STUDY ON THE EFFECT OF FREQUENCY AND MEDIUM RESISTIVITY ON THE PROPAGATION OF ELECTROMAGNETIC (EM) WAVE

By

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FINAL PROJECT REPORT

Submitted to the Electrical & Electronic Engineering Programme
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CERTIFICATION OF APPROVAL

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Approved by:

(Dr. Hasnah Bt. Mohd Zaid)
Project Supervisor

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK

May 2011

CERTIFICATION OF ORIGINALITY

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

MUHAMMAD FAISAL BIN MOHD NAWI

ABSTRACT

This project focuses on the effect of frequency and medium resistivity on the propagation of Electromagnetic (EM) wave toward its application in Sea-Bed Logging (SBL). SBL is an application of the Marine Controlled Source Electromagnetic (CSEM) method where the idea is to guide the electromagnetic energy in the thin resistive medium within conductive sediments. This method has been introduced for long time before but it application in SBL is relatively new. The application in hydrocarbon detection has not been developed until recently due to the problem of uncertainty of significant response from thin resistive layer where the EM energy is easily attenuated in sea water. This project will apply the same concept of SBL by using a scaled tank. Throughout the experiments, the value of frequencies is varied and different medium resistivity is used. Then, the data is analyzed and compared with the theoretical value and from there, the effects of the frequency and medium resistivity are determined. The data is taken by considering many perspectives and patterns in the real offshore structure.

ACKNOWLEDGEMENT

Thank to Allah SWT, whom with His willing giving me the opportunity to complete my Final Year Project. I am thankful to my supervisor, Dr Hasnah Bt. Mohd Zaid, whose encouragement, guidance and support from the beginning until the end that enable me to finish my FYP project within the time given. Also, I am grateful to Universiti Teknologi PETRONAS for providing me the facilities and equipments to complete the project. Lastly, I offer my regards and blessings to my family, friends and those who have helped me during the project.

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LIST OF ABBREVIATION

CSEM	Marine Controlled Source Electromagnetic
EM	Electromagnetic
EMGS	Electromagnetic Geoservices
FYP	Final Year Project
MHz	Megahertz
SBL	Sea Bed Logging
MVO	Magnitude versus Offset
UTP	Universiti Teknologi PETRONAS
Vp-p	Voltage peak-to-peak

CHAPTER 1

INTRODUCTION

This chapter discusses the background of study, problem statement, objectives and scope of study.

1.1 Background of Study

The principle of SBL is applied where the hydrocarbon-saturated rocks typically show higher resistivity than rock saturated with sea water. When the receiver indicates high resistivity at the place, there is high possibility that the place is covered with hydrocarbon. [1]

SBL employs EM source that is towed close to the seabed. The receiver nodes are placed on the seabed to measure the magnetic field from various offsets from the transmitter. Then, the data taken will be processed to create resistivity profiles using depth imaging, inversion and other techniques.

1.2 Problem Statement

SBL technique requires the emitting of low frequency signal both from overlying and downward of sea floor. But the problem is the receiver only detects a small amount of EM wave that has been reflected back by hydrocarbon due to high attenuated EM energy in conductive sediments.

In order to detect the hydrocarbon within the prospective area, it depends on the data received by the receiver. If the receiver indicates high resistivity at a certain places, most probably the places has hydrocarbon.

1.3 Objectives

The objectives of this project are:

1. To study the effect of frequency and medium resistivity on the propagation of EM waves
2. To demonstrate the detection of hydrocarbon using SBL method

1.4 Scope of Project

The project involved the study of EM wave's properties, attenuation of wave as it passes through different medium, the effect of different medium resistivity, and the effect of the frequency of the wave in its propagation. It also involves experimental work where the magnitude of EM wave which transmitted propagate in a scaled tank is measured using a receiver.

1.4.1 The Relevancy of the Project

SBL technique is still new in oil and gas industries and it is a good opportunity to involve in the development of the technique where many improvements can be done. Universiti Teknologi PETRONAS is one of the finest engineering universities that train the students into the field of technology for oil and gas research. The SBL application is one of the relevance projects that utilize the knowledge of oil and gas studied at the university and with this project, it will helps to improve this new technology in it field.

1.4.2 Feasibility of the Project within the Scope and Time frame

During FYP 1 period, the work was started by gathering the information from reliable sources such as journals, textbooks, articles and discussion with supervisor. Then, the scaled tank is setup and the initials data are recorded by using various values of frequencies and different medium resistivity.

During FYP 2, the work focused on the application of the EM wave to detect high resistivity layer which is hydrocarbon. The experiments used various values of frequencies and saline water as medium resistivity.

CHAPTER 2

LITERATURE REVIEW

This chapter discusses the various hydrocarbon detection methods and elaborates the concepts of the methods. It also explains the concepts of electromagnetic waves and challenges and issue in SBL.

2.1 Methods of Hydrocarbon Detection

2.1.1 Seismic Methods

Seismic method is widely used for many years in industry of oil and gas. Basically the seismic method uses the principle of seismology to determine the properties of subsurface that make up the underground structure from the reflected seismic waves.

The source of seismic wave is air gun or water gun where the transmitter produces acoustic vibration into the water. This wave will be emitted into the sea water and picked up by the receiver as the waves bounce back to the subsurface. Then, the data received by the detector will be processed to estimate the depth of the features generated from the reflection. From the data, the geologists will determine the possible location of oil around the area. [2] The problems with the seismic method are, the information receives only mapping the subsurface of the area without specified the location of the hydrocarbon and also, the seismic method is quite expensive. The application of seismic method is illustrated in Figure 1.

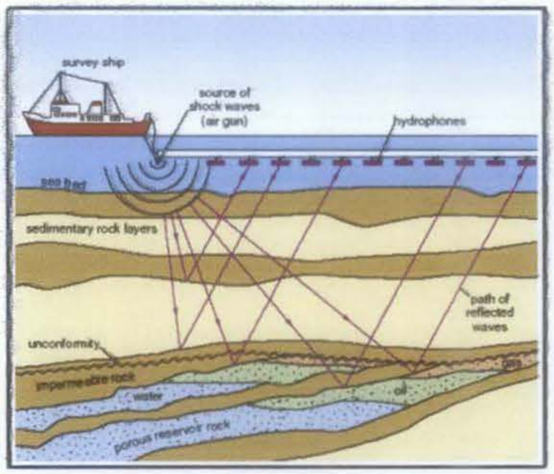

Figure 1: Application of Seismic method. *After [2]*

2.1.2 Sea Bed Logging Method

Sea Bed Logging (SBL) is the newest technique used in finding the oil and gas beneath the seabed. The principal used in this technique is, the hydrocarbon under the seabed has higher resistivity than the water. Therefore, the detection of hydrocarbon can be done by taking the measurement on the seabed that will determine subsurface resistivity. [3]

In SBL, a transmitter emits EM waves beneath the seabed and the wave will be reflected back to the subsurface. Receivers placed on the sea floor will measure the magnetic field received and the data processed to create a resistivity profile of the subsurface. From the data, the geologist can determine the location of hydrocarbon under the seabed. [4] The application of Sea Bed Logging is illustrated in Figure 2.

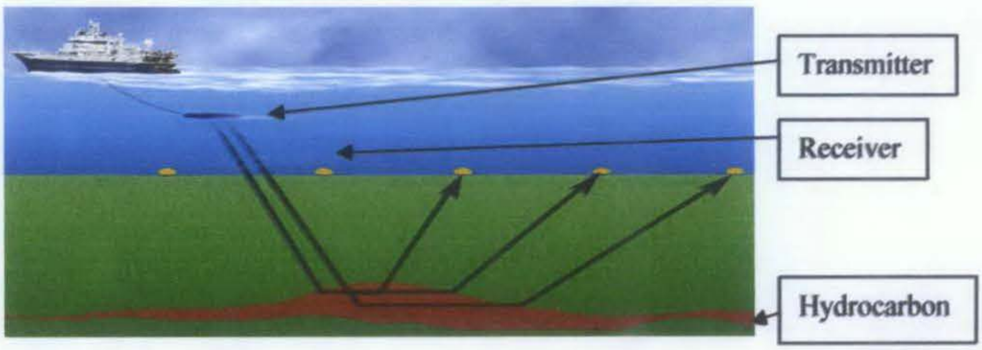

Figure 2: Application of Sea Bed Logging. *After [1]*

The advantage of SBL technique is that, it can determine the location of hydrocarbon and reduce the risk of drilling at the wrong location. This way, the company can save the expense of money as the drilling in the deepwater wells is so expensive.

2.2 Electromagnetic Wave

Electromagnetic waves are waves which can travel through the vacuum of outer space. Electromagnetic waves are created by the vibration of an electric charge. The speed of electromagnetic wave travel through vacuum is 3.00×10^8 m/s. [5]

In an EM wave, the electric and magnetic fields are mutually perpendicular. They are also both perpendicular to the direction in which the wave propagates or travels which is shown in Figure 3. The electric and magnetic fields oscillate together between maximum positive and maximum negative values.

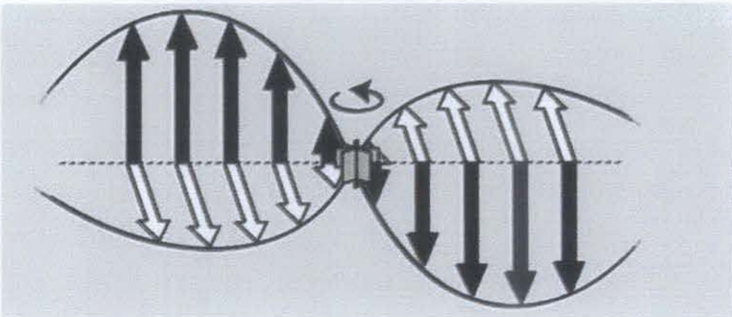

Figure 3: Electric field and Magnetic field perpendicular each other. *After [5]*

2.2.1 Propagation of Electromagnetic Wave

The propagation of EM wave through medium involved the vibration of electric charge where the vibration atom is transported from one atom to another atom. The mechanism of energy transport through a medium involves the absorption and reemission of the wave energy by the atoms of the material. [6]

When an electromagnetic wave impinges upon the atoms of a material, the energy of that wave is absorbed. The absorption of energy causes the electrons within the atoms to undergo vibrations. After a short period of vibration motion, the vibrating electrons create a new electromagnetic wave with the same frequency as the first electromagnetic wave. Once it reaches the next atom, the electromagnetic wave is absorbed, transformed into electron vibrations and then reemitted as an electromagnetic wave. [7]

2.2.2 Maxwell's Equations

The fundamental field equations of electromagnetic fields can be explained from Maxwell's equations. There are four laws of Maxwell's equation that describe the electric and magnetic fields arising from varying distributions of electric charges and currents, and how those fields change in time. [5] Shown in the Table 1 is the four laws of Maxwell's equation where E is the electrical field, φ_B is the integration of the linking magnetic field, H is the magnetic field, D is the electric displacement and q enclosed charge and B is the magnetic induction.

