Performance Evaluation of DL Open Loop SU-MIMO Schemes

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Purpose: to compare SU-MIMO schemes in terms of performance

Introduction

- This contribution compares several open loop schemes for a 4 Tx system with single codeword (SCW)
- Schemes compared are:
  - Rate 1:
    - [C802.16m-MIMO-08/007] STC with antenna hopping and common pilot (STC/AH), precoder is changed over every pair of tones in time and frequency direction.
    - [C802.16m-MIMO-08/017] STC with large delay CDD and common pilot (STC/LDCDD)
    - [C802.16m-MIMO-08/009] STC with antenna permutation and phase shift and dedicated pilot (STC/Permuted CDD)
    - [C802.16m-MIMO-08/014] STC with two dimensional phase shift and dedicated pilot (STC/2D-POD)
    - [C802.16m-MIMO-08/013] STC with 4x2 16e or DFT precoder and/or phase shift and dedicated pilot: Candidate 1, 2 or 4 (STC/16e+CDD, STC/16e, STC/DFT+CDD)
  - Rate 2:
    - [C802.16m-MIMO-08/016] Double STTD with antenna hopping and common pilot (DSTTD/AH), precoder is changed over every pair of tones in time and frequency direction.
    - [C802.16m-MIMO-08/007] SM with antenna hopping and common pilot (SM/AH), precoder is changed over every tone in time and frequency direction.
    - [C802.16m-MIMO-08/008] SM with subset antenna hopping and common pilot (SM/sub AH), precoder is changed over every tone in time and frequency direction.
    - [C802.16m-MIMO-08/017] SM with large delay CDD and common pilot (SM/LDCDD)
    - [C802.16m-MIMO-08/009] SM with antenna permutation and phase shift and dedicated pilot (SM/Permuted CDD)
    - [C802.16m-MIMO-08/014] SM with two dimensional phase shift and dedicated pilot (SM/2D-POD)
    - [C802.16m-MIMO-08/013]: SM with 4x2 16e or DFT precoder and/or phase shift and dedicated pilot: Candidate 1, 2 or 4 (SM/16e+CDD, SM/16e, SM/DFT+CDD)

Overall Summary of the Simulation Results

- Rate 1
  - STC/AH has the best goodput
- Rate 2
  - If only MMSE with 2×2 matrix inversion is feasible then SM/AH has the best goodput
  - If MMSE with 4×4 matrix inversion is feasible then DSTTD/AH has the best goodput
  - If MLD receiver is feasible then SM/AH has the best goodput.

Simulation Parameters

- **Channelization**
  - 10 MHz bandwidth with 48 physical RUs (PRU)
  - RU size is 18×6
  - 4 RUs allocated to a user
  - RU-based distributed RU (DRU). 4 RUs are randomly selected from 48 available PRUs.
  - tone-based DRU. Tones are distributed over 24 PRUs. 24 PRUs are randomly selected from 48 available PRUs.
- **Antenna**
  - 4 Tx, 2 Rx
  - uncorrelated
  - 0 dB receive power imbalance
- **Fading channel**
  - PB 3 km/h, VA 60 km/h
  - carrier frequency 2.5 GHz
  - 2D MMSE channel estimation
- **Receiver**
  - MMSE or MLD. Default receiver is MMSE unless otherwise specified.
- **Channel Estimation (CE)**
  - 2D-MMSE CE. CE is over one 1 PRU for dedicated pilots or 2 PRUs for common pilots.
- **Modulation and coding**
  - 16-QAM
  - rate ½ duo-binary turbo code with 10 decoding iterations
  - 1 or 2 MIMO layers
  - single codeword

Channel Estimation Difference between Common Pilot and Dedicated Pilot

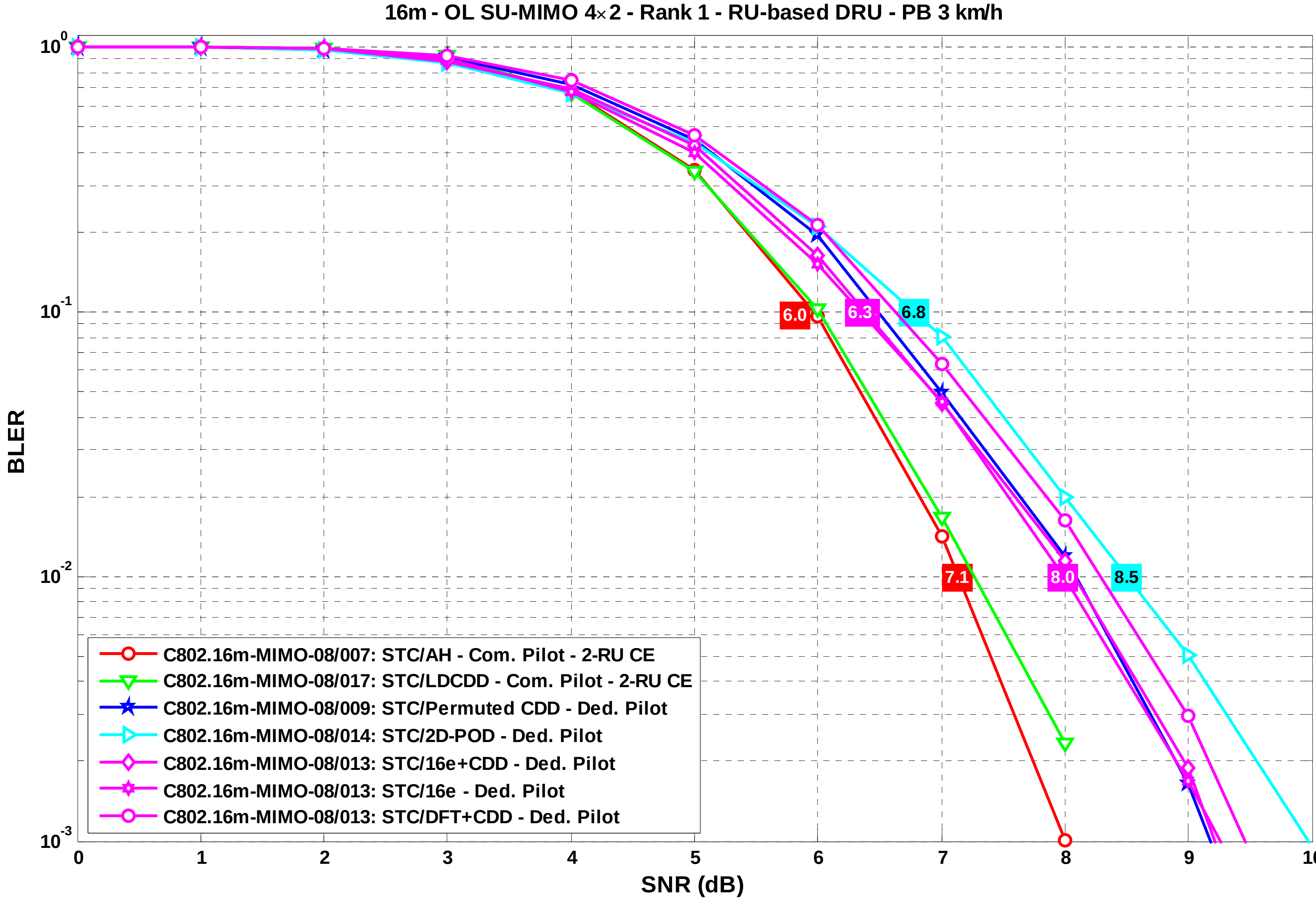
- With common pilots, CE can be done over multiple PRUs where common pilot exists
- With dedicated pilots, CE can only be done within one PRU
- As defined in the SDD (IEEE 802.16m-08/003r4), for non FFR case, the outer-permutation unit is 4 PRUs.
- For FFR case, the outer-permutation unit can be 1 or 2 PRUs.
  - To have reasonable sub-band feedback overhead, 2 PRUs are preferable.
  - E.g., in 10MHz, there are 48 PRUs. Assuming 4 FFR zones, each zone has 12 PRUs. 2 PRUs per sub-band will give 6 sub-bands for more reasonable feedback overhead.
  - For larger system bandwidth or lower number of FFR zones or unequal size FFR zones, the outer-permutation unit of 2 PRUs is even more crucial to ensure reasonable number of sub-bands per FFR zone and therefore reasonable amount of feedback overhead
- Even when there are multiple FFR zones, common pilots can exist across the FFR zones which can be used by an MS for channel estimation.
- In this contribution, we evaluate the performance of OL MIMO schemes with common pilot using 2 PRUs channel estimation. We evaluate the performance of OL MIMO schemes with dedicated pilots using 1 PRU channel estimation.

