Plan for astronomical testing of GBT Spectrometer modes

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Version 1.0

Following a successful engineering checkout of new Spectrometer modes by the Spectrometer engineering team, the following observing checks should be performed:

1. Frequency test-tone check

Inject a narrow-band, CW test tone at the input to the samplers. Set the frequency of the tone so that it is centered in a Spectrometer channel bin. The bandpass is inverted by the sampling process in the 800 MHz and 50 MHz bandwidth modes, and the channel bin centers are given by (R. Lacasse, private communication)

$$F(N) = F_{MAX} - \frac{BW * (N-1)}{nchan}$$

where

N = the channel index running from 1 to *nchan*
nchan = the number of lags (channels) in the mode
BW = is the mode bandwidth in MHz (800 MHz or 50 MHz)
F_{MAX} = the maximum frequency of the sampler in use (100 MHz or 1600 MHz) (the low-speed samplers sample from 50 to 100 MHz, and the high speed samplers sample from 800 to 1600 MHz.

The 12.5 MHz and 200 MHz Spectrometer modes do not invert the bandpass, so the frequency bin centers are given by

$$F(N) = F_{MIN} + \frac{BW * (N-1)}{nchan}$$

where

N = the channel index running from 1 to *nchan*
F_{MIN} = 25 MHz for the 12.5 MHz bandwidth mode and 800 MHz for the 200 MHz bandwidth mode.

BW = the mode bandwidth in MHz 12.5 MHz or 200 MHz

To avoid any sign or symmetry ambiguities, take three observations with the test tone set to the following frequencies

Band center (N=nchan/2)
40% of the bandwidth (N = (int)nchan*0.4)
70% of the bandwidth (N = (int)nchan*0.7)

Check that the line comes out precisely at the frequency expected using AIPS++. Plot and save each scan as an SDRecord (see below).

It would be useful to repeat this test with the test tone at the input of the IF down-conversion rack. In this case, band center is the IF center frequency. This will test proper operation of the IF down-conversion process.

2. Observations on the sky

Observe astronomical lines having different linewidths -- narrow, medium, and broad.

Suggested sources are:

Narrow line sources (0.5 - 1.5 km/s FWHM):

```
TMC-1      04:38:38.0      25:35:45.0 B1950      5.8 km/s   LSR
L134       15:51:00.0     -04:26:57.0 B1950      3.0 km/s   LSR
S146       22:47:30.0      59:39:00.0 B1950      -49.6 km/s LSR
```

Medium width sources (5-10 km/s):

```
OMC-1      05:32:47.0     -05:24:21.0 B1950      9.0 km/s   LSR
W51M       19:21:26.3      14:24:43.0 B1950      57.1 km/s  LSR
```

Broad line sources (10-25 km/s):

```
IRC+10216  09:45:14.8      13:30:40.0 B1950      -26.0 km/s LSR
NGC7027    21:05:09.5      42:02:03.0 B1950      24.2 km/s  LSR
```

Spectral Lines with rest frequencies below 10 GHz:

OH	1.667359 GHz	(thermal absorp. or maser emission)
HC_5N J=1-0	2.66287 GHz	(has hyperfine splitting)
H_2CO 1(1,0)-1(1,1)	4.8296639 GHz	(typically in absorption)
HC_5N J=2-1	5.325421 GHz	(has hyperfine splitting)
HC_3N J=1-0	9.0983321 GHz	(has hyperfine splitting)
H87-alpha	9.816865 GHz	(recombination line)

HC_3N and HC_5N should relatively strong in TMC-1, OMC-1, IRC+10216, and W51M. H2CO should be relatively strong in all the sources except IRC+10216 and NGC7027, where it will not exist at all. The recombination line may only be detectable in OMC-1 and W51M. Some experimentation with sources and lines may be necessary to get a good set of standards.

Observing methodology:

- Save all data as an AIPS++ SDRecord using the uni-jr 'keep' command or the Dish 'add' command. Use a file name of the form

  `spectest_bw_mode_date`

  where bw is the bandwidth, such as 50 or 12p5 (=> 12.5 MHz)
  mode is the Spectrometer configuration mode, such as A2B2
  date is the observation date, such as 29may02.

- Note the version of the Spectrometer software in use.

- Configure the system for Total Power OFF/ON observing.

- Set a OFF reference position to be the scan length + move-time overhead in right ascension. For an OFF observed first, the RA offset will be negative (to the west).

- Observe first with the Spectral Processor in the most closely comparable bandwidth mode. Save the data to disk and to hardcopy.

- Observe with the GBT Spectrometer in the 50 MHz, 9-level, 2-IF, 4-Quadrant, Hanning smoothing mode. Save the data to disk and hardcopy.

- Observe in the Spectrometer mode to be tested. Save the total power OFFs and ONs, and the calibrated spectrum to disk and hardcopy.

- On all spectra, be sure to integrate long enough so that line shapes and intensities are not noise dominated (e.g., SNR should be 15-20:1, if possible).

3. Line comparison

- Remove a 1st order baseline from all spectra, but no fits of higher order that can make profile comparison ambiguous.

- Smooth the spectra.

  Reference all spectra to the 50 MHz, 9-level mode, with 2-IFs, as described above. Compare profiles by smoothing higher resolution spectra to 50 MHz, or the 50 MHz spectrum to lower resolution, as the case may be. Use a smoothing operation that duplicates the point-spread function of the lower resolution. This can be done by means of a sinc(x) convolution or by truncating the autocorrelation function and performing data decimation before Hanning smoothing. Do not smooth by, for example, using a boxcar function.

- Difference the two spectra to be compared and look for any features in the residuals that are above the noise. Plot the results and save the hardcopy.

4. Integration Test

Choose a test source and line with a reasonably uncluttered bandpass and integrate for 1 hour in an observation composed of 6 OFF-ON pairs of 5 minutes integration time for each scan. Fit a baseline and determine the RMS for progressive averages of 1, 2, 3, 4, 5, and 6 scans. Plot the RMS versus integration time and determine if the RMS decreases with $t^{-1/2}$.

5. Document and archive

a. Make sure that the spectra are saved to an archive file (see above).

b. Make hardcopies and place in a notebook, organized by Spectrometer mode. Annotate the hardcopies with date and the observer who took it.

c. Create a web page with links to the spectra, organized by mode, source, and line. (This task will be assigned to one person – to be determined)

6. Sign-off

The commissioning scientists are responsible for leading this effort. When a new set of modes are evaluated, the hardcopies should be distributed to all commissioning scientists and to the Spectrometer engineering group (R. Lacasse, J. Ford, R. Fisher). After a suitable period for internal discussions, results will be reviewed in the Friday commissioning meetings. Modes that are operating properly will be signed off on at those meetings; anomalies will be flagged and taken outside the meeting for separate review and action.