The Impact of Polarization Mode Dispersion: Optical Duobinary vs. NRZ Transmission

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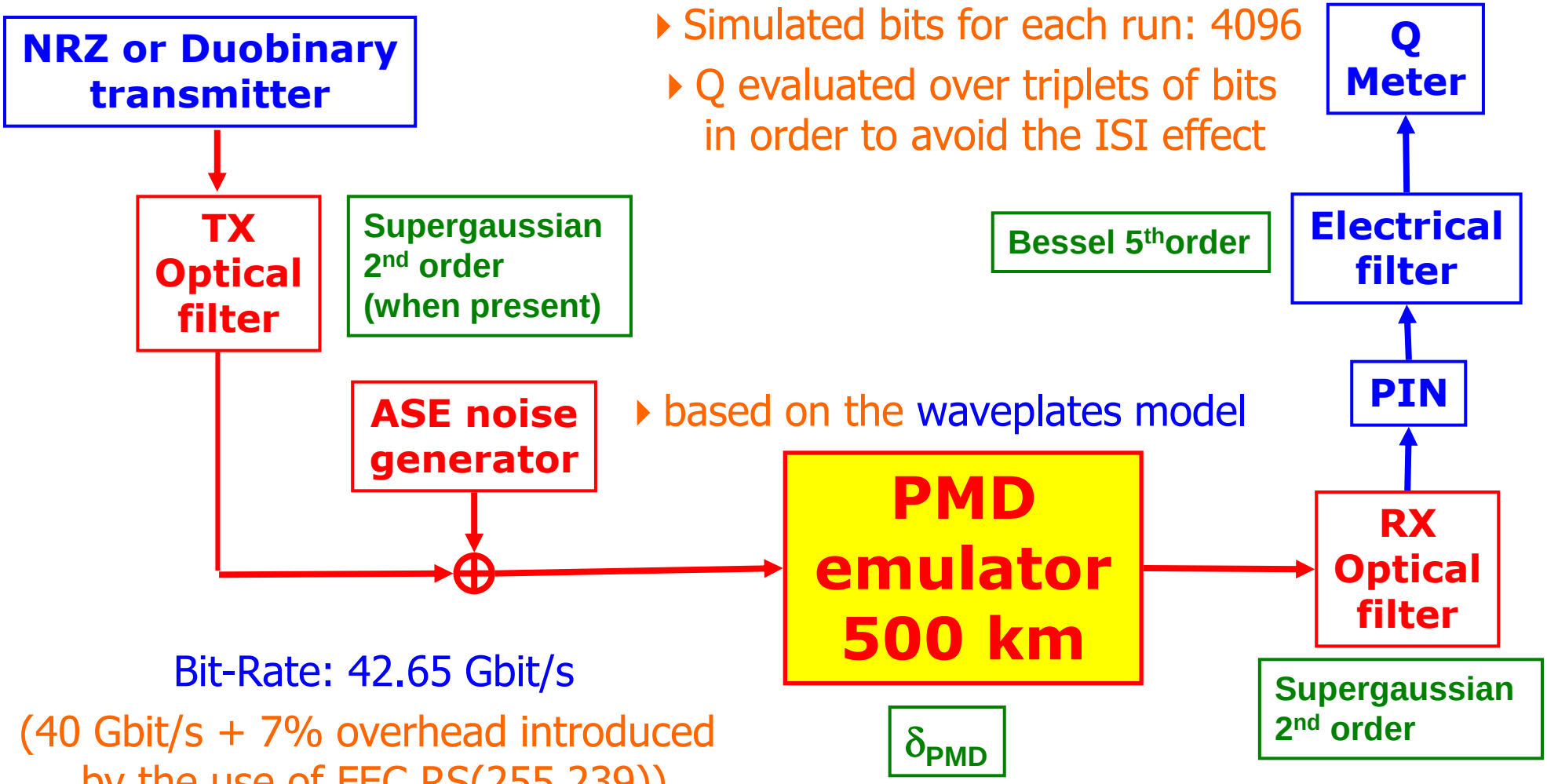
Introduction

- The optical duobinary data-coding is a promising technology for the implementation of ultra-dense WDM systems with spectral efficiency close to the Nyquist limit.
- Working at bit-rates as high as 40 Gbit/s, Polarization-Mode Dispersion (PMD) could strongly impair system performance.
- The purpose of this work is to compare the impact of PMD on optical duobinary with respect to its impact on NRZ in a OC-768 FEC-inclusive scenario.

