Project	**IEEE 802.16 Broadband Wireless Access Working Group** <http://ieee802.org/16>
Title	**Performance comparison of IEEE 802.16m OL-SU-MIMO**
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Re:	Call for Comments on Project 802.16m System Description Document (SDD), IEEE 802.16m-08/052 (MIMO section)
Abstract	In this contribution, we compare performance of OL-SU-MIMO candidates
Purpose	Discuss and adopt in TGm
Notice	
Release	
Patent Policy	

Performance comparison of IEEE 802.16m OL-SU-MIMO

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1. Introduction

The following features shall be accounted when we decide downlink open-loop single user MIMO scheme.

- Receiver complexity
- Precoded Pilot vs. Un-precoded Pilot
- Multiplexing different rank in distributed resource unit

2. OL-SU-MIMO candidates

In current SDD text [1], the open-loop SU-MIMO is defined as follows;

The output of resource mapping block is fed to the MIMO encoder block.

The MIMO encoder block maps L (≥1) layers onto M (≥L) streams, which are fed to the precoding block.

The precoding block maps streams to antennas by generating the antenna-specific data symbols according to the selected MIMO mode.

On a given frequency resource k, the precoding matrix **P** can be defined using the following equation:

$$\mathbf{P}(k) = \mathbf{W}(k).$$

$\mathbf{W}(k)$ is an $N_T \times M$ matrix, where N_T is the number of transmit antennas and M is the numbers of streams. The matrix $\mathbf{W}(k)$ is selected from a predefined unitary codebook, and changes every u subcarriers, and/or v OFDM symbols.

A. 4Tx Rate 1 OL-SU-MIMO candidates

Two different rate-1 OL-SU-MIMO is in SDD. In this contribution, we focus on M=2 case.
There are two candidates in 4Tx rate-1, M=2, OL-SU-MIMO mode: precoder cycling (PC) with 2Tx SFBC and antenna hopping (AH) with 2Tx SFBC.

AH with 2Tx SFBC requires pilot pattern for 4 stream pilots. Pilots shall not be precoded.

PC with 2Tx SFBC requires 2 stream dedicated pilot for data demodulation. Multiplexing different rank is discussed in section 3.

B. 4Tx Rate 2 OL-SU-MIMO candidates

There are three candidates in 4Tx rate-2 OL-SU-MIMO mode: DSFBC with AH, SM with PC and SM with AH.

DSFBC or SM with AH require pilot pattern for 4 streams. Pilots shall not be precoded.

DSFBC with AH shows best performance if MMSE receiver is assumed. But it requires high receiver complexity. If we consider receiver complexity when we compare performance, SM with AH outperforms DSFBC with AH. Complexity analysis is done in section 4.

SM with PC requires 2 stream dedicated pilot for data demodulation. Multiplexing different rank is discussed in section 3.

C. 4Tx Rate 3 OL-SU-MIMO candidates

There are three candidates in 4Tx rate-3 OL-SU-MIMO mode: SM with PC, SM with AH and SFBC+SM+AH.

SFBC+SM+AH requires extremely high receiver complexity. It requires 6 by 6 matrix inversion for MMSE receiver while other candidates require only 3 by 3 matrix inversion. Complexity analysis is done in section 4. So, we focus on comparison between SM with PC and SM with AH in this contribution.

3. Pilots for OL-SU-MIMO

We summarize pilot and different rate multiplexing in pair-tone based DRU in this section.

- Precoded Pilot vs. Un-precoded Pilot
  - To support 8Tx antenna OL-SU-MIMO scheme, we need to use precoded pilot since 8Tx common pilot overhead is very high
  - Some of OL-SU-MIMO scheme rely on un-precoded pilot
  - Proper design of W(k) and u and/or v enables dedicated pilot, which gives pilot overhead reduction gain while diversity gain can be achieved by W(k)
- In case of precoded pilot, we need to have further assumption for multiplexing different rate preferred MSs when allocation in pair-tone based DRU
  - There are multiple possible solution for this, the followings are suggested solution
    - Make two types of pair-tone based DRUs, one for 2 steam pilot and one for 4 stream pilot
      - TDM multiplexing is preferred
    - Limit pair-tone based DRU allocation for up to rate-2
      - Since OL-SU-MIMO in pair-tone based DRU will be used for high speed MS, there won't be many request for higher rank transmission
      - USCCH will be multiplexed with data, so it is reasonable to limit rank-2 in pair-tone based DRU for transmitting USCCH otherwise pilot pattern shall be indicated by non-user specific control information

4. Complexity analysis

A. 4Tx Rate 2 comparison

Table 1 4Tx rate-2 complexity comparison based on required number of multiplication per RU (See [2] for reference)

	Rate-2 SM with MMSE	Rate-2 DSFBC with MMSE	Rate-2 SM with Simplified MLD	Rate-2 DSFBC with Simplified MLD
QPSK	12672 (100%)	74304 (586%)	12960 (102%)	54432 (430%)

16QAM	23040 (100%)	84672 (368%)	43200 (188%)	120960 (525%)
64QAM	64512 (100%)	126144 (196%)	129600 (200%)	352512 (546%)

Simplified MLD for rate-2 SM is well known that the performance is almost same as conventional full MLD.

As seen in the table, rate-2 SM with simplified MLD is much less complex than rate-2 DSFBC with MMSE. So, it is fair to compare rate-2 SM with simplified MLD with rate-2 DSFBC with MMSE.

B. 4Tx Rate 3 comparison

Table 2 4Tx rate-3 complexity comparison based on required number of multiplication per RU (See [2] for reference)

	Rate-3 SM with MMSE	Rate-3 SFBC+SM with MMSE	Rate-3 SM with Simplified MLD	Rate-3 SFBC+AM with Simplified MLD
QPSK	35424 (100%)	241920 (683%)	28512 (80%)	147744 (417%)
16QAM	50976 (100%)	273024 (536%)	74304 (146%)	271296 (532%)
64QAM	113184 (100%)	397440 (351%)	222912 (197%)	730944 (646%)

As seen in the table, rate-3 SM is extremely simpler than rate-3 SFBC+SM. So, we focus on comparison between SM with PC and SM with AH in section 5.

5. Performance comparison

In this section, we show simulation results for paired-tone-based DRU and PRU-based DRU. Assume PRU-based DRU is spread over 48 PRUs. For paired-tone-based LDRU, subcarriers distributed over 24 distributed PRUs. Please note that PRU-based DRU is worst case study. In other words, PRU-based DRU will be worse than pair-tone-based DRU in terms of performance. Details of simulation assumption and simulated schemes can be found in Appendix section.
Furthermore, if not stated, the simulation results are based on one RU channel estimation and MMSE receiver (for rate-2 and 3).

