# SDR BASED MIMO-OFDM SYSTEM FOR FUTURE WIMAX

Jeong Kim (SK Telecom R&D, Seoul, Korea, , jeikim@sktelecom.com)
Seong Keun Kim (SK Telecom R&D, kimsk64@sktelecom.com)
Se-hyun Oh (SK Telecom R&D, shoh@sktelecom.com)
Hyong Rock Park (SK Telesys R&D ,Suwon,Gyeonggi, Korea, parkrock@sktelesys.com)
Jong Ho Park (SK Telesys R&D, johnpark@sktelesys.com)
Chong Hyun Lee (Dept. of Electronics, Seokyeong Univ, Korea chonglee@skuniv.ac.kr );

## ABSTRACT

MIMO technologies with OFDM air interface lead to a very compelling high-speed data transmission for future wireless systems. Since performance verification of MIMO system is important, Software Based Radio(SDR) -based MIMO testbed becomes essential to validate the theoretical performance gain. In this paper, we present SDR-based MIMO testbed system developed in the framework of SK Telecom. The frame work is based on IEEE standard of 802.16e adopting MIMO-OFDM. To evaluate the performance, MIMO system verification software tool is also developed and used for off-line performance evaluation. The proposed SDR-based MIMO testbed and verification software tool can be used as efficient tool for channel modeling, capacity of closed-loop MIMO capacity verification and etc. The performance of the system is verified by using data generated via METRA channel simulator.

## 1. INTRODUCTION

As wireless communication systems look to make the transition from voice communication to interactive Internet data, achieving higher bit rates becomes both increasingly desirable and challenging. Space-time coding (STC) is a communications technique for wireless systems that employ multiple transmit antennas and single or multiple receive antennas. Information theory has been used to demonstrate that multiple antennas have the potential to dramatically increase achievable bit rates [1], thus converting wireless channels from narrow to wide data pipes. Space-time codes realize these gains by introducing temporal and spatial correlation into the signals transmitted from different antennas without increasing the total transmitted power or transmission bandwidth. There is in fact a diversity gain that results from multiple paths between base station and user terminal,
and a coding gain that results from how symbols are correlated across transmit antennas. Significant increases in throughput are possible with only two antennas at the base station and one or two antennas at the user terminal, and with simple receiver structures. The second antenna at the user terminal can be used to further increase system capacity through interference suppression.

While theory and simulations typically show the corresponding gains under ideal conditions, hardware platforms and testbeds are essential in validating these gains in real channels and in the presence of implementation impairments. There are testbeds reported in the literature focusing on various wireless technologies. The TSUNAMI project [1] in Europe was aimed at promoting research and development in adaptive antennas. The testbed reported by Motorola Labs [2] is a 2 · 2 broadband multiple-input multiple output orthogonal frequency-division multiplexed (MIMO-OFDM) system. Iospan Wireless Inc. and Stanford University also reported
in [3] a MIMO-OFDM system operating as a 2 · 3 system on the downlink and a 1 · 3 system on the uplink. Research testbeds also play an important role in academia. They provide greater insight into various aspects of wireless system design, and provide hands-on experience to students and faculty.

In this paper, we present WiMAX testbed developed at SK Telecom. The architecture and specification of the testbed are introduced and the GUI verification tool for system evaluation are illustrated. The rest of this paper is organized as follows. The new SDR tested and MIMO verification tools are introduced in Section II and III, respectively. In Section IV. various simulation results are provided. Concluding remarks are given in Section V.

## 2. SOFTWARE-DEFINED TESTBED

In this section, we present SDR based WiMax testbed. The specification of the testbed is summarized in the following Table 1.

| Parameters | Value |
|---|---|
| Nominal Channel BW | 8.75 MHz |
| Sampling Frequency | 10 MHz |
| Sampling Period (1/*Fs*) | 100 nsec |
| No. of FFT points | 1024 |
| No. of sub-carriers | 864 |
| No. of sub-carriers for data | 768 |
| No. of sub-carriers for pilot | 96 |
| seperation of sub-carriers ($\Delta f$) | 9.765625KHz |
| Symbol period ($Tb$=1/$\Delta f$) | 102.4 µs |
| Cycle Prefix duration ($Tg$= $Tb$/8) | 12.8 µs |
| OFDMA duration ($Ts$= $Tb$+$Tg$) | 115.2 µs |
| TDD frame length | 5 ms |

**Table 1** Specification of Testbed

The developed receiver testbed is illustrated in Figure 1.

