# Wireless Power Transfer System (WPTS)

FUNCTIONAL REQUIREMENTS LIST AND PERFORMANCE SPECIFICATIONS


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## Introduction

In the late 1800s, Nikola Tesla and Heinrich Hertz **[1]** had developed the concept of power transmission via electromagnetic waves. Ever since, the concept still continues as research is constantly being done.

Several companies such as Sony **[2]**, Qualcomm **[3]**, and Witricity **[4]** are developing wireless power transfer (WPT) systems. These systems function based off an inductive coupling mechanism in which the distance of power transmission is fairly small, less than three feet; hence, these systems are regarded as near-field WPT systems.

The usage of radio frequency (RF) or microwave frequency electromagnetic signals allows for the development of a system in which the distance of power transfer is approximately 10 feet. This system is of interest to us. In this project two systems having different center frequencies, 915MHz and 2.4GHz, will be designed and tested.

*System #1:*

This system will be centered at a frequency of 915MHz. This design consists of an RF transmitter and an RF receiver that will convert the RF signal to a usable direct current (DC) signal. (Figure 1)

*System #2:*

This system is centered at a frequency of 2.4GHz. This system follows a different approach. The difference is noticeable in the receiver in which a rectifier circuit is embedded in an antenna; this configuration is referred to as a rectenna. (Figure 2)

