VERY HIGH FREQUENCY DISTILLED WATER ANTENNA

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UNIVERSITI SAINS MALAYSIA

2018

VERY HIGH FREQUENCY DISTILLED WATER ANTENNA

by

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Thesis submitted in fulfillment of the requirements for the
degree of
Bachelor of Engineering (Electronic Engineering)

JUNE 2018

ACKNOWLEDGMENT

In the name of Allah, the Most Gracious and the Most Merciful. First, I want to express my gratitude to the Most Gracious of God, for providing me numerous strength, uncountable time and opportunity to wrap up this final year project with a success.

I would like to express my sincere gratitude to my supervisor, Professor Ir. Dr. Mohd Fadzil Bin Ain, for giving me this precious opportunity to undertake this final year project entitled “Very High Frequency (VHF) Distilled Water Antenna”. He had always give me a lot of useful advices not just about the project, but also about the future life planning which is yet to come. My deepest thanks to him and my examiner, Dr. Intan Sorfina Binti Zainal Abidin for providing excellent assistance and continuous support throughout the completion of this project.

On top of that, I am sincerely grateful to my parents, Mr. Zulkifli Bin Abdul Aziz and Mrs. Nor Azian Bt Mohd Nizar for their prayers and non-stop encouragement. Without their blessing and full support, I will not be able to go until this far in my life’s journey.

I would like to extend my gratitude to the Communication Lab technicians, Mrs. Zammira Binti Khairuddin, Mr. Abdul Latip Bin Abd. Hamid and Mr. Elias Bin Zainuddin for assisting throughout this project. Lastly, I want to thank my colleagues for their support and suggestions during the difficult times that I have faced during the completion of this project.

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LIST OF ABBREVIATIONS

VHF	Very High Frequency
PVC	Polymerizing Vinyl Chloride
PCB	Printed Circuit Board
BNC	Bayonet Neill-Concelman
RCS	Radar Cross Section

HF	High Frequency
UHF	Ultra High Frequency
DRA	Dielectric Resonator Antenna
dB	Decibel
CST	Computer Simulation Technology
RF	Radio Frequency
SMA	SubMiniature version A
MHz	Megahertz

LIST OF SYMBOLS

P_S	Power received by the antenna
P_T	Power transmitted by the antenna
G_S	Gain of the receiver antenna
G_T	Gain of the transmitter antenna
d	Distance between transmitter and receiver antenna
f	Operating frequency of the antenna
τ_L	Reflection coefficient
S_{11}	Return loss

Z_{in}	Input impendence
Z_{out}	Output impendence
ε_r	Relative Permittivity/Dielectric constant
σ	Conductivity
μ_r	Relative permeability
f_1	Lower cutoff frequency
f_2	Upper cutoff frequency

ABSTRAK

Kajian ini menumpukan kepada kajian antena air, sejenis antena cecair yang istimewa yang telah menarik banyak perhatian sejak kebelakangan ini Antena air ini menggunakan air suling sebagai medium dan beroperasi pada VHF dalam jaluran frekuensi. Antena air suling yang dicadangkan boleh menjadi alternatif kepada antena tradisional untuk pelbagai aplikasi terutamanya dalam bidang ketenteraan, sistem komunikasi marin dan komunikasi jarak dekat bagi pesawat. Objektif utama dalam kajian ini adalah untuk merekabentuk, membina dan menguji antena air suling VHF. Bekas antena air terdiri diperbuat daripada bahan PVC. Dua tiub PVC yang berlainan diameter digunakan dalam eksperimen ini**.** Spesifikasi tiub PVC adalah seperti berikut; ketinggian = 150 cm, ketebalan = 0.2 cm, diameter = 2.54 cm (1-inci) dan 5.08 cm (2-inci). Sekeping plat aluminium dengan spesifikasi 34 cm x 43 cm digunakan sebagai satah bumi**.** Rod tembaga sepanjang 1 m diletakkan secara kekal di dalam tiub PVC. Prestasi antena ini ditentukan dalam terma kekerapan salunan, kehilangan pulangan, lebar jalur, keuntungan dan corak radiasi. Ketinggian paras air diselaraskan dalam julat 0.25-1.5 m dengan jurang 0.25 m setiap satu. Kedua-dua antena air 1-inci dan 2-inci menunjukkan penurunan dari segi kekerapan salunan apabila paras air meningkat. Antena tersebut juga bergema dalam julat VHF bagi setiap paras air. Dapat dilihat juga bahawa jumlah isipadu air memberi kesan kepada kekerapan salunan antena air. Kehilangan pulangan yang diukur adalah semua di bawah -10 dB dan lebar jalur yang direkodkan adalah sekitar 8 - 20 MHz. Kedua-dua keuntungan dan corak radiasi diukur menggunakan frekuensi bernilai 85.362 MHz. Dua antena monopol digunakan sebagai antena rujukan semasa pengukuran keuntungan. Selepas pengiraan, keuntungan bagi antena air telah dikenalpasti iaitu dengan nilai 1.915 dB. Antena air mempunyai lebar jalur yang lebih lebar dan kehilangan pulangan yang lebih baik berbanding antena rujukan monopol. Untuk analisis corak radiasi pula, antena air 1-inci mempunyai penerimaan kuasa yang paling tinggi sebanyak - 17.82 dBm pada 280˚ dengan mengunakan 0.25 m air suling. Manakala bagi antena air 2-inci pula, penerimaan kuasa yang paling tinggi ialah -17.17 dBm pada 20˚ dengan mengunakan 0.5 m air suling. Secara keseluruhannya, iamya dapat disimpulkan bahawa antena air suling VHF menunjukkan prestasi yang baik dengan kekerapan saluran yang tinggi, kehilangan pulangan yg baik dan lebar jalur yang lebar**.**

