Seabed Logging Modeling Using Comsol Multiphysic Software:

Effect of Hydrocarbon Geometry to the EM Wave

By

Fahim Anati binti Sulaiman

Dissertation submitted in partial fulfillment

of the requirements for the

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Perak

CERTIFICATION OF APPROVAL

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Approved:

_____
Assoc. Prof. Dr. Bambang Ariwahjoedi
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.

(Fahim Anati binti Sulaiman)

ABSTRACT

Among the many techniques used for hydrocarbon, Sea Bed Logging (SBL) is a technique from marine controlled-source electromagnetic (CSEM) sounding, which can be used to detect and characterize hydrocarbon bearing reservoirs in deep water areas. Compared to other techniques such as seismic methods, SBL can be considered as better in term of cost, effectiveness and environmental friendly. Yet, the real seabed logging still need large capital since the equipments and the process to put receivers and collecting them will consume large amount of money. Researchers need to spend much more time on finding various type of crude oil to do seabed logging survey. Hence, the objective of this project is to create SBL simulator such that it will be more realistic and close to the actual condition. At the same time, it is to test whether Comsol Multiphysics software is able to display the result of SBL simulation. The project is started with a literature survey on seabed logging and related items from relevant sources such as books and journals. Then, familiarization with the main software which is Comsol Multiphysics and survey on the related formulations for seabed logging will be carried out. The problem is solved and the result is plotted in a graph. From the experiment done, it is shown that the existence of hydrocarbon will results a high intensity of electrical field and also that the higher the depth of hydrocarbon is, the lower the intensity will be. Other results show the effect on shape and thickness of hydrocarbon as well as the frequency and current of transmitter used.

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CHAPTER 1

INTRODUCTION

1.1   Background of Study

Hydrocarbon exploration is an exploration by petroleum geologists and geophysicists for hydrocarbon beneath the Earth's surface. Among the many techniques used, Sea Bed Logging (SBL) is a technique from marine controlled-source electromagnetic (CSEM) sounding [1].

Seismic methods, which can only (under certain circumstances) point indirectly to the presence of hydrocarbons, have traditionally been used in this context. The seismic approach alone was evident by the level of offshore drilling activity and the subsequent production of oil. However, there are marine geological terrenes in which the interpretation of seismic data is difficult. The type of reservoir (water or hydrocarbon) usually discovered after drilling thus wasting capital in hydrocarbon exploration [4]. In other locations, seismic methods can be environmentally discouraged [5].

SBL has gained wide industry acceptance and surge of interest currently as exploration can be done without drilling wells. Detecting and assessing hydrocarbon reservoirs without the need to drill test wells is very importance to the petroleum industry [2]. It is evidently proven that SBL can increase the success rate of hydrocarbon finding [19].

1.2   Problem Statement

1.2.1   Problem Identification

Although seabed logging can be cheaper than other hydrocarbon exploration method, the real seabed logging still need large capital since the equipments and the process to put receivers and collecting them will consume large amount of money. Researchers need to spend much more time on finding various type of crude oil to do seabed logging survey.

Besides that, simulation of sea bed logging using small scale model will have restricted variation of result since the model itself is bounded.

1.2.2   Significance of the Project

Based on the statement in problem identification part, therefore by using software to create seabed logging simulator, varied condition can be experimented in order to learn more about seabed logging without using much capital, time and energy. The result can be quite accurate since the environment used in the simulator is similar to the real condition.

1.3   Objective and Scope of Study

1.3.1   Objective

i.   To simulate seabed logging using computational method in model such that it is more realistic and close to the actual condition

ii.   To test the capability of Comsol Multiphysics software to show and display the result of simulation of the seabed logging.

1.3.2 Scope of study

i.   Literature survey on the hydrocarbon exploration and seabed logging from various sources such as journals, articles, books, internet, previous report and etc.

ii. Comsol Multiphysics software familiarization and utilization.

iii. Simulation of seabed logging using various condition such as:

   a. Depth of hydrocarbon beneath the seabed

   b. Position of hydrocarbon under the transmitter

   c. Thickness of hydrocarbon

   d. Shape of hydrocarbon

   e. The amount of frequency and current of transmitter

iv. An analysis will be done based on the result collected from the various simulations.

v.   A written report of this project will be produced after all activities have been successfully conducted.

vi. Conclude the experiment by reflecting back to the objective and look into some recommendations for further development of the project.

By having these scopes of study to set the work boundaries for the author, the target of working on the project with the given time frame and budget constraint is deemed sufficient.

1.4 Feasibility of Project

Two semesters will be required to complete this project. For the first semester, author will start the project with research on seabed logging and also the development of the simulator using COMSOL. Learning the software is an important aspect in Final Year Project (FYP) I to prepare for final results in FYP II.

The second semester will be focusing on the simulation and data collection of the modeling in COMSOL. All the data will then be interpreted for technical report. With the resources that are available in the University, the project shall be completed within the given time frame.

CHAPTER 2
LITERATURE REVIEW

2.1   Theory of Hydrocarbon Formation

Seabed region which contain hydrocarbons are most likely from sedimentary rocks (rocks formed from fragments of other rocks or chemically precipitated). The reason is that sedimentary rocks are much more likely to have properties that allow hydrocarbons to generate, migrate, and be stored between their grains. When sedimentary rocks accumulate in water-rich environments, such as oceans, they tend to preserve and generate hydrocarbons more efficiently [11][12].

Marine life, whether they are the simplest plankton and single-celled life forms or the more complex organism and fish species, contains carbon molecules. When they die, they will decay over millions of years. The carbon molecules, through processes of heat and pressure (metagenesis, catagenesis, and diagenesis) mature into hydrocarbon compounds as illustrated in Figure 2.1. With time, accumulations may form oil and gas reservoirs if the volume is sufficient [2].
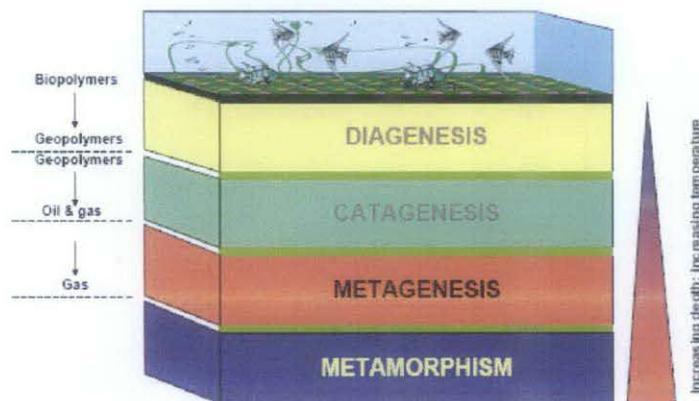
Figure 2.1: Maturation of Organic Matter

2.2   Geophysical Surveys

Geophysics is the study of the earth by quantitative physical methods. Geophysical techniques such as seismic surveys, gravity surveys, and magnetic surveys provide a way of measuring the physical properties of a subsurface formation for hydrocarbon exploration. These measurements are translated into geologic data such as structure, stratigraphy, depth, and position. These geophysical surveys lead to potential traps in reservoir rocks as well as documenting regional structural trends and overall basin geometry [13].

2.2.1   Seismic Method

Seismic imaging is one of the geophysics methods that have been used and established for quite a long period. However it is difficult to predict the existence of hydrocarbon with the elastic properties hence still encounters difficulty in differentiating types of reservoir fluids, such as brines, oil, and gas [6]. Traditionally, geophysicists will drill and record the resistivity logs to determine whether certain reservoir is water-bearing or hydrocarbon bearing reservoir [4].

This method uses artificial sources to generate seismic waves that bounce off boundaries between different types of rock layers material as illustrated in Figure 2.2. The reflections recorded are plotted as lines on a seismic section that shows features like faults, folds and lithologic boundaries [15]. Since the focus is not about seismic method, it will not be discussed further by the author.
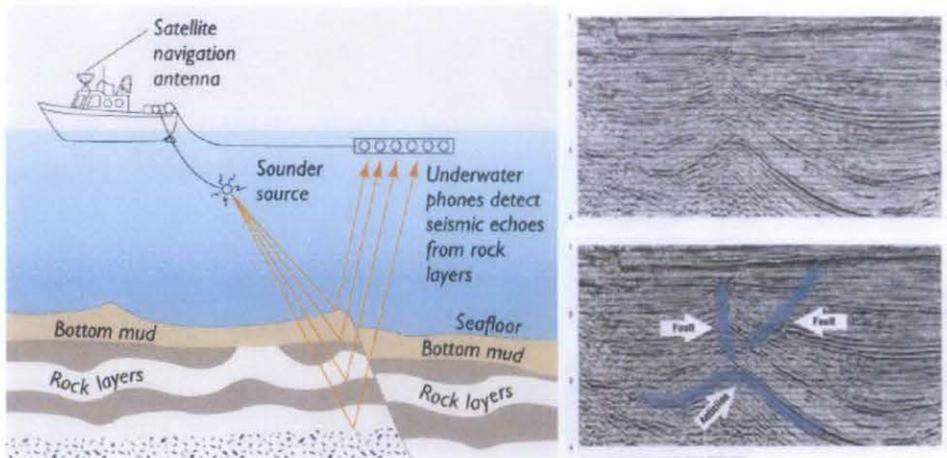
Figure 2.2: Seismic Method

2.2.2 CSEM and Seabed Logging

Controlled Source Electromagnetic (CSEM) technique was developed almost three decades ago to study the conductivity structure beneath the seafloor [7]. It is able to measure the electrical resistivity and related to hydrocarbon exploration. For the relationship between the hydrocarbon and resistivity, the electromagnetic sounding has the potential of directly indicating the hydrocarbon. CSEM techniques play an important role in hydrogeophysical investigations since the physical property sensed is linked petrophysically to hydrological variables of interest such as moisture content, hydraulic conductivity, and porosity. [8].

Theoretically, CSEM techniques cover all geophysical, electromagnetic surveys with an active source. When this technique is applied offshore, it may be known as marine CSEM, mCSEM or Seabed Logging (SBL) [16]. Thus, Sea Bed Logging (SBL) is a technique from marine controlled-source electromagnetic (CSEM) sounding, which can be used to detect and characterize hydrocarbon bearing reservoirs in sea water areas [1].

When this technology is appropriately applied and integrated with other data such as seismic, it can provide what seismic typically can't which is a direct hydrocarbon indicator [9]. This technology is also cost effective. The cost to do a seabed logging survey to confirm a drilling decision pales compared to the cost of drilling a deepwater well.

