Results on the Performance Evaluation of DL Open Loop SU-MIMO Schemes

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*<http://standards.ieee.org/faqs/affiliationFAQ.html>

Re: IEEE 802.16m-08/052 – Call for Comments and Contributions on Project 802.16m System Description Document (SDD), on the topic TGm SDD: Others for Session 59

Purpose: Discussion and to adopt the proposal into IEEE 802.16m System Description Document.

Motivation

- Link level simulation to compare different DL OL SU MIMO schemes proposed by several proponents to IEEE 16m

Contents

- Summary of results
- Simulation results and studies
  - Precoder cycling (PC) and random beamforming (RBF) vs. antenna hopping (AH)
  - Single RU vs. multiple-RU channel estimation (CE)
- Discussion on
  - Common pilot vs. dedicated pilot
  - Multiple-RU CE
  - RU-based vs. tone-based DRU resource allocation
- Conclusion

Summary of Results

Summary of Results

- 4 Tx rate 1
  - Regardless of the channel type and resource allocation method, SFBC/AH + common pilots + 2-RU CE provides the best BLER and one of the best goodput performance among the proposed schemes.
  - Recommendation:
    - SFBC/AH
    - Common pilot

Summary of Results

- 4 Tx rate 2
  - Overall, DSTTD/AH and SM/AH has the best BLER and goodput performance compared to other schemes evaluated.
  - SM/AH vs. DSTTD/AH
    - 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.
    - (not shown in this document) 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.
      - As opposed to MMSE receiver, MLD receiver does not need the covariance matrix of the interference + noise

Simulation Results and Observations

List of Schemes Compared

- Rate 1:
  - SFBC/AH: SFBC + AH precoder and unprecoded pilot
  - SFBC/RBF: SFBC + 16e codebook precoder and precoded pilot
  - SFBC/PC: SFBC + subset of DFT based precoder and precoded pilot
  - SFBC/PC 16e: SFBC + 16e precoder with cycling of 4 PRUs and precoded pilot
- Rate 2:
  - SM/AH: SM + AH precoder and unprecoded pilot
  - SM/RBF: SM + 16e codebook precoder and precoded pilot
  - SM/PC: SM + subset of DFT based precoder and precoded pilot
  - SM/PC 16e: SM+ 16e precoder with cycling of 4 PRUs and precoded pilot

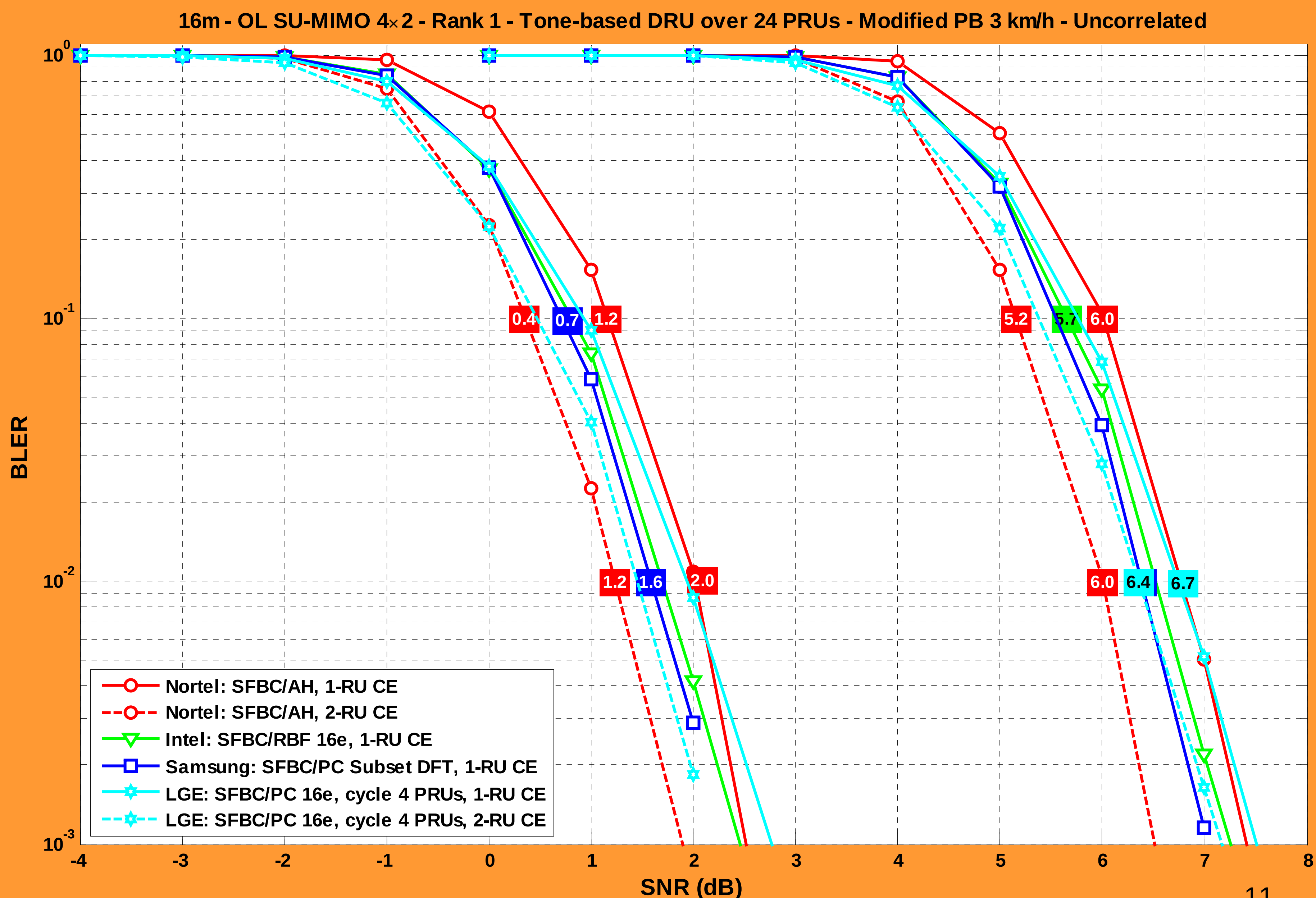
Simulation Parameters

- **Channelization**
  - 10 MHz bandwidth with 48 PRUs
  - RU size is 18×6
  - 4 RUs assigned to a user
  - RU-based DRU (LDRU). 4 RUs are uniformly selected from 48 available PRUs.
  - Tone-based DRU (DDRU). Tones are uniformly distributed over 24 or 8 uniformly distributed PRU.
- **Antenna**
  - 4 Tx, 2 Rx
  - uncorrelated
- **Fading channel**
  - extended PB 3 km/h, extended VA 30 km/h, and extended VA 120 km/h
  - carrier frequency 2.5 GHz
  - Croft fader
- **Channel estimation**
  - 2D-MMSE channel estimation (CE)
  - CE over one or two RUs
  - no pilot boosting
- **Receiver**
  - MMSE
- **Rank, modulation and coding**
  - QPSK and 16-QAM
  - rate ½ 3GPP turbo code and rate matching with 8 decoding iterations
  - single codeword

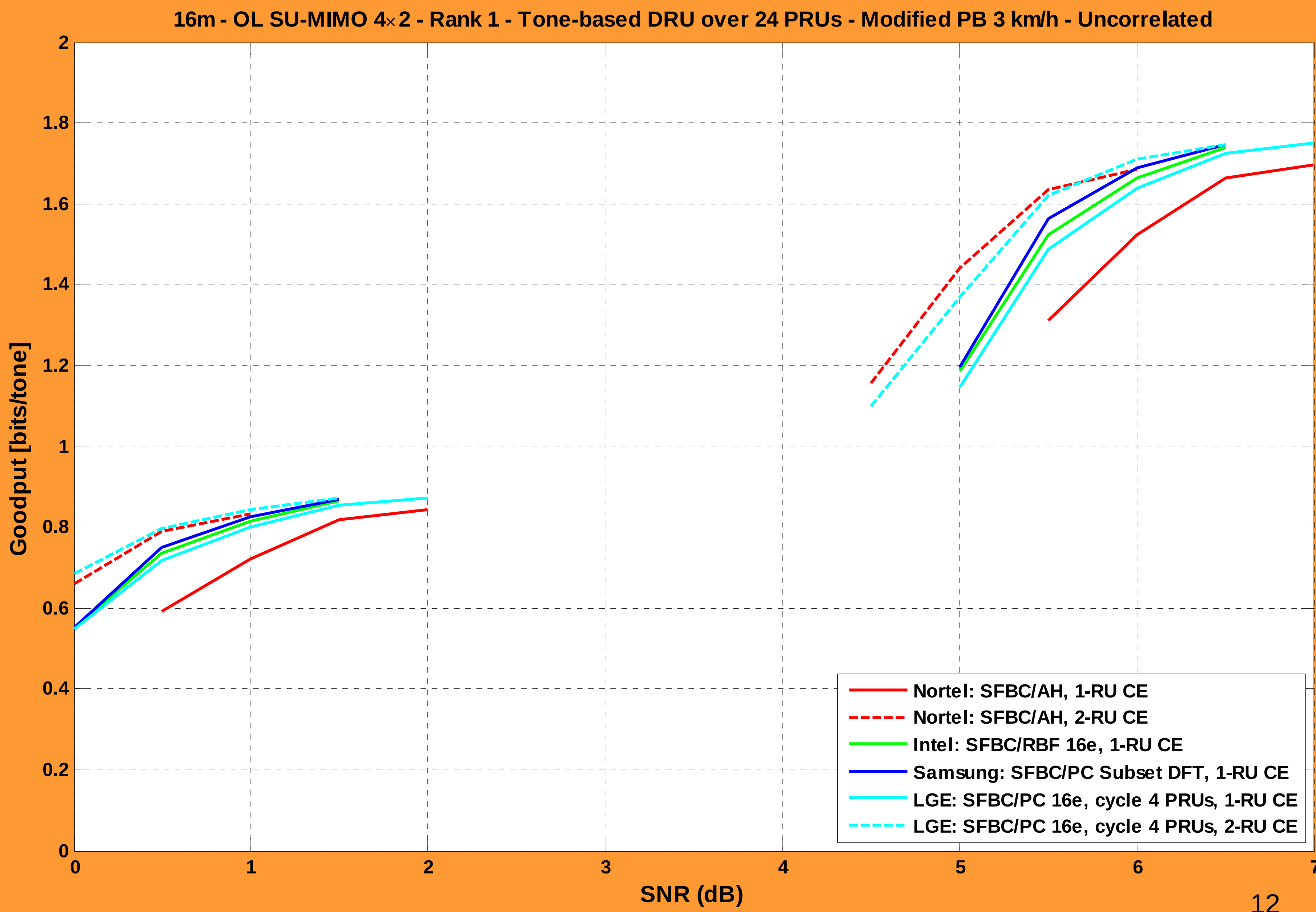
1

AH vs. PC and RBF

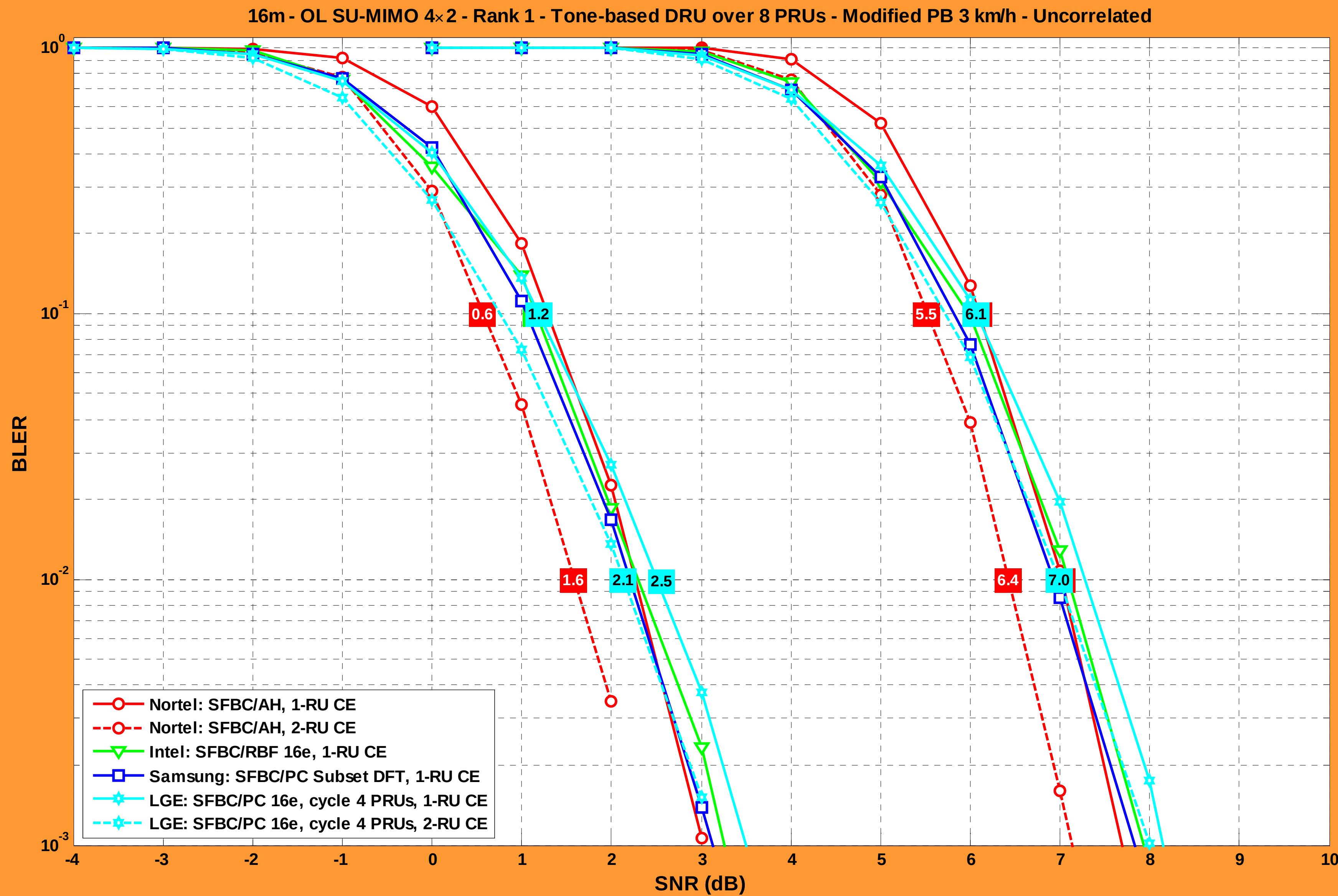
Rank 1



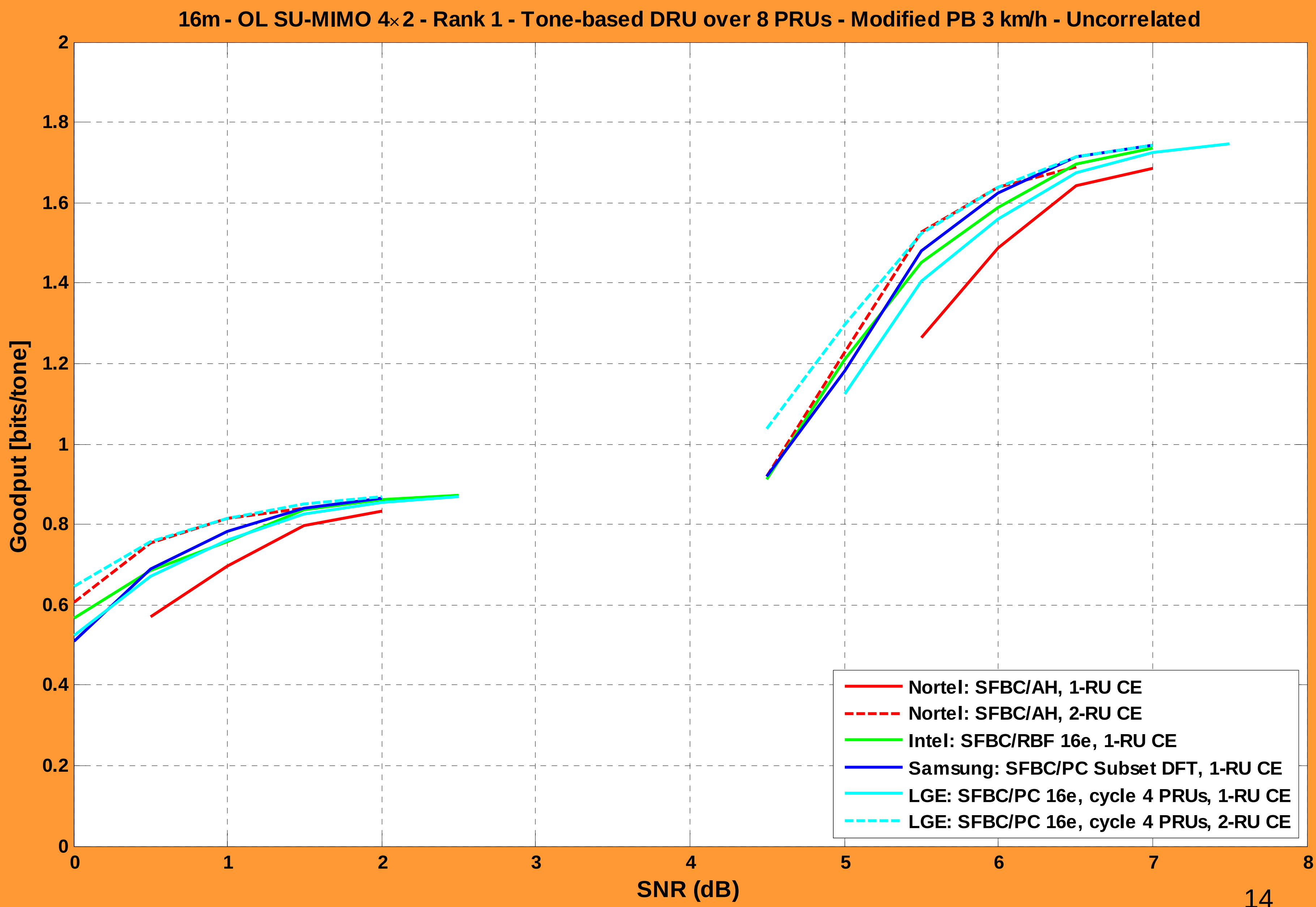
16m - OL SU-MIMO 4×2 - Rank 1 - Tone-based DRU over 24 PRUs - Modified PB 3 km/h - Uncorrelated
BLER
SNR (dB)
Nortel: SFBC/AH, 1-RU CE
Nortel: SFBC/AH, 2-RU CE
Intel: SFBC/RBF 16e, 1-RU CE
Samsung: SFBC/PC Subset DFT, 1-RU CE
LGE: SFBC/PC 16e, cycle 4 PRUs, 1-RU CE
LGE: SFBC/PC 16e, cycle 4 PRUs, 2-RU CE
0.4
0.7
1.2
5.2
5.7
6.0
1.2
1.6
2.0
6.0
6.4
6.7