A. 4Tx Rate 1 OL-SU-MIMO comparison

i. PRU-based LDRU

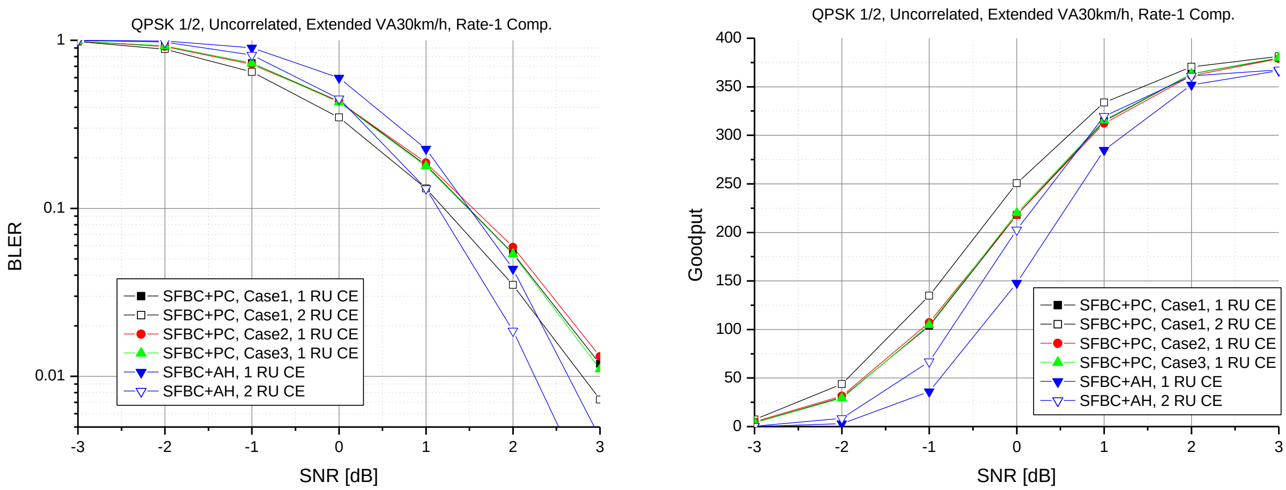

Figure 1 QPSK 1/2, Uncorrelated Channel, Extended Veh. A 30km/h, PRU-based LDRU

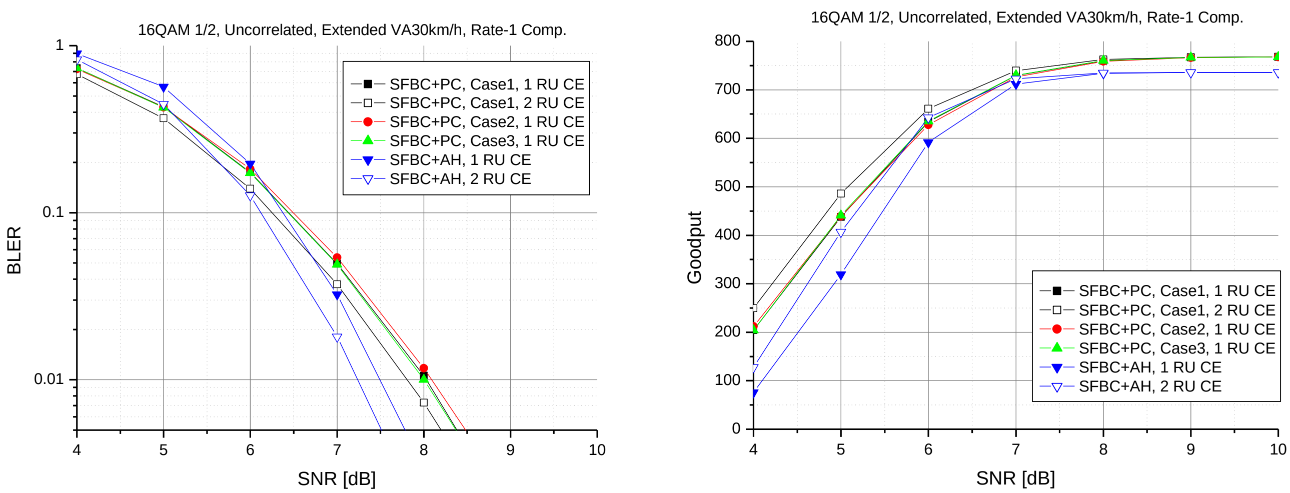

Figure 2 16QAM 1/2, Uncorrelated Channel, Extended Veh. A 30km/h, PRU-based LDRU

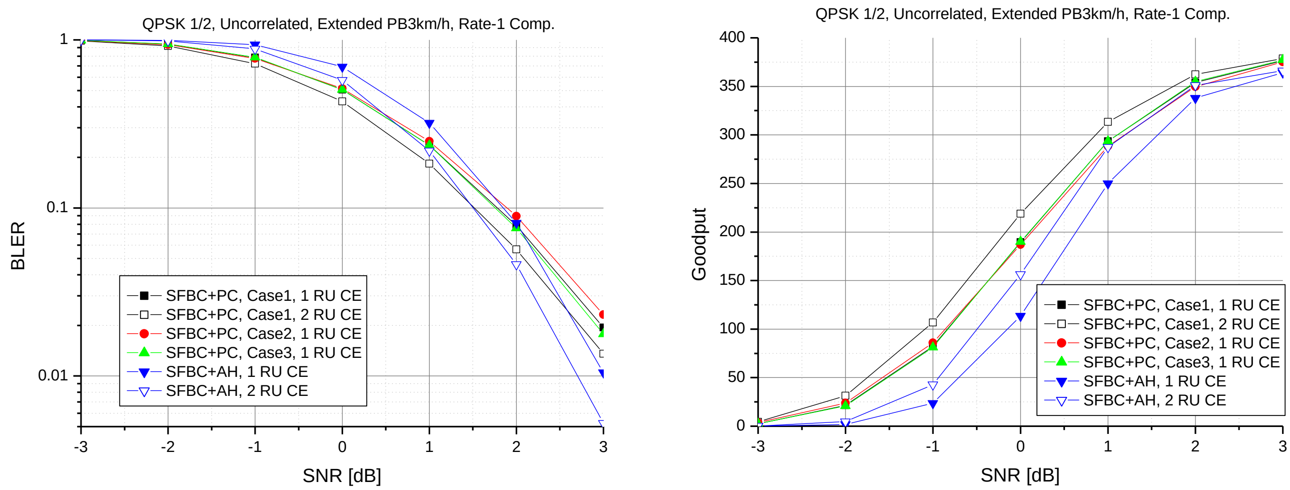

Figure 3 QPSK 1/2, Uncorrelated Channel, Extended Ped. B 3km/h, PRU-based LDRU

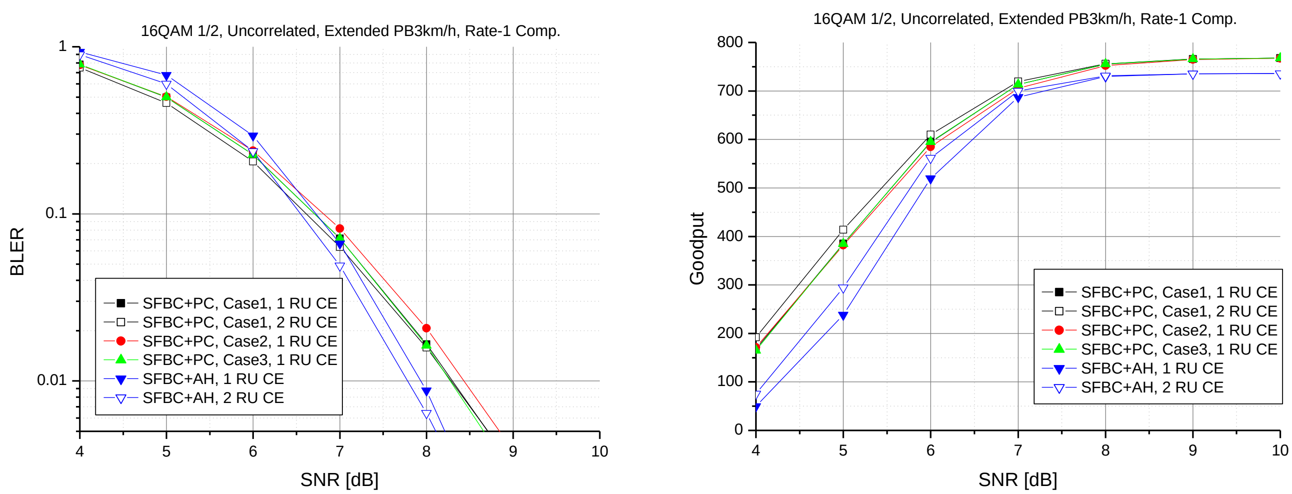

Figure 4 16QAM 1/2, Uncorrelated Channel, Extended Ped. B 3km/h, PRU-based LDRU

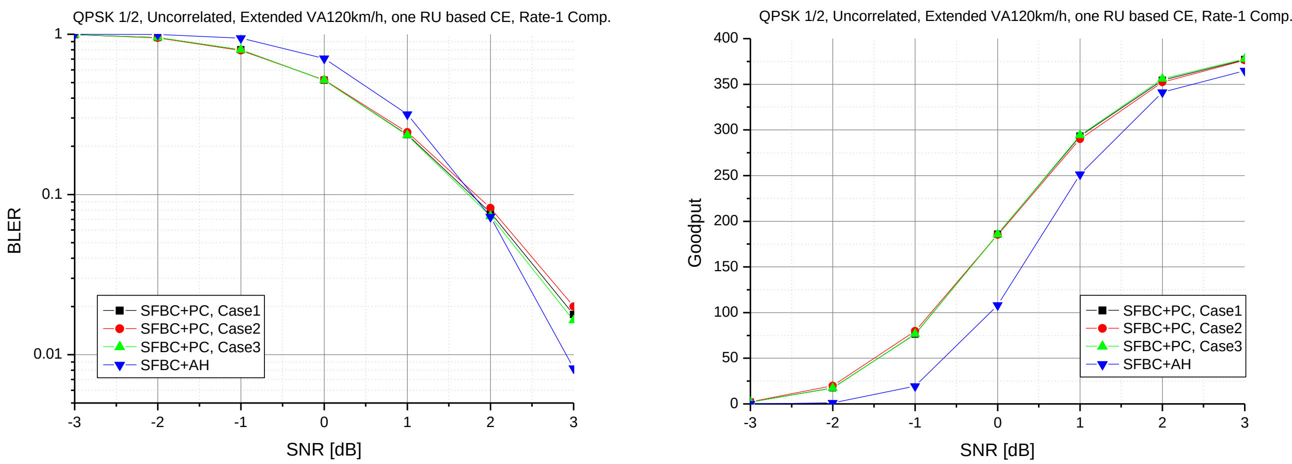

Figure 5 QPSK 1/2, Uncorrelated Channel, Extended Veh. A 120km/h, PRU-based LDRU

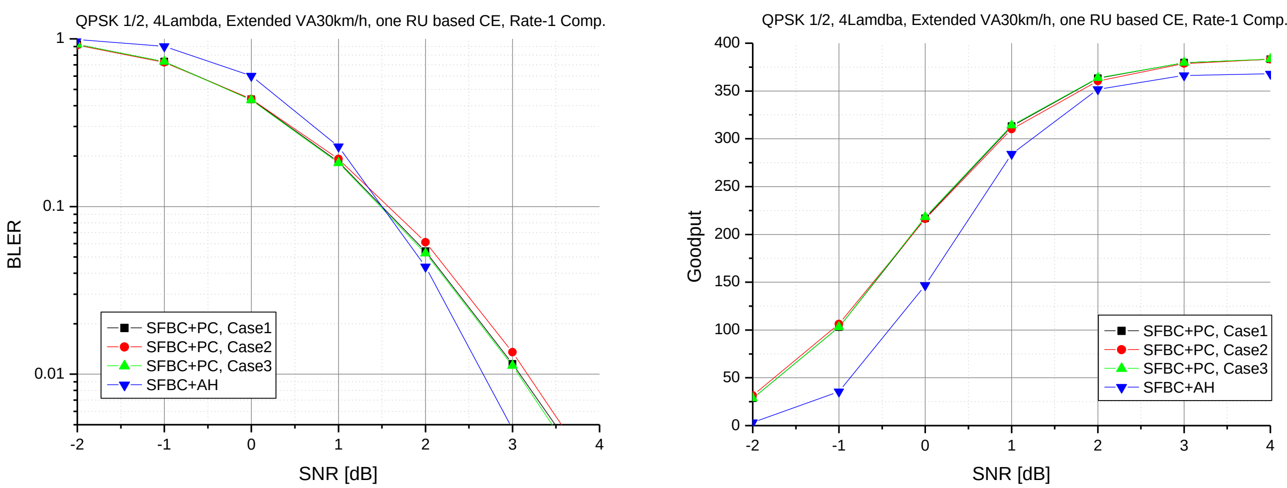

Figure 6 QPSK 1/2, Semi-correlated Channel, Extended Veh. A 30km/h, PRU-based LDRU

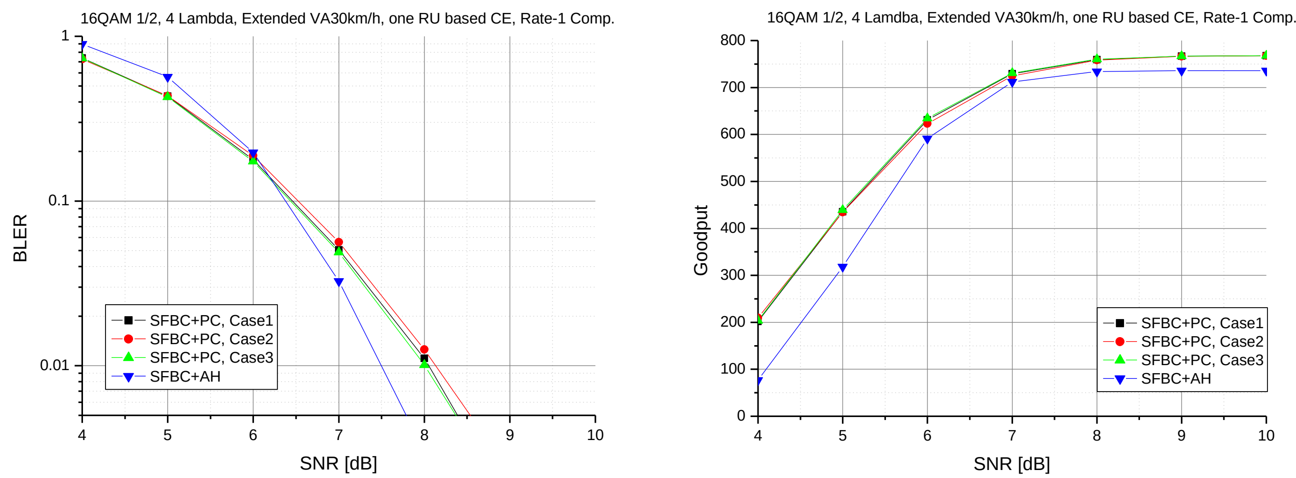

Figure 7 16QAM 1/2, Semi-correlated Channel, Extended Veh. A 30km/h, PRU-based LDRU

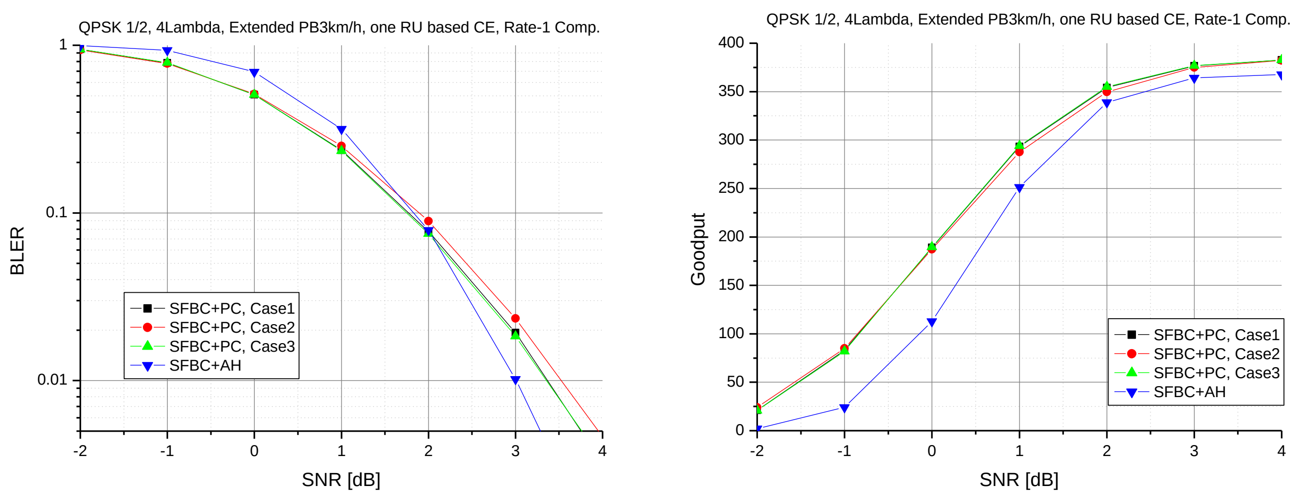

Figure 8 QPSK 1/2, Semi-correlated Channel, Extended Ped. B 3km/h, PRU-based LDRU

