

EE3209 - Communications Laboratory

Lab Manual

California State University, Los Angeles
College of Engineering, Computer Science, and Technology
Department of Electrical and Computer Engineering



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Lab 1: Introduction to USRP

Objective:

The purpose of this introductory laboratory exercise is to ensure that students have a working installation of LabVIEW on their computers and know how to connect to the USRP radio.

Introduction:

The Wireless Innovation Forum defines Software Defined Radio (SDR) as a “Radio in which some or all of the physical layer functions are software defined.” [1] SDR refers to the technology wherein software modules running on a generic hardware platform are used to implement radio functions. In this lab, we will use the software reconfigurable RF hardware called Universal Software Radio Peripheral (USRP) from National Instruments (NI), and combine it with the LabVIEW software in order to create a flexible and functional SDR platform for rapid prototyping of wireless signals. This rapid prototyping designs include physical layer design, record and playback, signal intelligence, algorithm validation, and more.

Pre-Lab:

Prior to beginning this lab, every student is expected to have LabVIEW installed on their laptops and familiarize themselves with its features using the information and tutorials provided in previous sessions.

NI USRP Hardware:

The NI USRP-2922 is the hardware being used in this lab and can be easily configured and controlled using computer and the LabVIEW software. Figure 1 shows how the basic communication system is configured between the computer and the USRP. Since the Base Band (BB) signals are suitable for transmitting over RF channel and equipment, so the TX data, which are either analog (like sound) or digital (like bits), are converted to BB signals by computer using the software (e.g. MATLAB or LabVIEW in this lab), and the results (BB I/Q signal samples) are passed to the transmit RF equipment (USRP) over the Ethernet gigabit cable with 16 bits of resolution and at up to 25 MS/sec sample rate.



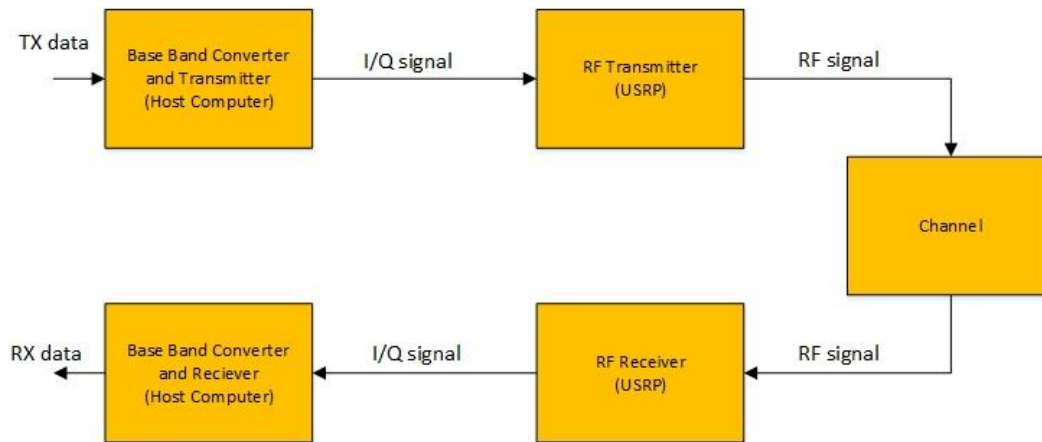


Figure 1: Basic Communication System Using NI-USRP

As the transmitter, the USRP hardware interpolates the incoming signal to a higher sampling rate using a Digital Up Conversion (DUC) process and then converts the digital signal to analog with a Digital to Analog converter (DAC). The resulting analog signal is then mixed up with the specified carrier frequency and sent over the channel.

At the receiver, the incoming signals are mixed down using a direct-conversion receiver to BB I/Q components, which are sampled by an Analog to Digital Converter (ADC) at 100 MS/sec. The digitized I/Q data follows parallel paths through a Digital Down Conversion (DDC) process that mixes, filters, and decimates the input signal to the user-specified rate. The down converted samples are passed to the host computer over the Ethernet gigabit cable. Figure 2 shows the detailed architecture of NI USRP.

