IIT PALAKKAD

Contents

PH5004: ELECTRONICS AND INSTRUMENTATION

Term Project report on:

SDR: Designing rapidly prototype wireless communication systems through Labview integrated NI Software Defined Radio with MIMO and LTE/WIFI testbed.

submitted by
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1 An Introduction to Software Defined Radio with Labview and NI USRP

Labview is a graphical programming environment used by millions of engineers and scientists to develop sophisticated measurement, test and control systems. At the same time, its virtual platform offers shortening designing process and tight hardware/software integration including NI USRP, that allows seamless transition from design to test. NI provides a full spectrum of RF/communication solutions: RF test, research and education.The Labview integrated NI USRP does the same functions like other SDRs wherein software modules running on a generic hardware platform are used to implement different radio functions; but it provides an accessible, easy to use and more user friendly software defined radio platform.

2 Scope of work [1]:

- Despite the growth achieved by multiple technologies, an interesting and potentially problematic issue common to all radio transmission techniques

is that their radios and protocols are mostly hardware based. Thanks to the hardware, reprogramming or reconfiguration options are minimal, at least regarding radio functions. This lack of flexibility is disturbing in the sense that if an error occurs in the hardware, firmware, or software then generally there is no reasonable way to correct the problem: the built-in vulnerabilities are not easy to remove.

- Precisely, the Software Defined Radio formed by the integration of Labview and NI USRP, subject of this article, aims to provide a solution to many of the problems described along with many other benefits like other SDRs.

- NI software radio with well equipped NI modulation toolkit transceivers,receivers and onboard FPGA, and paired with Labview communication design suite converts a standard PC into wireless prototype tool that in turn reduces the need of other modular devices. This simple work can result into out-of-the box standard based application framework.

- A typical Labview models of computation contains a number of well programmed VIs like Dataflow, HDL code,Textual math,multi-rate DSP. These

VIs make our task more easier.

- For communication design in Labview, modulation toolkit is used. We can use analog and digital modulation formats like AM,FM,PM,ASK,MSK,FSK,PAM and PSK. Rx and Tx implementation plays a crucial role in any digital communication system. NI USRP integrated with Labview provides an easy platform for Rx and Tx implementation.

