A Novel Design In Digital Communication Using Software Defined Radio

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***Abstract*— The most of the products and researches in present technology focus on analog communicate on and voice transmiss ion. In this paper, we propos e a Software platform with digital data communication capability.This platform consists of Field Programmable Gate Array (FPGA) based radio hardware and open source software modules. The main features include: 1) Radio Spectrum Sensing; 2) Programmable Radio Modules; 3) Establishing Digital Data Communication. Based on the proposed Software platform, we could easily reconfigure its radio modulesand discover the spectrum hole to achieve better communication quality. These features are important basis to accomplish Cognitive Radio (CR) technologies**

***Keywords*—** Digital Communication, Spectrum Sensing, Cognitive Radio,Soft ware Defined Radio.

I. INTRODUCTION

The development of radio technology brings new wireless applications into people's life. The mobile devices can provide the high speed in computation due to the advance in computing ability of the processor,such as PDA (Personal Digital Assistant), Smart Phone. Most of these mobile devices equipped with Wi Fi,WiMAX or other wireless modules making people be able to access services anywhere. However, different radio technologies and protocol standards need to be realized through different IC (Integrated Circuit) chips. How to integrate the various protocols and radio frequency (RF) chips into a small device is the most important challenge in recent years.Therefore, there is a design trade-off between the application variety and the size minimization of user device

The reason why Software Defined Radio (SDR) becomes popular is that people could use SDR technology to realize many applications without a lot of efforts in the integration of different components. We can change the different software module to adapt different modulators and demodulators in the SDR platform. The most radio and wireless related applications could be achieved. Users can use SDR on personal wireless device. For example, the vendors could integrate GSM (Global System for Mobile Communications),WCDMA(Wide band Code Division Multiple Access), GPRS (General Packet Radio Service), IS-95, EV-DO,Wi-Fi,WiMAX or Bluetooth in a single device and update the newest radio modules by download software modules. In the military applications,such as U.S. DoD Joint Tactical Radio Sys-tem (JTRS) program [1] develops a military radio communication device which supports more than 20 different communicational standards. In an emergency situation,the gateway device based on SDR could be used to bridge various types of incompatible radio equipments or establish a temporary communications infrastructure through SDR equipment.

To achieve the software radio functions, the base protocol of software modules, ADC/DAC conversion of hardware radios and multi-band antennas are necessary. Most roducts and research developments of SDR focus on the voice transmission. This paper utilizes Universal Software Radio Peripheral (USRP) [2] and GNU Radio [3] to implement a reconfigurable SDR platform which can support digital communications and wireless spectrum sensing. Although the concept of SDR has been proposed for a long time, the implementationwas stuck due to the insufficient technology until recent years.

This paper is organized as follows.We introduce the available SDR resources and our platform, including the design of GNU Radio and the architecture of USRP in section 2. The radio spectrum sensing and the reconfigurable digital communication, the implementation and experiment results are showed in section 3. Conclusion are finally drawn in section 4.

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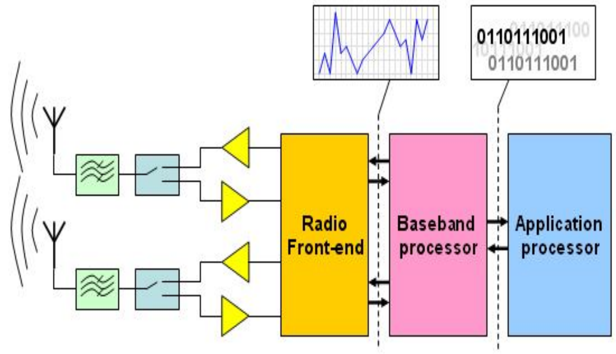
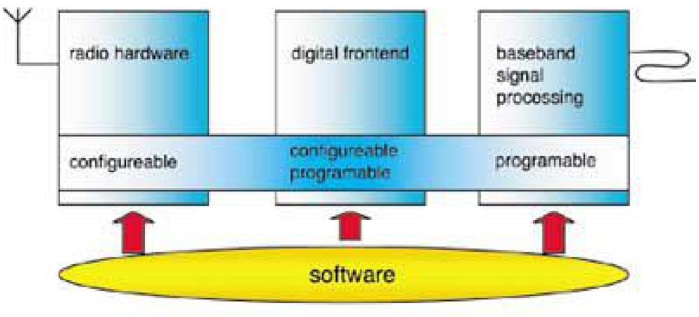


