Introduction

The purpose of this laboratory is to introduce the use of a software defined radio (SDR), specifically the ADALM-PLUTO (PlutoSDR), and apply the PlutoSRD to analyze the spectrum of a commercial HDFM signal. In this laboratory, the PlutoSDR will be used to observe, acquire, and process real-world RF signals. Students will learn how to configure receiver parameters such as local oscillator frequency, sampling rate, and RF bandwidth. They will also examine signals in the frequency domains and relate the observed spectra to the underlying communication theory developed in class.

The PlutoSDR is a low-cost, portable Software-Defined Radio (SDR) platform developed by Analog Devices for education, experimentation, and rapid prototyping of wireless communication systems (see https://wiki.analog.com/university/tools/pluto). Unlike traditional radios, where signal processing functions are implemented in dedicated hardware, an SDR performs many radio functions using DSP. This flexibility allows a single device to be configured for a wide range of applications including AM, FM, digital communications, spectrum analysis, radar experiments, and wireless networking.

ADALM-PLUTO is based on the AD9363 radio-frequency transceiver, which integrates RF circuitry, analog-to-digital converters (ADCs), digital-to-analog converters (DACs), and digital signal processing hardware on a single chip. The transceiver can both transmit and receive radio signals, enabling full experimentation with modern communication systems.

In receive mode, the PlutoSDR converts an RF signal captured by its antenna into digital in-phase (I) and quadrature (Q) samples. These complex baseband samples contain all of the information present in the received signal and can be processed using digital signal processing techniques to extract audio, data, or other information. In transmit mode, digitally generated I/Q samples are converted to RF signals and radiated by the transmitter.

The ADALM-PLUTO connects to a host computer through a USB interface and can be controlled using software tools such as:

IIO Scope

MATLAB/Simulink

GNU Radio

Python

C/C++

Custom embedded applications

By the end of this experiment, students should understand how a modern software-defined radio receives and processes RF signals, how I/Q samples represent a band of frequencies

around a selected center frequency, and how digital signal processing techniques can be applied to analyze wireless transmissions.

While the detailed structure of the PlutoSDR is complex, a high-level view of the receiver in the PlutoSDR is shown below.

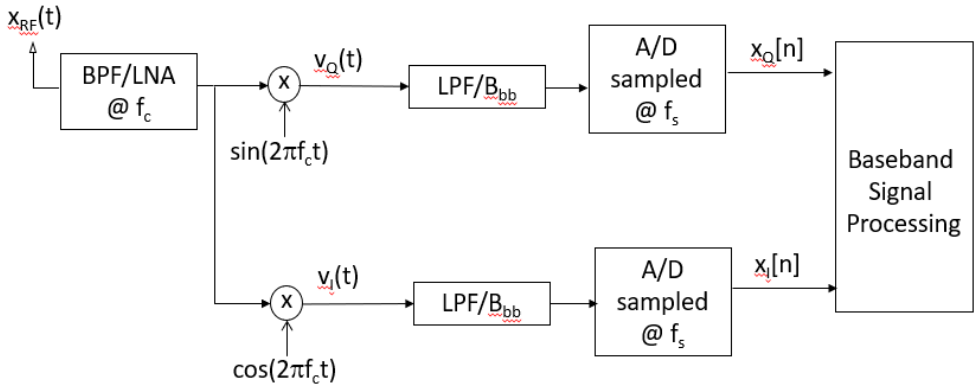

Figure A.8.1: SDR w Zero IF Architecture

A.8 – PlutoSDR

8.1 Experimental Setup for PlutoSDR



Figure A.8.2: SDR setup.