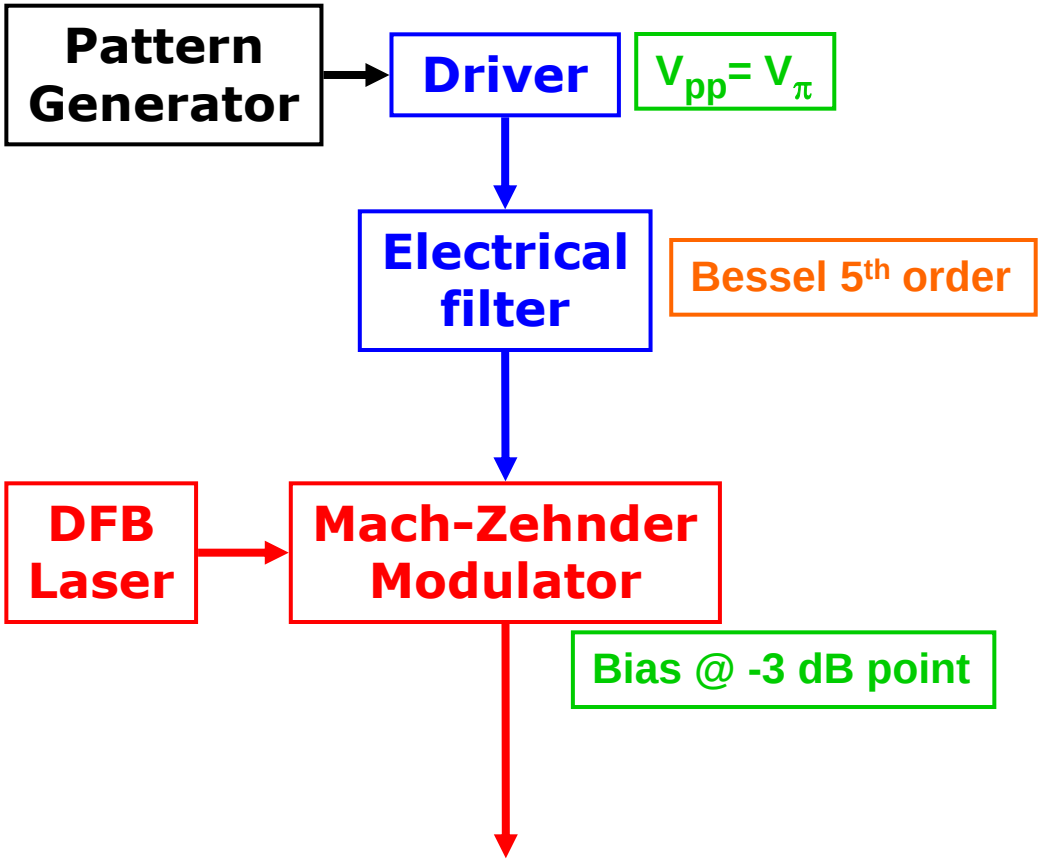
Summary

- Description of NRZ and Duobinary systems
- Simulation results
- Conclusions

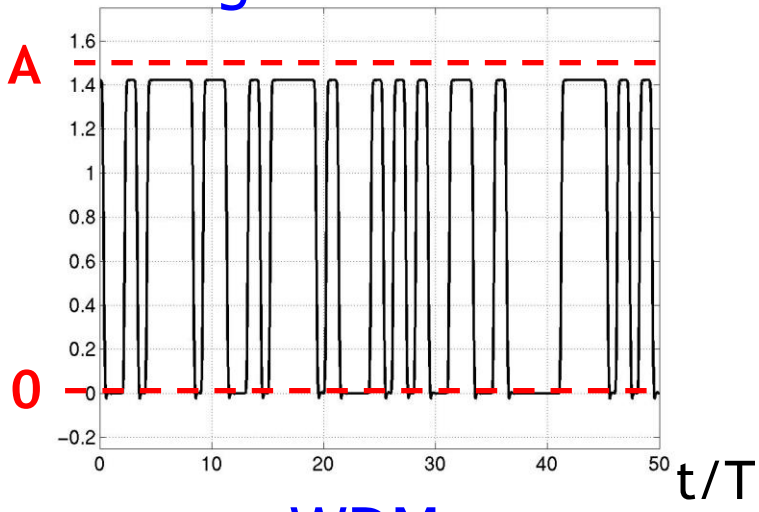
System layout



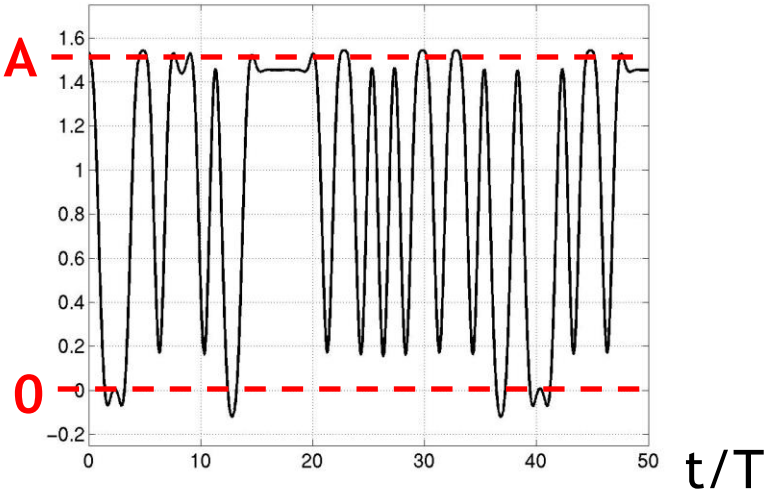
NRZ transmitter



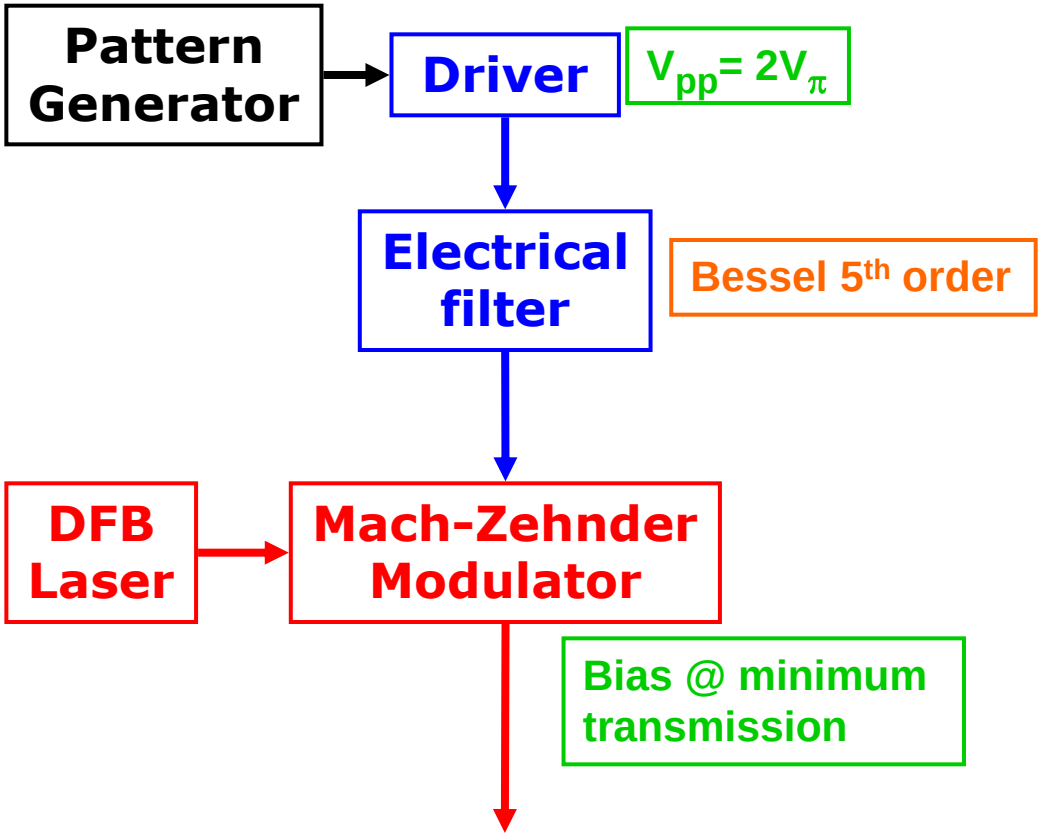
Single-channel



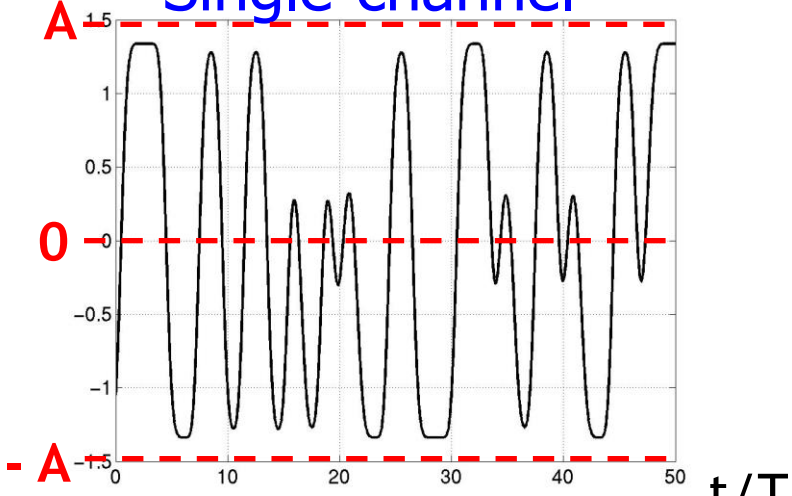
WDM



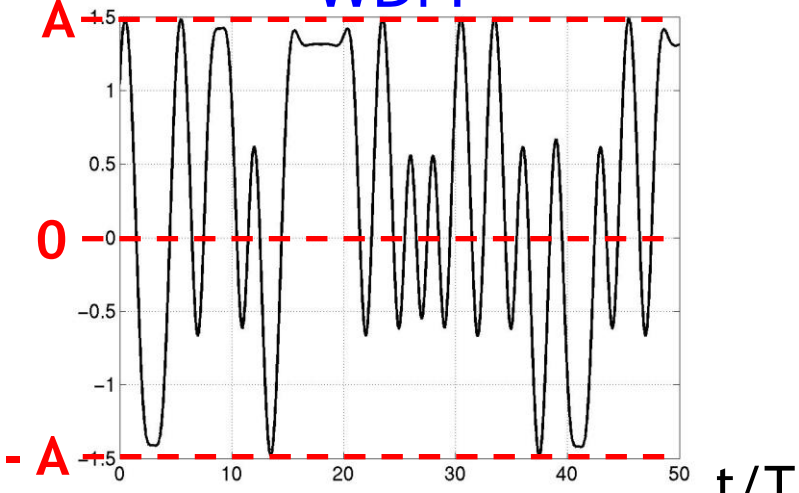
Duobinary transmitter



Single-channel



WDM



Analyzed systems description

DWDM system with channel spacing equal to 50 GHz

- Optical filters have been used both at TX and RX side for both NRZ and Duobinary
- Optical and electrical filters bandwidth have been optimized in a back-to-back configuration, in which only ASE noise and ISI impairments have been considered
- Maximum back-to-back Q values obtained:
  - 13.0 dB for NRZ
  - 15.3 dB for Duobinary

Analyzed systems description

Single channel system

- Three configurations of modulation formats have been considered:
  - Standard NRZ (without optical filter at the transmitter)
  - Duobinary (without optical filter at the transmitter)
  - Filtered duobinary (with optical filter at the transmitter)
- Optical and electrical filters bandwidth have been optimized in a back-to-back configuration, in which only ASE noise and ISI impairments have been considered
- Maximum back-to-back Q values obtained:
  - 15.8 dB for NRZ
  - 13.6 dB for unfiltered Duobinary
  - 16.9 dB for filtered Duobinary

