WIDEBAND DIGITAL SIGNAL PROCESSING TEST-BED FOR RADIOMETRIC RFI MITIGATION

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PROBLEM DESCRIPTION

Radio Frequency Interference (RFI) is a persistent and growing problem experienced by spaceborne microwave radiometers. Recent missions such as SMOS, SMAP, and GPM have detected RFI in L, C, X, and K bands [1, 2]. To proactively deal with this issue, microwave radiometers must:

- Utilize new algorithms for RFI detection
- Utilize fast digital back-ends that sample at hundreds of MHz

The wideband digital signal processing testbed (**WB-RFI**) is a platform that allows rapid development and testing various RFI detection and mitigation algorithms.

INTRODUCTION

- The WB-RFI system is based on UC Berkeley's Collaboration for Astronomy Signal Processing and Electronics Research (**CASPER**) (**ROACH-2**) (Reconfigurable Open Architecture Computing Hardware) FPGA-based signal processor.
- The SMAP Radiometer Digital Electronics (RDE-DSP) was emulated on WB-RFI. We then improved it by scaling the operational sample rate and adding the **complex signal kurtosis algorithm** (CSK) [4] in lieu of the real signal kurtosis for RFI detection.

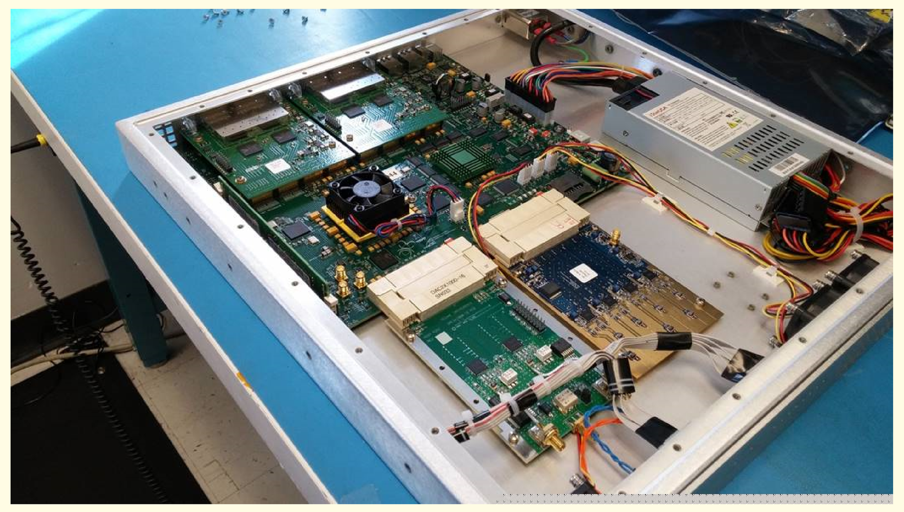

Figure 7: CASPER-ROACH2 Hardware.

ACKNOWLEDGEMENT

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WIDEBAND RADIOMETER DSP

The WB-RFI system was configured as a polarimetric radiometer back-end processor similar to the SMAP RDE [3]. Each polarization channel signal was downconverted to a complex baseband (I/Q) representation, motivating the use for the CSK algorithm. Like SMAP, the radiometer band was split into frequency subbands, but the CSK was applied to each band ℓ.

