Second Annual
Earth Science Technology
Conference (ESTC-2)

Pasadena, CA
June 11-13, 2002

Synthetic Thinned Aperture Radiometry (STAR) Technologies Enabling 10-km Soil Moisture Remote Sensing from Space

J.R. Piepmeier[1], F.A. Pellerano[1], P. O'Neill[2], D. LeVine[3], E. Kim[3], T. Doiron[1]
NASA's Goddard Space Flight Center
[1]Microwave Instrument Technology Branch/555
[2]Hydrological Sciences Branch/974
[3]Microwave Sensors Branch/975
Greenbelt, MD 20771

***Abstract* - Remote sensing of soil moisture at 1.4 GHz at 10-km spatial resolution from space requires the use of very large radiometer apertures (>20 m). Synthetic thinned aperture radiometry (STAR) is a viable solution to the large aperture problem, and several technologies are being developed to enable a spaceflight STAR instrument. The primary motivation for the development is a reduction in power and size, which is achieved by using low power microelectronics, including silicon germanium (SiGe) and ultra low power (ULP) CMOS. STAR system architecture, SiGe microwave radiometer receivers, ULP digital correlators, and calibration are discussed.**

I. INTRODUCTION

NASA's Earth Science Enterprise and the hydrology community are focused on achieving a 10-km spatial resolution global soil moisture mission towards the end of the decade. This type of resolution represents a significant technological challenge. Observation of soil moisture is based on relatively low frequency thermal microwave emission at L-band (1.4 GHz). The long wavelengths at this frequency coupled with the high spatial and radiometric resolutions required necessitates the use of very large apertures (>20 m) [1, 2].

An engineering trade study was completed by NASA Goddard Space Flight Center (GSFC) to determine alternative system configurations that could achieve the science requirements and to identify the most appropriate technology investments and development path for NASA to pursue in order to bring about such a mission [1]. The conclusion of this study was that Synthetic Thinned Aperture Radiometry (STAR) is the most promising technology to enable these very large non-rotating apertures in space. In this technique, the coherent product (correlation) of the signal from pairs of antennas is measured at different antenna-pair spacings (baselines). These products yield sample points in the Fourier transform of the brightness temperature map of the scene, and the scene itself is reconstructed by inverting the sampled transform [3]. The reconstructed image includes all of the pixels in the entire field-of-view of the antennas.

The main advantage of the STAR architecture is that it requires no mechanical scanning of the antenna. Using a static antenna simplifies the spacecraft dynamics and improves the time-bandwidth product of the radiometer. Furthermore, aperture thinning reduces the overall volume and mass of the instrument. A disadvantage is the reduction of radiometric sensitivity (or increase in rms noise) of the image due to a decrease in signal-to-noise for each measurement compared to a filled aperture. Pixel averaging is required for good radiometric sensitivity.

In essence, we are trading a nearly intractable mechanical problem for a tractable electrical one. Because a large STAR radiometer uses many receivers and correlators, the primary objective of our technology development has been to drive down electrical power dissipation, volume and mass. We accomplish this goal through the innovative use of low power microelectronics, including silicon germanium (SiGe) and ultra low power CMOS (ULP CMOS), for microwave receivers, analog-to-digital converters, and digital correlators. In addition, we are studying system architecture issues such as correlated calibration sources and signal distribution.

II. SYSTEM TECHNOLOGY

Technology development for the 10-km soil moisture remote sensing problem began with two investigations. First, a concept was developed for a space-based instrument through a science-driven architecture study [1]. From this study, engineering constraints were derived that motivated several component technology developments. Second, an aircraft instrument was developed to validate the two-dimensional STAR technique for soil moisture remote sensing [4]. The instrument is a research tool that will be used to address remote sensing and instrument systems engineering issues associated with development of a spaceflight STAR instrument.

IV. FUTURE TECHNOLOGY AND SUMMARY

Several technologies motivated by science-driven system studies for 10-km soil moisture remote sensing from space have been presented. The primary developmental drivers are low power and size requirements, which are met using state-of-the-art microelectronics and sensible system design. The next steps needed to advance towards a flight instrument have been proposed and include an integrated panel of SiGe receivers and antennas, the study of a fully integrated SiGe RF-digital receiver-on-a-chip, and the appropriate demonstration of a deployable STAR arm either on the ground or in space. These developments are on-track for a soil moisture mission launch in ~2008.