FRACTAL KOCH ANTENNA FOR INDOOR TV AND FM RECEPTION

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ABSTRACT

Many resources in the internet guide user to build an easy to construct and simple homemade TV and FM antenna. The antenna are just using some recycle materials and just two conductor such as copper wire as a dipole antenna. Since TV channel and FM is still in Very High Frequency (VHF) frequency band from 47MHz to 230MHz and Ultra High Frequency (UHF) frequency band from 470MHz to 798MHz, the maximum antenna height will be very long around 3 meters. Hence, half wavelength dipole antenna using Fractal Koch Curve technique was designed in order to miniaturize the antenna height with a given total surface area or volume. The standard dipole, Koch Curve Dipole Antenna with one iteration and 2 iteration was analysed and optimized at VHF and UHF using 3D simulator software Computer Simulation Technology (CST). Dipole with the Koch Curve iteration 1 and 2 has shown at least 11.87% and 16.1% reduction in size as compared to the standard dipole which have the same resonant frequency with a return loss magnitude less than -10dB.

ABSTRAK

Pelbagai sumber di internet memberi panduan kepada pengguna untuk membina antena TV dan FM buatan sendiri yang mudah dibuat. Antena tersebut hanya menggunakan bahan-bahan terpakai dan kitar semula dan hanya menggunakan 2 konduktor seperti wayar kuprum sebagai antena dwikutub. Kepanjangan antenna maksimum adalah lebih kurang 3 meter kerana frekuensi saluran TV dan FM berada dalam jalur frekuensi 'Very High Frequency (VHF)' iaitu dari 47MHz hingga 230MHz dan jalur frekuensi 'Ultra High Frequency (UHF)' iaitu dari 470MHz hingga 798MHz. Oleh itu, antena dwikutub separuh panjang gelombang dengan menggunakan teknik 'Fractal Koch Curve' telah direka untuk mengurangkan kepanjangan antena dwikutub dengan jumlah keluasan atau isipadu yang diberikan. Antena dwikutub yang lazim, antenna dwikutub 'Koch Curve' dengan satu lelaran dan dua lelaran telah dianalisis dan dioptimumkan pada VHF and UHF menggunakan perisian simulator 3D Computer Simulation Technology (CST) . Antena dwikutub 'Koch Curve' dengan satu lelaran dan dua lelaran telah menunjukkan pengurangan saiz sekurang-kurangnya 11.87% dan 16.1% berbanding dengan antenna dwikutub yang mempunyai frekuensi resonan yang sama dengan magnitud kehilangan balikan kurang dari -10dB.

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CHAPTER 1

INTRODUCTION

1.1 Research Background

Despite the development of the internet, television and radio is still one of the most important sources of information. It plays such a significant role in our lives that it is hard to imagine how our lives will be if there were no television and radio.

Nowadays, broadcasting stations such as Astro provide the subscribers to enjoy radio channel too. Hence, with only television sets, we can enjoy it as a radio. Television has been a part of our lives ever since. No matter how technology evolved in the past years, giving people more and more choices for their entertainment purposes, nothing can really substitute the television roles. It is impossible to find one single home that is without a television set.

Watching movies together with family members and listening to songs has been one of the favourite things that people love to do these days. Some people also made watching TV shows or dramas as their habit especially to those that cannot miss an episode of it. Hence, to have a good TV and FM radio reception signal is really necessary. The best way to achieve it is to have a better reception antenna that has the ability to obtain the best TV signal.

To receive the transmission signal from TV and FM broadcasting station, an antenna capable of receiving the VHF/UHF and FM frequencies is required. Many different creative designs of indoor antennas were developed such as bow-ties [1], yagis [2-4] and log-periodic antennas [5]. Due to cost saving, some of the antennas are developed using recycle material such as paper clip, milk tetrabrick, foam an metallic can [6].

Most of the do-it-yourself (DIY) hobbyist claims that simple and the most easy to construct TV antenna is using dipole antenna concept where the operating frequency is depend to the electrical length [7]. For UHF antenna, most of the design in the internet use around 7 inches to 9 inches. However, the wavelength of the VHF is much longer than UHF. Hence, the main concern of this project is to reduce the antenna size with a given total surface area or volume.

1.2 Problem statement

Nowadays, there are many simple and cheap antenna designs collection available in the internet. Most of the do-it-yourself hobbyists claim that the antenna perform well in receiving the signal but did not mention how good is the antenna reception in terms of gain, bandwidth and other antenna parameters. The conventional TV receiving antenna is quite large. Hence, this project attempts to shrunken the antenna size and addresses these missing parameters of a particular design to analysis the antenna performance.

1.3 Objectives

The objectives of this project are as follows:

i. To miniature the standard dipole antenna.
ii. To simulate the designed antenna for television and FM signal frequency bands
iii. To evaluate or identify the designed antenna performance in terms of antenna parameters.

1.4 Scopes

The scopes of this project are to:

i. Design the antenna based on previous similar works or available on the internet by do-it-yourself (DIY) hobbyists collection using antenna design software.

ii. Simulate the proposed antenna for VHF frequency band from 47MHz to 230MHz and UHF frequency band from 470MHz to 798MHz using antenna design software.

1.5 Organization of the Project Report

This project report consists of five chapters describing all the work done in the project. The project report organization is generally described as follows.

The first chapter explains the introduction and the motivation of the project. This chapter sets the work flows according to the objectives and scope of project.

Chapter two describes various antenna properties and terms associated with it, types of antennas, theories of dipole and the fractal structure for antennas. It also discussed the equation needed to design the proposed dipole antenna.

