VLBA Acquisition Memo # 004

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VLB ARRAY MEMO No. 328

TO: VLBA Correlator and Recorder Groups

FROM: Alan E.E. Rogers

SUBJECT: Single Sideband Fringe Rotation - The effect of the second quantization on the bandpass filter function

Larry D' Addario has shown that when SSB mixing is done with a 4 tap finite impulse response the bandpass response is

$$B(w) = (1+w_1 \sin w\pi + w_2 \sin 3w\pi) \quad (1)$$

where

$w$ = the normalized frequency $w = 1$ at bandedge

$w_1$ = weight of first pair of taps at $\pm$ 1 sample times

$w_2$ = weight of second pair of taps at $\pm$ 3 sample times

Larry has shown that $w_1 \simeq 1.2$ and $w_2 \simeq 0.4$ for minimum SNR loss. The output of the SSB mixer, before quantization is

$$Z_t = x_t \cos\phi + [(x_{t+1}-x_{t-1})w_1/2+(x_{t+3}-x_{t-3})w_2/2]\sin\phi$$

where $\phi$ is the rotation phase. The effective weights $e_1$ and $e_2$ depend on the quantizer function and equal $w_1$ and $w_2$ where enough levels are available to adequate represent $Z_t$. If the sine and cosine functions are quantized to 3-levels (+1, 0, -1) as in the present MK II and MK III processors $Z_t$ can have 27 descrete values for 2-level input data. Ideally the effective weights of each tap should be independent of the states of signals driving the other taps. This will be true if the signal is quantized to the 27 descrete levels but may not be true otherwise. I have done several simulations which show that weights depend, at least for simple quantization schemes, on the spectrum of x. To test the immunity of the descrete SSB filter to this potential defect I chose the following test case:

Initially perfectly correlated signals with flat spectrum, say from a continuum source, corrupted by a strong uncorrelated spectral line near D.C. edge of the band. The spectral line is strong enough to raise the effective system temperatures by a factor of 2 and hence lower the normalized correlation to approximately half.

