AT/20.1.1/012

Overall Systems & Performance
Technical Notes & Reports

PULSAR OBSERVATIONS WITH THE AUSTRALIA TELESCOPE

Graham J. Nelson

11 July 1985

Introduction

Pulsar observations on the AT will be of two main types:-
(1) Observations of the pulsar itself and (2) Observations of the emission from regions around the pulsar in the periods between pulses. In many cases both can be carried out at the same time. In nearly every case the full bandwidth will be used for observations of the pulsar itself but narrower bandwidths may be required for some observations of the surrounding medium or of fast pulsars where it will not be possible to remove wideband dispersion.

Two different observing techniques can be used depending mainly on the pulse width. These are determined by the following basic properties of the correlator. A 16 MHz clock rate is assumed.

1) The contents of the correlator chips can be read out to module memory in ≅ 2m sec in 2 bit mode.

2) 8 modules per baseline are provided. These can be used to give 8 separate products (i.e. 4 Stokes parameters at 2 frequencies) or can be time shared to give samples of the same product at different times.

3) Up to 4K separate lagged product accumulations can be stored per module. In normal mode these would contain up to 1K separate lags from the 16 XCELL chips, an additional 1K when recirculation is being used and another 2K to store a second phase of the above data when 90° phase switching is being used for image rejection. The memory can however be used to store many strings of shorter correlation functions accumulated at different times.

Long Period Pulsars

In this mode the basic integration time is the 2 msec readout time of the 16 XCELL chips. The number of separate intervals that can be sampled within a pulse period then depends on how the 8 x 4K module memories are allocated. The maximum number of samples (512) results when the widest bandwidth is used (64 lags per correlation function) and when only one product is required. If all four Stokes parameters are required then 128 samples can be accumulated. Figure 1 illustrates a sampling scheme that if implemented would cover most conceivable requirements. In each pulse period up to 4 sequences of integrations are carried out beginning at times t_i. The integration time for each of the n_i integrations in a sequence is τ_i. Thus $\sum_{i=1}^{4} n_i$ separate correlation functions per baseline per product are formed and stored separately in a pulsar period. In subsequent periods the same sequence of integrations is performed so that results are accumulated at $\sum_{i=1}^{4} n_i$ separate phases of the pulsar cycle.

