Wireless Power Transmission for the Internet ofThings (IoT)

[1]SANTHOSH SINGIREDDY, [2]K KARTHIK, [3] K BALA SUBRAMANYAM
[1, 2, 3] Assistant professor, Department of Electronics and Communication Engineering, St. Martin’s Engineering College, Secundrabad.
[1]santoshece@smec.ac.in, [2]kkarthikece@smec.ac.in , [3]kbalasubramanayamece@smec.ac.in

Abstract—**In some cases, long battery life may be essential to IoT devices, and early failures of actuators and sensors because of the rapid discharging of battery may lead to unacceptably high replacement costs. Critical to the implementation of this Internet Of Things (IoT) is the design of energy-efficient solutionsaiming toward a low consumption current and create a green society. Many IoT devices rely on small, rechargeable batteries, so charging a wireless battery is essential for several reasons. Much research and development are working on how can is powering IoT devices wirelessly. Wireless power transmission technology is the diffusion of microwave power transmission without using any physical support. The vision of future technology is the Internet of Things IoT charging device without wires. The objective of the scope of work is to combine the wireless power technology with a smart house using IoT. In this research paper, we designed and realized a wireless lighting technology using the fundamentals of microwave radiation. We will send microwave energy from (Position 1) to the receiver (Position 2) to turn up an LED lamp 10 W a distance (50 meters). So the proposed prototype takes account of all parameters above to deliver sufficient energy to turn on the LED lamp 10 W wirelessly on the distance of 50 meters at the smart house.**

Index Terms—**IoT network, Wireless Power Transfer, Microwave energy, Coil antenna, Rectenna, RF Rectifier.**

I. INTRODUCTION

The Internet of Things is an increasing infrastructure of internet-enabled objects ranging from sensors to LED light, all aimed at increasing control, data collection, and even automation [1], [2], [3], [4]. IoT can be a massive benefit for houses when used appropriately. To solve the connection of the electrical problem with IoT devices will be using microwave power transmission technology for future smart city planning. The question arises on how long-distance Wireless Power Electricity will change the concept of IoT [5], [6].

Charging can be realized in various ways, and applications using wireless power technology are expanding to mobile and portable devices, home appliances and office equipment, and electric vehicles. In particular, WPT technology is usefulin providing electrical power to the Internet of things (IoT) devices in constrained environments. Wireless Power Transmission (WPT), the Internet of things (IoT), and wireless power technology will become a cornerstone in the design of new and growth of human settlements [7], [8], [9].

In smart cities, legislation is requiring a change of old practices towards efficient use of resources. Nevertheless, electricity distribution still relies on cables for its delivery. The novelty of the system is that IoT devices and household use WPT for electricity supply. The energy is wirelesslysupplied from an access local power station already fixedat the top of the house. Both industry and academia knowthat WPT will be the solution to a variety of problems, including IoT devices [10], [11]. With WPT, the device has three significant advantages to contribute to the IoT and smarthouse positively. Firstly, the increase in renewable electricity integration decreases the change of batteries many times. Secondly, house growth will have a lesser impact on distribution and transmission capacity. Lastly, the proposed system will promote industrial investment by increasing IoT technology at the smart city, lowering implementation cost prices.

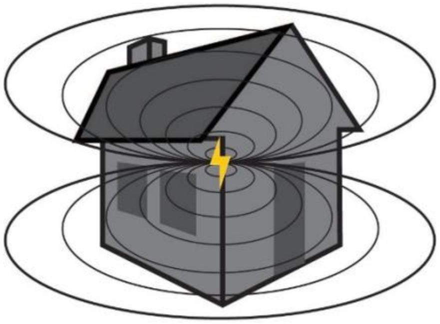

Fig. 1. How can is powering IoT devices wirelessly

This research is toward creating smart houses can combination between IoT and wireless power electricity.

By the way, in this study, already the portable microwave station exists and will be used in this research and the testing phase.