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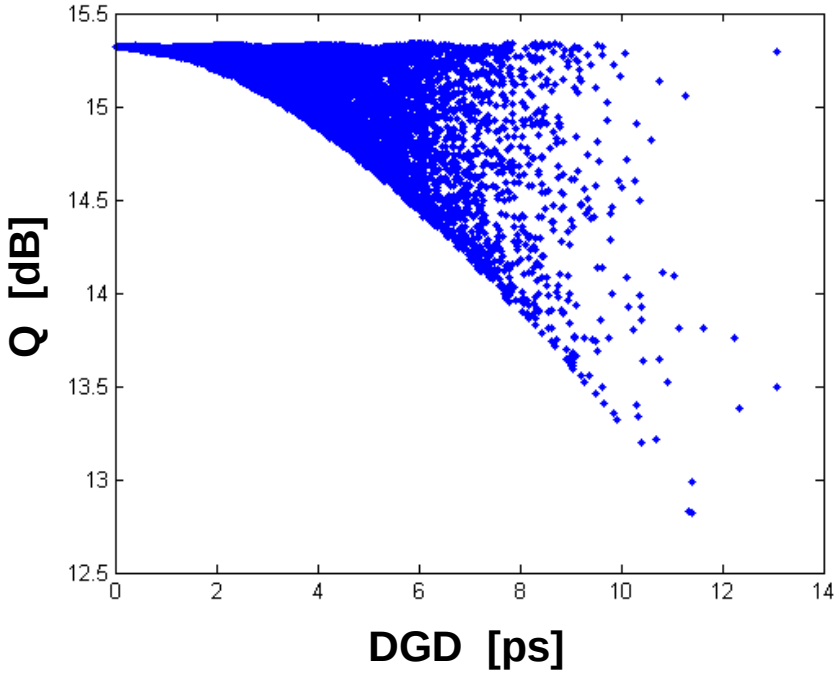
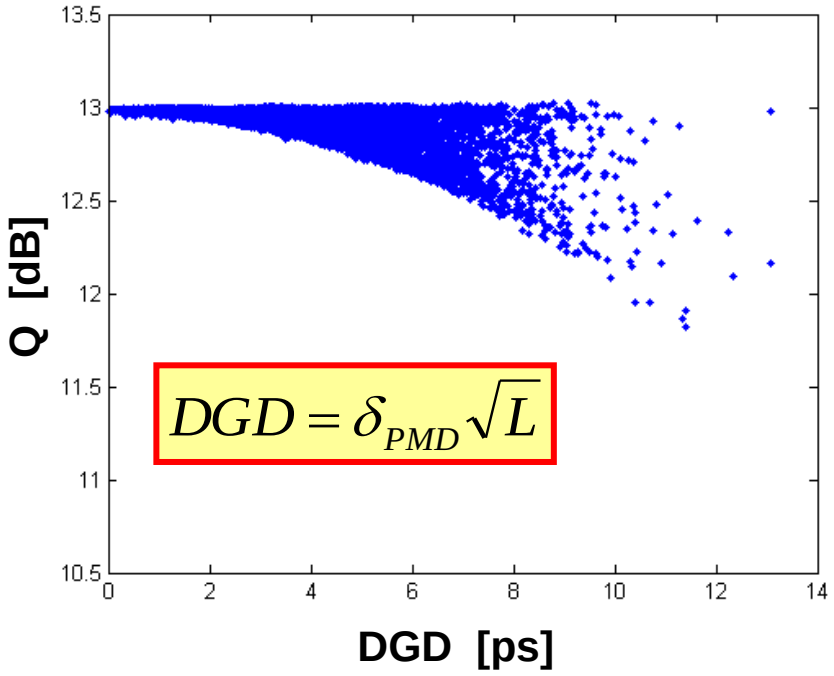
Simulation results: Q vs. DGD

DWDM system, δ_{PMD}=0.175 ps/√km

Duobinary



NRZ



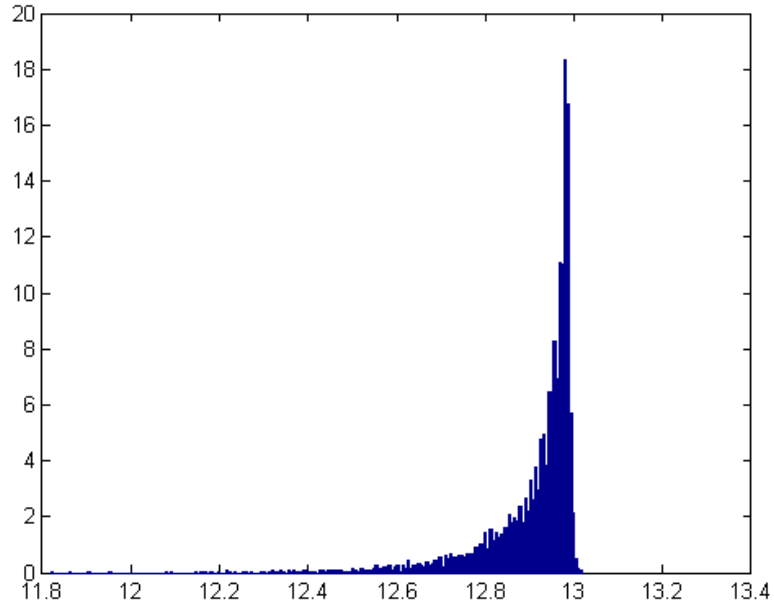
$$DGD = \delta_{PMD}\sqrt{L}$$

- Note the different flat top level due to different back-to-back performance
- Less Q values spreading, like for NRZ, indicates more PMD resilience

