

## WIDAR Correlator Sensitivity Losses

*NRC-EVLA Memo# 011*

Brent Carlson, January 30, 2001

### 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

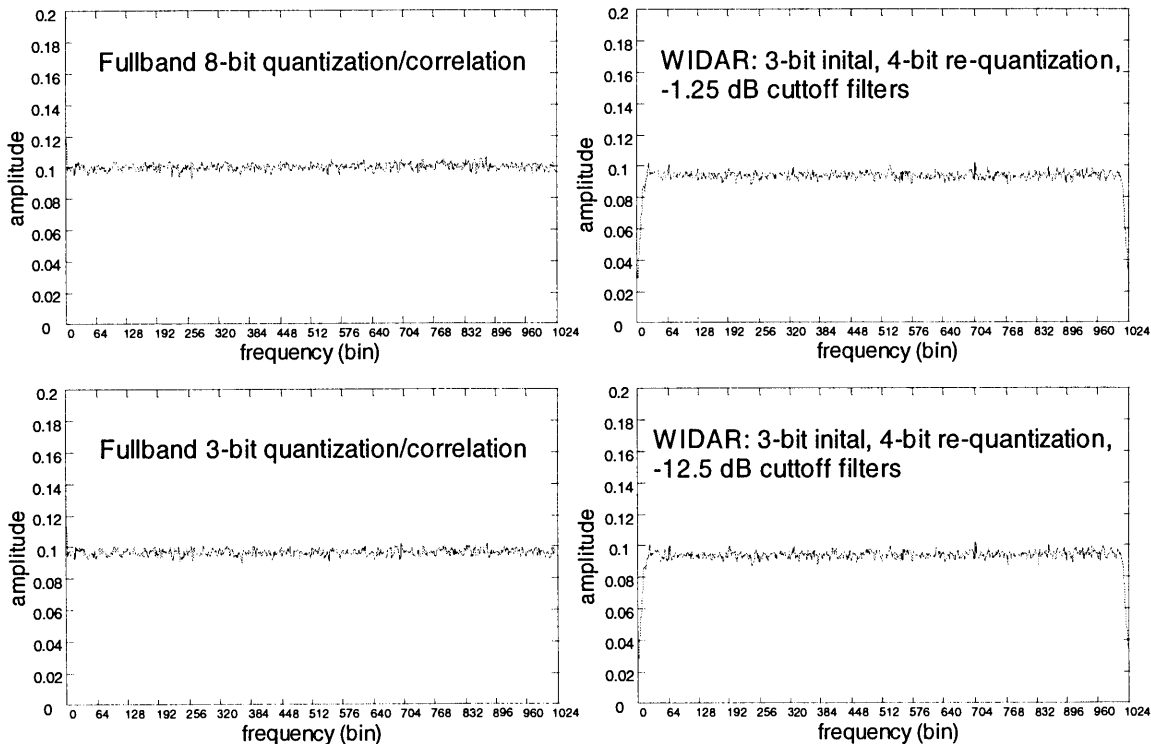
Sensitivity losses obtained from the simulations are tabulated in Table 1. Tests were run with an expected normalized correlation coefficient ( $\rho$ ) of 0.1 and 0.5. Sensitivity losses of 2.25% [1] due to 5-level fringe rotation are not indicated in these results.

No. of Bits	Fullband		WIDAR (-1.25dB)		WIDAR (-12.5 dB)	
	$\rho=0.1$	$\rho=0.5$	$\rho=0.1$	$\rho=0.5$	$\rho=0.1$	$\rho=0.5$
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  $\rho=0.1$  and  $\rho=0.5$ . In these tests, 100 million samples were correlated. For  $\rho=0.1$ , the calculated  $\pm 1\sigma$  error is  $\pm 0.07\%$  and for  $\rho=0.5$ , the calculated  $\pm 1\sigma$  error is  $\pm 0.02\%$ . Four-bit quantization has a threshold step of  $0.374\sigma$ ; 3-bit/8-level quantization has a threshold step of  $0.65\sigma$ , and 8-bit quantization has a  $1\sigma$  output of 25 levels. If the 3-bit threshold step was reduced to  $0.55\sigma$ , 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  $-0.3\%$ <sup>1</sup> for delay tracking loss [2] yields a total sensitivity loss of about 8%. If the 3-bit threshold is changed to  $0.55\sigma$ , 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  $2\%$ <sup>2</sup>—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 ( $\rho$ ) 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  $\rho=0.1$

<sup>1</sup> Averaged over the band rather than at the band edge reported in the Memo.

<sup>2</sup> Assuming that the 4-bit quantizer is ideal.

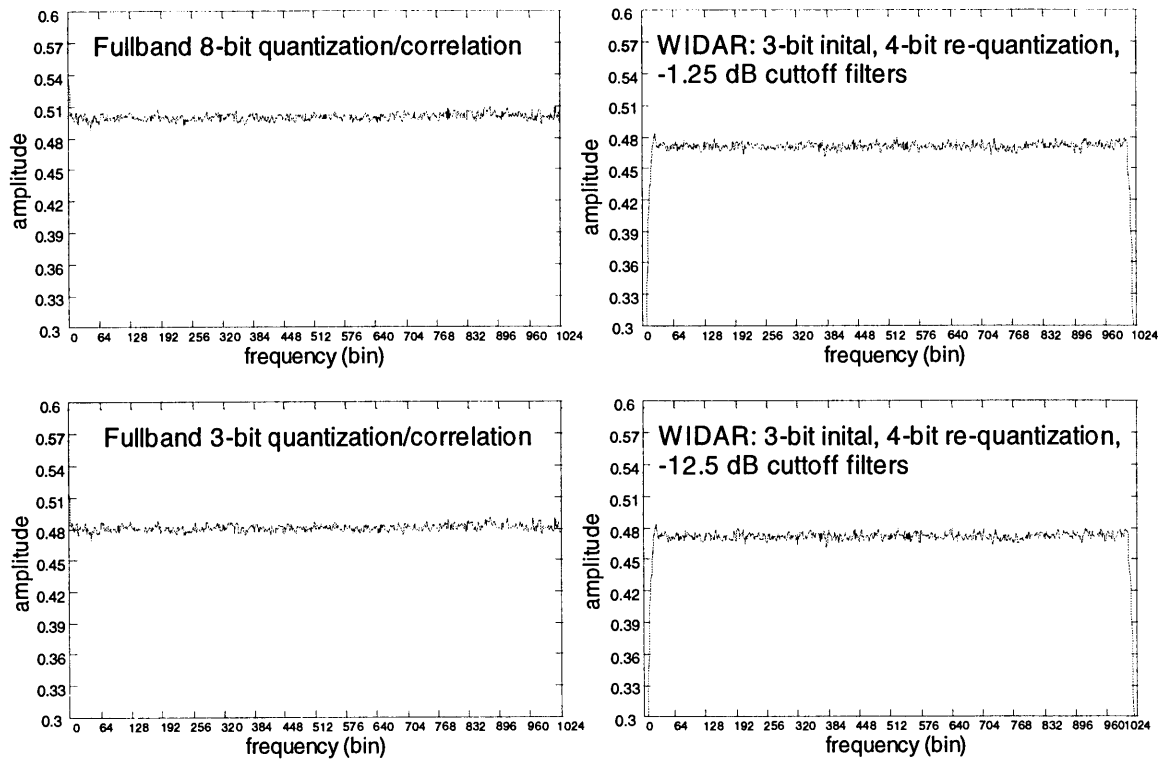


Figure 2 Selected cross-power spectral plots from tests in Table 1 for  $\rho=0.5$

## 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.