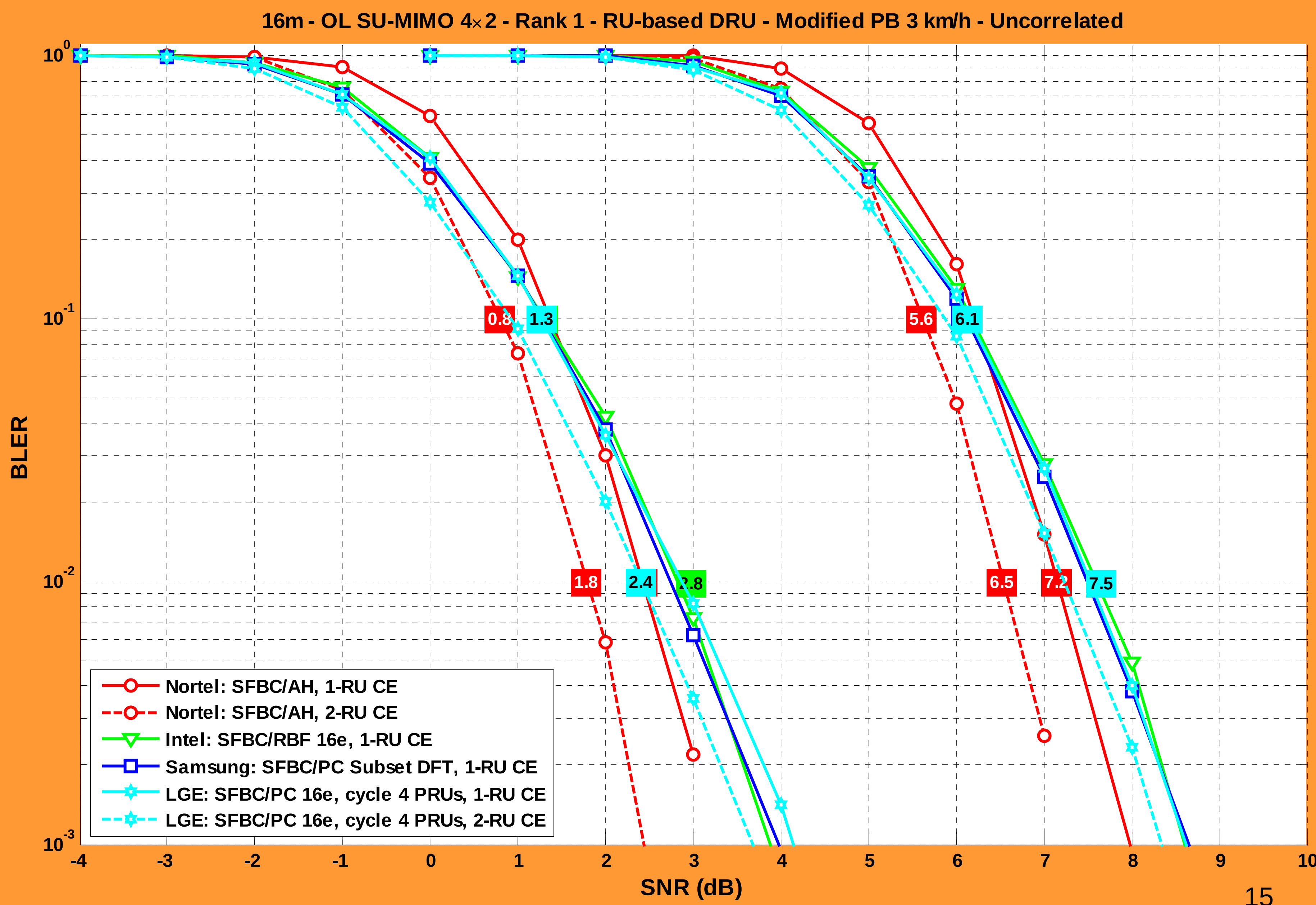


16m - OL SU-MIMO 4×2 - Rank 1 - Tone-based DRU over 24 PRUs - Modified PB 3 km/h - Uncorrelated
Goodput [bits/tone]
SNR (dB)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
0
1
2
3
4
5
6
7
Nortel: SFBC/AH, 1-RU CE
Nortel: SFBC/AH, 2-RU CE
Intel: SFBC/RBF 16e, 1-RU CE
Samsung: SFBC/PC Subset DFT, 1-RU CE
LGE: SFBC/PC 16e, cycle 4 PRUs, 1-RU CE
LGE: SFBC/PC 16e, cycle 4 PRUs, 2-RU CE

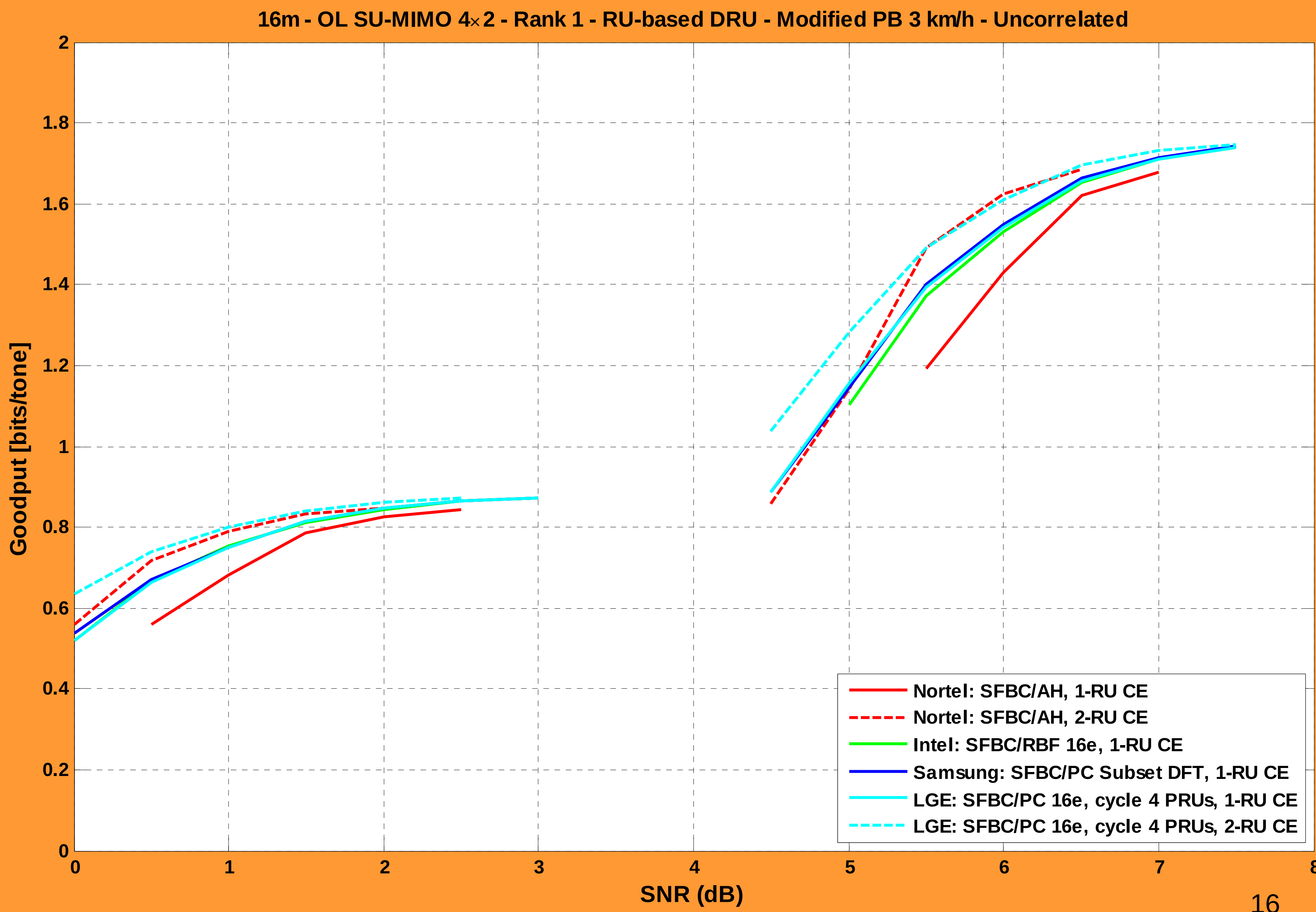


16m - OL SU-MIMO 4×2 - Rank 1 - Tone-based DRU over 8 PRUs - Modified PB 3 km/h - Uncorrelated
BLER
SNR (dB)
0.6
1.2
1.6
2.1
2.5
5.5
6.1
6.4
7.0
Nortel: SFBC/AH, 1-RU CE
Nortel: SFBC/AH, 2-RU CE
Intel: SFBC/RBF 16e, 1-RU CE
Samsung: SFBC/PC Subset DFT, 1-RU CE
LGE: SFBC/PC 16e, cycle 4 PRUs, 1-RU CE
LGE: SFBC/PC 16e, cycle 4 PRUs, 2-RU CE

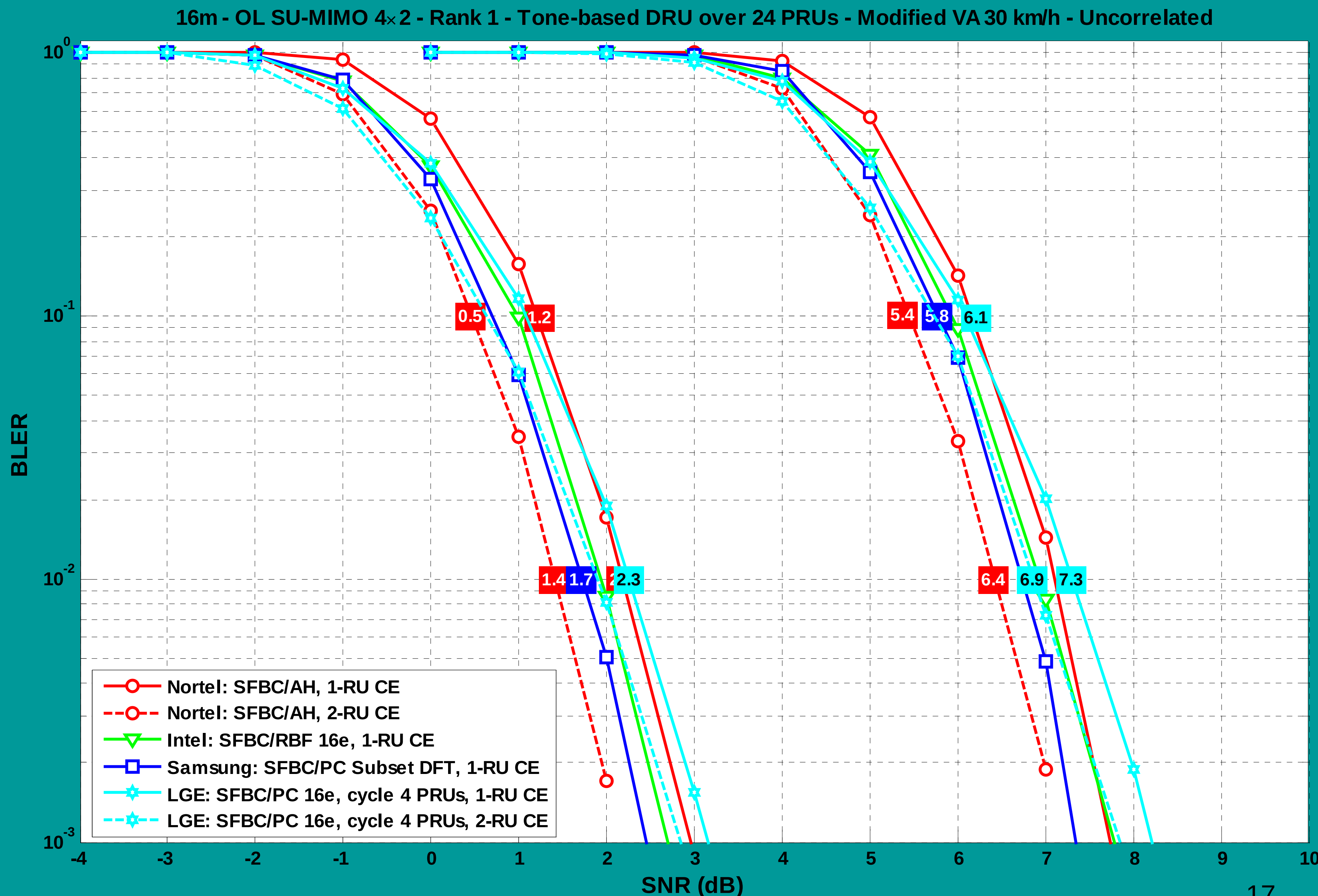

16m - OL SU-MIMO 4×2 - Rank 1 - Tone-based DRU over 8 PRUs - Modified PB 3 km/h - Uncorrelated
Goodput [bits/tone]
SNR (dB)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
0
1
2
3
4
5
6
7
8
Nortel: SFBC/AH, 1-RU CE
Nortel: SFBC/AH, 2-RU CE
Intel: SFBC/RBF 16e, 1-RU CE
Samsung: SFBC/PC Subset DFT, 1-RU CE
LGE: SFBC/PC 16e, cycle 4 PRUs, 1-RU CE
LGE: SFBC/PC 16e, cycle 4 PRUs, 2-RU CE



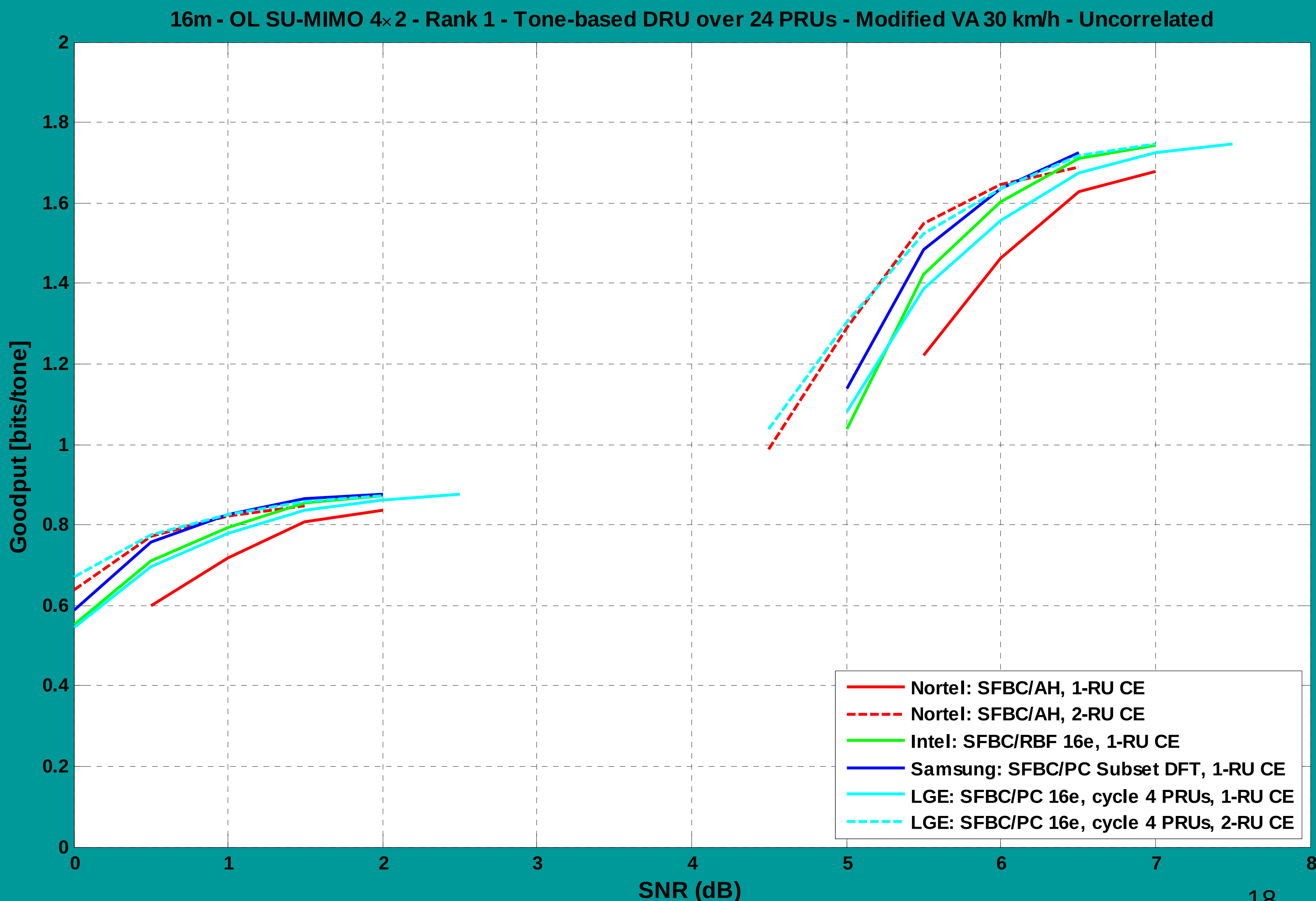
16m - OL SU-MIMO 4×2 - Rank 1 - RU-based DRU - Modified PB 3 km/h - Uncorrelated
BLER
SNR (dB)
10^0
10^{-1}
10^{-2}
10^{-3}
-4
-3
-2
-1
0
1
2
3
4
5
6
7
8
9
10
0.8
1.3
1.8
2.4
2.8
5.6
6.1
6.5
7.2
7.5
Nortel: SFBC/AH, 1-RU CE
Nortel: SFBC/AH, 2-RU CE
Intel: SFBC/RBF 16e, 1-RU CE
Samsung: SFBC/PC Subset DFT, 1-RU CE
LGE: SFBC/PC 16e, cycle 4 PRUs, 1-RU CE
LGE: SFBC/PC 16e, cycle 4 PRUs, 2-RU CE

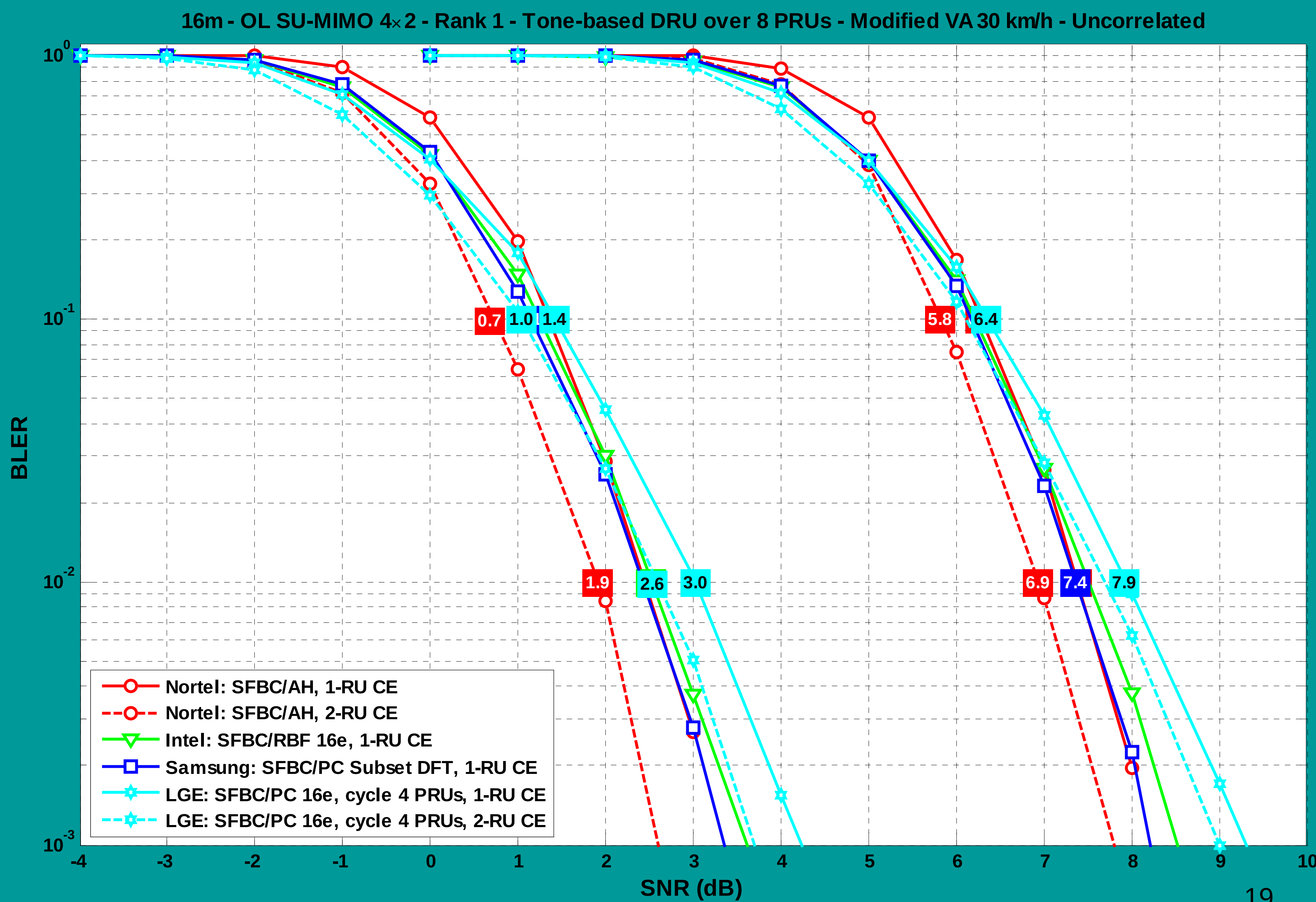


16m - OL SU-MIMO 4×2 - Rank 1 - RU-based DRU - Modified PB 3 km/h - Uncorrelated
Goodput [bits/tone]
SNR (dB)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
0
1
2
3
4
5
6
7
8
Nortel: SFBC/AH, 1-RU CE
Nortel: SFBC/AH, 2-RU CE
Intel: SFBC/RBF 16e, 1-RU CE
Samsung: SFBC/PC Subset DFT, 1-RU CE
LGE: SFBC/PC 16e, cycle 4 PRUs, 1-RU CE
LGE: SFBC/PC 16e, cycle 4 PRUs, 2-RU CE

