A Spectrum Sensing Test Bed based on Matlab and USRP2

Mahmod Ammar, Meftah Mehdawi, Nick Riley, Anwar Fanan, Kevin Paulson, and Mahsa Zolfaghari

Abstract— The spectrum monitoring has gained new aspects with development of the software defined radio SDR as its very important issue in the spectrum management area. In this paper a spectrum monitoring technique with SDR is proposed, the setup of the prototype based on USRP with Matlab is designed and implemented, the spectrum of 2.4-2.5 GHz band has been measured. The result of this prototype has proved that the module is capable of detecting the main radio signal within these bands, moreover this module had to be able to detect and automatically correct the offset resulted between the two USRP devices.

Keywords— Spectrum Sensing, Energy Detection, USRP.

I. Introduction

SOFTWARE Defined Radio (SDR) has been acquiring a great deal of attention in the past several years. Created in 1991 by Joseph Mitola [1], it is “a radio whose channel modulation wave-forms are defined in software”. This will allow users to operate the radio in different environments and applications.

Because the software is easily reconfigurable, the radio itself would become adaptable to a wide range of situations, depending on the user’s needs. This concept brought up a new idea, the Cognitive Radio (CR). Also devised by Mitola [2, 3], it is essentially a SDR that senses its environment, tracks changes, and reacts according to its findings. CR is widely regarded as being the next step in the evolution of radio systems, since it can adapt itself to every situation, replacing the traditional single function radios.

In this paper a spectrum sensing technique based on USRP2 and Matlab software is designed and the module measures the 2.4-2.5 GHz frequency band.

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II. Energy Detection

Energy detection is a signal detection mechanism based on Neyman-Pearson approach [4]. The concept of energy detection mechanism is very popular in the field of spectrum sensing. The detector computes the energy of the received signal and compares it to certain threshold value to decide whether the desired signal is present or not. The energy of the signal can be preserved in both time domain and frequency domain. The time domain representation of this mechanism is shown in Fig. 1.

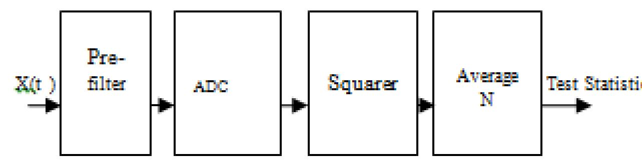

Fig. 1. Energy detection based on time domain

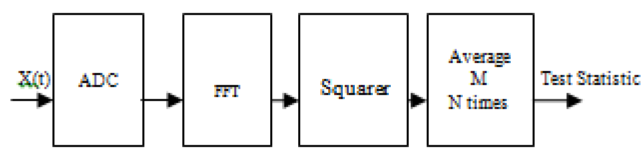

Fig. 2. Energy detection based on frequency domain

Fig. 2 above shows the frequency domain representation of this mechanism. Theoretically, whichever representation is used for signal detection and analysis makes no difference in result. However in the former representation a pre-filter matched to the bandwidth of the signal is required. This need makes this representation quite inflexible compared to the frequency domain representation. In this paper we have used the Energy detection based on frequency domain.

III. USRP2 Architecture And Overview

USRP2 is the device which is able to create a software radio with any computer having gigabit Ethernet interface. It’s the upgraded version of its earlier release USRP. USRP has a USB interface limiting the data throughput from USRP to Computer at a maximum bandwidth of 8MHz. The design of USRP and USRP2 is open source and all schematics and component information can be downloaded from the website of the manufacturer [5]. USRP2 contains field programmable gate arrays (FPGA) and RF transceiver board which is connected over FPG.

The idea behind the design of USRP is to perform all the signal processing tasks for example modulation and demodulation, filtering at the host computer. All the general purpose tasks such as decimation, interpolation, digital up conversion and down conversion are performed inside the FPGA of USRP2. Fig. 3 shows the USRP2 Daughterboard Architecture. USRP2 contains gigabit Ethernet controller, SD card slot and MIMO expansion slot at the front end with 8 LED indicators. SD card contains the driver for USRP2 mother board and RF transceiver. It requires 5V DC and 6A to power up USRP2 [5].

