Compatibility of Optical OFDM and NRZ in WDM Communication Links

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Abstract – The use of optical OFDM in fibre links also carrying NRZ channels is investigated. Simulations show little penalty on the OFDM channels if the NRZ power is less than 2 dB greater than the OFDM power.

1. Introduction

With constant progress in high-speed digital signal processing, using electronic alternatives to mitigate the intrinsic impairments of optical fibre has gained its popularity [1]. In particular, electronic processing can upgrade the existing fibre links without complex redesign, or changes to the outside plant.

Optical Orthogonal Frequency Division Multiplexing (O-OFDM), uses hundreds of closely-space sub-carriers and electronic equalization at the receiver [2]. Simulations and experiments have demonstrated O-OFDM as an effective modulation format for long-haul and high speed optical links [3-6].

In real networks, a common scenario may be that O-OFDM is used to upgrade a few wavelengths on a conventional WDM system carrying non-return to zero (NRZ) signals on other wavelength channels. Cross-Phase Modulation (XPM) and Four Wave Mixing (FWM) could cause cross-talk between the wavelength channels. Generally, their effects are proportional to power per channel and inversely proportional to channel spacing [7]. Given that OFDM uses lower power channels than NRZ, it is likely that the NRZ channels will affect the O-OFDM than vice versa.

This paper investigates the interaction of NRZ channels and neighbouring O-OFDM channels in an 800km transmission link. We find that the NRZ channels affect the signal quality of the O-OFDM channels but only for reasonably large NRZ channel powers. Increasing the O-OFDM channels' powers to compensate for the NRZ channels only marginally improves their signal quality.

2. System Description

We consider a system with 10 spans using numerical simulation. Each span contains an 80-km S-SMF and a noisy EDFA to compensate the optical loss. The fibre has a standard dispersion of 16 ps/nm/km, a loss of 0.2 dB/km, and a nonlinear coefficient of 2.6×10^{-20} m^2/W. Dispersion Compensating Fibre (DCF) was not included in the link, although some form of optical or electrical Dispersion Compensation (DC) would be required for the NRZ channels. O-OFDM requires no dispersion compensation.

To obtain an accurate comparison with previous work, we use the same OFDM transmitter model as in [4]. 10 Gb/s is transmitted using 4-QAM, giving a subcarrier band between 5 and 10 GHz from the optical carrier. Two OFDM channels were multiplexed with two NRZ channels with a channel spacing of 25 GHz. No attempt was made to restrict the bandwidth of the NRZ channels during multiplexing, so there is some crosstalk into with the OFDM channels, even in the case of a linear fibre. The performance of the middle OFDM channel that is surrounded by NRZ channels is analysed. To demultiplex this OFDM channel at the receiver, we used a tight rectangular filter with bandwidth of 15 GHz. The system was simulated with VPItransimissionMaker version 7.1 over a range of NRZ and O-OFDM channel powers.

3. Simulation Results

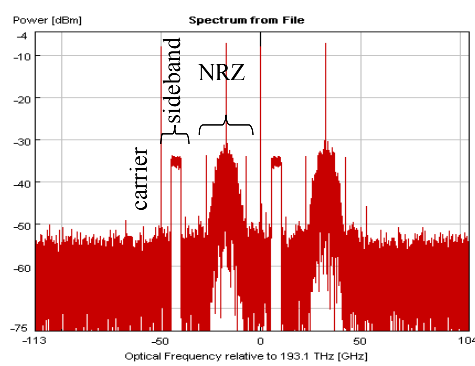

Fig. 1. Spectrum after propagation through 800km fibre.

Fig. 1 shows a typical received optical spectrum. The signal has propagated over 800 km with input power to each fibre span of -5 dBm per channel for both OFDM and NRZ. Intuitively, a strong NRZ power will increase XPM between the NRZ and the O-OFDM channels. As O-OFDM transmits information on the phase of each subcarrier, this is likely to cause errors on the O-OFDM channel. To characterise this, the quality of the O-OFDM signal, Q, [4], was simulated. For reference, Q = 9.8 dB gives a BER of 10^{-3}. The powers used in the results are defined at the input to each fibre span.

Fig. 2 shows the Q variation with OFDM input power for different NRZ powers. For low NRZ input powers (< -5 dBm), the performance of OFDM is mainly restricted by Amplified Spontaneous Emission (ASE). For higher O-OFDM powers, FWM [8] between subcarriers (i.e. within one WDM channel) reduced the

Q. This agrees well with previous results [4]. When the NRZ power is increased, Q decreases rapidly and the Q curve is flattened. Thus the NRZ channels are limiting the performance of the OFDM channels.

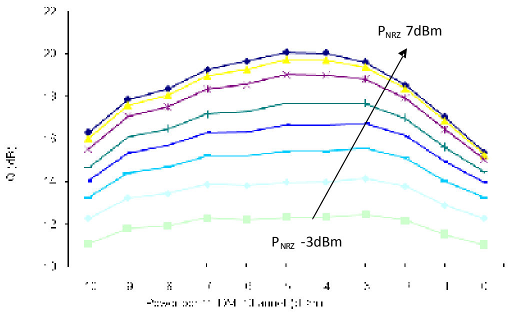

Fig. 2. Q versus input power of OFDM for various NRZ input powers.

Fig. 3 plots the best obtainable Q, which occurs at an OFDM channel power of -5-dBm against the NRZ power. The maximum Q drops with the increasing NRZ power: a 1-dB penalty in OFDM signal quality occurs with -3 dBm in each NRZ channel. A BER of 10^{-3} requires the power of each NRZ channel to be less than 5 dBm.

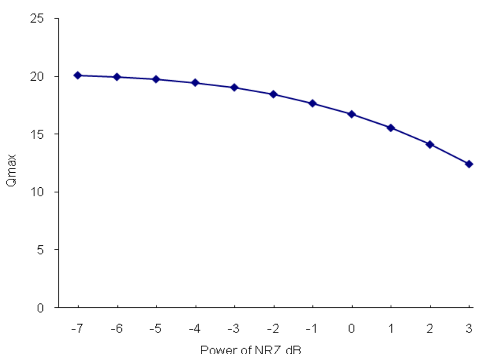

Fig. 3. Best available Q versus NRZ power.

Fig. 4 presents our results as a 2-D plot of Q_{OFDM} versus P_{NRZ} and P_{OFDM}. The locus of optimum O-OFDM powers shows some dependence on NRZ power. For high NRZ powers, the OFDM channel becomes limited by XPM effects caused by the neighbouring NRZ channels. In such cases, OFDM channel power has little effect on system performance when operating between the noise and nonlinear limits. For example, and NRZ power of 2 dBm will limit the quality of the OFDM channel to below 14 dB.

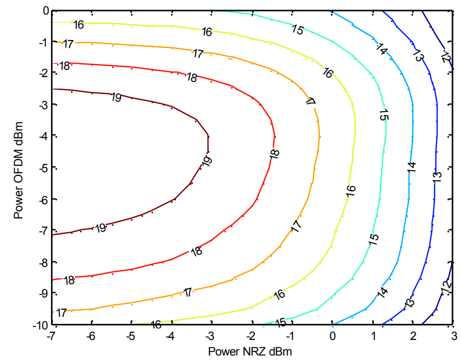

Fig. 4. Q of O-OFDM channel for different combinations of OFDM power and NRZ power

4. Conclusions

The performance of O-OFDM is largely dominated by the noise and nonlinearity limits within each channel unless powers greater than -3dBm are used in neighbouring NRZ channels.

References

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