

G-SLOT MICROSTRIP PATCH ANTENNA FOR RFID APPLICATION

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ABSTRACT

Radio Frequency Identification (RFID) systems have been widely used in industries due to its various advantages. The RFID systems demand low cost and low profile antennas. Microstrip patch antennas offer a potential solution for narrowband applications. It becomes popular and widely used because of its ease of analysis and fabrication, low cost, light weight, easy to feed and their attractive radiation characteristics. In this project, a new G-slot microstrip patch antenna has been design for RFID applications by involving parametric study. This patch antenna are designed using FR4 dielectric substrate with the permittivity $\epsilon_r = 4.9$. The proposed patch antenna is designed and simulated on CST Microwave Studio simulation software at 5 GHz with a gain of 3.885dB, return loss of -46.9dB and bandwidth of 9.73%.

ABSTRAK

Sistem Pengenalan Frekuensi Radio (RFID) telah digunakan secara meluas dalam industri kerana mempunyai pelbagai kelebihan. . Sistem RFID ini berkos rendah dan menggunakan antena berprofil rendah. Antena tampalan mikrojalur menawarkan penyelesaian kepada aplikasi berjalur sempit. Ia menjadi semakin popular dan banyak digunakan kerana ia mudah untuk dianalisis dan difabrikasi, berkos rendah, ringan, mudah disalurkan dan mempunyai ciri-ciri radiasi yang menarik. Melalui projek ini, satu kajian parametrik dilaksanakan terhadap antenna tampalan mikrojalur slot-G bagi tujuan dalam aplikasi sistem RFID. Antena ini menggunakan bahan FR4 dengan pemalar dielektrik 4.9. Ia direkabentuk dan disimulasi melalui perisian CST Microwave Studio pada frekuensi 5 GHz dengan gandaan 3,885 dB, kehilangan balikan, -46.9dB dan lebar jalur, 9.73%.

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LIST OF SYMBOLS AND ABBREVIATIONS

W	-	Width
L	-	Length
h	-	Substrate Thickness
ϵ_r	-	Permittivity
λ_o	-	Wavelength in free space
t	-	Patch Thickness
Γ	-	Reflection Coefficient
RL	-	Return Loss
P_{in}	-	Incident Power
P_{ref}	-	Reflected Power
ZL	-	Load Impedance
Z_o	-	Characteristics Impedance
G	-	Gain
η	-	Efficiency
D	-	Directivity
f_H	-	Upper frequency
f_L	-	Lower frequency
f_C	-	Center frequency
ϵ_{eff}	-	Effective dielectric constant
L_{eff}	-	Effective Length
f_r	-	Resonance Frequency
ΔL	-	Length extension
BW	-	Bandwidth
c	-	Speef of Light
φ	-	Electromagnetic Field Elevation Angle
θ	-	Electromagnetic Field Azimuth Angle

CHAPTER 1

INTRODUCTION

1.1 Project Background

Nowadays, Radio Frequency Identification (RFID) systems have been gaining growing interest in telecommunication system. The capability to mark objects and people with passive transponder (tag), allows easy development of cost-effective and low power consumption wireless sensor network.

The RFID is based on radio communication for tagging and identifying an object [1]. It consists of two blocks namely, RFID transceivers (readers) and RFID transponders (tags). A RFID tag consists of a small integrated circuit for storing information and an antenna for communication. A basic RFID system is based on wireless communication between a reader and a tag. RFID readers can read information stored in no line-of-sight RFID tags in their vicinity and communicate it to central database system through wired or wireless interface [2].

RFID tags contain small chips and antennas to allow them to receive and transmit radio signals from an RFID transceiver at the same time and same frequency. The antenna emits radio signals to activate the tag, read and write data as shown in Figure 1.1. Antennas are the conduits between the tag and the transceiver, which controls the system's data acquisition and communication. Antennas are available in a variety of shapes and sizes. They can be built into a door frame to receive tag data from persons or things passing through the door, or mounted on an interstate toll booth to monitor traffic passing by on a freeway. The reader using attached antennas captures data from tags then passes the data to a computer for processing.

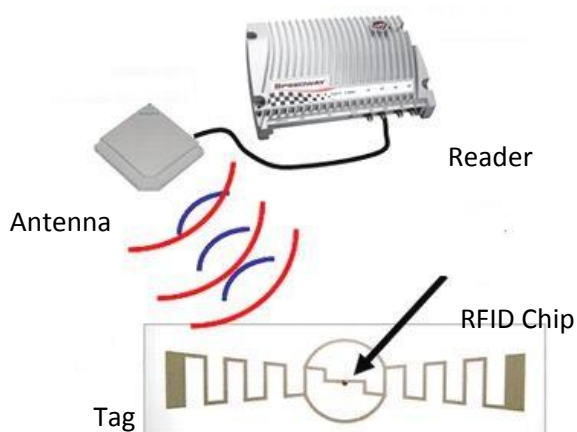


Figure 1.1: RFID system

There are a number of RFID frequencies, or RFID frequency bands that systems may use. The frequency used by the RFID system determines many of the characteristics about the way in which it will operate. Generally, the most common are low-frequency (around 125 kHz), high-frequency (13.56 MHz) and ultra-high-frequency or UHF (860-960 MHz). Microwave (2.45-5 GHz) is also used in some applications. As a result, determining the correct RFID frequency band is an important early decision in the development process.

