Implementing Software Defined Radio – a 16 QAM System using the USRP2 Board

Functional Requirements List and Performance Specifications

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Introduction

Radio systems exist in many facets of our daily life. In a wide range of applications, such as cellular telephones, global positioning systems, and military grade communications, it is challenging to keep up with the ever-increasing demands and the growing technologies. Software Defined Radio (SDR) has the promise to revolutionize the way of building communication systems. It has flexibilities in regards to cross-functionality and ease of modifications and allows for digital communication systems to easily adopt more sophisticated coding and modulation technologies in a cost-effective way. SDR takes what used to be ingrained physically within the radio and provides a variety of hardware and software alternatives that add more flexibility and functionality. This project is looking to embody this definition by using the USPR2 board and show the benefits of SDR by implementing a 16-QAM system.

Objective

The project aims to implement a 16-QAM communication system using two USRP2 boards. This will demonstrate the power, flexibility, and advantage of SDR. The progressive goals of the project are listed as follows.

1. Design16-QAM transmitter and receiver modules using GNU Radio companion (no USRP2 board is used at this point).
2. Add simulated noise resources to the communication channel within the prior system to introduce fading and multipath effect.
3. Design Phase-locked-loop (PLL) circuit to fully recover the transmitted data at the receiver end.
4. Explore the capabilities of GNU radio and boards by small side projects such as an FM receiver in order to more fully encompass the capabilities and span of SDR.

It is believed that a clear justification can be made on the practicality and usability of SDR by comparing the results of these systems and their ease of construction with previously completed projects without using SDR.

High Level Block Diagram

Figure 1 shows the block diagram of system that shall be implemented within the final objective. As can be seen, the entire communication system is software-based and only the ADC/DAC and RF are hardware-based. The 16-QAM system or other systems can be quickly changed through programming the Spartan3-2000 FPGA device on a USRP2 board. The BasicTX and RX daughter boards are available for the receiving and transmitting ends.

Transmitter (RF front end) Receiver (RF front end)

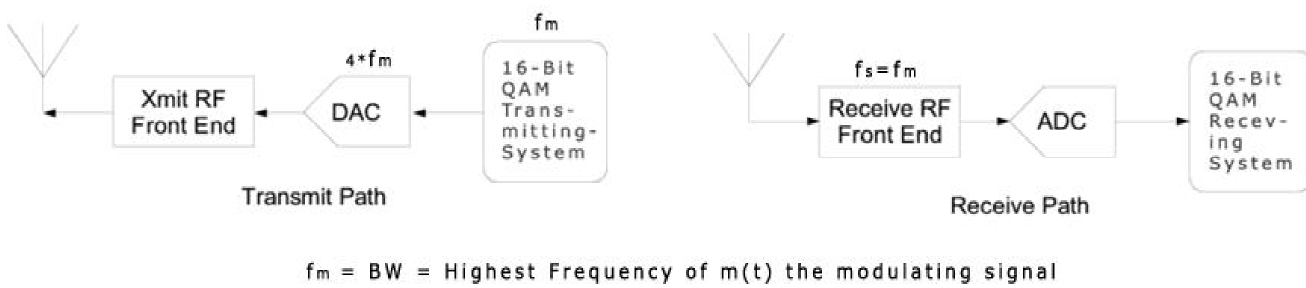

Figure 1. Software defined radio block system

Functional Requirements

This system shall able to transmit and receive within the frequency range of the Basic TX and RX daughterboard which is 1 MHz to 250 MHz. The signal that shall be generated or acquired via the receiver or transmitter will be sent through the ADC or DAC. The signal is then processed inside the 16 QAM system. The frequency f_m depends on the type of signal sent and stands as the frequency of the modulating signal m(t), which qualifies as the bandwidth. This is the frequency that modulates the information signal, m(t), onto the carrier signal. The DAC inherently upsamples by a factor of 4 to acquire more accurate readings and the ADC then samples at f_m, which effectively downsamples the signal by 4, thereby retrieving the original frequency f_m. The carrier frequency f_c shall be at least 4 times smaller than the USRP2 overall system clock, which is 100 MHz. As a result the f_c maximum value shall be 25 MHz.

The 16 QAM system has the following constraints. The sampling frequency of the receiving system shall be greater than or equal to twice the bandwidth, or twice f_c to satisfy Nyquist's Theorem. The QAM system shall minimize bit error rate. Once success has been reached on transmitting a variety of signals (random bit stream, picture, audio), flexibility and system performance shall be tested by introducing multipath effects. This shall test the strength and breadth of the phase locked loop in the QAM system.

Software and Equipment List

1. Two USRP2 Boards – Offers a Xilinx Spartan 3 2000 FPGA,14-bit AD and 16-bit DA converters, digital up/down converters, gigabit Ethernet interface, external memory, and SD card.
2. BasicTX and Basic RX Daughterboards – Gives access to all of the signals on daughterboard interface and provide AD/DC outputs with no mixers, filters, or amplifiers.
3. GNU Radio – an open-source software development similar to Simulink in nature whose applications are written in Python and the signal processing paths implemented in C++.
4. Python Interpreter – a software to write and debug code written in Python.\
5. Ubuntu – Version 8.04 or greater will provide the operating system required for GNU Radio and the USRP2 to function properly.

Summary

This project requires a great amount of new, unfamiliar software which may prove to be one of its biggest challenges. As familiarity increases with GNU radio, Python, the USRP2 and it's daughterboards, more specifics in regards to particular bandwidths, baud rates, ACD/DAC conversions, and power, more detail-oriented objectives will be able to be made. Regardless, this project will promote insight and instill education benefits of SDR.

References

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[2] Couch, Leon W. *Digital and Analog Communication Systems*. Upper Saddle River, NJ: Pearson Prentice Hall, 2007. Print.