SEAMS-Space Electric and Magnetic Sensor Mission

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Radio interferometry in astronomy combines signals from multiple telescopes to improve resolution and sensitivity. However, ground-based interferometers face challenges such as atmospheric interference and telescope alignment issues. Space-based interferometry missions like Orbiting stellar interferometer for astrometry and imaging, Darwin, SPECS, AERO and VISTA, and FARSIDE operate above Earth's atmosphere, offering optimal observing conditions. CubeSats are cost-effective and compact, can be used with tethers to form stable interferometer systems. Notable CubeSat missions include MAST. These advancements aim to revolutionize astronomical observations by enabling detailed, accurate high-resolution data collection. The SEAMS project introduces an innovative CubeSat mission designed to advance radio interferometry capabilities in Low Earth Orbit (LEO) while tackling challenges associated with Radio Frequency Interference (RFI) detection. The project utilizes CubeSat technology to explore applications in radio astronomy and prepare for future interferometric missions beyond Earth's immediate vicinity. Phase 1 aims to deploy a CubeSat-based radio telescope equipped with electric field vector sensors. Operating between 300 kHz and 16 MHz, this phase focuses on establishing RF front-end components capable of identifying RFI originating from Earth, as well as celestial phenomena such as Auroral Kilometric Radiation (AKR) and solar bursts. The utilization of Commercial Off-The-Shelf (COTS) components aims to reduce costs and streamline upgrades for subsequent missions, demonstrating the feasibility of CubeSats for space-based radio astronomy and validating essential technologies for interferometric applications in LEO. The Phase 2 aims to expand interferometric capabilities beyond LEO by proposing the establishment of an interferometric array on the far side of the Moon i.e. at the L2 Lagrange point. This phase seeks to mitigate Earth-originating RFI and enhance interferometric precision for detailed radio source measurements and astronomical observations. By leveraging platforms positioned away from Earth, Phase 2 aims to achieve higher resolution and sensitivity in radio interferometry.

Inspired from the phase two of the SEAMS a unique tethered CubeSat system designed to demonstrate two-element radio interferometry in LEO. This system consists of a 2U Main Satellite serving as the central hub housing critical subsystems such as the On-Board Computer (OBC), power management unit, communication unit, and processing unit. Integrated with a Lime-SDR USB software-defined radio, it facilitates the reception, digitization, and processing of radio frequency signals. Additionally, a 1U Deployable Sub-satellite equipped with a secondary patch antenna optimized for interferometric operations connects to the main satellite via a deployable tether, enabling interferometry up to 5 meters from the main satellite. To ensure structural integrity and thermal management across various CubeSat configurations (1U and 2U), Finite Element Analysis has been conducted. ANSYS simulations have validated the system's robustness under launch conditions and its ability to efficiently manage thermal regulation, maintaining operational temperatures within safe limits. The RFRI integrated into the CubeSat system includes a patch antenna tuned to 1.42 GHz, coupled with a Low Noise Amplifier (LNA) and Band Pass Filter (BPF) for signal enhancement and filtering. The digital backend utilizes GNU Radio scripts with Lime-SDR USB for functions such as FFT and data averaging, essential for refining and storing collected data. Field tests have confirmed the system's capability to differentiate signal clarity in controlled (anechoic chamber) and real-world (outdoor) environments, validating its readiness for flight and its potential to advance radio interferometry in space.

References

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