II. DESIGN OF THE HARVESTER COIL ANTENNA

The wireless power harvester device is an essential part of this technology. Coil antenna rises like the right candidate meeting these requirements due to its versatility of possible geometry and straightforward integrity with IoT devices. The efficiency of a coil antenna depends upon their geometrical

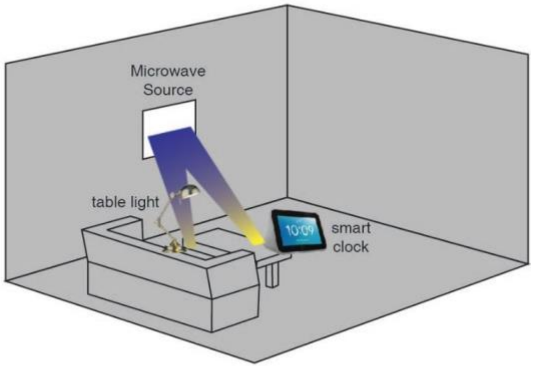

Fig. 2. Using microwaves source to power IoT devices

Shape, physical dimensions, and properties of the material [12]. In this research work, the size of the antenna is a significant parameter to be considered antennas are relatively broadband, typically useful over a range of frequencies relative to the diameter of the waveguide, especially the system will installed into a device. The ratio of the radiation intensity is related to the beam width of the feed antenna. At low frequency, the transfer of energy is efficient, butthe antenna footprint is significant, and in our research, we cannot increase it more than (100mm 100mm),× so caninstall the harvester antenna with rectifier circuit on any IoT device medium size.

Where:
Operating frequency f_r =2.45GHz
Speed of light $C = 3x10^8 m/s$
L(H)= Inductance in Henries

A. *Dimension of the receiver coil antenna*

The coil antenna size is generally dependent upon the resonant frequency f_r, and the center frequency $f_r = 2.45GHz$.

The geometry to install a harvester coil antenna into the IoT device has proved, as shown in Figure 3.

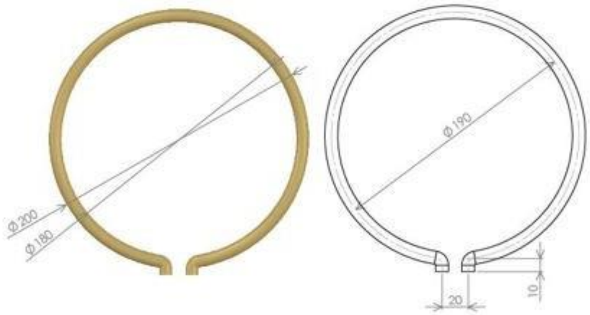

Fig. 3. Geometry of the proposed coil based antenna

Tabulated values present the parameters of the coil antenna shown in Table 1.

TABLE I
OPTIMAL ANTENNA PARAMETERS

Operating frequency	2.45 GHz
Number of turns on coil	10
Length of coil	36.58mm
Inner diameter of coil	180 mm
Outer diameter of coil	200 mm
Thickess of winding layer	1 mm
Copper condictivity	5.8 e7 S/m
Feed lenght	10 mm
R_{in}	50Ω

The optimized parameters for the antenna designed foran S-band frequency are shown above in Table I, and the performance results, it will be studied and analyzed in the following subsection.

B. *Simulation and discussion*

The design of the antenna schematic and layout is made using the CST microwave software, and it is further validated by confirming these results utilizing ADS keysight software. We affected many parameters like; Directivity, Reflection coefficient, VSWR plot, Radiation pattern 3D, and the current distribution.

1) Directivity: The directivity gain of the coil antenna showingat 2.419 GHz is 3.75 dB, as shown in Figure 4.

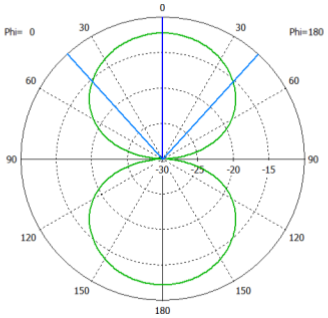

Fig. 4. Directivity of the proposed antenna

2) Reflection coefficient of the antenna: Return loss (S_{11}) presented in Figure 5, and we obtain a very high return loss, -9.372 dB at the designed frequency of 2.462 GHz. The bandwidth of about 25 MHz (2.74%).

