DESIGN AND DEVELOPMENT OF MAGNETIC RECEIVER FOR SCALE SEA MODEL OF SEA BED LOGGING FACILITIES

By

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FINAL PROJECT REPORT

Submitted to the Electrical & Electronics Engineering Programme
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CERTIFICATION OF APPROVAL

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Approved:

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Project Supervisor

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TRONOH, PERAK

December 2009

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.

Nik Mohd Fareez Bin Auddin

ABSTRACT

Seabed logging, SBL is an application of marine control source electromagnetic, CSEM sounding which can deliver a near perfect direct hydrocarbon indication. Thus, UTP has developed the simplified sea model measurement facility and current source for sea bed logging from their 2008 Final Year Project program; it was found that the receiver was not sensitive enough to pick up magnetic field signal. Therefore, improvement has to be carried out at the receiver to improve data acquisition of the magnetic fields for the scale sea model. By doing so, more reliable magnetic fields signal can be pickup which later will improve overall system in magnetic field measurement specific. This project was carry out with objectives to improved magnetic field receiver sensitivity, to integrate newly develop magnetic receiver to the scale sea model, to map magnetic field in the scale sea model and to analyze received signal from the mapping process. From the calibration process it is observed that the resistivity of magnetic receiver have capability to detect as low as 0.01 micro-Tesla as improvement from mili-Tesla range from previous setup and also magnetic field mapping process has shown promising result in finding buried object.

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LIST OF ABBREVIATIONS

AC	Alternating Current
CSEM	Controlled Source Electromagnetic
PVC	Polyvinyl Chloride
EM	Electromagnetic
SBL	Sea Bed Logging
ω	Angular frequency of the wave
σ	Electrical conductivity of the material of propagation
F	Source frequency
N	Number of turn
S	Surface of the loop.
L	length of solenoid
I	current supplied
Vsin	Sinusoidal Voltage

CHAPTER 1
INTRODUCTION

1.1 Background of Study

Seabed logging, SBL is an application of marine control source electromagnetic, CSEM sounding [1]. In oil and gas exploration, seismic is the far most important type of data used to image the subsurface. While the seismic waves have the ability to detect hydrocarbon, they often fail to discriminate between water and oil as pore fluid. On the contrary, electromagnetic (EM) waves are able to separate between the two fluids, based on their large differences in resistivity value. The reason for this is based on the fact that water supports free ions and easily transports electric current therefore less resistive whereas hydrocarbon acts as an insulator which is high resistivity. This observation has motivated the development of a marine EM-based remote sensing method for hydrocarbon denoted Sea Bed Logging (SBL) [2, 3].

The SBL logging is operated in the principle of a ship tows a horizontal electric dipole source close to the seabed to create large electromagnetic field. As the electromagnetic field propagates through the subsurface, it is perturbed by any variation in the subsurface resistivity. Propagation of the EM waves involved in three methods which are air-water interface, direct transmission through water and subsurface via a high-resistivity layer. The main concern of the measurement is the EM propagation through high-resistivity layer subsurface (reflected wave), since as the EM wave propagates through the layer; the EM wave constantly leak from the layer and back to seafloor. The electric and magnetic field are both measured and recorded by highly sensitive receiver unit distributed over the seabed in term of phase and magnitude. Once sufficient data has been recorded, an acoustic signal is sent to the receivers to trigger a release mechanism and the recorders return to the surface for data analysis [1, 4].

The SBL can deliver a near-perfect direct hydrocarbon indicator with more than 90% agreement between seabed-logging pore-fluid prediction and actual drilling experience compared to normal wildcat frontier which has success rates below 20% and drilling costs at all time high [2].

1.2 Problem Statement

Seabed logging, SBL is an application of marine control source electromagnetic, CSEM sounding which can deliver a near perfect direct hydrocarbon indication. Thus, UTP has developed the simplified sea model measurement facility and current source for sea bed logging (Scale Sea Model) by [5]. The scale sea model construction was constructed to provide scale modeling of real SBL operation. Therefore it wills used as facility that have ability to measure experimental data such as magnetic and electric field and also to measure resistance. Based on [5] it was found that the receiver was not sensitive enough to pick up magnetic field signal which only have capability to detect signal in mili-Tesla range. Therefore, improvement has to be carried out at the receiver to improve sensitivity of the receiver by introducing amplification circuit and proper induction coil. Amplification circuit serve to amplify induce voltage from induction coil induce by small magnetic field signal provided by the dipole antenna and the amplification circuit construction is based on [6]. The amplified induce voltage later connected to the voltmeter where the reading is possible. By doing so, more reliable magnetic fields signal can be pickup which later will improve overall system in term of signal recording and analysis.

1.2.1 Significant of Project

Scale sea model is used to replicate the real application of SBL. In other words it will be used as measurement facility and current source. As far as measurement facility is concern, it will involve three types of measurement which are magnetic field measurement, electric field measurement and receptivity measurement. The focal point of this project mainly is on the magnetic field measurement; specifically on the sensitivity improvement of magnetic field receiver and also the ability of the newly developed receiver to do magnetic field mapping. Based on [1], as the EM wave propagates the wave will experience attenuation. Most likely the most vital wave component which is reflected wave will be very weak due to the fact the wave propagates in longer distance (dipole antenna to hydrocarbon and back to receiver) it is therefore more attenuation involved. As far as sea scale model is concern, it is vital to have very sensitive magnetic field receiver because it will enable good detection on magnetic field signal especially on the reflected wave. This project serves to improve sensitivity of the magnetic receiver in order to improve scale sea model‘s magnetic field measurement capability.

1.3 Objective

The objectives of this project are:

- To improved magnetic field receiver sensitivity
- To integrate newly developed magnetic receiver to scale sea model
- To map magnetic field signal in the scale sea model
- To analyze received signal from mapping process

1.4 Feasibility of the Project within Scope and Time Frame

Basically, this project is divided into five stages, which are as follows,

1. Research
2. Receiver development
3. Calibration
4. Magnetic Field Mapping

Initial stage is gathering reports relevant to SBL works. This analysis provides information regarding study on basic knowledge of SBL, the scale sea model and suitable magnetic field receiver which will be covered in the first six months.

Based on the study, receiver is developed and prior to integrate with scale sea model the receiver will undergo calibration process where sensitivity of the receiver can be test.

The last stage is to map magnetic field in the scale sea model; therefore analysis of the result can be done. The analysis focus on detectability of magnetic field in the scale sea model and also on the reflected magnetic field wave which will determine the existence of buried object.

CHAPTER 2
LITERATURE REVIEW

2.1 Seabed Logging

Seabed logging was developed by Svein Ellingsrud and Terje Eidesmo, for detecting reservoir oil or water contact. They learned that EM can propagate 2 km or more in the subsurface. With this founding, the sea bed logging was developed [7].

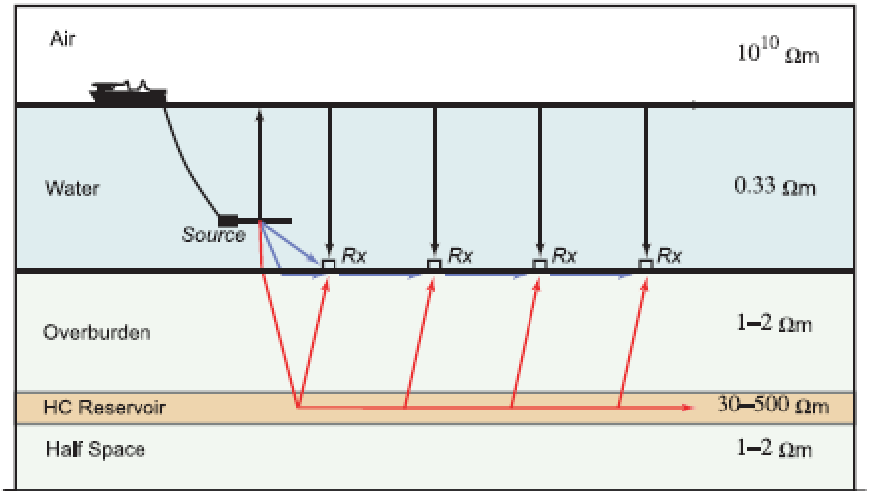


Figure 1 Sea Bed Logging Overview [8]

The basic operation of SBL in such away a ship tows a horizontal dipole source which is close to the seabed emits a low frequency electromagnetic propagates through subsurface [4]. Guided electromagnetic energy is constantly refracted back to the seafloor and is recorded by the electromagnetic receivers, Rx. Typical sensitivities of air, water, sediment and hydrocarbon are shown in Figure 1. The EM signal refracted via 3 methods: air-water interface, direct transmission through water and subsurface, via a high-resistivity layer subsurface. The refracted energy from high resistivity subsurface layers (hydrocarbon reservoir) will dominate over directly transmitted energy. The detection of this guided and refracted energy is the basis of SBL [8].

2.2 Skin Depth

Skin depth is the depth to which electromagnetic radiation can penetrate a conducting surface decreases as the conductivity and the oscillation frequency increase. An electromagnetic wave entering a conducting surface is damped and reduces in amplitude by a factor 1/e in a distance ∂ given by [9]:

$$\delta = \sqrt{\frac{2}{\omega \pi \sigma}} = \frac{1}{\sqrt{\pi f \mu \sigma}} \tag{1}$$

ω is angular frequency of the wave and σ is electrical conductivity of the material of propagation. This distance is referred to as the skin depth of the conductor. In SBL, the electromagnetic signals are rapidly attenuated in seawater and seafloor sediment saturated with saline water. The distance to attenuate an electromagnetic signal by the factor of ℓ^{-1} is defined as skin depth [8].

2.3 Electromagnetic Wave

If electrons are moving in a wire, changing electric fields will occur. The changing electric fields set up magnetic fields. These magnetic fields are also changing, so they set up changing in electric fields. In this way the electric and magnetic fields oscillate and propagate through space [10].

In an electromagnetic wave the electric and magnetic fields are mutually perpendicular. They are also both perpendicular to the direction in which the wave propagates or travels. The electric and magnetic fields oscillate together between maximum positive and maximum negative values. The frequency of these oscillations and the wavelength of the waves determines whether the electromagnetic wave is visible light (and its color), ultraviolet light, infrared light, radio waves, X-rays, or gamma rays as per Figure 2 [10].

