Performance Evaluation of DL Open Loop SU-MIMO Schemes

Document Number: IEEE C80216m-08_1193

Date Submitted: 2008-09-12

Source:

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Re: workplan IEEE C80216m-MIMO-08_005r1.doc

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

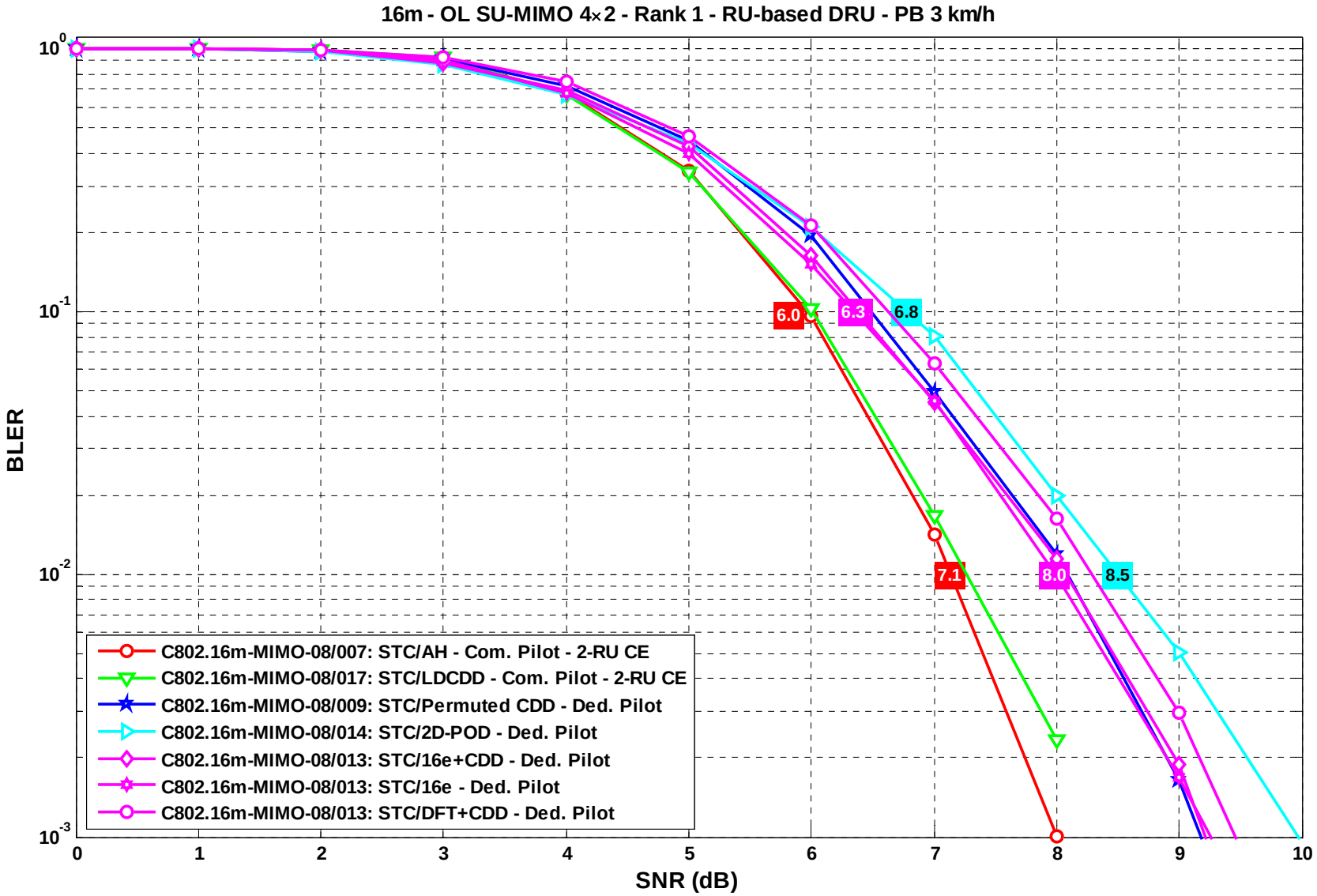
- With common pilots, CE can be done over multiple PRUs where common pilot exists
- With dedicated pilots, CE can only be done within one PRU
- As defined in the SDD (IEEE 802.16m-08/003r4), for non FFR case, the outer-permutation unit is 4 PRUs.
- For FFR case, the outer-permutation unit can be 1 or 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)

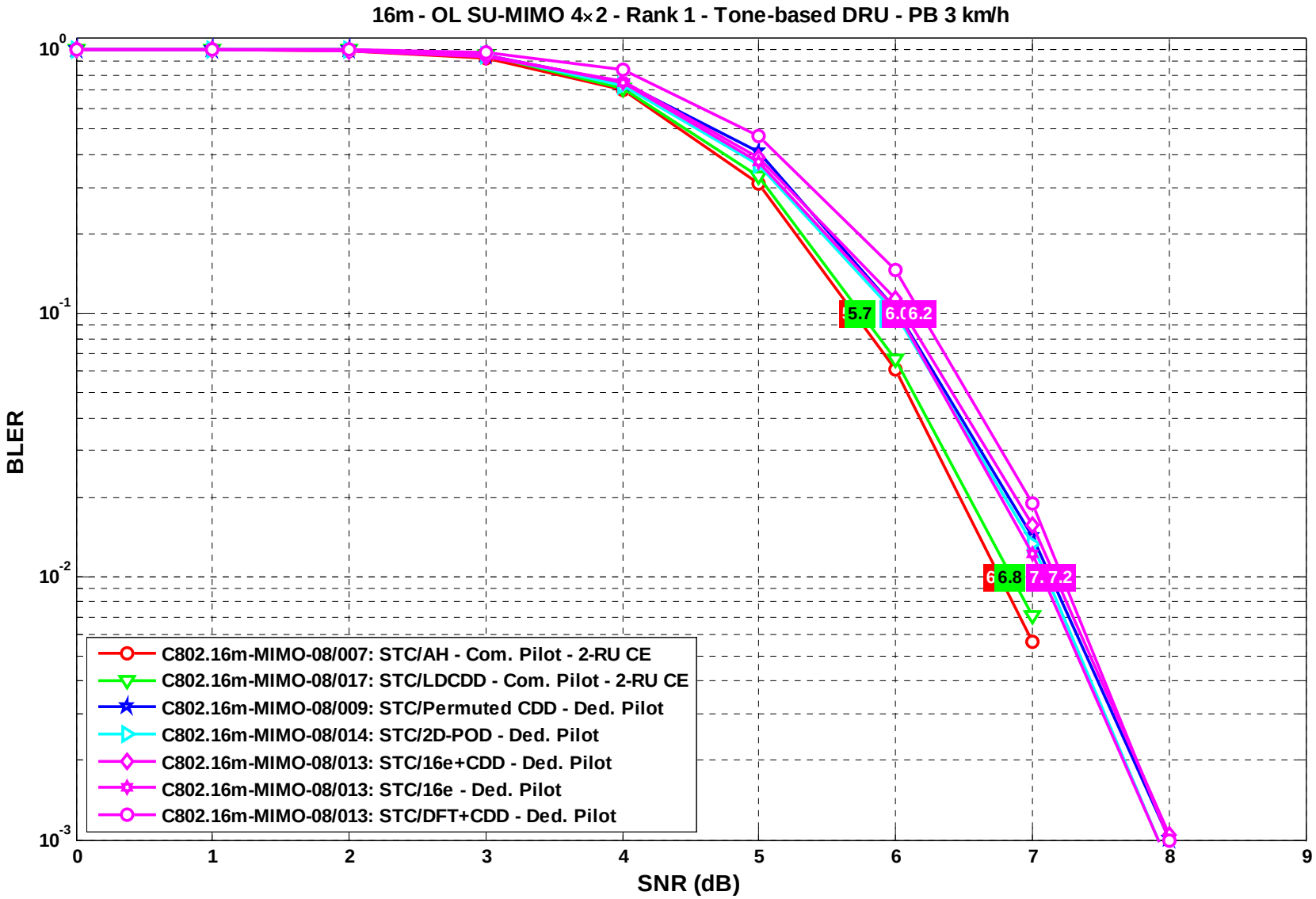
Link Level Performance Comparison for Rate 1

