CLEAR APERTURE FEED ON THE 300-FOOT TELESCOPE

Emission entering the feed that does not come through the main beam of the telescope, otherwise known as "stray radiation", has been a problem in galactic 21cm line observations. At high galactic altitudes, more than one-half of the observed HI can come via the far-out sidelobes of the telescope and hence stray radiation is the limiting factor in accurate galactic HI studies away from the galactic plane. Some amount of success has been achieved in getting around the problem of stray radiation, by modelling the beam pattern of the telescope and correcting the HI spectra by subtracting out a component determined from the convolution of the model beam pattern with the HI survey from another telescope. A better approach is to observe with an inherently clean telescope.

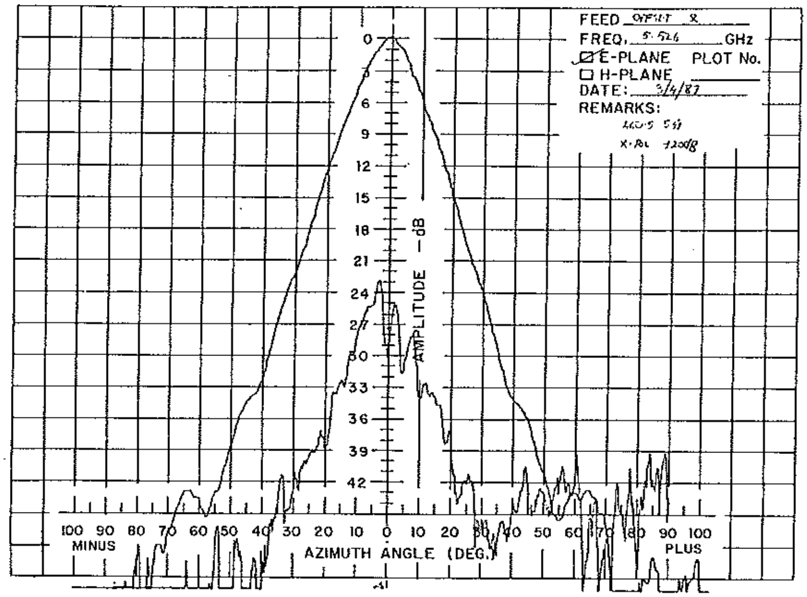
The Crawford Hill horn/reflector of Bell Labs is one such instrument. Its velocity and angular resolutions are poor, though. F.J. Lockman et al. have developed a technique to "bootstrap" 140-foot HI spectra to the Bell Labs survey, by which they have removed about 90% of the stray radiation. Rick Fisher proposed an offset feed for the 300-foot telescope which would reduce the stray radiation by an order of magnitude. The key factor is that the 300-foot telescope, having only two support legs, has large areas of unblocked aperture to the east and west of its main axis. By illuminating either of these areas by a feed, the scattering off the feed support legs and central blockage could be reduced considerably.

A design study was undertaken by computer analysis of the 300-foot telescope, with a goal of achieving very high main beam efficiency. The synthesized primary feed pattern is about 22db down at 30 degrees off the feed axis. This feed would illuminate the 300-foot telescope with its boresight tilted at 32.85 degrees to the axis of the telescope and about 30 degrees from the east west direction. The computed main beam efficiency is about 99.4% at 21 cms.

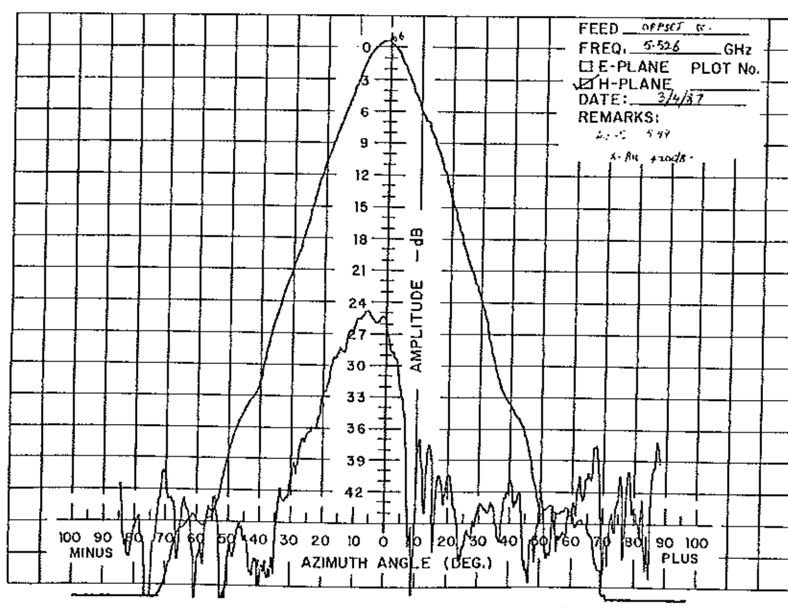
A scale model of the 21cm feed was made at 6cm. The radiation patterns of this feed are shown at the bottom. This feed was installed on the 2-5Ghz front end box and observations were made on the telescope on the 17th and 18th of August, 1987. Notes on the test are attached herewith. The tests seem to prove the basic concept that an L-band version of the feed will have an exceptionally clean main beam and few far sidelobes.

