# MULTIBAND AMATEUR RADIO ANTENNA DESIGN

**By**

**ZULFIKRI BIN SAAD**
**14571**

**Submitted to the Department of Electrical and Electronic Engineering**
**In Partial Fulfillment of the Requirements for the Degree**
**Bachelor of Engineering (Hons)**
**(Electrical and Electronic Engineering)**

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CERTIFICATION OF APPROVAL

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Approved:

_____________________

(Dr M Noh Karsiti)

Project Supervisor

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# 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.

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Zulfikri Bin Saad

# ABSTRACT

Amateur radio is the field of communication that can bring enjoyable for someone beside it can be used for emergency communication and military radio system. Normally, amateur radio running in the range of frequency from 3-30 MHz. The one of the main components used in amateur radio system is the antenna as transmission medium to transmit the signal. This report is highlight the simulation design for three, five and seven elements of half lambda Yagi antenna by using EZNEC Demo v.5.0 software while the substrate prototype is fabricated using some aluminums rod, RG 58 coaxial cable, FT-817ND transceiver and RF field strength meter. The report will discuss the result from the EZNEC simulation part with the actual prototype for three, five and seven elements Yagi in term of radiation pattern, maximum gain and Front-to-back ratio.

## ACKNOWLEDGEMENT

First and for most, all praise to Allah the almighty for his blessing and guidance to give me a strength to do a research on Multiband Amateur Radio Antenna Design systems. Alhamdulillah, a lot of fundamental and theory knowledge I had been discovered in a time to do this research. The credit also to my family and friends that don't stop to give support and motivation for me to do the project.

1 would like to express my gratitude to my final year project supervisor, Dr M Noh Karsiti for all his guidance and attention towards my research that has contribute a lot to achieve the objectives of this project. Lastly, my gratitude to all those that help me directly or indirectly to make sure my project will done within the time frame.

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## LISTS OF ABBREVIATIONS

IEEE Institute of Electrical and Electronics Engineer

SKMM Malaysian Communications and Multimedia Commission

ASAA Amateur Station Apparatus Assignment

SWR Standing Wave Ratio

RF Radio Frequency

F/B Front to Back Ratio

# CHAPTER 1: INTRODUCTION

## 1.1 Project Background

Amateur radio (known as ham radio) has been introduced and established for a long time ago. The uses of the amateur radio are for personal enjoyment, for emergency communications, for keeping in touch with family and friends and also for radio equipment. The definition of amateur radio according Communications and Multimedia (Spectrum) regulations 2000 is “a radio communications service (covering both terrestrial and satellite) in which a station is used for the purpose of Self-training, intercommunication and technical investigations carried out by authorized persons who are interested in radio technique solely with a personal aim and without any pecuniary interest”. In Malaysia, the amateur radio is regulated by the Malaysian Communications and Multimedia Commission (SKMM). The person who wants to establish one amateur radio’s station in Malaysia must receive the license and certificate from Radio Operator’s certificate and an Amateur Station Apparatus Assignment (ASAA). Only authorize person with valid license can transmit the signal in order to communicate with other person. The one of the main component of amateur radio is the antenna itself beside transceiver which is the transmitter and receiver in one device.


Figure 1.1: Example of transmitter and receiver in one device

The antenna will be connected to the transceiver as the medium for the transceiver to transmit and receive a radio signal. The design for the antenna is suitable or compatible with only a range of frequency like 2 meter band Yagi antenna suitable for frequency range from 140 MHz to 160MHz.  The have been establish various types design of antenna specifically for ham radio uses and each design will cover the specific purposes.

This project will focus on developing the improved design for current antennas that make the antenna is able to radiate and receive the signal as much as possible.

## 1.2 Problem statement

In this modern era, the communication systems become the one of important part in life of everyone. It easy for everyone to communicate with friends etc. by using wireless signal without waiting for one, two , three or more days to get replied. The most important devices that everyone must have in their pocket are a hand phone. But there will come to a certain time that a communication device like a hand phone can't be used to communicate with others especially in emergency time for example when a disaster happen which causes the power electricity fall down and communication breakdown. At this time maybe a hand phone can't be used to communicate with others. Beside for personal enjoyment, normal communications from one station to another station, an amateur (ham) radio system also are very useful in emergency time, when disaster happen the emergency team will use this ham radio system like a simple walkie talkie to communicate with others team.

However, the antenna designs for ham radio have limit ability to transmit and receive the signal in term of far distance range and gain received. It means that how far the antenna can transmit the signal to other station and how much the antenna can receive the signal from other station. This problem will be further discussed in this project in order to design and build an antenna that can have a good performance than the current antenna design.

## 1.3 Objective and Scope of study

The objectives of this project are as stated below:

- Design Multiband Antenna with broad specification for 144 MHz
- Simulate the design specification using EZNEC Demo V5.0 software
- Design the prototype antenna and testing the antenna using near-field and far-field method

## 1.4 Relevancy of the project

This project is relevant in mostly term of advanced design and development. Nowadays, there have many designs of antenna for a various function like the antenna for Wi-Fi, WI-Max, broadband, and Bluetooth. It developed faster from year to year to have a better useful in real life especially on wireless technology. Improvising the antenna system for amateur radio may enhance the big application in radio industry.

On the other hand, there is much to research in term the effectiveness of the current design on multiband antenna system. It is believe that the development of wireless industry have move faster and faster and this will cause the communications platform like radio, television, and internet need to follow the latest technology. Thus, a significant advance in this multiband antenna system may in several ways improvise the life and productivity of human being.

## 1.5 Feasibility of the project within the Scope and Time Frame

From the scope and time frame given, this project is feasible to finished within the range given. It will be two semesters which are equivalent to 28 weeks to do the entire necessary thing related to the project. This project is actually an ongoing project. Thus, it has many source and material available whether in the internet or information research center.

# CHAPTER 2:

## 2.1 Literature Review

Antenna transforms the high frequency of electrical energy into an electromagnetic wave and vice versa. The wave will propagate through the air for long distances (Joel R. Hallas, 2008).

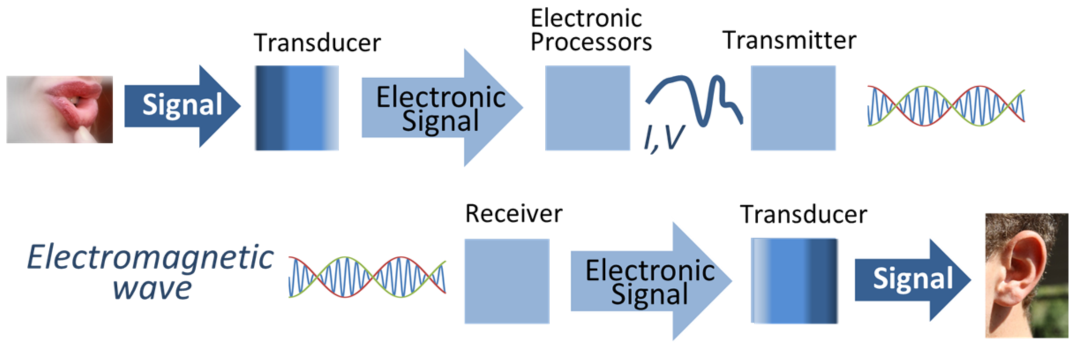


Figure 2.1: Illustration of transforming energy electrical energy into radio wave signal

When dealing with antennas, the basic concept of frequency, period and wavelength need to be familiar with. Frequency is defined as the rate in which an alternate current waveform in full cycle from zero voltage to maximum, back to zero and from voltage minimum and go back to zero. The basic unit is in hertz (Hz). The period is defined as the time taken to complete one cycle of wave. The formula is 1/F and the unit is seconds. The wavelength is defined as the length of wave travel in one cycle (measure peak to peak of the wave). A signal can be described as frequency or wavelength (Joel R. Hallas, 2008).

The purpose of radio is to send and receive the signals by using radio waves. Radio wave is a form of light and travel at 186 000 miles per second which is same speed as speed of light. An electric field and magnetic field carry the energy of radio waves. The electron moves in a wire in a specific ways. Its move parallel following the electric fields and move circular toward the magnetic field (Ward Silver, 2004).

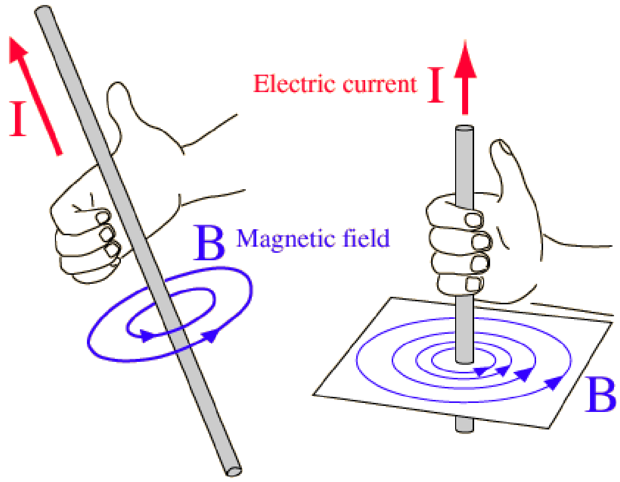


Figure 2.2: Electric Field and Magnetic Field

Transmitter is function to cause the electron move into the air and create moving fields of radio waves. Receiver then detects the radio waves coming and process the signal in form electric signals. The basic concept is the electron is transferred into radio waves so that it can propagate and travelling in the air and after that the radio waves is transferred back into electron at receiver at other station. The function of antenna is just to transmit and receive the signal from one station to be processed at that stations (the station that the antenna located) (Ward Silver, 2004).

There have several types of antenna, which are:

| | |
|---|---|
| Whip (rod) antennas | Used for mobile phones. |
| Dipole antenna | Used for amateur radio. |
| Yagi-Uda array | Used for television antenna. |
| Parabola antenna | Used for satellite broadcast. |
| Loop antenna | Used to capture the magnetic field in radio waves. |
| Dielectric antenna | Antenna which using high frequency dielectric ceramic to achieve high performance. |

The component that makes the interconnection between the antenna and transmitter or receiver is called a transmission line. Transmission line will be used beside the radio systems as example, power distribution line, telephone wire and cable TV connections. Transmission line is not just transporting the signal but it has several functions in amateur radio systems (Joel R. Hallas, 2008).

Transmission line consists of two conductors, either parallel wires or one wire surrounding the other, as in coaxial cable TV wire. The configuration is shown in Figure. Some transmission lines have certain inductance and capacitance per unit length. The configuration is shown in Figure. If the voltage or signal is applied into the line, the initial current flow independent on the way end of the line according to L (inductance) and C (capacitance) values. The initial current will charge the shunt capacitance which located in series inductors and if it connected to the resistor, the value is equal to the square root of L/C.  The matched condition occurred when the power in the line will be delivered to the load as the end of the line is terminated in resistive load. The situation determined in this way is called the characteristics impedance of the transmission line and it is very important parameter associated in transmission line (Joel R. Hallas, 2008).

Coaxial transmission line commonly has characteristics impedance between 35 and 100 ohm, and balance lines in the range of 70 to 600 ohm. These characteristics are very useful in radio's design for example the antenna system has impedance of 50 ohm and radio transmitter is designed to drive 50 ohm load, so it can connect the two with the coaxial cable and the antenna will receive most of transmitter power. But this is the ideal transmission line model. The real transmission line will not acted like this because due to real life phenomena, on the way of transmission line, there must happen loss of resistance, losses some signal due to the loss nature of the insulating material. So, the real design of transmission line are its made of larger conductors, thus it will reduce the resistance and the losses are reduced also as the dielectric material get s closer to low air (Joel R. Hallas, 2008).

The velocity of the signals in air is propagate almost same with the speed of light. The velocity is reduced by a factor one over the square root of relative dielectric constant. The most common cable that has the characteristics of this velocity is polyethylene cable. It has relative dielectric constant of 2.26. When 2.26 is squared root, it will get 1.5. So, the propagation velocity for polyethylene insulated coaxial cable is 1.5x10^8 or 2x10^8 m/sec whereas neared the velocity of light is 3x10^8 m/sec (Joel R. Hallas, 2008).

### 2.2 Critical analysis of literature review

A band is a range of frequencies that are assigned to a specific function. Multiband means a multiple of band that is combined in one antenna design in same space and using the same transmission line. The function of this multiband system is to provide an antenna that will transmit and receive a various range of frequencies only by using one antenna system (Joel R. Hallas, 2008).

There have two dipoles for multiple bands, which are:

i) **Parallel Dipoles for Multiple Bands**

ii) **Parasitically Coupled Multiband Antennas**

### 2.2.1 Parallel Dipoles for Multiple Bands:

The multiple antennas are joining together in the same space and they are using the same transmission lines. The concept is the antennas at widely different frequencies which will be resonant within its band. It will have enough high impedance from the other band thus it will not require a power from the transmission line(Joel R. Hallas, 2008).

