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A Experiment Method of Wireless Power Transfer for Charging Devices

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ABSTRACT : *Wireless Power Transfer Technology would be applied in the charging devices. For example Electric Vehicles. Due to the global warming is very serious, the fossil fuels are dwindling. For this situation, it can use the battery to operate the cars, we are looking for some of the renewable energy. Therefore, the electric vehicles technology and skill are most popularity and mature. Many people have replaced to an electric vehicle, although the cost more expensive than the petrol vehicle, to reduce the use of fossil fuels are worth. Since the electric vehicle supporting is not much, especially for the electric vehicle chargers. Government and manufacture not enough information & details of the electric vehicle, it is difficult to see the charger facility which locates at the public area or parking, therefore cause inconvenient. This technology is taken widespread to use of an electric vehicle. For this project separate in two stages, the first stage to find out the relationship of frequency(f), capacitance(C) and inductance(L) by the much lab experiment and calculation. In stage two, develop a hardware model to deliver the wireless power transfer system can be recharged for mobile phone and model car wirelessly and find out the better combination and method through comparing a different kind of coil density and distance.*

Keywords: *Wireless Power Transfer Technology, Electric Vehicles, Frequency, Capacitance, Inductance.*

I. INTRODUCTION

The Traditional vehicle relies on natural resources such as diesel or gasoline through engine combustion to generate required power to keep the vehicle running on the road. However, as we all known, the by-product from engineer combustion is green-house-gas (GHG). GHG emission is one of the main causes of globe warming. Nowadays, reduction in GHG emissions is the main topic in many countries. Some countries require the vehicle must be zero-emission, thus many vehicle manufacturers to develop the electric vehicle (EV), [1] one the most famous EV manufacturers is Tesla.

However, same as a traditional vehicle, after running several hundred kilometers, an EV required refill – battery recharge. Two commonly use battery recharging methods are either conductive wiring or fixed spot high frequency resonant wireless charging system. Unfortunately, neither method can fully re-charge the battery within few minutes. For busy city life and some business services which required hit on the road all day long, EV might not be the best choice.

In order to respond the rising trend of the use of EV, research and developed a mass and flexible battery recharge system is necessary. One of the choices is wireless power transfer (WPT) system. Wireless power transfer technology is no physical connection between the vehicle and charging the device. Compare with the traditional conductive method, wireless power transfer can reduce the inconvenience and hazard. The initial objective of this paper is instead of using the power cord to charge EV, this paper will go for WPT technology while maintaining a comparable power level and efficiency. The ultimate target is to develop a dynamic system to power the moving vehicles on the road. It will extend the driving range [2].

Nissan and Chevrolet have developed wireless charging system incorporation with Evertran for their EV models, the Nissan LEAF and Chevrolet Volt, [3] the power volume of those models can only support200km to 250 km movement. It means that they need to be re-charged after they are moved around 200km to 250km [4]. Also,the charging time is at least 4 hrs. Since people rhythm of life becomes rapidly, the charging time and driving range is needed to be enhanced. Thus, wireless power transfer technology trends will be introduced.

Our topic is about wireless charging system. It can be found in internet, library and Car catalog. Previous work has shown that how to select proper coils and components to maintain the high frequency suit the working conditions for charging.

The paper Author to discuss the battery charging use resonance inductive coupling methodology, the charging time is too shortly, it should provide more powerful energy to operate for EV and showing the improvement of the size of the batteries and the power efficiency over a longer distance.
They use a MATLAB to simulate the figure to show the actual situation. This MATLAB can tune the frequency and the size of the battery which is suitable for EV[5].
The paper Author to discuss the advantage and disadvantage of the inductive charging system and the result to show the details are below [6].
Advantage:
1)Tackle range anxiety, 2)Easy to use, 3)Safe (no cable), 4) Lower risk vandalism, 5) Landscape preservation
Disadvantage:
1) High Cost, 2) Lower energy efficiency, 3)EMI (safety)

There are a lot of articles to discuss wireless charging system. Authors have common acceptance that the EV is useful to the world. It can reduce the GHG emissions and avoid the global warming. Thus, this dissertation will carry out the WPT system to prove the inductive coupling methodology can charge the battery continuously to increase EV driving range.

II. THE OPERATION OF WIRELESS POWER TRANSFER SYSTEM

The According to [7],wireless power transfer system includes the three major parts, power supply, transmission parts and loading parts , the power supply includes power input port and bridge rectifier, the transmission parts include transmission coil and receiver coil.

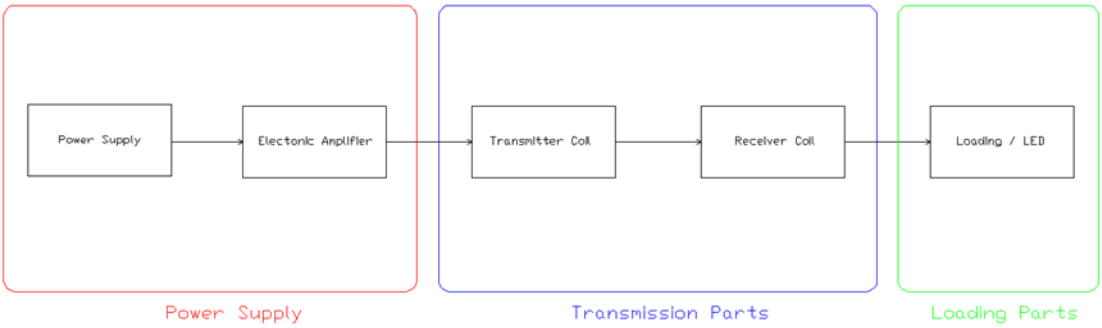

Figure.2.2.1 System Diagram

The power supply sources to be designed connect the transmitter parts.
The transmitter coil and Receiver coil are winding for the wireless power transfer method.
The load parts are target devices.

