Beam Characteristics of the Resurfaced 300-Foot Telescope at 21 cm

by

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The beam characteristics of the NRAO 300-foot telescope at Green Bank, W. Va., have been described by R. Harten (1969,1973). Since that paper was written, the telescope has been resurfaced. This paper reports the results of measurements of the 300-foot telescope beam characteristics, taken after the telescope was resurfaced in Fall 1970. Most data, including those of the beam pattern, were obtained in early July 1971; additional measurements of beamwidths as a function declination were obtained in Summer 1973. For a more complete description of the methods employed, we refer to Harten (1973). The measurements were made using feeds 3 and 4 of the 4-feed system at 21 cm, which is used for both line and continuum observations.

The aperture efficiency η_A was determined as a function of the declination from drift scans (letting a source with known flux density pass through the beam with the telescope stationary) and is given in Table 2. The resulting curve agrees well with the one determined by M. Davis in December 1970; the approximately 10% lower efficiency (peak 48.5% instead of 54.5%) was expected since Davis' data were obtained with a more efficient (single, on-axis) feed. The results for feeds 3 and 4 were identical, indicating that the thermal calibration of the noise tube (upon which η_A critically depends) for these two receivers agrees to within 3% on a relative scale. The absolute noise tube calibration, and hence the value of η_A, is believed to be correct to within $\pm$ 5% (maximum error).

The beam pattern $f(\theta,\phi)$ was determined down to 30 db using "wobbles" (moving the telescope rapidly up and down in declination during the transit of a source) about Cas A, and below 30 db, down to 69 db, using the Sun. Figure 1 shows the inner beam pattern using Cas A and feed 3. The peculiar lobe at the 20-db level appearing at negative right-ascension (which could not be completely mapped) is due to the feed (part of the four-feed system)

If one knew the shape of the beam pattern not only at 58°, but at all declinations, it would be possible to convert antenna temperatures T_A into brightness temperatures T_b by deconvolution. One often simplifies this by writing $T_A = \eta_B \overline{T}_b$ where the beam efficiency η_B is defined as the fraction of the total power, incident from the full beam, which is available at the antenna terminals, and where the full beam is "the part of the antenna pattern down to a level necessary for the problem under consideration". The quantity η_B is directly related to η_A, as $\eta_B = \eta_A \Omega' A_g/\lambda^2$. However, the beam solid angle Ω' depends on the "problem under consideration", and moreover, using η_B in this manner one assumes that $\overline{T}_b$, the brightness temperature averaged over the beam, is constant over the area Ω'. The approximation usually works reasonably well for objects which are of the order of size of the main beam, so that sidelobes do not play a role, but for more extended objects is in general a poor way of calculating T_b. In particular, as Table 1 shows, the larger the object, the larger the value of Ω' to be used and thus the larger η_B. Obviously, for larger objects covered by the sidelobes the value of T_A gets closer to $\overline{T}_b$. Taking the value of Ω'(0.0360) within the 42 db level (i.e. within an area of approximately 76 minutes of arc in deameter) and the maximum value of η_A(0.485) we find $\eta_B = 0.78$. On the other hand, for a gaussian beam at 40° declination (halfwidths 10!30 x 10!10, Table 2) we find $\Omega' = 0.0327$ and $\eta_B = 0.713$.

In spite of these shortcomings in the use of η_B, we calculated this quantity as a function of declination. Assuming a gaussian main beam, $\Omega' = 1.133 \times \theta_H \times \theta_E$, where θ_H is the halfwidth in right-ascension and θ_E in declination. A total of 65 values each of θ_H and θ_E were determined at declinations between -15° and +72°. The halfwidth in right-ascension was determined from drift scans, in declination from "wobbles". The measured values were corrected for the effect of the receiver time constant (Howard 1961). The r.m.s. deviations from a hand-drawn curve through plots of θ_H and θ_E vs declination were $\pm$ 0.25 and $\pm$ 0.35 minutes of arc, respectively. Average values of θ_H and θ_E were read from this curve every 10° in declination and are given in Table 2, together with Ω', η_A and η_B.

comparing Survey antenna temperatures with T_b values in other surveys) did not show any systematic variation ($\pm 5\%$) of intensity with elevation of the telescope. Moreover, the ratio T_A(Survey)/T_b(others) was approximately 0.80, indicating $\eta_B = 0.80$. This then suggests that the value of η_B for a region of the order of 1° diameter does not change appreciably with declination, in spite of the change in η_A.

It appears plausible that the reason for the variation in η_A is the formation of near-in sidelobes at larger zenith distances, which at a declination of -10°, together with the wider main beam, should then contain about 23% of the energy contained in the main beam in the Zenith. The main beam solid angle Ω' increases from 0.0327 square degrees in the Zenith to 0.0362 at $\delta = -10°$, taking up approximately 10% of the energy. If the remaining 13% is distributed in near-in sidelobes over an area 0°5 in diameter, this would indicate an average increase of the sidelobe level over this area of 2.5% or -16 db of the main beam response, an effect which would only be noticeable on the strongest sources. It would be of interest to attempt making accurate antenna pattern measurements down to -25 db for two or three sources at different Zenith distances to confirm this hypothesis. In the meantime, observers would do well to use the values of η_B given in Table 2 only for sources or features of the order of size of the main beam, i.e. 10 minutes of arc. For extended regions, i.e. larger than 1°, perhaps $\eta_B = 0.78$ should be used, and it seems likely that this value does not change by more than 5% or so from the Zenith ($\delta = 36°$) down to the limiting declinations of the telescope ($\delta = -19°$ and $+ 90°$). At the same time, however, it should always be realized that using such a simple transformation from T_A to T_b gives only a zero-order approximation to the real distribution of T_b.