Table 1: Maxwell's Equation

Law	Formula
Faraday's Law	$\oint E.dl = \frac{d\varphi_B}{dt}$
Ampere's Current Law	$\oint H.dl = i$
Gauss's Law for Electric Field	$\oint D.dA = q$
Gauss's Law for Magnetic Field	$\oint_S B.dA = 0$

Faraday's Law states that the time-changing magnetic flux induced electromotive force and Gauss's Law says the facts that the electric charges attract or repel one another with a force between them. The propagation of electromagnetic waves through space is explained in Ampere's Current Law where it state that the magnetic field is produce from time-varying electric fields. Lastly, Maxwell's fourth equation stated that there is no magnetic flux through any closed surface. [12] Generally, this four laws of Maxwell's equation proved that magnetic field can be generated by changing of electric field and we can conclude that, electromagnetic field can be represented in terms of four vectors which are:

E, electric field (volts/meter)

H, magnetic field (ampere turns/meter)

D, electric displacement (coulombs/sq meter)

B, magnetic induction (webers/sq meter)

2.2.3 Permeability and Permittivity

Permeability is a measure of the ability of a material to support the formation of magnetic field within them [13] and permittivity is the measure of resistance from electric charge when electric field is forming in a medium. [14] The relationship between permeability and permittivity is that the changing of electric field will produce magnetic field and it is important to understand the concept of these measurements in order to understand the effect of EM wave when it passed through different medium of resistivity.

2.2.4 Resistivity and Conductivity

The electrical resistivity is a measure of how strong a material opposes the flow of electric current. Low resistivity indicated that the material allows the movement of electrical charge. In the application of SBL, when the receiver detects the reservoir underneath the seabed, the data will indicate high resistivity.

The conductivity is a measure of how easily the electrons can travel through the material under the influence of an external electrical field. The data taken for the detection of reservoir will indicate low conductivity. The resistivity and conductivity of the material are the inverse of each other. The data taken for reservoir will indicate high resistivity and low conductivity.

2.2.5 *Reflection and Refraction of EM wave*

Reflection is referred to the phenomena when the wave changes direction at an interface between two different medium. The physical law of wave reflection is that the angle of incident waves equals the angle of reflected wave. Figure 4 shows the reflection of wave where θ_i is angle of incident and θ_r is angle of reflection

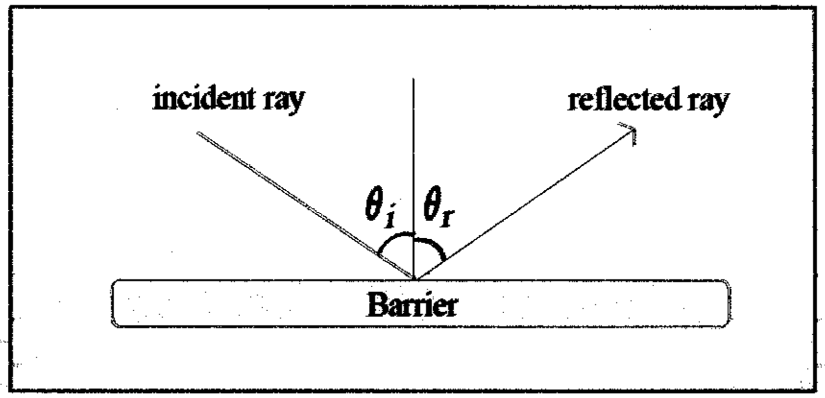

Figure 4: Reflection of wave

Refraction is the phenomena when the wave changes direction as the wave entered two different medium. This is most commonly observed when a wave passes from one medium to another at an angle other than 90°. [7] Refraction is described by Snell's law, which states that the angle of incidence θ_1 is related to the angle of refraction θ_2 by Snell's Law:

$$\frac{\sin\theta_1}{\sin\theta_2} = \frac{v_1}{v_2} = \frac{n_2}{n_1} \qquad (1)$$

where n_1 and n_2 are the indices of refraction of the two mediums and v_1 and v_2 are velocity of EM waves through the two mediums.

Figure 5 shows the example of refraction of light when it travels from one medium to another medium where the light is refracted which the angle of θ_2 is smaller than the angle of θ_1.

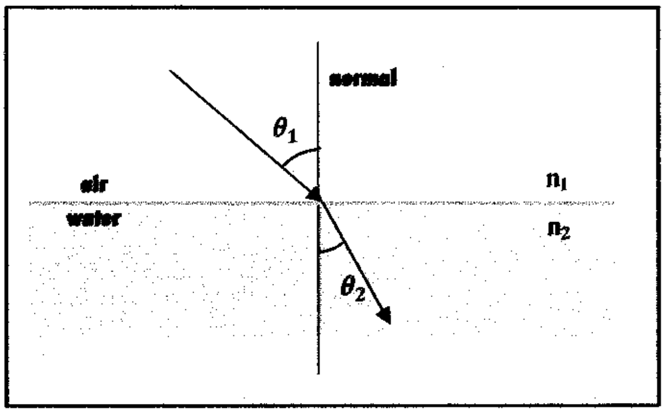

Figure 5: Refraction of light from difference mediums.

In Figure 6, it shows the example of light travels from dense medium (glass) to less dense medium (air). When the light travel from one medium to another at critical angle, θ_c the light will be refracted at 90^0, in other words, refracted along the interface. Critical angle is the angle of incident above which total internal reflection occurs. [9] The phenomenon of total internal reflection is when the light is transmitted to the second medium, the light seems to reflect off the boundary and transmit out the opposite direction. It happens when the wave is in the move from the dense medium and approaching the less dense medium.

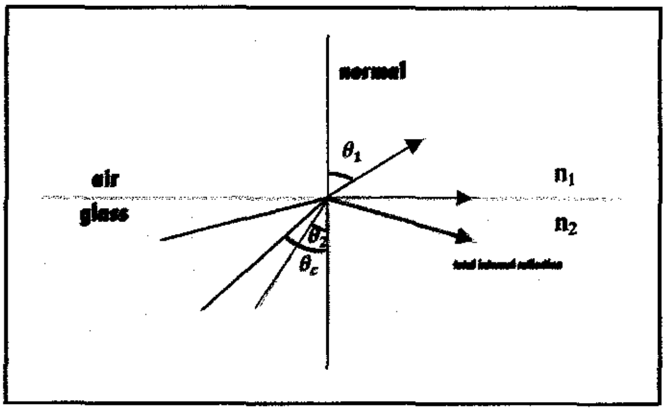

Figure 6: Total internal reflection.

Refraction of the wave is based on the arrival of EM wave to the receiver. The transmitter will transmit EM wave to the surrounding and the wave will be reflected and refracted when it hits the sea surface and hydrocarbon layer. The receiver will capture the data received and it will be analysed by the receiver to determine the differences of resistivity and conductivity. From the analysis data, the geologist can determine the location of hydrocarbon.

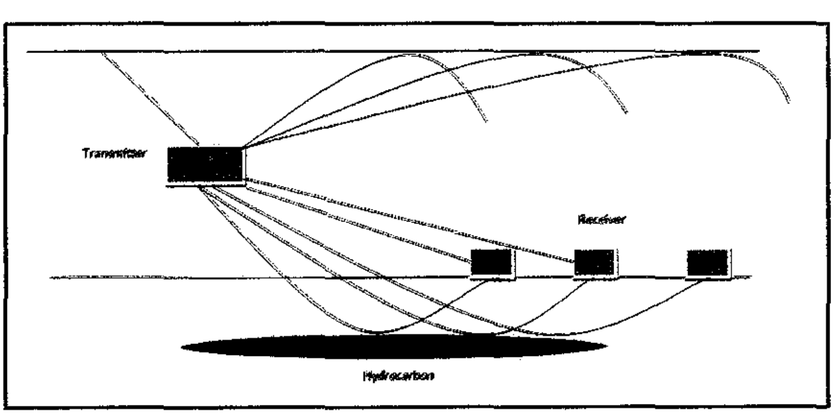

Figure 7: Refraction of EM wave in application of Sea Bed Logging

2.2.6 Attenuation and Skin Depth

Attenuation is the gradual loss in intensity of any kind of flux through a medium. Attenuation decreases the intensity of electromagnetic radiation due to absorption or scattering of photons. [7] Skin depth, δ is the depth which electromagnetic wave can penetrate through medium. The distance of penetration is referred to as skin depth of the medium. The effect is caused by electromagnetic induction in the medium which opposes the currents and set up by the E-field. [9] Skin depth can be determined by using Equation (2).

$$\delta = \sqrt{\frac{2}{\mu\sigma\omega}} \qquad (2)$$

where μ is permeability, σ **is conductivity, and** ω is angular frequency

In the application of SBL, the attenuation of EM wave that propagate in sea water is high. This will affect the propagation and refraction of detecting hydrocarbon. In order to overcome this, the propagation of EM wave will use low frequency whereby it will decrease the attenuation of EM wave.

