Research and Implementation of 2x2 MIMO-OFDM System with BLAST Using USRP-RIO

Jingyi Zhao, Yanhui Lu, Ning Wang[*], and *Shouyi Yang*
School of Information Engineering, Zheng Zhou University, China
[*]Corresponding author: Ning Wang, ienwang@zzu.edu.cn

Abstract:

In this paper, we use NI USRP-RIO and LabVIEW programming environment to successfully build a 2x2 MIMO-OFDM system. And based on this system, the Zero Forcing(ZF) detection algorithm, the Zero Forcing-ordered Successive Interference Cancellation(ZF-OSIC) detection algorithm and Bell Labs Layered Space-Time coding(BLAST) are adopted, the program diagrams of 2x2 MIMO-OFDM system with BLAST in simulated channel and real wireless channel are shown, the simulation of diagrams and measured results are all presented. The conclusion based on the simulation of diagrams and measured results is that either in real channel or in simulated channel, the performance of receiver under ZF-OSIC algorithm is superior to ZF algorithm.

Keywords: *MIMO-OFDM, BLAST, USRP-RIO, ZF, ZF-OSIC*

1 Introduction

As one of the key technology of wireless communication, the MIMO-OFDM technology has been a focus of academic research for decades. MIMO-OFDM system can not only enhance the spectrum efficiency and reduce the interference of multipath effect, but also increase the capacity of the system. Meanwhile, the detection module in the wireless communication system to a large extent determines whether the MIMO-OFDM system is a good thing or bad, so signal detection algorithm has become the focus of the research and hot spot. Especially, the complexity of detection algorithms is closely related to the detection performance of the receiver, therefore, the research is more meaningful and we can choose appropriate algorithms according to our own requirements in complex real wireless channel.

USRP-RIO with flexible on-converter and down-converter is made in NI company, and matches the high-speed Digital to Analog Converter (DAC) and Analog to Digital Converter (ADC). It also can be used to send and receive Radio Frequency (RF) signals. LabVIEW is the most widely used and fastest-growing graphical software, and has the most powerful development environment. With the LabVIEW, the software simulation of communication systems can be seamlessly integrated into USRP-RIO hardware platform to build a real wireless communication system.

The main goal of this paper is to use NI USRP-RIO hardware and LabVIEW software to build the 2x2 MIMO-OFDM system platform. The Paper is arranged as follows: The second part presents the composition and working principle of 2x2 MIMO-OFDM system platform based on NI USRP-RIO. The third part shows the program diagrams of 2x2 MIMO-OFDM system with BLAST in LabVIEW simulated channel and real wireless channel based on USRP-RIO, and the ZF algorithm and ZF-OSIC algorithm are adopted in this system. In the fourth part, we respectively complete the simulation and measurement of ZF algorithm and ZF-OSIC algorithm in simulated channel and real wireless channel, and analyze the simulation of diagrams and the measured results**.** Finally, conclusions are drawn in the fifth part**.**

2 NI USRP—RIO based experiment platform of 2x2 MIMO-OFDM system

2.1 The composition of platform

2x2 MIMO-OFDM system platform based on NI USRP-RIO consists of USRP-RIO made in NI company and LabVIEW programming environment running on computer. The connection of NI USRP-RIO and computer is by gigabit Ethernet, as showed in Fig.3. The NI USRP-RIO contains two data channel to send and receive, so according to the different configuration, the same USRP-RIO can be used as a transmitter, and also as a receiver.

Fig.1 The composition of 2 x2 MIMO-OFDM system platform based on the NI USRP-RIO

2.2Working principle of the platform

According to the reference[1], we can use LabVIEW programming environment running on the computer to compile 2x2MIMO-OFDM transceiver processing baseband signals, and the RF front-end of the platform can be implemented by the USRP-RIO. And in the process of modeling, we need to use the sending and receiving function in USRP-RIO driver.

Based on the principle diagram of the platform in reference[2], in transmitting link, the transmission of 32-bit I/Q baseband signals (each pair of I/Q is 16-bit) are synthesized by the transmitter of 2x2 MIMO-OFDM system on the computer, then the I/Q baseband signals are transmitted to the USRP-RIO through Gigabit Ethernet. The speed of I/Q signals will be became 400MS/s by DUC on USRP-RIO, and the DAC converts the input signals into analog signals. The resulting analog signals are mixed with a specified carrier frequency, namely IQ modulation, then the RF signals

generated by IQ modulation after amplification are transmitted by antennas to real wireless channel.