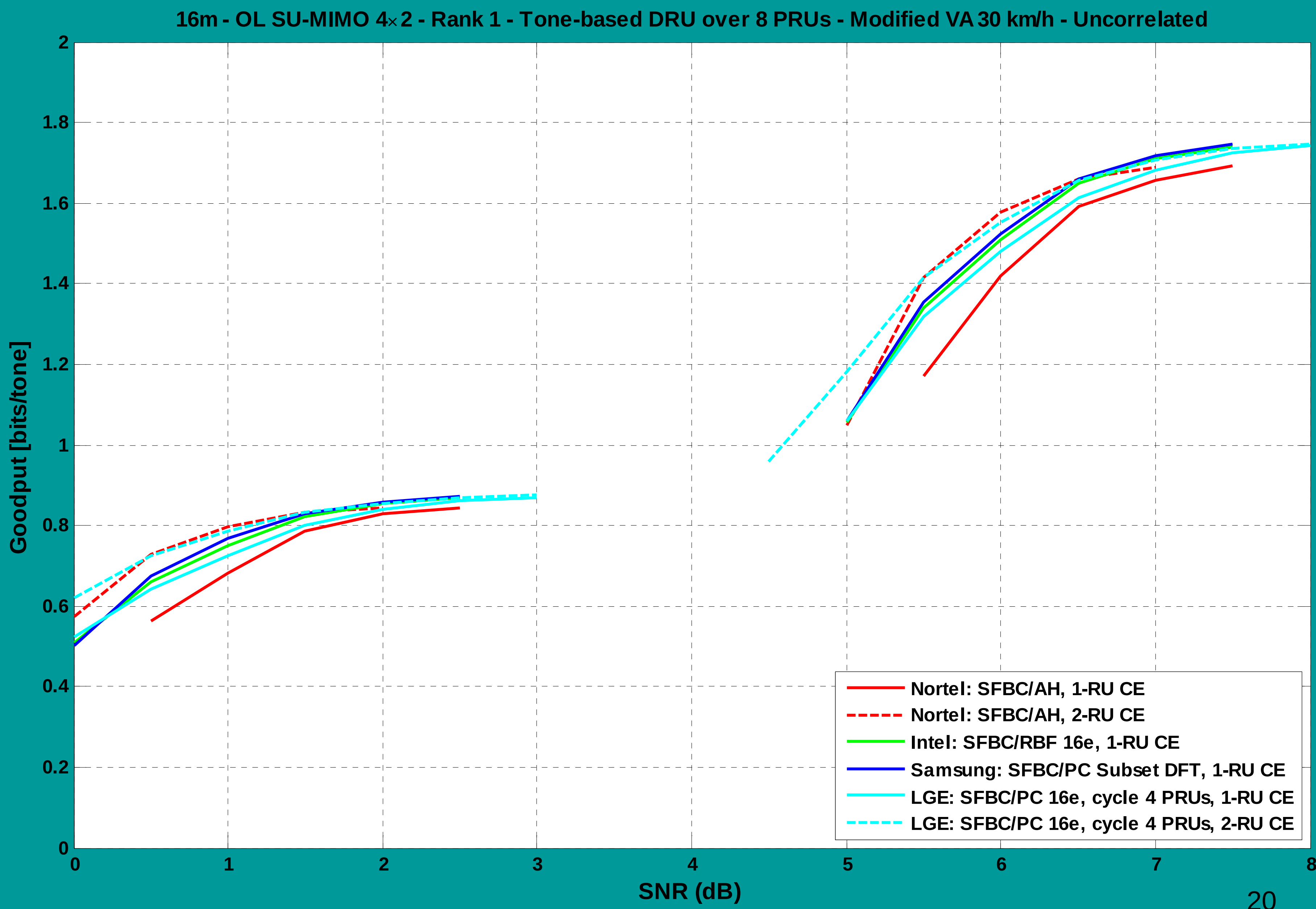


16m - OL SU-MIMO 4×2 - Rank 1 - Tone-based DRU over 24 PRUs - Modified VA 30 km/h - Uncorrelated
BLER
SNR (dB)
Nortel: SFBC/AH, 1-RU CE
Nortel: SFBC/AH, 2-RU CE
Intel: SFBC/RBF 16e, 1-RU CE
Samsung: SFBC/PC Subset DFT, 1-RU CE
LGE: SFBC/PC 16e, cycle 4 PRUs, 1-RU CE
LGE: SFBC/PC 16e, cycle 4 PRUs, 2-RU CE
0.5
1.2
1.4
1.7
2.3
5.4
5.8
6.1
6.4
6.9
7.3

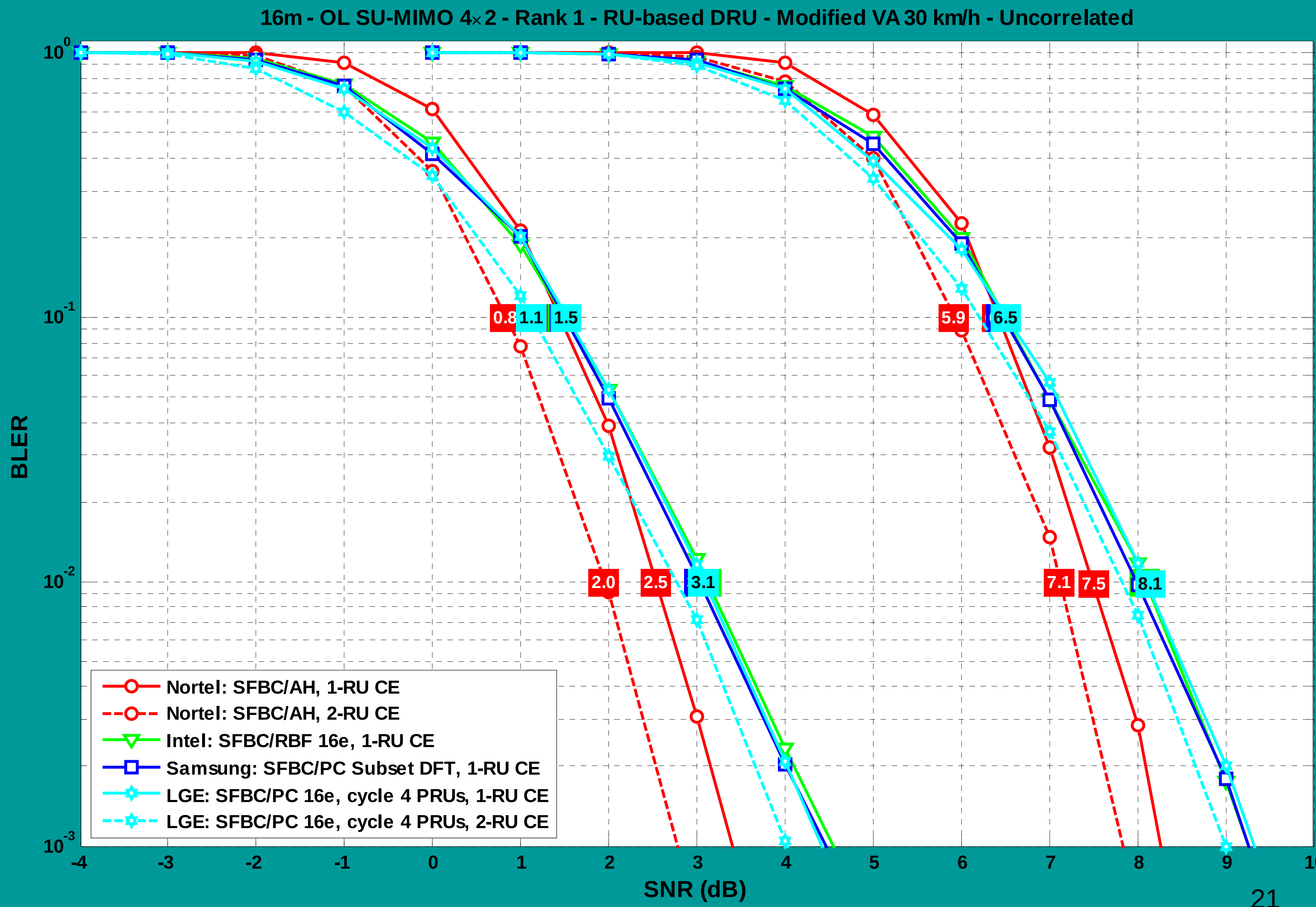

16m - OL SU-MIMO 4×2 - Rank 1 - Tone-based DRU over 24 PRUs - Modified VA 30 km/h - Uncorrelated
Goodput [bits/tone]
SNR (dB)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
0
1
2
3
4
5
6
7
8
Nortel: SFBC/AH, 1-RU CE
Nortel: SFBC/AH, 2-RU CE
Intel: SFBC/RBF 16e, 1-RU CE
Samsung: SFBC/PC Subset DFT, 1-RU CE
LGE: SFBC/PC 16e, cycle 4 PRUs, 1-RU CE
LGE: SFBC/PC 16e, cycle 4 PRUs, 2-RU CE

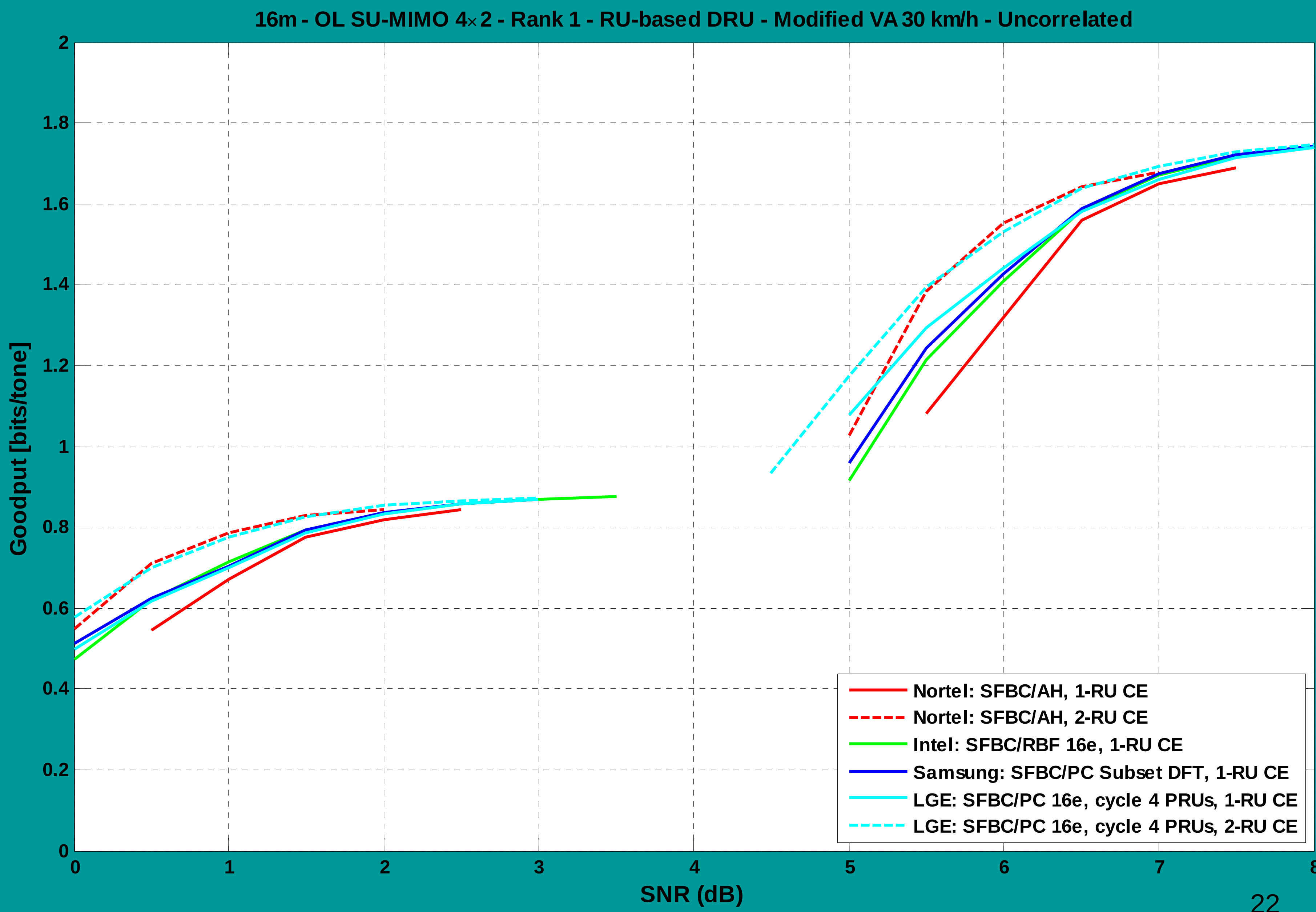


16m - OL SU-MIMO 4×2 - Rank 1 - Tone-based DRU over 8 PRUs - Modified VA 30 km/h - Uncorrelated
BLER
SNR (dB)
0.7
1.0
1.4
1.9
2.6
3.0
5.8
6.4
6.9
7.4
7.9
Nortel: SFBC/AH, 1-RU CE
Nortel: SFBC/AH, 2-RU CE
Intel: SFBC/RBF 16e, 1-RU CE
Samsung: SFBC/PC Subset DFT, 1-RU CE
LGE: SFBC/PC 16e, cycle 4 PRUs, 1-RU CE
LGE: SFBC/PC 16e, cycle 4 PRUs, 2-RU CE

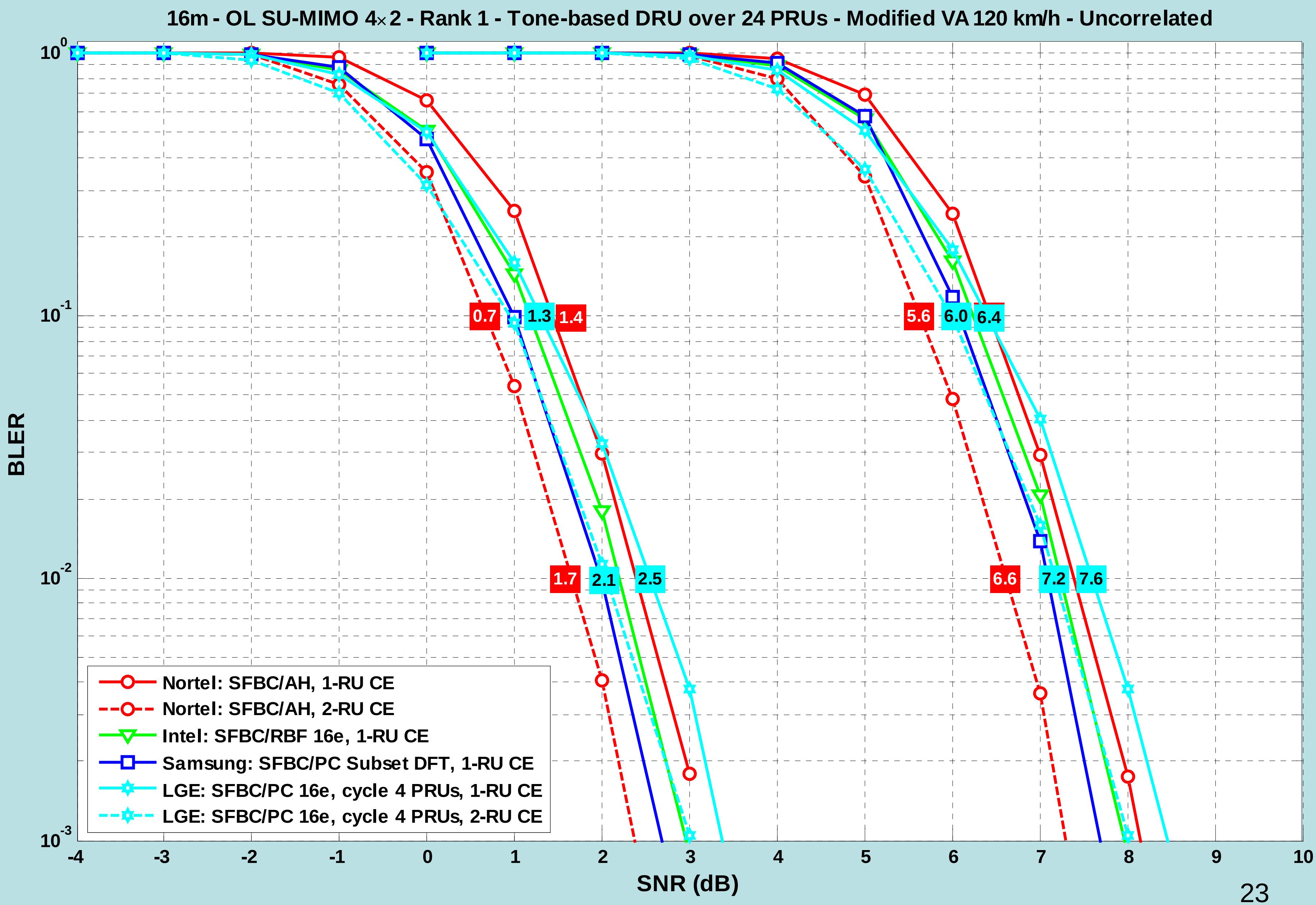


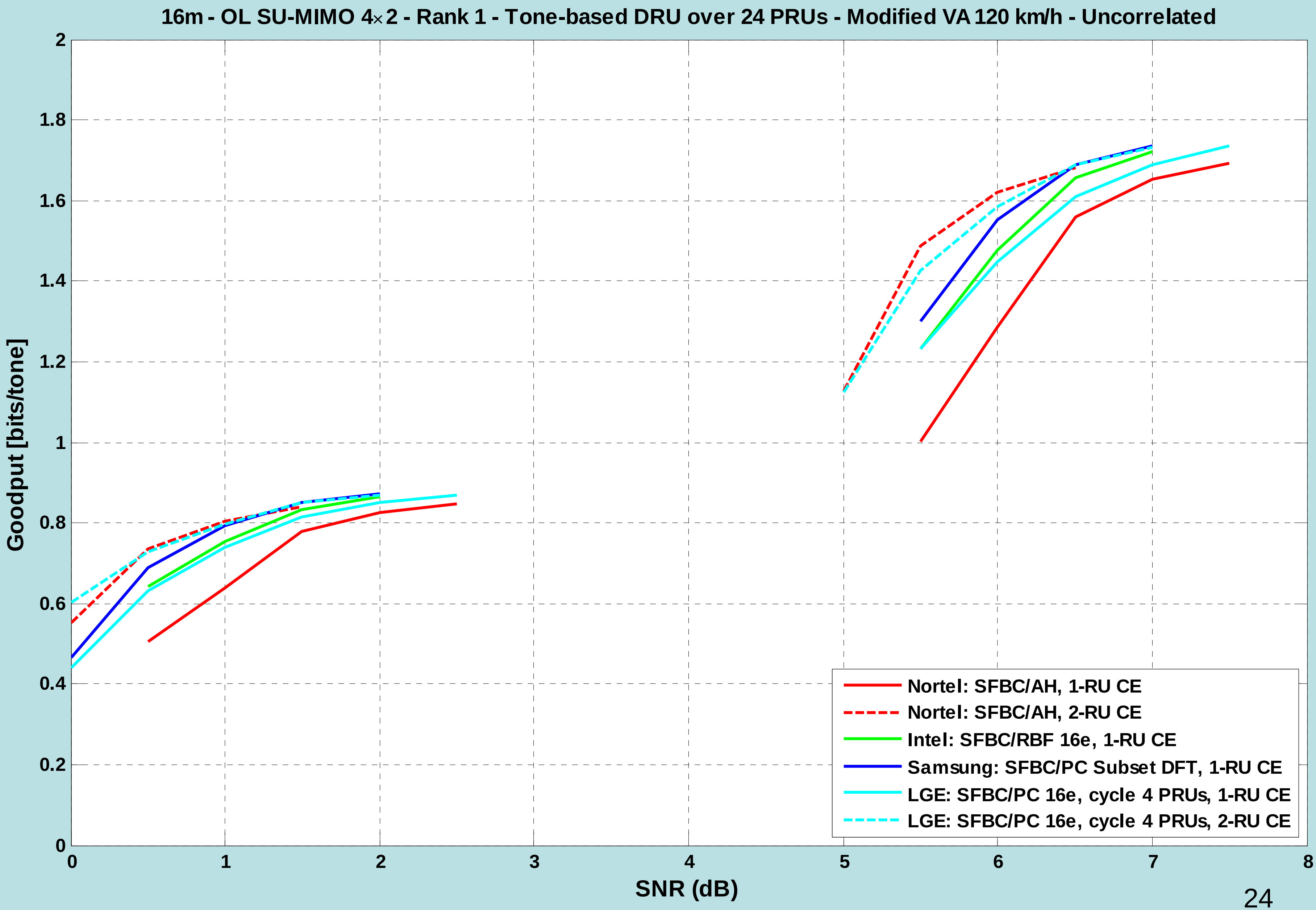
16m - OL SU-MIMO 4×2 - Rank 1 - Tone-based DRU over 8 PRUs - Modified VA 30 km/h - Uncorrelated
Goodput [bits/tone]
SNR (dB)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
0
1
2
3
4
5
6
7
8
Nortel: SFBC/AH, 1-RU CE
Nortel: SFBC/AH, 2-RU CE
Intel: SFBC/RBF 16e, 1-RU CE
Samsung: SFBC/PC Subset DFT, 1-RU CE
LGE: SFBC/PC 16e, cycle 4 PRUs, 1-RU CE
LGE: SFBC/PC 16e, cycle 4 PRUs, 2-RU CE


