Correlations between optimal temporal width and spectral characteristics of an optical signal in a wavelength-paired CS-RZ transmission with high spectral efficiency

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Abstract: We examine the correlations between the parameters of ultra-narrow off-centred filtering and pulse width on the performance of a wavelength paired Nx40Gbit/s DWDM transmission, consisting of carrier suppressed return-to-zero signal with 0.64 bit/s/Hz (without polarization-division multiplexing) spectral efficiency.

OCIS codes: (060.4080) Modulation, (060.4230) Multiplexing, (060.4510) Optical communications

References and Links

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1. Introduction

Development of communication systems with high channel rate is driven by a possibility to reduce the number of transmission terminals while keeping the same aggregate capacity.

In order for 40 Gbit/s optical transmission systems to compete with existing 10Gbit/s technologies and be cost effective, it is crucial not only to maintain a large aggregate capacity, but also to provide a high spectral efficiency – in other words, to send as much information as possible while using the least possible spectral bandwidth.

Recently, a number of promising approaches have been conceived in order to achieve higher spectral efficiencies at 40Gbit/s rate. It is feasible to obtain a 0.64bit/s/Hz spectral efficiency, by using a specific wavelength allocation scheme combined with vestigial side-

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band (VSB) filtering, as proposed in [1]. With the use of polarization-division multiplexing (PDM), as prescribed by [2], this spectral efficiency can be further increased to 1.28bit/s/Hz.

Another important approach in increasing spectral efficiency is using Carrier Suppressed Return-to-Zero (CS-RZ) modulation format. It enables a higher spectral efficiency among the RZ on-off keying formats [3-7]. Narrow filtering is realized at the expense of increasing non-linear penalties due to narrower channel spacing and an inherent temporal waveform distortion. Therefore, for any particular system it is important to find an optimum between the performance improvement gained by optimisation of the spectral domain filtering and determination of superior carrier pulse characteristics in the temporal domain.

This paper is focused on simultaneous optimisation of the signal pulse width and parameters of ultra-narrow off-centered VSB filtering in application to CS-RZ modulation format without the use of PDM.

2. Frequency allocation and VSB off-centre filtering

Though our approach is rather general, for the sake of clarity, we focus here on a particular example of a wavelength-paired Nx40Gbit/s DWDM transmission scheme with ultra-narrow, off-centre optical VSB filtering.

The following frequency allocation scheme first proposed by Bigo et al [1] has been considered. The WDM channels are grouped into pairs, with an alternating frequency separation. The two channels, within the pair, are separated by α [GHz]. The pairs are then spaced by β [GHz] as schematised in Fig. 1. Therefore, $(\alpha+\beta)/2$ gives the channel spacing for corresponding standard WDM transmission occupying the same bandwidth.