ABSTRACT

This research is focused on the study of water antennas, a type special type of liquid antenna that has drawn a lot of attentions recently. The water antenna utilized distilled water as the medium and operate within the VHF band. The proposed distilled water antenna can be an alternative to traditional antenna for many applications especially in a military field, marine communication system, and aircraft short range communication. The main objective of this research is to design, fabricate and test a VHF distilled water antenna. The container of the water antenna is made up from a PVC material. Two different diameters of PVC tubes are used in the experiment. The specifications of the PVC tubes are; height = 150 cm, thickness = 0.2 cm, diameter = 2.54 cm (1-inch) and 5.08 cm (2-inch). An aluminium plate with a dimension of 34 cm x 43 cm is used as the ground plane. A 1 m brass rod is permanently placed inside the PVC tube. The performance of the antenna is determined in terms of resonant frequency, return loss, bandwidth, gain and the radiation pattern. The height of water level is adjusted within the range of 0.25-1.5 m with a 0.25 m gap each. Both 1-inch and 2-inch water antenna showed a decrease in terms of resonant frequency when the water level is increased. The antenna also resonated within the VHF range for each water level. It is also observed that the volume of water affects the resonant frequency of the water antenna. The return losses measured are all below -10 dB and the recorded bandwidth are around 8 - 20 MHz. Both gain and radiation pattern are measured using a frequency of 85.362 MHz. Two monopole antennas are used as the reference antenna during the measurement of gain. After calculation, the gain of the water antenna has been identified with a value of 1.915 dB. The water antenna also has the wider bandwidth and a better return loss compared to the reference monopole antenna. For the analysis of radiation pattern, the 1-inch water antenna has the highest received power of -17.82 dBm at 280˚ using 0.25 m distilled water. While for 2-inch water antenna, the highest received power is -17.17 dBm at 20˚ using 0.5 m distilled water. Overall, it can be concluded that the VHF distilled water antenna shows a good performance with high resonant frequency, good return loss and a wide bandwidth.

CHAPTER 1

INTRODUCTION

1.1 Research Background

Antenna is undoubtedly one of the most frequent device that have been used by the human kind. We are depending too much on antennas and we are using it almost every single time. From the invention of antenna, it leads to the existence of abundant kind of technologies. There are a lot of electronic devices which we are using right now that have relation with antennas for an instance, laptops, cellphones, radios and others more. It is deniable that antennas played a huge and important role in human's daily life activities.

Water antenna is now recognized all over the world. It is one of the examples of liquid antenna. Water antenna is preferable due to its advantages which are inexpensive and accessible [1]. According to Lei et al. [2], there are now several water antennas that have been invented for example a monopole water antenna, a broadband water antenna and a broadband saline-water antenna. These water antennas specialized with some advantages which are compact in size, tunable, high conformability, portable, inexpensive and not polluting the environment.

The water antenna can be divided based on different working mechanisms. The water antenna can either be considered as a conducting antenna, a hybrid antenna or a water loaded antenna based on their working operations. The mechanism involved are tuning the salt concentration, integrating the radiating and feeding structure or by mixing water as a high dielectric medium with the air.

As studied by Lei et al. [3], a monopole water antenna combines two different properties of water which are conductivity and permittivity. At different conductivity, the antenna may act as a dielectric resonant antenna. When the properties are evenly combined, the efficiency of the water monopole antenna is 100 %. By adding salt into the water, the conductivity can be altered. The foam base plays an important role in this water antenna. Other than needed as to avoid any short circuit, it is also increases the bandwidth of the antenna.

This project will be focused on the fabrication and designing of the distilled water antenna for very high frequency (VHF) radio communication system. A polymerizing vinyl chloride (PVC) is used as the cylinder. Inside the cylinder, there is brass feeder that is connected to the conductor of BNC cable. At other end of the cable, a male BNC connecter is used for connection to the RF equipment. An aluminium plate acts as the ground plane and been placed below the container. The operating frequency of the water antenna can be altered by adjusting the height and volume of the distilled water in the container. If necessary, the dielectric can be inserted to avoid any short circuit in the distilled water antenna.

