Six Band RF Energy Harvesting From Ambient Signals

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***Abstract*—Six-band RF Energy Harvester has been featured in this report which can harvest DC voltage from ambient RF signals. GSM900, GSM1800, UMTS2100, Wimax3500 and Wi-Fi (2.4 GHz and 5 GHz) have been matched. Skyworks Detector Diode SMS7630 has been used for rectification and impedance matching has been done by using lumped components of Murata [2]. Maximum conversion efficiency at -15dBm power input is 33.5% at 1800 MHz and each branch is contributing approximately 500 mV for this power input. The total simulated output power is 60uW for single tone inputs (at -15dBm input) and 120uW for dual tone inputs.**

***Index Terms*—RF energy harvesting, Rectifier, Ambient RF signals, Matching Network**

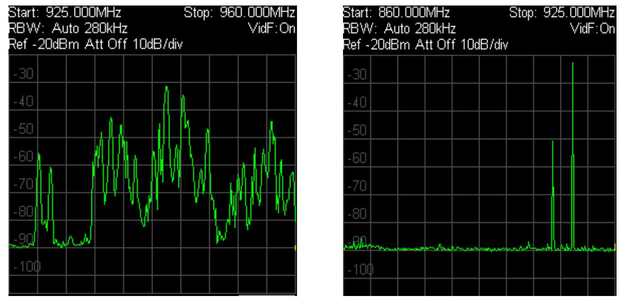
I. Introduction

WIRELESS sensor networks (WSNs) are of great importance these days. They are being used for various monitoring and process control applications by industry. The next step is to power them wirelessly. There are many mechanisms which can be used to develop wireless power technology for example magnetic resonance, laser-based optical power transfer and RF energy transfer. Due to long range and omnipresence RF energy transfer is a better candidate for development of such technology. There are a lot of RF signals present in environment. There are several publications about RF energy harvesting but they focus on single or dual band. If we include all the bands present in ambient environment we can harvest more energy and operate a larger number of devices by powering them wirelessly by taking DC voltage from these ambient signals. Due to this reason we chose to harvest energy from six bands.

II. System Design

A. Spectrum Analysis

To get exact bandwidth and power input level of RF signals in Pakistan we did spectrum analysis using hand held spectrum analyzer (PSA-2702) of TNT and some commercial antennas(Vert900,*2450)*. The power input level and bandwidth of the signals in ambient environment was recorded. This study gave us design goals for rectifier and antenna of our system.



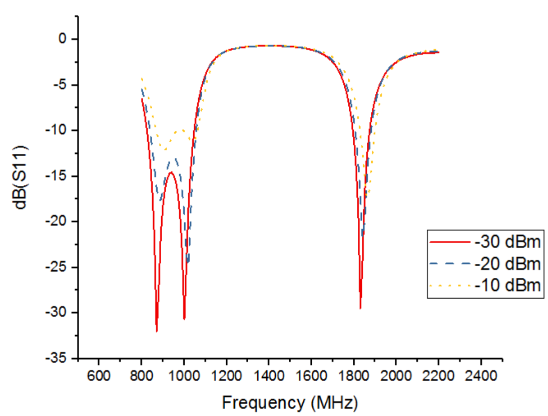
(a) GSM Downlink (b) GSM Uplink

Figure1 Spectrum of GSM

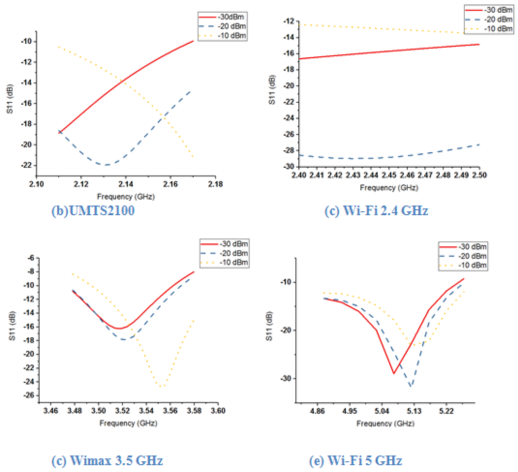
Due to limitation of space the spectrum of GSM900 band is attached only. (Fig1)

B. Rectifier Design

Rectifiers were designed for 6 bands (GSM900, GSM1800, UMTS2100, Wimax3500 and Wi-Fi (2.4 GHz and 5 GHz)) for ambient power signals. Since rectifier is a non-linear circuit so its impedance depends on input power and frequency its impedance matching in six bands was a challenge. LC matching networks were used to match impedance for a power range of -10dBm to -35dBm. LPQ03TN and GRM1555 series of MURATA chip components were used. Their models were imported in ADS and circuits were designed and optimized. Diode used for rectification is SMS7630 by Skyworks Technologies. Response of some of our rectifiers is shown in Fig2. It is evident from the responses that rectifiers are matched for the desired bands.



