STUDY AND SIMULATION ON THE EFFECT OF RESISTIVE MEDIUM TO THE PROPAGATION OF ELECTROMAGNETIC WAVE USING CST EM STUDIO SOFTWARE

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by

Zulfadli Bin Ahmad

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CERTIFICATION OF APPROVAL

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Approved by,

____
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Project Supervisor

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

JUNE 2010

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.

ZULFADLI BIN AHMAD

ABSTRACT

This dissertation discusses the project, "Study and simulation on the effect of resistive medium to the propagation of electromagnetic wave using CST EM Studio software". This project deals with electromagnetic theory, electromagnetic wave, radio frequency and also propagated signal. The objective of the project is to study and simulate the effect of resistive medium to the propagation of electromagnetic wave. This report also describes the oil exploration implemented widely nowadays and also electromagnetic wave as an alternative for hydrocarbon detection. The methodology chapter explained the procedure of handling the project, starting from problem statement until simulation, analysis and discussion. It also lists out the tools and equipments needed to execute this project. The last chapter discusses the summarized information of the overall project. Throughout this project, the student had deal with the new software and worked with a lot of people. Some information in this report had been taken from other source and all had been credited in the reference.

ACKNOWLEDGEMENTS

The author would like to take this opportunity to express his appreciation and gratitude to all persons and parties involved in making this project possible. First and foremost, a special thanks to respectable supervisor, Dr. Hasnah Binti Mohd Zaid for the opportunity given to the author to work under her supervision. Her helps, supports and guidance had been really useful throughout this project.

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Finally, the author would like thank to those who have given constructive comments and ideas in completing this project and to all those who have directly or indirectly played a part in the completion of this project. I hope this project could contribute advantage in terms of idea, understanding and knowledge for all readers.

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LIST OF ABBREVIATION

A	Ampere
B-Field	Magnetic Field
CSEM	Controlled Source Electromagnetic
D-Field	Electric Displacement Field
E-Field	Electric Field
EM	Electromagnetic
FYP	Final Year Project
H-Field	Magnetic Field Intensity
Hz	Hertz
SBL	Sea Bed Logging
UTP	Universiti Teknologi PETRONAS

CHAPTER 1

INTRODUCTION

1.1 Background of Study

The initial search for oil is carried out mostly by geologists. Many techniques are used to determine the potential location that contain oil reservoir, especially the study of landforms and seismic analysis. The area where oil reservoir is thought likely located will be drilled by test wells to confirm the existence of hydrocarbon and make sure the oil contained in the reservoir is in a commercial quantity. [1]

Oil exploration can cost tens or hundreds of billions of dollars. The actual costs depend on factors such as the location of possible oil reserves, size of the oil field is expected to be, quality and quantity of information about the exploration, and the type and structure of the rock below the ground. Oil exploration requires careful mapping of the surface in order to locate suitable sites such as types of geological structures, deep formation surveys, for example with two and three-dimensional seismic techniques, and test-drilling. [2]

Seismic exploration is the primary method of exploring for hydrocarbon deposits, on land, under the sea and in the transition zone which is the interface area between the sea and land. [3] However, recently marine controlled source electromagnetic (CSEM) had been touted as potential alternative for hydrocarbon exploration.

1.2 Problem Statement

Before undertaking the task of petroleum exploration, there are some surveys such as geological, geochemical and geophysical surveys that had to be conducted. These surveys are made to find out the type of rocks present, the environment in which the rocks have been deposited, thickness of the sediments in the particular area that could be expected in the sub-surface, occurrence of suitable traps and presence of oil and gas seepages.

If some positive results are obtained, then that area is recommended for exploration for oil and gas. As is known, oil well drilling is a very costly gamble and unless and until some positive indications are present, the particular area cannot be taken up for drilling. [3]

The cost for hydrocarbon exploration is huge. A company will lose a lot of money if the area contains no oil or gas after the exploration well or test well had been drilled. Therefore a more accurate and less risk method for detection of hydrocarbon is needed.

1.3 Objective

The main objective of the project is to study and simulate the effect of resistive medium to the propagation of electromagnetic wave. The simulation is done using CST EM Studio software. The result of the study can be used in the application of CSEM as a method for hydrocarbon detection. Thus, the outcome of this project can help to improve the success rate of finding hydrocarbon reservoir below the sea bed.

1.4 Scope of Study

The scope of study for the project involves the study of the characteristic and behaviour of electromagnetic wave and the effect of resistive medium to the propagation of electromagnetic wave. Some programming is also required for the simulation part.

1.5 Relevancy of the Project

This project is related to electromagnetic wave which is heavily involved in human's daily life. Electromagnetic wave appears in various telecommunication devices such as mobile phone and antenna. There is a lot of field such as health and telecommunications that can be developed and improved by understanding more about electromagnetic wave.

The application of the result from this project can help in advancing the hydrocarbon exploration which is a huge industry nowadays. This project could improve the success rate of finding hydrocarbon reservoir. Thus, this project is very relevant and should be continued by the student and supported by the supervisor and University.

1.6 Feasibility of the Project

This project took two semesters to complete. The first semester is to find the general ideas about the project. The author had conducted literature review and studied the concept of the project in the first semester. In the second semester, the project was conducted in more detail. This is a research-based project with application of simulation using software that is already available in the university. Simulation was conducted to test the information gathered from the research and help the understanding of the project.

CHAPTER 2

LITERATURE REVIEW

2.1 Hydrocarbon Exploration

There is a lot of method used in hydrocarbon exploration, for example direct indication, direct oil finding and geological exploration method. However none of the methods of prospecting and exploration can claim superiority over others, since they are complementary to one another. [3]

Measurements of electrical resistivity beneath the seafloor have traditionally played a crucial role in hydrocarbon exploration and reservoir assessment and development. In the oil and gas industry, sub-seafloor resistivity data has, in the past, been obtained almost exclusively by wire-line logging of wells.

However, there are clear advantages to developing non-invasive geophysical methods capable of providing such information. In deep water area the geological strata is dominated by shale or mud rocks with low resistivity. A hydrocarbon reservoir can have resistivity perhaps 10-100 times greater than its surrounding area. [4] Below are the methods for hydrocarbon exploration. Each method contains their own survey and techniques to achieve their objectives.

2.1.1 Direct Indication Method

Most of the oil provinces of the world show evidence of presence of petroleum on the surface. Such evidence are natural seepages of oil and gas, outcrop of oil bearing rocks, mud volcanoes, kerogen shales, mineral waxes, saline ground water and paraffin dirt. These indications mean that the area deserves attention but does not show in certain that oil and gas in that area exists in commercial quantities. Thus, geological and geophysical methods need to be conducted. [3]

2.1.2 Direct Oil Finding Method

Direct oil finding methods measure physic-chemical phenomena in rocks associated with presence of pooled hydrocarbons underground. These hydrocarbons must be in concentrated form rather than in disseminated form as in source beds. The process of hydrocarbon concentration is responsible for physic-chemical modifications in the overlying rocks. Such modifications have been detected by electric and gamma ray logs in wells and also observed at the surface of the earth. [3]

2.1.3 Geological Exploration Method

The geological exploration methods are applicable for those places where the outcrops are present, surface features such as elevations, dips, strikes of outcrops, lithological changes may be mapped as clues to sub-surfaces feature. The value of surface mapping is generally limited to shallow beds, as deeper structures are not reflected by surface features.

This type of survey is conducted by trained geologists and consists of mapping of rock strata, exposed on the surface, to find out the suitable structures which may indicate deep seated oil and gas traps. The physical nature of the formation indicates in what part of the major marine basin, the rocks have been exposed, and age. The superposition of the formation must be determined to provide information, on the sedimentary thickness and act as basis for determination of depths which must be reached by drill. [3]

2.1.4 Geophysical Exploration Method

There are many methods in geophysical exploration, but the common methods are magnetometric, gravimetric and seismic method.