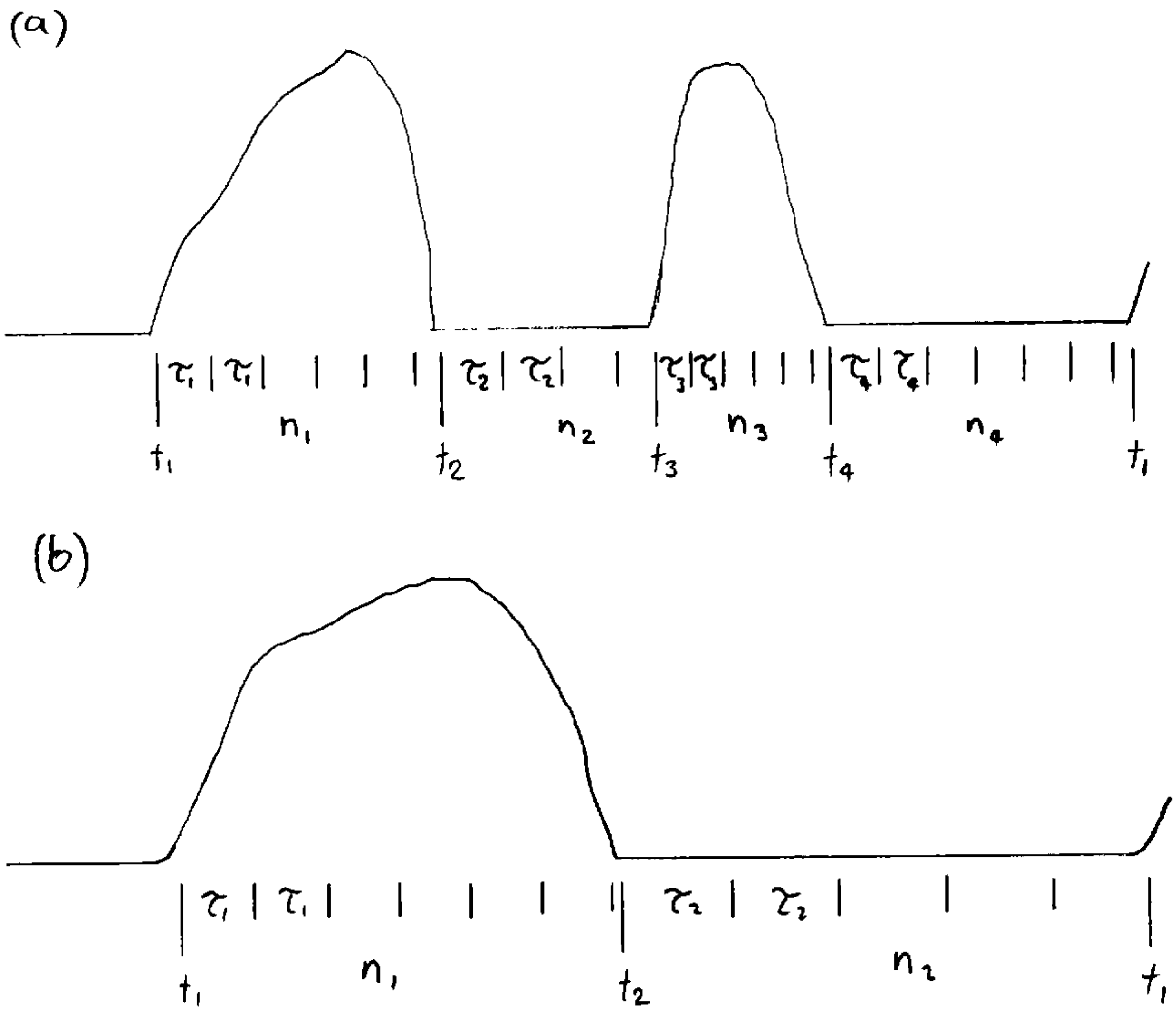

Figure 1.

Sampling scheme for pulsars with long periods. (a) Four sequences of integration intervals are defined per pulse period. A separate correlation function is determined for each of $\sum_{i=1}^{4} n_i$ intervals within a pulse period. These correlation functions are averaged for each interval over many pulses. (b) Two sequences of integration intervals are defined in this example.

The limitations on the parameters in Figure 1 are:-

$\tau_i > 2\text{m sec}$

$$\sum_{i=1}^{4} n_i < \frac{512}{P \times \frac{128}{BW}}$$ where P = No. of separate products required.

In most cases n_2 and n_4 would be 1 and τ_2 and τ_4 would cover the whole interpulse periods.

The precision with which the t_i should or can be synchronised to the pulse rate has not yet been defined. The average values of the t_i will be as accurate as the observatory clock. The jitter around the average would in the simplest implementation be ± 125/2 nsec.

Correlation functions at the selected phases of the pulse cycle are accumulated in separate segments of module memory for a total time determined by time smearing in the image. Typically this might be 5-20 seconds. At the end of this period the data are output to the array processor for correction and FFT etc. In the worst case where all module memories are used the total data to be transferred is 15 x 512 x 64 = 491,520 (32 bit) words. At 12.5 MBytes/sec these can be transferred in a time of 0.16 sec. The processing of this data will take less time than for worst case normal mapping where a similar amount of data consisting of 15 (or 30) 16, 384 point correlation functions have to be processed. The processing time in an AP500 is therefore << 6 seconds (see Technical Note by Andrew Hunt, AT/24.1.1/007.)

The processed data is in the form of time sequences of $\sum_{i=1}^{4} n_i$ terms in each of 16 x $\frac{128}{BW}$ frequencies.

These can now be de-dispersed and summed with a precision determined by the length of the sample interval if the dispersion measure is known. The 16 x $\frac{128}{BW}$ time series then become one. Further compression of data is also possible at this point if particular samples can be identified as containing the pulse and others the background. Certainly the n_2 and n_4 samples in Figure 1 are all background samples and can be summed, further reducing the amount of data to be output. Within the samples n_1 and n_3, only some samples will contain the pulse particularly after de-dispersion. It seems safer however to output all of these samples for further combining off-line if required. There is no reason however why the de-dispersion and combining of identifiable background samples should not also be done in the array processor before output to disk.

The maximum data rate after FFT and de-dispersion is 15 x 512 x 2 = 15,360 32 bit words per integration period (i.e. 5-20 sec). At 1 MByte/sec these can be output in ~ 60 ms. In many cases the data rate will be considerably less than this.

