CERTIFICATION OF APPROVAL

DESIGN AND DEVELOPMENT OF ANTENNA FOR THE SCALE DOWN MODEL OF A SEA BED LOGGING (SBL) FACILITY

by

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CERTIFICATION OF ORIGINALITY

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

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ABSTRACT

Controlled-source electromagnetic (CSEM) methods had been used for marine geological surveying for many years. The electromagnetic (EM) technique for marine hydrocarbon prospecting which first used commercially, has gained wide industry acceptance and many improvements have been made to operating practices, survey equipment, and data-processing techniques in the past few years. The objective of this project is to improve a small scale of SBL model measurement facility that had been earlier developed at Universiti Teknologi Petronas (UTP), to develop a better, well develop electrical dipole antenna to collect experimental data such as resistance and magnetic field measurement, and to verify the result through theoretical modeling. The lab scale model of SBL system was completed with several specification changes and modifications. Modifications are needed in order to simulate different skin depth effect. Theoretical modeling is done before lab experimentation is performed. Several experimentations have been made and the result is not very accurate. It is still unclear if there are something buried in the sand from the reading of the receiver. Therefore several factors have been identified to be the cause of the invalid result. Thus, future works based on current problem are also suggested.

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LIST OF ABREVIATIONS

CSEM	Controlled Source Electromagnetic
EM	Electromagnetic
SBL	Sea Bed Logging
DMM	Digital Multi-Meter

CHAPTER 1
INTRODUCTION

1.1 Background of Study

The time-domain and frequency-domain electromagnetic (EM) methods have come into use in minerals exploration for detection of conductive ore bodies and other geophysical exploration. Along with the development of the method and the applied field, it has been used in the sea-floor resource and engineering explorations and so on [1]. The EM technique for marine hydrocarbon prospecting, first used commercially in November 2002, identifies resistive reservoirs by measuring the energy received at long source–receiver offset distances [2]. Statoil (a Norwegian petroleum company) researchers first showed the potential of the approach during the late 1990s. Electromagnetic Geoservices AS (EMGS), based in Trondheim, Norway, was formed in 2002 to commercialize the technique. In the past few years, many improvements have been made to operating practices, survey equipment, and data-processing techniques. These developments have resulted in the acquisition of a considerable body of high quality data under a wide range of conditions, and the delivery of sophisticated answer products that now include depth-migrated images of resistive subsurface bodies.

In the late 1990s, Svein Ellingsrud and Terje Eidesmo then with Statoil, were conducting research into electromagnetic (EM) methods for detecting reservoir oil/water contacts [2]. While working on the use of borehole-deployed EM sources, they learned of a powerful new source with the potential to propagate EM energy 2 km or more in the subsurface. Controlled-source electromagnetic (CSEM) methods had been used for marine geological surveying for many years. CSEM takes controlled artificial field in order to measure the EM field, explore underground distributed electric character by calculating apparent resistivity and apparent depth [1]. Ellingsrud and Eidesmo now speculated about whether this new source could be used, in a novel CSEM surveying application, to detect offshore hydrocarbons without drilling a well. Working with others, they modeled the behavior of EM propagation at both long and short offsets, with encouraging results. They have made a conclusion under the right conditions, resistive bodies in the subsurface could guide EM energy over long distances with low levels of attenuation. Furthermore, their modeling showed that, in relatively deep water, this propagation mode could dominate others. The implication was that CSEM data recorded with long source-receiver offsets could be used to detect resistivity anomalies on the scale of many commercial hydrocarbon reservoirs [3]. Thus, the technique initially expected to complement deepwater seismic data by identifying the location of resistive hydrocarbon bearing formations within structures. The CSEM surveying and wellbore resistivity logging led to a new technique called seabed logging (SBL).

Considering this new technique of logging is the future of oil and gas, a study about the SBL was started few years back in University Technology of Petronas (UTP) as a final year project (FYP). A scaled down model with ratio of 100 was created using proper material. The model consists of polyethylene tank as the sea with sand as the seabed, coaxial antenna as transmitter and a coil as a receiver. There are several important involve this project and the hopes are huge, to prove, improve, and to have a better understanding and gain knowledge for those who are related and interested with the future exploration of oil and gas.

1.2 Problem Statement

Several limitations and constraints have been identified with the current simplified scaled down model of SBL that has been built. The main problem of the previous work was there is no such way to differentiate direct wave, air wave, and reflected wave from the previous model. The most important wave that needed to be observed is the reflected wave but since direct wave travel the least compared to others, it will dominate reading of receiver. Further than that, the receiver tends to be less sensitive with the waves transmitted by the transmitter.

Several frequencies of transmitted waves have been tested before and it is proven that frequency of 4 kHz has the minimum value of root mean square error. But, the current needed for the generated wave to be strong enough to be detected by a receiver is not studied yet. The effect of chemical reaction of a conductor carrying current in salted water also needs to be discussed. Furthermore, the effect of length and diameter of antenna also need to be clarified. By combining all of these uncertainty conditions, a better or improved antenna shall be develop and later on, by integrating with a improved receiver, a proper result can be achieved.

1.3 Objective and Scope of Study

The objective of this project is to improve a simplified small scale SBL model measurement facility which will focus on design and developing the electrical dipole antennas, and also to collect and identifying relevant data through experiment. These objectives are also shown below.

- To improve the small scale of SBL model measurement facility
- To develop a better, well develop electrical dipole antenna
- To integrate transmitter with receiver to produce convincing results

CHAPTER 2
LITERATURE REVIEW

2.1 Sea Bed Logging

The recording of electrical resistivity measurements for use in estimating the fundamental properties of rocks such as porosity, saturation, etc is known as electrical logging [5]. In many applications of marine CSEM and in SBL, the signal sources are electrical dipole antennas which are towed slightly above the seabed. These signals are recorded by stationary seabed receivers as shown in Figure 1 [4].

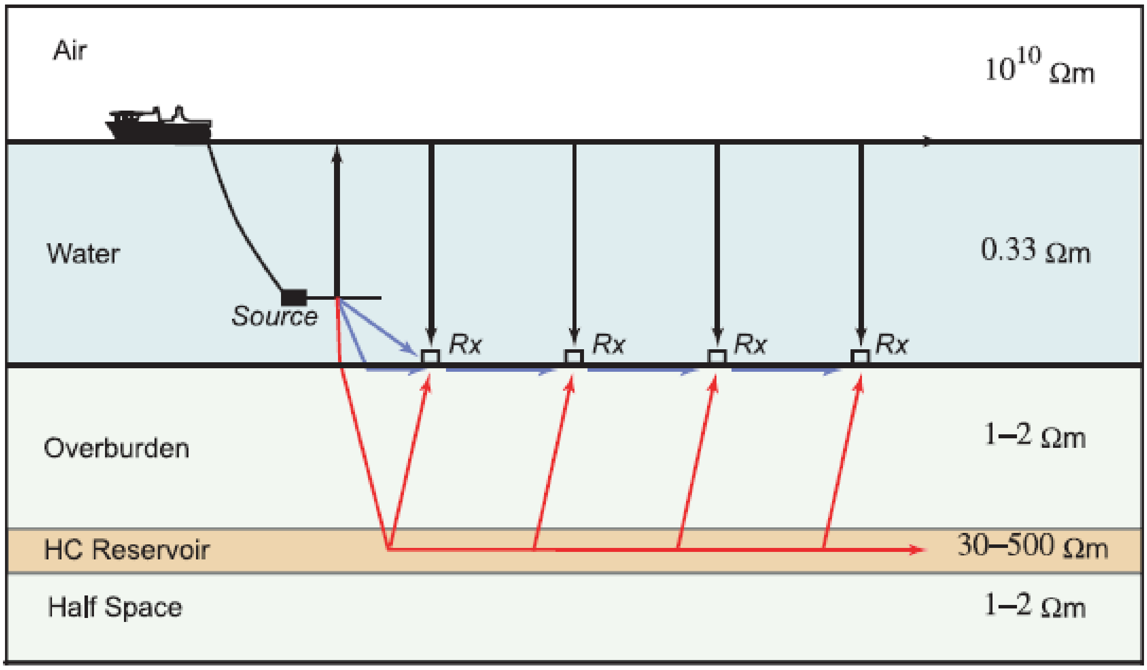

Figure 1 : Sea Bed Logging Overview [4]

The transmitting dipole emits a low frequency electromagnetic signal that diffuses outwards into both the overlaying water column and downwards into the seabed. The air wave component contains no information about the sub seafloor resistivity and can dominate the received signal in shallow water. However, in deep water the EM fields measured at the receivers are dominated by the source field that followed diffusion paths though the seabed due to the fact that skin depth in the sea bed are longer, i.e. less EM wave attenuation. In this case, the reflected energy from high resistivity subsurface layers will dominate over directly transmitted energy when the source-receiver distance is comparable to or greater than the depth to this layer. The detection of this guided and reflected energy is the basis of SBL [4].

