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IMPLEMENTATION OF A MIMO EVALUATION PLATFORM FOR SDR BASE STATION

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ABSTRACT

In this paper, we implement a MIMO Evaluation Platform with multimode functionality for SDR system. The presented platform contains PHY(Physical layer) including the baseband MODEM(modulation and demodulation) part with the MIMO and smart antenna functionality. The platform is designed to evaluate the performance of various MIMO detection scheme as well as smart antenna scheme utilizing the SDR technology. SDR technology enables a communication system to be reconfigured into MIMO or smart antenna mode through software downloads to the flexible hardware platform that is implemented using programmable devices.

We first describe the operations and functions required by MIMO and smart antenna. Then we explain a design procedure and hardware implementation of the evaluation platform. We also demonstrate our experimental circumstance to show the performances of MIMO and smart antenna which are compared and verified with presented platform.

1. INTRODUCTION

Software defined radio (SDR) technology enables various communication systems to be supported by one platform without hardware change through reprogramming and downloading software. Existing systems have been implemented using ASIC which could process a fixed hardware architecture only. With SDR technology, the flexibility for system implementation can be increased by programmable hardware platform which has been implemented using programmable devices such as DSPs, FPGAs and microprocessor, etc. In various communication system, MIMO(Multi Input Multi Output) and Smart Antenna systems are representative multiple-antenna communication systems. MIMO improves the spectral efficiency and the diversity performance using multiple-antenna. It can be achieved by MIMO precoding and independency of each MIMO channel. Smart Antenna improves the performance of communication system due to reduction of the effects of interference signals and noises. It can be achieved by beamforming which could control the directionality of a radiation pattern with array antenna.

This paper presents a design of the MIMO evaluation platform with multimode functionality for SDR system. With the platform we analyze the performance of MIMO and smart antenna in WiBro.

In chapter 2, we overview the frame structure, functions and block diagrams required by WiBro, and the theory of MIMO and smart antenna. In chapter 3, we represent the architecture and design of the platform. In chapter 4, we demonstrate the performance of platform by MIMO and smart antenna experimental result.

2. OVERVIEW

2.1. WiBro

WiBro is a technology for portable internet service that is using 10MHz bandwidth at 2.3GHz center frequency. It is based on OFDMA and TDD scheme and provides the mobility above 60 km per hour and the transmission speed of 1 Mbps level. It can provide the service coverage larger 10 times in radius than that of wireless LAN called Wi-Fi, which is only provided in the Hot Spot service area. The standard of WiBro technique HPI (high-speed portable internet) which is mainly developed by the Korean enterprise corresponds to the international technical standard IEEE 802.16e. IEEE 802.16e approved by IEEE recently is an international technical standard for the next generation wireless broadband transmission.

The frame of WiBro has 5ms duration and each frame begins with a preamble followed by a downlink transmission period and an uplink transmission period. Between the downlink and uplink transmission, a TTG is inserted and between the uplink and downlink a RTG is inserted as shown by Figure 1.

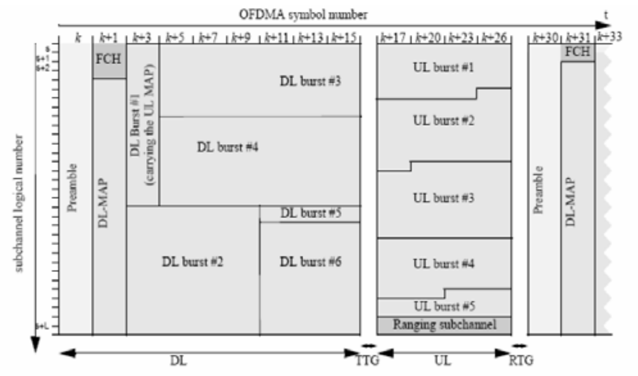

Figure 1. frame structure of WiBro system

The transmitter of WiBro system performs a randomization of information, channel encoding, interleaving, repetition followed by a modulation to generate data subcarriers and arrangement of the data subcarriers and pilot subcarriers corresponding to pre-defined pattern. After IFFT operation, it transmits the signals adding CP. The receiving process is a reciprocal one of transmission which consists of FFT, channel estimation using pilot subcarriers, demodulation of data subcarriers and symbol processing like summing, deinterleaving, decoding and derandomization, etc. Figure 2 shows the block diagram of transmitter and receiver for WiBro system.