In a RFID system, the reader is at heart, a radio transceiver that communicates with tags. Many different varieties of reader antennas are available and the proper choice is often guided by the regional regulations for maximum allowable radiated power and antenna beamwidth. As per applications demand, RFID systems can use advanced antennas such as switched beam antennas and smart antenna arrays. To reduce the size of the antenna and to achieve wideband, different techniques such as meandered ground plane, chip loading, feed modification, stacked shorted patch, slot-loading and teardrop dipole in an open sleeve structure have been reported [3].

In recent years, microstrip patch antenna has been gaining growing interest in the wireless telecommunication system. The microstrip patch antenna technology develops rapidly in the late 1970s. They are extremely compatible for embedded antennas in RFID application due to their lightweight, versatility, conformability, low cost and low sensitivity to manufacturing tolerance. However, it has a disadvantage of a narrow bandwidth. There are numerous methods to increase the bandwidth. The most common methods are varying the thickness and using a low dielectric constant substrate material. However, the bandwidth and the size of an antenna are generally mutually conflicting properties, that is, the improvement

of one of the characteristic normally results in degradation of the other [4]. In this project, the design flow of a new G-slot microstrip patch antenna for microwave frequency 5 GHz using CST Microwave Studio software will be described. This antenna design can produce the single resonant modes and a much wider bandwidth for the microwave frequency. It also can obtain a circular polarization where the polarization of the antenna will be following the direction of the maximum gain. The greatest strength of the 5 GHz is the availability less overlapping and greater number of available channels provides for increased density, which means that more wireless devices can be connected in the same radio environment. This antenna design will use center line fed patch method.

1.2 Objectives

This research is mainly concentrating on the concept and application of microstrip antenna patch in RFID system. The studies will include the design and the parametric study of the G-slot microstrip patch antenna. It is expected that the design should enhance the bandwidth capacity at 5GHz.

1.3 Scope

This research mainly focused on the G-slot microstrip patch antenna design at 5 GHz with less than -10 dB return loss. An optimization is used to fulfil the antenna specification or performance requirements. This model is designed and simulated using CST Microwave Studio software.

CHAPTER 2

LITERATURE REVIEW

2.1 Basic Concept of Microstrip Patch Antenna

A microstrip patch antenna has been one of the most innovative topics in antenna theory and design. Microstrip antennas are designed to have many geometrical shapes and dimensions but rectangular and circular microstrip patches have been used in many application. They are used in wide range of modern microwave applications because of their simplicity and compatibility with printed-circuit technology.

A microstrip patch antenna in its simplest form consists of a radiating patch on one side of a dielectric substrate and a ground plane on the other side as shown in Figure 2.1. The bottom surface of a thin dielectric substrate is completely covered with metallization that serves as a ground plane. The rectangular microstrip patch antenna is made of a rectangular patch with dimensions width (W) and length (L) over a ground plane with a substrate thickness (h) and permittivity (ϵ_r). The length (L) of the patch is usually $\lambda_0/3 < L < \lambda_0/2$ and the thick of the patch is very thin ($t \ll \lambda_0$).

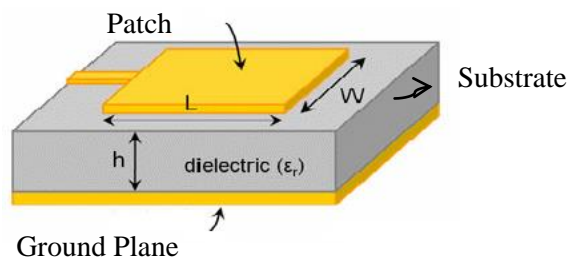


Figure 2.1: The simplest microstrip patch antenna.

The patch is generally made of a conducting material like gold or copper. The radiating patch and the feed lines are usually photo etched on the dielectric substrate. Microstrip patch antennas radiate primarily because of the fringing fields between the patch

edges by variety of methods. The patch is in fact electrically a bit larger than its physical dimensions due to its fringing fields.

Although rectangular microstrip has a very simple geometric structure, the electromagnetic fields involved are actually complex. Accurate and thorough analysis requires mathematical treatment. Some of the disadvantages of microstrip antenna configurations include narrow bandwidth, spurious feed radiation, poor polarization purity, excitation of surface waves, limited power capacity, and tolerance problem. However, narrow bandwidth disadvantage of patch antenna turns out to be advantage for RFID reader as its applications do not need much bandwidth because antenna rejects the signals that are out of the band and accordingly increases the quality factor [1].

2.2 Types of Microstrip Patch Antenna

There are different types of microstrip patch antennas which can be classified based on their physical parameters. The patch may be square, rectangular, dipole, circular, triangular, circular ring, elliptical or any other configuration. These are illustrated in Figure 2.2.

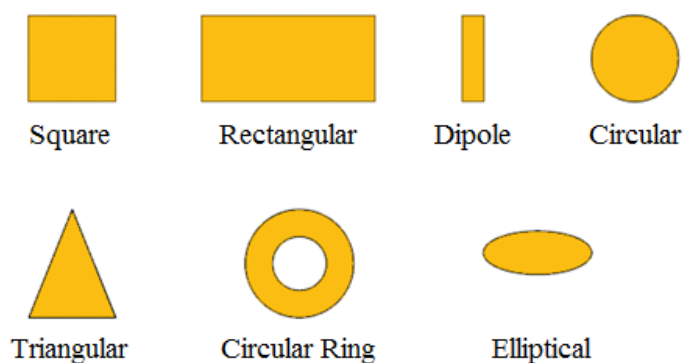


Figure 2.2: Common shapes of microstrip patch antenna.