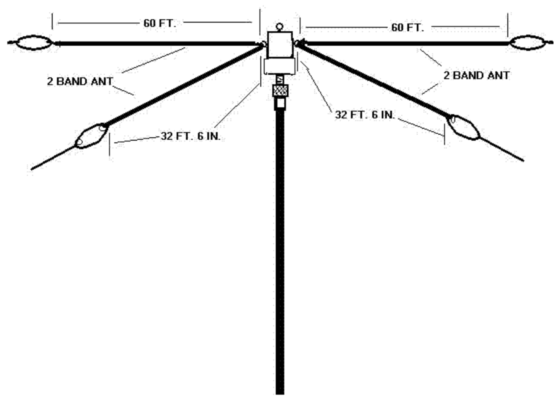


Figure 2.3: Configuration of parallel dipoles for two bands.

By the way, there are two traps that must be looked out when designing of this concept

- In order to have the additional dipole to the connected parallel impedance, there will have significant common coupled impedance that is difficult to predict. The ranges will change from negligible to significant when the direction of the second dipoles is change from perpendicular to toward being parallel to the first.
- In the situation of high impedance, it will generally be reactive resulting in a need to retune the antenna lengths compared to a single-band dipole.

### 2.2.2 Parasitically Coupled Multiband Antennas:

The coupled of one parallel dipole to another tuned to a different frequency without direct connection. In order to have a successful operation, the spacing between driven dipole and parasitically coupled element needs to be about 0.003 to 0.004 lamda to achieve appropriate coupling. The commercial manufacturers of amateur radio commonly will this concept of multiband antennas (Joel R. Hallas, 2008).

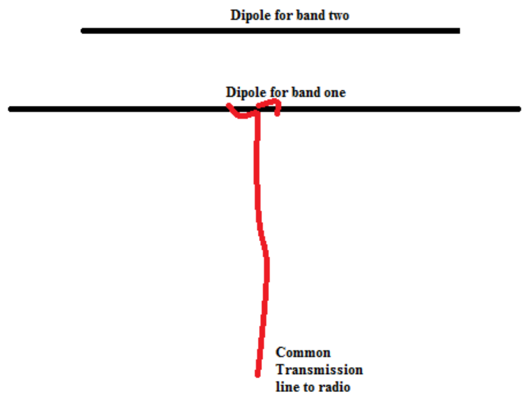


Figure 2.4: Configuration of parasitically coupled dipoles for two bands.

N. Huy, B. Nicholas, and B. Vishal (2000) in their report stated that the antenna design for ham radio could be in shape of:

i. Horizontal Dipole Antenna
ii. Vertical Dipole Antenna
iii. 3 Elements Yagi Antenna
iv. 1/4 Wave Ground Plane Antenna
v. 5/8 Wave Ground Plane Antenna
vi. Omni-Angle Horizontal Antenna

When the author compared in term of its radiation pattern for every design that they had stated in their report, the pattern of the radiate power is not well enough to direct the signal in one direction for all the design except for 3 elements Yagi. The performance of that 3 elements Yagi antenna can be improvised to get the optimum capacity of the antenna in term of it radiation pattern, front to back ratio and maximum gain. The maximum gain and F/B ratio can be obtained from the radiation pattern. The Figure 2.6 shows the radiation pattern for every design as stated in the lists.

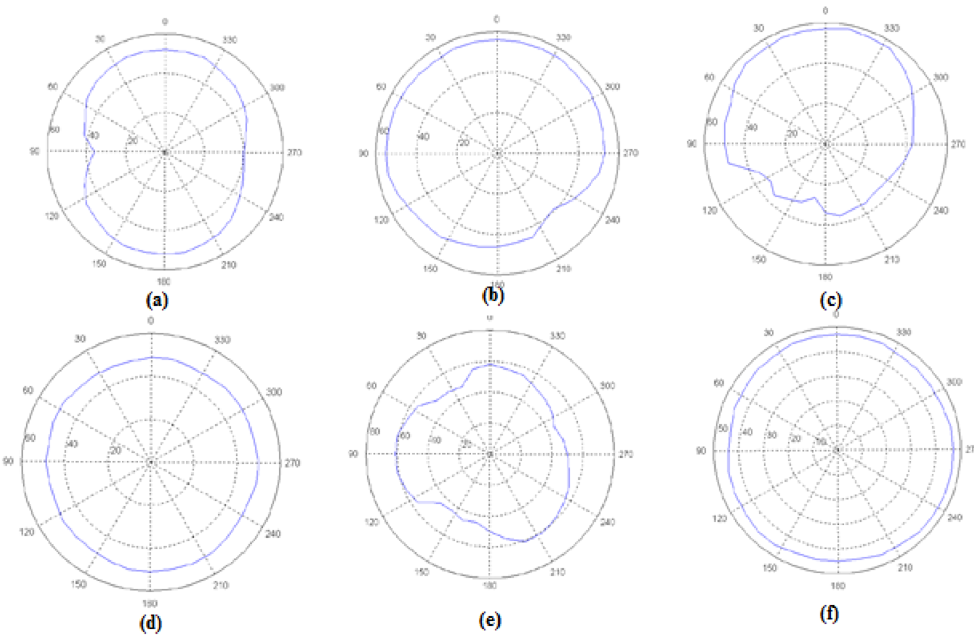


Figure 2.5: Radiation Pattern; (a) Horizontal Dipole Antenna, (b) Vertical Dipole Antenna, (c) 3 Elements Yagi Antenna,(d) 1/4 Wave Ground Plane Antenna (e) 5/8 Wave Ground Plane Antenna, (f) Omni-Angle Horizontal Antenna.

All the design will gives the advantages and disadvantages according to the specific purpose. So, it is very interesting to explore and develop a Yagi antenna which the performance of that antenna is better than the current design can give.

# CHAPTER 3:

### 3.1 Research Methodology

There are some research methodologies that will used to conduct the experiment and simulation to design multiband antenna system. Here are the project activities as the method of research that will be used to solve the problem.

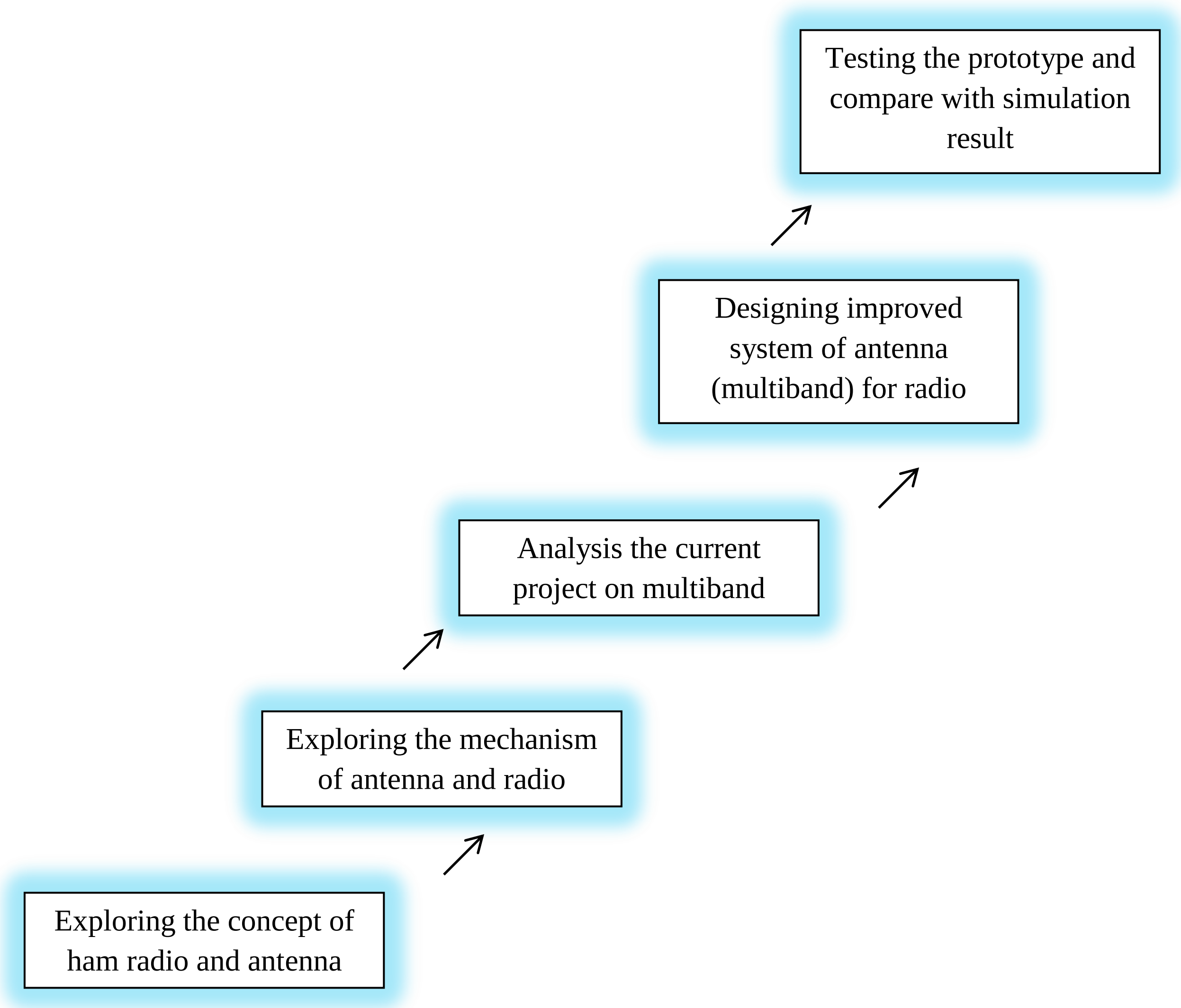


Figure 3.1: Research Method integrated with project activities flow chart

### 3.2 Project key milestone

Based on the objective with related to the methodology suggested, there are some explanation regarding the key milestone that the author are going to achieve.

- To study the basic concept of communication system and amateur radio.
  In this objective, the author need to study the fundamental of communication system like the frequency, wavelength, period, electromagnetic wave, transmitter, receiver and antenna systems. The principles of this concept are very important in order to shape the antenna design.
- To study and develop the antenna design by using software
  On the other hand, the software needs to be master with. To design the antenna the author using EZNEC demo V.50 software. This needs a particular design on how the antenna with multiband frequency is simulated with the software.
- To design a multiband antenna systems for amateur radio.
  After all the simulation have been done, the others part is to make the prototype of the antenna system. Thus, this objective can be achieved when the strong knowledge on the antenna and radio system are covered early in the beginning of the project.

### 3.3 Project design using software

After the analysis of current design for Yagi antenna had done, the author proceeds to design the simulation part using EZNEC demo V.5.0 software. This software is specifically made for simulate the antenna design for ham radio. The design starting with three elements, followed with 5 elements and 7 elements design. All the parameters of the antenna will be first calculated before it used in simulation design and this part will be discussed in Chapter 4. The authors had design the dimension of the antenna until it gave the best maximum gain and front to back ratio and this design will be implemented in prototype.

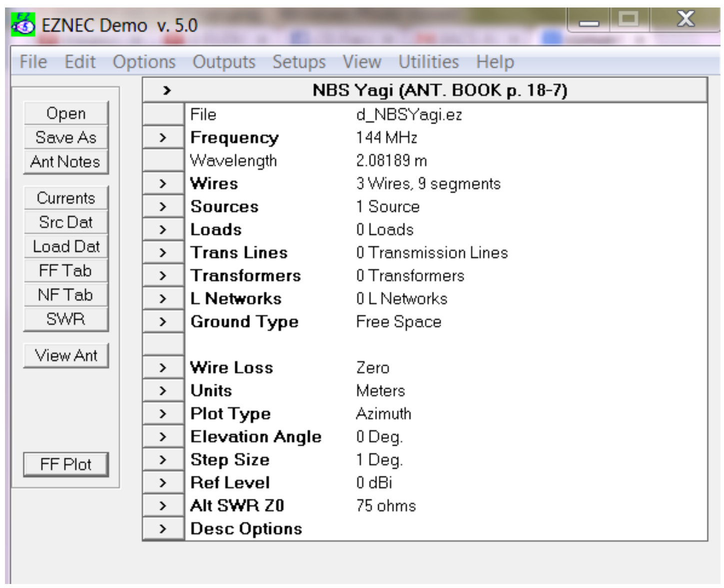


Figure 3.2: EZNEC demo V5.0 software

### 3.4 Testing the Prototype

After the author had the best design in simulation part using software, that design will be used to implement in prototype for testing purposes. The equipment needed for testing purposed are one set transceiver, the antenna(prototype) itself and Radio Frequency (RF) field strength meter.


Figure 3.3: Transceiver Set


Figure 3.4: RF field strength meter

The antenna will be mounted approximately at the height of 5 feet above the ground;

The Antenna will be connected to the transceiver (like in the figure below).

