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Optimized Optical Filtering For 40 Gb/s/Channel Optical Differential Quadrature Phase Shift Key (DQPSK), In DWDM Systems For Acces Network

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Abstract— ***The optimization of multiplexing (MUX) and demultiplexing (DMUX) 3-dB filter bandwidths for the optical differential quadrature phase shift key (DQPSK) combined with the return-to-zero (RZ) and carrier-suppressed return-to-zero (CS-RZ) is performed. The study of different optical signals in the 40 Gb/s dense wavelength division multiplexing (DWDM) system, with high spectral efficiency, is shown to be achievable with different filter types for access network. Performances of MUX and DMUX with different filter bandwidth is analyzed to get the best system performance for 40 Gbs/s DWDM transmission system with high spectral efficiency. The limitations imposed by misalignment of filters are also discussed.***

Keywords: Optical differential quadrature phase shift key (DQPSK), dense wavelength division multiplexing (DWDM), misalignment, optical filter, Bessel, Butterworth.

I. Introduction

In recent years, several modulation formats have been suggested as alternatives to the commonly used non return-to-zero (NRZ) and return-to-zero (RZ). These include, carrier-suppressed RZ (CS-RZ) [i, ii], duobinary [iii, iv], and optical differential quadrature phase shift key (DQPSK) . Due to its narrower spectra DQPSK is expected to provide improvements in terms of tolerance to chromatic dispersion (CD) and should allow increased spectral efficiency in dense wavelength division multiplexing (DWDM) systems. DQPSK modulation format is gradually becoming a research focus [i]. However, the relative performance of this modulation format strongly depends on the type of system (fiber type, amplifier spacing, etc.) [v]. In a WDM system, there is additional signal degradation compared to a single channel system. These impairments come from both the multiplexing/demultiplexing, and non-linear impairments in the fiber, such as cross-phase modulation (XPM) and four-wave mixing (FWM). In this paper, we investigate the penalty from multiplexing and then demultiplexing (MUX-DMUX penalty) [vi]. We assess numerically the influence of narrow optical filtering at the transmitter and at the receiver on the performance of a DWDM system for access network. Five channels are considered with a bit rate of 40 Gb/s and a channel spacing of 50 GHz using RZ/CS RZ - DQPSK. The optical filters used in the simulations were 3rd order Bessel (AWG transfer function) and Butterworth (TTF transfer function) filters [vii].

II. Simulation description

With DQPSK the data is encoded into one out of four different symbols, thus enabling simultaneous transmission of two bits per symbol. The main benefit of DQPSK is the reduced spectral width, which is about half that of a binary format at the same bit rate. DQPSK systems were sufficiently mature to allow demonstrations with good performance at bit rates above 10 Gbit/s [viii, ix]. The 40 Gb/s DQPSK modulation format, was generated using two Mach-Zehnder modulators (MZM) separately in series way. After the precoding, the branches of the in-phase (I) and quadrature-phase (Q) are respectively sent into two MZMs for four levels phase modulation. The code type of optical DQPSK is produced firstly through two MZMs for the phase modulations, then followed by the clock signal for shaping, thus code types of different duty cycle are obtained (RZ /CS RZ DQPSK), which concludes that three MZMs are needed as shown in figure2 [x].

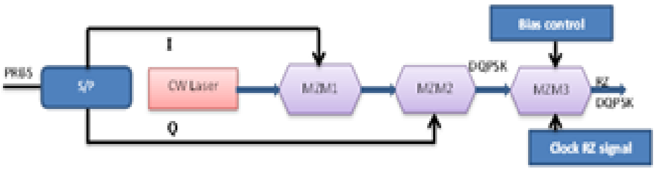


Figure1. RZ/CS RZ DQPSK transmitter setup.

The 40 Gb/s DQPSK signals are generated as described in [x], five DWDM channels spaced by 50 GHz are considered. A pseudo-random bit stream (PRBS) of length 2^7 -1 bits are considered to rigorously assess the performance of DWDM system [iii]. To achieve smaller channel spacing, the DQPSK signals are filtered by a narrow optical filter as MUX. The system set-up is shown in Figure 2 .The transmission line consisted in 20km single mode fiber (SMF) (17 ps/nm/km, 0.2 dB/km).