The rectangular microstrip patch antenna is the widely used because of ease of fabrication and analysis. This type is also robust design and very eases to handle.

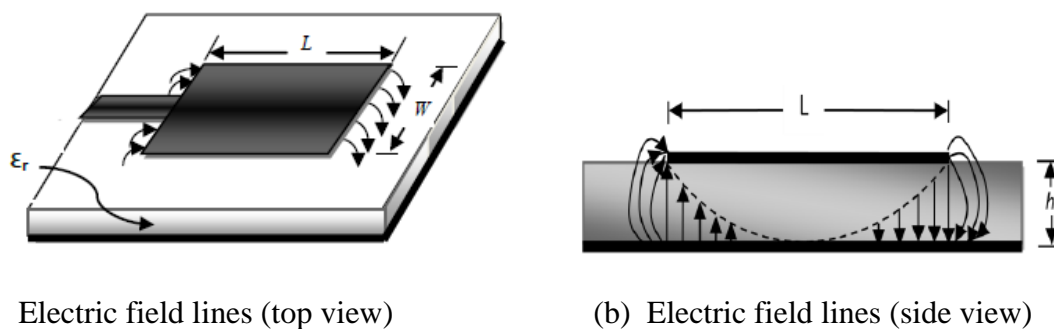
2.3 Feeding Techniques

Microstrip patch antennas can be fed by a variety of methods. These methods can be classified into two categories, contacting and non-contacting. In the contacting method, the RF power is fed directly to the radiating patch using a connecting element such as microstrip line. In the non-contacting scheme, electromagnetic field coupling is done to transfer power between the microstrip line and the radiating patch. The four most popular feed techniques used are the microstrip line, coaxial probe, aperture coupling and proximity coupling [5]. To obtain a desirable return loss at the resonant frequency, a microstrip patch antenna must be matched to the transmission line feeding it.

The microstrip line is also a conducting strip. It is easy to fabricate and simple to match by controlling the feed position and rather simple to model. This conducting strip is directly connected to the edge of the microstrip patch. The conducting strip is smaller in width as compared to the patch and this kind of feed arrangement has the advantage that the feed can be etched on the same substrate to provide a planar structure. This conducting strip and the patch are also made from the same material. However as the substrate thickness increases surface waves and spurious feed radiation increase, which for practical designs limit the bandwidth (typically 2-5%) [1].

2.4 Fringing Effects

Fringing fields have a great effect on the performance of a microstrip antenna. In microstrip patch antennas, the electric field in the center of the patch is zero. The radiation is due to the fringing field between the periphery of the patch and the ground plane. Figure 2.3 shows there is no field variation along the width and thickness. The amount of the fringing field is a function of the dimensions of the patch and the height of the substrate. Higher the substrate, the greater is the fringing field [6].



(a) Electric field lines (top view)

(b) Electric field lines (side view)

Figure 2.3: Electric field lines for rectangular microstrip patch antenna.

Due to the fringing effect, the microstrip patch antenna looks greater than its physical dimension. Thus, an effective dielectric constant is to be introduced. The effective dielectric constant takes in account both the fringing and the propagation in the line. Hence, when designing a patch antenna it is typically trimmed by 2-4% to achieve at the desired resonance frequency.

2.5 Radiation Pattern

The power radiated or received by an antenna is a function of the angular position and radial distance from the antenna. The radiation pattern is good represented in the form of a three dimensional graph of power versus elevation and azimuth angles but more commonly represented by E-plane or H-plane where one angle is held fixed while the other is varied as shown in Figure 2.4.

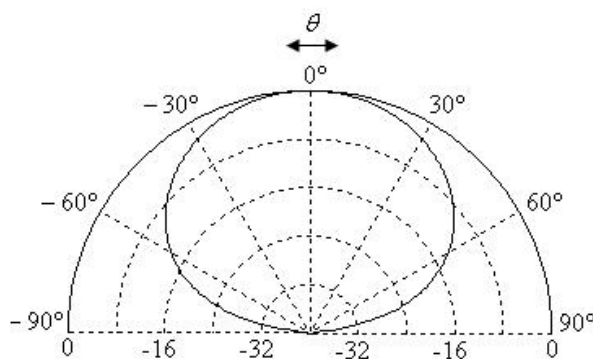


Figure 2.4: A radiation pattern for a microstrip antenna.

The microstrip patch antenna has radiation pattern that can be calculated easily. The source of the radiation of the electric field at the gap of the edge of the microstrip element and the ground plane is the key factor to the accurate calculation of the patch antenna.

2.6 Return Loss

Return loss is an important parameter when connecting an antenna. It is a way to characterize the input and output of signal sources. The return loss is related to impedance matching and the maximum transfer of power theory. When the load is mismatched, not all the available power from generator is delivered to the load. This return loss is also a measure of the effectiveness of an antenna to deliver power from the source to the antenna.

The return loss, RL shows the level of the reflected signal with respect to the incident signal in dB. It is defined by the ratio of the incident power of the antenna P_{in} to the power reflected back from the antenna of the source P_{ref} . The mathematical expression is:

$$RL = -20\log_{10}|\Gamma|(dB)$$

Where $|\Gamma|$ is determined by:

$$|\Gamma| = \frac{P_{in}}{P_{ref}} = \frac{Z_L - Z_O}{Z_L + Z_O}$$

The Z_L and Z_O are the load and characteristic impedance.

For good power transfer, the ratio P_{in}/P_{ref} shall be high. If the return loss is low, the standing wave phenomena's or resonances might occur, and it will end up in the frequency ripple or gain. During the process of the design of microstrip patch antenna there is a response taken from the magnitude of S_{11} versus the frequency which known as the return loss. In most practical circuits a return loss value of -10 dB is good enough.

