# SMART GROUND STATION ANTENNA FOR EXCELLENT QUALITY OF RECEIVED DATA SIGNAL

by

Mohd Hazizuddin Bin Ismail

Dissertation
Submitted in partial fulfilment of the requirements for the
Bachelor of Engineering (Hons)
(Electrical & Electronics Engineering)

DECEMBER 2009

Universiti Teknologi PETRONAS
Bandar Seri Iskandar
31750 Tronoh
Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

**Smart Ground Station Antenna for Excellent Quality of Received Data Signal**

by

Mohd Hazizuddin bin Ismail

A project dissertation submitted to the
Electrical & Electronics Engineering Programme
Universiti Teknologi PETRONAS
in partial fulfilment of the requirement for the
BACHELOR OF ENGINEERING (Hons)
(ELECTRICAL AND ELECTRONICS ENGINEERING)

Approved by,

_______________________________
(Dr. Mohamad Naufal Bin Mohamad Saad)
Project Supervisor

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

December 2009

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

MOHD HAZIZUDDIN BIN ISMAIL

ACKNOWLEDGEMENT

I would like to thank the various people involved in making this project a success. First and foremost, I would like to express my deep appreciation to my final year project supervisor, Dr. Mohamad Naufal Bin Mohamad Saad for giving me the opportunity to do this project under his supervision. I would like to thank him for his time in monitoring my progress. I am personally grateful for his commitment, advice, encouragement, guidance and patience throughout the duration of the project.

Special gratitude to Mr. Salehan, ITMS staff, who found time in a very busy schedule to guide me in completing the fabrication of the antenna and sharing his technical knowledge regarding communication field. His passion for communication field has really inspired me. I am deeply indebted to him who helps me in testing the antenna and willing to offer the equipments for the testing. I would like to thank him for his commitment, advice, encouragement and guidance.

My acknowledgement then goes to my colleagues for supporting me in my project. I want to thank them for all their help, support, interest and valuable hints.

Finally, I am sincerely grateful to my family their financial and emotional support throughout this course in order for me to complete my final year project.

# ABSTRACT

This report constitutes of, as the title for this project, Smart Ground Station Antenna for Excellent Quality of Received Data Signal. The objective of this project is to build an intelligent antenna in order to receive with less noise signal transmitted by nano-satellite. It will be a challenging project since the distance of satellite from antenna is quite far with a lot of noise can affect the transmission process. The antenna is a 6 elements Yagi-Uda type with frequency of 434MHz. A Yagi-Uda Antenna, commonly known simply as a Yagi antenna or Yagi, is a directional antenna system consisting of an array of a dipole and additional closely coupled parasitic elements (usually a reflector and one or more directors). The dipole in the array is driven, and another element operates as a reflector. Other parasitic elements shorter than the dipole added in front of the dipole and are referred to as directors. The antenna was design using software called QY4. The antenna consists of 4 director elements, 1 driven element and 1 reflector elements. Directional antennas, such as the Yagi-Uda, are also commonly referred to as beam antennas or high-gain antennas. Yagi antenna is chosen because of good range, highly directional and easier to aim than a parabolic dish.

# TABLE OF CONTENTS

## LIST OF FIGURES

# LIST OF TABLES

# CHAPTER 1
# INTRODUCTION

## 1.1 Background of Study

This project is a part of nano-satellite program by AeroUTP Team, supervised by Dr. Mohamad Naufal Bin Mohamad Saad. AeroUTP Team is designing and building a nano- scale satellite called EduSAT, which able to perform various scientific experiments such as pressure, humidity and temperature sensors. The physical configuration of the ground station is shown in Figure 1.

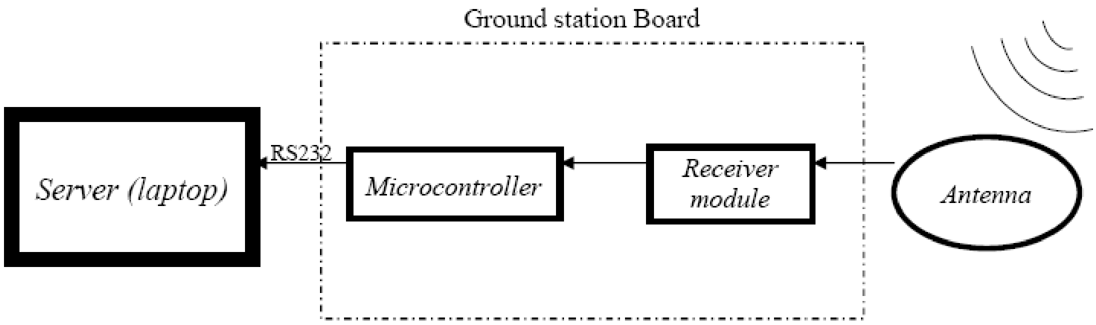


Figure 1: System overview of Ground Station

This FYP project will concentrate on building an intelligent antenna that can receive data signals with minimum noise. An antenna is a transducer designed to transmit or receive electromagnetic waves. In other words, antennas convert electromagnetic waves into electrical currents and vice versa. There are some types of antenna that available nowadays. Yagi antenna is one of the suitable antennas that can be used for ground station antenna.  Although the design of Yagi antenna is quite obtrusive, it offers good range with high directional ability.

## 1.2 Problem Statement

The previous project faced problem on the receiving side at ground station. It is difficult to get clear data signals from satellite which is about 150 meters up. There are a lot of noises that can interrupt the transmission of data signals from satellite to ground station. The antenna must be smart enough to get the best quality of signals. It is quite hard to understand the theory of antenna. There are several critical parameters affecting an antenna's performance that must be considered during the design process. These are gain, antenna efficiency, SWR, impedance, radiation pattern, polarization, and bandwidth.

## 1.3 Objectives

Objectives of this project include:

1. Understand a basic theory of an antenna.
2. Understand a simple transmission and receiving process.
3. To build a smart ground station antenna in order to receive the best signal transmitted by transmitter.

# CHAPTER 2
# LITERATURE REVIEW

## 2.1 Basic Antenna Theory

### *2.1.1 Antenna Efficiency and Gain*

The efficiency of an antenna relates the power delivered to the antenna and the power radiated or dissipated within the antenna. A high efficiency antenna has most of the power present at the antenna's input radiated away. A low efficiency antenna has most of the power absorbed as losses within the antenna. The losses associated within an antenna are typically the conduction losses (due to finite conductivity of the antenna) and dielectric losses (due to conduction within a dielectric which may be present within an antenna). Sometimes efficiency is defined to also include the mismatch between an antenna and the transmission line, but this will be discussed in the section on impedance. The efficiency can be written as the ratio of the radiated power to the input power of the antenna:

$$\varepsilon = \frac{P_{radiated}}{P_{input}}$$

The term Gain describes how much power is transmitted in the direction of peak radiation to that of an isotropic source. Gain is more commonly quoted in a real antenna's specification sheet because it takes into account the actual losses that occur. A gain of 3 dB means that the power received far from the antenna will be 3 dB (twice as much) higher than what would be received from a lossless isotropic antenna with the same input power.

Gain is sometimes discussed as a function of angle, but when a single number is quoted the gain is the 'peak gain' over all directions. Gain (G) can be related to directivity (D) by:

$$G = \varepsilon D$$

The gain of a real antenna can be as high as 40-50 dB for very large dish antennas (although this is rare). Directivity can be as low as 1.76 dB for a real antenna, but can never theoretically be less than 0 dB. However the peak gain of an antenna can be arbitrarily low because of losses. Electrically small antennas (small relative to the wavelength of the frequency that the antenna operates at) can be very inefficient, with gains lower than -10 dB (even without accounting for impedance mismatch loss). [1], [2]

### *2.1.2 SWR*

In telecommunications, standing wave ratio (SWR) is the ratio of the amplitude of a partial standing wave at an antinode (maximum) to the amplitude at an adjacent node (minimum), in an electrical transmission line. The SWR is usually defined as a voltage ratio called the VSWR, for *voltage standing wave ratio*. For example, the VSWR value 1.2:1 denotes maximum standing wave amplitude that is 1.2 times greater than the minimum standing wave value. It is also possible to define the SWR in terms of current, resulting in the ISWR, which has the same numerical value. The *power standing wave ratio* (PSWR) is defined as the square of the VSWR.

