Flexible Modulation Format For Future Optical Network

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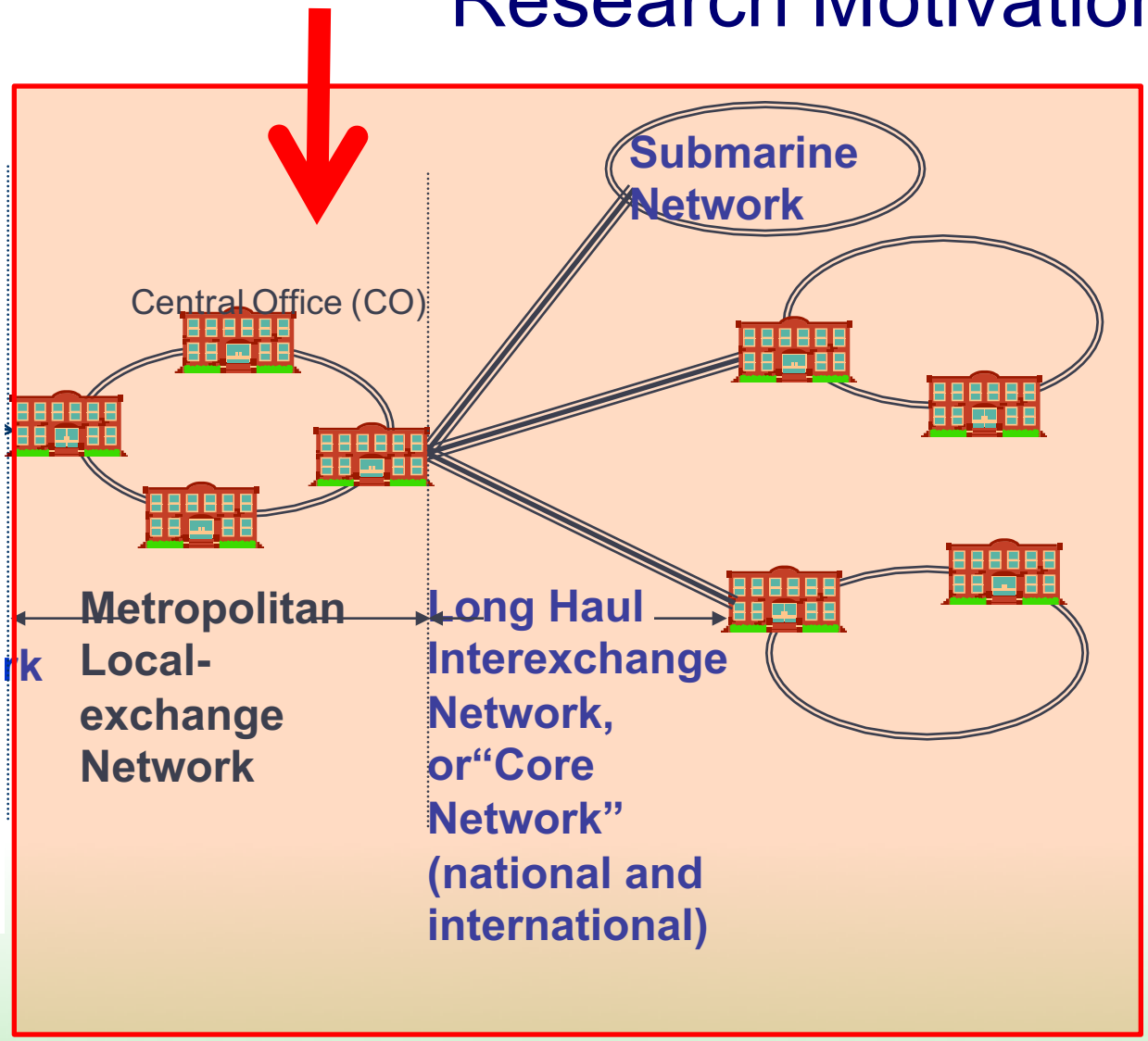
Research Motivation

- My work is aiming at these two parts of network, which is long haul and large capacity network.
- The goal is to increase the capacity for a given distance in a fixed grid according to the traffic demand.



