WITRICITY FOR WIRELESS SENSOR NODES

M. Karthika[1] and C. Venkatesh[2]
[1]PG Scholar, Erode Builder Educational Trust's Group of Institutions,
Kangayam, Tirupur, Tamilnadu, India
[2]Professor- ECE, Erode Builder Educational Trust's Group of Institutions,
Kangayam, Tirupur, Tamilnadu, India

ABSTRACT
A major challenge in the wireless sensor networks is to develop a way of supplying power to sensor nodes in an efficient and reliable manner. This paper explored a potential solution to this challenge by transferring energy using Radio Frequency (RF) signals. The RF signal was generated using oscillator, amplified using power amplifier, and transmitted through antenna. The wirelessly transmitted RF energy can be captured by the receiving antennas, transformed into DC power by a rectifying circuit, and stored in a battery to provide the required energy to the sensor node. Such a system has the advantage of eliminating battery replacement of the sensor nodes.

KEYWORDS: *Wireless Power Transmission, Wireless Electricity, Wireless Sensor Networks*

I. INTRODUCTION

Energy constraints are widely regarded as a fundamental limitation of wireless sensor networks. For sensor networks, a limited lifetime due to battery constraint poses a performance bottleneck and barrier for large scale deployment.
Recently, wireless power transfer has emerged as a promising technology to address energy and lifetime bottlenecks in a sensor network. As wireless sensor devices become pervasive, charging batteries for these devices has become a critical problem. Existing battery charging technologies are dominated by wired technology, which requires a wired power plug to be connected to an electrical wall outlet. Wireless power transfer (WPT) achieves the same goal but without the hassle of wires.
A small, low-cost, wireless sensor node is important for sensing the environment. However, the need for frequently replacing its battery has always been a problem, which has limited its use of WSNs. WSNs based on energy harvesting are partly in practical use. The use of solar energy in energy harvesting WSNs has increased for practical applications; this is because of the fact that solar panels are easily available and they have a higher energy density as compared to other energy harvesting techniques. This high energy density allows the development of smaller sensor nodes. However, solar power strongly depends on sunlight and can therefore hardly harvest energy during the nighttime ant the amount of harvested energy depends on the weather.
RF based Wireless Power Transfer is one of the key techniques used to solve this problem. This system focuses on using an ambient RF field as an energy source to power wireless sensor nodes. The use of this unutilized energy as a power source will not only reduce the battery replacement cost, but also enable a long period operation in WSNs.

1.1 Related Works

In paper [1], an Improved Energy Efficient Ant Based routing Algorithm energy management technique, which improves the lifetime of sensor network, was proposed. Using the harvested energy, the time of charging the battery powering the sensor nodes drastically reduced, while requiring time intervals of 91.9 hrs to recharge the battery. Paper [2] studied a power and data transmission system for strain gauge sensors. Two kinds of receiver antennas (dipole and patch) are evaluated in terms of

return loss and peak received power. Results show that dipole antenna have a better impedance matching with the conversion circuit than that of the patch antenna. The rectenna optimization, channel modeling and design of a transmit antenna are discussed in paper [3]. Paper [5] reviewed the history of wireless power transfer and described its recent developments. It showed how such technologies can be applied to sensor networks and addresses its energy constraints. Paper [7] presented the concept of transmitting power without using wires i.e., transmitting power as microwaves from one place to another is in order to reduce the cost, transmission and distribution losses. Paper [8] aimed at designing a prototype of wireless power transmission system. Detailed analysis of all the system components has been discussed.
This research paper is organized as follows. A brief description of existing and proposed systems is presented in Section 2. Section 3 discusses the transmitter and receiver circuits and the output of the each circuit. The brief discussion of result is described in Section 4. Finally, some concluding remarks have been highlighted in Section 5.

