NON-RADIATIVE WIRELESS POWER TRANSFER USING MAGNETIC RESONANCE COUPLING

Logesh Kumar. S, , ***Nandha College of Technology.***

Abstract: Recently, an efficient mid-range wireless power transfer that uses magnetic resonant coupling,Studies show that the resonance frequency of the antennas changes as the gap between the antennas change. However, when this technology is applied in the MHz range (which allows small sized antennas), the usable frequency is bounded by the Industrial, Science, Medical (ISM) band. Therefore, to achieve maximum power transmission efficiency, the resonance frequency has to be fixed within the ISM band. In this paper, the possibility of using impedance matching (IM) networks to adjust the resonance frequency of a pair of antennas at a certain distance to 13.56MHz which is used to transfer non-radiative power loss ie.power loss is minimized.

Keywords— wireless power transfer, EV charging, magnetic resonance, magnetic coupling, impedance matching

1. INTRODUCTION

As the power transmission through wire leads to a lot of power loss and billions of dollars are spent for construction ofelectric poles and cables, transformers etc. from the place of generation to place of usage. Another thing that people love to use isbatteries. They provide electrical energy which is portable. It must be noted that there are 40 billion batteries manufactured per year which disintegrates and adds up to the e-waste. Wireless power transfer is essential for the spread of EVs as it provides a safe and convenient way to charge the vehicles. When wireless power transfer is achieved, the process the process of charging the devices will be made a lot more convenient as we do not have to plug the cord into the socket. Furthermore, as power can beconstantly transferred to the vehicles, the battery size can be reduced. Also, the danger of being electrocuted due to the wear and tear of an old cord, or rain will be avoided as the process of handling the power cord is unnecessary, thus making the charging process safer. To achieve wireless charging, the wireless power transfersystem must satisfy these three conditions: high efficiency, large air gaps, and high power. Presently, the most popular wireless transfer technologies are the electromagnetic induction and the microwave power transfer. However, the electromagnetic induction method has a short range [3], and the microwave power transfer has alow efficiency as it involves radiation of electromagnetic waves. Recently, a highly efficient mid-range wireless power transfer technology using magnetic resonant coupling, WiTricity, was proposed. It is a system that transfers power in between two resonating antennas through magnetic coupling. It satisfies all three conditions to make wireless charging possible as it has a high efficiency at mid-range. (Approximately 90% at 1m and 50% at 2m [1] at 60W).

2. IDEA OF WIRELESS POWER TRANSFER

The idea of wireless power transfer goes back to 1800s when Tesla was trying to work out to transfer the electric power wirelessly all over the world. Tesla the scientist who invented alternating current built great tower The Wardenclyffe Tower using far field techniques.But his attempt was not really successful and this tower was taken down by FBI for security purpose.

3. THEORY OF MAGNETIC RESONANT COUPLING (MRC)

In this paper, we study this phenomenon using antenna design theories and circuit design theories.Using the equivalent circuit, the frequency characteristics of the antennas can be estimated upto an accuracy of 5% error.

2.1 Magnetic coupling

Consider a transformer, the power is transferred from the primary winding to secondary winding of the transformer almost wirelessly. The is no physical connection between the coils of the transformer and they do transfer power wirelessly by means of mutual inductance which can be termed as magnetic coupling of inductive coupling. The main disadvantage of the inductive coupling is the power loss and the distance of wireless transfer is very low say few centimeters. This type of inductive coupling does not use tuned inductors.

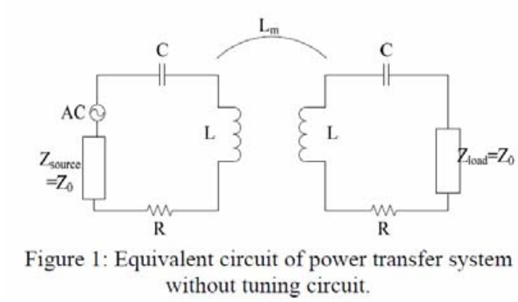


Figure 1: Equivalent circuit of power transfer system without tuning circuit.

2.1 Resonance coupling

Resonance is the property of system to operate at higher amplitude at a particular frequency than others.When 2 objects operate at same resonant frequency they transfer energy efficiently between them without interfering with the off resonant objects.

