PATCH ANTENNA FOR AIRCRAFT APPLICATION 5G

RAFHANAH SYAHIDAH BINTI MOHD ROSLEE

BACHELOR OF ENGINEERING TECHNOLOGY
(ELECTRICAL)

UNIVERSITI MALAYSIA PAHANG

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Full Name : DR.MOHAMMED NAZMUS SHAKIB

Position : SENIOR LECTURER

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Full Name	:	RAFHANAH SYAHIDAH BINTI MOHD ROSLEE
ID Number	:	TB17120
Date	:	10 FEBRUARY 2021

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RAFHANAH SYAHIDAH BINTI MOHD ROSLEE

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ABSTRAK

Gambaran keseluruhan antena patch padat untuk aplikasi pesawat disajikan. Tompok antena digabungkan dengan penapis yang digunakan dalam projek ini untuk meningkatkan komunikasi pada peniru. Saiz antena 21.5mm x 27mm digabungkan dengan penapis 20mm x 25mm. Antena patch mikro banyak digunakan kerana profil rendah, berat badan, dan struktur satah. Peranti bersepadu mudah dan direka untuk beroperasi dalam 5 GHz sesuai untuk komunikasi pesawat. Semua harta cth. kejayaan pulangan, keuntungan yang baik, kehilangan penyisipan yang rendah dan corak radiasi yang stabil menjadikannya sesuai untuk digunakan dalam peranti penapis bersepadu antenna ini untuk aplikasi pesawat.

ABSTRACT

An overview of compact patch antennas for aircraft applications is presented. Antenna patches are integrated with the filters used in this project to improve communication on imitators. The antenna size is 21.5mm x 27mm combined with a 20mm x 25mm filter. Micro patch antennas are widely used because of their low profile, light weight, and plane structure. The integrated device is simple and designed for operation in 5 GHz suitable for aircraft communication. All properties e.g. return success, good gain, low insertion loss and stable radiation pattern make it suitable for use in this antenna integrated filter device for aircraft applications.

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LIST OF SYMBOLS

$_{0}C$	Celsius
c	Speed of light
C_t	Capacitance
f	Operating frequency
G_R	Receive antenna gain
G_T	Transmitted antenna gain
P_R	Power receive
P_T	Power transmitted
Pout	Power output
n	Efficiency
pF	picofarads
nH	nanoHenry
mH	megaHenry
r	Distance
GHz	Gigabit Hertz
KHz	KiloHertz
GB/s	Gigabit per second
MB/s	Megabit per second
tW/h	TeraWatt per hour
kW	KiloWatt
mW	MilliWatts
V	Volt
D	Gain
εr	Effective dielectric constant
Ώ	Ohm
Γ	Reflection coefficient
ΔL	Patch length extension
B	Bandwidth
C	Speed of light 3×10^{8}
W	Width
L	Length

LIST OF ABBREVIATIONS

AC	Alternating Current
ADS	Advanced Design Systems
AGC	Automatic Gain Control
BSs	Base Stations
CFLs	Compact Fluorescent Lamps
DC	Direct Current
EH	Energy Harvesting
EMR	Electromagnetic Radiation
EM	Electromagnetic
ICT	Information Communication Technology
IMT	Information Management Technology
IoT	Internet of Thing
IMDs	International Material Data
LPF	Low Pass Filter
PHEV	Plug-in Hybrid Electric Vehicle
RF	Radio Frequency
RFEH	Radio Frequency Energy Harvesting
RFID	Radio Frequency Identification
UHF	Ultra Higher Frequency
UMTS	Universal Mobile Telecommunication Systems
VHF	Very High Frequency
Wi Fi	Wireless Fidelity
WPT	Wireless Power Transmission
5G	Fifth Generation
SBPWM	Simple Boost Pulse Width Modulation
ZSI	Z source inverter
HFSS	High Frequency Structure Software

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CHAPTER 1

INTRODUCTION

1.1 PROJECT BACKGROUND

An aircraft uses a range of radio frequencies to navigate to its destination and communicate with air traffic control. To do this successfully, the on-board radio equipment uses different uses different types and sizes of antennas, each designed for their own frequency band. Each of these antennas have their own characteristic regarding frequency and application and thus location on the aircraft. Even the connection between the antenna and avionics has its own set of specifications. Besides, wireless communication has become a common platform to exchange an extensive range of information between different systems which also includes transportation, aeronautic application etc. In some of the cases such as radars, electromagnetic (EM) waves are used to gather information about distant objects mainly measurement of near shore ocean and river surface current velocities. In such applications line of sight velocity component of ocean waves will be received by forward and aft squinted antennas and then combined together to estimate the actual velocity vector. The selection of the frequency band mainly depends on the requirements discussed below. Generally, the scattering strength from the oceanic surface in the microwave region is large for longer EM waves and also wavelength and size of the antenna can be related to its bandwidth. As higher frequencies are more prone to weather issues such as water absorption, the transmission is interrupted. Thus, by further considering the precipitation, decorrelation time, size of the antenna, and resolution C-band is advantageous for small aircraft. The frequency modulated continuous wave radar technique requires transmitting and receiving antennas.

1.2 PROBLEM STATEMENT

With a rapid development in the wireless communication of aircraft between the aircraft and aircraft to ground. A patch antenna is strongly recommended in the last several decades. A continuous development in patch antenna is under progressing in these days. The limitation of the patch antenna is low gain and high noise that affects the aircraft communication system. However, few of that problem can be improve by designing more appropriate and better structure of antenna integrated filter. The method to develop an antenna integrated filter can be designed through changing the material and shape of the structure. Several factors are needed to be considered as these affects the final outcome of frequency, noise, gain, radiation pattern, thickness of the substrate, shape and length of antenna integrated filter. Therefore, it is essential to find the more desirable structure to overcome the limitations. The place of antenna integrated filter installation also need to be considered whether placed on the top or bottom of the aircraft, the position of the structure may affect the transmission range A microstrip bandpass filter with defected ground structure is to be design having more than -50dB return loss (S11), 0dB of insertion less (S21) at 5GHz.

1.3 OBJECTIVE

The target for this project is to accomplish the following objectives:

1. To design a new 5GHz microstrip patch antenna for aircraft applications.
2. To develop a new microstrip patch antenna integrated filter for aircraft application.
3. To evaluate the performance of the newly design structure using simulation software.

1.4 PROJECT SCOPE

The scope for this project is to develop a new microstrip patch antenna design for aircraft applications. To come up with a new patch antenna design, firstly need to ensure the draft design has not been done by other researcher and able to work with an operating frequency of 5GHz. After ensure the draft is noble, proceed with full design of the patch antenna together with its substrate material and all other dimensions. The main rule of designing the new patch antenna is to ensure the total size of the patch antenna is small and compact as possible.

