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Laser Radar Architecture
multi-Aperature v. Single aperture

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Laser Radar Architecture: Multi-Aperture vs. Single Aperture

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Introduction

- Free space optical communication and laser radar links that operate within even a thin atmosphere can exhibit severe temporal short-term fading and cause tracking difficulties that are attributed to turbulence-induced scintillation
- Various system architectures can be developed to mitigate scintillation and other atmospheric effects
  - < Increased transmitter power (may not be practical)
  - < Increased aperture size (may not be practical)
  - < Multiple small apertures at the receiver (both direct and coherent detection)

Array Receivers: Direct Detection

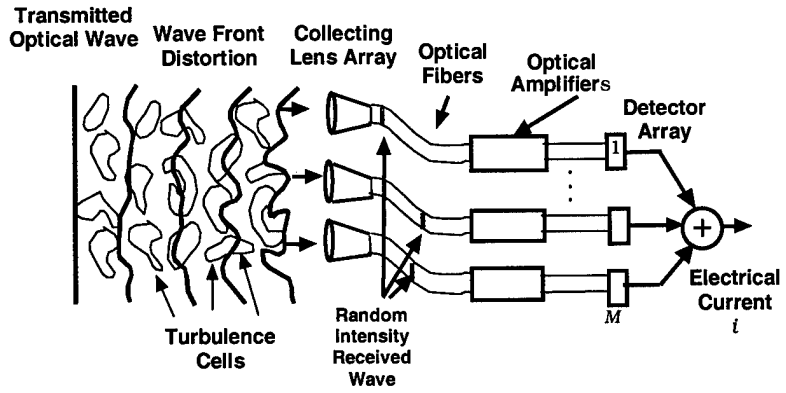


Figure 1 Array of M direct detection receivers.

Array Receivers: Direct Detection SNR

- Let the summed output of M statistically independent detectors be described by

$$i = \sum_{j=1}^{M} (i_{S,j} + i_{N,j}), \tag{1}$$

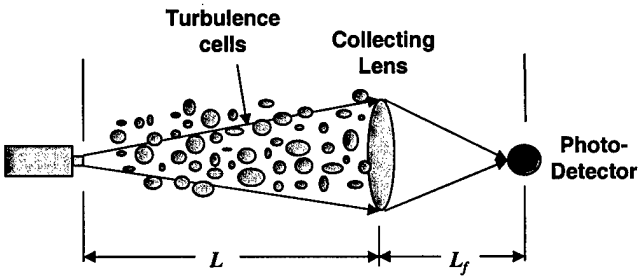
  - each i_S is a random signal and each i_N is a zero-mean noise current
  - we assume the mean and variance of each signal and noise current is identical

- It follows therefore that the *mean rms amplitude SNR* is simply

$$\langle \mathrm{SNR}_M \rangle = \frac{M \langle i_{S,1} \rangle}{\sqrt{M}\, \sigma_{N,1}} = \sqrt{M} \langle \mathrm{SNR}_1 \rangle, \tag{2}$$

where $\langle \mathrm{SNR}_1 \rangle$ is the mean SNR of a single detector.

Direct Detection: Aperture Averaging



- The reduction in scintillation with increasing telescope collecting diameter *D*, called *aperture averaging*, can be deduced from the normalized power fluctuations *P* over the area of the collecting aperture lens, i.e.,

$$\sigma_I^2(D) = \frac{\langle P^2 \rangle - \langle P \rangle^2}{\langle P \rangle^2}$$

Array Receivers: Direct Detection

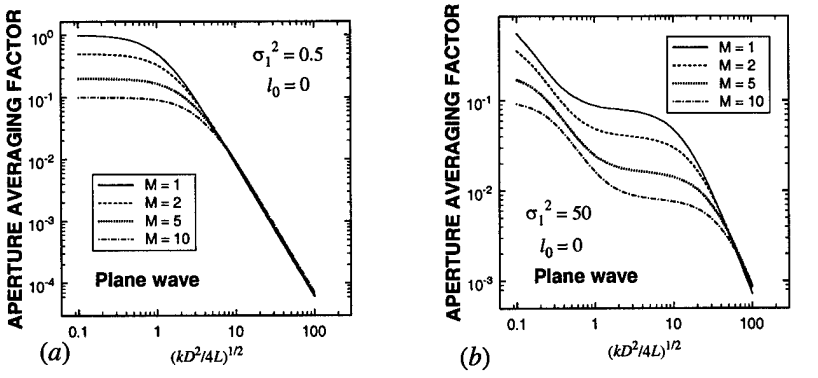


Figure 2 Predicted aperture averaging factor in (*a*) *weak irradiance fluctuations* and (*b*) *strong fluctuations*. ($\sigma_1^2 = 1.23 C_n^2 k^{7/6} L^{11/6}$)

NOTE: The glass area of the M collecting lenses is the same as that of the single large lens and inner scale $l_0 = 0$.

