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A Case Study of RF Energy Harvesting For Wireless Sensor Network

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***Abstract*—**From conservation law of energy not possible to create or to destroy the energy but we can transform or change one form into another. The main purpose of this paper is to put light on the characteristics of radio frequency based energy harvesting systems. In all the cases mentioned above that the devices or the appliances can be operated without the usage of cables battery panels connectors which can make these devices more mobile and portable while operation and charging as well. These all can be achieved by RF energy harvesting system and the main reason for this is that it is accordingly free energy. The sources of RF based energy harvesting system are increasing day by day same as mobile based transmitters from which more and more energy can bring in. This paper more importantly focuses on parameters to design the system, methods, different frequency ranges that can be utilized and the respective circuitry for converting Low voltage output to High voltage for various applications using RF based energy harvesting.

***Keywords*—**Wireless sensor network,RF energy,Harvesting

I. INTRODUCTION

The radio frequency (RF) energy is recently spread from various sources or transmitters which are mobile base stations, mobile, telephone, handheld radios, TV/radio broadcast stations. The propensity together or harvest RF energy from the committed sources empowers or authorizes wireless charging for low power appliances or devices which results in better product design dependableness and utilization[1,2]. The battery operating systems can be charged gradually and slowly to abolish battery replacements or to extend battery durability disposable batteries can be used. RF energy based devices which are battery free systems can be designed which will depend completely on the availability of sufficient charge. Method of delaying wireless network sensor from its highest potential is known as Energy Constraint. Wireless network sensors are generally designed to give long lifetime while sacrificing sensing capability due to duty cycling of sensors. Energy harvesting tech. is new for present world .Energy harvesting (RF) is the process of searching environmental energy from different sources of energy. This method is used to solve the issue of energy limitations of powered wireless devices [3]. This method is cheaper than other energy conservation method. However, in some cases practically as well as economically replacement of battery is impossible and dangerous for human life. The energy harvesting tech. is balanced to improve some of these effects by allowing sensors to re-charge energy storage capacitors from the incident RF radiation. Since energy is nourish able, the map of wireless sensor network is no longer finite by the period of time demand and the rending of network can be line with less energy constraint in mind. The main job strike in harvesting rule is the free-space path loss of the transmitted signal with distance. The conventional signal strength, slow with the square of the distance, requires special sensitivity weighing in the circuit design. Since, FCC regulations bound the maximum forwarding power in limited frequency bands [4-6]. For example, in the 900 MHz band, this maximum threshold is 4W. Even at this highest setting, the conventional power at a small distance of 20 m is reduce down to only 10 µW. The Friis transmission equation relates the received (Pr) and transmitted (Pt) power with the distance R as:

$$P_r = P_t G_t G_r (\lambda /4\pi R)^2 \qquad (1)$$

Design cause in energy harvesting networks is shown in Figure 1 by using blocks .we struggle a lot when we are connecting different components required for circuit diagram like antenna, diodes, capacitors and connecting wires etc.

II. SETUP

In Figure 2 an extra antenna used to harvest RF energy harvesting transfer to RF to DC converter where conversion takes place which again transferred to DC power management circuitry and from here it further transfer to battery and cell phone circuitry.

