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Design & analysis of Rectenna using Pentagonal patch Antenna for C-band applications

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Abstract— This work focuses on designing, measuring and testing each component of a Rectenna. A rectenna consists of an antenna and a rectifier circuit that is optimized for incoming signals of low power density. Objective of this work is to construct a rectenna to harvest electric energy from the RF signals that have been radiated at: 5 GHz. To collect electromagnetic power a modified Pentagonal patch antenna is designed and simulated. A Radial Stub Based Low pass filter designed to suppress the higher order harmonics generated by antenna. Since rectifier requires a single frequency to rectify therefore filter must have Sharp Cutoff Frequency response. Ordinary filter have a gradual Cutoff response, in this work an Elliptical Low Pass filter designed and simulated further which is converted in Radial stub based stepped impedance Filter. A rectifier circuit is designed and simulated; this circuit uses Schottky Diode for High Frequency rectification and a matching circuit. Finally, by using Harmonic Balance analysis the conversion Efficiency measured and analyzed.
Keywords— Solar Power Satellite (SPS), HFSS, ADS etc.

I. Introduction

Rectifying antenna, rectifies received microwaves into DC. A Rectenna comprises of a mesh of dipoles and diodes for absorbing microwave energy from a transmitter and converting it into electric power .Its elements are usually arranged in a mesh pattern, giving it a distinct appearance from most antennae .A simple rectenna can be constructed from a schottky diode placed between antenna dipoles as shown in Fig. 1.1.The diode rectifies the current induced in the antenna by microwaves. Rectenna are highly efficient at converting microwave energy to electricity. In laboratory ,efficiencies above 90% have been observed with regularity. In future rectenna will be used to generate large scale power from microwave beams delivered from orbiting SPS satellites.

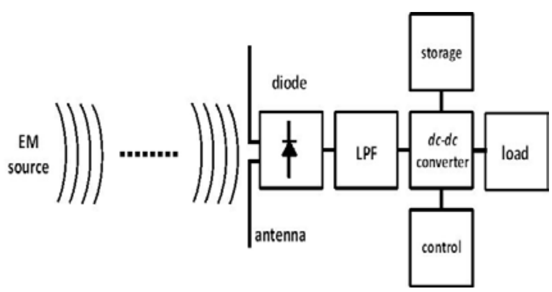

Fig.1 A simple Rectenna

The typical Rectenna basically consists of four elements: antenna, low pass filter (LPF), diodes and DC pass capacitor for the antenna integrated with nonlinear circuits, such as diodes and Field Effect Transistors, it is well known that harmonics of the fundamental frequency would be generated. The unwanted harmonics cause problems of harmonics re-radiation and efficiency reduction of Rectenna; then the LPF is required to suppress harmonics to improve system performance and prevent harmonics interference. To suppress re-radiation and to maximize the power conversion, LPF is placed between antenna and rectifier setup. The cut-off frequency for Low Pass Filter has been selected such that second harmonic signals are rejected and after the filter matching circuit is put which provide the impedance matching between the low pass filter and antennas input impedance by which rectifier setup provides the maximum conversion, i.e. maximum power transmission.

After this match circuit the rectifying diode is placed for rectification followed by DC pass filter which consists of capacitor for reducing ripples also called smoothing capacitor followed by load. The conversion efficiency depends on this DC pass filter set up i.e. its value and position. Wireless multimedia systems are receiving increasing research and application interests. But improvements are still required to provide higher data-rate links, for instance, the transmission of video signals. Therefore, ultra-wideband (UWB) communication systems are currently under investigation and the design of a compact wideband antenna is very essential. To overcome the inherently narrow bandwidth of microstrip antennas, various techniques have been developed to cover the entire UWB bandwidth, such as L/F shaped probe to feed the patch, triangular patch, U/V slot monopoles, in others.

And, why don't we use the same antenna to collect the energy that is being radiated at various frequencies? Clearly it is much more effective to harvest the energy of several services at the same time than collecting only one service energy; this is why the idea of an UWB antenna for harvesting energy is entirely feasible. The meaning of Energy Harvesting (also called energy scavenging or power harvesting), is the process by which energy from different sources is captured and stored. Generally, this definition applies when we talk about autonomous devices that require a low amount of energy to function. Another advantage of this kind of technology is that, unlike the generation of large-scale power, we can consider that the energy source is free if you take into account the electromagnetic energy of transmitting mobile stations and radio and TV broadcasting antennas.

The use of batteries has two demerits: the lifetime of the batteries is very limited even for low-power battery, requiring impractical periodical battery replacement, the use of commercial batteries usually overkills the power requirements for µW sensor nodes, adding weight and size while creating the problem of environmental pollution due to the deposition of these battery, as well as increases significantly the cost overhead of disposable nodes.

