CARBON NANOTUBE TRANSMITTER-RECEIVER SYSTEM FOR HYDROCARBON EXPLORATION

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By

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CERTIFICATION OF APPROVAL

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CERTIFICATION OF ORIGINALITY

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

Ahmad Badruzzaman B Ahmad Sallehim

ABSTRACT

Electromagnetic (EM) waves are able to distinguish between water and hydrocarbon due to their high different in resistivity value. The method that used EM technology to explore hydrocarbon is called Seabed Logging (SBL). Due to high demand of hydrocarbon, the improvement of this technology is needed. The project consists of modeling the prototype of EM transmitter and receiver for hydrocarbon exploration by using dipole of Carbon Nanotube (CNT), winding of aluminium and magnetic feeder in toroidal shape. CNT had been chose because it has high conductivity value that important to develop dipole antenna and receiver that can be use hydrocarbon exploration. The main objective of this project is the development of transmitter-receiver prototype. The design is based on Horizontal Electric Dipole (HED) which consist an electric field and the magnetic field which are perpendicularly to each other. The parameters that will be taking into account in designing the antenna and detector are the material, frequency, length and diameter of the antenna. Simulations and experiments have been conducted to study the effect of material, length, diameter and frequency in resulting magnetic field and electric field of the antenna. The required length and diameter has been obtained which are 20cm and 0.3mm respectively. The characterization of Zinc Oxide (ZnO) makes it suitable to be use as detector and being enhanced by adding CNT to the composite. The designed antenna which is CNT dipole antenna with 20 aluminium winding and 3 magnetic feeders achieve an increase in performance by 90.8%. The final prototype which consists of improved CNT dipole antenna and CNT-ZnO detector results in 192% of enhancement.

ACKNOWLEDGEMENTS

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CHAPTER 1
INTRODUCTION

1.1 Background of Study

This research is based on the study of dipole antenna based on electromagnetic wave and antenna propagation. The dipole antenna is one of the most important and commonly used types of radio frequency (RF) and microwave antenna. It has been widely used on its own and also being used or incorporated into many other radio frequency (RF) antenna and microwave antenna where it forms the radiating or driven element for the antenna [1]. One application of dipole antenna is to be use as transmitter in hydrocarbon exploration.

The exploration of hydrocarbon is a difficult task to oil and gas company. Long time ago, seismic technology has been widely employed to search for workable drilling wells. The weakness of this technology is it only can distinguish liquid and solid but unable to distinguish between water and hydrocarbon. The success rate of this technology is very low (10-30%) [2].The new technology on hydrocarbon exploration is using EM (electromagnetic) waves called SeaBed Logging (SBL). The implications are that EM data have the potential to increase detection rates by as much as 50%, or even more [3].

1.2 Problem Statement

The oil price has been increased because of their less production and many oil companies today is the lack of potential new exploration areas. Antenna and detector are very important tools to detect hydrocarbon. An enhancement of the antenna and detector by using material with high conductivity is required to increase the effectiveness of using Electromagnetic Technology in hydrocarbon exploration.

1.3 Objective and Scope of Study

The purpose of this project is to build a dipole antenna and a detector using Carbon Nanotube (CNT) as the material. The objectives of this project are:

- Simulation using Computer Simulation Technology (CST) software.
- Design and characterization of CNT dipole antenna and Zinc Oxide (ZnO) detector.
- Establish the working prototype.

The scope of this project comprises of doing literature research by reading journal related to the matter, laboratory work to demonstrate the effect of magnetic feeder, shape of the antenna, analyze and discuss the result, do the prototype and do testing to reach the target.. The reason that the author decided to choose CNT rather than other material due to it has higher electric conductivity that can propagate stronger EM wave. The CNT is very suitable for SBL application which is the antenna will be placed in the sea water. This project is relevant for the author since her majoring in electrical and electronic engineering. The author also believes to complete the project within the time frame.

1.4 Relevancy of the Project

This project is related to electromagnetic wave which is heavily involved in human's daily life nowadays. 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 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.

CHAPTER 2
LITERATURE REVIEW AND THEORY

2.1 Literature Review

2.1.1 Carbon Nanotube (CNT)

Carbon nanotubes, an extended structure of a fullerence in length, are composed of ultrathin carbon fiber with nanometer-size diameter and micrometer-size length [4]. What is so unique about CNT is due to the different electrical and thermal conductivities they exhibit when their hexagonal structures are orientated differently [4]. CNT also have extremely low electrical resistance and can carry the highest current density of any known material, measured as high 10^9 A/cm² [5]. The electrical conductivity is much higher than copper which is 1000 times conductivity of copper. Thus, that's why it has high potential to be further used as transmitter especially in hydrocarbon exploration.

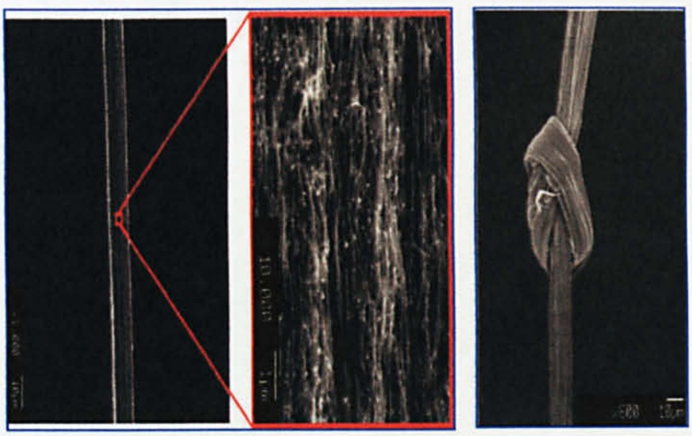


Figure 1: FESEM of Carbon Nanotube

2.1.2 Sea-Bed Logging

SeaBed 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 centre. [6]

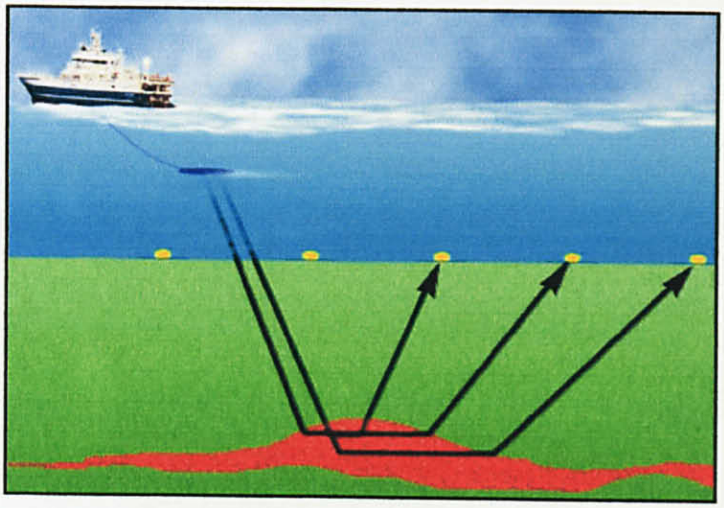


Figure 2: Sea-Bed logging process

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]

2.1.3 Dipole Antenna

A dipole antenna (referred to as half-wave antenna) consists of two lengths of wire rod, or tubing, each 1/4 wavelength long at a certain frequency [1]. It is the basic unit from which many complex antennas are constructed. For a dipole, the current is maximum at the center and minimum at the ends and voltage is minimum at the center and maximum at the ends. This current and associated voltage causes electromagnetic signal to be radiated [1]. Specifically, a dipole is generally taken to be an antenna that consists of resonant length of conductor cut to enable it to be connected to the feeder [1].

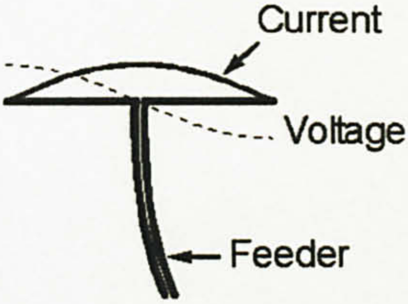


Figure 3: Basic half wave dipole antenna [1]

For a dipole to be resonant, a dipole must be electrically a half wavelength long at the operating frequency. A dipole's resonance occurs at the length at which its impedance has no reactance (only resistance) at a given frequency. The lowest frequency at which a dipole is resonant is known as its fundamental resonance [8]. A dipole works best at and above its fundamental resonant frequency.

2.1.4 Magnetic Feeders

A paper of Excitation of a long wire antenna by F.N. Kong, H. Westerdahl and F. Antonsen [7] is discussed about their finding on using different size of magnetic feeders (toroid ferrite rings) to enhance antennas with lengths 0.3m until 50m. The range of frequency that has been used also varied from 200 MHz and 1 Hz depends on the applications. According to this paper, when a metal cylinder (an antenna conductor) is inserted at the middle of the ferrite core, the energy of magnetic flux will transfer into the current flowing along the antenna conductor. They also had constructed an experiment to prove the efficiency of ferrite core in feeding long wire antennas by using two ferrite rings. One is for feeding the power to the antenna conductor which placed at 2m from one of the end wire and the other one is for receiving the power from the currents flowing along the antenna conductor that placed at 1m apart from the transmitter ring. From the result, it is proved that utilization of magnetic feeder can enhance electric field of the dipole antenna. They also mention that for Seabed logging application (frequency range from 0.1 Hz to 5 Hz), high μ ferrite material is important for implementing magnetic antennas at that frequency range. The advantage of using ferrite rings are it is simple and no physical contact between the feeder and the wire.

2.2 Theory

2.2.1 Electromagnetic Wave

An electromagnetic wave consists of two primary components which is electric field and magnetic field. The electric field results from the force of voltage, and the magnetic field results from the flow of current. Although electromagnetic fields that are radiated are commonly considered to be waves, under certain circumstances their behavior makes them appear to have some of the properties of particles. In general, however, it is easier to picture electromagnetic radiation in space as horizontal and vertical lines of force oriented at right angles to each other [9]. These lines of force are made up of an electric field (E) and a magnetic field (H), which together makes up the electromagnetic field in space.

