Study on the Effect of Crosstalk Attack in 40Gb/s Optical Fiber Communication System

Fang Li *, Qiwu Wu, Hao Chen and Yang Zhou
Engineering University of PAP, Xi’an, 710086, P. R. China
* Email: chenzaochun0126@163.com

Abstract. By using VPI simulation tool, the effects of intra-band crosstalk attack, inter-band crosstalk attack and gain competition on 40Gb/s optical fiber communication system are studied. The results show that the power of attack signal is the main factor that crosstalk attack damages the quality of user signal. The higher the power of crosstalk attack signal, the lower the signal quality of the attacked signal.

1. Introduction
Compared with wireless communication and general wired communication, optical fiber communication has the characteristics of high capacity, high bandwidth and high security. With the emergence of new devices, new protocols and new attack methods, there are still many security problems in optical networks based on optical fiber communication. By the optical network transmission of transparent optical signals, that is, not for photoelectric conversion, malicious users to the injection of high power optical crosstalk signals of normal legal cause of intra-band crosstalk attack, intra-band crosstalk attack and gain competition, the influence of optical network is bigger [1].

In 1997, Muriel Midgard et al. first raised the issue of optical layer security in AON at IEEE Networks. In 2005, Tao Wu and A. K. Somali published studies of high-power intra-band crosstalk attack, they put forward a transmission model of intra-band crosstalk attack, according to this model analyzes the attack warning and positioning a necessary condition[2]. Literature focuses on the effect of high-power inter-band crosstalk and gain competitive attack on the network.

Generally speaking, high power optical crosstalk attack mainly includes the following three types: intra-band crosstalk attack, inter-band crosstalk attack and gain competition [3]. Based on VPI simulation platform, mainly studies the intra-band crosstalk attack, inter-band crosstalk attack, belt joint the intra-band crosstalk attack, inter-band crosstalk attack of 40Gb/s optical fiber communication system, the influence of attack detection and positioning to provide data support for the next step[4].

2. Relevant Foundation
2.1. Inter-Band Crosstalk Attack
In the high-power optical crosstalk attack, the intra-band crosstalk attack is more common, mainly the high-power optical crosstalk signal and the normal legitimate signal wavelength are the same as the crosstalk attack [5]. For example, in figure 1, the propagation model involved in intra-band crosstalk attacks is described. Can be seen from the diagram, the user 1 normal legal signals by high power optical crosstalk through OXC1 start intra-band crosstalk attack, it can also for other user initiated after the intra-band crosstalk attack, then the user 2 by OXC2 normal legal signal to attack[6].
2.2. Inter-Band Crosstalk Attack

Inter-band crosstalk attack is mainly caused by the difference between high power optical crosstalk signal and normal legitimate signal wavelength. As shown in figure 2, there are some nonlinear effects in the optical fiber medium, which lead to inter-band crosstalk attack. These nonlinear effects mainly include: self-phase modulation SPM, cross-phase modulation XPM, four-wave mixing FWM, stimulated Raman scattering SRS and stimulated brilliant scattering SBS.

2.3. Gain Competition

Gain competition refers to the situation that when the high-power crosstalk signal enters the amplifier at the same time as the normal legitimate signal, the gain rate of other legitimate signals will decrease. Doped fiber amplifier bait EDFA is relatively common, one of the most critical element is mixed bait fiber, it can produce stimulated radiation, the wavelength of light waves with the same input signal, and then enlarge the input signal. Figure 3 shows the gain competition model.
3. Simulation Research on Crosstalk Attack

3.1. Simulation Research on Intra-Band Crosstalk Attack

The system consists of the following modules: Tx_OOK, Attenuator, WDM_MUX_N_1_Ideal, AmpSysOpt, FilterOpt, Rx_OOK_BER, NumericalAnalyzer2D, photobond, FilterEl, SignalAnalyzer, Const, Ground. The global parameter "InBandNoiseBins" must be set to "On," setting the sending frequency f1 and f2 to 193.1 * 10^{12} Hz. The signal transmission power is 0.5 * 10^{-3} W, and the attack signal power is also set to 0.5 * 10^{-3} W. The influence of intra-band crosstalk on the system is studied, as shown in figure 4:

![Simulation system of intra-band crosstalk attack](image)

Figure 4. Simulation system of intra-band crosstalk attack

Change the power of crosstalk signal to 500 * 10^{-3} W, and leave the rest unchanged. See figure 5 for the eye images.

