Performance Analysis of a Hardware Implemented Complex Signal Kurtosis Radio-Frequency Interference Detector

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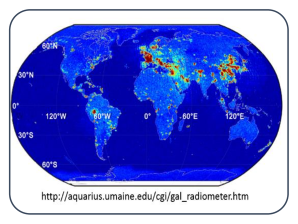
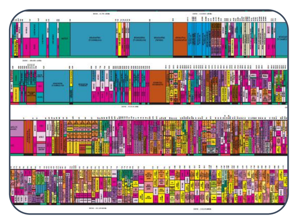
Motivation

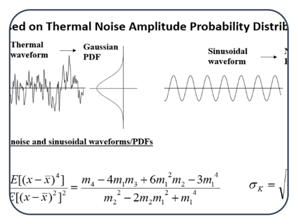


RFI compromises quality of science products.



Spectrum is becoming crowded and shared.

Hardware capabilities allow for digital radiometry.



Need more sensitive detectors for wide-band interference.

Complex Signal Kurtosis

Given a complex baseband signal $z(n) = I(n) + jQ(n)$, *moments* $\alpha_{\ell,m}$ of $z(n)$ are defined as

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

With $\sigma^2 = \alpha_{1,1}$, *Standardized moments* $\varrho_{\ell,m}$ can then be found as

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

Leading to the CSK (Complex Signal Kurtosis) rfi test statistic used [1,2].

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

Real Signal Kurtosis

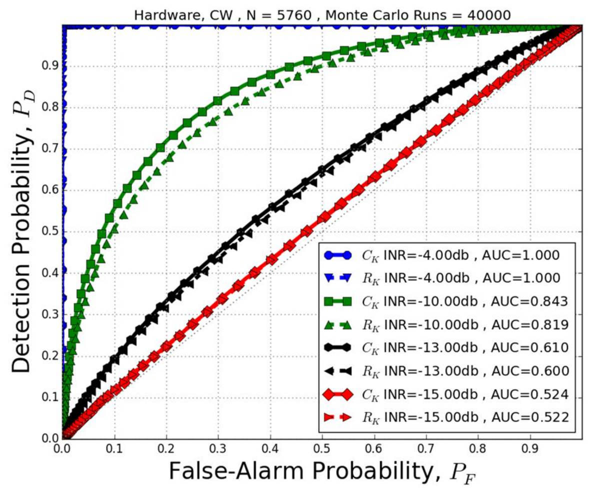
Given a complex baseband signal $z(n) = I(n) + jQ(n)$, the fourth standardized moment is computed independently for both the real and imaginary vectors, I and Q as was used in SMAP[3].

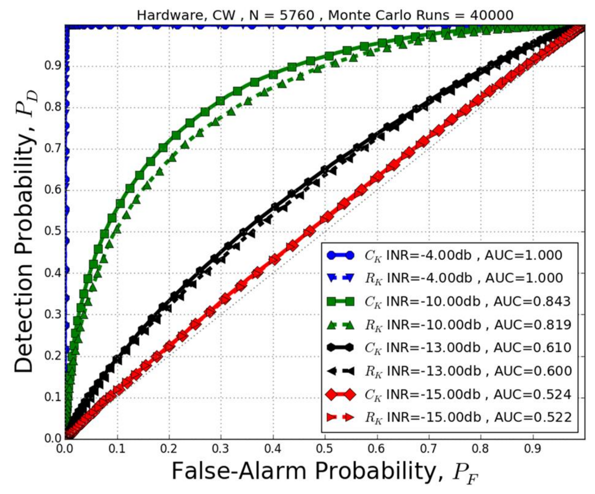
$$\mathrm{RSK_I} = \frac{\mathbb{E}[(\mathrm{I}-\mathbb{E}[\mathrm{I}])^4]}{(\mathbb{E}[(\mathrm{I}-\mathbb{E}[\mathrm{I}])])^2} - 3\ , \mathrm{RSK_Q} = \frac{\mathbb{E}[(\mathrm{Q}-\mathbb{E}[\mathrm{Q}])^4]}{(\mathbb{E}[(\mathrm{Q}-\mathbb{E}[\mathrm{Q}])])^2} - 3$$

