A Low-Power 64x64 ASIC 2-Bit Digital Correlator

David C. Austerberry, Darren S. McKague, Christopher S. Ruf
University of Michigan, Ann Arbor, MI, USA

The massively parallel high-speed correlators required for Fourier aperture synthesis can be among the primary drivers of power consumption in synthetic thinned-aperture radiometers. Power consumption by digital correlation operations among upwards of thousands of input pairs using FPGA architecture is a significant burden for existing ground-based systems and prohibitively high for satellite-based systems. For example, the ALMA telescope correlates among 66 antennas. The proposed Geostationary Synthetic Thinned Aperture Radiometer (GeoSTAR) for atmospheric microwave sounding would correlate a Y-array with 128 receivers per arm, which necessitates efficiency on the order of hundreds of microwatts per correlator element. A 2-bit digital correlator using an ASIC platform has been designed for use in a GeoSTAR prototype. An efficiency of less than 800 μW/correlation cell over a 64x64 cross-correlation matrix in a 21mm x 21mm BGA package makes the chip adaptable to variety of synthetic aperture radiometry applications where very low power consumption is required.

The chip digitizes and cross-correlates the 4,096 input pairs each clock cycle with a nominal clock speed of 1 GHz in an adjustable integration period, nominally 10 milliseconds. Several performance figures of merit are highly relevant to the NEΔT of synthetized T_B images. High correlation efficiency of mapped analog correlations is required, along with a flat frequency response across the IF passband. In addition, isolation between neighboring input channels must be sufficiently high. We present test procedures and results used to evaluate these figures of merit using a custom, arbitrary waveform generator-based means of creating analog input signals. Correlation efficiencies of 97 to 98% are observed for an input power level of -25 dBm. Frequency response is nearly flat, with 0.5 dB of ripple across the 10 to 500 MHz IF band. Isolation is better than 50 dB for nearest corner-neighbor correlator elements, and varies between 24 and 40 dB for nearest adjacent-neighbor correlator elements. Forthcoming tests on a fully-functioned test board will determine whether the observed cross-talk occurs on the test board or within the correlator chip.

GeoSTAR is designed for full Earth disk all-weather temperature and humidity soundings with spatial resolution matching existing low Earth orbit microwave sounders. This requires very large correlator arrays achievable through synchronous operation of multiple correlator chips. The GeoSTAR prototype will use four 64x64 chips for an effective 128x128 correlator. Other arrangements of the chip present potential applications in large ground-based phased-array radio telescopes and other remote sensing applications in planetary and Earth sciences.