CHAPTER 4

Crosstalk in Distributed Raman Amplifier for OOK and DPSK Modulation Format

4.1. INTRODUCTION

Optical communication systems can support Tb/s capacities over long distances making them an ideal technology for high capacity wireline networks. With the growing bandwidth demand of modern information systems such as internet, mobile voice and data services, multimedia broadcast systems, there is a tremendous interest in increasing the transport capacity and transmission distance of WDM system (Keiser, 2010). Expanding network functionality into the optical domain is another aim of fiber-optic communication research. Implementation of network functionality in optical domain leads to tremendous reduction in the cost of end to end transmitted bit. Optical networks with high spectral efficiency are being designed to have higher per fiber transport capabilities as well as low cost per transmitted bits. Modulation format such as intensity and phase modulation formats is a key technology that enables the design of such networks. On-off keying (OOK), carrier suppressed return to zero (CSRZ), Modified duo-binary (MDB), Alternate mark inversion (AMI) are some examples of intensity modulation format. Similarly, Differential Phase shift keying (DPSK), Quadrature phase shift keying (QPSK) and differential quadrature phase shift keying (DQPSK) are some examples of phase modulation formats (Gnauck and Winzer, 2005). These modulation formats helps to trade off noise resilience, fiber propagation characteristics and resilience to narrowband optical filtering. In this chapter, analytical expressions derived in chapter 3 for crosstalk due to nonlinear effects have been implemented for two modulation formats - one intensity modulation format i.e. OOK and other phase
modulation format i.e. DPSK. The reason for choosing the two formats stem from the fact that in literature a number of research work is available that deals with the performance of the two formats (Gnauck and Winzer, 2005; Xang, 2009; Essiambre and Winzer, 2006). In OOK the information is encoded in the amplitude of the signal i.e. a 1-bit is encoded by presence of amplitude and 0-bit is encoded by absence of amplitude.

![Fig.4.1 NRZ-OOK, NRZ-DPSK, RZ-OOK and RZ-DPSK (Winzer and Essiambre, 2006)](image1)

![Fig.4.2 Signal constellation of OOK and DPSK (Gnauck and Winzer, 2005)](image2)
In phase modulated format, the information is carried in the phase of the signal. In DPSK, information is encoded on a binary phase change between adjacent bits: a 1-bit is encoded onto a π phase change, whereas a 0-bit is represented by the absence of a phase change. A data modulation format gets the qualifier return to zero (RZ) when optical intensity of the signal returns to zero within each bit slot. In contrast, non return to zero (NRZ) formats permit constant optical intensity over several consecutive bits. Both OOK, DPSK can be implemented in RZ and NRZ format. Fig. 1 shows examples for RZ and NRZ versions of OOK and DPSK, respectively (Winzer and Essiambre, 2006). The main advantage of DPSK over OOK is the 3-dB receiver sensitivity improvement (Gnauck and Winzer, 2005; Winzer and Essiambre, 2006). This can be understood from Fig. 2 which shows that the symbol spacing for DPSK is increased by factor of $\sqrt{2}$ compared to OOK for fixed average optical power. This increased symbol distance makes DPSK accept a $\sqrt{2}$ larger standard deviation of the optical field noise than OOK for equal BER, which translates into a 3-dB reduction in OSNR.

Coherent detection system has gained considerable attention over past few years because of improved receiver sensitivity and increased spectral efficiency of wavelength division multiplexed (WDM) system compared to Intensity Modulation Direct Detection (IM/DD) systems (Agrawal, 2002). The advantage of coherent detection techniques is that the amplitude and phase of the detected optical signal can be measured and hence information can be transmitted in the form of amplitude, phase or frequency of optical signal. When OOK and DPSK modulation formats are implemented for coherent systems, it is required that phase of the electrical field associated with optical signals remains constant as the detector response depends on the phase of the received signal. When large number of signals simultaneously propagates in wavelength division multiplexed (WDM) system, due to high power confinement, nonlinear effect comes into play. Stimulated Raman Scattering (SRS), Cross-Phase modulation (XPM) and Self-Phase modulation (SPM) are some examples of nonlinear effects (Reis and Teixeira, 2010; Toulouse, 2005; Wu and Way, 2004; Chiang et. al., 1996; Cartaxo 1998; Cartaxo 1999) that affects the system performance. The amplitude of the signal gets affected due to SRS and phase of the signal gets affected due to XPM.
and SPM which we denote as crosstalk and hence the detector response changes in coherent detection system.