## Block Diagrams

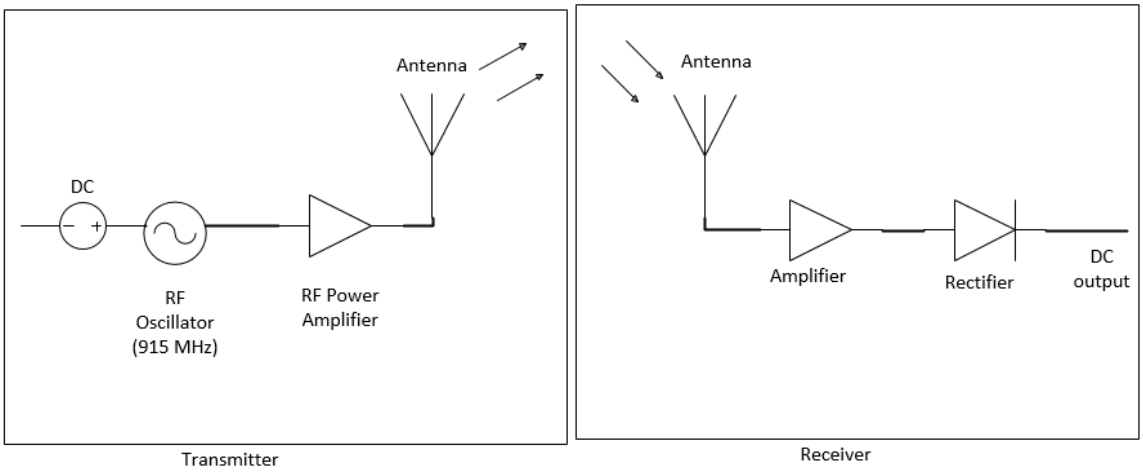


Figure 1: High-Level Block Diagram of System #1

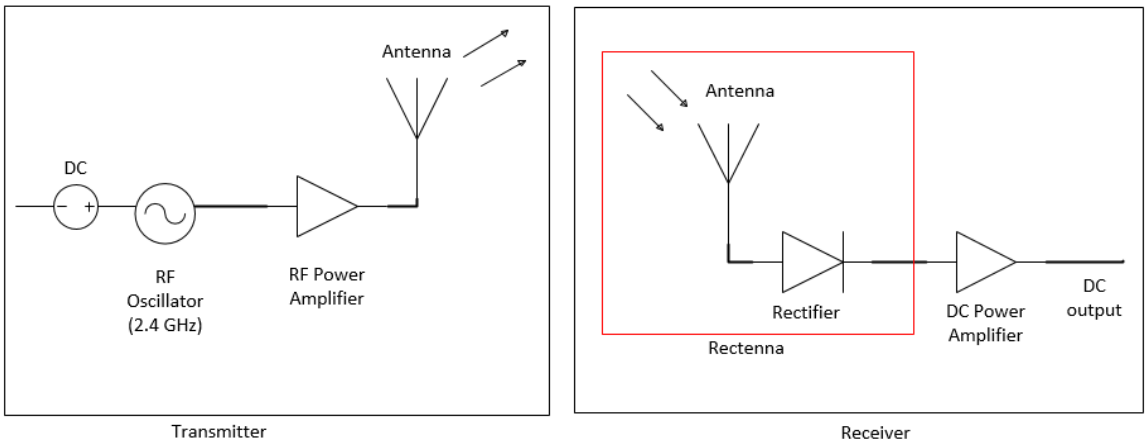


Figure 2: High-Level Block Diagram of System #2

## Functional Description of Subsystems

*Transmitter*:

A DC input signal is sent through an RF oscillator and is amplified via an RF power amplifier. The amplified signal is then emitted from an antenna.

*Receiver*:

Receives the transmitted RF signal as an input and converts it to DC. This is done by first taking the RF signal into the antenna and having it run through a rectifier circuit to provide the DC signal.

*Rectenna*:

This subsystem performs the same as the receiver of system #1 with the exception that the receiver consists of a rectifier circuit embedded in the antenna. If the output signal of the rectenna needs amplification then a DC power amplifier will be included as part of the design, otherwise it can be omitted.

## Challenges

*System #1*:

- Maximizing power transmission distance

*System #2*:

- Rectifier topology to be used for a maximum RF-to-DC conversion efficiency
- Maximizing power density for the receiving antenna
- Reducing harmonics in the receiving antenna

## Functional Requirements

Specifications such as transmitted distance, power transmitted, and power received may be derived from the Friis transmission formula **[5]**. (Figure 3)

$$\frac{P_{rec}}{P_t} = \frac{\xi_t \xi_r A_t A_r}{\lambda^2 R^2} = G_t G_r \left(\frac{\lambda}{4\pi R}\right)^2.$$

Figure 3: Friis transmission formula

From Figure 3:

- $P_{rec}$ = power received
- $P_t$ = power transmitted
- $G_t$ = gain of transmitter's antenna
- $G_r$ = gain of receiver's antenna
- Lambda = wavelength (speed of light/operating frequency)
- R = distance of power transmission

System #1 shall:

- Transmit approximately 1.158 W of power at a distance of 1.5 meters
- Receive approximately 1.395 mW of power at a distance of 1.5 meters
- Have a 74% RF-to-DC conversion efficiency
- Have a transmitter and receiver antenna gain of 3dB
- Have antennas that transmit in a directive manner
- Have dimensions not exceeding 4 in x 3 in
- Power a light bulb, or a cell phone

System #2 shall:

- Be designed with a proper rectifier topology for max RF-to-DC conversion efficiency
- Have an antenna designed for optimal gain
- Mitigate high-order harmonics to prevent radiation of the receiver's antenna
- Be designed with matching networks to reduce power losses
- Have a %60+ RF-to-DC conversion efficiency

## Overall Functional Description

The overall functional goal of the project is to wirelessly transmit power. A DC source will be the input. The DC signal produced will then go through an RF oscillator creating an RF signal. The signal can then be amplified, if needed, and outputted by the antenna. The radiated signal will be received by another antenna. Either system #1 or system #2 can be used for the receiving end. If system #2 is used, the receiving antenna will have a rectifier directly build into it; otherwise known as a rectenna configuration. However, if system #1 is used, then the receiver will consist of an antenna and a rectifier circuit separate from each other. After the signal is rectified, it may then be amplified and sent to the load as DC power, thus charging it.

## References

[1] Boaventura, Alírio, Ana Collado, Nuno B. Carvalho, and Apostolos Georgiadis. "Optimum Behavior." IEEE Microwave Magazine 6 Mar. 2013: 26-35. Print.

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[3] Nadakuduti,, Jagadish, Lin Lu, and Paul Guckian. "Operating Frequency Selection for Loosely Coupled Wireless Power Transfer Systems with Respect to RF Emissions and RF Exposure Requirements." (2013): 1-6. The Alliance for Wireless Power, 15 May 2013. Web. 22 Sept. 2013.

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