SRT Student Manual

MIT Junior Lab

August 2, 2011

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Chapter 1

The SRT Hardware

The small radio telescope, SRT, is a 7.5 foot diameter parabolic dish and receiver designed by Haystack Observatory and sold by Cassi Corporation.

1.1 Antenna

The antenna is a parabolic dish constructed from C/Ku band mesh supported by a rigid but light weight aluminum frame. The mesh will reflect all incident microwave energy if the holes in the surface are less than 1/10th of a wavelength.

The antenna is pointed by running motors to rotate it about the azimuthal axis or vary the length of the push rod to change the elevation. As the motors move, they send electrical pulses back to the ground controller box on the table beside the computer. (The azimuthal motor, for example, sends back 12 pulses for each revolution of the motor shaft.) The computer will move the antenna by asking the appropriate motor to move a certain number of pulses in the appropriate direction, and it knows where the telescope is pointing by keeping track of the number of pulses returned by each motor. (This is not the best way to do this, but it is significantly cheaper than better methods.)

Antenna Specifications

Diameter	90" (2.3m)
F/D Ratio	0.375
Focal Length	33.75" (85.7cm)
Weight with mount	160 lbs
Beam Width	7.0 Degrees (L-band)

1.2 Signal Chain

The SRT uses a phasing-type single-sideband scanning receiver. Figure 1.2 shows a block diagram of the radio receiver and subsequent signal processing stages. Radio power arriving from the sky is focused by reflection to the antenna feed horn. Signals then pass through a band pass filter, a low noise pre-amplifier and a mixer. The signal is digitized and sent back to the controlling computer over a serial RS-232 link.

1.2.1 Band Pass Filter

After the signals are picked up by the antenna they pass through a band pass filter which transmits a 100MHz band centered around 1420MHz (Figure 1.1). This filter was installed in 2011 after new cell phone towers were installed on campus in 2010. The filtering is done before any amplification in order to prevent the total radio power in the sky from saturating the amplifier and receiver.

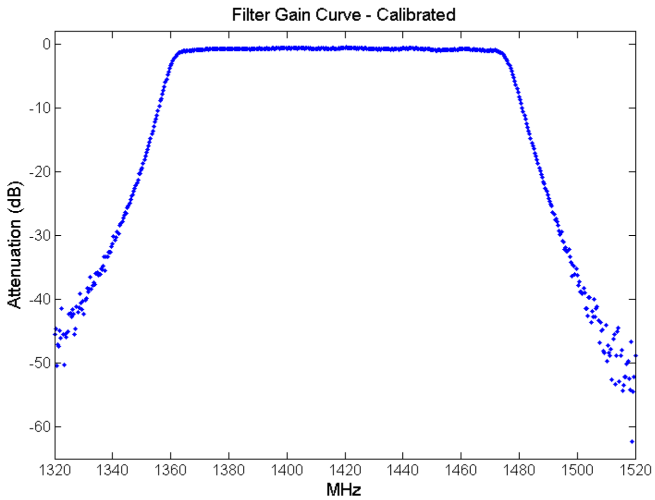

Figure 1.1: The Filter Gain Curve

1.2.2 Low Noise Amplifier

After the filter, the signals pass to a low noise amplifier (LNA) which gives about 25dBm amplification to signals between 1400 and 1440MHz. The LNA also serves as another band pass filter for signals outside that range. The signal must be filtered to only include the 40MHz bandwidth around 1420MHz in order to prevent intermodulation from occurring in the mixers.

1.2.3 Receiver

The receiver contains the phasing-type single-sideband scanning receiver, the analog-to-digital converter, and the chips which perform the Fourier transform.

In the single-sideband receiver, a signal from a local oscillator, set via a command from the computer, is mixed with the signal received from the sky. This mixing, called heterdyning, uses the properties of sine waves to create two new signals:

$$\cos\omega_1 t \cos\omega_2 t = \frac{1}{2}\cos{(\omega_1+\omega_2)t} + \frac{1}{2}\cos{(\omega_1-\omega_2)t}. \tag{1.1}$$

The sum and difference of the input signals are created. The summed signal is then removed, via a low pass filter, resulting in an analog signal which contains frequencies relative to the local oscillator. The analog signal is converted into digital form which is then Fourier transformed and sent to the computer over a serial RS-232 link.

Figure 1.3 shows the Antenna Feedhorn:

1. L-Band probe
2. Low Noise Amplifier
3. Universal Male F to F Coupler
4. Receiver mounting bracket
5. Video Port - Analog signal
6. Power and Communication - Digital Signal