2.2.7 Wave length

Wavelength, λ is defined as the distance in medium occupied by one cycle of a wave at any given instant and it periodic function with the period of 2π. [10] Different wavelength gives different types of wave, for example radio wave, infrared, X-ray and gamma ray. For the purpose of this project, the types of wavelength that should be used are long wavelength which is radio wave, in order for the wave to travel in long distance and further deeper under the seafloor. The wavelength λ can be determined by using the equation (4).

$$\lambda = 2\pi\sqrt{\frac{2}{\mu\sigma\omega}} \quad (3)$$

$$\lambda = \sqrt{\frac{8\pi^2}{\mu\sigma\omega}} \quad (4)$$

where μ is permeability, σ is conductivity, and ω is angular frequency

2.2.8 Phase Velocity

Phase velocity, C_p is the speed of wave that can travel through medium at any frequency and conductivity. [11] Phase velocity can be calculated by using the equation (6).

$$C_p = \sqrt{\frac{2\omega}{\mu\sigma}} \quad (5)$$

$$C_p = \sqrt{\frac{10^7 \times f}{\sigma}} \quad (6)$$

2.3 Challenges and Issues in SBL

SBL has become an important complementary tool to seismic exploration method in finding the location of hydrocarbon layers in the deep water. Currently the countries like Norway, Brazil, and also Malaysia are applying the method Electromagnetic Geoservices (EMGS). The analysis surveys with water depths from 100 m to 4000 m with the target depth from 200 m to 2500 m have been done and most of the oil companies are excited about the deepwater opportunities, where the stakes of finding the hydrocarbon are much higher. [16]

EMGS acquired it first commercial SBL survey in 2002. There are many companies that applying the same concepts, such as SHELL, PETRONAS, and Enterprise Oil in North Sea and the survey is a success and since then, many companies have used SBL technique. [1]

In SBL, the usage of the technique in the shallow water is still under improvement where it is consider difficult to analyze the location of hydrocarbon because of the strong effect airwave interference from the reflection of sea surface. The survey has been done by PETRONAS regarding the shallow water exploration (90m water depth) acquired in 2008. In this case study, the problem is due to strong effects of the refracted and reflected air wave from the sea surface. The researchers use many kind methods to overcome the problem such as the comparison of inversion methods and use advance processing analysis tools. [15]

CHAPTER 3
METHODOLOGY

This chapter discusses the scale model and scale tank model calculation, equipments used and experimental procedure.

3.1 Procedure Identification

Figure 8 shows the flow chart of the process activities that have been followed throughout this project.

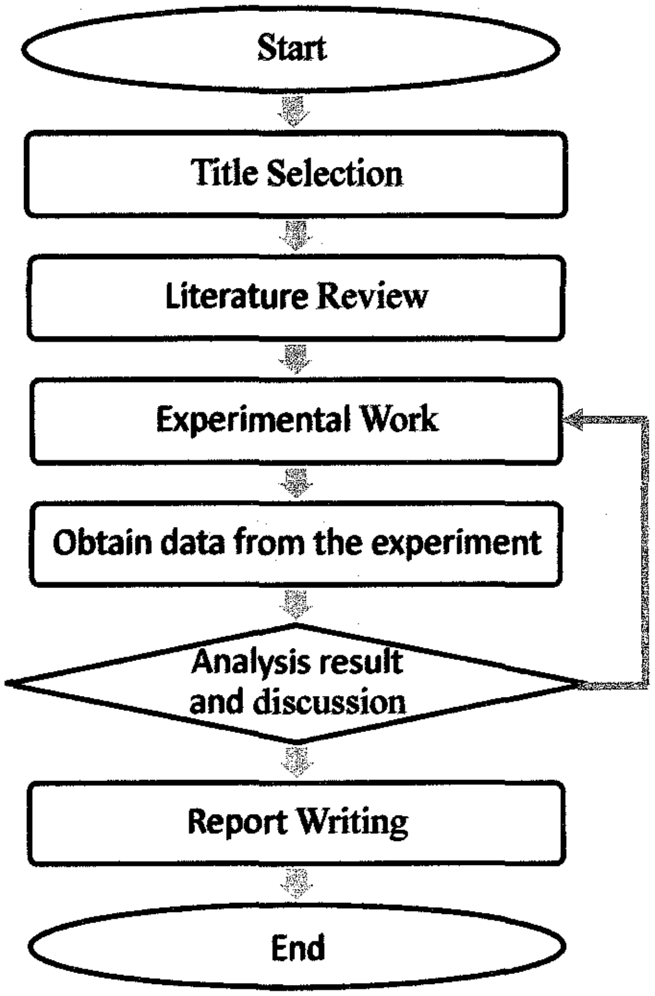

Figure 8: Project Activities Flow

3.2 Scale Model Calculation

In this project, the measurement of the full scaled SBL has been scaled out into the scaled tank model by defining the ratio between the two of them. It is important that the distances and frequencies used in the experiment could be scaled up to the real distances and frequencies that represent the actual SBL condition. The calculation is as shown below:

The ratio of the full scale and the laboratory scale dimensions is

$$\frac{d_{fs}}{d_{lab}} = n \tag{7}$$

where d_{fs} is full scale dimension and d_{lab} is laboratory scale dimension

If

$$\left(\frac{\rho}{\mu f}\right)_{fs} = n^2 \left(\frac{\rho}{\mu f}\right)_{lab} \tag{8}$$

where ρ is density, μ is permeability, f_{fs} is full scale frequency and f_{lab} is laboratory scale frequency

The full scale and the laboratory scale both generally concerned with nonmagnetic conductors $\mu = \mu_o$ the permeability of the free space, so that

$$\left(\frac{\rho}{f}\right)_{fs} = n^2 \left(\frac{\rho}{f}\right)_{lab} \tag{9}$$

For the frequency

$$\left(\frac{1}{f}\right)_{fs} = n^2 \left(\frac{1}{f}\right)_{lab} \tag{10}$$

$$n^2 f_{fs} = f_{lab} \tag{11}$$

The ratio of full scale and the laboratory scale dimension is

$$\frac{d_{fs}}{d_{lab}} = n \tag{12}$$

$$\frac{2000m}{0.5m} = 4000 \tag{13}$$

Therefore, for a frequency of 0.1 Hz used in full scale, the frequency used in the lab

$$n^2 f_{fs} = f_{lab} \tag{14}$$

$$(4000)^2 (0.1Hz) = 1.6MHz \tag{15}$$

In a real condition, the frequency used in the deep water is between 0.1 Hz to 1.0 Hz. [9] Therefore, the experiments is conducted by considering this range of frequencies. The conversion of f_{fs} into f_{lab} is simplified in Table 2:

Table 2: Conversion from f_{fs} into f_{lab}

f_{fs} (Hz)	f_{lab} (MHz)
0.1	1.6
0.2	3.2
0.3	4.8
0.4	6.4
0.5	8.0
0.6	9.6
0.7	11.2
0.8	12.8
0.9	14.4
1.0	16

2.3.1 Scaled Tank Model Calculation

SBL is effectively used in the deep water which is between 1000 m to 2000 m from the sea surface. The full scaled SBL is to be scaled down into scaled tank size in order to represent the actual condition of sea. For this project, the depth of sea used is 1600 m and the depth of overburden is 480 m. The condition of the full scaled SBL is shown in Figure 9.

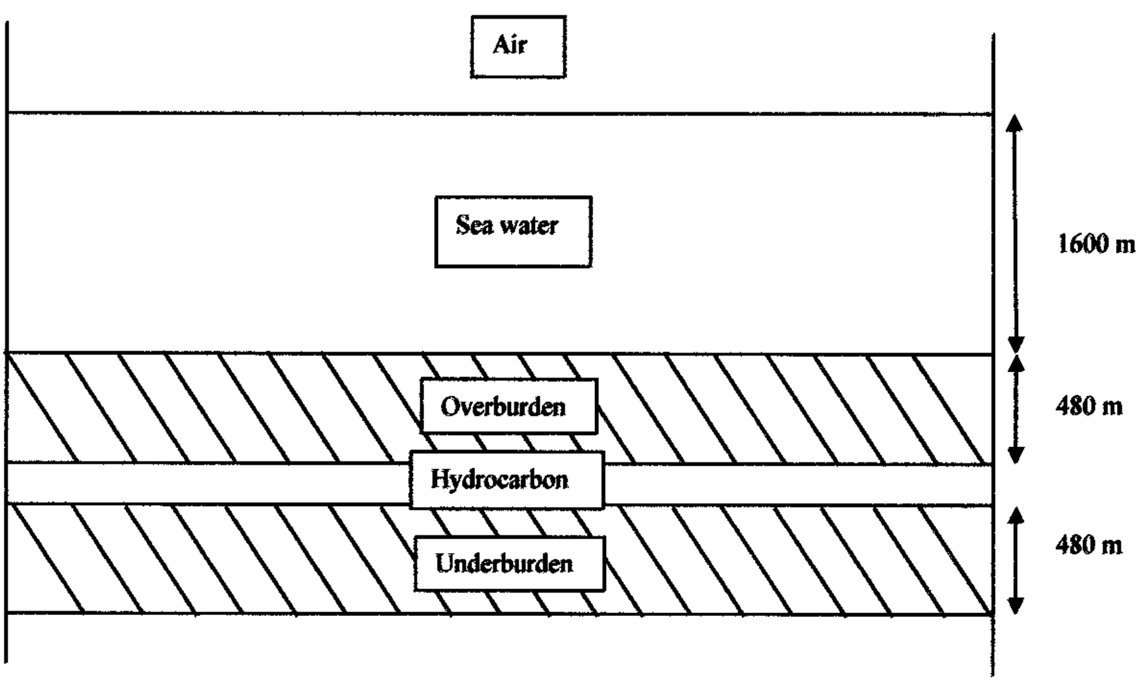

Figure 9: Full scaled SBL parameter

Based on the scale factor, $n = 4000$, the depth of saline water used is

$$\frac{1600m}{4000} = 0.4m \tag{16}$$

And for the depth of overburden layer used is

$$\frac{480m}{4000} = 0.12m \tag{17}$$

Therefore, the parameter of the depth of saline water and overburden layer used is 0.4 m and 0.12 m. In this case, the parameter of underburden layer is assumed to be neglected as the reflection of EM wave only concerned overburden and hydrocarbon layer. The condition of the scaled tank parameter is as shown in Figure 10.