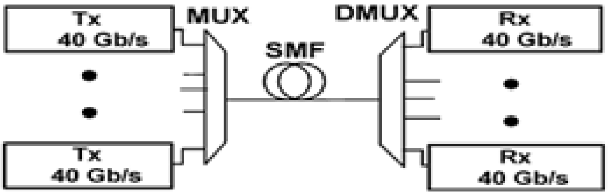


Figure2. The system setup for 5 x 40 Gb/s over 20 km of SMF-28 transmission.

At the receiver side, an optical filter of the same type as the one in the transmitter is used for demultiplexing the appropriate channel. The filtering function implemented in the receiver (electrical filter) consisted in a 3rd order Bessel . The signal was demodulated in a one bit-delayed interferometer and sent on to a balanced detector. the balanced detection is used in the demodulation receiver of DQPSK. Two Mach-Zehnder delay interferometers (MZDI) are employed to make the phases of branch I and Q to achieve the delay T (the value is 2/B, B is information transmission rate) in the two arms[x].

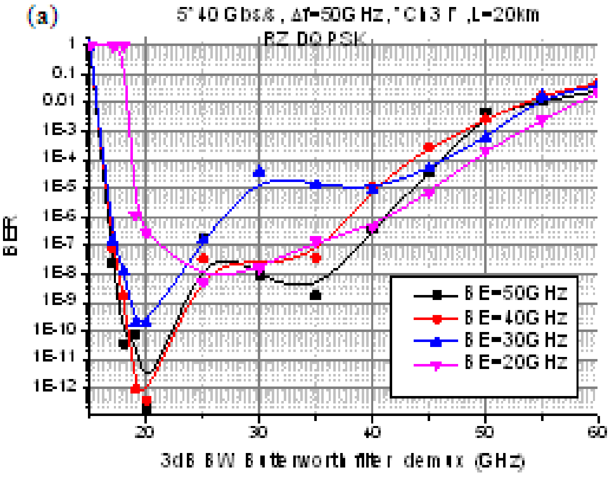
III. Results and Discussions

The 3-dB optical bandwidths of the MUX and DMUX are varied independently in order to optimize the system performance. The electrical filter was assumed a 26 GHz bandwidth 3th order Bessel filter. The Bit Error rate (BER) is used to evaluate system performance.

The optimization of the 3-dB bandwidth of MUX and DMUX filters is necessary to release a DWDM system with high spectral efficiency. Figure 3 shows the BER as a function of 3-dB optical bandwidth of DMUX for different MUX 3dB bandwith's for the 3rd order Bessel and Butterworth optical filter. DQPSK is a non-binary modulation scheme and can attain very narrow spectrum by encoding multiple bits per symbol.

The optimal Bessel filter bandwidths are 20 GHz for DMUX, and 50 GHz for MUX, and the optimal Butterworth filter bandwidths are 20 GHz for DMUX and 50GHz for MUX. With these bandwidths, a significant BER improvement is observed in comparison with very large and very small bandwidths.

This result from the trade-off between low optical bandwidths causing too high inter symbol interference and high bandwidths leading to unacceptable crosstalk. Due to the very large level of crosstalk in a DWDM system with narrow channel spacing, the narrower signal spectrum leads to wider MUX and DMUX optimal bandwidths. It is clear from Figure 3 that below 15 or after 40 GHz RZ/ CS-RZ DQPSK signals suffer from BER degradations due to adjacent signals, and that the CS-RZ DQPSK with the Butterworth filter presents the optimal performance compared to the other cases.