The most common case for measuring and examining SWR is when installing and tuning transmitting antennas. When a transmitter is connected to an antenna by a feed line, the impedance of the antenna and feed line must match exactly for maximum energy transfer from the feed line to the antenna to be possible. The impedance of the antenna varies based on many factors including: the antenna's natural resonance at the frequency being transmitted, the antenna's height above the ground, and the size of the conductors used to construct the antenna. [3]

When an antenna and feedline do not have matching impedances, some of the electrical energy cannot be transferred from the feedline to the antenna. [4] Energy not transferred to the antenna is reflected back towards the transmitter. It is the interaction of these reflected waves with forward waves which causes standing wave patterns. [4] Reflected power has three main implications in radio transmitters: Radio Frequency (RF) energy losses increase, distortion on transmitter due to reflected power from load and damage to the transmitter can occur. [3] Matching the impedance of the antenna to the impedance of the feed line is typically done using an antenna tuner. The tuner can be installed between the transmitter and the feed line, or between the feed line and the antenna. Both installation methods will allow the transmitter to operate at a low SWR, however if the tuner is installed at the transmitter, the feed line between the tuner and the antenna will still operate with a high SWR, causing additional RF energy to be lost through the feedline.

Many amateur radio operators believe any impedance mismatch is a serious matter. [3] However, this is not the case. Assuming the mismatch is within the operating limits of the transmitter, the radio operator needs only be concerned with the power loss in the transmission line. Power loss will increase as the SWR increases, however the increases are often less than many radio amateurs might assume. For example, a dipole antenna tuned to operate at 3.75MHz—the center of the 80 meter amateur radio band—will exhibit an SWR of about 6:1 at the edges of the band. However, if the antenna is fed with 250 feet of RG-8A coax, the loss due to standing waves is only 2.2dB. Feed line loss typically increases with frequency, so VHF and above antennas must be matched closely to the feedline. The same 6:1 mismatch to 250 feet of RG-8A coax would incur 10.8dB of loss at 146MHz. [4]

### *2.1.3 Resonant*

An antenna is said to be resonant if its input impedance is entirely real, i.e. Zin = R + j*0. In this case the voltage and current are in phase at the antenna's terminals. This property makes the impedance matching of an antenna to a transmission line and receiver easier, as the imaginary part of the impedance does not need tuned out. [1]

### *2.1.4 Bandwidth*

Bandwidth is another fundamental antenna parameter. This describes the range of frequencies over which the antenna can properly radiate or receive energy. Often, the desired bandwidth is one of the determining parameters used to decide upon an antenna. For instance, many antenna types have very narrow bandwidths and cannot be used for wideband operation. Bandwidth is typically quoted in terms of VSWR. For instance, an antenna may be described as operating at 100-400 MHz with a VSWR<1.5. This statement implies that the reflection coefficient is less than 0.2 across the quoted frequency range. Hence, of the power delivered to the antenna, only 4% of the power is reflected back to the transmitter. Alternatively, the return loss S11=20*log10(0.2)=-13.98 dB. [1], [2]

Note that the above does not imply that 96% of the power delivered to the antenna is transmitted in the form of electromagnetic radiation; losses must still be taken into account. Also, the radiation pattern will vary with frequency. In general, the shape of the radiation pattern does not change radically. There are also other criteria which may be used to characterize bandwidth. This may be the polarization over a certain range, for instance, an antenna may be described as having circular polarization with an axial ratio <3dB from 1.4-1.6 GHz. This polarization bandwidth sets the range over which the antenna's operation is roughly circular. The bandwidth is often specified in terms of its Fractional Bandwidth (FBW). [1], [2]

### *2.1.5 Effective Area*

A useful parameter calculating the receive power of an antenna is the effective area or effective aperture. Assume that a plane wave with the same polarization as the receive antenna is incident upon the antenna. Further assume that the wave is travelling towards the antenna in the antenna's direction of maximum radiation (the direction from which the most power would be received).

Then the *effective aperture* parameter describes how much power is captured from a given plane wave. Let *W* be the power density of the plane wave (in W/m^2).

If *P* represents the power at the antennas terminals available to the antenna's receiver, then:

$$P = A_e W$$

Hence, the effective area simply represents how much power is captured from the plane wave and delivered by the antenna. This area factors in the losses intrinsic to the antenna (ohmic losses, dielectric losses, etc.). This parameter can be determined by measurement for real antennas. A general relation for the effective aperture in terms of the peak gain (*G*) of any antenna is given by:

$$A_e = \frac{\lambda^2}{4\pi} G$$

Effective aperture will be a useful concept for calculating received power from a plane wave. [1], [2]

*2.1.6 Directivity*

Directivity is a fundamental antenna parameter. It is a measure of how 'directional' an antenna's radiation pattern is. An antenna that radiates equally in all directions would have effectively zero directionality, and the directivity of this type of antenna would be 1 (or 0 dB). An antenna's normalized radiation pattern can be written as a function in spherical coordinates:

$$F(\theta, \phi)$$

Because the radiation pattern is normalized, the peak value of F over the entire range of angles is 1. Mathematically, the formula for directivity (D) is written as:

$$D = \frac{1}{\frac{1}{4\pi} \int_0^{2\pi} \int_0^{\pi} |F(\theta, \phi)|^2 \sin\theta d\theta d\phi}$$

This equation then is just a measure of the peak value of radiated power divided by the average. [1], [2]

### *2.1.7 Front-to-Back Ratio*

The Front-to-Back Ratio is a parameter used in describing directional radiation patterns for antennas. If an antenna has a unique maximum direction, the front-to-back ratio is the ratio of the gain in the maximum direction to that in the opposite direction (180 degrees from the specified maximum direction). This parameter is usually given in dB. [1]

### *2.1.8 Radiation Pattern*

A radiation pattern defines the variation of the power radiated by an antenna as a function of the direction away from the antenna. This power variation as a function of the arrival angle is observed in the far field. As an example, consider the 3-dimensional radiation pattern in Figure 2, plotted in decibels (dB).

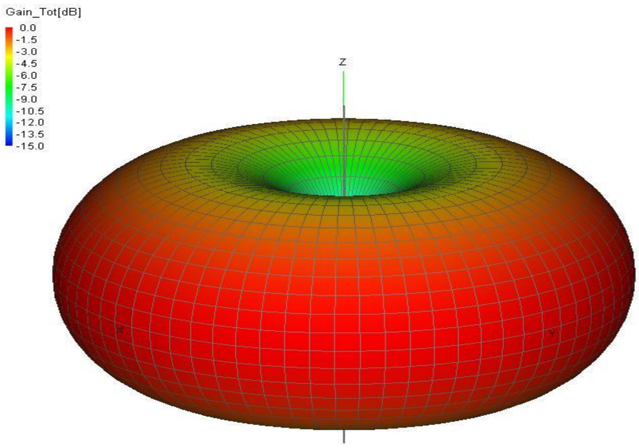


Figure 2: Example radiation pattern

This is an example of a donut shaped or toroidal pattern. In this case, along the z-axis, which would correspond to the radiation directly overhead the antenna, there is very little power transmitted. In the x-y plane (perpendicular to the z-axis), the radiation is maximum. These plots are useful for visualizing which directions the antenna radiates. Typically, because it is simpler, the radiation patterns are plotted in 2-d. In this case, the patterns are given as "slices" through the 3d plane. The same pattern in Figure 2 is plotted in Figure 3. Standard spherical coordinates are used, where $\theta$ is the angle measured off the z-axis, and $\phi$ is the angle measured counterclockwise off the x-axis.

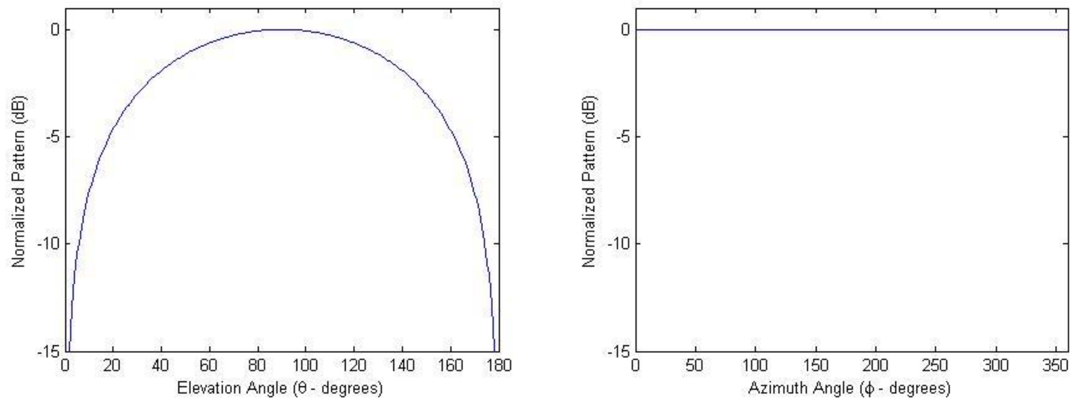


Figure 3: Two-dimensional radiation plots

The pattern on the left in Figure 3 is the elevation pattern, which represents the plot of the radiation pattern as a function of the angle measured off the z-axis (for a fixed azimuth angle). Observing Figure 2, the pattern is minimum at 0 and 180 degrees and becomes maximum at broadside to the antenna (90 degrees off the z-axis). This corresponds to the plot on the left in Figure 3. The plot on the right in Figure 3 is the azimuthal plot. It is a function of the azimuthal angle for a fixed polar angle (90 degrees off the z-axis in this case). Since the pattern in Figure 2 is symmetrical around the z-axis, this plot appears as a constant in Figure 3. A pattern is "isotropic" if the radiation pattern is the same in all directions. These antennas don't exist in practice, but are sometimes discussed as a means of comparison with real antennas. Some antennas may also be described as "omnidirectional", which for an actual means that it is isotropic in a single plane (as in Figure 2 above for the x-y plane). The third category of antennas is "directional", which do not have symmetry in the radiation pattern. [1], [2] *2.1.9 Frequency*

