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Author: Mr. Kai Nakamura
University of Tokyo, Japan

Prof. Norihide Miyamura
Meisei University, Japan
Dr. Ryo Suzumoto
ArkEdge Space Inc., Japan
Prof. Satoshi Ikari
Department of Engineering, The University of Tokyo, Japan
Prof. Shinichi Nakasuka
University of Tokyo, Japan

ULTRA-HIGH PRECISION CONTROL METHOD USING AN EXTENDED SOURCE IMAGE FOR THE FORMATION FLYING SYNTHETIC APERTURE TELESCOPE AND ITS APPLICATION FOR TELESCOPE-POINTING CONTROLS

Abstract

The Formation Flying Synthetic Aperture Telescope has been proposed to achieve high spatial and temporal resolution in the midinfrared or visible wavelength. This concept constructs a virtual large-aperture telescope by accurately controlling a formation of 50-kg class microsatellites' positions and attitudes with ultra-high accuracy in geostationary orbit. This enables high spatial resolution while keeping continuous or frequent observations of a certain area on the Earth. Its application will include disaster monitoring such as wildfire detection.

Achieving a large virtual aperture through formation flying requires controlling the relative positions and attitudes of each satellite's optical components with an accuracy of one-tenth of the observed wavelength. This stringent requirement necessitates advanced formation flying techniques. Moreover, a significant challenge is to solve the problem of the absence of a practical, high-precision absolute ranging device that can be implemented on microsatellites.

Previous research in our group has proposed and validated a method for controlling satellites so that the point spread function obtained by imaging stars matches its theoretically optimal shape, thereby realizing the aperture configuration that can generate high-resolution images of the target. In this paper, we extend this method so that images of ground objects, not star images, can be used for tuning the configuration. Specifically, we introduce an "extended source image optimization method" that utilizes feedback from images of extended sources (whose characteristics may vary) to control the effective aperture configuration with wavelength-scale precision. The key aspect of this method is a sequence in which the degree of interference is evaluated using the image's standard deviation and power spectral density. Then, this information is fed back to adjust the relative position and attitude of the satellite's optical unit.

We have validated our proposed method through numerical simulations and an experimental testbed on the ground. This on-ground experiment is conducted to verify the numerical simulation results. We demonstrated that relative positions and attitudes can be maintained within wavelength-level accuracy by feeding back extended source images without reliance on high-precision absolute distance measurements, thereby confirming the viability of our method.

Finally, we discuss applying our method to a sequence of telescope-pointing controls required to change the observation target on the observed. Even when the viewing direction changes, our approach

maintains wavelength-level control over the satellites' relative positions and attitudes, preserving high spatial resolution while scanning the ground.