Project: IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs)

Submission Title: Preliminary Performance of FEC Schemes in TG3d Channels

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Re: n/a

Abstract: This contribution provides a first assessment of the considered modulation and coding schemes for realistic channels from the TG3d channel model.

Purpose: Contribution towards developing the PHY for use in TG 3d

Preliminary Performance of FEC Schemes in TG3d Channels

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TU Braunschweig

Outline

- MCS / Scenario Overview
- MCS Performance
  - Close Proximity P2P
  - Intra-Device
  - Backhaul / Fronthaul
  - Data Center
- ISI Impact Estimation
- Implication to Link Budget

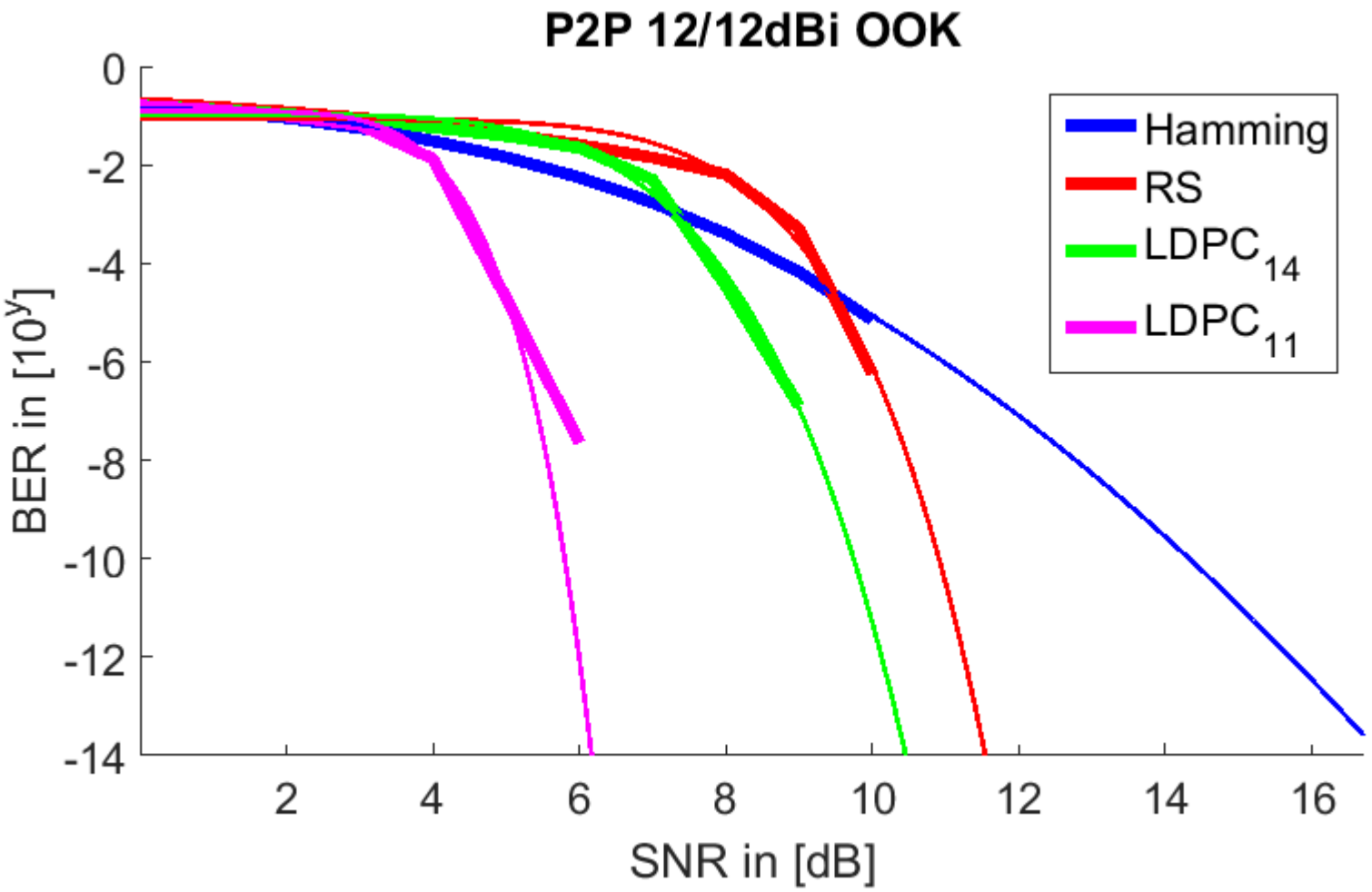
MCS/Scenario Overview

- The following modulation schemes have been simulated so far:
  - On/Off-Keying
  - BPSK
  - QPSK
  - 8-PSK
  - 8-APSK
  - 16-QAM
  - 64-QAM
- The following forward error correction types have been implemented:
  - (7,4) – Hamming code
  - Reed-Solomon Code (255,239) in GF(2^8)
  - Rate 11/15 LDPC (1440,1056)
  - Rate 14/15 LDPC (1440,1344)
- The following transfer functions from the data sets defined in the CMD have been utilized:
  - Close-Proximity: #m1 of CloseProximityP2P_S1_TX12_RX12.txt
  - Intra-Device: #m1 of TG3d_Intra_Device_B2Bv_6dBi.txt
    #m1 of TG3d_Intra_Device_B2Bv_18dBi.txt
  - Back-/Fronthaul: AWGN Channel
  - Data Center: #m1 of TG3d_Data_Center_Type_1&2_position_1_antenna_1.txt
    #m1 of TG3d_Data_Center_Type_1&2_position_1_antenna_3.txt

MCS Performance

- Up to now, the MCSs under test have been evaluated by simulations using **at most 10^8 modulation symbol**s.
- Above that, the SNR/BER **curves have been extrapolated** based on a function of the form $(BER_{log}) = a \cdot (SNR_{log})^b + c$ to predict at which SNR a target BER of 10^{-12} is reached
- When the simulations for all envisaged application cases and MCSs are finished, a selected sub-set of simulations will be performed with a higher number of symbols to **verify the extrapolated behavior**.

Close Proximity: 12dBi Tx / 12dBi Rx



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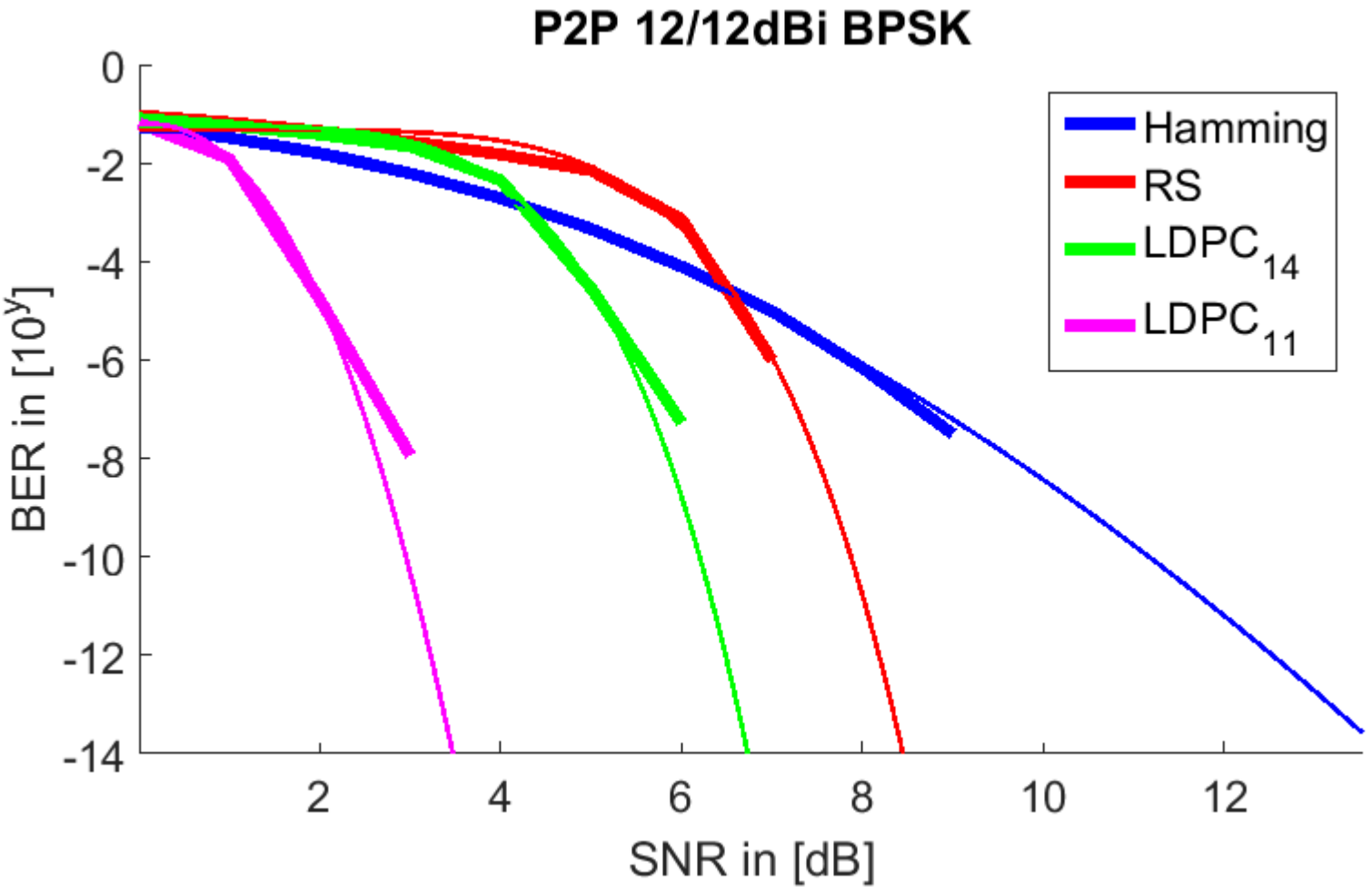

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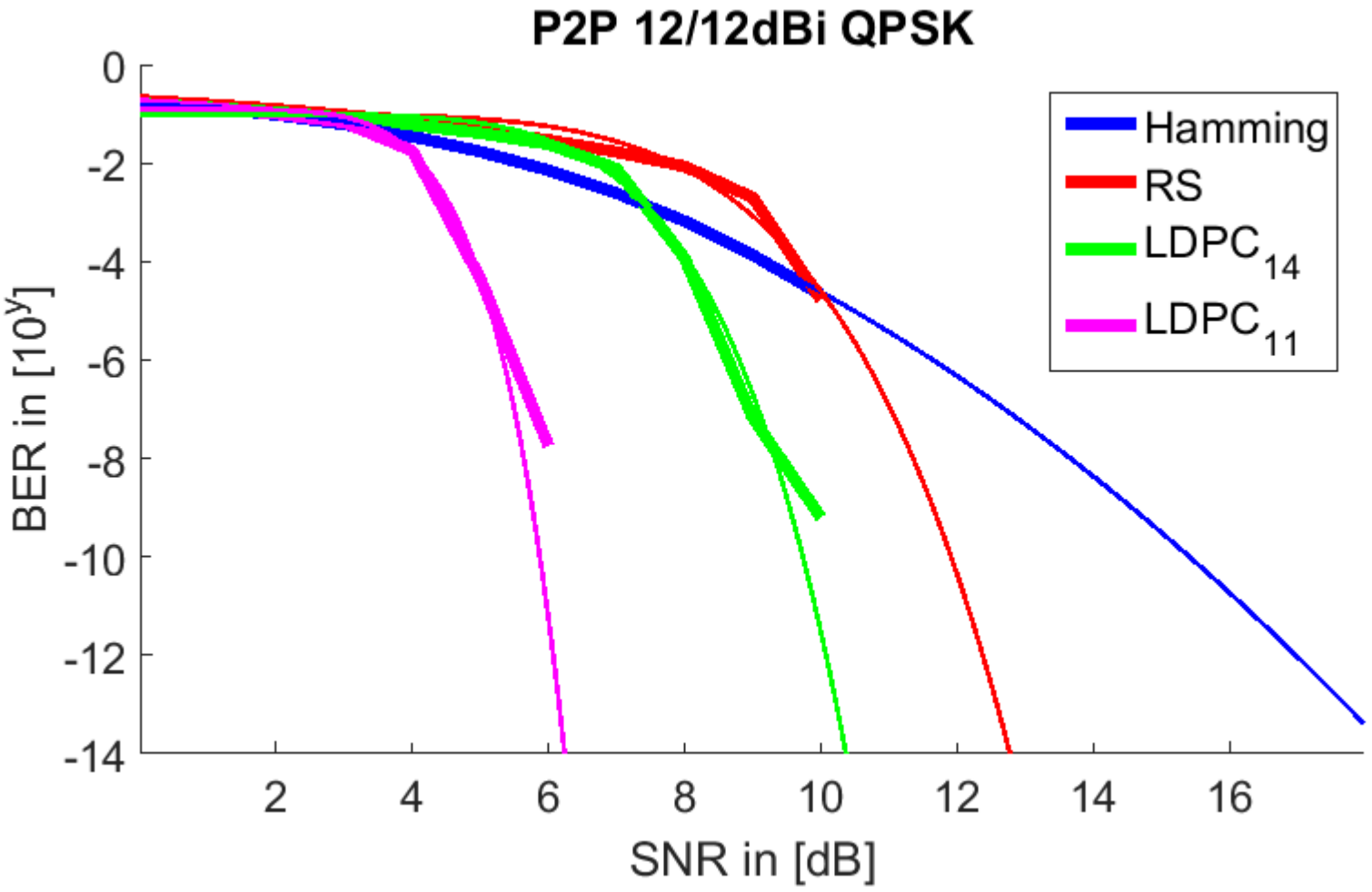

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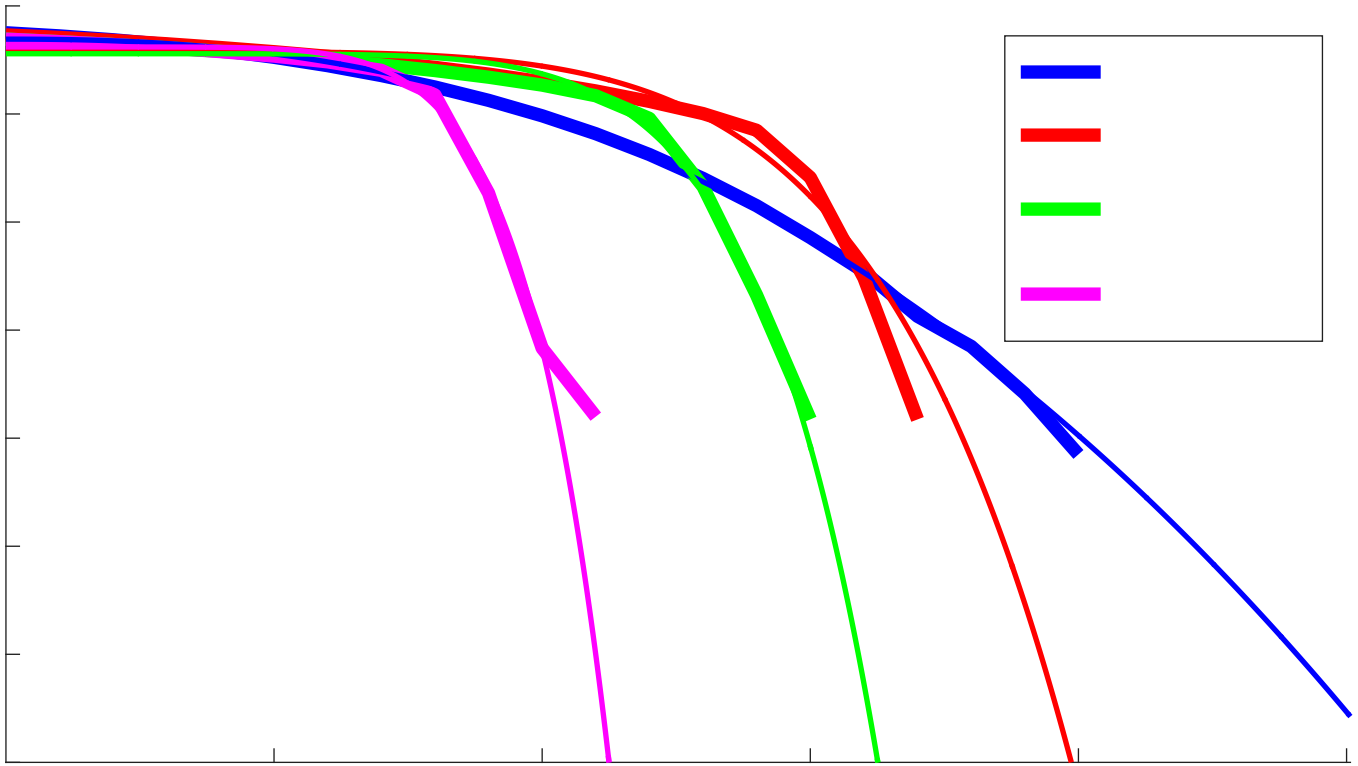

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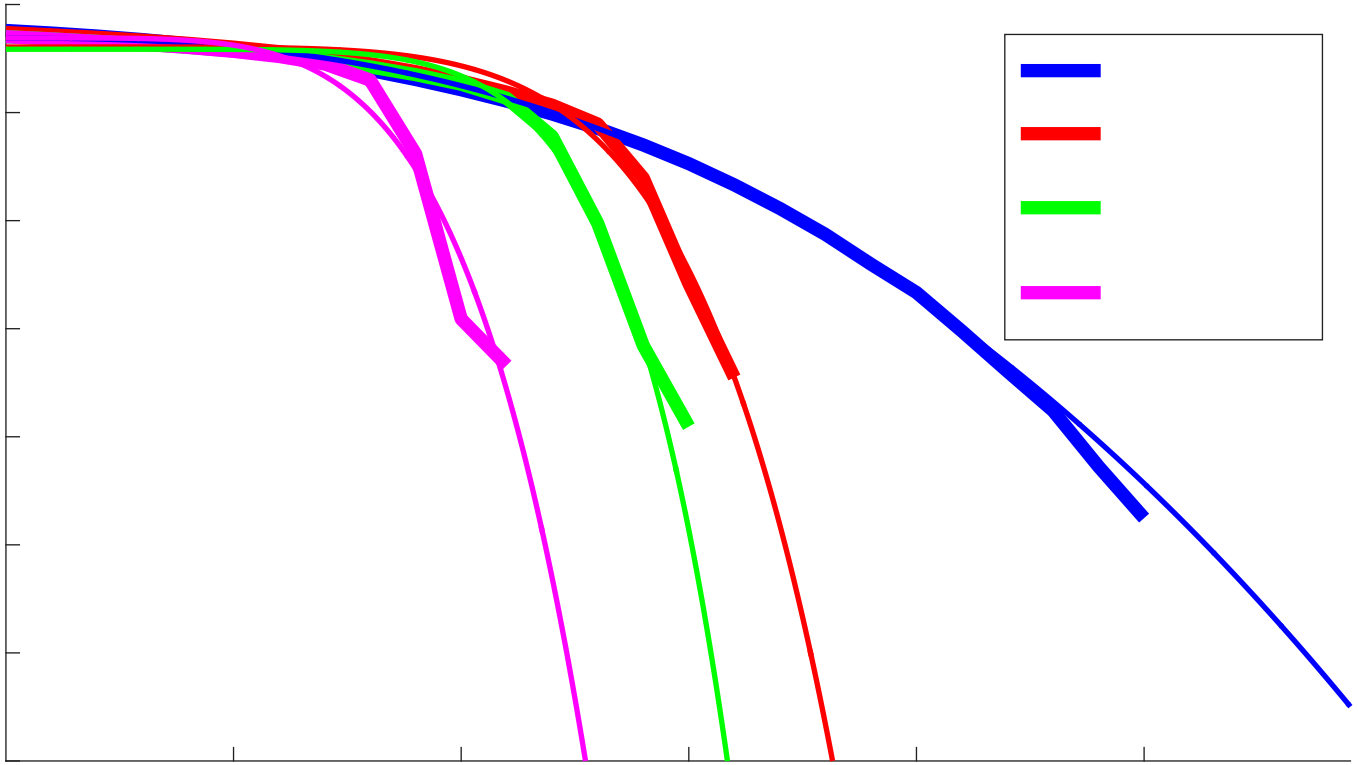

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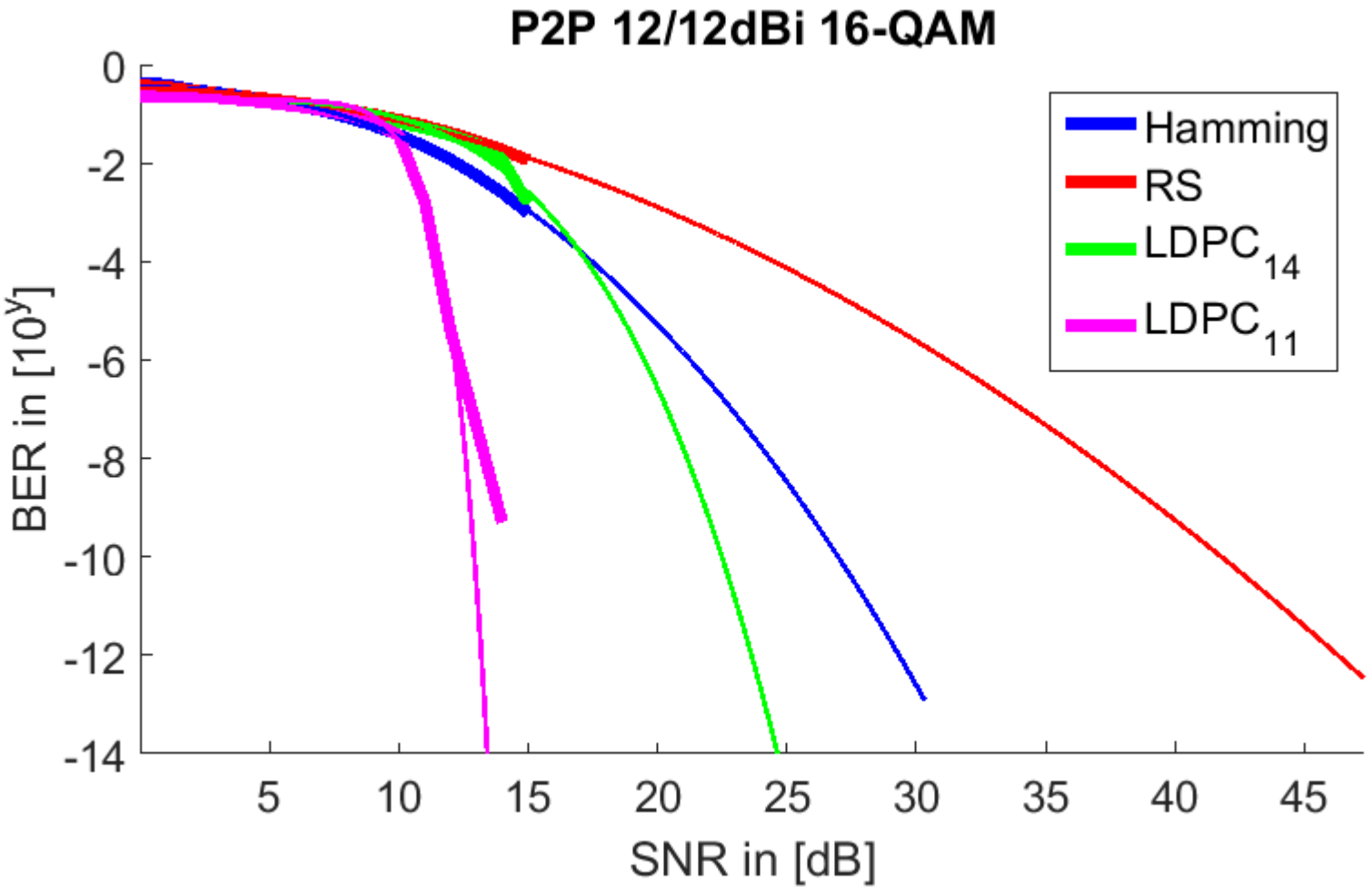

