GALFA SPECTROMETER (GALSPECT): SETUP, OPERATION, BASICS

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This material is from Jeff Mock, the person that designed the spectrometer. This document is a distillation of the full scoop, which is on the webpage *seti.berkeley.edu/galfa* . The distillation contains the following:

Contents

1. STARTING GALSPECT

The control program for GALSPECT is called *gdiag* . To run GALSPECT for conventional Galactic HI observations, perform the following steps:

1. **Obtain the encryption file** *galfa_key***.** If this is the first time you log into GALSPECT, you need to copy the file *galfa_key* from Jeff Mock's directory to your home directory. To do so, while working in your home directory, type the command

```
cp jmock/galfa_key .
```

2. **Log into the GALSPECT computer.** You should have already copied the file *galfa_key* to your home directory and made it read-only by the user (*chmod 0400 galfa_key*). Then the appropriate command is

```
ssh -i galfa@galfa1
```

3. **Check that no one else is already using GALSPECT**, i.e. that no one else is running *gdiag*

```
ps
```

This lists the programs running on the *galfa1* computer. Look for *gdiag* . If it is already running, *STOP HERE!*

4. **Check that the data disk is mounted and has free space.**

```
df /dump
```

5. **Run the basic operational check of GALSPECT.**

```
/var/diag
```

Let this run for 30 sec or so. If there are error messages, reboot GALSPECT (see §3.1). If you still get error messages, repeat until it works or until you or the equipment die of exhaustion.

6. **Set the DAC levels to 10 units rms.**

```
/var/levels
```

Setup the telescope and move it near the starting source before setting levels. The 1st IF and IF routing should be configured to provide a valid signal to galspect before setting levels.

Let this run until it finishes. It prints out its current action on the screen and, at the end, a summary. In the summary, the rms should be around 10, as you requested, and the DAC values should be around 90. Sometimes a large RFI pulse might interfere with this operation. If the levels do not look right, repeat this process.

Note: The gains increase with decreasing DAC number in a *highly nonlinear way.* From DAC=0 to $\sim$ 90 the gain decreases by $\sim$ 4 db; from DAC$\sim$ 90 to 255 the gain decreases by $\sim$ 36 db. Thus, low DAC values are very sensitive to signal levels. High DAC numbers should be very rare. A low DAC number is not a problem as long as the rms is acceptable.

7. **Decide how many one-second dumps per FITS file you want.** The example below assumes 600 (*–sdiv=600*), meaning that each FITS file lasts 10 minutes.

8. **Decide on a project name.** This should normally be the observing proposal number, e.g. A1943.

9. **Create a shell script file with observation parameters.** The file is usually the observing proposal number, it should be placed in /var, make executable (*chmod 775 /var/a1943*) and contains a galspect command that looks something like this:

```
#!/bin/sh
gdiag -galfa -sdiv=600 -scram -lo2=256.25 -proj=A1943 -vnc
```

10. **Start the observation.**

```
/var/A1943
```

The *–time* option allows you to decide the number of seconds you want to run the program. If you want to run forever, don't include the *–time* option.

The *–scram* option allows GALSPECT to listen to the network directly with the LO values. It replaces the obsolete option *–offset*.

The *–lo2=256.25* option sets the frequency of the LO2 frequency synthesizer located in the galspect rack to 2*256.25 MHz. The synthesizer is set to twice the LO2 frequency to account for the way the analog mixers work in galspect.

The *–vnc* allows you to view the online graphical output on your local terminal—and anyone else to view it on her terminal (simultaneously). And not only to view it, but also to change the display and (*yes, it's true!*) the value of *digitalmix*. So in principle some random hacker—or your collaborator in Timbuktu—could ruin your observation. If you replace the *–vnc* by *–run*, then nobody can view the online output, and nobody—not even the local keyboard on GALSPECT—can change things while you are running. If you invoke *gdiag* and specify neither *–vnc* nor *–run*, then GALSPECT's local display and keyboard both function.