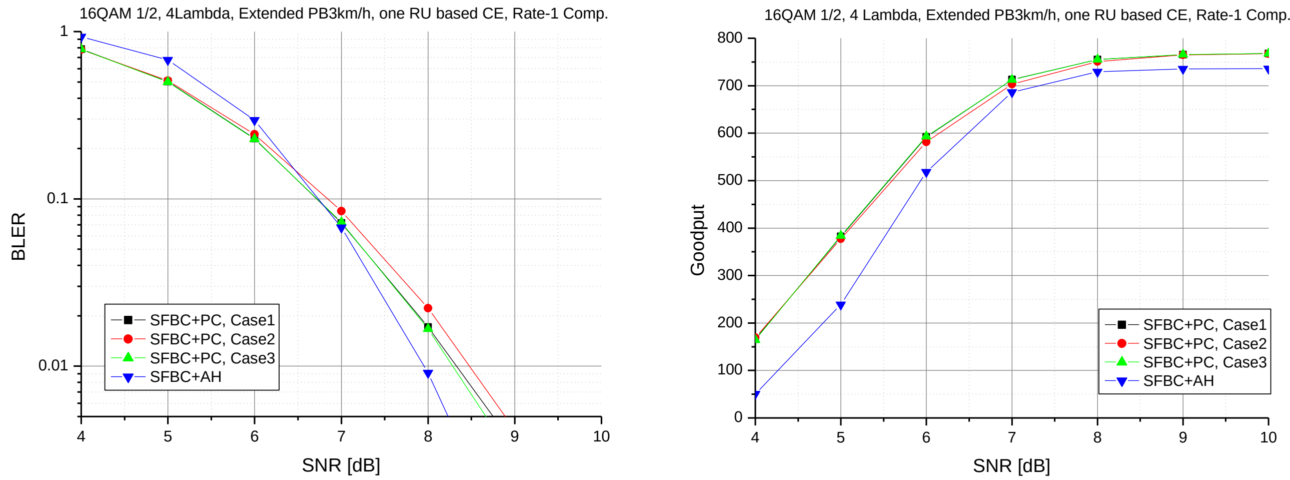

Figure 9 16QAM 1/2, Semi-correlated Channel, Extended Ped. B 3km/h, PRU-based LDRU

ii. Paired-tone-based LDRU

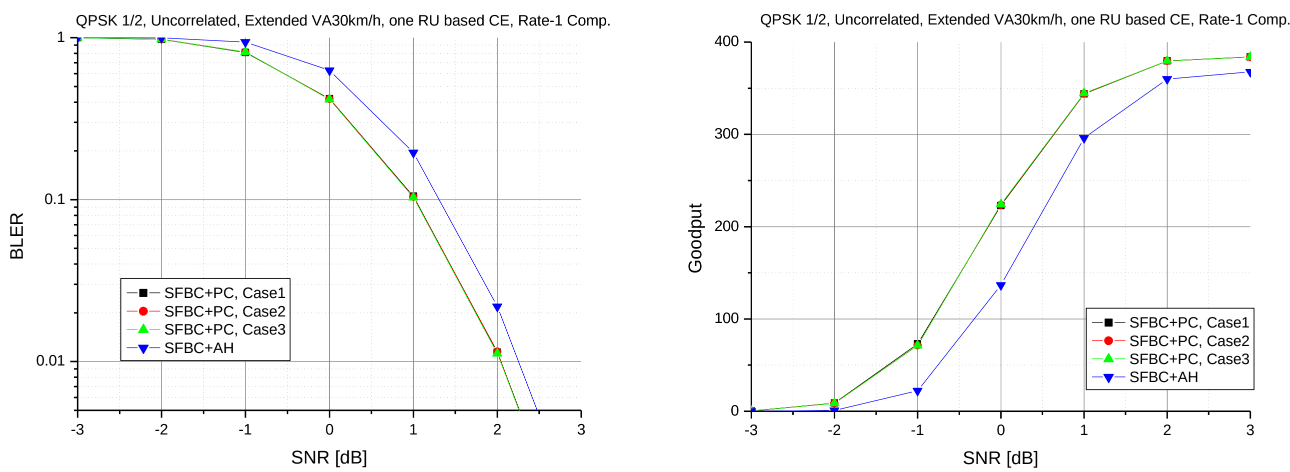

Figure 10 QPSK 1/2, Uncorrelated Channel, Extended Veh. A 30km/h, Paired-tone-based LDRU

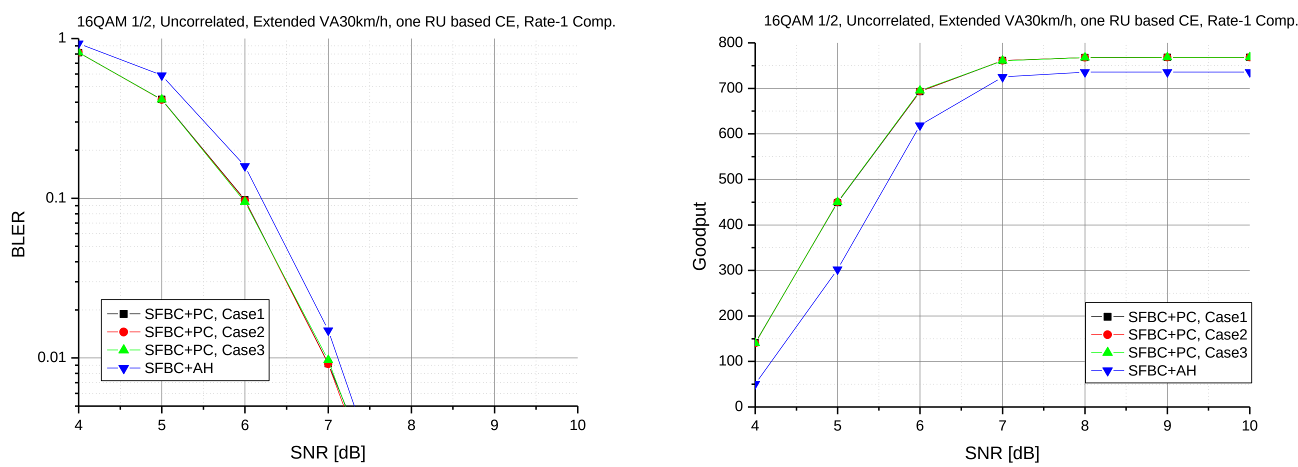

Figure 11 16QAM 1/2, Uncorrelated Channel, Extended Veh. A 30km/h, Paired-tone-based LDRU

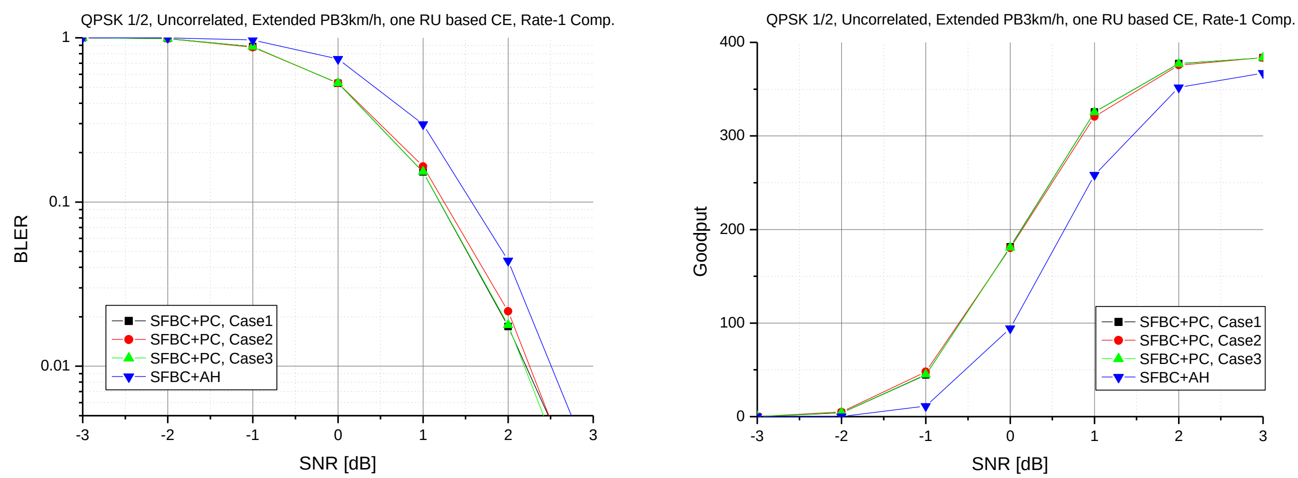

Figure 12 QPSK 1/2, Uncorrelated Channel, Extended Ped. B 3km/h, Paired-tone-based LDRU

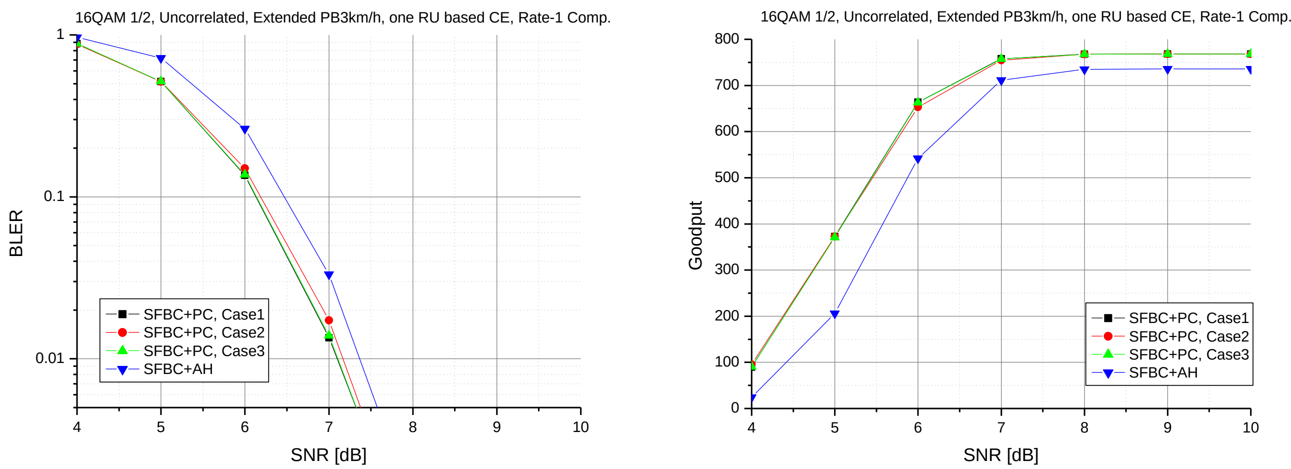

Figure 13 16QAM 1/2, Uncorrelated Channel, Extended Ped. B 3km/h, Paired-tone-based LDRU

B. 4Tx Rate 2 OL-SU-MIMO comparison

i. PRU-based LDRU

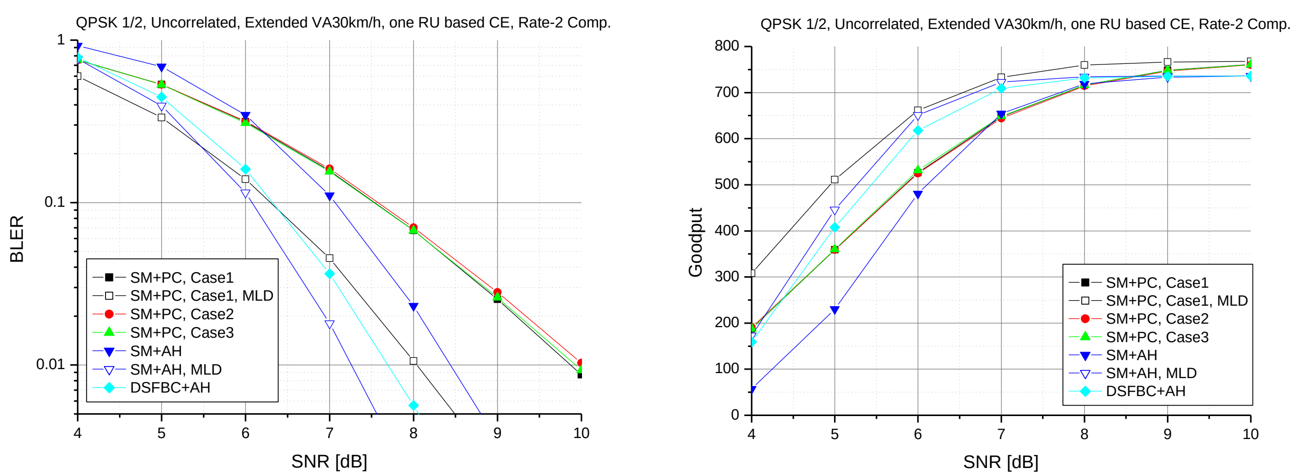

Figure 14 QPSK 1/2, Uncorrelated Channel, Extended Veh. A 30km/h, PRU-based LDRU

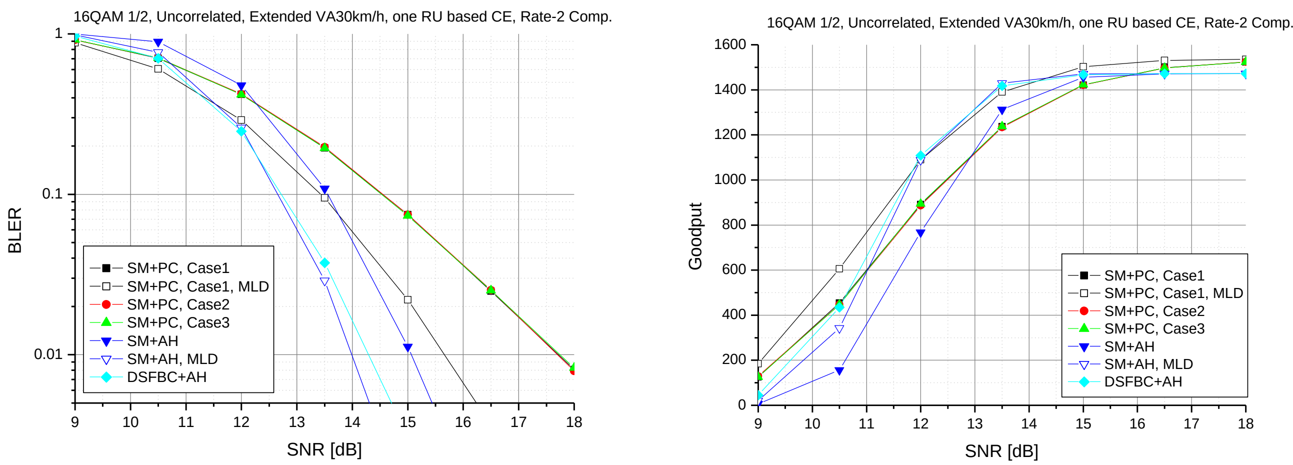

Figure 15 16QAM 1/2, Uncorrelated Channel, Extended Veh. A 30km/h, PRU-based LDRU

