Flexible FEC Optimization for Time-Domain Hybrid Modulation Formats

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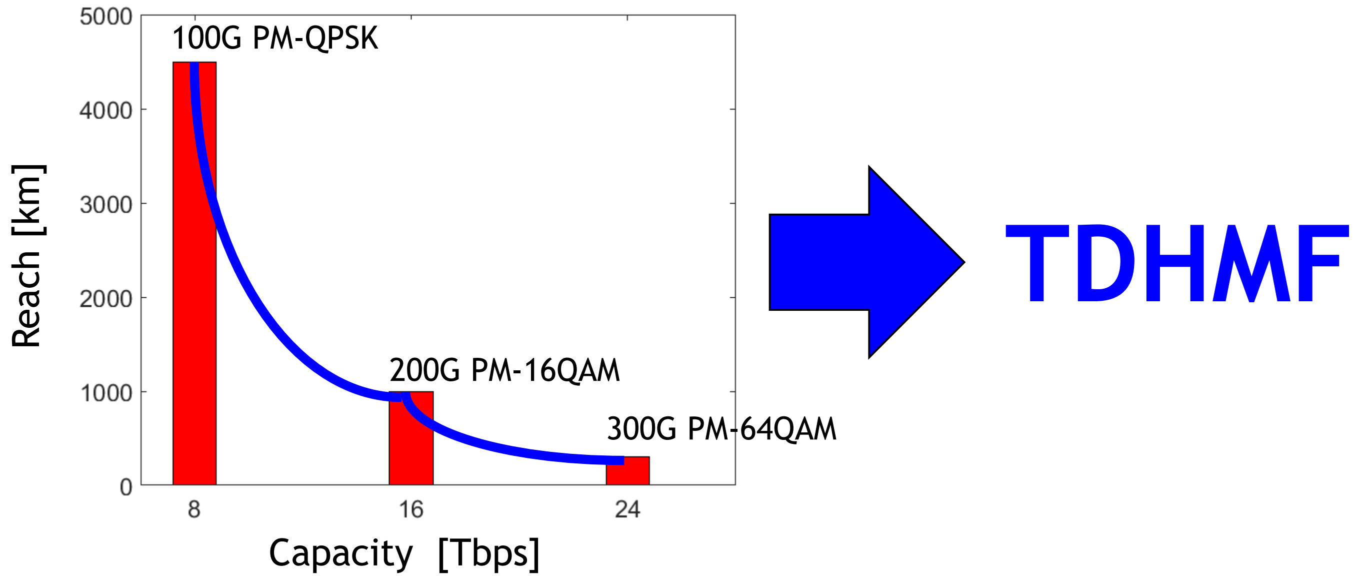
Outline

- Scenario
  - Why we need TDHMF?
  - What are TDHMF?
  - Transmitter operation strategies
- Flex-FEC: a new technique for TDHMF
- Results
- Conclusions and future analyses

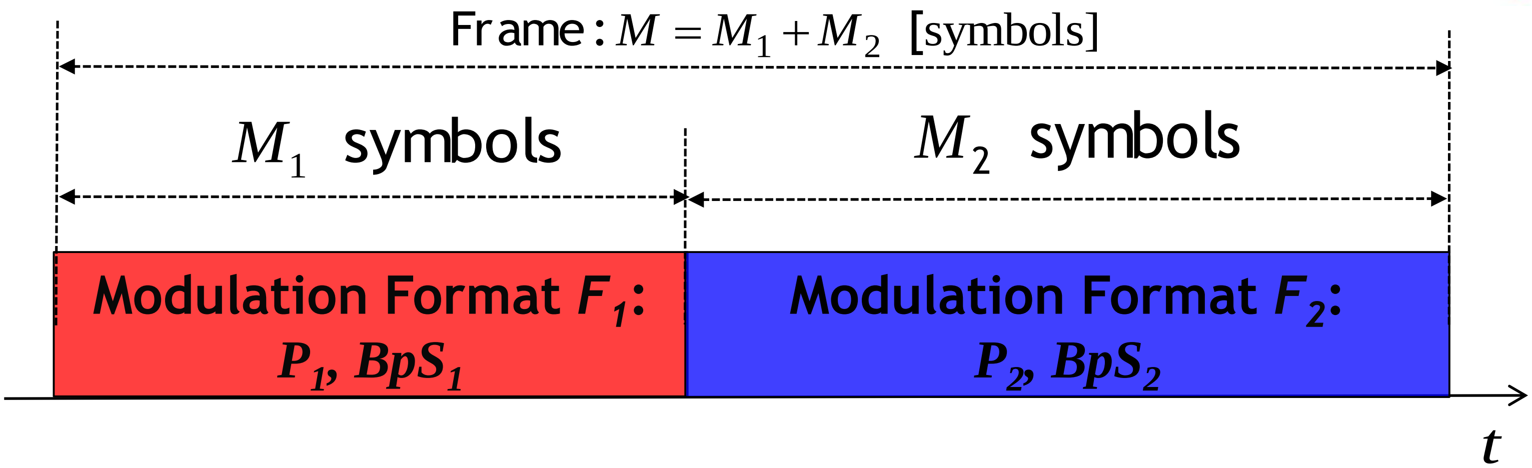
Why we need TDHMF?