2.1.4.1 Magnetometric Method

Anomalies in the earth's magnetic field are mapped and correlated with underground structure. Sedimentary rocks are non-magnetic, hence any magnetic irregularities are attributed to depth variations of basement rocks. A survey crew carried an instrument called the vertical magnometer or just flown the device in an aeroplane over the basin area. It measures the vertical changes in the earth's magnetic field. In general, the changes are an effect of the depth of the original floor of the basin. It possible to tell from the magnetometric results, which part of the basin has greater thickness of strata and which parts contain lesser thickness of strata. [3]

2.1.4.2 Gravimetric Method

This method was based on Newton's hypothesis that every particle in the universe attracts each other. By this method, a gravity meter is run over the area of interest to measure the minute changes in the vertical gravity intensity. Dense rock mass will exert a greater gravity pull at surface than a less dense rock mass at the same depth. Many structures that suitable for entrapment of oil and gas contain a dense core. [3]

2.1.4.3 Seismic Method

The seismograph is the most successful and widely applied geophysical tool in the exploration history. This method is based on the difference in propagation velocity of artificially induced elastic waves through various subsurface strata.

Along surveyed lines, holes are drilled which are loaded with dynamite and exploded. Each explosion generates shock waves which travel down into the subsurface. Strata of different hardness reflect these waves back to the surface, where their time of arrival is recorded on sensitive instruments. Mathematical formulae may then be applied to construct a picture of the rock strata at depth. In this manner, hidden deep seated structures can be found which may act as suitable traps for oil and gas. [3]

2.1.5 Geochemical Methods

These are based on assumption that the hydrocarbons found in an oil pool tend to migrate upwards because of their having a lower density and some of their molecules may reach the surface. In the proved oil and gas fields of some area, the samples of surface soil in such areas have shown a comparatively high percentage of hydrocarbons present. Higher than average chloride content could be expected around the edges of the pool left by waters which have migrated upwards and evaporated. [3]

2.2 Wireline Logging

Wireline logging refers to the practice within the oil and gas industry of lowering a logging device attached to a wireline into a borehole or oil well to measure the properties of the rock and fluids of the formation. The measurements obtained are then interpreted and used to determine the depths and zones where oil and gas can be expected to be found.

Wireline logging tools are typically cylindrical in shape. They range from a narrow diameter of around one and a half inches up to around five inches. There are three basic types of wireline logging tools.

The first type measures the spontaneous potential. This is the difference in voltage between an electrode in the wireline logging tool while it is in the oil well or borehole, and another electrode located on the surface. This type will usually also have additional instruments to measure the natural radiation coming from natural isotopes. In this way it can measure temperature and pressure.

The second type of wireline logging tool has a source of excitation or stimulation as well as a sensor. The sensing systems used in this type can be magnetic resonance, inductive, electric, acoustic, or other methods.

The third type of tool used is one that can perform some kind of mechanical maneuvers. This kind of wireline logging tool can retrieve rock samples at various depths to allow scientists to physically examine the actual formation. It can also retrieve oil samples at determined depths and bring them back up to the surface [8]

2.3 Seabed Logging

Sea Bed logging (SBL) is a resistivity-based tool for more directly detecting the presence of oil and gas reservoirs in exploration prospects prior to drilling. Information about resistivity variations beneath the seafloor is crucial in off-shore hydrocarbon exploration. Although various electromagnetic methods for remote mapping of resistivity in marine environments exist until recently, sub-seafloor resistivity data in the oil and gas industry were obtained almost exclusively by wireline logging of wells.

In the last few years, SBL has become an important complementary tool to seismic exploration methods to evaluate and rank possible hydrocarbon bearing prospects. The basic idea behind the SBL method is to exploit lossy guiding of electromagnetic energy in resistive bodies within conductive media for direct detection and characterization of hydrocarbon-filled reservoirs.

A process of seabed logging is shown in Figure 2.5. In a marine CSEM experiment an electric dipole antenna is used as source. The dipole emits a low-frequency signal into the surrounding media, and the signal is normally recorded by stationary seafloor receivers having both magnetic and electric dipole antennas. The marine CSEM technique was introduced by Cox et al. (1971), and has since then been successfully applied to study the oceanic lithosphere and active spreading centres (Young and Cox, 1981; Cox et al., 1986; Chave et al., 1990; Evans et al., 1994; Constable and Cox, 1996; MacGregor and Sinha, 2000). [9]

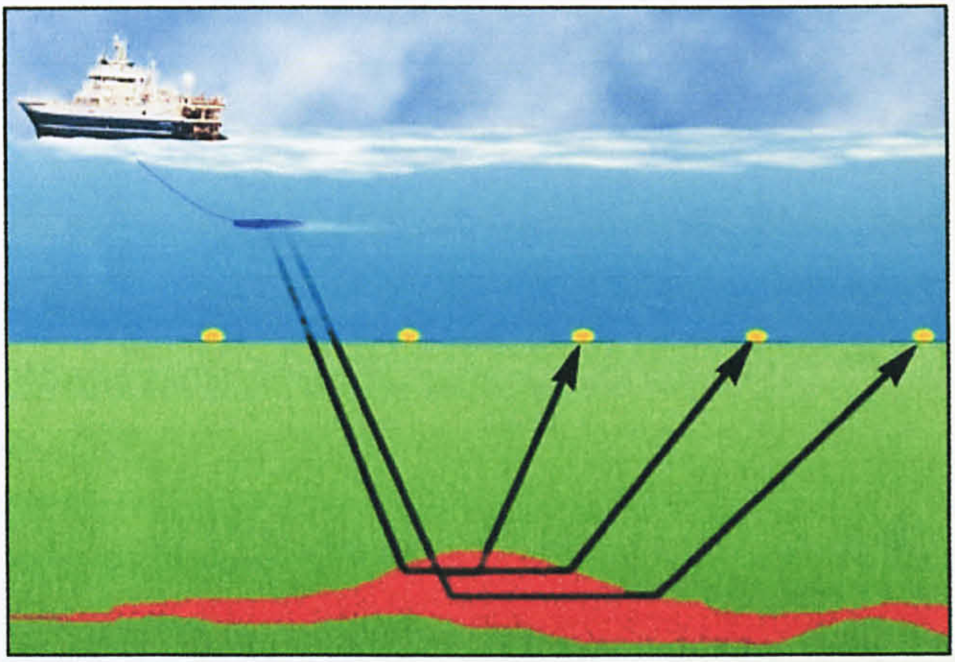

Figure 1: Seabed logging process

Sedimentary rocks with salt water in their pore spaces are good conductors for electricity. If the rocks are filled with hydrocarbon which in a pure state is electrical non-conductors, the conductivity will be lower which mean the resistance is greater. Thus, electromagnetic energy will transmit easier in the medium. This is how the SBL determine whether a reservoir is filled with hydrocarbon or not. [7]

2.4 Electromagnetic Waves

Electromagnetic (EM) waves were first postulated by James Clerk Maxwell and subsequently confirmed by Heinrich Hertz. Maxwell derived a wave form of the electric and magnetic equations, revealing the wave-like nature of electric and magnetic fields, and their symmetry. Because the speed of EM waves predicted by the wave equation coincided with the measured speed of light, Maxwell concluded that light itself is an EM wave.

According to Maxwell's equations, a spatially-varying electric field generates a time-varying magnetic field and *vice versa*. Therefore, as an oscillating electric field generates an oscillating magnetic field, the magnetic field in turn generates an oscillating electric field, and so on. These oscillating fields together form an electromagnetic wave. [4]

2.4.1 Propagation of EM Wave

Electromagnetic waves are waves which can travel through the vacuum of outer space. Mechanical waves, unlike electromagnetic waves, require the presence of a material medium in order to transport their energy from one location to another. Sound waves are examples of mechanical waves while light waves are examples of electromagnetic waves.