In receiving link, signals are connected to the SMA connector, then through the mixing operation in the USRP-RIO receiver, we can get the I/Q baseband signals, namely IQ demodulation. Then the baseband signals through ADC which is14-bit and has a second channel sampling, are converted into digital signals. Then the digital I/Q signals in parallel are dealt with the DDC, and after mixing operation, filtering operation, the rate of the input signal which is 100MS/s initially will reach a specified rate. Next， the resulting 32-bit variable frequency signals through the Ethernet are transmitted to the computer at a speed of up to 20 MS/s. Then the I/Q signals are processed by 2x2 MIMO-OFDM receiver on the computer, and finally we can get the output sequence.

3 Implement the 2x2 MIMO-OFDM transceiver

3.1 Implement 2x2 MIMO-OFDM system in real wireless channel

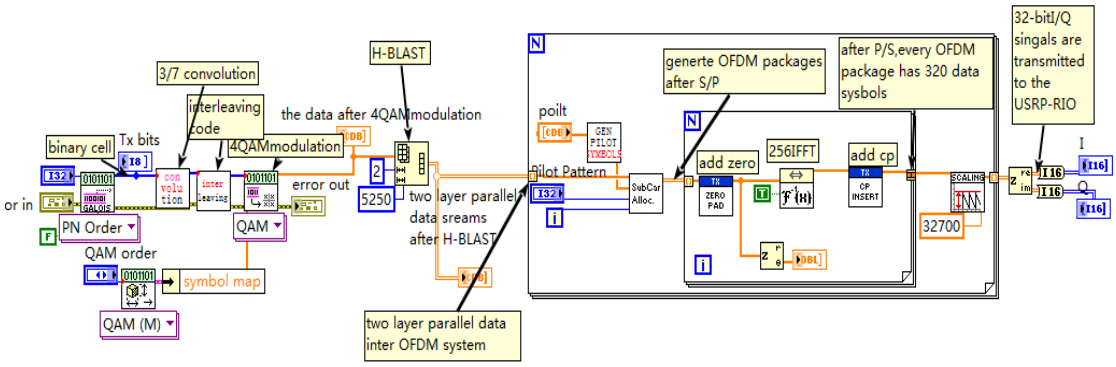

Fig.2 The program diagram of the 2x2 MIMO - OFDM transmitter

In real wireless communication based on USRP-RIO, Fig.2 shows the program diagram of the 2x2 MIMO-OFDM transmitter. According to the references[1],the design and implement of 2x2 MIMO-OFDM transmitter can be described as follows: first, generate bits used for baseband modulation in transmitter. Then the bits are handled by the 3/7convolution coding, interleaving coding, 4QAM modulation, and H-BLAST. According to the reference[3], after H-BLAST coding, we can get two layer parallel data streams, then, the two layer parallel data after modulation are directly sent by the corresponding antennas, there is no interaction between the information of the two layers. So in 2x2 MIMO-OFDM transmitter, the data in each layer after H-BLAST coding will be dealt with adding pilot, S/P, zero padding, IFFT, adding CP, and P/S, clipping the amplitude to prevent PAPR, then the OFDM symbols are generated, and the symbols in each layer after operation are converted to 32-bit baseband I/Q signals. Finally the parallel 32 I/Q baseband signals in two layers synthesized by computer

through Ethernet are transmitted to USRP-RIO. After treated by the USRP-RIO sending link, the signals in each layer are transmitted to the real wireless channel by corresponding antennas, and there is no interaction between the information of the two layers.

In receiver, the signals dealt with the USRP-RIO receiving link are transmitted to the computer via Ethernet. The 2x2 MIMO-OFDM system receiver on the computer handles signals by synchronous operation, S/P, to CP, deviation correction, FFT, go to zero, channel estimation and signal detection operation, P/S, then serial data streams are generated. According to the reference[4], We choose the frequency domain channel estimation to achieve channel estimation. In signal detection operation, we use two detection algorithm: ZF algorithm and ZF-OSIC algorithm. The ZF-OSIC algorithm detects signals based on the descending order of the norm of channel matrix. According to the references[5], the diagrams of the two detection algorithms are shown in Fig.3. Then the serial data streams are handled by H-BALST decoder, 4QAM demodulator, channel decoder, we can get the final sequence.