The next part is to achieve the second objective are design the integrated filter for the patch antenna. After that, finalizing the dimensions of the filter which is length, width and thickness. Lastly, the design filter must be able to receive only 5GHz signal and filter out any other noise that is presence at other frequencies.

After finishing the design, proceed with the performance evaluation of the new microstrip patch antenna. Evaluate the return loss of the antenna and ensure the return loss frequency is at 5GHz only. Then proceed with the evaluation of the antenna's radiation pattern as well as the total gain of the antenna.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter is discussed on the literature review for the topic of design of mimic aicraft for 5G applications. Firstly, the background of the patch antenna that discussed by compared with the conventional separated antenna and filter systems. Then, the basic antenna parameters also discussed in this chapter, which include conceptual and technique used in the preparation and designation of mimic aircraft application. This research will explain the design of mimic aircraft.

2.2 5G NETWORK

5G Network will be able to achieve very high data rates depending on the environment and the number of users. Specifically, for one user in an indoor environment. 5G could offer 1 GB/s data rate service. In an outdoor environment with a greater number of users, the data rate will decrease, reaching values of up to tens of Mb/s. Furthermore, this high data rate experienced should be achieved in 95% of the covered location (R.E. Hattachi 2015). The network capacity will significantly rise since the 5G spectrum will exploit frequencies in the mm-Wave bandwidth. The total estimated new bandwidth for 5G will be 10 GHz (Q.C.Li*et al.*, 2014). This entire spectrum will provide higher quality of service than that provided by the current 4G network.

5G will also be more energy efficient. Energy efficiency is the energy over the whole network defined by the number of bits that can be transmitted per Joule of energy. This will be achieved through intentional network design and device connectivity, leading to longer battery lifetimes. In 5G, the battery lifetime of the device is going to be increased to up to 3 days for the smartphone and up to ten times longer battery lifetime for lower-power devices Even for a low cost machine to machine communication device, up to 15 years of life expectancy are predicted

(D.A.Osseiran, 2013). 5G will offer many benefits. As it was described above, high data rate, mobility, number of users, lowlatency and of course low energy are the main benefits. One challenge of 5G is the interference between the cells (macro and micro cells to pico cells), since their number is going to be significantly greater (Panayiotis Efthymakis, 2018).

Compatibility studies must be carried out in each frequency band and each band must balance with the requirement of other existing services and allocations shown in Table 2.1.

Table 2.1: Possible new spectrum for IMT (GuntisAncans*et al.*, 2017)

Frequency bands to be Studied until WRC-19 for Possible identification for IMT, GHz	Band with, GHz	Primary allocations to radio communication services in Radio Regulation in ITU Region
37 - 40.5	3.5	EARTH EXPLORATION- SATELLITE(Earth to space),FIXED, FIXED SATELLITES(space to Earth), MOBILE,MOBILE except aeronautical mobile, MOBILE SATELLITE (space to earth), SPACE RESEARCH (Earth to Space), SPACE RESEARCH(space to Earth)
42.5 – 43.5	1	FIXED, FIXED-SATELLITE(Earth to space), MOBILE except aeronautical mobile, RADIO ASTRONOMY

2.3 MIMIC AIRCRAFT

A basic frame work for mimic aircraft structure is designed. The developed design frame work in the first part is used to arrive at the sizes of the various components of an mimic aircraft structure. The strength based design is adopted, where the design loads are extracted from the aerodynamic loads. The aerodynamic loads acting on a mimic aircraft structure are converted to equivalent distributed loads, which are further converted point loads to arrive at the shear forces, bending and twisting moments along the wing span. Based on the estimated shear forces, bending and twisting moments, the strength based design is employed to estimate the sizes of various sections of a composite mimic aircraft structure. A three dimensional numerical model of the composite mimic aircraft structure has been developed and analyzed for the extreme load conditions. Glass fiber reinforced plastic material is used in the numerical analysis. The estimated natural frequencies are observed to be in the acceptable limits. Furthermore, the discussed design principles in the first part are extended to the design of a morphing airfoil with auxetic structure. The advantages of the morphing airfoil with auxetic structure are (i) larger displacement with limited straining of the components and (ii) unique deformation characteristics, which produce a theoretical in-plane Poisson's ratio of–1. Aluminum Alloy 2024 is considered in the design of all the structural elements. The compliance characteristics of the airfoil are investigated through a numerical model. The numerical results are observed to be in close agreement with the experimental results in the literature.

2.4 ANTENNA PARAMETERS

Antenna parameters are used to characterize performance of an antenna when designing and measuring antenna. The performance of antenna very important parameters which is radiation pattern and gain.

2.4.1 RADIATION PATTERN

The radiation pattern of microstrip patch antenna is the power radiated or received by the antenna. This power variation as a function of the arrival angle is observed in the antenna's far field. It tells the strength and phase of radiation in a certain direction with respect to an isotropic radiator radiating the same energy (John Wiley & Sons, 2005). Antenna radiation pattern are taken one frequency, one polarization and one plane cut. The radiation property of most concern is the two or three-dimensional spatial distribution of radiated energy as the function of the observer's position along a path of surface of constant radius (JohnWiley & Sons, INC, Canada, 1997).

Usually the pattern is expressed as a function of the directional coordinates: azimuth angle φ and elevation angle θ. Strengths of radiated electric or magnetic fields in the far-field are referred to field patterns, while the power density of them is power pattern. The typical radiation pattern of rectangular patch antenna is as shown in Figure 2.1.

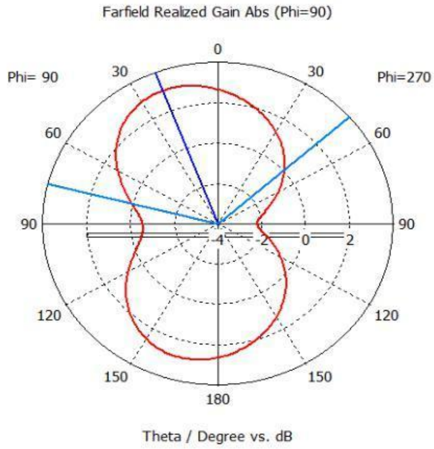

Figure 2.1 : Radiation pattern of rectangular patch antenna.
Source: John Wiley & Sons, INC, Canada, 1997

2.4.2 GAIN

The ratio of the power radiated or received by meticulous antenna in a prearranged direction, to the power radiated or received by a taking reference ideal isotropic antenna in cooperation fed by the similar power. Due the isotropic as ideal antenna we take in dBi as reference unit. The radiation intensity corresponding to the isotopically radiated power is equal to the power accepted by the antenna divided by 4π (JohnWiley & Sons, INC, Canada, 1997).

2.5 COMMUNICATION AIRCRAFT

Aviation communication is the means by which aircraft crews connect with other aircraft and people on the ground to relay information. Aviation communication is a crucial component pertaining to the successful functionality of aircraft movement both on the ground and in the air. Increased communication reduces the risk of an accident.