2.7 Gain

Gain is a useful measurement describing the antenna performance. Although the gain of the antenna is closely related to directivity, it is a measure that takes into account the efficiency of the antenna as well as its directional capabilities. Antenna gain usually

expressed in dB, simply refers to the direction of maximum radiation. Mathematically the maximum gain, G is obtained by using equation 1.

$$G = \eta D \quad (1)$$

Where, η = efficiency and D = directivity

2.8 Directivity

It is desirable to maximize the radiation pattern of the antenna response in a fixed direction to transmit or receive power. Likewise, the directivity is dependent only on the shape of radiation pattern. It is always referenced to an isotropic point source as in Figure 2.5. A quantitative measure of this response is the directive gain of the antenna for a given direction.

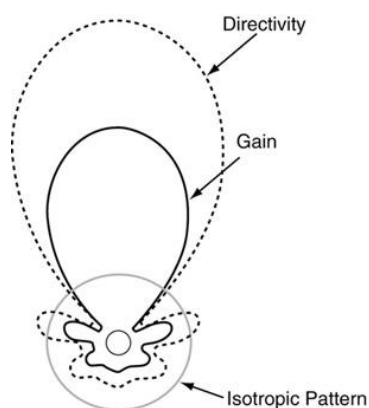


Figure 2.5: Directivity of an antenna

2.9 Bandwidth

The bandwidth of an antenna is defined as the range of usable frequencies within which the performance of the antenna, with respect to some characteristic, conforms to a specified standard [1]. The bandwidth can be defined as the ratio of the upper to lower frequencies of acceptable operation. The bandwidth of a narrowband antenna can be defined as the percentage of the frequency difference over the center frequency. The bandwidth is given by the expression:

$$\text{Bandwidth}_{\text{narrowband}}(\%) = \left[\frac{f_H - f_L}{f_C} \right] \times 100\%$$

Where,

f_H = upper frequency

f_L = lower frequency

f_C = center frequency

2.10 Antenna Efficiency

The antenna efficiency is defined as the ratio of total power radiated by the antenna to the input of the antenna. The total antenna efficiency is used to take into account losses at the input terminals and within the structure of the antenna. An antenna may dissipate power due to conductor loss or dielectric loss. A high efficiency antenna has most of the power present at the antenna's input radiated away. A low efficiency antenna has most of the power absorbed as losses within the antenna, or reflected away due to impedance mismatch.

2.11 Polarization

The polarization of an antenna is defined as the polarization of the wave transmitted or radiated by the antenna. Whenever, the direction is not stated, the polarization of the antenna will be following the direction of the maximum gain. It is known that a rectangular patch with a conventional feeding will radiate linearly. However, with some modifications on the feeding techniques or the patch itself can turn to a circular polarization. The main advantage of using circular polarization is because of it as a receiver orientation so that it can always receive a signal even from different axis of transmission.

2.12 Substrate

There are numerous substrates that can be used for the design of microstrip patch antenna. Their dielectric constants are usually in the range of $2.2 < \epsilon_r < 12$ [7]. The microstrip patch antenna radiate primarily because of the fringing fields between the patch edge and the ground plane. Therefore, the effective dielectric constant (ϵ_{reff}) must be obtained. The dielectric constants play a major role in the overall performance of the antenna.

When a dielectric substrate is selected, one is interested in a material with the lowest tangent ($\tan \delta$) available. The loss tangent is a metric of the quantity of electrical energy, which is converted to heat by a dielectric. The lowest possible loss tangent maximizes the antenna efficiency.

The relative dielectric constant, ϵ_r of the substrate determines the physical size of a patch antenna. The larger the dielectric constant the smaller the element size, but also the smaller the impedance, bandwidth and directivity and the surface wave loss increases. If the material has high dielectric constant, it reflects more RF energy and detunes the antenna more, which makes it harder to tag. The ones that are most desirable for antenna performance are thick substrates whose dielectric constant is in the lower end of the range because they provide better efficiency, larger bandwidth, loosely bound fields for radiation into space, but at the expense of larger element size [8].

Thin substrate with higher dielectric constants is desirable for microwave circuitry because they require tightly bound fields to minimize undesired radiation and coupling, and lead to smaller element sizes. However, they are less efficient and have relatively smaller bandwidth because of their greater losses. Since microstrip antennas are often integrated with other microwave circuitry, a compromise has to be reached between good antenna performance and circuit design. Table 2.1 shows types of dielectric constant for different materials.

Table 2.1: Dielectric and Loss tangent for different materials.

Material	ϵ_r	$\tan \delta$
Teflon (PTFE)	2.1	0.0005
Rexolite 1422	2.55	0.0007
Noryl	2.6	0.0011
FR4	4.9	0.02
Alumina	9.8	0.0003

2.13 Antenna Design Calculation

The most important parameters needed for the design of this antenna are the width and length of the rectangular patch antenna. An accurate value of the width and length affects the result very much. The following design equations are the basic calculation according to the microstrip patch antenna design procedure [1]. Refer to Figure 2.6.

The patch width (W) for efficient radiation is given by:

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

where, W is the patch width, c is the speed of light, f_r is the resonant frequency, and ϵ_r is the dielectric constant of the substrate.