2.2 Skin Depth

The skin depth characterizes how well an EM wave penetrates a conducting medium. It is a distance at which EM wave amplitude is attenuated by the factor $1/e$ (37%).

According to [7], the normalized magnitude of a uniform plane wave with a magnetic field $\widetilde{H} = \hat{y}\widetilde{H}_y(\mathrm{z})$ traveling in the positive z-direction decreases exponentially with (z) at a rate specified by the skin depth (δ_s) and is given by:

$$\frac{\widetilde{H}_y(z)}{H_y(0)} = e^{\frac{z}{\delta_s}} \tag{1}$$

Skin depth (δ_s) is a function of wave frequency (f) and medium characteristics such as conductivity (σ) and permeability (μ). For a good conductor such as sea water, the skin depth is calculated using the following formula:

$$\delta_s = \sqrt{\frac{1}{4\pi^2 \times 10^{-7}\sigma f}}\,(m) \tag{2}$$

Because the seabed is more resistive which is less conductive than sea water, skin depth in the sea bed are longer, even longer in hydrocarbon layers. This resistivity contrast between hydrocarbon layers and the surrounding sedimentary layers influence the SBL data collected above the reservoir and indicate its presence [2].

Conductivity of sea water depends on salinity and temperature. Around the world, salinity are varies. Generally in oceans, the average salinity is 3.5% by weight. At $0^o C$, sea water conductivity $\sigma = 2.94 - 4\ S/m$ and its reciprocal, the resistivity is approximately 0.34 Ωm.

2.3 Ampere's Law

Ampere's law stated that the line integral of magnetic field intensity (*H*) around a closed path *C* is equal to the sum of the conduction current (I_c) and the displacement current (I_d) flowing through the surface bounded by the path [7].

$$\oint_c H.dl = I_c + I_d \quad (3)$$

However for marine applications, the displacement current is ignored when signal transmission is at lower frequencies and sea water is a good conductor. Hence the magnetic field intensity (*H*) at radial distance (ρ) from a copper antenna with inner conductor radius (a), insulation radius (b), outer conductor radius (c) submersed in sea water with conductivity ($\sigma_{seawater}$) for a length ($l_{exposed}$) is given by:

$$H = \frac{I_{gen} - I_{ret}}{2\pi\rho}(A/m) \quad (4)$$

Where the current generated in the feed section of the antenna is:

$$I_{gen} = \frac{V}{(R'_{ic} + R'_{oc}) \times l_{feed} + (R'_{ic} + R'_{sw})l_{exposed}} (A) \quad (5)$$

Where R'_{ic} is resistance of inner conductor, R_{oc} is resistance of outer conductor, R_{sw} is resistance of sea water.

And the return (enclosed) current is:

$$I_{ret} = \frac{V}{(R'_{ic} + R'_{sw}) \times l_{exposed}} (A) \quad (6)$$

Ohm's law stated that the Direct Current (DC) Resistance per unit length (R') of any conductor with conductivity (σ) and cross-sectional area (*A*) is given by:

$$R' = \frac{1}{\sigma A}(\Omega/m) \quad (7)$$

Therefore,

$$R'_{ic} = \frac{1}{\sigma_{copper}\ \pi a^2} (\Omega/m) \tag{8}$$

$$R'_{oc} = \frac{1}{\sigma_{copper}\ \pi (c^2 - b^2)^2} (\Omega/m) \tag{9}$$

$$R'_{sw} = \frac{1}{\sigma_{seawater}\ \pi (h^2 - b^2)^2} (\Omega/m) \tag{10}$$

Since the radial distance (ρ) is the denominator, it is observed that the magnetic field (H) is inversely proportional to radial distance (ρ).

CHAPTER 3
METHODOLOGY

3.1 Procedure Identification

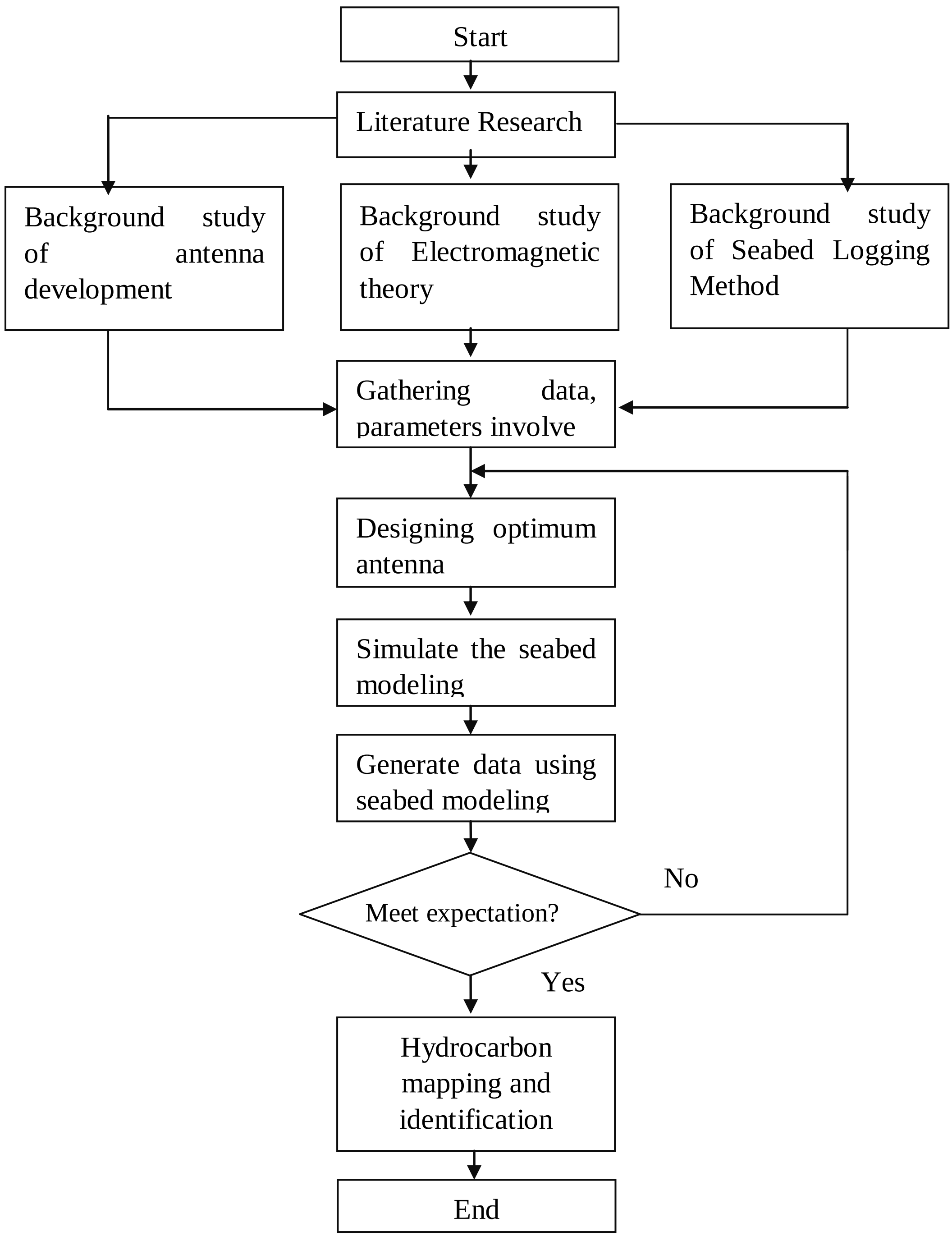

Figure 2 : Flow Chart of Project Work

3.2 Overview

Although the small scale SBL is already developed, it is required to study the existing model to make sure it works like it should be. Testing the model is the first step taken in the progress. The testing including functionality test for optimum performance as it already succeeded in the past. Several aspects should be taken care such as the current condition, apparatus and also functionality.

Designing process already done in FYP 1. Designing the optimum antenna include the best material, dimension, and also the best conditio. In FYP 2, testing and experimentaion is done. This is the crucial part as the result from the procedure will be affecting the whole project.

System integration is where the optimum antenna integrates with the full system. This is the climax of the project before the system is ready to be tested. This step include integration between the optimum antenna with the new develop sensitive receiver. Should everything run smoothly, a very good experimental result shall be got. Final test is then conducted to detect a high resistivity material buried under soils. This is the final part of this project and has been done. The results are shown in Chapter 4 – Result and Discussion.