Antenna Hopping Scheme

- Antenna hopping precoder is a simple matrix with 0/1 elements
- Antenna hopping uses common pilots
- As opposed to dedicated pilot schemes, with common pilots, we are free to change precoder matrix even within a PRU
  - more space diversity within one PRU
  - better performance and goodput (see simulation results)

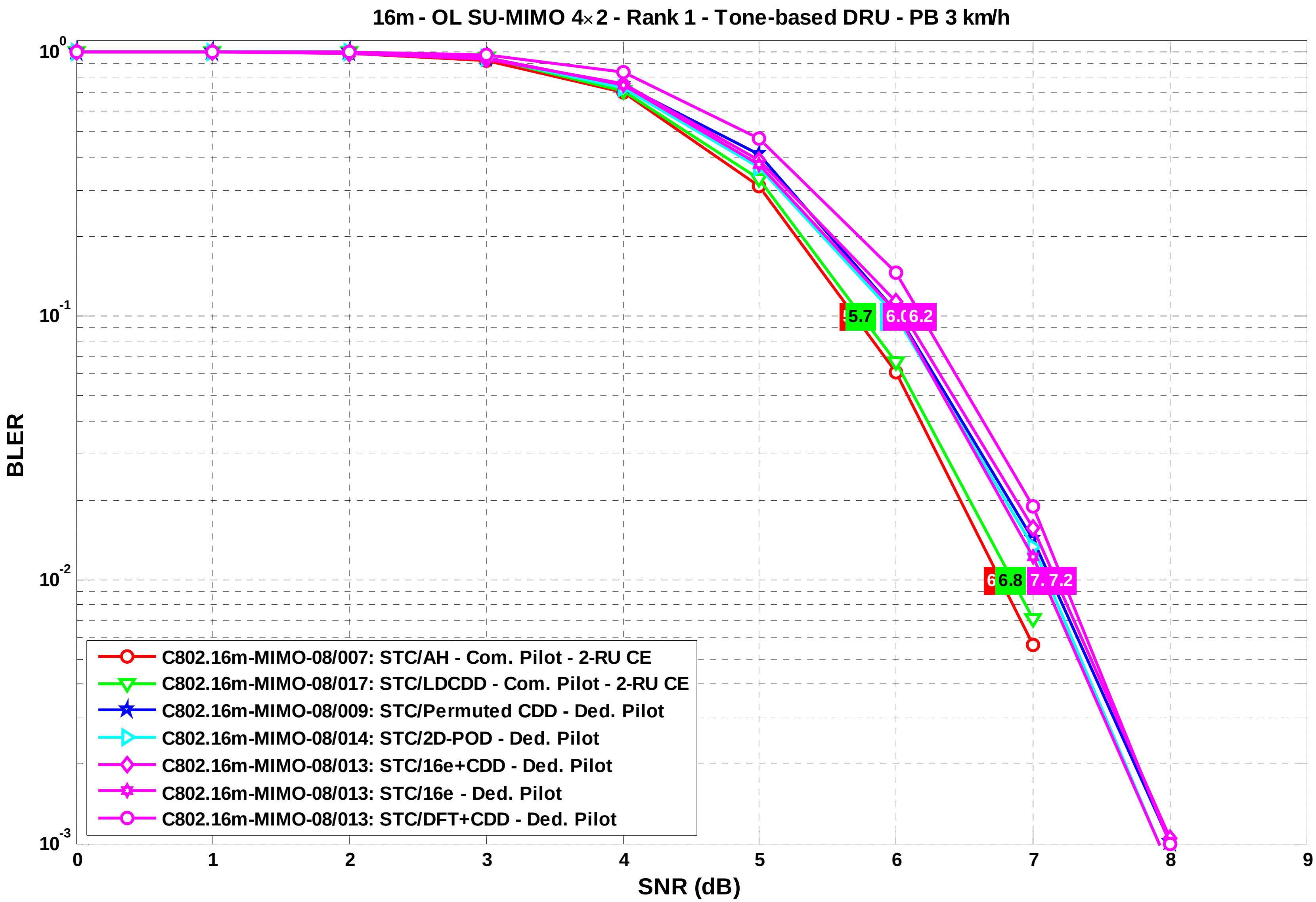
Link Level Performance Comparison for Rate 1

Comparing Rank 1 Schemes with RU-based DRU in PB 3 km/h



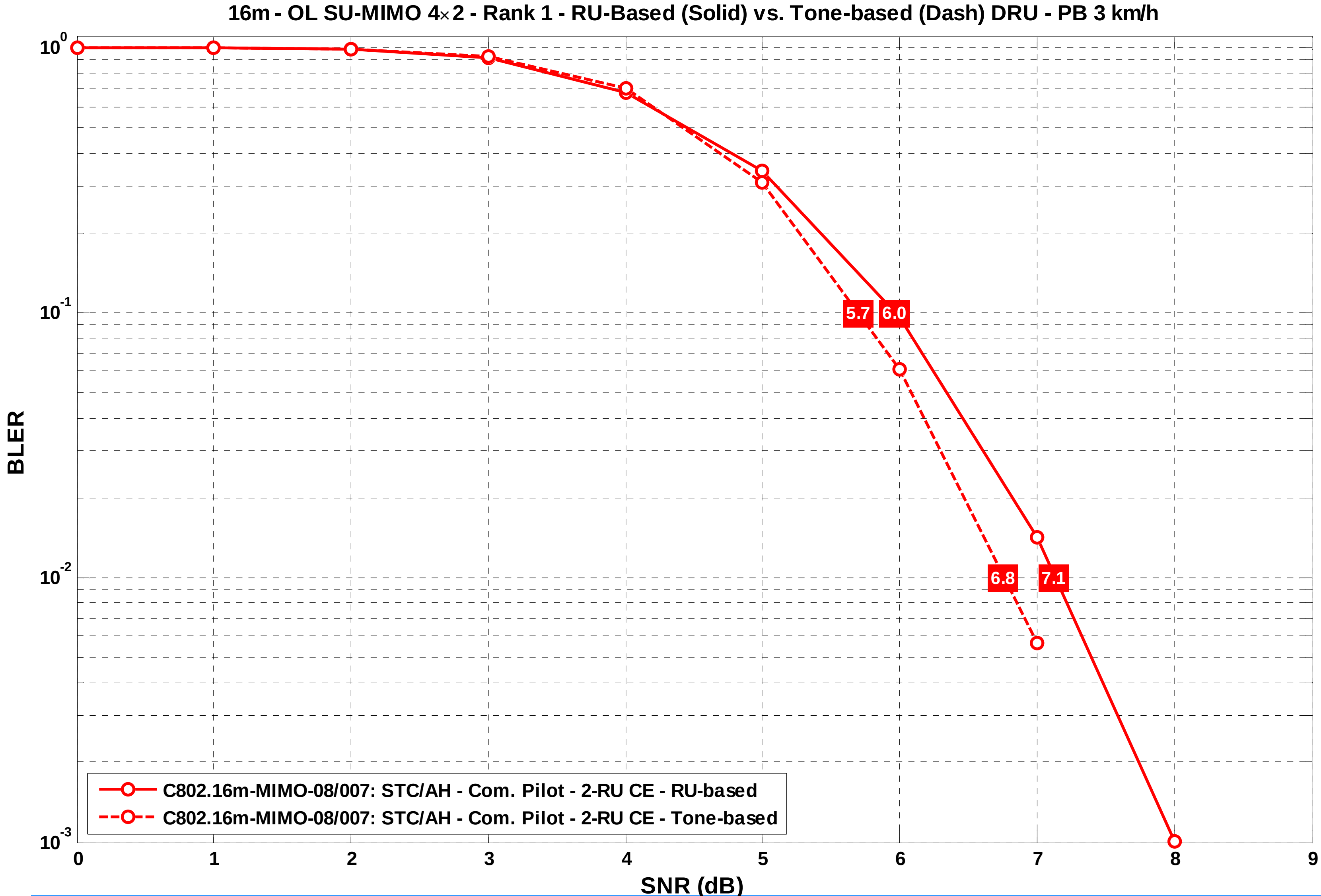
STC/AH has the overall best performance in PB channel with RU-based DRU.