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



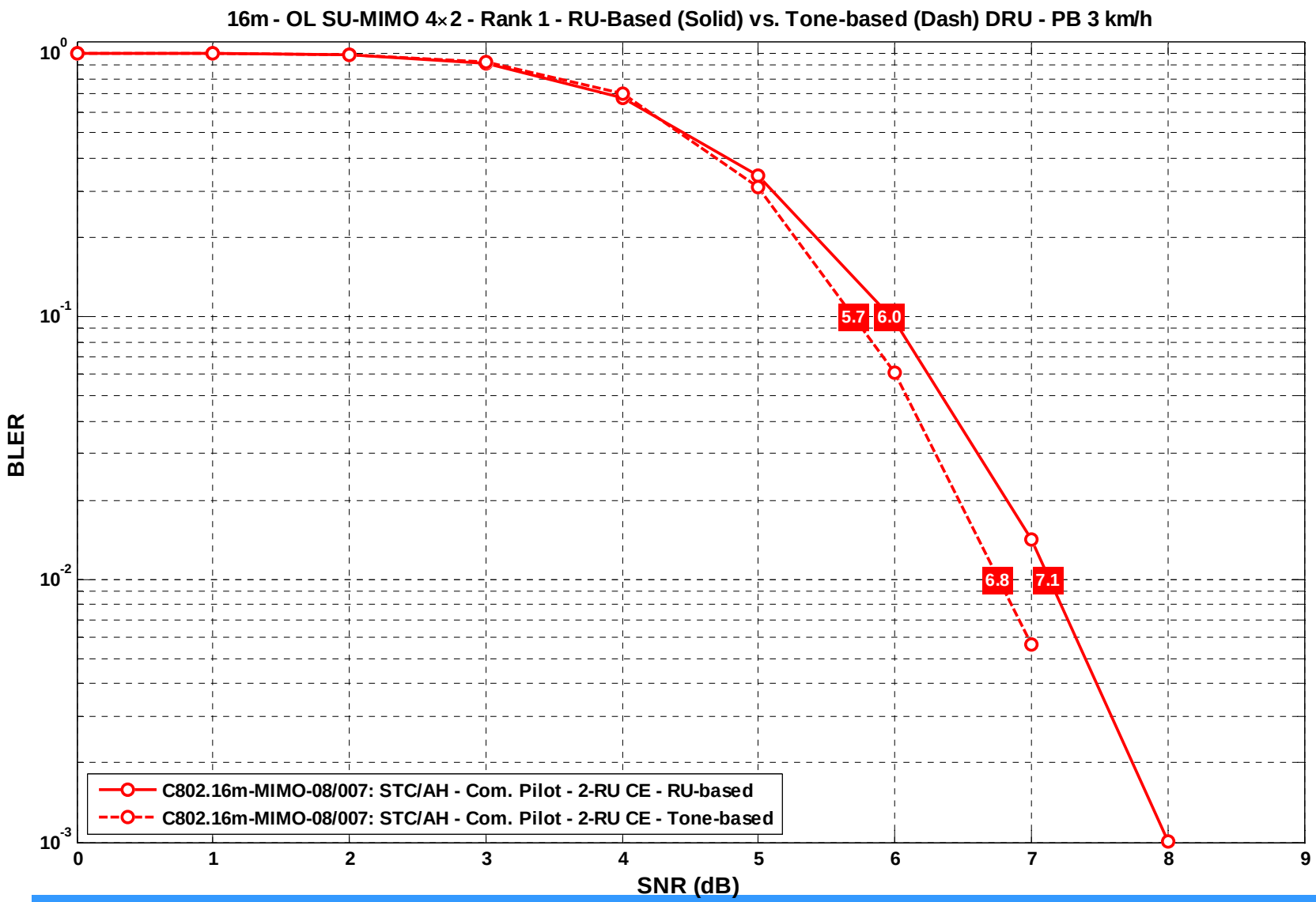
STC/AH has the overall best performance in PB channel with RU-based DRU.