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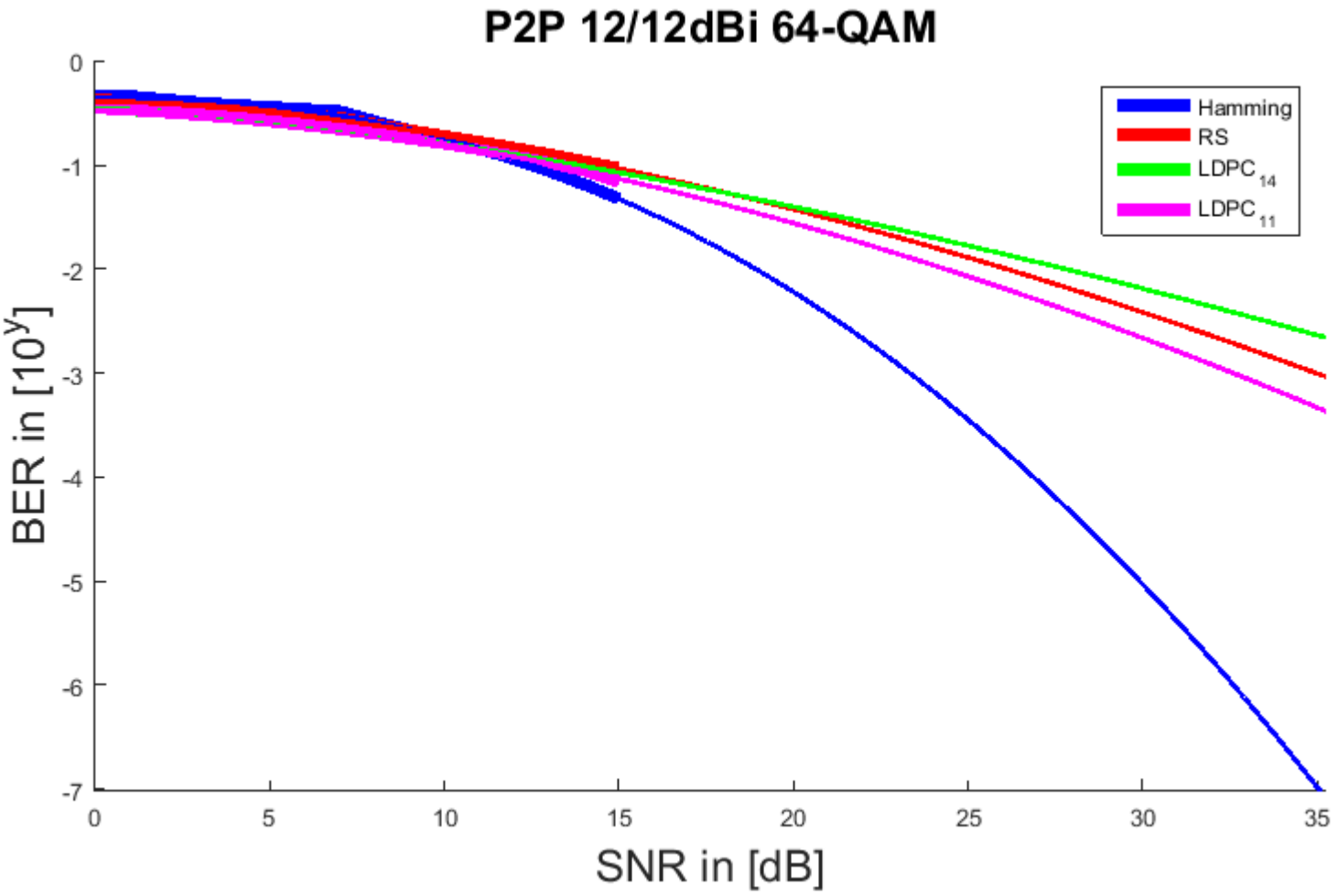

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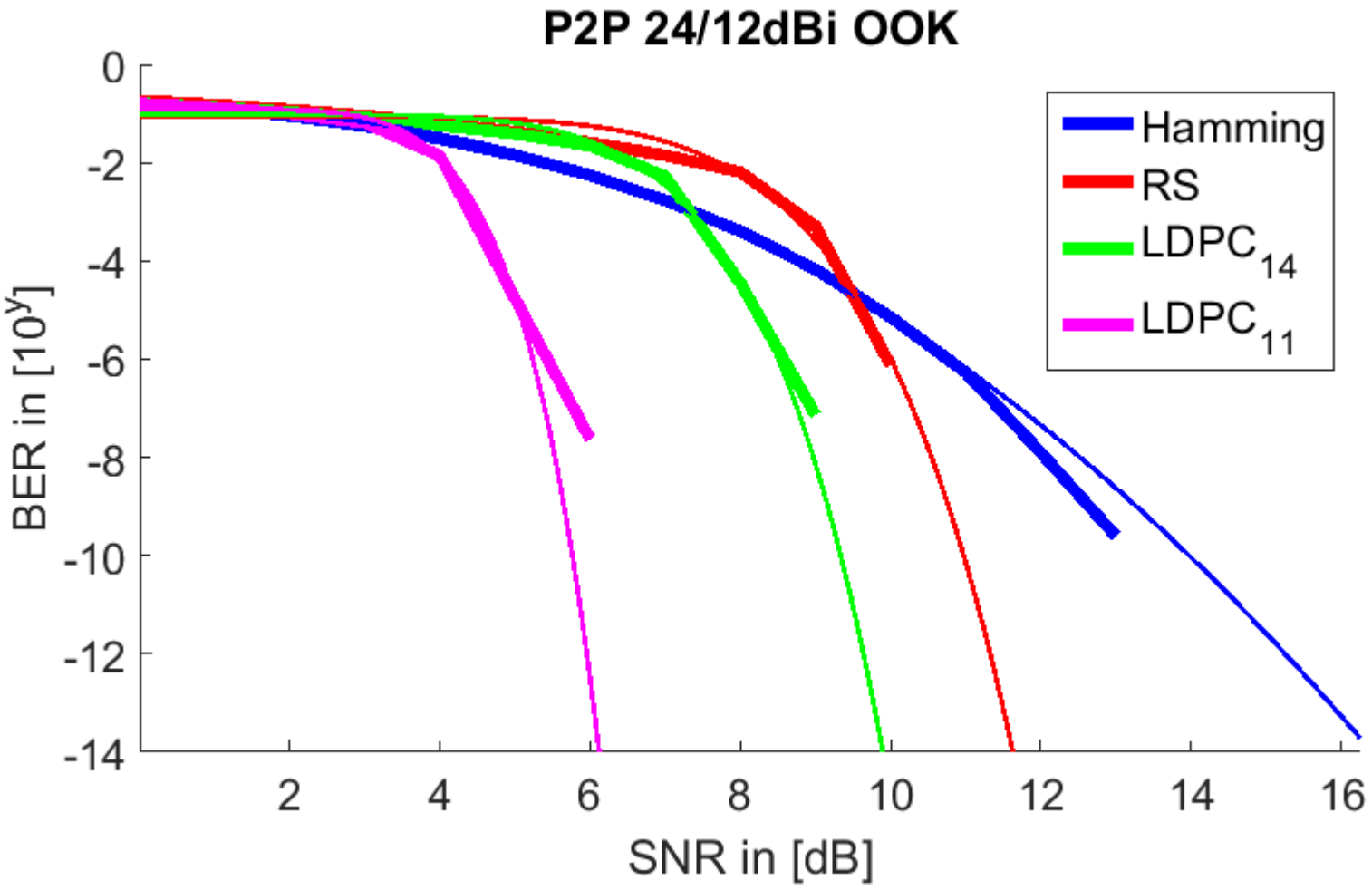

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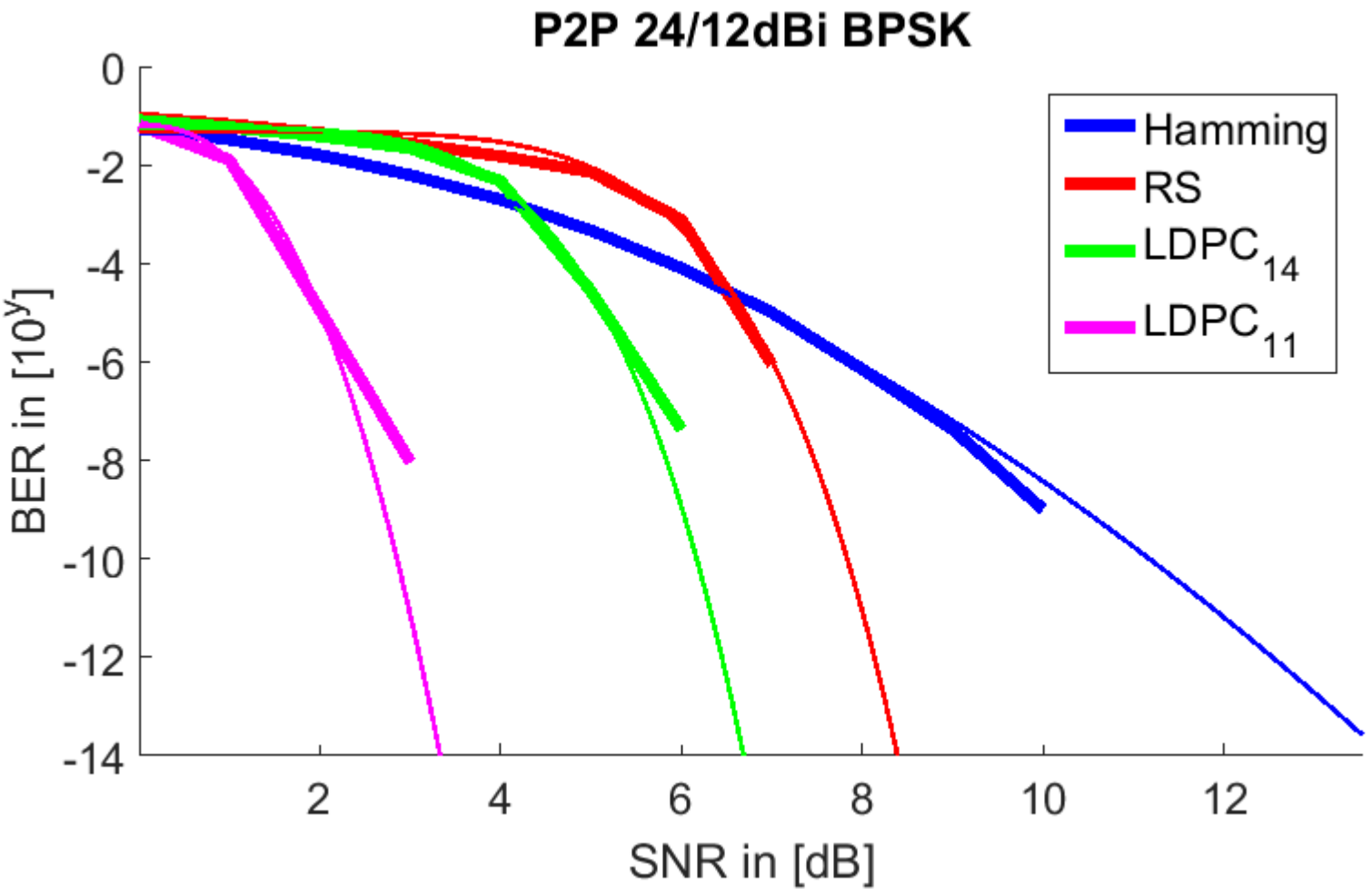

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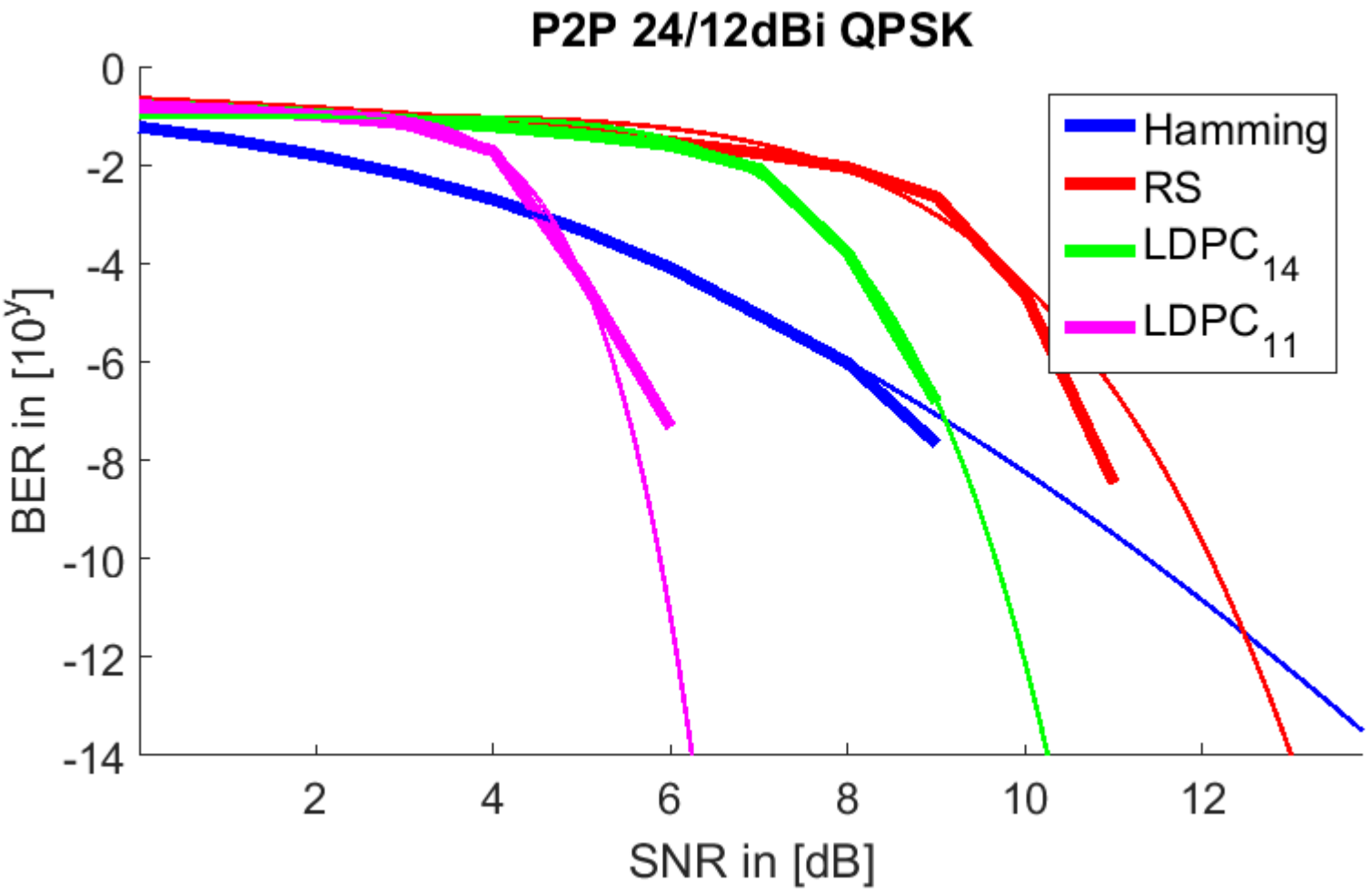
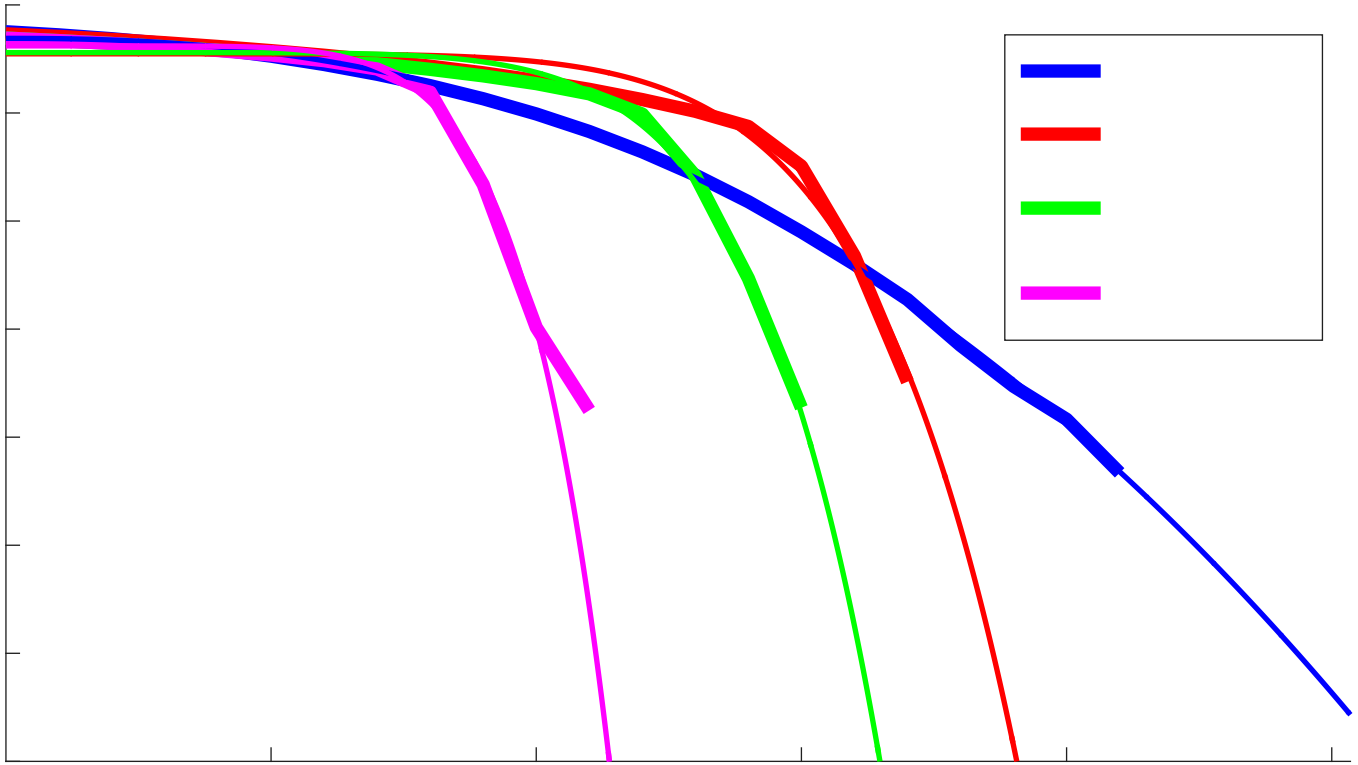


Close Proximity: 24dBi Tx / 12dBi Rx



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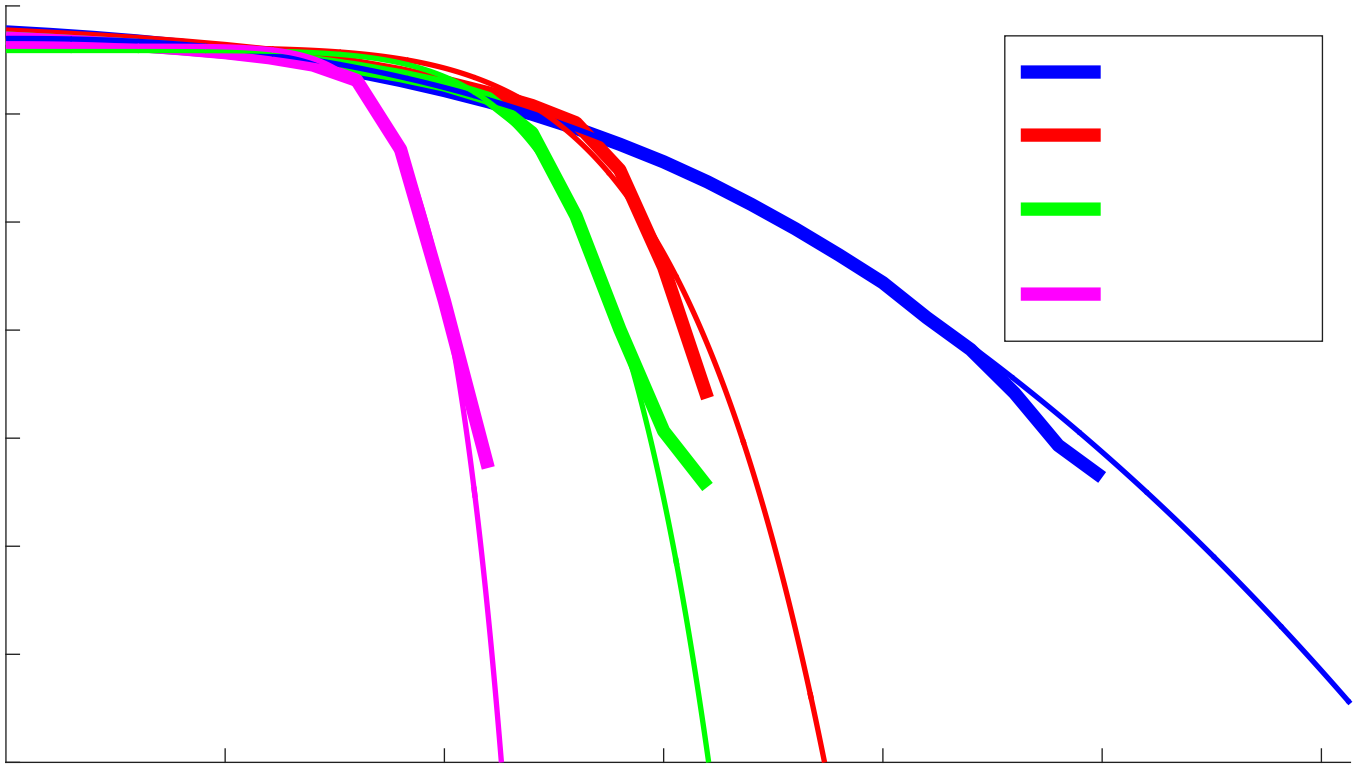

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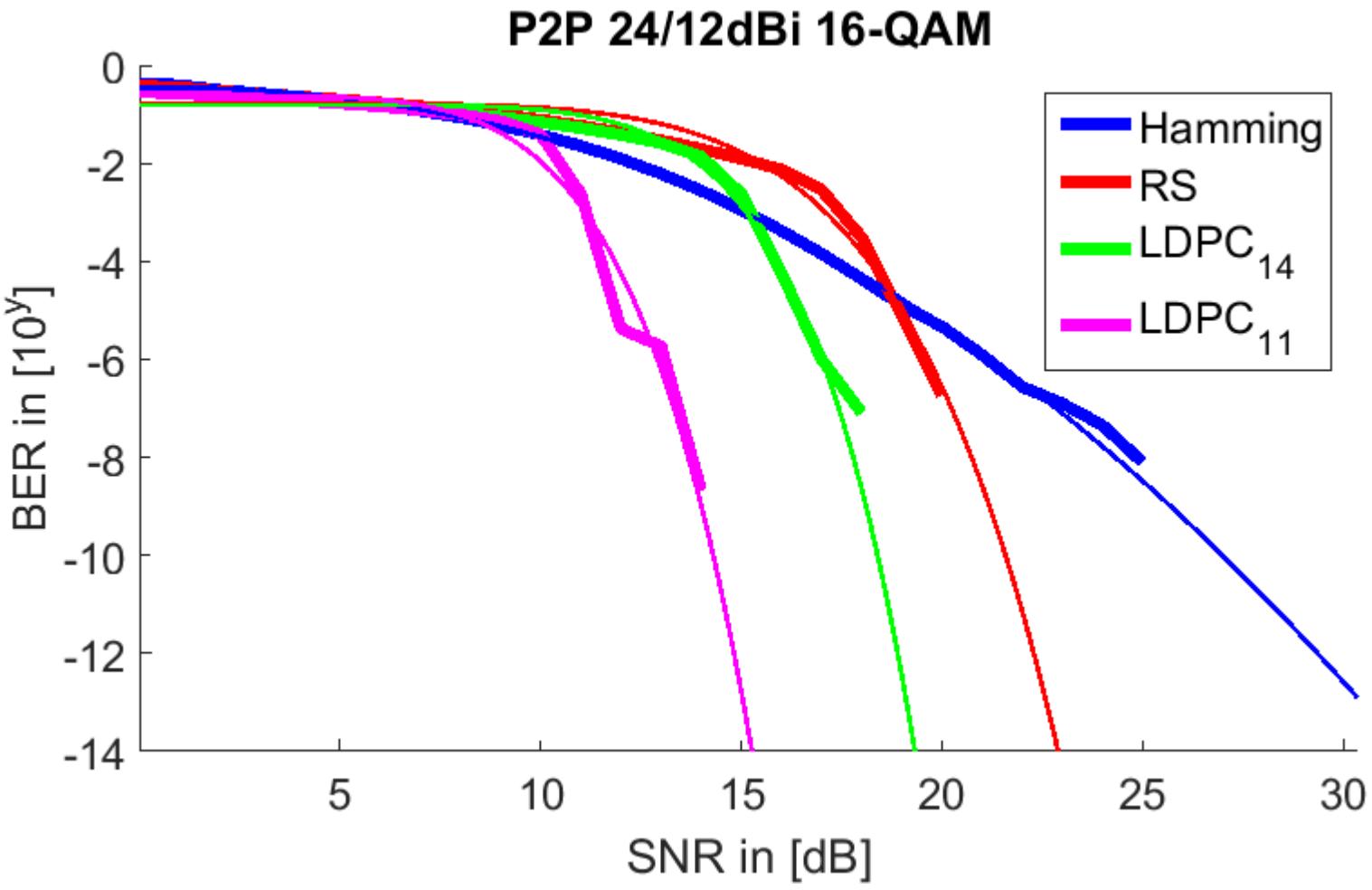

