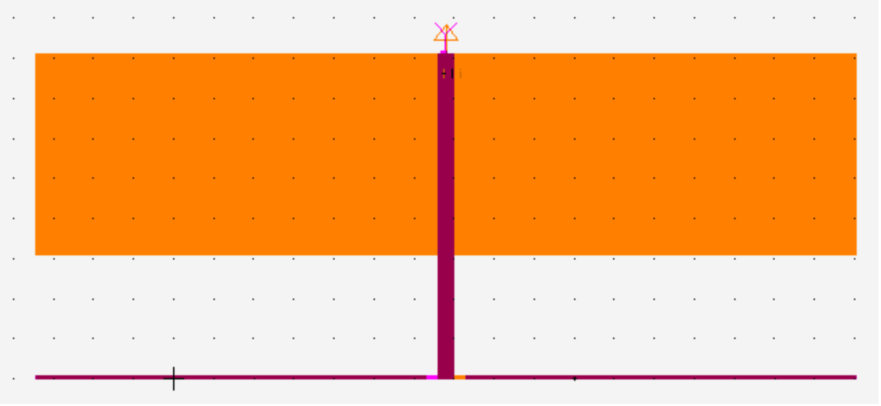
2.3 Dipole antenna

A dipole antenna is a practical linear wire antenna which has two conducting wires. It is fed at the centre of both the wires. The important variations of dipole antenna are the half wave dipole, monopole and short dipole [9] but a very commonly used antenna is the half wave dipole with a length of the free space wavelength radiated wave [10]. It can be constructed either using rod, printed or wire. As the project need to fabricate the design of the dipole antenna, then when printed, the dipole arm shapes will not be exactly as constructed and it can be differ according to the requirement of the design, instead of the normal rectangular patch [11], for instance, trapezoidal dipole is introduced in [12], square loop dipole arms for coupling improvement [13] and arc-shaped dipole arms [14].

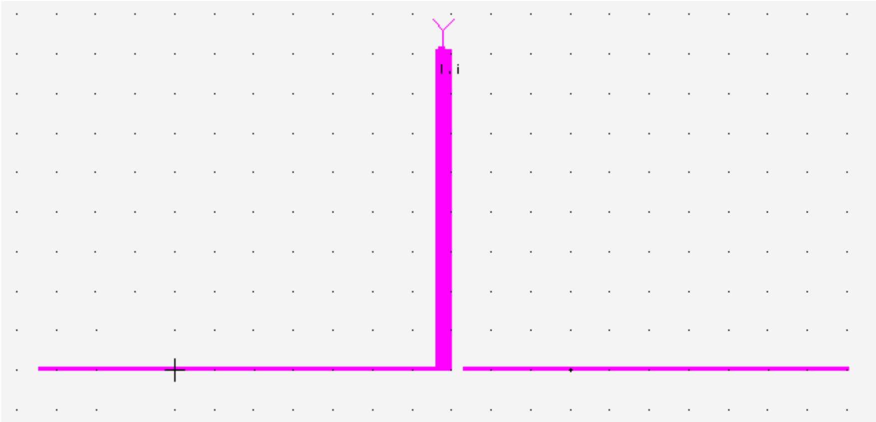
This dipole antenna can produce dual polarization execution and it go wide bandwidth, easily integrated into circuits, good radiation device characteristic, and able to be extended to from an array. In edict to perform dual polarization mathematical operation, two pairs of dipole which is horizontal dipole and vertical dipole are combined and placed orthogonally to each other to create a crossed dipole figure. But, one cannot depend solely on the aim of dipole antenna as it having the advantage of a wider bandwidth than patch antenna. To fulfil the wide bandwidth criteria, enhancements to the design need to be added [1].