If you are running from off-site you shouldn't use the display because of network latency, so you should not use *–vnc*; and if you want to make sure that local staff don't accidentally ruin your data, use *–run*.

```
gdiag -run -scram -lo2=256.25 -sdiv=600 -proj=A1943
```

11. **Open another xterm and invoke the online display with**

```
vncviewer galfa1
```

from LINUX machines, or

```
/pkg/misc/bin/vncviewer galfa1
```

from SOLARIS machines.

When running *vncviewer*, you can change the display as explained in its documentation (§5 below). Make sure that the RA, DEC, LO1 and LO2 values on the *vncviewer* display match those on the main observation panel.

It is advised that you do not run *vncviewer* remotely. The more people running it, the more network bandwidth it uses which might cause the lost of data.

12. Finally, the files are located in

    `galfaserv.naic.edu:/export/galfa.startdate.project.sequence.fits`

2. STOPPING GALSPECT

To stop GALSPECT:

- If you are running *vncviewer*, then stop GALSPECT by typing *q* while the cursor is in the plotting window.
- If you are not running *vncviewer*, then stop GALSPECT by typing CTRL-c.

3. PROBLEMS WHEN RUNNING GALSPECT

3.1. Rebooting GALSPECT

When there is a problem and you need to reboot GALSPECT, you can first stop GALSPECT by typing *q*, then type in *ps* to check the *pid*(process id) of *gdiag*. After that, type in $kill - 9pid$ to kill the process and finally type *reboot* to, well, reboot GALSPECT.

When the above method does not work, you can reboot GALSPECT by powering down (turn the key) *for 1 minute*. Power up and try again.

DO NOT REBOOT GALSPECT UNLESS ABSOLUTELY NECESSARY. Generally speaking, it is only absolutely necessary when the */var/diag* test fails.

3.2. Overflows

If the input gets too strong there are warning messages about overflows. For narrowband spectra these messages contain the string MLFS, in which each letter represents an internal digital operation, followed by a four digit number, one digit for each operation. All digital operations are done in integer arithmetic, and overflow means just that. When overflow occurs, the number saturates at the maximum value and there is no wraparound. The digits take on values from 0 to 3, with larger numbers being increasing severity.

For narrowband spectra, the operations are:

1. **A** means the analog to digital converter. The ADC is overflowing (saturating) when this is set.

2. **M** means the digital Mixer. Dan says that saturation is less serious than for the other processes. .
3. **L** means the digital Low Pass Filter.
4. **F** means the Fourier transform computation.
5. **S** means the accumulator (Sum).

The meanings of the numbers are:

1. **0** means almost perfect (0-15 overflows during 1s intergration)
2. **1** means pretty good (16-255 overflows during 1s integration)
3. **2** means pretty bad (256-4095 overflows during 1s integration)
4. **3** means horrible (¿= 4096 overflows during 1s integration)

For wideband spectra there are only two relevant overflow parameters, **F** and **S**.

Normally, when centered on Galactic HI, GALSPECT's wide (100 MHz) band covers about 1388 to 1488 MHz. Every 12 seconds the SJU radar, centered at 1350 MHz, partially saturates the RF electronics and causes saturation problems at the 1 level. These are not serious. It is surprising if you don't see error messages every 12 seconds. This can change depending on time of day, azimuth angle, and possibly other parameters.

Normally, when the EGALFA people are observing, GALSPECT's wideband is centered lower by about 30 MHz. The SJU radar comes directly into the wide band and produces saturation problems at the 3 level, which is very serious. But this *does not indicate a problem with GALSPECT* and you should just keep observing.

GALSPECT has a few birdies. One is at the center channel, i.e. baseband DC. You'll need to interpolate over this, or center the lines away from band center.