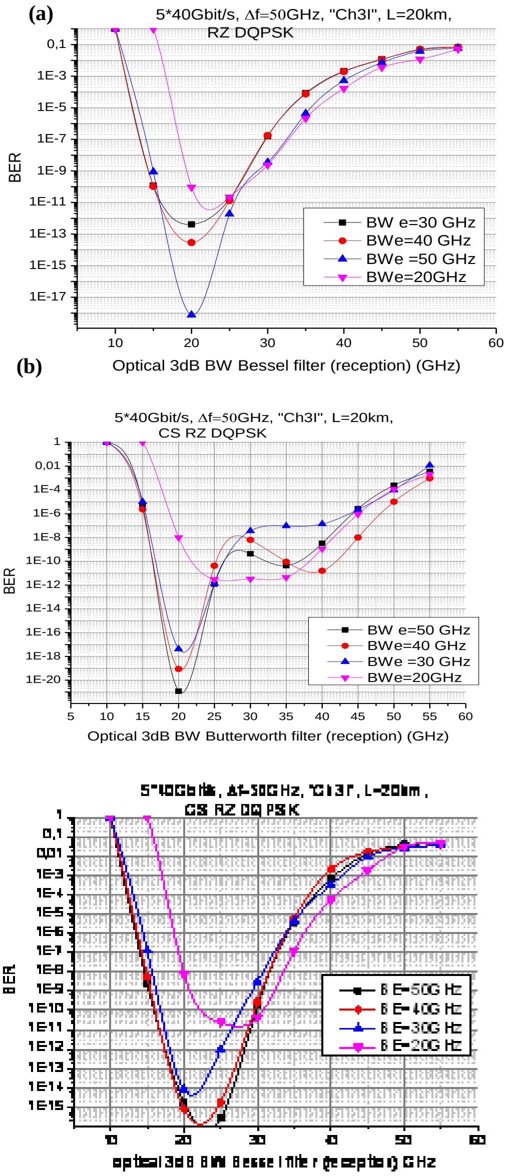


Figure 3. Numerical simulation of BER after 20km transmission with varying 3-dB optical filter bandwidth (ch#3) a) RZ DQPSK b)CS-RZ DQPSK

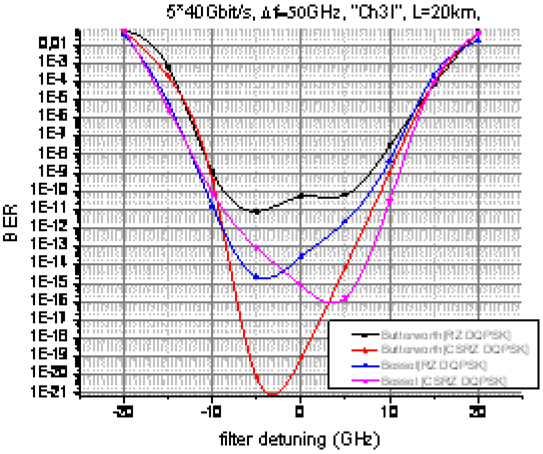


Figure 4. BER as a function of misalignment for Bessel and Butterworth optical filter.

The misalignment is defined as the difference between the center frequency of the signal frequency spectrum and the center frequency of the bandwidth of optical DMUX, which arises from manufacturing tolerances with specific limits. It also causes system performance impairment. In Figure 4, BER is calculated as a function of misalignment for Bessel and Butterworth optical DEMUX filter (3 dB Bandwidth = 20 GHz). Figure 4 shows a better system performance when the CS-RZDQPSK is used, this modulation format has broader spectrum bandwidth, and misalignment will have minor impacts on its system performance. It is also interesting to note that when the filter misalignment becomes larger than 10GHz, it indicates significant system penalties. The simulation results show that when the center frequency of all filters aligns with the laser's frequency, the Butterworth has the smallest influence to the signal.

IV. Conclusion

Optical filters are crucial elements in optical communications. The influence of filters in the optical signal will affect the communications quality seriously. In this paper we have studied and simulated the optical signal impairment caused by two kinds of filters which include Butterworth and Bessel. Optical signal impairment is analyzed from an Bit Error Rate (BER). The simulation results show that the CS-RZDQPSK modulation format shows the best performance compared to the RZ DQPSK. In the situation of frequency misalignment, the impairment caused by filters is more serious. Our research shows that with a frequency deviation of 10 GHz, with Butterworth optical filters the BER down half. This indicates that the optimum choice depends on the application and this study provides a set of relevant system design guidelines.

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