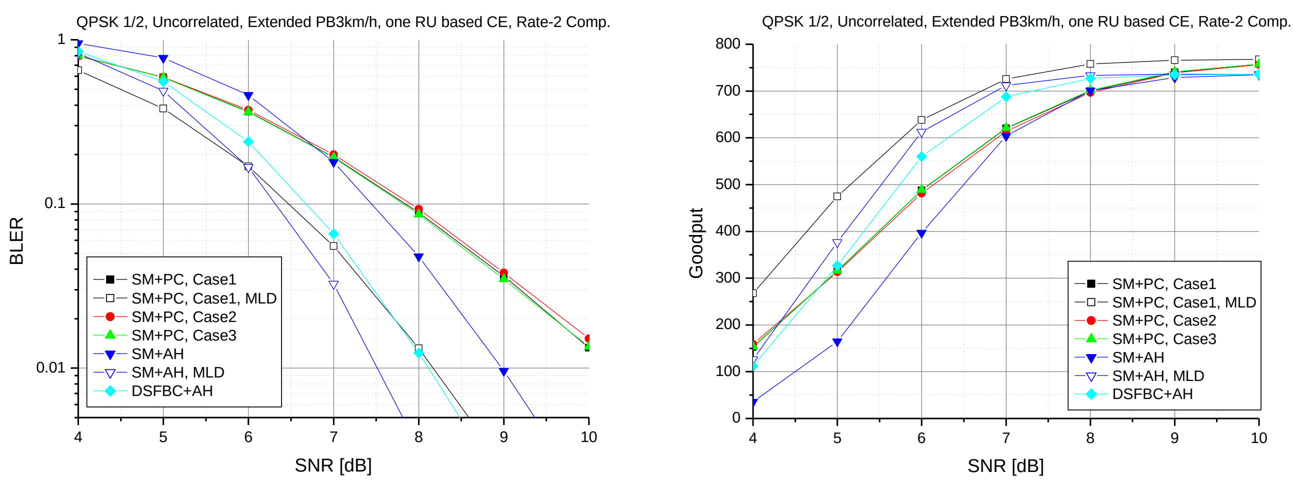

Figure 16 QPSK 1/2, Uncorrelated Channel, Extended Ped. B 3km/h, PRU-based LDRU

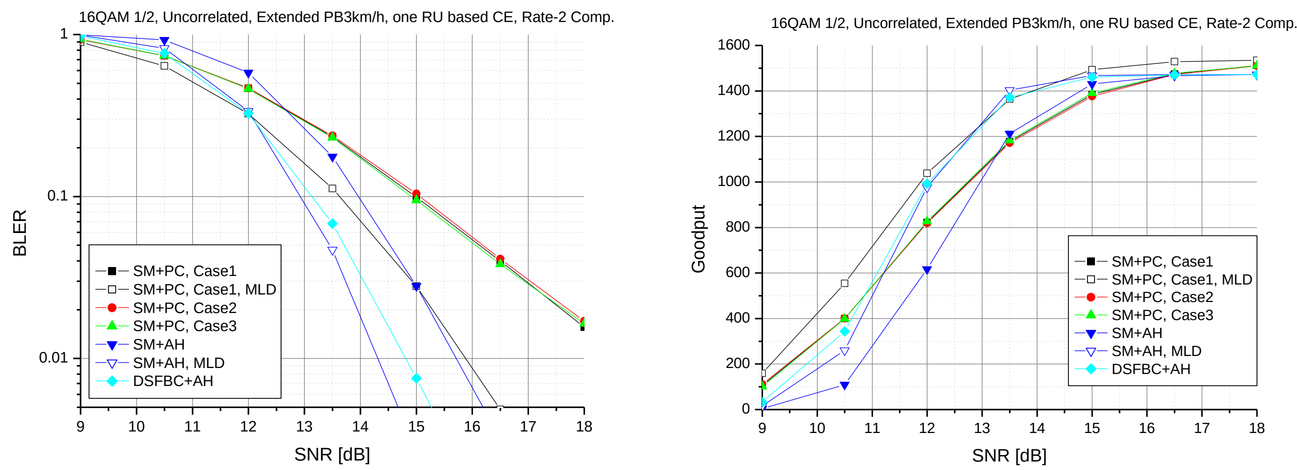

Figure 17 16QAM 1/2, Uncorrelated Channel, Extended Ped. B 3km/h, PRU-based LDRU

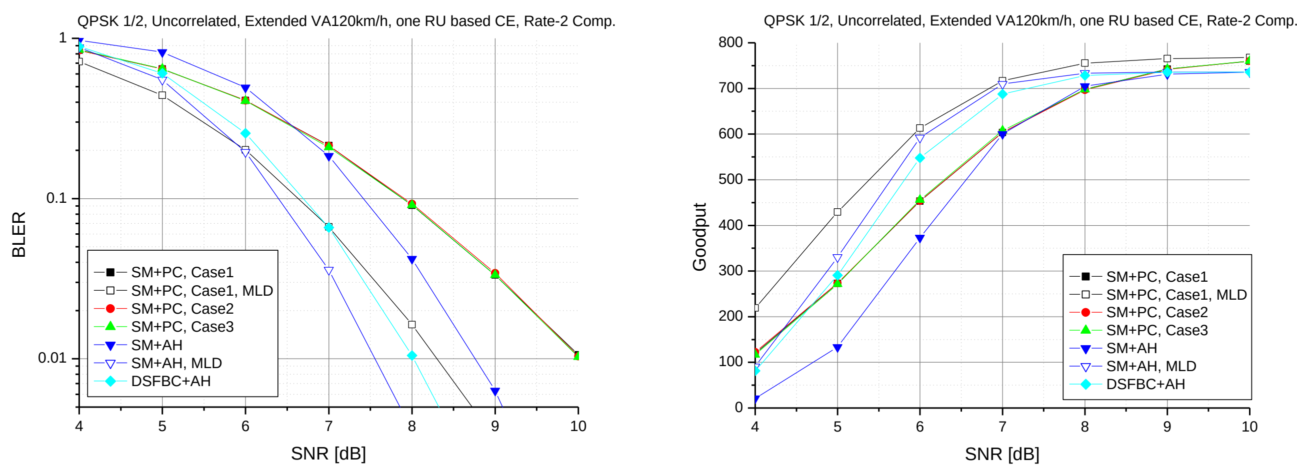

Figure 18 QPSK 1/2, Uncorrelated Channel, Extended Veh. A 120km/h, PRU-based LDRU

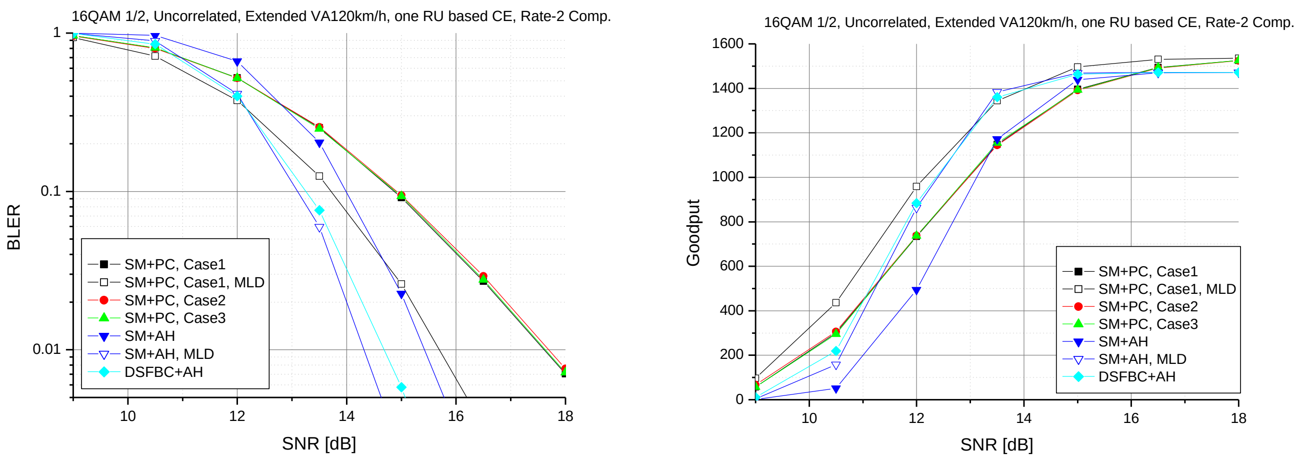

Figure 19 16QAM 1/2, Uncorrelated Channel, Extended Veh. A 120km/h, PRU-based LDRU

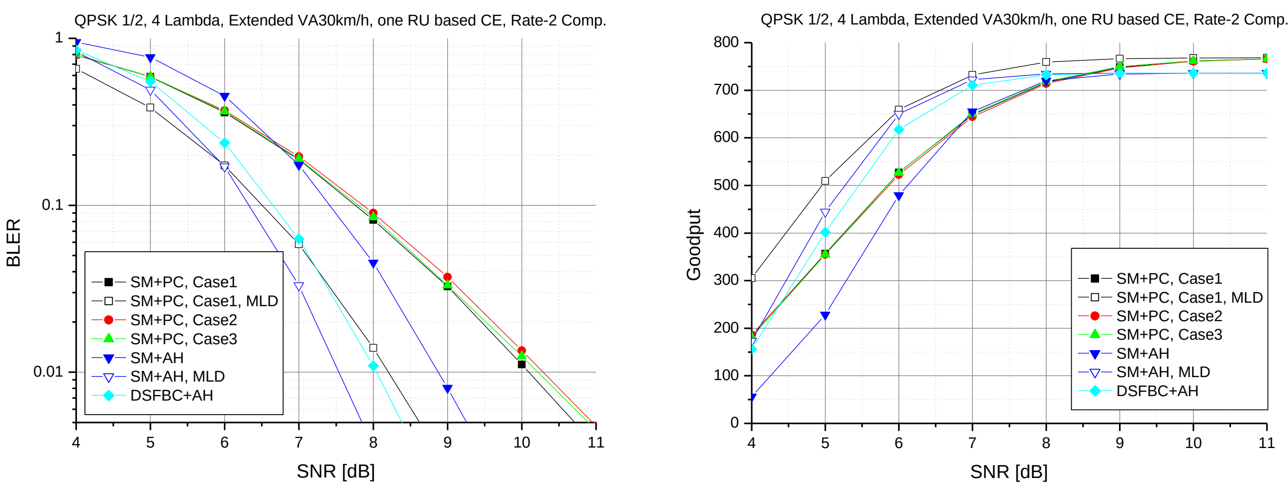

Figure 20 QPSK 1/2, Semi-correlated Channel, Extended Veh. A 30km/h, PRU-based LDRU

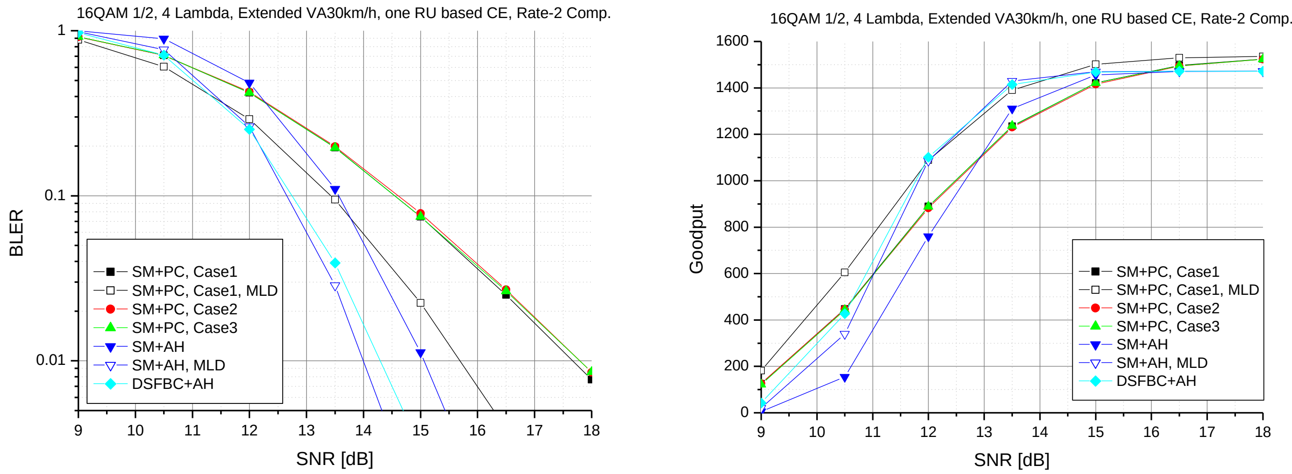

Figure 21 16QAM 1/2, Semi-correlated Channel, Extended Veh. A 30km/h, PRU-based LDRU

