POLITECNICO DI TORINO

INDEPENDENCE OF THE IMPACT OF INTER-CHANNEL NON-LINEAR EFFECTS ON MODULATION FORMAT AND SYSTEM IMPLICATIONS

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OUTLINE

- Motivation
- Observations through numerical simulations
  - Comparison with EGN model predictions
  - Nonlinear phase noise analysis
- Experimental validation
- Conclusions

MOTIVATION

- The EGN model predicts that inter-channel nonlinear interference (NLI) depends on modulation formats
  - Large power excursion formats (such as PM-16QAM or PM-64QAM) should produce a greater NLI variance than formats with limited power excursion (such as PM-QPSK)
  - This prediction appears to threaten the potential gains stemming from using Gaussian constellations
  - In particular, formats with large power excursion have been found to produce substantial amounts of Non- Linear Phase Noise (NLPN)

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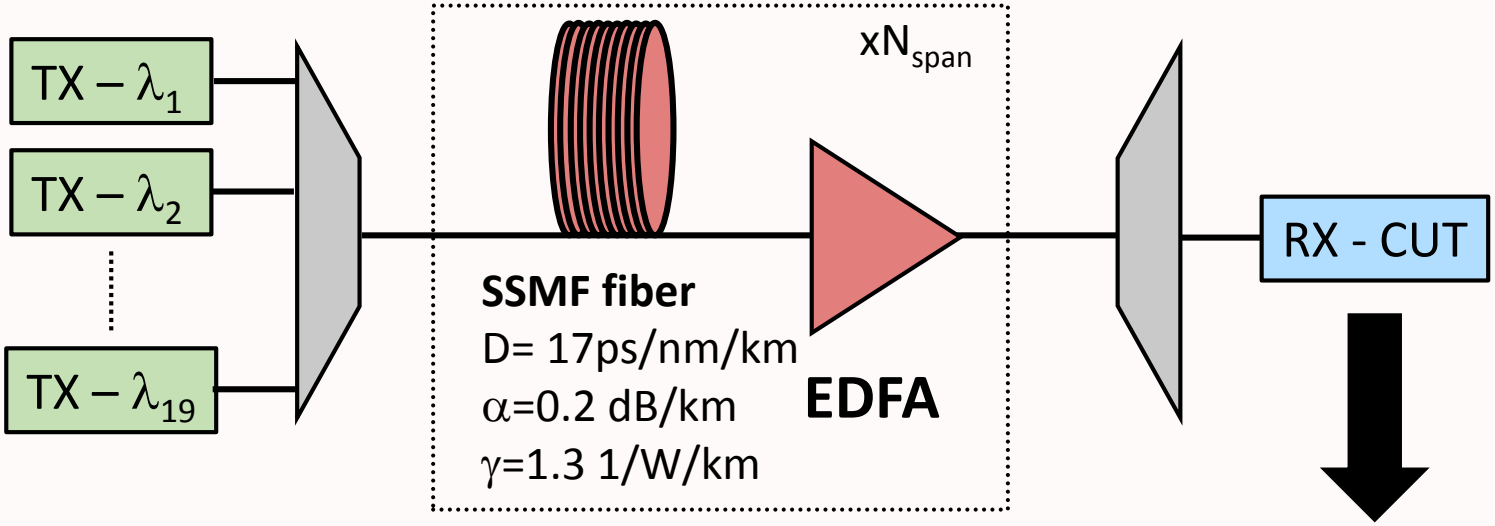
  - This prediction appears to threaten the potential gains stemming from using Gaussian constellations
  - In particular, formats with large power excursion have been found to produce substantial amounts of Non- Linear Phase Noise (NLPN)

- **Does the impact of NLI on performance depends on modulation formats?**

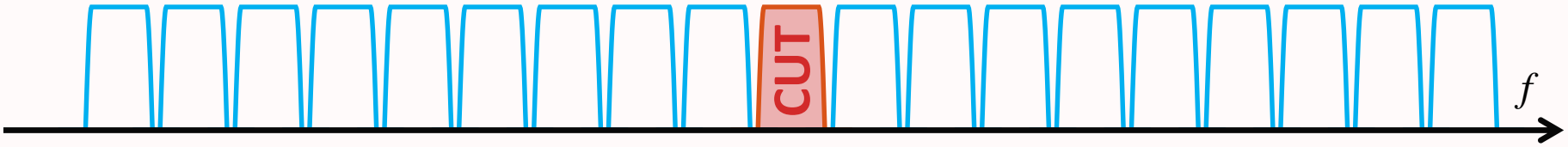
SYSTEM SETUP



- R_S= 32 Gbaud; RC roll-off: 0.05; Δf= 37.5 GHz
- Full-band split-step simulations
- Noiseless: no ASE added in the simulation

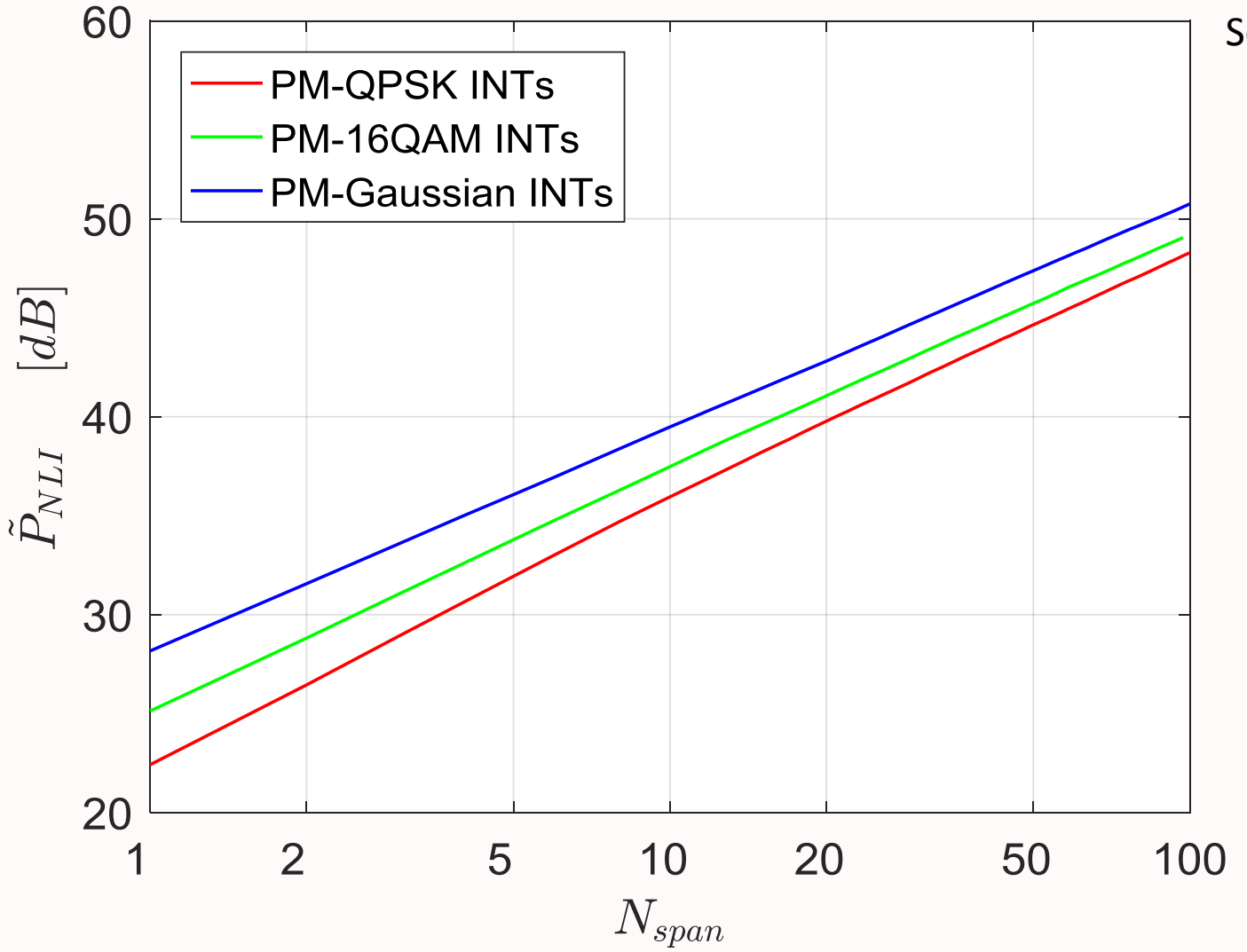
$$\tilde{P}_{NLI} = \frac{P_{NLI}}{P_{ch}^3}$$