II. SYSTEM OVERVIEW

2.1 Existing System

Comparing with sensor node or battery replacement approaches, the wireless charging technology allows a mobile charger to transfer energy to sensor nodes wirelessly without requiring accurate localization of sensor nodes or strict alignment between the charger and nodes [10].
The system consists of

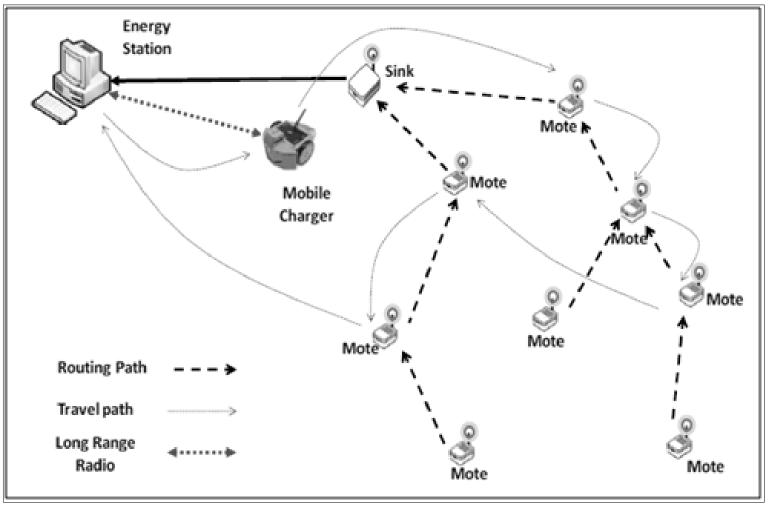

Figure 1. Energy Transfer through Moving vehicle charger

A moving vehicle charger (MVC): a mobile robot carrying a wireless power charger, a network of sensor nodes equipped with wireless power receivers, and an energy station that monitors the energy status of the network and directs the MVC to charge sensor nodes.
A network of sensor nodes equipped with wireless power receivers: Sensor nodes perform application tasks such as environment monitoring, generate sensory data, and periodically report the data to the sink. In addition, that also monitor the voltage readings of their own batteries, estimate energy consumption rates, based on which derive their own lifetime, and then report the information to the sink periodically.
An energy station: it is responsible for monitoring the energy status of sensor nodes, deciding the power charging sequences to be executed by the mobile charger (as shown in the Figure 1).
Problem in Existing System:
The existing system has the overhead of controlling and maintaining the MVC. The MVC takes more than 30% of energy for travelling between the sensor nodes and charging. The distance between MVC and sensor node is too small (in 5-40cm).

2.2 Proposed System

To overcome the energy constraint problem in WSN, WiTricity (Wireless Electricity) is proposed. Energy is transmitted from energy station to sensor node without wire connections. WiTricity is directly transmitted from energy station to sensor nodes.WiTricity is effectively achieved by RF based Wireless Power Transfer System. Wireless Power Transmission system using Radio frequency will be designed for sensor nodes which require low power to operate. RF-based wireless power transmission focus on passively powered sensor networks by improving the conversion efficiency. Attempting to maximize the output power by designing efficient antennas. Antennas can be made more directional, allowing longer distance power beaming.

2.2.1 Wireless Power Transfer System

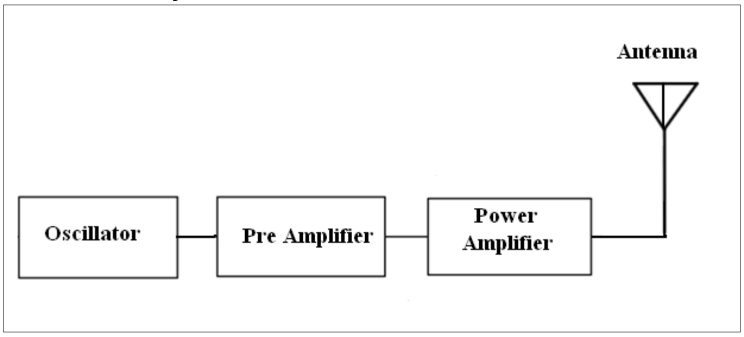

Figure 2. Transmitter Block Diagram

The Wireless power transfer system consists of two parts, transmitter side and receiver side. The block diagram of a typical transmitter unit of WPT system is shown in Figure 2. There is always a large amount of signal power loss in the free space while the RF signal propagates through it. To compensate this loss at the receiver side, the transmitter of the wireless power transfer system should be capable of transmitting a high power. For this reason the transmitting antenna should have high performance [6].

The receiver section contains the receiving antenna, rectifier, DC-DC converter and battery as shown in Figure 3. The receiver's main function is to receive the RF signal from the transmitter, convert it to DC signal which is used to charge the connected device's 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. In this paper, the current is obtained from the radio wave signal coming from the antenna [8].

