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MEMORANDUM

TO: 12 m Memo Series

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I. Doppler Correction for High Frequency, High Velocity Sources

The Doppler correction for the frequency synthesizer at the 12 m has traditionally been computed from the classical formula

$$f_{nr} = f_o(1 - v/c), \tag{1}$$

where f_o is the rest frequency of the spectral line, v is the LSR radial velocity of the source, c is the speed of light, and f_{nr} is the (nonrelativistic) shifted frequency. At 12 m observing frequencies and at velocities common for extragalactic sources, f_{nr} can differ significantly from the relativistic Doppler correction

$$f_r = f_o[(1 - v/c)/(1 + v/c)]^{1/2}. \tag{2}$$

Table 1 lists $f_r - f_{nr}$ for several velocities and the frequencies of the J=1-0, 2-1, and 3-2 CO lines.

Table 1
$f_r - f_{nr}$

Velocity (km/s)	f_o (MHz) 115271	230538	345796
1000	0.6	1.3	1.9
3000	5.7	11.4	17.1
10000	62	124	186
20000	240	480	721

Note that for velocities of 3000 km/s, the differences $f_r - f_{nr}$ are important; at higher velocities the line may be shifted completely out of the spectral bandpass. To address this problem, we have installed, as an option, a second order approximation to the relativistic Doppler formula:

$$f_2 = f_o(1 - v/c + \tfrac{1}{2} v^2/c^2). \qquad (3)$$

Table 2 lists the quantity $f_2 - f_r$ for the same frequencies and velocities as in Table 1.

Table 2
$f_2 - f_r$

Velocity (km/s)	f_o (MHz) 115271	230538	345796
1000	0.00	0.00	0.00
3000	0.05	0.12	0.17
10000	2.1	4.2	6.3
20000	16.3	32.6	48.9

<u>The nonrelativistic Doppler expression (Eq. 1) remains as the default option for frequency calculation</u>. To invoke the second order expression for frequency calculation (Eq. 3), ask the operator to type VREL at the control computer console when in the SPECTRA observing mode. To return to the nonrelativistic method, ask the operator to type VNONREL. The status of VREL/VNONREL will not be changed by loading the continuum program and later returning to SPECTRA. <u>If the</u>

control computer must be completely rebooted, the velocity option will default to VNONREL.

For very high velocities, even Eq. (3) may deviate significantly from Eq. (2). In such cases, the observer may wish to set the input velocity for the source to 0.0 km/s and calculate the sky frequency from Eq. (2).

II. Entering Large Source Velocities into the Control Computer

LSR radial velocities are stored as single precision (16 bit) integers in the FORTH control system. The maximum velocity that can be entered under normal circumstances is ±3276 km/s. Two words have been added to the control system vocabulary that will allow higher velocities to be entered. When in the SPECTRA observing mode if the operator issues the command LOWVEL (the default state), velocities entered from an observer's source catalog will be interpreted in the traditional sense, i.e., to the nearest 0.1 km/s with a maximum magnitude of 3276 km/s. If the operator issues the command HIGHVEL, the velocities will be expressed to the nearest whole km/s, up to a maximum of ±32768 km/s.

A single source catalog can contain both high and low velocities; the command HIGHVEL changes how those velocities are interpreted. If high velocity sources are entered in the catalog, we recommend that the entry have no digits beyond the decimal point (the decimal point should be included).

For example, use

5243. km/s
16521. km/s

When HIGHVEL is specified, the program reads up to 5 digits. A catalog entry of 1436.3 will be interpreted as 14363 when HIGHVEL is specified, so take care that the velocity displayed on the TV monitor is what you intend.

As with VREL and VNONREL, the status of LOWVEL/HIGHVEL will not change by switching between SPECTRA and CONTINUUM. Rebooting the system completely will leave SPECTRA in the default state of LOWVEL.

III. The Center Channel of the 30 kHz Filterbank

Marc Kutner pointed out that spectral lines observed in the 30 kHz filterbank appeared to be offset by 1/2 channel from lines in the spectrum expander. Indeed, the center frequency of the 30 kHz filterbank occurs at channel 65 (numbering from 1 to 128). The convention in effect for all other 12 m filterbanks is for the center frequency to fall at the exact center of the bank, either channel 64.5 or 128.5.