CUT: PM-QPSK



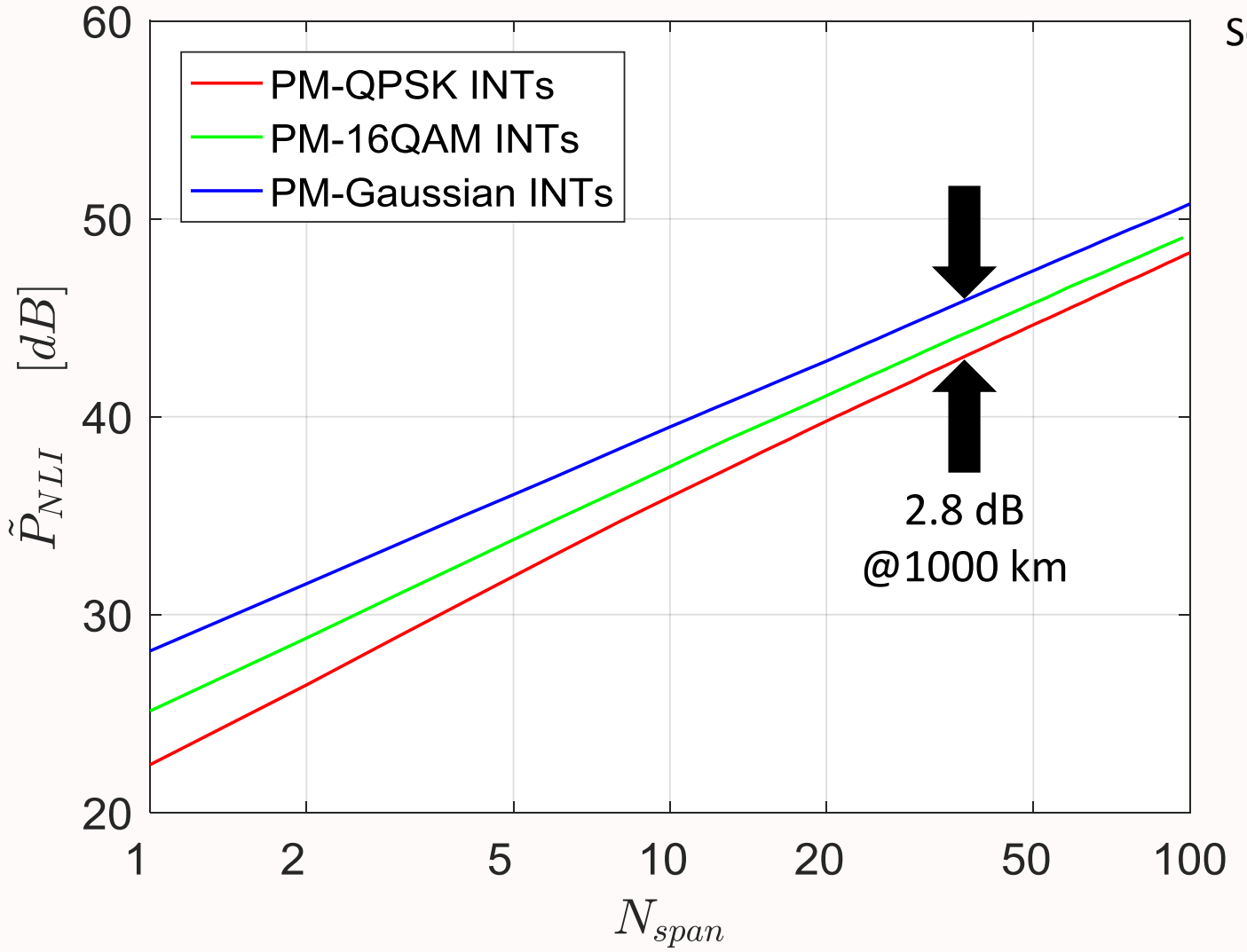
INT: PM-QPSK or PM-16QAM or PM-Gaussian

SIMULATION RESULTS: 25 KM



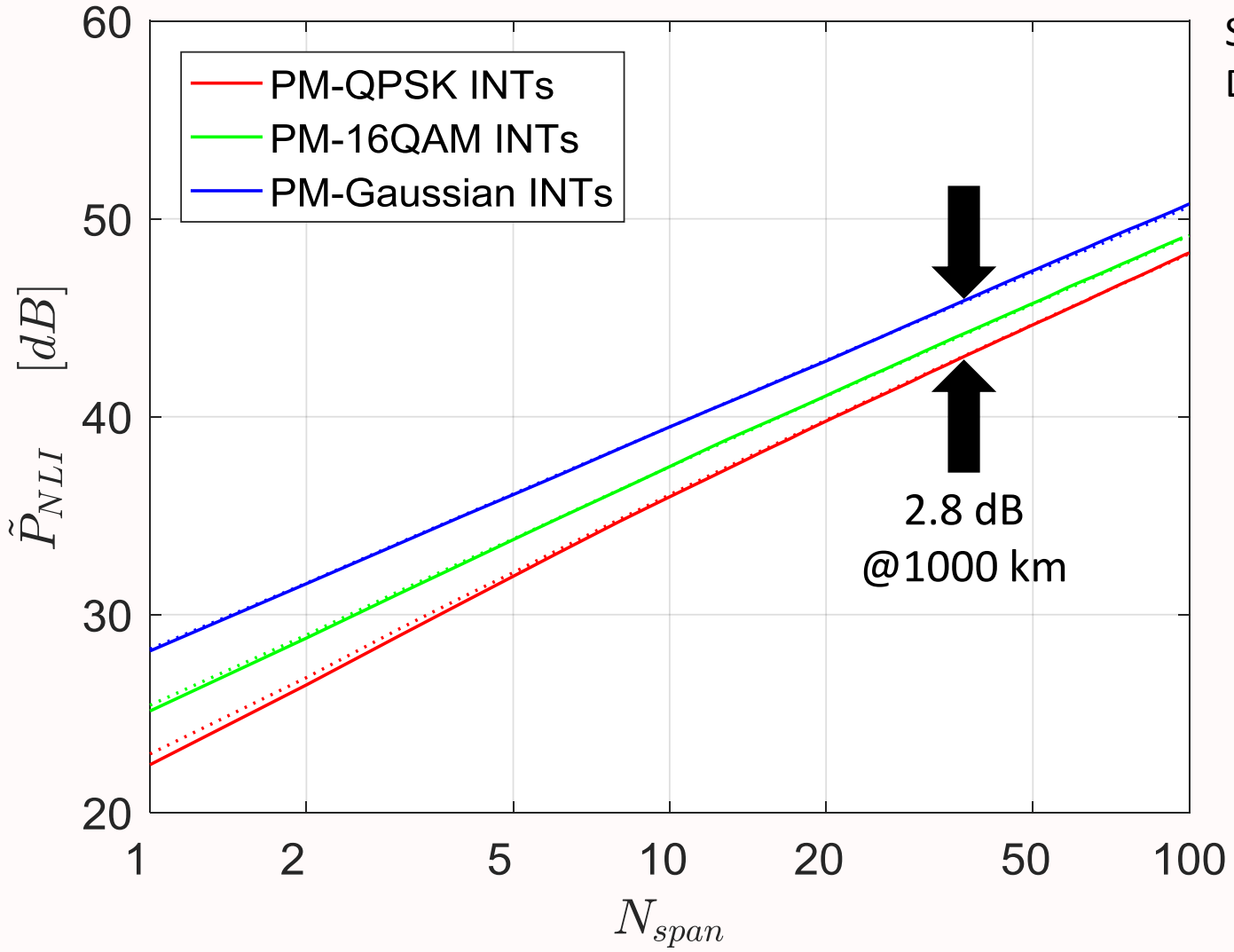
Solid: Split-Step

SIMULATION RESULTS: 25 KM



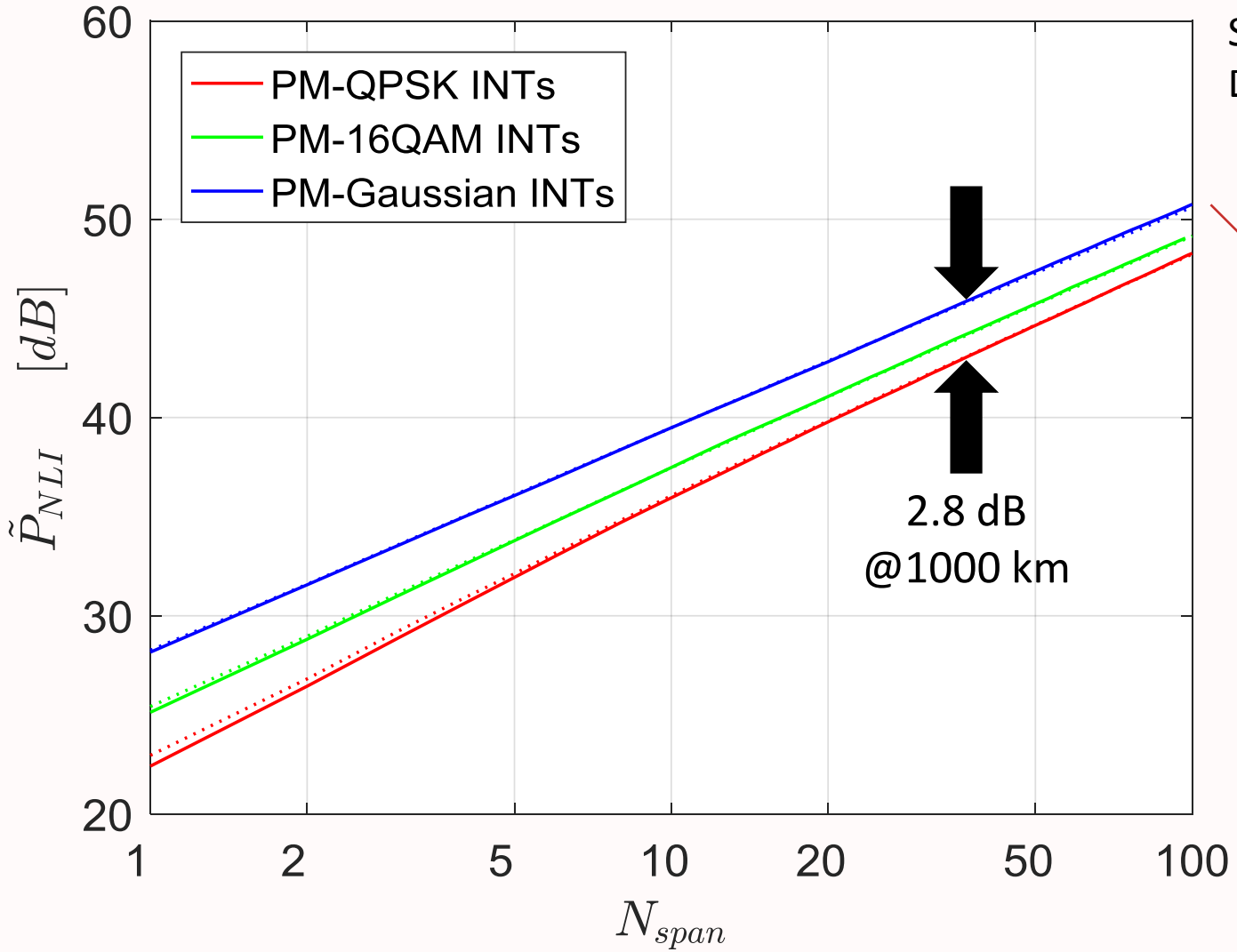
Solid: Split-Step

SIMULATION RESULTS: 25 KM