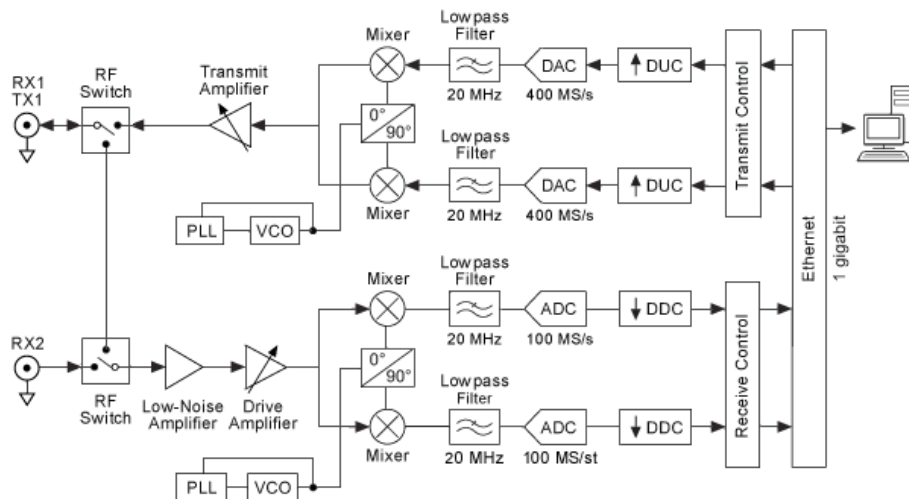


Figure 2: USRP-2922 Block Diagram



Note that the NI USRP-2922 has one transmitter (TX1) and two receivers (RX2), so if you're using the USRP-2922 as the transmitter, you must use the TX1 channel but if you intend to use it as a receiver, you can select either RX1 or RX2 as the receiver channel.

Lab Procedure:

Every team is given a kit containing the required components to do the experiments. Each team must follow the procedure in this manual and perform the experiment step-by-step. At the end, each team is supposed to provide a report based on the experiment covered in this session.

The Kit Contents:

Every team is given the following devices and materials:

1. One NI USRP-2922 and a power supply
2. Shielded Ethernet cable
3. SMA (m)-to-SMA (m) cable
4. 30 dB SMA attenuator
5. Two antennas
6. A LabVIEW VI
7. A .WAV sound track

Setting up the hardware:

As it's mentioned, the device communicates with the host computer over gigabit Ethernet cable. The students need to follow the following steps if they intend to use their personal laptop or computer. Setting up the IP on CSULA laptops have already been done by the lab technician.

First you need to set up the network to establish the communication. The default IP address for the NI-USRP-2922 is **192.168.10.2** so you need to configure the host Ethernet interface on the host computer in a way to establish the communication:

1. Go to Control Panel > Network and Internet > Network and Sharing Center
2. At the left menu bar select **Change adapter settings**.



3. Find the **Ethernet** icon, right click on it and go to **Properties**
4. Select **Internet Protocol Version 4 (TCP/IPv4)** and click on **Properties** and specify the static IP address using the Table 1 settings.