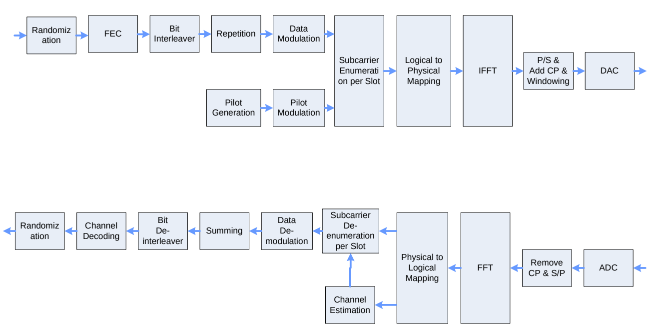

Figure 2. block diagram of WiBro system

2.2. MIMO

MIMO technology improves the channel capacity and the performance of communication system using multiple antenna without additional frequency assignment or transmission power.

MIMO technology is divided by STC(Space Time Coding) and SM(Spatial Multiplexing) that these two methods are related on trade off. It is determined method which is chosen, according to communication environment and user's demands.

2.2.1. STC

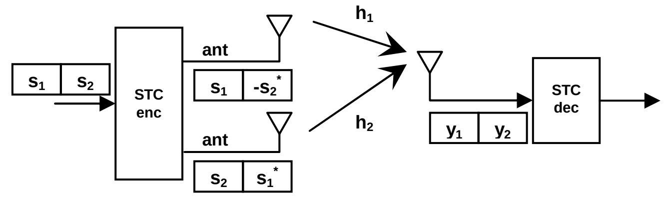

Figure 3. 2x1 STC block diagram

As shown in Figure 3, STC the same data are encoded, and transmitted through multiple antenna simultaneously. As the received signals which pass through each independent channel, are decoded in receiver, this process can complement the attenuation by channels. Thus reliability can be grown up. That means, it obtains diversity gain related on multiply of number of transmitter / receiver antennas. Below equations (1), (2), show received signal modeling and decoding equation modeling,

$$\begin{pmatrix} y_1 \\ y_2 \end{pmatrix} = \begin{pmatrix} s_1 & s_2 \\ -s_2^* & s_1^* \end{pmatrix} \begin{pmatrix} h_1 \\ h_2 \end{pmatrix} + \begin{pmatrix} n_1 \\ n_2 \end{pmatrix} \qquad (1)$$

$$\begin{pmatrix} \hat{s}_1 \\ \hat{s}_2 \end{pmatrix} = \begin{pmatrix} h_1^* & h_2 \\ h_2^* & -h_1 \end{pmatrix} \begin{pmatrix} y_1 \\ y_2^* \end{pmatrix} \qquad (2)$$

$$= \begin{pmatrix} (|h_1|^2 + |h_2|^2) \cdot s_1 + N_1 \\ (|h_1|^2 + |h_2|^2) \cdot s_2 + N_2 \end{pmatrix}$$

2.2.2. SM

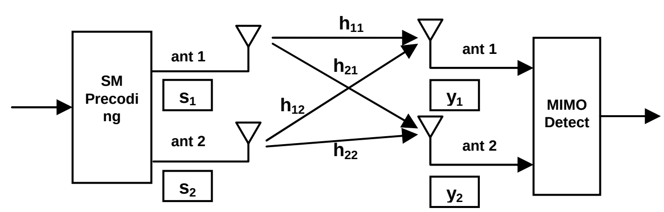

Figure 4. 2x2 SM block diagram

As shown in Figure 4, SM can increase data rate, as independent date symbols are transmitted at each transmit antenna. Signals received each antenna consist of the sum of transmitted data.

$$\begin{pmatrix} y_1 \\ y_2 \end{pmatrix} = \begin{pmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{pmatrix} \begin{pmatrix} s_1 \\ s_2 \end{pmatrix} + \begin{pmatrix} n_1 \\ n_2 \end{pmatrix} = \mathbf{H} \cdot \mathbf{s} + \mathbf{n} \qquad (3)$$

Various methods are investigated in order to detect each transmit signals in vector of receiving signals. Typical MIMO detection methods are ML(Maximum Likelihood), ZF(Zero Forcing) and MMSE(Minimum Mean Square Error) , etc..

SM can not get enough gain when multiple antenna is used by only one side, receiver or transmitter. Multiplexing gain is the same as minimum value of the number of transmitter / receiver antenna.

2.3. Smart Antenna

For all signals received by omni-directional Antenna which has fixed gains to all directions, its powers are influenced by distance between the transmission and receiving antenna, and it may have interference signals.

