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Analysis of crosstalk in mixed 40 Gb/s and 100 Gb/s DWDM system with alien wavelength

KRZYSZTOF PERLICKI[1, 2*], WOJCIECH OKRASA[2]

[1]Institute of Telecommunications, Warsaw University of Technology, Nowowiejska 15/19, 00-665 Warsaw, Poland

[2]Orange Labs, Research and Development Centre Branch, Telekomunikacja Polska, Obrzezna 7, 02-691 Warsaw, Poland

[*]Corresponding author: perlicki@tele.pw.edu.pl

The modern dense wavelength division multiplexing (DWDM) management system has no a priori knowledge of alien wavelength parameters. The result of this is unforeseeable impact of alien wavelength parameters on friendly wavelengths quality. The numerical results of the impact of alien wavelength on optical transmission quality are presented, and experimental demonstration based on Alcatel–Lucent 1830 Photonic Service Switch PSS 32 transmission system is shown. The obtained results indicate that alien wavelength bandwidth must be restricted.

Keywords: optical communications, dense wavelength division multiplexing (DWDM), optical crosstalk, alien wavelength.

1. Introduction

The optical dense wavelength division multiplexing (DWDM) transmission systems have been evolving from closed systems to open systems, where the optical layer is designed in a way that allows new transmitters and receivers to be connected to it without requiring changes to the physical layer, not to the planning and management tools that are needed to operate it. This trend is reflected in solutions for alien wavelength [1, 2]. The traditional DWDM system contains transponders which convert the signals suitable for coloured (DWDM) light paths. The alien wavelength solutions are based on the coloured interface which resides in the client equipment (*e.g.*, IP router) [3]. This potentially saves transmission system costs, increases provisioning speed and allows greater transparency. However, the DWDM management system has no a priori knowledge of alien wavelength signal parameters (wavelength, bandwidth) [3]. The result of this is unforeseeable impact of alien wavelength parameters on friendly wave-lengths quality. The wavelengths which are managed by the DWDM system are called friendly wavelengths [4]. The ability of DWDM networks to carry alien wavelengths has been demonstrated in context of 40 Gb/s alien wavelengths over DWDM networks that were designed for 10 Gb/s signals [5]. Today, we have to focus on 40 Gb/s or 100 Gb/s alien wavelengths over DWDM systems that were designed for 40 Gb/s signals. Additionally, we have to call attention to new and advanced formats for 40 Gb/s and 100 Gb/s optical signals.

In this paper we analyze the crosstalk penalties on a 40 Gb/s reference channel created by 100 Gb/s adjacent channels in numerical simulations as well as laboratory experiment. We present a numerical simulation of the impact of alien wavelength bandwidth on DWDM channels crosstalk. The simulation and experimental setups are focused on optical transmission systems with 100 Gb/s alien wavelength and 40 Gb/s, 100 Gb/s friendly wavelengths.

2. Numerical simulations and results

The simulation setup is shown in Fig. 1. The presented DWDM system consists of four channels. The friendly wavelengths (Tx1, Tx2, Tx4) are combined into an optical fiber by means of a multiplexer. In contrast, alien wavelength (Tx3) is added to the DWDM system via an optical splitter. The DWDM multiplexer and demultiplexer consist of optical Gaussian filters. The alien wavelength optical filter is also the Gaussian filter. The Gaussian filter of second order is considered. Considering 3 dB bandwidth of multiplexer and demultiplexer filters are varied in the region between 30 and 70 GHz for investigated modulation format and bit rates. We choose the ITU-T channel spacing 50 GHz and the following optical channels: λ_1 = 1543.73 nm (194.20 THz), λ_2 = 1544.13 nm (194.15 THz), λ_3 = 1544.53 nm (194.10 THz), λ_4 = 1544.92 (194.05 THz) [6]. Here, only the optical crosstalk between alien wavelength and friendly wavelengths is taken into account. The other effects (optical losses, chromatic dispersion, polarization dispersion or nonlinear effects) are neglected. The optical crosstalk (*i.e.*, difference between proper signal and crosstalk signals) is calculated at the demultiplexer port no. 2. The non-return to zero binary phase shift keying (NRZ BPSK) modulation format at 40 Gb/s and non-return to zero

