Relative Navigation Performance of a Constellation of Small Satellites for Radio Astronomy about the Earth-Sun L2 Point

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When performing radio astronomy from Earth, interferometers are constrained to observing within the “radio window" that extends from frequencies of 30 MHz to 1 THz due to the Earth’s ionosphere blocking frequencies lower than this window. There are consequently few observations of the early universe at wavelengths below the 30 MHz boundary despite evidence that there is rich information on the Big Bang at these low frequencies. For a high-resolution view of the universe at these low frequencies, space-based radio interferometers must be developed that are not constrained by atmospheric transmittance and noise effects. In this paper, we explore the potential of a drifting constellation about the Earth-Sun Lagrange-2 (L2) point in a Halo to perform space-based interferometry. We first link the performance of the interferometry imaging algorithm to the ability to maintain low position and velocity uncertainties. We then develop a centralized Extended Kalman Filter (EKF) for performing inertial navigation of the L2 Halo constellation by using both inertial Deep Space Navigation (DSN) measurements and relative ranging measurements. Finally, we perform an analysis of the relative baseline position uncertainty that the interferometer is able to maintain over the course of a 180 day mission. It is found that the relative baseline uncertainty is dependent on the cadence of DSN measurements: when the DSN measurement interval is 150 seconds, the mean baseline position uncertainty for the approximately 3 km radius baseline is approximately 1.8 meters; when the DSN interval is increased to 3000 seconds, the mean baseline position uncertainty jumps to approximately 7.5 meters. The implications of these baseline uncertainties are analyzed both quantitatively and quantitatively in order to understand the implications on radio astronomy image formation.

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