Research Questions

- How to increase the capacity per fiber?

1. Better device. (e.g. DAC, fiber, DSP)
2. More channels per fiber.(Total bandwidth in C band about 4 THz)
3. Higher spectral efficiency.(complex modulation format in physical level)

- Different method compare.

Approach 3 advantage: less investment, work under nowadays ITU grid, work with the existed equipment.

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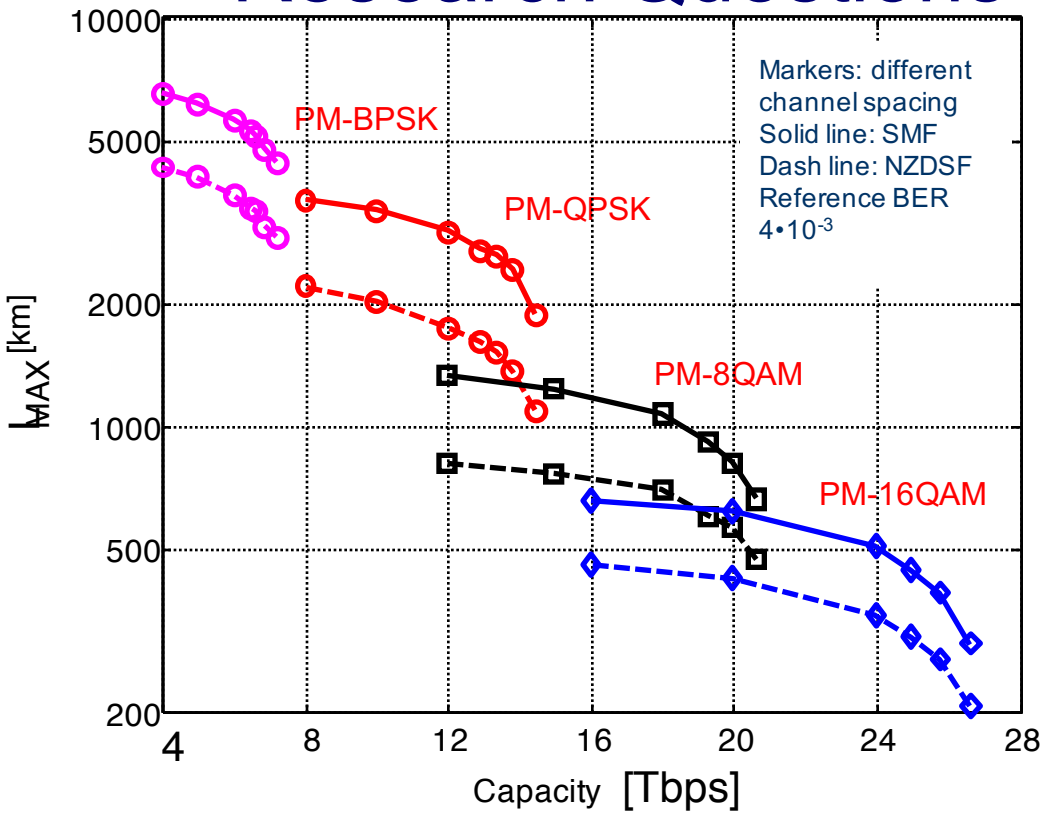
Research Questions

