Rectenna Design for RF Energy Harvesting: A Literature review

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Abstract--The ultimate energy sources are widely available in nature. Theses inexhaustible sources have no adverse effect on environment. In recent decades there is increasing demand of obtaining energy from external sources such as thermal energy, solar power, wind energy and RF energy. This paper basically focuses on RF energy harvesting by designing antenna for efficient RF-DC conversion. Most of the ruler regions affected due to Energy crisis problem which is much larger as compared to western countries. The reason may be due to less use of naturally available energy or various energy saving practices as per our study. This paper focuses mainly on various aspects of RF energy analysis and harvesting done by efficient antenna design. The efficient antenna design with less transmission loss, high RF-DC conversion rate and high throughput power as output corresponding to severity stages has been proposed by few researchers and gives better results whose analysis is done in this paper. The use of Microstrip patch antenna with cross shaped slots is one of the important methods explored by few researchers and has significant results. Highly compact Rectenna design, folded dipole antenna design used in many energy harvesting methods is also useful in low weight & RF-DC conversion analysis is finding of researchers. Basic Antenna design structure and basic model for energy harvesting is also described in paper. This paper mainly focuses on all important issues related to different antenna structures their affect on antenna gain parameter and basic methodologies for increasing gain used by various researchers.

Key words —WEH (Wireless Energy Harvesting), MTT-S(IEEE Microwave Theory and Techniques Society),Microstrip patch structured Rectenna ,HFSS (High Frequency Structure software), RIS(Reactive Impedance Surface)

I. INTRODUCTION

Remote sensing devices are becoming recent widely used domain in recent engineering trends. These devices does not require internal power or voltage circuitry to work their applications .Such application works on the platform of energy harvesting where the ambient energy is converted into electrical energies to charge the remote or local station electronic devices[1]. One of the best methods for such passive device is to harvest energy from propagating Radio Frequency (RF) which is widely available in GSM, DTV, Wi-Fi and tolling system applications. The Wireless Energy Harvesting (WEH) and International Microwave Theory and Techniques Society (MTT-S) states the term Energy Harvesting as "The process of conversion of ambient energy into electrical energy as the practice of capture, accumulation and storage of unexploited energy from circumambient environmental sources". In modern society RF wireless network performs a vital role of collecting and distribution of information .These structures involves radio and television bands,

GSM and UMTS cellular Network.The prior goal is to investigate with proper energy Harvesting system and Circuit design, the ultimate goal is to collect power of different RF spectrum signal which can be harvested to supply enough power to these passive devices. The functionality of this system depends on system design basically to achieve low power consumption and high efficiency [9][10]. This RF energy harvesting design is also suitable mainly for traditional battery replacements which is impractical and costs consuming. To satisfy all these aspects and use of naturally available ambient energy this paper proposes a model for RF energy harvesting, the collection of different frequency bands with throughput as power is achieved with the help of proper efficient antenna design with high gain.

This paper uses one of the RF energy harvesting method and which is RF Energy harvesting with Antenna design. The main task models of design are efficient antenna design, design of high RF-DC conversion rectifier and power storage and voltage doublers circuit design. The power conversion mainly depends on transmission characteristics. The big challenge in design is transmission loss i.e. available power may loss or change with distance and gain of antenna [8]. The different researcher proposes various antenna design models which involve use of folded dipole, Microstrip, Yagi-Uda, Circular Patch antenna for Energy harvesting[6][7]. In RF energy harvesting antenna design input impedances , SWR ,VSWR, antenna patterns its gain depend on position of director and reflector for high power output all these parameters are need to be checked for selection of antenna[11].

Objective of this paper is to discuss various building blocks for designing of RF energy harvesting circuit. The paper is organized into V sections including this introduction. Section II reviews Antenna Design and its types. Section III describes Rectifier and Matching Network Section IV Power management and V followed by conclusion.many issues and challenges that need to be considered and addressed in order for potential benefits to be realized.

II. ANTENNA DESIGN

The antenna which performs the function of rectification as RF-DC conversion is called as Rectifying Antenna or Rectenna which is first design aspects of this overall

system design[9][13]. The overall system design is as shown in figure below fig1.

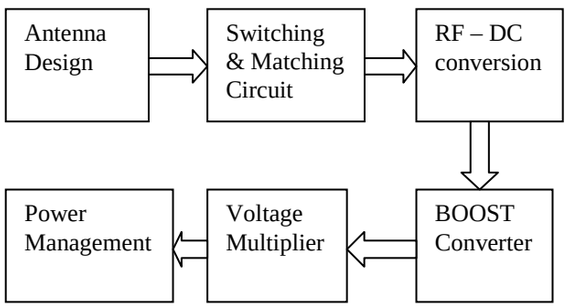

Fig. 1 RF Energy Harvesting System

The desired RF frequencies are collected at the receiving antenna .Depend on the various designs parameters like single or multiple applicable frequencies, aim of design like low weight , type of substrate and size shape and structure of antenna, antenna miniaturization[6][7][4]. Antenna structure design depends on SWE (Surface Wave Excitation) which causing poor gain and high loss [1][12]. Most widely used method for reduction of Loss is to reduce the overall dimension to achieve low weight antenna structure. The Microstrip patch antenna is used for shortening the posts in various energy harvesting regions [1]. The transmitted power and received power relation can be expressed by using Friis equation as follows,

