# Wireless Power Transmission System Based on Magnetic Inductive Resonance of Couple Circuit

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***Abstract*— In this paper, By magnetic inductive resonance method or wireless inductive power transfer method, a couple circuits can be used to transfer power wirelessly, where the individual nodes are battery less to make them maintenance free. The main working principal of magnetic inductive resonance is Electromagnetic field inductance between two coils that are tuned to resonate at the same frequency. This type of method has a high quality Factor (Q) and Consist of air cored to avoid iron losses. For energy harvesting wireless or battery less sensors can be use and possible to store in capacitors. One of the methods of wireless power transmission scheme is microwave power transmission, which can interfere with data transmission, where for data transmission and acquisition can easily possible by magnetic inductive resonance.**

***Keywords- resonance; capacitor bank; energy buffer; supercap;***

## I. INTRODUCTION

The transmission of electrical energy without wires or wireless energy transfer has been introduced around since about 1856 in the form of mutual induction [1]. Using induction method it is possible to transmit and receive signals over a considerable distance. However, it is important to set two inductors fairly close together to draw significant power flow in that way. If resonant coupling is use, where inductors are tuned to a mutual frequency, power may be transmitted over a range of many meters. Another form of wireless energy transfer is electromagnetic radiation method, such as radio waves. It has found that, in wireless power transmission method, household devices and chargers needs an essential distance to induce current and can only happen if the coils are close organized [2]. Again a larger, stronger field could induce current from farther away, where the process has found extremely inefficient. Since a magnetic field spreads in all orders, making a larger one would be waste a lot of energy. Effective ways to transfer power between coils separated by a few meters or extend the distance between the coils by adding resonance to the equation. A suitable way to understand resonance is to think of it in terms of sound. An object's physical structure, like the size and shape of a trumpet determines the frequency at which it naturally vibrates, known as resonant frequency.

## II. CONTEMPORARY WORKS ON INDUCTIVE APPROACH

Previously in a research, where, the primary goal was to able wirelessly transfer power (in watts) of an AC oscillating voltage into a DC voltage on the receiving end, which could be used to power an electrical load (in milliwatts) to exhibit instantaneous power transfer. In Fig. 1, Fig. 2 and Fig. 3 show the design of a tunable oscillator proficient of generating RF band frequency in range of (1MHZ – 20 MHz) and a power amplifier to supply sufficient power to be transferred for driving the load Circuit [3,4].

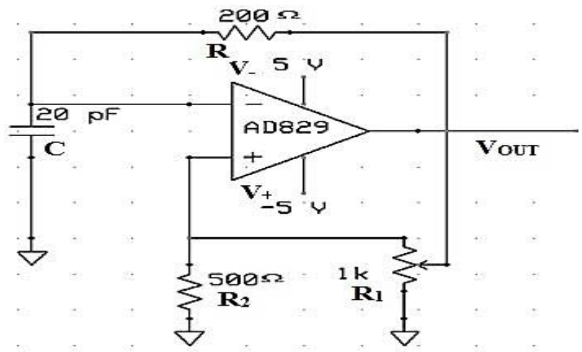


Figure 1. Oscillator part.

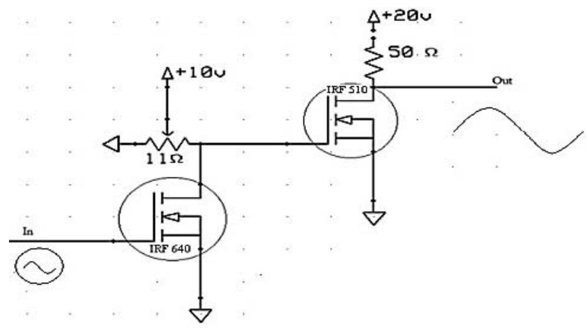


Figure 2. Amplification Part.

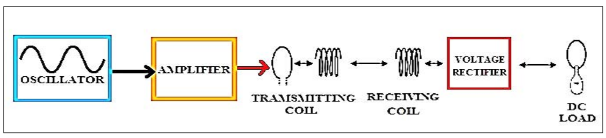


Figure 3. Circuit diagram.

Again, in another paper the research introduced that, the most efficiency depends on Power circuit, receiver quality and position of receiver [5]. Besides that, the tank and

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rectifier circuits were optimized in order to increase competence and improve inerrability. The experiments were done for best efficiency measurements for variability of accurate situations. Throughout all static experiments the new coil designs proved that, these are better than the previous one in case of transfer power efficiently Fig. 4 and Fig. 5.