Short Period Pulsars

If a minimum integration interval of 2 msec is too long another option is available. In this case the scheme outlined in Figure 1 still applies however only one sample is possible in each region (see Figure 2) but τ_i may be less than 2 msec. The data for each region are now accumulated in separate modules so if 4 pulse regions are defined then 2 products can be accumulated. Other combinations of course are 8 regions and 1 product or 2 regions and 4 products. Any normal bandwidth can be used in this scheme so the total data to be processed after a 5-20 second integration time depends on the bandwidth but is the same as for normal mapping at the same bandwidth. Only crude de-dispersion is possible with this scheme so narrow bandwidth observations may be necessary to reduce dispersion to acceptable values. However very narrow bandwidths are precluded by the requirement that the sample duration be large compared to the inverse channel bandwidth. (i.e. $\tau_i \gg 125 \times \left(\frac{128}{BW}\right)^2$ nsec).

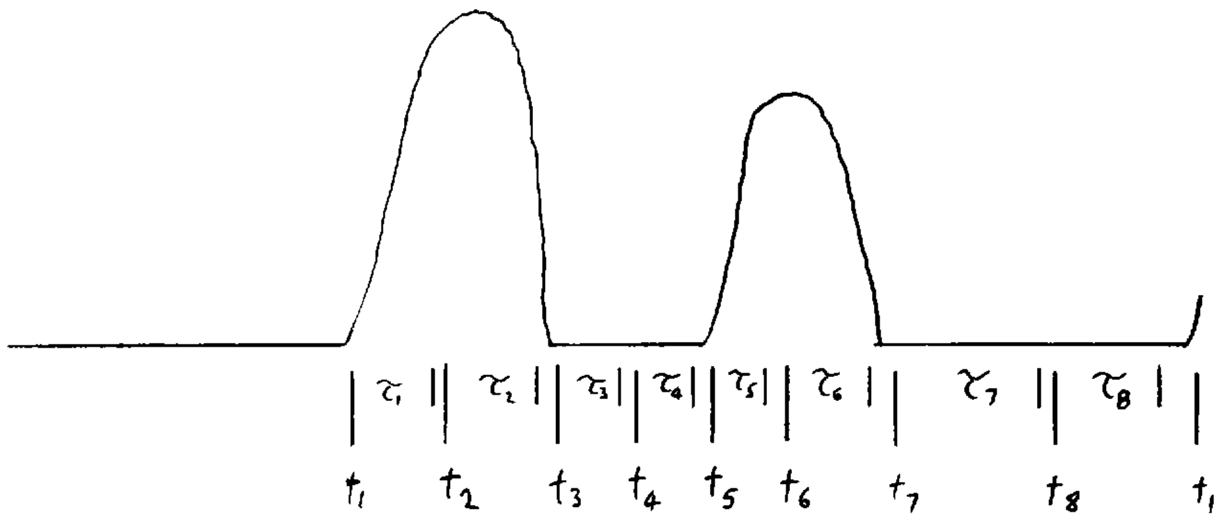

Figure 2

Sampling scheme for fast pulsars τ_i may be < 2 msec. A maximum of 8 integration intervals can be used if only one product per baseline is formed. If 2 products are formed only 4 intervals can be used etc.

Conclusions

Pulsar observations impose no additional requirements on memory, processing power or recording than are already required for worst case normal mapping. The main additional requirements on the correlator are the ability to start integration at predetermined times that may be different for each module and to accumulate data in the module memories in time ordered sequences.