Wireless power transfer (WPT) using magnetic resonance and magnetic induction technology which cannot use the direct wires to connect the electric devices. In fact, the WPT almost use in the low power device, such as mobile phone, toothbrush.WPT technology is developing rapidly in recent years[8]. At KW power level, the transfer distance increases from the meter to hundred meters with a grid to load efficiency above 90%. The advances made WPT very attractive to the electric vehicle (EV) charging applications in both stationary and dynamic charging scenarios [9]. As the charging facility compares with the electric vehicle, the charging facility is not enough. Thus, the WPT is feasible, it can reduce the waiting time and increase the driving range. In environmental, it can extend to use of electric vehicles to reduce the Carbon emissions will improve roadside air quality& reduce the waste of battery cost.

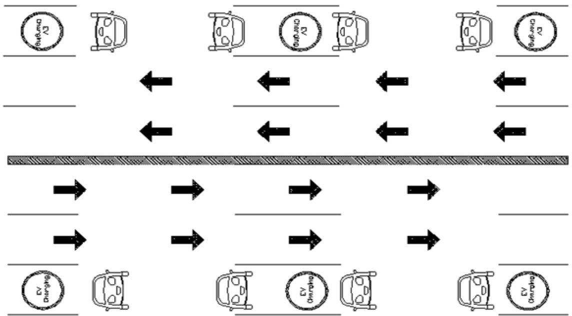

Figure.2.2.2 TheLayout Drawing to use wireless power system for charging on the road [10]

The Wireless Power Transfer (WPT) for ElectricVehicles (EVs)—Present and Future Trends. To explain the Dynamic WPT for EV Charging can be charged continuously while in motion and solve the battery problem with unlimited driving range [11].

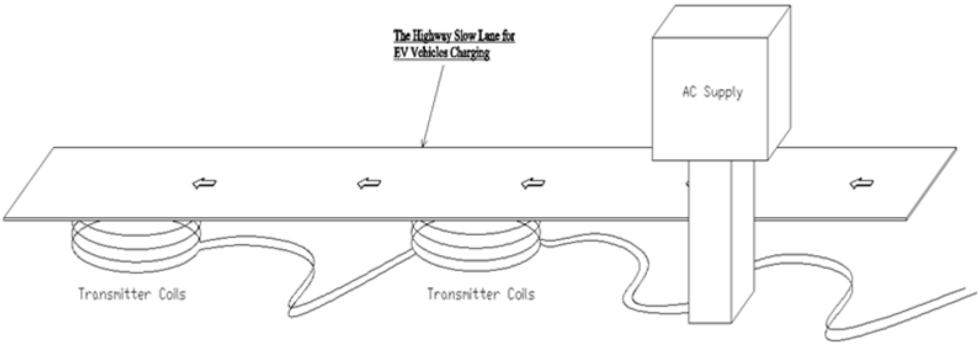

Figure.2.2.3 Dynamic WPT for EV Charging [11]

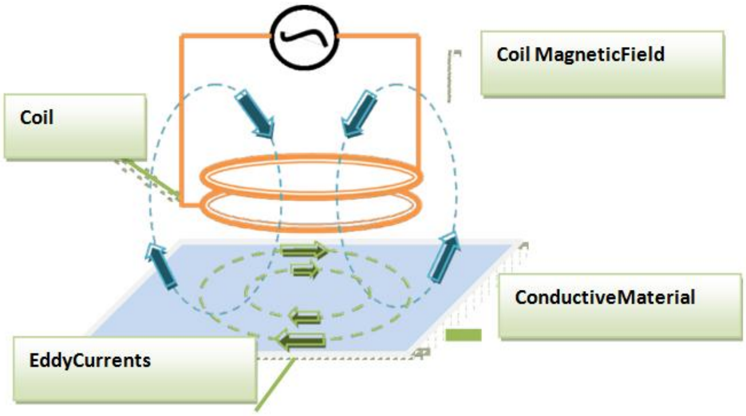

Figure.2.3.1 Eddy current occurs on the conductive material

The insulated platform has been developing for fix the coils. On the other hand, an insulated material is used to avoid the eddy current. Eddy current has been found in the swirls on the conductor. Once the coil connects to the electrical power source, the magnetic field would be found when the current flow through the coil. When the conductive metals have some movement and through a magnetic field, it will charge up the conductive metal and make a small circuit of current pass through the metal. It called 'Eddy current' [12]. As the eddy current flow through the metal, the eddy current magnetic field would occur on the conductive metal.It is a not good for the hardware model, the eddy current will make the magnetic field weak and the power transfer to the load side will decrease. The efficiency would be decreased. Furthermore, the eddy current will generate the EMF on the conductive metal; it will increase the mutual inductance from conductive metal to all of the coils. The system will be more complex. It is difficult to determine the equivalent circuit for analysis. To reduce or eliminate the eddy current effect, the conductive material has been used for build up the hardware model except for the coils.

III. STUDY ON THE ELECTRICAL CHARACTERISTIC OF THE TRANSMITTER AND RECEIVER COIL BY VARYING THE RESONANCE FREQUENCY

In this section, a two coil wireless power transfer system will be used to conduct two experiments. In experiment 1, two different physical sizes of copper coils will be tested. In experiment 2, two same physical sizes of copper coils will be tested. Through varying, the resonance frequency, changing of the electrical characteristic will be observed and record for further analysis.

3.1 Experiment 1(The size of different coil)

3.1.1 Copper Coils Physical Characteristic

In Table 3, it states the physical characteristic of both transmitter and receiver coils.

	No-nos. of turns	Conductor width	Dimension
Transmitter Coil	5 turns	0.1mm	200mm x 1mm
Receiver Coil	14 turns	0.05mm	52mm x 1mm

Table 3.1: Transmitter & Receiver Coil Physical Characteristic

Measured resistance of the transmitter coil is 2.48 MΩ.
Measured resistance of the receiving coil is 16.2 MΩ.

