OPTICAL ARRAY RECEIVERS FOR DEEP-SPACE COMMUNICATION

V. Vilnrotter, C.-W. Lau, M. Srinivasan

ABSTRACT:

The theoretical foundations of an optical array receiver consisting of relatively small telescopes is developed and analyzed. It is shown that optical array receivers can be designed to perform as well as a large single aperture receiver on the ground, while enjoying significant advantages in terms of operational reliability, ease of future expansion to achieve greater capacity, and further advantages in terms of cost and implementation due to the highly parallel architecture inherent in the array design. Optical array receivers for deep-space communication applications are analyzed using the accepted modal analysis for background radiation, however the signal fields are represented using a novel aperture-plane expansion that takes into account the characteristics of atmospheric turbulence. It is shown, based on this analysis, that for ground-based reception the number of array elements can be increased without suffering any performance degradation, as long as the telescope diameters exceed the coherence-length of the atmosphere. Maximum likelihood detection of turbulence degraded signal fields using an array of telescopes, each equipped with its own focal-plane detector array to mitigate turbulence effects, is developed for the case of pulse-position modulated signals observed in the presence of background radiation. The performance of optical array receivers is then compared to single-aperture receivers with diameters ranging from 4 to 8 meters, both in the presence of turbulence relevant to ground-based reception, and in a hypothetical turbulence-free environment: it is shown that without atmospheric turbulence to "break up" the signal fields prior to detection, as would be the case in space, single-aperture receivers outperform receiver arrays whenever significant background radiation is present. However, for ground-based reception of deep-space signals, we demonstrate that the number of array elements can be as great as several thousand without incurring any performance degradation relative to a large single-aperture optical receiver.