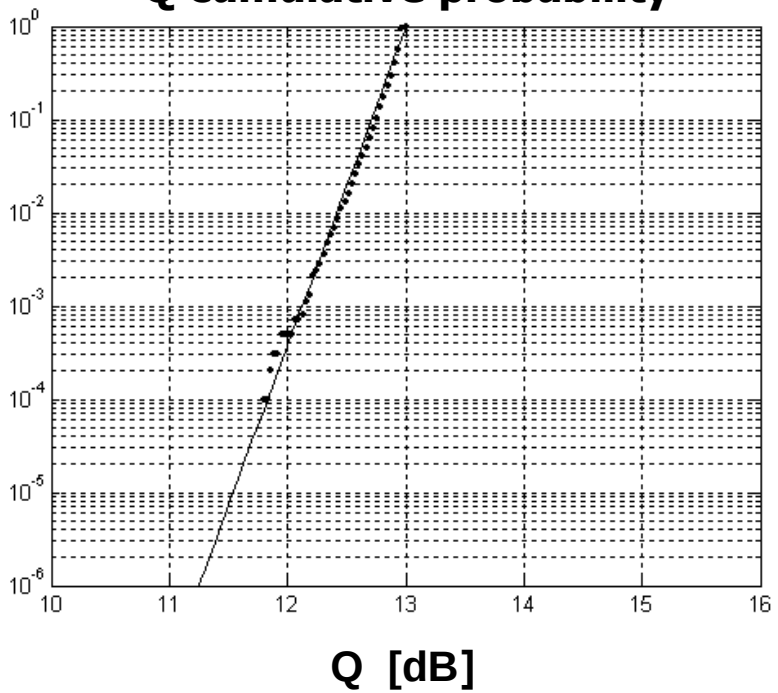
Exponential fitting

NRZ DWDM system, δ_{PMD}=0.175 ps/√km

Q probability density function

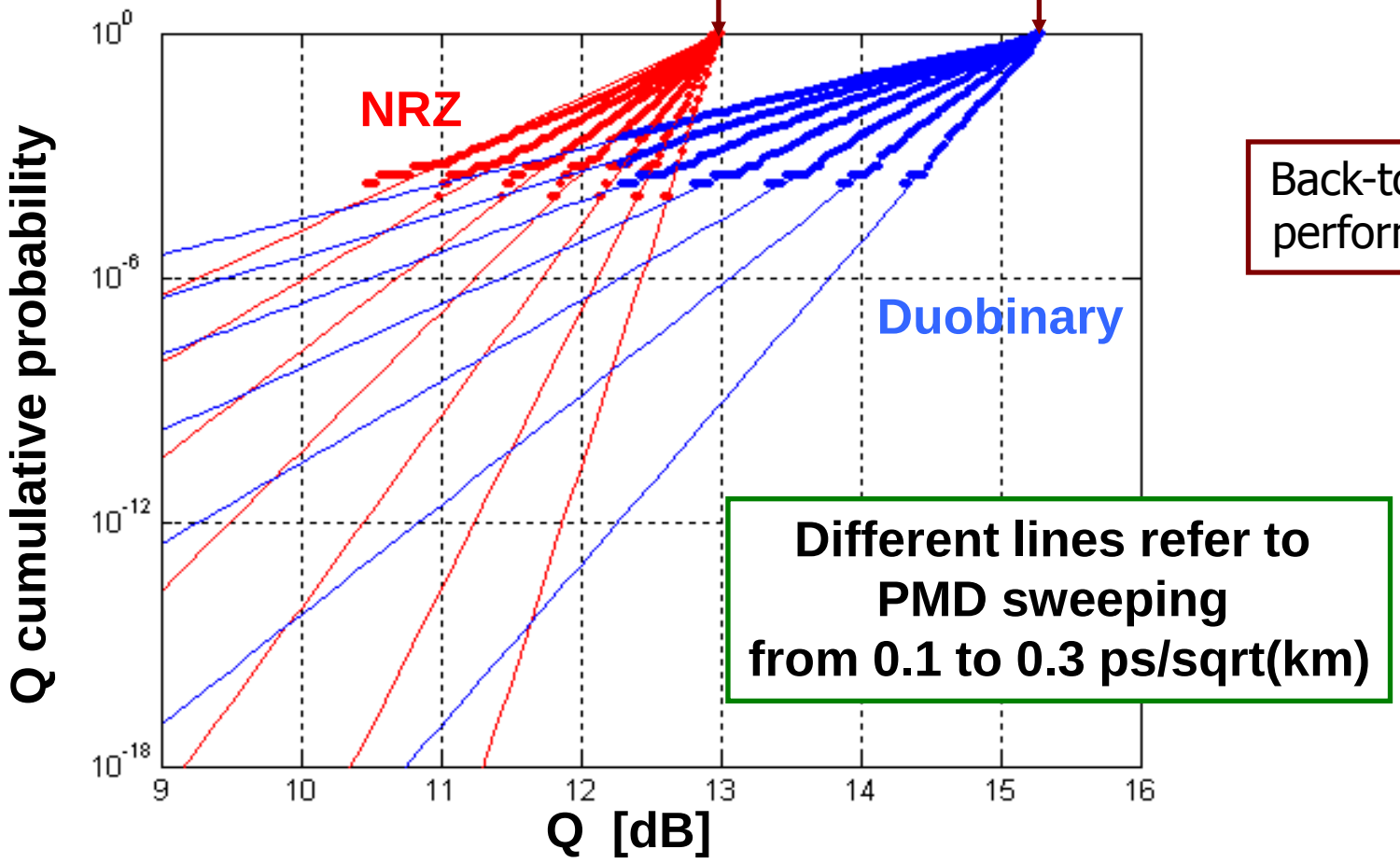


Q cumulative probability



- Q values distributed following an exponential function
- Least square fitting of cumulative probability with an exponential function, in order to extend the evaluation below 10^{-4}