3.1.2 Operation Electrical Characteristic

In experiment 1, it operated under the following listed electrical characteristic.
Voltage (Input): 12V DC
Current (Input): 1A
System frequency: 1MHz


Figure.3.1.2.1. Transmitter CoilFigure.3.1.2.2Receiver Coil

3.1.3 Study on the relationship Coils Resistance Vs. Operation Frequency

This section will study the resistance of both transmitter and receiving coils while varying the operation frequency. Through calculation, R=rN/(σaδ), Table 4 & 5 were constructed.

Frequency	2MHz	3MHz	4MHz	5MHz	10MHz
R_1	7.38 Ω	9 Ω	10.4 Ω	11.67 Ω	16.5 Ω
R_2	5.37 Ω	6.63 Ω	7.6 Ω	8.5 Ω	12 Ω

Table 3.2: Relationship between System Operation Frequency and Coil Resistance

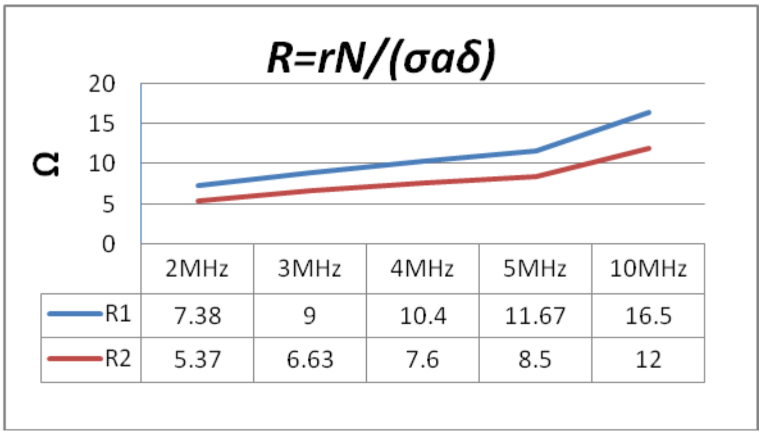

Table 3.3 Relationship between System Operation Frequency and Coil Resistance

3.1.4 Study on the relationship between the size of the capacitor and resonance frequency

In order to the build a proper resonance wireless power transfer system, properly size the size of the capacitor is very important. Through calculation, $L= [(2r)^2n^2] / (H + 0.9r)$, we can determine how much inductance we need for both transmitter and receiving coil.

	No-nos. of turns	Conductor width	Dimension	Inductance
Transmitter Coil	5 turns	0.1mm	200mm x 1mm	2.2uH
Receiver Coil	14 turns	0.05mm	52mm x 1mm	4.5uH

Table 3.4 Calculation of coils inductance

Through calculations, the inductance of the transmitter coil is 2.2uH and the receiver coil is 4.5uH respectively. Once the inductance has been obtained, the size of the capacitor can be calculated in order to generate different resonance frequency.

The formula of C= 1 / (w) ^{2}Lcan be used to find the size of capacitor required to generate desired resonance frequency. In Table 3.5, the calculation was performed. The size of capacitor requires for both transmitter and receiving coil under different resonance frequency was listed.

Transmitter Coil L=2.2uH,Receiver Coil L=4.5uH (Calculated value through Table 6)

Frequency	2MHz	3MHz	4MHz	5MHz	10MHz
C_1	2.9 x10 $^{-16}$F	1.2 x 10^{-16}F	7.2 x 10^{-17}F	4.6 x 10^{-17}F	1.1 x 10^{-17}F
C_2	1.4 x 10^{-16}F	6.2 x 10^{-17}F	3.5 x 10^{-17}F	2.2 x 10^{-17}F	5.6 x 10^{-18}F

Table 3.5 Determine of the two coil capacity

3.1.5 Study on the Relationship between the efficiency vs. distance

In figure 4.1.5.2, an experiment was performed and confirmed the power can be transmitted wirelessly. The input voltage was 12V DC and resonance frequency was 1MHz.

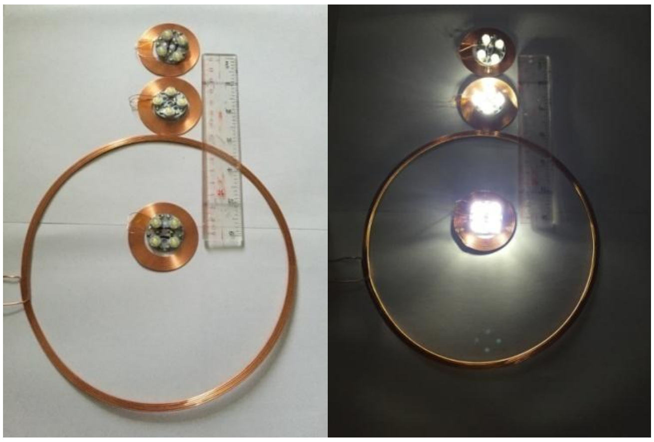

Figure.3.1.5.1 The result of Experiment 1Figure.3.1.5.2The Led over13cm

A detail data record on receiving coil's (Voltage V2 & Current I2) based on the distance measurement between 1cm and 13cm was indicated in Table 3.6.

Distance	1cm	2cm	3cm	4cm	5cm	6cm	7cm	8cm	9cm	10cm	11cm	12cm	13cm
$V_{2\ (peak)}$	6	3	2.6	2.8	2.8	2.2	1.8	1.6	1.4	1.3	1.25	1.2	1.19
$I_{2\ (peak)}$	0.5	0.48	0.48	0.45	0.44	0.41	0.4	0.4	0.38	0.37	0.37	0.35	0.35
η(%)	75	36	31.2	31.5	30.8	22.5	18	16	13.3	12	11.5	10.5	10.4

Table 3.6 Determine of the two coil distance

With the data collected from the experiment, power efficiency (η) = Pout / Pin = (Vout2 / RL) / (V2 x I2) x 100%can be calculated. Detail efficiency information was consolidated and presented in Table 9 as indicated below.

