Capacity of coherent free-space optical links using atmospheric compensation techniques

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Abstract…

- We analyze the ergodic capacity and ε-outage capacity of coherent optical links through the turbulent atmosphere. We consider the effects of log-normal amplitude fluctuations and Gaussian phase fluctuations, in addition to local oscillator shot noise, for both passive receivers and those employing active modal compensation of wavefront phase distortion. We study the effect of various parameters, including the ratio of receiver aperture diameter to wavefront coherence diameter, the strength of the scintillation index, and the number of modes compensated.

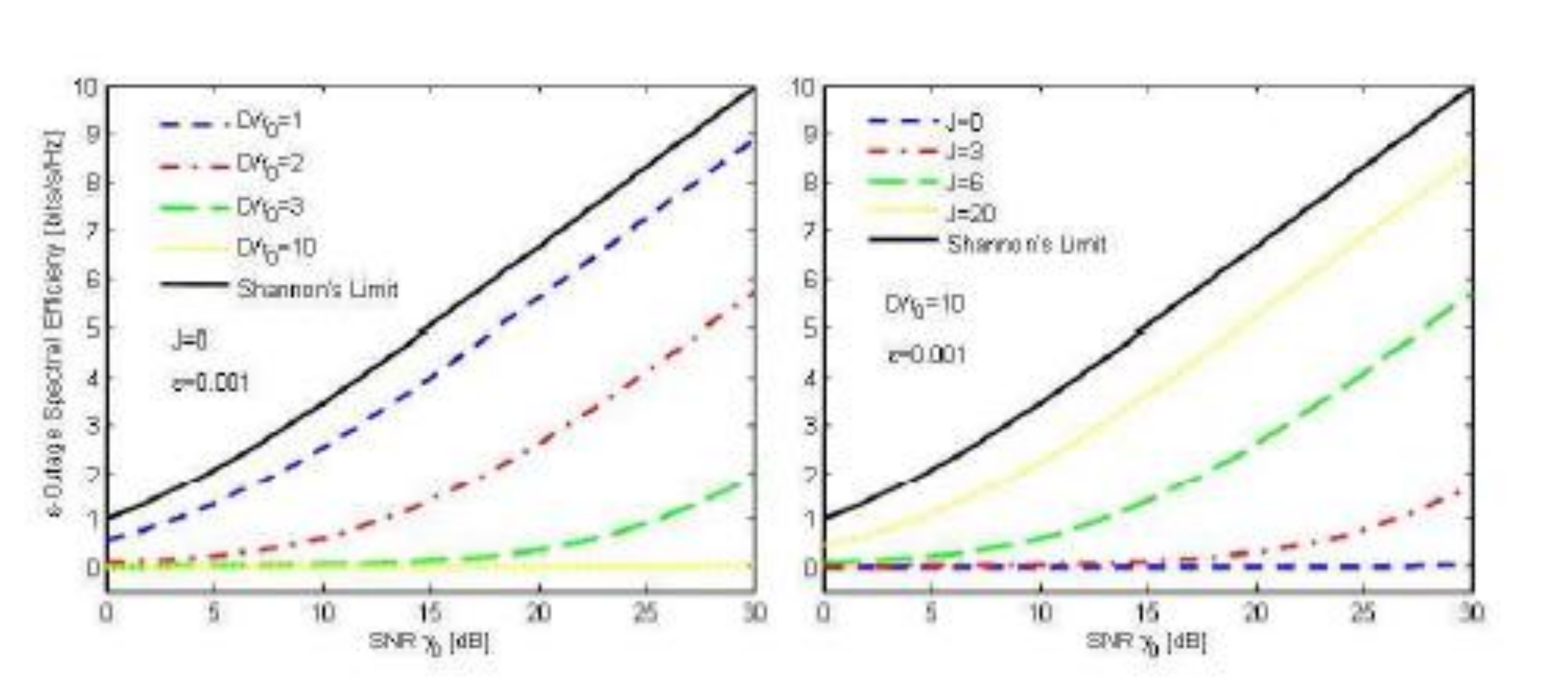
Introduction…

- In this study we study the maximal rate at which the information may be transferred through free-space optical communication links using coherent detection. Evaluating the performance of a heterodyne or homodyne receiver in the presence of atmospheric turbulence is generally difficult because of the complex ways that turbulence, acting as a time-varying, multiplicative noise, affects the coherence of the received signal that is to be mixed with the local oscillator.