16m - OL SU-MIMO 4×2 - Rank 1 - RU-based DRU - Modified VA 30 km/h - Uncorrelated
BLER
SNR (dB)
10^0
10^{-1}
10^{-2}
10^{-3}
-4
-3
-2
-1
0
1
2
3
4
5
6
7
8
9
10
0.8
1.1
1.5
5.9
6.5
2.0
2.5
3.1
7.1
7.5
8.1
Nortel: SFBC/AH, 1-RU CE
Nortel: SFBC/AH, 2-RU CE
Intel: SFBC/RBF 16e, 1-RU CE
Samsung: SFBC/PC Subset DFT, 1-RU CE
LGE: SFBC/PC 16e, cycle 4 PRUs, 1-RU CE
LGE: SFBC/PC 16e, cycle 4 PRUs, 2-RU CE

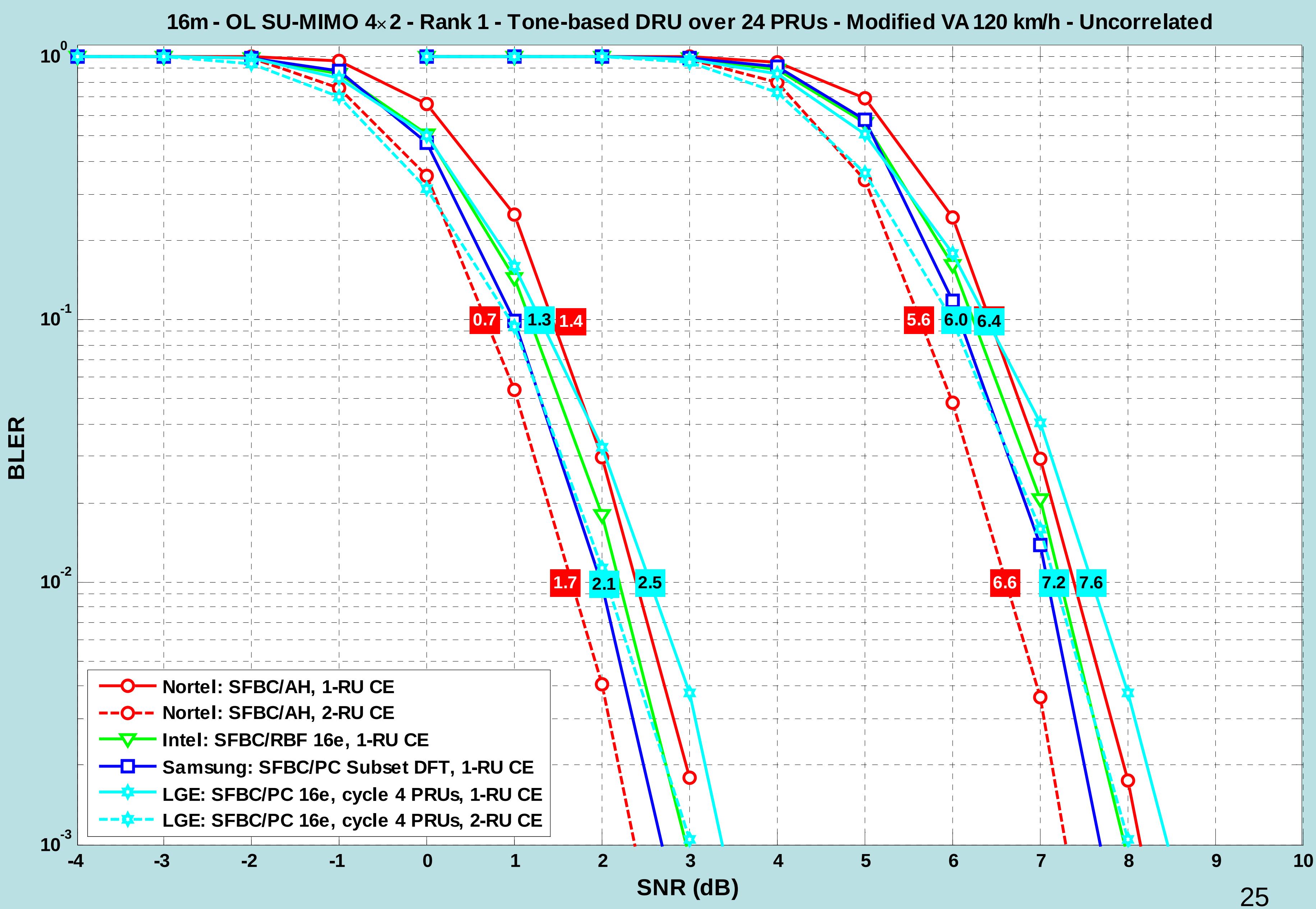


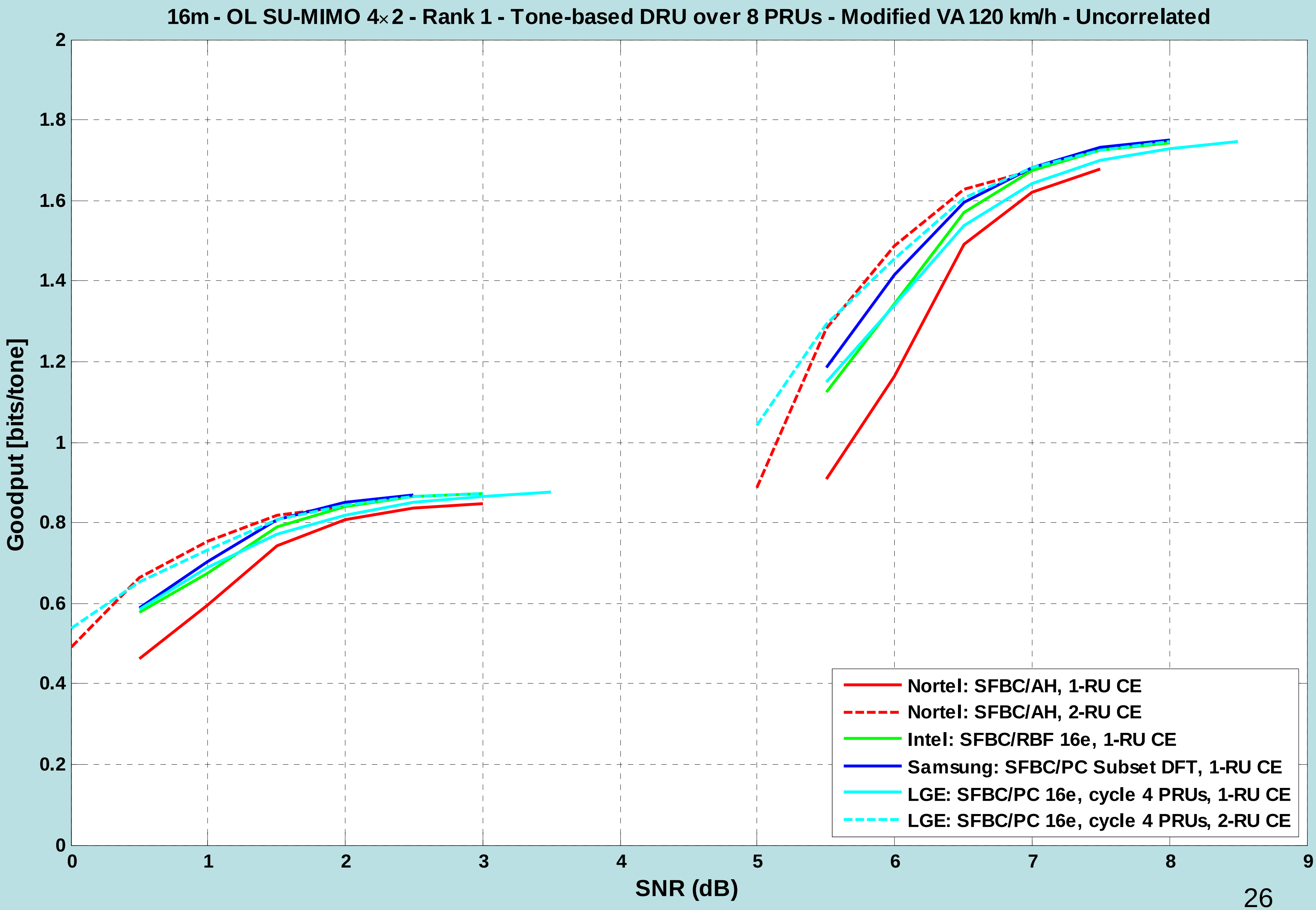
16m - OL SU-MIMO 4×2 - Rank 1 - RU-based DRU - Modified VA 30 km/h - Uncorrelated
Goodput [bits/tone]
SNR (dB)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
0
1
2
3
4
5
6
7
8
Nortel: SFBC/AH, 1-RU CE
Nortel: SFBC/AH, 2-RU CE
Intel: SFBC/RBF 16e, 1-RU CE
Samsung: SFBC/PC Subset DFT, 1-RU CE
LGE: SFBC/PC 16e, cycle 4 PRUs, 1-RU CE
LGE: SFBC/PC 16e, cycle 4 PRUs, 2-RU CE


16m - OL SU-MIMO 4×2 - Rank 1 - Tone-based DRU over 24 PRUs - Modified VA 120 km/h - Uncorrelated
BLER
SNR (dB)
0.7
1.3
1.4
1.7
2.1
2.5
5.6
6.0
6.4
6.6
7.2
7.6
Nortel: SFBC/AH, 1-RU CE
Nortel: SFBC/AH, 2-RU CE
Intel: SFBC/RBF 16e, 1-RU CE
Samsung: SFBC/PC Subset DFT, 1-RU CE
LGE: SFBC/PC 16e, cycle 4 PRUs, 1-RU CE
LGE: SFBC/PC 16e, cycle 4 PRUs, 2-RU CE

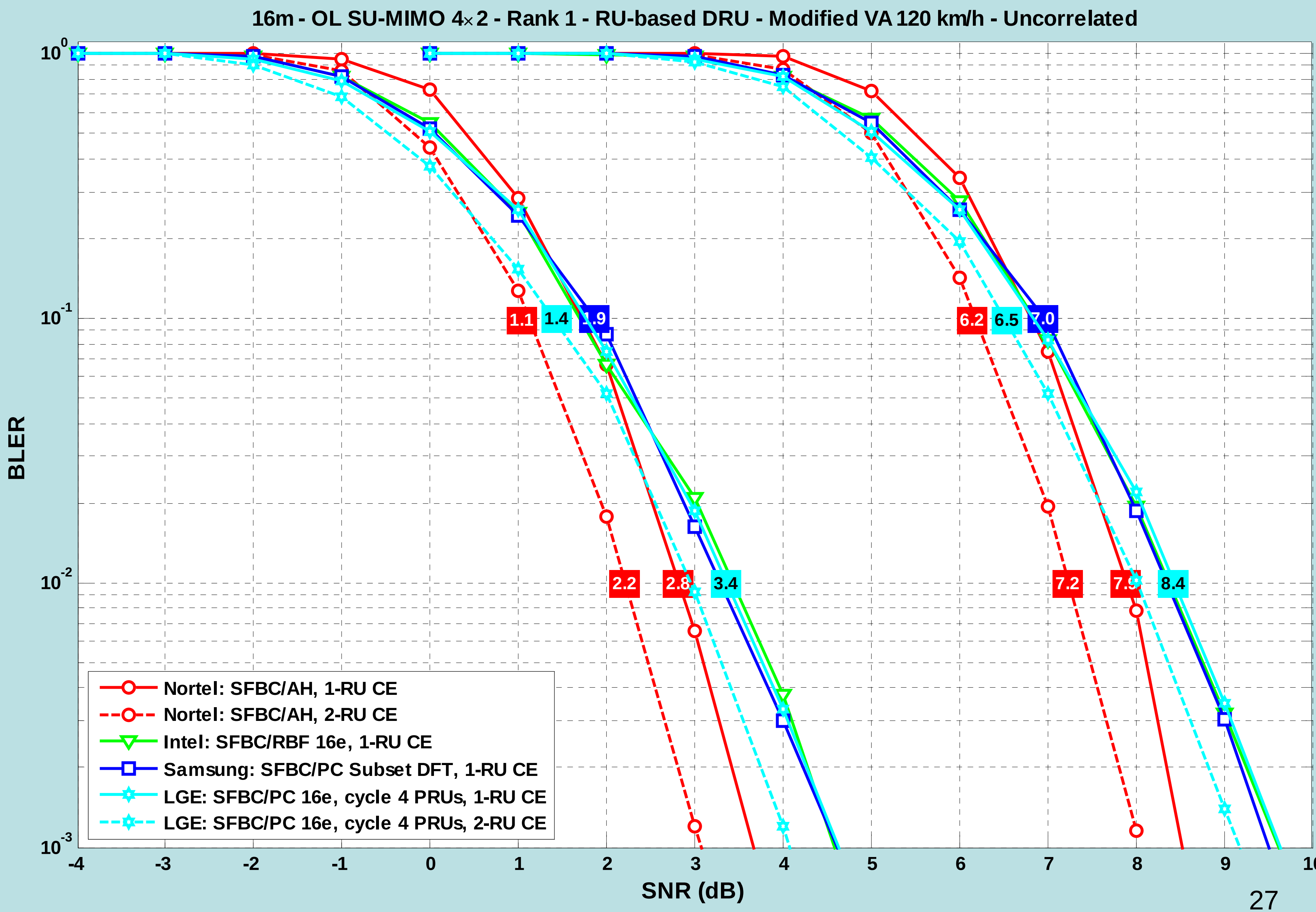


16m - OL SU-MIMO 4×2 - Rank 1 - Tone-based DRU over 24 PRUs - Modified VA 120 km/h - Uncorrelated
Goodput [bits/tone]
SNR (dB)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
1
2
3
4
5
6
7
8
Nortel: SFBC/AH, 1-RU CE
Nortel: SFBC/AH, 2-RU CE
Intel: SFBC/RBF 16e, 1-RU CE
Samsung: SFBC/PC Subset DFT, 1-RU CE
LGE: SFBC/PC 16e, cycle 4 PRUs, 1-RU CE
LGE: SFBC/PC 16e, cycle 4 PRUs, 2-RU CE

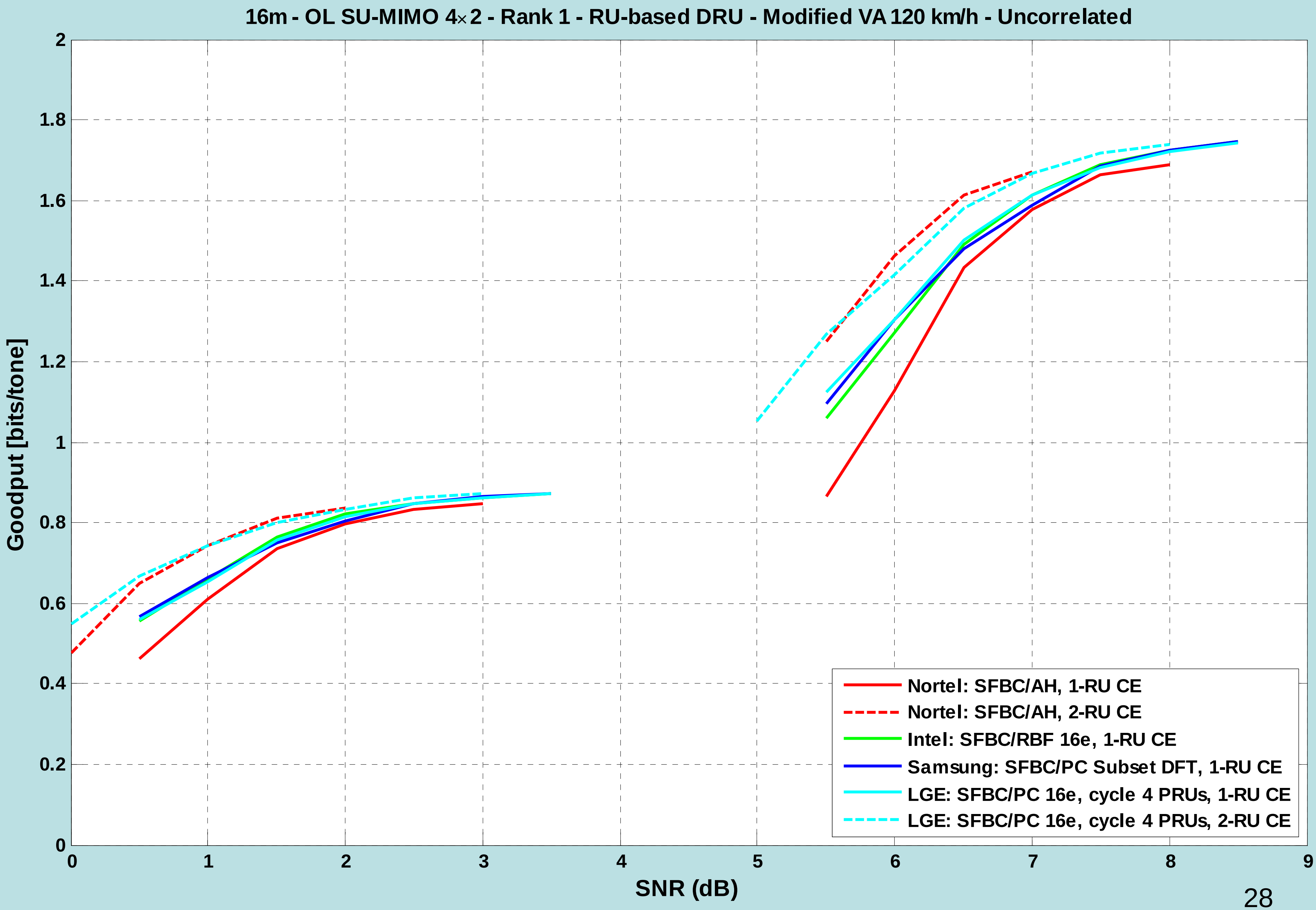

16m - OL SU-MIMO 4×2 - Rank 1 - Tone-based DRU over 24 PRUs - Modified VA 120 km/h - Uncorrelated
BLER
SNR (dB)
0.7
1.3
1.4
1.7
2.1
2.5
5.6
6.0
6.4
6.6
7.2
7.6
Nortel: SFBC/AH, 1-RU CE
Nortel: SFBC/AH, 2-RU CE
Intel: SFBC/RBF 16e, 1-RU CE
Samsung: SFBC/PC Subset DFT, 1-RU CE
LGE: SFBC/PC 16e, cycle 4 PRUs, 1-RU CE
LGE: SFBC/PC 16e, cycle 4 PRUs, 2-RU CE



16m - OL SU-MIMO 4×2 - Rank 1 - Tone-based DRU over 8 PRUs - Modified VA 120 km/h - Uncorrelated
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
Nortel: SFBC/AH, 1-RU CE
Nortel: SFBC/AH, 2-RU CE
Intel: SFBC/RBF 16e, 1-RU CE
Samsung: SFBC/PC Subset DFT, 1-RU CE
LGE: SFBC/PC 16e, cycle 4 PRUs, 1-RU CE
LGE: SFBC/PC 16e, cycle 4 PRUs, 2-RU CE



16m - OL SU-MIMO 4×2 - Rank 1 - RU-based DRU - Modified VA 120 km/h - Uncorrelated
BLER
SNR (dB)
10^0
10^-1
10^-2
10^-3
-4
-3
-2
-1
0
1
2
3
4
5
6
7
8
9
10
1.1
1.4
1.9
2.2
2.8
3.4
6.2
6.5
7.0
7.2
7.9
8.4
Nortel: SFBC/AH, 1-RU CE
Nortel: SFBC/AH, 2-RU CE
Intel: SFBC/RBF 16e, 1-RU CE
Samsung: SFBC/PC Subset DFT, 1-RU CE
LGE: SFBC/PC 16e, cycle 4 PRUs, 1-RU CE
LGE: SFBC/PC 16e, cycle 4 PRUs, 2-RU CE