3.3 Lab Scaled Model

For the scaled model to be an accurate representation of the full size system, the parameters that describe it must satisfy definition relations that are determined by the chosen scaled factor [8]. Table 1 shows the effect of choosing different scale factors on the scale model's frequency, physical dimension, current, magnetic fields, and conductivity.

Table 1 : Effect of Scaling Factors on the Scale Model Parameters

Parameters	Full Size Model	Ideal Scale Model	Actual Scale Model
Frequency (Hz)	0.25	25.0	**4000**
Dimension (m)	100	1.0	**0.70**
Current (A)	1000	0.45	**0.50**
H-Field (dB)	3	1	**-0.9539**
Conductivity (S/m)	2.94	294.0	**10.31**

A MATLAB® script (Appendix A) was originally developed is then modified to demonstrate the effect of the scaling factors on model's accuracy and results. A plot of Magnetic field intensity (H) versus the radial distance (ρ) was plotted for both the full size model and the scaled model as shown in Figure 3, Figure 4 and Figure 5.

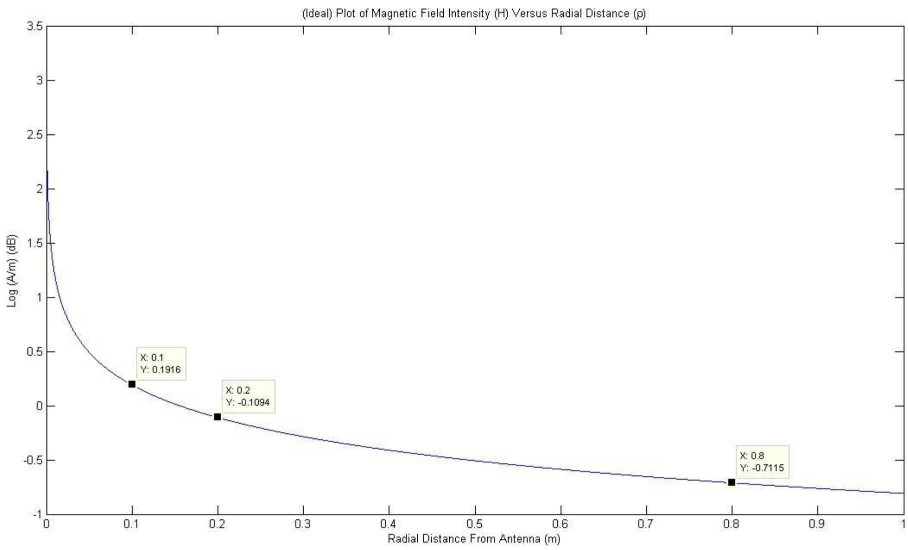

Figure 3 : Full Scale Model Simulation

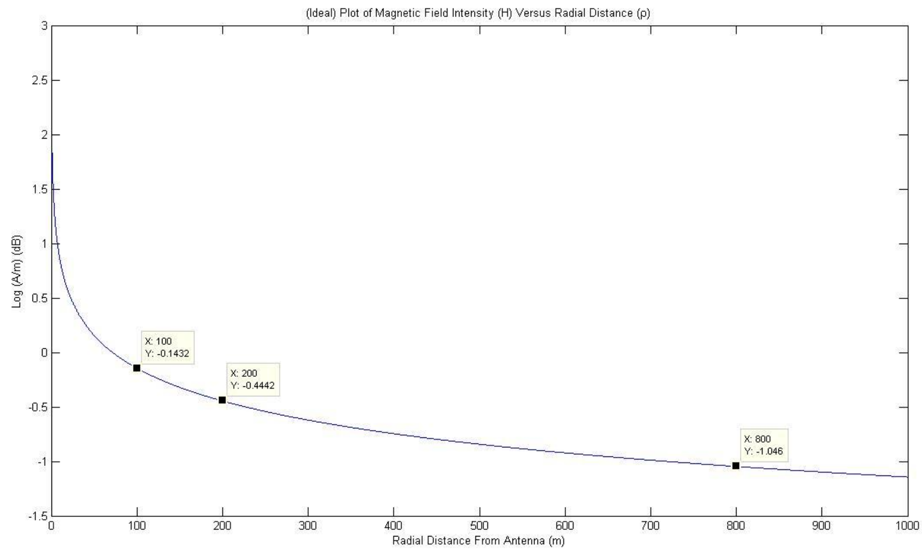

Figure 4 : Ideal Scale Down Model Simulation

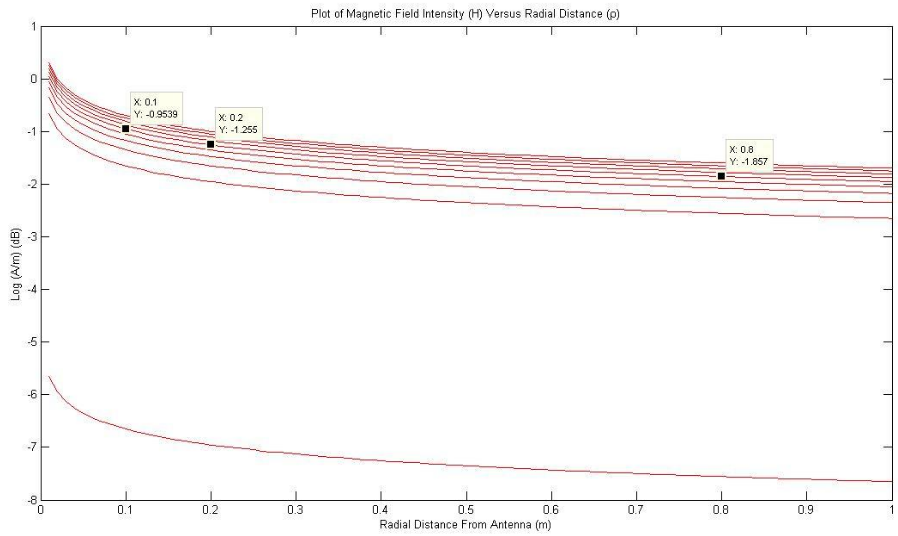

Figure 5 : Actual Scaled Down Model Simulation

It is possible to increase the operating frequency, hence the scaling factor, to attend to practical limitation such as model dimensions and source current. But in order to decrease the effect of Root Mean Square (RMS) error, frequency of 4000 Hz cannot be changed to avoid increased of RMS error. Table 2 shows the RMS error of the lab scale model.

Table 2 : Root Mean Square Error

Frequency (Hz)	**RMS Error (dB)**
25	0.8605
50	0.8292
200	0.7232
500	0.6033
1500	0.3877
2000	0.3262
4000	**0.2945**
5000	0.3585
9000	0.6775

It is also possible to increase the conductivity of available tap water adding an electrolyte such as Sodium Chloride (NaCl). However, according to [8], an upper saturation limit at a NaCl concentration of approximately 300 gram/liter, which results in water conductivity of about 30 S/m. According to [8], "*the inaccuracy introduced by a material in the model with a lower conductivity depends on the particular system to be modeled*". Therefore, this could limit the accuracy of the model. In order to continue previous works that has been done, several amount of NaCl is added to the water while maintaining level of the water so that the conductivity is around 10 to 10.5 S/m. The actual conductivity was measured using conductivity / pH meter and found to 10.31 S/m.

To simulate to reservoir in real application, cooking oil has been selected to represent the hydro-carbon. Cooking oil is chosen because it has high resistivity compared to salted water and since water-oil cannot be mixed, it can be easily remove if the oil is leaking from its container. The oil is buried 3 cm from the sea bed and has specification about 20 cm x 8 cm and has thickness about 2.5 cm.

3.3.1 Water Tank

A rectangular polyethylene tank was selected because plastics and mixture of plastics with other substances are suitable materials for many applications and easy to work with. The tank is deep enough such that the air wave component is not significant. The tank also has straight sides for easy access of measurement equipment. The tank chosen for this project has an effective capacity of 150 Gallons or equivalent to 567.8118 Liters. Figure 6 shows the dimension of the water tank used is this project.

10 cm layer of sand is added at the bottom of the tank. This will simulate the actual sea bed. Thickness of 10cm is chosen because of the skin depth effect of magnetic field. Magnetic wave need to go through the salted water, sand, and will be reflected back by a high resistivity material in this case hydrocarbon material. The wave is then going through back the sand, and the salted water. Summation of the distance to go in and go out of the sand, need to be less than the skin depth so that the intensity of the wave is relevant to be detected by the detector.