4. PROPOSED WIRELESS POWER TRANSFER SYSTEM

Fig. 6 shows the diagram of the proposedsystem to improve the efficiency of wirelesspower transfer via magnetic resonant coupling with a matching circuit.As shown in Fig. 6, the wireless power transfersystem involves resonating two antennas withidentical self-resonance frequency (13.56MHz)using a high frequency power source. The poweris transmitted through magnetic resonant couplingin between the two antennas at the resonancefrequencies. The power transferred is rectified and used to charge energy storage mediums such asbatteries and electric double layer capacitors(EDLC).As stated above, this research focuses on thetransmitting part of the system, and the load of thesystem is set at 50Ω. Under normal circumstances,the coupling factor k (affected by the air gap) andthe load (50Ω in this case) are variable andunknown. Only the voltage, current and powerreflection ratio can be measured in the powertransmitting side of the system. In this system, adirectional coupler is inserted before thetransmitting antenna to measure the reflectedpower in between the antennas. The measured values are input into a computer (PC) which isused to control the parameters of the IM circuit.The IM circuit functions as a tuner to change thecharacteristics of the antennas so that theresonance frequency can be adjusted to thefrequency of the power source. This can beachieved by tuning the parameters so that thereflected power ratio measured by the directionalcoupler reaches its minimum. The power transfer occurs only when the receiver coiled is tuned to the same frequency of that of the transmitter.

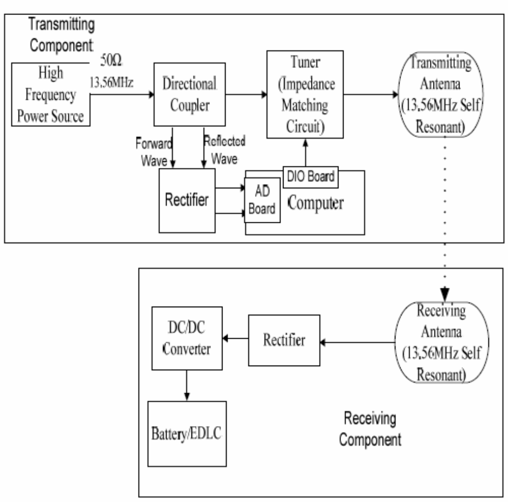


Figure 6: Wireless power transfer system with tuning circuits.

Figure 6: Wireless power transfer system with tuningCircuits.

5. EXPERIMENT RESULTS

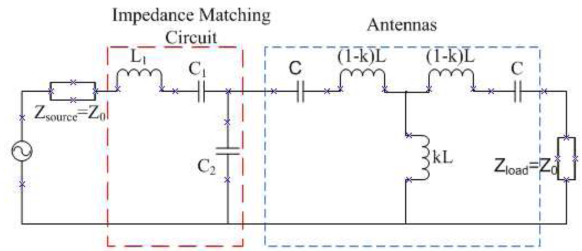
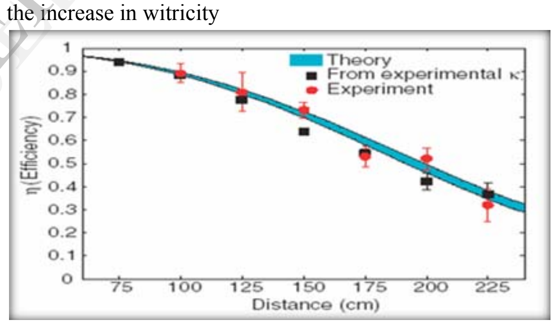


Fig. 4.1a Equivalent circuit of experiment setup

The equivalent circuit used in the simulations and experiments are shown in Fig. 4.1a, where an impedance matching network is inserted in between the power source and the transmitting antenna. The antenna used here is a 5 turn, 15cm radius, 5mm pitch, open type spiral antenna that is self-resonating at 13.56MHz (Fig 4.1b). Here both the input and output impedance, Zsource and Zload are set at Z0, 50Ω. Using the vector network analyzer (VNA), the L and C parameters of the antennas were calculated to be 10300nH and 13.26pF respectively. These experiments are conducted at low power. The system is expected to function similarly in high power situations [2].

