LAB 2: INTRODUCTION TO NI RF HARDWARE

I.   OVERVIEW

The objective of this laboratory session is to introduce the National Instruments (NI) radio frequency (RF) hardware and how to operate it using LabVIEW software. NI RF hardware is called as Universal Software Define Radio Peripheral (USRP).

USRP is a programmable radio hardware which can be controlled by a standard computer.

In the first part of this lab, we build a transmitter virtual instrument (VI) that is capable of communicating with the USRP hardware in order to send a constant sinusoidal signal at a defined carrier frequency. In the second part, we build a receiver virtual instrument (VI) that is capable of communicating with the USRP hardware in order to receive the signal which is sent by the transmitting USRP.

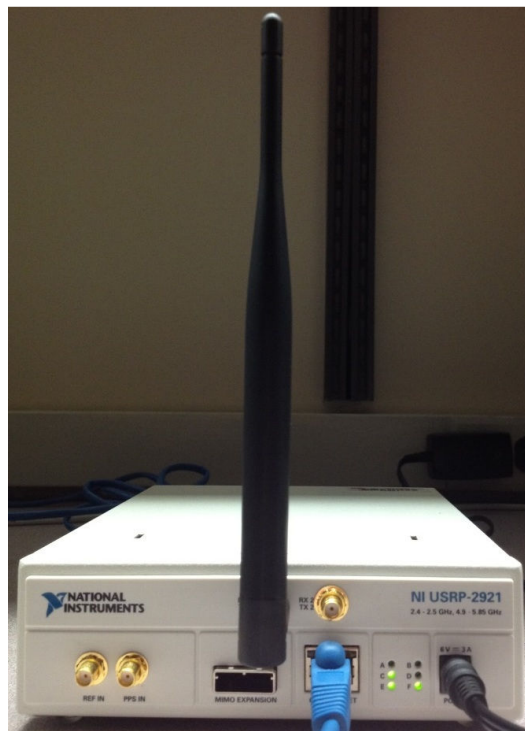A photo of the NI USRP hardware is shown in Fig. 1 below:

Fig. 1 – Photo of the NI USRP hardware

Wireless communication link has two main parts: Transmitter and receiver. The information sent via the transmitter unit is detected and estimated in the receiver side.

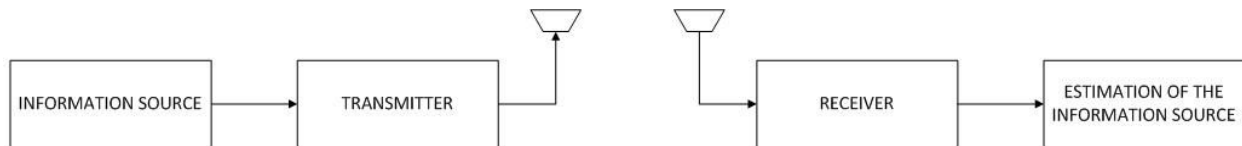A representation of a basic communication system is given in Fig. 2 below:

Fig. 2 – A representation of a basic communication system

We have a USRP connected to a PC with NI LabVIEW program as our transmitter and another USRP also connected to a PC with NI LabVIEW program as our receiver.

A representation of the USRP communication link is given in Fig. 3 below:
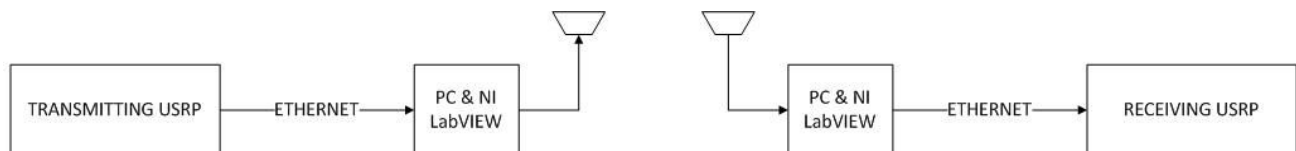

Fig. 3 – A representation of the USRP communication link

PART-1: TRANSMITTER

Information source illustrated in Fig. 2 can send any type of digital data (audio, video, text, etc). Transmitter converts the digital data into an RF that can be transmitted through the wireless channel.

Our USRP communication link consists two parts: PC&LabVIEW and USRP hardware. Transmitting PC performs the baseband processing, then transmitting USRP upconverts the baseband signal to the carrier frequency in order to obtain the passband signal to be transmitted.

Upconversion is necessary to increase the signal frequency to the range that is suitable for wireless transmission.

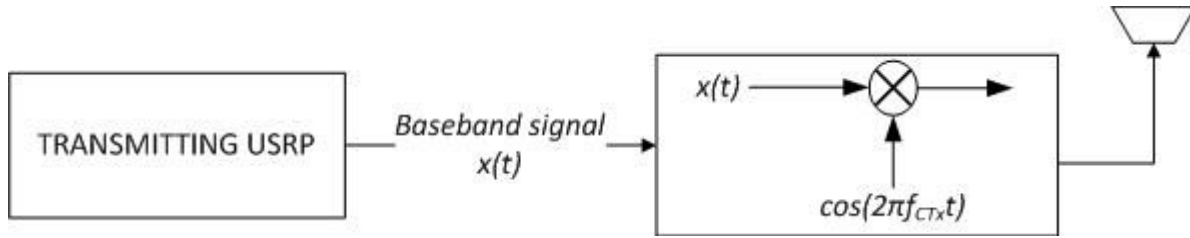Basic representation of the upconversion process is shown in Fig. 4 below:

Fig. 4 – Basic representation of the upconversion process

PART-2: RECEIVER

Receiver detects the RF signal which is sent by the transmitter and estimates the original digital data.

