

A Brief Overview of Wireless Power Transfer Techniques

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Abstract

The necessity to distribute energy wirelessly has been spurred by the tremendous growth in the use of portable devices. Mobile devices have become ubiquitous and the circuits within them have been optimized to consume extremely low amounts of power. Such portable electronic sets are in constant use and the frequent need to recharge them; using conventional wired mechanisms have hindered the mobility of users. Wireless transmission of energy to power-up devices has been proposed since the days of Tesla and since then many theories and methods have been invented. This paper discusses some of those techniques briefly.

Keywords: *Cordless Electricity, Wireless Electricity, Wireless Energy, Wireless Power*

1. Introduction

The transmission of energy without cords with the intent of charging or supplying power to a remote electronic device has been underway since the time of Tesla. One of Tesla's ambitious goals was to be able to demonstrate a system capable of worldwide distribution of wireless power [1]. The lack of funds together with the primitive technology caused the idea to be abandoned for many years since then. Interest in this field has resurfaced recently mainly due to the advent of mobile electronic devices that are constantly on the move and need to be frequently charged. A successful demonstration of wireless power transfer (WPT) was performed in 2007 by a team of researchers from the Massachusetts Institute of Technology (MIT). They were able to light a 60-Watt incandescent bulb located at a distance of two meters from the source without using wires [2]. The intent of wireless power transfer is to move electric charge stored in a reservoir to a distant location without the use of transmission cables. Such a system will increase the portability of light electronic devices and free users from the tedious task of transporting power cords. Since our society is already familiar with the concept of wireless communication provided by cellular phones and wireless local area networks, the obvious question to ask is what is preventing us from hauling energy wirelessly?

2. Methodology

Out of the numerous wireless energy transfer techniques that have been proposed in research labs and in theory papers, three of them stand out the most. The first method utilizes directed microwaves as the source of wireless energy and rectennas as the converters of microwaves back to electricity, the second scheme makes use of laser technology to beam photons onto photovoltaic cells which in turn convert the photons into electricity, and the third plan implements mutual induction between two coils operating at the same resonant frequency [1].

2.1 Microwave Assisted Wireless Power Transfer

In this process, a microwave oscillator produces microwaves having frequencies within the range of 1-GHz to 1000-GHz. These waves are then beamed to a remote distance with the help of directional antennas. The microwaves bombarding the receiving antenna are transformed back into electrical energy to power an attached load. The system installed at the receiving end whose responsibility is to convert microwaves into direct current is called a rectenna. The building blocks of a rectenna include a dipole antenna with a RF diode connected across the dipole elements [3]. The diode helps to rectify the alternating current that gets induced at the antenna terminals by the microwaves to generate direct current. Rectennas having conversion efficiencies of 95% have been reported [3]. Microwave assisted wireless power transfer has been proposed for the transmission of energy from orbiting solar powered satellites to Earth.

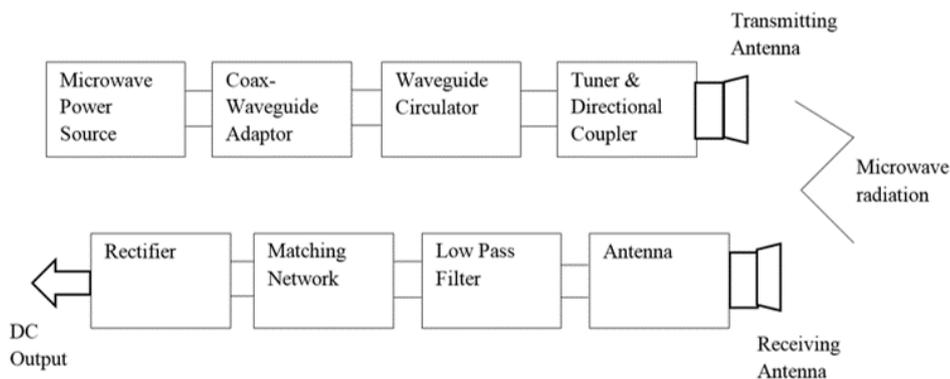


Figure 1. Block Diagram of Microwave based Wireless Power Transmission System [1]

As demonstrated in figure 1, first a microwave generator generates the microwaves. This radiation then passes through a coax-waveguide adaptor, which in turn is connected, to a waveguide circulator. The waveguide circulator protects the microwave source from reflected power [4]. The tuner matches the impedance between the transmitting antenna and the microwave source. The attenuated signals will then be separated based on the direction of signal propagation by a directional coupler. The transmitting antenna radiates the power uniformly through free space to the receiving antenna at which the microwave radiation passes through a low pass filter, followed by a matching network, and lastly through a rectifier as it is converted to DC power.