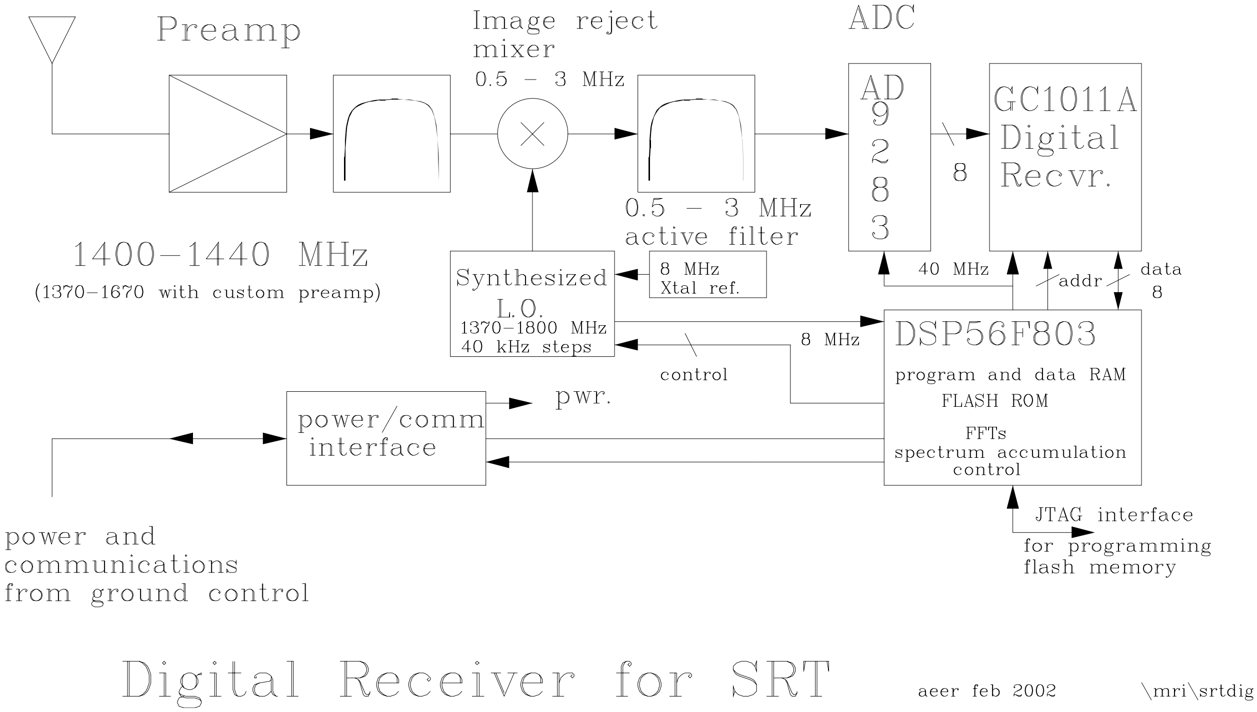

Figure 1.2: The Receiver Block Diagram

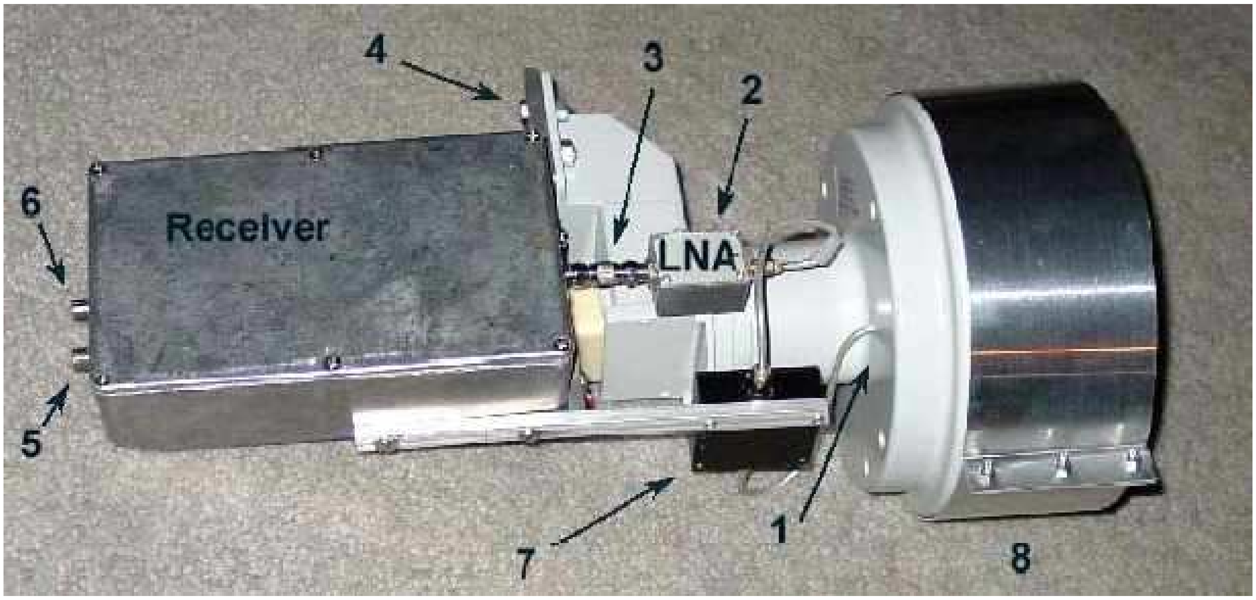

Figure 1.3: The Antenna Feedhorn

7. Band Pass Filter
8. Feed Horn Extension

The digital receiver will saturate (respond nonlinearly to changes in received power) if the count approaches 50 000. The count is shown in the JAVA program near the bottom left of the main window, below the 90° point on the azimuth scale.

Chapter 2

The SRT Software Package

Over the summer of 2009 a new program to run the SRT was installed. The new SRT program has two parts; the first part is a server that talks to the telescope over the RS-232 port and runs on the computer in 26-630. The second part is a user program that is similar to the original SRT program: it provides a GUI, stores data record files, logging files, and runs command files. It communicates with the server by TCP, is written in java, and can therefore run on any computer equipped with a Java run-time engine.

The program has some features that should be useful. There is a "parameter" window to make it easier for you to choose record and command file names, turn recording on and off, and run command files. You can do a lot more with an "npoint" scan than was possible before. There are several telescope parameters that you can change in the parameter window. Finally, most errors are saved in a log file so that you do not have to write them down and the can *en principe*, identify and fix them.

Over the summer of 2011 some additional changes were made to the program. The recording files were changed to also output the galactic coordinates and the file paths used to designate command and record files were changed to both begin in the top directory of the computer (root for linux, C: for windows). This guide was last updated on August 2, 2011.

2.1 The SRT server

The SRT server interfaces between the antenna controls and the user interface. It also handles multiple users attempting to access the telescope at once. Ideally the SRT server will be left running on the computer in 26-630 and you will not have to deal with it. However, as this is JLab and nothing ever goes as planned, how to start the SRT server is described below. See section 2.2 for how to tell if the server is not running.

The server gives you some information in its window and a menu lets you place it in simulation mode for the antenna pointing and/or radio functions (for testing the link between the user interface program and the server without an actual RS-232 connection to the SRT) if you should want that. The menu also enables the "beep" option to be turned on or off. Server error messages are written to the Terminal window, and a log of the IP addresses of permitted and rejected client computers is maintained in a log file. You may minimize the Terminal window and/or the Server window if you wish.

As the user interface program will run on any computer, it is possible that a user in Junior Lab (4-361) may try to run the telescope while it is being run by a user in 26-630 (or vice versa). In that case, the would-be user will be told the telescope is already in use and the domain name of the computer using the SRT. The actual users computer will also "beep" if the beep capability of the server is turned on.

2.1.1 Starting the SRT server

The server program will need to be started if it is not already running. To do that, you need to be logged into the computer in 26-630 (User: srt_user Password: 1420.4MHz) and the controller box on the table beside the computer must be turned on (never turn the controller box off). The SRTserver.jar file will be saved in

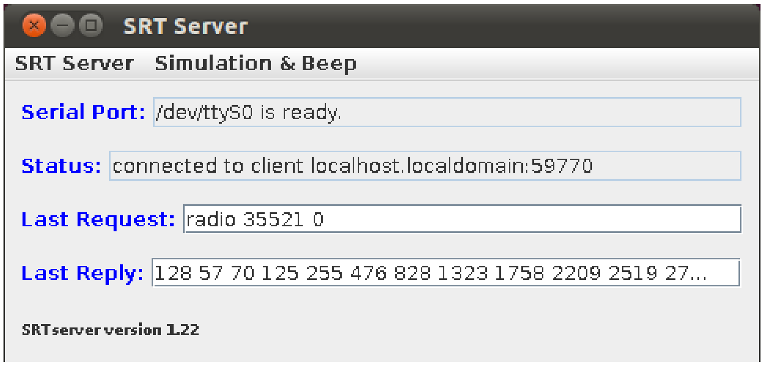

Figure 2.1: The SRT Server which must be running on the computer in 26-630

`/usr/local/bin/`. Open a terminal and type `cd /usr/local/bin/` to navigate to that directory. From there the server can be started with the command:

```
prompt> java -jar SRTserver.jar &
```

The server window should then appear as in figure 2.1.1.
The server program will prevent multiple instances of the server from starting.

Starting the server from a remote location

It is possible to start the server from a remote location, however this is suboptimal because the server can not be left on for the next user. If you're in lab or have the time, please actually go to 26-630 to start the server. This way you can leave it on for other students. However, if it's midnight the day before your oral and you need the telescope to work now, you can start the server remotely via ssh. This requires X11 forwarding, which is annoying to set up on Windows (to the point where I would suggest asking a friend for a Mac or Linux computer if it's possible). On a Mac or Linux machine, plug into a LAN for a better Internet connection, open a terminal, and enter:

```
prompt> ssh -X yourAthenaUser@jlab-24.mit.edu
```

It will ask for a password, which is your Athena password. From there you can follow the instructions above to get the server to start.