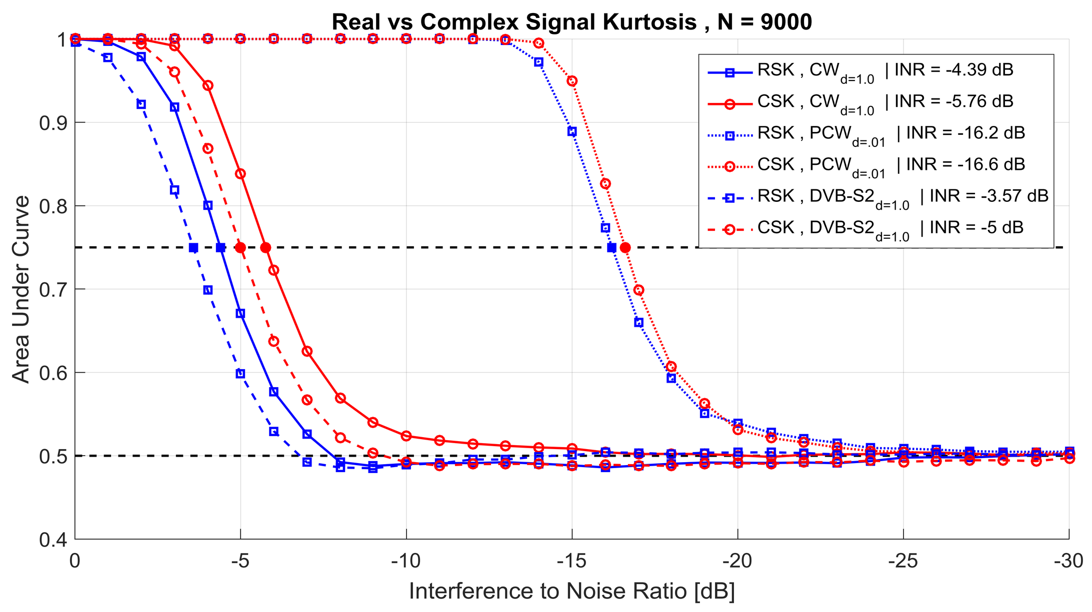
The test statistic, RSK (Real Signal Kurtosis), is then defined as