(a) GSM900 and GSM1800



At -15 dBm input power almost 500mV are harvested by each rectifier with a RF to DC conversion efficiency of 35%. In terms of power each branch can harvest 10uW of power from a tone input of -15dBm as shown in Fig3. If we combine the overall 6 branches and compute output power by exciting each branch by a tone at -15dBm we would be able to generate 60uW of power combined at output(Fig3). Dual tone inputs will approximately double the output of the system (120uW).

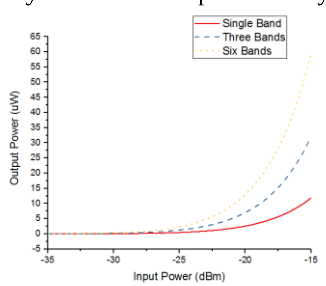
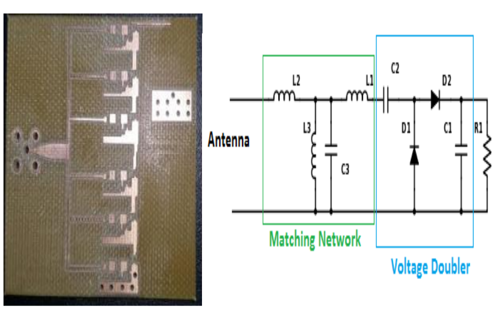


Figure 3 Output Power Harvested for multiple branches

C. *Layout Fabrication*

Layout for rectifiers has been designed in ADS Momentum and they have been fabricated by LPKF S103 fabrication machine. Layout for six branch rectifier is shown in Fig4a. Fig4b features the schematic of a single branch. Six individual branches are combined to form the overall system.



(a) (b)

Figure 4 (a) Fabricated Layout for Six Branches (b) Schematic for single branch rectifier

D. *Antenna Design*

A log periodic hex band antenna inspired by [1] is designed to receive ambient RF signals from required bands. S11 and gain of the antenna is in optimization phase so that it can receive signals from 3.5GHz and 5GHz band. Fig5 shows the simulated S11(dB) of the antenna for different bands.

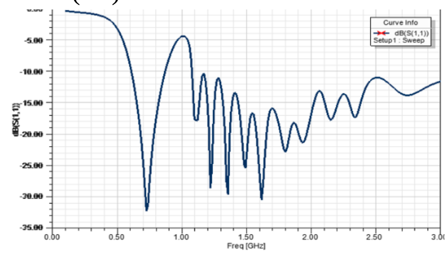


Figure 5 Simulated S11 (dB) of Antenna

III. Performance Comparison

The following table summarizes the comparison of performance of this work with some other related publications.

IV. Current Status of The Project

Design of the entire system is ready. Layout has been fabricated. Components have been ordered and are in process of custom clearance. We shall start the measurements as soon as components will be available to us.

Table 1 Comparison with Related Work

Ref	Bands [Freq(GHz)]	Output Power (uW)
[3]	2 (1.8,2.1)	28(measured)
[4]	4 (0.9,1.8,2.1,2.4)	15 (measured)
[5]	6 (0.55,0.75,0.95,1.8,2.1,2.4)	96(measured)
This Work	6 (0.9,1.8,2.1,2.4,3.5,5)	120 (simulated)

V. Career Plans

This scholarship was very helpful for me in exploring this interesting field of RF energy harvesting. It enhanced my research interest and helped in choosing a research oriented career. I am pursuing my Masters in Nanyang Technical University, Singapore where I am working on RF applications in biomedical devices and processes.

VI. References

[1] Chaoyun Song,Yi Huang,Paul Carter, Jiafeng Zhou, Sheng Yuan, Qian Xu, and Muayad Kod," A Novel Six-Band Dual CP Rectenna Using Improved Impedance Matching Technique for Ambient RF Energy Harvesting*" in IEEE transactions Antennas and Propagation,vol.64,no.7,July 2016*

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[3] Hucheng Sun, Yong-xin Guo, Miao He, and Zheng Zhong "A Dual-Band Rectenna Using Broadband Yagi Antenna Array for Ambient RF Power Harvesting " *in proc. IEEE Antennas and Wireless Propagation Letters,vol.12,2013*