Effect of Guard Band on the Performance of AP-DCDM Technique in 40 Gb/s Optical Fiber Communication system

A. Malekmohammadi, *Member, IEEE,* M.K. Abdullah, *Member, IEEE,* A. F. Abas, *Member, IEEE*

G. A. Mahdiraji

***Abstract*— The effect of guard band (GB) on the performance of 40 Gb/s Absolute Polar Duty Cycle Division Multiplexing (AP-DCDM) is investigated and reported. It is demonstrated that the spectral width occupied by 40 Gb/s AP-DCDM with GB is 100 GHz (with minimum spectral efficiency of 0.4 b/s/Hz) whereas, this value can be reduced to around 80 GHz for AP-DCDM without GB (with minimum spectral efficiency of 0.5 b/s/Hz). In addition to better spectral efficiency, this amount of saving in the spectral width leads to ~ 60 ps/nm improvement in chromatic dispersion tolerance.**

***Index Terms*—Optical Communication, Multiplexing, Guard Band, Absolute Polar Duty Cycle Division Multiplexing**

I. Introduction

Fueled by the seemingly inexhaustible human appetite for more bandwidth per user and, by the new requirements that are far less predictable than they have been before, the bandwidth utilization moved ever forward. Ever increasing demand for up-to-date information in today's world opens for new challenges to the telecommunication researchers to search for new technique that is able to support high utilization of optical fiber network capacity [1]. Increasing the bandwidth utilization can be realized by using advanced modulation formats [2-4] or more wavelength division multiplexing (WDM) channels [5]. Increasing the bit rate of Time division Multiplexing [6] or Absolute Polar Duty Cycle Division Multiplexing (AP-DCDM) [7-9] are another alternatives.

In general, ideal modulation format for long-haul, high speed WDM transmission links is the one with compact spectrum and good dispersion tolerance [10].

Absolute Polar Duty Cycle Division Multiplexing (AP-DCDM) was introduced in [7-9] as an effective multiplexing technique, which allows for increasing the spectral efficiency of WDM system. It was highlighted that the superior performance made this system to be an excellent candidate to be used in long-haul transmission systems.

The narrow optical spectrum on AP-DCDM reduces the inter-channel coherent crosstalk. The possibility of setting channel spacing as narrow as 62.5 GHz for 40 Gbit/s AP-DCDM signal was confirmed [9]. As reported in [9] a capacity of 1.28 Tbit/s (32 x 40 Gbit/s) was packed into a 15.5 nm EDFA gain-band with 0.64 bit/s/Hz spectral efficiency by using 10 Gbit/s transmitter and receiver.

In this paper, for the first time to the best of our knowledge, we report a model and numerical study on the influence of guard band on an AP-DCDM performance. In this study, commercial softwares namely OptiSystem and MATLAB were used to access the system performance. The performance evaluation of the system is based on Bit Error Rate (BER), which is described in [11].

II. Setup

Fig.1 shows the simulation setup. In AP-DCDM with GB, 4 channels, each at 10 Gb/s with PRBS 2^{10}-1 are carved with four electrical RZ pulse carver at 1/5, 2/5, 3/5 and 4/5 duty cycle, respectively (consider one slot for guard band). In AP-DCDM without GB, 4 channels, each at 10 Gb/s with PRBS 2^{10}-1 are carved with four electrical RZ pulse carver at 1/4, 2/4, 3/4 and 4/4 duty cycle, respectively.

The voltages for all users at the multiplexer input are identical. All users' data are multiplexed via a AP-DCDM multiplexer resulting in a multilevel signal. The signals are modulated onto a laser diode (LD) signal which operates at 1550 nm wavelength using a Mach-Zehnder Modulator (MZM). The eye diagrams of the modulator output for AP-DCDM with and without GB are shown in Fig. 2. At the receiver side, the optical signal is detected by a photodiode and passed through a low-pass filter (LPF) and clock-and-data-recovery (CDR) unit. The Gaussian low-pass filter is used for eliminating the photodiode noises. In the CDR unit, the received signal is fed into the sampling circuit. Outputs of the sampling circuit are fed into the decision and regeneration unit and the decision is performed based on the regeneration rules as described in [11].

