ScuDo

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WHAT YOU ARE, TAKES YOU FAR

35th Cycle

NLI Generation in Wideband and Disaggregated Optical Networks

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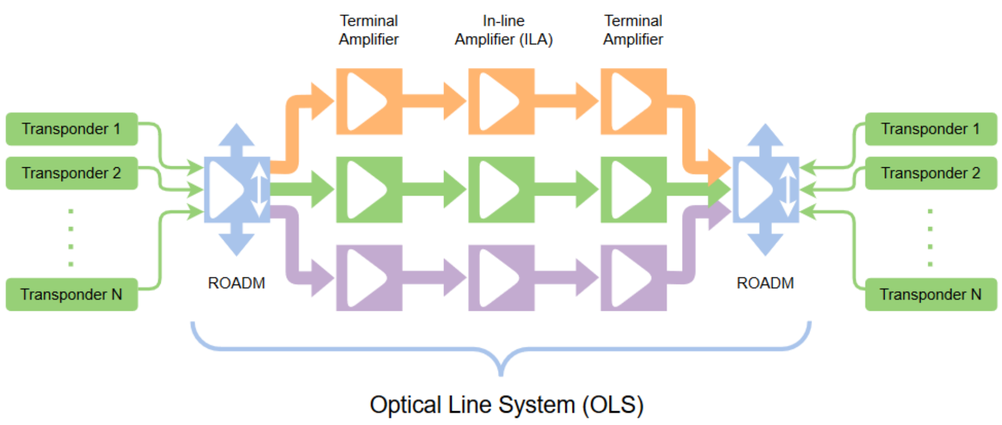
Research context and motivation

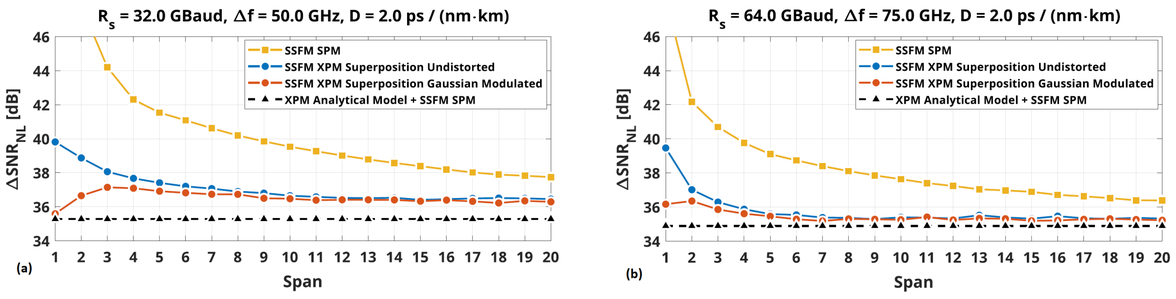
- Significant capacity and throughput increases are required for optical networks to manage accelerating user demands. Wideband transmission presents an attractive solution for this problem, with fast-developing technology that does not require installation of new fiber spans.



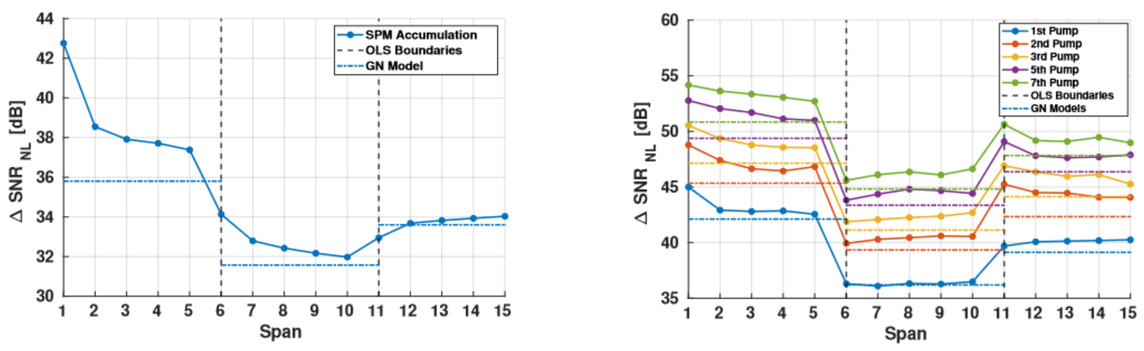
- The generation of nonlinear interference (NLI) in wideband networks is complicated by the effects of stimulated Raman scattering (SRS), frequency-dependent fiber parameter scaling, and the required disaggregation of NLI generation to enable progressive upgrades.
- Subsequently, advances in NLI modelling are required in order to accurately model quality of transmission (QoT) in these near-future optical network architectures.

Addressed research questions/problems

- First, to enable disaggregation, the spectral and spatial separability of the NLI contributors, the self-phase modulation (SPM) and cross-phase modulation (XPM) was investigated.
- The coherency of the SPM was observed, revealing a parameter, C_∞, which quantifies the maximum amount of SPM which may be generated for a given system configuration, scaling with $\theta \propto |\beta_2| L_s R_s^2$.
- These findings were combined with knowledge about the accumulation of the XPM, providing a fully disaggregated NLI model for the C-band.

