

Project	IEEE 802.16 Broadband Wireless Access Working Group < http://ieee802.org/16 >
Title	MIMO Pilot Allocation using cyclic shift
Date Submitted	2008-3-10
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Re:	IEEE 802.16m-08/005 - Call for Contributions on Project 802.16m System Description Document (SDD), shoot for "Pilot Structures as relevant to downlink MIMO" topic.
Abstract	This contribution proposes a time division multiplexing scheme using cyclic shift for MIMO pilot (CS pilot). Simple analysis and simulation performance show that the CS pilot can maintain the total pilot density and increase the pilot density per antenna, and improve channel estimation accuracy. The CS pilot could be one option for MIMO pilot, especially large number of antenna case.
Purpose	For discussion of Pilot Structures in MIMO case
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MIMO Pilot Allocation using cyclic shift

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1. Introduction

Legacy system defines several types of DL common STC/MIMO pilot allocations such as DL-PUSC, DL-FUSC, and DL optional AMC/ optional FUSC in 2/3/4 transmission antennas cases [1]. Legacy pilot allocations would cover the 4x4 antenna configuration for target peak data rate in SRD [2].

On the other hand, in the spreadsheet for frame, some companies support to consider more than 8 tx antennas. It might not imply to introduce 8 substreams transmission. However, in this session, it could be one discussion point for introducing the pilot of 8 substreams transmission in order to improve the spectral efficiency.

In this contribution, firstly, we discuss the issues regarding the pilot of 8 substreams. In order to overcome the issues, we propose time division multiplexing pilot using cyclic shift (CS pilot) [3,4] as new options. Finally, simulation evaluations show that the channel estimation accuracy of CS pilot outperforms that of Legacy pilot.

2. Issues of a simple expansion of pilot allocation

Legacy pilot multiplexed by time-frequency can be expanded to 8 antenna transmission. Total pilot densities for legacy pilots and their expansions are shown in Table 1. Total pilot densities are very large even in Table 1. And larger multiplexing number of streams requires higher accuracy of channel estimation and it results in much higher pilot density per antenna than that of the simple expansion of legacy pilots.

Table 1 Total pilot density for legacy pilots and their expansions

Number of antenna	1	2	3	4	5	6	7	8
PUSC	0.143	0.143	0.143	0.286	0.357	0.429	0.5	0.571
FUSC	0.083	0.083	0.167	0.167	0.208	0.250	0.292	0.333
Optional AMC/ optional FUSC	0.111	0.111	0.222	0.222	0.278	0.333	0.389	0.444

In following sections, time division multiplexing using cyclic shift (CS pilot) is proposed to improve the channel estimation accuracy keeping the total pilot density and increasing the pilot density per antenna..

3. Time division multiplexing pilot using cyclic shift (CS pilot)

A simple CS pilot consists of one OFDM symbol using whole FFT size which subcarrier symbols are same phase. Then the OFDM symbol becomes an impulse signal. The receiver can observe the multipath channel as impulse response. The antenna multiplexing scheme is based on cyclic shift. When the interval of each antenna transmission is longer than the multipath channel delay, the receiver can extract the multipath channel from each antenna using time-window based on the interval. However, the transmission signal is not a simple impulse signal due to the guard band and non-used DC carrier [5]. Then, the signals become sinc function and the received signals are the convolution of sinc function and multipath.

Figure 1 shows the diagram of the CS pilot and the channel estimation in time domain. The time domain

channel estimator extracts the multipath channel from each transmission antenna from the received total multipath channel. Subsequently, channel estimation values in frequency domain from each transmission antenna are calculated by FFT.

Figure 2 shows the details of channel estimator. Since the received signals are the convolution of sinc function and multipath, it is necessary to use time domain channel estimator based on successive cancellation with replica signals of sinc function in order to estimate the multipath removing the interfered signals of sinc function. The time domain channel estimation could reduce the noise effect comparing with frequency domain channel estimation. The time domain channel estimation could improve the estimation accuracy. The time domain channel estimator can be utilized not only for the CS pilot but also for the Legacy pilot.

