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OFDM Based Real Time Video Transmission Using USRP

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Abstract: Development in the wireless communication systems is the evolving field of research in today's world. The demand of high data rate, low latency at the minimum cost by the user requires many changes in the hardware organization. The use of digital modulation techniques like OFDM assures the reliability of communication in addition to providing flexibility and robustness. Modifications in the hardware structure can be replaced by the change in software only which gives birth to Software Define Radio (SDR): a radio which is more flexible as compared to conventional radio and can perform signal processing at the minimum cost. GNU Radio with the help of Universal Software Peripheral Radio (USRP) provides flexible and the cost effective SDR platform for the purpose of real time video transmission. The results given in this paper are taken from the experiment performed on USRP-1 along with the GNU Radio version 3.2.2.

Key words: OFDM · Software Define Radio · SDR · GNU Radio · USRP-1

INTRODUCTION

Advancements in the wireless communication systems are the major areas of research at the moment. The development includes the transfer of data, images, video etc. on the same medium which is being used for the voice transmission in the past decades. This imposes an additional capacity to the system and requires more comprehensive structure to be dealt with these types of signal processing. The modifications in the infrastructure might include the installation of new hardware like routers and switches etc. Another solution to this problem is to use the evolving technology of Software Define Radio (SDR): which requires change in the software only instead of hardware. It gives flexibility in the implementation process in addition to its cost effectiveness [1]. SDR can be implemented in the different environments like GNU Radio, Virtual Radio, OSSIE, Microsoft's Sora, IRIS etc. We choose GNU Radio environment for our real time video transmission.

GNU Radio is a powerful development tool and open source software to perform signal processing for the SDR [2]. In addition to the processing capabilities it has the added advantage of implementing spectrum analyzer, modulator/demodulator functions and error correction codes etc. Python language with the support of C++ is the master mind behind this development tool. The processing blocks are written in C++ and Python language is used to create a coordination link among these blocks [3]. The use of GNU Radio on different operating systems with the help of general purpose processors makes it feasible to effectively design wireless communication applications. Information regarding the documentation of GNU Radio block can easily be accessed from the website of GNU Radio, moreover it can be modified as per the user requirement.

The Universal Software Peripheral Radio (USRP) is a hardware device to support the GNU Radio software. It is developed by the Ettus Research Group, although its hardware is not free but the schematics/circuit diagram is open source and can be accessed easily [4]. USRP interlinks real and the digital world with the help of its architecture, which consists of a motherboard that can support different daughter boards. These daughter boards are used to implement the transmission/reception blocks of GNU Radio. The USRP device hosts Field Programmable Gate Array (FPGA) that can be reprogrammed, ADC/DAC and I/O ports. Universal Hardware Driver (UHD) is an open source software which acts as the driving force behind the operation of USRP [5].

Low latency, high date rate and spectral efficiency are the requirements in the case of transmitting multimedia applications. Orthogonal Frequency Division Multiplexing (OFDM) is a modulation scheme which proves effective

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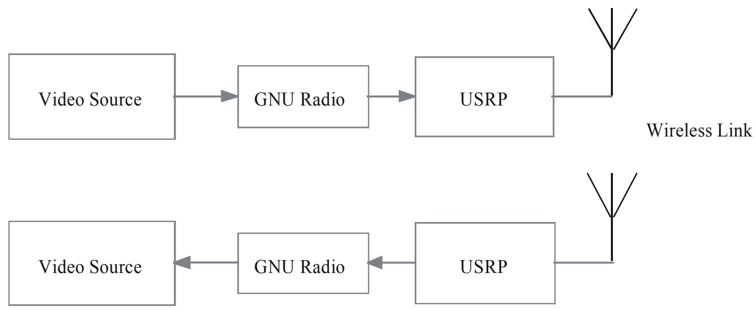

Fig. 1: Complete System Block Diagram

in this scenario and has the added advantage of tackling multipath effect. It is being used widely in the wireless standards like DAB, DVB-T and WiMAX IEEE 802.16 etc. In OFDM a wideband frequency selective channel is broken down into narrowband sub channels. Guard interval is incorporated between the symbols to mitigate the problem of Inter Symbol Interference (ISI). Addition of guard interval increases the symbol duration as compared to the delay spread and hence accounts for the ISI. Moreover it reduces the complexity of equalizer complexity by performing equalization process in the frequency domain [6].

System Overview: System model is broken down into three parts. First part discusses the complete system structure then a detailed architecture of GNU Radio will be explained followed by the USRP's insight view.

The overall system block diagram is shown in Figure 1. The input is a real time video source via webcam and is processed through the code written in python language using GNU Radio software. After this processing it is transmitted wirelessly on 2.45 GHz frequency using a USRP device. At the receiver end it is being received by the other USRP device which handovers the incoming information to the GNU Radio software. The video can be seen on the screen after the necessary manipulation of data.

