P5A.2

A Radar/Radiometer Instrument for Mapping Soil Moisture and Ocean Salinity

Peter H. Hildebrand, Laurence Hilliard, Rafael Rincon, David Le Vine
NASA Goddard Space Flight Center, Greenbelt, MD 20771
and
James Mead
ProSensing Corp, Amherst, MA

1. INTRODUCTION

The RadSTAR instrument combines an L-band, digital beam-forming radar with an L-band synthetic aperture, thinned array (STAR) radiometer. The RadSTAR development will support NASA Earth science goals by developing a novel, L-band scatterometer/ radiometer that measures Earth surface bulk material properties (surface emissions and backscatter) as well as surface characteristics (backscatter).

Present, real aperture airborne L-Band active/passive measurement systems such as the JPL/PALS (Wilson, et al, 2000) provide excellent sampling characteristics, but have no scanning capabilities, and are extremely large; the huge JPL/PALS horn requires a the C-130 airborne platform, operated with the aft loading door open during flight operation. The approach used for the upcoming Aquarius ocean salinity mission or the proposed Hydros soil mission use real apertures with multiple fixed beams or scanning beams. For real aperture instruments, there is no upgrade path to scanning over a broad swath, except rotation of the whole aperture, which is an approach with obvious difficulties as aperture size increases. RadSTAR will provide polarimetric scatterometer and radiometer measurements over a wide swath, in a highly space-efficient configuration. The electronic scanning approaches provided through STAR technology and digital beam forming will enable the large L-band aperture to scan efficiently over a very wide swath.

RadSTAR technology development, which merges an interferometric radiometer with a digital beam forming scatterometer, is an important step in the path to space for an L-band scatterometer/radiometer. RadSTAR couples a patch array antenna with a 1.26 GHz digital beam forming radar scatterometer and a 1.4 GHz STAR radiometer to provide Earth surface backscatter and emission measurements in a compact, cross-track scanning instrument with no moving parts. This technology will provide the first L-band, emission and backscatter measurements in a compact aircraft instrument and will be ideally suited to large apertures, possibly at GEO, and could possibly be implemented on a swarm of micro-satellites. This instrument will have wide application for validation studies, and will have application for other microwave frequencies.

2. SCIENCE GOALS

The RadSTAR instrument is designed to map soil moisture and ocean salinity, both important components of the water cycle. The instrument will also map sea ice density and thickness—an important factor in ocean-atmosphere heat exchange in polar regions.

Soil moisture is an important component of the water cycle; soil moisture measurements are necessary for understanding and predictions of vegetation and ecosystem health, and are strong factors in the prediction of regional precipitation on monthly to seasonal time scales. Measurement of soil moisture is based on observation of the microwave emission from the soil, which is a function of soil moisture and temperature. The measurements of soil moisture are required through the root zone, or down about 20 cm. Since soil penetration depth is proportional to wavelength, the longest practical wavelength, here L-band, is preferred. The L-band backscatter measurements measure soil and terrain roughness and biomass; additional components of the microwave emission. Evaluation of different components of the soil and biomass can therefore be provided through use of both backscatter and emission observations and through measurement of the polarization components of the signals.

Sea surface salinity measurements are also important aspects of the water cycle. When added to knowledge of oceanic precipitation, salinity provides

[1] *Corresponding author address:* Peter Hildebrand, NASA Goddard Space Flight Center, Greenbelt, MD 20771, 301-614-5671, peter.hildebrand@nasa.gov.

the potential to estimating oceanic evaporation. Salinity is also a strong forcing factor in the oceanic thermo-haline circulation; thereby climate variability. As with soil moisture, the microwave emission from the sea surface is a function of sea surface salinity and temperature, and is also a function of sea surface roughness. The combined RadSTAR observations of backscatter and emission, plus observations of SST, thus provide the needed basis for evaluating salinity. In the case of ocean salinity, the variability of the surface emission peaks at wavelengths near L-band; therefore, the protected 1.4 GHz wavelength is frequently chosen for this measurement.

RadSTAR science applications goals also include measurement of sea ice thickness. Sea ice thickness has a strong role in determining heat exchange, and subsequently ice production or melting, and for brine / freshwater release. The brine rejection from sea ice formation is, in turn, a critical force in the global thermo-haline circulation. The approach to measuring sea ice cover takes advantage of the variability in emissive and backscatter properties of sea ice with ice thickness and ice pack concentration. The depth to which microwave energy penetrates into sea ice increases with wavelength, thus making L-band an attractive frequency.

3. INSTRUMENT DESIGN CONCEPT

The goal of the project is to build a combined scatterometer and radiometer system capable of making *concurrent* measurements of radar cross-section and radiometric brightness temperature from *a common target*. The RadSTAR design approach shares a single array of patch antenna elements by the 1.26 and 1.4 GHz instruments. The goal of a compact instrument with matched beams and cross-track scanning will enable mapping of Earth surface characteristics while over-flying areas of interest in an airplane or spacecraft. Due to the long wavelength, development of a compact instrument is a significant design consideration, either for airborne operation or for eventual use in space.

The RadSTAR system employs a dual-polarization (horizontal and vertical) microstrip patch array antenna with a wide operational bandwidth to accommodate the 1.26 GHz radar and the 1.4 GHz radiometer. This type of antenna has been implemented on the GSFC ESTAR radiometer systems (Le Vine, 1999), but will be upgraded for wider bandwidth operation. Design issues relate to the details of the beam pattern resulting from the different frequencies of the two systems with the distributed array antenna, and the goal of having a high beam efficiency and matched beams.

The RadSTAR design will make use of digital beam-sharpening techniques for the radar measurements. The system will provide a dynamic range of 70 dB for the radar cross section measurements and a sensitivity of 1 K in T_b measurements to meet the different scientific measurement requirements for sea ice and snow pack measurements. The radar electronics will control the amplitude and phase of the signal at each antenna subarray to form a focused beam over scan angles of $\pm$ 50 degrees such that the radar swath will match that of the radiometer.

The RadSTAR radar system will consist of eight transmit channels driven by a pulsed modulated 1.26 GHz signal. The 1.26 GHz local Oscillator will be phase-locked to a 20 MHz ultra-stable crystal oscillator to achieve high amplitude and phase stability. The 1.26 GHz modulated signal will be equally divided among the eight channels before transmission. Each transmitter channel will incorporate a transmit/ receive module, containing a solid sate power amplifier, an 8-bit digital attenuator, and a 10-bit digital phase-shifter. Electronic beam scanning and beam sharpening at each angle scan will be performed in transmit mode by independently controlling the amplitude and phase of the modulated signal at each transmit channel.

The RadSTAR radiometer system's beam pattern can be closely matched if the scatterometer operates by illuminating the full scan swath on transmit, and then digitally forming the multiple beams on receive. Alternative approaches to the waveform and to signal processing will also be evaluated. The RadSTAR system will share front-end microwave hardware components and the data system unit. The data system will consist of digital receivers and a Field Programmable Gate Array processor, which will enable the implementation of a variety of digital beam forming algorithms.

A RadSTAR proof-of-concept aircraft instrument is currently nearing completion. It is designed for flight operation on the NASA P-3 or other aircraft at altitudes up to 8 km. RadSTAR improves on existing microwave technology through development of a combined scatterometer/ radiometer instrument system with an electronic scanning approach that is excellently suited for a very large aperture. This development will enable construction of highly compact instruments for space and airborne application.