Comparing Rank 1 Schemes with Tone-based DRU in PB 3 km/h



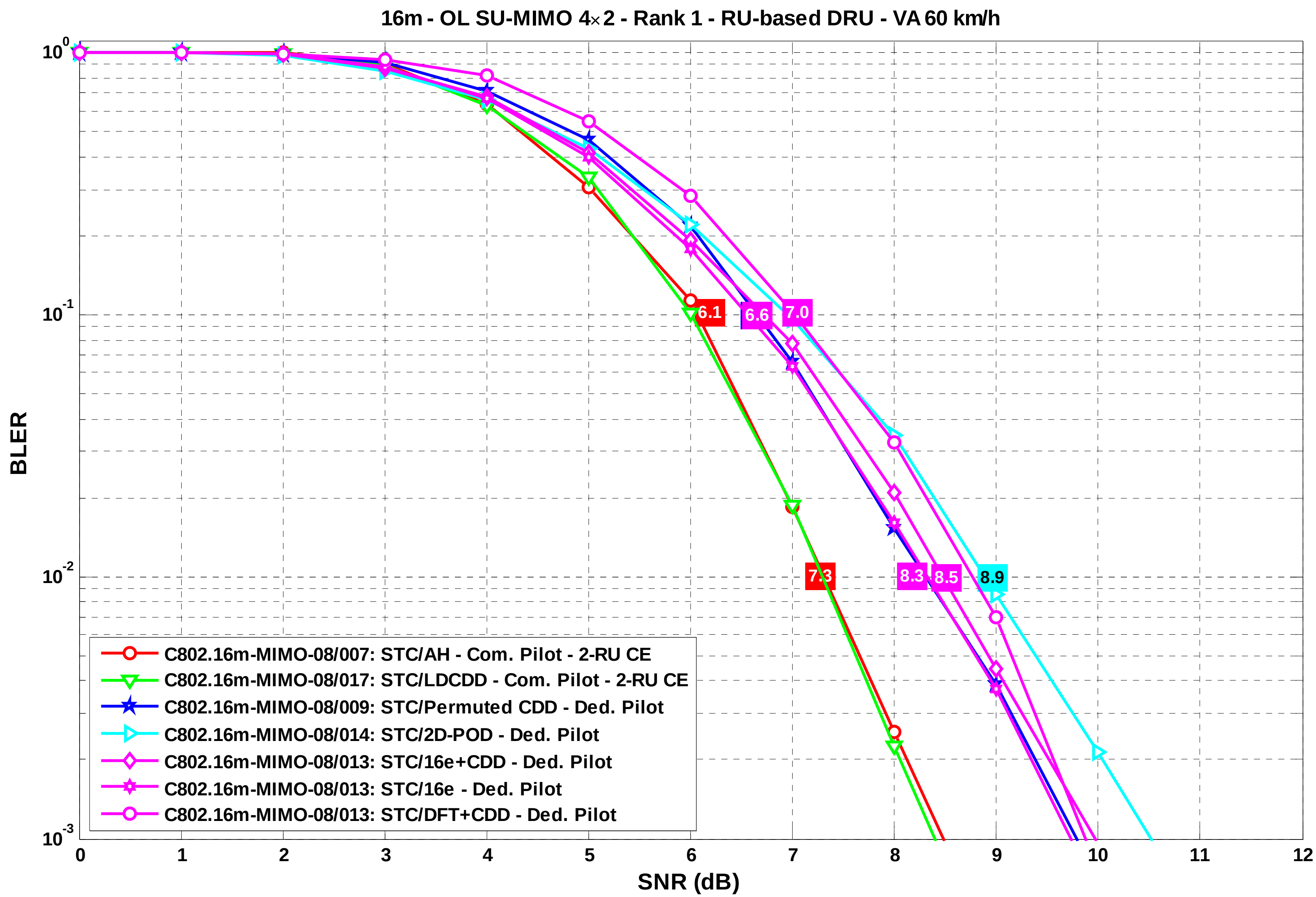
STC/AH has the overall best performance in PB channel with tone-based DRU.

RU-based vs. Tone based DRU for Best Rank 1 Schemes in PB 3 km/h



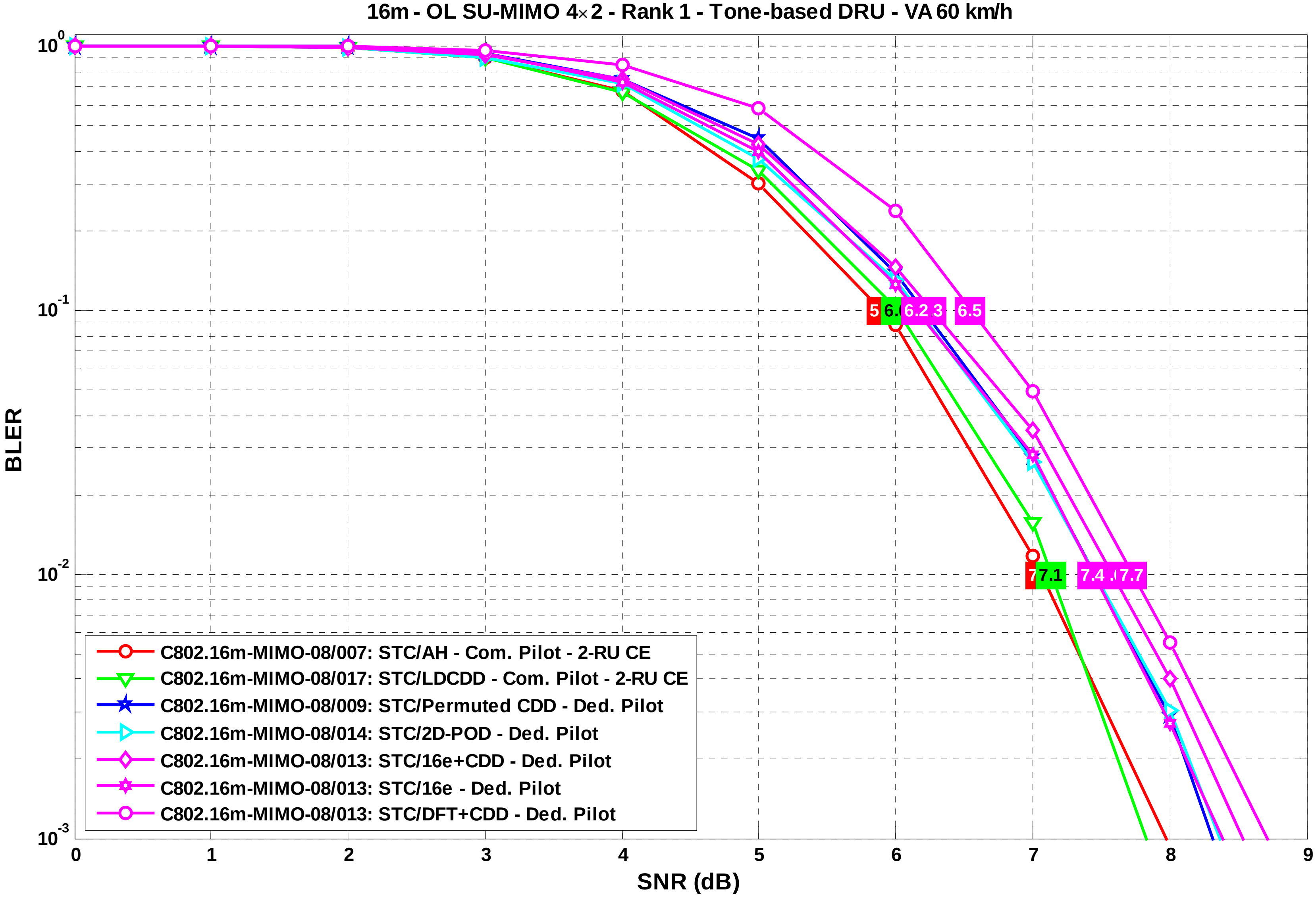
STC/AH with tone-based DRU has the best performance in PB channel. The difference of tone based and RU-based DRU is less than 0.4 dB.