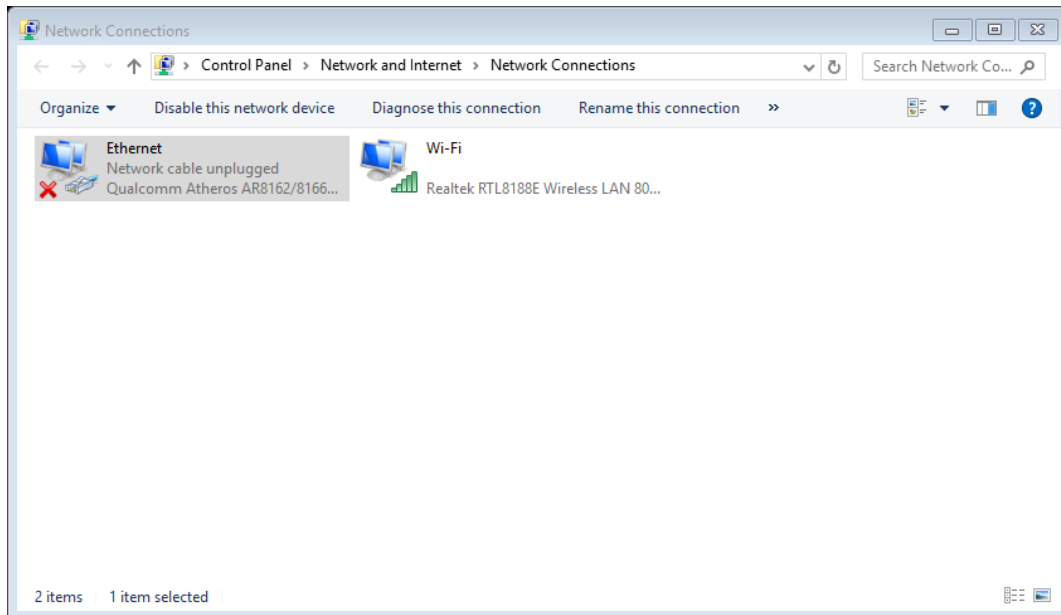


Figure 3: Network Connections

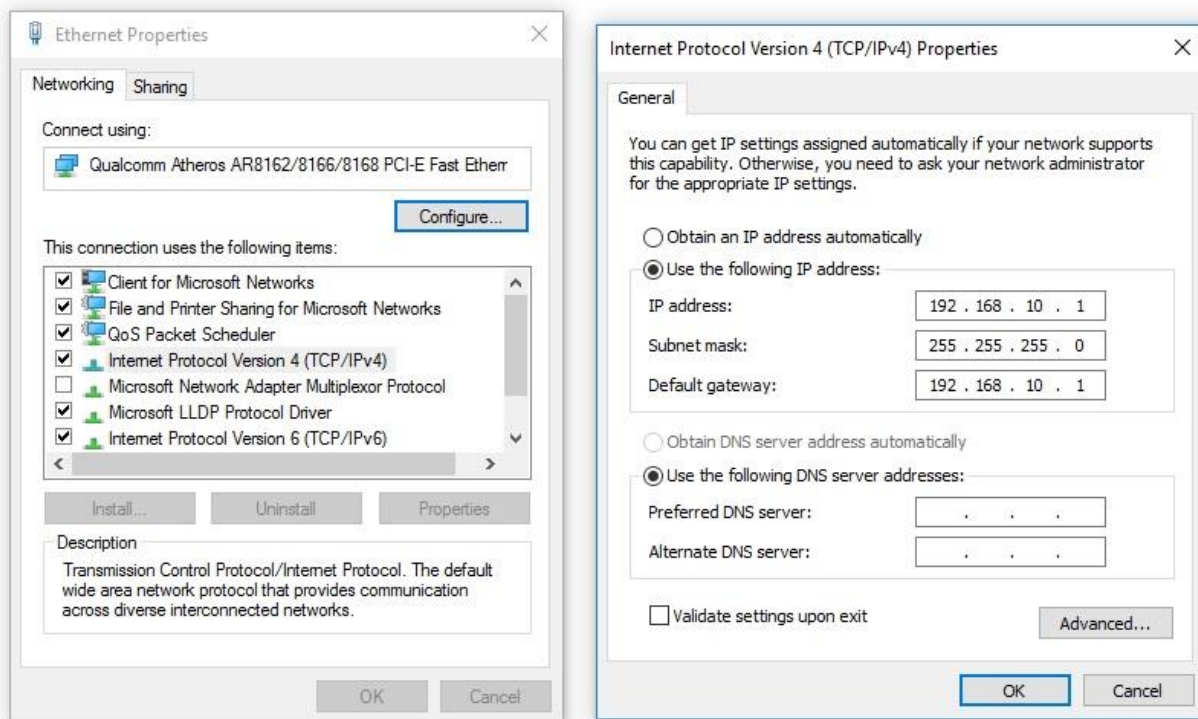


Figure 4: Ethernet Properties



Table 1: Static IP Address

Component	Address
Computer static address	192.168.10.1
Computer subnet mask	255.255.255.0

If you're provided with two USRPs (one for transmission (TX USRP) and the other one for reception (RX USRP)) you need to use two computers to set up the hardware. In order to set up the hardware, follow the following steps:

1. Connect the computer to the USRP using the provided Ethernet cable.
2. Open the **NI-USRP Configuration Utility** by going to Computer > Local Disc > Program Files (x86) > National Instruments > NI-USRP > utilities > USRP-utils.exe

The NI-USRP Configuration Utility software should open to the **Change IP Address** tab. If you have multiple USRP hardware connected to your computer, simply click on "Find Devices" to find the associated IP address for each of them.