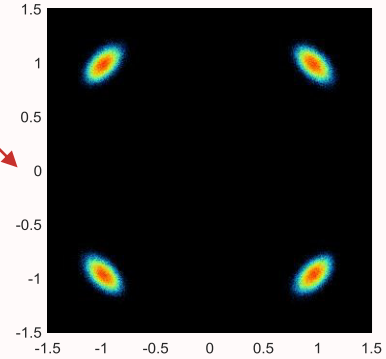


Solid: Split-Step
Dotted: EGN

SIMULATION RESULTS: 25 KM



Solid: Split-Step
Dotted: EGN



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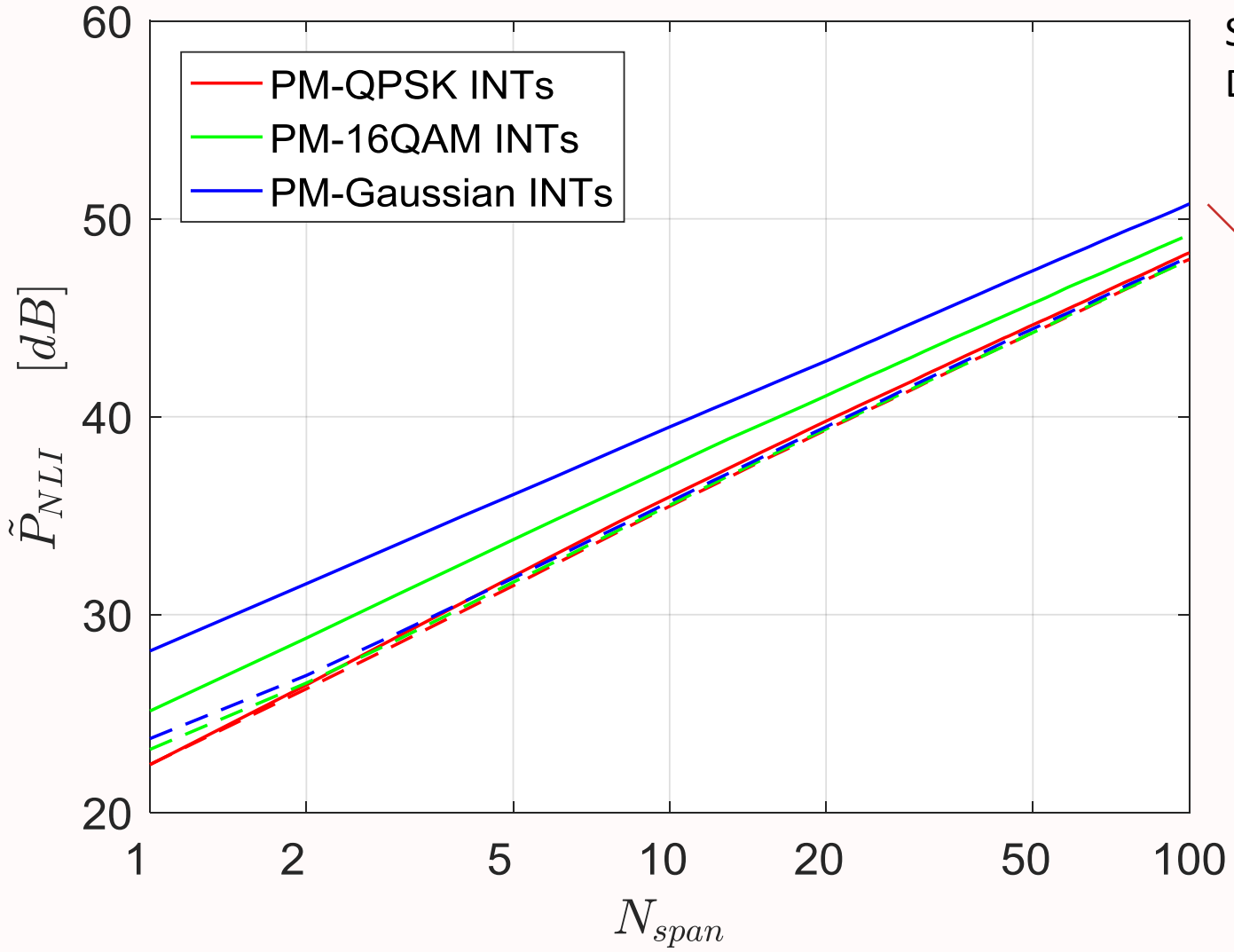
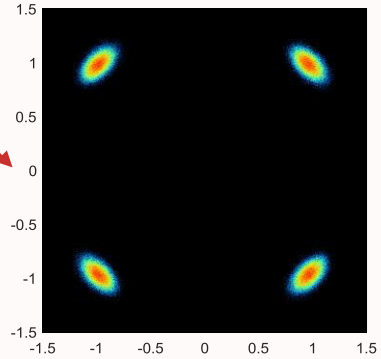
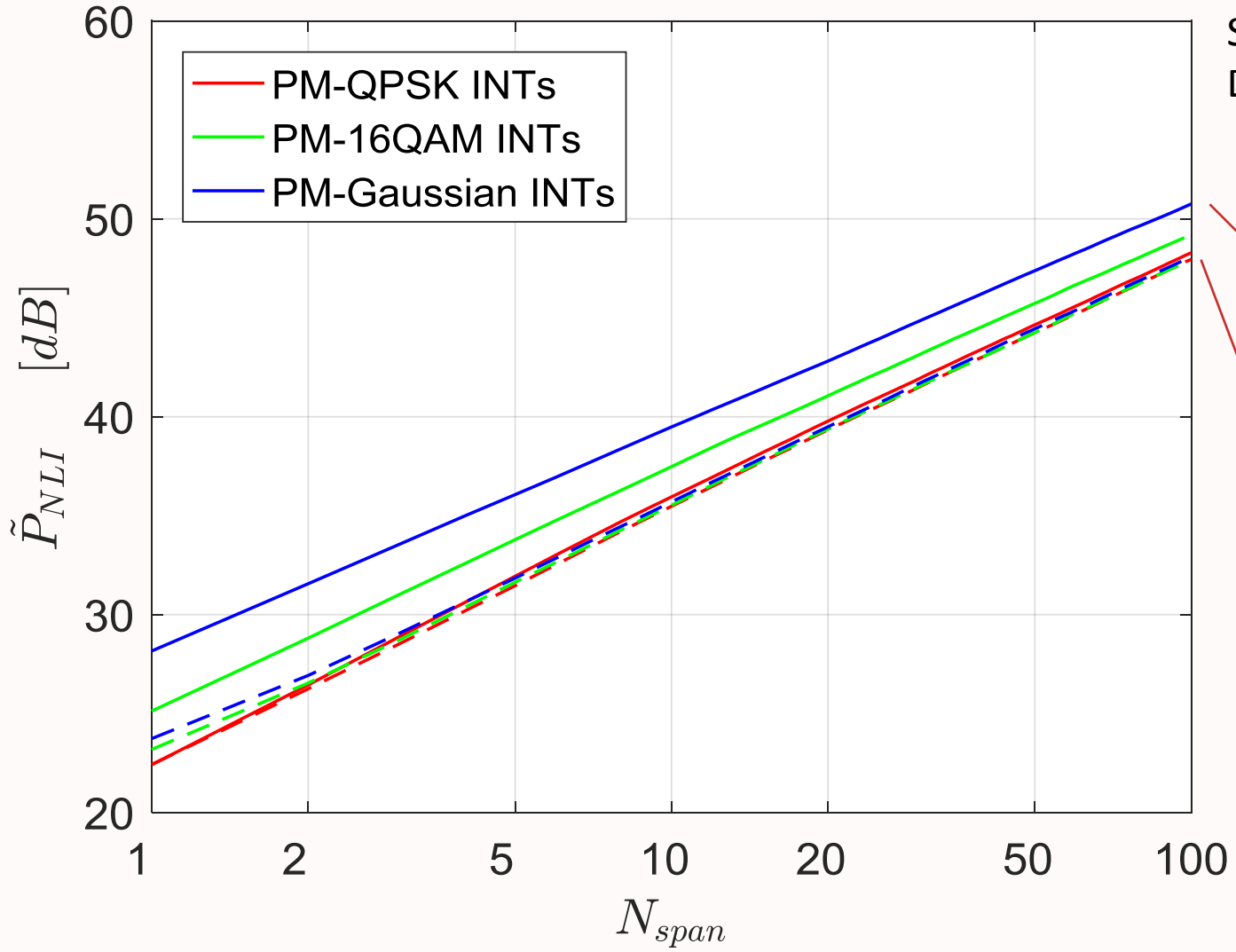