This feed will make the 300-foot telescope into an absolutely unique instrument for observing galactic HI. The designed 21cm feed is a conical corrugated horn with an aperture diameter of 48 inches and overall length of 57 inches. If this feed is made by machining out of cast aluminum, its estimated weight is close to 600lbs. By making the corrugations wider, the weight could be reduced by one-half. Still, this feed would be heavier than what could go on the sterling mount of the telescope. We are in the process of looking at various techniques by which the feed could be fabricated lighter than 200lbs, by use of honeycomb structures, for instance.

Sivasankaran Srikanth
September 22, 1987.



a. Radiation Pattern of 6cm Feed E-Plane



b. Radiation Pattern of 6cm Feed H-Plane

Notes on the 6cm Sidelooking feed test

This is based on a two-day test at the 300' which yielded about a day and a half's worth of useful data. Observations were made at 4.9 GHz in circular polarization. Unless noted, a focus of −430 mm was adopted.

System Temperature: With the telescope pointed at the zenith, the system temperature varied with feed rotation angle as shown in Figure 1. A rotation angle of zero is due south; −90° is due east. The receiver was drifting during this test (more on this later) as can be seen by comparing the levels before and after rotation.

The minimum Tsys is 37 K. This is the same temperature that Rich Bradley measured for this receiver with a hybrid-mode feed that illuminates the entire dish. That feed has significant contributions from spillover and scattering – contributions which we should not have. It thus appears that we have a higher Tsys than we expect. However, since Bradley's measurements were made (mid May) the receiver was struck by lightning. It has not been well since, and shows frequent drifts in total power. We do not have measurements of the receiver temperature (i.e. off the telescope) since the incident occured. Srikanth says that we may be getting about 2 K from the waveguide bend, which is not optimally designed.

Peaks in Tsys occur at angles where the feed illuminates the feed support legs. This illustrates the effect of scattering and, by implication, the extent of sidelobes. We do not understand the 2 K difference between the temperature of the legs. Similar measurements made with the dish at $\delta = -12°$ give 67 K for the North leg and 58 K for the south leg. We think that the difference arises because at this elevation the dish shields the south leg while exposing the north leg to the ground.

In summary, it would be nice to know why our minimum Tsys is not smaller than Bradley's, but otherwise the system temperature tests seem satisfactory. Perhaps tests can be made the next time the box is scheduled to go on the telescope. All subsequent measurements were made with the feed at a rotation angle of −60°, i.e. with the feed pointing toward the east-south-east portion of the dish.

Beam Shape. This section is based on a single drift through Virgo A. We also have a drift on the Crab nebula which is consistent with the statements here.

The central beam is Gaussian to a high degree. Deviations are $\lesssim$3% of the peak. Residuals from the gauss fits are shown in Figures 2a and 2b for the two channels. There is really nothing that looks like a sidelobe with the possible exception of a 20dB ledge on the west of each beam. (A linear baseline was removed from these spectra before the gauss fit. The baseline was fit to the first 300 and last 300 points.) If there are any "near" sidelobes, they at least 25dB down from the main beam. To put this in a little perspective, the hybrid-mode L-band feed that was mounted on the telescope immediately after our run has four near sidelobes (two on each side of the main beam) with amplitudes between 11dB and 16dB. The sidelooking feed has the smallest sidelobes, by far, of any feed/telescope combination I have ever measured.