$$\mathrm{RSK} = \frac{|\mathrm{RSK_I}| + |RSK_Q|}{2}$$

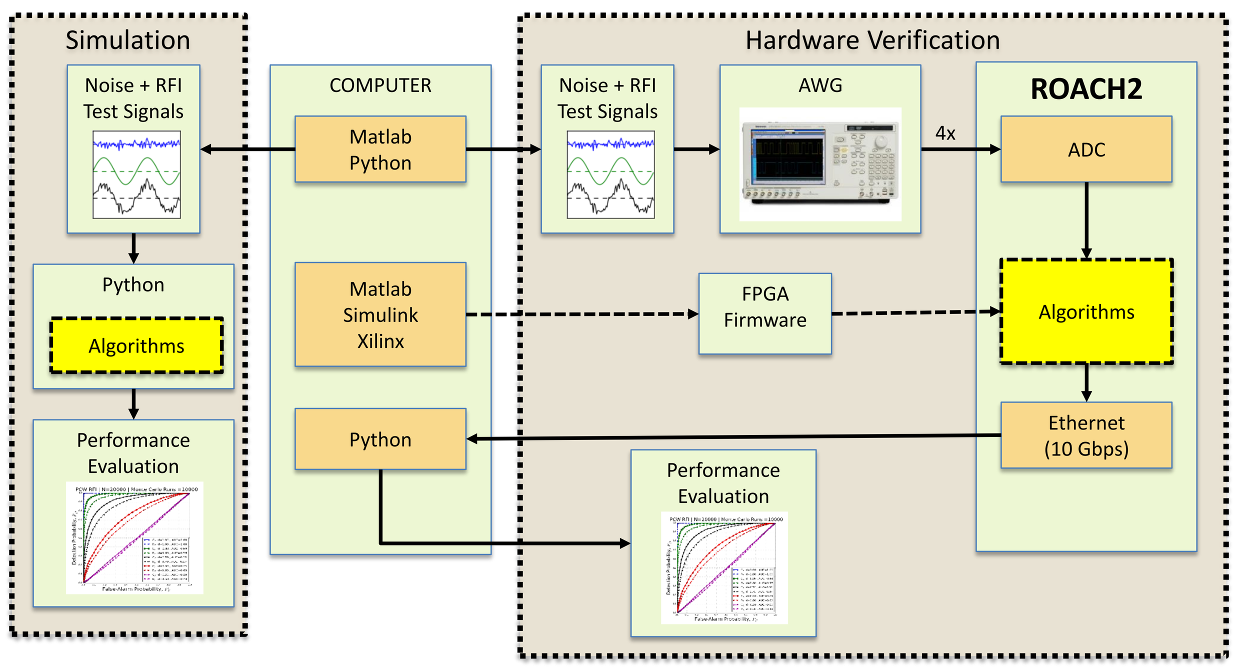
Hardware Results







Methodology



Moment Calculation

Using the nomenclature for raw moments of the rth power, $mI^r = \mathbb{E}[I^p]$, $mQ^r = \mathbb{E}[Q^p]$, full band moments produced to compute kurtosis include.

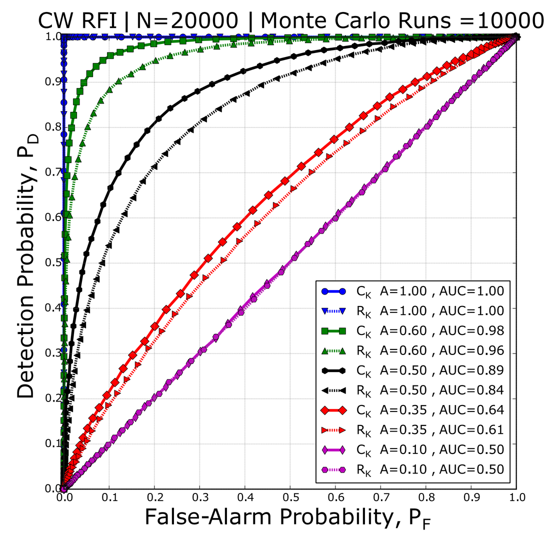
$$\{mI^r, mQ^r\}, \qquad r \in \{1,2,3,4\}$$

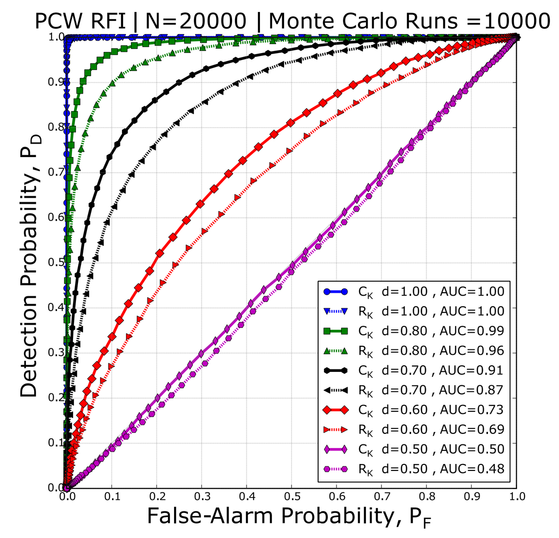
Additionally the following cross complex moments are generated.

