10Gb/s신호에 대한 광증폭 수신기의 수신 감도

The Sensitivity of 10Gb/s Optically Amplified Receiver

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The sensitivity of optically amplified receiver (OAR) is affected by the noise from the optical pre-amplifier in which signal-spontaneous beat noise is dominant[1]. Since the BER is related to the Q-factor, the receiver sensitivity should be denoted with the noise and the Q-factor to investigate the sensitivity of the OAR.

The receiver in an OAR is characterized by input power P_{in}, electrical bandwidth B_e, thermal noise N_{th}, signal-spontaneous beat noise $N_{s\text{-}sp}$, spontaneous-spontaneous beat noise $N_{sp\text{-}sp}$, and shot noise N_{sh}. The optical amplifier is exhibited with optical bandwidth B_o, gain G, and spontaneous emission factor N_{sp}. The optical power P_s coming into the optical amplifier is called the optical input power of the OAR.

Since the shot noise and the reflection noise are generally negligible, the sensitivity of optically amplified receiver[1] including thermal noise, signal-spontaneous and spontaneous-spontaneous beat noises can be written as:

$$P_s = 2\frac{B_e}{B_o}P_{sp}\frac{Q^2}{G} + \left[\left(2\frac{B_e}{B_o}P_{sp}\frac{Q^2}{G}\right)^2 + \frac{4kTB_e}{R_L}\left(\frac{h\nu}{e}\right)^2\frac{Q^2}{G^2} + 2m\frac{B_e}{B_o^2}P_{sp}^2\left(B_o - \frac{B_e}{2}\right)\frac{Q^2}{G^2}\right]^{1/2} \quad (1)$$

where the P_{sp} is the power of spontaneous emission, m is the number of transverse mode, and the quantum efficiency $\eta=1$. The Q-factor is defined as $Q=(I_1-I_0)/(\sigma_1-\sigma_0)$, where I_1, I_0, σ_1, and σ_0 are the total mean signal and noise photocurrents on the ones and zeros, respectively. The relation electrical $SNR(dB)=20\log Q$ is used for the fact that a 3dB increase in the Q-factor which maintain consistency with the linear noise from ASE[2]-[4]. In this case, the phase difference between the signal and noise results in $I_0 = -I_1$. When the gain is high, the $N_{s\text{-}sp}$ is dominant and Eq.(1) can be simplified as $P_s = 4B_e h\nu N_{sp}(G-1)Q^2/G$.

The ultimate value of receiver sensitivity with the electrical bandwidth B_e=5GHz and NF=3dB is about −39.0dBm. The receiver sensitivity of OAR has also relation to the optical signal-to-noise ratio(SNR_o)[4] as

$$SNR_o = \frac{4B_e/B_o}{[1/Q^2] - [(4kTB_e/R_L)(h\nu/eG)^2/P_s^2]} \quad (2)$$

When the signal-spontaneous beat noise is dominant at the higher P_{in}, the Eq. (2) can be given as $SNR_o = 4Q^2(B_e/B_o)$.

The receiver sensitivity is shown in Fig. 1. The measured optical bandwidth of the amplifier was 0.5nm, the electrical bandwidth of the receiver was 7.5GHz, and noise figure was about 4.9dB. As shown in the Fig. 2, the sensitivities of the OAR input were -33dBm at BER=10^{-9} and -31.7dBm at BER=10^{-12}. Considering the input/output coupling losses of the EDFA(~1.4dB), the receiver sensitivity of OAR was about -33dBm at BER=10^{-12}, improved about 17dB compared to the p-i-n receiver without EDFA. The eye pattern was measured at the p-i-n receiver input.

The SNR_o was measured with B_o=0.1nm and is shown in Figure 3[(4)]. BER or sensitivity was improved when B_o and B_e were reduced. For BER = 10^{-12}, the Q-factor was 7 and the SNR_o had the value of 22.5dB.

In conclusion, the receiver sensitivity was considered and estimated through both the sensitivity dependence on gain and noises. The sensitivity of OAR can be improved proportional to the gain of amplifier under low-gain condition below 25dB, and is saturated with different noises under high-gain condition over 30dB. The ultimate value of receiver sensitivity at BER = 10^{-12} is about -39.0dBm. The sensitivity was -31.7dBm at BER=10^{-12}. SNR_o were 13.9dB and 22.8 dB for the 0.5 and 0.1nm optical bandwidths, respectively, in this experiment.

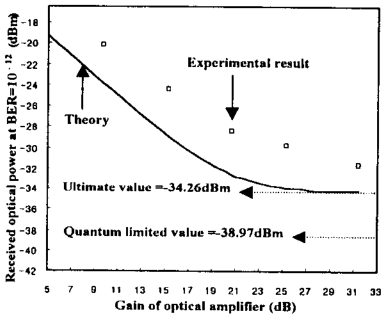

Fig. 1 Sensitivity variation with the gain of optical amplifier.

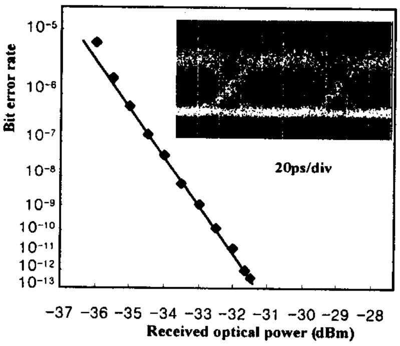

Fig. 2 BER curves at 10Gb/s

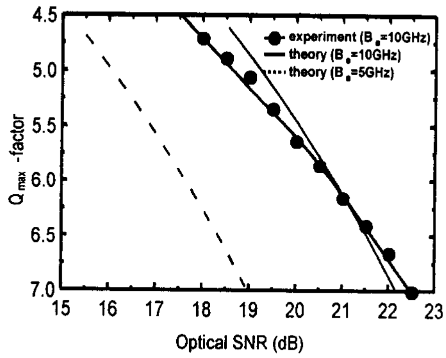

Fig. 3 Q_{max}-factor vs. optical SNR

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