There has been considerable research work on study of nonlinear effects and its effect on signal degradation (Ho, 1999; Yadin et. al., 2004; Ho and Wang, 2004 and Chung and Peleg, 2008) and interplay between them (Nguyen and Peleg, 2010; Luis and Cartaxo, 2005). XPM effect in WDM system for OOK and DPSK modulation format has been studied theoretically (Essiambre and Winzer, 2006), experimentally (Luis et. al., 2008) and numerically (Jansen et. al. 2007). Due to random temporal waveform alignments of WDM channels, large variations of XPM degradation have been predicted for OOK and DPSK signals (Luis et. al., 2008; Essiambre and Winzer, 2006). Raman crosstalk dynamics in OOK soliton WDM systems demonstrated the combined effect of delayed Raman response and bit pattern randomness on pulse propagation in optical fiber communication systems (Peleg 2007; Peleg 2004; Chung and Peleg, 2005; Chung and Peleg, 2008). The propagation was described by a perturbed stochastic nonlinear Schrödinger equation and extensive numerical simulations were performed with the model to analyze the dynamics of the frequency moments, the bit-error rate, and the mutual distribution of amplitude and position. In another study DPSK modulation was considered and stability of WDM DPSK transmission against Raman crosstalk effects under the influence of deterministic effects of inter-pulse Raman crosstalk in amplified WDM optical fiber transmission systems (Nguyen and Peleg, 2010) was quantitatively explained. The above studies along with other reported literatures (Lu et. al., 2004; Wang and Kahn, 2004; Xang 2009; Hayee and Willner, 1999; Xu et. al., 2004; Gnauck and Winzer, 2005; Ho and Wang et. al., 2006; Ho, 2004; Ho, 2005) show the applicability of OOK and DPSK in optical communication. In the present chapter, our motivation is to study the performance of OOK and DPSK modulation format for distributed Raman amplified WDM system.

In this chapter using statistical methods a comprehensive study of SRS, XPM and SPM induced crosstalk or nonlinear phase shifts has been done for WDM system employing DRA for DPSK and OOK signal in NRZ- and RZ- modulation format.
4.2. VARIANCE OF CROSSTALK FOR OOK AND DPSK SIGNAL

In this section, crosstalk variance is derived in a distributed Raman amplifier for bi-directional pumping scheme for OOK and DPSK and signal. A single span of DRA of length L with no repeater is considered. Thus power change and phase change of the $i^{th}$ channel due to $j^{th}$ channel transmission through distance $z$ is given as (Ho, 2004)

\[
x_{ij}(z,t) = K \int_0^L P_j(0,t - d_{ij}z') e^{-\alpha z'} g_F(z') g_B(z') dz'
\]

\[
\varphi_{ij}(z,t) = 2\gamma \int_0^L P_j(0,t - d_{ij}z') e^{-\alpha z'} g_F(z') g_B(z') dz'
\]

where $P_j(z,t)$ is the power of $j^{th}$ channel as a function of length $z$ and time $t$. $P_j(0,t)$ is the launched power at the transmitter, $\alpha$ is the fiber attenuation co-efficient, $\gamma$ is the nonlinear co-efficient, $d_{ij} (= 1/v_j - 1/v_i)$ is propagation time difference between the two different channels $(i, j)$ during a unit length transmission. In Eq. (4.1) and (4.2) it has been assumed that fiber dispersion causes just pulse walk-off and no pulse distortion (Christodouides and Jnader, 1996; Po Ho 2000). Assuming triangular approximation of Raman gain profile (Yamamoto and Norimatsu, 2003), $K$ is given as

\[
K = \frac{g_R}{\psi A_{\text{eff}}} \left( f_i - f_j \right) \quad \left| |f_i - f_j| \leq 15 \text{ THz} \right.
\]

\[
= 0 \quad \left| |f_i - f_j| > 15 \text{ THz} \right.
\]

where $g_R$ is the average slope of the triangular profile (Yamamoto and Norimatsu, 2003), the frequency of $i^{th}$ ($j^{th}$) channel is $f_i$ ($f_j$), polarization constant $\psi$ is equal to 2 and $A_{\text{eff}}$ is effective area of cross-section. The parameter $K$ takes a positive (negative) value if $f_i$ is greater (less) than $f_j$ which implies that optical power $P_i$ is depleted (amplified) by the $i^{th}$ channel. If $f_i = f_j$ then $K$ becomes zero, and there is no power exchange between the channels.