2.3.1 Printed dipole antenna

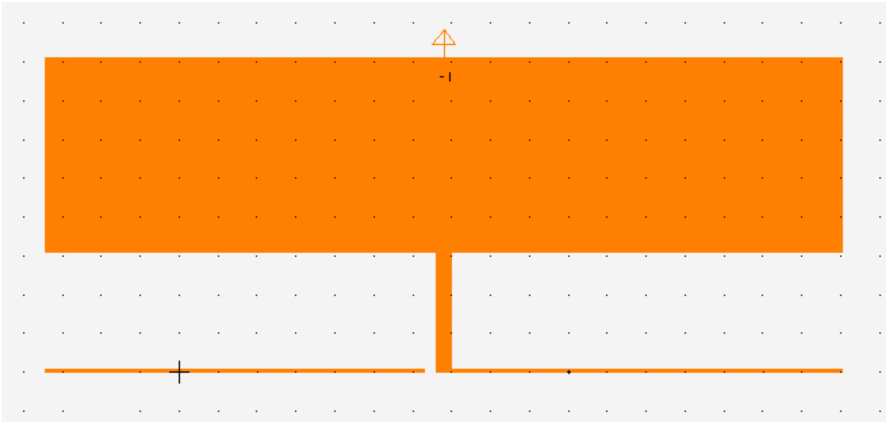
Printed antennas are very popular because of their ease of fabrication. If the antenna is to be implemented on the same PCB as the circuitry, practically no additional costs arise. For a system where an isotropic pattern is required, as for example in a portable device, a dipole is a good and easy approach. To get a good performance out of a dipole, one likes to design it as resonant dipole. This requires the dipole to be slightly less than half a wavelength long. A good guess is 0.47 times the wavelength [15].



(a) Top view dipole, all layers



(b) Top view dipole, top layer



(c) Top view dipole, bottom layer

Figure 2. 2 Printed dipole model *[15]*

2.4.1 Crossed dipole antenna

An array of Slant 45. degree polarized radiating elements is constructed using a linear or planar array of crossed dipoles located above a ground plane. A crossed dipole is a pair of dipoles whose centers are co-located and whose axes are (in general) orthogonal. The axes of the dipoles are arranged such that they are parallel with the polarization sense required. In other words, the axis of each of the dipoles is positioned at Some angle with respect to the vertical axis of the antenna array [16].

Crossed dipole antenna with planar and lightweight that exhibits cross polarisation radiation and broad bandwidth at the Ultra High Frequency Radio Frequency Identification (UHF RFID) band. The antenna is printed on both sides of a thin substrate with low density to achieve a light weight. The feeding structure used in the proposed design is based on the 90° phase delay line of a vacant-quarter printed ring. The design uses two techniques to reduce the size, namely, the use of printed inductors and the barbed shape at the end of the dipole arms [17].

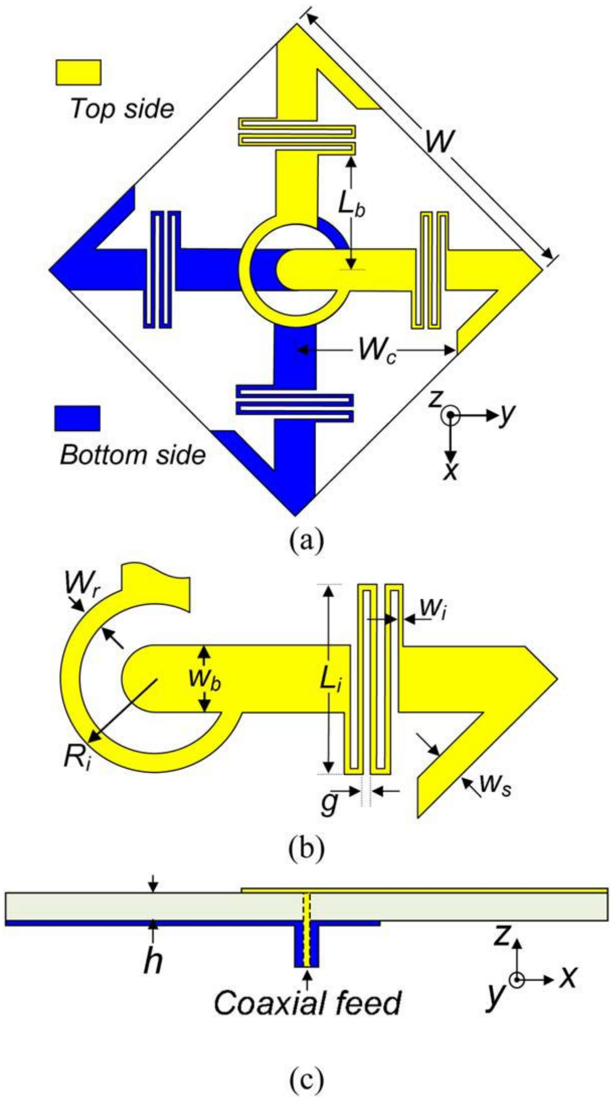


Figure 2. 3: Planar crossed barbed dipole. (a) Top view (b) Expanded view of the dipole arm with vacant quarter printed ring (c) Side view *[17]*