Solid: Split-Step

Dashed: Split-Step + CPE



SIMULATION RESULTS: 25 KM



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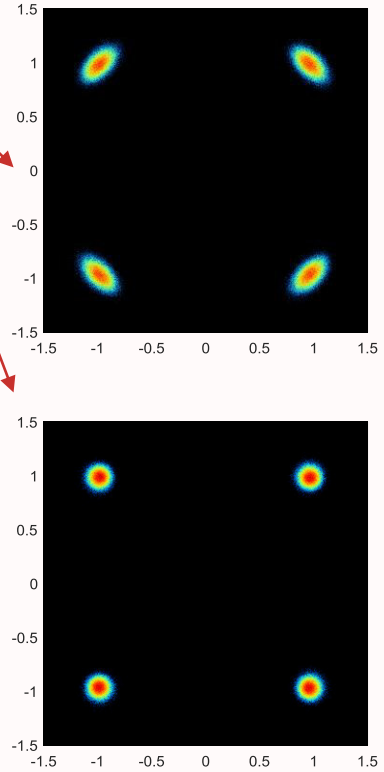
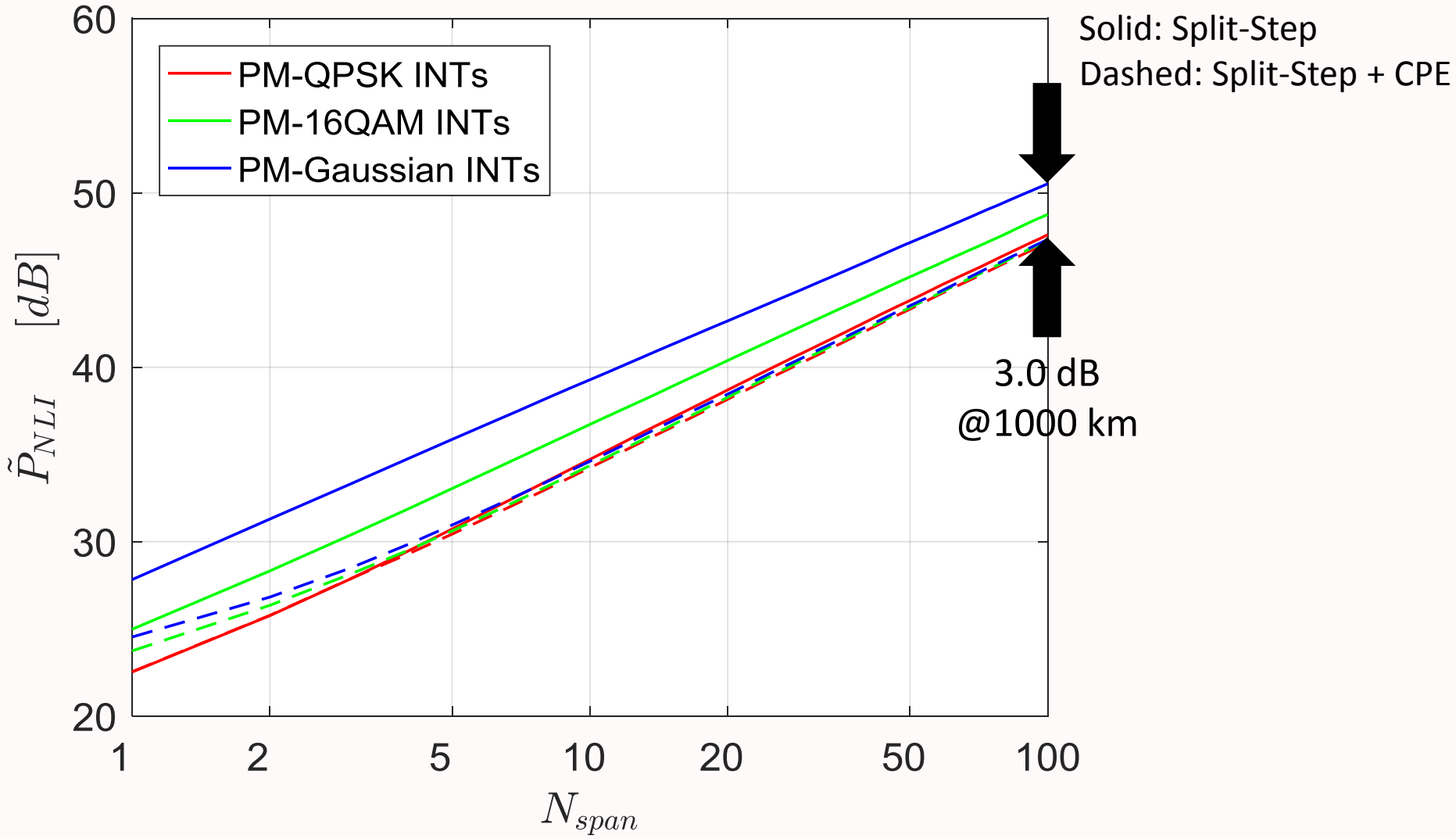
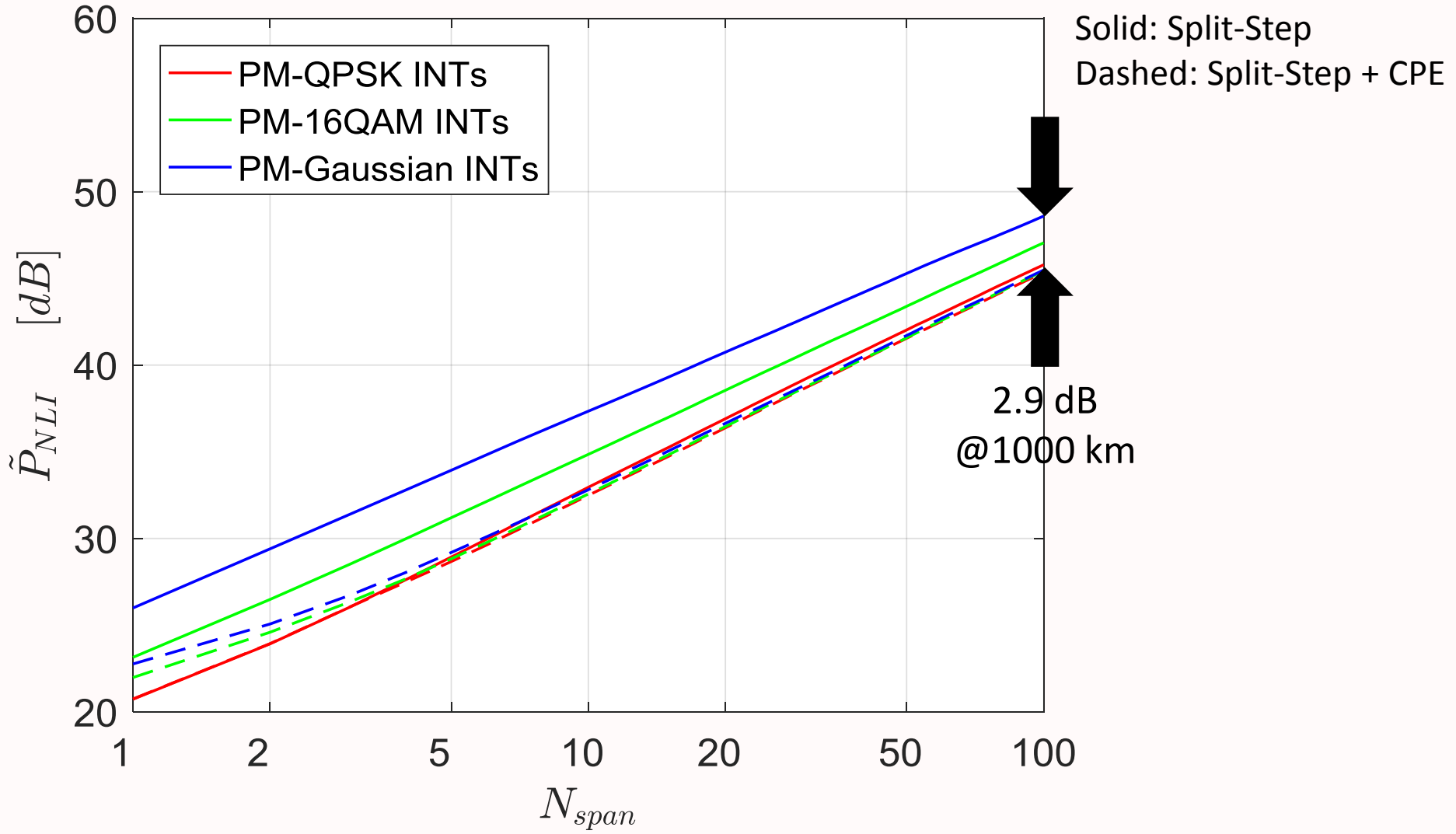