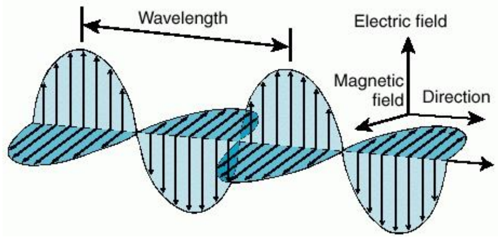


Figure 2 Electromagnetic Waves[10]

2.4 Faraday's Law

From Faraday's induction law a variation of the magnetic flux through a closed loop of wire generates a voltage at the loop's ends that is tied to the time rate of change of the flux denotes by [10]:

$$\varepsilon = -N\frac{\partial \Phi_B}{\partial t} = -N\frac{\partial}{\partial t}(A.B.\cos(\theta)) = -N\frac{\partial}{\partial t}(A.B.\cos(2\pi f.t)) \qquad (2)$$

Where, N is the number of turn, A is surface Area, B is magnetic field, f is frequency of magnetic field, t is time and θ is the angle between magnetic field direction to the normal of the surface. The negative sign is denotes by the Lentz Law.

2.5 Simplified Scale Sea Model

The simplified scale sea model measurement was developed by [5]. The purpose of the scale sea model of the full size SBL system is to collect experimental data such as resistance and magnetic field measurement. [5]

As per shown on Figure 3 and Figure 4, the scale sea model consists of water tank, antenna, suspension apparatus and receiver. The water tank was filled with salt water to assemble sea water, the antenna to produce electromagnetic wave, the suspension apparatus to allow the antenna to be suspended at certain height from the tank bottom, last but not least the receiver use for magnetic measurement. Sand was filled in the water tank to replicate seabed.

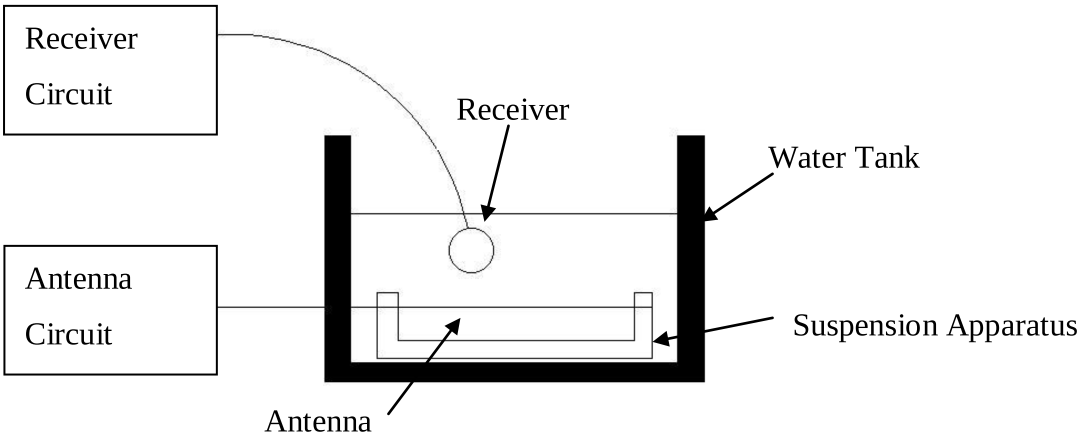


Figure 3 Lab Sea Scale model

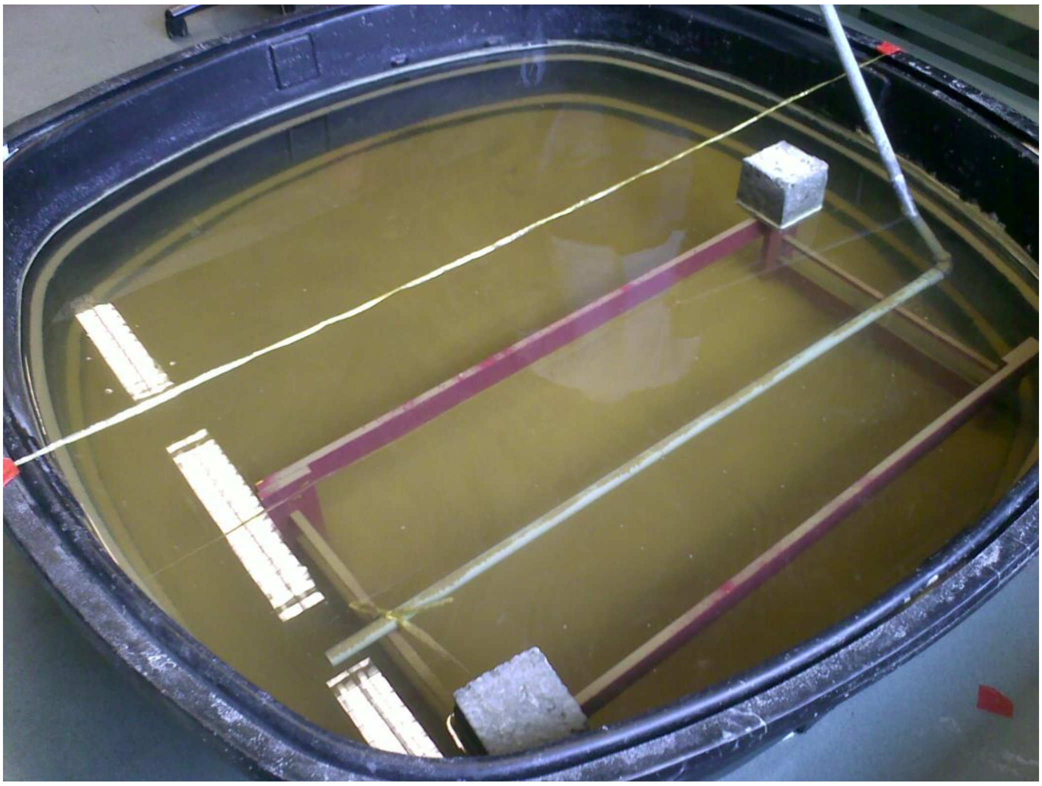


Figure 4 Water Tank, Antenna and Suspension Apparatus

2.6 Operational Amplifier

Operational amplifier amplifies the difference between the two voltages in other words it is called differential amplifier. Refer to figure 5.

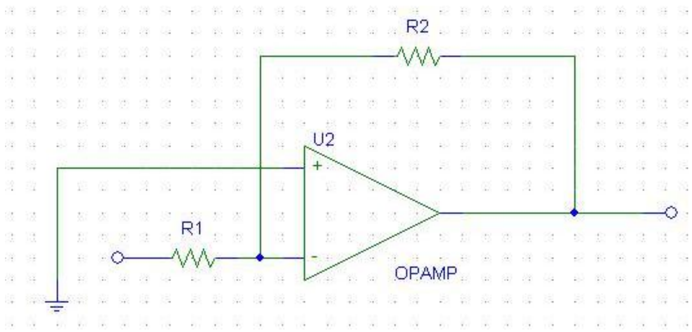


Figure 5 Operational Amplifier, Op-Amp

Op-Amp output voltage is define by $Vout\ \ is\ A(V_{+} - V_{-})$, where A is the Gain of the Op-Amp and V_{+} is voltage at non-inverting input and V_{-} is voltage at inverting input as for practical consideration; there are two major points that have to be considered:

- Saturation Effects

  The saturation effect will lead the signal to be appear flat at the top and bottom of the signal

- Slew Rate Limitations

  The rate of change in output of Op-Amp is really limited, meaning there will be a lag between the input and output.

CHAPTER 3
METHODOLOGY

3.1 Planning

The following generalized steps have been taken when this project is implemented. Firstly, designing process of the receiver has to be carry out based on material available in the internet and library (literature research), and discussion with supervisor, SV and other lecturers also has been carried out in order to get better understanding on project related knowledge. Secondly, the development process based on the design which is circuit construction has been carried out based on the founding of appropriate magnetic receiver for scale sea model from literature research. Thirdly, the receiver went through functional test. This functional test includes Pspice simulation and receiver calibration. During this process any calibration and modification (if any) will be done based on the result of the test. The entire project planning process is as per figure 5.

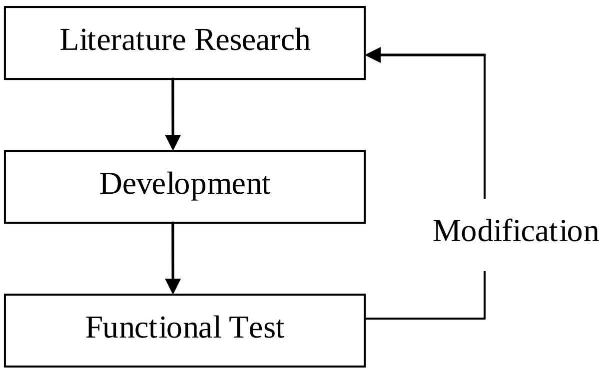


Figure 5: Generalized step of FYP1

After the development of the receiver, the project will undergo magnetic field mapping process that will be discussed on section 3.4.At all time, the overall project will track the Gantt chart as shown in Appendix 1.

3.2 Receiver Development

The previous setup of [5] for electromagnetic field measurement, applies only the usage of coil to measure induce current without any conditioning circuit. As for the new setup, the same principle is used instead conditioning circuit has been added which serve to amplify induced voltage from the magnetic receiver. The circuit design is based on [6].The basic operation of the magnetic receiver is that, magnetic field in the tank will induce voltage at the induction coil (magnetic receiver), this induce voltage then will be amplified using amplification circuit and the amplified signal will be display on voltmeter as Vac as per Figure 6 and Figure 7.