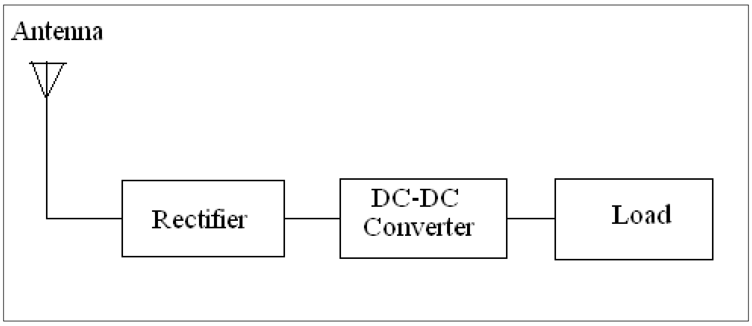

Figure 3. Receiver Block Diagram

III. SYSTEM IMPLEMENTATION

System implementation is based on designing the transmitter and the receiver. The transmitter part consists of oscillator, power amplifier and antenna. The receiver part consists of receiving antenna, rectifier, DC-DC converter and battery.

3.1 Oscillator

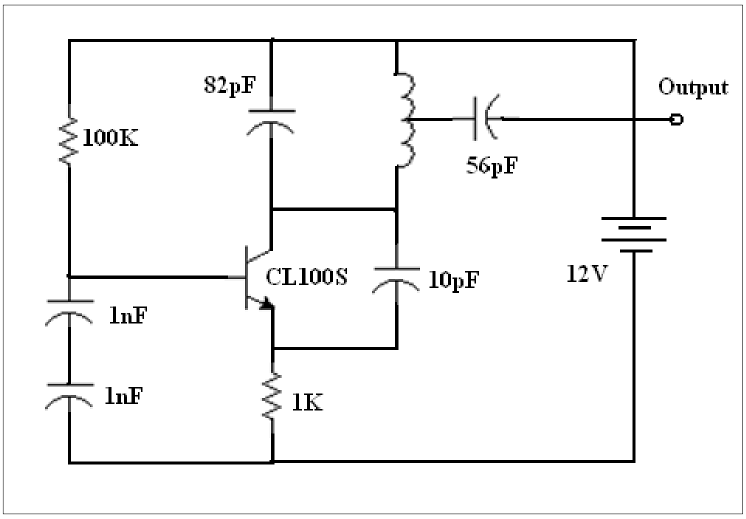

Figure 4. Oscillator Circuit Diagram

The oscillator circuit is based on the Hartley oscillato. The Hartley Oscillator is a particularly useful circuit for producing good quality sine wave signals in the RF range. The Hartley design can be recognized by its use of a tapped inductor. The frequency of oscillation can be calculated in the same way as any parallel resonant circuit, using:

$$\mathbf{f_r} = \frac{\mathbf{1}}{\mathbf{2\pi\sqrt{LC}}}$$

Where L = L1 + L2.

12V power supply is given to oscillator circuit. 82pF capacitor and the 120uH inductor which have 25 turns with 6mm diameter are acting as a tank circuit. Tank circuit is the responsible for the oscillator frequency. The center point of the inductor is given to the amplifier circuit. So that, with two inductors and one capacitor, the oscillator circuit is working with the principle of Hartley oscillator. The oscillator circuit frequency from this circuit is design for 56MHz with 2V amplitude. 1K resister and 0.5nF capacitor is used to give the basing voltage to the transistor**.**

3.2 Pre-Amplifier

Output from the oscillator circuit that is, 56MHz with 2V amplitude is given as an input signal to the power amplifier circuit. 12V power supply is given to the power amplifier circuit. BFW16A is a RF transistor that used to operate on the center frequency of 100MHz. This amplifier circuit is considered as a voltage divider amplifier because of 47K and 5.6K resister. The gain of 2 is achieved from this amplifier circuit. BFW16A is a multi emitter silicon planner epitaxial NPN transistor with extremely inter modulation properties and high power gain. For this reason, BFW16A was chosen.