If you must use a windows machine, you need to go to IS&T's website and download X-Win32. You will then have to set up a connection to the telescope computer. Host: jlab-24.mit.edu, User: your Athena username, password: your Athena password.

If your ssh connection fails while you're using the telescope, the telescope antenna **WILL NOT** be reset to stow. You need to reopen the server and user interface so that the program will recognize the antenna is not at stow and move it there. **Do not leave the antenna at any position other then stow**.

2.2 The Starting the SRT User Interface

The SRT User Interface is the part of the program designed to be run from a remote location. It is recommended that youu plug in to wired Internet before running the program to decrease the chances of your Internet connection dropping. Here is how to get the program started:
First: Acquire Program Files

There are two files required to start the User Interface, srt.jar and srt.cat, these files must be in the same folder. The .jar file is a Java executable and can therefore run on any computer which has a Java run-time engine installed on it. The .cat file is a catalog file which the srt.jar file uses to load correctly, it contains information such as the Sources to display and the location of the telescope. These files will be on the Junior Lab website and Student Wiki.

Second: Check that the srt.cat file is correct

The .cat file must contain a line which tells the program how to connect to the server. Open the .cat file in a text editor. If you are running the program from a remote location (a computer other than the one in 26-630) then make sure the file contains the lines:

```
*HOST localhost      /* host socket server is running on */
HOST 18.109.0.104   /* host socket server is running on */
```

The * indicates a comment. These lines tell the program the IP address of the computer running the SRT server. If you are running the program on the computer in 26-630 then the commented line should be switched:

```
HOST localhost      /* host socket server is running on */
*HOST 18.109.0.104   /* host socket server is running on */
```

Third: Start srt.jar

The srt.jar file functions as an executable, meaning you should be able to double click on the file and the program will start. However, if you'd like to see any error messages printed into a terminal or command prompt you can start the program via command line:

```
prompt> java -jar srt.jar &
```

Possible Failure Modes Any of these possible messages can appear:

1. "Cannot connect to 18.109.0.104. Is the server running?"
   The program believes that you are connecting from a remote location and cannot connect to the server. If you are connected to the Internet, the most likely cause of this message is that the SRT server is not on, see section 2.1.1 for how to start the server.

2. "Cannot connect to localhost. Is the server running?"
   The program believes you are using the computer in 26-630. If you are connecting from a remote location, make sure the srt.cat file is updated as described above. If you are connecting from 26-630, the server needs to be started, see section 2.1.1.

3. "Sorry, *IP address* is using the SRT. I have turned on simulation"
   Someone else is connected to the server and using the telescope.

Viewing the Telescope

When in 26-630 use the TV monitor to see the antenna, look through the hole in the wall, or send a partner outside to use the walkie-talkies. If you are running from a remote location, you can use the TV camera over the Internet. The IP is 18.109.1.176 (jlab-25.mit.edu) and, as it requires *ActiveX*, you can only see it with *Internet Explorer*.

Note for remote locations: TCP is designed to be a reliable protocol; it's what you use in encrypted form for on-line banking and other transactions. It will give no problems if the user interface program is on the computer in 26-630 and is very unlikely to have problems if it runs on another computer at MIT. However, if the Internet is very busy and you are trying to run the SRT from an off-campus computer, which is normally forbidden, communication with the server could fail. This is more likely to happen when you are using the TV camera, as it uses far more bandwidth then the communication between the server and user interface. If the TCP communication fails, the server program should recognize that, return the telescope antenna to stow position, and then wait for another request from a user interface program.

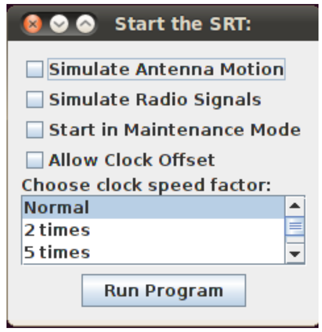

Figure 2.2: The Startup window

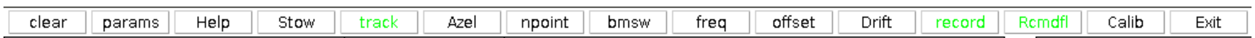

Figure 2.3: The Command Tool bar

2.3 Using the SRT User Interface

The user interface to the SRT is an interactive JAVA-generated window. The window consists of a 15 button tool-bar, a text entry command bar, an information side bar listing; times, coordinates, and source information, observing frequency and system temperatures, and a sky-map showing antenna travel limits, azimuth and elevation tick marks, as well as source plots and galactic coordinates. This section will discuss the control window in sections to provide the user with details about the display while allowing some easy navigation around the control panel.

2.3.1 Startup Menu

When the program begins a window (Figure 2.2) will open which allows the user to choose to run the program in a simulation mode. Clicking on **Run Program** will begin the program normally, with full communication from the telescope. This window gives the user the option to have the antenna motion, receiver data, or both to be simulated. The simulation modes are useful for testing.

2.3.2 Command Tool bar

The main command input device on the SRT Control Panel is the 15-button command tool bar arrayed across the top of the window. Pointing and clicking a mouse on any of these buttons will either initiate an automatic sequence (such as, **Calib** or **track**) or wait on further text input from the user (**freq** or **offset**).

Note: All input actions are delayed until the completion of any "in progress" frequency scan.

clear

As the label implies, the clear button will clear the control console display of accumulated spectral-line data, 25-point scan data. This function is useful if the user is accumulating multiple spectra from different sources or galactic coordinates. The system will treat new source spectra as additions to the accumulated spectrum.

params

Clicking **params** will open a window (Figure 2.4) that allows you to view and change some operating parameters for the SRT.

The window shows the file names for the command, record and error log files. You may edit the fields if you want to change the files used. (The default record file name will use a file with the name YYDDDHH.rad.) In

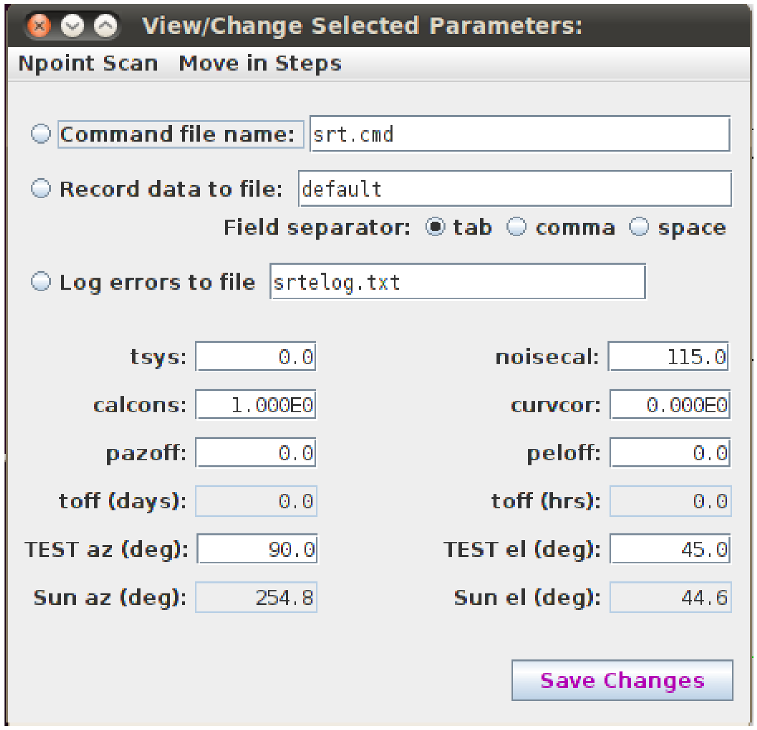

Figure 2.4: The Parameter Window

the window above, the radio button for the error log file is selectedindicating that error logging is turned on. The radio buttons for the two other files are not selected, indicating that SRT output is not being recorded and a command file is not in use. You may stop/start any of these processes by clicking the appropriate radio button to get the setting you want and closing the window by clicking the Save Changes button.

