WIRELESS POWER TRANSFER FOR LOW POWER DEVICE USING MAGNETIC RESONANT COIL

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LIST OF SYMBOLS

#N	Number of turns
%	Percent
^{o}	Degree
η	Efficiency
μr	Relative Permittivity
Ω	Ohm
λ	Wavelength
π	Pi
ω	Omega
a_r	Radially Directed Unit Vector
A_e	Defined as the area
B	Electromagnetic field
c	The speed of light
E	Electric Field Vector
G	Gain
H*	The complex conjugate of the magnetic field
I_o	Dipole current amplitude
K	Coefficient
P_{loss}	Power loss
P_{rad}	Radial Direction
P_t	Magnetic resonant coil
Q	Quality
r_S	Impedance ratio

R_r	Radiation resistance
R_L	Loss resistance
$\vec{S}$	Poynting vector
W_r	Radial components of complex power density
$\vec{W}$	Average power density
W_θ	Azimuthal components complex power density
W_i	Power density
Γ	Decay constant

LIST OF ABBREVIATION

1D	One Dimension
2D	Two Dimension
3D	Three Dimension
A	Ampere
AC	Alternated current
B	Magnetic field
C	Capacitor
cm	Centimetre
CST	Computer Simulation Technology
DC	Direct current
D	Diameter
E-field	Electric Field
F	Frequency
Fr	Resonant frequency
H-field	Magnetic Field Strength
Hz	Hertz
IC	Integrated Circuit
IEEE	Institute of Electrical and Electronic Engineers
I_{Tx}	Current of Transmitter
I_{Rx}	Current of Receiver
LCR	Inductor, Capacitor, Resistor
LED	Light Emitting Diode
L	Inductor

MKV	Metal Layer Vapor (Deposited on Two Sides of Paper)
MOSFET	Metal Oxide Semiconductor Field Effect Transistor
P	Power
PCB	Printed Circuit Board
P_{Tx}	Power of Transmitter
P_{Rx}	Power of Receiver
PQ	Power quality
R	Resistor
Rx	Receiver
Tx	Transmitter
V	Volt
V_{Tx}	Volt of Transmitter
V_{Rx}	Volt of Receiver
WPT	Wireless Power Transfer
μH	Micro Henry
V_{dc}	Direct current voltage
V_{out}	Output voltage
V_{rms}	RMS voltage
X_C	Capacitance impedance
X_L	Inductance impedance

Pengiriman Kuasa Tanpa Wayar untuk Peralatan Kuasa Rendah menggunakan Gegelung Salunan Magnetik

