1D MODELLING ELECTROMAGNETIC (EM) WAVES FOR OFFSHORE APPLICATION

By

KHAIRUL IHSAN BIN TALIB

FINAL PROJECT REPORT

Submitted to the Electrical & Electronics Engineering Programme
in Partial Fulfillment of the Requirements
for the Degree
Bachelor of Engineering (Hons)
(Electrical & Electronics Engineering)

Universiti Teknologi Petronas
Bandar Seri Iskandar
31750 Tronoh
Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

1D MODELLING ELECTROMAGNETIC (EM) WAVES FOR OFFSHORE APPLICATION

by

Khairul Ihsan Bin Talib

A project dissertation submitted to the
Electrical & Electronics Engineering Programme
Universiti Teknologi PETRONAS
in partial fulfilment of the requirement for the
Bachelor of Engineering (Hons)
(Electrical & Electronics Engineering)

Approved:

____

Puan Hanita bt. Daud
Project Supervisor

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK

June or December 2009

CERTIFICATION OF ORIGINALITY

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

Khairul Ihsan bin Talib

ABSTRACT

The aim of this project was to develop 1D and 3D electromagnetic plane layer modeling for offshore application by using MATLAB and C-Language programming software. Geophysicist has found that by using Electromagnetic (EM) wave technique give them very promising result compare to widely use technique, seismic survey due to cannot distinguish between hydrocarbon and water. EM wave technique have the ability to distinguish layer by their resistivity and due to hydrocarbon resistivity is much higher compare to water, this two layer can be distinguish. The problems with this technique is that it cannot use for shallow water hydrocarbon due to the EM waves is refracted and reflected back by the sea surface to the seafloor receiver. This project will involve with the application of the EM waves and the study 1D and 3D EM plane layer modeling. In the end, the EM wave technique can be implemented for shallow water hydrocarbon exploration. All the data obtained from the receiver will be process and use for 1D and 3D EM plane layer modeling.

ACKNOWLEDGEMENTS

First of all, there were many people, individuals and parties that involved while working for my final year project which has contributed immeasurable and invaluable amount of help, guidance, assistance, advice, supports, and also supervision. A very high gratitude and appreciation to all of them for the commitments and assistance in helping me to achieve the objectives and complete my final year project with flying colors.

Special thanks to Puan Hanita Daud, my final year project supervisor for your willingness to become my supervisor. I also like to say thank you again to her for given me many supportive, constructive advices, and sharing her technical knowledge. Without her guidance, the project cannot be completed.

Special thanks also go to both my parents for their endless support and encouragement. Their advices always motivate me to work very hard and never give up until my project finish.

I also gratefully acknowledge all my friends wo have given invaluable review and feedbacks on my project.

All your guidance, support and cooperation are very important in completing the industrial internship program.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF ABBREVIATIONS

EM	Electromagnetic
HED	Horizontal Electrical Dipole
SBL	Seabed Logging
GUI	Graphical User Interface Enter list of abbreviations here.

CHAPTER 1
INTRODUCTION

1.1 Background of Study

Since 1970, seismic method has become the most accurate and frequently used for hydrocarbon exploration. This is because this method permits very accurate conclusions on stratigraphic sequence and depth of geological bed. There are two types of seismic; seismic refraction method and seismic reflection method. For seismic refraction method, the energy waves are refracted at the interface between water and air. The energy waves are produce from explosives charge such as dynamite. The geophones are set up on the surface to record the refracted wave. For seismic reflection method, the energy waves are reflected at the interface between water and air. Same like refraction method, the reflected waves will be recorded by the group of geophone. For offshore application, the explosives previously used are not suitable and replaced with airgun due to great environmental damage where large fish stock exists. Although seismic techniques can provide very detailed information about layering, but it has limitation where it cannot distinguish between presence of water or hydrocarbon in pore fluid composition. To solve this problem, it is still remained challenging task.

New technique was introduced and it could overcome problem encounter by seismic technique. This new technique is known as Seabed Logging (SBL) where it uses Electromagnetic (EM) wave sound to detect hydrocarbon beneath the seafloor. The technique identifies resistive reservoirs by measuring the energy received at long source-receiver offsets distances. This technique uses a mobile Horizontal Electrical Dipole (HED) transmitter and array of seafloor electric receiver. The HED transmitter will transmit the EM wave through the layer beneath the seafloor and the receiver will collect and recorded all the data that been reflected back by the layer. This technique has very bright future in hydrocarbon exploration especially for offshore application, because it provides better imaging of layer and the ability to distinguish between hydrocarbon and water.Start entering text here.

1.2 Problem Statement

Seabed logging technique has been widely use for hydrocarbon exploration and give very promising result. Although this technique give very accurate result for deep water exploration but, for shallow water exploration it does not give accurate result and this become more challenging [4]. This is because, in shallow water, the receivers on the seafloor also measure a strong refraction and reflection from the sea surface and also possibly magnetotelluric fields. The effect is the observed anomalies become very weak.

1.3 Objectives

The objectives of this project are:

i. To determine suitable Electromagnetic (EM) modeling technique to differentiate between water, sediment, and hydrocarbon layer plane according to their resistivity.

ii. To develop seabed logging simulator using MATLAB Graphical User Interface

iii. To find the effect of airwave to receiver when depth of seawater is varied

iv. To fix a frequency and vary the hydrocarbon depth

v. To fix hydrocarbon depth and vary the frequencies

Both objectives are to find a suitable frequency for specific hydrocarbon depth

1.4 Scope of Study

This project is aim to develop 1D and 3D electromagnetic (EM) Plane Layer Modeling for shallow water hydrocarbon. During the process, research has to be made to find for the method how to remove the problem regarding refraction and reflection signal from sea surface. If this problem is not overcome, it will affect the 1D and 3D EM plane model of the shallow water.

The study on the 1D and 3D modeling of EM waves for offshore application is to be completed within approximately one year timeframe (two semesters). For the first phase (first semester) the scope the project are to do several research regarding offshore exploration especially for shallow water. This involves with technique use for in shallow water hydrocarbon exploration in this case it narrow down to by using electromagnetic wave and also. After that, also need to study of EM plane layer modeling for one dimensional and three dimensional. At the end of the first phase of the project, at least manage to finish with developing 1D EM plane layer modeling for shallow water hydrocarbon.

For the phase two (second semester), it will start with the study and developing 3D EM plane modeling. Compare to 1D, developing 3D EM plane modeling far more challenging. Therefore a lot of researches have to be made so 3D EM plane modeling can be developed. In the second phase also, the 1D and 3D EM plane modeling that has be developed will be implementing with the data obtained from transmitter and receiver that was developed by other student.

CHAPTER 2
LITERATURE REVIEW

2.1 Seismic Methods

One of the most frequently used hydrocarbon exploration technique is Marine seismic survey and this technique is widely use because it can detect potential hydrocarbon reservoir beneath the seafloor. This technique typically uses acoustic waves to map boundaries between layers with contrasting acoustic properties. A sound source that was attached to the ship sends sound waves through the water. As the sound waves are release, the rock layers beneath the seafloor reflect this sound. The reflected sound waves then are capture by the hydrophones and then were recorded on the magnetic tape that will use by geophysics for future analysis. Seismic method nowadays stills the common tools use to map boundaries layer with contrasting acoustic properties. Although this technique is widely used and provides accurate detailed information about layering, the weakness is not very well to discriminate between the presence of water or hydrocarbons.

2.2 Seabed Logging Method

Seabed logging technique use Electromagnetic (EM) sound wave to mapping boundaries beneath the seafloor and it can distinguish between hydrocarbon and water in the trap very well. It uses very low frequency Electromagnetic (EM) for example 0.25 Hz. Using of high frequency EM wave will cause high attenuation as the function of distance and this will affect the end result. Seabed logging (SBL) method uses a mobile Horizontal Electrical Dipole (HED) transmitter and an array of electric receivers on the seafloor. The receivers are placed at appropriate locations relative to the source and the electric dipole transmitter is typically towed at an elevation of 30 m. HED transmitter is towed starting 10 km before the first receiver and end 10 km after the last receiver. The transmitter emits low-frequency EM energy for example 0.25 Hz into the subsurface. The low-frequency electromagnetic energy able to propagate to reservoir depths where it is guided with low attenuation over long distances. Lines or grids of seabed receivers detect EM energy that has propagated through the sea and the subsurface. Crucially, some of the energy is guided with low attenuation by resistive bodies, such as hydrocarbon reservoirs. Data that was recorded by each receiver then will be used for processing and modeling, including inversion and depth migration of EM data result in maps, cross sections and 3D volumes that show the location and the depth of resistive bodies.

Figure 1 show the schematic of air water-sediment geometry and receiver (Rx1-Rx4) layout on seabed during towing the electromagnetic source. The schematic was divided into several layer like air, water, overburden, Hydrocarbon reservoir, and half space. As illustrated in figure 1, the solid line arrows denote refracted transmission of electromagnetic signals by the air-water surface. The dash arrow denotes direct transmission of electromagnetic signals through water and by refraction along the seabed. Lastly the dot arrows denote refracted transmission of electromagnetic signals by a buried high resistivity of hydrocarbon reservoir layer.