Chapter three discuss the steps on designing the proposed fractal dipole antenna, the software used for design and simulation, the structure of the designed antennas and the measurement techniques.

Result and analysis are presented in chapter four to compare the performance of all the designed antennas.

The last chapter highlights the overall conclusion of the project with future work suggestion to improve the design of the antenna. The project is summarized in this chapter to give general achievements and the future improvements can be made by other researchers in the future.

CHAPTER 2

LITERATURE REVIEW

2.1 Antenna

An antenna is a usually metallic device such as a rod or wire for radiating or receiving radio waves while the *IEEE Standard Definitions of Terms for Antennas* (IEEE Std 145–1983) defines the antenna or aerial as “a means for radiating or receiving radio waves.” In other words, the antenna is the transitional structure between free-space and a guiding device. The guiding device or transmission line may take the form of a coaxial line or a hollow pipe (waveguide), and it is used to transport electromagnetic energy from the transmitting source to the antenna or from the antenna to the receiver [8].

2.2 Frequency Allocation

TV signals can be broadcast over two different frequency ranges either Very High Frequency (VHF) or Ultra High Frequency (UHF) while the FM radio frequencies is within the VHF frequency range. The VHF TV channel range is from 2 to 13 while the UHF range is from channel 14 to 83. The frequency division for the TV and FM radio is given in the **Figure 2.1** and is summarized in the **Table 2.1, 2.2, 2.3** and **2.4**.

Table 2.1: VHF TV Broadcasting (Band I) Frequency Channels

Channel Number	Frequency Band (MHz)	Remark
2	47 – 54	Gunung Ulu Kali and Bukit Palong
3	54 – 61	Bkt. Tampalagus, Bkt. Penawar and Gunung Pulai
4	61 – 68	Bkt. Palong and Gunung Ledang

Table 2.2: VHF TV Broadcasting (Band III) Frequency Channels

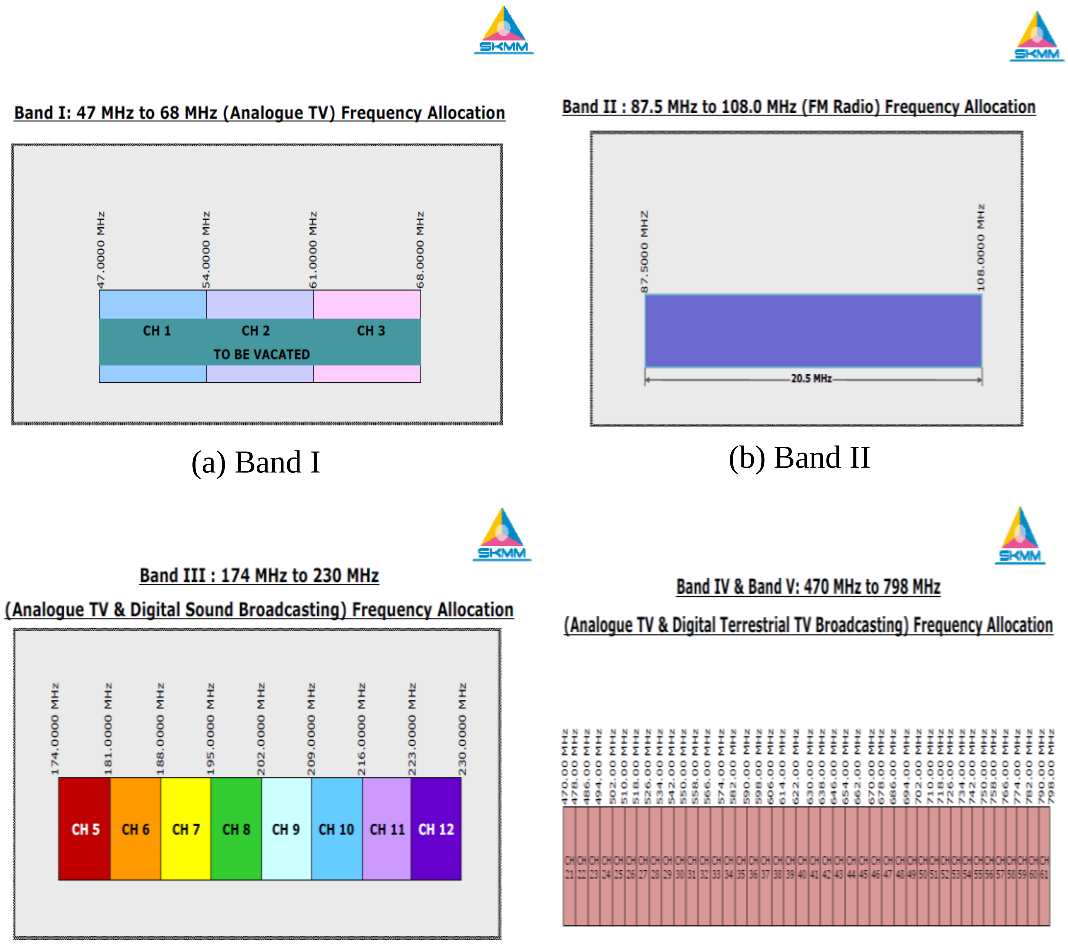
Channel Number	Frequency Band (MHz)	Remark
5	174 - 181	Existing analogue TV are to be shared with Digital Sound Broadcasting services until 2015.
6	181 - 188	
7	188 - 195	
8	195 – 202	
9	202 – 209	
10	209 – 216	
11	216 – 223	
12	223 - 230	

