Emerging Technology In Wireless Communication Design Using Software Defined Radio

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Abstract: This research article aims to motivate young researchers to investigate into the possibilities of Software defined radio to design (SDR) wireless prototype. SDR is a reconfigurable radio to design any radio designing prototype starting from RF communication standard to even 5G tested modelling. This research paper will take the reader the concept of software defined radio architecture with the support of basic experimental set up worked in our university research lab with the help of National Instruments NI 2920 Software Defined Radio kit. It is just basic preliminary experiments which is available in the example folder of NI 2920 radio suite. But, the experiments will reflect the distortion of QAM constellation diagram in the transmitter and receiver SDR kits when connected to terminal PCs tested in the parametric condition of distance and LOS and NLOS conditions. The future work of this initial experiment is to design OFDM, MIMO-OFDM, and even Massive MIMO modelling through Lab view which is the reconfigurable radio model design that supports NI 2920 SDR hardware.
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Index Terms: SDR, NI 2920, QAM Constellation, wireless prototype, LOS, NLOS, National Instruments

1 INTRODUCTION

A Software defined radio (SDR) is a reconfigurable radio with RF baseband modelling hardware with RF Front end. This hardware can be reconfigured and modelled using Lab view model based design. It means, if a researcher wants to set up a transmitter and receiver units to test for various wireless designs, it can be done through labview models that can configure National instruments NI 2920 SDR kit. The models can be in the area of modulation schemes, encoder designs in the transmitter, equalizer, decoder and demodulator model designs in the receiver. All these software models can be built in Lab view and could be interfaced to SDR. SDR units will be able to physically test the models and evaluate the performance of the wireless parameters according to its design criteria. The motivation to investigate this SDR specifically of National Instruments kit is because both SDR hardware and Lab view is enough to design even 5G prototype model designs. Yes, there are quite other SDR models [1] shown in Table 1. However, in order to design transceiver structures in these units require knowledge of FPGA synthesizing, VHDL or Verilog programming. It depends on the area of research the selection of boards, programming background a researcher can select. This article tries to project the interest of reconfigurable SDR for evaluation of wireless communication design. For this purpose, the available NI 2920 SDR kit and the example programming models provided by the installation of the equipment is used which is available in our research lab of the university.

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SDR Types	Soft Core	FPGA
KUAR	PC + 2 X PowerPC cores	Xilinx Virtex II Pro
LimeSDR	PC	Intel cyclone IV
Ziria	PC	Depends on App
Sora	PC	Xilinx Virtex-5
SODA	ARM Cortex M3	N/A
Iris	Dual Core ARM Cortex-A9	Xilinx Kintex-4
Atomix	TI 6670 DSP	N/A
Beagle-Board	2 x TIC66x DSP + 2 x ARM Cortex A15	N/A
Airblue	N/A	Intel cyclone IV
WARP v3	2xXilinx MicroBlaze cores	Xilinx Virtex-6
PSoC 5LP	ARM-Cortex M3	N/A
Zynq-based	Dual Core ARM Cortex-A9	Xilinx Kintex-4

Table. 1 *Comparison of various SDR (Image courtesy [1])*

1.1 SDR Architecture

SDR architecture could be visualized in transmitter and receiver blocks [1] as shown in Fig. 1. Any SDR platform will have these basic blocks. One flow at transmitter side and other at receiver side. The SDR hardware comprises of digital baseband unit and RF front end unit and to this connects the antenna. Signal processing, modulation, decoding will be done in baseband unit. RF front end do the up conversion and power amplification that is converting into RF High frequency band at the transmitter.

