SIMULTANEOUS TRANSMISSION OF AMPLIFIED OPTICAL SIGNALS OF SELECTED PHOTONIC SERVICES

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Abstract: This paper focuses on simultaneous transmission of selected photonic services by one single-mode optical fiber. The paper deals with the problem of simultaneous transmission of multiple photonic services by one optical fiber using the wavelength division multiplex technology and erbium-doped fiber amplifier (EDFA). Except common data transmission with a bitrate of 10 Gbps, a simultaneous high-speed data signal transmission with a bitrate of 200 Gbps and accurate time transmission are considered. During the simultaneous transmission of selected photonic services, the measurement of the transmission parameters was performed. In particular, the effect of possible mutual interference of individual transmission channels at 100 GHz spacing between individual signals was analyzed.

Keywords: accurate, data, dwdm, edfa, simultaneous, time

1 INTRODUCTION

Photonic services are a set of advanced optical network services that enable pure optical transmission without the need to convert optical to electrical signals. Photonic services are designed for the most demanding real-time communication applications. The most common real-time photonic services include accurate time and stable frequencies transmission [1].

Operation of these services is subject to the availability of dark fibers, unused optical fibres available for use in fibre-optic communication, and optical transmission networks beyond the capabilities normally available for transmission on, for example, the Internet. This can accommodate more demanding applications that have stricter requirements for accuracy. For some demanding applications, such as remote control of machines, medical operations or reproducible scientific experiments, it is necessary to achieve an extremely accurate and long-term stable transmission environment throughout the transmission path, as even small delay fluctuations can cause fatal consequences in these applications [2].

2 RELATED WORKS

Authors [3] performed simultaneous transmission of four photonic services with ITU DWDM 100 GHz grid spacing channels. Photonic services included 100G data signal, accurate time and stable frequency signal and sensing signal. Simultaneous transmission of all services was through two types of optical fibers, G.655 and G.653. FEC-BER and Q factor values were evaluated for the measurement results. The measurement results show that the G.653 fiber cause more interference of signal. Based on the results, 100 GHz channel spacing is not high enough and to eliminate possible interaction the higher spacing must be used.

However with utilizing frequency offset estimation before adaptive equalization enhances the performance capabilities of a digital coherent receiver in digital signal processing. This technique has a great importance for long-haul DP-QPSK DWDM system with 50 GHz channel spacing. The considered system performs with minimum bit error rate over a wide range of launch power [4].

Another simulations for WDM system show using pulse-overlapping super-Nyquist (Pol-SN) to improve spectral efficiency of coherent optical transmission. The results of simulations indicate that the channel spacing of 224 Gbps can be reduced up to 20 GHz [5].

3 MEASUREMENT SETUP

The effect of amplification of optical amplifier on simultaneous transmission of three selected photonic services was verified in further measurements. Photonic time transfer services and two data signals were selected for this measurement. 10 Gbps data signal generated by the EXFO FTB-1 measurement platform and 200 Gbps data signal generated by optical coherent transmission system Coriant Groove^{TM} G30. DWDM channels with 100 GHz spacing were assigned for each service, as shown in Table 1. Selected optical amplifier Keopsys KPS-BT-C-21-BO-FA is designed for wave multiplexes operating in the band 1530–1565 nm.

Table 1: Distribution of photonic services into DWDM channels with 100 GHz spacing

Channel	Frequency [THz]	Wavelength [nm]	Service
31	193.1	1552.52	Time signal
32	193.2	1551.72	Data 200 Gbps
33	193.3	1550.92	Data 10 Gbps

Figure 1 shows a detailed measurement diagram showing transmitted services and carrier wavelength settings for each.

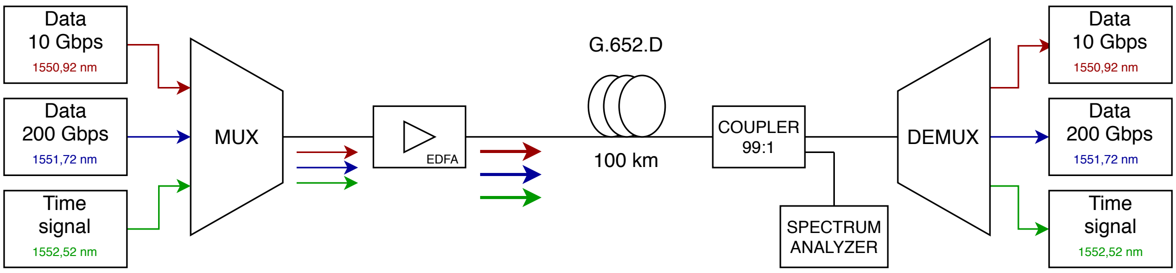

Figure 1: Scheme of simultaneous transmission amplified by EDFA

Optical signals for individual services were connected to neighboring DWDM channels. These signals were multiplexed together in a standard telecommunication multiplexer. The common optical signal was further amplified by an optical power amplifier, in the range of 10–15 dBm. The common optical signal was further coupled to an optical fiber of type G.652.D with a length of 100 km. A portion of the transmitted common optical signal was coupled at the end of the path using an optical power splitter with a 99:1 split ratio. The bound part of the transmitted common signal served as a source for the optical spectrum analyzer, by means of which individual optical signals were monitored for non-linear phenomena.

The common transmitted signal was further demultiplexed and the individual optical signals of the transmitted services were fed back to their source devices, where the transmission parameters of the received optical signals were evaluated.