The electric and magnetic fields radiated from an antenna form the electromagnetic field. This field is responsible for the transmission and reception of electromagnetic energy through free space. An antenna, however, is also part of the electrical circuit of a transmitter or a receiver and is equivalent to a circuit containing inductance, capacitance, and resistance [9]. Therefore, the antenna can be expected definite voltage and current relationships with respect to a given input [1]. A current through the antenna produces a magnetic field, and a charge on the antenna produces an electric field. These two fields combine to form the induction field [9].

Electromagnetic waves travel at the speed of light in vacuum, but they travel more slowly when they pass through various media such as air, glass, and water. A relationship among frequency, wavelength and speed exists for electromagnetic waves; the product of frequency and wavelength equals the speed of light. Thus wavelength and frequency are inversely related. The longer the frequency lower is the wavelength and vice versa.

$$c = f\lambda$$

Where,

c : Speed of the light = 3×10^{8} m/s

λ : Wavelength of EM wave [1]

From the Maxwell equation, we know that electric and magnetic field is perpendicular to each other. This phenomenon can be illustrated by this figure below:

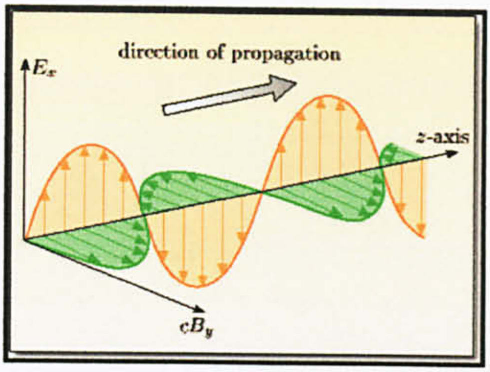


Figure 4: Spatial variation of E and H on plane wave [10]

2.2.2 Magnetic Field inside a Toroidal Core

A toroidal coil is a doughnut-shaped structure with closely spaced turns of wire wrapped around it as shown in this figure below:

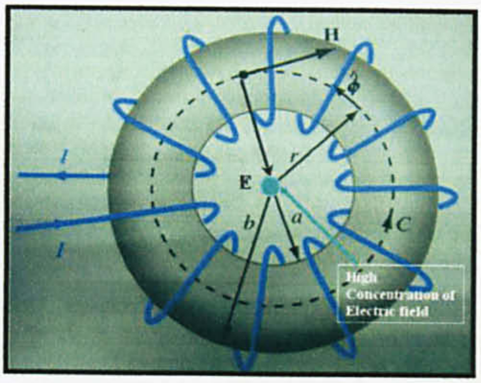


Figure 5: Toroidal coil with wire windings [11]

When we supply current through wire winding, magnetic field, H is enclosed in the toroid body. Since magnetic field is always perpendicular to the electric field, the electric field is concentrated at the centre of the toroid. When the dipoles are placed in the concentrated electric field, a high amount of current will flow in the dipole. [12]

2.2.3 *Skin Depth*

This theory states the capability of electromagnetic wave to penetrate a medium. By using the formula given, we know that the depth at which the amplitude of the EM wave is reduced to 0.37 factor of the original wave. The skin depth, D in an arbitrary material is given by:

$$D=\left(\frac{\sqrt{2}}{\omega\sqrt{\mu\varepsilon}}\right)\left[\sqrt{1+\left(\frac{\sigma}{\omega\varepsilon}\right)^{2}}-1\right]^{-\frac{1}{2}} \qquad [13]$$

Where μ is the permeability, σ is the conductivity and ε is the permittivity of the medium [14].

2.2.4 *Biot-Savart Law*

When a linear conductor is carrying a current I, there is a magnetic flux density is induced around the conductor. The phenomenon is illustrated in this figure below:

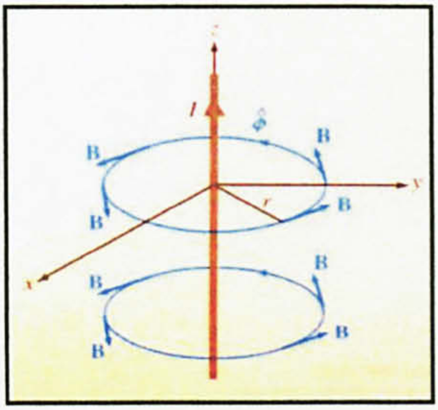


Figure 6: The magnetic field induced by a steady current flowing in z-direction [11]

From the Biot-Savart law equation, we can determine the strength of the magnetic flux density B by this following equation:

$$B = \frac{\mu_o I}{2\pi r} \qquad [3]$$

Where r is the distance between antenna and the point in space, μ_o is permeability in free space [11]. From this equation, it is proved that when the distance between antenna and the point in space is increased, the magnetic flux density will decreased. The other conclusion is current supply is proportional to magnetic flux density. When value of I is increased, B also have the higher value.

CHAPTER 3
METHODOLOGY

3.1 Procedure Identification

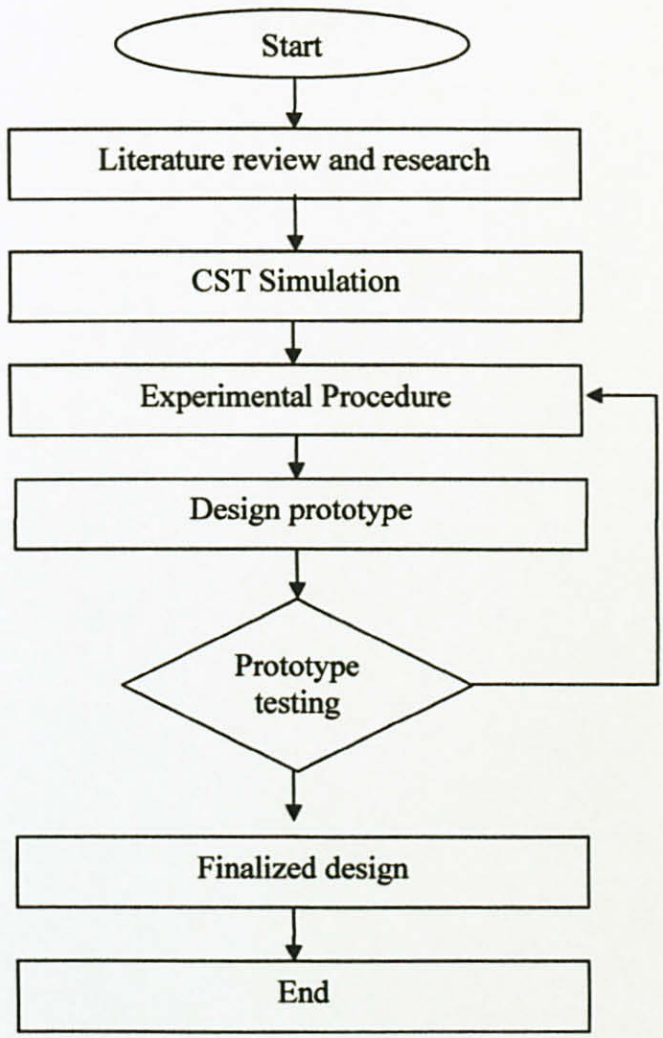


Figure 7: Flow chart of the project

3.2 Simulation

3.2.1 Material Selection

The material that will be used for the dipole antenna need to be determined by conducting preliminary experiment and simulation to see what material give best results for the antenna. The electrical conductivity of the material is the most important characteristic that must take into account for the material selection.

Electrical conductivity is a measure of how well a material accommodates the movement of an electric charge. It is the ratio of the current density to the electric field strength [11]. Table below shows conductivity of some materials:

Table 1: Conductivity of some materials

Material	Conductivity, σ (S/m)
Silver	6.2×10^{7}
Copper	5.8×10^{7}
Gold	4.1×10^{7}
Aluminium	3.5×10^{7}
Iron	10^{7}
Mercury	10^{6}
Carbon	3×10^{4}

As shown in table above, silver has the highest conductivity compared to others but because of its cost, copper and aluminium are the best material that can be take into consideration to be used as material in the simulation of this project to be compared to CNT.

3.2.2 Antenna Length

Antenna length is very important in designing a dipole antenna. A dipole can be any length, but it most commonly is just under 1/2 wavelength long. A dipole with this length, known as a resonant or half wave dipole has input impedance that is purely resistive and lies between 30 and 80 ohms, which provide a good match to commercially available 50 ohms coaxial cables as well as commercial transmitters and receivers, most of which have 50 ohm output and input impedances [4]. The length of a dipole can be approximately determined from the following formula [4]:

$$\ell = 468/f$$

where:

ℓ is the length in feet and

f is the frequency

The length of a dipole is the main determining factor of operating frequency of the dipole antenna. The effect of the length also will alter the radiation pattern of the antenna [1].

Simulations using CST have been done to investigate and obtain the optimum length of the dipole antenna. By fixing the material, diameter and frequency, various lengths have been simulated.

3.2.3 Antenna Diameter

A dipole antenna with right diameter also will elevate optimum transmission for hydrocarbon exploration. Simulations using CST have been done to investigate and obtain the diameter of the dipole antenna. By fixing the material, length and operating frequency, various diameters have been simulated and investigated.

3.3 Experimental Procedure

A CNT with parameters shown in Table 2 is being used for experiment 1, experiment 2 and experiment 3. The equipments used are function generator, oscilloscope, wires and receivers.

