



UNIVERSITI TEKNIKAL MALAYSIA MELAKA

**Development of Hybrid Helix-Patch Antenna Transmission System
for GPS-Guided Aerial Surveillance Application**

This report submitted in accordance with requirement of the Universiti Teknikal
Malaysia Melaka (UTeM) for the Bachelor Degree of Electrical Engineering
Technology (Telecommunication) with Honours

by

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APPROVAL

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Electrical Engineering Technology (Telecommunication) with Honours. The member of the supervisory is as follow:



ABSTRAK

Secara umumnya, projek ini bertujuan untuk merekabentuk dan mencipta satu antenna yang berkebolehan untuk menerima isyarat video dari suatu jarak yang jauh. Frekuensi yang digunakan merupakan 5.8GHz dimana frekuensi menawarkan jalur lebar tinggi dan ini amat popular di kalangan peminat *multi-rotor* dimana kualiti video yang dibawa lebih bagus dan jelas. Dengan keupayaan antenna untuk menerima isyarat sejauh 700 meter, ia dapat membantu untuk mengurangkan masalah jarak operasi yang dihadapi oleh pengendali *multi-rotor* yang menggunakan antenna asal dibekalkan. Dengan menggunakan perisian *Computer Simulation Technology (CST)*, antenna ini dapat di analisis sebelum melalui proses pembuatan. Dengan bantuan perisian ini, ia dapat mengurangkan kos untuk penyelidikan dan pembangunan dengan data yang lebih tepat untuk dianalisa

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ABSTRACT

Generally, this project is intended to design and create an antenna that had a capability to receive video signal from a long distance. The frequency that used are 5.8GHz band where this frequency offers high bandwidth data and very popular for multi-rotor users where the video quality that its carry are clear and much better. With the antenna capability to receive the signal about 700 meters, it will help the user (or pilot) to overcome the problem of the limited operation range compared to standart antenna that supplied with the system. With the help of this Computer Simulation Technology (CST) software, this antenna can be develop before manufacture. It will cut the cost to make research and development for this antenna and it provide an accurate data to be analyse

DEDICATION

I dedicated this to my beloved parents and siblings where they provide me effortless support for me to continue on this project. Also for my RC members at Ipoh where their suggestion, ideas and time that give to me for testing my project. Also to my supervisor which give me continuous support for me to complete this project within time despite whit a lot of programme to handle. Without this help form people around me, it will be far more difficult to me to complete this project and report.



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LIST ABBREVIATIONS, SYMBOLS, AND NOMENCLATURES

GPS	-	Global positioning System
FPV	-	First Person View
VTx	-	Video Transmitter
VRx	-	Video Receivers
CST	-	Computer Simulation Technology
MAVLink	-	Micro Air Vehicle Communication Protocol
SMA	-	Subminiature version A
RP-SMA	-	Reverse Polarity Subminiature version A

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CHAPTER 1

INTRODUCTION

1.0 Introduction

This section focused on preparing the entire report content including the graphical illustration which can be found in appendices. This chapter focuses on the project introduction, background, problem statement, objectives and project scope regarding the project. The Development of hybrid helix-patch antenna transmission system for GPS-guided aerial surveillance application will be explain more in detail. The problem statement states the reason why this project is being conducted. Then, at the end of the chapter the organization of the thesis will be explain.

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1.1 Project Background

In wireless transmission system, antenna play a vital role that communicate from end to end (transmitter and receiver). The purpose of an antenna is to collect and convert electromagnetic waves to electronic signals. The signal that are capture by the receiver and send it down to process the signal receive. Antennas are essential components of all equipment that uses radio. They are used in systems such as radio broadcasting, broadcast television, two-way radio, communications receivers, radar, cell phones, and satellite communications, as well as other devices such as garage door openers, wireless

microphones, Bluetooth-enabled devices, wireless computer networks, baby monitors, and RFID tags on merchandise.

This project focus on development of long range antenna for 5.8GHz video transmission system. This type of frequency band is commonly use in wireless video transmission. Because the video transmitter part (VTx) are available in much smaller package, it become famous among the increasingly user of multi-rotor application. In multi-rotor application, there are other frequency band such as 1.2Ghz, 1.3Ghz and 2.4Ghz. Each frequency band have its effect on video transmission quality. For example, 1.2Ghz and 1.3Ghz are very good on long distance transmission, but the quality of the video transmission is limited to black and white only and the

1.2 Problem Statement

Nowadays, the usage of 5.8Ghz frequency band are famous among multi-rotor user and it recognize when the event of Dubai Drone Race 2015 take place. The problem often occurs with the Omni-directional dipole antenna that supplied with the 5.8Ghz transmission system. Other type of antenna also available in the market such as clover leaf antenna that offer 360° radiation pattern but limited to its short distance. Helical antenna type also available but it only has radiation field about 45° . A hybrid type of antenna is needed so it can offer both properties. This antenna development is design to solve the problem that occur nowadays. To solve this problem, an intense problem will be conduct.

1.3 Objective

The project is implemented in order to achieve the following objectives which are:

- i. To analyses available antenna type in term of signal range, radiation pattern and the effect of transmitted power.
- ii. To develop a hybrid antenna design that offer 360⁰ radiation pattern and long range transmission.

1.4 Project Scope

The scope of this project is to study the antenna type that is used in multi-rotor application. This project also will go through the previous study of published papers, books, forum in internet as well as end-user experience of this type of antenna. This project mainly focuses on having the transmission quality improved and the signal transmission range obtain about 700 meter from the ground station. The only frequency that used is the 5.8GHz band.

For this project, it will be tested in open field with no obstruction. It only involves in study literature, design in software, fabricating it and test the antenna in real time. This project mainly focuses on transmission quality between existing antenna and new developed hybrid antenna.

1.5 Project Methodology

In this project, there are several procedures that must be followed. Initially, information about dipole antenna and also measure transmission distance using GPS-guided multi-rotor aircraft are identified. Then, more information about the 5.8GHz video transmission system is gathered from the journals, internet and also articles. Next, the researches continues with the search on the basic concept of excellence antenna transmission condition.

After completing the report of chapter 1, 2, 3 this project will continue to on how to design/modelling the hybrid antenna that will set up in open field that focused distance from the ground station. Next, the result between each type of antenna tested are compare for their performance.

1.6 Thesis Structure

Chapter 1:

The first chapter introduces brief idea of the project. It focused on the overview of the project, detailing the objectives, the problems statement, scope and outcome of the project.

Chapter 2:

Project background is discussed in this chapter. It only concentrates on the literature review that will describe all the information that was referred as a reference in order to finish up the project. Basically literature review will contain the facts or other aspect that we need that correspond to the project that will build. This chapter also defines terms used in this project and discussed the concept of the research and how it is related with the theory.

Chapter 3:

Chapter 3 describes the methodology used in this project. The schedule or steps that need to be completed and the detailed reports of studies that were done to achieve the aim of the project are presented. The methodology is the important aspect as it is the beginning process of planning. If the methodology are not organized only then will encountered the problem involve in the project.

Chapter 4:

This chapter is about the result and discussion. All the simulation, data collection and analysis obtained will be discussed in detail. The results will be compared with the objectives outlined in order to arrive to some hypothesis and conclusion.

Chapter 5:

Chapter 5 after through all the process and successful to achieve the objectives as stated in the earlier chapter. The project can be concluded and explain the detail in this chapter. Other than that, a future recommendation for this project also includes improving this project for the future improvement and upgrade.



CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

This chapter presents literature review on the development of long range antenna transmission system for GPS-guided aerial surveillance application. The development of the long range antenna technique in multi-rotor application that aim to harvest the full potential power of the transmitter and receiver antenna from a 5.8GHz system. The advantages and disadvantages of existing antenna are also presented and compared. This chapter also present the current development of video transmission system that will be utilized in this project.

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2.1 5.8GHz system

The common frequencies used for first person view (FPV) in multi rotor application are 1.2GHz, 1.3GHz and 5.8GHz. the higher the frequency, the more bandwidth it provides for high definition video transmission and wide channel number selectable. The equipment also is small in size. The down side of this type on frequency, its more susceptible to multipath interference than other frequency listed. The overall range also lower than other frequency band. That why FPV ground station required high gain antenna and will required antenna tracking for maximum video range transmission.

2.2 FPV antenna

In 5.8GHz system, the simple linear antenna is bad because of 5.8GHz frequency bounce of stuff so easily that causing multipath interference. Antenna are the component that will have the largest single impact on the video transmission quality and range.

There are four main FPV antenna choice, the antenna are need to use the different one from the aircraft and ground station.

- i. Linear polarized Omni directional antenna
- ii. Linear polarized directional antenna
- iii. Circular polarized Omni directional antenna
- iv. Circular polarized directional antenna



Figure 1: Linear polarized (Monopole) Omni directional antenna

2.3 Low-cost UAS ground station antenna for high quality video streaming at 5.8 GHz

Marta Martínez-Vázquez, Stefan Weitz (2014) has developed a 5.8GHz antenna used for ground station. This paper proposes an easy to produce, low cost RCHP (Right Hand Circularly Polarized) array antenna is presented, which can be used in the ground station of an UAS for receiving a 5.8 GHz video signal. The antenna design is based on the array presented in, by changing the stack-up and feeding topology, in order to improve both the performance and the manufacturability of the array.

The antenna array consists of 12 circularly polarized patches, each fed through a micro strip line. The single patches have a circular shape with an irregularity in order to provide two orthogonal modes for circular polarization, as shown in Fig. 1, left. The patches are tuned to radiate at 5.885GHz, with enough bandwidth to cover the most usual channels used worldwide.

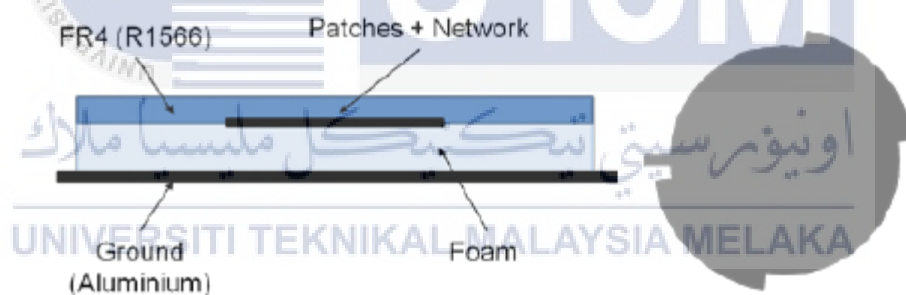


Figure 2: Single patch (left) and structure stack-up (right).

2.4 Radiation Pattern

The Skew Planar Wheel antenna is an omnidirectional antenna, Its radiation pattern has a doughnut shape. It radiates in the 360 degrees around its axis (and this is why it is called omnidirectional). The disadvantages is that it a deep radiation null along its axis, which doesn't mean it radiates in ALL directions and its means that it won't transmit if the transmitter antenna axis were aim towards the receiver, or vice versa. Using a 600mW transmitter, the range can be expected to reach 1.5Km range with good video signal.



