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PAPER M3C.2

POLITECNICO DI TORINO

EXPERIMENTAL COMPARISON OF PM-16-QAM AND PM-32-QAM WITH PROBABILISTICALLY SHAPED PM-64-QAM

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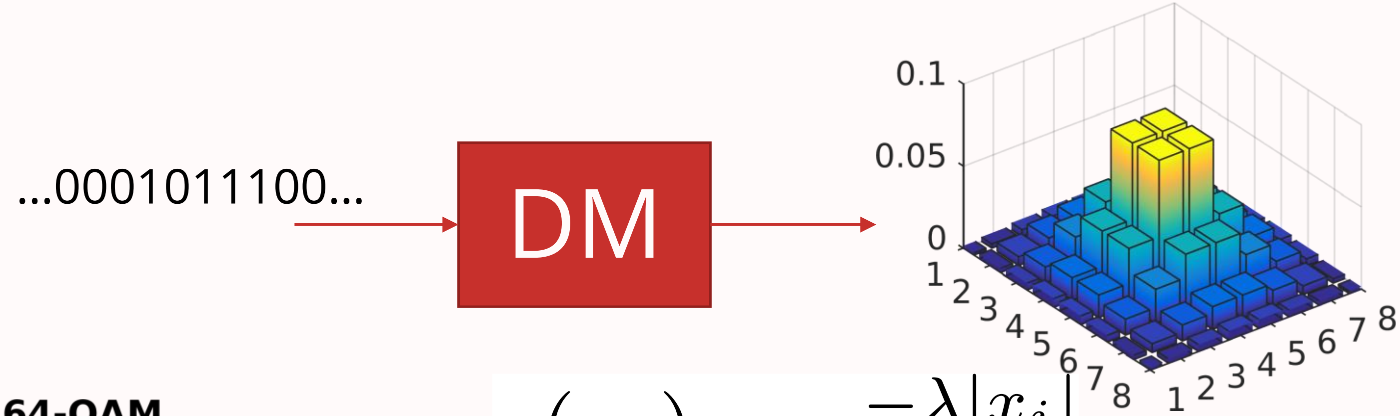
OPTCOM

INTRODUCTION

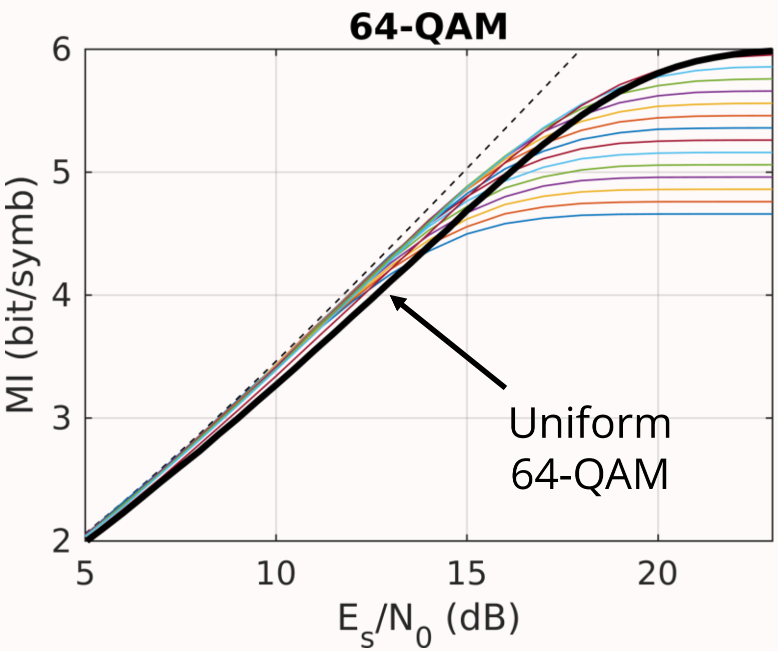
- The use of PS has been recently applied to increase both receiver sensitivity and transceiver flexibility
- Past works reported maximum reach gains ranging from 7%[1] to 40%[2]
  - However, these results have been obtained with different constellation entropies, target MI and FEC code rates
- The change of constellation probabilities may have an impact on non-linear interference noise