Due to the fringing and the wave propagation in the field line, an effective dielectric constant ($\epsilon_{r_{eff}}$) must be obtained. The effective dielectric constant ($\epsilon_{r_{eff}}$) is calculated as follows:

$$\epsilon_{r_{eff}} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \left(\frac{1}{\sqrt{1 + 12 \left(\frac{h}{w} \right)}} \right) \quad (2)$$

where, $\epsilon_{r_{eff}}$ is the effective dielectric constant, h is the height of the dielectric substrate.

The effective length ($L_{r_{eff}}$) for a given resonance frequency, f_r is given as:

$$L_{r_{eff}} = \frac{c}{2f_r \sqrt{\epsilon_{r_{eff}}}} \quad (3)$$

The length extension (ΔL) is given by the expression:

$$\Delta L = 0.412h \frac{(\epsilon_{r_{eff}} + 0.3) \left(\frac{W}{h} + 0.264 \right)}{(\epsilon_{r_{eff}} - 0.258) \left(\frac{W}{h} + 0.8 \right)} \quad (4)$$

The actual patch length (L) now becomes:

$$L = L_{r_{eff}} - 2\Delta L \quad (5)$$

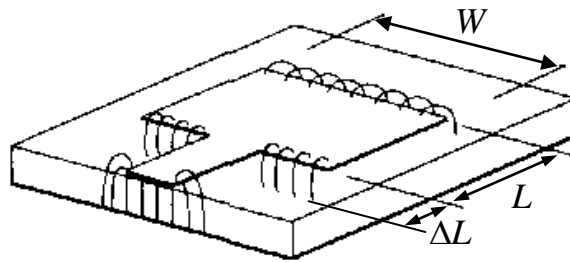


Figure 2.6: Elementary rectangular microstrip antenna and electric field distribution.

The bandwidth (BW) is calculated as:

$$BW\% = 3.77 \left(\frac{\epsilon_r - 1}{\epsilon_r^2} \right) \left(\frac{W}{L} \right) \left(\frac{h}{\lambda_0} \right) \times 100\% \quad (6)$$

where, λ_0 is the wavelength in free space.

2.14 Previous Project

By referring to previous project, it will describe about microstrip patch antenna design, the software used to simulate the circuit and the parameters. These previous projects are very useful to design the rectangular microstrip patch antenna.

2.14.1 Design of a Microstrip-Line-Fed Inset Patch Antenna for RFID Applications

The project was done by Irfan [9]. The work employed an inset fed microstrip patch antenna at resonant frequency of 2.42 GHz. The proposed design has simple design structure and can easily be constructed at low cost. The return loss was found to be -21.06 dB and the gain was 4.68 dB. The proposed antenna design can be a good solution for many RFID applications such as warehouse and supply chain automation.

2.14.2 Design of a Rectangular Microstrip Patch Antenna at 1 GHz.

The project was proposed by Dafalla [10]. By using a transmission line model, they demonstrated on how one can accurately model and analyze microstrip line inset fed rectangular microstrip patch antenna by using microwave office software. The result of this project showed very low return loss and VSWR which were typical parameters used to study

the behaviour of antennas. Also, choosing a proper position for terminating the feed line affect the overall performance of the antenna.

2.14.3 Compact Microstrip Antenna for RFID Application.

The project was done by Monti [11]. This work presents a planar for Ultra-High-Frequency (UHF) tags to be applied on metallic surfaces. The proposed radiating structure consists of a short-circuited patch antenna designed with fractal geometry, resulting in a very compact and cost effective tag. This project shows a very good platform tolerance, such a tag is also suitable for application on different kinds of materials.

2.14.4 Dual U-Shape Microstrip Patch Antenna Design for WiMAX Application

This project was done by Islam M.A. [12]. This project presents the dual U-shape microstrip patch antenna feed by the transmission line. The proposed antenna is designed for WiMAX applications and wireless systems. The two slots and one bridge elements have been applied to generate the three frequencies bands.

2.14.5 Design of a Novel Microstrip-Fed Dual Band Slot Antenna For WLAN Applications.

This project was done by Gai Et Al [13]. This project presents a novel dual-band rectangular slot antenna for WLAN applications in IEEE 802.11b/g/a systems. By introducing a pair of U-shaped strips, the proposed antenna can generate two separate impedance bandwidths. The low-band resonant frequency is located at about 2.4 GHz. The high-band resonant frequency is located at about 5.7 GHz.

2.14.6 Parametric Study on the Compact G-Shaped Monopole Antenna for 2.4 GHz and 5.2 GHz Application

This project was described by Ahmad B.H. [14]. This project presents a compact printed microstrip G-shaped monopole antenna for wireless local area network (WLAN) application. This G-shaped antenna is designed for the two resonance frequencies at 2.4 GHz and 5.2 GHz respectively. It is constructed by a non-conductor backed G-shaped strip with a microstrip feed line. The dual band performance can be easily achieved by fine tuning the

length of the resonant path. The parametric study with five different ground length had been done using parametric sweep.

2.14.7 CPW Fed Tapered Slot Antenna at 5.5 GHz for Wireless Application

This project was designed by Shanmuganatham T [15]. This project is developed a Coplanar Waveguide fed tapered slot antenna for various 5 to 6 GHz frequency band application. The fundamental parameters of the antenna such as bandwidth, return loss, gain, radiation pattern and polarized are obtained. The measured input impedance bandwidth (return loss > 10 dB) of the prototype antenna is 21 % (4.8-6 GHz). The simulated peak antenna gain is 3.1 dBi.