Figure 3: Clover Leaf Antenna

The axial mode helical is a directive antenna, which means it needs to be aimed towards the transmitter. Its radiation pattern has a cone shape, more or less wide depending on the number of turns of the helical (more turns equals more gain, but narrower cone). Using a 600mW transmitter with a SPW, and one 7-8 turns helical in the receiver, you can expect to achieve 5Km with crystal clear video.

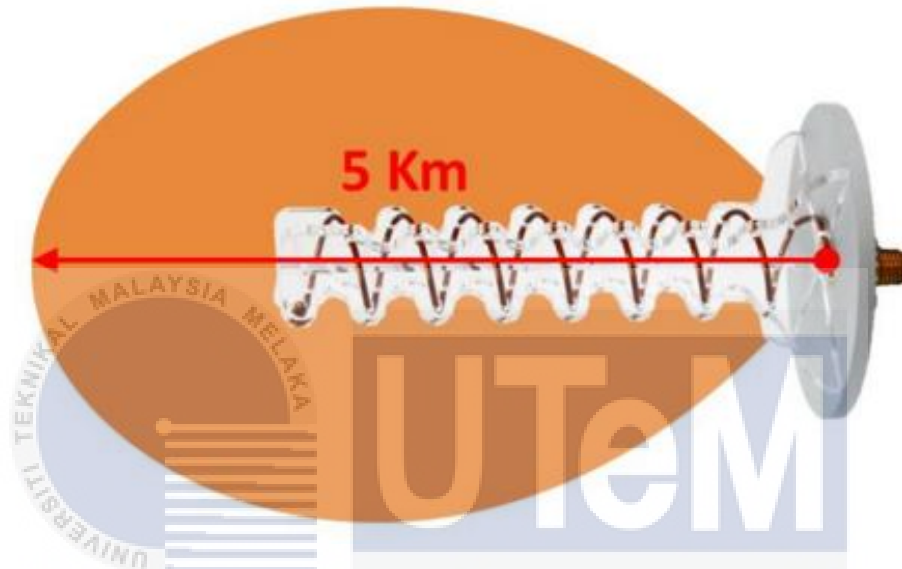


Figure 4: Helical Antenna

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2.5 Comparison Between Antenna Types

In this part, the most common type of antenna in FPV will be tabulate the result based on user experience. The antenna that include are dipole Omni directional antenna where it will be the benchmark for other antenna to overcome it.

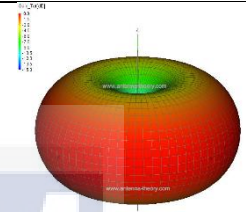
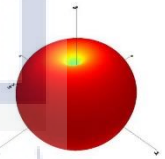
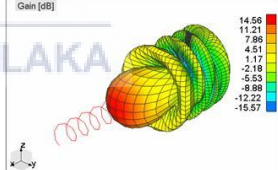
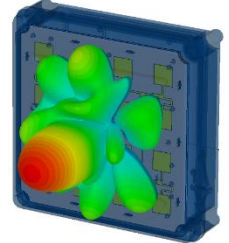
Antenna type	Description	Antenna range (estimated) with no obstruction	Radiation pattern
Dipole Omni directional antenna	It's a standard antenna type that most of the 5.8GHz transmission system come with in the package	50 meters and up to 150 meters	
Clover leaf Omni directional antenna	It's one of FPV racers choice design because of it coverage in 360° direction	Range up to 1.5 kilometers	
Helical directional antenna	This antenna have the longest stretch but limited in radiation radius	Range up to 5 kilometers	
Linear/circular patch directional antenna	It's the same with clover leaf only the signal travel in straight direction	Range up to 2 kilometers	

Table 1: Comparison between various type of antenna

2.6 Long range antenna development in surveillance multi-rotor platform

Multi-rotor technology has become increasingly demanding for many work scope. Because of its modular design the platform can be used in many different ways. As an intrinsically destructive science, archaeology has focused on balancing the preservation of a cultural heritage site with the need to continue uncovering new information. To this end, archaeological field expeditions have traditionally been composed of a well-structured protocol involving historical research, site survey, and selective excavation. While excavation generally produces the majority of new information from fieldwork, site survey and digital records techniques largely compose the formal documentation of the site.

Recent advances have greatly improved the techniques available to cultural heritage experts, adding technologies such. Eight-Rotor Airborne Camera Platform as digital photography and LIDAR modeling to the trusted repertoire of linear surveys and rock drawings. Additionally, fortunate sites have been able to leverage aerial imaging provided by satellite photography services (1 IEEE AC Paper #2717, Version 8, Updated 04/02/2014.). this project use the multi-rotor platform to done on cultural heritage research and it use live analog video transmission to view the video directly on the ground but it still have issues with limited range on video transmission.

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CHAPTER 3

METHODOLOGY

3.0 Introduction

This chapter will cover the method that will be used in this project to achieve the objective of developing long range antenna using 5.8GHz system. It will be focus on how to develop the antenna design base on previous study paper and the benchmark test for the data collection so the result can be compared. All the step in design the antenna using CST software and develop the antenna pattern on PCB board and ground test it on open field.



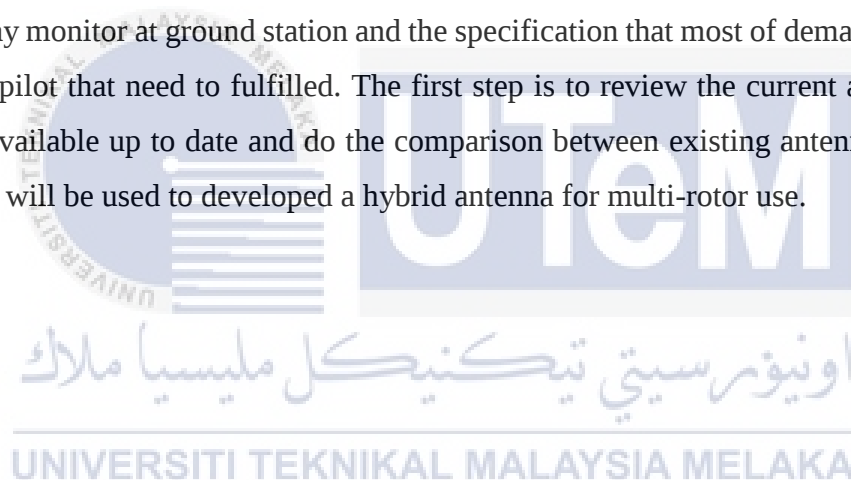
3.1 Project Overview

The first step is to obtain information on the development of antenna pattern from journal articles over the Internet. In this chapter, it's about the antenna radiation pattern that will affect the transmitted video signal to the ground station. The research is built to obtain the experience of multi rotor pilot operator itself where the transmission distortion of video signal that suddenly disperse and will cause trouble when the multi-rotor fly out of line of sight (LOS). This will involve in study of literature review, antenna design, antenna fabrication and the antenna analysis. The test includes simulation test, laboratory test and beta test (real test) as to find the best antenna design.

3.2 Project Flow Chart

This project methodology shows the steps of developing a hybrid antenna based on existing antenna design. The first step is to obtain information of 5.8GHz antenna from journal articles, books and internet. The journal obtains from IEEE, Science Direct and also in Google Scholar. Some of related project journal such as “Low-cost UAS ground station antenna for high quality video streaming at 5.8 GHz” and “

Base on this, the researches on basic antenna radiation pattern on coverage, the noise experience on every component for the transmission, the environment factor, the interference on other 5.8GHz frequency band on the same site, the noise level on the display monitor at ground station and the specification that most of demanded by multi-rotor pilot that need to fulfilled. The first step is to review the current antenna design that available up to date and do the comparison between existing antenna design. The result will be used to developed a hybrid antenna for multi-rotor use.



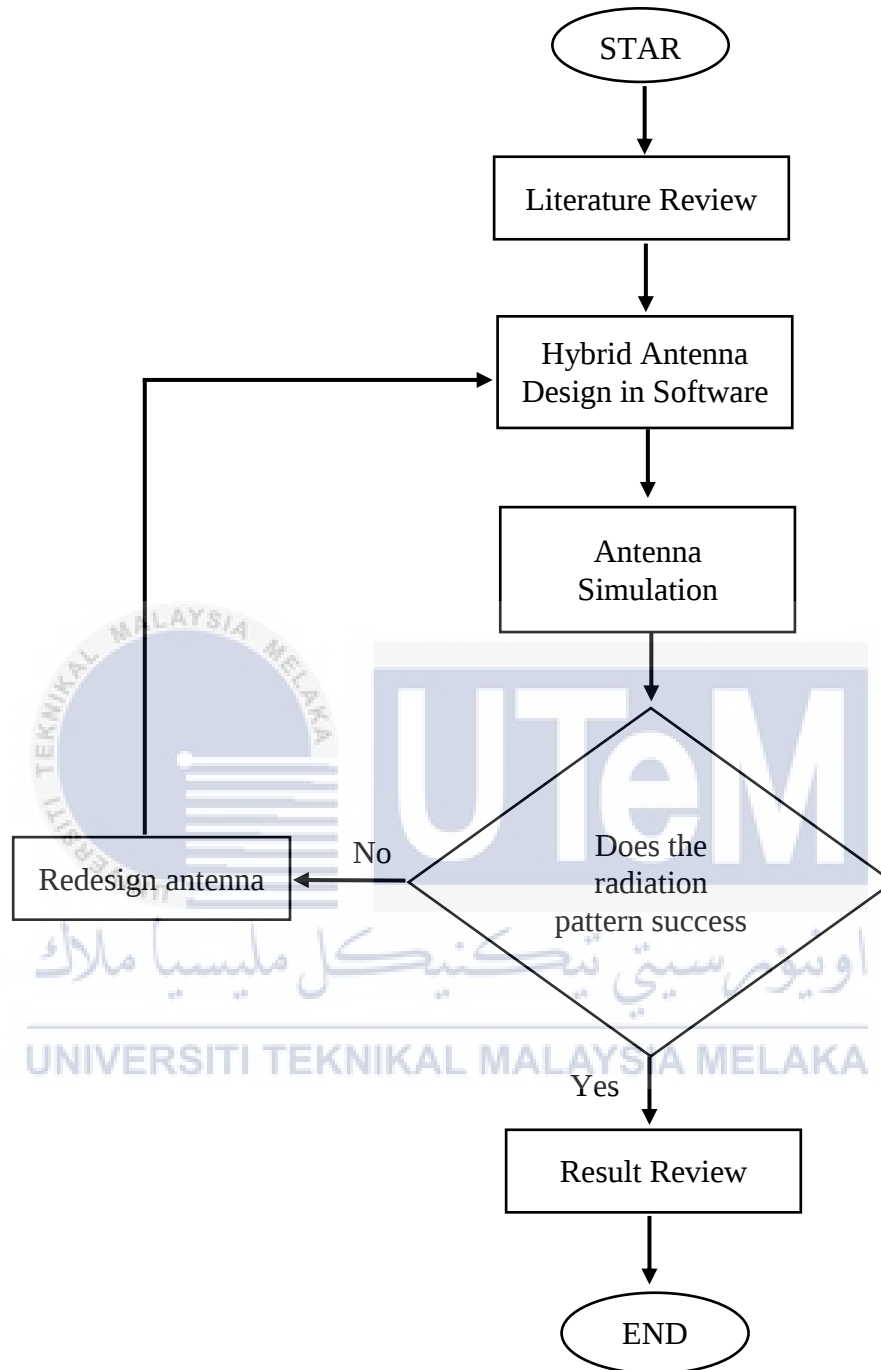


Figure 5: Flowchart for overall Project

3.2.1 Process flow

After studying the literature review, the antenna will be designed in the CST software where the antenna pattern are develop there and all the parameter such as radiation pattern, power emitted and the efficiency can be observed in the simulation.

