STEVENS INSTITUTE OF TECHNOLOGY

SDR Amateur Repeater

Functional Description

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This document provides a basic functional architecture (block diagram) description for the development of a Software Defined Amateur Radio Repeater. It was developed during the Spring 2011 semester as a part of the Engineering Design program at Stevens Institute of Technology, and provides detailed information about the hardware and software stages necessary for implementation

Contents

Team Member Responsibilities

Erik Thompson:
- Baseband Processing

Matt Schurmann:
- IF Subsection
- Website – http://personal.stevens.edu/~mschurma/d6

Scott Curtis:
- System-level Overview

Jon Pirog:
- RF Subsection

Collective Effort:
- Block Diagram

Introduction

Having done some extensive research into the requirements and practical considerations of an SDR-based repeater - it is important to have an idea of what *functions* the different components of the system will need to have, rather than moving directly into hardware/software implementation. This report is meant to explain in some detail, the functional block diagrams for the system found in the attachments section of this report.

System-Level Overview

The system is defined as a software-defined amateur radio repeater. Implementation of both hardware and software is required for the overall system to function to specifications and design parameters. The hardware sub-systems are in charge of the physical reception and transmission of any relevant signals. In addition, they are responsible for converting the signal into data that can be utilized by the baseband processing portion of the system. The hardware subsystem will modify the baseband processing output in order to prepare the signal for transmission.

The baseband processing sub-system is responsible for the user input and is the key component to the SDR system. The sub-system is responsible for the modulation and demodulation of the baseband signal in addition to managing tone access. The user input is responsible for manipulating the tone frequency; transmit power, transceiver frequency, and transceiver bandwidth. These parameters are processed through software which limits the amount of hardware exchange in order to change the input and output parameters of the system. All of the sub-systems congeal to create a repeater with a software-defined foundation with auxiliary hardware support.

RF Subsection

Antenna: Antennas transmit and receive RF (radio frequencies) with sufficient power and sensitivity on many frequencies, time frames, and spatial areas. An SDR antenna system must provide sufficient diversity for transmission and receive a wide range of frequencies and in many different environments. Much design time needs to be dedicated to implementation of duplexing and wideband antenna/antenna array system development. The antenna is solely connected to a duplexer in this SDR implementation.

Duplexer: Duplexers allow bi-directional (duplex) communication over a single channel. A duplexer must be designed for operation in the frequency band used by the receiver and transmitter, and must be capable of handling the output power of the transmitter. A duplexer must provide adequate rejection of transmitter noise occurring at the receive frequency, and must be designed to operate at, or less than, the frequency separation between the transmitter and receiver. A duplexer must provide sufficient isolation to prevent receiver desensitization. The duplexer will be communicating two separate signals to and from the RF filters to the antenna as shown in the diagram.

RF Filter: Radio frequency (RF) filters represent a class of electronic filter, designed to operate on signals in the megahertz to gigahertz frequency ranges. This frequency range is the range used by most broadcast radio, television, wireless communication (cellphones, Wi-Fi, etc...), and thus most RF and microwave devices will include some kind of filtering on the signals transmitted or received. Such filters are commonly used as building blocks for duplexers and diplexers to combine or separate multiple frequency bands. In the scope of this project, a band-pass filter is a type of RF filter that passes frequencies within a certain range and rejects (attenuates) frequencies outside that range.

LNA and PA: Very important to the system performance, is the addition of a low noise amplifier (LNA) and power amplifier (PA). On both the receiver and transmit sides, power amplification will be required – as received signals are generally low-power due to path losses, and for power concerns, is impractical/unnecessary to operate the entire system at enough power to transmit over a wireless channel. Most importantly, the LNA selected will need to be very linear, and have a considerably low noise figure. Amplification may generally be completed in multiple stages, especially at the transmit side, where linearity, and gain are equally important to system performance.

RF Mixer and Software LO: The functionality of the RF mixer is to mix the amplified analog signal down to a lower frequency before it can be sampled practically. Very high speed ADC modules will be prohibitively expensive in the RF regime, so a variable mixer is used to convert the signal to a more manageable frequency for ADC/DAC. The local oscillator (LO) used for mixing, can be controlled with software.

IF Subsection

The IF stage of an SDR system is where the RF signal that received/transmitted must make the transition from the digital to the analog realm on the transmit side, and vice versa on the receiver side. The SDR paradigm dictates that as much of the radio's function as possible should be implemented in software – necessitating digitization, even though the actual end-user functionality of the radio is analog (RF).