On the other hand, electromagnetic (EM) data makes a nice complement to seismic data, which typically gives better vertical resolution than horizontal resolution. EM data may be depth-limited but can often outline the boundaries of a reservoir with surprising accuracy [9]. When integrated with seismic imaging, the results can be more promising as shown in Figure 2.3 [10]. This method also appears to be quite harmless to the environment compared to seismic surveying since it only transmit wave [4].
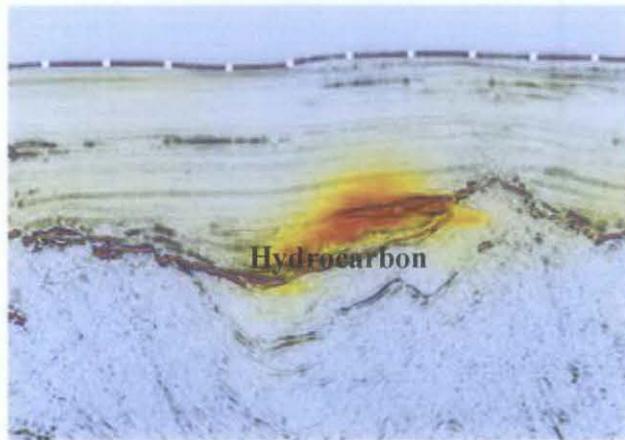
Figure 2.3: Image derived from Integration of SBL and Seismic Data

2.3   Seabed Logging Method

SBL basically uses a mobile horizontal electric dipole (HED) source and an array of receivers on the seabed as illustrated in Figure 2.4. The receivers which are sensitive to the earth's electrical and magnetic fields are deployed on the seabed in lines or grids. The array of seabed receivers measures the amplitude and phase of the transmitted signal [1].
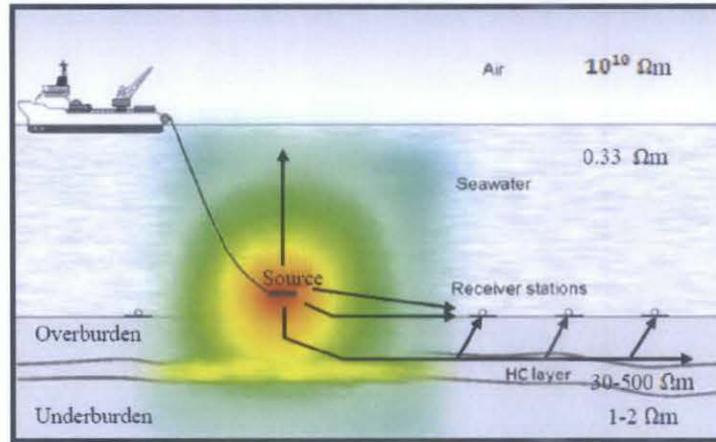
Figure 2.4: Seabed Logging

Sea water is water containing dissolved solids. It is saline, its freezing point is slightly lower than fresh water, its density is slightly higher, its electrical conductivity is such higher, and it is slightly basic. It is a good conductor of electricity, because it allows a current to pass through itself easily [17].

Electric field around a reservoir can be measured and the data used to infer the presence (or absence) of hydrocarbons. In practice sensors are deployed on the seabed to measure electric and magnetic fields that are created by the HED [18].

The presence of hydrocarbons in a reservoir changes the electrical resistivity of the rock. A survey consisting of many transmitter and receiver locations can determine a multidimensional model of the subsurface resistivity, thus indicating whether the subsurface contains a high resistivity hydrocarbon-saturated layer [4].

In many geological settings, rocks saturated with hydrocarbons exhibit significantly higher electrical resistivity than those saturated with brine [10]. Since oil is more resistive, the hydrocarbon bearing reservoir will have high resistivity compared to water bearing reservoir. As a result, hydrocarbon bearing reservoir will give more reflection value to the receiver as shown in Figure 2.5.
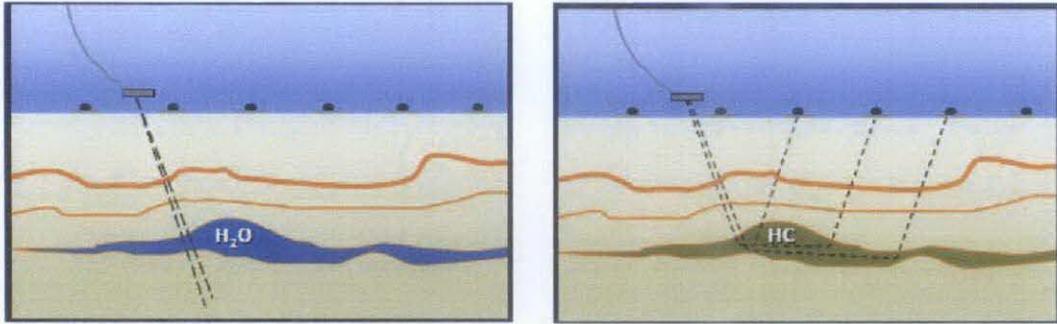
(a) Water bearing reservoir = low resistivity .Less Refraction of Waves to the receiver

(b) Hydrocarbon bearing reservoir = high resistivity. Reflection of Waves to the receiver

Figure 2.5 : Reflection from Different Reservoir

2.3.1 SBL Theory Based on CSEM

The CSEM approach is based on comparing the electric field amplitude as a function of the source-receiver offset with a similar measurement for a non-hydrocarbon bearing reservoir. The presence of hydrocarbon raises the amplitude of the measured electric field indicating the existence and to some degree determining the horizontal extent of the hydrocarbon zone [8].

The receiving data is processed and presented in two dimensional model to map a hydrocarbon reservoir. Figure 2.4 also shows five components of received EM waves which are [19]:

    i.   Direct waves – EM waves from transmitter.

    ii.   Air waves – EM waves reflected back at the boundary of air and seawater.

    iii.   Reflected waves – EM waves from seabed or host rock.

    iv.   Reflected waves – EM waves from hydrocarbon.

    v.   Guided waves – EM waves through hydrocarbon.

The reflected energy from high resistivity subsurface layers will dominate over directly transmitted energy when the source-receiver distance is large enough (approximate 3 times the target depth) [16]. The detection of this guided and reflected energy from hydrocarbon is the basis SBL. The airwave component will diffuse in the downward direction and be almost normal incident to seabed, whereas the guided modes (Reflected Wave from Hydrocarbon and Guided Wave from Hydrocarbon) associated with hydrocarbon will leak out and diffuse in the upward direction [20].

Most of the equation related to EM wave is based on Maxwell's equation. Maxwell's stated that magnetic field produced (B) is proportionally related to the current and the type of material used. The bigger the current flows inside a conductor and the higher the permeability of the material used, then the bigger the B field is produced [21]:

$$B = \frac{\mu_0 I}{2\pi r}$$

where

B is the magnetic field,

μ_0 is the permeability,

I is the current,

R is the distance, and

E is the electric field intensity

In addition, an electromagnetic wave entering a conducting surface is damped and reduces in amplitude by a factor $1/e$ in a distance ∂. This distance is referred to as the skin depth of the conductor. The effect is caused by electromagnetic induction in the metal which opposes the currents set up by the wave E-field. It given by [22]:

$$\partial = \sqrt{\frac{2}{\omega \mu_0 \sigma}}$$

10

where

ω is the angular frequency ,

σ the electrical conductivity of the material.

μ_0 is the permeability

The frequency transmitted for SBL must be carefully chosen since it must not be too low or high. If the frequency is too low, the skin depth in the seafloor is very long so the signal is not inductively attenuated between the source and the receiver thus cannot resolve seabed structure. If it is too high, the skin depth is very small and signals only penetrate the shallow part of the crust thus can no longer be detected [19]. Therefore, the most suitable frequency to be used is in the range of 0.1Hz to 10Hz.

2.4   Comsol Multiphysics Software Simulation

Comsol Multiphysics (COMSOL) software is a finite element analysis, solver and simulation software package for various physics and engineering applications, especially coupled phenomena, or multiphysics. This simulation software environment facilitates all steps in the modeling process such as defining geometry, meshing, specifying physics, solving, and then visualizing the results. This software is suitable for problems that require modeling the propagation of electromagnetic waves in and around structures that can be metallic, dielectric, gyro magnetic, or even met materials with engineered properties [23].

By using simulation and computational method, various conditions can be surveyed for the seabed logging with far lesser cost. The simulation can be done multiply to ensure the accuracy of results.

2.4.1 Finite Element Method

Finite element method is a powerful computer-based tool widely used by engineers and scientists for understanding the mechanics of physical systems. This method is said to be a better analysis because unlike the finite difference method it mesh the solution domain into simply shaped regions (or elements). As illustrated in Figure 2.6 instead of rectangular grid, the uses of elements provide more accurate approximation for irregularly shaped system. Using the finite element analysis (FEA), values of the unknown is able to be generated continuously across the entire solution domain [14].

(a) Meshing solution for finite difference analysis (FDA)

(b) Meshing solution for finite element analysis (FEA)
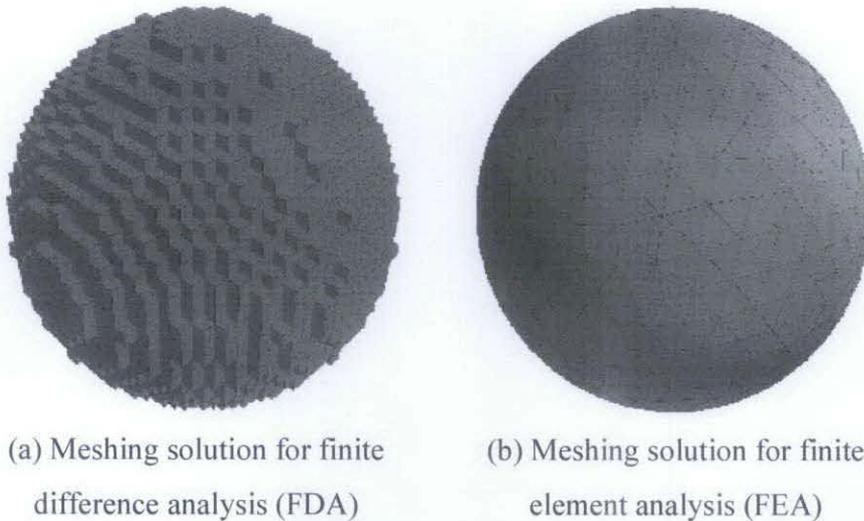
Figure 2.6: Comparison of Meshing with FDA and FEA

FEA uses a complex system of points called nodes which make a grid called a mesh. This mesh will be programmed to contain certain properties which define how it will react to certain conditions. Nodes are assigned at a certain density throughout the material depending on the anticipated stress levels of a particular area. Regions which will receive large amounts of stress usually have a higher node density than those which experience little or no stress which is shown in Figure 2.7 [24].

High density region
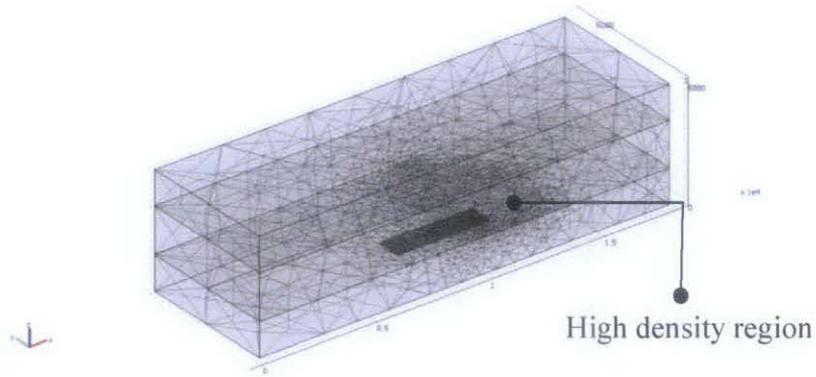
Figure 2.7: Mesh Product of FEA

2.4.2 Simulation Of SBL Using COMSOL

For initial survey, a simple block shaped hydrocarbon is used and inside a sphere shape domain. The layer for seabed logging is shown in Figure 2.8. At the external spherical boundaries, a scattering type boundary condition absorbs outgoing spherical waves. The following equation is solved for the electric field vector **E** inside the computational domain:

$$\nabla \times (\mu_r^{-1} \nabla \times \mathbf{E}) - k_0^2 \left(\varepsilon_r - \frac{j\sigma}{\omega \varepsilon_0} \right) \mathbf{E} = 0$$

where

μ_r is the relative permeability,

j is the imaginary unit,

σ is the conductivity,

ω is the angular frequency,

ε_r is the relative permittivity, and

ε_0 is the permittivity of free space.