- Reach has a trade-off with capacity
- Use of reduced-complexity “squared” constellations introduce strong granularity



- We achieve continuity of reach vs. spectral efficiency
- Flexible network optimization

What are TDHMF?



Overall bit-per-symbol

$$BpS = \left(1 - \frac{FR}{100}\right) \cdot BpS_1 + \frac{FR}{100} \cdot BpS_2$$

Format ratio : $FR = 100 \cdot \dfrac{M_2}{M}$ **Power ratio** : $PR = \dfrac{P_2}{P_1}$

BER(OSNR) depends on formats, format ratio and power ratio

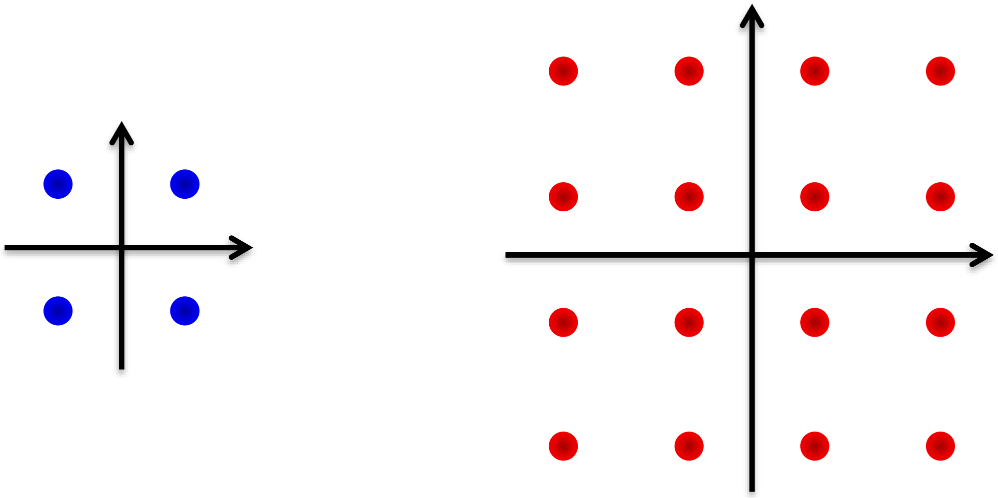
Transmitter operation strategies

OPTCOM

Given F_1, F_2 and FR, PR is the parameter to set according to one of the following strategies:

a) PR=0 dB: the power is kept constant during transmission (P_1=P_2)