In DRA, forward amplification gain (Kao and Wu, 1989) is

\[
g_F(z') = \exp \left( \frac{\gamma_p \left( \lambda_s A_{\text{eff}} \right) (P_{op} + P_{po})}{A_{\text{eff}} \alpha} \right) \left( 1 - e^{-\alpha z'} \right)
\]

where peak Raman gain $\gamma_p = 6.5 \times 10^{-14}$ m/W, $P_{po}$ and $P_{so}$ are the initial pump and signal power respectively, $\lambda_s$ ($\lambda_p$) is Signal (Pump) Wavelength.
Backward amplification gain (Kao and Wu, 1989) is

\[ g_B(z') = \exp \left( \gamma_p \left( \frac{\gamma_A \alpha P_{so} + P_{PL}}{A_{eff}} \right) (e^{\alpha(z'-L)} - 1) \right) \]  

(4.4)

where \( P_{PL} \) is initial backward pump power, \( L \) is the length of DRA and other parameters are same as (4.3).

For analysis a number of assumptions have been made:

a) The attenuation constant of pump and signal wavelength is same and equal to 0.2 dB/km. Variation in attenuation constant with wavelength has been neglected.

b) Noise power evolution and interpulse collision has been neglected.

c) Ideal pumping configuration has been assumed with no interaction between the pumps.

Power spectral density of \( x_{ij} (\varphi_{ij}) \) is found by taking the Fourier transform of auto-correlation function and is given as

\[ S_{x_{ij}}(\omega) (S_{\varphi_{ij}}(\omega)) = S_{P_{ij}}(\omega) |H_{ij}(\omega)|^2 \]  

(4.5)

Where

\[ S_{x_{ij}}(\omega) (S_{\varphi_{ij}}(\omega)) = \text{Power spectral density of } x_{ij}(t) (\varphi_{ij}(t)) \]

\[ S_{P_{ij}}(\omega) = \text{Power spectral density of } P_j(0, t) \text{ which depends on pulse shape } p(t). \]

A rectangular NRZ pulse is given as \( p(t) = \begin{cases} 2P_0 & (|t| < \frac{T}{2}) \\ 0 & (|t| > \frac{T}{2}) \end{cases} \)

where \( T \) is the bit period.

Fourier transform of \( p(t) \) is given as \( |P(\omega)| = 2P_0 \frac{\sin \frac{\omega T}{2}}{\frac{T}{2}} \)

Similar representation for RZ pulse of duty cycle \( \tau_b \) is obtained by replacing \( T \) with \( \frac{T}{\tau_b} \) in the expression for \( |P(\omega)| \), where \( \tau_b \) assumes value 2 and 3 for 50% and 33.3% duty cycle respectively. Hence power spectral density

\[ S_{P_{ij}}(\omega) = \frac{\sigma_b^2}{2\pi} |P(\omega)|^2 + \frac{2\pi m^2}{T^2} \sum_{k=-\infty}^{\infty} \left| P \left( \frac{2k\pi}{T} \right) \right|^2 \delta(\omega - \frac{2k\pi}{T}) \]  

(4.6)

Where \( \sigma_b^2 = E\{b_k^2\} - (E\{b_k\})^2 = \frac{1}{4} \) \( [E\{b_k\}] \) is the expected mean of \( b_k(0,1) = 1/2] \)
\( T_b = 2T \) for DPSK signal as one symbol duration \((T_b)\) is equal to two bit durations \((2T)\) in DPSK modulation format

\( T_b = T \) for OOK signal as one symbol duration \((T_b)\) is equal to one bit durations \((T)\) in OOK modulation format.

The second term of \( S_{P_{ij}}(\omega) \) is equal to zero for rectangular pulse shape at \( k = 1, 2, 3 \)… and very small for non-rectangular pulse shapes. Hence it is neglected in the present analysis.