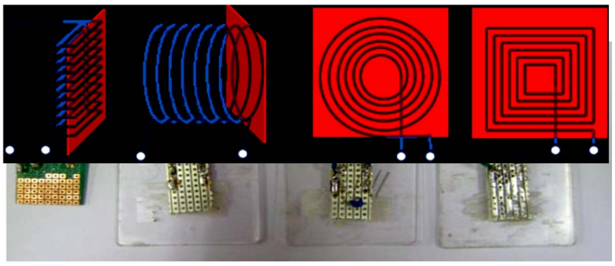

Figure 4. New efficient coil design

Figure 5. Rectangular (a), Solenoid (b), Planar Circular (c) and Planar Square (d) Coil Concepts.

The inductance of each coil is estimated using expressions for DC inductance based on the method of Harold A. An electric double- layer capacitor, also known as a super-capacitor (supercap) was chosen. The main recompenses of a supercap over an electrochemical battery are: very high rates of charging and discharging, longer lifespan, tremendously small internal resistance and extraordinary power density [6]. The arrangements for these tests are represented using the pairing coil surfaces defined in Fig. 6.

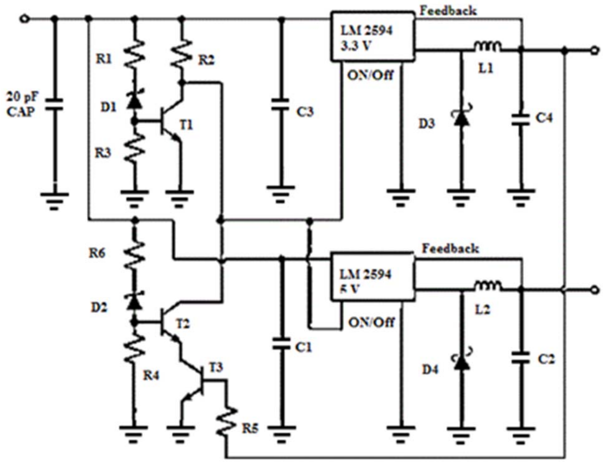


Figure 6. Voltage regulation circuit diagram

## III. Methodology

Based on above appraisal, we planned a new design for wireless power transmission. The circuit diagram of our proposed inductive pairing system is illustrated in Fig. 7. The input Voltage of the circuit is 12V AC Signaled with a square wave and amplified by a Class-E amplifier at 1.3MHz.

Class-E amplifiers can operate with smaller power losses by a factor of about 2.3 as compared with conventional Class-B or -C amplifiers using the same transistor at the same frequency and maximized output power. For example, a Class-B or -C power stage operating at 65% base to collector or drain efficiency (losses = 35% of input power) would have an efficiency of about 85% (losses = 15% of input power) if changed to Class-E (35%/15% = 2.3). So Class-E amplifiers can be designed for narrow-band operation or for fixed- tuned operation over frequency bands as wide as 1.8:1, such as 225-400 MHz.

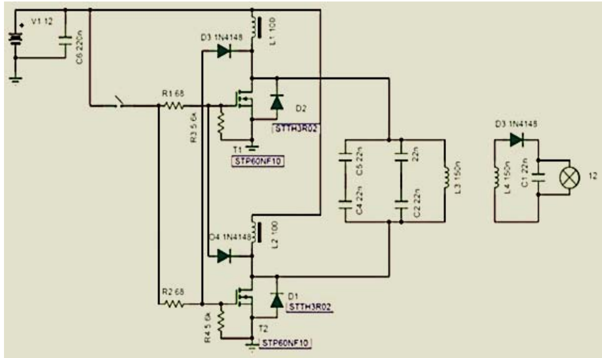


Figure 7. Circuit diagram of wireless power transfer via inductive coupling.

As shown in the circuit a capacitor bank, which can hold charges, attached to each end of the coils. In a short, theoretical analysis demonstrates that by conveyance electromagnetic waves around in a highly angular waveguide, fleeting waves are produced which carry no energy. A fleeting wave is near field stand exhibits exponential decay with distance. If a proper resonant waveguide can place near the transmitter, the fleeting waves can allow the energy to tunnel specifically fleeting wave coupling, the electromagnetic equivalent of tunneling to the power drawing waveguide, where they can be rectified into DC power. Since the electromagnetic waves would tunnel, they would not promulgate through the air to be absorbed or dissolute and would not disrupt other electronic devices. It's a non- radioactive energy transfer since it involves in stationary fields around the coils rather than fields that spread in all directions. The simplify circuit diagram is shown in Fig. 8.

