DUAL-BAND PLANAR INVERTED-F ANTENNA WITH U-SLOT PATCH FOR WIRELESS BODY AREA NETWORK (WBAN)

UNDERGRADUATE THESIS

Arranged in order to fulfill one of the requirements to complete
Undergraduate Study Program Telecommunication Engineering

Arranged by
ABDURRAHMAN GHIFARI
1101164459

FACULTY OF ELECTRICAL ENGINEERING
TELKOM UNIVERSITY
BANDUNG
2019

APPROVAL PAGE
UNDERGRADUATE THESIS

DUAL-BAND PLANAR INVERTED-F ANTENNA WITH U-SLOT PATCH FOR WIRELESS BODY AREA NETWORK (WBAN)

is verified and approved as an undergraduate thesis
Telecommunications Engineering
School of Electrical Engineering
Telkom University
Bandung

Abdurrahman Ghifari
1101164459

Bandung, April 5 2019
approved by:

Supervisor I	Supervisor II
Agus Dwi Prasetyo, S.T., M.T.	Trasma Yunita, S.T, M.T.
14850066	17860112

ORIGINALITY STATEMENT

Nama	:	Abdurrahman Ghifari
NIM	:	1101164459
Alamat	:	Antapani Lama Streets, Mitra Residence Comp. No C.18
No. Telepon	:	082217799345
Email	:	duulzg@rocketmail.com

Regarding with The Final Thesis is an original work, with the title :

ANTENA PLANAR INVERTED-F DUAL BAND DENGAN PATCH SLOT U UNTUK *WIRELESS BODY AREA NETWORK*(WBAN)
DUAL-BAND PLANAR INVERTED-F ANTENNA WITH U-SLOT PATCH FOR WIRELESS BODY AREA NETWORK (WBAN)

For this statement, I am ready to bear the risk /sanction imposed on me if it is found that there is a violation of academic honesty or scientific ethics in this work, or found evidence that shows the authenticity of this work.

Bandung, April 9 2019

Abdurrahman Ghifari
1101164459

ABSTRACT

The technology has grown significantly supporting a range of applications in every sectors such communication and medical sectors. Wireless Body Area Network(WBAN) is a one of the innovation. WBAN is a special purpose sensor network designed to operate autonomously to connect various sensors and appliances. One of the component for WBAN is data base external to perform its transmitting and receiving the data from the sensor with its antenna.

Data base external of WBAN needs the antenna that can be compatible for its device. The antenna has to be small dimension, light weight, ease realization, and low profile specification that can be beneficial in the implementation of antenna for WBAN and save for human body. The antenna has to work on two resonance frequencies, 900 MHz and 2.4 GHz for WBAN configuration. Based on existing PIFA research, PIFA is a microstrip antenna that can be designed to be a multi-band antenna, work in wide range frequency, and decrease the occupancy required area. The addition of U-slot is also needed to make a multi-band frequencies. PIFA antenna can fulfil the needs for data base external of WBAN.

This undergraduate thesis focused on design, simulate, fabricate, and measure the PIFA for WBAN's data base external antenna with a Dual-Band frequency. This PIFA is focused where the resonance frequency are 900 MHz and 2.4 GHz, and also return loss is less than -10 dB. The result that obtained on this undergraduate thesis is fulfilled the requirement, but the resonance frequency got shifted to 820 MHz and 2.37 GHz with its return loss -16 dB and -19 dB.
Keywords: PIFA, Dual-Band, microstrip antenna, WBAN.

PREFACE

Alhamdulillahirobbil ‘alamin, Praise is merely to the Almighty Allah SWT for the gracious mercy and tremendeous blessing that enables me to accomplish this bachelor thesis entitled: Dual Band Planar Inverted-F Antenna for Wireless Body Area Network (WBAN). This undergraduate thesis is presented to fulfill one of the requirements in accomplishing S-1 Degree in Telecommunication Engineering Study Program, Faculty of Electrical Engineering, Telkom University Bandung.

I would like to express my special appreciation to my first supervisor, Agus Dwi Prasetyo S.T, M.T. and my second supervisor, Trasma Yunita, S.T, M.T. for their valuable assistance and inspiration to the completion of this bachelor thesis.

The greatest honor and appreciation would be finally dedicated to my beloved parents, family, and best friends. It is truly undoubted that loves, cares, spirits, motivation, patience and willingness to wait for my graduation and timeless prayers during days and nights are everything for me.

Bandung, April 9 2019

Abdurrahman Ghifari

ACKNOWLEDGE

On this occasion, the author would like to sincerely thanks and grateful to the all parties who have been involved to support and assist in the process of this undergraduate thesis. These expression of gratitude are addressed to:

1. Allah SWT formercy, guidance, and pouring his infinite grace and always provide the best for His servants

2. For two important people in my life, Ayah dan Ibu. The author wants to say: "*Terima kasih untuk selalu mendoakan, menyayangi, sabar, dan mendukung apapun dengan keputusan dan apa yang telah saya kerjakan.*".

3. Mr. Agus Dwi Prasetyo S.T., M.T., as the first supervisor and Mrs. Trasma Yunita as the second supervisor of the author who always take the time to guide, assist, provide the advice, and motivation to the author in completing this Undergraduate thesis.

4. Nuraulia Mugniza ,as my un-biological sister, the author wants to say: "*Terima kasih telah bersabar menghadapi dan menemani saya selama mengerjakan tugas akhir ini, terima kasih juga atas dukungan dan doa yang diberikan.*".

5. Believa Dyanneley A. and Devina Kristi, the author's friends who accompany the author to do the undergraduate thesis writing. The author wants to say: "*Terima Kasih telah menemani saya mengerjakan penulisan sembari meminum kopi dan menjadi teman yang baik dan pengertian selama perkuliahan yang melelahkan ini.*".

6. Ben Hughie and Ghalib Mahendra, the author 's friends in college. The author wants to say: "*Terima kasih kepada kalian yang telah menemani saya dan menghibur saya ketika saya sedang lelah dan kritis pada saat mengerjakan tugas akhir ini.*".

7. Marita Fauziah, Queen Hesti, Adam Anugeraha, and Rifqi Naufal. The author's friends from TT-40-INT who help the author on the simulation, writing thesis, advice, homework, college's tasks, and good friends in these 3 years of college life.

8. Farhan Edwan, Ahmad Aufa, Kahfi Prasetyo, the author's friends since high school who always care about the author's condition.

9. Antenna Lab and Bang Yuda, Thanks for the help on simulation and measurement the author's undergraduate thesis.

10. Mr. Edwar as lecturer on Telkom University and Ichsan as Assistant Elkom Laboratory that allows the author to do the measurement with the Vector Network Analyzer (VNA).

11. Mr. Ruqman from PT. Radar Telekomunikasi Indonesia (RTI) as an assistant to do the measurements, thanks for the help and guidance on measurements in RTI.

Bandung, March 1st 2020

Abdurrahman Ghifari

CONTENTS

APPENDICES

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENEDICES

1. Fabrication at Plaza Jaya.
2. Design of Antenna's Simulation.
3. Measurement of VSWR and Return Loss with VNA.
4. Measurement Activity with VNA.
5. Antenna's Configuration on VNA.
6. Mr. Ruqman on PT. RTI, Assist and Guide The Measurement.
7. Oscillator to do the Radiation Pattern's Measurement Activity.
8. Oscillator.
9. Configuration Antenna's for Radiation Pattern Measurement.
10. Radiation Pattern's Activity.
11. Measurement Result on First Resonance Frequency.
12. Measurement Result on Second Frequency.

CHAPTER 1
INTRODUCTION

1.1 Background

The technology is developing and increasing in this period of time. Especially, when it comes to the telecommunication devices. One of the telecommunication devices that people and the scientist try to invent and develop is Wireless Body Area Network (WBAN). WBAN is a special purpose sensor network designed to operate autonomously to connect various medical sensors and appliance, and this WBAN can be located inside or outside human body[1]. WBAN consists of a number of tiny sensor nodes and a gateway node used to connect to the external data base server. With the decreasing size and increasing capability of WBAN, this WBAN inevitable that small and portable devices would be developed for communications around human bodies [2].

One of the component for WBAN sensor is the antenna to perform its transmition and receiving the signal. The antenna that ca be applied for WBAN sensor is microstrip antenna. WBAN needs the antenna such small dimension, light weight, ease realization, and low profile specification that can be beneficial in the implementation of antenna for WBAN in medical sectors [3]. The microstrip antenna can be designed with low frequency and radiation to purpose avoid the risk for human body. So it does not damage or change any part of human body structure while keeping its performance sufficient in satisfying the specified requirement [1]. The microstrip antenna has lots of design and shape. Planar Inverted-F Antenna is one of the microstrip antenna design and can be implemented for WBAN. Specific Absorption Rate (SAR)'s method is needed. SAR is a measure of how transmitted radio frequency energy is absorbed. This SAR is a method to know this antenna has a low radiation and save for human body.

Based on existing PIFA research, PIFA antennas can be designed to be a multiband antenna where these antennas can work on certain frequencies and needs, such as WiMax and Wi-fi application [1][4][5]. This undergraduate thesis focused on PIFA to be an antenna that can produce two resonance frequency, based on the requirement of WBAN that following the standard of ISM [2]. PIFA antenna for WBAN is definitely effective. The specification of this antenna can solve and fulfil the needs, because this microstrip antenna can do its antenna function to transmit or receive the signal performance [6]. The performance is save for human body with its low frequency and low radiation. PIFA Antenna can be a new innovation to be implemented on the WBAN [7].

This undergraduate thesis focused on design, simulate, fabricate, and measure the PIFA as microstrip antenna with a Dual-Band. The design of this microstrip antenna is a Planar Inverted-F Antenna (PIFA). PIFA is used for wireless circuitry implemented in microstrip. PIFA can decrease the occupancy required area and work in low frequency. The expected of this antenna can be worked in two frequencies, which this antenna is a Dual-Band Antenna. The frequencies are 900 MHz and 2.4 GHz for WBAN's configuration. The return loss is less than -10 dB.

1.2 Formulation of Problems

The formulation of problem in this undergraduate thesis is WBAN is configured to human body. Which the antenna needs to be has small dimension, light weight, and low radiation so the antenna can be save for human body. The antenna is also has to be work for WBAN's configuration, where the WBAN resonance frequencies in 900 MHz and 2.4 GHz. The antenna has to be proved that is save for human body with SAR's method.

1.3 Purpose of The Research

The purpose of this undergraduate thesis is to design and realize the compatible antenna on WBAN's configuration. The antenna is applied on data base external. The function of data base external is to transmit and receive the data from sensor that located outside or inside of human body. This undergraduate thesis is also to fulfil the requirement for final thesis for graduate from Telkom University.

1.4 Scope of Problems

The scope of this thesis is as follows:

1. The undergraduate thesis is focused on design and the realization of the antenna, not the whole system of WBAN.
2. The undergraduate thesis is designing and realization of the PIFA antenna with two resonance frequencies, 900 MHz and 2.4 GHz as an antenna for WBAN.