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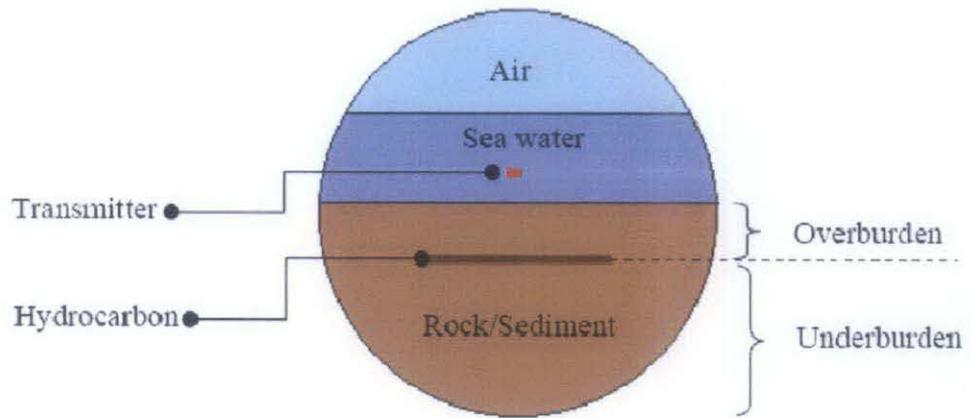
Figure 2.8: Sliced View of Domain in SBL Modeling

The method of using COMSOL will be explained in detail in methodology part. Nevertheless the basic domain to be used in this entire project will be similar to Figure 2.8. COMSOL will solve the computational part of after all parameter and settings are set prior to solving the problem.

CHAPTER 3
METHODOLOGY

3.1   Project Workflow

The workflow diagram is developed to show the flow of this project to meet the objectives. The overall steps involved are shown in Figure 3.1. The first step, literature survey involved is to understand the problem identified and then underline the objectives to be achieved. After that, a research has to be done regarding seabed logging itself the software that will be used throughout this project which is Comsol Multiphysics (COMSOL). The sources that can be used are journals, books, articles, previous reports, internet, etc. Then, parameters are selected according to the scope of study and data needed to run simulation are gathered as well.

Since the author has never been exposed to COMSOL before, there will be need to study the software for some period of time. This software can be learned by using manual and a simple model will be developed for testing. A basic model of the reservoir boundary or simulator is then being developed and the simulation is performed. After that, the simulation data is being analyzed and evaluated to ensure that the expectation is met. If failure happened, simulation and research is done simultaneously until expectation is met. After experiments are done, the results will be interpreted in terms of electromagnetic field reflected and a report is written to conclude the result of this project.
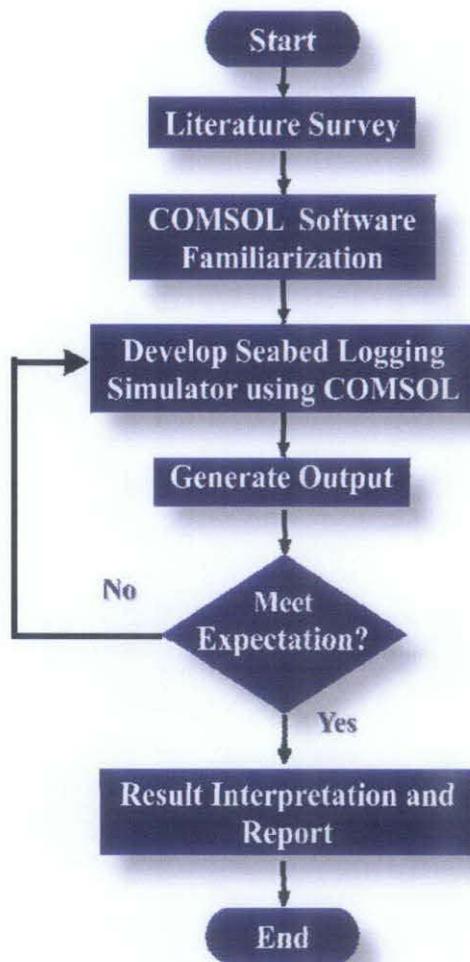
Figure 3.1 : Full Project Workflow

3.2 Schedule

The schedules of the project have been made by the author to keep track of her progress regarding the project. Schedule for FYP I can be referred in Appendix I while schedule for FYP II in Appendix II.

3.3 Tools/Equipment Required

The tool to be used in this project is Comsol Multiphysics (COMSOL) simulation software. Mainly, the author will be using the RF module throughout the completion of the project since it provides a unique environment for the simulation of electromagnetic waves in three dimension modeling. The environment used for this simulator was based on data gathered from research of a real seabed logging environment. Basically this project is done under ideal condition.

There are several steps that need to be followed to work with COMSOL. The first one is to choose suitable 3D model for seabed logging. The model to be chosen is RF Module harmonic propagation which is under the electromagnetic wave from the "Model Navigator" as shown in Figure 3.2 that will pop up after COMSOL software is run.
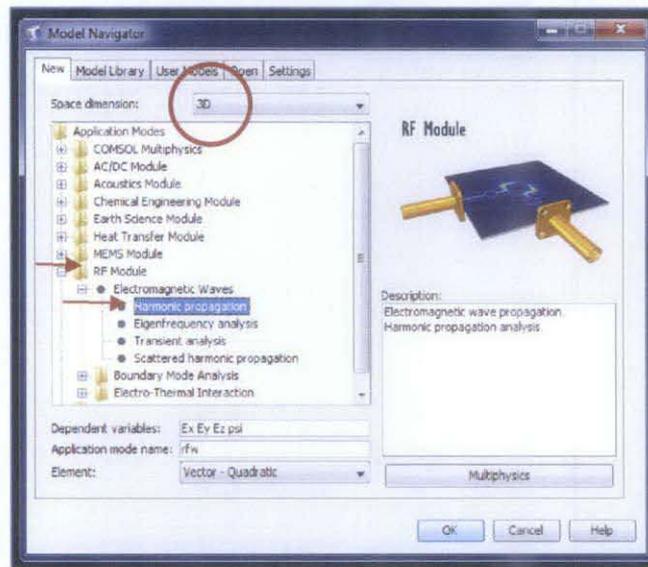
Figure 3.2 : COMSOL Model Navigator

After RF Module is chosen, the next steps in working with COMSOL are as shown in Figure 3.3. All of the experiments will basically use these steps repetitively until post processing of simulation is generated.

Subdomain geometry is drawn according to the data	→	Value of the physic setting for each subdomain is set	→	Mesh is initialized and created

Results are intepreted	←	Post-processing of the solved problem is conducted	←	Finite element is solved using COMSOL problem solver
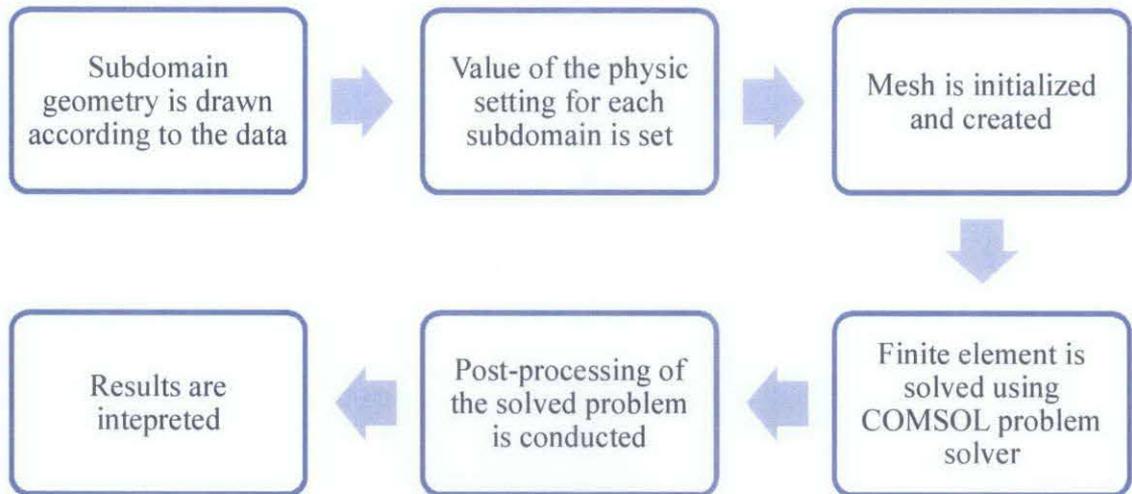
Figure 3.3: Flow Diagram of SBL Modeling with COMSOL

3.4 SBL Modeling Using COMSOL

As shown in Figure 3.3 the basic steps to do modeling in this software are including:

i. Subdomain geometry is drawn according to the data.

ii. Value of the physic setting for each subdomain is set.

iii. Mesh is initialized and created.

iv. Finite element is solved using COMSOL problem solver

v. Post-processing of the simulator

vi. Results are interpreted

3.4.1 Drawing Domain Geometry

As a beginning, two geometry are drawn using drawing tools provided in COMSOL as shown in Table 3.1 to create the sea water domain. Draw menu can be selected as shown in Figure 3.4. When user click on any tools a window will pop up to fill the dimension as shown in Table 3.1

Table 3.1: Geometry for Creating Sea Water Domain

Shape	Dimension
Sphere	Radius, R = 5 km
Cylinder	R_x = 6km ; Height = 1km
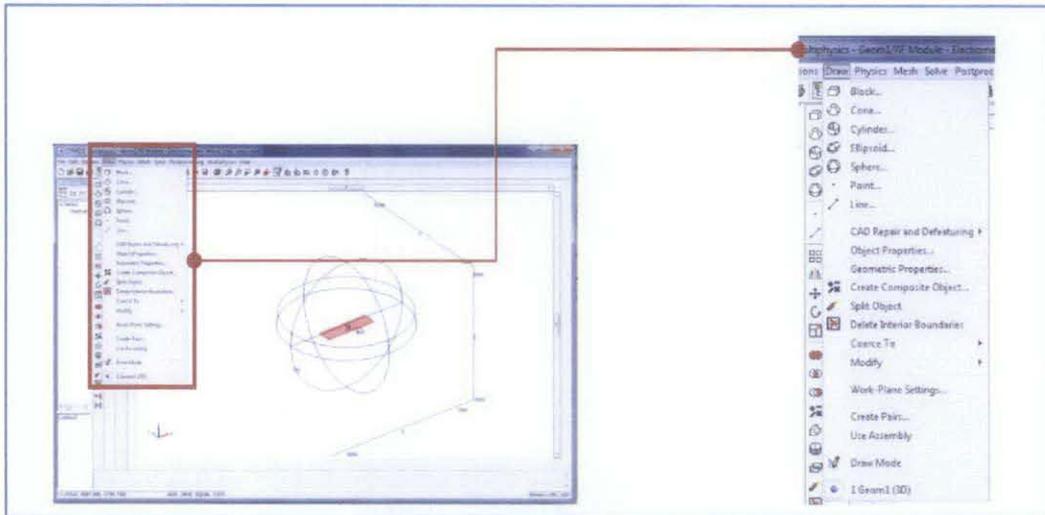
Figure 3.4: Draw Menu

These two shapes will be intersected, which is also in drawing tool menu to create the sea water domain as shown in Figure 3.5.
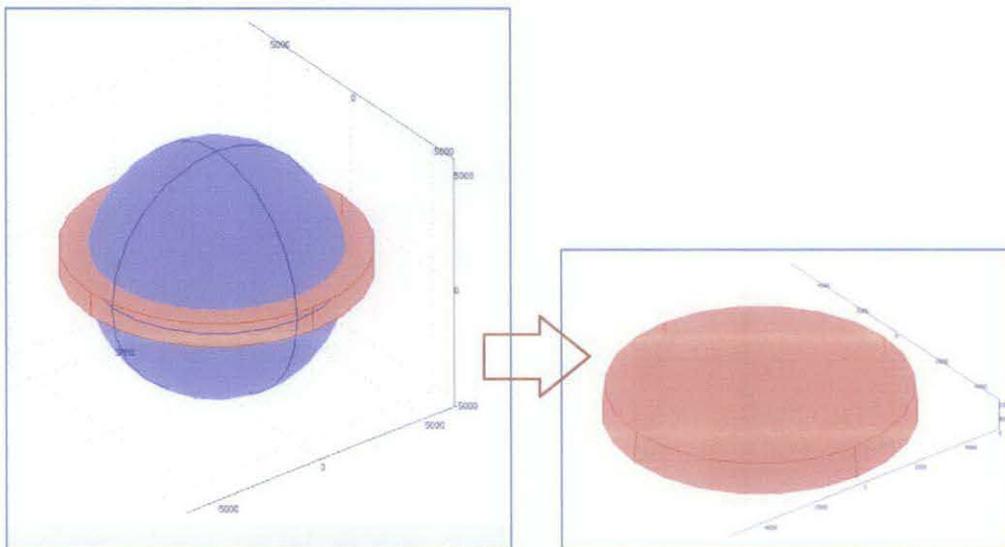
Figure 3.5: Seawater Domain