Figure 3.5: Three elements Yagi is mounted and connected to transceiver for testing purposed

Then, the author will need the help of one person to push the microphone button for transmit the signal and the author will adjust the reading of RF field strength meter very near to the antenna that will give the full reading of RF field strength meter. This way is call near-field method and will be discussed in Chapter 4. After that, the author will move further 1, 2 meter and check again the reading of RF field strength meter and all the reading will be recorded. The step is repeated for every 30 degree angle around the antenna.

### 3.5 Project timeline (Gant- Chart)

| No | Activities | Week 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | **Selection of Project Topic** | | | | | | | Mid-Semester Break | | | | | | | |
| 2 | **Preliminary Research Work**<br>Exploring the implementation of multiband antenna design | | | | | | | | | | | | | | |
| 3 | **Submission of Extended Proposal Defense** | | | | | | | | | | | | | | |
| 4 | **Proposal Defense** | | | | | | | | | | | | | | |
| 5 | **Project Work Continues**<br>Analysis the current project on multiband antenna systems<br>Designing improved system of antenna (multiband) for radio system in software | | | | | | | | | | | | | | |
| 6 | **Submission of Interim Draft Report** | | | | | | | | | | | | | | |
| 7 | **Submission of Interim Report** | | | | | | | | | | | | | | |

| No | Activities | Week | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 1 | Build the prototype for 3 elements | | | | | | | Mid-Semester Break | | | | | | | |
| 2 | Testing the prototype of 3 elements | | | | | | | | | | | | | | |
| 3 | Build the prototype for 5 elements | | | | | | | | | | | | | | |
| 4 | Testing the prototype of 5 elements | | | | | | | | | | | | | | |
| 5 | Submission of the Progress Report | | | | | | | | | | | | | | |
| 6 | Build the prototype for 7 elements | | | | | | | | | | | | | | |
| 7 | Testing the prototype of 7 elements | | | | | | | | | | | | | | |
| 8 | Pre SEDEX presentation | | | | | | | | | | | | | | |
| 9 | Submission of Draft Final Report | | | | | | | | | | | | | | |
| 10 | Submission of Technical Report | | | | | | | | | | | | | | |
| 11 | Submission of Draft Final Report | | | | | | | | | | | | | | |
| 12 | Final VIVA presentation | | | | | | | | | | | | | | |

# CHAPTER 4: RESULT AND DISCUSSION

## 4.1 Fundamental findings

An antennas system consists of three fundamental properties which are gain, direction and polarization. Gain is defined as a measure of increase in power which means the increase in energy that an antenna adds to a radio frequency (RF) signal. Direction is defined as the shape of the transmission or propagation pattern.  When we are trying to get the higher gain of directional antenna, it will affect the angle of radiation which the angel will be decreased. It will provides the greater coverage distance of propagate wave but at the same time it reduced a coverage angle. Normally, the coverage area or as known as radiation pattern is measured in degrees and is called beam widths. An antenna is the device that simply redirects the energy it receives from the transmitter. It will redirect more energy in one direction but less energy in all other directions.

Beam widths are measure in horizontal and vertical plains. It is the angular separation between the half points in the radiation pattern of the antenna in any plane (normally in 3 dB).

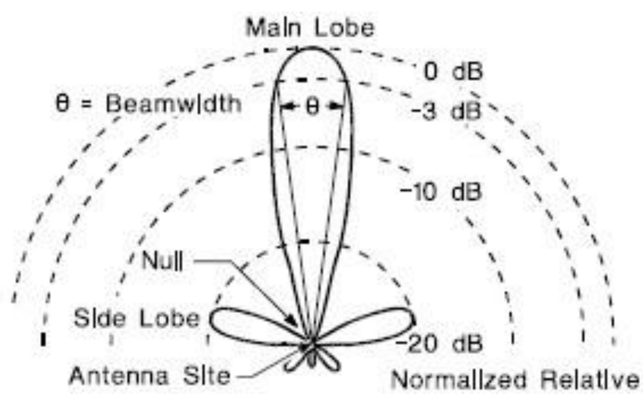


Figure 4.1: Beam width of Antenna

Isotropic antenna is the antenna with uniform 3D radiation pattern (with no reflector). It is theoretical isotropic which has a perfect 360 degree vertical and horizontal beam width and can radiate in all directions. An antennas can be classified as omnidirectional and directional antennas which depend on it directionality.

### 4.2 Omnidirectional Antenna

Omnidirectional antennas have a similar radiation pattern. It will provide a 360 degree horizontal radiation pattern in all direction (A, B, C and D). Polarization is the orientation of the element on the antenna that transmits RF energy. In omnidirectional antenna, it usually a vertical polarized antenna.

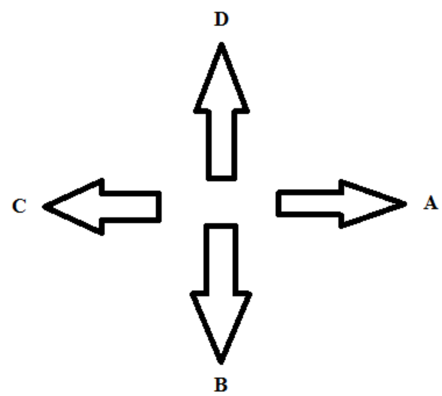


Figure 4.2: Direction of Omnidirectional Antenna

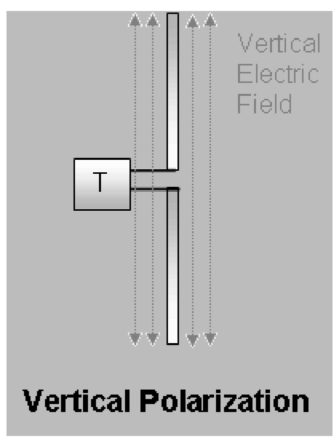


Figure 4.3: Polarization of Omnidirectional Antenna in vertical shape

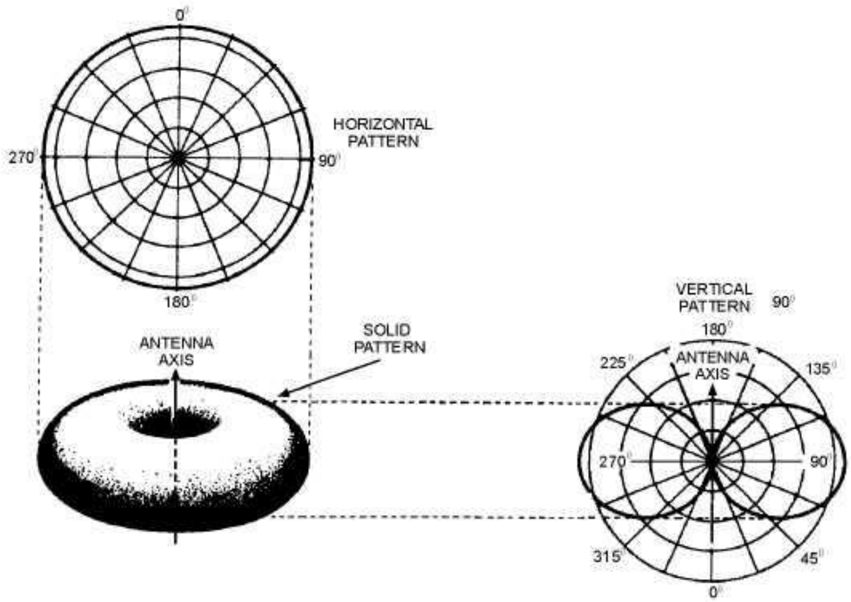


Figure 4.4: Radiation Pattern of an Omnidirectional Antenna

**4.3 Directional antenna**

Directional antenna will emit RF energy in a particular or specific direction. As the gain of a directional antenna increase and get more coverage distance, it will affect the coverage angle that causes the coverage angle to decrease.

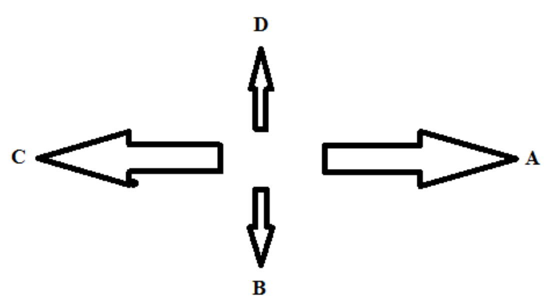


Figure 4.5: Direction of directional antenna

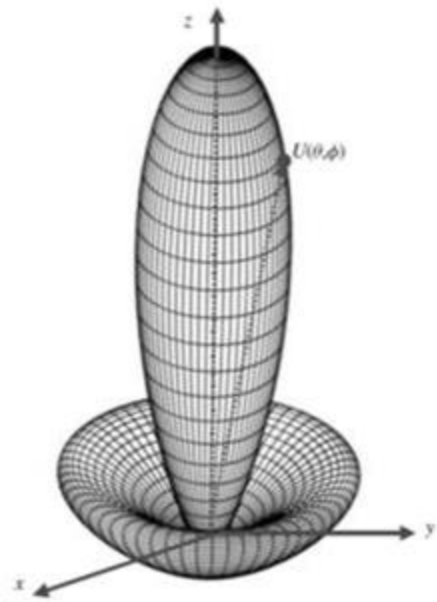


Figure 4.6: Radiation pattern of a directional antenna

Others important aspect that need to be considered on the antenna is it front-to-back ratio. Front-to-back (F/B) is measure the directivity of the antenna. Front-to-back is the ratio of energy which the antenna is directing in a particular direction and the energy which is left behind the antenna. Normally, good antenna will get front-to-back ratio in 20dB. The more the gain of the antenna, the more the front-to-back ratio is but in sometime it will come to phase where the gain is higher but the F/B will get lower and at that time, it is not a suitable design for directional antenna.

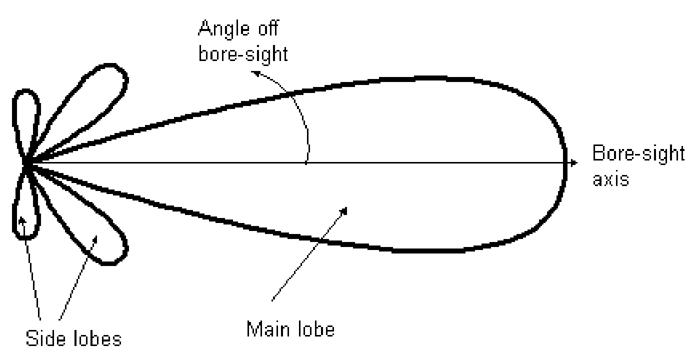


Figure 4.7: Typical radiation pattern of a directional antenna with calibrated lobes

### 4.4 Directional Finding Antenna and Fox-Hunting Sport

Directional finding antenna is the antenna to detect the radio signal from unknown or hidden antenna systems. It is known as radio for directional – finding (RDF). Radio directional finding antenna normally will be used by Federal Communications Commission (FCC) to locate an illegal station that is transmitting by using radio direction finders to triangulate. The RDF will be placed in two stations and make the unknown antenna as the intersection. Using the formula of triangular parameter, the location of that unknown antenna can be detected.

Fox hunting sport was the popular activity for ham radio operator in the 1960s. The sport is about to place a transmitter in the distance of 10 or 75 m hidden, the operator or "hunters" will find the directions of the transmitter in two or three stations and then they will find the location of that transmitter. Nowadays, the important of this radio directional finding antenna is the government can locate, searching and finding the illegal transmitter which transmits by unknown person or the person with have no certificate to run ham radio signals.

The finding of this research is to find and design the suitable parameters to build an antenna system which can be transmitting in one direction with the most high gain and front-to-back gain. The antenna is very useful for fox hunting, to find illegal transmitter purposes and many more. After had done some reading, searching and comparing the current design of antenna system, the author is more interesting in build a Yagi antenna system because Yagi antenna is most suitable for ham radio band, it can be design to transmit for a long coverage distance with high gain and F/B gain compared to others. The next discussion, we will see the most suitable band for Yagi antenna and we will choose whether 3 elements, 5 elements or 7 elements Yagi antenna that can give the higher gain and F/B gain.

### 4.5 Yagi Antenna systems

YAGI antennas come from simple dipole antenna. The dipole antenna only consists of one element and can radiate in two directions.

Figure 4.8: Dipole antenna

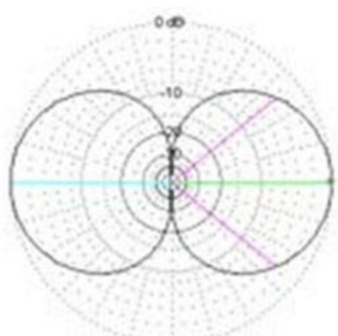


Figure 4.9: Radiation pattern of dipole antenna

Figure 4.8 and Figure 4.9 shows the example of dipole antenna design and its radiation pattern. Yagi antenna comes when the dipole antennas are added with reflector and director that make the design of Yagi consists of three element compare one elements in dipole antenna.

