Energy Efficient Input-Output Section for RF Application

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Abstract— In RF application the power management and charging of batteries for wireless low power devices is a big issue. In this paper we are presenting the efficient energy at input output section of RF application. Analysis of input impedance using three matching topology is necessary to get maximum power transformation which is then converted into DC signal. The voltage level of incoming input signal is 359.26mV which is further passes through Step-Up transformer which increases the voltage level upto 3.659V. Here we used, MOSFET in spite of diode in voltage multiplier because it gives an linear output compare to diode and noise free DC signal output. We observed that at 0dBm input power, output DC voltage is greater than the output DC voltage at -5dBm which gives an output of 1.778V and at -10dBm which gives an output of 1V. It gives an pure output DC voltage of 3.162V at 0dBm input power and stored the energy of 3.79×10^{-10} J while it is dissipated the power of 0.189W at 2ns time period. And it gives an voltage efficiency of 86.18% at 50Ω load. It can develop sufficient voltage for driving low power electronic devices.

Key words: RF Energy Harvesting Circuit, RF Application

I. Introduction

Nowadays RF power has attracted huge attention from industry and research community to power the wireless sensor network through RF energy harvesting wirelessly. It sort out the problem of the system dependency on external power supply and battery replacement, leads the system self powered. Energy harvesting is natural or man made sources with no injurious environmental effect. It uses the ambient energy available in environment to make it usable for driving low power devices which require power in µW to mW.

Energy harvesting from ambient RF signals can be accomplished by matching network and rectifier circuit in which we matched the antenna impedance with rectifier impedance. By which we get the maximum power transfer and then converting that microwave energy into DC energy.

We have to be careful for designing an RF energy harvesting circuit because of (a) Its operating frequency (b) Type of matching network (c) Voltage level (d) Stages of voltage multiplier. It can be judge by its DC output voltage and RF to DC conversion efficiency signal. These parameters are very less immune to noise and getting highly affected by surrounding environment and signal strength at a particular frequency totally depend on these parameters. Blocking and shadowing due to large obstacles, by time and by reflection also differs the strength of frequency.

There are three major approaches for achieving high conversion efficiency. First approach is to gather maximum power by operating in different topologies, second pass the signal through the step-up transformer and securely deliver it to the rectifying circuit. If we used multiples antenna in place of single antenna and increasing the multiplier stages will increase the efficiency but it will also increase the overall circuit size.

There are two power level region for RF energy harvesting i.e. low power energy ranges from -30dBm to 0dBm and high power energy ranges from 0dBm to 20dBm.In high amount of power it is difficult to harvest energy because it need more antennas to receive this amount of power which leads to increase the size of circuit, therefore for RF energy resources low power region gives better performance.

Here, the transformer is used to increase the incoming voltage level and pass it to the rectifier. We have chosen the MOSFET in place of diode for rectification because it gives better performance in linear application. MOSFET is used as a diode through correct biasing voltage which works as a full wave rectifier.

The promising approach to strengthen the weak RF signals is resonator circuit which is exhibit of discrete inductor and capacitor. It represents the resonant behavior of particular frequencies of interest at which maximum amplification is achieved called resonant frequency. It raise the amplitude of RF signal as well as its efficiency. It act as a matching input and gives resonant behavior between RF input power source and internal resistance of 50Ω and the rectifier circuit.

We demonstrate the input matching with L-topology which is further passed by step-up transformer to increase its voltage level, after that it will be rectified to give an pure output DC voltage. Which is stored by an load capacitor.

II. Design Specification for RF Energy Harvesting Circuit

A. Selection of Matching Circuit

The most important requirement of the energy harvesting is to transfer maximum power by antenna to the rectifier circuit. Because of some parasitic capacitance there will be some noise created by transistor which create unmatched impedance between rectifier and the received RF power and its frequency that affect the circuit performance. To overcome this situation we introduced an matching network between antenna and the rectifier. If RF power source is not matched then some amount of power get reflected back, an standing wave will be created which leads to reduction in output voltage. Proper matching is possible by selecting proper components value and proper matching topology, which gives the efficiency of energy conversion is maximum with particular frequency.

