Switching of Band Selection for Micro Scale RF Energy Harvesting

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Abstract - **Radio-frequency energy harvesting keeps a significant space for gathering a small amount of electrical power to drive specific circuits in wireless electronic devices. This paper presents the concept for band selection in order to provide a fair spectrum management process for micro scale energy harvesting in the radio frequency spectrum. The performance based on the associated power of the frequency channels at ambient and busy conditions is investigated in this work.**

Keywords: Micro-sscale RF Energy Harvesting, Switching Mechanism, Spectrum Management, Quality of Service

I. Introduction

In this research a prototype for a micro scale RF energy harvesting device is introduced. Energy is derived from the RF energy sources in the environment around us in the RF energy harvesting technology and is widely getting popular for small stand-alone applications [1-2]. Here the RF energy harvesting at all frequencies used in cellular communications is considered. Cellular communication uses different frequency bands with the three frequency bands centered at 900 MHz, 1800 MHz, and 2100 MHz. Using a broadband antenna all the three bands which are used are captured [3]. Most of the research in this area rarely addresses fair usage policy. Since RF energy sources are man-made energy sources, it is essential to introduce a fair usage policy for this energy harvesting technology. Hence to suffice the fair usage policy an intelligent switching mechanism of band selection is introduced in this paper. There are four main functions namely the spectrum sensing (signal frequencies detection and determination of the RF power density of these signals), the spectrum management (determine the frequencies of the signals without breaking the fair usage policy), the spectrum sharing (energy harvest from a signal at a particular frequency without disturbing the other users who use the same frequency), the spectrum mobility (continuous detection of the RF power density levels of the signals in different frequencies used in cellular communication and identify the situations where cellular communication frequencies break the fair usage policy and bypassing them at these situations from harvesting energy).

II. Literature Review

The mechanism of the cognitive radio described in the literature is used for the design of prototype. Cognitive radio is a novel approach for enhancing the utilization and thereby increasing the efficiency of the electromagnetic spectrum [4]. It encompasses an intelligent wireless system outside the environment and to adapt its internal states by building to learn with the statistical variations of the incoming RF stimuli. This is performed effectively through changes in certain operating parameters such as transmit-power, carrier-frequency, and modulation in real-time, with high reliability and through the effective utilization of the radio spectrum [5]. For effective operational capability the cognitive radio requires significant memory, computational resources, and communications bandwidth [6]. The performance indicators of such a cognitive radio are the awareness, the intelligence, the learning, the adaptability, the reliability and the efficiency [7-10]. Due to spectacular advances in the domain of the digital signal processing, the network architecture, the machine learning the design of such type of cognitive radio is feasible much more easier today [9-10].

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III. RADIO FREQUENCY SPECTRUM

Within the frequency range specified for the GSM-900 system mobile radio networks, 124 frequency channels with a bandwidth of 200 KHz are available for both the uplink and downlink directions. The uplink uses the frequencies between 890 MHz - 915 MHz and the downlink uses the frequencies between 935 MHz - 960 MHz. The E-GSM band adds 50 frequency channels and the R-GSM another 20 frequency channels to the spectrum. For the frequency range specified for GSM-1800 System mobile radio networks, 374 frequency channels with a bandwidth of 200 KHz are available for both the uplink and downlink direction. The uplink uses the frequencies between 1710 MHz - 1785 MHz and the downlink uses the frequencies between 1805 MHz - 1880 MHz. GSM uses a variety of channels in which data is carried. These channels are used for user data (payload) or signaling to enable the system to operate correctly. A channel maps to the recurrence of one burst every frame. It is defined by its frequency and the position of its corresponding burst within a TDMA frame. In GSM traffic channel and control channel are more commonly used.

1) **Traffic channels (TCH):** Traffic channels carry digitally encoded user speech or user data on both the up and down links. Therefore power control is allowed for both the directions and a reduction of transmission power is happened according to the actual path loss. As well discontinuous transmission is also allowed. If there is no voice or no data then nothing is transmitted. Hence in the ambient conditions TCH does not appear.

