DEMONSTRATION OF INTERFERENCE SUPPRESSING RADIOMETRY AT C-BAND

Year One Report

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I. Introduction

This document reports on activities of IPO sponsored project IGS DG133E-04-CN-0049 during calendar year 2004, as well as plans for the one-year contract option. As described in the original proposal [1], the project involves studies of C-band RFI through joint flights of a digital receiver backend developed at Ohio State University with the PSR/I system of NOAA ETL.

II. Summary of Calendar Year 2004 Activities

A. System design and development

The design of the joint PSR/I and digital backend system was completed in early 2004. This design (as documented in [2]) involves observations in the band 5.5 to 7.7 GHz through use of a tuned 100 MHz channel. The total power in this 100 MHz channel is recorded by the PSR/I "spectrometer channels", while the digital receiver backend performs simultaneous high spectral and temporal resolution observations in several modes. A detailed description of the observation process is provided in [2]. The combined PSR/I and digital backend system is referred to as the C-band Interference Suppressing Radiometer or CISR.

After completion of the design, all systems were implemented in the second quarter of calendar year 2004. Delivery of the OSU components to NOAA ETL was accomplished in June for integration and testing with PSR/I.

B. Flight operations

Due to the requirement that flight observations for the project be based on a "piggy-back"

(i.e. no charge) basis during previously planned PSR/I operations, only two opportunities were available in 2004 for measurements. The first of these was the Soil Moisture Experiment 2004 (SMEX04), with flights between August 2nd and 27th on the Navy P-3 aircraft. The second was the deployment of PSR/I in the AMSR-E Antarctic Sea Ice (AASI) 2004 cal/val campaign, which took place October 8th through November 1st, again on the Navy P-3 aircraft.

Unfortunately numerous complications occurred during SMEX04 that made data acquisition by CISR difficult. In particular, strong internal coupling of the CISR local oscillator to the PSR main subchannels required the tuned system to be powered down until this issue could be solved. When this issue was solved on approximately Aug 15th, the P-3 aircraft experienced an engine failure that delayed further flights until the 24th. While CISR did record a small data set from flights between the 24th and 27th, cabling and computer card failures in the digital backend for these flights resulted in loss of much of the possible digital data. The PSR/I spectrometer channels were successfully recorded in a larger subset of these flights. In addition, cabling failures resulted in loss of the time synchronization between the PSR/I and digital backend, making processing of the measured data more difficult. An initial summary of the small dataset obtained is provided in [3].

The majority of the digital backend cabling issues were addressed before re-deployment into the AASI campaign, with flight integration beginning Oct 5th. Internal coupling of the system LO to the direct detection channels was also reduced significantly through efforts by the NOAA ETL team before re-deployment. The combined system operated successfully throughout a test flight on Oct 8th, gathering approximately 1.5 hours of useful data over the Chesapeake Bay region. An initial summary of this data is provided in [4]. However a computer card failure occurred once again in the digital backend on successive flights, resulting in no digital backend data throughout the rest of the AASI campaign. Data from the PSR/I spectrometer channels remains partially available. The remainder of the AASI campaign was significantly impacted by aircraft failures, with only three polar region flights being completed before return to base on Nov. 1st.

C. Data analysis

Due to the difficulties in processing the unsynchronized SMEX04 data, data analysis efforts to date have concentrated on the AASI results, available since Oct. 8th. Complete time-synchronization post-processing of the SMEX04 data is still in progress, and will allow further use of SMEX04 results.

The focus of data analysis efforts is to analyze and catalog properties of the RFI sources ob-

served, as well as to test several possible mitigation techniques against these sources. In the latter case, the PSR/I 4 main channel algorithm already in existence [5] serves as a basic standard against which to compare other strategies. The possible limitations of this algorithm against low-level RFI, as well as in cases in which all 4 channels are corrupted, are areas of particular interest. Some evidence already suggests that this algorithm may fail to remove low-level RFI that is large enough to introduce geophysical parameter retrieval errors.

