NLSRT Memo No. 58

Subreflector Diameter and f/D Ratio for an Axisymmetric Antenna

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The diameter of the subreflector in a cassegrain antenna for minimum blockage condition is given by

$$d_m = \sqrt{k\lambda f}$$

where f is the focal length of the paraboloid for the main dish, λ is the longest wavelength of operation in cassegrain geometry, and k is a dimensionless constant dependent on the feed pattern. For a -10 dB edge taper, k = 2. The value of d_m/D for the 140-foot telescope and the VLBA antenna is given in Table 1 where D is the diameter of the main dish. The value of k = 2.5 in the table. Also included in the table is ratio of subdish to main dish diameters.

TABLE 1

Telescope	Lowest Freq. (GHz)	dm	Dia. of Main Dish D	d_m/D	Dia. of Subdish d	d/D	d/λ
140'	5	1.656	42.672	0.039	3.162	0.074	52.7
VLBA	1.42	2.161	25.0	0.086	3.194	0.128	15.1

Note: All linear dimensions in meters.

Figure 1 gives the blockage efficiency for different ratios of d/D. If d_m/D is < 0.1, a value of d/D = 0.1 should be considered. For a 100-meter antenna, d_m/D varies between 0.043 and 0.047 at 1.4 GHz and f/D between 0.35 and 0.42. A subreflector of 10 meters in diameter for a 100-meter antenna with d/D = 0.1 is physically very large. For the Green Bank telescope, since we are pushing for minimum blockage, d/D = 0.07 is a good compromise between blockage loss and diffraction loss at the lowest frequency. Figure 2 gives the diffraction efficiency versus d/λ. A 7-meter subdish is about 33 wavelengths at 21 cms, which is twice the value of the VLBA subreflector. This size would keep the diffraction loss at the subreflector to less than 0.05%.

After the subreflector diameter is chosen, a value of f/D (between 0.35 and 0.42) for the main dish is to be arrived at. The feed housing at the secondary focus should lie inside the cone shown in Figure 3, in order that the feed housing itself does not contribute to any additional blocking. A reasonable range to be considered for the f/D ratio is between 0.35 and 0.42. Below 0.35 prime focus feeds are no longer optimum and above 0.42 the subreflector location may warrant the need for longer and bulkier struts, thus increasing blockage. Table 2 lists the position of the secondary focus (h_s) above the vertex of the main dish for a half cone angle of the subdish $\theta_s = 6.66°$ (concept design in NLSRT Memo 51) from the secondary focus as shown in Figure 4 at different f/D. The maximum diameter of the feed housing d_h varies from 6.25 to 5.32 meters. If the secondary focus was located at the vertex of the main parabola (h_s=0), θ_s varies from 5.91° to 4.99°, as shown in the lower half of Table 2. A cassegrain feed for the half cone angle of $\theta_s = 6.66°$ is over 25 wavelengths in diameter at its aperture. At 21 cms, this dimension is at least 5.28 meters. The table also lists the ratio of the maximum size of the feed house diameter to the aperture of the biggest feed (d_f) at the secondary focus, for instance, the 21 cms feed. In order to reduce the size of the feeds, θ_s can be increased by either moving the feed closer to the subreflector or increasing the size of the subreflector. Table 3 lists the same parameters as in Table 2 for $\theta_s = 7.14°$ (as in the case of the 140-foot) with d = 7 meters. The lower half of the table gives the radius of the subreflector for $\theta_s = 7.14°$ and the secondary focus at the vertex of the main dish. The aperture of the feed for $\theta_s = 7.14°$ is approximately 18 wavelengths.

TABLE 2

f/D	d/2	θ_s	θ_m	h_s	d_h (max. dia. of feed housing)	Blockage Loss (%)	d_h/d_f
0.35	3.5	6.66°	71.075°	3.82	6.25	.49	1.18
0.40	3.5	6.66°	64.011°	8.35	5.55	.49	1.05
0.42	3.5	6.66°	61.525°	10.15	5.32	.49	1.01
0.35	3.5	5.91°	71.075°	0	7		
0.40	3.5	5.22°	64.011°	0	7	.49	
0.42	3.5	4.99°	61.525°	0	7		

Note: All linear dimensions in meters.

The ratio dh/df is higher as seen from the last column of Table 3.

TABLE 3

f/D	d/2	θ_s	θ_m	h_s	d_h (max. dia. of feed housing)	Blockage Loss (%)	d_h/d_f
0.35		7.14°	71.075°	5.86	5.84		1.54
0.40	3.5	7.14°	64.011°	10.35	5.20	.49	1.36
0.42		7.14°	61.525°	12.16	4.98		1.31
0.35	4.234	7.14°	71.075°	0	7	0.71	
0.40	4.796	7.14°	64.011°	0	7	0.92	
0.42	5.023	7.14°	61.525°	0	7	1.00	

Note: All linear dimensions in meters.

The ratio d_h/d_f is larger in Table 3, which means it is easier to accommodate a number of cassegrain feeds. If θ_s is increased to 9°, the feed aperture size decreases to about 13 wavelengths and d_h/d_f further increases as shown in Table 4.