The variance of crosstalk is given as

\[
\sigma_X^2 = \frac{1}{2\pi} \int_{-\infty}^{\infty} S_{\xi_{ij}}(\omega)(S_{\phi_{ij}}(\omega)) \, d\omega \quad (4.7)
\]

The variance of SRS induced crosstalk for DPSK and OOK signal and XPM induced crosstalk for OOK signal is calculated by performing the infinite integral given in Eq. (4.4). This integration is quite similar to the one performed in Chapter 2 and can be easily derived by following similar method. Only appropriate change in value of \( T_b \) has to be made for DPSK and OOK signals. At OOK receiver, the nonlinear phase shift \( \phi_{ij}(L,t) \) adds to the phase of the signal. The difference arises in the variance of XPM induced crosstalk in DPSK signal. At the DPSK (Ho, 2004) receiver, the differential nonlinear phase shift \( \Delta \phi_{ij}(L,t) = \phi_{ij}(L,t) - \phi_{ij}(L,t-T) \) adds to the differential phase of the signal. Here \( T \) is the bit period. Hence power spectral density of \( \Delta \phi_{ij}(L,t) \) is

\[
S_{\Delta \phi_{ij}}(\omega) = 4S_{P_{ij}}(\omega) |H_{ij}(\omega)|^2 \sin^2(\omega T/2) \quad (4.8)
\]

The variance of XPM induced crosstalk is given as the infinite integral of \( S_{\Delta \phi_{ij}}(\omega) \).

After performing the integration using similar steps as in chapter 3, the variance of XPM crosstalk for DPSK is

\[
\sigma_{XPM}^2 = \left( F(T) + F_1(T) + F_2(T) + F_3(T) + F_4(T) + F_5(T) \right) - \frac{1}{4}(F(2T) + F_1(2T) + F_2(2T) + F_3(2T) + F_4(2T) + F_5(2T)) \quad (4.9)
\]

where

\[
F(T) = \frac{c^2P_0^2}{\alpha^3L_w} \left\{ (1 - e^{-\alpha L})^2 P_1(\alpha) + e^{-\alpha L} P_2(\alpha) \right\} \quad (4.10)
\]

\[
F_1(T) = \frac{c^2k^2P_0^2}{8\alpha^3L_w} \left\{ (1 - e^{-2\alpha L})^2 P_1(2\alpha) + e^{-2\alpha L} P_2(2\alpha) \right\} \quad (4.11)
\]
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\[
F_2(T) = \frac{8C^2K^2P_0^2e^{-2\alpha L}}{3d_{ij}^2T} \min \left( \frac{T^2}{4}, \frac{d_{ij}L^2}{4} \right) \left\{ 3 \max \left( \frac{T}{2}, \frac{d_{ij}L}{2} \right) - \min \left( \frac{T}{2}, \frac{d_{ij}L}{2} \right) \right\} 
\]

(4.12)

\[
F_3(T) = \frac{-C^2K'P_0^2}{\alpha^3L_w} \left[ (1 + e^{-3\alpha L} - e^{-2\alpha L} - e^{-\alpha L}) \left( \frac{P_1(\alpha)}{3} + \frac{2P_2(2\alpha)}{3} \right) + \frac{1}{2} (e^{-\alpha L} + e^{-2\alpha L}) \right] 
\]

\[
+ \frac{C^2K'P_0^2}{24\alpha^3L_w} \left[ \frac{P_3(2\alpha)}{4} - P_3(\alpha) \right] 
\]

(4.13)

\[
F_4(T) = \frac{-C^2K''P_0^2}{\alpha^3L_w} \left[ (1 + e^{-\alpha L})P_2(\alpha) - (1 - e^{-\alpha L})P_3(\alpha) \right] 
\]

\[
+ \frac{C^2K''P_0^2}{2\alpha d_{ij}} \left[ (1 - e^{-\alpha L})P_4(T, d_{ij}L) \right] 
\]

(4.14)

\[
F_5(T) = \frac{-C^2K''P_0^2}{8\alpha^3L_w} \left[ (1 + e^{-2\alpha L})P_2(2\alpha) - (1 - e^{-2\alpha L})P_3(2\alpha) \right] 
\]

\[
+ \frac{C^2K''P_0^2}{2\alpha d_{ij}} \left[ (1 - e^{-2\alpha L})P_4(T, d_{ij}L) \right] 
\]

(4.15)

where

\[ C = K \quad \text{for SRS} \]

\[ = 2\gamma \quad \text{for XPM and SPM} \]

\[
P_1(\alpha) = (e^{-\alpha L_w} + \alpha L_w - 1) 
\]

