CSIRO DIVISION OF RADIOPHYSICS

THE AUSTRALIAN TELESCOPE

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LABELLING DIGITIZED IF DATA WITH TIME INFORMATION

Absolute time will be provided at each antenna with a resolution of 1μ second by Geoff Crapps' clock. If proper account is taken of propagation delays the time of a given clock transition at an antenna with respect to time at the central clock will be known to $\sim$ 20-50 nano-seconds. The LO system, however, is capable of $\sim$ 2 picosecond stability. Thus, absolute timing to this precision is possible in principle, provided absolute timing can be determined at same epoch.

The aim of this note is to define how we might use the clock and LO signals to:-

(a) control the sampling clocks to the required precision ($\sim \frac{\tau_s}{32}$ = 60 pica-seconds for $\tau_s = \frac{1}{512}$ MHz) and;

(b) ensure that the appropriate samples from different antennas are multiplied in the correlator.

Basically, we require a stable clock derived from the LO at each antenna wich has a resolution of order τ_s (the sampling interval) and stability better than 60 p second on all time scales. Initially the absolute time for this clock will be known to $\sim$ 20-50 n sec from comparison with the normal station clock. This error will remain stable in principle to $\sim$ 2 p sec but to at least 60 p sec for as long as the LO system maintains its integrity. The magnitude of the error for each antenna can be determined from the phase slope across the output channels of the correlator during observations of point source calibrators. This measurement should be done separately for each IF channel as part of the set up procedure before an observation and checked at each return to the calibrator during an observation. The duration of the calibration observation and the strength of the calibration source must be sufficient to allow the delay error to be measured to better than 60 p sec.

At the start of each integration period the LO clock will be used to label a particular sample at each antenna. This will indicate to the correlator which sample from one antenna should be correlated with its counterpart from each of the other antennas. The details of how the labelling might be done will be discussed later. These sync. pulses should be timed to be simultaneous in the frame of the wavefront. They will of course deviate from this ideal by up to 50 n sec (or $\sim$ 25 sample intervals of 512 MHz sampling rate) when first set up. This gross error will be measured as described above and corrected for as follows:-

(i) The phase of the sampling clock will be adjusted by a fraction (fi) of a sample interval so that the remaining error is an integral number (n_i) of sample intervals.

(ii) The sync. pulse can then be shifted by the appropriate number of sample intervals. Alternatively rather than begin correlating at the time of the sync. pulse. The start can be delayed by n_i sample intervals. Of course, in this case an equal delay n_0 has to be added to all antennas so that $n_i + n_0$ is always positive.

FIGURE 1

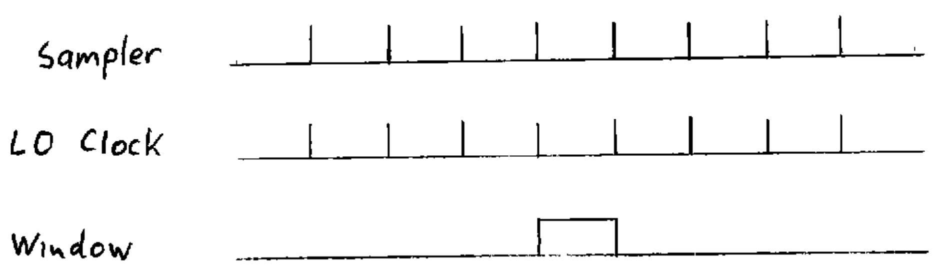
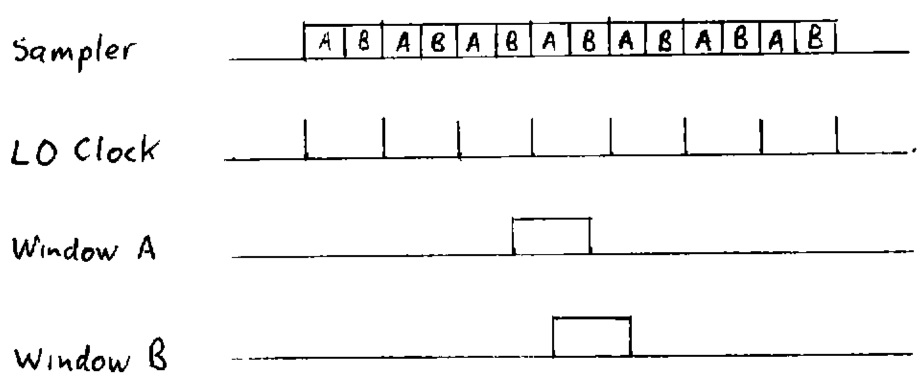


FIGURE 2



The labelling of a given sample as the sync. pulse is not entirely straightforward. The problem arises partly because of indecision due to jitter when the pulse trains representing the sample time and the clock are nearly in phase and partly because of the varying sampling rate. Figure 1 shows a simple implementation that illustrates the problem. One train of pulses is derived from the LO clock and has a fixed pulse rate. After counting an appropriate number of these pulses a window is defined between two of these pulses in which the sync. pulse should occur.

The second train of pulses define the times at which samples will be taken and the pulse rate, although similar to that of the LO clock, is a slowly varying function of time. It may equally be greater than or less than the LO clock rate. Thus, it is clear that in the near synchronous situation shown in Figure 1, two, one or none of the sampler pulses may fall in the window. If we then consider the jitter and agree that we will label the first sampler pulse to occur in the window it is still uncertain which, if either, of the two possible pulses will be labelled.

The solution to this problem was pointed out by Mike Kesteven and is relatively simply implemented. Figure 2 shows how we might proceed. The important point is that the phase difference between the two pulse trains is essentially that phase which is calculated and then applied by the phase shifter associated with the sampler (there may also be a fixed instrumental offset in phase that must be accounted for in the phase shift calculations). Consequently, we always know when uncertainties may arise. Thus, simply by specifying two different windows which will be applied for different ranges of relative phase between LO clock and sampler the correct sample can always be chosen as the sync. pulse. Figure 2 shows these ranges of phase difference and the appropriate windows. The windows are simply advanced or retarted by $\frac{\tau_s}{4}$ relative to the window in Figure 1.