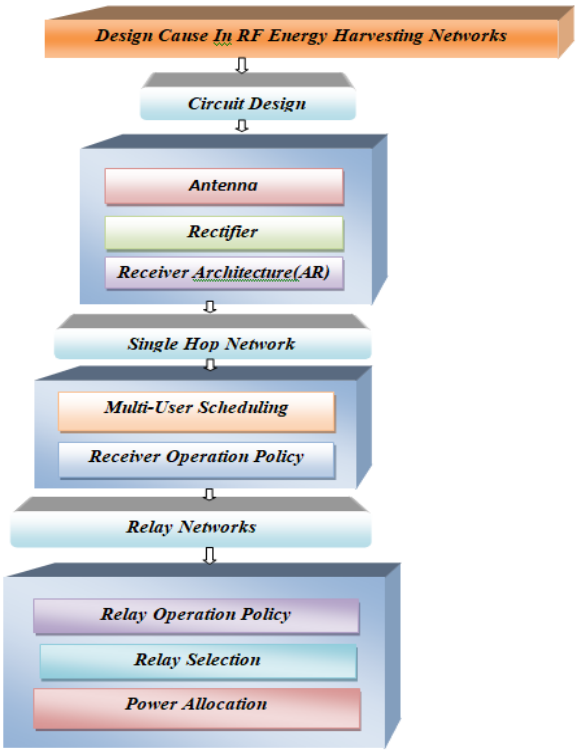

Figure 1: Outline of design cause in RF-EHNs

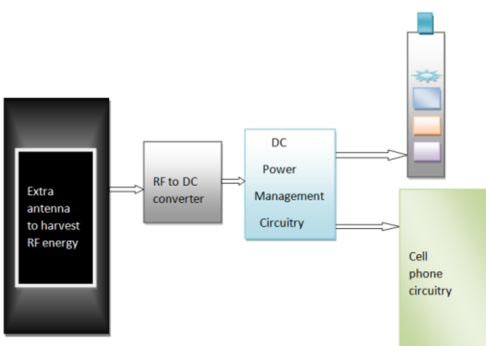

Figure 2: Basic Block Diagram of proposed temperature control system

In Figure 3, five (Base station ,wireless internet ,Radio and television ,Satellite communication ,User generated) RF sources are used which are connected through Wireless Communication to Antenna, Matching circuit, voltage multiplier, charging controller and from here it transfer to battery and Device terminal function(DTF). Figure 4 represents that an antenna is used which is directly connected to impedance matching which goes to rectifier RF to DC which transfer to power management circuitry (PMC) which is irreversible to energy storage and reversible to ultra low power which transfer to sensor and radio directly connected to another antenna.

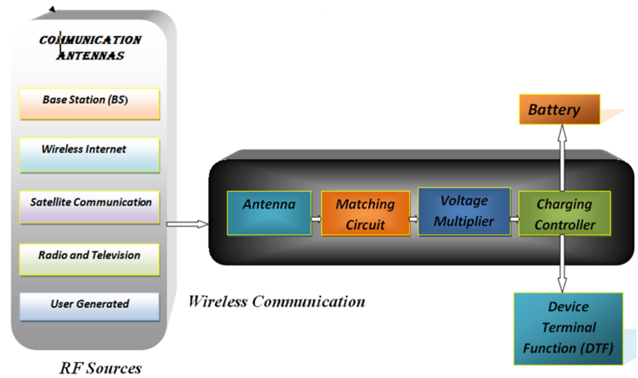

Figure 3: Basic Block Diagram of proposed temperature control system

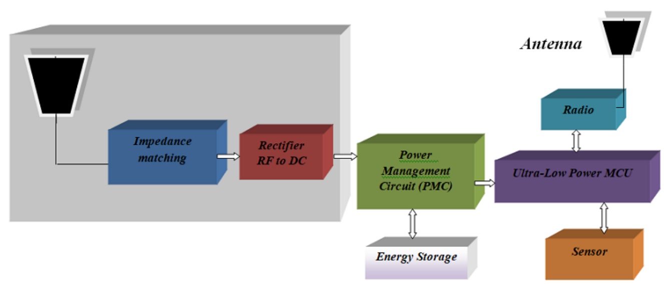

Figure 4: Block diagram of powered WSN

III. CIRCUIT DIAGRAM

Figure 5 shows one antenna of the type AE1 245AT18100E is used that acts as transformer to provide a good match between the feeding line as a local source of power and free space. Four Capacitor of 1uF is used to store electrical and give this energy again to the circuit when necessary. Four diode of type 1N4448 is used to allow the passage of electric current only in one direction.

