Performance Degradation due to Crosstalk in Underwater Wireless Optical Communication Systems with a Two-Beam Configuration

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1. Introduction

Space diversity-based two-beam configuration has an advantage in tolerance for floating matter in underwater wireless optical communication systems [1]. In this paper, performance issues due to crosstalk for this configuration are discussed theoretically.

2. System Configuration

Figure 1 shows an OOK transmission system in the two-beam configuration in which separate laser–photodetector pairs are used to transmit the same signal at the same wavelength and polarization. The photocurrent of the two detectors is mixed electronically together. Optical beams are assumed to have the circle cross section of radius kR, which are detected separately by the detection areas having a radius R at a distance d apart. If the optical beams spread considerably outside their detection areas, $kR > d–R$, their fields overlapping on the detection area, referred to as crosstalk, can degrade the system performance.

3. Probability Density Function of the Intensity

If the received signal field is mixed with the crosstalk beam at the same wavelength and polarization, the probability density function of its detected power P is given as [2]

$$f(P/P_0) = \left[4P_1/P_0 - (1 + P_1/P_0 - P/P_0)^2\right]^{-1/2}/\pi, \quad (1)$$

where P_0 and P_1 represent the signal and crosstalk beam powers, respectively. Such a phenomenon inducing fluctuations is referred to as phase to intensity noise conversion.

4. Bit-Error Rate Degradation and Power Penalty

Figure 2 plots the minimum BER at the optimum threshold value for several values of crosstalk level P_1/P_0 by using Eq. (1). The system Q-factor has been assumed to be 6 for −23 dBm of average received power. The system performance is severely degraded even if the crosstalk level is only 1%. The power penalty calculated for two different values of BER plotted as a function of crosstalk level P_1/P_0 is shown in Fig. 3. As predicted from Fig. 2, the power penalty becomes quite large for the beam with a large crosstalk element. The penalty can be kept below 3 dB to maintain a BER of 10^{-6} for values of crosstalk level as large as 0.1 (10%).

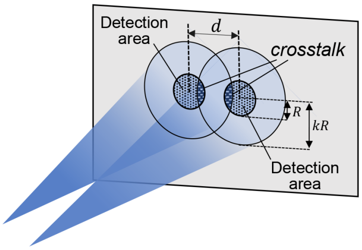

Fig. 1 Crosstalk of separate laser–photodetector pairs.

Figure 4 shows how the detection area separation d required to keep the power penalty below 3 dB varies with the beam radius kR. The region with $d/R \geq k+1$ represents the absence of crosstalk, while the shaded region between the two lines corresponds to the power penalty below 3 dB.

5. Conclusion

The impact of crosstalk in underwater wireless optical communication was discussed theoretically. From the presented results, we can point out that bit-error rates are severely degraded even if the crosstalk power is only 1% of signal.

References

[1] R. Yoshino, *et. al.*, *Annual Meeting of The Laser Society of Japan*, S07-14a-XI-06, Jan. 2022.
[2] T. Yoshino, *et. al.*, *IEICE Trans, B-I*, J74-B-I, 3, pp. 228–237, 1991.

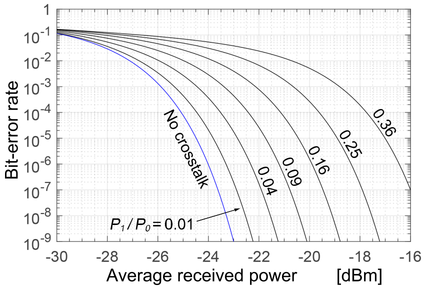

Fig. 2 Bit-error rate versus the received power.

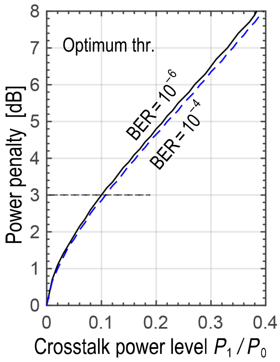

Fig. 3 Crosstalk power penalty.

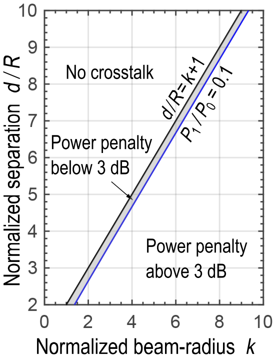

Fig. 4 The separation d required for the power penalty below 3 dB.

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