Array Receivers: Coherent Detection

Three common multiple-receiver architectures are the following:

- **Selection combining**
  - signal from receiver with largest SNR is switched to output (all others discarded)
  - simplest architecture but does little to improve SNR
- **Maximal-ratio (MR) combining**
  - RF signals are co-phased, have their amplitudes adjusted, and adjusted signals summed to generate composite signal
  - considered optimal design but requires major effort in instrumentation to achieve proper weighting factors
- **Equal-gain (EG) combining**
  - equal gains are applied to all RF signals
  - only the phase is adjusted to match signal field
  - performance close to that of MR receiver

Array Receivers: Coherent Detection SNR

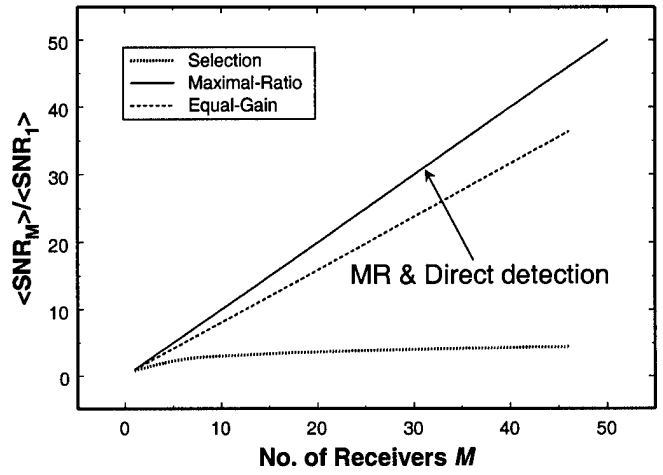


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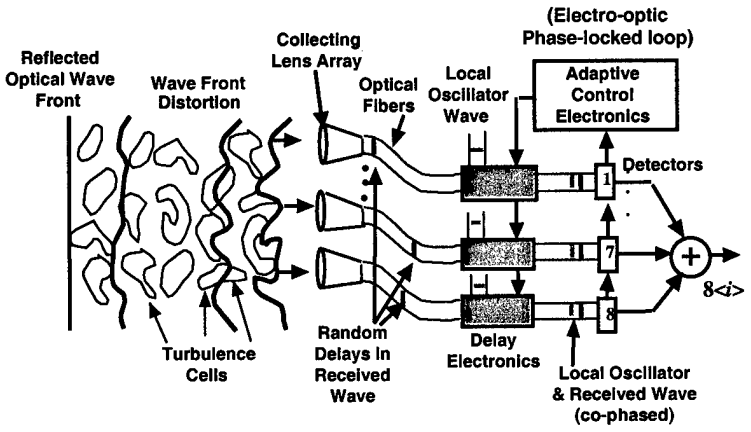
Diagram of EG Coherent Array Receiver



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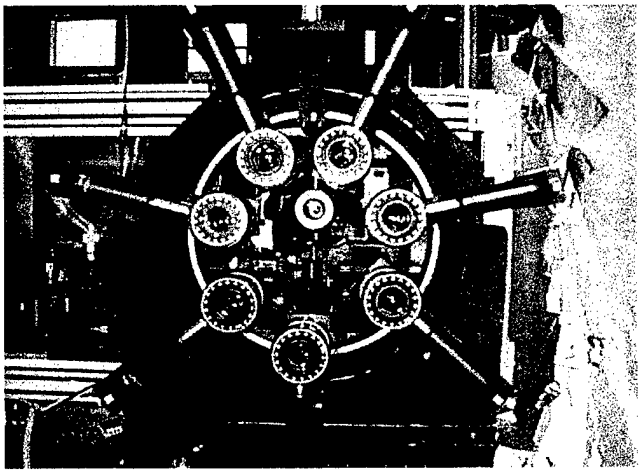
EG Coherent Array Receiver



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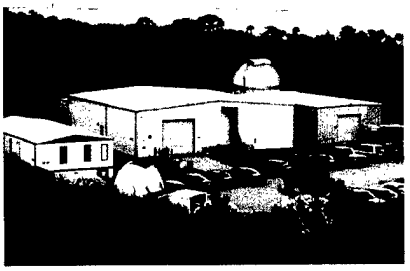
ISTEF Site

(BMDO Innovative Science and Technology Experimentation Facility)



- **ISTEF brings together electro-optics, sensors, and lasers developed for experiments observing launches, etc. at KSC**
- **ISTEF site at sea level with 1 km and 12.5 km ranges**
- **ISTEF operated by Nichols Research**

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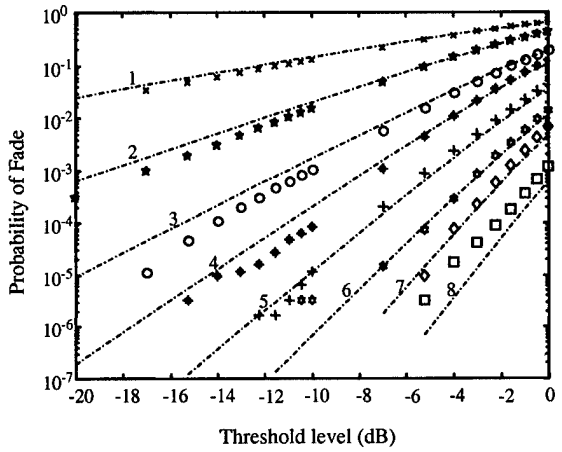
ISTEF Experiment: EG Coherent Array