# Wireless Power Transmission*

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***Abstract*—In this paper, methods of wireless power transmission will be investigated for use in driving portable electronic devices. Several methods are discussed as a means to inform. Ultimately, this information will be used to complete a senior project over the course of two quarters. This paper aims to investigate whether or not implementation will remain within time and budget constraints.**

**The goal is to wirelessly charge portable electronic devices over a distance of 50+ meters. It was decided that microwaves were the best option to transmit power wirelessly, due to the requirements. We decided to use a parabolic dish antenna for the microwave transfer and an array of stacked microstrip patch antennas as the load receiver.**

***Index Terms*—Rectenna, Wireless Power Transfer, Wireless Energy Transfer, WPT, Microwave, laser**

## I. INTRODUCTION

Nikola Tesla is known for his incredible work in electric systems. In 1891, he demonstrated at the World Columbian Exposition in Chicago, also known as the Chicago's World Fair, that transferring power through wireless means was possible. The applications of such are too profound to cover within this paper, but without a doubt have far reaching implications.

Currently, almost all electronic devices are tethered in some manner, whether it is a device that must be connected to a power outlet to operate continuously or a portable device that requires renewing the battery life every 7-8 hours of heavy use, and up to several days in stand-by/idle use. Even with the recent release of the Wireless Power Consortium (WPC) low-power specification, otherwise known as Qi, we are still limited. This is because Qi charging stations transmit power using magnetic induction, which requires physical contact with the receiver [6], [12], [13]. The technologies that do not require such limitations also require very little power to operate, such as RFID tags and smart cards, both of which are usually powered by magnetic fields using inductive coupling as they typically operate with short-range needs. Other methods that are employed for short-range or mid-range use are resonant inductive coupling, capacitive coupling, and magnetodynamic coupling.

Since the topic of this paper will be on long-range wireless power transmission, we will consider using electromagnetic radiation methods such as microwaves or laser beams as the delivery method is focused instead of omnidirectional. However, the challenge of Wireless Power Transmission (WPT) rests in meeting efficiency needs, or in other words, transmitting enough power over a large distance to another receiving system. This contrasts radio communication where the only requirement is that the signal-to-noise ratio is high enough that the information received is not corrupted or muddled.

## II. FAR FIELD TECHNIQUES

### A. Lasers

With this method, electricity is converted into a laser beam which is then pointed at a photovoltaic cell receiver. The problems of this method are not limited to scattered laser beams posing a hazard to the human eye, conversion inefficiencies, atmospheric attenuation, and line-of-sight requirements.

### B. Microwaves

Microwave power transmission can be utilized quite easily for long distance purposes. A rectifying antenna, or *rectenna* that converts microwave energy into electricity acts as the receiver, and has achieved efficiency values around 85% in the conversion process [1], [2]. This makes it a much more promising technique over lasers. Interestingly, for space-to-earth applications, diffraction of microwaves require rectennas with much larger apertures on the receiving end. For example, NASA's 1978 study [4] on transmitting power from a satellite realized a 1 km diameter transmitting antenna was needed for a 10 km diameter receiving rectenna located on the ground. For much smaller distances, signal loss is still an issue for microwaves propagating through free space. However, adjusting for high-power transmittance will reduce the loss at receiver side.

## III. EQUIPMENT AND SCHEMATICS

### A. Near-Field

In the simplest case, one could easily set up an Arduino-based circuit to light up an LED at a distance of 2-3 cm. In this case, the parts list would be fairly inexpensive. Table 1 lists the bill of materials and costs while figures 1 and 2 showcase circuit schematics for transmitting and receiving devices [8].

Beginning with the transmitter, A 9V battery supplies a positive voltage to the collector terminal of an NPN transistor. Once the base terminal has been switched to its "on" state with a sufficient current, current flows from the collector terminal to the emitter terminal. If the transistor were to connect and disconnect the emitter and collector terminals at a rapid pace, the inducer coil would experience changing magnetic fields–to which the receiving coil in close proximity would then undergo induced current flow. The receiving coil is connected to a full-wave bridge rectifier and a voltage regulator circuit.

*An Investigation of WPT, its viability as a senior project, and a rudimentary foundation for future implementation.