Table 2: CNT properties for experiment

Length (cm)	10.0
Diameter (mm)	0.5
Electrical Conductivity	5.8×10^{10} S/m

3.3.1 Experiment 1

Figure 8 and 9 below show the experimental setup in ambient environment:

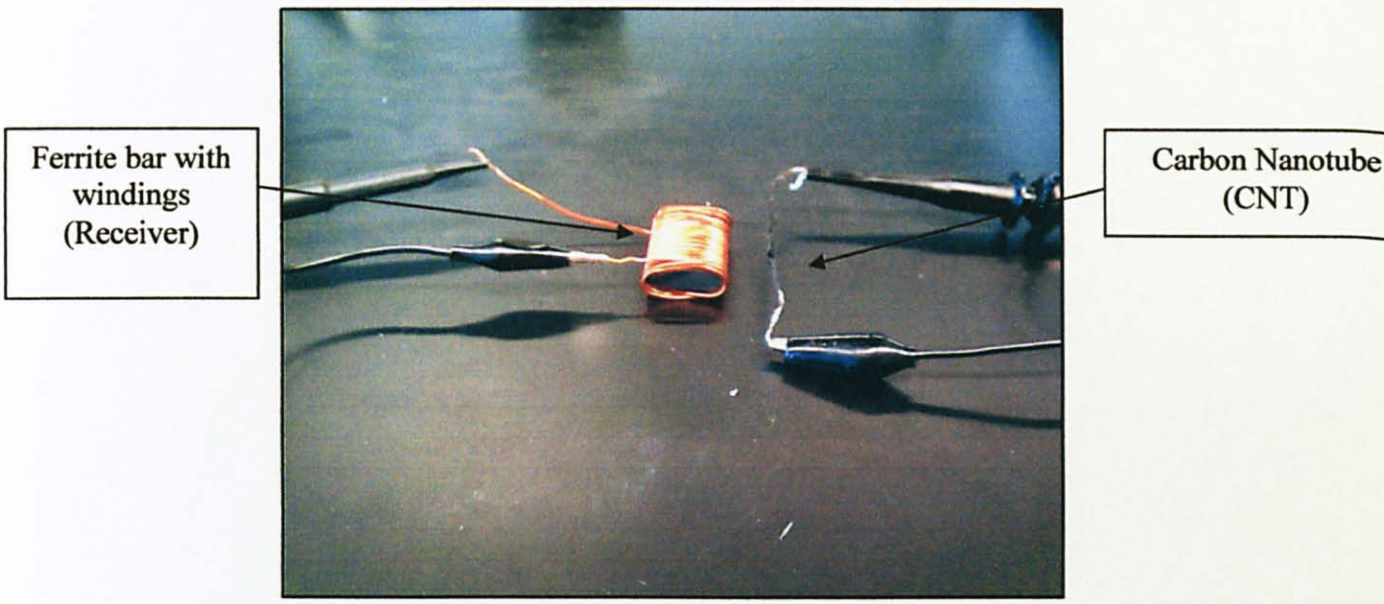


Figure 8: Experiment using CNT and ferrite bar

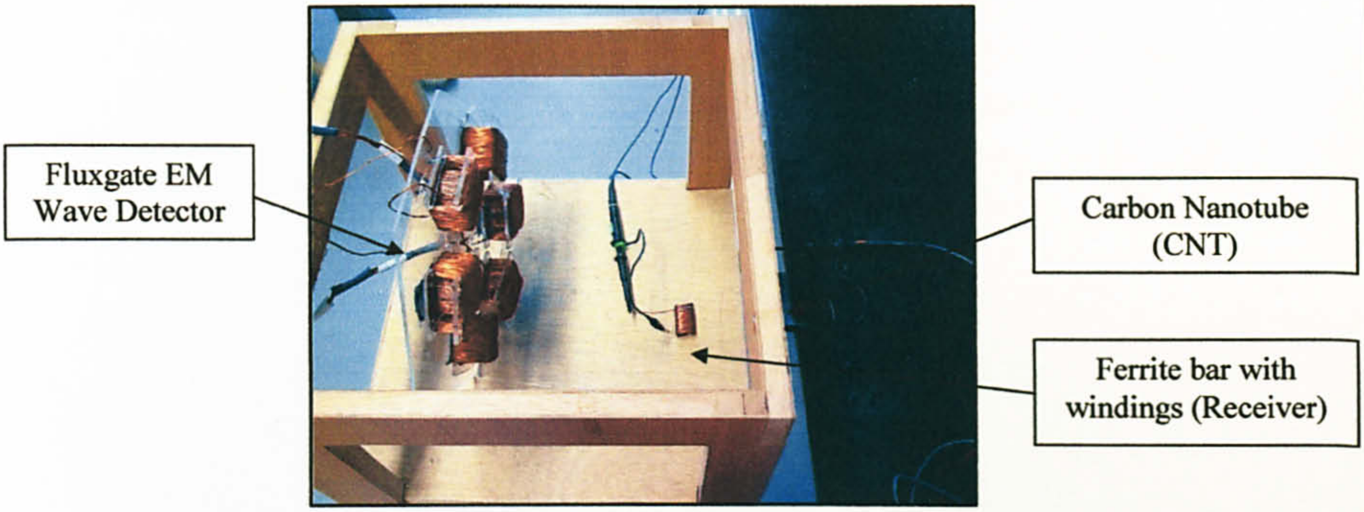


Figure 9: Experiment using CNT, ferrite bar and fluxgate EM detector

The purpose of the experiment is to test the transmitting signal of the CNT for different distances from the receiver. The experiment also was done to test the transmitting signal received by different type of receivers. Summary of the experiment shown in table 3 below:

Table 3: Summary of experiment 1

Frequency	40MHz
Distance (CNT to the receivers)	i. 20cm ii. 40cm iii. 60cm iv. 80cm v. 100cm
Type of receivers	i. Ferrite bar with 30 copper windings. ii. Fluxgate EM Wave Detector

3.3.2 Experiment 2

Figure 10 below shows the experimental setup for salt water environment. The objective of testing the dipole antenna in salt water is to observe and test the transmitting signal of the antenna in resistive environment. The experiment also was done to investigate the antenna capability to transmit with different operating frequency.

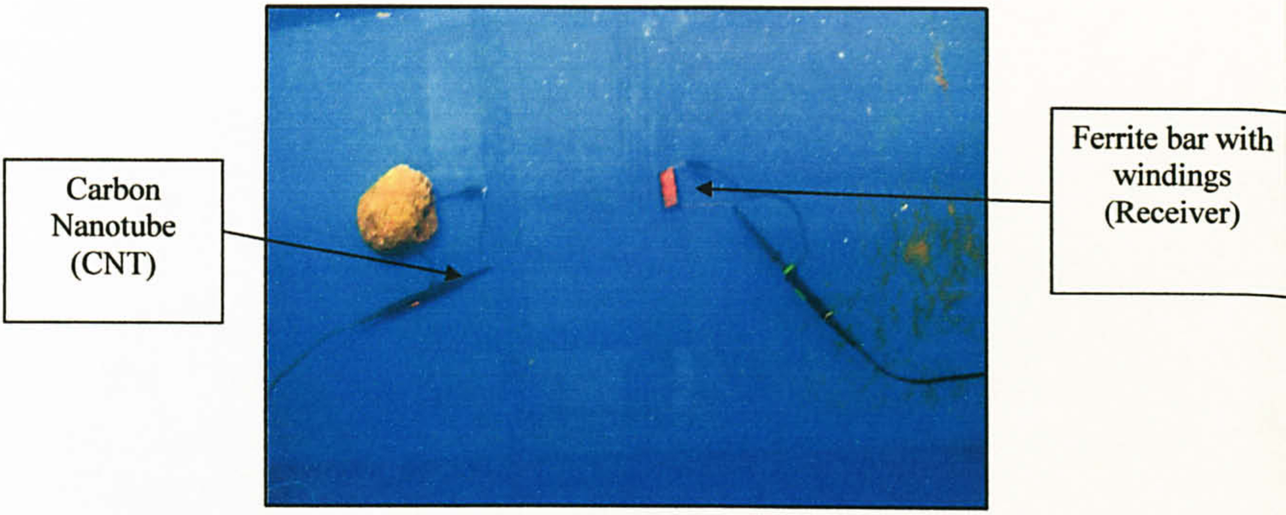


Figure 10: Experiment in salt water

Summary of the experiment:

Table 4: Summary of experiment 2

Resistivity of salt water	1.7 ohm
Frequency	10MHz – 50MHz
Receiver	Ferrite bar with 30 copper windings
Distance (CNT to the receiver)	i. 0.5m ii. 1.0m iii. 1.5m

3.3.3 Experiment 3

Experiment using aluminium and CNT was done to verify that CNT is the best material for this project. The objective of the experiment is to compare the output voltage detected for aluminium and CNT to verify that CNT is the best material

Table 5: Summary of CNT and aluminium comparison experiment

Material	CNT	Aluminium
Length	20cm	20cm
Frequency	40MHz	40MHz
Distance to receiver	100cm	100cm

The CNT dipole antenna then was wind with 20 turns of aluminium rod. Experiment to compare the CNT and CNT with aluminium winding were done and investigated.

3.3.4 Experiment 4

The best design obtained from the comparison of CNT and CNT with aluminium winding then had been enhanced by adding magnetic feeders. The magnetic feeder was added one by one until four. The magnetic feeders used are shown in figure 11 below. The objective of this experiment is to investigate the effect of magnetic feeders towards the magnetic field strength of the antenna.

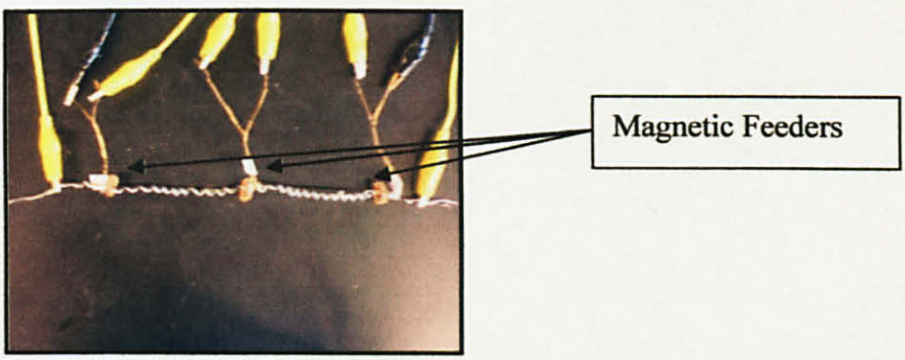


Figure 11: Magnetic feeders and CNT dipole antenna

3.3.5 Experiment 5

Different shapes of the antenna being tested to obtain the best design of the antenna. The objective of this experiment is to investigate the effect of different curves towards the focus point and magnetic field strength of the antenna. Five shapes of curve as illustrate in figure 12 below were investigated

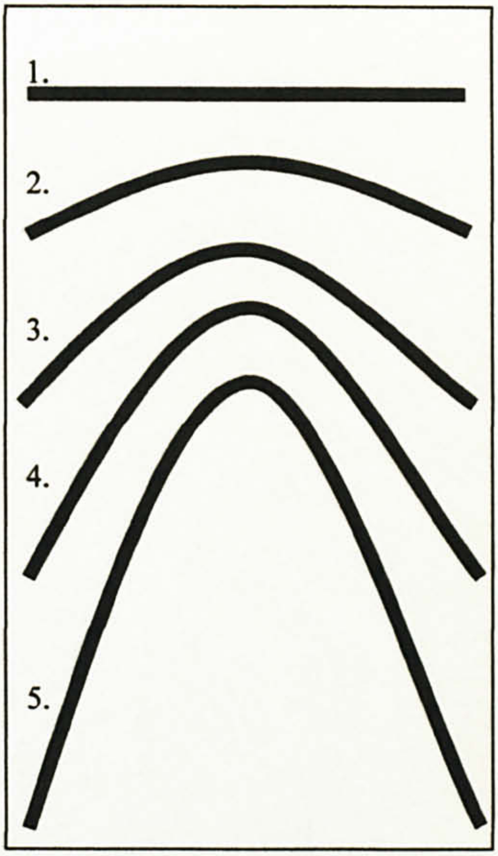


Figure 12: Different curves of the antenna

3.3.6 CNT-ZnO Receiver Preparation

The preparation of CNT-ZnO receiver requires few steps to be completed. The steps are simplified as below:

i. 0.8g of CNT being dispersed using mixture of H_2SO_4 and HNO_3 at 50^0C for 7 hours time. The dispersed CNT then being dried at 60^0C.