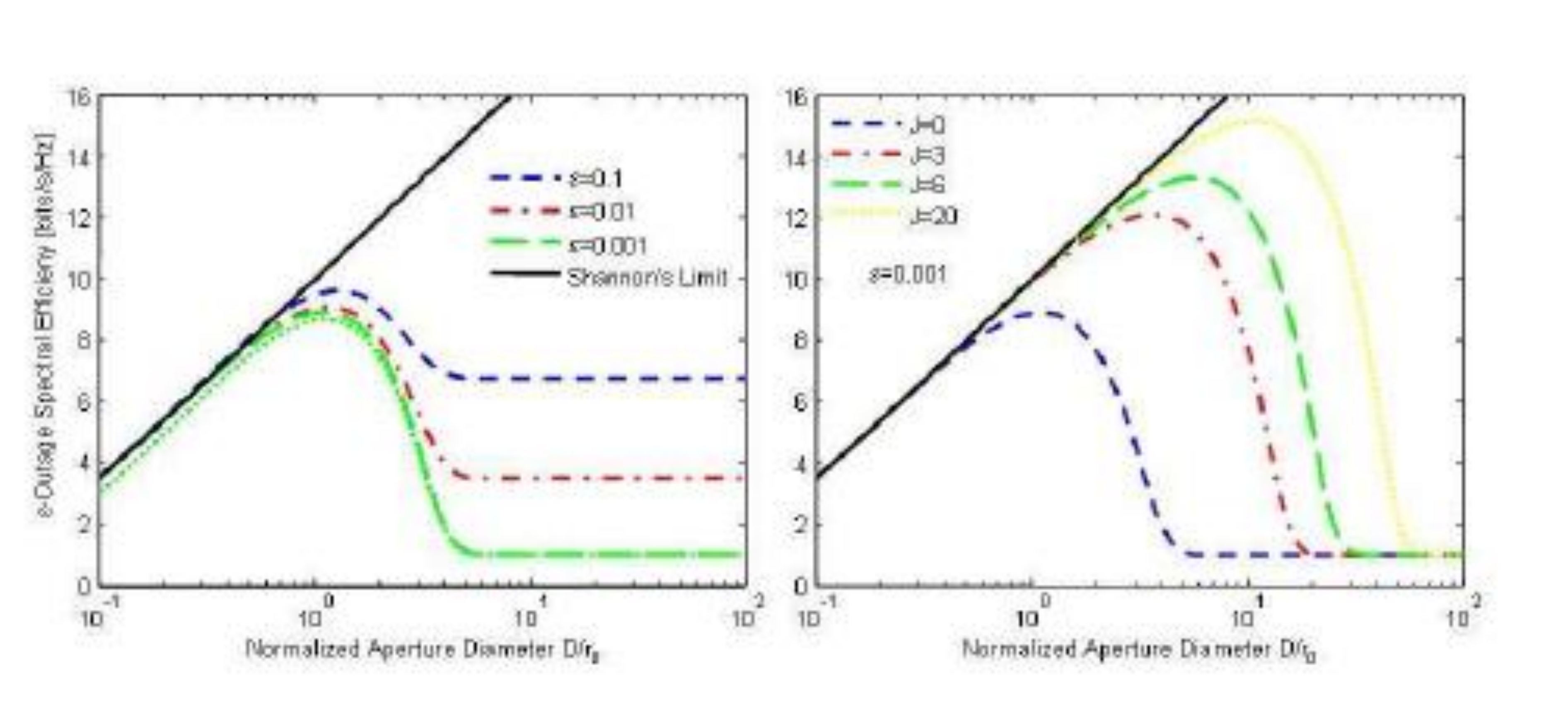
Introduction…

- In free-space optical communication through the turbulent atmosphere, we must consider fading channels, which are a class of channels with multiplicative noise. The complex baseband representation of an atmospheric channel *y*[*t*]=a[*t*]x[*t*]+*n*[*t*] includes the multiplicative effect of the fading process a[*t*] at time *t*. We let a2 denote the atmospheric channel power gain and (*P*/*N*0*B*)a2= γ0a2 denote the instantaneous received SNR per symbol. Conditional on a realization of the atmospheric channel described by a, this is an AWGN channel with instantaneous received SNR γ=γ0a2 and the maximum rate of reliable communication supported by this channel is log2(1+γ0 a2) bits/s/Hz. This quantity is a function of the random channel power gain a2, and is therefore random. The statistical properties of the atmospheric random channel fade a2, with probability density function (PDF) pa2(a2), provide a statistical characterization of the SNR γ=γ0a2 and, consequently, of the maximal spectral efficiency achievable for the free-space optical link. Although information theory has been applied to free-space optical communication links using direct detection [2-4], the ultimate classical information capacity when coherent (homodyne or heterodyne) detection is used needs to be properly considered.