3. Antenna design does not include the cover and shield for antenna.

4. The antenna parameters measured and analyzed such as Return Loss and Voltage Standing Wave Ratio (VSWR).

5. The focus of this undergraduate thesis are the value of return loss and VSWR, where the expected of value for return loss is less than -10 dB.

6. The antenna is not focused on installation WBAN, where the distance of this antenna is not reviewed.

7. Designing antenna simulation is using software.

8. This undergraduate thesis is not using any SAR's simulation and measurement.

1.5 Research Methodology

The stages of research methodology proposed in this thesis are carried out as follows.

1. Identification of Problems
   Identify problems by conducting literature studies related to microstrip antenna, PIFA, WBAN, and how to create the PIFA with slots to purpose the antenna can be worked in two frequencies.

2. System Planning
   The next step is to define the system planning. analysing the problem and find the solution to solve the problem.

3. Simulation
   The solution of the problem have to be tested and reviewed. Also, if in the simulation has a problem that must to be solved by finding out the problem and solution.

4. After the final design from simulation, the fabrication is needed to realize the PIFA antenna.

5. The comparison between simulation and fabrication measurement.

6. Conclusion
   Analyse the result of comparison, and make the conclusion and suggestion for this undergraduate thesis.

1.6 Structure of Thesis

The structure of thesis writing consist of several stages as follows:

- Chapter 2 BASIC CONCEPT
  This literature review is including WBAN, PIFA, Impedance Matching, Method to produce multi-band frequency.
- Chapter 3 SYSTEM MODEL AND THE PROPOSED METHOD
  Create the system design, simulation, optimization, and the final configuration for the fabrication.
- Chapter 4 RESULTS AND ANALYSIS
  This chapter contains the fabrication of PIFA antenna, the result of measurement, and the comparison between simulation and fabrication's result.
- Chapter 5 CONCLUSION AND SUGGESTION
  Create the conclusion and suggestion based on the data from the results that have been obtained on the Chapter 4.

CHAPTER 2
BASIC CONCEPT

This chapter explained about concepts that is used for this undergraduate thesis.

2.1 WBAN

WBAN is a special purpose sensor network designed to operate autonomously to connect various medical sensors and appliance, located inside and outside of a human body. Wireless body area network is situated in the clothes, on the body or under the skin of a person. WBAN consists of a number of tiny sensor nodes and a gateway node used to connect to the external database server. The gateway node is to connect the sensor node to a ange of telecommunication [3].

The network typically expands over the whole human body and the nodes are connected through a wireless communication channel. WBAN for medical monitoring and other applications will offer flexibilities and cost saving options to both health care professionals and the users.

Wearable antennas is a type of small size antenna that can be implemented in every technology. This type of technology is save for human body, because the frequency of its antenna is less than equal than 1 GHz [8]. Not only because its frequency, this wearable antenna has a specification that safe for human body. WBAN has been applied in lots of technology and becoming increasingly common in consumer electronics and technology. The configuration for WBAN is described on Figure 2.1.

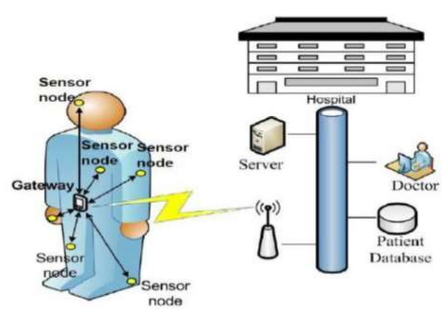


Figure 2.1 WBAN Configuration

WBAN's work frequency allocation located in the industrial, scientific, and medical (ISM). The examples are smartwatches (which typically have integrated bluetooth antennas), glasses (such as Google Glass which has WIFI and GPS antennas), GoPro action cameras (which have wifi and bluetooth antennas, and are often strapped to a user to obtain their footage), and even the Nike+ Sensor (which communicates to a smartphone via bluetooth, and is placed in a user's shoe) [8].

2.2 Planar Inverted-F Antenna

Antenna designers are always looking for creative ways to improve performance. One method used in patch antenna design is to introduce shorting pins (from the patch to the ground plane) at various locations. PIFA can be considered as a kind of linear Inverted F antenna (IFA) with the wire radiator element replaced by a plate to expand the bandwidth. Lots of advantages that PIFA has, first PIFA can be put in a small place comparable with another type of antenna [3]. PIFA is reduced backward radiation toward the user, minimizing the electromagnetic wave power absorption (SAR) and enhance antenna performance.

PIFA also exhibits moderate to high gain in both vertical and horizontal states of polarization. The Planar Inverted-F antenna (PIFA) is increasingly used in the mobile phone market. The antenna is resonant at a quarter-wavelength (thus reducing the required space needed on the phone), and also typically has good SAR properties. This antenna resembles an inverted F, which explains the PIFA name. The Planar Inverted-F Antenna has a low profile and an omnidirectional pattern [7]. Three main components of PIFA are patch, ground plane, and short pin. Figure 2.2 showed the main components of PIFA.

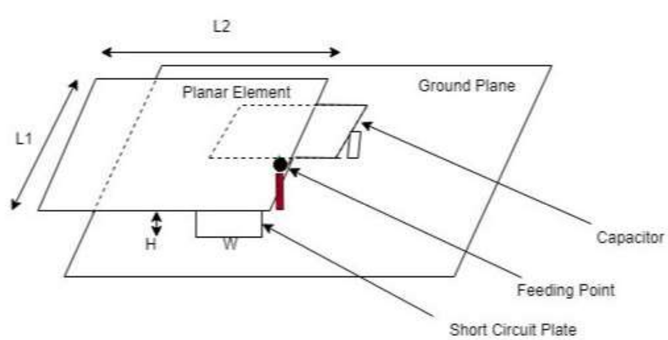


Figure 2.2 PIFA Antenna.

2.2.1 Resonance Frequency

PIFA has a different specifications such as Dimension, Resonant Frequency, impedance matching, radiation pattern, electric field distribution, current distribution, effects of substrates parameters, and the efficiency that differently with another type of antenna. The capacitive loading of PIFA reduces the resonance length from $\frac{\lambda}{4}$ to less than $\frac{\lambda}{8}$ at the expense of bandwidth and good matching impedance [7]. Based on the papers, The equation for PIFA dimension can be obtained by this equation that almost same with microstrip antenna.

$$W + L = \frac{\lambda}{4} \tag{2.1}$$

2.2.2 Current Distribution

The impedance matching of the PIFA is obtained by positioning of the single feed and the shorting pin within the shaped slot, and by optimizing the space between feed and shorting pins. The radiation pattern of the PIFA is the relative distribution of radiated power as a function of direction in space. Radiation properties include power flux density, field strength, phase, polarization, Electric field Distribution, Current Distribution,and Effects of Substrates parameters. Impedance bandwidth of PIFA is inversely proportional to the quality factor Q that is defined for a resonator. The equation is described as

2.2.3 Bandwidth

Bandwidth in PIFA is influenced by the ratio of the width and height values of the short pin. The narrower the width of the short pin, the narrower the bandwidth. The higher of the height , the wider the bandwidth. The width and height of the short pin in this undergraduate thesis is defined by sho and h. The methods to make bandwidth wider in PIFA are described as follows.

1. Adjust the placement and distance between the short pin and the feeding circuit.
2. Use thick air substrates to minimize factor Q by increasing the value of h.
3. Decrease the size of the ground plane.
4. provides a slot on the ground plane to expand the bandwidth.

2.2.4 Impedance Matching

Impedance Matching is the process of designing the antenna's input impedance (Z_{in}) to the corresponding RF circuity's output impedance, which the results close to the 50 *Omega* [9]. A perfect impedance matching is perfect when $Z_{in} = Z_{out}$. The perfect condition gives *Gamma* a value of zero, and the SWR becomes unity. The equation are described as follows.

$$\Gamma = \frac{Z_L - Z_O}{Z_L + Z_O}. \tag{2.2}$$

PIFA antenna's impedance matching can be obtained by adjusting the position of the points and short pins. Also, this needed optimizing the distance between the feeding circuit and the short pin.

2.2.5 Voltage Standing Wave Ratio

Voltage Standing Wave Ratio (VSWR) is an indication of the amount of mismatch between an antenna and the transmission line or optical fiber [9]. VSWR is referred to as standing wave ratio (SWR). Standing waves represent power that is not accepted by the load and reflected back to the transmission line or feeding circuit. One of the antenna's requirement to has a good performance when the value of VSWR is less equal than 2. This value means that the reflection coefficient (Γ) equal or closes to the zero. The VSWR equation is same with SWR equation, described as follows.

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

2.2.6 Return Loss

Return loss is the loss of power in the signal reflected by a discontinuity in a transmission line or optical fiber. The discontinuity can be a mismatch with the load or device inserted in the transmission line. Return loss is related with SWR and reflection coefficient (Γ). The equation for return loss described as follows.

$$RL = 10 \log_{10} \frac{P_i}{P_r} \tag{2.4}$$

$$RL = 20 \log |\Gamma| \tag{2.5}$$

2.2.7 Antenna Feeding Circuit

Antenna Feeding Circuit is giving an antenna canal to purpose connecting the antenna with feeder. Rationing that can be used on microstrip commonly are microstripe line, coaxial probe, aperture coupling, and proximity coupled, microstrip line technique is the usual technique to for the rationing design [1]. The method that used for this undergraduate thesis is a coaxial probe.

2.3 Method to Produce Multi-band Frequencies

To make the antenna has two or more resonance frequency, several methods are obtained. The methods are Orthogonal-Mode Dual-Frequency Patch Antennas, multi-patch dual-frequency antennas, and reactively-loaded patch antennas. Reactively loaded patch antennas is required for this undergraduate thesis because the range between of two resonance frequencies is wide.

2.3.1 U-Slot Dimension

To generate multiple resonance frequencies on antenna, U-slot is needed. U-slot method is giving an antenna slot that is known as reactively-loaded. The Reactively-loaded method is a method to generate multiple frequencies by adding a load to the antenna. The load can be in the form of stubs, slots, pins, slots and pins, or capacitors. This method is shown on Figure 2.3. Based on the research [1][7][2], U-slot can give a new resonance frequency with a wide range between of each antenna. The u-slot can fulfil the needs for WBAN's antenna configuration, where the WBAN's antenna works on 900 MHz and 2.4 GHz with a wide range of each resonance frequency [9].

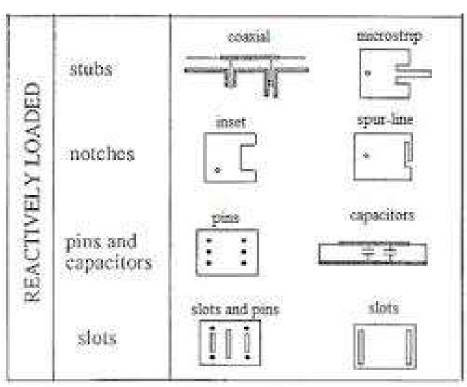


Figure 2.3 The Reactively-loaded Antenna Method.