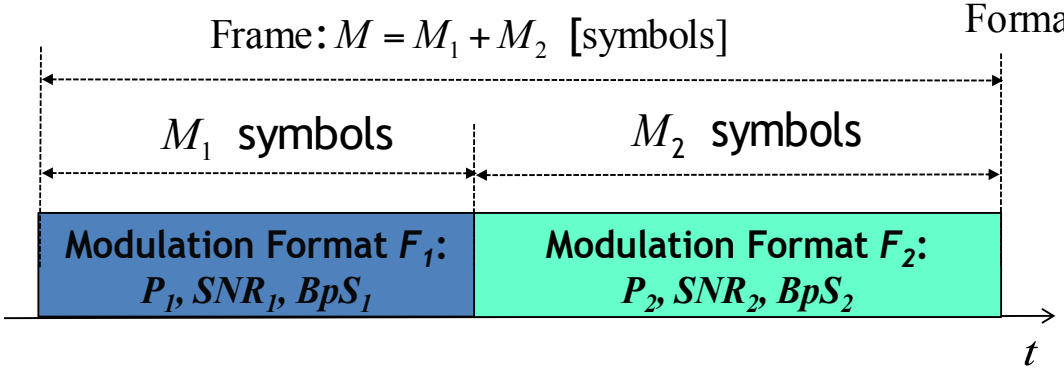
- Standard multilevel modulation format optical transmission system “Max distance vs. Capacity”, but with a flexible grid.
- Gap between different curves and markers.
- Finding a new modulation format that has the largest capacity at a given distance in a fixed grid according to the traffic demand..



On the Performance of Nyquist-WDM Terabit Superchannels Based on PM-BPSK, PM-QPSK, PM-8QAM or PM-16QAM Subcarriers *Bosco,G et al. Lightwave Technology, Volume: 28, Page: 53-61*

Time-Division Hybrid Modulation Format (TDHMF)

- By using TDHMF, we can design the



$$\text{Format ratio}: FR = 100\frac{M_2}{M} \qquad \text{Power ratio}: PR = \frac{P_2}{P_1}$$

$$P_{Tx} = \left(1 - \tfrac{FR}{100}\right)\cdot P_1 + \tfrac{FR}{100}\cdot P_2$$

$$SNR = \left(1 - \tfrac{FR}{100}\right)\cdot SNR_1 + \tfrac{FR}{100}\cdot SNR_2$$

$$\text{Bit-per-symbol}: BpS = \left(1 - \tfrac{FR}{100}\right)\cdot BpS_1 + \tfrac{FR}{100}\cdot BpS_2$$