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



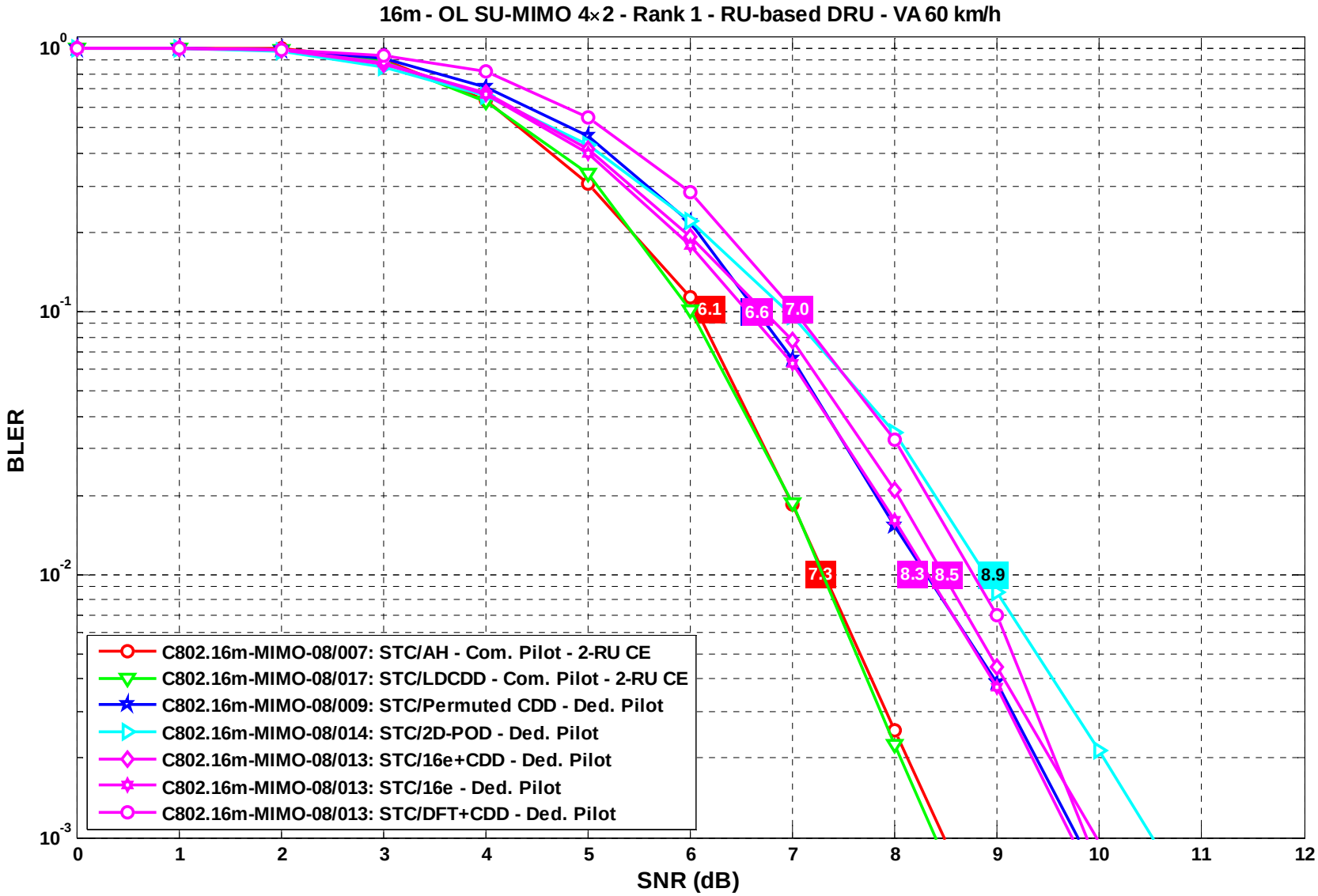
STC/AH has the overall best performance in PB channel with tone-based DRU.

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



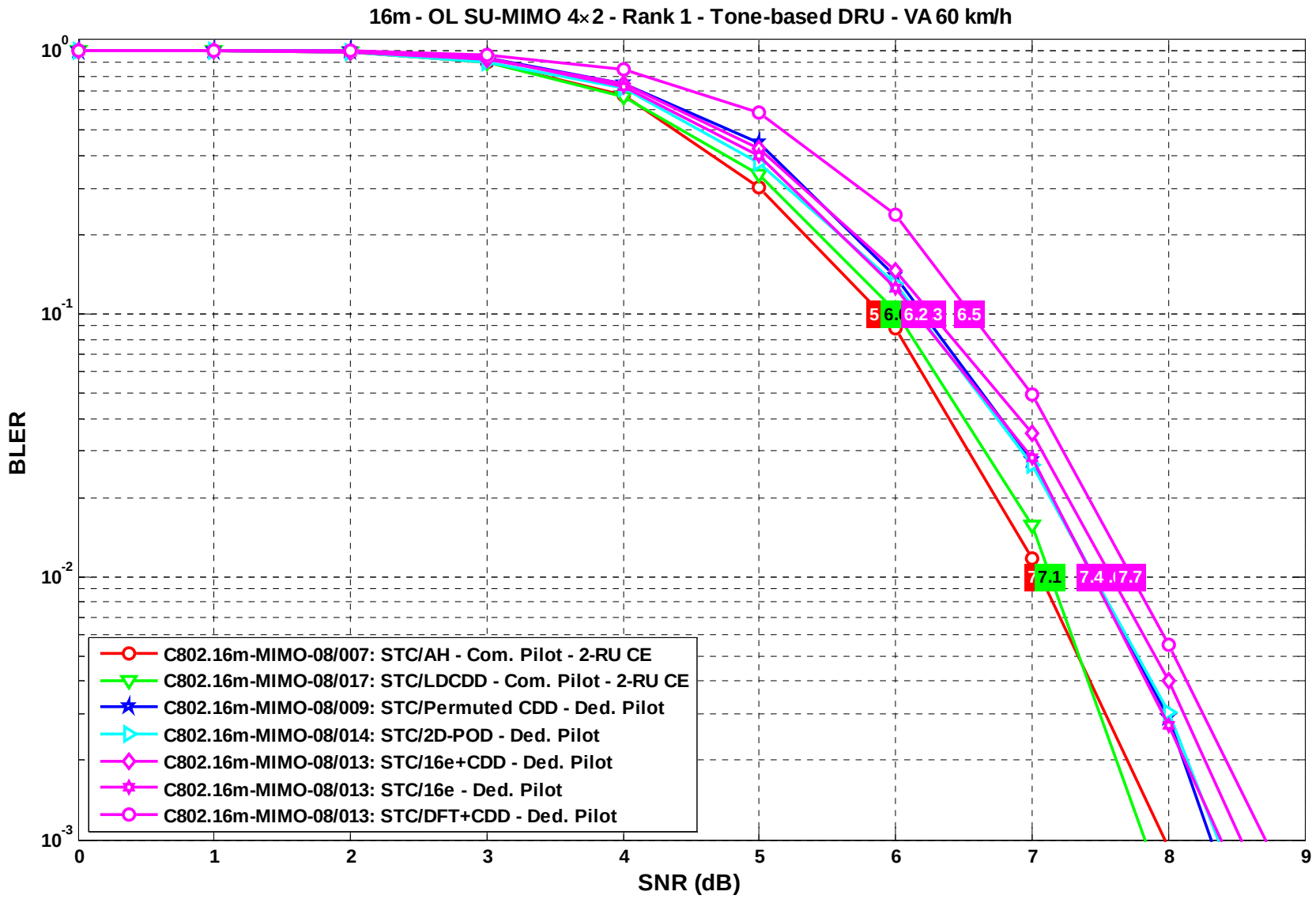
STC/AH with tone-based DRU has the best performance in PB channel. The difference of tone based and RU-based DRU is less than 0.4 dB.

