PRINTED WI-FI RADIATING ELEMENT INTEGRATING WITH LIGHT EMITTING DIODE (LED)

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This report is submitted in partial fulfillment of the requirements for the degree of Bachelor of Electronic Engineering with Honours



2023

DECLARATION

I declare that this report entitled "Printed Wi-Fi Radiating Element Integrating with Light Emitting Diode (LED)" is the result of my work except for quotes as cited in the references.

APPROVAL

I hereby declare that I have read this thesis, and in my opinion, this thesis is sufficient in terms of scope and quality for the award of Bachelor of Electronic Engineering with Honours.



Date

DEDICATION

This work is dedicated to my beloved family and those people who have guided and inspired me throughout my journey of education, I have also dedicated this work to my supervisor, Prof. Madya Dr. Maisarah Binti Abu who has been a constant source of knowledge and inspiration. Thank you for supporting me and for all the

encouragement.

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ABSTRACT

This project presents the Printed Wi-Fi Radiating Element Integrating with Light Emitting Diode (LED). The purpose of this project is to design and optimize the radiating element integrated with Light Emitting Diode (LED) to have dual functionality in one device which is illumination and wireless communication. The other purpose is to verify the performance of the fabricated printed radiating element with LED in terms of return loss, Voltage Standard Wave Ratio (VSWR), bandwidth, and directivity. The radiating element is designed using Computer Simulation Technology (CST) and operated at 2.4 GHz. The placement of LEDs is located on the slotted area between the radiating elements. The design is fabricated using Rogers RT 5880 substrate with permittivity, $\varepsilon r = 2.2$, and thickness, h = 1.575mm. The performance parameter was verified through Vector Network Analyzer and Anechoic Chamber room. The result between simulation and measurement shows the radiating element performance with and without the integration of LED.

ABSTRAK

Projek ini memperkenalkan "Printed Wi-Fi Radiating Element Integrating with Light Emitting Diode (LED)". Tujuan projek ini adalah untuk mereka bentuk dan mengoptimumkan elemen penyinaran yang disepadukan dengan Diod Pemancar Cahaya (LED) untuk mempunyai dwi fungsi dalam satu peranti iaitu pencahayaan dan komunikasi tanpa wayar. Tujuan lain adalah untuk mengesahkan prestasi elemen penyinaran bercetak yang direka dengan LED dari segi kehilangan balikan, Nisbah Gelombang Piawai Voltan (VSWR), jalur lebar dan kearahan. Elemen penyinaran direka menggunakan Teknologi Simulasi Komputer (CST) dan dikendalikan pada 2.4 GHz. Penempatan LED terletak pada kawasan berlubang antara elemen penyinaran. Reka bentuk ini direka menggunakan substrat Rogers RT 5880 dengan kebolehtelapan, $\varepsilon r = 2.2$, dan ketebalan, h = 1.575 mm. Parameter prestasi telah disahkan melalui "Vector Network Analyzer" dan bilik "Anechoic Chamber". Keputusan antara simulasi dan pengukuran menunjukkan prestasi elemen penyinaran dengan dan tanpa penyepaduan LED.

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TABLE OF CONTENTS



1.4	Scope of project	3
СНА	PTER 2 BACKGROUND STUDY	4
2.1	Introduction	4
2.2	Microstrip patch antenna	5
2.3	Feeding technique for microstrip patch antenna	6
2.4	Rogers RT/ Duroid 5880	8
	2.4.1 Microstrip patch antenna using substrate Rogers RT/Duroid 5880	8
2.5	Slots loaded on microstrip patch antenna	9
2.6	Light Emitting Diode	10
	2.6.1 Surface Mount Device LED	10
	2.6.2 The stacked antenna integrated with ring LED	11
	2.6.3 The microstrip monopole antenna integrated with LED	12
2.7	SummaryRSITI TEKNIKAL MALAYSIA MELAKA	14
СНА	PTER 3 METHODOLOGY	15
3.1	Introduction	15
3.2	Project planning	16
3.3	Project flow chart	17
3.4	Project Gantt chart	18
3.5	Detail description of the methodology research	19
	3.5.1 Studies of literature reviews	19

v

	3.5.2 Design and simulation of the radiating element integrating with LE	D 21
	3.5.3 Fabrication of the radiating element with LED	29
	3.5.4 The measurements using Vector Network Analyzer and Anechoic Chamber	33
3.6	Summary	34
CHA	APTER 4 RESULTS AND DISCUSSION	35
4.1	Introduction	35
4.2	Preliminary simulation result analysis	36
4.3	Simulation and measurement result	39
	4.3.1 Design outcome	39
	4.3.2 Experimental result	41
	4.3.2.1 Return loss, dB	41
	4.3.2.2 VSWR and bandwidth calculation	44
	4.3.2.3 Radiation pattern	47
4.4	Summary	48
4.5	Discussion	49
CHA	APTER 5 CONCLUSION AND FUTURE WORKS	54
5.1	Conclusion	54
5.2	Future works	55
REF	ERENCES	57

LIST OF FIGURES

Figure 2.1 Structure of microstrip patch antenna
Figure 2.2 Rectangular patch antenna with the microstrip feed line
Figure 2.3 Microstrip inset-fed patch antenna design7
Figure 2.4 Slot loaded and coaxial feed rectangular microstrip patch antenna [12]9
Figure 2.5 SMD 5050 LED 10
Figure 2.6 Return loss of stacked antenna integrated with the ring without LED 11
Figure 2.7 Return loss stacked antenna integrated with the ring LED 12
Figure 2.8 Layout of microstrip monopole antenna integrated with LED
Figure 2.9 Measurement 4 LED in parallel of microstrip monopole antenna integrated with LED
Figure 3.1 Project flow chart17
Figure 3.2 Project Gantt chart 18
Figure 3.3 Layout of rectangular microstrip patch antenna
Figure 3.4 The layers of materials arrangement for the patch antenna
Figure 3.5 Project template from CST Studio
Figure 3.6 The platform for the design of the radiating element