Comparing Rank 1 Schemes with RU-based DRU in VA 60 km/h



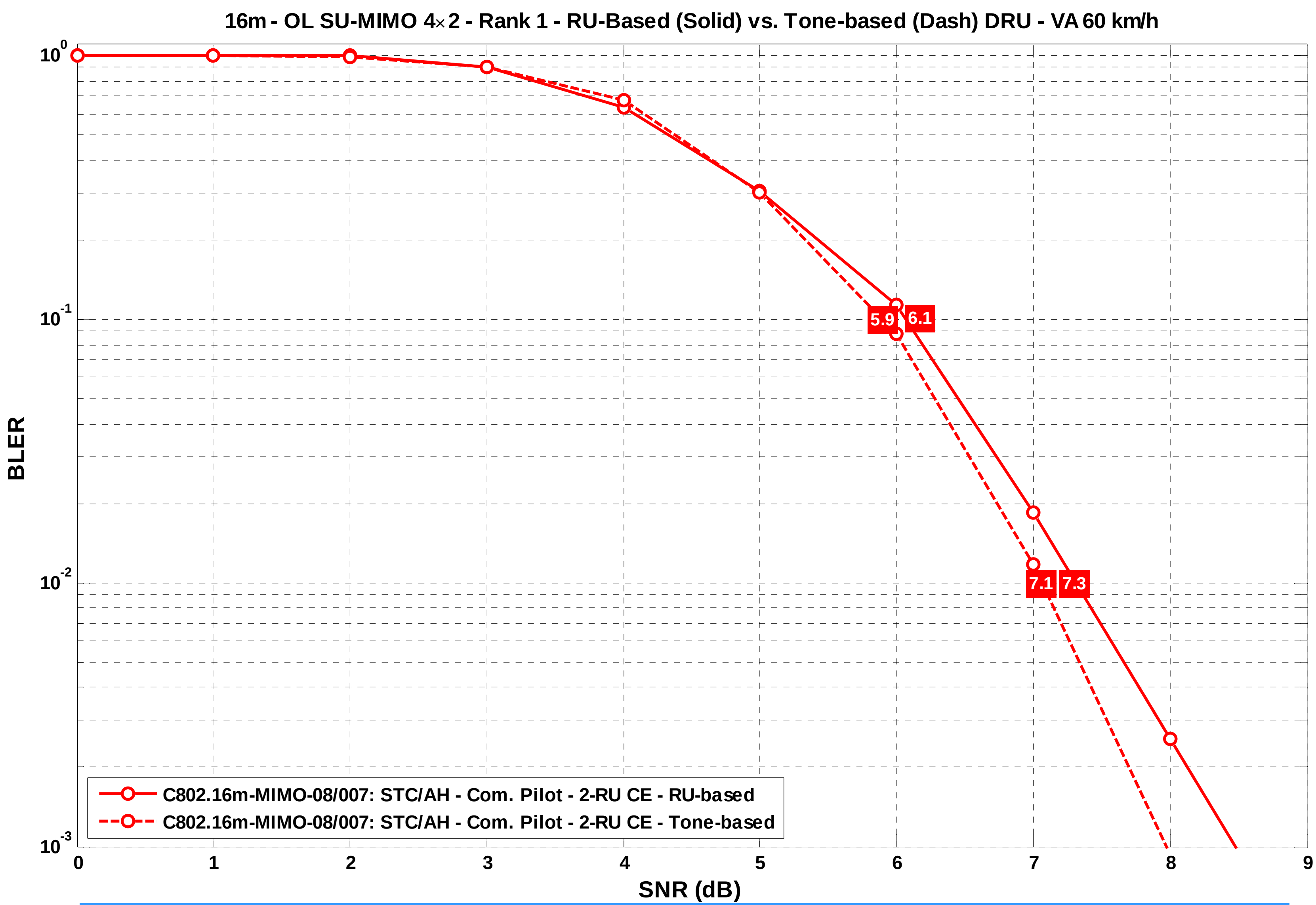
STC/AH and STC/LDCDD have the overall best performance in VA channel with RU-based DRU.

Comparing Rank 1 Schemes with Tone-based DRU in VA 60 km/h



STC/AH has the overall best performance in VA channel with tone-based DRU.

RU-based vs. Tone based DRU for Best Rank 1 Schemes in VA 60 km/h



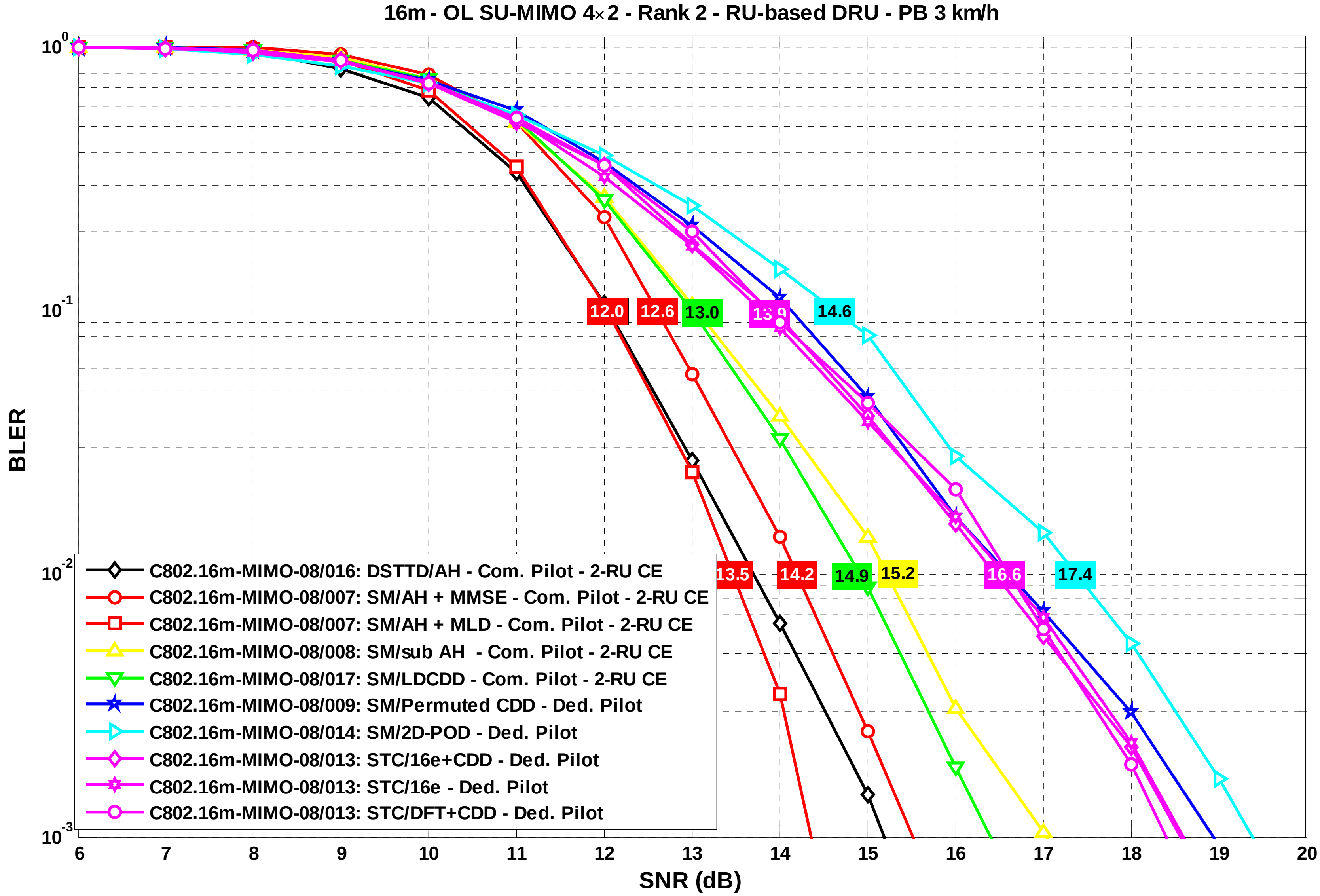
The difference of tone-based and RU-based DRU is less than 0.2 dB.