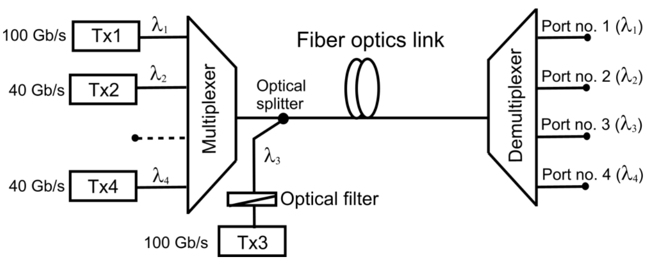

Fig. 1. Diagram of simulated DWDM system with alien wavelength; Tx1, Tx2, Tx4 – friendly wavelength transmitters, Tx3 – alien wavelength transmitter, λ_1, λ_2, λ_3 – friendly wavelengths; λ_4 – alien wavelength.

quadrature phase shift keying (NRZ QPSK) at 100 Gb/s channels are chosen for our investigation. Numerical simulations are realized with VPItransmissionMaker 8.6 (VPIsystems Inc.).

Tables 1–5 show the crosstalk values for 3 dB bandwidth of multiplexer (3 dB MUX) and demultiplexer (3 dB DMUX) filters equal to 30–70 GHz. The alien wave-

T a b l e 1. The crosstalk values for alien wavelength bandwidth 30 GHz, (bold – proper value).

		3dB DMUX				
		30 GHz	40 GHz	50 GHz	60 GHz	70 GHz
3 dB MUX	30 GHz	**–58.5**	**–32.0**	–18.3	–11.5	–7.4
	40 GHz	**–39.8**	**–26.2**	–16.1	–10.2	–6.6
	50 GHz	**–28.7**	**–21.3**	–14.4	–9.4	–6.2
	60 GHz	**–23.3**	–18.3	–13.1	–8.9	–5.9
	70 GHz	**–20.6**	–16.6	–12.3	–8.5	–5.7

T a b l e 2. The crosstalk values for alien wavelength bandwidth 40 GHz, (bold – proper value).

		3dB DMUX				
		30 GHz	40 GHz	50 GHz	60 GHz	70 GHz
3 dB MUX	30 GHz	**–39.7**	**–26.0**	–15.9	–10.1	–6.5
	40 GHz	**–36.8**	**–23.7**	–14.5	–9.2	–5.9
	50 GHz	**–28.3**	**–20.4**	–13.3	–8.6	–5.5
	60 GHz	**–23.2**	–17.8	–12.3	–8.1	–5.3
	70 GHz	**–20.6**	–16.2	–11.6	–7.8	–5.1

T a b l e 3. The crosstalk values for alien wavelength bandwidth 50 GHz, (bold – proper value).

		3dB DMUX				
		30 GHz	40 GHz	50 GHz	60 GHz	70 GHz
3 dB MUX	30 GHz	**–28.5**	**–21.1**	–14.1	–9.2	–5.9
	40 GHz	**–28.3**	**–20.3**	–13.2	–8.5	–5.4
	50 GHz	**–25.7**	–18.5	–12.3	–7.9	–5.1
	60 GHz	**–22.2**	–16.7	–11.5	–7.5	–4.9
	70 GHz	**–20.0**	–15.4	–10.9	–7.3	–4.7

T a b l e 4. The crosstalk values for alien wavelength bandwidth 60 GHz, (bold – proper value).

		3dB DMUX				
		30 GHz	40 GHz	50 GHz	60 GHz	70 GHz
3 dB MUX	30 GHz	**–23.2**	–18.1	–12.9	–8.6	–5.6
	40 GHz	**–23.2**	–17.7	–12.2	–8.0	–5.1
	50 GHz	**–22.2**	–16.6	–11.5	–7.5	–4.8
	60 GHz	**–20.3**	–15.4	–10.8	–7.2	–4.6
	70 GHz	–18.8	–14.4	–10.3	–6.9	–4.5

T a b l e 5. The crosstalk values for alien wavelength bandwidth 70 GHz, (bold – proper value).

		3dB DMUX				
		30 GHz	40 GHz	50 GHz	60 GHz	70 GHz
3 dB MUX	30 GHz	**–20.4**	–16.3	–12.0	–8.2	–5.3
	40 GHz	**–20.5**	–16.1	–11.5	–7.6	–4.9
	50 GHz	**–20.0**	–15.4	–10.9	–7.2	–4.6
	60 GHz	–18.7	–14.4	–10.3	–6.9	–4.4
	70 GHz	–17.6	–13.6	–9.9	–6.6	–4.3

T a b l e 6. The crosstalk values for alien wavelength without optical filter.