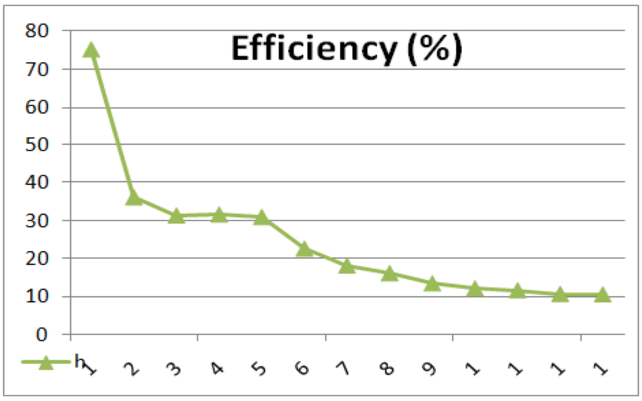

Table 3.7 Power Efficiency on Different Coil Size

3.1.6 Experiment 1 Conclusion

From experiment 1, following listed points were observed.

1. From Table 3.2, the resistance for both the transmitter and receiving coils will be gradually increased when resonance frequency increase. The increasing trend seems to be a linear form.
2. The placing distance between two coils also was playing a major role. Further, apart between transmitters and receiving coils, less power will be transfer wirelessly.
3. Power transmission capability and placing distance between two coils have adirect relationship with efficiency. In Table 3.7, it clearly shows if two coils were placed close to each other, high power transmission efficiency. On the other hand, if two coils were placed far from each other, less power transmission efficiency.
4. During efficiency vs. distance experiment, the input voltage was only set at 12VDC and the resonance frequency was set at 1MHz. The reason behind that because if the resonance frequency increase, the operation temperature of the coil will increase. Hence, to prevent burnt out the coil, the resonance frequency for the experiment was set at 1MHz.

3.2 Experiment 2(The size of the Same coil)

In experiment 2, all the test producers will remain the same as experiment 1. However, both transmitter and receiver coil will remain the same. Details as indicated below.

3.2.1 Copper Coils Physical Characteristic

In Table 10, it states the physical characteristic of both transmitter and receiver coils.

	No-nos. of turns	Conductor width	Dimension
Transmitter Coil	3 turns	1.3mm	150mm x 1.3mm
Receiver Coil	3turns	1.3mm	150mm x 1.3mm

Table 3.8 Transmitter & Receiver Coil Physical Characteristic

Measured resistance of the transmitter coil is 1Ω.

Measured Resistance of the receiving coil is 1Ω.

3.2.2 Operation Electrical Characteristic

As previously mentioned, the operation electrical characteristic will be same as experiment 1. Therefore, the operation electrical characteristic for experiment 2 will be same as experiment 1. Details as indicated below.

Voltage (Input): 12V DC

Current (Input): 1A

System frequency: 1MHz to 10MHz

Figure.3.2.2.1. Transmitter CoilFigure.4.2.2.2Receiver Coil

3.2.3 Study on the relationship Coils Resistance Vs. Operation Frequency

Same as experiment 1, in this section, both the transmitter and receiving coils' resistance characteristic will be monitored and recorded while varying the operation resonance frequency. Through calculation, R=rN/(σaδ), Table 11 & 12 were constructed.

Frequency	2MHz	3MHz	4MHz	5MHz	10MHz
R_1	0.072Ω	0.088Ω	0.1Ω	0.11Ω	0.16Ω
R_2	0.072Ω	0.088Ω	0.1Ω	0.11Ω	0.16Ω

Table 3.9 Relationship between System Operation Frequency and Coil Resistance

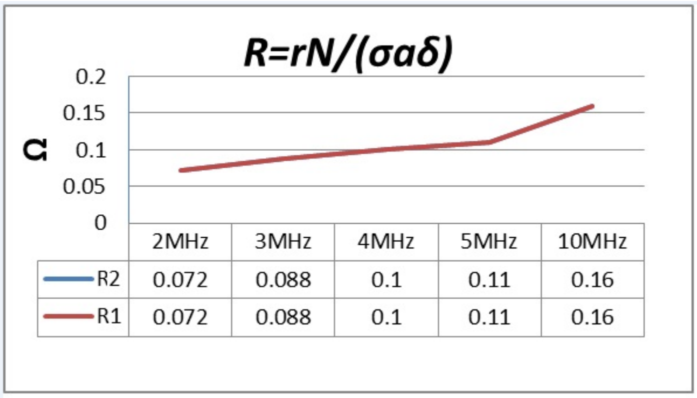

Table 3.10 Relationship between System Operation Frequency and Coil Resistance

3.2.4 Study on the relationship between the size of the capacitor and resonance frequency

Same as experiment 1, through calculation, L= [(2r)2n2] / (H + 0.9r), we can determine how much inductance we need for both transmitter and receiving coil. In Table 3.11, require inductance for both transmitter and receiving coil was calculated.

