Project	**IEEE 802.16 Broadband Wireless Access Working Group** <http://ieee802.org/16>
Title	**Performance comparison of IEEE 802.16m DL OL-SU-MIMO**
Date Submitted	**2008-09-05**
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Re:	PHY: MIMO; in response to the TGm Call for Contributions and Comments 802.16m-08/033 for Session 57
Abstract	In this contribution, we compare performance of DL OL-SU-MIMO candidates
Purpose	Discuss and adopt in TGm
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Performance comparison of IEEE 802.16m DL OL-SU-MIMO

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1. Discussion points for downlink open-loop single user MIMO

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
- Minimize number of option

2. OL-SU-MIMO candidates

We can divide OL-SU-MIMO into two major groups.

First group, schemes requires common pilot. The following schemes are in this group; IEEE 802.16e 4Tx A, B matrix, STC with antenna hopping, DSTTD with or without antenna hopping and so on.

Within first group, IEEE 802.16e 4Tx B matrix or DSTTD with antenna hopping shows best performance but it requires very high receiver complexity. If we consider receiver complexity when we compare performance, SM with AH outperforms matrix B.

Second group, schemes can work with precoded pilot. The following schemes are in this group; small delay with codeword cycling with 2Tx STC, codeword cycling with 2Tx STC, antenna permuted CDD with STC, 2D-POD with 2Tx STC, small delay CDD with 2Tx STC.

Some of this features changes codebook element for different sub-frame in same physical RU. This increases CQI mismatch. Sometimes MS will be allocated *N* RU x 1 sub-frame, and sometimes MS will be allocated *N* RU x 2 sub-frames. MS does not know it will be allocated one sub-frame or two sub-frames when it calculates CQI. So we suggest same codebook element shall be applied in same physical RU for a certain period.

3. Pilots for OL-SU-MIMO

We summarize pilot and different rate multiplexing in DRU issue in this section.

- Precoded Pilot vs. Un-precoded Pilot
  - To support 8Tx antenna OL-SU-MIMO scheme, we need to use precoded pilot.
  - Some of OL-SU-MIMO scheme rely on un-precoded pilot (common pilot).
  - Even with common pilot, we can’t use the whole pilots in the subframe since localized permutation and distributed permutation is multiplex in FDM manner. And since in localized

permutation, it is more likely to have dedicated pilot.

- Even with common pilot, we do need midamble or measurement pilot since distributed permutation can't cover whole bandwidth.
- Proper design of D(*k*) and W(*k*) enables dedicated pilot, which gives pilot overhead reduction gain while diversity gain can be achieved by D(*k*) and W(*k*).
- Scheme derived by current SDD text, P(*k*) = D(*k*)W(*k*), with dedicated pilot shows best performance among OL-SU-MIMO candidates.
  - See section 4 for simulation results.

- When allocation in subcarrier level DRU, we need to have further assumption for multiplexing different rate preferred MSs
  - There are multiple possible solution for this, the followings are examples.
    - Make two types of DRUs based on subcarrier level permutation, one for 2 steam pilot and one for 4 stream pilot.
      - One possible solution for this is indicating which pilot structure is used for the allocation (1bit) in USCCH (MAP) (This is FFS.)
    - Limit subcarrier level DRU allocation for up to rate-2.
      - Since OL-SU-MIMO in subcarrier level DRU will be used for high speed MS, there won't be many request for higher rank transmission.

4. Performance comparison

In this section, we show simulation results for distributed permutation (two subcarrier level) and localized permutation. For distributed permutation, we simulate typical scenario which is ITU VEH-A 60km/hr. For localized permutation, we simulate worst scenario which is ITU PED-A 3km/hr.

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

In this sub-section, we compare IEEE 802.16e 4Tx matrix A, small delay CDD with codeword cycling with 2Tx STC and small delay with codeword cycling (rank-1, stream-1). The detailed simulation assumption for small delay CDD with codeword cycling is as follows;

- W(*k*) is chosen based on DFT-based codebook
- Size of *u* is one P_{sc}
- Size of *k* is 1, and $\theta_0 = 0$, $\theta_1 = -2\pi d/N_{fft}$, $\theta_2 = 2\theta_1$, $\theta_3 = 3\theta_1$, with d is 2
- MIMO encoder is 2Tx SFBC

For localized permutation and codeword cycling scheme, we use first pilot stream pattern of pilot pattern A. For other precoded pilot, we use pilot pattern A. For un-precoded pilot, we use pilot pattern for 4 stream pilots.