**Figure 1**. The developed MIMO receiver testbed

The testbed is composed a few functional blocks. The functional block diagram of the testbed is also shown in the Figure 2. The testbed is designed to operate in quite general mode so that it works in 2 transmit and 2 receive antenna mode and can be extended for 4 transmit and 4 receive antennas.

## 3. MIMO VERIFICATION GUI

In this section, we present MIMO verification GUI software tool based on Matlab. The software is designed to evaluate to transmit and receive signal qualities and the overall system performance. For verification, we generate test frame pattern at the first stage.

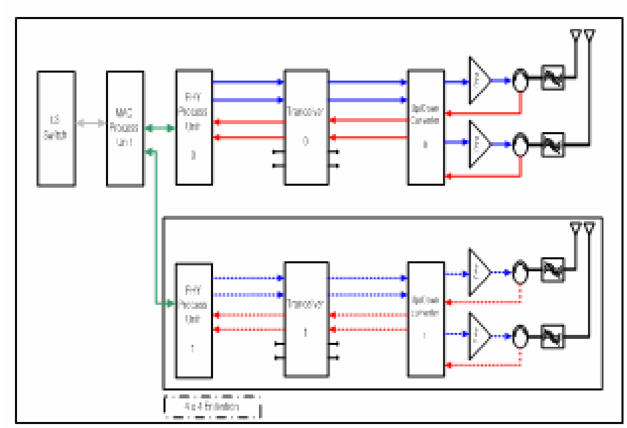


**Figure 2**. The functional block diagram of MIMO Testbed

The one example of test frame pattern is illustrated in Figure 3. As seen in the Fig. 3, test frame can be divided into symbols which can be assigned to different modulation, ID cell and permutation types such as Partial Usage Sub Channel (PUSC) and Full Usage Sub Channel (FUSC).

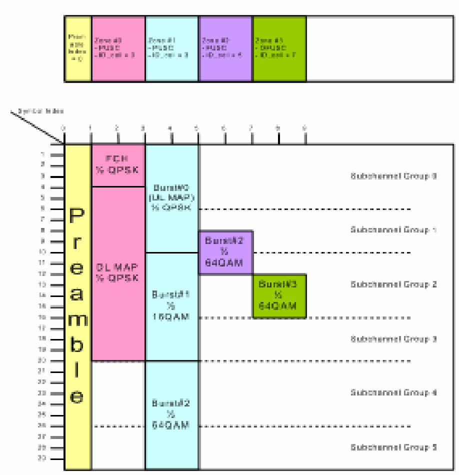



**Figure 3.** The one example of test data frame

Once test data frame is fixed, we can select arbitrary subchannel and symbol to verify the quality of transmit and received signal. To verify the selected section of data, we develop the GUI software which is shown in Figure 4.

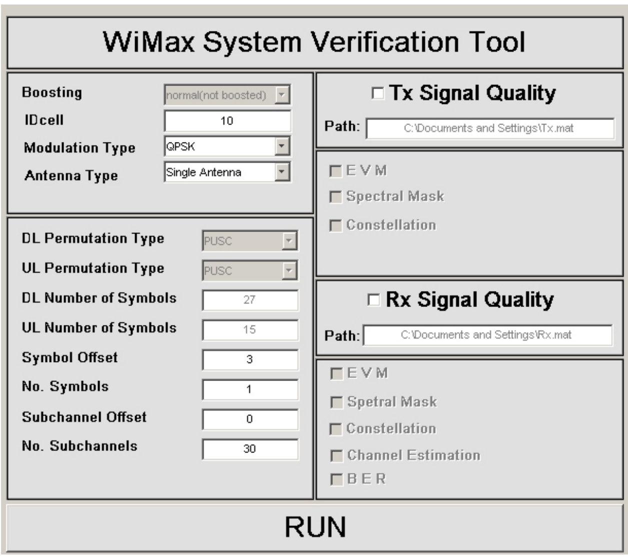



**Figure 4**. The verification GUI software

As seen in the figure, we can select arbitrary block of data to verify. The data to be verified can be either transmit or received data. The outputs of the verification software are spectral flatness, constellation and Error Vector Magnitude (EVM). The other parameters of BER, channel estimates and SNR also can be produced. The one example of transmit and received signal waveform quality are depicted in Figure 5.