Figure 3.7 The brick for inserting input parameter value for dimension	24
Figure 3.8 Rectangular microstrip patch with SMA connector	25
Figure 3.9 Top view design 1 of the radiating element	26
Figure 3.10 Top view design 2 of the radiating element	26
Figure 3.11 Design 3 of the radiating element without LED2	28
Figure 3.12 Design 3 of the radiating element with LED	28
Figure 3.13 Printed design from software2	29
Figure 3.14 Dry Film Sheet Laminator	30
Figure 3.15 UV Exposure 3	30
Figure 3.16 The process before and after the patch is put into the etching machine 3	31
Figure 3.17 Rinse and remove the unwanted layer of the patch	31
Figure 3.18 Dry the patch using Conveyorized Drying Oven Air	32
Figure 3.19 Real SMD5050 LED and simulation LED	32
Figure 3.20 Measured the radiating element using Vector Network Analyzer	33
Figure 3.21 Measured the radiation pattern in the Anechoic Chamber room	34
Figure 4.1 Return loss for designs 1 and 2 of radiating element without LED	36
Figure 4.2 Radiating element without LED	39
Figure 4.3 Radiating element with LED OFF State 4	10
Figure 4.4 Radiating element with LED ON state 4	10
Figure 4.5 Simulation and measurement return loss radiating element without LE	D 11
Figure 4.6 Simulation and measurement return loss radiating element with LED 4	12
Figure 4.7 Measurement return loss radiating element with No LED, and LED O and OFF State	N 13

Figure 4.8 2-D radiation pattern simulation and measurement without LED	47
Figure 4.9 2-D radiation pattern with and without LED	48
Figure 4.10 Soldered LED on the radiating element	51
Figure 4.11 Radiating Element with battery supply	51
Figure 4.12 Simulation return loss with permittivity 2.2 and 3.5	52



LIST OF TABLES

Table 1 Microstrip patch antenna parameters for 2.5GHz compare between Ro	gers
RT/Duroid 5880 and FR4 Epoxy [11]	9
ALAYSI.	
Table 2 Proposed radiating element parameter list	24
Table 3 New parameter list of radiating elements	27
Table 4 Simulation result of radiating element without LED (preliminary)	38
Table 5 Comparison of performance of radiating element without and with LED	44
اونيومرسيتي تيكنيكل مليسيا ملاك	
17	

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LIST OF SYMBOLS AND ABBREVIATIONS



HFSS : High-Frequency Structure Simulator

CHAPTER 1

INTRODUCTION



Nowadays, due to the high demand to use the integration of antenna, a new antenna concept is introduced to support wireless communication such as plasma antenna. However, the current issue with the plasma antenna is not environmentally friendly because it is known as an antenna with ionized gas enclosed in a tube that could harm the environment. Therefore, the project presents the Integration of Light Emitting Diode (LED) with the Printed WI-FI Radiating Element. The purpose of this project is to design the dual functionality of the device which is for wireless communication and illumination. This project also focused on the performance of the radiating element that can resonate at 2.4 GHz with the integration of the LED. The design is simulated in the Computer Simulation Technology software for testing out the performance of the radiating element that integrates with LED. At the end of this project, the fabricated design is measured its parameter in terms of the return loss, VSWR, bandwidth, and directivity during the condition LED is turned ON and OFF for both measurement and simulation results to analyze its overall performance of the design.

1.2 Problem statement

The growth of wireless communication systems is increasing at an amazing speed. The demand from the user and service provider is required to use especially the antenna that has high gain performance for wireless communication. The current issue that has been proposed for a long time is the matter of the performance of the antenna to achieve better bandwidth and directivity. The inconsistency of the antenna's performance would be unable to support especially for Wi-Fi applications. Even though the new concept of the antenna introduced was the plasma antenna which can support the wireless communication system, the limitation of the plasma antenna could bring harm to environmental uses. It was because inside the fluorescent tube that acts as a plasma element contains the mercury substance which is harmful to the surroundings if did not manage properly. The use of plasma antennas is not environmentally friendly. Therefore, the proposed solution is to develop a printed radiating element that can support Wi-Fi functionality.

The project design is also integrated with the Light Emitting Diode (LED) to enhance the antenna's performance. The project is designed through Computer Simulation Software (CST) and fabricated in the laboratory.

1.3 **Objectives**

The research is focused on the design of the radiating element integrated with the Light Emitting Diode at 2.4 GHz. The main objectives of this project:

- To design and optimize the radiating element integrated with Light Emitting Diode (LED) to have dual functionality in one device which is the illumination and wireless communication.
- 2. To verify the performance of the fabricated printed radiating element with LED in terms of Return Loss (S11), VSWR, bandwidth, and directivity.

1.4 Scope of project

The project scope is covered software, hardware, and equipment. The design of radiating elements is developed in the CST Microwave Studio. The parameters were verified in the simulation. The hardware components consist of material Rogers RT/Duroid 5880 substrate, Subminiature version A (SMA) Connecter, Battery AA of 3V, and Surface Mount Device (SMD) 5050 LED. Then, the design is fabricated using the wet etching technique. The design outcome is measured in the laboratory and the equipment used is Vector Network Analyzer and Anechoic Chamber room. The measurement is conducted during the condition of LED ON and OFF state. The operating frequency of 2.4 GHz is set as a benchmark for this project.

CHAPTER 2

BACKGROUND STUDY



2.1 Introduction UNIVERSITI TEKNIKAL MALAYSIA MELAKA

This section is explaining about the background study of the research which is the significance of the previous project taken to review and support this project's research regarding the radiating element. The project design needed to be an experiment so that it can support wireless communication and the addition of LED into the radiating element.

2.2 Microstrip patch antenna

A low-profile radio antenna that can be installed on a low surface is called a microstrip patch antenna. It is made by etching the antenna element pattern on the metal trace that is adhered to the dielectric to create a narrow band, wide beam-fed antenna. a substrate, like a printed circuit board, that has a continuous metal layer adhered to the side that faces the ground plane. In their conventional form, microstrip patch antennas are narrow-band devices. "The range of their impedance is typically 1% to 2%. This can be attributed to its resonant form, which allows it to transmit effectively only across a limited range of frequencies" [1]. "Even though microstrip antenna typically has a small bandwidth, it is widely believed to be ideal for many wireless applications. A ground plane is located on the opposite side of a dielectric substrate that has a radiating patch on one side" [2].