Antennas function by transmitting or receiving electromagnetic (EM) waves. Examples of these electromagnetic waves include the light from the sun and the waves received by your cell phone or radio. Eyes are basically "receiving antennas" that pick up electromagnetic waves that are of a particular frequency. The colours that can be seen (red, green, blue) are each waves of different frequencies that eyes can detect. All electromagnetic waves propagate at the same speed in air or in space. This speed (the speed of light) is roughly 671 million miles per hour (1 billion kilometers per hour). This is roughly a million times faster than the speed of sound (which is about 761 miles per hour at sea level). The speed of light will be denoted as c in the equations that follow. The "SI" units for the equation (length measured in meters, time in seconds and mass in kilograms) as shown below:

$$c = 300{,}000{,}000\,\frac{\text{meters}}{\text{second}} = 3.0 * 10^8\,\frac{\text{m}}{\text{s}}$$

"Electromagnetic wave" is an electric field that travels away from some source (an antenna, the sun, a radio tower, whatever). A travelling electric field has an associated magnetic field with it, and the two make up an electromagnetic wave. The universe allows these waves to take any shape. [1] The most important shape though is the sinusoidal wave, which is plotted in Figure 4. Electromagnetic waves vary with space (position) and time. The spatial variation is given in Figure 4, and the temporal (time) variation is given in Figure 5.

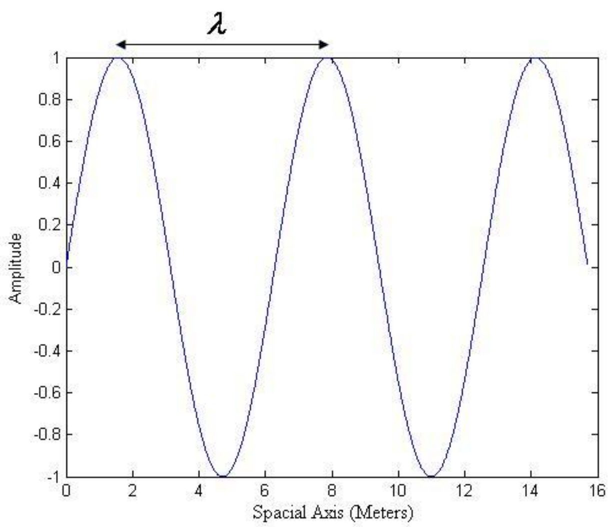


Figure 4: Sinusoidal Wave, function of position

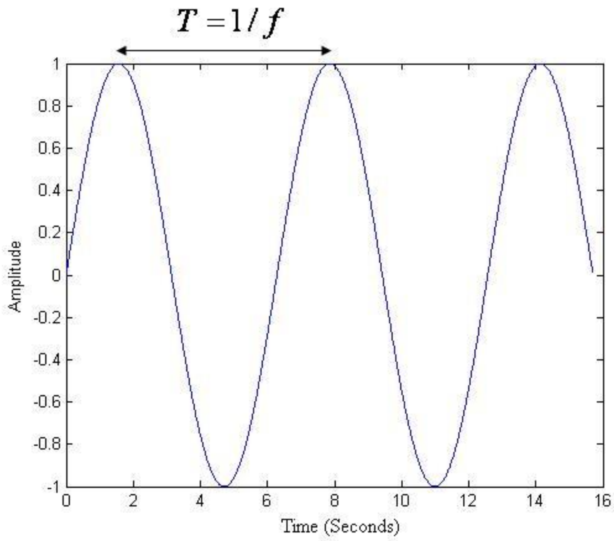


Figure 5: Sinusoidal Wave, function of time

The wave is periodic, it repeats itself every T seconds. Plotted as a function in space, it repeats itself every $\lambda$ meters, which we will call the wavelength. The frequency ($f$) is simply the number of complete cycles the wave completes (viewed as a function of time) in one second (two hundred cycles per second is written 200 Hz, or 200 "Hertz"). [1] Mathematically this is written as:

$$f = \frac{1}{T}$$

How fast someone walks depends on the size of the steps they take (the wavelength) multiplied by the rate at which they take steps (the frequency). The speed that the waves travel is how fast the waves are oscillating in time ($f$) multiplied by the size of the step the waves are taken per period ($\lambda$). The equation that relates frequency, wavelength and the speed of light is as below:

$$c = f\lambda$$

Basically, the frequency is just a measure of how fast the wave is oscillating. And since all electromagnetic waves travel at the same speed, the faster it oscillates the shorter the wavelength. And a longer wavelength implies a slower frequency. [1], [2]

### *2.1.10 Impedance*

Impedance is a simple concept, which relates the voltage and current at the input to the antenna. Let's say an antenna has an impedance of 50 ohms. This means that if a sinusoidal voltage is input at the antenna terminals with amplitude 1 Volt, the current will have an amplitude of 1/50 = 0.02 Amps. Since the impedance is a real number, the voltage is in-phase with the current. Let's say the impedance is given as Z=50 + j*50 ohms (where j is the square root of -1). Then the impedance has a magnitude of

$$\sqrt{50^2 + 50^2} = 70.71$$

and a phase given by

$$\tan^{-1}\left(\frac{\mathrm{Im}(Z)}{\mathrm{Re}(Z)}\right) = 45°$$

This means the phase of the current will lag the voltage by 45 degrees. To spell it out, if the voltage (with frequency $f$) at the antenna terminals is given by

$$V(t) = \cos(2\pi f t)$$

then the current will be given by

$$I(t) = \frac{1}{70.71}\cos(2\pi ft - \frac{\pi}{180}\cdot 45)$$

The real part of an antenna's impedance represents power that is either radiated away or absorbed within the antenna. The imaginary part of the impedance represents power that is stored in the near field of the antenna (non-radiated power). An antenna with real input impedance (zero imaginary part) is said to be resonant. Note that an antenna's impedance will vary with frequency. [1], [2]

### *2.1.9 Antenna Polarization*

The polarization of an antenna is the polarization of the radiated fields produced by an antenna, evaluated in the far field. Hence, antennas are often classified as "Linearly Polarized" or a "Right Hand Circularly Polarized Antenna". This simple concept is important for antenna to antenna communication. First, a horizontally polarized antenna will not communicate with a vertically polarized antenna. Due to the reciprocity theorem, antennas transmit and receive in exactly the same manner. Hence, a vertically polarized antenna transmits and receives vertically polarized fields. Consequently, if a horizontally polarized antenna is trying to communicate with a vertically polarized antenna, there will be no reception.

In general, for two linearly polarized antennas that are rotated from each other by an angle $\phi$ , the power loss due to this polarization mismatch will be described by the *Polarization Loss Factor* (PLF):

$$PLF = \cos^2 \phi$$

Hence, if both antennas have the same polarization, the angle between their radiated E-fields is zero and there is no power loss due to polarization mismatch. If one antenna is vertically polarized and the other is horizontally polarized, the angle is 90 degrees and no power will be transferred. Circular polarization is a desirable characteristic for many antennas. Two antennas that are both circularly polarized do not suffer signal loss due to polarization mismatch. Antennas used in GPS systems are Right Hand Circularly Polarized. [1], [2]

### 2.2 Yagi Uda Antenna

A Yagi-Uda Antenna, commonly known simply as a Yagi antenna or Yagi, is a directional antenna system consisting of an array of a dipole and additional closely coupled parasitic elements (usually a reflector and one or more directors). The dipole in the array is driven, and another element, typically 10% longer, effectively operates as a reflector. Other parasitic elements shorter than the dipole may be added in front of the dipole and are referred to as directors. This arrangement gives the antenna directionality that a single dipole lacks. [5] Directional antennas, such as the Yagi-Uda, are also commonly referred to as beam antennas or high-gain antennas (particularly for transmitting).