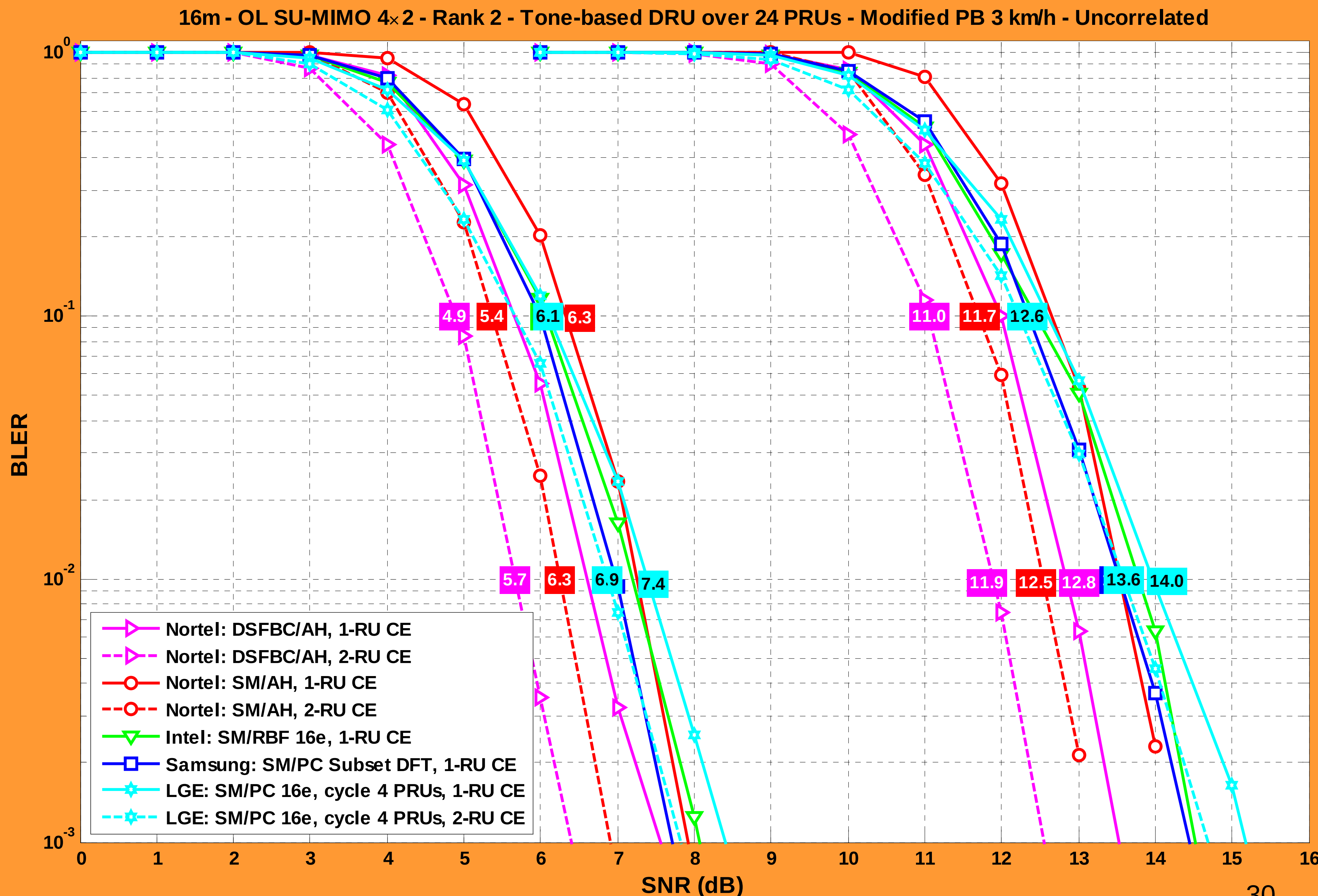


16m - OL SU-MIMO 4×2 - Rank 1 - RU-based DRU - Modified VA 120 km/h - Uncorrelated
Goodput [bits/tone]
SNR (dB)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
0
1
2
3
4
5
6
7
8
9
Nortel: SFBC/AH, 1-RU CE
Nortel: SFBC/AH, 2-RU CE
Intel: SFBC/RBF 16e, 1-RU CE
Samsung: SFBC/PC Subset DFT, 1-RU CE
LGE: SFBC/PC 16e, cycle 4 PRUs, 1-RU CE
LGE: SFBC/PC 16e, cycle 4 PRUs, 2-RU CE

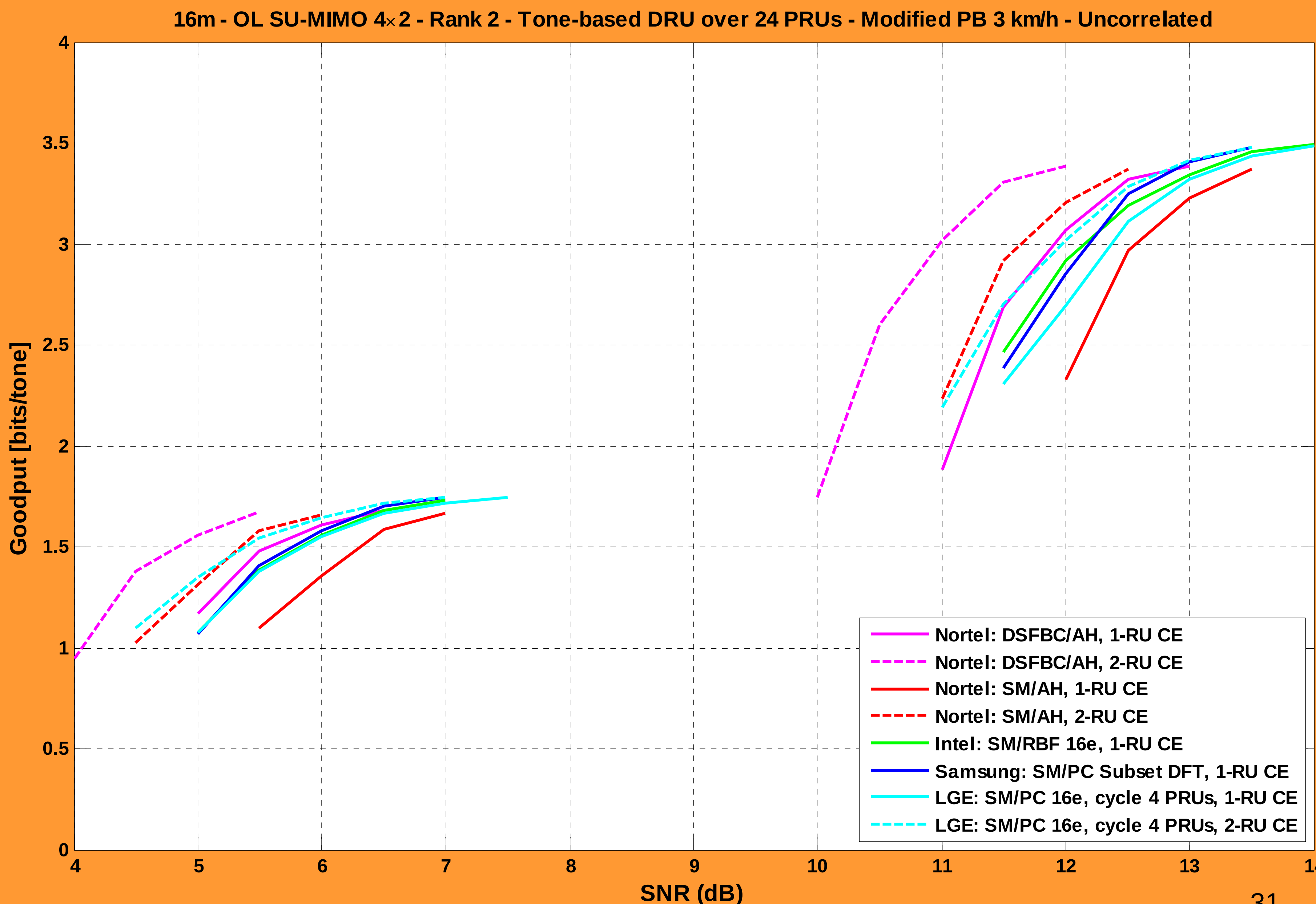
2

AH vs. PC and RBF

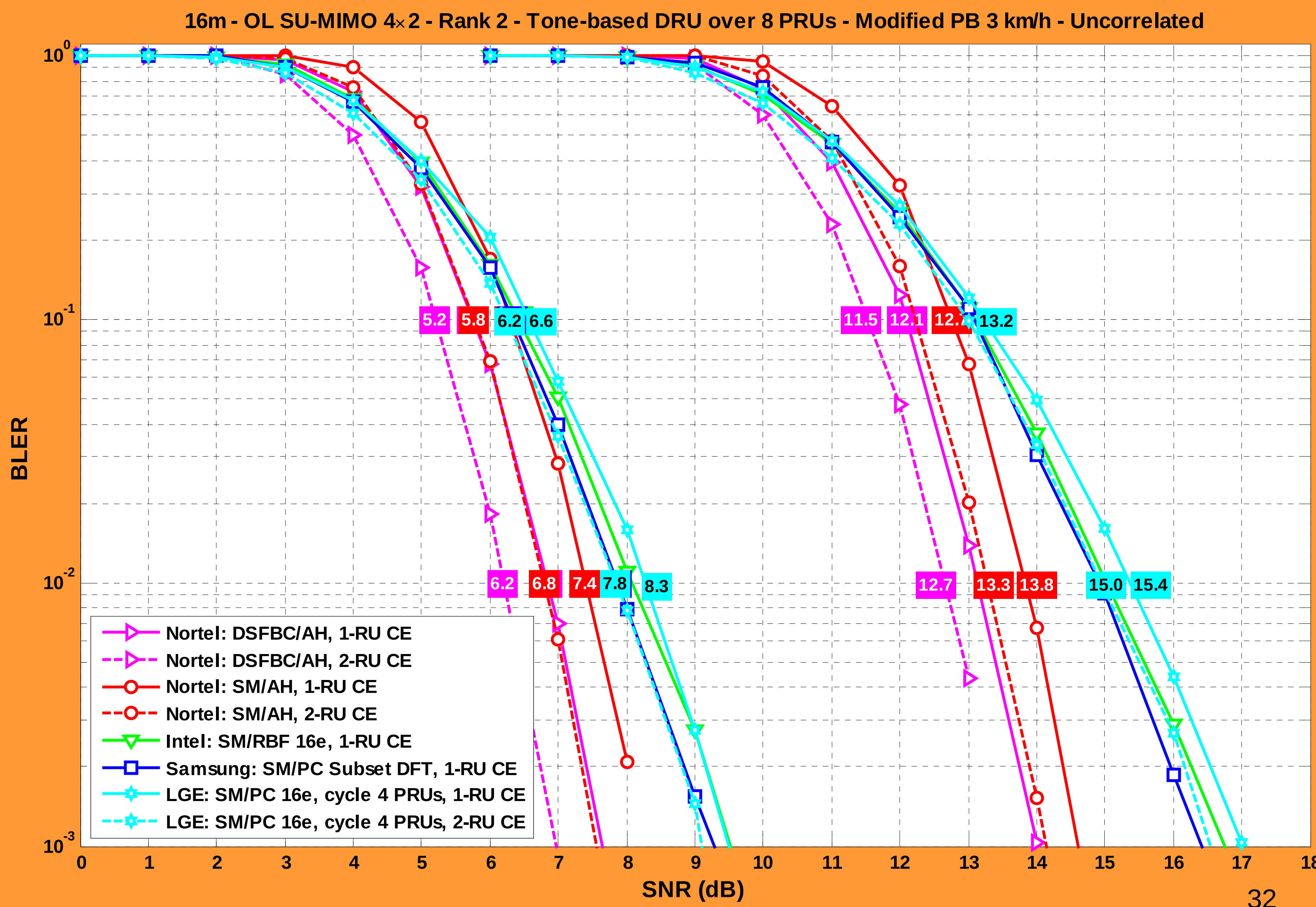
Rank 2

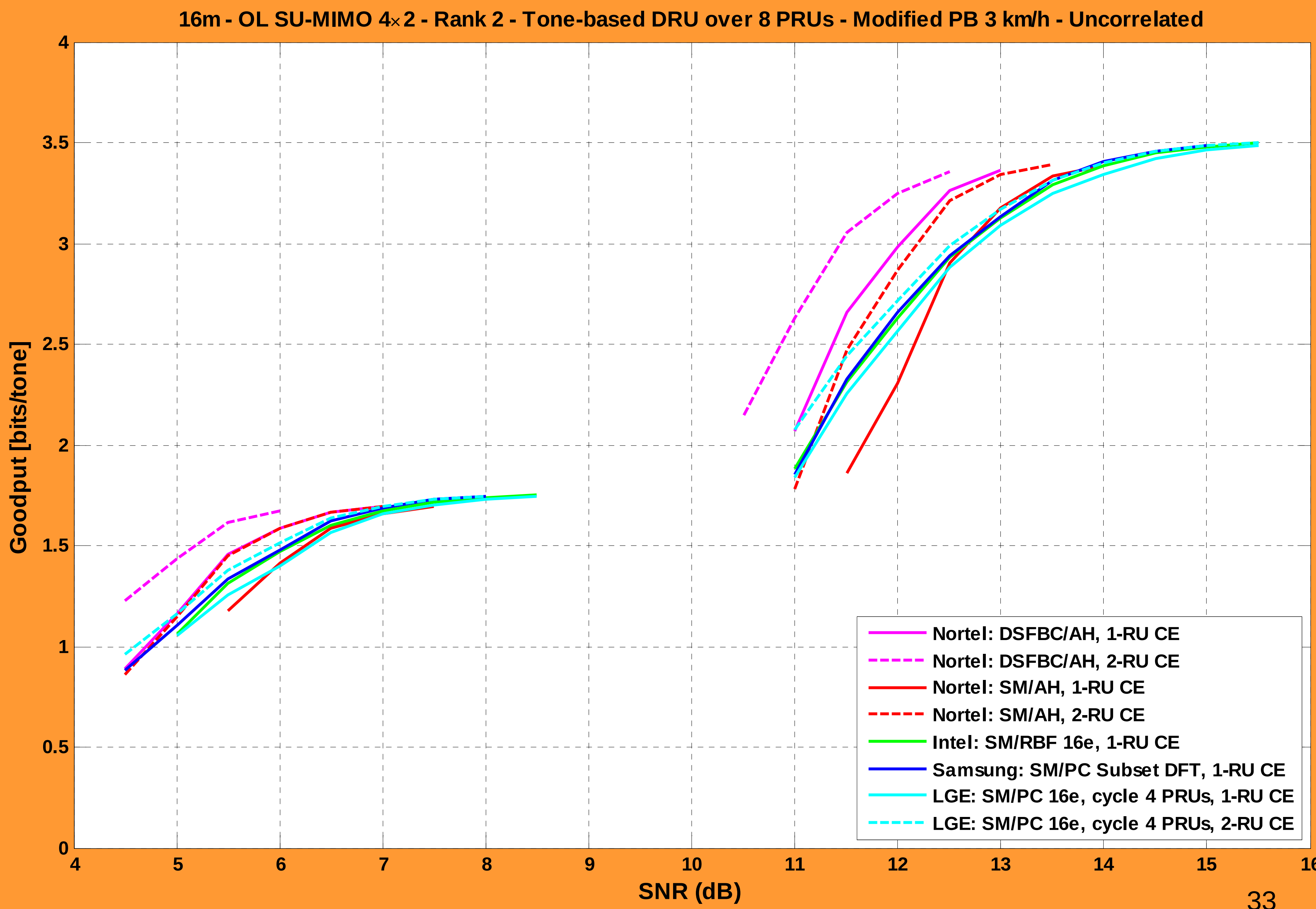


16m - OL SU-MIMO 4×2 - Rank 2 - Tone-based DRU over 24 PRUs - Modified PB 3 km/h - Uncorrelated
BLER
SNR (dB)
4.9
5.4
6.1
6.3
11.0
11.7
12.6
5.7
6.3
6.9
7.4
11.9
12.5
12.8
13.6
14.0
Nortel: DSFBC/AH, 1-RU CE
Nortel: DSFBC/AH, 2-RU CE
Nortel: SM/AH, 1-RU CE
Nortel: SM/AH, 2-RU CE
Intel: SM/RBF 16e, 1-RU CE
Samsung: SM/PC Subset DFT, 1-RU CE
LGE: SM/PC 16e, cycle 4 PRUs, 1-RU CE
LGE: SM/PC 16e, cycle 4 PRUs, 2-RU CE

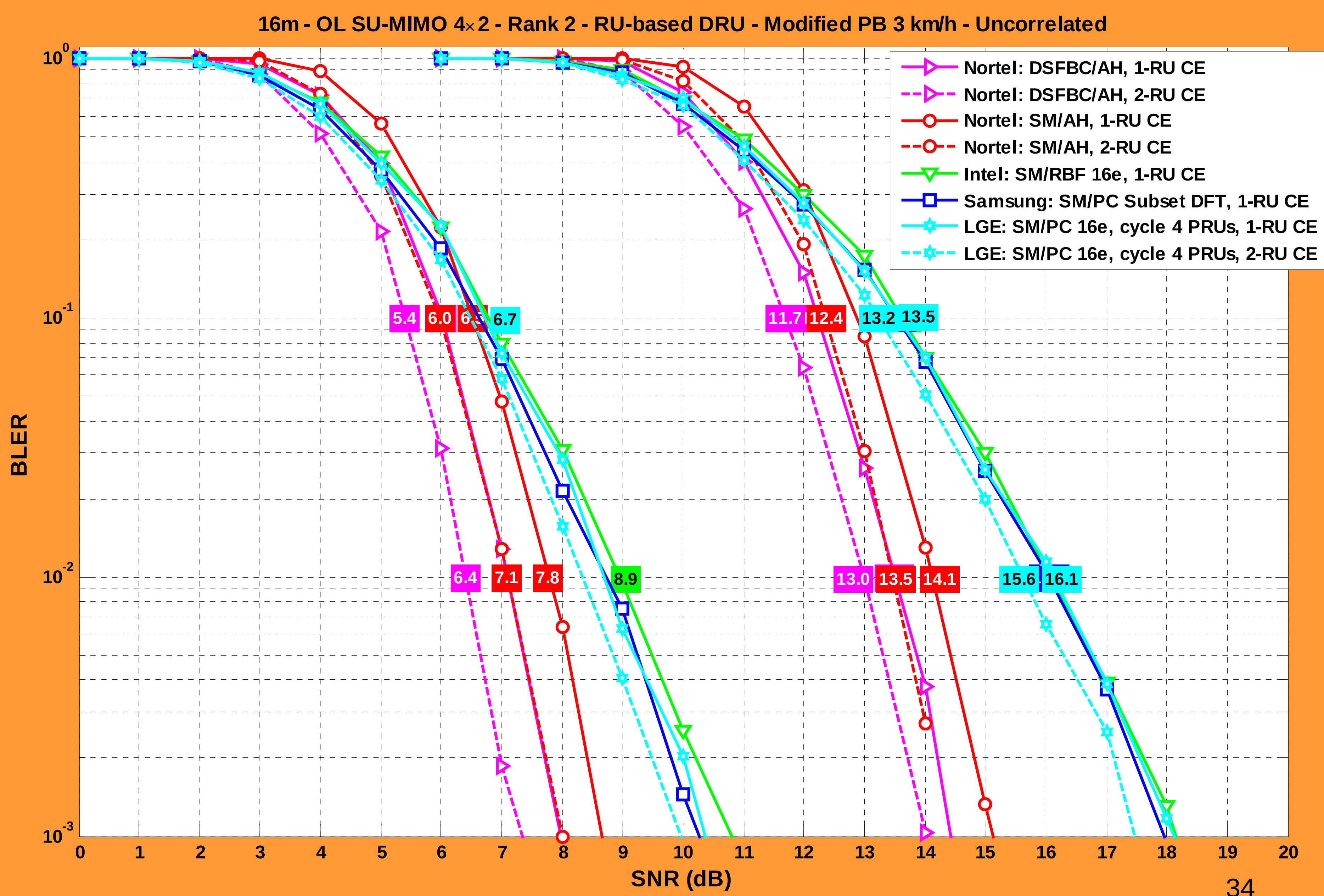


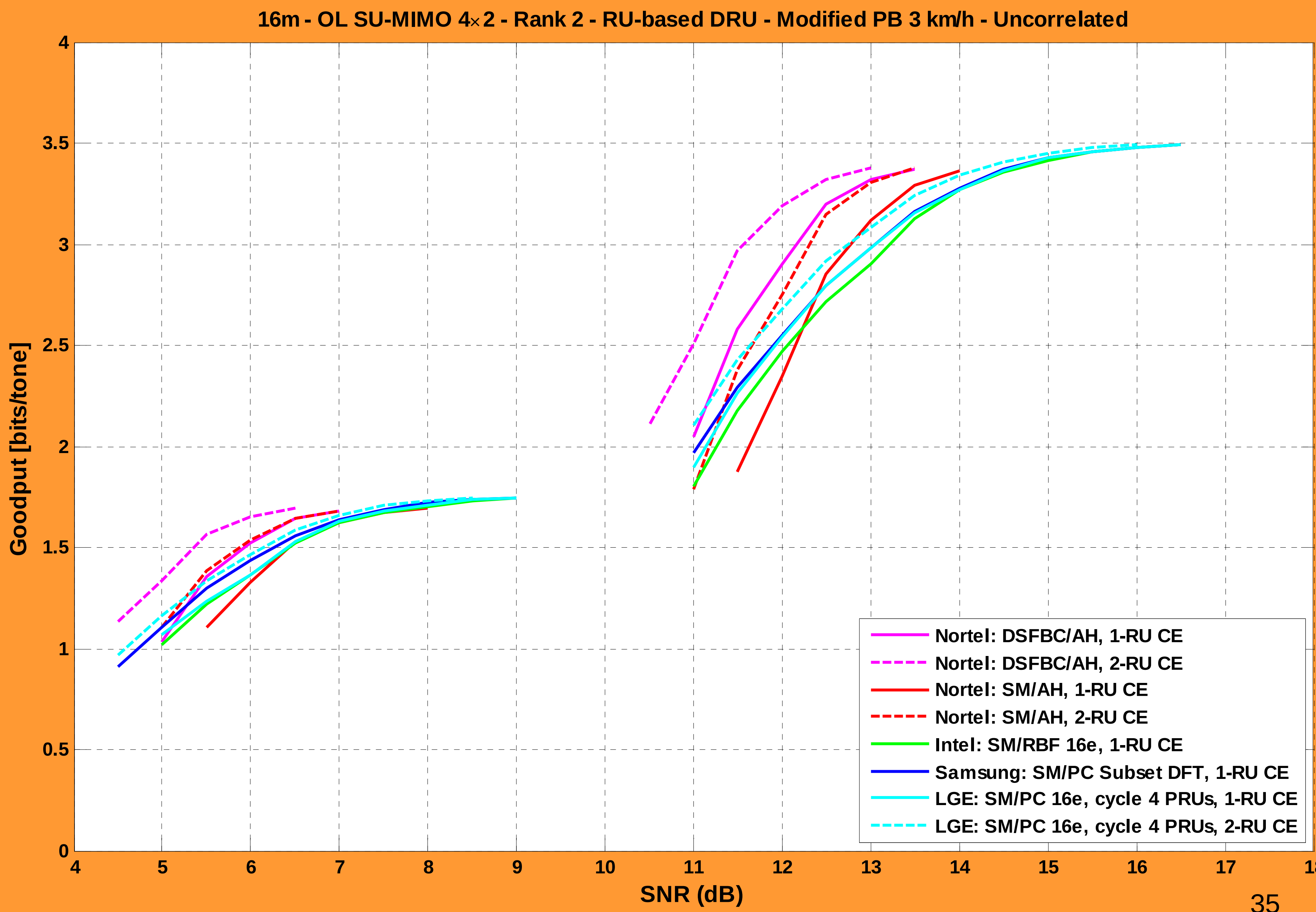
16m - OL SU-MIMO 4×2 - Rank 2 - Tone-based DRU over 24 PRUs - Modified PB 3 km/h - Uncorrelated
Goodput [bits/tone]
SNR (dB)
0
0.5
1
1.5
2
2.5
3
3.5
4
4
5
6
7
8
9
10
11
12
13
14
Nortel: DSFBC/AH, 1-RU CE
Nortel: DSFBC/AH, 2-RU CE
Nortel: SM/AH, 1-RU CE
Nortel: SM/AH, 2-RU CE
Intel: SM/RBF 16e, 1-RU CE
Samsung: SM/PC Subset DFT, 1-RU CE
LGE: SM/PC 16e, cycle 4 PRUs, 1-RU CE
LGE: SM/PC 16e, cycle 4 PRUs, 2-RU CE