1.2 Problem Statement

First of all, it is crucial to determine the ideal specifications in order for the water antenna to operate within the VHF band. Thus, further investigations are conducted by varying the height of water level and diameter of the water antenna. In military field, communication devices are as important as their weapons. The VHF communication system is very important for long distance communication especially for tactical based camp for army. For them to access an easy movement especially in jungle, a simple and easily made antenna system is required. Therefore, it will be a challenge to reduce the size and weight of the water antenna, to enable smaller units to quickly rush anywhere in the world and achieve high-bandwidth connectivity. In the jungle, there are lot of interferences that can distort the signal transmitted by the water antenna. The abundant of tress, leaves and humidity can be the resistance factor to the signal. Other than that, the material used to fabricate the water antenna are very important. A water proof, inexpensive and durable material is required to prevent any quick damage to the water antenna. Moreover, it is found that most of the discovered water antennas were operating in a frequency higher than VHF. Thus, there would be a lack of substantial result regarding the water antennas in the VHF range. Horn antennas are important to measure some of the antenna's parameters such as gain and radiation pattern. The horn antennas that are available in the Communication Lab have a high operating frequency which are not within the VHF range. Therefore, new reference antennas need to be fabricated to replace the horn antenna. As the antenna is utilizing water as the medium, the problem of water leakage is most likely to happen. Hence, several solutions need to be identified first as a precaution step. As most of the water antenna from the previous works operate in a frequency band above than VHF, suitable RFs equipment are also required so that the performance of the VHF water antenna can be measured effectively.

1.3 Objectives

The objectives of this project are listed as below:

1. To design and fabricate a distilled water antenna that can operate in VHF band.
2. To fabricate two monopole reference antennas that can operate within VHF range to replace the horn antennas.
3. To measure the performance and characteristic of the water antenna in terms of resonant frequency, return loss, bandwidth, gain and radiation pattern.

1.4 Scope of Research

The aim of this project is to design and fabricate a distilled water antenna that can operate in a VHF band. The prototype is built based on some researches and calculations regarding the materials that need to be used, specification of the materials and effect of the materials to the antenna. As the water antenna is going to be implemented by the army platoon in the jungle, the environmental factors need to be considered such as humidity, trees and other else. These external factors will surely affect the performance of the water antenna to be less efficient. The VHF water antenna can be made with light weight, however to shrink its size is quite impossible. To achieve a low frequency like VHF, a high level of water is required, thus indicating that the container need to be tall or big in size. After consideration, the variables that will affect the performance of the water antenna are the height of water level and the diameter of water antenna.

1.5 Thesis Outline

This thesis is organized into six main chapters as listed below:

Chapter 1: Introduction

The current chapter serves to inform the reader of a brief introduction that describes the overview of project background. The chapter also include the problem statements, objectives and scope of the research.

Chapter 2: Literature Review

In this chapter, all the relevant theory, conceptual, fundamental background and related technique that has been used in the design are provided. All the important parameter regarding the antenna will be presented and discussed. A review of several previous works that has been done is also explained in this chapter.

Chapter 3: Methodology

Only hardware part is involved in this chapter. The process and working procedure are explained in this chapter. All the designs and testing process that are involved throughout this project is discussed in a more specific way. The method used to design and fabricate the water antenna is presented in this chapter. All the material, component/tool, and equipment that are used in this project are listed.

Chapter 4: Result and Discussion

This chapter consists of the experimental result that has been collected using network analyzer, signal generator, and spectrum analyzer. Analyzation and discussion are made based on the results.

Chapter 5: Conclusion

This chapter will give the summary of this project. A suggestion for the future project for distilled water antenna and its improvement will be provided at the end of this chapter.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

This chapter consists of 6 sections, starting from Section 2.1 to Section 2.6. Firstly, Section 2.1 explains the summary of Chapter 2. In section 2.2, the theoretical background of an antenna will be explained as well as the important antenna parameters. Section 2.3 will be mainly about the dielectric resonator antenna (DRA). Different type of water antenna and its mechanism will be discussed in Section 2.4. Section 2.5 will summarize the previous works of water antenna. The last section, Section 2.6 will conclude this chapter.

2.2 Theoretical Background

In this subtopic, the basic parameters that are used in designing water antenna will be discussed. In addition, the working operation of an antenna will be explained. Other than that, VHF radio spectrum, basic of antenna, parameters that specify the antenna performance and formulae that will be used in this project are also provided in this subtopic.