$$\text{Spectral efficiency}: SE = BpS\frac{R_s}{\Delta f}$$

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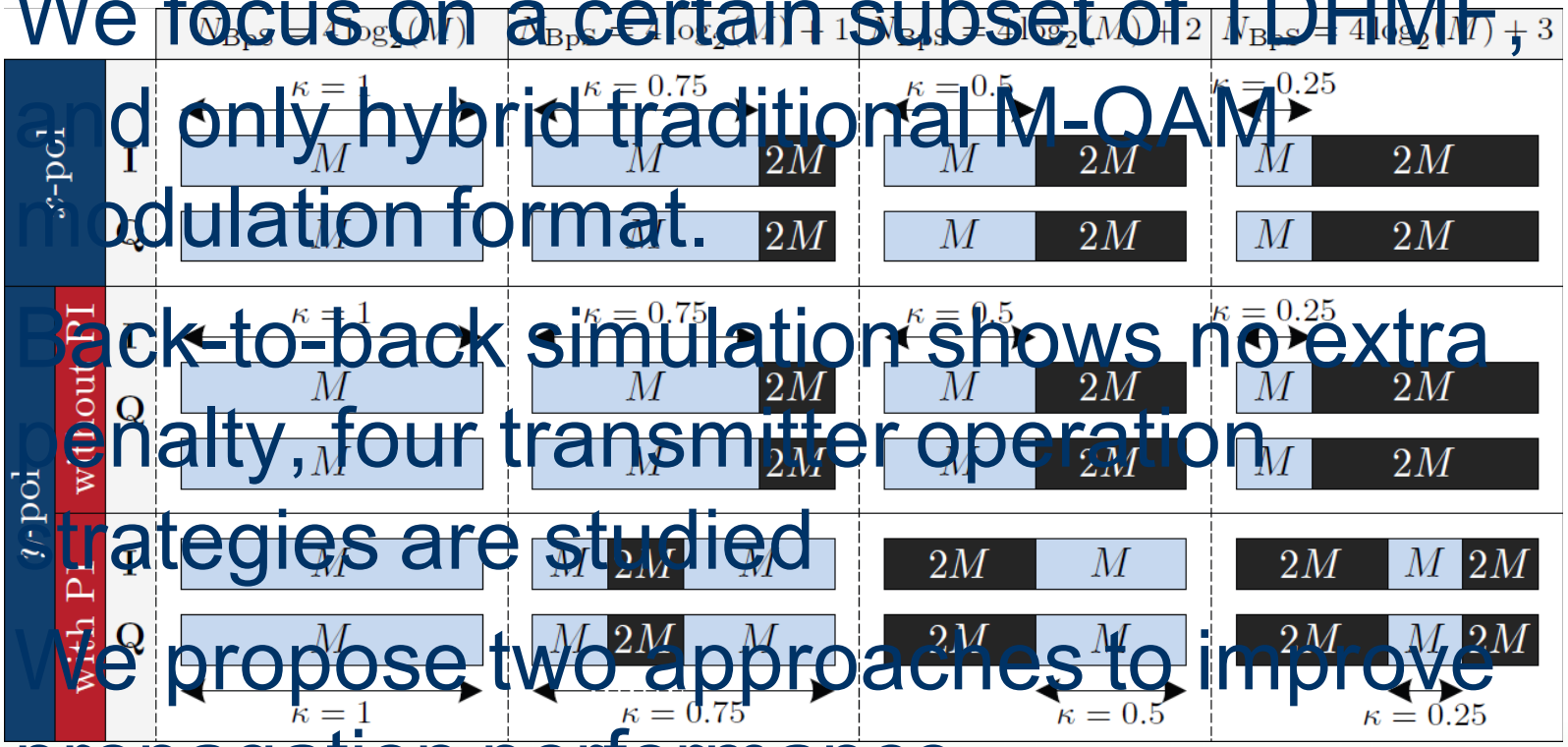
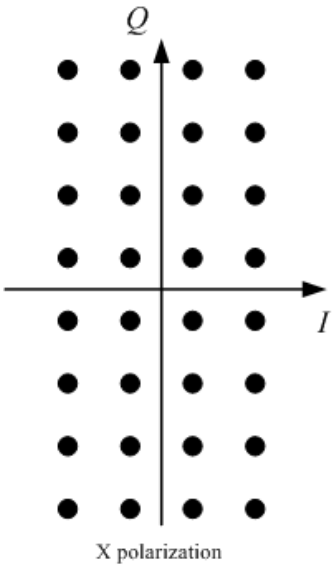
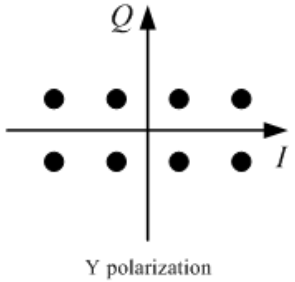
A subset of TDHMF

- We focus on a certain subset of TDHMF, and only hybrid traditional M-QAM modulation format.
- Back-to-back simulation shows no extra penalty, four transmitter operation strategies are studied
- We propose two approaches to improve propagation performance.



Flexible M-PAM Modulation Format (Flex-PAM)





		$N_{\mathrm{BpS}} = 4\log_2(M)$	$N_{\mathrm{BpS}} = 4\log_2(M)+1$	$N_{\mathrm{BpS}} = 4\log_2(M)+2$ without PI	$N_{\mathrm{BpS}} = 4\log_2(M)+2$ with PI	$N_{\mathrm{BpS}} = 4\log_2(M)+3$
x-pol	I	M	M	M	M	M
	Q	M	M	M	$2M$	$2M$
y-pol	I	M	M	$2M$	M	$2M$
	Q	M	$2M$	$2M$	$2M$	$2M$
		$\kappa = 1$	$\kappa = 0.75$	$\kappa = 0.5$	$\kappa = 0.5$	$\kappa = 0.25$

$$\mathrm{BER} = \frac{1}{\mathrm{BpS}_{tot}} \cdot \sum_{i=1}^{4} \frac{m_i - 1}{m_i} \cdot erfc\left(\sqrt{\frac{3}{m_i^2 - 1} \cdot 2 \cdot \frac{P_i}{P_{tot}} \cdot SNR}\right)$$

1. Unlike TDHMF, Flex-PAM offers limited possibility of system capacity. But it will have advantage in optical network level.
2. For different network tributary, we can arrange one m-PAM for it according to traffic demands.
3. It has a much simpler Tx/Rx and DSP structure against TDHMF.
4. Like TDHMF four different TX operation strategies are proposed.
5. Two approaches are proposed to improve propagation performance.