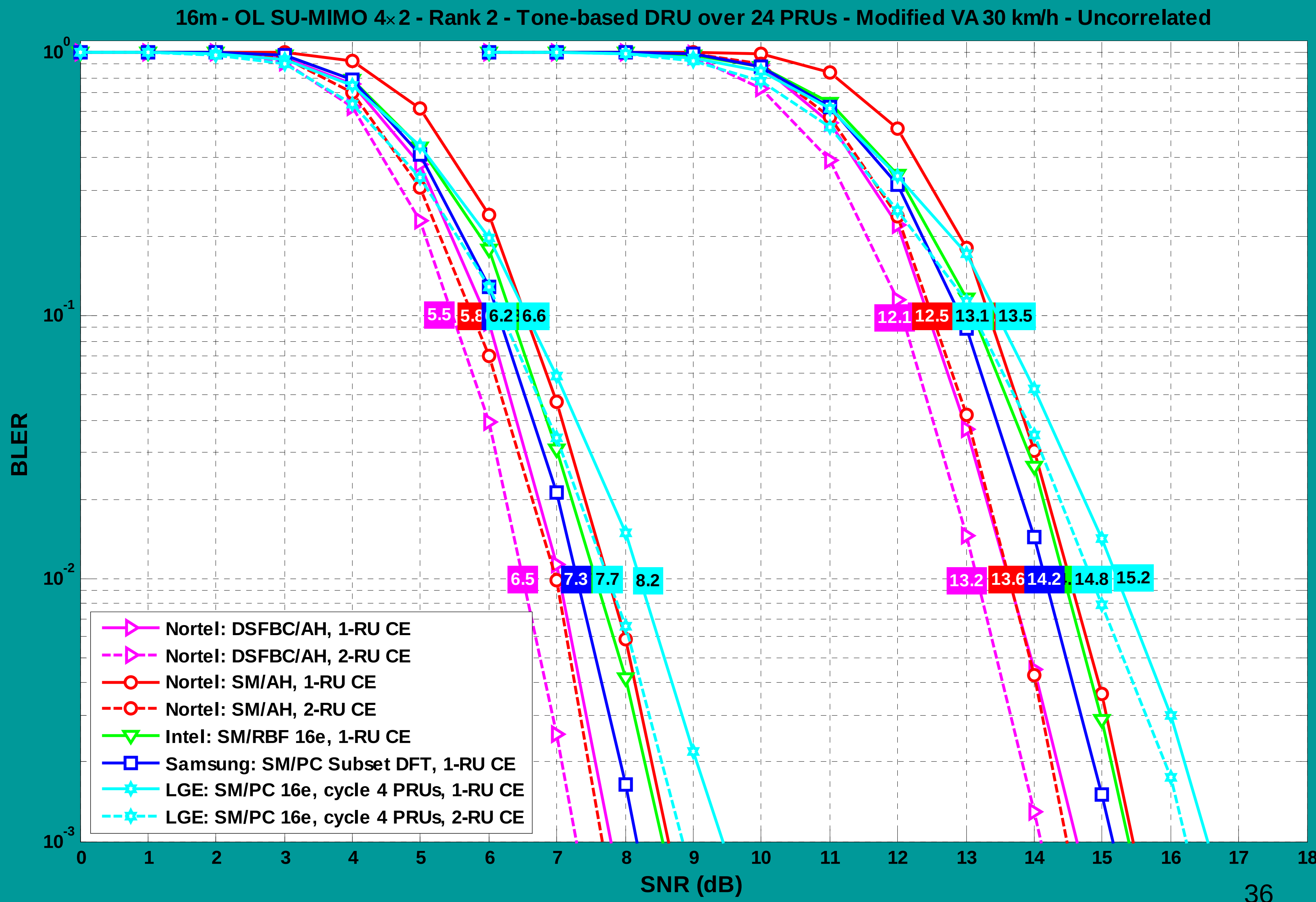

16m - OL SU-MIMO 4×2 - Rank 2 - Tone-based DRU over 8 PRUs - Modified PB 3 km/h - Uncorrelated
BLER
SNR (dB)
10^0
10^-1
10^-2
10^-3
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
5.2
5.8
6.2
6.6
11.5
12.1
13.2
6.2
6.8
7.4
7.8
8.3
12.7
13.3
13.8
15.0
15.4
Nortel: DSFBC/AH, 1-RU CE
Nortel: DSFBC/AH, 2-RU CE
Nortel: SM/AH, 1-RU CE
Nortel: SM/AH, 2-RU CE
Intel: SM/RBF 16e, 1-RU CE
Samsung: SM/PC Subset DFT, 1-RU CE
LGE: SM/PC 16e, cycle 4 PRUs, 1-RU CE
LGE: SM/PC 16e, cycle 4 PRUs, 2-RU CE



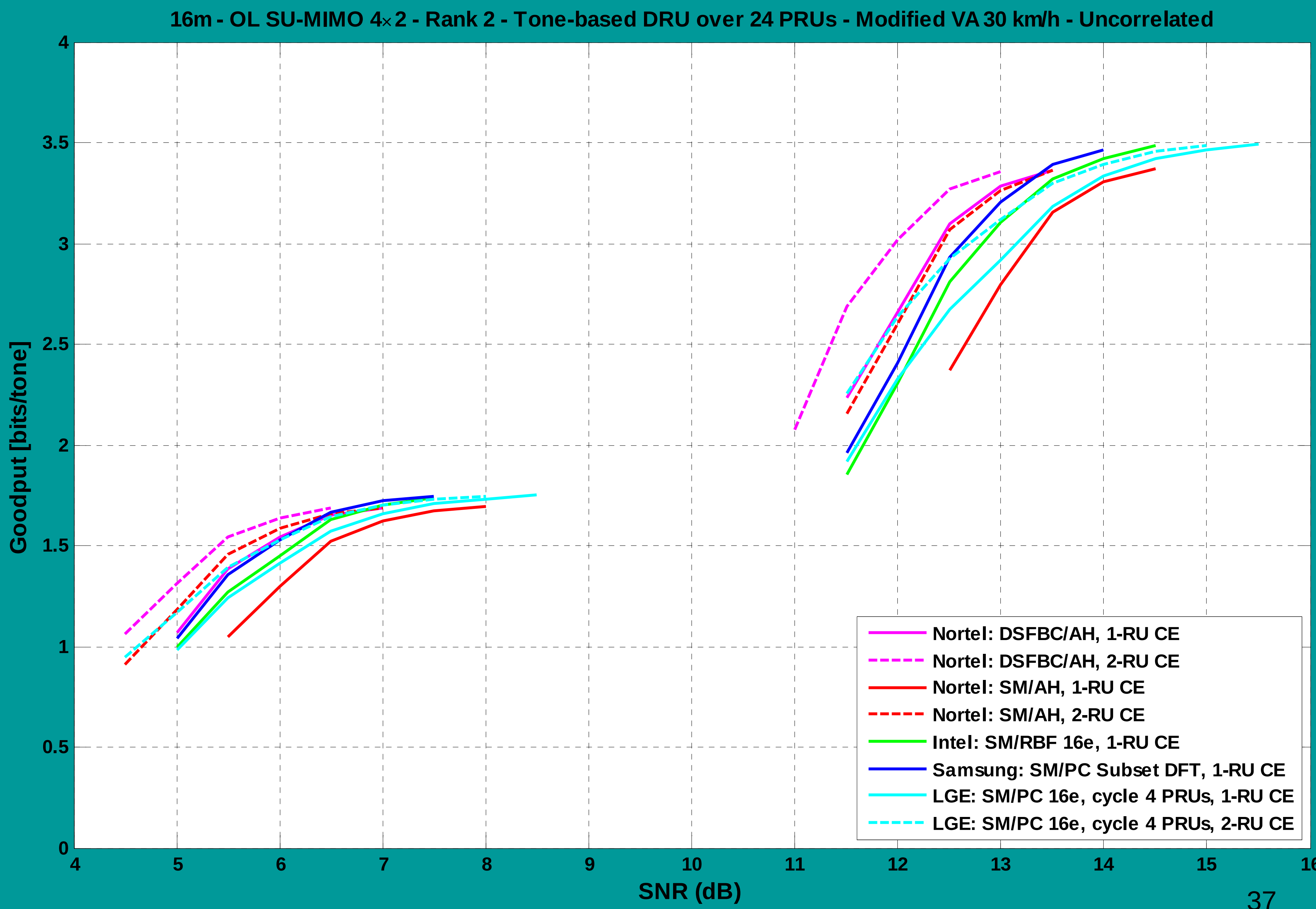
16m - OL SU-MIMO 4×2 - Rank 2 - Tone-based DRU over 8 PRUs - Modified PB 3 km/h - Uncorrelated
Goodput [bits/tone]
SNR (dB)
0
0.5
1
1.5
2
2.5
3
3.5
4
4
5
6
7
8
9
10
11
12
13
14
15
16
Nortel: DSFBC/AH, 1-RU CE
Nortel: DSFBC/AH, 2-RU CE
Nortel: SM/AH, 1-RU CE
Nortel: SM/AH, 2-RU CE
Intel: SM/RBF 16e, 1-RU CE
Samsung: SM/PC Subset DFT, 1-RU CE
LGE: SM/PC 16e, cycle 4 PRUs, 1-RU CE
LGE: SM/PC 16e, cycle 4 PRUs, 2-RU CE


16m - OL SU-MIMO 4×2 - Rank 2 - RU-based DRU - Modified PB 3 km/h - Uncorrelated
BLER
SNR (dB)
Nortel: DSFBC/AH, 1-RU CE
Nortel: DSFBC/AH, 2-RU CE
Nortel: SM/AH, 1-RU CE
Nortel: SM/AH, 2-RU CE
Intel: SM/RBF 16e, 1-RU CE
Samsung: SM/PC Subset DFT, 1-RU CE
LGE: SM/PC 16e, cycle 4 PRUs, 1-RU CE
LGE: SM/PC 16e, cycle 4 PRUs, 2-RU CE
5.4
6.0
6.7
11.7
12.4
13.2
13.5
6.4
7.1
7.8
8.9
13.0
13.5
14.1
15.6
16.1

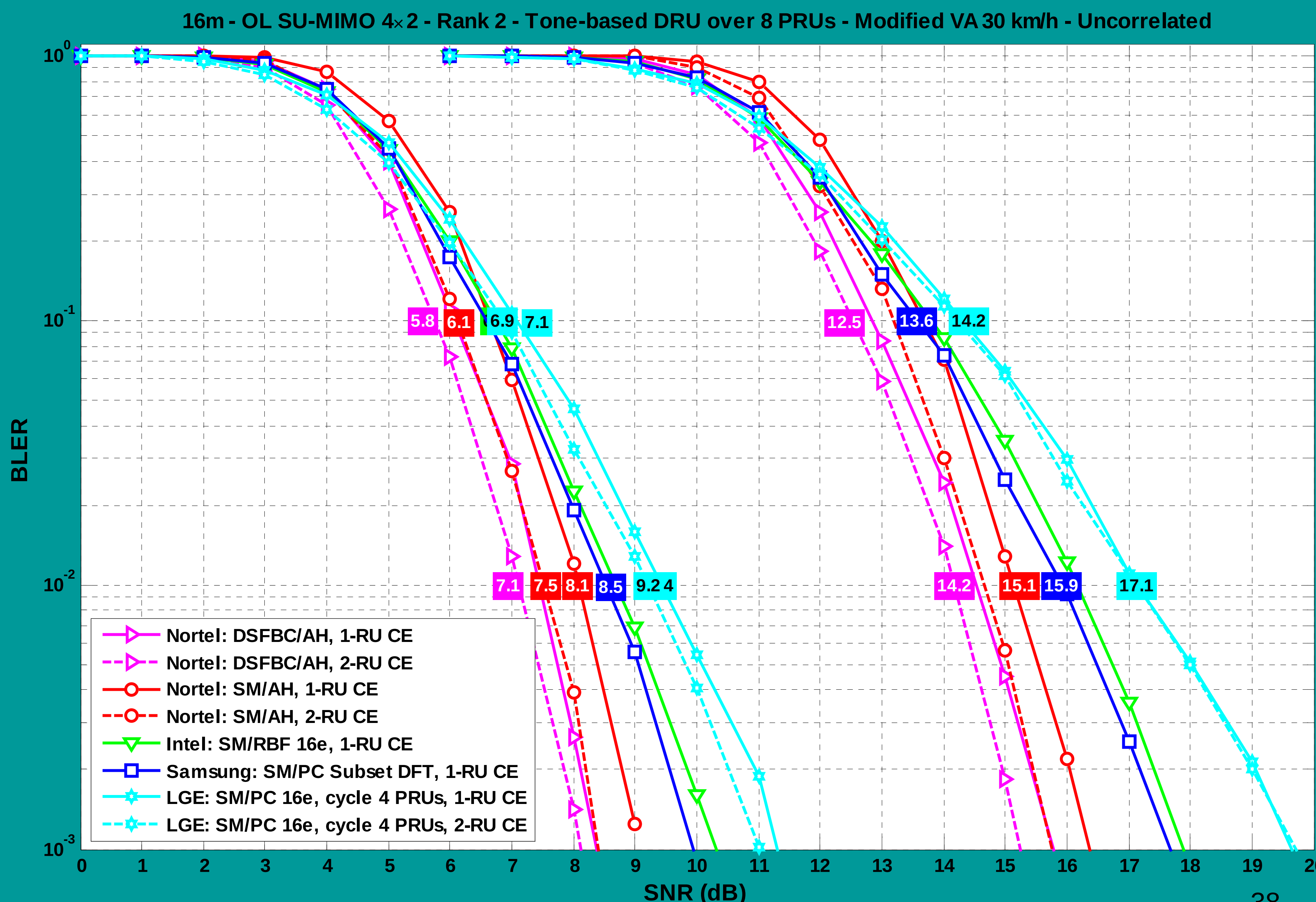

16m - OL SU-MIMO 4×2 - Rank 2 - RU-based DRU - Modified PB 3 km/h - Uncorrelated
Goodput [bits/tone]
SNR (dB)
4
3.5
3
2.5
2
1.5
1
0.5
0
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
Nortel: DSFBC/AH, 1-RU CE
Nortel: DSFBC/AH, 2-RU CE
Nortel: SM/AH, 1-RU CE
Nortel: SM/AH, 2-RU CE
Intel: SM/RBF 16e, 1-RU CE
Samsung: SM/PC Subset DFT, 1-RU CE
LGE: SM/PC 16e, cycle 4 PRUs, 1-RU CE
LGE: SM/PC 16e, cycle 4 PRUs, 2-RU CE

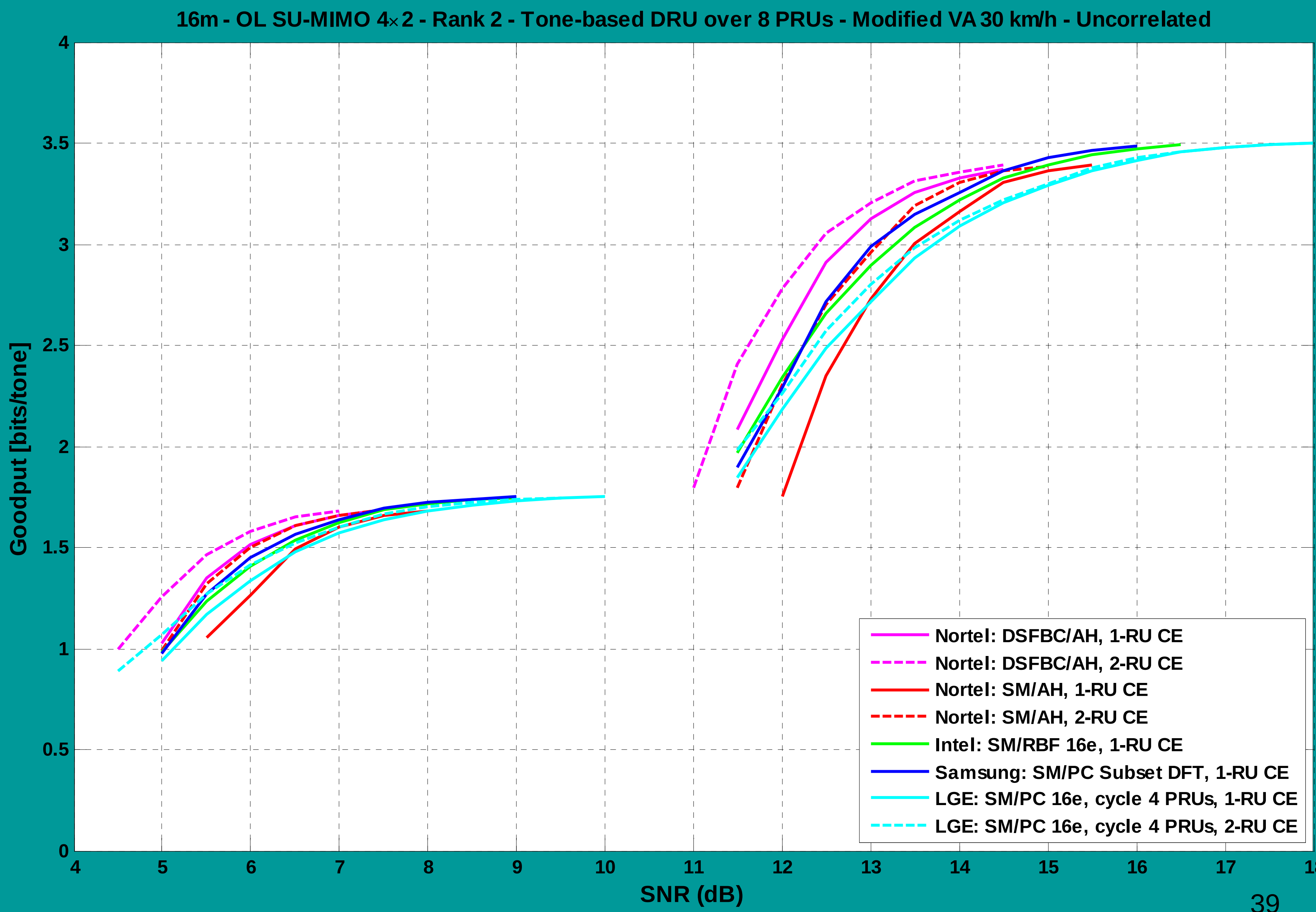


16m - OL SU-MIMO 4×2 - Rank 2 - Tone-based DRU over 24 PRUs - Modified VA 30 km/h - Uncorrelated
BLER
SNR (dB)
5.5
5.8
6.2
6.6
12.1
12.5
13.1
13.5
6.5
7.3
7.7
8.2
13.2
13.6
14.2
14.8
15.2
Nortel: DSFBC/AH, 1-RU CE
Nortel: DSFBC/AH, 2-RU CE
Nortel: SM/AH, 1-RU CE
Nortel: SM/AH, 2-RU CE
Intel: SM/RBF 16e, 1-RU CE
Samsung: SM/PC Subset DFT, 1-RU CE
LGE: SM/PC 16e, cycle 4 PRUs, 1-RU CE
LGE: SM/PC 16e, cycle 4 PRUs, 2-RU CE

