UNIVERSITI TEKNIKAL MALAYSIA MELAKA

WIRELESS POWER TRANSFER MONITORING

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Bachelor of Electrical Engineering

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SUPERVISOR'S ENDORSEMENT

"I hereby declare that I have read through this report entitle "*Wireless Power Transfer Monitoring*" and found that it has complied the partial fulfillment for awarding the Degree of Bachelor of Electrical Engineering (Control, Instrumentation and Automation)"

Signature : ....

Supervisor's Name : ....

Date : ....

WIRELESS POWER TRANSFER MONITORING

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A report submitted in partial fulfilment of the requirements for the degree

Of Electrical Engineering (Control, Instrumentation and Automation)

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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2014

STUDENT DECLARATION

"I declare that that this reports entitle "*Wireless Power Transfer Monitoring*" is the result of my own research expect as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ……………………………………………

Name : ……………………………………………

Date : ……………………………………………

ACKNOWLEDGEMENT

In preparing this report, I was in contact with many people, researchers, academicians and practitioners. They have contributed towards my understanding and thought. In particular, I wish to express my sincere appreciation to my main project supervisor, Encik Ahmad Fairuz Bin Muhammad Amin, for encouragement, guidance critics and friendship. I am also very thankful to my lecturers who have been giving me guidance, advices and motivation. Without their continued support and interest, this project would not have been same as presented here.

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ABSTRACT

Wireless power transfer is the transmission of electrical energy from power source to an electrical load without conductor attached to them. Wireless transmission is useful in case where interconnecting wire is inconvenient. The problem of wireless power transfer is different from wireless telecommunication such as radio. The proportions of energy received become critical only if it is too low for signal. The most common form of wireless power transfer is carried out using direct induction follow by resonant magnetic induction. In this project we are using resonant magnetic induction as coil of wireless power transfer. By using two types of wires, we need to see the performance transferring power each type of wire. We will only using copper wire and enamel copper wire.

ABSTRAK

Penghantar kuasa tanpa wayar adalah penghantaran tenaga elektrik dari sumber kuasa kepada beban elektrik tanpa konduktor yang menyambung antaranya. Penghantar kuasa tanpa wayar berguna dalam kes di mana wayar bersambung adalah menyusahkan. Masalah pemindahan kuasa tanpa wayar berbeza daripada telekomunikasi tanpa wayar seperti radio. Perkadaran tenaga diterima menjadi kritikal hanya jika ia terlalu rendah untuk isyarat. Kebiasaannya, pemindahan kuasa tanpa wayar dijalankan menggunakan induksi sendiri dan diikuti salunan aruhan magnet. Dalam projek ini, kita menggunakan salunan aruhan magnet dengan menggunakan dua jenis wayar iaitu wayar tembaga biasa dan wayar enamel tembaga. Dengan menggunakan dua jenis wayar ini, kita perlu melihat prestasi pemindahan kuasa setiap wayar.

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CHAPTER 1

INTRODUCTION

1.1 Overview

Nowadays technologies growing rapidly and many of the companies produce the latest gadget that suits in modern world. People will buy the gadget to make their life comfortable. Many of gadgets at certain area will face a problem of having many wires that sharing a limited amount of power socket, it also will make the wires become unmanageable and scattered. Hence, with the idea of Nikola Tesla, wireless power transfer is invented.

Wireless power transfer can be applied or used in our daily live to get more manageable or tidy area that free of wires. It also can be used in other area such as medical machine, industrial machine, electric car and other things. Wireless power transfer is easy to manage without affecting user health.

In this chapter will be discussing on project motivation, project objective, problem statement, scope of project.

1.2 Project Motivation

The motivation for wireless power transfer system comes from wires complex and untidy. With a large number of gadgets are using nowadays that focus on smartphone, there are demands for convenience in managing their power supplies. Other than that, it can help user easily to use technology at anywhere and anytime without worrying their battery draining quickly on their smartphone.

1.3 Problem Statement

Most of the people use gadgets to improve their daily routine work. Most of the gadget are using power socket as their power supply. If they use too many gadgets in their daily life it will cause lack of power socket. Nowadays, people are using smartphone to make their life easier. The problem they facing are the life time or standby time of smartphone battery is draining quickly with using multi-application usage. To overcome the problem is wireless power transfer were invented by Nikola Tesla in 1893, where he demonstrate the illumination of vacuum bulb without using wires. Wireless power transfer is used for exchanging the power through the resonance coil. Figure 1.1 shows the comparison of using wire charging and wireless power transfer charging. The difference is the wireless power transfer charging is more tidy and manageable, it also make user more confortable to using smartphone without charging using wires.

The problem need to be highlight in this project are does the wireless power transfer can transferring power in the long range or only for a short range. Then, the performance of wireless power transfer can be effect from the material that been used in coil.

Wireless power transfer needs to be implemented in our life. It will make people use gadget for better life. In this project, an experiment need to carried out on analytical and prove the wireless power transfer can be used and also to get the efficiency of wireless power transfer.

In other hand, we need to consider the health environment of radiation of wireless power transfer.

Figure 1.1: Comparison of using wire charging and wireless power transfer charging.

1.4 Objective

There are several objectives that need to be achieved in order to make this project successfully.

- To investigate a wireless power transfer system using a resonant coil.
- To develop and study the system and test it to establish its functionality.
- To validate the performance coil of wireless power transfer using LabVIEW Software.

1.5 Scope of the project

The scope of this project is:

- Using only normal copper wire and enamel copper wire to do resonant coil on the existing circuit that had been commercialized.

- Develop the wireless power transfer system using a hardware and analytical by using existing circuit that had been commercial.
- The project only focused performance of the system with two type of material on the coil.

1.6 Report Outline

In this section, the outline of project report is presented. This report includes of five chapters and each chapter is explained.

Chapter 1 discusses on introduction regarding to the wireless power transfer system. The problem statement, objectives and significant of project are stated briefly and clearly.

Chapter 2 discusses the literature review on wireless power transfer systems. History of wireless power transfer.

Chapter 3 discussing more about the methodology of wireless power transfer system. The flow charts of project are listed by following the sequence in phase 1 and phase 2.

Chapter 4 representing the result from an experiment of normal copper wire coil and enamel copper wire coil.

Chapter 5 representing the analysis of result by functionality and validate the performance using an LabVIEW that will be represent in graph (Voltage vs. Distance)

Chapter 6 is the conclusions on the whole project done and also the recommendation for improving the future works.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

Wireless power transfer system has been attempted many times throughout the last past centuries. The concept ideas were began from the experimented of Heinrich Hertz and Nikola Tesla around year 1890's and has continued until this day. Although Nikola Tesla was confident with his hypothesis to transfer power and nobody has been able to validate the idea. Nowadays, wireless power transfer is largely exhibited through induction. Although the functional of wireless power transfer through induction is constrained to a very small distances. In this chapter provides a literature review of history of wireless power transfer.

2.2 Early History of Wireless Power Transfer

The early history of wireless power transfer involves of two main inventors namely Heinrich Hertz and Nikola Tesla.

2.2.1 Heinrich Hertz

Heinrich Hertz was born in Hamburg, Germany on 22th February 1857. Heinrich Hertz was gifted not only in school but also as a mechanic, sculptor, draftsman, linguist, and athlete (Susskind 1988). Heinrich Hertz studied at numerous university, most prominently studying at the university of Berlin under Hermann Helmholtz (Susskind, 1988). Hertz proved that electricity can be transmitted in electromagnetic waves. Heinrich Hertz died on 1st January 1894 at the age of 36. [2]

2.2.2 Nikola Tesla

Nikola Tesla was born in the stroke of midnight 9th July 1856 in Yugoslavia. Nikola Tesla had a special give of being able to imagine things so well that they seemed real. This allows him to build mental rather than physical prototypes that led to successful finished designs. The downside to this was that Nikola Tesla took very poor notes, he only wrote down those things that he deemed absolutely necessary. Nikola Tesla was far beyond his time in his experimentations. It wasn't until 1970 that Robert Golka became the first to replicate the Tesla coil.

In 1899, Nikola Tesla went to Colorado Springs to build a laboratory and try out some new ideas. One of these ideas was the wireless transmission of power. In his experiment he was able to light 20 lamps, 26 miles away from his lab.

Nikola Tesla theory of wireless transmission of power was a little different than today's vision; it was centred on his consideration of the earth as a giant conductor. Nikola Tesla died on 7th January 1943. [3]

2.3 Basic Principles of Wireless Power Transfer.

Radio was invented by a person name Nikola Tesla also known “Father of Wireless”, [1] he is the one who the first person that conceived the idea of transmitting power through the air has been around for over century, with the Nikola Tesla’s pioneer idea and his experiments attempts to do so. Most of the approaches to wireless power transfer are using an electromagnetic (EM) field of some of frequency as the means by which the energy is sent. [1] Figure 2.1 shows the simple block diagram of wireless power transfer.

There are three type of wireless power transfer that can use in wireless power transfer that is radiative transfer, inductive coupling and resonant coupling. [4] Radiative transfer are suitable to exchange information and transfer a small power in miliwatts, most of it were wasted into free space. For inductive coupling, it can be transmitted the power with high efficiency but in very short distance.

Last type is resonant coupling, it can transfer high power at medium distance. Basic principle is that two separate coils with the same resonant frequency are possible to form a resonant system based on high frequency magnetic coupling and exchange power in high efficiency. [4]

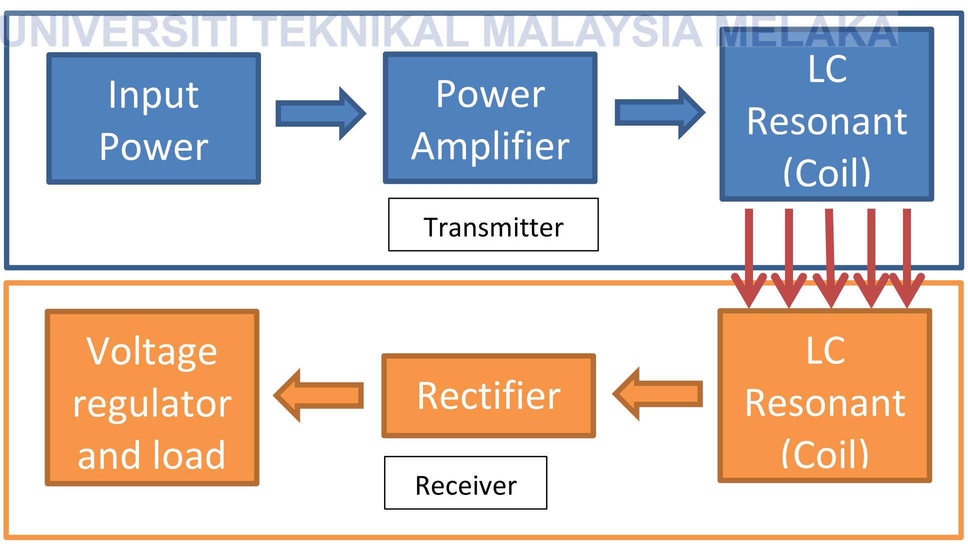

Figure 2.1: Basic Block Diagram of Wireless Power Transfer.

