Wireless Communications: Principle and Applications, Fall 2014
6x6 MIMO Project Report

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Contents

1 Introduction

We setup an advanced SDR-based (Software-defined Radio) 6x6 MIMO system testbed in lab.

MIMO (multiple-input and multiple-output) technology offers significant increases in data throughput and link range without additional bandwidth or increased transmit power. And MIMO is an important part of modern wireless communication standards such as IEEE 802.11n (Wi-Fi), 4G, 3GPP, WiMAX and HSPA+.

With MIMO, you can increase wireless system performance without increasing power consumption. It is based on the idea that when using multiple antennas, the transmitted signal progresses through different wireless channels, from the transmitter antennas to the receive antennas, to create a capacity gain by exploiting channel diversity.

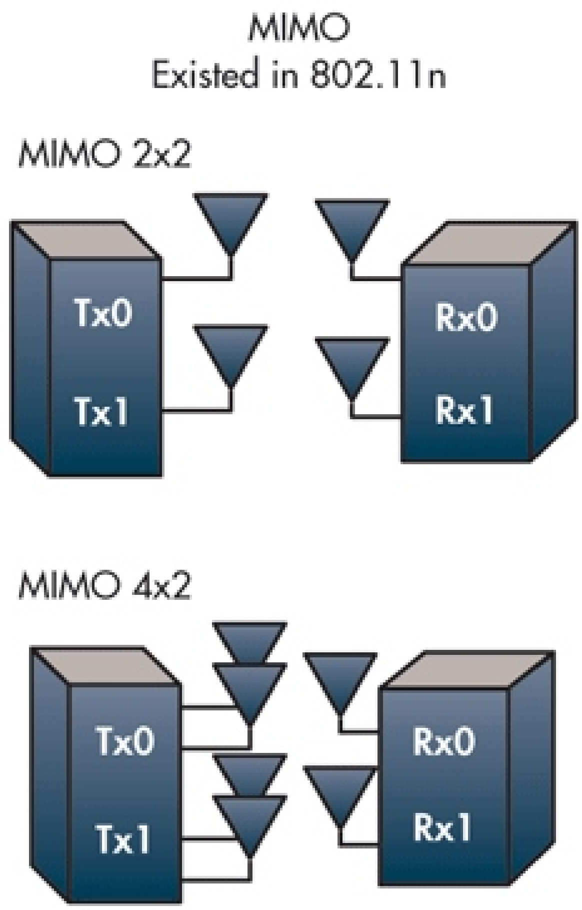

Figure 1: Simple MIMO Scheme

The USRP (Universal Software Radio Peripheral) is the commputer-hosted software radio. The USRP product family is intended to be a comparatively inexpensive hardware platform for software radio, and is designed for accessibility, and many of the products are open source.

Figure 2: The NI USRP^{TM}-2920 Device

2 Implementation

We implemented our MIMO testbed on NI USRP-2920 hardware. By using up to 16 USRP-2920 devices, we combine them to form a phase-coherent antenna array for transmission and reception, which scales from 2x2 to 6x6 antenna configurations (consisting of up to 6 transmitters and 6 receivers).

The system configuration for our 6x6 MIMO Testbed follows the centralized manner:

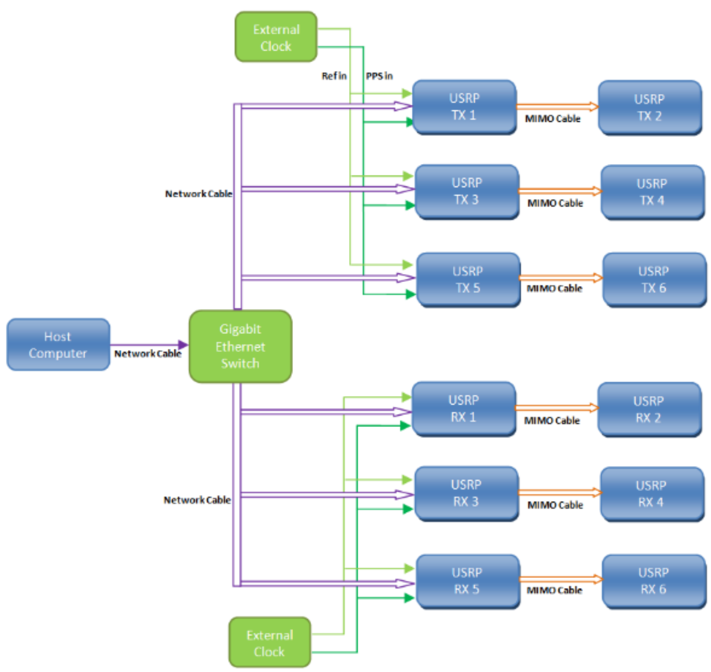

Figure 3: 6x6 MIMO system configuration

3 6x6 MIMO System

3.1 Hardware Configuration

We need twelve NI USRP transceivers for a 6x6 system because individual transceivers are not capable of two simultaneous transmits or receives. The following configuration is recommended:

- One PC with a free Gigabit Ethernet port.

- Gigabit Ethernet switch
- 12 USRPs (NI USRP-292X recommended)
- 12 antennas
- 2 external clocks

The detailed configuration procedure to set up the transmitter side is given here (the receiver configuration follows the same procedure):

1. Connect one antenna to each of the 6 USRPs that are going to serve as the transmitter (NI recommends using RX1/TX1 port for simplicity). For desired operation, the transmitting antennas should be at least half a wavelength (of the carrier frequency used) apart.
2. Out of the 6 USRPs that are going o serve as the transmitter, connect any three of them (USRP TX2, USRP TX3, and USRP TX5) directly to the Gigabit Ethernet Switch with appropriate gigabit Ethernet cable.
3. Connect USRP TX2, USRP TX3, and USRP TX5 to the external clock to receive the reference signal and the PPS signal.
4. Connect USRP TX1 to USRP TX2, USRP TX3 to USRP TX4, and USRP TX5 to USRP TX6 via MIMO cables.
5. Power up all 6 USRPs and the external clock to complete the hardware configuration procedure.

And then repeat the same steps on the receiving side of your system.

3.2 Software Configuration

This 6x6 MIMO example is a LabVIEW application that requires the following software components:

- NI LabVIEW Version 2011 (or later) system design softwareFull, Professional, or Student Edition
- NI-USRP Version 1.1
- NI LabVIEW Modulation Toolkit Version 4.3.1
- 6x6 MIMO Example VIs

3.3 In LabVIEW

This section describes the key components of the 6x6 MIMO system:

i Preparing the Signal for Transmission:

  Figure 4 presents the block diagram of the usrp_mimo_tx.vi. As can be seen from the block diagram, it calculates the pilot tones based on the OFDM Parameters. Pilot tones are spread over the frequency range. In this example, we have added one pilot tone after every twelve data tone. The positions of null tones also have to be considered while adding pilot tones.