Overall Summary of Comparison of OL SU-MIMO Schemes for Rate 1

- STC/AH has the overall best performance and lower complexity due to:
  - simple precoders with binary components
  - no need for phase shift matrix
- STC/AH has the best performance regardless of DRU resource allocation type
  - the difference of tone-based and RU-based DRU is less than 0.4 dB for STC/AH in PB 3 km/h and VA 60 km/h

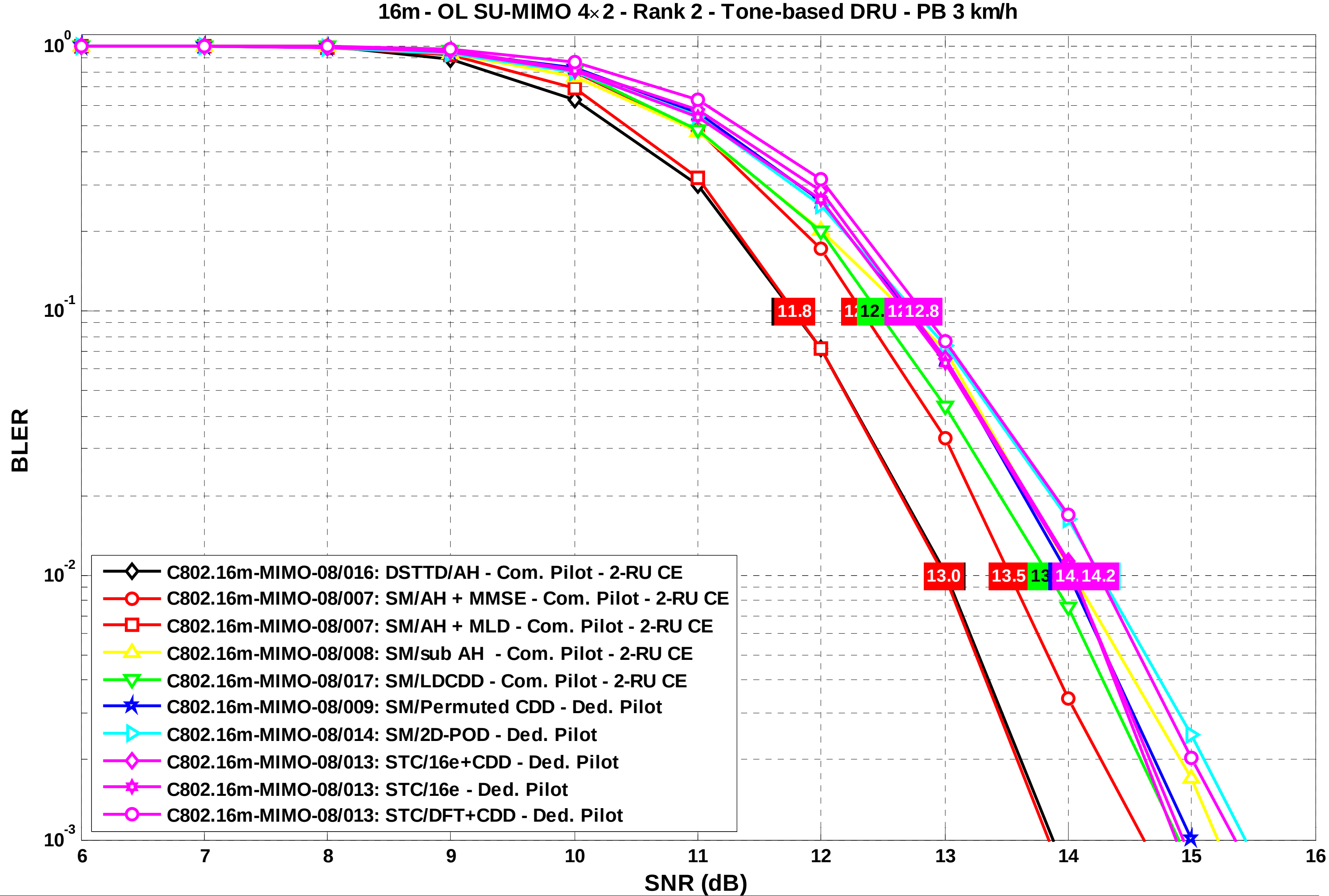
Link Level Performance Comparison for Rate 2

Comparing Rank 2 Schemes with RU-based DRU in PB 3 km/h



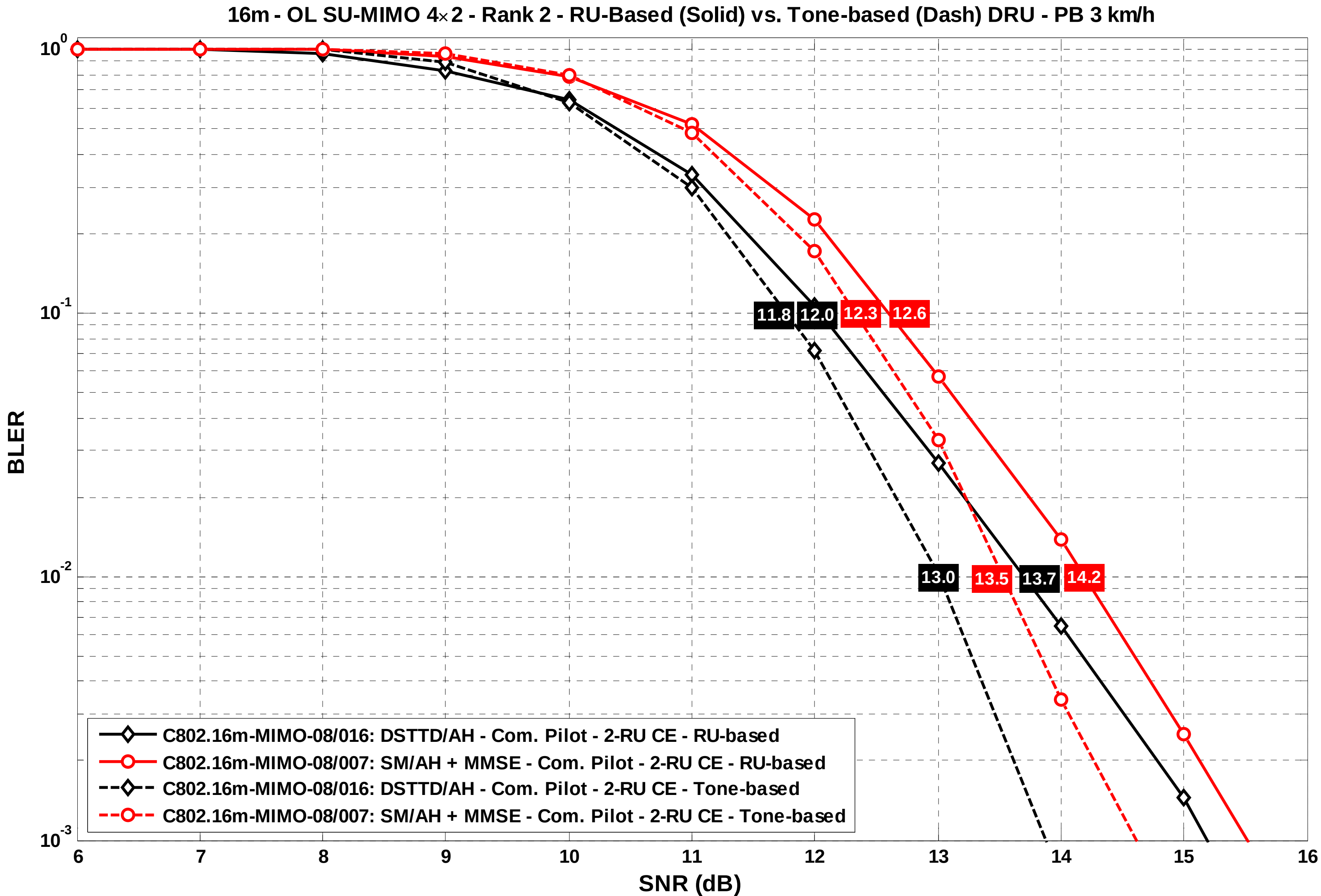
If MMSE receiver used, DSTTD/AH has the overall best performance in PB channel with RU-based DRU. Performance of SM/AH + MMSE is 0.6 dB worse than DSTTD/AH but with lower receiver complexity. SM/AH + MMSE needs only 2x2 matrix inversion. SM/AH + MLD outperforms DSTTD/AH + MMSE.