Electromagnetic waves are created by the vibration of an electric charge. This vibration creates a wave which has both an electric and a magnetic component. An electromagnetic wave transports its energy through a vacuum at a speed of 3.00×10^8 m/s (a speed value commonly represented by the symbol **c**). The propagation of an electromagnetic wave through a material medium occurs at a net speed which is less than 3.00×10^8 m/s.

The mechanism of energy transported through a medium involves the absorption and reemission of the wave energy by the atoms of the material. When an electromagnetic wave impinges upon the atoms of a material, the energy of that wave is absorbed. The absorption of energy causes the electrons within the atoms to undergo vibrations. After a short period of vibrational motion, the vibrating electrons create a new electromagnetic wave with the same frequency as the first electromagnetic wave. While these vibrations occur for only a very short time, they delay the motion of the wave through the medium. Once the energy of the electromagnetic wave is reemitted by an atom, it travels through a small region of space between atoms. Once it reaches the next atom, the electromagnetic wave is absorbed, transformed into electron vibrations and then reemitted as an electromagnetic wave. While the electromagnetic wave will travel at a speed of **c** which is 3×10^8 m/s through the vacuum of interatomic space, the absorption and reemission process causes the net speed of the electromagnetic wave to be less than **c**. [6]

2.4.2 Effect of Different Medium to the Propagation of EM Wave

The actual speed of an electromagnetic wave through a material medium is dependent upon the optical density of that medium. Different materials cause a different amount of delay due to the absorption and reemission process. Furthermore, different materials have their atoms more closely packed and thus the amount of distance between atoms is less. These two factors are dependent upon the nature of the material through which the electromagnetic wave is traveling. As a result, the speed of an electromagnetic wave is dependent upon the material through which it is traveling. [6]

2.5 Resistivity and Conductivity of Material

Resistivity is material's opposition to the flow of electric current. Resistivity is measured in ohms. [12] A low resistivity indicates a material that readily allows the movement of electrical charge.

Conductivity is an opposite of resistivity. [13] Electrical conductivity or specific conductance is a measure of a material's ability to conduct an electric current. When an electrical potential difference is placed across a conductor, its movable charges flow will giving rise to an electric current.

2.6 Permittivity of Material

The permittivity of a substance is a characteristic which describes how it affects any electric field set up in it. A high permittivity tends to reduce any electric field present. The permittivity of free space (or a vacuum), e_0, has a value of 8.9×10^{-12} F m^{-1}.The permittivity of a material is usually given relative to that of free space, it is known as relative permittivity, e_r. [11]

2.7 The Effect of Frequency to the propagation of EM waves

The signal used in well logging has frequencies between 16 kHz and 2 KHz and gives little spatial depth in resistivity measurements. High frequency signals will quickly lose energy and penetrate only a decimetre into the formation. This is because low frequency has long wave length while high frequency signal has short wave length. Short wave lengths are more easily absorbed by the molecules in the medium. To achieve deep penetration which is several thousand meters down through the sedimentary layers, it is necessary to have significant greater current strength and lower frequency (<1 Hz) in the outgoing signal. [7]

CHAPTER 3

METHODOLOGY

3.1 Research Methodology

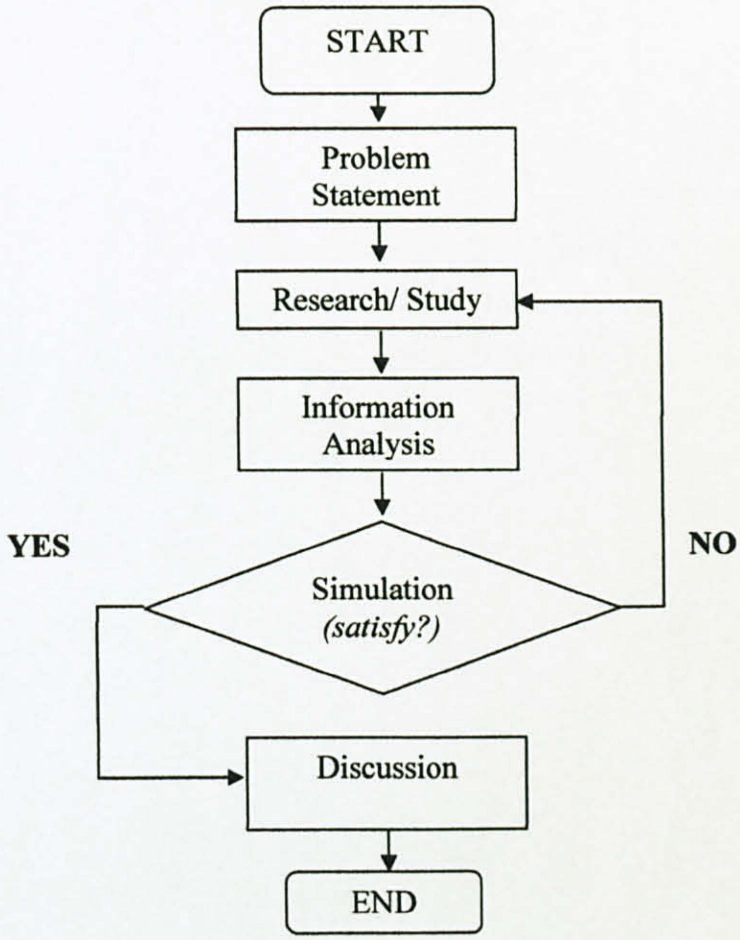

Figure 2: Project Flow Chart

3.1.1 Problem Statement

The project kick started after a problem statement had been identified. The problem statement was determined after some background study on the technologies in hydrocarbon exploration was done. After the problem statement had been recognized, objectives for the project were set. The objectives are very important as it will determine the direction and outcome of the project.

3.1.2 Research/ Study

Researches and studies were conducted in order to get the better understanding about the problem and at the same time to investigate the potential solution for the problem. The researches and studies for the project had been discussed in Chapter 2: Literature Review.

3.1.3 Information analysis

Information was gathered during the research and study period. The collected information were analysed in order to help preparation for the simulation. The information is also useful because it helped to get the values of parameters and expected result for the simulation.

3.1.4 Simulation

Simulations were done to test the information that had been gathered. If the simulation results agree with the expected, the result was analysed. If it does not, another simulation was conducted after further research had been done.

3.1.5 Discussion

After the simulations had been satisfied, the results of the simulations were compared with the expected results based the information that had been gathered. The discussion was done to explain about the result and thus conclusion was made. The conclusion tells whether the objectives of the project were achieved or not.

3.2 Project Activities

Most of the activities are doing research on electromagnetic wave, its characteristic and behaviour. The research also will cover the hydrocarbon exploration and detection, current and new technologies.

Besides that, simulation using CST EM Studio had been conducted to test the information gathered from the research and help the understanding of the project.

3.3 Key Milestone

These are the list of some of the simulations that had been conducted.

Simulation 1: Single pole antenna.

Simulation 2: Single pole antenna in vacuum medium.

Simulation 3: Single pole antenna in seawater (saltwater) medium.

Simulation 4: Single pole antenna in oil medium.

Simulation 5: Half ring antenna.

Simulation 6: Effect of frequency to the propagation of EM wave.

Simulation 7: Simulation of based Seabed Logging method.

However not all simulations are included in this report. Some of simulation is discussed in Chapter 4: Result and Discussion.

3.4 Tool Used

This is the important tools that had been used to complete in this project:

CST EM Studio software

3.4.1 A brief introduction about CST EM Studio software

CST EM Studio software enables the user to characterize, design and optimize electromagnetic devices before creating the actual prototype. This can help save substantial costs especially for new or cutting edge products, and also reduce design risk and improve overall performance and profitability.CST EM Studio software is ideal for the analysis of static and low frequency devices. It enables full 3D EM simulation in a wide application range including magnet and coil design. [10]

CHAPTER 4

RESULT AND DISCUSSION

4.1 Result

4.1.1 Preliminary Simulation

The objective of the preliminary simulation is to test and determine capability of CST EM Studio Software. This is important in order to make sure that the software is capable to run the simulation needed in order to study the effect of resistive medium to the propagation of EM wave.