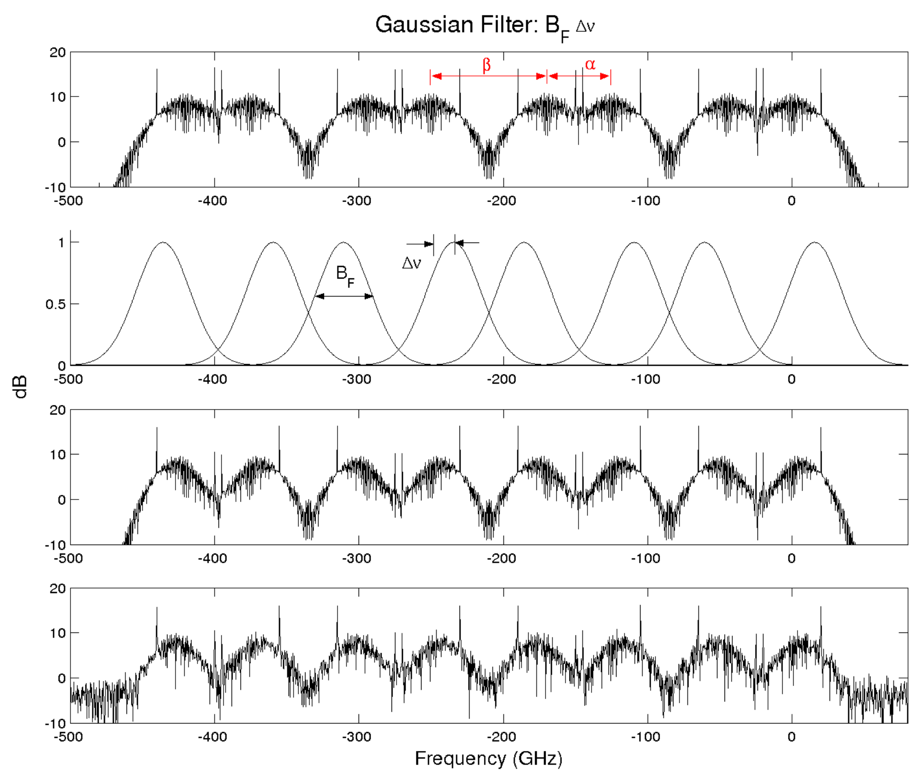

Fig. 1. Channel spectra of CS-RZ signal before filtering (top); VSB filters (second from the top);Spectra after filtering (third from the top); Spectra after propagation over 600 km of TL/RTL (bottom).

To achieve 5Tbit/s capacity over C and L bands (8THz total bandwidth), the condition $\alpha+\beta$ = 125 GHz has to be met [1]. It has been previously shown [1], that asymmetric channel allocation α/β = 50 GHz/75 GHz leads to better performance than the standard periodic channel spacing with α = β = 62.5GHz. The wavelength allocation scheme described above is here applied to CS-RZ modulation format.

The aim of VSB filtering is to reshape the channel spectra with the aim to isolate one of the two single side bands (SSBs) and further reduce cross-talks between adjacent channels. This approach makes use of either upper side band (USB) or lower side band (LSB) of adjacent channels [3]. Detuning the narrow passband filter off the carrier enhances the favoured side-band, while making efficient reduction of cross-talk. The detuning is always done away from the centre of a pair of closely spaced channels. Thus, the side-band having the smallest overlap with adjacent channels is isolated while the impact of the cross-talk affecting the other side-band is minimized [1, 3].

The resulting best performance is a rather complex trade-off between crosstalk suppression and waveform distortion leading to propagation penalties. Therefore, important system parameters to be optimised in this scheme are: optical filter bandwidth, filter detuning and duty cycle. Our goal now is to find optimal correlations between impacts of ultra-narrow off-centred VSB filtering and a duty cycle parameter on the performance of a specific line described below.

3. System set-up and results

Without loss of generality, we now examine a particular fibre transmission link. The VSB off-centre filtering has been employed at both the transmitter and at the receiver, in order to suppress cross-talks during transmission. The scheme of the frequency allocation and VSB Gaussian filtering detuned off the centre frequency of the channel by Δν is shown in Fig 1. The considered dispersion map consists of 50km of TeraLight fibre and 25km Reverse TeraLight fibre followed by EDFA (NF = 4.5 dB) and a similar block with the reverse order of TL and RTL. The span average dispersion is zero. A VSB filtering has been realized at MUX and DEMUX.

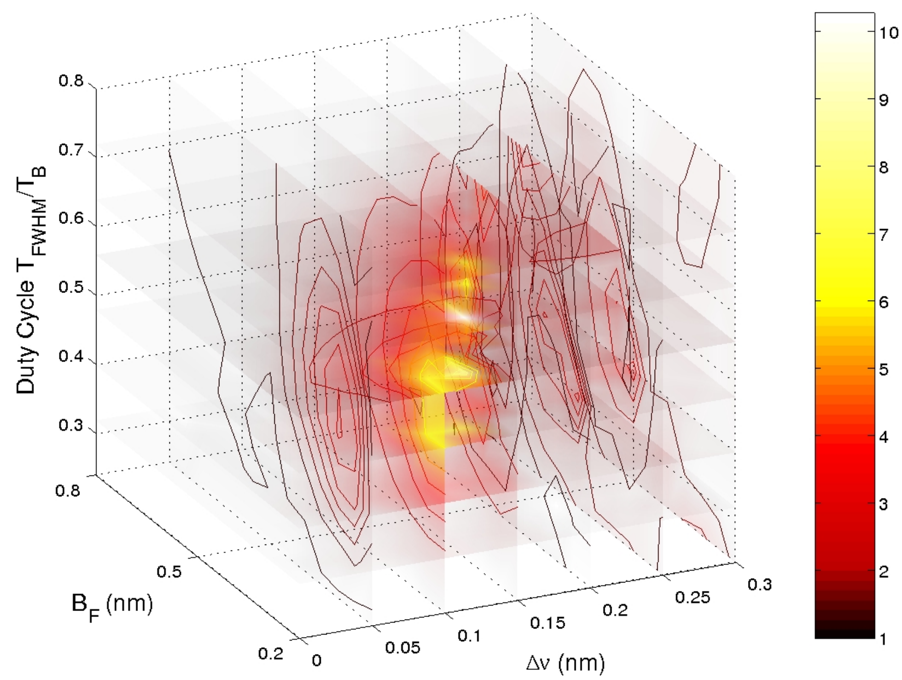

Fig. 2. 3D volume plot of linear Q-factor in the space of system parameters (duty cycle, filter bandwidth B_F and detuning Δν).