During the early stages of aviation, it was assumed that skies were too big and empty that it was impossible that two planes would collide. However, in 1956 two planes famously crashed over the Grand Canyon, which sparked the creation of the Federal Aviation Administration (FAA). Aviation was roaring during the Jet Age and as a result, communication technologies needed to be developed. This was initially seen as a very difficult task: ground controls used visual aids to provide signals to pilots in the air. With the advent of portable radios small enough to be placed in planes, pilots were able to communicate with people on the ground. With later developments, pilots were then able to converse air-to-ground and air-to-air. Today, aviation communication relies heavily on the use of many systems. Planes are outfitted with the newest radio and GPS systems, as well as Internet and video capabilities.

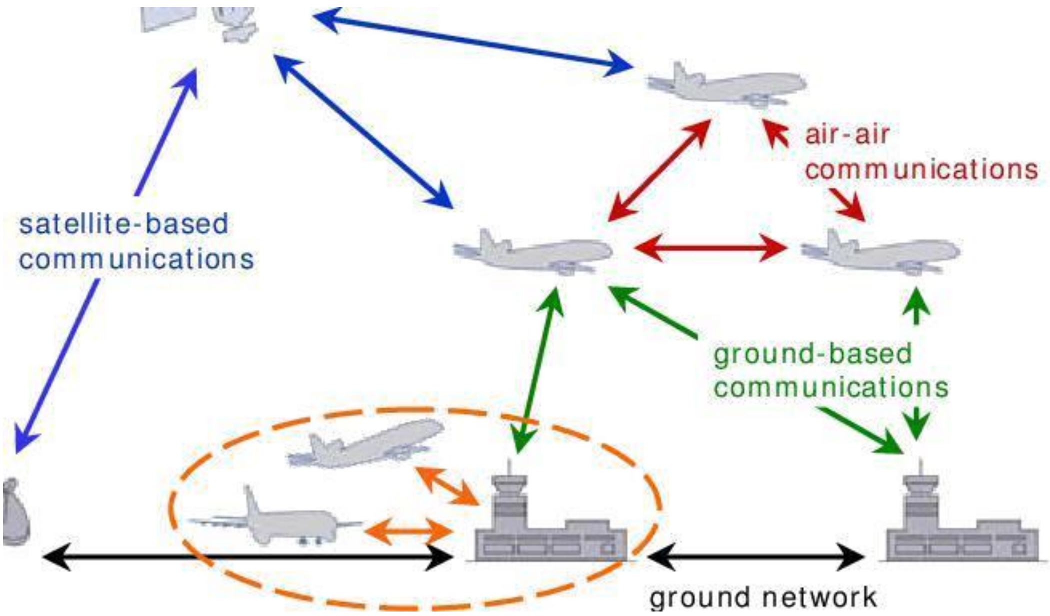

Figure 2.2 : Communication Aircraft

2.5.1 Aircraft between aircraft

Inter-aircraft communication is a standard international practice for monitoring airspace using two radar systems, primary and secondary. The main radar is based on the earliest form of radar developed in the 1930s, detecting and measuring the aircraft's position using reflected radio signals. It does this whether the subject wants to be tracked or not. The secondary radar, which depends on the target equipped with the transponder, also requests additional information from the aircraft - such as its identity and altitude. All commercial planes come with a transponder (short for "transmitter responder"), which automatically sends unique four-digit codes when they receive radar-transmitted radio signals. The code provides the aircraft identities and radar stations continuously running to determine speed and direction by monitoring consecutive transmissions. This flight data is then passed to the air traffic controller. However, when the aircraft is more than 240km (150 miles) deep into the sea, fading radar coverage and air crews remain in contact with air traffic control and other aircraft using high-frequency radio. In addition, VHF communication is also a tool used in aircraft to communicate with towers and other aircraft.

2.5.2 Aircraft to ground communication

Aircraft Communication Addressing and Reporting System (ACARS) is a digital datalink system for the transmission of short messages between aircraft and land stations via radio or satellite radio. ACARS as a term refers to a complete air and land system, consisting of on-board equipment, on-board equipment, and service providers. The main function of ACARS is to automatically detect and report changes to the main flight phase. At the beginning of each flight phase, an ACARS message is sent to the ground describing the flight phase, the time at which it occurred, and other information such as the amount of fuel on board and the origin and destination of the flight. This message is used to track the status of aircraft and crew. ACARS sends real-time information from aircraft to land stations on the state of various aircraft systems and sensor. Automatic ping messages are used to test the aircraft's relationship with the communication station. In the case of the aircraft serves to meet its needs. ACARS can send messages via VHF if a network of VHF ground stations exists in the current area of the aircraft. ACARS message using VHF data links using the 117.975–137 MHz band. Where is VHF absent, HF network or satellite communications may be used if available

2.6 CONCLUSION

This chapter explains the topic of imitative aircraft and the materials to be used to make imitative aircraft. It also describes the use and application of the results based on the parameters of the material used and the suitability of the material. in addition, in this topic also describes the communication between aircraft and ground.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This methodology will include a detailed explanation of the steps that are being used to make this project a success. This method is used to achieve the goal of the project that will be achieved and the problem statement was studied and identified in detail. This project begins by developing the project workflow and conducting a literature review of the project can be completed on time, the scheduling must be carried out and must also serve as a guideline for the work schedule of the project.

