Noise Sources in Optical Receivers



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

Optical receivers experience noise from multiple sources, including photodetector shot and thermal noise, amplifier noise, laser intensity fluctuations, and transmission-induced distortions.

Photodetector Noise

Photodetectors, such as PIN diodes or avalanche photodiodes (APDs), convert optical signals into electrical currents. Shot noise arises from the discrete nature of photon detection and the random generation of charge carriers, while thermal noise (Johnson-Nyquist noise) results from the thermal agitation of electrons in the detector circuitry.

AP

Ds introduce additional multiplication noise due to the stochastic avalanche process, which increases the overall noise level in the receiver output.

Laser Noise

Lasers used as optical sources contribute relative intensity noise (RIN) caused by spontaneous emission and fluctuations in the laser output power. This noise adds directly to the optical signal and can degrade the signal-to-noise ratio (SNR) at the receiver.

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Amplifier Noise

Optical amplifiers, such as erbium-doped fiber amplifiers (EDFAs), are necessary to compensate for signal attenuation over long distances. However, they introduce amplified spontaneous emission (ASE) noise, which adds random fluctuations to the signal and limits the achievable SNR.

Transmission-

Induced Noise

The optical fiber itself can introduce noise through attenuation, dispersion, and nonlinear effects. Attenuation reduces signal power, making the signal more susceptible to noise. Dispersion causes pulse broadening, leading to intersymbol interference (ISI).

Nonlinear effects, including self-phase modulation (SPM), cross-phase modulation (XPM), and four-wave mixing (FWM), distort the signal and generate additional noise components.

Electrical and System Noise

Additional noise sources include amplifier noise in the electrical domain, dark current in photodetectors, and circuit-induced fluctuations. These contribute to the overall degradation of the receiver's sensitivity and increase the bit error rate (BER) for a given optical power.

Summary

In optical receivers, noise originates from both optical and electrical components as well as the transmission medium. Key contributors are: Photodetector shot and thermal noise, plus APD multiplication noiseLaser intensity fluctuations (RIN)Amplified spontaneous emission from optical amplifiersFiber-induced noise from attenuation, dispersion, and nonlinear effectsElectrical circuit noise and dark current Understanding these noise sources is essential for optimizing receiver design, improving SNR, and minimizing BER in optical communication systems.

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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

Noise Processes in Optical Receivers

The sources of noise processes observed in optical receivers originate from a wide range of devices, including photodetectors and receiver circuits, optical sou

Optical Receivers | part of Fiber-Optic Communication Systems

The design of an optical receiver depends on the modulation format used by the transmitter. The chapter deals with various noise sources that limit the signal-to-noise ratio in optical receivers, and also

Optical Fiber Receiver Noise Analysis

This document discusses noise sources in optical receivers, including shot noise, thermal noise, dark current noise, and 1/f noise. It examines these noise sources in PIN photodiodes and avalanche

What are the noise sources known in Optical fiber network?

Active sources such as optical plugs,lasers, receivers, and amplifiers generate noise in the fiber link. Passive sources such as connectors, fiber, splices, and WDMs cause interference by

Lecture 15: Receiver Design

Electrical Signal-to-Noise Ratio (SNR) At the receiver, there is noise on the signal arriving at the input and there is noise that is injected at various stages of the receiver

NOISE IN FIBER OPTIC COMMUNICATION LINKS Robert Dahlgren

The fiber can have its own sources of noise, which would appear at the receiver. Noise sources in the transmission medium are often controlled by design rules, and upon careful examination can be often

Optical Communication Systems (OPT428)

Forward Error Correction (FEC) Optical Receivers Front end converts optical signal into electrical form. Linear channel ampli es and lters the electrical signal. Data recovery section creates electrical bit

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The FOA Reference For Fiber Optics

Typically both transmitters and receivers have receptacles for fiber optic connectors, so measuring the power of a transmitter is done by attaching a test cable to the

Optical Noise

Receiver noise in optical systems is a sum of electronic thermal noise from the front-end amplifier and shot noise. The thermal noise is well modeled as an additive white Gaussian noise

Photograph of PerkinElmer enhanced silicon avalanche photodiode optical ...

Download scientific diagram | Photograph of PerkinElmer enhanced silicon avalanche photodiode optical receiver from publication: Photon Detectors with Large Dynamic Range and at Near Infrared ...

Chapter 5

5.1 INTRODUCTION This chapter attempts to provide a simplified interpretation of the meaning of “noise,” present its underlying theories, and enumerate various noise sources that contaminate the

Shot Noise Calibration (SNC)

In that setting SNC quantifies whether the receiver noise floor is dominated by optical shot noise rather than electronics or technical LO noise (Gurses et al., 8 Apr 2026). In continuous

Optical Receiver Noise

Optical receivers convert incident optical power Pin into electric current through a photodiode. The relation Ip = RPin assumes that such a conversion is noise free. However, this is not the case even

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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

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Lecture 15: Receiver Design

Optical Signal-to-Noise Ratio (OSNR) OSNR is an extremely important parameter in optically amplified systems A poor OSNR cannot in principle be improved at the receiver It is mainly determined by:

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