Nonlinear transmission performance of reduced guard interval OFDM and quasi-Nyquist WDM

Sean Kilmurray*, Tobias Fehenberger, Polina Bayvel and Robert I. Killey
Optical Networks Group, University College London (UCL), Electronic & Electrical Engineering, Torrington Place, London, WC1E 7JE, United Kingdom
*s.kilmurray@ee.ucl.ac.uk

Abstract: The nonlinear transmission performance of reduced guard interval OFDM and quasi-Nyquist-WDM (PDM-QPSK, PDM-QAM-8 and PDM-QAM-16) with high information spectral densities is compared over ULAF and SMF, both by simulations and analytically.

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1. Introduction

The concept of the super channel, in which several optical carriers are combined to create a composite signal with a desired capacity, has recently been proposed to enable transmission with Tb/s per-channel data rates [1]. Nyquist wavelength-division multiplexing (N-WDM) [2] and orthogonal frequency division multiplexing (OFDM) [3] have both been shown as suitable formats for achieving high spectral efficiency super channels capable of achieving Tb/s per channel transmission capacity.

The first approach achieves a high spectral efficiency by using electrical or optical Nyquist filtering to reduce the channel spacing to the symbol rate per carrier without incurring significant penalties from inter-channel crosstalk or intersymbol interference. Quasi-Nyquist wavelength-division multiplexing (qN-WDM) transmission can be realized by relaxing the Nyquist condition and using a filter that approximates the ideal case with a channel spacing slightly larger than the symbol rate. The alternative format, OFDM, has a very well defined narrow optical spectrum resulting from overlapping orthogonal subcarriers spaced at the modulation rate allowing signalling at or close to the Nyquist rate without the use of sharp cutoff filters.

The question facing system designers is which is the optimal format in terms of spectral efficiency and achievable transmission distances. We have recently compared their performance over standard single-mode fibre [4] and in this paper we extend the work and compare for the first time the nonlinear transmission performance of quasi-Nyquist WDM and reduced guard interval (RGI) OFDM (PDM-QPSK, PDM-QAM-8 and PDM-QAM-16) for ultra large area fibre (ULAF) and single mode fibre (SMF).

2. Simulation setup and results

The simulation setup is described in detail in [4]. The ULAF parameters used in this work are: attenuation $\alpha = 0.185\,\text{dB/km}$, dispersion $D = 19.9\,\text{ps/nm/km}$, dispersion slope $S = 0.06\,\text{ps/nm}^2/\text{km}$, nonlinear parameter $\gamma = 0.81\,\text{W/km}$ and polarization mode dispersion $D_p = 0.1\,\text{ps}/\sqrt{\text{km}}$ [5].

To investigate the long distance transmission performance of both formats a 9 channel WDM transmission system was simulated and the maximum reach, for a BER of $10^{-3}$ evaluated for different channel launch powers, swept from -8dBm to 3dBm, in increments of 1dB. All the results obtained were plotted for the central channel. The channel spacing for both qN-WDM and RGI-OFDM PDM-QPSK was 28.875GHz giving a spectral efficiency of 3.43 bits/s/Hz. For PDM-QAM-8 and PDM-QAM-16 a 28.4375GHz channel spacing was used giving spectral efficiencies of 5.25 bits/s/Hz and 7 bits/s/Hz respectively.

The maximum transmission distances versus channel launch power for both qN-WDM and RGI-OFDM are plotted in figure (1) for ULAF and figure (3) for SMF. Figures (2, 4) show the maximum transmission distance achieved at an optimal launch power of -2dBm, versus the spectral efficiency. Results obtained with closed-form expressions, describing the nonlinear transmission performance of densely spaced coherent optical systems, for N-WDM [6] and OFDM [7] are also shown as solid lines in each figure.

Very good agreement between the simulation results and the analytical curves can be seen. The maximum transmission distances for qN-WDM and RGI-OFDM are approximately the same for each modulation format and both
By using ULAF an approximately 50% increase in transmission reach can be achieved when compared to SMF. We also investigated the nonlinear transmission performance over pure core silica fibre (PCSF) using the fibre parameters from [8]. The results (not shown) were almost identical to the results obtained for ULAF. This is due to the approximately equal fibre parameters.

3. Conclusion

We have compared the nonlinear transmission performance of quasi-Nyquist-WDM pulse shaping and reduced guard interval OFDM for PDM-QPSK, PDM-QAM-8 and PDM-QAM-16 at near baud rate channel spacing using ULAF and SMF, both numerically and analytically. The results show that both systems would be expected to achieve similar maximum transmission distance of approximately 10,200km, 4,000km and 2,000km over ULAF and approximately 6700km, 2600km and 1100km over SMF for the same spectral efficiencies of 3.43 bits/s/Hz, 5.25 bits/s/Hz and 7 bits/s/Hz respectively.

References

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