Innovative Wireless Battery Charger- A Study

Peeyush Chandra, Shikhar Bahl, Vandana Rathore, Alka Shukla

Abstract- In this paper, an innovative design of a simple type wireless battery charger for portable electronic devices especially for mobile is proposed. The wireless charger will convert the RF/ microwave signal into a DC signal, and then store the power into a battery. The charger is divided into parts: transmitter, antenna, and charging circuit. A complete discussion of the specifications of the battery charger is provided after data measurements. This report also includes component lists, financial, data results, and other key information.

Keywords- Wireless Charger, Yagi Antenna, Schottky Diode ,Bridge Rectifier, RC Circuit, Connector, Battery.

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I.INTRODUCTION

Wireless battery charging or wireless inductive charging as it is also called a method for transferring electrical energy from a charger to a device without the need for a physical wire connection. Portable electronic devices are very popular nowadays. As the usage of these portable electronic devices is increasing, the demands for longer battery life are also increasing. These batteries need to be recharged or replaced periodically. It has many advantages in terms of convenience because users simply need to place the device requiring power onto a mat or other surface to allow the wireless charging to take place. It would be convenient not having to worry about charging or changing the batteries and still have a working device. The advantage of this device is that it can wirelessly charge up the batteries which can save time and money in a long run for the general public.

II. LITERATURE SURVEY

Espejel et.al, 1996 [1] proposed a model in which he design an innovative receiver architecture which heavily improves the power conversion efficiency is presented. Hagerty et.al, 1999 [2] proposed a model in which he developed a unit and demonstrated to show how power can be transferred through free space by microwaves. Lin et.al, 2002 [3] proposed that power converters have a lot of protective circuitry in addition with circuit to reduce noise. Pylarinos et.al, 2004 [4] proposed a model that the peak voltage of the ac signal obtained at the antenna is generally much smaller than the diode threshold. Stremler et.al, 2006 [5] proposed that radio waves cannot be captured efficiently if the length of an antenna is not accurately right for the frequency used. T. Salat et.al, 2008 [6] proposed that battery charger works using a transformer that's used to step down the AC mains input voltage to the required level as per the rating of the transformer. DW Harrist et.al, 2010 [7] proposed that if the two impedances aren't matched then there is reflection of the power back into the antenna meaning that the circuit was unable to receive all the available power. Leo Yu et.al, 2012 [8] proposed that to charge the battery of an electric circuit without plugging it into the wall would change the way people use wireless systems.

III. DESIGN OVERVIEW

This wireless battery charger is designed to operate at900 MHz. In this project, a power transmitter acts as the power source.

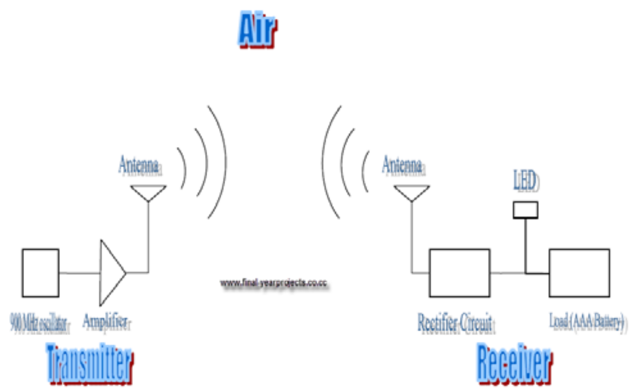

Fig.1. Overall Wireless Battery Charger Design

It will transmit power to the receiver side. And then, the rectifier circuit in the receiver will convert the RF/ microwave signal into DC signal [1]. After the DC signal is produced, the charging circuit will store the power into the battery is shown in Fig.1.

IV. ENGINEERING PROCEDURE

A. Transmitter

Since the group does not design the transmitter, therefore the design is mainly focus on the receiver side. A power transmitter is bought from a commercial website. It is a 900 MHz video/audio transmitter. Here are the specifications of the transmitter shown in table 1.The power of wireless charger is about 12V DC, 900 mA. The output power is 3 watts and the operating frequency is 900 MHz. In this operation, the connector type used is SMA-Female and the output impedence is about 50 ohm.

Table 1. Transmitter Specifications

Power	12V DC, 900 mA
Output Power	3 Watts
Operating Frequency	900 MHz
Connector Type	SMA – Female
Output Impedance	50 Ohm

B.Antenna

The antenna plays a very important role. To charge a battery, a high DC power signal is needed. The wireless battery charger circuit must keep the power loss to the minimal. Therefore, there are many considerations to choose the correct parts for the design.

