

Capacity scale of fiber optic communication



AI Overview

The capacity of fiber-optic systems is determined by bandwidth, signal-to-noise ratio, fiber nonlinearity, modulation format, and multiplexing techniques, with practical limits approaching 5 bits/s/Hz per polarization over long distances. Key Factors Affecting Fiber Capacity

1. Bandwidth and Signal-to-Noise Ratio (SNR) The fundamental limit of fiber capacity is governed by Shannon's theorem, which relates channel capacity to bandwidth and SNR. In optical fibers, amplified spontaneous emission (ASE) noise from optical amplifiers can be modeled as additive white Gaussian noise (AWGN), allowing Shannon's theory to estimate capacity. For a single polarization, advanced systems can achieve around 5 bits/s/Hz over 2000 km using coherent detection and nonlinear compensation techniques.
2. Fiber Nonlinearity The Kerr effect introduces nonlinear interactions between signals, limiting capacity at high power levels. Nonlinear effects include self-phase modulation, cross-phase modulation, and four-wave mixing, which distort signals and reduce achievable information rates. Techniques like pre-distortion, reverse nonlinear propagation, and multi-level modulation help mitigate these effects.
3. Modulation Formats Capacity depends on the choice of modulation. Multi-level amplitude and phase modulation (e.g., N-ASK/PSK) allows better spectral efficiency than simple PSK, especially below the nonlinearity threshold. Spectral packing efficiency also affects capacity, with practical raised-cosine filters slightly reducing achievable rates compared to ideal square-spectrum modulation.
4. Multiplexing Techniques
 - Wavelength-Division Multiplexing (WDM): Multiple wavelengths increase total system capacity by parallel transmission.
 - Polarization-Division Multiplexing (PDM): Using two orthogonal polarizations doubles the effective capacity.
 - Space-Division Multiplexing (SDM): Mul...

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