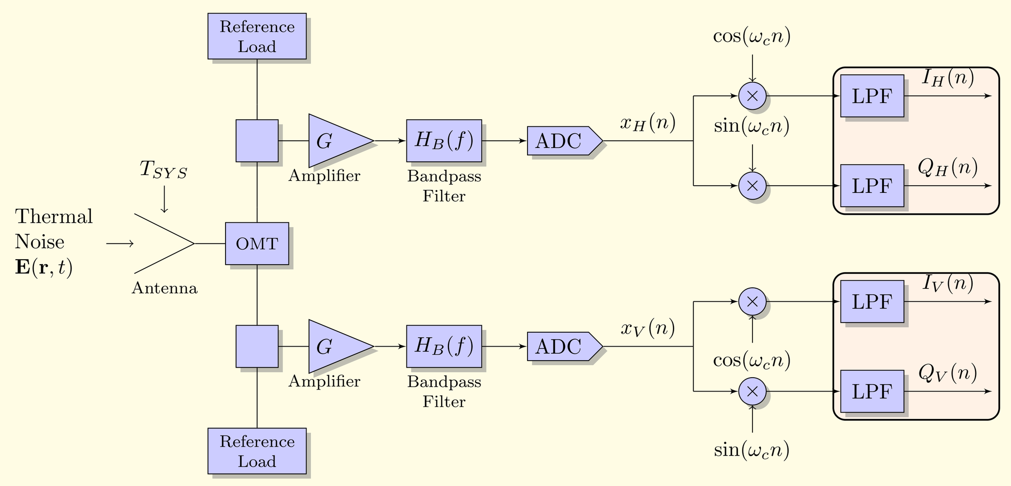

Figure 1: Polarimetric radiometer configuration with identical processing channels for horizontal and vertical polarizations.

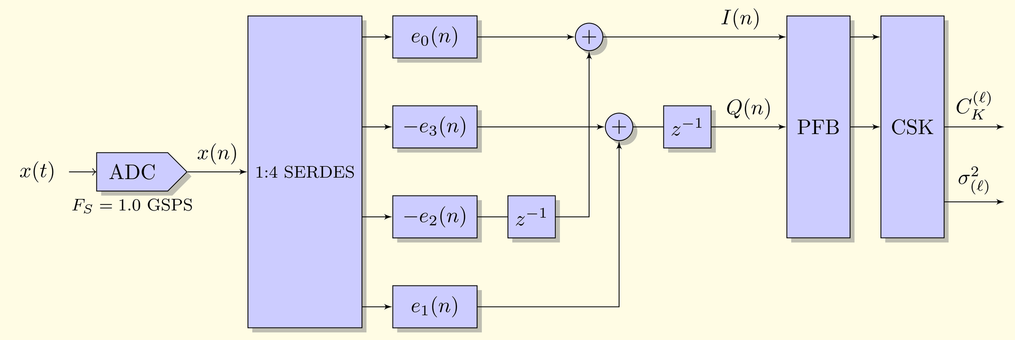

Figure 2: Single-Channel Implementation for 200 MHz bandwidth K-band radiometer. The 200 MHz band was downconverted using a SERDES-polyphase FIR filter that combined mixing, image rejection, and downsampling into polyphase partition filters $e_k(n)$.

COMPLEX SIGNAL KURTOSIS

Consider the complex baseband signal

$$z(n) = I(n) + jQ(n). \tag{1}$$

Its moments $\alpha_{\ell,m}$ are defined by

$$\alpha_{\ell,m} = \mathbb{E}\left[(z - \mathbb{E}[z])^{\ell}(z - \mathbb{E}[z])^{*m}\right], \quad \ell, m \in \mathbb{Z}_{\geq 0}, \tag{2}$$

where $\mathbb{E}$ is the expectation operator and * is the complex conjugate. *Standardized moments* are defined by

$$\varrho_{\ell;m} = \frac{\alpha_{\ell,m}}{\sigma^{\ell+m}}, \tag{3}$$

where $\sigma^2 = \alpha_{1,1}$. The complex signal kurtosis is given by $\varrho_{2;2} - 2 - |\varrho_{2;0}|^2$ and is used to make the RFI test-statistic C_K

$$C_K = \frac{\varrho_{2;2} - 2 - |\varrho_{2;0}|^2}{1 + \frac{1}{2}|\varrho_{2;0}|^2}. \tag{4}$$

If $z(n)$ is Gaussian, then $C_K = 0$. Otherwise, C_K is nonzero. Therefore C_K is a test statistic for non-Gaussianity that can be used for RFI detection. We implemented (4) on the WB-RFI system.

PERFORMANCE RESULTS

The CSK was evaluated for continuous and pulsed (Figures 3 & 4) RFI+noise signals as a function of SNR to characterize its receiver operating characteristic (ROC) performance, and compared to the average kurtosis of I and Q components. The system linearity and subband performance were tested in addition (Figures 5 & 6) using bandlimited noise.

