Evaluation of Spectral Issues in Sparse Aperture Imaging Systems

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ABSTRACT

Sparse aperture telescopes represent a promising technology for increasing the effective diameter of an optical system while reducing overall weight and stowable size. Although conceptually explored in the literature for decades, the technology has only recently matured to the point of being considered potentially viable for remote sensing applications. In general, a sparse aperture system involves the synthesis of a larger effective primary aperture through the combination of separate smaller optical systems (or sub-apertures) that are phased to form a common image field. This design solution provides the opportunity for increasing the effective collection aperture size, thereby enabling detection at higher resolution while avoiding issues with fabricating a large, monolithic mirror.

The models used to date to create predictions of sparse aperture imagery typically make use of a "gray-world" assumption, where the object field is represented by a resampled black and white panchromatic image. This input is then degraded and resampled with a so-called polychromatic system optical transfer function (OTF), which is a weighted average of hundreds of quasi-monochromatic OTFs over the spectral bandpass. In reality, a physical OTF manifests a character that is spectrally dependent, exhibiting varying structure with spatial frequency (especially in the presence of optical aberrations or sub-aperture phase errors). As a result, previous simulation effort has generally not adequately addressed the potential image quality implications of the detected scene's natural spectral content.

Given the spectral variation of the sparse aperture system OTF with spatial frequency, there is some concern the traditional gray-world resampling approach may not address important features of the image quality associated with these systems, especially those involving aberrated, low-fill factor configurations under moderately low signal-to-noise (SNR) conditions. This research effort has been investigating the subject of how the image quality of a sparse aperture system varies with respect to a conventional telescope from a spectra-radiometric perspective, with emphasis on whether restored sparse aperture imagery displays deleterious spectral artifacts. In this vein, the study is exploring the image quality of multiple aperture types, including tri-arm, Golay, annular, and phased petals with a principal focus on wideband, panchromatic collection scenarios. The general theoretical approach, methodology, and preliminary prediction results acquired from the first-principles modeling effort performed to date will be presented during this discussion. The initial results acquired through this investigation seem to indicate that the imagery acquired from moderately aberrated, low-fill factor sparse aperture systems manifest spectral sensitivity that is not characteristic of filled apertures. In addition to the above, the presentation will highlight follow-on effort, which will focus on trying to further understand the sensitivity of various sparse aperture configurations to key design parameters and quantify the incidence and severity of observed spectral issues on overall image quality.

About the Presenter:

Rob Introne received his B.S. in aeronautical and astronautical engineering from the Massachusetts Institute of Technology in 1989 and an M.S. in aerospace engineering from the Georgia Institute of Technology in 1990. He has served over 13 years in the United States Air Force in a variety of technical and management roles, with a principal focus on the design and development of advanced ground-based, space-based and airborne imaging sensors. His current research at the Chester F. Carlson Center for Imaging Science has focused on the development of a spectra-radiometric model for evaluating electro-optic, sparse aperture imaging systems.