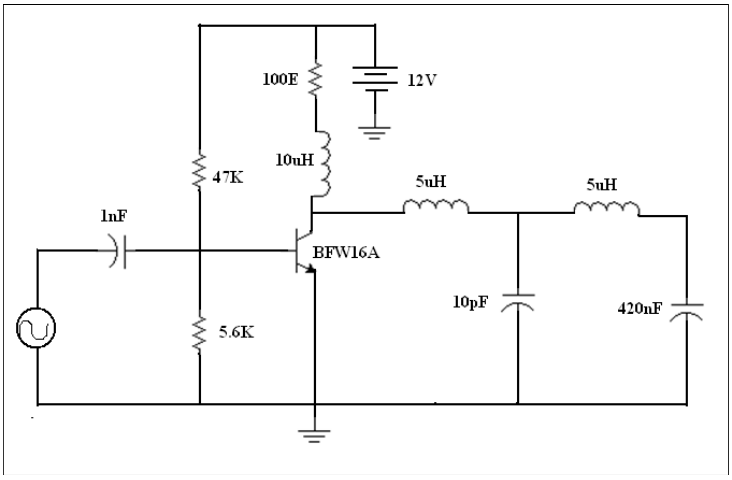

Figure 5. Power Amplifier Circuit Diagram

Oscillator, Pre-Amplifier Output

In Figure 6, Channel 1 shows the output of the oscillator and the scale for the channel 1 is 5V. The channel 2 shows the output of the amplifier and the scale for the channel 2 is 5V. The oscillator output was measured as 5V and the amplifier output was measured as 13V.

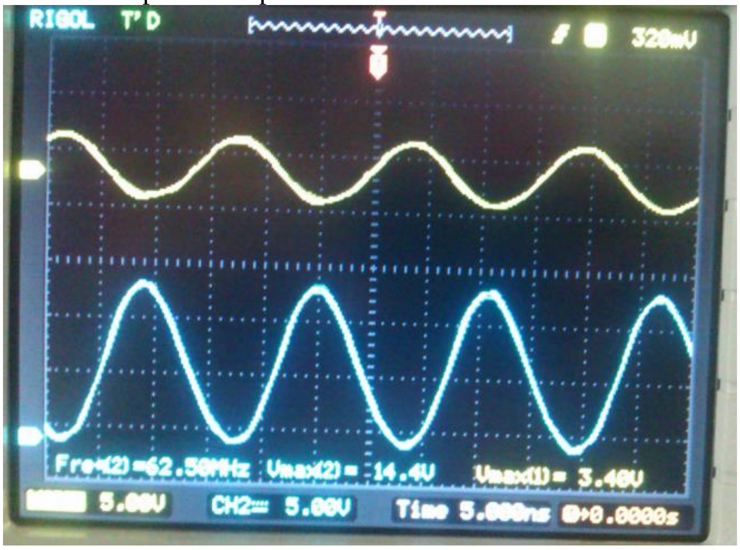

Figure 6. Oscillator and Amplifier Output

3.3 Power Amplifier

A push pull amplifier is an amplifier which has an output stage that can drive a current in either direction through the load. Advantages of push pull amplifier are low distortion, absence of magnetic saturation in the coupling transformer core, and cancellation of power supply ripples which results in the absence of hum. Push-Pull power amplifier is shown in Figure 7. MJE15032 and MJE15033 are 8.0 amperes, complementary silicon power transistors of 250 volts, 50 watts with high DC current gain, high current gain – bandwidth product. For this reason, MJE15032 and MJE15033 were chosen. Output from the pre-amplifier is given to the power amplifier with frequency of 62 MHz and voltage of 6V.