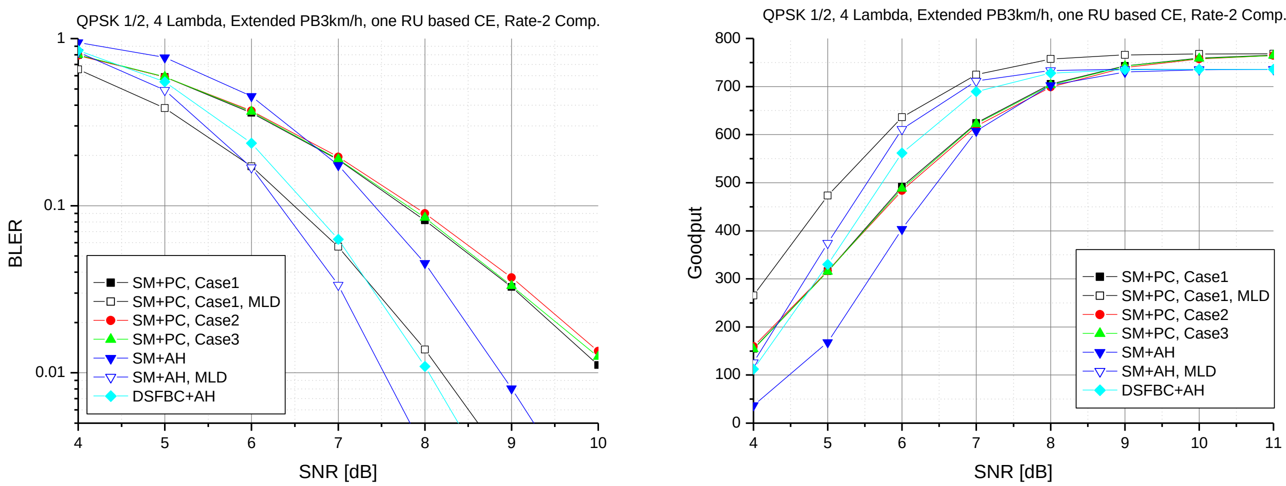

Figure 22 QPSK 1/2, Semi-correlated Channel, Extended Ped. B 3km/h, PRU-based LDRU

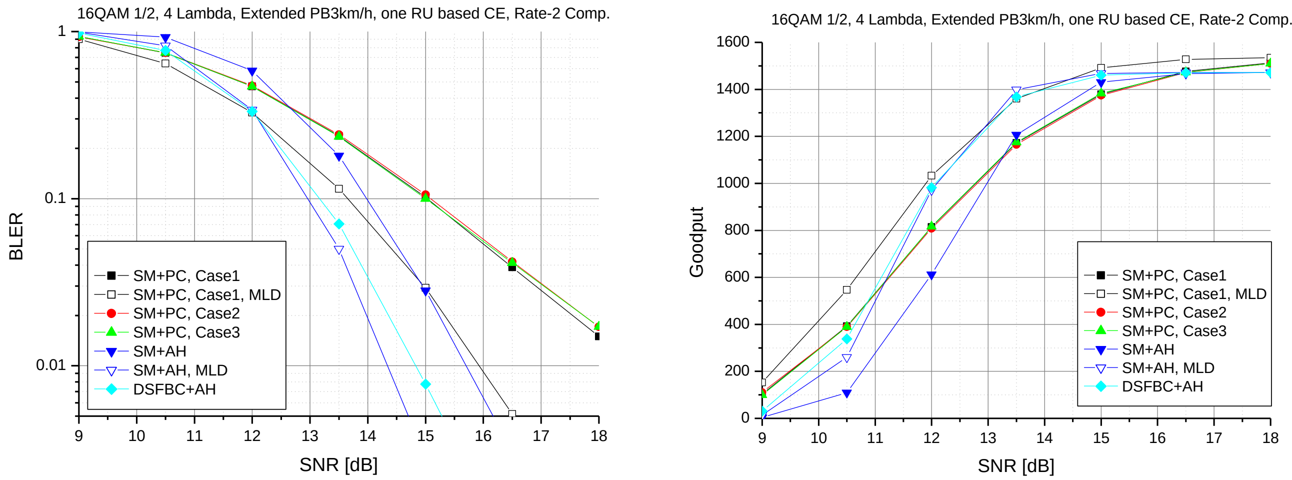

Figure 23 16QAM 1/2, Semi-correlated Channel, Extended Ped. B 3km/h, PRU-based LDRU

ii. Paired-tone-based LDRU

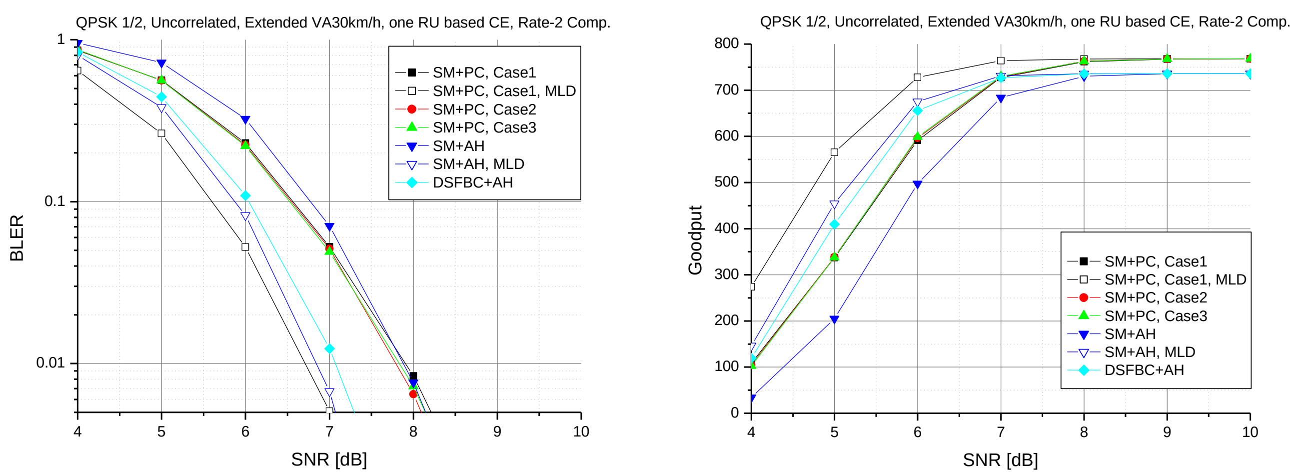

Figure 24 QPSK 1/2, Uncorrelated Channel, Extended Veh. A 30km/h, Paired-tone-based LDRU

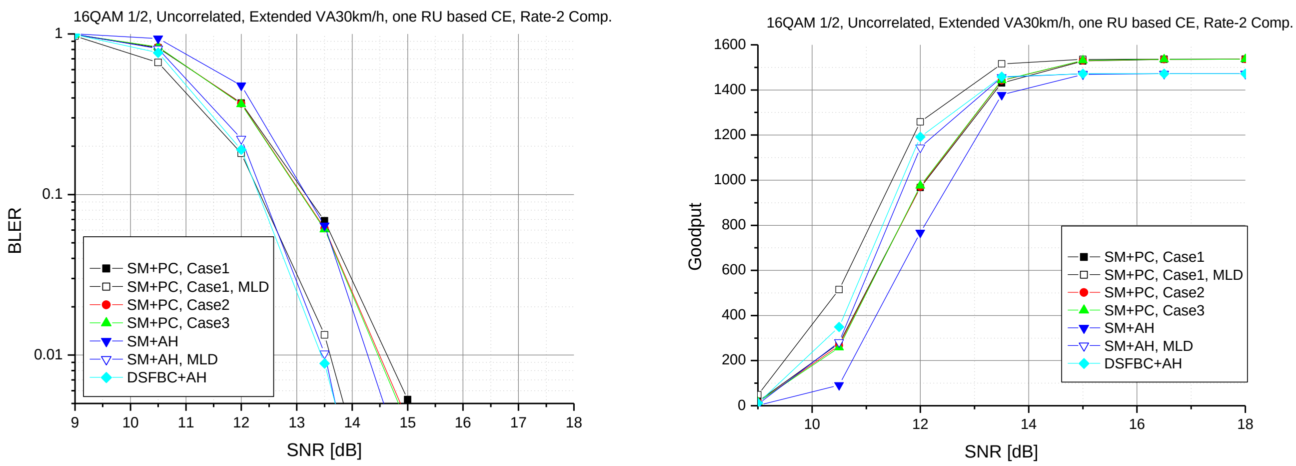

Figure 25 16QAM 1/2, Uncorrelated Channel, Extended Veh. A 30km/h, Paired-tone-based LDRU

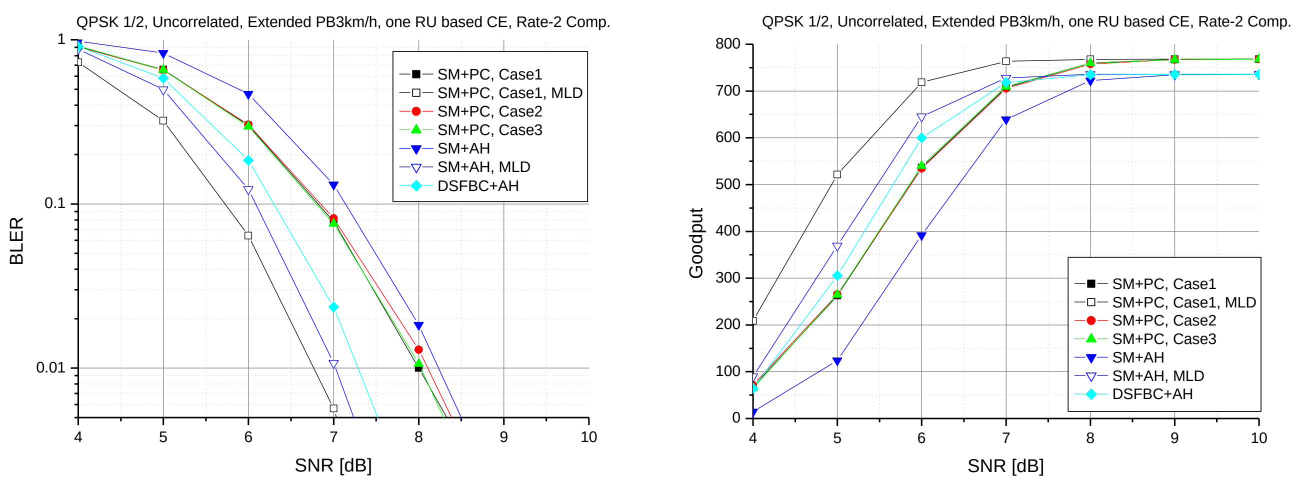

Figure 26 QPSK 1/2, Uncorrelated Channel, Extended Ped. B 3km/h, Paired-tone-based LDRU

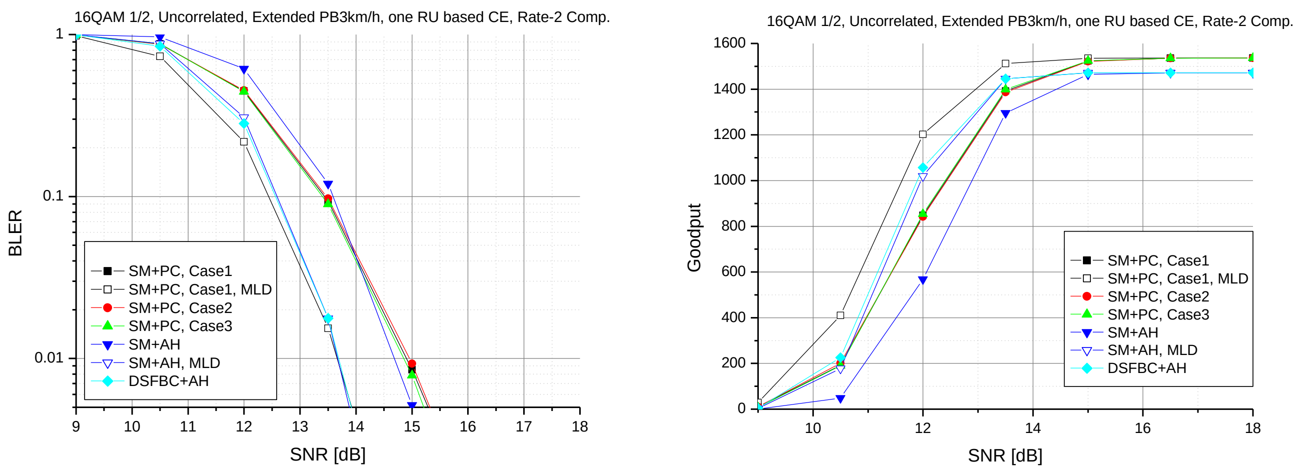

Figure 27 16QAM 1/2, Uncorrelated Channel, Extended Ped. B 3km/h, Paired-tone-based LDRU