Fig. 3 USRP2 Daughterboard Architecture

IV. MODEL DESIGN

The sensing test bed consists of two USRP2 of Ettus Research™, shown in Fig.4 , each one connected to host PC running a processing program designed with Matlab®/Simulink® Software. USRP™ Hardware Driver (UHD) used to provide a host driver and API to connect the USRP with system objects supported by Simulink® in Communication with USRP™ Toolbox.

The model is built using Signal Processing Toolbox incorporated with Simulink™ and extensive Communication System Toolbox. RF front-end XCVR2450 daughterboard is interfaced with USRP™ supporting frequency of 2.4 GHz turn the test bed into a complete RF transceiver system. A VERT2450 Vertical Antenna at 3 dBi gain is used for two-way high-bandwidth communication.

The USRP2 board is an evolution of a previous USRP computer-hosted hardware for software radio and It features a Xilinx Spartan 3-2000 Field Programmable Gate Array (FPGA), 2 Analog -to Digital Converters (ADCs) at 100 MS/s, 14 bits, and 2 Digital to- Analog Converters (DACs) at 400 MS/s, 16 bits [6]. It also features a Secure Digital (SD) card reader for the firmware.The internal clock is a 100 MHz Voltage Controlled Oscillator (VCO) with nominal accuracy of 10 ppm, but the board also provides connection to an external reference clock as well as a Pulse Per Second (PPS) port. USRP2 can be interfaced with the host PC through Gigabit Ethernet.

In Fig. 5 - a common software-defined radio architecture, an USRP hardware implements a direct conversion analog front end with high-speed analog-to-digital converters (ADCs) and digital-to-analog converters (DACs) featuring a fixed-personality FPGA for the digital down conversion (DDC) and digital up conversion (DUC) steps.


Fig . 4 Experimental prototype

The receiver chain begins with a highly sensitive analog front end capable of receiving very small signals and digitizing them using direct down conversion to in-phase (I) and quadrature (Q) baseband signals[6]. Down conversion is followed by high-speed analog-to-digital conversion and a DDC which can reduce the sampling rate and packetizes I and Q for transmission to a host computer using Gigabit Ethernet for further processing. The transmitter chain starts with the host computer where I and Q are generated and transferred over the Ethernet cable to the USRP hardware. A DUC prepares the signals for the DAC after which I-Q mixing occurs to directly up convert the signals to produce an RF frequency signal, which is then amplified and transmitted [6].

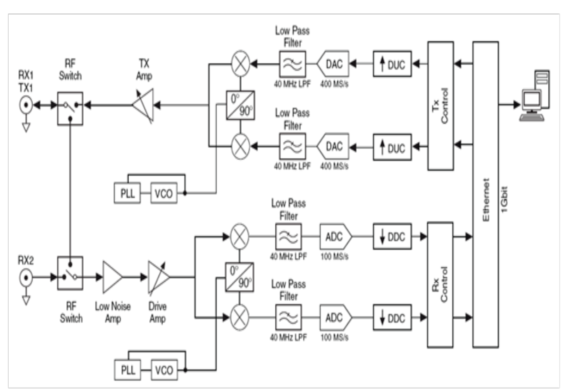

Fig. 5 SDR architecture

V. SIMULINK-USRP

One of the software packages that is compatible with the USRP is the Simulink-USRP blockset. Simulink-USRP is used with Matlab Simulink and was developed and made available by the Communications Engineering Lab at the Karlsruhe Institute of Technology [5]. Simulink-USRP equips Matlab Simulink with the capability to control the USRP and transfer data between a host computer and the USRP. Simulink-USRP allows the user to process the data from the USRP in real-time utilizing Matlab and Simulink's extensive list of built-in functions that many engineers are familiar with. Simulink provides a graphical environment to build an SDR system with the USRP using USRP source and sink blocks. The USRP's reconfigurable parameters can be set through the software. In Simulink-USRP the SDRU receiver and SDRU transmitter blocks are used to define parameters such as the gain, center frequency and the sampling rate from the USRP through decimation and interpolation, respectively, Fig. 6 below shows the SDRU Receiver block.

SDRU receiver and SDRU transmitter blocks pass data through vectors and therefore the vector size must also be defined.