CHAPTER 3

METHODOLOGY

3.1 Overview

In this chapter the main topics that will be discussed is the methodology and approaches used to complete this project. In this experiment, loop coils, and the performance wireless power transfer system will be analysed. This topic will consist:

i. Project flow chart
ii. Case study wireless power transfer using magnetic resonance coupled.
iii. Experiment on wireless power transfer coils
iv. Develop the system and validate the performance.
v. Analyse result
vi. Result and analysis

3.2 Project Flow Chart

Figure 3.1 show the project flow chart used to make sure this project is successfully done before the due date of this project:

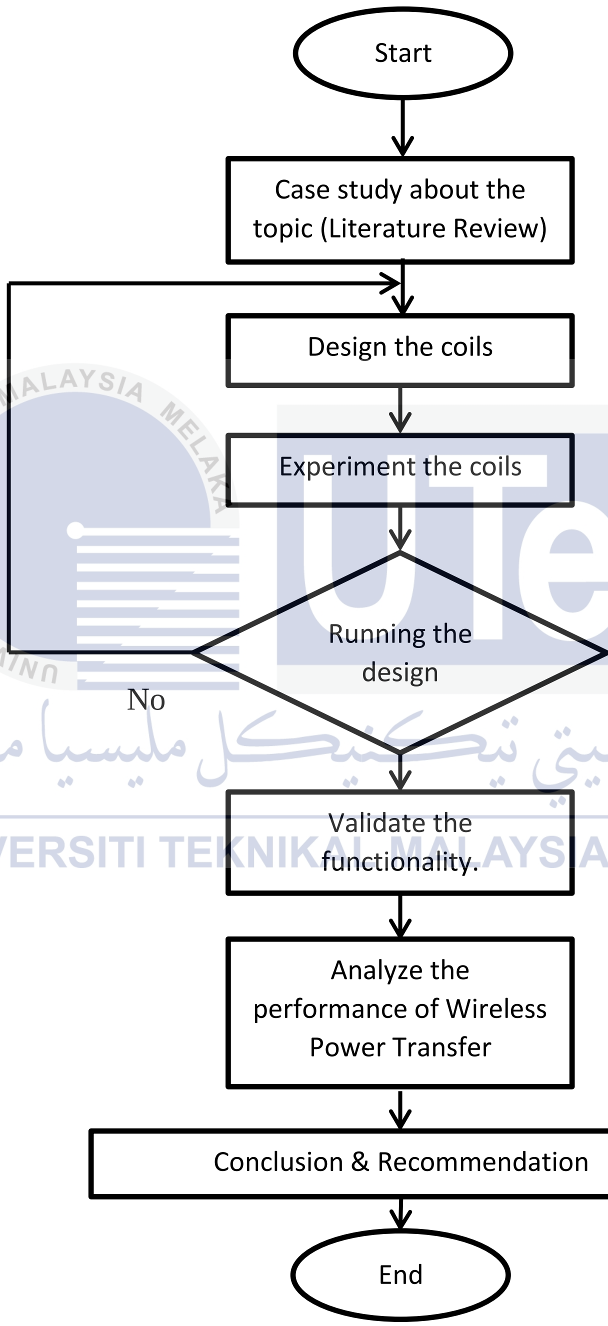

Figure 3.1: Flow chart for the methodology of the Project.

3.3 Operating Principles

The principles of operation of wireless power transfer system are very similar to the surface based wireless power transmission system used for communication within robot swarms [9]. In a resonant system, the circular current in the resonant coil is greater that the drive coil by the quality factor, Q. Wireless power transfer system circuit use power MOSFET to get a desired transfer frequency. Figure 3.2 show the block diagram of wireless power transfer transmitter.

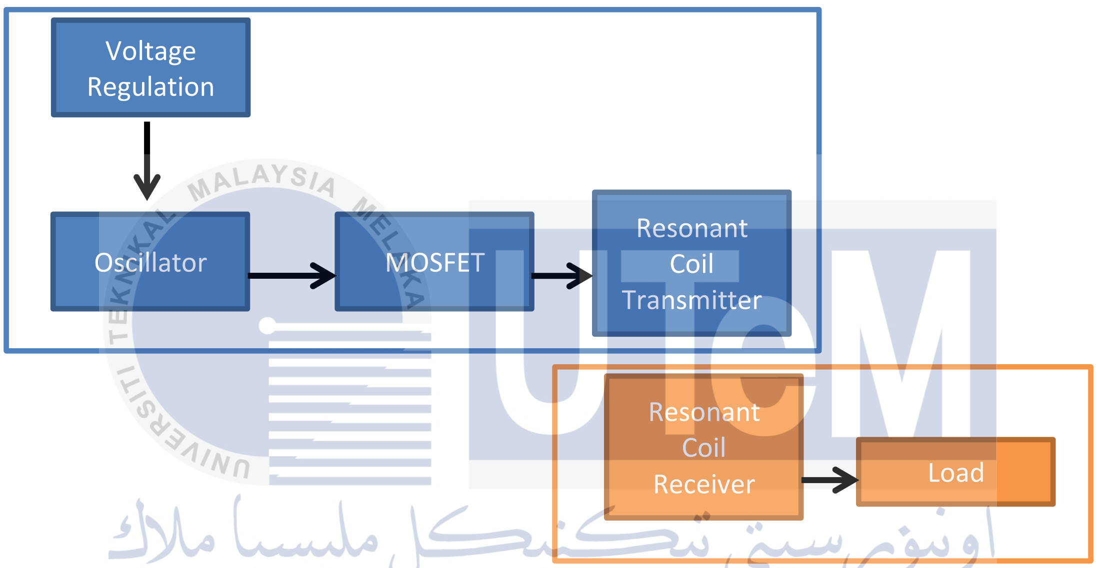

Figure 3.2: Block diagram of wireless power transfer system

A time varying current flows in a coil transmitter that is coupled with a resonance LC receiver coil. Current is induced in receiver coil at the transmission frequency, which set as resonance frequency. The resonance frequency can be calculated from the inductance and capacitance of LC circuit.

3.4 Magnetic Resonance Coupling

Resonance is a phenomenon that occurs in nature in many different forms, it involves energy oscillating between two modes. In a system at resonance, it possible to have large build-up of stored energy having only a weak excitation to the system and it occurs if the rate energy inject into the system is greater than the rate of energy loss by the system.[6] Figure 3.3 is the example circuit for resonator

The behaviour of an isolated resonator can be defined by two fundamental parameters, its resonance frequency, ω_0 and its intrinsic loss rate, Γ. The ratio of these two parameters define the quality factor or Q of the resonator ($Q = \omega_0/2\,\Gamma$) a measure of how well it stores energy.

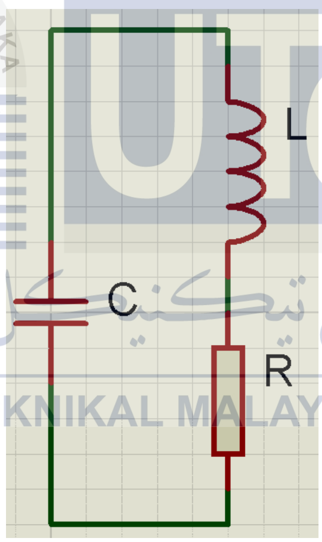

Figure 3.3: Example of a resonator

In this wireless power transfer will use magnetic resonance coupling method, this method has an advantage of transmit power in a long distance with a highly efficiency and robust to positional shift of transmitting and receiving antenna or also known coil. [4] The coil concept will be designed is solenoid.

Two resonators are placed in approximate to one another, it will coupled between them and possible to resonates to exchange energy. Efficiency of exchange energy depends on characteristic parameters for each resonator and energy coupling rate between them.

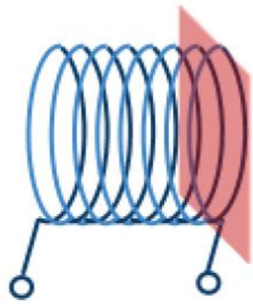

Figure 3.4: Solenoid form for coil

Figure 3.4 shows concept coil of wireless power transfer that is solenoid. Every of each coil is approximated using DC inductance calculation based on Harold A.Wheeler approximation theory [7]. The calculation theoretical of solenoid coil is calculated as shown in Equation (1). All of these dimensions must in inches. [5]

$$L = r^2 x \frac{N^2}{9\ x\ r + 10\ x\ l} \qquad (1)$$

Where:

L = inductance in μH

r = radius of coil

N = number of turn

l = length of the coils

For theoretical of planar coils inductance is used in Equation (2), but for planar square coil there no specific formula given or derived. [5]

$$L = r^2 x \frac{N^2}{8\,x\,r + 11\,x\,w} \qquad \textbf{(2)}$$

Where:

L = inductance in μH

r = inner radius

N = number of turn

w = wire diameter

The inductance is determined experimentally and the resonant frequency must be above 10MHz to gain a strong magnetic field, we need to calculate the series capacitor by using Equation (3). With using these equations we can designed resonant coil and can be applied in this project. [5]

$$C = \frac{1}{(2\pi f_{res})^2 L} \qquad \textbf{(3)}$$

Where:

C = Capacitance

L = inductance in μH

f_{res} = Frequency Resonance

For above equation is for a single loop coil and this project it will consist of two loop coils that consist of transmitter antenna and receiver antenna. The Figure 3.5 shows the equivalent circuit of Wireless Power Transfer system. The distance between two coils is smaller than working wavelength, the mutual inductance is formed. Mutual inductance is the most importance factor for designing Wireless Power Transfer Monitoring system since it relates directly to the coupling coefficient. [4]

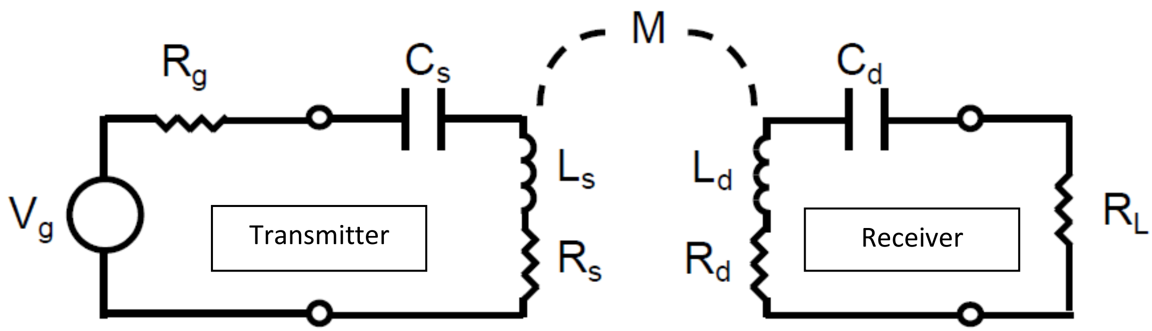

Figure 3.5: Equivalent circuit for the couple resonator.

The magnetic flux between two resonant coils is made by resonated current and makes the mutual inductance also the influences on both coils. The coupling coefficient can be express by Equation (4). [4]

$$k = \frac{L_m}{\sqrt{L_1 L_2}} = \frac{L_m}{L} \tag{4}$$

Where:

k = Coefficient

L_m = mutual inductance

L_1 = self-inductance of transmitter coil

L_2 = self-inductance of receiver coil

L = single inductance of coil

With this equation, it expressed the relationship between L_m and k. When the distance between two coils are increased, L_m and k will decrease due to the reduction of magnetic flux between two coils.

3.5 LabVIEW

LabVIEW is used for a wide variety of applications and industries. LabVIEW itself is a software development environment that contains numerous components which require for any type of test, measurement or controlling the application.

LabVIEW also used for hardware support such as scientific instrument, data acquisition devices, sensor, camera, motor and actuator. Integrating difference of hardware devices can be major pain when automating any test, measurement or control system, with LabVIEW it makes the process of integrating hardware much easier by using consistent programming approach no matter what hardware is using.

In this project we use LabVIEW for analysis, user interface (UI) component. Using the LabVIEW we can take data from the transmitter and receiver coil in a form of graph or signal like using oscilloscope. We also can collect many data and stored in Microsoft Office Excel for future analysis. Meanwhile, the UI component is to show the graph as shows in Figure 3.6.

