A CONCEPT FOR WILDLIFE TRACKING USING ULTRA HIGH FREQUENCY (UHF) RADIO

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ABSTRACT

Wildlife tracking technology is a method routinely used in the detection of small animals or big animals. Normally, a radio tracking using a low frequency between 30MHz to 300MHz known as Very High Frequency (VHF). In this study, a band of Ultra High Frequency (UHF) with a frequency 315MHz is used as a transmitter. While a encoder HT12E is used as a function of generate a data signal to the RF Transmitter module 315MHz to transmit. The signal sent by the transmitter detected by Yagi antenna as a receiver and was designed at a frequency of 315MHz with a gain is 10.68dBi. Received power detected by Yagi antenna shown at Anritsu Spectrum Analyzer. The highest differences between power received at vegetation area compared to open area is about 10dBm while the furthest distance of the receiver can be traced in the vegetation area is about 67 meters, and for open area is more than 70 meters. The results of this study agreed with Tamir'model for propagation in forest whereas can be used in a prediction of initial pattern of power received signal which is gradually decrease if a receiver moves away from the transmitter over much larger distances.

ABSTRAK

Pengesanan hidupan liar merupakan kaedah teknologi yang sentiasa digunakan dalam mengesan haiwan samada haiwan kecil atau haiwan besar. Kebiasaannya, Radio Frekuensi yang digunakan adalah pada frekuensi rendah diantara 30MHz sehingga 300MHz yang dikenali sebagai Very High Frekuency (VHF). Dalam kajian ini, penghantar yang digunakan menggunakan frekuensi 315MHz iaitu dalam jalur Ultra High Frekuency (UHF). Enkoder yang digunakan adalah HT12E yang berfungsi untuk menghantar isyarat kepada *RF Transmitter module* yang berfrekuensi 315MHz. Isyarat yang dihantar oleh penghantar akan dikesan oleh antenna berarah sebagai penerima iaitu Yagi antenna yang direka pada frekuensi 315MHz dengan gain adalah 10.68dBi. Yagi antenna akan mengesan kuasa penerima menggunakan Anritsu Spectrum Analyzer. Data di kawasan berpokok renek dan kawasan dibandingkan dimana perbezaan tertinggi di antara dua kawasan adalah 10dBm manakala jarak yang paling jauh kuasa penerima dapat dikesan dalam kawasan berpokok renek adalah 67 meter manakala untuk kawan lapang adalah lebih daripada 70 meter. Hasil kajian ini mengesahkan Tamir model boleh digunakan dalam menjangkakan corak awal kuasa penerima dengan pertambahan jarak receiver dari transmitter.

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LIST OF ABBREVIATIONS AND SYMBOLS

VHF - Very High Frequency

UHF - Ultra High Frequency

ASK - Amplitude Shift Keying

RF - Radio Frequency

P_r - Power Received

OOK - On Off Keying

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CHAPTER 1

INTRODUCTION

1.1 Overview

To determine the behavior and location of wild animal, they need to be monitored in some way. Typically, to be able to detect animals remotely, an electronic tracking device is tagged on the animal. After many years searching a new method of tracking animal, finally scientist found a new ways to track or determine a movement of animal by using a radio tracking system. Radio tracking systems have been used today can be divided into three types; VHF Radio Tracking, Satellite tracking and Global Positioning System (GPS) Tracking. Each types of system have advantages and disadvantages.

A radio tracking system using VHF tracking, first used in 1963 [1]. In order to use a VHF radio tracking, once a radio transmitter is placed on animal, it begins periodically emits a signal to a radio antenna and receiver. If we want to locate an animal using radio tracking, we must be close enough to the animal with the radio antenna so a signal from a radio transmitter on the animal can be detect. But no signal will be detected if a receiver is out of a range or a far away.

While Satellite tracking is similar with VHF radio tracking but instead of radio signal being sent to receiver a radio signal from transmitter on animal is sent directly to a special satellite. Particularly, satellite tracking using the AGROS system (launched in 1978 [2]), which allow researchers to automatically determine the position of animals anywhere in the world [3]. Therefore, a researcher can be picks up a signal without stay close with the animal and it can be track using computer. It mean that, position is inferred from the Doppler shift of the carrier wave received at the satellite while from the data, approximate can be determined. A tracking device must be larger than VHF tag due to a signal has to be strong enough to be received in space. In additional, ARGOS tags are expensive and have to be paid annually. An accuracy of location determines using satellite tracking is quite poor, often with errors in a few hundred meters [2]. Therefore, it is suitable being used for migratory species.

And the newest technology being used to track animal is GPS tracking [4]. A difference between two types before, a radio receiver, not a transmitter is placed on animal and it picks up a signal from special satellite. A computer at the receiver will calculate a location and animal activities then it will be sent to another satellite and the data will be analysis after received it from second set of satellite. GPS tracking has had a significant impact on wildlife research by enabling the acquisition of detailed location information anywhere in the world with excellent accuracy. A GPS receiver is able to acquire locations on demand, something which is impossible with satellite tracking, due to the sparsely of satellite coverage. The locations obtained by GPS tracking are much more accurate than satellite tracking (typical accuracy for GPS is 5 m, whereas the best satellite tracking accuracy is in the order of 100 m).

A great advantage of GPS tracking in comparison to VHF tracking is that minimal time is needed in the field. As the GPS unit calculates its position itself, the labour costs associated with GPS tracking are substantially lower In addition, the possibility of bias introduced through disturbing the habitat of the subject being studied is greatly reduced. VHF tracking also has very limited coverage – it is not suitable for wide ranging animals, as the maximum range that an animal can be detected is 8 – 10km (or 15 – 30 km from air). GPS on the other hand is a global tracking system.

The main drawback of GPS tracking in comparison to VHF tracking is the power consumption of the GPS receiver. For this reason, GPS receivers are duty-cycled such that they spend the majority of their time in low power sleep mode. As a (simple and optimistic) example, a GPS receiver acquiring locations every 10 minutes, with an average time-to-first-fix (TTFF) of 20 s, consumes an average power of 3.3 mW, if the power consumption when the receiver is active is 100 mW. In comparison, a VHF beacon transmitting at a power of 10 mW every second for 30 ms at an efficiency of 40% will consume an average power of 0.75mW. Thus, for the same lifetime, the GPS unit must have more than four times as much battery capacity as for the VHF unit. As the majority of the weight of the unit is due to the energy source, this has the implication that the GPS unit will weigh approximately four times more than the VHF unit. Due to their complexity, GPS collars are more expensive than VHF beacons. A typical VHF transmitter costs in the region of U$100 – U$200 [5], whilst a GPS collar will cost in the region of U$2500–U$4500, depending on which options (such as satellite upload) are installed [6]. It is much costing, therefore more discussion will be focus on VHF radio tracking in this study.