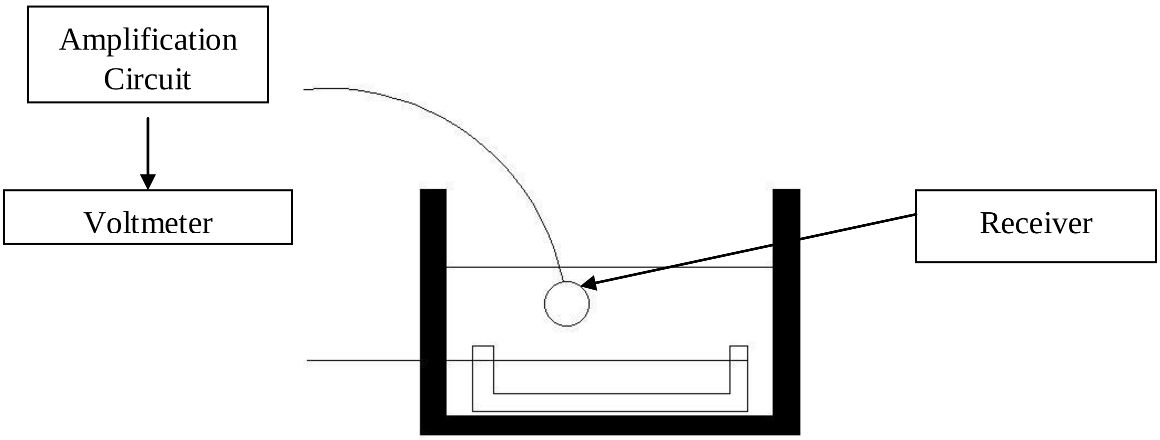


Figure 6 Receiver System Layout

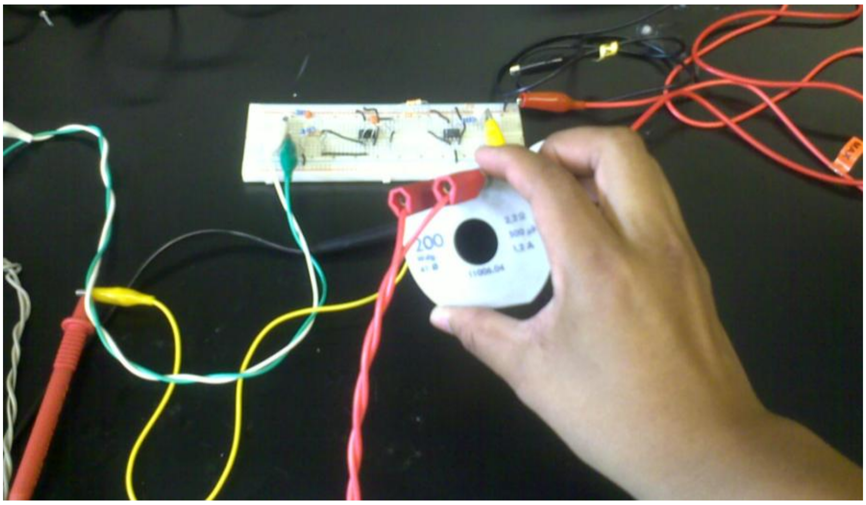


Figure 7 Amplification Circuit and Receiver

3.2.1 Receiver

The receiver basically an induction coil with has 200 winding, 2.2 Ohm and 500uH inductivity. The selection of the receiver is based on the availability in the UTP physics lab, in term of number of coil and size of the induction coil that would be appropriate for the scale sea model. As for the dimension, the receiver is 11 cm height and 4 cm in diameter as shown on Figure 8 and Figure 9.

Figure 8 Receiver

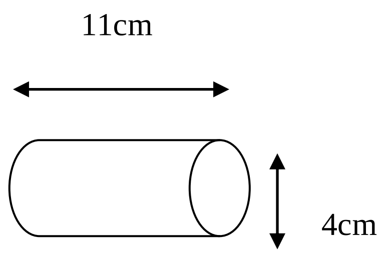


Figure 9 Receiver Dimension

3.2.2 Amplification Circuit

The new receiver circuit will be based on from [6], as shown on Figure 9 is the circuit for the amplification circuit. The purpose of the amplification circuit is to amplify the induced voltage from the receiver as per Figure 9 and Figure 10. The coil or magnetic receiver is amplified by two LM308N Op-Amp and the circuit is powered by 9 Volt from power supply; it is expected the gain of this circuit, G is 100.

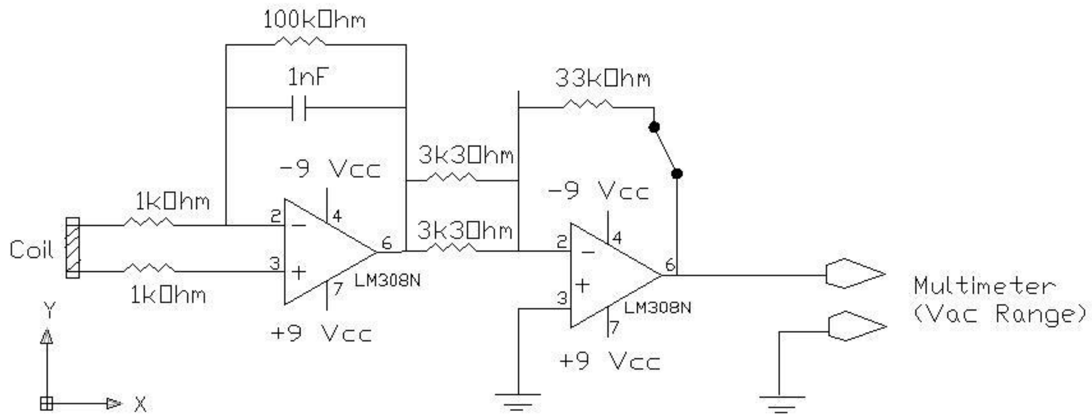


Figure 10 Overall amplification system

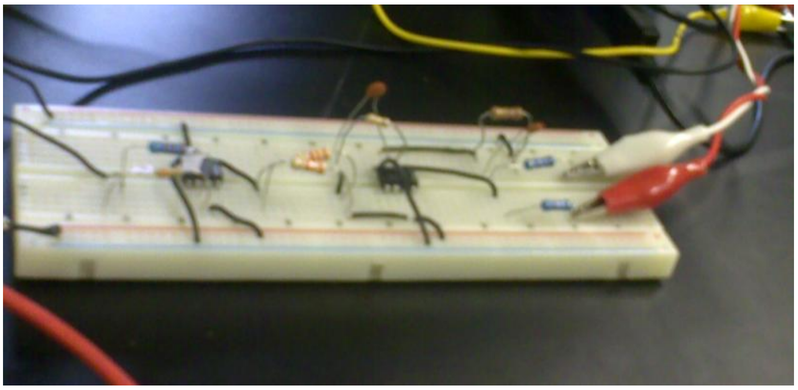


Figure 11 Overall amplification circuit that been constructed

3.2.3 Pspice Simulation

The circuit undergoes Pspice Simulation as per Figure 11 in order to predict functionality of the amplification circuit design. Vsin represent induced voltage at the receiver, with frequency 60 Hz and amplitude with 2mV increment at the input. Bubbles were placed at the input and output side, in order to measure input voltage, Vinput and output voltage, Voutput.

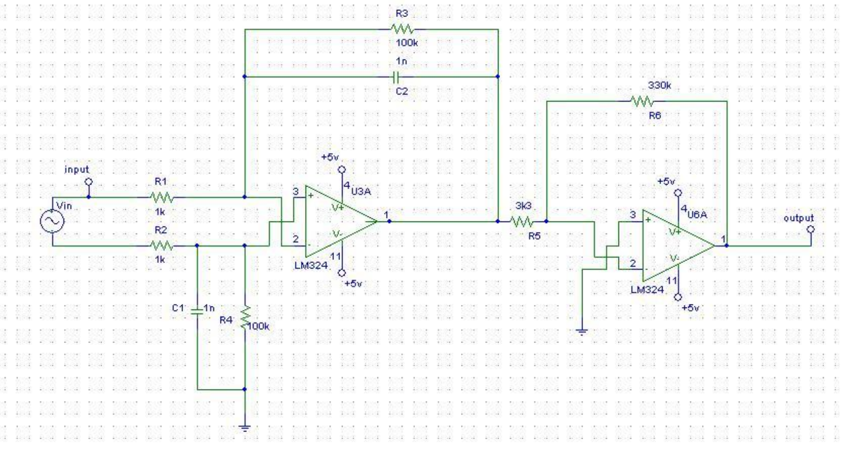


Figure 12 Pspice simulation

Transient analysis been conducted for Vinput and Voutput comparison. The transient setting are 5ns print step and 100ms final time. The result for the simulation is discussed on section 4.1.

3.3 Calibration

Calibration to the receiver have been done in such way that, constant magnetic field from Helmholtz coil will replicate the magnetic field produce by the antenna inside the sea scale model. For the calibration a voltage supply and resistor is used to vary current supply to the Helmholtz coil in order to create desired constant magnetic field. The receiver been placed at the centre of the Helmholtz coil and was connected to the amplification circuit and voltmeter. The configuration for the calibration is as per Figure 12 and Figure 13.