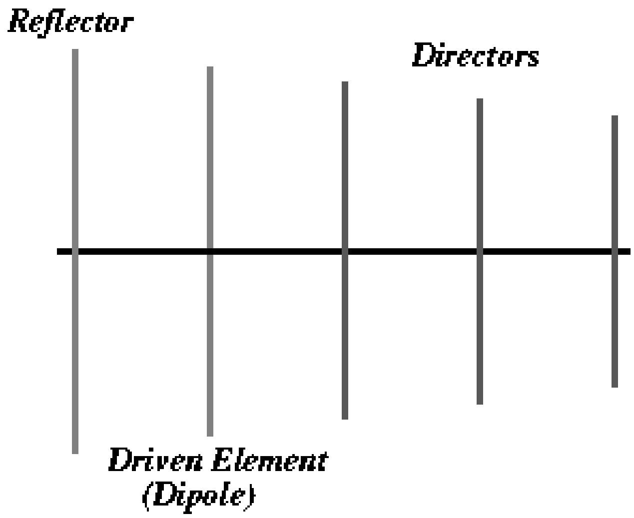


Figure 4.10: Yagi Antenna with 5 elements

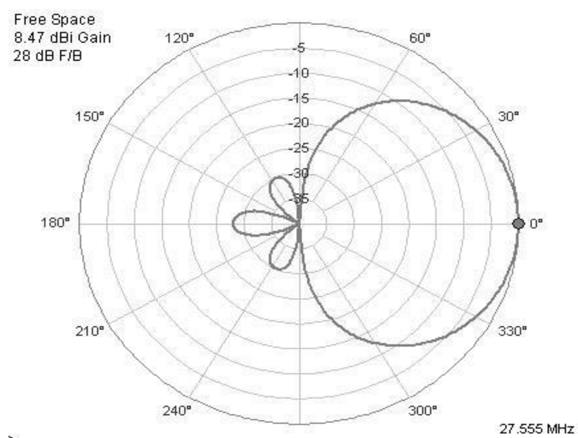


Figure 4.11: Radiation pattern of Yagi antenna

Figure 4.10 shows the example of 5 elements Yagi antenna, the antenna consists of one reflector which located the most in front of others element, the second element is the radiator or driven element which the sources will be feed here to give a power to others elements so that it can radiate a power in the form of propagation wave. The others element are director element which function to direct a signal in specific direction. Sometime, the more director elements used will get the higher gain but sometimes it can get lower gain, it's according to the specification of the design. Figure 4.11 shows the example of radiation pattern for Yagi antenna, in the picture it's stated the frequency is 27.555 MHz, the gain is 8.47 dBi and the Front-to-back ratio is 28 dB. Refer to the picture, the red lines show the radiation signal of that antenna, it radiates a big circle for main lobe and some small circles for the others lobes. It shows the antenna is transmitting in one direction only.

Normally, the amateur radio will be operated in a range of 3 MHz until 30 MHz frequency band. The design for Yagi antenna will be tested and simulate by using the software EZNEC. The simulation design will be done in this software and all the parameters for the antenna will be finalized before it will be implemented.

At the first stage, the author will design the Yagi antenna at 28.5 MHz frequency. A frequency of 28.5 MHZ will give approximately 10 meter lambda. The calculation to determine the frequency and the lambda is:

$$f = \frac{c}{\lambda}$$

Where:

f – Frequency, c – speed of light (3x10^8) and $\lambda$ – wavelength

$$\lambda = \frac{c}{f} = \frac{3\ x10^{8}}{28.5\ x10^{6}} = 10.53m$$

So, the sizes and dimensions of the antenna also will be in 10 – 15 meter (34.5113ft).

The simple EZNEC software will show the specification like from the figure below:

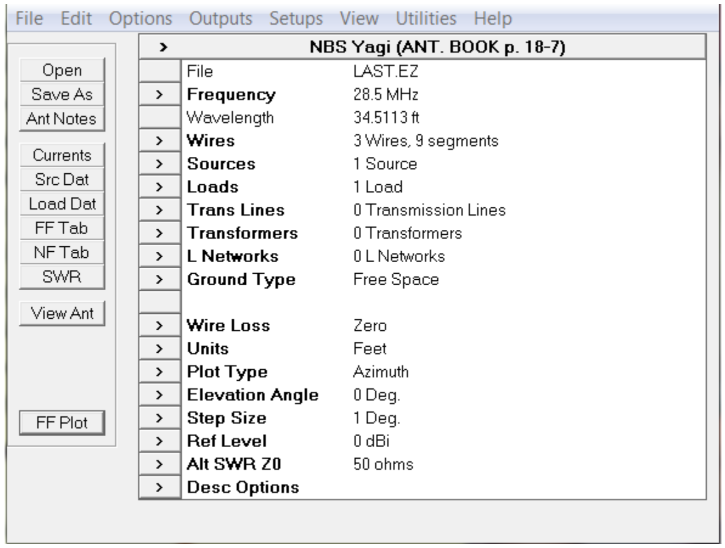


Figure 4.12: software EZNEC home page view

Yagi antenna can be designed with 2, 3, 5, 7 and many more elements. Each number of elements will give the specific value for maximum gain and F/B ratio also it radiation pattern. This research will measure and compared the best design from 3 elements, 5 elements and 7 elements Yagi. The designs that give the higher maximum gain and F/B ratio will be chosen to implement in prototype form.

The author started with 3 elements Yagi design. The important values or parameters need to look for are the maximum gain that the antenna will get and the front-to-back ratio gain of the propagation pattern. The definition of gain and front-to-back ratio (F/B) has been explained in the early part of this chapter. The higher the gain and F/B ratio, the better the design is but at some time it will be the gain gets is higher while the F/B ratio keep lower, so this design is not the suitable design for the antenna.

The propose design parameters for 3 elements Yagi is available in the book but when the author trying to apply the parameters in the software, the maximum gain and F/B ratio is not good enough. Then, the author keep adjusting the parameters until the maximum gain and F/B ratio values are at optimum values. The propose design parameters that are available in the book are as follow:

Table 4.1: Specification of wire and the length of every element

| No. | End 1 X (ft) | End 1 Y (ft) | End 1 Z (ft) | End 1 Conn | End 2 X (ft) | End 2 Y (ft) | End 2 Z (ft) | End 2 Conn | Diameter (in) | Segs | Insulation Diel C | Insulation Thk (in) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | -8.5 | 20 | | 0 | 8.5 | 20 | | 0.5 | 3 | 1 | 0 |
| 2 | 3 | -4 | 20 | | 3 | 4 | 20 | | 0.5 | 3 | 1 | 0 |
| 3 | 4.5 | -7.5 | 20 | | 4.5 | 7.5 | 20 | | 0.5 | 3 | 1 | 0 |

The radiation pattern, maximum gain and F/B ratio are as follow:

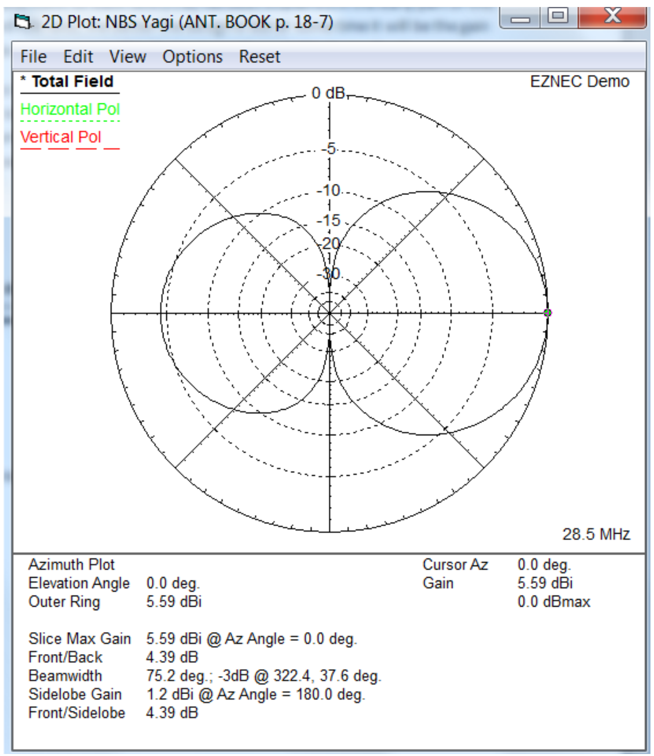


Figure 4.13: Simulation result for 3 elements Yagi

Through the figure above, we can see the shape of radiation pattern, maximum gain and F/B ratio. After some modification on the spacing between the elements, the author gets more optimum and high maximum gain and F/B ratio and the best design will be chosen for 3 elements Yagi. The result of others modification are as from table 4.2 **(refer appendix 1).**

From the table 4.2, the author trying to adjust the spacing between the elements starting from 2 ft. until 8 ft. and every maximum gain and F/B ratio are noted and get remark. As we can see from the table, the most suitable design for 3 elements Yagi are with spacing 7 ft. from reflector to driven element and 7 ft. from driven element to director element with maximum gain 7.8 dBi and F/B ratio 19.01 dB. This is the best and optimum result for 3 elements Yagi design. The figure below will shows the table of wire and radiation pattern of the design.

Table 4.3: Parameter for the best design of 3 elements Yagi

Wires

Wire Create Edit Other

☐ Coord Entry Mode ☐ Preserve Connections ☑ Show Wire Insulation

| No. | End 1 | | | | End 2 | | | | Diameter | Segs | Insulation | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | X (ft) | Y (ft) | Z (ft) | Conn | X (ft) | Y (ft) | Z (ft) | Conn | (in) | | Diel C | Thk (in) |
| 1 | 0 | -8.5 | 20 | | 0 | 8.5 | 20 | | 0.5 | 3 | 1 | 0 |
| 2 | 7 | -4 | 20 | | 7 | 4 | 20 | | 0.5 | 3 | 1 | 0 |
| 3 | 14 | -7.5 | 20 | | 14 | 7.5 | 20 | | 0.5 | 3 | 1 | 0 |

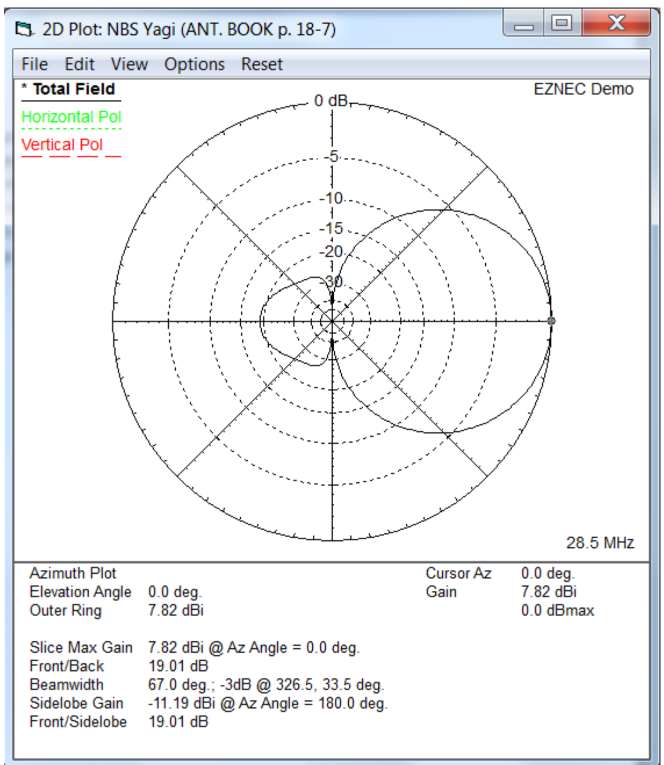


Figure 4.14: The radiation pattern, maximum gain and F/B ratio of the best design 3 elements Yagi

Then, the simulation will continue for 5 elements Yagi design; the steps are same with the previous one. The table 4.4 **(refer appendix 2)** shows the result of spacing between the elements:

The higher and optimum gain for 5 elements design is at 5 ft. distance from reflector to driven and 8ft. distance from driven to director element with the maximum gain is 10.13 dBi and F/B ratio is 30.27. As compared from the best design for 3 elements Yagi with this the best design 5 elements Yagi, it shows 5 elements Yagi is better than 3 elements Yagi because the maximum gain and F/B ratio for 5 elements Yagi is higher than 3 elements. We will check and see whether the maximum gain and F/B ratio for 7 elements is higher than this or not. The table and figure below shows the wire length for every elements and the radiation pattern for 5 elements Yagi.

