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

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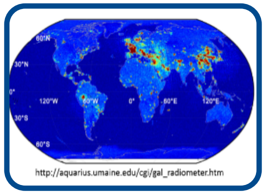
Acronym List

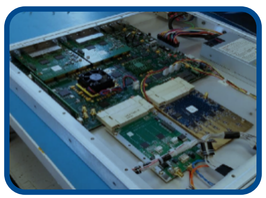
Acronym	Definition
AUC	Area Under Curve
CSK	Complex Signal Kurtosis
CW	Continuous Wave
dB	Decibel
DVB-S2	Digital Video Broadcasting - Satellite - Second Generation
FB	Full Band
Gbps	Billions of Bits per Second
INR	Interference to Noise Ratio
NASA	National Aeronautics and Space Administration
RFI	Radio Frequency Interference
ROC	Receiver Operating Characteristic
RSK	Real Signal Kurtosis
SB	Sub Band

Motivation

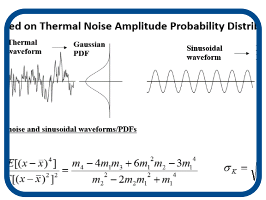


RFI compromises quality of science products.

Spectrum is becoming crowded and shared.



Hardware capabilities allow for digital radiometry.



Need more sensitive detectors for wide-band interference.

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].

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

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

$$RSK = |RSK_I| + |RSK_Q|/2$$

Complex Signal Kurtosis

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

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

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

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

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

$$C_{K}=\frac{\varrho_{2;2}-2-|\varrho_{2;0}|^{2}}{1+1/2\,|\varrho_{2;0}|^{2}}$$

Moment Calculation

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

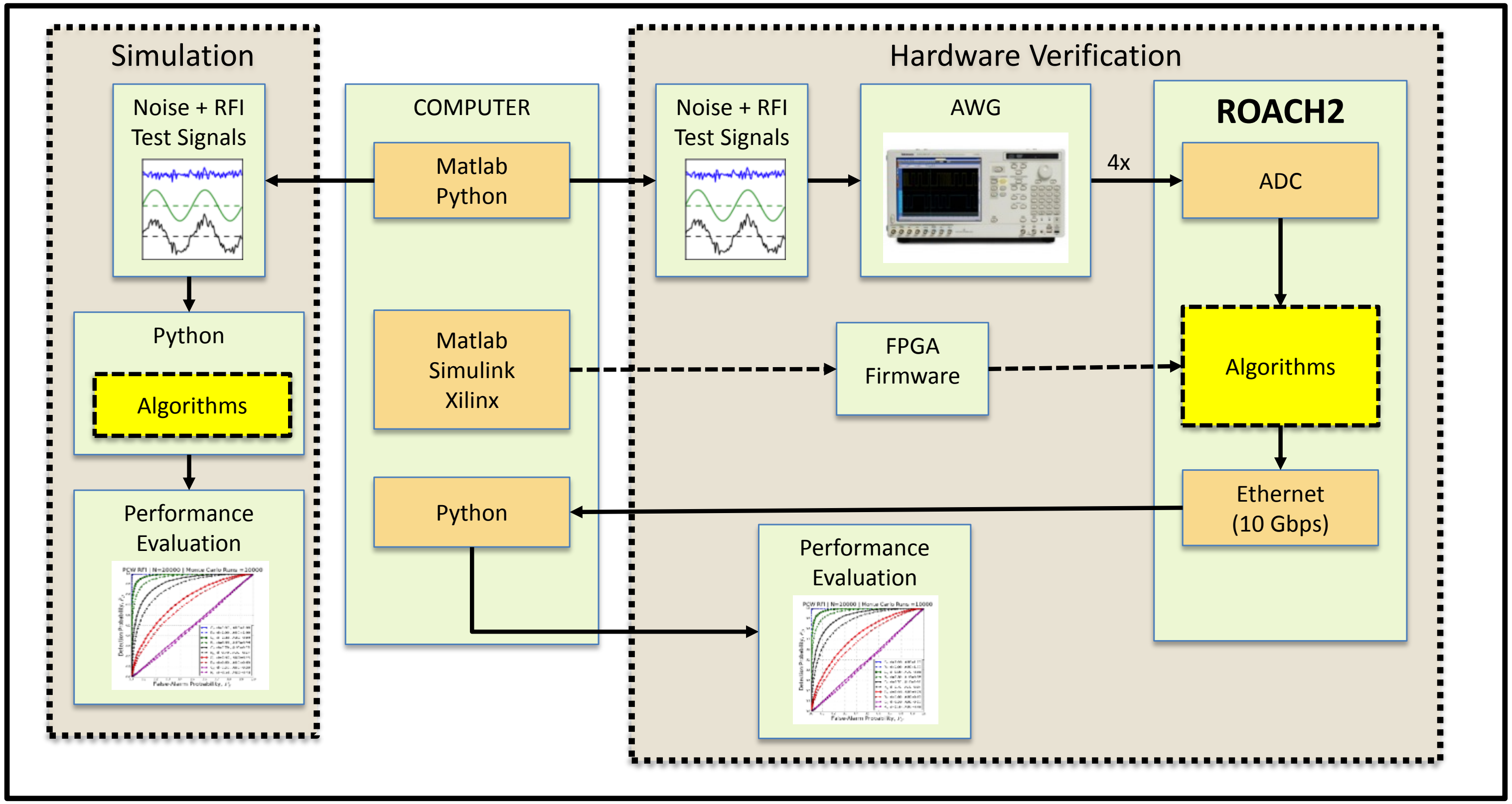
$$\{m_I^r, m_Q^r\},\ r \in \{1,2,3,4\}$$