II. BACKGROUND

A. Software Defined Radio

Traditional hardware radios are implemented with analog and solid poly-Si elements. In SDR, the traditional hardware is replaced by software modules such as Figure 1. SDR was proposed by Joseph Mitola in the beginning beginning of 1990 [4]. Unlike adopt Application Specific Integrated Circuit (ASIC) to implement radio elements in the past, the technologies such as Field Programmable Gate Array (FPGA), Digital Signal Processor (DSP) and General-Purpose Processor (GPP) are used to build the software radio elements.

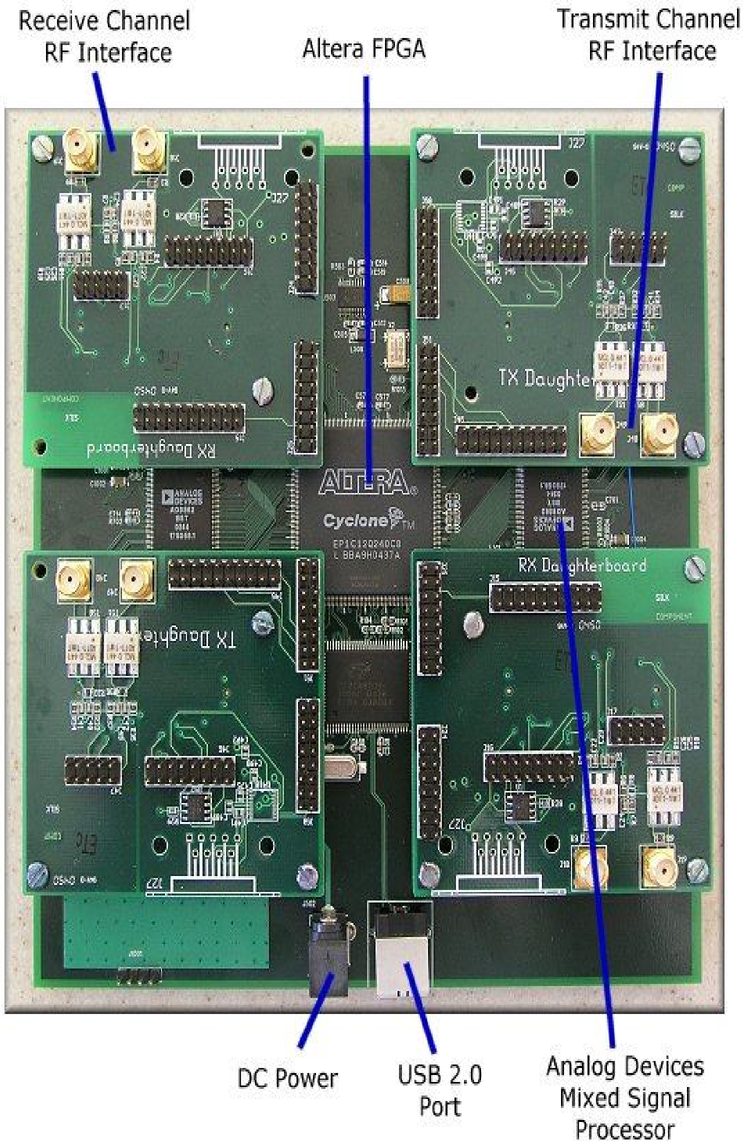
The fundamental architecture of SDR is shown in Figure 2. It includes front-end, processing engine and application. The Radio Frequency (RF) front-end module digitizes the radio frequency data from antennas. After the baseband is digitized by front-end, the processing engine converts baseband data and date frames. The application side receives data frames at last.