1. Pan et al., JLT **34**, pp. 4285-4292 (2016)
2. Buchali et al., JLT **34**, pp. 1599-1609 (2016)

BASICS OF PROBABILISTIC SHAPING



$$p(x_i) \propto e^{-\lambda |x_i|}$$



1. Decrease of constellation entropy
2. Increase of MI at the same SNR

Schulte et al., IEEE IT **62**(1), pp. 430-434 (2016)

PAS ENCODING SCHEME

- Uniformly-shaped constellations:

$$\mathrm{AIR_U} = r_\mathrm{U} m_\mathrm{U}$$

FEC code rate (r_U)

Constellation bit/symb. (m_U)

- Probabilistic shaping with PAS scheme:

$$\mathrm{AIR_{PS}} = \mathcal{H}(P) - (1 - r)m$$

Entropy of PS constellation ($\mathcal{H}(P)$)

FEC code rate (r)

Constellation bit/symb. (m)

Böcherer et al., IEEE COM **63**(12), pp. 4651-4665 (2015)

GOALS OF THIS WORK

1. Comparison of **PS-64-QAM** with lower-cardinality uniform constellations (16- and 32-QAM) *at the same net data rate*:
   - "Same-entropy" comparison: $\mathcal{H}(P) = m_{\mathrm{U}}$

$$r = 1 - (1 - r_{\mathrm{U}})\frac{m_{\mathrm{U}}}{m}$$

   - "Same FEC rate" comparison: $r = r_{\mathrm{U}}$

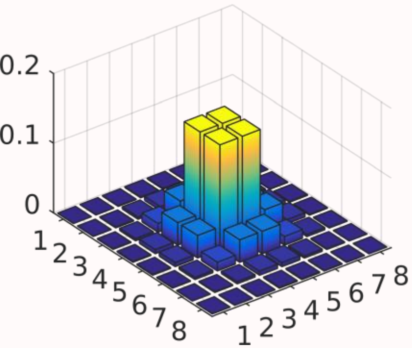
$$\mathcal{H}(P) = m + r(m_{\mathrm{U}} - m)$$

2. Impact of non-linear effects, comparing with EGN[1] predictions

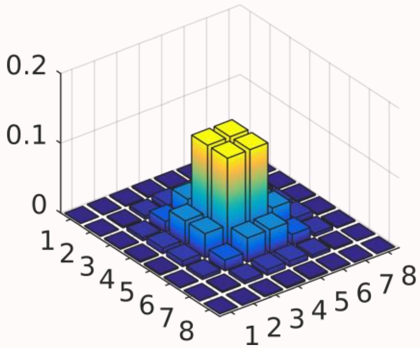
1. Carena et al., Opex **22**(13), pp. 16335-16362 (2014)

PS 64-QAM CONSTELLATIONS

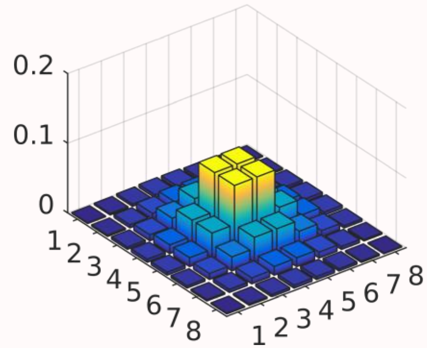
Entropy (bit/symb)	Compared with	Comparison type
4	16-QAM	Same H(P)
4.33		Same FEC
5	32-QAM	Same H(P)
5.17		Same FEC