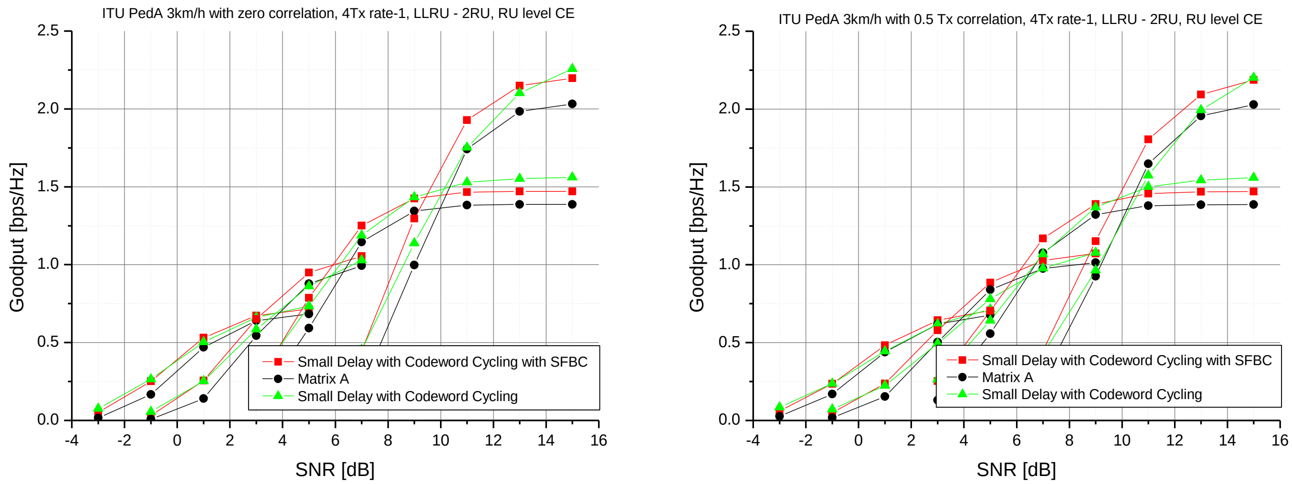

Fig 1. Localized permutation, ITU-PED-A 3km/hr, randomly selected 2 RU

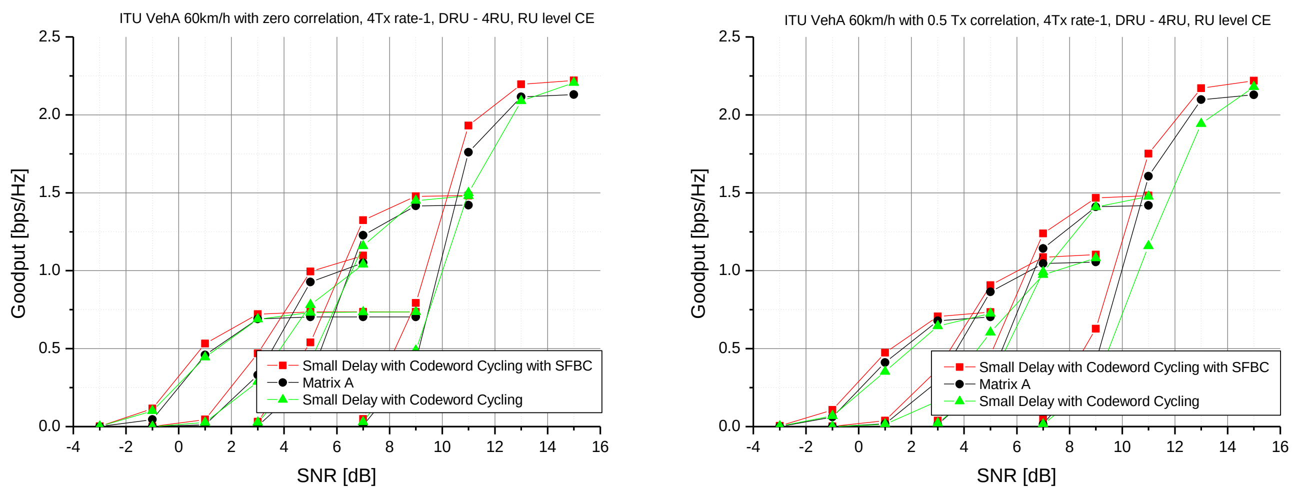

Fig 2. Distributed permutation, ITU-VEH-A 60km/hr, randomly selected 4 RU

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

In this sub-section, we compare SM with antenna hopping, small delay CDD with codeword cycling. The detailed simulation assumption for small delay CDD with codeword cycling is as follows;

- W(*k*) is chosen based on DFT-based codebook
- Size of *u* is one P_{sc}
- Size of *k* is 1, and $\theta_0 = 0$, $\theta_1 = -2\pi d/N_{fft}$, $\theta_2 = 2\theta_1$, $\theta_3 = 3\theta_1$, with d is 2

For precoded pilot, we use pilot pattern A. For un-precoded pilot, we use pilot pattern for 4 stream pilots.