Comparing Rank 2 Schemes with Tone-based DRU in PB 3 km/h



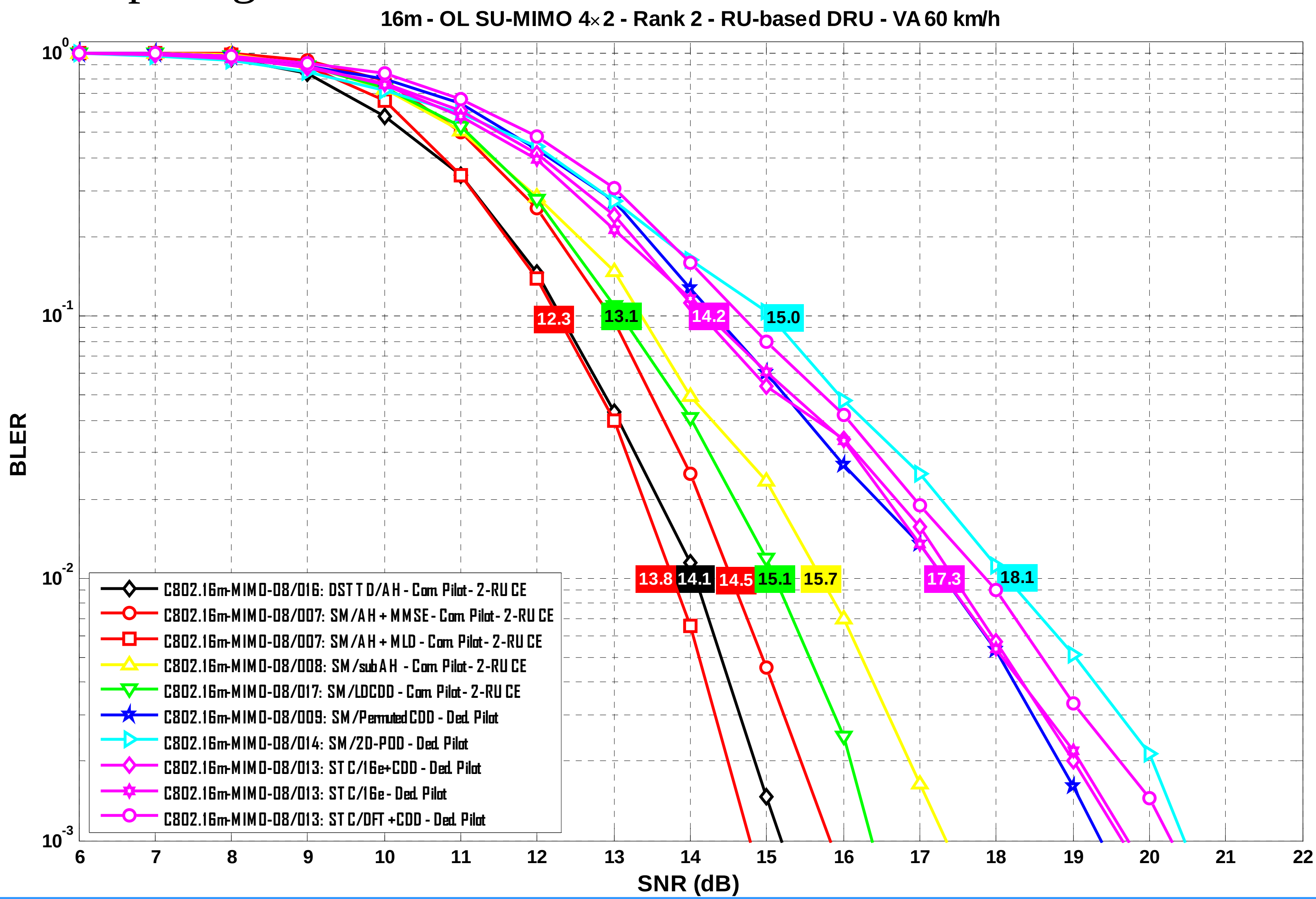
If MMSE receiver used, DSTTD/AH has the overall best performance in PB channel with tone-based DRU. SM/AH + MLD performs close to DSTTD/AH.

RU-base vs. Tone based DRU for Best Rank 2 Schemes in PB 3 km/h



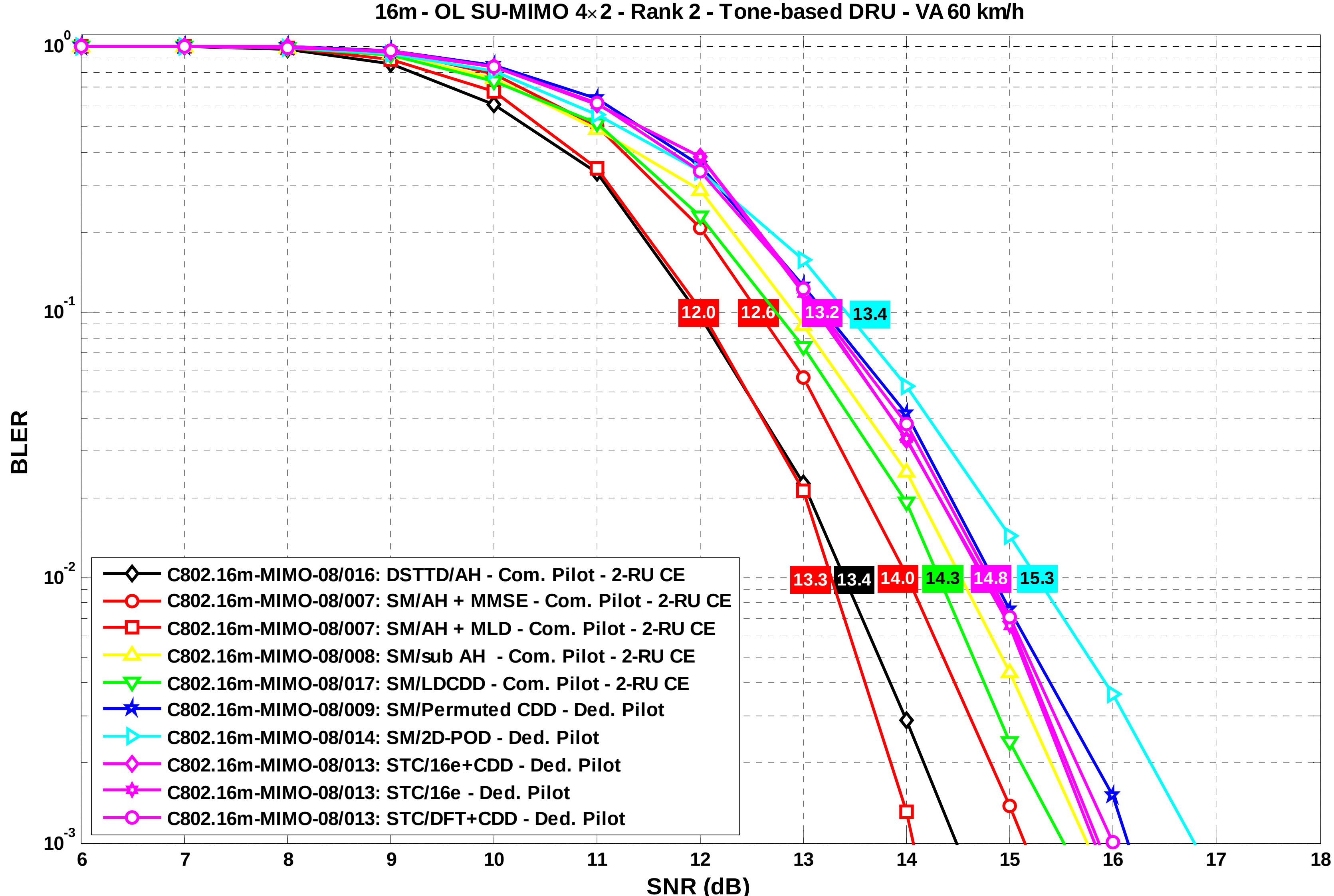
The difference of tone-based and RU-based DRU is about 0.5 dB for DSTTD/AH and SM/AH.