5.1 Efficiency chart of magnetic resonance coupling

The efficiency of the wireless resonance energy transfer is inversely proportional to the distance of the power transfer. The resonance coupling is the key reason for the increase in witricity



To increase the distance of power transfer without affecting the efficiency a passive component of coil tuned to same frequency is placed in between the receiver and the transmitter. This circuit of passive element is called as repeater. This repeater can be placed at the boom part of table ,mat flooring etc.

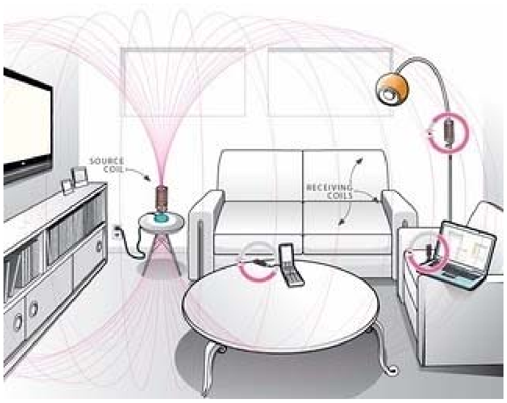
6. SAFTY

The magnetic resonance wireless power transfer is really safe as it is a non-radiatve power transfer. This technique uses only the magnetic field to transfer power. This magnetic field is similar to that of the earth's magnetic field. The usage of this method of power transfer is 100% safe for humans and animals. They can produce a strong resonance couple only with the receiver coil tuned to the same frequency. They are designed to meet the internationalstandards for safety and guidance.

5. APPLICATIONS

Direct wireless power. Your TV, your toaster and your lamps won't need any cords, as they'll derive the power they need wirelessly from your Witricitysource .

Automatic wireless charging. In the same way you're laptop can automatically connect to a nearby network when it detects one, any electrical device could connect to a wireless power source where available, and charge while in use or when idle, without need for human interaction. A great leap forward in terms of convenience, efficiency and productivity.



A cordless world, inside and outside. Most of the electric infrastructure of today, such as the endless networks of ugly, above-ground wires, would be obviated. The same naturally applies to homes and offices, which will appear cleaner and tidier.

Reduced battery-related costs. Batteries, the most expensive form of electricity, won't be thrown away once they're empty, but rather we'll have new kinds of batteries that will recharge themselves once near a power source.

More practical electric vehicles. Electric cars haven't quite taken off yet, and one reason is because they must be charged (using a cord). It's just not practical. But when you can drive right into your home garage or a parking lot and have it charge while you're gone, all of a sudden it's more practical than gasoline.

6. CONCLUSION

The frequency characteristics and the power transfer efficiency of the antennas were studied using equivalent circuits, electromagnetic analysis, simulations and experiments. The resonance frequency of the antennas changes as the air gap changes. When this is applied in the MHz range (which allows smaller size antennas), the usable frequency range is bounded by the ISM band. Since the maximum power transfer efficiency occurs at the resonance frequency, a system which uses an IM network to match the resonant frequency of the antennas to a power source at a fixed frequency (13.56MHz) was proposed. The tuning parameters of the IM circuits were estimated using the equivalent circuits. The effects were analyzed with equivalent circuits, electromagnetic analysis, simulations and experiments. The experiments and simulations show that the resonance frequency of the system can be changed using IM circuits for different air gaps and displacements. The matching can be achieved by tuning the circuits so that the power reflection ratio (measured by the directional coupler) of the system reaches its minimum. Experiments show that the stability and ohmic loss of the components in the tuning circuit contributes to the drop in efficiency around the resonance frequency. Therefore, core losses of the coils and the stable range of the variable condensers will have to be put into consideration when designing the circuit.

REFERENCES

[1] N. Tesla, "Apparatus for transmitting electrical engergy," Patent US 1 119 732, Dec. 1, 1914.

[2] A. Kurs, A. Karalis, R. Moffatt, J. D. Joannopoulos, P. Fisher, and M. Soljai, "Wireless power transfer via strongly coupled magnetic resonances," Science, vol. 317, no. 5834, pp. 83–86, 2007.

[3] A. Karalis, J. Joannopoulos, and M. Soljai, "Efficient wireless nonradiative mid-range energy transfer," Annals of Physics, vol. 323, no. 1, pp. 34 – 48, 2008.

[4] W. Brown, "The history of power transmission by radio waves," Microwave Theory and Techniques, IEEE Transactions on, vol. 32, no. 9, pp. 1230 – 1242, sep 1984.