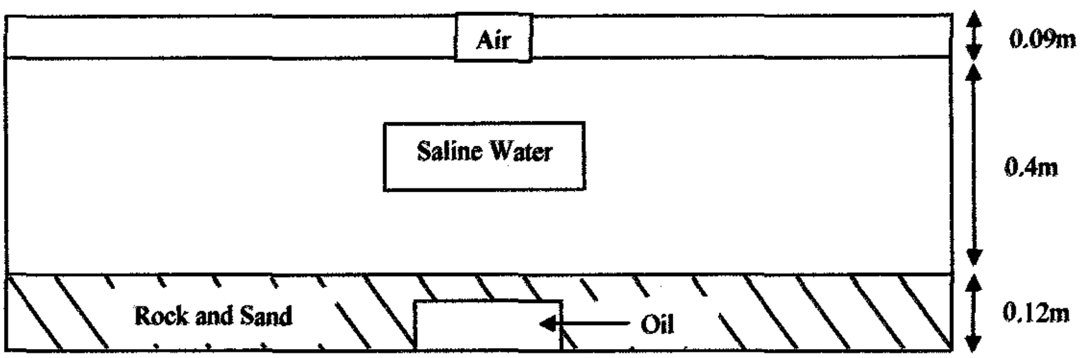

Figure 10: Scaled Tank parameter

3.2 Equipments of the Experiment

Before we go details into the experiment, we need to know the function of each equipment used during the experiment. Below are the list of equipments used

1. Fiber tank
2. Function generator
3. Curve Transmitter
4. Oscilloscope
5. Receiver
6. Packet of Oil

1. Fiber Tank

The experiment is carried out by using a fiber tank which represents the actual condition of the offshore. The fiber tank is used because it is proven to support the weight of water and it is a strong material. The dimensing of the fiber tank is shown in Figure 11 and 12.

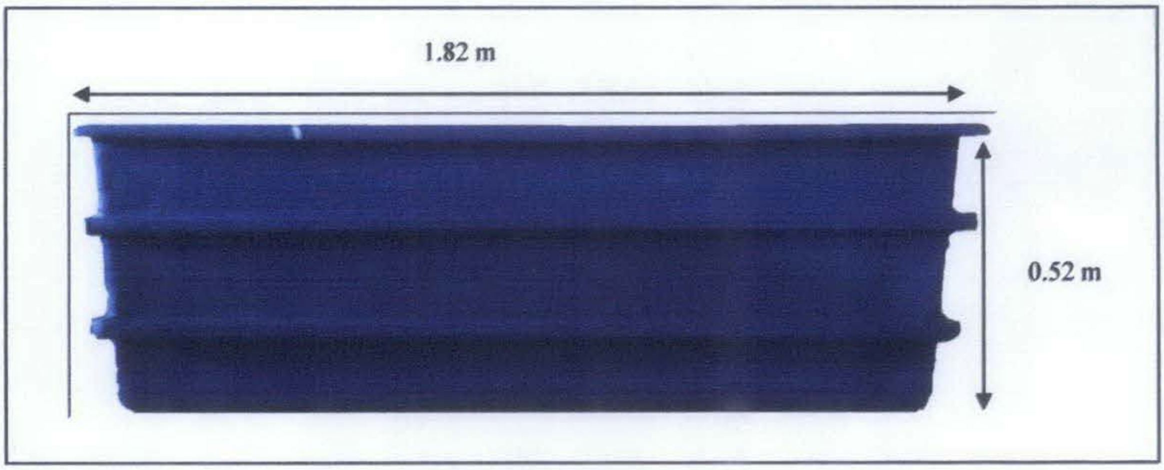

Figure 11: Fiber Tank (Side View)

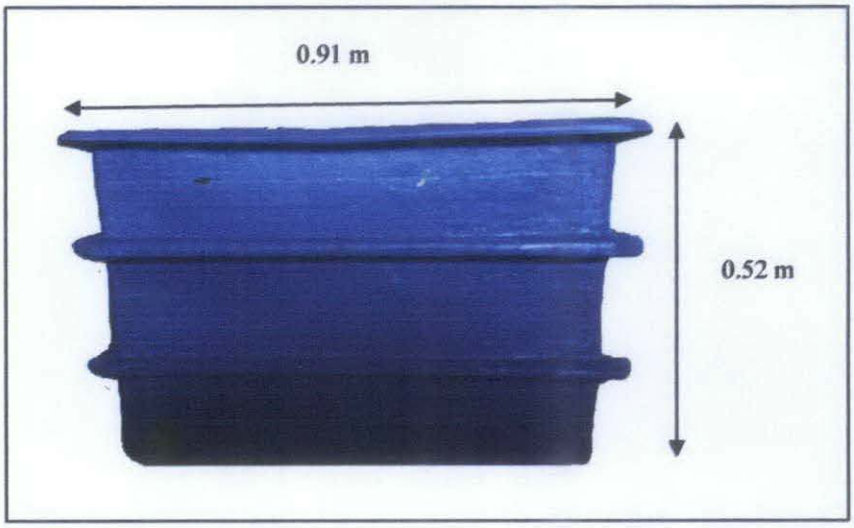

Figure 12: Fiber Tank (Front View)

2. Function Generator

A function generator is an electronic device used to generate electrical waveform. It is specifically used to provide a certain values of frequency that propagate through medium and the function generator used can generate frequency up to 80 MHz. Figure 13 shows the function generator used.

Figure 13: Function generator

3. Curve Transmitter

The transmitter is used to transmit EM wave into the water. Curve transmitter has better penetration of EM wave than the straight transmitter where the penetration is focus at a certain point. The transmitter is connected to the function generator and work as a device to propagate the EM wave into the water. The size of transmitter used is as shown Figure 14.

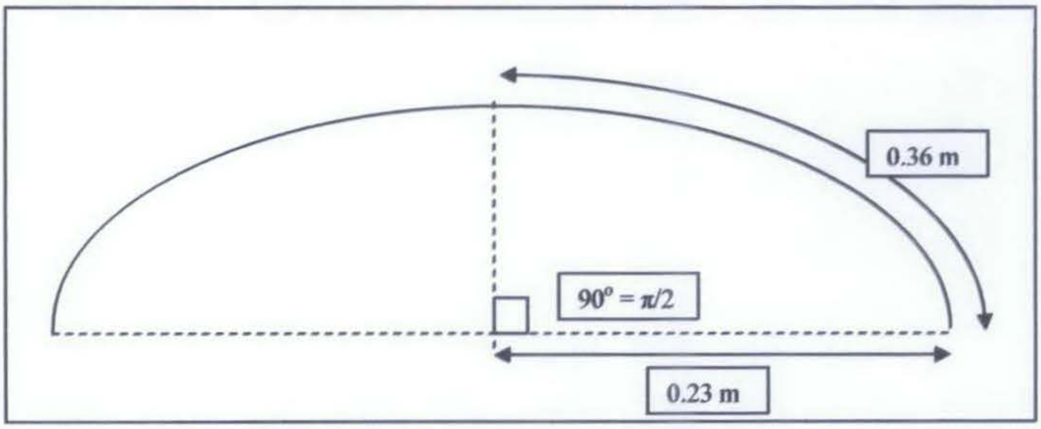

Figure 14: Size of curve transmitter

4. Oscilloscope

The oscilloscope is connected to the receiver and it is used to read the data receives from the receiver. Then, the data will be recorded and analysed. This oscilloscope can measure the reading of frequency up to 60 MHz. Figure 15 shows the oscilloscope used.

Figure 15: Oscilloscope

5. Receiver

The receiver is used as a detector to detect the EM wave propagated from the transmitter. The receiver will detect the propagation of EM wave emitted in the water and transfer the reading of EM wave to the oscilloscope as data. The receiver is made by winding the carbon rod with copper wires and it is shown in Figure 16.

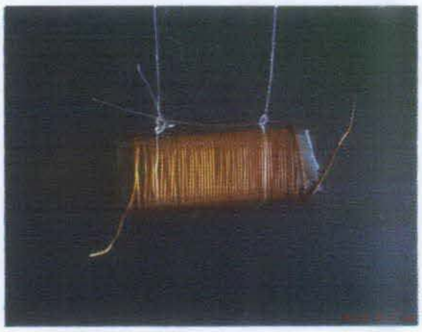

Figure 16: Receiver

6. Packet of Oil

A packet of oil is placed at the bottom of the tank where it will represent hydrocarbon layer under the seabed. When the EM wave propagate downward reached the oil layer, the wave will be refracted back and the receiver will measure the reading of EM wave. The dimension of the packet of oil is as shown in Figure 17.

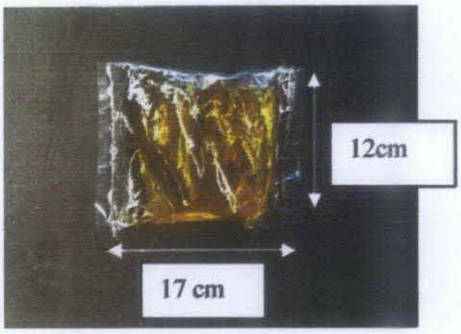

Figure 17: A packet of oil

3.4 Experimental Procedure

For this project, the procedures of the experiment are to vary the values of frequencies and medium resistivity used. The lists of experiments that have been carried out are

1. Experiment 1: Comparison between curve and straight transmitter
2. Experiment 2: Effect of varying frequencies value
3. Experiment 3: Effect of different medium resistivity
4. Experiment 4: Effect of hydrocarbon and without hydrocarbon layer
5. Experiment 5: Effect of varying the depth of hydrocarbon layer

For Experiment 1, the procedures of the experiment that have been followed are:

1. The equipment setup is as shown in the Figure 18 and 19. Curve transmitter is used as transmitter.
2. The function generator is setup to 12.8 MHz. The reading of Vp-p will be taken from the oscilloscope while varying the distance of receiver every 10cm from 0 cm to 90 cm. The data taken is repeated three times to ensure the persistent of the data. From the data received, the graphs are plotted and analyzed.
3. Then, the same procedure is used by changing the frequency to 14.4 MHz and 16 MHz.
4. Step 1 until 3 is repeated by using straight transmitter.