2.14.8 A Wideband E-Shaped Microstrip Patch Antenna for 5-6 GHz Wireless Communications

This project was done by Ang B.K. [16]. A wideband E-shaped microstrip patch antenna has been designed for high-speed wireless local area networks (IEEE 802.11a standard) and other wireless communication systems covering the 5.15-5.825 GHz frequency band. Two parallel slots are incorporated to perturb the surface current path, introducing local inductive effect that is responsible for the excitation of the second resonant mode. The length of the center arm can be trimmed to tune the frequency of the second resonant mode without affecting the fundamental resonant mode. A comprehensive parametric study has been carried out to understand the effects of various dimensional parameters and to optimize the performance of the antenna. The reflection coefficient at the input of the optimized E-shaped microstrip patch antenna is below -10 dB over the entire frequency band. The measurement results are in excellent agreement with the HFSS simulation results.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter explains the methodology of project in detail. The project starts with the research project background and problem statement definition. Theories and previous research have been the basic reference in order to define the logic specification to achieve for the microstrip patch antenna. The define specification will also be considered at the application, particularly for the RFID. Figure 3.1 shows the flow of steps required in designing the microstrip patch antenna.

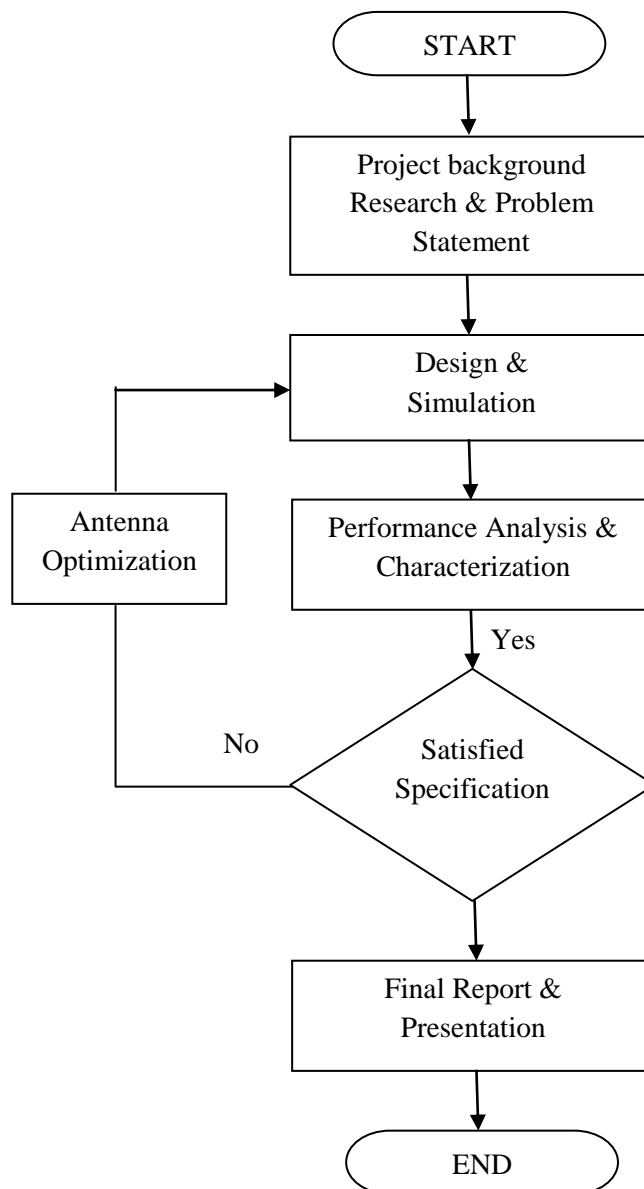


Figure 3.1: Project flow chart.

3.2 Antenna Specification

Basically, the performance of the antenna depends on its resonant frequency, dimension, operating frequency, radiation efficiency, directivity, and return loss. The characteristics of the antenna are defined mainly by their geometries and the material properties. The design of patch antenna requires precise physical dimensions and power feeding method for the antenna.

The G-slot microstrip patch antenna is designed based on three parameters. The substrate used is FR4 which has a dielectric constant of $\epsilon_r = 4.9$ and height, $h = 1.6$ mm. The frequency of interest was $f_o = 5$ GHz. The define specification is as shown in Table 3.1. The patch is considered fed by a 50Ω coaxial feed line.

Table 3.1: Defined Antenna Specification

Parameters	Specification
Operating Frequency	5 GHz
Gain	> 3 dB
Return Loss	< -10 dB
-10dB Bandwidth	3% - 5%
Polarization	Circular

A low dielectric constant of the substrate material is used in the prototype design because it gives better efficiency and higher bandwidth. The low value of the dielectric constant will increases the radiated power. The design has a patch size independent of the dielectric constant. Therefore, the reduction in the patch size is accomplished by using higher dielectric constant. Thus, FR4 is good in this agreement. Another important design parameter is the substrate thickness, h . The thickness of the substrate increases the fringing field at the patch periphery. Therefore, the substrate height of 1.6 mm has been chosen.

Typically, gain is a useful measurement describing the performance of the antenna. Although the gain of the antenna is closely related to the directivity, it is measure that takes into account the efficiency of the antenna as well as its directional capabilities [1]. In this project, it is a requirement to obtain more than 3dB as the antenna is expected to transmit the signal at the microwave frequency which is 5GHz, applied to the RFID application.

The return loss is required to be less than -10 dB. The lesser the value indicates the better losses of the antenna. This can be achieved by providing a correct geometrical parameters and transmission line system. For the bandwidth, it is defines as 3-5% for a greater path of the transmission signal.