The IF section is notable for the fact that it places quite a number of practical constraints, and necessitates a number of trade-offs for an SDR system design. Analog and digital conversion technologies are not yet sufficiently fast, cheap, and accurate enough to adequately sample RF communications in a practical manner. These constraints require the use of a mixer in the RF subsection to decrease the operating frequency of a signal prior to analog/digital conversion, so that some of these requirements can be relaxed a bit.

In addition to the use of a mixer to relax ADC/DAC constraints, a digital conversion stage is also necessary to synchronize the signal to the operating frequency of the baseband section.

Baseband Processing

In the baseband processing stage of the repeater, the first module is the demodulation of the signal. The demodulated signal is then fed to both the tone access module and the modulation module. The tone access module looks at the demodulated signal for a constant tone at a certain sub-audible frequency. If this tone is present, the tone access module enables the modulation module. If the modulation module is enabled, it modulates the signal.

The bandwidth occupied by this new signal is controlled by the user interface, which also controls the tone access frequency, transmit and receive frequencies, as well as the transmit power.

SWOT Analysis

The SWOT analysis points here are listed in addition to those from previous reports, for the sake of brevity, they have not been repeated.

Strengths/Opportunities:

- The architecture of the project is now pretty well-defined
- Hardware components needed to implement the block diagrams will not be overly hard to come by

Weaknesses/Threats:

- Some serious thought will be needed to decide about hardware for the baseband section for the next report.
- A method of software tuning hardware components such as filters and amplifiers will need to be devised

References

This report mainly references information collected in previous reports through research of journal articles, book chapters, and online resources.

Attachments

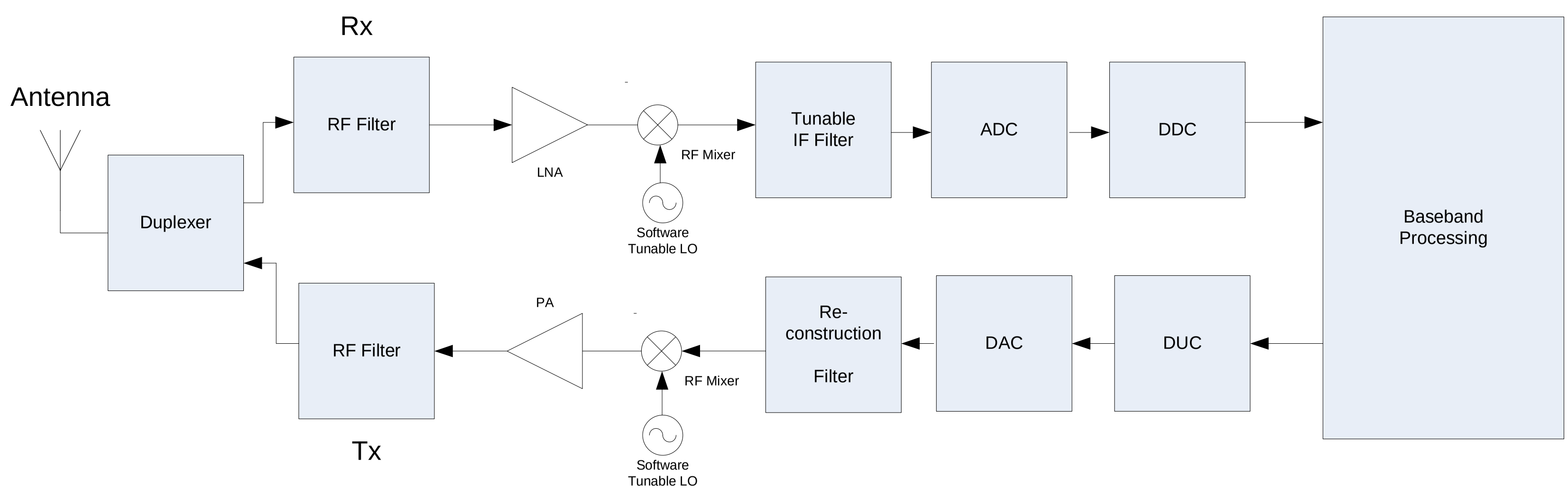
Project Website:

http://personal.stevens.edu/~mschurma/d6

Functional System Block Diagram:

(see next page)

RF and IF Sub-Systems



Baseband Processing Sub-System