Comparing Rank 2 Schemes with RU-based DRU in VA 60 km/h



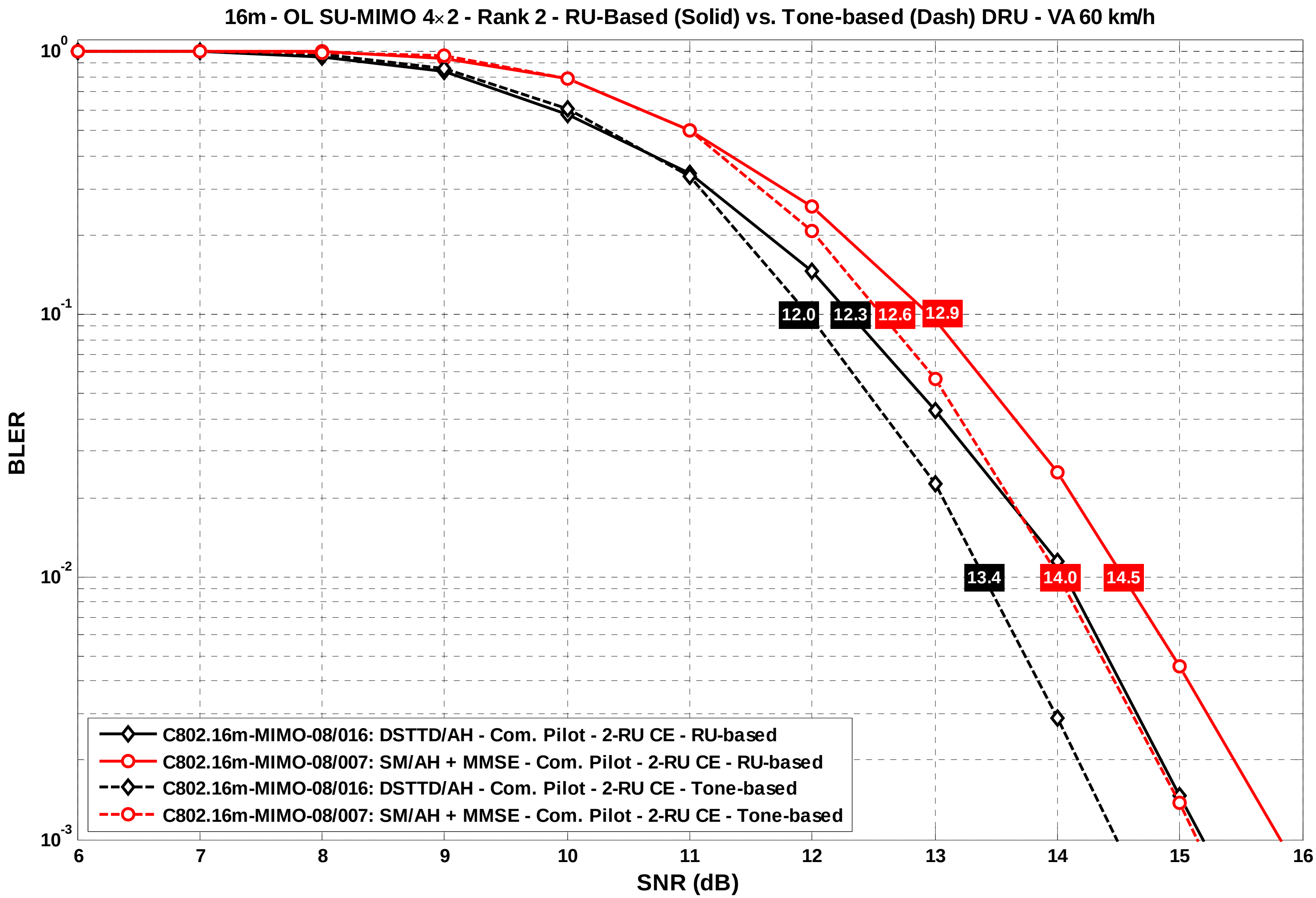
If MMSE receiver used, DSTTD/AH has the overall best performance in VA channel with RU-based DRU. SM/AH + MMSE has about 0.4 loss compared with DSTTD/AH. SM/AH + MLD outperforms DSTTD/AH + MMSE.

Comparing Rank 2 Schemes with Tone-based DRU in VA 60 km/h



If MMSE receiver used, DSTTD/AH has the overall best performance in VA channel with tone-based DRU. SM/AH + MMSE has about 0.6 loss compared with DSTTD/AH. SM/AH + MLD has the best performance.

RU-base vs. Tone based DRU for Best Rank 2 Schemes in VA 60 km/h



The difference of tone-based and RU-based DRU is about 0.6 dB for DSTTD/AH and SM/AH.

Overall Summary of Comparison of OL SU-MIMO Schemes for Rate 2

- If only MMSE receiver is used at the terminal, DSTTD/AH has the overall best performance at the expense of 4x4 matrix inversion for MMSE receiver
- SM/AH + MMSE can be used to reduce complexity of MMSE receiver to 2x2 matrix inversion. The performance degradation compared to DSTTD/AH + MMSE is about 0.6 dB.
- If MLD receiver used for SM/AH, the performance of SM/AH is the same or even better than DSTTD/AH + MMSE receiver, while having comparable receiver complexity.
- The difference of tone-based and RU-based DRU is about 0.6 dB for both DSTTD/AH and SM/AH schemes.
- Overall, DSTTD/AH and SM/AH has the best performance compared to other schemes evaluated.

Comparison of Common pilot and Dedicated Pilot (1/4)

- With the current pilot pattern for 4 streams, the overhead of common pilot for 4 Tx antennas is 16/(18*6) = 14.81%
- With the current pilot pattern for 2 streams, the overhead of dedicated pilot is 12/(18*6) = 11.11%
- The overhead of common pilot is 3.7% more than dedicated pilot.
- For dedicated pilot, midamble has extra overhead (~2%) as well.
  - Assume 1 OFDM symbol over 5 msec (48 OFDM symbols)
  - Midamble overhead = 1/48 ~ 2%

Comparison of Common pilot and Dedicated Pilot (2/4)

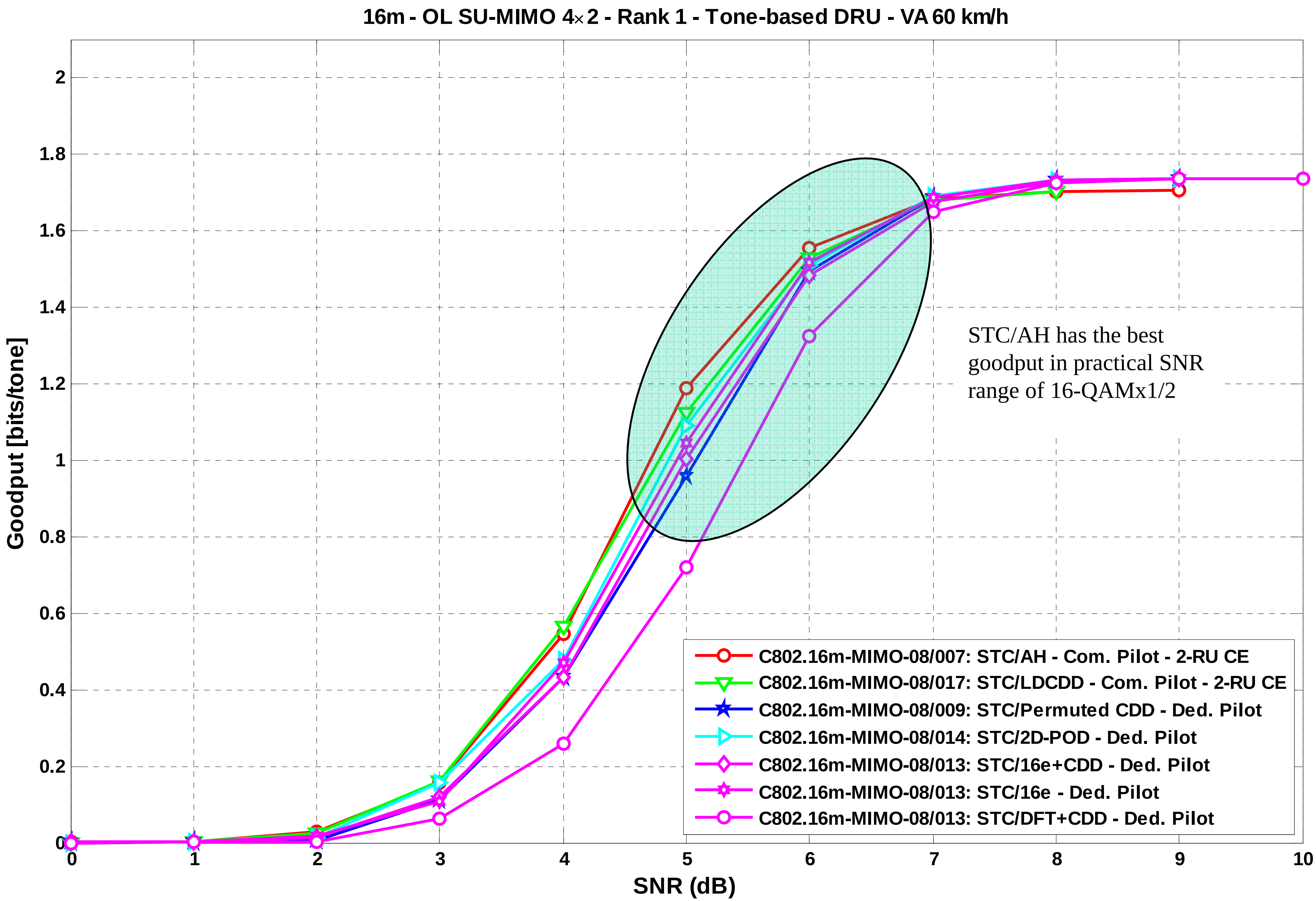
- With dedicated pilot, only 1-RU channel estimation is possible.
- With common pilot, it is possible to use pilots of the adjacent RUs to improve channel estimation of each RU.
- If pilots are common, in addition to pilots of the current RU, the neighboring RU can be used for better channel estimation.