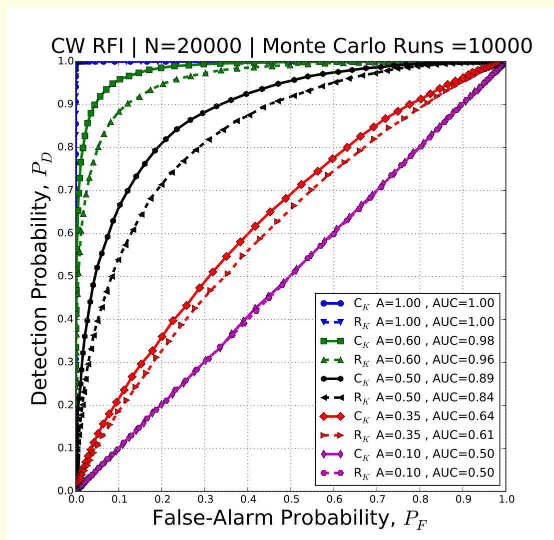

Figure 3: ROC: CW-RFI

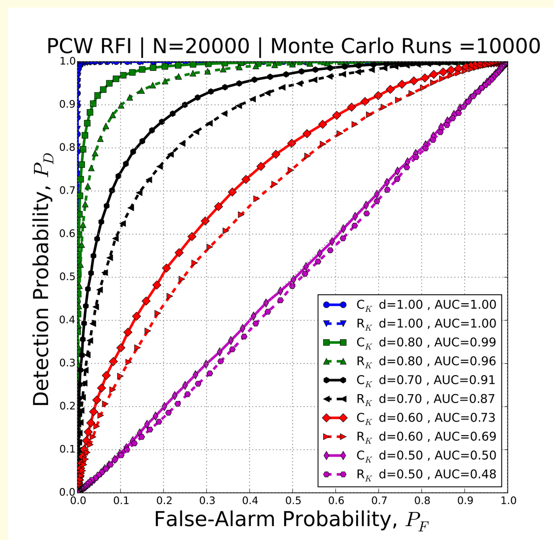

Figure 4: ROC: PCW-RFI

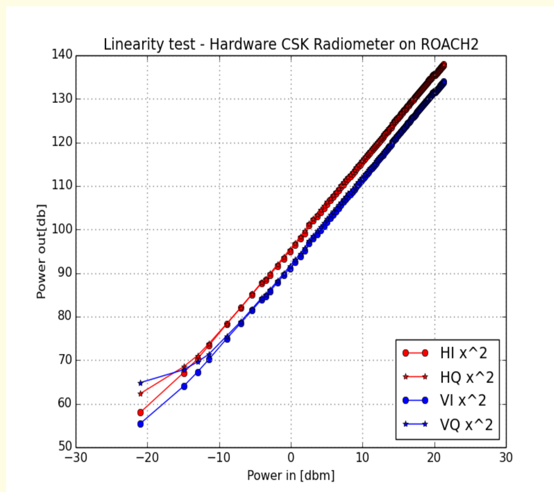

Figure 5: Linearity

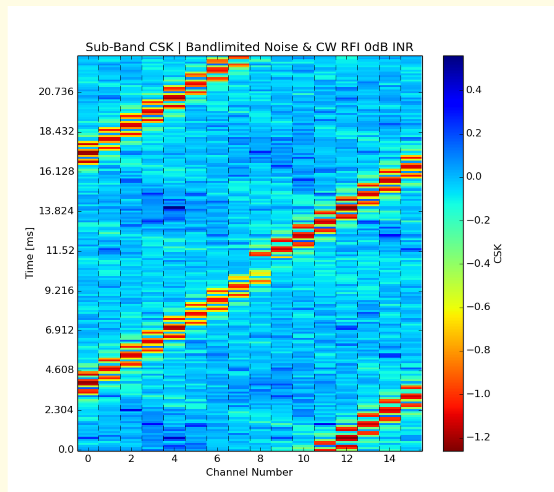

Figure 6: Subband CSK

CONCLUSIONS & FUTURE WORK

- The CSK has a better ROC performance than the average kurtosis of I and Q component signals. It uses the natural complexity of the baseband signal to maximize detection probability.
- The CSK implemented on the WB-RFI system is ideal since the sample rate is so high. It allows for RFI detection in baseband which is also convenient for minimizing subsequent system sample rate after downconversion.
- We plan to fly this system in airborne campaigns and develop additional RFI mitigation algorithms using this platform.

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