Figure 13: CNT dispersion using Sonicator

ii. Mixing of PVDF (Polyvinylidene fluoride) + Propylene carbonate + CNT + ZnO (Zinc Oxide). The calculation of raw material for preparation of PVDF shown below:

Density of propylene carbonate = 1.205 g/ml

At 25ml of propylene carbonate used,

M= 1.205*25

= 30.125 g

For 10% PVDF in propylene carbonate,

$M_{PVDF} = 0.1*30.125 = 3.0125g$

For 5 % of ZnO in PVDF,

$M_{ZNO} = 0.05*3.0125 = 0.1506g$

For 5% of CNT in PVDF,

$M_{CNT} = 0.05*3.0125 = 0.1506g$

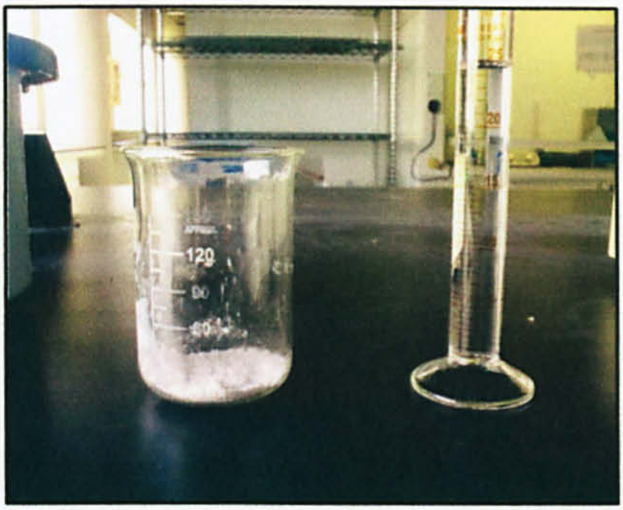


Figure 14: 3.0125g of PVDF and 25ml of propylene carbonate

3.4 Prototype Testing

The final part of this project is to test the designed CNT dipole antenna with CNT-ZnO detector. The objective of the experiment is to demonstrate the effect of ZNO detector as well as CNT-ZnO detector. Summary of the prototype testing is shown in Table 6 below.

Table 6: Summary of prototype testing

Frequency	40MHz
Distance (CNT to the receivers)	100cm
Type of receivers	i. ZnO only ii. ZnO + CNT

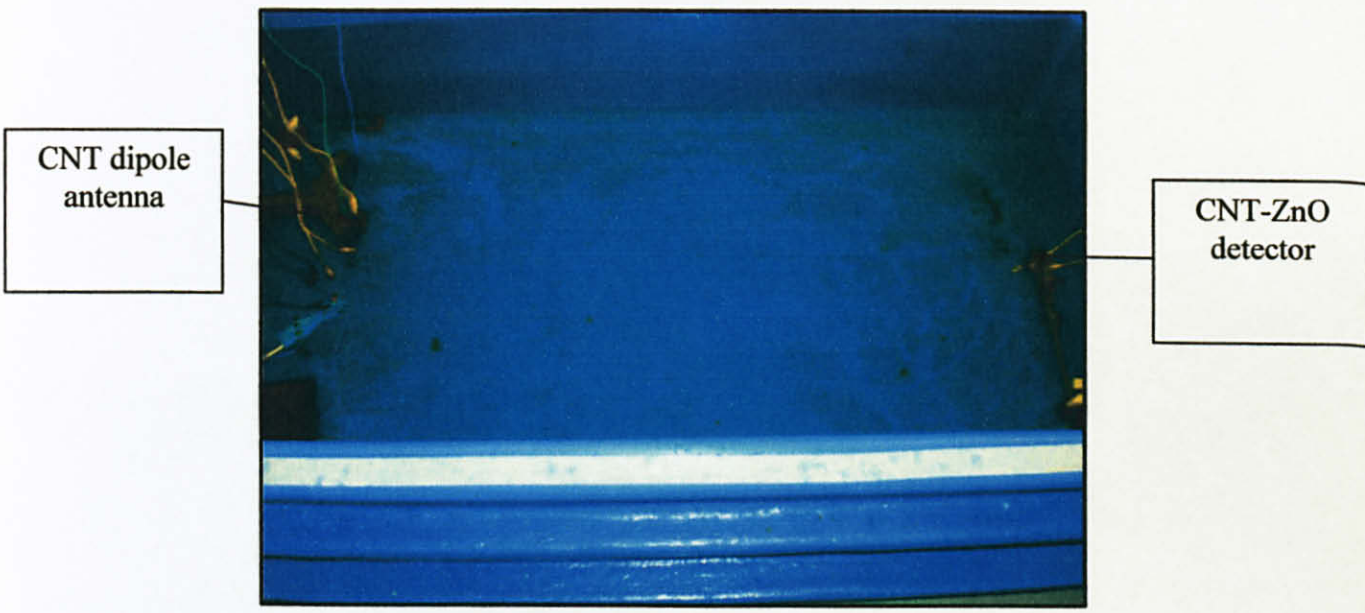


Figure 15: Experimental setup for prototype testing

CHAPTER 4
RESULT AND DISCUSSION

4.1 Simulation

4.1.1 Material Simulation

A simulation using CST (Computer Simulation Technology) has been done to determine the best material to be used in designing the antenna. For this simulation, copper and aluminium have been simulated to see the magnetic field, electric field, magnetic field density and electric field density. The current path, frequency, radius and length are fixed to 0.5A, 1kHz, 2mm and 20mm respectively. The simulation results shown below:

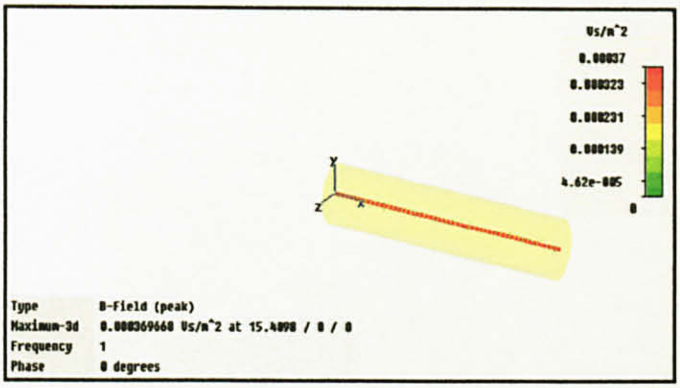


Figure 16: Simulation for copper

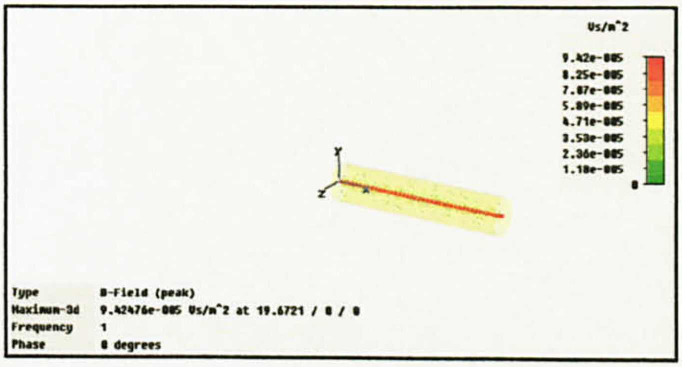


Figure 17: Simulation for aluminium

Table 7: Simulation results for copper and aluminium

Material	Copper	Aluminium
Magnetic Field (T)	3.697×10^{-3}	9.425×10^{-5}
Electric Field (V/m)	0.0217	0.00308
Magnetic Field Density (A/m)	294.172	74.998
Electric Field Density (C/m^2)	1.922×10^{-14}	2.730×10^{-14}

From the results, we can see that copper is better than aluminium. Thus the material that will be used throughout this project to be compared to CNT is copper.

4.1.2 Effect of the Length

Simulations have been done to study the effect of the length in antenna design. For these simulations, there are five lengths that been simulated which are 5cm, 10cm, 15cm,20 cm and 25 cm.