A higher possibility to build two orthogonal elliptically polarized antenna can be made by deliberately creating cross polarisation between their linear components, whereas in a circular case the cross polarisation is expected to be negligible. Therefore, the design aims to make a consistent cross polarization between two antennas that will enable the possibility to form orthogonal ellipses based in the phasing applied to the linear element.

The design is based on two dipole antennas which is one vertical and one horizontal. The dipole is spaced apart at a distance but as they consume unnecessary space particularly at lower frequencies, therefore using two antennas spaced at a distance is undesirable. For that reason, a more compact design was formed which is termed as crossed dipole with the two linear elements co-located as can be seen in Figure 2.2 [18]. However, due to the presence of the cross polarisation that been generated because of the co-located elements which are subject to cross coupling, the crossed dipole design is unable to transmit perfect dual linear polarization or circular polarization [1].

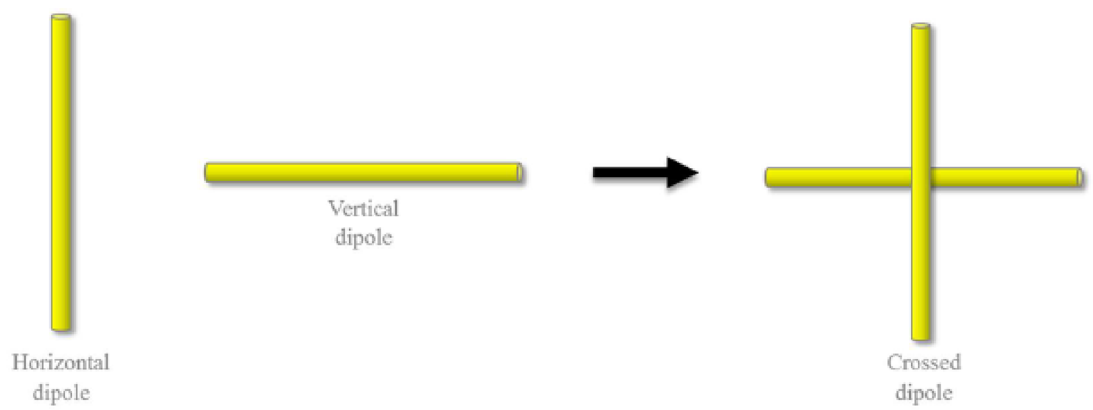


Figure 2. 4 : Step by step on building a crossed dipole *[1]*

2.4.2 STAR dipole antenna

To supress the cross polarization in a crossed dipole, the linear antenna will be reform to deliberately generate cross polarization. By reducing the four arms in a crossed dipole down to three arms to form a STAR antenna as illustrated in Figure 2.3, supressing the cross polarization is achieved thus it will subsequently make the polarization highly elliptical. The two radiating arms of the STAR dipole antenna are connected to a corresponding inner core of two separate coaxial feeds, while the third arm would be connected to a ground branch of both the coaxial feeds. Hence, there now just one ground arm to the two dipoles. The antenna looks like a star shape after re-formed, hence the name STAR dipole is given which can deliberately generate elliptical polarisation far removed from circular or linear polarization. One of the electric field components for both polarizations will be weakened and no longer will be zero when the ground arm is taken away, as in the case of linear polarization. Thus, the structure then loses its symmetry [1].