ABSTRAK

Kuasa dipindahkan tanpa wayar melalui gegelung salunan magnetik, yang mana salunan magnetik adalah secara antena untuk menghantar dan menerima kuasa. Kaedah ini, tidak lagi rumit dengan berlalunya kabel di sekeliling, dengan bekalan elektrik tanpa wayar ia boleh digunakan sebagai sumber kuasa kepada peralatan elektronik seperti telefon bimbit, pemain MP3, semua peralatan yang menggunakan sumber bateri atau pendawaian elektrik. Komponen yang digunakan untuk membina pemindahan kuasa secara tanpa wayar boleh dibahagikan kepada 4 komponen; seksyen pemancar akan menukarkan voltan arus terus (DC) kepada bentuk arus ulang alik (AC) maka penerima akan menukarkan AC kepada DC yang serasi dengan peranti kuasa rendah. Manakala, di bahagian penerima yang mengandungi dengan gegelung penerima planar, penerima litar penerus, pengatur voltan litar terkamil (IC) dan bateri telefon bimbit. Sumber DC yang bersambung dengan pemancar disediakan dari sumber DC yang voltan dan arus boleh laras. Fungsi gegelung pemancar untuk menukarkan kuasa DC dari pengayun kepada isyarat kuasa AC berfrekuensi tinggi. Arus frekuensi tinggi yang dikaitkan dengan tanpa wayar gegelung kuasa pemancar akan mewujudkan medan magnet dalam gegelung kerana kuasa salunan magnetik digunakan untuk menghantar kuasa. Dalam pengecas kuasa seksyen penerima tanpa wayar, gegelung penerima menerima tenaga sebagai voltan ulang alik yang disebabkan oleh gegelung salunan dalam gegelung dan penerus dalam seksyen kuasa penerima tanpa wayar menukarkan voltan AC kepada voltan DC. Voltan DC akan memberi arus searah kepada beban melalui seksyen pengawal voltan. Fungsi utama pengecas bateri penerima mudah alih seksyen tanpa wayar adalah untuk mengenakan kuasa bateri mudah alih melalui gegelung salunan magnetik. Dari eksperimen keseluruhan dilaksanakan, pelbagai rekabentuk litar penerus dan penerima menggunakan transistor dan mosfet, diameter gegelung, saiz gegelung dan jenis bahan gegelung salunan magnetik. Faktor-faktor ini adalah kaedah dan aspek yang diperlukan untuk pemindahan kuasa tanpa wayar untuk pengecas telefon mudah alih. Dari ujian transistor dan mosfet untuk pemindahan kuasa tanpa wayar dengan menggunakan gegelung salunan magnetik, ia menunjukkan bahawa IRFP450 mosfet mempunyai kecekapan yang paling tinggi berbanding dengan mosfet IRFZ44N, transistor BC639 dan transistor BD139. Mosfet IRFP450 juga ditambah dengan 50µH daripada torroidal dan 61.2nF kapasitor dengan kadar galangan yang terbaik berbanding 100, 150, 200, 250, 300µH dan 6.8 ke 54.4nF yang tidak meningkatkan kecekapan pemindahan kuasa. Eksperimen penggunaan gegelung magnetik antara tiub tembaga dan dawai enamel di mana hanya mosfet IRFP450 dengan 50µH daripada torroidal dan juga 61.2nF dari nilai pemuat. Hasil kajian menunjukkan bahawa kecekapan tertinggi diperolehi dengan wayar enamel daripada copper tubing yang merupakan 25.41% dengan saiz gegelung 0.05cm. Keputusan ini menunjukkan bahawa kecekapan pemindahan kuasa tanpa wayar boleh mencapai sehingga jarak 50cm, hasil penyelidikan ini dicadangkan supaya menggunakan enamel gegelung alternatif saiz kecil gegelung dan diameter untuk pengecas telefon bimbit. Penyelidkan juga menunjukkan tenaga tanpa wayar dengan menggunakan gegelung salunan magnetik tidak banyak dipengaruhi oleh tangan, buku dan berbagai jenis plastik.

Wireless Power Transfer for Low Power Device using Magnetic Resonant Coil

ABSTRACT

The power is transferred wirelessly through a magnetic resonant coil as an antenna to transmit and receive the energy. This method no longer need complicated with the cable passing around us, with wireless electricity we can charge and make wireless electricity as an input source for electronic equipment such as Handphone, MP3 Player, everything works as a battery source or electrical wiring. The components used to build wireless power transfer can be divided into 4 parts components, transmitter section will convert Direct Current (DC) voltage to Alternating Current (AC) form then receiver will convert AC to DC form that compatible for low power device. Whereas, at receiver section containing with receiver planar coil, receiver rectifier circuit, voltage regulator Integrated Circuit (IC) and mobile phone battery. The DC source that connected to transmitter was provided by the DC source regulator which voltage and current can be adjusted separately. The transmitter coil is function to converts the DC power from an oscillator to a high frequency AC power signal. This high frequency alternating current, which is linked with the wireless power transmitting coil, would create an alternating magnetic field in the coil due to magnetic resonant to transmit energy. In the wireless power charger receiver section, the receiver coils receives that energy as an induced alternating voltage due to resonant coil in its coil and a rectifier in the wireless power receiver section converts that AC voltage to a DC voltage. Rectified DC voltage would be feed to the load through a voltage controller section. That is, the wireless mobile battery charger receiver section main function is to charge a power mobile battery through magnetic resonant coil. From the overall experiment conducted from various design transmitter and receiver circuit using transistor and mosfet, diameter, size and type of materials of magnetic resonant coil. These factors are the norms and necessary aspect of wireless power transfer for mobile phone charger. From the transmitter circuit design using transistor and mosfet test for wireless power transfer by using magnetic resonant coil, it shows that the mosfet IRFP450 has the highest efficiency comparing to mosfet IRFZ44N, transistors BC639 and BD139. The receiver circuit design using full bridge rectifier has the better output DC comparing to half bridge rectifier. Mosfet IRFP450 are also added with 50μH of torroidal and 61.2nF of capacitor has the best impedance rate compared to 100, 150, 200, 250, 300μH and 6.8 to 54.4nF which did not increase the power transfer efficiency. The results show that the highest efficiency is obtained by enamel wire rather than copper tubing which is 25.41% with coil size 0.05cm. The investigation for mobile phone application with small diameter (4, 4.5 and 5cm) and coil size 0.05cm of enamel wire, the distance of power transfer can be up to 50cm. The investigation also showed that the wireless power transfer by using magnetic resonant coil is not much influenced by the presence of hands, books and types of plastics.