2) **Control channels:** Control channels carry signalling and synchronizing commands between a base station and mobile station (in some cases, without the user's knowledge). They are in the environment all the time. According to their functions three different categories of control channels are used.

a) **BCH (Broadcast Channels):** Transmitted by the Base Station (BS) to the Mobile Station (MS). BS tells mobile information about the network and the current serving cell. These channels help the mobile in the network selection process with parameters needed to identify the network, synchronize time and frequency with the network, and gain access to the network. This is a down link channel and appears at ambient conditions. Some of the BCH are FCCH (Frequency Correction Channel),

SCH (Synchronization Channel) and BCCH (Broadcast Control Channel).

b) **CCCH (Common Control Channels):** CCCH are uplink and downlink channels within GSM systems. The CCCH are used in setting up calls from either the MS or network side, and are necessary to establish the dedicated link with the network. It consists with PCH (Paging Channel), RACH (Random Access Channel) and AGCH (Access Grant Channel).

c) **DCCH (Dedicated Control Channels):** DCCH is a dedicated channel used to carry signalling information in both the up and down links. This channel does not appear at the ambient conditions. It includes SDCCH (Standalone Dedicated Control Channel), SACCH (Slow Associated Control Channel) and FACCH (Fast Associated Control Channel).

IV. RESEARCH OBJECTIVE

The measure on the quality of network is defined as the Quality of Service (QoS) that is essential for both the customer and to the service provider. The most common performance factor is the Call Setup Success Rate (CSSR). The successive rate of such quality of service is measured using Equation (1) [11].

CSSR = SDCCH Accessibility * (1-SDCCH Drop) * TCH Accessibility * (1-TCH Drop).

Another performance indicator is the handover success rate that is used to measure whether the incoming handovers are handled appropriately by the relevant sectors. In order to measure this the service provider takes the ratio between success incoming handover to total incoming handover requests. There are some other performance indicators such as the Immediate Assignment Success Rate, the TCH Assignment Success Rate, TCH Congestion Rate (TCHCR) and Random Access Success Rate [12]. Service provider gives much attention to these performance indicators to keep the QoS stable and at the maximum value. Energy harvesting highly affect this QoS and a typical spectrum that is captured with a spiral antenna in ambient conditions is shown in Figure 1 with a power of -28.6 dBm. It should be noted that when a call is not connected the service provider is broadcasting only BCH signals with no effect on the QoS. Figure 2 shows the spectrum that is captured with the spiral antenna when a call is connected. In this situation additional channel increase the power level to about 12.8 dBm. The

reason is the addition of other components to the signal, such as the CCCH and DCCH. The service provider put a great effort to increase this power level to keep the QoS at maximum and at a stable position. If RF energy harvester captured this signal power during a call process, the QoS is reduced. In this approach a mechanism to capture only BCH signals and to avoid capturing CCCH and DCCH signals is developed because it does not minimize the QoS. This helps the service provider to keep the quality of the network at a constant level.
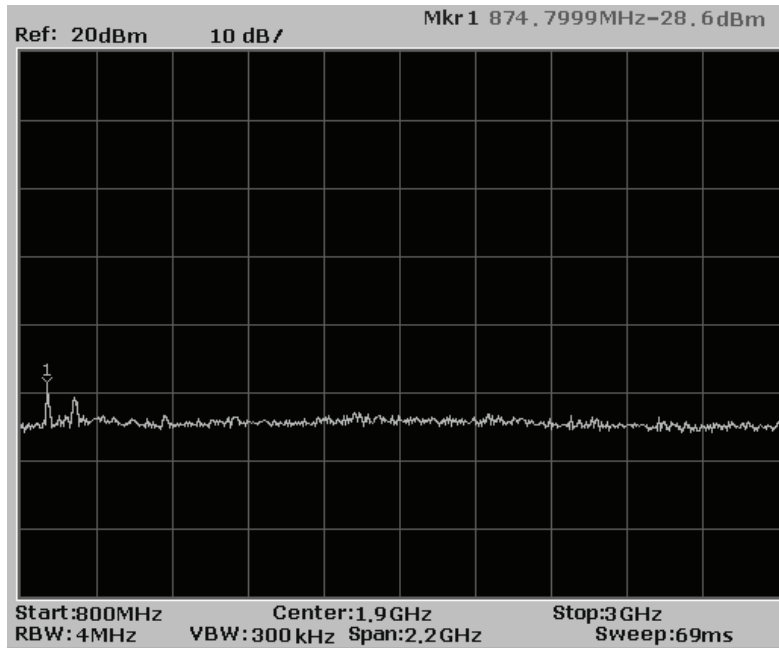