Over many years, a microstrip patch antenna has been developed into many shapes and patterns used for many applications demanded by people. One of the applications of microstrip antenna was commonly used for wireless communication. "It became widely useful among the antenna users because of its advantages such as lightweight, compact design and ease of fabrication" [3].

Because of how simple the microstrip patch structures are to make, microstrip analysis has become a significant research issue. In the twenty-first century, research on microstrip antennas focused on reducing size, improving gain, wide bandwidth, various functionality, and system-level integration. "Higher dielectric constants, which are less effective and lead to a narrower bandwidth, must be used to produce a small Microstrip patch antenna. Therefore, a balance between antenna size and performance is required" [4]. Figure 2.1 shows the structure of the microstrip patch.



Figure 2.1 Structure of microstrip patch antenna

2.3 Feeding technique for microstrip patch antenna

The feeding technique is one of the methods used to enhance the gain of the patch antenna. "To optimize the antenna input impedance matching and ensure the effective operation of the antenna, feeding plays an important role" [5]. The most basic feeding technique is microstrip line feeding. A microstrip line with a 50 Ohm impedance is joined to the patch, and the port is connected to the opposite end of the added microstrip line. This extra microstrip line serves as a feeder for the rectangular microstrip patch antennas. The length of the feeding line is unaffected by other factors, whereas the width is computed using older formulas for the same frequency and impedance of 50 ohms. In the previous findings mentioned case study works "the width of the microstrip feed line out to be around 3 mm and the feed line is measured in 10 mm" [6]. Figure 2.2 shows a rectangular patch with a microstrip feed line.



Figure 2.2 Rectangular patch antenna with the microstrip feed line

"The benefit of this type of feed arrangement is that the feed can be etched on the same substrate to create a planar structure" [7]. Although the findings have improved, it still not meets the criterion of an acceptable antenna response. As a result, the method is switched to the Microstrip inset feed technique.

Microstrip inset feed is a step forward from the microstrip feed line that was previously introduced. It is a form of microstrip line feeding technique that has the benefit of enabling a planar structure through the narrow width of the conducting strip relative to the patch. "The inset cut in the patch is designed to match the input impedance of the patch to the feed line without the use of any extra matching elements" [8] [9]. By correctly setting the inset cut position and dimensions, this can be accomplished. In these findings, a feed point is measured someplace on the surface of the rectangular patch where the patch's impedance equals the microstrip feed line's impedance of 50 ohms in this feeding approach. The feed cable is then connected to that specific antenna position. In general, the feed point where the rectangular patch's impedance is 50 ohms is at around one-third of the width and the length's center. Figure 2.3 show the microstrip inset-fed patch antenna design



Figure 2.3 Microstrip inset-fed patch antenna design

2.4 Rogers RT/ Duroid 5880

Rogers is a substrate that has a low dielectric constant and low dielectric loss, RT/ Duroid 5880 is ideal for high-frequency and broadband applications. "It is often advised to use the Rogers material, which has a dielectric constant value of 2.2 when building a microstrip patch antenna" [10]. By utilizing these materials, the designing parameters' values are lowered, the antenna's size is almost within the small range, and the maximum radiation pattern is produced along the structure's transmission side. The cost of the designing process is cheap, the antenna's complete structure is simplified, and the microstrip patch antenna's output is improved using these materials.

2.4.1 Microstrip patch antenna using substrate Rogers RT/Duroid 5880

The review has been done on a design and simulation of a rectangular microstrip patch antenna operating at a frequency of 2.5 GHz for wireless communication that has a broad beam radiation pattern. The Rogers RT/Duroid 5880 material is used as a substrate during the designing process, and the coaxial probe feed method is used to provide the antenna's excitation value in comparison to Flame Retardant 4 (FR4) Epoxy. The High-Frequency Structure Simulator (HFSS) program is used to design and implement the antenna because it has numerous practical applications, including WLAN and WI-FI. Using the HFSS program, the rectangular microstrip antenna was calculated and examined over a frequency range of 2.5GHz. The results viewed the parameters of the antenna, and the frequency response is achieved as shown in Table 1.

QUANTITY	Rogers RT/duriod	FR4 Epoxy
	5880	
Gain (dB)	9.8475	3.6475
Directivity(dB)	9.3172	3.6457
Peak gain(dB)	8.9800	4.3251
Peak	9.9631	4.3622
directivity(dB)		
Peak realized	3.1432	1.2356
gain(dB)		
VSWR	9.9998	3.6589
Radiation	1.6993	1.3691
efficiency(dB)		

Table 1 Microstrip patch antenna parameters for 2.5GHz compare between Rogers RT/Duroid 5880 and FR4 Epoxy [11]

2.5 Slots loaded on microstrip patch antenna

The previous finding explained a method for microstrip antennas to function better by containing loading slots on the patch, suitable feed positions, and radiating patch design rules. The first method explains the design rules which is the equation of the patch for a rectangular shape. "For rectangular patch, the width of the patch(W) is depending on the resonant frequency(fr) and dielectric constant(ϵr) of the material" [12]. Next, the suitable feed position using is the coaxial feed position for the microstrip patch antenna. In a coaxial feed, the inner conductor is linked to the radiating patch and the outside conductor to the ground plane. The feed point needs to be in the right place for the transmission line and port's impedances to meet.



Figure 2.4 Slot loaded and coaxial feed rectangular microstrip patch antenna [12]

Additionally, the slot on the patch must be loaded with the correct dimensions to improve the performance of the antenna, the value of the parameter may go wrong if it is set up incorrectly. In fact, "the performance parameter of the antenna is mostly affected by the slots loaded on the patch, and slotting is required to increase bandwidth" [13].

2.6 Light Emitting Diode

LED stands as Light Emitting Diode is a vibrant, durable, and dense lighting source. When they provide high light levels, less heat is produced, saving electricity. Since its invention in the 1960s, LEDs have grown consistently quickly in terms of efficiency, attainable emission spectrum, higher power, higher speed, and implementation approaches. LEDs have quickly gained popularity in a range of applications [14].

2.6.1 Surface Mount Device LED

Surface Mount Device Light Emitting Diode is referred to as SMD LED.