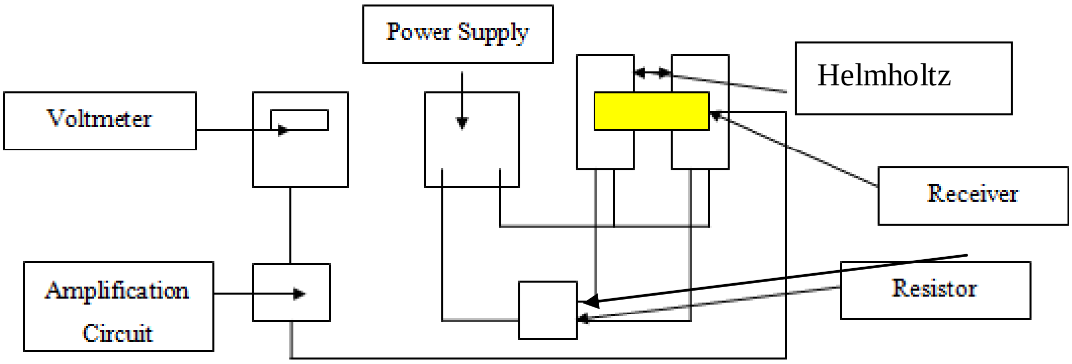


Figure 13 Calibration Configuration

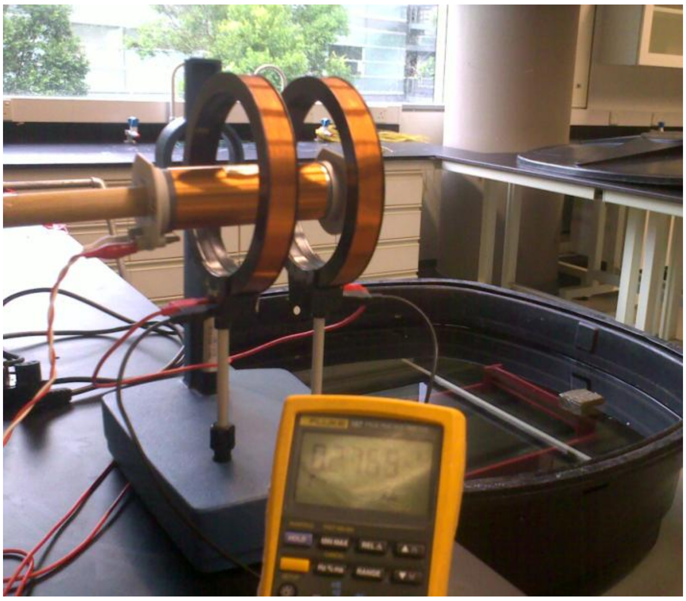


Figure 14 Receiver position in the Helmholtz Coil

3.3.1 Helmholtz Coil

Constant homogenous magnetic field been produce at the Helmholtz following based on [11]:

$$B = \frac{32\pi N I}{5\sqrt{5a}} \times 10^{-7} \, tesla \tag{3}$$

Where N is the number of circular coil turn, I is carrying current of the circular coil turn and a is radius of circular coil.

Helmholtz coil is connected to power supply in between resistor is placed. The receiver located at the centre of Helmholtz coil where the uniform magnetic field is available as per equation (3). By ohm's law, in order to varied current supply to Helmholtz coil, the voltage supply and resistor have to be varied, and the value of the current will generates specific magnetic field based on equation [3]. The desired magnetic fields are 0.01uT, 0.10uT, 0.20uT, 0.40uT, 0.60uT, 0.80uT, and last but not least 1uT. As per table 1, Magnetic Field is indicate the strength of magnetic field at the centre of Helmholtz coil, meanwhile Current indicate the value of current to be apply to equation (3) so that desired Magnetic Field can be achieve and resistor and voltage supply, indicate the variation of resistor and DC voltage supply based on Ohm's Law to get desired Current, I.

Table 1 Helmholtz Applied Current

NO	Magnetic Field,B (uT)	Current, I (A)	Resistor, (Ohm)	Voltage Supply (Vdc)
1	0.01	2.75×10^{-6}	90k	0.25
2	0.10	2.75×10^{-4}	9k	2.48
3	0.20	5.50×10^{-4}	900	0.50
4	0.40	1.10×10^{-3}	900	1.00
5	0.60	1.64×10^{-3}	900	1.48
6	0.80	2.20×10^{-3}	900	1.98
7	1.00	2.75×10^{-3}	900	2.48

The result for the calibration is in section 4.2.

3.4 Magnetic Field Mapping in Scale Sea Model

Magnetic mapping process of scale sea model has been carried out with objective:

- To map magnetic field without putting magnetic field shield with buried cooking oil.
- To map magnetic field with magnetic field shield applied with buried cooking oil.

The mapping process was carried out at the scale sea model. The scale sea model was initially be filled with salt water and sand, which have 10 cm thickness from the bottom of the water tank. Figure 15 show a packet of 1kg cooking oil which buried 3cm inside sand and located at the centre of the water tank. The packet has 20cm × 8 cm × 2cm in dimension. This is to replicate the real SBL situation where the hydrocarbon is buried in the seabed.

The dipole antenna was located 40cm offset the cooking oil packet (centre of the tank) and magnetic field supplied is at 2.459M Hz that has skin depth 10 cm. As the antenna transmitting magnetic field, the magnetic wave will transmit in three directions; first direct wave, second air wave and third reflected wave. Direct wave define as movement of the wave from dipole antenna to magnetic receiver. Meanwhile for air wave is based on the movement of the wave through the water and air gap first then reflected back to the magnetic receiver. Last but not least, reflected wave is define as the magnetic wave will propagates through cooking oil packet first then be reflected to the magnetic receiver as per Figure 15 and Figure 16.

The magnetic field barrier where place next to antenna and on top of cooking oil packet to block direct magnetic field and air gap wave to the receiver so that only reflected wave is available. The barrier was basically, an aluminum sheet which have length equivalent to dipole antenna. The basic operation of the barrier is since the aluminum sheet is conductive it is therefore the sheet will absorb thus the magnetic field that try to go through it as per Figure 17 and Figure 18.

The location of the mapping only interest at the other half of the tank since we want to consider the reflected magnetic field for the objective 3. Each grid box is 20cm × 15 cm in area, in total 24 grids with correspond to 4 grids in Y direction and 6 grids in X direction as show as Figure 19.

The magnetic receiver was placed at 45° position from the ground. It was supported by intercept sticks in order to maintain 45° position and placed as near as possible to the sand. This is vital to maintain the receiver in 45° position and to avoid vibration due to external cause such as human movement and wind as per Figure 20. Total of three measurements has been taken for each phase and the result is discussed on section 4.3.