Software defined radio application in the future

B. USRP

Universal Software Radio Peripheral (USRP) was designed by Matt Ettus [2]. It was combined with radio front-end, Analog to Digital Converter (ADC) and Digital to Analog Converter (DAC) via Universal Serial Bus 2.0 (USB 2.0) on GPP platform. According to the Statements as mentioned above, the USRPis available to realize a reconfigurable and adaptable SDR. Figure 3 shows the components on USRP motherboard.The 4 ADCs which can sample 60 _ 10^6 times per second on each ADC, and 4 DACs which samples 128 –10^6 times per second on every DAC. Additionally, there are one Altera Cyclone EP1C12 FPGAchip and one programmableCypress FX2USB 2.0 controller on the USRP motherboard. In USRP, the block diagram as shown in Figure 4 represents whole work flow and function components. It can be divided into two parts based on the transmission



III. ACCOMPLISH DIGITAL COMMUNICATION

We connect the USRP hardware device with the GNU Radio software tool, and then we use software to define the parameters about radio communication. After setting up the connection between two SDR platforms,we utilize the spectrum sensing ability to detect the free spectrum bands in the environment. The tunable feature can reconstruct the connection at a spectrum hole, so that we can use the finite spectrum to accomplish digital data communication. In the ultimate aim, we attain to enhance the spectrum utility rate by reusing the limited spectrum resource efficiently.

A. Spectrum Sensing

Federal Communications Commission (FCC) defines the usage of spectrum allocation explicitly. There is a serious impact on the emerging multi-media applications because it's unable to use the limited spectrum resource efficiently. Cognitive radio [8_10] is a popular technology due to it is based on software to define the wireless sensing echniques. Thus, it is able to enhance the spectrum utility rate evidently. The concept of Cog-nitive Radio is originated from: 1) radio sensing and learning; 2) recognizes and allocates spectrum opportunity ;3) realizes spectrum opportunity. And CR utilizes the intelligent sensing method to acquire the spectrum usage information and environment parameters then chooses the most feasible network or the spectrum reconfigurable network architecture. Therefore the spectrum sensing ability in SDR is extremely important in order to accomplish the goal of digital data communication.

In this paper, we implement the spectrum sensing program in GNU Radio and integrate it with GNUPlot [11] function in order to present the spectrum utilization in graphics. The GNUPlot function draws the spectrum sensing information through Python language, thus it can detects the spectrum holes by the results of spectrum usage. The range of our spectrum sensing is from 2.397 GHz to 2.479 GHz, which is the standard range of IEEE 802.11 standard, and the allocation of IEEE 802.11 channels plan is shows in Table

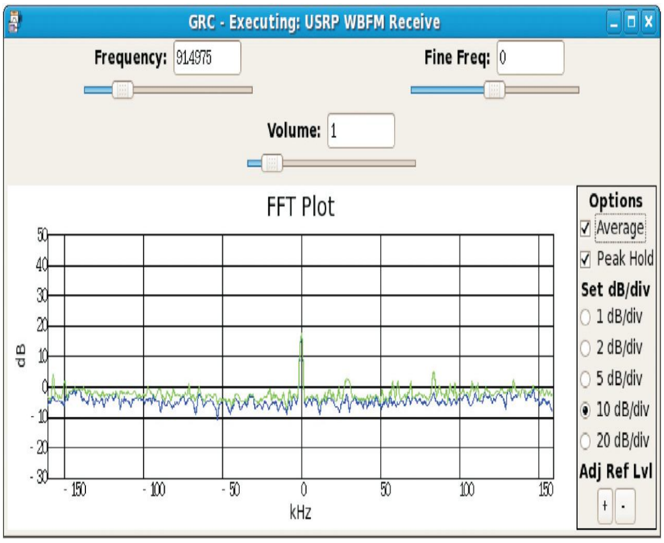
In order to verify our spectrum sensing function, we use a laptop to get the wireless network usage authority from National I-Lan University. The Access Point (AP) in our environment is allocated at Channel 6, and we download a file from Internet through this AP. After that, we take another laptop which equips with our SDR platform, which includes USRP motherboard, RFX 2400 daughterboard, GNU Radio and our spectrum sensing program. We can analysis the spectrum usage through this platform. As Figure 10 shows, the range of red frame is Channel 6 in the IEEE 802.11 standard, and it is known that Channel 6 is allocated from 2.422 GHz to 2.452 GHz in IEEE 802.11 from Table 2. When we start to download the file, the Power dB value will raise distinctly. We can comprehend that Channel 6 is used from this phenomenon

