

300-900 MHz Beamforming Array for the Lunar Farside Technosignature and Transient Telescope (LFT3)

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The Lunar Farside Technosignatures and Transients Telescope (LFT3) will search the lunar sky for radio emissions from known and unknown sources and create an unprecedented historical record of radio observations on the moon. The lunar farside offers a unique environment to measure radiation from the Universe with essentially zero radio frequency interference. An early design study of LFT3 is being conducted under the auspices of Breakthrough Listen, one of the Breakthrough Initiatives. LFT3 will operate continuously for 100 weeks through both lunar day and night and will feature a sensor array spanning 300-900 MHz and single antennas for 1-50 MHz, 60-110 MHz and 900-2700 MHz. The 300-900 MHz midband array on the lander top surface will form multiple beams on the lunar sky. Design requirements include low power operation, physical size within lander constraints, and high sensitivity.

The proposed design for the midband array consists of 48 dual-polarized Vivaldi antenna elements. The array element design was prototyped as antipodal Vivaldi antennas on PCB substrate. The final antenna will be a modified version of the dual-polarized Vivaldi feed used for the HERA instrument [N. Fagnoni et al., “Design of the New Wideband Vivaldi Feed for the HERA Radio-Telescope Phase II,” IEEE Trans. Ant. Propag., Vol. 69, no. 12, pp. 8143-8157, Dec. 2021]. Array elements are connected via a transmission line with high thermal resistivity to a low-noise amplifier gain stage. To avoid the nontrivial power consumption of a digital beamformer, the preferred design uses an analog beamformer. The array design has 48 dual polarized elements and the beamformer combines amplified element outputs into 11 x 2 beam outputs. Formed beams are aligned along a fan pattern that rotates across the sky over the course of a lunar day. The array geometry was optimized to achieve high beam sensitivity and low sidelobes. To reduce the complexity of the beamformer, the element locations were constrained so that elements are located in rows in the cross-beam direction.

The analog beamformer is the major new technology development effort for the array. The obvious approach is a combiner tree architecture with meander line phase delays integrated on one PCB per beam, but this would require 22 beamformer boards and power splitters to distribute signals from the array to the beamformers. To reduce the size of the brute force combiner tree, a Blass matrix design that combines the beamformers into one board is in development. Other designs were considered including a Rotman lens on high dielectric constant substrate but likely not feasible due to the large required size.

Leveraging the spectrometer developed for the LuSEE-Night lander (to be launched early next year), signals from the midband array and other antennas on the lander will be downconverted to a 50 MHz bandwidth tuned in steps over the 300-900 MHz midband array operating frequency. A multichannel digitizer and FPGA-based spectrometer will be used to compute frequency spectra for transmission to a lunar orbiter and downlinking to earth. The spectrometer will operate in full mode during lunar day and a reduced power mode during lunar night. Spectra will be computed for 50 MHz subbands with a high resolution (on the order of 1 kHz), specifically targeting technosignature searches. The spectrometer will be prototyped using an FPGA board based on the Collaboration for Astronomy Signal Processing and Electronics Research (CASPER) toolflow.