A software flag has been installed to change the header values for rest frequency f_o and center velocity v_o of 30 kHz data to correspond to channel 64.5 for data written to the VAX analysis system disk. The data on the FORTH disk and binary tape are not altered. Two cases exist:

1) Upper Sideband Observations (SB = 0 or 2) - Increasing I.F. frequency (and increasing FB channel number) corresponds to increasing sky frequency. The rest frequency in the header is replaced by f_o - 15 kHz; the center velocity is replaced by $v_o + (15\ \text{kHz})(c/f_o)$.

2) Lower Sideband Observations (SB = 1 or 3) - Increasing I.F. frequency corresponds to decreasing sky frequency. The rest frequency in the header is replaced by f_o + 15 kHz; the center velocity is replaced by $v_o - (15\ \text{kHz})(c/f_o)$.

This action does not alter the channel in which the line appears, it merely changes the frequency and velocity axes to read correctly. Also, since the change involves only 1/2 channel, the alignment of data during stacking will not be altered since alignment adjustments must be in whole channels.

IV. FORTH Limited Data Analysis Capabilities

For some time now, the FORTH Telescope Control System has operated with all available memory completely allocated. Anytime a new feature is added to the control system, something old must be thrown out to make room for it. A new control system, not FORTH-based, is under development with an expected installation date of Summer Shutdown 1987. Until then, we must survive with the present system as best we can.

Since data analysis is now done with the VAX, the data analysis routines in the FORTH system have been off-loaded to make room for observing tasks. Upon occasion, e.g., when the VAX dies, FORTH data analysis is still needed. This capability can still be provided, but some observing tasks must be eliminated to do so. To provide analysis capability the operator must reboot the system, loading LANALYSIS for spectral line analysis capability or CANALYSIS for continuum analysis capability. A list of benefits and costs are given below.

<u>LANALYSIS</u>

Benefits: Allows spectra to be displayed and stacked, including alignment of LO-shifted data, for up to 50 scans.

Cost: Automatic generation of mapping grids is lost. (One can generate a mapping grid of up to 34 positions using the regular program, then reboot, loading LANALYSIS.)

<u>CANALYSIS</u>

Benefits: Allows the display of ON-OFF sequences, and the fitting of continuum five points and focus checks.

Costs: The system must be rebooted before loading the spectral line system.

The commands for FORTH analysis are described in Computer Division Internal Report No. 18 (by J. M. Hollis) or in the Change Memos to that report.

V. The I.F. Leveler

During the past Summer Shutdown, the Tucson Electronics Division installed a total power leveler in the I.F. section. The leveler is designed to improve performance of the filter-banks by insuring that they are at the same voltage operating point at all times. The leveler has already proved beneficial in reducing the "spikey channel" problem of the filterbanks. The leveling is done at the first I.F. frequency of 1.5 GHz. The leveler attenuators have a very flat frequency response at 1.5 GHz and, as far as we can tell, the leveler adds no baseline curvature to the spectra.

Since the leveler will level out all broadband signals coming from the front end, it must be turned off during observations in which broadband signals are to be received. This includes spectral line vane calibrations and all continuum observations. When a vane calibration is performed in spectral line mode or when the continuum observing task is loaded, the computer turns off the leveling action of the device. A constant attenuation level, equal to the last attenuation level before the leveling loop was turned off, is held. A red light on the front of the leveler panel comes on when the leveler is off. The leveler can be turned off entirely by a switch on the front panel. The attenuation level for each polarization channel can be set from the front panel.

Two possible disadvantages to the leveler exist. For very strong spectral lines (e.g., CO in Orion A) that contribute significantly to the total power, the calibration of the spectrum may be altered by the leveler. Observers may wish to turn the leveler off during such observations. Secondly, the leveler will mask changes in atmospheric emission on the total power chart recorder, i.e., the chart recorder trace will be a straight line. Thus, the observer loses his ability to monitor the atmosphere by watching the chart recorder. Changes in atmospheric conditions will still be reflected by changing system temperatures, however.