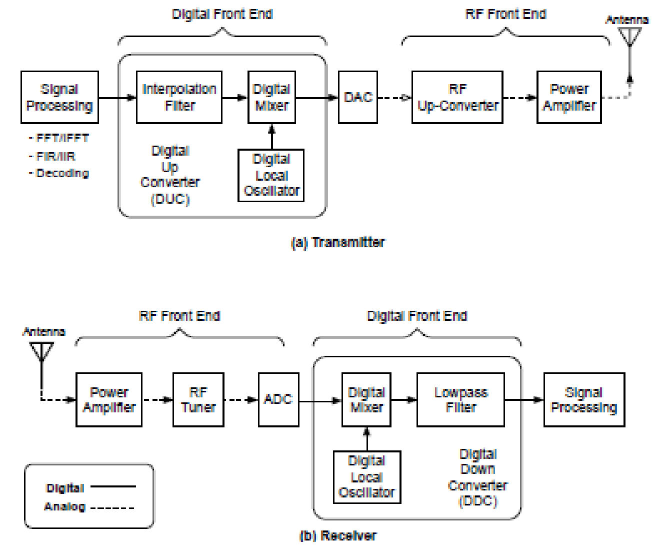

***Fig. 1**. System block diagram - NI 2920 (Image Courtesy [3]*

1.2 NI2920 SDR ARCHITECTURE

In our university research lab, we have SDR NI 2920 hardware kits. The specification of this series of SDR NI- National Instruments - Universal Software Radio Peripheral (USRP) 2920 kits are: Tunable frequency of 50 MHz to 2.2 GHz, with transmit power of 30 to 100 mW. This reconfigurable radio can be interfaced to several applications that includes broadcast FM, public safety, land mobile, low power unlicensed devices, sensor networks, cell phones, amateur radio and others. This device is suitable for initial level prototype designing and testing as it covers cellular range of 2.2 GHz. In the development of 5G testbed at University of Bristol (USRP Rios) are used. This example is brought here to understand the use of SDR in prototyping one of the technology Massive MIMO in 5G. Several applications in sensor networks, IoT and Wireless transceivers are developed using SDR prototyping.NI USRP 2920 system block diagram is provided in Fig. 2.

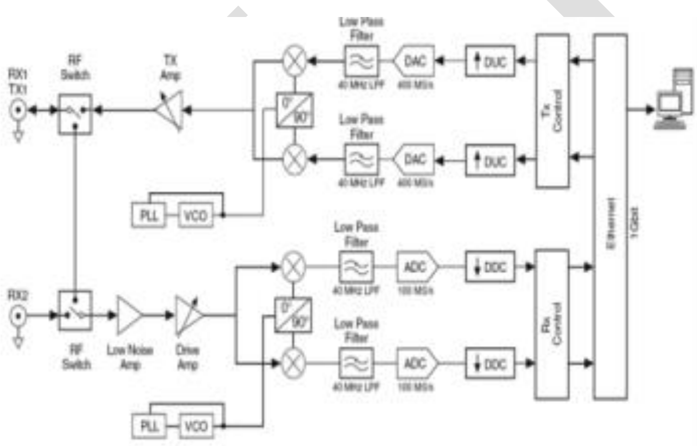

***Fig 2.** NI USRP 2920 System Block diagram*

The spectral efficiency is estimated as performance metric. QAM modulation is chosen and over 100 USRP Rio hardware SDRs are used to set a Massive MIMO testbed [2]. The design criteria for SDR platform is to understand where to partition the software and hardware. MAC layer is controlled by the software and baseband signal processing and RF Signal processing is cone through hardware peripheral of the radio. Now, the researchers can work in the modulation and demodulation unit primarily. Fig. 3. Shows the distinction between hardware and software and the design area a researcher can target.