When the transmitter is moved or the DOA(Direction of Arrival Angle) are variable, the effect of interference can be decreased by using array that consists of several antenna element. Array antenna is used when it finds a position of signals from long distance or transmits/receives preferential signals from them. As well as it can be used to eliminate interferences around them. For smart antenna system the desired signal, of desired direction, can be selectively transmitted/received using controlling the phase of array antenna as well as drastically decrease the effect of interference. That means, the smart antenna system forms the beam to each transmitter between transmitters and receiver, minimizes the powers of undesired signals by beamforming, maximizing the gain to the desired direction. Thus, as it can decrease the noise of the received signal drastically, the smart antenna technology can improve the communication capacity and quality forming the adaptive beampattern to each transmitter.

3. IMPLEMENTATION OF PLATFORM

3.1. Structure of Platform

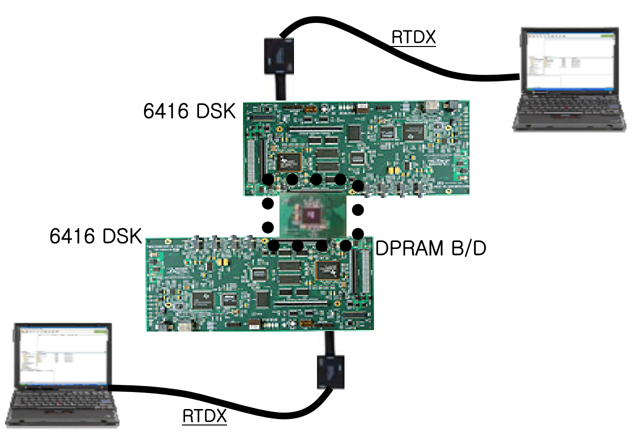

Figure 5. structure of platform

The proposed MIMO evaluation platform for SDR system consists of two 6416 DSKs(DSP Starter Kit), one DPRAM(Dual Port Random Access) daughter board and two PCs.

DSK is TI(Texas Instrument) commercial evaluation board for TMS320C6416T DSP, DPRAM daughter board is made to interface between two DSKs. RTDX(Real Time Data eXchange), which is communication protocol using TI JTAG(Joint Test Action Group), is used for interface between PC and DSK.

3.2. Interface

3.2.1. Interface between DSK and DSK

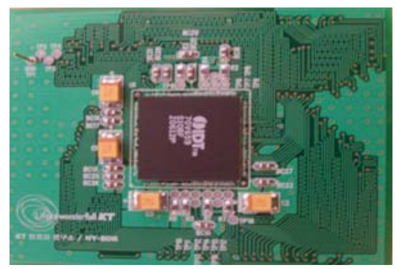

Figure 6. DPRAM Board

DSKs communicate with each other by DPRAM daughter board. Both transmitter and receiver set up the flag at the engaged memory address, keep up polling each flag. When flag is set, data is accessed as shown in Figure 7.

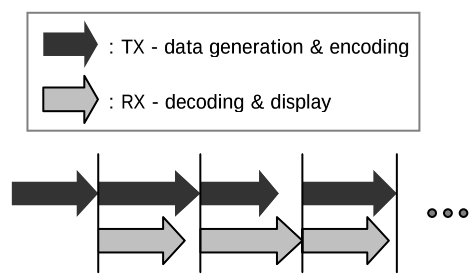

Figure 7. data communication Protocol

The DSP in DSK performs encoding in the receiver when the generated data reaches from the transmission PC. This indicates the TX in Figure 7. Figure 7 exhibits the process of displaying the decoded data on a PC after the DSP in DSK receives raw data from the transmitter. Both the Tx and Rx operate coherently to a PC through RTDX. The data processing of the DSP in DSK maintains constant time, while other processes related to a PC show irregularity with the performance time. Therefore, both the Tx and Rx are to begin the operation at the same time when Tx executes and to take up again when both the operation of Tx and Rx end for reducing data loss, transmitting, and receiving time. In this manner overall operation time reduces in comparison with the sequential process for both Tx and Rx. The flag polling indicates the end of both Tx and Rx.

3.2.2. Interface between DSK and PC

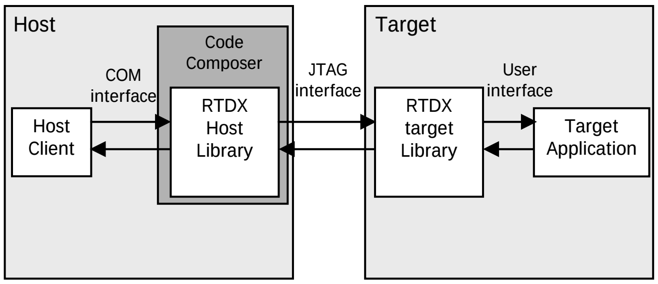

Figure 8. RTDX S/W & H/W block diagram

RTDX is a communication protocol to communicate with PC using TI JTAG emulator. Maximum data rate is theoretically 39.06 KB/s. In Figure 8, target is for DSP and host is for PC. In case that target sends data to host, data are sent to Code Composer, TI DSP evaluation tool, by JTAG emulator using RTDX target Library, supported by TI. These data is communicated to an application in PC by COM interface in PC. In case that host sends data to target, if target requests host to transmit data, host confirms the request in RTDX Host Library. Then, host sends data to target.