Another 5km sphere and a block are drawn to represent the whole domain and hydrocarbon. The block dimension will be varied according to the condition of hydrocarbon itself. As for the transmitter and receiver, it will be represented by a polyline situated 150m above x-axis. All the tools required to draw the geometry will be found under the "Draw Menu". The whole domain geometry is shown in Figure 3.6.
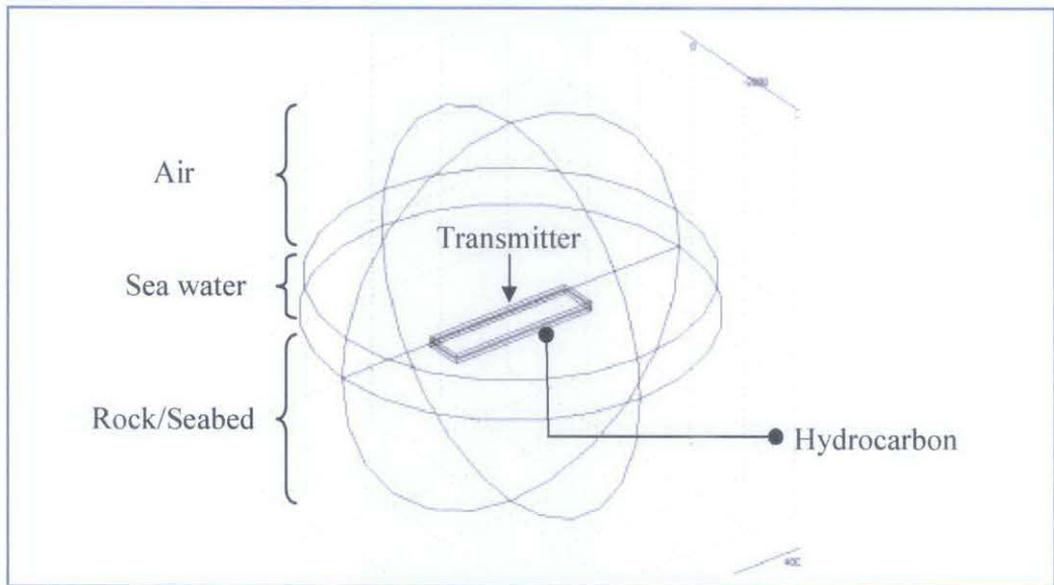
Figure 3.6: Geometry Modeling of Domain

3.4.2 Physics Setting

The value of physic setting are to be input to the "Physics Menu" which can be found at the menu bar with the same row as File, Edit, Plot Processing and Mesh. There are four main setting that need to be set for seabed logging which are:

i.   Subdomain setting : parameters value for air, sea water, sea bed and hydrocarbon

ii. Boundaries setting : wave propagate by transmitter

iii. Edge setting : transmitter current

iv. Scalar variable setting. : frequency used in the experiment.

"Subdomain setting" as shown in Figure 3.7 is to set the material properties and for the seabed logging application. User need to set up the relative permittivity and electric conductivity of the seabed environment.
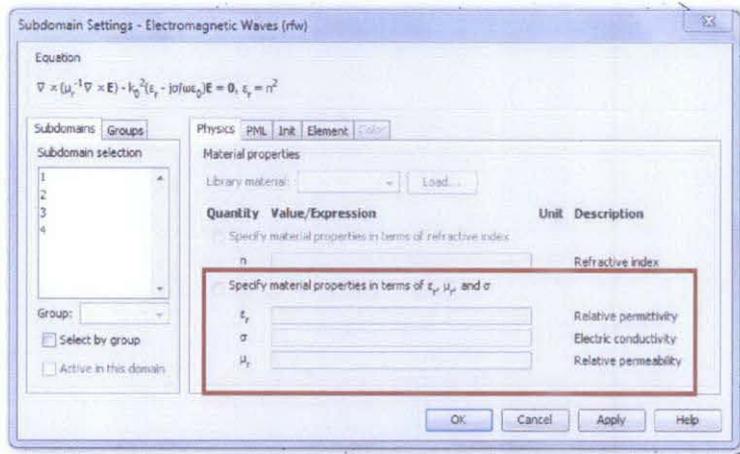
Figure 3.7: Subdomain Setting

"Boundary setting" as shown in Figure 3.8 is to set the different dielectric regions in the domain. From boundaries tab select the region by group and click on the boundary selection list. At condition tab select scattering boundaries condition and spherical wave type.
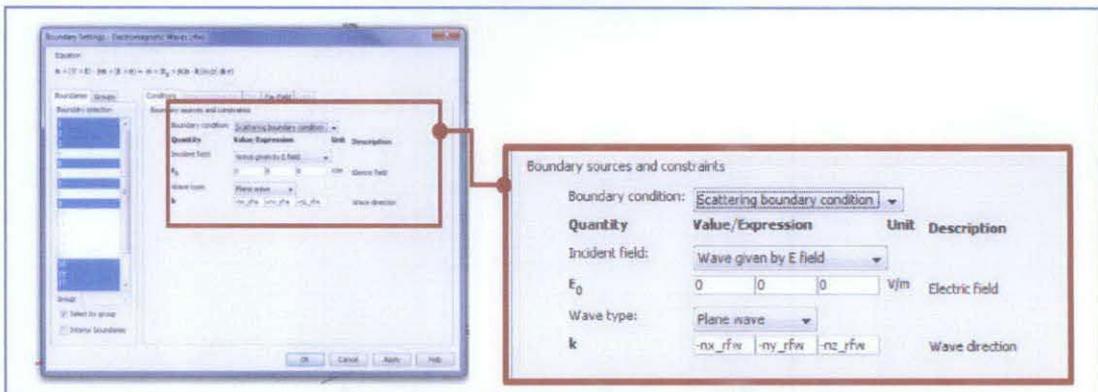
Figure 3.8 : Boundary Setting

"Edge setting" as shown in Figure 3.9 is to describe the physics on a model's main domain and work similar way as the point settings. On edge selection, select point that being assign to be the transmitter point. Than at coefficients tab, select current in edge segment direction and key in the value for the transmitter current. Based on research, transmitter current used for seabed logging are 10 kA.

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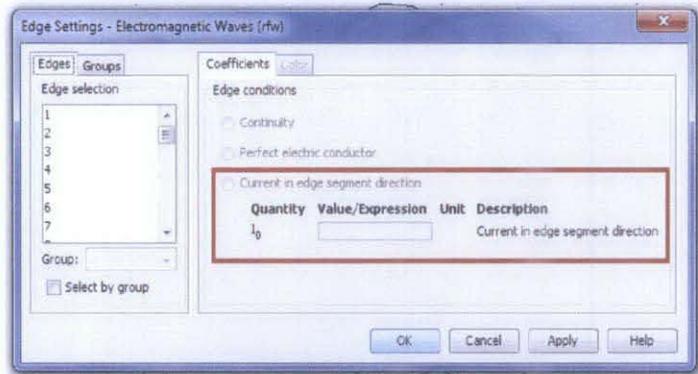
Figure 3.9: Edge Setting

"Application Scalar Variable" setting as shown in Figure 3.10 can be used to change the values of each scalar variable by making an entry in the edit field in the Expression column. For this seabed model, user needs to change the Expression of frequency description only.
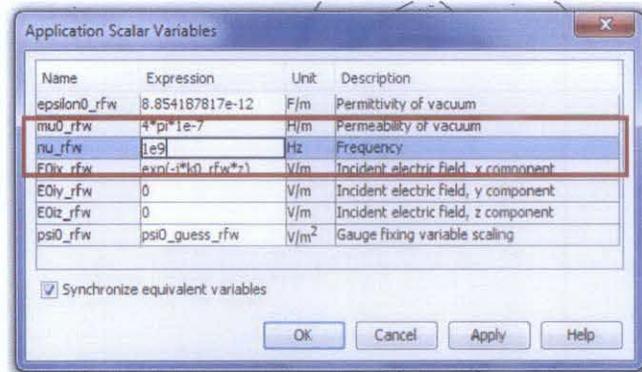
Figure 3.10 : Scalar Variable Setting

3.4.3   Meshing Geometry

Before solving the problem, geometry is meshed and user can find the "Mesh" menu at the menu bar with the same row as File, Edit, Plot Processing and Physic. Inside the mesh menu user need to set for the Free Mesh Parameters only as shown in Figure 3.11. From Global tab select the custom mesh size and set the maximum element size. For this model the maximum element size is set to be 1e3.
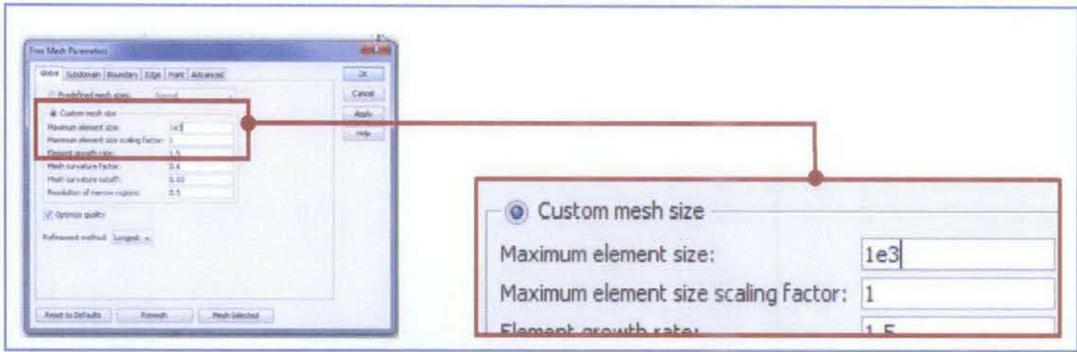
Figure 3.11: Free Mesh Parameter

After the free mesh parameter is set, user need to click the "initialize mesh" under the same Mesh menu to start meshing the geometry. After meshing is done the meshed geometry will be created as shown in Figure 3.12.
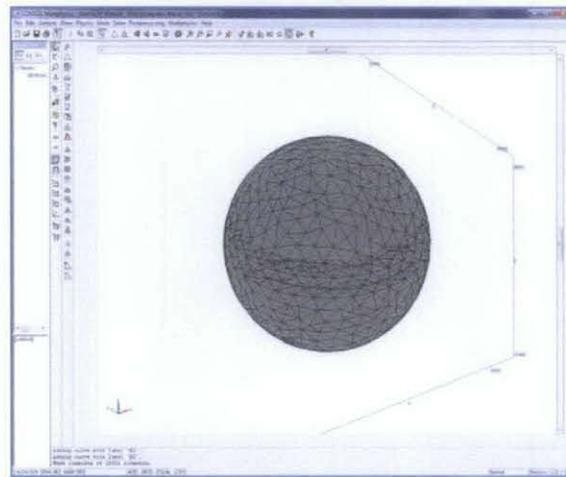
Figure 3.12: Meshed Geometry