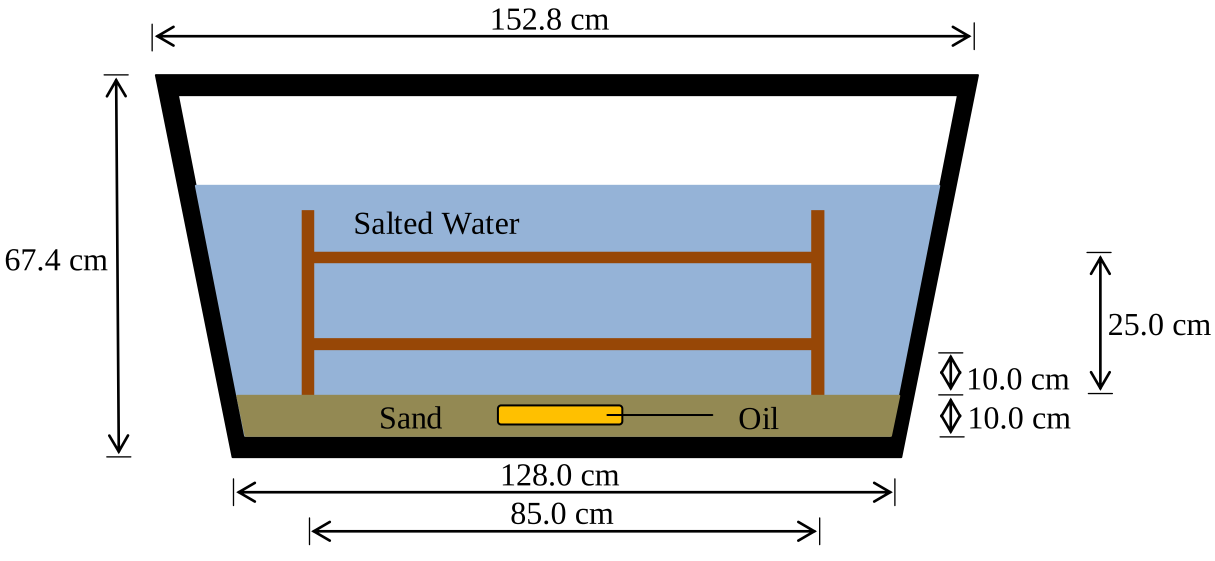

Figure 6 : Water Tank Specification

3.3.2 Antenna

A 2 meter coaxial cable (RG59-U) is chosen for replacing current antenna which is RG58 which already broken because of aging factor. The new antenna will have 75 Ω of nominal impedance instead of 50 Ω for RG58. The antenna is divided into two sections. The first section is the feed section, from the signal generator with or without audio amplifier. While the second section has the centre copper conductor exposed to water for about 5 cm. The feed section consist of four 4 cylinders and is short as practically possible (about 1.3 meters) in order to minimize the effect of the feed section impedance. The inner cylinder is the centre copper conductor (95% bare copper maid) followed by a dielectric layer, copper braid, and an outer dielectric protective layer. In the exposed section, the braid is not fully covered with the outer dielectric and is exposed to water for about 5 cm to provide return path for the current. Figure 7 show the specification of the new RG59-U antenna.

To support high power antenna, a large diameter of coaxial cable is needed in order to reduce the resistance. By reducing resistance, heat can be reduced since I^2R, when R is reduced so does the power. Current antenna is simulate and tested to withstand high current and the result will determine what diameter of cable is needed.

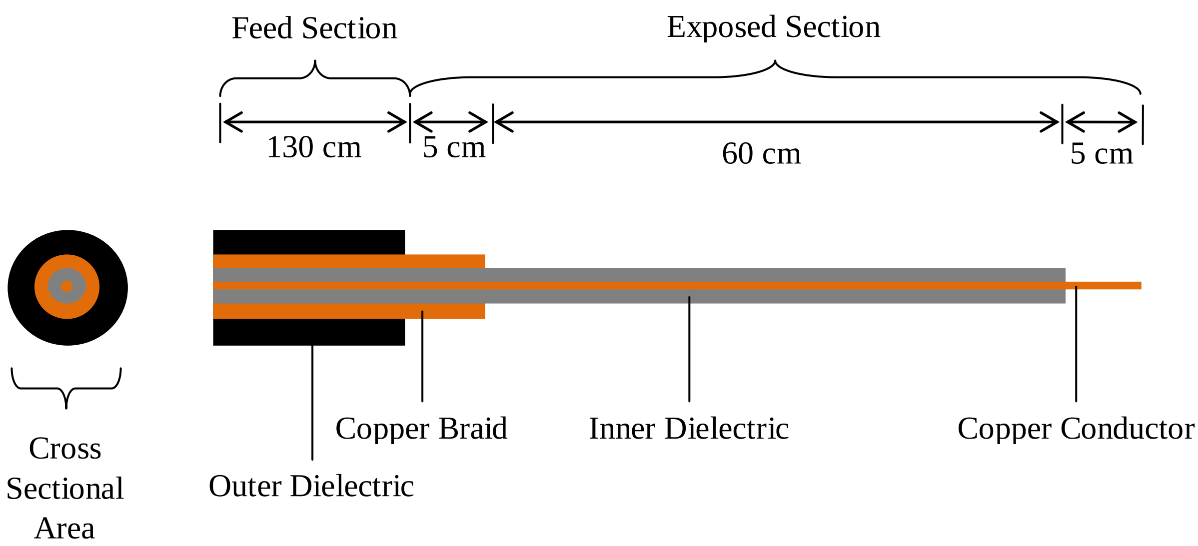

Figure 7 : RG59-U Antenna

3.3.3 Audio Amplifier

A power amplifier, which generally uses a plurality of transistors or integrated circuit (IC) devices, is an apparatus that allows an input to control a power source to produce some useful output [6]. For this project purposes, the electrical signal should be amplified before delivered to the antenna so that the magnetic field induced is big enough to be received by the receiver. A 50W audio amplifier is used to amplify the signal from function generator. The audio amplifier is capable of operating at range of frequencies from 10 Hz to 30 kHz. The amplifier can deliver 50W over two channels or 100W over single channel in bridged mode to 2 Ω loads. This means that the amplifier can deliver low output impedance with high currents up to 14 amperes. This amplification is necessarily to induce high current into the antenna therefore H-fields can be detected. Figure 8 and Figure 9 shows the audio amplifier used in this project.

Figure 8 : Front View of the Power Amplifier

Figure 9 : Tuning Interface of the Power Amplifier

3.3.4 Magnetic Shield

A magnetic core is a piece of magnetic material with a high permeability used to confine and guide magnetic fields in electrical and electromechanical devices such as electromagnets, transformers, electric motors, and inductors. It is usually made of ferromagnetic metal such as iron, or ferromagnetic compounds such as ferrites. The high permeability, relative to the surrounding air, causes the magnetic field lines to be concentrated in the core material. The magnetic field is often created by a coil of wire around the core that carries a current. The presence of the core can increase the magnetic field of a coil by a factor of several thousand over what it would be without the core.

Usually a magnetic core is used to concentrate the strength and increase the effect of magnetic fields produced by electric currents and permanent magnets. But in our application, the magnetic material is used to contain the unwanted magnetic field from disturbing receivers reading.

There are two different shields used in this project. The first is used to contain magnetic field from unwanted source to disturb receiver. The only part of the antenna that should be transmitting EM waves is the part where the inner conductor exposed to the salted water. To prevent EM waves that transmitted at other parts of the coaxial cable, iron pipe (galvanized steel) is used. Iron pipe is chosen because it has good conductivity (electron can move freely). The iron pipe will absorb the energy of EM waves that goes through it and attenuate the electron within the pipe. Figure 10 shows the iron pipe used in the project model.

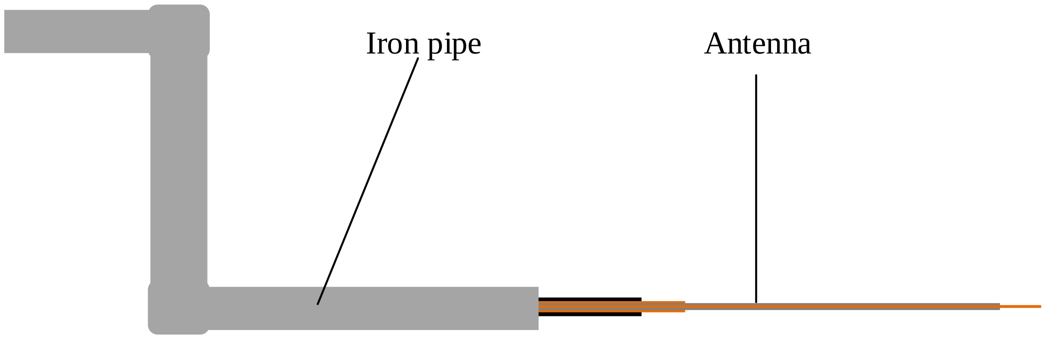

Figure 10 : Iron Pipe as Magnetic Shield

In order receiver to only receive reflected signal and to prevent direct wave, a sheets of zinc 90cm x 50 cm is used. The zinc is then located at the center of the tank, between antenna and receiver. It is important it is correctly placed just above the sea bed and placed vertically so that all unwanted waves (air waves, direct waves) are blocked from arrived at the receiver. Figure 11 shows the specification of the zinc as magnetic shield.

