An Interference Mitigation Technique for Passive Remote Sensing of Soil Moisture

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Abstract- Anthropogenic interference from terrestrial sources of microwave emission have been observed in passive C-band radiometric data using both the NOAA Environmental Technology Laboratory’s (ETL) PSR/CX airborne imaging instrument, and the JAXA AMSR-E instrument on the NASA EOS Aqua satellite. Simultaneous observations using multiple ~300 MHz subbands, incorporated into the PSR/CX instrument, have provided one means of interference mitigation that is useful under moderately contaminated conditions. ETL has developed a new C-band spectrometer that observes emissions within relatively narrower bandwidths and is tunable from 5.8 to 7.5 GHz. The spectrometer is able to reduce the effects of the interference at the expense of radiance sensitivity and observation time. Preliminary data analysis suggests the spectrometer to be an effective component for improving the accuracy of remotely sensed soil moisture measurements using C-band radiometry.

I. INTRODUCTION

As the cost of microwave hardware declines, an increasing amount of microwave communication equipment is in use on a global scale. As a result, interference from anthropogenic emissions has begun to noticeably influence the accuracy of passive C-band radiometry data used to generate soil moisture products. Interference has been observed in both regional imagery from the NOAA Environmental Technology Laboratory’s (ETL) PSR/CX airborne imaging instrument and global imagery from the JAXA AMSR-E instrument on the NASA EOS Aqua satellite. Both the PSR/CX and AMSR-E instruments include C-band dual-polarized radiometers operating at fixed frequencies with approximately 200 to 300 MHz bandwidth. Simultaneous observations using multiple subbands, incorporated into the PSR/CX instrument, have provided one means of interference mitigation that is useful under moderately contaminated conditions [1]. To extend the mitigation capabilities of PSR/CX, ETL has developed a tunable C-band spectrometer for use within the PSR/CX instrument. The spectrometer observes emissions within narrower bandwidths of 10 and 100 MHz, and is tunable from 5.8 to 7.5 GHz. Because anthropogenic emissions currently have relatively narrow bandwidths the ETL spectrometer is capable of accurately sampling microwave emission within any 10 or 100 MHz band that is found to be free of such interference, thereby detecting and eliminating the interference at the expense of some bandwidth, and (because the instrument has to be tuned) at the expense of observation time. As of this publication, the spectrometer collected data during the 2004 Soil Moisture Experiment (SMEX04), the 2005 Arctic Sea Ice Experiment (AASI05), and a high-altitude test flight on the NASA WB-57F aircraft.

II. SATELLITE AND AIRBORNE SENSOR INTERFERENCE

Extensive radio frequency interference to the normal operation of the JAXA AMSR-E sensor has been documented, as has interference to ETL’s PSR/CX. In 2004, Jet Propulsion Laboratory (JPL), NOAA, and Naval Research Laboratory (NRL) scientists published a preliminary survey of the interference to the AMSR-E sensor [2]. Previously, in August 1998, ETL proposed an approach to mitigating this interference to the AMSR-E sensor [2].

Figure 1. AMSR-E sensor brightness temperatures illustrating values measured at greater than 320º K for populated areas over the United States, from [2].

Figure 2. Raw PSR/CX temperature brightness measured in two of four C-band subbands with interference greater than 300º K during the SGP99 experiment.
interference using a multiple subband technique which implemented and tested during the 1999 Southern Great Plains Experiment [3]. The new C-band spectrometer was integrated into the PSR/CX in 2004 (now called PSR/CXI), and has been assessed as an additional means for interference mitigation.