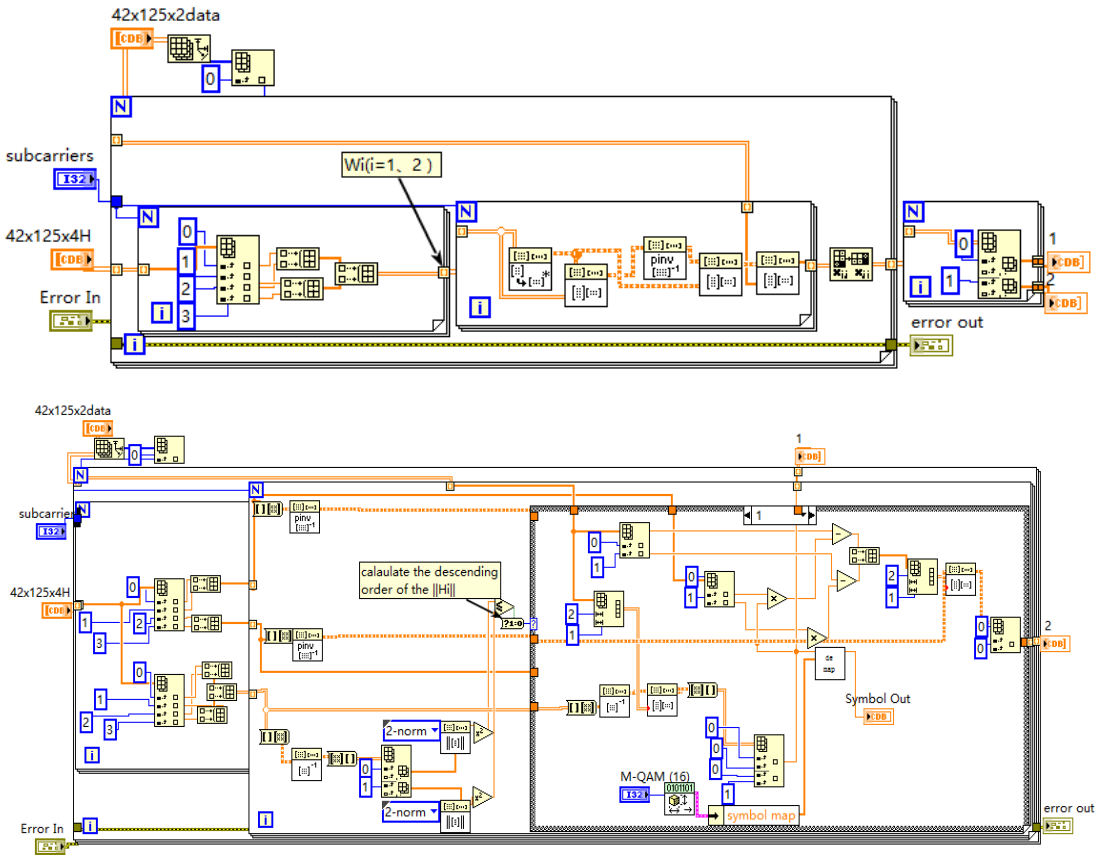

Fig.3 The program diagram of the the ZF algorithmthe and ZF-OSIC algorithm

3.1 Implement 2x2 MIMO-OFDM system in simulated channel

In LabVIEW simulated environment, the program diagram of 2x2 MIMO-OFDM system is shown in Fig.4, the simulated channel is slow Rayleigh fading channel, and

introduces the additive white gaussian noise. The program diagram of transmitter is the same as Fig.2. The signals after the simulated channel are transmitted to the receiver, and the program diagrams of ZF algorithm and ZF-OSIC algorithm in the receiver are the same as Fig.3.