As reported in [4], a MATLAB based tool for processing the joint PSR/I + digital backend data set has been developed. This tool combines existing calibration and imaging algorithms for the PSR/I main channels with new imaging and analysis tools for the spectrometer and digital backend data. An initial catalog of basic properties of the RFI observed (approximate location and bandwidth) is provided in [4], and current efforts are focused on more detailed examination of source characteristics (temporal properties, modulation schemes, etc.) as well as tests of mitigation strategies. In the latter case, the effectiveness of the digital backend asynchronous pulse blanking (APB) algorithm will be tested, as well as a set of spectral RFI excision methods.

Unfortunately, experiment scheduling has delayed data analysis tasks until the final quarter of year one. However significant progress has been made with both tool development for analysis and in the initial data assessment [4]. More detailed analysis plans for both the SMEX04 and AASI datasets will be described in Section IV.

D. RFI studies

To assist with interpreting CISR data and with assessing the implications of CISR data for satellite observations, a parallel analysis of C- and X- band RFI observed in existing satellite sensors was initiated. At present, the study has focused on measurements from the WindSAT sensor, as a set of WindSAT observations from Oct 2003 to Feb 2004 is publicly available. Reports documenting WindSAT observed RFI in the SMEX04 [6] and Chesapeake Bay [7] regions have been completed. Although these observations are separated temporally from the CISR measurements, and at a dramatically coarser spatial resolution, RFI sources that remain fixed in time should be consistent in both data sets. The process of comparing satellite observations with the AASI and SMEX04 CISR data has begun following completion of the CISR data analysis tools.

Although not the focus of the current project, basic information on WindSAT RFI properties observed over the continental US has also been obtained, and is reported in [8] and [9].

III. Current Financial Status

The project is a joint effort among researchers at the Ohio State University (OSU, led by J. T. Johnson), NOAA ETL (led by A. J. Gasiewski), and Virginia Tech (VT, led by S. W. Ellingson). The discussion below focuses on the financial status of the OSU and VT portions; NOAA ETL support has been arranged under a separate inter-agency agreement with the IPO. The OSU and VT portions of the project have been funded through a contract between the IPO and OSU, with VT supported through a sub-contract from OSU. Both OSU and VT are involved in all project components, including digital backend design issues, joint PSR/I and digital backend analysis, and studies of RFI from satellite sensors, although the digital backend implementation was performed primarily by OSU. A summary of financial information is provided below.

CY 04 Support	125K (89.0K OSU, 36.0K VT subcontract)
Remaining as of 10/31	14.9K (7.0K OSU, 7.9K VT subcontract)
CY 05 (option) proposed support	125K (77.0K OSU, 48.0K VT subcontract)

Note the increased support to VT in the second year results due to cessation of overhead on the OSU to VT sub-contract charged by OSU in year one.

IV. Plans for Option Year

A. System development

To ensure improved operation of the digital backend in future flight deployments, a review of system design and implementation will be performed early CY 2005. If deemed necessary, all digital backend components will be remounted in an improved enclosure. A review will also be performed for the PSR/I LO and timing systems in order to assess if improvements in these aspects are possible. These modifications will be completed before the first possible flights, scheduled for Feb 05.

B. Flight operations

At present, it appears that two possibilities for flights are available in 2005, including the WB-57 Ascent Video Experiment (WAVE) in February (a mission supporting the Space Shuttle return to flight) and a WindSAT cal-val campaign in August. Several aircraft will be deployed in the latter campaign, but the preferred host for PSR/I is the WB-57. At present, it is not clear if the PSR/I scanhead (i.e. C- and X-bands) will be utilized in the WAVE campaign, so this deployment

is more uncertain than the WindSAT cal-val mission. Both deployments should provide moderate opportunities for observation of RFI rich environments: the WAVE mission will involve a transit flight from the Houston WB-57 base to the Cape Canaveral area, while the WindSAT cal-val mission would be based in the Chesapeake Bay area. RFI studies could be enhanced through additional support from the IPO (estimated on the order of 30K) to the WindSAT cal-val mission, in order to provide for additional flight hours to other US East coast regions.