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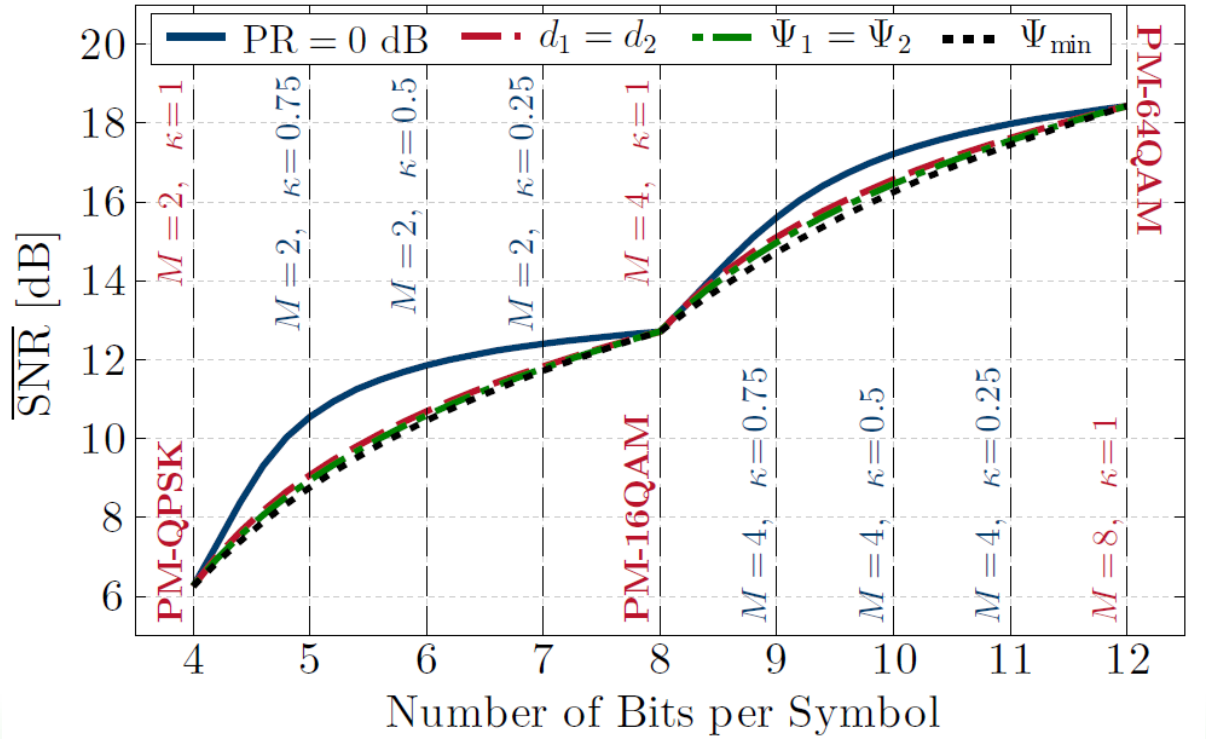