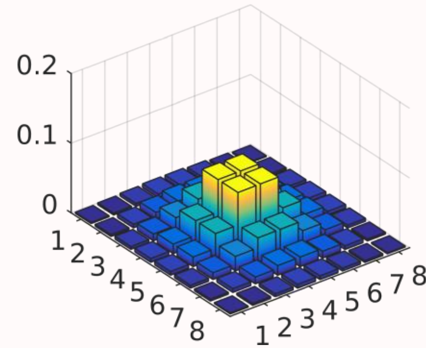
4 bit/symb



4.33 bit/symb

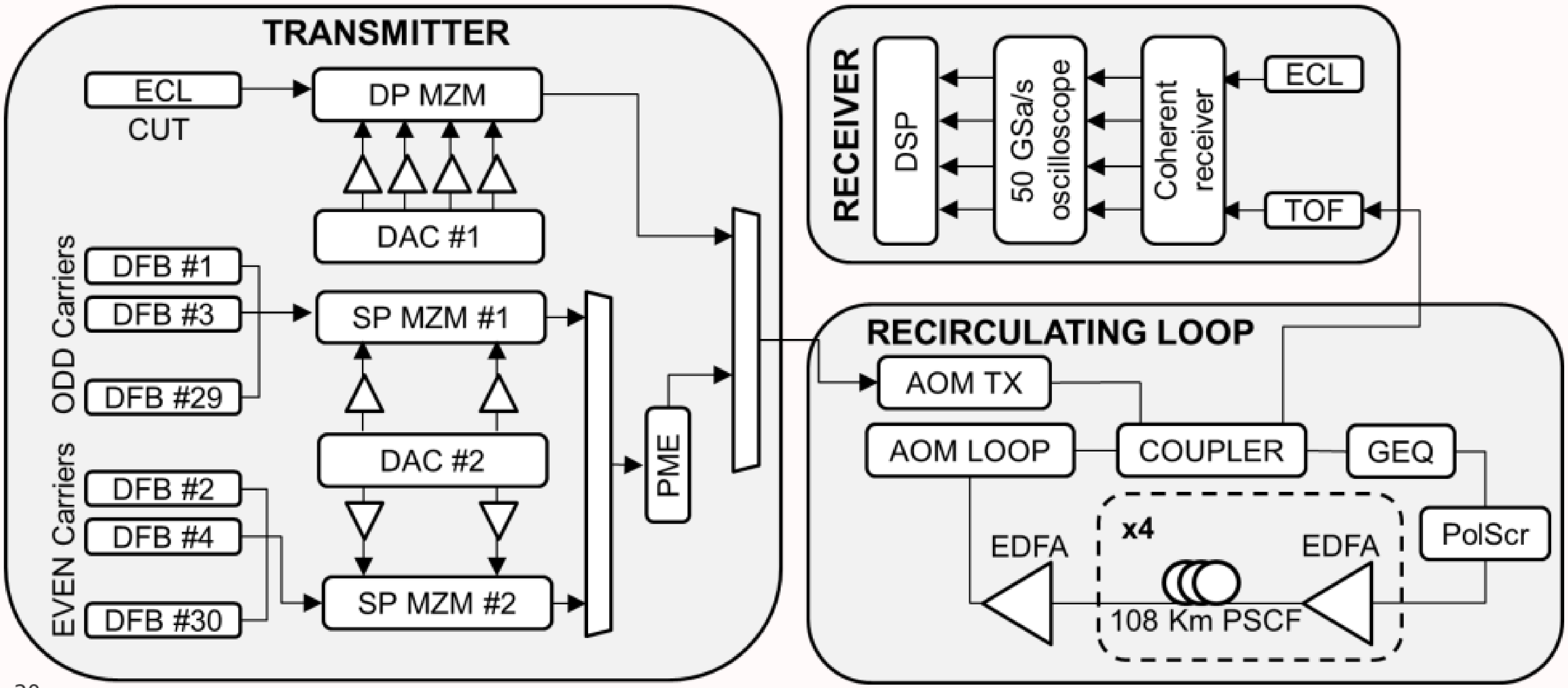


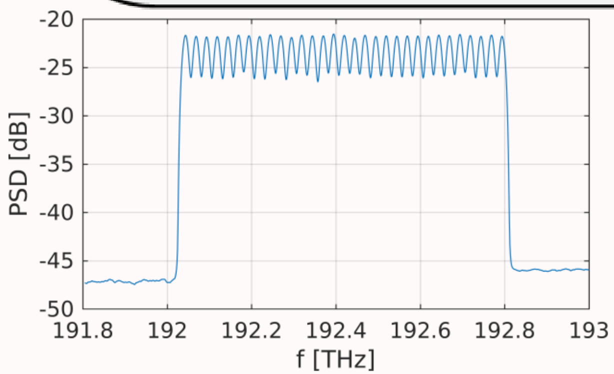
5 bit/symb



5.17 bit/symb

EXPERIMENTAL SETUP