4. PERFORMANCE ANALYSIS

This chapter presents numerical results of the evaluation platform performance obtained by operating in WiBro. Transmitted data which experience communication channel is made by computer. The assumption for MIMO channel is that each channel is independent. Common parameters for performance analysis are shown as :

- WiBro Uplink
- Modulation : QPSK
- FFT Size : 1024 points
- Bits per Frame : 3000 bits
- Channel : Rayleigh Fading
- Mobile Speed : 60km/h
- Num of Path / User : 1 path / 1 user
- Channel Estimation : Perfect Channel Estimation
- Coding Rate : 1/2

4.1. MIMO Performance

This section presents numerical results of the platform for MIMO. The assumption for analysis is that for multiple antenna system the sum of the transmission powers at each antenna is equal to the transmission power for single antenna system.

4.1.1. STC Performance

In this section we show the performances of platform implemented for STC, 2 transmission antennas, 1 receiving antenna, in WiBro. Figure 9 illustrates the performances of STC system in rayleigh faing. It is obvious that STC system has about 10dB gain compared with single antenna system at 10^{-3} BER. We can show the STC system has the diversity order of 2 in the Figure 9.

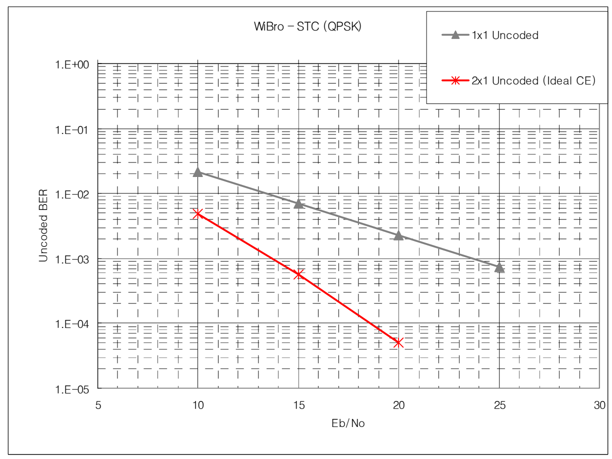

Figure 9. Uncoded BER performance in WiBro STC mode

4.1.1. SM Performance

In this section we show the performances of platform implemented for SM, 2 transmission antennas, 2 receiving antennas, in WiBro. ML(Maximum Likelihood), ZF(Zero Forcing) are applied to MIMO detection method. Figure 10 illustrates the performances of SM system in rayleigh faing. As shown in the figure, it is observed that the BER performance of ML has the diversity order of 2.

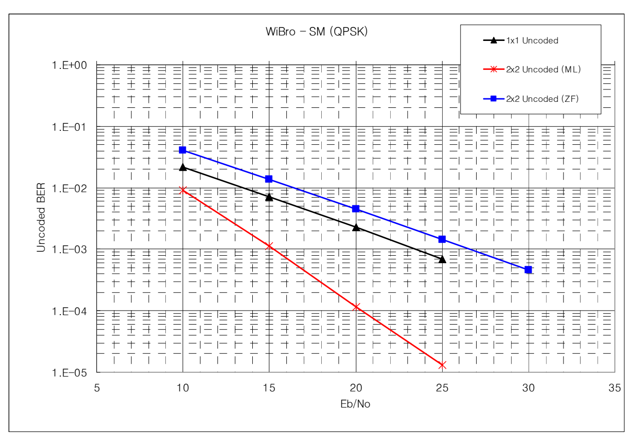

Figure 10. Uncoded BER performance in WiBro SM mode

As shown in Figure 11, it is observed that ML improves the throughput of the system. Max data rate is double that of single antenna system.