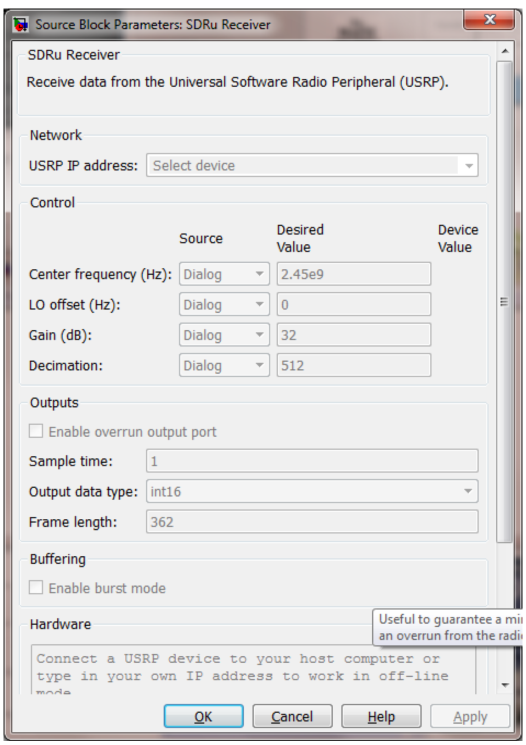

Fig. 6 SDRU Receiver

VI. SPECTRAL ANALYSIS

The designed test bed operates at frequency of 2.4-2.5GHz which is a license –free band representing the real-world radios channel in which the transmitter and receiver can both handle the data. The data was transmitted via the sender USRP, the receiver senses the frequency range between 2.4 and 2.5 GHz with Automatic detection and correction of the offset frequency.

The output rate set to be 200k samples/second. The default IP address of USRP™ transmitter block is set to 192.168.10.2, while the host's Ethernet interface is set to 192.168.10.1 and subnet mask is 255.255.255.0. Simulink™ is set with 'Rapid Accelerator' mode to facilitate higher compiler performance and rapid optimization level. The receiving system module follows the energy detection method as described in earlier section.

The main goal of spectral estimation is to describe the distribution (over frequency) of the power contained in a signal, based on a finite set of data. Estimation of power spectra is useful in a variety of applications, including the detection of signals buried in wideband noise[7].

There are various methods of spectrum estimation available in the Matlab toolbox which are categorized as follows:

- Nonparametric methods
- Parametric methods
- Subspace methods

In this paper we have used the Nonparametric methods in which the PSD is estimated directly from the signal itself. The most used such method is the periodogram..Fig. 7 below depicts the test bed block Components.

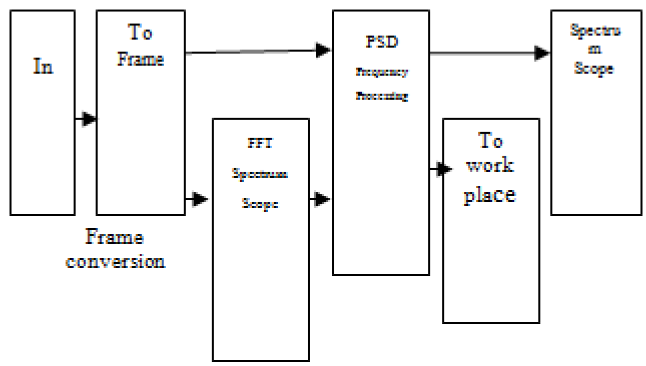

Fig. 7 Test Bed Block Components

It consists of frame conversion block, PSD Frequency processing block, FFT Spectrum scope block and to workspace block. The frame conversion block is responsible for setting sampling mode of output signal, which can be either frame-based or sample-based, and here we choose frame-based type. Frequency processing block receives the data from the TO FRAME block and estimates the PSD (Power Spectrum Density).

FFT spectrum scope block is used to compute and display the power spectral density of each input signal.

VII. EXPERIMENTAL RESULT

The designed test-bed facilitates experimentation with spectrum sensing capabilities while examine the communication between USRP2 and Simulink USRP system objects. The model aims to investigate the performance of spectrum sensing and examining the energy detection method deployment.

A 20 KHz Sinusoid signal was generated at the transmitter side and then sent at 2.415 GHz , fig. 8 shows the FFT plot of the transmitted signal .