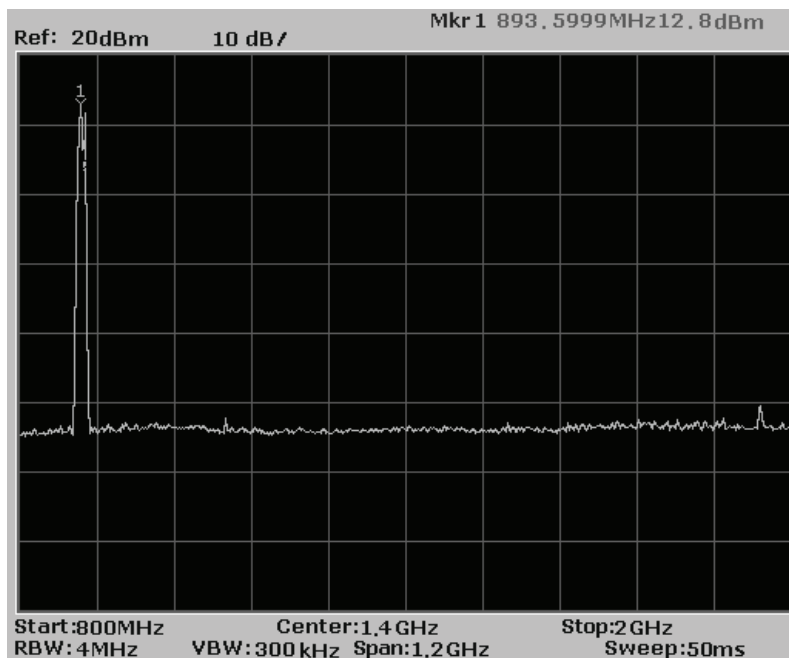Fig.1 Spectrum of the spiral antenna in ambient condition

