Spire Data Processing Considerations

Digital filtering

The current baseline is to over-sample the interferogram by a factor of 4 or 5. The number of points in the interferogram may be reduced without transforming the data by the application of a digital filter. This requires the initial interferogram is convoluted with a symmetric filter (the inverse transform of the bandpass function), figure 1. For N coefficients in the filter (N is an odd number) this requires approximately (N+1)/2 multiplication operations and N addition operations per output data point. The number of coefficients determines the steepness of the filter rolloff, as shown in figure 2, with 63 coefficients from a standard filter providing reasonable performance. (Optimisation of the coefficients could reduce N somewhat with little loss of performance). If each pixel generates a 1000 point interferogram in 30 seconds this corresponds to a processing requirement of about 3200 add/multiply operations per second per pixel. It should be noted that digital filtering is required to eliminate aliasing of high frequency noise into the spectral region when the number of samples is reduced. If the signal filtering is such that there is no noise at higher frequencies then there is not need to digitally filter.

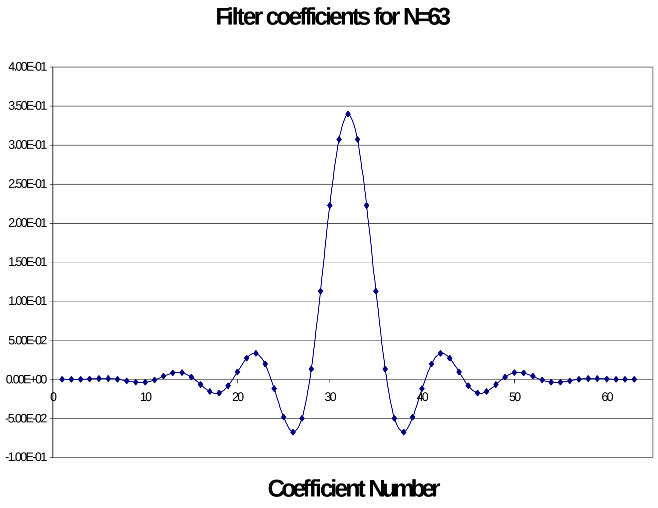

Figure 1 Values of filter coefficients for N=63

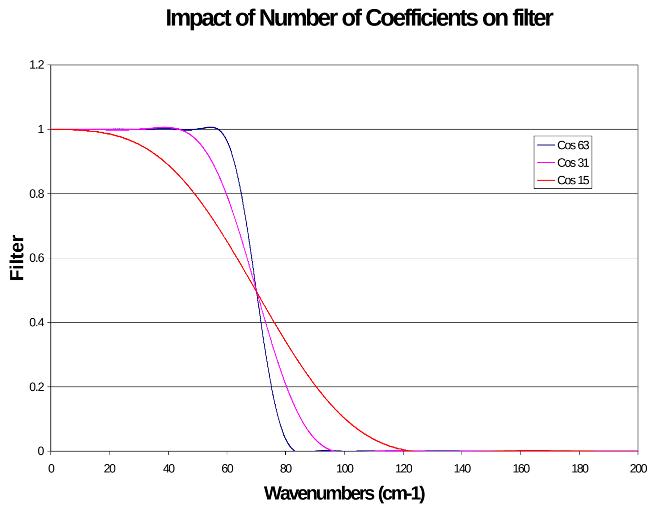

Figure 2 Roll-off of numerical filter in spectral domain

Time Sampling

The time sampling technique has the potential to correct for the effects of velocity changes during the scan. The use of digital filtering to reduce the number of data points in the interferogram causes an averaging of velocity changes over time. The average time for each filtered interferogram point can of course be determined by applying the numerical filter to the time channel, but the time information is still blurred by the filtering. If the velocity changes are slow with respect to the time taken to measure the N (unreduced) points used in the filtering then the time measurement will be the same for all points in the filter and hence digital filtering will have no effect on the time correction. If the velocity changes are fast with respect to the sampling time, the velocity (hence time) of each sampled point will have independent random errors. The filtering will then have the effect of averaging these errors giving a reduction in this error of up to $N^{1/2}$. In practise the velocity variation will probably be intermediate between these extremes providing both some velocity correction capability and some averaging of the errors.