3.2 FLOWCHART

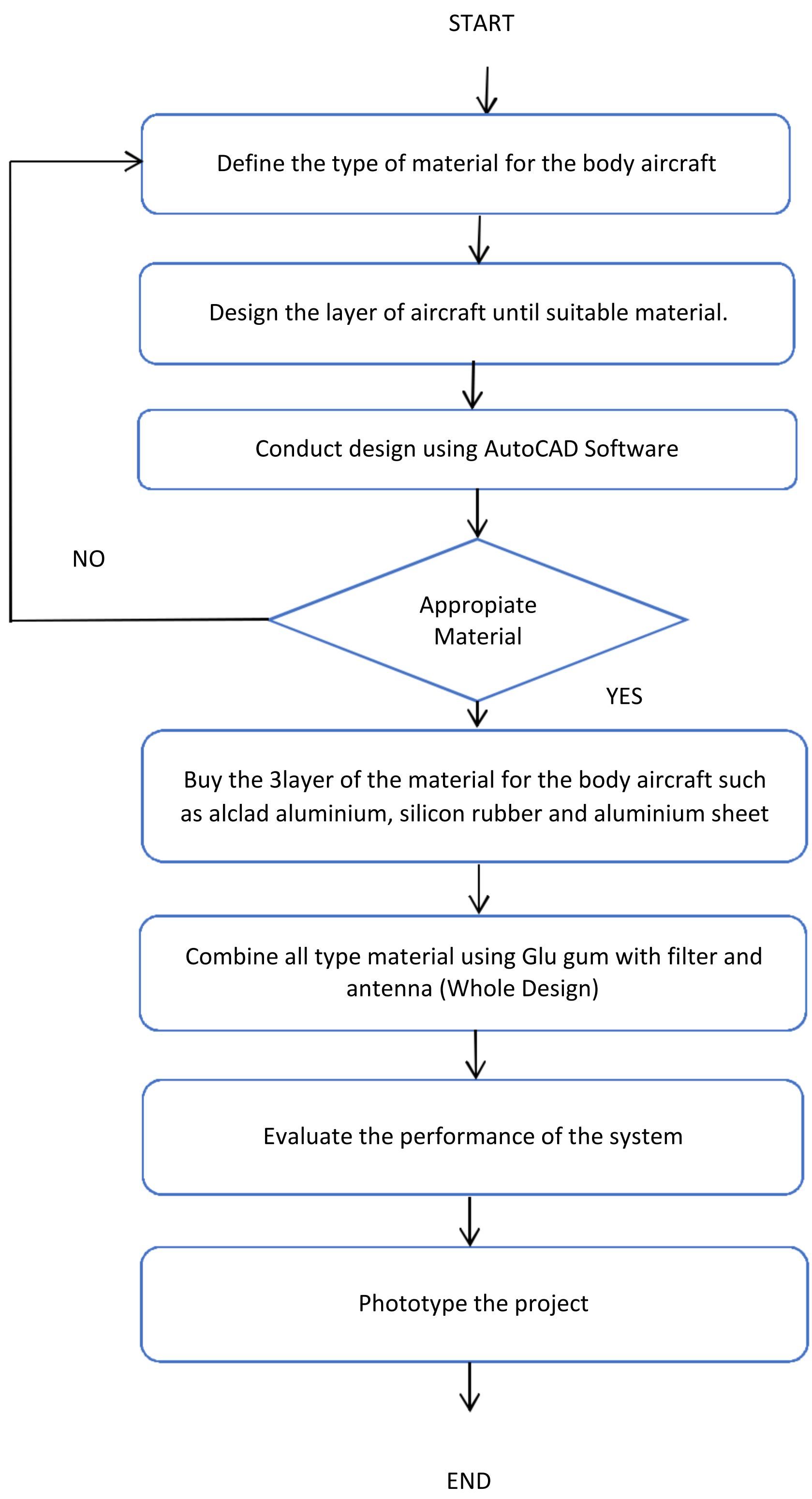

Figure 3.1 : Flow chart of the project

Figure 3.1 shows the flow of the beginning project until end. Firstly, find the resource literature review on energy harvesting system and the components, then design of the rectifier circuit for 5G operation using AutoCAD software after design must simulated to get the result achievable then after get a good result, design of the rectifier circuit must fabricated and doing the prototype.

3.3 SELECTION OF DIELECTRIC MATERIAL

The selection of the dielectric substrate that needed to develop a material required suitability for low frequency, efficiency, losses gain and compactness of the material to achieved. Table 3.1 show the material of substrate was selected with their length, width and relative permittivity of substrate. This material very important to achieve the target frequency 5GHz with efficiency.

Table 3.1: Dielectric substrate material

Material	**Thinkness**	**Length x Width**	**Dialectric constant**
Aluminium Alclad	0.64mm	500mm x 500mm	10.8
Silicon Rubber	3mm	500mm x 500mm	2.9
ALuminium Sheet	0.2mm	500mm x 500mm	10.8

3.4 ANTENNA PLACEMENT

Different aircraft have the different placement of antenna. So, we choose decide to put the antenna on top of aircraft. This is because it can be directed towards the transmitting satellite while the plane is in the air. It is an improvement over the air to ground system because it speed can get up to 30-40Mbps.

In addition, for drawing autoCAD aircraft model used is airbus model. Airbus in terms of the use of technology uses composite materials widely in aircraft in the present era. Selection of engines, Competitive strength in the passenger aircraft market is quite influenced by the choice of available engines.

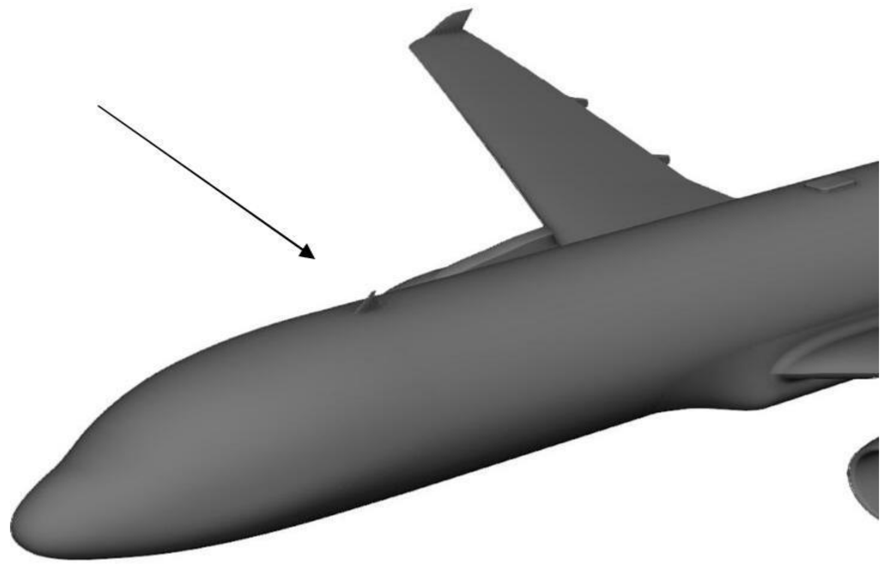

Figure 3.2 : Aircraft model with antenna placement

3.5 MIMIC AIRCRAFT PORTION

AutoCAD is a computer-aided design (CAD) program used for 2-D and 3-D design and drafting. AutoCAD is developed and marketed by Autodesk Inc. and was one of the first CAD programs that could be executed on personal computers. AutoCAD was initially derived from a program called Interact, which was written in a proprietary language. The first release of the software used only primitive entities such as polygons, circles, lines, arcs and text to construct complex objects. Later, it came to support custom objects through a C++ application programming interface. The modern version of the software includes a full set of tools for solid modeling and 3-D. AutoCAD also supports numerous application program interfaces for automation and customization. DWG (drawing) is the native file format for AutoCAD and a basic standard for CAD data interoperability. The software has also provided support for Design Web Format (DWF), a format developed by Autodesk for publishing CAD data.

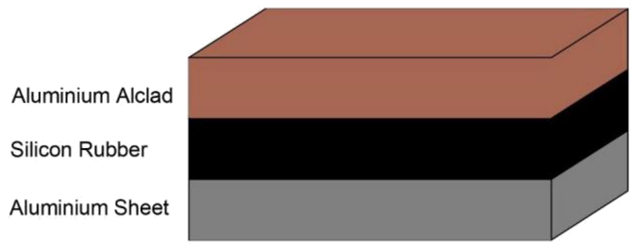

Figure 3.3 : Layer of mimic aircraft portion

Figure 3.3 shows the layer of the mimic aircraft portion that the patch antenna going to be mounted on.