b) d_1=d_2: the minimum Euclidean distance is kept equal for both F_1 and F_2

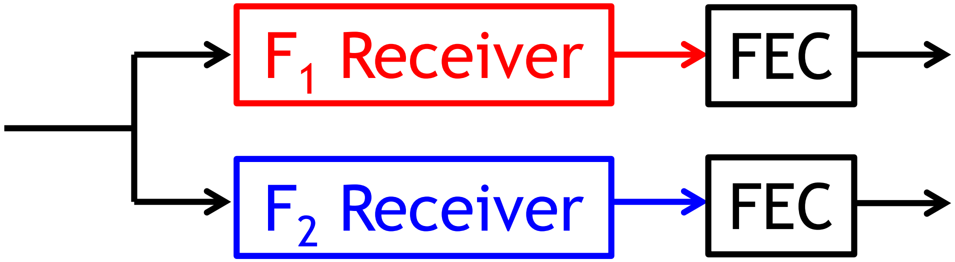


PR=7 dB

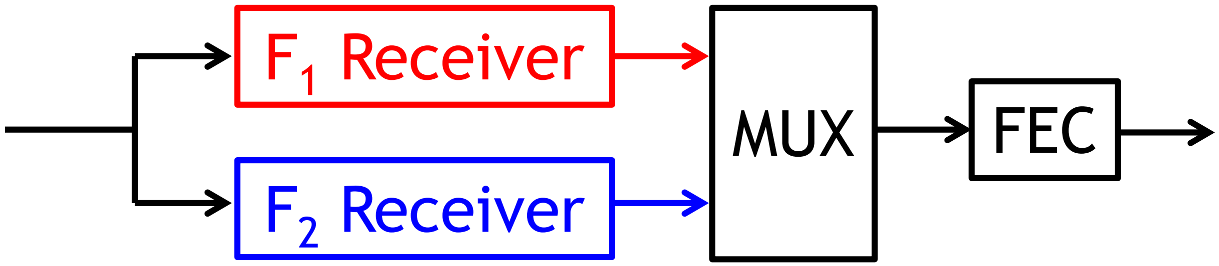
Transmitter operation strategies

Given F_1, F_2 and FR, PR is the parameter to set according to one of the following strategies:

c) *Same-OH*: both F_1 and F_2 are forced to operate at the FEC cliff assuming same FEC is applied to both formats

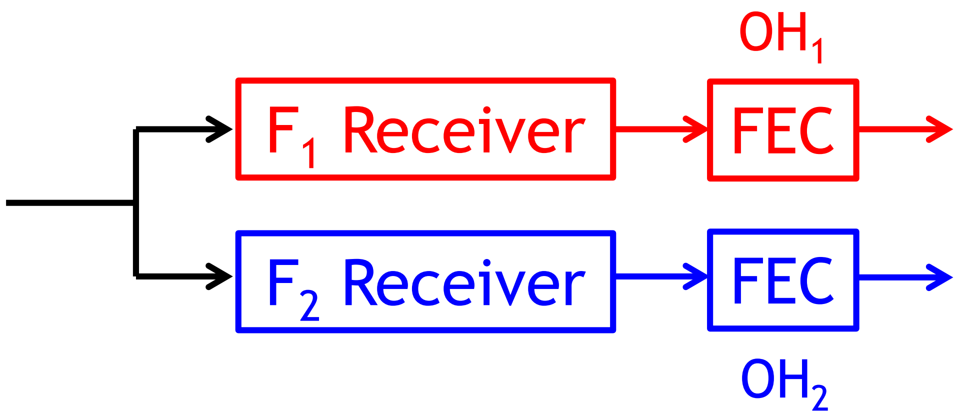


c) *Min BER*: PR is obtained minimizing SNR in BER equation



Flexible-FEC

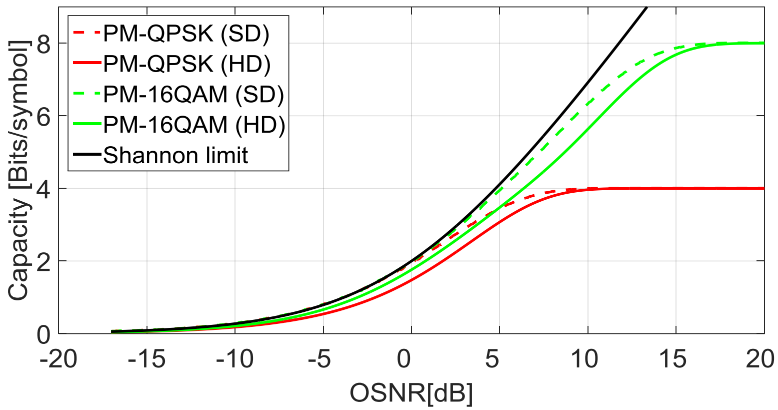
- In our previous studies, we considered the same-OH approach where the same FEC is applied to both formats
- Here, we propose to relax such constraint and optimize the overhead for each format



Optimization process

- We fix an overall OH
- For each Format Ratio (FR), we optimize the choice of OH_1 ad OH_2 in order minimize the required OSNR
  - This defines the power ratio (PR) between formats
- We base our study on ideal FEC, derived from capacity curves