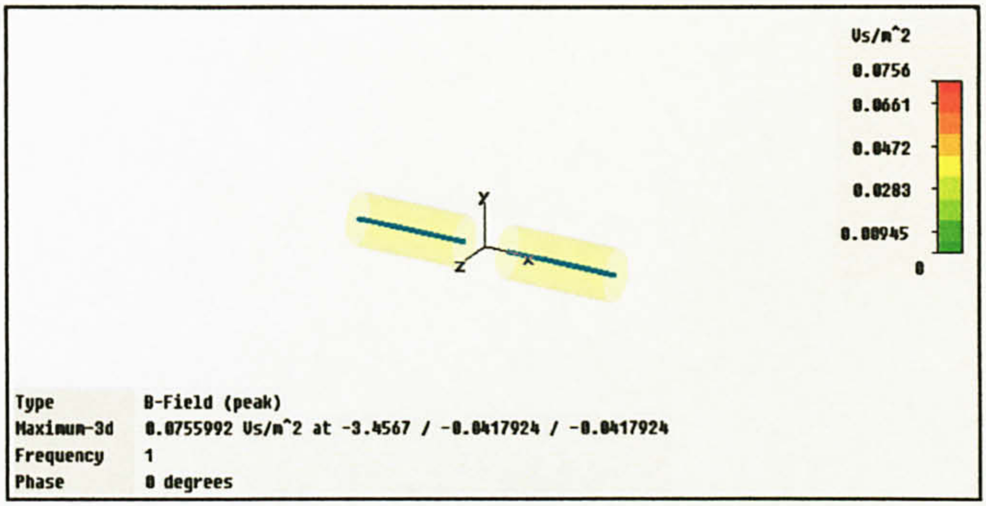


Figure 18: Simulation to determine the effect of the length

The material, voltage path and radius are fixed to copper, 5V, and 2mm respectively. The simulation results are shown in table below:

Table 8: Simulation results for different length

Length (cm)	5	10	15	20	25
Magnetic Field (T)	0.0756	0.0764	0.0868	0.1117	0.1203
Electric Field (V/m)	14848.0	14801.0	14743.2	14767.9	14670.9
Magnetic Field Density (A/m)	60159.9	60770.0	69117.7	88891.9	95809.0
Electric Field Density (C/m²)	$1.315\text{x}10^{-7}$	$1.311\text{x}10^{-7}$	$1.307\text{x}10^{-7}$	$1.303\text{x}10^{-7}$	$1.299\text{x}10^{-7}$

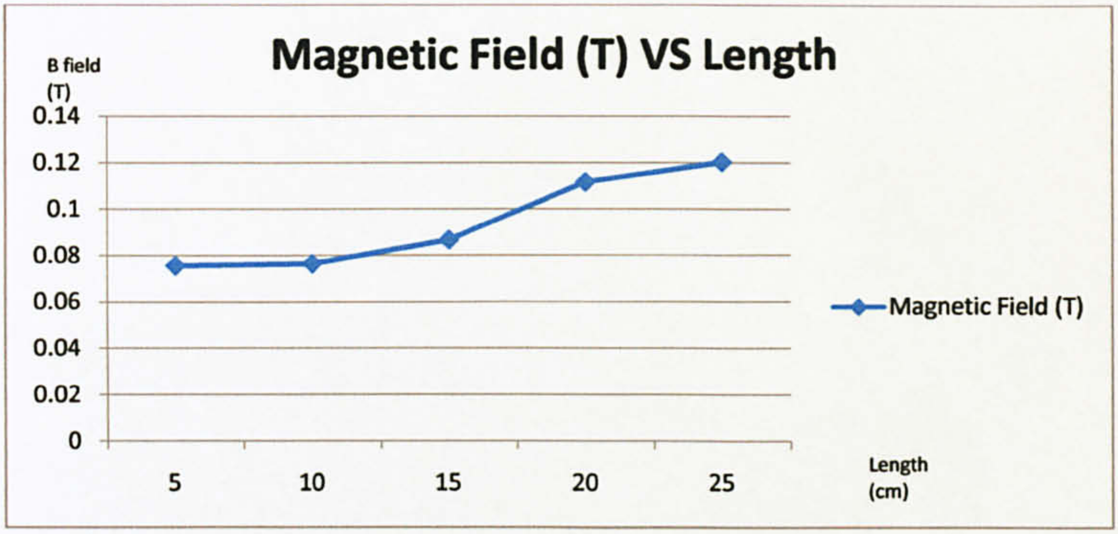


Figure 19: Magnetic field versus length of the antenna

The results show that increase in length of the dipole antenna from 5cm to 25cm will result in increasing the magnetic field by 59.1%.

4.1.2 Effect of Diameter

The possible diameter to be use for small dipole antenna for microwave hyperthermia is between 0.2mm to 1.4mm. Thus, simulations have been done to investigate and obtain the required diameter for the small dipole antenna. The parameters used are:

Table 9: Parameters for diameter simulation

Parameters	
Frequency	1kHz
Length	20mm
Material	Copper

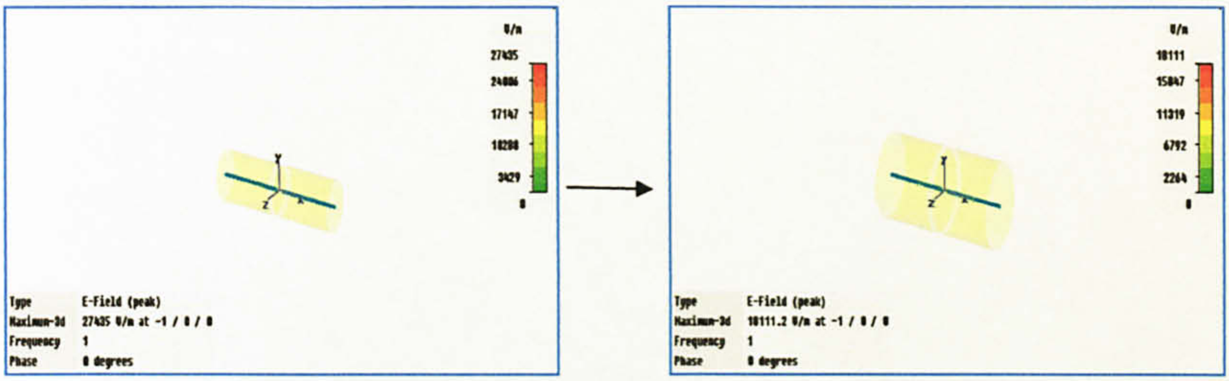


Figure 20: Diameter simulation from 0.2mm to 1.4mm

Table and figure below shows the results of diameter simulation from 0.2mm to 1.4mm.

Table 10: Simulation results for different diameter

Diameter (mm)	Magenetic field (T)
0.2	0.0752
0.4	0.0817
0.6	0.0963
0.8	0.1046
1	0.1124
1.2	0.1226
1.4	0.1274

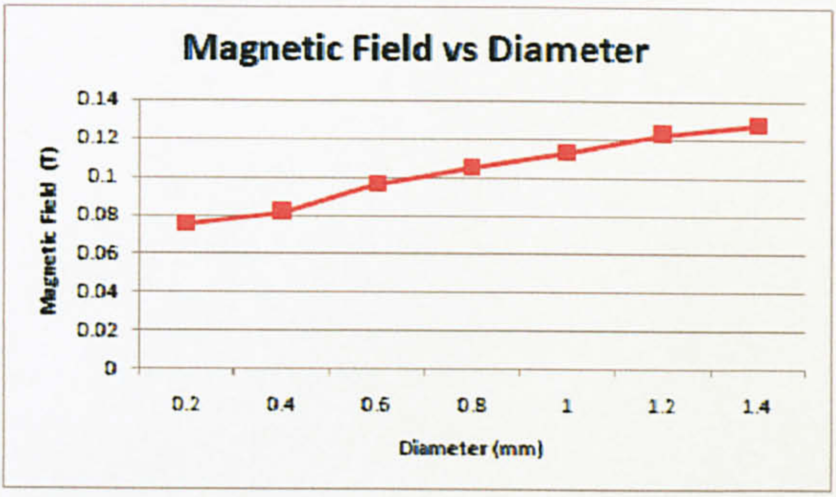


Figure 21: Magnetic field vs diameter of dipole antenna

The results show that increase in diameter of the dipole antenna from 0.2mm to 1.4mm will result in increasing the magnetic field by 69.4%. Thus, the magnetic field increase when diameter increase for diameter ranges that concerns the author.

4.2 Experimental Result

4.2.1 Experiment 1

For this experiment, the author had varied the distance between the antenna and the detector. The objective of this experiment is to demonstrate the effect of magnetic field strength over the distance. Distance between antenna and detector was increased gradually from 20cm until 100cm.

Table 11: Ambient environment result

Distance (cm)	Output voltage, V_{p-p} (mV)	
	Ferrite bar	Fluxgate EM Wave Detector
20	58.1	134.4
40	51.3	123.6
60	45.6	108.2
80	39.4	92.8
100	32.7	71.3

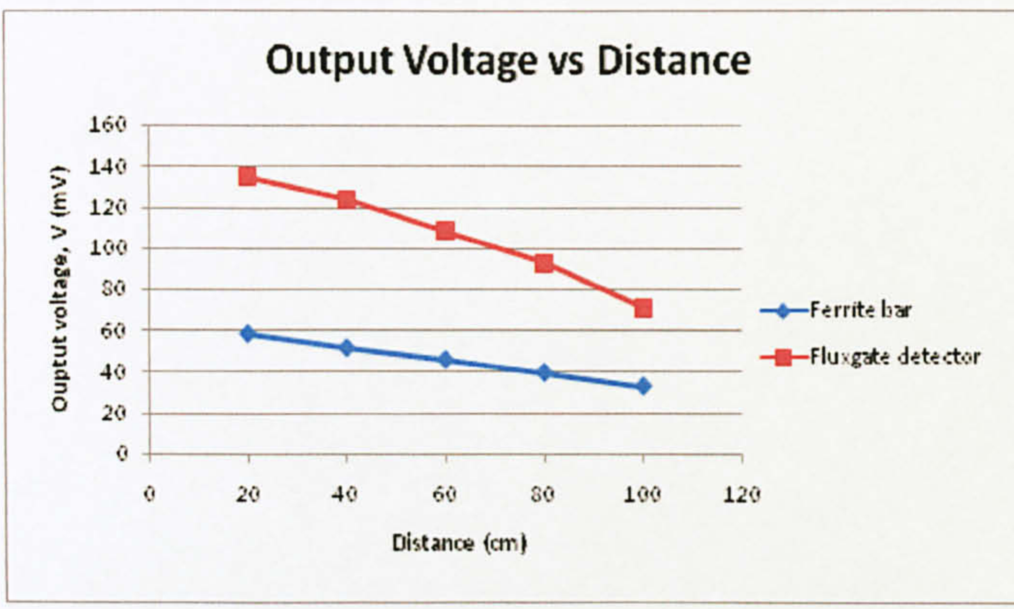


Figure 22: Output voltage vs distance between the receivers

From the result, it shows that as when the distance between the antenna and detector is increased, the output voltage that received at detector is decreased. The signal wave attenuation is proportional to the distance due to losses caused by ohmic resistive losses in the conductive earth and to the dielectic properties of the earth [15]. These losses are happen during the propagation of signal wave. As the output voltage received at detector is voltage induced from the ferrite plate with copper winding, it is consider as magnetic flux density. According to Biot-Savart law equation:

$$B = \frac{\mu_o I}{2\pi r} \qquad [2]$$

We can see the relationship between magnetic flux density B with distance r is inversely proportional to each other [11].

