International Journal of Electrical and Computer Engineering (IJECE)
Vol.2, No.4, August 2012, pp. 495~502
ISSN: 2088-8708

A Prototype System for Transmitting Power through Radio Frequency Signal for Powering Handheld Devices

Olakanmi O. Oladayo
Departement of Electrical and Electronic Engineering,
Technology Drive, Office 6, New Faculty of Engineering Building.
University of Ibadan, Ibadan Nigeria
Email: Olakanmi.oladayo@ui.edu.ng

Article Info

Article history:

Received Jun 17, 2012
Revised Aug 3, 2012
Accepted Aug 10, 2012

Keyword:

Radio wave
Power
Green Energy
Wireless Power transmission

ABSTRACT

Miniature devices development has been greatly complementing the technology developmental trend in telecommunication. This makes the new communication technology to sail smoothly into the society and creating unexpected market for both the telecommunication providers and embedded system manufactures. However power has been the major problem in the usage of some of these devices most especially in third world countries where power is epileptically supplied.This paper proposes a prototype system which wirelessly generates DC for charging and powering power-critical handheld and remotely located devices. The design captures 900MHz radio frequency signal with a dipole antenna, which is converted into DC and stores the power in the device's battery or use it to power it. The major aim of this paper is to provide a prototypical system which provides a cheap, constant and environmental friendly system for powering and charging power critical handheld and remote devices thereby prevents systems failure due to power loss.

Corresponding Author:

Olakanmi .O Oladayo
Departement of Electrical and Electronic Engineering,
Technology Drive, Office 6, New Faculty of Engineering Building.
University of Ibadan, Ibadan Nigeria
Email: Olakanmi.oladayo@ui.edu.ng

1. INTRODUCTION

Many researches had been done on how power can be generated and transmitted. The common means of generating power are through hydro, nuclear, solar, biomass etc. However, the major challenge is how can we generate and transmit uninterrupted power to power critical remote devices such as satellites in the orbits. Also, the researches have shown that the use of cell phone and other miniatures devices has exponentially increased in developing countries, however some of these countries are experiencing interrupted power supply and most time charging these devices has become burden on the users.

As the wireless technology is getting popular nowadays, the demand for power is also increasing. Batteries need to be recharged or changed eventually, hence the need for a system that is capable of supplying uninterrupted cheap power to some of these devices. The prototype eliminates the hassle of looking for power outlet or carrying cabled charger whenever devices or batteries are flat.

This paper is looking at possibility of capturing the RF signals of telecommunication providers' base stations which abound in our environment to power some of handheld and remote power critical systems such as cell phones, cameras, and satellites. It therefore proposes a system, which is capable of trapping 900

MHz radio frequency from any source and convert it to DC which can be used to charge any handheld devices.

The remaining part of the paper is arranged as follows: section 2 is the review of related work on wireless transmission of power. The design methodology of the system and working principles of some of the components used are explained in section 3. Section 4 contains the test results and conclusion

2. RELATED WORKS

Nikola Tesla in about 100 years ago worked on transmitting energy through air [2][7]. William C. Brown in [1] demonstrated how power can be transferred through free space by microwaves. The primary components of his project include a microwave source, a transmitting antenna, and a receiving rectifier and antenna called rectenna. The microwave source consists of a microwave oven magnetron with electronics to control the output power. The output microwave power ranges from 50 W to 200 W at 2.45 GHz. A coaxial cable connects the output of the microwave source to a coax-to-waveguide adapter. This adapter is connected to a waveguide ferrite circulator which protects the microwave source from reflected power. The circulator is connected to a tuning waveguide section to match the waveguide impedance to the antenna input impedance. The slotted waveguide antenna consists of 8 waveguide sections with 8 slots on each section. These 64 slots radiate the power uniformly through free space to the rectenna. The slotted waveguide antenna is ideal for power transmission because of its high aperture efficiency (> 95%) and high power handling capability [1][7].

A rectifying antenna called a rectenna receives the transmitted power and converts the microwave power to direct current (DC) power. The rectenna consists of 6 rows of dipoles antennas where 8 dipoles belong to each row. Each row is connected to a rectifying circuit which consists of low pass filters and a rectifier. The rectifier is a GaAs Schottky barrier diode that is impedance matched to the dipoles by a low pass filter. The 6 rectifying diodes are connected to light bulbs for indicating that the power is received. The light bulbs also dissipated the received power. This rectenna has a 25% collection and conversion efficiency, but rectennas have been tested with greater than 90% efficiency at 2.45 GHz. In spite of the efficiency of this technique in producing DC at receiving end the high cost compare to generated current defeated the economy value of its usage in charging hand held devices. Also micro wave require line of sight. This may not be guarantee always which reduces the flexibility of this technique.