3.4.4 FEA by COMSOL Problem Solver

This is the stage where the finite element analysis is done by the computer using computational method. It is done by clicking on the solve icon " = " as shown in Figure 3.13. User only has to wait for the problem iteration to be solved by the software.
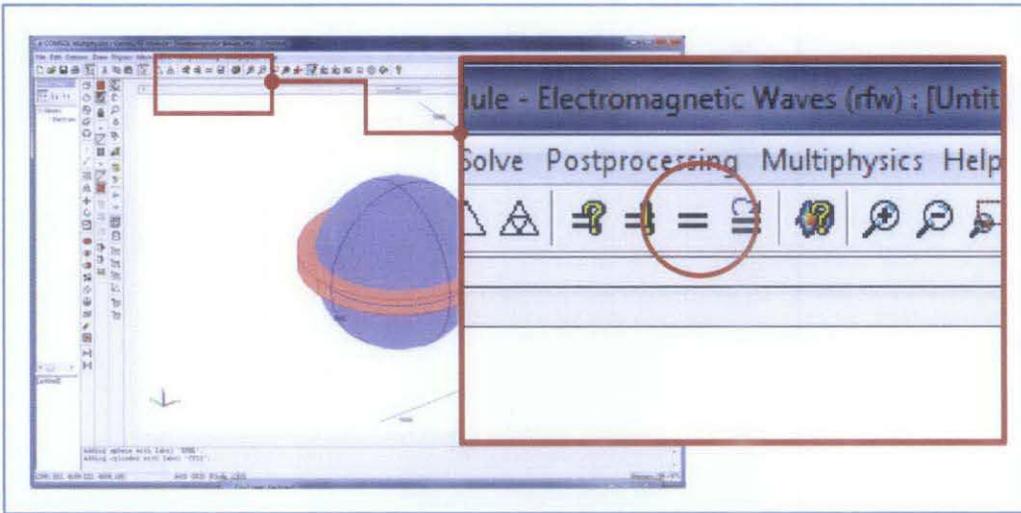
Figure 3.13: Solve Icon

3.4.5 Post-Processing of the Simulator

User can find the "Post Processing" menu at the menu bar with the same row as File, Edit, Mesh and Physic. "Plot Parameter" setting as being illustrate in Figure 3.14 is to get visualizations on the solution domain using the common plot types. From plot parameter select on the slice tab and key in 20*log10(norm_rfw) in the expression. Number of levels is set for x=0, y=1, and z=0. The slice plot is default type and it displays a quantity as a set of colored slices through geometry.
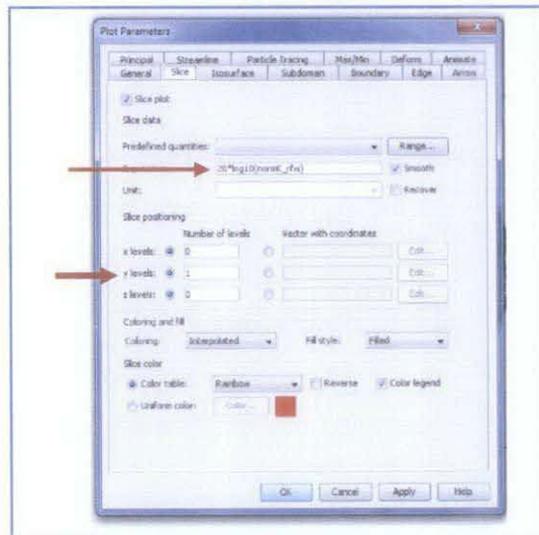
Figure 3.14: Plot Parameter

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"Domain Plot Parameters" setting as shown in Figure 3.15 is to visualize on one or several surfaces as a quantity in time or along a parameter range. On surface tab key in 20*log10(norm_rfw) in the expression and select the boundary to plot in the boundary selection list. Boundary to be plot is the receiver boundary which can be checked and found in the list. If the edge is chosen correctly, it can be seen to be highlighted. Then x-axis is to be chosen from the x-axis data list.
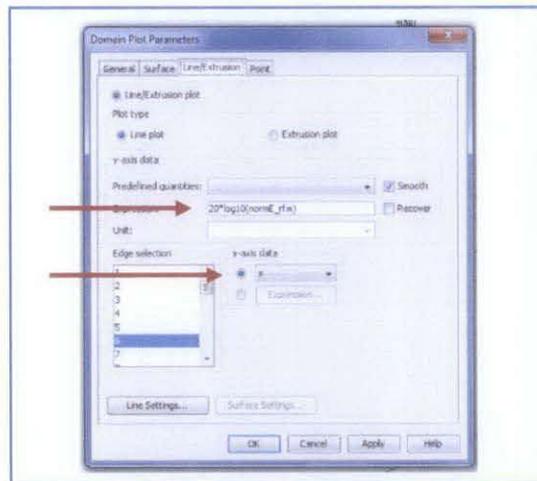
Figure 3.15: Domain Plot Parameters

3.4.6 Interpretation of Results

After all the setting, meshing, solving and post-processing is done, the results will be generated in term of graph as shown in Figure 3.16. Results will be analyzed and compared to conclude the experiment. In addition, the sliced view (Figure 3.17) of domain is also generated to be compared and analyzed too.
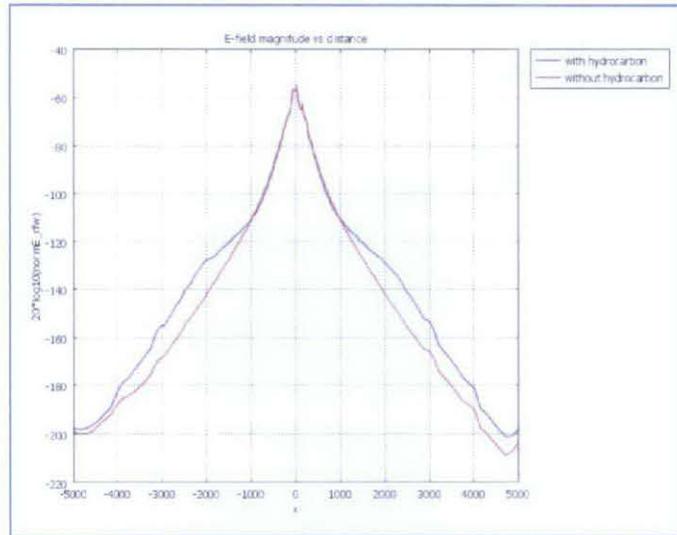
Figure 3.16: Graph Electric Field Magnitude on Seabed as a Function of Distance
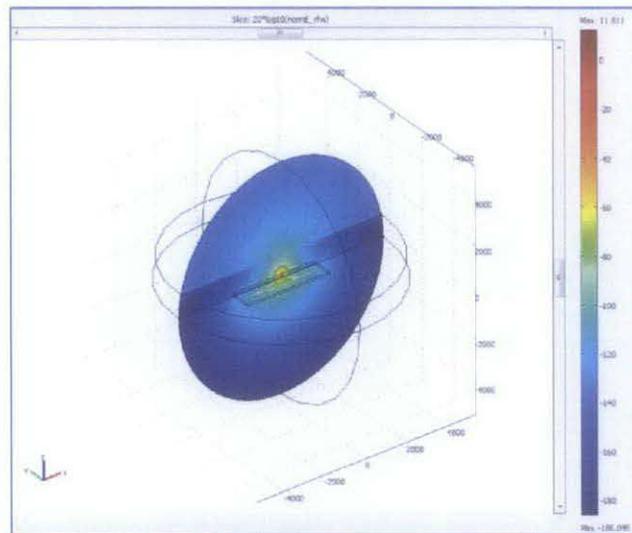
Figure 3.17: Guiding Effect inside the Spherical Boundary

CHAPTER 4

RESULTS AND DISCUSSION

4.1   Data Gathering

The computational domain for modeling the simulator is a sphere of 5 km radius as illustrated by Figure 2.8. The top region of this sphere represents air. At such a low frequency for SBL, some numerical stabilization is required in this domain so an artificial conductivity of 0.001 S/m is specified. A 1000 m deep ocean water domain with a conductivity of 5 S/m and a relative permittivity of 80 is specified above the mid plane of the sphere. Below the midplane, a conductivity of 1.5 S/m and a relative permittivity of 30 is specified for the rock. Embedded in the rock at certain depth, there is a block-shaped hydrocarbon reservoir. The conductivity of the hydrocarbon layer is 0.01 S/m and the permittivity is 4. The transmitter is modeled as a short AC line current segment 150 m above the midplane. At the external spherical boundaries, a scattering type boundary condition absorbs outgoing spherical waves. The summary for parameter's values are listed in Table 4.1 as followed:

Table 4.1: Parameters for Each Region in Calculated Domain

REGION	MATERIAL	CONDUCTIVITY (S/m)	PERMITIVITY
Top	Air	0.001	1
Cylinder (1000m thickness)	Water	5	80
Bottom Half Space	Rock/Seabed	1.5	30
Block	Oil/Hydrocarbon	0.01	4

Some models have been developed by using COMSOL that reflect the seabed logging 3D simulation. However, the simulator has been modified to observe the differences on the results by changing the following parameters:

    i.   Presence of hydrocarbon

    ii.   Depth of hydrocarbon beneath the seabed

    iii.   Position of hydrocarbon under the transmitter

    iv.   Thickness of hydrocarbon

    v.   Shape of hydrocarbon

    vi.   The amount of frequency and current of transmitter

4.2   Results and Discussions

4.2.1   Presence of Hydrocarbon

Initial experiment is done to study the effect of hydrocarbon presence to the simulation of seabed logging. Using the 5km radius domain and parameters in Table 4.1 experiment is conducted. The frequency and current of transmitter is fixed to 1Hz and 10 kA. As discussed in literature review section, the frequency used is very low and high magnitude of current.

After meshing process is done, the meshed geometry is shown in Figure 4.1 and Figure 4.2 respectively for without hydrocarbon and with hydrocarbon. It shows higher number of elements as where the hydrocarbon located. For FEA, it means higher density to where the elements are concentrated.

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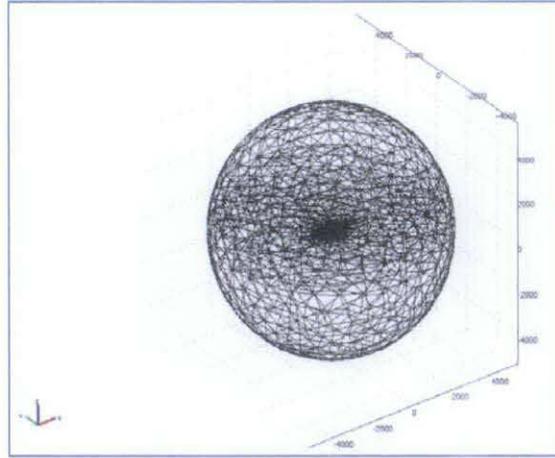
Figure 4.1: Meshed Geometry without Hydrocarbon Presence
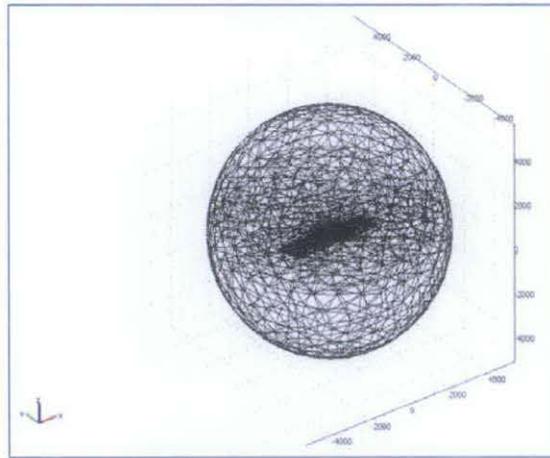
Figure 4.2: Meshed Geometry with Hydrocarbon Presence