Table 2.3 : UHF Mobile services

Channel Number	Frequency Band (MHz)	Remark
21	470– 478	Currently shared by the analogue mobile and analogue TV. Planned fordigital TV in 2025.
22	478 - 486	
23	486 - 494	
24	494 - 502	
25	502 - 510	

Table 2.4 : UHF Television Broadcasting Frequency Channels

Channel Number	**Frequency Band (MHz)**	**Channel Number**	**Frequency Band (MHz)**
26	510 – 518	44	654 – 662
27	518 – 526	45	662 – 670
28	526 – 534	46	670 – 678
29	534 – 542	47	678 – 686
30	542 – 550	48	686 – 694
31	550 – 558	49	694 – 702
32	558 – 566	50	702 – 710
33	566 – 574	51	710 – 718
34	574 – 582	52	718 – 726
35	582 – 590	53	726 – 734
36	590 – 598	54	734 – 742
37	598 – 606	55	742 – 750
38	606 – 614	56	750 – 758
39	614 - 622	57	758 – 766
40	622 - 630	58	766 – 774
41	630 - 638	59	774 – 782
42	638 - 646	60	782 – 790
43	646 - 654	61	790 – 798



(a) Band I

(b) Band II

(c) Band III

(d) Band IV and V

Figure 2.1: The Malaysia Television Channel Allocations and FM Radio Frequency Band [9]

2.3 Antenna Parameters

Several important antenna characteristics should be considered when choosing a reception antenna which as follows:

2.3.1 Resonant Frequency

The operating frequency is the frequency range through which the antenna will meet all functional specifications. It depends on the structure of the antenna in which each antenna types has its own characteristic towards a certain range of frequency. The operating frequency can be tuned by adjusting the electrical length of the antenna.

Hence, the antenna is different in size to receive signals at the correct wavelength due to different frequencies.

2.3.2 Return Loss (RL)

Return Loss represents the amount of power which is reflected back to the source due to impedance mismatching. It is a ratio of electric field strength of the reflected wave to incident wave. It is usually expressed as a ratio in dB. Hence, the value of return loss should be as small as possible.

For example, - 20dB is better than -10dB. We defined that the standard merit of RL is -10dB. Return loss can be expressed in dB as follow:

$$\text{Return loss (dB)} = -20\log_{10}|\Gamma| \text{ and } \Gamma = \frac{V^-}{V^+} \qquad (1)$$

where V^- and V^+ are incident and reflected wave, respectively.

2.3.3 Voltage Standing Wave Ratio (VSWR)

Voltage standing wave ratio is also measure of the impedance mismatch between the transmitter and the antenna. For example, if the antenna is not match, some of the power would be reflected back and it would produce a standing waves. The equation is :

$$\text{VSWR} = \frac{1+|\Gamma|}{1-|\Gamma|} \text{ and } \Gamma = \frac{V^-}{V^+} = \frac{Z_{in}-Z_s}{Z_{in}+Z_s} \qquad (2)$$

Γ is reflection coefficient where Z_s and Z_{in} are transmitter and antenna impedance. Practically, input impedance is either 50Ωor 75Ω.

VSWR must be less than 2 to ensure the antenna is in good performance.

2.3.4 Bandwidth

It means the usable frequency range with reasonable performance and specified standard. It is usually defined as the frequency difference between the highest and lowest frequency with specified standard and divided by the center frequency. Normally, is at -10dB.

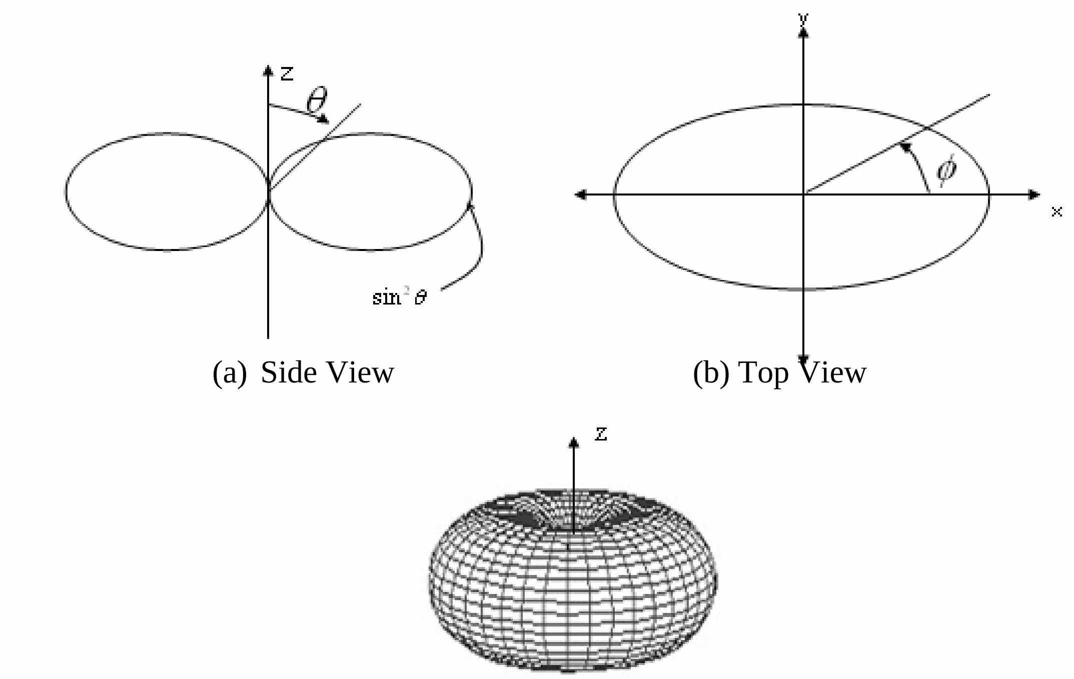
$$\text{Bandwidth}(\%) = \frac{f_H - f_L}{(f_H + f_L)/2} \times 100\% \qquad (3)$$

where f_H and f_L are upper and lower frequency at -10dB.