Manuscript received Feb 28, 2010.

A.Malekmohammadi is with the Electrical and Electronic Engineering Department, The University of Nottingham, Malaysia Campus (phone: +60-17 6568014; e-mail: aminmalek_m@ieee.org).

M. K. Abdullah is the Director and Chief Technology Officer at Significant Technologies.

A. F. Abas is with the Computer and Communication Systems Department, University Putra Malaysia.

G.A.Mahdiraji is with USCI university, Malaysia

978-1-4244-7187-4/10/$26.00 ©2010 IEEE

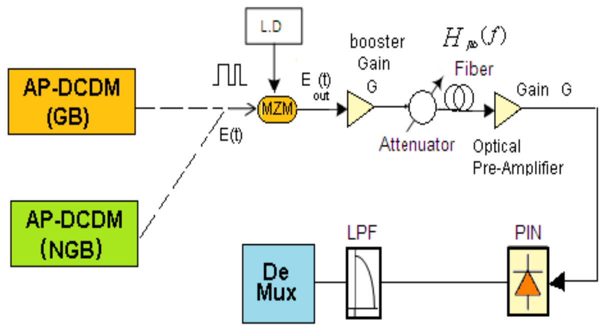

Fig. 1. Simulation Setup

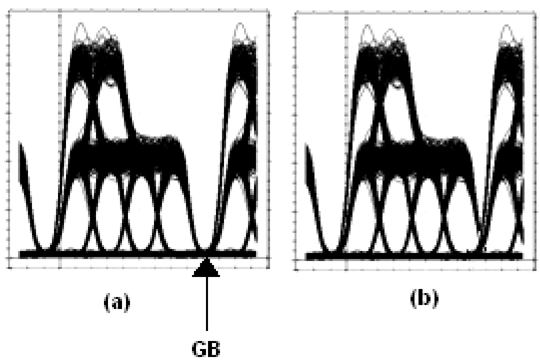

Fig. 2. Generated eye diagram (a) AP-DCDM with GB (b) AP-DCDM without GB

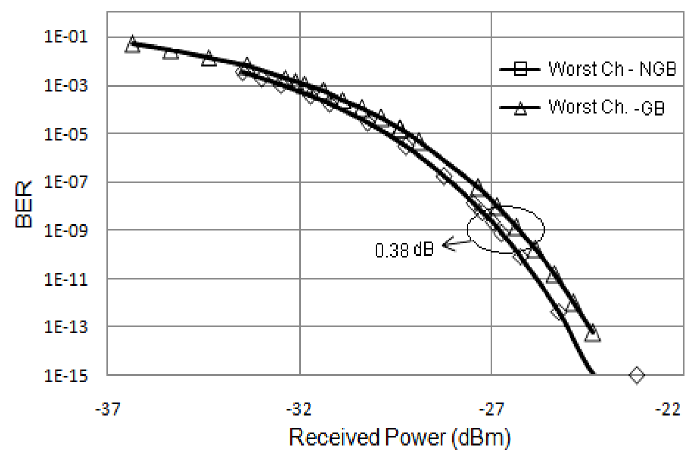

Fig. 3. Receiver sensitivity comparison between AP-DCDM with and without GB

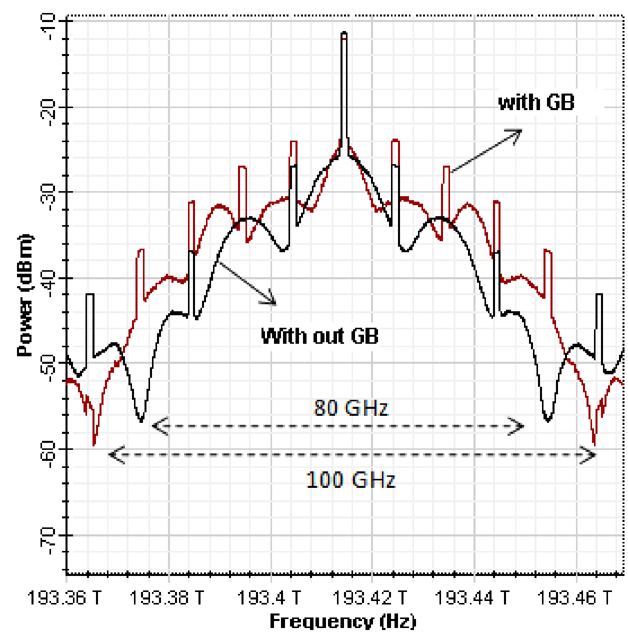

Fig. 4. Spectral width comparison between AP-DCDM with GB and without GB

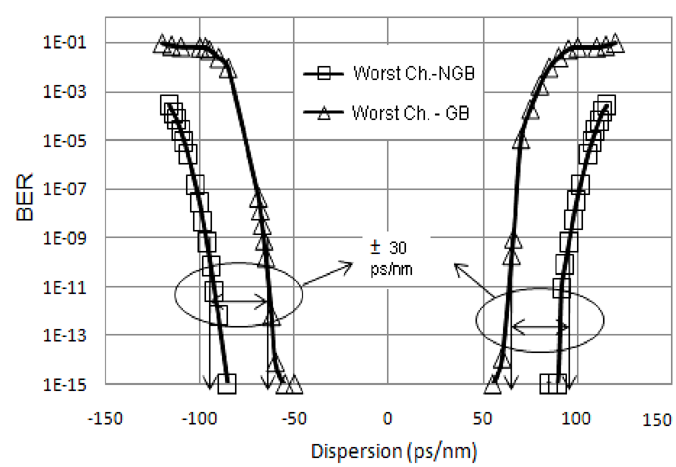

Fig. 5. Chromatic Dispersion tolerance comparison between AP-DCDM with GB and without GB

III. Result and Discussion

Figure 3 shows the receiver sensitivity comparison between AP-DCDM with GB and without GB (4 x 10 Gb/s). As illustrated in Fig. 3 with reference to AP-DCDM with GB, the system power requirement in AP-DCDM without GB can be relaxed up to ~ 0.38 dB for the worst channel, due to 5 % increment of worst channel duty cycle in AP-DCDM without GB. The difference between best channels is around ~0.08 dB which is negligibly small (not shown in the graph).