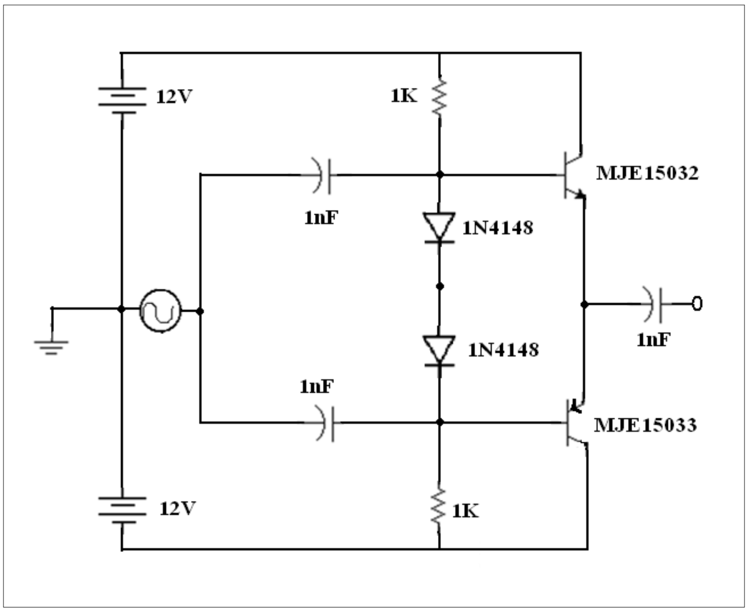

Figure 7. Push-Pull Power Amplifier Circuit Diagram

Power Amplifier Output

The push-pull power amplifier circuit was shown in Figure 8. 10V was given to this circuit as the input power supply. The output current and the voltage were measured as 300mA and 20V respectively. The total power achieved from the circuit was 6W.

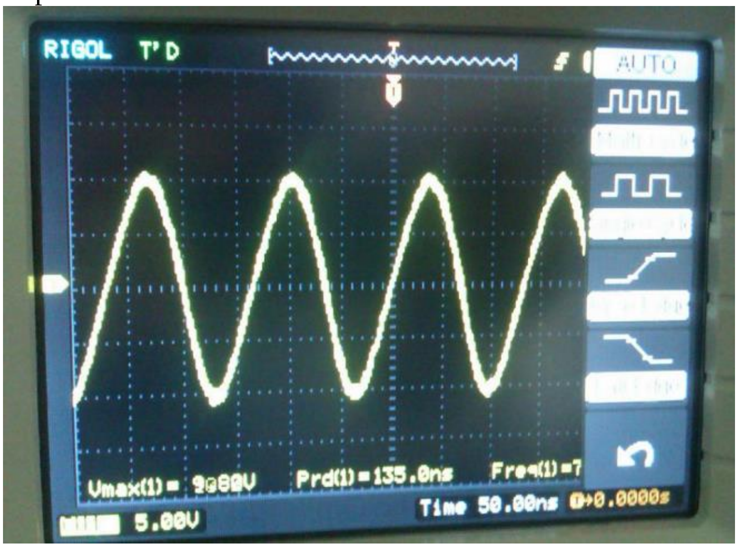

Figure 8. Power Amplifier Output

3.4 Antenna

The telescopic (whip) antenna is used as transmitting and receiving antenna as shown in Fig.9. The whip antenna can be considered half of a dipole antenna, and like a vertical dipole has an omnidirectional radiation pattern, radiating equal radio power in all azimuthal directions (perpendicular to the antenna's axis), with the radiated power falling off with elevation angle to zero on the antenna's axis.

Figure 9. Telescopic Antenna

3.5 Rectifier

Bridge rectifier is used to convert the RF energy to the dc voltage as shown in Fig.8. Its elements are usually arranged in a multi element phased array with a mesh pattern reflector element to make it directional. A simple rectifier can be constructed from a switching diode placed between antenna dipoles. The diode rectifies the current induced in the antenna by the RF signal. Switching diodes are used because they have the lowest voltage drop and highest speed and therefore waste the least amount of power due to conduction and switching. Rectifier is highly efficient at converting RF energy to electricity.

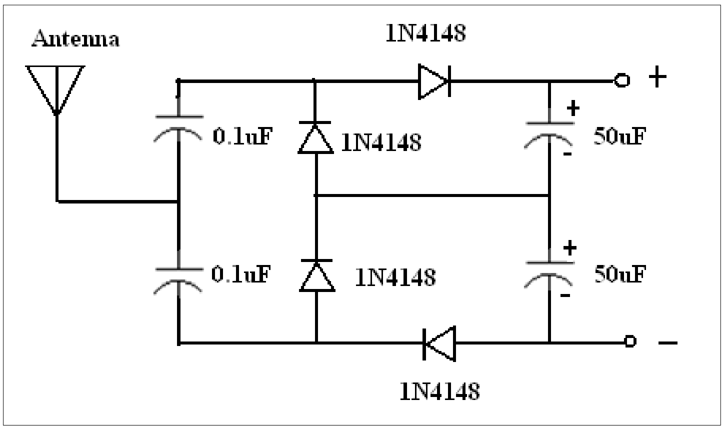

Figure 10. Rectifier Circuit Diagram

The telescopic antenna is used to receive the RF signal. This AC signal is given to the bridge rectifier circuit. The bridge rectifier has two ceramic capacitors of value 0.1pF, two electrolytic capacitors of value 50uF and four PN diodes of 1N4148. This has converted the signal from the antenna to the DC voltage.