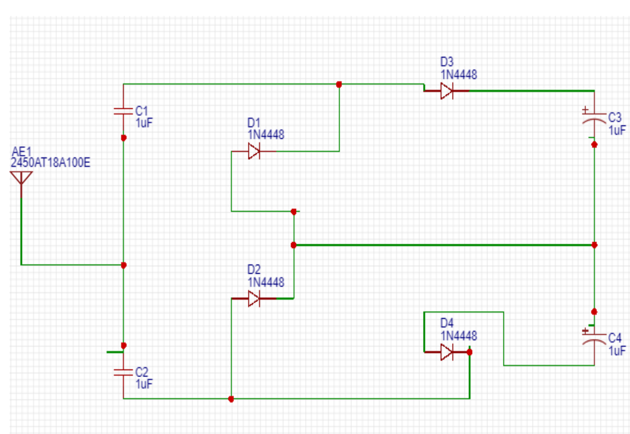

Figure 5: Circuit diagram for RF energy harvesting network

Table 1: Rectifying Circuit published by Researchers

Year	Scholar(s)/ researcher(s)	Focus of study	References
2005	H. Yan, J. G. Macias Montero, A. Akhnoukh, L. C. N. de Vreede and J.N. Burghartz	Testing circuits are implemented in a Silicon-on-Glass technology and simulation results show that a DC voltage of 0.8 V can be achieved at -20dBm input energy level at 868.3 MHz ISM band.	K.Buisman et. al.,2005
2008	Triet Le and KartiMayaram	Passive rectifier circuits are designed in a 0.25 m CMOS technology using floating gate transistors as rectifying diodes	S. Mandal and R. Sarpeshkar, 2007
2009	Raymond E. Barnett	Three diode doublers and three multistage rectifiers were fabricated in a 130 nm CMOS process with custom no-mask added Schottky diodes	J. Yi, W.H. Ki, and C. Y. Tsui, 2007
2010	Christian Peters	A two stage concept is used including a first passive stage and an active diode as second stage by using CMOS technology	D. Maurath and F. Michel, 2008
2011	Jason Lee	Self-powered rectifier in CMOS process using standard components and poly–poly capacitors for single and four-stage rectifier	C. Peters and J. Handwerker, 2011
2012	Taris Thierry	AC to DC converter is based on a Cockcroft-Walton Voltage Doubler	A.S. Boaventura et. al., 2011

IV. CONCLUSION

We have go through various circuit topologies which can be further applied for the application purposes i.e. stepping up the output voltage according to the requirement. The system was studied in detail with different losses related to the circuit.

Table 2: Comparison of published work on integrated RF rectifier circuit techniques [15-24]

Year	Tech nm	Rectifier topology	Enhancement technique	Frequency MHz	Peak PCE	V_{out} (V)	Lowest report-ed sensitivity (dBm)	Max tested load
2006	300	3-stage, Dickson	Bias-voltage generator	950	11% for no-load @ - 6 dBm	1.5	-14	n.a
2007	350	1-stage, Dickson	Internal-Vth cancellation	953	36.6 % for 80 lW @ - 6 dBm	3	N.A	N.A
2008	250	16/36stage, Dickson	Floating-gate transistor	906	60% for 30 lW @ 100 mV	2	-22.6	0.33 M ohm
2011	90	17-stage, Dickson	Self-Vth compensation	915	11% for 1 MX @ -18.83 dBm	1	-22.44	0.5M ohm
2012	90	20-stage, Dickson	Floating-gate transistor	2450	1% for 1 MX @ 125 mV	1.2	-14.9	0.5M ohm
2013	130	2-stage, Dickson	Cross-coupling transistor	868	50% for no-load @ -17 dBm	2	-21	n.a
2014	65	12-stage, Dickson	Tunable-Vth compensation	904.5	n.a	1.7	-20	n.a

There are different frequencies available for utilizing the RF energy which is being provided in the introduction as well as the RFID part of the respective paper. In upcoming future we will search using various types of antenna such as patch antenna, micro strip antenna, horn antenna and rising actual application based circuit and closing by approximate study of the o/p achieved by all of them.

Table 3: Example of WSN nodes prototype deployment application [25]

Application	Type	Distinct features	Scale and density
Island monitoring	Environmental monitoring	Data storing; web-based access	32 NODEs per sq. km area
Container training	Tracking	Monitoring inside container	200NODEs1 per 50meters
Detection of flood	Disaster management	Prompt warning;	200NODEs, 1per

		condition monitoring	50meters
Artificial rectina	Health	Image identification, real-time processing	100 sensors per rectina
Human monitoring	Health	Security alerts with high quality	Several NODE
Target	Military	Real-time object identification	Random NODE
Identification machine condition monitoring	Machinery	Data aggregation and machine lifetime projection	Ten of NODE per machine

Table 4: Published works on RF energy harvesting in various application nodes [26-31]

Year	Application system	sensitivity	Frequency	Process	Efficiency
2013	Civil infrastructure degradation	−39dBm@2.5V	AM broadcasting	PCB	>60%
2014	RFID	−40dBmto −25dBmfor 0.5mV–2.2V	915MHz	20nm HTFET	>50%
2015	RFID healthcare	−13dBm@1.4V	925MHz	0.18μm CMOS	-
2016	RFID sensor tag	−11to−5dBm, 1.7V,70μA	869MHz	0.18μm CMOS	33%@−8dBm
2017	Wireless battery charger	−10dBm,5μA, 11.5μW	900MHz	-	44%@−10dBm

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Kousik Roy obtained his M.Tech from Burdwan University, West Bengal, India in RF & Microwave Engineering and Ph.D (Engineering) from Kalyani University, West Bengal, India in the area of solar radio astronomy. Presently he is doing as an assistant professor in the Department of Electronics & Communication Engineering at Asansol Engineering College, Asansol, West Bengal; India. He has more than 12 years of teaching and about 8 years of research experience. He has published more than 50 research papers in reputed journals, national and international conferences. His research interest includes Astronomy, Astrophysics, Atmospheric physics, Microstrip Antenna and Computational Electromagnetics.

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