Capacity

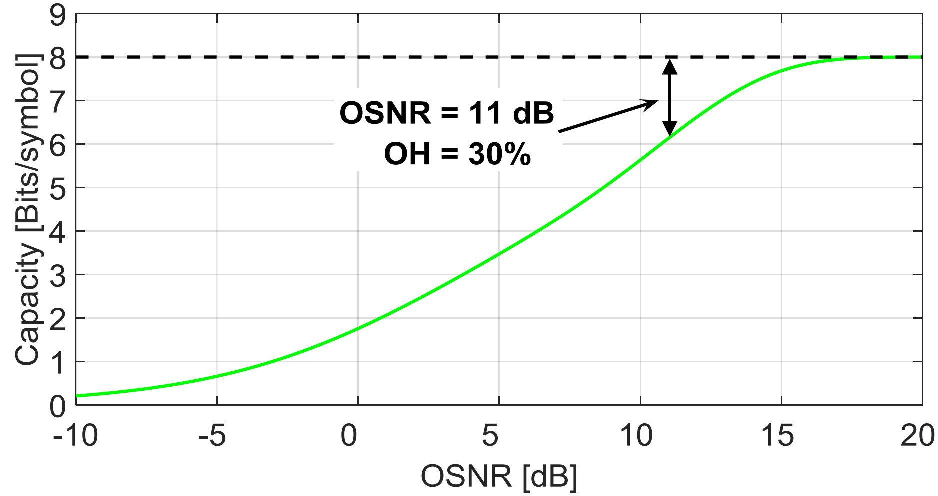


$$C_{\text{hard}} = 2\frac{1}{M}\sum_{a\in X, b\in Y} P_{Y|X}(b|a)\log_2\left(\frac{P_{Y|X}(b|a)}{P_Y(b)}\right)$$

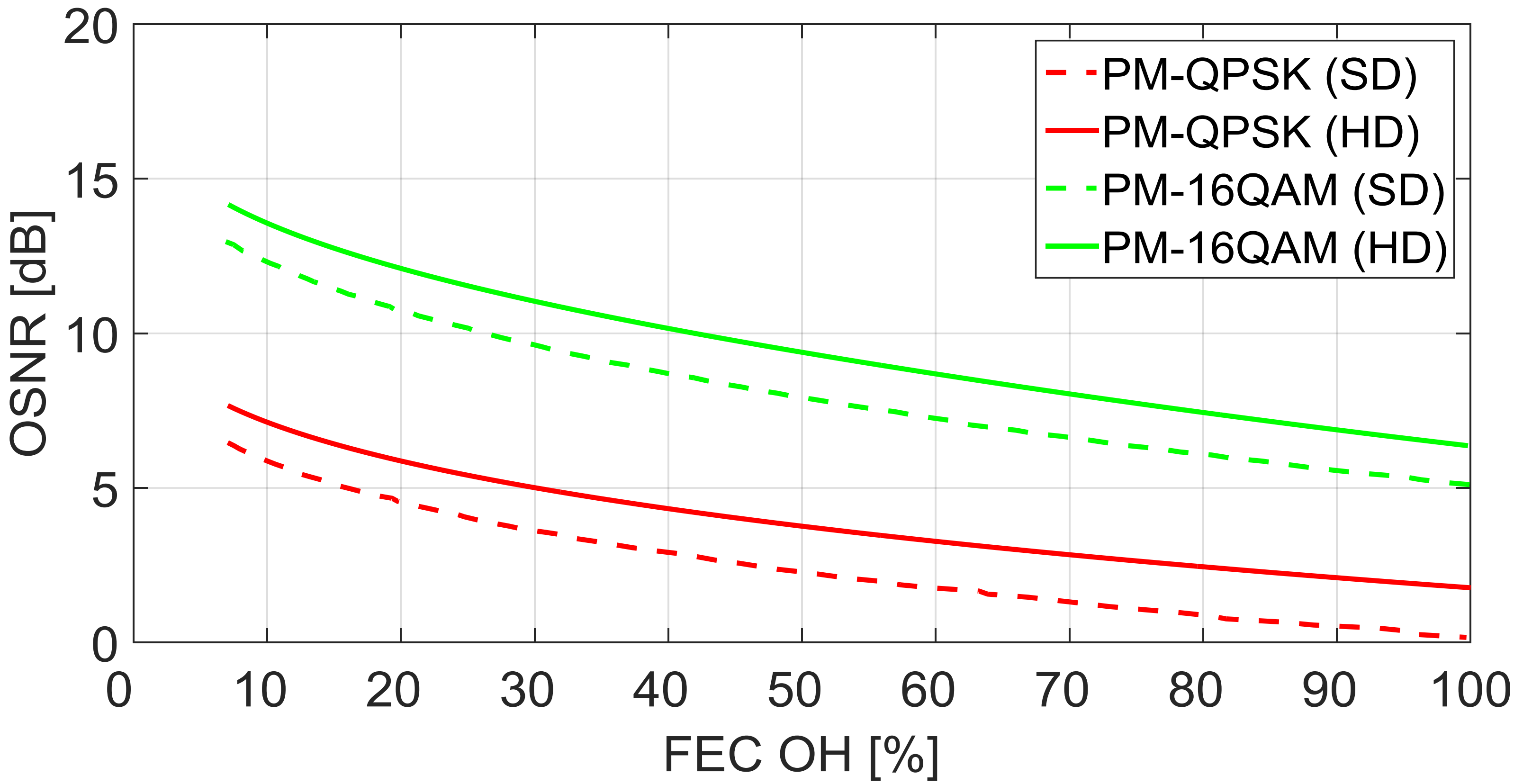
$$C_{\text{soft}} = 2\frac{1}{M}\sum_{a\in X}\int P_{Y|X}(y|a)\log_2\left(\frac{P_{Y|X}(y|a)}{P_Y(y)}\right)dy$$