2.2.1 Antenna

Antenna is a vital component of any communication system which is used at both transmitting end as well as receiving end. Antenna is basically a conversion device that can either be directional or omnidirectional. At the transmitting end, it converts electrical energy into electromagnetic wave and then radiate into free space. At the receiving end, it receives electromagnetic wave and then transforms them into electrical signal which acts as input for receiver. In a simple word, no wiring is involved during the transmission of the signal. The antenna is the transitional structure between free space and a guiding device, as shown in Figure 2.1. 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 [4].

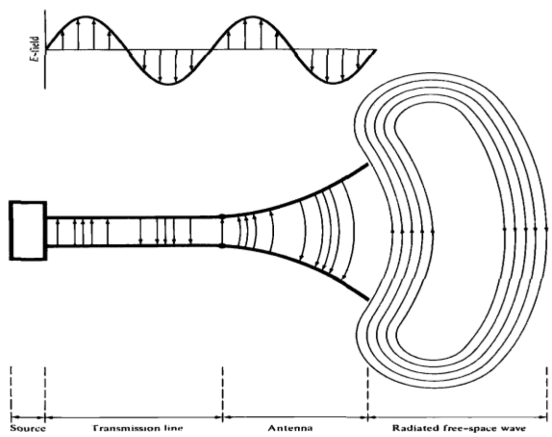

Figure 2.1: Antenna as a transition device [5]

2.2.2 VHF Radio Spectrum

In antenna system, different type of electromagnetic wave involved a different range of frequency bands. With the variety of frequency ranges, the wavelength displayed is also different. For example, radio waves have the lowest operating frequency and as a result it has the widest wavelength. While, a VHF antenna which is designed to operate in the VHF range has their own frequency range and their corresponding wavelength. Table 2.1 shows the electromagnetic wave spectrum for each frequency band.

Table 2.1 Radio band chart [5]

Band	Frequency range	Wavelength range
Extremely low frequency (ELF)	Less than 3 kHz	More than 100 km
Very low frequency (VLF)	3-30 Hz	10-100 km
Low frequency (LF)	30-300 kHz	1-10 km
Medium frequency (MF)	300 kHz- 3 MHz	100 m-1 km
High frequency (HF)	3-30 MHz	10 -100 m
Very high frequency (VHF)	30-300 MHz	1-10 m
Ultra high frequency (UHF)	300 MHz-3 GHz	10-1 m
Super high frequency (SHF)	3-30 GHz	1-10 cm
Extremely high frequency (EHF)	30-300 GHz	1 mm- 1 cm

Skywave propagation is a condition where radio waves in VHF band are being reflected to the earth by the ionosphere layer in the atmosphere. Ionosphere is basically a layer of electrically charged ions at the top of the earth's atmosphere. Long distance communication in VHF band is possible, with the abundant of reflections between this layer and the earth. VHF spectrum is widely implemented in many kinds of field such as air traffic control, marine radios, and military communication systems. This type of propagation has a disadvantage. As the ionosphere varies a lot during the daylight hours, the waves are reflected unevenly due to this variation. This may cause the waves to take different directions over a period of time. In addition, the output will fade out caused by the variations of signal strength at the receiver.

2.2.3 Basic Antenna Parameters

An antenna performance is determined based on several parameters. The parameters involved are the antenna gain, radiation pattern, S-parameter and bandwidth. These

parameters are crucial indicators to investigate and most importantly to evaluate the antenna's performance.

(a) Antenna Gain

The investigation of the antenna gain is of practical importance, as it is the most vital parameters that will illustrate the performance of the antenna. The equation below shows the formula used to find the value of gain:

$$\left(\frac{P_S}{P_T}\right)_{dB} = G_T + G_S - (32.5 + 20log_{10}\, d + 20log_{10}\, f) \quad (2.1)$$

Where;

P_S = Power received by the antenna

P_T = Power transmitted by the antenna

G_T = Gain of the transmitter antenna (dB)

G_S = Gain of the receiver antenna (dB)

d = Distance between transmitter and receiver antenna (km)

f = Operating frequency of the antenna (MHz)

(b) Radiation Pattern

The radiation pattern or antenna pattern is basically a plot of the gain as function of the direction away from the antenna. From the studies of Balanis [4] , the radiation patterns (amplitude and phase), polarization, and gain of an antenna, which are used to characterize its radiation capabilities, are measured on the surface of a constant radius sphere. Figure 2.2 shows a typical antenna pattern using a horn antenna which is plotted in polar form versus the elevation angle.