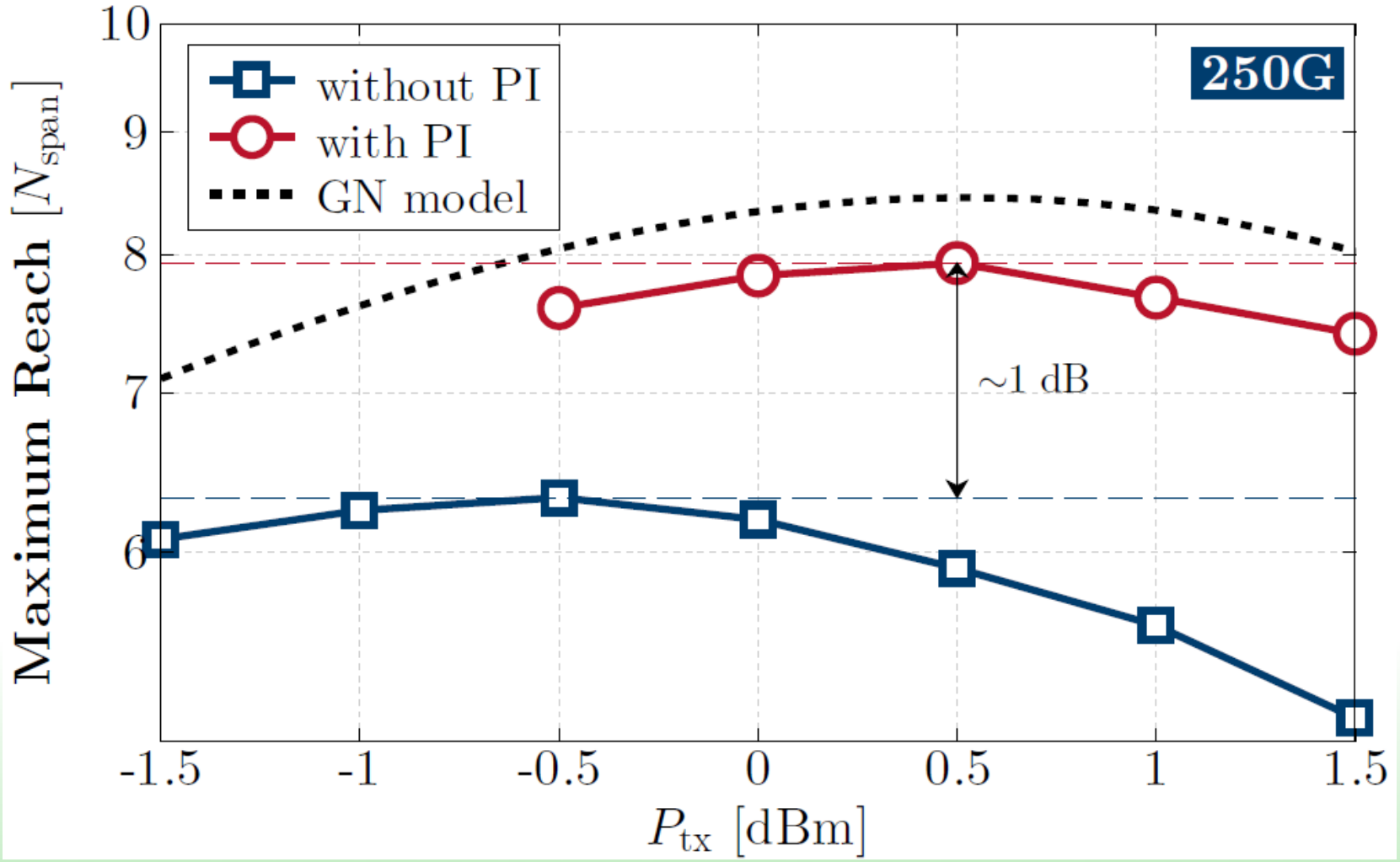
Four Operation Strategies Compare