The driven element of a Yagi is the feed point where the feed line is attached from the transmitter to the Yagi to perform the transfer of power from the transmitter to the antenna. A dipole driven element will be "resonant" when its electrical length is 1/2 of the wavelength of the frequency applied to its feed point. The director/s is the shortest of the parasitic elements and this end of the Yagi is aimed at the receiving station. It is resonant slightly higher in frequency than the driven element, and its length will be about 5% shorter, progressively than the driven element. The director/s length/s can vary, depending upon the director spacing, the number of directors used in the antenna, the desired pattern, pattern bandwidth and element diameter. The number of directors that can be used are determined by the physical size (length) of the supporting boom. The director/s are used to provide the antenna with directional pattern and gain. The amount of gain is directly proportional to the length of the antenna array and not by the number of directors used. The spacing of the directors can range from 0.1 wavelength to 0.5 wavelength or more and will depend largely upon the design specifications of the antenna. The reflector is the element that is placed at the rear of the driven element (the dipole). It's resonant frequency is lower, and its length is approximately 5% longer than the driven element. It's length will vary depending on the spacing and the element diameter. The spacing of the reflector will be between 0.1 wavelength and 0.25 wavelength. It's spacing will depend upon the gain, bandwidth, F/B ratio, and sidelobe pattern requirements of the final antenna design. The antenna's radiation pattern or polar plot as it is sometimes called plays a major role in the overall performance of the Yagi antenna. The directional gain, front-to-back ratio, beamwidth, and unwanted (or wanted) sidelobes combine to form the overall radiation pattern. The antenna's radiation pattern bandwidth is the range of frequencies above and below the design frequency in which the pattern remains consistent. [6]

Yagi-Uda antennas are directional along the axis perpendicular to the dipole in the plane of the elements, from the reflector through the driven element and out via the director(s). If one holds out one's arms to form a dipole and has the reflector behind oneself, one would receive signals with maximum gain from in front of oneself. Typically, all elements are arranged at approximately a one-quarter-wavelength mutual spacing, with directors progressively shorter than a half wavelength to couple signals of increasingly higher frequencies onto the dipole. (See also log-periodic antenna.) All elements usually lie in the same plane, supported on a single boom or crossbar; however, they do not have to assume this coplanar arrangement. For example, some commercially available Yagi-Uda antennas for television reception have several reflectors arranged to form a corner reflector behind the dipole. [5]

The bandwidth of a Yagi-Uda antenna, which is usually defined as the frequency range for which the antenna provides a good match to the transmission line to which it is attached, is determined by the length, diameter and spacing of the elements. For most designs, the bandwidth is small, typically only a few percent of the design frequency. The gain of a Yag-Uda antenna is proportional to its length, rather than simply the number of elements. The Yagi-Uda antenna or Yagi is one of the most brilliant antenna designs. It is simple to construct and has a high gain, typically greater than 10 dB. These antennas typically operate in the HF to UHF bands (about 3 MHz to 3 GHz), although their bandwidth is typically small, on the order of a few percent of the center frequency. The basic geometry of a Yagi-Uda antenna is shown in Figure 6.

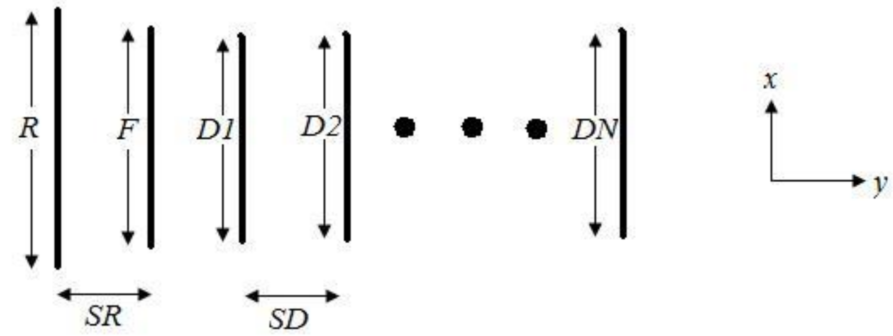


Figure 6: Geometry of Yagi-Uda antenna

The antenna consists of a single 'feed' or 'driven' element, typically a dipole or a folded dipole antenna. This is the only member of the above structure that is actually excited (a source voltage or current applied). The rest of the elements are parasitic - they reflect or help to transmit the energy in a particular direction. The length of the feed element is given in Figure 6 as *F*. The feed antenna is almost always the second from the end, as shown in Figure 6. This feed antenna is often altered in size to make it resonant in the presence of the parasitic elements (typically, 0.45-0.48 wavelengths long for a dipole antenna). [5]

The element to the left of the feed element in Figure 6 is the reflector. The length of this element is given as *R* and the distance between the feed and the reflector is *SR*. The reflector element is typically slightly longer than the feed element. There is typically only one reflector; adding more reflectors improves performance very slightly. This element is important in determining the front-to-back ratio of the antenna. There are two purposes why the reflector slightly longer than resonant. The first is that the larger the element is, the better of a physical reflector it becomes. Secondly, if the reflector is longer than its resonant length, it makes the impedance of the reflector capacitive. Hence, the current on the reflector leads the voltage induced on the reflector. The director elements (those to the right of the feed in Figure 6) will be shorter than resonant, making them inductive, so that the current lags the voltage. This will cause a phase distribution to occur across the elements, simulating the phase progression of a plane wave across the array of elements. This leads to the array being designated as a travelling wave antenna. By choosing the lengths in this manner, the

Yagi-Uda antenna becomes an end-fire array - the radiation is along the +y-axis as shown in Figure 6. The rest of the elements (those to the right of the feed antenna as shown in Figure 6) are known as director elements. There can be any number of directors *N*, which is typically anywhere from *N*=1 to *N*=20 directors. Each element is of length *Di*, and separated from the adjacent director by a length *SDi*. As alluded to in the previous paragraph, the lengths of the directors are typically less than the resonant length, which encourages wave propagation in the direction of the directors. [5]

The above description is the basic idea of what is going on. Yagi antenna design is done most often via measurements, and sometimes computer simulations. For instance, lets look at a two-element Yagi antenna (1 reflector, 1 feed element, 0 directors). The feed element is a half-wavelength dipole, shortened to be resonant (gain = 2.15 dB). The gain as a function of the separation is shown in Figure 7. [7]

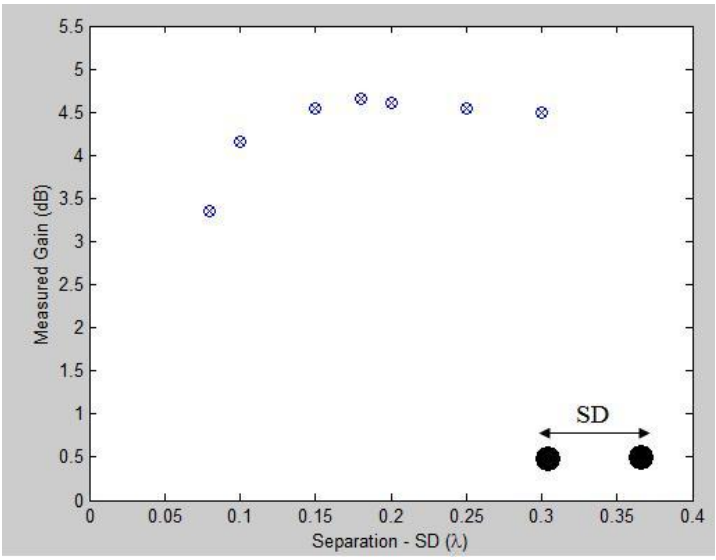


Figure 7: Gain versus separation for 2-element Yagi antenna

The above graph shows that the gain is increases by about 2.5 dB if the separation *SD* is between 0.15 and 0.3 wavelengths. Similarly, the gain can be plotted as a function of director spacing, or as a function of the number of directors used. Typically, the first director will add approximately 3 dB of overall gain (if designed well), the second will add about 2 dB, the third about 1.5 dB. Adding an additional director always increases the gain; however, the gain in directivity decreases as the number of elements gets larger. For instance, if there are 8 directors, and another director is added, the increases in gain will be less than 0.5 dB. [7]

There are many ways to feed the Yagi, but they can be condensed into two main categories: The balanced feed and unbalanced feed. The balanced feed system gives a broader impedance bandwidth, but the main problem is that the driven element must in most cases be split in the center and insulated from the boom. Construction considerations aside, it is the better of the feed systems. Meeting the requirements of a balanced matching system is usually the main problem, but there are many methods available. One method is to not split the driven element and use a "T" match, which can be described as two gamma matches on each side of the center of the element, fed with a 1:1 balun at the center. The main drawback is that it's difficult to adjust.