Matching networks is designed by lumped elements (resistor, inductor and capacitor). A single resistor is also sufficient to design matching network because resistor dissipated more power and it only match the real part of impedance. Therefore L-type matching is the promising approach. It can be increased by adding more element to form an π-type matching, but it gives an noise figure of 2.7dB at 900MHz frequency after applying an external noise signal of 1μV, whereas T-type matching having an noise figure of 2.7dB but, L-type matching gives an noise figure of 2.5dB which is less immune to external noise if created in the circuit by the components. With an input reflection coefficient of -43.71dB which is good for operating it in circuit. Fig. 1shows the L-type matching with input reflection coefficient in Fig.2 and noise figure in Fig.3.

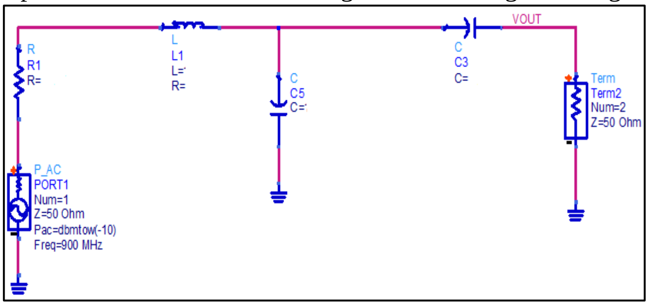

Fig. 1: L-type match

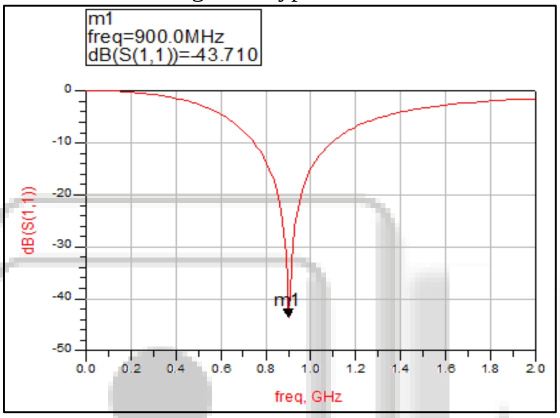

Fig. 2: Input Reflection Coefficient for L-type

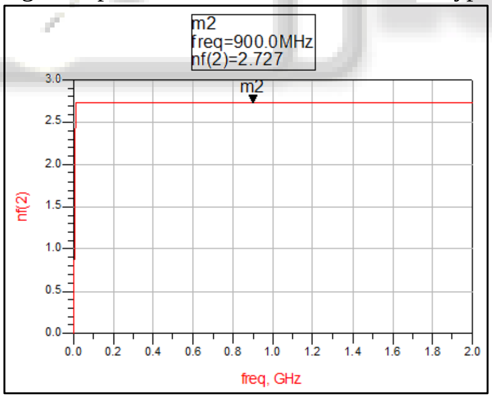

Fig. 3: Noise figure

B. *Selection of Transformer*

After matching the incoming signal having 359.26mV which is very low voltage level to make it DC signal. Hence to increase the voltage level we introduced an Step-Up Transformer which increase its voltage level and gives 3.659V.

Here, we have used an air core base transformer which is mostly used in telephony application. Incoming signal is applied to primary winding having N1 number of turns and the output signal is getting out at secondary winding having N2 number of turns.

$$\frac{V1}{V2} = \frac{N1}{N2}$$

This is turns ratio of transformer which is 0.2 in this circuit. Turns ratio need to be minimum because to achieve maximum of voltage. It is used here to increase the voltage level of the incoming signal and pass it to the rectifier.

C. *Selection of MOSFET*

The RF energy resources are usually of low power region so the peak voltage of the signal in this region is much smaller. Therefore MOSFET with very low turn on voltage and high switching speed is required. N-MOSFET in inversion region is used here.