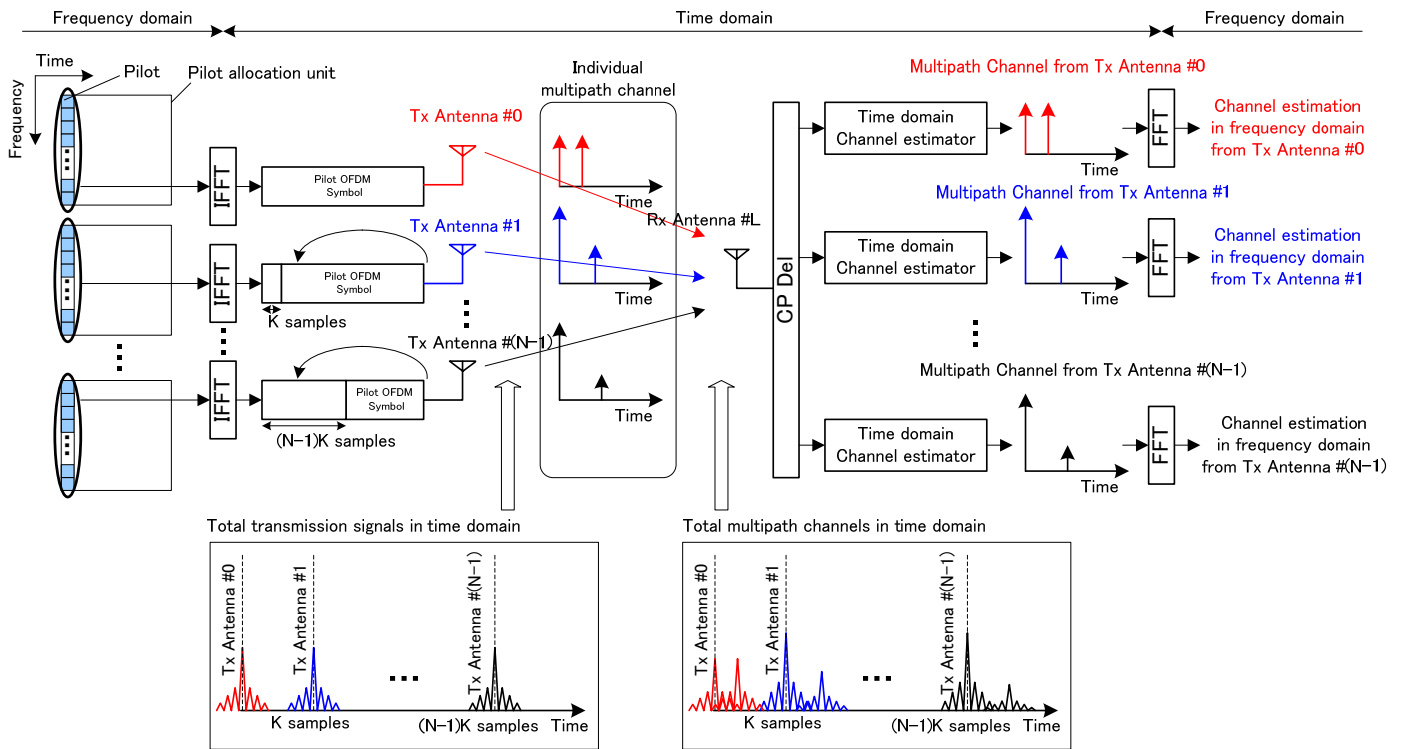


Figure 1 Block diagram of the CS pilot and the channel estimation

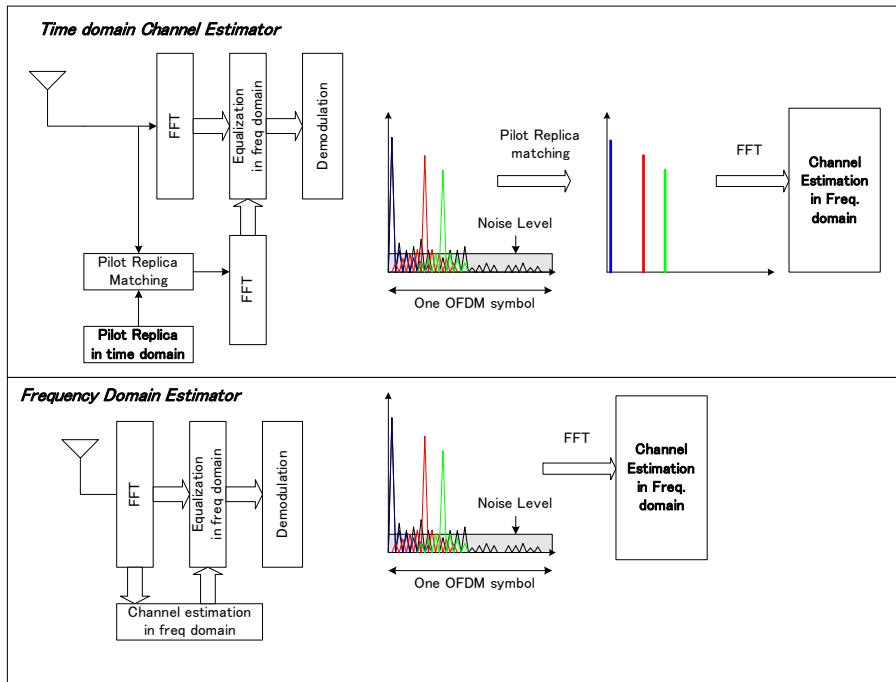


Figure 2 Time domain channel estimator

4. Pilot density comparison

In this section, pilot densities are compared between the legacy pilot and the CS pilot. Figure 3 and Figure 4 illustrate pilot allocations for the Legacy pilot and the CS pilot in case of 4 and 8 antennas case respectively. The Legacy pilot allocation in 4 antennas case is FUSC case extracted from 8.4.8.2.2 of [6] and the legacy pilot allocation in 8 antennas case is simply extended version of 4 antennas case.