Comparing the spectral width at the same aggregate bit rate of 40 Gb/s between AP-DCDM with and without GB, the later technique shows 20% spectral width reduction. As shown in Fig. 4, the spectral width of 40 Gb/s AP-DCDM with GB is 100 GHz (with minimum spectral efficiency of 0.4 b/s/Hz), whereas, this value is reduced to 80 GHz (with minimum spectral efficiency of 0.5 b/s/Hz) for 40 Gb/s AP-DCDM without GB. In addition to better spectral efficiency as illustrated in Fig. 5, this amount of saving in the spectral width leads to ~ 60 ps/nm improvement in chromatic dispersion tolerance (Fig. 5). Note that the tolerance difference between best channels is less than 1 ps/nm which is negligibly small (not shown in the graph).

IV. CONCLUSION

The influence of guard band (GB) on performance of 40 Gb/s Absolute Polar Duty Cycle Division multiplexing (AP-DCDM) is investigated and reported. Comparing the spectral width at the same aggregate bit rate of 40 Gb/s between AP-DCDM with and without GB, the later technique shows 20% spectral width reduction. This amount of saving in the spectral width leads to ~ 60 ps/nm improvement in chromatic dispersion tolerance.

REFERENCES

[1] P. J. Winzer, G. Raybon, and M. Duelk, "107-Gb/s optical ETDM transmitter for 100G Ethernet transport," presented at the Eur. Conf. Optical Commun. (ECOC), Glasgow, U.K., 2005, Paper Th4.1.1

[2] P. Winzer, R. Essiambre, "Advance modulation formats for high-capacity optical transport networks", *J. Lightw. Technol.* , vol. 24, pp. 4711-4728, 2006

[3] N. Kikuchi, K. Sekine, and S. Sasaki, "Multilevel signaling for high-speed optical transmission", presented at the Eur. Conf. Optical Commun. (ECOC) Cannes, France, 2006, Paper Tu3.2.1.