Cumulative probability (DWDM)



Given the same PMD value, the Q cumulative probability for duobinary shows a reduced slope with respect the NRZ one: this means stronger PMD impact

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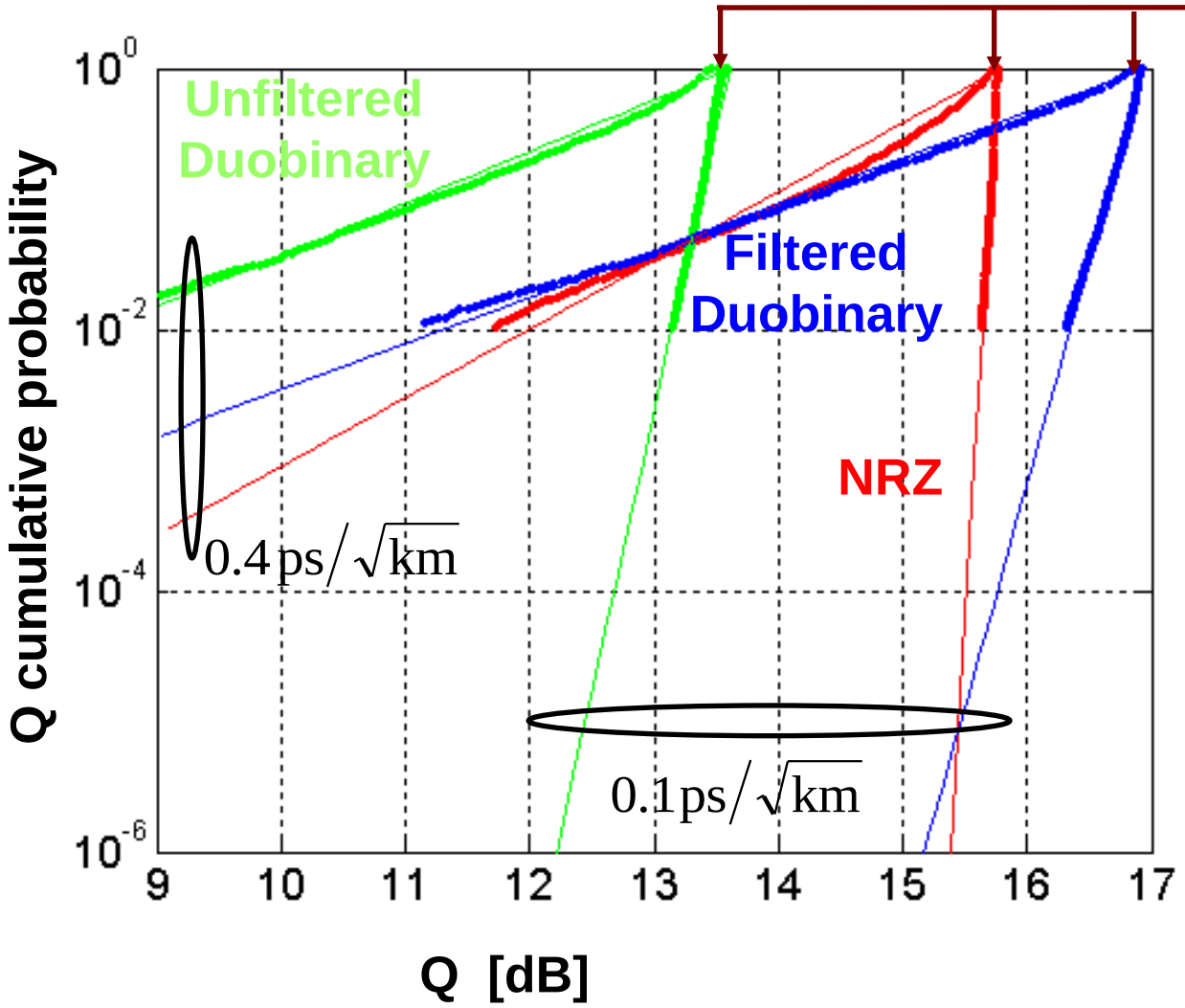
Cumulative probability (single-channel)



PMD sensitivity of unfiltered duobinary is slightly worse than the NRZ', while filtered duobinary presents a much more relevant sensitivity.