B. Digital Data Communication

The environment of our digital data communication is shown as Figure 11. Both two laptops are equipped our SDR platform and Linux based operating system (OS). The two laptops are named Host A and Host B respectively. The two hosts connect to the USRP devices through USB 2.0 and GNU Radio provides a simple Media Access Control (MAC) layer example to do the data connection. Finally, the virtual interface TUN/TAP [12] in our laptops will configure the USRP device as a virtual network interface, and then connect to another host through IP protocol to achieve the digital data communication experiment.

Table 2. The spectrum allocation of 802.11 channel plan

Channel ID	Central Frequency (GHz)
1	2.412 (2.397 GHz_2.427 GHz)
2	2.417
3	2.422
4	2.427
5	2.432
6	2.437 (2.422 GHz_2.452 GHz)
7	2.462 (2.447 GHz_2.479 GHz)



C. Figures and Tables

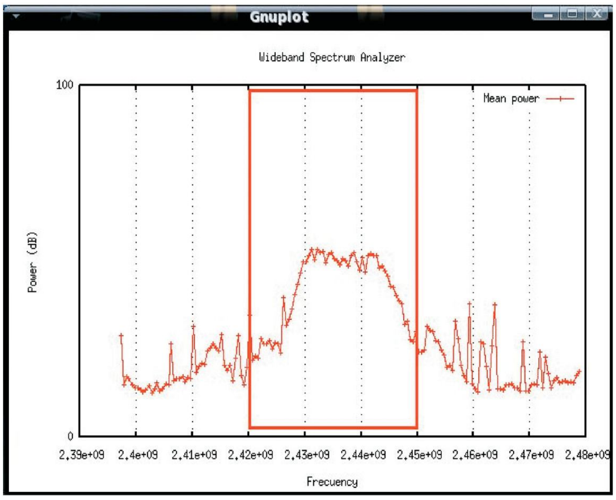


Fig 1. Spectrum Usage Status in 2.4 Ghz

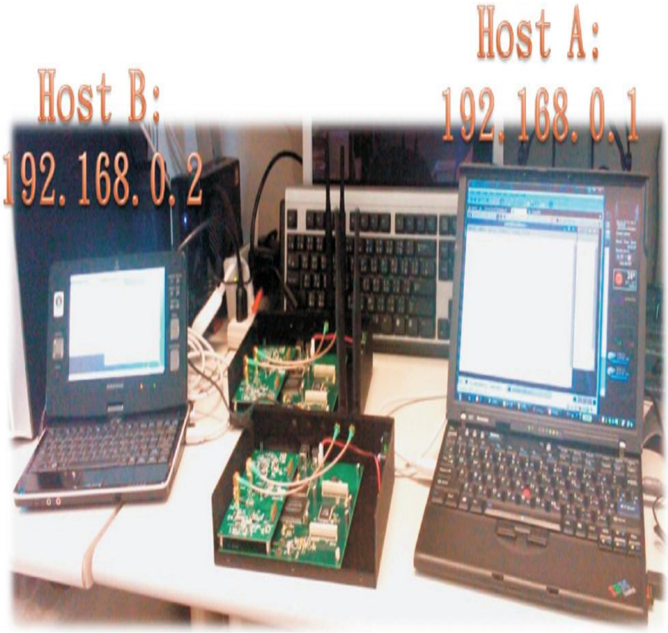


Fig 4.Hard Ware set up

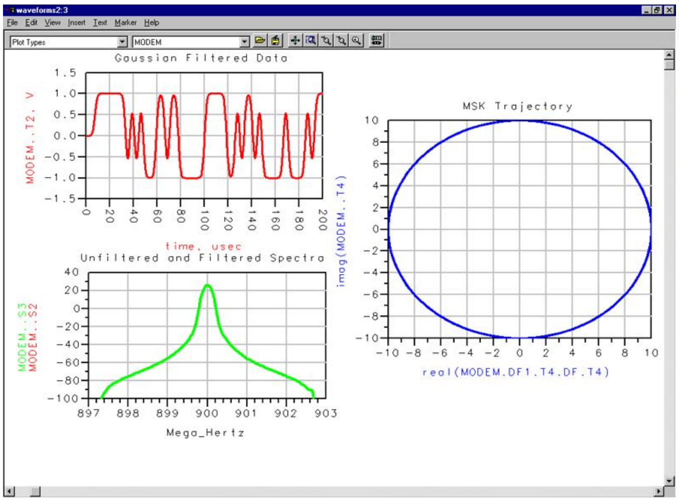


Fig 2. Receiver Output

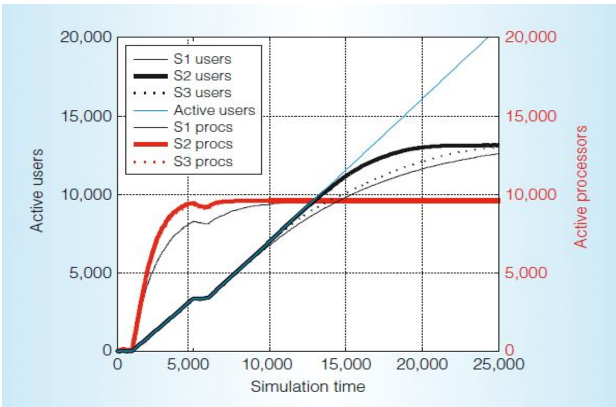


Fig 3.Simulation analysis