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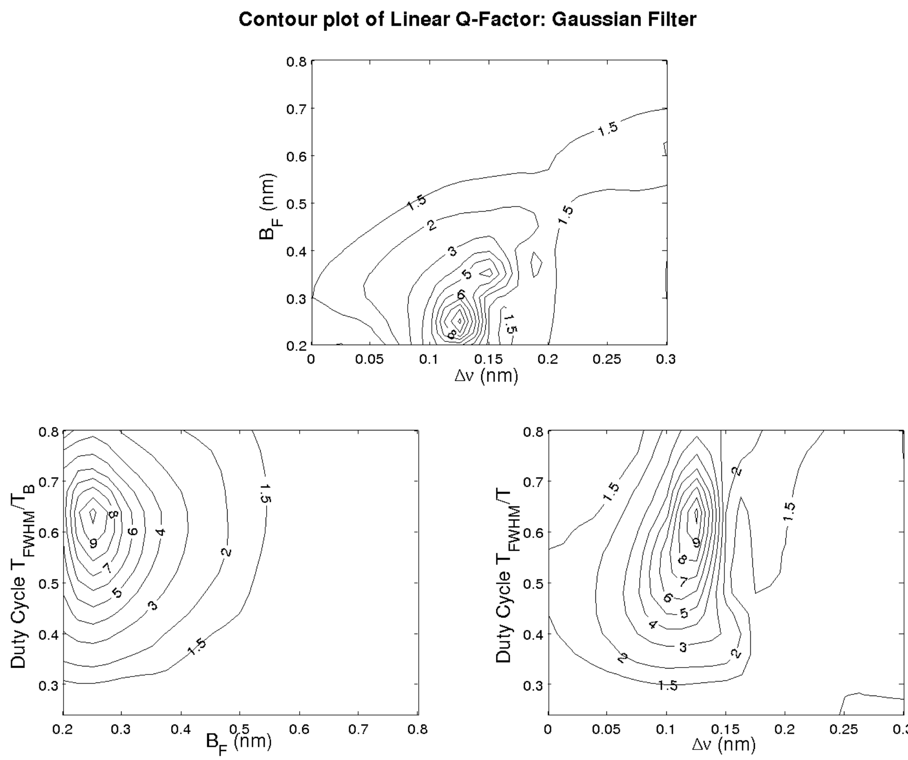

Fig. 3. Contour plots of linear Q-factor illustrating the cross section of the best point, in the space of system parameters (duty cycle, filter bandwidth B_F and detuning $\Delta\nu$).

First, the best set of WDM system parameters was determined in back-to-back performance. At least five numerical runs have been performed for each set of parameters to account for pattern dependences.

Figures 2 and 3 illustrate performance in terms of Q-factor versus three optimisation parameters (filter bandwidth, detuning and duty cycle). It was found that a duty cycle value of 0.64 maximizes Q-factor provided that both channel allocation and VSB filter detuning and bandwidth are optimal. This finding is very important from the practical viewpoint as the 66% duty cycle can be realized using Mach-Zender interferometer. Figure 4 shows the dependence of Q-factor versus channel allocation parameter α/β. The best system/signal parameters found correspond to α=45GHz and β=80 GHz.

Next we investigate performance of the optimal back-to-back configuration in transmission. Optical transmission system performance has been modelled by propagating 2^7-1 pseudorandom binary sequence CS-RZ signal. Error-free transmission distance was defined using the standard definition of Q-factor based on Gaussian statistics. In this case a linear Q of 6 is equivalent to a bit-error rate (BER) of 10^{-9}. The input signal power, duty cycle and span average dispersion have been optimised to maximize transmission distance. Figure 5 confirms that, indeed, a right choice of temporal pulse characteristics is important for realization of the optimal narrow filtering.