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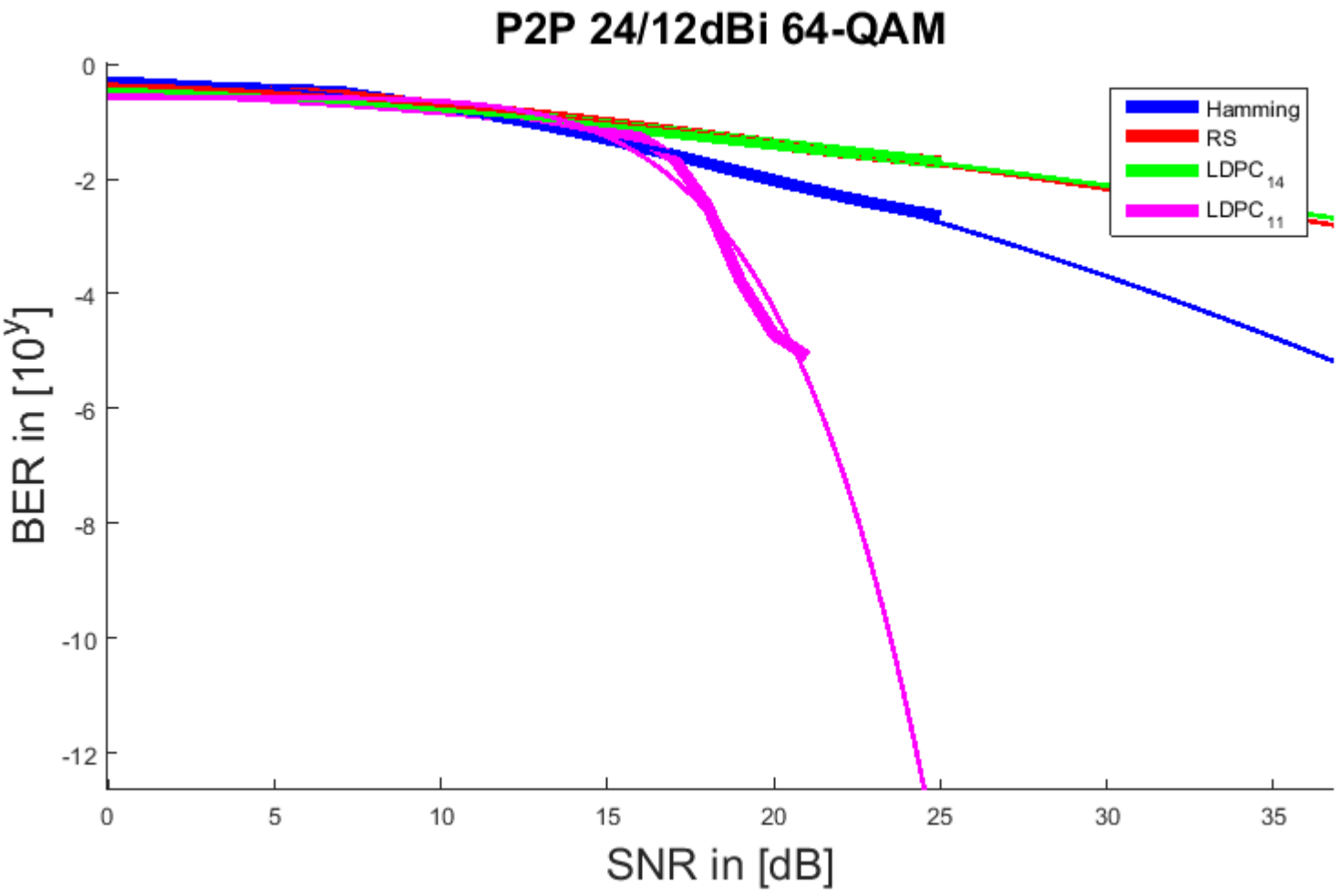
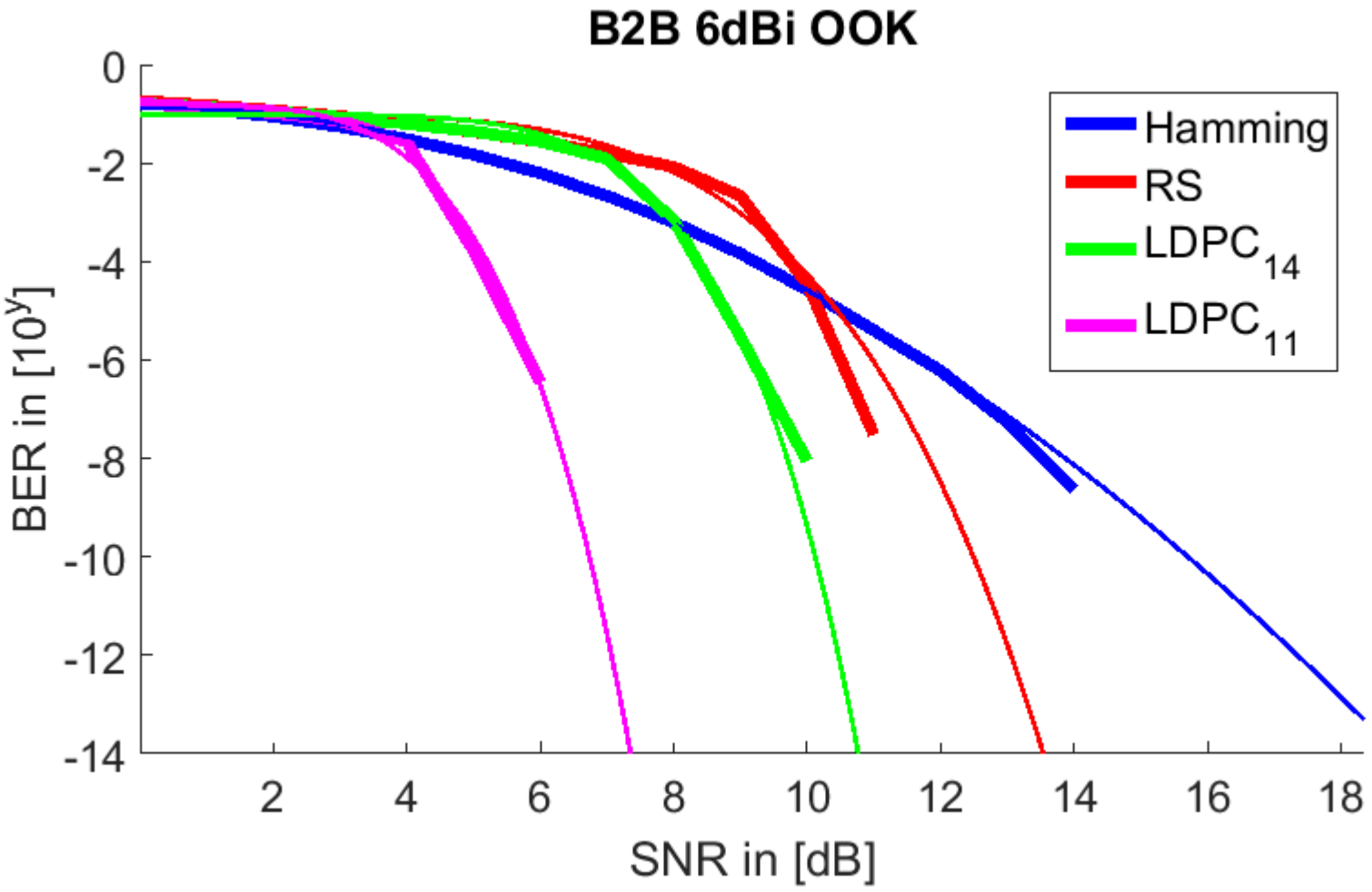


Intra-Device: 6dBi



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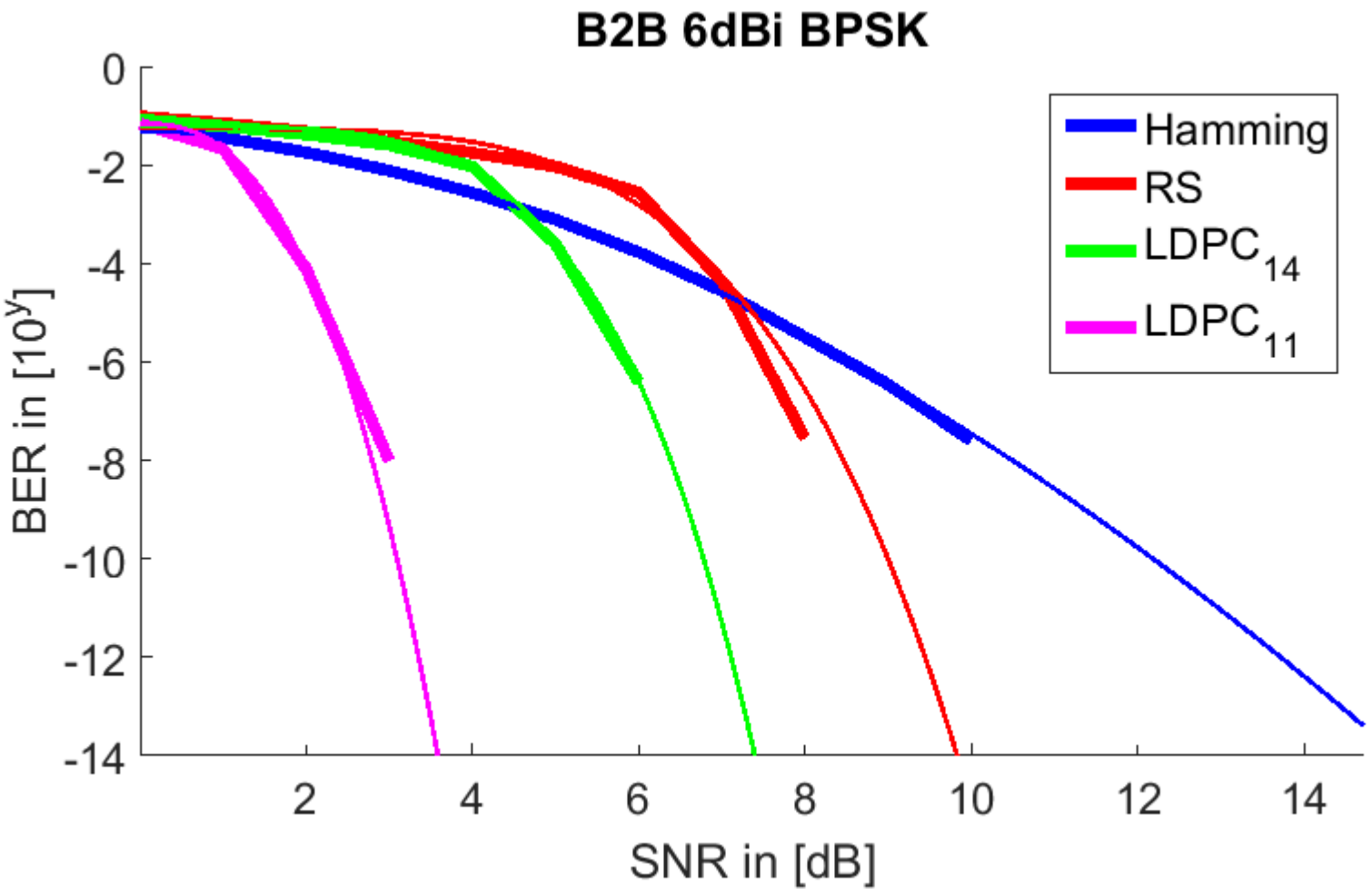

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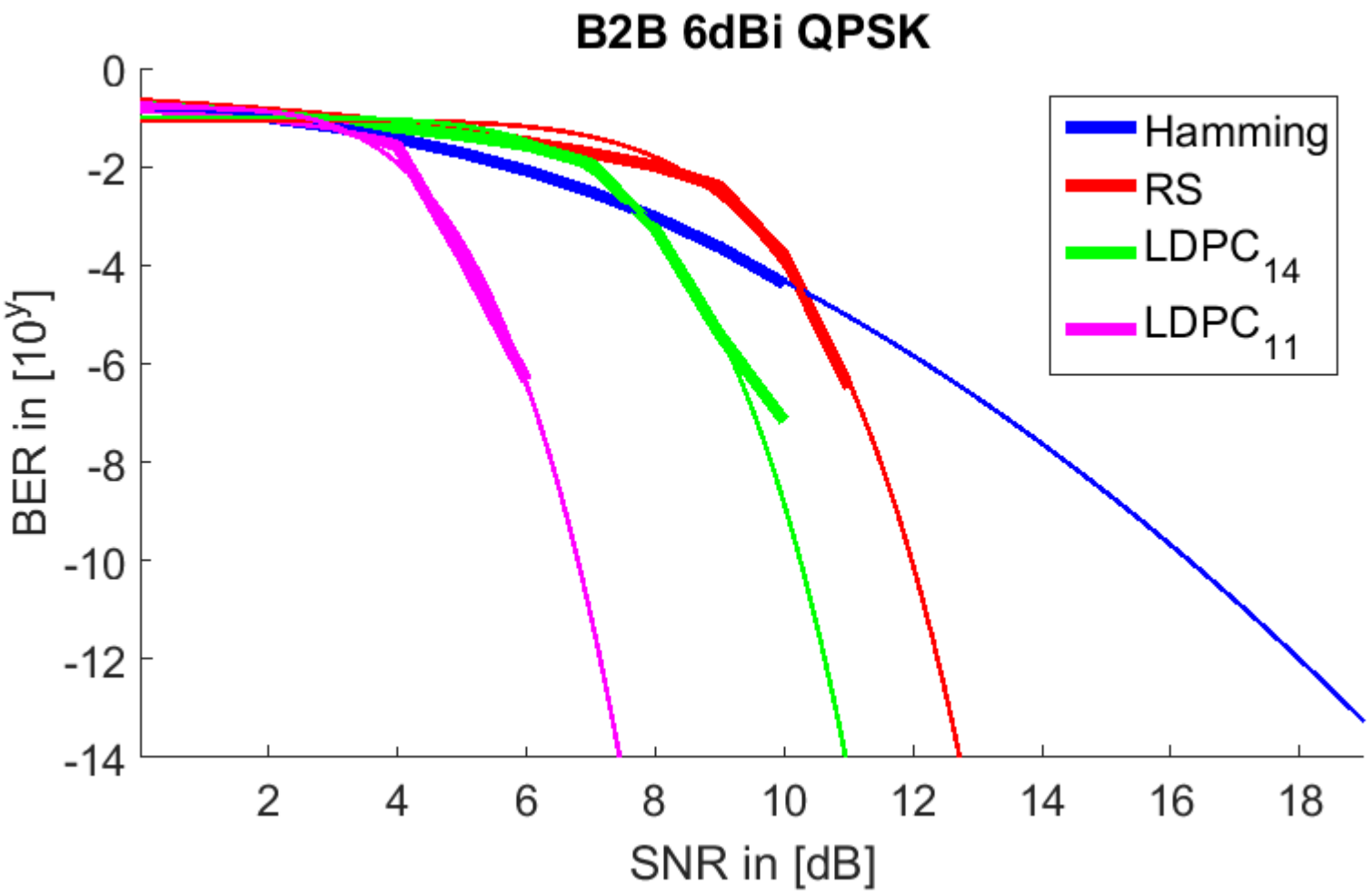

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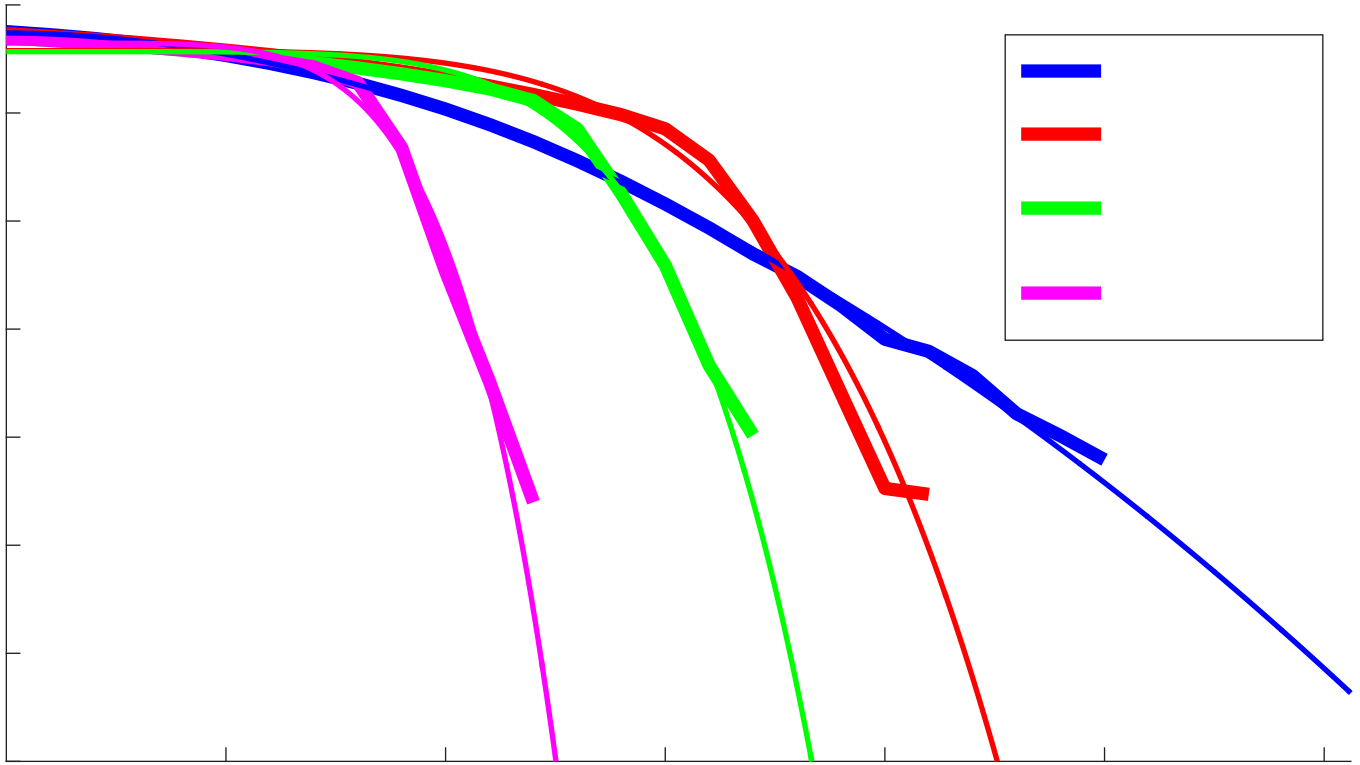

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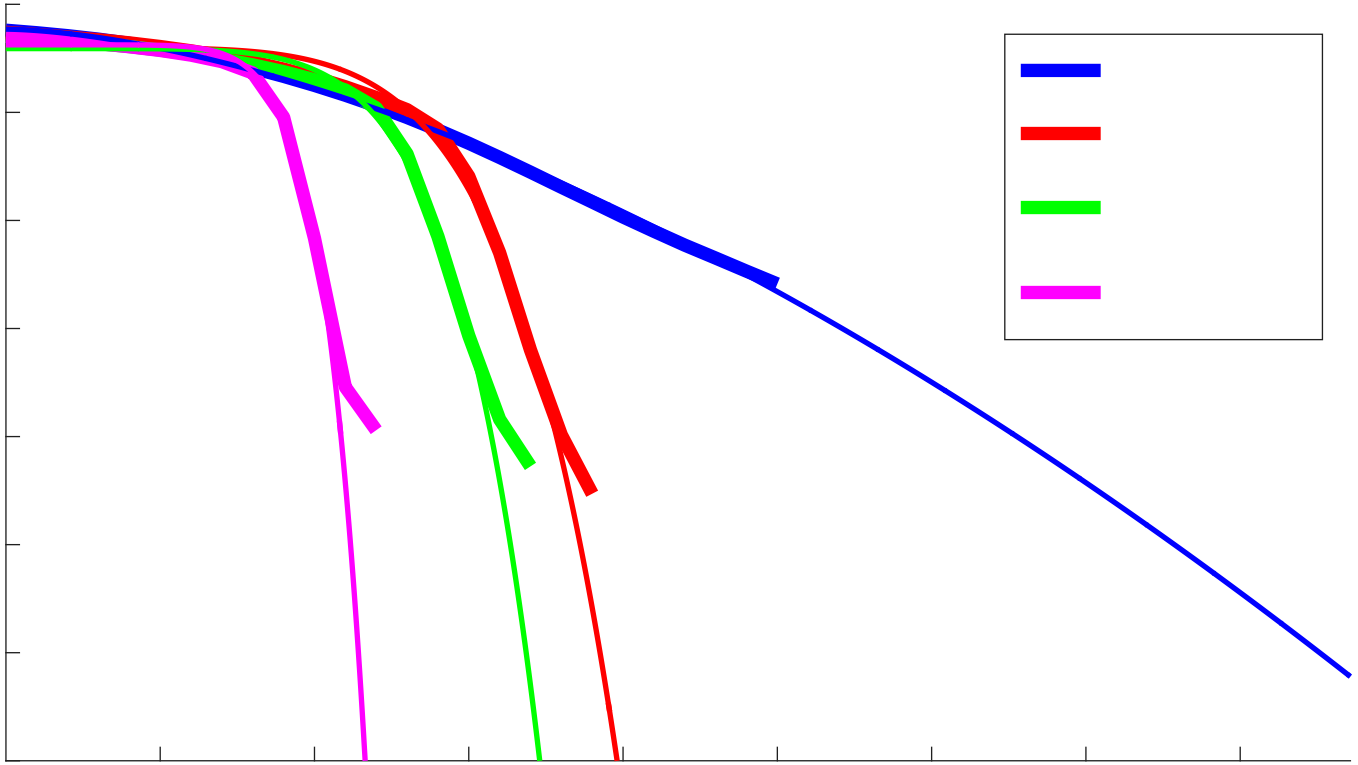