Use of the WB-57 aircraft will place more stringent requirements on the digital backend enclosure. Although these issues were considered in the initial design, no tests of operation in low pressure, low temperature environments (as in the open bomb bay of the WB-57 at high altitude) have been performed. These issues will be addressed in the system development efforts discussed in the previous section.

C. Data analysis

A major focus of the option year will be more detailed processing of the existing SMEX04 and AASI datasets, in order to obtain more quantitative analyses of source properties and RFI strategy effectiveness. Current efforts will be expanded to include development of calibration methods for the spectrometer channels, as well as analysis of all spectrometer measurements in addition to the digital backend dataset. An initial summary of RFI in the 4 PSR/I X-band channels will also be performed. Data from the WAVE and WindSAT campaigns will be incorporated when available.

D. RFI Studies

Studies of WindSAT RFI will continue in support of CISR operations and in order to determine effective means for extrapolating data observed by aircraft-based sensors to data observed from satellite platforms. Discussions with D. Kunkee (Aerospace Corp.) have been initiated regarding comparisons of CISR measurements with the existing IPO database of registered emitters at C-band. Because this database has been utilized to generated RFI "scenarios" for testing CMIS design proposals, assistance will be provided to IPO in updating these scenarios as appropriate to incorporate new information from the current project. The RFI source catalog to be obtained from CISR data will also provide a more detailed basis from which to generate future scenarios. An assessment of various RFI strategies against the sources observed will be included in this catalog, with recommendations for the most effective strategy determined. Finally an assessment of the estimated effectiveness of proposed CMIS revisions will be provided based on these results.

V. Statement of Work and Deliverables

- Review and revise CISR design/implementation as necessary to improve reliability in future flights, particularly on the WB-57 platform
- Support system integration/deployment in WAVE (if available) and WindSAT cal-val missions
- Continued analysis of data from SMEX04 and AASI campaigns, along with WAVE and WindSAT data
- Continue inter-comparison of RFI mitigation strategies, including PSR/I sub-channel algorithm and other temporal/spectral excision methods
- Continue development of catalog of algorithm/RFI properties observed
- Provide analysis of estimated effectiveness of proposed CMIS revisions
- Develop final project recommendations for future spaceborne radiometers

Project Year Two Deliverables:

- Quarterly technical/financial progress reports
- Year two report detailing year two progress, results, RFI/algorithm properties observed, detailed implications for CMIS
- Year two briefing detailing year two report contents

Specific information on project deliverables, including report due dates, is available in the project contract.

References

[1] IGS project DG133E-04-CN-0049, "Demonstration of RFI suppressing radiometry at C-band," project proposal, 2003.

[2] J. T. Johnson, A. J. Gasiewski, G. A. Hampson, S. W. Ellingson, R. Krishnamarachi, and M. Klein, "Airborne radio frequency interference studies at C-band using a digital receiver," *IEEE Geoscience and Remote Sensing Symposium,* paper in conference proceedings, 2004.

[3] J. T. Johnson, A. J. Gasiewski, G. A. Hampson, S. W. Ellingson, R. Krishnamarachi, and M. Klein, "Airborne radio frequency interference studies at C-band using a digital receiver," *IEEE Geoscience and Remote Sensing Symposium,* conference presentation, 2004.

[4] "Airborne RFI measurements with PSR/CXI and CISR in the Chesapeake Bay Region: Initial Data Examination," project technical report, 2004.

[5] Gasiewski, A. J., M. Klein, A. Yevgrafov, and V. Leuski, "Interference mitigation in passive microwave radiometry," *IGARSS'02* conference proceedings, 2002.

[6] Ellingson, S. W., "A preliminary survey of C-band RFI in the SMEX04 area of operations using WindSAT radiometry," project report, May 2004.

[7] Ellingson, S. W., "A survey of C-band RFI in the Chesapeake Bay region using WindSAT radiometry," project report, June 2004.

[8] Ellingson, S. W., "A polarimetric survey of radio frequency interference in C- and X-bands in the continental United States using WindSAT radiometry," project report, Oct 2004.

[9] Ellingson, S. W. and J. T. Johnson, "A study of RFI in the WindSAT C- and X-band channels," presentation at WindSAT science team workshop, November 2004.