2.3.5 Radiation Pattern

An antenna radiation pattern or antenna pattern is defined as a mathematical function or a graphical representation of the radiation properties of the antenna as a function of space coordinates [1]. An antenna radiation pattern is a 3-D plot of its radiation far from the source or known as the far field region.

Antenna radiation patterns usually take two forms, the elevation pattern and the azimuth pattern. The elevation pattern is a graph of the energy radiated from the antenna looking at it from the side as can be seen in Figure 2.2(a). The azimuth pattern is a graph of the energy radiated from the antenna as if looking at it from directly above the antenna as illustrated in Figure 2.2(b). The combination of the two graphs shows the 3-D representation of how energy is radiated from the antenna (Figure 2.2(c)).



(a) Side View (b) Top View

(c) 3D

Figure 2.2**:** Radiation Pattern of an Antenna [10]

2.3.6 Power Gain

The power gain of an antenna is a ratio of the power input to the antenna to the power output from the antenna. This gain is most often referred to with the units of dBi, which is logarithmic gain relative to an isotropic antenna. An isotropic antenna has a perfect spherical radiation pattern and a linear gain of one.

2.3.7 Directivity

The directive gain of an antenna is a measure of the concentration of the radiated power in a particular direction. It may be regarded as the ability of the antenna to direct radiated power in a given direction. It is usually a ratio of radiation intensity in a given direction to the average radiation intensity.

2.4 TV Antenna

Until now, there is no manufacturer that dares to claim that their antenna able to deliver excellent TV reception in every location. The main factors are the distance and direction from the TV station transmitters to the received location. Besides that, the other factors such as the transmitter's power and the height of its tower, the terrain between the tower and the antenna, and the size and location of any large buildings in the path of the transmission.

If the received location is a few kilometres from the transmitter and the signal path is relatively unobstructed, we may be able to get adequate reception using a small set-top indoor antenna. But as the location farther away, obtaining the usable signal strength becomes trickier. This is where careful antenna selection and installation become essential.

There are many different creative designs of UHF indoor antennas [11-13]. As long as VHF reception is considered, all indoor antennas are nearly the same. VHF band occupied the larger wavelength portion of the electromagnetic spectrum which requires larger antenna elements. VHF antennas have to be much larger than their UHF counterparts for satisfactory reception. Hence, mostly all indoor VHF antennas are some form of rabbit ears. Some antennas only provide good reception of VHF or UHF channels, but not both. For example, indoor “rabbit ears” usually need to be augmented with an additional “wire loop” or “bowtie” antenna in order to pick up signals on UHF channels as shown in **Figure 2.3**.

Figure 2.3**:** Simple indoor antennas will usually be sufficient for locations having strong TV signals [14]

Spotty reception is a common problem for the indoor antenna. It can be reduced by moving the antenna around when switching channels. Indoor antenna is different with outdoor antenna where it has limitation on space or environment. An indoor antenna almost never has a line of sight (LOS) to the transmitting towers. It always receives an echo, a reflected signal that bounces off the surroundings and off the house walls or known as multipath. The path and strength of the reflected signal highly depends on weather, time of a day and frequency. One may have good reception of channel A in a particular spot but not for the channel B because signals of two different channels, being at different frequencies, do not follow the same path even if transmitted from the same site.

The gain of a TV antenna indicates the relative strength of signal it can deliver to a receiver. The higher the TV antenna gain, the stronger the signal at the antenna output terminals.

Directivity is the ability of an antenna to intercept signals from only one direction and reject those from other directions. Directivity indicates the TV antenna’s ability to intercept signals arriving at its front and reject signals coming from the sides and rear. Generally, the more highly directive an antenna, the better it can reject signals from the sides and rear.

The front-to-back ratio of an antenna can be helpful when attempting to determine its directivity. Front-to-back ratio is expressed in decibels (dB) and it indicates an antenna's ability to reject signals coming from the rear. For example, a TV antenna with a front-to-back ratio of 25 dB will receive about 18 times more signal strength from the front than from the back.

Beamwidth of an antenna can affect its directivity. Beamwidth is related to an TV antenna's overall gain and indicates how wide or narrow the antenna's reception area is. For example, if two TV antennas have the same front-to-back ratio, the one with the highest overall gain will have the narrowest beamwidth and consequently, will be the most directive. An antenna with a relatively narrow beamwidth generally is best suited for areas where interference from sides is a problem. An antenna with a broad beamwidth is best suited for areas where a broad beam is needed to capture the signals from widely separated stations, and where interference is minimal. Beamwidth information is usually displayed by use of polar plots.

2.5 Half Wavelength Dipole Antenna

The half-wavelength dipole is a balanced antenna consisting of two radiators that depicted in Figure 2.4. Each arm length is quarter-wavelength, making a total of a half-wavelength. The antenna is usually installed horizontally with respect to the earth's surface, so it produces a horizontally polarized signal.