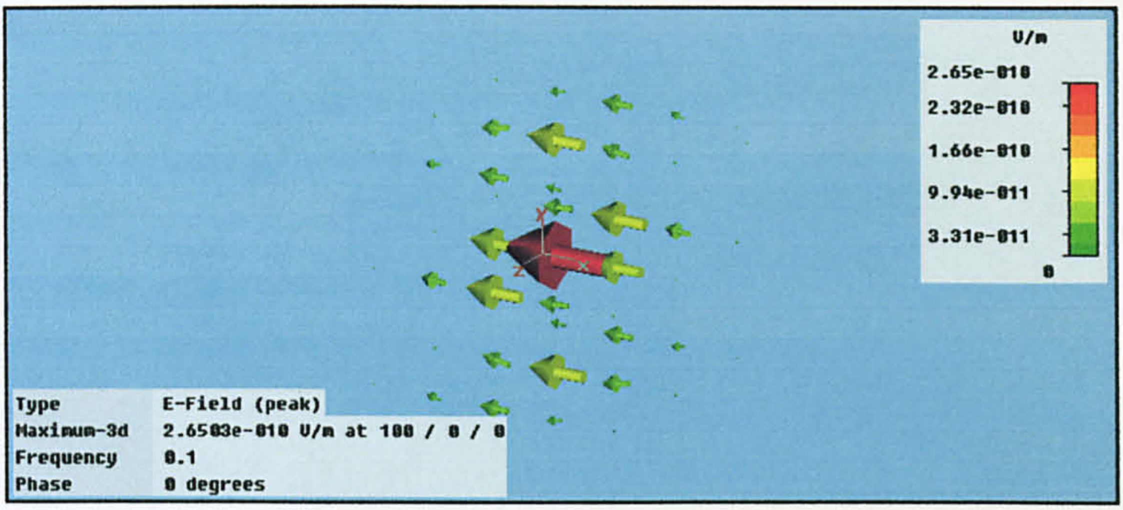

Figure 3: E-Field of 0.1 Hz, 305 Ampere antenna in seawater medium

Figure 3 show the E-Field resulted from an antenna which gives 305 Ampere and 0.1 Hz transmission frequency. The arrows on the centre of the figure indicate the direction of E-Field at phase 0 degrees. The direction of the field will changed as the phase change from 0 degrees to 360 degrees.

There is a legend that shows the strength of the fields at the top right side of the figure. The strength of the fields is represent by the color, in this figure light green represent the weakest field which is in the range of from 0 to 3.31e-11 V/m, and the strongest field which is in the range of 2.32e-10 to 2.65e-10 V/m is represent by orange color.

Information about the field is shown at the bottom left corner of the figure. The available information is the type of field shown by the figure, maximum three dimensional (3d) of the field which also include the location of the maximum 3d, the frequency and also the current phase of the simulation.

Beside E-Field, CST EM Studio also can give a lot of other the reading such as source current, Eddy-current, total current, D-Field, B-Field, H-field, magnetic energy density and electric loss density.

By using CST EM Studio, the design of the antenna and the parameters such as the calculating frequency, current and voltage can be set. The environment, temperature of the surrounding and type of material can also be set.

4.1.2 Effect of Different Medium to the Propagation of EM Wave

The objective of these simulations is to study the effect of different medium to the propagation of EM wave. The design for the antenna for these simulations is as follow:

Type:	Single pole antenna
Length:	100 meter
Supplying Frequency:	0.5 Hz
Supplying Current:	305 Ampere

First the medium is set to be seawater with resistivity of 0.3 Ohm meter. The simulation was run and the reading of the strength of E-Fields and B-Fields was collected at the every 100 meters horizontally from the antenna. After that, the simulation was repeated by changing the medium to oil and then sediment. The result of the simulations is shown in Table 1, Figure 2 and Figure 3.

Table 1: Effect of different medium to the strength of EM field

Distance from antenna (m)	Seawater (Resistivity = 0.3 Ohm.m)		Oil (Resistivity = 50 Ohm.m)		Sediment (Resistivity = 1.0 Ohm.m)	
	E-field (V/m)	B-field (Vs/m^2)	E-field (V/m)	B-field (Vs/m^2)	E-field (V/m)	B-field (Vs/m^2)
0	2,15E-10	2,43E-19	2,18E-08	5,16E-14	2,36E-09	1,10E-17
100	2,24E-10	2,17E-19	1,98E-08	4,74E-14	2,35E-09	1,10E-17
200	1,65E-10	1,79E-19	1,63E-08	4,10E-14	2,35E-09	1,10E-17
300	1,10E-10	1,46E-19	1,04E-08	2,86E-14	2,35E-09	1,10E-17
400	6,33E-11	9,43E-20	5,48E-09	1,82E-14	2,35E-09	1,10E-17
500	8,18E-12	2,35E-20	8,67E-10	6,09E-15	2,35E-09	1,10E-17
600	5,61E-12	3,36E-20	1,07E-10	4,06E-15	8,41E-11	2,77E-19
700	4,14E-12	3,36E-20	9,05E-10	3,53E-15	8,41E-11	2,77E-19
800	2,69E-12	3,36E-20	8,20E-10	3,20E-15	8,41E-11	2,77E-19
900	2,41E-12	3,36E-20	7,25E-10	2,83E-15	8,41E-11	2,77E-19
1000	1,68E-12	3,36E-20	6,41E-10	2,49E-15	8,41E-11	2,77E-19