We also can see that the type of the detector also an important aspect of wave detection. Since the concern of the author for this project is in the CNT transmitter, further discussion about the detector will not be discuss.

4.2.2 Experiment 2

For this experiment, the author had varied the distance between the antenna and the detector as well as different operating frequency in the salt water. The objective of this experiment is to demonstrate the effect of magnetic field strength over the distance and operating frequency. Distance between antenna and detector was increased from 0.5m until 1.5m. The frequency was varied from 10MHz to 40MHz.

Table 12: Salt water environment result

Frequency (MHz)	**Distance (m)**	**Ouput voltage Vp-p (mV)**
10	0.5	38.4
	1	32.1
	1.5	27.8
20	0.5	41.6
	1	34.7
	1.5	31.4
30	0.5	42.7
	1	37.2
	1.5	31.3
40	0.5	44.6
	1	40.2
	1.5	33.9
50	0.5	41.3
	1	34.8
	1.5	29.1

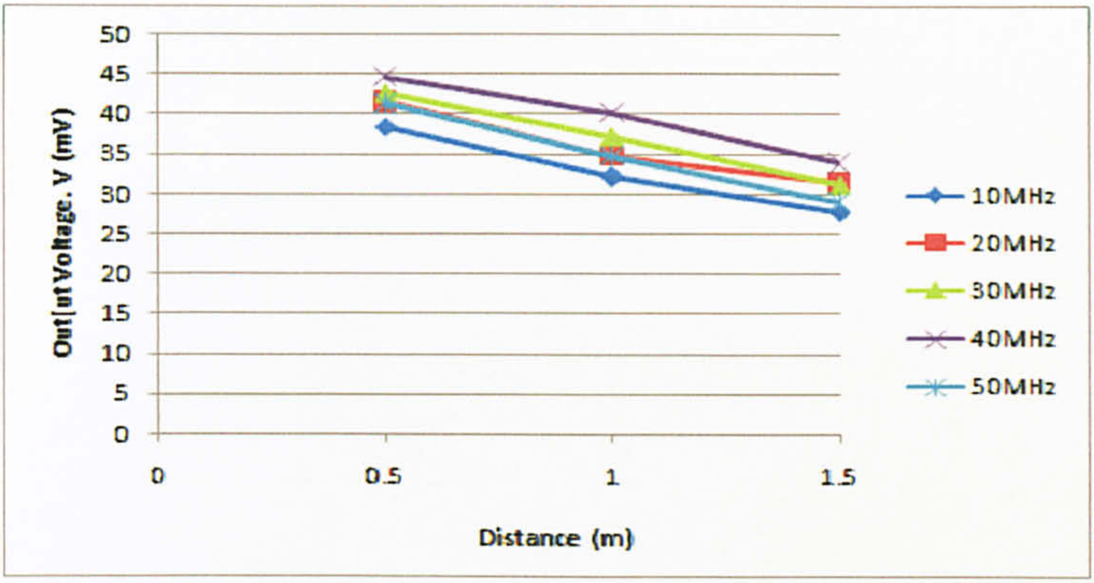


Figure 23: Distance, frequency and output voltage relationship

From the result it shows that the output voltage increase as the frequency increase and the output voltage decrease as the distance from the receiver increase. It shows at frequency 40MHz give highest magnitude of magnetic field. Thus, the suitable operating frequency for the CNT dipole antenna is 40MHz.

4.2.3 Experiment 3

Comparison between aluminium and CNT to verify the magnetic field strength of CNT is better than aluminium has been done. The results shown as in Table 13 below. The distance from antenna to receiver is fixed at 100cm and the frequency is 40MHz.

Table 13: Magnetic field strength of different material

Output Voltage, Vp-p (mV)		
Aluminium	CNT	CNT with 20 aluminium winding
39.2	43.7	68.3

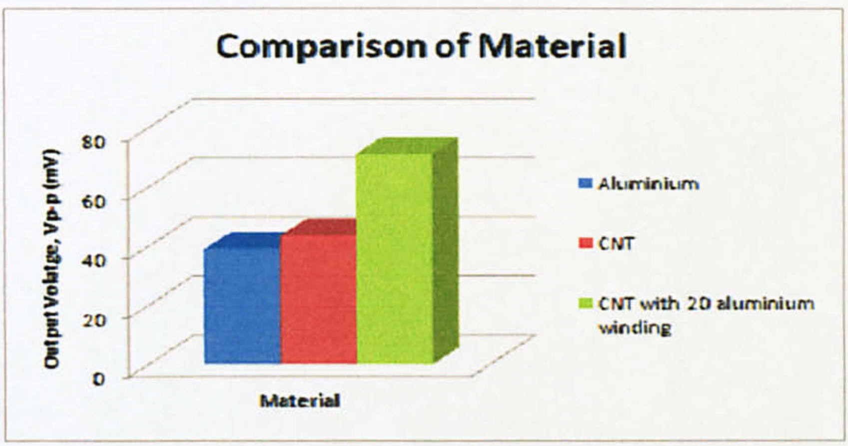


Figure 24: Comparison of magnetic field strength for different material

From the results, CNT with 20 aluminium winding give the best result. Addition of the winding give 56.3% increase of magnetic field strength compared to CNT only.

4.2.4 Experiment 4

For this experiment, magnetic feeder is added to the CNT dipole antenna with aluminium winding. The objective of this experiment is to demonstrate the effect of magnetic feeder and their connection on dipole antenna. The number of winding for magnetic feeder is constants to 25 turns and the distance between antenna and detector also constant to 100cm while the quantity of magnetic was increased gradually from 1 until 4. The graph of output voltage was observed and the voltage value at the detector is included in the table 14.

Table 14: Effect of magnetic feeder

Quantity of magnetic feeder	Output voltage, $V_{p\text{-}p}$ (mV)
0	68.3
1	77.6
2	78.0
3	79.6
4	79.3

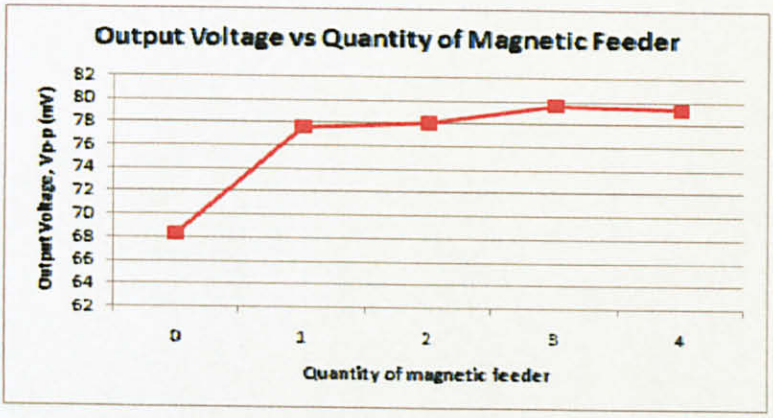


Figure 25: Output Voltage versus quantity of magnetic feeder

From the result, it shows that the highest output voltage is when three magnetic feeders being used. We also can see that with three magnetic feeder that been used, the output voltage is increase about 82% from dipole only (means CNT with no winding and zero magnetic feeder).

4.2.5 Experiment 5

For this experiment, the shape of the antenna is investigated. The objective of this experiment is to find the antenna's focus point and the magnitude of output voltage at the focus point. The latest design of antenna (CNT with winding and three magnetic feeders) was used. Five different curves of the antenna were investigated and the result shown as in table 15. The most far focus point is set at 100cm.

Table 15: Effect of different shape (curve)

Shape	Focus Point (cm from antenna)	Output Voltage, Vp-p (mV)
Curve 1	100	79.6
Curve 2	100	81.3
Curve 3	100	83.4
Curve 4	78	86.2
Curve 5	45	91.4

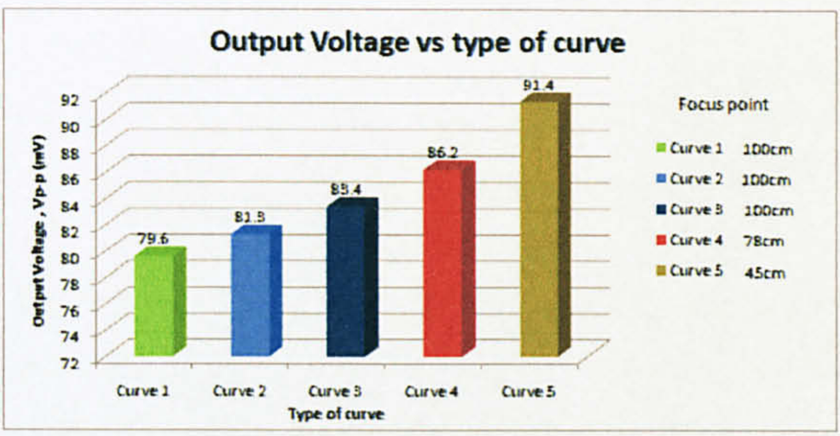


Figure 26: Output Voltage versus type of curve

From the results obtained, it shows that highest output is at 45 cm from the antenna which is too short. The author choose curve 3 since it gives high output and elevate farther than curve 4 or 5. With the chosen design of curve 3, the magnetic field strength (output voltage) of the dipole antenna is increase by 90.8 %.

4.3 ZnO (Zinc Oxide) Analysis

4.3.1 X-Ray Diffractions (XRD)

X-Ray Diffractions analysis were done at 200°C and 300°C. Figure 27 below shows that the XRD analysis of the ZnO nanoparticles which demonstrates a clear diffraction peak of [101] plane at 36° of the 2θ.