Table 2 shows the total pilot densities and pilot densities per antenna comparison of the FUSC pilot and the CS pilot. Since one CS pilot contains pilots of all antennas, the CS pilot can keep the total pilot density and increases the pilot density per antenna.

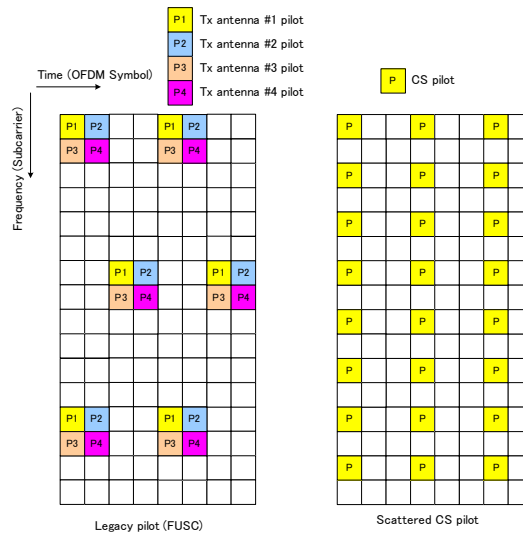


Figure 3 Pilot allocation in 4 antennas case

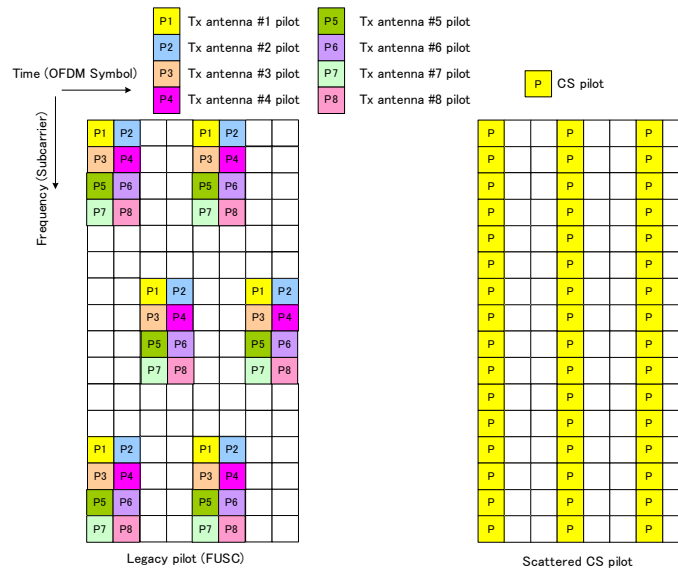


Figure 4 Pilot allocation in 8 antennas case

Table 2 Pilot density comparison

Number of antenna	4	8
<i>CS total pilot density</i>	<i>0.167</i>	<i>0.333</i>
FUSC total pilot density	0.167	0.333
<i>CS pilot density per antenna</i>	<i>0.167</i>	<i>0.333</i>
FUSC pilot density per antenna	0.042	0.042

