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To: Correlator Memo Series
From: Martin Ewing Date: 29 July 1985
Subject: Phase/Delay Specification - philosophy

The NRAO review of VC041 rightly asked what we mean by the phase and delay tracking spec of Section 2.4. We discussed this recently, and I want to summarize the state of the debate as I see it at the moment.

"Tracking" is not a very well-defined property for real-world correlators. At the mathematical level the "true" interferometer phase and delay can not be calculated precisely, since the baseline vectors depend on earth rotation and tidal parameters that are not fully known. At the most detailed bit-shuffling level, phase and delay values are only updated at certain intervals, and then only to a certain precision.

For simplicity we can speak only of delay values, since delay converts to phase if you know the frequency. I would make a little hierarchy of delay values and errors as follows:

1. "True delay" is calculable given precise baseline vectors and source positions. However, in a realistic case, various uncertainties and errors prevent us from computing true delay.

2. What we actually calculate is "model delay". Model delay is a practical approximation to the true delay. Its accuracy is limited by uncertainties in geometry and practical limits on computation. The limitations include those listed in the following table:

Error Group 1

Baseline uncertainties:	Earth tides, polar wander, etc.
Source position errors:	Truncation errors, precession, etc.
Other systematic errors:	Imperfect atmospheric geometry, refraction, aberration, etc.
Calculation errors:	roundoff, interpolation, etc.

The delay model is written out to the archive (along with phase) often enough so that there will be no substantial uncertainty about what delay and phase values were actually used. For this reason, it is not necessary to be particularly precise in calculating the delay model in the correlator. In many cases, the correlator model will be removed and replaced in later processing. The primary concern is that the source remain reasonably well centered in the field of view and that closure phases are "right."

3. The "applied delay", the actual corrections applied to the input data streams, will not exactly equal the model delay. Hardware limitations of sampling and update rates will add error sources including those in the following table:

Error Group 2

Delay quantization:	Nyquist sampling or small oversampling factor. "Fractional Bit Shift" error.
Delay update interval:	New delays applied only every N bits.
Phase rate quantization:	Synthesizer programmable in steps of 10^{-N} Hz.
Phase quantization:	Phase is settable to 10^{-N} turns at each update.
Phase update interval:	New phases applied only every N bits.
Undelayed phases:	A unique phase should in principle propagate along with each data sample. (Different phases should be applied at different taps of any data delay line in the correlator.)

These effects, in most cases, are not reported to the archive. Corrections must be applied later, either in a correlator processor or in "postprocessing".