MAPIR: AN AIRBORNE POLARIMETRIC IMAGING RADIOMETER IN SUPPORT OF HYDROLOGIC SATELLITE OBSERVATIONS

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ABSTRACT

In this age of dwindling water resources and increasing demands, accurate estimation of water balance components at every scale is more critical to end users than ever before. Several near-term Earth science satellite missions are aimed at global hydrologic observations. The Marshall Airborne Polarimetric Imaging Radiometer (MAPIR) is a dual beam, dual angle polarimetric, scanning L band passive microwave radiometer system developed by the Observing Microwave Emissions for Geophysical Applications (OMEGA) team at MSFC to support algorithm development and validation efforts in support of these missions. MAPIR observes naturally-emitted radiation from the ground primarily for remote sensing of land surface brightness temperature from which we can retrieve soil moisture and possibly surface or water temperature and ocean salinity. MAPIR has achieved Technical Readiness Level 6 with flight heritage on two very different aircraft, the NASA P-3B, and a Piper Navajo.

MAPIR consists of an electronically steered phased array antenna comprised of 81 receiving patch elements and associated electronics to provide the required beam steering capability (Fig. 1). The antenna produces two independent beams that can be individually scanned to any user-defined scan angle. The antenna is connected to four microwave radiometers and a microwave spectrum analyzer. Two radiometers operate over a narrow band (science band) between 1400-1427 MHz. Two other radiometers operate over a wider bandwidth (1350-1450 MHz) and are used for Radio Frequency interference (RFI) surveillance. The outputs of the four radiometers are routed to the digital backend module that digitizes and filters the signal into 16 well isolated spectral sub-bands [1] and computes the first four statistical moments in each sub-band from which the radio brightness temperature and kurtosis (a statistical measure, indicative of RFI, [1]) can be computed in post-processing.

MAPIR can operate in two user-selectable modes: Single-Beam Dual (simultaneous) Polarization and Dual (simultaneous) Beam Single Polarization. In the first mode, both beams of the antenna are directed to scan to the same angle, but the radiometers are observing orthogonal polarizations (horizontal and vertical) at the same time

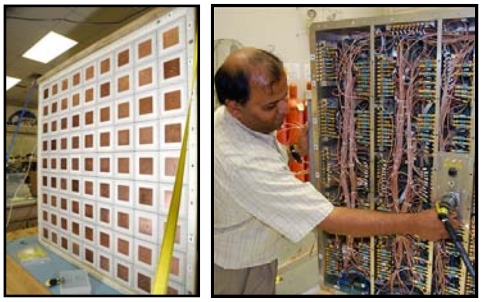

Fig. 1. MAPIR antenna showing the front and back side and electronic control components for each antenna element.

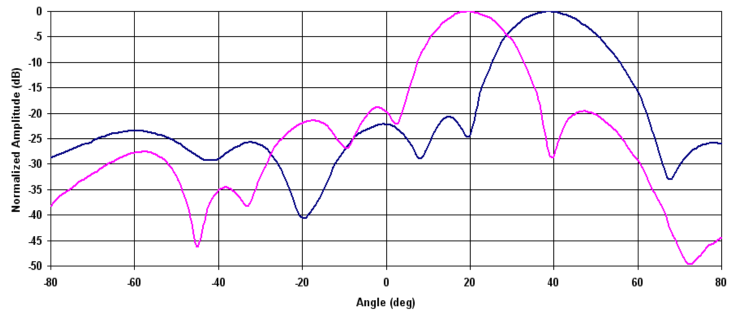

Fig. 2. Beam steering for one beam demonstrated in anechoic chamber.

(Fig. 2). In the second mode, the two antenna beams can be directed to different azimuth and/or angles and the radiometers observe the same polarization at the same time. The instrument is capable of electronic beam steering to one-degree of resolution from 0-40 degrees in elevation and 0-360 degrees azimuth in both beams. MAPIR precision is 0.01K and brightness temperature accuracy is 5 degrees K accuracy over a 10 ms integration interval, but is capable of achieving 0.5K sensitivity over a 1 second integration interval. Near-term improve-ments to MAPIR will bring that accuracy to 3 K over a 10 ms integration period.

Calibration of MAPIR is performed prior to a campaign in anechoic and electromagnetic isolation chambers. During flight, calibration is continuously performed using internal warm and cold loads, injected diode noise and radiated diode noise [2]. Additional calibration data is acquired during flights from water bodies. Thermal management of the MAPIR instrument is achieved through the use of active heater elements in the MAPIR antenna system. Humidity control in the antenna enclosure is accomplished through the use of gaseous nitrogen.

MAPIR achieved TRL 6 with successful flight heritage on the NASA P-3B in the fall of 2008 and was also integrated into a much smaller Piper Navajo to further demonstrate performance. MAPIR integration into the Navajo required building an adapter structure to interface the antenna to the belly of the aircraft with custom fairings to surround the antenna (Fig. 2). The instrument rack is configured to a compact (16U) form factor.

MAPIR was integrated into the NASA P-3B aircraft in September 2008 as part of the SMAP-VEX '08 experiment. Eight engineering flights ranging from 0.7 to 2.7 hours long were conducted over the course of two weeks from September 29 to October 13, 2008. Each mission has a slightly different profile designed to evaluate different scanning modes and to determine how the instrument was performing. Much was learned about MAPIR's performance and the functionality of operational software. After further testing and modifications, MAPIR was then integrated into a Piper Navajo in the summer of 2009 operated by the University of Tennessee Space Institute in Tullahoma, Tennessee (Fig. 3). The aircraft was modified with additional GPS antennas, nadir and forward-looking video, nadir thermal sensor, and gaseous nitrogen purge system. A series of four additional test flights were conducted between August 12 and October 20, 2009. During these flights, the overall sensitivity

Fig. 3. MAPIR enclosed in fairings beneath a Piper Navajo.

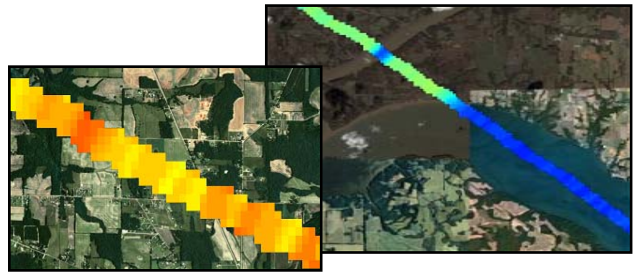

Fig. 4. Brightness temperatures observed during test flight on September 8, 2009 using a narrow scan mode.

of MAPIR and different scan modes were evaluated. Additionally, 100 MHz of bandwidth was monitored for RFI. Flights were conducted over reservoirs of the Tennessee Valley Authority adjacent to nuclear power facilities to observe thermal effluent plumes and over USDA Soil and Climate Analysis Network (SCAN) stations for surface temperature and surface soil moisture validation (Fig. 4). Results of these test flights demonstrate that MAPIR, with a few exceptions being addressed, is performing as designed and will be a valuable contribution in support of near-term hydrologic satellite missions. RFI, a concern for any instrument operating in the passive L band frequency, has been observed in significant quantity and characterized with a spectrum analyzer. Engineering design and system performance results will be discussed in detail in the conference proceedings and oral session.

REFERENCES

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