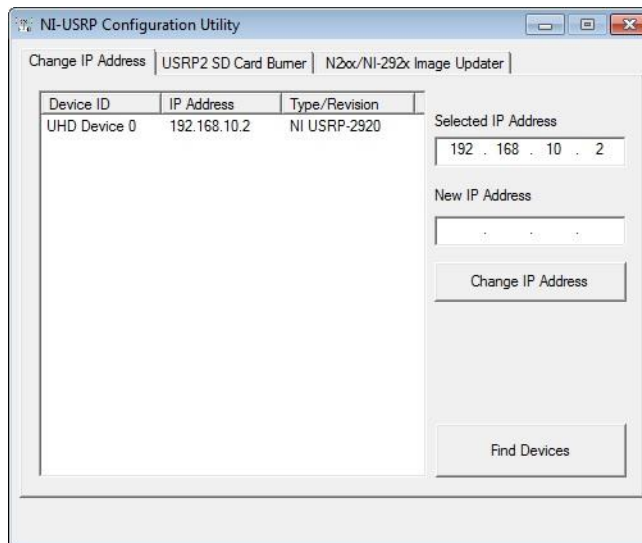


Figure 5: NI-USRP Configuration Utility

If the IP address does not appear in the window, then make sure the device is powered properly and also check your connections. If the device IP address is something other than the default IP, enter 192.168.10.2 as the **New IP Address** and press **Change IP Address**.



Before setting up the software, you need to set up the channel and select the communication path. There are two possible ways to set up the communication between the channels of USRP:

1. Loop-back (Cable Carrier)
2. Point to Point Wireless (P2PW)

Loop-back communication:

In this type of communication, a loopback cable (SMA (m) to SMA (m) cable) is used as the transmission media. Figure 6 and Figure 7 show the loopback cable and the USRP-2922's front panel. You need to use the loopback cable and make a proper connection from the USRP transmitter's TX to USRP receiver's RX. Make sure to use the 30 dB attenuator between the USRP's RX and the loopback cable.



Figure 6: SMA (m) to SMA (m) Cable

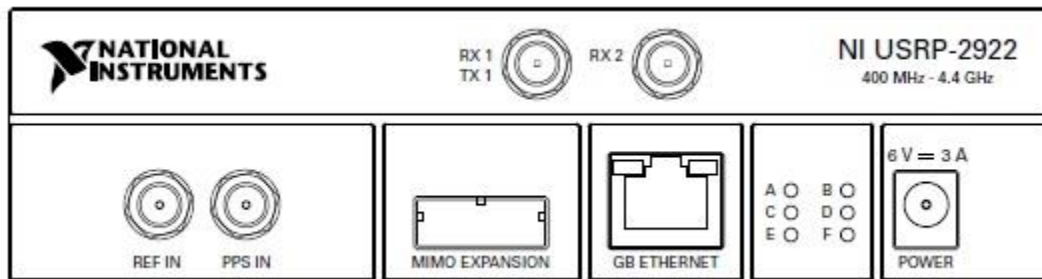


Figure 7: USRP-2922 Front Panel

Point to Point Wireless (P2PW) communication:

In this section, instead of using the loopback cable (wired channel), the wireless communication will be tested. To establish a wireless communication, connect one antenna to the RX1/TX1 of the transmitter USRP and connect the second one to the RX2 input of the receiver USRP. Remember to use the 30dB attenuator between the antenna and the RX2 input.



Setting up the Software in LabVIEW:

After setting up the hardware correctly, you need to run the VI file in the LabVIEW to test the hardware and the connections. As a simple start, the “USRP_fm_sound_transmitter 2010.vi” is provided with this material along with a “.wav” sound track. This program implements an FM transmitter to transmit the contents of a wav file to the receiver over wired and wireless channels. To set up the transmitter follow the following steps:

1. Open the LabVIEW software on your local machine
2. Go to File > Open and select the “USRP_fm_sound_transmitter 2010.vi”. Figure 8 shows the TX Front Panel.