CHAPTER 1

INTRODUCTION

1.1 Background

Wireless power transfer (WPT) has been a dream of human beings. Many scientists have researched it uninterruptedly, but little progress has been made. Recently, the wireless power transfer has become interesting topic of research in electrification of the transportation system. Researchers are studying the ways to change electric or plug in hybrid electric to charge mobile phone using wireless power transfer while the mobile phone are charged by wireless power and wireless power while they are in motion.

Wireless power transfer is possible because of resonant circuits. When a transmitter circuit is tuned to resonate at the same frequency as a receiver circuit, power is transmitted wirelessly through the magnetic coil of the inductive coils found in the circuits. Because the power is transferred by magnetic coils, there is a little electric contact danger to any biological entity. Electronics within the charging area are also unaffected unless they are resonant at the same frequency.

Scientists have researched the wireless power transfer since the classical work dates back from Hertz (1888), who first demonstrated the electromagnetic wave propagation in free space. Thereafter there was keen research interest and experimental tests were carried over by (Nicola Tesla, 1899). He inculcated the idea of power transfer through RF-signals. A classical breakthrough is the transmission of signals by (Marconi, 1901) over the Atlantic Ocean. This paved the way and turned the attention of scientist towards the RF-signals.

One of the earliest research papers about submeter, high power, and efficient wireless power transfer was published by (Karalis, A. Joannopoulos, J.D. & Soljacic, M, 2008). In that paper, the authors presented a non-radiative scheme based on magnetic resonance coupling. They analyzed the strong coupling regime of two resonating dielectric disks, capacitively-loaded conducting-wire loops with Coupled Mode Theory (CMT). Since they used CMT, the characteristic equations of the two resonating objects were decoupled, the analysis of the system was very simple and quality factor and power transfer efficiency of the coupled objects could be easily calculated. However, the paper did not provide a design-oriented model for such wireless power transfer systems, suitable for designing or validating a design.

In 2009, Waffenschmidt and Staring published a paper about the limitations of the inductive power link system in consumer electronics. They derived optimal system parameters for efficient power transfer and investigated the effects of distance and size of coil on power transfer efficiency. However, their analysis only used a resonant circuit of the receiver coil, not on the transmitter, and as a result, they concluded that inductive power transfer is only effective over short distances. They did not explore how power transfer capacity of a wireless power transfer system can be improved significantly if both the transmitter and the receiver are tuned LC resonant circuits as demonstrated in. (Yang, T.Y. Li, X.H. Zhang, H.R. Peng, F. Li, Y. Wang & B. Fang, D.M., 2012) published a paper about inductor modeling in wireless links for implantable devices design. However, in general, the rated power of these applications was a few milliwatts and the distance between two coils was just a few centimeters. As a result, the models in these papers are not applicable to far distances and higher power systems.