It is a chip-shaped light-emitting diode. The SMD LED is an LED that can be installed directly on a Printed Circuit Board (PCB) or light strips because surface mount devices are those that can be mounted on PCBs with ease.



Figure 2.5 SMD 5050 LED

2.6.2 The stacked antenna integrated with ring LED

"The method describes a stacked configuration technique to enhance antenna performance while reducing the impact of changing resonant frequency caused by the addition of more parasitic elements at the antenna structure" [15]. A previous study has been developed on the design of a stacked antenna integrated with ring LED. It was operated at 2.45 GHz. "A development of LED has several benefits, especially in terms of green technology, low power consumption, and simple integration. The next generation of incandescent and fluorescent lights are expected to be replaced by LEDs, which are also expected to play a significant role in future indoor lighting" [16] [17]. The previous study also states, "the performance of the antenna in terms of frequency response will be affected by the LED". In this study, simulated and measured results are compared to identify the achievability of the integrated antenna. The result is shown in Figure 2.6 and Figure 2.7 regarding the return loss performances with and without LED.





LED



Figure 2.7 Return loss stacked antenna integrated with the ring LED

2.6.3 The microstrip monopole antenna integrated with LED

Previous research has developed a microstrip monopole antenna integrated with a light-emitting diode (LED). The study reviews the design of an antenna that is based on the monopole antenna and operated at 3.6 GHz. "Green technology, which is environmentally friendly, is supported by the usage of LED. Since the power consumption of LED is lower than that of incandescent and fluorescent lamps, it is being used to replace them in the future generation" [18]. Other advantages of employing LEDs over traditional light sources are their extended lifespan, great luminosity, increased efficiency, and ease of maintenance. The objective of this research is wireless communication and illumination. The result obtained is when the condition of LED ON and OFF is measured in its parameters. The improvement of this work is needed to enhance the gain of the antenna since, during the ON state, the gain drops drastically. The result can be seen in Figure 2.9 for return loss performance.



Figure 2.8 Layout of microstrip monopole antenna integrated with LED



Figure 2.9 Measurement 4 LED in parallel of microstrip monopole antenna

integrated with LED

2.7 Summary

All the review of the background study above is important to this project research. The review was necessary as the key to supporting the current project is to design the radiating element with the integration of LED. The design mostly is referred to the method of the previous research with the addition of new techniques for better performance.



CHAPTER 3

METHODOLOGY



3.1

UNIVERSITI TEKNIKAL MALAYSIA MELAKA This section comprises a detailed explanation of the methodology that is being

used to make this project complete and work well. Many methodologies or findings from this field are mainly generated in the journal for others to improve the upcoming studies. The method is used to achieve the objective of the project that will accomplish the desired result. Project planning, flowchart, Gantt chart, milestone, and detailed description of methodology research are used to show the activities performed during the duration of the project.

3.2 Project planning

The project research starts by reviewing the study background of the previous research to make a new design or improvement of the older design. It was to verify the parameter of the radiating element which can also support the Wi-Fi application. In designing the model, a mathematical equation is needed to determine the dimension of the radiating element required. The radiating element is designed in CST Studio. The substrate used in this project is Roger RT 5880 with the permittivity of $\epsilon r = 2.2$, thickness h = 1.575 mm. In the process, the dimension of the radiating element is calculated automatically through software by setting up the input value and the description until the shape of the design is created. Primarily, the plan is to design the rectangular shape of the microstrip patch by adding the element of the feeding method which is the inset feed. Furthermore, there are two slots between the patch pattern for LED to be inserted in that location. Two conditions of the patch are designed in the slotted area.

Then, the simulation is run and optimized until the desired frequency is

obtained. Finally, the fabrication part is conducted to get the physical hardware of the project. The testing section is running through Vector Network Analyzer (VNA) in the laboratory and measured also in the Anechoic Chamber room. After that, the soldering process involved SMD LED and port SMA connectors that are soldered onto the patch. The measurement was taken to compare the simulation and actual results obtained.

3.3 Project flow chart

This is a flow of the project which is to show the method of this project process in development to achieve the aims of the expected result.



Figure 3.1 Project flow chart

3.4 Project Gantt chart

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Figure 3.2 Project Gantt chart

3.5 Detail description of the methodology research

To achieve the objectives, some steps need to be considered for the research. The explanation of the process flow of the project is described step by step in the following order.

3.5.1 Studies of literature reviews

The review related to the previous work is done regarding the significant study of the future design for analyzing the parameter in terms of the return loss, VSWR, bandwidth, and directivity. The studies also developed the feeding method to use for the radiating element. The research is done regarding the pattern design and effect of LED integrated with the antenna contributed to the performance antenna's performance.

To begin the design of the radiating element, the first thing that needs to be considered before planning is to design the model in the software using a mathematical formula equation for calculation. The equation is to determine the dimension required for the design model. Firstly, before calculating the dimension, a parameter such as a permittivity, operating frequency, the type of substrate, and the height of substrate needs to be specified.

Width:
$$W = \frac{Vo}{2fr} \sqrt{\frac{2}{\epsilon r+1}}$$
 (1)

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



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Figure 3.3 Layout of rectangular microstrip patch antenna
3.5.2 Design and simulation of the radiating element integrating with LED

The design of radiating element with LED operated at 2.4 GHz and simulated in the Computer Simulation Technology (CST) Software. The input value is inserted into the software to design the patch. The design is viewed in a 3-D perspective in the software. The rectangular shape of the microstrip patch is designed by adding the feeding method element to optimize the performances and parameters obtained. There were a few steps taken to design the Radiating Element using CST Studio. But, before starting to create a design, three main materials of the patch antenna need to be considered first.

i. Substrate

The substrate is a base on which a microstrip patch (metallic sheet) antenna is produced, and it is critical to the operation of the antenna. In microstrip antennas, the substrate is primarily used to sustain the antenna mechanically. The substrate should be made of a dielectric material to offer this support, as the electrical performance of the antenna, circuits, and transmission line may be affected. As a result, a substrate must meet both electrical and mechanical requirements at the same time, which can be challenging.