Table 4.5: Length and Dimension for 5 elements Yagi

Wires

Wire Create Edit Other

☐ Coord Entry Mode ☐ Preserve Connections ☑ Show Wire Insulation

| No. | End 1 | | | | End 2 | | | | Diameter | Segs | Insulation | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | X (ft) | Y (ft) | Z (ft) | Conn | X (ft) | Y (ft) | Z (ft) | Conn | (in) | | Diel C | Thk (in) |
| 1 | 0 | -8.5 | 20 | | 0 | 8.5 | 20 | | 0.5 | 3 | 1 | 0 |
| 2 | 5 | -4 | 20 | | 5 | 4 | 20 | | 0.5 | 3 | 1 | 0 |
| 3 | 13 | -7.5 | 20 | | 13 | 7.5 | 20 | | 0.5 | 3 | 1 | 0 |
| 4 | 21 | -7.5 | 20 | | 21 | 7.5 | 20 | | 0.5 | 3 | 1 | 0 |
| 5 | 29 | -7.5 | 20 | | 29 | 7.5 | 20 | | 0.5 | 3 | 1 | 0 |
| * | | | | | | | | | | | | |

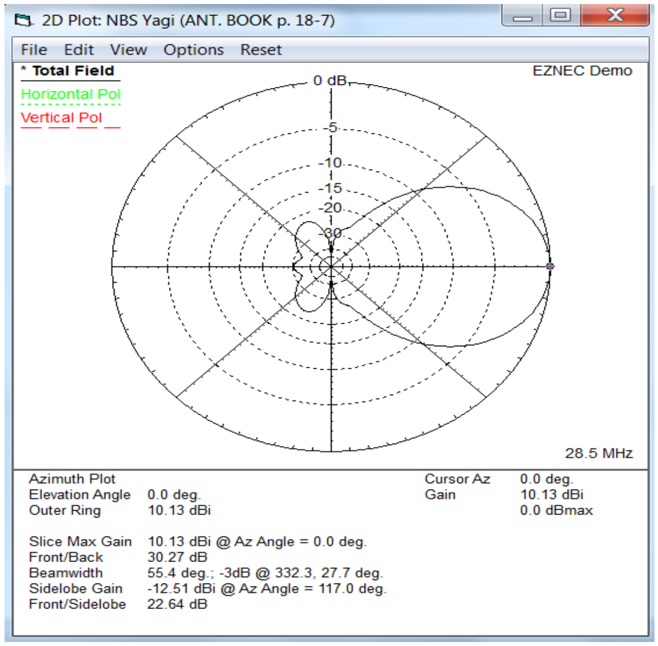


Figure 4.15: Radiation pattern, maximum gain and F/B ratio for 5 elements Yagi

Next, the author proceeds with the design for 7 elements Yagi with the same dimension for the length and diameter but the differences in the spacing between each element. The maximum gain and F/B ratio of 7 elements Yagi design are in table 4.6 **(refer appendix 3).**

From the table 4.6, the best and suitable spacing is 5 ft. from reflector to driven and 8ft. distance for every element between driven and director and the director with another director. The maximum gain is 11.51 dBi and F/B ratio is 35.048 dB. The table below shows the best design for 7 elements YAGI, 5 elements YAGI and 3 elements Yagi.

Table 4.7: Comparison the result of max gain and F/B ratio for 7, 5 and 3 elements YAGI

| Element | Spacing | | Gain | |
|---|---|---|---|---|
| | R - Dr | Dr-Dir | Max (dbi) | F/B (db) |
| 7 | 5 | 8 | 11.51 | 35.048 |
| 5 | 5 | 8 | 10.13 | 30.27 |
| 3 | 7 | 7 | 7.8 | 15.87 |

The table shows that 7 elements Yagi is better than 5 elements and 3 elements Yagi with maximum gain 11.51 dBi and F/B ratio 35.048 dB. So, for the implementation part, the 7 elements Yagi will be selected to be created and the antenna will be tested in the lab to get the practical or real value for radiation pattern, maximum gain and F/B ratio.

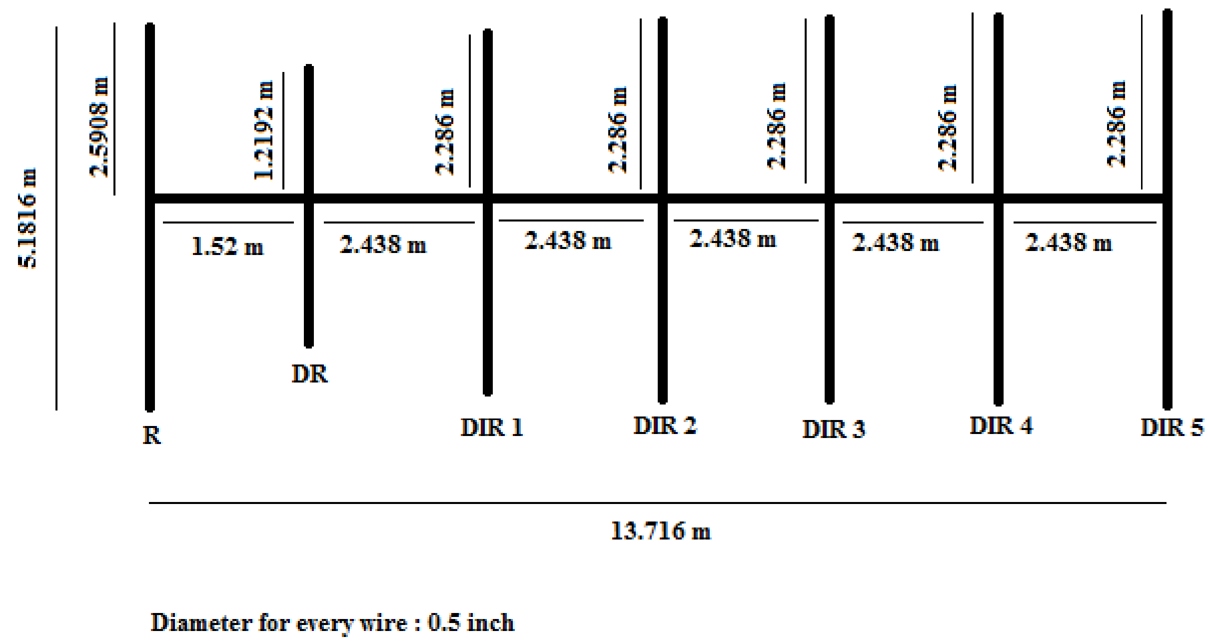


Figure 4.16: Total dimension of 7 elements Yagi

5 ft. = 1.52 m

8 ft. = 2.438

From the total dimension of 7 elements Yagi in the frequency of 28.5 MHz, the estimate size for the antenna is 5.1816 m width and 13.716 m length. It slightly a big sizes thus it very incompatible to be carrying out all the time. It only suitable to be installed in one placed. The author aiming to build a Yagi antennas that are very compatible, portable, adjustable and easy to carry out at all time and place because the one objective of the antenna is for fox-hunting and directional finding antenna purpose. The smaller the frequency is, the bigger the antenna could be. It follows the calculation of wavelength, frequency and speed of light. The suitable antenna to be carried out is 2 meter or 3 meters band. The frequency to get for 2 meters band can obtain from the formula:

$$f = \frac{c}{\lambda}$$

$$f = \frac{3x10^8}{2} = 150\ Mhz$$

So, the suitable frequency for 2 meter band is 150 MHz but the author will use the frequency 144MHz. After some adjusting with the spacing between every element, the table 4.8 below shows the best dimension of 3 elements for 144 MHz which will be used in prototype design.

Table 4.8: Dimension for 3 elements 144 MHz

| Wires | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | End 1 | | | | End 2 | | | | Diameter | Segs | Insulation | |
| | X (m) | Y (m) | Z (m) | Conn | X (m) | Y (m) | Z (m) | Conn | (mm) | | Diel C | Thk (mm) |
| 1 | 0 | -0.51 | 1.524 | | 0 | 0.51 | 1.524 | | 12.7 | 3 | 1 | 0 |
| 2 | 0.396 | -0.46 | 1.524 | | 0.396 | 0.46 | 1.524 | | 12.7 | 3 | 1 | 0 |
| 3 | 0.792 | -0.445 | 1.524 | | 0.792 | 0.445 | 1.524 | | 12.7 | 3 | 1 | 0 |
| * | | | | | | | | | | | | |

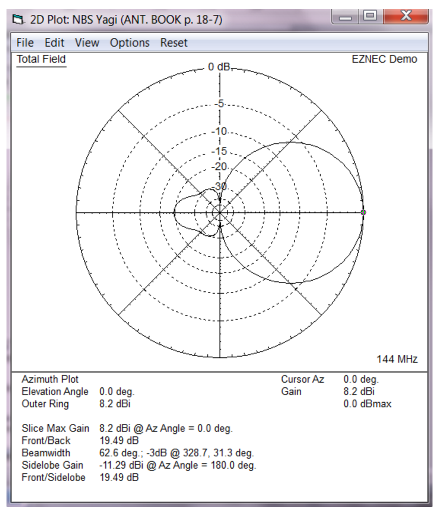


Figure 4.17: Radiation pattern, maximum gain and front-to-back ratio of 3 elements 144 MHz

The maximum gain is 8.2 dBi, front-to-back ratio 19.49 dB.

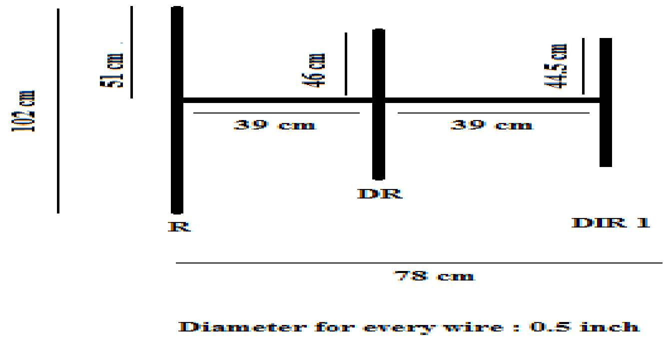


Figure 4.18: Total dimensions for the design

Figure 4.19: Prototype for three elements

## 4.6 Testing the prototype

The three elements then will be mounted approximately 5 feet above the ground and will be connected to the transceiver for testing purposed like from the figure 4.18 but before the antenna is used to transmit the signal, the author will measure the Standing Wave Ratio (SWR) by using VSWR meter, the antenna need to have below 1.5 ratio then it will be possible to be used to transmit the signal. The antenna's SWR get 1.3 which is possible to be used to transmit the signal.

Figure 4.20: Three elements Yagi mounted above the ground level

The antenna is connected with coaxial cable RG58 from dipole sources connect to the transceiver. The author using the near-field and far-field method to check and measure the strength of the prototype by using Radio Frequency (RF) field strength meter. The results of the measurement are as in the table 4.9 below. The angle is refer to the angle around the antenna, the reading at 90 degree will show the maximum gain that the antenna radiate.

Table 4.9: Reading of RF field strength Meter

| 2 Meter | 3 elements | |
|---|---|---|
| Angle | RF detector (uA) | Power (dB) |
| 0 | 4 | -29.9 |
| 30 | 43 | -9.27 |
| 60 | 50 | -7.96 |
| 90 | 70 | -5.04 |
| 120 | 62 | -6.09 |
| 150 | 26 | -13.6 |
| 180 | 14 | -19.02 |
| 210 | 10 | -21.94 |
| 240 | 26 | -13.64 |
| 270 | 36 | -10.81 |
| 300 | 32 | -11.84 |
| 330 | 2 | -35.9176 |

The power in dB is calculated by using the formula of power ratio.

$$dB = 10\ log_{10} \frac{P_2}{P_1}$$

$$P_2\ is\ power\ in\ RF\ field\ strenth\ meter$$

$$P_1\ is\ power\ out\ from\ the\ transciever$$

The reading of RF field meter will be shown in small current that indicate the small voltage is induced at the resistor in the circuit of RF field strength meter. The resistor is about 10K ohm. So, to calculate the induced voltage at RF field strength side:

$$V = \text{IR}$$

$$V_2 = (4\text{u})(10\text{K}) = 0.04$$

The power that come out from the transceiver is about 2.5 W and the transmit current is 2.0 A. So, to calculate the voltage at transceiver side is:

$$P = \text{VI}$$

$$2.5\ W = \text{V}(2.0\text{A})$$

$$V_1 = 1.25$$

The power in dB can also be calculated by using voltage value.

$$dB = 20\ log_{10} \frac{V_2}{V_1}$$

$$dB = 20\ log_{10} \frac{0.04}{1.25}$$

$$Power\ (dB) = -29.9$$

Then, all the value of power in dB will be plot in the graph to see the radiation pattern of the antenna and will be compared with the simulation radiation pattern.