In [5] a prototype power transmission through radio frequency with expected 3W power at the receiving end was developed but due to design setback could only get 1W and very low voltage output. Toshiyuki Umeda et al also design a 950MHz wireless power transmission system for sensor network tags using a high-sensitivity rectifier with dynamic gate-drain [6].

3. RESEARCH METHOD

The prototype is designed to operate at 900MHz. The design is divided into two main parts; the transmitter and the receiver parts as shown in Figure 1. A transmitter section is design to act as RF signal source. This is intended to be replaced with nearby base station of telecommunication providers. The transmitter section contains oscillator, amplifier and transmitting antenna while the receiver section consists of receiving antenna, rectifier and charging point for the handheld device.

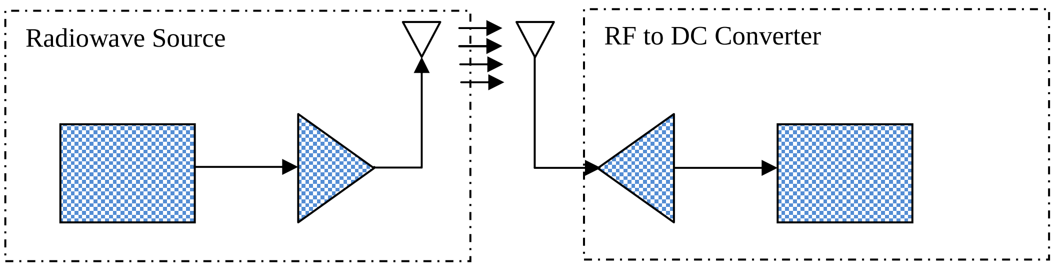

Figure 1. Block diagram of Handheld Charger

The transmitter is made of the Oscillator, Amplifier, and the transmitting antenna, while the receiver consists of the Receiving Antenna, Rectifier and the Charging point for the battery.

3.1 THE TRANSMITTER

This is a miniature transmitter which generates 900MHz radio frequency. It is built to represent the source of radiowave as shown in Figure 2. It contains Voltage controlled Oscillator (MAX2326), Preliminary Amplifier (MAR-4SM), Power Amplifier (PF08109B) and Unity Amplifier-Buffer Circuit.

3.1.1 Voltage Controlled Oscillator (MAX2326)

The MAX2326 is monolithic self-contained voltage-controlled oscillators (VCOs) which combines an integrated oscillator and output buffer in a miniature 8-pin µMAX package. The inductor and varactor elements of the tank circuits are integrated on-chip, greatly simplifying application of the part. In addition, the center frequency of oscillation and frequency span are factory preset to provide a guaranteed frequency range versus control voltage. An external tuning voltage controls the oscillation frequency. The output signals are buffered by an amplifier stage matched on-chip to 50Ω. The MAX2623 operate from a +2.7V to +5.5V supply voltage and require only 8mA of supply current. In shutdown mode, the supply current is reduced to 0.1µA [4].