	No-nos. of turns	Conductor width	Dimension	Inductance
Transmitter Coil	3 turns	1.3mm	150mmx 1.3mm	2uH
Receiver Coil	3 turns	1.3mm	150mmx 1.3mm	2uH

Table 3.11 Calculation of coils inductance

Once the required inductance obtained, the size of the capacitor can be determined through calculation.
Transmitter Coil L=2uH,Receiver Coil L=2uH (Calculated value through Table 3.11)

Frequency	2MHz	3MHz	4MHz	5MHz	10MHz
C_1	1.2 x 10^{-18}F	5.5 x 10^{-19}F	3 x 10^{-19}F	1.9 x 10^{-19}F	2 x 10^{-9}F
C_1	1.2 x 10^{-18}F	5.5 x 10^{-19}F	3 x 10^{-19}F	1.9 x 10^{-19}F	2 x 10^{-9}F

Table 3.12 Determine of the two coil capacity

3.2.5 Study on the Relationship between the efficiency vs. distance

Once the size of the capacitor was defined and implemented on the electronic device, a study on the relationship between the efficiency vs. distance can be started. In order to compare with the previous set of data, the input voltage and resonance frequency was set as 12VDC and 1MHz to 10 MHz respectively. Details of the experiment result as indicated in Table 3.13.

Distance	1cm	2cm	3cm	4cm	5cm	6cm	7cm	8cm	9cm	10cm	11cm	12cm	13cm
$V_{2\ (peak)}$	10	13.5	14	14.2	14.2	14.1	14.1	14	13.3	11.2	11	9.5	8
$I_{2\ (peak)}$	0.3	0.2	0.2	0.21	0.2	0.17	0.15	0.14	0.14	0.13	0.11	0.1	0.09
η(%)	80	67.5	70	74.55	71	59.9	49.3	49	46.5	36.4	30.2	23.75	18

Table 3.13 Determine of the two coil distance

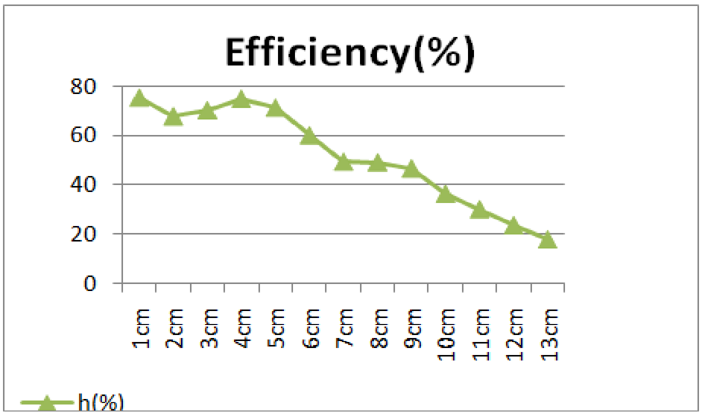

Table 3.14 The efficiency of Experiment 2

3.2.6 Experiment 2 Conclusion

From experiment 2, following listed points were observed.

1. From Table 3.10, the resistance for both transmitter and receiving coils were the same and was gradually increased when resonance frequency increase. The increasing trend seems to be a linear form which similar to the rising trend observed from experiment 1.
2. In regard the placing distance, same as experiment 1, further apart between transmitters and receiving coils, less power will be transfer wirelessly.
3. Same as experiment 1, from Table 3.14, the power transmission efficiency is relying on placing distance. The closer of coils put together, the high efficiency of power transmission.

3.3 Experiment Conclusion

Through experiment 1 & 2, following listed points have been observed.

1. The resistance of both the transmitter and receiving coil will increase while increasing the resonance frequency. The rising trend is linear form regardless the both transmitter and receiving coil are the same size or not.
2. In order to generate the proper resonance frequency, both inductance and size of the capacitor shall be properly calculated. Both experiment 1 & 2 has already demonstrated how to perform the calculation and obtain the size of the capacitor for each resonance frequency.
3. Despite the transmitter and receiving coil are the same size or not, the power transmission efficiency has a great relationship with the placing distance of the two coils. The closer of the placing distance, the higher power transmission efficiency. However, through the experiments, we believe same size coils might have better overall efficiency by comparing Table 3.7& Table 3.14.

IV. DEMONSTRATION AND COMPARE ON TWO COILS ARRANGEMENT FOR WIRELESS POWER TRANSMISSION

This chapter will be divided into three parts. First, further study on coil size in related to wireless power transmission capability. Second, demonstrate the capability of wireless power transmission of the finished product. Third, compare the charging capability of two proposed two coil wireless charging systems.

4.1 Further Study on Coil Size In Related To Total Power Transmission Capability

In order to conduct further analysis, three different sizes of the copper coil were built. Their physical characteristic as indicated in Table 4.1 below.

Type	Diameter	Turns	Copper Thickness
A	10cm	8	1mm
B	5cm	8	1mm
C	15cm	10	1mm

With those three different sizes of the coil, a total of five different combinations of power transmission arrangements methods was tested and the result was observed and recorded in Table 4.2 indicated in below respectively.

Transmitter	Receiver	5cm	10cm	15cm	20cm	30cm	40cm
A	A	24V	20V	13V	7V	5V	NA
A	B	4V	0.5V	NA	NA	NA	NA
B	B	8V	5V	0.7V	NA	NA	NA
B	A	3V	0.5V	NA	NA	NA	NA
C	C	26V	24V	18V	10V	8V	5V

