ADVANCED COMPONENT DEVELOPMENT TO ENABLE LOW-MASS, LOW-POWER HIGH-FREQUENCY MICROWAVE RADIOMETERS FOR COASTAL WET-TROPOSPHERIC CORRECTION ON SWOT

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Introduction

Critical microwave component and receiver technologies are under development to reduce the risk, cost, volume, mass, and development time for a high-frequency microwave radiometer that is needed to enable wet-tropospheric correction in the coastal zone on the NRC Decadal Survey-recommended Surface Water and Ocean Topography (SWOT) Mission.

Scientific Motivation

Current satellite ocean altimeters include a nadir-viewing, co-located 18-37 GHz multi-channel microwave radiometer to measure wet-tropospheric path delay. Due to the large diameters of the surface instantaneous fields of view (IFOV) at these frequencies, the accuracy of wet path retrievals begins to degrade at approximately 50 km from the coasts. Conventional microwave radiometers do not provide wet path delay over land. In order to meet the needs of the recommended SWOT mission, higher-frequency microwave channels need to be added to the JASON-class radiometers in order to improve retrievals of wet-tropospheric delay in coastal areas and to increase the potential for over-land retrievals.

This concept is summarized as follows. Over the open ocean, where spatial resolution is not as critical, only the low-frequency brightness temperatures (TBs) would be needed, and the path-delay retrieval performance would be equivalent to that of current space-based altimeters, better than 1 cm RMS. As the radiometer approaches land, the low-frequency TBs will be contaminated by the coastline, and the high-frequency TBs will be used to extrapolate the path delay from the last uncontaminated ocean pixel to the coast. Extrapolation methods have been commonly used by investigators seeking estimates of the path delay near the coast [1]. In general, the nearest uncontaminated pixel > 50 km from the coast is fit by a linear or higher-order polynomial and used to extrapolate the path delay to the coast. This technique will suffer from large errors in the presence of large water vapor gradients near the coast. The high-frequency extrapolation technique is similar, but it has the advantage that additional water vapor information with finer spatial resolution is provided by the high-frequency radiometer measurements.

In related SWOT activities, a mission concept study is being performed in which a radiometer simulator and a coupled, high-resolution Weather Research and Forecasting (WRF) model are being implemented to assess retrieval performance and determine instrument requirements. As shown in Figure 1, simulation results show that the path delay errors using solely 18-37 GHz radiometer channels increase substantially at closer than 40 km from the coast. However, the addition of 90-170 GHz radiometer channels improves the path delay errors to about 0.5 cm. In addition, the performance of a 183-GHz sounding radiometer for over-land retrievals was assessed using a Bayesian retrieval algorithm over land and over ocean. NCEP model fields were used to generate simulated global 183 GHz brightness temperatures, and errors were binned as a function of path delay (PD). RMS errors over land were approximately 2.5 cm, and over ocean or large water bodies vary from 0.5 cm at low PDs to 2 cm at high PDs.

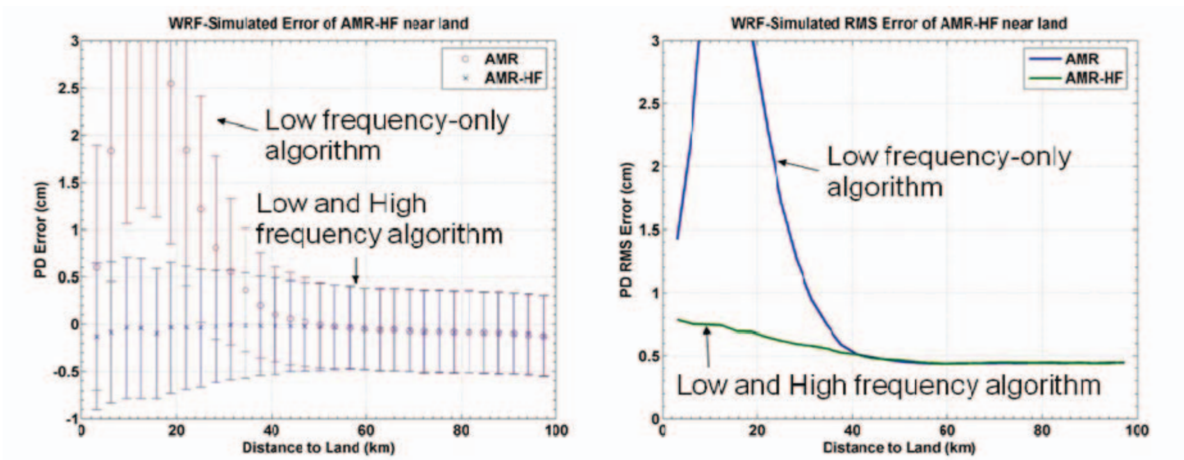

Figure 1. High-resolution WRF model results show reduced wet path-delay error using both low-frequency (18-37 GHz) and high-frequency (90-170 GHz) radiometer channels.