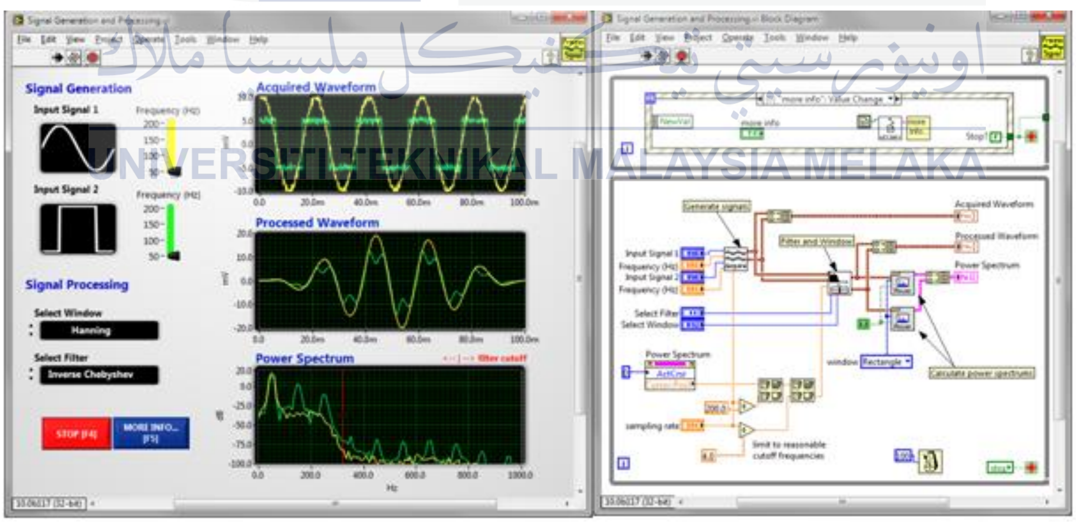

Figure 3.6: Example UI component in LabVIEW.

3.6 Wireless Power Transfer Circuit

In this project we will use the existing circuit for carried out the experiment, the circuit we using is the same circuit on the market that had been commercialized. We just need to change the coil to see the performance each of the material. Figure 3.7and Figure 3.8 show the circuit of wireless power transfer. Figure 3.9 show circuit that had been etching for wireless power transfer.

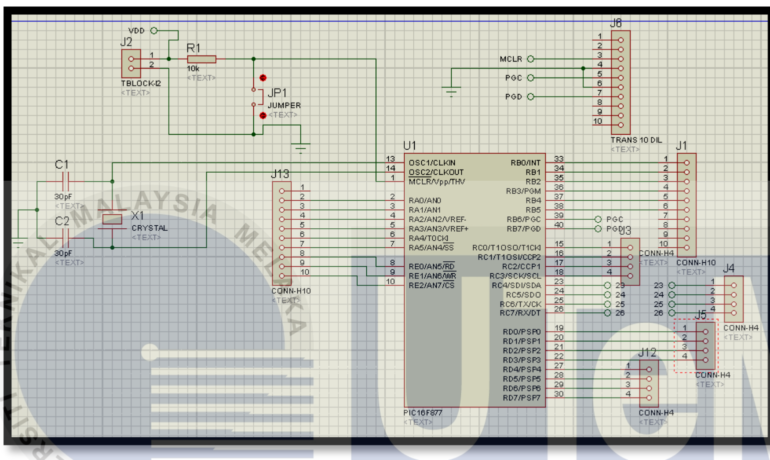

Figure 3.7: Circuit from Proteus before etching.

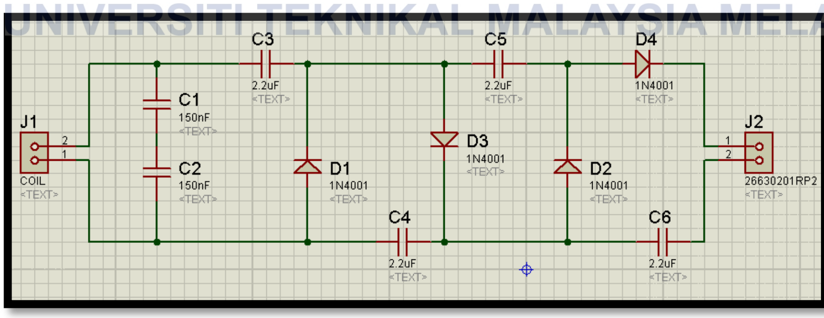

Figure 3.8: Circuit receiver from Proteus before etching.

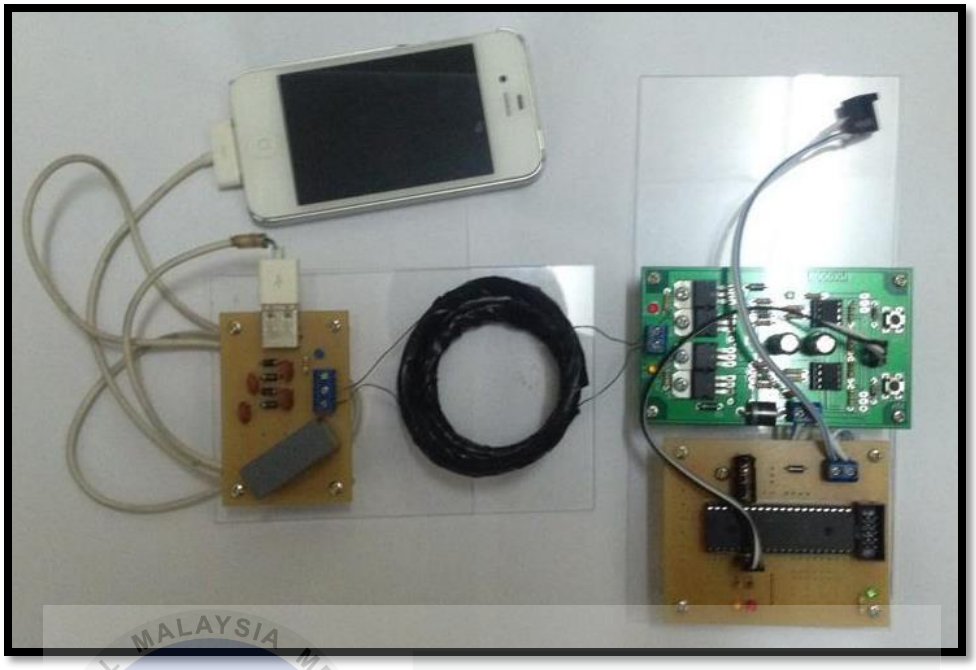

Figure 3.9: Circuit for wireless power transfer.

3.7 Type Wire for Wireless Power Transfer Coil

There are two types of coils we will be used in this project namely are normal copper wire coil and enamel copper wire coil.

3.7.1 Copper Wire Coil

For first experiment we were using copper wire coil, copper has been used in electrical wiring since the invention of the electromagnetic and the telegraph in around 1820 [10]. Copper is the electrical conductor in many field of electricity, copper usually used in power generation, power transmission, distribution, telecommunication and many more in electrical equipment [10]. Figure 3.9 shows normal copper wire.

Figure 3.10: Normal Copper Wire

3.7.2 Enamel Copper Wire Coil

Second experiment will be set up by using second material of coil that is enamel copper wire. Enamel wire or also known as magnet wire is actually a copper or aluminium wire that been coated with a very thin layer of insulation. It is widely used in construction of transformer, speakers, motors, electromagnets and other application that require tight coils of wires. Figure 3.10 shows the enamel copper wire.

Figure 3.10: Enamel Copper Wire

CHAPTER 4

RESULT

4.1 Overview

This chapter presents the result from experiment that carries out from LabVIEW that measure voltages vs distance, with this result it can be observed the behaviour of the system on two type of wire. The efficiency of the resonance coil transfer power will be analysed and discussed in the next chapter.

4.2 Experiment Transfer Power Using Normal Copper Wire

Experiment need to carry out to see the behaviour of the system on each type of wire, that is normal copper wire and enamel copper wire. From this experiment, we can see the performance transfer the power due to the distance. Table below is the result of experiment from normal copper wire at transmitter and receiver side that obtained from several distance using LabVIEW software.

Table 4.1: Voltage vs Distance for normal copper wire.

NO	Transmitter	Receiver	Distance
1	17.9 V	14.6 V	0 cm
2	17.9 V	10.5 V	1 cm
3	17.9 V	7.0 V	2 cm
4	17.9 V	4.1 V	3 cm
5	17.9 V	2.7 V	4 cm
6	17.9 V	1.8 V	5 cm
7	17.9 V	1.4 V	6 cm
8	17.9 V	1.1 V	7 cm
9	17.9 V	0.7 V	8 cm
10	17.9 V	0.6 V	9 cm
11	17.9 V	0.4 V	10 cm

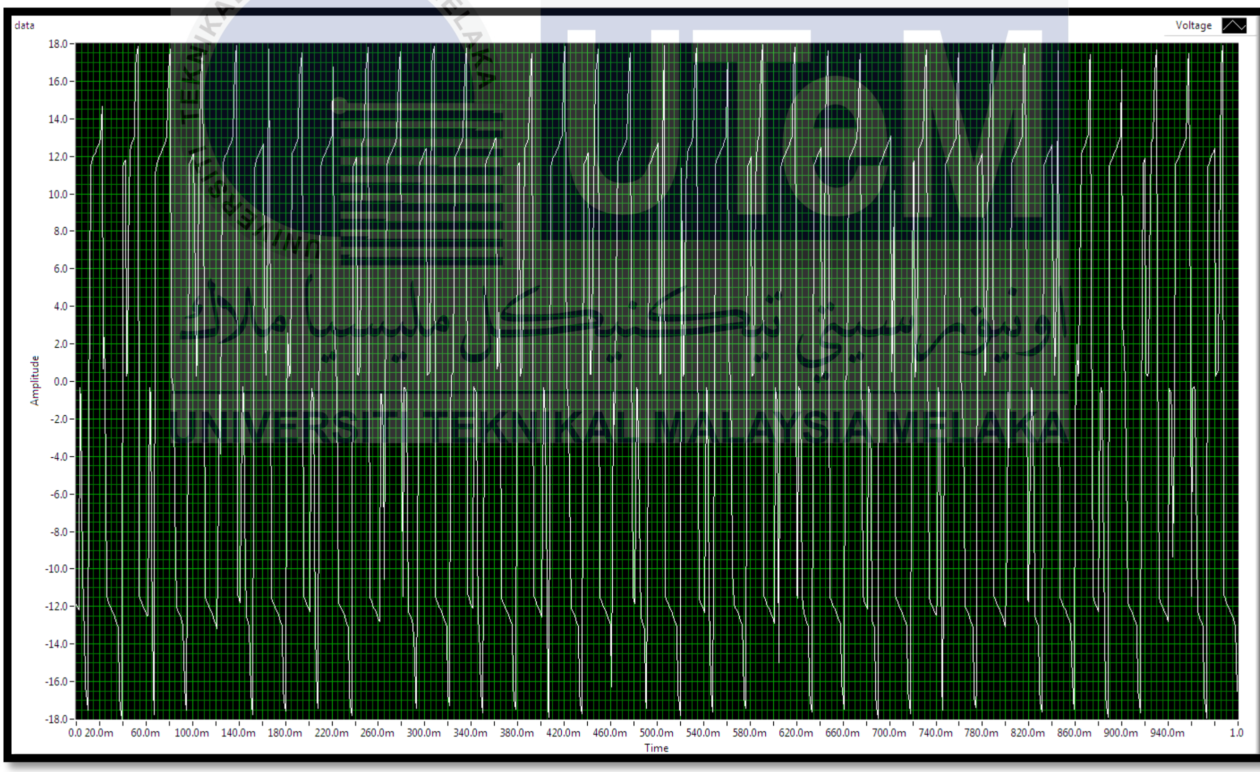

Figure 4.1: Copper wire at transmitter using LabVIEW.