The G-slot antenna design needs to have a circular polarization for the RFID application. Circular polarization is more practical compared to the linear polarization. The signal is able to transmit and received for not only in single direction. There are many ways to obtain the circular polarization for example, modification on the patch or the feed arrangement. In this project, modification on the rectangular patch antenna with the G-slot has obtained the circular polarization.

3.3 Antenna Design Equations

The following equations are the basic calculation according to the microstrip antenna design procedure. For an efficient radiation, the practical width of the patch can be determined by:

$$\begin{aligned} W &= \frac{c}{2fr} \sqrt{\frac{2}{\epsilon_r + 1}} \\ &= \frac{3 \times 10^8}{2 \times 5G} \sqrt{\frac{2}{4.9 + 1}} \\ &= 17.467 \text{ mm} \end{aligned}$$

The length of the patch is based on the frequency and dielectric constant value. Due to the fringing and the wave propagation in the field line, an effective dielectric constant (ϵ_{eff}) must be obtained. The effective dielectric constant (ϵ_{eff}) is calculated as follows:

$$\begin{aligned} \epsilon_{eff} &= \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \left(\frac{1}{\sqrt{1 + 12 \left(\frac{h}{W} \right)}} \right) \\ \epsilon_{eff} &= \frac{4.9 + 1}{2} + \frac{4.9 - 1}{2} \left(\frac{1}{\sqrt{1 + 12 \left(\frac{1.6}{17.467} \right)}} \right) \\ &= 4.3 \end{aligned}$$

The effective length (L_{eff}) for a given resonance frequency, f_r is obtained as:

$$\begin{aligned} L_{eff} &= \frac{c}{2f_r \sqrt{\epsilon_{eff}}} \\ &= \frac{3 \times 10^8}{2 \times 5G \sqrt{4.3}} \\ &= 14.467 \text{ mm} \end{aligned}$$

The length extension (ΔL) is given by the expression:

$$\begin{aligned} \Delta L &= 0.412h \frac{(\epsilon_{eff} + 0.3) \left(\frac{W}{h} + 0.264 \right)}{(\epsilon_{eff} - 0.258) \left(\frac{W}{h} + 0.8 \right)} \\ &= 0.412(1.6) \frac{(4.3 + 0.3)(10.92 + 0.264)}{(4.3 - 0.258)(10.92 + 0.8)} \\ &= 0.715 \text{ mm} \end{aligned}$$

The actual patch length (L) is obtained by:

$$\begin{aligned} L &= L_{eff} - 2\Delta L \\ &= 14.467 - 2(0.715) \\ &= 13.037 \text{ mm} \end{aligned}$$

3.4 Antenna Design Parameters

The actual values might differ during resonant frequency tuning and antenna parameterized is performed. The actual size will be obtained during the construction and simulation in the software. The calculated and optimized values are shown in Table 3.2.

Table 3.2: The calculated and optimized values.

Parameters	Calculated Value (mm)	Optimized Value (mm)
Patch width, W	17.467 mm	19 mm
Patch length, L	13.037 mm	12.54 mm

The graphical diagram of G-slot microstrip antenna as per Figure 3.2.

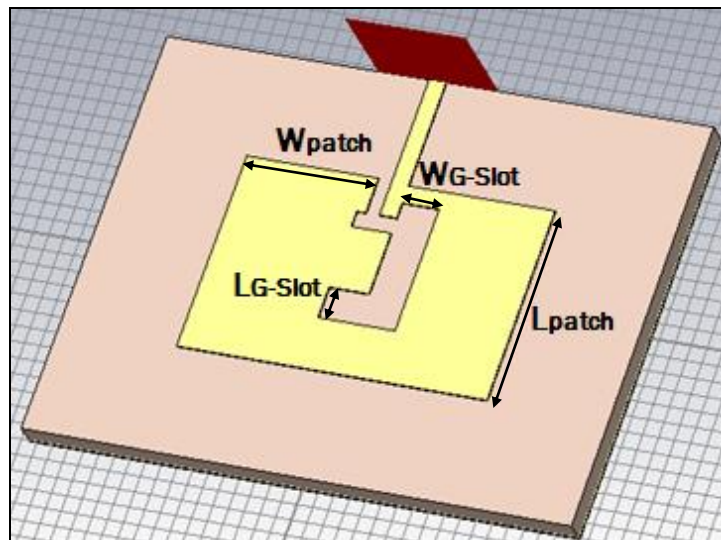


Figure 3.2: G-slot microstrip patch antenna.

However, the major problem for this G-slot microstrip patch antenna design is impedance mismatched. To solve this problem, a variety of designs with modified G-slot parameter have been reported. It has been demonstrated that by adding narrow slit with 0.03 mm length at the edge of the patch as shown in Figure 3.3, the suitable operating frequency

with minimal return loss is obtained. By introducing narrow slit, the surface current distribution at the center of the radiating patch is enhanced, causing the minimum at 5GHz.