Additionally, the following cross complex moments are generated

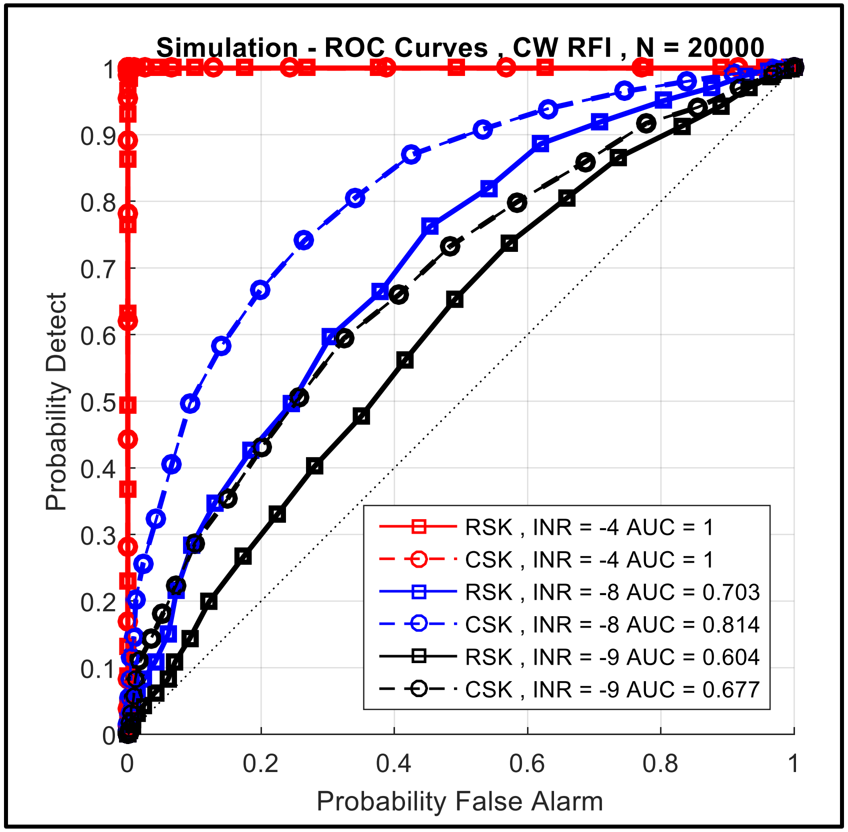
$$\{mIQ, mIQQ, mIIQ, mIIQQ\}$$

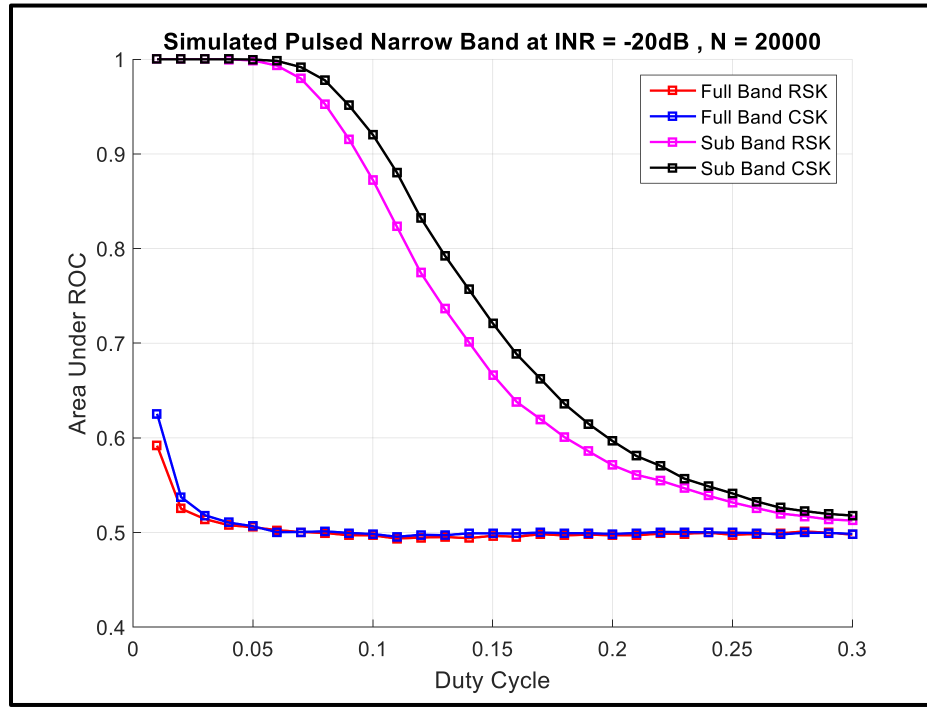
In the case of sub-banding , all 12 moments for each polarization are produced for every sub-band.