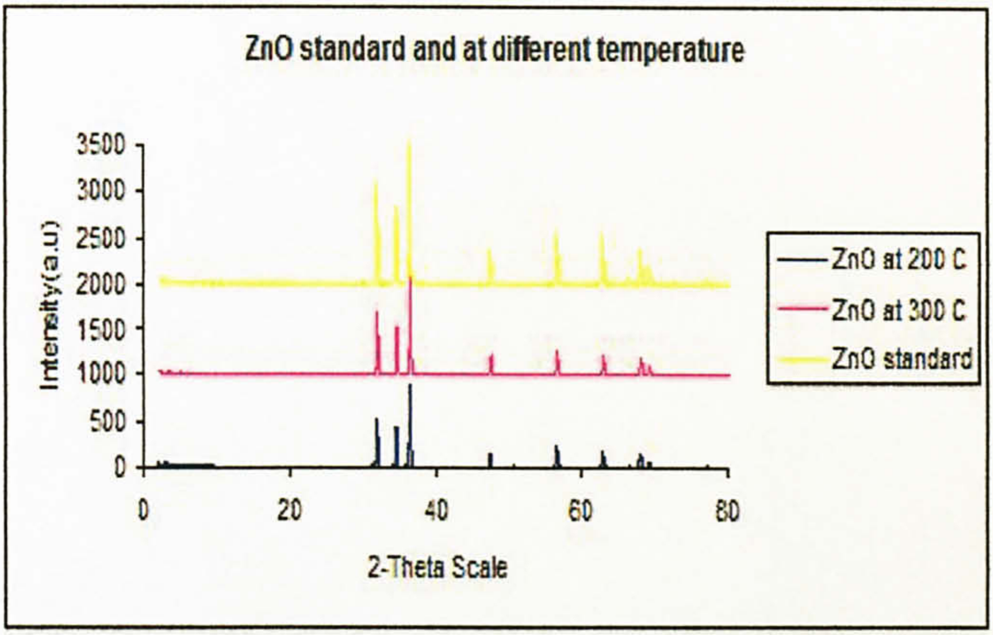


Figure 27: XRD analysis of ZnO nanoparticles

From the result, both ZnO at 200°C and 300°C demonstrate same diffraction peak as standard ZnO. Analysis at 300°C shows higher intensity than analysis at 200°C. Thus, it shows that Zno at 300°C is better than Zno at 200°C.

4.3.2 Raman Spectra

Figure 28 and 29 below show the Raman spectra were obtained for ZnO at 200°C and 300°C temperatures.

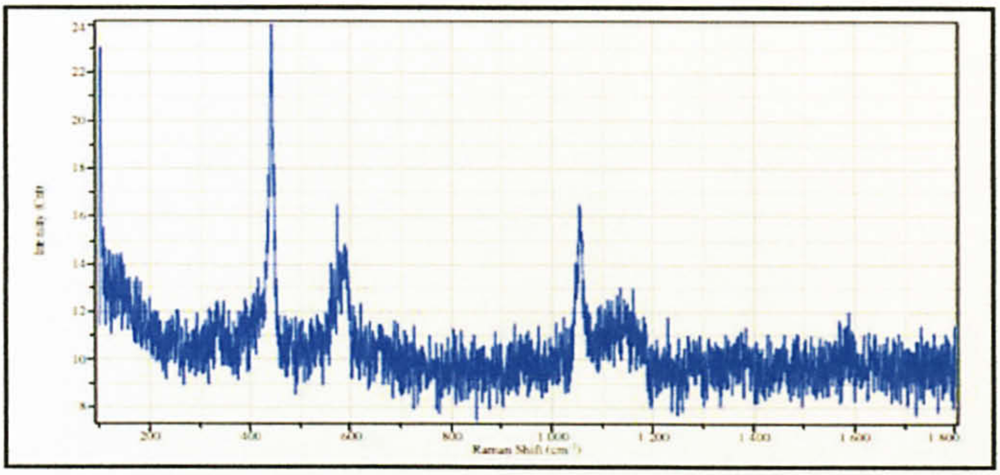


Figure 28: Raman spectroscopy of ZnO sintered at 200°C

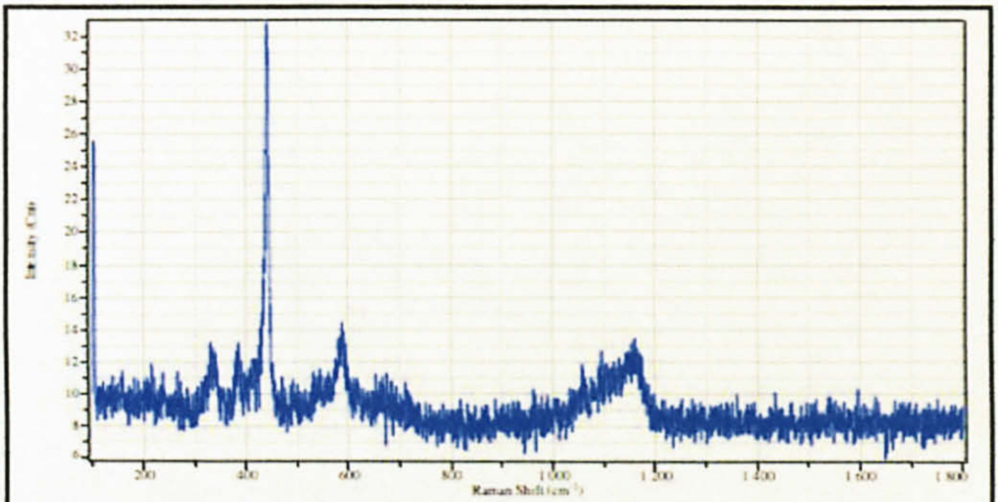


Figure 29: Raman spectroscopy of ZnO sintered at 300°C

From the results, the intensity of Raman spectra of ZnO sintered at 300°C is higher than at 200°C. Hence, the results show that ZnO sintered at 300°C is better than ZnO sintered at 200°C.

4.3.3 FESEM

The FESEM images of the nanoparticles synthesised by self-combustion at 200°C and at 300°C are shown in Figure 30 and 31 respectively. The micrograph revealed rod-like structures.

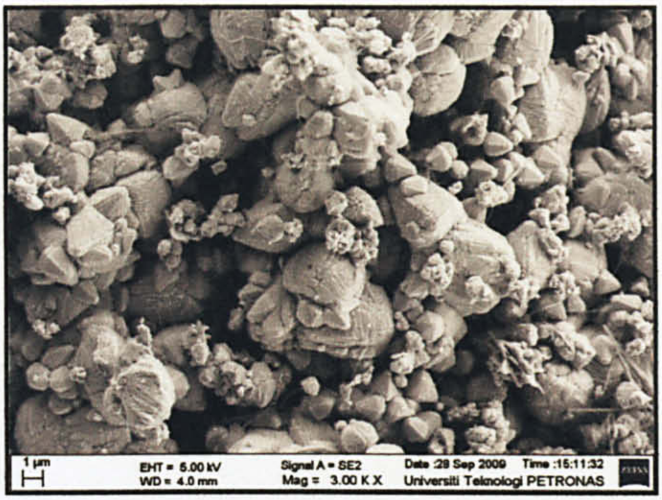


Figure 30: FESEM micrograph of ZnO nanoparticles by self combustion at 200°C

Figure 31: FESEM micrograph of ZnO nanoparticles by self combustion at 300°C

The micrograph results show that the morphology of ZnO nanoparticles by self combustion at 300°C is more homogene compared to self combustion at 200°C. Hence, it proves that ZnO nanoparticles by self combustion at 300°C is better.

4.3.4 Vector Network Analysis

The initial permeability, Q-factor and relative loss factor were measured using vector network analyser. Results show a high value of Q-factor (~43) of the ZnO at frequency between 20-30 MHz, reaching a maximum value for frequency between 20 to 40 MHz (Fig. 32). The nanoparticles also show low relative loss factor for frequencies above 10 MHz (Fig. 33).

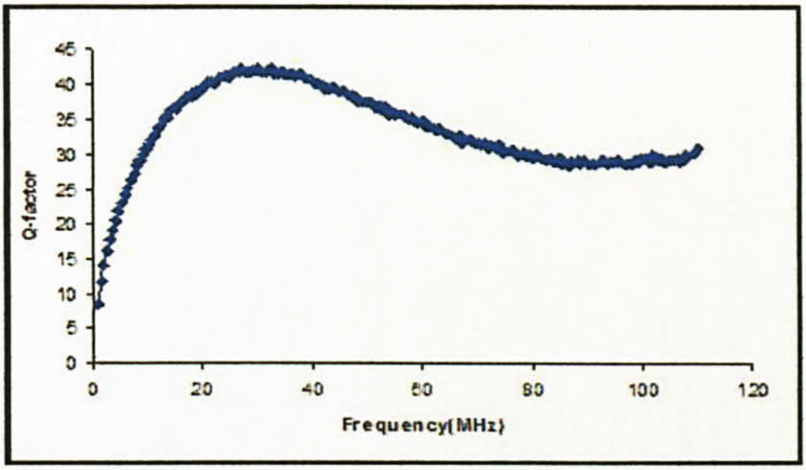


Figure 32: Q-factor of ZnO + PVDF composite

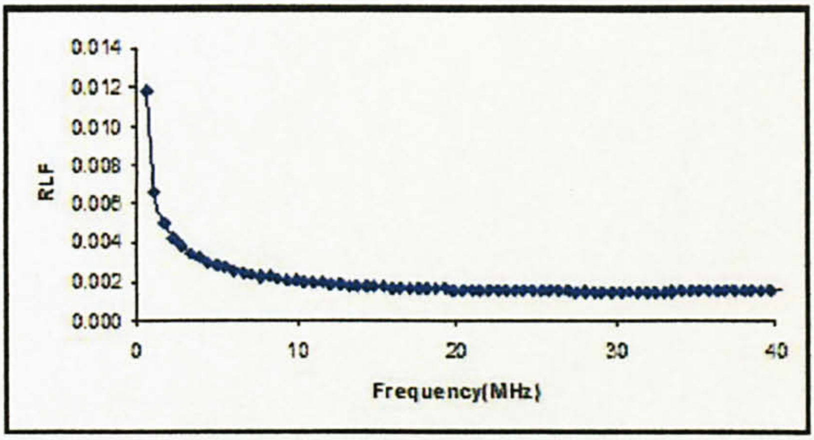


Figure 33: Relative loss factor of ZnO + PVDF composite vs. Frequency

From the results, we can conclude that ZnO + PVDF composite are material with good magnetic properties. This is because the results show high value of Q-factor and low value of relative loss factor.