This work focuses on incident low-power density; designing, measuring and testing a Rectenna to harvest electric energy from the RF signals that have been radiated by public communications systems (GSM-900 and GSM-1800) and the 2.4 GHz ISM band; also the work is motivated by two types of applications: powering low-power sensor networks and RF energy recycling.

II. PENTAGONAL PATCH ANTENNA

The antenna proposed here is fabricated on commercially available FR4 substrate with h=1.6mm ε_r =4.4 , and tan δ=0.02. To simplify the design and discussion, the width of the feed line is chosen to be 3 mm, which corresponds to the characteristic impedance of 50 . The antenna is fed by a microstrip line through proximity (electromagnetically) coupling. A quarter-wave is used as the matching circuit. The HFSS electromagnetic (EM) field simulation tool is used for antenna design. Fig. 2 shows the simulated for the proposed antenna with different perturbation lengths . The side length of the slot is selected to be 23.5 mm. The other parameter values used are mm and mm. The impedance matching condition can be optimized when mm and mm. In here, the length is altered while fixing at 0.7 mm. The simulated results show that an increase in the length of the perturbation causes a greater split between two degenerated modes and thereby widens the 10dB bandwidth. Fig. 3 & 4 demonstrates the CP Performance of the proposed antenna when the perturbation length is varied. It is observed that the simulated 3-dB axial ratio (AR) bandwidth increases a little when the perturbation length varies from 5 to 8 mm. In this letter, it is observed that minimum AR has the optimum value as the length mm. Fig.3 shows the performance of the proposed antenna with different widths of the perturbation. The other dimensions are the same as the above. As increased, so did the 10-dB bandwidth. With the width chosen to be 0.6 mm, the CP performance had the optimum value in this study.

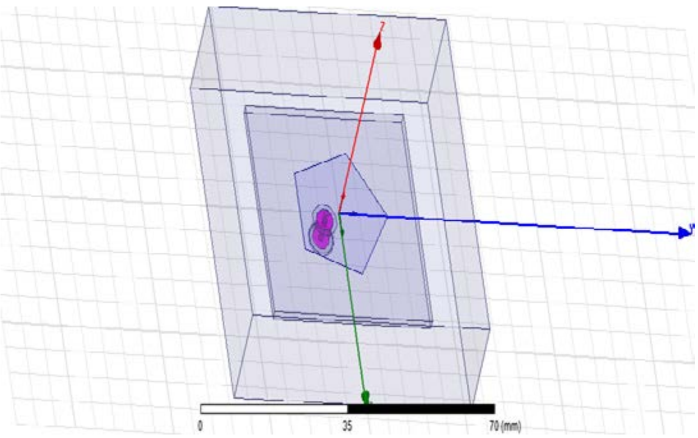

Fig 2 Pentagonal Patch Antenna

III. SIMULATED RESULT FOR ANTENNA

Return loss:-This mathematically designed circular patch antenna did not fulfilled the Frequency requirement since operating frequency is 5 GHz. that minimum return loss obtained is -18.2635dB at 5 GHz.

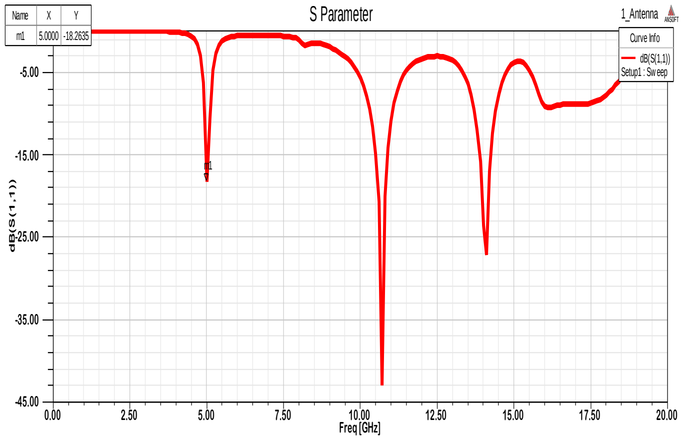

Fig 3: The S11 (return Loss) response of Pentagonal Patch antenna

VSWR: - it is an important property of antenna to fulfill the requirement of matching. The VSWR of an antenna should be less than or equal to 2.the VSWR curve shows that antenna is near to 1.2782 at frequency 5 GHz.