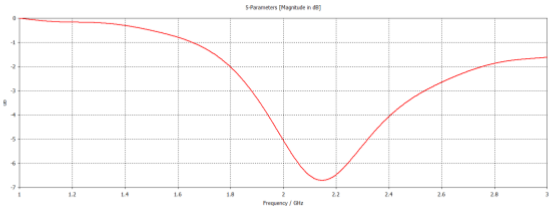

Fig. 5. Simulated reflection coefficient of the antenna

3) VSWR PLOT: The voltage standing wave ratio (VSWR) of 1.159 at the 2.45 GHz, as shown in Figure 6.

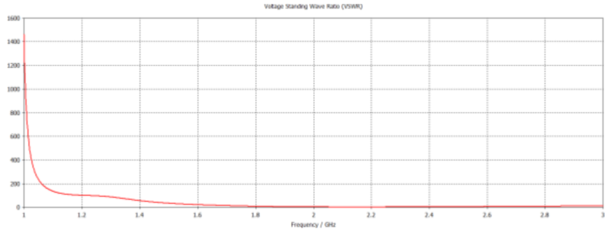

Fig. 6. Simulated VSWR frequency plot

4) Radiation pattern 3D: Figure 7 shows the 3D radiation pattern of the proposed antenna which shows that there are minimized back lobe, least side lobes and a maximum gain of -3 dB.

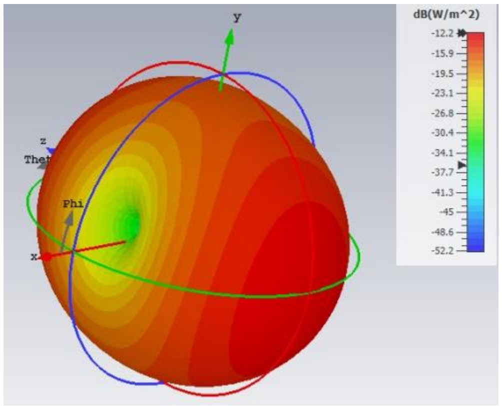

Fig. 7. Isometric 3D view of 2.45 GHz antenna radiation pattern

5) Current distrubition: The 3D current distribution plot gives the relationship between the co-polarization (desired) and cross-polarization (undesired) components. The maximum surface current is 13.8179 A/m at f_r =2.433 GHz, as shown in Figure 8. Precisely, the designed antenna has a simulated Gain of 5.399 dBi, the directivity of 3.75 dBi and the power flow 165559 V.A/m2 at f_r =2.433 GHz.

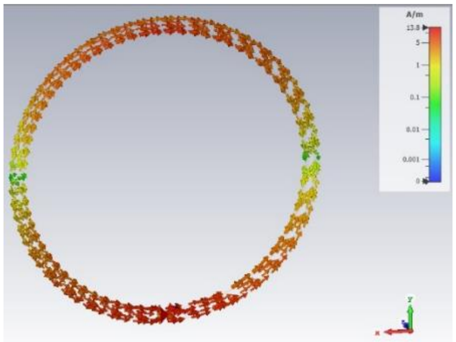

Fig. 8. Plot showing the antenna current distribution

III. ENERGY HARVESTER DESIGN AT 2.45 GHZ

The coil antenna captures electromagnetic radiation from the microwave power station. This microwave signal is transferred to the full-wave bridge rectifier by an impedance matching circuit, to convert into DC power, which is accumulated in a battery of IoT devices. The rectifier is a Schottky diode which impedance is matched to the dipoles by a low pass filter. Then, the receiver signal is efficient via the rectifier circuit that utilizes HSMS2850 (Avago) Schottky diodes [13], [14], [15]. A final subsystem acts as a backup system by storing power in the IoT battery device. The first storage device stores and accumulates charge thereon from the rectified (DC) signal outputted by the rectifier circuit. As for the rectifier topologies, the choice of the full-wave bridge rectifier, it will be studied and analyzed in the following subsection.