Table 4.2 Comparison with the different coil to 4 situations

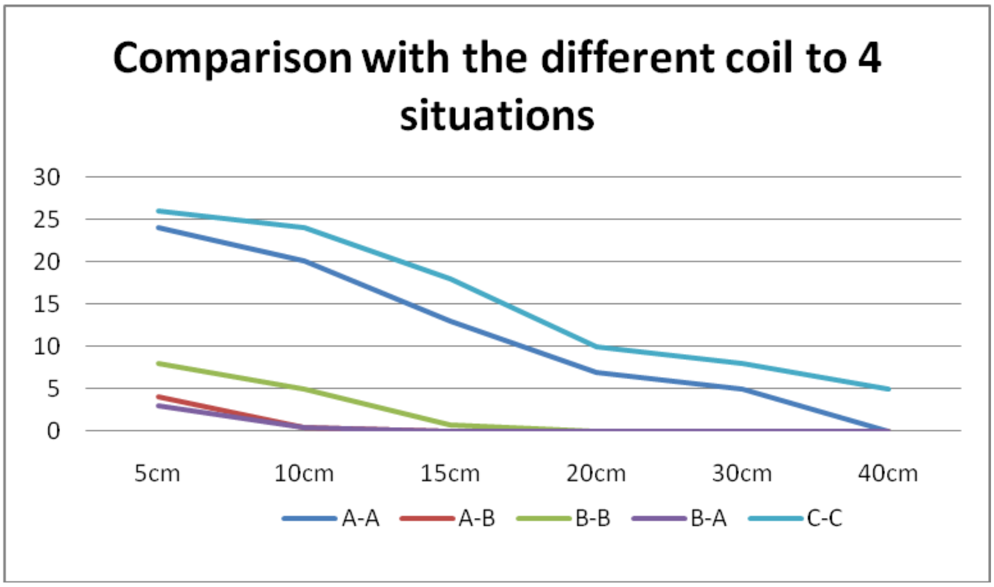

Table 4.3 The result of Comparison with the different coil to 4 situations

Based on the experiment test result, a conclusion can be drawn.

1. Same size of transmitter and receiving coils are having better wireless power transmission capability. (Compare the result with Coil A-A, A-B, B-B, B-A & C-C)
2. Bigger in coil diameter has better power transfer capability. (Compare the result with Coil A-A, B-B)
3. Coils with bigger coil diameter and turns have better power transfer capability. (Compare the result with Coil A-A, B-B & C-C)

4.2 Demonstration of Wireless Power Transfer System

With the finished product, the electronic circuit board, transmitter and receiving coils, power can be transfer wirelessly in between the transmitter and receiving coil through high-frequency resonance transmission to power a cell phone as well as a model car as photos indicated in Figure 4.2.1 &4.2.2.

These photos demonstrated the experimental kit was successfully assembled.

4.3 WTP Simulation for Dynamic Use

Many static or fixed WTP has been developed and used worldwide nowadays. The disadvantage of this type of WTP methods, as mentioned previously, is the EV must park on afixed spot for a period of time for battery recharge. Charging time will take anywhere between 4 to 8 hours. Such charging time does not fit for the business nature which required hit on the road all day long, such as courier service, taxi, buses etc.

Hence, a dynamic WTP charging system was study and developed[11].

In this section, two dynamic WTP charging approaches will be tested and compared.

4.3.1 Dynamic WTP Simulation (Method 1)

In method 1, three transmitter coils will line up one by one. Each coil was apart 4cm. The diameter of the coil is 5cm with 10 turns. They served as a transmitter which lay under the road. A receiving coil is also constructed with the same material, size and turns. During the experiment, the receiving coils were placed 5cm above the transmitter coil and moving back and forward. With the voltage measure instrument, changing of the voltage was observed during moving. The peak voltage was recorded at 18V and the minimum voltage was recorded at 6V.

Through the experiment, the method cannot provide steady charging voltage during the moving of the receiving coil. Charging voltage will fluctuate between 6V and 18V. Such fluctuation of the charging voltage cannot charge the EV on the road effectively and efficiently.

4.3.2. Proposed Dynamic WTP Simulation (Method 2)

In method 2, a new proposed transmitter coil was constructed differently from method 1. This time, the radius of transmitter coil is 5cm. The total length of the transmitter coil is 30cm with 10 turns. The receiving coil will be same as method 1 radius is 5cm and will be moving back and forward within the transmitter coil. Through observation, the voltage was capable of maintaining at 18V without fluctuation. Therefore, method 2 shall be deemed as better improved dynamic WTP and shall be considered for further study.

V. EXPERIMENT RESULT, DISCUSSION AND ANALYSIS

This chapter will consolidate the data observed from chapter 4 & 5 to make a summary. A detail discussion and analysis will be made at the end of this chapter. This chapter will focus on three major study areas. First, the wireless charging abilities. Second, comparison of the coil transmission abilities due to their construction characteristic. Third, comment on the construction and select which dynamic WPT system shall be proposed for the use on roads and highways.

5.1 Discussion on Wireless Charging Abilities

5.1.1 Transmitter and Receiver Coils Characteristics

	Number of turns	Conductor wire	Dimension
Transmitter Coil	3 turns	1.3mm	130mm (D) x 3.9mm (H)
Receiver Coil	3 turns	1.3mm	130mm (D) x 3.9mm(H)

Table 5.1: The hardware model information

5.1.2 Result of the Coils Resistance, Inductance, and Capacitance:

Through actual measurement and calculation, the resistance, the inductance and the capacitance of the transmitter coil (R1, L1 & C1) and receiver coil (R2, L1 & C2) were obtained in different resonant frequency (2MHz, 4MHz, 6MHz & 10MHz)

	2MHz measure	2MHz Cal	4MHz measure	4MHz Cal	6MHz measure	6MHz Cal	10MHz measure	10MHz Cal
R1	27mΩ	29mΩ	38mΩ	41mΩ	55mΩ	51mΩ	70mΩ	66mΩ
R2	30mΩ	59mΩ	70mΩ	83mΩ	95mΩ	102mΩ	143mΩ	132mΩ
L1	0.36uH	0.38uH	0.33uH	0.38uH	0.33uH	0.38uH	0.3uH	0.36uH
L2	1.1uH	1.29uH	1.15uH	1.29uH	1.08uH	1.28uH	1.05uH	1.28uH
C1	10nF	16.6nF	4.79nF	4.16nF	2.13nF	1.85nF	844pF	703pF
C2	5.75nF	4.9nF	1.37nF	1.22nF	651pF	549pF	214pF	197pF

Table 5.2: The result of hardware model

The efficiency calculates by

Output Power = $I_{rms}V_{rms}\cos\theta$

η = (Output Power / Input Power) x 100%

Hence we obtained the efficiency information as indicated in Table 22 as indicated below.