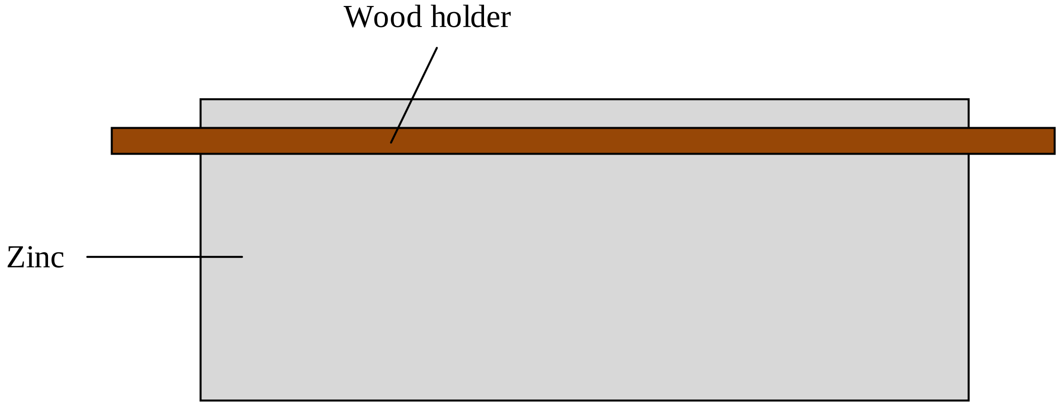

Figure 11 : Zinc as Magnetic Shield

3.3.5 Overall Arrangement

The lab scale model has the overall arrangement shown in Figure 12

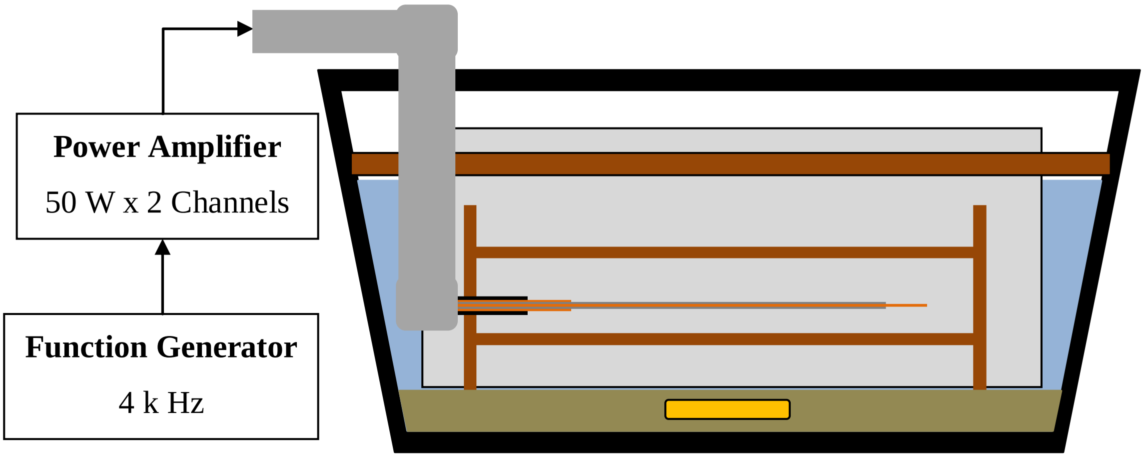

Figure 12 : Overall Arrangement

3.4 Lab Model Measurement

3.4.1 Current and Resistance Measurement

An oscilloscope is used for the measurement without the amplifier connected to calculate the input impedance of the model as shown in Figure 13. A 4.7Ω power resistor is connected in series with the coaxial cable, channel 1 is connected to measure V_A and channel 2 is connected to measure V_B. the purpose of the resistor is to inferentially measure the current through the measurement of the voltage drop from point (A) to point (B).

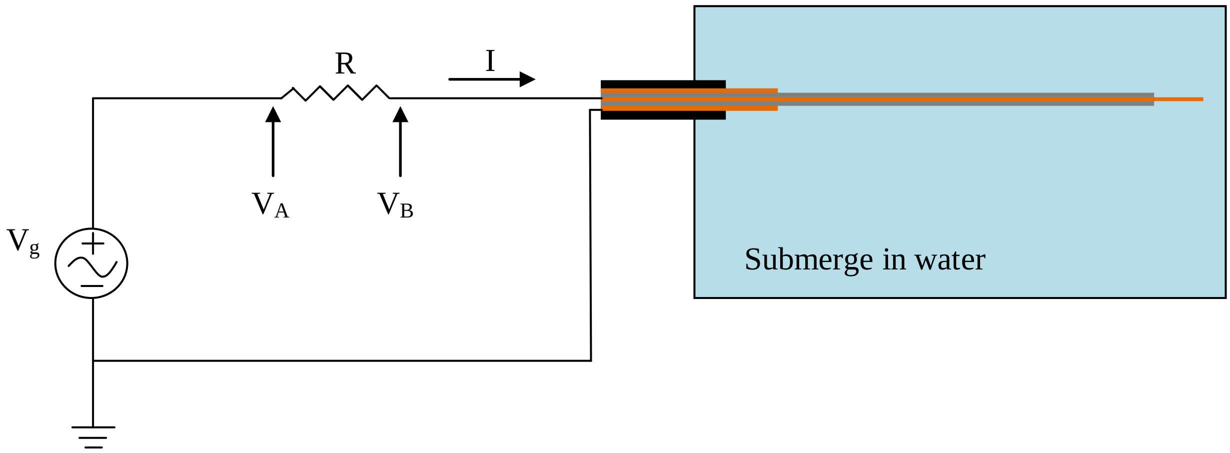

Figure 13 : Lab Measurement Diagram

The function generator is then operated at frequencies ranging from 1Hz up to 3MHz and the input current and impedance are then calculated based on the measures voltages, at various frequencies as follows:

$$I = \frac{V_A - V_B}{R} (A) \tag{11}$$

$$Z = \frac{V_B}{I} (\Omega) \tag{12}$$

3.4.2 Dry Test for the Antenna

In order to simulate the effect of high current to the antenna, several resistors are used. The resistor will simulate the resistance of salted water where testing is done in dry condition. These procedures will clarity the reliability of the antenna to withstand high current. Circuit for this testing is showed in Figure 14.

It is true that all of the resistors can be replaced with only one low resistance resistor but for safety purposes, this kind of connection is needed. The heat generated because of high current will equally dissipated among the entire resistor. If only one resistor is used, the heat cannot be dissipated and equipment can be broken. Result of these simulating and testing is very important so that we can determine the threshold current that can be supplied to the antenna before it fails.

Resistance of the resistor connected in parallel is calculated using this formula:

$$R_{total} = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}} \quad (13)$$

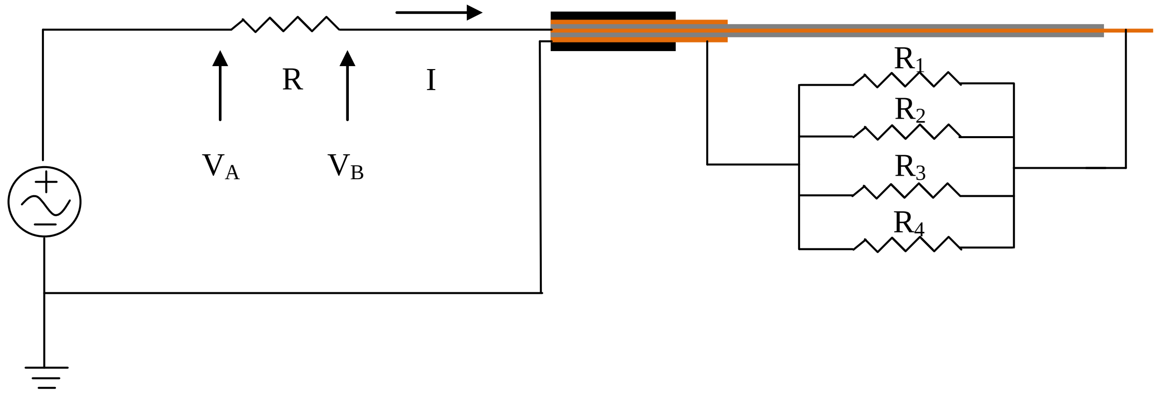

Figure 14 : Circuit for Dry Test for Antenna

3.4.3 Magnetic Field Measurement

A boosting circuit is used to gather with a coil that has 200 loops of wire as receiver. It is then connected to a Digital Multi-Meter (DMM) to measure the receiver's reading. Calibration has been made to make sure the reading the DMM is directly proportional with the magnetic field intensity. Several modes or situations of experiment have been done and the method that has been used is shown in Figure 15, Figure 16 and Figure 17.

