The Optical Modulation Format Impact on Polarization Mode Dispersion

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Summary
This article describes the impact of polarization mode dispersion on optical fibre link. There is analysed PMD effect of bit error rate on optical channel, on modulating signal and on close of eye diagram. All article calculates only with losses that are caused of polarization mode dispersion. It is not calculated with losses that are caused of chromatic dispersion and attenuation.

Key words:
OPTICAL FIBRE, DESIGN, APLICATION, PMD, POLARIZATION MODE DISPERSION, MODULATION, EYE DIAGRAM.

1. Introduction

Polarization mode dispersion (PMD) is effect which is limiting factor for data transmission in optical fibre. For bit rate B = 2,5 Gb/s is this effect insignificant. For bit rate B = 10 Gb/s, 40 Gb/s or 1 Tb/s the polarization mode dispersion is the main problem of high-speed optical fibre transmissions.

2. Analyse

Polarization mode dispersion is caused of polarization of light. Individual parts of light are diffused with different speed in two parts. These parts are called PSP (Principal States of Polarization). As a consequence of external and internal effects individual parts of lights are diffused with different speeds in the direction of slow (s) or fast axis (f), or in horizontal and vertical level. Polarization modes have between those time delay $\Delta\tau$ (DGD - Differential Group Delay) at the end of the trace and therefore occurs dispersion of modes and limitation of its maximum bit rate. See figure 1.

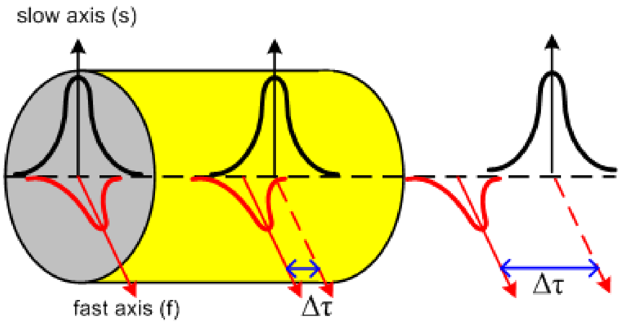

Figure 1 – Polarization mode dispersion and DGD

Polarization mode dispersion, precisely DGD, has big impact on pulse enlargement, which is different according to currently used modulation format. Basic modulation format for optical communication systems is ASK (Amplitude Shift Keying), known also as modulation OOK (On-Off- Keying). Next modulation format is DBPSK (Differential Binary Phase Shift Keying) or DQPSK (Differential Quadrature Phase Shift Keying).

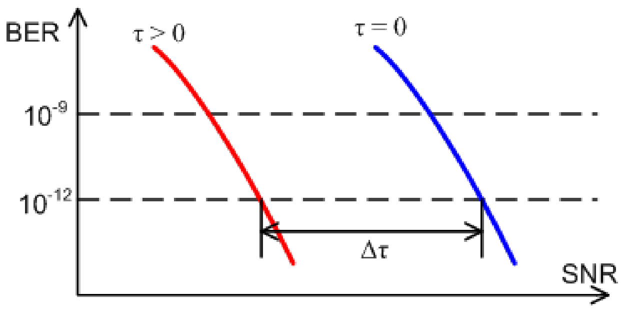

Figure 2 – Dependence BER on SNR

All these kinds of modulation may be NRZ (Non Return to Zero) – without return to zero - or RZ (Return to Zero) – with return to zero.

Manuscript received May 5, 2008
Manuscript revised May 20, 2008

Eye diagram is used to evaluate the impact of polarization mode dispersion on bit error rate on optical fibre link. Eye diagram is connected with bit error rate (BER) and signal-to-noise ratio (SNR) [4]. See figure 2 – dependence BER on SNR.

Bit error rate depends on bit rate and is different for every modulation format. BER is the more decreasing, SNR is the more increasing and the transmission over optical fibre link is better. If DGD is decreasing, then SNR will be lower, eye diagram is closing and receiver is not able to analyse signal correctly. Closing of eye diagram means fall of eye in horizontal and vertical direction. The value of the fall of eye diagram, we call Power Penalty (ε) [2]. See figure 3.