5. Channel estimation performance

In this section, channel estimation performances are compared between the legacy pilot (FUSC) and the CS pilot. The simulation assumes 8x8 MIMO ITU Pedestrian-B model and mobility of 3km/h and 30km/h. The pilot allocations are shown in Figure 4 and the frame structure is compliant with 5MHz downlink parameters of [7, table3]. For the channel estimation method of the CS pilot allocation, time domain channel estimator is applied. For the FUSC pilot, both time domain channel estimation and zero forcing are evaluated.

Figure 5 and Figure 6 show the NMSEs (Normalized Mean Square Error) of these pilot allocations in case that velocity equals to 3km/h and 30km/h respectively. In both cases, the CS pilot has 6dB better performance than FUSC pilot using time domain channel estimator. This is due to the difference of pilot density per antennas between these allocations. Also, FUSC using time domain channel estimator has 8dB better performance than that using ZF receiver due to the difference of noise elimination effect.

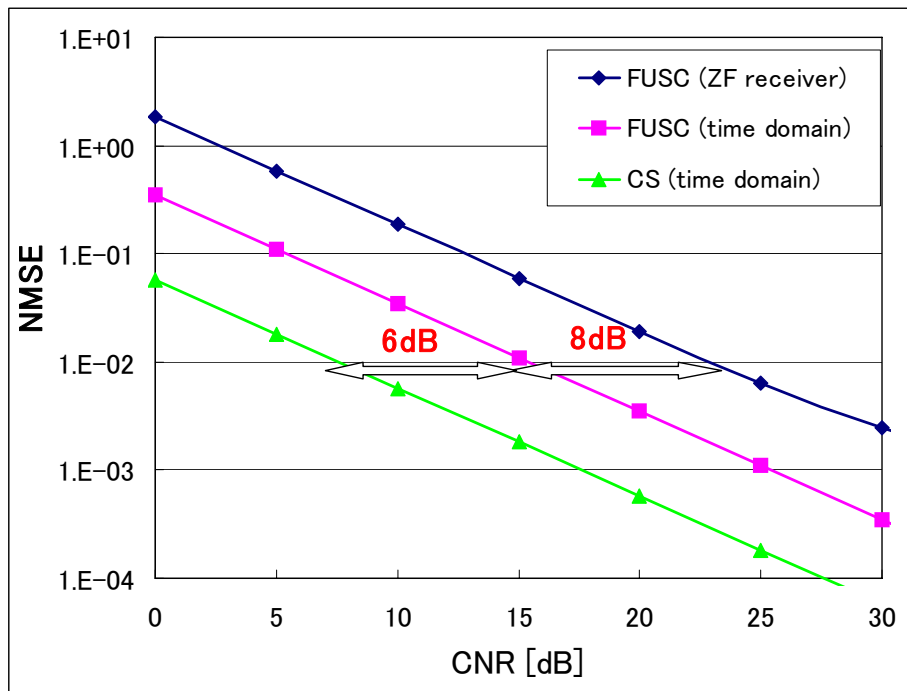


Figure 5 NMSE Comparison (8x8 MIMO, PB 3km/h)

