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14 October 1982

Mr. Bill Brundage
National Radio Astronomy Observatory
P. O. Box 2
Green Bank, West Virginia 24944

Dear Bill:

Enclosed are my comments on the proposed NRAO Pulsar Signal Processor. I am very enthusiastic about the device and hope that it will receive high priority. The nominal parameters as they stand in Memo 12 are good ones (apart from a few changes mentioned in my comments). During the meeting at Green Bank on 30 September, a number of us pushed for additional capabilities, such as fast (10μs) sampling. Although Arecibo certainly has such capability and a signal-to-noise advantage at <u>some</u> frequencies, it is certain that fast sampling at NRAO would be used on pulsars not observable at Arecibo and also in a dual-observatory mode where we would operate at two different frequencies. I still feel, however, that fast sampling should be an add-on or developed in parallel, rather than determining the overall parameters of the filter bank and dedisperser. A slower dedisperser with the specs of Memo 12 would still be enormously useful.

Sincerely,

Jim

James M. Cordes

JMC:ra
Enclosures
cc: V. Boriakoff
T. Hankins
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<u>Comments on the Proposed NRAO Pulse Signal Processor</u>

[cf. Memos - 12 and 13 of 1982 September]

J. M. Cordes
Cornell University

1. The proposed 20 MHz total bandwidth per spectrometer is fine but the 30 KHz minimum Δf should be reducible to 0.1 KHz for some purposes such as scintillation observations of distant pulsars and other spectroscopic applications. Perhaps coarser (than $\div$ 2) steps in Δf could be made or such fine resolution may be considered an add-on at a later date (but with sufficiently flexible design at present).

2. I expect 0.1 ms Δt is sufficient for many applications. Smaller Δt ($\leq 10\mu s$ say) would be useful (and used) but probably less so. Like Δf above, the fine Δt might be included as an add-on such as a fast buffer to tape just after an A/D rather than building the dedisperser to run as fast as $10\mu s$ per output sample.

3. For some applications (pulsar scintillations) it would be useful to dump the filter bank outputs in as short a time as possible, e.g. 1-10 ms. This would be used to get spectra as a function of time through a pulsar pulse, as per the enclosed paper ("An Attempt to Resolve Pulsar Magnetospheres Using Interstellar Scintillations").

4. Re Display: it would be useful for display on an oscilloscope to have access to the pulsed cal control signals and the "on-pulse" data-taking window for burst-sampling mode.

5. In Table 1 under the "Polarization and Scintillation" column, the 30 KHz should be reduced to 0.1 KHz as above and for scintillation measurements, the "Dedispersion" parameter should be "none."

6. Figure 1: the "A+jB" output on the analog polarizer should be replaced by "B-A."

7. I <u>strongly</u> support the concept of an FFT (or otherwise digital) spectrometer because one use of such a device will be to look for small pulse-shape fluctuations from month-to-month or year-to-year, (e.g. for looking for neutron star precession and other rotation fluctuations). Analog filter banks have limited stability so that instrumental pulse shape changes are induced.

8. It is difficult to specify the parameters of the RFI excising (especially the dynamic range of each filter) without knowing the algorithms that are being considered and without knowing the actual interference environment as a function of frequency, time of day, and season. The kinds of RFI

that have blown me off the air are:

1) lightning
2) 60 Hz from arcing power lines
3) narrowband voice (aircraft)
4) auto ignition

Our (C195) observing run of 1982 September on the 300' telescope at 360 MHz showed RFI types 2-4, but we got data ~ 80% of the time with no excising. In 1981 October, RFI type 2 prohibited us getting <u>any</u> usable data at 350 MHz. It is not clear to me how 60 Hz RFI can be excised. As far as lightning is concerned, it can cause considerable loss of data but since it is broadband, why couldn't a broadband detector (with large dynamic range) be run in parallel to the spectrometer which then could have lower dynamic range in individual filters?

Would the hardware requirements be lessened if RFI detectors simply flagged suspected bad data rather than excising it? This would imply short dump times to tape but that is usually the nature of pulsar data taking anyway.