MOSFET is voltage controlled device having a majority carrier device. It has lower switching losses due to low turn on and low turn off voltage. But MOSFET is used here instead of diode because diode has an non linear behavior while, MOSFET work in linear region which make it better to used than that of diode. MOSFET has no reverse blocking capability due to integral reverse diode. Because of non linearity property of the diode there will be noise is created which can be eliminated by adding filter which is used to eliminate the ripple and harmonics of the diode and increases the circuit size. Therefore for smaller circuit size mosfet is better than diode. MOSFET can act as a diode by connecting gate to source and gate to drain. And it is used as full wave rectifier.

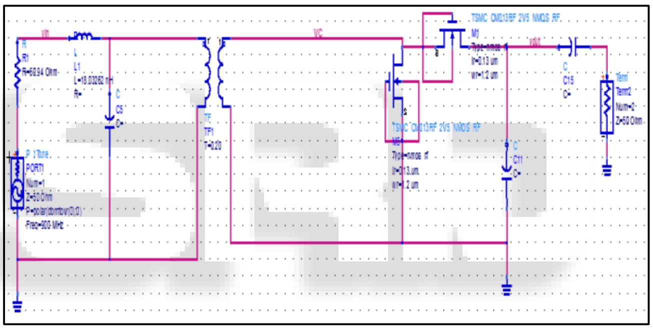

Fig. 4: Circuit Design

III. WORKING OF CIRCUIT DESIGN

As like the diode in full wave rectifier, MOSFET is also has the same working principle. At the positive half cycle of the incoming signal MOSFET M5 works and change it into DC signal while at negative half cycle M1 MOSEFT works which convert it into DC signal. There is an capacitor which blocks the DC signal and pass the AC signal to the MOSFET which again convert it into DC signal and finally at load capacitor we got the pure DC signal as shown in figure 5.

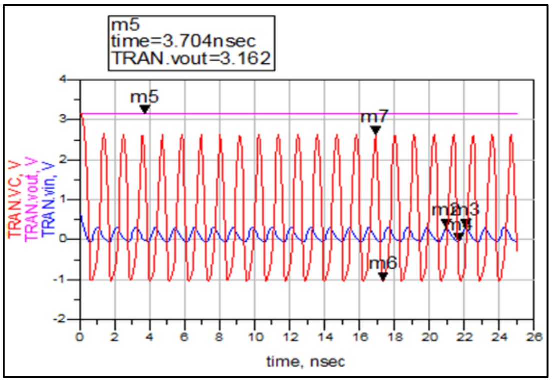

Fig. 5: Output Waveform

We have observed an DC output of 3.162V at 900MHz input power of 0dBm, 50Ω impedance with an input reflection coefficient of -19.302 dB which is less than -10dB and gives good impedance matching. We have observed an output voltage at two different input power i.e. at -5dBm and at -10dBm.

Sr. No	Input power (dBm)	Frequency (MHz)	Vin (mV)	Stepped Up Voltage (V)	Vout (V)
1.	0	900	359.93	3.66	3.162
2.	-5	900	165.9	2.298	1.778
3..	-10	900	64.54	1.514	1

Table 1: Comparison Table

There is load capacitor which is used here to stored the energy(U).the energy stored by the capacitor is given by

$$U=\frac{1}{2}CV^2$$

Whereas, voltage value is 3.162V, and it gives the energy of 3.79×10^{-10}J. The power dissipated(P) at one time cycle is

$$P=\frac{U}{T}$$

The power deliver is 0.189W which is more efficient than the incoming power, and the efficiency of the circuit is represented by the formula

$$\eta = \frac{\text{Output voltage}}{\text{Input voltage}}\times 100$$

Which gives an efficiency of 86.86%.

