

Original Research Paper

Analysis of Jitter Impact on High Speed Transmissions of Wavelength-Division Multiplexing Networks

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Abstract: In this study, we conduct a thorough assessment of the effect of jitter occurrence in high speed 10 Gbps and 200 GHz Wavelength-Division Multiplexing (WDM) optical network. First, we present a simulation model to study the effect of jitter presence in the proposed network and then determine the maximum amount of jitter which the network can withstand. The model is then employed to predict the types of jitter received at the end of the transmission line. For the input power level of 0 dBm and Bit Error Rate (BER) of $1E^{-09}$, the observed total jitter, J_T , random jitter, J_R and deterministic jitter, J_D is 0.2676 UI, 0.1602 UI and 0.1073 UI, respectively.

Keywords: Jitter, WDM Networks, Noise

Introduction

Timing Jitter is one of serious issues in the voice and data transmission which directly contributes to signal degradation in high speed data communications systems. At transfer rates exceed 1 Gbps, digital signal appears to resemble the nature of analog signals. Jitter can be defined as the deviation of received bits as compared to a reference clock, thus leads to bit errors in signal transmission. It is known that, jitter appears to be one of important limitations to the performance of data transmission especially in optical Wavelength Division Multiplexing (WDM) system. Measurement of timing jitter or phase distortion is important to determine the sources, hence further precautions can be taken to reduce the jitter generation.

The overall jitter, J_T is composed of both deterministic, J_D and Gaussian (random), J_R content. J_R is generally generated from laser source's random noise that produces thermal noise and shot noise (Hancock, 2004), while J_D is not intrinsic or random. J_D has a specific cause and often periodic and narrowband. For instance, deterministic noise may be caused by imperfection of the transmitter circuit, poor circuit termination, etc. Ultimately, J_D is correlated to Inter-Symbol Interference (ISI), duty cycle distortion and bandwidth limitation (Corrigan, 2000).

The presence of jitter can be measured intuitively by eye diagram analyzer. Eye diagram displays a composite view of each transition points over the Unit Interval (UI). Deploying eye diagram analyzer, the relative magnitudes of J_D and J_R can be revealed through immediate visual of jitter characteristic profile. Various mathematical estimation and simulation approaches can be used to predict the performance of a network system with jitter existence. Our work applied the OptiSystem software from Optiwave to study the behavior of jitter in the high speed optical transmission link especially for Wavelength Division Multiplexing (WDM) network.

Jitter Tolerance Evaluations

Figure 1 displays the proposed network setup to test jitter tolerance along the optical transmission line. The transmitter section consists of a Pseudo Random Bit Sequence (PRBS) generator, a Non Return Zero (NRZ) pulse generator, a Continuous Wave (CW) laser, Mach-Zehnder Modulator (MZM) and a coupler. PRBS generator is used as the data source that provides the basis for the formation of binary pattern. Bit sequences are fed into a PRBS generator using the NRZ modulation format and Mach-Zehnder is used as a modulator which transforms the electrical signals to optical signals.