(These questions are my first reactions to the concept of excising; I imagine NRAO staff has already considered these.)

9. For pulsar observing at Arecibo, I have had dynamic range problems for strong pulsars when we had 12 bits resolution at 430 MHz with $T_{sys} \sim 150^{\circ}$ $\Delta\nu$ = 2MHz, τ = 3.3 ms so the rms noise was 0.1 Jy. The strongest pulses were ~ 400 Jy in single samples of 3.3 ms. Larger flux densities are sometimes seen, so 40dB dynamic range might be better.

[See attached figure of pulse energy histograms for pulsar 0950+08]

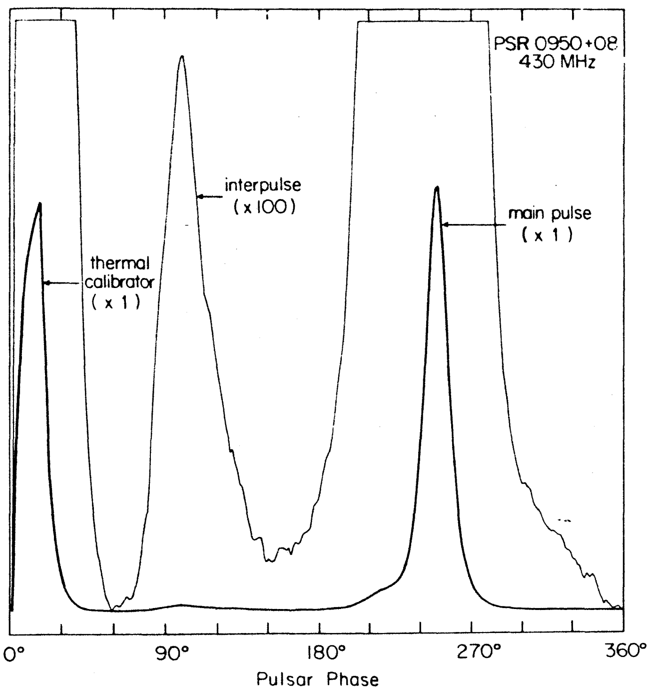

FIG. 3.—Average profile of the total intensity of 430 MHz calculated from 9600 pulses. The expanded (× 100) plot shows emission over at least 300° of longitude.

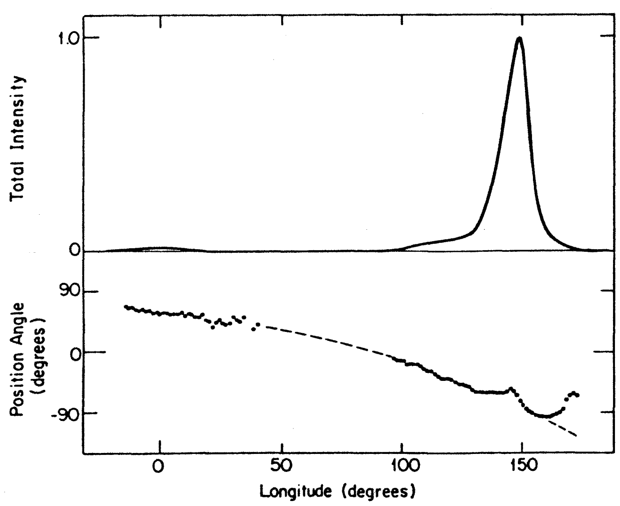

FIG. 4.—Average profile of the total intensity and the polarization position angle of PSR 0950+08 at 430 MH_3. The position angle is a composite from work by Backer and Rankin (1980), Lyne, Smith, and Graham (1971), and unpublished data. The position angle at longitudes greater than 150° does not always increase as shown by the filled circles; sometimes it follows the dashed curve. This variation is probably due to a mixture of two othogonal polarization modes, whose relative strength varies over a timescale equal to that for computing the average (2083 pulses).