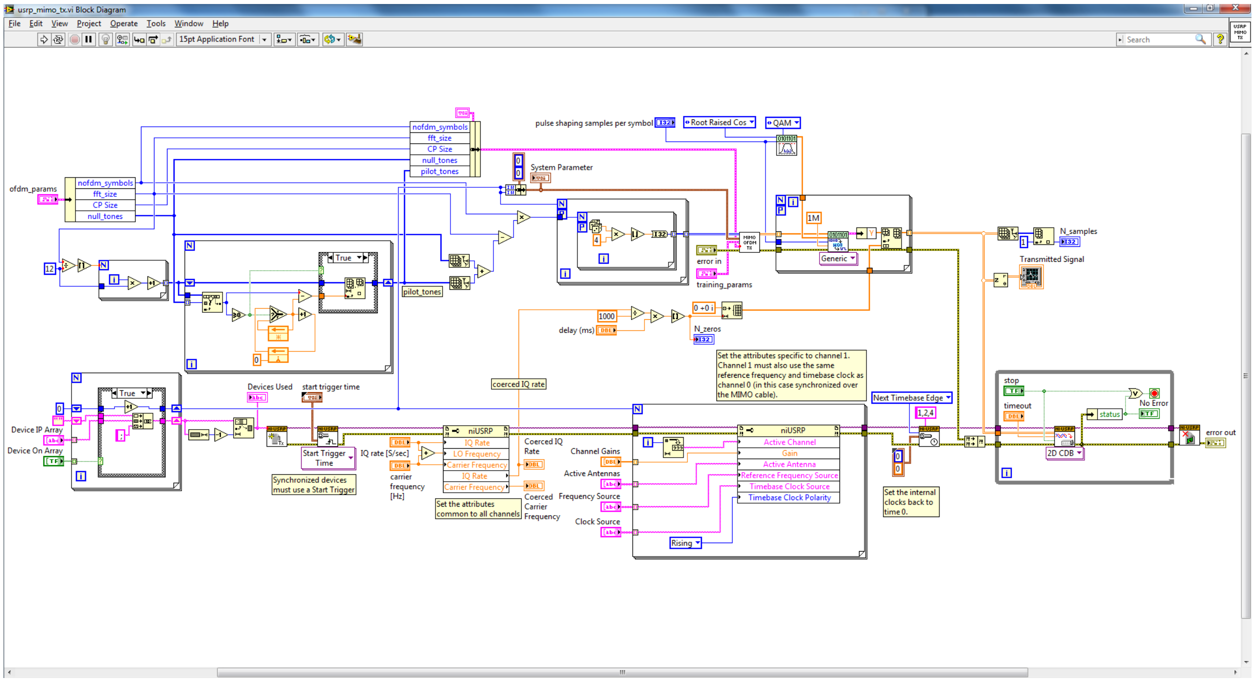

Figure 4: Block diagram of the usrp_mimo_tx.vi

Then the VI calculates the data length (FFT size C length of pilot tones C length of null tones) and generates required number of data bits. These generated bits along with all the parameters from the front panel and the calculated pilot tone positions are fed into the mimo_ofdm_tx.vi to get the QAM modulated OFDM signal with training and synchronization sequence for all the six transmitting antennas. The TX VI also makes sure all the devices in the transmitter are properly configured for the transmission operation. The mimo_ofdm_tx.vi prepares the signal for transmission and the block diagram (Figure 5) of the VI shows that the signal processing is done using MathScript Node in LabVIEW.

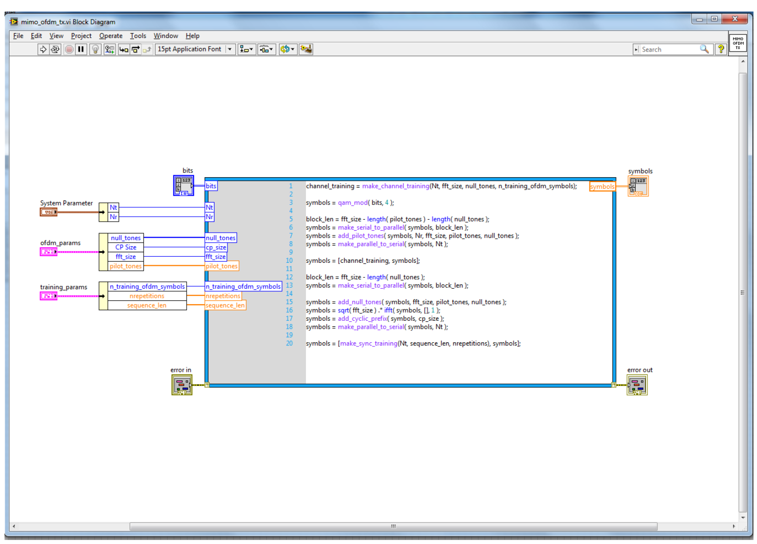

Figure 5: Block diagram of the mimo_ofdm_tx.vi

ii Signal Recovery:

As can be seen from the block diagram of mod_classifier_RX.vi (Figure 6 and Figure 7), the RX VI first calculates the pilot tone positions from the OFDM parameters as was done in the transmitter. It also sets up all the USRPs at the receiver to have the appropriate operating configurations. In order to fetch a particular number of samples for each processing cycle, the RX VI then calls the usrp_rxrf_trigger_and_capture.vi subVI.