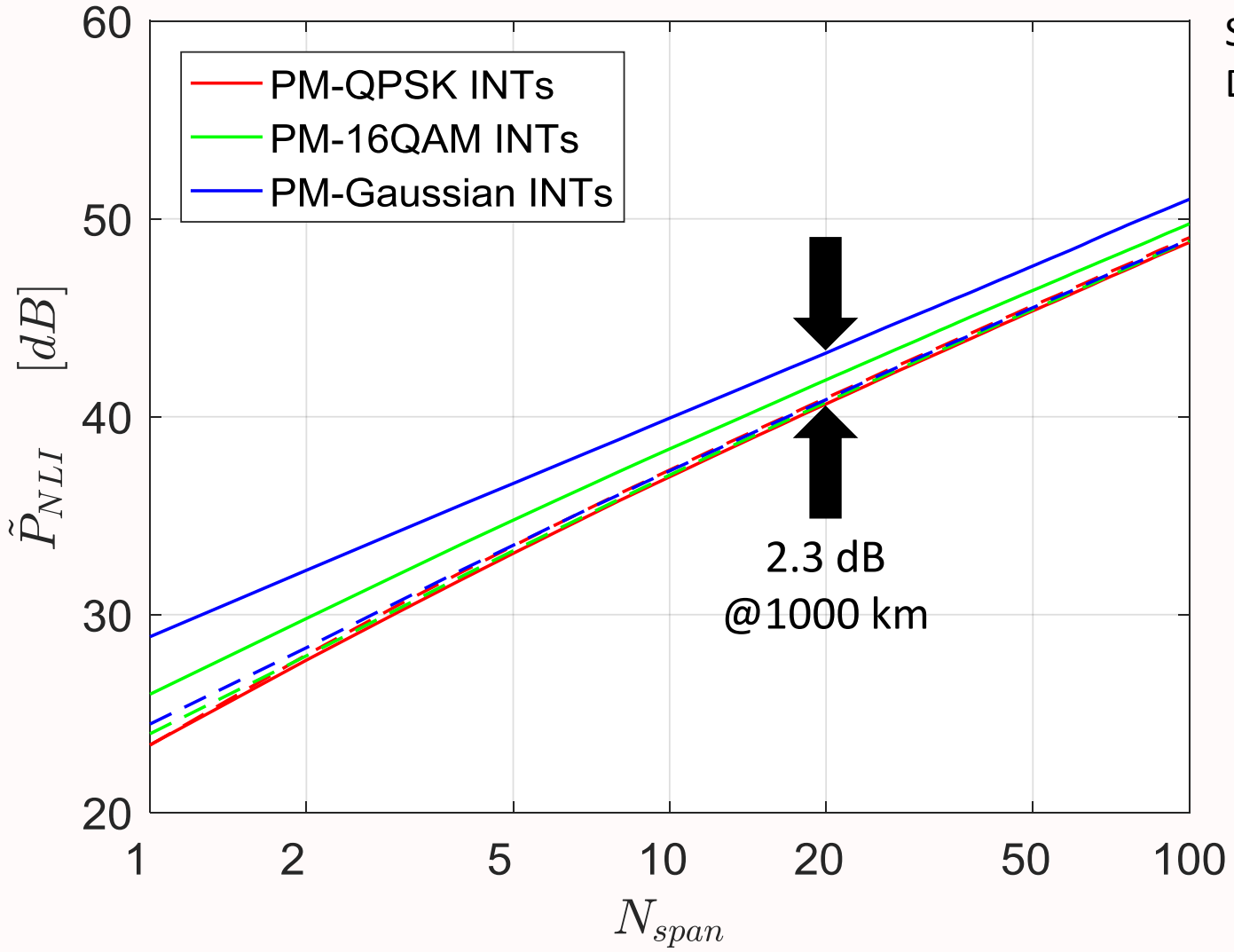
SIMULATION RESULTS: LOSSLESS



SIMULATION RESULTS: 10 KM



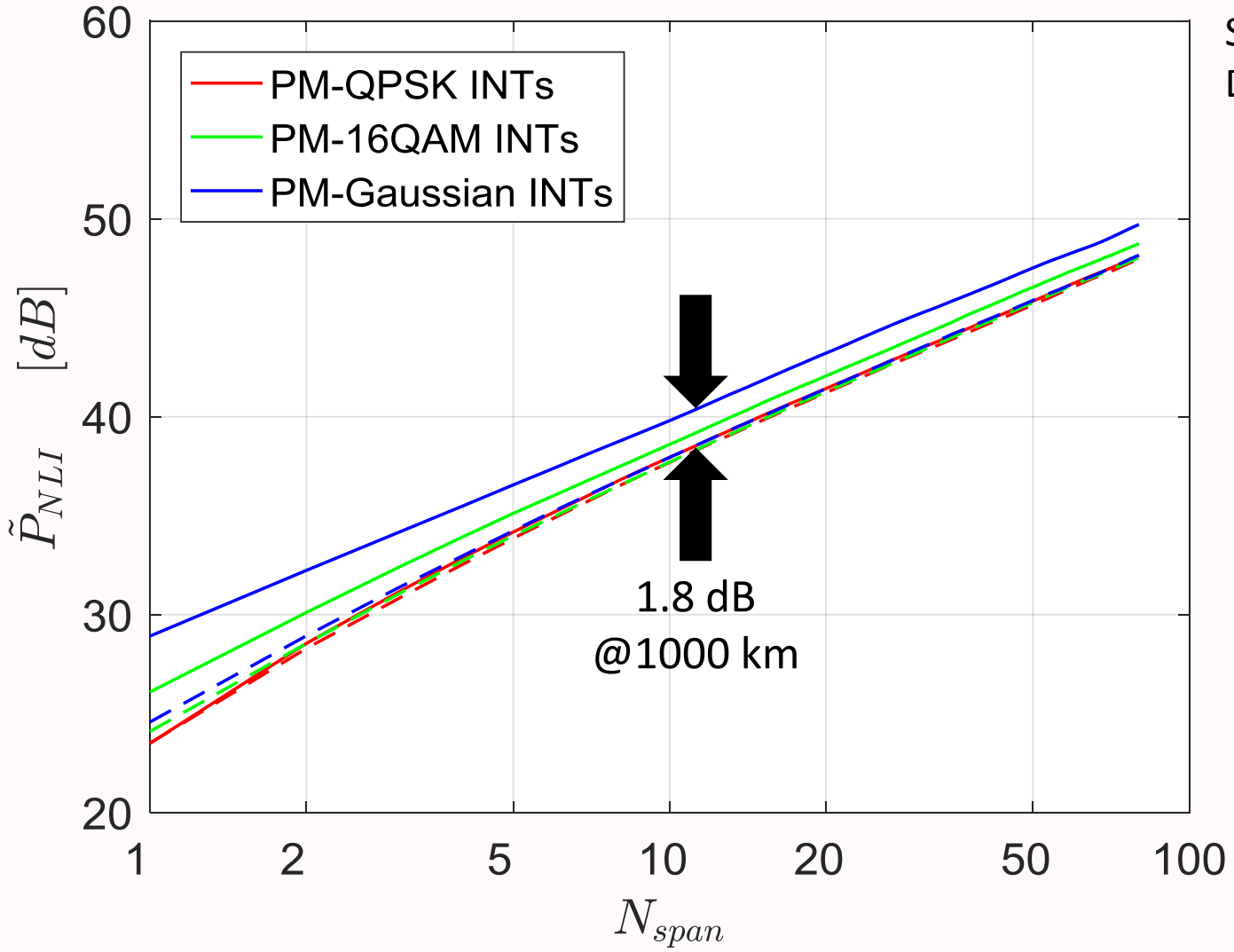
SIMULATION RESULTS: 50 KM



Solid: Split-Step

Dashed: Split-Step + CPE

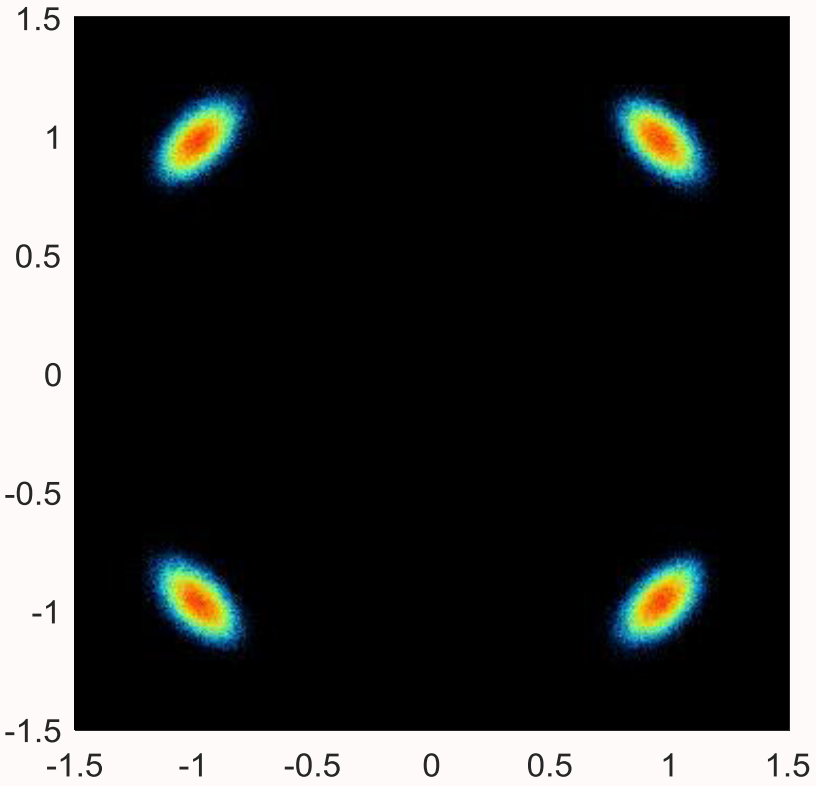
SIMULATION RESULTS: 80 KM



