Astrophysics 611 - Term Project
November 3, 2005 - Julie Grant

**Galactic HI Emission:**

The plane of our galaxy is consider the best place to locate HI. The most compact HI region in the galactic plane is _______________ and has a temperature of _____K. For our project we need to be able to have an HI detection. Thus our telescope needs to be sensitive enough to measure this value at minimum.

The HI line has been measured numerous times and it is known that the range in the width of the line is ______________MHz. Thus our bandwidth needs to be at least this wide. In order to get a good detection we need to have at least 3 channels, one around the peak and the other two at the wings of the peak. However most radio telescopes have at least 256 channels.

However, we may want to use extragalactic sources as calibration sources or we may just want to observe them. Therefore, we need to know the redshift range of extragalactic sources. We can then compare this with our values for galactic HI and see if it is feasible to do both galactic and extragalactic astronomy with our telescope.

**Selection of Bandwidth and Scanning Rate:**

Nyquist sampling theory states that in order to fully sample a source, samples should be taken at the minimum frequency of twice the highest frequency. So if our band is centered at 3.6 MHz and our bandwidth is 2MHz, then the highest frequency in our band is 4.6 MHz. Twice that frequency is 9.2 MHz, so our sampling rate should be at least 9.2 MHz.

The problem lies in figuring out the bandwidth. The optimum bandwidth provides a compromise between the amplitude and the frequency resolution. The filter should be as narrow as possible in order to solve the exact frequency of a line component, but this will cause the amplitude resolution to be badly degraded. The temperature resolution is given by

$$\Delta T_{min} = \frac{T_{sys}}{\sqrt{(\Delta \nu_{HF} t_{LF})}}$$

where $T_{sys}$ is the system temperature, $\Delta \nu$ is the bandwidth and t is the integration time (see pg. 7-8 in *Radio Astronomy 2nd Edition* J.D. Kraus). Thus the filter bandwidth should be as wide as possible.

**Computer Issues:**

The process of the whole system is as follows: the signal from the sky is detected at a rate that needs to be determined, the signal is then Fourier transformed and outputted in a frequency range determined by our sampling frequency, the frequency data is then smoothed and selected to our specified bandwidth, the data is then dumped into the appropriate channels in the bandwidth, then the channels are time averaged and the final step is to write that time averaged data to disk.

By sampling at the above mentioned rates, it was noticed that the amount of data coming through is enormous. The FT of the time domain data when sampled at 12.5 MHz (the closest value to and greater than 9.2 MHz that we could get) would range from 0 Hz to 6.25 MHz (half of 12.5 MHz). In this window we will have a finite number of channels which we will need to base our bandwidth around.

The number of data points returned from the FFT is $2^{14}$ bytes which gives us 4096 floats. This means that we have 4096 minimum spectral points. If we want 256 channels and our sampling rate is 125 MHz, then the frequency range of the FFT is (12.5MHz/2) 6.25MHz and the channel width of each spectral point is (6.25MHz/4096) 1.5 KHz. Thus our bandwidth for 256 channels is (1.525KHz*256) 390.6 KHz at the bare minimum. If the bandwidth that we are trying to target is 2MHz with 256 channels, then we could use 5 spectral points per channel. Then our actual bandwidth is (5*390KHz) = 1.95MHz and each channel will have a width of (1.5KHz*5) 7.6KHz, (email conversation with Jeff).