Figure 15 Cooking Oil Packet

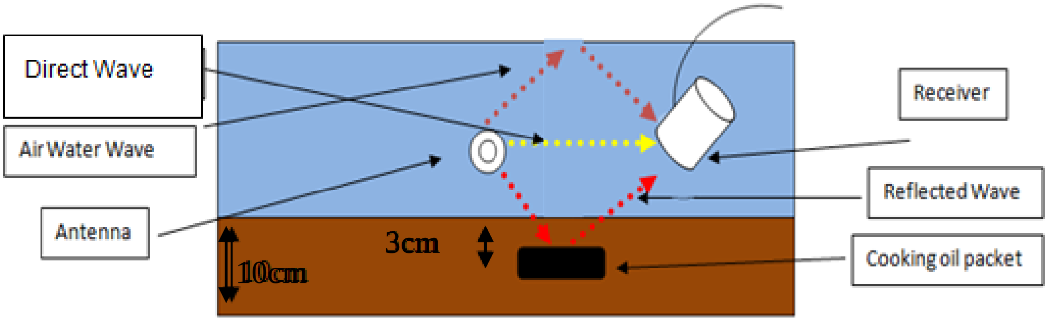


Figure 16 Sea Scale Model without Magnetic barrier

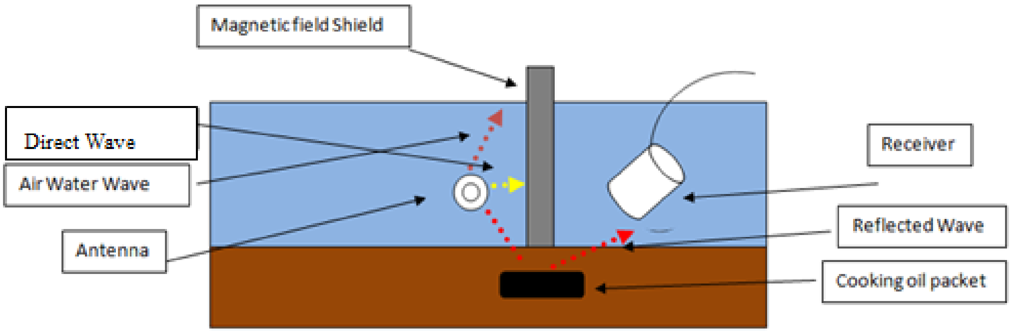


Figure 17 Sea Scale Model with Magnetic barrier

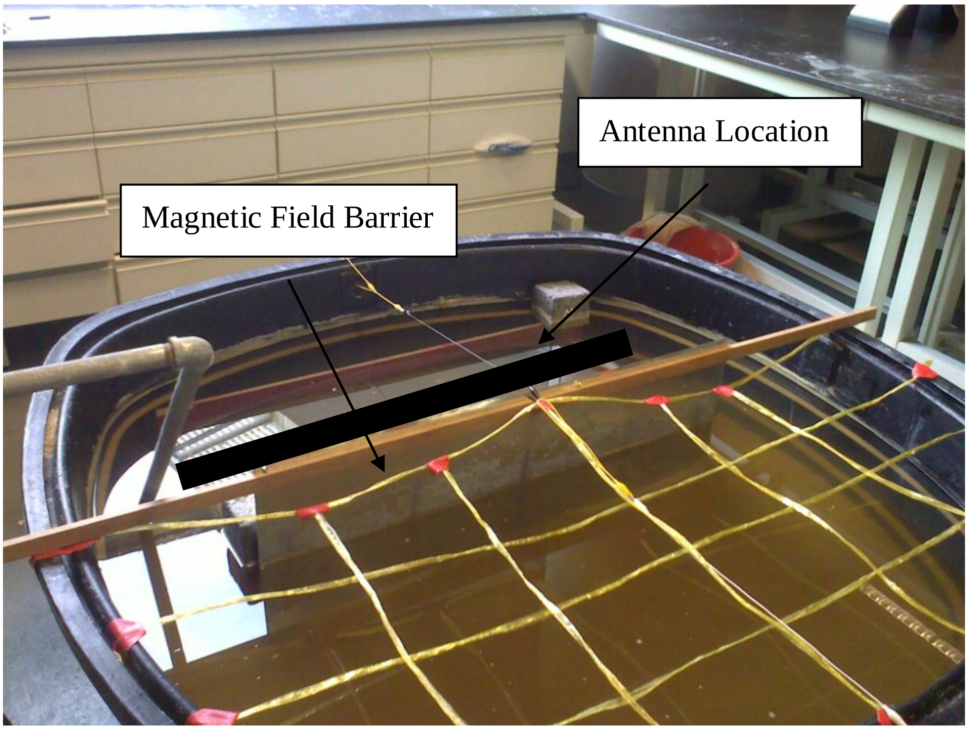


Figure 18 Magnetic Field Barrier

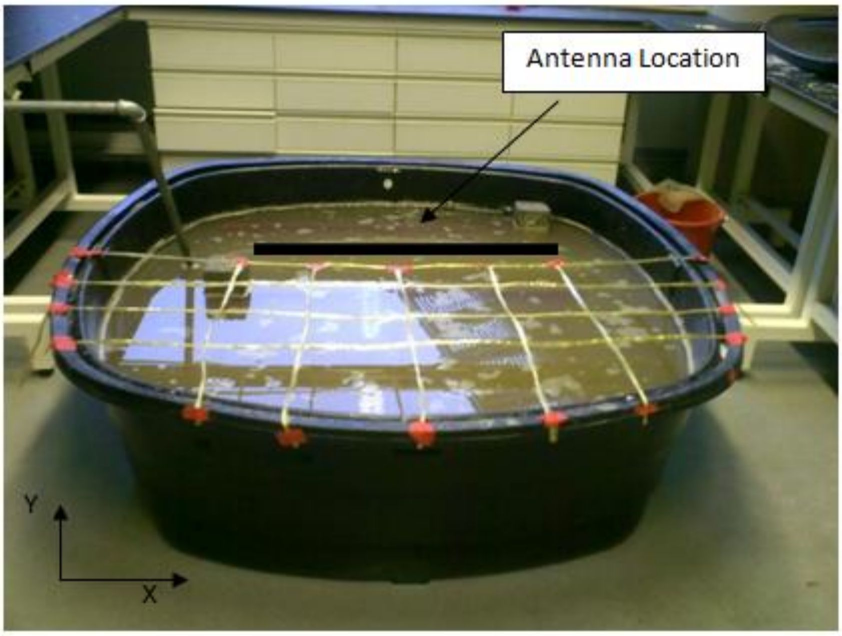


Figure 19 Grid located on the other half of the tank

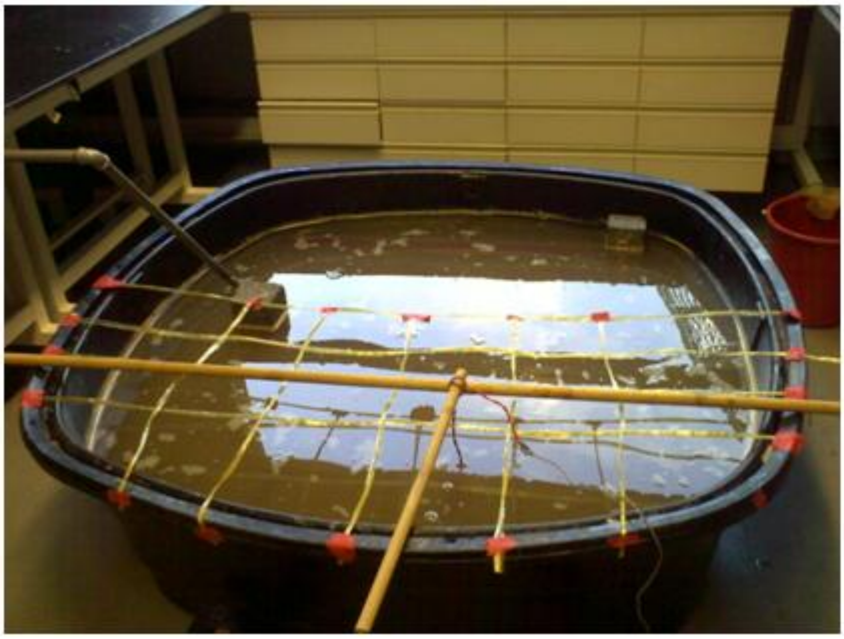


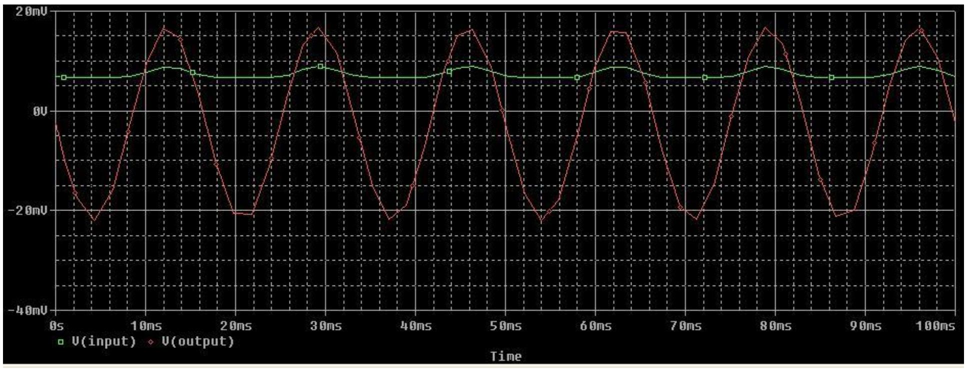
Figure 20 Intercept sticks place the receiver on place

CHAPTER 4
RESULT AND DISCUSSION

4.1 Pspice Simulation

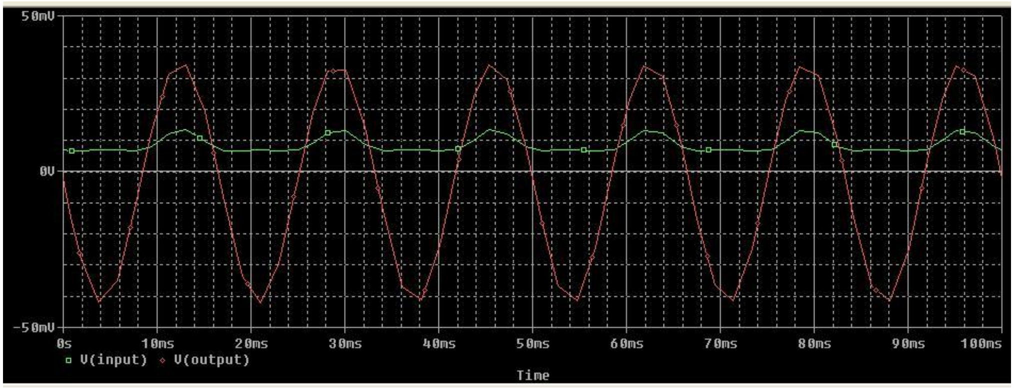
Psice simulation has been carried out to see the functionality of the circuit before the circuit can be constructed. The amplitude of the Vsin amplitude has been set to 0.2mV, 0.4mV, 0.6mV and 0.8mV that yield the input of 8mV, 13mV, 20mV and 30mV at 60 Hz in frequency. Below shown the graph for specified Vsin amplitude:

<u>Vsin amplitude = 2mV</u>



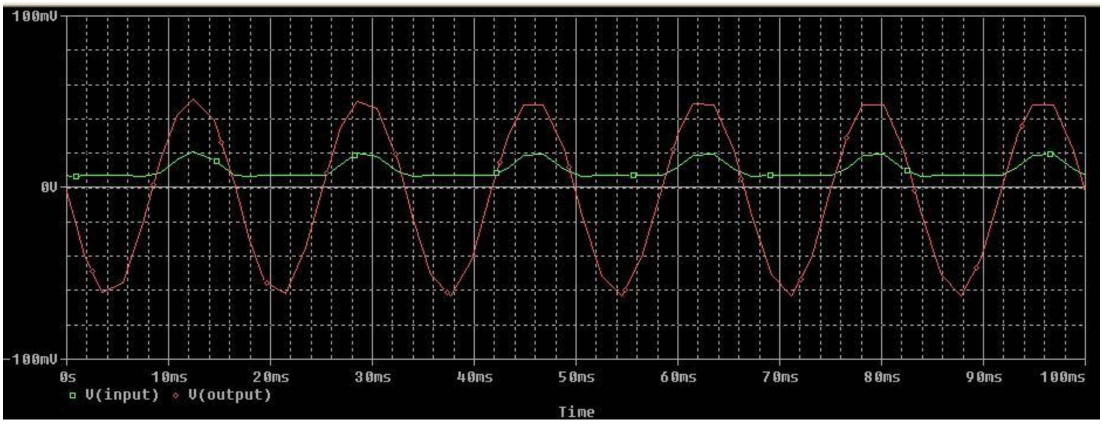
Vinput = 8mV, Voutput = 16mV, so gain = 2.00

<u>Vsin amplitude = 4mv</u>



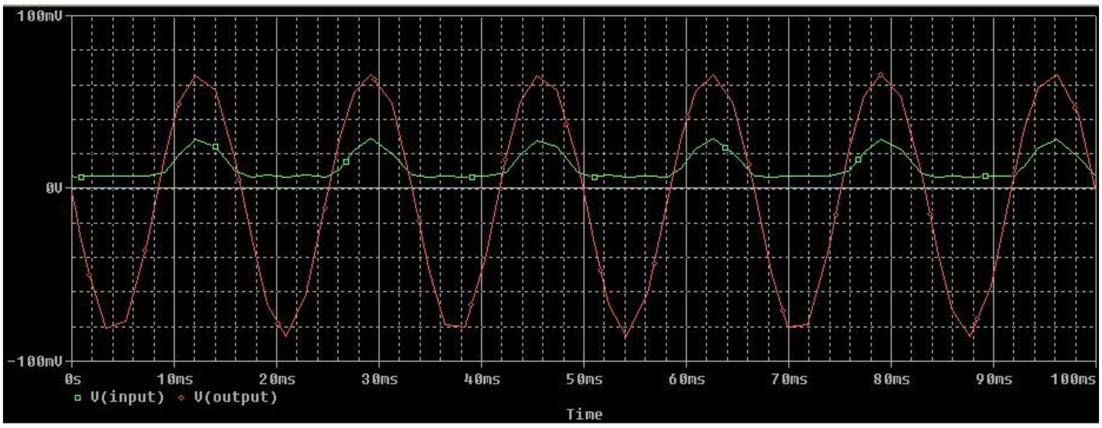
Vinput = 13mV, Voutput = 35mV, so gain = 2.92

Vsin amplitude = 6mv



Vinput = 20mV, Voutput = 50mV, so gain = 2.5

Vsin amplitude =8mV



Vinput = 30mV, Voutput = 65mV, so gain = 2.16

It is shown for the graphs above, the circuit is amplifies the signal (induce voltage) in the simulation by the gain of 2. However the value of the gain is not consistent with the predicted gain. This might due to technical error in setup for using Pspice simulation. Due to this reason the development of magnetic receiver was still preceded.