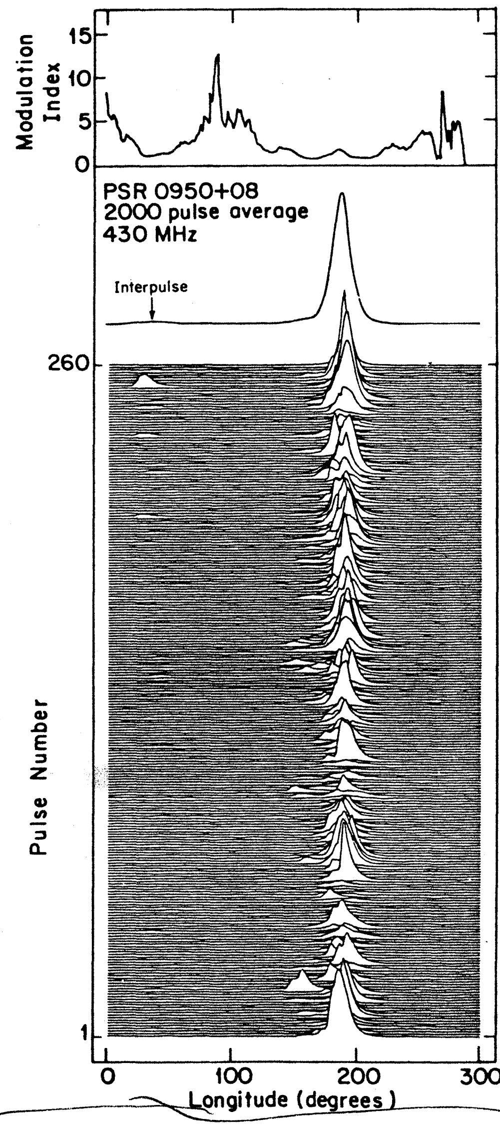

FIG. 5.—A sequence of 260 pulses that shows strong subpulses at the position of the interpulse. Also plotted is the modulation index [eq. (1)].

IV. MAIN PULSE AND INTERPULSE FLUCTUATIONS

a) *Subpulse Fluctuations*

It is well known that average intensity profiles measure both the average *strength* and the *frequency of occurrence* of pulse features (subpulse and micropulses). Figure 5 is a sequence of 260 pulses in which it is clear that the most intense single pulses occur near the peak of the average profile but that intense subpulses occasionally occur near the leading edge of the main pulse and even at the longitude of the interpulse. Also plotted in the figure is the modulation index

$$m = (\sigma_{\rm on}{}^2 - \sigma_{\rm off}{}^2)^{1/2}/(\langle I_{\rm on}\rangle - \langle I_{\rm off}\rangle)\,, \qquad (1)$$

where $\sigma_{\rm on}$, $\sigma_{\rm off}$ are the on-pulse and off-pulse standard deviations of the intensity, $\langle I_{\rm on}\rangle$ is the average on-pulse

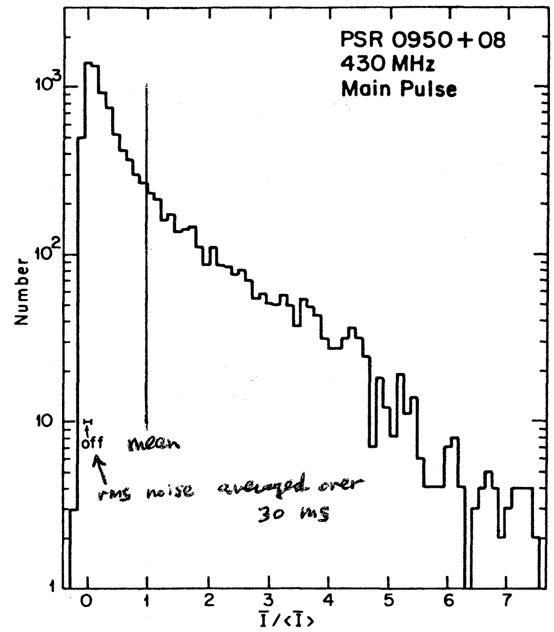

FIG. 7a (averaged over ~30 ms)