3 NI 2920 HARDWARE DIAGRAM AND DIGITAL SYSTEM:

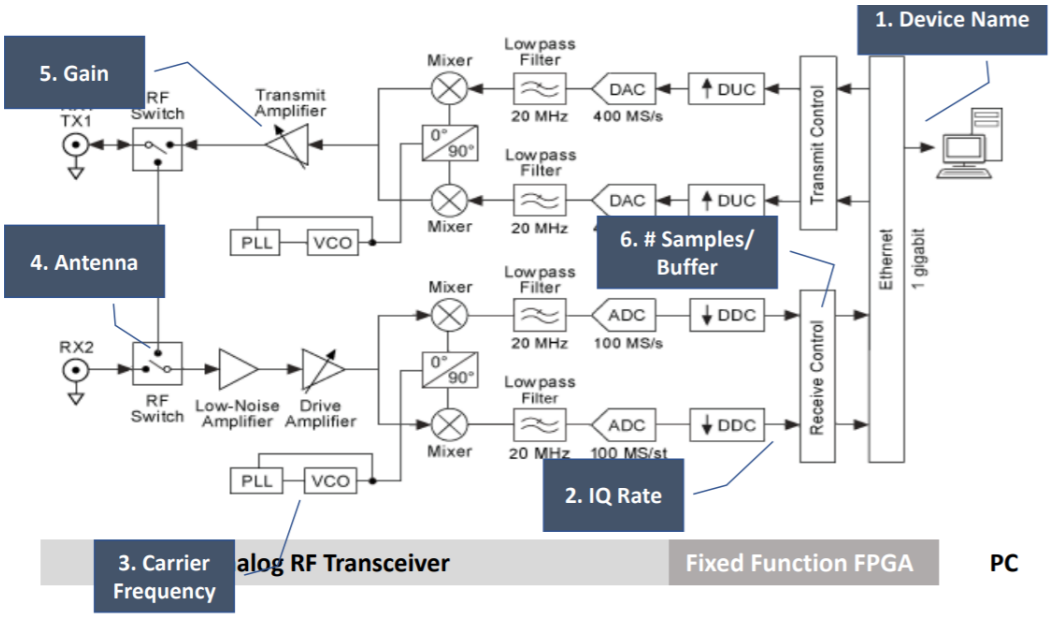


Figure 1: NI 2920 HARDWARE DIAGRAM

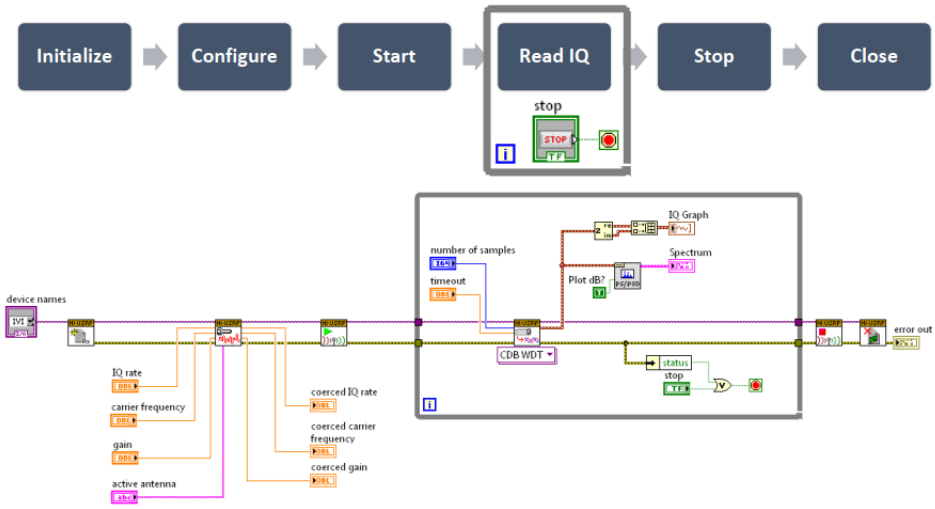


Figure 2: NI USRP DRIVER SOFTWARE WITH LABVIEW ENVIRONMENT

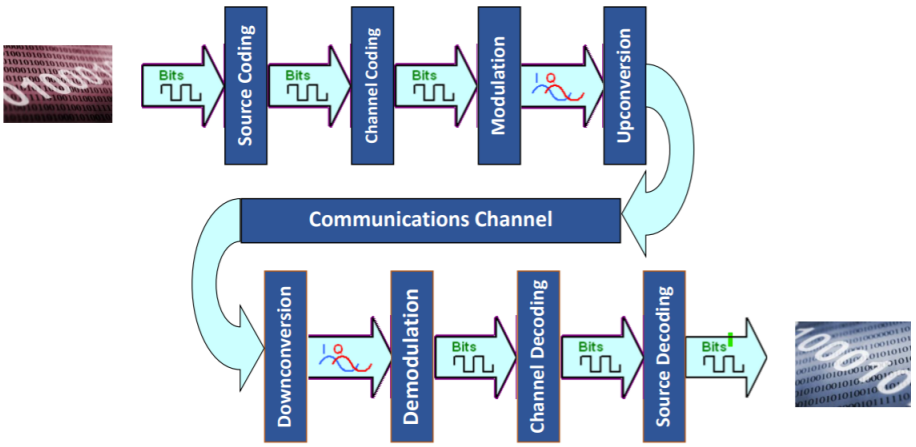


Figure 3: Digital Communication System

4 DESIGN DETAILS: COMMUNICATION DETAILS IN SDR AND DESIGN LABVIEW

4.1 SDR architecture

- H/W variants from 50 MHz to 6 GHz
- 40 MHz Real time Bandwidth
- 800 MB/s PCIe Connectivity
- LabVIEW Programmable FPGA

4.2 I/Q modulator

IQ modulator, is used for RF signal generating. A fundamental piece of IQ SDR (IQ modulator) is given as below:

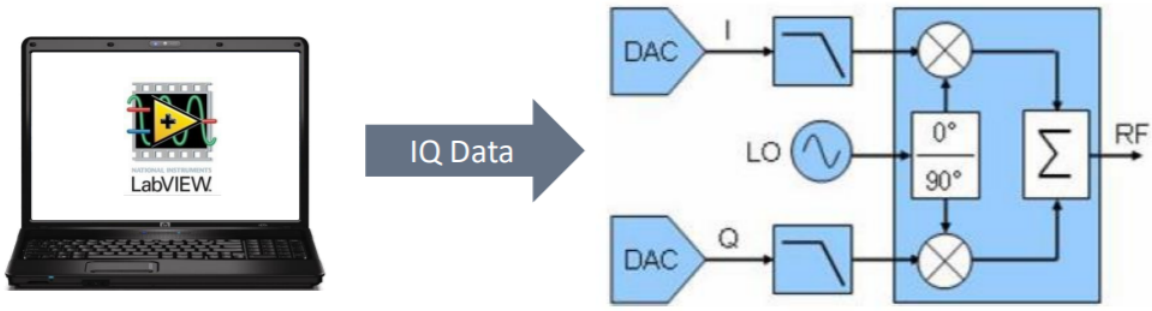


Figure 4: IQ modulator

4.3 Modulation toolkit

4.3.1 Analog and Digital modulation formats

- AM,FM,PM
- ASK,FSK,GMSK,PAM,PSK,QAM
- Custom

4.3.2 Visualisation

- 2D and 3D Eye, Trellis,Constellation

4.3.3 Modulation Analysis

- BER, MER, EVM, burst timing, frequency deviation

4.3.4 Impairments

- Additive White Gaussian Noise (AWGN)
- DC offset, Quadrature skew, IQ gain imbalance, phase noise
- Equalization, Channel Coding, Channel Models

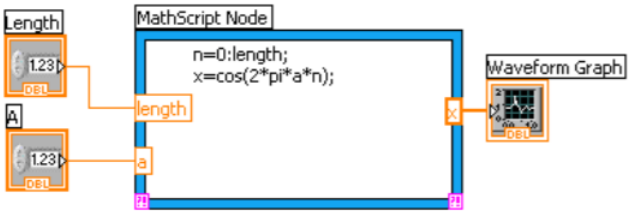
4.4 Labview Math Script mode

- Implement equations and algorithms textually
- Input and output variables created at the border
- Generally compatible with popular .m file script language
- Terminate statements with a semicolon to disable immediate output

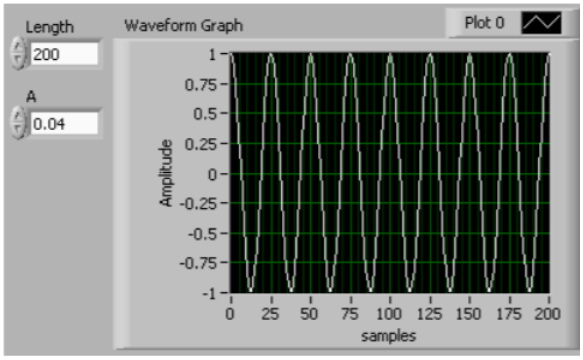
4.5 Frequency Demodulation Algorithm

- Detection of carrier phase(arc tan of baseband IQ sample)
- Unwrapping of phase (remove discontinuities)
- Differentiation of Phase (change in phase..)

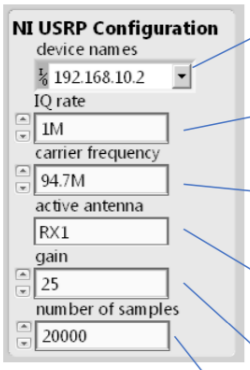
4.6 PROTOTYPE OF EQUATIONS IN LABVIEW MATH-SCRIPT MODE



(Functions»Programming» Structures»MathScript)



4.7 USRP CONFIGURING IN SIX PARAMETRES



1. Device Name – IP address of one or multiple USRP

2. IQ Rate – Quadrature sampling rate, equivalent to bandwidth

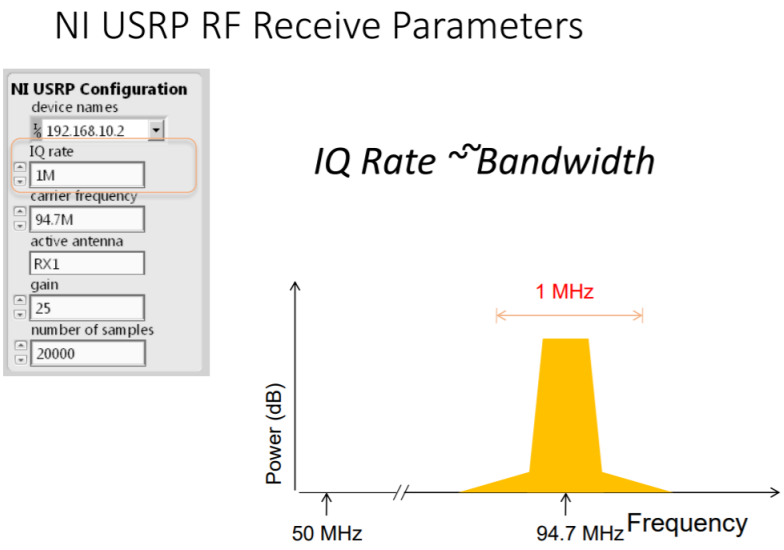
3. Carrier Frequency – Frequency of interest