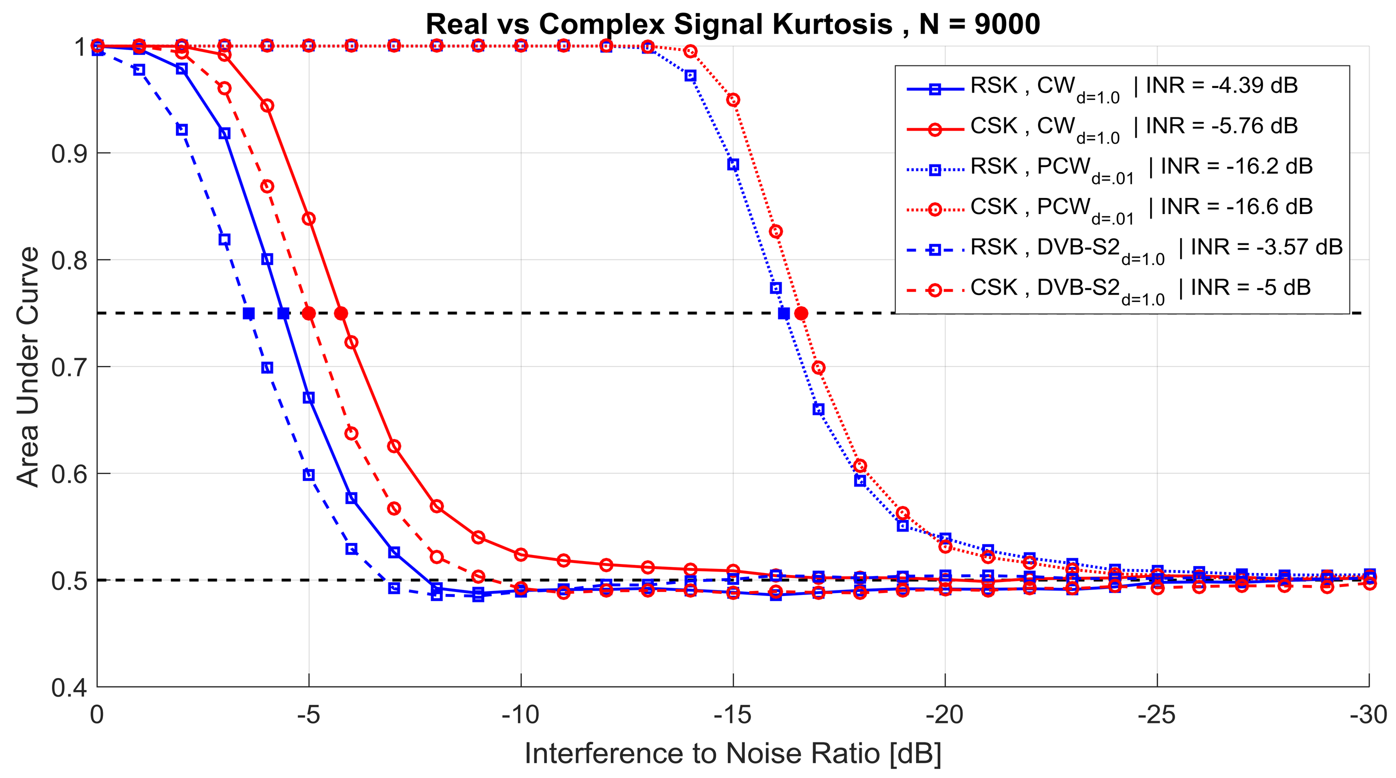
$$\{mIQ, mIQQ, mIIQ, mIIQQ\}$$

In the case of sub-banding , all 12 moments for each polarization are produced for every sub-band.

Simulation Results







Conclusions

CSK (*Complex Signal Kurtosis*) provides a better detection rate than real signal kurtosis.

Interference becomes detectable at an INR (*Interference to Noise Ratio*) of 2dB lower than what can be detected using RSK (*Real Signal Kurtosis*).

References

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3. J. Piepmeier, J. Johnson, P. Mohammed, D. Bradley, C. Ruf, M. Aksoy, R. Garcia, D. Hudson, L. Miles,and M. Wong, "Radio-frequency interference mitigation for the soil moisture active passive microwave radiometer," IEEE Transactions on Geoscience and Remote Sensing, vol. 52, no. 1, pp. 761–775, January 2014.

Acknowledgments

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