Figure 4.3 and 4.4 shows the guiding effect of the hydrocarbon layer where red color in the middle of the model shows the area that have the highest total energy density. The effect can be seen reflected with hydrocarbon presence. The sliced view of distribution shows the electrical field inside a sphere domain with a hydrocarbon. The red color shows the highest magnitude while the dark blue shows the lowest intensity. The maximum is obtained right under the antenna where there is little difference between the two cases. When you move away from the antenna, there is notably higher signal strength when the hydrocarbon layer is present.
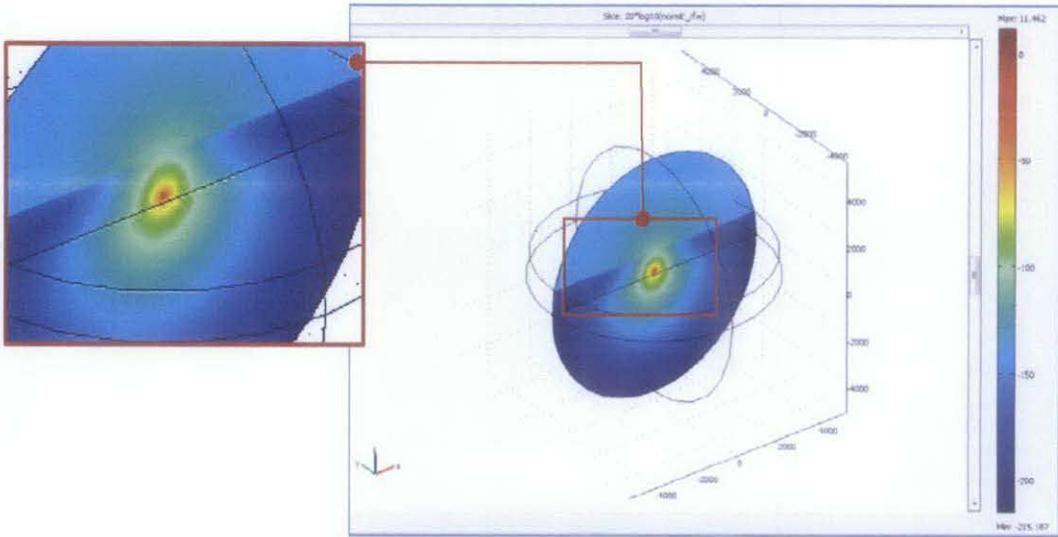
Figure 4.3: Guiding Effect without Hydrocarbon Presence
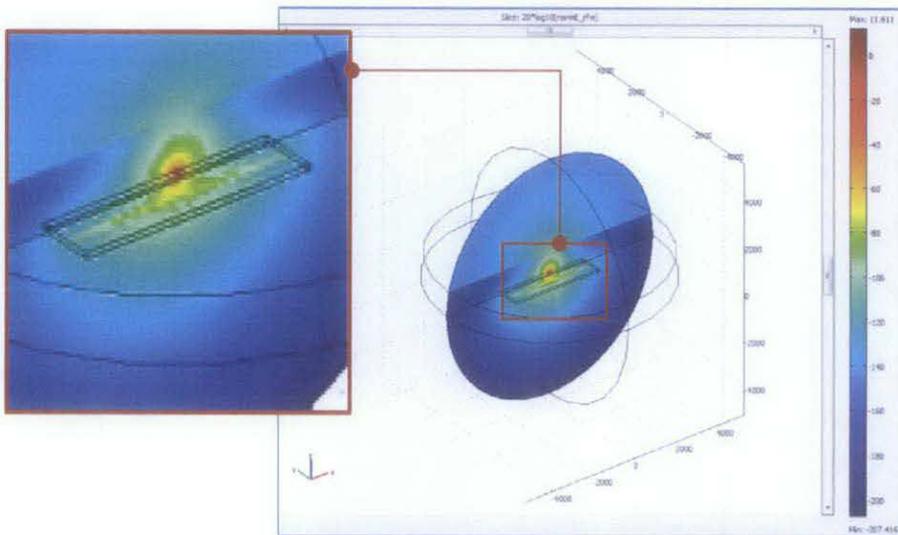
Figure 4.4: Guiding Effect with Hydrocarbon Presence

The difference between Figure 4.3 and 4.4 is that when hydrocarbon is present, there is notably refraction to the guiding effect. This complements the theory where hydrocarbon will result in refraction to the EM wave.

Result and Discussion:
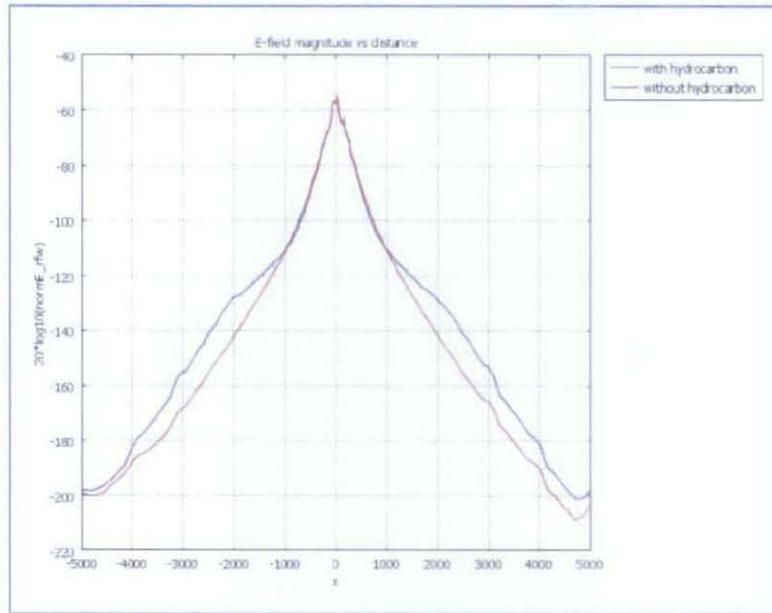
Figure 4.5 : Result for Presence of Hydrocarbon Experiment

Figure 4.5 shows Graph for electric field magnitude on sea floor as function of distance to differentiate the effect of hydrocarbon presence. It is clearly shown that with hydrocarbon, the intensity will be higher. Therefore, presence of hydrocarbon will give result in higher intensity of E-field in the graph.

4.2.2   Depth of Hydrocarbon beneath the Seabed

For the effect of hydrocarbon depth, the shape of the hydrocarbon used is block-shaped.   The frequency and current of transmitter is fixed to 1Hz and 10 kA. Parameters used are as followed:

- dimension : 4000m x 1000 m x 100m
- depth :shown in Table 4.2

Table 4.2: Depth of Hydrocarbon beneath Seabed

Variation	Depth (m)
1	250
2	400
3	-no hydrocarbon-

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Meshed geometry resulted when conducted this experiment is similar to Figure 4.2 which shown the effect of hydrocarbon presence. Guiding effect resulted from this experiment is also similar to Hydrocarbon Presence (Figure 4.4) since refraction and reflection occur to it. The graph of electric field intensity on the seabed versus distance that results from this experiment is shown in Figure 4.6:

Result and Discussion:
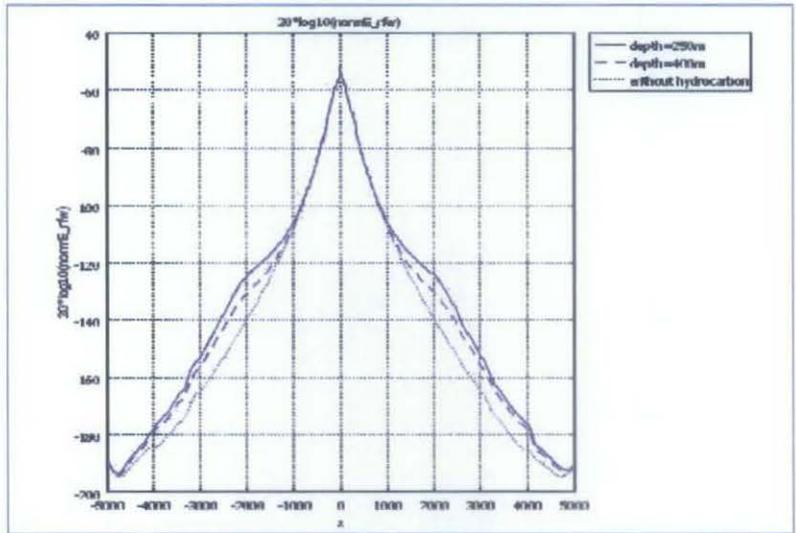
Figure 4.6: Result for Depth of Hydrocarbon beneath the Seabed

In Figure 4.6, the blue dashed line is higher than the red line. The graph shows that the existence of hydrocarbon will results a high intensity electric field as it should be. In addition, the solid blue line shows higher value than the blue dashed line. It can be concluded that the higher the depth of hydrocarbon beneath the seabed is, the lower the intensity of E-field will be.

4.2.3   Position of Hydrocarbon under the Transmitter

For the effect of hydrocarbon position under the transmitter, the shape of the hydrocarbon used is block-shaped and is located 250m beneath the seabed. The frequency and current of transmitter is also fixed to 1Hz and 10 kA. The experiment variation is shown in Table 4.3 with the same hydrocarbon dimension which is 4000m x 1000 m x 100m.

Table 4.3: Position of Hydrocarbon

Variation	Position
1	under transmitter
2	2000km to the left of transmitter
3	2000km to the right of transmitter
4	- without hydrocarbon-
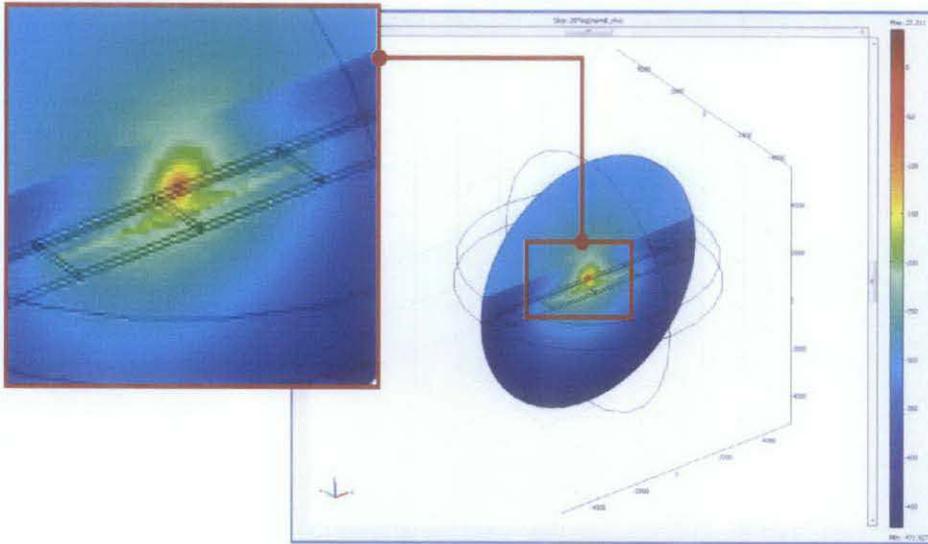
Figure 4.7 : Guiding Effect for Hydrocarbon under Transmitter
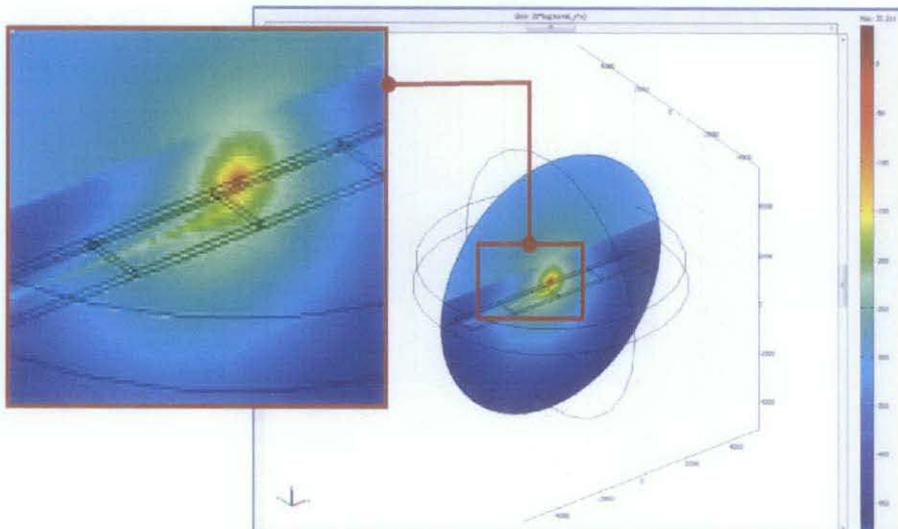
Figure 4.8 : Guiding Effect for Hydrocarbon 2000km to the Left of Transmitter
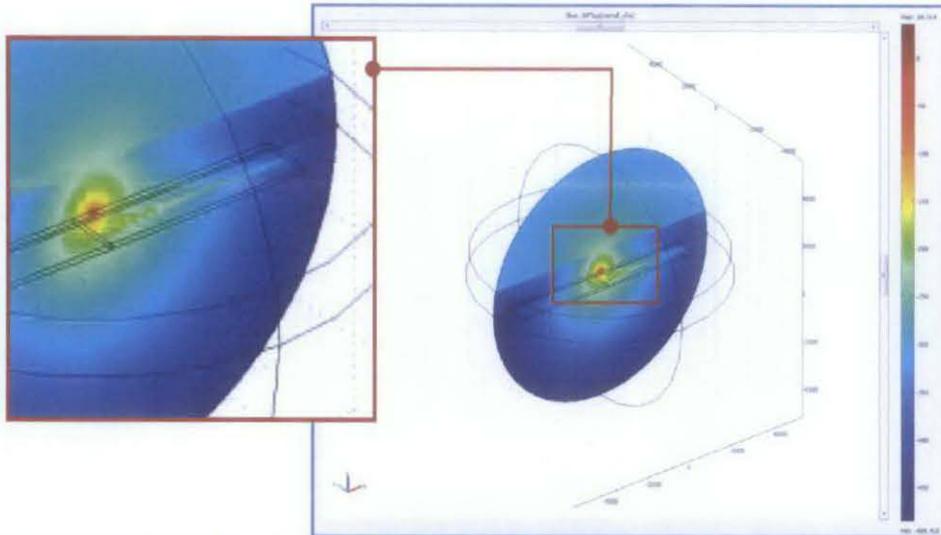
Figure 4.9 : Guiding Effect for Hydrocarbon 2000km to the Right of Transmitter