4. Antenna – Select which antenna port to receive from

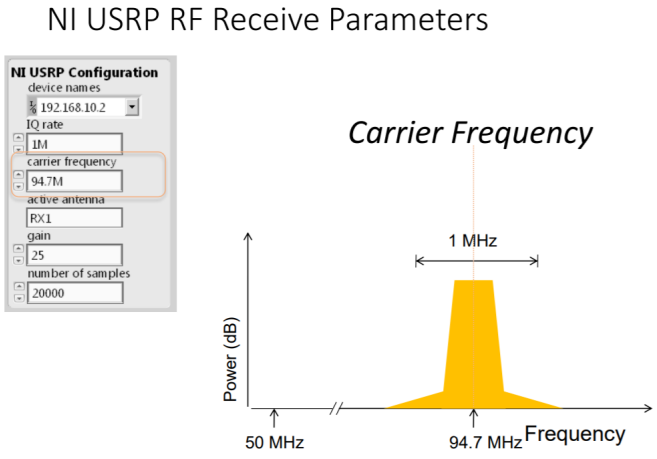
5. Gain – Amplification of signal before digitizing the signal

6. Fetch size – how many samples to acquire each fetch

5 RECEIVING PARAMETRES AND RF SIGNAL GENERATOR:

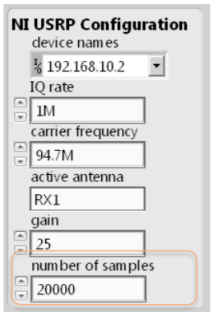


5.1 RF RECEIVE PARAMETRE: CARRIER FREQUENCY



5.2 RF RECEIVE PARAMETRES : NUMBER OF SAMPLES

NI USRP RF Receive Parameters



number of samples

Time Domain

$$\frac{1}{IQ\_rate} * number\_samples = fetch\_time$$

Frequency Domain

$$\frac{IQ\_rate}{number\_samples} = resolution\_bandwidth$$

5.3 GENERATION OF RF SIGNAL

Using IQ Modulator to Generate any RF Signal

$$\cos(\alpha + \beta) = \cos(\alpha)\cos(\beta) - \sin(\alpha)\sin(\beta)$$

$$A\cos(2\pi f_c t + \phi) = A\cos(2\pi f_c t)\cos(\phi) + A\sin(2\pi f_c t)\sin(\phi)$$

I Q

$$A\cos(2\pi f_c t + \phi) \equiv I\cos(2\pi f_c t) + Q\sin(2\pi f_c t)$$

6 FUNCTIONING

6.1 Exploring a digital communication system:

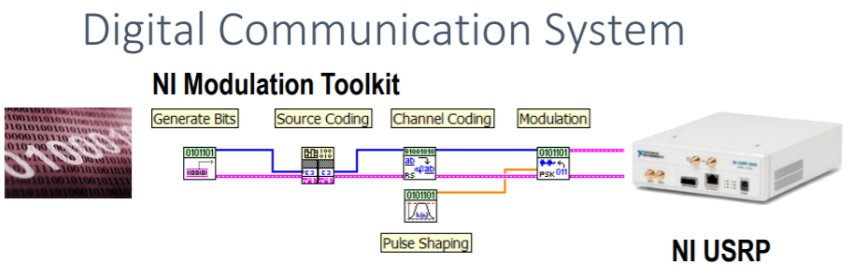
- Open and run a digital communications reference design.
- Identify the part of a more advanced LabVIEW block diagram.
- Overview of the modulation and demodulation process.