Fig. 2 Spectrum from the spiral antenna at the origination of a call

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V. Mechanism

The power of TCH, CCCH and DCCH signals are relatively higher than the power of the BCH signal. Therefore when harvesting RF energy, using BCH signals alone generate a lower voltage value when compared to the voltage value generated by harvesting with other signals. This characteristic is used to separate these signals and effectively filter one of them. The schematic block diagram for the proposed switching between frequency bands is shown in the Figure 3. It ensures that the energy harvesting device captures only the BCH ambient signals while refusing the other traffic signals. Since the antenna is a multiband one it captures all the 900 MHz, 1800 MHz and 2100 MHz frequency signals. Three matching circuits are used to filter these signals at different frequencies from the antenna output separately. The purpose of the RF power detector is to measure the voltage levels at related frequencies and direct it to the controller. The controller compares this voltage signal value with a reference voltage value which is between the voltage values that are generated by BCH and other signals. At ambient conditions only BCH signals are available. Hence RF power detector passes the voltage signal corresponding to the BCH signal to the controller. In this situation the voltage value passed to the controller by the RF power detector value is less than the reference value. The controller then identifies this situation as an ambient condition BCH signal and keeps the switch of the related frequency in the "ON" condition. The energy captured from BCH signals is directed to the energy storage device via the voltage multiplier. If the voltage output of any RF power detector is higher than the reference voltage, the controller identifies that as a situation where TCH traffic signals exist. Then the controller disconnects the line between the matching circuit and the voltage multiplier by operating the related switch. Therefore it avoids harvesting energy from the TCH signals. This schematic architecture describes an intelligent switching mechanism between the frequency bands to avoid capturing TCH signals while capturing the BCH signals. It ensures that RF energy harvesting does not affect the QoS of the service providers.
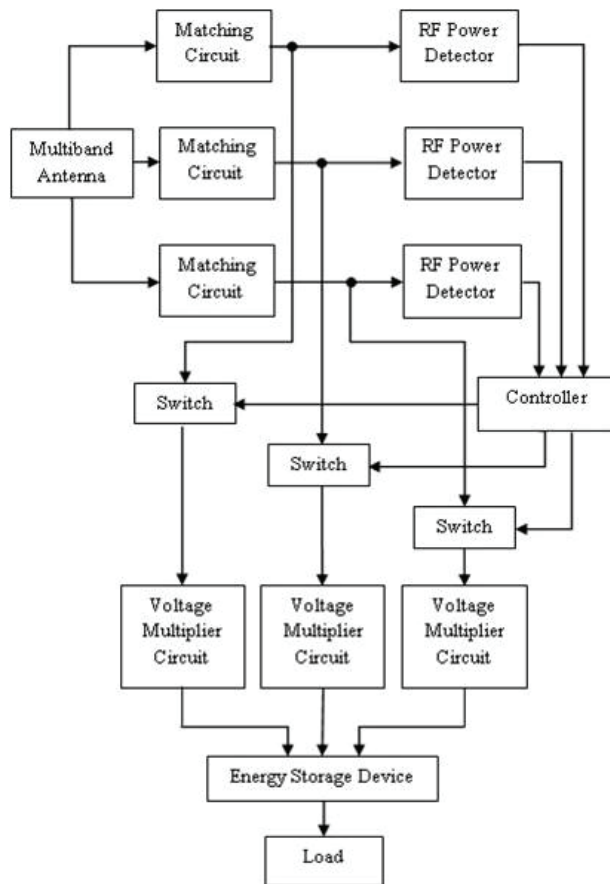

Fig.3 Intelligent switching mechanism between frequency bands

VI. DESIGN AND SIMULATION

MATLAB/Simulink is used to design and simulate the model of the proposed mechanism. Three signal generators are used to generate three signals separately for 900 MHz, 1800 MHz and 2100 MHz. An example of the 900 MHz signal is shown in Figure 4. Then a multiplexer is used to multiplex the separately generated three signals. After multiplexing the signals a multiband signal of 900 MHz, 1800 MHz and 2100 MHz is shown in Figure 5. That is similar to the output of an antenna which is capable of receiving all the three RF bands simultaneously. Now the multiplexer and the three signal generators together is considered as a multiband antenna which receives RF signals and feeds them to the matching circuit as input. From this multiplexed signal the power level of each frequency cannot be measured. To do

that it has to be separated in to the three frequency bands of 900 MHz, 1800 MHz and 2100 MHz because the circuits are designed for those frequencies. This is sufficed with the use of three band pass filters.

Then the band pass filters are used to filter frequency bands separately to feed the harvester circuits in suitable frequency band. After filtering the multiband signal a signal for the 900 MHz harvester circuit is shown in Figure 6. This is the first step of the switching process. Then the power level of each signal has to be determined. To do that the power level of each signal should be manually initiated in MATLAB and an initial value function is used with each of the signals independently. Now the power level of each signal is determined separately by comparing the received power level with a predetermined reference.
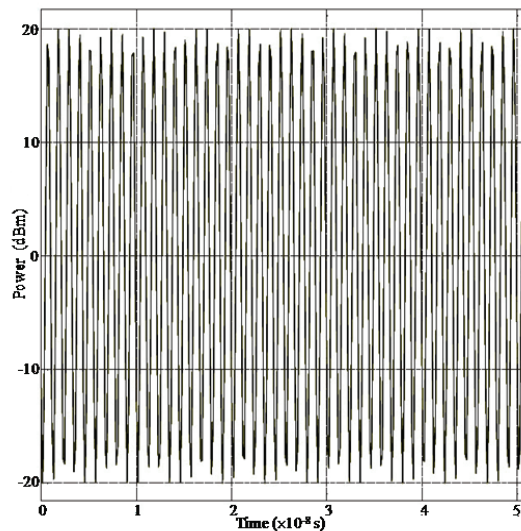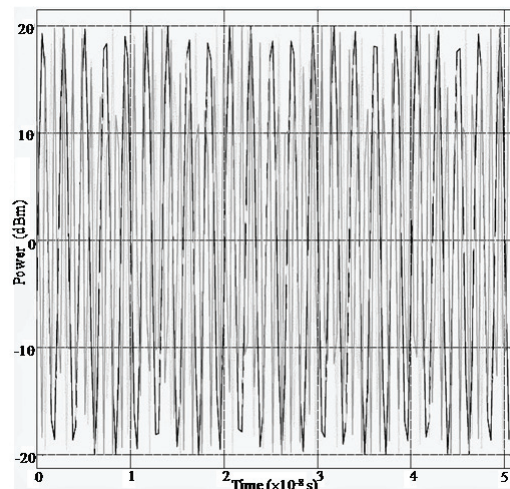