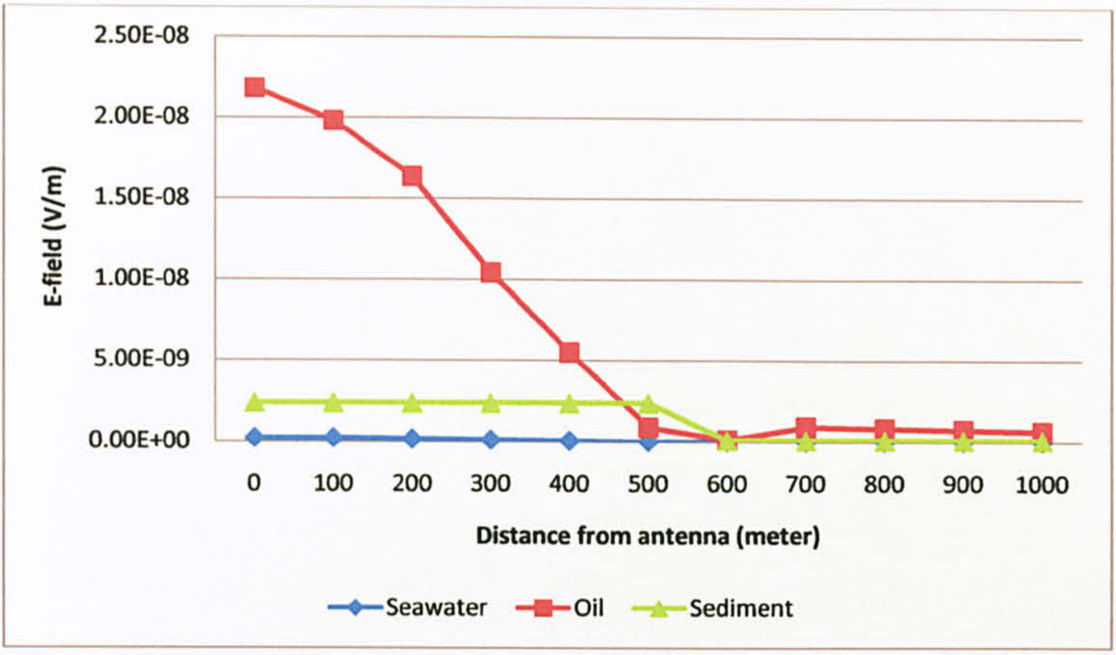

Figure 4: Strength of E-fields vs Distance from Antenna

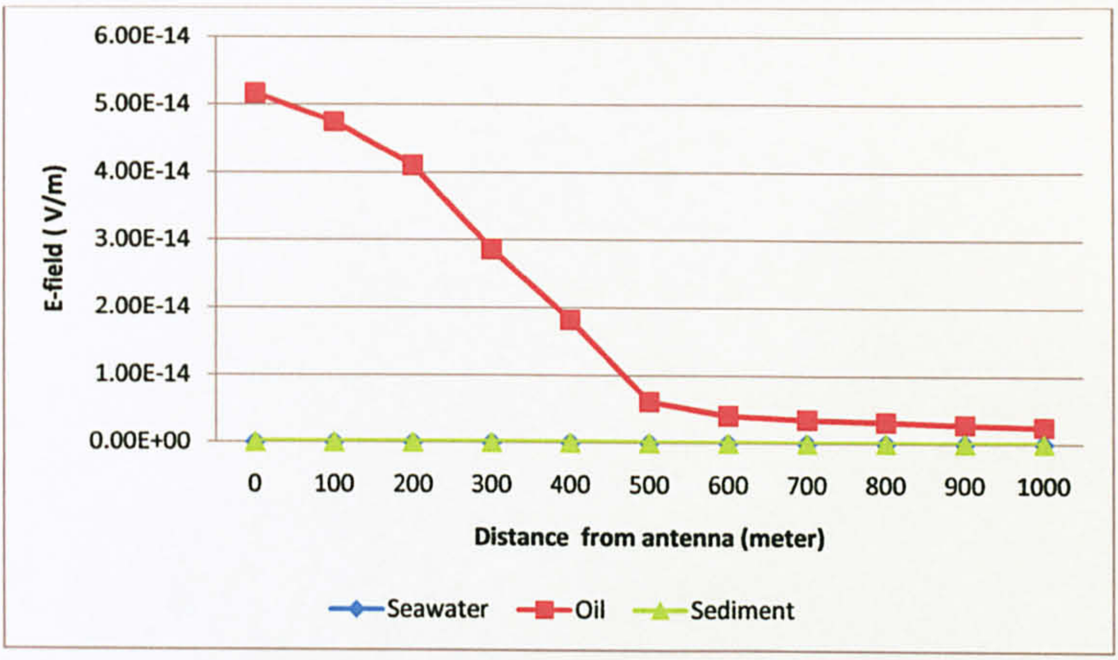

Figure 5: Strength of B-fields vs Distance from Antenna

4.1.3 Effect of Different Frequencies to the Propagation of EM wave

The objective of these simulations is to study the effect of different frequencies to the propagation of EM wave. The design for the antenna for these simulations is as follow:

Type:	Single pole antenna
Length:	100 meter
Supplying Frequency:	0.1 Hz
Supplying Current:	305 Ampere

The medium is set to be seawater with resistivity of 0.3 Ohm meter. The simulation was run and the reading of the strength of E-Fields and B-Fields was collected at the every 100 meters horizontally from the antenna. After that, the simulation was repeated by changing the operating frequency of the antenna to 1.0 Hz and then 10 Hz. The result of the simulations is shown in Table 1, Figure 2 and Figure 3.

Table 2: Effect of frequency to the strength of EM field

Distance from antenna (m)	Frequency = 0.1Hz		Frequency = 1.0Hz		Frequency = 10Hz	
	E-field (V/m)	B-field (Vs/m^2)	E-field (V/m)	B-field (Vs/m^2)	E-field (V/m)	B-field (Vs/m^2)
0	2.13E-10	2.52E-19	2.12E-10	2.44E-19	2.08E-10	2.36E-19
100	1.92E-10	2.37E-19	1.90E-10	2.28E-19	1.83E-10	2.18E-19
200	1.49E-10	1.94E-19	1.42E-10	1.86E-19	1.37E-10	1.74E-19
300	1.11E-10	1.48E-19	9.15E-11	1.37E-19	7.28E-11	1.18E-19
400	4.85E-11	9.53E-20	4.36E-11	8.46E-20	2.42E-11	7.73E-20
500	2.15E-11	2.64E-20	8.42E-12	2.04E-20	3.73E-12	1.68E-20