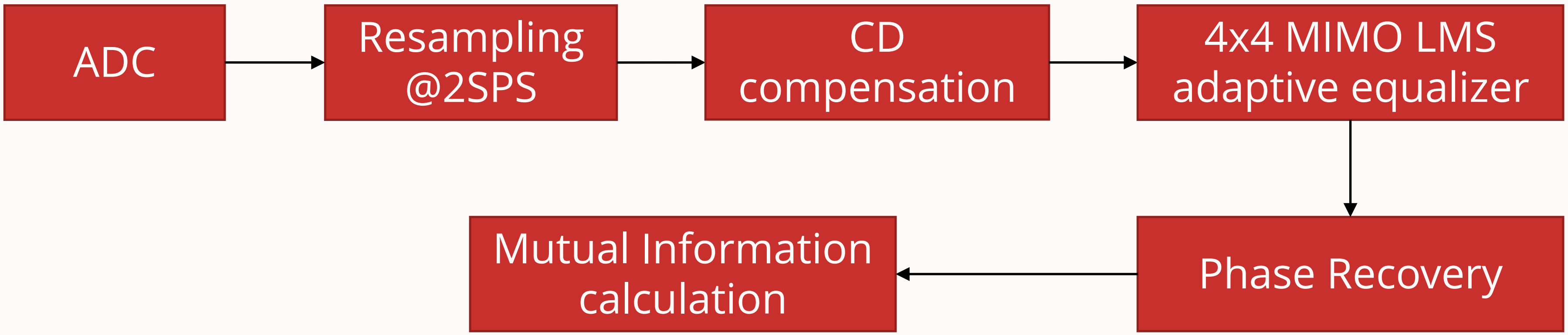
R_s=16 GBd, Δf=25 GHz

Parameter	Value
EDFA noise figure	5.2 dB
Chromatic dispersion	20.17 ps/(nm km)
Non-linearity coeff.	0.75 1/(W km)
Attenuation	0.16 dB/km