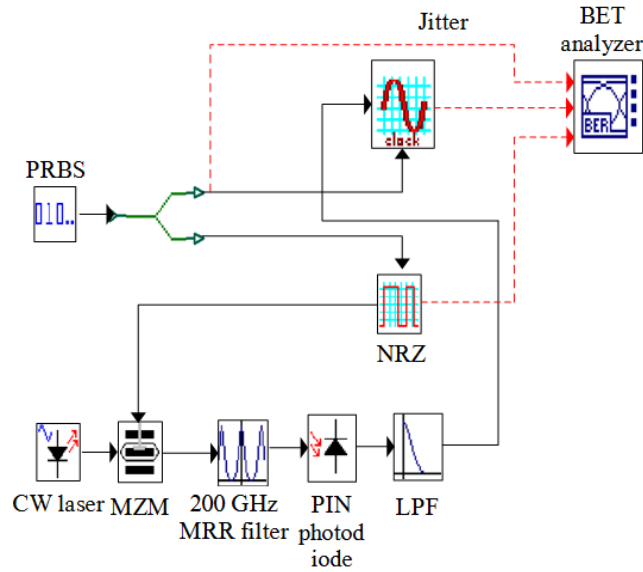


Fig. 1. Simulation setup for the WDM network with jitter generator

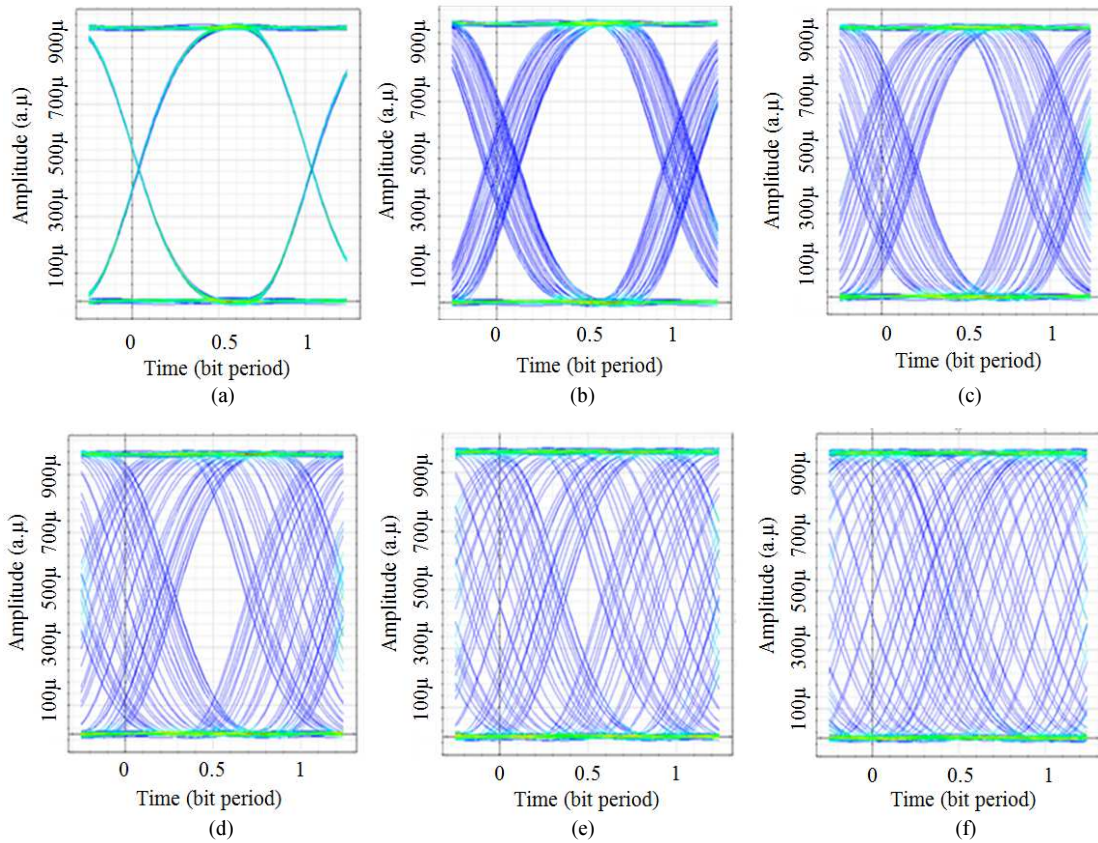


Fig. 2. Eye diagram in the presence of jitter of (a) 0 UI (b) 0.2 UI (c) 0.4 UI (d) 0.6 UI (e) 0.8 UI and (f) 1 UI

Table 1. Simulation parametric values for MRR filter

Parameter (Unit)	Value
λ_1 (nm)	1546.00
IL (dB)	0.13
BW (nm)	0.90
Q-Factor	1711.00

The CW laser launched an optical power of 0dBm with a data rate of 10 Gbps, at 1546 nm wavelength. At the receiver side, the incoming signal was fed to the 200 GHz optical filter with Microring Resonator (MRR) filtering structure. The PIN photo diode serves as the

optical signal detector and converts it into the electrical signals, while Bessel type Low Pass Filter (LPF) was used to filter the electrical signals and the signal is then fed to jitter generator. The noise generated at the receivers is set to be random and uncorrelated and the performance of the network with the presence of jitter was evaluated by referring to the Bit Error Rate (BER).