6.2 Functioning Processes:

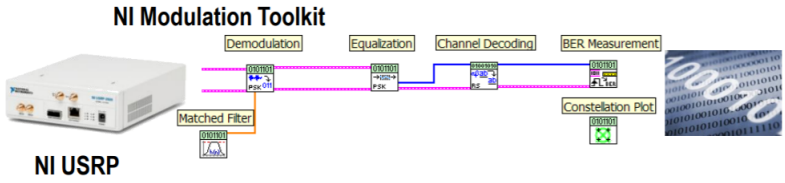
- The NI USRP should be integrated with the Labview communication design environment as per the diagram given above. It has NI modulation toolkit,transceivers,receivers and onboard FPGA. The USRP should be configured in 6 parametres such as Device name, IQ rate,Carrier frequency,antenna, gain and fetch size.
- As mention above, for communication design in Labview, modulation toolkit is used.We can use analog and digital modulation formats like AM,FM,PM,ASK,MSK,FSK,PAM and PSK. For visualiation,the functions like 2D and 3D eye,Trellis and constellation are implemented.Additive white Gaussian noise, DC offset,IQ gain imbalance,Quadrature skew can be well studied and analysed through the Labview environment. In order to establish a digital communication system, the processes like source coding,channel coding,modulation and upconversion at the transceivers end along with downconversion,demodulation,channel decoding and source decoding at the receivers end can be done effectively with the NI software defined radio(SDR).
- As we know that IQ modulator is the fundamental part of software defined radio which is used to generate RF signal. A waveform data type is used by Labview to dispaly and store periodic signal measurements. Similar to waveform data types, clusters are available in the Labview environment which will help in grouping variables and error handling.
- For demodulation, we have to use the frequency modulation algorithm.The program for demodulation is given below.

6.3 DIGITAL COMMUNICATION PROCESSES ANALYSIS

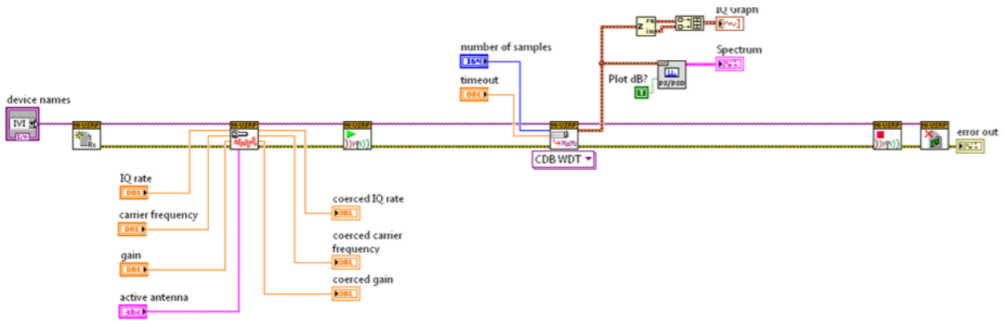
6.3.1 UPCONVERSION AND MODULATION



6.3.2 DOWNCONVERSION AND DEMODULATION



6.3.3 SIMPLE Tx and Rx IMPLEMENTATION USING USRP



6.3.4 Frequency demodulation Programming

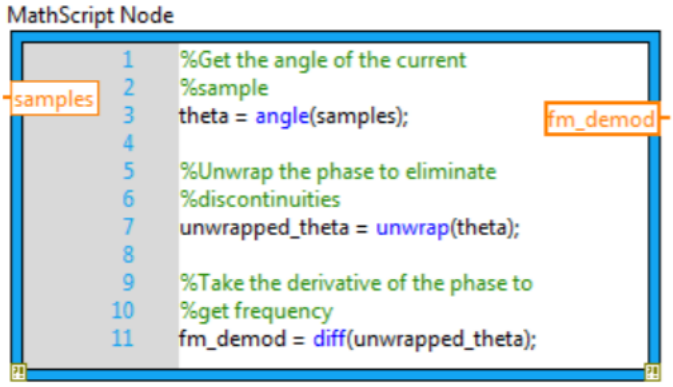


Figure 5: Frequency demodulation

7 APPLICATIONS

- FM radio
- Passive Radar
- Dynamic spectrum access
- GPS
- GSM

8 Conclusion

NI modulation toolkit and Labview add-ons to simulate or process live signals accelerates more component specific innovation as compared to many other traditional devices.The simplest thing one can observe that this SDR toolkit not only gives unprecedented hardware and software integration but also picturises everything in a virtual Labview environment.

References

[1] José Raúl Machado-Fernández. [http://www.scielo.org.co/pdf/rfing/v24n38/v24n38a07.pdf].