III. INSTRUMENT HARDWARE

The PSR/CXI spectrometer functions as a tunable radiometer capable of simultaneously observing 10 and 100 MHz wide bands with center frequencies between ~5.5 and ~7.7 GHz in both horizontal and vertical polarizations. The spectrometer includes four logarithmic detector channels each with a ~100 dB dynamic range and an integration time of 10 msec. The four logarithmic detectors observe each combination of polarization and bandwidth. This configuration allows strong sources of interference to be accurately measured without saturation. For accurate measurement of weaker sources of interference two linear detectors with 100 MHz bandwidths are implemented for each polarization. A digitally
tunable local oscillator (LO) with absolute tuning accuracy of 5 MHz can be swept at up to 200 MHz per millisecond. The tuning resolution of the LO is ~1.05 MHz. The spectrometer is equipped with 125 MHz downconverted (100 MHz wide) IF output for use with a high spectral resolution FFT spectrometer developed at the Ohio State University [4]. The single IF output is digitally selectable between polarizations. The spectrometer was designed specifically to interface with the C-band radiometer of the PSR/CXI. The temperature of the local oscillator is measured using thermistors since this component has been observed to drift predictably up to ~1 MHz between ambient and operating temperature. To stabilize the temperature of the instrument three separate heaters in addition to the LO’s internal heater are placed throughout the instrument.

Figure 3. Block diagram of the PSR/CXI showing the C-band radiometer and spectrometer components. The X-band hardware is not shown.
IV. EXPERIMENTS

The spectrometer has collected data during three airborne experiments. The first deployment of the spectrometer was during SMEX04 in August of 2004. The second deployment was during AASI05, during which the spectrometer was activated for one test flight from Wallops AFB in Virginia, USA. A portion of this data is presented. Most recent to the time of this publication, the spectrometer was used during a high-altitude flight on the NASA WB-57F aircraft. During all experiments the spectrometer was programmed to scan 22 equally spaced subbands of 100 MHz bandwidth each from 5.5 to 7.7 GHz.

V. PRELIMINARY DATA ANALYSIS

A segment of the data collected by the spectrometer from the 2005 AASI check flight from Wallops AFB has been calibrated and mapped by subband. However, due to the airspeed velocity (~210 kts), scanning period (~3 seconds), and low flight altitude (~300 m), the subband maps are somewhat low resolution and have been interpolated from highly undersampled imagery.

Figure 4. The spectrometer components as arranged within the PSR/CXI: 1) 6.65 GHz filter, 2) dual junction isolator, 3) 4.6 to 8.9 GHz digitally tunable oscillator, 4) lower sideband image reject mixers, 5) two-way power splitter, 6) -20 dB directional coupler, 7) log channel components, 8) linear channel components, 9) diode polarization switch, and 10) DC pulse modulator.

Figure 5. Data for the test flight segment. Upper left: 3d-plotted GPS data. Lower left: USGS aerial photograph with waypoint labels. Right: 6.0 GHz horizontal polarization subband C-band imagery, including front and back looks.

Figure 5 shows one flight segment from the AASI'05 experiment. Notice the strong interference in the 6.0 GHz subband of the C-band radiometer just below point B, and (when the instrument passes over that area again) below point D. The darker (cooler) portions of the image are when the sensor passed over a nearby body of water shown on the right of the USGS aerial photograph in Figure 5.

All four of the PSR/CXI C-band radiometer subbands show some level of interference for this flight segment. However, the 6.92 GHz subband shows almost none.

Figure 6. Spectrometer horizontally-polarized 100 MHz logarithmic channel at 6.15 GHz
The twenty-two 100 MHz wide spectrometer subbands are able to more specifically isolate and quantify, by frequency, the interference. Shown in Figures 6-9 are selected subband maps in horizontal polarization. Some spectrometer subbands are seen to be completely free of interference (e.g., Figure 8, 6.65 GHz). In practice, and under some conditions, the spectrometer might not be able to identify a 100 MHz band free of interference. In these cases, the frequency sweep pattern can be modified for 10 MHz wide observations and data from the 10 MHz bandwidth logarithmic detectors can be analyzed to find interference free subbands.

VI. CONCLUSION

With the expected continued and increased utilization of C-band in consumer electronics and industrial applications the use of a frequency tunable radiometer for passive soil moisture sensing in airborne or satellite observations may become necessary. We have illustrated here the use of such a tunable imaging radiometer for soil moisture remote sensing applications.

REFERENCES


Figure 7. Spectrometer horizontally-polarized 100 MHz logarithmic channel at 6.25 GHz

Figure 8. Spectrometer horizontally-polarized 100 MHz logarithmic channel at 6.65 GHz

Figure 9. Spectrometer horizontally-polarized 100 MHz logarithmic channel at 7.45 GHz