ii. Ground

The antenna ground plane acts as a simulated ground, as the name implies. The ground acts as a plane to reflect the radio waves for a monopole antenna like a quarter wavelength vertical, resulting in an image of the top half of the antenna being visible on the Earth. This function can be simulated by replacing the real earth with a conductive plane. The conducting surface must extend at least a quarter wavelength from the antenna base to operate as an antenna ground plane.

iii. Patch

A patch, which is a very thin metallic strip or sheet placed above the ground plane and separated by a substrate made of a dielectric substance, makes up a microstrip antenna. The dielectric constant and height of the substrate both affect how well microstrip antennas perform. For thick substrates with lower dielectric constant substrate materials, microstrip antenna performance is good. The main drawback of microstrip antennas is that they have a narrower impedance bandwidth on thin substrates. However, the antenna size should be tiny for handheld devices and wireless communication, and for that, the height of the substrate should be as low as feasible. A patch antenna is also a low-profile radio antenna that can be installed on a flat surface. A rectangular, circular, triangular, or any other geometrical sheet or "patch" of metal is installed over a larger sheet of metal called a ground plane. Figure 3.4 shows the layer materials arrangement for the patch antenna





Firstly, the new project from the template given is created. The project template under the Microwaves and RF Optical section is chosen, and then the type of Antenna is selected.



Figure 3.5 Project template from CST Studio

Next, there is frequency selection which needs to be decided for the antenna operation. In this project, a frequency of 2.4 GHz is selected. Figure 3.6 shows the platform where the design started to be developed.



Figure 3.6 The platform for the design of the radiating element

Then, to make the work easy before starting to design, it is better to make a parameter list for the dimension of the radiating element viewed in Table 2.

Name	Value (mm)	Description		
wg	80	Width of the ground plane		
lg	80	Length of the ground plane		
hc	0.018	Height of copper cladding layer		
hs	1.575	Height of substrate		
wp	47.6	Width of patch		
lp	40	Length of patch		

Table 2 Proposed radiating element parameter list

After setting up the parameter list, in the modeling section, the ground, the substrate layer, and the patch is designed by inserting the input into the brick as shown in Figure 3.7. The brick is the place to create the geometrical dimension of the object shape. It can also choose the material type to use for the object such as metal, copper, or any substrate materials.

Name:		ОК
Veries		Cancel
0	0	Preview
Ymin:	Ymax:	Help
2min:	Zmax:	
Component:		
Antenna	~	

Figure 3.7 The brick for inserting input parameter value for dimension



Figure 3.8 Rectangular microstrip patch with SMA connector

The basic design of the microstrip patch is designed in rectangular shape according to the equation followed. After the following adjustment to the design's dimension, the design is created to be more promising by adding the feeding method (inset feeding) and the slotted between the patch patterns. That method is required to be implemented for improving the bandwidth of the patch. The SMA connector is also included as part to connects the radiating element not only physically but also electrically. These microwave connections are impedance matched, with a 50-ohm impedance that is required for most radio frequency circuits. A properly matched connector ensures that the antenna's radio frequency signals are not influenced by discontinuities, which can result in signal interference. SMA antennas are frequently employed in applications involving microwave or sub-microwave wavelength. Figure 3.9 and Figure 3.10 shows the proposed design of radiating element.



Figure 3.9 Top view design 1 of the radiating element wg wp 47.60 mm ś Ş 5.00 mm UNIVE YSIA MEL K 80.00 mm 40.00 mm lp lg 4.88 mm

Figure 3.10 Top view design 2 of the radiating element

The next phase design of radiating element is the augmented version of the previous design. The first and second designs involved simulation only. The third version of the design is the integration of LED with the radiating element and fabricated using the wet etching technique. Table 3 shows the new parameter list of modified dimensions. Design 3 of radiating element shows in Figure 3.12 and Figure 3.13.

Name	Value (mm)	Description		
wg	65	Width of the ground plane		
lg	65	Length of the ground plane		
hc H	0.018	Height of copper cladding layer		
hs E	1.575	Height of substrate		
wp	50	Width of patch		
lp 🎒	کل ۵۰ پسیا ما	Length of patch		

Table 3 New parameter list of radiating elements

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Figure 3.11 Design 3 of the radiating element without LED



Figure 3.12 Design 3 of the radiating element with LED

3.5.3 Fabrication of the radiating element with LED

The fabrication process is performed in the laboratory by using suitable substrates for the material such as Rogers RT/Duroid 5880 with permittivity of εr =2.2 and thickness, h =1.575 mm. The wet etching technique is applied to fabricate the design. The fabrication procedure:

1. Firstly, the design has been exported from the CST software to get the actual physical size of the design that needed to be fabricated.



Figure 3.13 Printed design from software

2. Secondly, the lamination of the substrate is done by laminating the negative film photoresist on both sides of the substrate so that the negative film is properly patched onto the surface of the substrate.



Figure 3.14 Dry Film Sheet Laminator

3. Then, the substrate is exposed to UV exposure with the printed design put on the surface of the substrate.



Figure 3.15 UV Exposure

4. Next, the etching process is started by removing the negative film photoresist on the substrate using the Double-Sided Spray Etching Machine.



Figure 3.16 The process before and after the patch is put into the etching

machine

5. After that, the patch is rinsed with clean water until the unwanted layer is removed. This process is repeated by putting it again into another type of etching machine to completely remove the unwanted layer that is stuck on the surface of the patch.



Figure 3.17 Rinse and remove the unwanted layer of the patch

6. Lastly, the patch is dried using the Conveyorized Drying Oven Air, and the fabrication process is completely done.



Figure 3.18 Dry the patch using Conveyorized Drying Oven Air

Another part involving the soldering process regarding the placement of LED onto the patch is done in separate work. Six SMD LEDs were used and slotted between the radiating element. SMD 5050 LED, which is white LED, is the type of LED used in this design. The LED's dimension and size are 5 mm which are the same in simulation and production. The necessary total voltage is lower than that for a series connection because the LEDs were connected in parallel. 3V is the total voltage needed to turn on all the LEDs.