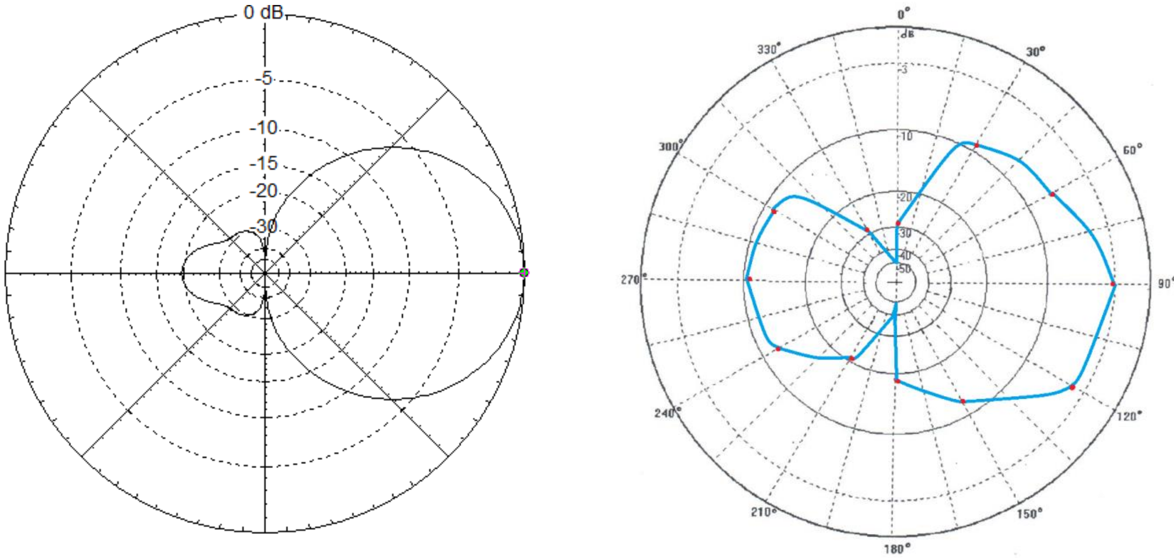


Figure 4.21: Comparison in term of radiation pattern between the simulation (left side) and experimental result (right side) for three elements.

These all the steps are repeated to test the prototype of five and seven elements. The author wants to see the effect of maximum directivity when the number of element added. The calculation to calculate the power ratio and steps to draw the radiation pattern also the same steps as three elements' part.

The figure 4.20 and 4.21 below shows the comparison in term of radiation pattern for five elements and seven elements. The table 4.10 shows the power ratio in dB for every 30 degree around the five and seven elements **(refer appendix 4).**

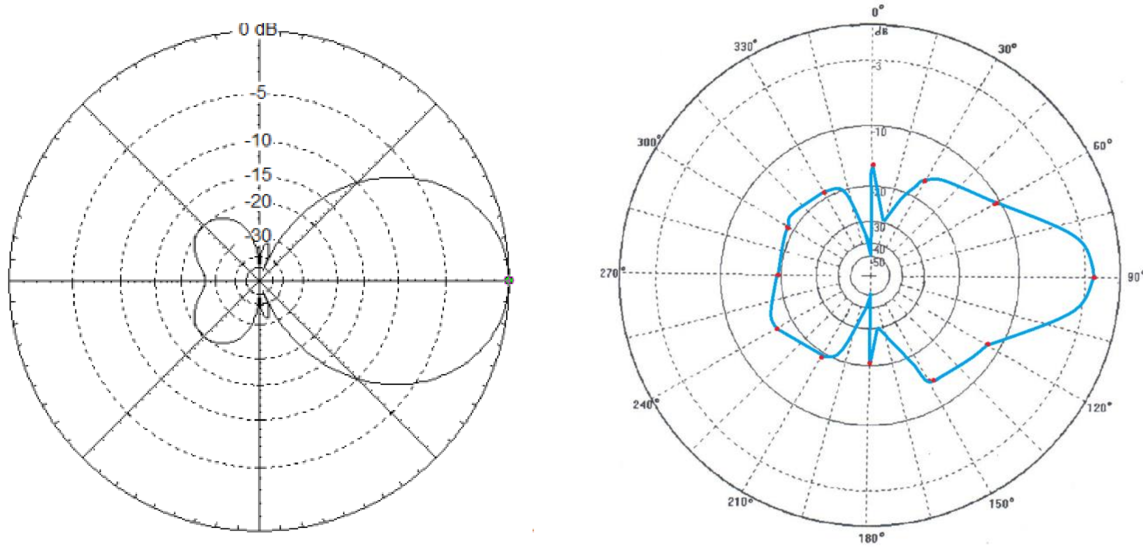


Figure 4.22: Comparison in term of radiation pattern between the simulation (left side) and experimental result (right side) for five elements.

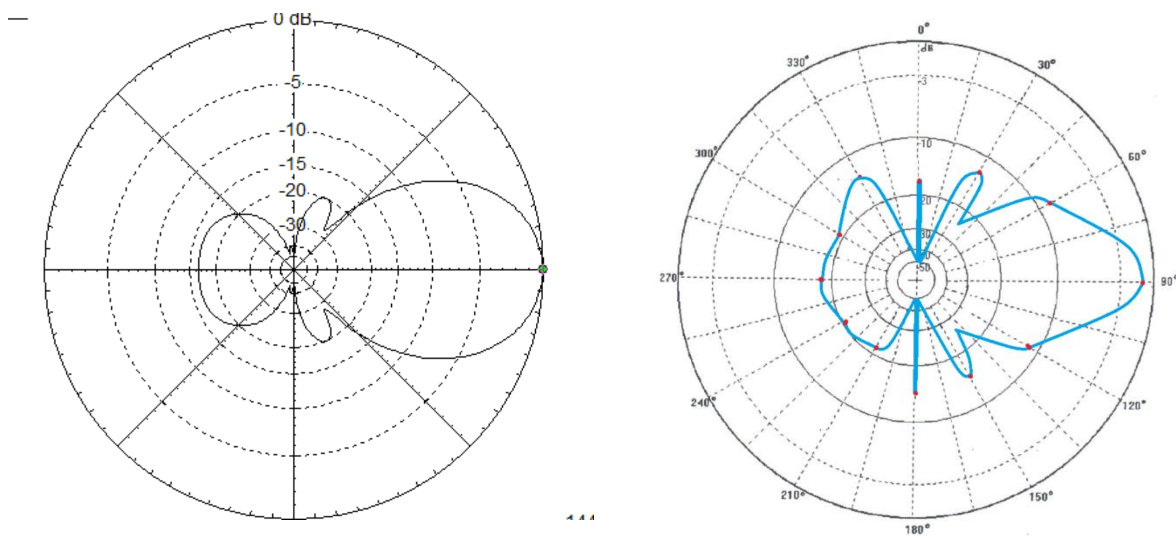


Figure 4.23: Comparison in term of radiation pattern between the simulation (left side) and experimental result (right side) for seven elements

From the plotting radiation pattern, the pattern shows that the antenna is transmit the signal in one direction as the main lobe is bigger than the other lobe thus it proved that these Yagi Antenna for three, five and seven elements are transmitting the signal in one direction. The pattern also are quite similar with the simulation part, the errors are estimate at 5%, 4% 3% for three elements, five elements and seven elements.

These radiation patterns can be used to calculate the directivity (in dB) of the antenna by calculate the beam width from the pattern plot, normally half power at 3 dB after the maximum gain. The formula to calculate the directivity as follow:

$$\text{Directivity, D} = 10\, log_{10} \frac{41253}{\theta_1 \theta_2}$$

$$\theta_1 = angle\ from\ \ a\ to\ b$$

$$\theta_2 = angle\ from\ b\ to\ a$$

$$*\ please\ refer\ to\ the\ calculation\ in\ the\ next\ page$$

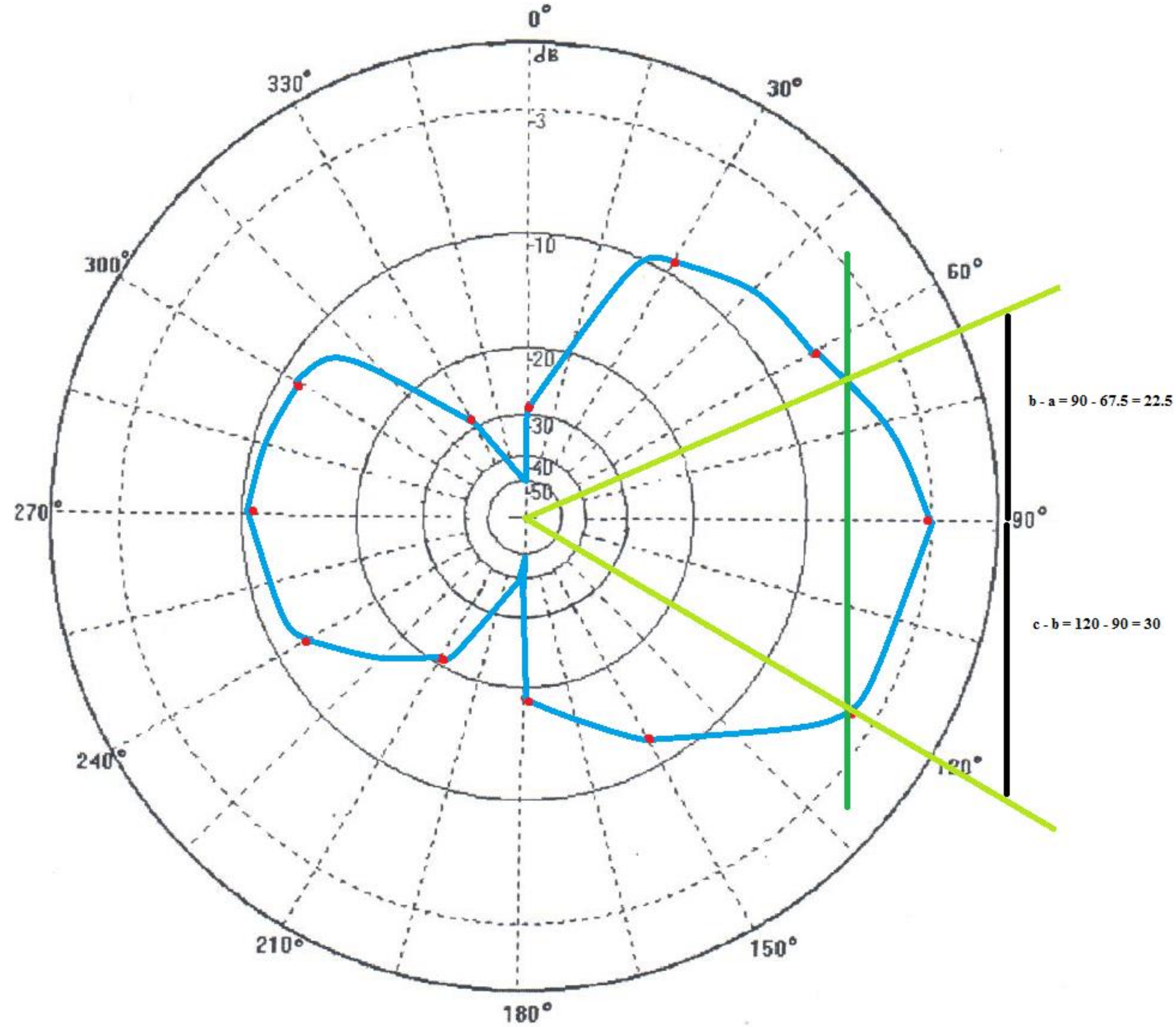


Figure 4.24: Beam width for three elements

For three elements, the maximum gain at 5.04 dB, half power will be at 5.04+3 dB= 8.04 dB.

