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Some Remarks About Phase Switching

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The phase switching waveforms for the VLBA must be either applied in a geocentric time frame (with attendant problems in exactly reproducing the switching time algorithm at playback time) or must consist of waveforms that are orthogonal independent of lag.

It turns out that the general Walsh functions do not have this property; the only lag independent orthogonal Walsh functions are of the form

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and so forth. On the other hand, symetric square waves are lag independent orthogonal over a period commensurate with the two periods of the different square waves involved. It seems appropriate to search for a good set of these.

Let a "tick" be the shortest time interval on the boundary of which one is willing to perform a phase switch. This might be a single sample time, a sync block of 128 bits, or some other natural time in the system. Then the best collection of 20 square waves (one for each playback unit in the correlator) that I have been able to find is those with periods of 2, 4, 6, 8, 10, 12, 16, 20, 24, 30, 32, 40, 48, 60, 80, 96, 120, 160, 240, and 480 ticks. These are lag-independent orthogonal over a period of 480 ticks.

Let us inquire a little further how short a tick might be. If, in the interest of system simplicity, we require a fixed tick length for all observations, then the limiting case comes at narrow bands. There is an interaction between minimum switching times and the width of the baseband filter. Since we wish to observe with a baseband filter as narrow as 62 kHz, the minimum phase switching interval must be long compared to the reciprocal of this, 16 microseconds. How much longer is a question which has not been investigated, and which I am too lazy to investigate here. I suggest, as a reasonable guess, that if we eliminate the two tick period of the set suggested above (after all, one station can remain unswitched and still be orthogonal to the other nineteen), that a 16 microsecond tick would be supportable.

This makes the period of orthogonality 7.68 milliseconds. This is also the period of the lowest beat frequency between the square waves.

When the fringe frequency for any baseline is equal to the phase switching beat frequency, rejection of sampler DC offsets, etc., is essentially lost. Therefore, when the fringe frequency on one of the correlators which has this minimum beat frequency of 130 Hz is equal to that beat frequency, this correlator will have an anomalous result, corresponding to the zero fringe frequency case with no phase switching. Although a correlator would normally dwell in the neighborhood of 130 Hz for only a few seconds, the worrysome case will occur for some baseline and declination, when the maximum fringe rate is around 130 Hz. In this situation, the correlator would have a fringe rate within 0.1 Hz of the phase switching beat for up to 18 minutes. This situation is, albeit very improbable, extremely serious when it does occur.

After these specific remarks, I can perhaps add one general one. That is, that any search for a general solution to the DC fringe problem based on phase switching or the equivalent, LO offsetting, is probably doomed to failure, because the highest fringe rates we have to deal with are so much greater than the narrowest bandwidths we have to deal with; there is no convenient hole in the spectrum into which we can shove the problems. In particular, doing the phase switching in a geocentric time frame, where one could use the efficient Walsh Functions and a correspondlingly shorter maximum beat period only gets a factor of about seven, moving the minimum beat frequency to about 1 kHz, and the worst case to that in which a source with a fringe frequency maximum equal to that minimum beat frequency is within 0.1 Hz of it for six minutes.

If phase switching is used to eliminate sampler DC offsets, it seems to me that it is required to search for cases like those mentioned above, and to avoid them by dynamic allocation of switching waveforms to stations. I am not pleased with the prospect of writing the program that does this allocation. I would much rather see the DC fringe problem handled by corrections based on a measured state probability. Admittedly this does not provide protection against low level coherent signals introduced with the final LO or with the sampling clock, but I would hope that these could be sufficiently controlled by other means in a well regulated system.