7.2 Laboratory Exercise for PlutoSDR

i. Connect the PlutoSDR to the PC as shown in Figure A.8.2.

ii. Confirm that the PlutoSDR is operating in extended frequency mode. Explain why the PlutoSDR must be in extended frequency mode.

a. Open a command window on the PC.

b. Log into the PlutoSRD by typing "ssh root@192.168.2.1". The password is analog. If you get a WARNING: REMOTE HOST IDENTIFICATION HAS CHANGED! Then type in ssh-keygen -R 192.168.2.1.
c. When to see "Are you sure you want to continue connecting (yes/no/[fingerprint])?" type in yes, then enter the password-analog.
d. To check mode input "fw_printenv compatible", if it responds "compatible=ad9364" then the PlutoSDR is in extended frequency mode.
e. If it is not in extended frequency mode type "fw_setenv compatible ad9364". The type reboot and check the mode again.

iii. Open the ADI IIO Oscilloscope and click on AD936X

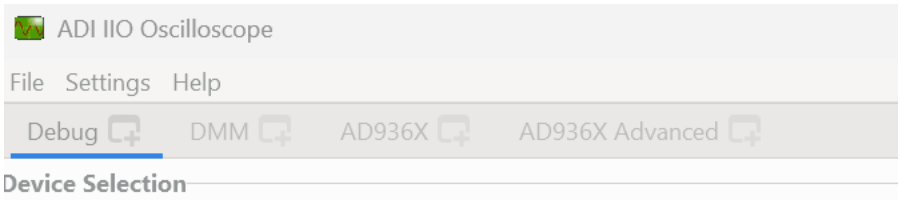

Figure A.8.3: Select AD936X

iv. In the ADI IIO Oscilloscope set the RF Bandwidth Sampling rate, RX LO, and RF Port select as shown below. Relate these parameters to the SDR with Zero IF Architecture shown is in Figure A.8.1.

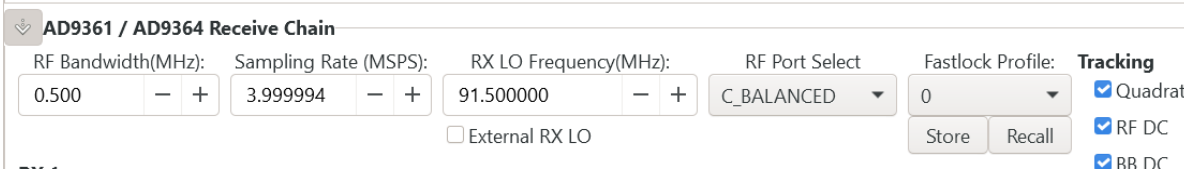

Figure A.8.4: Select Receiver Parameters

v. In the ADI IIO Oscilloscope set Gain Control Modes: to slow_attack.

vi. Open the ADI IIO Oscilloscope-Capture. Disable the capture by making sure the arrow in the top buttons is not red. You can only switch between time and frequency domain mode and change some parameters when the capture is off. When you click the arrow it will turn red and the signal capture is on.

vii. Open the ADI IIO Oscilloscope-Capture, set Plot type to Frequency domain FFT size to 16384, Window to Boxcar, Average to 5. Turn on the capture.

viii. Take a screen shot of the spectrum. Confirm that this is an HDFM spectrum. This is the spectrum of what radio station, give its call letters.

ix. Change the Average to 1 and take a screen shot of the spectrum. And explain the impact of changing the averaging.

x. Stop the capture and change the FFT size to 512, take a screen shot of the spectrum. And explain the impact of changing the FFT size.

xi. Stop the capture and change the RF Bandwidth to 2 MHz with FFT size set back to 16384. Take a screen shot of the spectrum. And explain the impact of changing the RF Bandwidth. Also discuss the impact of changing the filter on the spectrum of the transmitter at 90.7 FM (KJHK). JKHK is the student-run campus radio station from the University of Kansas featuring variety, local music, and specialty shows.

xii. With the RF Bandwidth set to 2 MHz with FFT size set to 16384 change the sample rate to 16 MSPS. Take a screen shot of the spectrum. What is the displayed range of frequencies. Explain the impact on the spectrum of changing the sample rate.