U-slot is added specifically to the type of radiation material, the example is copper. In this undergraduate thesis, slots are added on the patch, so it can produce a new resonance frequency and wider resonance distance, where the length of this resonance is related to the generation of other frequencies. The slot can give a new resonance frequency and wide range frequency because it gives a new current distribution on a patch antenna. The result of new current distribution on antenna's radiation material is a new resonance frequency [2]. Slot is also increasing the value of return loss or VSWR value, because slot can increase the current distribution of each side the copper on patch and u-slot.

CHAPTER 3
SYSTEM MODEL AND THE PROPOSED METHOD

This chapter explained about system method and proposed method for this undergraduate thesis.

3.1 System Design

Dual Band PIFA Antenna with U-Slot for is working on frequency 900 MHz and 2.4 GHz for WBAN application. The process that carried out in this antenna design is as follows.

1. Determine the characteristics each of the component that will be used.
2. Define the desired working frequency.
3. Design antenna dimensions in accordance with the desired frequency.
4. Simulate the design of antenna with CST 2016 Software.
5. Characterize and add the methods needed to get the desired frequency, VSWR, and return loss values.
6. Fabrication of the antenna that has been designed.
7. Perform fabricated antenna measurements.

3.2 Equipment Section

The equipment used in this undergraduate thesis consist of hardware and software. The equipment is used for various purposes in simulation, fabrication, and antenna measurement.

3.2.1 Hardware

The hardware equipment that used for antenna design can be described as follows.

1. Personal Computer (PC) to do a simulation in CST Design 2016 software.

2. (tools for measuring fabrication results).

3. Connector.

4. Copper, FR-4, and Solder as material for antenna design.

5. Vector Network Analyzer (VNA).

3.2.2 Software

The Software equipment that used for antenna design can be described as follows.

1. CST Studio Suite 2016 software for design and simulation of antenna.

2. Latex Software for undergraduate thesis's journal and paper.

3. Microsoft Excel 2017.

3.3 Antenna Design Process Flowchart

Figure 3.1. shows the flowchart for this undergraduate thesis.

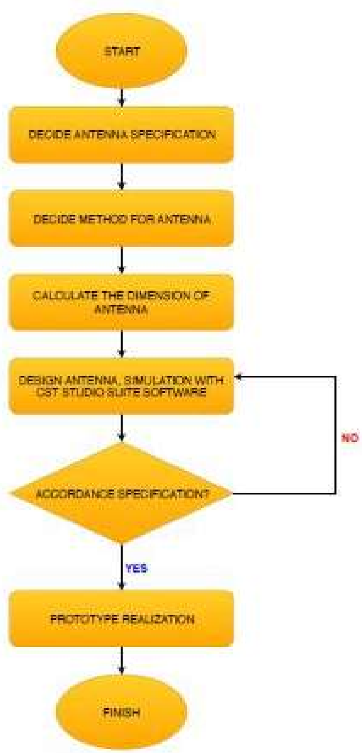


Figure 3.1 Antenna System Block Diagram.

Table 3.1 Table of Material Specification.

No.	Parameter	Amount of Parameter
1.	Material	FR-4
2.	Relative Permittivity	4
3.	Relative Permeability	1
4.	Material Thickness	1.6

3.4 Material Section

Each material has different characteristics. It takes the selection of the right material in order to get the right and optimal results. The material used for the substrate is explained on the Table. 3.1.

3.5 Antenna Dimension

The first step of designing the antenna is to determine each of the size of antenna. The design that obtained has to be simulate on the software. The dimension starts from patch, u-slot, ground plane, short pin, and the feeding circuit. After the design get simulated, the optimization is needed to achieve the required needs for PIFA antenna. The design for simulation of PIFA antenna can be described on The Figure 3.2. The Table 3.2 describes the value of each parameter for the dimensions for PIFA antenna.

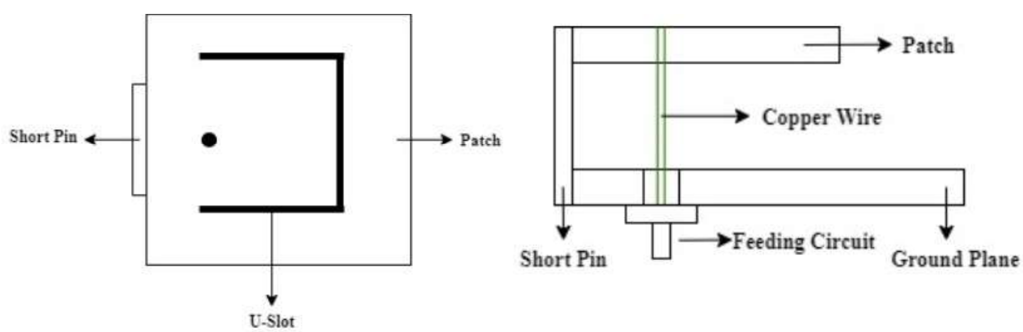


Figure 3.2 Design of PIFA.

Table 3.2 Antenna Parameters.

No.	Parameter	Length (mm)	Information
1.	W	50	Width of Patch Dimension.
2.	L	33.3	Length of Patch Dimension.
3.	Wp	9	Width of U-shaped Slot.
4.	Lp	15	Length of U-shaped Slot.
5.	Wl	3	Width of L-shaped Slot.
6.	Ll	4	Length of L-shaped Slot.
7.	Sho	12	Width of Short Pin.
8.	Ws	1.5	Thickness of U-shaped and L-saped Slots.
9.	Q	6	Width of Ground Plane Slots.
10.	Wg	59.6	Width of Ground Plane.
11.	Lg	42.9	Length of Ground Plane.

The each value on The Table 3.2 is obtained by the several method that is described o the subsections below.

3.5.1 Antenna Patch Dimension

The design of antenna is a dual band antenna with 900 MHz and 2.4 GHz frequency. Calculation to determine the dimensions of this antenna is using the equation 2.1, where the frequency for the antenna is 900 MHz. It obtained for antenna patch dimension, $W + L = 83.3mm$. The obtained of width and length of patch antenna is 50 mm and 33.3 mm.

3.5.2 Antenna U-Slot Dimension

The shape of the U-Slot is basically made from a rectangular shape for 2.4 GHz frequency. Then the U-Slot combined with elements for 900 MHz frequency. This technique is called reactive loaded patch antenna, or additional load. The load is a slot. The purpose of slot is to produce two working frequencies. The dimensions of this U-shaped slot are calculated with the same equation as the patch dimension equation, using the equation 2.1. So it is obtained $W + L = 31.25mm$. The width and the length of its u slot is 16 mm and 15.25 mm. Figure 3.3 describe the combination of patch and U-Slot antenna dimensions.

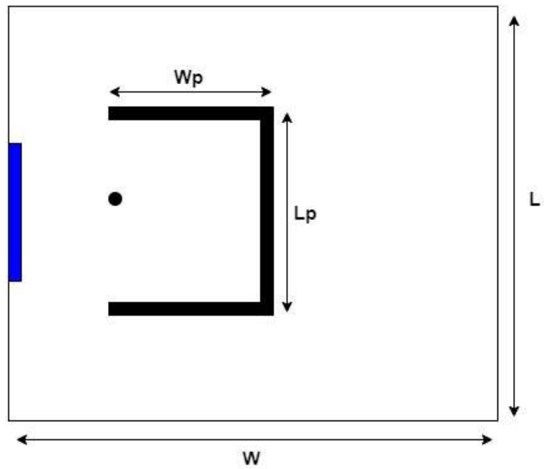


Figure 3.3 Patch Antenna Dimension.

3.5.3 Antenna Ground Plane Dimension

The antenna ground plane dimension is using the following equation.

$$WGP = 6 \times h + w \tag{3.1}$$

$$LGP = 6 \times h + L \tag{3.2}$$

Based the calculation with the equation above, the dimension is obtained with width 59.6 mm and length 42.9 mm.

3.5.4 Short Pin

The short pin is one of the component of PIFA antenna. The purpose of short pin is to sustain and strengthen the configuration of PIFA. Short pin is also improve the current distribution from ground plane to patch. The dimension of this short pin is rectangular shape. The width and length for this short pin is parametric characterization. The width and the length is 12 mm.

3.5.5 Feeding Circuit

The feeding circuit for PIFA antenna is a coaxial probe. Coaxial probe dimension is adjusted to the size with the market's standard. The coaxial probe has a copper wire to connect from ground plane to patch, the purpose is to distribute the current from source so each of dimension is getting current distribution.

3.6 Antenna Simulation

The antenna simulation is a next progress to simulate the antenna design results with the software CST Studio Suite 2016. The first process is to make the simulation based on the dimension that has been obtained on the antenna dimension design. The Figure 3.5 is the result of return loss on first antenna design before any optimization and without an addition of u-slot on the patch. Based on The Figure 3.5, it shown that without an u-slot additional on the patch the resonance frequency is only obtained one of resonance frequency. The frequency value is still inadequate with the first frequency value. The Figure 3.4 is the process of adjusting the width and length of the patch to obtained the closest value for first resonance frequency. The best result is obtained when the W and L values is 42 mm and 41 mm. The value of return loss is -22.08 dB and the bandwidth is 49 MHz.

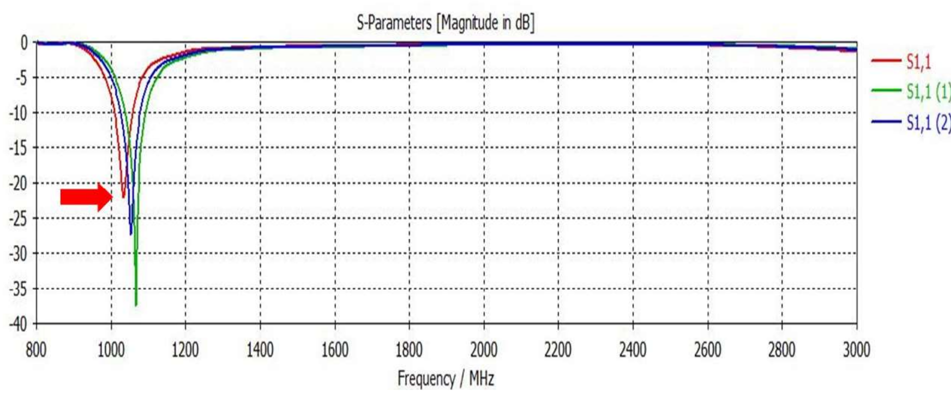


Figure 3.4 Adjusting Width and Length of Patch Dimension.