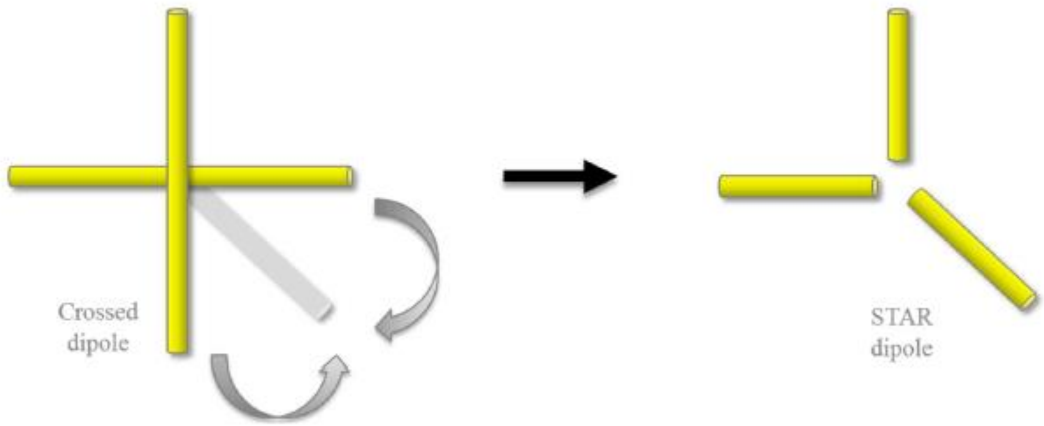


Figure 2. 5 : Forming STAR dipole from crossed polarization *[1]*

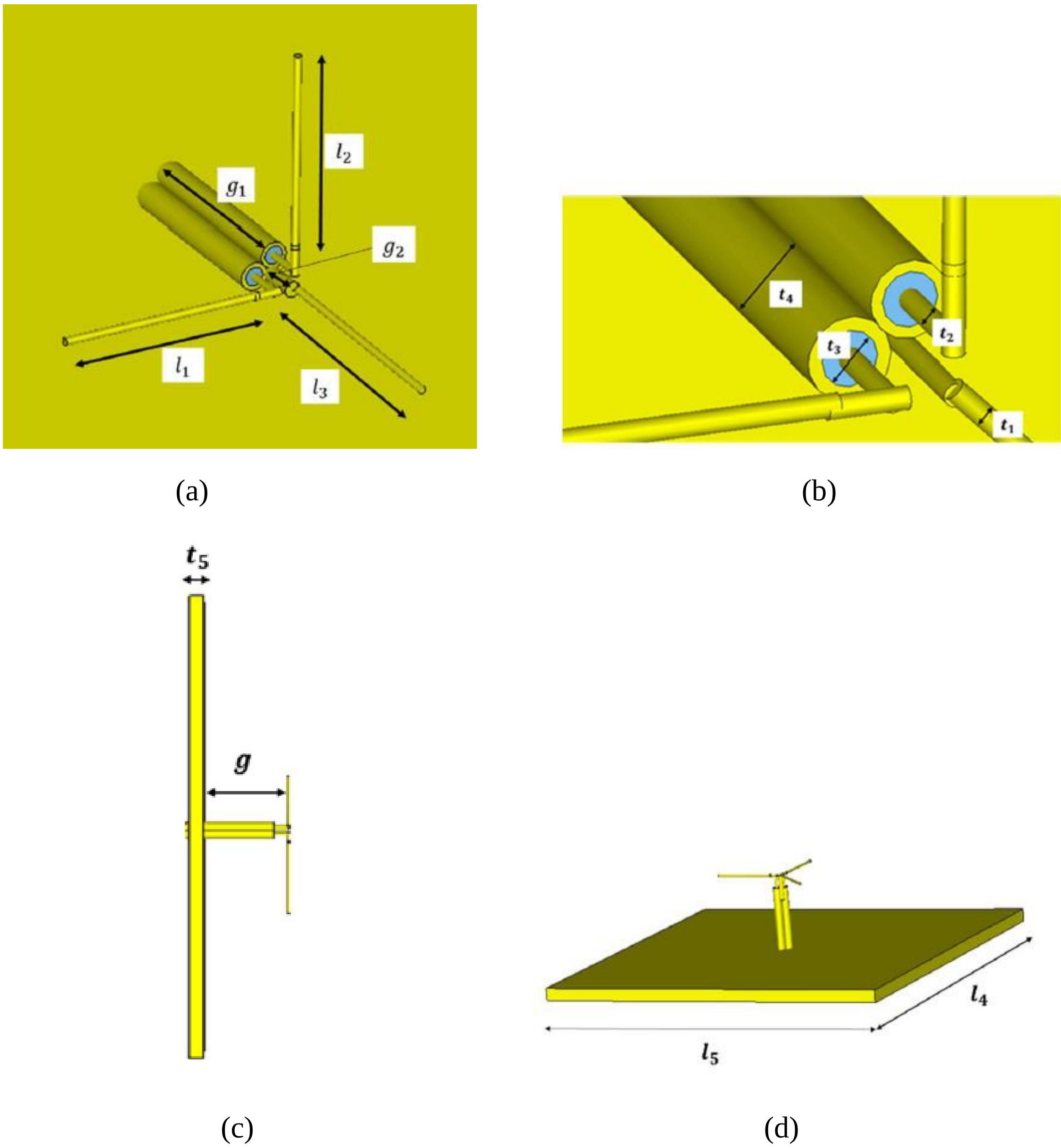


Figure 2. 6: Design of STAR Dipole antenna (a) Top View (b) Close-up view (c) Side view (d) Perspective view *[1]*

2.4 S-Parameters

Often, values that are derived from S-parameter measurements are of more concern in production testing because accurate assessment of S-parameter often requires details analysis, and as a result the measurements take more time. Values such as return loss, gain or isolation are needed [19]. There are some examples for two-ports which is transmission lines, waveguides, amplifiers and filters. For circuit, each port corresponds to a wire pair leaving the device. For devices in general, each port corresponds to an input/output interface to the device. The S-parameters for a two-port device form a 2x2 matrix as in equation 2.1,

$$S = \begin{bmatrix} S11 & S12 \\ S21 & S22 \end{bmatrix} \tag{2.1}$$

The coefficients S_{11} and S_{22} are the reflection coefficients at port 1 and port 2, respectively. The coefficients S_{12} is the transmission coefficient from port 2 to port 1 (backward gain). The coefficient S_{21} is the transmission coefficient from port 1 to port 2 (forward gain) [20].