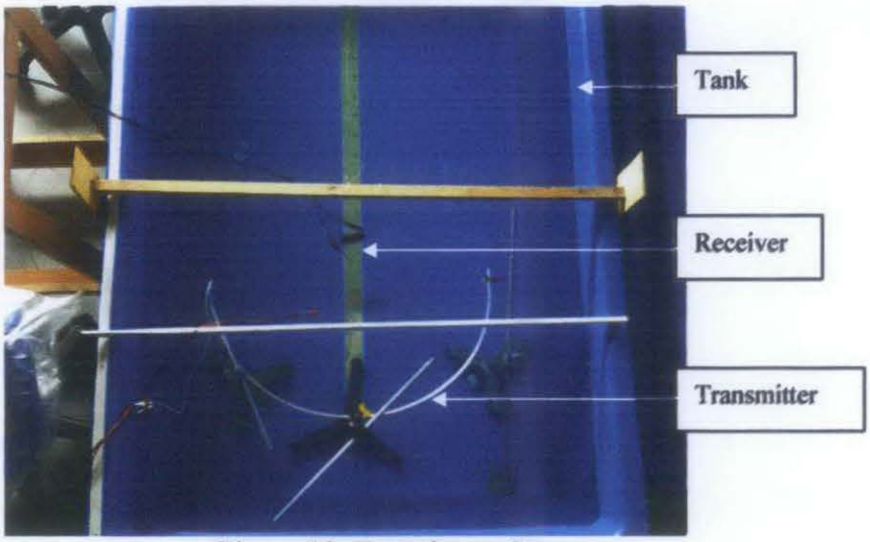

Figure 18: Experiment Setup

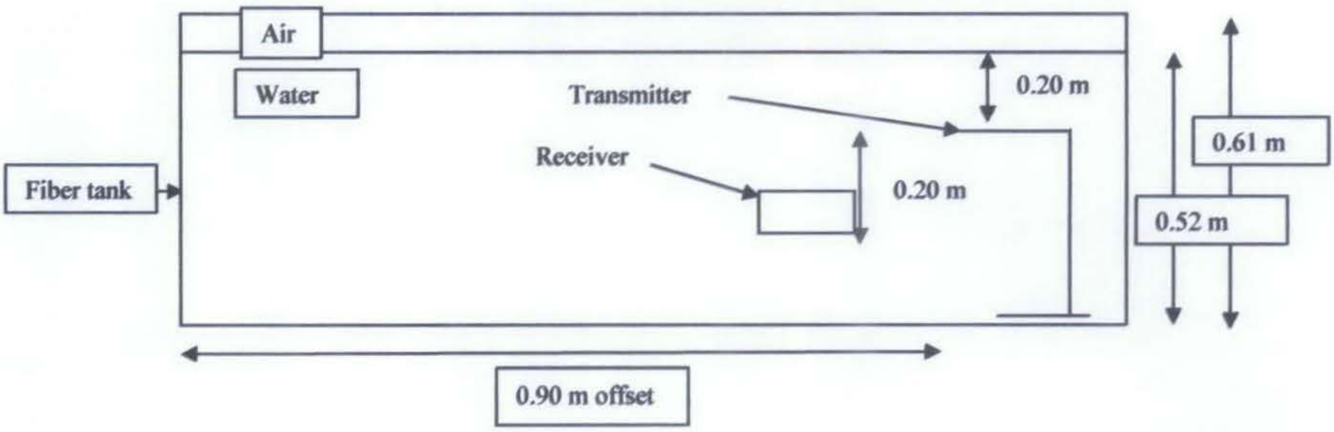

Figure 19: The experimented setup

For Experiment 2, the procedures are as followed:

1. The equipment setup is as shown in the Figure 18 and 19. Curve transmitter is used as transmitter.
2. The function generator is setup to 1.6 MHz. The reading of Vp-p will be taken from the oscilloscope while varying the distance of receiver every 10 cm from 0 cm to 90 cm. The data taken is repeated three times to ensure the persistent of the data.
3. Then, the same procedure is used by changing the frequency to 3.2 MHz, 4.8 MHz, 6.4 MHz, 8.0 MHz, 9.6 MHz, 11.2 MHz, 12.8 MHz, 14.4 MHz and 16 MHz.
4. From the data received, the graphs are plotted and analyzed.

For Experiment 3, the procedures are as followed:

1. The equipment setup is as shown in the Figure 18 and 19. Curve transmitter is used as transmitter.
2. The function generator is setup to 1.6 MHz. The reading of Vp-p will be taken from the oscilloscope while varying the distance of receiver every 10 cm from 0 cm to 90 cm. The data taken is repeated three times to ensure the persistent of the data. From the data received, the graphs are plotted and analyzed.
3. Then, the same procedure is used by changing the frequency to 3.2 MHz and 4.8 MHz.
4. Step 1 until step 3 is repeated by taking the reading in air and saline water.

For Experiment 4, the procedures are as followed:

1. The equipment setup is as shown in the Figure 20. Curve transmitter is used as transmitter.
2. The function generator is setup to 12.8 MHz. The reading of Vp-p will be taken from the oscilloscope while varying the distance of receiver every 10 cm from 0 cm to 90 cm. The data taken is repeated three times to ensure the persistent of the data.
3. Then, the same procedure is used by changing the frequency to 14.4 MHz and 16 MHz.
4. From the data received, the graphs are plotted and analyzed.
5. Next, a packet of oil is placed at the bottom of the tank between the offset of 60 cm to 70 cm from the transmitter.
6. Step 2 until step 4 is repeated.

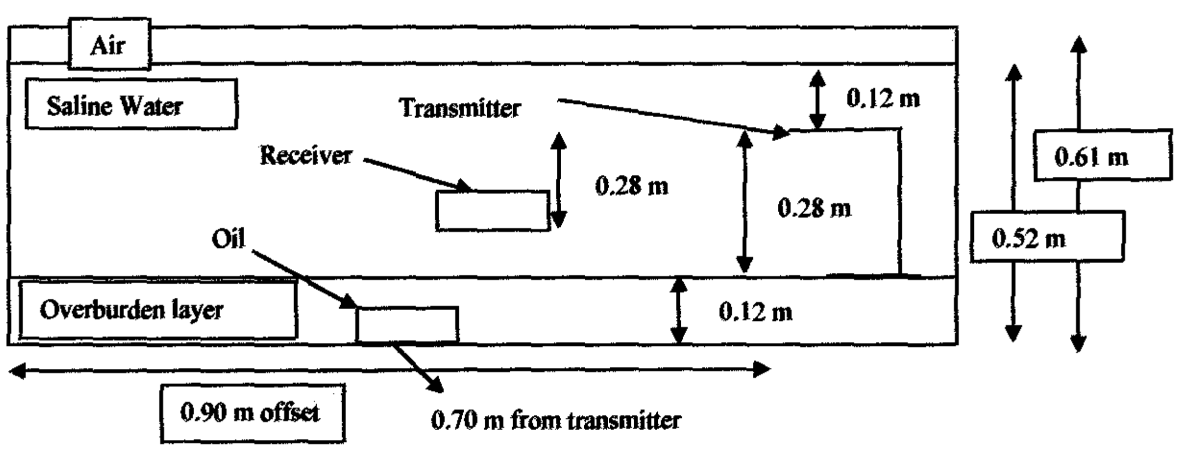

Figure 20: Experimental setup for Experiment 4

For Experiment 5, the procedures are as followed:

1. The equipment setup is as shown in the Figure 21. A packet of oil is placed at the depth of 10 cm from the receiver.
2. The function generator is setup to 12.8 MHz. The reading of Vp-p will be taken from the oscilloscope while varying the distance of receiver every 10 cm from 0 cm to 90 cm. The data taken is repeated three times to ensure the persistent of the data.
3. Then, the same procedure is used by changing the frequency to 14.4 MHz and 16 MHz.
4. From the data received, the graphs are plotted and analyzed.
5. Then, the depth of oil is changed to 5 cm and 2 cm from the receiver. Step 2 until step 4 is repeated.

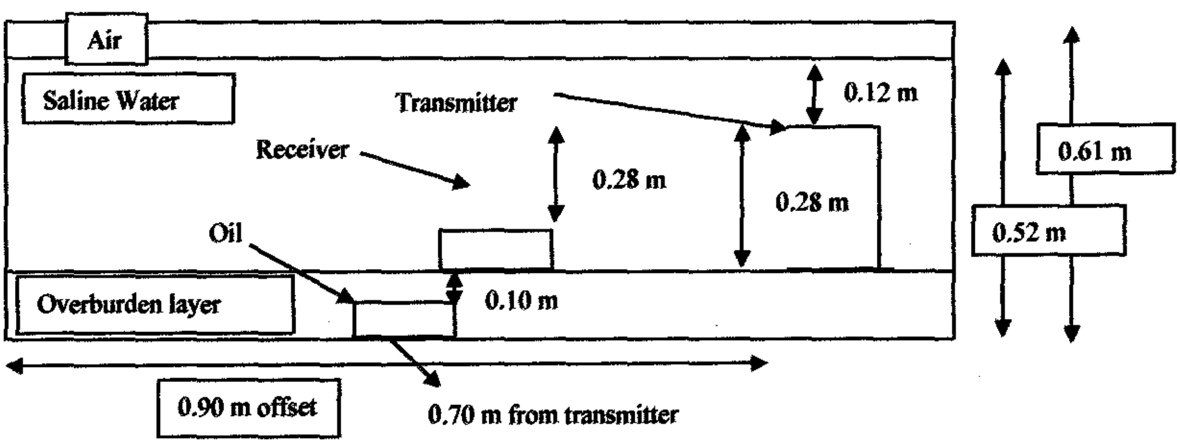

Figure 21: Experimental setup for Experiment 5

CHAPTER 4

RESULTS AND DISCUSSION

For this project, there are five main experiments that have been carried out to study the effect of the resistive layer and signal received by the receiver. Each experiment is done using the scaled tank which resembles the full scaled size of SBL.

4.1 Comparison between curve and straight transmitter

The objective of Experiment 1 is to find the suitable shape of transmitter which can propagate higher intensity of magnetic field for effective transmission. A curve transmitter and a straight transmitter are used to compare the intensity of magnetic field transmitted from both transmitters. The data received from the receiver was analyzed to determine which transmitter is more suitable to use. The graph in Figure 22 shows the result of the experiment. The data taken consist of three different values of frequencies, 12.8 MHz, 14.4 MHz and 16 MHz. Table 3 shows the reading of Vp-p taken from both transmitters.

