PROJECT 2.625
PULSAR SIGNAL PROCESSOR
MEMO NO. 2

NATIONAL ASTRONOMY AND IONOSPHERE CENTER

Reply to:
Cornell University
Space Sciences Building
Ithaca, N. Y. 14853
Telephone: 607-256-3734
Telex: 932454

Cornell University
Industrial Research Laboratory
Brown Road
Ithaca, N. Y. 14853
Telephone: 607-256-5274
Telex: 932454

Arecibo Observatory
Post Office Box 995
Arecibo, P. R. 00612
Telephone: 809-878-2612
Telex: 385638

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Dr. J. Richard Fisher
National Radio Astronomy Observatory
P. O. Box 2
Green Bank, WV 24944

Dear Rick:

Thank you for your letter of July 15, 1981. Indeed the 300-foot antenna and the new GaAs FET low frequency receivers are a very good combination and given low interference and a good back end system, pulsar observations with it will be scientifically very interesting. The system you have outlined is of interest, but I would like to suggest some changes.

First I would like to answer some of your questions: 1) Is NRAO justified in spending a fair amount of money on a back end system with main application in pulsars? As the main competitor of Arecibo and covering much more sky than Arecibo the answer is an emphatic yes. Although the collecting area is 10 times less than at Arecibo the much broader sky coverage allows study of 79 pulsars (out of 350 known) outside the -2° to 38° declination range of Arecibo. Recent studies done mostly at Arecibo have produced a host of new and interesting results (for some of them see IAU Symposium No. 95, Pulsars, 1980), and the 300-foot offers the possibility of extending these studies to non-Arecibo pulsars. 2) Interference problem? Because pulsar signals are very similar to impulsive noise, automatic rejection by hardware or software is a dangerous approach. Below 1 GHz I have noticed at the 300-foot the two most common types of interference are: aircraft two-way radio and intense impulsive sequences of spikes modulated by 120 Hz, apparently caused by arc-discharges in power lines. The first are narrowband and confined to a certain frequency range, hence they can be avoided by tuning to another frequency. The impulsive noise is exceedingly broadband ($\sim$1 GHz) and is impossible to avoid. Any good automatic discriminating scheme may be useful (when observing in the 300 to 400 MHz range) to eliminate the first type, but it will not be useful for impulsive noise because of its similarity with pulsar signals. Dedisperser devices improve matters somewhat by dispersing wideband simultaneous impulses (while at the same time dedispersing pulsar signals), but since the signal-to-noise ratio of the interference is so high this improvement is of no consequence. I see two ways of improving the impulsive interference problem: eliminate the arcing in the power lines, and reduce the 300-foot sidelobes by improving the feeds. I would not spend any time or money on automatic rejection systems, but only provide the following: manual elimination of observer-designated filters and replacement of their output by 0.0 volts (to keep them within the A/D conversion range). ?

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3) More observations? An improved pulsar-oriented 300-foot system would definitely be of more use to me and to other pulsar observers, and I definitely would do more observing with it. The degree of improvement will be of importance here; following are improvements in an approximate order of "desirability":

a) Less interference; b) better sampling rate capability (1-5 microsec sampling rate of 4 analog inputs with 8 bits [min.] accuracy); c) a dedispersing system coupled to two or three filter banks (digital with analog outputs); d) an improved receiver system sky noise temperature (currently in the 100° K plus region although the receivers are in the 20° K or so); e) a computer controlled frequency synthetizer operating an appropriate timing system, and f) a fast A/D and digital recording system (enough to write on tape with a 10% duty cycle at an A/D speed of 1-5 microsec [4 inputs]).

The hardware improvements that I would recommend are:

1) Antenna improvements. Better illumination of the reflector surface for improvement of the surface will improve the interference pickup, lower the sky system noise temperature and improve the antenna gain (° K/f.u.). A second very desirable improvement is to make the feed focusable; this will increase the gain at the edges of the track by 1 db, maybe more. Some other front end improvements may be desirable; for example, one of the 500-700 MHz upconverters should be replaced because of its low gain (Wu, NRAO Electronic Division Internal Report No. 216, July 1981, page 15).

2) Timing system improvements. A timing system with a microsecond absolute accuracy is necessary. A computer controlled synthetizer should provide a fraction of microsecond accuracy periods for pulsars, this should include doppler correction every 15 or 30 seconds. The computer should consult a periodically updated file of pulsar parameters in response to a pulsar name and with day and time information provide the period and a doppler corrected master clock that will do the sampling. The Modcomp computer is quite probably able to handle this operation.

3) Dedispersion. There are two possibilities: a) post-detection dedispersion (filter banks) and b) fast sampling-FFT-software dedispersion-IFFT. The (b) system requires a very fast on-line dedicated machine. To take advantage of the instantaneous bandwidth of the 300-ft receivers multibit ($\sim$8) sampling of the order of 30-60 MHz should be done. Fast FFT devices and special algorithm devices to carry out the dedispersion should be built. Such a machine (with no fast recording included) is in the $60 K to $80 K cost, and has a fairly long lead time. It is quite possible that the Modcomp can serve as a digital data acquisition and tape recording device; that is, it would take the digital output of the (b) device, perhaps do some data packing, and put it on tape. Some design work has been done at NAIC for a machine along these lines; however, the requirements for the 300-foot are different (specifically, larger bandwidths).

The (a) approach (post detection dedispersion) requires a much smaller cash outlay by NRAO. Essentially it requires the construction of four digital multibit delay lines with intermediate adding stations (one station per each filter) which can process the simultaneous output of four filter banks (one

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for each of the polarimeter outputs). A description of such a device built by me in 1971 for the Arecibo Observatory and still in operation is in my Ph.D. thesis (sent to you separately). NRAO has many filter banks available (in fact some have been given away recently) and it is quite possible that three or four filter banks of 50 channels each x4 (four polarimeter outputs) can be collected for use at the 300-foot. The individual filter bandwidths found useful at Arecibo in the 200 MHz - 2 GHz range are: 20 KHz, 100 KHz, 250 KHz, and 1 MHz. These will also cover occasional uses at higher frequencies. This dedisperser is an analog-in and can have both an analog-out and a digital-out. Again the Modcomp can assume the functions of data taking by A/D converting of the output of the dedisperser or by directly recording the digital output of the dedisperser. Some refinements in the design of such a dedisperser can be incorporated in the NRAO version; for example, a digital channel by channel gain adjustment pushbutton actuated at the beginning of an observing run. Cost will be in the $10 K - $15 K range (no filters included) and will adequately serve the needs of most pulsar observations, the exception being the extremely short (<1 microsec) sampling for some special studies of pulsar microstructure. These studies are probably carried out better at Arecibo anyway, they require exceedingly high signal-to-noise ratios. A similar device to the one I describe is occasionally used by Joe Taylor and collaborators at the 300-foot, who bring this device with them. Taylor's version of the device is purely analog, this causes many problems (drift, gain changes, etc.). Amongst others the following observations have been done with the Arecibo dedisperser: pulsar searches, microstructure studies, PSR 1913+16 binary pulsar observations, timing observations, deep searches of low level emission outside the main pulse, etc. Several students' observations for their degrees were done with this dedisperser (including mine!).

I will be glad to continue this dialogue and help specify a new pulsar system for the 300-foot. Please let me know. Thank you.

Truly yours,

Valentin Boriakoff

vb/it

cc: Martha Haynes, NRAO, Green Bank
Mike Balister, NRAO, Charlottesville
Mark Damashek, NRAO, Green Bank.