S-parameters relate to familiar quantities, such as gain, return loss and output match. They provide insight into the component behaviour. Table 2.1 lists the four complex S-parameters and their corresponding interpretation for generic linear 2-ports. The third column expresses common amplifier quantities in terms of the corresponding S-parameters.

Table 2.1: S-parameters of a generic 2-port and the corresponding figures of merit of a two-port amplifier *[21]*

S-Parameters	Generic 2-port (with input and output ports properly terminated)	Amplifier figure of merit
S_{11}	Input reflection coefficient	Return loss: dB$\vert S_{11}\vert$
S_{12}	Reverse transmission coefficient	Isolation: db$\vert S_{12}\vert$
S_{21}	Forward transmission coefficient	Gain: dB$\vert S_{21}\vert$
S_{22}	Output reflection coefficient	Output match: db$\vert S_{22}\vert$

2.4.1 Return Loss

The reflection coefficient, Γ is a scalar reflection measurement that is directly related to S_{11} or S_{22}. From the value measured for the reflection coefficient, other meaningful parameters such as return loss can be calculated [22]. The return loss is what is returned to the incident port and lost to the transmitted signal. The return losses, S_{11} and S_{22}, are equal when the interconnect is symmetrical from on end to the other [23]. It is one of the important parameters to be measured. It means that the difference between transmitted signal power and the power signal reflection caused by matching impedance.