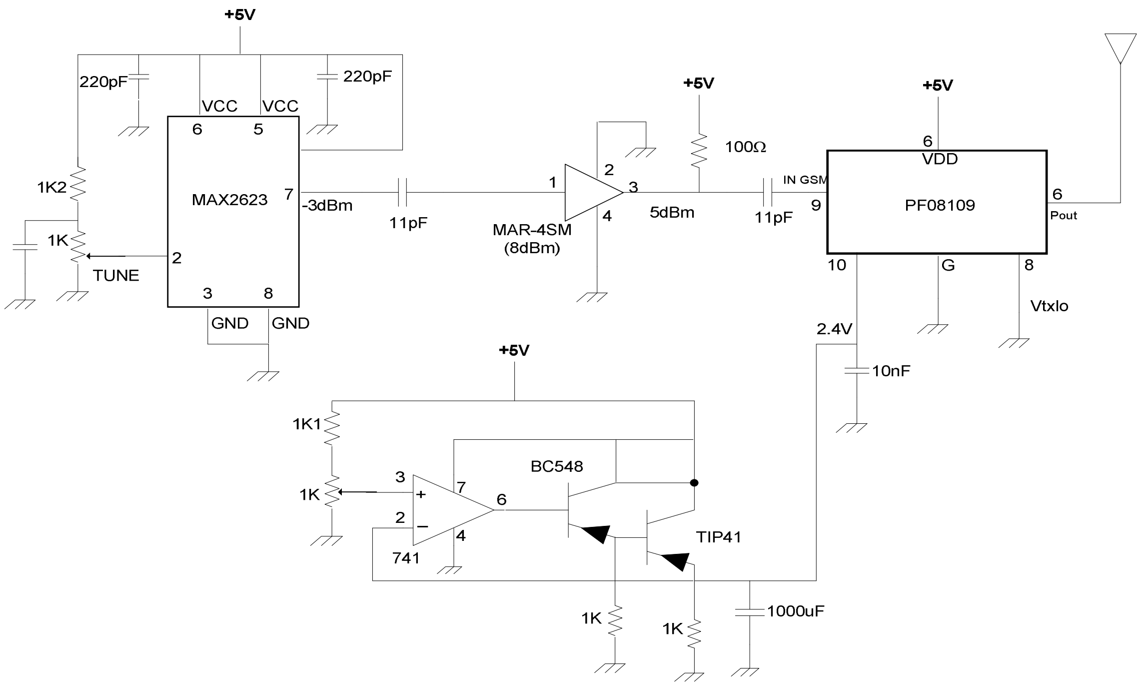

Figure 2. Transmitter circuit

3.1.2 Preliminary Amplifier

The preliminary amplifier, MAR-4SM, is used to boost the RF oscillation generated by the VCO by a frequency gain of 8dbm.

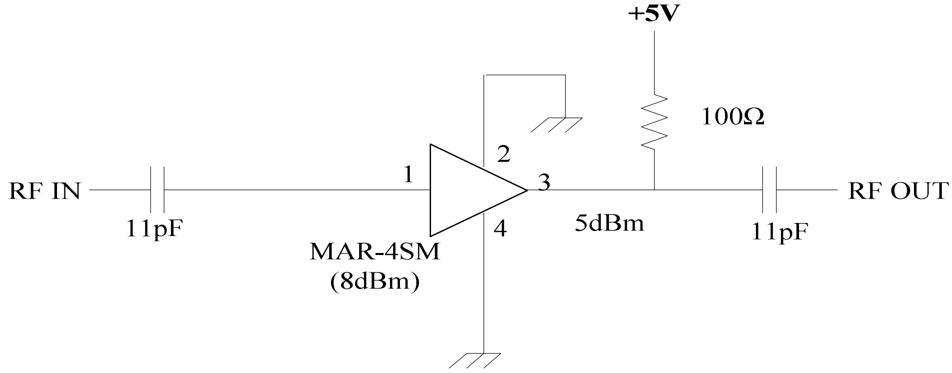

Figure 3. Biasing Configuration of MAR-4SM

3.1.3 Power Amplifier

The power amplifier used (PF08109B) is a Dual Band MOSFET Power Amplifier Module for E-GSM and DCS1800 Handy Phone with dual frequency ranges of E-GSM (880 MHz to 915 MHz) and DCS1800 (1710 MHz to 1785 MHz). It contains 2 in / 2 out dual band amplifier, Simple external circuit including output matching circuit, High efficiency: 50% type at nominal output power for E-GSM 43% type at 32.7dBm for DCS1800.