Advanced Component Development for SWOT Radiometers

Development of a new high-frequency radiometer measurement technique for SWOT requires key technology developments in both: (1) a low-power, low-mass and small-volume direct-detection millimeter-wave radiometer with integrated calibration sources covering frequencies from 90 to 180 GHz that fits within the overall SWOT mission constraints, and (2) a multi-frequency feed horn covering the same frequency range. This involves scaling the design of the Advanced Microwave Radiometer (AMR) currently on the OSTM/Jason-2 altimetry mission. The MMIC-based AMR receiver has three integrated radiometer channels at 18.7, 23.8 and 34.0 GHz and a single multi-frequency feed horn.

Radiometer System Design

The new components being developed under this program will be integrated into a MMIC-based low-mass, low-power, small-volume radiometer at 92, 130 and 166 GHz, as shown in Figure 2. This radiometer will serve as a breadboard demonstration, providing realistic mass, volume and power estimates to feed into the mission concept study.

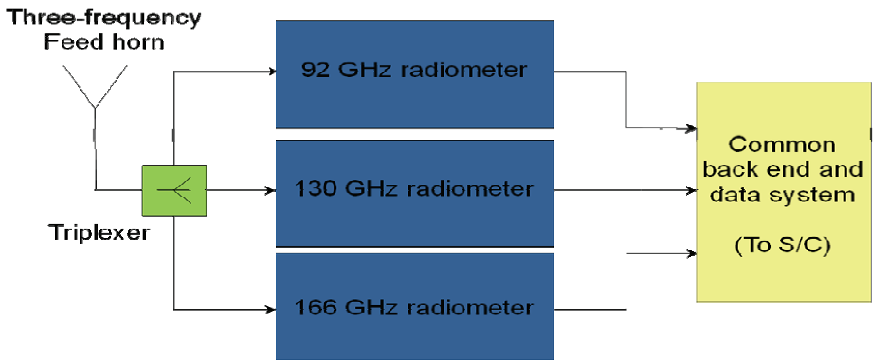

Figure 2. High-frequency demonstration radiometer system block diagram

The passive components for this radiometer are custom designed, including the RF band-definition filters, attenuators and the probe to couple received energy from the waveguide-based antenna input to MMIC-compatible microstrip transmission lines. Integrated calibration circuitry, i.e. PIN-diode switch and noise source, is required due to the fixed viewing geometry of the radiometer, making external calibration infeasible. MMIC-based PIN-diode switches are being designed for at least 90-180 GHz. Modeling results to date predict very good performance, i.e. < 1 dB insertion loss and > 20 dB return loss.

An LNA-based front end will be required to achieve the low noise figure for this technique, and direct detection is the lowest power and mass solution for these high-frequency receivers. Keeping the radiometer power at a minimum is critical to fit within the overall mission constraints, including the power requirements of the radar interferometer. In order to minimize mass, power and volume of the receivers shown in Figure 2 to the extent possible, MMIC-based components will be housed in custom-designed multi-chip modules. CSU has recently demonstrated that the use of MMIC-based multi-chip modules can achieve a significant reduction in mass, volume, and power consumption of these sections, and ultimately of the entire sensor, as compared to state-of-the-art ground-based microwave radiometers [2,3].

Three-Frequency Feed Horn for SWOT Radiometer

A multi-frequency feed horn is required to maintain acceptable antenna performance, since separate feeds for the each of the high-frequency channels would need to be moved further off the antenna focus, degrading this critical performance factor. To this end, a three-frequency feed horn is being developed for 90, 130 and 166 GHz. The lower two bands show very good broadband performance, while the 166 GHz band is limited to a fairly narrow band due to its return loss characteristics.

Summary

Critical technologies are under development for the microwave radiometer for the SWOT mission, in order to improve its spatial resolution and retrieval of wet path-delay. Retrievals over land may be possible using a 183-GHz sounder channel. The entry TRL for the RF components is 2 and the feed horn is 3; an exit TRL of 4 is anticipated.

Bibliography

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