The reflection coefficient is defined as the magnitude of the ratio of reflected to incident voltages. The equation 2.2 and 2.3 below shows the connection of reflection coefficient in order to find the return loss:

$$\text{Reflection coefficient}(\Gamma) = \left|\frac{V_{\text{reflected}}}{V_{\text{incident}}}\right| = \left|\frac{V_1^-}{V_1^+}\right| = |S_{11}| \quad (2.2)$$

Or

$$\text{Reflection coefficient}(\Gamma) = \left|\frac{V_{\text{reflected}}}{V_{\text{incident}}}\right| = \left|\frac{V_2^-}{V_2^+}\right| = |S_{22}| \quad (2.3)$$

Return loss is simply the logarithmic representation of the reflection coefficient as in equation (2.4):

$$\text{Return loss (dB)} = -20\log(\Gamma) \quad (2.4)$$

2.4.2 Insertion Loss

Another important parameter is the insertion loss, $S_{21.}$ It is indicate that the wave transmitted from port 1 to port 2. The transmission coefficient, γ, is defined as the magnitude of the ratio of transmitted to incident voltages. The equation 2.5 and 2.6 show how the transmission coefficient are related in order to find insertion loss:

$$\gamma = \left|\frac{V_{\text{transmitted}}}{V_{\text{incident}}}\right| = \left|\frac{V_2^-}{V_1^+}\right| = |S_{21}| \quad (2.5)$$

Or

$$\gamma = \left|\frac{V_{\text{transmitted}}}{V_{\text{incident}}}\right| = \left|\frac{V_1^-}{V_2^+}\right| = |S_{12}| \quad (2.6)$$

Insertion loss is a measure of what is lost from the signal when the interconnect is “inserted” between the two ports of a network analyzer [24]. Based on the transmission coefficient, an alternative definition for insertion loss of a passive device is simply the logarithmic representation of the transmission coefficient as shown in equation 2.7:

$$\text{Insertion loss (dB)} = -20\log(\gamma) \tag{2.7}$$

2.4.3 Antenna Gain

The definition of the antenna gain is close to the antenna directivity where the directivity is a parameter related to the far field power pattern as it measures the amount of radiated energy to a specific direction, usually the maximal energy. The difference between these two parameters is that the gain takes into account the efficiency of the antenna and its directivity together, therefore the gain of a lossless antenna is equal to its gain. Hence, the gain is given by

$$G = e_t D \tag{2.8}$$

where et is the total efficiency of the antenna and D is its directivity. In many cases, the gain is provided in logarithmic units referred to an isotropic antenna in dBi [25].

As a transmitting antenna, the gain can describes on how well the antenna can converts input power into radio waves headed in a specified direction. For receiving antenna, the gain can describes how well the antenna converts radio waves arriving from a specified direction into electrical power. When no direction is specified, therefore the gain is understood to refer to the peak value of the gain. A plot of the gain as a function of direction is called radiation pattern.

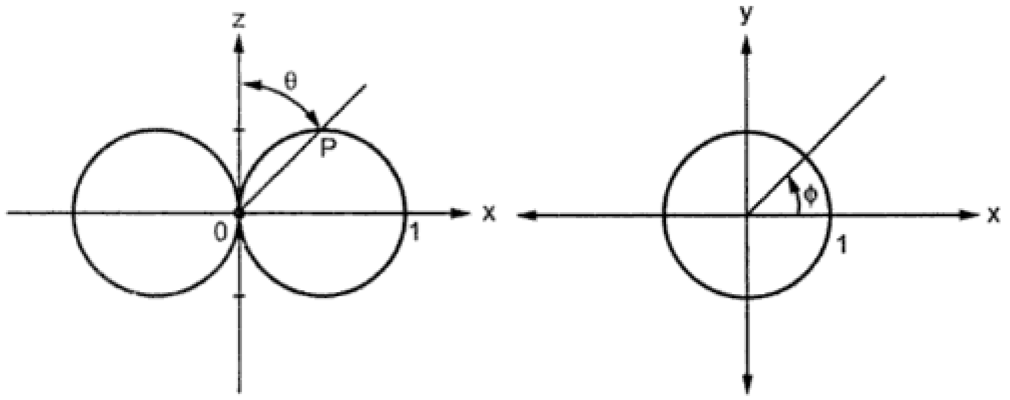
2.4.4 Radiation pattern

A radiation pattern is a graphical representation of the radiation properties of an antenna. It is determined from the calculated or measured fields radiated from the antenna [26]. Practically any antenna can not radiate energy with same strength uniformly, in all directions. The radiation is large only in one direction while the other directions is zero or minimum. The radiation from the antenna in any direction is measured in terms of field strength at a point located at a particular distance from an antenna. The field strength can be calculated by measuring voltages at two points on an electric lines of force and then dividing by distance between two points. Hence, the unit for the radiation pattern is volts per meter. The radiation pattern of an antenna is the important characteristic of antenna because it indicates the distribution of the energy radiated by an antenna in the space [27].