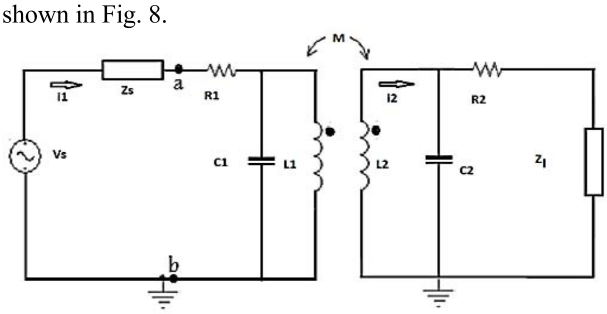


Figure 8. Simplify Circuit Diagram

Applying KVL to the source loop, we get,

$$V_s = ( Z_s + R_1 + \frac{1}{j\omega C_1} + j\omega L_1)\, I_1 - j\omega M I_2 \qquad (1)$$

where, $V_s$, $R_1$, , $L_1$ , $M$ and $I_1$ are the source voltage, resistance, capacitance, inductance, mutual inductance and current of primary loop respectively. Applying KVL to the load loop, we get,

$$0 = -j\omega M I_1 + \left(R_2 + j\omega L_2 + Z_L + \frac{1}{j\omega C_2}\right) I_2 \quad (2)$$

where, $R_2$, $C_1$ , $L_2$ , $I_1$ are the resistance, capacitance, inductance and current of load loop respectively. Let us assume, $Z_{11} = (Z_s + R_1 + \frac{1}{j\omega C_1} + j\omega L_1)$ and $Z_{22} = (R_2 + j\omega L_2 + Z_L + \frac{1}{j\omega C_2})$, where $Z_{11}$ and $Z_{22}$ are the total self-impedance of source loop and load loop. Therefore we can rewrite the equations (1) and (2) respectively as follows:

$$V_s = Z_{11} I_1 j\omega M I_2 \quad (3)$$

$$0 = -j\omega M I_1 + Z_{22} I_2 \quad (4)$$

Using Cramer's rule from equation (3) and (4) we can determine the current flowing in the source loop and the load loop,

$$I_1 = \frac{\begin{vmatrix} V_s & -j\omega M \\ 0 & Z_{22} \end{vmatrix}}{\begin{vmatrix} Z_{11} & -j\omega M \\ -j\omega M & Z_{22} \end{vmatrix}} = \frac{Z_{22} V_s}{Z_{11} Z_{22} + \omega^2 M^2} = \frac{V_s}{Z_{11} + \frac{\omega^2 M^2}{Z_{22}}} \quad (5)$$

$$I_2 = \frac{\begin{vmatrix} Z_{11} & V_s \\ j\omega M & 0 \end{vmatrix}}{\begin{vmatrix} Z_{11} & -j\omega M \\ -j\omega M & Z_{22} \end{vmatrix}} = \frac{j\omega M V_s}{Z_{11} Z_{22} + \omega^2 M^2} \quad (6)$$

From equation (6) we can also write $I_2 = \frac{j\omega M}{Z_{22}} I_1$. The internal impedance $Z_{int}$ on the source loop side can be defining as follows:

$$Z_{int} = \frac{V_s}{I_1} = \frac{Z_{11} Z_{22} + \omega^2 M^2}{Z_{22}} = Z_{11} + \frac{\omega^2 M^2}{Z_{22}} \quad (7)$$

$$Z_{int} = Z_{11} + Z_{rp} \quad (8)$$

But when we can see the impedance only from the terminal a-b,

$$Z_{a-b} = Z_{int} - Z_s = R_1 + j\omega L_1 + \frac{\omega^2 M^2}{Z_{22}} \quad (9)$$

From the equation (9) we can see that the $Z_{22}$ Impedance is reflected into the primary side and the equivalent circuit would be like the circuit in Fig. 9.

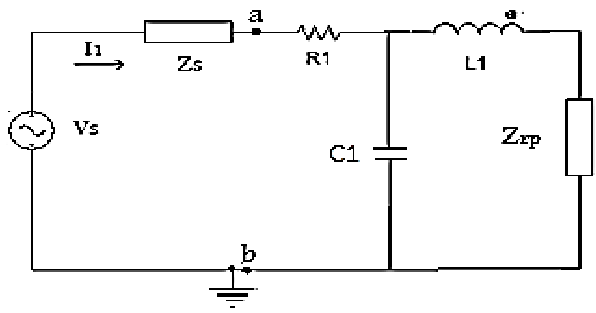


Figure 9. Reflected impedance in primary coil.