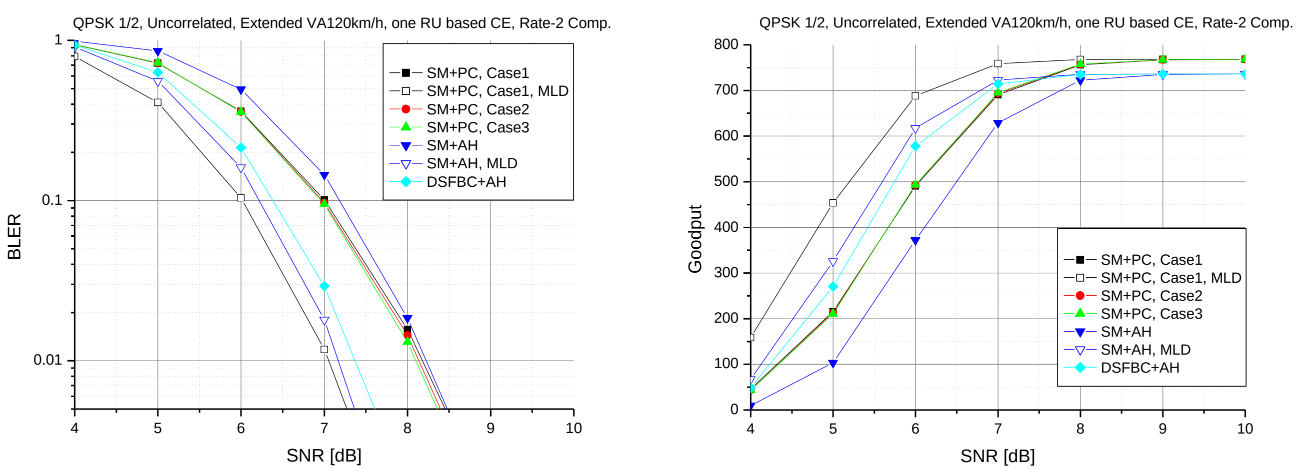

Figure 28 QPSK 1/2, Uncorrelated Channel, Extended Veh. A 120km/h, Paired-tone-based LDRU

C. 4Tx Rate 3 OL-SU-MIMO comparison

i. PRU-based LDRU

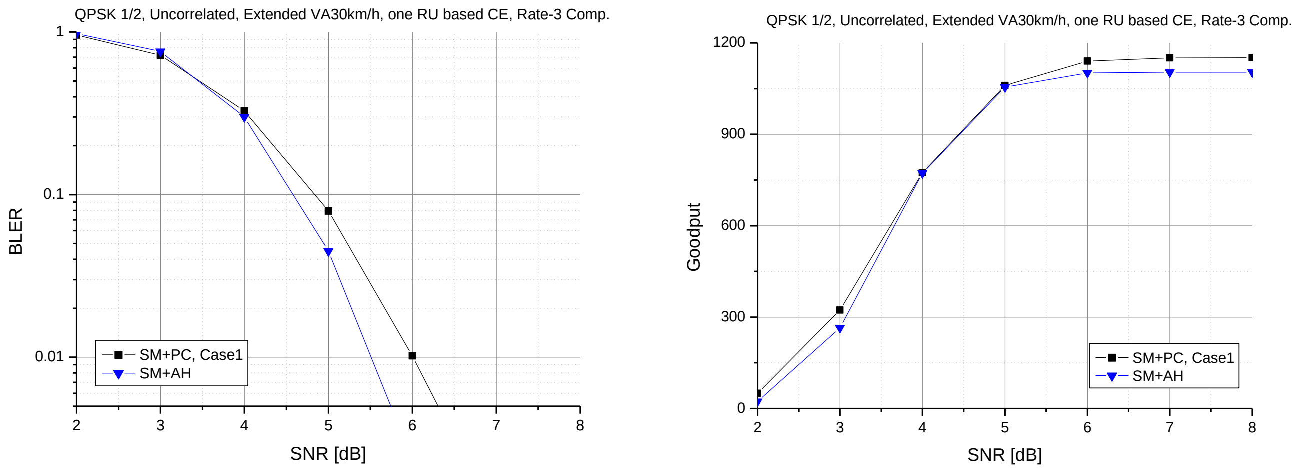

Figure 29 QPSK 1/2, Uncorrelated Channel, Extended Veh. A 30km/h, PRU-based LDRU

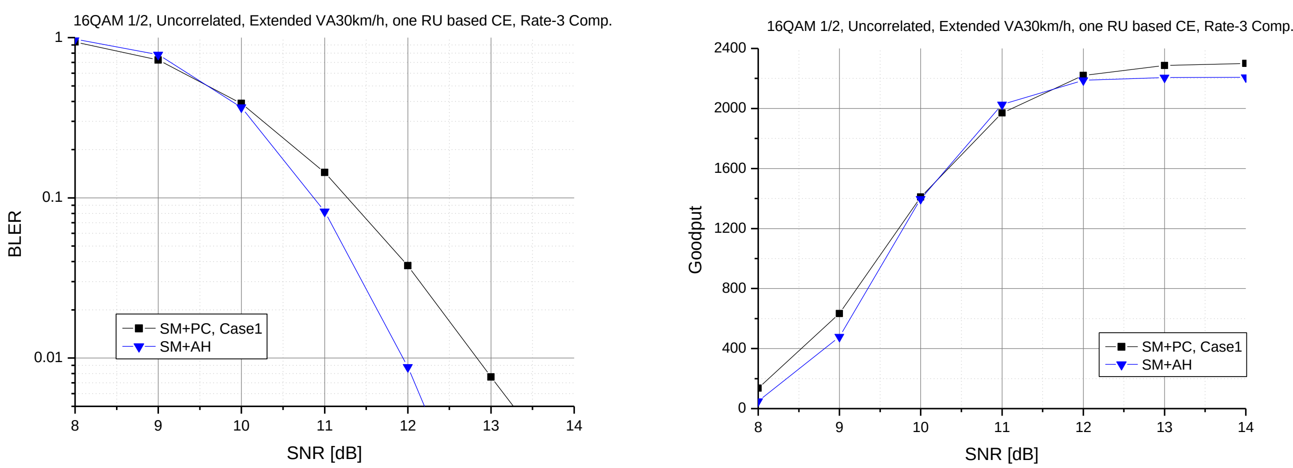

Figure 30 16QAM 1/2, Uncorrelated Channel, Extended Veh. A 30km/h, PRU-based LDRU

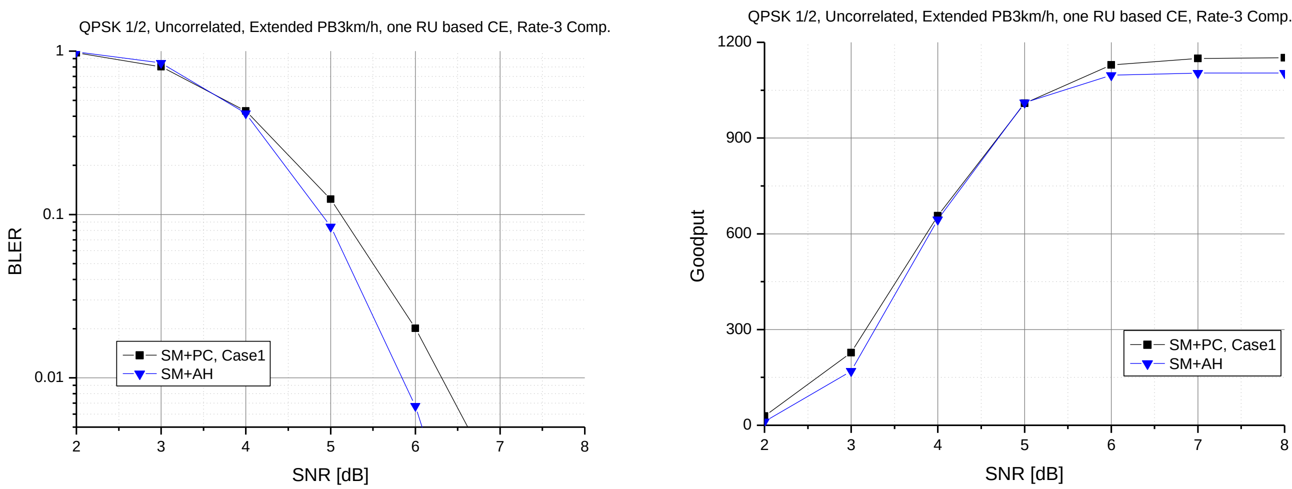

Figure 31 QPSK 1/2, Uncorrelated Channel, Extended Ped. B 3km/h, PRU-based LDRU

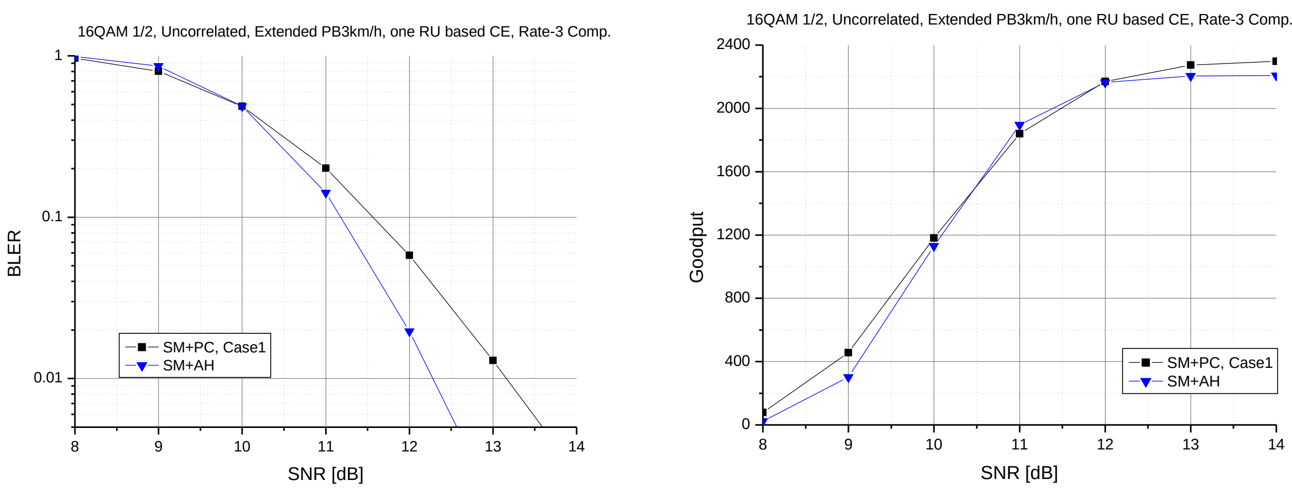

Figure 32 16QAM 1/2, Uncorrelated Channel, Extended Ped. B 3km/h, PRU-based LDRU

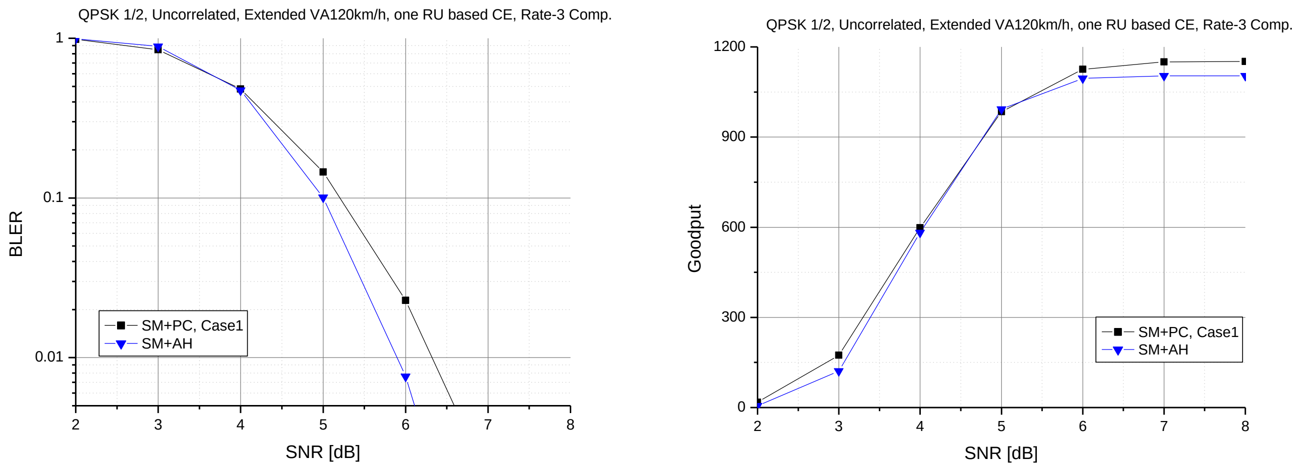

Figure 33 QPSK 1/2, Uncorrelated Channel, Extended Veh. A 120km/h, PRU-based LDRU