		3dB DMUX				
		30 GHz	40 GHz	50 GHz	60 GHz	70 GHz
3 dB MUX	30 GHz	–14.8	–12.4	–9.8	–6.9	–4.6
	40 GHz	–14.9	–12.4	–9.5	–6.6	–4.3
	50 GHz	–14.8	–12.1	–9.1	–6.2	–4.0
	60 GHz	–14.4	–11.6	–8.7	–6.0	–3.9
	70 GHz	–13.9	–11.2	–8.4	–5.8	–3.7

length 3 dB bandwidth is 30, 40, 50, 60, and 70 GHz, respectively. In turn, Table 6 shows the crosstalk values for alien wavelength without optical filter.

We assume that the proper transmission quality is achieved for crosstalk values equal to or less than –20 dB [7]. The results show that the narrow band filtering at alien wavelength optical filter, multiplexer and demultiplexer filter is required in order to achieve a proper crosstalk value. Through the narrow band filtering a better separation of alien and friendly wavelengths can be realized and a overlap between adjacent DWDM channels is reduced. Table 6 shows the impact of alien wavelength without filtering on the crosstalk. The result of this are large crosstalk values (greater than –20 dB). These crosstalk values are inappropriate for telecommunication applications.

3. Experimental setup and results

Figure 2 shows a schematic diagram of the experiment.

The Alcatel–Lucent 1830 Photonic Service Switch PSS 32 transmission system consists of four transponder cards: 43SCX4 (40 G/s NRZ BPSK) and 112SCX10 (100 Gb/s NRZ QPSK). The transponders include the optical filters; the 3 dB bandwidth of this optical filters is 30 GHz. The channel spacing is 50 GHz, the optical channel wavelengths are: λ_1 = 1543.73 nm (194.20 THz), λ_2 = 1544.13 nm (194.15 THz), λ_3 = 1544.53 nm (194.10 THz), λ_4 = 1544.92 nm (194.05 THz). The wavelength λ_3 is alien wavelength. The combiner is used to combine all four DWDM channels into a standard single mode optical fiber. The fiber optics link range is 180 km. The optical

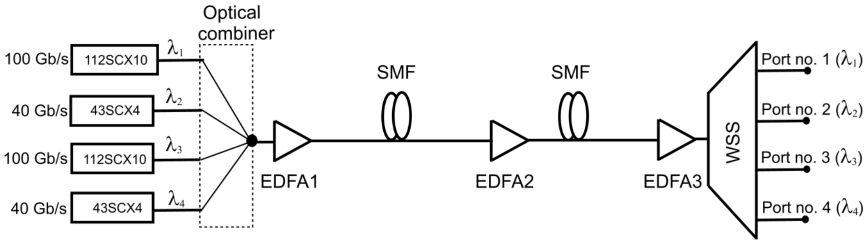

Fig. 2. Diagram of the experiment setup: 43SCX4, 112SCX10 – transponders; SMF – standard single mode fiber; EDFA1, EDFA2,EDFA3 – optical amplifiers; WSS – wavelength selective switch; λ_1, λ_2, λ_4 – friendly wavelengths; λ_3 – alien wavelength.

amplifiers EDFA2 and EDFA3 are added to compensate for transmission losses. At the receiver end, the DWDM channels are separated by WSS (wavelength selective switch); information about WSS filter parameters is not available in technical specification for Alcatel–Lucent 1830 Photonic Service Switch PSS 32 system. The optical crosstalk is measured at WSS port no. 2.

We achieved the crosstalk value equal to –33.2 dB. This result is similar to the theoretical result for multiplexer, demultiplexer and alien wavelength bandwidth equal to 30, 40 and 30 GHz, respectively.

4. Conclusions

The obtained results indicate that unfiltered (or improperly filtered) 100 Gb/s alien wavelength induce large crosstalk. The alien wavelength bandwidth must be restricted by an optical filter. The narrow band filtering at multiplexer, demultiplexer and alien wavelength filter is essential and required in order to achieve a proper crosstalk value for mixed 40 Gb/s and 100 Gb/s DWDM systems.

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