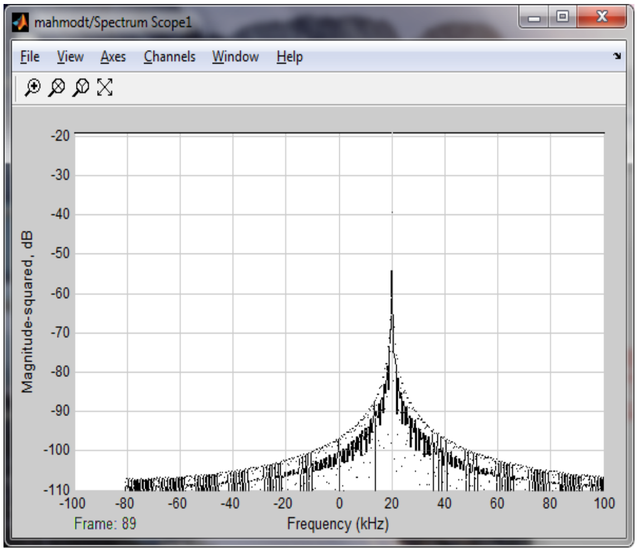

Fig. 8 FFT plot of the transmitted signal

At the receiver end, another USRP2 was used to receive the signal at 2.415 GHz . In fig. 9 the FFT plot for the original signal (without offset modification) was observed . The signal is not at 20 KHZ as sent and this caused by the offset between the devices. This offset has been successfully corrected in fig. 10 using our module.

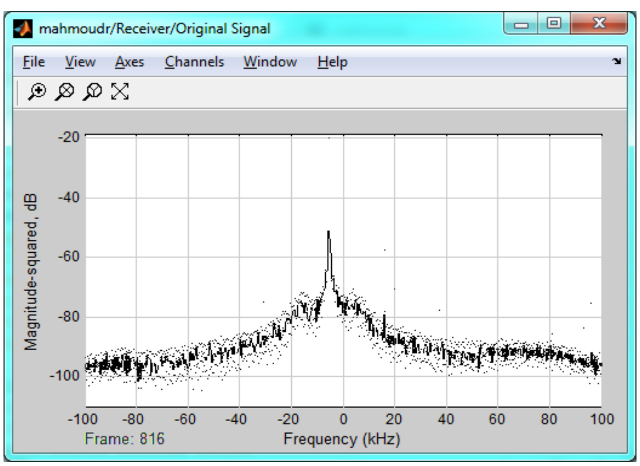

Fig. 9 FFT plot of the Original signal without modification

In fig. 10 the offset frequency was first measured and then we were able to detect and correct this offset , the signal was plotted and adjusted to the actual value as sent from the transmitter side (without any offset).

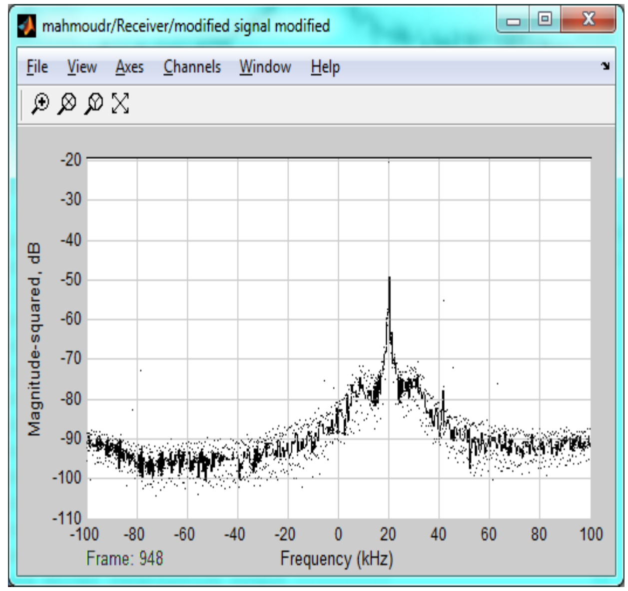

Fig. 10 FFT plot of the adjusted signal without Offset

VIII. CONCLUSION

A spectrum monitoring technique based on USRP2 has been proposed and the prototype equipment was designed. The module can measure the spectrum of 2.4-2.5 GHz band , by this monitoring setup we were able to detect and correct of the offset frequency between the transmitter radio and receiver radio. Moreover this prototype will help to improve the SDR applications. The prototype provides a test bed for study and implementation of techniques for use in cognitive radio. More research work based on this prototype is currently in progress and will published later

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