(4.16)

\[
P_2(\alpha) = 2(e^{-\alpha L_w} + e^{-\alpha L} - 1) - (e^{-\alpha |L+L_w|} + e^{-\alpha |L-L_w|} + \alpha |L + L_w| - |L - L_w|) 
\]

(4.17)

\[
P_3(\alpha) = \left[ \text{sign}(d_{ij}L)(2 - 2e^{-\alpha L}) + \text{sign}(T - d_{ij}L)(1 - e^{-\alpha |L-L_w|}) - \text{sign}(T + d_{ij}L - e^{-\alpha L+L_w}) \right] 
\]

(4.18)

\[
P_4(T, d_{ij}L) = \text{sign}(d_{ij}L + 2T) \left( \frac{(d_{ij}L)^2}{8} + \frac{d_{ij}L+T}{2} + \frac{T^2}{2} \right) - \text{sign}(d_{ij}L) \frac{(d_{ij}L)^2}{4} 
\]

\[
+ \text{sign}(-d_{ij}L + 2T) \left( \frac{(d_{ij}L)^2}{8} + \frac{(d_{ij}L+T)^2}{2} - \frac{T^2}{2} \right) 
\]

(4.19)

\[
L_w = \frac{T}{|d_{ij}|} 
\]

(4.20)

The integration has been performed using 3.826.1, 3.824.1, 3.725.1 and 3.725.3 of (Gradshetyn and Ryzhik, 2000) and basic trigonometric and algebraic functions.

Study on Interchannel Crosstalk in WDM Optical Fiber Communication Link
In N-channel WDM system, each channel is modulated independently by random data. Thus, the variance can be approximated as

\[ \sigma^2_x(i) = \sum_{j=1}^{N} \sigma^2_x(i,j) \quad (i \neq j) \]  

(4.21)

4.3. RESULTS AND DISCUSSION

The optical signals generated by N transmitters at N wavelengths separated by \( \Delta \lambda \) interchannel separation are multiplexed onto a single optical fiber using a WDM multiplexer. The multiplexed signals then propagate over the fiber and are amplified by the WDM pumping scheme of DRA. The WDM channels are separated using a WDM demultiplexer, and detected by per-channel receiver. The generalized formulae are derived for WDM system employing bi-directional pumped DRA. The forward and backward pumping are considered to be special cases of bi-directional pumping by taking into account the launched pump power. For analysis purpose standard SMF fiber is used with following parameters: \( \gamma \) (Nonlinear Co-efficient) = 1.18 W\(^{-1}\) km\(^{-1}\), \( g'_R/A_{\text{eff}} \) (Slope of Raman gain curve) = 0.57 x 10\(^{-16}\) m\(^{-1}\) W\(^{-1}\) Hz\(^{-1}\), \( A_{\text{eff}} \) (Effective Area) = 80 \( \mu \)m\(^2\), Zero Dispersion Wavelength = 1265.5 nm, Dispersion Slope = 0.058 x 10\(^3\) ps /nm/nm/km, \( \alpha \) (attenuation co-efficient) = 0.2 dB/km, L (length) = 80 km. In the previous chapter we had investigated the effect of bit rate on SRS, XPM and SPM induced crosstalk. It was observed that with the increase in bit rate of the signals, crosstalk decreases and minimum crosstalk is observed for 40 Gbps signal. After selecting the best performing bit rate i.e. 40 Gbps, effect of variation in duty cycle of pulse was investigated.