If you close the parameter window by clicking the params button on the main window or the [X] on the parameter window, none of the changes you may have made in the parameter window will be implemented by the SRT program; to implement the changes close the window with the Save Changes button.

The record and Rcmdfl buttons on the main window work to start and stop recording output or using command files, but you will have to choose the file names in the parameter window. The file paths for the command and record files are from the home folder of the computer. Once you have chosen a record file name you should be able to turn recording to it on and off with the record button on the main window.

The parameter window also displays several numerical parameters that you may change, as well as the current coordinates of the Sunwhich you may not change. There are two pull-down menus at the top of the window; this is what you can do with them.

Npoint Scan: With this menu you have some control over what happens when you start an npoint scan with the npoint button on the main menu. The default behavior is a 5×5 grid scan centered around the catalog target you have pointed the antenna at; the points in the scan are spaced 1/2 of the antenna beam-width (the antenna beam-width is 7° for our telescope at MIT). You may use the menu to change this to 3×3, 7×7, 9×9 or 11×11 grid scans. It seems unlikely that you would want to do a 9×9 or 11×11 grid scan, but further down the menu you have the choice to do either an Azimuth or an Elevation line scan through the target; then you may find the larger dimensions useful. In all cases, the points are spaced by 1/2 beam-width, and the program will tell you if the scan would run into a limit switch. Normally the antenna returns to point at the astronomical object after the npoint scan; the last item on the menu allows you to choose to have it point to the peak of the scan.

Move in Steps: On the sky plot a red cross hair usually indicates the current antenna pointing spot.

When you move the antenna, a blue cross hair shows the target you have sent it towards. Normally, these are not updated until the antenna is pointed at the target, when it will turn red. With this menu, you may move the antenna to the target in various step sizes, and the red cross-hair will be updated after each step. This has mostly cosmetic value, but it adds little to the time for the antenna to get to the target and you might like to have a progress report.

Antenna Pointing: The antenna is pointed by running motors to rotate it about the azimuthal axis or vary the length of the push rod to change the elevation. As the motors move, they send electrical pulses back to the ground controller box on the table beside the computer. (The azimuthal motor, for example, sends back 12 pulses for each revolution of the motor shaft.) The computer will move the antenna by asking the appropriate motor to move a certain number of pulses in the appropriate direction, and it knows where the telescope is pointing by keeping track of the number of pulses returned by each motor. (This is not the best way to do this, but it is significantly cheaper than better methods.)

The antenna orientation is calibrated when the SRT program starts up; it reduces the azimuth and the elevation until the limit switches open at the stow point. (The azimuth and elevation of the stow point are set in the *srt.cat* file, hopefully to correspond to the actual antenna orientation when the limit switches open.)

You may find *pazoff* and *peloff*, which you can set in the parameter window, useful as a private correction for pointing errors of the antenna. When the SRT program starts up *pazoff* and *peloff* are set to zero, but once you set them in the parameter window they will keep the values you set until you change them or the SRT program is restarted.

One way to see if you should set *pazoff* and *peloff* would be to do an npoint grid scan of the sun. You can see if the peak signal position is in the center of the scan and the program will also estimate the offsets of the peak from the center. If you set *pazoff* and *peloff* to these offsets, the signal peak should be in the center of subsequent npoint scans. (Clicking the offset button on the main window will also open or close the parameter window.)

If you click on the sky map to ask the telescope to point to an astronomical object, such as the Sun, the program will calculate the azimuth and elevation from the time and date of the computers clock and the information in the srt.cat file; then it will add the values of *pazoff* and *peloff*, respectively, to the destination azimuth and elevation coordinates it calculatedwhich were found using the coordinates of the stow point as a reference. This should correct for pointing errors; then clicking on targets in the sky map should point the antenna in the right direction. If you set pazoff=0 and peloff=3.0, for example, the red cross that shows the antenna position will appear 3° above the astronomical object that you have selectedas the cross represents where the computer thinks the antenna is pointing from counting motor pulses. The coordinates that appear in the data output files will still be the ones calculated from the time and date information, but they should now be where the antenna is actually pointing. The values of pazoff and peloff do not appear in the record file, as they were the corrections needed to make the reported coordinates correct. However, whenever you change *pazoff* and *peloff* in the parameter window, that is recorded as a comment in the record file. The offsets you sometimes see in a record file data output line are the temporary offsets needed to point the antenna during a beamsw or npoint scan of an astronomical object.

Help

Clicking Help opens a window titled srthelp that contains a 6-button taskbar.

- **srt.cat** – Contains a list of keywords available to the SRT user that can be set in the srt.cat file. A brief explanation of the keyword use is included.
- **srt.cmd** – Lists the general rules and usage of command file entries with a few examples.
- **plots** – A Brief explanation of all the plot windows seen on the SRT console
- **outputfile** – Contains a key to reading the ASCII output of a recorded data file
- **cmdline** – This button will show a brief list of commands used at the ***MSDos prompt*** or ***Command prompt*** to select the desired operating mode of the SRT.

- **howto** – Contains information about adjusting pointing, checking receiver and antenna communication and possible adverse interaction between the SRT program and some screen savers.

Stow

Clicking on the **Stow** button will return the telescope to the "normal" stow position in the north-most, low-elevation position of the main Az/El travel zone. The travel zone is established by the AZLIMIT and ELLIMIT commands in the srt.cat file.

track

The **track** button enables the antenna to slew to the selected source from clicking on the map, selecting from the source list or after typing the source information on the command entry text box. The track sequence will work automatically when a source is selected from a command (.cmd) file.

Azel

The **Azel** button allows the user to enter a fixed azimuth/elevation position in the command entry text box.

npoint

Initiates an 5×5 scan/map of the source selected. The **params** window can be used to change this to 3×3, 7×7, 9×9 or 11×11 grid scans. It seems unlikely that you would want to do a 9×9 or 11×11 grid scan, but further down the menu you have the choice to do either an Azimuth or an Elevation line scan through the target; then you may find the larger dimensions useful. In all cases, the points are spaced by 1/2 beam-width, and the program will tell you if the scan would run into a limit switch. Normally the antenna returns to point at the astronomical object after the npoint scan; the last item on the menu allows you to choose to have it point to the peak of the scan.