Next step is to produce the antenna either using copper board and copper wire. The copper board will undergo etching process where using etching machine will do it.

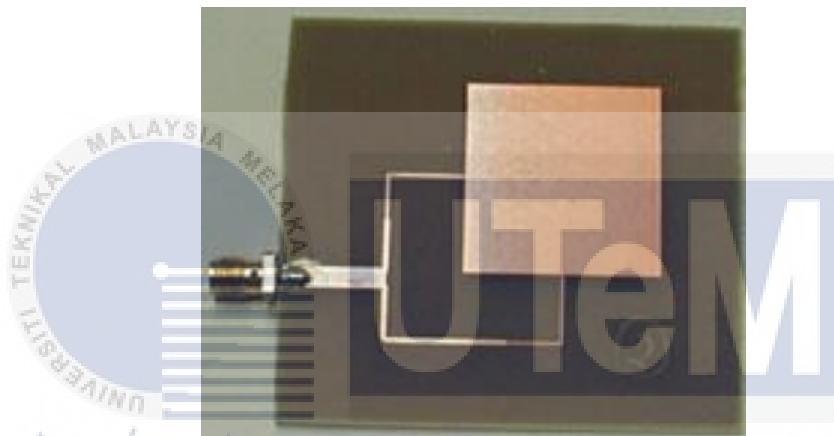


Figure 6: Patch antenna on copper board

As for the copper wire the it will be wind up by using 3D printed part. The dowel is 5 turn and the base will be 7 turn helical.

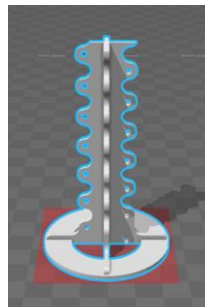


Figure 7: 7 Turns helical antenna



Figure 8: 5 Turns helical dowel

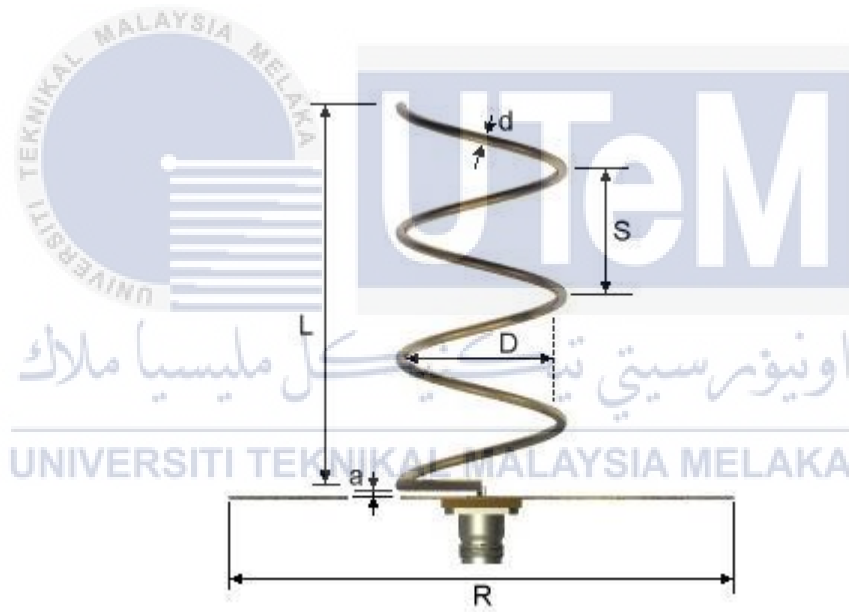


Figure 9: Helical antenna parameter

The helical are constructed base on frequency and the desired number of turns also it include the turn spacing. The ideal parameter for 5.685Ghz and seven turn spacing are referring as follow:

Ideal diameter (internal), D	18mm
Conductor diameter, d	1mm
Winding step (between centers), S	12.1mm
Seperation of adapter section, a	0.5mm
Minimum Reflector Diameter, R	32.7mm
Total antenna length, L	84.9mm

Table 2: Calculated parameter for helix 5.8GHz

This parameter in table 3 also fit with existing design of the helix 3D-printed model and the helix base will be printed directly. The dowel on figure 8 are used as a templet to wind the copper wire into helix shape that fit with the helix antenna base (figure 7) After done the fabrication part. The antenna will be tested at open field within line of sight (LoS). This LoS is essential as during testing, even we have the live feed through the monitor, the experimental antenna might be malfunction and loss in transmission signal may occur.

After succeed the antenna during LoS testing (100 meter from the ground station). The test will carry on with the GPS guided multi-rotor. During this test, the flight controller is already uploaded the coordinate and the altitude.

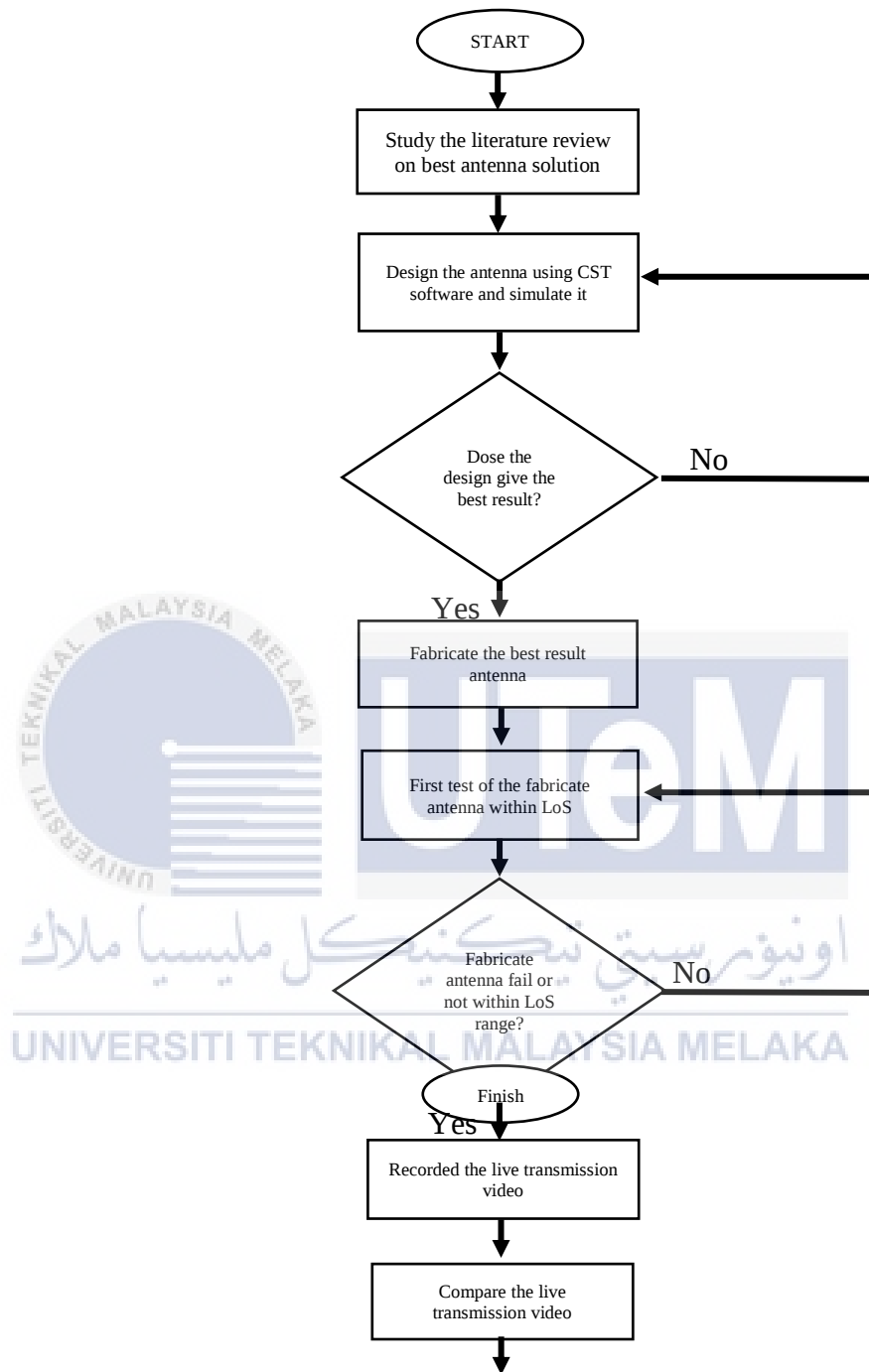


Figure 10: Process Flow chart

3.2.2 Block Diagram of test flow system

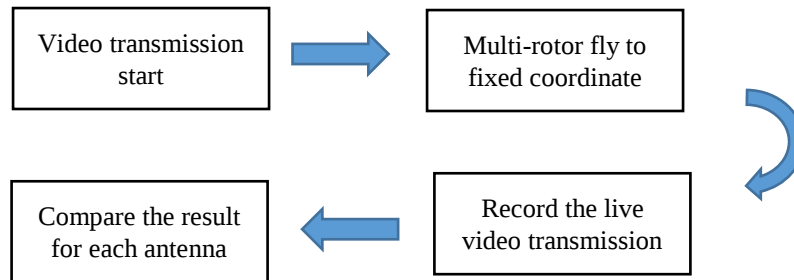


Figure 11: Block diagram of process flow

The figure 3.2 above show that the basic diagram for the video transmission process for comparing the noise level that user sees on the ground station screen. The main component of this project are mainly the antenna itself and the transmission component such as video transmitter (vTx), video receiver (vRx). Other part is the camera where it provides the view from the multi-rotor and the ground station monitor for pilot live view.

