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A LOWER LIMIT TO LBA CLOCK ACCURACY

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<u>SUMMARY</u> If fringe rotation is done at the antennas, then considerations of accumulated frequency error show that, for a 20GHz observing frequency and a 10s integration time, fringes will be decorrelated within one integration period. The problem can be rectified by either

1. Equipping each LBA station with a time standard (additional to the frequency standard) accurate to 0.05μs absolute, or 5.10^{-13} on a weeks timescale, which is likely to cost about $50k per station, or

2. Using real-time satellite LO links, or

3. Performing the fringe rotation at the correlator, or

4. Providing real-time fringe detection (e.g. using telephone lines) to adjust the frequency standards at each station.

The following notes were prompted by a conversation with Jim Roberts.

WHAT THE PROBLEM IS <u>NOT</u>:

In a conventional VLBI setup, where fringe rotation is performed at the correlator, the clocks at the individual stations are frequently wrong by several μs. This has the effect of shifting the fringes in delay, and so at the start of a session the first job is to determine clock offsets. This is done relatively easily by searching for fringes on calibrator sources. The clocks subsequently drift typically by a fraction of a μs per day, and this is easily followed throughout the VLBI session. This source of error is easily corrected for in the LBA, regardless of where the fringe rotation is done. This is therefore <u>not</u> a problem.

WHAT THE PROBLEM <u>IS</u>:

An additional source of error arises from the error in the <u>frequency</u> standard used at each station. I assume for the purposes of this discussion that this is tied to the clock in use at each station. Suppose that the frequency standard is wrong by 1 part in 2.10^{11} (this is the current error in the Parkes Rubidium standard). Note that this is still consistent with an Allan variance of, say, 1 part in 10^{12} since the latter measures the <u>change</u> in frequency as a function of time, rather than the accumulated offset. However, this error in frequency implies that two stations observing at, say, 20 GHz will have LO's which differ by about 0.1Hz. Thus, if the phase rotation is done at the antennas, the correlated signal will have an apparent residual fringe rate of 0.1Hz, and so will decorrelate in the 10s integration time of the correlator.

It is important to note two points here. First, this error is <u>not</u> the same as the well-known decorrelation due to random fluctuations of the standards on a minutes timescale. That might cause the 20GHz signals to decorrelate on a timescale of 100s for a 10^{-12} Allan variance, whereas here we are talking about an <u>accumulated</u> error which might be ten times worse.

The second point is that, in a conventional VLBI system, this LO error could be measured from calibrator sources, and then applied as an extra term in the fringe rotation. However, if fringe rotation is done at the antennas, we have no such option. We may be able to alleviate the problem by reducing the integration time to, say, 0.5s. but this may produce unacceptably large volumes of data.

The problem is: how do you detect and correct such an error in frequency.

SOLUTION 1 : COMPARISON WITH ABSOLUTE TIME

The most obvious solution is to look at the <u>clock</u> error, since this frequency offset implies that the clocks drift by 0.5μs per day. Thus in the case of the LBA we must ensure that the clocks used at each site are always accurate to 0.05 μs/day (corresponding to a residual fringe rate of 0.01Hz at 20GHz, or 1 part in 2.10^{12}).

To measure such a drift rate requires an absolute time accurate to, say, 0.05μs. This can probably be achieved using a full-blown GPS system, costing about $50k per station (ACY, private communication).

SOLUTION 2: USE ASTRONOMICAL MEASUREMENTS

The drift rate can easily be measured using observations of calibrator sources. However, with the present system this would involve making the observations, taking the data to Culgoora for processing, and then taking those results back to the LBA stations to adjust the clocks. Therefore, probably a week might elapse between taking the data and adjusting the clocks. Thus, a week before an LBA session, preliminary runs would have to be made to do this. In practice, we might use observations from the previous run to calibrate the following run. Either way, we need standards which will not change their drift rate appreciably between the calibration observations and the astronomical measurements, and so we require time standards with an accuracy of 5.10^{-13} on a time scale of weeks, and H-masers don't have this accuracy.

Our best bet then with this option seems to be to install real-time fringe detection, using telephone lines. There are also strong arguments for having these anyway for checking the LBA operation, but such equipment and software has not yet been designed.

SOLUTION 3: USE REAL-TIME SATELLITE LO LINKS

This option may well turn out to be attractive if the cryo cavity oscillators turn out not to reach our specifications. However, if we do use the cryo cavities, it would be hard to justify installing satellite links as well.

SOLUTION 4: PERFORM THE FRINGE ROTATION AT THE CORRELATOR

This has other arguments in its favour too.