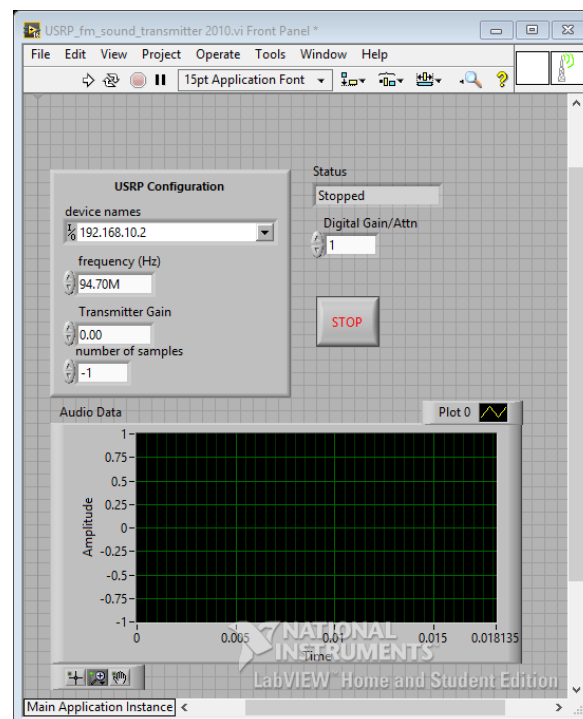


Figure 8: TX Front Panel

3. Enter the correct IP address for the connected USRP
4. Set the carrier frequency to 915.1MHz
5. Change the number of samples to 10

For the receiver, you must use one of the predefined examples provided by LabVIEW from the following either ways:



1. Toggle to the Block Diagram and find it from Functions > Express > Output > Instrument Drivers > NI-USRP > Examples > ModulationToolkitExamples > niUSRP EX FM Demod Sound Card (Queue).vi
2. Toggle to the Block Diagram, press < Ctrl + Space > and type niUSRP EX FM Demod Sound Card (Queue)
3. Start Menu > All Programs > National Instruments > NI-USRP > Examples > LabVIEW > ModulationToolkitExamples > niUSRP EX FM Demod Sound Card (Queue).vi

Once you select the receiver, double click on it to open it in a new window and delete the icon from the TX Block Diagram. Figure 9 show the RX Front Panels:

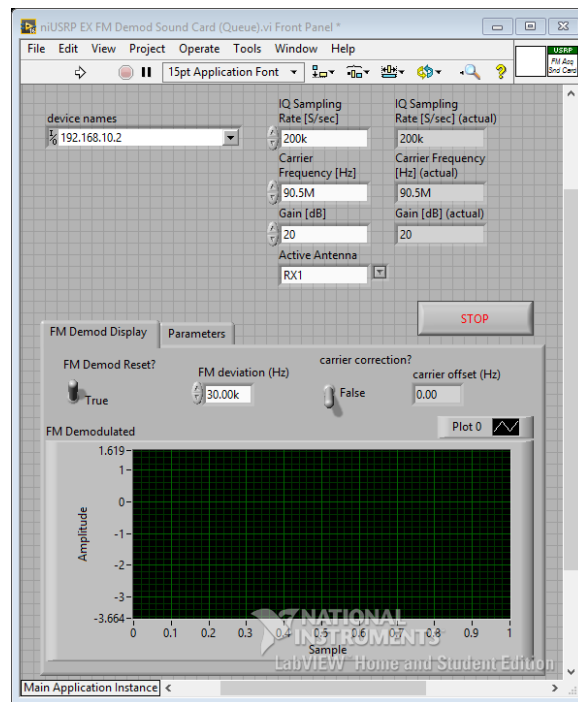


Figure 9: RX Front Panel

1. Enter the correct IP address for the connected USRP.
2. Set the same carrier frequency as the transmitter.
3. Change the active antenna to RX2 since TX1/RX1 channel is already selected as transmit channel.
4. If multiple NI USRPs are connected together either through a wired channel or a wireless channel, make sure to connect the 30 dB attenuator to the RF input (RX1 or RX2) of the receiving devices.



Running the software:

1. Always run the RX software first and then run the TX. By this method, you're sure that your receiver is set up and ready to receive the signal before pushing any data into the wired channel.
2. When you run the receiver software, you should be able to see the noise in "Waveform Graph" and hear it on your local machine's speakers.
3. Run the TX software. You'll be asked to choose a .wav file, then the transmitted wav file should be audible on the RX computer.

The transmitter software opens the .wav file, reads and converts it to the binary. Then it uses the FM modulator to modulate the data. The modulated data are sent to the USRP to be converted to analog and transmits over the channel. At the receiver side, the USRP converts the analog received signal to the digital one, then the LabVIEW software demodulates the received FM signal, extracts the data and converts it to the .wav file to be audible on the local machine's speakers.