$$OH(OSNR) = \frac{C_{max} - C(OSNR)}{C(OSNR)} \ [\%]$$

PM-16QAM (HD)



Sensitivity vs. Overhead for Ideal FEC



- These curves are input data for the optimization process

Comparison

Same-OH	Flexible-FEC

F1 and F2 formats have:

Same-OH

- Same gross symbol rate
- Same FEC
- Same net symbol rate
- Slightly different pre-FEC BER

Flexible-FEC

- Same gross symbol rate
- Different FEC
- Different net symbol rate
- Strongly different pre-FEC BER

Overall TDHMF:

Same-OH

- Same net symbol rate

Flexible-FEC

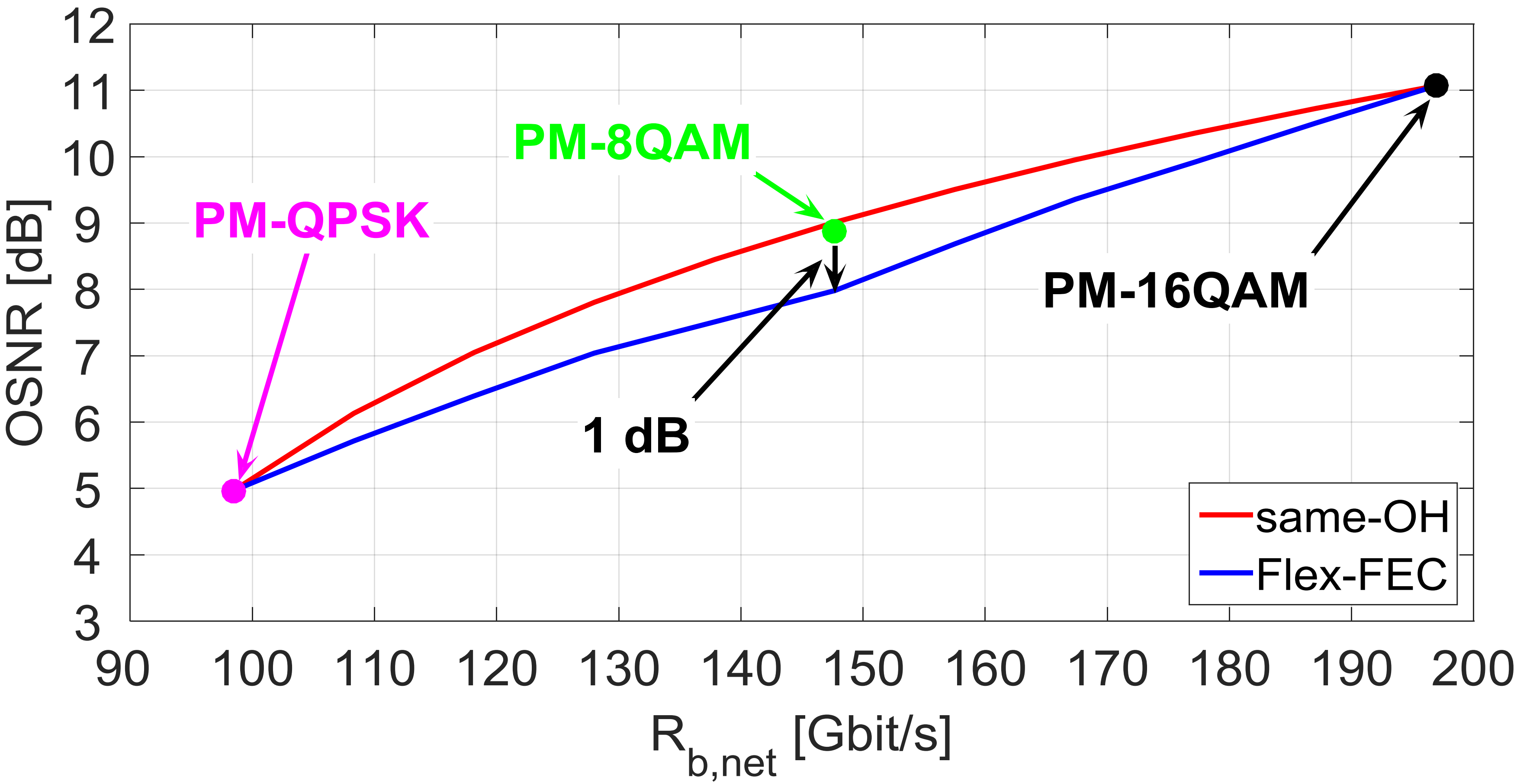
- Same net symbol rate

Setup data

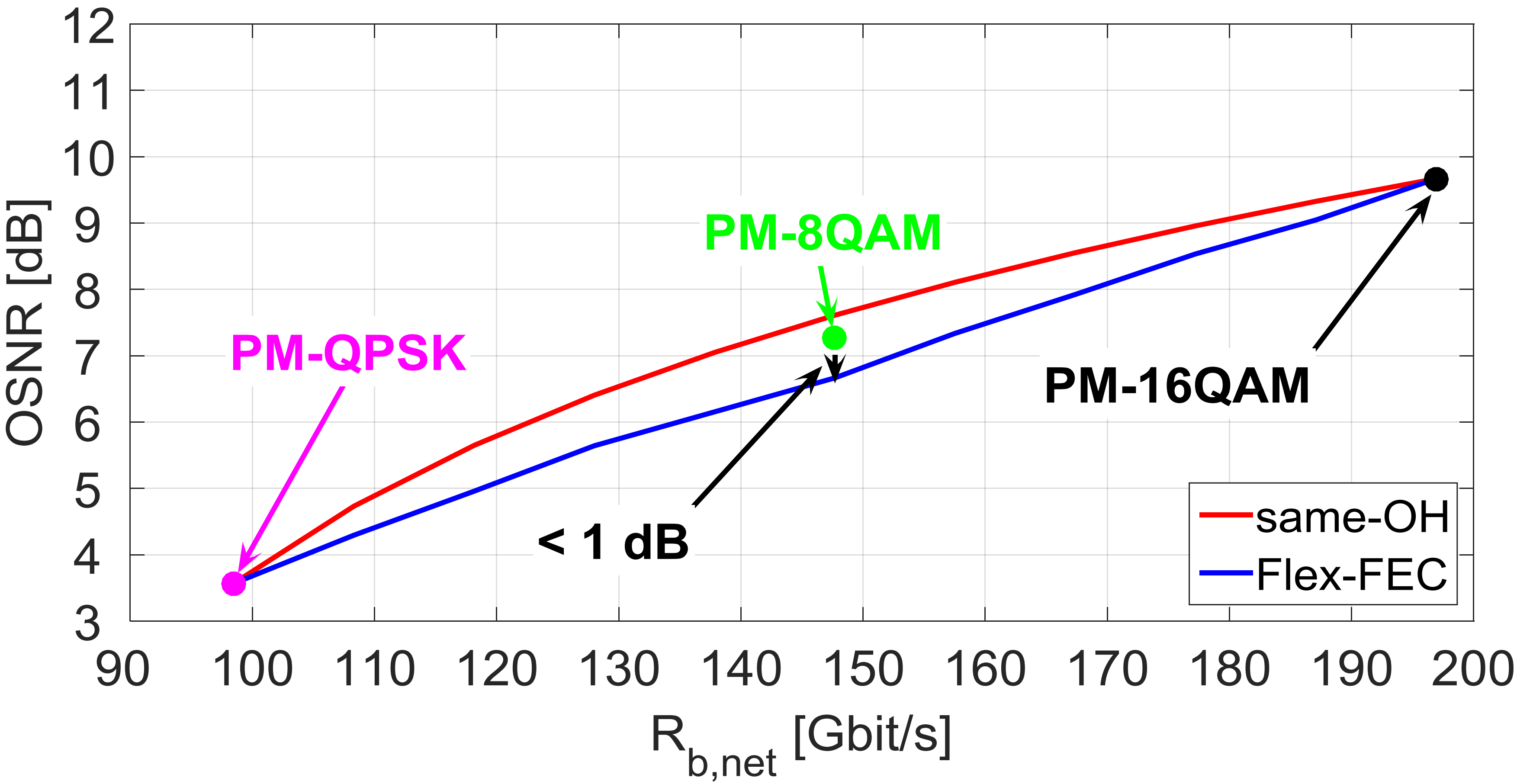
- PM-QPSK + PM-16QAM
- 32 Gbaud
- 30% overall OH
- FR swept from 0 to 100%
- OH maximum: 60%