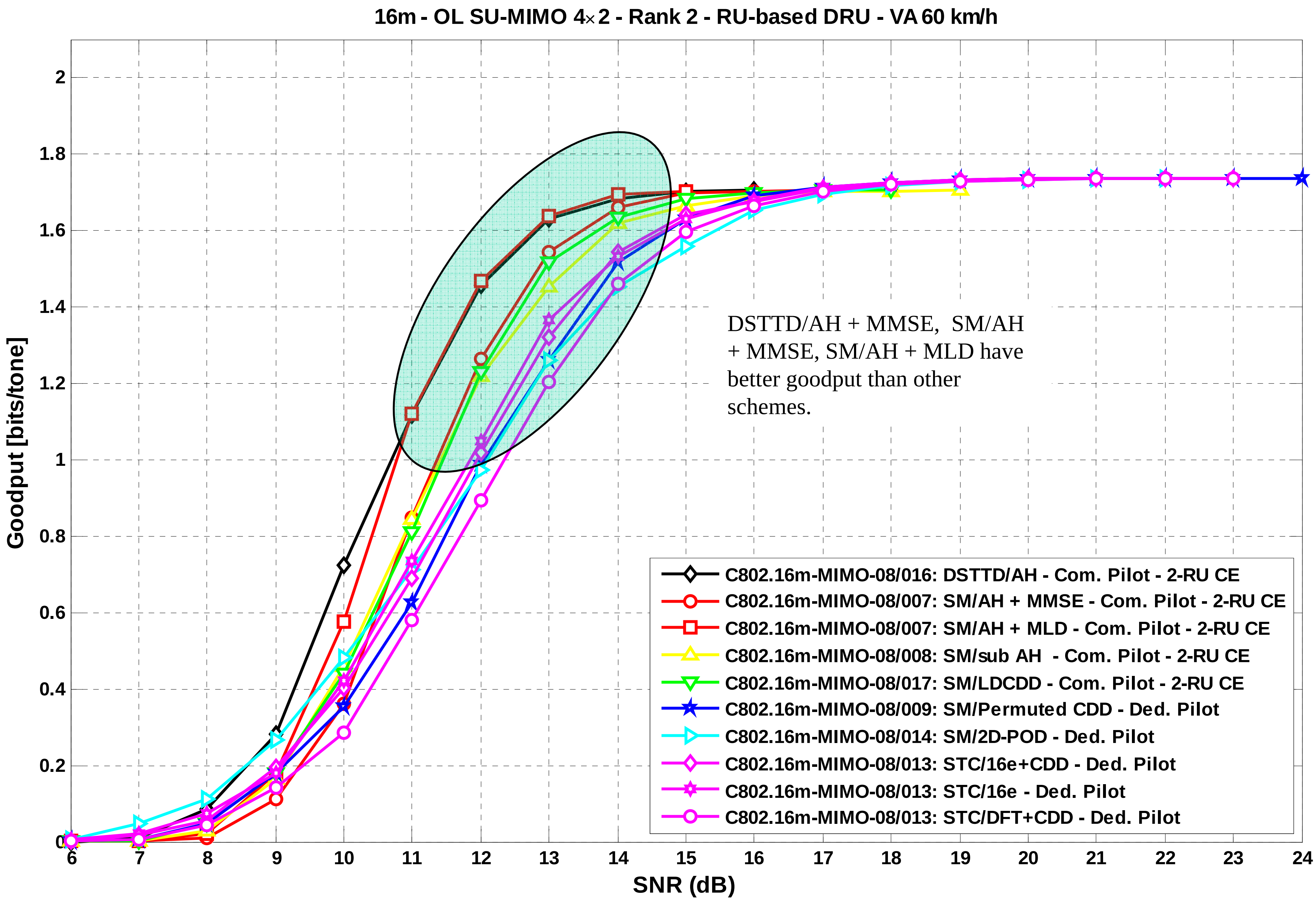
Comparison of Common pilot and Dedicated Pilot (3/4)

- Although dedicated pilot reduces pilot overhead, due to further channel estimation loss, the overall goodput of a system with dedicated pilot is worse than common pilot.
- The following slides compare OL SU-MIMO schemes in terms of goodput including the pilot overhead as well as mid-amble overhead for the case of dedicated pilot schemes.

Comparison of Common pilot and Dedicated Pilot (4/4)

- Dedicated pilot + tone-based DRU needs 2 zones: i) rate 1/2 zone, and ii) rate 3/4 zone
  - Lower MAC efficiency
  - If 4 FFR zones exist, then 8 zones must be defined ➔ 6 PRUs per zone for 10 MHz ➔ the maximum PRUs allocated to a user is 6
    - DL control overhead is high
    - Maximum rate per user is low
  - To mix SM rate 3 and rate 4 in one PRU zone, precoder must be applied to the SM rate 4 as well while in the current SDD text SM rate 4 is without precoding. It means system needs 3 zone one for rate 1/2, one for rate 3, and another one for rate 4. It dramatically reduces the MAC efficiency.
  - If we includes the localized zone, the reduction of Mac efficiency is even more serious.
  - Unicast control needs to be sent on common pilot zone not rate 1/2 or rate 3/4 zone, since MS doesn't know a priori whether what rate is it going to be scheduled
- Dedicated pilot limits the CE to one PRU ➔ CE loss is high. With common pilots CE over multiple PRUs is possible to reduce CE loss
- Dedicated pilot + RU-based DRU needs one precoder per PRU.
  - System can not capture space diversity within one PRU.
  - The problem is more serious when number of PRUs allocated to a user is 1 or 2. In that case, space diversity is low. If common pilot used, we are free to change precoder even within one PRU to capture space diversity even within the coherence time and coherence bandwidth of the channel


16m - OL SU-MIMO 4×2 - Rank 1 - Tone-based DRU - VA 60 km/h
Goodput [bits/tone]
SNR (dB)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
0
1
2
3
4
5
6
7
8
9
10
STC/AH has the best
goodput in practical SNR
range of 16-QAMx1/2
C802.16m-MIMO-08/007: STC/AH - Com. Pilot - 2-RU CE
C802.16m-MIMO-08/017: STC/LDCDD - Com. Pilot - 2-RU CE
C802.16m-MIMO-08/009: STC/Permuted CDD - Ded. Pilot
C802.16m-MIMO-08/014: STC/2D-POD - Ded. Pilot
C802.16m-MIMO-08/013: STC/16e+CDD - Ded. Pilot
C802.16m-MIMO-08/013: STC/16e - Ded. Pilot
C802.16m-MIMO-08/013: STC/DFT+CDD - Ded. Pilot



16m - OL SU-MIMO 4×2 - Rank 2 - RU-based DRU - VA 60 km/h
Goodput [bits/tone]
SNR (dB)
DSTTD/AH + MMSE, SM/AH + MMSE, SM/AH + MLD have better goodput than other schemes.
C802.16m-MIMO-08/016: DSTTD/AH - Com. Pilot - 2-RU CE
C802.16m-MIMO-08/007: SM/AH + MMSE - Com. Pilot - 2-RU CE
C802.16m-MIMO-08/007: SM/AH + MLD - Com. Pilot - 2-RU CE
C802.16m-MIMO-08/008: SM/sub AH - Com. Pilot - 2-RU CE
C802.16m-MIMO-08/017: SM/LDCDD - Com. Pilot - 2-RU CE
C802.16m-MIMO-08/009: SM/Permuted CDD - Ded. Pilot
C802.16m-MIMO-08/014: SM/2D-POD - Ded. Pilot
C802.16m-MIMO-08/013: STC/16e+CDD - Ded. Pilot
C802.16m-MIMO-08/013: STC/16e - Ded. Pilot
C802.16m-MIMO-08/013: STC/DFT+CDD - Ded. Pilot

Summary of Goodput Comparison

- Same observation as described in slides 14 and 22
- For rate 1, STC/AH has the best performance
- For rate 2, DSTTD/AH and SM/AH have the overall best performance compared to other schemes
  - If only MMSE receiver is used at the terminal, DSTTD/AH has the overall best performance at the expense of 4x4 matrix inversion for MMSE receiver
  - SM/AH + MMSE can be used to reduce complexity of MMSE receiver to 2x2 matrix inversion.
  - If MLD receiver used for SM/AH, the performance of SM/AH is the same or even better than DSTTD/AH + MMSE receiver, while having comparable receiver complexity