![Eye images before and after crosstalk](image)

(a) Before the change (b) After the change

Figure 5. The eye view before and after the change of the intra-band crosstalk attack power

By looking at the eye chart, we can clearly observe the change of signal quality. Simulation results show that the crosstalk attack signal will cause intra-band crosstalk to the original signal, and the power of the crosstalk attack signal will increase, which will lead to the quality of the attacked signal will decrease.

3.2. Simulation Research on Inter-Band Crosstalk Attack

The inter-band crosstalk attack simulation system is mainly composed of the following modules: TxExtModLaser, Attenuator, WDM_MUX_N_1_Ideal, AmpSysOpt, Rx_OOK_BER,
NumericalAnalyzer2D, photobond, FilterEl, SignalAnalyzer, Const, Ground. The global parameter "InBandNoiseBins" must be set to "On," setting the sending frequency $f_1$ and $f_2$ to $193.1 \times 10^{12}$ Hz. The signal transmission power is $1 \times 10^{-3}$ w, and the attack signal power is also set to $1 \times 10^{-3}$ w. The influence of inter-band crosstalk on the system is studied, as shown in figure 6:

![Simulation system of inter-band crosstalk attack](image)

**Figure 6.** Simulation system of inter-band crosstalk attack

Change the power of crosstalk signal to $100 \times 10^{-3}$ w, and leave the rest unchanged, and get the eye images at "1" and "2" respectively as shown in figure 7.

![Eye chart before and after the change of inter-band crosstalk attack power](image)

(a) Before the change  
(b) After the change

**Figure 7.** Eye chart before and after the change of inter-band crosstalk attack power

As can be seen from the figure above, the "eyes" of the eye image become smaller after increasing the power of crosstalk attack signal. Simulation results show that the crosstalk attack signal will cause inter-band crosstalk to the original signal, and the power of the crosstalk attack signal will increase, which will reduce the quality of the attacked signal.

3.3. Simulation Study on the Combined Intra-Band and Inter-Band Crosstalk Attack

The simulation system of combined intra-band and inter-band crosstalk attacks is mainly composed of the following modules: TxExtModLaser, Attenuator, WDM_MUX_N_1_Ideal, AmpSysOpt, Rx_OOK_BER, NumericalAnalyzer2D, photobond, FilterEl, SignalAnalyzer, Const, Ground. The global parameter "InBandNoiseBins" must be set to "On", the sending frequency $f_1$, $f_2$ are set to $193.1 \times 10^{12}$ Hz, and the sending frequency $f_3$ is set to $193.2 \times 10^{12}$ Hz. The signal transmission power is $1 \times 10^{-3}$ w, and the attack signal power is also set to $1 \times 10^{-3}$ w. The influence of inter-band crosstalk on the
system is studied, as shown in figure 8:

![Simulation system of combined intra-band and inter-band crosstalk attacks](image)

**Figure 8.** Simulation system of combined intra-band and inter-band crosstalk attacks

The power of both intra-band and inter-band crosstalk attacks signals was changed to $500 \times 10^{-3}$W to get error codes.

![Waveforms](image)

(a) Intra-band crosstalk before change  
(b) Inter-band crosstalk before change  
(c) Intra-band crosstalk after change  
(d) Inter-band crosstalk after change

**Figure 9.** An eye view before and after the change in the power of an intra-band and inter-band combined crosstalk attack

As can be seen from the figure above, when the power of crosstalk attack signal is increased, both intra-band and inter-band, the original eye image of the signal changes greatly, and the eye image is not clear. The simulation results show that the intra-band and inter-band crosstalk attack signals will cause crosstalk to the original signal, and the power of the crosstalk attack signals will increase,
leading to the quality of the attacked signal will decrease.

4. Conclusion
This paper mainly uses VPI simulation software to study the effects of intra-band crosstalk attacks, inter-band crosstalk attacks and their combined attacks on the 40Gb/s optical fiber communication system. By the optical network with nonlinear characteristics, when high power attack signals into optical network, for in the same optical network transmission normal signal crosstalk attack, make it a serious distortion. Simulation results show that if the power of crosstalk attack signal increases, the quality of the attacked signal will decrease.

5. References
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