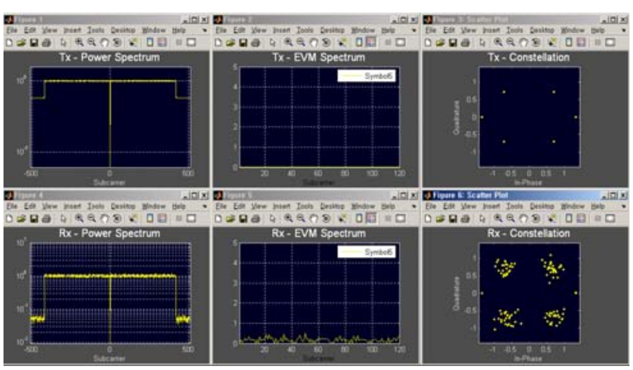



**Figure 5**. The one example of verification software

For channel estimation we use the minimum mean square estimation (MMSE) algorithm which is given by

$$\tilde{h}_{j,i} = \frac{r^j \cdot P_i}{\|P_i\|^2}$$

where $r^j$ is the receive signal at $j^{th}$ receive antenna, $P^i$ is the
pilot symbol at $i^{th}$ transmit antenna and $h_{ij}$ is the channel estimate. For channel estimation in which pilot signal is absent, we use interpolation technique. In short, time domain interpolation is applied and then frequency domain interpolation follows with the obtained interpolated channel estimate.

### 4. SIMULATION RESULTS

In this section, we present computer simulation results by using the presented GUI software. For computer simulation we adopt the Multiple Element Transmit Receive Antenna (METRA) channel model in [5] and [6]. The simulation parameters are summarized in table 2

| | |
|---|---|
| Chip rate | 3.84e8 |
| Carrier frequency | 2.15e9 |
| Number Of Iterations | 128 |
| Over-sampling factor | 1 |
| Number of chips | 128 |
| Chip over-sampling factor | 1 |

**Table 2** Simulation Parameters used in METRA

In order to verify the performance of channel estimation, we present the generated and estimated channel result. The channel B model is chosen and the speed of vehicle is 40km and SNRs are 15dB and 30dB. The channel generated is shown in Figure 6 and the estimated channel is depicted in Figure 7.

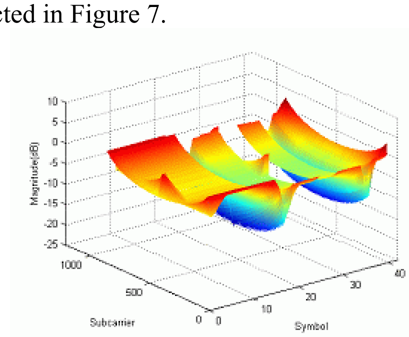
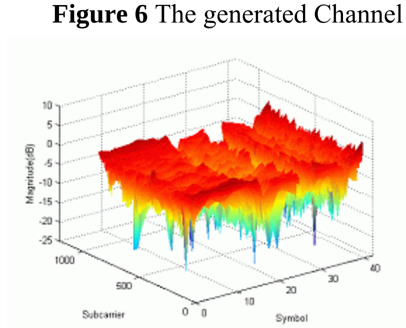
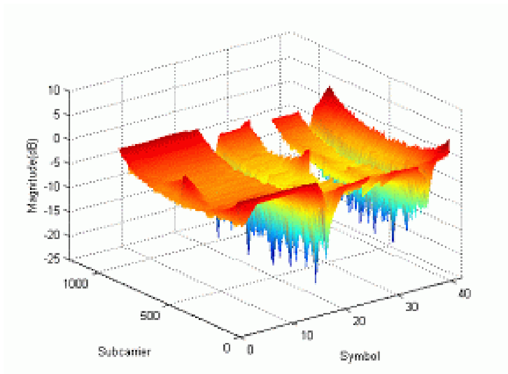



**Figure 6** The generated Channel




(a)




(b)

**Figure 7** Estimated channel(a)SNR=15dB (b)SNR=30 dB

The channel estimation error at the speed of 3km, 40km and 120km are plotted in Figure 8.

