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ROTATING SYNTHETIC APERTURE SPACE TELESCOPES FOR EARTH OBSERVATION

Abstract

Optical imagery from space-based telescopes is one of the most valuable tools for understanding various large and small-scale processes on Earth. Generally, the better an instrument's ability to collect light is, the higher quality its data products are in terms of resolution and signal to noise ratio (SNR). Improvements in optical Earth imagery resolutions have plateaued since the traditional strategy for improvement has been to increase the diameter of the light collecting area of the optical telescope assembly (OTA). Larger instruments become prohibitively expensive to launch into orbit due to increased volume and mass resulting in only incremental advances. Nevertheless, as discussed in NASA's most recent Surface Topography and Vegetation decadal survey, scientists continue to seek measurements with higher spatial and temporal resolutions. A rotating synthetic aperture (RSA) telescope is a space-based observatory concept that has the potential to address measurement demands while simultaneously minimizing OTA cost. RSAs employ a high aspect ratio rectangular aperture that is spun about its principal optical axis. A complete image is formed after a 180° rotation during which multiple frames are acquired to fully sample the imaging system's optical transfer function. The first contribution of this work is to establish the utility of RSA telescopes within the context of Earth science data acquisition by presenting imaging performance comparisons with the current state of the art. Presented results showcase RSA super resolution in spatially oversampled target regions enabling image resolutions an order of magnitude greater than traditional filled-aperture systems depending on the amount of oversampling. This work's second contribution is to address a significant operational challenge in controlling the pointing dynamics of a simultaneously spinning and slewing spacecraft to the degree of accuracy required for acceptable image acquisition. This work defines the requirements for an RSA attitude determination and control system (ADCS) by modeling a variety of Earth orbiting RSA satellites using Analytical Graphics Inc. (AGI) Systems Tool Kit (STK). Imaging parameters including ground sampling distance (GSD), parallax, and SNR recorded during the simulations are used to determine RSA dynamics parameters including spin and slew rates. Spin and slew rates range from $5°/s$ to $-50°/s$ and $0.5°/s$ to $-5°/s$ respectively for a range of Earth orbital regimes. Finally, the presented results are summarized to quantify the tradeoff between increasing data product quality and easing actuator torque requirements.