The multi-rotor itself are the platform which will be used for testing. The platform already has global positioning system (GPS) to have its accurate flight. This altitude and distance can be programmed using Mission Planner software where all the parameter of the multi-rotor platform can be adjusted. With this system, during test the distance and altitude can be fixed so all type of antenna will have the same fixed variable. After each test, the video will be recorded to compare the result.

The result can be compare with other parameters such as, distance, altitude and environment condition can be obtained during test and the signal strength (RSSI), output power from vTx, receive power will be included.

3.3 Hardware Implementation

3.3.1 Multi-Rotor Platform

Multi-rotor is the name given because it has multiple rotor used to take it to the sky. The platform varying from three rotors and up to eight rotors. Each platform behaves differently compare to one another. The more rotor number, the more stable and heavier payloads it can carry. The factor that use different platform depends on what type of gear that the multi-rotor wants to carry. The size also plays important role, it measures in millimeters (mm) and the size vary from 120mm up to 1000mm.

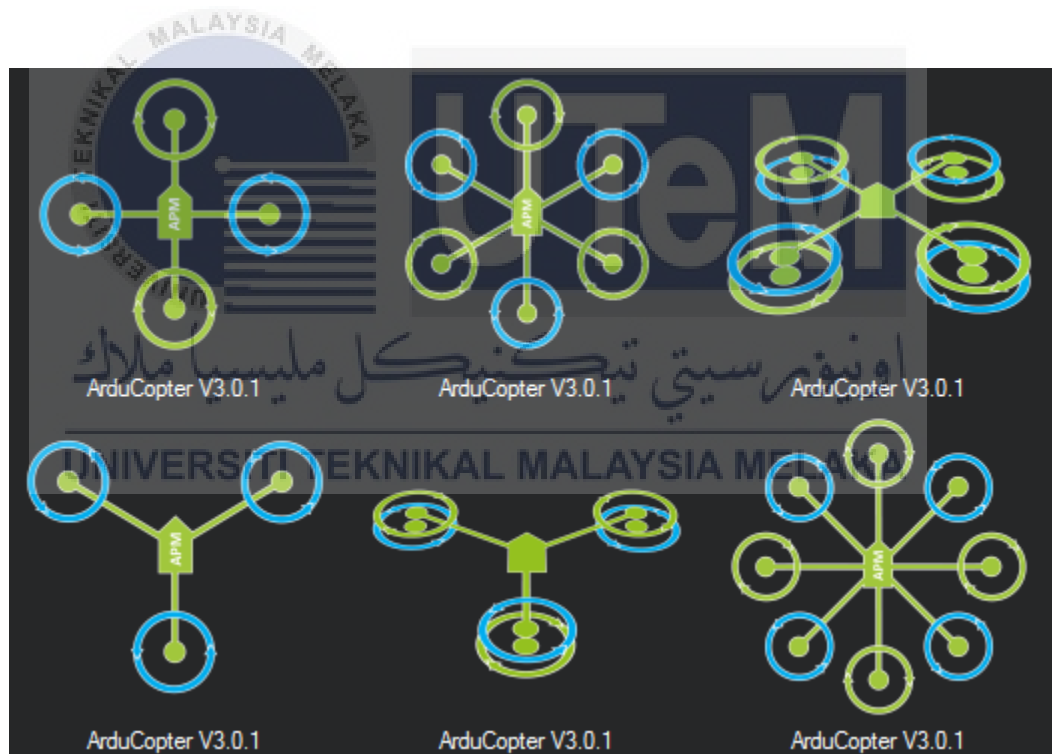


Figure 12: Different Multi-Rotor Layout.

In this development, the platform will be based on quad-rotor frame size 650mm. This type of setup is good enough to carry the required gear for testing and it can lift payload about four (4) kilograms in weight.



Figure 13: Multi-Rotor Platform that will be used.

3.3.2 Video Transmitter and Video receiver

The video transmitter (VTx) and video receiver (VRx) is the part of transmission system before the signal are send to the antenna for transmission wirelessly. The video transmitter model is integrated 25mW transmitter and camera. This type of VTx are the smallest in its class by having 40selectable channel and the power input from 12 volts.

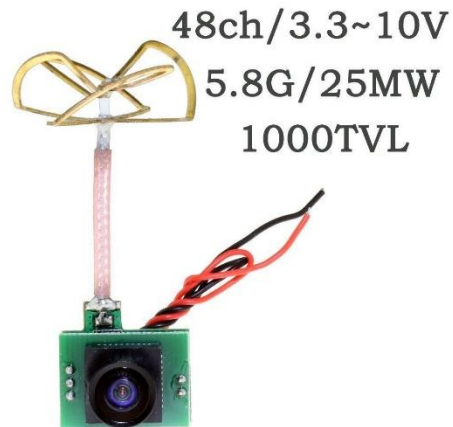


Figure 14: Specification of VTx

At the receiver part, a built in receiver with monitor is used. This is 5.8GHz diversity receiver which it has two receiver built in it. It will automatically select the best receiver reception to display at the monitor.



Figure 15: 32ch diversity monitor.

3.3.3 Antenna fabrication

During fabrication, it's important to select the best component and material. The purity of the copper will affect the signal emitted on the copper board and wire. The connecting component such as SMA and RPSMA connector must be at the highest grade so there will be no losses in the transmission line.

Using high quality component will increase the fabrication cost. Each method can only be used with certain type of antenna. For example, copper board can produce patch antenna where copper wire can be fabricating into helical and clover leaf antenna.

	SMA	RPSMA
Male		
Female		

Table 3: Different Type Of Connector

One important part is the printed circuit board (PCB), there are verity of board that can be selected. The best board available are FR-4 type, 'FR' stand for flame retardant. This board consist of fiberglass wool with epoxy resin binder. It's easy to cut and doesn't leave any shrapnel when cut it. The dielectric constant of FR-4 is good for high frequency application

3.4 Software Implementation

3.4.1 Mission Planner

Mission planner is a software for the multi-rotor platform to operate. This software provides the parameters for the multi-rotor be set such as the rotor number, channel calibration, IMU calibration, GPS calibration and much more features. In this project, this software will use to pre-set the flight path and the position where the multi-rotor will be stay on for certain period of time.

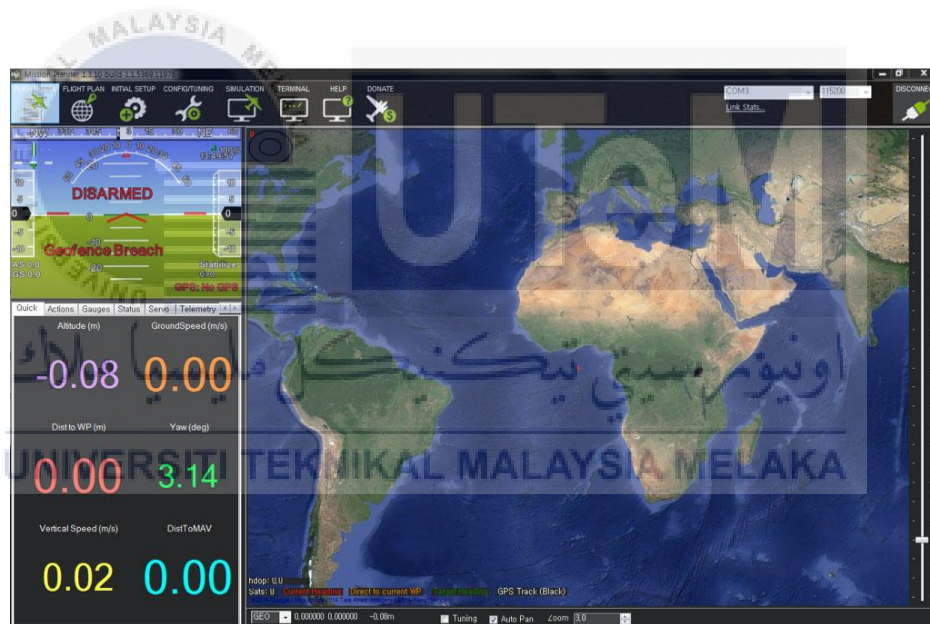


Figure 16: Mission Planner user interface

3.4.2 Computer Simulation Technology (CST)

The CST software are essential to design and analyze the antenna that design. Before fabrication the antenna parameter, radiation pattern and the power emitted can be simulate and estimated. By using this software, it can save on fabrication cost. The other parameter that must aware is where the other noise that present during the simulation that will affect the result in the real time testing.

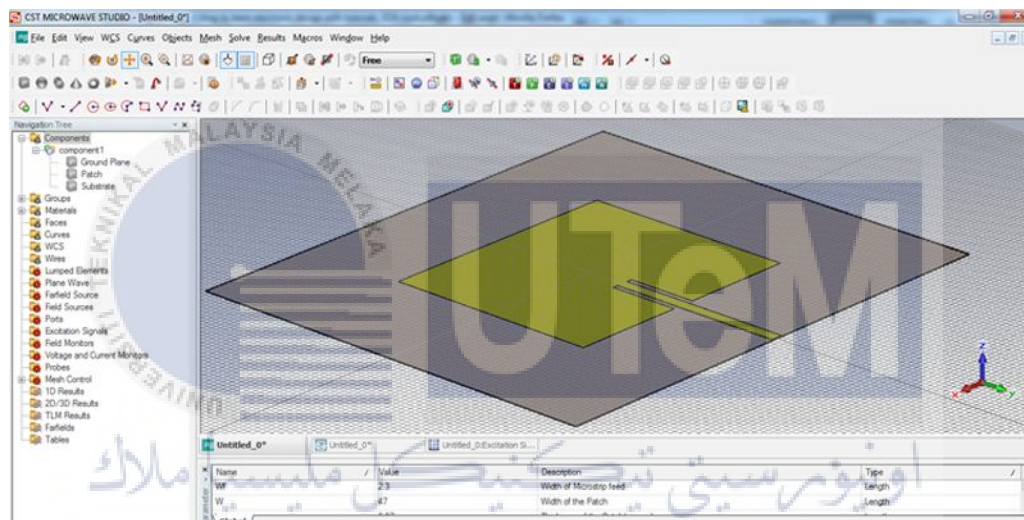


Figure 17: Example of Computer Simulation Technology software

3.5 Project Scope

This project only applied to multi-rotor application where the antenna is used for video transmission system only. It does not include the 2.4GHz frequency part of the multi-rotor control parameter (remote control). As for the frequency, the antenna is design to best fit with 5.8GHz frequency spectrum and all the transmitter and receiver devices. The test will be conduct during calm weather on open field. The target distance

about 750 meter from ground station. At that point. The signal strength, noise level and the celerity of the screen displayed are at minimum compare to the benchmark test.

