Submission to IGARSS 2009, Capetown, South Africa
Paper No. 2890

DIGITAL MICROWAVE RADIOMETERS: DIGITAL SIGNAL PROCESSING DEVICE CAPABILITIES VS. RADIOMETER SENSOR PERFORMANCE

Christopher Ruf, Steven Gross and Jinzheng Peng
Space Physics Research Laboratory
University of Michigan
2455 Hayward St., Ann Arbor, MI, 48109-2143 USA
734-764-6561 (V), 734-936-0503 (F), cruf@umich.edu (E)

Abstract

Digital radiometers replace as much of the conventional analog circuitry as possible with an Analog-to-Digital Converter (ADC) followed by a high speed Digital Signal Processing (DSP) stage. The conversion to digital technology improves the long term stability and independence from temperature variations of the radiometer, thus improving and simplifying its calibration. Digital technology can also add capabilities to a radiometer that would be much more difficult (and often cost prohibitive) to include otherwise. The signal bandwidth can be digitally subdivided into many well isolated sub bands. This simplifies the removal of RFI, which tends to have a highly localized spectrum. The DSP stage can also be programmed to detect other moments of the signal amplitude, in addition to the second moment that is detected by a conventional analog square-law detector diode. In particular, the second and fourth central moments have been shown to be an extremely sensitive detector of RFI (Ruf *et al*., 2006; De Roo *et al*., 2007). Thus, digital radiometers are much more capable than analog designs of both detecting and removing RFI from the observations. If a radiometer operates with two orthogonal linear polarization channels, then the DSP stage can also be used to perform a complex correlation between the two polarizations, in addition to the conventional self-correlation. This results in a fully polarimetric radiometer (including 3rd and 4th Stokes brightness temperatures) for little additional cost or complexity over that of a two polarization analog design. Fully polarimetric radiometers can be useful in two ways. They allow for the retrieval of additional geophysical information related to the partial coherence between orthogonal linear polarization signals. The retrieval of near surface wind direction over the ocean is one example of this (Bettenhausen *et al*., 2007; Yueh *et al*., 2006; Brown *et al*., 2006). A fully polarimetric radiometer is also able to more accurately compensate for leakage between polarization channels and, thus, produce more accurately calibrated measurements of the conventional vertical and horizontal linear polarization brightness temperatures (Njoku *et al*., 1977; Gasiewski and Kunkee, 1993).

There are two critical performance characteristics for devices used in digital radiometers – their clock rate and, for the DSP stage, the size of the firmware processing core that performs its mathematical operations. The clock rate is determined by the analog bandwidth of the signal to be digitized. The firmware size is set by the level of

complexity of the DSP operations (*e.g*. the number of digital sub band filters and the quality of their out-of-band rejection, and whether or not fully polarimetric channels are desired). Spaceflight qualified digital devices are already available that can perform the necessary ADC and DSP functions. Radiation tolerant and flight qualifiable ADC and DSP devices are currently available commercially with sufficiently high clock rates to support th required bandwidths. The implementation details associated with assembling them into a functioning subsystem will be described. Projected performance estimates will also be presented, parametrically dependent on the devices used. A brassboard spaceflight prototype subsystem has been fabricated and is currently undergoing extensive testing. The current status of those tests, and a comparison of the measured and predicted performance will also be discussed.

References

Bettenhausen, M.H., C.K. Smith, R.M. Bevilacqua, N.-Y. Wang, P.W. Gaiser and S. Cox (2006). “A nonlinear optimization algorithm for WindSat wind vector retrievals,” IEEE Trans. Geosci. Remote Sens., **44**(3), 597-610.

Brown, S.T., C.S. Ruf and D.R. Lyzenga (2006). “An Emissivity Based Wind Vector Retrieval Algorithm for the WindSat Polarimetric Radiometer,” IEEE Trans. Geosci. Remote Sens., **44**(3), 611-621.

De Roo, R., S. Misra and C. Ruf (2007). “Sensitivity of the Kurtosis Statistic as a Detector of Pulsed Sinusoidal RFI,” IEEE Trans. Geosci. Remote Sens., **45**(7), 1938-1946.

Gasiewski, A.J., and D.B. Kunkee (1993). “Calibration and applications of polarization correlating radiometers, “IEEE Trans. Microwave Theory Tech., **41**(5), 767-773.

Njoku, E.G., E.J. Christensen and R.E. Cofield (1977). “The SeaSat scanning multichannel microwave radiometer (SMMR): Antenna pattern correction development and implementation,” IEEE J. Oceanic Eng., **5**(2), 125-137.

Ruf, C.S., S. M. Gross and S. Misra (2006). “RFI Detection and Mitigation for Microwave Radiometry with an Agile Digital Detector,” IEEE Trans. Geosci. Remote Sens.,**44**(3), 694-706.

Yueh, S.H., W.J. Wilson, S.J. Dinardo and S.V. Hsiao (2006). “Polarimetric microwave wind radiometer model function and retrieval testing for WindSat,” IEEE Trans. Geosci. Remote Sens., **44**(3), 597-610.