Results HD

OPTCOM

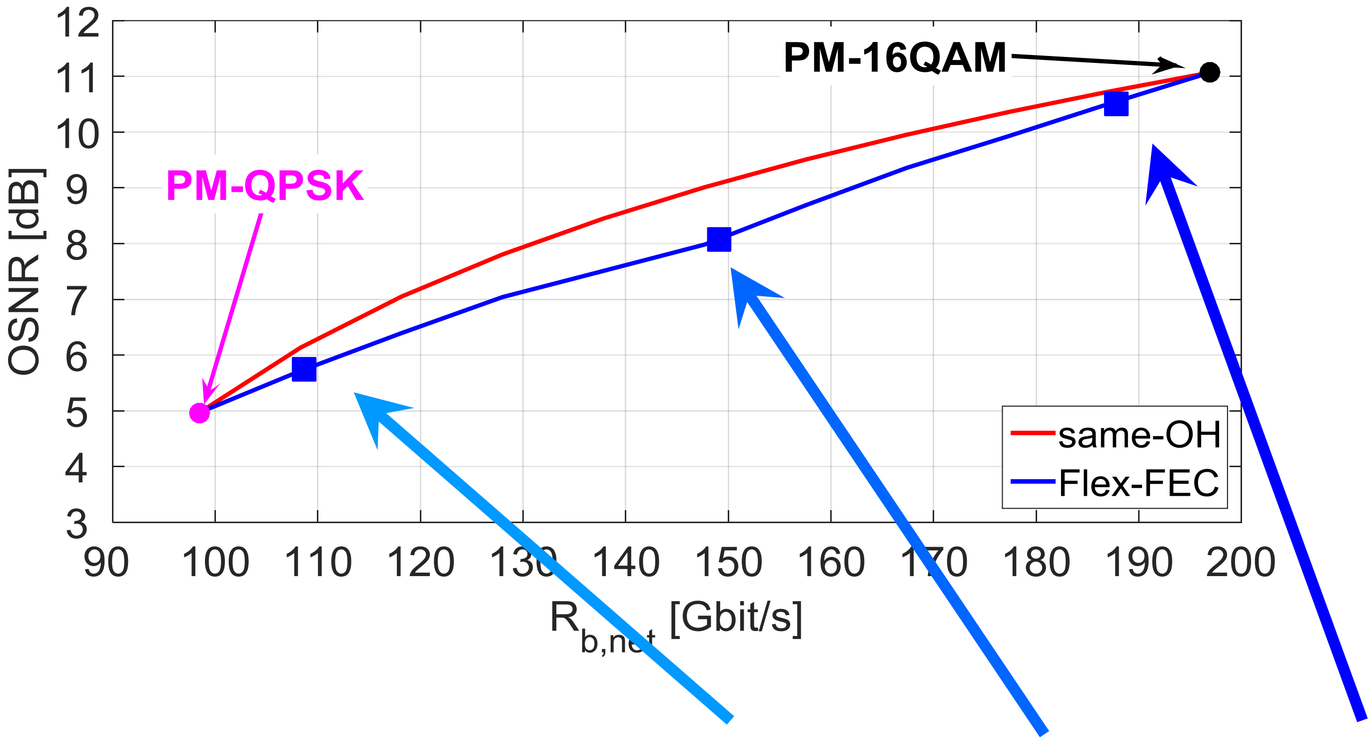


Results SD



PM-QPSK
PM-8QAM
PM-16QAM
< 1 dB
same-OH
Flex-FEC
OSNR [dB]
12
11
10
9
8
7
6
5
4
3
90
100
110
120
130
140
150
160
170
180
190
200
R b,net [Gbit/s]

Optimal FEC: Hard decision



Format Ratio	10%	50%	90%
Power Ratio [dB]	3.7	1.5	3.8
F1: PM-QPSK OH	25%	10%	10%
F2: PM-16QAM OH	60%	60%	35%

Conclusions

- Flex-FEC technique shows up to 1 dB advantage compared to standard single FEC approach
- Flex-FEC imply a PR reduction that should results in a lower NLI impact

Future analyses

- Mix other modulation formats
  - PM-16QAM & PM-64QAM
- Consider realistic FECs
- Consider other optimization targets
  - Minimize PR
- Propagation analysis to verify reduced NLI impact with respect to same-OH

Thanks for your attention!