GNU Radio is a software part of SDR. It works well on Windows with the help of Cygwin and MinGw and on Linux it is commonly used on Ubuntu, Fedora etc environment. We have used Ubuntu 10.04 for our experimental work. In GNU Radio we have two main parts commonly known as the Flow Graph and Block. The Block refers to the signal processing block and is written in the C++ language due to its better efficiency. There comes many signal processing blocks with the installation of GNU Radio which performs different functions like filters, modulation schemes, mathematical calculations, block codes etc. The users can also add different processing blocks written in C++ as per their own requirement. The Flow graph, as the name suggests, is used to create a flow between the processing blocks to perform a certain function. Flow graphs are built with the help of python language due to its flexibility and ease of programming. Simplified Wrapper and Interface Generator (SWIG) is an efficient tool in the GNU Radio which assures the compatibility among C++ blocks and the python language so that C++ classes can be used by python [7]. In this way GNU Radio exploits the benefits of both the languages and hence makes it a powerful tool for computation. The architecture of GNU Radio is displayed in Figure 2.

USRP Structure: Project implementation on GNU Radio environment can be performed by using USRP device. It is the hardware part of the SDR. USRP provides connectivity with the host computer through USB port or it can be via Ethernet port. Different types of USRP's are available depending upon the operating frequency and conversion capabilities, like USRP1, USRP2, E100 and B100 etc. We used USRP1 for our experiment work which has the frequency range of 2300 MHz to 2900 MHz with the step size of 4 MHz. This step size determines the frequencies on which you can operate e.g. if we choose to transmit on 2300MHz then the next transmitting frequency will be 2304 MHz accordingly. It has a RFTX power of 50 mW which is about 17 dBm with the bandwidth in the range of 1MHz to 33 MHz [8].

The USRP1 moduleis comprised of a mother board which processes the information and has four slots that supports four daughter boards which are used for transmission/reception. Motherboard act as the heart of the USRP and performs all the computational work like Analog to Digital and Digital to Analog Conversion, the conversion of baseband signal to the Intermediate Frequency (IF) stage, up/down conversion, decimation