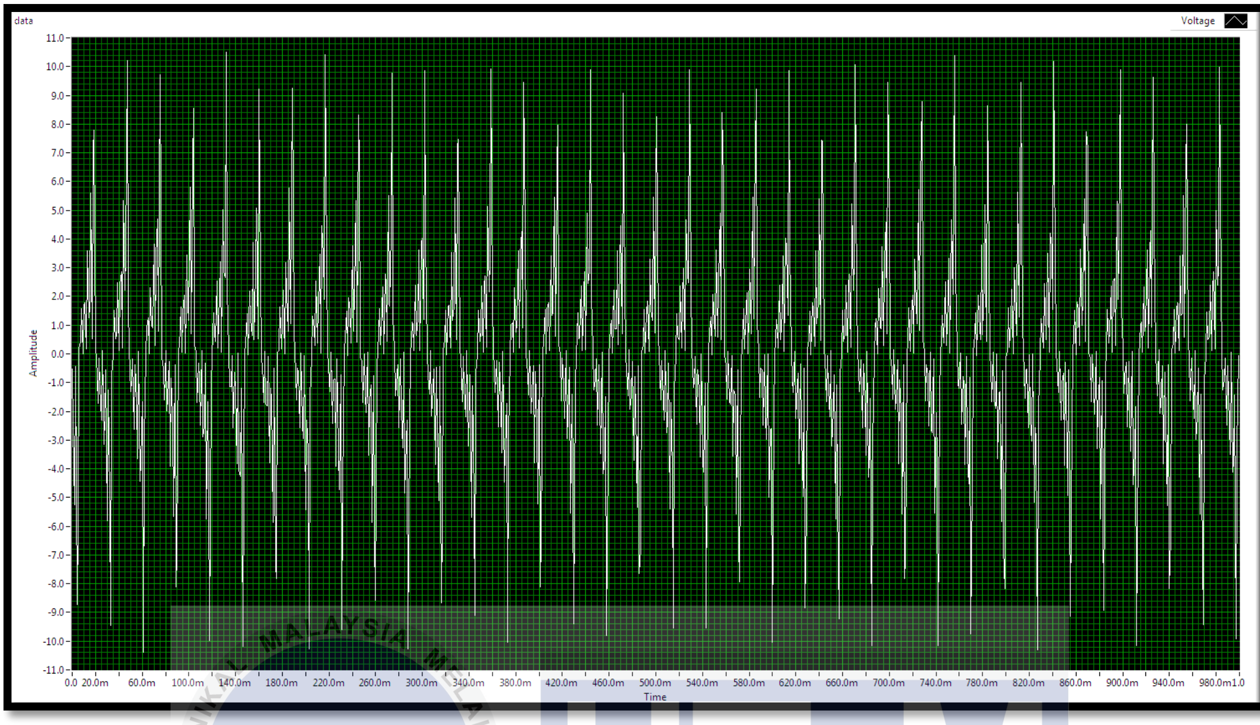

Figure 4.2: Copper wire at receiver using LabVIEW.

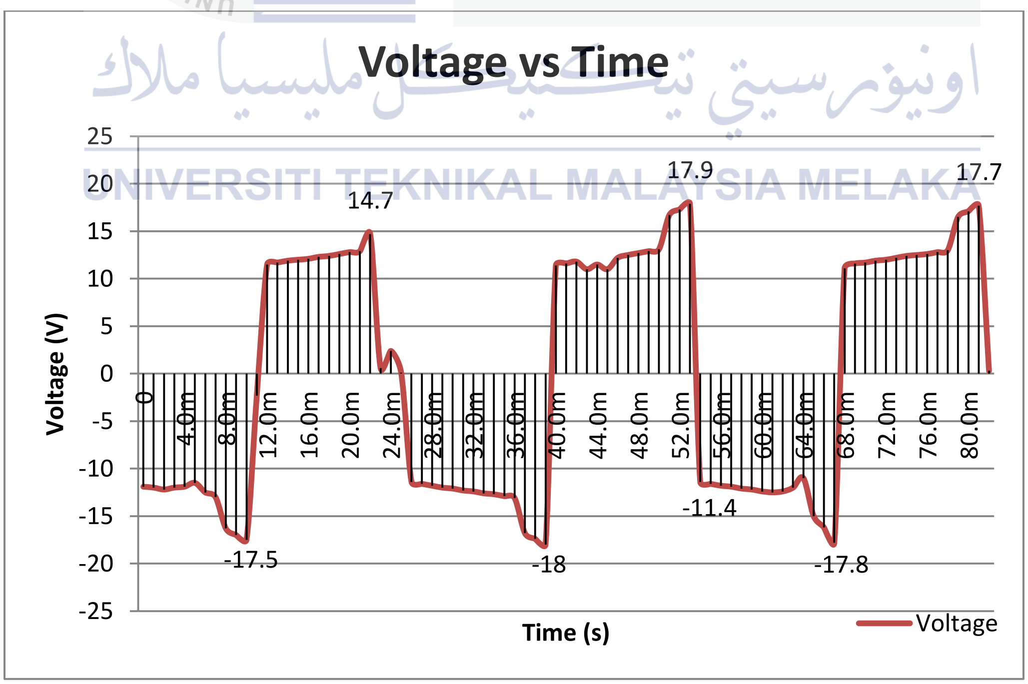

Figure 4.3: Copper wire at transmitter.

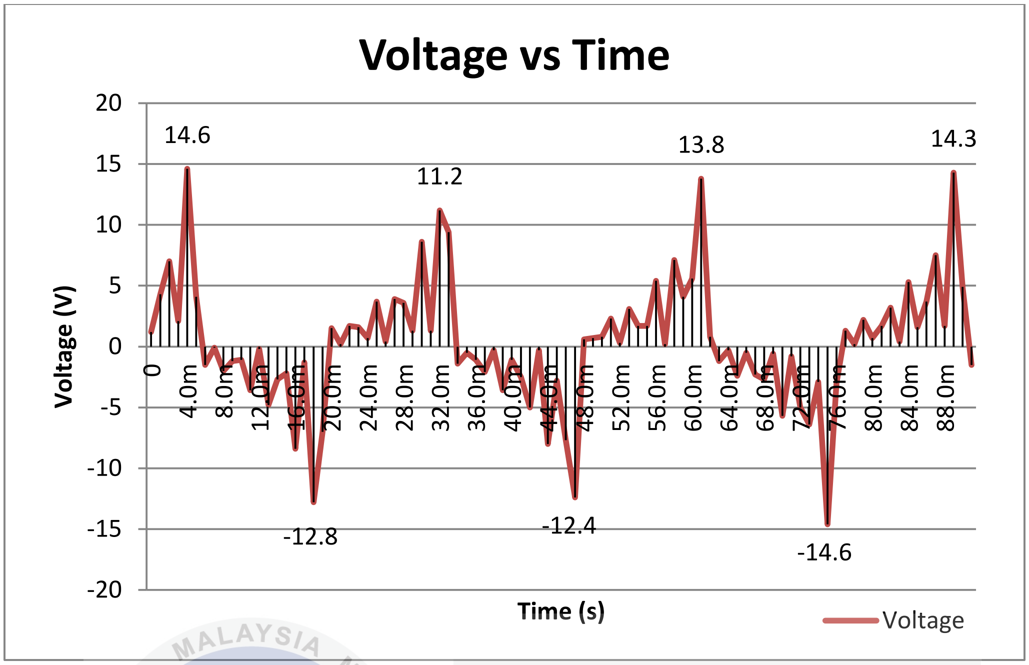

Figure 4.4: Copper wire at receiver at distance 0cm.

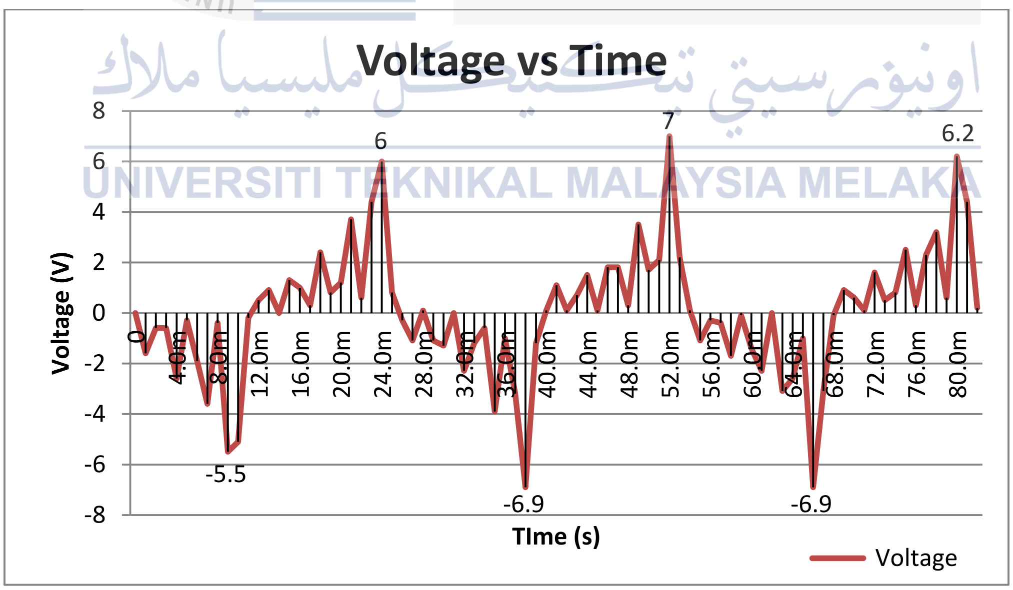

Figure 4.5: Copper wire at receiver at distance 2 cm.

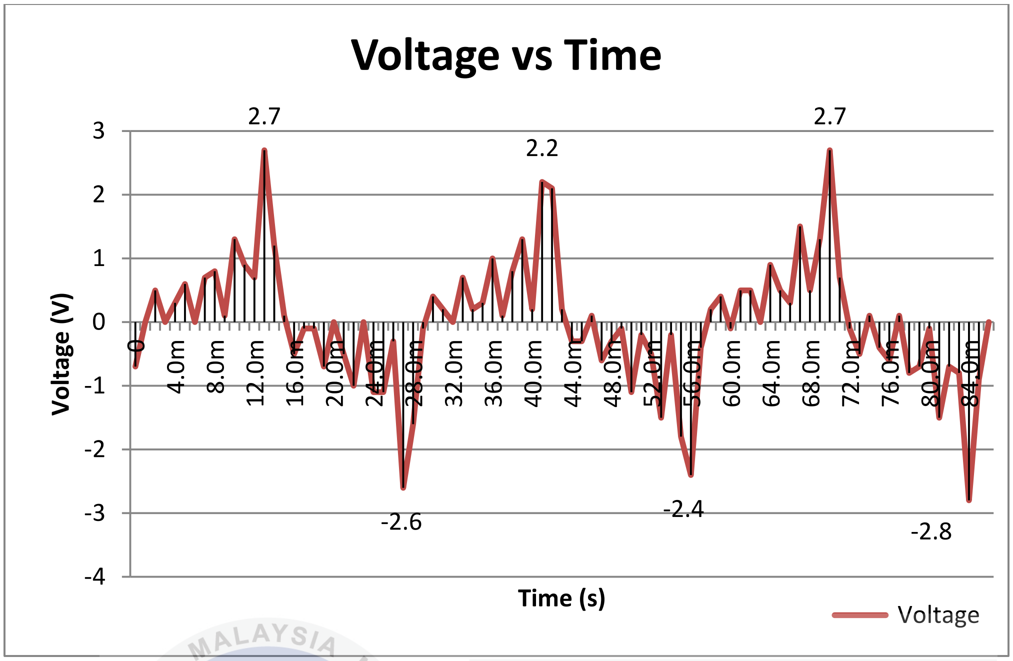

Figure 4.6: Copper wire at receiver at distance 4 cm.

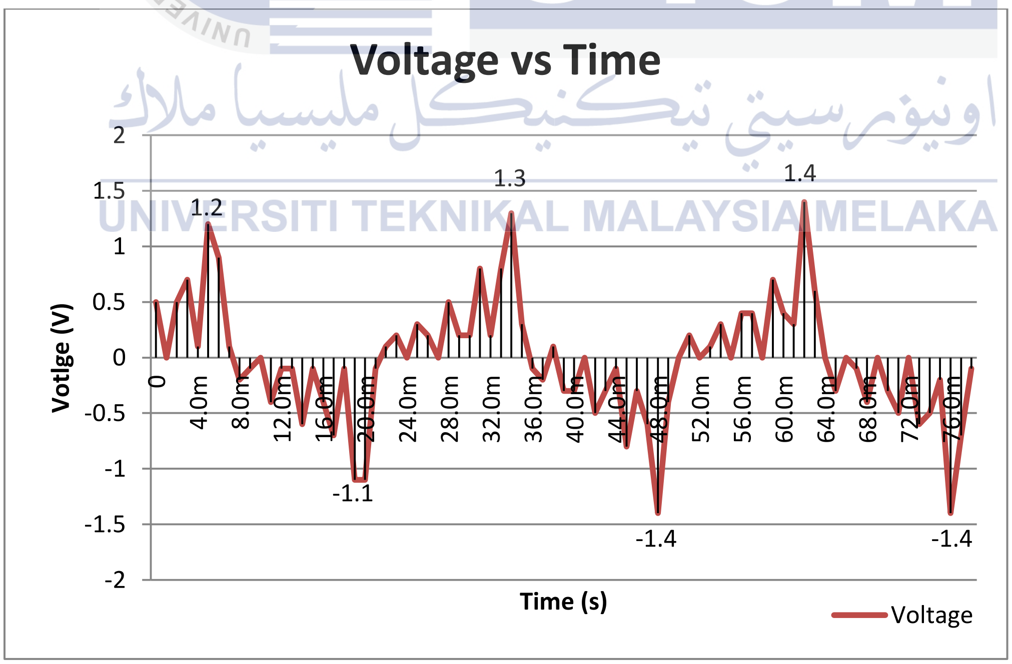

Figure 4.7: Copper wire at receiver at distance 6 cm.