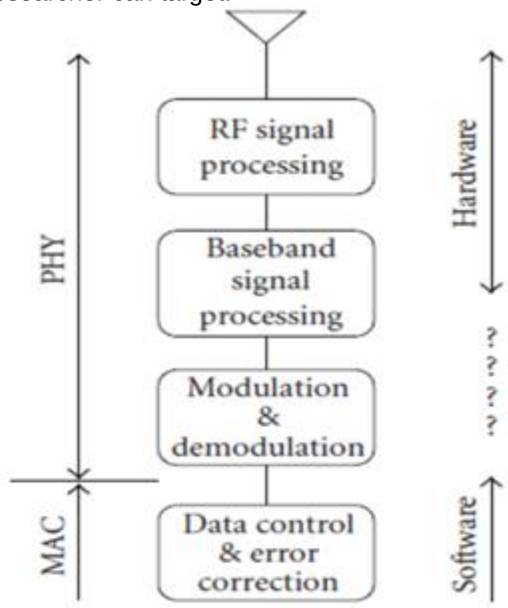

***Fig 3**. Hardware and Software Processing in SDR*

2 EXPERIMENTAL SETUP

The experimental set up used in the research study is to test the transmitter and receiver functions of SDR for different QAM modulation schemes, a model of transmitter and receiver need to design in lab view. Fortunately, several initial test models are available while installing USRP hardware. This will be able to locate in the example folder to launch the lab view model. After selecting one terminal as transmitter connected to transmitting SDR unit, other terminal PC connected to receiving SDR unit. Select the QAM transmitting model in the lab view. Select appropriate modulation scheme such as 8-QAM, 16-QAM, 32-QAM and so on. Similarly select the receiver QAM model in the receiver PC terminal and select appropriate QAM demodulation schemes. Observe the constellation diagram. Two parametric test cases taken are the influence of constellation diagram clarity considering Line of Sight (LOS) and the distance between transmitter and receiver units. Several measurements are taken considering these two parameters. The experimental set up in three stages; i. selection of modulation and demodulation schemes in transmitter and receiver stations, ii) vary the distance (increase and decrease the distance between transmitter and receiver and observe the clarity of the constellation diagram in the receiver and iii) change the antenna orientations, that is Line of Sight (LOS) and Non Line of Sight (NLOS). The experimental set up is by configuring the SDR NI 2920 hardware in the user terminal PCs as in Fig. 4. The selected experiment is 16 QAM considering the effect of constellation diagram varying the parameters. The unpacking of SDR and initial device connectivity to the terminal PCs are reflected in getting started manual. Tri band vertical antennas need to be connected in two hardware units, one at transmitter and other at receiver unit. If observed the devices are connected to two PC terminals. Vertical antenna is connected. If selected example folder from USRP utility, will be able to select modulation scheme (transmitter) and demodulation scheme based model (Receiver). In the figure, the antennas are at LOS condition and the distance is very close between the units. In Fig. 5. The 16 QAM modulation scheme is selected and the constellation diagram at the receiver unit is checked. The devices are not in LOS condition, therefore the constellation diagram in the receiver unit is full of noise levels. It infers that NLOS and the angle of arrival at receiver base station are important parameters in receiving proper signal. In Fig. 6. Shows the transmitter and receiver unit is placed at a considerable large distance even though it is in LOS.

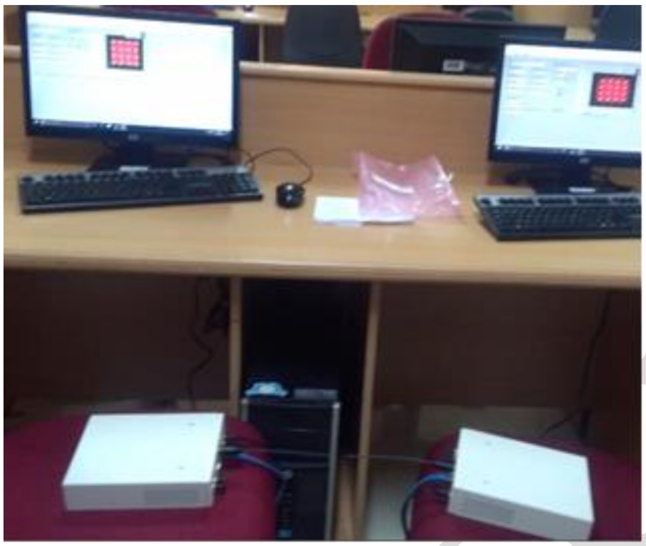

Fig. 4. *Transmitter (Right side) and Receiver (Left side) connected to two NI 2920 USRP devices*

Fig. 6. Indicates that the received signal is acceptable in shape but is highly distorted because the two units are in NLOS condition. Distances between them is reduced when compared to Fig. 5. Therefore, the resulted constellation diagram is comparatively acceptable.

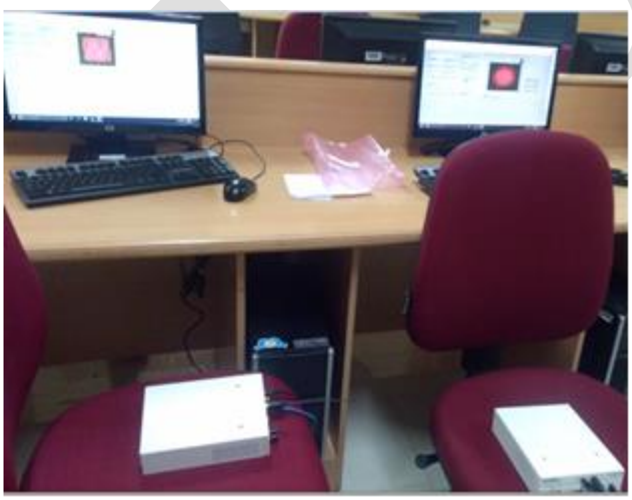

Fig. 5. *Transmitter and receiver in NLOS condition.*

Fig. 6. *NLOS condition but at a smaller distances between transmitter and receiver*

3 RESULTS AND DISCUSSION

This research paper brings out the discussion of the results obtained in the experimental set up done in our university research lab. Three factors are mainly responsible to change the receiver signal constellation diagram. First one is the modulation format itself. If higher order modulation schemes are selected in QAM, chances of distortions are high. Second is the distance between transmitter and receiver. If distances are large, received signal is noisy, but, maintains the shape of the signal to a considerable level. During NLOS conditions, even though the transmitter and receiver are of smaller distances noises prevails and if at larger distances, signal vanishes completely. Therefore, LOS conditions with a considerable distances between the transmitter and receiver terminal will bring an appreciable results. However, proper mathematical modelling and equations not presented in this paper. This article provide an ambience for the reader to model an angle of arrival function and distance between transmitter and receiver units as varying parameters between transceiver stations. The bigger question is the modelling of transmitter block, receiver block and the multipath channel modelling by the user customization. The available result in this experimental set up is shown in the Table 2.