- "PR=0dB" suboptimal choice
- "BER min" has the best performance
- "BER same" has close performance as "BER min" but it is easy implementatio n.



FlexPAM Polarization Interleaving



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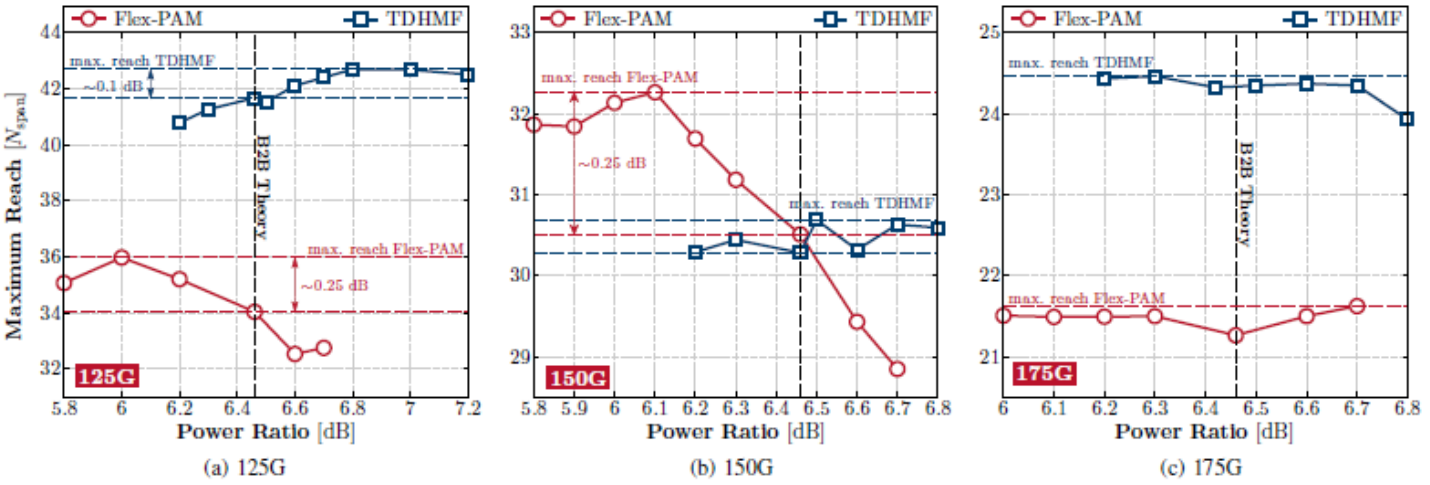
Power Ratio Tuning



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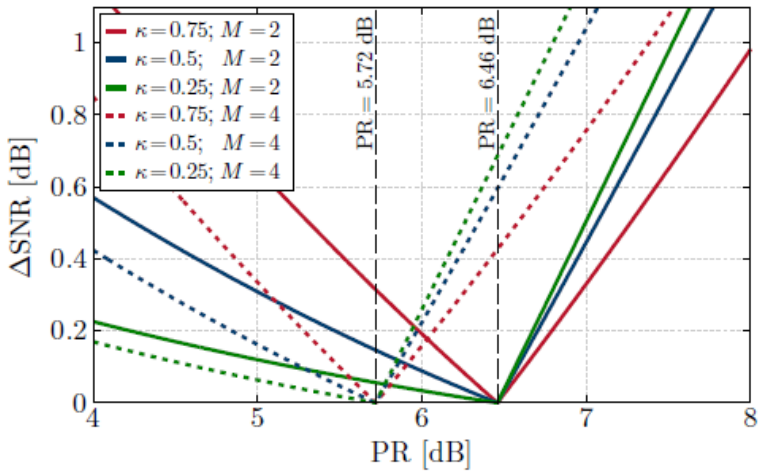
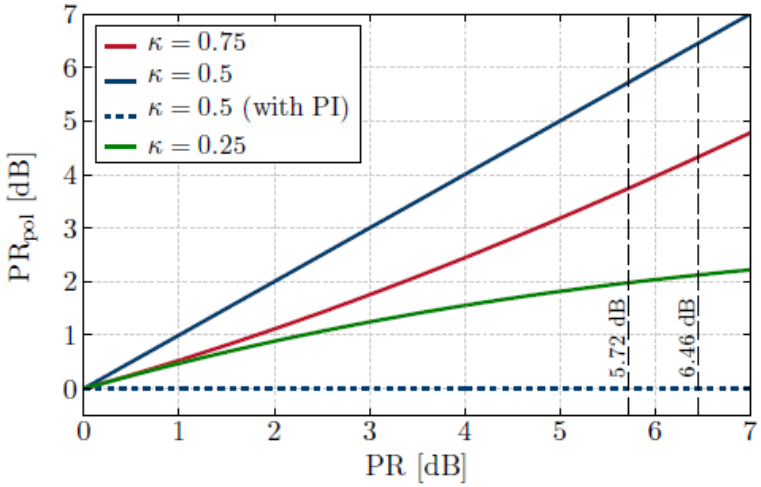
FlexPAM PR tuning

