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On a Proposal for an Optical Receiver Achieving High Sensitivity

Pierre A. Humblet

Abstract—**We clarify the capability of the receiver structure introduced in [1] and show that although it improves the signal-to-noise ratio, it does not allow communication with fewer photons per bits than the traditional limit.**

THE paper by Kikuchi [1] considers a phase modulated optical signal. It suggests a novel receiver structure that reduces the noise along the radial component in the two-dimensional phasor space, leaving the angular noise component unchanged. Although doing so increases the signal-to-noise ratio, it cannot improve the sensitivity, the number of photons per bit at the input of the receiver required to achieve a given error probability. The facts that the signal-to-noise ratio is increased, but the sensitivity is not improved, are not mutually exclusive. For phase modulation the radial component of the noise is irrelevant, and it does not help to reduce it.

The front end of the proposed receiver consists of an optical amplifier with gain G. Using the classical field model and the notation of [1], the power of the signal at the output of the amplifier is given by GN_o photons/second, and the average number of photons per bit at the input is $n_o = N_oT$. The noise at the output of the amplifier is Gaussian, with single-sided spectral density $(G-1)n_{sp}$, with $n_{sp} \geq 1$.

To minimize the error probability in this situation, communication theory [2] teaches that the rest of the receiver should consist of matched filters, samplers, and comparators (this cannot be quite implemented at optical frequencies, but this fact is irrelevant to the argument). For uncoded binary phase modulation with equally likely symbols, the minimum probability of error is given by $P_e = Q(\sqrt{2n_oG/((G-1)n_{sp})})$, which simplifies to $Q(\sqrt{2n_o/n_{sp}})$ for large G. Here $Q()$ denotes the complementary unit Gaussian distribution. For P_e equal to 10^{-9}, n_o, n_{sp} must be 18.

The last stage of the proposed design is a homodyne receiver. Used alone, without any optical preamplifier, this receiver has $P_e = Q(2\sqrt{n_o})$, as correctly implied in [1]. Only nine photons per bit are required for $P_e = 10^{-9}$. For comparison, a binary DPSK receiver can be designed [3] solely with an optical preamplifier, an optical filter, and photodetectors. It achieves the same probability of error with $n_o/n_{sp} = 20$.

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The author is with the Laboratory for Information and Decision Systems, Massachusetts Institute of Technology, Cambridge, MA, 02139.

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