WIDAR Correlator Sensitivity Losses

NRC-EVLA Memo# 011

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ABSTRACT

This short memo presents the results of simulation tests that empirically quantify quantizer sensitivity losses in the WIDAR correlator for the EVLA. These results demonstrate that 3-bit/8-level quantization suffers a ~3.7% sensitivity loss and that 4-bit/15-level quantization suffers ~1.3% sensitivity loss. The results will also show that a WIDAR correlator with 3-bit initial quantization and 4-bit requantization with 5-level fringe rotation suffers a net sensitivity loss of about 7.8%.

Quantization Sensitivity Loss Table

Sensitivity losses obtained from the simulations are tabulated in Table 1. Tests were run with an expected normalized correlation coefficient (ρ) of 0.1 and 0.5. Sensitivity losses of 2.25% [1] due to 5-level fringe rotation are not indicated in these results.

No. of Bits	Fullband		WIDAR (-1.25dB)		WIDAR (-12.5 dB)	
	ρ=0.1	ρ=0.5	ρ=0.1	ρ=0.5	ρ=0.1	ρ=0.5
8	+0.1%	-0.047%	-	-	-	-
4	-1.2%	-1.3%	-	-	-	-
3	-3.8%	-3.8%	-	-	-	-
3 initial; 4 requant	-	-	-6.1%	-5.9%	-6.0%	-5.7%
4 initial; 4 requant	-	-	-3.6%	-3.4%	-3.4%	-3.2%

Table 1 Tabulated results of sensitivity losses for a fullband and WIDAR correlator with expected correlation coefficients of ρ=0.1 and ρ=0.5. In these tests, 100 million samples were correlated. For ρ=0.1, the calculated ±1σ error is ±0.07% and for ρ=0.5, the calculated ±1σ error is ±0.02%. Four-bit quantization has a threshold step of 0.374σ; 3-bit/8-level quantization has a threshold step of 0.65σ, and 8-bit quantization has a 1σ output of 25 levels. If the 3-bit threshold step was reduced to 0.55σ, an improvement of ~0.2% was obtained. The central 896 of 1024 spectral channels were averaged and Hanning windowing was used in all cases. All tests use ideal quantizers.

From Table 1, with 3-bit initial quantization, 4-bit requantization, and using sub-band FIR filters with a –12.5 dB cutoff, the sensitivity loss is about 5.7%. Factoring the sensitivity loss of 2.25% for 5-level fringe rotation [1] and the sensitivity loss of ~0.3%[1] for delay tracking loss [2] yields a total sensitivity loss of about 8%. If the 3-bit threshold is changed to 0.55σ, then the loss is about 7.8%. If 4-bit initial quantization and re-quantization is used, the total sensitivity loss is about 5.7%. Thus, using 4-bit initial quantization rather than 3-bit initial quantization yields a gain in sensitivity of about 2%[2]—probably not worth the additional expense in the fiber-optic transmission system. It is important to note that raw correlation coefficients were converted to normalized correlation coefficients (ρ) by simply dividing the data by the geometric mean of the lag 0 autocorrelation coefficients. This does not take into account the very slight non-linearity in the raw data versus normalized data curve. Taking this into account may reduce the tabulated sensitivity losses by a small amount.

The following figures are plots of the cross-power spectrum for selected tests from Table 1. The roll-off at the upper and lower edges of the band in the WIDAR correlator results are due to the single-sideband mixer in the noise generator used to generate the small frequency shifts. The effect of this roll-off on the tabulated correlation coefficients has been properly accounted for [3] (i.e. this roll-off artificially raises the amplitude of the cross-power spectrum).