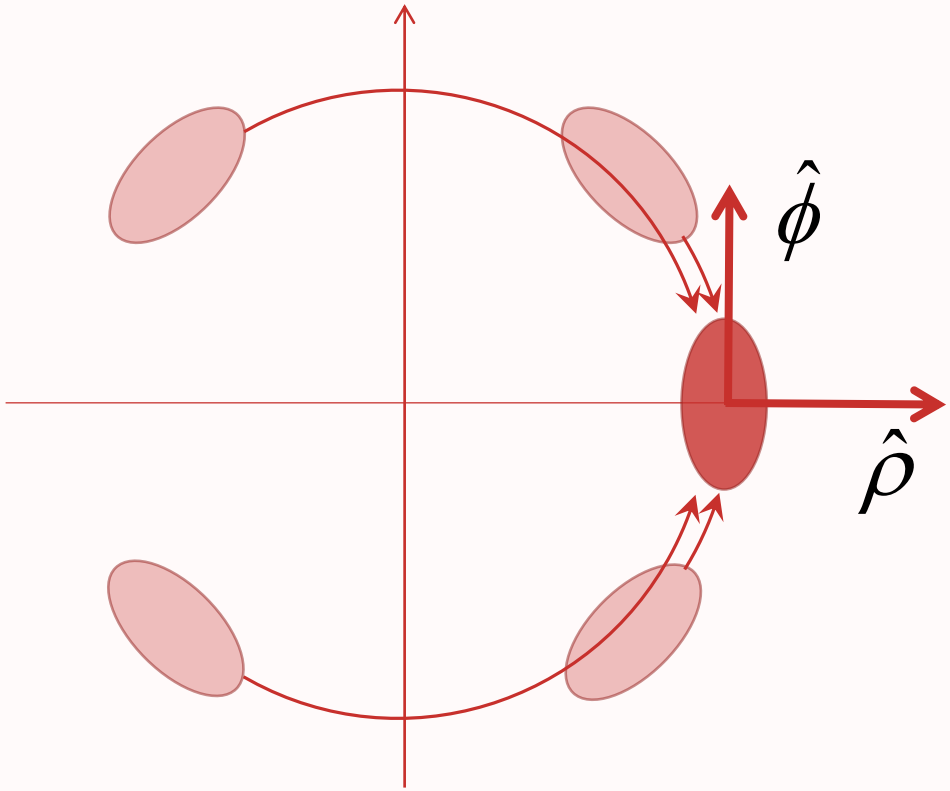
Solid: Split-Step

Dashed: Split-Step + CPE

NLPN ANALYSIS

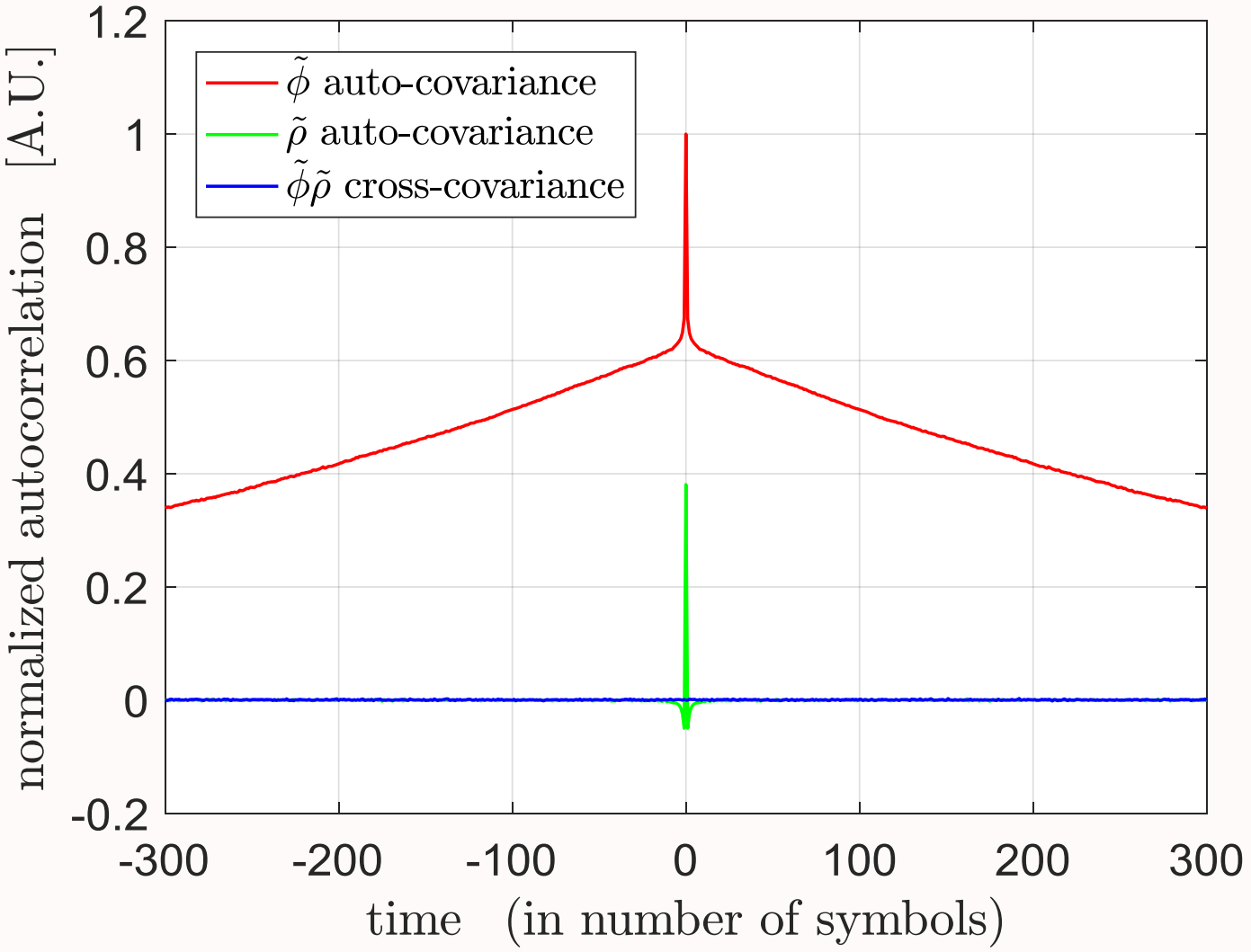


NLPN ANALYSIS

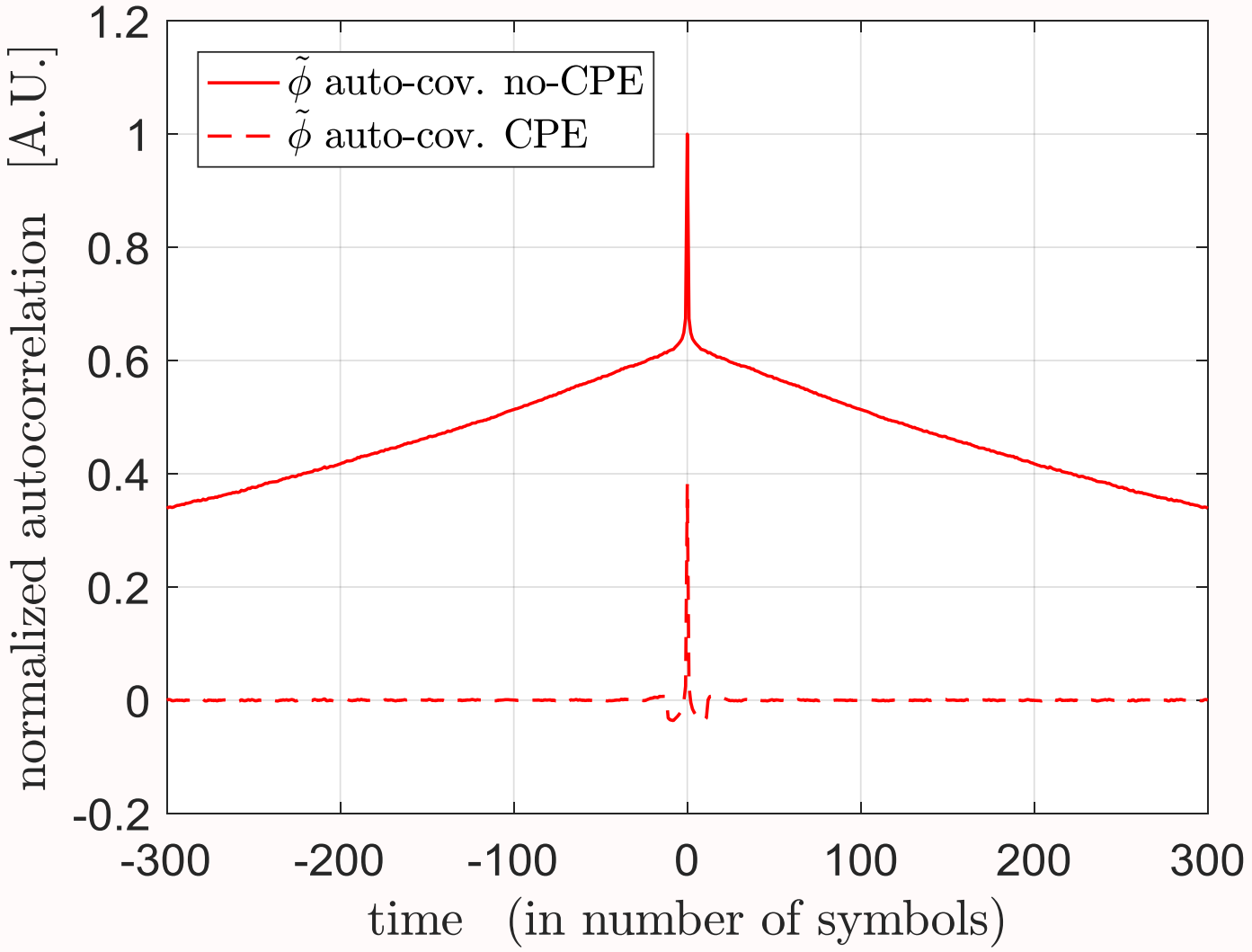


- We map all points onto one
- We look at the tangential and radial variances of NLI noise