2.2 Laser Assisted Wireless Power Transfer

This method is similar in concept to the generation of electricity via solar cells, whereby solar energy from the sun gets converted into electricity. However, in this method the source of light will be a laser that beams

photons across a distance to a receiving unit. Photons emerging from the laser diverge as the distance between transmitter and receiver increases, and so to focus the beam onto a narrow spot, the photons are made to pass through converging lenses as they travel towards their destination [5]. The receiving system is composed of a group of photovoltaic cells designed to convert light of a particular wavelength into electricity to energize a load connected at the output stage of the photovoltaic cells [5].

As shown in figure 2, laser power beaming (LPB) uses electricity from a common source, such as the electrical grid or a portable generator, and converts it into light via a laser [6]. This laser beam is then shaped with a set of optics, and directed via a gimbaled mirror (also known as the beam director) to a remote photovoltaic (PV) receiver. The PV receiver converts the light back into electricity to be used to charge a battery, run a motor, or to do other work [6]. In many ways, the system can be viewed as a kind of extension cord, with electrical power going in at one end, and electrical power coming out at the other end. The best form of current laser technology is a fiber laser, which can produce peak powers in the hundreds of kilowatts [6].

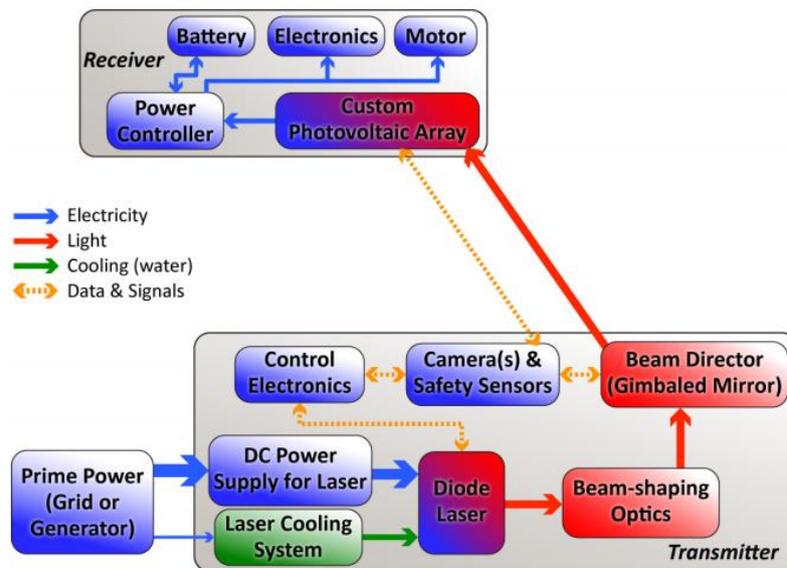


Figure 2. Block Diagram of Laser based Wireless Power Transmission System [6]

2.3 Magnetic Resonance Assisted Wireless Power Transfer

From Maxwell's equations it can be seen that a time varying current passing through a coil produces a magnetic field around its surrounding space. As this time-varying magnetic field interacts with another coil placed in the vicinity of the coil producing the magnetic field, an induced current arises in the second coil [2]. This is called mutual induction between the two coils, and the frequency at which the coupling waves attain their maximum amplitude is called the resonant frequency. In this method, primary and secondary coils serve as transmitting and receiving antennas respectively. Some of the critical parameters affecting the performance of this system include the operating frequency, diameter, resistance and the number of turns of the coils [2]. As shown in figure 3, inductive power transfer works by creating an alternating magnetic field (flux) in a transmitter coil and converting that flux into an electric current in the receiver coil. Depending on the distance between the transmitting and receiving coils, only a fraction of the magnetic flux generated by the transmitter coil penetrates the receiver coil and contributes to the power transmission [7]. The more flux reaches the receiver; the better the coils are coupled.

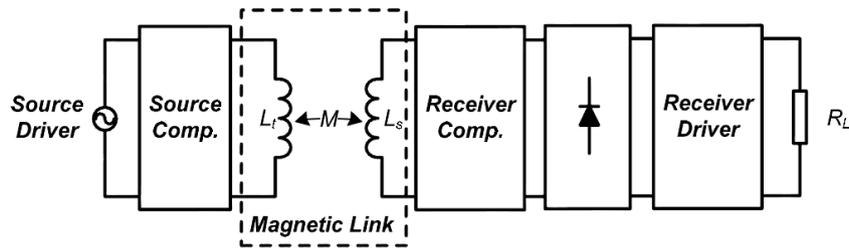


Figure 3. Concept of Magnetic Resonance based Wireless Power Transmission System [8]