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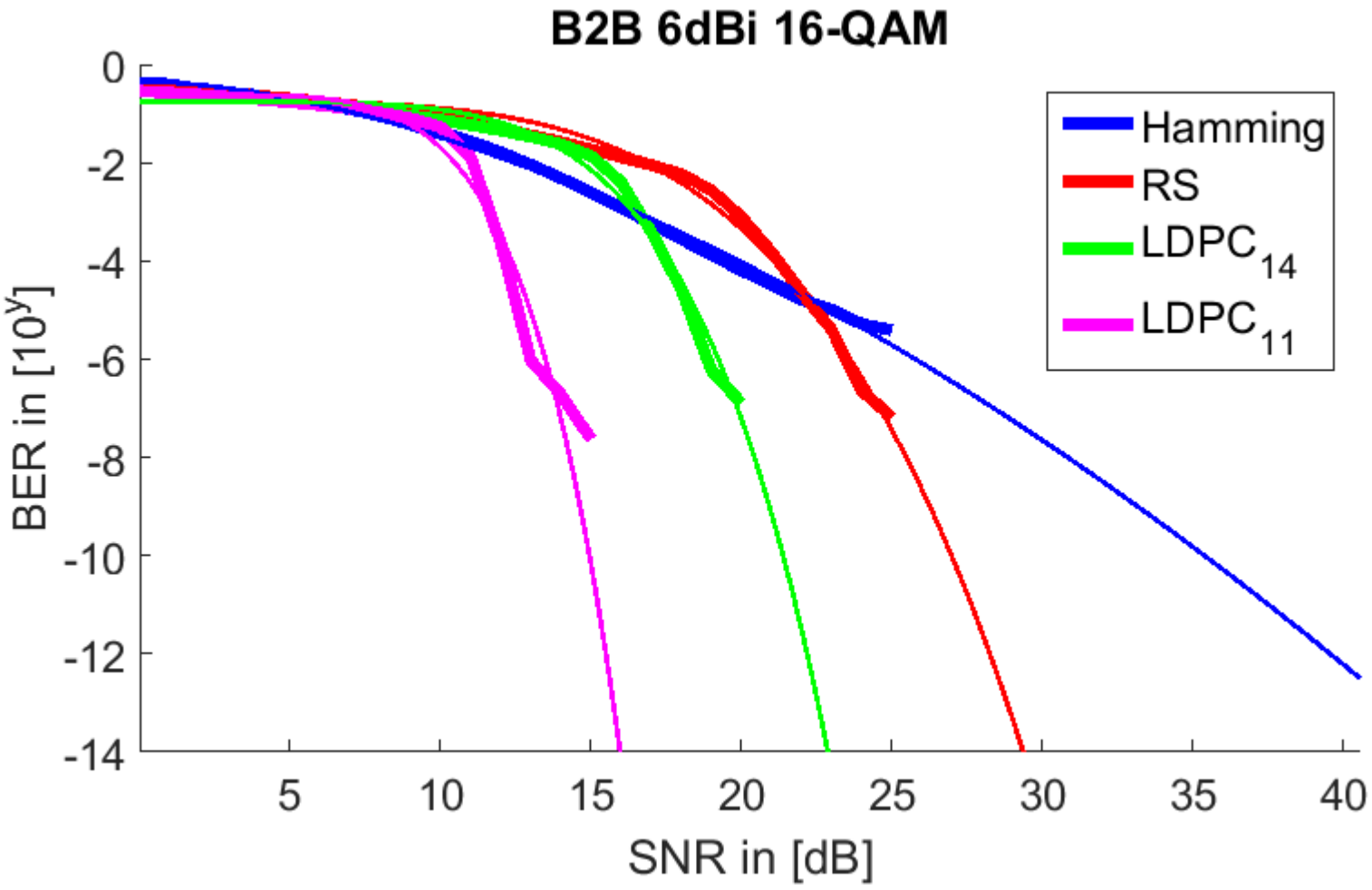

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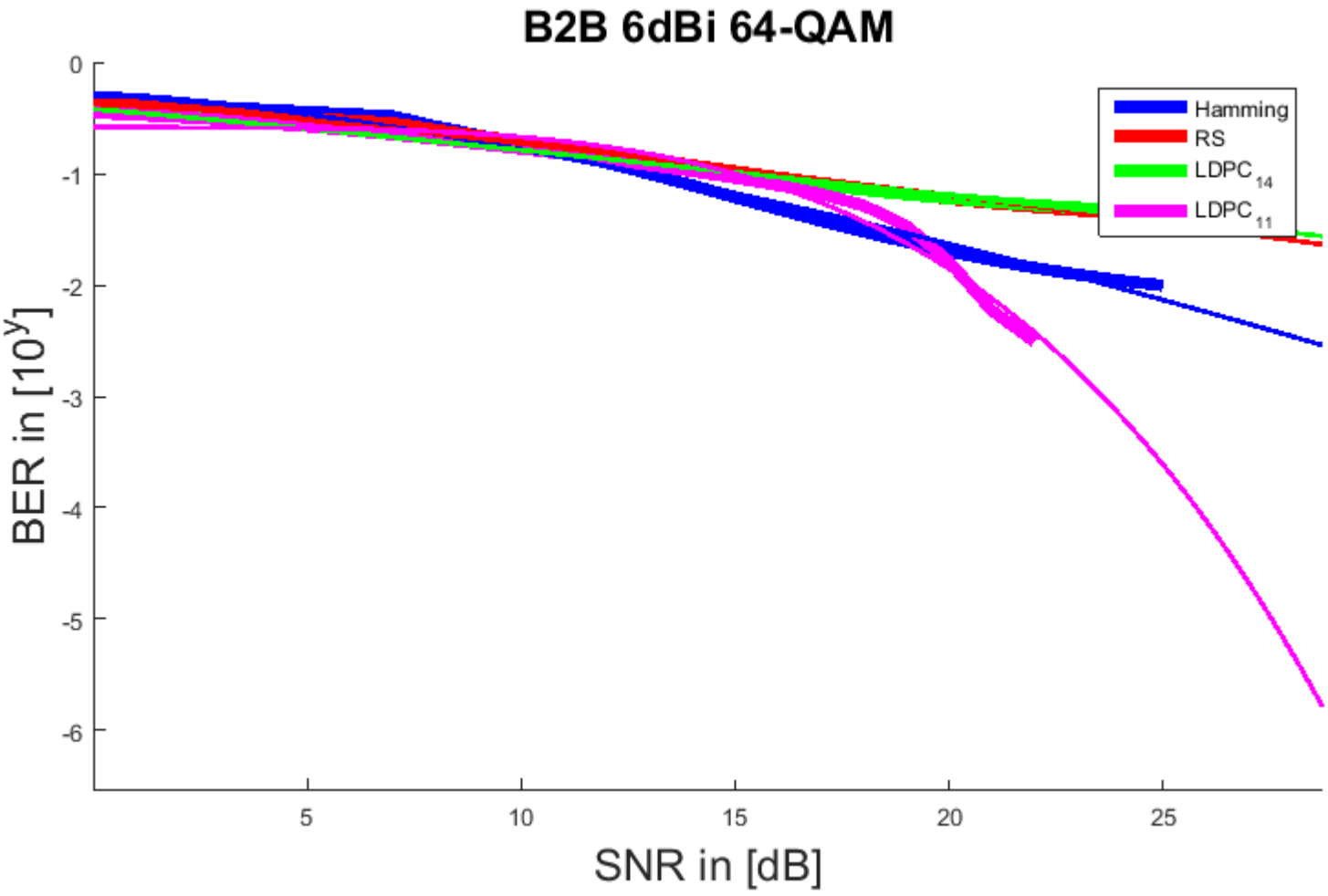

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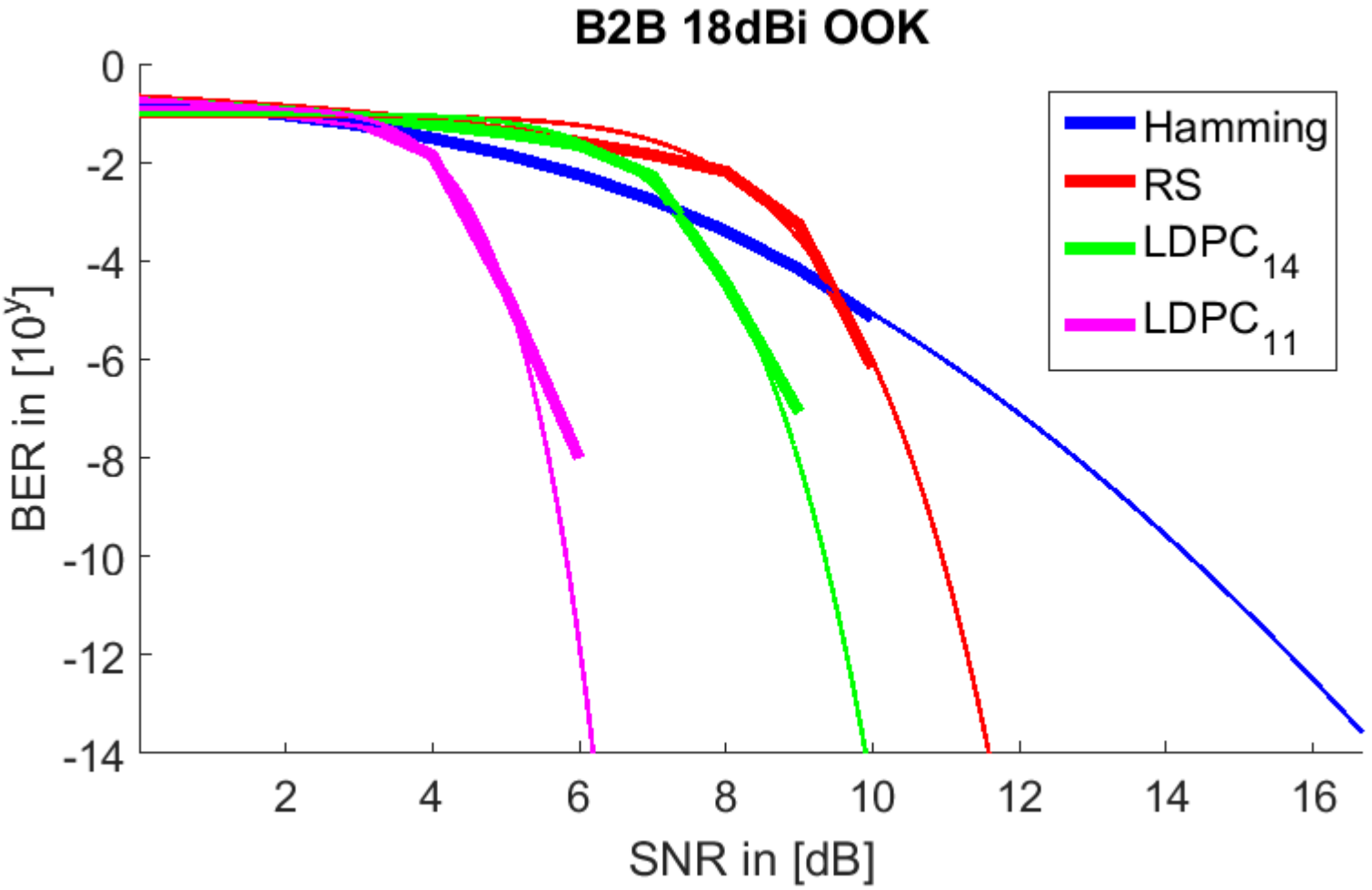

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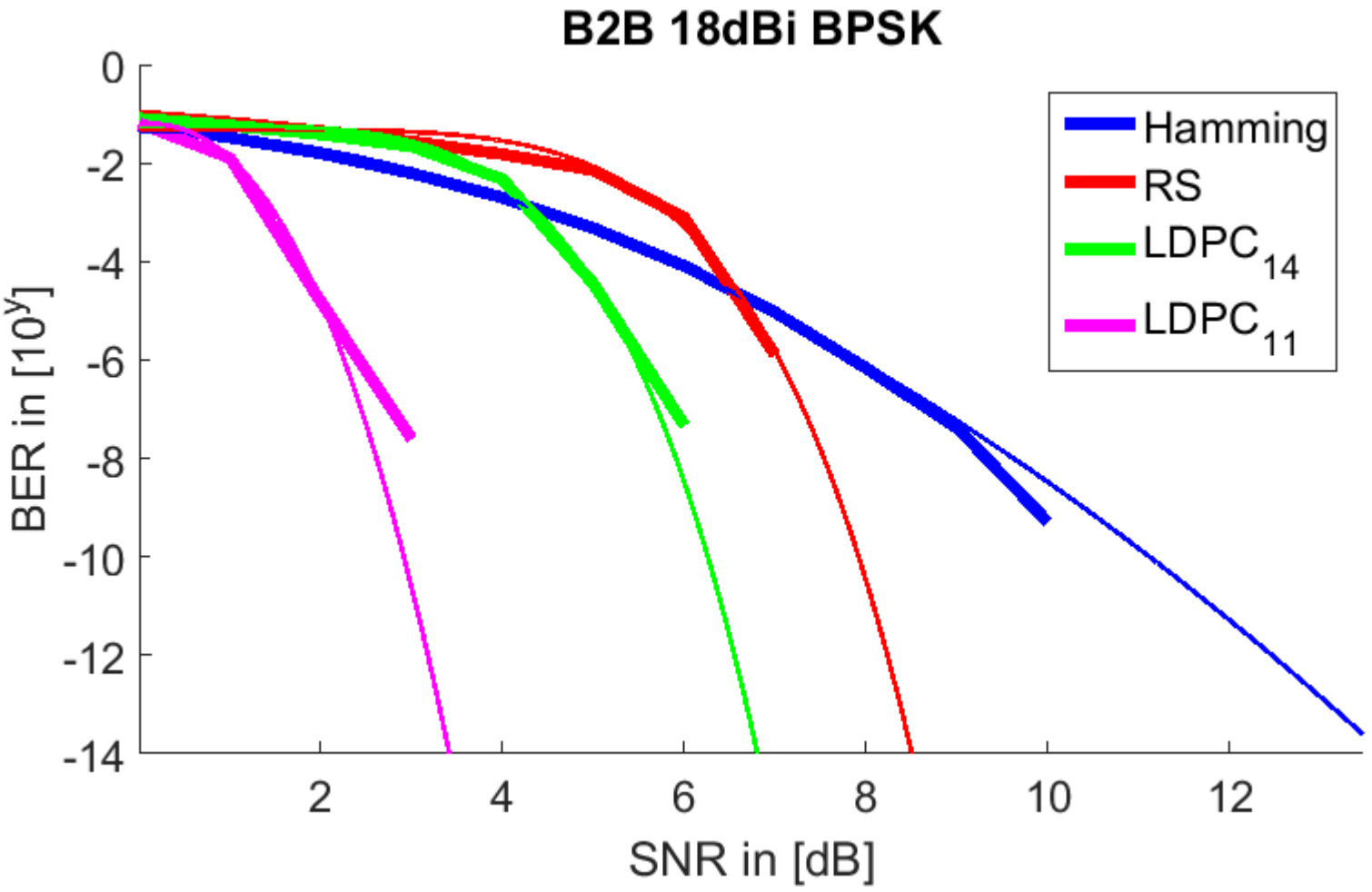

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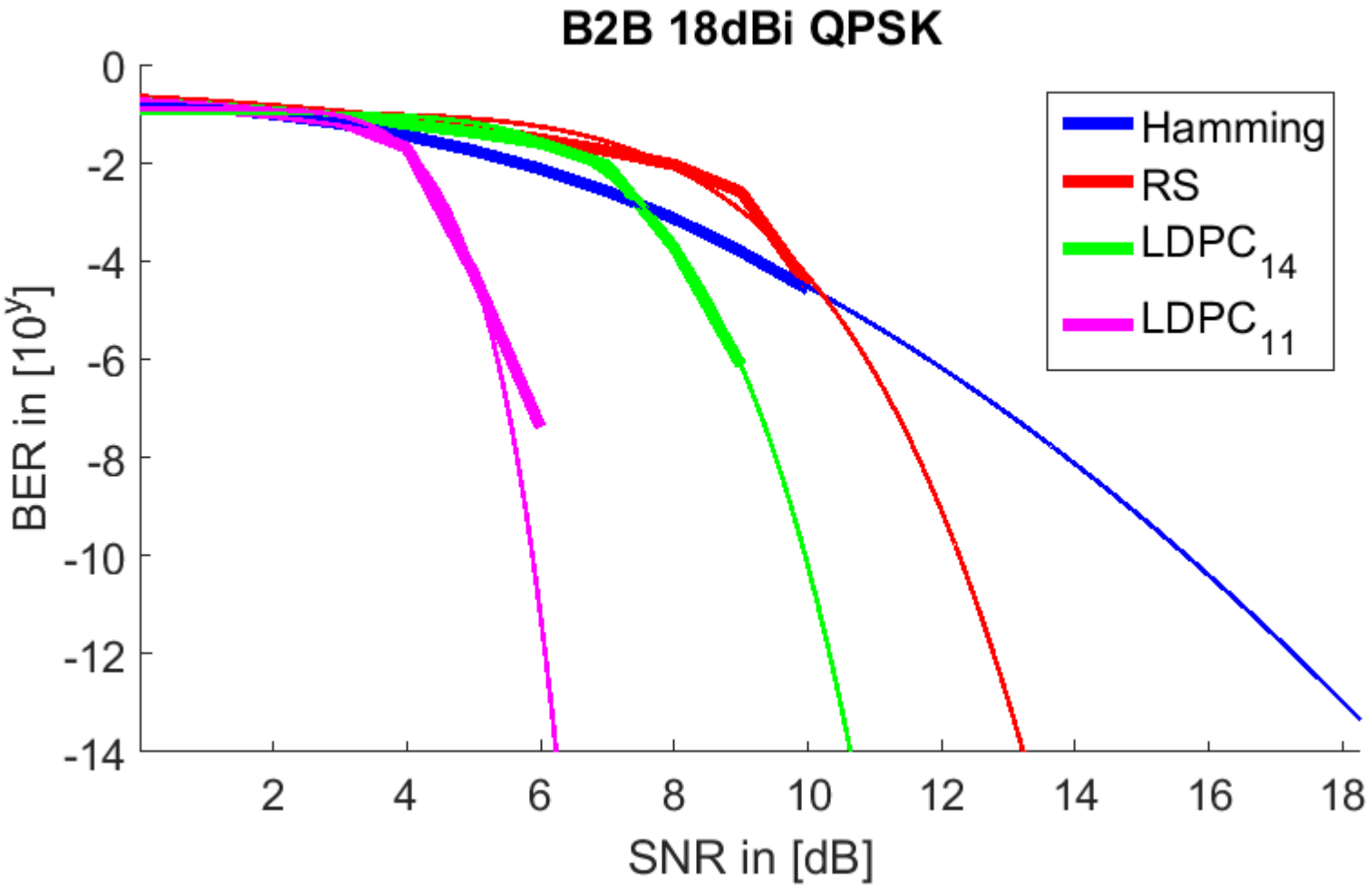

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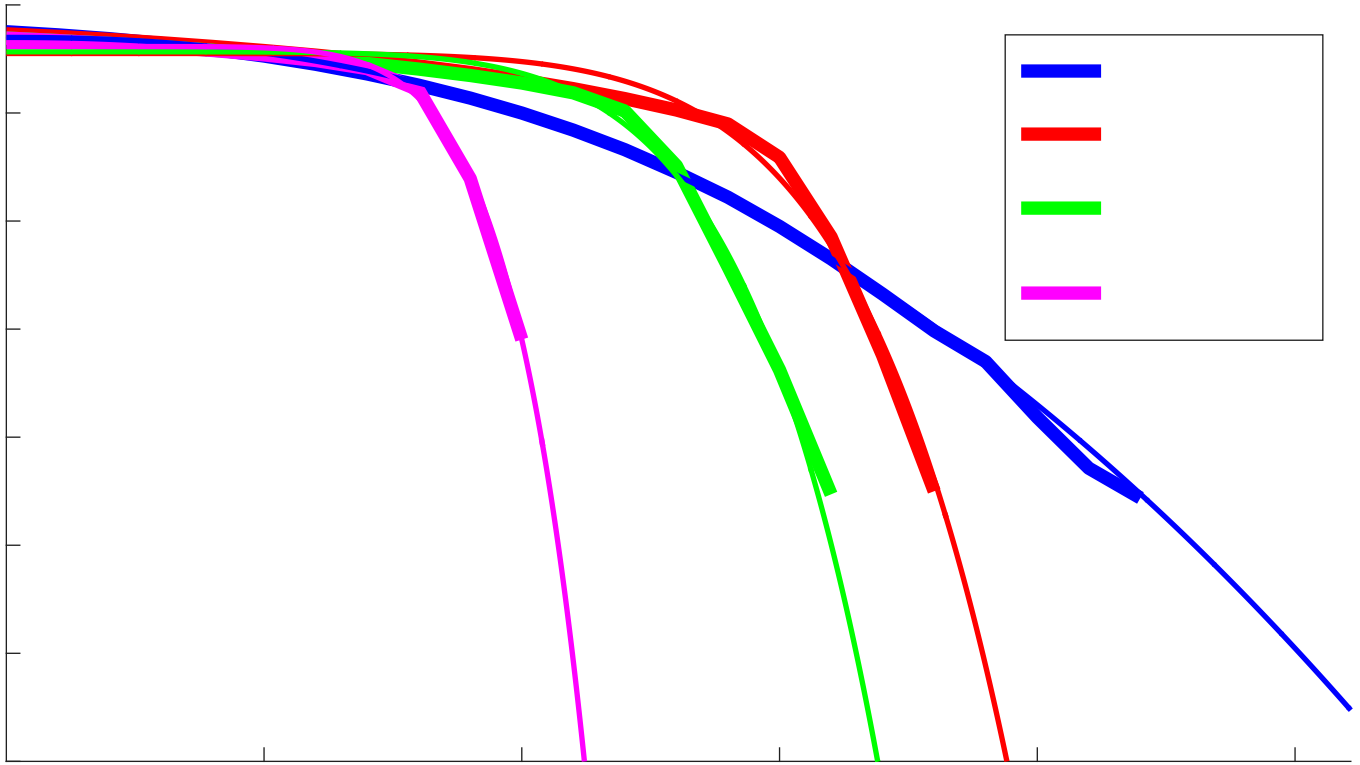

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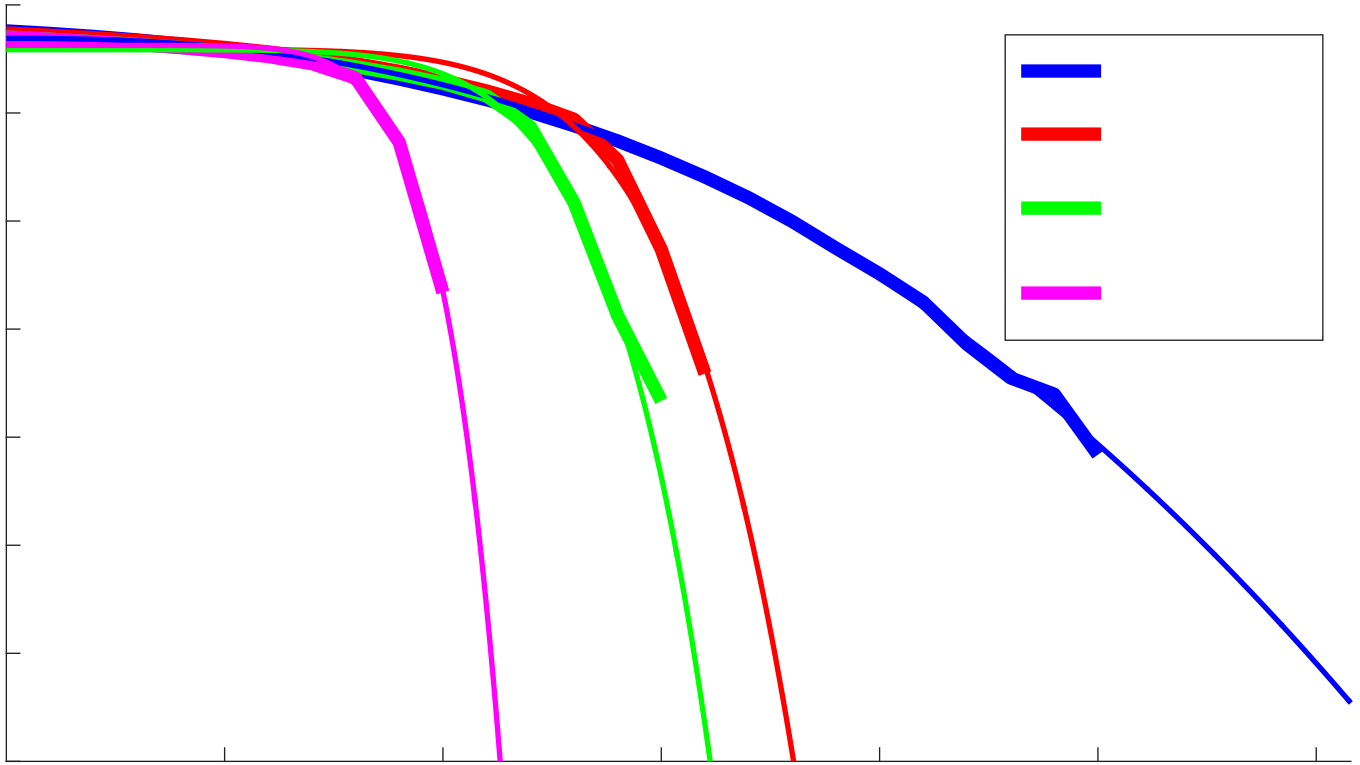