Figure 3.19 Real SMD5050 LED and simulation LED

3.5.4 The measurements using Vector Network Analyzer and Anechoic Chamber

The result analyzed the effect of LED integration with the printed WI-FI radiating element when the LED is ON state and OFF state to observe and compare the parameters between both the measured and the simulated result of the design. The results for return loss, VSWR, and bandwidth are measured using Vector Network Analyzer while the radiation pattern is measured in the Anechoic Chamber room as shown in Figure 3.20 and Figure 3.21



Figure 3.20 Measured the radiating element using Vector Network Analyzer



Figure 3.21 Measured the radiation pattern in the Anechoic Chamber room

3.6 Summary

A details explanation of the methodology that is being used to make this project complete is covered. The method is used to achieve the objective of the project to accomplish a good result. By completing this chapter, the flow chart, Gantt chart, and milestone clearly explained the flow of the project and the activities shown performed during the duration of the project.

CHAPTER 4

RESULTS AND DISCUSSION



In this chapter, the preliminary simulation result is shown for the early performance of radiating element in terms of return loss, VSWR, and bandwidth. Then, after optimization, the measurement is taken after the fabrication process of the design. The measurement is observed between both radiating elements with and without LED.

4.2 Preliminary simulation result analysis

The preliminary result is based on the radiating element of design 1 and design 2 through simulation. Only return loss, VSWR, and bandwidth were taken to compare the early performance.



Figure 4.1 Return loss for designs 1 and 2 of radiating element without LED

In Figure 4.1, the frequency at 2.32 GHz shows a return loss of -23.67 dB is indicated for design 1. At a frequency of 2.40 GHz, the return loss shows -29.40 dB for design 2. Design 2 shows the return loss is greater than -10 dB and is well performed to the corresponding frequency which is at 2.4 GHz. To prove the simulation result obtained is the same as the theoretical calculation. The VSWR and bandwidth were calculated based on the results taken in the simulation. If VSWR is known, the following formulas are used to determine the reflection coefficient (Γ), return loss (RL), and mismatch loss (ML).

Design 1:

Reflection Coefficient, $r = \frac{VSWR - 1}{VSWR + 1}$, $r = \frac{1.1402523 - 1}{1.1402523 + 1} = 0.0655307$

Return Loss, $RL = -20 Log_{10}(r)$, $RL = -20 Log_{10}(0.0655307) = 23.6711 dB$

Mismatch Loss, $ML = -10Log_{10}(1 - r^2)$, $ML = -10Log_{10}(1 - 0.0655307^2) = 0.0187 dB$

Bandwidth at -10 dB, BW = f2 - f1, BW = 2.3455 - 2.3127 = 32.8 MHz

Design 2:

Reflection Coefficient, $r = \frac{VSWR - 1}{VSWR + 1}$, $r = \frac{1.0702075 - 1}{1.0702075 + 1} = 0.0339166$

Return Loss, $RL = -20 Log_{10}(r)$, $RL = -20 Log_{10}(0.0339166) = 29.3917 dB$

Mismatch Loss, $ML = -10Log_{10}(1 - r^2)$, $ML = -10Log_{10}(1 - 0.0339166^2) =$

 $0.005 \ dB$

Bandwidth at -10 dB, BW = f2 - f1, BW = 2.4186 - 2.3848 = 33.8 MHz

Design	Design 1	Design 2
Parameter		
Frequency (GHz)	2.33	2.40
Return Loss (dB)	-23.67	-29.40
Bandwidth (MHz)	32.80	33.80
VSWR	1.14	1.07

 Table 4 Simulation result of radiating element without LED (preliminary)

The overall comparison of designs 1 and 2 has been summarized in Table 4. The return loss results show design 2 has better performance than design 1 because design 2 did meet the required operating frequency which is measured at 2.40 GHz. The bandwidth of both simulated designs shows a bit significant value while for VSWR, design 2 has a value of 1.07 which is near the ideal value. However, VSWR for design 1 is still acceptable since the value is below 2. When the return loss is greater than -10 dB, it has a good VSWR which is less than the value of 2.

38

4.3 Simulation and measurement result

The simulation and measurement results are obtained through design 3 in which LED placement is involved. Design 3 is officially called by name of the radiating element. The measurement is taken after the fabrication process to compare both performances between simulation and measurement.

4.3.1 Design outcome

The outcome of the design becomes the physical product after the fabrication involved and the soldered process of LED placed on the slotted area between the radiating elements. In addition, the radiating element with LED is supplied by an external battery of 3V to turn ON the 6 LEDs.



Figure 4.2 Radiating element without LED



Figure 4.4 Radiating element with LED ON state

4.3.2 Experimental result

The result analysis was collected to observe all the comparisons of parameters given return loss, VSWR, bandwidth, and directivity. The analysis involved simulation and measurement with and without LED. In addition, measurements during LED ON and OFF states were also taken.

4.3.2.1 Return loss, dB

One of the essential factors that are used to measure the amount of reflected power from the antenna is caused by an impedance mismatch. The antenna's return loss is 0 dB if the input power and the reflected power are both equal. Only when the return loss is extremely minimal is the antenna considered to be efficient.



Figure 4.5 Simulation and measurement return loss radiating element without LED

Figure 4.5 shows the return loss of -18.811 dB at 2.413 GHz is indicated for the simulation result. The measurement result shows a return loss of -18.707 dB at 2.730 GHz. The value signifies the simulation without LED has a slightly greater return loss than the measurement without LED.



Figure 4.6 shows the return loss of -17.690 dB at 2.407 GHz is directed for the simulation result. For measurement, it shows the return loss at -20.509 dB for 2.830 GHz. The value implies the simulation with LED remains at 2.4 GHz while measurement with LED had shifted its frequency even though the return loss is slightly greater than the simulation.



Figure 4.7 Measurement return loss radiating element with No LED, and LED ON and OFF State

In this case, the findings distinguished the return loss result of the radiating element with No LED, during the condition of LED ON, and OFF. Figure 4.7 shows the return loss of -18.707 dB at 2.730 GHz is implied for No LED placement while the return loss of -20.509 dB at 2.830 GHz is when the LED is turned OFF. The return loss at -22.943 dB for 2.83 GHz is when the LED is turned ON. The measurement shows the shifted frequency is about 0.1 GHz between with and without LED placement.

