Performance comparison of optical 8-ary differential phase-shift keying systems with different electrical decision schemes: Comment

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Abstract: We summarize three electrical decision schemes that have been proposed for 8-level differential phase-shift keying, briefly discuss their performance and complexity, and comment that two of these schemes have been confused in an earlier comparison in Optics Express.

OCIS codes: 060.2330 Fiber optics communications; 060.5060 Phase modulation

References and links

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In [1], Yoon *et al.* compared the performance of two optical receiver structures for 8-level optical differential phase-shift keyed (8-DPSK) transmission. One was based on four Mach-Zehnder delay interferometers (DI), each with a single decision gate, and the other consisted of two DI's, each with a four-level decision gate. The decision thresholds in signal space for these implementations are shown in Fig. 1(a) and (b), respectively. The receiver of Fig. 1(b) was attributed to Ohm [2], which we believe is incorrect. Instead, the Ohm receiver [2] has a

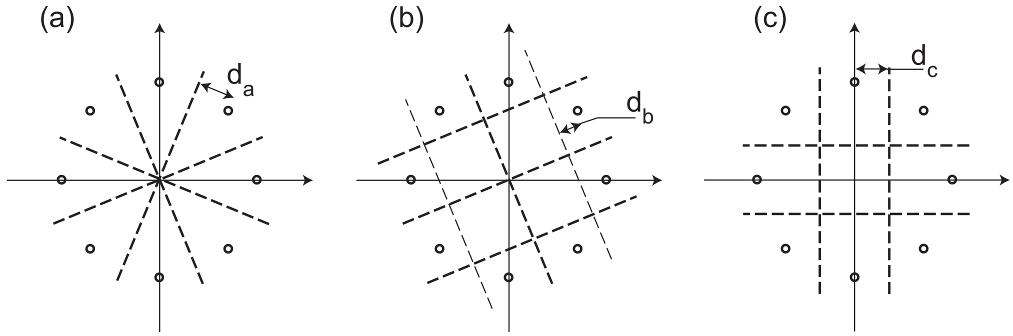

Fig. 1. Decision boundaries (dashed) of 8-DPSK receivers used in various publications; receiver (a) was used in [1, 3–6], (b) in [1, 7], and (c) in [2]. The scale is proportional to optical amplitudes.

decision diagram according to Fig. 1(c). The purpose of this comment is to clarify where in the literature all these different receivers have been used and to quantify the performance and the implementation complexity of the three proposed 8-DPSK receivers.

The bit-error rate (BER) performance of the receivers depends significantly on the choice of decision levels. We consider a system dominated by amplified spontaneous emission noise and use the same model as in [1], where the transmitted power for a given BER is proportional to the square of the minimum Euclidian distance between a signal point and a decision threshold. Assuming that the signal points lie on the unit circle, the squared minimum distances for the three receivers in Fig. 1 are $d_a^2 = \sin^2(\pi/8) = 2^{-1} - 2^{-3/2} \cong 0.146$, $d_b^2 = (\cos(\pi/8) - \sin(\pi/8))^2/4 = 2^{-2} - 2^{-5/2} \cong 0.073$, and $d_c^2 = 2^{-3} = 0.125$. Obviously, receiver (a) is the best one, and it is commonly called the *maximum likelihood* receiver. The optical signal-to-noise ratio (OSNR) penalties of receivers (b) and (c) with respect to receiver (a) are $10\log_{10}(d_a^2/d_b^2) = 3$ dB (as observed in [1]) and $10\log_{10}(d_a^2/d_c^2) = 0.7$ dB.

Most studies published to date on optical 8-DPSK have implemented the maximum likelihood receiver (a), e.g., theoretically in [1, 3–5] and experimentally in [6]. It appears to us that receiver (b) did not appear in the literature before being discussed in [1] and receiver (c) has not been compared with the ideal receiver (a) previously. After [1] appeared, however, a simplified version of receiver (b) was used by Ohm *et al.* in [7], where it was observed that the four-level decision in one of the two receiver branches can be replaced with a simple binary decision, without loss in performance. This corresponds to removing the thin dashed lines in Fig. 1(b).

The systems in [2, 7] use nonoptimal bit-to-symbol mappings. The BER for high OSNR can in both cases be reduced by 20 % by instead employing Gray mappings. To be precise, Gray mappings can be obtained by replacing the expressions for $\hat{b}_2$ in [2] and [7] with $\overline{e_{12}} + \overline{e_{11}} \cdot \overline{e_{22}}$ and $\overline{e_{11}} \cdot e_{13}$, resp., with the corresponding changes in the transmitters. The gain is marginal, but it comes at no cost in logic complexity.

The requirement of four DI's to implement receiver (a) can be relaxed, because any vector in two-dimensional signal space can be realized as a linear combination of two linearly independent vectors, each corresponding to one DI. Receiver structures for 8-DPSK with only two DI's have been presented by, e.g., Han *et al.* [4] and Okunev [8, pp. 114, 233]. The idea generalizes straightforwardly to larger constellations, so that two DI's are sufficient to realize maximum likelihood receivers even for 16-DPSK and above.

In conclusion, receiver (a) can be realized with the same optical complexity as (b) and (c) and yields lower BER. It should thus be the preferred choice in future optical 8-DPSK systems.