NEROC Haystack Observatory

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Memorandum

To: Distribution

From: John Ball 1993 September 16

Subject: Spectral Merge Preprocessor

Abstract

The Spectral Merge Preprocessor (SpctMrgPp) is a C program to run on fourier or gauss that reads two, three, or four spectra made simultaneously (same number suffix, *yydddnnnn*) with different video converters (VCs) offset in frequency and combines these spectra to give a composite spectrum with an effective bandwidth spanning the whole. The format of the output spectrum is the same as the input.

Observing Requirements

Assign two, three, or four VCs with the same bandwidth to the same receiver but offset in frequency with some overlap.

Observing Recommendations

Assign the same number of lags (same number of modules) to each VC. (Otherwise the resolution will not be the same across the composite spectrum.)

Adjust the frequency overlap to be 10% to 20% of *BW* (i.e., offset by 80% to 90% of *BW*) rounded to an integer times *BW*/*L*, where *BW* is the bandwidth, *L* is the number of lags on each VC, and *BW*/*L* is the Nyquist spacing. (Hint: 12.5% works.) The frequency offsets are set in hardware and typed into Setup.

Choose a center velocity, then offset the VCs symmetrically (half the offset plus and minus) around it.

Caveats

The resolution is not affected, but the point spacing will be larger and the number of points will be smaller in the combined spectrum than in each of the component spectra. The header of the combined spectrum has the correct numbers.

Using SpctMrgPp

Several shell scripts are available to facilitate using SpctMrgPp. PlotSm (m for merged), for example, runs on fourier, reads prescribed real-time spectra, processes them through SpctMrgPp, and makes a screen plot (TEK 4014) of the result. GetCLASSm runs on Haystack Sun 4s, fetches spectra from fourier, processes them through SpctMrgPp, and converts them first to CLASSy FITS and then to a CLASS-format file. Appendix A has examples of such shell scripts.

Processing Steps in SpctMrgPp

Following is a summary of the processing steps in SpctMrgPp.

1. Read up to four spectra with the same number suffix (*yydddnnnn*). (Later we may need to add a way to exclude spectra to allow for two VCs on each of two receivers.)

2. Check: All spectra must have the same bandwidth, and the sum of the number of overlaps must be $2N$-2, where N is the number of spectra. The amount of frequency overlap must be within prescribed limits (presently 5% to 50%). This insures that one continuous spectrum can be generated.

3. Renumber the spectra in order of decreasing frequency offset (i.e., from left to right in velocity). For each spectrum in renumbered order, calculate a weighted temperature offset in the overlapping region to the right, accounting for any previously calculated offset, and record this new offset to be subtracted from the lower-frequency spectrum to the right. Thus the left-most (highest-frequency-offset) spectrum becomes the reference. The average temperature across the composite spectrum is not necessarily zero. The weighting function is discussed in Appendix B.

4. For each input spectrum: Omit points as appropriate (i.e., omit one out of two for N = 2 or omit three out of four for $N > 2$). (We are still guaranteed to have at least two points per Nyquist.) Offset the temperatures (from calculations above) and sum into the output array with the same weighting as above. Convert to average.

5. Recalculate the number of data (this will be an arbitrary number less than 8192), the center datum, the center velocity, the span frequency (effective bandwidth), and the span velocity (the Haystack-format header contains 80% of the full bandwidth). The number of autocorrelations is zero. Put this in a revised header. Write it all to stdout.

Appendix B) Weighting Function

The top half of Figure 1 shows the edge of a typical bandpass spectrum. The tic marks on the abscissa are in steps of 4% of the total bandwidth, so they line up approximately with the abscissa on the bottom half of the figure. The function plotted in the bottom half, which is intended to match the shape of the spectrum above, is

$$W = 1 - \frac{1}{1 + (bx)^8}$$

where b = 13, which places the half-power point at about 7.7%.

Appendix C) Recommended Wide-Band Setup

To obtain the widest possible bandwidth, four video converters, each set to 160-MHz bandwidth, can be placed edge-to-edge in frequency. A recommended overlap is one eighth or 12.5%. With the first LO tracking the desired center velocity, the frequency offsets should be set to ±70 MHz and ±210 MHz. Any VC can be set to any of these offsets, but the numbers typed into Setup must agree with the hardware settings. The resulting total effective bandwidth is 580 MHz, and, with one module on each VC, the uniform-weighted resolution is 1.508 MHz, the point spacing is 78.125 kHz, there will be 7424 points in the merged spectrum, and the center point is number 3713. Note that row M in the spectrometer's setup table has two modules on VC 1, which gives it narrower resolution than the other three. With a little extra bother, one could take four spectra with the VCs permuted so that each occupies each offset in turn. Averaging these four should eliminate the variation of resolution across the composite spectrum and also reduce VC-related instrumental effects.

Appendix D) Tests

Figure 2 shows a test of SpctMrgPp made using VCs 1 and 2 set for 160-MHz bandwidth. Into VC 1 we put a test signal 40 MHz below the center. The default line frequency was 22235.080 MHz, so the test signal appears at about +539 km/s. VC 2 was given a fake offset of 85% (overlap of 15%) or +136 MHz) fake because actually no offset was possible. SpctMrgPp combined these two spectra to give a composite spectrum 296 MHz (3991 km/s) wide, most of which is plotted in Figure 2. The left-most (in velocity) component spectrum is used as the temperature reference, and since this spectrum has no signal, the zero offset is quite good. The ringing in the right component spectrum is characteristic of a zero-width signal and uniform weighting.

Figure 3 shows a nearly identical test differing only in that the fake offset for VC 2 was set to −100 MHz (+1348 km/s), which was chosen so that the two component spectra overlap in the region of the test signal. This signal is in VC 1 only, so its amplitude on the composite spectrum should be reduced to about half. The left spectrum is used for the temperature reference, so the baseline should be somewhat negative on the left side of the composite, slightly positive in the region of overlap, and more positive on the right side. There should be a step at about 436 km/s on the left edge of the overlap region and another step at about 913 km/s on the right edge. (With a signal present and coincident in both component spectra, there should be no steps.)