Then we can obtain $Z_{rp} = \frac{(\omega M)^2}{|Z_{22}|} Z_{22}^*$. In order to findout the load current when the source side is transferred to the load side, the equivalent circuit would look like the one provided in Fig. 3 and applying Thevenin's Theorem to the Thevenin's equivalent circuit can also be obtained. For the circuit, the reflected impedance $Z_{rs} = \frac{(\omega M)^2}{|Z_{11}|} Z_{11}^*$. Therefore, the Thevenin's voltage as, $V_{TH} = \frac{V_s}{Z_{11}} j\omega M$. This would lead to define the current $I_g$ as,

$$I_g = \frac{V_{TH}}{Z_{TH}} = \frac{V_{TH}}{Z_{TH} + Z_{rs}} \quad (10)$$

We can also obtain,

$$Z_{TH} = R_2 + j\omega L_2 + \frac{\omega^2 M^2}{Z_{11}} \quad (11)$$

$$I_2 = \frac{V_{TH}}{Z_{TH} + Z_L} \quad (12)$$

Using equation (5), (7) and (12) we can write

$$P_{eff} = \frac{P_{received}}{P_{sent}} \times 100\% \quad (13)$$

The power transfer efficiency ($P_{eff}$) is,

$$P_{eff} = \frac{\omega^2 M^2 R_L}{|Z_{22}|\,|Z_{22} Z_{22} + \omega^2 M^2|} \times 100\% \quad (14)$$

As permeability of free space and the relative permeability of the iron core respectively, then we can get,

$$M = \frac{\mu_0 \mu_r N_1 N_2 A}{l} \quad (15)$$

## IV. RESULTS

In order to prepare the plots analytically, MATLAB was used and for simulation PSPICE was used then the circuit in Fig. 10. It shows that the source voltage is of 1volt, both the inductors are of the same value, C=1.94n, L1=4uH and L2=4uH. The coupling coefficient was taken as k=0.25, the load resistance was kept at 700 ohms and the source side resistance was kept at 200 ohms. For the analytical plots the equations mentioned in Fig. 11.

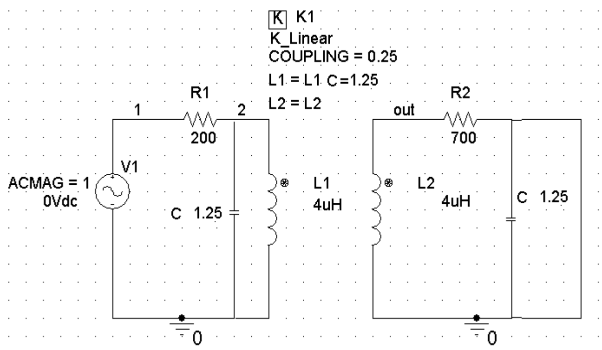


Figure 10. Circuit setup for two loop inductor coupled system.

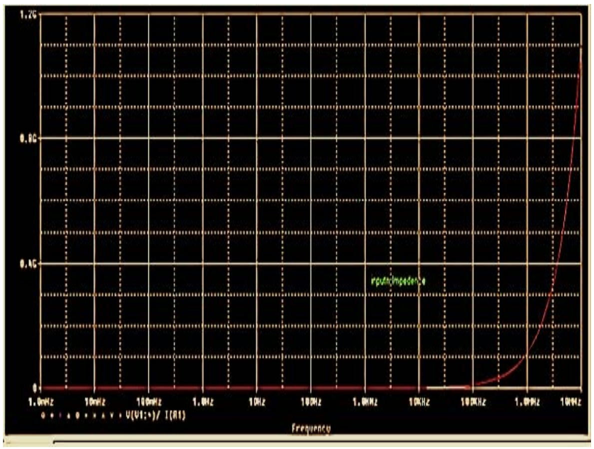


Figure 11. The analytical plot for the magnitude of input impedance as a function of frequency.

## V. DISCUSSION AND CONCLUSION

In short theoretical analysis it is demonstrate that by sending electromagnetic waves around in a highly angular waveguide, evanescent waves are produced which carry no energy. An evanescent wave is near field standing wave exhibiting exponential decay with distance. If a proper resonant waveguide is brought near the transmitter, the evanescent waves can allow the energy to tunnel (specifically evanescent wave coupling, the electromagnetic equivalent of tunneling to the power drawing waveguide, where they can be rectified into DC power. Since the electromagnetic waves would tunnel, they would not propagate through the air to be absorbed or dissipated, and would not disrupt electronic devices. Whether or not it incorporates resonance, induction generally sends power over relatively short distances. But some plans wireless power involves moving electricity over a span of miles.

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