ε-outage capacity…



ε-outage capacity…



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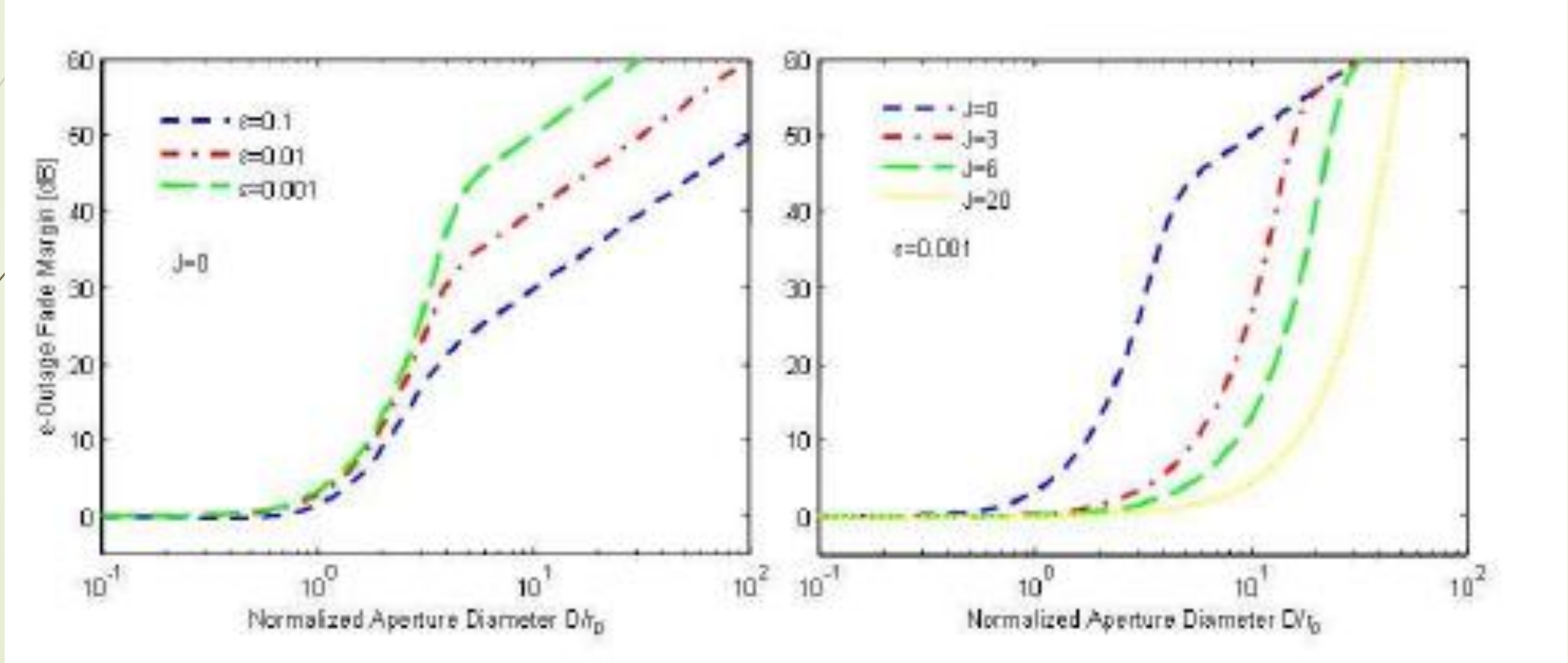
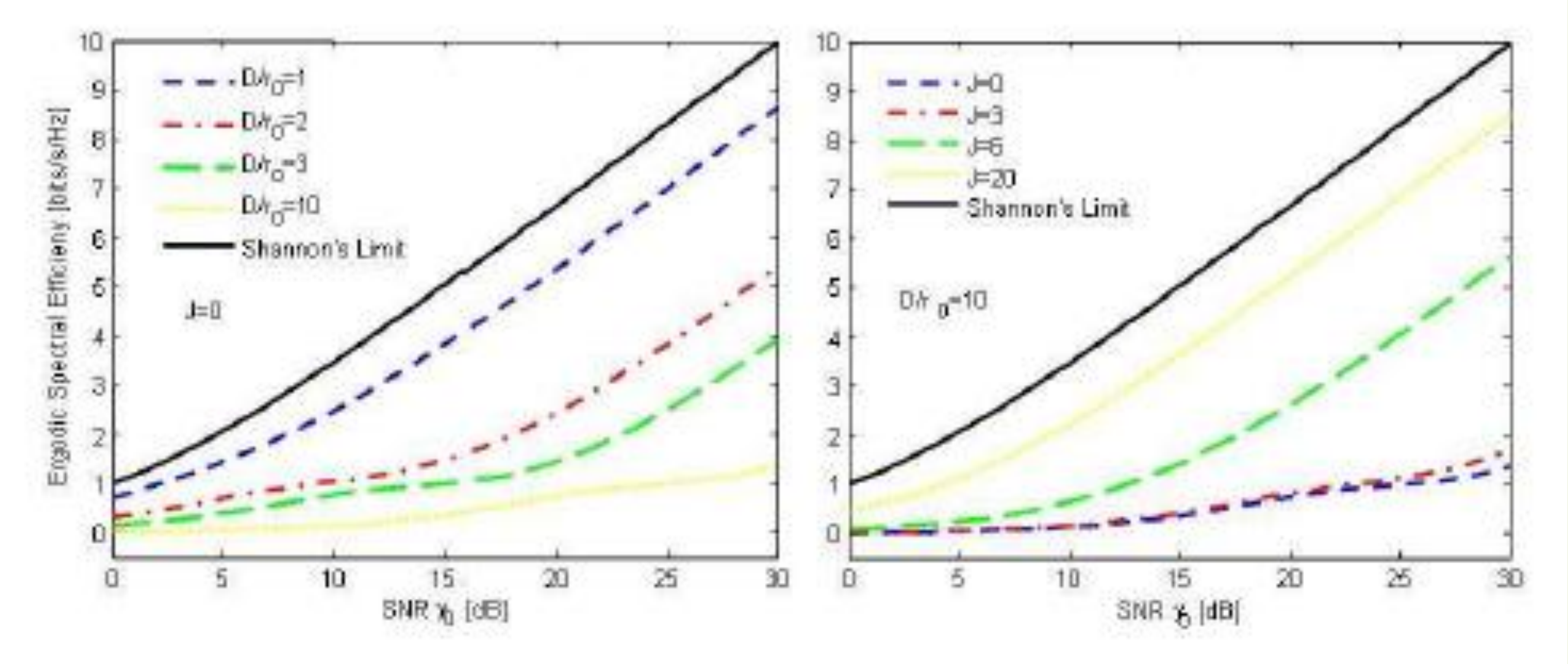
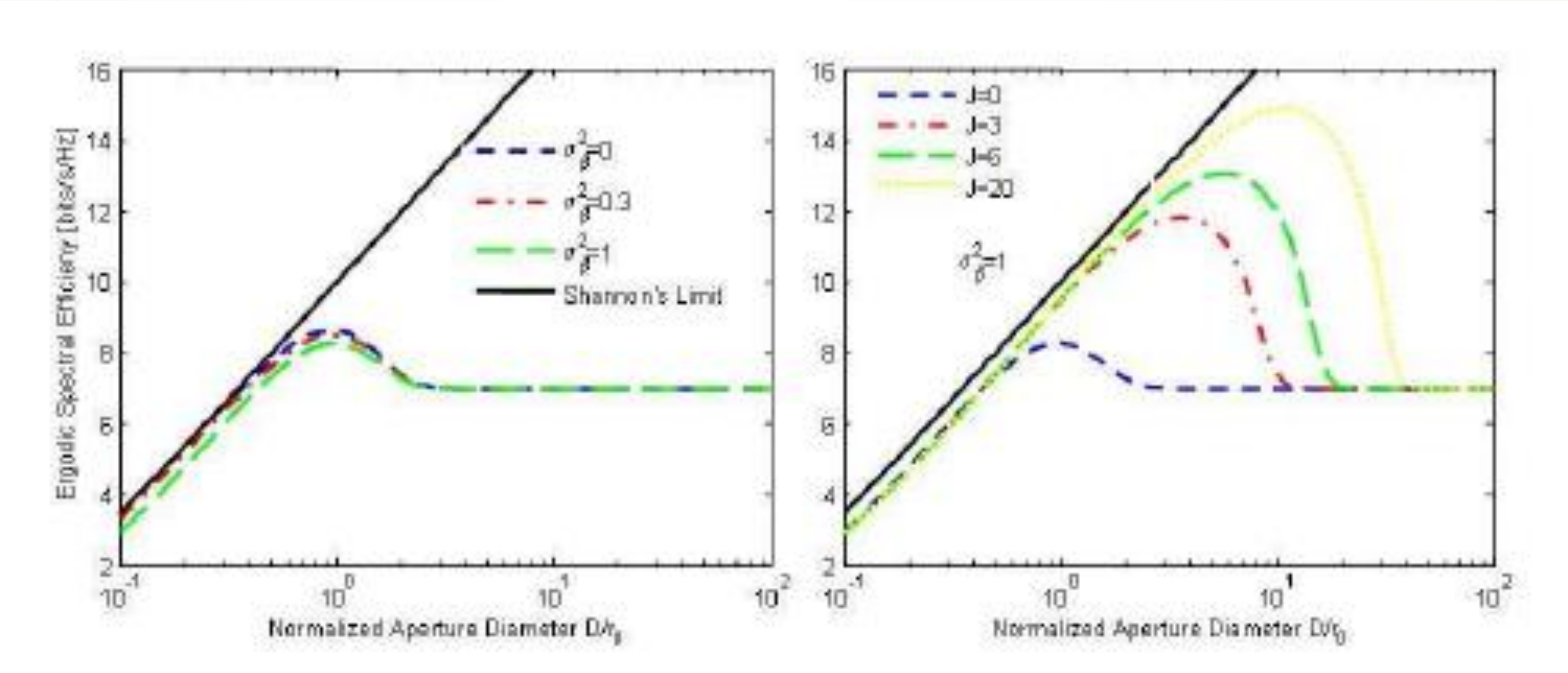


Ergodic capacity…



Ergodic capacity…



Conclusions…

- We have developed analytical expressions for the ergodic and outage capacities for free-space optical communication links using coherent detection and active modal compensation of wavefront phase distortion to overcome turbulence-induced fading. We have studied the effect of various parameters, including turbulence level, signal strength, receive aperture size, and the extent of wavefront compensation. We have separately quantified the effects of amplitude fluctuations and phase distortion, and have identified the impact of the number of modes compensated on the maximal rate at which the information may be transferred. In most situations considered, amplitude fluctuations effects become negligible, and phase distortion become the dominant effect, so phase compensation becomes effective in increasing link capacity. We have examined information-theoretic bounds on the outage capacity, and have obtained simple and tight bounds on the ergodic capacity. For typical turbulence conditions, large gains in achievable rate are realizable by correcting a fairly small number of modes and using optimum receiving aperture diameters.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