Integrating Software Defined Radio with USRP

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ABSTRACT

The USRP1 is the original Universal Software Radio Peripheral hardware (USRP) that provides entry-level RF processing capability. Its primary purpose is to provide flexible software defined radio development capability at a low price. You can control the frequency you receive and transmit by installing different daughter-boards. The authors’ USRP model had been configured to receive a signal from local radio stations in the DC, Maryland metropolitan area with the BasicRX model daughterboard. The programmable USRP was running python block code implemented in the GNU Radio Companion (GRC) on Ubuntu OS. With proper parameters and sinks the authors were able to tune into the radio signal, record the signal and extract the in-phase (I) and quadrature phase (Q) data and plot the phase and magnitude of the signal. Using the terminal along with proper MATLAB and Octave code, they were able to read the I/Q data and look at the Fast Fourier Transform (FFT) plot along with the I/Q data. With the proper equations, you could determine not only the direction of arrival, but one would also be able to calculate the distance from the receiver to the exact location where the signal is being transmitted. The purpose of doing this experiment was to gain experience in signal processing and receive hands on experience with the USRP and potentially add a tracking system to the authors’ model for further experiments.

KEYWORDS

FFT, GNU, GRC, Software Defined Radio, USRP

INTRODUCTION

What follows is a research report detailing the steps taken to apply SDR algorithms to USRP. One should be able to follow these steps with the specified set of hardware and software to get the same configuration on the proper USRP device. These projects were implemented under the supervision of NASA scientists and faculty advisors in dedicated NASA labs. Following lessons learned here and authors’ previous experiences in data visualization and signal processing research and training (SJ, JS, 1992, 2002, 2006, 2007, 2008, 2010, 2011, 2012) relevant labs were designed to enhance the Computer Engineering program at the Virginia State University (VSU).

In-phase (I) are the components of a waveform that have the same frequency and travel through time together. Quadrature phase (Q) are the components of a waveform that are 90° out of phase with the main, or in-phase, carrier. We have used the BasicRX Daughterboard (Figure 1) that is a low-cost daughterboard that can receive frequencies between 1-250 MHz. We chose to receive 93.9 WKYS radio station that is located in Silver Spring, MD. The radio station is approximately 15 miles away from NASA Goddard Space Flight Center (A, 2014), (M, 2014), (E, 2014).

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USRPs can be programmed to be a FM receiver if the right blocks in GRC are used. We wanted to know why and which blocks were being used and what purpose they served. We reconfigured a couple of sample programs in GRC. These included dial tones, sirens, and some other sounds. We experimented with the functions and parameters and studied the variations in output due to the changes in these parameters. That helped us understand a lot about the function blocks and their parameters.

METHODOLOGY

We programmed an FM receiver in GRC using the RFX2400 daughterboard

As shown in Figure 2, the USRP could receive clear radio signals from the targeted radio station. Then we switched the RFX2400 daughterboard to the FLEX900 daughterboard, and we started receiving radio signals. The FLEX900 daughterboard receives frequencies around 750MHz; whereas, FM radio frequencies only range from 88MHz to 108MHz. Then we took out the FLEX900 daughterboard and put in the BasicRX daughterboard because it is supposed to read frequencies that are actually in the range. The BasicRX receives frequencies ranging from 1MHz to 250MHz. We found that the BasicRX works with our program and received radio signals and outputted them to the soundcard like we expected. The FFT plots of the radio signals without the antenna and with the antenna are shown in Figures 3 and 4. The Google Doc shown in Figure 5 explains what each block did and how it worked.

The next step was to get the I/Q data from the signals we were receiving. I/Q data show the changes in amplitude and phase of a sine wave. These changes can then be used to encode information upon a sine wave, which is a process called modulation. We saved the I/Q data as a binary file. We opened the file in Ubuntu using the terminal and programmed Octave, to plot the I/Q file and the FFT of the data (Figure 5). We then sampled the I/Q data from different radio playbacks. We plotted the I/Q data showing their slow response time and the peaks (Figures 6 and 7, 8).

The next step was to repeat this experiment at three different locations around the GSFC campus so that we could triangulate the data to calculate direction of arrival of the signal. I/Q data shows the changes in magnitude (or amplitude) and phase of a sine wave. The resulting carrier signal changes between 2 distinct frequency states. Each frequency state represents the high and low state of the message signal. If the message signal were a sine wave, there would be a more gradual change in frequency, which would be more difficult to see. If only the carrier sine wave amplitude changes with respect to time, we should see changes in the I/Q plane only with respect to the distance from the origin to the I/Q points. We can control the amplitude, frequency, and phase of a modulating RF carrier sine wave by manipulating the amplitude of the separate I and Q input signals. When you modulate a carrier with a waveform that changes the carrier’s frequency, you can treat the modulating signals as a phasor. It has both a real (I) and imaginary (Q) part. I/Q plane shows 2 things:

1. What the modulated carrier is doing relative to the unmodulated carrier.
2. What baseband I and Q inputs are required to produce the modulated carrier.

CONCLUSION

The frequency we chose to receive was 93.9 MHz. We received transmission from 3 different locations with latitude, longitude, time, and the compass information. By moving away from different locations from which measurements were made and listening to the radio station as it faded away, we could confirm that the radio station transmitting at 93.9 MHz was located in the South-Southeast direction. Due to constraints, such as power supply for USRP we could not pick up data from locations far away from each other and as a result the latitude and longitude barely changed when we changed locations. The project has been a great learning and research experience for students involved. While
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