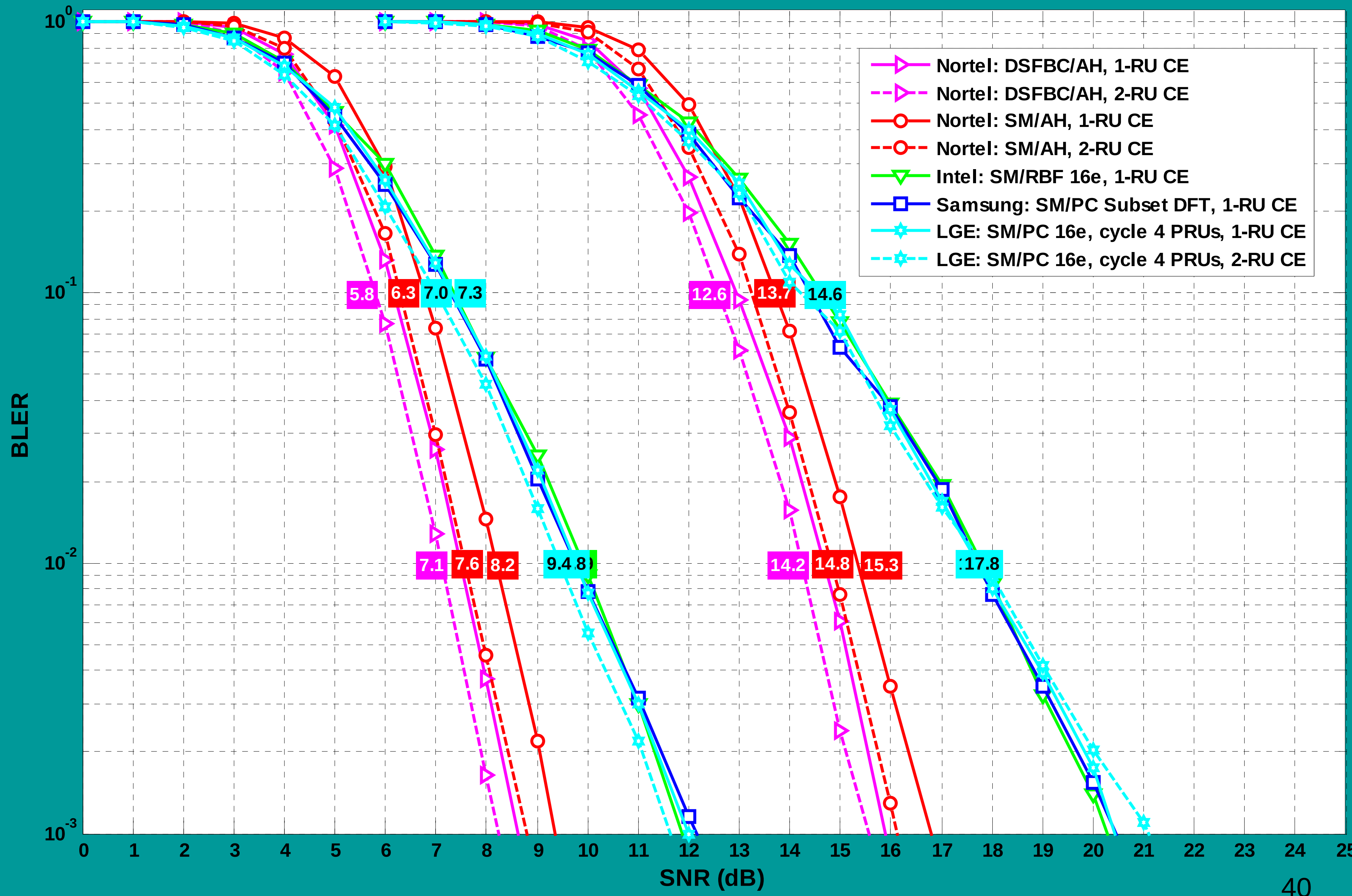


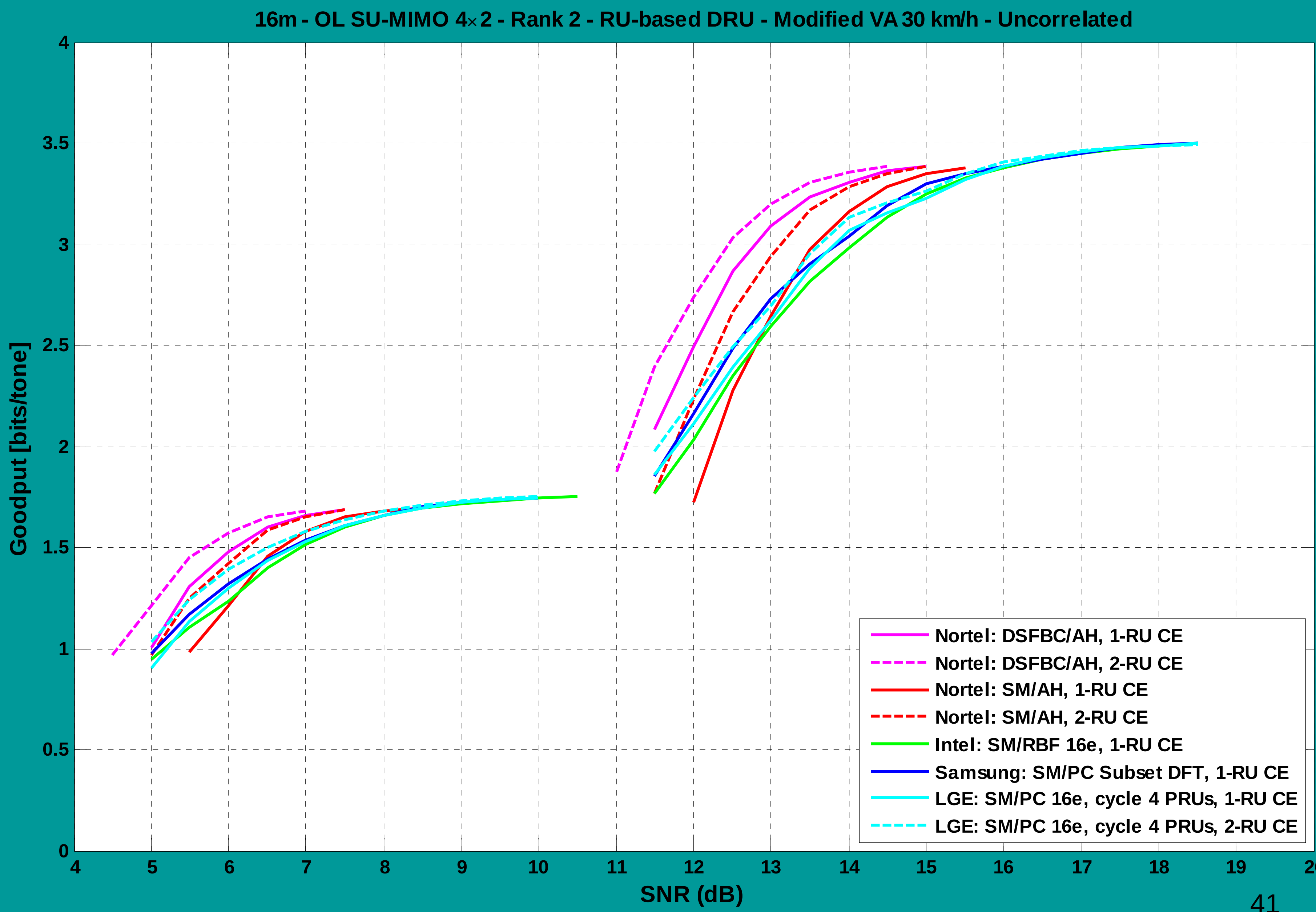
16m - OL SU-MIMO 4×2 - Rank 2 - Tone-based DRU over 24 PRUs - Modified VA 30 km/h - Uncorrelated
Goodput [bits/tone]
SNR (dB)
0
0.5
1
1.5
2
2.5
3
3.5
4
4
5
6
7
8
9
10
11
12
13
14
15
16
Nortel: DSFBC/AH, 1-RU CE
Nortel: DSFBC/AH, 2-RU CE
Nortel: SM/AH, 1-RU CE
Nortel: SM/AH, 2-RU CE
Intel: SM/RBF 16e, 1-RU CE
Samsung: SM/PC Subset DFT, 1-RU CE
LGE: SM/PC 16e, cycle 4 PRUs, 1-RU CE
LGE: SM/PC 16e, cycle 4 PRUs, 2-RU CE

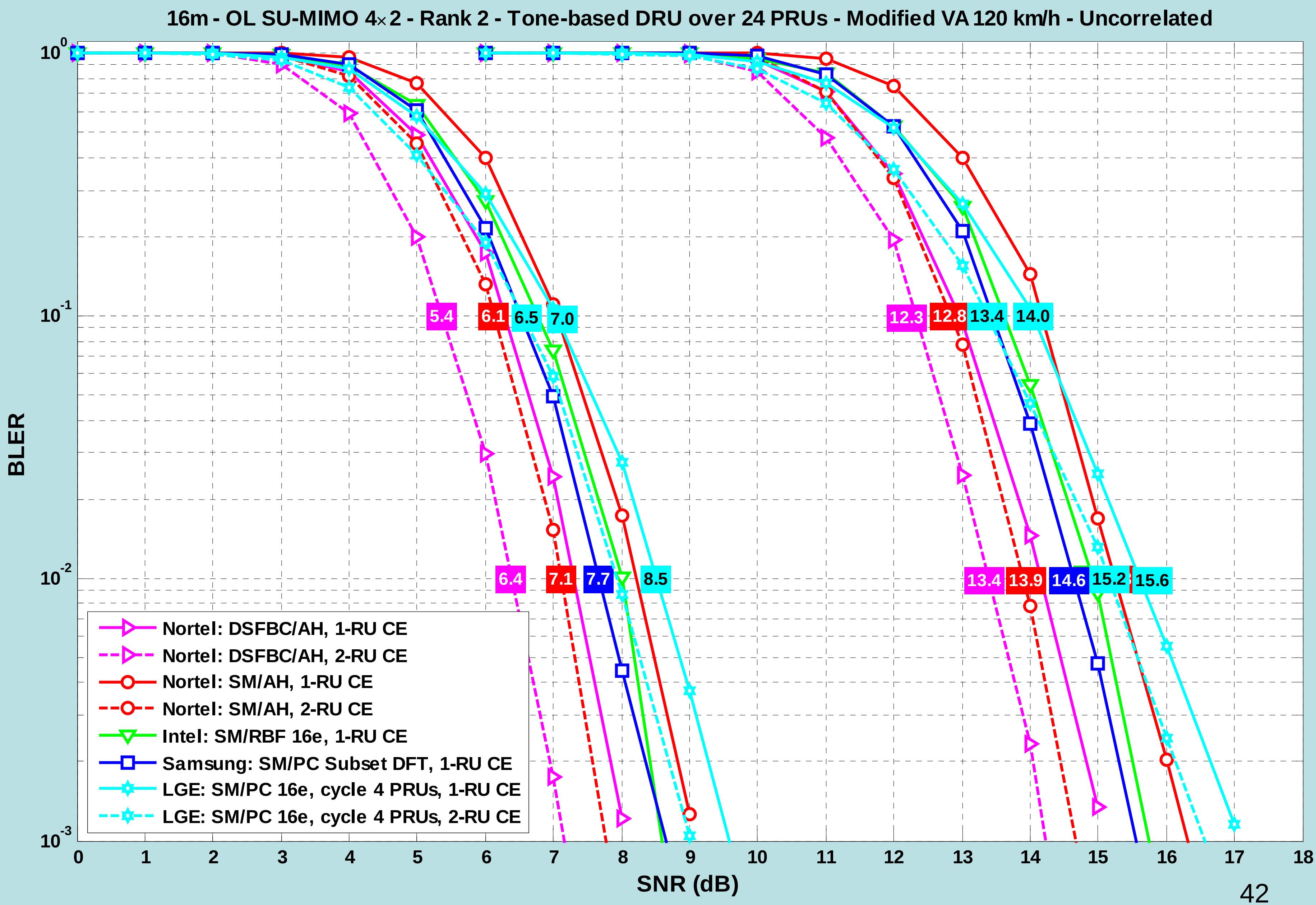

16m - OL SU-MIMO 4×2 - Rank 2 - Tone-based DRU over 8 PRUs - Modified VA 30 km/h - Uncorrelated
BLER
SNR (dB)
Nortel: DSFBC/AH, 1-RU CE
Nortel: DSFBC/AH, 2-RU CE
Nortel: SM/AH, 1-RU CE
Nortel: SM/AH, 2-RU CE
Intel: SM/RBF 16e, 1-RU CE
Samsung: SM/PC Subset DFT, 1-RU CE
LGE: SM/PC 16e, cycle 4 PRUs, 1-RU CE
LGE: SM/PC 16e, cycle 4 PRUs, 2-RU CE
5.8
6.1
6.9
7.1
12.5
13.6
14.2
7.1
7.5
8.1
8.5
9.2
4
14.2
15.1
15.9
17.1


16m - OL SU-MIMO 4×2 - Rank 2 - Tone-based DRU over 8 PRUs - Modified VA 30 km/h - Uncorrelated
Goodput [bits/tone]
SNR (dB)
0
0.5
1
1.5
2
2.5
3
3.5
4
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
Nortel: DSFBC/AH, 1-RU CE
Nortel: DSFBC/AH, 2-RU CE
Nortel: SM/AH, 1-RU CE
Nortel: SM/AH, 2-RU CE
Intel: SM/RBF 16e, 1-RU CE
Samsung: SM/PC Subset DFT, 1-RU CE
LGE: SM/PC 16e, cycle 4 PRUs, 1-RU CE
LGE: SM/PC 16e, cycle 4 PRUs, 2-RU CE

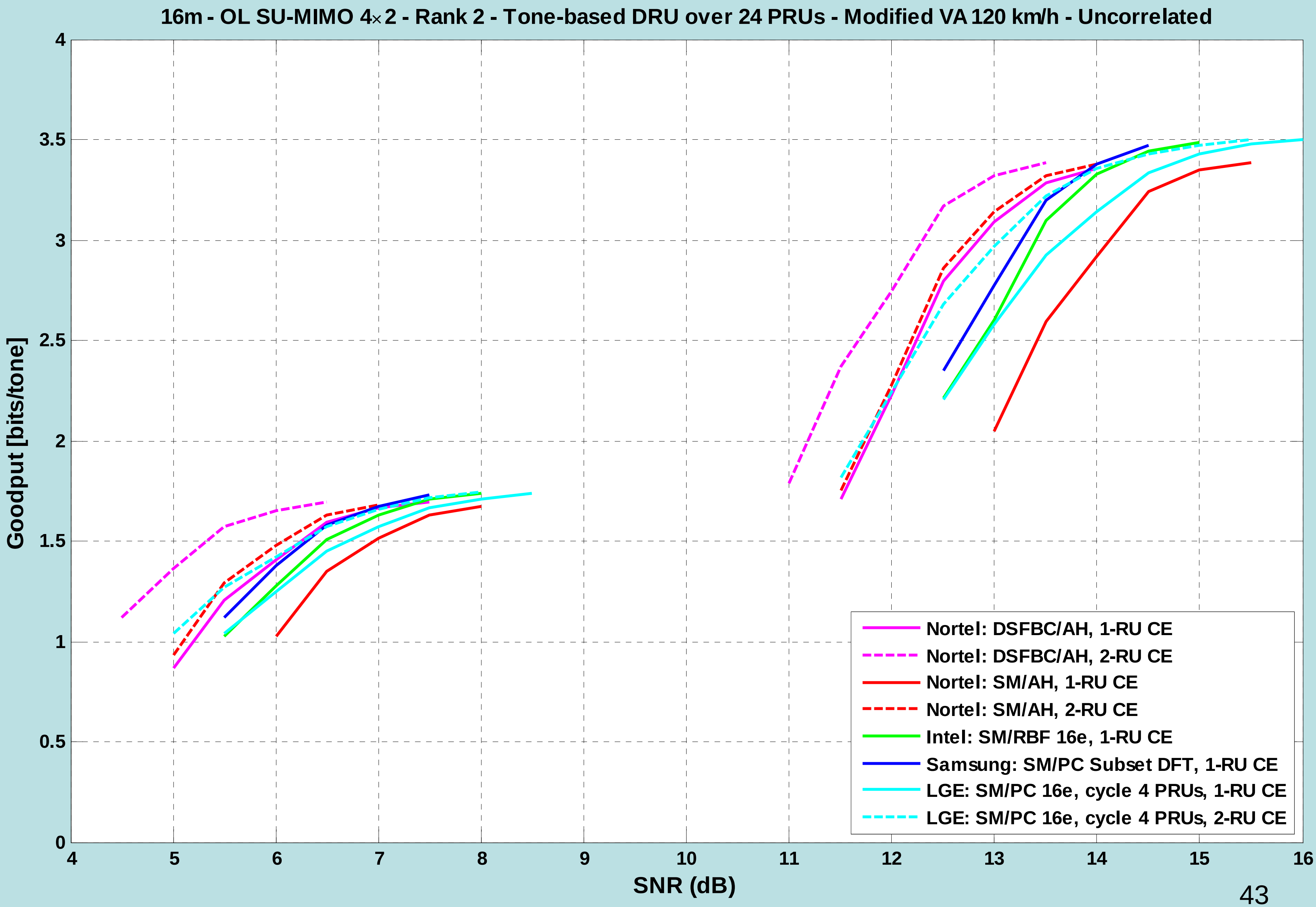
16m - OL SU-MIMO 4×2 - Rank 2 - RU-based DRU - Modified VA 30 km/h - Uncorrelated



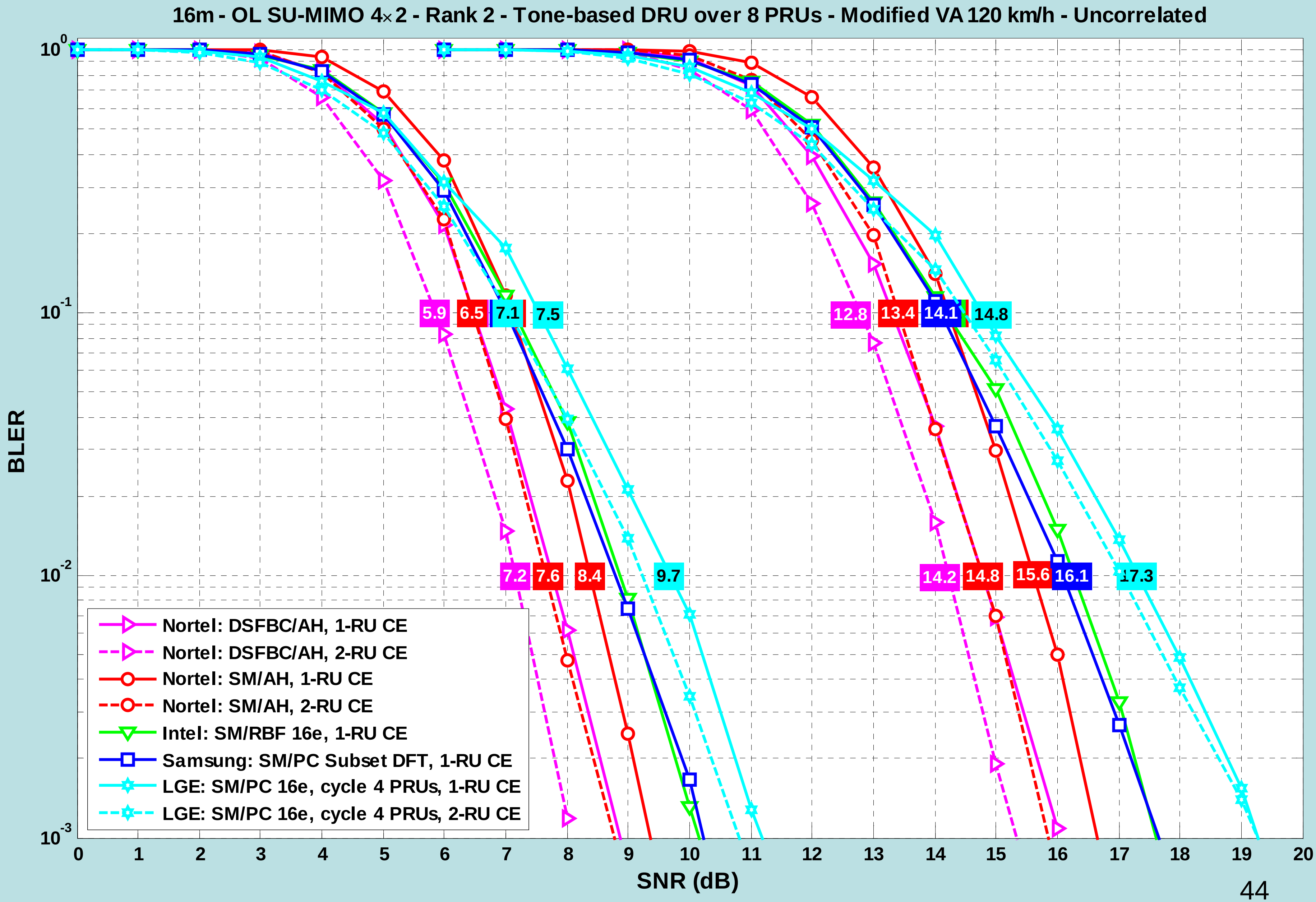

16m - OL SU-MIMO 4×2 - Rank 2 - RU-based DRU - Modified VA 30 km/h - Uncorrelated
Goodput [bits/tone]
SNR (dB)
0
0.5
1
1.5
2
2.5
3
3.5
4
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
Nortel: DSFBC/AH, 1-RU CE
Nortel: DSFBC/AH, 2-RU CE
Nortel: SM/AH, 1-RU CE
Nortel: SM/AH, 2-RU CE
Intel: SM/RBF 16e, 1-RU CE
Samsung: SM/PC Subset DFT, 1-RU CE
LGE: SM/PC 16e, cycle 4 PRUs, 1-RU CE
LGE: SM/PC 16e, cycle 4 PRUs, 2-RU CE