3.5.1 MATERIAL BY LAYER

The metals used in the aircraft manufacturing industry include aluminium alclad, silicon rubber, aluminium sheet, and their alloys. Aluminium alloys 2024 are characterised by having lower density values compared to steel alloys (around one third), with good corrosion resistance properties.

However, aluminium alclad have a greater tensile strength, as well as a higher elastic modulus. As a result, alclad is used in the parts of aircraft for which strength is very important. Typically used in aircraft skins, cowls, aircraft structures. Also used for repair and restoration

Silicon rubber one of the first oil resistant synthetic rubbers. The rubber Seal solid strip is exceptional durability, stretch and strength. It remains firm and flexible in a wide range of temperatures and condition, suibtable for wide use. It is applications include sound-proofing with long lasting and resistant to abrasion and oils. Can be used to seal cover alclad aluminum coating and even protect your floors with its cushioning properties.

In addition to material, aluminum sheet is ideal for aircraft manufacture because it's lightweight and strong. Aluminum is roughly a third the weight of steel, allowing an aircraft to carry more weight and or become more fuel efficient. Furthermore, aluminum's high resistance to corrosion ensures the safety of the aircraft and its passengers.

3.6 FABRICATION

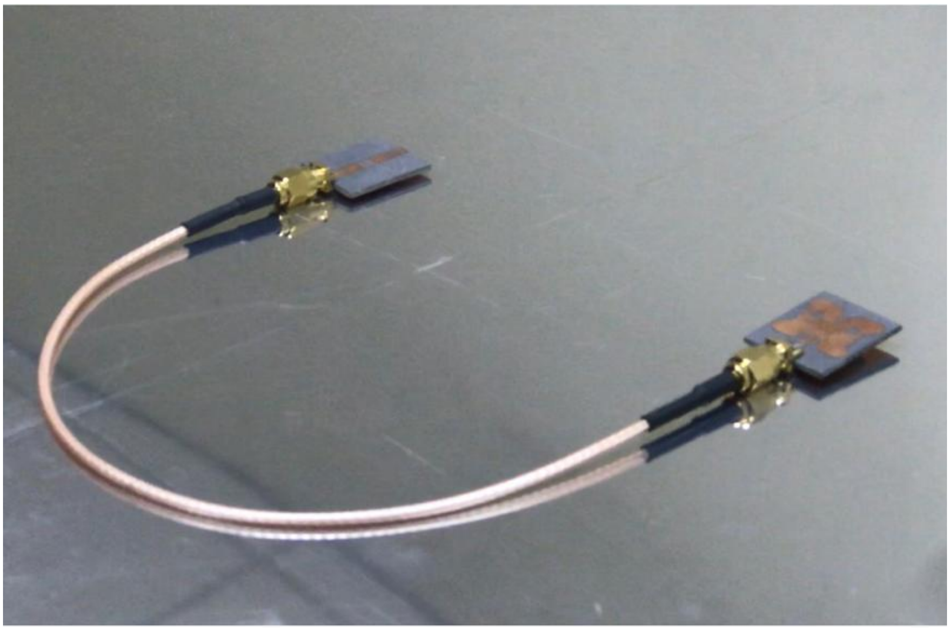

Figure 3.4 : Prototype for Patch antenna

Figure 3.4 shows the combined prototype between the antenna and the filter. After being combined using the wire, then placed on aluminum alclad to be used as a prototype.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

The simulation result from Ansoft High Frequency structure simulator (HFSS) software of the material by layer will resolve around the scattering S-parameter to determine material from input port to output port. The result also shows the return loss for target frequency 5Ghz to shows up the efficiency this material by layer.

4.2 RETURN LOSS S11

A return loss of -10 dB will be achieved at frequency range between 5GHz.

4.2.1 Aluminium Alclad S11

The return loss are shown in Figure 4.1 of the designed alclad is simulated using HFSS. We could observe from the results obtained that the designed alclad has low a return loss of -55.8410 dB and 4.9880GHz.

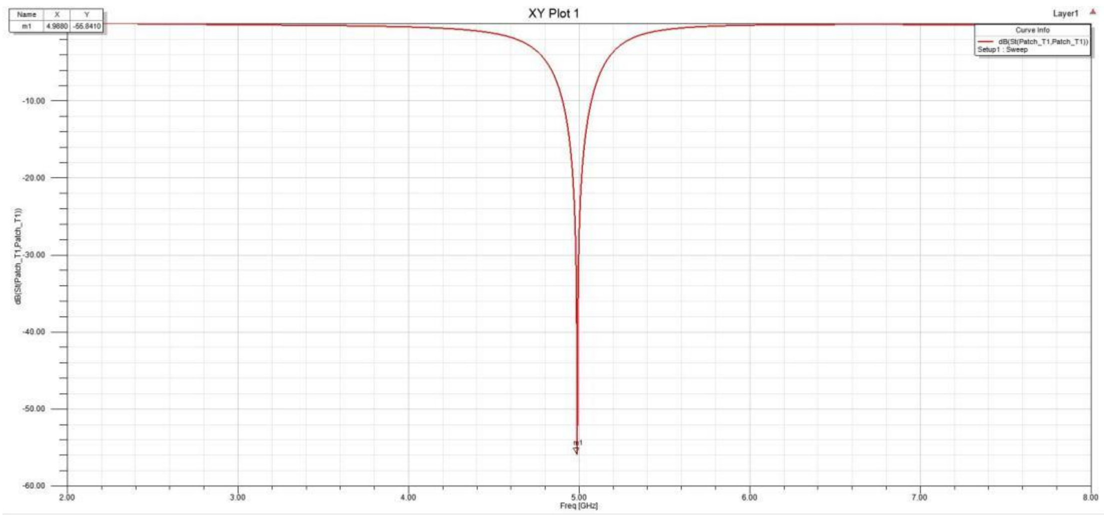

Figure 4.1 : Return loss graph of S11 for Aluminium Alclad

Table 4.1 : Result of S11 for Aluminium alclad

Name	Frequency in GHz	Simulated Return loss (S11) in dB
M1	4.9880	-55.8410

4.2.2 Silicon Rubber S11

The return loss are shown in Figure 4.2 of the designed silicon rubber is simulated using HFSS. We could observe from the results obtained that the designed silicon rubber has low a return loss of -39.0706dB and 4.9990GHz.