Table 3: Reading Vp-p of curve and straight transmitter

Frequency used (Hz) / Offset (cm)	(Curve) 12.8 MHz (V)	(Straight) 12.8 MHz (V)	(Curve) 14.4 MHz (V)	(Straight) 14.4 MHz (V)	(Curve) 16 MHz (V)	(Straight) 16 MHz (V)
0	3.22	3.12	2.89	2.56	1.77	1.65
10	3.12	3.02	2.53	2.42	1.54	1.49
20	2.89	2.83	2.44	2.39	1.40	1.33
30	2.77	2.71	2.33	2.33	1.32	1.24
40	2.60	2.51	2.25	2.21	1.25	1.22
50	2.55	2.49	2.22	2.19	1.22	1.15
60	2.54	2.44	2.20	2.12	1.23	1.10
70	2.52	2.41	2.22	2.11	1.21	1.15
80	2.48	2.35	2.19	2.11	1.2	1.16
90	2.44	2.32	2.20	2.10	1.23	1.14

Figure 22: Comparison between curve and straight transmitter

The graph in Figure 22 shows the comparison reading of Vp-p between the curve and straight transmitter. The reference point is at offset 60 cm to compare the differences between curve transmitter and straight transmitter. At 12.8 MHz, the reading of Vp-p of curve transmitter is 2.0 % higher than the reading of Vp-p of straight transmitter. At 14.4 MHz, the reading of Vp-p of curve transmitter is 2.1 % higher than the reading of Vp-p of straight transmitter. Then, at 16 MHz, the reading of Vp-p of curve transmitter is 5.6 % higher than the reading of Vp-p of straight transmitter. The result of the experiment shows the curve transmitter can propagate higher intensity of magnetic field compared to the straight transmitter. Therefore, the curve transmitter will be used as transmitter for the next experiment.

4.2 Effect of frequencies

For Experiment 2, the study will be on the effect of varying the frequencies values. The objective is to analysis the data receive and see what happen if different value of frequency is used. Figure 23 shows the result of the experiment. The data taken consist of ten different values of frequencies, 1.6 MHz, 3.2 MHz, 4.8 MHz, 6.4 MHz, 8.0 MHz, 9.6 MHz, 11.2 MHz, 12.8 MHz, 14.4 MHz and 16 MHz. The results of the reading Vp-p is shown in the Table 4.

Table 4: Reading Vp-p for different frequencies

Frequency used (MHz) /Offset (cm)	1.6MHz (V)	3.2MHz (V)	4.8MHz (V)	6.4MHz (V)	8.0MHz (V)	9.6MHz (V)	11.2MHz (V)	12.8MHz (V)	14.4MHz (V)	16MHz (V)
0	2.38	2.34	1.92	1.62	1.47	1.32	1.25	1.22	1.15	1.02
10	2.25	2.2	1.78	1.48	1.35	1.24	1.22	1.19	1.13	0.996
20	2.22	2.18	1.75	1.38	1.30	1.22	1.18	1.16	1.10	0.982
30	2.22	2.14	1.75	1.34	1.27	1.20	1.15	1.14	1.08	0.956
40	2.20	2.10	1.72	1.32	1.25	1.18	1.12	1.10	1.06	0.946
50	2.18	2.10	1.74	1.32	1.26	1.18	1.12	1.08	1.06	0.932
60	2.13	2.08	1.74	1.3	1.26	1.15	1.12	1.04	1.01	0.93
70	2.12	2.08	1.74	1.32	1.25	1.14	1.11	1.03	1.00	0.928
80	2.12	2.06	1.72	1.28	1.24	1.12	1.08	1.03	0.985	0.896
90	2.10	2.06	1.72	1.26	1.23	1.10	1.05	1.03	0.975	0.888

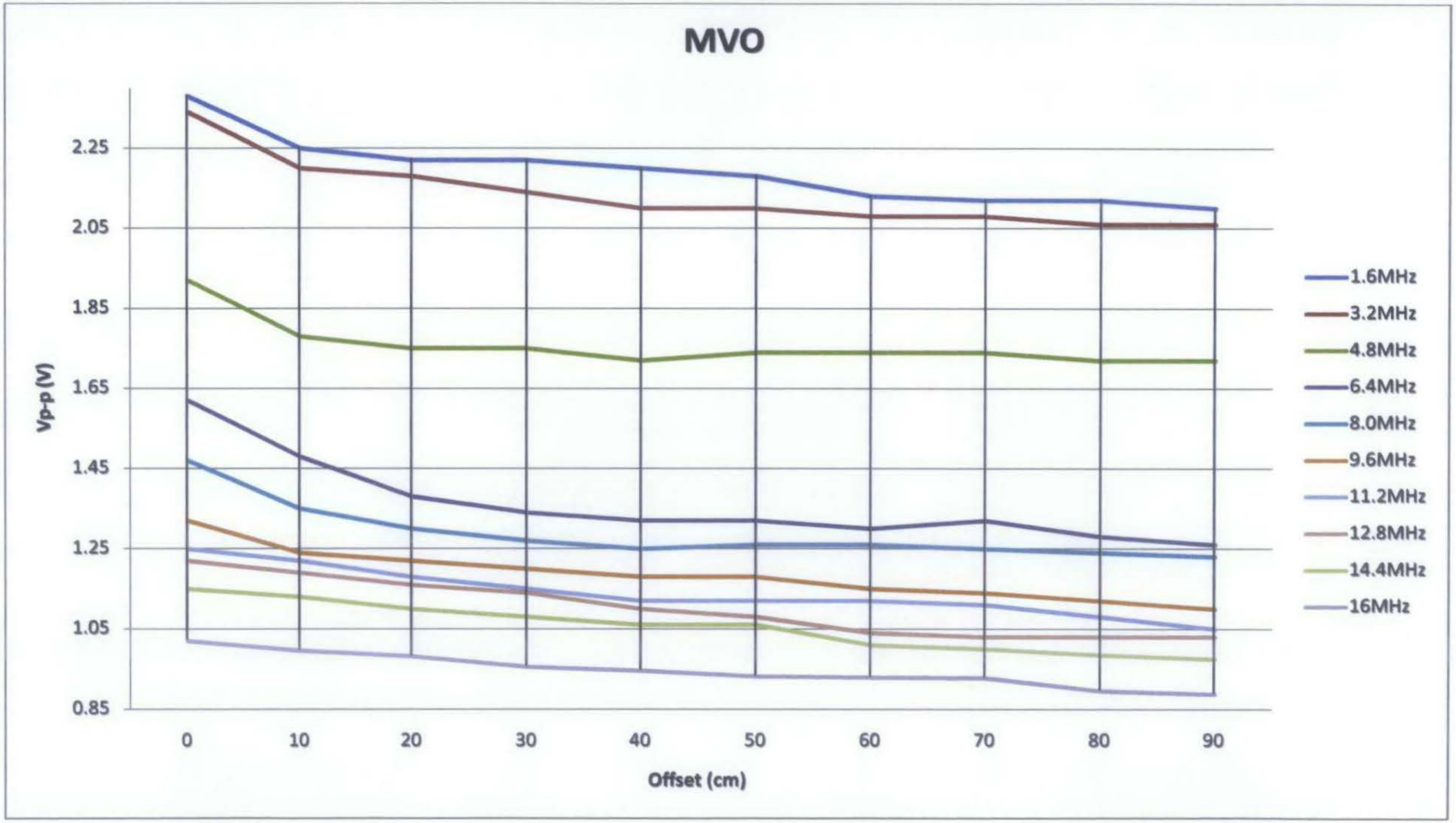

Figure 23: Effect of frequencies

The graph in Figure 23 shows the decreasing of reading Vp-p as the offset of transmitter increased. The smaller the value of frequency used, the higher the value of Vp-p. It is because low frequency has higher wavelength compare to high frequency. In real application of SBL, low frequency is used to propagate the EM wave, in the range 0.1 Hz to1.0 Hz

4.3 Effect of different medium resistivity

The main objective of this experiment is to study the effect of different medium resistivity used toward the propagation of EM wave. The value of frequency used is 1.6 MHz, 3.2 MHz and 4.8 MHz which is low frequency. The medium resistivity used is varies into three medium which are water, saline water, air. Figure 24 shows the result of the experiment. The reading of Vp-p is as shown in Table 5.

Table 5: Reading Vp-p for different medium resistivity

Frequency used (MHz) / Offset (cm)	(Water) 1.6 MHz (V)	(Saline water) 1.6 MHz (V)	(Air) 1.6 MHz (V)	(Water) 3.2 MHz (V)	(Saline water) 3.2 MHz (V)	(Air) 3.2 MHz (V)	(Water) 4.8 MHz (V)	(Saline water) 4.8 MHz (V)	(Air) 4.8 MHz (V)
0	2.38	4.58	1.02	2.24	4.32	1.090	2.22	4.23	1.09
10	2.25	4.23	0.955	2.20	4.23	0.992	2.14	4.12	0.991
20	2.22	4.12	0.922	2.18	4.19	0.993	2.16	4.09	0.985
30	2.22	4.05	0.956	2.15	4.09	0.994	2.15	3.96	0.976
40	2.20	3.95	0.946	2.11	3.98	0.954	2.09	3.85	0.965
50	2.18	3.90	0.892	2.11	3.90	0.912	2.05	3.78	0.927
60	2.13	3.85	0.888	2.13	3.86	0.887	2.01	3.65	0.875
70	2.12	3.67	0.865	2.09	3.55	0.892	1.99	3.45	0.823
80	2.12	3.62	0.856	2.05	3.46	0.867	1.98	3.32	0.805
90	2.10	3.56	0.812	2.00	3.35	0.832	1.89	3.12	0.781

