BER and Power Penalty Measurement of Burst-Mode Receiver for All-Optical Multiaccess Networks

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Abstract

We have measured the power penalty versus the decay parameter of burst-mode receivers. The measured result agrees well with a recently proposed theoretical model. This is the first experimental verification of such a model.

Summary

Optical burst-mode receiver is a key component for all-optical multiaccess packet networks in which various nodes communicate with one another via short bursts (or packets) of data [1]. Recently a theoretical model has been proposed [2,3] which shows that the BER performance is affected by a decay parameter K [3] of the adaptive threshold control circuit in the receiver. In this paper, we have performed BER and power penalty measurement of burst-mode receivers versus the decay parameter K. The experimental results agree with the theoretical model very well.

The BER measurement for burst-mode receivers is complicated by the gap time between packets. Assuming a uniform gap time, the BER of the receiver can be written as:

\[ P_b \approx (1 - \beta)P_e + \frac{\beta}{n} \sum_{i=1}^{n} \exp\left(-\frac{Q(i)/2}{\sqrt{2\pi}Q(i)}\right). \]  

Here, \( \beta \) is the capacity penalty [2] of the network which can be expressed as:

\[ \beta \approx \frac{n}{n + N}. \]

where \( n \) and \( N \) are the length of the gap time and packet respectively. \( P_e \) is the BER of the receiver when the input data is in continuous mode [3], and \( Q(i) \) is the Q-function of the \( i - th \) bit in a consecutive string of "0"s [3].

The burst-mode receivers used in the measurement have been described previously [1]. In Fig. 1 is shown the power penalty versus the decay parameter \( K \) for different capacity penalty at a BER of \( 10^{-9} \) with the voltage offset of the threshold set to be zero. Here, the power penalty means the sensitivity penalty between the continuous mode and the burst mode. The solid lines are computed from Eqn. (1) and the discrete dots are the experiment results. They agree very well with one another.

Fig. 2 is similar to Fig. 1, except that the offset of the threshold is set to be 1.2\( \sigma \), where \( \sigma \) is the RMS noise in the receiver. In the experiment, the bit rate of the data link is 100 Mb/s, the responsivity of the photo-detector is 0.94, the packet length is 53 bytes, the gap time length is generated by a programmable HBR counter [HP71000B], and \( K \) is changed by replacing the capacitor in the adaptive threshold control circuit in the receiver. The receiver sensitivity is around -32 dBm for continuous mode.

The overall BER performance is 1dB better for the case with an offset than that without an offset. This is because the receiver has a better BER during the gap time when there is an offset. However, a large offset will result in pulse width distortion (PWD) [1] which will degrade the receiver performance.

When the threshold of the receiver is offset by \( V_{offset} \), the sampling error \( \tau \) in Fig. 3 can be estimated by:

\[ \tau \approx \frac{V_{offset}}{dV/dt} \approx \frac{t_r}{g(0)/V_{offset}}, \]  

(3)
where \( t_\epsilon \approx 0.75/BW \), \( BW \) is the bandwidth of the receiver, and \( g(t) \) is the peak voltage of the pulse. With a voltage offset, the \( Q \)-function must be modified by:

\[
Q = \begin{cases} 
\frac{2}{\sqrt{2\pi}} Q_c - V_{	ext{offset}}/\sigma & \text{for } "1" \\
Q(i) + V_{	ext{offset}}/\sigma & \text{for } "0" 
\end{cases}
\]

(4)

where \( Q_c = (V_i - V_o)/2\sigma \) is the conventional \( Q \)-function of the receiver, and \( g(t) \) is the waveform of the pulse. By substituting Eq. (4) into Eq. (1), we can get the power penalty versus the offset for the normalized gaussian and raised cosine waveform as shown in Fig. 4.

It can be seen that the performance for gaussian and raised cosine waveform are about the same. The power penalty can be reduced by increasing the offset but the inherent sensitivity of the receiver will degrade due to this offset.

In conclusion, we have experimentally characterized the BER and power penalty of burst-mode receivers versus the decay parameter \( K \) under continuous and burst mode conditions, and with different capacity penalties. The results agree with a recently proposed model [2,3] very well. We have also computed the BER penalty for different offsets and found that the power penalty can be reduced but the inherent sensitivity of the receiver will degrade.

Reference