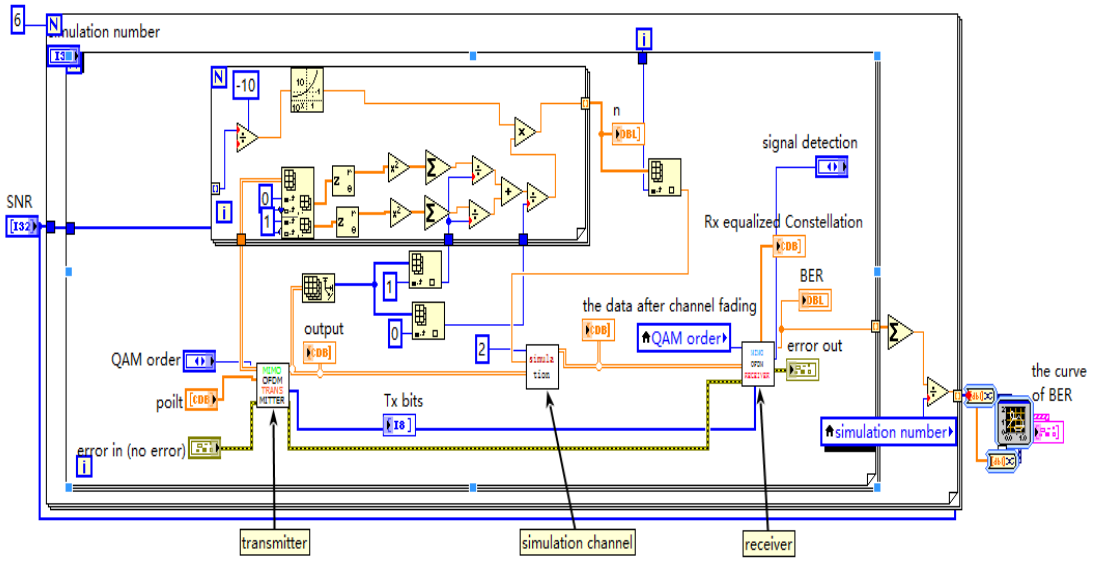

Fig.4 The program diagram of the 2x2 MIMO - OFDM system in simulated channel

4 Experimental results

We can assume 42000 bits are generated in transmitter. In LabVIEW simulated environment, the simulated channel is slow Rayleigh fading channel, the noise in receiver is the additive white Gaussian noise, and the receiver has realized the precise synchronization and accurately estimated the channel coefficient. In actual channel based on USRP-RIO, we choose the indoor environment and adjust the antenna direction to choose the optimal channel environment. According to the reference [6], we estimate the range of the SNR in receiver is 13dB ~ 21dB.

As is shown in Fig.5, the SNR is as the abscissa, and BER is as the ordinate. From Fig.5, we can get that either in the real channel or in simulated channel, the performance of ZF-OSIC algorithm in receiver is better than that of ZF algorithm, and the detection performance of the two algorithm in the real channel are all worse than that in simulated channel. The ZF-OSIC algorithm sacrifices the computational complexity is for improving system performance. So in practical situations, we can choose an appropriate detection algorithm according to our own requirements.

5 Conclusion

This paper quickly built a 2x2 MIMO-OFDM system platform by using advantages of LabVIEW software and NI USRP-RIO hardware. Based on this system, we adopt ZF detection algorithm and ZF-OSIC detection algorithm, and present the program

diagrams of 2x2 MIMO-OFDM transceiver in real wireless channel and simulated channel. When the premise of other conditions are the same, according to the experimental results we can conclude that whether in the LabVIEW simulated channel or in actual channel based on USRP-RIO, the BER and the detection performance of ZF-OSIC algorithm in 2x2 MIMO-OFDM receiver are all better than that of ZF algorithm. But ZF-OSIC algorithm sacrifices the computational complexity for improving the performance of the system. So in practice, we can choose the appropriate detection algorithm according to our own requirements.

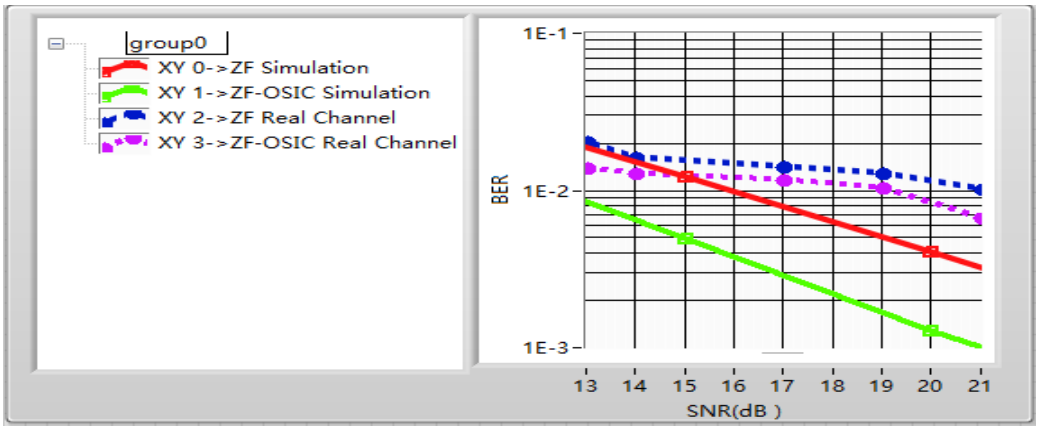

Fig.5 BER of ZF and ZF - OSIC detection algorithm in real channel and simulated channel

References:

1. *J.A.C. Bingham,* Multi-carrier modulation for data transmission: an idea whose time has come. IEEE Commun Mag.,28 (1999) 17-25.
2. NIUSRP 292x Specifications. *http://www.ni.com*
3. *G.J. Foschini,* Layered space-time architecture for wireless communication in fading environment when using multiple antennas. Bell Labs Technical Journal,1996 41-59.
4. *Y.(G.) Li, N. Seshadri, S. Ariyavisitakul,* Channel estimation for OFDM systems with transmitter diversity in mobile diversity in mobile wireless channels. IEEE J. Select. Areas Commum, 17(1999)461-471
5. *P.W. Wolniansky, G. J. Foschini, G. D. Golden, R.A. Valenzuela,* V-BLAST :An Architecture for Realizing Very High Data Rates Over the Rich-Scattering Wireless Channel. Signals Systems and Electronics, 3(1998)295-300
6. *B. Li, Y. Luo,* The calculation of SNR and the selection of modulation mode and device in MIMO system. CN. Pat. Appl.200810213660.2, 3. Mar.2010.