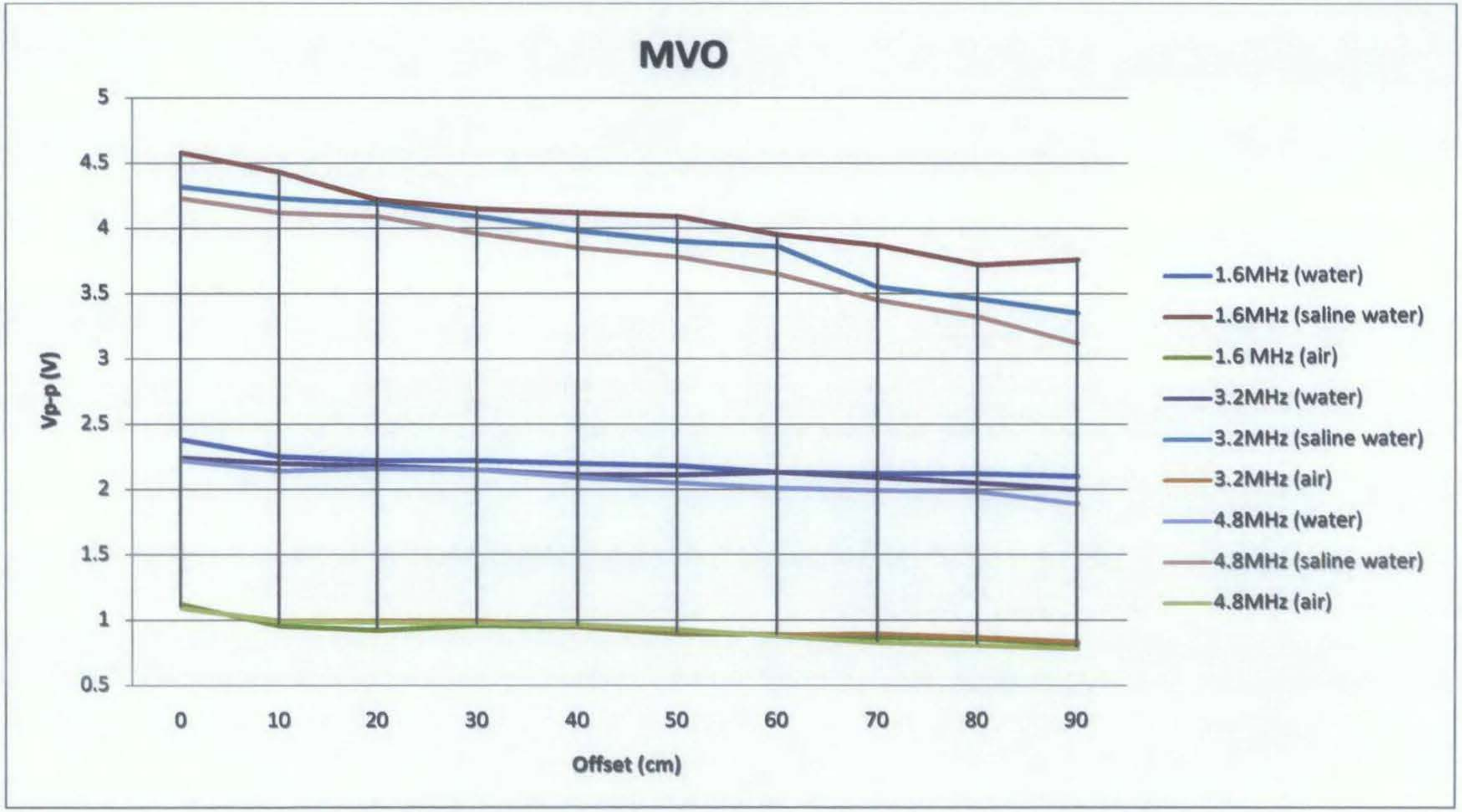

Figure 24: Effect of different medium resistivity

The graph in Figure 24 shows the different value of Vp-p for each different medium resistivity used. The comparison between water and saline water is made by referring at offset 60cm. Overall, the value of Vp-p is higher in saline water than in water and air. At 1.6 MHz, the value of Vp-p taken in saline water is 28.76 % higher than the value of Vp-p in water. At 3.2 MHz, the value of Vp-p taken in saline water is 28.88 % higher than the value of Vp-p in water. At 4.8 MHz, the value of Vp-p taken in saline water is 26.84 % higher than the value of Vp-p in water. It is because saline water has higher conductivity compare to the water and air. The value of Vp-p in air is very low because there are noises and distortion from the surrounding.

4.4 Effect hydrocarbon and without hydrocarbon layer

The objective of this experiment is to determine the location of hydrocarbon layer buried between the sediment layers. Suppose that, the reading of Vp-p will be high if the place has hydrocarbon layer. The reading taken consists of three different values of frequency, 12.8 MHz, 14.4 MHz and 16 MHz. Figure 25 shows the result of the experiment. A packet of oil is places between the offset of 60 cm to 70 cm. The reading of Vp-p is as shown in Table 6.

Table 6: Reading Vp-p with hydrocarbon and without hydrocarbon layer

Frequency used (MHz) / Offset (cm)	(Without oil) 12.8 MHz (V)	(With oil) 12.8 MHz (V)	(Without oil) 14.4 MHz (V)	(With oil) 14.4 MHz (V)	(Without oil) 16 MHz (V)	(With oil) 16 MHz (V)
0	3.22	3.23	2.89	2.89	1.77	1.78
10	3.12	3.12	2.53	2.54	1.54	1.55
20	2.89	2.79	2.44	2.45	1.4	1.41
30	2.77	2.77	2.33	2.34	1.32	1.34
40	2.6	2.61	2.25	2.25	1.25	1.25
50	2.55	2.55	2.22	2.23	1.22	1.24
60	2.54	2.54	2.2	2.26	1.23	1.23
70	2.52	2.62	2.22	2.36	1.21	1.25
80	2.48	2.6	2.19	2.37	1.2	1.25
90	2.44	2.54	2.2	2.34	1.23	1.23

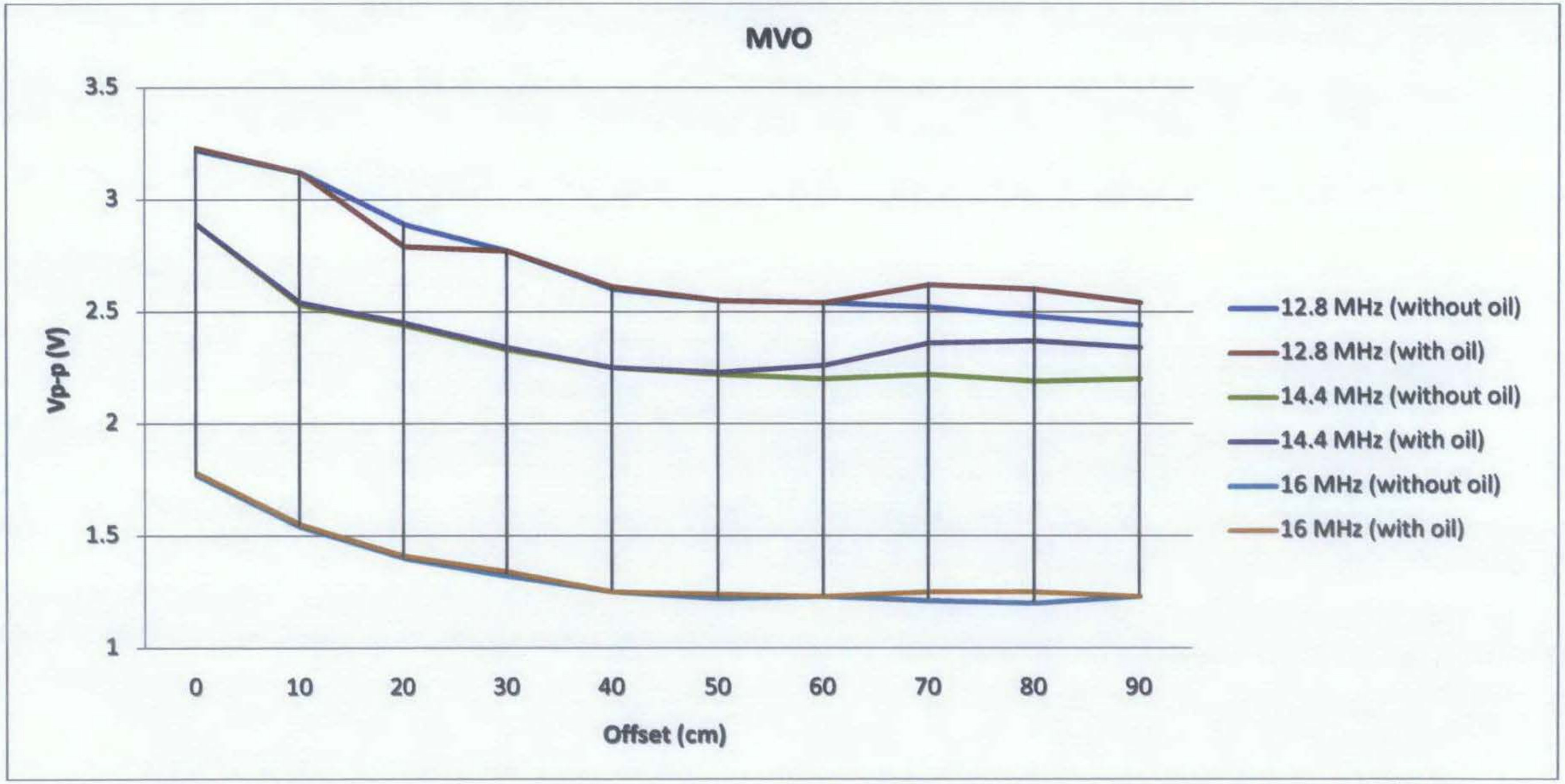

Figure 25: Effect with hydrocarbon and without hydrocarbon layer

The graph in Figure 25 (with oil) shows that at 12.8 MHz, the reading of Vp-p increased from the offset 60 cm until 80 cm. It indicated that, there is oil between the offset of 60 cm to 80 cm. The value of Vp-p increased about 1.9 % compare to the reading of Vp-p taken when there is no oil layer at the offset 70 cm. At 14.4MHz, the reading of Vp-p increased from the offset 60 cm until 80 cm. It indicated that, there is oil between the offset of 60 cm to 80 cm. The value of Vp-p increased about 3.06 % compare to the reading of Vp-p taken when there is no oil layer at the offset 70 cm. At 16 MHz, the reading of Vp-p increased from the offset 65 cm until 80 cm. It indicated that, there is oil between the offset of 65 cm to 80 cm. The value of Vp-p increased about 1.6 % compare to the reading of Vp-p taken when there is no oil layer at the offset 70 cm.