$$\text{Directivity, D} = 10\ log_{10} \frac{41253}{30 * 22.5} = 17.86\ dB$$

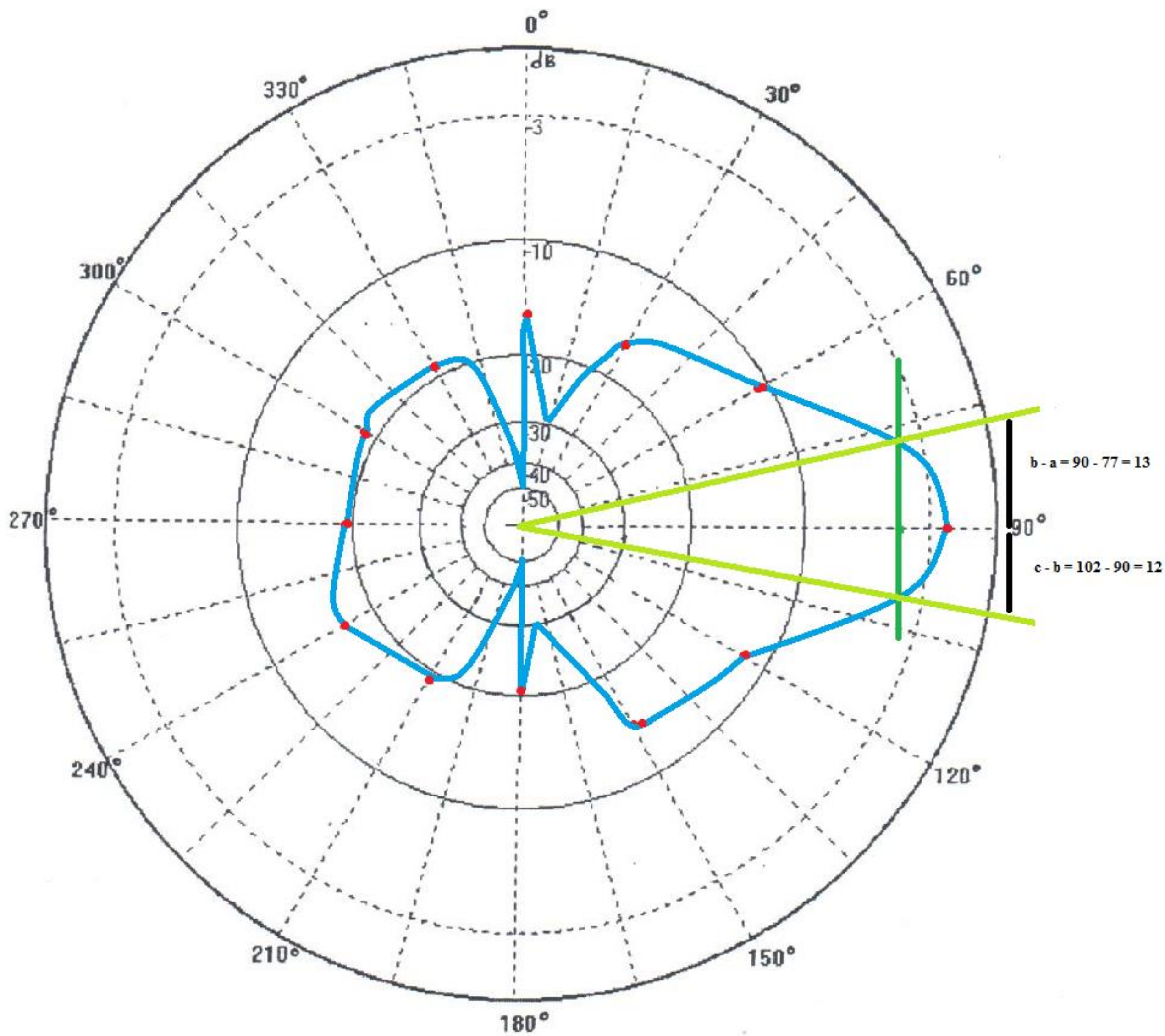


Figure 4.25: Beam width for five elements

For three elements, the maximum gain at 5.04 dB, half power will be at 4.32+3 dB= 7.32 dB.

$$\text{Directivity, D} = 10\ log_{10}\frac{41253}{13 * 12} = 24.22dB$$

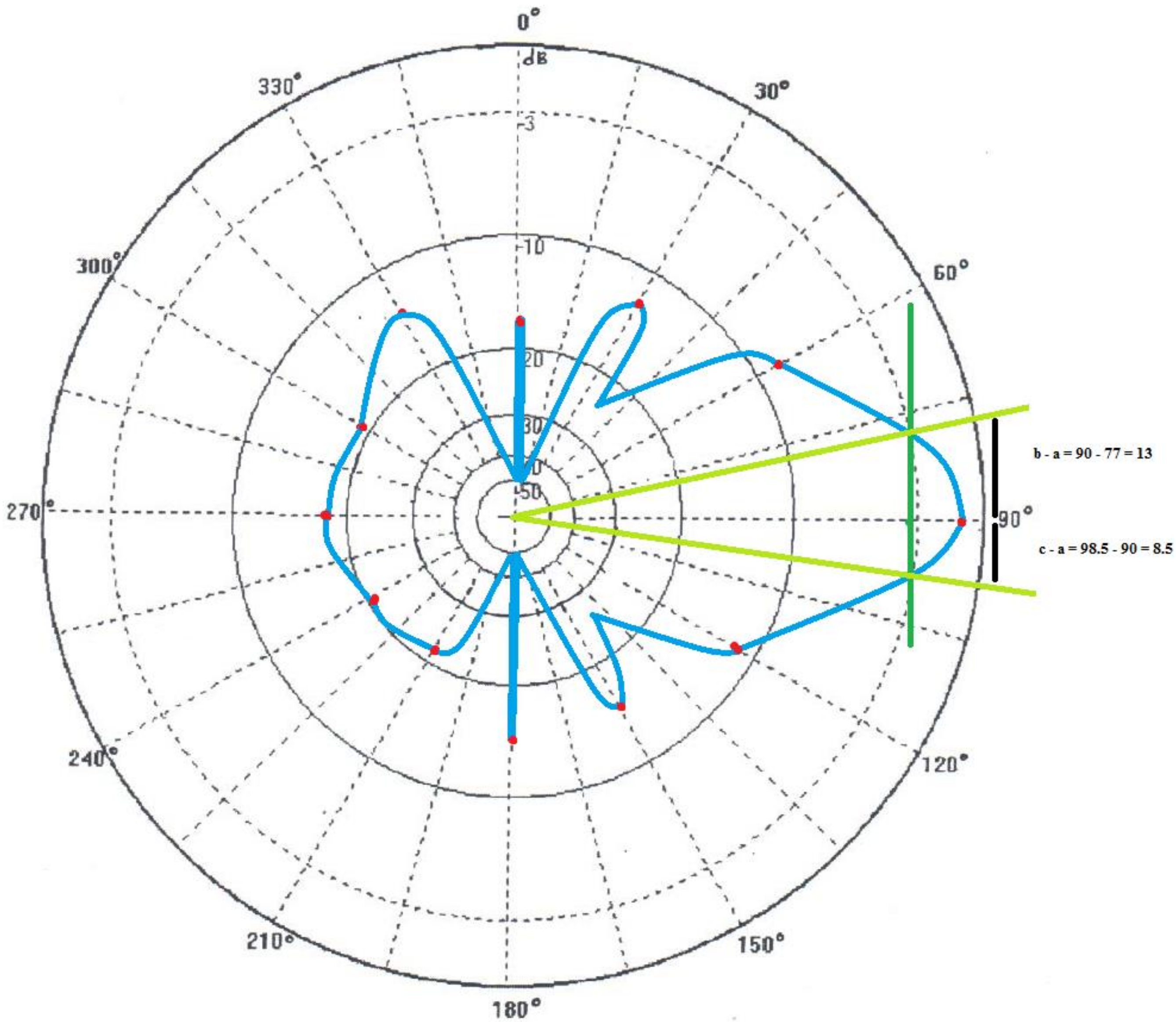


Figure 4.26: Beam width for seven elements

For three elements, the maximum gain at 5.04 dB, half power will be at 2.85+3 dB= 5.85 dB.

$$\text{Directivity, D} = 10\ log_{10}\frac{41253}{13 * 8.5} = 25.72dB$$

As we can see from the calculation above, as the number of elements increased thus the directivity of the antenna also will be increased.

Table 4.10 Comparison in term of directivity for three, five and seven elements

| Number of elements | Directivity, dB |
|---|---|
| 3 | 17.86 |
| 5 | 24.22 |
| 7 | 25.72 |

From the directivity value, the author can calculate the maximum gain for three, five and seven elements by using the following steps:

$$\text{Gain, G} = \eta\text{D}$$

$$\eta = \text{antenna efficiency}$$

$$\text{D} = \text{directivity in dB}$$

The antenna efficiency can be calculated by using the following formula:

$$\eta = \frac{P_r}{P_r + P_{ohm}} = \frac{R_r}{R_r + R_L}$$

$P_r$ is radiated power

$P_{ohm}$ is the power losses

$R_r$ is the radiated resistance

$R_L$ is the ohmic resistance

From Power Radiated formula, the value of ohmic resistance can be calculated. The power transmit is equal to power radiated which is at 2.5 W, the RMS voltage is 1.25 Vrms and the transmit current is 2.0 A, while the radiated resistance is 1.25ohm. These values are getting from the datasheet of the transceiver. So, to get radiated resistance and ohmic resistance, the author using the following formula:

$$P_r = \frac{|V_g|^2 R_r}{(R_r + R_L)^2}$$

$$P_{ohm} = \frac{|V_g|^2 R_r}{(R_r + R_L)^2}$$

So, it can be said that the total amount of the power transmit is equally to the total amount of power losses, $P_r = P_{ohm} = 2.5$.

So, the antenna efficiency is:

$$\eta = \frac{P_r}{P_r + P_{ohm}} = \frac{2.5}{2.5 + 2.5} = 0.5$$

So, to calculate the maximum gain by using the following formula:

$$\text{Gain, G} = \eta \text{D}$$

For three elements, the maximum gain is:

$$\text{Gain, G(dBi)} = 0.5 * 17.86 = 8.937$$

For five elements, the maximum gain is:

$$\text{Gain, G(dBi)} = 0.5 * 24.22 = 12.11$$

For seven elements, the maximum gain is:

$$\text{Gain, G(dBi)} = 0.5 * 25.72 = 12.86$$

The table 4.10 below shows the comparison of maximum gain and F/B ratio between the simulation result and experimental result.

Table 4.11: Comparison of maximum gain and F/B ratio between the simulation result and experimental result

| Element | Maximum Gain, dBi | | F/B ratio, dB | |
|---|---|---|---|---|
| | Simulation | Prototype | Simulation | Prototype |
| 3 | 8.2 | 8.937 | 19.49 | 15.85 |
| 5 | 10.16 | 12.11 | 26.34 | 22.18 |
| 7 | 11.37 | 12.86 | 16.53 | 20.71 |

The most important part that the author wants to see is the direction of propagation signal because the focus of the project wants to build a directional antenna that will transmit and receive a signal in one direction. The experimental result shows that the one of the objective is achieved.

Next, the author will compared the author's prototype result with the existing design of same three element Yagi antenna for 140MHz-160MHz ranges.

| Model | No. Element | Max Gain (dBi) | F/B ratio (dB) | Distance Travel (m) |
|---|---|---|---|---|
| David | 3 | 6.28 | 17 | 643 |
| DK7ZB | 3 | 6.80 | 20 | 724 |
| JOSE EB8AUV | 3 | 8.12 | 20 | 1600 |
| YAGIMAX | 3 | 8.15 | 20 | 1900 |
| GOKSC LFA | 3 | 8.67 | 19.86 | 2414 |
| My Antenna | 3 | 9.06 | 15.85 | 3540 |

Table 4.12: Comparison between the prototypes with the existing antenna design

From the comparison, it shows the author's design (My Antenna) have the good maximum gain and F/B ratio compared to the others existing design. It will give the advantages to the design because for example in case of emergency, the antenna can transmit or receive a signal very far then the existing design can gives.

### 4.7 The significant of the project to real life application

The significant of this project is applicable for wireless communication field. Some people which don't want to use a hand phone to communicate with their friends will use this amateur radio system as their platform. Besides that, the existent of amateur radio systems play a big important role in emergency communication system, for military radio system and to communicate with friend in short of distance like walkie talkie so that they will not waste the money to use their hand phone.

This project also has been explored and improved the existing design for three, five and seven elements YAGI antenna and the data shows in results are more better than the existing design can give thus it can be implement in real life uses. For example, the best gain for the current design is from GOSKA LFA (type of antenna, refer to table 4.11) with 8.67 dBi. 8.67dBi means it can transmit the signal for approximately 2414m distance but the antenna of three elements in this project can get the maximum gain 9.063 dBi which approximately can transmit the signal for 3540m distance. The added distances that the signal can travel is 1126m. Imagine that there has an emergency case happen where the soldier's team in jungle needs to communicate with the station (military station) in fastest time and they can't communicate with the station because the signal only can transmit 2414m by using the current existing design and because of that they needs to walk almost 1.2 km further in order to be able to transmit the signal to the stations, if they are using the antenna that is built from this project, they are able to communicate with the station without wasting the time to walk around 1.2km. Thus, this example shows that the important of the project to help and improved the current design to make sure it can benefit to the people in real life case.

# CHAPTER 5: CONCLUSION AND RECOMMENDATION

In conclusion, the project has come to the analysis part which is the ending part of this project research. The project only focusing to build and analysis the design specification for three, five and seven elements of half-wave lambda dipole Yagi antenna.

For this time being, the theoretical sides of the system need to be focused on how to analyses the result in term of the fundamental knowledge about the radiation pattern, calculation of maximum gain and directivity and the mechanism of RF field strength. Based on the objectives of the project, the progress of the project has come to the third of three objectives which are to design multiband antenna with broad specification for 144 MHz, simulate the design specification using EZNEC Demo V5.0 software and after that to design the prototype antenna and testing the prototype of three, five and seven elements of Yagi antenna near-field and far-field method. All the data in result make the author satisfy and it proved that all the objectives of this project are achieved.

In summary, the method to do this project is firstly the fundamental of electromagnetic theory and antenna characteristics need to be cover early in the project. The strong fundamental knowledge about this project will help a lot to make the calculation to calculate the dimensions of the antenna. After that, make familiar with the software and learn on how to use the software. EZNEC software is very easy to use and the manual to run this software is available in internet. Then, the implementation part which to convert the simulation design into real design prototype is something that we need to look for. The steps to connect a coaxial cable to the driven elements of the antenna also need to learn first. After the antenna is mounted approximately 5 feet above the ground, the transceiver and RF field strength meter will be used to measure the field strength around the antenna and after all the readings has been recorded, analyses the data using the fundamental knowledge that has been discovered early in this project.