After analysis done by the computer, the sliced view generated for Variation 1, 2 and 3 are shown in Figure 4.7, 4.8 and 4.9 respectively. The difference in intensity can be viewed clearly as the position where hydrocarbon is located will show higher intensity.

Result and Discussion:
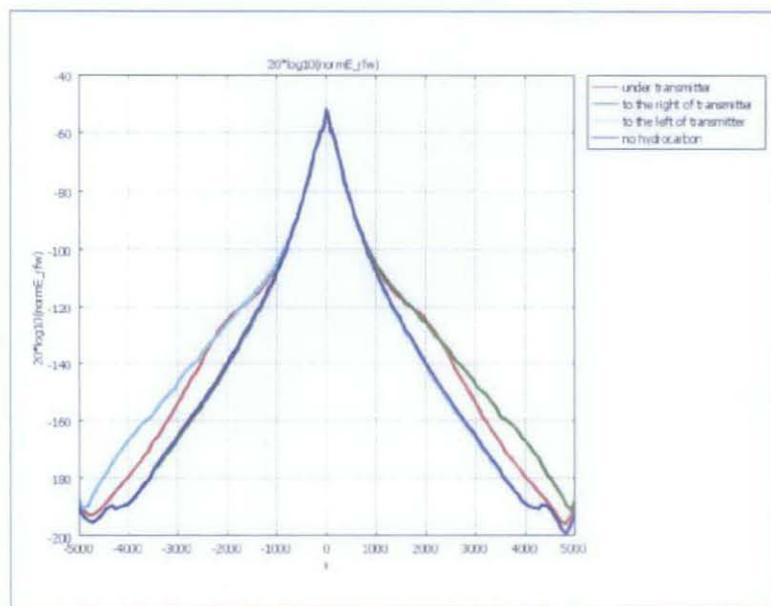
Figure 4.10: Result for Position of Hydrocarbon under the Transmitter

The result after varying the position of hydrocarbon under transmitter is shown in Figure 4.10. As expected, the magnitude of E-field when there is no hydrocarbon will be the lowest. When hydrocarbon is in the left side of transmitter, the result will also show rise in the left side of the graph as shown by cyan color line. The similar case results to hydrocarbon situated at the right side of transmitter. It is shown by green color line which gives rise in magnitude at the right side of graph. Therefore it can be concluded that the graph of E-field as a function of distance can be used to detect the position of hydrocarbon.

4.2.4   Thickness of Hydrocarbon

For the effect of hydrocarbon position under the transmitter, the shape of the hydrocarbon used is block-shaped and is also located 250m beneath the seabed. The frequency and current of transmitter is fixed to 1Hz and 10 kA. The experiment variation is shown in Table 4.4 with the same hydrocarbon dimension which is 4000m x 1000 m x 100m.

Table 4.4 : Variation of Hydrocarbon Thickness

Variation	Thickness (m)
1	50
2	100
3	200

Meshed geometry resulted when conducted this experiment is similar to Figure 4.2 which shown the effect of hydrocarbon presence. Guiding effect resulted from this experiment is also similar to Hydrocarbon Presence (Figure 4.4). The graph of electric field intensity on the seabed versus distance that results from this experiment is shown in Figure 4.11:

Result and Discussion:
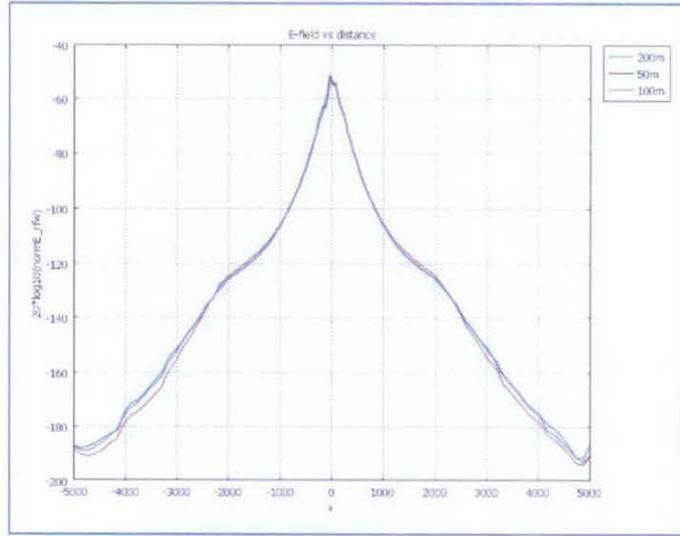
Figure 4.11 : Result for Hydrocarbon Thickness Variation

The graph shows a little variation for the thickness of hydrocarbon hence the thickness of hydrocarbon is not as significant as the other effect to the result. However, it still can be seen that the higher line is green line which is for thickness of 200m. Moreover the lowest line is shown by red line which represents the thickness of 50m. Therefore, the E-field will be higher if the hydrocarbon is getting thicker.

4.2.5 Shape of hydrocarbon

For the effect hydrocarbon shape, hydrocarbon is located 250m beneath the seabed. The frequency and current of transmitter is also fixed to 1Hz and 10 kA. While having different shape, the geometry of hydrocarbon fixed to 100m thick. The shapes of the hydrocarbon and each dimension are shown in Table 4.5.

Table 4.5: Dimensions for Each Shape

Variation	Shape	Dimension(m)
1	block	4000 x 1000 x 100
2	oblate	$r_x = r_y = 2000$; $r_z = 50$
3	prolate	$r_x = 2000$; $r_y = r_z = 50$

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The following figures are the sliced view of electric wave inside the spherical boundary that results from the parameters defines before. Figure 4.12 shows the slice view of block shape results; Figure 4.13 shows sliced view of oblate results and Figure 4.14 show the sliced view of prolate shaped results.
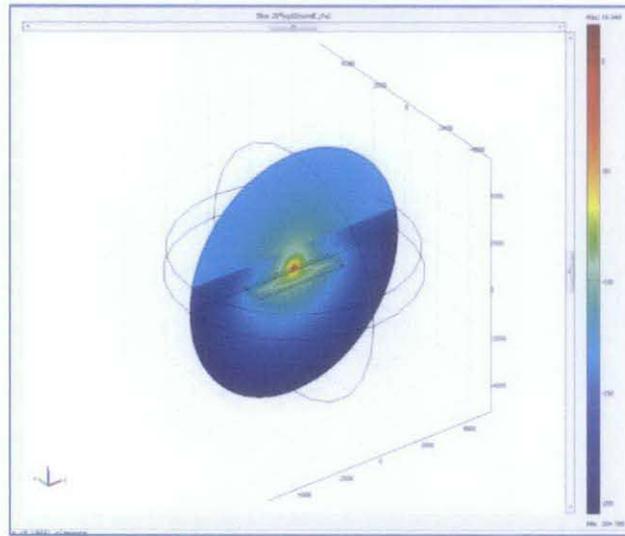
Figure 4.12 : Guiding Effect for Block Shaped Hydrocarbon
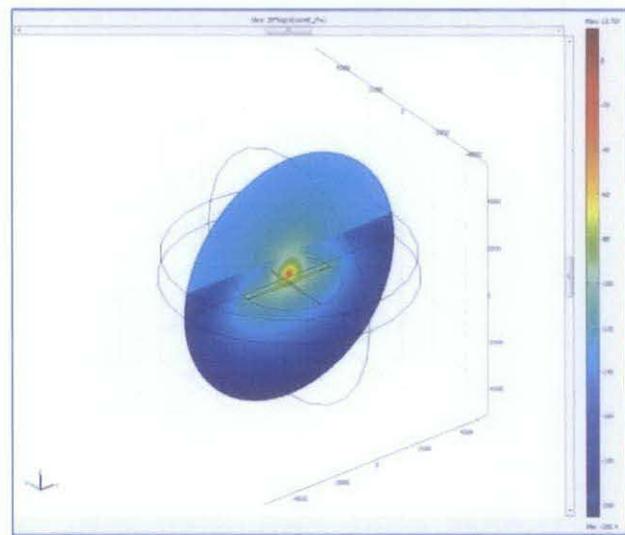
Figure 4.13: Guiding Effect for Oblate Shaped Hydrocarbon
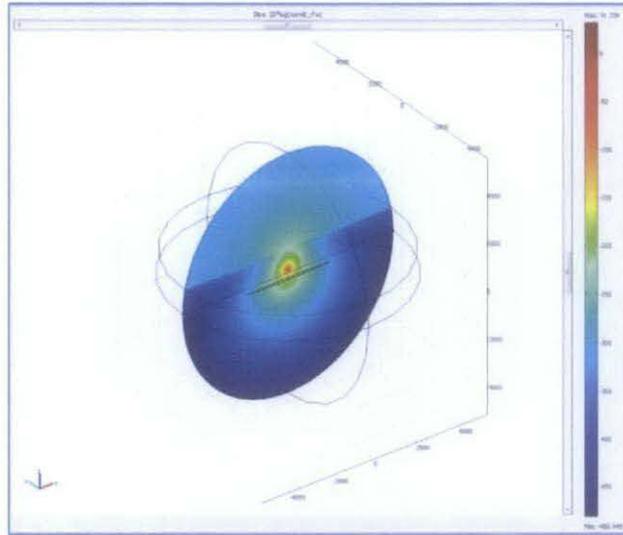
Figure 4.14: Guiding Effect for Prolate Shaped Hydrocarbon

Result and Discussion:

The graphs of electric field intensity on the seabed versus distance for these three shapes that results from this experiment is shown in Figure 4.15:
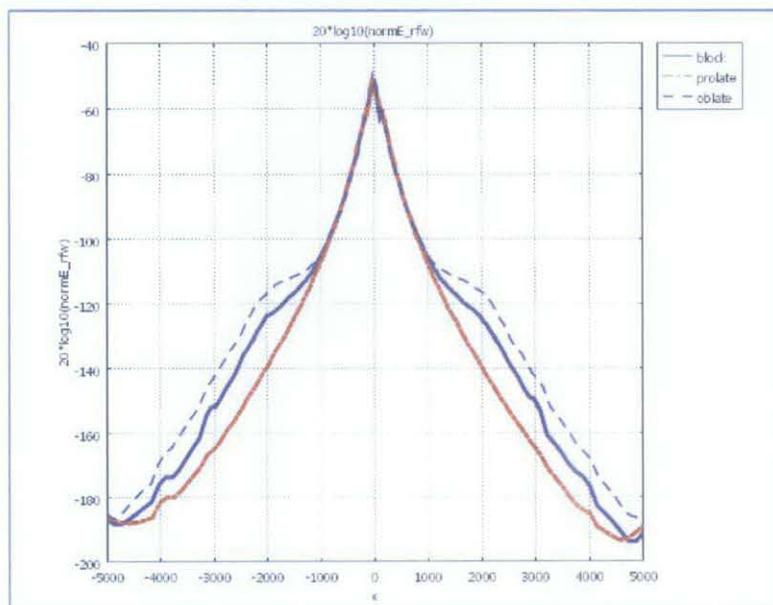
Figure 4.15: Result for Variation of Hydrocarbon Shape

The graph shows that with the same thickness, different shape will results in different electric field reflected. Oblate has the highest intensity electric field while prolate has the lowest intensity. This is due to that the volume is different. Although from the simulation the result is obtained, however in real situation it is difficult to confirm the shape. The reason is that hydrocarbon shape will follow its trap shape which is not certain.

4.2.6   Transmitter Frequency and Current

Last but not least, the experiment to observe effect of amount of frequency and current used is conducted. Similar to previous experiment, the shape of the hydrocarbon used is block-shaped and is located 250m beneath the seabed. The current of transmitter is fixed to 10 kA. The experiment variation for frequency and current variation is shown in Table 4.6 and 4.7 respectively. The same block dimension for hydrocarbon is used which is 4000m x 1000 m x 100m.

Table 4.6: Frequency of Transmitter Variation

Variation	Frequency
1	0.5 Hz
2	1 Hz
3	2 Hz

Table 4.7: Current of Transmitter Variation

Variation	Frequency
1	0.5 Hz
2	1 Hz
3	2 Hz

For variation of transmitter frequency, the guiding effect for 0.5, 1 and 2 Hz frequency can be viewed in Figure 4.16, 4.17 and Figure 4.18 respectively. While for the variation of current, no significance different is observed to the graph. The graphs are similar to Figure 4.4.
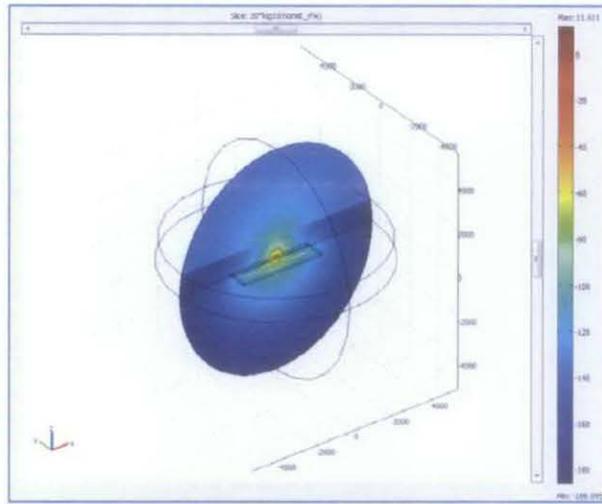
Figure 4.16: Guiding Effect for 0.5 Hz Transmitter
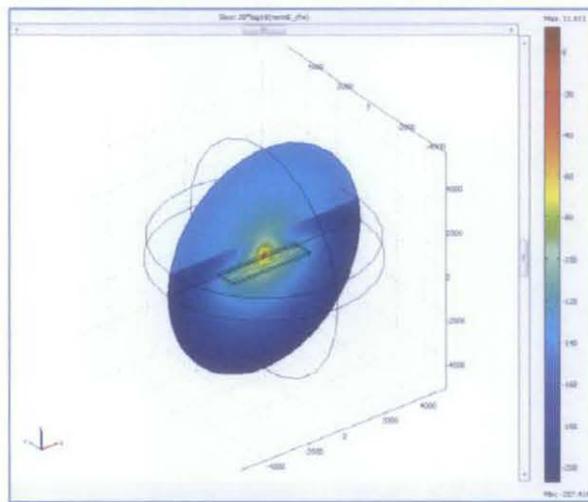
Figure 4.17: Guiding Effect for 1 Hz Transmitter
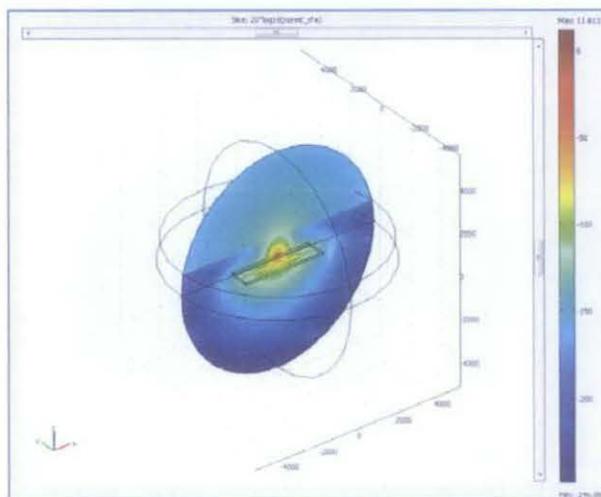
Figure 4.18: Guiding Effect for 2Hz Transmitter

Result and Discussion:
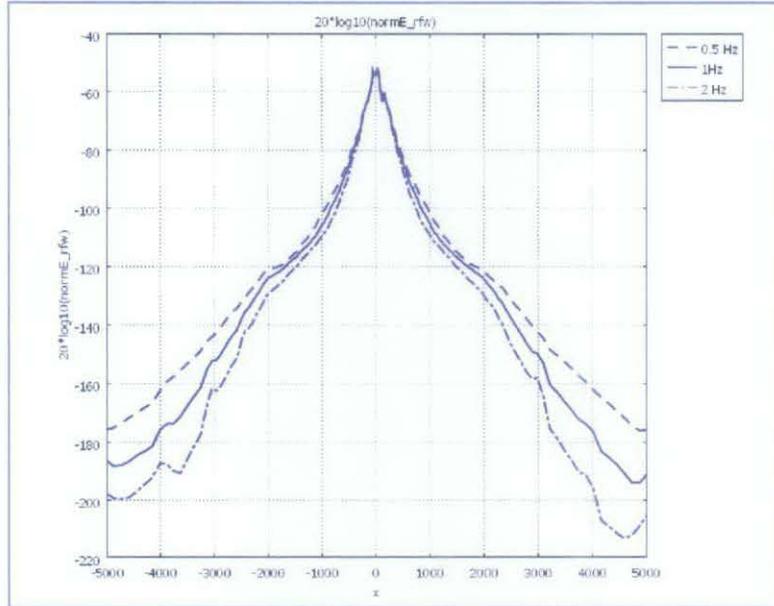
Figure 4.19: Result for Effect of Frequency Variation

The above Figures 4.19 are the graphs of electric field intensity on the seabed versus distance for frequency variation experiment. It can be observed that higher frequency will results in low intensity electric field and also that the lower the frequency is, the higher the intensity will be. It can be concluded that SBL indeed need to use low frequency for better result.
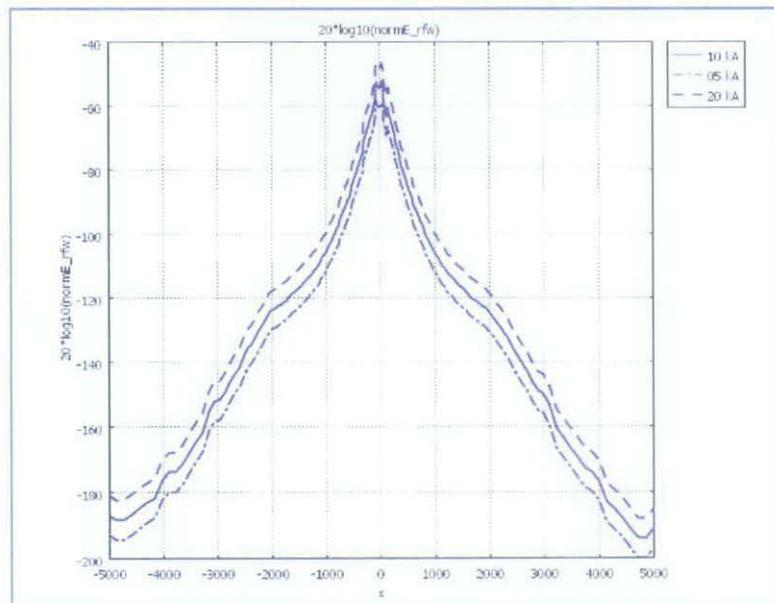
Figure 4.20: Result for Effect of Current Variation

On the other hand, Figures 4.20 are the graphs of electric field intensity on the seabed versus distance for current variation experiment. It can be observed that higher current will results in high intensity electric field and also that the higher the frequency is, the lower the intensity will be. It can be concluded that SBL indeed need to use high current for better result.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

After completing this project, all the experiments regarding simulation of SBL using COMSOL software have been conducted. The results have been obtained and analyzed by the author upon writing this report. The conclusion that have been made upon completion of the project is that COMSOL can also improve the difficulty to predict the existing of hydrocarbon beneath the sea floor based on several variation which are :

i.   Presence of hydrocarbon

ii.   Depth of hydrocarbon beneath the seabed

iii.   Position of hydrocarbon under the transmitter

iv.   Thickness of hydrocarbon

v.   Shape of hydrocarbon

vi.   The amount of frequency and current of transmitter

In addition, the author concludes that this project will bring a lot of benefit to the future and can be applied for the study of SBL for hydrocarbon exploration. As the competition rising among Oil and Gas Company in hydrocarbon exploration, simulation can give them an upper hand to compete with other company internationally.

5.2   Recommendation

Based on this project, the recommendation that can be highlighted to assist future work for expansion is to do joint venture with real company. Since the data for this project are quite limited due to privacy, the experiment is also conducted with limited parameters. Simulation can be done with real condition in offshore for example at Sarawak basin to study the SBL more realistically.

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Gantt Chart for FYP I

No.	Detail/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	Selection and Confirmation of Project Title	▓																	
2	Gathering information on Seabed Logging	▓	▓	▓	▓														
3	Submission of Preliminary Report				●			MID SEMESTER BREAK								STUDY WEEK		EXAM WEEK	
4	Study on COMSOL architecture and Seabed Logging Model					▓	▓		▓										
5	Submission of Progress Report									●									
7	Seminar									●									
8	Finalize project work											▓	▓						
9	Submission of Interim Draft Report												●						
10	Submission of Interim Final Report														●				
11	Oral Presentation														●				

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Gantt Chart for FYP II

No.	Detail/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	Seabed Logging model development and modification work	███	███	███	███												
2	Submission of Progress Report								●								
3	Project work continues								███	███	███						
4	Testing and Validation work								███	███	███						
5	Pre-EDX											●					
6	Finalize results and findings											███	███				
7	Submission of Draft Report													●			
8	Submission of Final Report and Technical paper.														●		
9	Oral Presentation														●		

(Week 7 column: MID SEMESTER BREAK; Week 15 column: STUDY WEEK; Week 16 column: EXAM WEEK)

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