3.6 Testing Parameters

This project need to have some testing and analysis to be done. There are various test need to be done and each stage have its own unique test. During design stage, the antenna design in the software can be simulated before fabricating. By doing this, the expected result can be predicted at early stage and with this also, it can help in reducing the cost when the antenna fabricated cannot be use.

During simulation also, the software can provide with type of signal injected, the antenna gains, the antenna radiation pattern, antenna gain and the S-parameters where the most of the power will be emitted at certain frequency.

After achieve a satisfying result in simulation, the design can be proceeding to fabricate. There are various ways to fabricate an antenna and that depends on the design. The materials that use must be in the highest quality because antenna is the part where losses cannot be tolerated.

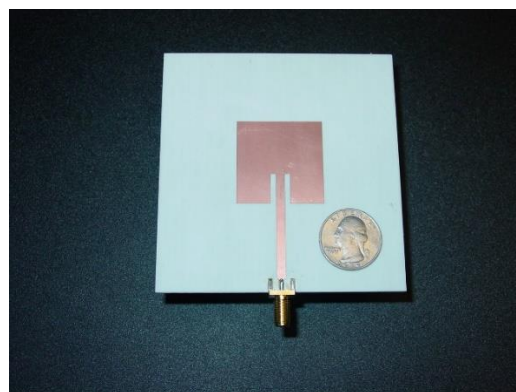


Figure 18: Example of patch antenna fabrication.

After fabrication, the antenna will be done a laboratory test where depends on facilities. This antenna will be test on the real radiation pattern. The signal will be provided by using signal generator to generate the 5.8GHz frequency.

Beta test or the real test. It will be done when all the laboratory test is completed. This test is more straight forward. The antenna will be attached to the receiver and the multi-rotor platform will be mount a Omni-directional antenna and with pre-set the coordinate on the multi-rotor it will bring it to the specific distance that already pre-set in the Mission Planner.



Figure 19: Multi-Rotor Ground Station

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CHAPTER 4

RESULT & DISCUSSION

4.0 Introduction

In this chapter, testing and analyzing the result are presented in this chapter. the outcome is presented in the form of comparison between multiple design created. The analysis will be comparing between three types of antenna that are include the software simulation, lab testing and field test.

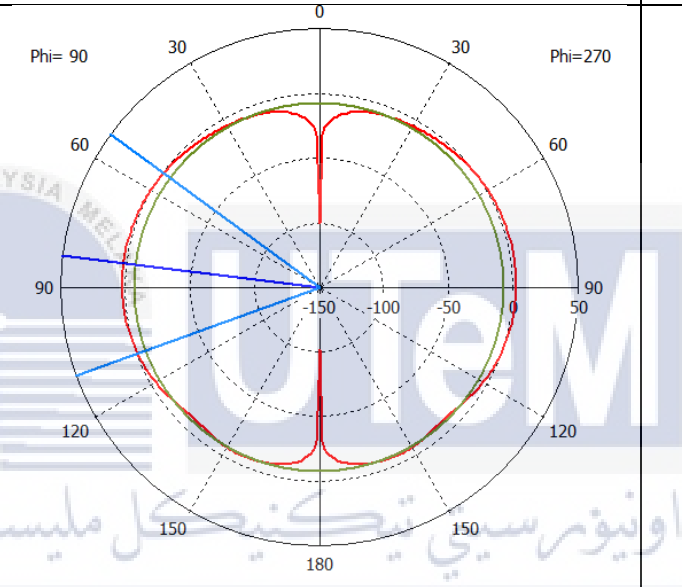
4.1 Expected result

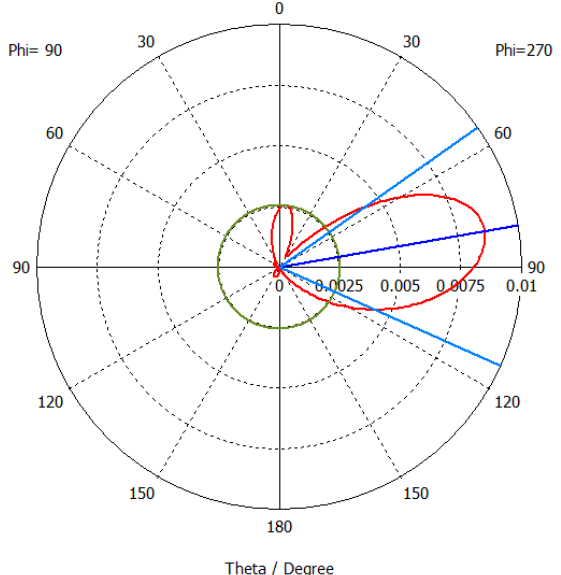
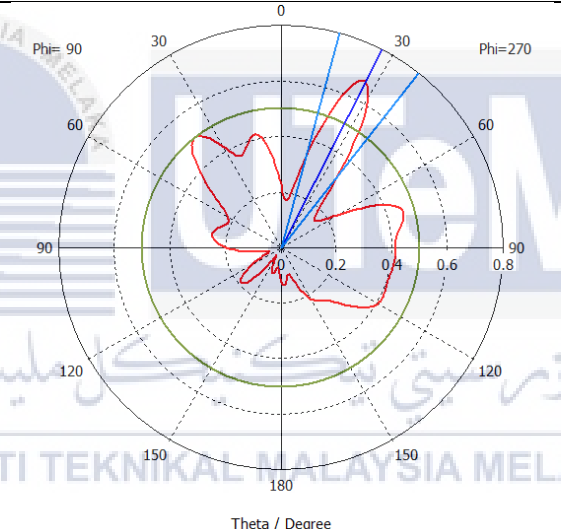
As expected, the helical antenna dose provides extra distance. Combination with patch antenna add up the gain from the helical alone. Thus, during beta test, it does provide extra 470 meters of range compare to patch antenna alone and provide up to 620 meters when compare with the standard monopole antenna. Compare to the aftermarket antenna, the price different also significant where the cost of manufacturing one antenna is half from the price of the aftermarket antenna.

4.2 Result from CST simulation

Each antenna is design resemble the original antenna (for monopole and patch)
table below show the result from simulation. The frequency used are 5.685Ghz

Table 4: Result for radiation pattern in CST

Antenna pattern	Radiation Pattern	Realize gain (dB)
Monopole		0.6326

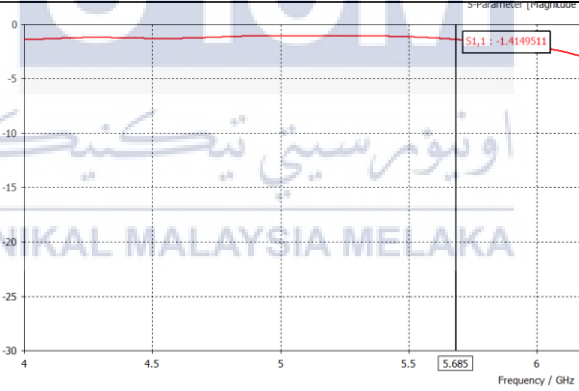
Aomway Patch		0.00854
Hybrid helix-patch		9.120

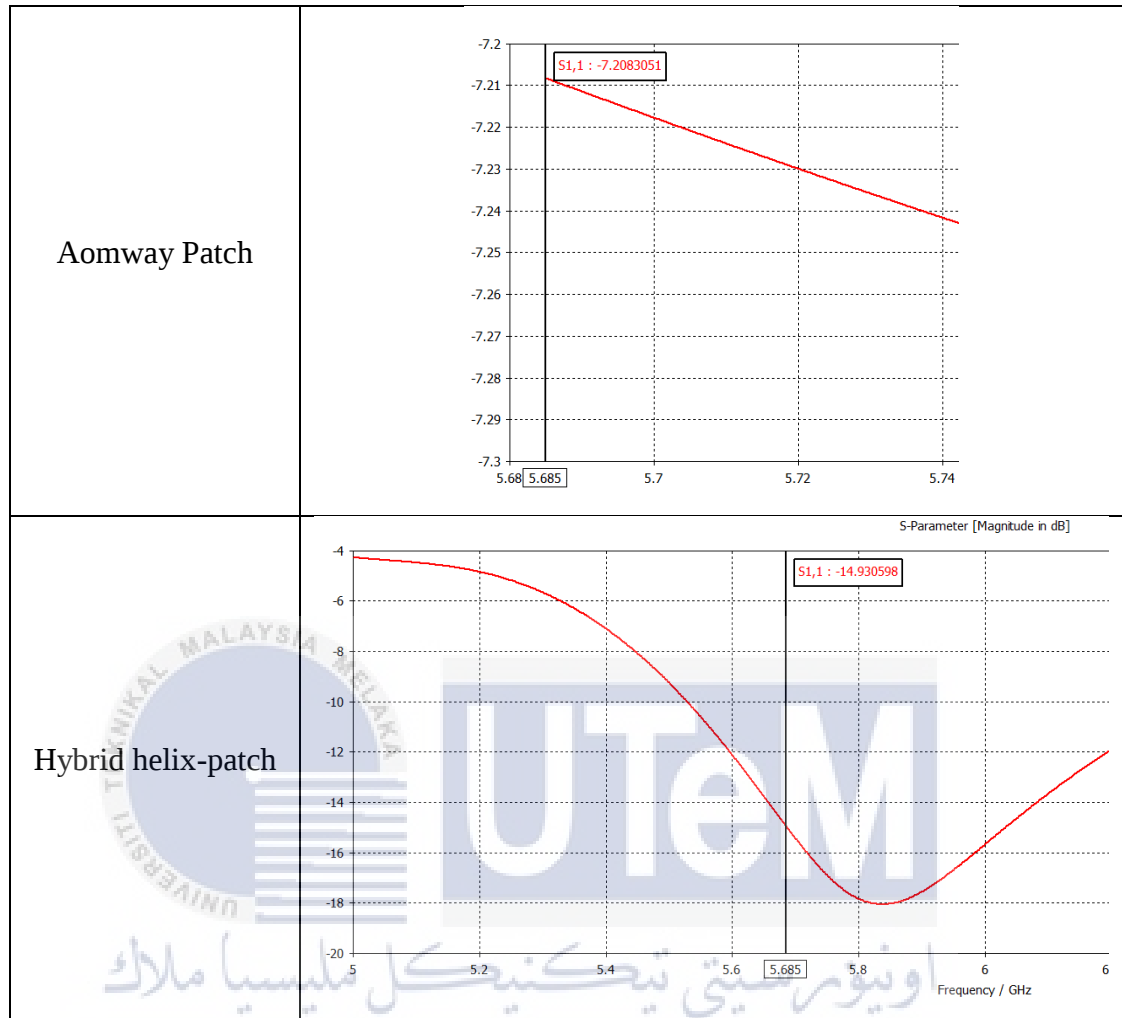
From table 5, the monopole has an omnidirectional radiation pattern where it radiates equal power in all direction perpendicular to the antenna. On a single plane, we can see the radiation pattern are widely spread. But as the radiated power are increases in angle, the power that emits when in vertical will be dropping off to zero. So that explain the donut like shape for the monopole antenna.