For unbalanced feed system, another method (for low impedance feed points) uses a split element insulated from the boom, and is fed with a "down-step 4:1 balun" made by combining two 1/4 wavelength sections of coaxial feedline in parallel, attaching an equal length of insulated wire to the outside of these sections, and connecting it to the center conductors at the feed point end and to the shields at the feed-line end. The impedance of this type of "balun" should be at or near the mid-point value between the feed point impedance and the feedline impedance. For example, two 75 ohm sections paralleled will equal 37.5 ohms and will match a 25 ohm feed point to a 50 ohm feedline with a 1.0 to 1 SWR. [9] The most common method in use by hams today is the gamma match. It will provide an easy and sure method of matching to the feed point without any loss of bandwidth. [7]

### 2.3 Gain Relationship With Impedance and Front-Back Ratio

The gain alone should not be the primary choice in Yagi-Uda array design, since front-back ratio and impedance bandwidth value are highly influenced. Yagi-Uda design needs compromises in gain, Front/Side-lobes ratio for both E and H plane and the Impedance bandwidth to avoid impractical or unusable antenna to meet your own requirements. [8] Generally, a loss gain has required to getting better overall and stable antenna performance, the dream antenna not exists in the physical world. It is very hard to get high front-back ratio, i.e. a low noise antenna, when antenna project require maximal gain. Lowering the radiator impedance seems to help to get better front-back ratio but minor side lobes should be take in consideration. [8] The skin loss and the Joule effect in the elements can dissipate a lot of energy at lower impedance values, resulting in an effective lowers gain than what would expected by the theoretical calculus. If the space lengths between elements have too closed, a severe instability could result such as both elements length and position tolerance as a small fraction of inch; very high susceptibility to environment condition could result also.

About the feeder, an open dipole radiator is easier to match as driven element much better than a folded dipole in home brew design. To perfect match avoid to move the first radiator, instead but move slightly the radiator element backward to reflector or forward to the director. Then a nice and stable antenna could show a lower gain than an extreme gain antenna design. Better performance could result but intrinsic impedance and bandwidth drop down when both low noise antenna and higher gain is required. [8]

### 2.4 Frequency Selection and MU-1-R

Based on some search and study, it been decided that frequency that will be used for the antenna is 434MHz since the frequency is same as frequency of transceiver, MU-1R that being used by AeroUTP team. Figure 8 shows the MU-1R. The frequency falls under Ultra high frequency (UHF). Ultra high frequency (UHF) designates a range (band) of electromagnetic waves with frequencies between 300 MHz and 3 GHz (3,000 MHz). It also known as the decimetre band or decimetre waves as the wavelengths range from ten to one decimetres.

AeroUTP team is using MU-1R due to rules of SiawaSAT Competition. MU-1-R is a radio modem for transmission of serial data. Using a simple system of commands, the user can concentrate on designing the transmitting and receiving protocols for the data using the commands, without needing to be aware of the radio component control. By using a UART interface for transmitting and receiving data and for issuing commands, it is possible for the user to develop systems quickly. [9]

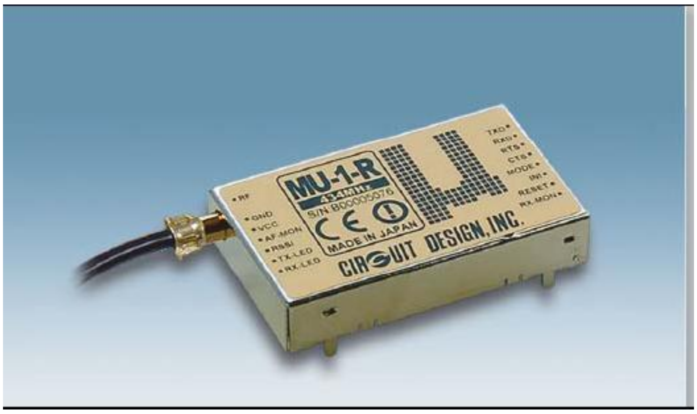


Figure 8: MU-1R

# CHAPTER 3
# METHODOLOGY

## 3.1 Procedure Identification

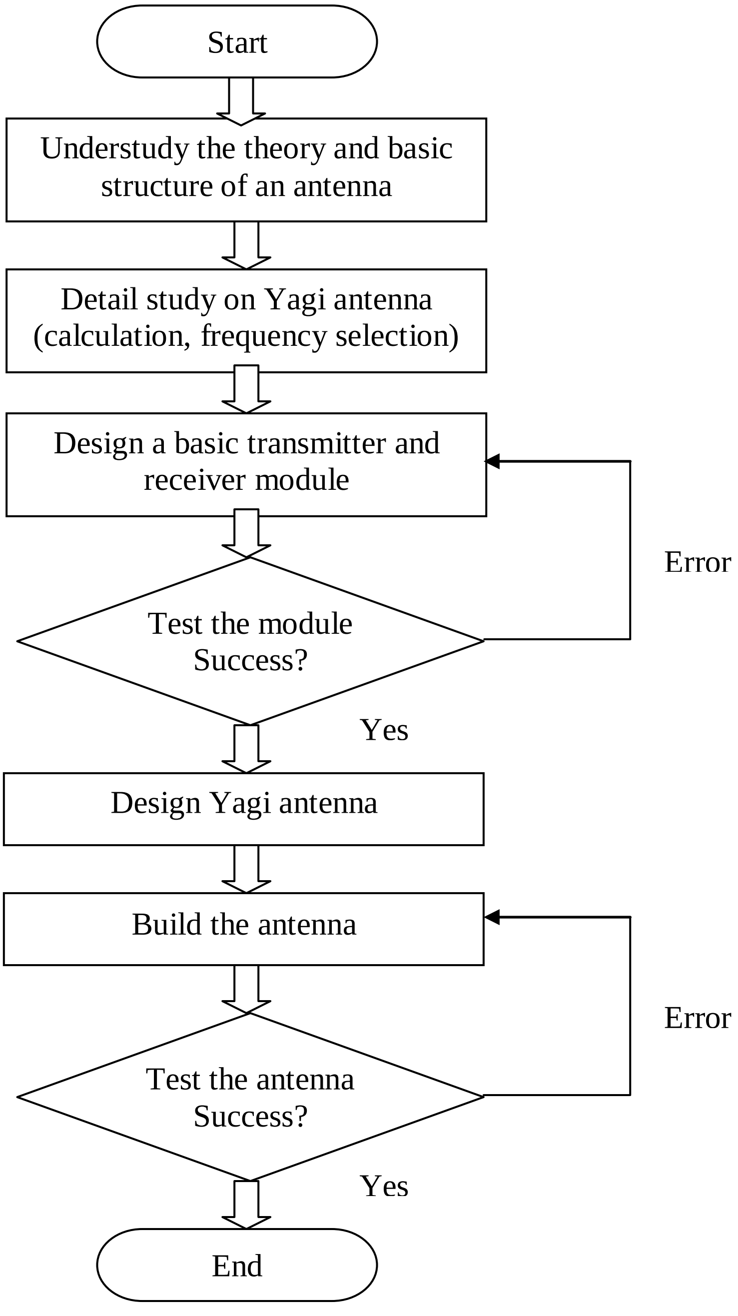


Figure 9: Project methodology

## 3.2 Tools and Equipments Required

For antenna:

1. Aluminium rods 10mm
2. RG58 cable connector
3. Aluminium rods 12.5mm x 25mm
4. Boom 15mm x 10mm
5. Bazooka tube
6. 50 ohm coax
7. Wires
8. Rivet

For transmitter and receiver module:

1. Transmitter TX9906A
2. Receiver RX208
3. HT12E encoder
4. HT12D decoder
5. Resistors (220Ω, 1MΩ, 470Ω and 47KΩ)
6. Capacitors (0.001uF, 10uF 6.3V, 470uF 16V)
7. Diode IN4007
8. Transistor C1815
9. Relay 12V
10. 78L05 voltage regulator
11. 3-state address code
12. LED
13. 12V power supply
14. Circuit board
15. Wires
16. Solder iron

**Software**

1. QY4

This software is only for Yagi antenna modelling. This software is free of charge and available to the Ham Radio community. It is very user friendly, highly accurate, and is loaded with features. Its features include:

- Folded dipole option
- Models tapered elements
- Auto design and auto optimize
- VSWR, gain, and F/B bandwidth graphs
- Choice of US foot-inch or int'l metric input/output
- Elevation, azimuth, and bandwidth pattern polar plots

This project was managed based on project milestone as main guidance. For more detail on project milestone, refer Appendix A.