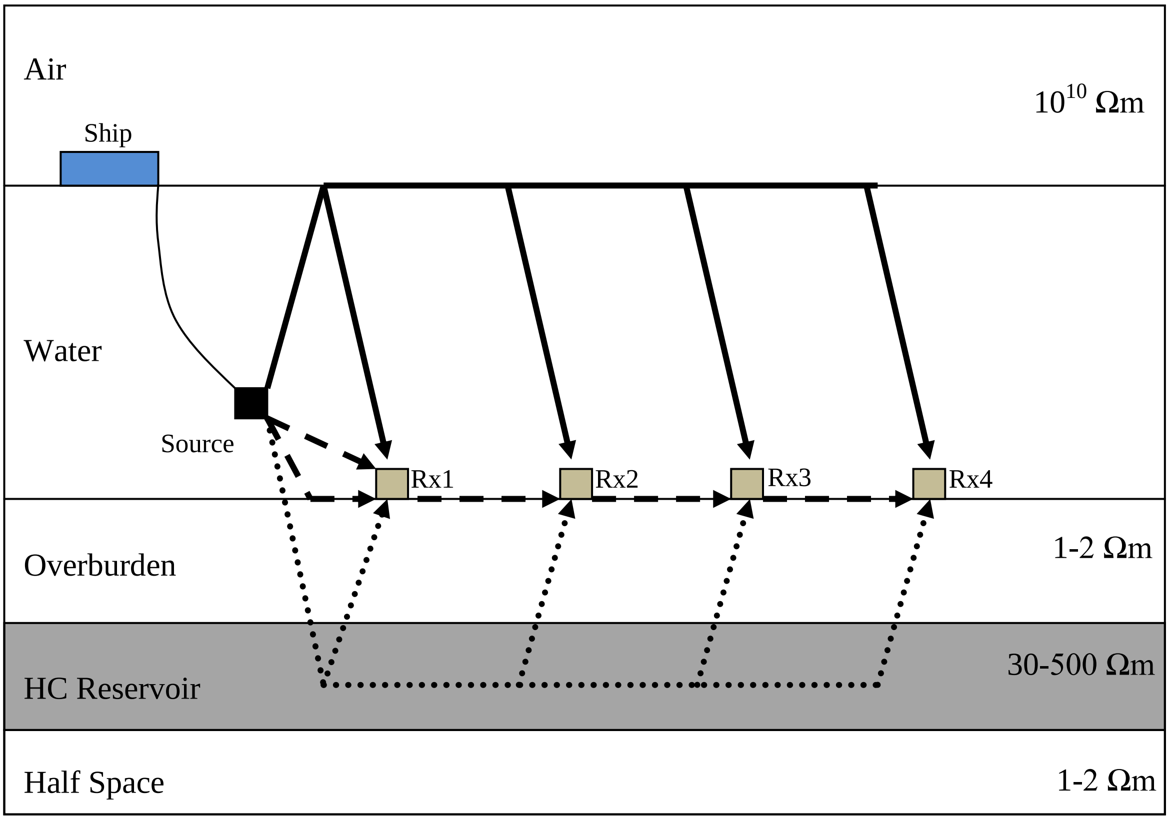


Figure 1   The Components of EM wave received by receiver

EM wave transmitted by the source is used to detect contrasts in subsurface resistivity and due to the resistive nature of hydrocarbon filled rock, the EM wave experiences little attenuation and leaks energy up to the seafloor. The electric and magnetic field receiver will recorded this leakage field. Each layer beneath the seafloor has different resistivity [3]. For example, oceanic crust has high resistivity around 100-1000Ωm. Sedimentary rocks can exhibit a wide range of resistivity around 0.2-1000Ωm and mainly controlled by variation in porosity. Hydrocarbon filled reservoir also have high resistivity around 30-500Ωm compared to water that very conductive around 0.5-2Ωm. Due to different resistivity between water and hydrocarbon, therefore both of the layer can be distinguish by this method. Data that obtained from this receiver then can be use for 1D and 3D plane layer model and then for boundaries mapping

When planning out to carry seabed logging survey, certain important factors must be considered. The factors are water depth, water and seabed conditions, burial depth of the HC accumulation (overburden), electrical properties of the overburden, geometrical and electrical properties of the reservoir, and electrical properties beneath the HC accumulation. It was also important to simulate an oblique crossing of the HC accumulation.

2.3 Seabed Logging application

Seabed logging technique has been tested in two hydrocarbon provinces which are in West Africa in 2000 and in the Norwegian Sea in 2001. In this report, the hydrocarbon exploration in the Norwegian Sea will be highlighted.

2.3.1 Troll West Gas Province (TWGP)

The test was took place at the Troll Field complex which is the largest gas discovery on the Norwegian Continental Shelf. This field was subdivided into three separate compartments. From the three compartments, Troll West Gas Province (TWGP) was choose for the SBL verification test due to much smaller compare to Troll East which cover two thirds of the hydrocarbon reserves. Figure two show the simplified geological section across TWGP and the resistivity data obtained from the exploration.

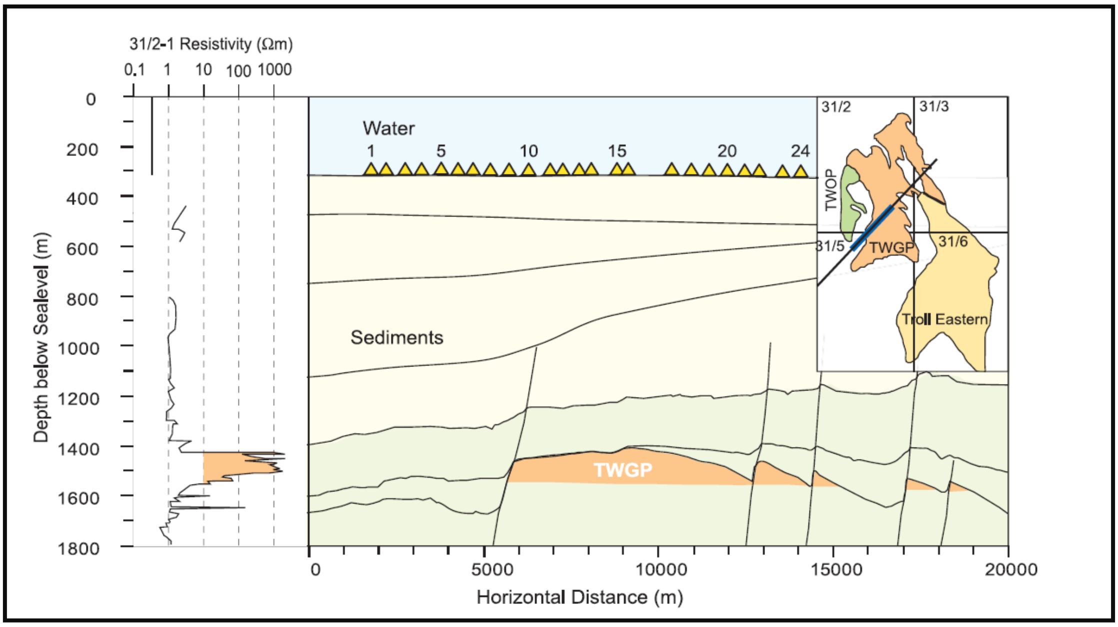


Figure 2 TWGP simplified geological cross section with resistivity data

Base from the figure two above, hydrocarbon filled layer show high average resistivity around 200-500 Ωm and it is located 1400 below the sea level. Seawater and overburden sediment layer show much lower resistivity which is around 0.5 – 2 Ωm compared to hydrocarbon filled layer. Due to the high reservoir resistivities, well defined field edges, the low and relatively constant resistivities in the geological layers above the reservoir (overburden), constant water depth, smooth sea floor, and the moderate distribution of the HC filled reservoir, the TWGP is well suited for testing of the SBL method.

Data that was obtained from this exploration then will be used for modeling. There are two objectives why modeling is needed. First objective from this modeling is to establish the optimal survey location and receiver geometry. Second objective is to quantify the expected SBL response from the subsurface HC accumulation relative to that of a reference area outside the accumulation.

2.4 Second Section Heading

In this project, the modeling technique that will be used is forward modeling of electromagnetic wave. It is very important to understand what is actually forward modeling technique. In forward modeling technique, simulation for geological model was develops. The purpose of this simulation is to generate the synthetics data and this synthetic data then are comparing with the real data acquired in the field. If the two data agree within an acceptable level of accuracy, the geological model that was developed before can be used as accurate model of the subsurface. If not, the new synthetic data are computed and again, it will be compared with the real data. The process will continue until the synthetic data computed are match with the real data obtained.

Forward modeling approach is opposite of inverse modeling approach. In inverse modeling approach the parameters of the geological model are computed from the acquired real data. Both of this technique has the same purpose which is to determine the geological structure of the subsurface, although the technique is different.

CHAPTER 3

METHODOLOGY

3.1 Procedure Identification

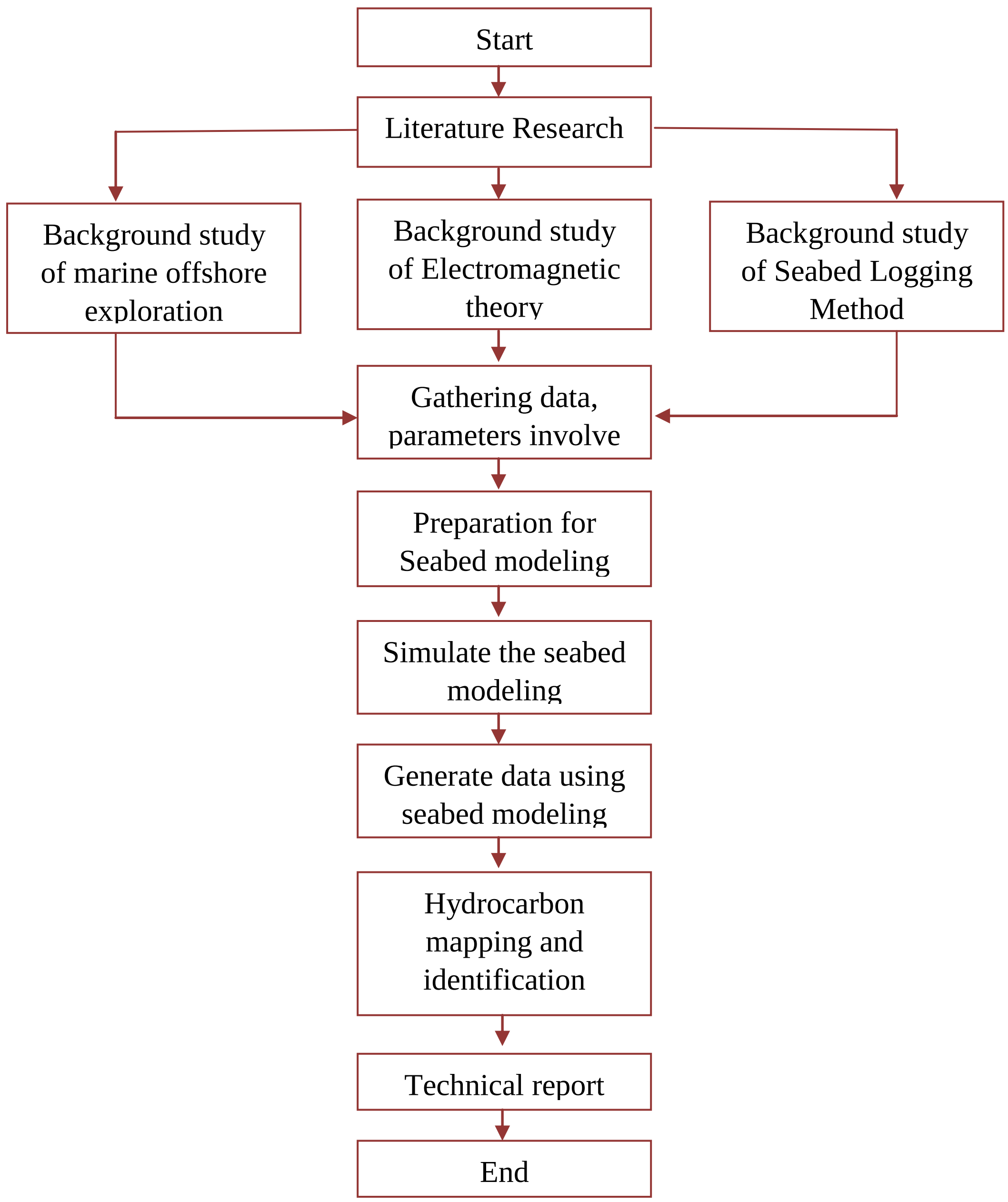


Figure 3 Flowchart of the project

3.2 Detailed of the procedure

Throughout this project, there are some procedures to be followed. This is to ensure that the project can be accomplished within the given timeframe.