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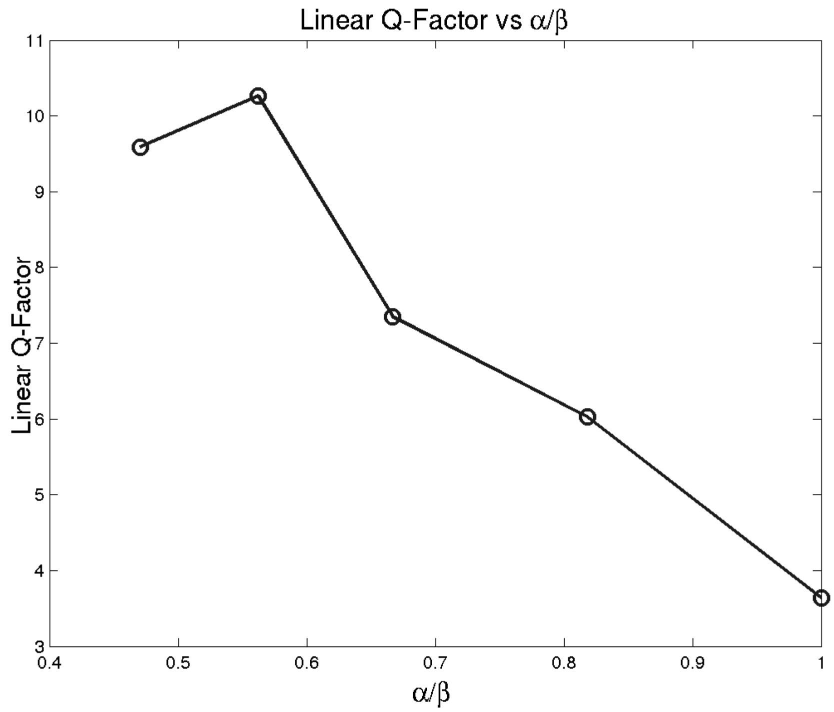

Fig. 4. Q-factor versus α/β parameter

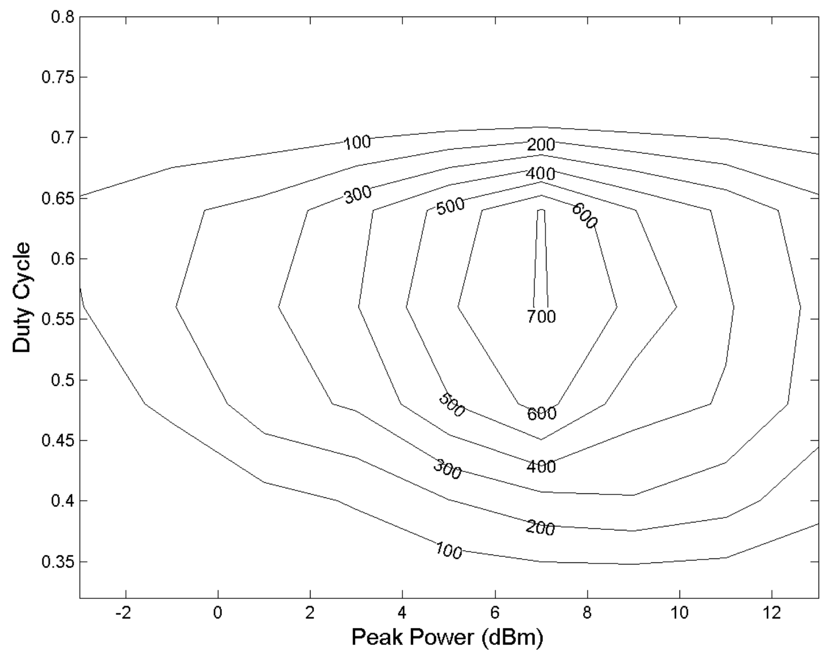

Fig. 5. Contour plot of the error-free transmission distance in the plane (duty cycle, input peak power).

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4. Conclusions

We have studied the correlations between the impact of a duty cycle and the characteristics of ultra-narrow off-centred VSB filtering on the performance of a wavelength-paired Nx40Gbit/s DWDM CS-RZ transmission with a 0.64 bit/s/Hz spectral efficiency without using PDM. We have demonstrated that the selection of an optimal duty cycle close to 0.6 can improve system performance without decrease of the spectral efficiency.

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