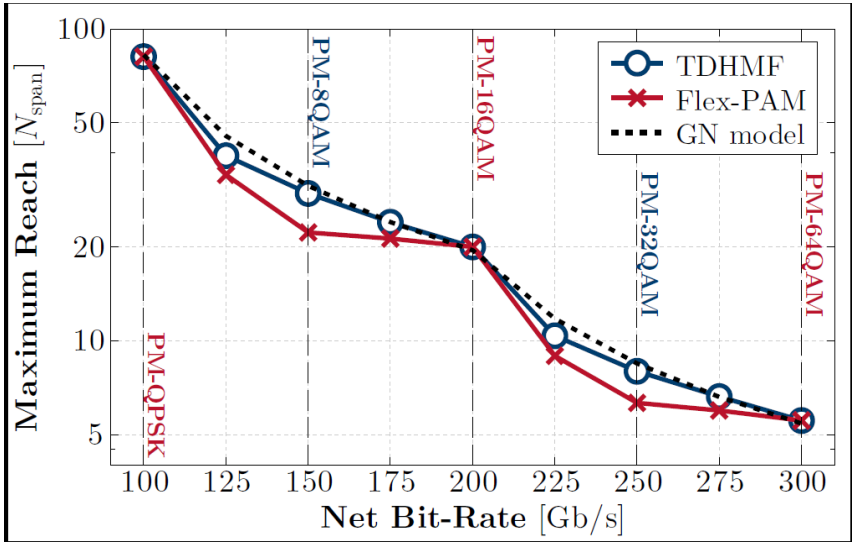
1. Tuning down the power ration between two M-PAM can reduce the power ratio between 2 polarization and make it more power balanced, and this will help improve propagation.
2. On the other side, there will be a penalty of SNR when tuning the PR away from the optimum working point.
3. The slope represent how fast this will change.



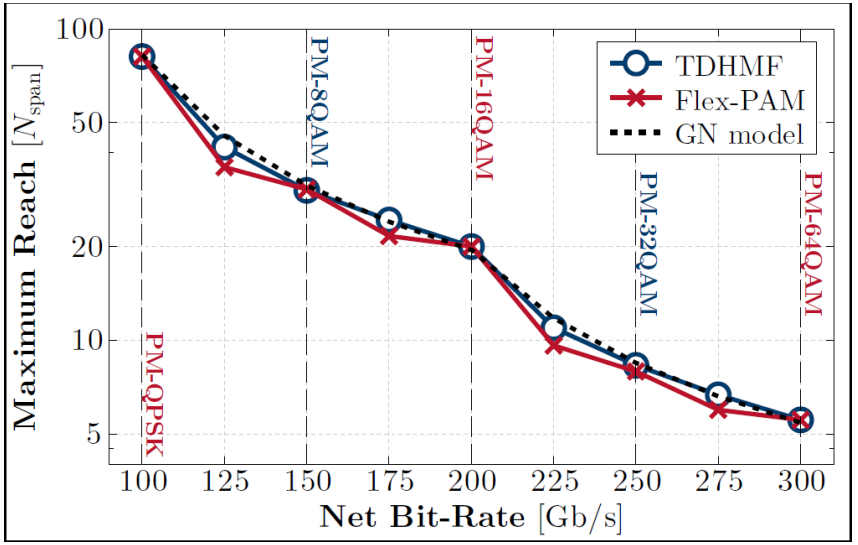


Propagation performance

Without countermeasure



With countermeasure



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Papers

- R. Li, P. Cortada, V. Curri, and A. Carena, “Flex -PAM modulation formats for future optical transmission system,” in Fotonica AEIT Italian Conference on Photonics Technologies, 2015.
- R. Li, V. Curri, and A. Carena, “Bit-rate maximization for elastic transponders operating in WDM uncompensated amplified links,” in Proc. Optical Fiber Communication Conf. and Exposition (OFC), paper Th2A.45, 2016.
- F.Guiomar, R. Li, “Hybrid Modulation Formats Enabling Elastic Fixed-Grid Optical Networks” (works in submission, submitted to Journal of Optical Communication and Network)