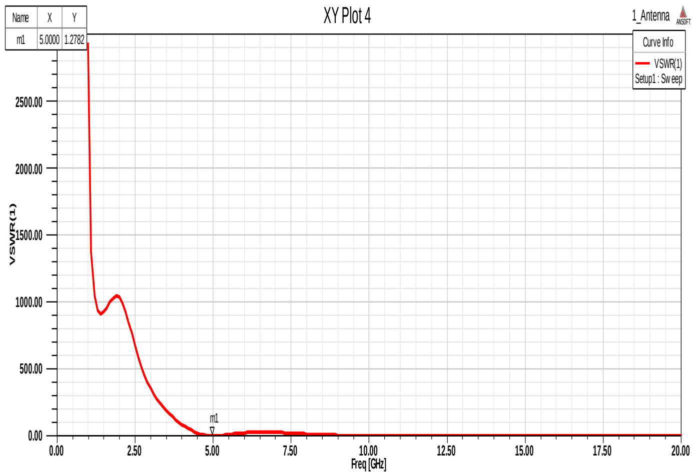

Fig4 : The VSWR response of Pentagonal Patch antenna

IV. ANTENNA & FILTER RESULTS

A Pentagonal Patch Antenna and a elliptical low pass filter for 5 GHz has been designed and fabricated. In this section we present the structure and results of combination of Antenna and Low Pass Filter.

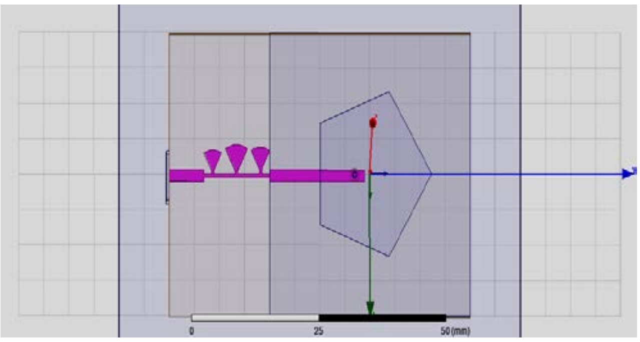

Fig.5 Antenna With Filter

Input Impedance & VSWR: This combined unit's VSWR of antenna and it remains 1.5828 at 5 GHz. however for higher order harmonics it increases. On the other hand input impedance of antenna without filter was found 60.51Ω but after using filter it also decreased to 52 Ω which is near characteristic impedance.

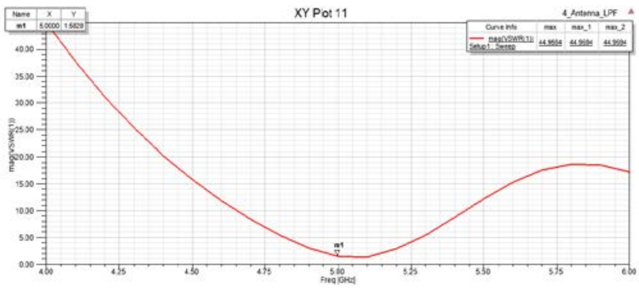

Fig 6. *Combined antenna & filter in term of VSWR*

Radiation Pattern: The gain and beamwidth of antenna with filter is decreases with minor value than antenna without filter. For operating frequency 5 *GHz* & front to back ratio (FBR) is found about 32.

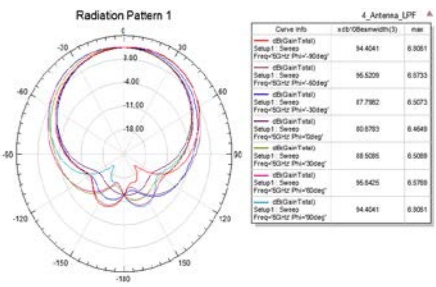

Fig 7 Combined antenna & filter response in term of Beamwidth & Gain

V. CONCLUSION

As a conclusion of this work there are two main aspect to mention. First this work shows that rectennas can be simulated using harmonic balance simulation for the circuit by chosen properly model-library component, and electromagnetic simulators for the antenna part, being careful with the greater coupling sensibility between antenna and circuit. Second, the measured results presented indicate that rectennas will work as RF recyclers with an output power level enough to be efficiently stored and reused.