The considerations of choosing the appropriate antenna are:

1. Impedance of the antenna.
2. Gain of the antenna.

The higher of the antenna gain yields a better result of design. However, higher gain will also increase the cost and the size of the antenna [2].
Higher quality, lower resistance antennas play a big role, Babcock said," The reason that the higher quality factor matters is because we can achieve the necessary charging efficiency with thinner antennas; with smaller antennas we can keep your phone which allows us to maintain charging speed.

Taking the above design specfications in consideration, the team found Yagi antennas that fit our specification as shown inFig.2.

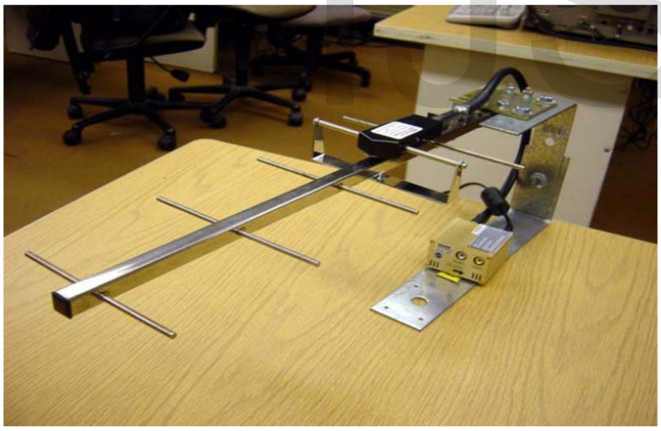

Fig. 2.A Picture of the Yagi Antenna

The impedance of the antenna should match with the output impedance of the power transmitter and input impedance of the rectifier circuit. Non-matching impedance between circuits can cause a tremendous power loss due to signal distortion. Since the output impedance of the transmitter is 50 ohm, the antenna should also have 50 ohm impedance.

C. Receiver

The receiver's main purpose is to charge an AAA battery. A simple battery charging theory is to run current through the battery, and apply a voltage difference between the terminals of the battery to reverse the chemical process. By doing so, it recharges the battery [3].

There are other efficient and faster ways to charge the battery, but it requires a large amount of energy which the wireless battery charger can not obtain, yet. Therefore, in our design, we use a straight forward method to charge the battery as shown in Fig. 3.
Microwave signal is an AC signal with a frequency range of 1 GHz – 1000 GHz. 900 MHz is in between the RF/ Microwave range. No matter how high the frequency is, AC signal is still AC signal. Therefore, the signal can also be treated as a low frequency AC signal. In order to get a DC signal out of the AC signal, a rectifier circuit is needed.

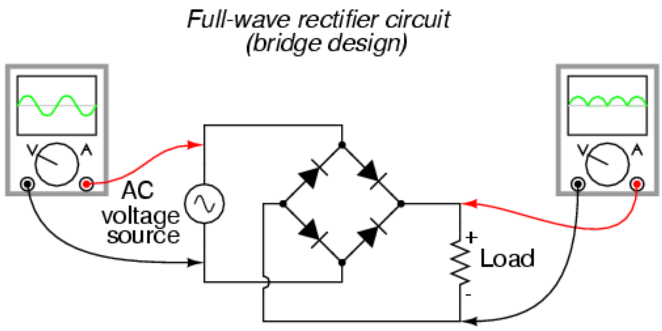

Fig.3. Full Wave Rectifier Circuit

A full-wave rectifier is chosen for the project due to its simplicity and efficiency in converting the AC signal. The full-wave rectifier circuit consists of four diodes. Since the power received by the receiver will be relatively low and the signal frequency is high, the diodes are required to have a very low turn on voltage and operating frequency at 900 MHz [6]. For this reason, a Schottky diode by Skyworks is chosen for the design (SMS3929-021 Bridge Quad Schottky Diode) as shown in Fig.4.
At the output of the rectifier, the signal is not a fully DC signal yet. Thus, by adding a capacitor and a resistor can smooth out the output to become DC signal. However, the time constant produced by the capacitor and the resistor should be calculated carefully to fit the desired time constant.
As the spaces between each half- wave developed by each diode is now being filled in by the other diode. The average DC output voltage across the load resistor is now double than that of the single half-wave rectifier circuit and is about 0 .637 V_{max} of the peak voltage, assuming no losses.