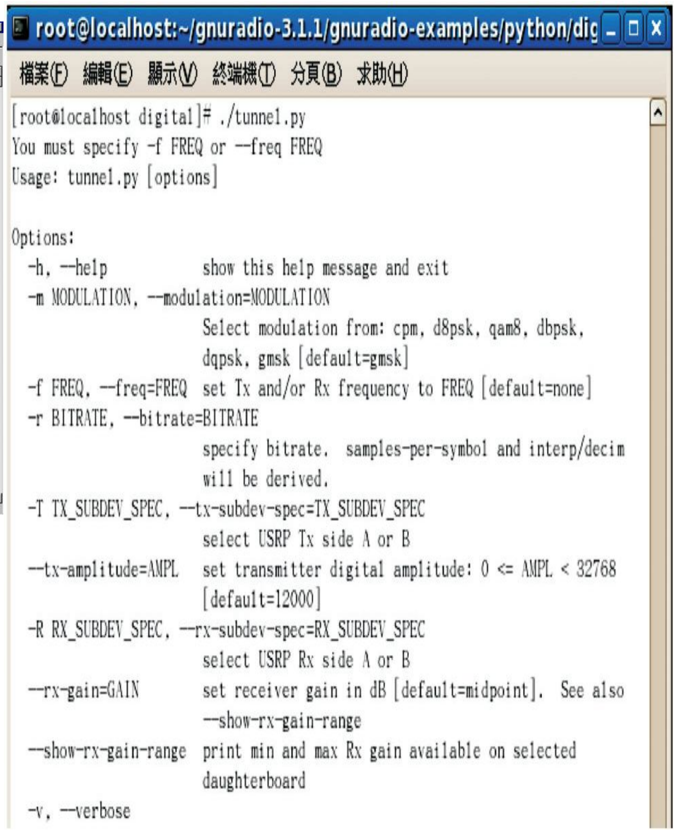


Fig 5.parameter configuration of USRP device

IV. Conclusions

We proposed and implemented a reconfigurable SDR platform by combing USRP and GNU Radio. Furthermore we realize digital data communication by applying SDR applications. In the scarce radio spectrum resource, we perform spectrum usage sensing at first. Then we find available spectrum holes to establish the digital data communication link to transmit the digital data. From the steps above, we can avoid the radio interference, which causes lower transmit performance, and provide an efficient wireless digital communication.

We also use the flexible feature of SDR to switch the communicational spectrum in our research. When the primary user or interference appears in the current frequency, we reconfigure SDR to do spectrum hopping. Thus, the spectrum band is feasible in our environment. In order to enhance spectrum utilization, we can adjust the working frequency to other available spectrum bands through SDR's reconfigurable capability. These functions are necessary conditions to accomplish the popular cognitive radio.

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