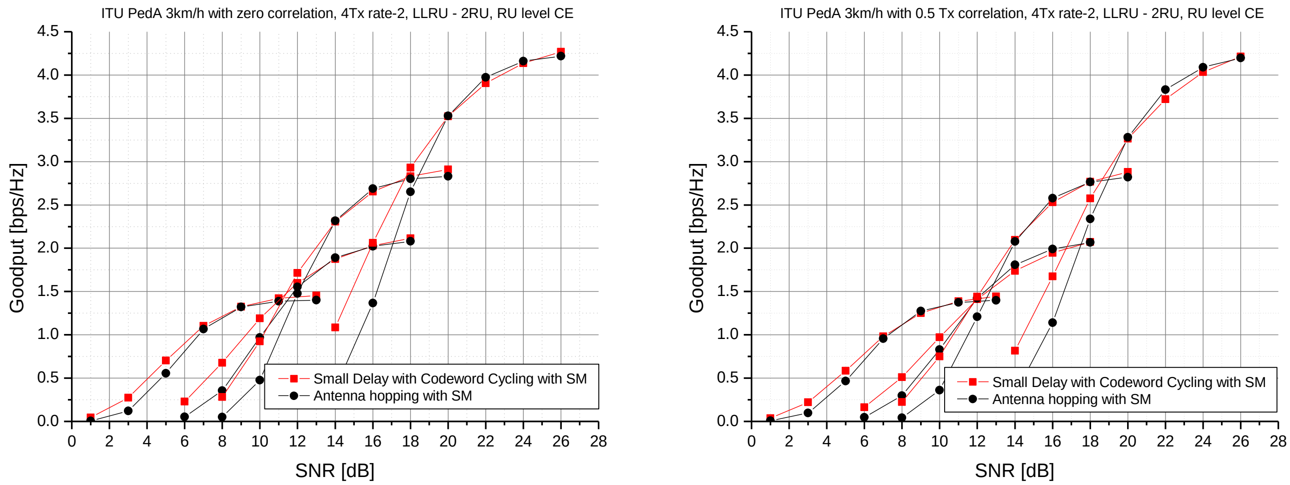

Fig 3. Localized permutation, ITU-PED-A 3km/hr, randomly selected 2 RU

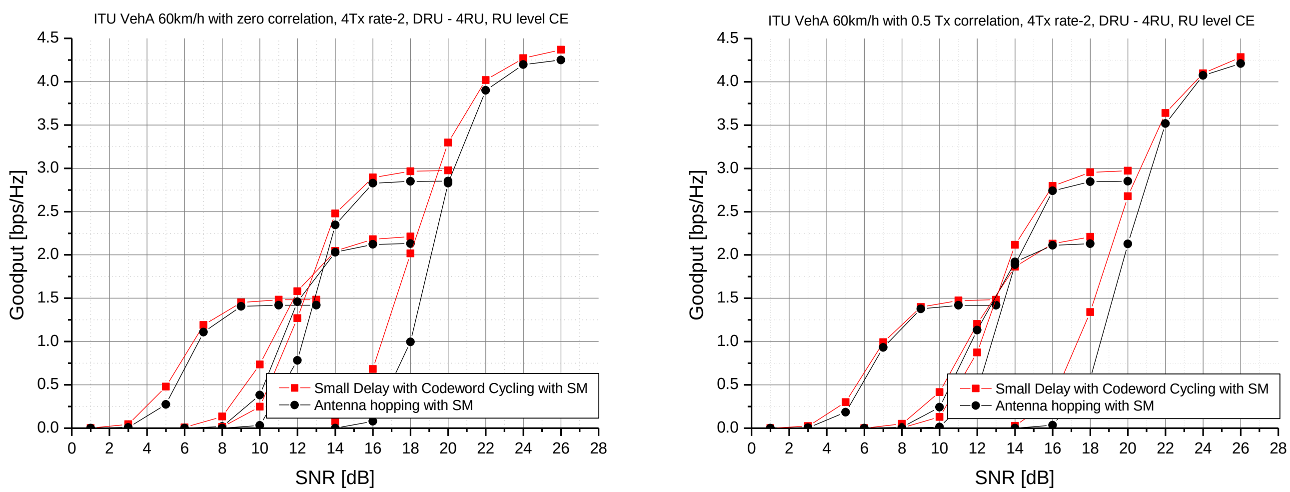

Fig 4. Distributed permutation, ITU-VEH-A 60km/hr, randomly selected 4 RU

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

In this sub-section, we compare SM with antenna hopping, small delay CDD with codeword cycling. The detailed simulation assumption for small delay CDD with codeword cycling is as follows;

- W(k) is chosen based on DFT-based codebook
- Size of u is one P_{sc}
- Size of k is 1, and $\theta_0 = 0$, $\theta_1 = -2\pi d/N_{fft}$, $\theta_2 = 2\theta_1$, $\theta_3 = 3\theta_1$, with d is 2

For localized permutation and small delay with codeword cycling with SM scheme, we use first three pilot stream pattern of pilot pattern for 4 stream pilots. For distributed permutation, we use pilot pattern for 4 stream pilots.