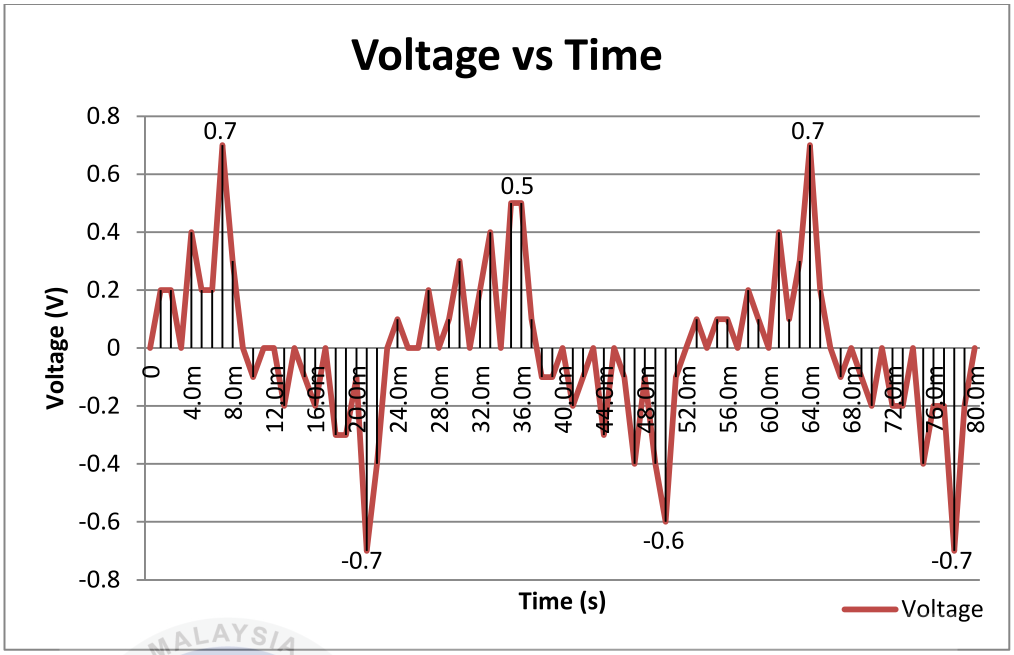

Figure 4.8: Copper wire at receiver at distance 8 cm.

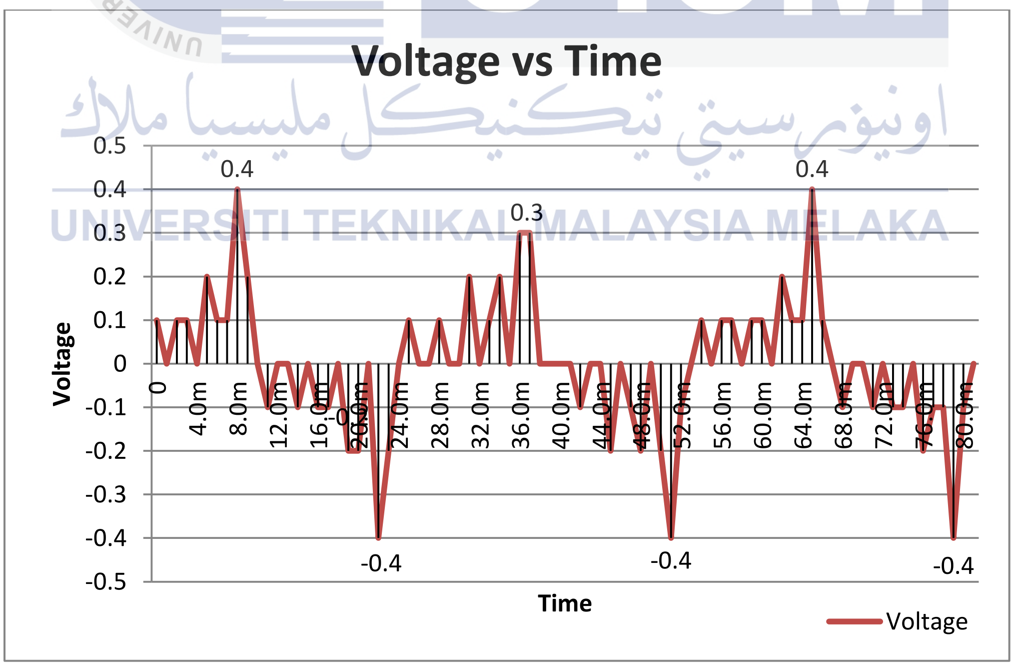

Figure 4.9: Copper wire at receiver at distance 10 cm.

Figure 4.1and Figure 4.2 is a graph that had been produced from LabVIEW using a user interface (UI) and the data had been collected as continuous data in Microsoft Excel and represent in graph form in Figure 4.3 until Figure 4.9 for copper wire coil. Based on Figure 4.4 the voltage that been produced to transfer power at the transmitter average at 17.9 Volt, and by referring Figure 4.5 at the receiver side at 0 cm distance the power that transmitted from transmitter is average 10.5 Volt. The analysis and efficiency of this normal copper wire will be explained on the next chapter.

4.3 Experiment Transfer Power Using Enamel Copper Wire

Then the second experiment had been done using the second material for transmitter and receiver coil that is enamel copper wire. They are a lot of difference when it transfer the power and will be analysed at next chapter with their own performance and efficiency.

Table 4.2: Voltage vs Distance for Enamel Copper Wire.

NO	Transmitter	Receiver	Distance
1	20.9 V	20.9 V	0 cm
2	20.9 V	11.1 V	1 cm
3	20.9 V	6.8 V	2 cm
4	20.9 V	5.9 V	3 cm
5	20.9 V	3.9 V	4 cm
6	20.9 V	2.5 V	5 cm
7	20.9 V	1.9 V	6 cm
8	20.9 V	1.3 V	7 cm
9	20.9 V	0.9 V	8 cm
10	20.9 V	0.7 V	9 cm
11	20.9 V	0.6 V	10 cm

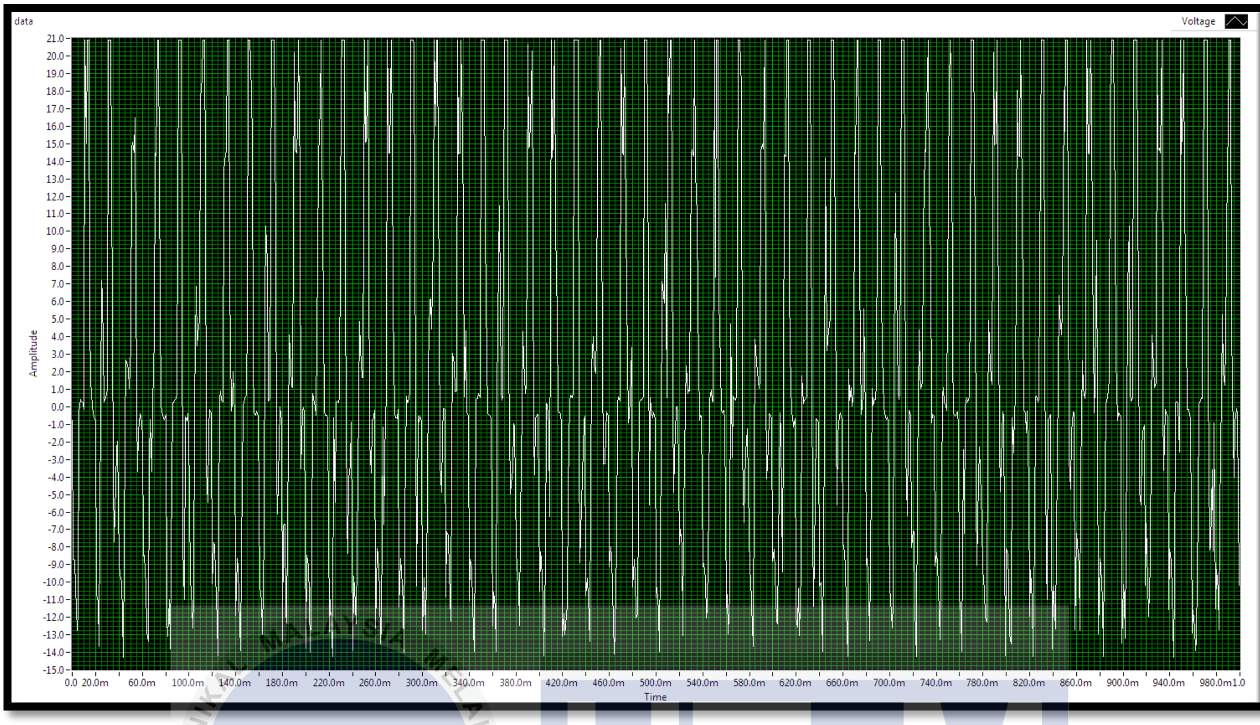

Figure 4.10: Enamel wire at transmitter using LabVIEW.

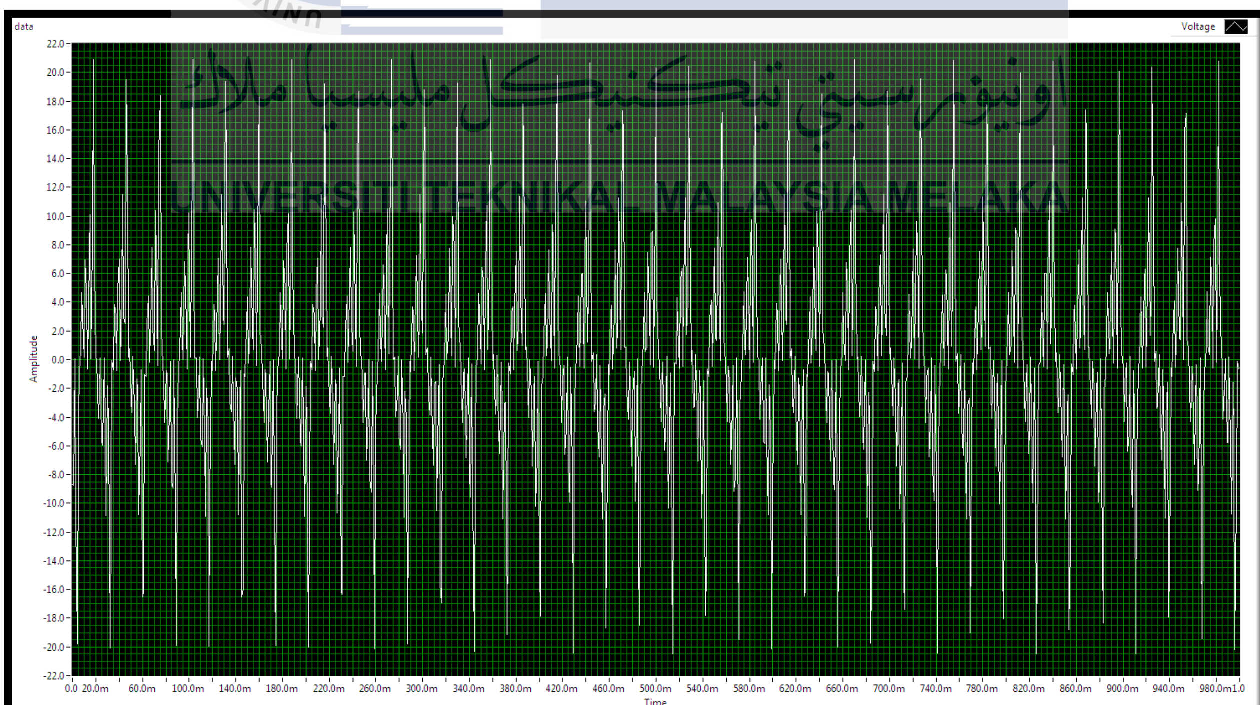

Figure 4.11: Enamel wire at receiver using LabVIEW.