Modulation Scheme	Distance	LOS	NLOS
QAM - 8	20 cm	Good Signal received	Acceptable signal level
QAM – 16	30 cm	Signal received with distortion	Heavy distorted signal
QAM - 32	40 cm	Signal received with heavy distortion	No signal

4 CONCLUSION AND FUTURE SCOPE

This research work aims in bringing a focus towards SDR based prototyping of wireless design. Be it a single transmitter and receiver or a MIMO set up or Massive MIMO set ups, any performance metric of wireless design can be evaluated in hardware if you have a reconfigurable radio device. This paper starts with architecture of SDR and different SDRs available where experimentation going on currently. Here, NI USRP is taken to conduct basic experimental set up in the research lab. This research uses NI USRP as an example SDR for doing basic operations in QAM modulation schemes considering distances between transmitter and receiver and angle of arrival of the signal at receiver terminal, by putting in LOS and

NLOS conditions. We observed that LOS with considerable distances of say 50 cm is appreciable to get the signal at receiver. If changed these parameters, say, distances or positions, the constellation diagram is weakened. The results looks simpler, but, it opens a huge research outcome to motivate researchers in this field to try various possibilities to develop models of transmitter and receiver schemes. The future work in this SDR prototyping could be algorithms and models could be in modulation, encoder, equalizers or filter designing in lab view model that could be verified and tested in SDR hardware. Several prototypes models are tested using SDR NI USRP Rios in several universities for a 5G Tested [7, 8, 9, 13]. Various performance metric could be taken such as spectral efficiency, data rate, energy efficiency or may be in latency reduction.

REFERENCES

[1] Akeela, Rami, and Behnam Dezfouli. "Software-defined Radios: Architecture, state-of-the-art, and challenges." Computer Communications 128 (2018)

[2] Harris, Paul, Wael Boukley Hasan, Henry Brice, Benny Chitambira, Mark Beach, Evangelos Mellios, Andrew Nix, Simon Armour, and Angela Doufexi. "An overview of massive MIMO research at the University of Bristol." (2016): 1-5.

[3] El-Hajjar, Mohammed, Quoc A. Nguyen, Robert G. Maunder, and Soon Xin Ng. "Demonstrating the practical challenges of wireless communications using USRP." IEEE Communications Magazine 52, no. 5 (2014): 194-201.

[4] J. Proakis and M. Salehi, Digital Communications, 5th ed., McGraw Hill, 2010

[5] Heath, Robert W. Digital Wireless Communication: Physical Layer Exploration Lab Using the NI USRP: Student Lab Manual. National Technology & Science, 2012.

[6] Farrell, Ronan, Magdalena Sanchez, and Gerry Corley. "Software-defined radio demonstrators: An example and future trends." International Journal of Digital Multimedia Broadcasting 2009.

[7] Björnson, Emil, Erik G. Larsson, and Thomas L. Marzetta. "Massive MIMO: Ten myths and one critical question." IEEE Communications Magazine, vol. 54, no. 2, pp. 114-123, 2016.

[8] Zhang, Changchun, and Robert C. Qiu. "Massive MIMO testbed-implementation and initial results in system model validation." arXiv preprint arXiv:1501.00035 (2014).

[9] Larsson, Erik G., Ove Edfors, Fredrik Tufvesson, and Thomas L. Marzetta. "Massive MIMO for next generation wireless systems." IEEE communications magazine, vol. 52, no. 2,pp 186-195, 2014.

[10] Wang, Jian, Aixiang Jin, Dai Shi, Lei Wang, Liang Hu, Liang Gu, and Anass Benjebbour. "Field Trials on Spectral Efficiency Improvement in Massive MIMO Systems." IEEE 87th Vehicular Technology Conference (VTC Spring), pp. 1-5. IEEE, 2018.

[11] Guey, Jiann-Ching, Pei-Kai Liao, Yih-Shen Chen, Alex Hsu, Chien-Hwa Hwang, and Gabriel Lin. "On 5G radio access architecture and technology [industry perspectives]." IEEE Wireless Communications , vol. 22, no. 5, pp. 2-5, 2015.

[12] Boccardi, Federico, Robert W. Heath, Angel Lozano, Thomas L. Marzetta, and Petar Popovski. "Five disruptive technology directions for 5G." IEEE Communications Magazine, vol. 52, no. 2, pp. 74-80, 2014.

[13] Malkowsky, Steffen, Joao Vieira, Liang Liu, Paul Harris, Karl Nieman, Nikhil Kundargi, Ian C. Wong, Fredrik Tufvesson, Viktor Öwall, and Ove Edfors. "The world's first real-time testbed for massive MIMO: Design, implementation, and validation." IEEE Access, vol. 5, pp. 9073-9088, 2017.