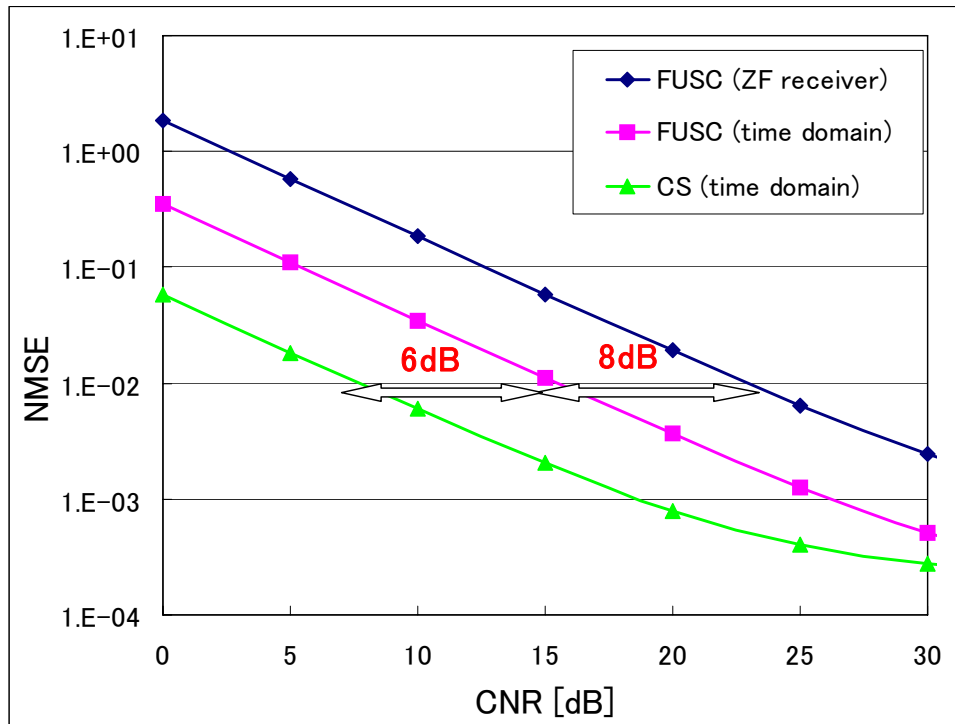


Figure 6 NMSE Comparison (8x8 MIMO, PB 30km/h)

6. Conclusion

In this contribution, we have proposed Time Division multiplexing pilot using cyclic shift (CS pilot). Our analysis shows the simple expansion of legacy pilot for larger number of antenna is not so appropriate. On the other hand, we have shown that CS pilot can keep the total pilot density and increase the pilot density per antenna and improve channel estimation accuracy. CS pilot could be one option for MIMO pilot, especially large number of antenna case. Detail CS pilot allocation is FFS.

Proposed Text

[Insert the following into section 11 of SDD]

----- **Text start** -----

11.x DL pilot for STC/MIMO

The pilot signals for STC/MIMO are orthogonally multiplexed by time and frequency or cyclic shift. The detail pilot allocation depends on the permutation requirements.

----- **Text end** -----

Reference

- [1] WiMAX Forum™ Mobile System Profile Release 1.0 Approved Specification (Revision 1.4.0: 2007-05-02)
- [2] 802.16m-07/002r1 “ Draft IEEE 802.16m Evaluation Methodology”
- [3] 802.16m-07/210 “MIMO Pilot Allocation”
- [4] 802.16m-08/068 “Scattered MIMO Pilot Allocation using cyclic shift”
- [5] K. YOKOMAKURA, S.SAMPEI, H. HARADA, N. MORINAGA, “A Carrier Interferometry Based Channel Estimation Technique for MIMO-OFDM/TDMA Systems,” IEICE Trans. COMMUN., Vol.E90-N, NO.5 MAY 2007
- [6] IEEE Standard 802.16e-2005
- [7] WiMAX FORUM, “Mobile WiMAX – Part I: A Technical Overview and Performance Evaluation”, August, 2006

Appendix: PAPR issue of CS pilot

CS Pilot with scrambling

Since the pilot pattern of the CS pilot in frequency domain has same amplitude and phase, the CS pilot has high PAPR. In this section, the CS pilot with scrambling in order to reduce the PAPR is evaluated.

Figure 7 shows the block diagram of the transmitter of the Scattered CS pilot with scrambling in case that M equals to 2 (M means that pilot symbols are allocated in every M -th subcarrier.).

QPSK modulated pilot symbols is multiplex a scrambling code. The scrambling code has random phase of QPSK. In Figure 1, the time division multiplexing uses the cyclic shift. Since the cyclic shift in time domain can be expressed by the phase rotation(linear phase offset) in frequency domain, Figure 7 uses the frequency domain explanation avoiding additional FFT operation.