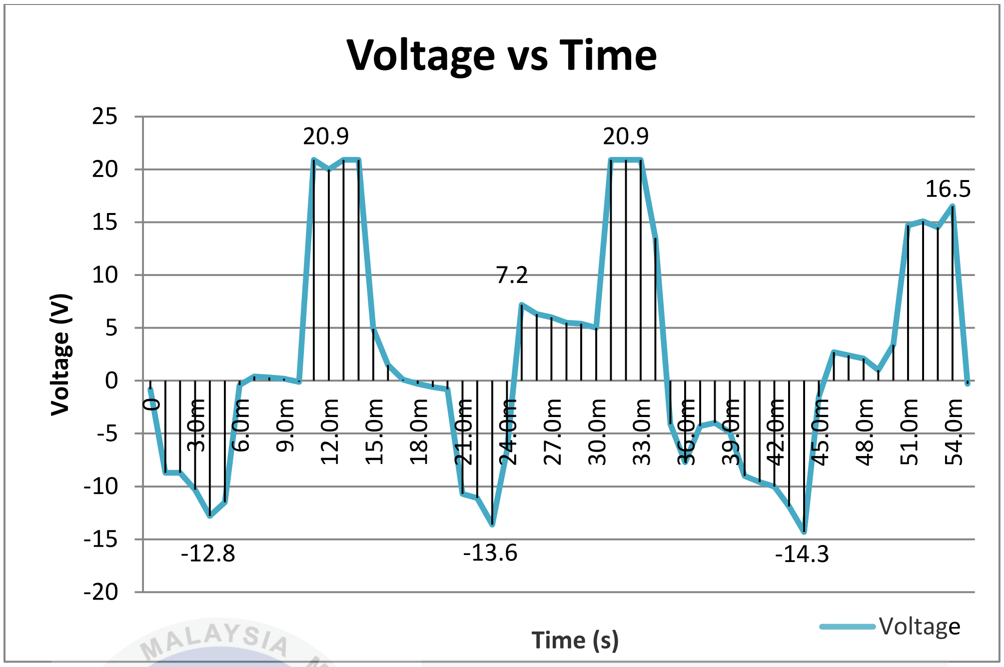

Figure 4.12: Enamel wire at transmitter.

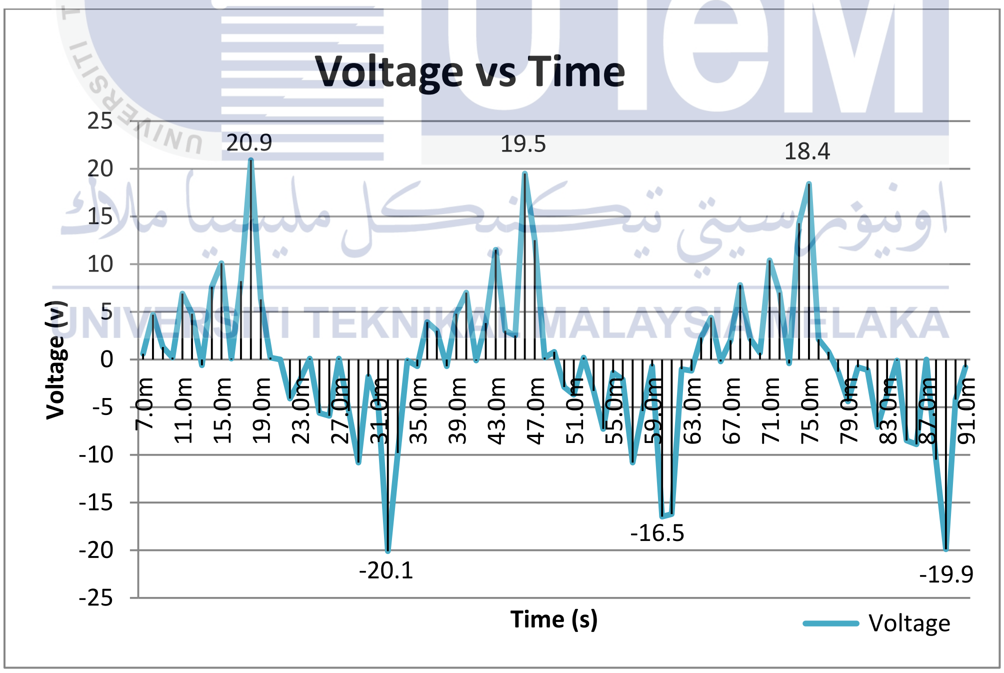

Figure 4.13: Enamel wire at receiver at distance 0 cm.

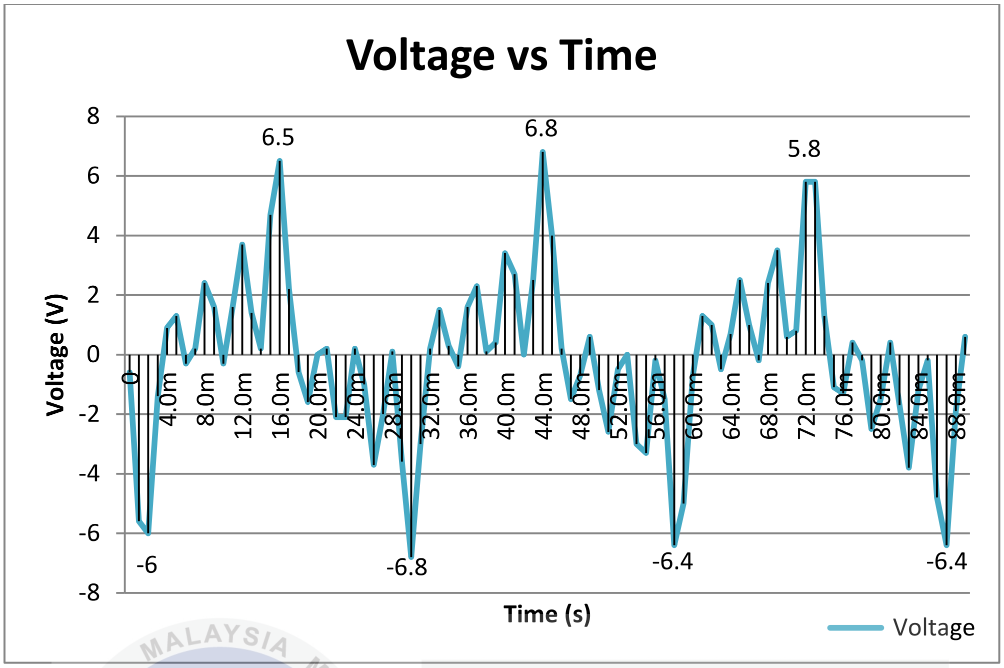

Figure 4.14: Enamel wire at receiver at distance 2 cm.

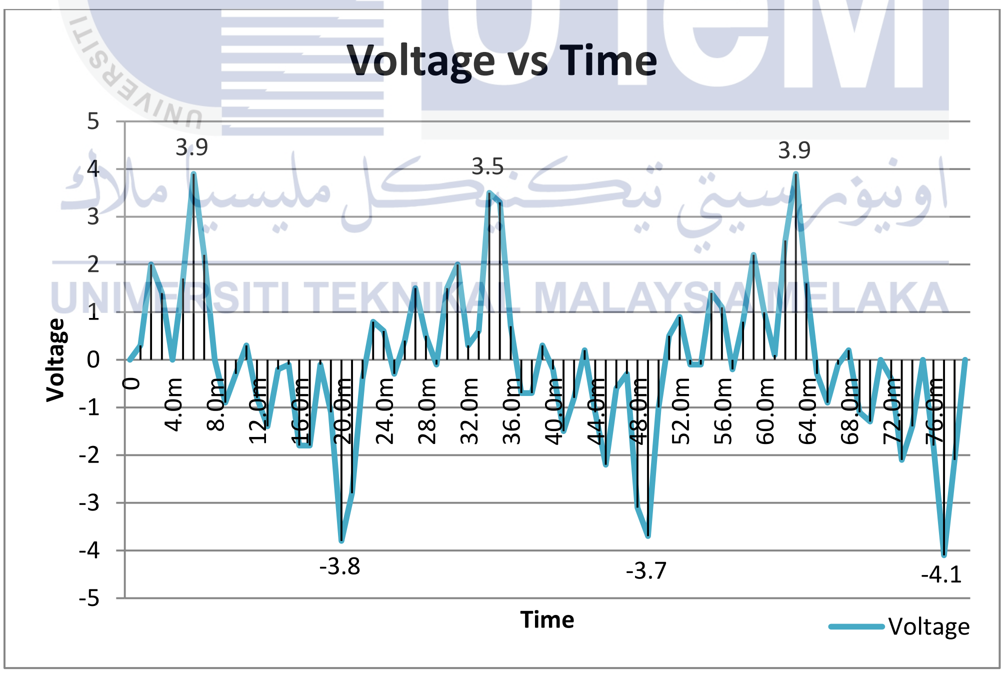

Figure 4.15: Enamel wire at receiver at distance 4 cm.

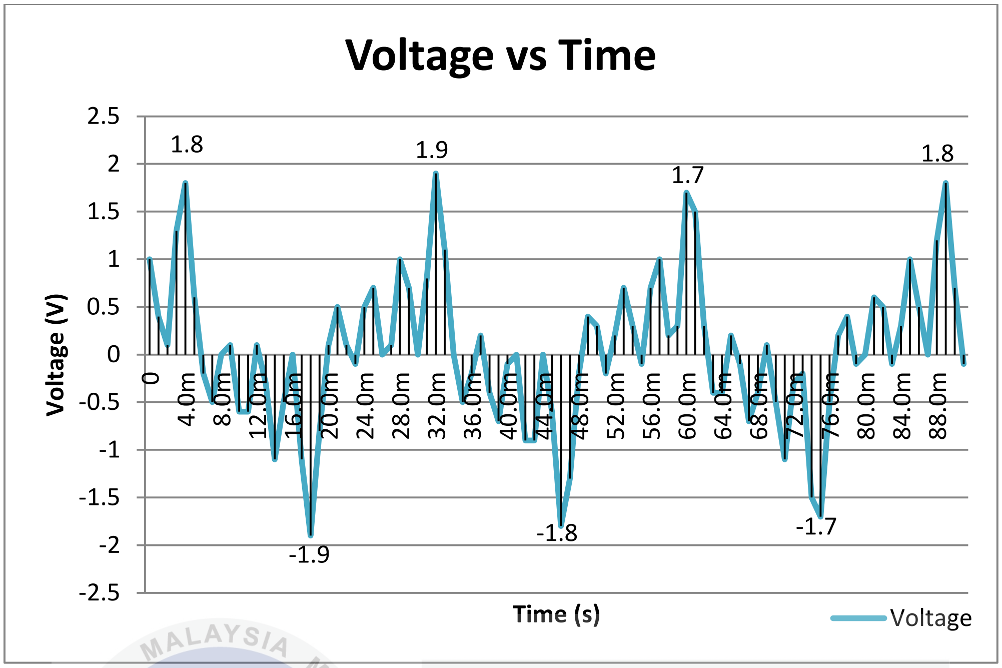

Figure 4.16: Enamel wire at receiver side distance 6 cm.