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



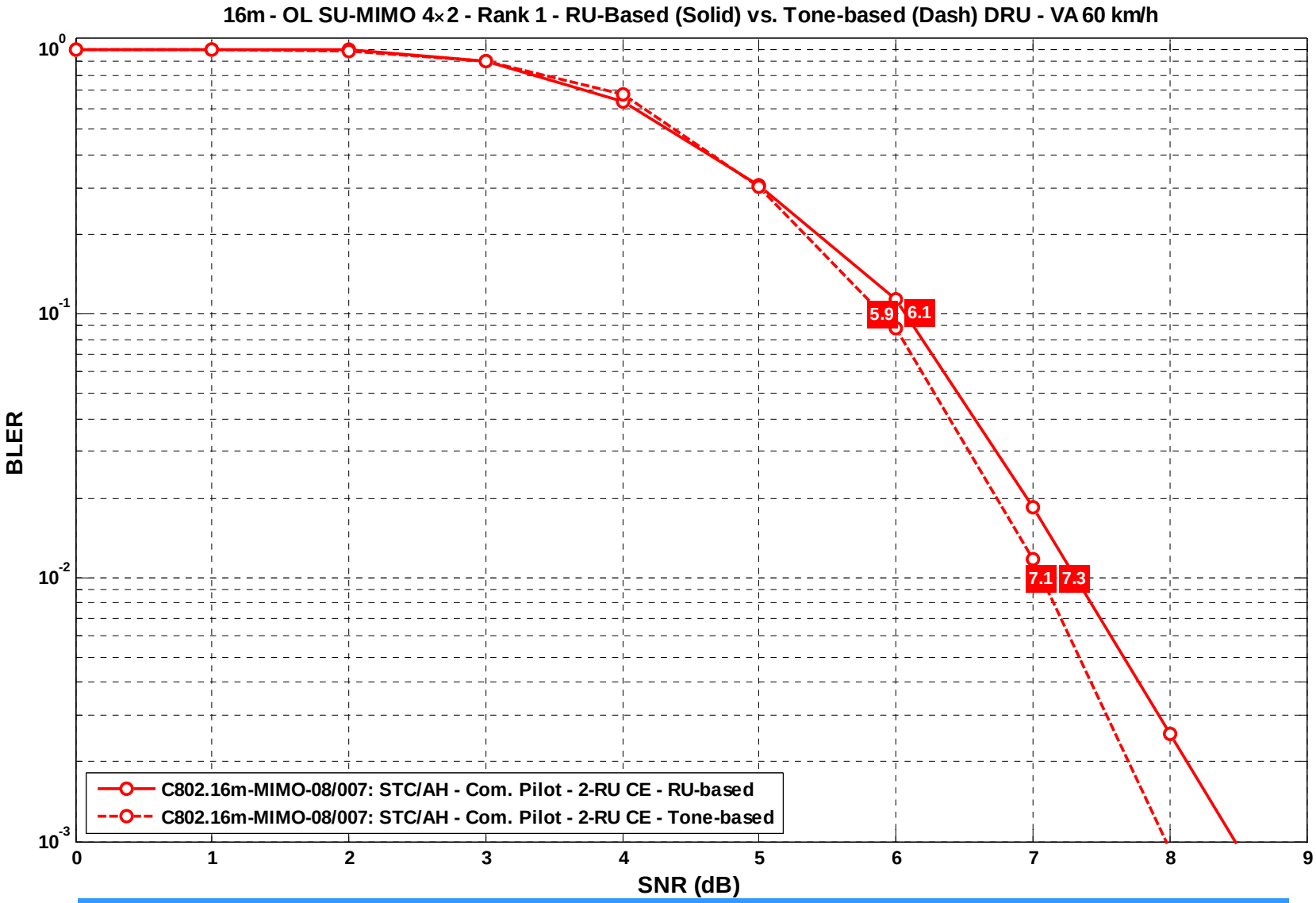
STC/AH and STC/LDCDD have the overall best performance in VA channel with RU-based DRU.

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



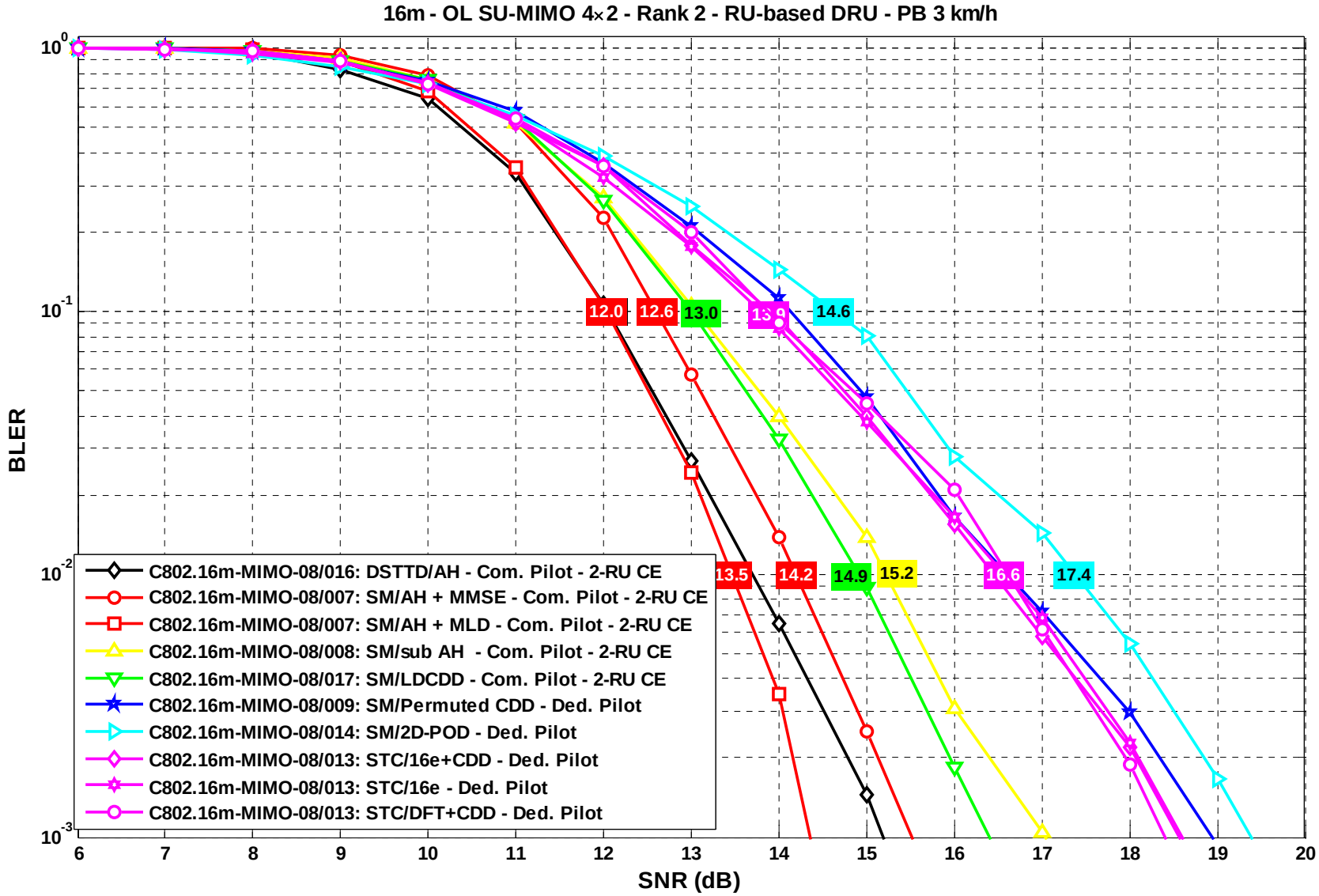
The difference of tone-based and RU-based DRU is less than 0.2 dB.