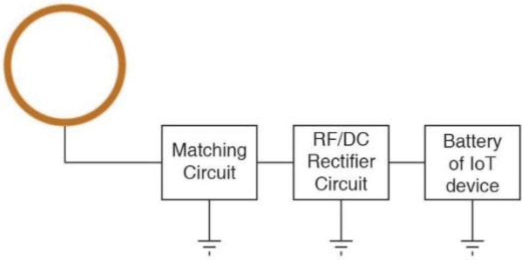

Fig. 9. Block diagram of the proposed harvester circuit

A. *Design Rectanna a full-wave bridge rectifier*

In this part, the RF-DC conversion circuit is designed using the bridge rectifier. The input impedance of the rectifier is designed to match the output impedance to maximize the power transfer and to increase the signal reflected from the load. Knowing the receiving antenna is designed to operate at 2.45 GHz with the output impedance of 50Ω [16], [17]. Figure10 shows the schematic design of the rectifier circuit.

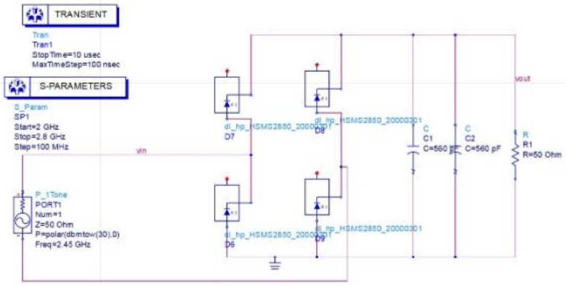

Fig. 10. Schematic diagram of microwave harvesting circuit of full wave bridge rectifier with HSMS 2850 diode (Agilent ADS)

Figure 11 shows the simulation result of the full-wave bridge rectifier using diode HSMS2850. The below simulation shows the output voltage (1.979V).

We noticed that using only one RF harvester circuit with the full-wave bridge rectifier, and it is not enough to produce electricity for charging a battery to any IoT device. So we study the topology to make a multi-coil high-efficiency wireless power harvester system to prove to be highly efficient to

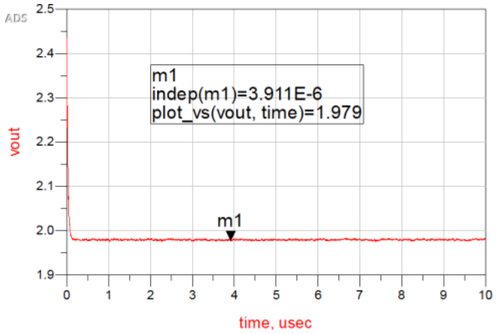

Fig. 11. The simulated output voltage (V) of the full-wave bridge rectifier circuit

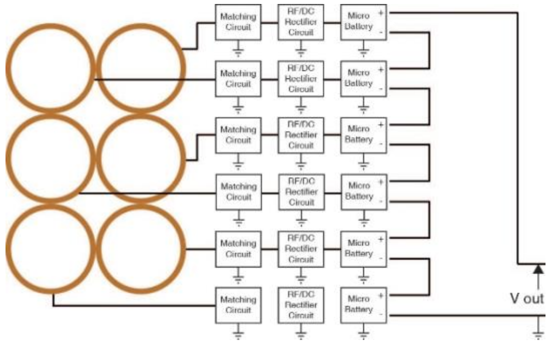

Fig. 12. Multi-coil High-efficiency wireless power harvester system

supply enough output current to charge an IoT device battery [18], [19], [20], as shown in figure 12.

The topology to harvested maximum power according to the coupling methods between the antenna and the rectifier circuit.

IV. PROTOTYPE RESULT AND DISCUSSION

Figure 13 shows the portable microwave power transmission station with an operating frequency of $f_r = 2.45GHz$ and microwave power 100 Watts.

Fig. 13. The microwave transmitter system

The receiver antenna is tested and measured using the spectrum analyzer successfully. Then, the antenna prototype is ready to be tested with an ENA Vector Network Analyzers.

Figure 14 shows the measured reflection coefficient (S11) in the Magnitude plot. It was around -9.5 dB from 2.455 GHz, and it is not the same simulation results. Also, the antenna can reach a maximum Gain of 3.25 dBi.

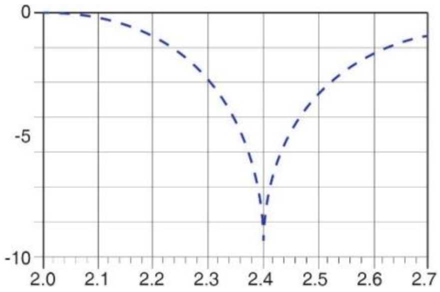

Fig. 14. Measured return loss (S11) of the 2.45 GHz

The radiation efficiency is 77.23%. All the antenna parameters have been tested and optimized to deliver high-performance receivers. The results are satisfactory and show the advantage of using a multi-coil antenna for acquiring microwave energy to charge the battery of IoT devices.