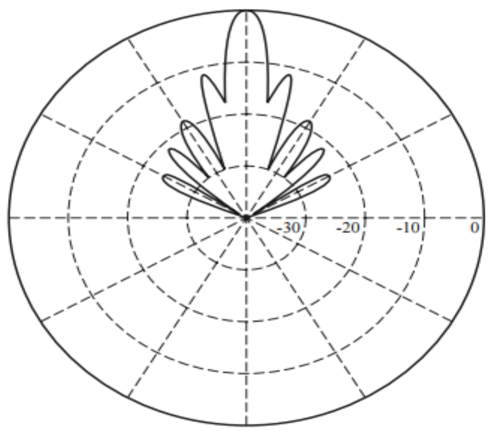

Figure 2.2: The E-plane radiation pattern of a small horn antenna [4]

(c) Scattering Parameter

Scattering parameter or S-Parameter refer to the travelling waves which are scattered when an n-port is placed into a transmission line. It is a parameter that is used to show the connection of input and output between ports system. Basically, S_{11} is represented by the return loss of an antenna. The S_{11} are calculated by using the equations below. According to Pozar [6], the S-parameter of an antenna can be directly measured by using the network analyzer.

$$\tau_L = \frac{Z_{in} - Z_{out}}{Z_{in} + Z_{out}} \quad (2.2)$$

$$S_{11} = -20 \, log \, |\tau_L| \quad (2.3)$$

Where;

Z_{in} = Input impedance

Z_{out} = Output impedance

τ_L = Reflection coefficient

(d) Bandwidth

The bandwidth of antenna is defined as the range of frequencies within which the performance of the antenna [4]. The value of bandwidth is simply obtained by calculating the difference value between upper cutoff frequency with lower cutoff frequency. Equation below shows the formula of bandwidth.

$$BW = f_2 - f_1 \quad (2.4)$$

Where;

f_2 = The lower cutoff frequency

f_1 = The upper cutoff frequency

2.3 Dielectric Resonator Antenna

As stated by Petosa [7], the dielectric resonator antenna (DRA) can be regarded as a kind of resonator fabricated from low-loss microwave dielectric materials and the resonant frequency is predominantly a function of its size, shape, and material permittivity. It has been developed due to some advantages which are small in sizing, high radiation efficiency, easy to fabricate, and inexpensive. Much work has been done in studies of this type of antenna. Different shapes, feed structures as well as antenna arrays have been considered, also in how to make it compact and wideband. DRAs have a special type of its own, known as liquid antenna. Liquid antenna is the fluid that transmits charged particles in the form of ions. This liquid acts as the radiating medium. Due to its fluidity and high dielectric constant, liquid antenna always is the most suitable to use as the antenna design. Water antenna is the most popular liquid antenna [8]. According to Lei et al [3], there are a few advantages of water antenna that make it the most popular one which are:

i. Conformability- it is easy to make the antenna to the desired shape which may hard to achieve using other dielectric or metal
ii. Tunability- the operating frequency and bandwidth can be controlled by using the height, length and width of the liquid stream
iii. Small radar cross section (RCS)- it can be turned off or drained when not in use
iv. Portable- especially for large antenna
v. Low cost- if it used water or seawater
vi. Improvement in electromagnetic coupling- an air gap between probe and dielectric introducing unneeded changes in resonance and impedance can be improved

2.4 Design of Water Antenna

The investigation of water antenna has recently immerged in the recent years. It is a special type of antenna that make use of water as part of its crucial material. There are many reasons why water is good material to design an antenna. As stated by Lei et al. [3], water is inexpensive, accessible and eco-friendly. A part of that, the antenna size can also be reduced hence making it portable and lightweight. According to Meng et al. [9], water itself has their own electrical properties. Thus, make it dividable into types, known as pure water and salt water. Pure water acts as a dielectric with high permittivity.

Salt water which is almost similar with seawater, acts as a conductor at HF and VHF bands. As studied by Y. Kosta [10], when an electromagnetic field is applied to seawater, the ions will migrate, thus producing an electric current. Water monopole antenna is one of the invention that make use of sea water due to its high efficiency. Following are the example of water antennas and all the related works that contribute to this report.

2.4.1 Sea-Water Half-Loop Antenna

From the studies of Fayad & Record [11], the sea-water half-loop antenna is invented for maritime wireless communications. This antenna can save much space in ships due to its convenient small space. Other than that, it is tunable and can be turned off in real time. However, it has a disadvantage. The sea-water half-loop antenna operation may be affected to poor sea weather like thunderstorm. Figure 2.3 simply explained about the design of the sea-water half-loop antenna. The antenna consists of a capacitive coupling feeding structure and a stream of sea water that is supplied by water pump. A metallic tube antenna with a tilt angle, θ, a dielectric-filled parallel-plate capacitor and a feeding post. After activating the antenna, the seawater will be first pumped into the metallic tube, resulting a water stream to be shot out from the metallic tube. Thus, form a half-loop.