When finished the program displays a false-color, Gaussian plot to the left of the accumulated spectrum plot. (This plot will clear when the **clear** button is enabled). The resulting maximum T(ant) (with associated offset) is displayed under scan results in the information sidebar. The color plot will NOT refresh if the SRT window is reduced then refreshed.

bmsw

Initiates a continuous "off/on/off " beamswitched comparison observation of the selected source at the frequency settings entered with **freq**. The off/on/off measurements are a set and are complimentary, meaning that the two off-source positions switch sign within each set. The off-source measurements are spaced at +/- 1 beam-width in azimuth (offset = +/- beam-width/cos EL). "BEAMWIDTH" is set in the **srt.cat** file

A left mouse click on the **bmsw** button after the scan has started will abort the beamswitch operation.

Results of the bmsw observation appear in the left (red) spectral plot window.

freq

Sets the center frequency, number of frequency steps and the step width in MHz. Clicking on the freq button prompts the user to enter the desired settings in the command entry window.

There are two different frequency modes relevant to Junior Lab students, Mode 1 and Mode 4. Mode 1 is a single scan with a bandwidth of approximately 0.5MHz. Mode 4 is three Mode 1 scans patched together to give a bandwidth of approximately 1.2MHz. Scans of galactic hydrogen should be made using Mode 4 due to the higher bandwidth.

Example: To observe the hydrogen line at 1420.4 MHz, move the mouse pointer to the freq button. Left click the button then move the cursor to the lower text input section and enter:

```
1420.4 4 (4 = mode 4)
```

where: 1420.4 is the center frequency of an observation and 4 is the digital observing mode. In this case, mode 4 = 3 x 500 MHz bandwidth with a 7.81 kHz spacing.

Mode 4 Matching: The GUI program (version 1.81s) offers three ways to join the mode 4 measurements together, with a srt.cat line of the form MATCH N, where N is 0, 1 or 2. If N is 0 (the default and original Haystack method) the center frequency powers for each measurement are left unchanged and the three measurements are each tilted about an axis through their center frequencies to try to join them smoothly. If N is 1, the middle measurement powers are not changed and the top and bottom measurements each have a (possibly different) number added to all frequency bins to join them smoothly to the middle measurement. When N is 2, the result is similar except that all power measurements in the top and bottom measurements are multiplied by a constant factor chosen to join them smoothly to the middle measurement.

offset

Enables the user to enter any az/el offset pair desired. Left click the **offset** button and enter the offsets in the command entry box. Usage: Azimuth_offset Elevation_offset, default sign is positive.

Drift

A left mouse click on **Drift** will offset the SRT in Right Ascension and Declination to allow the selected source to drift through the 7-degree beam of the telescope.

record

Toggles output file recording on and off. Output data files are by default labeled in the form:

`yydddhh.rad`

The file name can be designated using the **params** window.

Rcmdfl

Initiates reading of the default command file (srt.cmd) and begins data recording. The current line number and text being read is echoed on the message board above the text entry box. To start automatic recording and reading of a file other than the default srt.cmd, the desired command file name (with the .cmd suffix) can be entered in the **params** window.

Calib

Starts an automatic calibration sequence during which a noise source, located at the apex of the antenna surface, is enabled for 1 second. The system then takes a data sample without the noise source enabled. The resulting system noise temperature is reported in the information side bar as "Tsys".

Calibration should be performed when the telescope is receiving at 1420.4 MHz and pointing to an empty location in the sky.

Exit

Returns the telescope to stow and then quits the User Interface program.

2.3.3 Message Board and Text Input

The command text-input box and the system message board are located at the bottom of the SRT control-panel window (Figure 2.5). Many of the actions initiated by clicking the command toolbar are implemented by entry of parameter settings in the text box. Information regarding the correct entry is printed in a message board above the text entry area when the mouse pointer is moved over the desired command button.

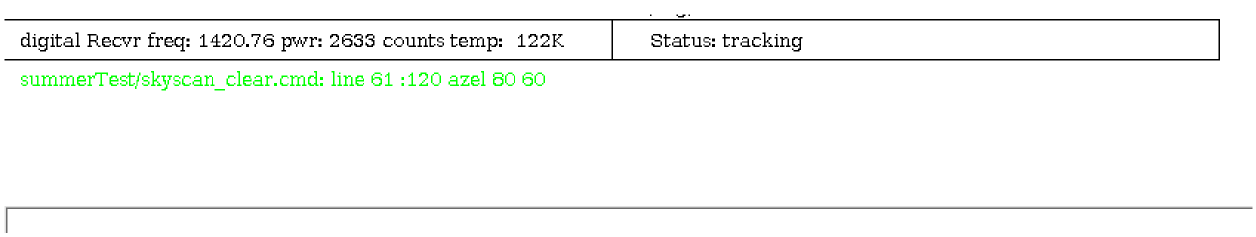

Figure 2.5: The Message Board and Text Input

The message board will also display the current active line command from a command file and the line number. This text will appear green in the form: filename.cmd: line nn: text command.

To the right of the message board text area is another space used to echo information after a text command is entered. Printed in blue, it will repeat the issued command or advise the user that the issued command is waiting on some other action of the telescope.

Receiver output and telescope status can be read in two small text boxes just above the message board and below the map azimuth scale.

- In the left box, reading from the left is the current: frequency sweep (set in ”freq”), receiver ”counts” (uncorrected power level detected by the receiver), the real-time system temperature.
- In the right box the user can reading the current status of the telescope as a whole: Stowed, slewing, or tracking.

2.3.4 Information Sidebar

The information sidebar lists nearly all of the pertinent information the user needs to monitor real time observing with the telescope. The sidebar is illustrated in Figure 2.6 and displays from top to bottom:

- Antenna Coordinates:
  - Command (computer command)
  - Azel (actual position)
  - Total Offsets (User input, mapping, etc)
  - Pointing Corrections (degrees)
  - Axis Corrections (mechanical, user set)
  - Galactic Coordinates
  - RA and DEC (Hrs and Deg)
- Time:
  - Universal Time (UT)
  - Local Sidereal Time (LST)
- Source:
  - Source Name
  - RA and DEC
  - Azimuth and Elevation
- Center Frequency:
  - Frequency (MHz) spacing:
  - number of bins
- Tsys: degrees K
- calcons
- Trec: degrees K
- Scan Results:
  - Max K, offset
  - Az/El Widths
- VLSR: Velocity Local Standard of Rest
- Vcenter: Center velocity of the current observation.
- Vpeak: Velocity of peak signal
- Fpeak: Frequency bin of peak signal