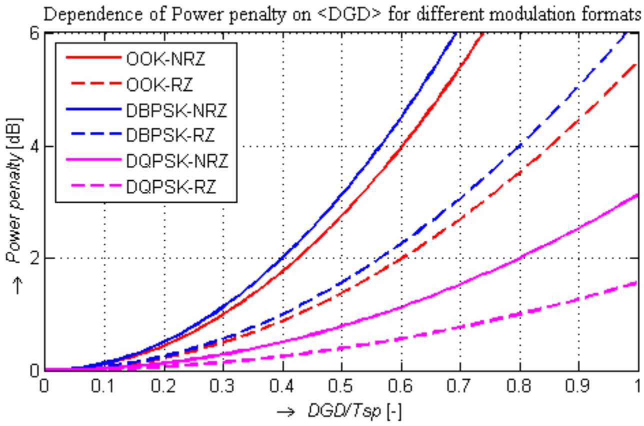

Figure 3 – Dependence of Power penalty on <DGD> for different modulation formats

3. Simulation and Results

For simulation we have chosen bit rate B = 40Gb/s (STM - 256) with BER = 10^{-12}. In all calculations it is counted only with losses that are caused of polarization mode dispersion. It is not calculated with losses that makes chromatic dispersion and attenuation. According to the specification ITU the value is of maximum differential group delay with bit rate B = 40Gb/s is DGD = 2,5ps [7]. Every value, which will exceed maximum of differential group delay from the specification ITU, makes transmission impossible and eye diagram is closing. On purpose, we choose long length optical fibre L = 1000 km, because we want high values of differential group delay. We use optical fiber G.652d, because it has low value of polarization mode dispersion D_{PMD} = 0,2 ps/$\sqrt{\text{km}}$ [11]. We can use fibre G.655b too, but it has higher value of polarization mode dispersion. On figure 4, we can see eye diagrams of all kinds of modulation formats with using optical fibre G.652d.

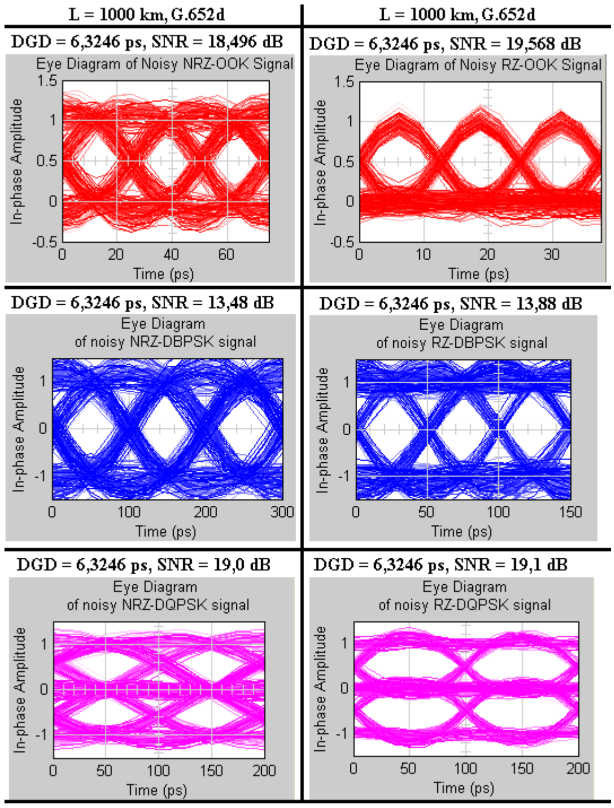

Figure 4 – Eye diagrams of kinds modulation formats with using optical fibre G.652d.