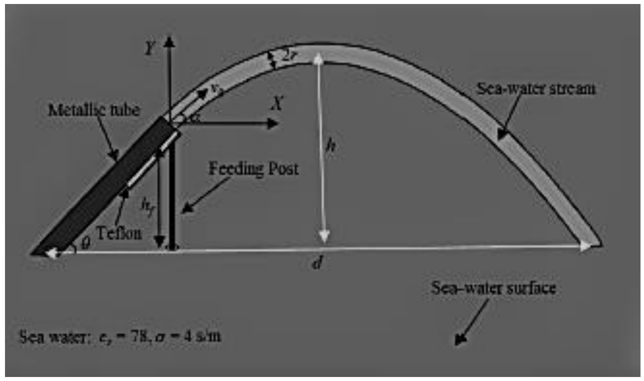

Figure 2.3: Design of the sea-water half-loop antenna [1]

The measurements to find the impendence bandwidth, gain and radiation efficiency are done to determine the antenna's performance. The test is conducted at the sea for real side environment. For the result, the bandwidth of the antenna is 27 %, measured gain is -0.2 dB at operating frequency of 0.11 MHz and a radiation frequency of 35 %. As stated by Changzhou et al. [1], the lossy conducting ground of the sea surface caused the measured maximum gain of the sea-water half-loop placed above the sea surface to be smaller than the gain above the perfectly conducting ground.

2.4.2 A Monopole Water Antenna

Based on the studies of Lei et al. [3], the monopole water antenna using a concept of varying the height of liquid column. It is proposed with a dielectric layer. Table 2.2 shows the parameters that are used to design an antenna that operates at 1.8 GHz. The water antenna height is set at 50 mm. The seawater has the following properties; relative permittivity, ε_r = 81, and conductivity, σ = 4.7 S/m. To invent a monopole water antenna, both properties need to combine. The relative permittivity will determine the dielectric properties. Without the dielectric properties, the seawater will act as a conductor. Meanwhile, the conductivity will determine the performance of the water antenna. Without the conductivity of water, the water can be used as an alternatives material for DRAs. If there is no conductivity, the efficiency will be high. When the conductivity increases, the efficiency will be distorted and finally the efficiency will be 100 % if the value of conductivity is infinity. As the conclusion, the conductivity and antenna efficiency are closely related to each other. The simulation is done by using CST Microwave 2014. By analyzing the efficiency and conductivity of the antenna through simulation process, the function of the antenna can be determined whether it acts as a high permittivity dielectric antenna (DRA), combination of dielectric and conducting antennas or a normal conducting antenna [3].

Table 2.2: List of design parameters for a 1.8 GHz antenna [3].

Parameter	**Value**
Seawater relative permittivity, ε_r	81
Seawater relative permeability, μ_r	1
Seawater conductivity, σ	4.7 S/m
Water antenna height	50 mm

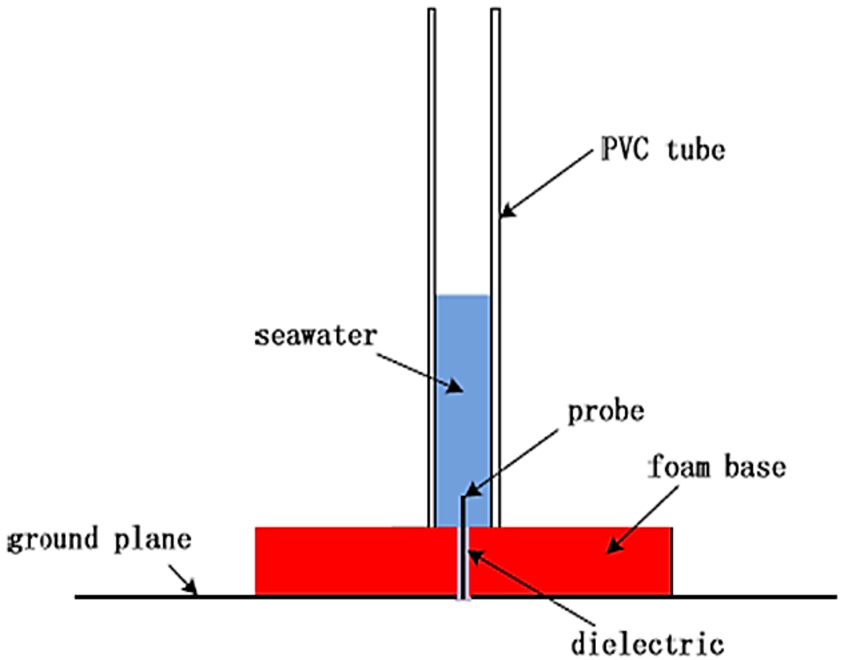

Figure 2.4: Geometry of monopole water antenna [3]

Figure 2.4 shows the design of the water monopole antenna. The foam layer acts as separator between the seawater with the ground plane. The dielectric foam base is used to increase bandwidth and can avoid any short circuit. The relative permeability, μ_r, and the relative permittivity, ε_r, of the foam layer are 1 respectively. The PVC tube is filled in with seawater. The PVC tube parameters are shown in table 2.3. Before finalizing the usage of foam as the base, there are other two other types of base that have been analyzed which are teflon and paxolin. After being tested by using the network analyzer in terms of bandwidth and efficiency, foam base obtained the best result among these three. With the widest bandwidth and the highest efficiency at -10 dB, foam base clearly shows the best performance. However, foam base is difficult to make thus paxolin is used as the base.