4 MESUREMENT RESULTS

The main evaluated transmission parameter for data signals was bit error rate (BER), furthermore the parameters of chromatic dispersion, group delay, optical signal-to-noise ratio and Q-factor were monitored for data signal 200 Gbps. For the time signal, the time delay of the signal during optical fiber transmission was evaluated. The monitored transmission parameters and time delays depending on the amplification of the optical amplifier were evaluated by individual systems and recorded in the Table 2.

Table 2: Measured transmission parameters for amplified common signal

	Data 10 Gbps	**Data 200 Gbps**					**Time signal**
EDFA	**BER**	**DGD**	**CD**	**OSNR**	**Q**	**BER**	**Delay**
[dBm]	[Bit-ratio]	[ps]	[ps/nm]	[dB]	[dB]	[Bit-ratio]	[ns]
10	1.36E−09	2	1684	18.2	7.3	9.88E−03	495 986.118
11	7.06E−11	2	1686	18.7	7.3	9.69E−03	495 986.734
12	1.41E−12	2	1685	18.8	7.4	8.86E−03	495 987.628
13	3.49E−13	2	1687	19.1	7.5	8.34E−03	495 988.699
14	3.31E−13	2	1687	19.5	7.6	7.92E−03	495 989.771
15	<1.00E−14	3	1687	20.2	7.7	9.52E−03	495 992.371

The average bit error rate measured for the 10 Gbps data signal showed a clear proportion to the gradual amplification of the common signal by the optical amplifier. The lowest bit error rate was achieved by the 15 dBm optical amplifier data signal, when the bit error rate reached the minimum limit value of 1.00E–14, which the FTB-1 measuring platform can still detect.

Relatively the same bit error values were measured for the 200 Gbps data signal. Average measured values of bit error rate differed only very slightly in mantissa value, depending on amplification by optical amplifier, they were of the same order of magnitude. Similarly, the group delay (DGD) and chromatic dispersion (CD) values did not differ significantly depending on the amplification of the common signal. The dependence on common signal amplification was reflected in the average measured values of the optical signal-to-noise ratio (OSNR) and the Q-factor, which are closely related. From the measured average values we can see the improvement of these transmission parameters depending on the amplification of the common signal.

Accurate delay time values and deviations of successive delay values were monitored during time signal transmission. As the Table 2 shows, the deviation from the mean value was always in nanoseconds. The average delay value, for all gain values, was approximately the theoretical assumption for the optical signal propagation time over a given path. The increasing trend in the time delay values is caused by the gradual heating of the fiber; at a higher temperature of the optical fiber, the propagation time of the optical signal through the optical fiber is prolonged.

Figure 2 shows the spectrum of simultaneous transmission of time and data optical signals, indicating the corresponding DWDM channels for the three different gain values of the optical power amplifier. The optical spectral analyzer graph shows the amplification of individual optical signals after passing through an optical power amplifier.

5 RESULTS

From the measured transmission parameters and especially from the graph of the optical spectral analyzer it can be deduced that the simultaneous transmission of time and data optical signals did not affect the transmission channels, which would significantly affect the stability of some of the transmitted photonic services. By gradually amplifying the power of the optical amplifier, some

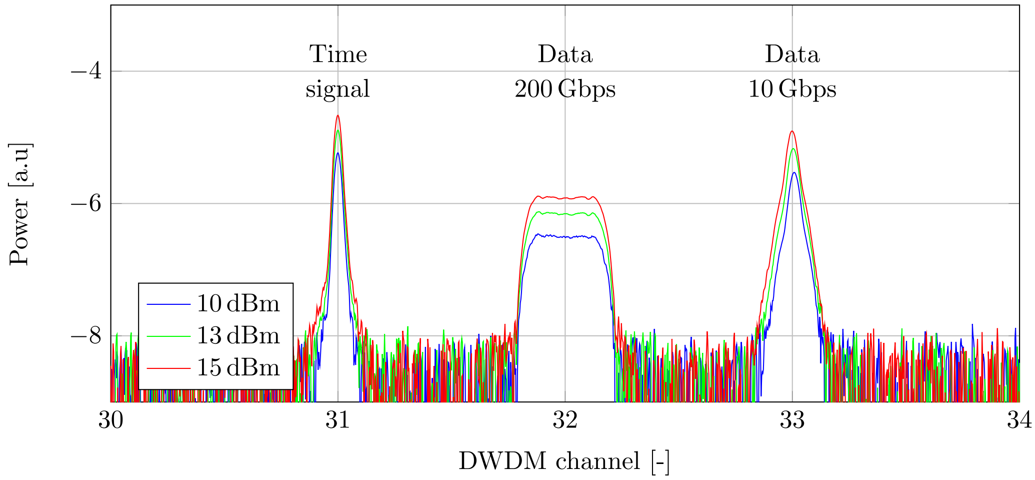

Figure 2: Spectrum of amplified common signal of selected services

transmission parameters for data signals were improved. In particular, it was the bit error rate for the 10 Gbps data signal and the optical-to-noise ratio and the Q-factor for the 200 Gbps data signal.

6 CONCLUSION

From the results of the measurements it can be deduced that, for DWDM transmission channels 100 GHz, there was no significant interaction between individual transmitted photonic services by one optical fiber, which would disrupt the successful transmission of these services.

Based on the measurements made, the selected bandwidth of 100 GHz for selected photonic services is sufficient for successful simultaneous transmission over one optical fiber. There were no non-linear phenomena interfering with the successful simultaneous transmission of photonic services.

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