Finally, using η_A, we can calculate the beam solid angle Ω (integral of the antenna pattern over the entire sky), since $\frac{1}{\Omega} = \eta_A A_g/\lambda^2$. For $\delta = 58°$, we find $\Omega = 0.0474$. Since $\Omega'_{42db} = 0.0360$, the solid angle outside the 42 db level is 0.0114, which, if distributed evenly over the 40,000 square degrees of sky, leads to an average power response of -65.5 db in the sky outside the 42 db level.

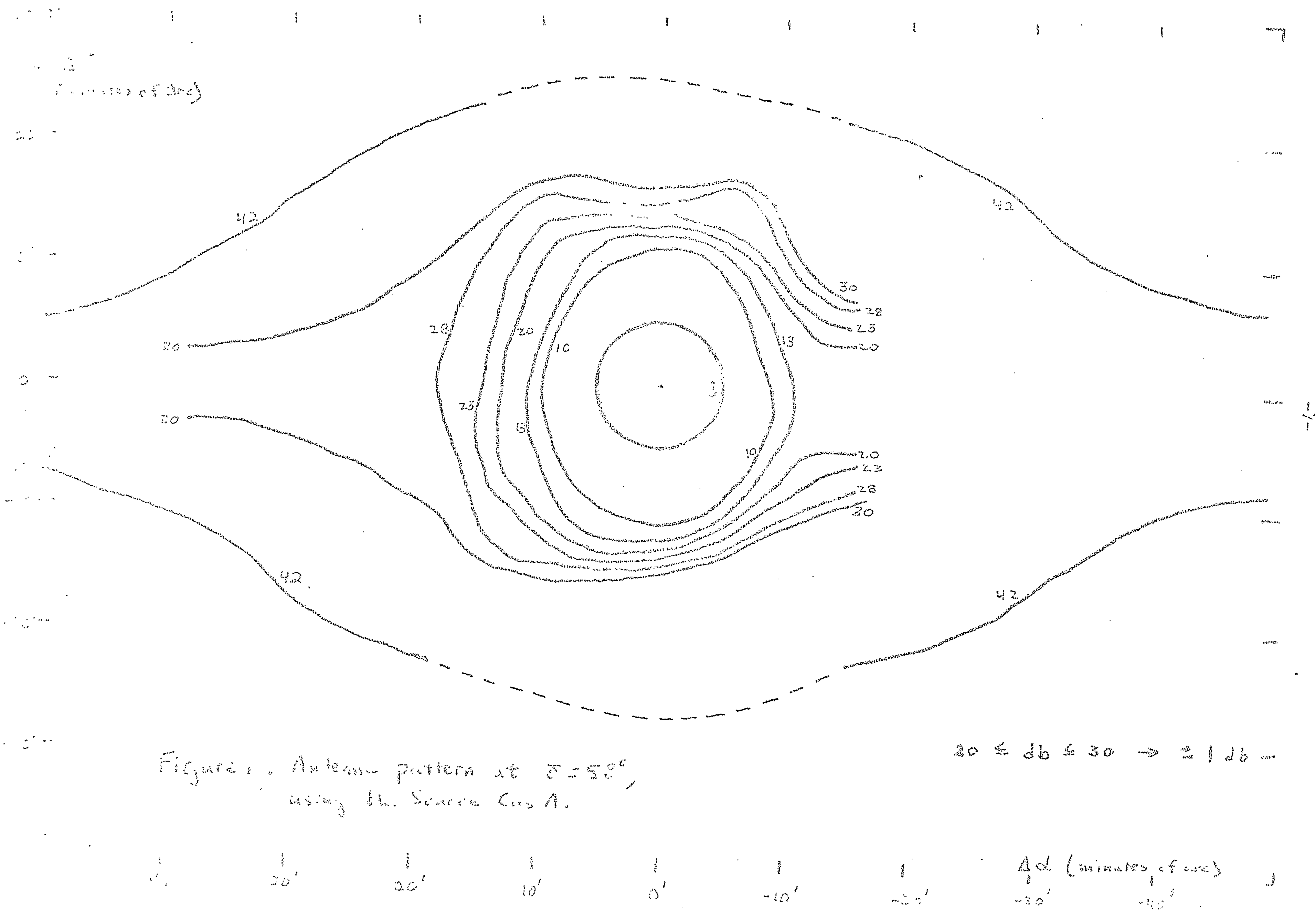

Figure . Antenna pattern at δ = 58°, using the Source Cas A.