A conventional VHF radio tracking system consists of transmitting and receiving systems. Therefore several aspects of the way radio-waves behave to be consider such as attenuation by trees and dense vegetation, reflection, diffraction and a last is polarization of receiving antenna whether it may be horizontally or vertically polarized and the best signal reception the element on a receiver antenna (e.g Yagi Uda) should be in the same orientation.

VHF tracking is a simple, relatively low cost method of tracking animals. A typical transmitter tag (depending on options) costs in the range of U$100 to U$200 [5]. Because of the low transmitter power and duty cycle of the VHF tags, battery capacities do not have to be large. The smallest VHF transmitters available weigh approximately 0.2 g, but these have a limited output power and a very short lifetime (two – three weeks) [7]. For longer studies, a tracking collar that weighs approximately 500 g can transmit an RF signal for over 4 years [5]. VHF tracking is applicable to a wide range of animal species, from very small animals (and even insects [7]) to large mammals. The main disadvantage of VHF tracking is the labour (and costs associated with labour) involved in triangulation, leading to a paucity of fixes [8].

Although the cost of the equipment is the lowest of the three tracking methods (being VHF, satellite and GPS tracking), the cost per fix is very high – one study found that the cost per fix for VHF was U$65 in comparison to U$8 for GPS [9]. Although a cost per fix is high but VHF tracking is better for overall costing.

In order to detect signal from an animal, there are a lot of antenna have been used such as Adcock (H), or loop antenna but the most commonly used antenna is the Yagi Antenna [10]. This antenna looks the most like the typical TV antenna. It is the most popular, in spite of its huge, unwieldy size, because it is the most directional. A Yagi Antenna pinpoints the direction the signal is coming from better than most. Still, with a Yagi, the loudest signal will cover a range of about 60 degrees [11]. It is best to record the direction at which this loud signal begins and ends and then to calculate the midpoint for use in analysis. If the signal covers more or less than 60 degrees, it needs to adjust the gain (decrease or increase, respectively).

1.2 Problem Statement

For many years the only way to track wildlife was to simply follow and observe the movement and habits of animal or to capture an animal and put a tag on it and hope that at sometime in the future the same animal would be captured.

But today, scientists have new tools like a radio tracking system to determine an animal's behavior. One of the types of radio tracking systems used today is VHF Radio Tracking. By using this technology, animals can be track easily but how a system can operate in a different distance at various area and weather conditions. Therefore, a study in this research focus on a pattern of received radio signal from a radio transmitter tagged on animal in a different weather. Consideration of distance and surrounding condition will be calculated in order to have a pattern of animal's activities in that area.

1.3 Objectives

The objective of my research is to study a concept of radio tracking for wildlife

1. To design and fabricate a wild animal tracking system consisting of an RF transmitter system and a receiver for animal tracking.

2. To study patterns of received radio signal to approximate animal's position and distance at various area.

1.4 Scope

1. To design an RF transmitter operated at 315 MHz with power received between -0dBm into -120dBm.

2. To design and fabricate a directional antenna (e.g Yagi Uda) for detection purposes.

3. Tracking mechanism is based on the received signal strength amplitude measured using spectrum analyzer (Model Anritsu).

4. Studies will be done around Bukit Bauk area, Dungun.

CHAPTER 2

FUNDAMENTAL OF ANIMAL TRACKING SYSTEMS

2.1 Introduction

Wildlife tracking involves acquiring information about the behavior of animals in their natural habitat. The purposes of this information is used both for scientific and conservation. The primary form of information that needs to be obtained is the location of the animal (such as mousedeer, fox etc.) at certain points in time and this is generally referred to as tracking or radio–tracking

Basically, an animal tracking system can be divided into parts such as radio transmitter, receiver and directional antenna as receiving antenna (Yagi antenna).

2.2 Radio Frequency (RF)

Radio frequency (RF) is a frequency or rate of oscillation within the range of about 3 Hz to 300 GHz. This range relates to frequency of alternating current electrical signals used to produce and detect radio waves. Then most of this range is beyond the vibration rate that most mechanical systems can respond to, RF usually refers to oscillations in electrical circuits. Different range of oscillation will have different wavelength, which determine the power of the transmission. For example, at ultrahigh frequency (UHF-300–3000MHz), wavelength is 1–10 m which can travel in the range of hundreds of kilometers is suitable applied in FM broadcasting, broadcast television, GPR, amateur radio, aviation, MRI and etc.. In other word, RF is considered long range wireless communication technology. Radio frequency (RF) offers greater range and penetrating power compare to other wireless communication technology. VHF signals will have better penetration of vegetation and buildings than UHF, which is a significant reason why they're popular for outdoor "fox hunting" and animal tracking etc.

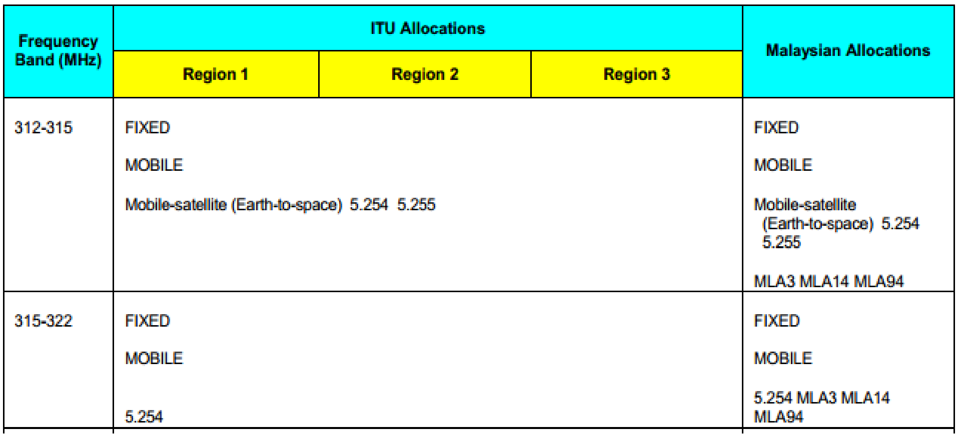
2.3 Spectrum Management in Malaysia

The International Telecommunications Union ('ITU'), a specialized agency under United Nations, is responsible for the harmonization on the global use of the spectrum including Malaysia. The ITU Radio regulations ('Radio Regulations') is an international treaty that contains the world's frequency allocation table (see 'ITU Allocation Table'). This table is important as it forms the framework for international, regional and national spectrum planning, allocations and assignments.

