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PERIODIC SIGNAL ERRORS AND THE FX CORRELATOR

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The possible effect of periodic errors in VLBA signal streams arose during a discussion of interference from the SOWRBALL radar of the U.S. Customs Service. Periodic errors could also result from loss of a tape track. The SOWRBALL radar will operate at L-band, and one unit will be located in a tethered balloon within line-of-sight of the Kitt Peak VLBA antenna. The prf (pulse recurrence frequency) of the radar is 375 Hz[1], so that out-of-band emissions of the pulse spectrum that fall within the VLBA response will cause pulses of interference at intervals of 2.667 msec. Craig Walker pointed out that for a VLBA baseband bandwidth B, the sequence of 1024[2] samples that are Fourier transformed in the FX correlator recurs at intervals of 1024/2B, and thus for a VLBA bandwidth less than 250 kHz, a short burst of interference will occur during every 1024 sample sequence. (The baseband bandwidths of the VLBA are 16, 8, 4, 2, 1 MHz, and 500, 250, 125, 62.5 kHz.) The duration of the interference from a single radar pulse will probably be a few microseconds, or a few reciprocal receiver bandwidths, whichever is the greater. Thus, as a guess, I would expect the number of contaminated samples resulting from a single radar pulse to be as high as, say, 100 for 16 MHz bandwidth, or as low as 4 for the narrower bandwidths. If the corresponding samples are deleted, i.e., given zero weight in the Fourier transformation, then the absence of these components results in sidelobes in the frequency response function. The measured cross power spectrum of the signals from two antennas is the true spectrum convolved with an instrumental frequency response function that is the Fourier transform of the cross correlation of the weighting (window) functions of the data-sample sequences involved. Thus for uniform weighting at the FFT inputs, the frequency response function is of sinc-squared form. Deleting samples from the FFT input modifies the weighting and distorts the frequency response. Several tens to several hundreds of such consecutive spectra contribute to each integrated visibility value, and if the total

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[1] 375 Hz is the average prf. The pulse intervals actually follow a sequence of non-identical values that repeats every 21 pulses, to avoid 'blind spots' in the Doppler velocity. This detail will be ignored here: it would complicate any pulse blanking scheme but does not change the basic considerations discussed.

[2] The FFT can handle 2048 samples, but zero-padding would reduce this to 1024. Submultiples of 1024 can also be accommodated, but for simplicity only 1024 is considered here.

deleted samples in one integration period are approximately uniformly distributed across the 1024 input locations of the FFT, the overall distortion is likely to be small. Nevertheless, the effect of deletion of samples cannot be ignored if the highest spectral dynamic range is required. The distortion of the frequency response can be corrected for after integration if the number of deleted samples in each of the 1024 input locations is known, for each integration period. Since the integration is performed on the cross products from two antennas, such a correction would have to be applied on a baseline basis.

An antenna-based weighting correction can also be implemented as follows. We assume that the FFT recurrence frequency is neither equal to, nor an integral submultiple of, the radar prf. The locations of the input samples that are given zero weight in one FFT sequence will then contain uncontaminated samples in the following sequence. The data in these locations in the second FFT sequence are then given weight 2, to produce an approximately equal and opposite distortion of the frequency response function. This process is repeated, so that the effect of deleted samples in any one sequence is compensated for in the next sequence. The cancellation of the distortion in the summing of a pair of spectra will not be exact, because the signals in the FFT inputs are Gaussianly distributed quantities, but the overall effect in the integrated visibility should be satisfactory. This scheme requires that data samples at the FFT input should have assignable weights of zero, one, or two. Its use is likely to be most important for low bandwidths in which most FFT sequences contain interference, and hence the corresponding data clock rates are low. It need only be incorporated in one or two of the tape playback channels, since most antennas will be free from periodic errors most of the time.

Another possible cause of periodic errors can occur when the data from a sampler is spread sequentially over a number of tracks on the tape, and the data on one such track is lost due to a recording-head malfunction. Again the double-weighting scheme described above can be applied, so long as the missing-data locations in one 1024-sample sequence are not the same as those in the following sequence. Since the number of data tracks recorded simultaneously, which is 32, is a submultiple of 1024, the missing-data locations may indeed repeat for some recording formats. A possible way of avoiding such repetition would be to make consecutive 1024-sample sequences overlap by one sample, or to omit a sample between sequences.

In conclusion, it would be useful to verify the effectiveness of the double weighting scheme described above by a numerical simulation using Gaussianly distributed signals. If this scheme is successful, we should consider incorporating it, or some similar weight-adjusting capability, in the VLBA correlator.