The limitations of this project also need to be stated first so that the range or scope of the project is within the scope of study. It important to make sure the focuses of this project are keep constantly controlled. Like this research project only focusing to discuss the design for half-lambda Yagi antenna with three elements, five elements and seven elements for frequency range from 140-160 MHz. Any others design will not be discussed in this project.

In order to ensure the progress is going smoothly, some recommendations are suggested so that if any problem occurs in the future, there is always a backup plan to fix it. The issues that might be faced are the difficulty to get EZNEC software in free version, the budget allocation, and the system prototype is not working. All of these possible issues need contingency plan to make sure the progress of the project is smooth and follow the timeline.

The other recommendation that the author want to highlight is using the MATLAB software to the draw the radiation pattern after the data obtained from the testing. The MATLAB software will give more accurate value than the simple drawing in this project and the shape of the pattern also is nice to see. Besides, before the materials to make the prototype of the antenna are purchased, make sure the materials types are truly finalized so that we don't purchase a wrong material thus it waste our money.

For the next project, the author recommends to design and analysis for nine and above elements besides can apply the full-wave lambda dipole and also can design the others type of antenna and compare it characteristics.

**References**

[1] J. R. Hallas, Basic Antennas: Understanding Practical Antennas and design, 1st. ed., USA: 2008-2009

[2] W. Silver, Ham Radio for Dummies, Indiana, Wiley Publishing, 2004

[3] Jothilakshmi, P. and Raju, S. 2011. Development of Multiband Antenna for High Frequency Applications. ECE Velammal College of Engineering & Technology,Madurai, India

[4] Kurniawan, A. and Mukhlishin, S. 2013. Wideband Antenna Design and Fabrication for Modern Wireless Communication Systems. School of Electrical Engineering and Informatics, Institut Teknologi Bandung, Bandung , Indonesia

[5] D. Mike, 2010. G7FEk Limited Space Antenna: Multiband "Nested Marconi" Antenna Retrieved March 27, 2010 at www.g7fek.co.uk

[6] W. James," Antenna here is a Dipole", June 1991, p23-26

[7] V. B. Lamont and W. L. Maurice, "Antenna Parameters," in Antennas: Fundamental, Design, Measurement, 3rd Ed. USA: SciTech Publishing, Inc, 2009, pp. 87-115.

[8] S. E. Robert, "The Far-Field Integrals, Reciprocity, Directivity," in A Classic Reissue: Antenna Theory and Design, Revise Ed. USA: A JOHN WILEY & SONS, INC PUBLICATION, 2003, pp. 3-53.

[9] E. Bob, (2014): My Quad Project A 2 Element Cubical Quad for the 10/11 Meter Band by N1UUE. Available: http://www.hamuniverse.com/n1uue2el1011quad.html.

[10] SoftWrightLLC, (1999): Field Intensity Units. Available: http://www.softwright.com/faq/engineering/FIELD%20INTENSITY%20UNITS.html

[11] Cisco Systems, Inc, (2007, Feb 27): Omni Antenna vs. Directional Antenna. Avaiable: http://www.cisco.com/c/en/us/support/docs/wireless-mobility/wireless-lan-wlan/82068-omni-vs-direct.html

[12] Hamuniverse, (2014): BASIC YAGI ANTENNA DESIGN FOR THE EXPERIMENTER. Available: http://www.hamuniverse.com/yagibasics.html.

[13] Gowans. A, (2014): RF Field Strength Meter. Available: https://altered-states.net/trifield/rf_fieldstrengh.htm

[14] GlobalSources, (2008, Feb 18): Fundamentals and design principles of RF antennas (Part 1). Available: http://www.eetasia.com/ART_8800504656_499488_NT_4d77f6f9.HTM?jumpto=view_welcomead_1416961731111

[15] G0KSC, (2014, Oct 22): Free Yagi Antenna Designs for Ham Radio. Available: http://www.g0ksc.co.uk/

[16] DK7ZB, (2014): Bandwidth of some Amateurbands . Available: http://www.qsl.net/dk7zb/DK7ZB-Match/theory_28ohm.htm

[17] F. Michael, (2009, Sept 5): Maxwell's Equations and Electromagnetic Waves. Available: http://galileoandeinstein.physics.virginia.edu/more_stuff/Maxwell_Eq.html

[18] Richard, (2014, June 27): Antenna Directivity and Effective Area . Available: http://farside.ph.utexas.edu/teaching/jk1/lectures/node105.html

Appendix 1

| Element | Spacing | | Gain | |
|---|---|---|---|---|
| | R - Dr | Dr-Dir | Max (dbi) | F/B (db) |
| 3 element | 2 | 7 | 6.54 | 4.23 |
| | 2 | 8 | 6.71 | 4.27 |
| | 2 | 9 | 6.91 | 4.04 |
| | 2 | 10 | 7.12 | 3.69 |
| | 2 | 11 | 7.33 | 3.26 |
| | 3 | 3 | 6.65 | 6.58 |
| | 3 | 4 | 6.78 | 7.29 |
| | 3 | 5 | 6.94 | 8.01 |
| | 3 | 6 | 7.14 | 8.67 |
| | 3 | 7 | 7.38 | 9.12 |
| | 3 | 8 | 7.65 | 9.2 |
| | 3 | 9 | 7.93 | 8.84 |
| | 3 | 10 | 8.18 | 8.14 |
| | 4 | 5 | 7.13 | 10.69 |
| | 4 | 6 | 7.38 | 11.73 |
| | 4 | 7 | 7.67 | 12.4 |
| | 4 | 8 | 7.96 | 12.32 |
| | 4 | 9 | 8.24 | 11.5 |
| | 5 | 7 | 7.77 | 14.48 |
| | 5 | 8 | 8.08 | 13.94 |
| | 5 | 9 | 8.34 | 12.57 |
| | 6 | 6 | 7.49 | 15.32 |
| | 6 | 7 | 7.81 | 15.58 |
| | 6 | 8 | 8.1 | 14.43 |
| | 6 | 9 | 8.35 | 12.7 |
| | 7 | 5 | 7.13 | 14.88 |
| | 7 | 6 | 7.47 | 16.16 |

| | | | | |
|---|---|---|---|---|
| | 7 | 7 | 7.8 | 19.01 |
| | 7 | 8 | 8.08 | 14.26 |
| | 7 | 9 | 8.29 | 12.37 |
| | 8 | 4 | 6.71 | 13.61 |
| | 8 | 5 | 7.06 | 15.46 |
| | 8 | 6 | 7.41 | 16.42 |
| | 8 | 7 | 7.74 | 15.59 |
| | 8 | 8 | 8.01 | 13.73 |

Table 4.2: the maximum gain and F/B result after modification in the spacing of the elements

Appendix 2

| Element | Spacing (ft.) | | Gain | |
|---|---|---|---|---|
| | R - Dr | Dr-Dir | Max (dbi) | F/B (db) |
| 5 element | 3 | 3 | 10.47 | 5.88 |
| | 3 | 4 | 10.81 | 9.65 |
| | 3 | 5 | 11.36 | 17.1 |
| | 3 | 6 | 11.17 | 26.56 |
| | 3 | 7 | 11.26 | 15.26 |
| | 4 | 4 | 9.76 | 15.52 |
| | 4 | 5 | 9.9 | 16.44 |
| | 4 | 6 | 9.96 | 17.78 |
| | 4 | 7 | 10.14 | 21.1 |
| | 4 | 8 | 10.41 | 22.48 |
| | 4 | 9 | 10.61 | 18.63 |
| | 5 | 5 | 9.53 | 12.71 |
| | 5 | 6 | 9.59 | 14.22 |
| | 5 | 7 | 9.8 | 19.91 |
| | 5 | 8 | 10.13 | 30.27 |
| | 5 | 9 | 10.34 | 16.984 |
| | 6 | 5 | 9.37 | 11.51 |
| | 6 | 6 | 9.43 | 13.45 |
| | 6 | 7 | 9.68 | 19.51 |
| | 6 | 8 | 10.04 | 22.64 |
| | 6 | 9 | 10.23 | 14.72 |
| | 7 | 4 | 9.27 | 11.03 |
| | 7 | 5 | 9.27 | 10.67 |

Table 4.4: the maximum gain and F/B ratio result for 5 elements YAGI

Appendix 3

| Element | Spacing | | Gain | |
|---|---|---|---|---|
| | R - Dr | Dr-Dir | Max (dbi) | F/B (db) |
| 7 element | 5 | 5 | 11 | 20 |
| | 5 | 6 | 11.13 | 13.97 |
| | 5 | 7 | 11.17 | 16.56 |
| | 5 | 8 | 11.51 | 35.048 |
| | 5 | 9 | 11.65 | 15.87 |
| | 5.5 | 6 | 11.04 | 13.18 |
| | 5.5 | 7 | 11.08 | 16.46 |
| | 5.5 | 8 | 11.45 | 28.66 |
| | 6 | 5 | 10.91 | 17.74 |
| | 6 | 6 | 10.88 | 12.47 |
| | 6 | 7 | 11.02 | 15.86 |
| | 6 | 8 | 11.4 | 25.43 |
| | 6 | 9 | 11.5 | 14.17 |
| | 7 | 7 | 10.93 | 16.04 |
| | 7 | 8 | 11.33 | 21.93 |
| | 7 | 9 | 11.32 | 13.24 |

Table 4.6: The simulation result for 7 elements YAGI design

| Element | Spacing | | Gain | | Element | Spacing | | Gain | |
|---|---|---|---|---|---|---|---|---|---|
| | R - Dr | Dr-Dir | Max (dbi) | F/B (db) | | R - Dr | Dr-Dir | Max (dbi) | F/B (db) |
| 3 elements | 1 | 1 | 2.8 | 99.99 | 5 elements | 1 | 1 | 5.7 | 1.82 |
| | 1 | 2 | 7.3 | 9.31 | | 1 | 2 | 5.43 | 0.81 |
| | 1 | 3 | 7.72 | 9.35 | | 1 | 3 | 8.86 | 13.2 |
| | 1 | 4 | 6.28 | 6.39 | | 1 | 4 | 5.03 | 5.06 |
| | 2 | 1 | 7.3 | 9.31 | | 2 | 1 | 9.19 | 10.24 |
| | 2 | 2 | 7.17 | 99.99 | | 2 | 2 | 10.41 | 10.83 |
| | 2 | 3 | 6.65 | 0.69 | | 2 | 3 | 9.22 | 4.57 |
| | 3 | 1 | 7.72 | 9.35 | | 3 | 1 | 9.23 | 14.04 |
| | 3 | 2 | 6.65 | 0.69 | | 3 | 2 | 10.49 | 15.4 |
| | 3 | 3 | 4.5 | 99.99 | | 3 | 3 | 6.61 | 3.36 |
| | 3 | 4 | 4.31 | 4 | | 4 | 1 | 8.25 | 12.94 |
| | 4 | 1 | 6.28 | 6.39 | | 4 | 2 | 9.02 | 12.29 |
| | 4 | 2 | 5.52 | 2.76 | | 4 | 3 | 5.79 | 6.75 |
| | 4 | 3 | 4.31 | 4.06 | | 5 | 1 | 7.78 | 11.32 |
| | 4 | 4 | 0.95 | 99.99 | | 5 | 2 | 8.11 | 10.24 |
| | 4 | 5 | 2.17 | 0.51 | | | | | |
| | 5 | 1 | 5.09 | 5.11 | | | | | |
| | 5 | 2 | 5.95 | 4.25 | | | | | |
| | 5 | 3 | 5.17 | 3.78 | | | | | |
| | 5 | 4 | 2.17 | 0.51 | | | | | |
| 7 elements | 1 | 1 | 7.06 | 2.28 | 7 elements | 5 | 1 | 3.17 | 1.04 |
| | 1 | 2 | 6.33 | 3.03 | | 5 | 2 | 7.35 | 2.76 |
| | 1 | 3 | 9.18 | 17.08 | | 5 | 3 | 6.62 | 0.62 |
| | 1 | 4 | 5.83 | 5.78 | | 5 | 4 | 7.66 | 11.8 |
| | 2 | 1 | 9.82 | 4.35 | | 6 | 1 | 2.34 | 0.5 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2 | 2 | 10.61 | 4.47 | | 6 | 2 | 8.95 | 2.55 |
| | 2 | 3 | 10.03 | 7.99 | | 6 | 3 | 7.81 | 7.37 |
| | 2 | 4 | 5.84 | 3.47 | | | | | |
| | 3 | 1 | 9.77 | 5.71 | | | | | |
| | 3 | 2 | 10.78 | 4.25 | | | | | |
| | 3 | 3 | 7043 | 6.37 | | | | | |
| | 3 | 4 | 4.98 | 4.17 | | | | | |
| | 4 | 1 | 8.23 | 4.3 | | | | | |
| | 4 | 2 | 8.31 | 2.09 | | | | | |
| | 4 | 3 | 6.39 | 9.71 | | | | | |