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

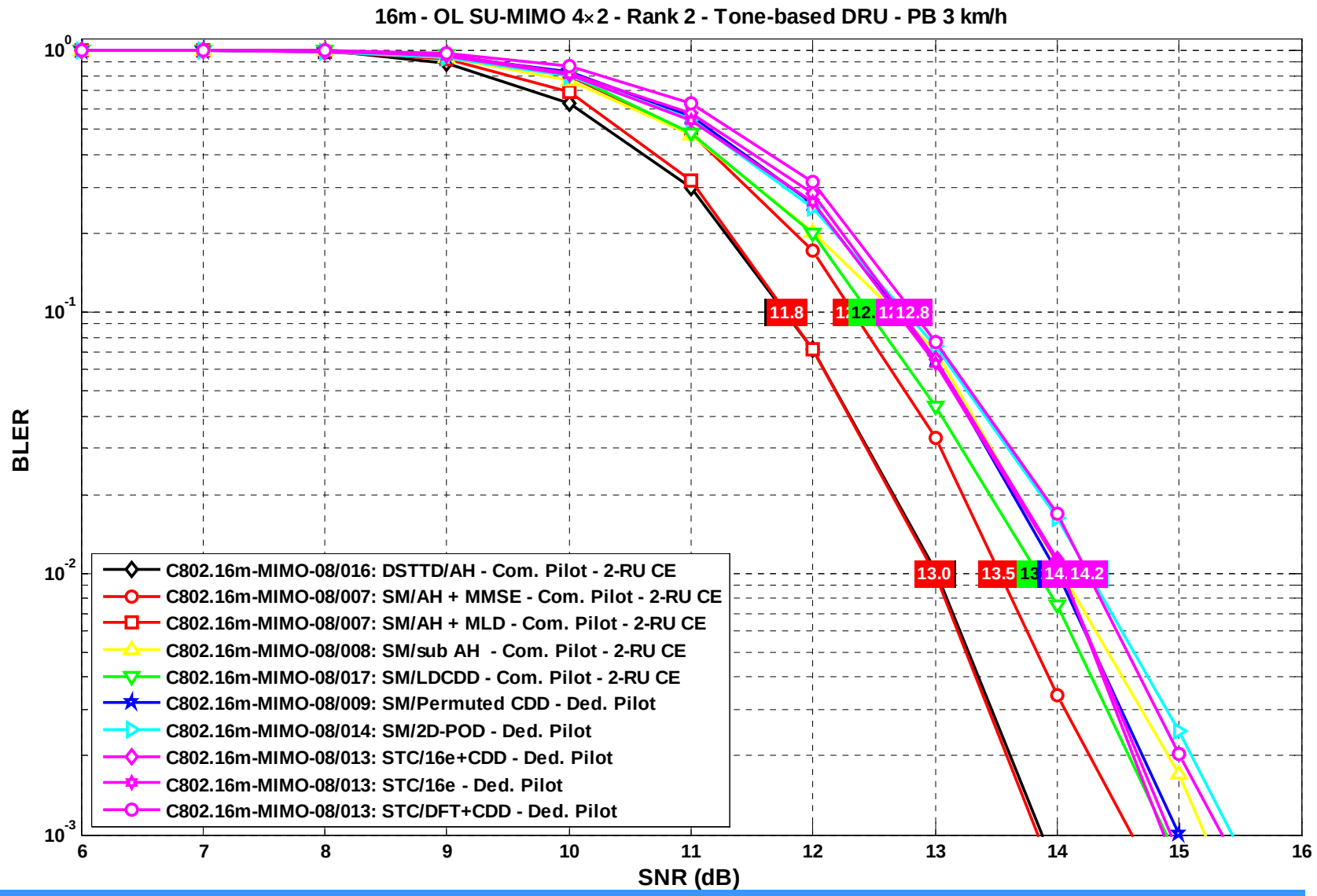
Link Level Performance Comparison for Rate 2

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



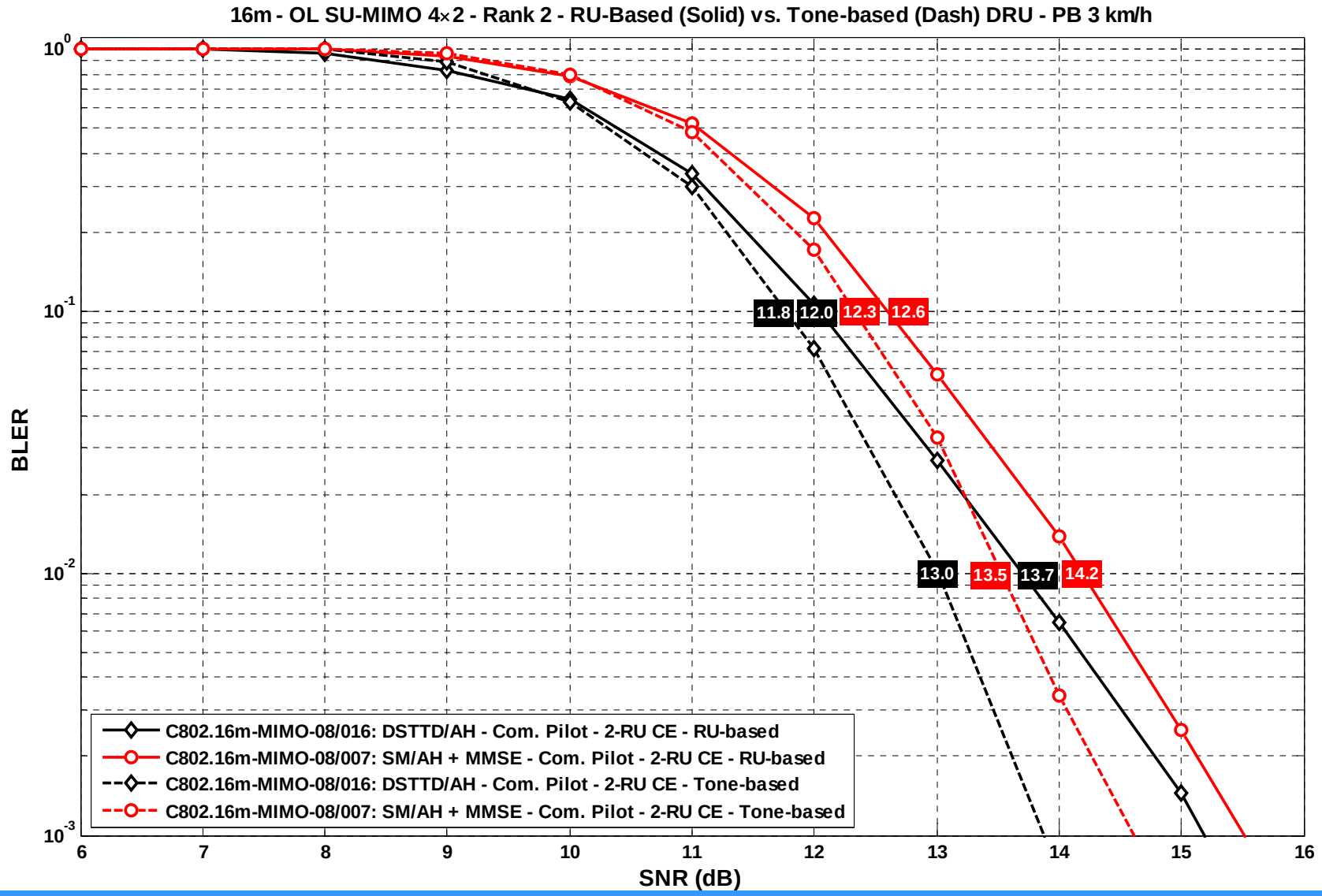
If MMSE receiver used, DSTTD/AH has the overall best performance in PB channel with RU-based DRU. Performance of SM/AH + MMSE is 0.6 dB worse than DSTTD/AH but with lower receiver complexity. SM/AH + MMSE needs only 2x2 matrix inversion. SM/AH + MLD outperforms DSTTD/AH + MMSE.