VI. FUTURE WORK

Further work would include devices that are able to collect and store energy from power levels that correspond to the rectenna output. Increase the frequency bandwidth of the antenna, achieved an arbitrarily polarized reception are other important tasks to do, it might be by multi frequency or broadband operation by changing the antenna's design, would be by stacking microstrip patches or a more complex designs as spiral antenna. Even if only insufficient amount of energy is scavenged from single rectenna, it is also possible to arrange multiple elements to receive more energy. Shrinking the size of the rectenna is another aspect that requires more work. The frequency behavior might stay constant if the of the substrate increases with the decreasing size of the antenna. Furthermore, measurements of situations with more than one incident frequency, as they occur in real life, can be done. Two incident waves with different frequencies can interfere destructively as well as constructively. As a recommendation, in order to increase the RF-DC conversion efficiency; a carefully chose of components and build of rectifier circuit are vital

REFRENCES

[1] W. C. Brown, "The history of power transmission by radio waves," *IEEE Trans. Microwave Theory Tech.*, vol. MTT-32, pp. 1230–1242, Sept.1984

[2] A.S. Weddell, N. R. Harris, and N. M. White, Alternative Energy Sources for Sensor Nodes: Rationalized Design for Long-Term Deployment. In: International Instrumentation and Measurement Technology Conference, Victoria, British Columbia, Canada, May 2008.

[3] Kurt Roth and James Brodrick, "Energy Harvesting For Wireless Sensors", ASHRAE *Journal, May 2008.*

[4] Bergqvist, U. et al., *'Mobile Telecommunication Base Stations - Exposure to Electromagnetic Fields, Report of a Short Term Mission within COST-244bis'*, COST-244bis Short Term Mission on Base Station Exposure, 2000.

[5] Moghe, R., Yi Yang, Lambert, F. Divan, D. , "A scoping study of electric and magnetic field energy harvesting for wireless sensor networks in power system applications."

[6] *T.* Starner, 'Human powered wearable computing', *IBM systems journal*, vol. 35, no. 3-4, 1996

[7] H. J. Visser, A.C.F. Reniers, J.A.C. Theeuwes, *Ambient RF Energy Scavenging: GSM and WLAN Power Density Measurements*, European Microwave Conference 2008, Amsterdam, Netherlands.

[8] S.M. Mann, T.G. Cooper, S.G. Allen, R.P. Blackwell and A.J. Lowe, "*Exposure to Radio Waves near Mobile Phone Base Stations*", Report NRPB-R321, June 2000.

[9] S.I. Henderson and M.J. Bangay, "Survey of RF Exposure Levels from Mobile Telephone Base Stations in Australia", *Bioelectromagnetics*, Vol. 27, No. 1, pp. 73-76, January 2006

[10] N. Shinohara and H. Matsumoto, "Experimental study of large rectenna array for microwave energy transmission,"

IEEE Trans. Microwave Theory Tech., vol. 46, pp. 261–267, Mar. 1998 97

[11] Y. Fujino, T. Ito, M. Fujita, N. Kaya, H. Matsumoto, K. Kawabata, H. Sawada, and T. Onodera, “A driving test of a small DC motor with a rectenna array,” *IEICE Trans. Commun.*, vol. E77-B, no. 4, pp. 526–528, Apr 1994

[12] C. Gómez, José A. García, A. Mediavilla, and A. Tazón, “A High Efficiency Rectenna Element using E-pHEMT Technology”, *12th GAAS Symposium – Amsterdam*, pp. 315 – 318, 2004.

[13] H. Schantz, *The Art and Science of Ultra wideband Antennas*, Artech House, Boston, Mass, USA, 2005.

[14] C. A. Balanis, Antenna Theory, Analisys and Design, John Wiley & Sons, USA, 1997

[15] Taeyoung Yang, Seong-Youp Suh, Randall Nealy, William A. Davis, and Warren L. Stutzman, “COMPACT ANTENNAS FOR UWB APPLICATIONS”, Virginia Tech, Blacksburg, VA, USA.

[16] Zhi Ning Chen, Terence S. P. See and Xianming Qing, “Small Printed UWB antenna with reduced Ground Plane Effect”, *IEEE Trans. Microwave Theory Tech.*, vol. 48, pp. 111–120, Jan. 2000.

[17]S. Maas, *Nonlinear Microwave and RF Circuits*, second edition ed. www.artechhouse.com, 2003.

[18]http://www.lpkf.es/productos/creacion-rapida-prototipos-pcb/metalizacion-agujeros/chemiefrei/index.htm

[19] Maciej Klemm, Gerhard Tröster, “Textile UWB antenna for on-body communications”, *Proc. „EuCAP 2006ʺ,* Nice, France 6–10 November 2006

[20] Amin Rida, Li Yang, Rushi Vyas, and Manos M. Tentzeris, “Conductive Inkjet-Printed Antennas on Flexible Low-Cost Paper-Based Substrates for RFID and WSN Applications”, *IEEEAntennasand Propagation Magazine*, Vol. 51, No.3, June 2009

[21] Griffin, Joshua David, “A Radio Assay for the Study of Radio Frequency Tag Antenna Performance”, *School of Electrical and Computer Engineering Georgia Institute of Technology*, August 2005