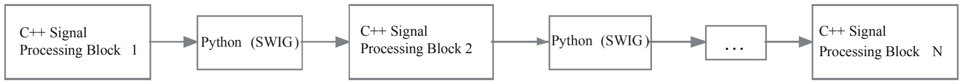

Fig. 2: GNU Radio Architecture

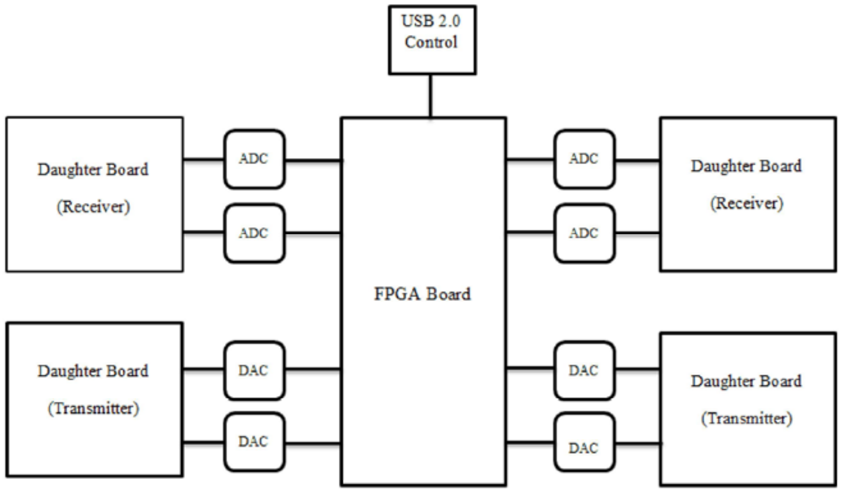

Fig. 3: USRP Structure

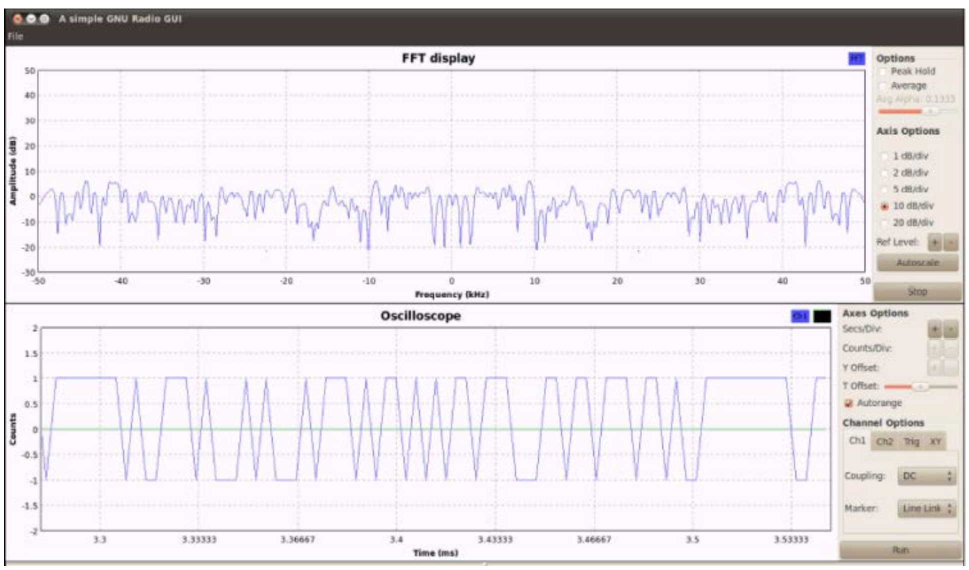

Fig. 4: Packet Data Generated via Camera

and interpolation etc. Mother board consists of four high speed 14-bit Digital to Analog Converters (DAC), which operates on the clock frequency of 128 Mega Samples per sec (MS/sec). It also includes four Analog to Digital Converters (ADC), which operates on the clock frequency of 64 Mega Samples per sec (MS/sec). Two Digital Up Converters (DUC) and four Digital Down Converters (DDC) are supported by the mother board which perform conversions accordingly. DAC and ADC are connected to the FPGA as shown in Figure 3. FPGA on the mother board is of type Altera Cyclone II [8], plays central role in mathematical computational work and perform complex digital signal processing in addition to control data rate to be compatible with the USB port rate. USRP is connected to the computer via USB port with the help of its USB drivers. USB version 2.0 is supported while the old versions like USB 1.x does not work properly. This USB port supports 32 MB/sec of data rate at a time with a bandwidth of 12 MHz for a real time data and about 6MHz for I/Q complex data, a report suggested. The complete structure of USRP is shown in Figure 3 [9].

Fig. 5: IFFT Output

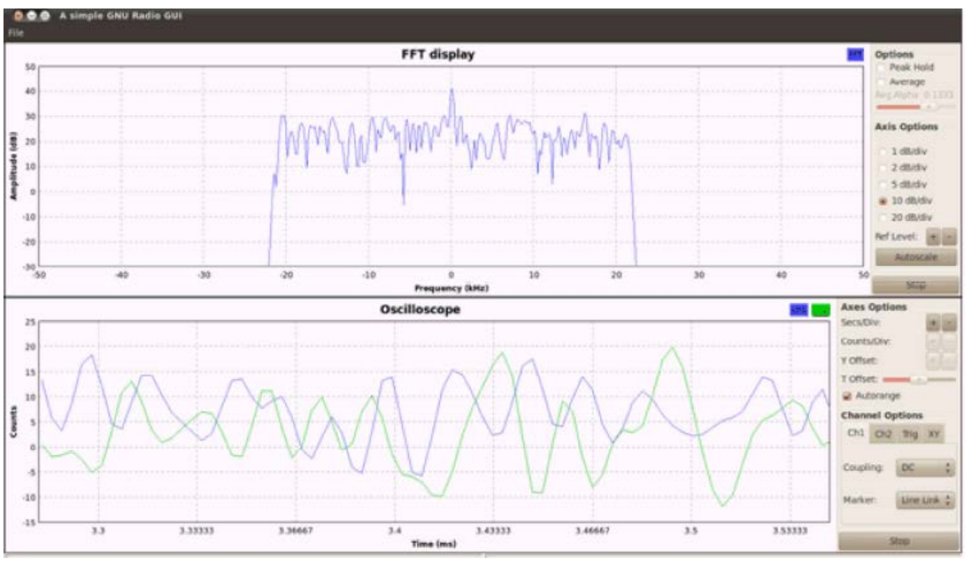

Fig. 6: Channel Filter Response at Receiver

USRP act as a transceiver device; two of the four daughter boards are used for transmission and remaining two is being utilized for the reception at a time. Due to these features it can be used to implement the Multi-input Multi-output (MIMO) systems efficiently.

Simulation Results: As mentioned earlier, OFDM is used in conjunction with GNU Radio and USRP to transmit real time video signal. Signals are shown hierarchically at different points by the help of python using FFT and scope plots. The data is generated using camera and the packets are made correspondingly. The data is in the form of 1's and 0's. Then this is modulated using BPSK modulation in our case. The symbols at the output of modulation block are shown in Figure 4.

Some known symbols are now added into this stream before going further with the system. These are used for synchronization purposes mostly and more commonly known as "Preambles". Preambles are considered to be the modulated symbols and their plots are much like in Figure 4.

This interleaved data with preambles are given at the input of an IFFT block. This is responsible for translating data into different carriers making a typical band of OFDM. This is shown in Figure 5.

The IFFT output is given to the CP adder block. Now the OFDM formulation is complete AND the data is now sent to USRP which is tuned at 2.45GHz. The corresponding receiving filter used just after the USRP is shown in Figure 6. It is a bit wider than that shown in Figure 5 to allow that signal while mitigating noise.

CONCLUSION

GNU Radio is quite helpful in real time implementation of live Video streaming. Correct use of blocks with python makes the job real easy. OFDM provides a robust data flow with a great grip OF ISI and ICI. Plots at different points are taken and corresponding change in parameters can be made to adjust the data in allocated bandwidth. Aforementioned OFDM uses orthogonal sub carriers to decrease BER, which can be further reduced in LTE-A under Carrier Aggregation. GNU Radio can be a good tool to implement it achieving much higher data rates covering a band of hundreds of MHz.

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