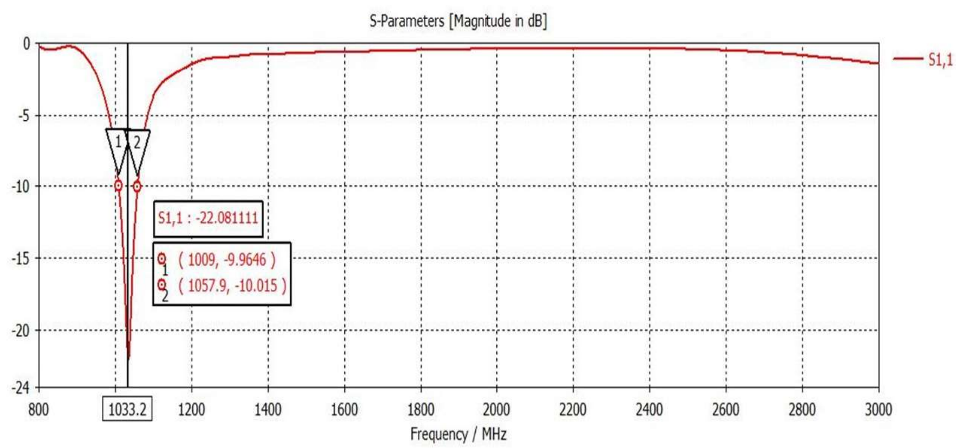


Figure 3.5 Return Loss of First Resonance Frequency.

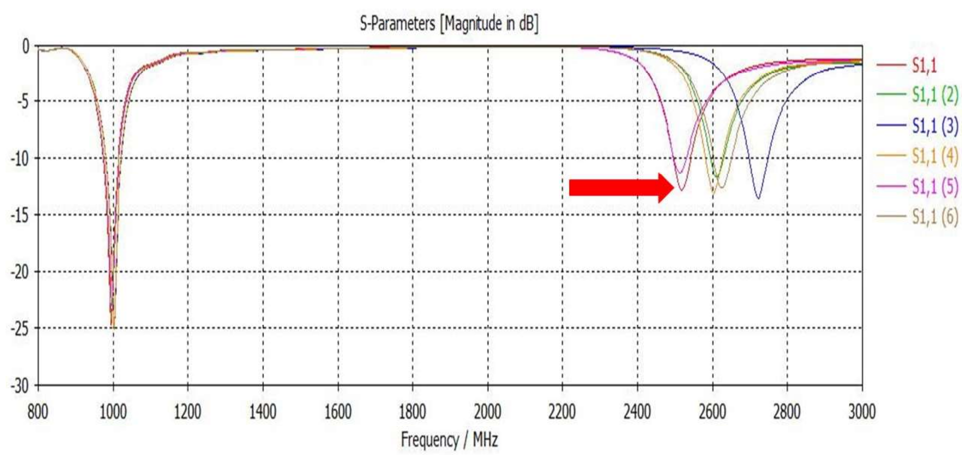


Figure 3.6 Dual Frequency Return Loss.

To obtained the second resonance frequency, the u-slot shaped is added. The result of addition of u-slot can be described on The Figure 3.7. The u-slot shaped with width of length 15 mm and 16.25 mm is also need to adjusted to achieve the best result that close to the second resonance frequency at 2.4 GHz. The Figure 3.6 is the process of adjusting to get the best result with and ideal size for u-slot. After the addition of u-slot, it obtained the new frequency for the second resonance frequency on 2.51 GHz with the return loss -12.79 dB. The best value that obtained when the width and length of u-slot is 15 mm and 19 mm. Not only new resonance frequency, the first resonance frequency also got shifted after u-slot addition. It shows that giving a slot on antenna can also shift the frequency and increase the value of bandwidth. Based on the previous results, the required resonance frequency is still not obtained. To shift the frequency, the simplest way is to increase the size of the dimensions of the U-shaped slot. But this is not possible because the first frequency will shift far from the target, and must increase the dimensions of the patch. The dimensions of the antenna for the WBAN must not be too large because this is not fulfilled the standards described in chapter 2 for WBAN. Therefore, additional slot shapes are required. The slot to be added is an L-shaped slot that serves to reduce the frequency of 2.6 GHz to 2.4 GHz.

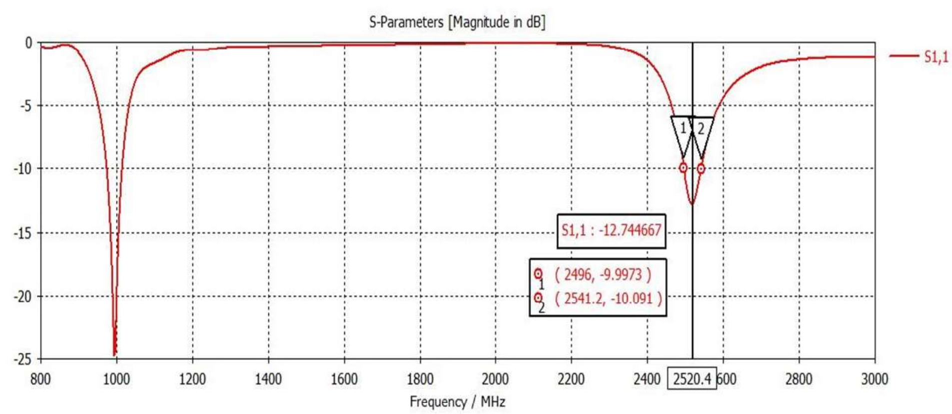


Figure 3.7 Return Loss of Second Resonance Frequency.

The slot must be still combined with u-slot. Because the new unnecessary resonance frequency is obtained, if the slot is not combined with u-slot. This means slot addition on patch can make a new resonance frequency. L-shaped slot is added, with parameters Wl and Ll. The final result of the antenna design which has been combined with the addition of the L slot on the second working frequency is shown on Figure 3.8.

3.7 Antenna Design Optimization

To get the best frequency, return loss, and bandwidth, the characterization and optimization process is required. Changing the parameters include the L-shaped slot, height of antenna, size of short pin, and the addition of the slot method to the ground plane section. The purpose of the slot on the ground plane section is to make the bandwidth wider, so the first frequency can be shifted to the required frequency.

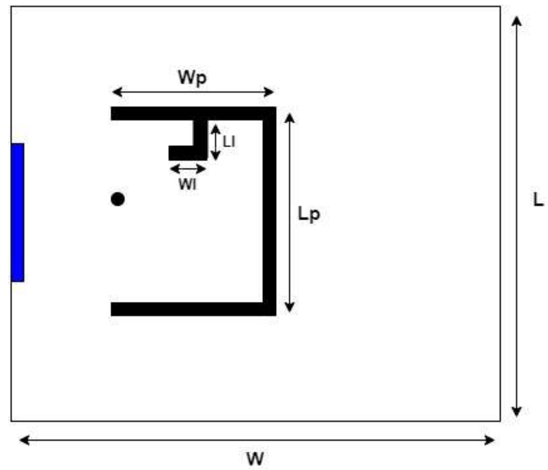


Figure 3.8 Patch Dimension with L-shaped Slot.

3.7.1 L-Shaped Slot Optimization

The function of the L-shaped slot is to reduce the frequency at the second working frequency in order to obtain the 2.4 GHz frequency. For a fixed Ll value is 4.55 mm, while the Wl varies from 3-6 mm, Figure 3.9 shows a graph of return loss and frequency. The change on the value of Wl the value of the second resonance frequency changes while for the first working frequency only the return loss value changes. The bigger of the value of Wl, the lower the frequency. This is due to the greater Wl causing the larger slot size so that the path current is getting longer and the electrical length is increasing so that the frequency drops. The frequency obtained near 2.4 GHz is 3 mm for 2,37 GHz shown by the red graph. After the ad-

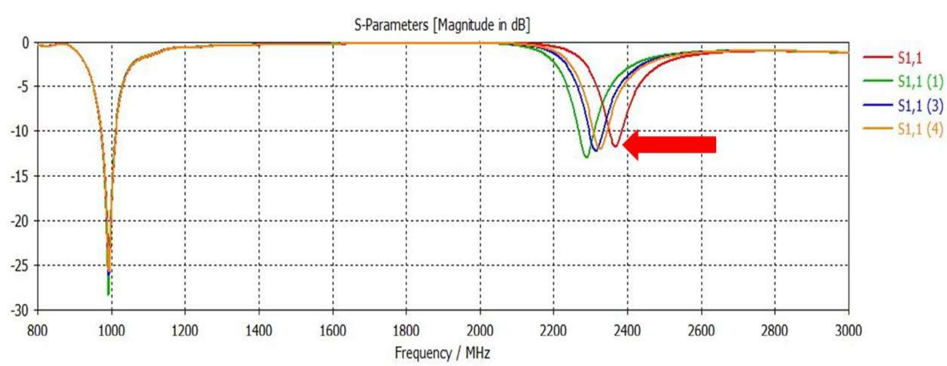


Figure 3.9 L-shaped Slot Optimization.

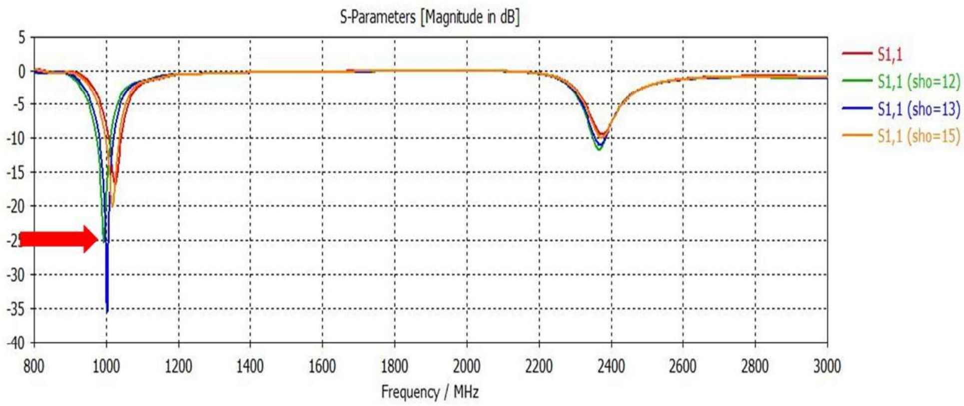


Figure 3.10 Short Pin Optimization.

dition of the L-shaped slot, the desired frequency of the first and second frequency resonances have not yet been reached. The addition of the L-shaped slot does not affect the first working frequency, because the L slot is connected in the U-shaped slot, so the second resonance frequency is affected. Obtained values close to the value of Width and length of l-slot is 3 mm and 4 mm.

3.7.2 Short Pin Optimization

Short pin parameter needs to get an optimization. The value of width short pin parameter is 10-15 mm. The value of another parameters are still the same. Return loss graphic for short pin showed on Figure 3.10. The Figure 3.10 shows the reduced width of the short pin, the frequency decreases, and the value of return loss is increasing. The value of bandwidth does not have much effect. Return loss with a best value is obtained when the length of short pin is 12 mm, showed by the green colour line.

3.7.3 Height of Antenna Optimization

The antenna height is changed in value starting from 5-10 mm. For other parameters fixed value. The Figure 3.11 shows the change value of return loss.