Moving on to the next antenna, the AOMWAY patch antenna radiation pattern dose emits on one plate, in simulation there are off 90°. This based on the data that CST software available to interpreted base on the exact design of the real antenna. This antenna is the aftermarket product.

The Hybrid helix-patch antenna have the 360° radiation pattern requirements and the radiation pattern are off to right hand side. This are cause mainly because the turn of helix is right-hand circular polarize. This pattern are possible cause by the layout of the ground plane that are 10mm apart from the positive side.

Table 5: Result for S-parameter in CST

Antenna pattern	S-parameter
Monopole	



S-parameters or scattering parameters determine the best radiating frequency of the antenna. From the table 6, the monopole antenna radiates about -1.414 dB at 5.685GHz. The AOMWAY antenna radiates about -7.208 dB at the same frequency. Whereas the hybrid Helix-Patch radiates at -14.9305 dB. This is twice as much as the AOMWAY antenna and it will radiate -18 dB around 5.9GHz. The key to have this stronger radiation is on the ground plane distance. When the ground plane is directly at the back of the board, the maximum gain will fall on 8.5GHz upwards and when the ground plane is 20mm apart, the gain obtained is below 5.5GHz. The ideal distance is 10mm apart where the PCB stand-off is easily available for 10mm height.

4.3 Antenna Lab Test Result.

After fabricating the antenna, by etching process and 3D-printed part, the antenna is assembled and test with MATS-1000A antenna trainer to obtain the radiation pattern. This are non-ideal test as the test conduct in open space, not in chamber room.



Figure 20: Completed Hybrid Helix-Patch Antenna

For testing purpose, the antenna is mounted on the PCB (figure 18) that are hold by hot glue and for the separation of the ground plane four pieces of 10mm plastic stand-off are used to separate the two board. It is important to use non-conductive material so it won't affect the radiation pattern.

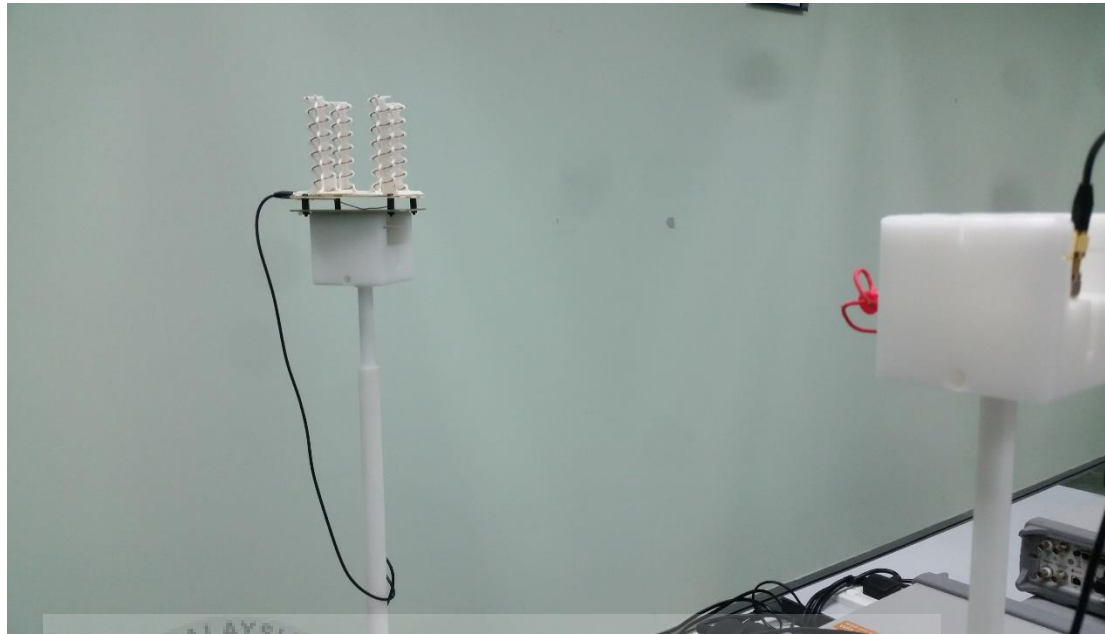


Figure 21: Antenna Test (Non-Ideal Test)

During lab testing, by using fixed height about 600mm from the table top for transmitter and receiver antenna. The distance from both antennas are 800mm apart. All three type antenna are test with the same parameter and using 5.685GHz frequency. The result from MATS-1000A equipment are shown in table 7. This machine can support up to 6GHz frequency to test the radiation pattern. Noted that this test is not an ideal test as there are no chamber room available. The receiver antenna is rotated 360° so the radiation pattern can be observed on the software.

The antenna use for transmitter are cloverleaf antenna which has the same properties of the build in antenna for the VTx. Although the cloverleaf had omnidirectional radiation pattern like the monopole, but the radiation are cover up until the center of the antenna (vertical axis) refer to table 1.

Table 6: Laboratory radiation pattern test

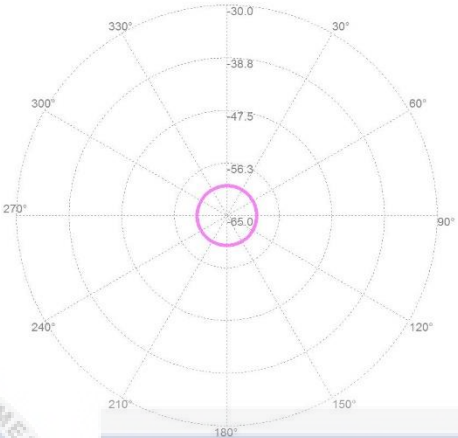
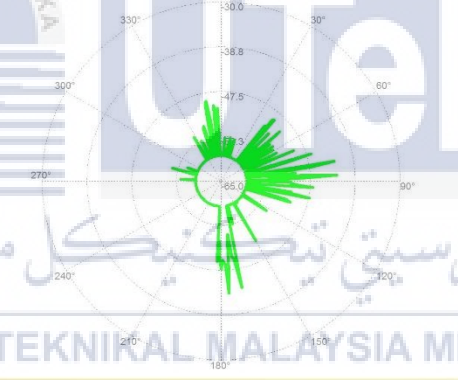
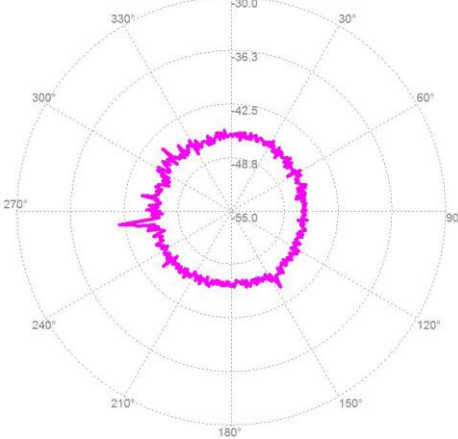
Antenna pattern	Radiation Pattern	Frequency (GHz)
Monopole		5.685
Aomway Patch		
Hybrid helix-patch		

Table 7 show that the radiation pattern receives of each antenna by fixed the same condition in the laboratory testing. For monopole antenna, it is noted that the omnidirectional pattern but the range are noticeably small thus it will not have as much the receive signal, this will result in shorter operation range.

As for the AOMWAY and the Hybrid Helix-patch, both have a great distance to cover. Noted that the scale for this two antenna are not the same. For the AOMWAY, it has certain angle which the signal is stronger on one side and null to the other side. As we known the patch only transmit one direction only. As the Hybrid Helix-patch antenna, the radiation pattern had full 360° while maintaining the same received power all round it, thanks to it separated ground plane that give off the full radiation.

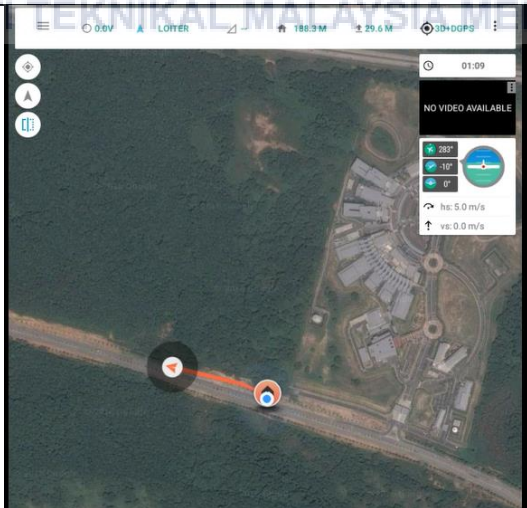


4.4 Field Test

This test is carry out at open space where the location is far from other buildings and it is the straightest path as possible as it can get. This test is using 5.685GHz frequency. Each test is carry out at the same location and on the same day. The camera with transmitter are mounted up front of the multi-rotor platform which the camera facing in front of the multi rotor and the transmitter antenna is placed to the lowest position of the multi-rotor for un-obstruct radiation transmission to the ground station.

The connection from the Ground Control Station (GCS) on android tablet to the multi-rotor are used by means of Micro Air Vehicle Communication Protocol (MAVLink) which are very lightweight, header-only message to communicate and send the data required. The frequency used for this communication are 915MHz which are not disturbing the video transmitter frequency.