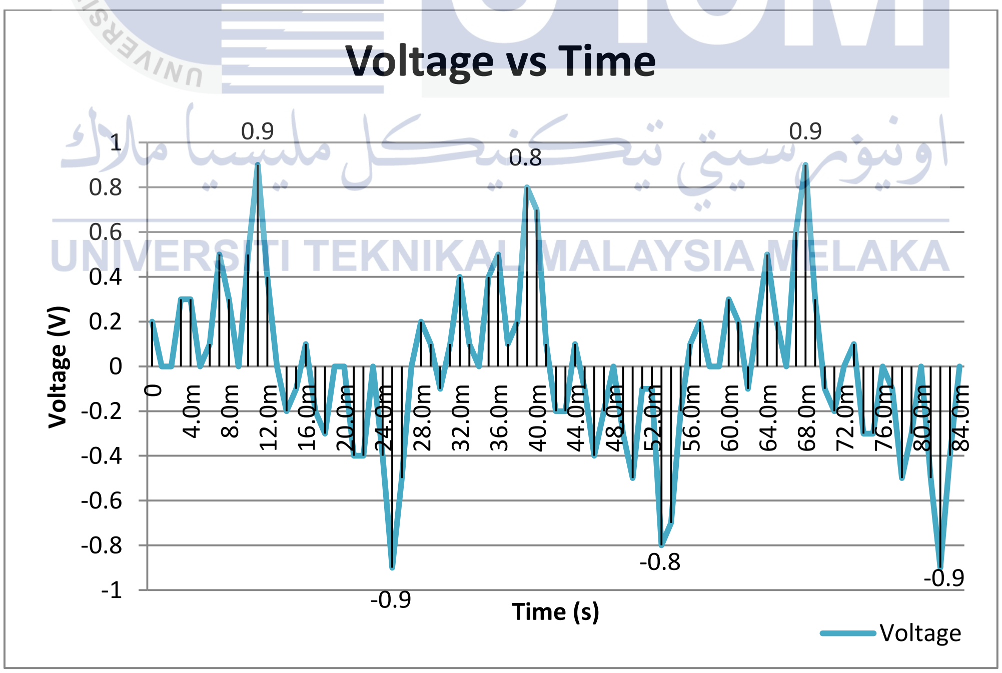

Figure 4.17: Enamel wire at receiver side distance 8 cm.

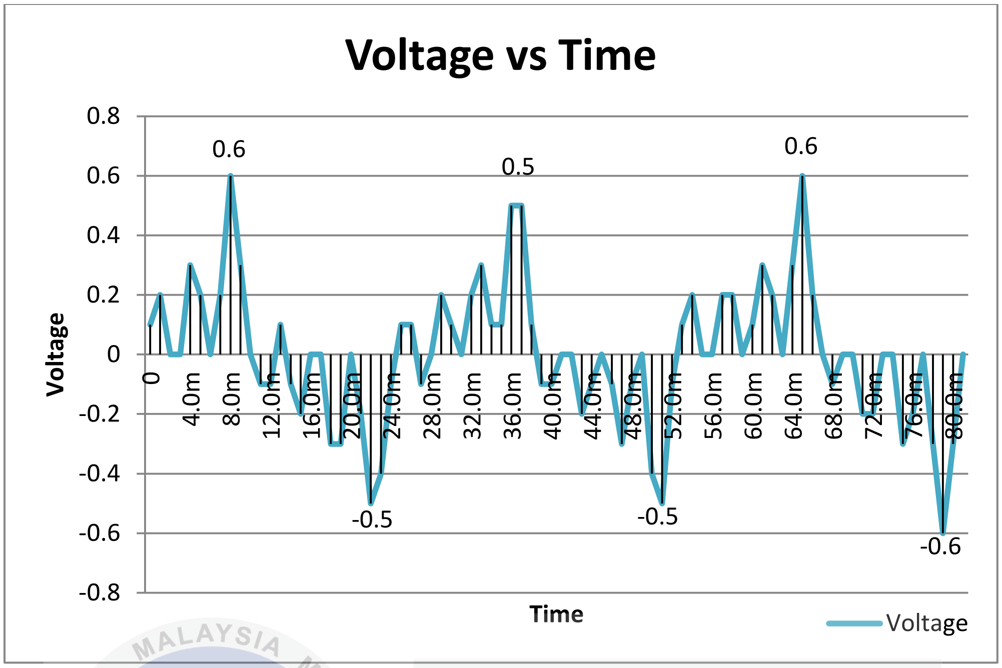

Figure 4.18: Enamel wire at receiver side distance 10cm

As we can see at Figure 4.10 and Figure 4.11, the figure shows the user interface (UI) that had been produced by LabVIEW from transmitter and receiver of wireless power transfer. For enamel copper wire coil, the data collect continuous in Microsoft Excel and represent in graph in Figure 4.12 until Figure 4.18. By refer Figure 4.12, we can see the voltage that been produce using enamel copper wire is more high that normal copper that is average 20.9 Volt. Then we can see figure 4.13 at the receiver side on 0 cm, the transfer power from transmitter to receiver is average 20.9 volt. They had a lot of difference of the two material uses for coil. The analysis will be discussing more on the following chapter.

CHAPTER 5

ANALYSIS AND DISCUSSION

5.1 Overview

This chapter presents the analysis and discussion of this project based on the result obtained from the previous chapter. In this analysis section, the important parts that need to be analysed are the performance of the material coil at the system by referring the experiment result. There are two analysis have been conducted. The analysis process includes the comparison power transfer between two materials that is normal copper wire and enamel copper wire versus to distance and also analysis on the performance and efficiency of each material on distance.

5.2 Analysis of Power Transfer

Table 5.1: Voltage vs Distance for Normal Copper Wire Coil.

NO	Transmitter	Receiver	Distance
1	17.9 V	14.6 V	0 cm
2	17.9 V	10.5 V	1 cm
3	17.9 V	7.0 V	2 cm
4	17.9 V	4.1 V	3 cm
5	17.9 V	2.7 V	4 cm
6	17.9 V	1.8 V	5 cm
7	17.9 V	1.4 V	6 cm
8	17.9 V	1.1 V	7 cm
9	17.9 V	0.7 V	8 cm
10	17.9 V	0.6 V	9 cm
11	17.9 V	0.4 V	10 cm

Table 5.1 shows the voltage vs distance using normal copper wire as resonance coil to transmit and receive the power transfer. Due to distance, voltage will drop because lack of magnetic field to generate current. When we increased the distance, the voltage will decrease more. By referring Figure 4.3 at the transmitter, we can see that at graph the oscillator oscillate the voltage to transfer power from transmitter to receiver. At the normal copper wire coil, current will flowing through along a coil. The magnetic field or magnetic flux will be produce on the coil and will act as primary coil. On the second coil it will called secondary coil, the magnetisation due to the current in the primary coil runs all the way of coil it will be magnetization the secondary coil and will produce current.

Figure 4.4 shows the voltage had been transferred from the transmitter to the receiver at a distance of 0 cm. At 0 cm, the wireless power transfer were measure when transmitter and receiver coil were stack up each other's. We can see also the graph had losses when transferred power due to certain factor. The main factor in wireless power transfer is heat losses or known as copper losses, heat losses in the winding materials contribute the largest part of the losses. It will created resistance of the conductor to flow current or electrons, the electron motion causes the conductor molecules to move and produce friction and heat. As we can see Figure 4.5 until Figure 4.9 the voltage that transferred from transmitter to receiver had been decrease. This is because of the magnetic field that been produced from transmitter becoming weak due to the distance and cannot magnetize the receiver properly.

Table 5.2: Voltage vs Distance for Enamel Copper Wire Coil.

NO	Transmitter	Receiver	Distance
1	20.9 V	20.9 V	0 cm
2	20.9 V	11.1 V	1 cm
3	20.9 V	6.8 V	2 cm
4	20.9 V	5.9 V	3 cm
5	20.9 V	3.9 V	4 cm
6	20.9 V	2.5 V	5 cm
7	20.9 V	1.9 V	6 cm
8	20.9 V	1.3 V	7 cm
9	20.9 V	0.9 V	8 cm
10	20.9 V	0.7 V	9 cm
11	20.9 V	0.6 V	10 cm

We can compare the power transfer from transmitter to receiver by refer Table 5.2 for enamel copper wire coil with Table 5.1, there are a lot of difference of transfer the power. At the transmitter the voltage produce by enamel copper wire coil is 20.9 V rather than normal copper wire coil, it only produce 17.9 V. it is about 3 V the difference of them. For the receiver side at distance 0 cm, the enamel copper wire coil does not have any of losses in transfer the power. As we informed earlier, Enamel wire also known as other name that is magnetic wire. Enamel wire is a copper wire coated with very thin layer of insulation. At 0 cm, we use the same method as normal copper wire where the wireless power transfer were measure when transmitter and receiver coil were stack up each other's. Figure 4.10 and Figure 4.11 is a data from wireless power transfer using user interface (UI) from LabVIEW, it is hard to analyse the data and had been transferred to Microsoft Excel to easier the analysis. Figure 4.12 is representing the transmitter of wireless power transfer using enamel copper wire coil. Figure 4.13 we can see the graph had ripple, this is due to poor of filter to minimize the ripple. Enamel wire also got the same problem as normal copper wire that is heat losses. Figure 4.13 until Figure 4.18 the voltage that been transferred become decreasing and the magnetic field became weak due to distance of receiver.

Table 5.3: Difference Voltage between the Coils.

NO	Copper Wire Coil	Enamel Copper Wire Coil	Difference
1	14.6 V	20.9 V	6.3 V
2	10.5 V	11.1 V	0.6 V
3	7.0 V	6.8 V	0.2 V
4	4.1 V	5.9 V	1.8 V
5	2.7 V	3.9 V	1.2 V
6	1.8 V	2.5 V	0.7 V
7	1.4 V	1.9 V	0.5 V
8	1.1 V	1.3 V	0.2 V
9	0.7 V	0.9 V	0.2 V
10	0.6 V	0.7 V	0.1 V
11	0.4 V	0.6 V	0.2 V

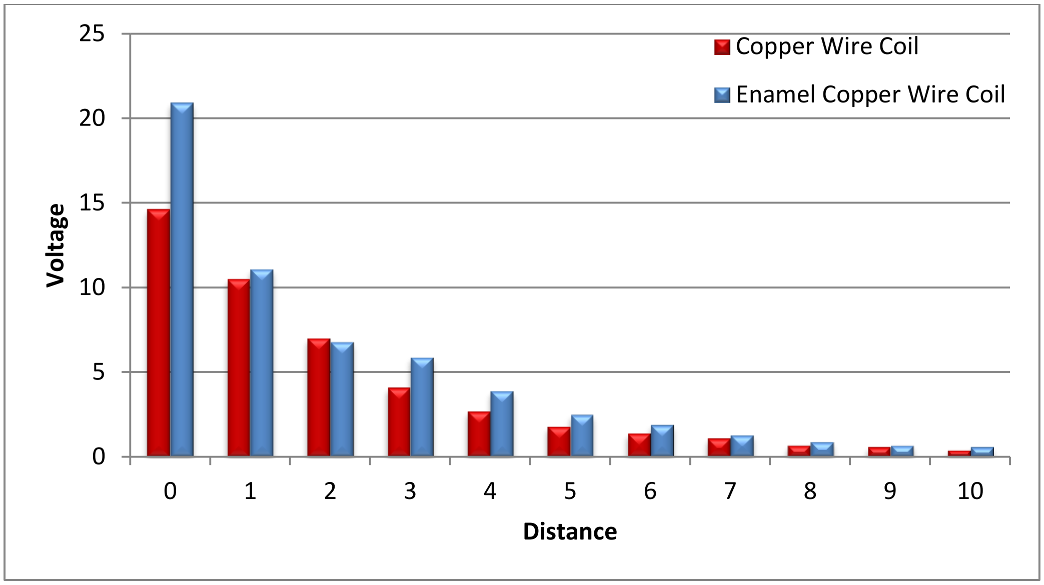

Figure 5.1: Visual Difference Voltage from Table 5.3.

