RADIO-FREQUENCY INTERFERENCE (RFI) MITIGATION FOR THE SOIL MOISTURE ACTIVE/PASSIVE (SMAP) RADIOMETER

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1. INTRODUCTION

Radio-frequency interference (RFI) has detrimentally affected soil moisture remote sensing data since 1978 when it was first observed at 6.6 GHz with SMMR on SeaSat [1]. Over the last several years it has started to seriously impact remote sensing science products and is expected to continue to do so. This is primarily because the frequency requirements of remote sensing have begun to overlap active radio service allocations. Until recently, soil moisture was being sensed in the C-band, for which there is no passive service allocation. The launch of ESA's Soil Moisture Ocean Salinity (SMOS) mission [2] begins a new era of L-band remote sensing from space, which has been long desired for remote sensing of soil moisture through vegetation. The L-band record from space will be continued with NASA's Aquarius [3] and SMAP [4] missions.

Although there is a primary exclusive allocation to passive use in the L-band, it is still highly susceptible to RFI because of the proliferation of the active services in bordering frequency allocations. Thus, RFI detection and mitigation strategies are needed so SMAP can meet its requirements. The chosen approach for SMAP is to use a digital processing backend in lieu of microwave power detectors. Johnson and Ellingson produced the first RFI-mitigating digital radiometer [5] and Ruf et al. introduced the kurtosis statistic as an RFI detector and classifier [6]. Using their previous research plus work done for the Hydros mission [7] as its basis, the SMAP digital backend will provide both time and frequency diversity data at each footprint to enable the ground processing algorithms to detect and remove of RFI. To do so, it will use digital signal processing (DSP) techniques to measure 1200 samples in time and frequency for each SMAP footprint. This paper summarizes the DSP algorithms and electronics implementation using field-programmable gate arrays (FPGAs) in the SMAP preliminary design.

2. SMAP FLIGHT HARDWARE IMPLEMENTATION

2.1 **Digital Subsystem**

The SMAP Radiometer Digital Electronics (RDE) subsystem consists of three processor boards. The first two identical boards are called analog processing units (APU)'s. These cards, APU-H and APU-V, digitize the incoming analog signals corresponding to horizontal and vertically polarized received electromagnetic fields, respectively. The third processor board is called the digital processing unit (DPU). The DPU collects and packetizes processed data from each APU card. In addition, the DPU receives unprocessed fullband and subband signals from each APU card in order to perform fullband and subband cross-correlation between them.

2.2 **FPGA-based Signal Processing**

Two identical RTAX-2000 Field-Programmable Gate Arrays on each APU card perform the bulk of the digital signal processing required to compute the first four fullband and first four subband sample moments. The APU cards generate these moments by channelizing and integrating the fullband signal, and integrating each of the subband signals resulting from channelizing on both APU boards. Raw sample moments are computed onboard instead of central moments because they require significantly less memory than their centralized counterparts. For example, computation of signal variance would require an entire integration period worth of samples to be stored on-board. This requirement is eliminated if instead the first and second raw sample moments are computed onboard and sent to the ground, where variance is computed by taking their difference.

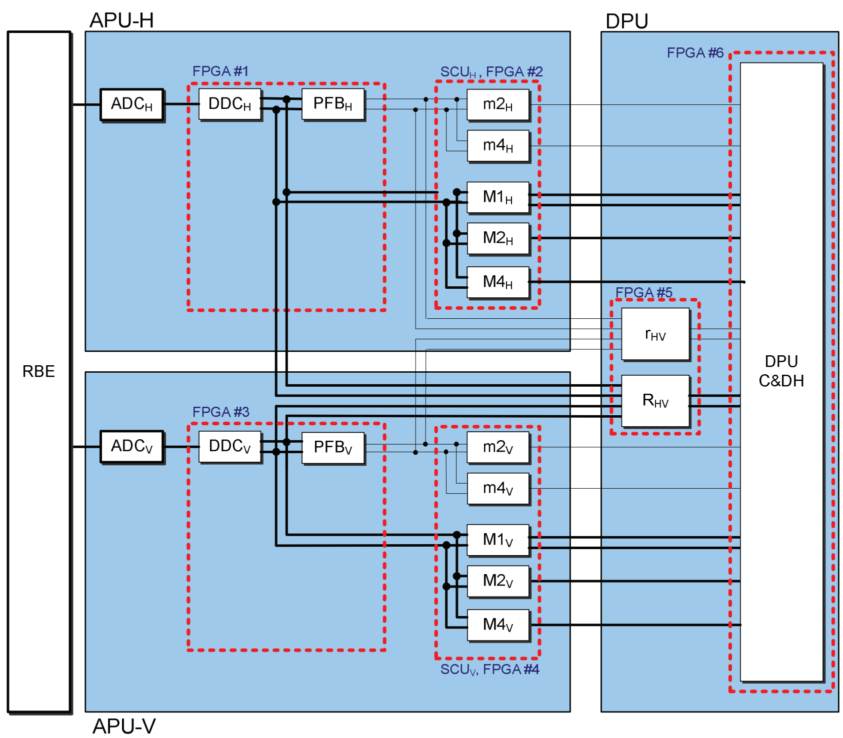

Figure 1: Functional block diagram of SMAP-RDE signal processing chain. The processing is divided into logical modules called the digital downconverter (DDC), Polyphase Filter Bank (PFB) Statistics Calculation unit, and two cross cross correlators. The partitioning of the modules is shown across electronics boards and across FPGA devices.

To arrive at a logic-area efficient FPGA implementation of the spacecraft portion of the RFI detection algorithm, we employ a number DSP techniques [8-11] commonly found in digital communications receivers and radar. We first employ IF-subsampling at 96MHz. This allows us to use currently-available spaceflight-qualified analog to digital converters to digitize the radiometer IF signal. In addition, this allows us to apply Fs/4 downconversion using a polyphase digital downconverter. We then take the downconverted signal and split it into 16 subband signals. The choice of 16 uniformly-space subbands leads to implementation of a computationally efficient polyphase Weighted-Overlap-Add (WOLA) FFT filter bank that uses a Radix-2 pipelined FFT for subbanding and automatic subband interleaving [13,14]. The interleaving of subbands means that the subband moments are computed efficiently by sharing a single squaring, 4^{th}-power, and block accumulator circuit, instead of 16 of these circuits for each subband signal. Finally, all data products are packetized and prepared for transmission to the ground using the DPU command and data handling (C&DH) subsystem.

3. GROUND ALGORITHMS

Using the detailed information provided by the SMAP instrument, the ground processing algorithms will detect RFI in the raw data, remove it, and output calibrated nearly RFI-free brightness temperature estimates. The diversity of the SMAP data product allows several different detectors to be utilized. A time domain pulse detector can be used on the full band product for removing radar interference. A cross-frequency detector can be used to remove persistent narrow band sources. It is envisioned the kurtosis products will aid in classifying RFI, if not in detecting less well behaved sources. A maximum likelihood decision process will be used to combine the detector outputs and produce a single estimate of antenna temperature with RFI removed.

4. REFERENCES

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