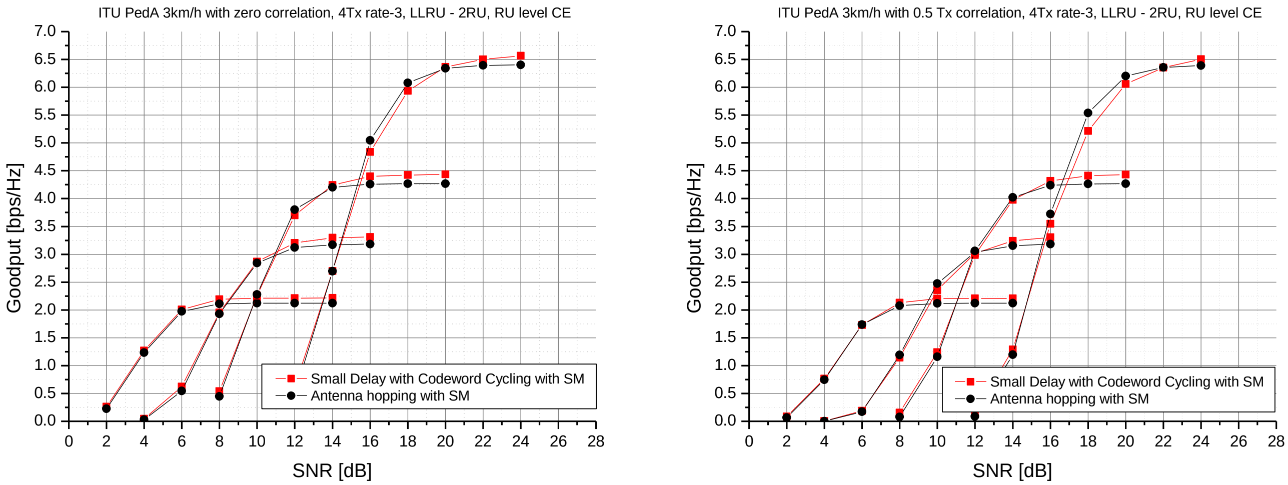

Fig 5. Localized permutation, ITU-PED-A 3km/hr, randomly selected 2 RU

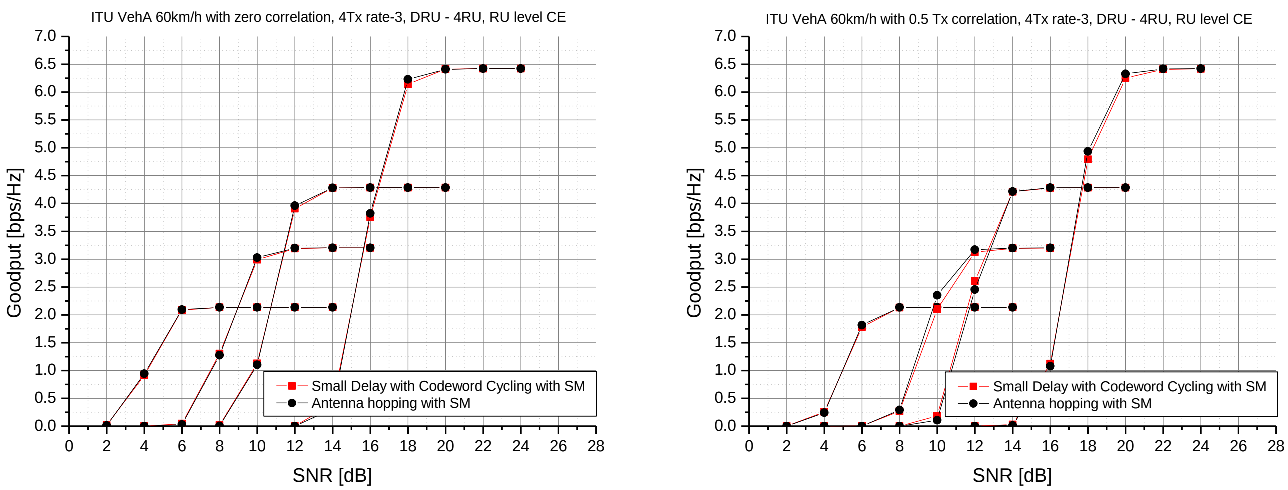

Fig 6. Distributed permutation, ITU-VEH-A 60km/hr, randomly selected 4 RU

5. Conclusions

Scheme with dedicated pilot shows better performance than scheme with common pilot due to pilot overhead gain.

Basically the concept of scheme with dedicated pilot is very similar. The difference is from different codebook element. To reduce memory requirement, we suggest CL-SU-MIMO codebook shall be a codebook in this case. We can't find any reason that we want to use other codebook element so far.

Some of this schemes change codebook element for different sub-frame in same physical RU. This increases

CQI mismatch. Sometimes MS will be allocated *N* RU x 1 sub-frame, and sometimes MS will be allocated *N* RU x 2 sub-frames. MS does not know it will be allocated one sub-frame or two sub-frames when it calculates CQI. So we suggest same codebook element shall be applied in same physical RU for a certain period.

In current frame structure, odd numbers, 5 and 7, of OFDM symbols can be in one sub-frame. Since it is difficult to map STBC in odd numbered symbols, we suggest only SFBC shall be used in 2Tx rate-1 OL-SU-MIMO.
Moreover, for rank-1 transmission, SFBC with precoding shows better performance than rate-1, stream-1 scheme.

- Precoded demodulation pilot shall be used for OL-SU-MIMO, in other words, pilots are precoded with same precoder as in OL-SU-MIMO, D(*k*)W(*k*)
- W(*k*) shall be chosen based on CL-SU-MIMO codebook or its subset
- Size of *u* shall be one or multiple of P_{sc}
- Transmit diversity scheme, rate-1 OL-SU-MIMO scheme, shall be SFBC for 2Tx and SFBC with precoder for higher number of transmit antennas

6. Proposed Remedy

Remedy #1

Add the following sentence after line 3, page 67

Demodulate pilot is precoded. For closed-loop SU-MIMO, MU-MIMO, the number of pilot stream is same as number of data stream. For open-loop SU-MIMO transmitted via LLRU, the number of pilot stream is same as number of streams. For open-loop SU-MIMO in subcarrier based DRU, the number of pilot stream is either two or four depending on MS multiplexing.