# CHAPTER 4
# RESULT AND DISCUSSION

## 4.1 Antenna Design

The antenna is a 6 elements Yagi antenna with frequency 434MHz. This frequency was selected due to SiswaSAT Competition's Rules. The antenna consists of 6 elements which are 1 driven element, 1 reflector element and 4 director elements. The antenna being designed using software called QY4. The design is as shown in Figure 10 below.

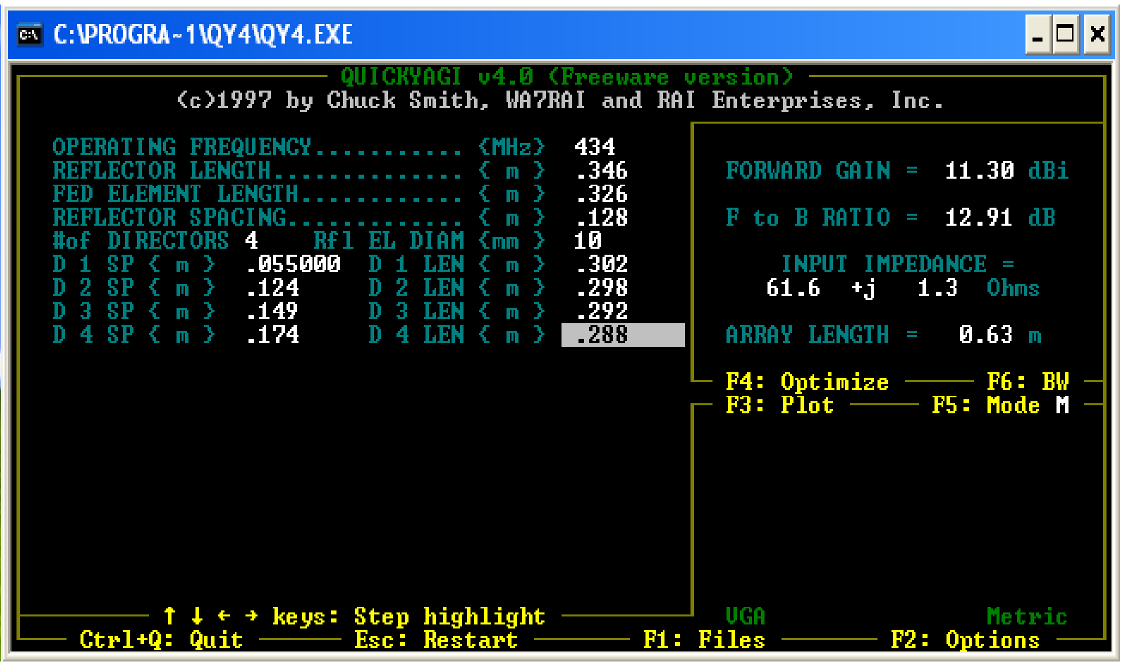


Figure 10: Design using QY4 software

The technical specifications for the antenna are as below:

Forward gain = 11.30 dB

Front-Back ratio = 12.91 dB

SWR at 434MHz = 1:1

Bandwidth = 10MHz

The results for the design are shown in Figure 11. The result shows that VSWR is 1:1 at 434 MHz.

C:\PROGRA~1\QY4\QY4.EXE

QUICKYAGI v4.0 (Freeware version)

| Freq.(MHz) | Gain(dBi) | F/B(dB) | Input res. & react.(Ω) | | | VSWR |
|---|---|---|---|---|---|---|
| 439.425 | 11.335 | 12.067 | 61.333 | -j | 13.91 | 1.25:1 |
| 438.883 | 11.332 | 12.121 | 62.586 | -j | 12.36 | 1.22:1 |
| 438.340 | 11.329 | 12.181 | 63.552 | -j | 10.72 | 1.19:1 |
| 437.797 | 11.326 | 12.249 | 64.222 | -j | 9.02 | 1.16:1 |
| 437.255 | 11.323 | 12.323 | 64.597 | -j | 7.31 | 1.13:1 |
| 436.712 | 11.319 | 12.404 | 64.685 | -j | 5.63 | 1.10:1 |
| 436.170 | 11.316 | 12.492 | 64.504 | -j | 4.01 | 1.07:1 |
| 435.627 | 11.311 | 12.586 | 64.077 | -j | 2.48 | 1.05:1 |
| 435.085 | 11.306 | 12.687 | 63.432 | -j | 1.07 | 1.02:1 |
| 434.542 | 11.301 | 12.794 | 62.598 | +j | 0.21 | 1.00:1 |
| 434.000 | 11.295 | 12.907 | 61.608 | +j | 1.34 | 1.03:1 |
| 433.457 | 11.289 | 13.027 | 60.491 | +j | 2.31 | 1.05:1 |
| 432.915 | 11.282 | 13.153 | 59.277 | +j | 3.13 | 1.08:1 |
| 432.372 | 11.274 | 13.285 | 57.992 | +j | 3.80 | 1.10:1 |
| 431.830 | 11.266 | 13.423 | 56.661 | +j | 4.32 | 1.13:1 |
| 431.287 | 11.256 | 13.568 | 55.302 | +j | 4.69 | 1.16:1 |
| 430.745 | 11.247 | 13.718 | 53.935 | +j | 4.93 | 1.19:1 |
| 430.202 | 11.236 | 13.875 | 52.573 | +j | 5.05 | 1.22:1 |
| 429.660 | 11.225 | 14.037 | 51.229 | +j | 5.06 | 1.24:1 |
| 429.117 | 11.213 | 14.205 | 49.912 | +j | 4.96 | 1.27:1 |
| 428.575 | 11.200 | 14.378 | 48.628 | +j | 4.77 | 1.30:1 |

P: Print G: Graph B: BW Plot Esc: Exit

Figure 11: Result of the design

The graph of the result is shown in Figure 12.

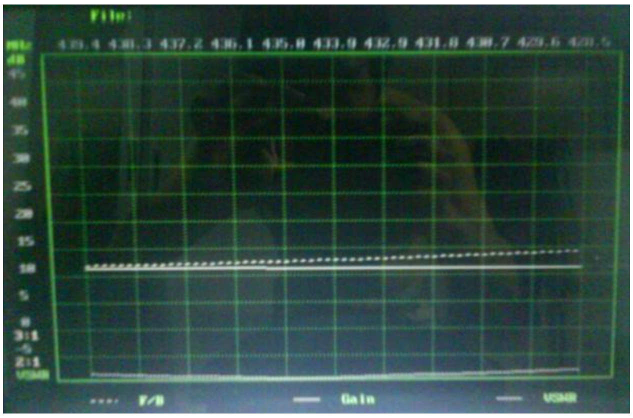


Figure 12: Graph for the design

Figure 13 shows the plot of SWR.

Figure 13: SWR

The antenna was fabricated to match the final design as shown in Figure 14.

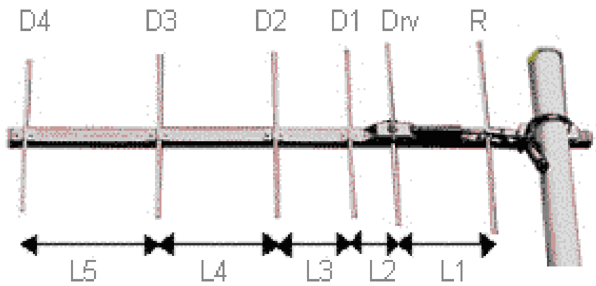


Figure 14: Design of the antenna

Length of elements:

R = 346mm

Dr = 326mm

D1 = 302mm

D2 = 298mm

D3 = 292mm

D4 = 288mm

Spacing of the elements:

L1 = 128mm

L2 = 55mm

L3 = 124mm

L4 = 149mm

L5 = 174mm

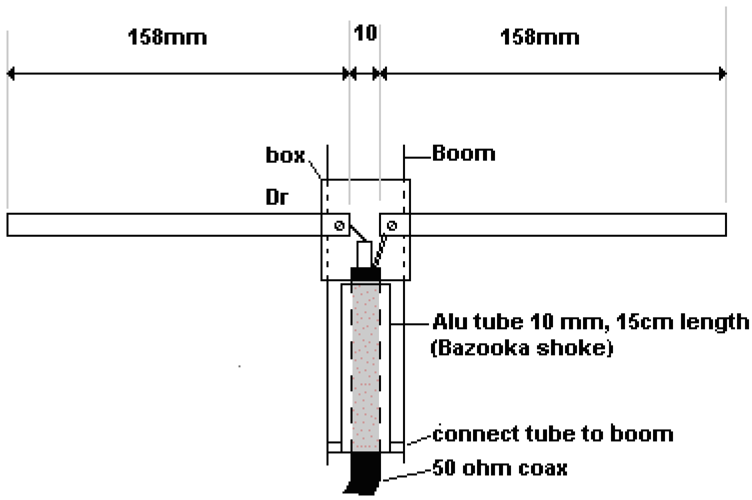


Figure 15: Driven element

Figure 15 shows connection of driven element and other elements. The length need to be adjusted if needed because the dipole is not connected to the boom. So, it must be mounted isolated from the boom. In order to fine tune the SWR (in both cases), the dipole length must be increased or decreased or by moving the dipole between the first director and reflector a bit. Refer Figure 16 for connection between tube and boom.