The test is performed to test the resilience of the system, particularly with the use of MRR devices as optical filters. The simulation values of the MRR filter was summarized as in Table 1, obtained from previous research works (Mulyanti *et al.*, 2014; Haroon *et al.*, 2012; 2013).

Figure 2 portrays the results of the eye diagram observed with the existence of various jitter values. Horizontal axis eye opening was narrowed with the increase of jitter in the system. The phenomenon restricted the transmission of the data samples and further contributes to bit error. The presence of jitter in optical communication systems will cause noise margin to decrease and as the result, the systems are more vulnerable to transmission errors.

From Fig. 2, it can be clearly seen that, as the jitter presence closes the data eye, the BER is increasing. With the existence of 1 UI jitter as shown in Fig. 2(f), the eye opening was completely closed. Through this research, the maximum jitter tolerance that the network can withstand as for the BER $<1 \times 10^{-9}$ is 0.639 UI. A research conducted by Intel discovered that the jitter tolerance for 10 Gbps digital system with the specifications recommended by the ITU-T G.825 is 0.5 UI, in which any optical transmission systems operated

under this specific value, will function properly without any high impact degradation (Christensen, 2000). Therefore, it can be concluded that the point-to-point optical network as shown in Fig. 1 is working under the permitted jitter tolerance.

Jitter Measurement and Discussion

Details research on the network performance with the presence of jitter has been performed with the network architecture as shown in Fig. 3. The realized WDM direct scheme has eight channels and consists of three parts: A transmitter, an optical fiber and a receiver. Eight channels with 200 GHz channel distributions were combined into a single transmission line by a multiplexer where each signal carry a data rate of 10 Gbps and complied the ITU-T G.692 frequency grid recommendations (Iyer, 2011).

The fiber optic was set to ITU-T G.652 standard includes the attenuation, group delay, group velocity dispersion and effective index of refraction. Other parameters considered as per the practical scenario of WDM system were listed in Table 2.

Through the eye diagram analysis, the three types of jitter as explained before were calculated and plotted as in Fig. 4. It can be clearly seen that the resulted jitter was correlated with the BER value. It can be concluded that, as the BER value getting better, the amount of jitter will be decreased. It is interesting to note that the observed value of J_R remains almost unchanged despite the variation of BER.

