Ph 343 Lab 1 Measuring the Telescope Beam Using the Sun

Due: Thursday, September 19, 2002
(but finish the observations by September 12)

Purpose: The beamwidth of a radio telescope is the solid-angle measure of the half-power point of the main lobe of the antenna pattern. The half-power beamwidth (HPBW) can be measured by moving the telescope in short steps across a very bright radio source. Except for the possibility of Cygnus-X or certain geo-synchronous satellites, the only source available to the SRT for this purpose is the Sun.

Before the lab period: Read the SRT Users Manual and write a command file to perform the scan of the Sun in elevation and azimuth described below. If possible, bring your command file to the lab on a floppy.

Procedure:
Log onto Parkes using the account radiotel, which has the password cygnus. Use the Start menu to get a DOS command window (programs → accessories → command prompt). In the command window, start the SRT control window by typing

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cd srt\srt-java
java srt 0
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Once the SRT control window is running, go to a point at the same elevation as the Sun, but offset by 30 degrees in azimuth (your choice of direction). Do a calibration with the noise source at this location. Record the time, location (azimuth and elevation), and the resulting system temperature, "calcons", and receiver temperature.

Go to the Sun and do a 25 point raster scan (the npoint button). Record the time, the azimuth and elevation of the Sun at the time of the observation, the azimuth and elevation offsets of the maximum of the antenna temperature, and the value of the maximum antenna temperature. In my experience, the "pointing corrections" are set to the location of the peak for the first raster scan done in an observing session. See if this is the case for you. These corrections are then applied to all subsequent observations during the session.

Use your command file (or, rather, the consensus command file of you and your lab partners) to measure the radio signal at 51 points spaced by 1 degree, starting at a –25 degree offset from the Sun and going to a +25 degree offset. Do this both along a line of constant azimuth and a line of constant elevation. Your results should be stored in a file. Use a frequency of 1419.0 MHz, 5 samples, and a frequency step of 0 MHz (i.e., five samples at the same frequency; the larger number of samples improves the signal to noise).

Repeat your azimuth and elevation scans two more times (a total of three scans in both directions).

Analysis:
1. Find the average of your five measurement at each scan position and the uncertainty in the average. I suggest reading the data file into an Excel spreadsheet to do this.

2. Plot the average values (with error bars) for your three elevation scans on one plot and those for your three azimuth scans on another. How well do the three scans agree with each other? As well as you expect from the uncertainties?

3. Estimate the half-power beam width (HPBW) 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 HPBW for this effect to get the true beamwidth in that direction. Is the HPBW the same in the elevation and azimuth directions?

4. Overplot on your two plots the beam pattern expected for a uniformly illuminated circular aperture with the width of your 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 might even have $J_1(x)$ preprogrammed for all I know. 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.