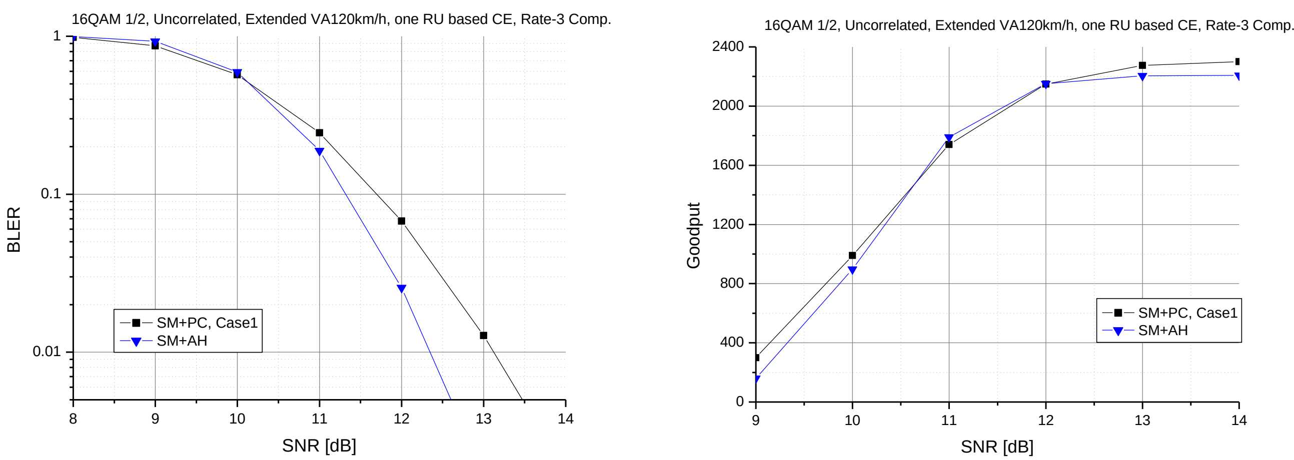

Figure 34 16QAM 1/2, Uncorrelated Channel, Extended Veh. A 120km/h, PRU-based LDRU

ii. Paired-tone-based LDRU

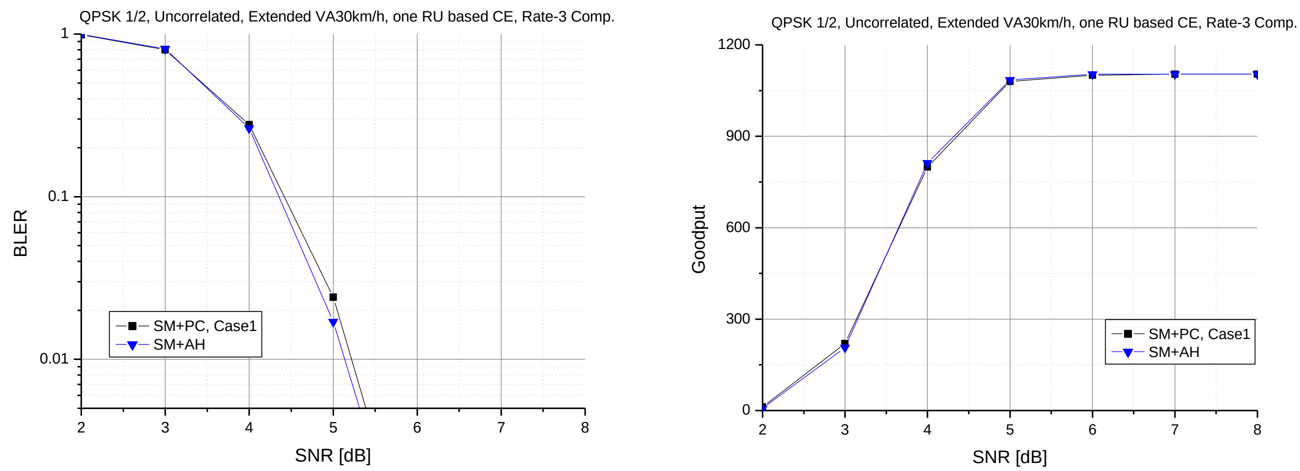

Figure 35 QPSK 1/2, Uncorrelated Channel, Extended Veh. A 30km/h, Paired-tone-based LDRU

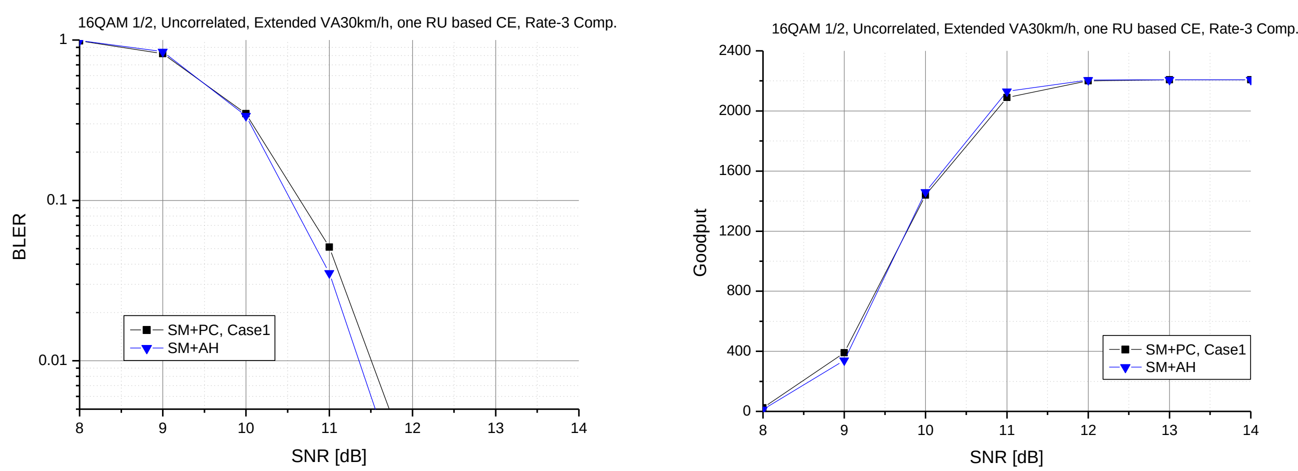

Figure 36 16QAM 1/2, Uncorrelated Channel, Extended Veh. A 30km/h, Paired-tone-based LDRU

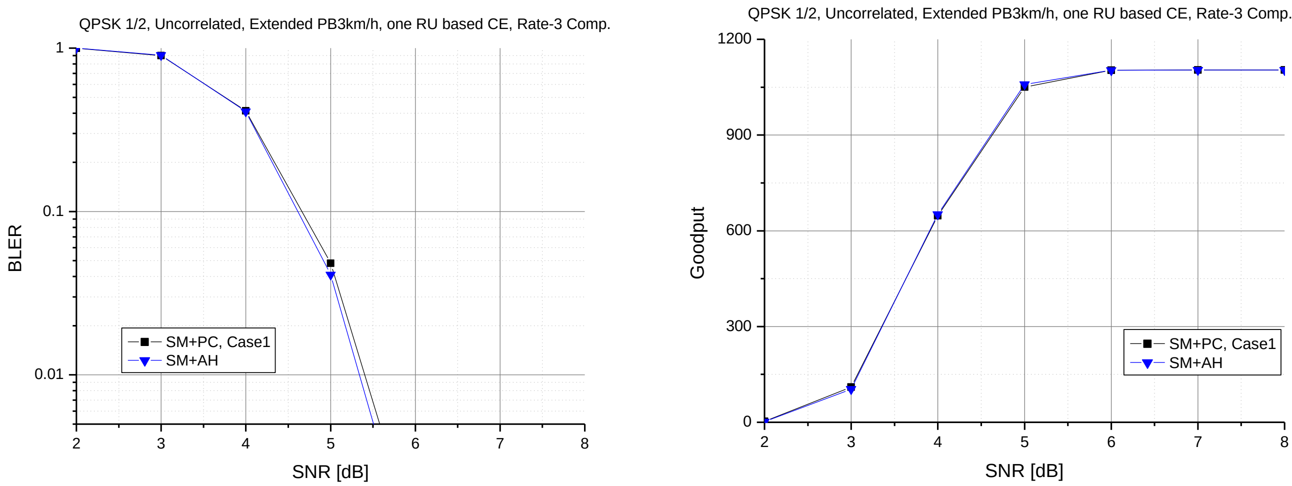

Figure 37 QPSK 1/2, Uncorrelated Channel, Extended Ped. B 3km/h, Paired-tone-based LDRU

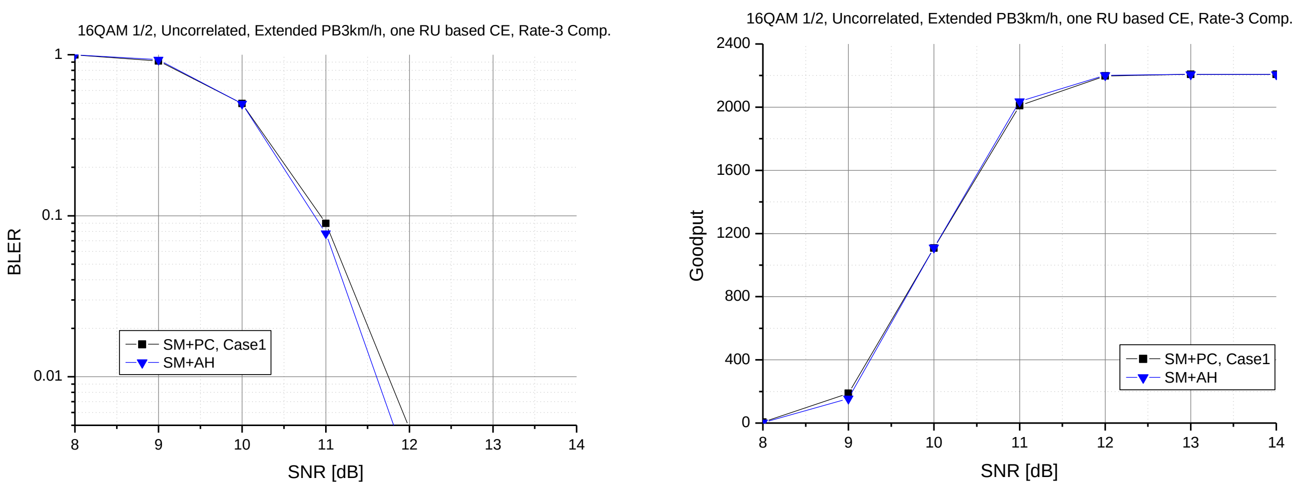

Figure 38 16QAM 1/2, Uncorrelated Channel, Extended Ped. B 3km/h, Paired-tone-based LDRU

6. Conclusions

Scheme with dedicated pilot shows better performance than scheme with common pilot due to pilot overhead gain as well as channel estimation gain (number of pilot per stream is higher for dedicated pilot aided scheme) .

To reduce memory requirement, we suggest using CL-SU-MIMO codebook for OL-SU-MIMO. In this case, MS can further share its CQI estimation module.

CQI mismatch will be increased if codebook element is changed for different subframe in same physical RU. This is because sometimes MS will be allocated *N* RU x 1 subframe, and sometimes MS will be allocated *N* RU x 2 subframes. MS does not know it will be allocated to one subframe or two subframes when it calculates CQI. So we suggest same codebook element shall be applied in same physical RU for a certain period. In other words, the precoder shall not be changed over time.

To enable subband selection gain as well as possible multiple RU channel estimation, we further propose precoder cycling duration as one subband. A subband size in IEEE 802.16e is 4PRU. As seen in the simulation results, this size does not impact on performance.

Here is the summary of proposed details of OL SU-MIMO.

