Profiling an Antenna Beam with the Sun **by Jon Wallace** (Written in December 1995)

Author's note: After four years of effort, I finally have a working radio telescope. Although I have begun taking formal classes, I am a relative neophyte with little previous knowledge of electronics and am proof that anyone can enjoy radio astronomy through the help available from SARA members. Paul Schuler's article in Radio Astronomy (October 1991) was the source of ideas for my project).[1]

Surmising that the system operation could be greatly enhanced with a larger antenna (although my previous results were good), I purchased a new 10' antenna to profile the beam pattern and check the aim of the horn. For fifteen days, I observed the sun, changing the antenna position with respect to solar position and gathering the data shown in the tables below. The antenna output was first fed to two LNAs and then to a receiver tuned to 1420 MHz. This output was subsequently fed to a DC amplifier, then to a twelve-bit A/D converter, and ultimately stored on an IBM computer.

Because my antenna cannot point due south, I adjusted for an azimuth of 160 degrees to ensure that the correct declination was being observed.[2] The equation is:

$$\text{Sin D} = ((\text{Sin A})\ (\text{Sin L})) + ((\text{Cos A})\ (\text{Cos L})\ (\text{Cos Az}))$$

D = declination, A = altitude, L = latitude, Az = azimuth angle

To calculate the sun's declination, I used the Radio-Sky Planetarium (version 1.2).[3] Using the following relationship, I had some question as to the conversion of time data to degrees for the beam pattern graph (see below):

1 hour right ascension = 15 degrees

Thus, I have included graphs with time in both minutes and degrees in order to make both scales of the graph directly comparable (i.e., both in degrees).

Conclusion. The focus was about half a degree below center, and the upper two values of declination were skewed to the left. The skewing may be caused by interference from trees (both were at almost identical altitudes). Although the central focus is free from obstruction, leaves on the tree may have interfered as the sun passed the central focus.

I would appreciate feedback on the validity of my tables and graphs. Although I took pains to be careful, a logical error or wrong assumption may have inadvertently crept in.

****

1. Many thanks to Paul Schuler for fielding questions and helping me over the past four years. Thanks also to Jeff Lichtman of Radio Astronomy Supplies, who sold me the 1.4 GHz radio telescope I am presently using. Carl Lyster (Lyster Engineering), who builds radio telescopes for Radio Astronomy Supplies, helped me tremendously with the setup and theory of operation.
2. I used a method described in a Radio Astronomy article (January 1992) by Hal Braschwitz.
3. Purchased from Jim Sky (Radio-Sky Publishing); I now use it as an observation planner.

Table 1. Declinations			
Date	Solar Declination	Antenna Declination	Difference
8/5/95	17.20	18.94	1.74
8/7/95	16.65	19.90	3.25
8/19/95	13.04	13.63	0.59
8/20/95	12.72	15.08	2.36
8/21/95	12.39	16.53	4.14
8/22/95	12.06	10.26	-1.80
8/23/95	11.72	7.84	-3.20
8/24/95	11.38	5.42	-5.96
8/25/95	11.04	5.91	-5.13
8/30/95	9.29	8.81	-0.48
9/2/95	8.21	5.42	-2.79
9/6/95	6.75	4.46	-2.29
9/11/95	4.83	9.83	5.00
9/12/95	4.46	9.26	4.80

Note: The accuracy above is not true but is reported to indicate tendencies in the data.

Table 2. RMS Values				
Date	RMS Left (min.)	RMS Right (min.)	RMS Left (deg.)	RMS Right (deg.)
8/5/95	-8.10	7.30	-2.025	1.825
8/7/95	-6.60	6.48	-1.65	1.62
8/19/95	-7.98	7.80	-1.995	1.95
8/20/95	-7.50	6.96	-1.875	1.74
8/21/95	-5.70	5.70	-1.425	1.425
8/22/95	-7.98	7.80	-1.995	1.95
8/23/95	-7.92	7.26	-1.98	1.815
8/24/95	-1.38	0.78	-0.395	0.195
8/25/95	-4.08	4.80	-1.02	1.20
8/30/95	-7.78	8.27	-1.945	2.068
9/2/95	-7.38	7.15	-1.845	1.787
9/6/95	-7.53	7.70	-1.883	1.925
9/11/95	-4.53	2.41	-1.133	0.603
9/12/95	-5.02	3.85	-1.255	0.963

Note 1: Normalization was not done since the flux values for the dates above were all given as between 51 and 55 x 10^{-22} (Wm^1/Hz) by the Solar Environments Lab (Sagamore Hills, MA) (1415 MHz). This resulted in very little difference in the values and was not performed.

Note 2: RMS values were calculated from the a/d chart data for each solar recording. Positional data above were measured setting the peak value position to zero and measuring with respect to this position as negative (to the left) or positive (to the right).

A Summary of How I Performed the Analysis

- While I was performing the scans I decided to go back and analyze my antenna aperture and 'pointing'.
- I learned from Paul Schuler that you could use the sun as a pretty good point source and plot the width of the solar plot (left and right of center) versus the number of degrees away from the actual/calculated declination.
- Find as many charts as you can with a good solar peak and determine from the chart the width, or if possible, the width left of center and width right of center for each.
- List them in order from the most negative width (Center is zero) to the most positive.
- Look up the correct Declination for the sun for the Azimuth you use for each chart's day (I used Jim Sky's (RSP12) Radio Sky Planetarium 1.2).
- I also used this program to check my true azimuth by checking the time of peak intensity of the sun and comparing it to the value listed. I found it to be 140o, approximately what I found using the compass.
- After you have made a list of the Widths (from above) and the Degrees Off True Solar Transit (from RSP12), input this data to Excel.
- Use the Chart Wizard and create an X-Y Scatter Plot of the data.
- I found that my antenna is a little asymmetrical and my pointing is off by a couple of degrees.