In general, the radiation pattern is a graph shows the variation of actual field strength of electromagnetic field at all points equidistant from the antenna. Therefore, it is a three dimensional graph. There are two basic radiation patterns which is field strength pattern and power radiation pattern. The graphical field strength pattern is called if the radiation of the antenna is expressed in terms of the field strength, E. If the radiation of the antenna is expressed in terms of the power unit solid angle, therefore the graphical representation is called power radiation pattern.

2.4.4.1 Field radiation pattern

In general, the 3-dimension pattern is the completed field radiation pattern. To represent the radiation for all angles of Φ and θ, three dimensional representation is required. As the three dimensional pattern can not be plotted in a plane, three dimensional representation is avoided. Therefore, the polar plots of the relative magnitude of the field in any desired plane are sketched. These polar plots are plotted in two planes which is called as principle planes and the two plots or patterns are called principle plane patterns. By plotting the magnitude of the normalized field strength, these patterns are obtained. The pattern is called E-plane pattern or vertical pattern when the magnitude the normalized field strength is plotted versus θ with constant Φ. The E-plane pattern is as shown in the Figure 2.6(a). When the normalized field strength is plotted versus Φ for $\theta = \frac{\Pi}{2}$, the pattern is called as H-plane pattern or horizontal pattern. The H-plane pattern is as illustrated in the Figure 2.6(b).



(a) (b)

Figure 2. 7 E-Plane pattern and H-plane pattern for the hertzian dipole (a) E-plane pattern (b) H-plane pattern *[27]*

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Introduction

As had been discuss in chapter 2, there are some related elements and techniques that will be used in this project. In this chapter, there will be a further explain project implementation flow. The explanation starts on listing the S-parameter design specification followed by development of the STAR dipole antenna by using CST software. This chapter ends with explaining about the calibration process of the Virtual Network Analyzer (VNA).

3.2 Project Implementation Flow

Figure 3.1 shows that the process of designing and fabricating printed star dipole. The process starts with create the designing model into desired specification by using CST software. The design will then be simulated and if there is any error or does not get the desired results, the design will need to check back. Then, s-parameter will be checked after simulation is done to measure the input and output of the design if there is no error. The process of finding the best design parameters that will satisfy the project will be through design optimization. Next, the fabricated design will be print onto microstrip and the prototype will be test. S-parameter of the prototype will be measure again. Lastly, the result obtained will then be analysed.