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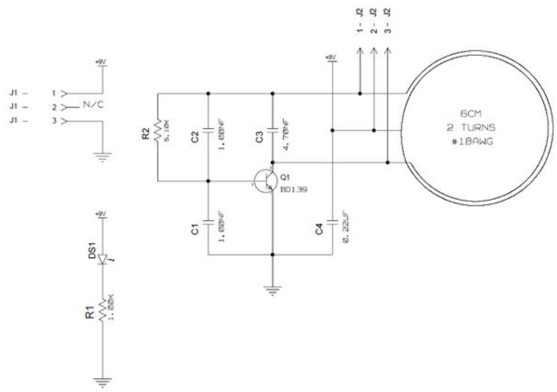


Fig. 1: The schematic for a near-field transmitter

TABLE I

| Bill of Materials | | | |
|---|---|---|---|
| Quantity | Element | Part ID | Price |
| 4x | 1N4148 | CR1 CR2 CR3 CR4 | 0.10ea |
| 1x | LED | DS1 | 0.20 |
| 1x | 0.01UF, 10%, 50V | C8 | 0.20 |
| 3x | 0.10UF, 10%, 50V | C5 C6 C9 | 0.20ea |
| 2x | 1.00NF, 20%, 100V | C1 C2 | 0.20ea |
| 1x | 0.22UF, 10%, 100V | C4 | 0.20 |
| 1x | 4.70NF, 20%, 100V | C3 | 0.20 |
| 1x | BD139 | Q1 | 0.50 |
| 1x | 470, 5%, 0.25W | R3 | 0.10 |
| 1x | 1.00K, 5%, 0.25W | R1 | 0.10 |
| 1x | 2.70K, 5%, 0.25W | R4 | 0.10 |
| 1x | 5.60K, 5%, 0.50W | R2 | 0.10 |
| 1x | 1000UF, 20%, 35V | C7 | 0.20 |
| 4x | Terminal Block | J1 J2 J3 J4 | 0.64ea |
| 1x | LM317 | U1 | 0.50 |
| 2 turns | 6cm Magnet Wire | #18AWG | - |
| 5 turns | 6cm Magnet Wire | #18AWG | - |
| | | | \$10 |

Both schematics (Fig. 2) are relatively simple. Since the scope of this paper is to realize long-distance WPT, this near-field schematic would only serve as a proof-of-concept. However, their use is still valuable in delivering power in small-scale situations where using wired solutions might be problematic.

### *B. Far-Field*

Considering that the goal of this project is to reach distances of 50+ meters, there are several requirements to be realized.

- The transmitting antenna must be able to operate in the microwave range.
- The transmitting antenna must have a significant degree of directivity and gain.
- The entire system must be mobile to reach distances of 50 meters.
- The receiving antenna must collect enough wireless power to charge some portable device.
- The circuit on the receiving side must be able to detect the correct frequency of the power band and output power in DC.
- The rectenna must have a high gain.

Based on the requirements above, a parabolic dish antenna is suitable to transmit (see Fig. 3), and microstrip antennas

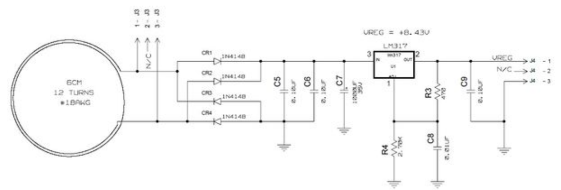


Fig. 2: The schematic for a near-field receiver

work well to receive (see Fig. 4). In general, rectennas are very efficient at converting microwave energy [1], [2]. The rectifying process ideally uses a Schottky diode, as its properties include low voltage drops and high speeds. The cost of these materials are minimal, as the parabolic dish is readily available and custom microstrip antennas can be manufactured cheaply.

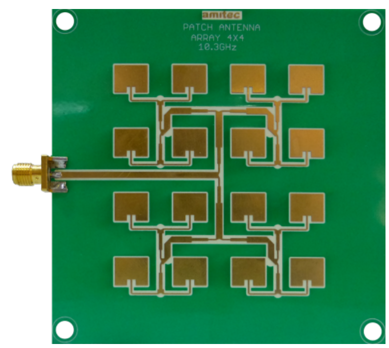

Fig. 3: An example of an array of microstrip patch antennas.

Fig. 4: An example of a parabolic dish antenna

Microstrip antennas can be manufactured in any number of different ways, with variable design emphases on project needs such as linear or circular polarizations, dual-frequency or dual-polarization designs, and so on. Microstrip antennas are characterized by various geometric shapes and sizes, including squared, rectangular, circular, ringed, triangular, elliptical, or disk shaped for the more common shapes. There also exist non-conventional microstrip antenna shapes such as semi-ringed, disk sectors, L-shaped, cross-junctions, and etc.

Since microstrip antennas work like dipoles, their geometric differences still yield similar radiation profiles. Typically, a microstrip patch antenna (MPA) has a gain between 5 and 6 dB with a 3db beam-width between 70° and 90°. MPAs consist of a conducting patch of any geometry on one side of a dielectric substrate and a grounded plane on the other [3].

In order to receive enough power to charge some portable device, an MPA array is needed. properties of the antenna design relies on end-goal power needs, the fixed distance, radiation interference, operating frequencies, etc.

## IV. CONCLUSIONS

The most promising WPT method is in using a parabolic dish antenna to transmit microwaves and stacked microstrip patch antennas, respectively as the method of transmittance and load collector. Far-Field WPT can be done easily, with success, and within the parameters of a far-field senior project.

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