Buffering

Digital filtering requires buffering of a number of raw data points which is at least equal to the number of coefficients being used in the filter. Buffering of the raw data is also required to remove particle hits that will effect the interferogram over a time period of about 4 time constants. For a 5 fold oversampling this corresponds to about 20 raw points which will generally be less than the number required for the digital filter buffer (e.g. 63 points). The particle hit correction however does require additional processing during which time the processor is not available for digital filtering. Estimating the required processing for particle hit correction as say 1000 operations this corresponds to a delay of about 1 msec (assuming the digital processing is running at about 10^6 operations per second). This is less than 1 point per pixel, which implies that negligible additional buffering is required to allow for particle hit processing time. Given that 63 coefficients are probably sufficient for the digital filtering a buffer size of about 80 points per pixel (1280 bits using 16 bit numbers) will be sufficient.

Particle Hit Correction

Digital filtering has the effect of smoothing the sharp edge associated with particle hits. Although large hits are still readily discerned in the data, it is preferable to remove these hits prior to digital filtering.

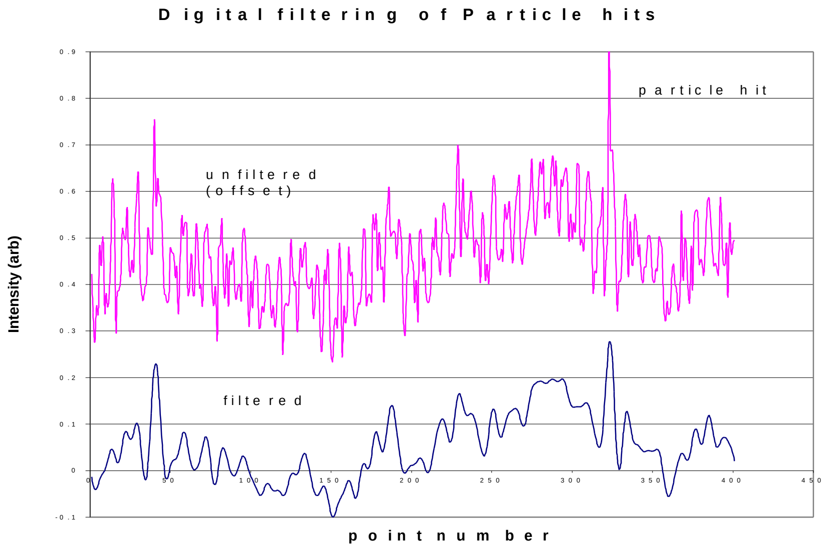

Figure 3. Effect of digital filtering on particle hits. The detector response in the breadboard system is higher than expected for Spire so the particle hits appear somewhat narrower in this test data.

The simplest procedure for detecting particle hits is detect when the point to point difference in the interferogram is larger than some threshold (possibly related to signal size). This requires only a single subtraction and comparison per raw data point which is a small computational requirement compared to the digital filtering requirements. If an adjustable threshold is used to allow for large signals near ZPD then a running average of signal magnitude will be required, amounting to an additional 3 or 4 operations per raw data point.

Upon detection of a particle hit some algorithm to remove them is needed. A simple linear interpolation procedure between unaffected points is probably adequate in the first instance. This would only require a few add/subtract/multiply operations per affected point. As particle hits are relatively rare events more sophisticated correction procedures involving several hundred operations could realistically be implemented without undo computational load.

Compression

To minimise the download requirements the interferograms should be scaled so that the noise is on the order of 2 to 4 bits. In the limit of pure noise no further compression will be viable so each data point will require about 4 bits. In high signal situations some compression will be possible as the ZPD region of the interferogram will require 14 bits but most of the interferogram will require fewer bits. A simple loss-less compression procedure therefore would be to segment the interferogram into several intensity regions and use an appropriate number of bits for each region. This simple algorithm was tested on real spectra from the breadboard spectrometer at QMW, typical spectra used are shown in figure 4. Spectra were taken which roughly represent the large signal case and the small signal (ZPD nulled) case. To simulate low resolution only the central portion of the interferogram was taken. After compression the number of bits was reduced by only about 25% to 30% for the large signal case which corresponds to about 10 or 11 bits per interferogram point. Slightly lower compressions were achieved for low resolution scans, e.g. 20% to 25%. In the small signal case the reduction achieved was typically less than 10% as it approaches the noise limit. There is very little difference between high resolution and low resolution scans in this case. Although no compression is achieved in the small signal limit, it should be noted that the number of bits required will be lower due to the reduced dynamic range, so again the data to be downloaded will typically require about 10 bits per point.