Loan Radar Architecture
Multi- aperture vs. Single aperture

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LOAN DOCUMENT
Laser Radar Architecture:
Multi-Aperture vs. Single Aperture

Ronald L. Phillips, Director
Florida Space Institute
University of Central Florida
Kennedy Space Center
E-mail: phillips@creol.ucf.edu

Larry C. Andrews
Department of Mathematics and
School of Optics/CREOL
University of Central Florida
E-mail: landrews@pegasus.cc.ucf.edu
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

$$i = \sum_{i=1}^{M} (i_{ij} \% i_{j})$$

- each $i_{ij}$ is a random signal and each $i_{j}$ 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

$$\langle SNR_{M} \rangle = \frac{M \langle i_{ij} \rangle}{\sqrt{M} \langle i_{j} \rangle}$$

where $\langle SNR_{i} \rangle$ 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.,

$$
\delta_i^2(D) \approx \frac{\langle P^2 \rangle - \langle P \rangle^2}{\langle P \rangle^2}
$$
Array Receivers: Direct Detection

Figure 2 Predicted aperture averaging factor in (a) weak irradiance fluctuations and (b) strong fluctuations. ($\sigma_i^2 = 1.23C_n^2 k^2 L_1^{1/5}$)

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

![Graph showing SNR vs. number of receivers](image)

- Selection
- Maximal-Ratio
- Equal-Gain

MR & Direct detection
Diagram of EG Coherent Array Receiver

Reflected Optical Wave Front
Wave Front Distortion
Turbulence Cells
Collecting Lens Array
Optical Fibers
Random Delays in Received Wave
Local Oscillator Wave
Delay Electronics
Local Oscillator & Received Wave (co-phased)
Adaptive Control Electronics
(Electro-optic Phase-locked loop)
Detectors
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
ISTEF Experiment:
EG Coherent Array