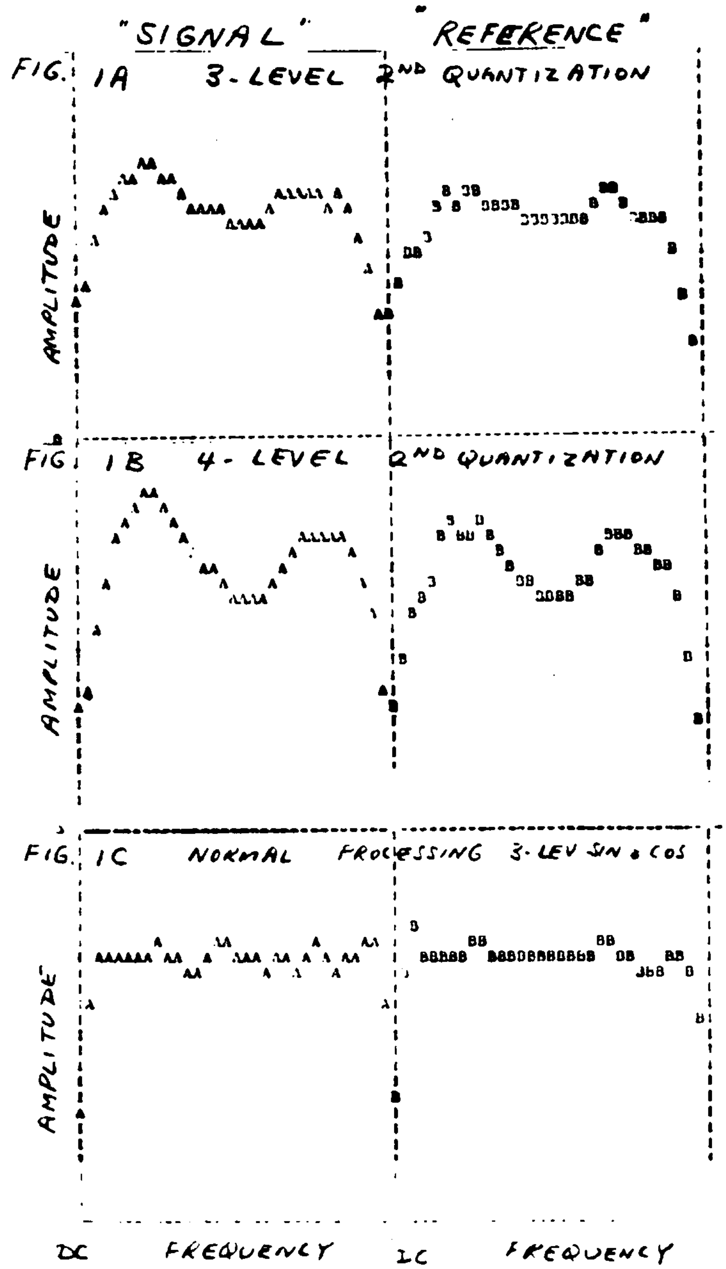


FIG. 1 BANDPASS DISTORTION VARIATIONS WITH DIGITAL SSB MIXING

NOTES:
1] Input data is 2-level
2] Nominal tap weights in 1A & 1B are 1.2 and 0.4
3] Quantization in 1B is $Z_q = 2$ for $Z > 1$ ; $Z_q = 1$ $1 \geq Z \geq 0$ etc.
4] Note that amplitude of sin $3\omega T$ appears to increase in 1A, 1B for the 'signal' case. Also 1st peak ≈ 10% higher than 2nd peak
5] see text for definition of signals in 'signal' and 'reference' cases
6] The same data were used for each of the three types of processing

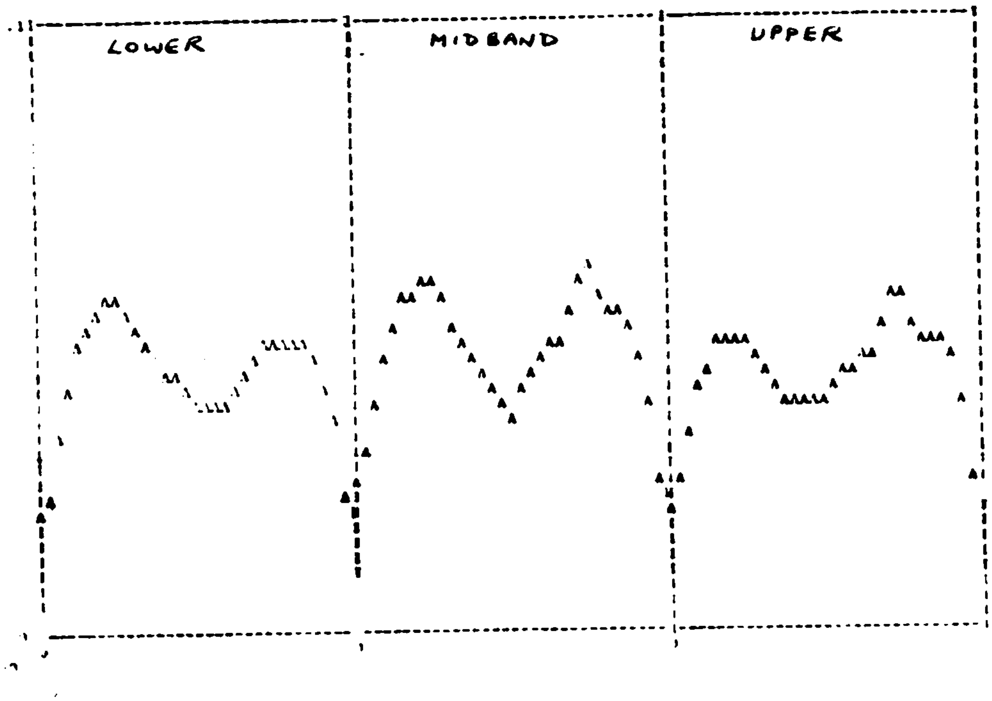


FIG. 2 BANDPASS DISTORTION VS LOCATION OF UNCORRELATED SPECTRAL SOURCE

Note: The bandpass distortion shown in figure 1B changes when the spectral source is moved to the middle and then to the upper portion of the band. Apparently the spectrum effects not only the effective tap weights but also introduces a slope across the band which changes sign as the spectral line is moved from the lower to the upper portion of the band.

A reference case is one of partially correlated signals with flat spectrum and 0.5 normalized correlation.

Figure 1A shows the correlation spectrum for both signal and reference for 3-level quantization at 0.383 using perfect sine and cosine functions. Figure 1B shows the correlation spectrum for 4-level quantization at 1.0 (i.e. for $Z>1$ $Zq = + 2$, for $1 \geq Z \geq 0$ $Zq = + 1$ etc). Figure 1C shows the same "signal" and "reference" cases using the conventional VLBI processing method with the standard 3-level sine and cosines.

Comments on the results:

The effective bandpass is a function of the input spectrum as a result of the second quantization. It may be possible to find quantization levels which ameliorate the effect, but I doubt that it can be reduced to the 1% level. The conventional processing method is completely free from this defect and the bandpass remains flat (it gets noisier, as it should, at the lower nd where the spectral line raises the system temperature). All those simulations are somewhat noisy since only 138,000 data samples were processed in a simple Fortran program. No tests have been done with fringe rotation in both data streams, presumably this would make the bandpass predictability even harder. Obviously this problem would make the calibration of spectral line data especially difficult when there are strong signals in the bandpass as is often the case.