Fig. 4 Output of 900 MHz signal generator

Fig. 5 Output of the multiplexer

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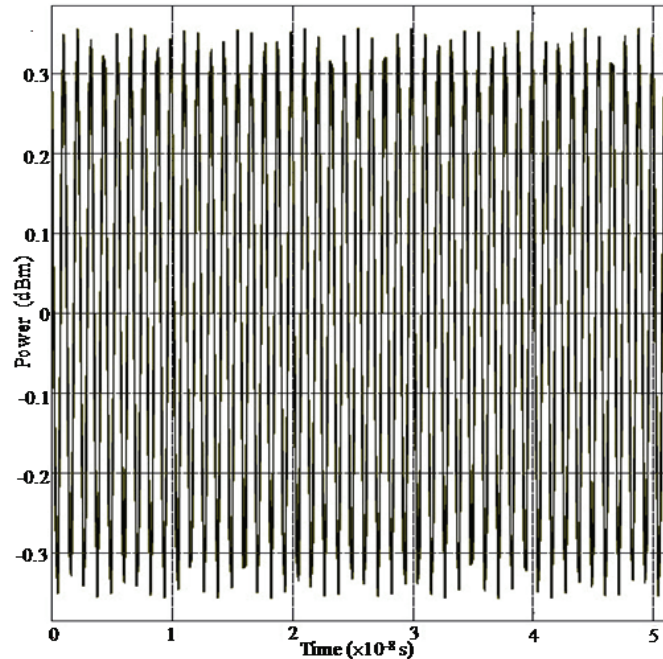
Fig. 6 Filtered Signal of 900MHz band pass filter

As already described the power level of the signal becomes high during the busy conditions. To save the QoS of the service provider this increased power should not be harvested by the harvesting circuit. This is done by dropping the signal input to the harvester circuit at busy conditions. Hence the reference value threshold should be the minimum value of the power level during busy condition. When the power level increases beyond the reference level it is indicated. As an example if the reference level is set as 10, as the initial level goes less than 10 it indicates Boolean 1 on the display. If the initial value is higher than 10 it indicates boolean 0. If all three signals have the initial value as 5, it is less than the reference level of 10 and hence it displays 1. The initial conditions of the three signals are set separately. Therefore when one of the signals is at the busy condition harvester circuits is operated from the other two signals. A switch to switch "ON" and "OFF" the path between the matching circuit and the voltage multiplier circuit is used. Hence the input to the relevant energy harvesting circuit is connected and disconnected according to the reference level and the power level of the signal.

VII. CONCLUSIONS

In this paper the basic channels which are responsible for the power transmission in RF energy harvesting and QoS of the service provider are identified. The channels are clearly distinguished according to their appearance in ambient conditions and during the calling process. The difference between the power levels in the two situations is defined and according to them the reference value is defined. When the power level of any band is raised over the reference limit the circuit for that band is disconnected. To perform this task the proposed system consists of a multiband antenna, matching circuits, RF power detectors, controller and switches. The model is designed and simulated using MATLAB simulink. This mechanism reduces the disturbances for the network users and for the QoS of the network due to the RF energy harvesting.

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