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



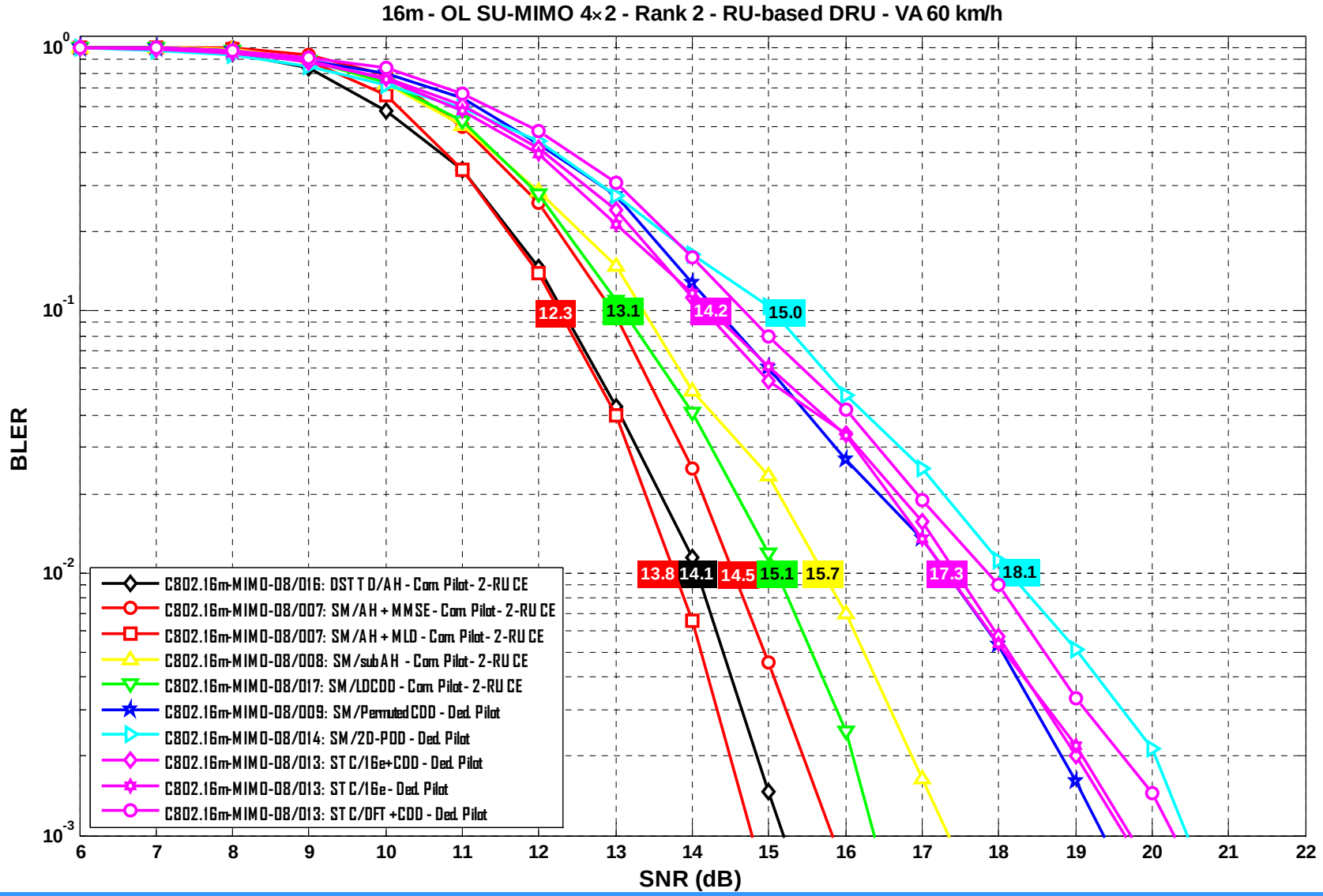
If MMSE receiver used, DSTTD/AH has the overall best performance in PB channel with tone-based DRU. SM/AH + MLD performs close to DSTTD/AH.

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



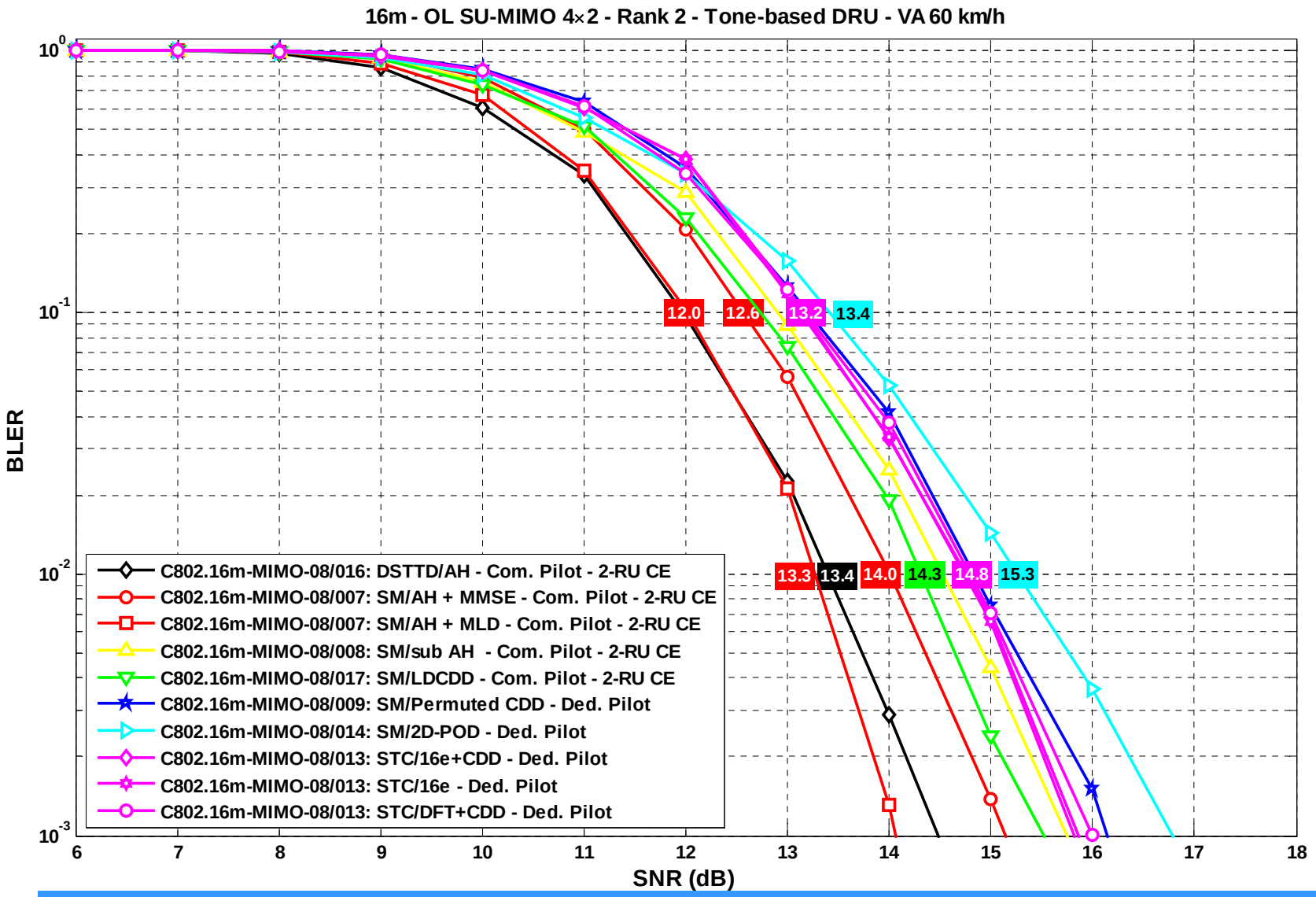
The difference of tone-based and RU-based DRU is about 0.5 dB for DSTTD/AH and SM/AH.