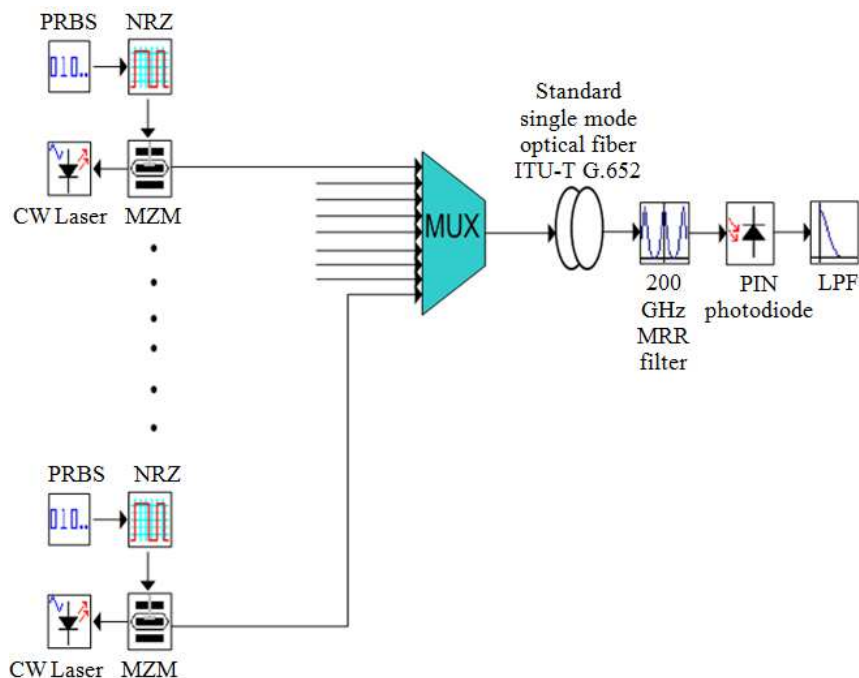


Fig. 3. Simulation setup for the 8 channel WDM network for jitter test

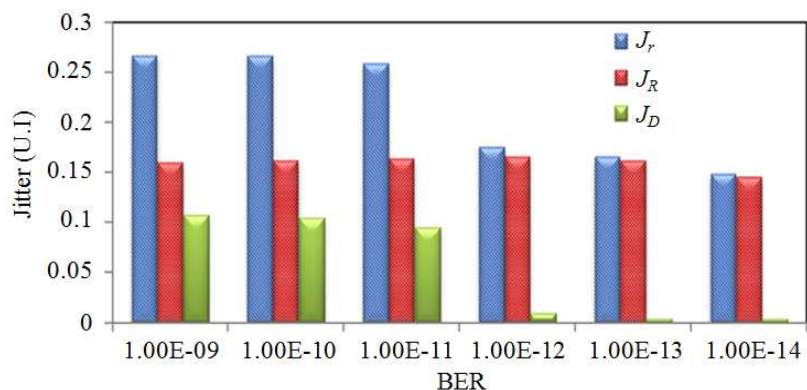


Fig. 4. The overall jitter, J_T , deterministic jitter, J_D and random jitter, J_R for 8-channel WDM system with various BER

Table 2. Network setting parameters

Parameter (Unit)	Value
Receiver Noise Temperature (K)	300.000
Fiber Optic Attenuation Coefficient (dB/km)	0.300
Dispersion 9ps/nm/km	16.750
Dispersion slope coefficient (ps ² /km)	0.075
PIN photodetector responsivity (A/W)	1.000

In WDM optical transmission system, the J_R occurrence is due by a laser source which produces thermal noise and shot noise, whereas J_D resulted from the white noise produced by the components in optical communication systems (Yang and Lee, 2004). Since the presence of J_R was due to random noise and has no specific boundaries, it is complicated to determine the contributing factors, nevertheless the J_D was predictable and the source that lead to the jitter presence can be determined and eliminated to improve the overall system performance. J_D can either be reduced with a good network composition layout, perfect line termination or reduce the line crosstalk (Zarr, 2012).

Conclusion

We have successfully investigate the impact of jitter in high speed 10 Gbps and 200 GHz Wavelength-Division Multiplexing (WDM) optical network using commercially available software. In particular, we have focused on an 8 channel WDM network consists of a transmitter, an optical fiber and a receiver. The observed total jitter, J_T , random jitter, J_R and deterministic jitter, J_D is 0.2676 UI, 0.1602 UI and 0.1073 UI, respectively.

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Author's Contributions

Hazura Haroon: Participated in experiments, data acquisition, data analysis and drafting the manuscript.

Hanim Abdul Razak: Participated in data acquisition, data analysis and contributed to the writing of the manuscript.

Sahbudin Shaari: Designed the research plan and organized the study, helping in interpretations of data, coordinated the data-analysis and reviewing the manuscripts.

P. Susthitha Menon: Assisted in designed the research plan and organized the study, interpretations of data, contributed to the writing of the manuscript and reviewing the manuscripts.

Ethics

All authors approved the final manuscript. This manuscript has not been published elsewhere.

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