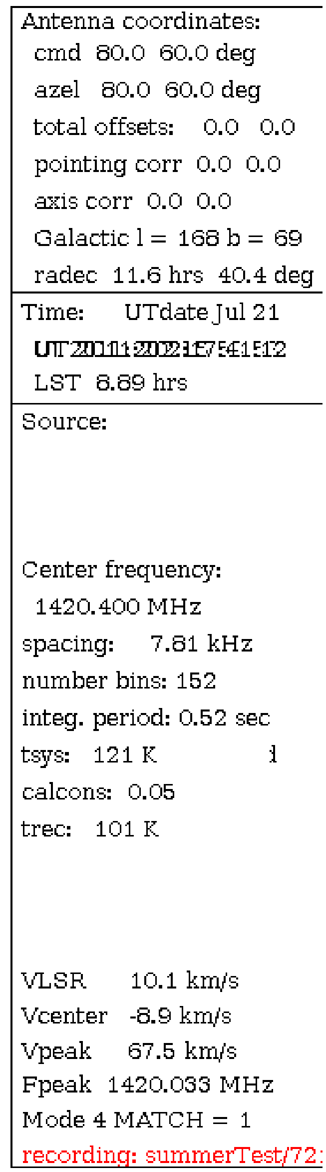

Figure 2.6: The Information Sidebar

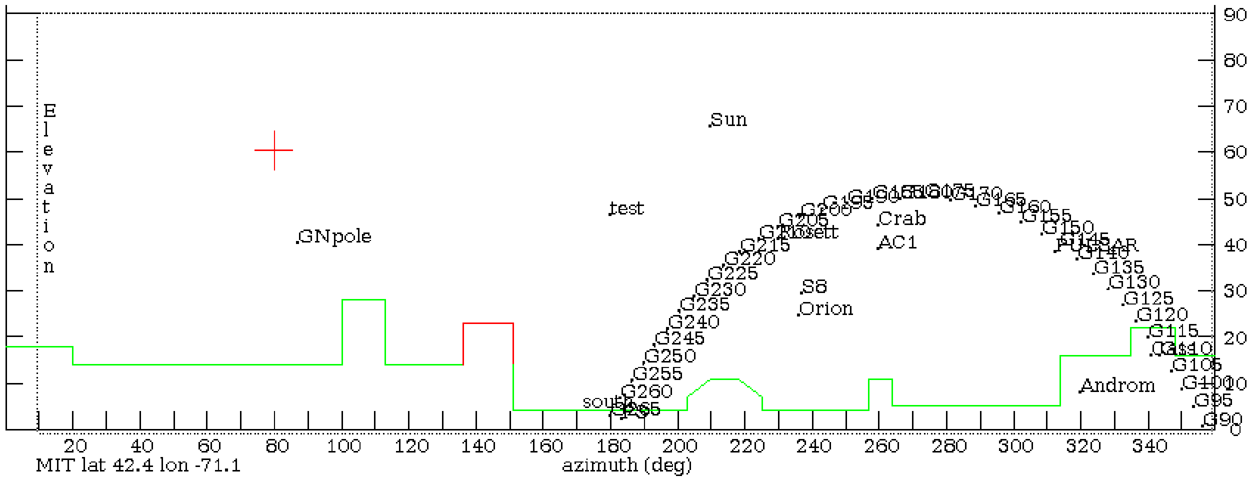

Figure 2.7: The Sky Map

2.3.5 Sky Map

The most obvious feature of the SRT control panel window is the sky map (Figure 2.7). The map shows full sky coverage in azimuth and elevation with 10-degree tick marks in both axes. The azimuth axis is labeled every 20 degrees, the elevation every 10 degrees. The elevation scale is exaggerated 33% from the azimuth scale.

Plotted automatically and labeled are the sources listed in the srt.cat file. Geo-synchronous communications satellites in the catalog are indicated by blue dots. The galactic equator is plotted. The north galactic pole and the 0, 90, 180 and 270 galactic longitude quadrants are also plotted since they have been placed in the catalog.

An outline of the buildings surrounding the telescope is plotted in green. Remember that the telescope has a nontrivial beam-width, if any part of the beam-width intersects with a building your data will be strange. The red box indicates the location of a new (circa 2010) cell phone tower. The telescope has been upgraded since the installation of the cell phone tower, so it no longer causes significant problems. However, be sure to sanity check data taken near the tower as significant amounts of radio power can cause strange behaviors.

The user can move the pointer to any plotted source and click on that source to select it from the source list. When the source is selected, the source plot, label and the telescope "crosshairs" will be colored red. Selecting a source in this manner does not initiate telescope motion to the source however, only an additional action such as clicking the track button will engage the telescope controls.

While the SRT is slewing, the right side information box below the map will carry the message Status; slewing. The sky map will show the telescope "crosshairs" superimposed on the selected source and illuminated yellow until the SRT arrives at the source.

2.3.6 Spectral-line Display

Figure 2.8 displays the spectral-line plotting area of the SRT control panel. There are two spectral windows.

Discrete Spectrum

The right side (black) is the plot of each individual spectrum as it finishes the user input span in MHz (see "freq" in section 2.3.2). The top of the display lists the input center frequency and the frequency step. The bottom line lists the difference of the maximum and minimum values measured during the frequency scan. There is also an arrow indicator showing the direction of increasing frequency.

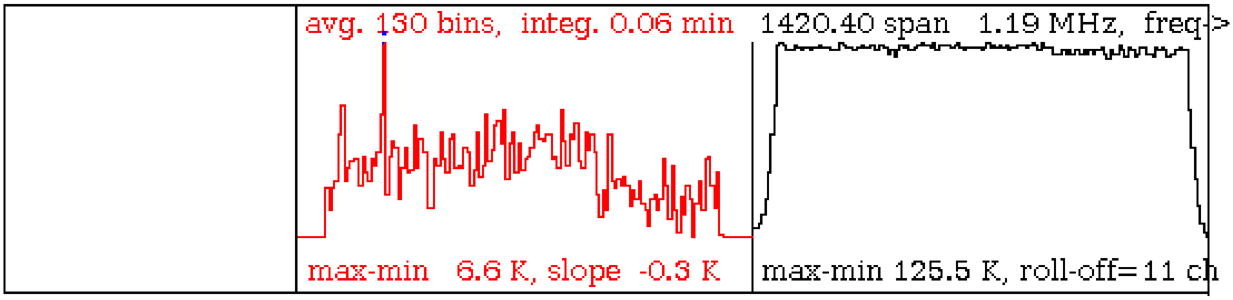

Figure 2.8: The Spectral Line Plots

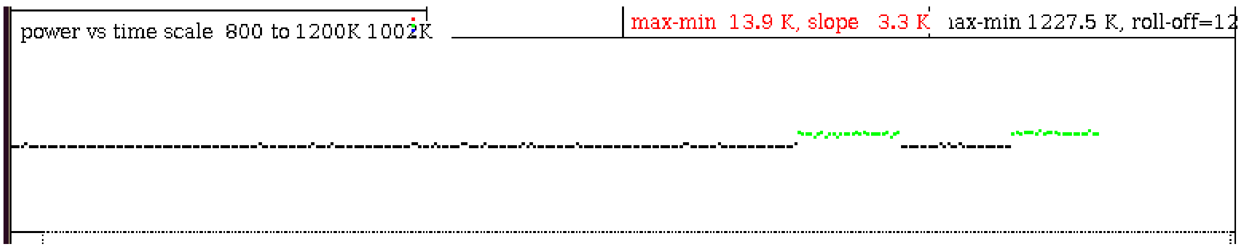

Figure 2.9: Total-Power Chart Recorder

Accumulated Spectrum

The left side (red) spectral-line plot shows the accumulated spectra since the selected observation began. Listed at the top of this window is the title "av. Spectrum" as well as the total "integration" time. The bottom script shows the same max-min difference and increasing frequency direction.