Table 7: Field range test (Beta Test)

Antenna pattern	Radiation Pattern	Frequency (GHz)
Monopole	 Distance : 188.3 meter Altitude: 29.6 meter	5.685

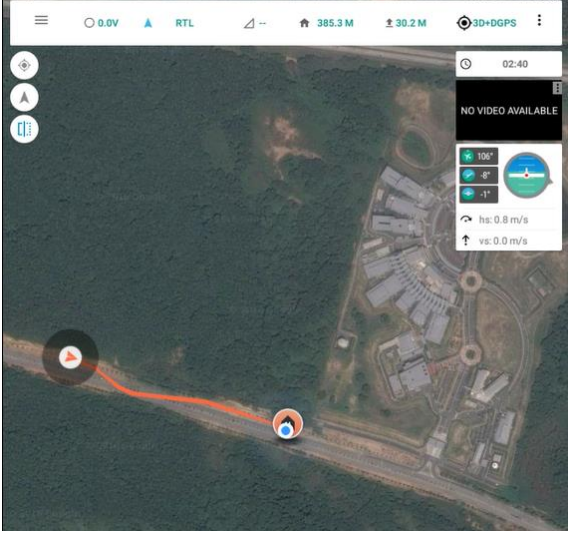
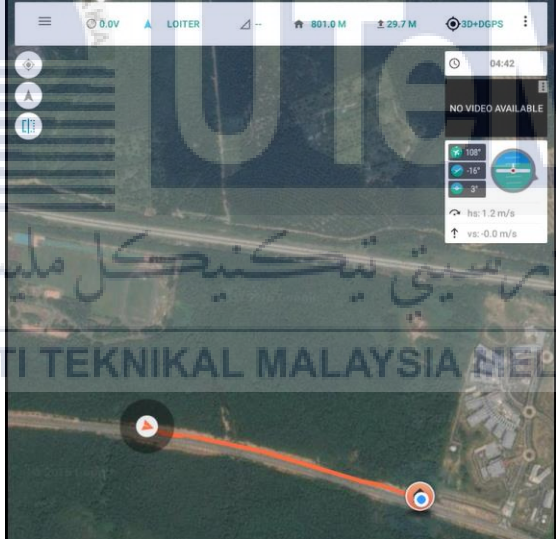
Aomway Patch	 Distance: 385.3 meter Altitude: 30.2 meter	5.685
Hybrid helix-patch	 Distance: 801.0 meter Altitude: 29.7 meter	



Figure 22: RSSI indicator on screen (in circle)

The only indicator displayed on the monitor is the RSSI bar, the display in figure 20 is upside down as the camera mounted on the multi-rotor is also upside down. This bar gives the idea how strong the signal receives by the receiver. Noted that this is diversity monitor which have dual receiver and on the indicator, only receiver A are used (RF A)

By referring to the table 9, as the distance of the ground control station increases, the RSSI bar drop until zero where there is no image receive to be display on the screen. By far, the most distance covered are from the Hybrid Helix-Patch antenna where the last image receive by the monitor are at 800 meter from the ground station.

Table 8: RSSI bar on the monitor

Distance (meter)	Signal Indicator bar (RSSI)		
	Monopole	Aomway Patch	Hybrid helix-patch
50	5	5	5
100	3	5	5
150	1	5	5
200	0	4	5
250	0	4	5
300	0	3	5
350	0	1	4
400	0	0	4
450	0	0	3
500	0	0	4
550	0	0	3
600	0	0	3
650	0	0	2
700	0	0	1
750	0	0	2
800	0	0	0

4.5 Result

After done all the test at the beginning of chapter four, it is clear that the hybrid antenna dose offers further range compare to the other antenna that tested. During the first fabrication, at that time only standard fiber glass PCB available to fabricate. The condition of the board a bit rough especially when cutting and soldering the copper wire to the printed layout. Another problem that arise is the copper cable that used to wind the helix antenna. Newer cable has diameter about 0.75mm and it is not a pure copper cable. To overcome this, older cable (coaxial) had larger 1.0mm copper cable and it's suitable for this 5.8GHz helix setup.

4.6 Discussion

This project is about design an antenna that offer a good receive range compare to the standard monopole antenna that it is supplied with the package it came with. The developments of this hybrid antenna start with single patch antenna and combine it with any antenna that can be made from copper wire. There are two option on wired antenna, first it is helix type and another one is clover leaf. And, between this two, helix type is the possible solution as it can be mounted directly on the PCB patch antenna. Helical antenna also provides a narrow beam with high gain and patch antenna provide wider beam but the gain are significantly smaller than helix type. Combine both of this, the radiation pattern offered are 360°. Another part is the ground plane, if the ground plane sit directly on the single plane, the S-parameter are far from the desired signal.

During the design, when the ground plane are bring further 10mm apart, the highest gain are obtain at the signal needed where it can go up to -21dB. Other that distance, the size of the ground plane also affects the wave propagation and the S-parameters. By increasing the size to the allowable maximum size, the result are obtain as the figure? Below. With this, this antenna design stratifies the objective requirements.

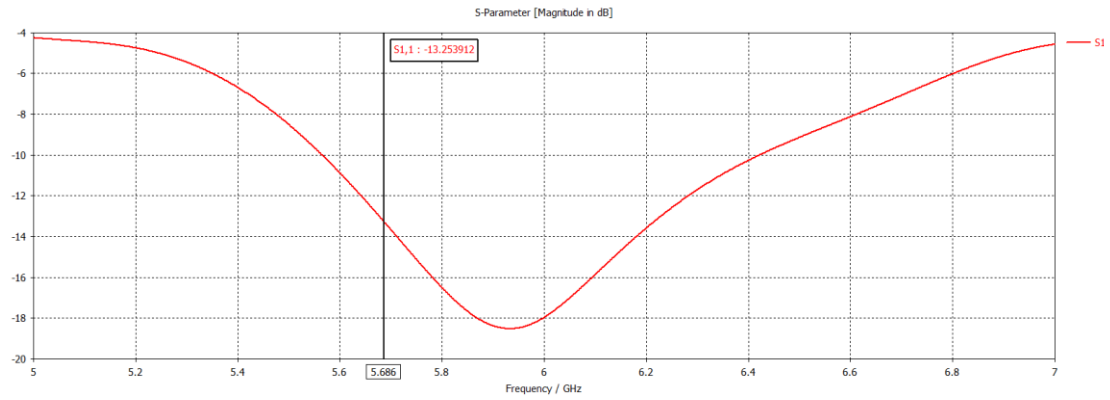


Figure 23: S-parameter gain for hybrid patch helix antenna



CHAPTER 5

CONCLUSION AND RECOMMENDATION

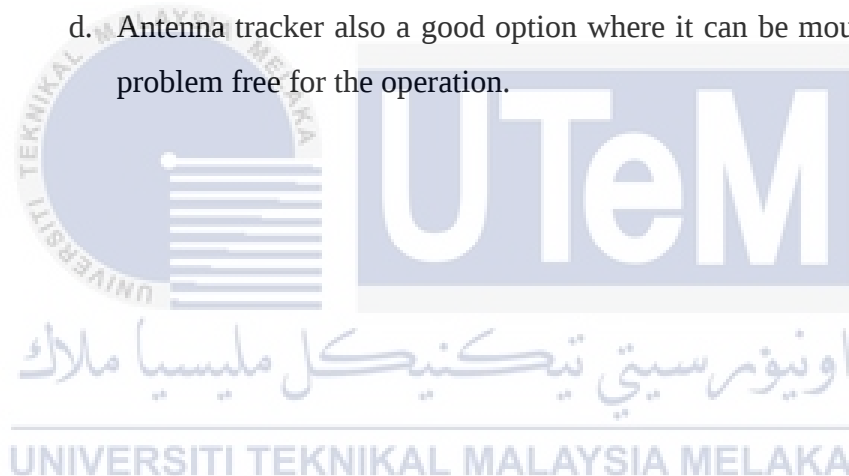
5.1 Conclusion

The conclusion for this project was achieved the objective which to analyses available antenna type in term of signal range, radiation pattern and the effect of transmitted power. Base on the reference antenna, both of that antenna (AOMWAY patch and monopole) are the popular choice for intermediate user for multi-rotor application where their offer good range and good signal transmission quality. In antenna field, the limitation is still the gain that each antenna offers. By combining both helix and patch, the gain are sum up and it is able to obtain up to -21dB gain. The radiation pattern also satisfies the second objective where during the lab testing, the pattern has 360° compare to other antenna. The VTx used in this test are from the lowest transmission power available where the rating only 25mW and for that power level, it is considering excellent as the range obtain are around 800 meters that are 77% increases compare to the aftermarket antenna (AOMWAY patch). With this, the hybrid antenna is successful in term of objective achieve and the performance during the beta test.

5.2 Future Work

Many Improvement that can be done on this project to improve its design, function and reliability. Some suggestion for the future research and development are:

- a. Make smaller size by calculating the ratio that will the same or improved output.
- b. Design a swivel mount which the antenna can be turn 360° without turning the whole ground station
- c. Add a cover case that are function as protective equipment to protect the internal part form outside environment and it must have the highest permeability rate so it will not affect the signal propagation.
- d. Antenna tracker also a good option where it can be mounted and have problem free for the operation.