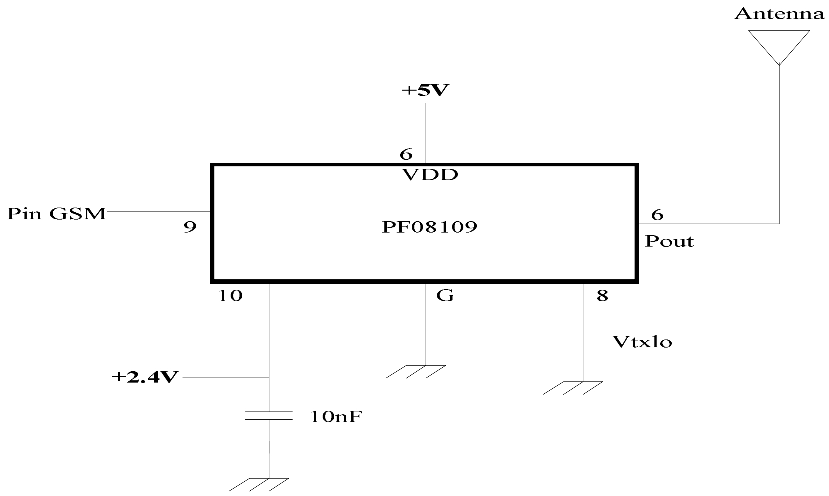

Figure 4: Biasing Configuration of PF08108B

3.1.4 Unity Amplifier-Buffer Circuit

The Unity Amplifier-Buffer circuit consists of a voltage divider, unity gain operational amplifier, a buffer and a Darlington pair as illustrated in the Figure 5.

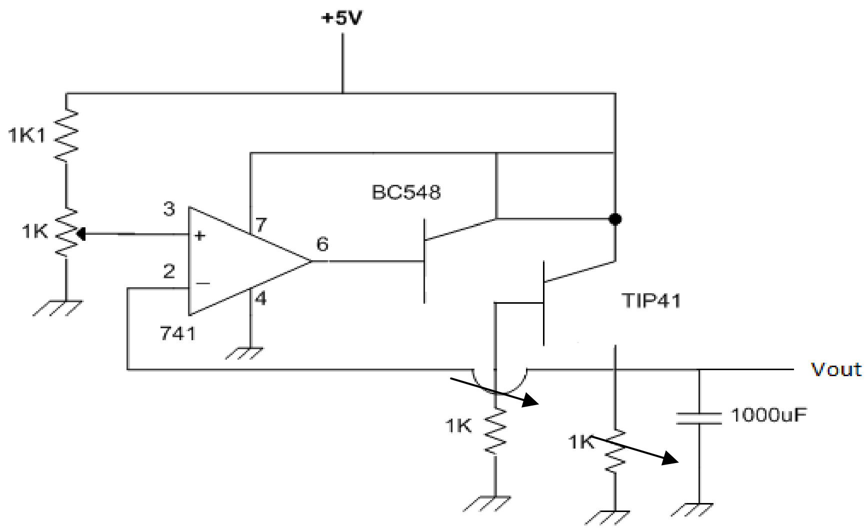

Figure 5. Unity Amplifier-Buffer circuit diagram

The voltage divider generates an input voltage of about 2.5V into the unity gain op-amp which in turn provides an effective impedance matching and stage interface between the power supply and the power amplifier (PF08109B). The Darlington Pair is made up of two transistors arranged as shown Figure 5 to amplify the current input from the supply to the 3mA required to energize the PF08109B. It is also an emitter follower or buffer amplifier circuit, where the output is simply equal to the input minus a diode forward drop (about 1.4V). The advantage of this is that the transistor can provide current and power gain by drawing little current from the input. It provides low output impedance to the PF08109B using the output of the follower, meaning that the output will not drop under load. This is necessary to achieve an RF output power of about 5W required for the prototype.

3.2 THE RECEIVER

The receiver section contains the receiving antenna and rectifier circuit as shown in Figure 6. 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. By doing so, it recharges the battery. In this work, the current is obtained from the radio wave signal coming from the antenna.

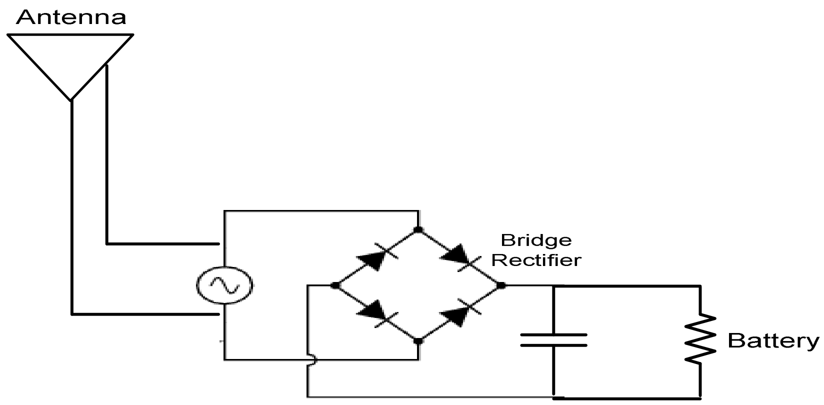

Figure. 6: Full-wave Rectifier Circuit

3.2.1 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:

i. Impedance of the antenna
ii. Gain of the antenna

Eric (2005) used Yagi antenna, but it make the prototype to be bulky and inefficiency. An improvement is made by use of the Half-wave Dipole Antenna. This antenna enhances the simplicity of the design without diverting from the desired specification as highlighted above. It also has an advantage over the quarter wave monopole antenna ($\lambda/4$ length) having a lesser gain of 0dBi and an impedance value lesser than 50Ω.