The linear phase offset symbols are mapped to subcarriers of the pilot OFDM symbol. After IFFT and addition of cyclic prefix (CP), the CS pilot signal is transmitted from each antenna.

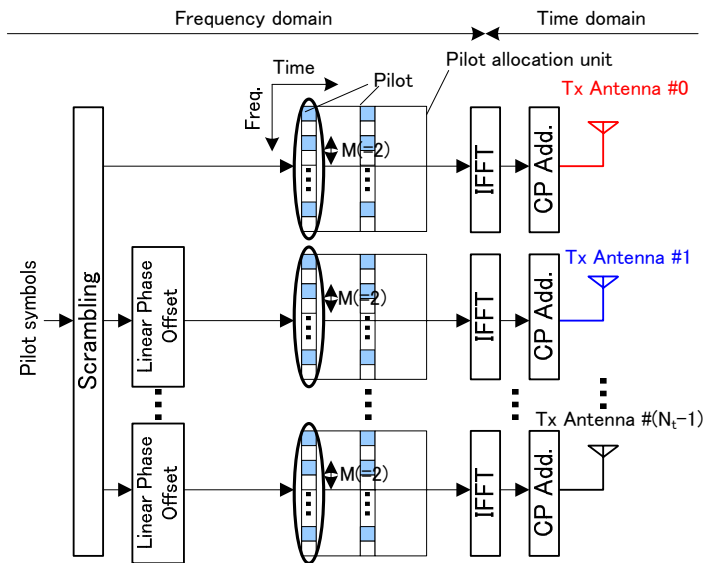


Figure 7 Block diagram of transmitter of the Scattered CS pilot ($M=2$) with scrambling

PAPR comparison

In this section, PAPRs of the Legacy and the CS pilot with and without scrambling are evaluated.

The pilot allocations are shown in Figure 3 and the frame structure is compliant with 5MHz downlink parameters of [7, table3]. The PAPRs of only 1st pilot OFDM symbols in the pilot allocation unit are evaluated. For the data portion except the pilot symbols in the pilot OFDM symbol, random QPSK data are mapped. As a comparison criterion, random QPSK data over all subcarriers in the pilot OFDM symbols is also evaluated.

Figure 8 shows the complementary cumulative distribution function (CCDF) of PAPR. The results show that,

[in case without scrambling]

- The Scattered CS pilot without scrambling has very high PAPR (21.5dB at the point where CCDF is $1E-3$) since energy of all the subcarriers to which the Scattered CS pilot is allocated is concentrated to certain sampling time..

[in case with scrambling]

- PAPR where CCDF is $1E-3$ of the Scattered CS pilot with scrambling are extremely improved by 10.5dB compared to that without scrambling.
- PAPR of the Scattered CS pilot with scrambling are equal to that of random QPSK data and the Legacy pilot without scrambling.

From above results, it is shown that the PAPR reduction of the Scattered CS pilot applying scrambling is efficient.

