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SOLARA/SARA: FIRST STEPS TOWARD A SPACE-BASED RADIO INTERFEROMETRY CONSTELLATION

Abstract

The Solar Observing Low-frequency Array for Radio Astronomy (SOLARA) and accompanying Separated Antennas Reconfigurable Array (SARA) communications system is a medium to long-term project being developed at MIT and JPL. SOLARA is a space-based sparse aperture radio telescope capable of aperture synthesis imaging in the spectral region between 300 kHz and 20 MHz. This spectral band is below the ionospheric cut-off, so astronomical signals in this range cannot be observed from the surface of the Earth. Interferometry is required to obtain reasonable angular resolution at long wavelengths, so SOLARA will be composed of multiple CubeSat-sized spacecraft flying in loose formation. Relaxed baseline measurement requirements at long wavelengths (cm to m) compared to higher frequency radio interferometry (micron to mm) or optical interferometry (nm) make this a tractable problem for CubeSats. Furthermore, tight formation flight is not required if baselines between spacecraft do not change significantly during integration times (seconds to minutes). SOLARA will focus primarily on observations of the sun and space weather as well as magnetospheric radio emission from the Earth and the giant planets.

This paper presents initial analysis of the mission concept as well as more detailed studies of the beam pattern of the interferometer. A novel inter-satellite and constellation-to-ground communication architecture (SARA) is also presented in detail. SARA will use the SOLARA constellation as a platform to test a MIMO antenna system in space by phase-combining S-band signals from each spacecraft into a single beam with much higher gain than the individual spacecraft. The SARA system will significantly increase the data rate from the constellation to the ground even without bulky directional antennas on each CubeSat.

In addition to the system concept, radio science, and communications system, this paper presents a path to the full constellation involving precursor missions to demonstrate key technologies for SOLARA/SARA. The first precursor mission will demonstrate an electric propulsion system which will be used for SOLARA's constellation management and attitude control. The second precursor mission is a Low-Earth orbit demonstration mission composed of two to three spacecraft. The second precursor mission will validate the radio science payload, SARA system, and constellation maintenance control algorithms.