Table 2.3: The PVC tube parameters [3]

Parameter	**Value**
Tube height	100 mm
Diameter	25 mm
Permittivity	4
Conductivity	0
Permeability	1
Conducting ground plane thickness	1 mm

The water antenna is measured by using a network analyzer. The efficiency of the antenna is measured in a reverberation chamber while the radiation pattern is measured in an anechoic chamber. The conductivity of water can be altered by adding salt into water. The higher the amount of salt added to water, the wider the bandwidth of the water antenna.

2.4.3 Sea-Water Antenna

Sea-water antenna is suitable to use especially in a maritime environment. However, instead of being dynamic and reconfigurable, sea-water antenna also has some disadvantages. The efficiency of the antenna is low at upper VHF and UHF bands as the sea water stream is thin. Other than that, sea-water antenna also has a low radiator efficiency. This is because when sea water stream becomes thinner, it will increase the loss resistance. Hence, give a negative effect to the radiation efficiency.

Sea-water antenna can be divided into two types:

i. Static-type Sea-Water Antenna

This type of water antenna made from a clear acrylic tube and a top-loaded feeding probe. The acrylic tube sustains the sea water cylinder and the ground plane is underneath the teflon base. The design is simple and according to **C**hangzhou et al [12], the sea-water antenna is reconfigurable. However, in HF band, the height of water in the tube must be high. Thus, it requires a long tube to hold the water making it less portable and difficult to assemble.

ii. Dynamic-type Sea Water Antenna

As studied by Changzhou et al. [13], dynamic-type sea water antenna is invented to overcome the problem faced by static- type sea water antenna. Figure 2.5 shows the design of the antenna. Electrolytic fluid antenna is one of the example of the dynamic-type sea water antenna as shown in Figure 2.6. It Is invented by SPAWAR System Center Pacific [14].

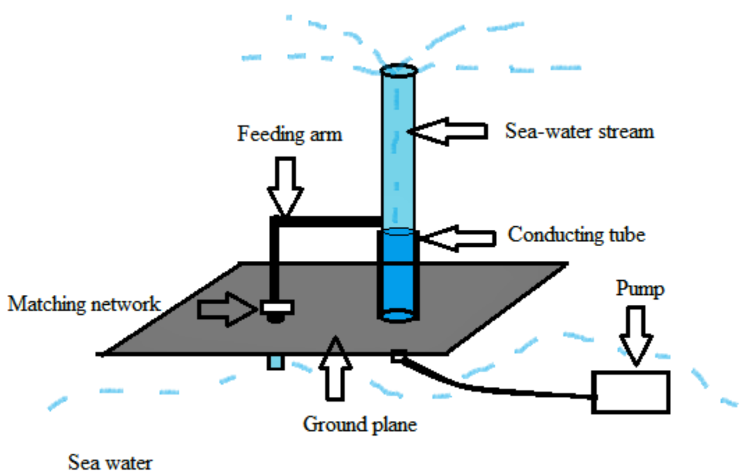

Figure 2.5: Example of dynamic-type sea-water antenna [13]

Figure 2.6: Electrolytic fluid antenna [14]

This antenna system works by using a current probe to couple magnetic field into the fluid stream. A stream of water is pumped through the current probe, then the height of the stream would determine the frequency of the antenna. While the antenna's bandwidth is determined by the diameter of the stream. The current probe mainly consists of a ferrite core and a metallic housing as shown in Figure 2.7. The dynamic-type sea water antenna is more enhanced compare to static-type sea water antenna. It can be turned off when not in the use, tunable, dynamic in real-time and portable. However, it also has several disadvantages. It has low efficiency, low efficiency radiator and complicated feed structure.

Figure 2.7: Example of a current probe [14]

2.4.4 Reconfigurable Water Antenna

There are two types of reconfigurable of reconfigurable water antenna which are water-grating leaky-wave and sea-water monopole antenna [8].

i. Water-grating leaky-wave antenna

   This antenna is used for wide-angle beam scanning

ii. Sea-water monopole antenna

   It is mainly used in maritime wireless communication. In the middle of the ocean, sea water is can be easily attained. Therefore, an antenna known as reconfigurable sea-water antenna is invented mainly for the use of naval and maritime wireless communication. As shown in Figure 2.8, teflon container is used and be put on a ground plane. A pipe is used to filled in the water into the antenna. The ground plane is placed with feed probe. The container and the feed probe are concentric so that the desired TM mode excitation can be achieved resulting a steady structural symmetry. As the antenna be activated, the sea water is filled in the container and then a stream of water will be bursting out form the container. Hence, form a monopole antenna. Since the sea-water monopole antenna can be reconfigurable, it also means that the operating frequency and bandwidth of the sea-water stream [1].