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



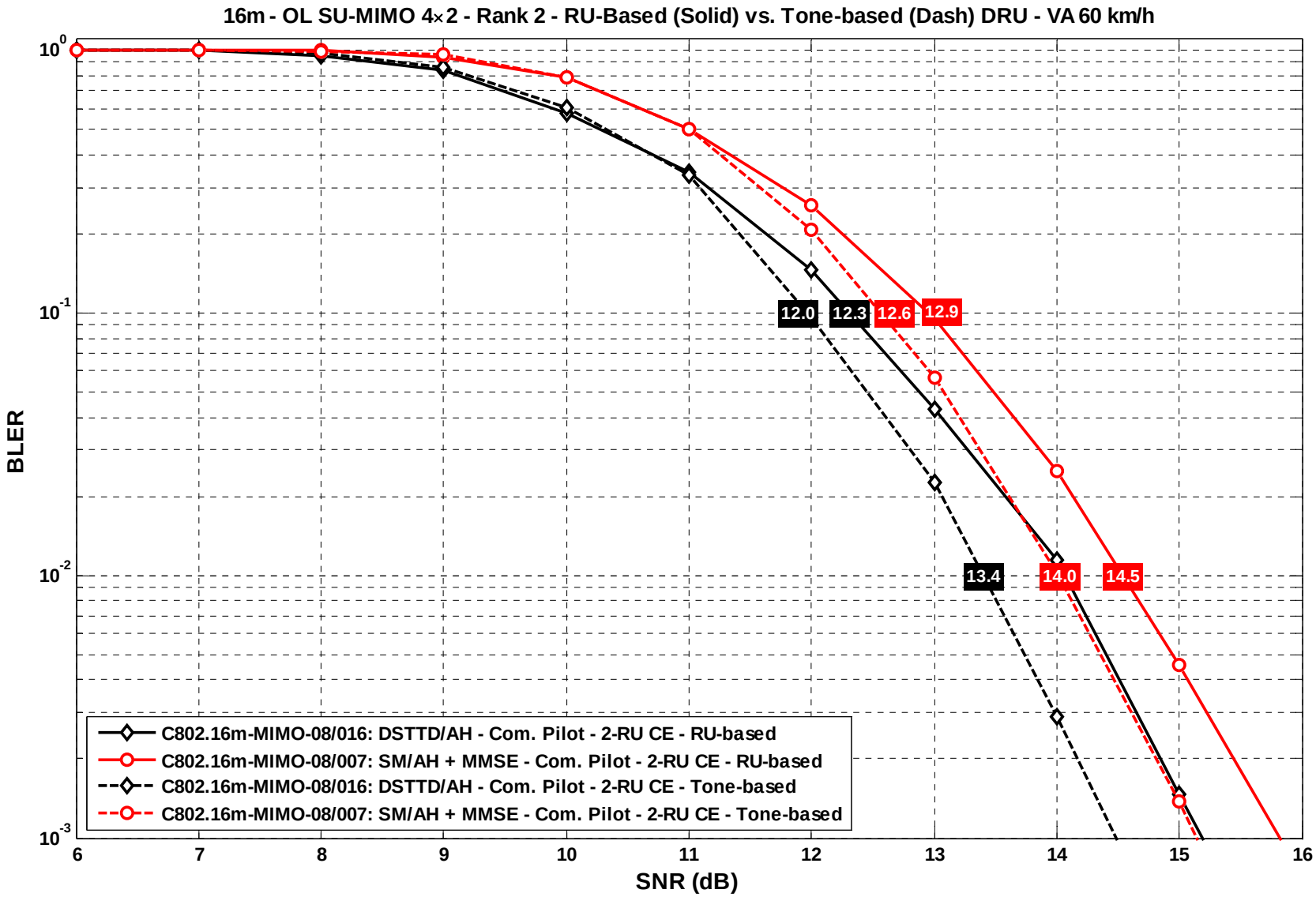
If MMSE receiver used, DSTTD/AH has the overall best performance in VA channel with RU-based DRU. SM/AH + MMSE has about 0.4 loss compared with DSTTD/AH. SM/AH + MLD outperforms DSTTD/AH + MMSE.

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 (1/3)