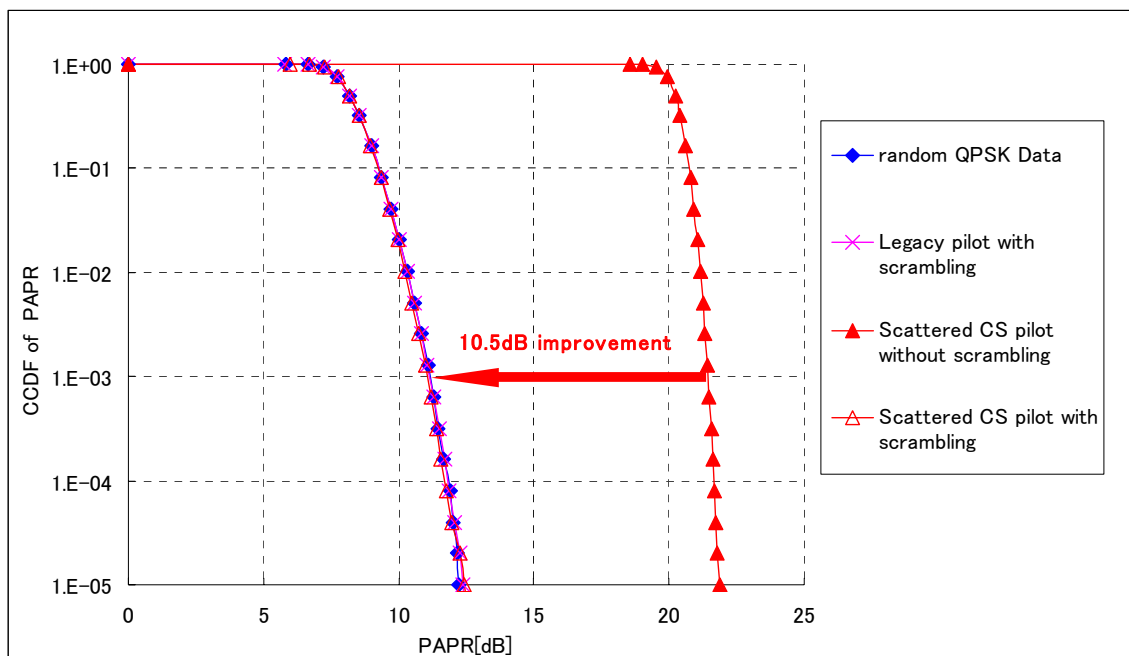


Figure 8 Complementary Cumulative Distribution Function of PAPR

NMSE comparison between the Scattered CS pilot with and without scrambling

NMSEs of the channel estimation for the Scattered CS pilot with and without scrambling are evaluated.

The simulation assumptions are same as those for Figure 5 except for antenna configuration. This simulation assumes 4x4 antenna configuration.

Figure 9 shows the NMSEs of the Scattered CS pilot with and without scrambling. This results shows that the CS pilot with scrambling have the same channel estimation performance as that without scrambling.

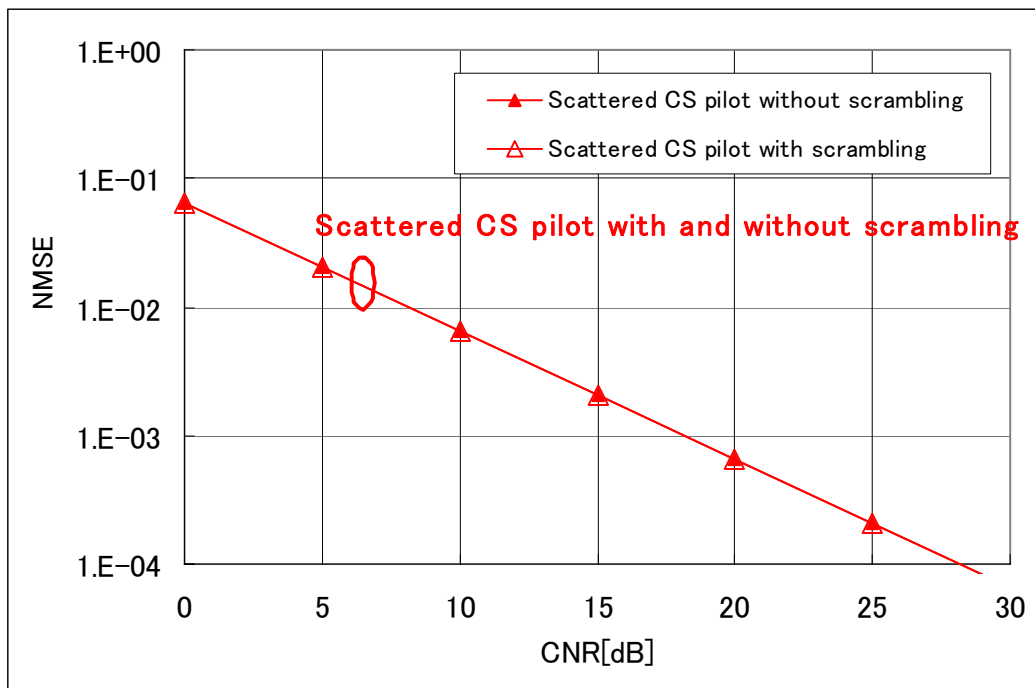


Figure 9 NMSE Comparison (4x4 MIMO, PB 3km/h)

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