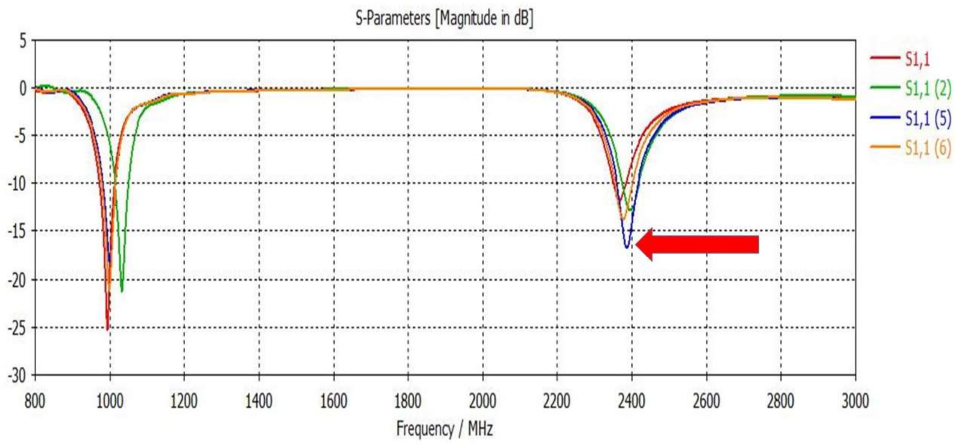


Figure 3.11 Height of Antenna Optimization.

Based on Figure 3.11, the higher of the antenna, the lower of the value of frequency, the smaller return loss, and the wider bandwidth. Increasing the PIFA antenna height means increasing the air substrate in the PIFA. Bandwidth is increasing substrate thickness and decreasing dielectric constant permittivity of the substrate. Increasing the thickness of the air substrate will make the ground plane farther from the patch, thereby reducing the energy stored under the patch.

Bandwidth impedance on PIFA is inversely proportional to the quality factor Q. The smaller the energy stored will cause a small Q value and increase bandwidth. The best result is when h is 10 mm, showed on Figure 3.11 with blue line.

3.7.4 Slots on Ground plane

To get the best frequency, return loss, and bandwidth for first resonance frequency 900 MHz, slots on ground plane is needed. The purpose of slots on ground plane is to move and shift to obtained the frequency that required 900 MHz, all of the optimization still not make any change to the first frequency close to 900 MHz. The Figure 3.12 shows the slots on the ground plane.

To obtain the required resonance frequency, the width of slots on the ground plane have to optimized with range 2-6 mm. The best result that obtained first resonance frequency, the best width is 6 mm and 2 slots with an additional 1 mm, described in the figure 3.12. The Figure 3.13 shows the result of y optimization for slots on the ground plane. After the addition of slot on the ground plane, each resonance frequency got shifted to the required frequency, it proves that slot can shift the resonance frequency.

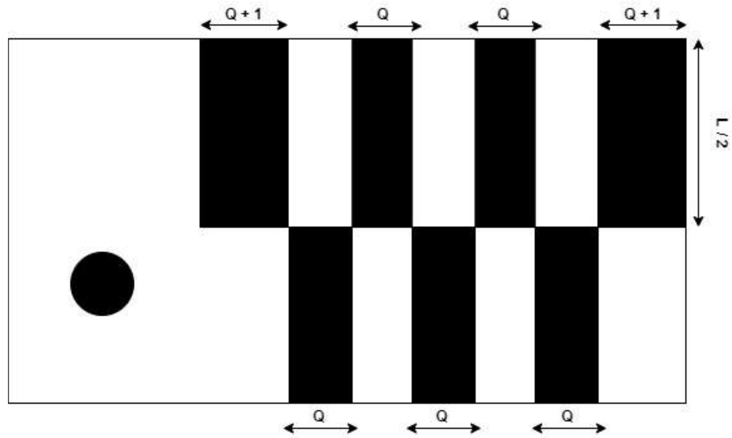


Figure 3.12 Slot on The Ground Plane.

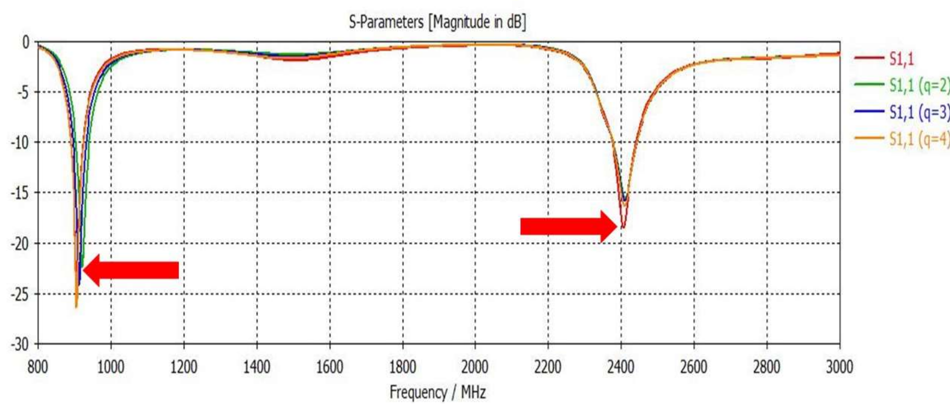


Figure 3.13 Width Slot of Ground Plane Optimization.

3.8 Final Result of Antenna Design

After the characterization process, the most precise and suitable quantities for the antenna parameters are obtained. The antenna parameters can be seen on Table 3.3.

Table 3.3 Length of Antenna Parameters.

No.	Parameter	Length (mm)	Information
1.	W	42	Width of Patch Dimension.
2.	L	41	Length of Patch Dimension.
3.	Wp	9	Width of U-shaped Slot.
4.	Lp	15	Length of U-shaped Slot.
5.	Wl	3	Width of L-shaped Slot.
6.	Ll	4	Length of L-shaped Slot.
7.	Sho	12	Width of Short Pin.
8.	Ws	1.5	Thickness of U-shaped and L-saped Slots.
9.	Q	6	Width of Ground Plane Slots.
10.	Wg	70	Width of Ground Plane.
11.	Lg	40	Length of Ground.

The Figure 3.14 and Figure 3.15 described the final design of PIFA antenna for patch and ground plane dimension with addition of slots to improve and achieve the frequency that required for WBAN.

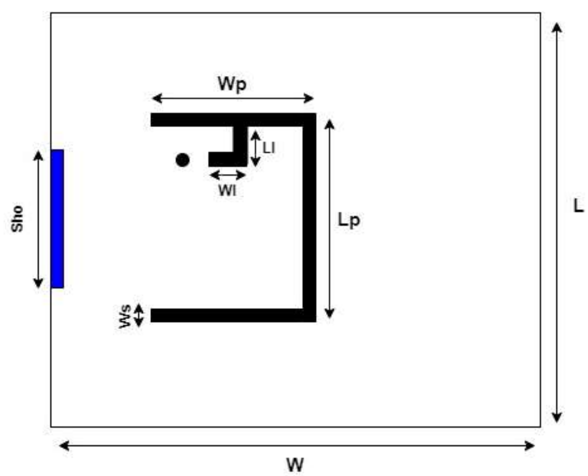


Figure 3.14 Final Result of Patch Design.

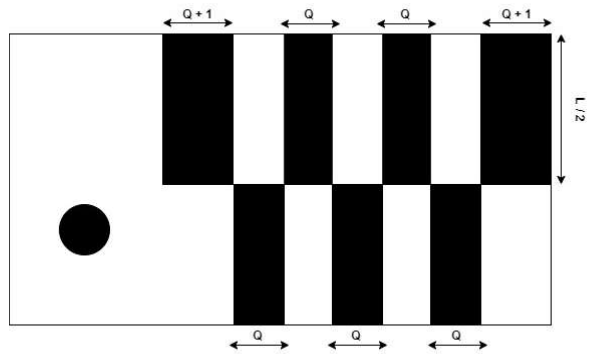


Figure 3.15 Final Result of Ground Plane Design.

3.9 Result of Antenna Design Simulation

The Figure 3.16 showed the simulation result of return loss from Dual Band PIFA Antenna. From The Figure 3.16 can be seen the design obtained the antenna with two resonance frequency. This can be seen through the graph where it has two return loss results under -9.54 dB. On the first resonance frequency, the return loss is -23.32 dB with the range frequency 892.4-925.4 MHz. This resonance frequency has fulfilled the WBAN requirement that has a resonance frequency at 900 MHz. The second resonance frequency is obtained at 2.37-2.44 GHz with the return loss -18.41 dB. This frequency is cover the resonance frequency of WBAN at 2.4 GHz. The bandwidth for first resonance frequency is obtained 34 MHz showed on Figure 3.17, and the bandwidth for the second resonance frequency is obtained 67 MHz showed on Figure 3.18.

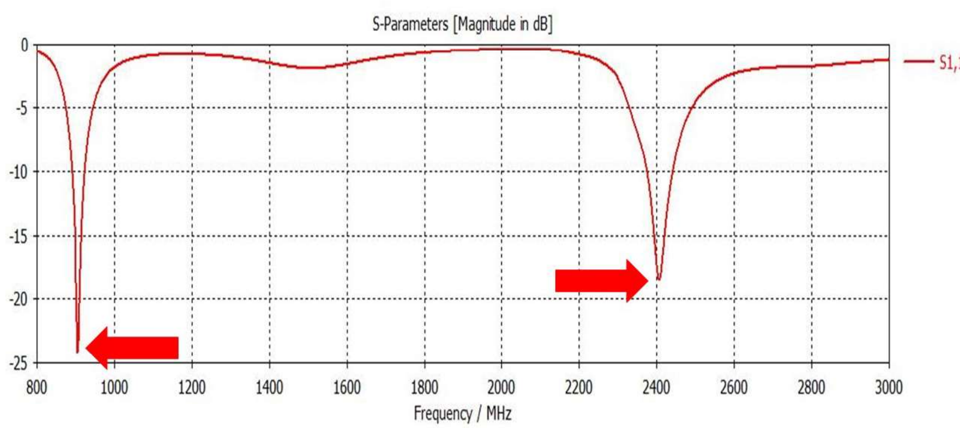


Figure 3.16 Return Loss's Graph Simulation Result.

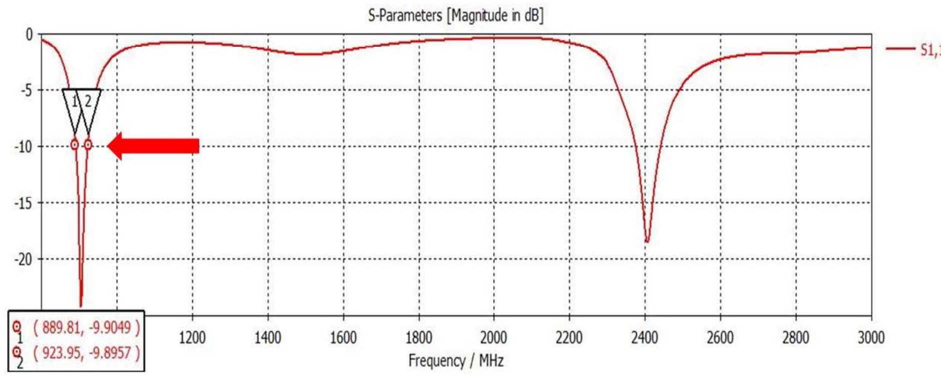


Figure 3.17 Bandwidth for 900 MHz Frequency.