Malaysia is a signatory to the Constitution and Convention of the ITU and the Radio Regulations which are reviewed or revised at the ITU World Radio communications Conference ('WRC'), held every three or four years. The structure of Malaysia's Spectrum Plan is based on the ITU Allocation Table contained in the Radio Regulations. For easy reference, the ITU Allocation Table has been reproduced in this Spectrum Plan together with the relevant accompanying footnotes.

This Spectrum Plan divides the spectrum in Malaysia into a number of frequency bands and specifies the general purposes for which the bands may be used and this process is referred to as the allocation of frequency bands to the identified radio communication services. The Malaysian allocations listed herein sets out the Malaysian Table of Frequency Allocations ('Malaysian Table'). Accompanying Malaysian footnotes (denoted as MLA) and international footnotes have been included, where necessary, to assist in the understanding of matters which are relevant to Region 3 and Malaysian specific conditions. Table 1 shown ITU Allocation Table for frequency 315 MHz have been used in this project.

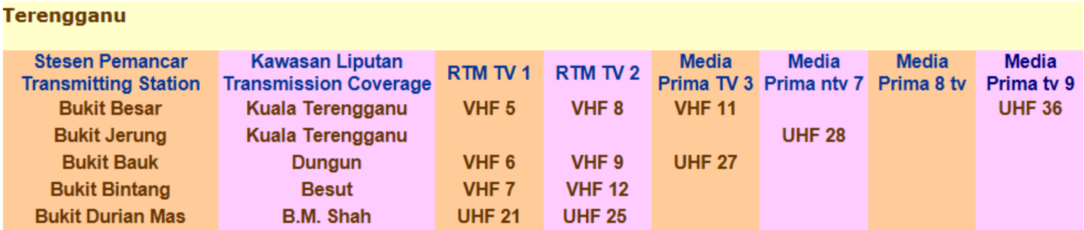
Table 2.1 Table of Frequency Allocations ("Malaysian Table')



Frequency Band (MHz)	ITU Allocations			Malaysian Allocations
	Region 1	Region 2	Region 3	
312-315	FIXED MOBILE Mobile-satellite (Earth-to-space) 5.254 5.255			FIXED MOBILE Mobile-satellite (Earth-to-space) 5.254 5.255 MLA3 MLA14 MLA94
315-322	FIXED MOBILE 5.254			FIXED MOBILE 5.254 MLA3 MLA14 MLA94

The Malaysian Table allocates the spectrum between 9 kHz and 420 THz. It should be noted that although the Malaysian Table is generally aligned with the Article 5 of the Radio Regulation for Region 3, some differences do exist. This is because, where necessary, variations have been incorporated to reflect Malaysian domestic requirements. Nevertheless, any variation undertaken is subject to the conditions contained in the Radio Regulations that the associated radio installations do not cause harmful interference to the radio services or communications in the jurisdiction of the rest of the ITU member states that operate in accordance with the provisions of the Radio Regulations.

Terengganu is one of a state in Malaysia and have a lot of transmitting station including Bukit Bauk which a transmission coverage a Dungun area shown in figure 2.1



Terengganu

Stesen Pemancar Transmitting Station	Kawasan Liputan Transmission Coverage	RTM TV 1	RTM TV 2	Media Prima TV 3	Media Prima ntv 7	Media Prima 8 tv	Media Prima tv 9
Bukit Besar	Kuala Terengganu	VHF 5	VHF 8	VHF 11			UHF 36
Bukit Jerung	Kuala Terengganu				UHF 28		
Bukit Bauk	Dungun	VHF 6	VHF 9	UHF 27			
Bukit Bintang	Besut	VHF 7	VHF 12				
Bukit Durian Mas	B.M. Shah	UHF 21	UHF 25				

Figure 2.1 A Transmitting station in Terengganu

2.4 Modulation Technique (ASK)

Modulation is a process where a Radio Frequency (RF), amplitude, frequency or phase is changed in order to transmit intelligence. The characteristics of the carrier wave are instantaneously varied by another "modulating" waveform. The main purpose of modulation is to overcome any inherent incompatibilities between the electromagnetic properties of the modulating signal and those of the transmission medium. In most applications of modulation the carrier signal is a sine wave, which is completely characterized by its amplitude, its frequency, and its phase relative to some point in time.

The modulation technique consists of analog modulation in which the modulating signal is analog and digital modulation in which the modulating signal is digital. There are three types of analog modulation techniques such as amplitude modulation (AM), frequency modulation (FM) and phase modulation (PM). In digital modulation, the three types basic of digital modulations technique are known as Amplitude Shift Keying ASK), Frequency Shift Keying (FSK) and Phase Shift Keying (PSK).

The fundamental properties of the carrier signal are varied in accordance with the digital base band information signal. Digital modulation provides more information capacity, compatibility with digital data services, higher data security, better quality communications, and quicker system availability.

Digital modulation schemes have greater capacity to convey large amounts of information than analogue modulation schemes. Frequency Shift Keying (FSK) and Phase Shift Keying (PSK) used a constant amplitude carrier and the information in phase or frequency variations while Amplitude Shift Keying (ASK) transmits the information in carrier amplitude variations. For this project, it focused on Amplitude Shift Keying (ASK) [12]

Amplitude Shift Keying (ASK) refers to the digital modulation technique which the amplitude of the carrier is varied in accordance with the binary source. Amplitude Shift Keying (ASK) is also known as On-Off Keying (OOK). The carrier is turned ON and OFF for every n seconds. The ON state represents binary 1 and the OFF state represent binary 0. OOK usually use in the ISM Bands to transfer data between computers. Beside that, OOK also is related with Morse code. It commonly used by amateur radio operators to transmit Morse code over radio frequencies.

2.5 RF Transmitter Module 315 MHz

These RF Transmitter Modules are very small in dimension but have a wide operating voltage range (3V-12V). There are 2 types of RF Transmitter Modules, either 315MHz or 433MHz. The RF Transmitter module used in this project is 315MHz. Figure 2.2 shows the RF Transmitter module.

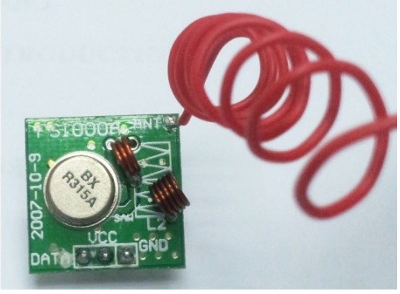


Figure 2.2 RF Transmitter module

The low cost RF Transmitter can be used to transmit signal up to 100 meters. However, it is also depends on the antenna design, working environment and supply voltage which will seriously impact the effective distance. When the voltage is higher, the range becomes greater. It is good for short distance and device's battery power development. It uses the ASK Transmitter Module, where it is based on SAW resonator and accepts digital inputs, which can operate from 3 to12 Volts-DC. This feature makes the RF enabled products very easy to build. It has benefits of the device in deep sleep mode when data pin is grounded. The specification of the RF Transmitter Module is shown in Table 2.2 below.