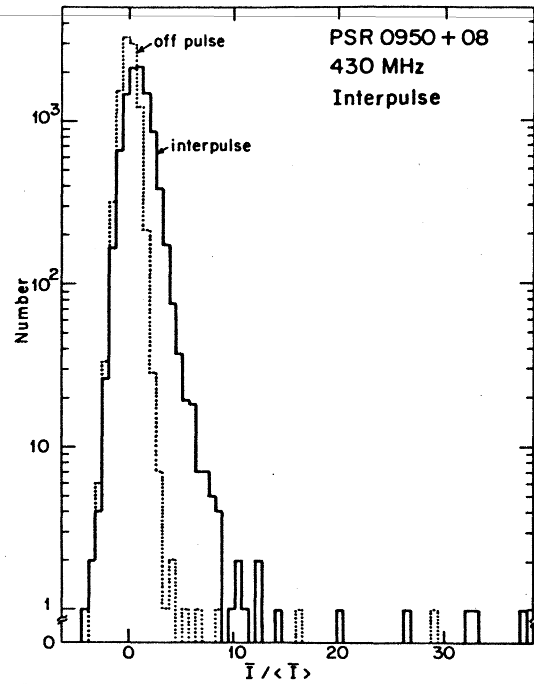

FIG. 7b

FIG. 7.—Histograms of mean pulse intensities for the main pulse and interpulse components and for a nominal offpulse portion of pulse longitude, calculated from 9600 pulses. The histograms are of the quantity I, the average intensity in the relevant component in a single pulse. The horizontal scale is normalized to the mean average intensity over 9600 pulses, $\langle I \rangle$.

V. CONSISTENCY WITH SINGLE POLE AND DOUBLE POLE INTERPRETATIONS

Interpulses were initially interpreted as emission from the "opposite" magnetic pole for two reasons: (1) they occur at a large ($\gtrsim 150°$) longitude separation from the main pulse, and (2) emission from single poles appeared to be confined to much smaller ($\lesssim 25°$) longitude regions. Manchester and Lyne (1977) pointed out that emission from the Crab pulsar, whose interpulse and main pulse are of approximately equal amplitude (in the radio), and the Vela pulsar, whose optical and γ-ray interpulse and main pulse do not appear in the radio, can more easily be understood as arising from a single pole. The main arguments in favor of a single pole model for Crab and Vela are: (1) a bridge of emission connects the main and interpulse components; (2) the main pulse–interpulse component separation is frequency dependent for the Vela pulsar; and (3) a histogram of component separations for many pulsars no longer appears to be bimodal, suggesting that both large and small component separations can be produced by the same mechanism.

The results on PSR 0950+08 contradict our expectations from both a single-pole and the double-pole models. Table 2 lists the supporting evidence for each kind of model along with the problems that each faces.

TABLE 2

EVIDENCE FOR AND AGAINST INTERPULSE MODELS

Model	Supporting Evidence	Problems
Single pole	$\Delta\theta^{a} = 150°$ (not 180°) bridge of emission; monotonic rotation of polarization position angle through $\lesssim 180°$.	Frequency independence of $\Delta\theta$; bifurcation of main pulse; amplitude difference of main and interpulse; (why no pulsars with four components?).
Double pole	Frequency independence of $\Delta\theta$; frequency dependence of *all* other separations; microstructure in both interpulse and main pulse; 2 poles predicted by polar cap models.	$\Delta\theta^{a} = 150°$ (not 180°); monotonic rotation of polarization position angle through $\lesssim 180°$; communication between poles necessary.

[a] $\Delta\theta$ = main pulse–interpulse separation in degrees longitude.

only to B. Brundage.

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AN ATTEMPT TO RESOLVE PULSAR MAGNETOSPHERES USING INTERSTELLAR SCINTILLATIONS

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June, 1982

ARECIBO, PUERTO RICO ITHACA, N. Y.