4. Redo the transmission with wireless antenna and observe the differences.

In this lab we don't go through the details of designing the FM transmitter and receiver, but if you go to the "Block Diagram" of each transmitter and receiver software, you can see how LabVIEW icons and "While Loops" and "For Loops" are wired and connected to each other to provide the communication means. In order to make the LabVIEW software ready to interact with the USRP hardware, you need to use the predefined USRP library and icons. For more information about these essential blocks, go to Appendix I. In each lab, a template software with the required USRP icons will be provided, your task is to follow the manual step by step to complete the template software and observe the results.

Report:

The reports must be prepared in PDF or Microsoft Word format and should follow the standard of laboratory report. The report shall consist of:

1. A title page, including the name and number of the lab
2. The object, purpose and goal of the experiment shall be on the second page



3. A quick description on how the experiment is being done in 1-2 paragraphs
4. Calculations
5. Graphs
6. Results
7. Conclusion

All reports are due one week after the experiment is completed and each team must submit only one report along with all the results and necessary files in a zip format file to the Moodle page.



Appendix I:

LabVIEW interacts with the USRP transmitter by means of four functions located on the block diagram's palette under Hardware Interfaces > NI-USRP > Tx. The following figures show the basic transmitter structure. This structure is the starting point for all of the laboratory exercises in this series.



Open Tx Session initiates the transmitter session and generates a session handle and an error cluster that are propagated through all four functions. When you use this function, you must add a control called “device names” that you will use to inform LabVIEW of the IP address or resource name of the USRP.



Configure Signal is used to set parameter values in the USRP. Attach four controls and three indicators to this function as shown in the figure. To get started, set the IQ rate to 200 kS/sec (the lowest possible rate), the carrier frequency to 915.1 MHz, the gain to 0 dB, and the active antenna to TX1. When the function runs, the USRP will return the actual values of these parameters. These values will be displayed by the indicators you connected. Normally the actual parameter values will match the desired values, but if one or more of the desired values is outside the capability of the USRP, the nearest acceptable parameter value will be chosen, rather than returning an error.



Write Tx Data writes the baseband signal to the USRP for transmission. Placing this function in a while loop allows a block of baseband signal samples to be sent over and over until the “stop” button is pressed. Note that the while loop is programmed to terminate if an error is detected. Baseband signal samples can be provided to the Write Tx Data as either an array of complex numbers or as a complex waveform data type.



Close Session terminates transmitter operation once the while loop ends. Note that the function should be terminated using the STOP button rather than with “Abort Execution” on the toolbar. This is so that the Close Session function will be sure to run and will correctly close out the data structures that the function uses.

LabVIEW interacts with the USRP receiver by means of six functions located on the block diagram in



Hardware Interfaces > NI-USRP > Rx. The following figures show the basic receiver structure. This structure is the starting point for all of the laboratory exercises in this series.



Open Rx Session initiates the receiver session and generates a session handle and an error cluster that are propagated through all six functions. You must add a control called “device names” that you will use to inform LabVIEW of the IP address or resource name of the USRP.



Configure Signal has the same function as the corresponding function in the transmitter. Attach four controls and three indicators to this function as shown in the figure. This time, set the IQ rate to 1 MS/sec, the carrier frequency to 915.0 MHz, the gain to 0 dB, and the active antenna to RX2. When the function runs, the USRP will return the actual values of these parameters.



Initiate sends the parameter values you selected to the receiver and starts it running.



Fetch Rx Data retrieves the message samples received by the USRP. Placing this function in a while loop allows message samples to be retrieved one block at a time until the “stop” button is pressed. Note that the while loop is programmed to terminate if an error is detected.

A “number of samples” control allows you to set the number of samples that will be retrieved with each pass through the while loop. In later lab projects in this series, we will not use the while loop, and will fetch only a single block of data from the receiver. Fetch Rx Data can provide message samples to the user as either an array of complex numbers or as a complex waveform data type. A pull-down tab allows you to choose the data type for the message samples.



Abort stops the acquisition of data once the while loop ends.





Close Session terminates receiver operation. As noted above, use the STOP button to terminate execution so that Close Session will be sure to run.



References

- [1] "What is Software Defined Radio?," Wireless Innovation Forum, [Online]. Available: http://www.wirelessinnovation.org/Introduction_to_SDR. [Accessed 27 1 2018].