Currently, long life lithium ion batteries and methanol fuel cells have been persuaded as ways to make the electrical components more mobile, consumers' expectations are still far from being met due to the added weight and expenses for battery replacement. In this thesis, a wireless power transfer system is developed. The discovery of witricity, as a new option, is revolutionizing the wireless industry, and holds great promise to leave the oversized battery as a thing of the past. Without using any expensive equipment. The use of wireless power transfer is one of the most promising approaches to obtain both high performance.

1.2 Aims and Objectives

The aim of this research is to analyze the newly reported where one or more tune resonators are added to the two resonator systems to extend the wireless power transfer distance, increasing wireless power transfer efficiency, and allow for a curved wireless transmission path in space. This thesis also presents a novel spectral analysis approach to facilitate system optimization and evaluation based on energy exchange in both the time and spectral domains. Theoretical analysis has been presented to enhance the understanding of the wireless power transfer by using magnetic resonant coil. Our analytical results in good agreement with the experimental results.

The objectives of this research are :

a) To design wireless power transfer in terms of the transmitter and receiver for mobile phone charger.
b) To analyze the effect of Diameter, Size, Type of Material magnetic resonant coil on wireless power transfer performance.
c) To evaluate the performance of the wireless power transfer towards voltage, current, power, and efficiency.

1.3 Problem Statement

Live in advanced technological, nowadays increase our desired to make life simpler. From year to year, portable electronic devices are very popular. But the case of charging a device for decades, still use an old traditional style of wired system. This existed system is build from / having snake look a like wires. The expected to eliminated all snake looked wired with the solution is to go with wireless power transfer using mutual inductance principle.

Furthermore the existing charger on the world now a day, commonly have different type of “plug”. For example the “SONY” mobile phone user cannot use charger of “I phone” or “Apple” mobile phone user cannot use charger of “NOKIA” mobile phone. This is because the different types of universal charger exist.

Moreover, it make life become inconvenience to charge mobile phone when goes to some areas with limited power outlet. The existing mobile charger need plug or socket to charge. The problem become worse if the power outlet or socket is unreachable. So this project is an approach that can be effective used in areas where wire system is unreachable.

Conversion performance of WPT significantly depends on the frequency and distance of WPT (Qu, Mei Ling, Xin Zhi Shi, Chang Qi, and Gao Feng Wang, 2012), hence in this study, appropriate distance of wireless power transfer studied.

1.4 Scope

The scope of this thesis revolves around the understanding of wireless power transfer system. It is important to know the effect of distance on wireless power transfer performance, and also to know the efficiency wireless power transfer by using magnetic resonant coil.

This project of WPT is to construct and develop a prototype of wireless power transfer in application of wireless mobile battery charger. To achieve the aim of this project, the analysis are divided into two major parts which are through simulation using software and hardware implementation. In order to make it success, simulation using MULTISIM Version 13.0 are used. The method using MULTISIM is aimed to construct the circuits (transmitter and receiver) because MULTISIM easy to use, simple and many part of component needed. As the result, this software show the oscillating frequency appear at output of transmitter and waveform of input and output of transmitter and receiver circuits. So MULTISIM Version 13.0 to construct circuit footprint into PCB layout from final circuit. In this research, technical skill is needed to create the suitable size of circuit on PCB. All working procedures are discussed in next chapter.

The prototype of wireless mobile battery charger is developed. Procedure from printing PCB layout until testing circuit is discussed in methodology chapter. An accurate component and materials used is important in hardware making. This is because practically testing of circuit is high dangerous rather than simulation.

1.5 Project Outline

This thesis mainly containing 5 chapters. All the activities, project working principle and output are presented in this thesis according to the chapter. The chapter is briefly arranged as ;

Chapter 2 presents the research and studies of others who published into thesis, article, journals and books on information about WPT.

Chapter 3 presents the methodology conducted in this research. The methodology introduces flow process in theoretical, simulation, hardware, experimental equipment set up, and the functions of all material needed to built wireless power transfer.

Chapter 4 presents the results achieved from this project. All the result are compiled then presented into table and graph. The result are also analyzed and discussed.