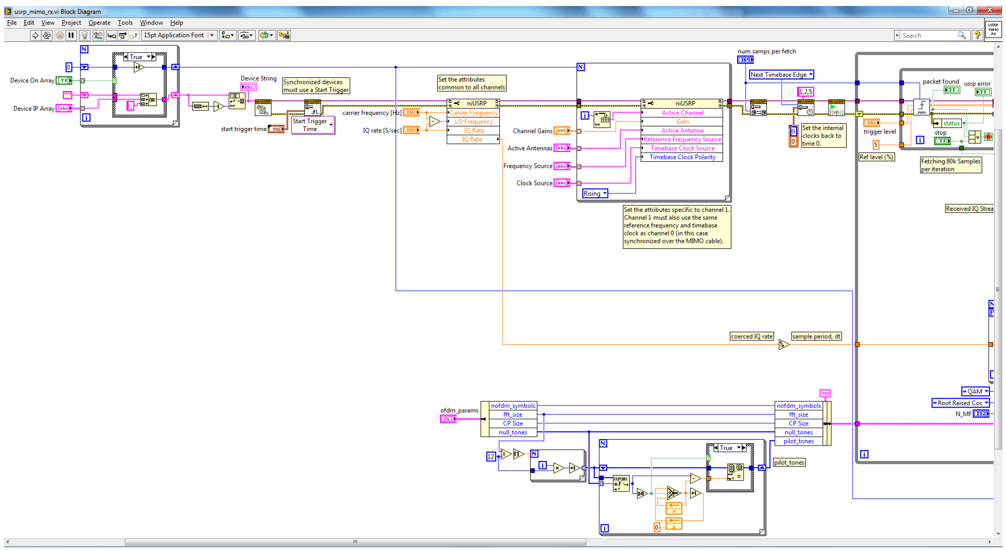

Figure 6: Block diagram of the usrp_mimo_rx.vi C part 1

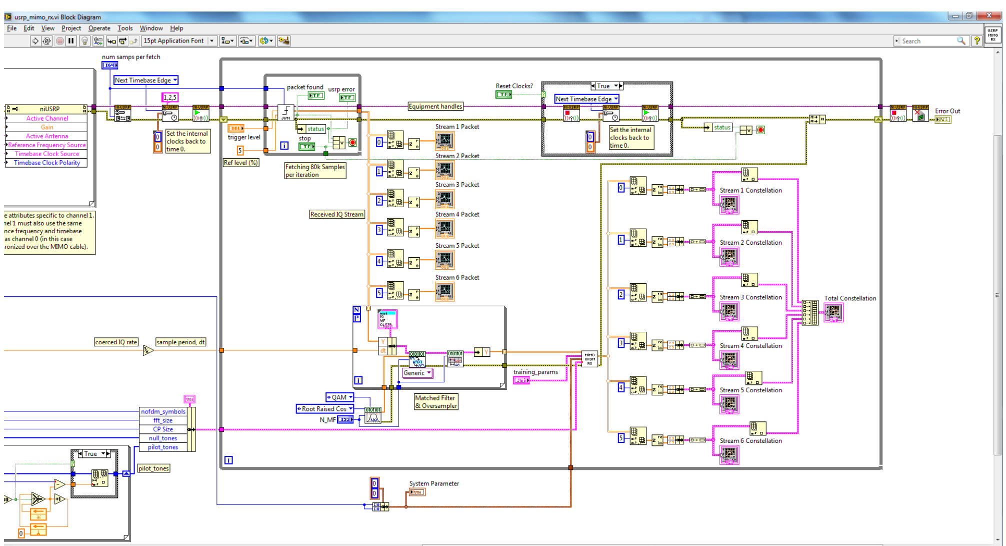

Figure 7: Block diagram of the usrp_mimo_rx.vi C part 2

The block diagram of the usrp_rxrf_trigger_and_capture.vi subVI is given in Figure 8. As can be seen from Figure 8, the subVI captures a particular number of samples (80k for this example) and compares them to the given threshold to detect the presence of the transmitted signal. When the received signal samples are above the threshold, the subVI returns the IQ samples and a packet found flag. The IQ samples are then passed through matched filtering and oversampling operation (Figure 7). The processed IQ samples along with all the training parameters from the front panel and the calculated pilot signal positions are then fed to the mimo_ofdm_rx.vi subVI to get all six demodulated data streams. The usrp_mimo_rx.vi also presents the received packet streams and the demodulated QAM constellations to justify successful receiver operation. The block diagram of the mimo_ofdm_rx.vi is given in figure 9:

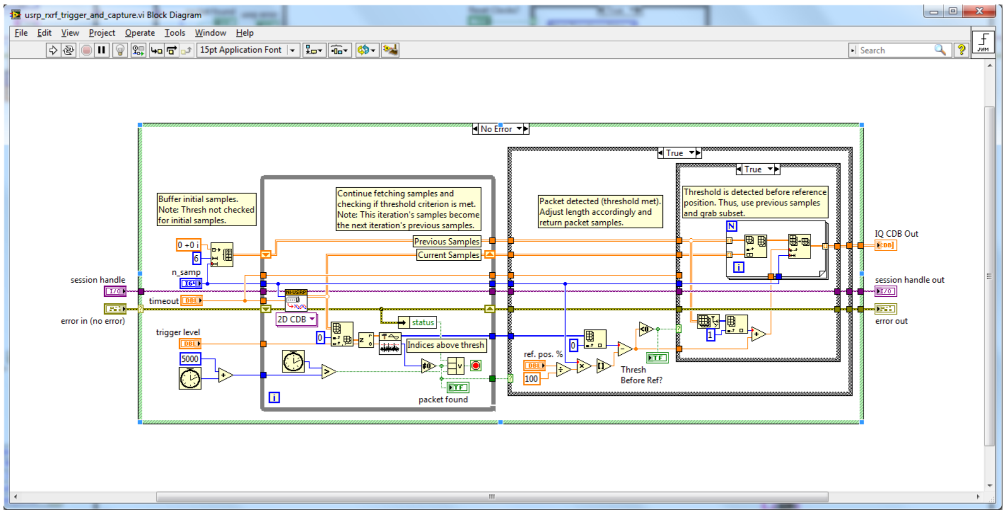

Figure 8: Block diagram of the usrp_mimo_rx.vi C part 2

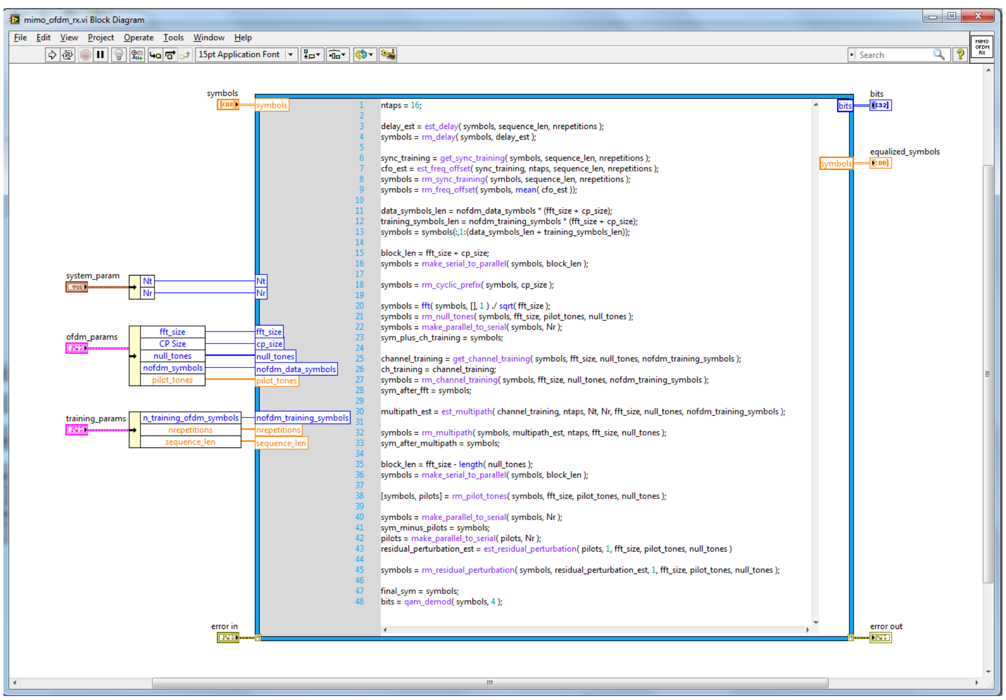

Figure 9: Block diagram of the usrp_mimo_rx.vi C part 2

4 Results

Figure 10 shows the six RX signal constellations from a test run of the 6x6 MIMO system running on twelve NI USRP transceivers. The receiver addresses