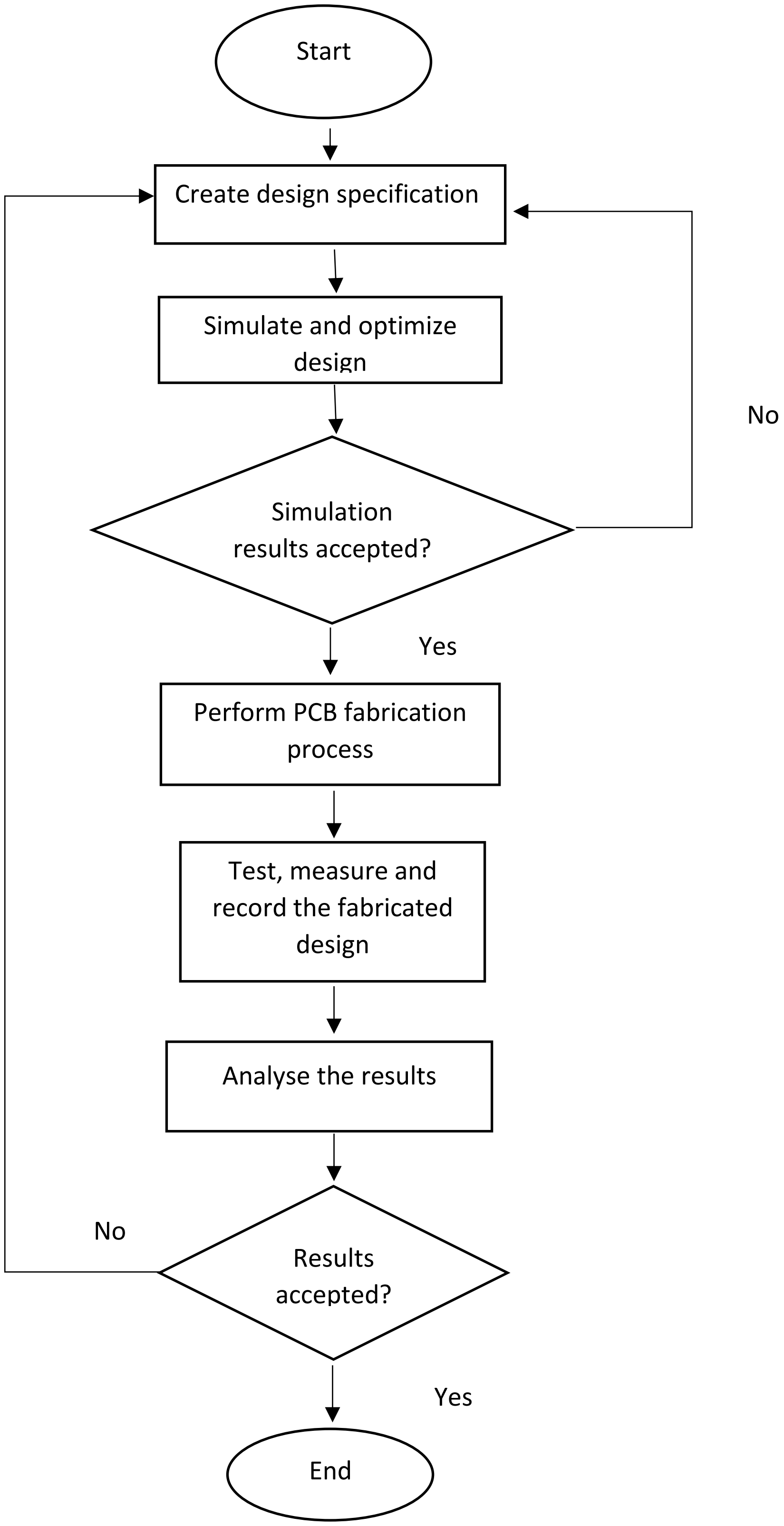


Figure 3.1: Process of designing and fabricating printed dipole antenna

3.3 Parameter Setting

In this project, the parameter involved in developing the STAR dipole antenna is defined after setting the desired frequency which is 2.4GHz by using CST software. The parameters which are width, *w*, and length, *l*, are need to determine so that this project can achieve with the ideal design. The material that will be used for substrate is RO 4003C and the thickness of substrate, *h* is based on the datasheet that are suitable to use in this project. Therefore, the thickness of the substrate, *h* after wisely choose is 0.81mm and the thickness of the copper, *t* is 0.1mm, respectively. All of these specifications are shows in Table 3.1 are determined before starting the STAR dipole antenna design.

Table 3. 1 : Table shows the S-parameter design specifications

Design Specification	
Operating Frequency	2.4GHz
Return Loss, S_{11}	< -10dB
Isolation Loss, S_{12}	< -10dB
Gain	>7dB
h	0.81mm
t	0.035mm
Dimension	250mm x 250mm

3.4 Development of the STAR Dipole Antenna

The STAR dipole antenna is designed based on the original design that was taken from the previous research which is illustrated in Figure 3.2. The design then is form in CST software thus the simulation result will be taken. The thickness of the 3 ports which are port 1, port 2 and port GND are 0.035mm with copper as a material. The STAR dipole antenna was operating at 2.4GHz with interval frequency between 2.2GHz – 2.6GHz. The design of the STAR dipole by using CST software is illustrated in Figure 3.3 and Table 3.2 shows that the parameter setup on designing the STAR dipole.

(a)

(b)

(c)

Figure 3. 2 Original STAR dipole (a) STAR dipole arms (b) Top view of STAR dipole arms with ground plane (c) Side view of STAR dipole *[1]*