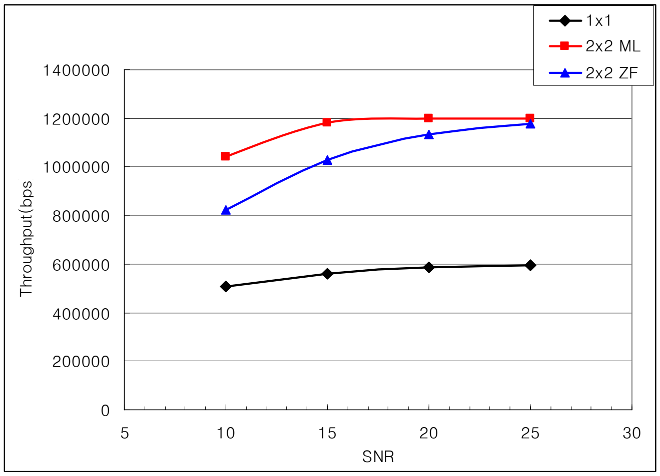

Figure 11. Throughput in WiBro SM mode

4.2. Smart antenna Performance

In this section we show the performances of platform implemented for smart antenna, 6-array antenna, in WiBro. Lagrange algorithm is applied to forming the beam pattern.

First, we observe the beam pattern which is formed by smart antenna, and we present beampattern is formed to desired direction with accuracy. Figure 12 illustrates the beampattern when SNR is 6dB, DOA is 0°. Figure 13 illustrates it when SNR is 6dB, DOA is 30°.

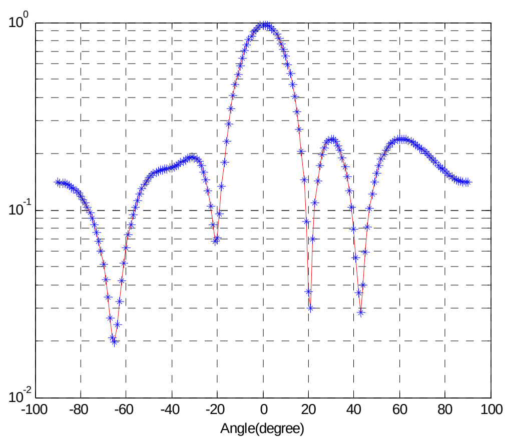

Figure 12. Beam pattern (DOA 0°)

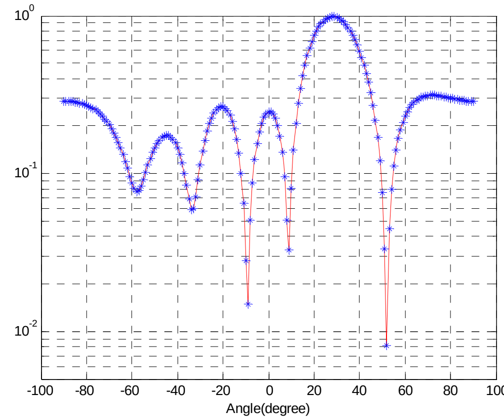

Figure 13. Beam pattern (DOA 30°)

Secondly, as shown in Figure 14, it is observed that smart antenna system has about 7dB gain compared with single antenna system at 10^{-3} BER.

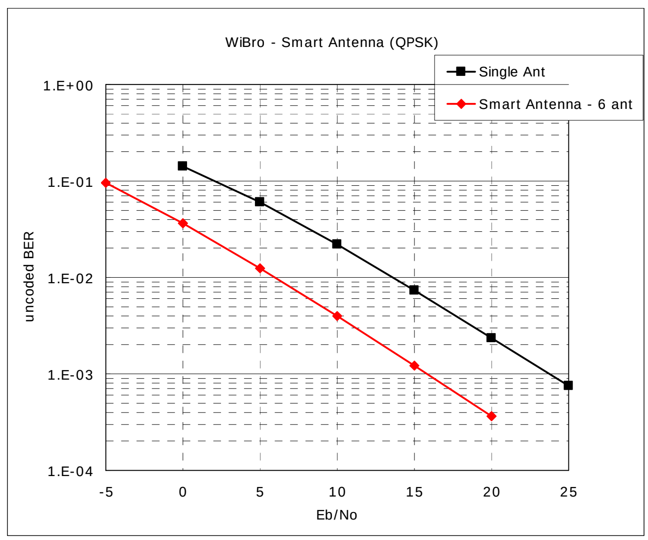

Figure 14. Uncoded BER performance in WiBro smart antenna

5. CONCLUSION

This paper has presented a design and a performance analysis of MIMO evaluation platform with multimode functionality for SDR base station. We have overviewed the frame structure, functions and block diagram required by WiBro, presented MIMO and smart antenna technology which are representative multiple antenna systems for improvement of wireless communication system. Then, we have proposed the design of the MIMO evaluation platform for SDR base station which has 2 DSK, 1 DPRAM board. Finally, we demonstrate the performance of the platform by MIMO and smart antenna experimental result.

6. ACKNOWLEDGMENT

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