4.4 Prototype Testing

For this experiment, the overall system of the CNT dipole antenna and CNT-ZnO detector was tested. The objective of this experiment is to demonstrate the improvement of the system by using different detector. Two type of detector which were ZnO only and ZnO-CNT were used and the result shown as in table 16.

Table 16: Output voltage for different detector

Output Voltage, Vp-p (mV)	
ZnO	ZnO-CNT
112.3	127.6

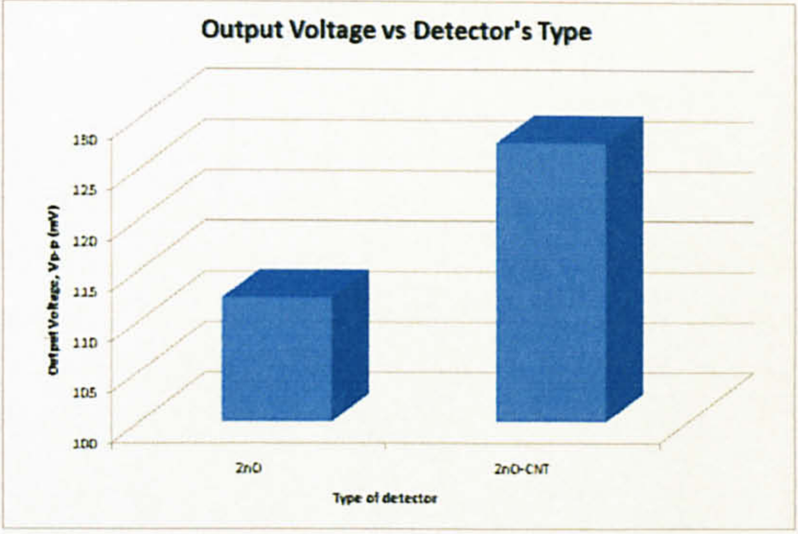


Figure 30: Output Voltage versus detector type

From the results obtained, it shows different magnitude of output voltage for the two type of detector. The system using ZnO-CNT detector recorded 127.6Vp-p, shows an increase by 13.6% from ZnO detector. For overall, the transmitter-receiver system using improved CNT dipole antenna and CNT-ZnO detector has enhanced by 192%.

CHAPTER 5
CONCLUSION AND RECOMMENDATION

5.1 Conclusion

As to date, the development of transmitter-receiver system using Carbon Nanotube (CNT) for hydrocarbon detection is found to be successful. The simulations and experiments fulfill the objectives which are to determine the characteristics of dipole antenna and detector to make it a useful transmitter-receiver system for hydrocarbon detection. By using CNT which has higher conductivity than copper, approximately a thousand times conductivity of copper, the CNT dipole antenna is found to be high potential in electromagnetic wave transmission. Simulations show that material with high conductivity elevate high magnetic field. The increase in length and diameter of dipole antenna will result in increase of magnetic field strength of the antenna. The characterization of Zinc Oxide (ZnO) makes it suitable to be use as detector and being enhanced by adding CNT to the PVDF-ZnO composite. The achievement of this project is the system which consists of improved CNT dipole antenna and CNT-ZnO detector results in 192% of enhancement.

5.2 Recommendation

Potential work that can be done is to test the CNT transmitter-receiver system by increasing the length and diameter of the systme. The CNT dipole antenna also can be further study to be use as transmitter for microwave hyperthermia and for Enhanced Oil Recovery (EOR). The designed transmitter can be scale up to meet the specification for the oil and gas industry.

REFERENCES

[1] 'Dipole Antenna' from www.radioelectronics.com/info/antennas/dipole

[2] Anwar Bhuiyan, Tor Wicklund and Stale Johansen, 'High-Resistivity Anomalies at Modgunn Arch in the Norwegian Sea', first break volume 24, January 2006.

[3] Rocksource , 'EM in Exploration' from http://www.rocksource.com

[4] Introduction to Carbon Nanotubes and Its Applications in Semiconductor Industry, MaTE297, Dr.Zhen Ghuo

[5] Carbon Nanotubes Based Composites – A Review, Rupesh Khare*, Suryasarathi Bose

[6] L.O. Løseth, H.M. Pedersen, T. Schaug-Pettersen, S. Ellingsrud, T. Eidesmo, *A scaled experiment for the verification of the SeaBed Logging method,* Journal of Applied Geophysics 64 (2008) 47–55.

[7] F.N. Kong and H. Westerdahl, 'Excitation of a Long Wire Antenna', Tenth International Conference on Ground Penetrating Radar, 21-24 June 2004.

[8] Electricity and Magnetism, John Melcher and Peter Dourmashkin

[9] 'Introduction to Wave Propagation, Transmission Lines and Antennas', Integrated Publishing from www.tpub.com

[10] 'Electromagnetic Waves' by The Open University from http://openlearn.open.ac.uk

[11] Fawwaz T.Ulaby, 'Electromagnetics for Engineers', ISBN 0 13 197064 X, Pearson Education, 2005.

[12] T. Eidesmo, S. Ellingsrud, L. M. Macgregor, S. Constable, M.C. Sinha, S.Johansen, H. Westredahl, F. N. Kong, 'Remote Detection of hydrocarbon filled layers using marine controlled source electromagnetic sounding' by EAGE 64th Conference & Exhibition – Florence, Italy, 27 - 30 May 2002.

[13] F. N. Kong, Harald Westerdahl, Svein Ellingsrud, Terje Eidesmo and Stale Emil Johansen, 'Seabed logging: A possible direct hydrocarbon indicator for deepsea prospect using EM energy', Oil and Gas Journal, 13 May 2002.

[14] Rudy Severns N6LF, 'Skin Depth and Wavelength in Soil' from www.antennabyn6lf.com

[15] Joseph J. Carr, 'Practical Antenna Handbook', Fourth Edition by 2001, New York, McGraw-Hill

APPENDICES

APPENDIX A
PROJECT GANTT CHART

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 (simulation)																		
9	Submission of Dissertation Final Draft																		
11	Submission of Project Dissertation																		
10	Oral Presentation																		
11	Submission of Project Dissertation																		

Suggested/Plan Progress
Actual Progress

Table 17: Project Gantt chart for FYP II

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 (experiment)																		
2	Submission of Progress Report 1																		
3	Project Work Continue																		
4	Submission of Progress Report 2																		
5	Seminar																		
5	Project work continue (experiment)																		
6	Poster Exhibition																		
7	Submission of Dissertation (soft bound)																		
8	Oral Presentation																		
9	Submission of Project Dissertation (Hard Bound)																		

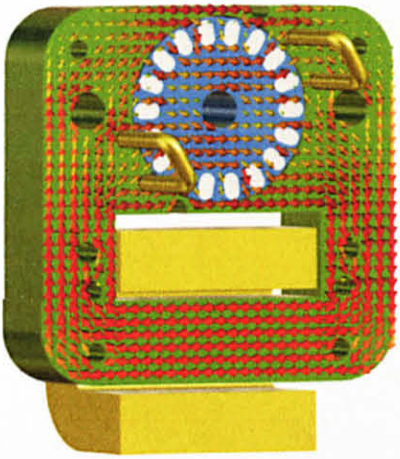
Suggested milestone/plan

Actual Progress

Table 18: Project Gantt chart for FYP II

APPENDIX A
CST EM STUDIO PRODUCT FLYER

CST EM STUDIO
Low Frequency Electromagnetic Design and Simulation

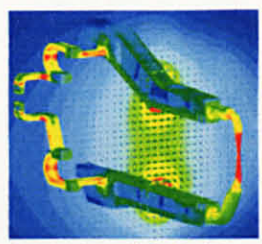

Magnetic flux density under no-load conditions for a shaded pole induction motor

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

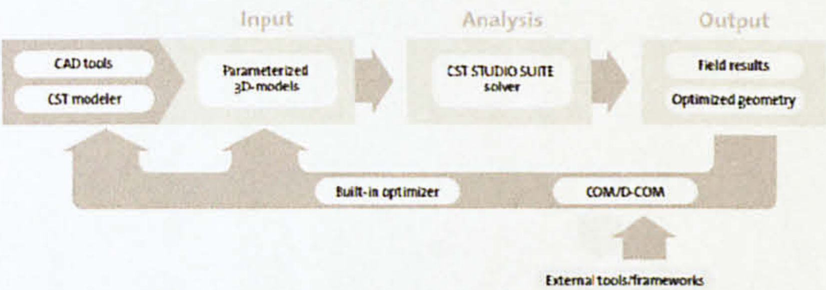
CST
CHANGING THE STANDARDS

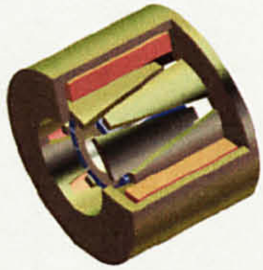
Static and Low Frequency Electromagnetic Design and Simulation

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

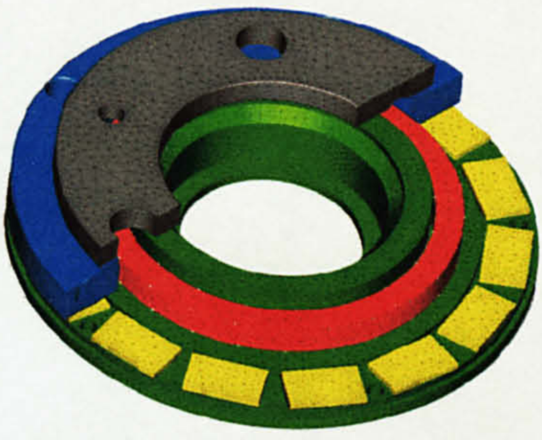




Model of a claw pole induction generator

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