Table 2.2 Specification of the RF Transmitter Module

No	Specification	RF transmitter Module
1	Operating voltage	3v-12v
2	Operating current Max	≤ 40mA (12V), Min ≤ 9mA (3V)
3	Oscillator SAW	(Surface Acoustic Wave) oscillator
4	Frequency	315MHz~433.92MHz
5	Frequency error	±150kHz(max)
6	Modulation	ASK/OOK
7	Transfer rate	≤ 10Kbps
8	Transmitting power	25mW (315MHz@12V)
9	Antenna length	24cm (315MHz), 18cm (433.92MHz)

2.6 Yagi Antenna

An array antennas can be used to increase directivity. The arrays we examined had all elements active, requiring a direct connection to each element by a feed network [13]. Array feed networks are considerably simplified if only a few elements are fed directly. Such an array is referred to as a parasitic array. The elements that are not directly driven (called parasites) receive their excitation by near-field coupling from the driven elements. A parasitic linear array of parallel dipoles is called a Yagi-Uda antenna, a Yagi-Uda array, or simply "Yagi." Yagi-Uda antennas are very popular because of their simplicity and relatively high gain. In this section, the principles of operation and design data for Yagis will be presented.

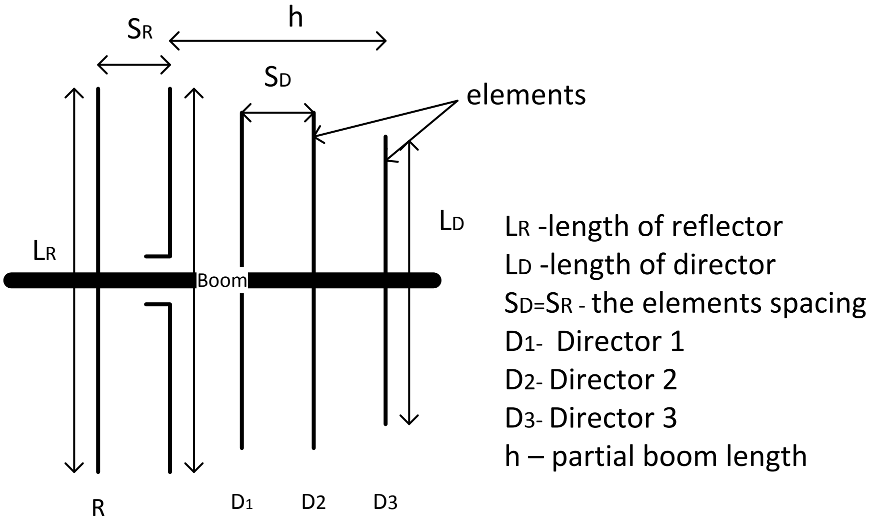


Figure 2.3 Configuration for a general Yagi-Uda antenna

The basic unit of a Yagi consists of three elements. Therefore, to understand the principles of operation for a three-element Yagi, let begin with a driven element (or "driver") and add parasites to the array.

The general Yagi configuration is shown in Figure 2.3. The maximum directivity obtainable from a three-element Yagi is about 9 dBi or 7 dBd while the optimum reflector spacing S_R (for maximum directivity) is between 0.15 and 0.25 wavelengths as shown in Figure 2.4.

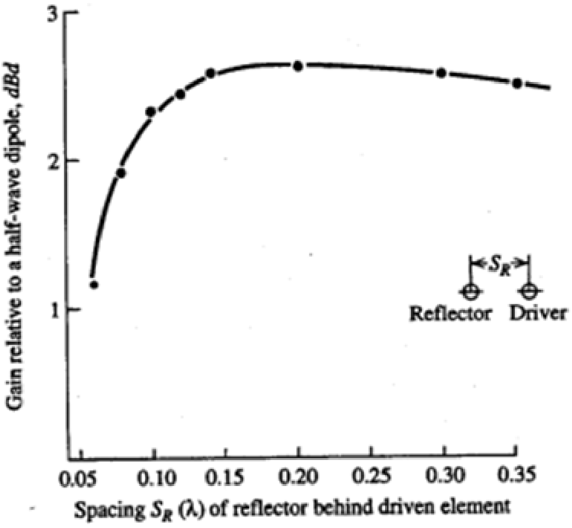


Figure 2.4 Measured gain in dBd of a dipole and reflector element for different spacings S_R

Note that the gain above an isolated dipole is more than 2.5 dBd, whereas if a flat plate were used, instead of a simple wire-like element, the gain would be 3 dBd. Thus, a single wire-like reflector element is almost as effective as a flat plate in enhancing the gain of a dipole.

Director-to-director spacings are typically 0.2 to 0.35 wavelengths, with the larger spacings being more common for long arrays and closer spacings for shorter arrays. Typically, the reflector length is 0.5λ and the driver is of resonant length when no parasitic elements are present . The director lengths are typically 10 to 20% shorter than their resonant length, the exact length being rather sensitive to the number of directors N_D and the inter director spacing S_D.

The gain of the Yagi is related to its boom length as our study of uniform line sources in the previous chapter suggests, but for a parasitic array such as the Yagi, there is a smaller increase in gain per element as directors are added to the array (if we assume S_D is fixed) since the Yagi is not uniformly excited.

In fact, the addition of directors up to about 5 or 6 provides a significant increase in gain expressed in dB, whereas the addition of more directors is beyond the "point of diminishing returns" as figure 2.4 shows.

Figure 2.5 show a plots of the gain versus the number of elements N in the array (including one reflector and one driver) for an inter element spacing for all elements of SR = SD = 0.15λ.

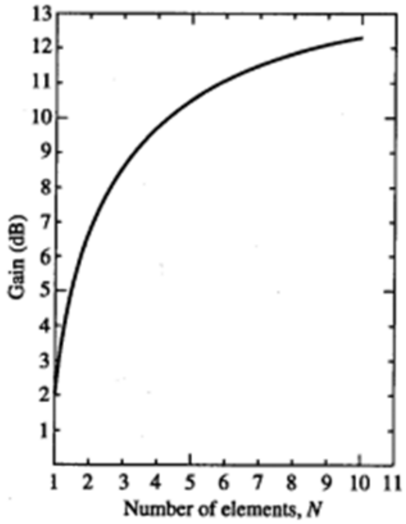


Figure 2.5 Gain of a typical Yagi-Uda antenna versus the total number of elements

Note that adding one director to increase N from 3 to 4 gives about a I-dB gain increase, whereas adding one director to increase N from 9 to 10 yields only about an additional 0.2-dB gain.