4.5 Effect of varying the depth of hydrocarbon layer

This experiment is to study the effect of varying the depth of hydrocarbon layer. The hydrocarbon layer is placed at three different places which are 2cm, 5cm and 10cm from the receiver. The graph in Figure 26 shows the result of the experiment. A packet of oil is places between the offset of 50cm to 60cm. The reading of Vp-p taken is as shown in the Table 7.

Table 7: Reading Vp-p of different depth of hydrocarbon layer

	Depth (2cm from receiver)			Depth (5cm from receiver)			Depth (10cm from receiver)		
Frequency used (MHz) / Offset (cm)	12.8 MHz (V)	14.4 MHz (V)	16 MHz (V)	12.8 MHz (V)	14.4 MHz (V)	16 MHz (V)	12.8 MHz (V)	14.4 MHz (V)	16 MHz (V)
0	3.23	2.89	1.78	3.21	2.9	1.76	3.22	2.89	1.74
10	3.12	2.54	1.55	3.12	2.54	1.53	3.11	2.53	1.54
20	2.79	2.45	1.41	2.8	2.43	1.41	2.81	2.45	1.42
30	2.77	2.34	1.34	2.76	2.33	1.33	2.77	2.33	1.32
40	2.61	2.25	1.25	2.61	2.25	1.25	2.6	2.26	1.25
50	2.55	2.23	1.24	2.54	2.21	1.22	2.56	2.24	1.23
60	2.54	2.26	1.23	2.52	2.22	1.23	2.58	2.23	1.24
70	2.62	2.36	1.25	2.62	2.35	1.25	2.56	2.32	1.27
80	2.6	2.37	1.25	2.58	2.34	1.24	2.53	2.29	1.24
90	2.54	2.34	1.23	2.5	2.32	1.22	2.51	2.27	1.23

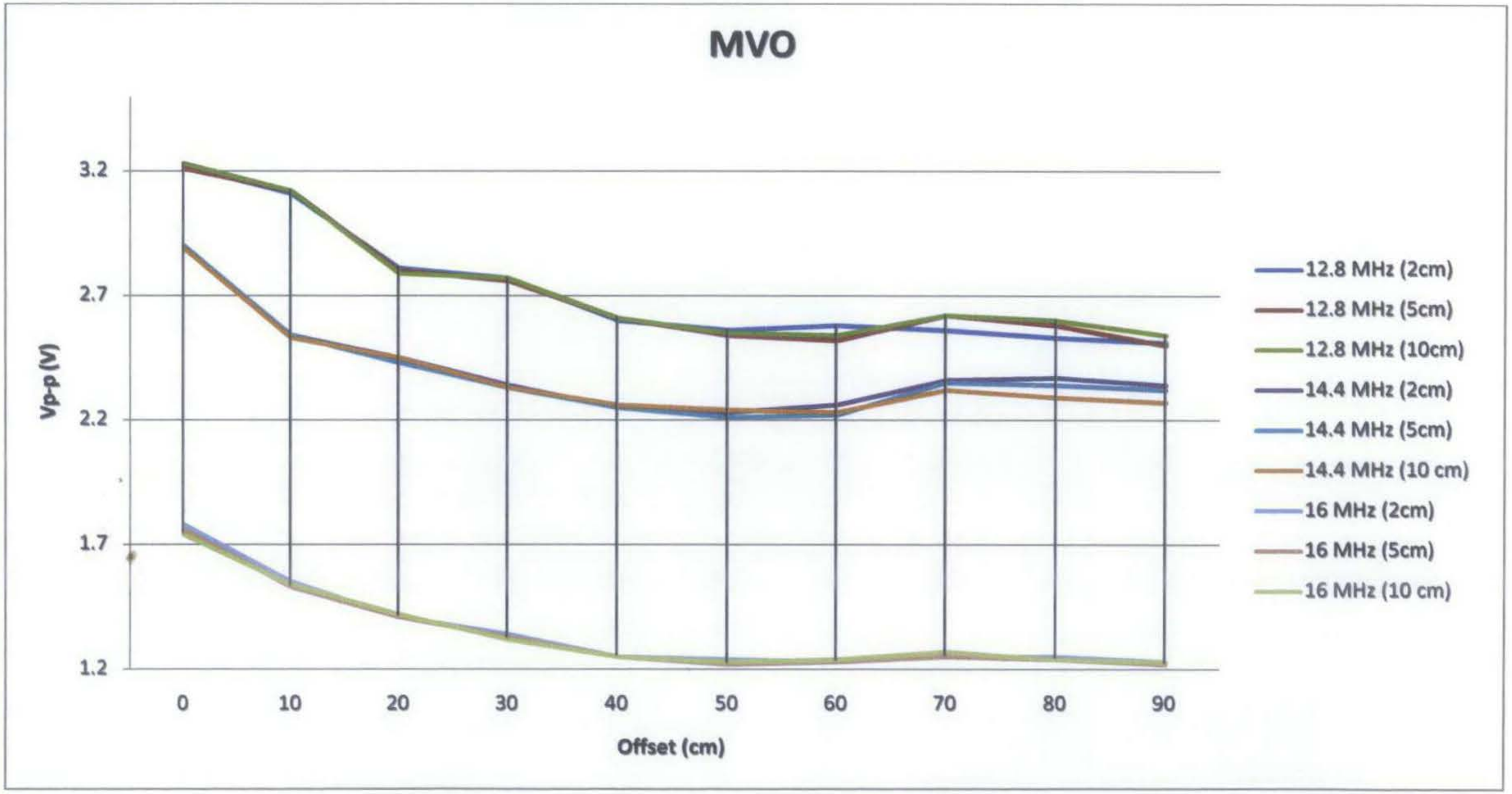

Figure 26: Effect of varying the depth of hydrocarbon layer

The graph in Figure 26 shows an increment of reading of Vp-p at different offset for different depth of hydrocarbon layer. At 12.8M Hz, for 2 cm depth of hydrocarbon layer from the receiver, the reading of Vp-p increased starting from the offset 55 cm to 65 cm. For 5 cm depth of hydrocarbon layer from the receiver, the reading of Vp-p increased starting from the offset 60 cm to 70 cm. Then, for 10 cm depth of hydrocarbon layer from the receiver, the reading of Vp-p increased starting from the offset 60 cm to 70 cm.

At 14.4 MHz, for 2 cm depth of hydrocarbon layer from the receiver, the reading of Vp-p increased starting from the offset 55 cm to 70 cm. For 5 cm depth of hydrocarbon layer from the receiver, the reading of Vp-p increased starting from the offset 60 cm to 70 cm. Then, for 10 cm depth of hydrocarbon layer from the receiver, the reading of Vp-p increased starting from the offset 60 cm to 70 cm.

At 16 MHz, for 2 cm depth of hydrocarbon layer from the receiver, the reading of Vp-p increased starting from the offset 60 cm to 80 cm. For 5 cm depth of hydrocarbon layer from the receiver, the reading of Vp-p increased starting from the offset 60 cm to 70 cm. Then, for 10 cm depth of hydrocarbon layer from the receiver, the reading of Vp-p increased starting from the offset 60 cm to 70 cm.

From the results obtained, we can conclude that, the closer the distance of oil layer to the sand surface, the closer the offset of increasing value of Vp-p from the location of oil layer. The further the distance of oil layer to the sand surface, the further the offset of increasing value of Vp-p from the location of oil layer. It is because the different depth of oil will refract the EM wave at different distance.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The objectives of studying the effect of frequency and medium resistivity and SBL modelling are achieved. It was found that the curve transmitter can propagate high intensity of magnetic field compared to the straight transmitter. Low frequency shows better penetration of EM wave compared to high frequency because low frequency travels with lower attenuation.

The set of scale tank that represent the sea water environment shows that EM wave can be used to detect the present of hydrocarbon layer. The receiver shows higher reading when there is hydrocarbon layer below the seabed compared to when there is no hydrocarbon layer. Also, when the depth of hydrocarbon layer is far from the seafloor, the offset of reflected EM wave received by the receiver is further from hydrocarbon layer compared when the depth of hydrocarbon layer is closer to the seafloor.

5.2 Recommendation

The results obtained from the experiments are relevant with the objective. If this project is to be expanded in wider scope, we will able to find lot of significant theories and at the same time gain more knowledge in applied of science. One of the suggestions that can be made to improve the project is the use of the tank. The size of the tank used can be a bigger tank than the previous size which can ratio the closer size of the actual full scale of sea size. Besides that, there are other parameters that can be consider into analyze such as temperature and pressure of the water since that both of them can affect the resistivity of the sediment and hydrocarbon.

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APPENDICES

APPENDIX A
Gantt Chart FYP 1

No.	Detail/ Week	1	2	3	4	5	6	7		8	9	10	11	12	13	14	15
1	Title Selection								Mid- Semester Breaks								
2	Research Work																
3	**Submission of Preliminary Report**																
4	Equipments Survey																
5	**Submission Progress Report**																
6	Seminar																
7	**Submission Draft Report**																
8	Submission Final Report																
9	**Oral Presentation**																

APPENDIX B
Gantt Chart FYP 2

No.	Detail/ Week	1	2	3	4	5	6	7	Mid- Semester Breaks	8	9	10	11	12	13	14	15
1	Assemble the project - Vary medium resistivity - Use oil as hydrocarbon	■	■	■	■	■	■	■									
2	Submission of Progress Report									■							
3	Continue assemble the project - Use saline water as medium resistivity - Use sand and rock as layers									■	■	■					
4	Poster Exhibition											■					
5	Submission of Dissertation (soft bound)													■			
6	Poster Presentation (Electrex)														■		
7	Submission Project Dissertation (Hard Bound)															■	
8	Oral Presentation																■