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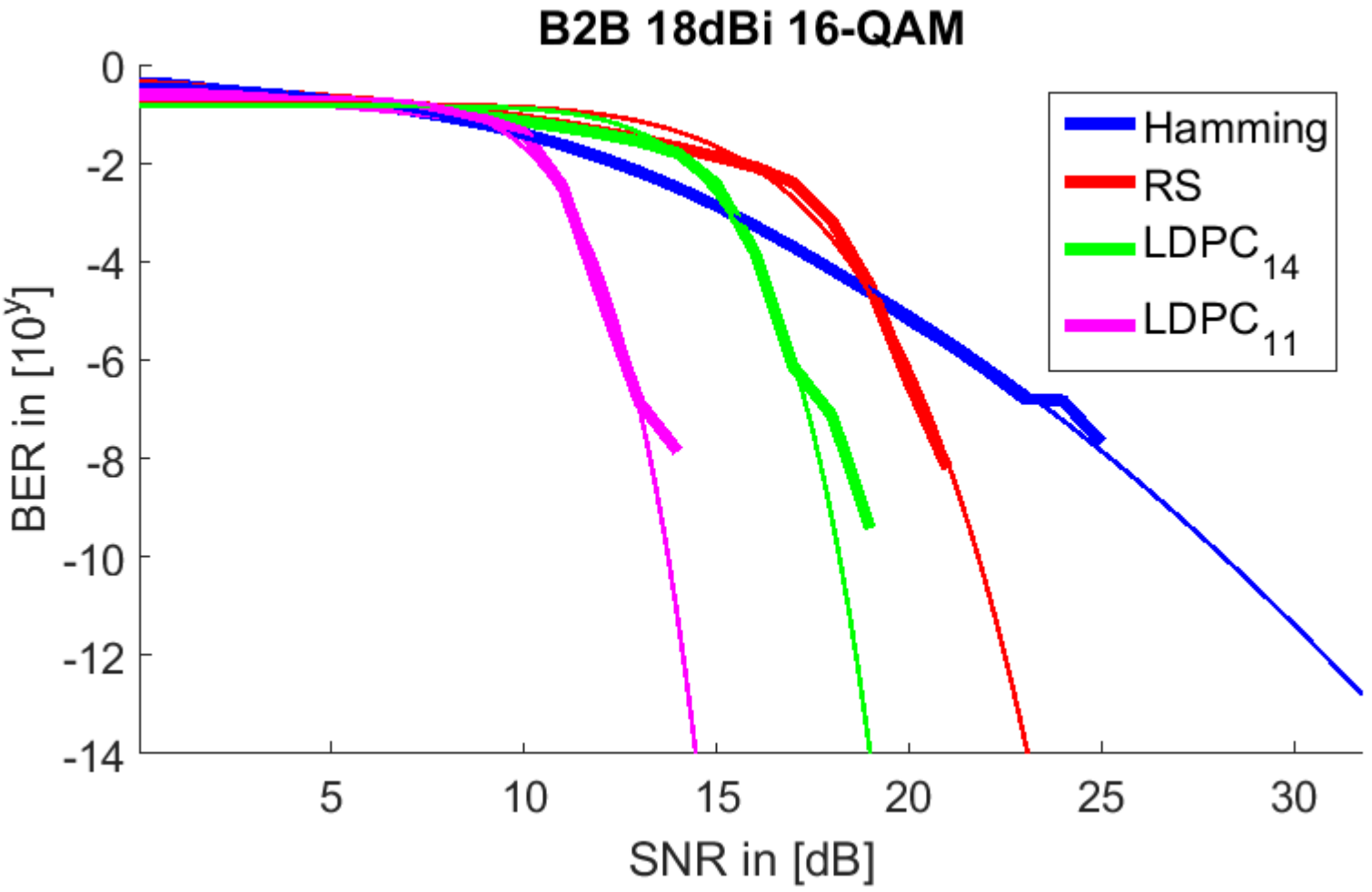

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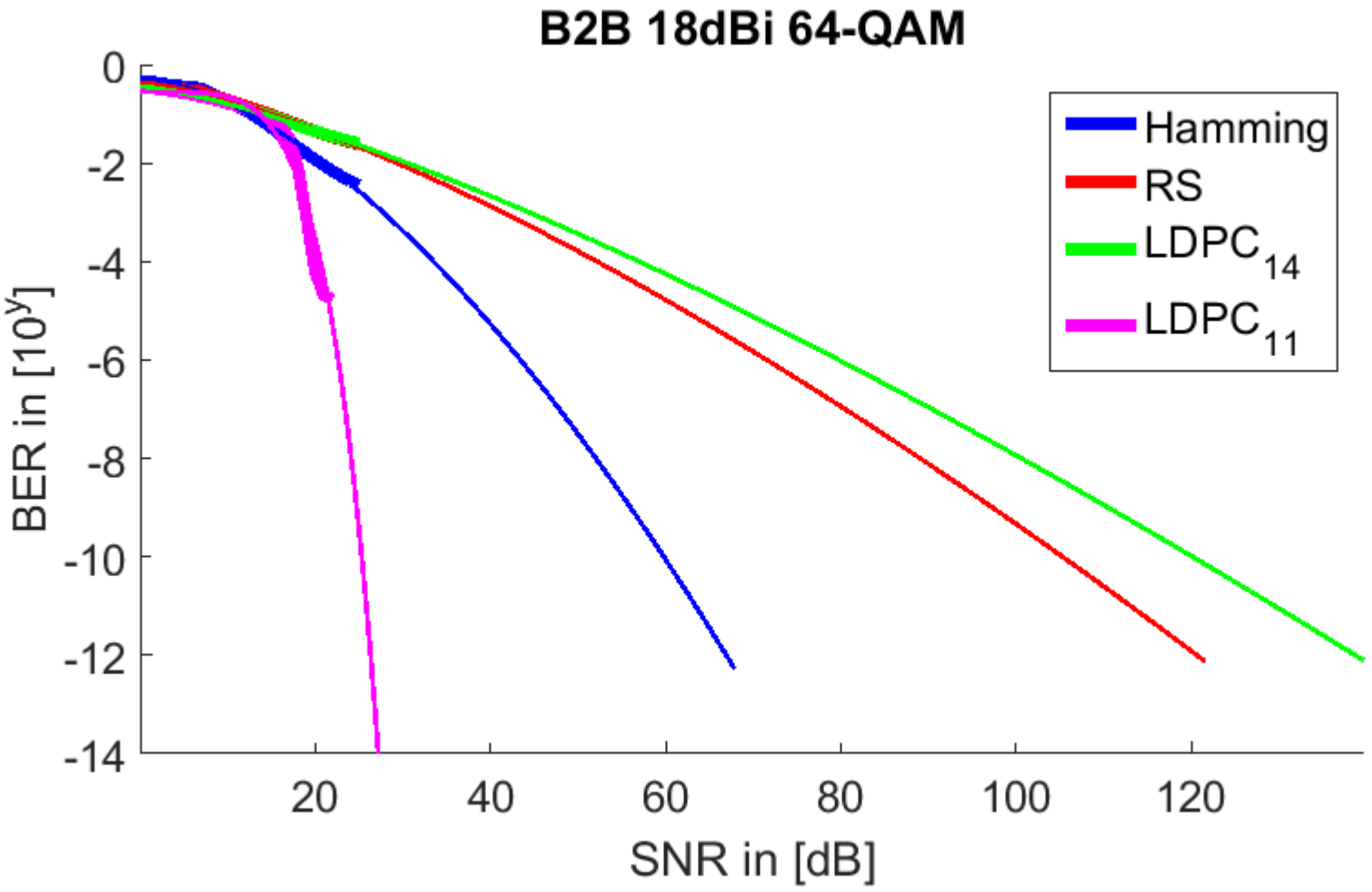
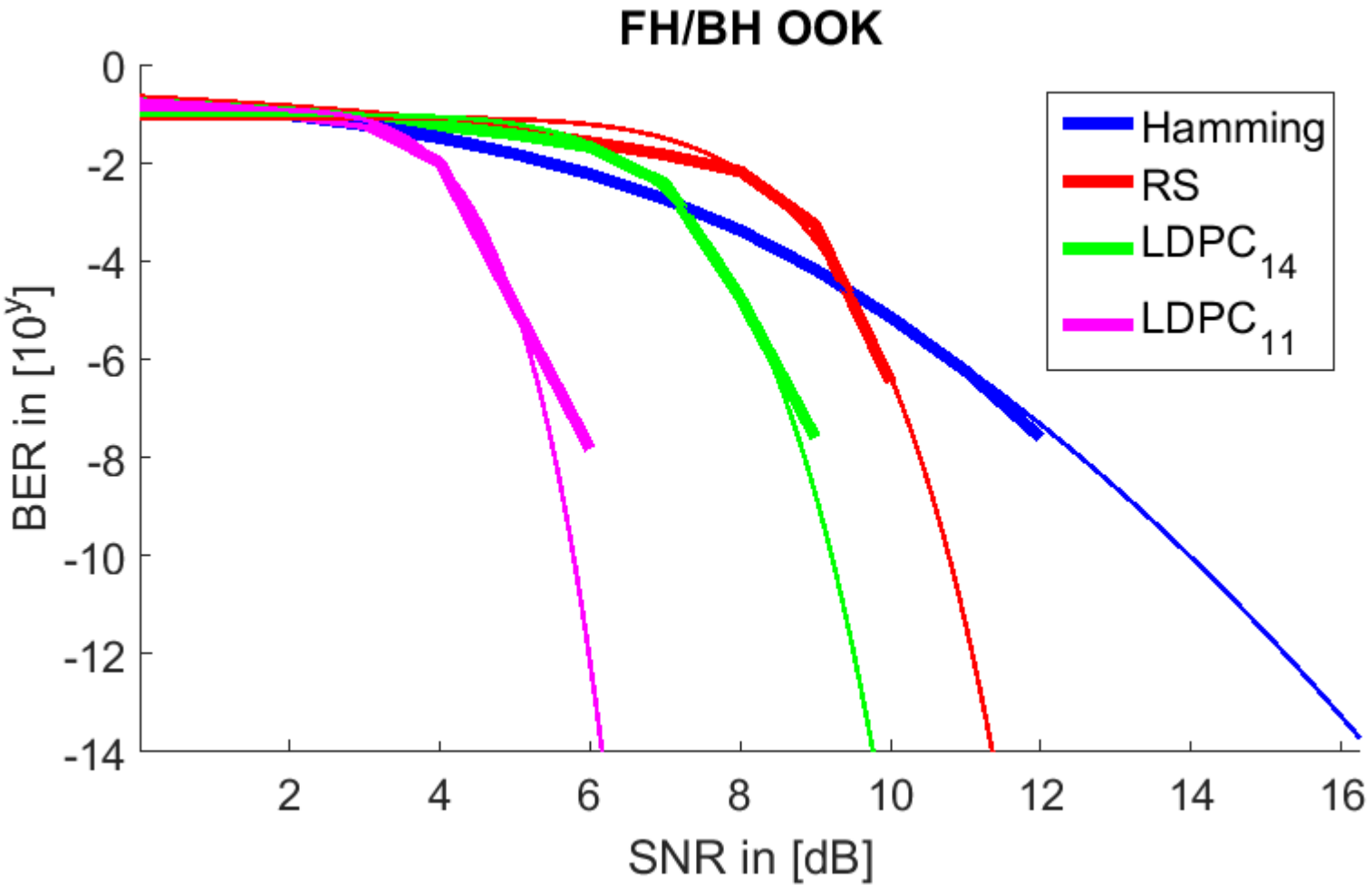


Backhaul/Fronthaul: AWGN



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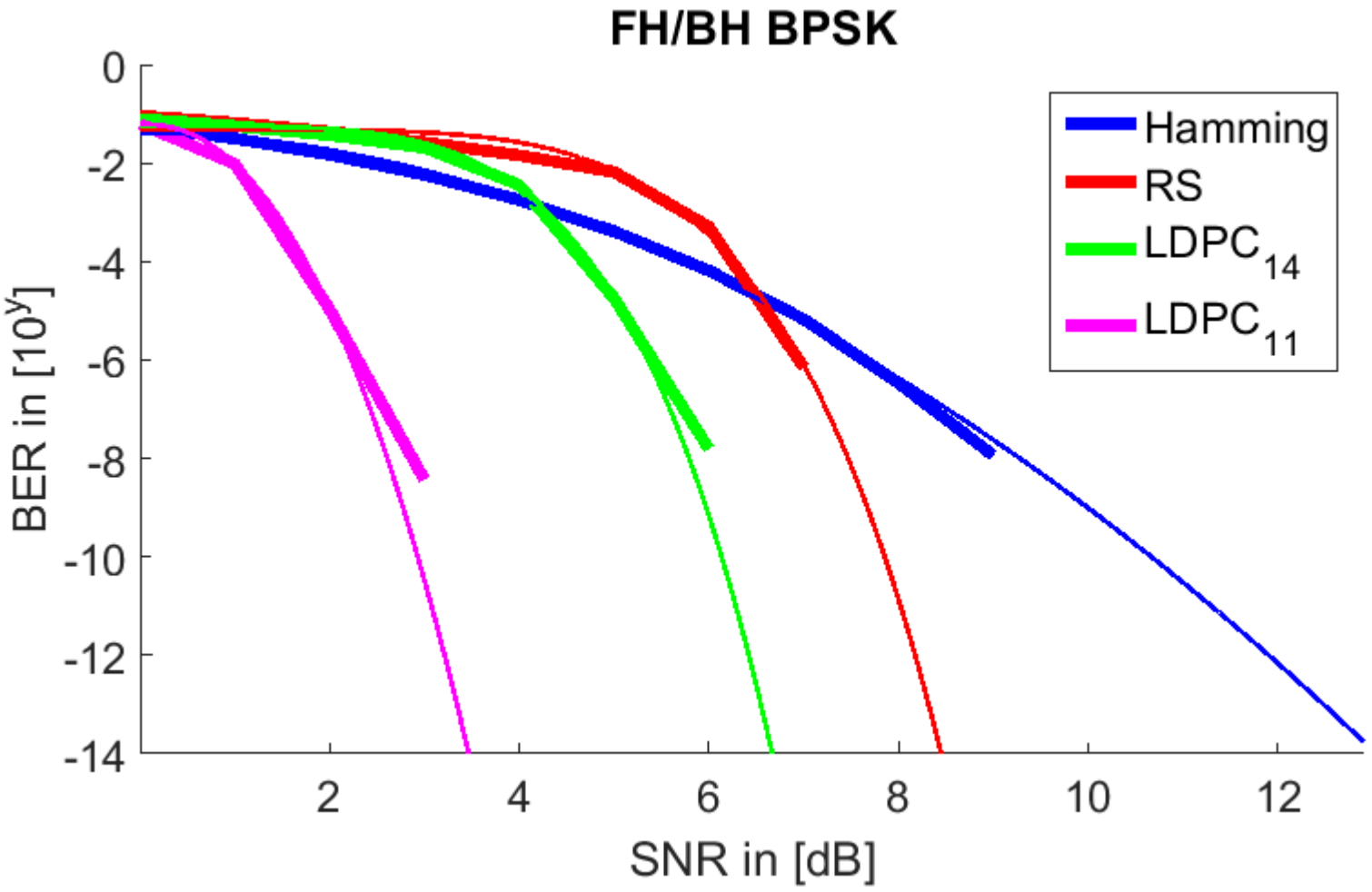
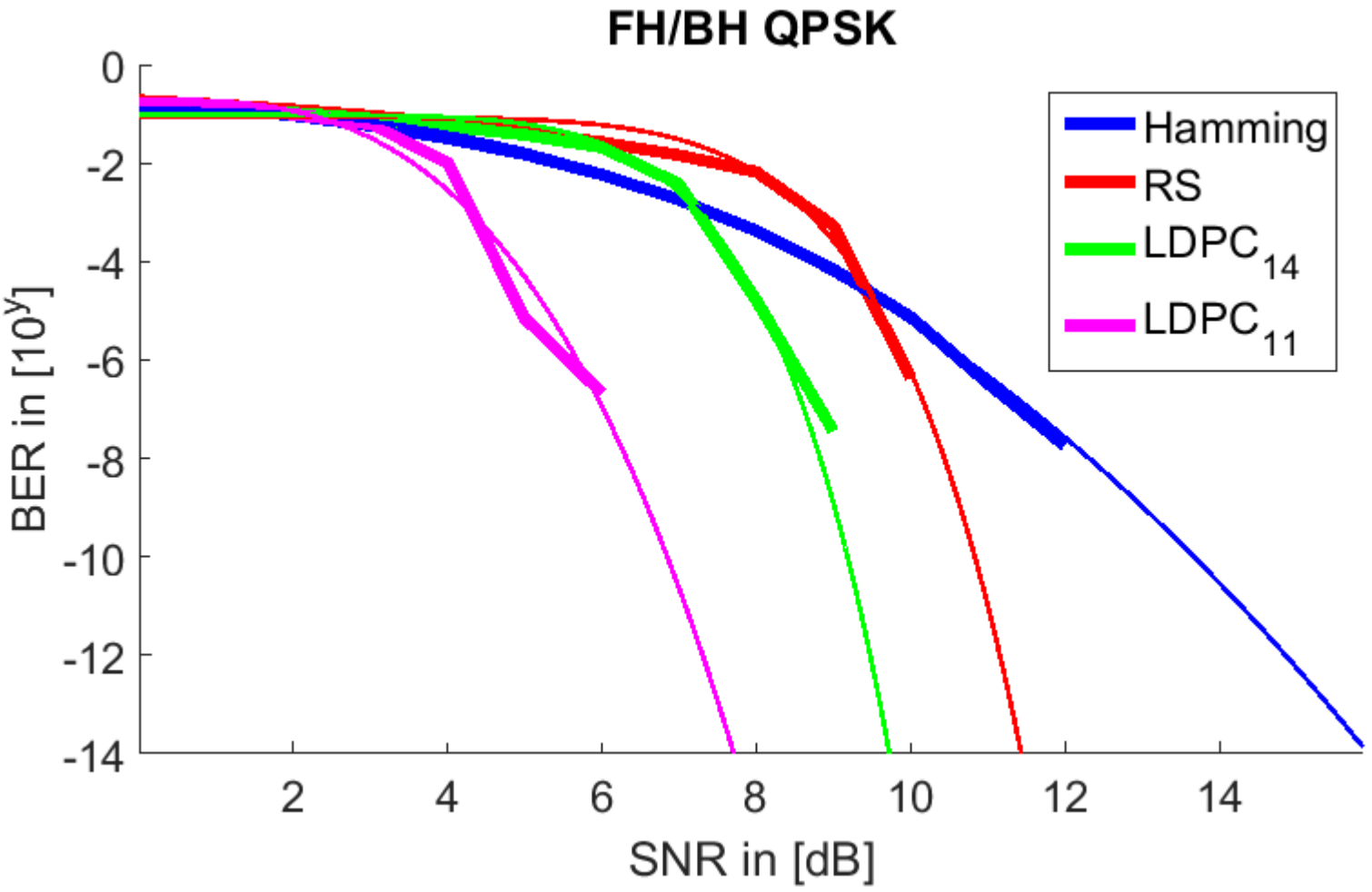


Backhaul/Fronthaul: AWGN



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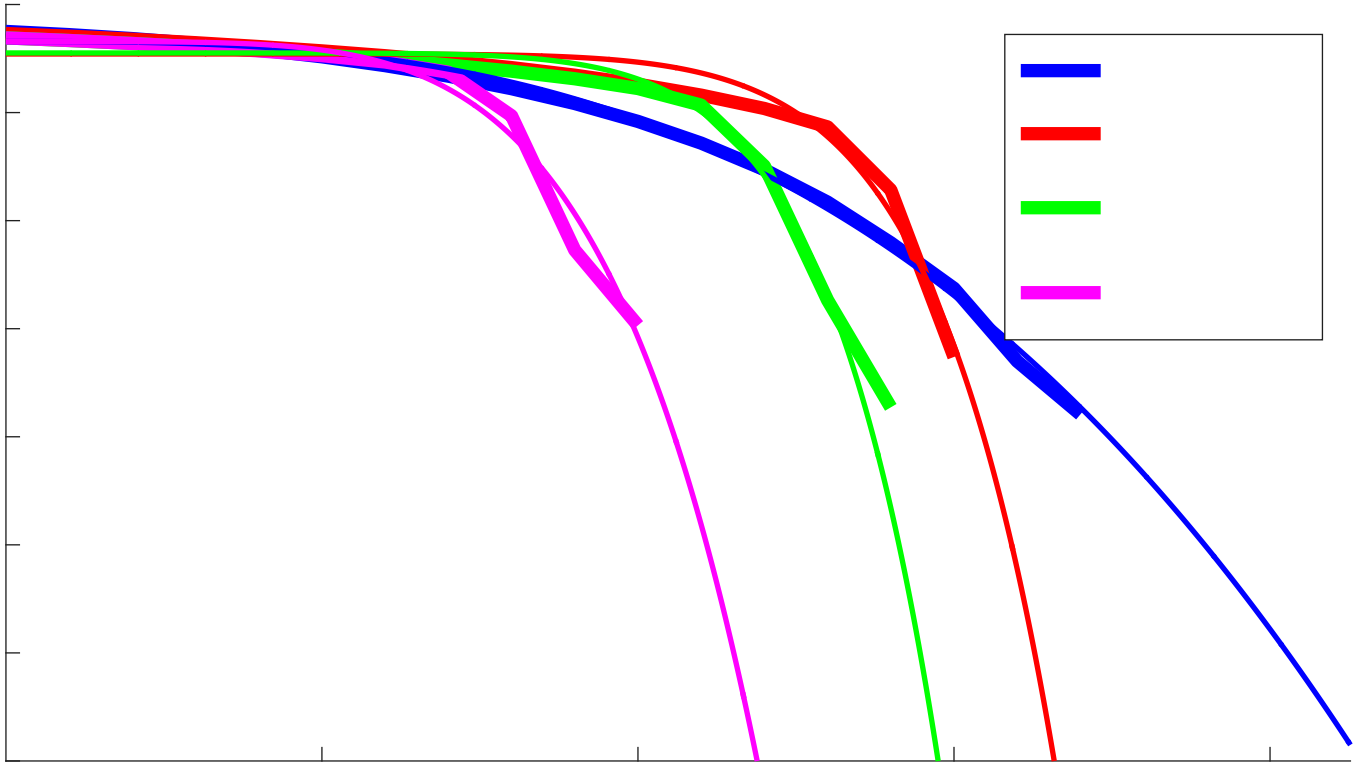

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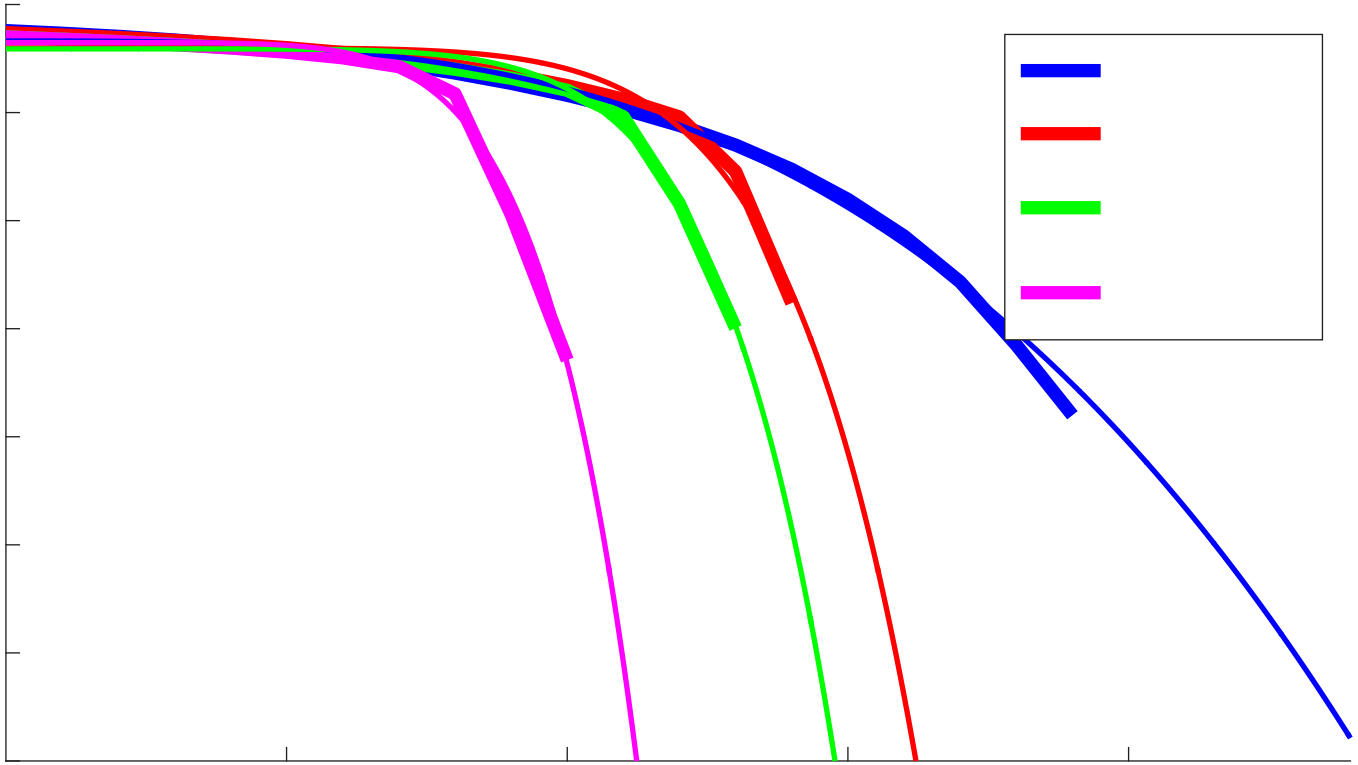