The addition of more reflector elements results in a fractional dB increase in gain and is usually not done. The main effects of the reflector are on the driving point impedance at the feed point and on the back lobe of the array. Pattern shape, and therefore gain, are mostly controlled by the director elements. The director spacing and director length are interrelated, but the more sensitive parameter is the director length, which becomes more critical as the boom length increases. An extensive decade-long experimental investigation by Viezbicke at the National Bureau of Standards (later known as NIST) has produced a wealth of information on Yagi-Uda antenna design. An objective of the experimental investigation was to determine optimum designs for a specified boom length. Boom lengths from 0.2 to 4.2λ were included in the study. Some of Viezbicke's work is summarized in Table 2.3, which can be used for design purposes. Viezbicke's work and its summaries show how to correct the free-space parasitic element lengths for both the diameter of the conductors used shows in figure 2.6 and for the diameter of a metal boom (see Figure 2.7), if a metal boom is used.

A metal boom may be used because the voltage distribution on the parasitic elements goes through a zero at the element center. Ideally, an infinitely thin metallic boom down the center of the array would not change the voltage distribution. However, metallic booms of practical size do have an effect that must be compensated for by increasing the parasitic element lengths. Alternatively, the parasitic elements may be insulated from the boom, in which case no compensation is required.

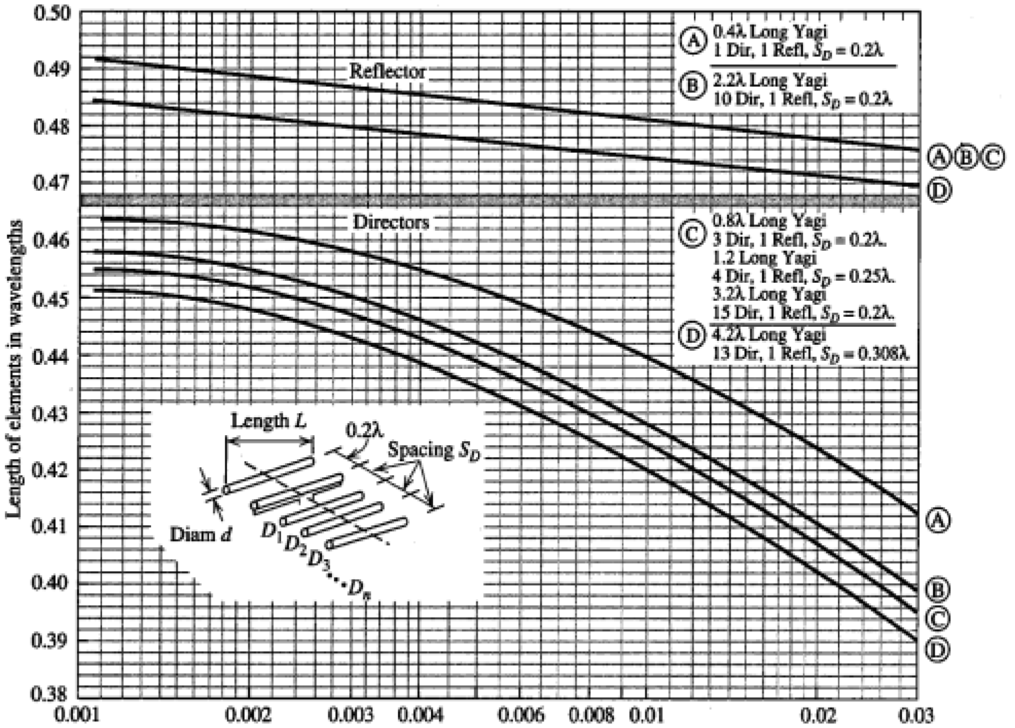


Figure 2.6 Design curves for Yagis in Table 2.3

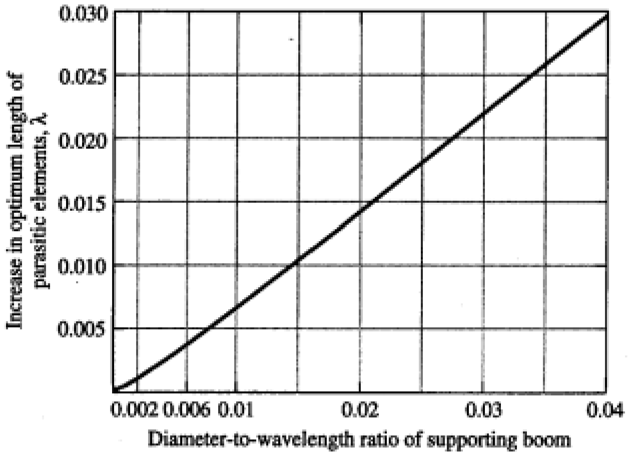
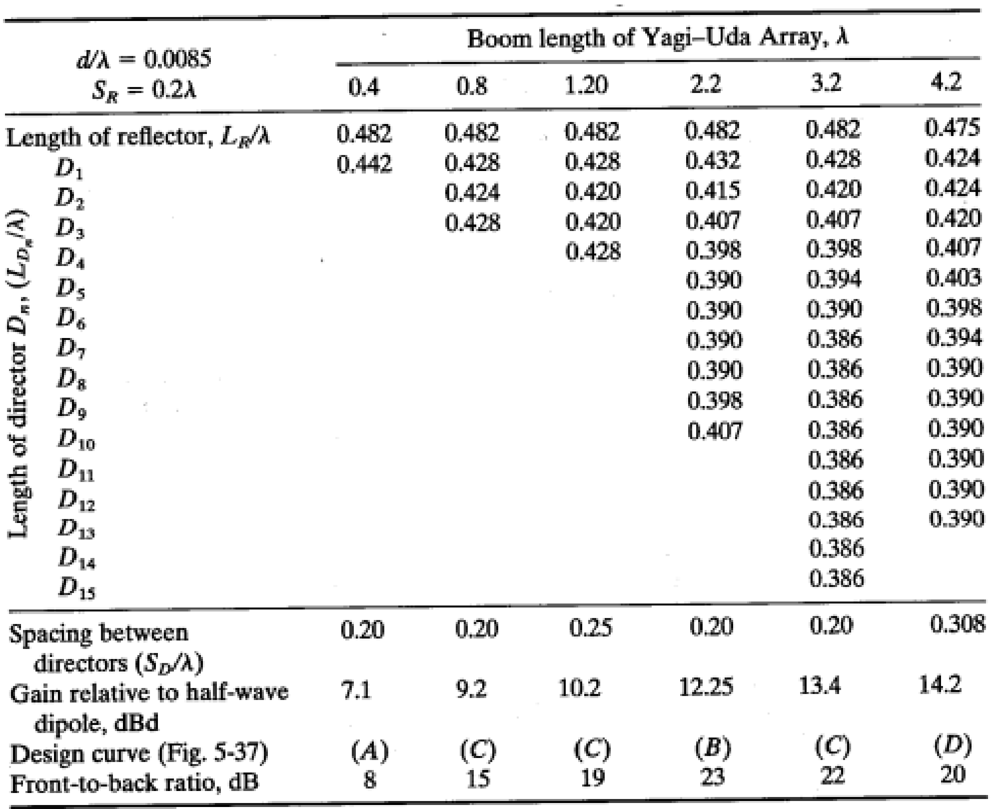


