NATIONAL RADIO ASTRONOMY OBSERVATORY
Green Bank, West Virginia

Spectral Processor Memo No. 34

January 3, 1989

To: Spectral Processor Group
and Mailing List

From: J. Richard Fisher and Roger Foster

Subj: **Pulsar Timing Logic**

The subject report is attached.

JRF/cjd

To: Roger Foster
From: R. Fisher
Subject: Pulsar timing logic

Here's a preliminary description of how we will set up the timing for your experiments on the 140-ft. I will assume that you will be accumulating data in an N frequency-channel by M time-bin matrix.

The hardware triggers the start of data sampling by starting an offset counter at a specified 1-second UTC tick. All that you will have to specify is the start time in UTC (hh mm ss.sssssss), and the computer will take care of the rest. The time resolution of the offset counter is +/- 100 nanoseconds, but you should specify the UTC start time to 10 ns so the cumputer can pick the nearest offset value.

Since the time resolution is necessarily quantized by the spectrum production rate, synchronization of the time axis of the matrix with the pulsar period requires that we pick the nearest integer number of spectra in each time bin, the nearest integer number of time bins in the matrix, and a spectrometer clock frequency to produce spectra at exactly the right rate. This makes things a bit tricky because the bandwidth depends on the spectrometer clock frequency, but all is known and can be accounted for.

Some definitions:

P = Pulsar period
M = Number of time bins per pulse period
w = Width of a time bin
B = Spectrometer bandwidth for one IF channel
N = Number of frequency channels in one IF channel spectrum
t = Spectrometer time resolution (time between spectra from the FFT)
F = Spectrometer clock frequency, nominally 160 MHz
t', w', B' = t, w, B when F not equal to 160 MHz

There are a finite number of combinations of number of IF's, frequency channels, bandwidths, and time resolutions in the spectral processor. The wider bandwidth selections are shown below.

Number of Spectra (IF's)	Frequency Channels per Spectrum (N)	Bandwidth per IF (B)	Time Between Spectra (t)
1	1024	40 MHz	25 us
2	512	20	25
2	256	20	12.5
4	256	10	25
8	128	5	25
1	1024	20	50
2	512	10	50
2	256	10	25
4	256	5	50
8	128	2.5	50
etc.			

The 2 x 256 configuration is sort of a special case to get better time resolution for pulsar observations. Eventually there will be two independent spectrometers with the above specs, but the second one will not be finshed until late in 1989. We are not sure how many IF drawers will be ready in early 89, but we will certainly have two which may be all you will need to start. We have budgeted for only 8 IF drawers, total, so the 8-IF configuration will probably not see any use when there are two spectrometers.

Since the table parameters are not independent, you need specify only three of the four: number of IF's, number of channels per IF, and bandwidth per IF. The time resolution, t, depends only on the last two,

$$t = (N * 40MHz * 25us) / (1024 * B).$$

The actual bandwidth depends on the spectrometer clock frequency

$$B' = (F * B) / 160, \text{ where F is in MHz.}$$

We have to juggle F, M, and n to get an integer number of time bins in the pulsar period, P. You specify P and M, and the computer will use the following logic to get F and n, and reduce M if necessary to keep B' within range of the IF anti-aliasing filters.

As a first guess, let

$$w' = P / M \quad \text{and}$$

$$n = \text{next integer} >= w' / t.$$

Now, P < (M * n * t) so we have to reduce M or n to get the spectrometer period below the pulsar period since we cannot run the logic at a higher clock speed. Use the following logic to arrive at the final values:

```
If n = (n - 1) produces  (B * (1 - e)) < B' < B
     use M and n = (n - 1)
else if n > M
     reduce n until B' < B
else
     reduce M until B' < B.
```

The first test above is made to see whether there is any possibility of holding the M that was requested. In fact, there may be no B' within tolerance, but the second test makes the best of it. Now,

$$F = (M * n * t * 160MHz) / P,$$

$$B' = (M * n * t * B) / P,$$

$$t' = P / (M * n), \quad \text{and}$$

$$w' = P / M,$$

where e is a chosen tolerance on the allowable fractional bandwidth change.

As an example, take

P = 0.1238536 sec
M = 128
B = 20 MHz
N = 256
e = 0.015.

The first guess gives

w' = 967.6063 us
t = 12.5 us
n = 78.

For n = 77, B' = .9947 * B, which is within tolerance. Hence,

F = 159.1556 MHz
B' = 19.89446 MHz
t' = 12.56631 us
w' = 967.6063 us.

The accumulator memory size is restricted to (M * N) < (2 ** 15). In Rich's memo to you called "Spectral Processor pulsar observing modes" he lists a number of configurations that require frequency averaging of adjacent channels to reduce the number of channels per IF. My number N is before frequency averaging. Because of the way the memory is split up, two of his configurations are not available (128 and 32 Points/IF channel), and the max # of time slots for 64 and 16 points per channel are 256 and 1024, respectively.

Any comments or suggestions?

Rick