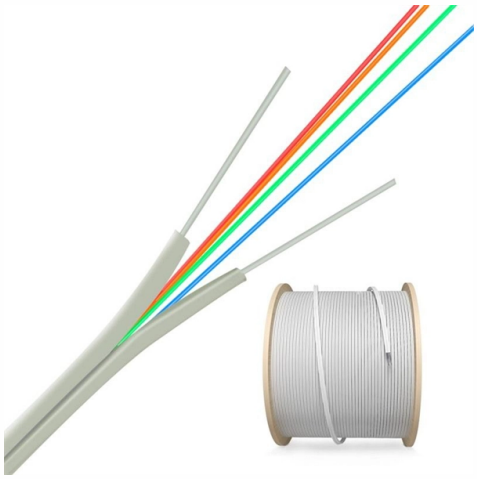
Shot noise of optical receiver



Overview

Optical systems can be subject to shot noise and optical noise, in addition to the standard thermal noise. These require somewhat different models and performance expressions.

Key Takeaways

Shot noise is a fundamental quantum noise in optical receivers, arising from the discrete nature of photons and electrons, and it sets a lower limit on the achievable signal-to-noise ratio.

Origin of Shot Noise

Shot noise occurs because photocurrents are generated by discrete electrons in response to incident photons, which arrive randomly over time. Even when the optical signal has constant power, the current fluctuates due to the probabilistic nature of photon absorption events in the photodiode. These fluctuations follow Poisson statistics, often approximated as Gaussian for large photon numbers, and are independent of frequency, making shot noise a type of white noise (constant spectral density) in the receiver output.

Mathematical Description

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For a photodiode with average photocurrent Ip, the shot noise current is(t) can be expressed as: I(t)=Ip+is(t) The power spectral density of shot noise is given by Si(f)=2eIp for a one-sided spectrum, where e is the elementary charge. This shows that shot noise increases with the average photocurrent, meaning higher optical power leads to higher absolute shot noise, though the relative noise decreases. Impact on Optical Receiver PerformanceShot noise limits the signal-to-shot-noise ratio (SSNR) in optical receivers.

In intensity modulation direct detection (IM/DD) systems, the SSNR can be optimized using receiver filters such as integrators or matched filters. For coherent detection systems, the SSNR improves significantly when the local oscillator power exceeds the received signal power, approaching the quantum limit of detection. Shot noise is particularly important in low-light or high-speed optical communication, where it often dominates over thermal noise.

Avalanche photodiodes (APDs) introduce additional multiplication noise, which combines with shot noise to affect the overall SNR.

Mitigation and Measurement

To accurately measure shot noise, high quantum efficiency photodetectors and low-noise electronics are required. Balanced detection schemes are often used to subtract common-mode noise and isolate the shot noise contribution. While shot noise is intrinsic and cannot be eliminated, receiver design and filtering can maximize the SSNR and approach the quantum-limited performance.

In summary, shot noise is an unavoidable quantum effect in optical receivers, arising from the discrete nature of photons and electrons, and it fundamentally limits the sensitivity and performance of optical communication systems. Proper receiver design can optimize performance relative to this noise floor.

Article Content

Optical Noise

Optical systems can be subject to shot noise and optical noise, in addition to the standard thermal noise. These require somewhat different models and performance expressions. Receiver

Shot Noise Optimal Receiver Filters for Coherent and Non-Coherent

ABSTRACT In this paper, we investigate optimal receiver filter design with respect to shot noise in both non-coherent and coherent fibre optic communication systems.

Optical Receiver Noise

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The shot noise and thermal noise are the two fundamental noise mechanisms responsible for current fluctuations in all optical receivers even when the incident optical power P in is constant.

Shot noise

The shot noise of a coherent optical beam (having no other noise sources) is a fundamental physical phenomenon, reflecting quantum fluctuations in the electromagnetic field.

Lecture 15: Receiver Design

Electrical Shot Noise The shot noise generated in the photodetection process is physically due to the “quantum granularity” of the received (and photo converted) optical signal

Shot Noise Optimal Filters for Phase-Diversity Homodyne Receivers

Analytical expressions for the signal to shot noise power ratio (SSNR) of phase diversity homodyne (PDH) optical fiber communication systems with arbitrary waveform and receiver filter are derived.

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When observing the detector current output, it is difficult to tell which noise was present at the optical input and which noise was generated internal to the detector.

Shot Noise

Shot Noise A significant limitation in the performance of analog optical receivers is shot noise. Shot noise is generated in the receiver photo diode, caused by the statistical variation in the arriving

Receiver Noise—Shot Noise Enhancement with APD

Optical receivers with APD generally provide a higher SNR for the same incident optical power. The improvement in the SNR is due to the internal gain that increases the photocurrent by the

4 ways signal noises impact optical devices

Shot noise, dark noise, 1/f noise, and thermal noise are all types of optical noises that can impact a sensor''s performance. Learn how these various optical noises affect sensor accuracy and

Optical Fiber Communication Part 3 Optical Digital Receiver

It elaborates on the factors influencing signal integrity and noise, such as receiver design, shot noise, and preamplifier types, along with their impact on system performance.

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Noise Principles in Optical Fiber Communication

This chapter contains sections titled: Introduction Receiver Thermal Noise Dark Shot Noise Signal Shot Noise Multiplication Shot Noise Optical Amplification and Beat Noises Optical Nois...

Noise Theory of Coherent Optical Receivers

This chapter analyzes the noise components impairing the coherent optical detection, comparing two receiver architectures, the dual-polarization quadrature coherent receiver and the

Analysis of shot noise in the detection of ultrashort optical pulse trains

Received February 8, 2013; revised May 3, 2013; accepted May 10, 2013; posted May 13, 2013 (Doc. ID 185050); published May 31, 2013 We present a frequency domain model of shot noise in the

Shot-Noise in optical detectors

Shot noise increases as n−−√ n $sqrt{n}$, assuming that the signal is proportional to the detected photons as in CCD or CMOS photodetctors. So the SNR is given by the first equation you

Sub-shot-noise-limited fiber-optic quantum receiver

We experimentally demonstrate a quantum receiver based on the Kennedy scheme for discrimination between two phase-modulated weak coherent states. The receiver is assembled

Understanding Shot Noise

Various optical nonlinearities can create light with quantum noise below the shot noise limit. For instance, amplitude-squeezed light can be produced by transforming an initial coherent state through

4. Shot Noise and Thermal Noise

4. Shot Noise and Thermal Noise It is wel known that electronic amplifiers introduce noise. The noise can be heard in any radio receiver tuned between stations. Some of the noise comes from the

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