Image processing for a formation flying synthetic aperture telescope

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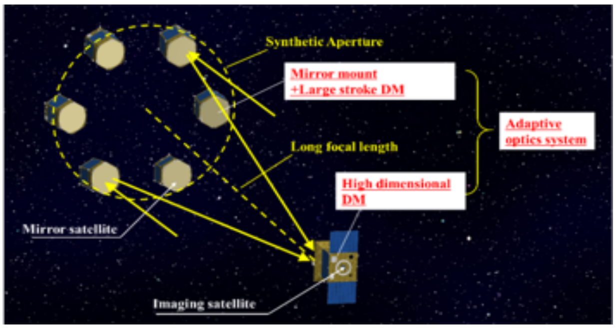
Introduction

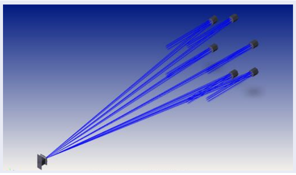
GEO remote sensing which enables observation of high temporal resolution is getting important. We propose a synthetic aperture telescope by small satellites formation flying. The synthetic aperture telescope is composed of several mirror satellites constituting a primary mirror of the telescope and an imaging satellite having a focal plane assembly. By optically synthesizing the light collected by each mirror satellite with the imaging satellite, a virtual large aperture telescope is constructed. This system is achieved through the cooperation of high-precision formation flying technology and adaptive optics technology.



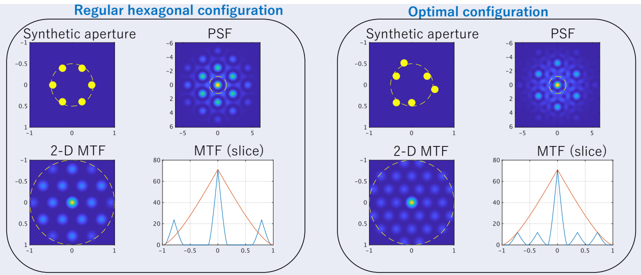
System model and optical performance of FFSAT

We consider forest fire detection as an observation target. Since the observation wavelength is longer than the visible wavelength, the accuracy required for formation flying and adaptive optics is relaxed.

Focal length [m]	21.5
Synthetic aperture diameter [m]	5.82
Pixel size [μm]	18
Number of pixels	3000×3000



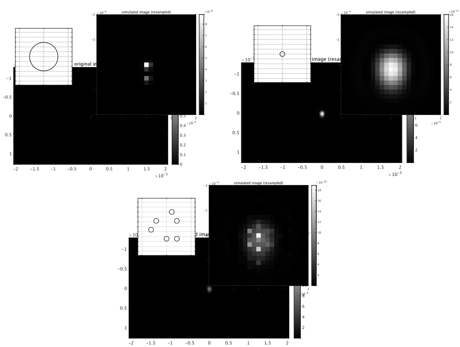
Ray tracing results when optical parameters are set in the FFSAT mechanical model. The rays are calculated results when observing a point light source on the optical axis and at infinite distance.

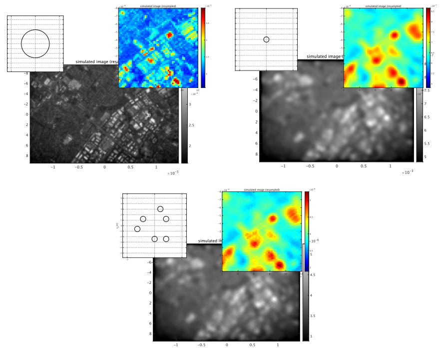


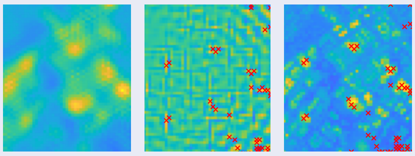
For calculating the optimal configuration, we defined the evaluation function as the area of the where the value of the MTF is below the threshold. The positions of the six mirror satellites were determined to minimize the merit function. The result was almost the same arrangement as Golay-6 configuration. Here, all spatial frequencies were weighted equally. It is possible to determine the configuration of mirror satellites that increase the MTF value for the spatial frequency region by weighting in calculating the merit function.

Simulation results of observed images and extraction of high spatial frequency information

Numerical simulation results of images observing two aligned high-intensity point sources and urban area from GEO. The two high-intensity pixels are clearly distinguishable. In urban area images, the images observed are similar to those obtained with a small-aperture telescope. However, when we focused on the details of the image, a fine structure could be observed.







The left image shows a part of the synthetic aperture image. In the middle image is the reconstructed image after applying a high-pass filter. In this image, the region with a value larger than the reference value was extracted as the region with high spatial frequency. The position of the region is indicated by the red x symbol in the figure. In addition, the extracted positions are superimposed on the image of the large aperture single mirror to show the detection results.

Summary

We proposed the synthetic aperture telescope, FFSAT, which reconstructs a virtual large-aperture telescope by arranging small-aperture mirrors in an orbit using formation flying. We have shown a method to extract this information by image processing in the spatial frequency domain, and to identify the regions in the image where the high spatial resolution information appears.