As we can see on figure 4, that modulation format RZ has better toleration to polarization mode dispersion than format NRZ. The best modulation format from the formats NRZ-OOK, RZ-OOK, NRZ-DBPSK, RZ-DBPSK, NRZ-DQPSK and RZ-DQPSK is the RZ-DQPSK format. Generally the modulation format DQPSK has double toleration to polarization mode dispersion than DBPSK, because it has four signal bits.

4. Conclusion

The best modulations which have high toleration to polarization mode dispersion are RZ-DQPSK and NRZ-DQPSK. The biggest advantage is that we can use them for long distances. The main disadvantage of these modulations is its high price and complexity of realization. The worst modulations that have low toleration to polarization mode dispersion are NRZ-DBPSK and NRZ-OOK. Their benefits are low price and low complexity of realization, but the biggest disadvantage of this solution is that we can use them only for short distances. Compromise between distance, price and complexity of realization are the RZ-DBPSK and RZ-OOK modulations. See figure 5.

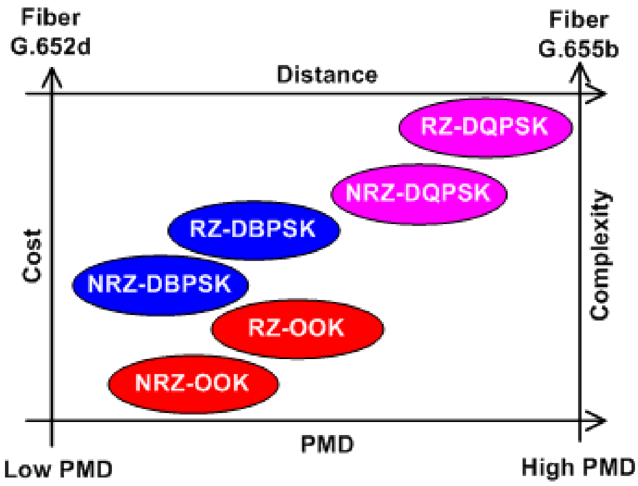

Figure 5 – Summary of all kinds modulation

References

[1] Galtarossa A., Menyuk C.R.: Polarization Mode Dispersion, Springer, Padova, ISBN 0-387-23193-5

[2] Saleh, B. E. A., Teich, M. C.: Základy fotoniky II, Matfyzpress, Praha, 1994, ISBN 80-85863-01-4

[3] Fischer, S., Randel, K., Petermann, J.K. PMD outage probabilities of optical fiber transmission systems employing bit-to-bit alternate polarization, IEEE Photonics Technology Letters, Volume: 17, Issue: 8, pp. 1647-1649, August 2005.

[4] Martin Hájek: Zkušenosti s měřením polarizační vidové disperze (PMD) jednovidových optických kabelových tras, OPTICKÉ KOMUNIKACE, Praha 2002

[5] Damask J. N.: Polarization Optics in Telecommunications, Springer, New York 2004 ISBN 0-387-22493-9

[6] KYSELÁK, M. The Optimalization of the High-Speed Optical Networks, Wave and Quantum Aspects of Contemporary Optics, XV Czech-Polish-Slovak Optical Conference. Technical University Liberec, Czech Republic, 2006. s. 75 (1 s.). ISBN: 80-86742-13-X.

[7] KYSELÁK, M. Způsoby řešení polarizační vidové disperze u stávajících optických tras, Optické komunikace 2006. Praha: Agentura Action M, 2006. s. 85-174. ISBN: 80-86742-16-4.

[8] KYSELÁK, M. FILKA, M. KOVÁŘ, P. Novell Approach to the Solution of Optical Fibre Dispersion Effects, Telecommunications and Signal Processing TSP - 2006. Brno, 2006. s. 25-28. ISBN: 80-214-3226-8.

[9] ITU-T Recommendation G.652: Characteristics of a single-mode optical fibre cable. ITU-T, April1997

[10] ITU-T Recommendation G.653: Characteristics of a dispersion-shifted single-mode optical fibre cable. ITU-T, April1997

[11] ITU-T Recommendation G.655: Characteristics of a nan-zero dispersion shifted single-mode optical fibre cable. ITU-T J October 1996

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