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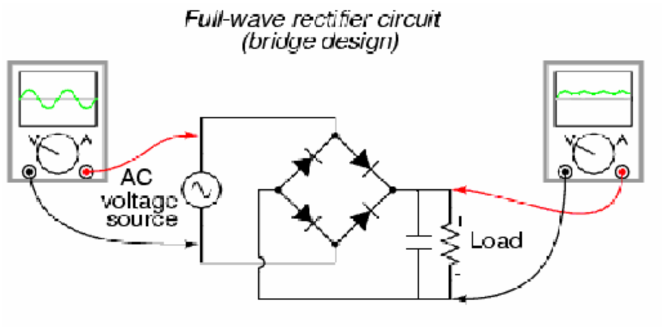

Fig .4. Full Wave Rectifier Circuit with Capacitor

V.DESIGN CIRCUIT

The design of the wireless battery charger consists of 5major components:

1. Transmitter
2. Yagi antennas
3. Full-wave rectifier circuit
4. RC circuit
5. Battery holder

Fig.5. A Picture of the Transmitter with the Yagi Antenna.

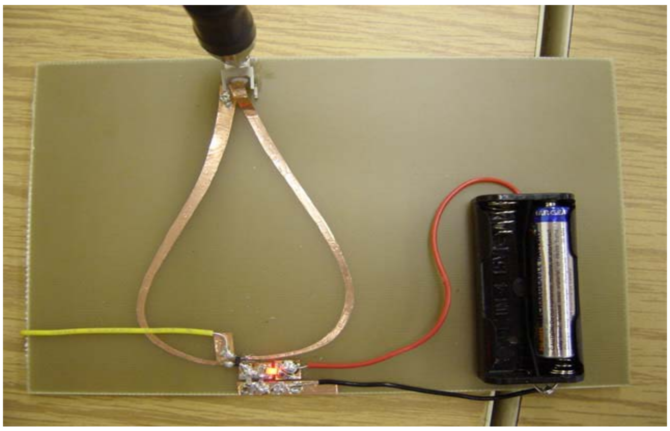

Fig. 6. A Picture of the Circuit of the Charging Circuit

The input impedance of the Quad Bridge Rectifier diode is non-linear. Based on the I-V curve of a diode, the impedance of a turned-on diode is relatively high. The data sheet does not provide the I-V curve data, thus the group assume that the impedance of the rectifier is very high. Therefore, the width of input transmission line is getting thinner as it gets closer to the input rectifier as shown in Fig.6.

The length and the shape of the transmission line need to be considered. The length of the transmission line has to be approximately a quarter wave of the wavelength [5]. The shape of the transmission line needs to be as smooth as possible to avoid power loss. Our design uses a circular shape and gives us the best results.

VI. SPECIFICATIONS

The design is separated into three subsystems: the transmitter, the antenna, and the charging circuit. This charger will charge the battery by utilizing the microwave signal at 900 MHz frequency. It will convert the microwave signal to DC signal, and then it will use the DC signal to charge the battery. The design specifications of the charger circuit are shown in table 2. The source frequencies which it will operate are 900 MHz. The charging distance is about 1 feet and the voltage output is 2.0 V. The power output is 60 Mw and the battery type used is one AAA.

Table 2. Design Specifications

Design Specifications	
Source frequencies	900 MHz
Charging distance	1 feet
Voltage output	2.0V
Power output	60 mW
Battery type	One AAA

This is achieved by using a 3 Watt 900 MHz transmitter. The charging distance can be improved by using a high power transmitter and the high gain antenna.

VII.ADVANTAGES

- Convenience- It simply requires the appliance needing charging to be placed onto a charging area.
- Reduced wear of plugs and sockets - As there is no physical connection, there are no issues with connector wear, etc. Physically the system is more robust than one using connectors.

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- Resilience from dirt - Some applications operate in highly contaminated environment [7]. As there are no connectors, the system is considerably more resilient to contamination.
- Applications in medical environment - Using wireless charging no connectors are required that may harbour bacteria, etc. This makes this solution farmore applicable for medical instruments that may require being battery powered.

VIII. DISADVANTAGES

- Added complexity- The system requires a more complicated system to transfer the power across a wire-less interface.
- Added cost-As the system is more complicated than a traditional wired system; a wireless battery charger will be more expensive.
- Reduced efficiency-There are losses on the wireless battery charging system; resistive losses on the coil, stray coupling, etc. However, typical efficiency levels of between 85-90 % are normally achieved [8].
- Incompatibility- Unlike (for example) a standardized micro USB charging connector, there are no de-facto standards, potentially leaving a consumer, organization or manufacturer with redundant equipment when a standard emerges.

