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VLB ARRAY MEMO No. 351

Dear Craig,

I read VLBA Memo 343 yesterday and noted my name with regard to pulsar VLBI specifications. I have the following comments to contribute to the discussion.

The primary interest in pulsar VLBI is astrometry: proper motions trigonometric parallaxes, and fundamental reference frame. The limitations are sensitivity and ionospheric calibration errors. These effects lead to 1400 MHz as a near optimum band for observations. The ionosphere can be calibrated by dual frequency observations on a reference star or by an independent monitoring system. The former is most desireable and Norbert Bartel might have comments on his attempts at this mode with S/X observations. The latter is less desireable. Joe Taylor has used spatially separated monitoring data with some success [e.g., Boulder data to calibrate OVRO path]. Have there been discussions of an ionospheric monitor device at each site ?

The log n - log S density at 1400 MHz for pulsars above dec -30d is:

Smin - Smax (mJy)	n
>200	0
100 - 200	1
50 - 100	2
25 - 50	9
12 - 25	14
<12	many

This distribution suggests that a 1400 MHz detection level of a few mJy is needed to dip into the bulk of the pulsars. In addition the detection is required in a few minutes to allow beam switching with a reference star. Thus pulsar astrometry with the VLBA requires: (1)maximum bandwidth, (2) gating, and (3) a large, and therefore nonVLBA, antenna.

The 1.5 millisecond pulsrar, 1937+21, is particularly important for fundamental reference frame work owing to the precision with which its position can be determined with respect to the Earth's orbit, 0.001" now and probably 0.0001" in the coming years. At 1400 MHz dispersion results in a full pulse period of delay over a bandwidth of 8 MHz. Sensitive, astrometric observations of this important pulsar, and other fast pulsars with moderate dispersion measures, will require a technique other than gating, even if the phase of the gate can be set for each 2-4 MHz receiver channel.

An alternative to gating is to use the fringe-rate and delay offset technique developed by Bill Erickson for MKI VLBI observations of the Crab pulsar at 111 MHz (1972 ApJ 177 101). Application of this technique for pulse arrival time measurement (autocorrelation rather than cross correlation) has been discussed by Backer and Kulkarni (1983 internal memo). In this technique the Nth Fourier component of the pulsar waveform in the frequency-time plane is measured by adding a fringe rate of N times the apparent pulsar frequency and a delay of N times the inverse of the pulse spacing in frequency to the geometric fringe rate and delay. Most of the SNR enhancement of optimum gating is obtained by extracting ~10 complex Fourier amplitudes. The advantage is that no hardware gating is needed. All that is required is the software to compute the fringe rate and delay offsets. The disadvantage is that the same data must be reprocessed ~20 times to obtain the 10 complex Fourier amplitudes. Since this astrometry is likely to use only a large aperture, phased VLA or Arecibo 300 m, against the VLBA elements, or a subset of them, many of the Fourier amplitudes can be obtained in parallel using the many baseline capacity of the processor. For example, a 14-station processor could process a 5-station pulsar scan (4 baselines between the large aperture and the small ones) for 22 different fringe rates and delays simultaneously if every baseline had independently settable rate and delay. The processor is probably not this flexible; it certainly won't be if the rate is done at the telescope. The rate offsets range from +/- max harmonic x pulsar freq = +/- 10 or 20 x 1000 Hz; the maximum delay is no trouble, a microsecond or so for 1400 MHz.

I will welcome further questions.

Regards,
D. C. Backer

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