3.6 DC-DC Converter

The output voltage of the rectifying circuit is too low for charging a battery. A DC-to-DC voltage converter will adapt the rectified voltage to a stable output voltage high enough for charging a rechargeable battery [3].

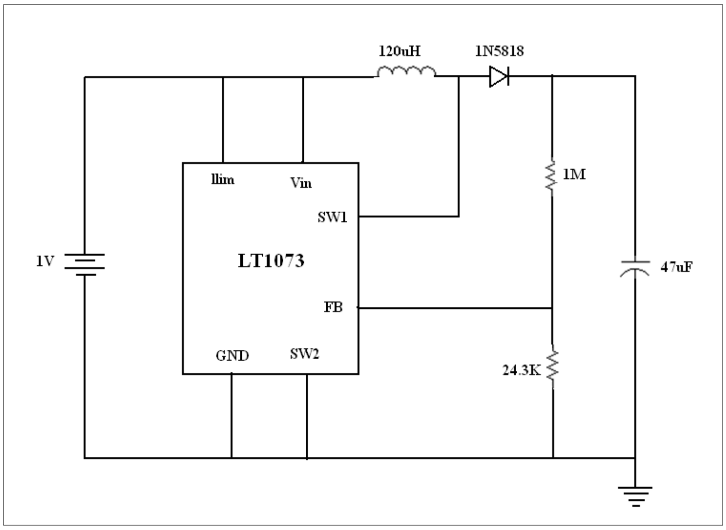

Figure 11. Dc to DC Converter Circuit Diagram

DC to DC converter is used to boost up the DC signal to the fixed DC voltage. 1V DC voltage is given to the DC to DC converter circuit and the output DC voltage is measured as 9V because of the DC to DC module LT1073. The LT1073 is gated oscillator switcher. This type architecture has very low supply current because the switch is cycled only when the feedback pin voltage drops below the reference voltage.

DC to DC Converter Output

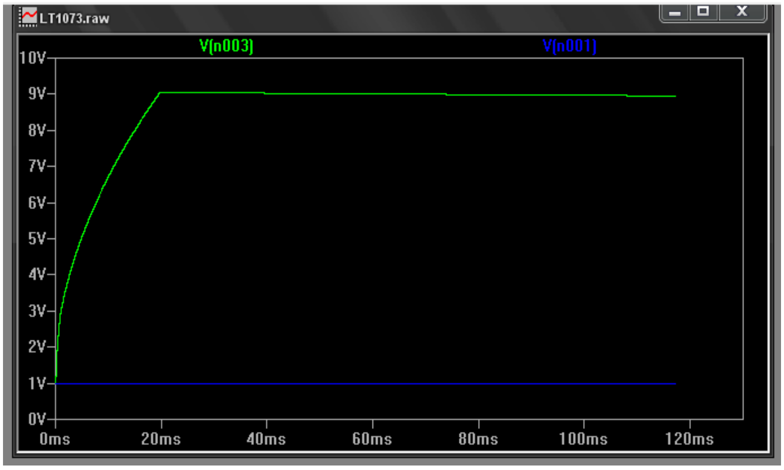

Figure 12. DC to DC Converter Output

Figure 12 shows the simulation output of the DC to DC converter module. 1V input was given to the DC to DC converter and the output was measured as 9V. In practical experiment, 8V is measured from the DC to DC converter circuit.

IV. RESULT

In this paper, transmitter produced the radio signal with the voltage of 20V and current 300mA. This power was transmitter through the telescopic antenna. In receiver side, another antenna was place at the distance of 2m from the transmitter to receive the radio signal and fed to the rectifier circuit. The output of the rectifier was measured as 1.15V and that was given to the DC to DC converter. The output of the DC to DC converter was measured as 8V.

V. CONCLUSION AND FUTURE WORK

WiTricity for wireless sensor nodes project propose a wireless charging system for sensor networks. This project presents the design and implementation of oscillator, pre-amplifier, push-pull power amplifier, rectifier and DC to DC convert. The transmitter produced the radio signal of 6W and transmitted through the distance of 2m. The output of the rectifier circuit was measured as 1.15V.
The design of the antenna at the transmitter and the receiver plays an important role in transferring the voltage level at 1V to the DC to DC converter. Also the design of either a Tor π network at both the transmitter and the receiver end plays a major role in power transfer. Integration of all the stages leads to impedance mismatch which can be overcome using EDA tools like Advance Wave Research, HFSS etc. Very low power DC to DC convertor can be designed to generate a reasonable propagation of voltage and current.