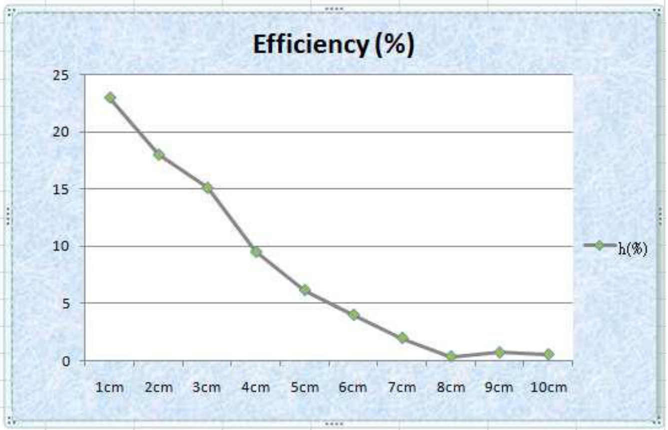

Table 5.3: The curve of efficiency

Although the actual value was different from calculated value, but this is normal because the actual value might be affected by the different factors such as losses, temperature, humidity, etc.

6.1.3 Real Lift (Small Scale) Application

This section will show how to apply the wireless power transfer technology in practical use. Therefore, a cell phone battery wireless charging system was built. The cell phone battery was rated at 3.7VDC.

In this section both transmitter and receiver coils were using 1.3mm copper conductor 3 turns with 150mm diameter. The input voltage is 12VDC with a resonant frequency at 1MHz.

Since previous experiment kits were built for input voltage at 12VDC, in order to provide proper charge voltage for cell phone charger, the input voltage require proper reduction. Calculation as indicated below.

Since the Diode is used for the rectifier. Diode with a low voltage drop (0.3V)

Vpeak; Require input voltage at the transmitter side.

Vdc; Require charging voltage at receiving side. In this case, 3.7V
Vdc= 2Vpeak/π- (0.3 x 2)
3.7 = 2Vpeak/ππ- (0.3 x 2)
Vpeak = [(3.7+0.6)π] / 2
Vpeak = 6.75V
Based on the calculation as shown in the above, in order to charge the battery with a proper charging voltage, the input voltage is required to reduce from 12VDC to 6.75VDC through additional resistance. Below is the power condition capture from the scope for reference at the transmitter end and receiving end for reference.

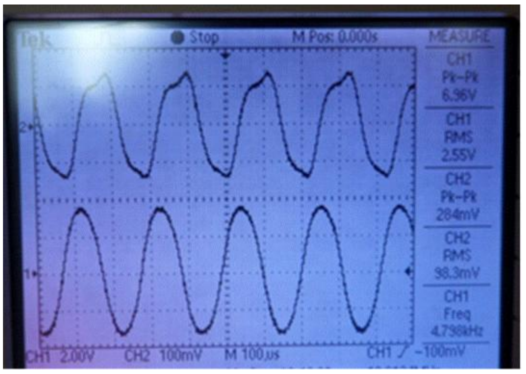

Figure.5.1.3.1 Input: 6V (peak)

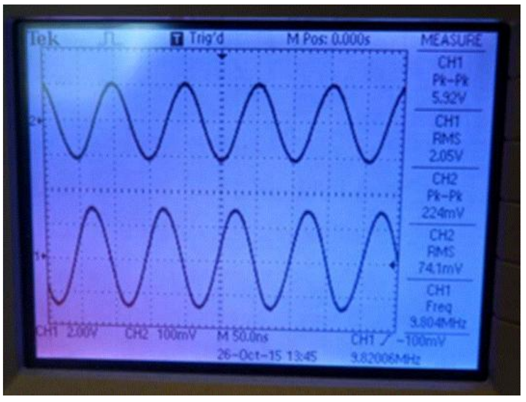

Figure.5.1.3.2 Output: 6.2(peak))

The measurement of the load coil voltage V2 and current I2 on from 1cm to 10cm:

Distance	1cm	2cm	3cm	4cm	5cm	6cm	7cm	8cm	9cm	10cm
V2(DC)	4.6	4.3	4.1	3.8	3.57	3	2.3	1.2	1.2	1
I2(DC)	30m	25m	22m	15m	10m	8m	5m	5m	3.5m	3.2m
(%)	23	18	2.81	15	6.16	4	1.97	0.36	0.7	0.533

Table 5.4: The efficiency of hardware model

5.2 Comparison Coil Transmission Abilities Vs. Construction Characteristic.

Through experiment, the construction characteristic of the transmitter coil and receiver coil are playing very important role in high resonant frequency wireless power transmission system. In chapter 4, through section 4.1 and 4.2, the experiment clearly indicated the both transmitter coil and receiver coil with the same size will have maximum power transmission capability. Through observation, these phenomena can be explained because the power transmission ability will be limited by the coil with smaller diameter or turns.
In short, wireless power transmission ability is based on the turns and diameter of the coils. Bigger in diameter and turns, more magnetic flux can be generated and being induced. Therefore, in Table 4.2, the combination of C-C is better than other. Furthermore, the maximum separation distance for this group can be further.

5.3 Results for WTP Simulation for Dynamic Use

In section 5.3, two simulations were carried out. The first experiment was based on the Figure.1.2.3 Dynamic WPT for EV Charging's model. The charging voltage was fluctuated in between 6V and 18V during moving the receiver coil back and forward. However, when we changing the sharp of the transmitter coil as

indicated in the second experiment (proposed model), induce charging voltage can maintain at 18VDC within the transmitter coil without any fluctuation.
Therefore, this paper highly suggests the new proposed WPT modeling system shall be required further study to confirm its wireless power transfer capability under different condition.