Similar to the transmitting process, receiving USRP downconverts the received passband signal then the receiving PC performs the baseband processing.

Downconversion is necessary to reduce the signal frequency to the range that is suitable for signal processing.

Basic representation of the downconversion process is shown in Fig. 5 below:
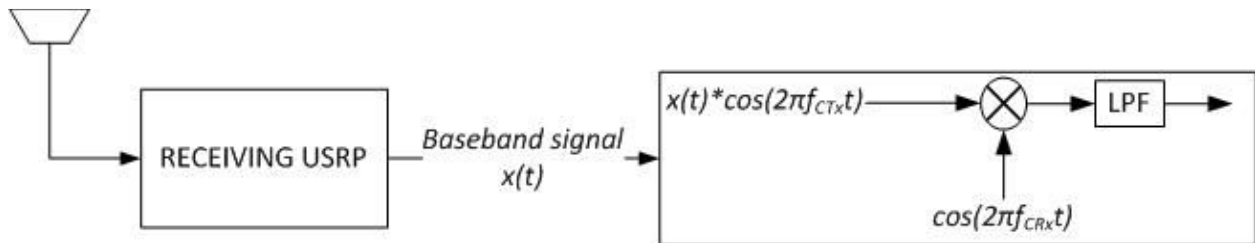

Fig. 5 – Basic representation of the downconversion process

As represented in Fig. 6 and Fig. 7, carrier frequencies of transmitter and receiver (respectively, f_{CTx} and f_{CRx}) are slightly different due to hardware imprecision.

Frequency offset occurs because of this difference between carrier frequencies. Mathematical expression is given in (1.1) below:

$$x(t)*\cos(2\pi f_{CTx})*\cos(2\pi f_{CRx}) = \frac{x(t)}{2}\left[\cos(2\pi(f_{CTx}-f_{CRx})t)+\cos(2\pi(f_{CTx}+f_{CRx})t)\right] \quad (1.1)$$

The received signal after low pass filter (LPF) is given in (1.2) below:

$$\hat{x}(t) = \frac{x(t)}{2}\left[\cos(2\pi(f_{CTx}-f_{CRx})t)\right] \qquad (1.2)$$

As it is clear, frequency offset is the difference between transmitter and receiver carrier frequencies which is given in (1.3) below:

$$f_{OFFSET} = f_{CTx} - f_{CRx} \tag{1.3}$$

Now, (1.2) becomes:

$$\hat{x}(t) = \frac{x(t)}{2}\cos(2\pi f_{OFFSET}t) \tag{1.4}$$

BASEBAND AND PASSBAND SIGNALS

Basic frequency domain representation of a baseband signal is given in Fig. 6 below:
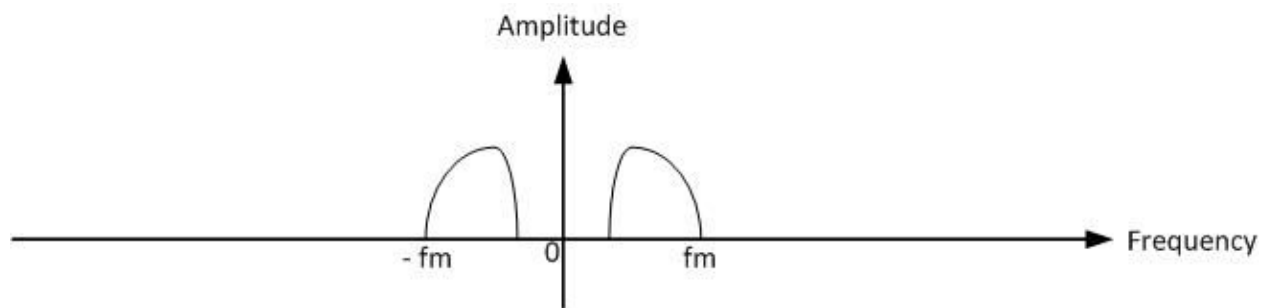
Fig. 6 – Frequency domain representation of a baseband signal

Basic frequency domain representation of a passband signal is given in Fig. 7 below:
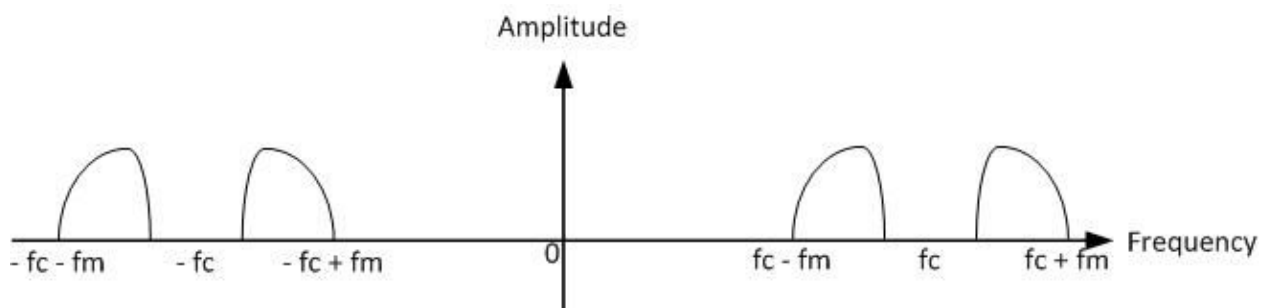
Fig. 7 – Frequency domain representation of a passband signal

The baseband signal $x(t)$ is a discrete signal. Sampling period (time between two consecutive samples) is also known as IQ period, T_{IQ}. IQ rate (or IQ frequency) is calculated as $\dfrac{1}{T_{IQ}}$.