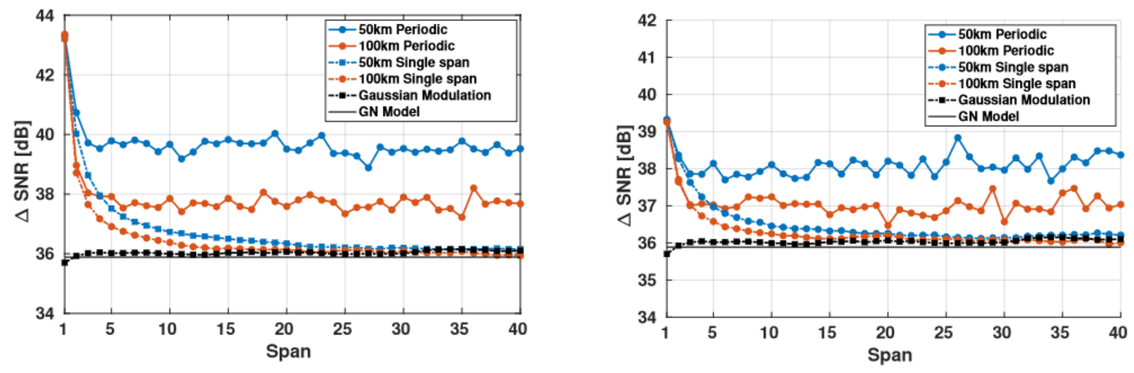


- Wideband adaptations were then made to the model and simulation framework, extending it to the L and S bands.
- This model was verified also for realistic network architectures, which include non-uniform links, and for channels with unknown memory, serving as an upper bound in all cases.



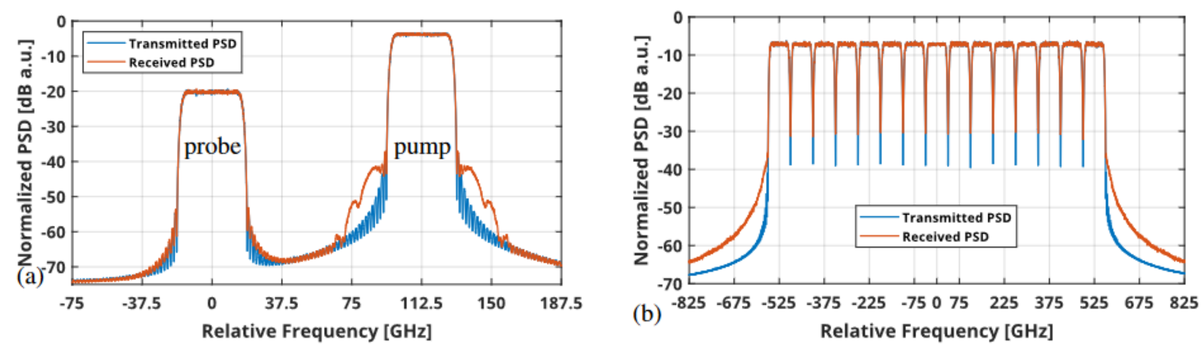
Novel contributions

- Within this project, novel contributions were made to NLI modelling, both for wideband and disaggregated optical network architectures.
- A simple relation quantifying the upper bound of the SPM accumulation was found, and then combined with an XPM to model to create the first fully disaggregated NLI model.
- The model was then extended to wideband regimes, non-periodic network layouts, and also permitting QoT prediction for alien wavelengths.



Adopted methodologies

- Research was performed primarily using two advanced simulation frameworks:
- Split-step Fourier method (SSFM) simulations performed within MATLAB, edited to enable wideband and disaggregated transmission, with full modelling of all frequency dependent effects.



- An internal branch of the open-source GNPy library, with similar modifications, providing fast and accurate approximations of the NLI generated within an OLS.
- These two frameworks were both independently verified and used together in order to investigate NLI generation in a variety of network architectures, performing full spectrum, single channel, and pump-and-probe simulations.

Future work

- The final piece of the puzzle is to calculate how the XPM accumulates in dispersion-compensated links and in mixed-fiber optical network layouts, further improving accuracy.
- Both scenarios introduce dispersion-dependent effects which do not guarantee the incoherent accumulation of XPM.
- However, preliminary investigations suggest that these effects still fall below the upper bounds of our model.
- This investigation is currently underway, with results to be submitted to OFC 2023, followed up with a journal paper, to summarize our findings, and the project.

Submitted and published works

- E London, E Virgillito, A D'Amico, A Napoli, V Curri, "Simulative assessment of non-linear interference generation within disaggregated optical line systems", Optics Continuum 3 (12) 3378-3389.
- A D'Amico, E London, E Virgillito, A Napoli, V Curri, "Quality of transmission estimation for planning of disaggregated optical networks", ONDM 2020, 1-3.
- A D'Amico, B Correia, E London, E Virgillito, G Borraccini, A Napoli, V Curri, "Scalable and disaggregated GGN approximation applied to a C+L+S optical network", Journal of Lightwave Technology 40 (11) 3499-3511.
- E London, A D'Amico, E Virgillito, A Napoli, V Curri, "Modelling non-linear interference in non-periodic and disaggregated optical network segments", Optics Continuum 1 (4) 793-803.
- E London, E Virgillito, A D'Amico, A Napoli, V Curri, "Observing cross-channel NLI generation in disaggregated optical line systems", Asia Communications and Photonics Conference, W3B. 3
- A D'Amico, E London, E Virgillito, A Napoli, V Curri, "Inter-band GSNR degradations and leading impairments in C+L band 400G transmission", ONDM 2021 1-3.
- A D'Amico, E London, B Le Guyader, F Frank, E La Rouzic, E Pincemin, N Brochier, V Curri, "Experimental validation of GNPy in a multi-vendor flex-grid flex-rate WDM optical transport scenario", JOCN 14 (3), 79-88.

List of attended classes

- 01TRLRV – Optical Transport Networks (23/07/2021, 50)
- 01MNFIU – Parallel and distributed computing (01/10/2020, 41.67)
- 01QFFRV – Tecniche innovative per l'ottimizzazione (26/06/2021, 33.33)
- 01NDLRV – Lingua italiana I livello (13/07/2022, 0)
- Lake Como Machine Learning Photonics Online School (15/03/2021, 27)

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