VI. DISCUSSION

A modified model of wireless power transfer technology was successfully built and tested.
The result was surprisingly better than any previous formation. It can provide steady chargeable energy through high resonance frequency in order to achieve wireless power transmission. In section 5.1 to 5.3, different experiments were performed and confirmed the electrical energy can be transmitted wirelessly through high resonant frequency.

1. The advantage of high resonant frequency wireless power transmission system is wireless. Image without using any cord and plug to draw the power from the socket base, the chance of electrocuting will be greatly reduced. Besides, we can use the electricity anywhere and anytime without any limitation or restriction. Overall can achieve safety and convenience.
2. The disadvantage of these kinds of wireless power transmission system is high frequency resonant. Up to this moment, there is no study in related to the effect of human response to high resonant frequency. All we know the high-frequency waveform, microwave for example, could lead to a very bad result and harm for a human. However, for small power transmission application, such as battery recharge for cell phone, man shaver, model car, smart watch etc., high resonant frequency wireless power transmission system is one of the simple and convenience methods. With further study, the electricity could be applied to appliances with the wiring.

5.5 Difficulties Encountered, Problem Solving & Suggestion

During experiments, there have some problems found during the process:

5.5.1 Temperature Effect

During the experiment, the receiving coil was found hotter compared with the transmitter. Based on the observation, heat generation from the receiving coil might cause an electrical fire. Such heat built up due to different kinds of electrical losses, such as core loss, eddy current loss, hysteresis loss, magnetic saturation etc. in order to improve the heat dissipation heat sink or cooling fan can be considered. Some other control sensor, a thermal sensor, can also be installed as warning alarm to prevent overheat.

5.5.2 Avoid Eddy Current

In section 2.3, an eddy current is one of the electrical losses which could reduce the system operation. Therefore, non-conductivity material, Mu-Metal, shall be employed. Silicon steel core cannot only improve the generation of the magnetic flux but also can reduce the eddy current loss.

5.5.3 Different Value Obtained Through Actual Measurement and Calculation

Different between actual measured value and calculated valve of inductance and resistance was observed. The calculated valve of the inductance and resistance were having a great different compared with the actual measured valve. One of the reasons is the coil winding affect the measured inductance value. Also, the formula used in this paper was designed for general DC circuit application. For a high-frequency application, it might not the same. Therefore, in order for the calculated value to match with measured valve, further studies and experiments are required in order to define the coefficient factor of K for high resonant frequency circuit.

5.5.4 Accuracy of Resonant Generation

At the beginning, a simple PCB have been set up for testing. However, the values of resistance and capacitor do not match with each other to generate proper resonant for the test. As a result, the output power is lower. The reason is the coil does not match the resonant frequency. To solve this problem, EAGLE software has been used to simulate the circuit to troubleshoot which parts or components were wrong.

5.5.5 Distance Effect

Through experiment, distance apart from the transmitter and receiver coils was demonstrated. The result was further apart between both coils, less power and less efficiency for wireless power transfer.
In order to overcome the distance effect, few things can be done.
1. Increase the coil diameter.
2. Increase number of turns of the coil.
3. Reduce the distance.

5.5.6 Protection & Safety

As mentioned in the previous section, heat built up during charging an EV on the road is a threated. Protection and thermal sensor devices shall be in place in order to provide proper protection for the WPT system. When the abnormal condition was detected, the power must be cut off immediately and automatically.

5.6 WPT Application Outlook

Although the sale of EV is on the increasing trend worldwide, but not often to have papers to evaluate the possible of WPT systemforEV on the road. The mainly reasons are:

1) Road Planning and WPT Implementation

Road and highway are mainly built and maintain by the government authorities. Without the participation of the government, road and highway planning alone is insufficient. Public utilities, such as water and gas pipe, underground electricity supply, and network cabling system, are required coordination between different parties. Since the charging system is needed to be close to the electric vehicle, thus the government is required to establish the corresponding safety requirement to avoid any conflict with public utility systems.

2)Safety Issues

Insufficient researches and studies in related to the magnetic field generated by WPT affect the health of human body. Therefore, further study, research and even the long time observation of influence of human being are required.

3) Battery Standardization

The battery is the heart of the EV. It stores the required energy for the EV to run on the road. However, different electric vehicle manufacturers are using different battery manufacturers. The plug-inadaptor, construction of the battery, battery specification, etc. are not the same. Furthermore, battery manufacturers are hard to design and build a battery one and for all. Hence, further research and study on battery standardization are required.

VII. CONCLUSION

Electric Vehicle is in the rising trend. People have paid more attention to environment protection. The GHG emission from the traditional vehicle has been strictly restricted. For some countries or areas, vehicles running on the traditional fuel source, diesel or gasoline, are even prohibited. However, current battery recharging methods, either conductive wiring or fixed spot wireless power transfer technology, do not meet and fulfill the busy city life. Research and develop a mass and flexible's dynamic battery recharging system is the aim of this paper.

[11] proposed a dynamic WPT system in 2014, hence, we learned that dynamic wireless power transfer is possible. However, through experiments, this paper found the charging voltage fluctuated when the receiving coil passing through a series of transmitter coils. Therefore, through experiment as indicated in section 4.3.2, this paper is proposing a new architect of next generation of dynamic WPT system. By using the same high-frequency resonant operation theories but changing the sharp of the transmitter coil, the experiment result collected by this paper has confirmed the modified system can provide steady chargeable voltage throughout the small scale model.

With the successful of building different modeling kits and sampling kits, this paper successfully collected diffident valuable data such as, the relationship of resonant frequency vs power transmission level and range; the relationship of transmitter coil and receiving coil's size, construction characteristic vs. power transmission level and range; and through cell phone battery charging experiment, section 5.1.3, this paper obtain how to calculate and determine the system input voltage vs. charging voltage. Hence, this paper seems to cover the basic operation principle of wireless high-frequency resonant power transfer system.

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