In summary, all the simulated and real measurements indicate that the harvester multi-coil antenna has an excellent performance. The present energy acquiring device is capable of receiving microwave power transmitted from the S-band, and converts the received signals into electrical energy. Figure 15 show the photograph of the receiver harvester circuit,a multi-coil high-efficiency harvesting wireless microwave circuit.

Fig. 15. Photograph of the receiver harvester cicruit

S_{11} in the rectifier circuit is a parameter that states the total of power that delivered to the load and does not return as reflection, Return loss (S_{11}), we obtain a very high return loss, -10.15 dB at the designed frequency of 2.462 GHz. Actual test, it can be observed the efficiency of the harvester circuit changes according to the distance. The amount of power received change according to the gap between the microwave power station and receiver station, as is presented in table 2.

An examination of the prototype in Figure 16, reveals that the values of the calculated results are approximately the same results of the simulation by computer.

TABLE II
THE EFFICIENCY OF THE HARVESTER CIRCUIT CHANGES ACCORDING TO THE GAP DISTANCE

The gap distance between emitter and The IoT device	Receiver power
10 meters	39.77 W
15 meters	27.58 W
20 meters	22.23 W
25 meters	19.51 W
50 meters	10.75 W

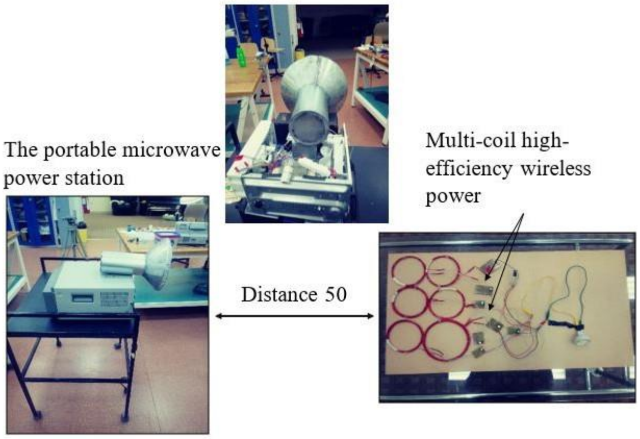

Fig. 16. Photograph of the prototype to powering IoT devices wirelessly

V. CONCLUSION & PERSPECTIVES

In this paper, we studied how can is powering IoT devices wirelessly. We proved the possibility of using the microwave system to transport energy from one side to the other inside a house. In this research, we tested, and we approved that we can produce electricity from S-band frequency to charge IoT electronic devices batteries.

The coil receiver antenna achieves a reflection coefficient in a real test of -9.372 dB and the maximum gain direction at 5.399 dB at the operating frequency. All these performances measured results make this antenna suitable for S-band.

As for the full-wave bridge rectifier topologies, we a choice of the Schottky diode HSMS2850 and the dimension of the receiver antenna; we tested it and approved.

The multi-coil high-efficiency circuit achieves high output power and high output electricity efficiency. Each one harvester circuit can supply 1.92V, so the total of the multi-coil high-efficiency circuit can reach 11.4V and this power enough to turn up light wirelessly.

The conversion efficiency of 10.75% was achieved at S-band at an input power level of 10.75W a distance of 50 meters. In this research, we approved that we can upgrade the structure of the IoT system and the smart house system and charging all IoT electronics devices wirelessly.

VI. ACKNOWLEDGMENT

This publication was made by NPRP grant # NPRP11S-0113-180276 from the Qatar National Research Fund (a member of the Qatar Foundation). The statements made herein aresolely the responsibility of the authors.

REFERENCES

[1] Ahmed and Kim, “ Attack Mitigation in Internet of Things Using Software Defined Networking,” Proceedings of the IEEE Third Inter- national Conference on Big Data Computing Service and Applications, San Francisco, USA. 69 April 2017.