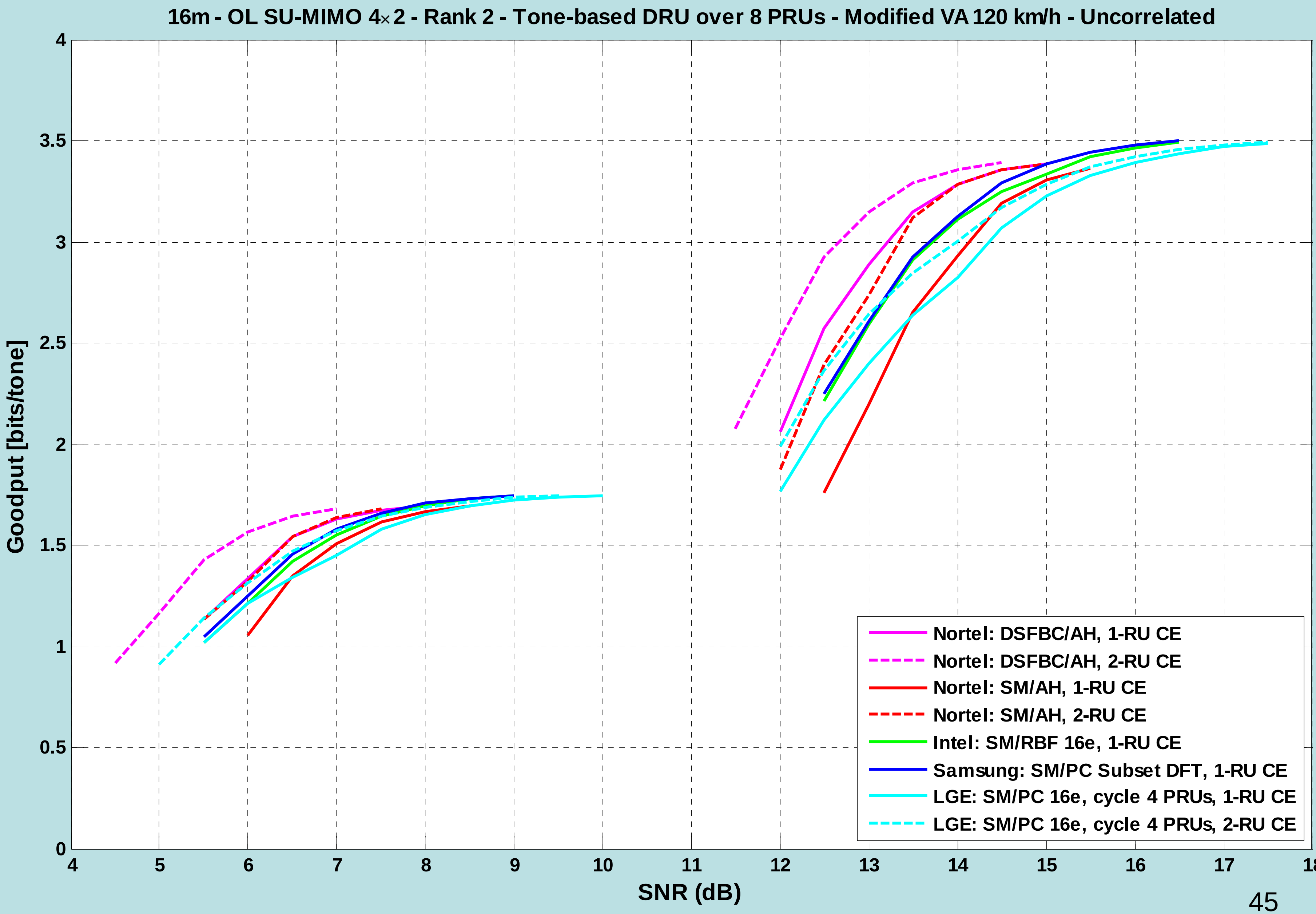


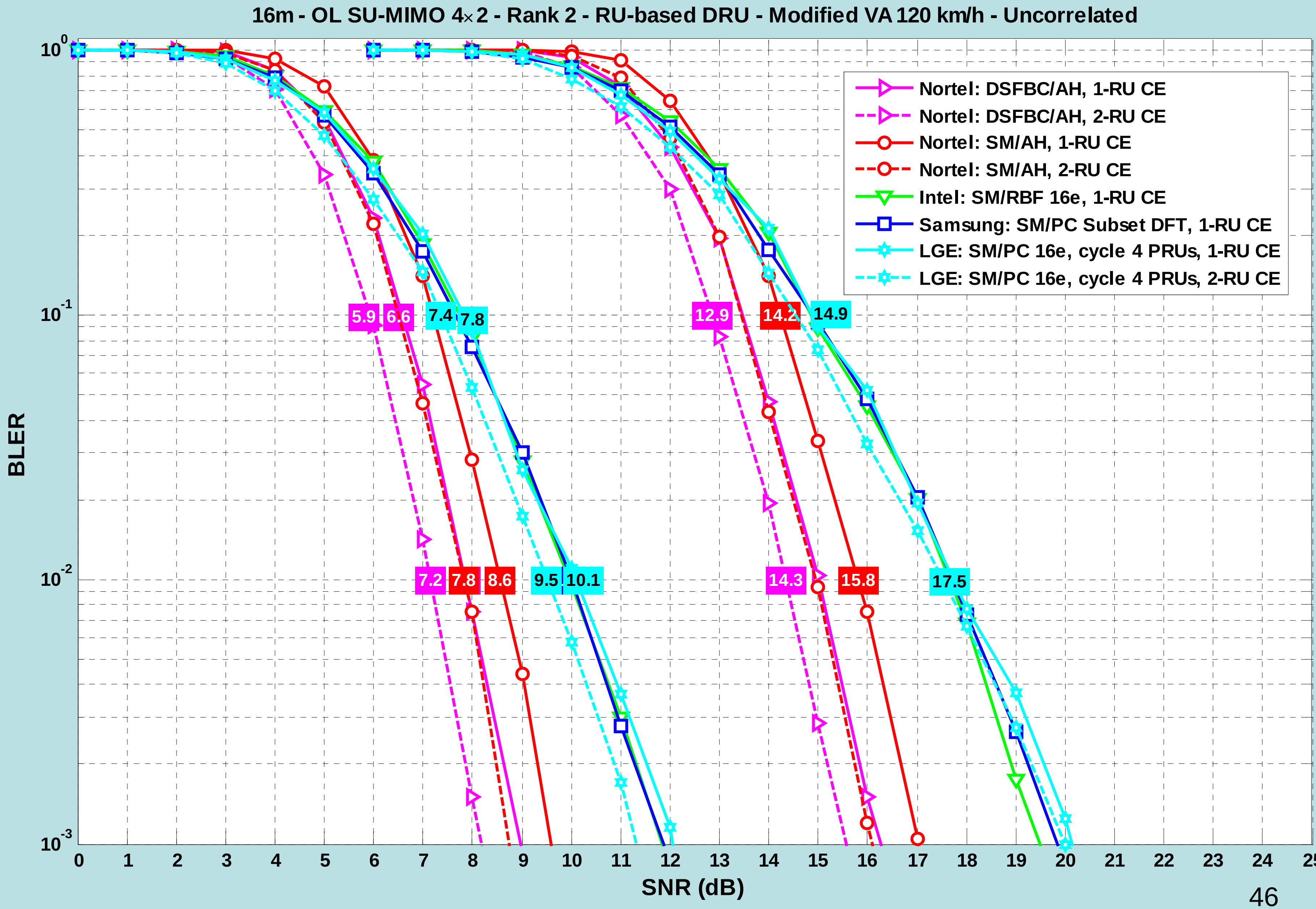
16m - OL SU-MIMO 4×2 - Rank 2 - Tone-based DRU over 24 PRUs - Modified VA 120 km/h - Uncorrelated
BLER
SNR (dB)
5.4
6.1
6.5
7.0
12.3
12.8
13.4
14.0
6.4
7.1
7.7
8.5
13.4
13.9
14.6
15.2
15.6
Nortel: DSFBC/AH, 1-RU CE
Nortel: DSFBC/AH, 2-RU CE
Nortel: SM/AH, 1-RU CE
Nortel: SM/AH, 2-RU CE
Intel: SM/RBF 16e, 1-RU CE
Samsung: SM/PC Subset DFT, 1-RU CE
LGE: SM/PC 16e, cycle 4 PRUs, 1-RU CE
LGE: SM/PC 16e, cycle 4 PRUs, 2-RU CE

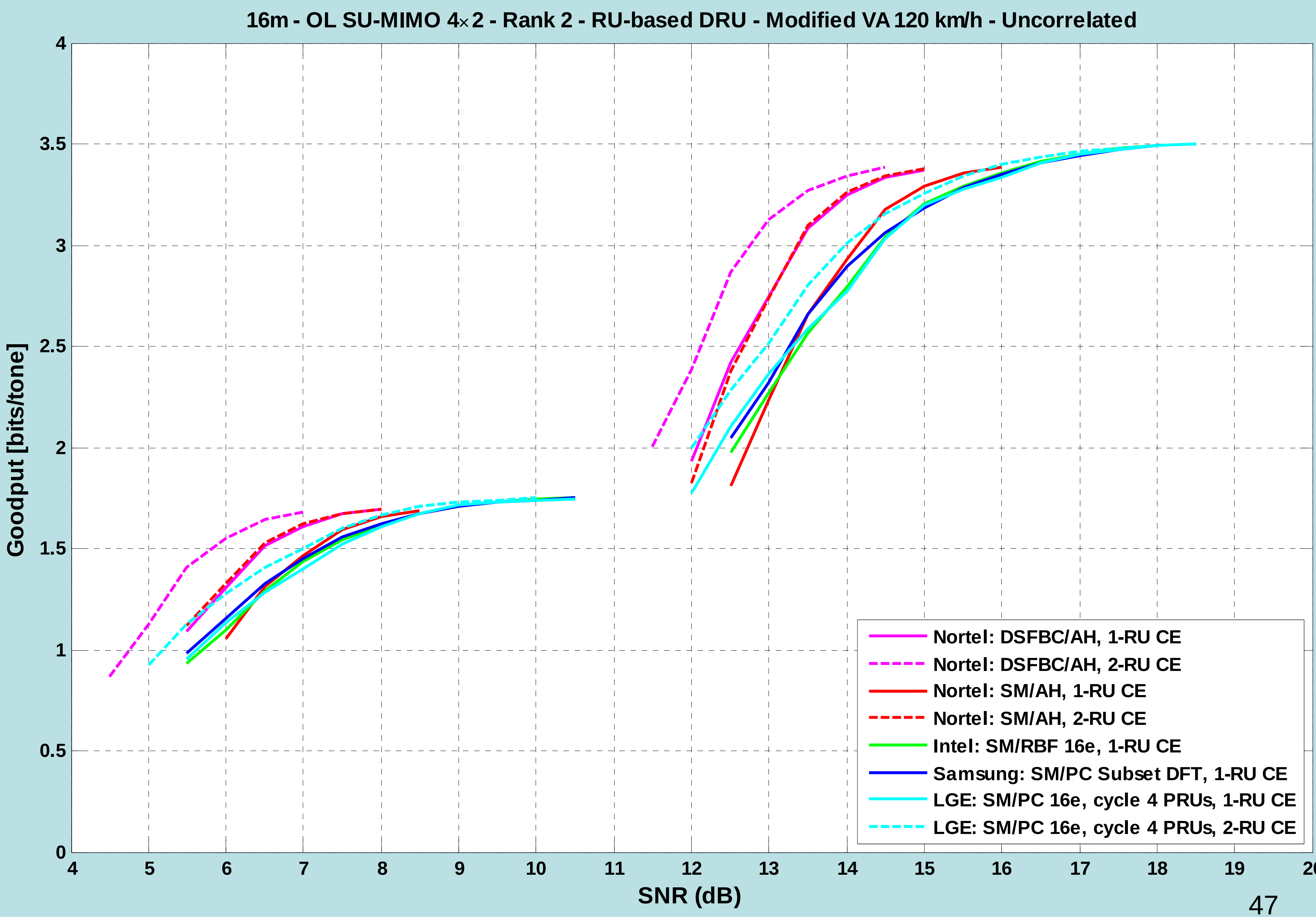


16m - OL SU-MIMO 4×2 - Rank 2 - Tone-based DRU over 24 PRUs - Modified VA 120 km/h - Uncorrelated
Goodput [bits/tone]
SNR (dB)
0
0.5
1
1.5
2
2.5
3
3.5
4
4
5
6
7
8
9
10
11
12
13
14
15
16
Nortel: DSFBC/AH, 1-RU CE
Nortel: DSFBC/AH, 2-RU CE
Nortel: SM/AH, 1-RU CE
Nortel: SM/AH, 2-RU CE
Intel: SM/RBF 16e, 1-RU CE
Samsung: SM/PC Subset DFT, 1-RU CE
LGE: SM/PC 16e, cycle 4 PRUs, 1-RU CE
LGE: SM/PC 16e, cycle 4 PRUs, 2-RU CE


16m - OL SU-MIMO 4×2 - Rank 2 - Tone-based DRU over 8 PRUs - Modified VA 120 km/h - Uncorrelated
BLER
SNR (dB)
5.9
6.5
7.1
7.5
12.8
13.4
14.1
14.8
7.2
7.6
8.4
9.7
14.2
14.8
15.6
16.1
17.3
Nortel: DSFBC/AH, 1-RU CE
Nortel: DSFBC/AH, 2-RU CE
Nortel: SM/AH, 1-RU CE
Nortel: SM/AH, 2-RU CE
Intel: SM/RBF 16e, 1-RU CE
Samsung: SM/PC Subset DFT, 1-RU CE
LGE: SM/PC 16e, cycle 4 PRUs, 1-RU CE
LGE: SM/PC 16e, cycle 4 PRUs, 2-RU CE


16m - OL SU-MIMO 4×2 - Rank 2 - Tone-based DRU over 8 PRUs - Modified VA 120 km/h - Uncorrelated
Goodput [bits/tone]
SNR (dB)
4
3.5
3
2.5
2
1.5
1
0.5
0
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
Nortel: DSFBC/AH, 1-RU CE
Nortel: DSFBC/AH, 2-RU CE
Nortel: SM/AH, 1-RU CE
Nortel: SM/AH, 2-RU CE
Intel: SM/RBF 16e, 1-RU CE
Samsung: SM/PC Subset DFT, 1-RU CE
LGE: SM/PC 16e, cycle 4 PRUs, 1-RU CE
LGE: SM/PC 16e, cycle 4 PRUs, 2-RU CE


16m - OL SU-MIMO 4×2 - Rank 2 - RU-based DRU - Modified VA 120 km/h - Uncorrelated
BLER
SNR (dB)
10^0
10^{-1}
10^{-2}
10^{-3}
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
Nortel: DSFBC/AH, 1-RU CE
Nortel: DSFBC/AH, 2-RU CE
Nortel: SM/AH, 1-RU CE
Nortel: SM/AH, 2-RU CE
Intel: SM/RBF 16e, 1-RU CE
Samsung: SM/PC Subset DFT, 1-RU CE
LGE: SM/PC 16e, cycle 4 PRUs, 1-RU CE
LGE: SM/PC 16e, cycle 4 PRUs, 2-RU CE
5.9
6.6
7.4
7.8
12.9
14.2
14.9
7.2
7.8
8.6
9.5
10.1
14.3
15.8
17.5



16m - OL SU-MIMO 4×2 - Rank 2 - RU-based DRU - Modified VA 120 km/h - Uncorrelated
Goodput [bits/tone]
SNR (dB)
0
0.5
1
1.5
2
2.5
3
3.5
4
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
Nortel: DSFBC/AH, 1-RU CE
Nortel: DSFBC/AH, 2-RU CE
Nortel: SM/AH, 1-RU CE
Nortel: SM/AH, 2-RU CE
Intel: SM/RBF 16e, 1-RU CE
Samsung: SM/PC Subset DFT, 1-RU CE
LGE: SM/PC 16e, cycle 4 PRUs, 1-RU CE
LGE: SM/PC 16e, cycle 4 PRUs, 2-RU CE

Discussion

The Difference Between Common Pilot and Dedicated Pilot (1/2)

- Common pilot
  - It is possible to change OL MIMO precoder form tone to tone (not form RU to RU) to get more space diversity within the coherence time and coherence bandwidth of the fading channel
  - No need for midamble for the sake of channel measurement
  - Ability of multiple-RU channel estimation to reduce channel estimation loss
    - More than 0.7 dB gain even for 2-RU channel estimation
  - Overhead is 14.8% which is higher than dedicated pilot
    - According to the simulation results, antenna hopping with common pilot provides better goodput compare to precoder cycling with dedicated pilot

The Difference Between Common Pilot and Dedicated Pilot (2/2)

- Dedicated pilot
  - One OL precoder is used for each PRU and pilots are passed through the same precoder as the data tones
    - Lower space diversity due to the fixed precoder within one PRU
  - Channel estimation is limited to one PRU
    - Channel estimation loss is higher compare to common pilot with multiple-RU channel estimation capability
    - If one fixed precoder applied to multiple contiguous PRUs, it is possible to do multiple-RU channel estimation for dedicated pilots as well. However, fixed precoder over multiple RUs reduces the space diversity of the system and eventually the gain due to multiple-RU channel estimation is negligible.
  - Need for midamble for the sake of channel measurement
    - If a punctured OFDMA symbol is assigned to midamble every superframe, it causes 8/18 x100/46% ~ 1% extra overhead
      - For 4 Tx case, 2 pilots per PRU, in total 8 pilots/PRU are needed for midamble
  - Pilot overhead is 11.1% which is lower than common pilot
    - Although overhead is less, according to the simulation results, AH with common pilot provides better goodput compare to precoder cycling with dedicated pilot

Multiple-RU Channel Estimation Is Possible Even for FFR Case

- 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-08/003r5), 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 subband 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.

Comparison of RU-Based and Tone-Based DRU Resource Allocation (1/4)

- Tone-based DRU provides more frequency diversity only if the number of RUs allocated to LDRU zone is large enough, otherwise RU-based and tone-based DRU performs identically.
  - If 4 FFR zone exist and each FFR zone is partitioned into two equal size LDRU and LLRU zones, the number of RUs allocated to the LDRU partition of each FFR zone is limited to only 6 RUs for 10 MHz bandwidth

Comparison of RU-Based and Tone-Based DRU Resource Allocation (2/4)

- Higher frequency diversity of the tone-based DRU helps to improve the performance only if one or two RUs is allocated to a user
  - If number of RUs allocated to a user is two or more, the advantage of tone-based over RU-based DRU diminishes

Comparison of RU-Based and Tone-Based DRU Resource Allocation (3/4)

- Antenna hopping (AH) scheme reduces the performance gap between tone-based and RU-based resource allocation
  - According to the simulation results, the performance degradation of AH scheme with RU-based DRU is less than 0.8 dB with respect to AH with tone-based DRU allocation

Comparison of RU-Based and Tone-Based DRU Resource Allocation (4/4)

- If AH scheme is used with RU-based DRU, there is no need for tone-based DRU zone partitioning
  - better MAC efficiency since there is no need to define multiple DRU zones per sub-frame

Conclusion

Overall Conclusion

- 4 Tx Rate 1
  - SFBC/AH where precoder is changed form tone to tone in the both frequency and time directions
  - Common pilot
- 4 Tx Rate 2
  - SM/AH where precoder is changed form tone to tone in the both frequency and time directions
  - Common pilot
- FFR zone outer-permutation unit should be set at 2 or more PRUs to leverage from the channel estimation performance gain of 0.7dB or more