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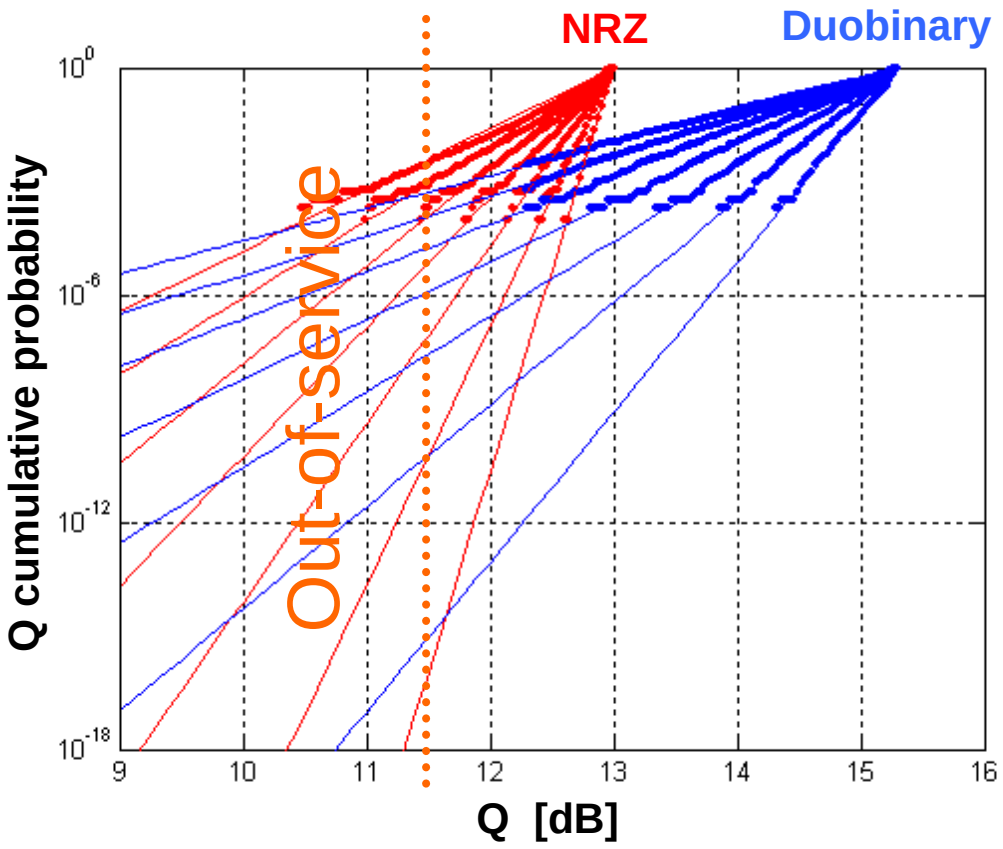
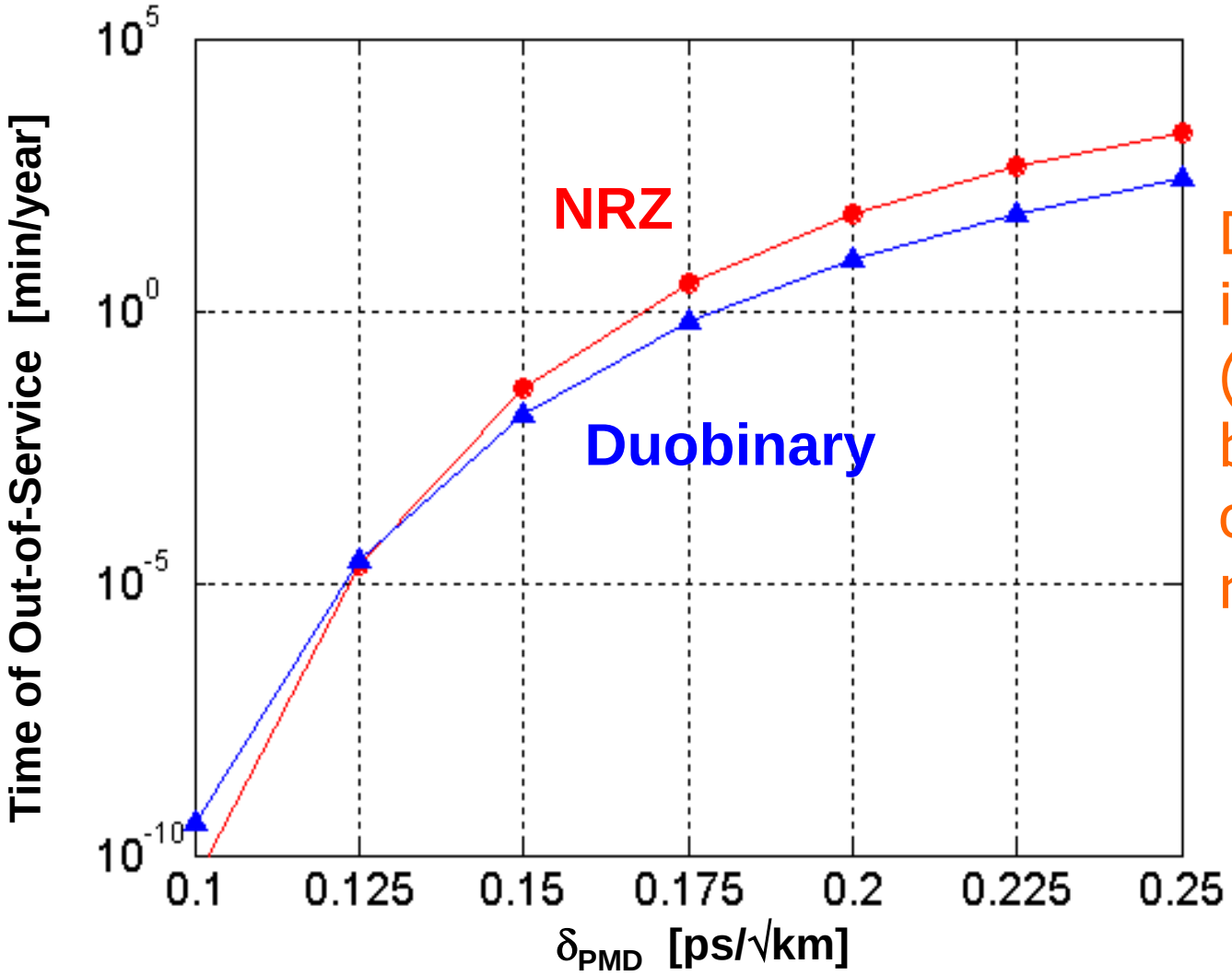
Out-of-service evaluation