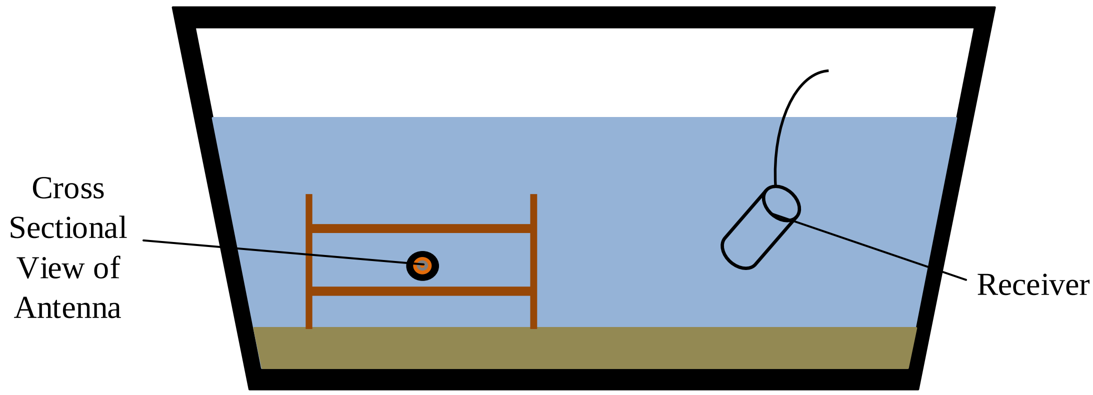

Figure 15 : Mode 1 – No Oil Packet, No Magnetic Shield

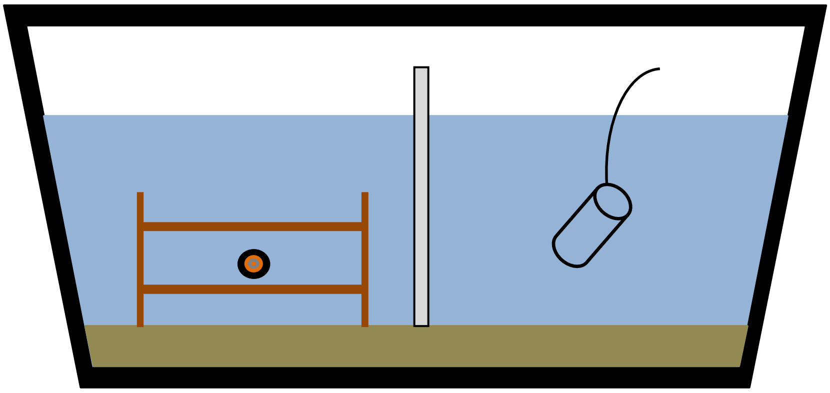

Figure 16 : Mode 2 – No Oil Packet, Magnetic Shield Installed

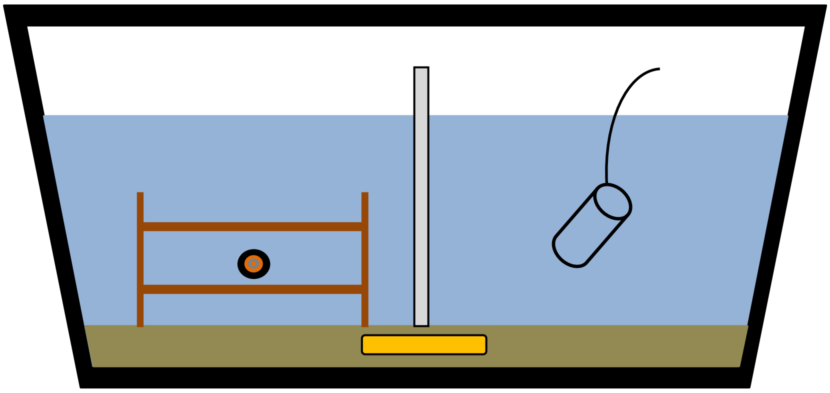

Figure 17 : Mode 3 – Oil Packet Submerged, Magnetic Shield Installed

Mode 1 is used to measure magnetic field intensity when air wave and direct wave are combined with each other. Assumption has been made that there are no reflected wave reflected from the bottom of the tank as the wave goes deeper beneath the seabed and dispersed. In the other hand, Mode 2 is used to measure only the unwanted waves that interfere with the system. The noise can be coming from the antenna itself as there are no such guaranties that the magnetic shield can handle all of the waves that coming towards it. And last, Mode 3 is used to measure magnetic field intensity of waves that reflected by the oil packet. This is the most important and critical as result from this experiment will prove or disapprove the main idea of SBL.

It is important that the angle of the receiver must be around 45^o so that all fluxes that reflected from the oil packet is received in parallel with the coil. This will ensure the receiver got all the fluxes that supposedly need to be take into consideration.

Half-tank grid measurement has been made in order to study the relation between location and magnetic field intensity. The grid only applied to half-tank because lack of space in the tank to put the entire equipment together, e.g. oil packet, receiver, antenna. The magnetic field intensity also assumed to be symmetrical so that measurement from only one side will also applicable to the other side. Figure 18 shows the actual tank with half-tank grid.

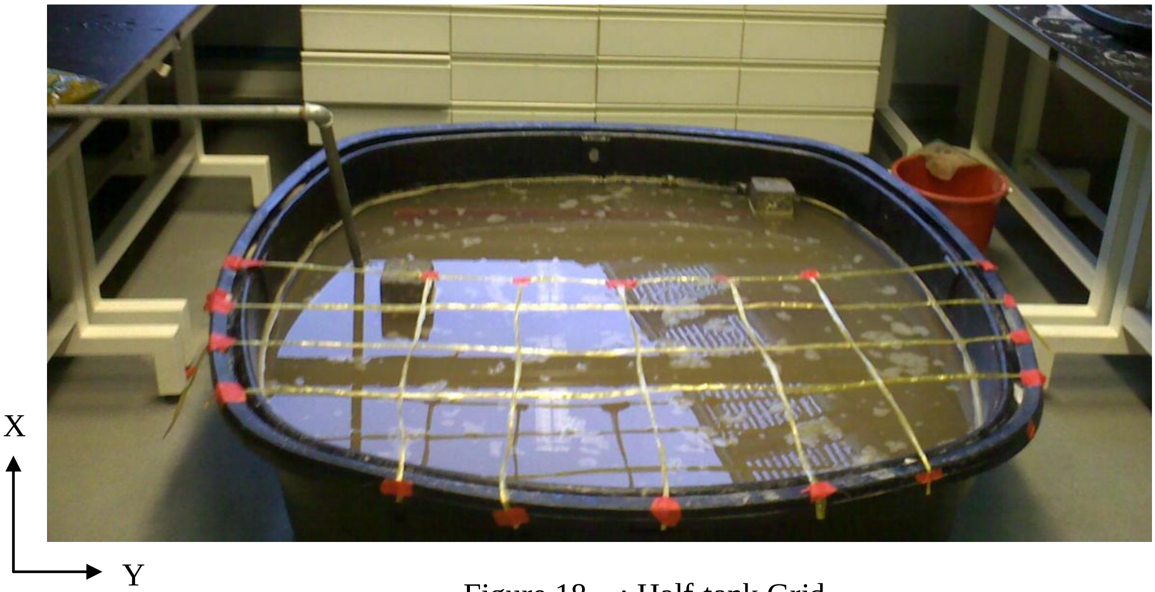

Figure 18 : Half-tank Grid

CHAPTER 4
RESULT AND DISCUSSION

4.1 Lab Model Measurement Result

4.1.1 Result for Dry Test of Antenna

Table 3 shows the result of the dry test that has been conducted.

Table 3 : Dry Test Result

Voltage (V)	**Current (A)**
0.0	0.0
3.0	0.12
6.0	0.23
9.0	0.37
12.0	0.46
15.0	0.61
18.0	0.72

It is proven that the antenna can withstand high current as the linearity relationship between voltages and current is a straight line. Thus, assumption can be made that when a conductor carrying a high current, under influence of large number of ions in salted water result in oxidation of the conductor (copper).