A snapshot of the accumulated spectrum can be seen in a pull-down window by moving the mouse pointer to the accumulated spectrum window and clicking the left mouse button.

Npoint scan Display

The third window in the plot area (far left square field) is the output display for 25-point spectral and continuum maps. When a 25-point scan is complete, a false color image of the map area will automatically display.

2.3.7 Total-Power Chart Recorder

The area of the SRT control console above the Sky Map is a continuously running chart recorder showing relative power of the signal received vs. time (Figure 2.9). The plot will continually overwrite as it paints from left to right and will reset to the bottom of the chart when the plot value reaches the 400K vertical scale maximum. To minimize confusion when the scale resets (400K steps), the plot is color-coded (note the color-dot icon to the right of the temperature indicator):

```
black 0-400, blue 400-800, green 800-1200, red 1200-1600
```

2.3.8 Antenna Drive/Motion Status Display

This box, at the upper left of the control console display, (Figure 2.10) shows the station name, latitude and longitude as read from the srt.cat file. The second line lists the current antenna drive status, such as, moving, simulate, stopped ...

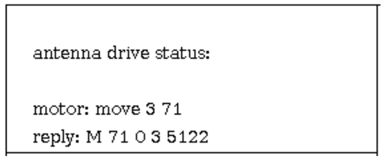

Figure 2.10: The Antenna Drive/Motion Status Display

2.3.9 Manual Command Entry

Most users will start SRT observations by entering text commands into the text box at the bottom of the control console. Most of the button actions can be duplicated with command lines or must be supplemented with manual command entries.

Example: The user may want to conduct a simple test observation of hydrogen along the galactic equator. The required steps are:

1. Move the SRT to an empty location in the sky.
2. Set the observing frequency and observing mode.
3. Calibrate.
4. Move the SRT to the intended source.
5. Decide on a suitable integration time.

A combination of Buttons and text inputs can be used to accomplish this:

1. Click on **azel** and enter coordinates for a place in the sky away from the Sun and Galaxy. Ex: **240 60**
2. Click on **freq** and enter **1420.4 4** (for mode 4 observation)
3. Click on **calib**
4. Click on desired source in the Sky Map
5. Observe the accumulated spectrum

While use of the mouse and the text box can quickly start observations or change observer settings, it can get cumbersome if the user wants to do many observations or long integration or other long-term measurements. Section 2.3.10 discusses the construction of automatic input command files and the recording of SRT data.

2.3.10 Input Command Files

The use of input command files (***filename.cmd***) will speed the entry of SRT commands as well as reduce command entry mistakes. The command file is ASCII and can accept instruction lines (those that are read and take some action), blank lines (they are ignored) and comment lines (also ignored by the system).

Comments: Start with an asterisk and can be any text the user wishes.

```
* The following are examples of command file entries
*2005:148:00:00:00 Cas
*
```

Each instruction line has two parts, a time mark and a command. The time mark tells the computer how long to remain, taking data, before moving to the next line in the command file.

The Time Mark: The line must start with either a UT, LST, or a colon:

- **: cmd** /execute the command and proceed to the next line. (A Space is required between colon and command.)

- **:120 cmd** /execute the command and wait 120 seconds, taking data, before proceeding to the next line. (There can be no space between a colon and a wait time.)

- **:120** /wait 120 seconds, taking data, before proceeding to the next line. this is a convenient way of increasing the radiometer integration to more than one scan

- **LST:06:00:00** /wait until LST 06:00:00, taking data, before proceeding to the next line

- **2011:148:00:00:00** /wait until UT = yyyy:ddd:hh:mm:dd before proceeding to the next line

Valid Command File Commands follow a time mark:

- Command [Input_1] [Input_2] ... (Optional_1) ...
- sourcename /any name in catalog
- azel [az_deg] [el_deg]
- radec [ra_hh:mm:ss] [dec_dd:mm:ss] (epoch)
- galactic [glat_deg] [glon_deg]
- stow
- noisecal
- record (filename) (recmode)
- roff /turns off data file
- n /npoint scan
- b /beamswitch mode
- freq fcenter_MHz mode
- grid `[n] [a || e]` /*n* is the number of steps (3, 5, 7, 9, or 11) and *a* or *e* specify azimuth or elecation lines scans

Example Set: Instructions can be set in order to perform an observation. The following set of instructions will command the SRT to take 1420.4 MHz hydrogen spectra in 5 degree spacing along a section of the galactic equator. The user must start data recording, unstow the telescope, calibrate the receiver, set the observing frequency center and frequency scan and then repeat the spectral line observations for ten points along the equator. *Note: Allow a space between the colon and the command*

: record rotation.rad	(Start data recording of file rotation.rad)
: galactic 206 20	(unstow and move to calibration position)
: freq 1420.4 4	(Set center frequency mode 4)
: noisecal	
: galactic 205 0	(Move to first data point)
: galactic 210 0	(Next point)
: galactic 215 0	
: galactic 220 0	
: galactic 225 0	
: galactic 225 20	(move to calibration position)
: noisecal	
: galactic 230 0	(Move to sixth data point)
: galactic 235 0	(Next point)
: galactic 240 0	
: galactic 245 0	
: galactic 250 0	
: roff	(End data recording)

If this input command file were named **galactic.cmd**, the user could initiate this observation by opening the **params** window and entering **galactic.cmd** in the Record File text box.
The SRT will read each line in turn and report the current line read as green text in the message board area. If, for example, the start time was 1400 Universal Time on March 15, 2002; and no output file name was entered, the default OUTPUT file would automatically be written and labeled **0414814.rad**. Where the file label is: **yydddhh.rad**

2.3.11 Output Data Files

The output data file (**yydddhh.rad**) is an ASCII text file. Data reduction on the raw output can be done with a spreadsheet program like MS Excel with some effort. The development of spreadsheet MACROS to reduce the data are desirable for large files and long integrations. MATLAB parsers for these .rad files *may* exist on the Junior Lab Student Wiki.

Comment lines:
Start with an asterisk and list the STATION LAT and LONG(E/W) on the first line.

```
* STATION LAT= 42.50 DEG LONG= 71.50
```

When the output data is the result of an input command file, the next comment line could be the listing of the first command line in the input file.

```
* filename.cmd: line 1 : command
```

Calibration results will also follow an asterisk:

```
* tsys 215 calcons 0.98 trecvr 195 tload 300 tspill 20
```

Data lines: Start with a time mark (yyyy:ddd:hh:mm:ss), then list: azimuth, elevation, offsets, galactic coordinates, start frequency, frequency spacing and data points.

```
2011:205:22:30:38  239.9  20.0   0.0   0.0 249.1  39.3  1419.84 0.00781250   4 152  ...
```

Data points listed in the .rad file are multiplied by the calibration constant produced prior to the data taking.