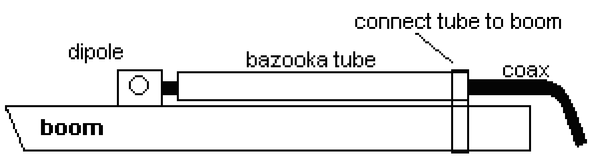


Figure 16: Connection between tube and boom

The elements diameter of the antenna may vary between 5mm to 8mm and the dipole diameter may vary between 8mm to 12mm without the need of changing anything to the length or spacing. All elements except the dipole are electrically connected to the boom and be mounted on top or through it. The thickness/diameter of the boom may vary between 10 to 15mm. Isolator type boom (plastic tube, wood, fiberglass) is used if mount the antenna vertically to prevent distortion of the radiation pattern. The completed antenna is shown in Figure 17.

Figure 17: Completed Antenna

## 4.2 Antenna Testing

The antenna was tested based on SWR. The ideal SWR is 1:1. So, the target of this testing is to get SWR 1:1 at 434 MHz. Equipments used for testing are as below:

1. Transmitter UHF/VHF Yeasu FT8800
2. SWR & Power Meter - Diamond SX1000
3. MFJ-269 HF/VHF/UHF Antenna Analyzer
4. 1Meter Belden RG8 Cable ( From transmitter to antenna )


Figure 18: MFJ-269 HF/VHF/UHF Antenna


Figure 19: Testing Equipments

### 4.3 Testing Results

The testing results of frequency vs SWR are shown in Table 1. The results were obtained by measuring the SWR of antenna at certain frequency starting with 433.9750 MHz. The increment of frequency is 0.0125 MHz or 12.5 KHz. The results were obtained until 434.1750 to get up to 17 measurements. Based on the results, SWR is 1:1 at 434.0000 MHz and 434.0125. That's mean the antenna will function best at 434.0000 MHz and 434.0125.

Table 1: Frequency vs SWR

| MHz | SWR |
|---|---|
| 433.9750 | 1.2 |
| 433.9875 | 1.2 |
| 434.0000 | 1.1 |
| 434.0125 | 1.1 |
| 434.0250 | 1.2 |
| 434.0375 | 1.2 |
| 434.0500 | 1.2 |
| 434.0625 | 1.3 |
| 434.0750 | 1.3 |
| 434.0875 | 1.3 |
| 434.1000 | 1.3 |
| 434.1125 | 1.4 |
| 434.1250 | 1.4 |
| 434.1375 | 1.4 |
| 434.1500 | 1.4 |
| 434.1625 | 1.5 |
| 434.1750 | 1.5 |

The obtained results were plotted as shown in Figure 20.

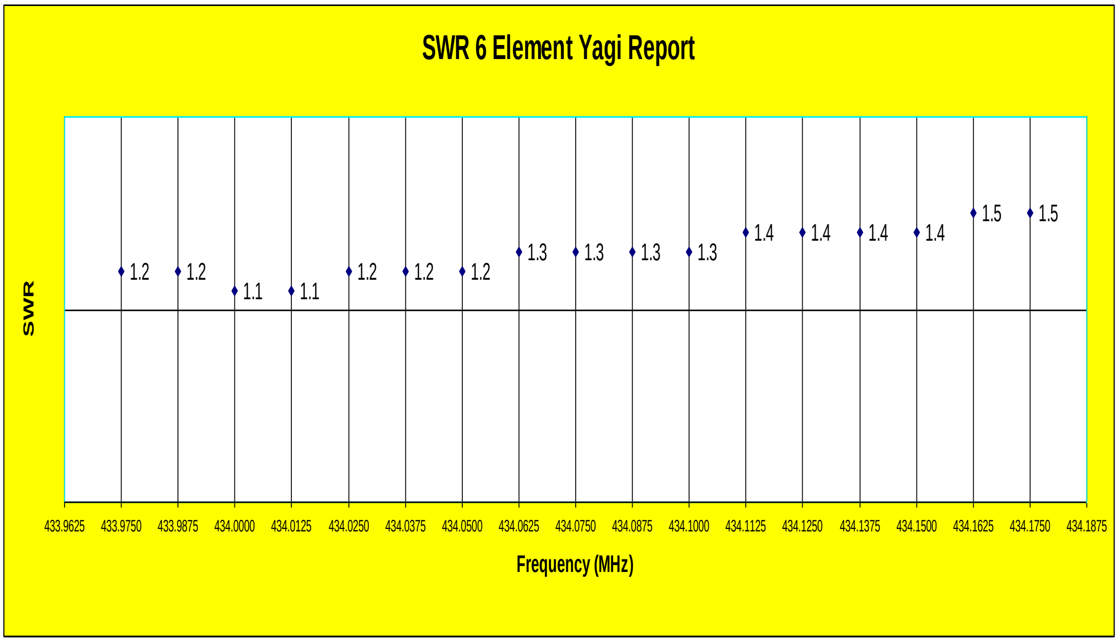


Figure 20: Testing Result

### 4.4 Transmitter and Receiver Module

The purpose of doing this module is to understand basic transmission and receiving process. For transmitter and receiver module, RF module is used. The module is a simple channel remote control switch using TX9906A (refer Figure 21) model as transmitter and RX208 (refer Figure 23) model as receiver.

Technical specification of TX9906A: [10]

Operating voltage (Vcc): 3 ~ 12 DC

Operating current: Max < = 45 mA(12V) , min <= 2 mA (3V)

Oscillator: SAW filter stabilized

Modulation: OOK, ASK

Frequency: 315 MHz or 433.92 MHz

Frequency tolerance: ± 150 KHz (max)

Transmission (RF) power: 50 mW (at 315 MHz & 12V)

Data transmission rate: <= 10Kbps

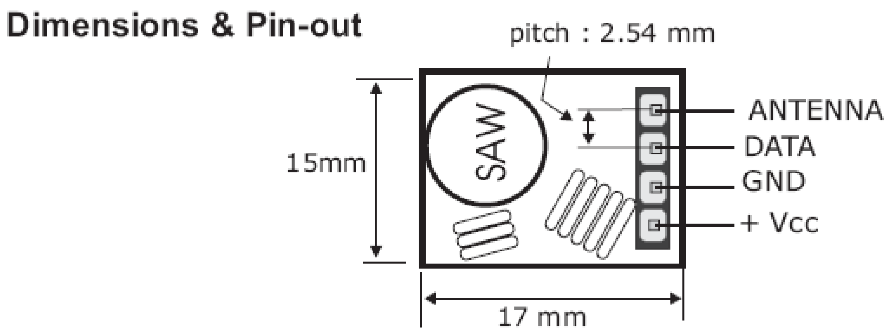


Figure 21: TX9906A

Figure 22 shows the schematic for transmitter:

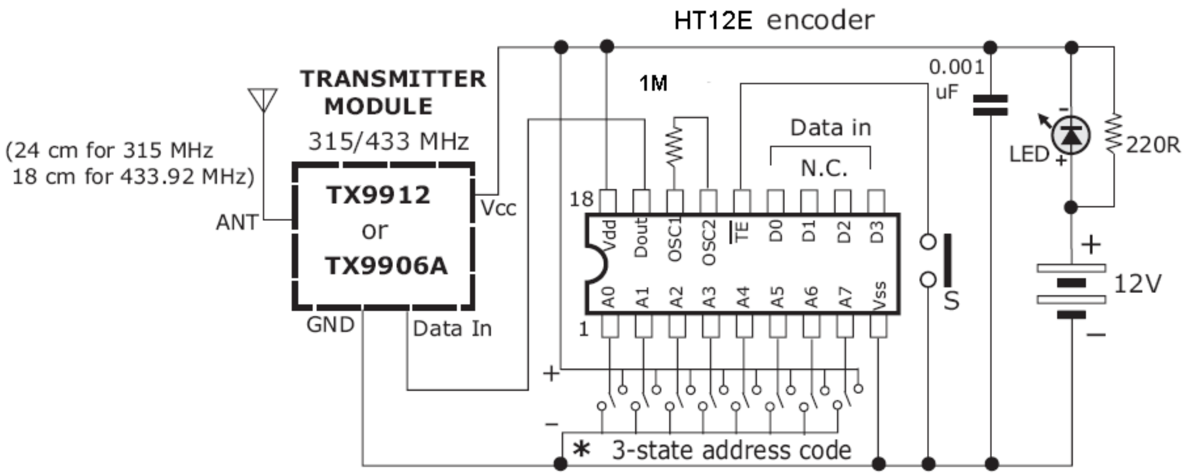


Figure 22: Transmitter schematic

Technical specification of RX208: [10]

Operating voltage: 5.0 DC ± 0.5V

Standby current: < 3 mA @Vs=5V

Operating mode: Super-regenerative

Modulation: OOK, ASK

Frequency: 315 MHz or 433.92 MHz

Bandwidth: 2MHz ( f=315 MHz, @3 dBm rolloff)

Sensitivity: better than - 105dBm (@ 315MHz)

Data transmission rate: <5Kbps

Output signal: Digital, TTL level

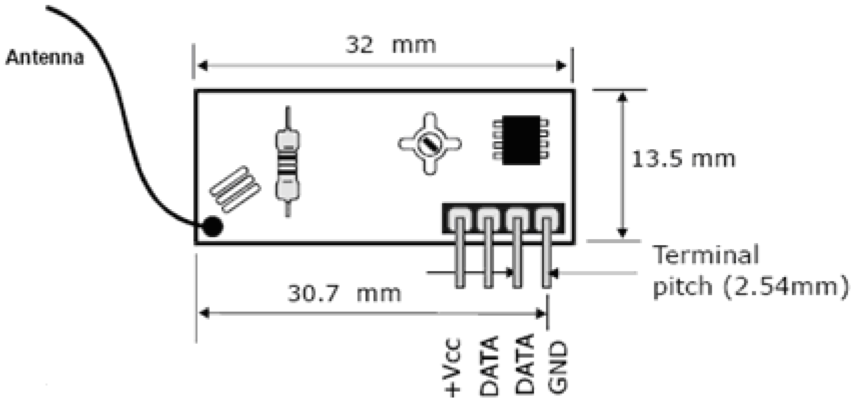


Figure 23: RX208

Figure 24 shows the schematic for receiver:

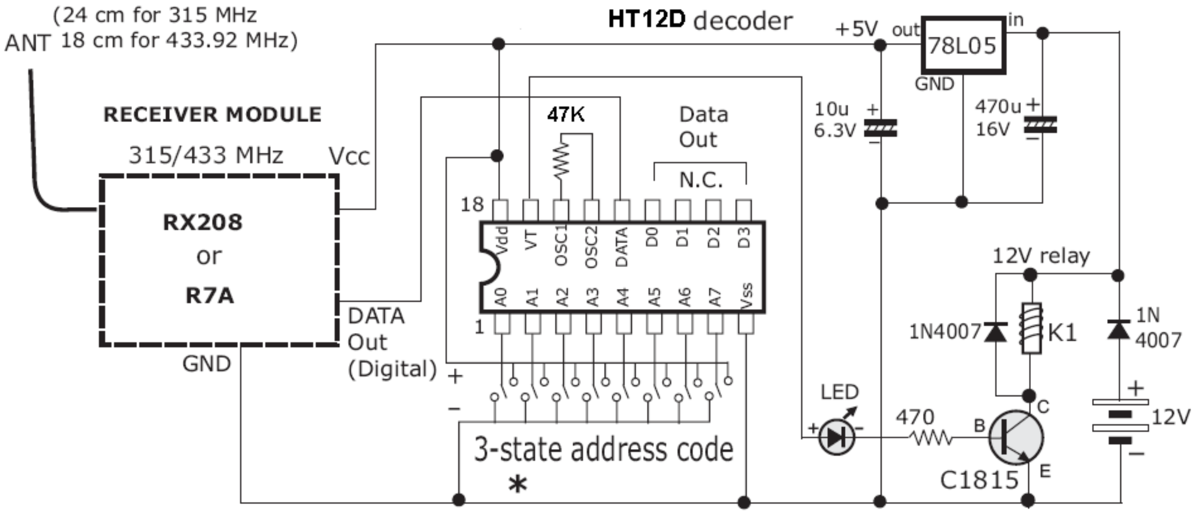


Figure 24: Receiver schematic

Each address pin (A0~A7) of the encoder and decoder should be connected to either positive, negative or left floating (no connection). The encoder and decoder must always have matching address codes in order for the receiver to respond correctly to the command of the transmitter. When the button switch of the transmitter is depressed, pin 17 (VT) of the decoder will go high and the relay actuated and remains so until the button is released.

# CHAPTER 5
# CONCLUSION AND RECOMMENDATION

## 5.1 Conclusion

Yagi antenna was chosen because of some important factors. It has good range, highly directional and easier to aim than a parabolic dish. Yagi antenna can be constructed with low cost compared to other type like parabolic and disc.

From theory of an antenna in chapter 2, there are some parameters that being considered in designing the antenna. All the parameters have significant impact on antenna performance. The theory was applied during design and fabrication process in order to produce antenna that can receive best signal with minimum noise.

The methodology chart is one of important guidance that being followed. The flow shows the step taken to complete the project. The chart being followed to avoid any disturbance so that this project can be completed as planned. Transmitter and receiver module used as described in chapter 4 help to understand transmitting and receiving process.

The antenna was tested based on SWR. From the design using QY4 software, the SWR at 434 MHz is 1:1. The testing results match the results of QY4 design. That’s mean the antenna operate in optimum condition at 434 MHz which is required by AeroUTP Team. Based on result of the project, the objectives of this project already been achieved.

## 5.2 Recommendation

The antenna can be improved by using motor that rotate to find the signal automatically without manual pointing. Once the location of the satellite being locked using programming, the antenna will find the signal itself based on the location of satellite. This is much easier compare to manual pointing which can cause loss of signal.

# REFERENCES


[1] C. Balanis, Wiley (1997). *Antenna Theory (2nd edition)*, CT: Chapter 2 – Fundamental Parameters of Antennas. page 28 – 98. ISBN 0-471-59268-4

[2] W. Stutzman and G. Thiele, Wiley (1997). *Antenna Theory and Design (2nd edition)*, CT: Chapter 1 - Antenna Fundamentals and Definitions, page 1-52. ISBN 0-471-02590-9.

[3] Hutchinson, Chuck, ed. (2000). *The ARRL Handbook for Radio Amateurs 2001*. Newington, CT: ARRL—the national association for Amateur Radio. pp. g. 20.2, 19.6, 19.13 ISBN 0-87259-186-7.

[4] Ford, Steve (April 1997). "The SWR Obsession" *QST* (Newington, CT: ARRL—The national association for Amateur Radio) 78 (4): 70–72. http://www.arrl.org/tis/info/pdf/49470.pdf. Retrieved 2008-09-26.

[5] Yagi Uda Antenna
http://yagi-uda.com

[6] Yagi Antenna
http://en.wikipedia.org/wiki/Yagi_antenna

[7] Basic of Yagi Antenna
http://www.hamuniverse.com/yagibasics.html

[8] Antenna Theory
http://www.antenna-theory.com

[9] MU-1-R Figure, Critical Design Review, UKM Team.



[10] Component Datasheet
www.laipac.com

# APPENDICES

# APPENDIX A

# PROJECT MILESTONE

| No. | Detail/ Week | 1 | 2 | 3 | 4 | 5 | 6 | 7 | | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Project work continues | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | |
| 2 | Submission of Progress Report 2 | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | |
| 3 | Seminar (compulsory) | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | |
| 4 | Project work continue | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | |
| 5 | Poster Exhibition | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | |
| 6 | Submission of Dissertation (soft bound) | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | |
| 7 | Oral Presentation | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | |
| 8 | Submission of Project Dissertation (Hard Bound) | | | | | | | | | | | | | | | |

Suggested milestone

Process