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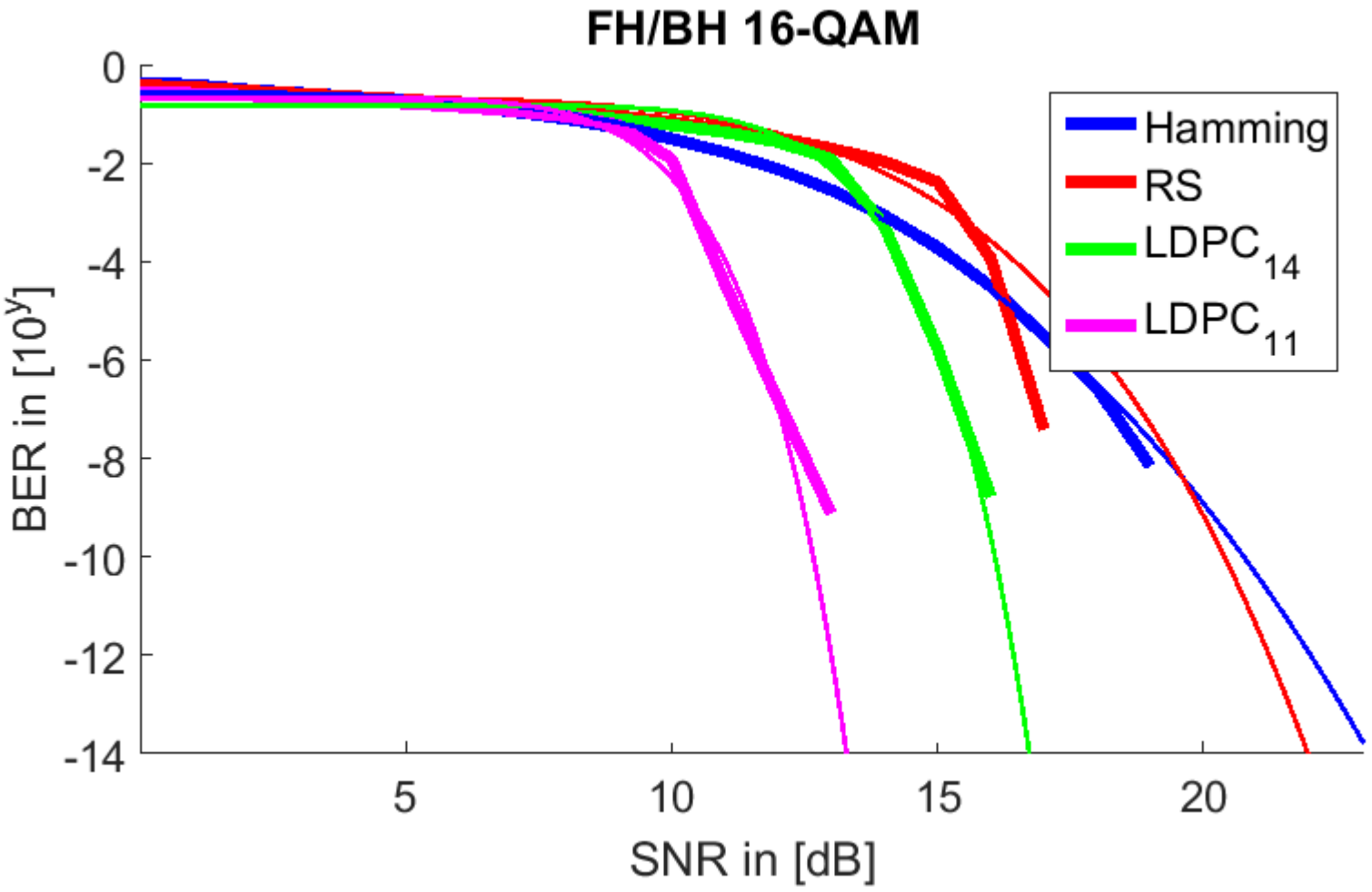

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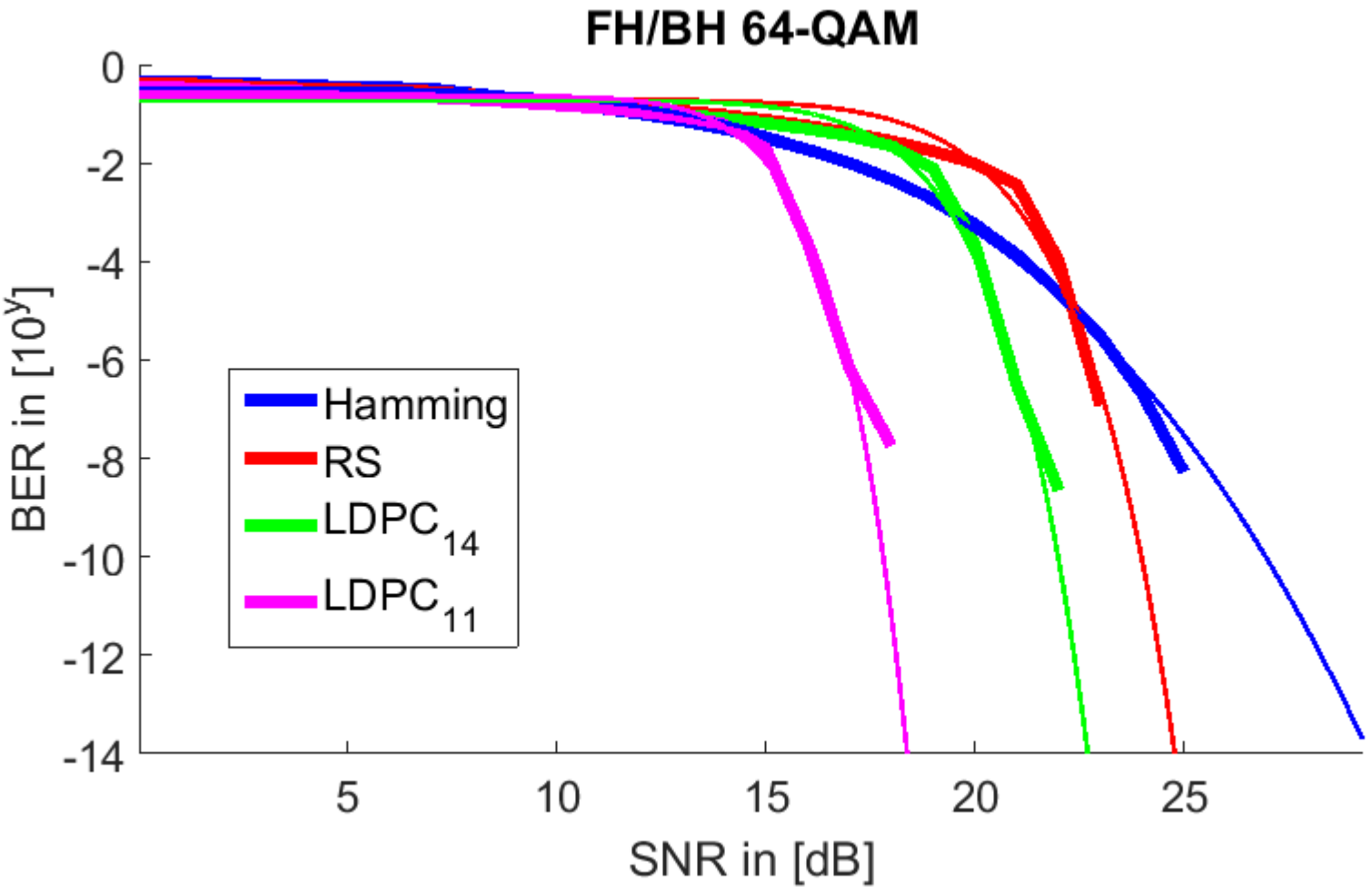
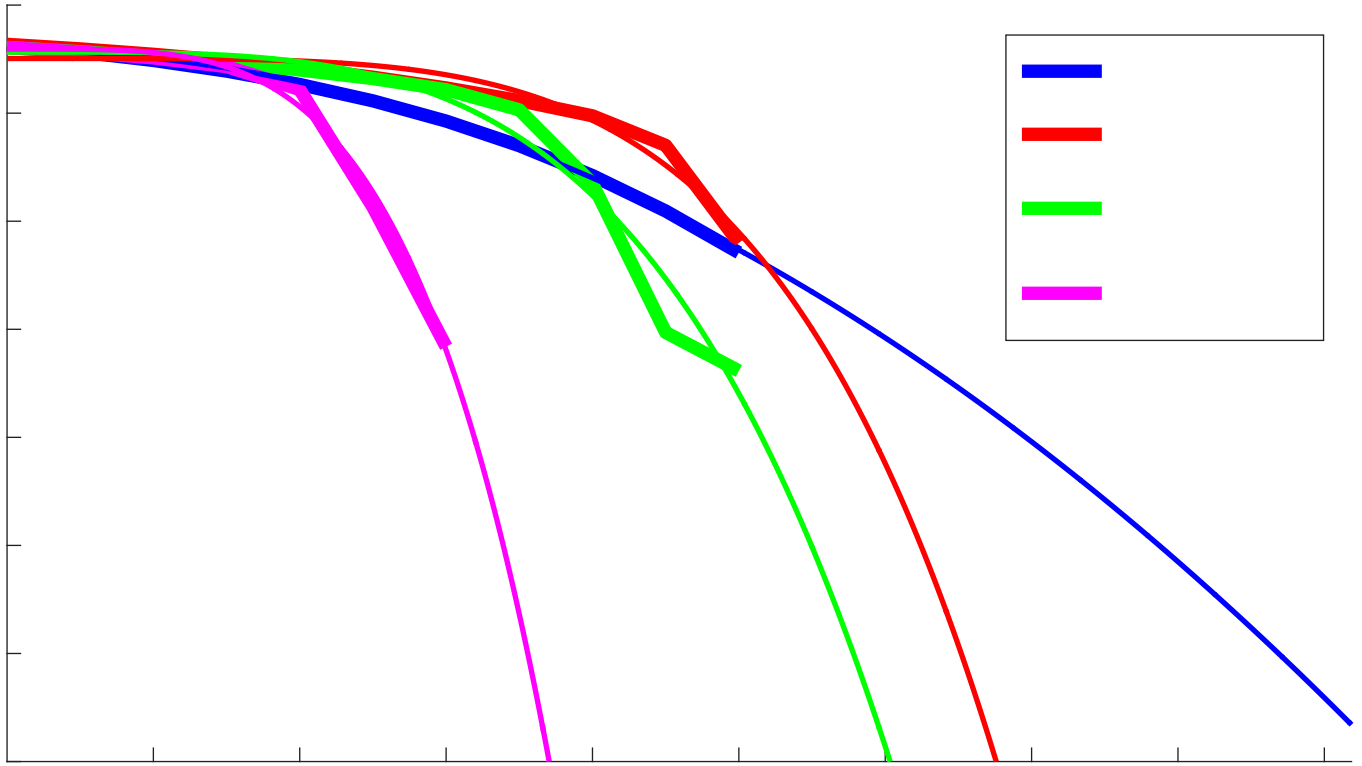


Data Center: 6dBi



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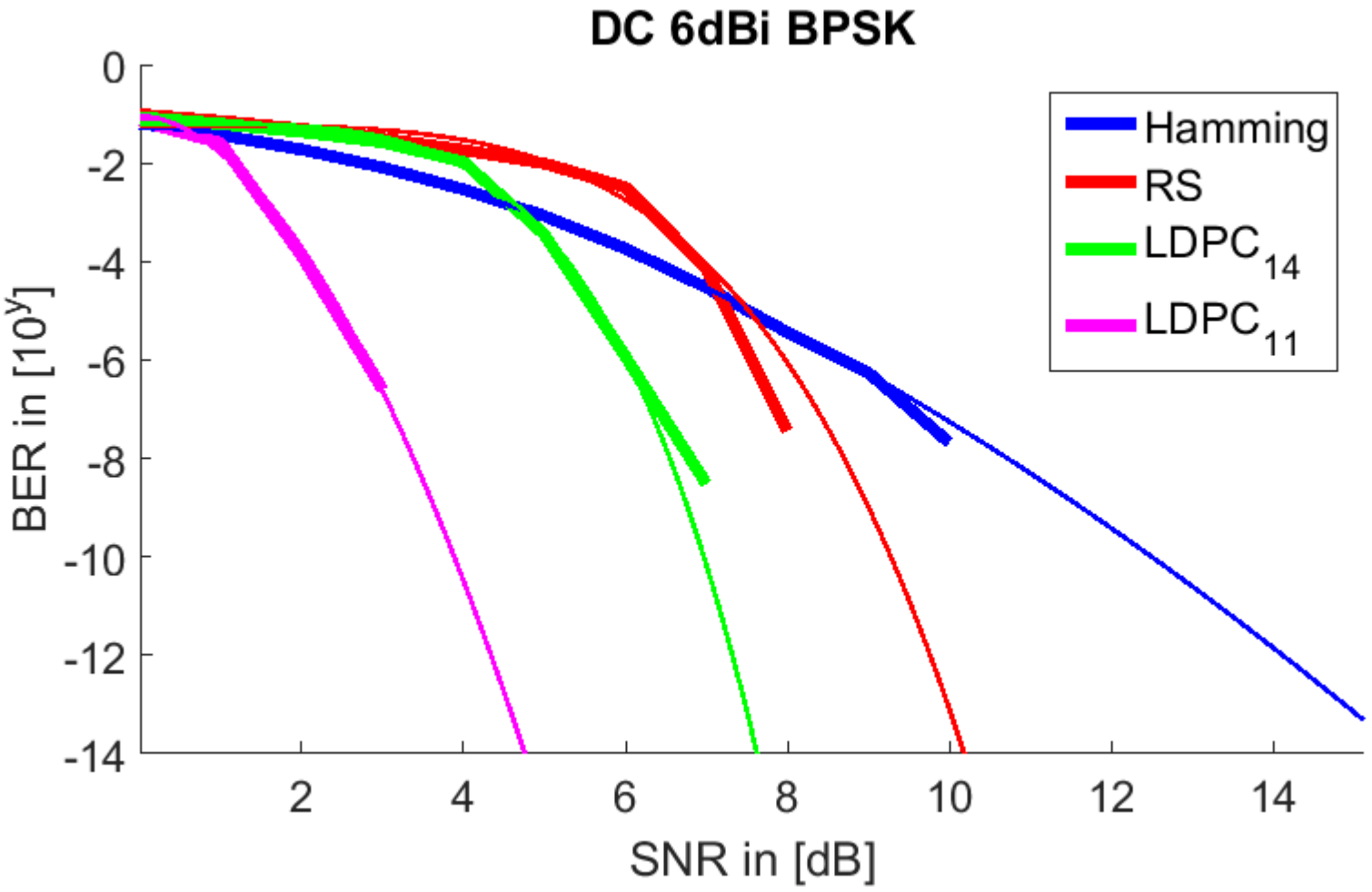

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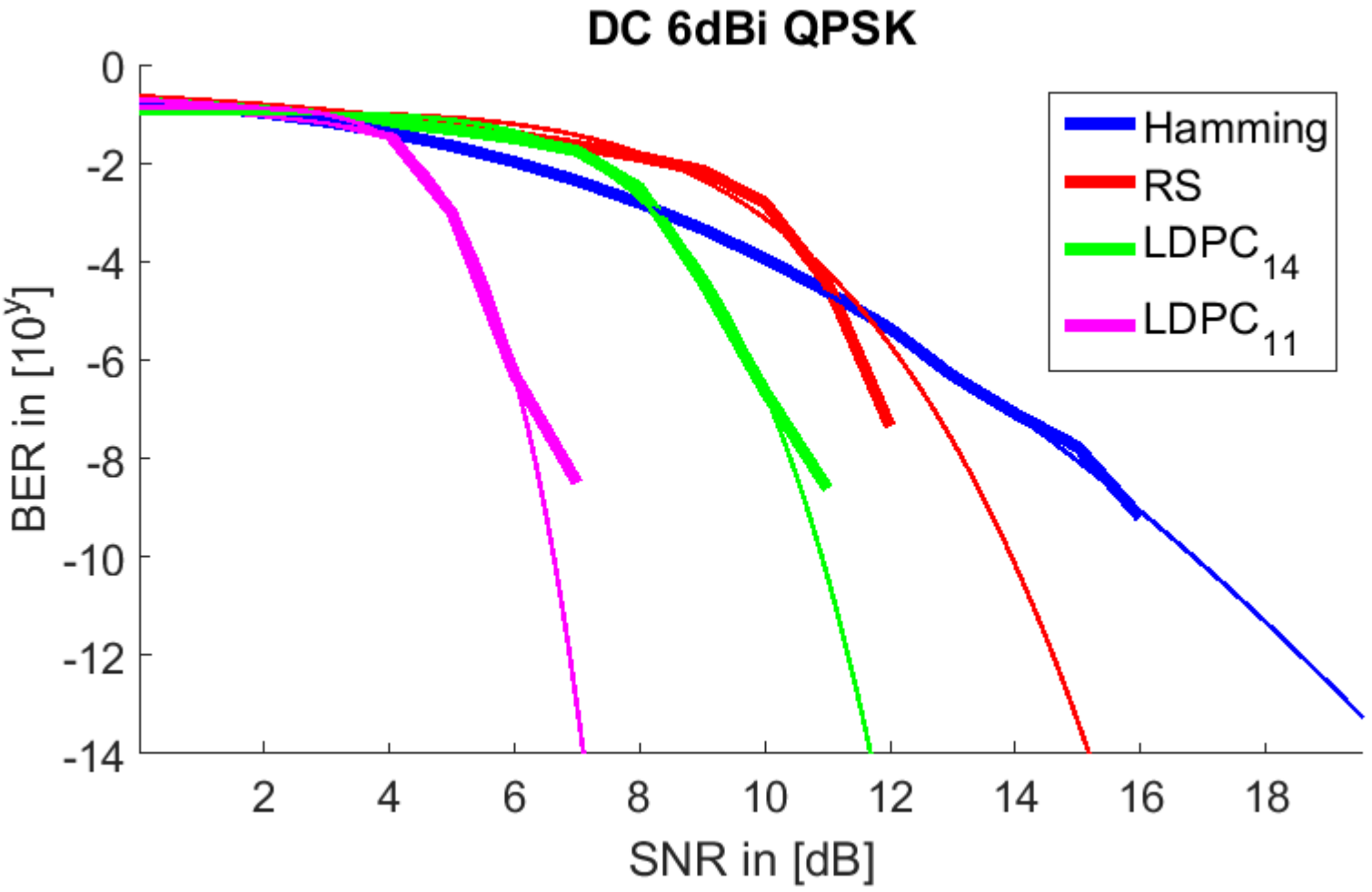

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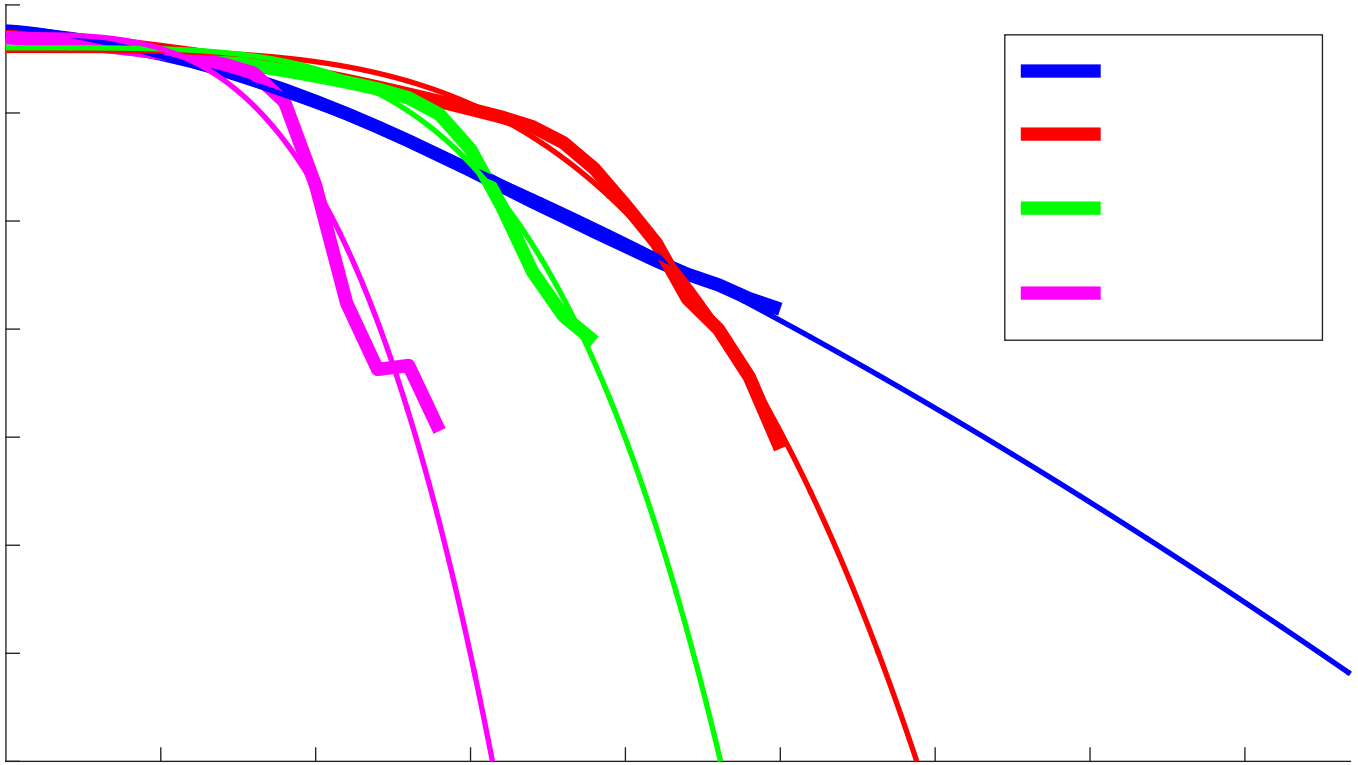