In conventional inductive coupling, efficiency drops off rapidly as distance increases. Magnetically coupled resonators with sufficiently high quality factor (Q) coils exhibit a surprising behavior [9]. Maximum power transfer efficiency can be achieved over a broad range of distances and orientations. The transmit antenna consists of a LC based transmitting coil. As electricity travels through this coil, the coil begins to resonate. The oscillator generates a signal at a frequency where maximum power transfer takes place; the signal is then amplified through a power amplifier thus resulting in an oscillating magnetic field [10]. The magnetic waves resonating at a specific frequency are transmitted from the transmitter to a receiver [11]. These magnetic waves interact with a coil at the receiver to induce an electric current at the receiver. If the receiving coil is tuned so that its resonant frequency matches the frequency of the magnetic waves, the current it produces is amplified. The received power would have an alternating current, which is undesirable for powering a DC load, thus a rectifier would be needed to rectify the AC into a smooth DC. Each of the three WPT methods discussed in this paper has its own merits and demerits. The three WPT methods have been compared with respect to output power, transmitting distance range, economic feasibility, system efficiency, and biologic effects. Table 1 summarizes the results.

Table 1. Performance Comparison of Wireless Power Transfer Methods

WPT Methods	Comparison Parameters				
	Output Power	Distance	Cost	Efficiency	Biological Effects
Magnetic Resonance	60 Watts [10]	Few Meters [10]	Inexpensive	Up to 45% [10]	No harmful effects [11]
Microwave	100 Kilowatts [12]	Few Kilometers [12]	Expensive	Up to 54% [12]	Damages living tissue [12]
Laser	Several hundred Kilowatts [13]	Few Kilometers [13]	Expensive	Up to 30% [13]	Damages living tissue [13]

3. Conclusion

The idea behind wireless power transfer is groundbreaking and its large-scale adoption will be the greatest breakthrough in the field of energy transfer. Just as wireless communication has changed the way we communicate, wireless electricity will open doors to new scientific avenues. To make wireless energy transfer commercially viable, researchers still need to increase energy transfer efficiency and develop circuits that can work with minute levels of power. In this paper we have presented a short overview of the techniques currently being explored to transfer power without cords. Out of the various methods of transferring energy wirelessly, the choice depends upon factors such as distance, medium, application, complexity and cost.

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References

- [1] M.V. Reddy, K.S. Hemanth, C.V. Mohan, "Microwave Power Transmission: A Next Generation Power Transmission System," *IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE)*, Vol. 4, Issue 5, January 2013.
- [2] K. Aristeidis, J. D. Joannopoulos, and M. Soljačić, "Efficient wireless non-radiative midrange energy transfer," *Annals of Physics*, Vol. 323, No. 1, pp. 34-48, 2008.
DOI:10.1016/j.aop.2007.04.017
- [3] S. Kumar, et al., "Wireless power transmission – a prospective idea for future," *Undergraduate Academic Research Journal (UARJ)*, ISSN 2278-1129, Vol. 1, Issue 3, 2012.
- [4] W. Huang, et al., "Study on an S-Band Rectenna Array for Wireless Microwave Power Transmission," *Progress In Electromagnetics Research (PIER)*, Vol. 135, pp. 747-758, 2013.
- [5] G. A. Landis, "Applications for Space Power by Laser Transmission," in Proc. SPIE Optics, Electro-optics & Laser Conference, Vol. 2121, pp. 252-255, Jan. 24-28, 1994.
- [6] S. Joshi, "Wireless Transmission of Power: A New Era of Development," *International Journal of Research and Engineering (IJRE)*, Vol. 1, Issue 4, pp. 15-17, 2014.
- [7] W. Ke, D. Choudhury, and H. Matsumoto, "Wireless Power Transmission, Technology, and Applications," in Proc. Institute of Electrical and Electronics Engineering (IEEE), Vol. 101, No. 6, June 2013.
- [8] A. Kurs, et al., "Wireless Power Transfer via Strongly Coupled Magnetic Resonances," *Science*, Vol. 317, No. 5834, 2007.
- [9] A. Kurs, et al., "Wireless Power Transfer via Strongly Coupled Magnetic Resonances," *International Journal of Advanced Engineering & Applications (IJAEA)*, Vol. 4, Issue 2, pp. 177-181, January 2010.
- [10] P. Fisher, et al., Goodbye wires... MIT experimentally demonstrates wireless power transfer, MIT News, June 2007. <http://web.mit.edu/newsoffice/2007/wireless-607.html>
- [11] H. Matsumoto, "Research on Solar Power Satellites and Microwave Power Transmission in Japan," *IEEE Microwave Magazine*, pp. 36-45, December 2002.
- [12] D. R. Criswell and R. D. Waldron, "Lunar System To Supply Solar Electric Power To Earth," in Proc. of the 25th Intersociety Energy Conversion Engineering Conference, Aug. 12-17, 1990.
- [13] S. Srinath and S. Bhandari, "Optic based wireless power transmission for wireless sensor networks," *International Journal of Engineering Research & Technology (IJERT)*, ISSN 2278-0181, Vol. 1, Issue 10, December 2012.