Design	Without LED		With LED		
Parameter	Simulated	Measured	Simulated	Measured	Measured
				OFF State	ON State
Frequency (GHz)	2.413	2.730	2.407	2.830	2.830
Return Loss (dB)	-18.811	-18.707	-17.690	-20.509	-22.943
Bandwidth (MHz)	26.30	10.00	32.40	105	125
VSWR	1.259	1.250	1.300	1.200	1.220
Directivity (dB)	5.079	6.819	5.060	6.957	6.957

 Table 5 Comparison of performance of radiating element without and with LED

From Table 5, it is observed that the measured results for radiating elements without LED are in proximity to simulated results. While with LED condition, the measured results were considered in the acceptable range even though the measured frequency is slightly shifted from the simulated frequency.

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UNIVERSITI TEKNIKAL MALAYSIA MELAKA 4.3.2.2 VSWR and bandwidth calculation

Calculation of VSWR is done to prove the reflection coefficient, mismatch loss, and return loss has approximated values near the measurement taken. In addition, the bandwidth results can be achieved by referring to the S11 parameter.

If VSWR is known from the simulation and measurement result, the following formulas are used to determine the reflection coefficient (Γ), return loss (RL), and mismatch loss (ML).

Simulation radiating element without LED

Reflection Coefficient,
$$r = \frac{VSWR - 1}{VSWR + 1}$$
, $r = \frac{1.259 - 1}{1.259 + 1} = 0.1147$

Return Loss, $RL = -20 Log_{10}(r)$, $RL = -20 Log_{10}(0.1147) = 18.809 dB$

Mismatch Loss, $ML = -10Log_{10}(1 - r^2)$, $ML = -10Log_{10}(1 - 0.1147^2) = 0.0575 \ dB$

Bandwidth at -10 dB, BW = f2 - f1, BW = 2.4271 - 2.4008 = 26.3 MHz

Simulation radiating element with LED

Reflection Coefficient, $r = \frac{VSWR-1}{VSWR+1}$, $r = \frac{1.30-1}{1.30+1} = 0.1304$ Return Loss, $RL = -20 \ Log_{10}(r)$, $RL = -20 \ Log_{10}(0.1304) = 17.694 \ dB$ Mismatch Loss, $ML = -10 \ Log_{10}(1 - r^2)$, $ML = -10 \ Log_{10}(1 - 0.1304^2) = 0.0745 \ dB$

UNIVERSITI TEKNIKAL MALAYSIA MELAKA Bandwidth at -10 dB, BW = f2 - f1, BW = 2.4251 - 2.3927 = 32.4 MHz

Measurement radiating element without LED

Reflection Coefficient,
$$r = \frac{VSWR - 1}{VSWR + 1}$$
, $r = \frac{1.25 - 1}{1.25 + 1} = 0.1111$

Return Loss, $RL = -20 Log_{10}(r)$, $RL = -20Log_{10}(0.1111) = 19.086 dB$

Mismatch Loss, $ML = -10Log_{10}(1 - r^2)$, $ML = -10Log_{10}(1 - 0.1111^2) = 0.0539 \, dB$

Bandwidth at -10 dB, BW = f2 - f1, BW = 2.735 - 2.725 = 10 MHz

Measurement radiating element LED OFF State

Reflection Coefficient, $r = \frac{VSWR-1}{VSWR+1}$, $r = \frac{1.20-1}{1.20+1} = 0.0909$ Return Loss, $RL = -20 \ Log_{10}(r)$, $RL = -20 \ Log_{10}(0.0909) = 20.829 \ dB$ Mismatch Loss, $ML = -10 \ Log_{10}(1 - r^2)$, $ML = -10 \ Log_{10}(1 - 0.0909^2) = 0.0360 \ dB$

Bandwidth at -10 dB, BW = f2 - f1, BW = 2.895 - 2.79 = 105 MHz

Measurement radiating element LED ON State

Reflection Coefficient, $r = \frac{VSWR - 1}{VSWR + 1}$, $r = \frac{1.22 - 1}{1.22 + 1} = 0.0991$

Return Loss, $RL = -20 Log_{10}(r)$, $RL = -20Log_{10}(0.0991) = 20.079 dB$

Mismatch Loss, $ML = -10Log_{10}(1 - r^2)$, $ML = -10Log_{10}(1 - 0.0991^2) = 0.0429 \ dB$

Bandwidth at -10 dB, BW = f2 - f1, BW = 2.915 - 2.79 = 125 MHz



Figure 4.8 2-D radiation pattern simulation and measurement without LED

In the radiation pattern obtained in Figure 4.8, the directivity is observed between simulation and measurement without LED. The directivity for simulation was viewed at 5.079 dB while the measurement was at 6.819 dB. Although directivity was favored in measurement, the directional radiation pattern by simulation is greater than the measurement result.



Figure 4.9 2-D radiation pattern with and without LED

The measurement results are taken for the 2-D radiation pattern less satisfied than the pattern that has already been achieved by the simulation result. Figure 4.9 shows the measurement taken is low on performance. The directional radiation pattern for measurement with LED is greater than without LED. The directivity for both with and without LED was the same at 6.957 dB.

4.4 Summary

To put it concisely, all the results gathered by measurement are less impressive than expected because of external factors. Nevertheless, the comparison made for the 2-D radiation pattern can be plotted to distinguish the results for the data analysis.

4.5 Discussion

The findings perceived the performance of parameters for simulation was better than the overall measurement taken because the measurement results were unable to obtain the operating frequency of 2.4 GHz and the outcome frequency achieved was 2.730 GHz and 2.830 GHz correspondingly for both radiating elements without and with LED. During the ON and OFF state, the frequency maintains at 2.830 GHz. Even though the frequency is shifted by 0.3 GHz from the simulation result, the return loss for radiating element with LED ON and OFF state was slightly greater than radiating element without LED for both simulation and measurement.

The reason for the frequency shift by 0.3 GHz from the simulation result is because of the factor dimension of the patch which gives major influences on the frequency behavior. Possibly the shifted frequency happened because of physical hardware dimension is not accurate enough. So, the solution needed is to adjust the patch length to get an accurate operating frequency.

