VLB ARRAY MEMO No. 367

Center for Astrophysics

Harvard College Observatory
Smithsonian Astrophysical Observatory

9th July 1984

MEMORANDUM

To: Craig Walker

From: Norbert Bartel

Subject: Pulsar Dedispersion Mode and Ionospheric Correction

Dear Craig,

As I noticed my name on VLBA Memo 343 with regard to the necessity of a dedispersion mode for pulsar VLBA correlations and on Memo 351 with regard to our experience with ionospheric corrections via S/X-band observations, I would like to respond here.

A) Dedispersion Mode

Besides astrometry, which Don Backer mentioned in Memo 351, the investigation of the ISM is another major field that can benefit from pulsar VLBI. Thus, VLBA observations of all detectable pulsars at all available frequencies are desirable.

To increase the number of detectable pulsars, gating and dedispersion are necessary. The improvement of the SNR through gating for the average pulsar with a 10 deg pulse width is about a factor of 6. This improvement can be roughly maintained only by some kind of dedispersion, e.g., by gating the processor separately for each narrow frequency channel and by adjusting the phase of the gate to the dispersion sweep time. With DM = 100 pc cm^{-3} (3 pc cm^{-3} $\lesssim$ DM $\lesssim$ 1100 pc cm^{-3}) and ν = 0.33 GHz, the sweep time over a bandwidth $\Delta\nu$ = 30 MHz is ~ 690 ms, a typical pulse period, in contrast to ~ 46 ms over $\Delta\nu$ = 2 MHz. Thus, only with dedispersion can gating develop its full potential in many cases. See Don Backer's Memo 351 for limitations of this technique and for an alternative.

Perhaps it is worthwhile to think about modifying the spectral line mode of the VLBA processor to allow for dedispersion within the narrow-band (2 MHz) frequency channels.

B) Ionospheric Correction

i. Dual-band observations

The ionospheric correction $\tau_{\nu_1}^{ion}$ of the phase delay observable τ_{ν_1} at frequency ν_1 can be determined from observations at two widely separated frequencies ν_1, ν_2 via:

$$\tau_{\nu_1}^{ion} = \{(\tau_{\nu_2} - \tau_{\nu_2}^{struc(2)} - c_{12}) - (\tau_{\nu_1} - \tau_{\nu_1}^{struc(1)})\}\{\frac{\nu_1^2}{\nu_2^2} - 1\}^{-1}$$

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The variable τ_{ν_2} is the phase-delay observable at frequency ν_2. The variables $\tau_{\nu_2}^{struc(2)}$ and $\tau_{\nu_2}^{struc(1)}$ are the structure phase-delays of the source at frequencies ν_2 and ν_1 relative to positions (α_2,δ_2) and (α_1,δ_1) at the sky. The variable c_{12} accounts for the difference of these two positions. Only if we had the same reference point in the brightness distributions $B_1(\nu_1,\alpha,\delta)$ and $B_2(\nu_2,\alpha,\delta)$ at each of the frequencies ν_1 and ν_2 to register the maps, as we have for pulsars or other pointlike sources, c_{12} could be chosen to be zero and the ionospheric correction could be determined with high accuracy, with the limitations being only the receiver noise and systemic effects on the propagation of the signal in the antenna-receiver system. However, depending on the opacity effects of the source, the maps of the source at the two frequencies may be misregistered by up to a few milliarcseconds. The error in the ionospheric correction would be $c_{12}\ \{\frac{\nu_1^2}{\nu_2^2} - 1\}^{-1}$.

With an uncertainty of, e.g., 2 mas in the separation of positions (α_1,δ_1) and (α_2,δ_2), i.e., $c_{12} \lesssim 260$ ps for a baseline of 8000 km, and with $\nu_1/\nu_2 = 8.3$ GHz/2.3 GHz, the position (α_2,δ_2) is uncertain by $\lesssim 0.17$ mas.

ii. Single-frequency broad-band observations

The ionospheric correction $\tau_{\nu_2}^{ion}$ can also be estimated from the group-delays and phase-delays or phase-delay rates at a single frequency ν_2, as group- and phase-delay observables are oppositely affected by charged particles. We recently had some success in determining a pulsar position largely freed from the effects of the ionosphere by using group-delays and phase-delay rates.

iii. Combination of both kinds of observations

Especially fruitful is a combination of both kinds of observations for the calculation of the ionospheric correction. In the special case of the quasar pair 3C 345 - NRAO 512, we first used dual-band observations to estimate the relative position (α_1,δ_1) with an accuracy of about 0.2 mas. Then we used group- and phase-delay observables at the lower frequency ν_2 to estimate the relative position (α_2^*,δ_2^*), which is largely freed from the effects of the ionosphere. With this new position determination, the uncertainty in the registration of the maps at both frequencies is much smaller than with the old position determination (α_2,δ_2), i.e., c_{12} is much smaller, and the relative position (α_1,δ_1) of a reference point in the map at frequency ν_1 can be determined more accurately. As a byproduct, spectral index VLBI maps can be made more reliably than without the ionospheric correction.

I welcome further discussion on this subject.

Sincerely,

Norbert