3.2.2 Rectifier

A full-wave rectifier is chosen for the prototype due to its simplicity and efficiency in converting the AC signal. The full-wave rectifier consisted 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 [2]. Therefore, a Schottky diode by Skyworks is used for the prototype (SMS3929-021 Bridge Quad Schottky Diode). 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.

4. RESULTS AND ANALYSIS

After implementing the complete design circuit, the output voltages, current and power of the prototype with respect to various distances between the transmitter and receiver were measured. Table 1 shows the output voltage, current and power against the distance between the transmitter and receiver antenna. Figure 7 depicts the output open voltages and load voltages for various distances between transmitter and receiver. It shows that the output voltage depends on the distance between the receiver and transmitter antenna. Figure 8 shows the output current (mA) for various distances.

Table 1. Output voltage (V), current (mA) and power (mW) against the distance (ft)

		With 10 ohm Load		
Distance (m)	Open Loop Voltage (V)	Load Voltage (V)	Current (A)	Temperature °C
10	22.5	37.8	0.34	56
20	19	20.4	0.13	56
30	8	16.2	0.012	56
40	7.9	11.8	0.005	56
50	7.9	10.4	0.002	56

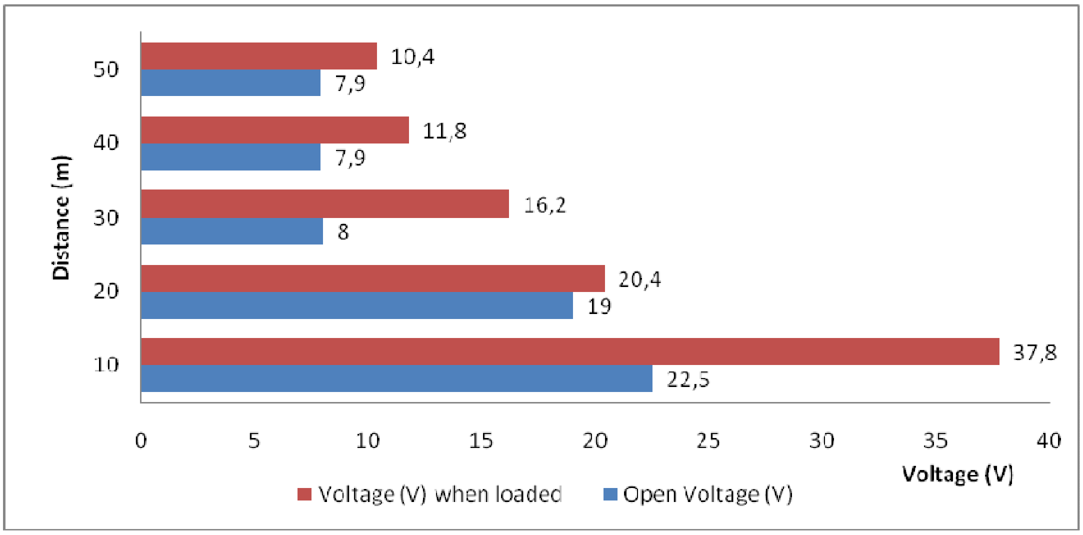

Figure 7. Loaded and Open Output Voltage (V) against the distance

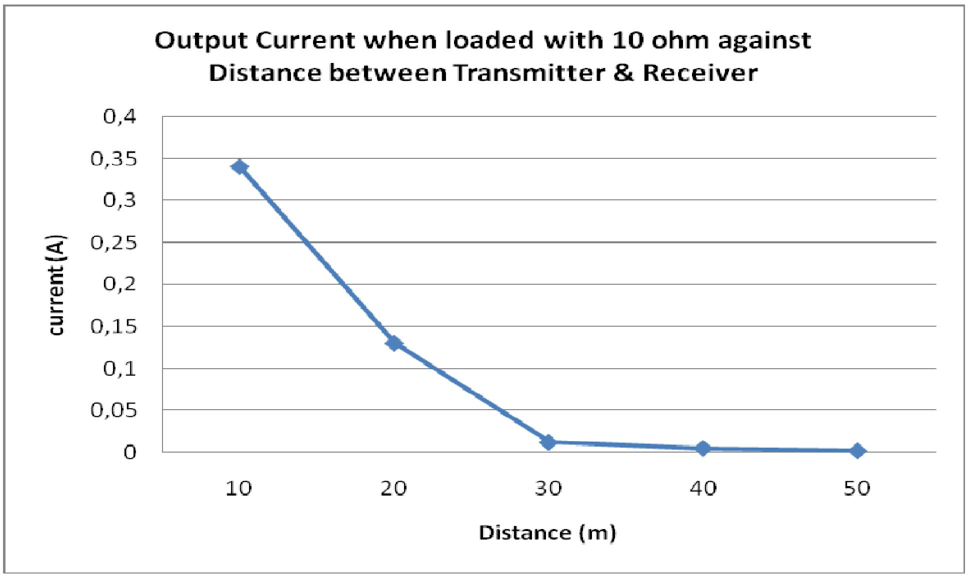

Figure 8. Load and Open Output Voltage (V) against the distance

5. CONCLUSION

The prototype system with the experimental results have shown an alternative means of charging hand held devices like mobile phones. The base stations of some of the telecommunication companies can replace the transmitter section of the prototype, and the receiver section can be incorporated in a silicon chip that can be embedded in any power critical device. This will apart from solving the power problem, but will proffer a cost effective means of powering the device. As wireless technology is getting popular nowadays, the demand of battery is also increasing. Batteries need to be recharge or changed eventually, hence the need for this kind of work. The prototype will eliminate the hassle of looking for power outlets around to charge batteries when they are flat, and carrying cabled chargers around. As of now, there are no known companies developing the RF source battery charger, this implies a very good market opportunity for this product, as people will be willing to spend more money for convenience.