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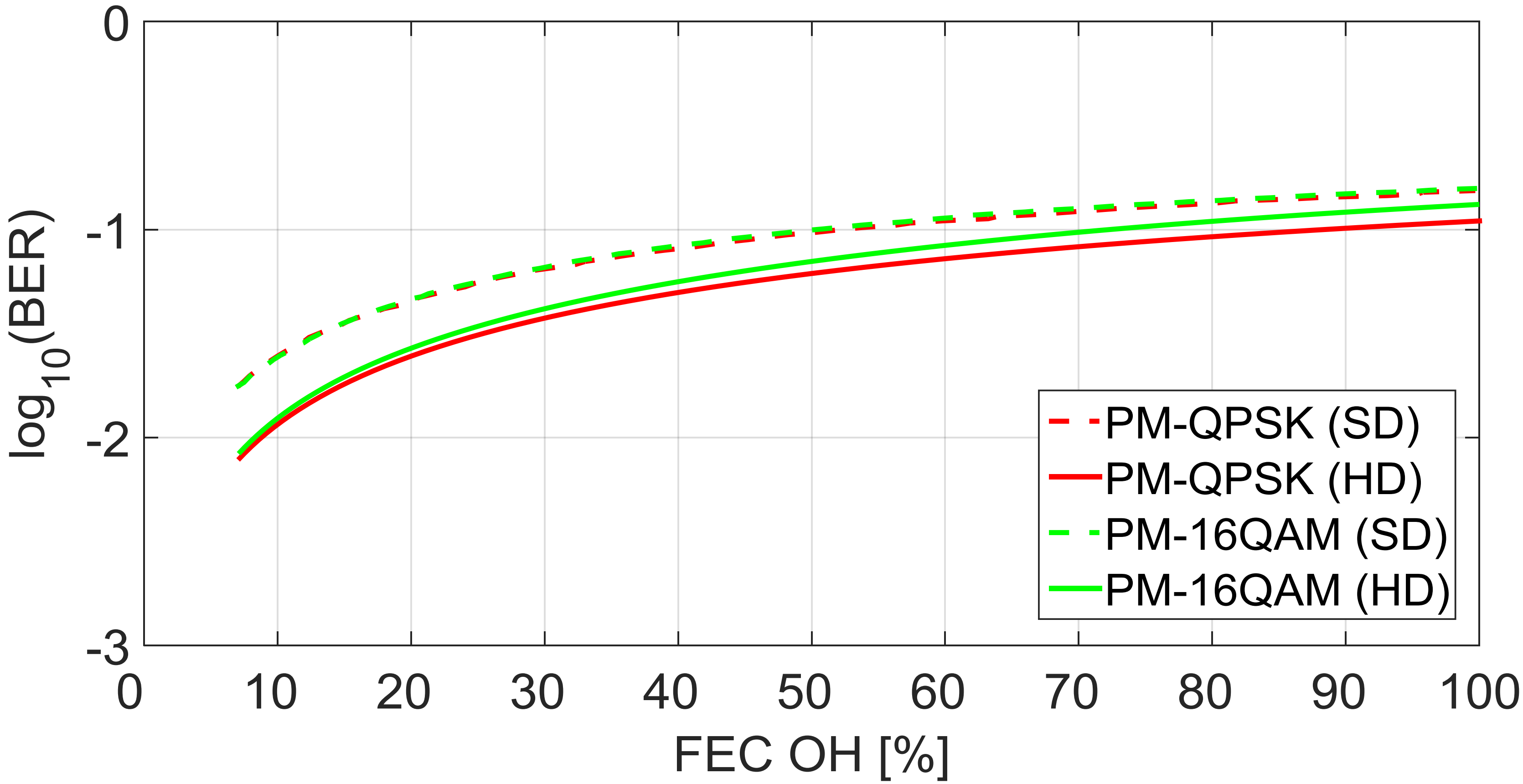
BER vs OH



0
-1
-2
-3
log10(BER)
0
10
20
30
40
50
60
70
80
90
100
FEC OH [%]
PM-QPSK (SD)
PM-QPSK (HD)
PM-16QAM (SD)
PM-16QAM (HD)