TRANSMITTER DSP

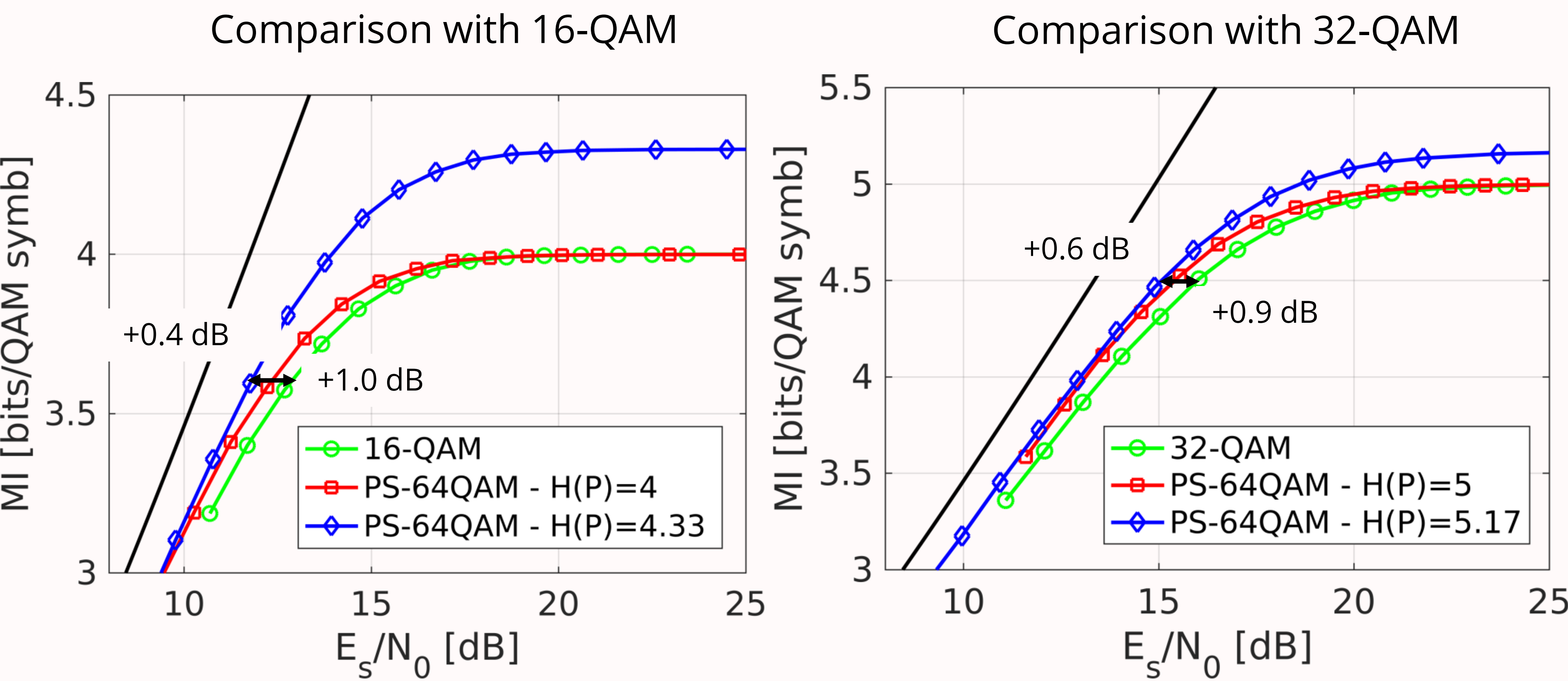
Parameter	Value
RRC roll-off	15%
Symbol rate	16 GBaud
DAC sampling rate	64 Gs/s
DAC 3-dB bandwidth	13 GHz
Sequence length	2^{14}