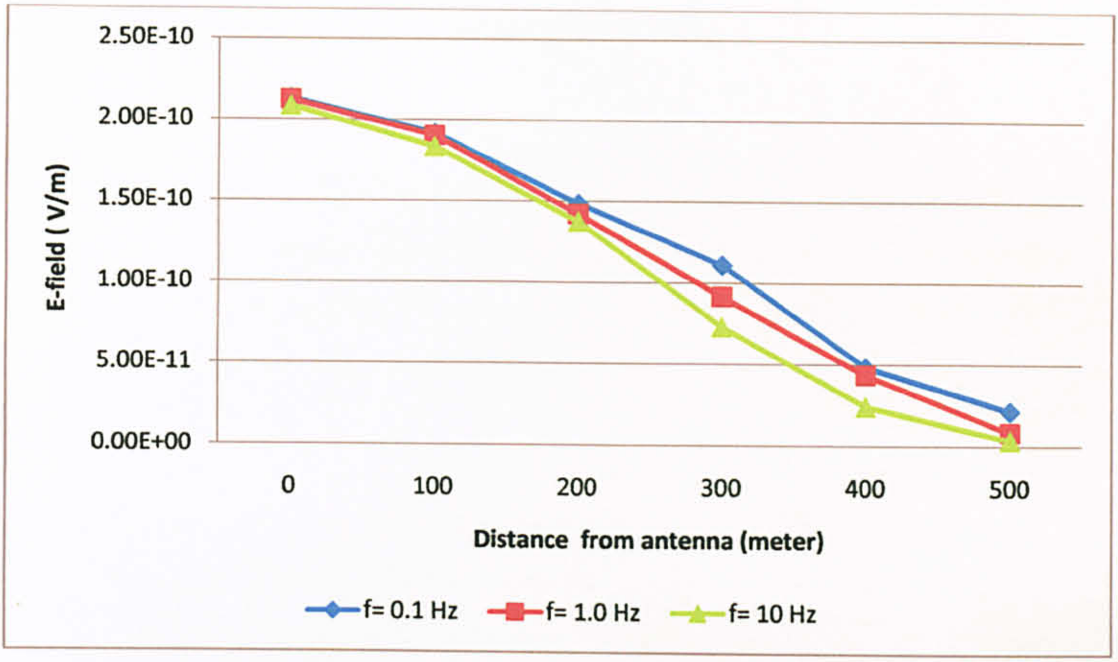

Figure 6: Strength of E-fields vs Distance from Antenna

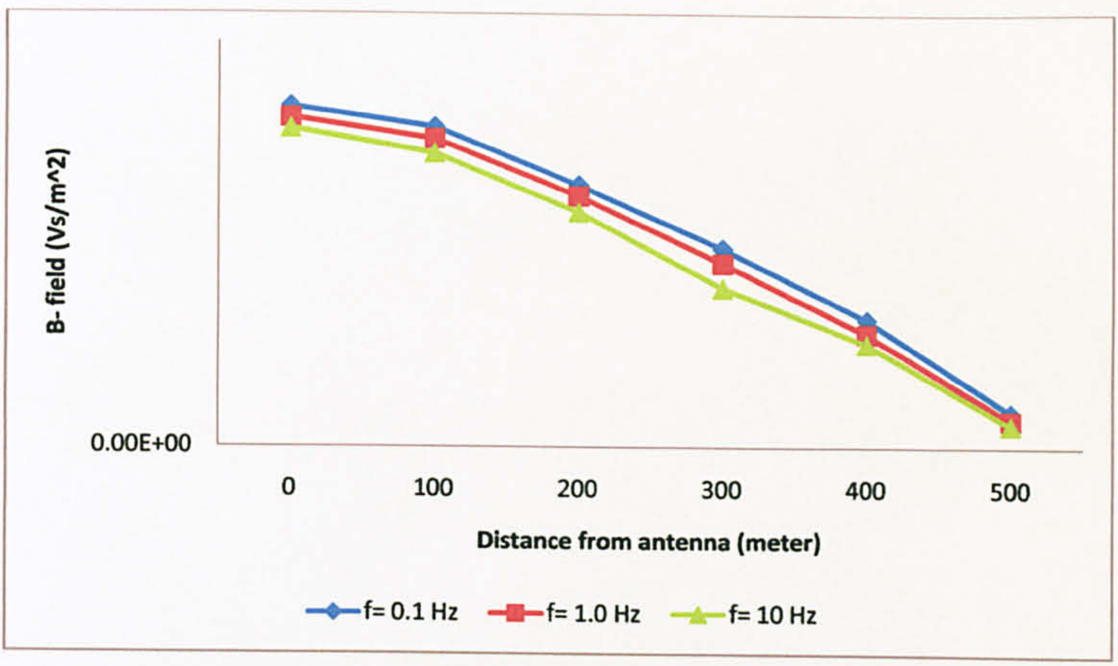

Figure 7: Strength of B-field vs. Distance from Antenna

4.1.4 Simulation Based on Sea Bed Logging Method

There is one more simulation of seabed logging. The objective for the simulation is to investigate the effect of different layer of medium and different frequency to the propagation of EM wave. A simple single pole antenna is used. The specification of the antenna is as followed:

Type	: Single Pole Antenna
Length	: 100 meter
Supplying Current	: 305 Ampere
Supplying Frequency	: 0.25Hz, 0.5Hz and 1.0 Hz

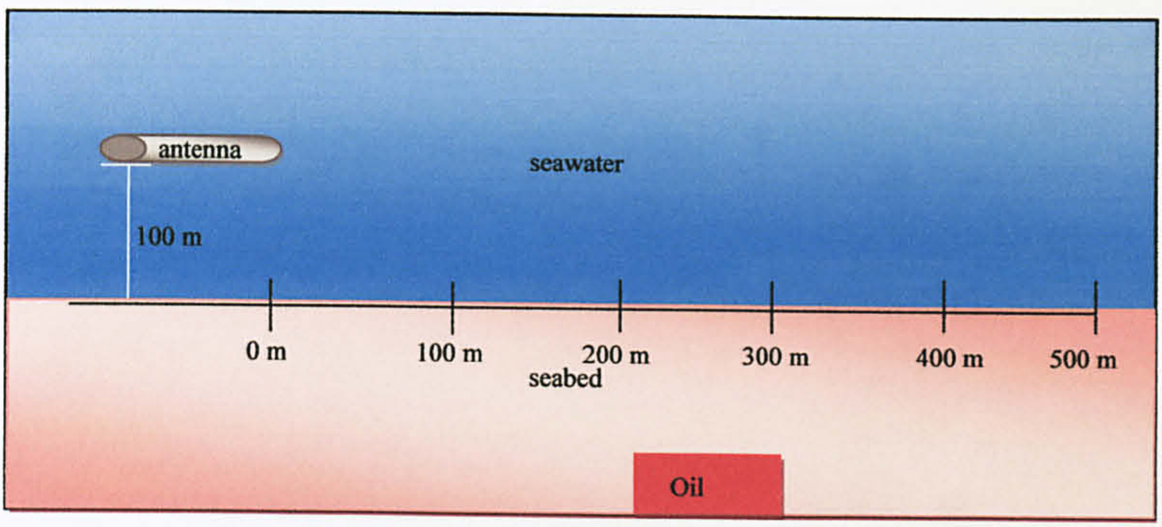

Figure 8: Simulation model

The depth of the ocean was set at 1150 meter. The sediment has depth of 1000 meter and there is an oil reservoir that located between 200 meter and 300 meter distances from antenna. The oil reservoir is located 850 meter vertically from the seafloor. The distance between the antenna and seabed is set to be 100 meter which is common in Seabed Logging method. The strength of fields is taken on the seafloor from 0 to 500 meters from the antenna. The result of the simulation is shown below.

Table 3: Simulation based on SBL method

Distance from antenna (m)	Frequency = 0.1Hz		Frequency = 1.0Hz		Frequency = 10Hz	
	E-field (V/m)	B-field (Vs/m^2)	E-field (V/m)	B-field (Vs/m^2)	E-field (V/m)	B-field (Vs/m^2)
0	6,73E-09	1,33E-12	5,77E-09	1,21E-12	4,34E-09	3,135E-13
100	1,37E-09	1,58E-13	1,28E-09	1,49E-13	1,11E-09	1,225E-13
200	4,83E-10	6,52E-14	4,73E-10	5,36E-14	4,89E-10	3,535E-14
300	3,27E-10	3,3E-14	3,80E-10	2,28E-14	3,69E-10	1,34E-14
400	2,71E-10	2,01E-14	2,71E-10	4,33E-15	3,05E-10	4,325E-15
500	1,83E-10	1,46E-14	2,31E-10	7,42E-15	1,98E-10	1,665E-15