Therefore, after observed the reaction of the antenna with respect of current flowing within it, 0.5 A is chosen to be the maximum current that can be used in order to prevent rapid oxidation from occur on the antenna. If higher current is supplied to the antenna, break down will occur the rates depend on how big the current is.

4.1.2 Result for Magnetic Field Measurement (f = 4 kHz)

Table 4, Table 5 and Table 6 show result from experimentation of magnetic field measurement. All readings are average of three readings and are in mV.

Table 4 : Mode 1 – No Oil Packet, No Magnetic Shield

358	360	363	380	360	335
358	358	365	375	363	380
363	360	365	370	387	390
365	365	370	362	385	384

X (↑) Y (→)

Table 5 : Mode 2 – No Oil Packet, Magnetic Shield Installed

287	285	285	287	287	287
288	287	287	287	287	287
287	290	288	287	287	282
287	290	288	288	287	287

X (↑) Y (→)

Table 6 : Mode 3 – Oil Packet Submerged, Magnetic Shield Installed

294	305	306	310	308	300
285	300	293	300	299	295
300	302	303	304	303	299
303	305	311	314	293	302

X (↑) Y (→)

MATLAB® has been used to plot the intensity of the result from Table 1, Table 2 and Table 3. Magnetic field intensity map generated by MATLAB® is showed in Figure 19, Figure 20 and Figure 21 respectively.

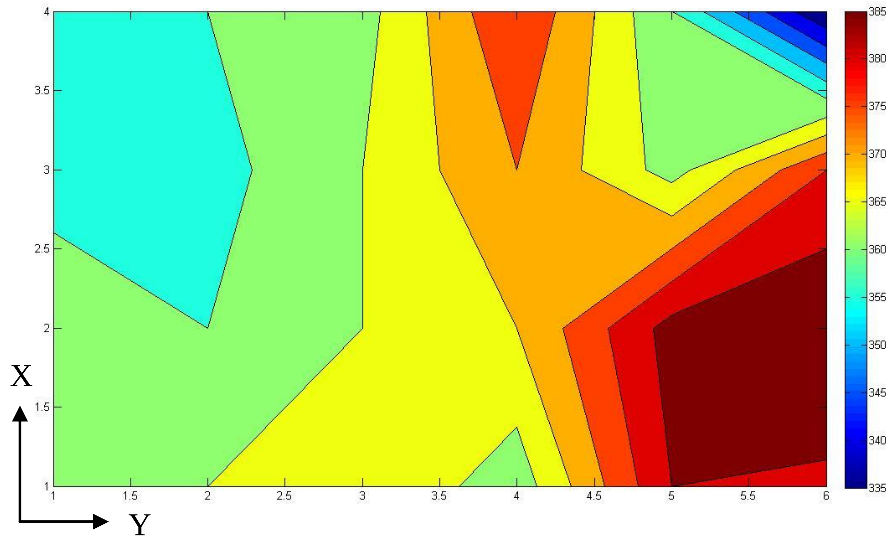

Figure 19 : Mode 1 – No Oil Packet, No Magnetic Shield

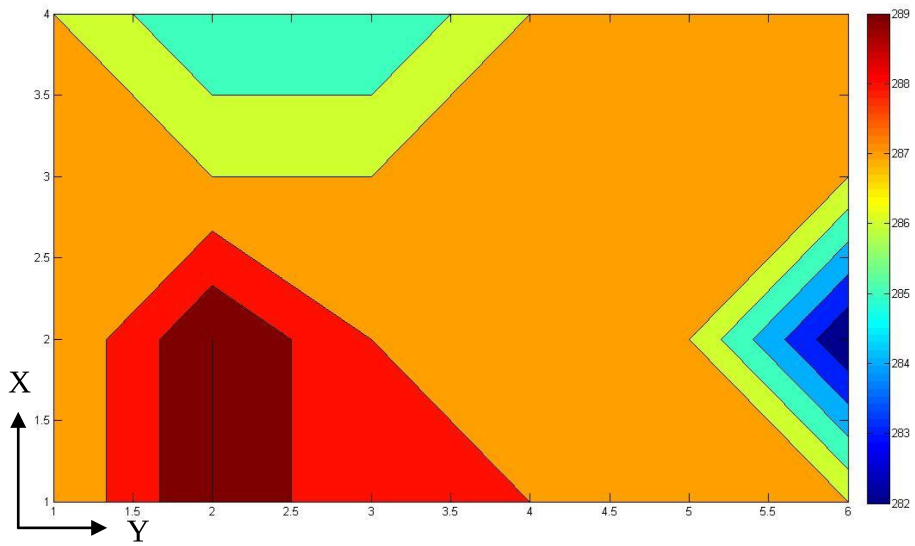

Figure 20 : Mode 2 – No Oil Packet, Magnetic Shield Installed

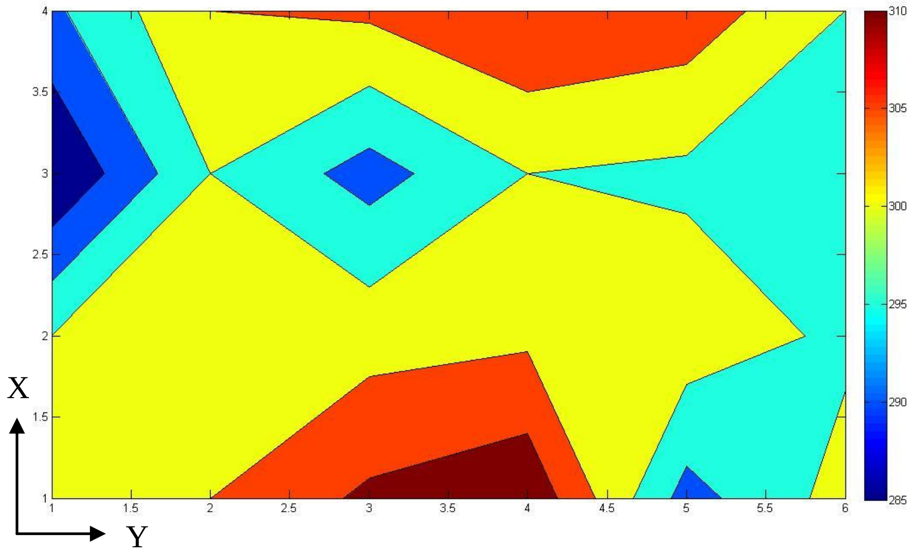

Figure 21 : Mode 3 – Oil Packet Submerged, Magnetic Shield Installed

4.1.3 Result for Magnetic Field Measurement (f = 2.459 MHz)

Table 7 and Table 8 show result from experimentation of magnetic field measurement when frequency is increased to 2.459 MHz in order to reduce the skin depth effect to only 0.1 m. All readings are average of three and are in mV.

Table 7 : Without Magnetic Barrier Installed

X ↑, Y →

492.1767	488.2833	491.3533	491.29	493.2233	495.3667
492.4133	489.31	493.9633	493.62	493.8767	502.8933
497.2233	489.8133	491.6767	495.0367	496.96	500.0867
497.3633	490.4367	492.8933	496.53	497.91	500.6333

Table 8 : With Magnetic Barrier Installed

X ↑, Y →

475.0333	475.1749	475.0557	474.9933	476.374	480.6211
475.4967	475.0649	475.0524	474.3031	477.954	480.2645
475.2767	474.9369	474.9784	474.2771	477.86	480.6325
481.95	476.4275	476.2935	476.1185	477.9599	481.5899

Magnetic field intensity map for frequency equal to 2.459 MHz generated by MATLAB® is showed in Figure 22 and Figure 23 respectively.