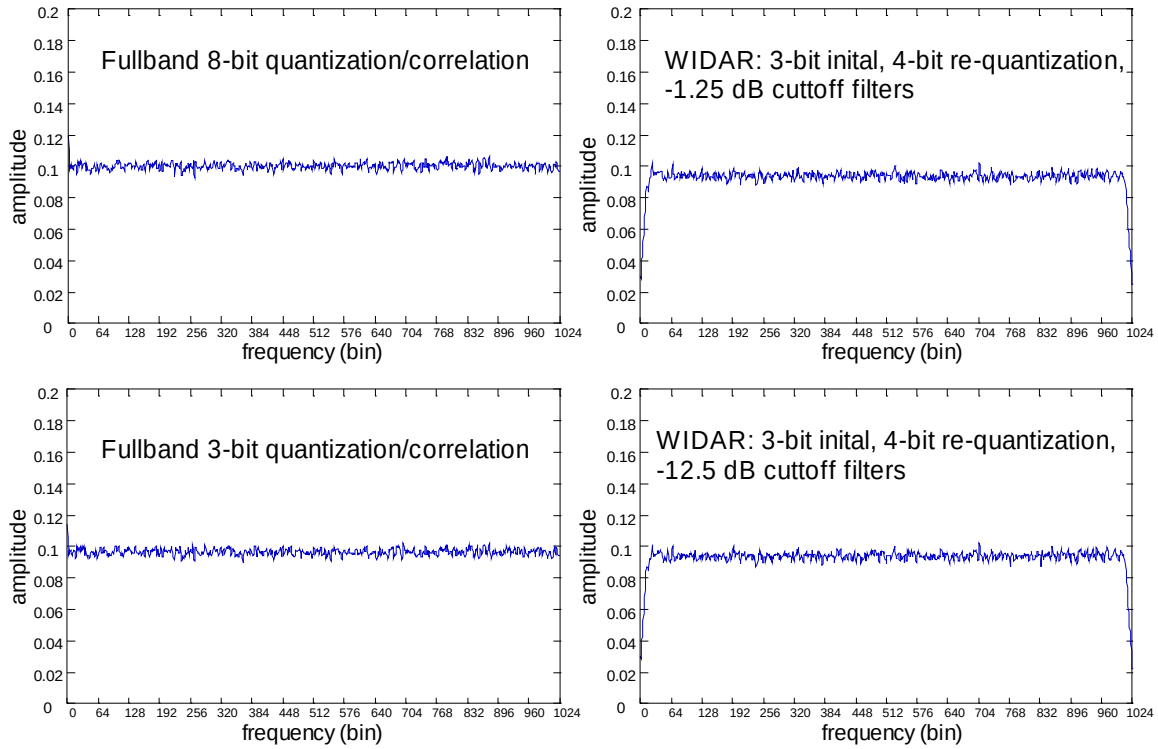

Figure 1 Selected cross-power spectral plots from tests in Table 1 for ρ=0.1

[1] Averaged over the band rather than at the band edge reported in the Memo.
[2] Assuming that the 4-bit quantizer is ideal.

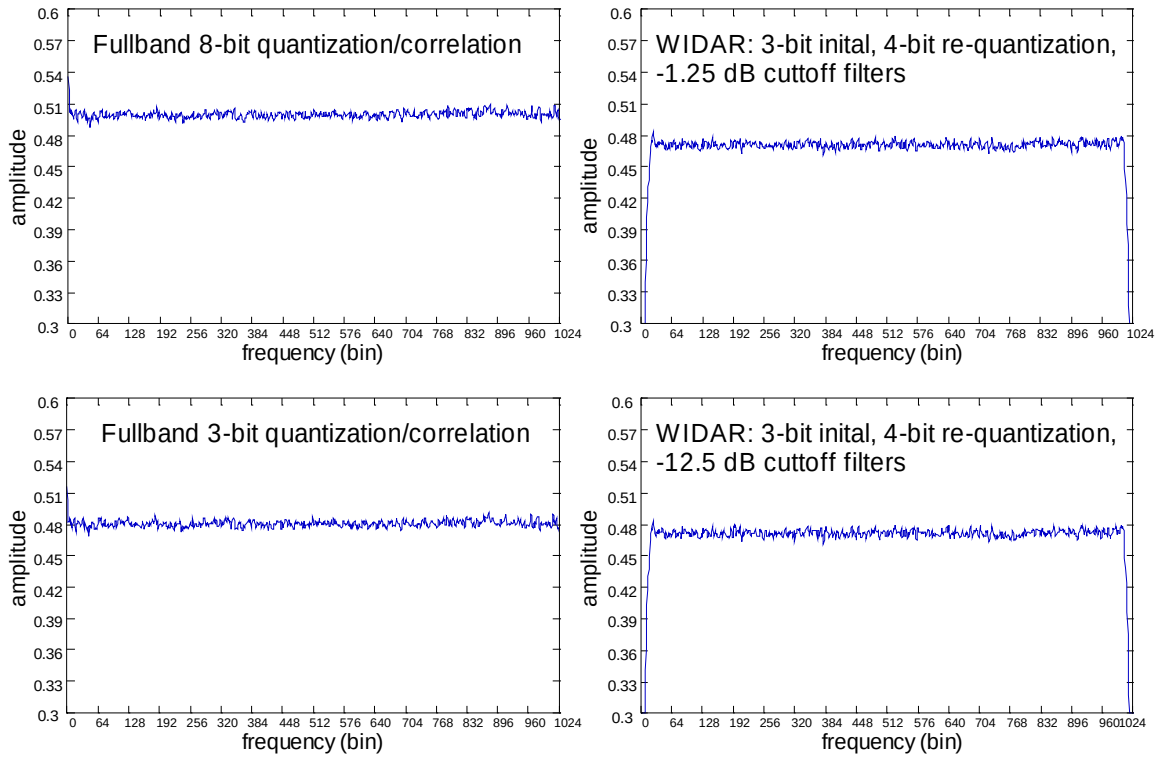

Figure 2 Selected cross-power spectral plots from tests in Table 1 for ρ=0.5

References

[1] Carlson, B., An Analysis of the Effects of Phase Dithering in a Lag-based Fringe-Stopping XF Correlator, NRC-EVLA Memo# 002, May 26, 2000

[2] Carlson, B., Simulation Tests of Sub-Sample Delay Tracking in the Proposed WIDAR Correlator for the Expanded Very Large Array, NRC-EVLA Memo# 007, October 3, 2000.

[3] Carlson, B., A Proposed WIDAR Correlator for the Expansion Very Large Array Project: Discussion of Capabilities, Implementation, and Signal Processing, NRC-EVLA Memo# 001, May 18, 2000.