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Quantum Receivers

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Abstract

Low photon number optical signals are an expanding research field, thanks to its wide forthcoming diversity of applications. Such signals may be deliberately prepared with a low photon number for each transmitted symbol as for cryptography applications, either in optical fibers or in free space. The low level of the signal may also be the result of its intrinsic emission weakness or of a strong attenuation system as in sensing, aeronautics, space sensors, tomography, and instrumentation applications.

However, the weak optical signals do not anymore behave as classical ensemble average over a large photon population, but display, and also allow taking benefit of, their quantum nature, which is no more averaged out.

We start with a short recall of (or a self consistent first introduction to) the basic concepts related to optical quantum signals and noise. As the thermal noise in any photo detector electronics circuit remains a strong limitation, it vanishes out at the carrier optical frequency. Then the fundamental quantum fluctuation, so-called vacuum fluctuation, takes place as a first manifestation on the quantum nature of the signal. As the representation of light as classical particle flow, leading to the Poisson shot noise, is no more relevant, we focus on a wave a representation of light as a 2-quadrature coherent state. This representation most closely resembles the classical wave description of the electrical engineering, making many quantum concepts more understandable. Furthermore, coherent states are easily produced by standard laser sources and easily related to applications.

As the Heisenberg's indetermination principle leads to the impossibility of a linear noiseless amplification of 2 quadrature signals, we present the best achievable Bit Error Rate, referred as Helström bound, for BPSK signals. The idealistic single detector Kennedy and Dolinar receivers and the more realistic 2-detectors balanced arrangement, based on the interference of the signal with a local reference are presented and compared. Phase referencing appears as a key issue.

As an illustration, we finally present our 2 balanced homodyne experiments using self-referencing of pulsed light at 1550 nm wavelength.

Biography

Philippe Gallion, M.Sc.(72), PhD.(75) and "Docteur es Science"(86) is now an Emeritus Professor at Télécom Paris, part of the Institut Polytechnique de Paris, and formerly "Ecole Nationale Supérieure des Télécommunications" where he served as Chairman of the Communications and Electronics Department. He was also Lecturing at Paris Sorbonne University, "Ecole Polytechnique" and many other engineering degree institutions over the world.

He has made pioneering contributions on semiconductor lasers, optical signal amplification noise and non-linearity and on optical and quantum communications and cryptography systems. Author of several books, more than 150 international technical publications and more than 150 communications and lectures at conferences, including many invited one. He has supervised 45 theses and participated to more than 150 thesis committees.

Philippe Gallion is a Life Member of the Institute of Electrical and Electronics Engineers (IEEE) and Member of the Optical Society of America. He is the Chairman of the French Chapter of the IEEE Photonics Society. He serves on the Editorial Board and Scientific Committee of several technical journals and as member of Program or Steering Committee of international scientific conferences and institutions. He acts as expert for research program, evaluation and accreditation of engineering degree institutions.