- Since each run is independent of each other, we can assume the percentage of runs as a percentage of time
  - Therefore, for a given Q value, the cumulative probability becomes the percentage of time with Q values lower than that level: fixing a minimum Q for system in-service we can evaluate the percentage of out-of-service



- **Target BER is 10^{-13}**
  - **RS(255,239) needs Q_{input}=11.5 dB**

Time of out-of-service (DWDM systems)



Due to its better intrinsic performance (2.3 dB margin in back-to-back), the use of duobinary may still result convenient.

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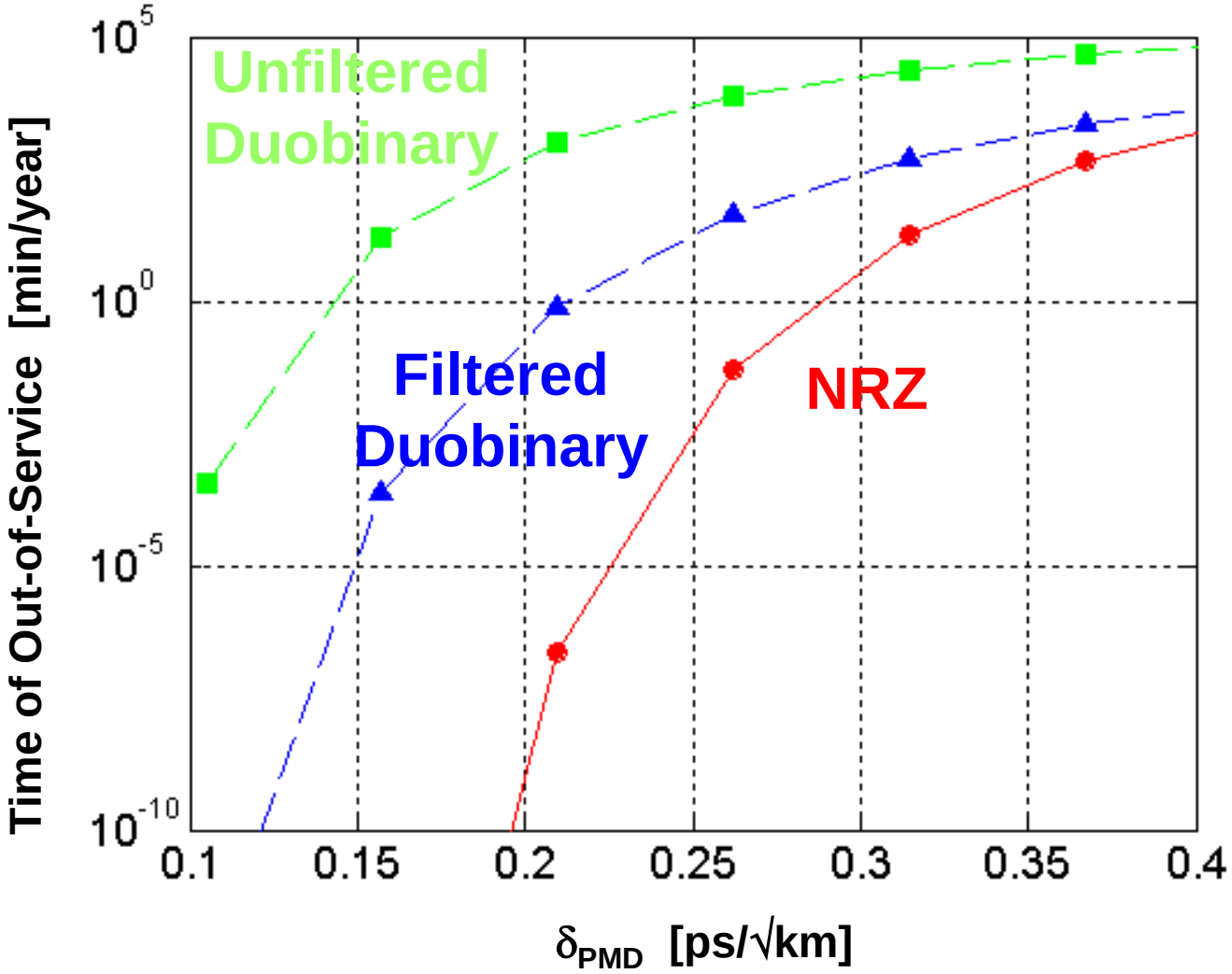
Time of out-of-service (single-channel)



Despite of its better intrinsic performance (1.1 dB gain in back-to-back), the performance of filtered duobinary in presence of PMD is worst than that of NRZ in this scenario.

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Conclusions

- The impact of PMD is stronger on duobinary than on NRZ.
- Due to its better intrinsic performance (2.3 dB gain in back-to-back), the use of duobinary may still result convenient in some scenarios.
- Future work:
  - analysis if duobinary and NRZ modulation formats in systems employing PMD compensation techniques