Physics 629 **Lab 1** **Due: 27 Sept 2004**

The SRT Beam and Calibration

Purpose: The "beam" of a radio telescope is a common name for the main lobe of the antenna pattern. This pattern measures the sensitivity of the telescope as a function of location on the sky when the antenna is pointed in a fixed direction. Thus, the beam defines the angular resolution of the telescope. The beam can be measured by moving the telescope in short steps across a very bright radio source. Except for – maybe – Cygnus-X or certain geo-synchronous satellites, the only source available to the SRT for this purpose is the Sun. The goal of this lab is to measure the beam along the two perpendicular lines parallel to and perpendicular to the horizon, and to compare the beam to theoretical expectation. You will also also use your measured brightness of the Sun to measure the effective area and maximum gain of the SRT.

Procedure:
Before observing:
(1) Read the "SRT Users Manual" using the link on the class homepage.

(2) Write a command file to perform the scan of the Sun in elevation and azimuth described in point (8) below. Pointing the telescope at the Sun and then using a sequence of offset commands is the best way to produce the desired telescope motion.

(3) Log into one of the PCs in room 401 and start the SRT control program in simulation mode by bringing up a DOS command window (in the Start menu: programs → accessories → command prompt) and typing in it:

cd c:\srt\srt-java
java srt 1 1

Read the on-line help available within the program. Test your command file by running it with the simulator. If you wrote your command file on a departmental Sun or Linux computer, you can transfer the file by using ssh from the room 401 PCs.

Observing:
(4) Log onto the computer which controls the radio telescope: blanco in room 403b (greenbank in room 401 can also control the telescope depending on the setting of the A/B switch in room 403b). Start the control program by typing

cd c:\srt\srt-java
java srt 0

into a DOS command window.

(5) Set the receiver to use a frequency of 1415.0 MHz with 10 samples at each point, and a frequency step of 0 MHz.

(6) Go to a point at the same elevation as the Sun, but offset by 30 degrees in azimuth (your choice of direction). Avoid any bright source shown on the sky map in the program. Do a calibration with the noise source at this location (the Cal button). Record all relevant information including the resulting system temperature, "calcons", and receiver temperature.

(7) Check for systematic errors in the telescope pointing by moving the telescope to the Sun and doing a 25 point raster scan (the npoint button). Again record the relevant information including the resulting azimuth and elevation offsets of the maximum of the system temperature, and the value of the maximum system temperature.

The npoint scan ends by offsetting from the source to the location of the maximum signal. Unfortunately, this offset remains in force only until a new source is selected or a new offset command is issued.

(8) You and your lab partner should work out a "consensus" command file to measure the radio signal at two sets of 51 points spaced by 1 degree, starting at a –25 degree offset from the Sun and going to a +25 degree offset. The first set of points should use offsets in azimuth and the second should use offsets in elevation. If the offsets of the location of the maximum system temperature from the previous step are significantly different from zero, then these offsets should be incorporated into your command file so that the scans are centered on the center of the Sun.

Continue to use 10 samples at a frequency of 1415 MHz. The ten samples at each pointing improve the precision of the measurement and also allow an estimate of the uncertainty in the result.

Your command file should open a file with a unique name, store your results in that file, and close it when the measurement is done.

(9) Repeat your azimuth and elevation scans until each member of your experimental group has a dataset of his/her own. Remember to edit the procedure to change the name of the output file each time. I suggest that your name be part of the file name.

Analysis:
The data analysis should take place is two phases.

- Each individual student should analyze his/her own data set and prepare it for comparison with results from the other members of his/her lab group.
- When that is done, you should get together and compare your results.

(10) I strongly recommend that each of you copy your data files to a computer where you can work offline and which has Excel. You can read your data files into an Excel spreadsheet and eliminate the lines in the output file which do not contain useful data. **Because it is easy to make an Excel error which wipes out or scrambles your data, make a backup copy with a slightly different name before you start.**

(11) Find the average of your ten measurements at each scan position and the uncertainty in the average. Excel has "Functions" to do this.

(12) Plot the average values (with error bars) for your elevation scan on one plot and those for your azimuth scan on another.

(13) Estimate the half-power beam width (BWHP) in both azimuth and elevation. A complication with the azimuth scan is that each change of 1 degree in azimuth is really only (1 deg)cos(elevation) on the sky. Correct your azimuth BWHP for this effect to get the true beamwidth in that direction. Is the BWHP the same in the elevation and azimuth directions?

(14) Overplot on your two plots the beam pattern expected for a uniformly illuminated circular aperture with the width of the antenna dish:

$$P(\theta) = \left(\frac{2J_1(x)}{x}\right)^2, \tag{1}$$

where $x = \pi\theta/(\lambda/D)$ and θ is the angular offset from the center of the beam in radians. Here $J_1(x)$ is the spherical Bessel function of the first kind with order 1. Look up in your favorite math reference book for tables of values or convenient polynomial approximations. Excel has $J_1(x)$ preprogrammed as BESSELJ(x,1). Multiply $P(\theta)$ by a constant and then add another constant so that the theoretical beam pattern has the same peak value and value at large offsets as your real profile. Comment on the difference in shape between the theoretical and observed beam pattern.

(15) Get together with your lab partner and share your results. How well do the two scans agree with each other? As well as you expect from the uncertainties? Cooperate in making the a "consensus" Excel plot which shows both of the data sets on the same graph.

(16) Estimate the measured flux density of the Sun at 1415 MHz at the time of your "npoint" observations of the Sun. Measurements are given under "Solar Radio Flux" on the web page: http://www.sec.noaa.gov/Data/solar.html. Use this flux with your maximum antenna temperature measured for the Sun in point (7) to calculate the effective area and maximum gain for the SRT.

(17) Each of you must prepare an individual lab report giving your results and conclusions. Your writeup and conclusions should be your own, not the results of a group effort. However, some parts, *e.g.* the graphs combining results from everyone in the group, are group efforts and they should be clearly labeled as such.