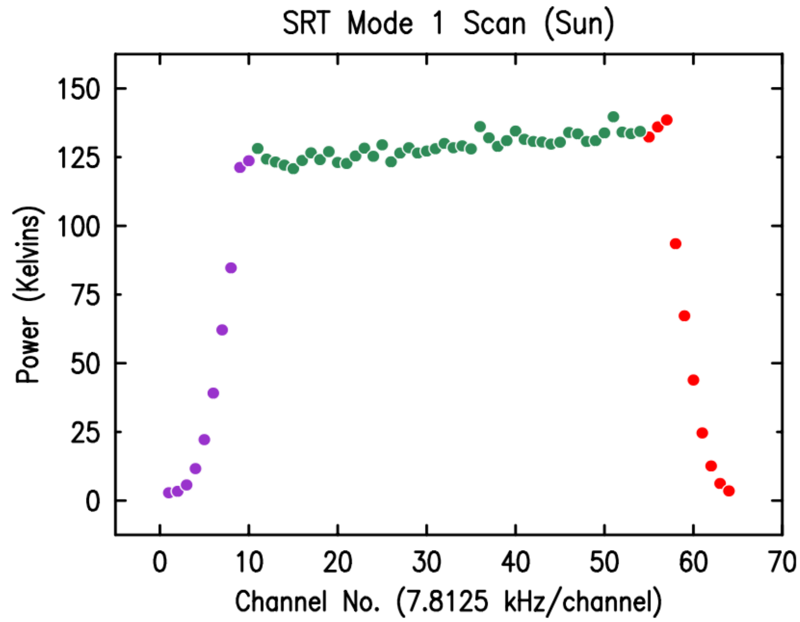

Figure 2.11: Typical mode 1 scan

2.4 Roll-of Channels

The first and last few frequency channels in a measurement are not reliable because the receiver gain rolls off. A typical mode 1 scan looks like figure 2.11.

Normally the SRT GUI program is compiled to ignore the first and last 10 channels when calculating the average power and also when patching three measurements together to make a mode 4 scan. However, if more than the first/last 10 channels were to have low gain then the patching in mode 4 scans could show steps where the measurements join or even a sawtooth shape; some users have seen this type of thing happen. There is a version of the GUI program srt that allows the number of roll-off channels to be set by an entry in the srt.cat file. The entry should be a line that says `ROLLOFF N` in the file. It will be ignored by the older srt program and if it is missing the new program (version 1.80s) will use the default 10 channels. If you experience strange behavior on mode 4 scans, you might want to try changing the number of roll-off channels to 11 or 12. The three measurements that make up a mode 4 scan are taken a few seconds apart, and if the signal to the receiver were fluctuating rapidly enough there will still be problems patching them together.

The number of channels in a mode 4 scan depends on the number of roll-off channels. The table below gives this.

`ROLLOFF`	Channels Used (`spec[]`)	Mode 4 Bandwidth
10	055, 74119, 138191	156 channels (1.219 MHz)
11	054, 75118, 139191	154 channels (1.203 MHz)
12	053, 76117, 140191	148 channels (1.156 MHz)
13	052, 77116, 141191	144 channels (1.115 MHz)
14	051, 78115, 142191	140 channels (1.094 MHz)

The channel numbers given in the center column are those used from each of the three measurements. The first (low frequency) measurement channels are numbered 063, the middle (center frequency) measurement channels are numbered 64127, and the third (high frequency) measurement channels are numbered 128191. They are patched together so that all channels end up spaced by 7.8125 kHz.

Chapter 3

The SRT Software - Advanced

3.1 Server Troubleshooting

If the server fails to start correctly there are a few possible causes:

3.1.1 No Ports Found

If the server doesn't find any ports, this is most likely because the user running the program doesn't have permissions to access the port. This should not happen because a start-up script has been installed to change the port permissions when the computer reboots. However, if this fails then, as root, you need to run

```
prompt> chmod a+rw /dev/ttyS0
```

in the terminal. This should change the permissions of the port so that all users can access it.

3.1.2 Failed to remove stale lock file

The server creates a lock file when it opens port 1421. If the server is not closed correctly (ex: ssh connection breaks unexpectedly) then the lock file will not be removed. If this happens, only the user who created the lock file will have permission to remove it. Anotherwords, if srt_user didn't close the server correctly, then srt_user could restart the server but any kerberos login could not.

A stale lock file can be removed by root. To do this, become root, open a terminal, and enter:

```
prompt> cd /var/lock/
prompt> rm LCK..ttyS0
```

Then the server can be started by any user.

3.2 Server Test Mode

Dont try this unless you know what you are doing; the server is not idiot-proof.
If you start the server as

```
prompt> java SRTserver -t
```

it will run in test mode. This is intended for maintenance and testing of the SRT antenna motion. In test mode, the server will not listen for TCP socket connections, but it will respond to certain commands typed into the Last Request field. The commands it will respond to are stow and move m n where m is the motor number and n is the number of steps.

When the server is in test mode a Move Motor button will be visible at the lower right of the window. Click this button to ask the SRT to execute the command that you typed in. To run the server in its normal mode, you will have to restart it. In the normal mode, the server will try to send the antenna to stow position when it starts up and also when you stop the program using the Quit item of the pull-down menu under SRT Server in the main menu bar. In test mode, it only does the antenna motions that you explicitly ask it to do.

The server also has a mode in which it will simulate antenna motion and radio signals in case you want to test the link between it and the GUI program. Normally it will simulate eight roll-off channels in the receiver data. You can change the number to something else when you start it up. For example

```
prompt> java SRTserver -s10
```

will start it up in simulation mode with 10 roll-off channels.

3.3 User Interface Class Summaries

3.3.1 cat

The cat class contains the code for loading information from the .cat file as well as the code for running the .cmd files designated by the user. For some reason it is also where the RA and DEC are calculated from gralactic coordinates.

3.3.2 checkey

Manages user input.

3.3.3 disp

The disp class extends frame and is the main frame of the GUI. It contains the buttons along the top and functions for painting text and lines onto the frame.

3.3.4 geom

The geom class is the class that does all the math for the coordinates. It also does this thing where one function will calculate multiple variables which are then returned using different functions. Ex: get_galactic_ra calculates the RA, DEC, latitude, and longitude.

3.3.5 global

The global class is a repository for variables which are shared between all the other classes in the program. It has a get and set function for each variable.

3.3.6 hdisp

Displays the help dialog.

3.3.7 map

Plots the contour map which results from the npoint scan.

3.3.8 outfile

The outfile class manages the .rad file where the program is recording data.

3.3.9 params

The params class was created by Prof. Litster. It creates and manages the window which is displayed when the params button is selected. It allows users to select .cmd and .rad files and to enter pointing offsets.

3.3.10 plots

The plots class is used to create the plots which are displayed at the top of the window. It also creates the map of the sky, along with the building outlines.

3.3.11 procs

The procs class stores functions which are used often. It contains the function which requests and receives a new spectrum from the telescope and the function which requests a noise calibration.

3.3.12 sockport

The sockport class is used for communication between the SRT program and the server.

3.3.13 srt

The srt class contains the main function in the program. It sets initial values and then loops. The loop checks for commands from a command file and/or the user, takes a spectra, records it if necessary, and repeats.

3.3.14 startup

The startup class was created by Prof. Litster to get rid of the command line code necessary to start the srt in different modes. It allows the user to indicate if any parts of the telescope should be started in simulation mode.

3.3.15 time

This time class seems to be a rewrite of the java.util.calendar class. It handles all the time stuff.

3.3.16 velspec

The velspec class is used to create the popout window with the average spectrum vs velocity and frequency.