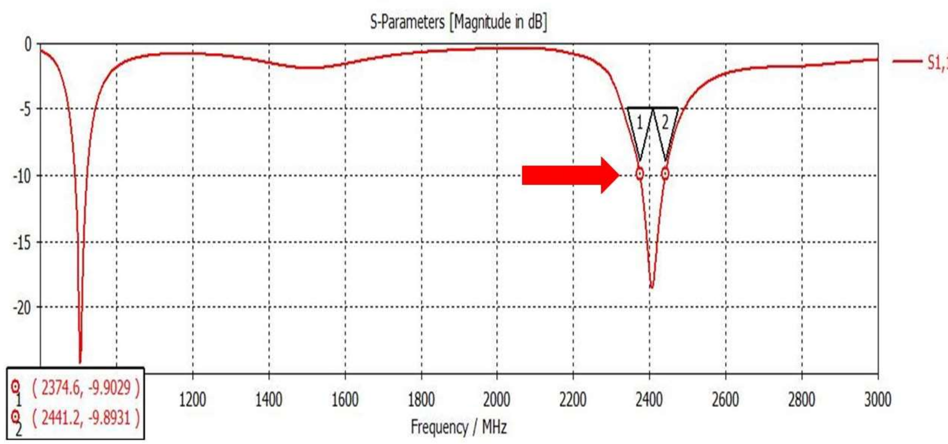


Figure 3.18 Bandwidth for 2.4 GHz Frequency.

The Figure 3.19 and Figure 3.20 show the VSWR each of the frequency.

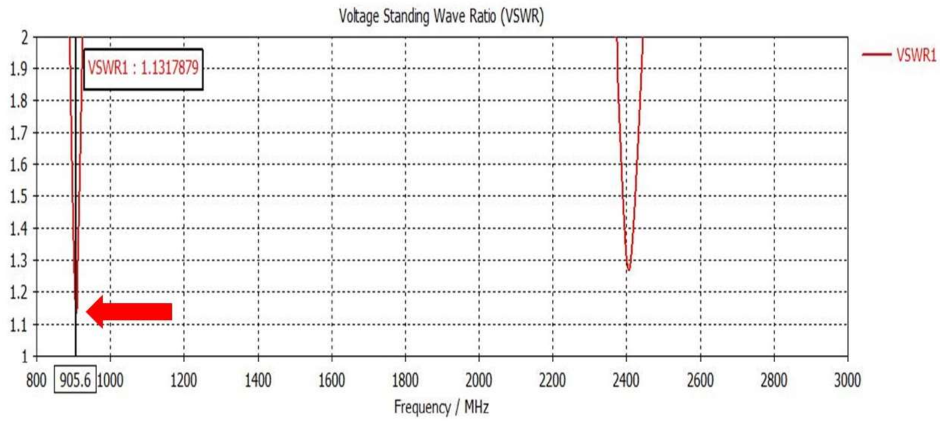


Figure 3.19 VSWR of First Resonance Frequency

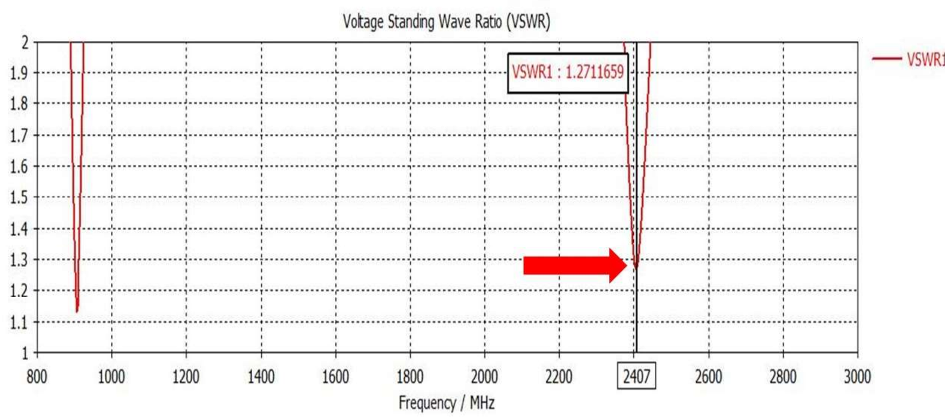


Figure 3.20 VSWR of Second Resonance Frequency

CHAPTER 4
RESULTS AND ANALYSIS

4.1 Antenna Measurements Result

After the design and simulation, as explained in chapter 3, the next procedure is to fabricate the design that has been made. After fabrication is complete, antenna measurements are then performed. The measurements is a single port measurements. Measurements were taken in the Telkom University lab using a Vector Network Analyzer (VNA). VNA is a measuring instrument (instrument) that is widely used in measurement systems in the telecommunication world. VNA is a form of RF network analyzer that is widely used for RF design applications. VNA can also be called a phase-gain meter or automatic network analyzer. The Lab Room at Telkom University is not an Anechoic Chamber room so it affects the measurement results where there is a lot of interference. The Figure 4.1 is the result of antenna design fabrication.

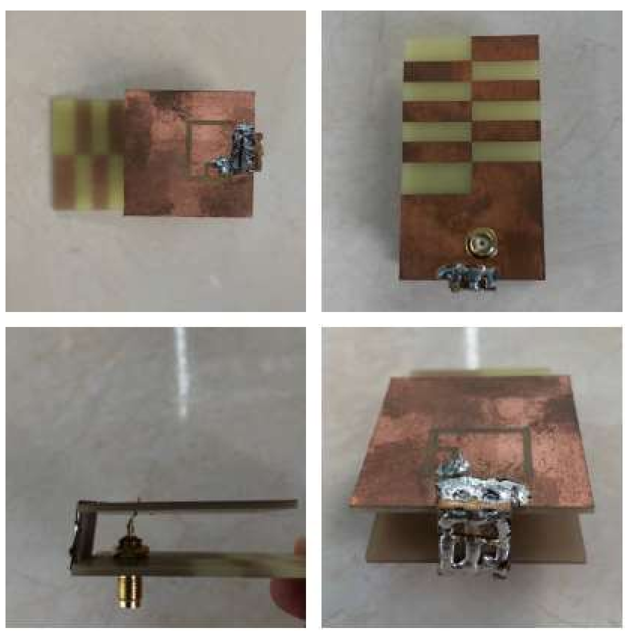


Figure 4.1 PIFA Antenna Fabrication.

4.1.1 Return Loss Measurement

The process of single port measurement using VNA, the parameters of the antenna that can be measured are the return loss and the input impedance of the antenna. The configuration from measurements using a single port VNA can be seen on Figure 4.2. The measured return loss value can be seen on Figure 4.3.

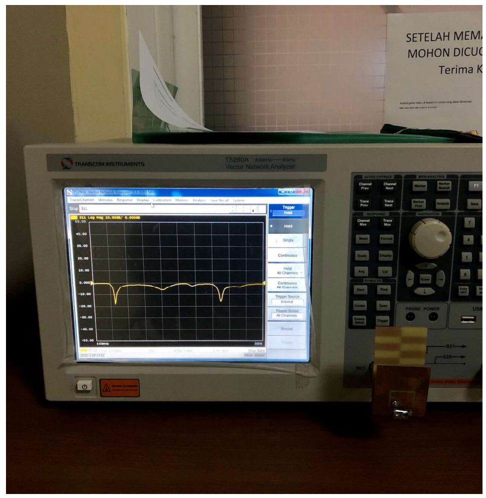


Figure 4.2 Vector Network Analyzer (VNA).

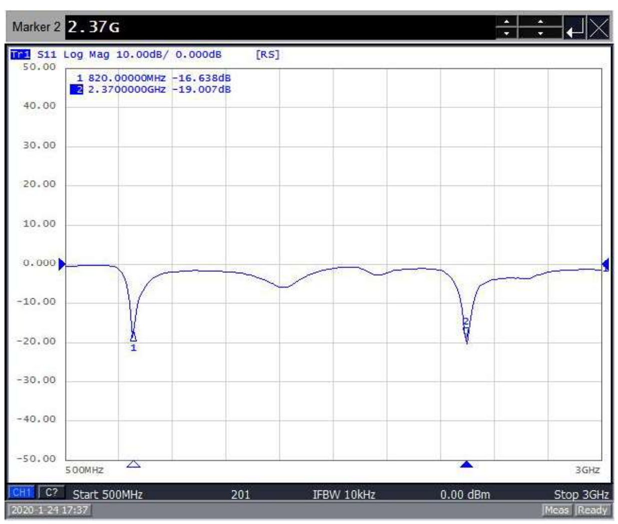


Figure 4.3 Return Loss Measurement.

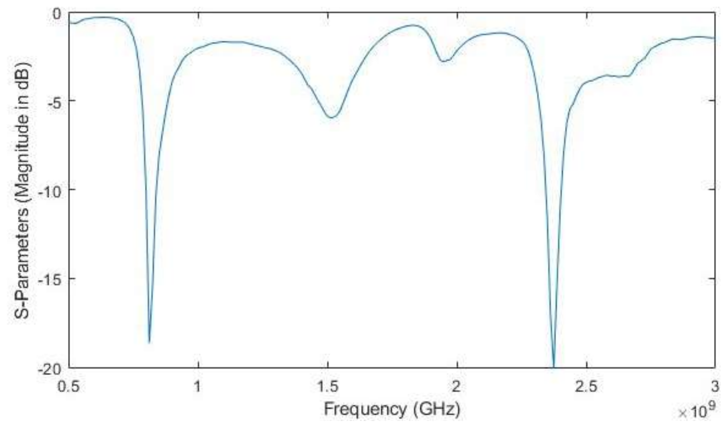


Figure 4.4 Return Loss Measurement with Microsoft Excel.

The Figure 4.4 is the graph result from Data processing using Microsoft Excel. From The Figure, this can be seen that the process of fabrication a dual band PIFA gets an antenna that have two resonance frequencies. This can be seen where the resonance frequencies have a return loss value below -10 dB, there are two resonance frequencies. The first resonance frequency works at 798-837 MHz with the lowest return loss value reaching -16 dB , and the second resonance frequency is 2.34-2.41 GHz with the lowest return loss value reaching -19 dB Bandwidth at each working frequency is 50 MHz and 70 MHz. The Figure 4.5 is the comparison between the measurement and simulation results. Based from Figure 4.5, the results can be seen that the resonance frequencies does not cover the WBAN frequency, each resonance frequency has shifted to the smaller frequencies.