Methodology

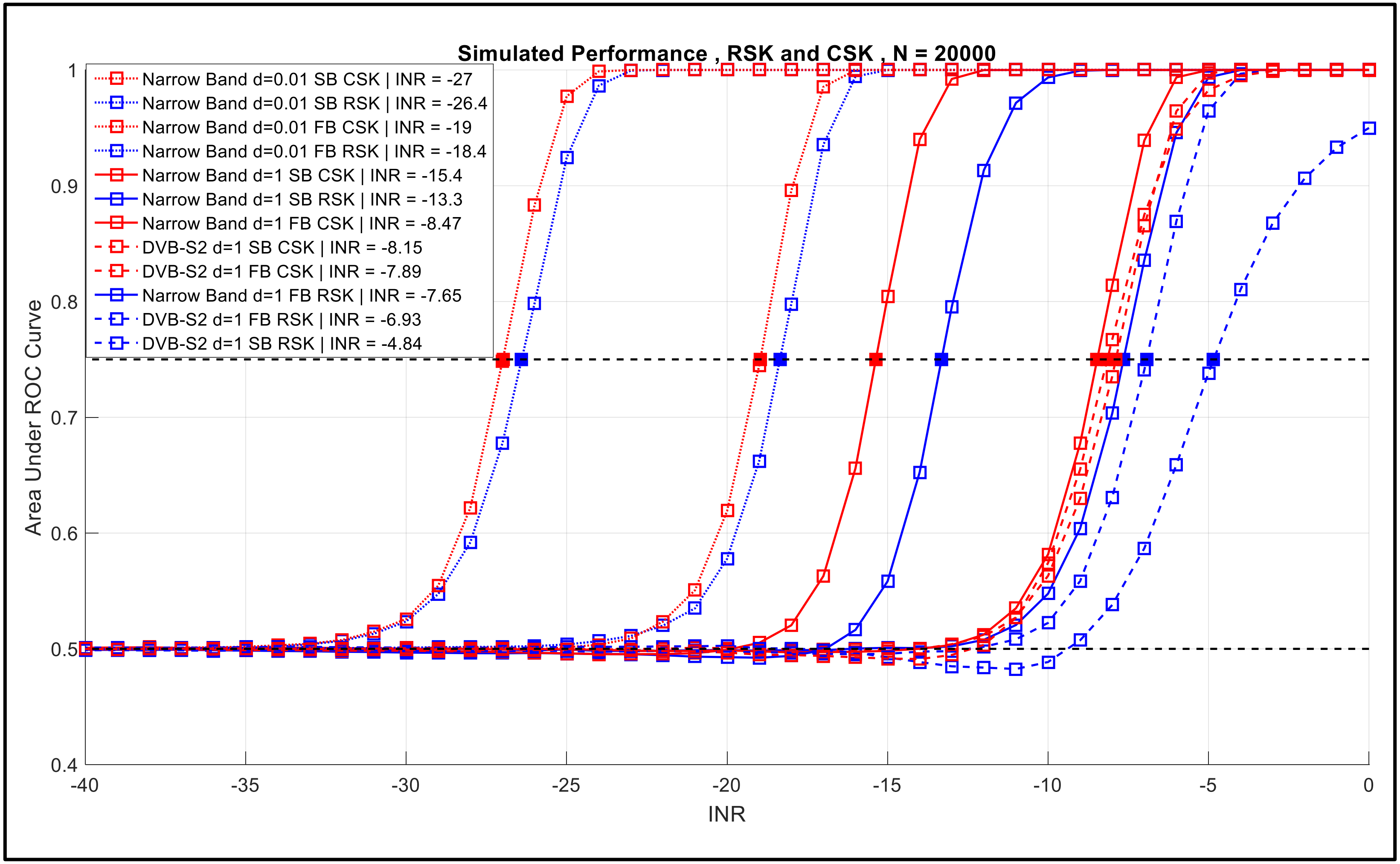


Simulation Results

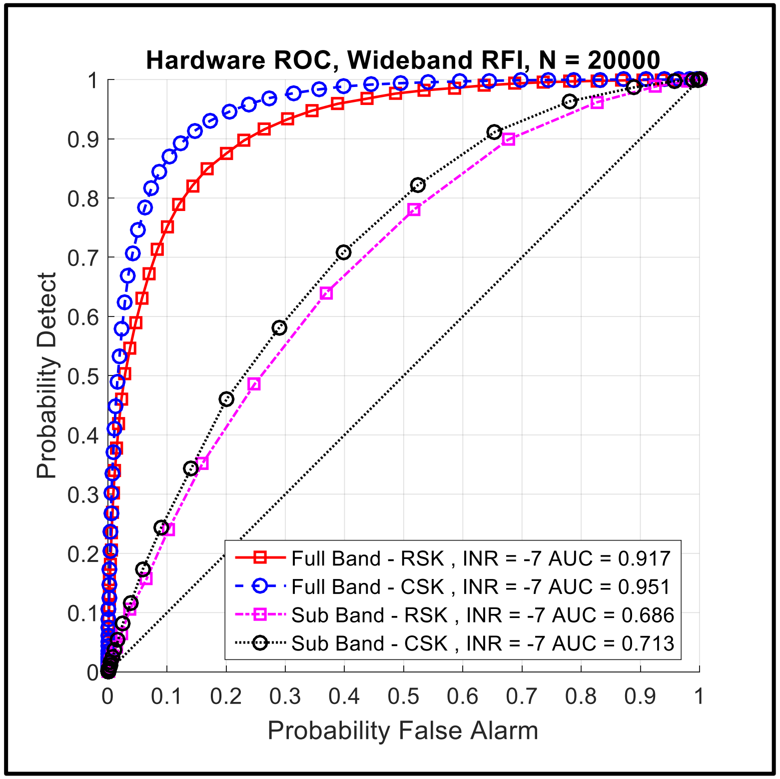


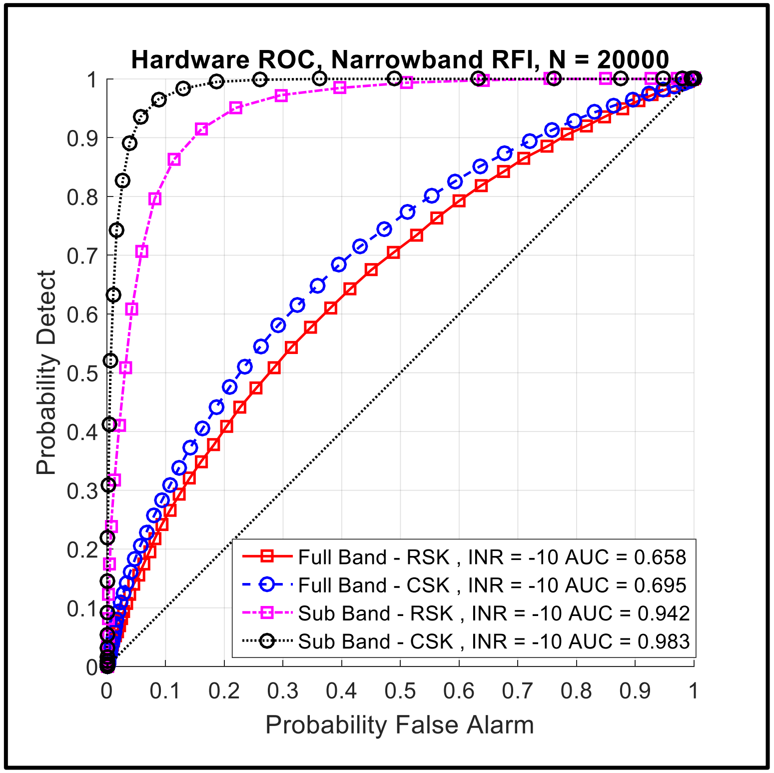