[4] S. Walklin and J. Conradi, Multilevel signaling for increasing the reach of 10 Gb/s lightwave systems, *J. Lightw. Technol*. Vol.17, pp. 2235-2248, 1999

[5] J. M. Kahn and K.-P. Ho, "Spectral efficiency limits and modulation/ detection techniques for DWDMsystems," *IEEE J. Sel. Topics Quantum Electron.*, vol. 10, no. 2, pp. 259–272, Mar./Apr. 2004

[6] H. Miyamoto, M. Yoneyama, T. Otsuji, K. Yonenaga, and N. Shimizu, "40 Gbit/s TDM transmission technologies based on ultra high-speed IC", *IEEE J. Solid-State Circuits*, vol. 34, pp.1246-1253, 1999

[7] A. Malekmohammadi, M. K. Abdullah, A. F. Abas, G. A. Mahdiraji, M. Mokhtar, "Analysis of RZ-OOK over Absolute Polar Duty Cycle Division Multiplexing in Dispersive Transmission Medium**",** *IET Optoelectron.* Vol. 3, no.4, pp. 197-206, 2009

[8] A. Malekmohammadi, A. F. Abas M. K. Abdullah, , G. A. Mahdiraji, M. Mokhtar "Realization of High Capacity Transmission in Fiber Optic Communication Systems Using Absolute Polar Duty Cycle Division Multiplexing (AP-DCDM) Technique" *Opt. Fiber Technol.*, vol .15, no.4, pp.337-343

[9] Amin Malekmohammadi, A. F. Abas, M. K. Abdullah, G. A. Mahdiraji, M. Mokhtar, M. Fadlee.A. Rasid, "Absolute Polar Duty Cycle Division Multiplexing Technique over Wave Length Division Multiplexing system", *Optics Communications*, vol 282, PP. 4233-4241 (2009).

[10] N. Yoshikane and I. Morita, "Performance comparison of 85.4 Gb/s pre-filtered DQPSK signals with and without RZ pulse carving", presented at the Eur. Conf. Optical Commun. (ECOC) 2004, paper We3.4.6.

[11] A. Malekmohammadi, M. K. Abdullah, G. A. Mahdiraji, A. F. Abas, M. Mokhtar, M. F.A.Rasid, "Decision Circuit and Bit Error Rate Estimation for Absolute Polar Duty Cycle Division Multiplexing", *International Review of Electrical Engineering*, vol. 3 pp.592-59*9,* 2008

A. Malekmohammadi, (PhD), *MIEEE , IEEE-LEOS and MOSA*, received his Bsc. In Computer Engineering, Tehran, iran and his M.Sc. in Electronic Engineering from Indian Institute of Science (IISc.), Bangalore, India in 2006 and PhD degree in Computer System Engineering (Optical Fiber Communications) at University Putra Malaysia, 2009. Currently he is working at the Department of Electrical and Electronic Engineering, University of Nottingham as an assistant professor. He has authored and coauthored 30 technical papers which include journals articles and conference proceedings. He has filed 4 patents for his inventions and scientific works. Email: aminmalek_m@ieee.org

Mohamad Khazani Abdullah (PhD) obtained his B.Sc. and M.Sc. degrees in Electrical Engineering from University of Missouri at Rolla, USA, in 1990 and 1993, respectively, and a Ph.D. degree in Physics from University Malaya, in 1999. He has filed 11 patents for his inventions and scientific works. His latest research focus is on a novel multiplexing technique known as Duty Cycle Division Multiplexing (DCDM). Professor Abdullah, a member of IEEE LEOS-Malaysian Chapter, was the Deputy Dean of Graduate School Office, and Head of the Photonics and Fiber Optic Systems Laboratory, Universiti Putra Malaysia (UPM) until April 2008.
Now he is the Director and Chief Technology Officer at Significant Technologies, a company specializing on fiber optic products and services

Ahmad Fauzi Abas, ***Dr.-Ing***.*, MIEEE,* received his Doctor of Engineering (Dr.-Ing.) degree from University of Paderborn, Germany, in the field of Optical Fiber Communications. Currently he is working at the Department of Computer and Communication Systems Engineering, University Putra Malaysia as a lecturer. He has authored and coauthored around 100 technical papers which include journals articles, conference proceedings, book chapters and consultancy reports.