The length of the antenna is a half-wavelength. Keep in mind that the physical length of the antenna, and the theoretical electrical length, is often different by about 5 percent. A free-space half-wavelength is found from:

$$\lambda = \frac{492}{f(MHz)} \text{ (feet)} \qquad (4)$$

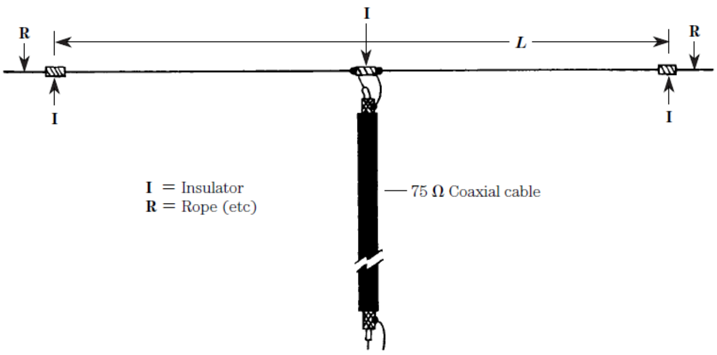


Figure 2.4: Simple Half Wavelength Dipole [15]

The average physical length is shortened by up to about 5 percent because of the velocity factor of the wire and capacitive effects of the end insulators. A more nearly correct approximation of a half-wavelength antenna is:

$$\lambda = \frac{468}{f(MHz)} \text{ (feet)} \qquad (5)$$

Where *L* is the length of a half-wavelength radiator, in feet
f (MHz) is the operating frequency, in megahertz

2.6 Previous Work

i. Compact Folded Dipole Antenna for DTV Signal Reception [16]

A compact simple folded dipole antenna was proposed for digital television (DTV) signal reception in the 470 - 850MHz (UHF) band is proposed. The antenna consists of two metal thin meander lines and narrow rectangular radiating patches. It was feeded by 50-Ω SMA connector and printed on a dielectric substrate FR4. The designed antenna has only compact volume with 80 *x* 28 *x* 0*:*4 mm^3. The antenna can be excited to provide a wide bandwidth (-5 dB return loss) of larger than 55%.

ii. Wall-Hanging Type of Self-Complementary Spiral Patch Antenna for Indoor Reception of Digital Terrestrial Broadcasting [17]

A printed spiral antenna with a self-complimentary configuration was developed. It consists of spiral shaped metal strips and slots provided on ground planes as their counterparts. For balanced and unbalanced feeds, two types of antenna configurations such as single and twin spirals were fabricated and their antenna performances were investigated. From evaluation of carrier noise ratio of digital terrestrial broadcasting channels at UHF band, it was confirmed that the presented self-complimentary spiral antenna has capability to apply into an indoor terrestrial broadcasting TV antenna.

iii. Log Periodic Fractal Koch Antenna For UHF Band Applications [18]

The proposed antenna was a Log Periodic Fractal Koch Antennas (LPFKA) for Ultra High Frequency (UHF) band applications. Three designs using different numbers of iterations were proposed. Using fractal Koch technique, the size of the antenna can be reduced up to 27% when the series iteration is applied to the antennas without degrading the overall performances.

iv. Multimode Multiband (VHF/UHF/L/802.11a/b) Antennas for Broadcasting and Telecommunication Services [19]

The proposed antennas composed three different types and contact with a portable media player (PMP) case with ε_r which was used as a substrate for the compact design. Also, the designed antennas have good impedance matching and radiation characteristics for Digital Video Broadcasting-Terrestrial (DVB-T) service of VHF (174–230 MHz) band, Digital Video Broadcasting-Handheld (DVB-H) service of UHF/L (470–862 MHz/1452–1492 MHz) bands and also wireless local area network (WLAN) service of IEEE 802.11b/a (2.4–2.5 GHz/5.15–5.825 GHz) bands.

v. Ultra Wideband Fractal Microstrip Antenna Design [20]

New fractal geometry for microstrip antennas was presented on hexagonal and several iteration was applied on initial shape. This antenna has low profile, lightweight and was easy to be fabricated and has successfully demonstrated multiband and broadband characteristics. It was applied in all frequencies (0.1 GHz–24 GHz) and the the $S_{11} < -10$ dB and VSWR <2. The simulated results showed that proposed antenna has very good performance.

2.7 Fractal Antenna

2.7.1 Introduction

Fractal means broken or irregular fragments. Fractal antennas can obtain radiation pattern and input impedance similar to a longer antenna, but take less area due to the many contours of the shape. It uses a self similar design to maximize the length, or increase the perimeter of material that can transmit or receive EM radiation with a given total surface area or volume [21].

Conventional antenna operates at a single or dual frequency bands, where different antennas are needed for different applications. Fractal shaped antennas have been proved to have some unique characteristics that are linked to the various geometry and properties of fractals. Fractals were first defined by Benoit Mandelbrot in 1975 [18] as a way of classifying structures whose dimensions were not whole numbers.

2.7.2 Advantages

By applying fractals to antenna, it has many benefits such as

i. miniaturization or smaller antenna size,
ii. achieve resonance frequencies that are multiband, and
iii. achieve wideband frequency band.

2.7.3 Fractal Geometry

There are many fractal geometries [22-23] that have been found to be useful in developing new and innovative design for antennas. Figure below shows some of these unique geometries.