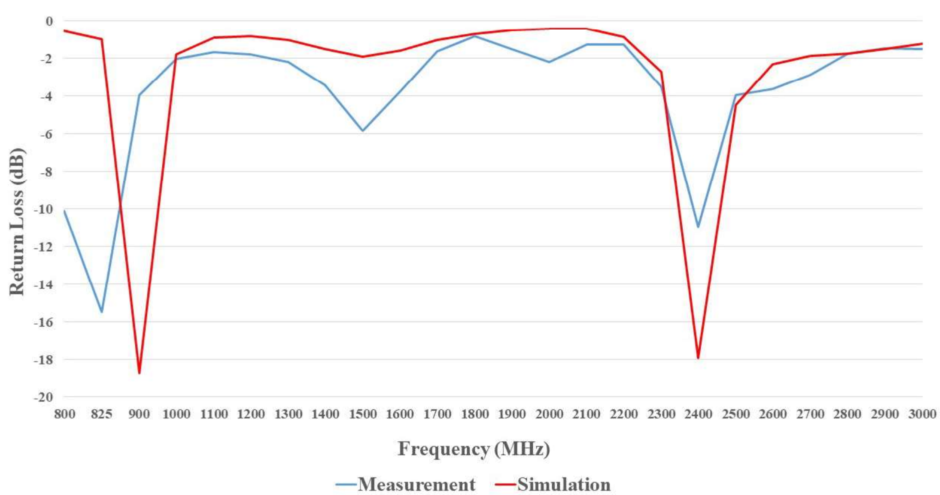


Figure 4.5 Comparison Return Loss Results Between Simulation and Measurement.

4.1.2 VSWR Measurement

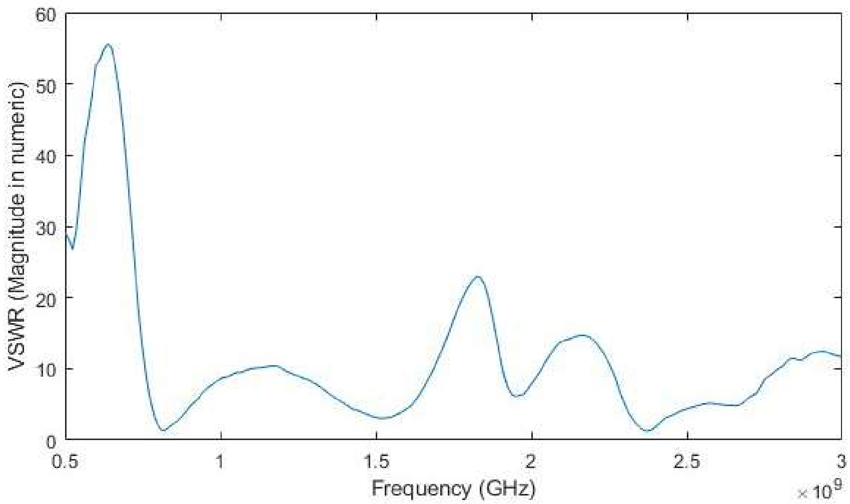


Figure 4.6 VSWR Measurement with Microsoft Excel.

The VSWR results for each resonance frequencies using VNA is described on Figure 4.7. The Figure 4.6 is the measurement of VSWR from data processing using software. This graph obtained the amount of VSWR for first resonance frequency 820 MHz is 1.42 and for the second resonance frequency 2.37 GHz is 1.23. The Figure 4.8 described about the comparison between simulation and measurement results using software. The frequencies are also get shifted to the same resonance frequencies that appropriate with the return loss result.

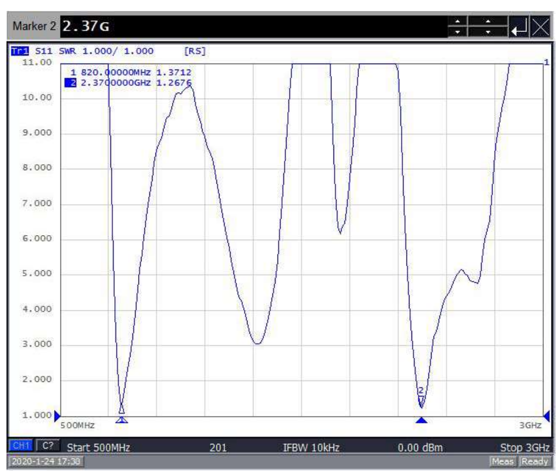


Figure 4.7 VSWR Measurement.

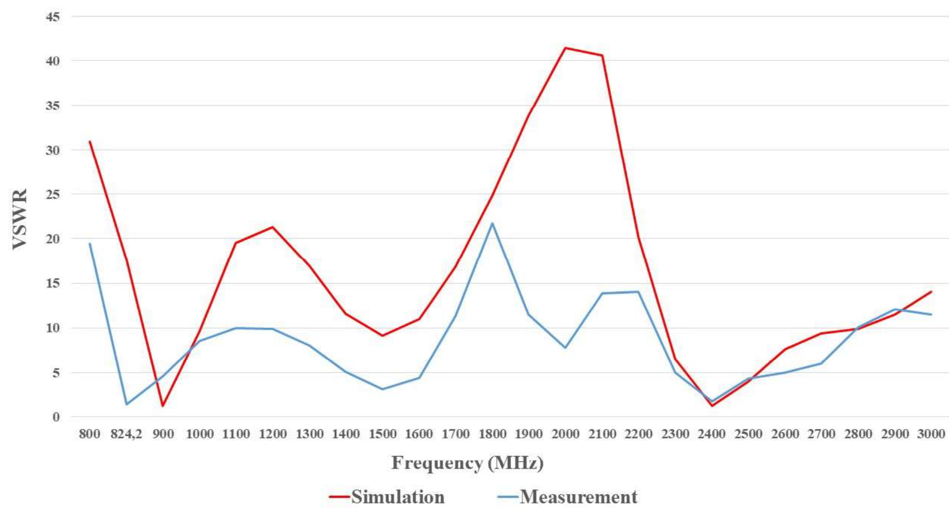


Figure 4.8 Comparison VSWR Results Between Simulation and Measurement.

4.2 Analysis of Measurement Result

4.2.1 Analysis of Return Loss and VSWR

The measurement results show that there is a shift in the first and second resonance frequency are shifted to a smaller resonance frequency. This can be seen from the value of return loss and VSWR measurements. The first and second resonance frequency shifted to the left, or the frequency of the measurement results is smaller than the frequency of the simulation results. But the second resonance frequency is not shift as much as the first resonance frequency. The factors that influence PIFA frequency are width of patch and slot size. The frequency values got shifted to a lower frequency, caused by the manufacturing process and fabrication that is not accurate, so the dimensions of the patch and slot become larger. Patch width and slots are actually appropriate. But, the fabrication of feeding point on the patch and short pin fabrication that add lead when soldered causes additional dimensions to be added to the patch. Return loss and matching impedance are strongly influenced by the location and distance between the short pin, slot and also the point of supply. One of the most influential problems in the design process is the solder of PIFA components that are less tidy. This can cause additional losses. The comparison between simulation and measurement can be described on Table 4.1 and Table 4.2 .

Table 4.1 Comparison Result on First Resonance Frequency.

Parameter	Simulation Result	Measurement Result
Bandwidth	892.4-925.4 MHz	798 - 837 MHz
Return Loss	-23.32 dB	-16 dB
VSWR	1.13	1.42

Table 4.2 Comparison Result on Second Resonance Frequency.

Parameter	Simulation Result	Measurement Result
Bandwidth	2.37 - 2.44 GHz	2.34 - 2.41
Return Loss	-18.41 dB	-19 dB
VSWR	1.27	1.23

4.2.2 Bandwidth Characteristic

The results obtained in the design and fabrication results show that there are two bandwidths which are the resonance frequency of the antenna. The PIFA obtained more than one resonance frequency due to the existence of U and L shaped slots. Significant factors affecting to bandwidth for PIFA are antenna height and dielectric permeability of the substrate. From the results of simulations and measurements of bandwidth differences occur in both the first and second frequencies. This is caused by cabling between the substrate to the substrate is not accurate, the cable can be too high or too low.

4.2.3 Error Value

The following given equation is the resonance frequency antenna design error value. To find the percentage error, the following equation is used.

$$Error = \left| \frac{MeasurementFrequency - SimulationFrequency}{SimulationFrequency} \right| \tag{4.1}$$

for the first below resonance frequency 900 MHz.

$$Error = \left| \frac{798 - 892.4}{892.4} \right| x100\% = 10.57\%$$

. for the first above resonance frequency 900 MHz.

$$Error = \left| \frac{837 - 925.4}{925.4} \right| x100\% = 9.55\%$$

. for the second below resonance frequency 2,4 GHz.

$$Error = \left|\frac{2.34 - 2.37}{2.37}\right| x100\% = 1.26\%$$

. for the second above resonance frequency 2,4 GHz.

$$Error = \left|\frac{2.41 - 2.44}{2.44}\right| x100\% = 1.22\%$$

The differences that occur between simulation and measurement results can be caused by various kinds of causes. These causes include the following.

1. On the simulation all the conditions that occur are ideal, Meanwhile in fabrication and measurement are not in an ideal state.
2. The fabrication processes is not neat and efficient, such as installation of components and solder.
3. Coaxial probe, cable, and hardware that give additional losses.
4. Measurement error that caused by measurement environment. conditions still give a reflective waves generated by walls or objects around the measurement object.

CHAPTER 5
CONCLUSION AND SUGGESTION

5.1 Conclusion

1. Antenna measurement results work at frequencies 892.4 MHz - 925.4 MHz and 2.37 GHz - 2.44 GHz.

2. the result of return loss for each resonance frequency is 1.42 and 1.23 and the return loss is -16 dB and -19 dB.

3. The first frequency bandwidth is 50 MHz and the bandwidth at the second working frequency is 70 MHz.

4. The error value on the first frequency obtained 10.57 % and 9.55 % because an addition of new dimension at fabrication such connecting a short pin with additional lead and also the accuracy of solder in fabrication affect the result of measurement.

5. The accuracy fabrication of antenna affects the result is also affect the result, based on the difference between simulation and measurement results.

5.2 Suggestion

1. To obtain optimal measurement results, measurements must be carried out in an ideal room such as an anechoic chamber.

2. PIFA antenna is still vulnerable to easily get damage, so new methods and techniques are needed to strengthen the antenna.

3. This undergraduate thesis needs improvement that PIFA antenna configuration is save for human body, Specific Absorption Rate (SAR)'s simulation and measurement are needed.

BIBLIOGRAPHY

[1] D. Angela, D. Yamato, and C. Panjaitan, "Desain dan realisasi planar inverted-f antenna(pifa) berbentuk u-slot dan l-slot pada frekuensi 1800 mhz dan 2300 mhz," 2017.

[2] R. F. Heile, R. Alfvin, P. W. Kinney, J. P. K. Gilb, and C. Chaplin, "Part 15.6: Wireless body area networks - ieee standard for local and metropolitan area networks," 2012.

[3] J. Y. Khan and M. R. Yuce, "Wban for medical applications," *Creative Commons Attribution NonCommercial-ShareAlike 3.0 License*, 2010.