From the simulation and measurement, the VSWR value is taken and analyzed in its calculation. The voltage standing wave ratio (VSWR) is a measurement of how well radio frequency energy is transferred into a load. If a power amplifier is linked to an antenna through a transmission line, there should be no reflections and all of the power amplifier's signal should be transferred to the antenna. VSWR is the measure of how much signal gets reflected into the system. It is the ratio between transmitted and reflected waves. A high VSWR indicates poor transmission-line efficiency and reflected energy. From the 2-D radiation pattern, it can be said that measurement results for the overall radiating element with and without LED turned out imperfectly displayed. The expected pattern that should be happened is unachievable. The reason might be the performance of the radiating element is unfavored. However, the measurement directivity was higher than the simulation.

The outcome of the design after the fabrication process was not good enough, so another fabrication needs to be done. The reason was the fabrication of the design can only use the photolithographic method to produce the physical outcome because there was no equipment and facilities to produce a better physical design. The unneeded metal areas of the metallic layer are removed using the photolithographic method, a chemical etching technique. The microstrip patch's etched pattern is produced using a highly accurate photolithographic technique. Since microstrip patch antennas are narrow-band resonant structures that typically operate in the microwave spectrum, fabrication precision is extremely important. The resonance frequency of the patch will change due to fabrication flaws in its dimensions.

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Frankly, during the soldering process, the difficulties that occurred when soldering LED, the amount of solder lead, and flux need to be considered cautiously. It was because soldering had too many major influences on the performance of the radiating element. The suggestion should use an air soldering iron as an alternative method to solder SMD LED on the patch. Figure 4.10 shows the soldered LED on the radiating element.



Figure 4.10 Soldered LED on the radiating element

There was a minor discovery that interrupted the resonance frequency during measurement taken at the lab which is the battery that was used as supply to the LED power source affected the result performance when put near the radiating element. The result will not be affected if the battery is far away from the radiating element. The battery supply with radiating elements is shown in Figure 4.11.



Figure 4.11 Radiating Element with battery supply

Furthermore, there was an alternative experiment as an attempt to improve the performance of the design by trying a different permittivity of substrate Rogers 5880 which is 3.5. The return loss is shown in Figure 4.12. The frequency shift decreased by 0.36 GHz which is a frequency of 2.413 GHz with a permittivity of 2.2 and 2.050 GHz with a permittivity of 3.5. The result turned out to be a failure because the same pattern was used in the original design. The suggestion necessary to obtain the ideal frequency which is tuned to 2.4 GHz was by possibly need to decrease the length of the patch and changing the overall design pattern of the original design.



Figure 4.12 Simulation return loss with permittivity 2.2 and 3.5

The radiating element is a type of printed antenna that is created using common photolithography technology. It emitted radiation energy and the relative field strength transmitted from or received by the antenna is graphically represented by the radiation pattern. The relationship of the radiating element effect to the environment is a communication-based application. In addition, because the radiating element is integrated with LED, the effect on the environment is just for illumination. The microstrip patch antenna has many uses in wireless communication. For instance, circularly polarized radiation patterns are needed for satellite communication and can be achieved using either a square patch microstrip antenna or a circular patch microstrip antenna. Due to their placement, they are highly pricey and quite small.

The relationship of this project with the Sustainability Development Goals number 9 is related to industry innovation and infrastructure. The SDG target 9.8, states that "universal access to information and communication technology. It means increasing access to information and communications technology significantly, and by 2020, work to make Internet access universal and reasonably priced in the least developed nations" [20]. So, this project is to have wireless communication which is internet access to all people.

To sum up the discussion, the result appeared undesirable outcome by assessing all the data analysis that has been done in the result and discussion part. The causes for radiating element's low performance are due to the connection of the LED to the patch may going wrong and the possibility has a short circuit or interference radiation that cannot be identified and observed with sight.

CHAPTER 5

CONCLUSION AND FUTURE WORKS



5.1 Conclu

The process to complete the project as planned is tricky because of the many problems and obstacles encountered. After several months of development and improvement, the project was able to be completed successfully, however, the performance of the outcomes is less satisfying than expected standards. Nevertheless, the project's aim and main objectives have been partially accomplished. Even though the result obtained cannot prove that LED improves the performance of the antenna, it does not mean that LED cannot affect the patch. It was proved by LED is used for illumination purposes and affected the parameter's performance. The Printed Wi-Fi Radiating Element Integrating with LED is mainly the patch antenna that is used for Wi-Fi connection and the addition of illumination from LED. The research was made from the previous study to learn and improvised the performance of the antenna when the radiating element is integrated with LED. The requirement of LED is needed for integration because a study stated that LED improves the antenna's bandwidth. Using the small radiating patch will interest the user or client to buy it. Moreover, it gives an illumination effect to the environment plus the cost of the patch is cheap, and the size is small. Therefore, such a reason is enough for them to be interested in using this kind of antenna because higher directivity equals higher signal connectivity.

This paper has brought to light a variety of challenges and obstacles encountered when developing such a system. Overall, the development of the final project has been halfway completed.

5.2 Future works

This project has a lot of room for improvement. Although the design has already been created and optimized, many more features can be added and adjusted to the design to ensure its flawless performance.

One of the weaknesses of this Radiating Element is the substrate Rogers 5880 used at that time is an old material that had been used to create the physical hardware. It was because there was a limited resource to use the specific substrate. Therefore, the suggestion should use another specification of the substrate such as Rogers but with different permittivity. The old material should not be used for the project because the material properties are sensitive to the environment surrounding it. After all, this kind of material is quick to oxidize.

Another suggestion is to create a new brand pattern for this project because even though the simulation was good enough to be performed, the measurement is disfavored. Hence, the design pattern and calculation should be carefully studied to get better performance. In addition, when soldered LED onto the patch, the amount of solder lead, and flux need to be considered because it will affect the signal if put too much.

The issue of this project has been thoroughly analyzed in this chapter, and the issues that arose have been addressed using a few techniques that can stop future occurrences of the issues that could cause the project to fail. The next section makes a few recommendations for more research that will help the field advance and grow so that future generations can utilize this project as a model and create high-caliber outcomes.

EKNIKAL MALAYSIA MELAKA

56
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