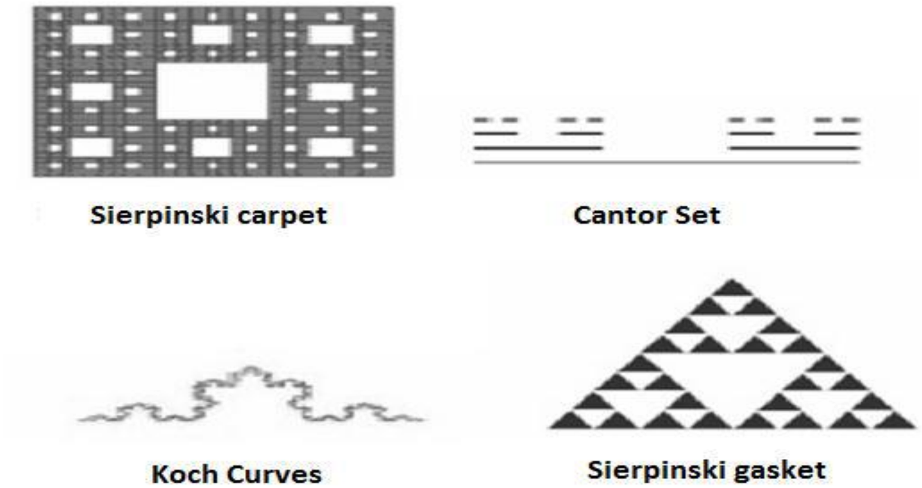


Figure 2.5: Types of fractal geometries

2.7.4 Koch Curves

The geometric construction of the standard Koch curve [21-23] is fairly simple. It starts with a straight line as an initiator. This is partitioned into three equal parts, and the segment at the middle is replaced with two others of the same length. This is the first iterated version of the geometry and is called the generator. The process is reused in the generation of higher iterations.

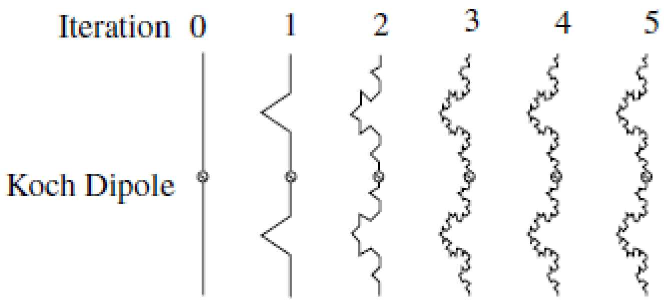


Figure 2.6: Fractal Koch Dipole for Five Iterations [8]

Each iteration will adds length to the total curve which results in a total length that is 4/3 of the original geometry.

$$\text{Length}_{\text{Koch}} = h.\left(\frac{4}{3}\right)^{n} \qquad (6)$$

Where h = length of the initiator

n = number of iterations

The miniaturization of the fractal antenna is exhibited by scaling each iteration to be resonant at the same frequency. The miniaturization of the antenna shows a greater degree of effectiveness for the first several iterations. The amount of scaling that is required for each iteration diminishes as the number of iterations increases [23].

The percentage compactness offered by the Koch curve is obtained by using the equation below [24].

$$\text{Compactness} = \left(\frac{(\mathrm{L}_1 \times \mathrm{FR}_1) - (\mathrm{L}_2 \times \mathrm{FR}_2)}{\mathrm{L}_1 \times \mathrm{FR}_1}\right) \times 100\% \qquad (7)$$

Where FR_1 and FR_2 = resonant frequencies

L_1 and L_2 = length of the dipoles

Size reduction of the antenna between straight dipole and fractal dipole can be calculated as follow:

$$Size\ Reduction = \frac{L_{sd} - L_{fd}}{L_{sd}} \times 100\% \qquad (8)$$

Where $L_{sd} = length\ of\ standard\ dipole$

$L_{fd} = length\ of\ fractal\ dipole$

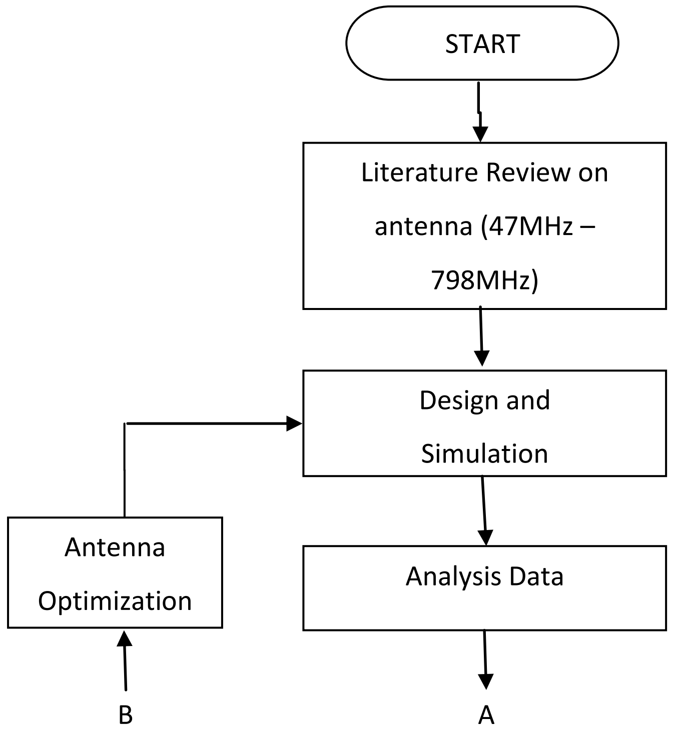
CHAPTER 3

METHODOLOGY

3.1 Introduction

This project is regarding simulation of an antenna based on previous works or available in the internet in terms of antenna parameters. Literature review on TV and radio frequencies is the most essential due to designing an antenna, while the electrical length of the antenna depends on the frequency.