4.2 Calibration

Calibration process serves to justify sensitivity of magnetic receiver toward magnetic field. The uniform magnetic in the Helmholtz coil has been setup at 0.01uT, 0.02uT, 0.04uT, 0.06uT, 0.08uT, and 1.00uT and receiver voltage measurement has been taken for each magnetic field value as been discussed on section 3.3. From table 2 and Figure 20, it was noted that, the receiver output is directly proportional to the magnetic field input of Helmholtz coil. However the graph is not entirely linear at all range of measurement meaning the graph only linear at 0 to 0.4uT, followed by 0.4uT to 0.6uT and lastly at 0.7uT to 0.8uT . This is due to the effect of external magnetic field noise that might influence the measurement. Based on the result obtained, the receiver can be concluded as sensitive to the variation of magnetic field at micro-Tesla, uT range.

Table 2 Result Of Calibration

NO	Magnetic Field, B (uT)	Voltage Reading, Vac (mV)
1	0.01	330
2	0.20	393
3	0.40	394
4	0.60	395
5	0.80	400
6	1.00	410

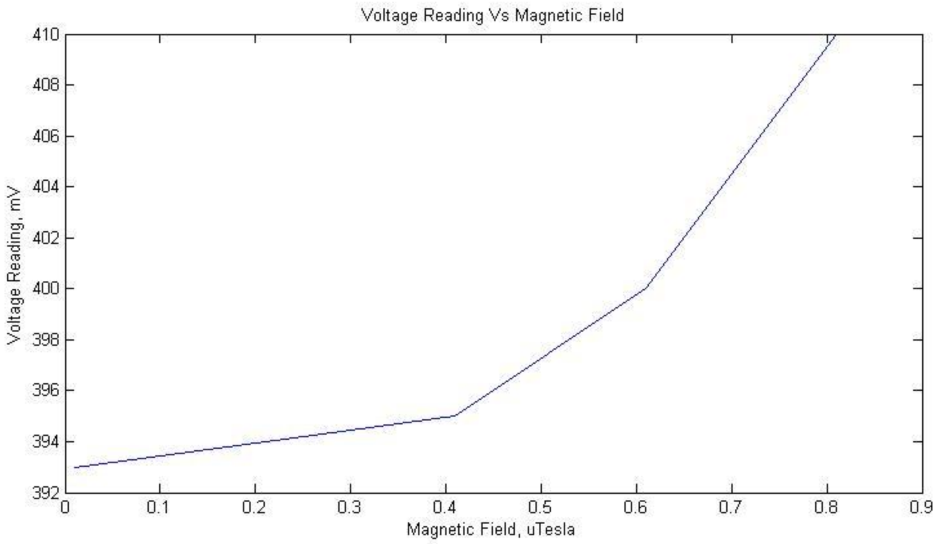


Figure 21 Calibration Graph

4.3 Magnetic Field Mapping

Magnetic field mapping was carried out with respect to section 3.4. The mapping process was carried out, in two phases, first, mapping without magnetic field barrier and second, mapping with magnetic barrier. For each phase three runs have been carried out and the average of all runs in each phase was calculated. The dipole antenna used 2.459M Hz that has skin depth 10 cm. Then all the tables were tabulated and be plotted using Matlab 7.1 as 2-D filled contour graph.

4.3.1 Result for Magnetic Field Mapping Without Barrier

Magnetic field mapping without barrier is serve to map, the effect of all three waves (direct wave, air gap wave and reflected wave) to the magnetic measurement in scale sea model.

The measurement has been plotted according to their location on the scale sea model; with color intensity indication which red noted the highest intensity meanwhile blue the lowest. The value for all three runs is different due to the fact that the magnetic field in scale sea model always changing, and based on receiver design its only can get measurement at the specific time, not continuous. To settle this problem, the average values for all three runs have been tabulated.

Based on average value as per table 6 and figure 25, it is observed that as the distance from the antenna increase the intensity of the magnetic field decrease.

Table 3 Magnetic Field Without Barrier, Run #1

Magnetic Mapping without barrier
Run #1

Y/X	1	2	3	4	5	6
1	506.5	505.8	505.6	504.6	503.6	505
2	507.1	505.4	503.8	504	504.1	503
3	507.7	505.5	504.4	503.6	503.3	504
4	508.6	505.1	503	503	502	503.5

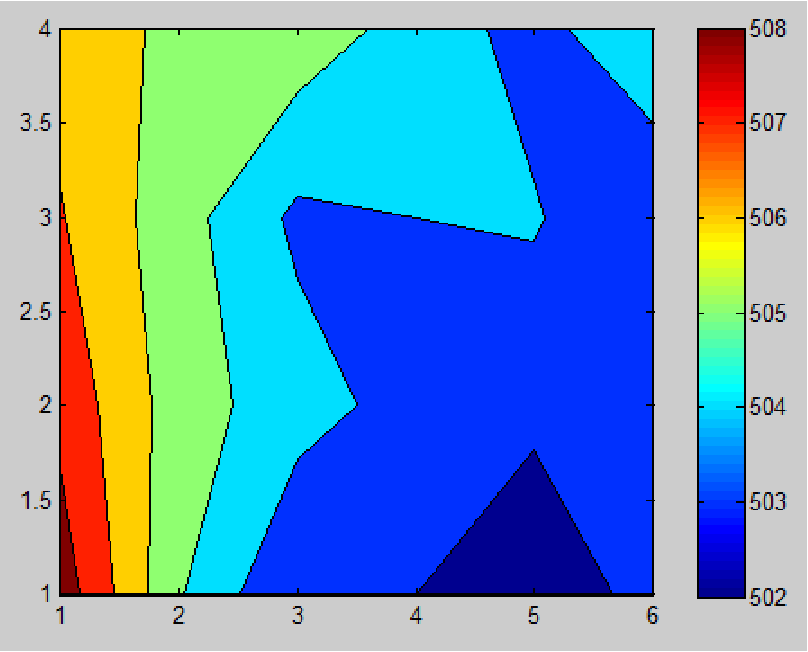


Figure 22 Magnetic Field Without Barrier, Run #1

Table 4 Magnetic Field Without Barrier, Run #2

Magnetic Mapping with barrier
Run #2

Y/X	1	2	3	4	5	6
1	486.87	488.67	490.13	493.6	495.6	497
2	485.92	488.52	490.06	490.04	495.5	501.2
3	485.67	488.37	490.23	491.64	496.1	499.9
4	485.97	486.28	490.39	490.8	496.5	497.9

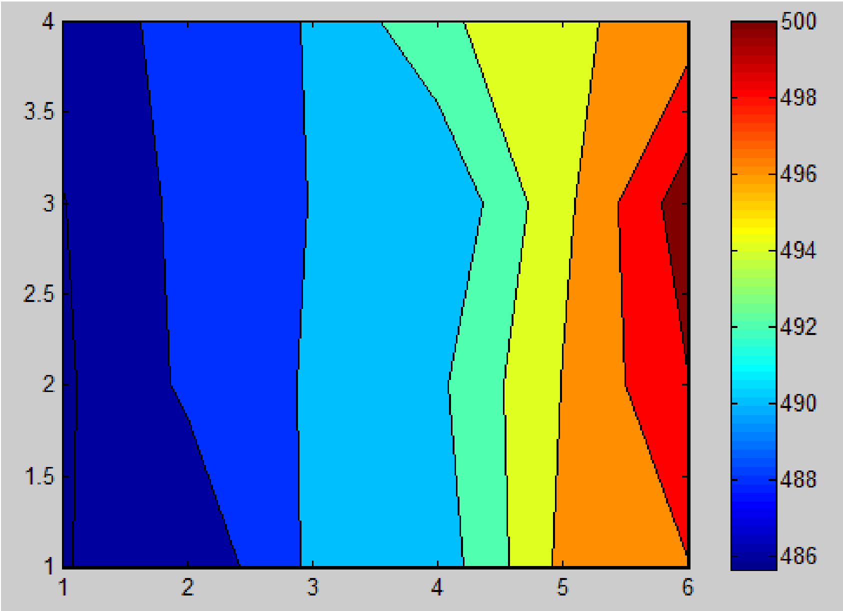


Figure 23 Magnetic Field Without Barrier, Run #2

Table 5 Magnetic Field Without Barrier, Run #3

Magnetic Mapping with barrier
Run #3

Y/X	1	2	3	4	5	6
1	498.72	476.84	482.95	491.39	494.53	499.9
2	498.65	475.52	481.17	491.07	491.28	496.06
3	483.87	474.06	487.26	485.62	482.23	504.78
4	481.96	473.47	480.67	480.07	481.17	484.7

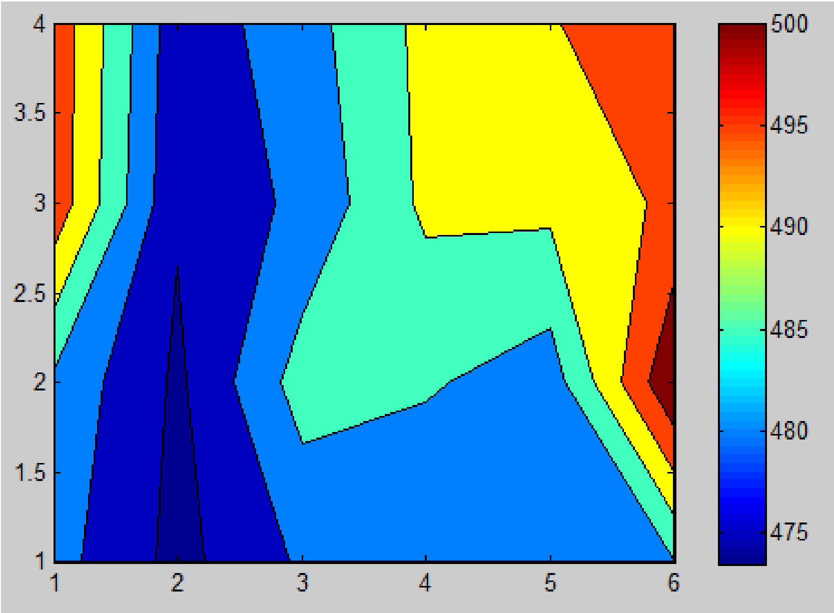


Figure 24 Magnetic Field Without Barrier, Run #3

Table 6   Magnetic Field Without Barrier, Average Calculated

Magnetic Mapping with barrier
Average

Y/X	1	2	3	4	5	6
1	497.3633	490.4367	492.8933	496.53	497.91	500.6333
2	497.2233	489.8133	491.6767	495.0367	496.96	500.0867
3	492.4133	489.31	493.9633	493.62	493.8767	502.8933
4	492.1767	488.2833	491.3533	491.29	493.2233	495.3667