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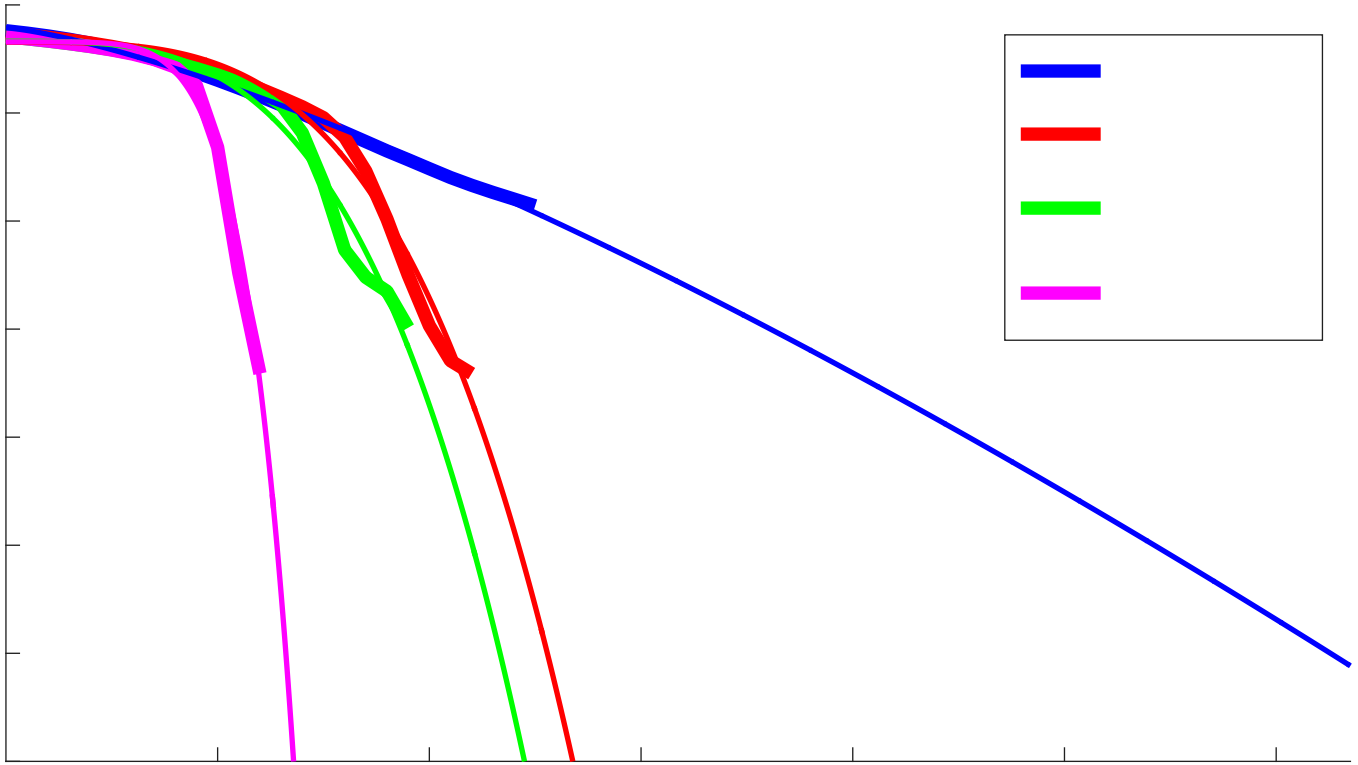

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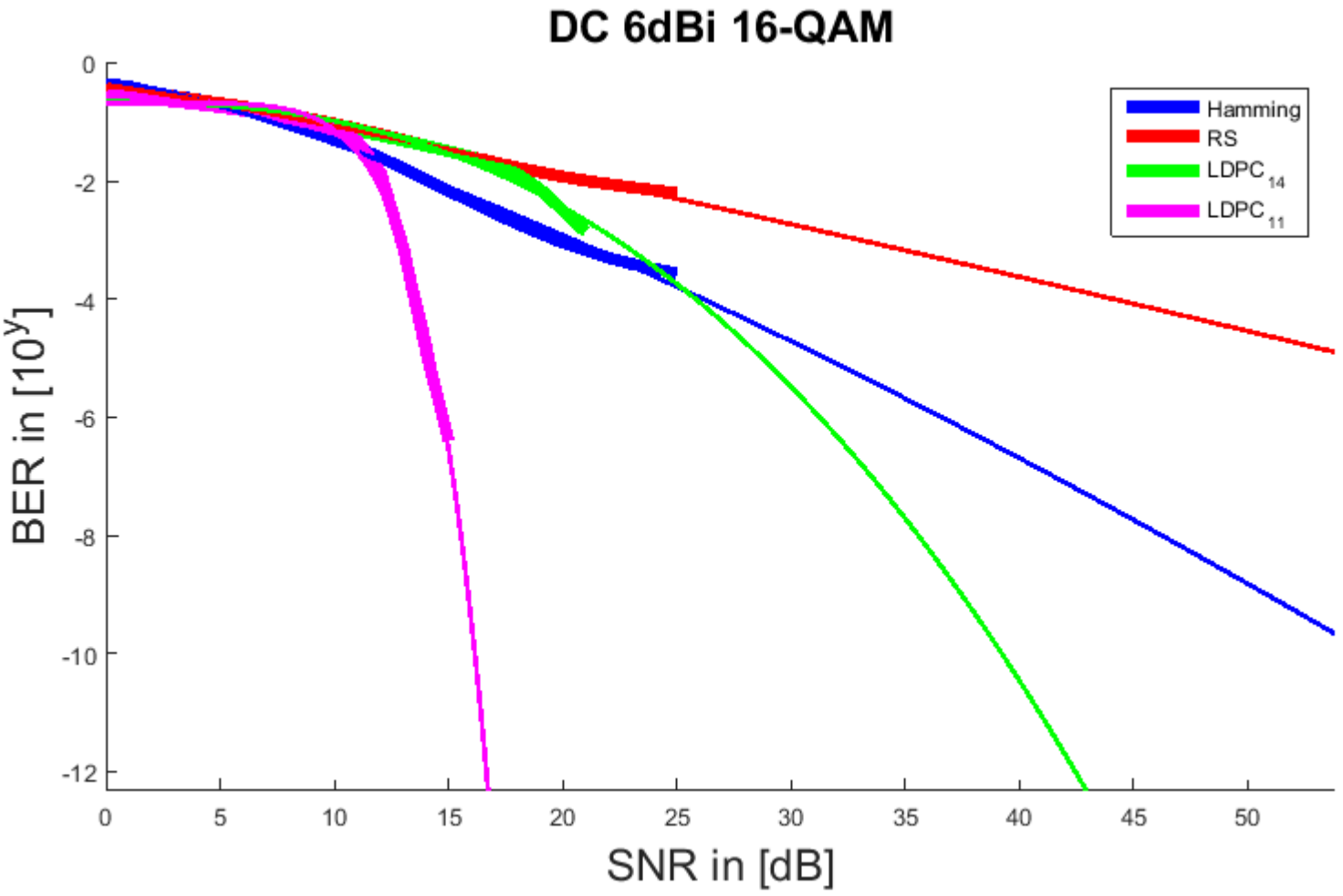

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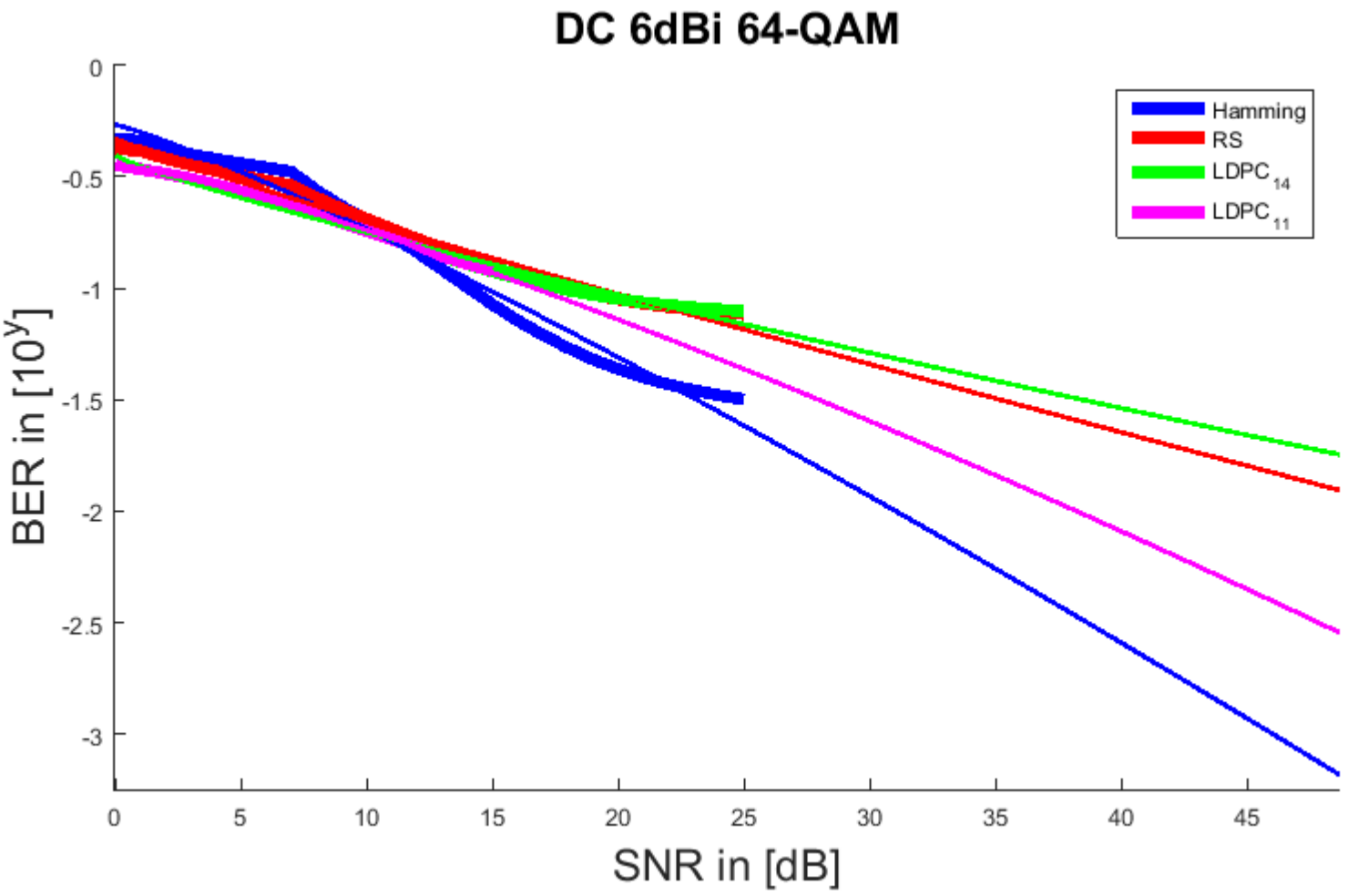

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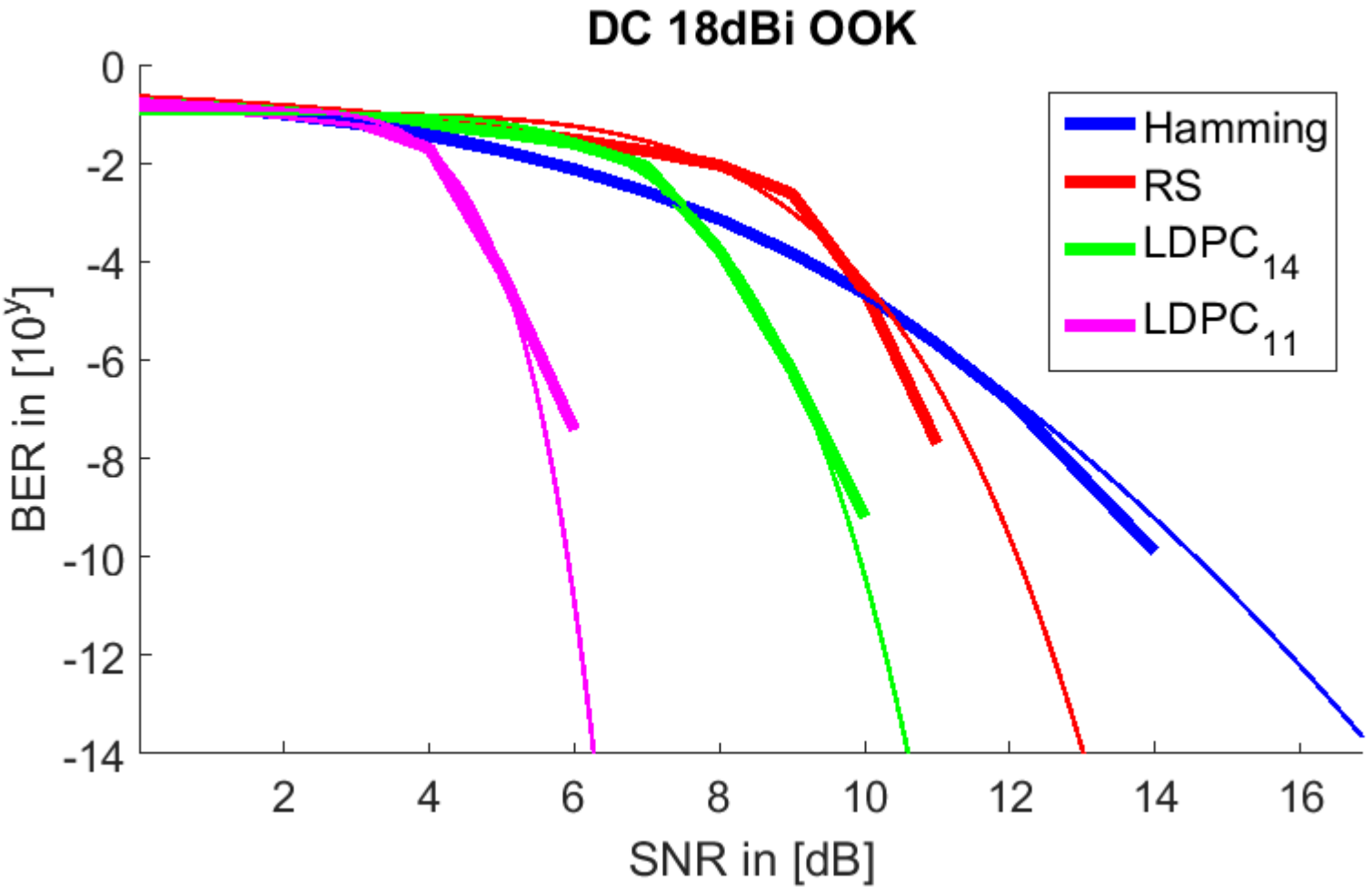

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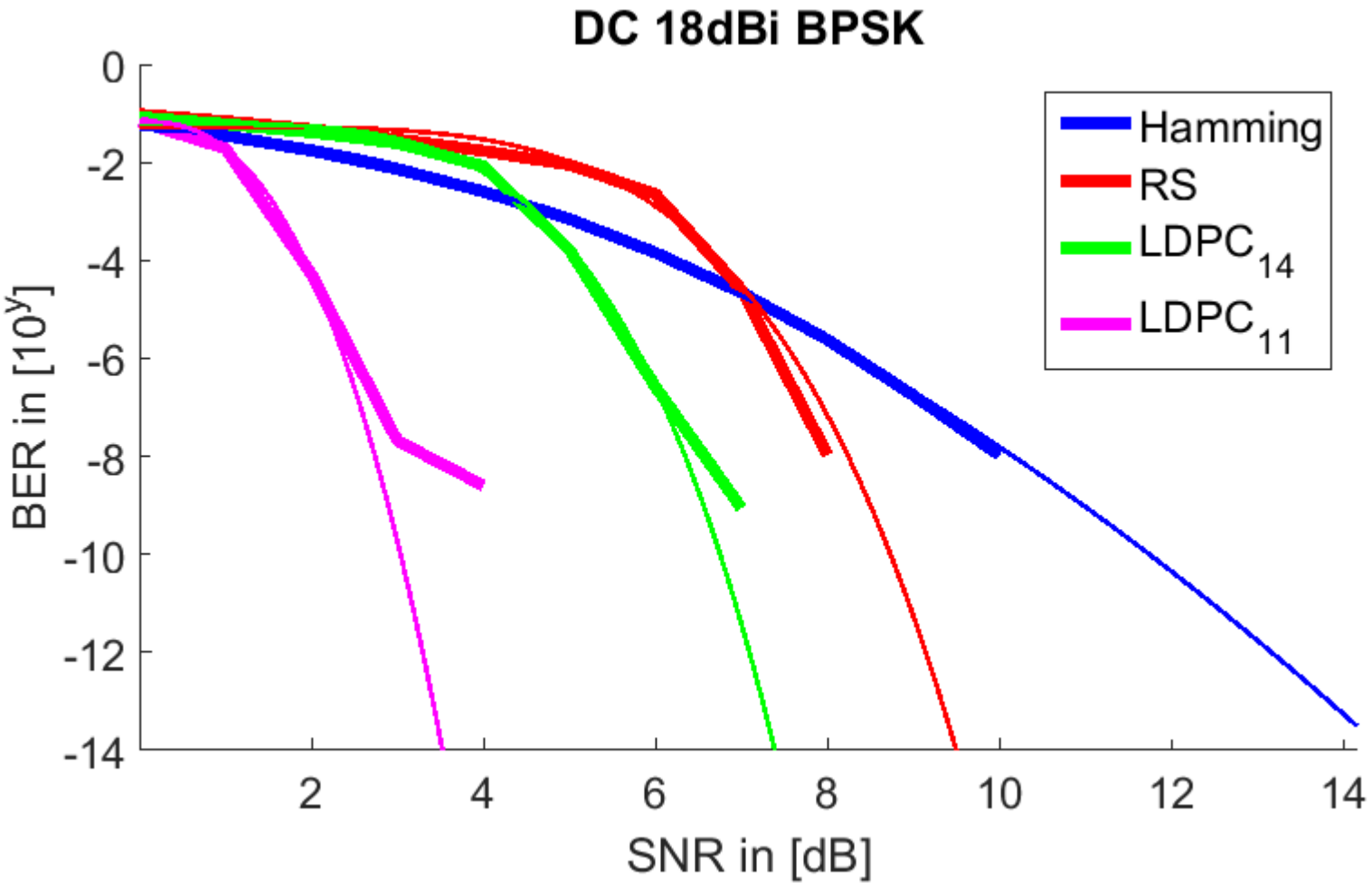

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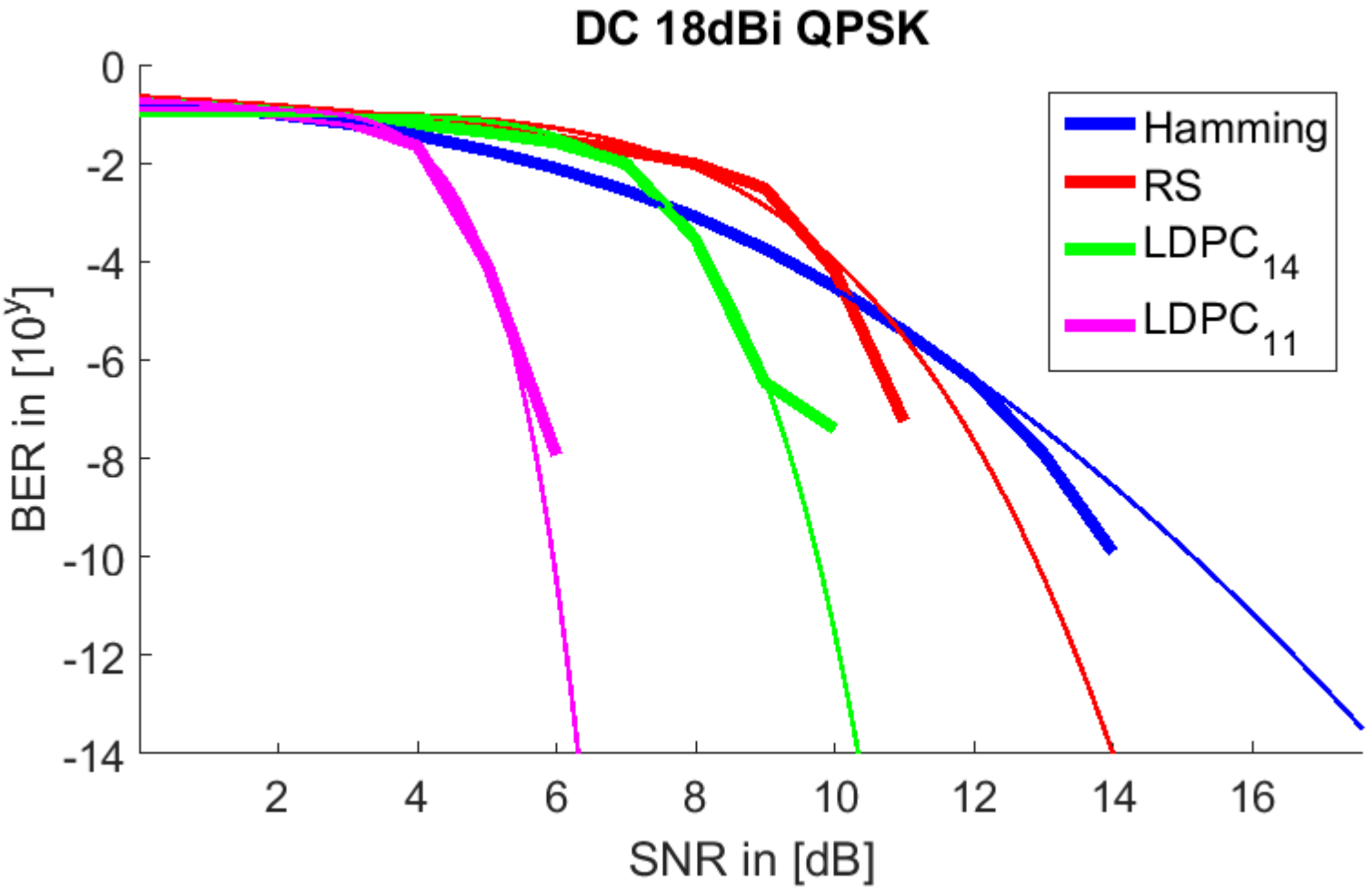

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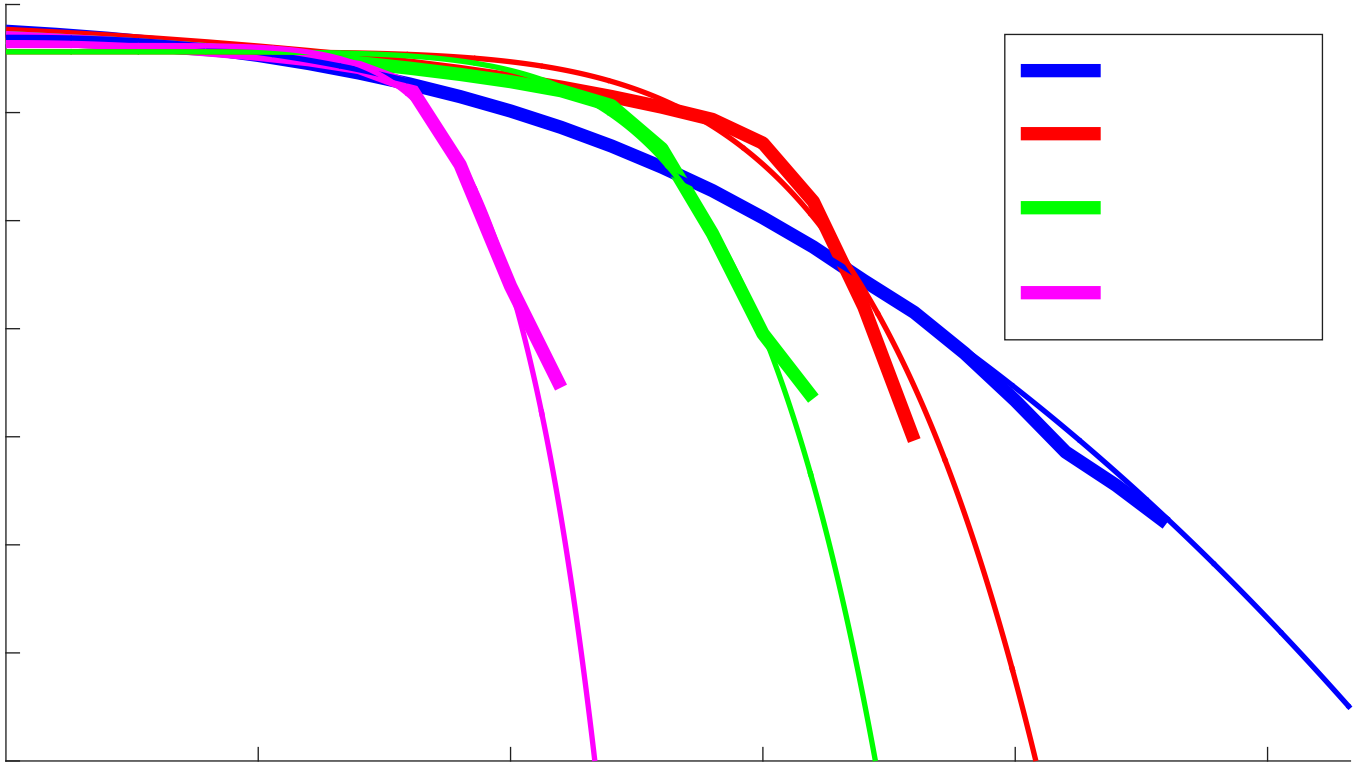