RECEIVER DSP

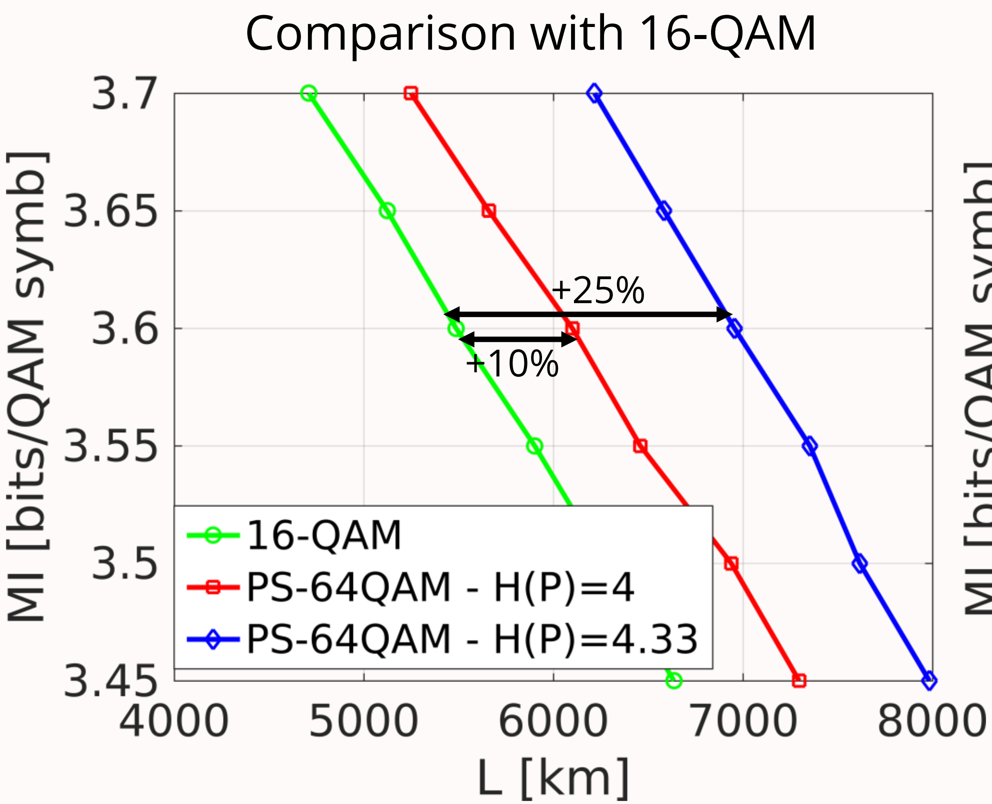


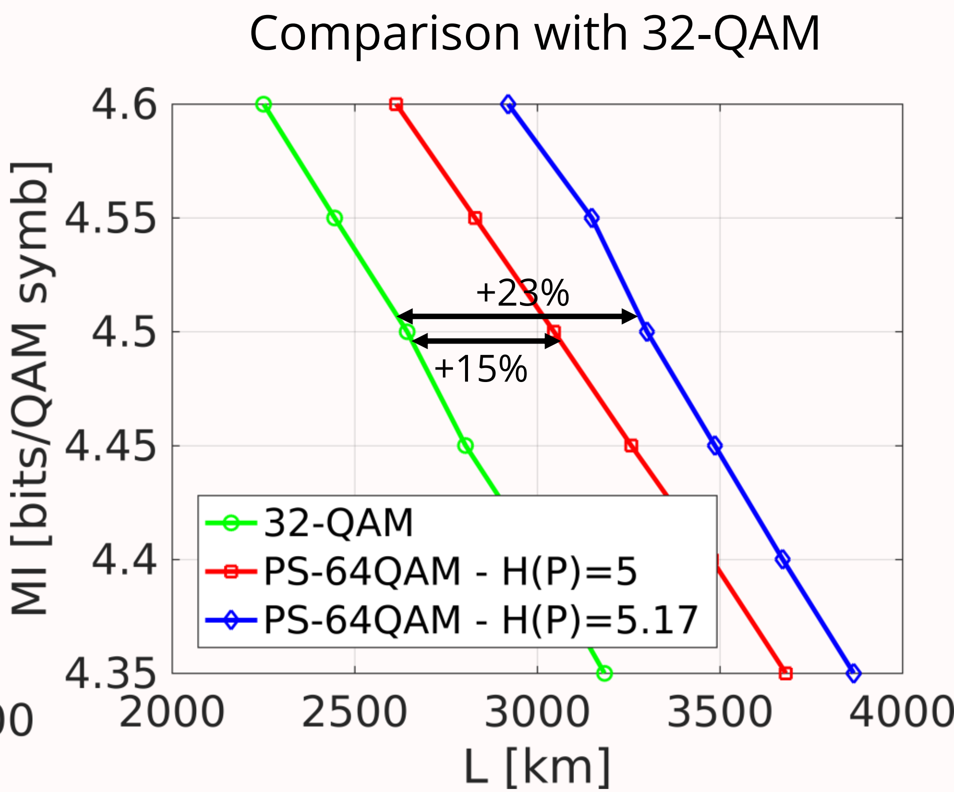
Parameter	Value
ADC sampling rate	50 Gs/s
ADC bandwidth	33 GHz
Equalizer taps	60
CPE memory	32 samples