3.2.1 Data research and gathering

Elements of projects involved in this stage include the study of electromagnetic (EM) wave characteristic and it application, offshore hydrocarbon exploration, EM plane layer modeling and material regarding MATLAB.

3.2.2 Development of 1D and 3D plane layer modeling

After finish comparing synthetic data with actual data obtained, next is to develop the plane layer modeling. If the two data agree within an acceptable level of accuracy, the geological model that was developed before can be used as accurate model of the subsurface. If not, the new synthetic data are computed and again, it will be compared with the real data. The process will continue until the synthetic data computed are match with the real data obtained.

3.2.3 Hydrocarbon mapping

In this stage, data that was processes will be used for 1D and 3D plane layer modeling. From the modeling it can show the hydrocarbon reservoir.

3.3 Tools

3.3.1 Matlab /C programming

The software will be use for seabed logging modeling and for simulation.

3.4 Developing Simulator

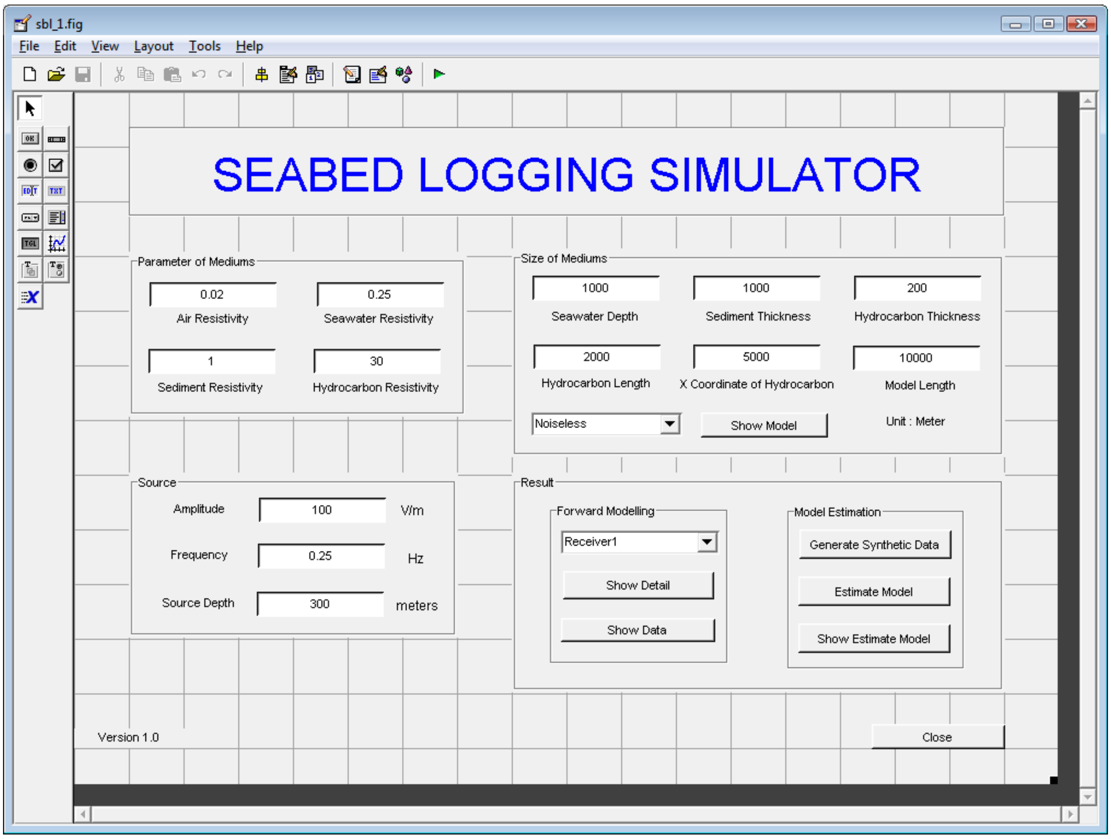


Figure 4 GUI Tool

In this project, the seabed logging simulator is develop by using Graphical User Interface (GUI) function in MATLAB 2007a version. GUI function was choose because the value of the parameter for example positions of receivers, source depth, seawater depth and other parameter can be easily change. Figure 4 show the interface of the GUI tools in MATLAB that will be used to develop the simulator. As shown in the figure, the simulator still under developing stage. Certain parameter and function are not in the simulator yet. Although in the developing the simulator use GUI function, but there are still programming involve such as calculation, plotting the graph and to show the result estimation.

3.5 Seabed Logging Simulator

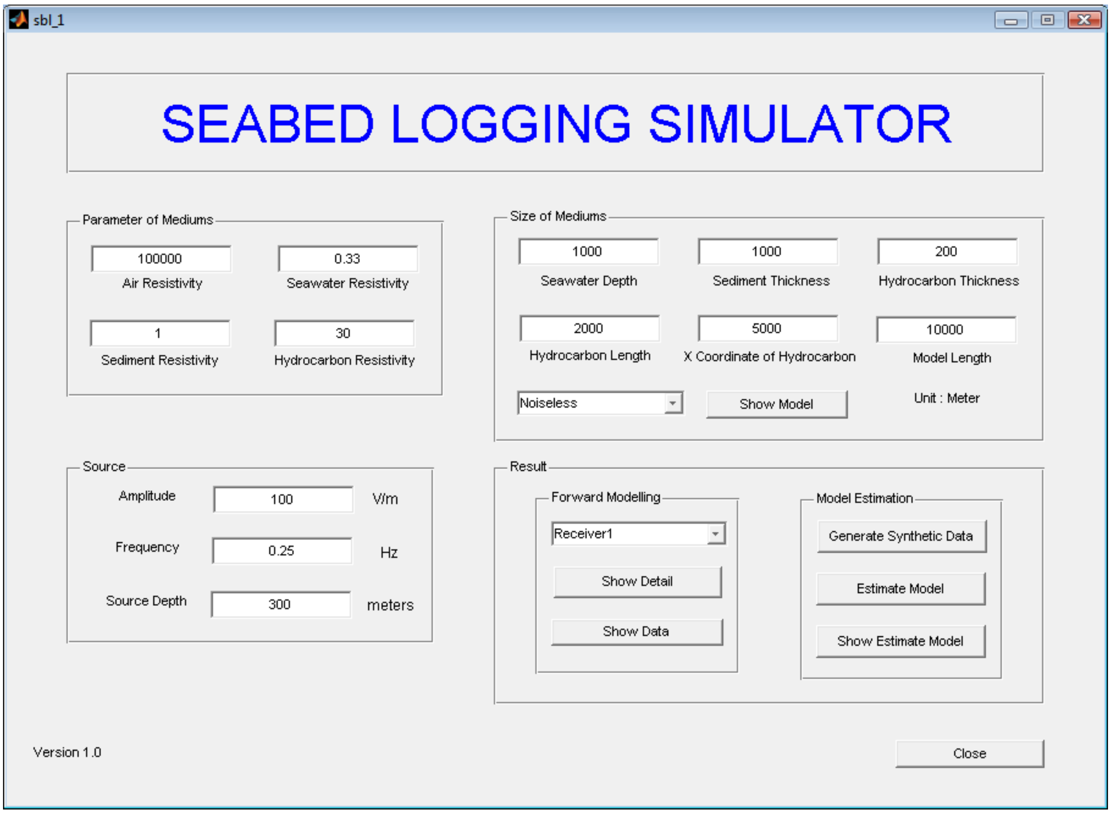


Figure 5 Seabed logging simulator

Figure above show the Seabed Logging Simulator that was design using MATLAB Graphical User Interface. From the simulator, we can change and set each parameter value base on the condition that we desire. To do this, we just type in the value that we want in the input box. There are three main parameters which is parameter of mediums, size of the medium and source parameter

For parameter of medium it consists of input inbox for air resistivity, seawater resistivity, sediment resistivity and hydrocarbon resistivity.

For size of medium it consists of input inbox for seawater depth, sediment thickness, hydrocarbon thickness, hydrocarbon length, coordinate of hydrocarbon and model length.

For source parameter it consists of input inbox for amplitude, frequency and source depth.

In this Seabed Logging simulator, there are also options for noiseless and White Gaussian Noise. If user chose for noiseless option, noise is excluded from the synthetic data at receivers. While if user chose for When the white Gaussian Noise, noise is added to the synthetic data at the receivers.

After all the parameter input has been set, we can see the model just by clicking the Show Model button. An image will appear right after few seconds the button was clicked that show the model set. Below is the example of the image.