$$Pr = Pt * Gt * Gr * (\lambda / 4\pi R)$$

Where, G_t and $G_r$is antenna gains, λ are wave length of transmitted signal, P_t and P_r are transmitted and received powers. Antenna miniaturization is simply achieved by employing high dielectric substrate. The various antenna designs involves circular patch antenna, cross shaped patch structure, square patch antenna. The antenna overall dimensions are reduced with the help of proper position of Slits to increase surface current path, to increase electrical length, inductive or capacitive loadings, selection of substrates. The antenna design was simulated in HFSS to analyze its various parameters like SWR, gain, directivity [1]. The vector analyzer is basically used for checking input frequency response of receiving frequency. Some researcher uses A25N substrate for linearly polarized Microstrip patch antenna [1]. A Yagi-Uda design can be used with fixed dc load for dual frequency tone application to achieve linear vertical polarization in Rogers Ultralam substrate. The Yagi-Uda antenna design uses position of Reflector, driver and director element [3].The circularly polarized design uses FR4 substrate is proposed by previous researcher [4].

III. RECTIFIER AND MATCHING NETWORK

The rectifying circuits rectify the incoming Signal achieved as power from Antenna and convert it into DC power. The received power depends on free path loss of transmitted signal with distance [9]. The rectified output Dc power also depends on intermediate stages and conversion efficiencies. The Matched circuit network is as follows in fig 2,

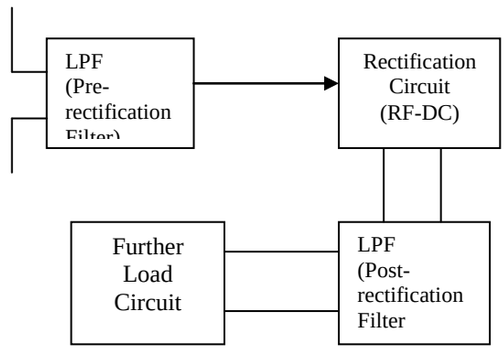

Fig. 2 Rectifier and Matched Circuit Design

The overall rectifier circuit design receives the transmitted signal from transmitting antenna these signals are filtered with the help of LPF Pre-amplification filter whose cut of frequency is such that it will matches with over all low RF output signal. Rectifier Circuit is as follows in which the conversion efficiency depends on rectifier circuit parameters like diode non linear capacitance C_d (V_d), the reverse breakdown voltage V_b, forward turn on voltage V_f [3]. For all of these the most energy harvesting circuit uses Schotty Diode [5][4] basically for Rectifier circuit design due to its low turn on voltage[2].

It basically fabricated by depositing n or p type semiconductor material with threshold levels at 0.2V to 0.3V.The diode impedance matching with antenna consideration parameters is the most important part in rectifier circuit design. The preamplifier circuit should have low cutoff voltage to operate a low RF power circuit. A band pass filter and maximum power transfer through rectifying circuit is final goal to achieve perfect combination of matched filter and Antenna design consideration[4] because maximum power transfer can only be attain when the antenna impedance is well matched to rectifying circuit impedance.

The efficiency of RF energy harvesting signal is defined as

$$\eta = (Pdc / Pr) * 100$$

where, Pdc is rectified power and Pr received power. The rectified output depends on Vout and Iout and number of stages of conversion.

IV.POWER MANAGEMENT SYSYTEM

The ultimate gain of proposed system is to deliver power to passive remote devices or to further electronic application. The converted DC Power is need to be store in energy store devices before passes through voltage doubler

circuit. The power management system involves following models as shown in fig 3

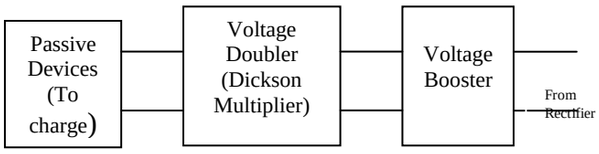

Fig. 3 Power Management System

The power management system involves boost converters which uses lumped C and R parameter of rectifier design also it uses CMOS circuits to avoid power loss in switching The most widely used voltage doublers for energy harvesting system are basically of Dickson Multiplier topology. It basically used for threshold canceling and Antenna impedance matching.

V. CONCLUSION

This paper is useful for comparative study of analyzing different RF energy harvesting antennas and their technical studies. The RF energy antenna design through Microstrip patch antenna mostly suitable for low weight and Loss SWE losses. The use of Schotty diode in Dual diode rectification circuit increase overall RF to DC conversion due to its low turn on voltage. Voltage doubler circuit basically involves Dackson multiplier to avoid losses during intermediate stages.

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