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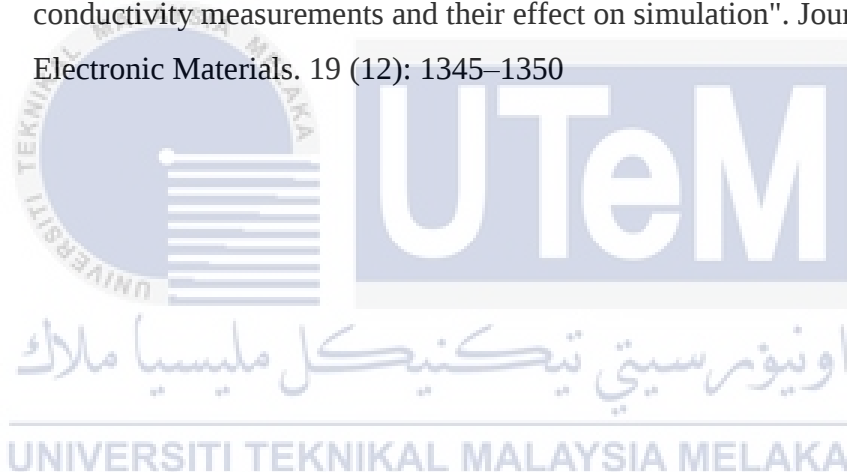
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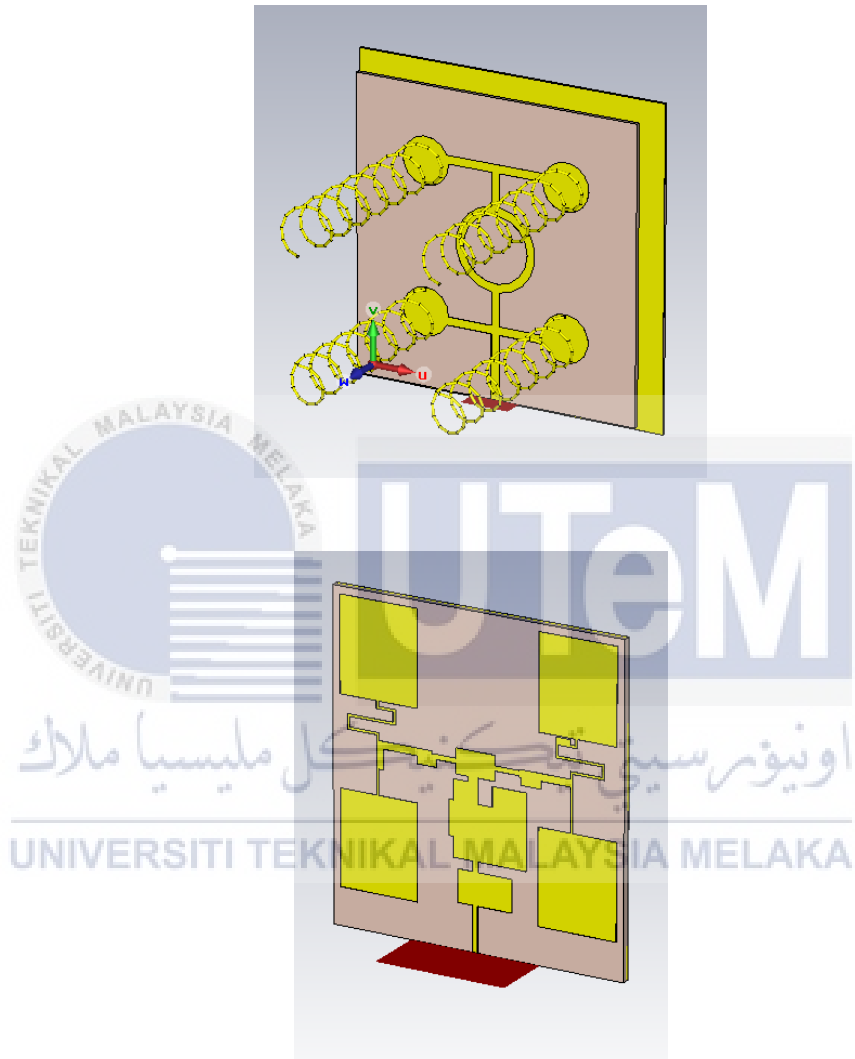
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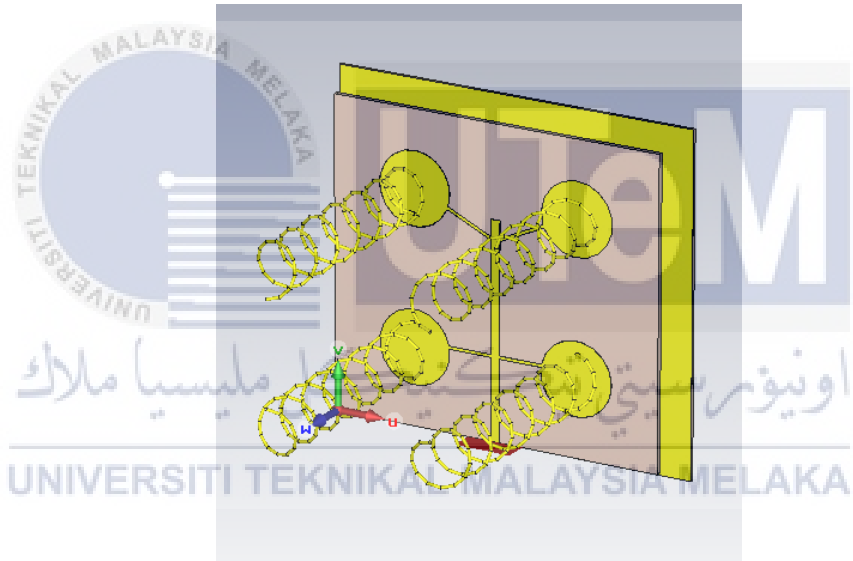
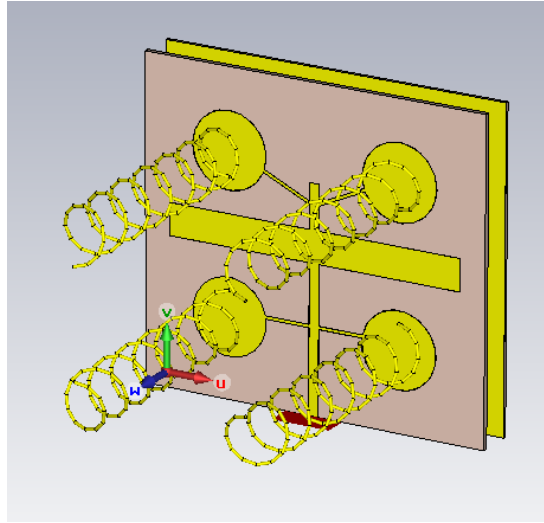
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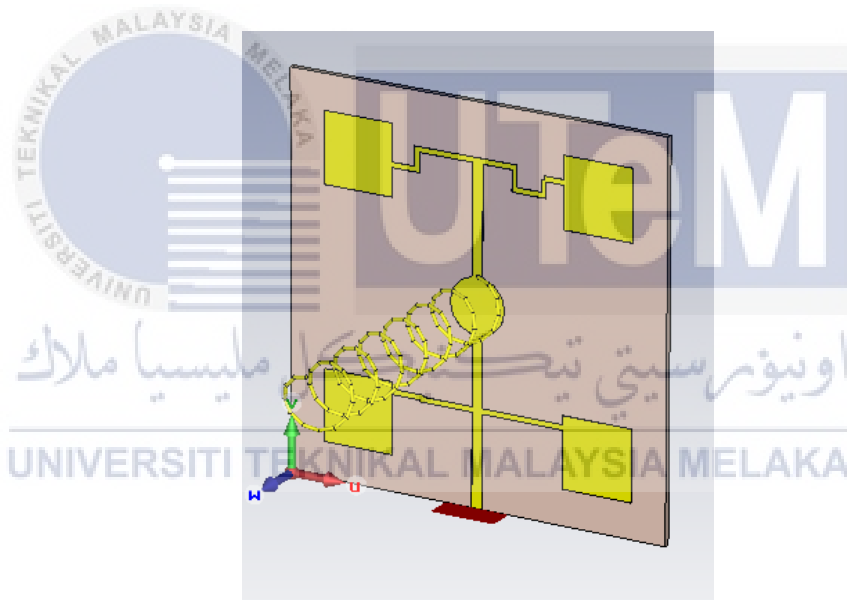
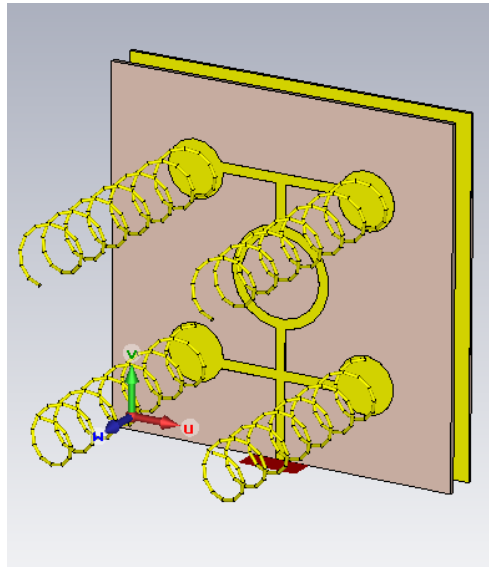
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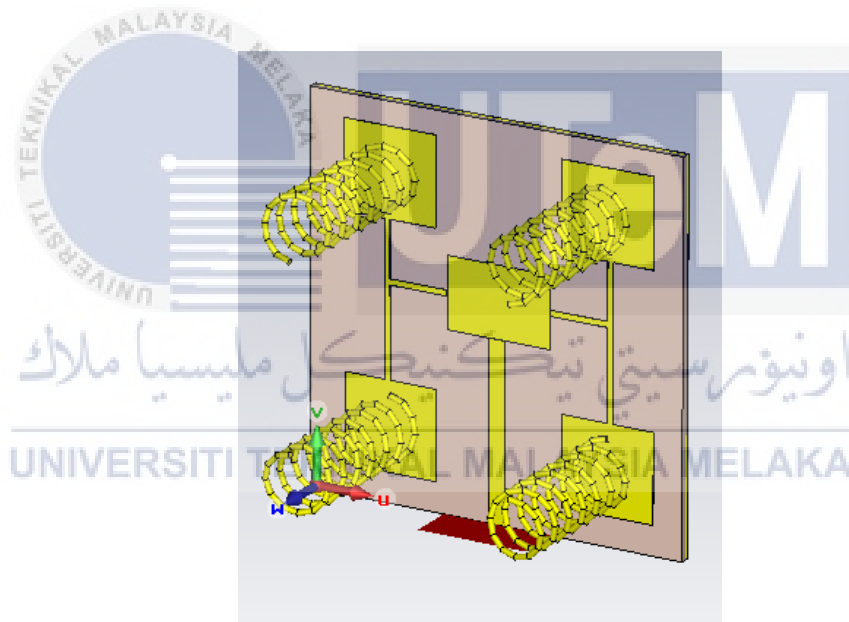
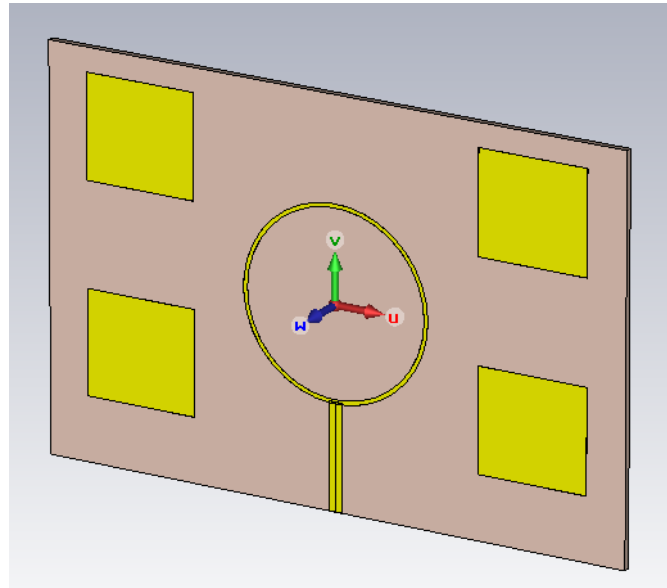


APPENDIX A
(VARIOUS ANTENNA DESIGN in CST)









APPENDIX B
(FREQUENCY CHANNEL TABLE ALLOCATION)

FR	CH	CH							
		CH1	CH2	CH3	CH4	CH5	CH6	CH7	CH8
FR	FR1 or (A)	5865M	5845M	5825M	5805M	5785M	5765M	5745M	5725M
	FR2 or (B)	5733M	5752M	5771M	5790M	5809M	5828M	5847M	5866M
	FR3 or (E)	5705M	5685M	5665M	5645M	5885M	5905M	5925M	5945M
	FR4 or (F)	5740M	5760M	5780M	5800M	5820M	5840M	5860M	5880M

For Video Receiver 32 channel



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CH FR		CH							
		CH1	CH2	CH3	CH4	CH5	CH6	CH7	CH8
FR	FR1 or (A)	5865M	5845M	5825M	5805M	5785M	5765M	5745M	5725M
	FR2 or (B)	5733M	5752M	5771M	5790M	5809M	5828M	5847M	5866M
	FR3 or (E)	5705M	5685M	5665M	5645M	5885M	5905M	5925M	5945M
	FR4 or (F)	5740M	5760M	5780M	5800M	5820M	5840M	5860M	5880M
	FR5 or (R)	5658M	5695M	5732M	5769M	5806M	5843M	5880M	5917M

For Video Transmitter 40 channel