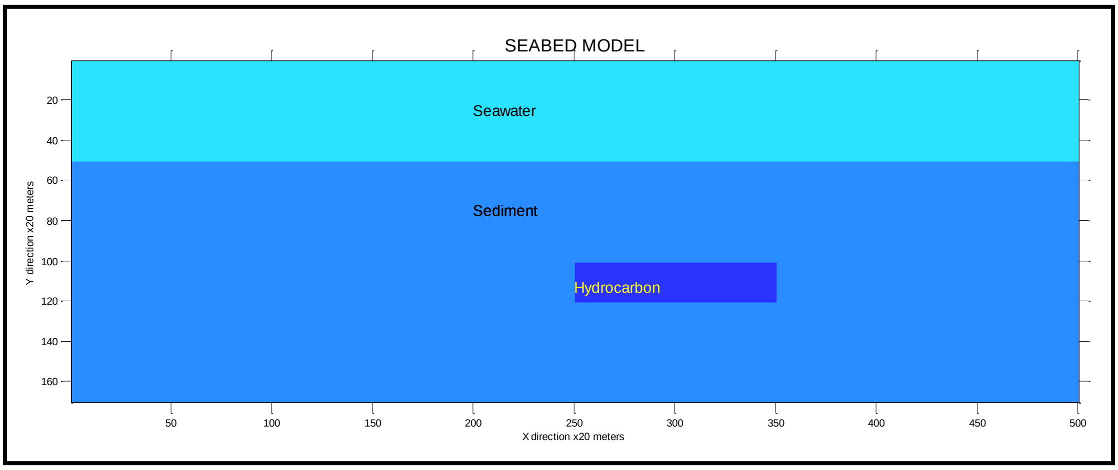


Figure 6 Example of the image model after the button Show Model was clicked

To see the result of the electromagnetic wave to each receiver, first of all we need to choose the receiver we want just by selecting the receiver position that we want from the pop-up menu button. Then press the Show Detail or Show Total button to see the result. If user clicks the Show Detail button, the simulator will show the result for each electromagnetic wave component at the receiver. If user clicks the Show Total button, the simulator will show the total data at the receiver. Graph magnitude vs. distance of receiver will be shown.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Experimental Setup

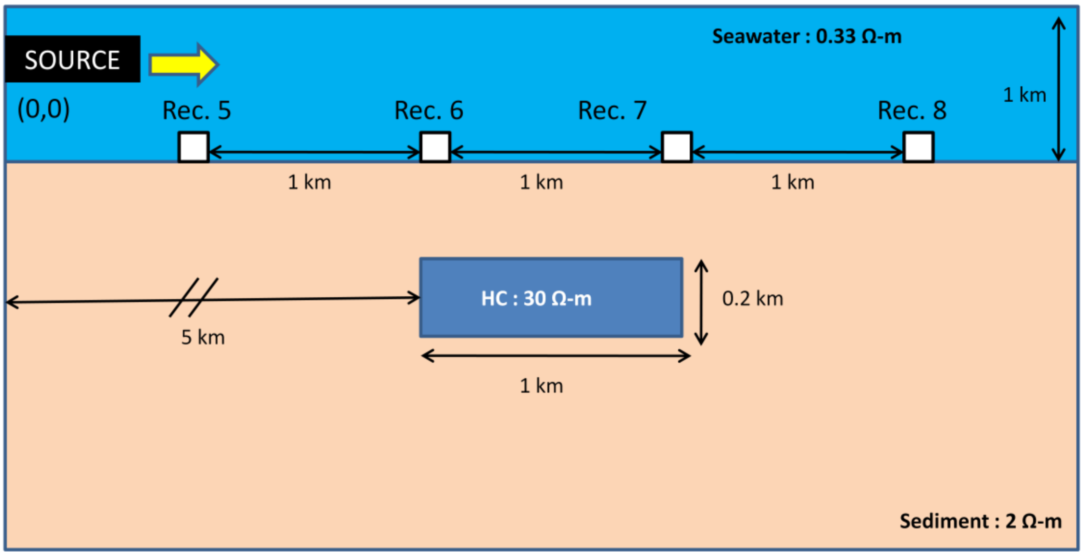


Figure 7 Simulation model for forward modeling

The figure above shows the experimental setup for this simulation. The source transmitter will be moved from origin until the last receiver. From receiver 1 to receiver 11 in the simulator, data from receiver 5, receiver 6, receiver 7, and receiver 8 were chosen. This is because from the figure 6 above, hydrocarbon position is within the receiver 5 to receiver 8. 2 experiments were conducted; forward modeling of Electromagnetic wave propagation and experiment to see the effect of air wave to the receiver when the depth of seawater is vary. All results are shown in section 4.2.

4.2 Results

4.2.1 Forward modeling of Electromagnetic wave propagation result

Magnitude and phase of direct wave electric field at:

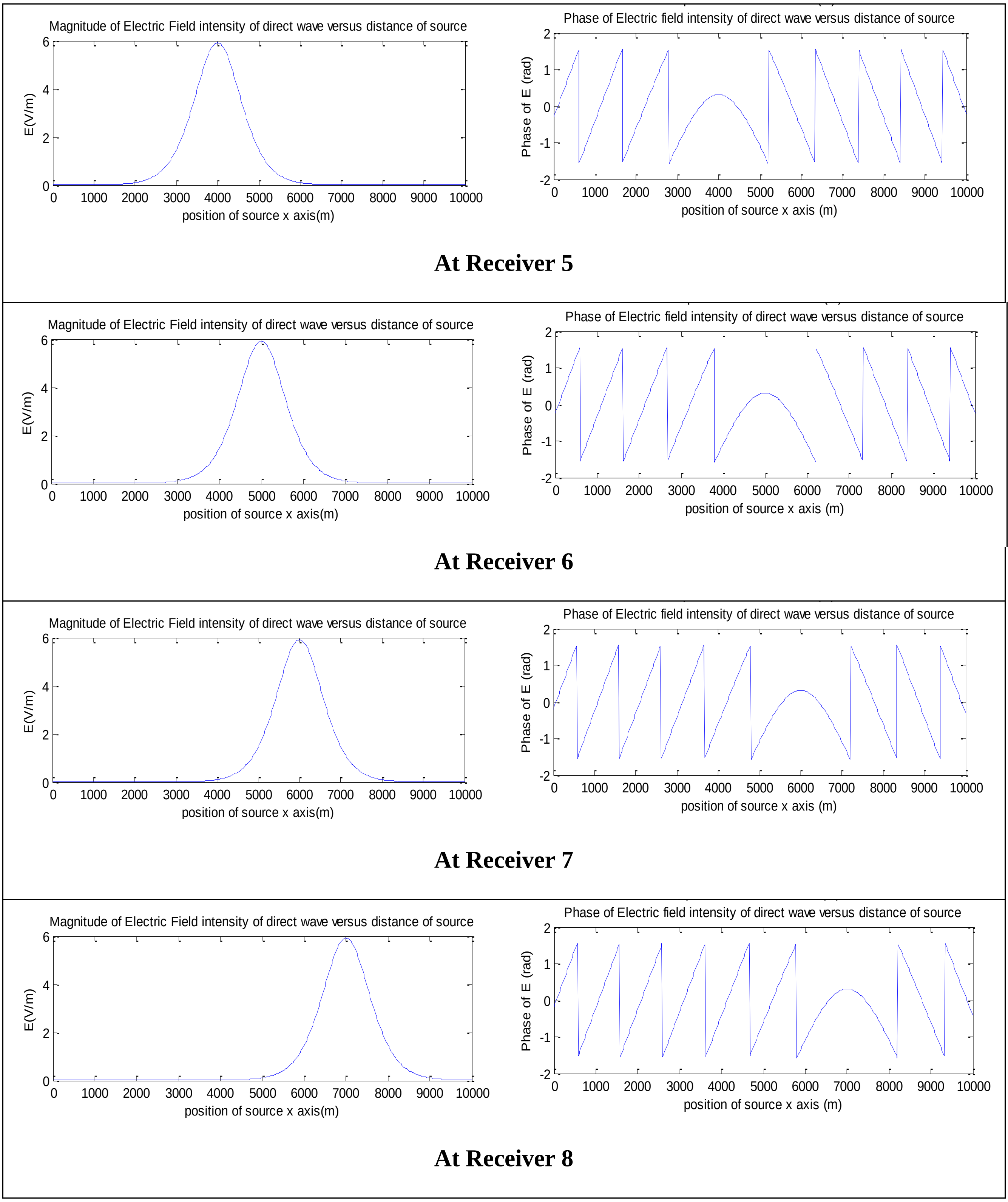


Figure 8 Magnitude and phase of direct wave

Magnitude and phase of airwave electric field at:

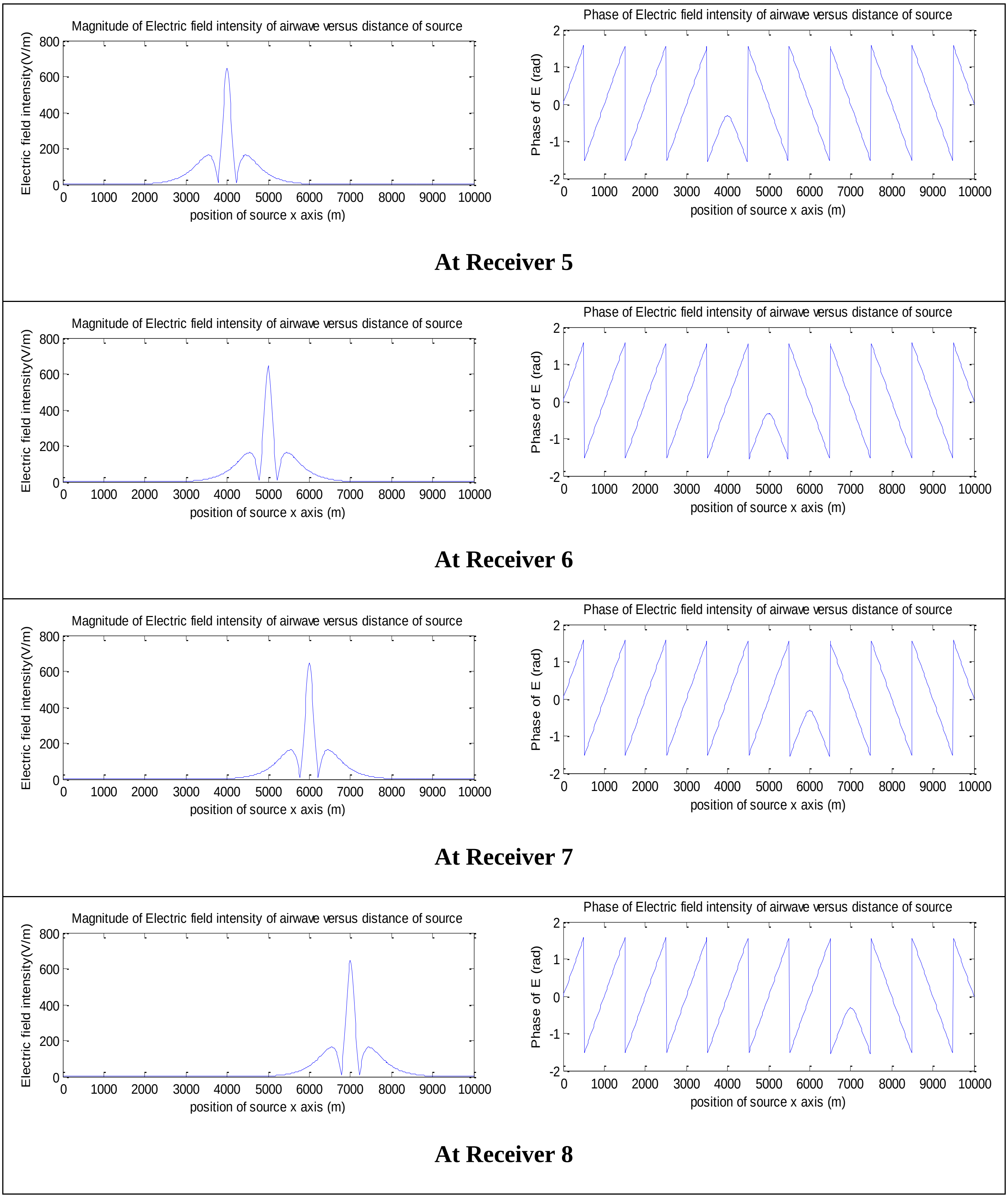


Figure 9 Magnitude and phase of airwave

Magnitude and phase of reflected EM wave from seafloor electric field at:

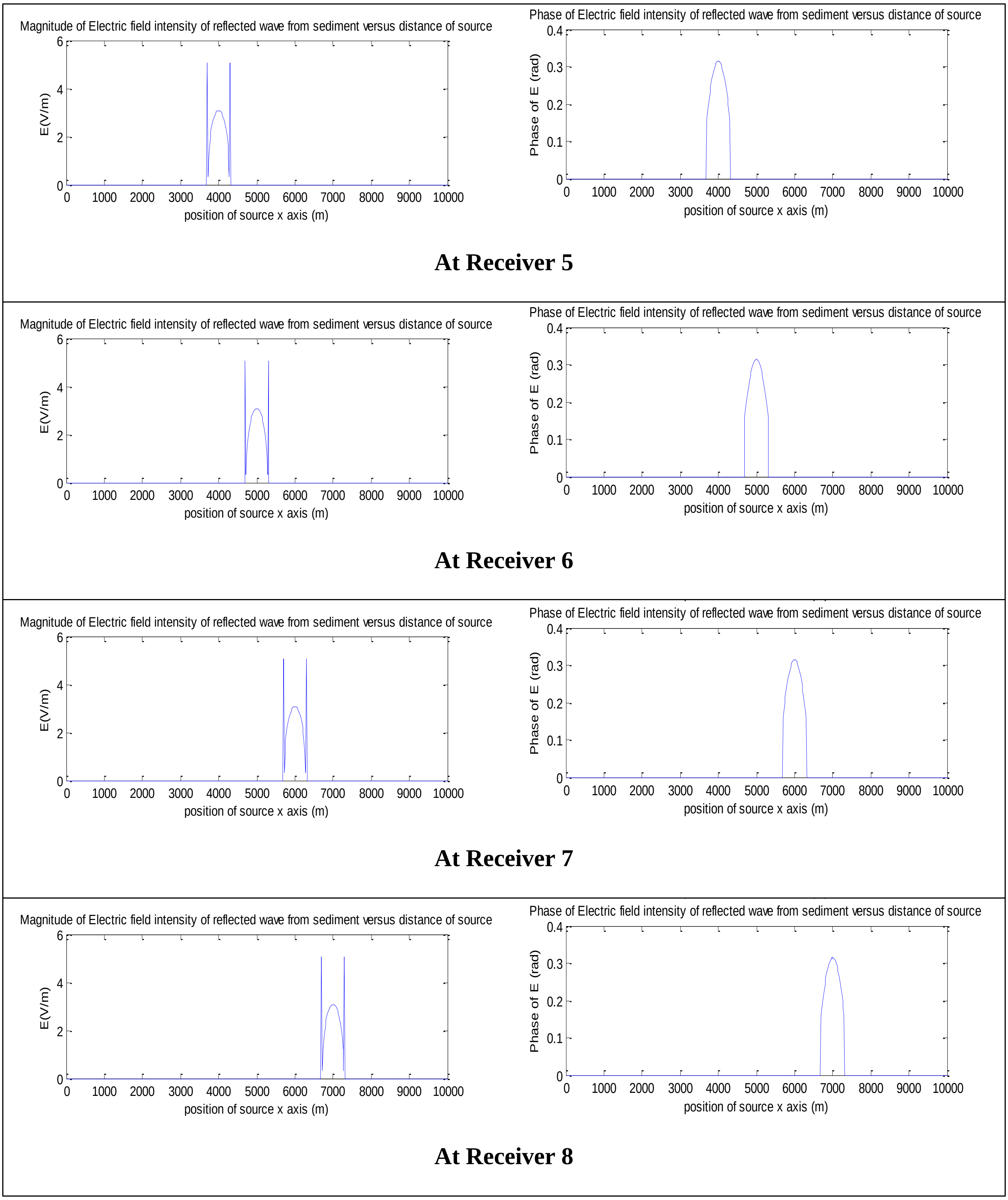


Figure 10 Magnitude and phase of reflected EM wave from seafloor electric field

Magnitude and phase of reflected EM wave from hydrocarbon electric field at:

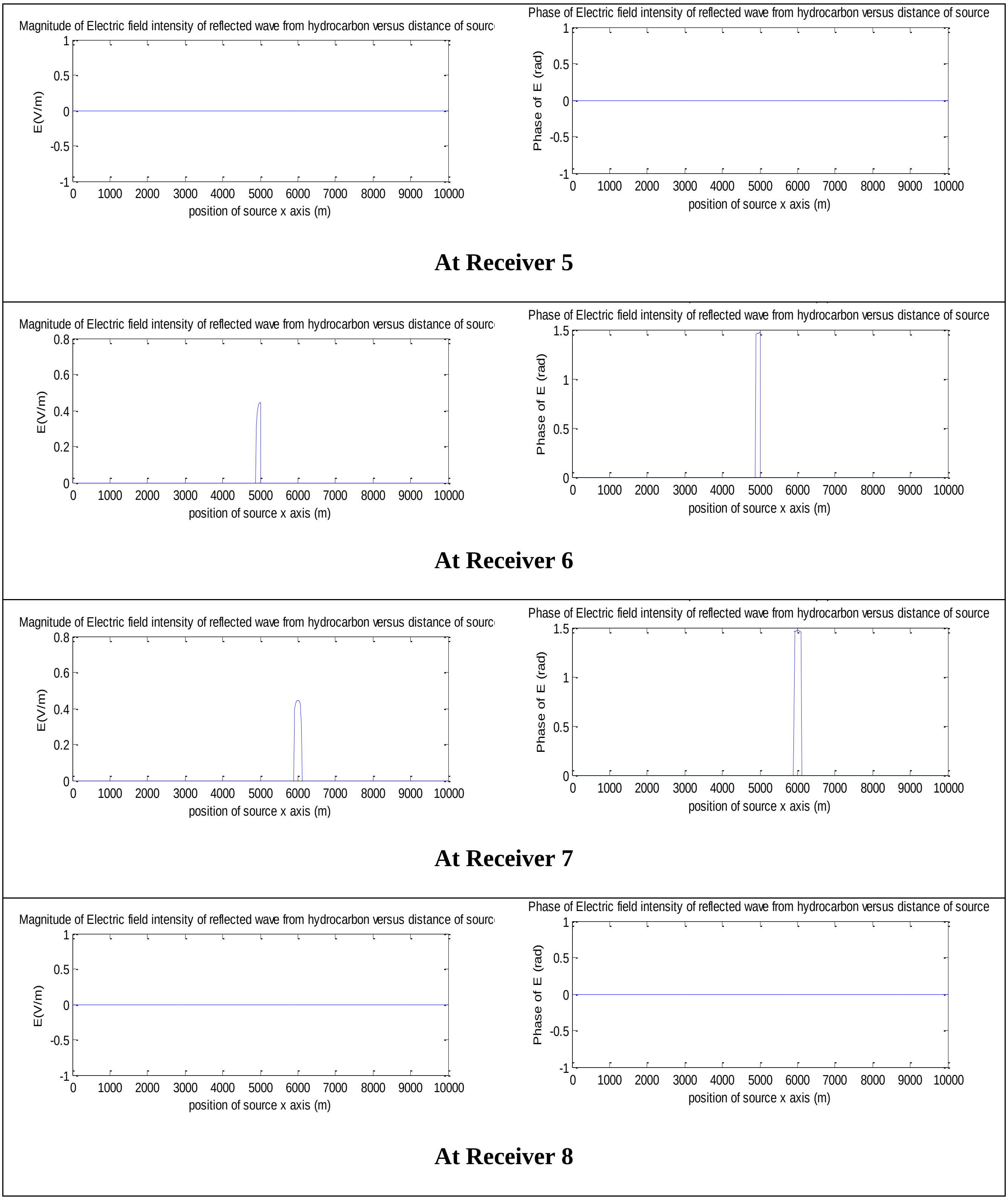


Figure 11 Magnitude and phase of reflected EM wave from hydrocarbon electric field

Magnitude and phase of guided EM wave from hydrocarbon electric field at:

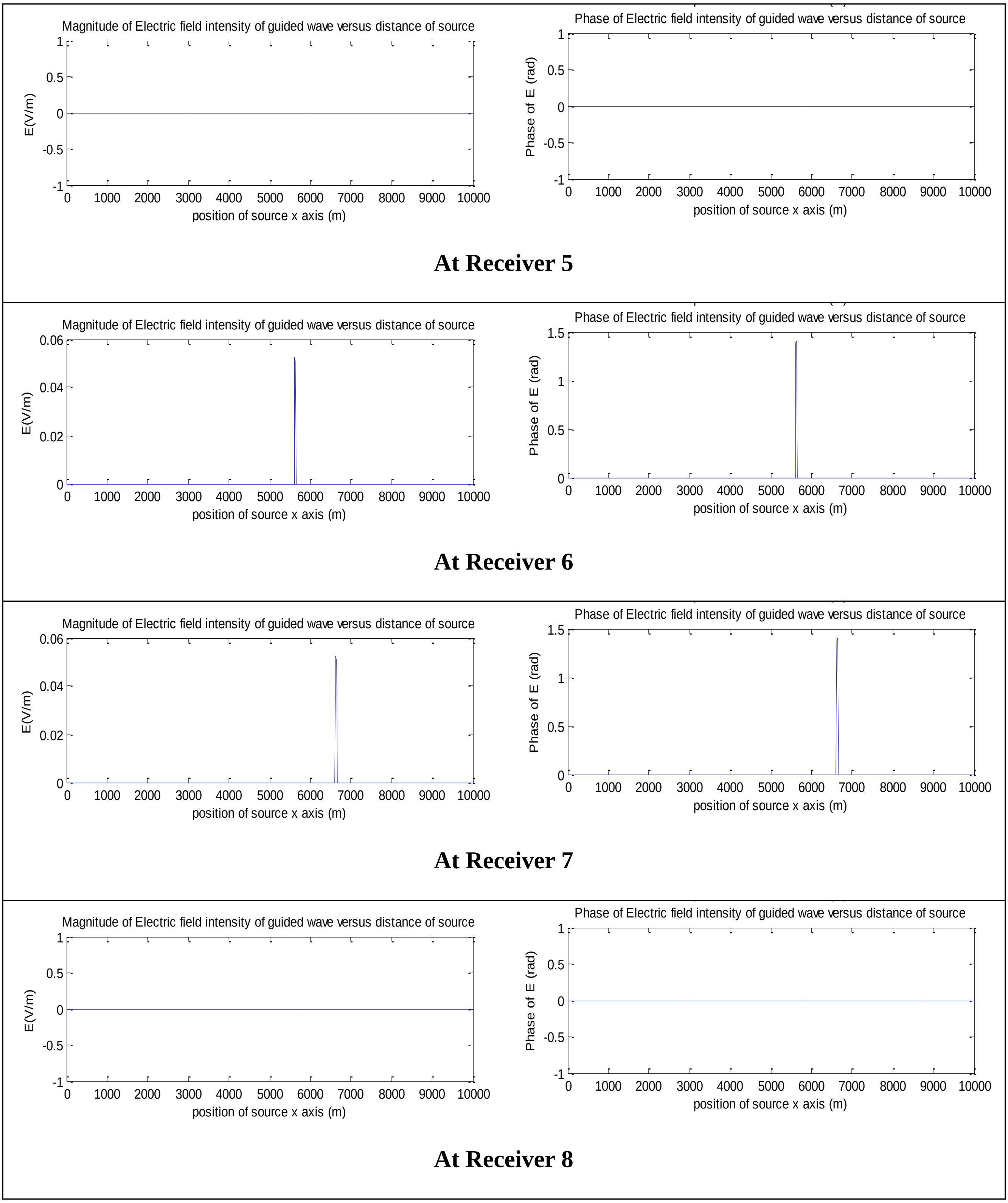
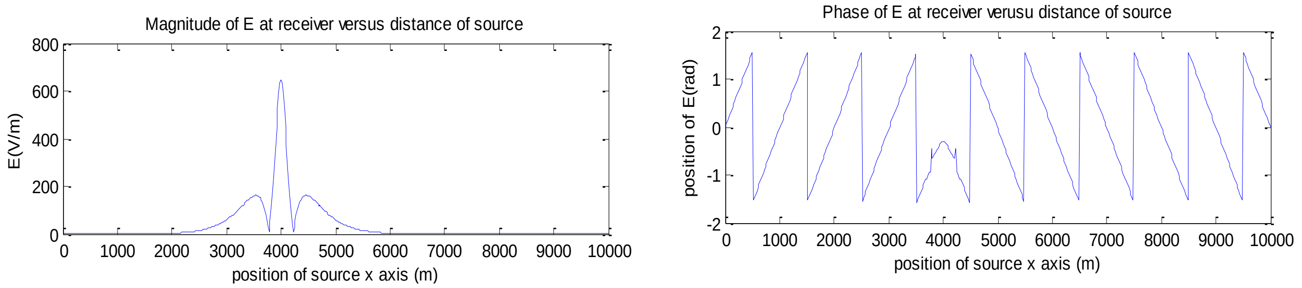
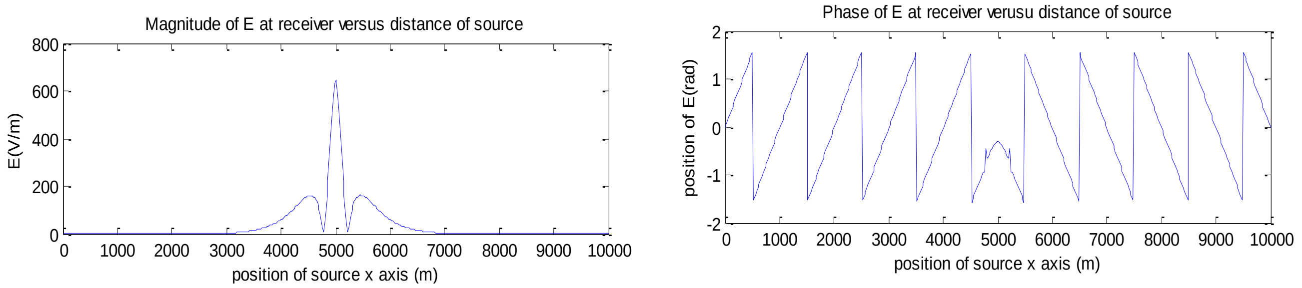


Figure 12 Magnitude and phase of guided EM wave from hydrocarbon electric field

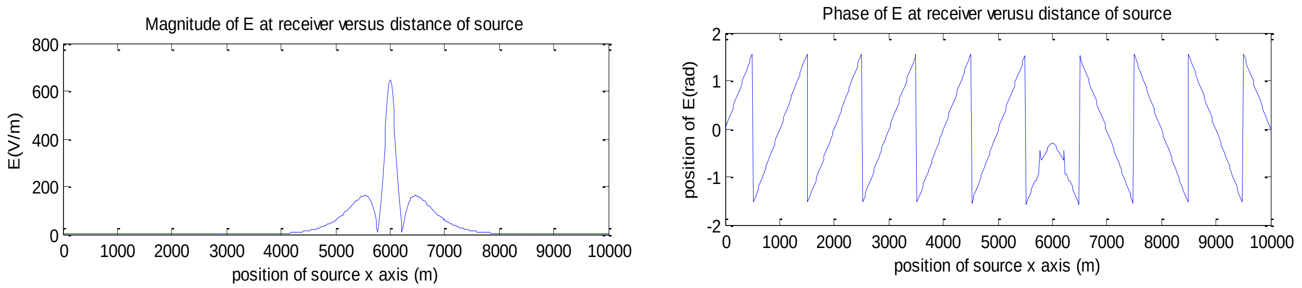
Magnitude of Total EM wave at:



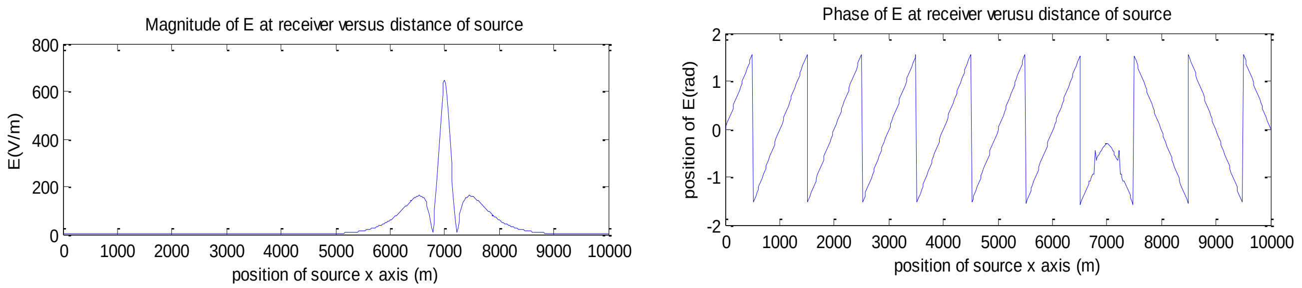
At Receiver 5



At Receiver 6



At Receiver 7



At Receiver 8

Figure 13 Magnitude and phase of Total EM wave

4.2.2 Result of airwave effect to the receiver when seawater depth is vary

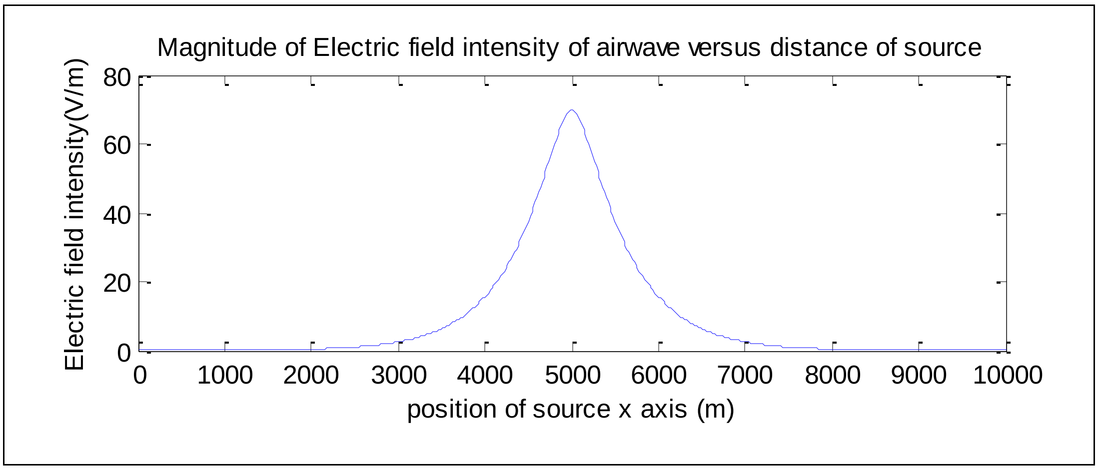


Figure 14 Seawater depth at 250m

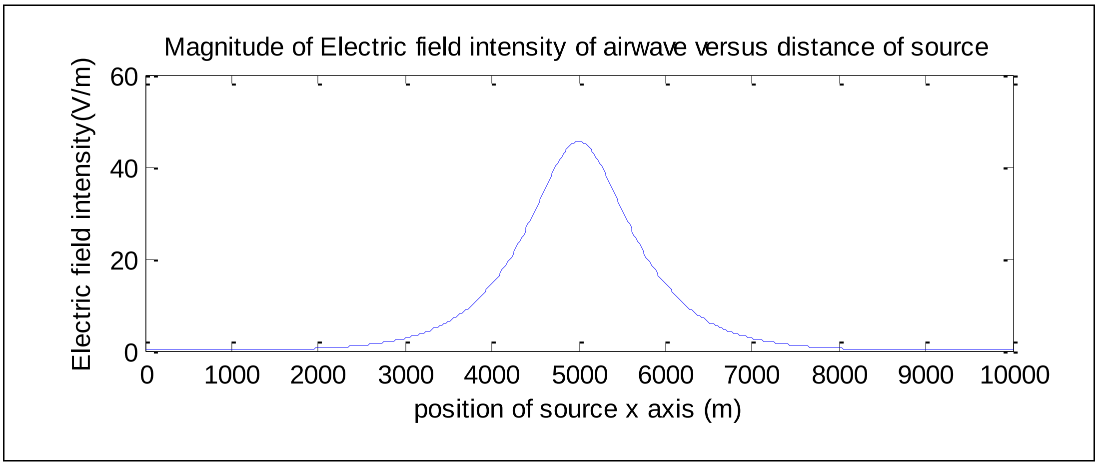


Figure 15 Seawater depth at 500m

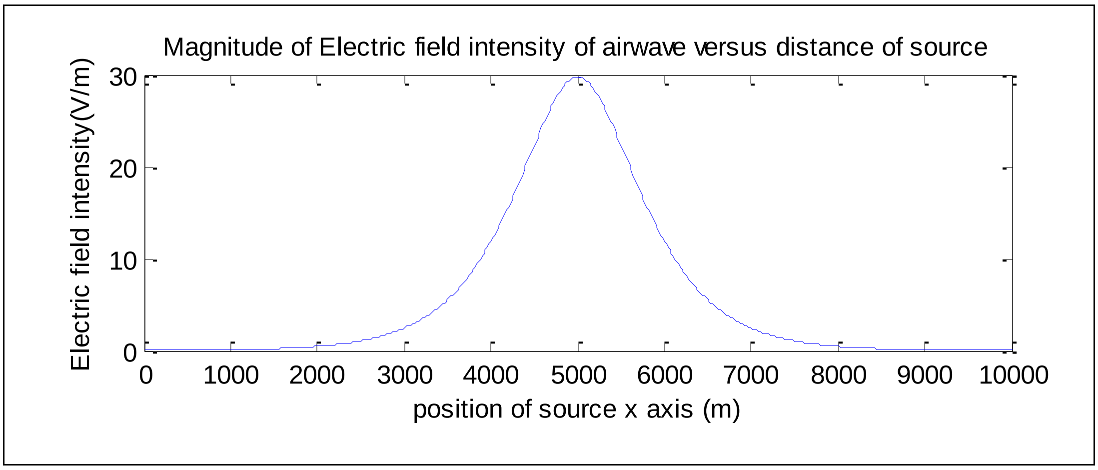


Figure 16 Seawater depth at 750m

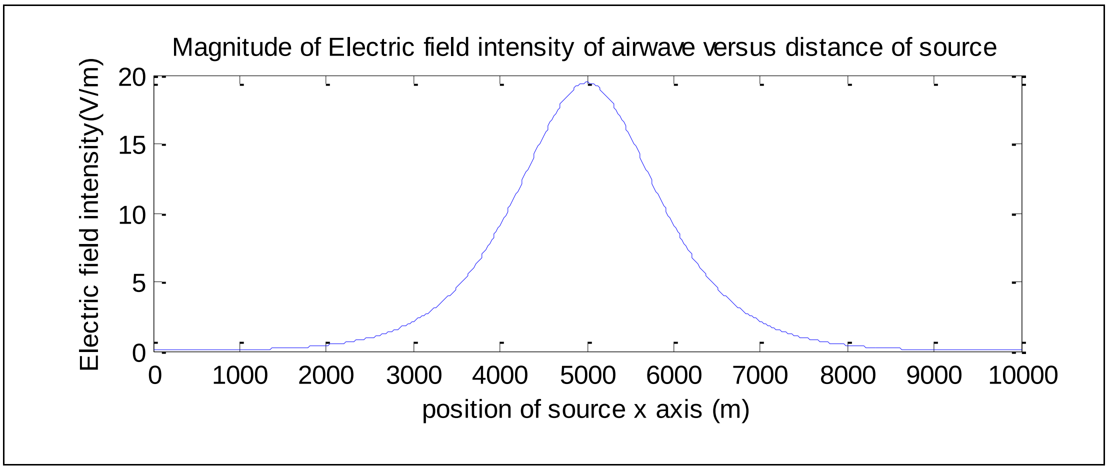


Figure 17 Seawater depth at 1000m

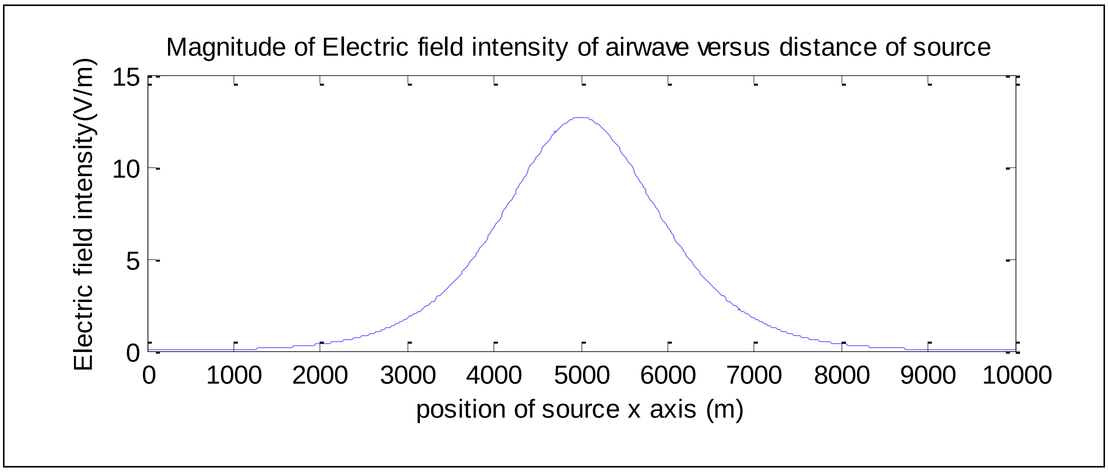


Figure 18 Seawater depth at 1250m

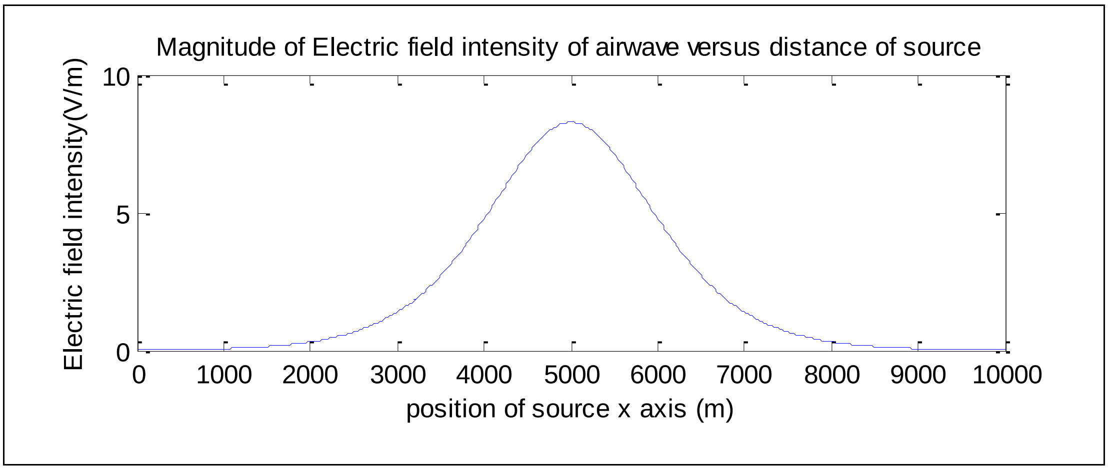


Figure 19 Seawater depth at 1500m

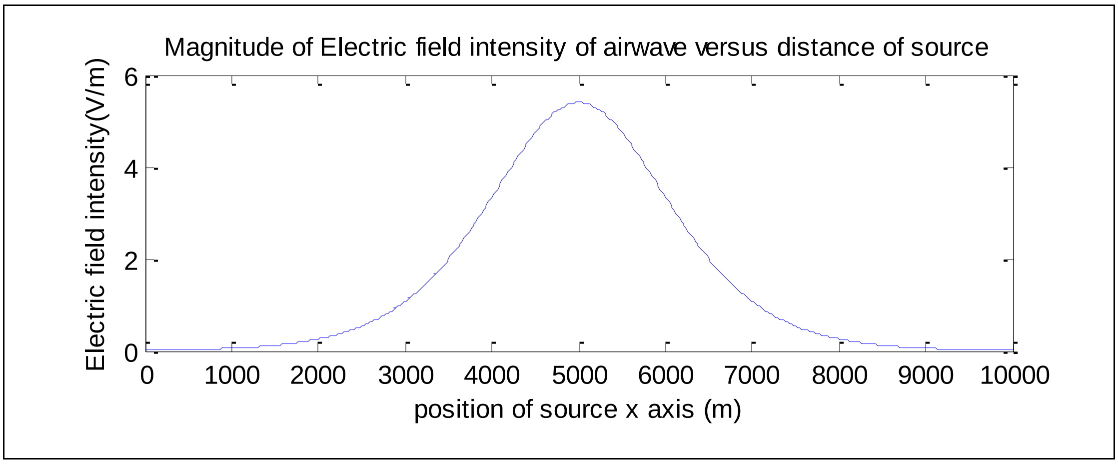


Figure 20 Seawater depth at 1750m

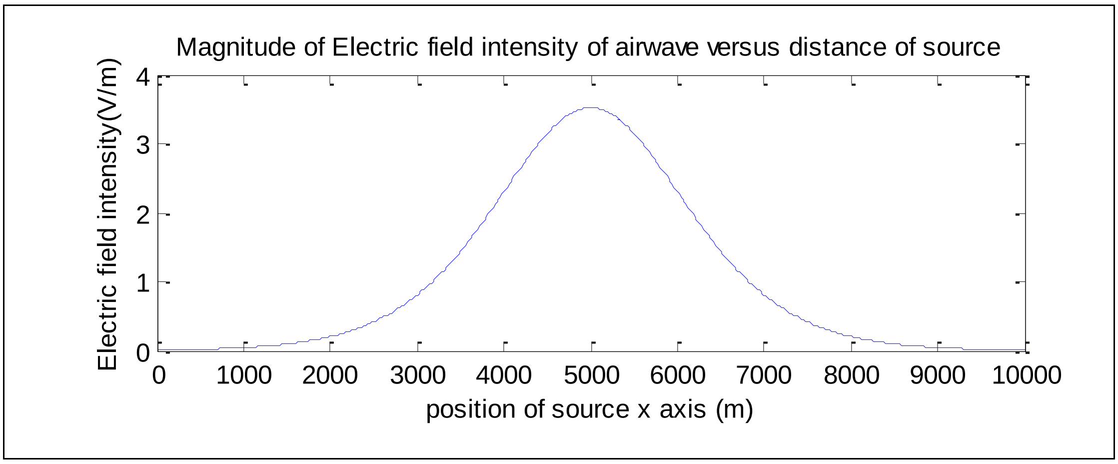


Figure 21 Seawater depth at 2000m

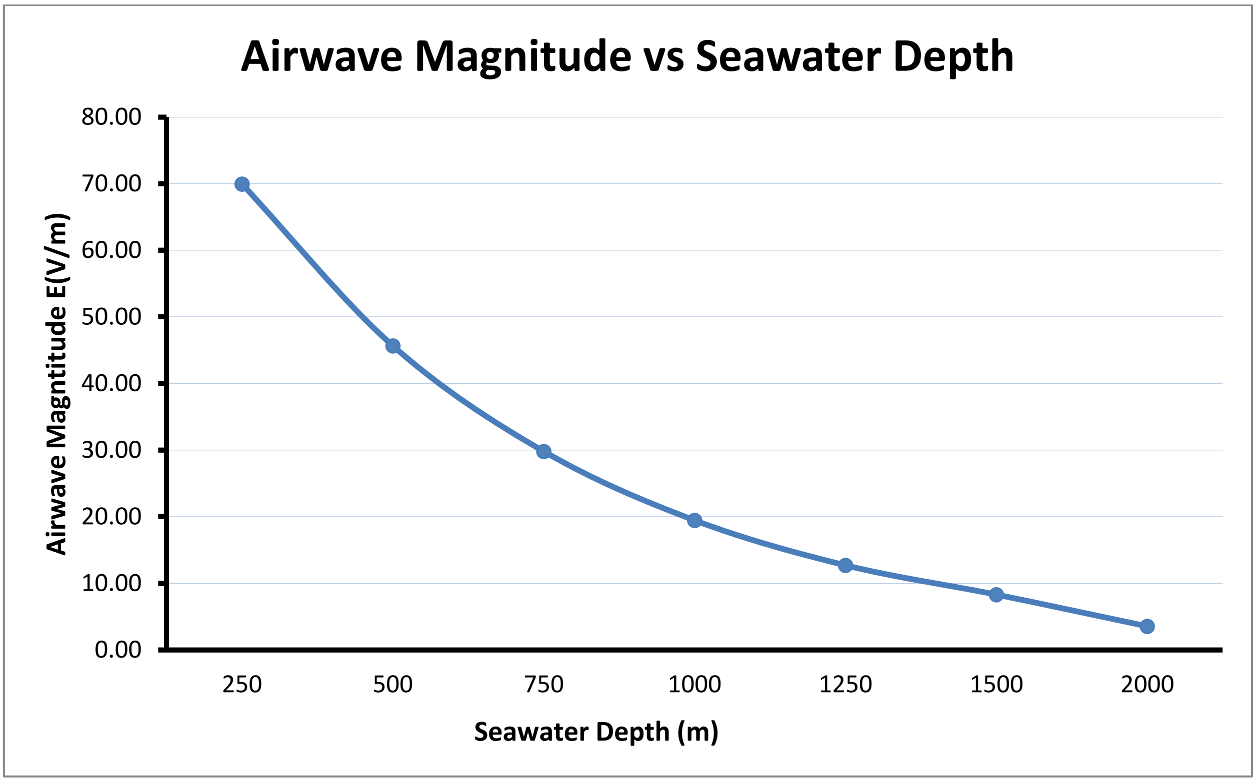


Figure 22 Magnitudes of Airwave vs. Seawater depth at receiver 6

4.3 Discussions

4.3.1 Forward modeling of Electromagnetic wave propagation

From the figure it shows the forward modeling result of direct wave, airwave, reflected EM wave from seafloor, reflected and guided EM wave from hydrocarbon, and the total wave at the receiver 5, receiver 6, receiver 7, and receiver 8. Base from the result achieved, certain conclusion can be made.

The direct wave, airwave and reflected wave from seafloor component, the magnitude and the phase value are the same at all receivers. The direct wave is come from the wave transmitted directly from source transmitter to the receiver. For airwave, the wave is reflected wave from the air water layer and the capture by the receiver. Reflected wave from seafloor is the wave when the source transmitter transmitted EM wave and then was reflected from the seafloor to the receiver. Due to this reason, this direct wave, airwave, and reflected wave from seafloor do not contain any hydrocarbon information.

The result at receiver 6 is same with the result at receiver 7 while the result at receiver 5 is same with the receiver 8. Receiver 6 and receiver 7 show some reading because these receivers capture the reflected and the guided wave from the hydrocarbon. Result at receiver 5 and receiver 8 does not show any reading because there are no reflected and guided waves from hydrocarbon below these receivers.

From the simulation result, we can confirm that there is hydrocarbon reservoir below receiver 6 and receiver 7 with length approximately two kilometers. When running the simulation, certain assumptions were made where the conditions is free from internal and external source, there was no various shape of hydrocarbon reservoirs and other aspects which could happen in real-world survey.

The airwave simulation result shows some error. The experimental was setup for deep water condition. Therefore, there should not be airwave component. From my assumption, the error may be occurring at developing stage of the simulator or maybe some error with the experimental setup. For future work, this problem will be overcome by trying to search the cause of the problem.

4.3.2 Airwave effect to the receiver when depth of seawater increases

The purpose of this experiment is to see the effect of airwave to the receiver when the depth of seawater is increases. Receiver 5 was chosen because we assume that the effect of the airwave is the same at all receivers, regardless with or without present of the hydrocarbon reservoir below it.