3.3. Missing Records in the FITS output file.

GALSPECT writes out about 2 GB per hour. If the output filesystem is being stressed by another user, GALSPECT might complain that it has missed writing out some records. This is serious: you are not recording data! Tell Arun; this has happened before and he has tried to arrange that it will never happen, so he is familiar with the problem and needs to know about it. If you want to investigate yourself, then stop GALSPECT and take a look at the activity on your output file system.

3.4. What Time Is It?

If there is a problem with time, check that the machine time on galfa is NTP locked:

```
ntpdc galfa1.naic.edu
> peers

remote           local      st poll reach  delay   offset    disp
=======================================================================
*mosquito.naic.e 192.231.93.131   1  512  377 0.00104  0.000107 0.00780
=cuca.naic.edu   192.231.93.131  16 1024    0 0.00000  0.000000 0.00000
ntpdc>
```

The offset should be within a few ms; here, it is off 0.1 ms.

4. THE LO ARRANGEMENT FOR GALSPECT

4.1. Frequencies

GALSPECT is a baseband spectrometer that samples complex inputs, meaning that it separates negative and positive frequencies. Thus the baseband center of each GALSPECT spectrum is DC. The IF is mixed with the second LO, called $LO2$. The wideband baseband center frequency of DC corresponds, at IF, to the frequency of $LO2$. The narrowband baseband center frequency of DC corresponds, at IF, to the frequency of $LO2 - digitalmix$, where $digitalmix$ is digitally generated within GALSPECT.

Suppose you are observing the HI line at 1420.400 MHz (for this example, rounded from 1420.405752 MHz and no Doppler correction) and you want it centered in the narrowband spectrum. To accomplish this, set the first LO to

$$LO1 = 1695.400 \text{ MHz} = 1420.400 + 275.000 \text{ MHz}$$

This makes the IF line frequency 275.000 MHz. The IF center of the wideband (width = 100 MHz) GALSPECT spectrum is at the frequency of $LO2$, normally set to

$$LO2 = 256.250 \text{ MHz}$$

and the IF center of the narrowband (width $= \frac{100}{14} = 7.142857\ldots$ MHz) is at $LO2 - digitalmix$. Normally, $digitalmix = -18.75$ MHz, so the narrowband IF center frequency is normally

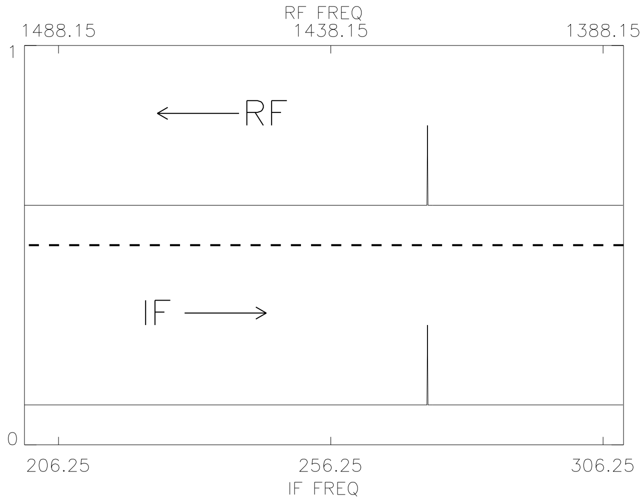

Fig. 1.— IF and RF frequencies for GALSPECT. $LO1$ = 1695.4 MHz, $LO2$ = 256.25 MHz, $digitalmix = -18.75$ MHz.

$$LO2 - digitalmix = 256.25 - (-18.75) = 275.000 \text{ MHz}$$

At RF, the wideband spectrum is centered at 1439.150 MHz and the narrowband one at 1420.400 MHz.

These frequencies are set as follows:

1. The $LO1$ frequency is set by the observing software.

2. The $LO2$ frequency is set by the -lo2 commandline option. The synthesizer is actually set to twice the LO2 frequency to account for the way the mixers operate.