Figure 2.7 Graph showing effect of supporting metal boom on the length of Yagi

Table 2.3 Optimized Lengths of Parasitic Dipoles for Yagi-Uda Array Antennas



	$d/\lambda = 0.0085$ $S_R = 0.2\lambda$	Boom length of Yagi–Uda Array, λ					
		0.4	0.8	1.20	2.2	3.2	4.2
	Length of reflector, L_R/λ	0.482	0.482	0.482	0.482	0.482	0.475
Length of director D_n, (L_{D_n}/λ)	D_1	0.442	0.428	0.428	0.432	0.428	0.424
	D_2		0.424	0.420	0.415	0.420	0.424
	D_3		0.428	0.420	0.407	0.407	0.420
	D_4			0.428	0.398	0.398	0.407
	D_5				0.390	0.394	0.403
	D_6				0.390	0.390	0.398
	D_7				0.390	0.386	0.394
	D_8				0.390	0.386	0.390
	D_9				0.398	0.386	0.390
	D_{10}				0.407	0.386	0.390
	D_{11}					0.386	0.390
	D_{12}					0.386	0.390
	D_{13}					0.386	0.390
	D_{14}					0.386	
	D_{15}					0.386	
	Spacing between directors (S_D/λ)	0.20	0.20	0.25	0.20	0.20	0.308
	Gain relative to half-wave dipole, dBd	7.1	9.2	10.2	12.25	13.4	14.2
	Design curve (Fig. 5-37)	(*A*)	(*C*)	(*C*)	(*B*)	(*C*)	(*D*)
	Front-to-back ratio, dB	8	15	19	23	22	20

Source: P. P. Viezbicke, "Yagi Antenna Design," NBS Tech. Note 688, National Bureau of Standards, Washington, DC, Dec. 1968.

The Yagi is one of the more popular antennas used in the HF-VHF-UHF frequency range. Besides it provides moderately high gain while offering low weight and low cost. It has a relatively narrow bandwidth (e.g., a few percent), which may be improved somewhat by using feeds other than a dipole, such as a folded dipole. The folded dipole also provides higher input impedance than a dipole whereas the driving point impedance of both are usually reduced considerably from their self-impedances by mutual coupling effects. Arraying or "stacking" Yagi antennas can obtain further, increased gain. Maximum gain results for a separation of almost one wavelength. Hence, for a given application, if a somewhat narrow bandwidth can be tolerated, the Yagi-Uda antenna can provide good gain (e. g., 9-12 dB) at low cost.

2.7 YagiCAD

Yagicad is a fully integrated analysis and design package for yagi, quad, and quagy, aerials. With Yagicad it is possible to enter a base design from scratch or use one of a number of saved well known designs. It was designed by Paul McMahon.

This design can then be optimised or scaled to suit particular requirements. Once this has been done a matching unit can be estimated and overall performance characteristics can be calculated and displayed graphically. Also available are radiation patterns and hardcopy print-out of results. Allowances in an analysis can also be made for element cross sections other than simple circular ones, as well as boom mounting techniques. This program is based on a theoretical model of a yagi antenna, many assumptions and simplifications have been made. The results obtained with this program must therefore be taken with some caution.

Therefore ,no expectation to get it working exactly as calculated without at least some experimental iterations. ie. Yagicad is no substitute for a vswr meter etc., and at least some trial and error. Anyone who does not at least use a variable capacitor or have some means of varying a gamma arm length is expecting too much from this or any other antenna program. Some common sense should also be exercised when optimising designs. By using this software, a design can be more easier where yagicad is varying lengths or spacings by less than a millimeter. Therefore an extra gain is being obtained by doing a fine tune on final antenna with a nail file, so the results are close to calculations. Basically, Yagicad is limited to yagis with less than 24 elements.

CHAPTER 3

LITERATURE REVIEW

Wildlife tracking and ecological monitoring are important for scientific monitoring, wildlife rehabilitation, disease control, and sustainable ecological development [4]. Wildlife tracking involves acquiring information about behavior of animals in their natural habitat. The main point of information is to obtain the location of the animal a certain time and this is generally referred to as tracking or radio tracking.

Radio-tracking is the technique of determining information about an animal through the use of radio signals from or to a device carried by the animal. “Telemetry” is the transmission of information through the atmosphere usually by radio waves, so radio-tracking involves telemetry, and there is much overlap between the two concepts. [14]. Essentially, tracking involves determining where an animal is, and telemetry refers to recording data that can be used to infer its activity, at certain points in time. Technologies are used today for tracking wild animals have been discussed (refer introduction).

Very High Frequency (VHF) technology was the earliest modality used for tracking and identifying individual wild animals electronically. The first successfully tested system was demonstrated in 1963 [15] . A VHF tracking system consists of two components – the transmitter (mounted on the animal) and the remote receiver (Yagi Antenna). Each radio transmitter consists of electronic parts and circuitry, usually including a quartz crystal tuned to a specific frequency. Frequencies used in wildlife telemetry usually range from 27 MHz to 401 MHz. VHF transmitters typically give a ground-to-ground range of 5-10 km which is increased to 15-25 km when received aerially. Lower frequencies propagate farther than higher frequencies since they reflect less when traveling through dense vegetation or varying terrain. The commonest frequency ranges used for VHF tracking are 148-152 MHz, 163-165 MHz, and 216-220 MHz [14]. The higher frequencies bounce more (e.g. off mountains) but have the advantage of requiring smaller antennas. Lower frequencies require long antennas (for example, a quarter wave whip at 148 MHz needs to be 50 cm long) which are often impossible to place on smaller animals. Higher frequencies, although requiring a shorter antenna, suffer more from ‘signal bounce’ due to more pronounced multipath effects from the environment, affecting their useful detection distance. An additional frequency-choice consideration involves proximity of other research projects using similar frequencies. Coordination among projects is necessary in order to avoid duplicating frequencies for individual study animals that may use the same areas [14].