Simulation Results

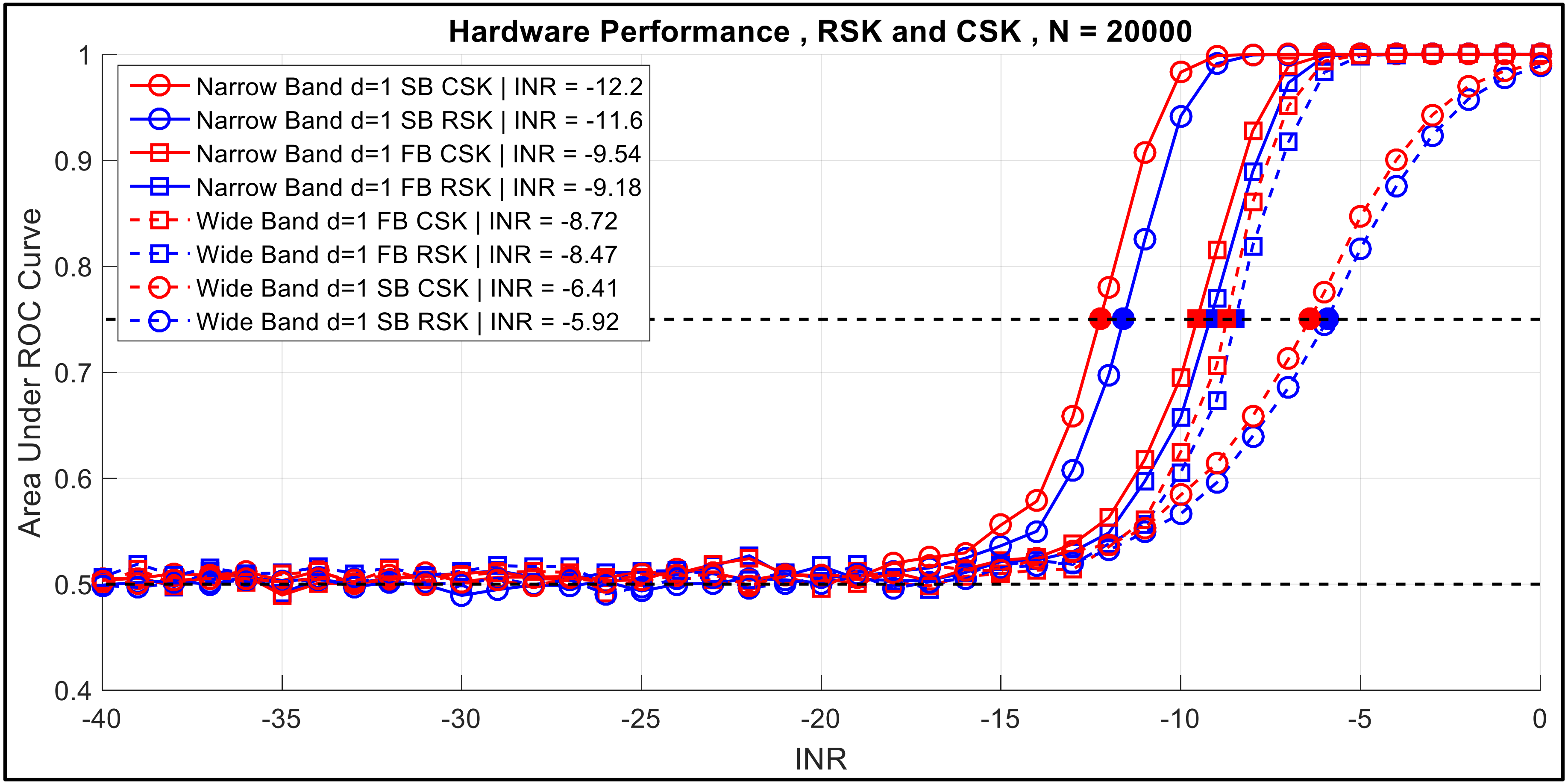


Hardware Results





Hardware 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*).

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References

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