VLA Test Memorandum #177

Report on VLA Technical Issues Seminar #2 held on August 25, 1993

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VLA observations of pulsars and the HTRP

The discussion was led by D. Frail and T. Hankins and what follows is my summary of it.

D. Frail described the currently available options and stated that they limit the use of the VLA for currently interesting research. The VLA is used as a phased array which makes it equivalent to a 130 meter single dish. The analog sum is formed for both R and L circular polarizations using the A and D IFs sampled at a maximum rate of 100 MHz. These are fed to the VLBI MkIII filterbank which produces 28 channels of data which can use anyone of six sets of filters of widths between 0.125 MHz and 4 MHz (stepped by powers of 2) which are fed into the HTRP (High time-resolution processor).

The HTRP is a multi-purpose, multi-channel data acquisition system (although it has only proven to be generally useful for observations of pulsars). It consists of: detectors and multipliers, A/D converter and sampler (rated at 100 kHz although it does only work reliably at rates up to 12.5 kHz) and a Compaq-386 control computer which can write the data to a hard disk as well as onto an exabyte tape.

The detector consist of a square-law detector and cross-multipliers which produce the products RR, RL, LR and LL.

The sampler card is a LabMaster 64-channel card, a sample-track-and-hold circuit. It can accept up to 56 channels and performs 12-bit sampling.

An alternative option is to send the output of the detector and cross-multipliers to the "Princeton-MkIII system" which accepts 32 channels with 6-bit sampling up to 12.8 μs. It is used for pulsar-timing observations and can also be used to gate the VLA or the HTRP samples. It also allows signal averaging and determination of mean pulse-profiles.

It consists of three specialized boards: a multiplexer (A/D), a frequency synthesizer and a signal averager.

It also includes a control computer which is a Compaq 386.

The following documentation for these systems is available:

The HTRP operations guide ("cookbook" style)

The Princeton MkIII system

HTRP memo series

The Intel signal averager: Users guide

Gated mode observing at the VLA

Applications:

(1) Continuous multi-channel sampling (time series): This includes high time-resolution processing as well as pulsar searches, studies of interstellar scintillation, time variability, pulse profiles, polarimetry and rotation measures.

(2) Gating: Synchronous averaging of the analog sum for the purpose of data selection. Gating is accomplished with the use of the Princeton MkIII system. This can be used for high time-resolution studies, for example for single-pulse research. In interferometric mode this allows work in astrometry, off-pulse observations and measurements of HI absorption.

Pulsar timing: For example, synchronous averaging using the Princeton MkIII system for observations of young pulsars and millisecond pulsars.

Limitations of the present system:

(A) Software:

(1) Monitor and Control: The system lacks the ability to adjust the gains of the individual video converters, which vary significantly (this is not important for VLBI users). This should be possible under computer control.

J. Uson: Could this be fixed using the VLBA backend?

D. Frail: There are no plans to use the VLBA backend. The system is designed to use the MkIII filterbank.

(2) Data acquisition: Data normalization and compression are not possible. It is wasteful to use 16-bits for pulsar searches, it would be satisfactory to use 4-bits for these.

There is no Modcomp header-information presently written with the data. (K. Sowinski indicated that a serial-line was available).

There are no data-integrity checks made.

The start times are not controlled exactly, but await a 10 s tic. The start times are unknown with the continuous multi-channel sampling mode.

(3) Off-line processing: There is no software available (this is normal for pulsar work).

There are some tools available for data-quality inspection, editing and calibration.

(B) Hardware

(1) Sample rate: The ADC (analog to digital converter) card is rated at 100 kHz but this spec is not being met as the card can only be run reliably at 12.5 kHz. Upgrading of the cpu to a 486 will provide a rate of 25 kHz, to achieve a rate of 100 kHz will require better coding.[1]

[1] P. Dooley believes that this might not be possible as the sampler might not work reliably above 50 kHz even with better software (private communication)

(2) Data normalization and compression should be addressed.

(3) There is at present only one output. Three outputs would be desirable in order to run the HTRP, the Princeton timing system as well as to monitor gains.

(4) Interference (RFI): The analog sum is plagued with spurious, periodic signals.

A forest of lines dominates the power spectrum. Some are always present, others are intermittent. They are impredictible and dominate the power spectrum so as to prevent batch-processing of the data.