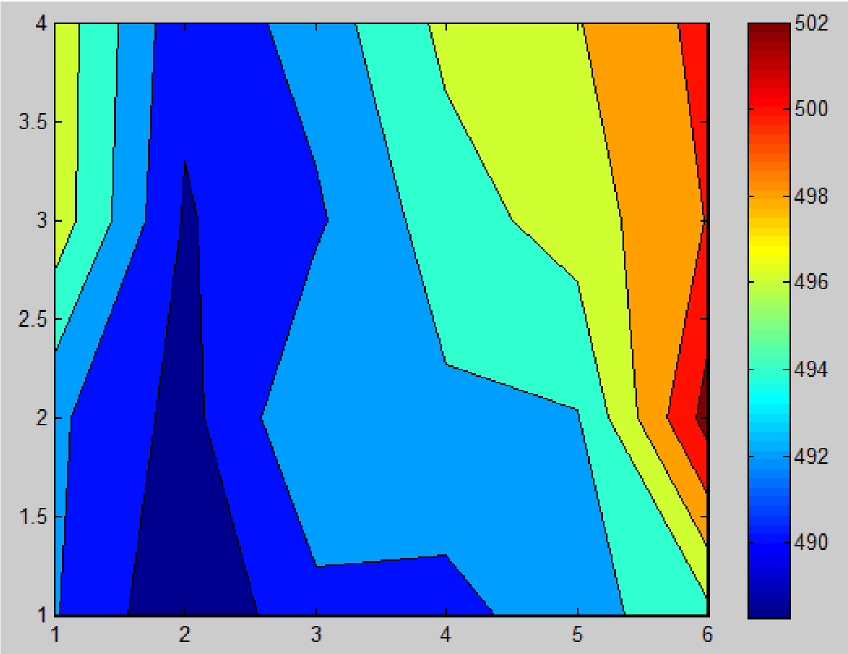


Figure 25   Magnetic Field Without Barrier, Average Calculated

4.3.2 Result for Magnetic Field Mapping With Barrier

Magnetic field mapping with barrier is serve to map, the effect of reflected wave only eliminating the effect from direct wave and air gap wave to the magnetic measurement in scale sea model.

From the results it is observe that the value of magnetic field receiver reading much lower compare to mapping without magnetic field barrier simply because the effect of direct and air gap waves has been reduce. By doing so, the measurements of this phase are only with respond to the reflected wave.

Based on average value as per table 10 and figure 29, it was observed that at grid (1-3, 2-4) there is distinct outcome that indicated huge magnetic field drop at the area specific. This is due to the fact that, as the reflected wave penetrates cooking oil which located at grid (3-4, 1) at the centre of scale sea model, the magnetic field experience attenuation and the magnetic field reflected back to the receiver at much lower value. It is therefore, from the figure 29; the high drop in intensity indicated the existence of cooking oil (hydrocarbon) in the scale sea model in parallel with it.

Table 7 Magnetic Field Mapping With Barrier, Run #1

Magnetic Mapping with barrier
Run #1

Y/X	1	2	3	4	5	6
1	486	486	487.1	487.8	488.3	490.9
2	486.2	486.4	487.3	487.6	488.5	490.1
3	486.6	486	487.9	487.9	488.4	489.1
4	487.3	487	487.9	487.7	490	489.1

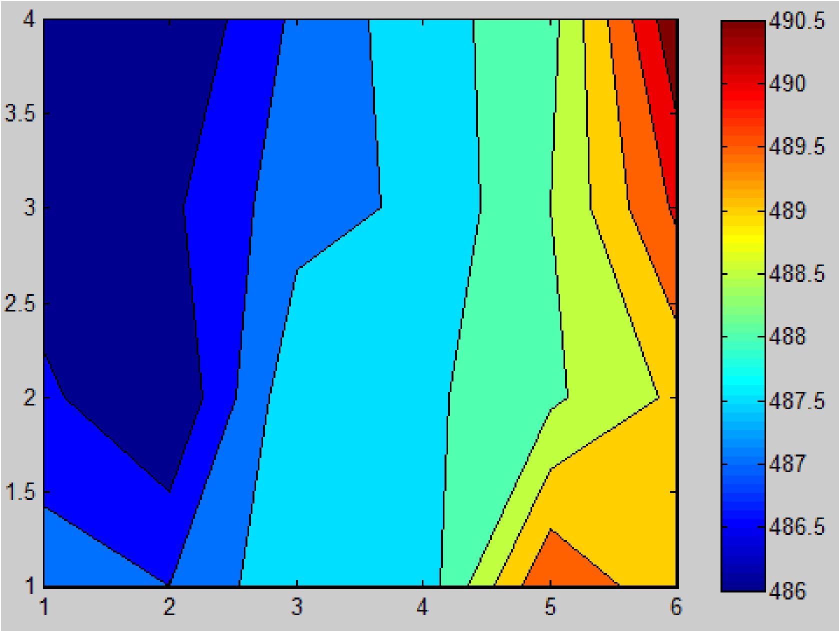


Figure 26 Magnetic Field Mapping With Barrier, Run #1

Table 8 Magnetic Field Mapping With Barrier, Run #2

Magnetic Mapping with barrier
Run #2

Y/X	1	2	3	4	5	6
1	495.26	473.45	472.95	469.86	482.72	510.6
2	475	472.46	472.62	469.66	481.72	488
3	474.86	473.62	472.42	469.55	482.77	487.6
4	473.03	473.18	472.02	473.16	471.88	489.5

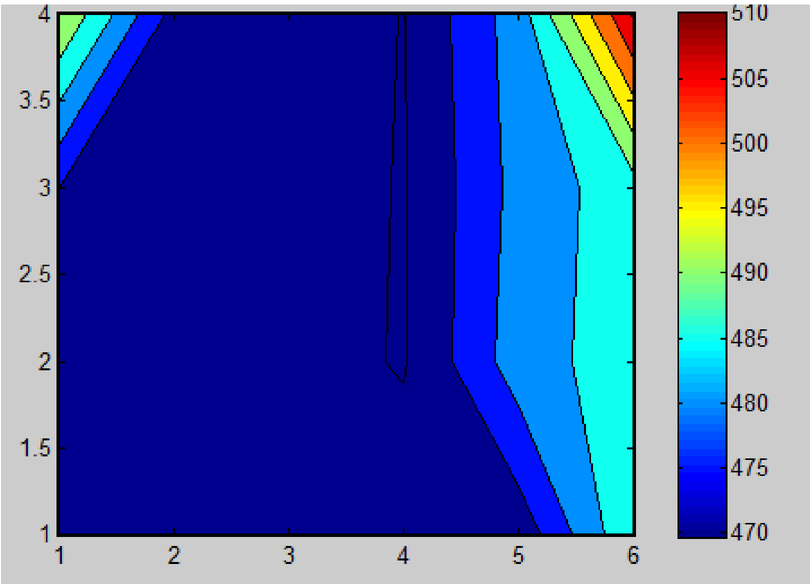


Figure 27 Magnetic Field Mapping With Barrier, Run #2

Table 9 Magnetic Field Mapping With Barrier, Run #3

Magnetic Mapping with barrier
Run #3

Y/X	1	2	3	4	5	6
1	464.59	464.31	463.04	464.38	463.91	462.47
2	464.63	464.46	463.7	463.73	463.26	462.84
3	465.03	464.34	463.67	463.67	462.78	462.4
4	464.77	464.44	464.09	464.12	462.59	462.64

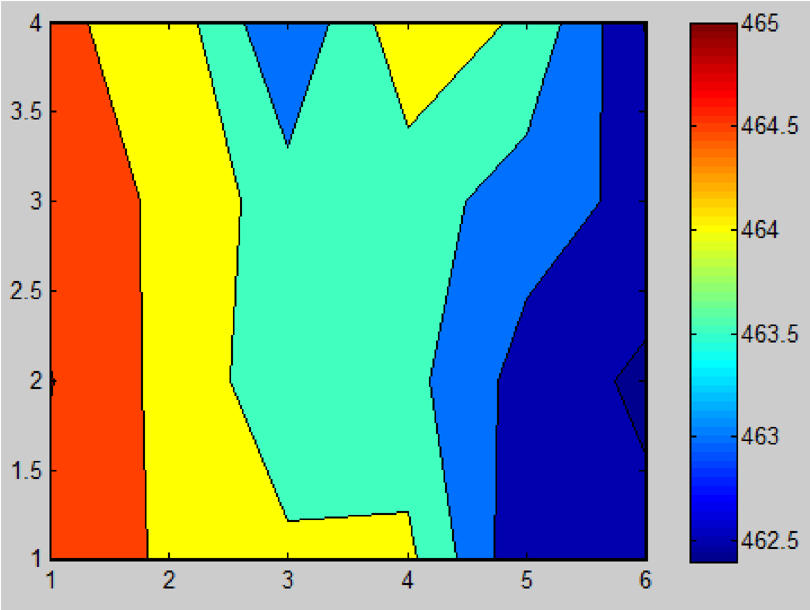


Figure 28 Magnetic Field Mapping With Barrier, Run #3

Table 10 Magnetic Field Without Barrier, Average Calculated

Magnetic Mapping with barrier
Average

Y/X	1	2	3	4	5	6
1	481.95	476.4275	476.2935	476.1185	477.9599	481.5899
2	475.2767	474.9369	474.9784	474.2771	477.86	480.6325
3	475.4967	475.0649	475.0524	474.3031	477.954	480.2645
4	475.0333	475.1749	475.0557	474.9933	476.374	480.6211