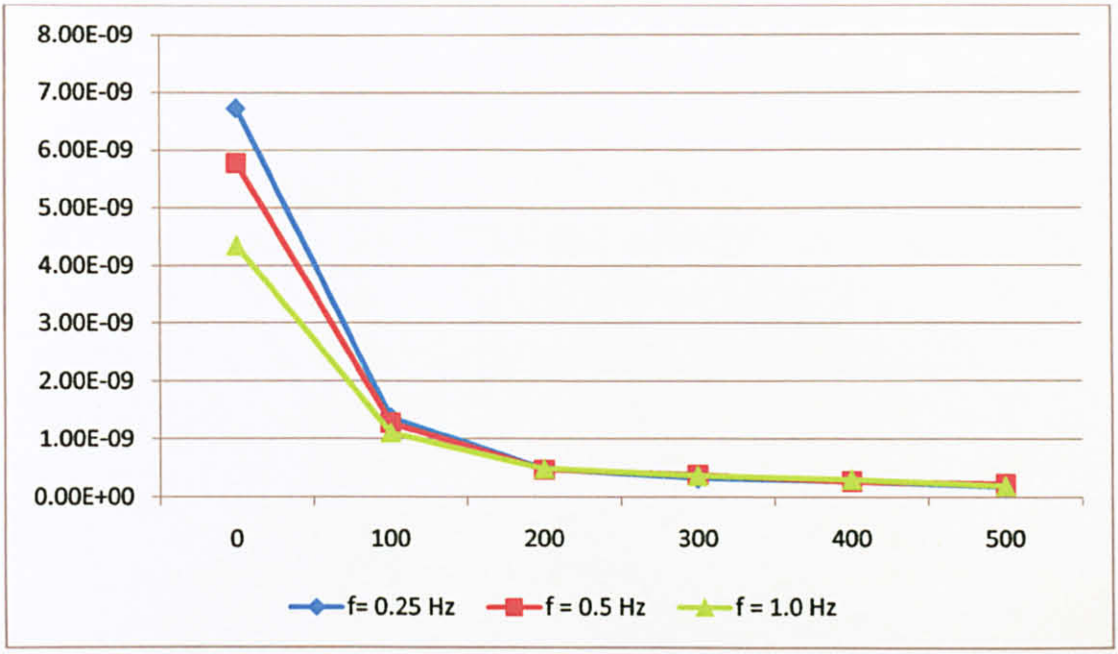

Figure 9: Strength of E-fields vs Distance from Antenna

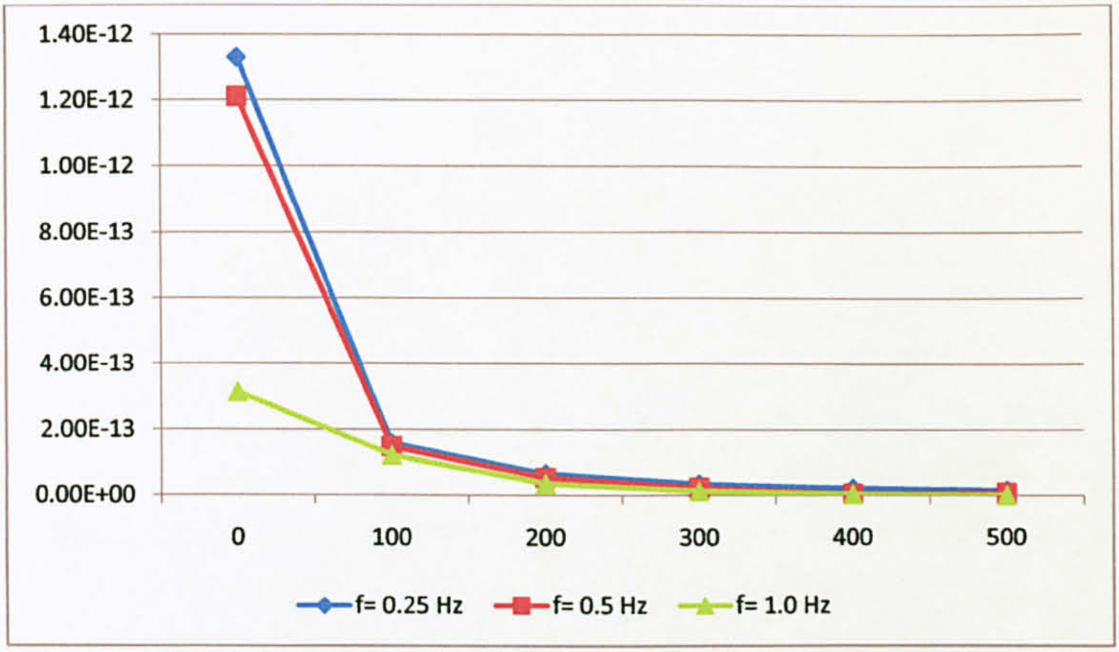

Figure 10: Strength of B-field vs Distance from Antenna

4.2 Discussion

4.2.1 Preliminary Simulation

Based on the result of the preliminary simulation, clearly the effect of resistive medium to the propagation of EM wave can be simulated using the CST EM Studio software. Using this software, antenna can be designed, all the parameter for the medium such as conductivity, resistivity and permittivity can be set, and most important thing is the software able to simulate the EM wave and give the reading.

4.2.2 Effect of Different Medium to the Propagation of EM Wave

Based on Figure 4 and Figure 5, when the distance from the antenna increased, the strength of E-Field and B-Field for all the mediums decreased. This is because as the EM wave travel further, some energy loses due to the absorption and reemission process.

Oil gives the strongest reading for both E-Field and B-Field compared to seawater and sediment. At 0 meter distances from the antenna, the E-Field for oil is 2.18e-8 V/m, while seawater gives 2.15e-10 V/m and sediment gives 2.36e-9 V/m. Oil has resistivity of 50 Ohm which is far greater than seawater and sediment. This shows the EM wave can be easily detected in medium that have greater resistance.

In Figure 4 and Figure 5, as E-Field and B-Field for oil is far greater than seawater and sediment, the resulted curves for E-Field and B-Field for those mediums look almost like a straight line.

4.3.3 Effect of Different Frequency to the Propagation of EM Wave

Same as like the effect of the different medium to the propagation of EM wave earlier, strength of E-Field and B-Field for all the frequencies while decreased as the distance from antenna increased. This is because of absorption and reemission process.

Based on Figure 6 and Figure 7, 0.1 Hz frequency gives the strongest reading for both E-Field and B-Field compared to 1.0 Hz and 10 Hz frequency. At 0 meter distances from the antenna, 0.1 Hz gives 2.13e-10 V/m of E-Field and 2.52e-19 Vs/m^2 of B-Field, 1.0 Hz gives 2.12e-10 V/m of E-Field and 2.44e-19 Vs/m^2 of B-Field while 1.0 Hz gives 2.08e-10 of V/m E-Field and 2.36e-19 Vs/m^2 of B-Field. O.1 Hz also gives strongest reading of E-Field and B-Field at any distances from the antenna compared to 1.0 Hz and 10 Hz frequency. Thus, this shows that lower frequency can travel further than higher frequency. This also indicates that lower frequency will lose less EM energy when travel through medium.

4.2.3 Simulation Based on Sea Bed Logging Method

The result for simulation based on the actual data of Sea Bed Logging is not taken like the result in previous simulations. In the other simulations, the strength of EM fields was taken at every 100 meter distance horizontally from the antenna. However, in this simulation the reading is taken at every 100 meter on the seafloor, 100 meter distances vertically from the antenna. Thus, this resulted the initial reading for the EM fields for the frequency have a lot different than other simulations. In 4.1.3, the resulted EM fields started at almost the same point for all the frequencies because there is not much loss in E-Field because the distance travel is not far. The initial result of EM field which is at 0 meter distances from the antenna for this experiment is show different from 0.25 Hz to 1.0 Hz because the EM wave had travelled further that is 100 meter vertically than simulations on 4.1.3.

However, the trend of the curves is still same. Lower frequency which is 0.25 Hz still shows the strongest reading and indicates that it can travel further and loss less energy while travelling. Unfortunately, there is no increase of EM field at point between 200 meter and 300 meter where the oil reservoir is located. The result of this experiment is almost same as 4.1.3 except the initial reading. The expected result will be an increasing E-Field and B-Field in between 200 meter and 300 meter distances from the antenna as the EM energy that went to the sediment and oil reservoir refracted and reflected back into the seafloor and thus making the reading of EM field at that area higher.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The purpose of this project is to study and simulate the effect of different medium of resistivity to the propagation of electromagnetic wave. The simulation had given the result that needed and show that indeed it is possible to study the effect resistive medium to the propagation of EM wave using CST EM Studio.

Based on the result, strength of EM field will decreased as distance from antenna increased. Thus for hydrocarbon exploration, it is suggested that the distance between antenna and receiver is keep as close as possible to get the optimal result.

The simulations also show that resistivity of medium will have an impact to the propagation of EM wave. EM wave can easily be detected at the medium that have high resistivity. Therefore, this had validated the application of EM wave as tool hydrocarbon detection based on the resistivity differences between material or medium.

On the effect of frequency, higher frequency will lose EM energy thus did not travel further. Therefore, choosing the lower frequency will helps to get the better result for the hydrocarbon exploration application.

Unfortunately, the simulation based on the actual data of Sea Bed Logging did not give the expected result. To overcome this problem probably a receiver had to be put into the simulation. The receiver did not put in this project because CST EM Studio software can give reading of EM fields at any points thus author feels that there is no need for receiver. The other reason might be the reading was only given by the direct EM field's that transmitted by the antenna. However, the result of simulation still show the effect of frequency to the propagation of EM wave had agreed with the result on the previous simulations.

5.2 Recommendation for Future Work

Having spent two semesters dealing with this project, there are some recommendations in order to improve this project. There are some parameters such as temperature of the medium and the pressure of the ocean that had not being look in more detail that might affected the outcome of the project. Thus, for future work to improve the result of this project is by adding the parameters into the simulations.

For the simulation of SBL technique, the expected result was not achieved. This is probably because the reading given was from the EM wave transmitted directly from the antenna only. Thus, it is recommended for the future work to investigate whether CST EM Studio can refract and reflect signal when the EM wave was moving from one medium to other medium.

It is also recommended that for further improvement, receiver will be added in the simulation to maximum the accuracy of the data obtained.