J. Uson: How good a spectrum analyzer is the HTRP?

D. Frail: A very good one if it were possible to compute FFTs quickly with the cpu. At this time, the data can be moved to an on-site workstation for processing.

Next, T. Hankins discussed a plan for future development of this system. He indicated that D. Moffett is building a new box which will allow multifunction, that is the use of the HTRP, the Princeton timing system as well as allow monitoring of the 4 $\times$ 14 channels multiplexed on an oscilloscope. It will also accomodate a next-generation processor. However, this box will still not allow adjusting the gains of the video converters.

Next steps

(1) Computer controlled gain of the video converter inputs, although it is necessary to get 4 MHz bandwidth.

(2) Faster sampling: This should be as fast as possible. The sample rates that are required are:

For pulsar searches: 32 channels at $(100\mu s)^{-1}$ or 320000 samples/s.

For pulsar polarimetry: 64 channels at $(100\mu s)^{-1}$ or 640000 samples/s.

For pulsar timing: 32 channels at $(40\mu s)^{-1}$ or 800000 samples/s.

For coherent de-dispersion: 2 channels at $(1 — 4)\times 10^6$ samples/s.

For digital channelization by FFT: 2 channels at $(10^6 — 10^7)$ samples/s.

For digital channelization by VLBA correlator boards: 3×10^7 samples/s.

The reason for fast sampling and multiple channels is that interesting pulsars can be found and studied if fast pulsars can be observed as well as those whose dispersion measures are large.

Some possibilities

Gain compensation: This would require some custom-made circuitry and computer-controlled multiplying DACs (digital to analog converters).

A current limitation comes from the A/D converter card which has an 8-bit data bus (designed in 1981).

Faster sampling and real-time processing could be achieved in several ways:

A PC-based solution could speed-up the system but the system would still be limited by the bus. This could be achieved either with a 486 or a Pentium (586) system. Further enhancements should include a new A/D with fifo (first-in, first-out) buffering, a new 64-channel multiplexer, a DSP (digital signal processor) co-processor card (Motorola 96002, INTEL i860, ...), as well as an external direct-digital-synthesis frequency synthesizer which is needed because quite a bit of the sampling is Doppler-shifted.

A great leap forward would come from a VME-based system. This might require building a suitable multiplexer. It would use DSP cards with mezzanine A/D, DDS (direct-digital-synthesis) frequency synthesizer and would be easily expandable. It would also use a convenient real-time operating system.

A variation on the previous one would be a SPARC-based system.

It might be possible to use VLBA-correlator boards.

D. Backer (UC Berkeley) has been developing a coherent de-disperser.

Real-time processing:

This would include operations such as removal of the mean, normalization and synchronous detection of the noise tube. In addition, synchronous averaging would be used for timing, polarimetry and gating. Other possibilities include smoothing, decimation and packing of the data. Digital channelization would allow real-time simulation of a filter bank. It would also be possible to do coherent de-dispersion.

Data recording requirements are mostly modest except for studies of microstructure which might require recording in excess of 2 Mbyte s^{-1} as for pulsar searches which might require even larger rates.

F. Owen: What is the long-term role of the VLA for pulsar research?

D. Frail: In the long term, gating is desirable. The VLA will not be too useful as a single-dish.

T. Hankins: There is a window of opportunity of at least two years. The typical gestation period for customized pulsar processors has been between three and ten years so an off-the-shelf solution should be sought.

The discussion became somewhat general. Among the points addressed were the difficulty in obtaining good data at P-band, the limited non-pulsar uses of the HTRP especially due to the software although the poor sensitivity of the VLA to observe flare stars and the small beam on the Sun also discourage alternative uses.

T. Hankins stated that the VME-based system would require about 6 man-months of software development with the Motorola processor or even with the SPARC in addition to about $50000 in hardware. There was a consensus of support for the upgrade of the HTRP's processor to a 486 or a Pentium which would require no more than about one week of manpower. Because of the price-tag but mostly because of the long timescale, there was little enthusiasm for further development.

T. Hankins raised the possibility of coordinating our development with that which should occur in Green Bank for the GBT and suggested that the VLA could develop a VME-based system which could eventually be of use to the GBT. The timescale seemed unfavorable and it seemed likely that this option would have to await the GBT-based development which might result in a system that could be easily cloned for the VLA if appropriate.