3. The offset between centers of the wideband and narrowband spectra, –18.75 MHz in this example, is the quantity *digitalmix*. You can set it two ways, one *gdiag –mix=nn* and the other with the *w* option in *vncviewer*. There are 32 possible values, spaced by $\frac{100}{32}$ MHz. For $nn < 16$ *digitalmix* is negative, and for $nn \geq 16$ *digitalmix* is positive. The default value is -18.75 MHz.

These relationships are illustrated in the Figure.

4.2. Channels

Both GALSPECT's wideband and narrowband spectra have RF frequency increasing with channel number. The wideband spectra has 512 channels and the center channel is number 256 (counting from zero). This wideband channel has a big DC spike.

Each narrowband spectrum has 8192 channels in the Fourier transform computation. When writing out to a file, 513 are removed and replaced by other numbers (512 are the wideband spectrum; the 512th is a flag). This leaves 7679 channels in the narrowband spectrum. The center channel is number 3839 (counting from zero), and again RF frequency increases with channel number.

5. OPTIONS FOR *gdiag* AND *vncviewer*

You can get this list by invoking *gdiag* with no options.

```
Usage: gdiag [options]

Main operating modes
    -adc       Print out buffer of ADC samples as text
    -rfft      Plot real FFT of ADC channel samples
    -cfft      Plot complex FFT of ADC channel samples
    -scope     Plot oscilloscope view of ADC samples
    -patt      Pattern test for data acquisition
    -dump      Print galfa acquisition as text
    -galfa     Plot galfa data and write FITS file
    -run       Collect galfa data and write a FITS file
    -dac       Set DACs for input level of f dBM

Other options
    -vnc       Run as VNC server instead of console
    -avg=n     Average interval for histograms and FFTs
    -max       Add max-hold line FFT displays
    -input=n   Take input from channel n
    -ppdb=f    Pixels per dB for vertical scale
    -adcfreq=f Use f as ADC sample frequency (MHz)
    -nshift=n  Set upshift of narrowband PFB before acc
    -wshift=n  Set upshift of wideband PFB before acc
    -npfb=x    Set narrowband PFB downshift vector
    -wpfb=x    Set wideband PFB downshift vector
```

```
    -beam=n    Select beam for single beam operations
    -scram    Listen to the network with the LOs
    -mix=0..31 Select mixer for narrowband
    -ta=f      Signal generator A frequency
    -tb=f      Signal generator B frequency
    -lpf=x     Use LPF output instead of ADC for time domain displays
    -ppsint    Beam 0 gets PPS from internal source
    -proj=s    Project portion of filename for FITS dump file
    -sdiv=n    Number of seconds per FITS file
    -time=n    Run --run for n seconds
    -level=f   RMS units for analog level setting

During graphical operation
    Press 'q' to quit program
    Press 'p' to create raw image file in /tmp
    Press 'r' to toggle max-hold
    Press 'a' to toggle through galfa display modes
    Press '0-6' to select beam in galfa display
    Press 'c/v' to modify pixels per dB on log display
    Press 'z/x' to change pre-accum shift in galfa display
    Press ',/.' to scroll through narrow band displays
    Press '</>' to scroll faster through narrow band displays
    Press 'o' to swap drawing order for polarizations
    Press 'm/n/b' to manually move marker
    Press 'w' to change mix frequency for narrowband
    Press 'K/L' to zoom in/out x-axis in narrowband displays
    Press 'd/f' decrease/increase PFB downshift vector
    Press 'h' to toggle linear/log vertical display

Be careful not to hit 'w' accidentally because it changes the mixer frequency
and can cause serious problems.
```

6. CHANGING THE PICTURE ON THE VNCVIEWER DISPLAY

It is understood that astronomers can get really bored sitting in the control room for hours. Changing the small picture on the lower right corner of the vncviwer display can provide some entertainment. To do so, rename a JPEG file (use one with a black background for best results) to *egg.jpg* and *scp* it to the */var* directory. 102x82 is a nice size for the mascot image.