IV. Conclusion and Future Scope

These papers propose RF energy harvesting circuit with three different input power. Simulation result from proposed design show that RF will be one of the solutions on the problem of repeated charging of mobile device because received RF signal are used for charging of battery of mobile device. Resonator, transformer and multiplier increase the strength of signal by 50-70 %. RF to DC conversion efficiency has emerged as a challenging issue narrow band pass filter can be used to complete this objective by removing the second and third harmonics at antenna. It enhances the efficiency and output voltage. If the band of this circuit increase than more efficient signal can be received for charging of the battery but interference problem will also increase.

References

[1] P. Nintanavongsa, U. Muncuk, D. R. Lewis, and K.R. Chowdhury, ”Design Optimization and Implementation for RF Energy Harvesting Circuits”, IEEE Journal on Emerging and Selected Topics in Circuits and Systems, vol. 2, no. 1, pp. 24-33, Mar. 2012.
[2] T. Umeda, H. Yoshida, S. Sekine, Y. Fujita, T. Suzuki, and S. Otaka, ”A 950 MHz rectifier circuit for sensor network tags with 10-m distance”, IEEE J. Solid-State Circuits, vol. 41, no. 1, Jan. 2006.
[3] H. Nakamoto, D. Yamazaki, T. Yamamoto, H. Kurata, S. Yamada, K. Mukaida, T. Ninomiya, T. Ohkawa, S. Masui, and K. Gotoh, ”A passive UHF RFID Tang LSI with 36.6% efficiency CMOS-Only rectifier and current-mode demodulator in 0.35 um FeRam technology”, in Proc. IEEE ISSC Conf. 2006, Feb. 6-9, 2006, pp. 1201-1210.
[4] J. P. Curty, N. Joehl, F. Krummenacher, C. Dehollain, and M. J.Declercq, ”A model for u-power rectifier analysis and design”, IEEE Trans. Circuits Syst., vol. 52, no. 12, pp. 2771-2779, Dec. 2005.
[5] Gaurav Singh, Rahul Ponnaganti, T.V. Prabhakar, K.J. Vinoy, ”A tuned rectifier for RF energy harvesting from ambient radiations”, AEU - International Journal of Electronics and Communications, Volume 67, Issue 7, July 2013, Pages 564-569, ISSN 1434-8411.
[6] R. E. Collin,”‘Foundations for Microwave Engineering”, 2nd edition,IEEE Press, New York, NY, 2001.
[7] Sachin Agrawal, Sunil Pandey, Jawar Singh, P. N. Kondekar, ”An Efficient RF Energy Harvester with Tuned Matching Circuit”, VLSI Design and Test, Communications in Computer and Information Science,Volume382,pp138-145,2013.
[8] Sika Shrestha, Sun-Kuk Noh, and Dong-You Choi,”Comparative Study of Antenna Designs for RF Energy Harvesting”, International Journal of Antennas and Propagation, vol. 2013, Article ID 385260, 10 pages, 2013. doi:10.1155/2013/385260.
[9] David M. Pozar. ”Microwave Engineering”, Wiley,3rd edition.
[10] A. Sample and J. R. Smith, “Experimental results with two wireless power transfersystems,” in IEEE Radio Wireless Symp., Jan. 2009, pp. 16–18.
[11] D.W.Harrist,“Wireless battery charging system using radio frequency energy harvesting,’’M.S. thesis,Univ.Pittsburgh,PA,2004.
[12] M.M.Tentzeris and Y.Kawahara,“Novel energy harvesting technologies for ICT applications’’in IEEE Int. Symp. Appl.Internet,2008,pp.373–376.
[13] T. Ungan and L. M. Reindl, “Harvesting low ambient RF-sources for autonomous measurement systems,”in Proc.IEEE Int.Instrum. Meas. Technol. Conf., May 2008, pp. 62–65.
[14] H. Javaheri and G. Noubir, “iPoint: A platform-independent passive information kiosk for cell phones,” in Proc. 7th IEEE SECON 2010, Jun. 2010, pp. 1–9.