Remedy #2

line 7 and line 8, page 68, modify sentence as follows:

where $y_{i,j}$ is the output symbol to be transmitted via the *i*-th physical antenna on the *j*-th subcarrier~~/symbol~~. Note N_F is the number of subcarriers~~ or symbols~~ used to transmit the MIMO signals derived from the input vector **x**. For open-loop SU-MIMO, the rate of a mode is defined as $R = M / N_F$.

line 19, 20 and 21, page 69, delete "STBC/" in the texts

Remedy #3

Table 5, page 68, modify table as follows:

N_T	Rate	M	N_F
~~2~~	~~1~~	~~1~~	~~1~~
2	1	2	2
~~4~~	~~1~~	~~1~~	~~1~~
4	1	2	2
~~8~~	~~1~~	~~1~~	~~1~~
8	1	2	2
2	2	2	1

4	2	2	1
8	2	2	1
4	3	3	1
8	3	3	1
4	4	4	1
8	4	4	1

line 19, 20 and 21, page 69, delete ", and rank-1 precoder" in the texts

Remedy #4

line 5, page 69, add the sentence as follows:

The matrix W(k) is selected from a predefined unitary codebook, and changes every *u* subcarriers. Size of *u* is K×Psc. [K is FFS.]

line 6, page 69, delete "and the parameter u are FFS."

Remedy #5

line 6, page 69, add the following sentence.

The unitary codebook shall be based on CL-SU-MIMO codebook.

line 6, page 69, delete "[The detailed unitary codebook, and the parameter u are FFS.]"

Remedy #6

line 19, page 70, modify the sentence as follows:

- 4Tx rate-4: rate 4 SM with precoding

line 26, page 71, modify equation 22 as follows:

~~y=z~~ $\mathbf{y} = \mathbf{D} \times \mathbf{W} \times \mathbf{z}$

Appendix : 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 and correlated
Mobile station correlation	Uncorrelated
Resource block size	18 sub-carriers × 6 OFDM symbols
Number of resource block	Randomly selected 4 resource blocks spanning one sub-frame for distributed permutation Randomly selected 2 resource blocks spanning one sub-frame for

	localized permutation
Distribution mode	Localized and distributed (2 subcarrier level distributed)
Channel encoding	3GPP Turbo code (It is very difficult to encode with 16e CTC for current sub-frame structure) , QPSK ½, QPSK ¾, 16QAM ½, 16QAM ¾
Channel Model	ITU PED A – 3 km/hr for localized permutation ITU VEH A – 60 km/hr for distributed permutation
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	MMSE receiver

Reference

[1] IEEE 802.16m-08/003r4, “The Draft IEEE 802.16m System Description Document.”

[2] C80216m-MIMO-08/013, “Proposed harmonized OL-SU-MIMO formula based on SDD text.”

[3] C80216m-MIMO-08/014, “SU OL MIMO Proposals.”

[4] IEEE 802.16m-07/002r4, “IEEE 802.16m System Requirements.”

[5] C80216m-MIMO-08/010, “Proposal for DL OL SU-MIMO Transmit Diversity Schemes.”

[6] P80216Rev2/D6, “DRAFT Standard for Local and metropolitan area networks Part 16: Air Interface for Broadband Wireless Access Systems.”

[7] C80216m-MIMO-08/007, “Proposal for DL OL SU-MIMO Schemes.”

[8] C80216m-MIMO-08/009, “Formulation for a proposal of DL OL SU-MIMO.”

[9] C80216m-MIMO-08/017, “Proposal for DL OL SU-MIMO in the Form of y=DxWxz.”

[10] C80216m-DL_MIMO-08/010r1, “Performance Evaluation of DL Open Loop MIMO Schemes.”

[11] C80216m-MIMO-006, “A two-stream Alamouti scheme for MIMO DL in 802.16m.”

[12] C80216m-08/861, “Downlink open-loop single user MIMO.”

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

[14] C80216m-MIMO-08/011, “Rate-3 hybrid SM+STBC/SFBC scheme for Upto 2 Codewords with 4 Tx.”

[15] C80216m-MIMO-08/054, “Performance comparison of IEEE 802.16m DL OL-SU-MIMO.”