Beamwidth. We have data on the HPBW in right ascention for two values of the focus, and in declination for one focus. It is summarized:

$$Focus = -430 : HPBW(\alpha) = 6.5', HPBW(\delta) = 7.2'$$

$$Focus = -350 : HPBW(\alpha) = 5.9', HPBW(\delta) = ??.$$

The difference in HPBW with focus seems real, although the scatter is fairly large. The HPBW in dec is larger than in ra. Is this expected? There is a *slight* trend for the beamwidth to **increase** with δ at $focus = -430$, and to **decrease** with δ at $focus = -350$ mm. Srikanth says that we expect a HPBW of about 5.5'. Are the observed values larger because of astigmatism of the dish? It is possible that we have not yet found the optimum focus for the feed.

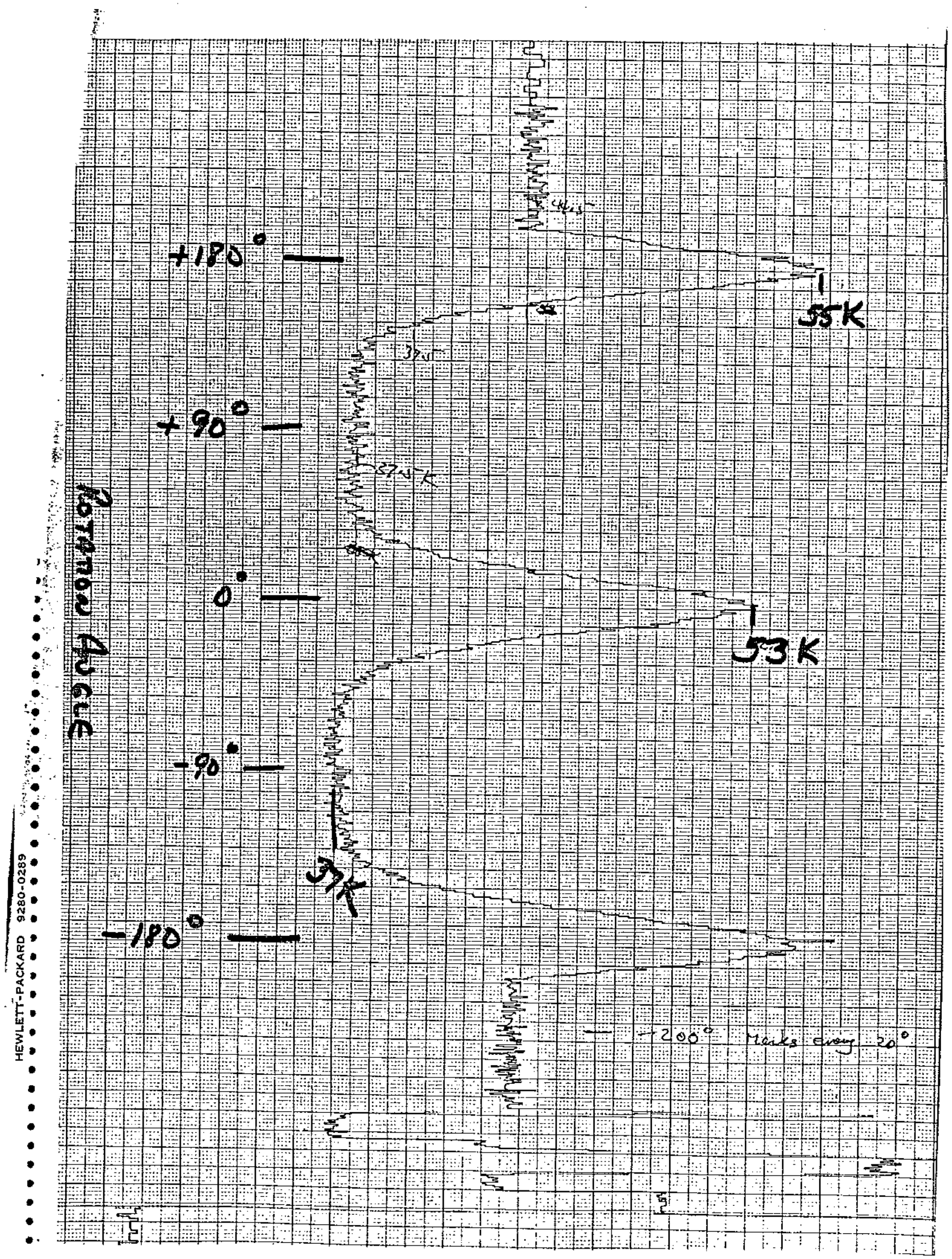
Aperture Efficiency: At a focus of −430 mm the sidelooking feed has an aperture efficiency of 8.8% (adopting lab values for the noise diodes). At a focus of −350 mm the efficiency is 9.0%. The difference is not significant. There is no obvious trend in efficiency with declination, although this conclusion is weak because the scatter is large (measured efficiencies are in the range $7 - 11\%$) and the data cover a limited declination range. We expect to be illuminating about 1/4 of the dish, so our measured efficiencies of $8 - 9\%$ imply a maximum aperture efficiency of 35% for full illumination, which is the value that is actually measured at 6 cm.