In order to evaluate the designed antenna, the steps are shown in the flowchart below:



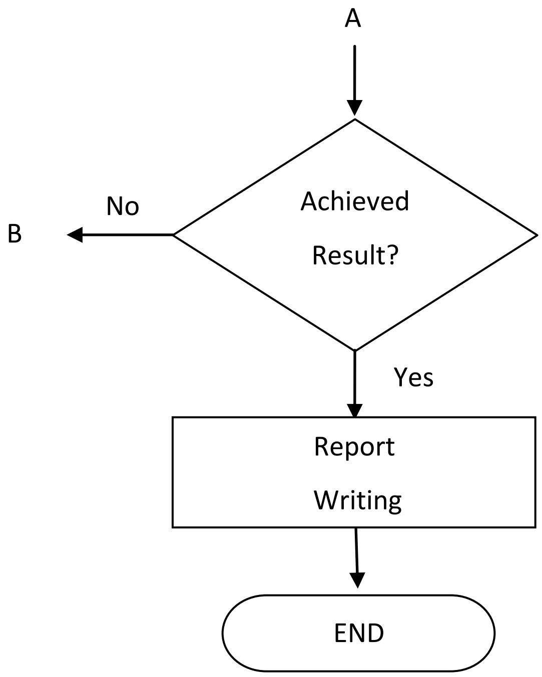


Figure 3.1: Flowchart of the Project

3.2 Frequency and Wavelength

The wavelength, λ is given by:

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

where c is the speed of light, 3.00×10^8 m/s and f is the wave's frequency.

Table 3.1: Half Wavelength (mm) for each Channel

Channel #	Centre Frequency (MHz)	Half wavelength in free space (mm)	Channel #	Centre Frequency (MHz)	Half wavelength in free space (mm)
2	50.5	2970.3	5	177.5	845.1
3	57.5	2608.7	6	184.5	813.0
4	64.5	2325.6	7	191.5	783.3
FM	88-108	1704.5-1388.9	8	198.5	755.7

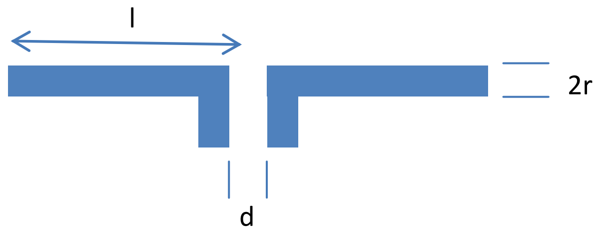
Channel #	Centre Frequency (MHz)	Half wavelength in free space (mm)
9	205.5	729.9
10	212.5	705.9
11	219.5	683.4
12	226.5	662.3
21	474	316.4
22	482	311.1
23	490	306.0
24	498	301.1
25	506	296.3
26	514	291.7
27	522	287.3
28	530	282.9
29	538	278.7
30	546	274.6
31	554	270.7
32	562	266.8
33	570	263.1
34	578	259.4
35	586	255.9
36	594	252.4
37	602	249.1
38	610	245.8
39	618	242.6

Channel #	Centre Frequency (MHz)	Half wavelength in free space (mm)
40	626	239.5
41	634	236.5
42	642	233.6
43	650	230.7
44	658	227.9
45	666	225.2
46	674	222.5
47	682	219.9
48	690	217.3
49	698	214.8
50	706	212.4
51	714	210.0
52	722	207.7
53	730	205.4
54	738	203.2
55	746	201.0
56	754	198.9
57	762	196.8
58	770	194.7
59	778	192.7
60	786	190.8
61	794	188.9

3.3 Antenna Design Dimension and Specification

From the **Table 3.1**, the wavelength of the VHF is much larger than UHF. Hence, the designed antenna for VHF is tending to be much larger in size than UHF antenna. Besides that, the variation of the wavelength in VHF channel is much more different than in UHF. Hence, the proposed antenna for the VHF antenna is using half-wavelength dipole antenna. Its length can be adjusted to the desired channel. This kind of antenna is known as Rabbit Ear.

i. Half Wavelength Straight Dipole Parameter



where l = length of the half wavelength dipole/2

2r = diameter of the wire

d = feeding gap

Figure 3.2: Structure of the Half-Wavelength Dipole

ii. Calculation

Dipole antenna was designed as resonant dipole to have a good performance. The length of the dipole for first resonance is about l = 0.47λ to 0.48λ [8]. Hence, the proposed antenna design is defined as 0.475.

$$l = 0.475(\frac{\lambda}{2}) = 0.475\frac{c}{2f}$$

The radius of the wire can be obtained by using a common copper wire.

$$r = 0.0625'' = 1.5875mm$$

The feeding gap equation will be as follow:

$$d = 1.25'' = 31.75mm$$

Hence, if the desired frequency is 57.5 MHz,

l = 2608.7 mm

r = 1.5875 mm.

d = 31.75 mm.

The following plot shows the structure of standard dipole as depicted in **Figure 3.3**. The defined parameters are listed in the **Table 3.2** below.

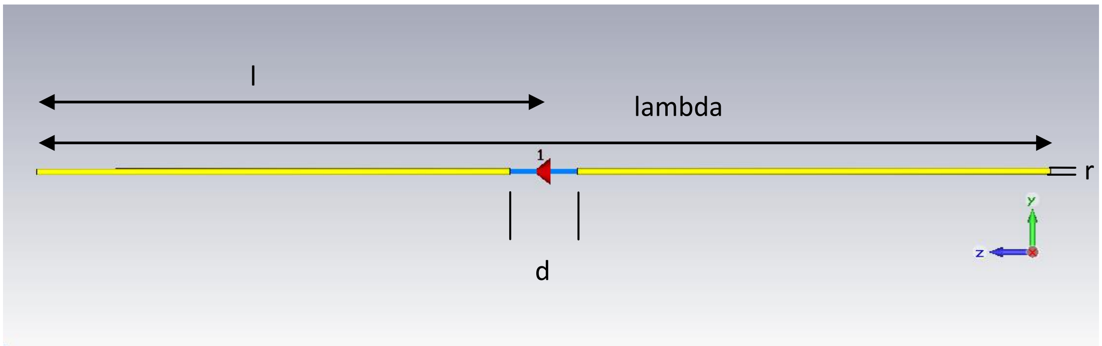


Figure 3.3: Koch Curve Dipole Antenna with Zero Iteration (Standard Dipole)