[2] Shervin Erfani, Majid Ahmadi and Long Chen, “ The Internet of Things for smart homes: An example,” 8th Annual Industrial Automation and Electromechanical Engineering Conference (IEMECON), 16-18 Aug. 2017.

[3] Tiago, Radu, Eduardo, Matias, and Joo, “Smart home communication technologies and applications: Wireless protocol assessment for home area network resources,” Energies, vol. 8, no. 7, pp. 7279-7311, 2015.

[4] Martin, Lars, Daniel, Roger, Bernhard, and Klaus, “A comprehensive approach to privacy in the cloud-based Internet of Things,” Future Generation Computer Systems, vol. 56, pp.701-718, 2016.

[5] Jianliang Li, “Research progress of wireless power transmission tech- nology and the related problems,” School of construction machinery college, AIP Conference Proceedings 1820, 2017.

[6] Jian, Fang, Tong, and Lin, “Wireless green energy power transmission system based on assembly method and pivoting antenna module,” International Conference on Applied System Innovation (ICASI), pp. 14, 2016.

[7] Jan, Khan and Alam, “Usman M. A payload-based mutual authentication scheme for Internet of Things,” Future Gen. Comput. Syst. 2019;92:10281039

[8] Hammi, Livolant, Bellot, Serhrouchni and Minet, “Mobile and Wireless Technologies,” Springer; A Lightweight Mutual Authentication Protocol for the IoT, pp. 312, Singapore 2017.

[9] Kumari, Li X, Wu, Das, Arshad, Khan, “A user friendly mutual authentication and key agreement scheme for wireless sensor networks using chaotic maps,” Future Gen. Comput. Syst, 63:5675, 2016.

[10] Sanjana, Chau, Wayes, Wen-Tai Li, Chao-Kai, Kun Hu, Cheng, and Xiang, “System design of the internet of things for residential smart grid,” IEEE Wirel. Commun. pp.9098, April 2016.

[11] Tao Li, Liheng Wu, and Zheng Chen, “Research Overview on Wireless Power Transmission Technology,” MATEC Web of Conferences, 2015.

[12] Rahman, NagshvarianJahromi, Mirjavadi, and Hamouda, “Compact UWB Band-Notched Antenna with Integrated Bluetooth for Personal Wireless Communication and UWB Applications,” Electronics 2019, 8,158.

[13] Mohamed M. Mansour and Haruichi Kanaya, “ Novel L-Slot Matching Circuit Integrated with Circularly Polarized Rectenna for Wireless Energy Harvesting,” MDPI, Electronics 8, 651, June 2019.

[14] Manolis, Demosthenes, Dimitrios, “ Discone Rectenna Implementation for Broadband RF Energy Harvesting,” International Conference on Modern Circuits and Systems Technologies (MOCAST), 13-15 May 2019.

[15] Achraf, Romain, Marjorie, “ Energy Harvesting with 2.45 GHz Rectenna for urban application,” 25th IEEE International Conference on Electron- ics, Circuits, and Systems (ICECS), Bordeaux, France, 9-12 December 2018

[16] Faruk Erkmen, Thamer S. Almoneef, and Omar M. Ramahi, “Electromagnetic Energy Harvesting Using Full-Wave Rectification,” IEEE Transactions on Microwave Theory and Techniques, 1843-1851, 2017.

[17] Yanyan Shi, Jianwei Jing, Yue Fan, Lan Yang, and Meng Wang, “ Design of a Novel Compact and Efficient Rectenna For WiFi,” Energy Harvesting Progress In Electromagnetics Research C, Vol. 83, 5770, 2018.

[18] Chen Xu, Yuan Zhuang, Hongjian Han, Chaoyun Song, Yi Huang, Jiafeng Zhou, “ Multi-coil high efficiency wireless power transfer system against misalignment,” IEEE MTT-S International Wireless Symposium(IWS), China, 6-10 May 2018.

[19] Rui Wang, Xiaoxuan Zhou, Jian Zheng, Dongsheng Yang, “Research on the Efficiency of Wireless Power Transfer System Based on Multi- Auxiliary Transmitting Coils,” 4th International Conference on Infor- mation Science and Control Engineering (ICISCE), China, 21-23 July 2017.