[4] D. K. Mayang and M. Dr. Fitri Yuli Zulkifli S.T., "Rancang bangun dual band planar inverted-f antenna (pifa) untuk aplikasi wimax 2,3 dan 3,3 ghz," 2009.

[5] M. F. Rakhman, A. Muayyadi, and Y. Wahyu, "Desain dan realisasi antena planar inverted-f antenna (pifa) multiband (900 mhz, 1800 mhz dan 2400 mhz)," 2018.

[6] N. B. Ali, "Flexible metasurface-enabled antenna for wearable medical body area network application," 2016.

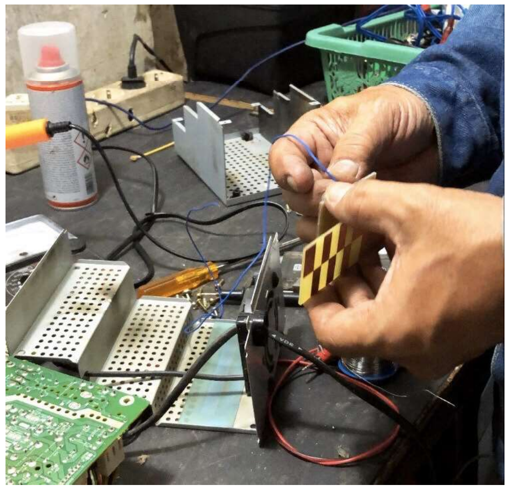
[7] I. Rosu, "Pifa – planar inverted f antenna," 2009.

[8] N. H. M. Rais1, P. J. Soh1, F.Malek, S. Ahmad, N. Hashim, and P. Hall, "A review of wearable antenna," 2009.

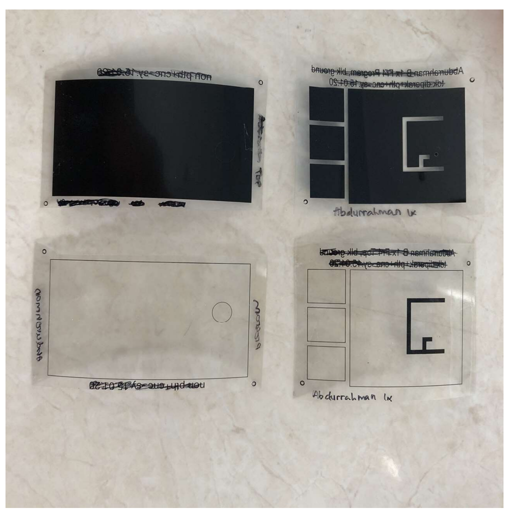
[9] P. K. Sharma, T. V. Sai, and D. Sharma, "Path loss calculation at 900 mhz and 2.4 ghz in wireless body area network (wban)," 2019.

APPENDICES

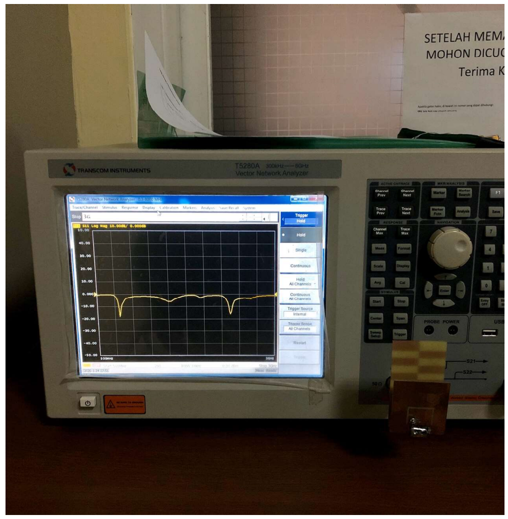
1. Fabrication at Plaza Jaya.



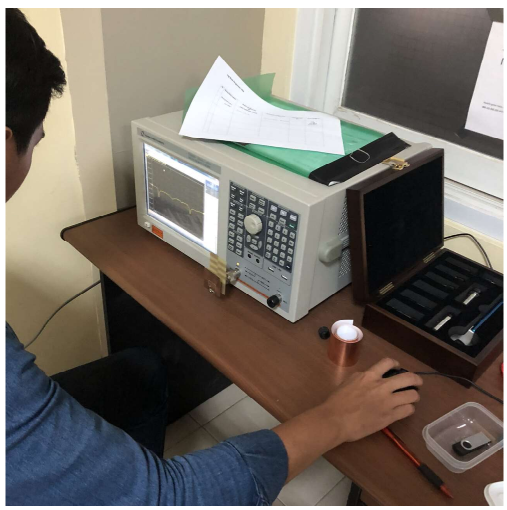
2. Design of Antenna’s Simulation.



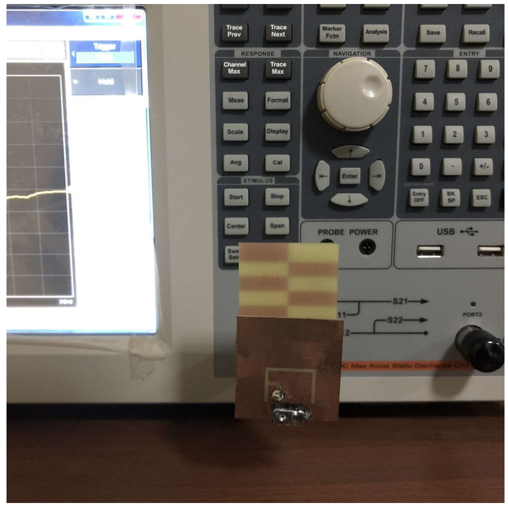
3. Measurement of VSWR and Return Loss with VNA.



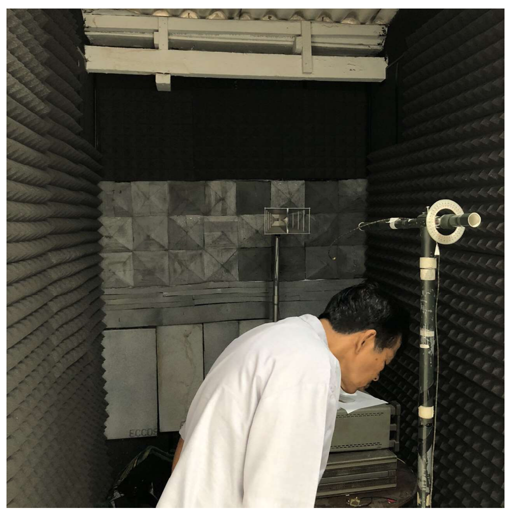
4. Measurement Activity with VNA.



5. Antenna's Configuration on VNA.

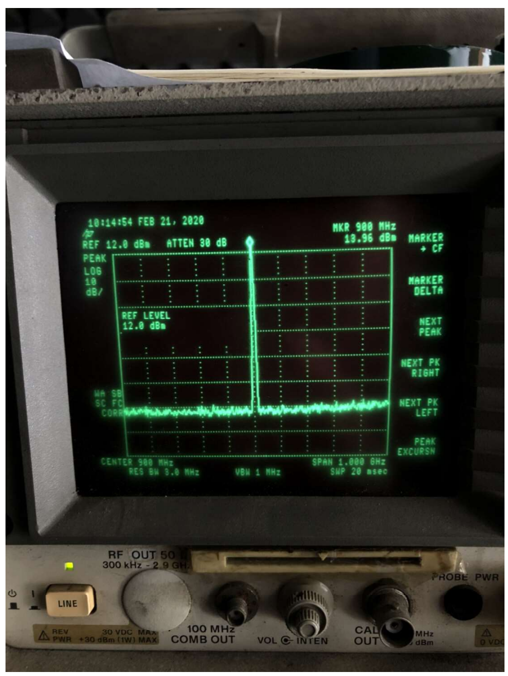


6. Mr. Ruqman on PT. RTI, Assist and Guide The Measurement.

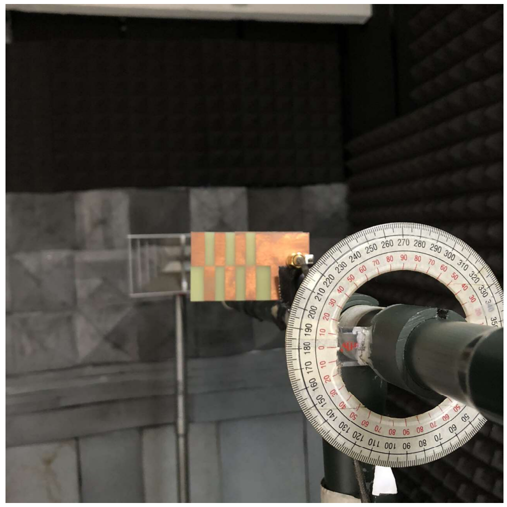


7. Oscillator to do the Radiation Pattern's Measurement Activity.

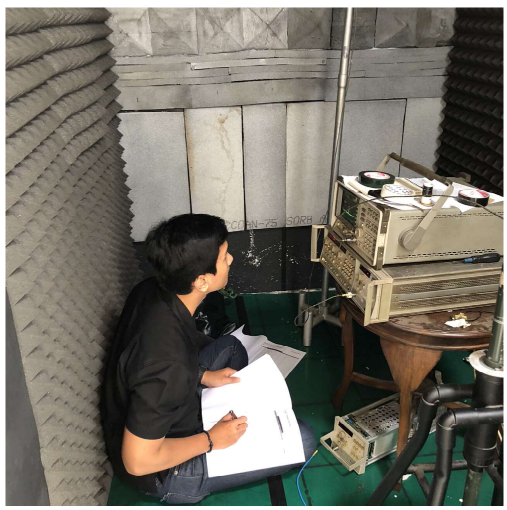
8. Oscillator.



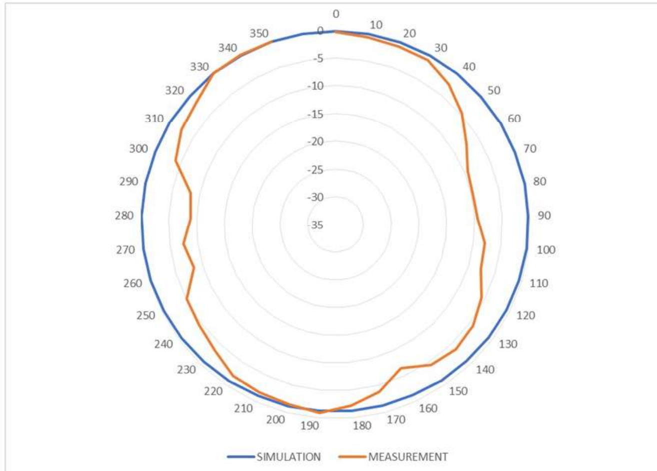
9. Configuration Antenna's for Radiation Pattern Measurement.



10. Radiation Pattern's Activity.



11. Measurement Result on First Resonance Frequency.



12. Measurement Result on Second Frequency.