From the result obtain, we can see that as the depth of the seawater increases the airwave effect signal magnitude decreases. This is the distance travel by the airwave also increases. During the travel, some of the signal strength is absorb by the seawater and the remaining signal will continue to travel until it been recorded by the receivers. Larger the depth of seawater will cause the airwave to take more time to travel and therefore more signal strength is absorb by the water.

From the result for this model we can see that the airwave give very high to the receiver for the seawater depth less than 1000m (shallow water condition). Seawater depth more than 1000m, airwave effect can be treated as noise to the receiver.

CHAPTER 5
CONCLUSION AND RECOMENDATION

For conclusion we can see that, the existing of the hydrocarbon can be determined from the result of the reflected and guided waves from the hydrocarbon reservoirs capture at the receivers. Base from the result obtained, we can see that the hydrocarbon reservoir exist below receiver 6 until receiver 7 not below receiver 5 and receiver 8. The receiver 6 and receiver 7 capture the reflected and guided wave from the hydrocarbon reservoir.

With model estimation, the mapping of the hydrocarbon reservoir in 2D image can be done. This model estimation use least absolute error method where the real actual data is compare with the synthetic data generate using forward modeling to find the minimum absolute error. This method also shows very accurate result but time consuming to process the data.

With finish of developing the Seabed Logging Simulator although few adjustments must be made to correct the airwave issue, the objective of the first part of the project is achieved. With this simulator, the parameter value for the seabed model can be varying and the simulator will generate forward modeling and the estimated model result. The simulator also can generate result for noiseless and noise condition.

This Seabed Logging Simulator will be used for the second part of the project. In second part of the project, we will focus on three different cases. The first case is for airwave effect. In this case the depth of seawater will be varied from deepwater to the shallow water condition. This is to see at what depth, the airwave start to take effect. For second case are where the frequencies of the source transmitter vary and the hydrocarbon depth stay and for the third cases is when the source frequency constant but the hydrocarbon depth varies. The purposes of both cases are to find suitable source frequency for different hydrocarbon depth.

If time permit, the project will continue to develop 3D mapping of seabed logging. For this part, current technique that used to develop 2D mapping, will be used and expand for 3D mapping.

REFERENCES

[1] Dyke Kate Van Fundamentals of Petroleum [Book]. - Texas : Petroleum Extension Services, 1997. - Vol. Fourth Edition.

[2] Petroleum Technology [Book]. - New Jersy : John Wiley and Sons, Inc., 2007. - Vol. I.

[3] S.E. Johanse H.E.F. Amundsen, T. Rosten, S. Ellingsurd, T. Eidismo and A.H. Bhuyian Subsurface Hydrocarbons detected by electromagnetic sounding [Journal]. - [s.l.] : First Break, 2005. - Vol. 23.

[4] F. Roth F. A. Maao Improving Seabed Logging Sensitivity in Shallow Water Through Up-Down Separation [Journal]. - Trondhiem, Norway : EGM 2007 International Workshop, 2007.

[5] EN Kong H. Westerdhal 'Seabed Logging': A possible direct hydrocarbon for deepsea prospects using EM energy [Journal]. - Oslo : Oil & Gas Journal, 2002. - May 13, 2002 edition.

[6] Chapman Stephen J. MATLAB Programming For Engineers [Book]. - Pasific Groove : Brooks/Cole, 2002.

[7] Ulaby Fawwaz T. Electromagnetics for Engineers [Book]. - New Jersy : Pearson Education, 2005.