In order to remotely determine the position of the animal, the tracking signal must be received and detected. A typical receiver consists of an antenna, an amplifier and a detector. The detector discriminates between the presences or absence of the RF signal, and in some cases also gauges the strength. The detector can be a researcher listening to the demodulated radio signal (this is called manual tracking) or a data-logger (this is termed automatic tracking). Therefore, receivers must be able to detect and distinguish signals of specific frequencies.

Generally, frequency determines the size of receiving antennas, the higher the frequency, the smaller the antenna required. The simplest kind of receiving antenna is a straight wire or “dipole” (one half the wavelength of the transmitted frequency) attached to the receiver’s antenna jack. Dipole antennas are omni-directional and therefore, are most appropriate for presence /absence studies [16] .These antennas are often used at a stationary reception site in an automatic tracking system or as part of a portable unit mounted on vehicles. Loop antennas can be a circle, an oval, or diamond-shaped, with, like other antennas, dimensions dictated by the signal frequency. Loop antennas are especially useful for minimizing the size of lower-frequency antennas so they can be used as hand-held portable units [17].

Although loop antennas are bi-directional (the signal can be received equally strong from two different directions simultaneously), by merely moving a few hundred meters perpendicular to the bearings, and taking a second bearing, once can determine the direction of signal origin. A more complicated antenna, the multi-element Yagi, is the most commonly used antenna in North America [18]. It consists of a horizontal length of metal (usually aluminum) with 3-17 vertical lengths attached to it, all in one plane. The length of the vertical elements and their spacing depend on signal frequency. Yagi antennas are directional with shorter elements at the distant end of the antenna. The signal's origin can be determined by swinging the antenna and determining the direction of the strongest signal when the tip of the Yagi (the shortest element) is farthest from the user [16].

In wildlife tracking research, if funding for study is low or if a large animal are to be studied for long period, VHF radio tracking is the only option could be consider compare to the others [14]. Another researcer from University of Texas has been designed a method for tracking small animal and slow moving objects using different type of antenna; Array antenna, Horn antenna and Yagi antenna [11]. A MATLAB code has been used to simulate how the object will be obtained and a triangulation method is used to calculate a location of objects. A result shows that the array antenna has a slightly high gain compare to Yagi antenna.

The basic Yagi–Uda array consists of a parallel set of linear dipole radiators shown in figure 3.1. The left-most element is typically slightly larger than resonant length and is called a reflector. The next element is a dipole element with a feed line. The right-most elements are typically slightly less than resonant length and are called directors. This descriptive terminology originated in Yagi's paper and is still used today. Spacing between elements is typically 0.2–0.3. In operation, radiation is predominantly to the right of the array, and the gain of the array increases with the number of directors that are used. In this way, it is rather easy to achieve gains ranging 10–20 dB. This is in contrast to a single dipole element, having a gain of 2.2 dB. Note the important feature that only one element in the Yagi–Uda array is directly driven; this greatly simplifies the construction of the array.

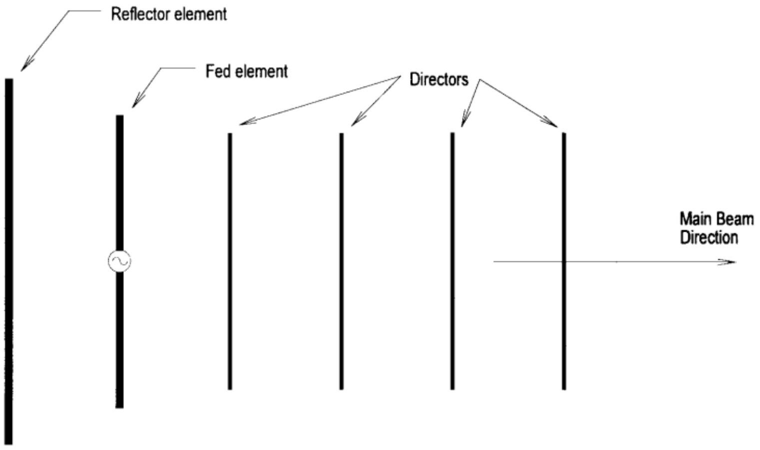


Figure 3.1 Geometry of the Yagi–Uda dipole array antenna

In operation, the Yagi–Uda antenna functions as an end-fire array, meaning that radiation is along the axis of the array in the direction of the director elements. The non driven, or parasitic, reflector and director elements are excited through mutual coupling between themselves and the fed dipole. We can provide an intuitive explanation for the operation of the array by considering a three-element Yagi–Uda array. Quantitative consideration of mutual coupling effects will show that the current excited on the reflector element will lag in phase from the driven element current, while the current excited on the director element leads in phase by approximately the same amount. These phase shifts are typically greater than the free-space phase delay between the elements, so basic array theory leads to the conclusion that the main beam of the array will be in the direction of the director elements. Adding more reflector elements to the left of the feed has little effect on the array, since radiation is predominantly along the director elements.

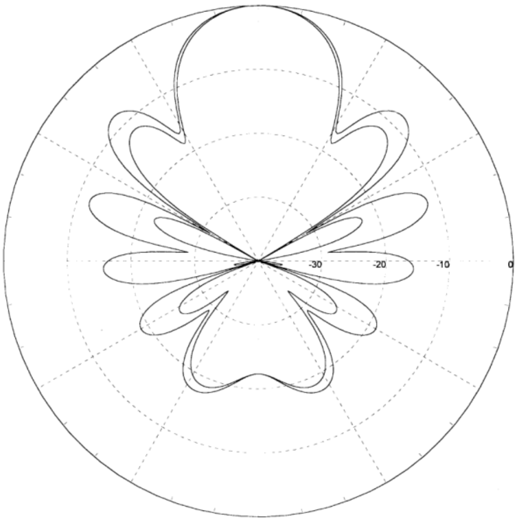


Figure 3.2 Calculated radiation patterns of a 14-element Yagi–Uda dipole array antenna. The outer curve is the H-plane pattern; the inner curve is the E-plane pattern. The array is positioned vertically, with the directors on the top.

An increase in the number of directors increases the directivity of the array, although this increase reaches the point of diminishing returns after about 10–15 director elements. figure 3.2 shows calculated radiation patterns for a Yagi–Uda array having 12 directors.

A new approach of tracking radio tags using autonomous unmanned vehicle (UAV) offers a number of advantages such as better line-of-sight, terrainindependence and faster localization [19]. To improve the detection performances and range as well, authors suggested to use a sophisticated radio tags with high signal.

Other researcher proposed a method using wireless sensor network using GPS for monitoring a wildlife animal. Their suggestion is to construct a rapid prototype of targeted network before establishing a large scale wildlife monitoring network. Compared with existing approaches, it is more scalable and could better facilitate wildlife tracking [4].