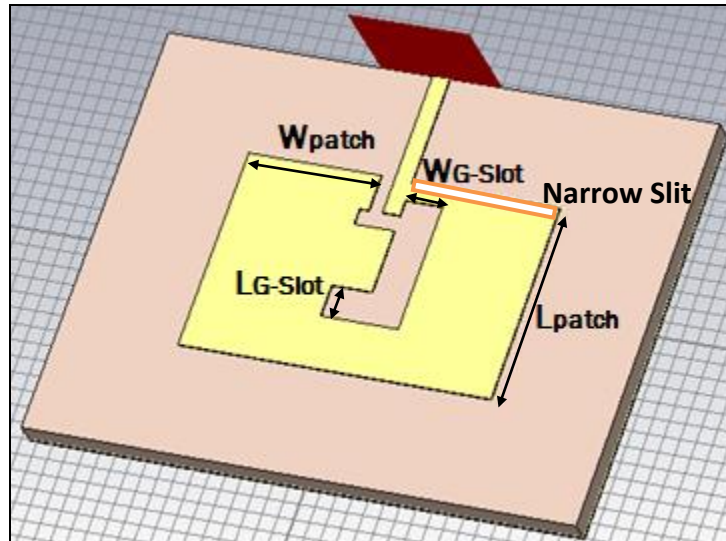


Figure 3.3: G-slot microstrip patch antenna with narrow slit.

3.5 Antenna Simulation

The software used to model and simulate the G-slot microstrip patch antenna is CST Microwave Studio. Figure 3.4 shows a screenshot of CST Microwave Studio's main window. This software provides a user-friendly interface to handle multiple projects and views at the same time. Modelling with CST Microwave Studio allows the use of an interactive mouse for data input, design capture, template assistance for specific applications and fully parametric 3D modelling. The navigation tree is an essential part of the user interface where the structural elements and simulation results may be accessed.

A history list permits unlimited 'undo' and 'redo' functions for editing. The software also has advanced solid modelling features and Boolean operations such as adding and subtracting solid objects from existing structures. Simulation materials can be arranged in layers, whether they are isotropic or anisotropic, linear or non-linear, magnetic or non-magnetic. RF energy excitation sources include waveguide ports, plane wave incident fields, and discrete voltage and current sources.

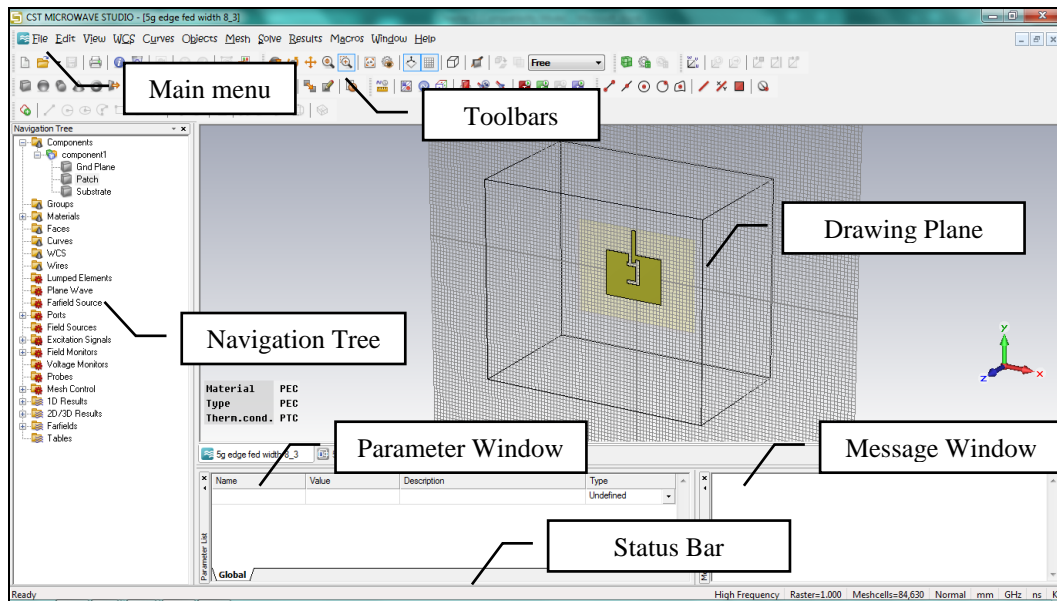


Figure 3.4: A screenshot of CST Microwave Studio's main window

The post-processing includes the VSWR and Smith chart plots, port signal plots, polar radiation pattern plots, and 2D and 3D field plots. The software can also calculate and plot the antenna axial ratio, which is important for circularly and elliptically polarized antennas. The first step in the antenna design processes is determining the criteria to use in selecting an optimal antenna. The first criterion is to achieve power transfer from the feed transmission line to the antenna. This is accomplished by matching the antenna input impedance to the characteristic impedance of the transmission line.

3.6 Parametric Study

A parametric study was completed to determine the performance effect to develop a design procedure. The operating frequency and percent bandwidth was observed for each configuration. The parametric study has been done by varying the patch width, patch length, G-slot width and G-slot length.

However, there are two major weaknesses in this method. First, only one permittivity substrates were studied and the applicability of the design equations to other permittivity substrates was not documented. Second, the tuning technique requires significantly more iterations to achieve an optimized design.

CHAPTER 4

DATA ANALYSIS AND RESULT

4.1 Introduction

This chapter presents the simulated of the design antenna. The software used to model and simulate the antenna design is CST Microwave Studio. Theoretically, calculations and parametric studies were performed to develop G-slot microstrip patch antenna that could operate in the microwave frequency. All the calculation of EM field was done using ‘transient solver’ with default setting. Initially, simulation was performed using analytically computed antenna parameters. However, an optimization of the antenna parameters was performed to obtain satisfactory results.

4.2 Parametric Modeling Studies Using CST Microwave Studio

The relationship between the G-slot geometry and the S11 characteristics of the patch was investigated using CST Microwave Studio. The parameters studied were patch width, patch length, G-slot width and G-slot length. The results of the parametric modelling studies using CST Microwave Studio are discussed in the following paragraphs.

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