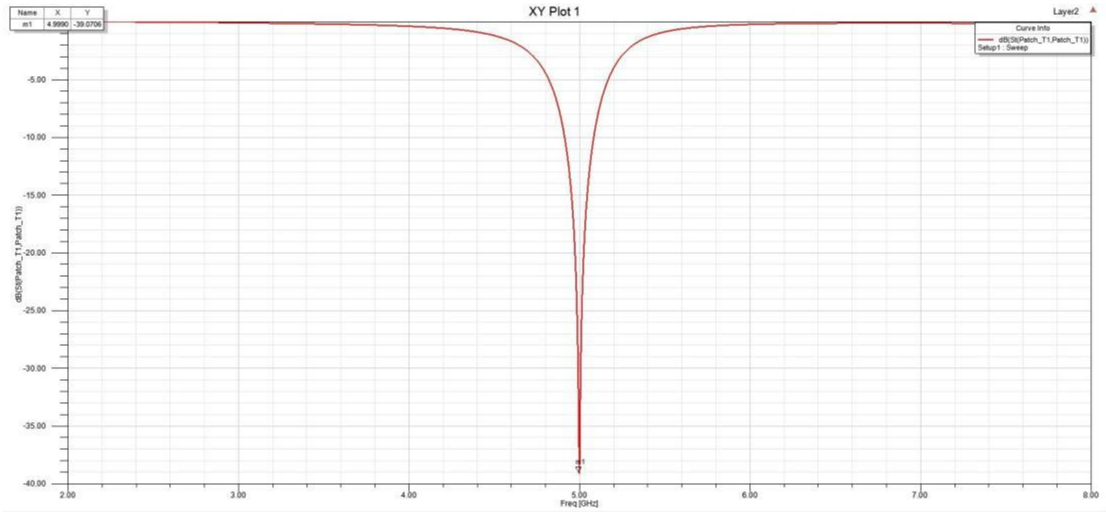

Figure 4.2 : Return loss graph of S11 for Silicon Rubber

Table 4.2 : Result of S11 for silicon rubber

Name	Frequency in GHz	Simulated Return loss (S11) in dB
M1	4.9990	-39.0706dB

4.2.3 Aluminium sheet S11

The return loss are shown in Figure 4.3 of the designed aluminium sheet is simulated using HFSS. We could observe from the results obtained that the designed aluminium sheet has low a return loss of -42.1583dB and 4.9990GHz.

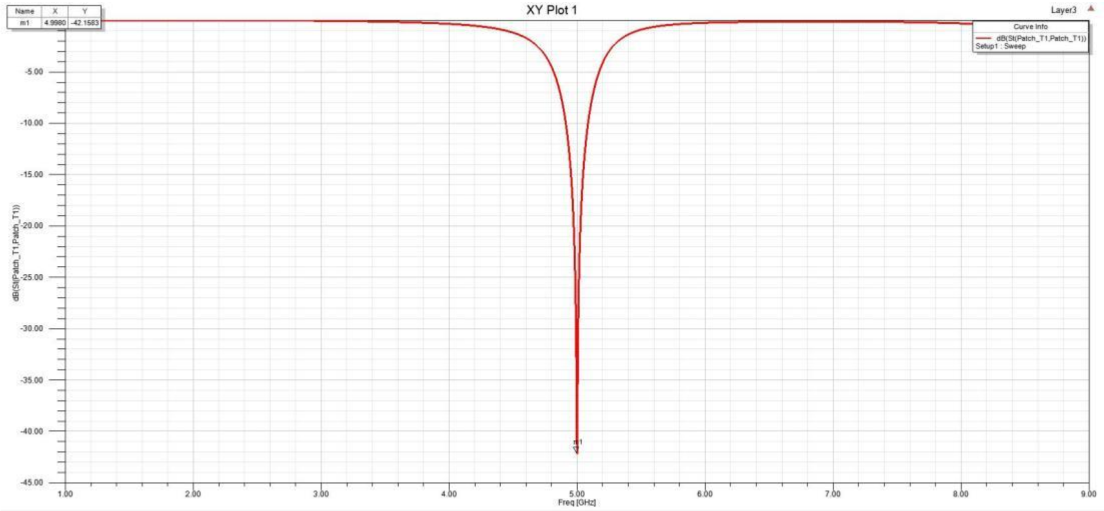

Figure 4.3 : Return loss graph of S11 for Aluminium sheet

Table 4.3 : Result of S11 for Aluminium sheet

Name	Frequency in GHz	Simulated Return loss (S11) in dB
M1	4.9990	-42.1583

4.3 RADIATION PATTERN

The newly designed patch antenna radiation pattern where the antenna radiates at frequency of 5GHz. The shape of the radiation pattern is in omni-directional but with a heavier concentration on the top area. This mean the antenna able to radiates power on all direction and the top area has the highest power compare to other regions.

4.3.1 Aluminium Alclad

For the gain in layer 1, the gain of the patch antenna is decreased from the original 6.4180dBi to 5.2382dBi. Figure 4.4 shows the return loss of the simulated design for layer 1.

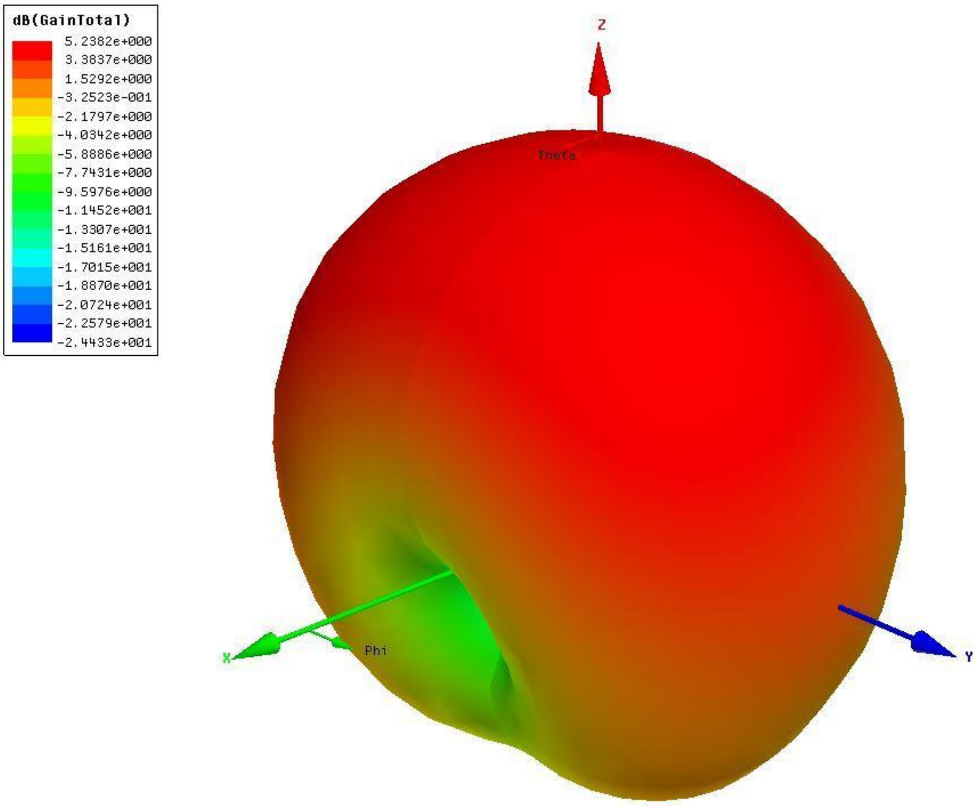

Figure 4.4 : Radiation pattern of Antenna Mounted in Layer 1

4.3.2 Silicon Rubber

For the gain in layer 2, the gain of the patch antenna is decreased from the original 6.4180dBi to 5.1041dBi. Figure 4.5 shows the return loss of the simulated design for layer 2.