the impact of different channel impairments such as time delay, carrier frequency offset, multipaths, and residual channel perturbation by estimating and correcting them through appropriate signal processing operations. This image shows that the receiver works successfully.

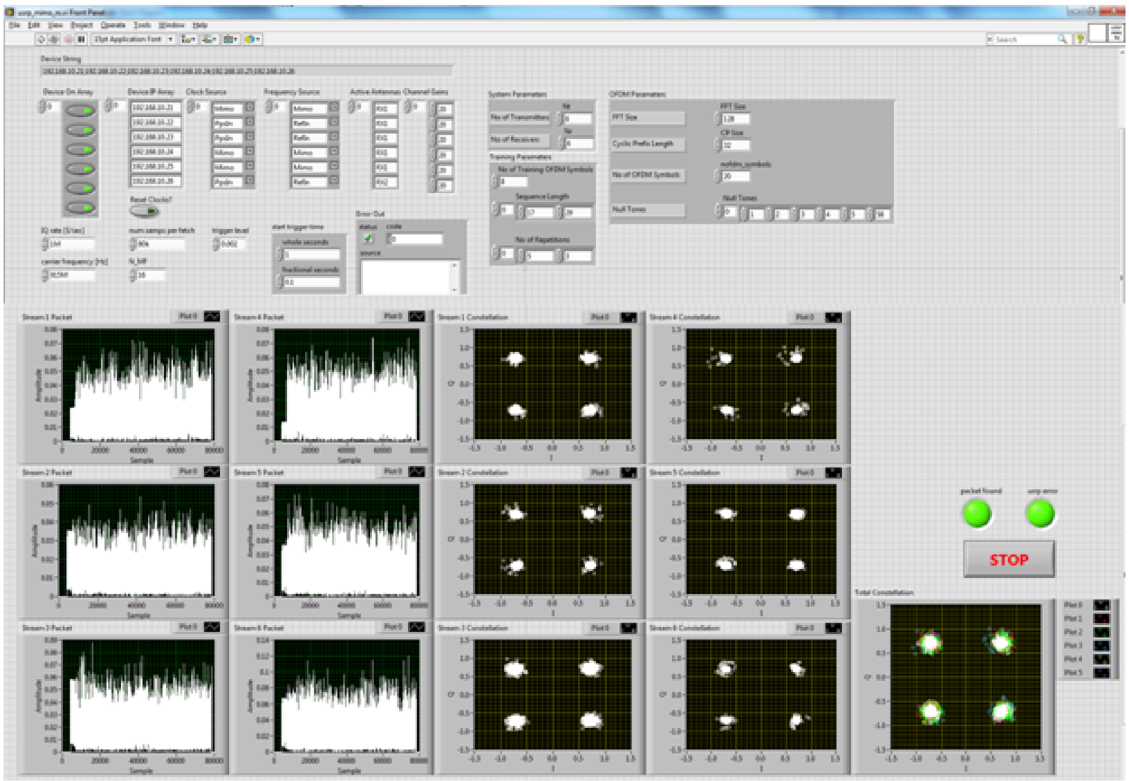

Figure 10: Front panel of the usrp_mimo_rx.vi