Fig. 4.3, 4.4, 4.5 and 4.6 shows the variation of SRS, XPM and SPM crosstalk with signal wavelength for different duty cycle of the pulse for both OOK and DPSK signal at 40 Gbps data rate. The configuration of fiber link is as shown in Fig. 3.1. It can be seen from the figures that with the decrease in duty cycle of the pulse, crosstalk decreases for both OOK and DPSK signal. The reason for RZ-pulse suffering less crosstalk compared to NRZ-pulse is because in RZ-pulse, the ‘1’ bit occupy only a fraction of the time slot. Hence the probability of overlap of ‘1’ bit in neighbouring channels decreases. Another factor responsible for RZ-pulse suffering less crosstalk is walk off length \( L = (T/\tau_b) / (D\Delta \lambda) \) where T is the time period, \( \tau_b \) is the duty cycle, D is
the dispersion co-efficient and $\Delta \lambda$ is the wavelength separation between the channels. The interference between intensity occurs mainly in the walk-off length, so the larger the walk-off length greater the intensity interference. As RZ- pulse has small walk off length compared to NRZ- pulse, the crosstalk suffered by RZ- pulse is less. It can be concluded that crosstalk suffered by a pulse varies inversely with duty cycle ($\tau_b$) of the pulse. Hence RZ pulse with small duty cycle suffers minimum crosstalk. On comparing figures it is found that all the pulse shapes suffer decrease in crosstalk from OOK to DPSK modulation format. The reason for the DPSK signal suffering less XPM and SPM induced crosstalk stems from the fact that in the DPSK signal only differential phase of the signal is affected. On the contrary in OOK signal the total phase of the signal gets affected due to XPM induced phase shift. Thus detector response gets more affected in case of OOK signal compared to DPSK signal. The reason for the DPSK modulation format suffering less SRS crosstalk stems from the fact that in DPSK signal one symbol duration ($T_b$) is equal to two bit duration (2T), while in OOK signal one symbol duration ($T_b$) is equal to one bit duration (T). Hence RZ- DPSK signal with 33.3% duty-cycle suffers minimum crosstalk compared to NRZ- DPSK signal, NRZ-OOK signal, RZ-DPSK and RZ-OOK signal with 50% duty cycle.

![Graph](image)

**Fig. 4.3:** Variation of SRS Crosstalk (dB) with signal wavelength (nm) for NRZ-OOK, RZ-OOK (50% duty cycle) and RZ-OOK (33% duty cycle).
Fig. 4.4: Variation of SRS Crosstalk (dB) with signal wavelength (nm) for NRZ-DPSK, RZ-DPSK (50% duty cycle) and RZ-DPSK (33% duty cycle).

Fig. 4.5: Variation of XPM and SPM Crosstalk (dB) with signal wavelength (nm) for NRZ-OOK, RZ-OOK (50% duty cycle) and RZ-OOK (33.3% duty cycle).
Fig. 4.6: Variation of XPM and SPM Crosstalk (dB) with signal wavelength (nm) for NRZ-DPSK, RZ-DPSK (50% duty cycle) and RZ-DPSK (33% duty cycle).

On the basis of above analysis it can be observed that for 40 Gbps RZ-DPSK signal (33.3% duty cycle) minimum SPM and XPM crosstalk is induced in WDM system. Using the above observation, variation of SPM and XPM induced crosstalk with signal wavelength is studied for 40 Gbps RZ-DPSK signals (33.3% duty cycle) for different pumping scheme. The expression of variance of SPM and XPM induced crosstalk was used to investigate crosstalk in forward pumped DRA and backward pumped DRA by taking into account the launched pump power i.e. by making backward pump $P_{PL}$ strength equal to zero in the generalized formulae of bi-directional pumped DRA for analysis of forward pumped DRA and vice versa. It can be observed from the Fig. 4.7 and Fig. 4.8 that backward pumping scheme suffers minimum crosstalk. Hence it can be said that backward pumped DRA with RZ-DPSK signal (33.3% duty cycles) at 40 Gbps suffers from minimum crosstalk and is apposite for optical communication.
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Fig. 4.7: Variation of SRS Crosstalk (dB) with signal wavelength (nm) for RZ-DPSK signal (33% duty cycle) at 40 Gbps for forward, backward and bi-directional pumped DRA.

Fig. 4.8: Variation of XPM and SPM Crosstalk (dB) with signal wavelength (nm) for RZ-DPSK signal (33.3% duty cycle) at 40 Gbps for forward, backward and bi-directional pumped DRA.
4.4. SUMMARY

Crosstalk in WDM system employing bi-directional pumped DRA has been evaluated using closed form formulae and performance of different modulation formats (DPSK and OOK) and pulse shapes (RZ and NRZ) have been compared. It is found that 40 Gbps RZ-DPSK signal has best crosstalk performance compared to 10 Gbps NRZ DPSK, 40 Gbps RZ–OOK and 40 Gbps NRZ–DPSK signal. The duty cycle of pulse also helps in minimizing crosstalk. The results based on the statistical analysis shows that a 40 Gbps RZ-DPSK signal (33.3 % duty cycle) among the chosen duty cycles offers the best crosstalk performance in a WDM communication system.