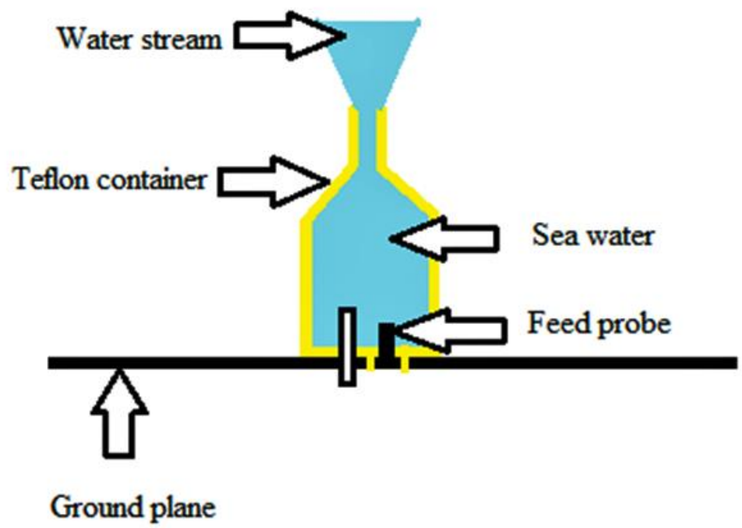

Figure 2.8: Design of a reconfigurable sea-water monopole antenna [8]

2.4.5 High Efficiency Sea Water Monopole Antenna

Basically, the high efficiency sea water monopole antenna is the modification made to the sea-water monopole antenna. As studied by Lei et al. [3], the sea-water monopole antenna has a low efficiency at VHF and UHF bands. This is due to the thin sea-water which is not an efficient radiator. These disadvantages make it not suitable for maritime wireless communications. Therefore, a modified sea-water antenna is proposed so that it can operates at VHF bands.

From the studies of Changzhou et al. [12], the seawater monopole antenna composed of a transparent plastic tube filled with seawater and a top-loaded feeding probe as shown in Figure 2.9. This proposed antenna has much better efficiency because it uses an efficient feeding structure and a thick sea-water cylinder. The excitation mode of TM mode is improved by loading a disk on top of the feeding probe. Table 2.4 shows the dimension of the design seawater monopole antenna.

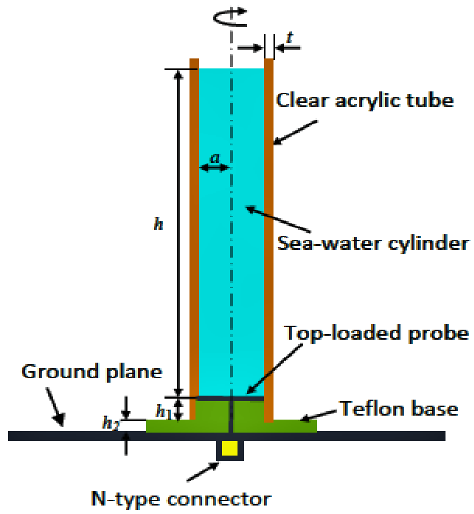

Figure 2.9: Geometry of seawater monopole antenna [12]

Table 2.4: Dimensions of the seawater monopole antenna [12]

Parameter	**Value**
Height of the sea water, h	1 m
Thickness of the tube, t	3 mm
Height from top-loaded probe to teflon base, h_1	30 mm
Height from teflon base to the ground plane, h_2	20 mm
Radius of the tube, a	50 mm

The sea-water antenna has several advantages. It is reconfigurable as its center frequency and bandwidth can be modified by changing the height and radius of the water cylinder. It is also high transparency, high radiation efficiency, has a simple feeding structure and inexpensive. The limitation of this sea-water monopole antenna is the electrical properties of sea water that depends on its chemical composition. This limitation is due to the electrical properties of sea water that varies with the temperature, frequency, and pressure [12].

2.4.6 Water Antenna

From the studies of N.I.M.Ikhwan et al. [15], a water antenna has been designed which utilizing distilled water as the medium. The water antenna operates at UHF band. The aim of this project is to fabricate a water antenna that used distilled water as the medium. The objectives of this paper are as follows:

i. To design and fabricate the water antenna.
ii. To characterize the water antenna based on the different samples of water antenna.
iii. To measure the characteristics of the water antenna.

A. Design and fabrication of the water antenna

Figure 2.10 shows the prototype of the water antenna. An acrylic cylinder is used to contain the water and the dimensions are as follows: height = 200 mm, thickness = 2 mm, diameter = 25 mm. Acrylic material is used as the base part of the antenna. The ground plane is a PCB board cut into a round shape and been sandwiched together with the previous acrylic