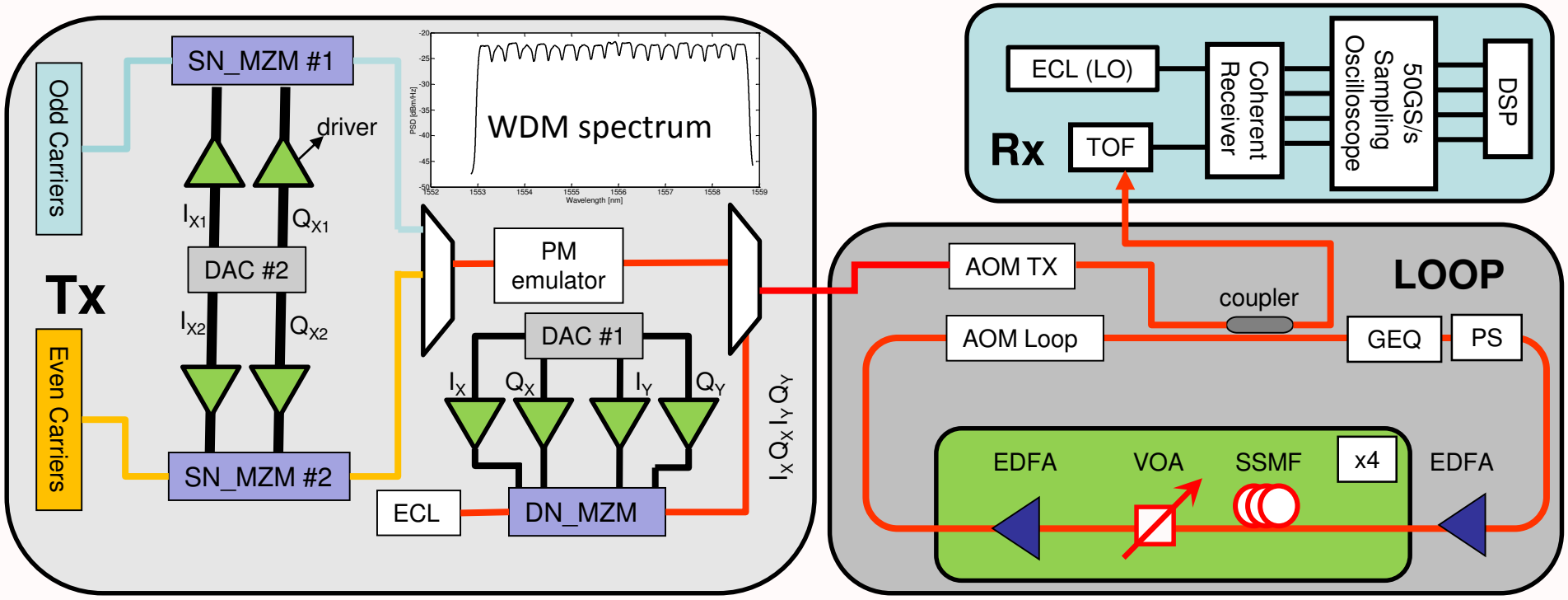
COVARIANCE FUNCTIONS



COVARIANCE FUNCTIONS



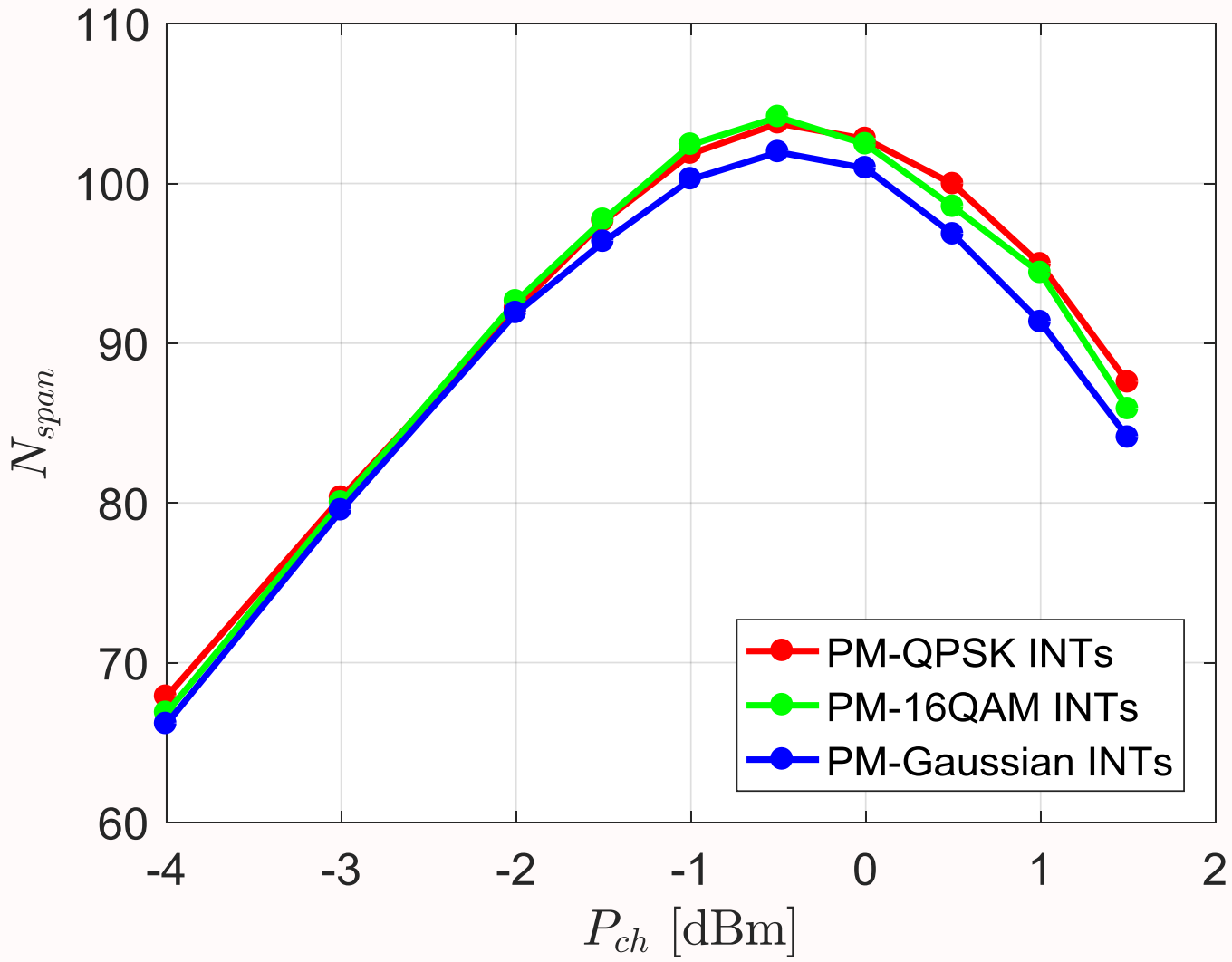
TRANSMISSION EXPERIMENT SETUP



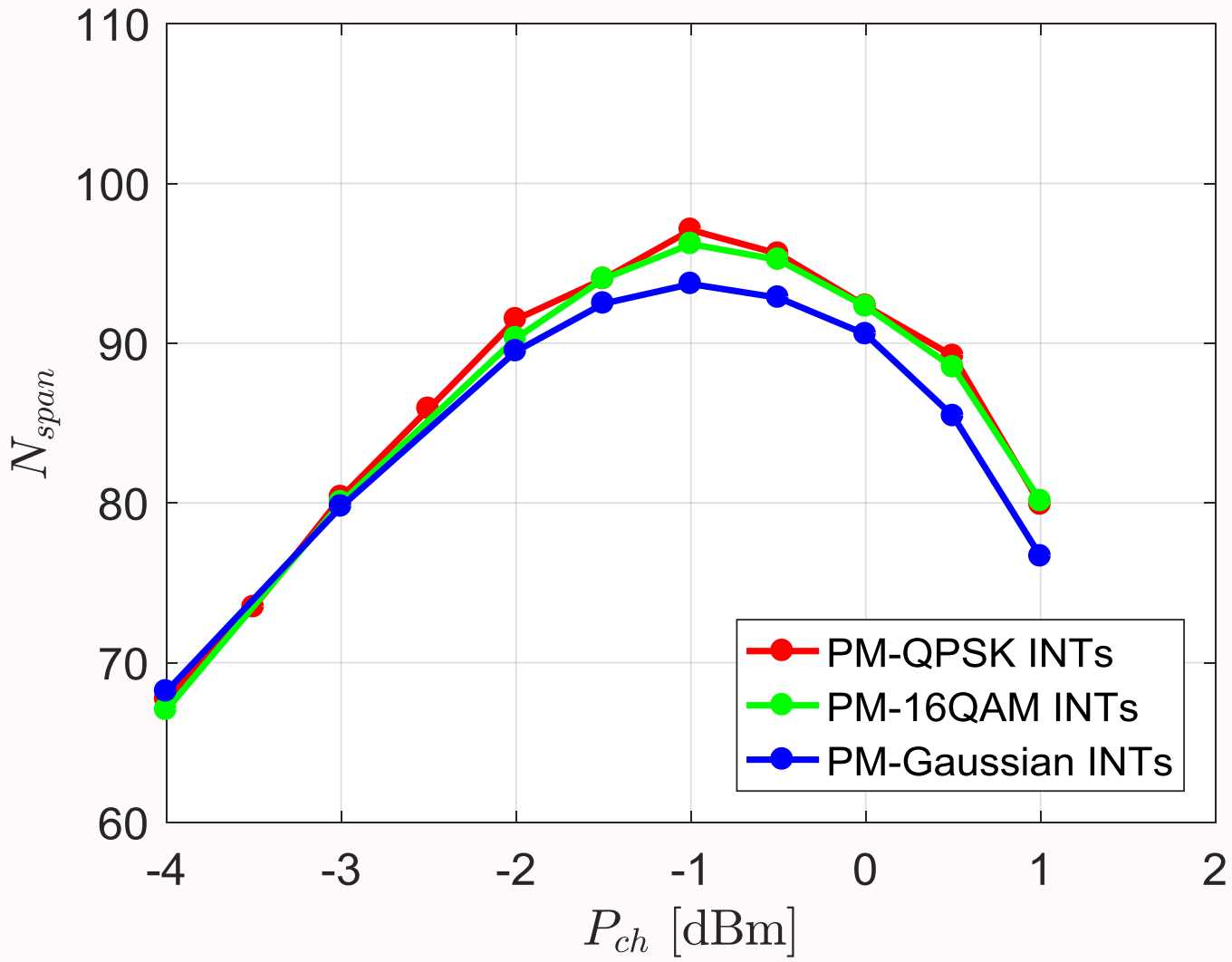
SN_MZM: single-nested Mach-Zehnder mod.
DN_MZM: double-nested Mach-Zehnder mod.

GEQ: Gain Equalizing programmable filter
PS: synchronous Polarization Scrambler
AOM: Acousto-Optic Modulator (used as switch)
TOF: Tunable Optical Filter
VOA: Variable Optical Attenuator

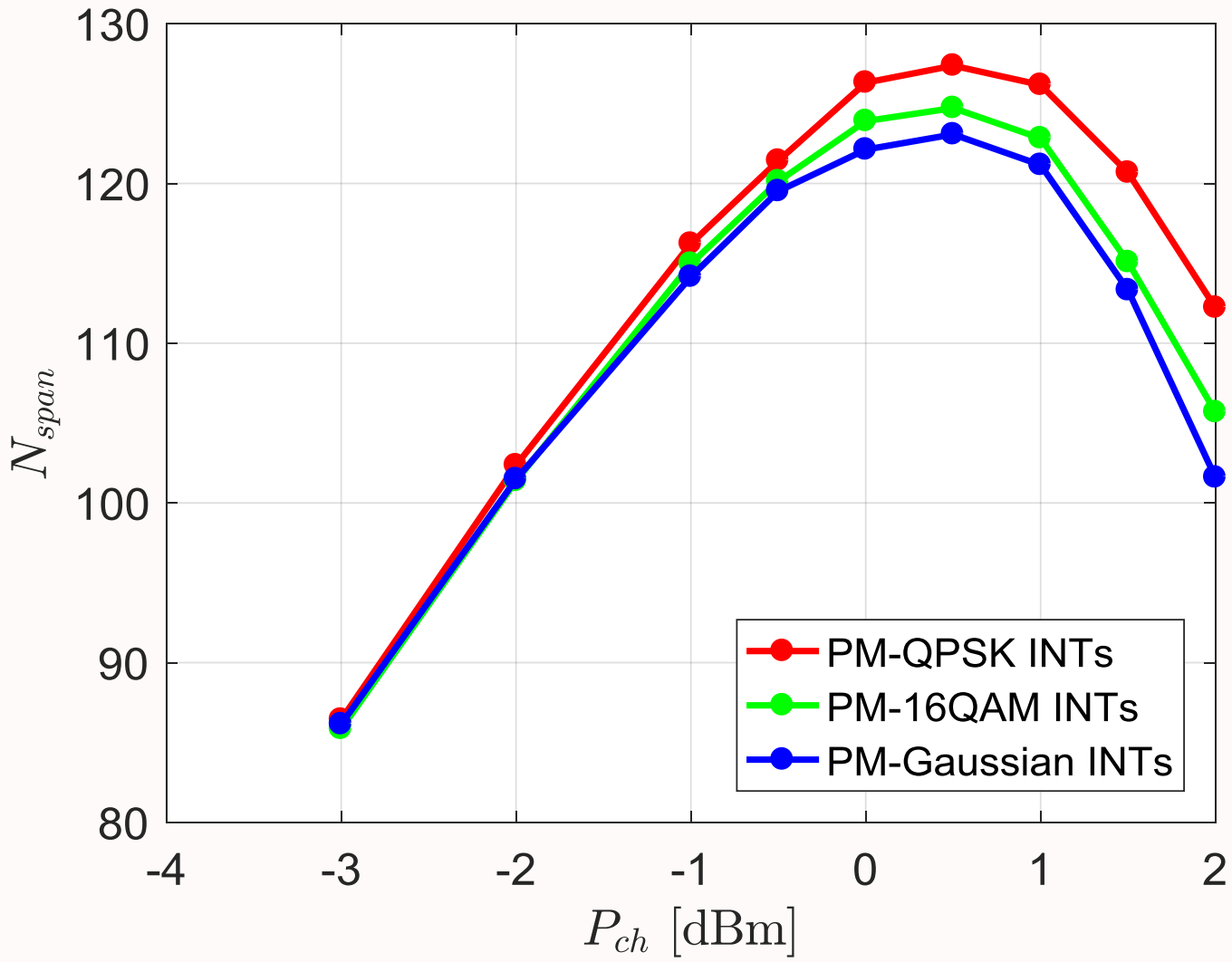
MAXIMUM REACH – 25KM



MAXIMUM REACH – 80KM



MAXIMUM REACH – 10KM



CONCLUSIONS

- We have shown by simulations that the amount of NLPN is modulation format dependent but it is characterized by long-correlation
  - It can be easily removed with a standard CPE block
- When NLPN is fully suppressed, format-dependence completely disappears
- Experimental results based on maximum reach have confirmed our findings

ACKNOWLEDGMENTS

THANK YOU!

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