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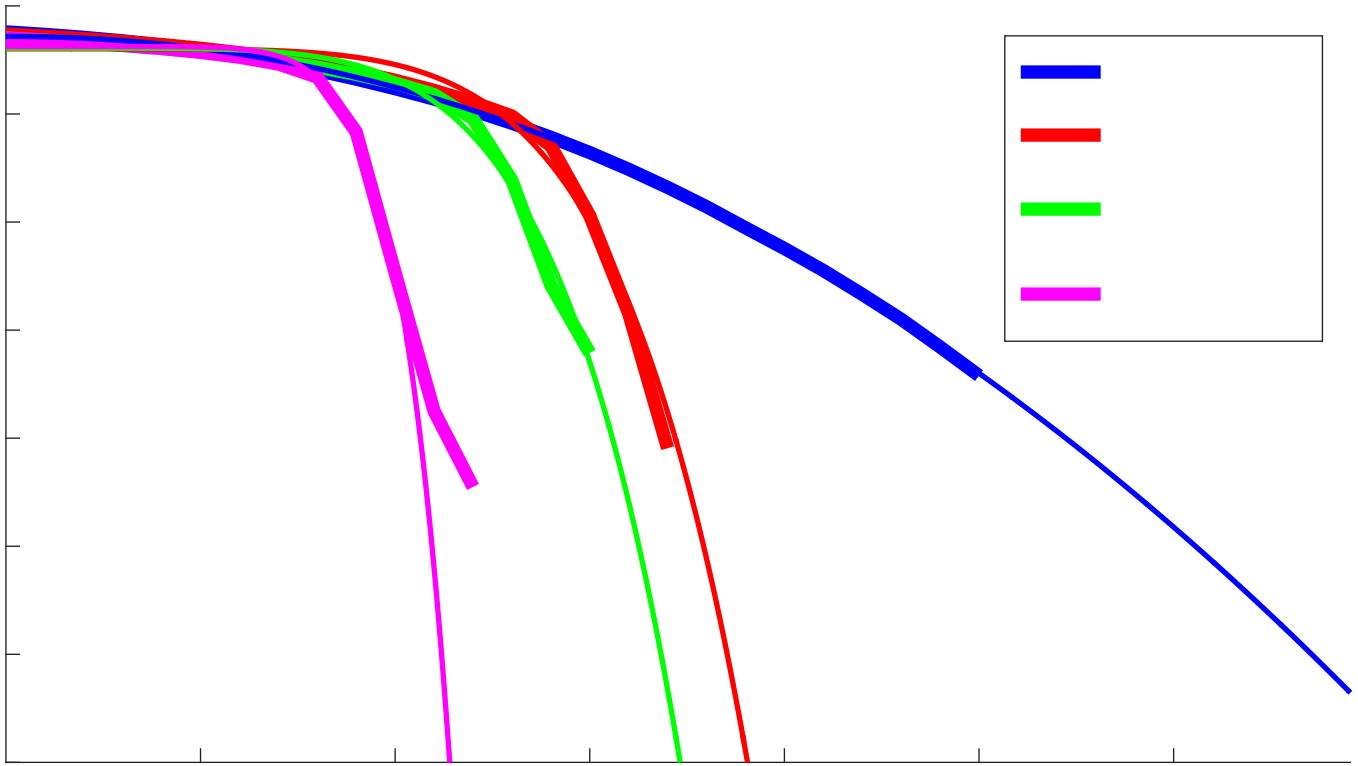

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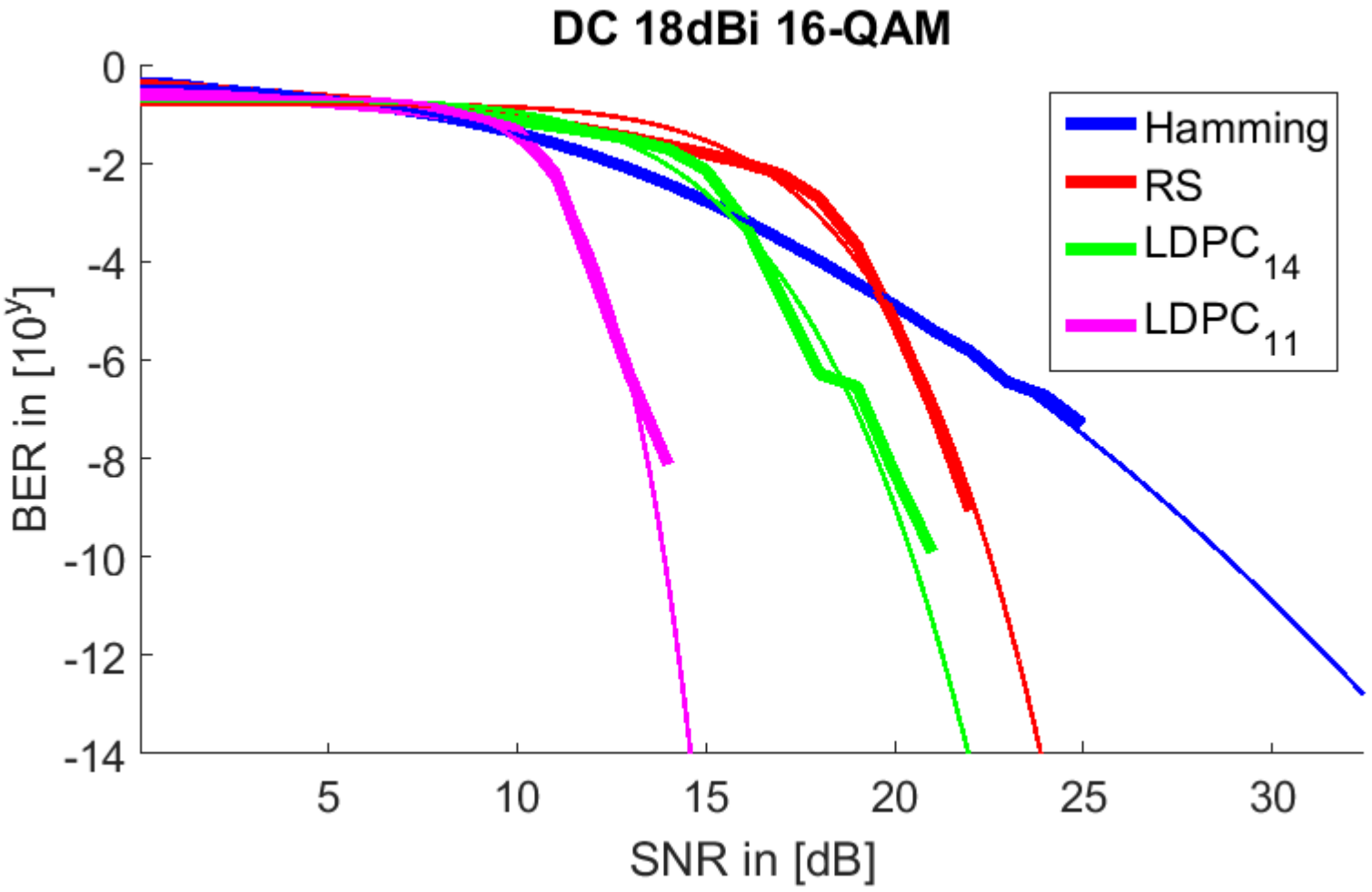
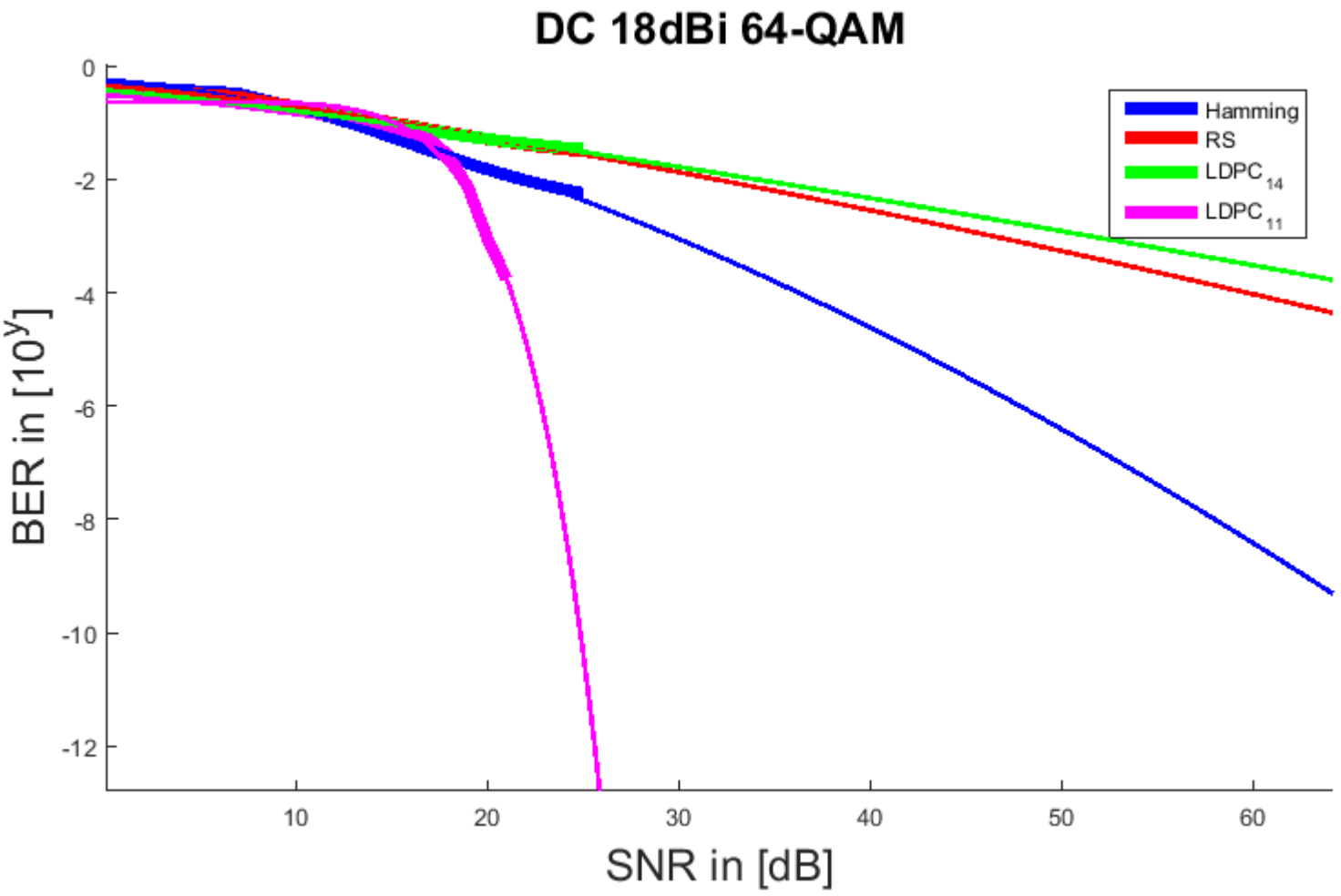


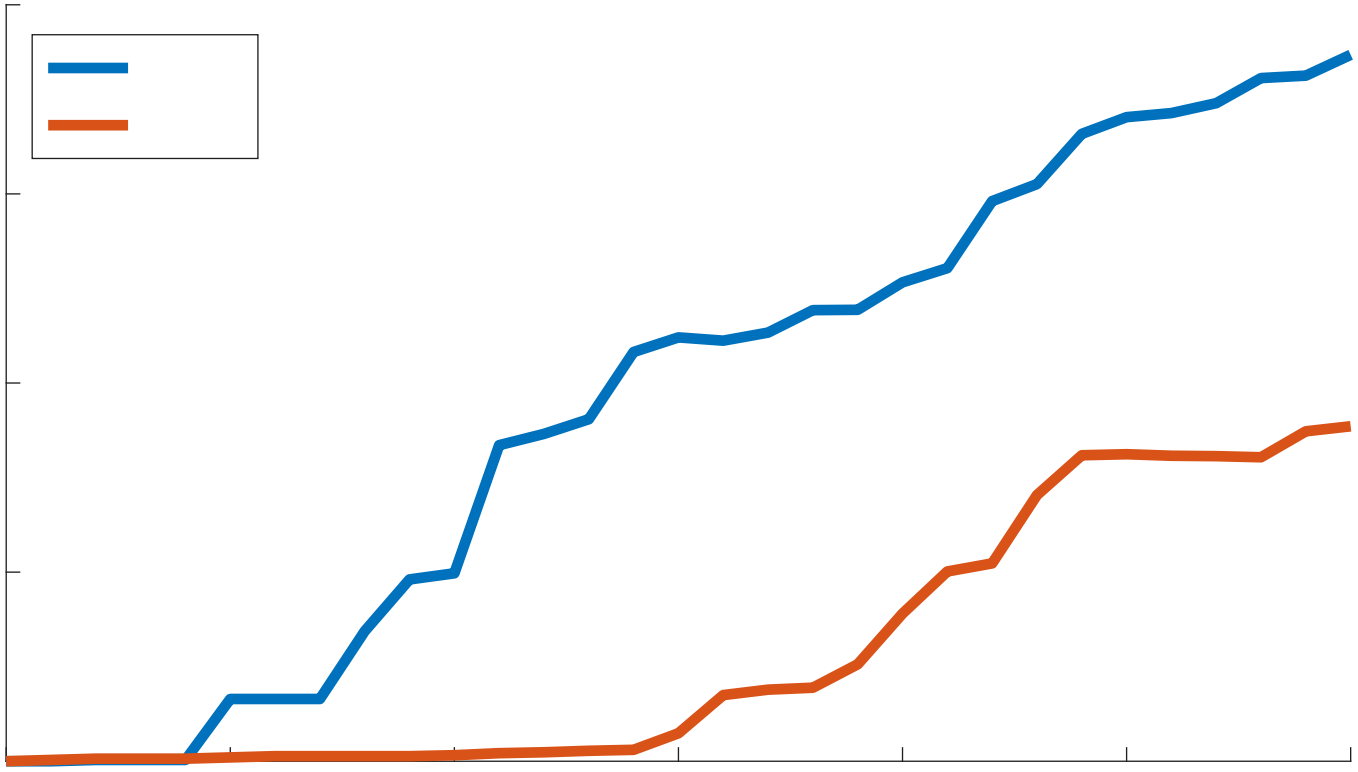
Data Center: 18dBi



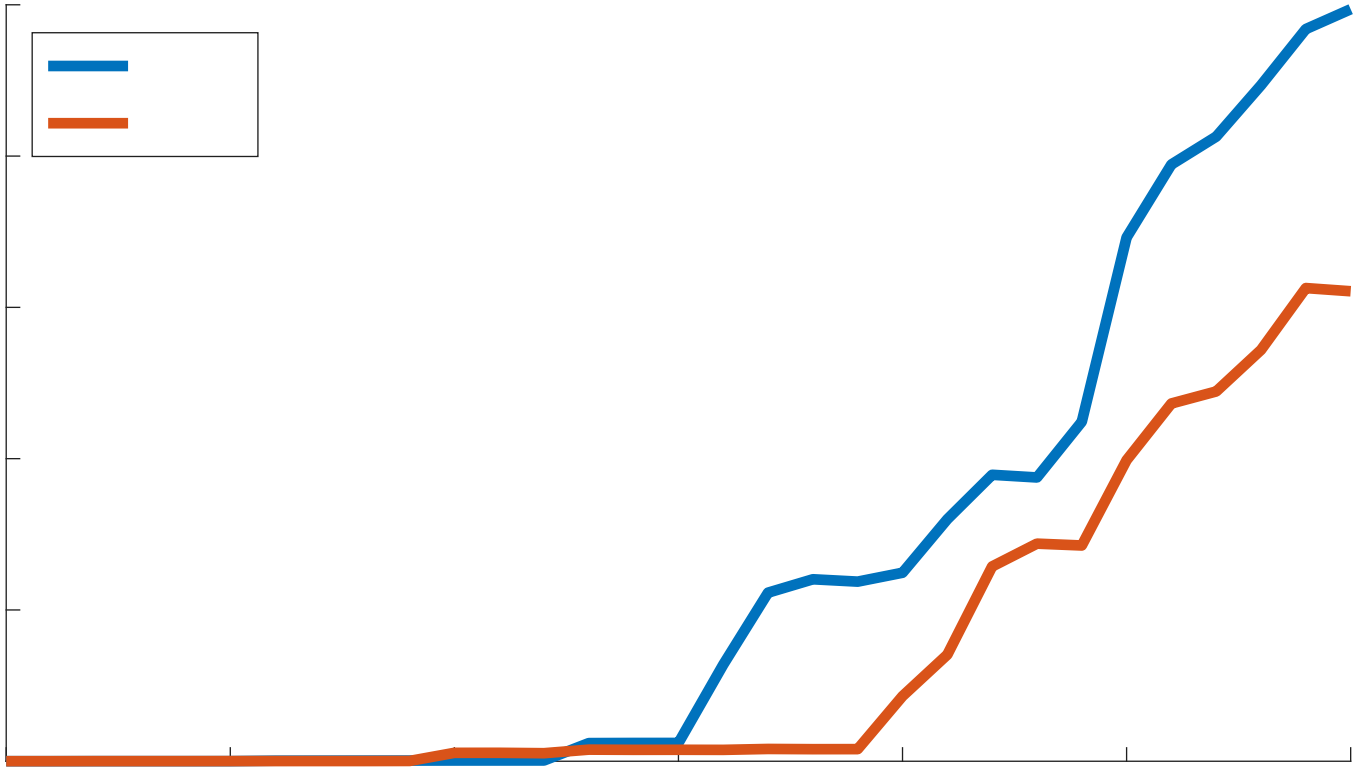
Impact of ISI

- The FEC simulations have so far not shown any error floor
- Since at most 10^9 bits have been simulated so far, the SNR-BER curves have been extrapolated to allow an estimate of the SNR required to reach the target BER of 10^{-12}
- Error floors may appear due to intersymbol interference (ISI)
- As a rough estimate to check whether ISI may become an issue the RMS delay spread for each scenario is calculated
- In order to calculate the RMS delay spread, noise clipping has to be applied, i.e. multipath signals with an amplitude of less than 30dB below the respective main signal are disregarded. Hence, the delay spread becomes a function of the SNR
- If the RMS delay spread is much smaller than the symbol duration (chip duration), ISI may be neglected
- The chip duration lies between ~0.023ns (bandwidth of 69.120 GHz) and ~0.568 ns (bandwidth of 2.160 GHz)

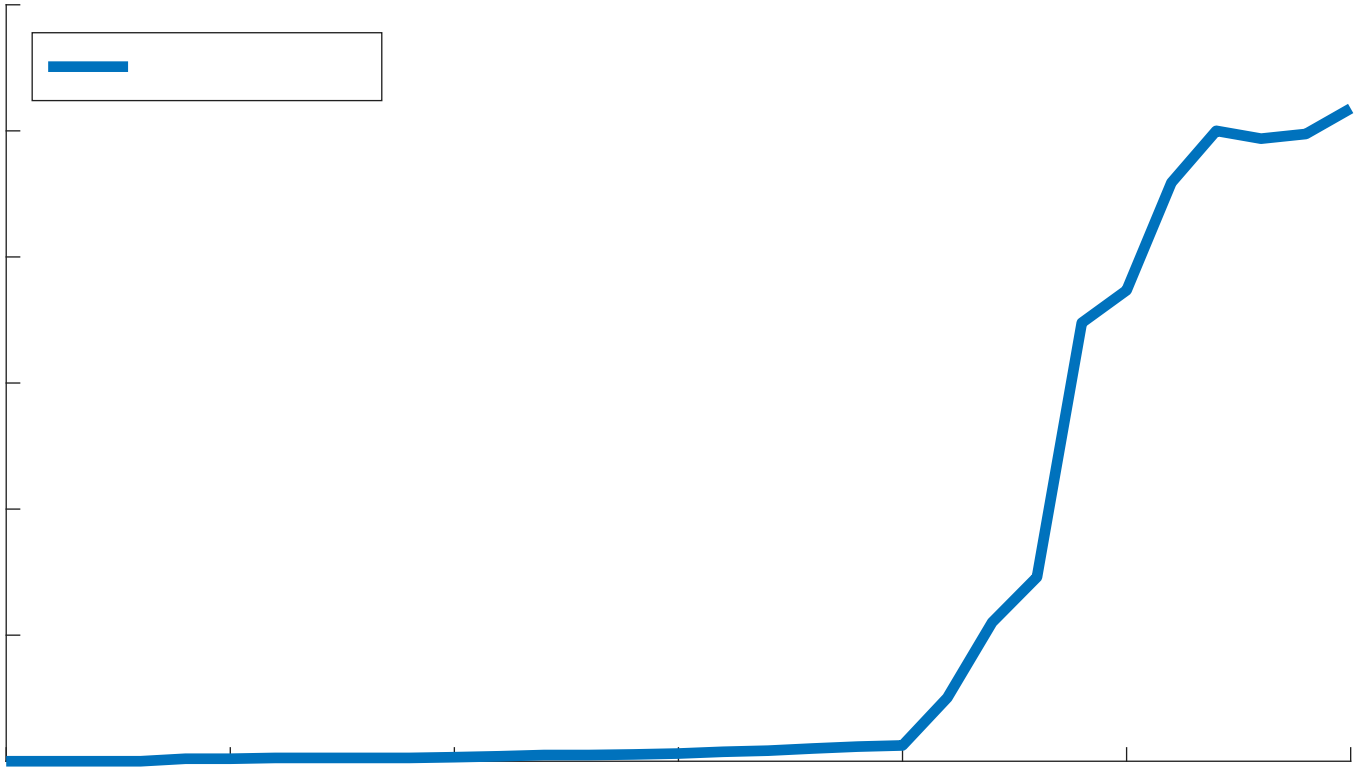
ISI Impact Estimation



ISI Impact Estimation



ISI Impact Estimation



Implication to Link Budget: SC PHY

MCS Identifier	Modulation	Coding	Required SNR for BER 10^-12 [AWGN]	Required SNR for BER 10^-12 [Worst Case]
0	BPSK	11/15 LDPC	3,10 dB	4,34 dB
1	BPSK	14/15 LDPC	6,42 dB	7,32 dB
2	QPSK	11/15 LDPC	6,07 dB	7,31 dB
3	QPSK	14/15 LDPC	9,48 dB	11,33 dB
4	8PSK	11/15 LDPC	10.98 dB	14,99 dB
5	8PSK	14/15 LDPC	14.46 dB	17,84 dB *
6	8APSK	11/15 LDPC	10.98 dB	13.22
7	8APSK	14/15 LDPC	14.44 dB	16,86 dB *
8	16QAM	11/15 LDPC	13,00 dB	16,64 dB
9	16QAM	14/15 LDPC	16,43 dB	23,63 dB*
10	64QAM	11/15 LDPC	18,11 dB	35,15 dB**
11	64QAM	14/15 LDPC	22,37 dB	NA ******

* no. of scenarios w/ error floor

Implication to Link Budget: OOK PHY

MCS Identifier	Modulation	Coding	Required SNR for BER 10^-12 [AWGN]	Required SNR for BER 10^-12 [Worst Case]
0	OOK	RS	11.09 dB	13.05 dB
1	OOK	11/15 LDPC	5.95 dB	7.12 dB
2	OOK	14/15 LDPC	9.51 dB	11.56 dB

* no. of scenarios w/ error floor

Conclusion on Preliminary Results

- The simulation results show that a BER of 10-12 can be achieved in most cases for a SNR in the order of 4-10 dB for OOK, BPSK and QPSK
- First results for 16-QAM and 64-QAM show that it might be difficult to achieve the target BER for reasonable SNR. More simulations are needed to confirm this
- The RMS delay spread is significantly below the chip duration for SN < 15 dB if antennas with 18dBi gain are assumed
- In the intra-device case, when using antennas with a gain of 6 dBi, ISI may become a critical issue

Thank You
for Your Attention