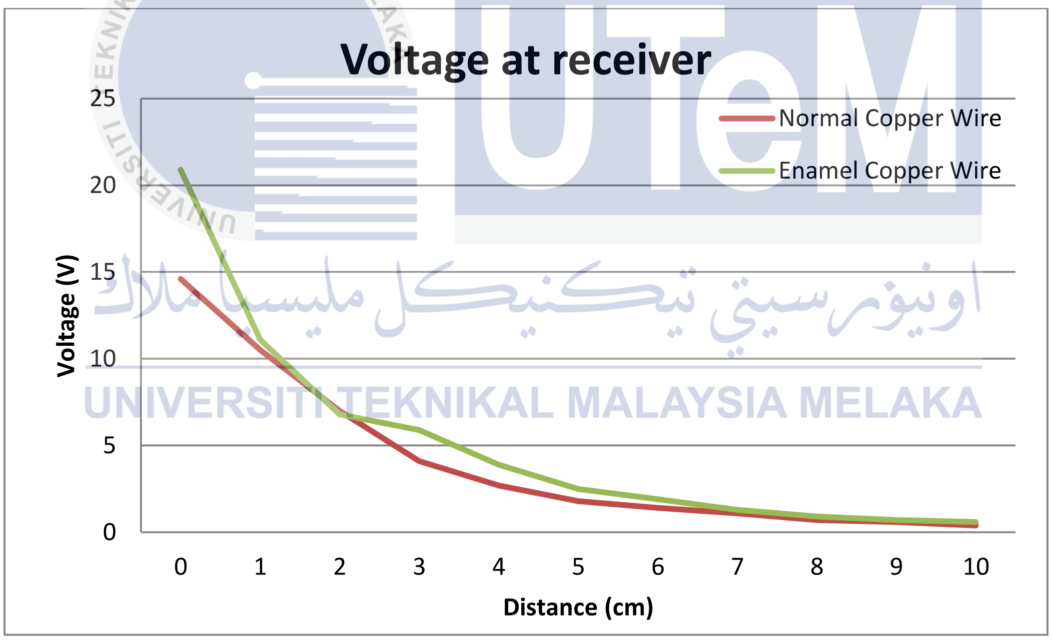

Figure 5.2: Different Voltage at receiver of two type wire coil.

As we can see Figure 5.1, it had a difference voltage when it transfers power using each of the coils. At 0 cm, the difference is too large between enamel copper wire coil and normal copper wire coil. With this data we can determine that enamel copper wire coil transfer power more high than copper wire coil. Enamel copper wire coil also has a quite good in electromagnetic, this can be proved using the Figure 5.1 that the enamel copper wire coil transfers voltage more than copper wire. Most of the transfer power we can see at Figure 5.1, Majority the power transfer is on enamel copper wire coil rather than copper wire coil just only at 2 cm the copper wire coils data is higher that enamel copper wire coil. Enamel copper wire produce strong magnetic field than normal copper wire. From Table 5.1 and Table 5.2, we can plot a graph shown in Figure 5.2 where the amplitude voltage at receiver are decreasing when the distance increase between transmitter and receiver.

5.3 Efficiency of Resonant Coil

This calculation is to show how much the performance or efficiency of power transfer from transmitter to receiver on the resonance coils each type. This calculation is being calculated using the following formula:

$$\% \text{ Efficiency} = \frac{\text{Receiver}}{\text{Transmitter}} (100\%)$$

5.3.1 Percentage Normal Copper Coil

Table 5.4: Efficiency of Copper Wire Coil vs Distance

NO	Distance	% Efficiency
1	0 cm	81.56
2	1 cm	58.60
3	2 cm	39.11
4	3 cm	22.91
5	4 cm	15.10
6	5 cm	10.06
7	6 cm	7.82
8	7 cm	6.15
9	8 cm	3.91
10	9 cm	3.35
11	10 cm	2.23

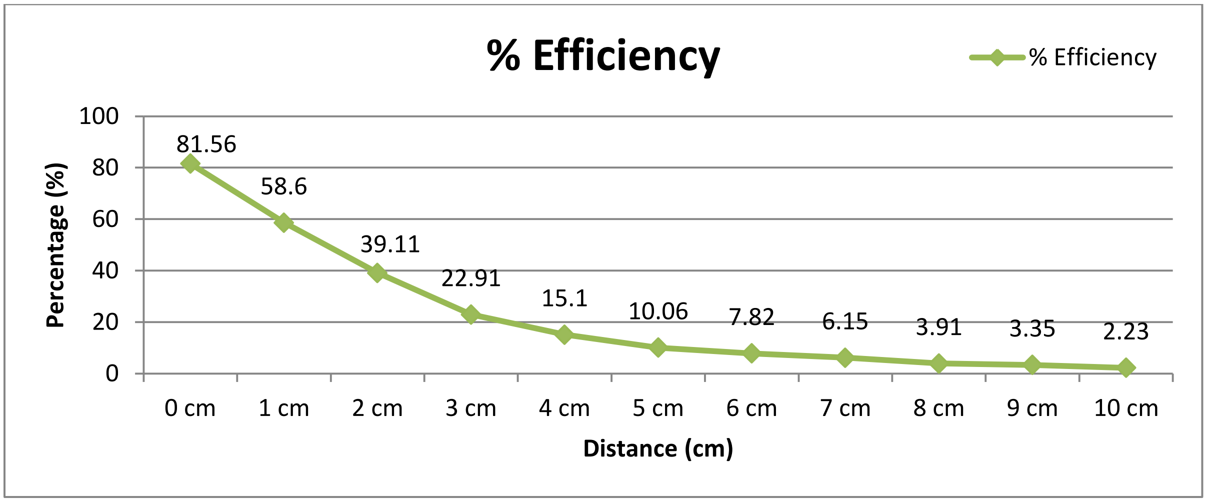

Figure 5.3: Efficiency of Copper Wire Coil VS Distance

As we can see at Table 5.4 and had been visualized in Figure 5.3, the performance or the efficiency of this coil had been greatly decreased and will be affected on transferring the power. The best power transfer using this coil is at 0 cm, where the efficiency is 81.56% at transferring the power. This efficiency of this wireless power transfer is depending on the magnetic field than had been produced on the transmitter. It became inefficiency when the distance increased due to a weak magnetic field.

5.3.2 Percentage Enamel Copper Coil

Table 5.5: Efficiency of Enamel Copper Wire Coil VS Distance.

NO	Distance	%Efficiency
1	0 cm	100
2	1 cm	53.11
3	2 cm	35.54
4	3 cm	28.23
5	4 cm	18.66
6	5 cm	11.97
7	6 cm	9.10
8	7 cm	6.22
9	8 cm	4.31
10	9 cm	3.35
11	10 cm	2.87

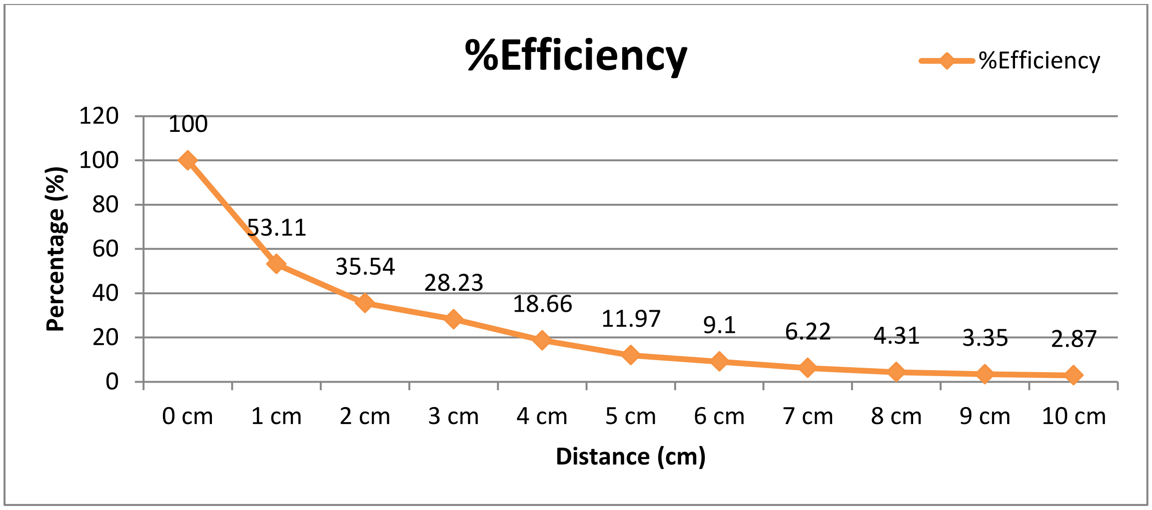

Figure 5.4: Efficiency of Enamel Copper Wire Coil vs Distance.

By referring Table 5.5 and been visualize in Figure 5.4, the efficiency of this enamel copper wire coil had a difference compared to the copper wire coil. At the beginning, the power transfer without any losses and the performance become decrease when we add some distance. As we can see Figure 5.5, majority of data show that the enamel copper wire coil is more efficient in transfer power due to strong magnetic field.

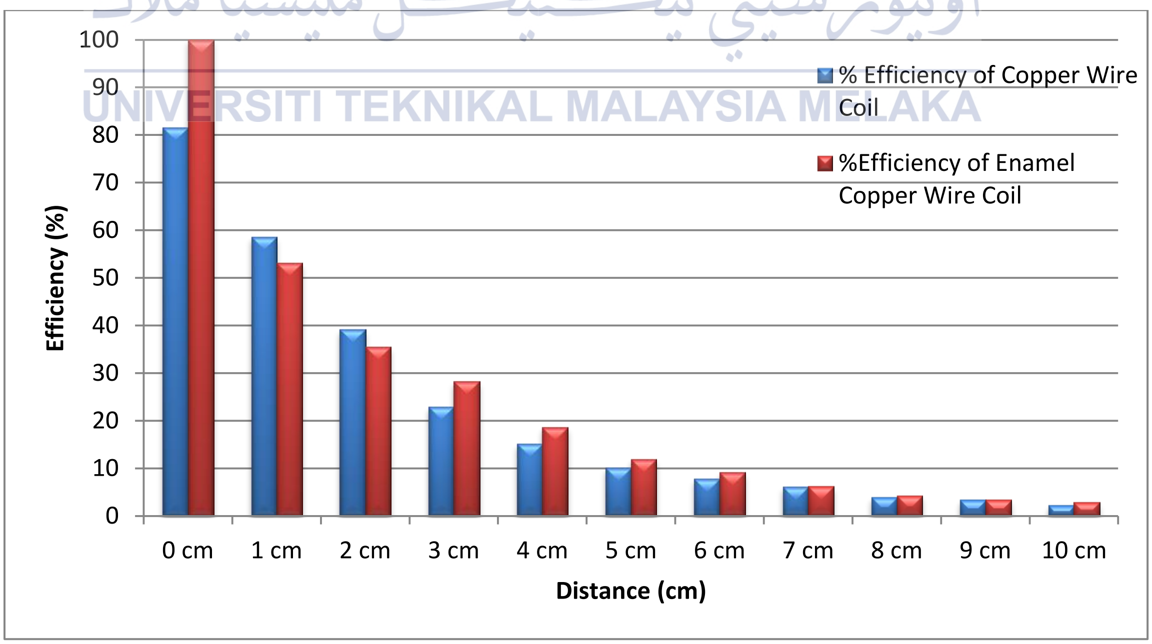

Figure 5.5: Difference Efficiency of Each Type of Coil.

CHAPTER 6

CONCLUSION AND RECOMMENDATION

6.1 Overview

In this chapter, the conclusion of the report is described and some future recommendations are suggested.

6.2 Conclusion

Wireless power transfer monitoring project objective have been achieved with the outstanding result. From the first objective, investigate wireless power transfer system using resonant coil has been achieved successfully with suitable circuit that used for commercialization.

For second objective, develop and test it to establish its functionality. By etching the board and then test it to see the functionality. The circuit just follow existing circuit that had been commercializing, as the board functioned then we succeed the objective.

The third objective is the main part, to validate the performance coil of wireless power transfer using LabVIEW. An experiment had been carried out by several of distance to see the decreasing power transfer each type of wire coil. As we done this experiment, we need to analyse and see the efficiency to validate it, with this we have fulfil the third objective.

6.3 Recommendation

After completing this final report, there are some suggestions or recommendation to improve the wireless power transfer. The improvement that can be done is:

I. Develop a wireless power transfer that can transfer power in a medium or long range without harm environment and health.

II. Make a study to find a suitable coil to transfer power without having a great losses and stable when transfer the power.

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