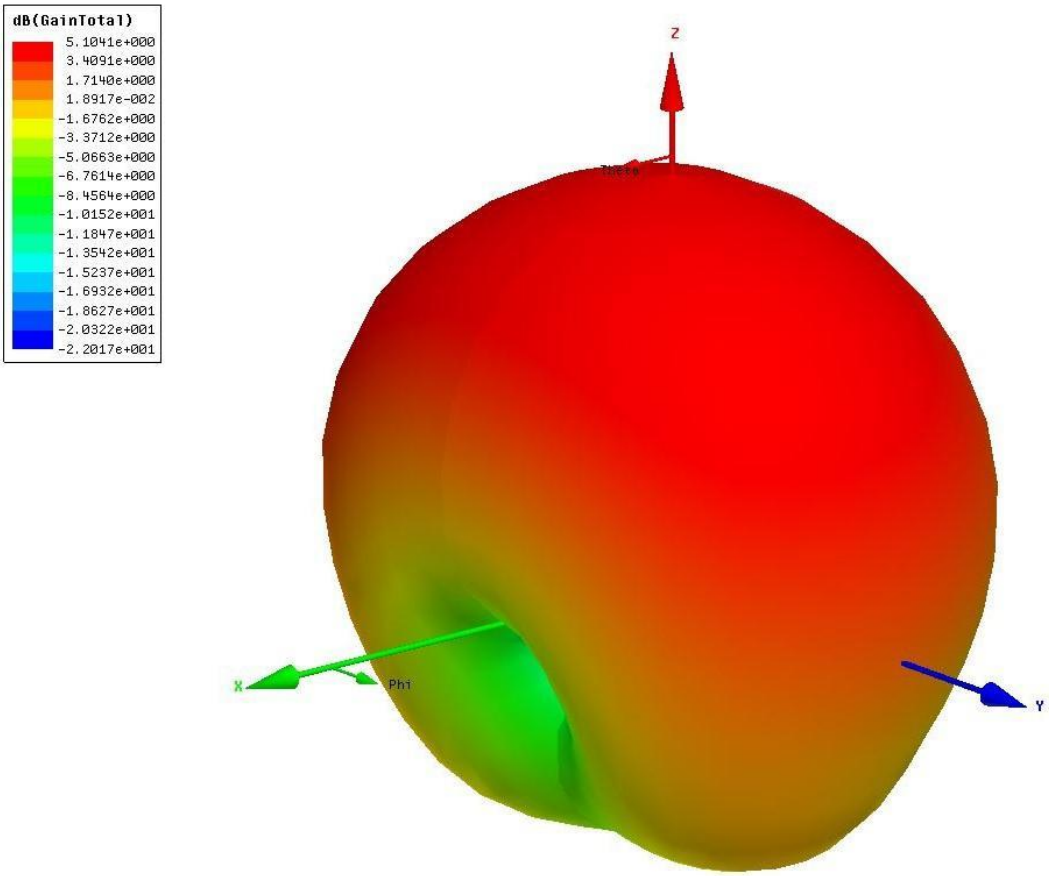

Figure 4.5 : Radiation pattern of Antenna Mounted in Layer 2

4.3.3 Aluminium sheet

For the gain in layer 3, the gain of the patch antenna is decreased from the original 6.4180dBi to 5.8805dBi. Figure 4.6 shows the return loss of the simulated design for layer 3.

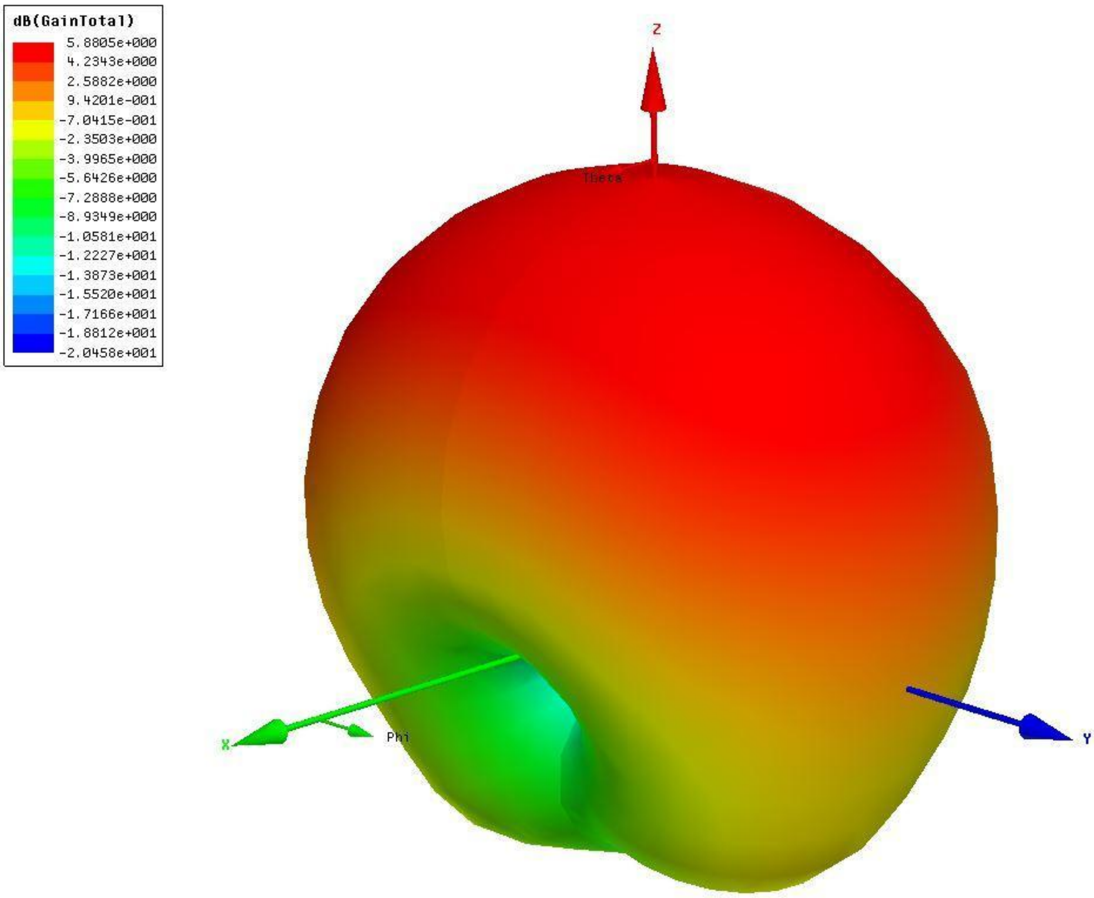

Figure 4.6 : Radiation pattern of Antenna Mounted in Layer 3

4.4 CONCLUSION

In this chapter, the author have explained on the newly designed material by layer results of return loss and radiation pattern.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION OF THE PROJECT