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APPENDICES

APPENDIX A

PROJECT GANTT CHART FOR FIRST SEMESTER

No.	Detail/ Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	Selection of Project Topic																		
2	Preliminary Research/Design Work																		
3	Submission of Preliminary Report (Initial Proposal)																		
4	Seminar 1																		
5	Project Work (Research/study)																		
6	Submission of Progress Report																		
7	Seminar																		
8	Project work continue (preliminary simulation)																		
9	Submission of Dissertation Final Draft																		
11	Submission of Project Dissertation																		
10	Oral Presentation																		
11	Submission of Project Dissertation																		

Suggested/Plan Progress

APPENDIX B

PROJECT GANTT CHART FOR SECOND SEMESTER

No.	Detail/ Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	Project Work Continue (simulation)																		
2	Submission of Progress Report 1																		
3	Project Work Continue																		
4	Submission of Progress Report 2																		
5	Seminar																		
5	Project work continue (simulation)																		
6	Poster Exhibition																		
7	Submission of Dissertation (soft bound)																		
8	Oral Presentation																		
9	Submission of Project Dissertation (Hard Bound)																		

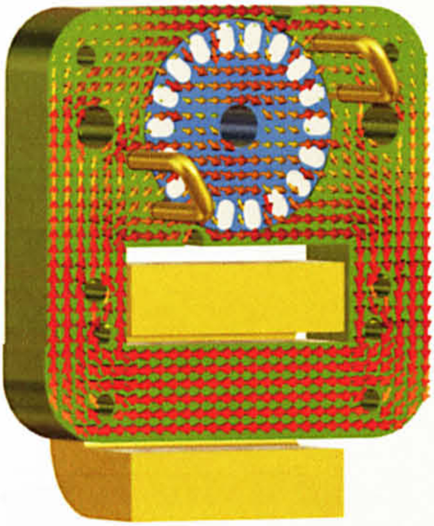
Suggested milestone/plan

Actual Progress

APPENDIX C

CST EM STUDIO PRODUCT FLYER

CST EM STUDIO
Low Frequency Electromagnetic Design and Simulation



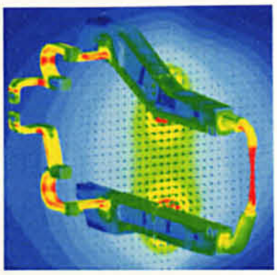
Magnetic flux density under no-load conditions for a shaded pole induction motor

CST STUDIO SUITE™ enables you to characterize, design and optimize electromagnetic devices before creating your first prototype. This can help save substantial costs especially for new or cutting edge products reduce design risk, and improve overall performance and profitability.

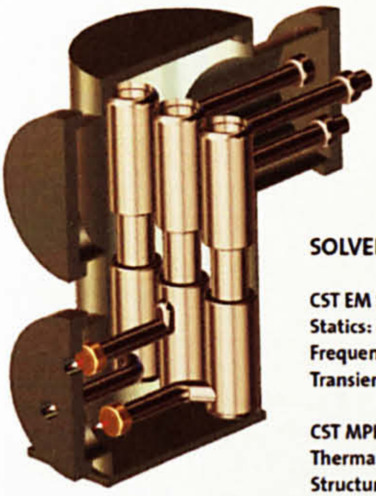
CST STUDIO SUITE includes various solver modules that are ideally suited to the analysis of static and low frequency devices. CST EM STUDIO® (CST EMS) is dedicated to full 3D EM simulation in a wide application range, including sensors, circuit breakers, magnets and coils. Modules include static, quasi-static, full-wave, and transient electromagnetic field solvers. Additionally CST MPHYSICS STUDIO™ (CST MPS) enables thermal and mechanical stress analysis. CST STUDIO SUITE unites all solver modules in one user-friendly interface. This gives you the flexibility to choose the technology best suited to your application. Advanced design flow integration with mechanical tools, versatile post-processing capabilities and inbuilt automatic optimization schemes, make CST STUDIO SUITE an invaluable part of your toolbox.

APPLICATIONS

- Coil and magnet design
- Sensors and actuators, NDT
- Electromechanical devices
- Motors, generators and transformers
- Shielding
- Electrostatic and high voltage devices
- Biomedical applications
- Magnetic recording
- Induction heating



Current and magnetic flux density in a resistance spot welding gun at 50 Hz



50 Hz gas-insulated switch

SOLVER MODULES

CST EM STUDIO®
Statics: electrostatic, magnetostatic and DC current
Frequency domain: electroquasistatic, magnetoquasistatic, full wave
Transient: magnetoquasistatic transient

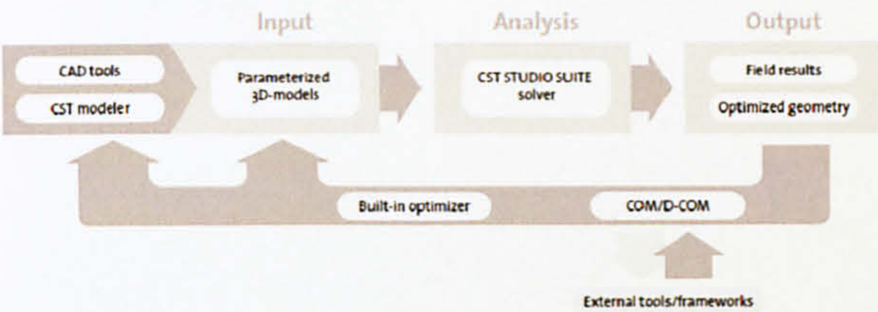
CST MPHYSICS STUDIO™
Thermal: static and transient thermal
Structural mechanics: stress and deformation

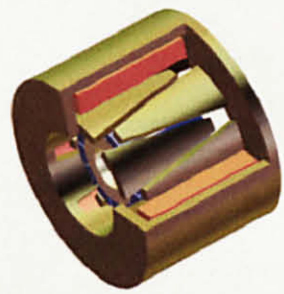
Static and Low Frequency Electromagnetic Design and Simulation

CST EMS graphical user interface showing the workflow for the magnetostatic simulation of a stepper motor with torque versus permanent magnet angle parameterisation results.

CST consistently promotes the best-in-class approach. We specialize in developing 3D EM software and provide straight-forward, easy-to-use links with other best-in-class vendors, connecting all available expertise. A wide range of import/export filters enable the easy exchange of geometrical data with CAD tools. Furthermore, imported structures can be modified and parameterized, and used for optimization and design studies.
Moreover the powerful VBA based and OLE-compatible macro language allows direct communication with programs such as MATLAB®.

SIMULATION WORKFLOW IN THE CST DESIGN ENVIRONMENT

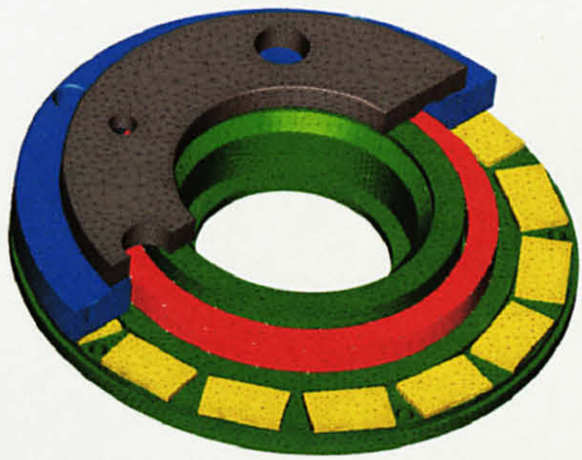




Model of a claw pole induction generator

KEY FEATURES

- Powerful, intuitive and easy-to-use user interface
- CAD import, automatic healing, structure modification, and export
- Tetrahedral and hexahedral mesh topologies
- State-of-the-art multi-grid solver technology with 2nd order elements for high accuracy
- Automatic adaptive mesh refinement
- Automatic extraction of secondary electromagnetic quantities
- Fully integrated optimization and parameterization modules
- Automatic calculation of force, torque, inductance and capacitance, flux linkage and induced coil voltages
- Potential and charge definition, voltage sources, coils and current paths, permanent magnets, nonlinear materials and current ports
- Electromagnetic power loss and force density export to CST MPS for thermal and structural mechanics simulation
- Magnetostatic co-simulation between CST EMS and CST MWS for ferrite simulations



Automatic tetrahedral mesh generation in a magnetic brake