Main Beam Efficiency. This feed is supposed to have a very high main beam efficiency. If we just integrate the gaussian fits to the drift curves, we get an average main beam efficiency of only 45%. Rick Fisher suggests (reasonably) that the large surface errors in the dish produce a broad weak pedestal of response upon which the main beam sits. The pedestal is removed with the baseline. I think that we can accept Rick's explanation for the discrepant beam efficiency because 1) the telescope illumination seems to be as expected, 2) we get about the right values for the aperture efficiency, beamwidth, and system temperature, and 3) there are very small near sidelobes. An L-band version of this feed should have a main beam efficiency close to the theoretical value (> 95%).

The bottom line. As far as I am concerned, the 6cm sidelooking feed tests give no reason to doubt that an L-band version of this feed will have an exceptionally clean main beam, and few far sidelobes, and thus be a great tool for observing galactic HI. I do not think that additional test time with the 6cm feed is necessary, unless Harry or Sri turn up problems with our understanding of the pointing and focus. It is difficult to study this kind of feed at 6cm because the dish is not very good. Based on our experience with the 6cm feed, it will take several days (maybe five) on the 300' telescope to make a thorough study of a similar L-band feed's performance.

F.J. Lockman, September 8, 1987

Tsys →



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37.5K
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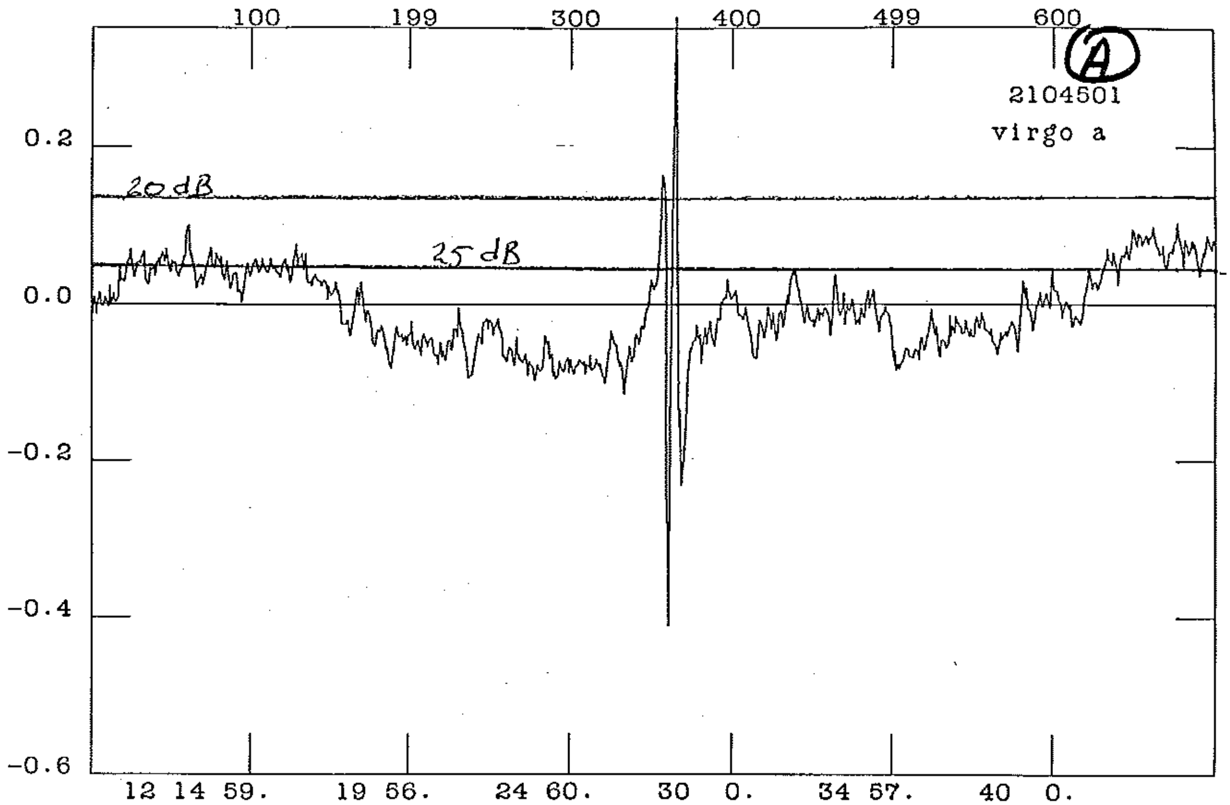
Fig 1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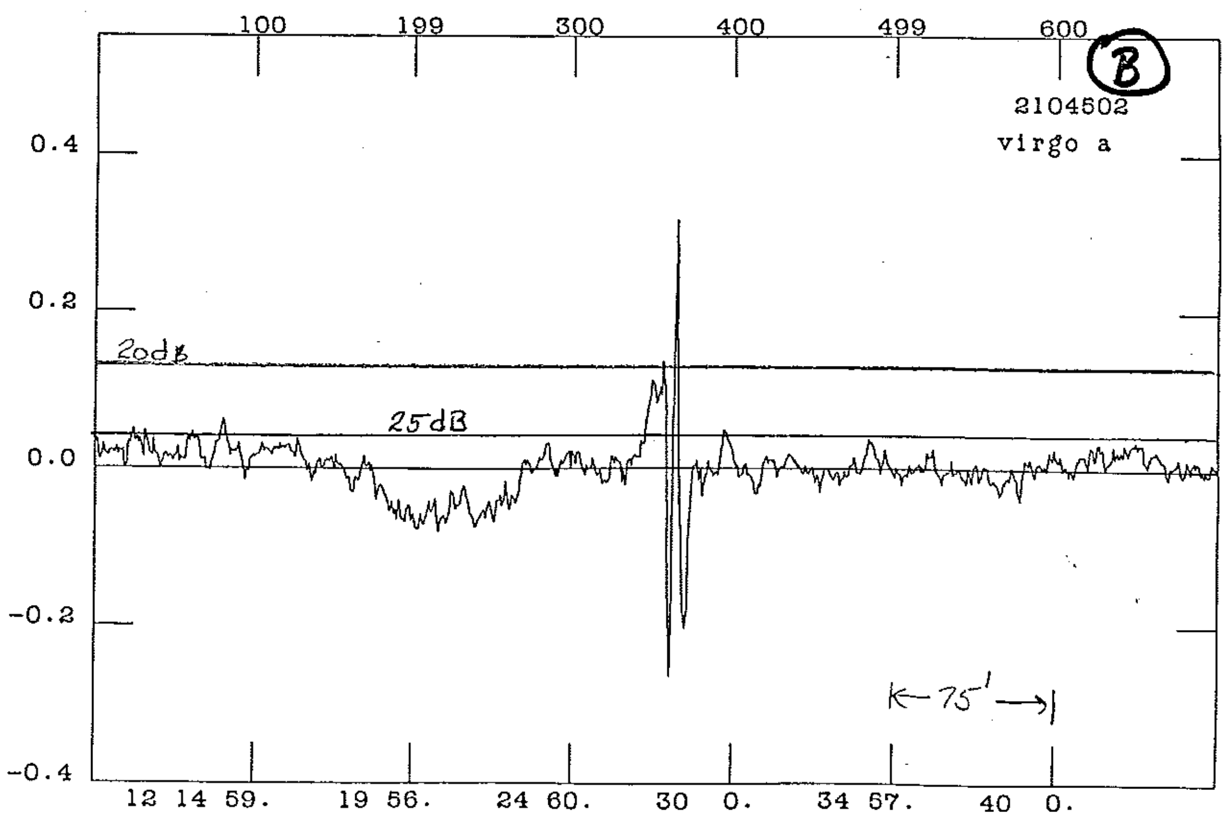
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Fig 2