IX. COMPARISON TABLE

The comparison table of various wireless communication devices is given in Table 3.

Table I- Comparison of various Communication devices

Brand Name	Wi-Fi	Bluetooth
Battery Life	Several hours	Several days
Max. Distance	100 m	10 m
Communication Speed	11 Mbps	1 Mbps
Security Method	SSID	64,128 bit
Maximum Network Capacity	32 Nodes	7 Nodes
Application	Wireless LAN	Wireless Speech

The comparison of various communication devices like Wi-Fi and Bluetooth is shown in Table 3. The battery lifes of Wi-Fi and Bluetooth are several hours and several days respectively. The maximum distance used in Wi-Fi is 100 m and of Bluetooth is 10 m. The communication speed used in Wi-Fi is 11 Mbps and that of Bluetooth is 1 Mbps. The security methods used in Wi-Fi and Bluetooth are SSID and 64,128 bit respectively. The maximum network capacity used in Wi-Fi and Bluetooth are 32 and 7 nodes respectively. In the end, the applications of Wi-Fi and Bluetooth are Wireless LAN and Wireless Speech respectively.

X.CONCLUSIONS

In this paper, we have discussed about power loss and efficiency, are the major problems of wireless battery charger. We have also noticed about the potential problem that whether the converted DC power will be significant enough to charge up the battery. The design specifications of transmitter and the wireless charger are discussed. The use of Yagi antennas, the advantages and the disadvantages of wireless battery charger are also discussed. The wireless technology is getting popular nowadays; the demand of battery is also increasing. The battery needs to be recharged or changed eventually.
As for now, there are no known companies which develop the wireless battery charger. This means that the opportunity is very big. Also, people tend to spend more money for convenience. It gives more reason that this device will have a very good market.

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Peeyush Chandra is pursuing M.Tech from Ajay Kumar Garg Engineering College, Ghaziabad (affiliated to Uttar Pradesh Technical University, Lucknow) in electronics and communication engineering. His areas of interest are digital electronics, electronic devices and circuits and wireless communication .He completed his B.Tech from Institute of Technology &Management, Gorakhpur (affiliated to Uttar Pradesh Technical University, Lucknow) in Electronics and Communication Engineering with first degree in the year 2012.During his career he did his industrial training at BSNL. He did his major work on project in Infrared Remote Control based Home Appliances with Fan speed control.

Shikhar Bahl is pursuing M.Techfrom Ajay Kumar Garg Engineering College, Ghaziabad (affiliated to Uttar Pradesh Technical University, Lucknow) in electronics and communication engineering. His areas of interest are control systems, electronic devices and circuits and wireless communication. He completed his B.Tech from Meerut Institute of Engineering and Technology, Meerut (affiliated to Uttar Pradesh Technical University, Lucknow) in Electronics and communication Engineering with first degree in the year 2013.During his career he did his industrial training at BSNL and RRVNL. He did his major work on project in filter design and its specifications in the respective branch for consecutive four years during his B.Tech.

Vandana Rathore is pursuing Mtech from Ajay Kumar Garg Engineering College, Ghaziabad (affiliated to Uttar Pradesh Technical University, Lucknow) in electronics and communication engineering. Her areas of interest are wireless communication, digital electronics and control system. She completed her B.Tech from Bhabha Institute of Technology, Kanpur (affiliated to Uttar Pradesh Technical University, Lucknow) in Electronics and Communication Engineering with first degree in the year 2012. During her career she did her industrial training at DLW Varanasi. She did her major work on project in TV remote work as cordless mouse in the respective branch for consecutive four years during his B.tech.

Alka Shukla is pursuing M.tech from Ajay Kumar Garg

Engineering College, Ghaziabad(Affiliated to Uttar Pradesh Technical University, Lucknow) in Electronics and Communication Engineering. Her areas of interest are Digital Communication, Wireless Communication and Optical Fiber Communication. She completed her B.tech from Greater Noida Institute of Technology, Greater Noida (Affiliated to Uttar Pradesh Technical University, Lucknow) in Electronics and Communication Engineering with 1st degree in the year 2011.During her carrier she did her Industrial training at BSNL in Communication Systems. She did her major project in Interactive Voice Response System (IVRS).