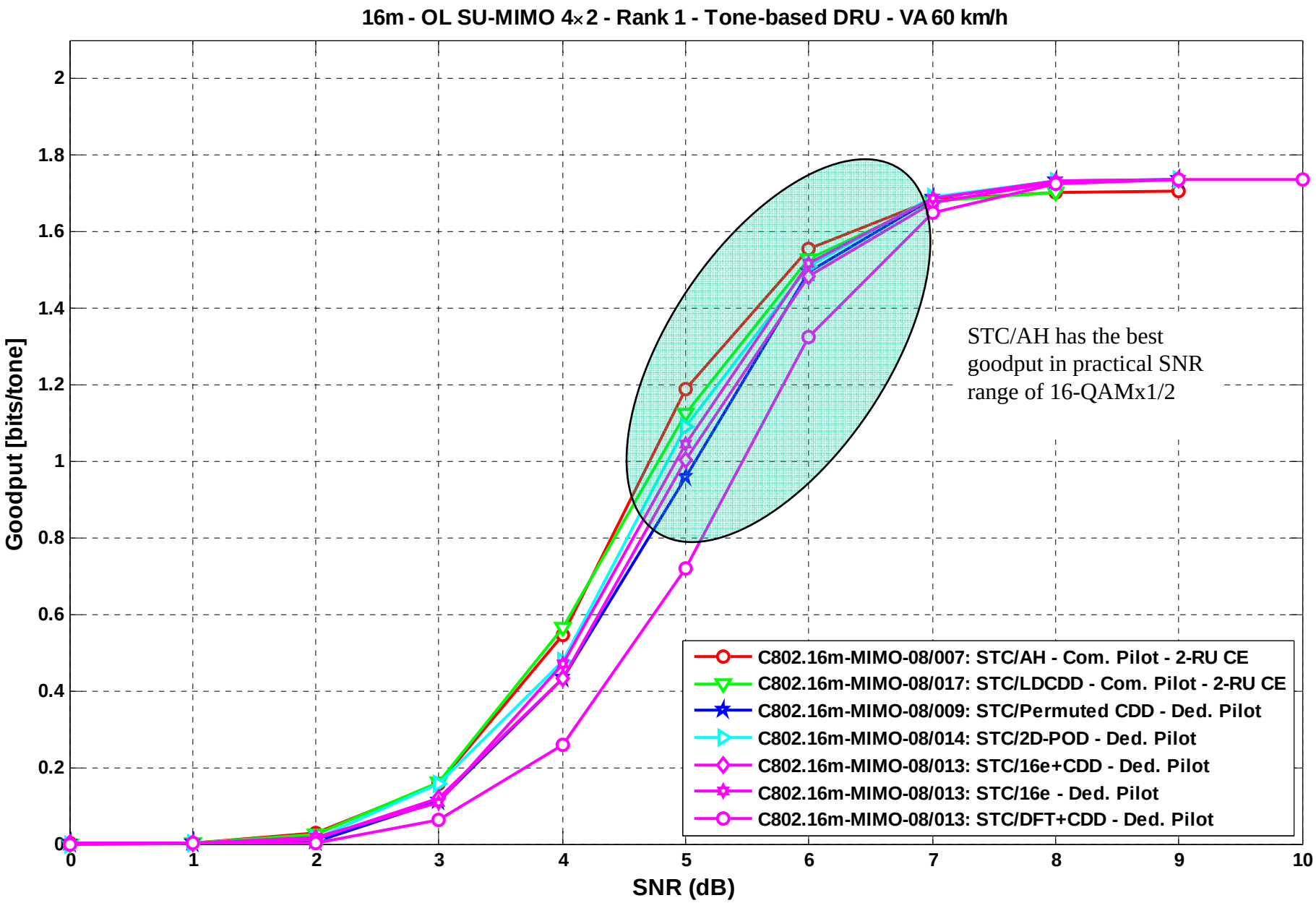
- With the current pilot pattern for 4 streams, the overhead of common pilot for 4 Tx antennas is 16/(18*6) = 14.81%
- With the current pilot pattern for 2 streams, the overhead of dedicated pilot is 12/(18*6) = 11.11%
- The overhead of common pilot is 3.7% more than dedicated pilot.
- For dedicated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

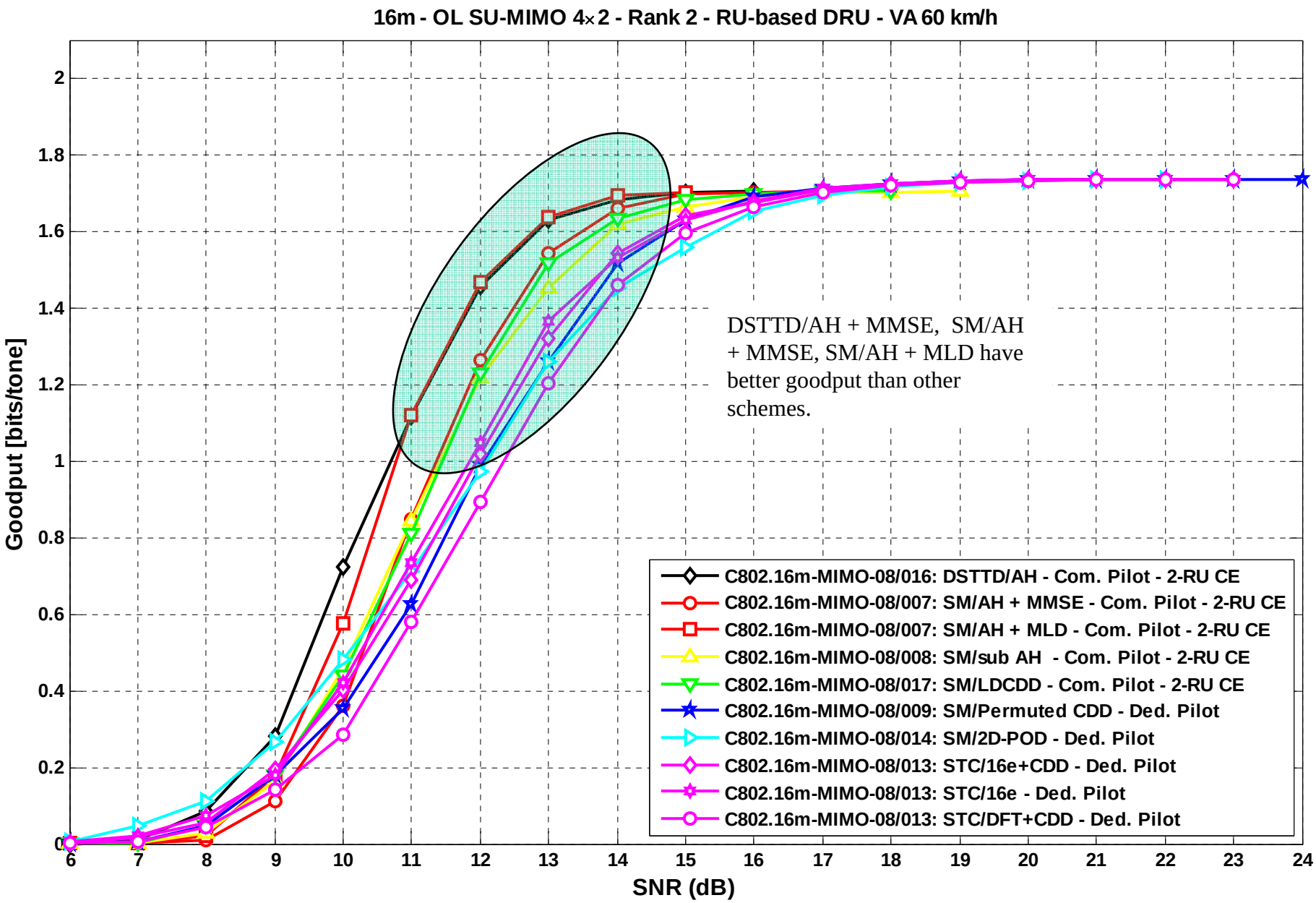
Comparison of Common pilot and Dedicated Pilot (2/3)

- 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 (3/3)

- 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.


16m - OL SU-MIMO 4×2 - Rank 1 - Tone-based DRU - VA 60 km/h
Goodput [bits/tone]
SNR (dB)
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