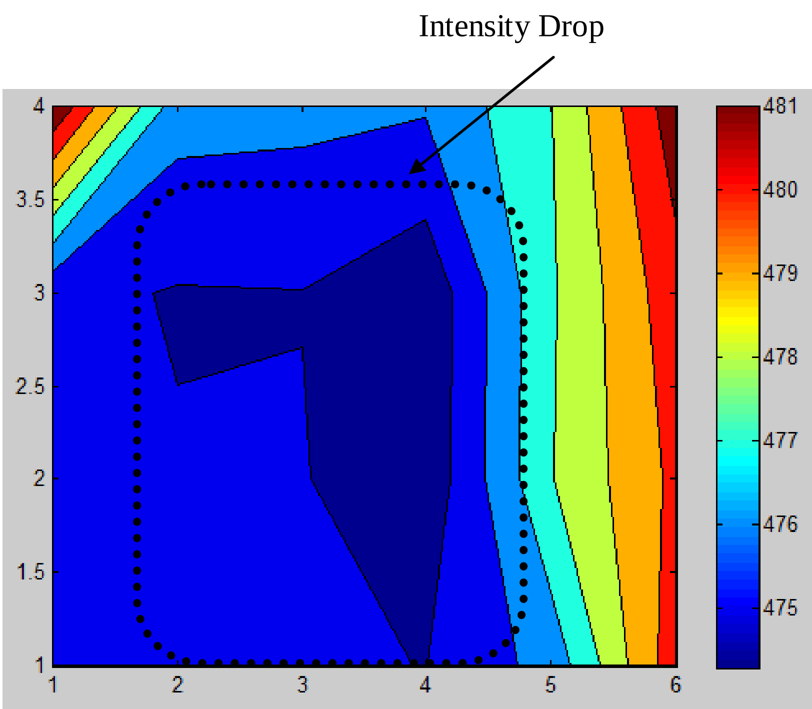


Figure 29 Magnetic Field Mapping With Barrier, Average Calculated

4.3.3 Comparison Between With and Without Barrier Mapping Outcome

Based on figure 30, it was shown the effect of magnetic barrier was basically reduce the measurement intensity in this case direct and air gap wave to the receiver. It was also noted, at the right most of the grid, there are highest intensity value, simply because the magnetic field somehow has passed through the barrier even though the length of magnetic barrier and dipole antenna is the same. However, as shown in the figure, as the location move from the right side and the antenna of the scale sea model, the intensity of magnetic field is drop. As far as hydrocarbon detection of scale sea model, the outcome of the project has shown promising result. And not effecting by the leakage magnetic field. There is significant effect of cooking existence by significant intensity drop at location align with where the cooking oil was buried.

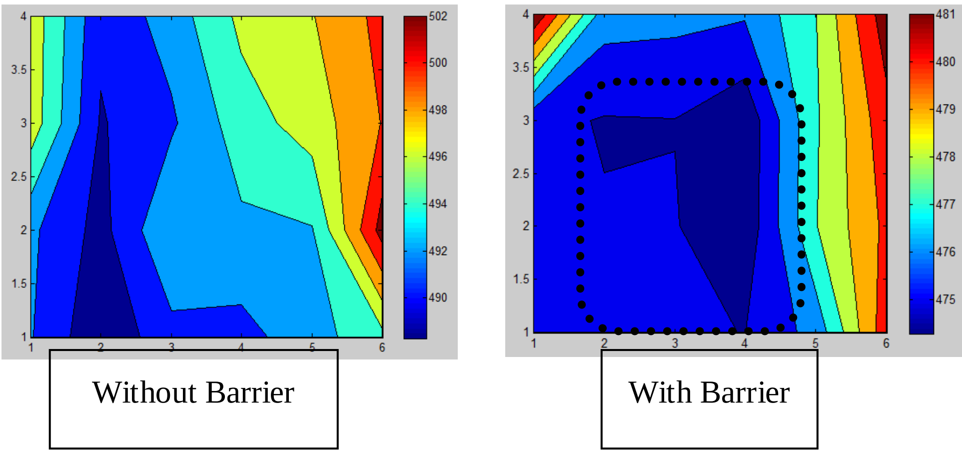


Figure 30 Comparison Between With and Without Barrier Mapping Outcome

CHAPTER 5
CONCLUSION AND RECOMMENDATION

5.1 Conclusion

This entire project was carried out with objective to improved magnetic field receiver sensitivity, to integrate newly develop magnetic receiver to the scale sea model, to map magnetic field in the scale sea model and to analyze receive signal from the mapping process.

As far as first objective is concern, the author has managed to increase sensitivity of the magnetic field signal based on calibration result and magnetic field mapping process in the scale sea model from mili-Tesla range from previous setup to micro-Tesla range. However, the receiver was found to be very sensitive to the surrounding such as room wiring, hand phone signal, physical movement and others related. These eventually have impact on the magnetic field measurement, in such away that it was difficult to get consistent result in using the receiver.

Meanwhile, for the integration to the scale sea model, the receiver was perform well to the scale model in such away the receiver was interact with the magnetic field inside the scale sea model.

As for mapping process and data analysis of the scale sea model, the receiver has able to map the magnetic signal at the scale sea model and based on data analysis, there was promising result based on magnetic field intensity, that, buried object can be detected. This indicates that, the receiver able to detect very small magnetic field variation in this case reflected wave.

5.2 Recommendation for Future Work

- To place an array of receiver in the lab sea scale model that have capabilities to simultaneously record the electromagnetic fields transmitted by the antenna at various positions in the water tank.

- To do mapping with other material besides cooking oil for example hydrocarbon, plastic and other material to get more convincing result.

- Study the co-location of the source and receivers especially on the reflected wave penetration's angle to the buried object.

- To install water stirred in the water tank to stimulate the effect of the waves and noises in the magnetic field mapping process.

- To replace salt water and sand with actual sea water and sand.

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APPENDICES

APPENDIX A

GANTT CHART

APPENDIX B

CALIBRATION OF MAGNETIC RECEIVER

Calibration of Magnetic Field Receiver

Date: 8th September 2009

Procedure:

1. The setting of the calibration in such away that the circuit is connected to the voltmeter in order to get the value.
2. The value of magnetic field is determined by the amount of current entering the helmholtz coil. It is possible by adjusting the value of resistor used and also the DC voltage supplied. Refer to table 1 for detail.
3. The receiver later than will be replaced at the centre of the helmholtz coil and voltage reading can be obtain.
4. Plot the voltage vs magnetic field.

Theory and Calculation:

1. Helmholtz Coil
    - Homogenous magnetic field, B in the mid-plan between two circular coil is defined by the equation:

$$B = \frac{32\pi\, N\, I}{5\sqrt{5a}} \times 10^{-7}\ tesla$$

N = number of circular coil turn

I = carrying current of the circular coil turn

a = radius of circular coil

2. Carrying current
    - The carrying current for the circular coil is obtained by the Ohm's Law:

$$V = IR$$

$$I = \frac{V}{R}\ Ampere, A$$

V = Supply voltage from power supply

R = Resistor

3. Setting value

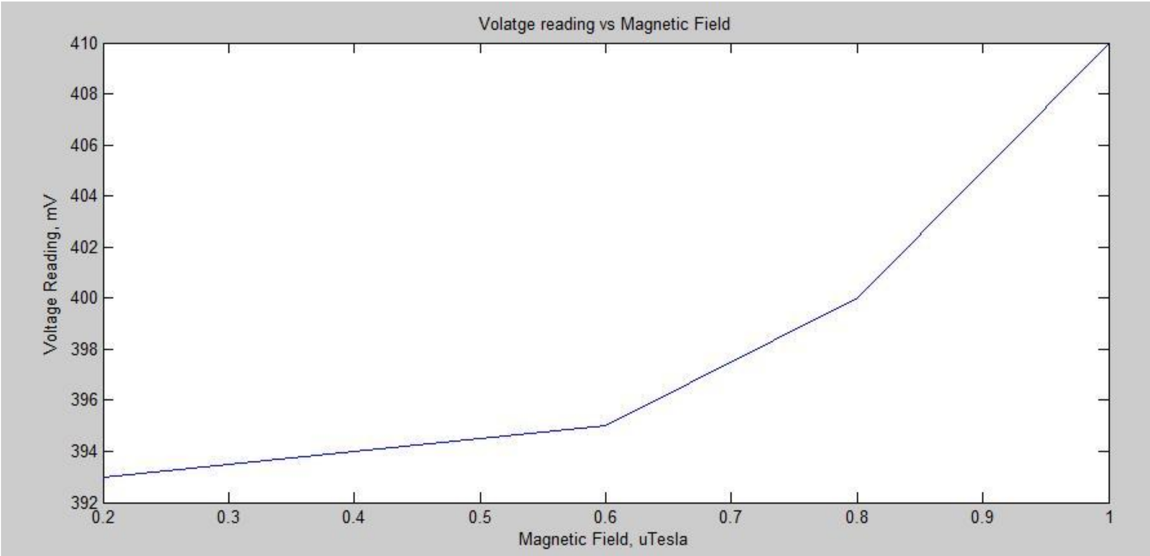
NO	Magnetic Field, B (uT)	Current, I (A)	Resistor, (Ohm)	Voltage Supply
1	0.01	2.75×10^{-6}	90k	0.25
2	0.10	2.75×10^{-4}	9k	2.48
3	0.20	5.50×10^{-4}	900	0.50
4	0.40	1.10×10^{-3}	900	1.00
5	0.60	1.64×10^{-3}	900	1.48
6	0.80	2.20×10^{-3}	900	1.98
7	1.00	2.75×10^{-3}	900	2.48

Table 1: Control Magnetic Field at Helmholtz Coil

Result:

NO	Magnetic Field, B (uT)	Voltage Reading, Vac (mV)
1	0.01	322
2	0.10	330
3	0.20	393
4	0.40	394
5	0.60	395
6	0.80	400
7	1.00	401

Result of calibration.



Graph of calibration

Conclusion:

1. The reading sometimes becoming unstable due to effect of outside magnetic field

The reading voltage is directly propotional to the Magnetic Field.