Table 3.2: Standard Dipole Antenna Parameters

Parameter	***Value***
d	31.75mm
l	0.475×lambda
Lambda	**Length of Half Wavelength Antenna
r	1.5875mm

**depend to operating frequency

In this project, it have 53 center frequencies that as listed in **Table 3.1** where TV channel have 52 channels and a FM frequency band. Hence, 4 frequencies were chosen to represent the whole project which the main purpose is to simplify and reduce the simulation time. 58 MHz is to represent the Low-VHF Frequency Band, 98 MHZ represent FM band, 202 MHz is to represent the Hi-VHF Frequency Band and 634 MHZ is to represent the UHF Frequency Band.

iii. Koch Curve Dipole Antenna

The Koch curve antenna is formed by replacing the linear arms in the dipole antenna with the Koch curve. Two Koch curve dipoles are simulated, the first one with a single iteration of Koch curve and the second with two iterations of the Koch curve geometry.

Both of the Koch curves dipole antenna are optimized in CST Microwave Studio 2009 for the same resonant frequency as the standard dipole by varying the electrical length of the antenna. The following plot shows the structure of 1st Iteration and 2nd Iteration of Koch Curve Dipole Antenna as depicted in **Figure 3.4** and **Figure 3.5**. The defined parameters for the feeder gap, d, wire radius, r was same as the standard dipole.

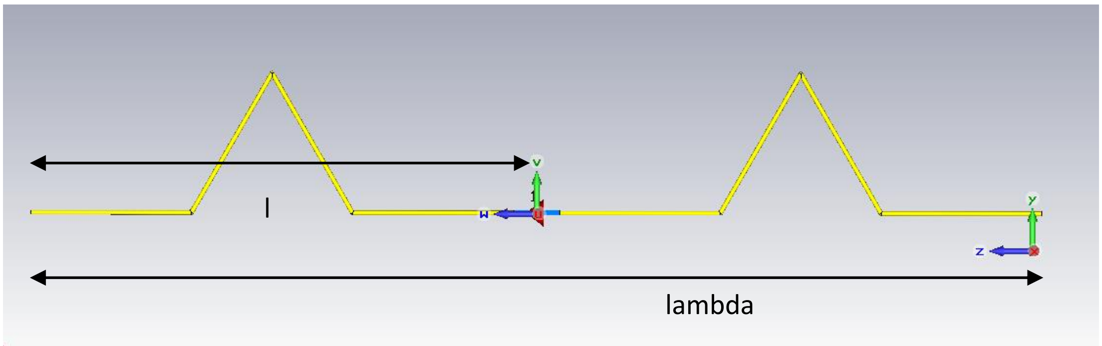


Figure 3.4: Koch Curve Dipole Antenna with One Iteration

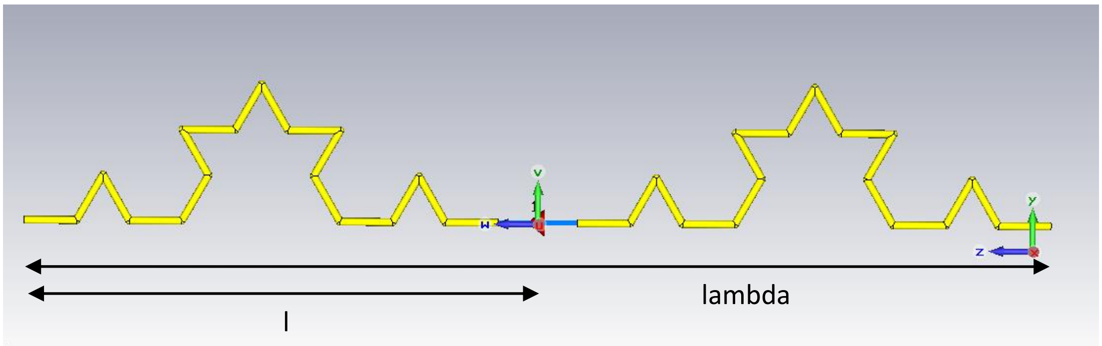


Figure 3.5: Koch Curve Dipole Antenna with Two Iterations

CHAPTER 4

DATA ANALYSIS AND RESULTS

4.1 Introduction

The results for the proposed antenna designed in this project was simulated Computer Simulation Technology, CST 2009. It was used to calculate and predict the performance of the designed antenna in terms of antenna parameters such as radiation pattern, return loss (dB) and gain. The designed antenna can be categorized as a good reception if it inhibits the following characteristics:

a. VSWR < 2

b. Return Loss < -10dB

4.2 Antenna Simulation Result for the Proposed Design Antenna with the Same Antenna Length

4.2.1 S-Parameter

The simulation results are based on the antenna design in Chapter 3. From the structure of the standard dipole antenna on **Figure 3.3**, first Iteration Koch Curve on **Figure 3.4** and second Iteration Koch Curve on **Figure 3.5**, simulation result was depicted in **Figure 4.1**, **Figure 4.2**, **Figure 4.3** and **Figure 4.4** based on its length. Length of the half wavelength antenna was stated in **Table 4.1**.

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