REFERENCES

[1]. A.M. Zungeru, L.-M. Ang, SRS. Prabaharan, K.P. Seng A.M. Zungeru, "Radio Frequency Energy Harvesting and Management for Wireless Sensor Networks", In: Energy Scavenging and Optimization Techniques for Mobile Devices. V. Hrishikesh, and G -M. Mountean (Eds.) USA: Chapter 13, pp. 341-367, CRC Press, Taylor and Francis Group, 2011. (ISBN-13: 978-1439859896).

[2]. Guocheng Liu1, Nezih Mrad, George Xiao, Zhenzhong Li, and Dayan Ban," RF-based Power Transmission for Wireless Sensors Nodes", SMART MATERIALS, STRUCTURES & NDT in AEROSPACE Conference, NDT in Canada 2011, 2 - 4 November 2011, Montreal, Quebec, Canada.

[3]. Hubregt J. Visser, "Indoor Wireless RF Energy Transfer for Powering Wireless Sensors", Radioengineering, Dec2012, Vol. 21 Issue 4, p963-973. 11p.

[4]. Ke Wu, Debabani Choudhury, Hiroshi Matsumoto," Wireless Power Transmission, Technology, and Applications", Proceedings of the IEEE, Vol. 101, No. 6, June 2013.

[5]. Liguang Xie, Yi Shi, Y. Thomas Hou, and Wenjing Lou, “Wireless power transfer and applications to sensor networks”, to appear in IEEE Wireless Communications Magazine (Accepted Dec. 2012, impact factor: 2.575).
[6]. Md M. Biswas, Member, IACSIT, Umama Zobayer, Md J. Hossain, Md Ashiquzzaman, and Md Saleh, “Design a Prototype of Wireless Power Transmission System Using RF/Microwave and Performance Analysis of Implementation”, IACSIT International Journal of Engineering and Technology, Vol. 4, No. 1, February 2012.
[7]. M.Venkateswara Reddy, K.Sai Hemanth, CH.Venkat Mohan, “Microwave Power Transmission – A Next Generation Power Transmission System” IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE), e-ISSN: 2278-1676 Volume 4, Issue 5 (Jan. - Feb. 2013), PP 24-28.
[8]. Olakanmi O. Oladayo ,Departement of Electrical and Electronic Engineering, University of Ibadan, Ibadan Nigeria, “A Prototype System for Transmitting Power through Radio Frequency Signal for Powering Handheld Devices”, International Journal of Electrical and Computer Engineering (IJECE) Vol.2, No.4, August 2012.
[9]. P. Powledge, J.R. Smith, A. Sample, A. Mamishev, S. Roy, "A wirelessly powered platform for sensing and computation,” Proceedings of Ubicomp 2006: 8th International Conference on Ubiquitous Computing. Orange Country, CA, USA, September 17-21 2006, pp. 495-506.
[10]. Yang Peng, Zi Li, Wensheng Zhang, Daji Qiao, "Prolonging Sensor Network Lifetime Through Wireless Charging", In Proc. IEEE RTSS'10, San Diego, CA, November 30 - December 3, 2010.

BIBLIOGRAPHY OF AUTHOR

M KARTHIKA received her B.Tech in Information Technology from Bannari Amman Institute of Technology, Sathyamanagalam in 2010. She started his career as a Test Engineer in Wipro Technologies, Chennai (2010 to 2012). She is presently a student of M.E Computer and Communication Engineering in Erode Builder Educational Trust’s Group of Institutions, Kangayam.

C. VENKATESH, graduated in ECE from Kongu Engineering College in the year 1988, obtained his master degree in Applied Electronics from Coimbatore Institute of Technology, Coimbatore in the year 1990. He was awarded PhD in ECE from Jawaharlal Nehru Technological University, Hyderabad in 2007. He has a credit of two decade of experience which includes around 3 years in industry. He has 18 years of teaching experience. He is supervising 12 Ph.D., research scholars. He is a Member of IEEE, CSI, ISTE, FIE and Fellow IETE. He is presently a Professor, Dean- Faculty of Engineering in Erode Builder Educational Trust’s Group of Institutions.