ACKNOWLEDGEMENTS

Appreciation goes to the Electrical & Electronic Engineering department for providing all the necessary equipment for building the prototype. Also, the implementation was achieved with the help of my project students Omotosho Femi and Asake Abosede who dared all the challenges in order to implement my thought.

REFERENCES

[1] W.C Brown, J.R Mims and N.I Heenan, "An Experimental Microwave-Powered Helicopter" 965 IEEE International Convention Record Vo. 13, Part 5, Pp. 225-235.
[2] Nikola Tesla, "The Transmission of Electrical Energy Without Wires as a Means for Furthering Peace," *Electrical World and Engineer. Jan. 7, p. 21, 1905.*
[3] Invention of Radio, retrieved from http://en.wikipedia.org/wiki/Invention/Invention_of_radio.
[4] Lin G, "Topological Generation of Voltage Multiplier Circuits" 2003.
[5] Loo .E etal "Wireless Charger (RF/Microwave to DC Conversion) 2005.
[6] Umeda .T et al, "A 950MHz Rectifier Circuit for Sensor Network Tags with 10m Distance" IEEE Journal of Solid State Circuits Vol. 41 No. 1.
[7] S. Sheik Mohammed, K. Ramasamy, T. Shanmuganantham, "Wireless Power Transmission – A Next Generation Power Transmission System" International Journal of Computer Applications (0975 – 8887), 2010 Vol.1. No.13.

BIBLIOGRAPHY OF AUTHOR

Olakanmi Olufemi Oladayo received his B.Tech in Computer Engineering from Ladoke Akintola University of Technology, Nigeria in 2000. He started his career as a Lecturer in Computer Engineering Department, Federal Polytechnic Oko, Nigeria (2002 to 2007) before he later pursued his Master of Science in Computer Science from University of Ibadan, Nigeria. He consulted for RCM of Power Holding Company Nigeria (PHCN), Ijora District on Geographic Information System. Later, he moved to Electrical and Electronic Engineering Department, Federal Polytechnic Nekede, Nigeria as a Lecturer (2007). He is presently a Lecturer in Electrical and Electronic Engineering Department, University of Ibadan, Nigeria. He is currently pursuing his PhD researching on Hybridized Multiprocessor System at University of Ibadan, Nigeria. His research area includes Data Security, Parallel and Distributed Computing.