BACK-TO-BACK RESULTS



PROPAGATION RESULTS

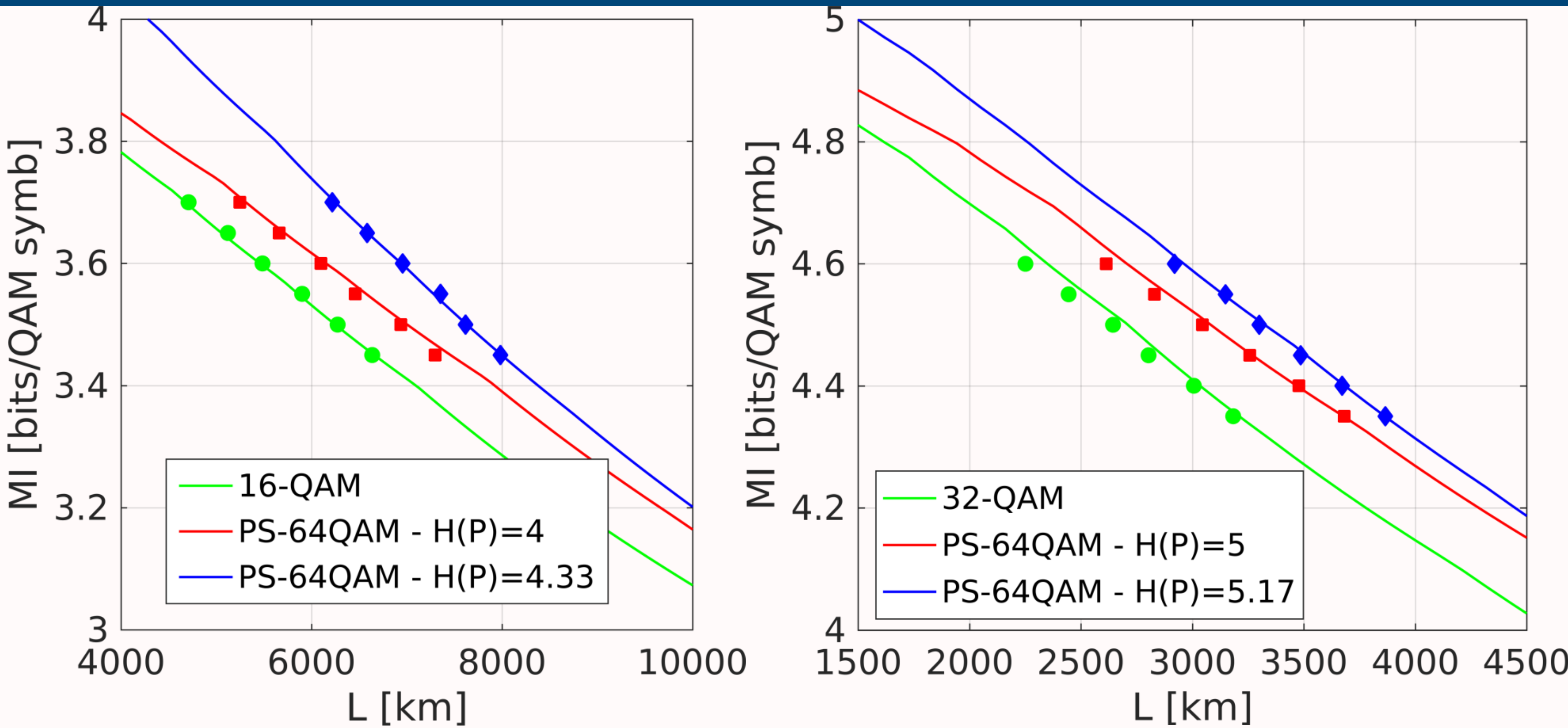




- Optimal P_{ch}= -1.5 dBm
- Same gains as back-to-back[1]

1. Curri et al., JLT **33**(18), pp. 3921-3932 (2015)

COMPARISON WITH EGN PREDICTIONS



- **Solid lines**: EGN predictions with correction factor for *PM-QPSK*[1]
- **Dots**: experimental measurements

1. Nespola et al., proc. of ECOC2016

CONCLUSIONS

- By comparing *at the same net data rate* PS-64-QAM with 16- and 32-QAM, we measured maximum reach gains ranging from **10%** to **25%** at the same MI
  - A more theoretical comparison will be presented with our poster W2A.57 (Wed 03/22 10am-12pm)

- Thanks to phase recovery, PS-64-QAM constellations have no propagation penalty with respect to uniform lower-cardinality QAM constellations
  - Performance of these systems is predicted with great accuracy by the EGN model with PM-QPSK correction factor

THANK YOU

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