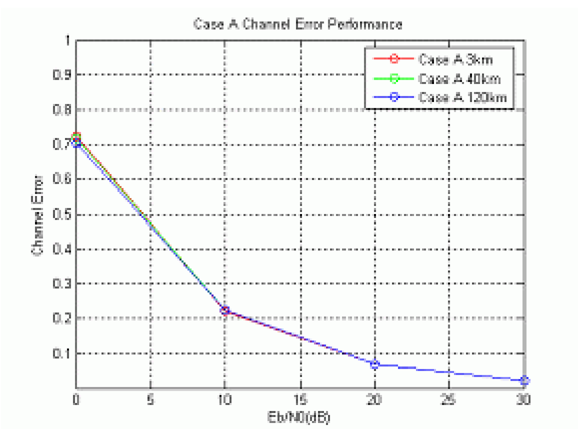



**Figure 8** Channel Estimation Error with speed of 3km, 40km, 120km

In this figure, we observe that the estimation error according to speed of mobile is not significant.

Finally, we present BER performance in Figure 9. We can observe that in low SNR the BER performance is almost same. However, as SNR increases, the BER performance is quite different with the speed of mobile

## 5. CONCLUSION

The MIMO technologies with OFDM air interface gain much attraction in order to obtain high-speed data transmission for future wireless systems. In this paper, we present SDR-based MIMO testbed system developed in the framework of SK Telecom, which is based on IEEE standard of 802.16e adopting MIMO-OFDM. To verify and evaluate the performance, verification software

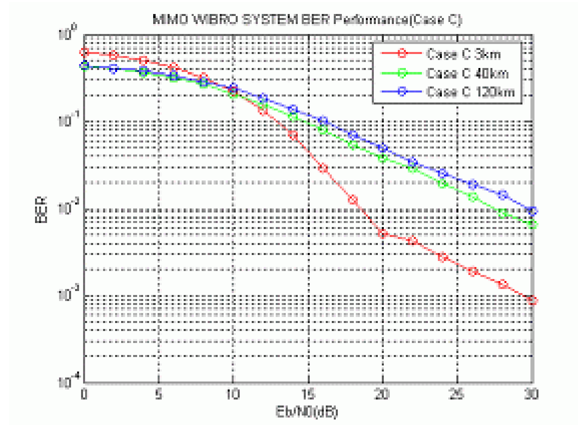



**Figure 9** BER of Case C channel at speed 3km, 40km and 120km

tool is also developed for off-line performance evaluation. At present we present the performance result of the system by using METRA channel simulator to generate received data. Thorough system verification by using the collected data would be future work. Nevertheless, the developed SDR-based MIMO testbed and verification software tool can be used as efficient tool for channel modeling, capacity evaluation of closed-loop MIMO capacity verification as well as open-loop MIMO system.

## 6. REFERENCES

[1] I. E. Telatar, “Capacity of multi-antenna Gaussian channels,” AT & T Bell Labs, Tech. Rep. , 1995.

[2] G. Tsoulos, M. Beach, and J. McGeehan, “Wireless Personal Communications for the 21st Century: European Technological Advances in Adaptive Antennas,” IEEE Commun. Mag., Sept. 1997.

[3] M. D. Batariere et al., “An Experimental OFDM System for broadband Mobile Communications,” IEEE VTC-2001/Fall, Atlantic City, NJ.

[4] H. Sampath et al., “A Fourth-Generation MIMO-OFDM Broadband Wireless System: Design, Performance, and Field Trial Results,” IEEE Commun. Mag., Sept. 2002.

[5] J. P. Kermoal, L. Schumacher, K. I. Pedersen, P. E. Mogensen, and F. Frederiksen, “A Stochastic MIMO Radio Channel Model with Experimental Validation,” *IEEE JSAC*, vol. 20, pp. 1211-1225, Aug. 2002.

[6] Kermoal,et al. “A Stochastic MIMO Radio Channel Model With Experimental Vaildation”, IEEE Journal of Selected Areas in Communications, Vol. 20, No.6, August, 2002