VLB ARRAY MEMO No. 349

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27 April 1984

TO: VLBA Design Team

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SUBJECT: Further Comments on Phase and Delay Tracking at the Stations

The advantages of a simple acquisition system with phase and delay tracking at the processor has been summarized in VLB Array Memo #326. A case for phase and delay tracking at the antennas has been made in Memo #345. In response to Memo #345, a few additional comments are needed:

1] Double Sideband Front Ends

At millimeter wavelengths many low noise amplifiers are double sideband. In May 1983 for example, fringes were obtained in both sidebands simultaneously (at 89 and 86 GHz). Fringe rotation by offsetting the baseband L.O. will only do the rotation correctly for one sideband. With rotation at the processor all sidebands and image bands can be processed.

2] Low Fringe Rates

At 300 MHz fringe rates are less than 1 KHz and on short baselines are so low that local oscillator offsets will probably be required if phase tracking and phase switching is not done at the stations. However, in these cases, fringe rates can be maintained high by using a different fixed L.O. offset at each station. For example, if stations offset from 0 to 90 KHz for stations one through ten, there will never be any fringe rates below 9 KHz on any baseline at 300 MHz. More sophisticated offsetting schemes could be used to reduce the span of offsets.

We also point out that a processor with fringe rotation, if properly implemented, can process fringe rates down to order 1 Hz or below with no ill effects.

3] Delay Calibration

Phase rotation at the stations makes pulse injection calibration very difficult and it is suggested that delay calibration be dropped. It would be a nice goal for the electronics to be so stable that the complex gain variations are limited only by the hydrogen maser but we should be aware of what this implies. Since masers are stable to 1 in 10^{14} electronics drift should be maintained below 10 picoseconds in 1000 seconds. This should present no difficulty in phase delay - but group delay stability (used in Astrometry/Geodesy) is more difficult. The typical delay through at 500 MHz bandwidth receiving system is about 10-20 nanoseconds (excluding all cables) and temperature coefficients use about 1%/°C or 100-200 picoseconds/°C. New receivers may be better but temperature coefficients are still likely to be in the 10-100 ps/°C range and the electronics on the antenna will have to be very well temperature controlled in order to keep the group delay from changing by less than 10 picoseconds when the elevation changes between observations of different sources.

The pulse calibration electronics is quite simple and has a delay in the 1-2 nanosecond range and a temperature coefficient under 6 ps/°C. Even if it turns out that the receivers are more stable than the H-maser the pulse calibration provides a very useful check for equipment malfunction and intermittent "glitches".

4] Bandpass Offsets

A study (see VLBA Acquisition Memo #14) shows the closure errors from bandpass offsets are quite small.

5] Phase Tracking Electronics

When fringe rotation is done at the processor, it is performed by digital signal processing in a completely deterministic and accountable manner to a very high accuracy (certainly much better than 1 degree of phase even at the high fringe rates encountered at 89 GHz). When phase tracking is done by offsetting local oscillators the fringe rotation is not entirely digital. For example, the fractional-N synthesis technique relies on analog methods to take the difference between the phase register and phase detector. Some preliminary information we have obtained from HP on the performance of their "state-of-the-art" fractional-N synthesizer model 3325A which shows that is has a temperature coefficient of 50 degrees/°C/GHz and a phase accuracy of 10 degrees at 1 GHz. While we are trying to borrow a unit for more complete evaluation, we are not optimistic that the fractional-N method will meet our requirements because even if the analog accuracy can be made sufficienty accurate there may still be a problem with variations in propagation time through the phase-lock loop which will produce phase errors due to the phase acceleration. A more conservative, and much more expensive approach would be to mix a fixed synthesizer with a digitally generated wave-form as in the VLA electronics. In this case a better approach might be to offset the 100 MHz reference by multiplying it up to about 10 GHz, applying an offset and dividing back down. The fractional accuracy requirements are the same and doing the job at 100 MHz will accomplish both phase and delay tracking for all frequencies with just one unit per station.

In summary, we do not favor phase tracking at the stations mainly because in our opinion it will result in a substantial technical risk which might delay the project. The advantages of both approaches might be achieved (at extra cost) by providing the capability for phase and delay tracking at both the stations and the processor.