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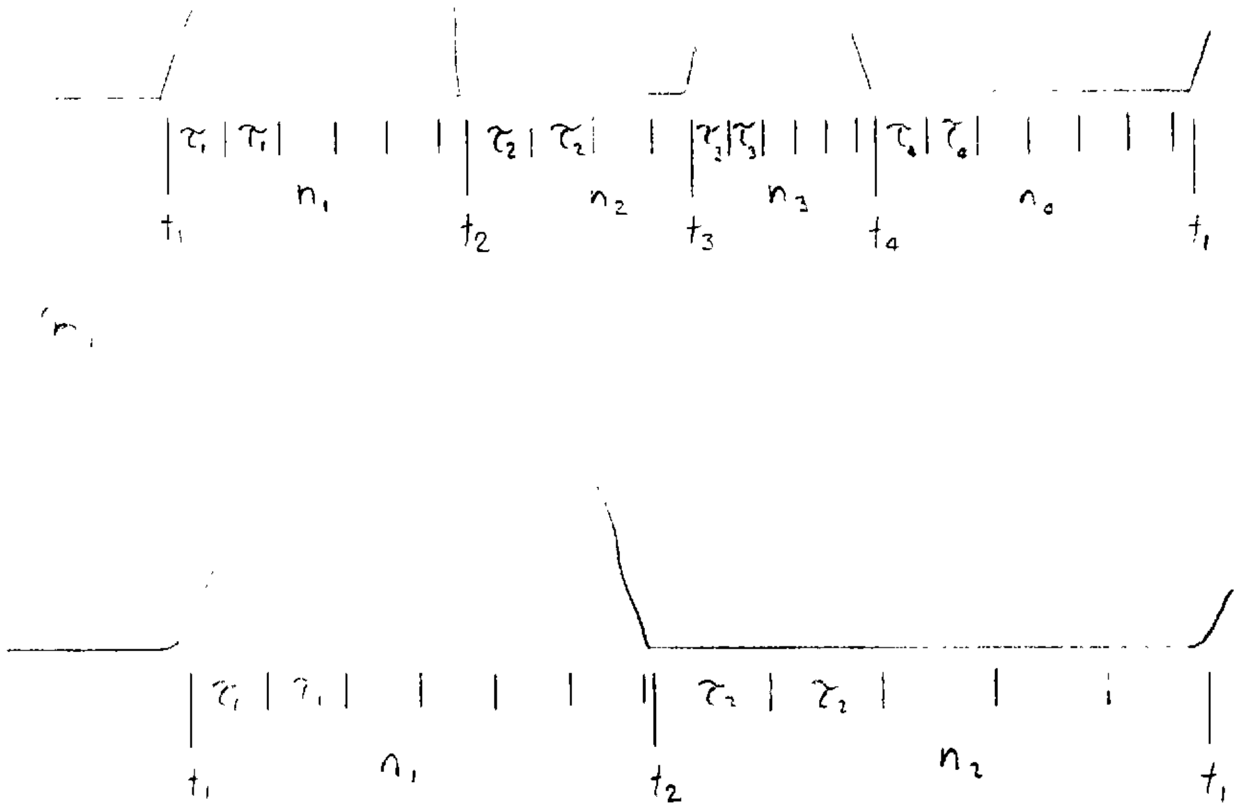

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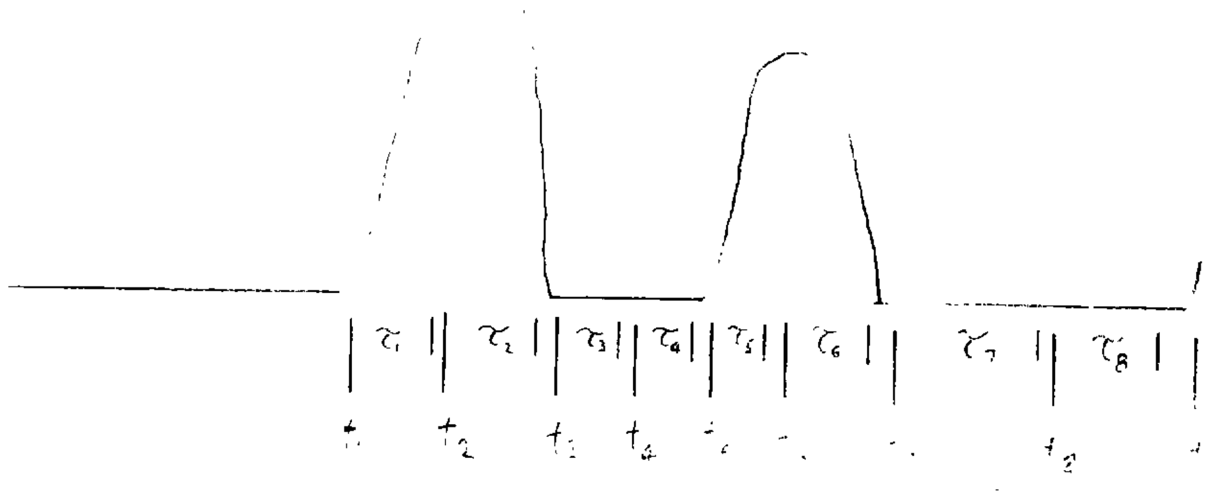

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