- Precoded demodulation pilot shall be used for OL SU-MIMO, in other words, pilots are precoded with same precoder as in OL-SU-MIMO, $W(k)$
- $W(k)$ shall be chosen based on CL SU-MIMO codebook or its subset
- Size of u shall be same as subband, typically 4PRU
- Precoder shall be fixed over time

7. Proposed remedy

Remedy 1 - In line 2-6, page 101, modify the texts as follows:

$W(k)$ is an $N_T \times N_S$ matrix, where N_T is the number of transmit antennas and N_S is the numbers of streams. The matrix W(k) is selected from a predefined unitary codebook, and changes every ~~u~~ $N1 \cdot P_{SC}$ subcarriers~~, and/or v OFDM symbols~~. ~~The matrix $W(k)$ can be identity matrix for 2Tx rate-2 and 4Tx rate-4.~~ A codebook is a unitary codebook if each of its matrices consists of columns of a unitary matrix. [The detailed unitary codebook~~, and the parameter u and v are~~ is FFS. The CL SU MIMO and OL SU MIMO may use different unitary codebooks.]

Remedy 2 - In line 6-10, page 119, modify the texts as follows:

$W(k)$ is an $N_T \times N_S$ matrix, where N_T is the number of transmit antennas and N_S is the number of streams. The matrix $W(k)$ is selected from a predefined unitary codebook, and changes every ~~u~~ $N1 \cdot P_{SC}$ subcarriers~~, and/or v OFDM symbols. The matrix $W(k)$ can be identity matrix for 2Tx rate-2 and 4Tx rate-4 spatial multiplexing case.~~ A codebook is a unitary codebook if each of its matrices consists of columns of a unitary matrix. [The detailed unitary codebook~~, and the parameter u are~~ is FFS.]

Appendix1 : Simulation assumptions

Carrier frequency	2.5 GHz
System bandwidth	10 MHz
Number of transmit antennas	4
Number of receive antennas	2, 4 (for rate-3 comparison)
Base station correlation	Uncorrelated semi-correlated : 4 lambda with 15 degree AS with -60:60 AoD, randomly selected for each snapshot
Mobile station correlation	Uncorrelated

Resource block size	18 sub-carriers × 6 OFDM symbols
Number of resource block	4 resource blocks
Distribution mode	• PRU-based LDRU – 4 RUs distributed over 48 PRUs • Paired-tone-based LDRU – 4 RUs: subcarriers distributed over 24 distributed PRUs
Channel encoding	3GPP LTE Turbo code: QPSK ½, 16QAM ½
Channel Model	ITU Extended Ped B – 3 km/hr ITU Extended Veh A – 30 km/hr, 120 km/hr
Channel Estimation	2D MMSE channel estimation
Pilot pattern	Dedicated or Common pilots
Pilot density	According to SDD pilot text
Simulation scenario	Noise limited
Receiver type	MRC for rate 1 schemes LMMSE (for all ranks) MLD for rate-2 SM

Appendix2 : Details of OL SU-MIMO Schemes

		Precoders W applied to physical antennas ($\mathbf{y} = \mathbf{W} \times \mathbf{z}$)
Rate 1	SFBC+AH : Non-precoded pilots - Pattern B	$\mathbf{z} = \begin{bmatrix} s_1 & -s_2^* \\ s_2 & s_1^* \end{bmatrix},\ W = \begin{bmatrix} 1 & 0 \\ 0 & 1 \\ 0 & 0 \\ 0 & 0 \end{bmatrix}, \begin{bmatrix} 1 & 0 \\ 0 & 0 \\ 0 & 1 \\ 0 & 0 \end{bmatrix}, \begin{bmatrix} 1 & 0 \\ 0 & 0 \\ 0 & 0 \\ 0 & 1 \end{bmatrix}, \begin{bmatrix} 0 & 0 \\ 1 & 0 \\ 0 & 1 \\ 0 & 0 \end{bmatrix}, \begin{bmatrix} 0 & 0 \\ 1 & 0 \\ 0 & 0 \\ 0 & 1 \end{bmatrix}, \begin{bmatrix} 0 & 0 \\ 0 & 0 \\ 1 & 0 \\ 0 & 1 \end{bmatrix}$: Cycling duration (*u, v*) – (2, 1), The precoder cycling must be done in the both frequency and time directions. 1- Cycle through the precoders every pair of tones of an OFDM symbol. 2- For the next OFDM symbol repeat step 1 but start form another precoder index to make sure to adjacent tones in the time direction are not identical.
	SFBC+PC, Case1 : Precoded pilots - Pattern A	$\mathbf{z} = \begin{bmatrix} s_1 & -s_2^* \\ s_2 & s_1^* \end{bmatrix}$, W_S is first two columns of rate-4 IEEE 802.16e 6bit codebook's *S*'s indexed Codebook Matrix. Here *S* is also index of physical subband (1 subband = 4PRU). : Cycling duration (*u, v*) – (4PRU, and constant in time)
	SFBC+PC, Case2 : Precoded pilots - Pattern A	$\mathbf{z} = \begin{bmatrix} s_1 & -s_2^* \\ s_2 & s_1^* \end{bmatrix}$,

		$W=\frac{1}{2}\begin{bmatrix}1 & -1\\ -1 & -1\\ 1 & 1\\ -1 & 1\end{bmatrix},\frac{1}{2}\begin{bmatrix}1 & -1\\ -1 & 1\\ 1 & 1\\ -1 & -1\end{bmatrix},\frac{1}{2}\begin{bmatrix}1 & -1\\ 1 & -j\\ 1 & 1\\ 1 & j\end{bmatrix},\frac{1}{2}\begin{bmatrix}1 & -1\\ 1 & j\\ 1 & 1\\ 1 & -j\end{bmatrix}$: Cycling duration (*u, v*) – (1PRU, and constant in time)
	SFBC+PC, Case3 : Precoded pilots - Pattern A	$\mathbf{z}=\begin{bmatrix}s_1 & -s_2^*\\ s_2 & s_1^*\end{bmatrix}$, W_S is the codeword with index *s* of IEEE 802.16e V(4,2,6) codebook. Here *s* is the index of PRU. If the number of PRU is larger than the codebook size, the codeword is cycling used. : Cycling duration (*u, v*) – (1PRU, and constant in time)
Rate 2	SM+AH : Non-precoded pilots – Pattern B	$\mathbf{z}=\begin{bmatrix}s_1\\ s_2\end{bmatrix},\ W=\begin{bmatrix}1 & 0\\ 0 & 1\\ 0 & 0\\ 0 & 0\end{bmatrix},\begin{bmatrix}0 & 0\\ 0 & 0\\ 1 & 0\\ 0 & 1\end{bmatrix},\begin{bmatrix}1 & 0\\ 0 & 0\\ 0 & 1\\ 0 & 0\end{bmatrix},\begin{bmatrix}0 & 0\\ 1 & 0\\ 0 & 0\\ 0 & 1\end{bmatrix},\begin{bmatrix}1 & 0\\ 0 & 0\\ 0 & 0\\ 0 & 1\end{bmatrix},\begin{bmatrix}0 & 0\\ 1 & 0\\ 0 & 1\\ 0 & 0\end{bmatrix}$: Cycling duration (*u, v*) – (1, 1) The precoder cycling must be done in the both frequency and time directions. 1- Cycle through the precoders every tone of an OFDM symbol. 2- For the next OFDM symbol repeat step 1 but start form another precoder index to make sure to adjacent tones in the time direction are not identical.
	DSFBC+AH : Non-precoded pilots - Pattern B	$\mathbf{z}=\begin{bmatrix}s_1 & -s_2^*\\ s_2 & s_1^*\\ s_3 & -s_4^*\\ s_4 & s_3^*\end{bmatrix},\ W=\begin{bmatrix}1 & 0 & 0 & 0\\ 0 & 1 & 0 & 0\\ 0 & 0 & 1 & 0\\ 0 & 0 & 0 & 1\end{bmatrix},\begin{bmatrix}1 & 0 & 0 & 0\\ 0 & 0 & 1 & 0\\ 0 & 1 & 0 & 0\\ 0 & 0 & 0 & 1\end{bmatrix},\begin{bmatrix}1 & 0 & 0 & 0\\ 0 & 0 & 1 & 0\\ 0 & 0 & 0 & 1\\ 0 & 1 & 0 & 0\end{bmatrix}$: Cycling duration (*u, v*) – (2, 1) The precoder cycling must be done in the both frequency and time directions. 1- Cycle through the precoders every pair of tones of an OFDM symbol. 2- For the next OFDM symbol repeat step 1 but start form another precoder index to make sure to adjacent tones in the time direction are not identical.
	SM+PC, Case1 : Precoded pilots - Pattern A	$\mathbf{z}=\begin{bmatrix}s_1\\ s_2\end{bmatrix}$, W_S is first two columns of rate-4 IEEE 802.16e 6bit codebook's *S*'s indexed Codebook Matrix. Here *S* is also index of physical subband (1 subband = 4PRU). : Cycling duration (*u, v*) – (4PRU, and constant in time)
	SM+PC, Case2 : Precoded pilots - Pattern A	$\mathbf{z}=\begin{bmatrix}s_1\\ s_2\end{bmatrix}$, $W=\frac{1}{2}\begin{bmatrix}1 & -1\\ -1 & -1\\ 1 & 1\\ -1 & 1\end{bmatrix},\frac{1}{2}\begin{bmatrix}1 & -1\\ -1 & 1\\ 1 & 1\\ -1 & -1\end{bmatrix},\frac{1}{2}\begin{bmatrix}1 & -1\\ 1 & -j\\ 1 & 1\\ 1 & j\end{bmatrix},\frac{1}{2}\begin{bmatrix}1 & -1\\ 1 & j\\ 1 & 1\\ 1 & -j\end{bmatrix}$: Cycling duration (*u, v*) – (1PRU, and constant in time)

	SM+PC, Case3 : Precoded pilots - Pattern A	$\mathbf{z}=\begin{bmatrix} s_1 \\ s_2 \end{bmatrix}$, W_S is the codeword with index *s* of IEEE 802.16e V(4,2,6) codebook. Here *s* is the index of PRU. If the number of PRU is larger than the codebook size, the codeword is cycling used. : Cycling duration (*u, v*) – (1PRU, and constant in time)
Rate 3	SFBC+SM+AH : Non-precoded pilots – Pattern B	$\mathbf{z}=\begin{bmatrix} s_1 & -s_2^* \\ s_2 & s_1^* \\ s_3 & s_5 \\ s_4 & s_6 \end{bmatrix},\ W=\begin{bmatrix} 1&0&0&0 \\ 0&1&0&0 \\ 0&0&1&0 \\ 0&0&0&1 \end{bmatrix},\begin{bmatrix} 0&0&1&0 \\ 0&0&0&1 \\ 1&0&0&0 \\ 0&1&0&0 \end{bmatrix}$: Cycling duration (*u, v*) – (2, 1) The precoder cycling must be done in the both frequency and time directions. 1- Cycle through the precoders every pair of tones of an OFDM symbol. 2- For the next OFDM symbol repeat step 1 but start form another precoder index to make sure to adjacent tones in the time direction are not identical.
	SM+AH : Non-precoded pilots – Pattern B	$\mathbf{z}=\begin{bmatrix} s_1 \\ s_2 \\ s_3 \end{bmatrix},\ W=\begin{bmatrix} 1&0&0 \\ 0&1&0 \\ 0&0&1 \\ 0&0&0 \end{bmatrix},\begin{bmatrix} 1&0&0 \\ 0&1&0 \\ 0&0&0 \\ 0&0&1 \end{bmatrix},\begin{bmatrix} 1&0&0 \\ 0&0&0 \\ 0&1&0 \\ 0&0&1 \end{bmatrix},\begin{bmatrix} 0&0&0 \\ 1&0&0 \\ 0&1&0 \\ 0&0&1 \end{bmatrix}$: Cycling duration (*u, v*) – (1, 1) The precoder cycling must be done in the both frequency and time directions. 1- Cycle through the precoders every tone of an OFDM symbol. 2- For the next OFDM symbol repeat step 1 but start form another precoder index to make sure to adjacent tones in the time direction are not identical.
	SM+PC, Case1 : In case of tone based DRU - Pattern B In case of PRU based DRU- First 3 pilot streams of Pattern B	$\mathbf{z}=\begin{bmatrix} s_1 \\ s_2 \\ s_3 \end{bmatrix}$, W_S is first three columns of rate-4 IEEE 802.16e 6bit codebook's *S*'s indexed Codebook Matrix. Here *S* is also index of physical subband (1 subband = 4PRU). : Cycling duration (*u, v*) – (4PRU, and constant in time)
	SM+PC, Case3 : In case of tone based DRU - Pattern B In case of PRU based DRU- First 3 pilot streams of Pattern B	$\mathbf{z}=\begin{bmatrix} s_1 \\ s_2 \\ s_3 \end{bmatrix}$, W_S is the codeword with index *s* of IEEE 802.16e V(4,3,6) codebook. Here *s* is the index of PRU. If the number of PRU is larger than the codebook size, the codeword is cycling used. : Cycling duration (*u, v*) – (1PRU, and constant in time)

Reference

[1] IEEE 802.16m-08/003r6, "The Draft IEEE 802.16m System Description Document."

[2] C80216m-08/426r1, “An Open-loop MIMO Scheme based on Phase Shift Diversity.”