In the land radio communication scenario, the wave propagation behaviors in forest and vegetation area have to take into account. Researchers from military Institute of Engineering, Brazil presented a relationship of path loss versus distance and frequency and are compared to Tamir's model [20]. Tamir's model is the most referenced analytical methods to calculate the HF and VHF radio propagation loss in forests [21] as shown in figure 3.3.

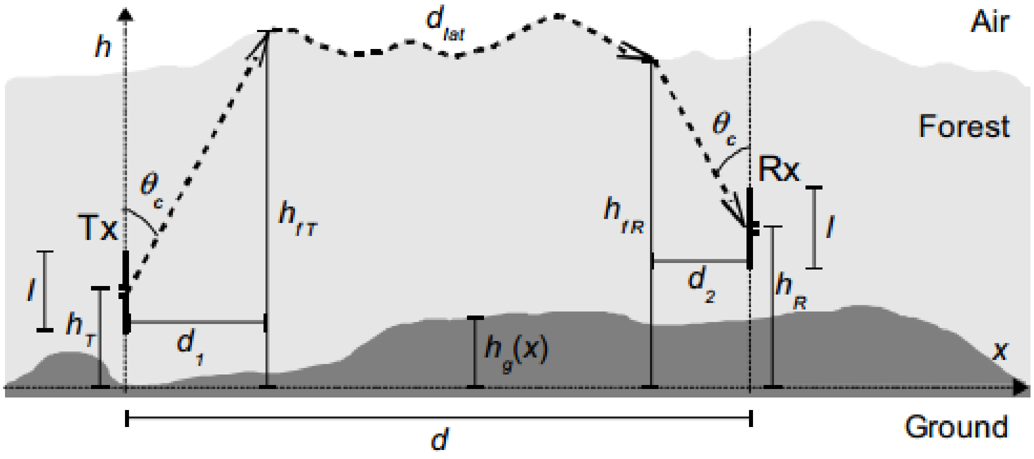


Figure 3.3 Adaptation of Tamir's concept of lateral wave for irregular terrain and Canopy, with the most significant propagation path indicated (dashed line)

CHAPTER 4

METHODOLOGY

Very High Frequency (VHF) technology was the earliest modality used for tracking and identifying individual wild animals electronically. The first successfully tested system was demonstrated in 1963. However in this research, Ultra High Frequency (UHF) has been used for frequency 315MHz in a range 300MHz to 3GHz. While a VHF band is from 30MHz to 300MHz. A UHF tracking system consists of two components – the transmitter (mounted on the animal) and the remote receiver (Yagi Antenna).

4.1 Transmitter

According to the data sheet (see appendix D), a data signal from HT12E encoder can be transmit using RF transmitter module with operating voltage between 2.4 volt to 12 volt. For the HT12E encoders, transmission is enabled by applying a low signal to the TE pin. Then a data will be sent to D_{out} on pin 17. Then a signal transmit through a wire antenna at RF Transmitter Module. The artwork Printed Circuit Board and a complete transmitter shown in figure 4.1 and figure 4.2

By using equation 4.1, a wavelength, $\boldsymbol{\lambda}$ for a Yagi antenna is 0.95 meter can be determined for a frequency 315MHz.

$$\boldsymbol{\lambda = \frac{C}{f}} \tag{4.1}$$

$C - Speed\ of\ light$

$f - frequency\ of\ transmitter$

$\lambda - wavelength\ of\ this\ frequency$

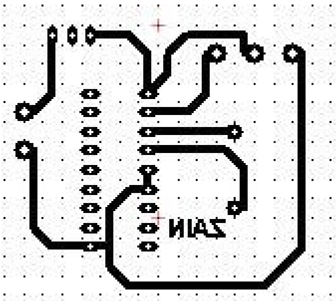


Figure 4.1 Transmitter circuit on PCB

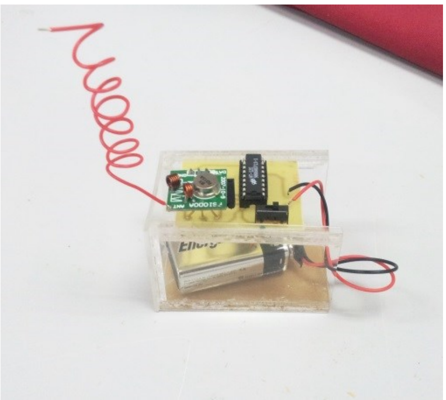


Figure 4.2 A transmitter with 315MHz frequency

4.2 Yagi Antenna Design

One of the most popular directional antenna is a Yagi-Uda antenna. There are a lot of software used to design a Yagi antenna including YagiCAD6 6.2 designed by Paul McMahon. Therefore, a basic information must calculate before using this software.

This design is based on National Bureau of standard (NBS). In designing a Yagi antenna, the following basic information is required and it will depend upon on individual requirements.

1. Frequency of operation, f(wavelength, λ)
2. Antenna gain required, G (dB)
3. Diameter of parasitic elements used in construction , d/λ
4. Diameter of supporting boom used in construction, D/λ

In designing of a 5-elements, 0.8λ Yagi antenna for frequency 315MHz with gain about 9.2dBm (table 2.3). The elements shall be constructed of 0.0032 m diameter of copper with the boom of 0.02m diameter of plastic conduit. A step by step procedures are;

Frequency 315 MHz, $\lambda = \frac{\mathrm{c}}{\mathrm{f}} = \frac{3.0x10^8}{316x10^6} = 0.95\mathrm{m}$

Elements diameter, d = 0.0032m= $0.95m$

$$\frac{d}{\lambda} = \frac{0.0032}{0.95} = 0.003362$$

Boom diameter, D =0.02m

$$\frac{D}{\lambda} = \frac{0.02}{0.95} = 0.0210$$

By referring to table 2.3

Element spacing $S_R=S_D = 0.2\lambda = 0.2\ (0.95m) = 0.19m \approx 0.2\mathrm{m}$

Overall length ,$\cong 0.8\lambda = 0.8 \times 0.95m = 0.76m$

For step 1 is the length of the parasitic elements obtained from table 2.3 for 0.8λ long yagi antenna on corresponding curve in figure 2.6. For clarify, these curves are reproduced in figure 4.3. Points $L_{D1}= L_{D3}$, L_{D2}, L_R are established and the parasitic element lengths determined for d/λ =0.0085. Thus

$L_{D1}= L_{D3}= 0.428\lambda$

$L_{D2} = 0.424\lambda$

$L_R = 0.482\lambda$

The next step is referring to this design for frequency 315 MHz where the element diameter to wavelength ratio d/λ = 0.0033, then the point is plotted and established on the director curve and indicated by mark (x) shown in figure 4.3. This is the uncompensated director length of $D_1=D_3=0.406\lambda$.

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