CALIFORNIA INSTITUTE OF TECHNOLOGY
Radio Astronomy 105-24
Pasadena, California 91125

To: Local Correlator Distribution
From: Martin Ewing MSE Date: 29 July 1985
Subject: Revised Phase/Delay Specification

PREFACE

Historically, correlators, especially VLBI correlators, have been specified in detail only after they have been built. Despite this, we continue our attempt to specify the VLBA correlator in the difficult areas of phase and delay tracking.

THE REVISION - DISCUSSION

I have revised the specification of Section 2.4 to reflect recent discussions. I propose to add Section 2.4.1 to specify the relevant astronomical parameters. (See below.) Another new section, 2.4.2, is required to specify the model quality.

Section 2.4.3 includes an improved specification of the peak instantaneous delay error. The instantaneous correlator delay will deviate from the model delay by up to ±(0.5+X) samples. If the delay were updated for every sample, X would be zero. However, if delay updates are performed on a 1 ms schedule, an excess peak error X = 0.03 samples on the extreme terrestrial baseline (2 μs/s delay rate) would be allowed. Since the update is fixed in wall-clock time, the excess error will increase with the speedup factor.

The new Section 2.4.3 is consistent with a 1 ms delay update interval and Level I or II geometry.

Section 2.4.4 describes phase tracking. It allows tracking for the worst terrestrial 3 mm experiment. It permits our scheme of updating phase only every N (~8) bits and of differencing station phases in the correlator by permitting a certain SNR loss.

[Loss due to update rate alone is currently estimated at 0.2% at 66 kHz and

0.9% at 150 kHz from a simple-minded calculation of

SNR = const * sin(u)/u; $u = \pi * FR / 2\,MHz$.

The requirements of the specification should be less restrictive, however.]

REVISED ARCHITECTURE SPECIFICATION (to replace Section 2.4 in VC041)

2.4.1 Astronomical Parameters. The following table represents the extreme geometrical parameters of the VLBA to be handled at various levels of precision. These are station parameters relative to the center of the earth; worst-case baseline parameters will be double these values, except for delay.

PARAMETER	Level I "7 mm"	Level II "3 mm"	Level III "1.3 cm Quasat"
Max. Fringe Rate (kHz)	66.	150.	490.
Max. Fringe Acceleration (Hz/s)	4.8	11.	210.
Max. Delay (ms)	+21.	+21.	±63.
Max. Delay rate (μs/s)	1.6	1.6	21.
(samples/s)	26.	26.	340.
Max. Delay Acceleration (ps/s^2)	110.	110.	9000.

Level I is a set of parameters that contains all terrestrial VLBA observations with currently planned receivers. If L is wavelength, R = 6,400 km, and ZA is zenith angle,

$L = 7\,mm$, $R/L = .91 \times 10^9$, $ZA < 90$ deg.

Level II represents an extension to 3 mm, perhaps with overly optimistic baseline lengths:

$L = 3\,mm$, $R/L = 2.1 \times 10^9$, $ZA < 90$ deg.

Level III corresponds to the Quasat proposal (after J. Romney), for

reference only. Quasat is not supported by this correlator design. Quasat data might be handled in the future by upgrading some SE modules, by offsetting L.O.'s, and/or other means.

L = 1.3 cm, Rmax = 19,000 km, R/L = 1.5×10^9, ZA < 180 deg,
Vmax = 6,300 m/s, Amax = 2.7 m/s^2.

Note that for terrestrial baselines, delay is non-negative; but for extra-terrestrial baselines, the required delay (relative to the center of the earth) can be negative. Earth blockage is not so severe for space telescopes.

2.4.2 Geometric Modeling. The delay and phase model shall be computed to sufficient accuracy that residual delay error shall be less than ±32 ns (1/2 sample) and residual fringe rate shall be less than 10 mHz under Level I conditions. (Atmospheric effects are expected to dominate.) At least one set of calculated model values shall be written to the archive with every correlator data integration. Calculated model phase, fringe rate, and delay shall be known, smoothly varying functions, such that interpolation of the output model values as written to the archive shall recover the instantaneous model values within 0.01 degree of phase or equivalent in delay.

2.4.3 Delay Tracking.

Delay Range, per station:

Static:	over 1 min. with DPS offset
Dynamic:	0 - 21 ms with RAM buffer

Delay Rate Range,
per station: -100 to +100 samples/s

Delay rates are stated in terms of "correlator time"; they do not scale with tape Speedup Factor (SUF) at playback time. E.g., if SUF = 4, the effective observing delay rate range is ±25 samples/s.

A delay update rate of less than the sample rate is permitted. However,

the instantaneous correlator delay shall not deviate from the smoothly varying model delay by more than

$\pm(0.5 + 0.03*[DR/2]*SUF)$ samples

at a given delay rate (DR) specified in μs/s and speedup factor. E.g., ±0.53 samples at 2 μs/s and no speedup.

2.4.4 Phase Tracking.

Fringe rate range, per station:	±150. kHz
Fringe rate acceleration:	±11. Hz/s
SNR loss due to phase update and differencing method*:	< 1.% (Level I conditions) < 2.% (Level II conditions)
Closure phase error, averaged over 0.1 sec:	< 0.01 degree
Difference of applied phase and model phase, averaged over 0.1 sec:	< 0.01 degree

* Includes loss of SNR due to phase being updated at less than sample rate and loss due to station-by-station calculation of phase with differencing to limited precision in correlators.

The fringe rate and fringe rate acceleration ranges permit Level II observations with no speedup (SUF = 1), or Level I observations with SUF = 2. If SUF = 4, many VLBA observations are still permitted, at longer wavelengths and/or shorter baselines.