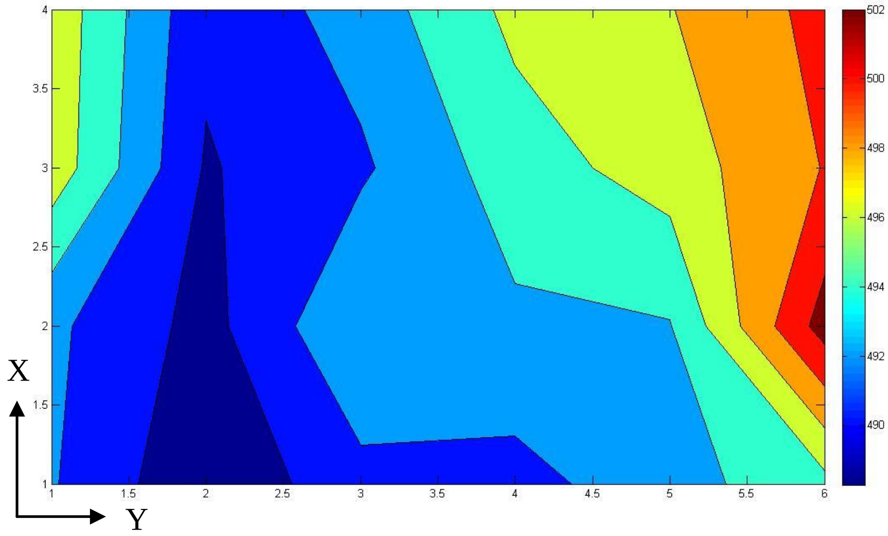

Figure 22 : Without Magnetic Barrier Installed

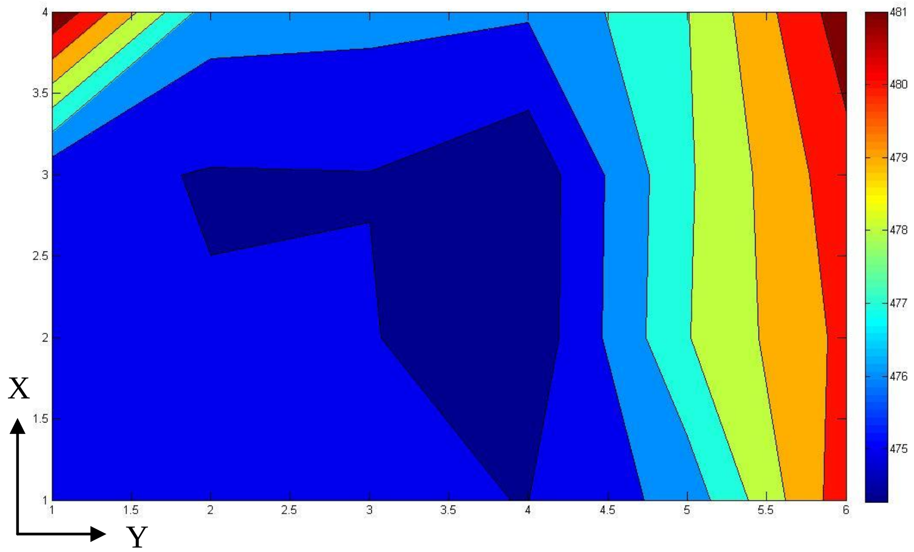

Figure 23 : With Magnetic Barrier Installed

4.2 Discussion and Finding

4.2.1 Magnetic Field Measurement (f = 4 kHz)

By referring to Figure 19 and Figure 20, there are some error occur to the result obtain from the experimentation. Ideally, the magnetic field intensity will gradually decrease as the receiver move further away from center of the tank. The intensity tend to be randomized thus several action must be taken out so that the error could be corrected.

Although the result from Figure 21 is not very accurate, the magnetic shield (zinc) tends to play its job by blocking direct and air wave from reaching the receiver. We can see that overall reading of DMM for Mode 2 is less than reading for Mode 1. Thus, zinc act as magnetic shield and the DMM reading is mainly calculated the zero error.

Mode 3 shows the result considering only reflected waves by oil packet. The result actually quite convincing as we can see that the intensity at middle top and middle bottom is higher compared to the other location. The only error is, supposedly the intensity is high from middle top until middle bottom.

There are several aspect can be assume as the main reason for the errors. Large amount of concrete and iron under the tank can be influence the reading of the receiver. Some EM waves will reflect by the concrete thus reading of the receiver not only applied to waves that reflected only by the oil packet but also unwanted waves are calculated. Electrical wiring surrounding also affecting the reading of the receiver. Any electrical wire that carrying current will act as antenna (transmit EM waves). Current flowing within the wiring also very high thus, this is a big influence of the reading of receiver. Telecommunication signal also can causes interfere with the system. This is proven since there is a moment while doing the experiment, an incoming call causes reading of DMM jumps up two times larger than expected.

4.2.2 Magnetic Field Measurement (f = 2.459 MHz)

Although modification has been made from the original specification of frequency, skip depth and permeability of salted water, the results are still unclear. Figure 22 shows that the magnetic field pattern still randomizes. The intensity should be high at top and should be decreased to the bottom (as goes far away from antenna). Moreover when oil packed is installed, seems like there are no reflection of the magnetic field towards oil packed that buried in the tank. As showed in Figure 23, magnetic field detected at the middle the figure seems to be the lowest. If there are any magnetic field is reflected by the oil packed, the reading should be high at the middle of the partition.

One explanation that can be made is the skin depth is too short (0.1 m) for the magnetic field to be detected. The waves go through the salted water, sand and disappears. This explains why we got a low reading that supposedly high but it would not explain why there are several of our readings are high that supposedly low.

One of the major problem is current receiver could not taken reading in real time. The reading taken is based on how much magnetic flux is passes through the coil without considering the time lag for the signal to reach the receiver. A good receiver is a receiver that runs in real time, can differentiate which one waves comes first, which one comes next and so on. Only then we can differentiate direct wave, air wave and reflected wave without use of magnetic shield.

There are also difficulties in order to follow the real model and implement into a small scale model. A bigger and deeper tank is required to model the SBL as the current model could not posses enough skin depth as required. Large tank also needed because we need to consider that in real world application, antenna is comparatively very small compared to hydrocarbon reservoir. But in this lab scale model, antenna current in is very large compared to the 'reservoir' buried in the sand. This problem will affect the receiver's reading because waves from many direction of the antenna pass through and reflected by oil packet, thus affecting the reading of the receiver. The situation is demonstrated by Figure 24.

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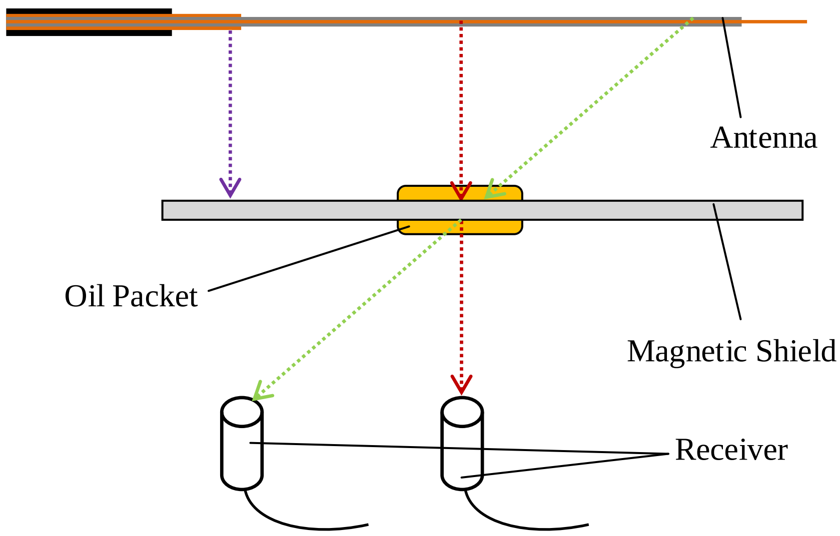

Figure 24 : Unwanted Waves Reflected to Receiver

CHAPTER 5
CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

As far as first objective is concern, the small scale of SBL model measurement facility has been improved. Several modifications have been made to increase the performance of the SBL model. The effect of surrounding such as room wiring, hand phone signal, physical movement and others related interference are taken into account because all these effect eventually have impact on the magnetic field measurement. Nevertheless, there are also several constraints that limit the accuracy of the model such as small size of the tank and conductivity of the salted water.

The electrical dipole antenna also been improved as simulation and experimentation has been done to get a better transmitter. The new antenna has bigger diameter and can withstand higher current thus providing higher intensity of magnetic field. Simulation shows that only 0.5 Amperes of current is needed in order to make sure the magnetic filed generated is sufficient enough to be detected by the receiver.

Integration between antenna and receiver produced result which can be used for further research. The result shows that the barrier blocked the direct waves but not successful enough to block all the waves. A better barrier is needed to improve the accuracy of the reading. Oil packed buried under the sand seems not very effecting to reflect the magnetic waves. Even though the result is not very convincing, several recommendation can be used in order to improve the accuracy.

5.2 Recommendations for Future Works

Several improvements are suggested for the future works. These suggestions are issued to make sure in future works, the SBL can be performed accurately by considering all factor.

1) Real time date acquisition to differentiate different waves that arrived at the receiver.
2) Use bigger and deeper tank to demonstrate proper skin depth.
3) Smaller size of antenna with high mobility to perform like real model experimentation.

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APPENDICES

APPENDIX A: Matlab Modeling Of Magnetic Field Via Changing Of Current

APPENDIX B: Several Project Activities