A new microstrip patch antenna is has been designed. The patch antenna integrated filter have a very low deviation in frequency range and also have a average gain, so this wireless communication system is proposed and discussed in this work to possible to be used in various size of aircraft also any radome cover the antenna. The antenna operates at the frequency 5GHz with a very low deviation compare to several previous works. the result of 11 and gain of antenna when apply on the layer of airbon close to the original result. The simulated antenna shows better performance in term of frequency losses due to effect of the substrates below the patch antenna. The accuracy of this model is verified with electromagnetic software (HFSS) computation. This antenna has physical size with a compact size, simple structure and high efficiency to be high market potential. All these properties make it a good candidate for future millimetre wave application.

5.2 RECOMMENDATION

To summarize, to improve this project in future, several recommendation have been identified including, term of structure, the design can further improve in terms of basic parameters such as the type of substrate, dielectric constant and the thickness of substrate.. Secondly, must be investigated the challenges that the design of circuits have in antenna frequencies and chosen filter suitable with range frequencies which is have fast switching rate and improve increases voltage output.

Lastly, Future work should focus on further refining the design of the rectifier to allow for more effective signal harvesting, as well as investigating the design using a “real” source.

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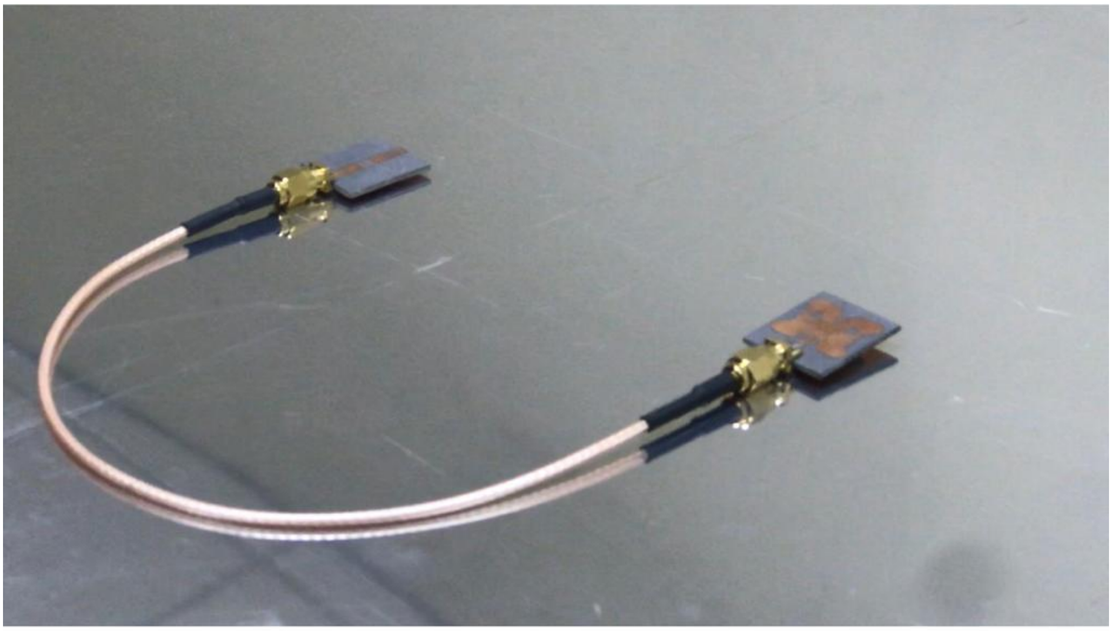
APPENDICES

Appendix A: Possible new spectrum for IMT

Table 1: Possible new spectrum for IMT

Frequency bands to be Studied until WRC-19 for Possible identification for IMT, GHz	Band with, GHz	Primary allocations to radio communication services in Radio Regulation in ITU Region
24.25- 27.5	3.25	EARTH EXPLORATION- SATELLITE(space to Earth),FIXED, FIXED SATELLITES, MOBILE,RADIONAVIGATION, SPACE RESEARCH (space to Earth)
37 - 40.5	3.5	EARTH EXPLORATION- SATELLITE(Eath to space),FIXED, FIXED SATELLITES(space to Earth), MOBILE,MOBILE except aeronautical mobile, MOBILE SATELLITE (space to earth), SPACE RESEARCH (Eath to Space), SPACE RESEARCH(space to Earth)
42.5 – 43.5	1	FIXED, FIXED-SATELLITE(Earth to space), MOBILE except aeronautical mobile, RADIO ASTRONOMY
45.5-47	1.5	MOBILE, MOBILE SATELLITE, RADIONAVIGATION, RADIONAVIGATION-SATELLITE
47.2-50.2	3	FIXED, FIXED-SATELLITE(Earth to space), FIXED-SATELLITE(space to earth), MOBILE
50.4-52.6	2.2	FIXED, FIXED-SATELLITE(Earth to space),MOBILE
66-76	10	BROADCASTING, BROADCASTING SATELLITE, FIXED, FIXED SATELLITE (space to earth), to space), RADIONAVIGATION, RADIONAVIGATION-SATELLITE
81-86	5	FIXED, FIXED SATELLITE (earth to space), to space), MOBILE, MOBILE SATELLITE(Earth to space), RADIO ASTRONOMY

Appendix B: Design and prototype



Appendix C: Gantt chart project planning of SDP 2

Table 2: Gantt chart project

ACTIVITY	WEEKS																											
	SDP 1														SDP 2													
	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14
TOPIC UNDERSTANDING	■	■	■																									
BASIC DESIGN				■																								
DETAIL DESIGN					■	■	■																					
MATERIAL SELECTION								■	■																			
DRAFT PROJECT PROPOSAL										■	■																	
PRESENTATION												■																
FULL PROJECT PREPARATION													■	■														
REDESIGN PROJECT															■	■	■											
PURCHASING															■	■	■											
FABRICATION																		■	■	■								
TESTING																					■	■	■					
REPORT																								■	■			
PRESENTATION																										■		
FULL REPORT PROJECT																											■	■