TABLE 4

f/D	d/2	θ_s	θ_m	h_s	d_h (max. dia. of feed housing)	Blockage Loss (%)	d_h/d_f
0.35	3.5	9°	71.075°	11.701	4.671	.49	1.701
0.40	3.5	9°	64.011°	16.195	4.174	.49	1.520
0.42	3.5	9°	61.525°	18.003	4.006	.49	1.459

From size point of view of the largest feed, θ_s should be fixed at, at least, 7.14°. For the focal ratio, 0.4 is a good compromise. The loss in gain (due to additional blockage by extra length of support struts) going from f/D = 0.35 to 0.40 is 0.01 dB. Preliminary calculations on a 100-meter dish (f/D = 0.40) with feed support structure proposed by L. King show that the peak of the sidelobes lies below the 32-25logθ level. The computation was done at 5 GHz. An f/D = 0.4 would allow the feasibility of going to prime focus at 21 cms if required. The prime focus hybrid mode feeds become less optimum for f/D less than approximately 0.4. The reason for this being the HE_{11} mode in the single mode feed and HE_{12} mode in the two mode feed are already close to cutoff and, hence, the pattern width is close to maximum.

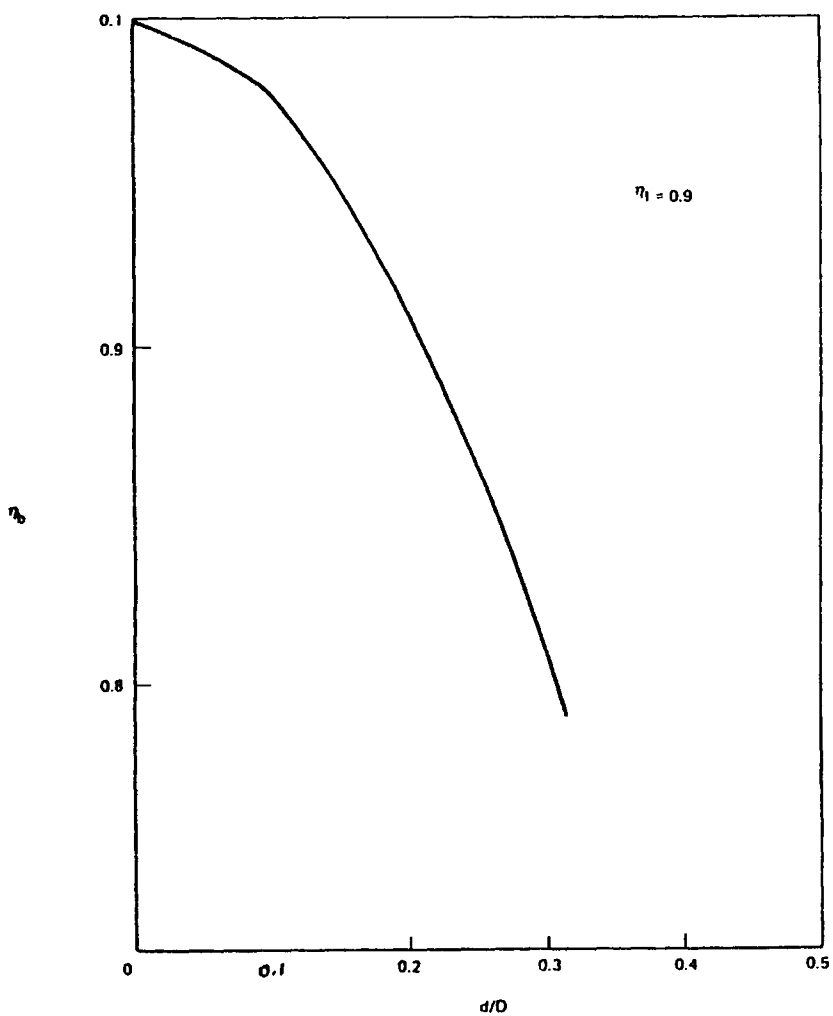

Figure 1. Blockage efficiency Vs. Blockage Ratio

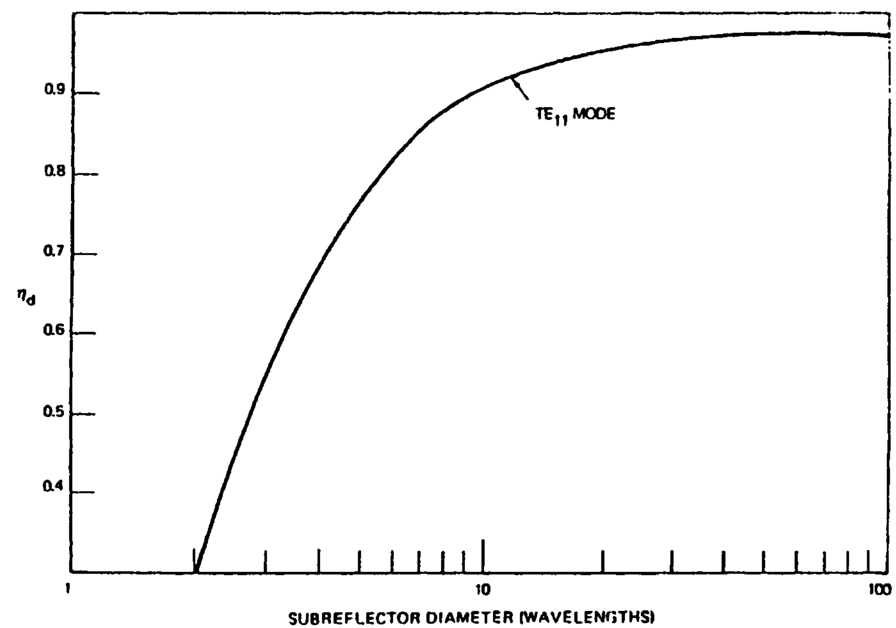

Figure 2. Diffraction efficiency Vs. Subrefl. size

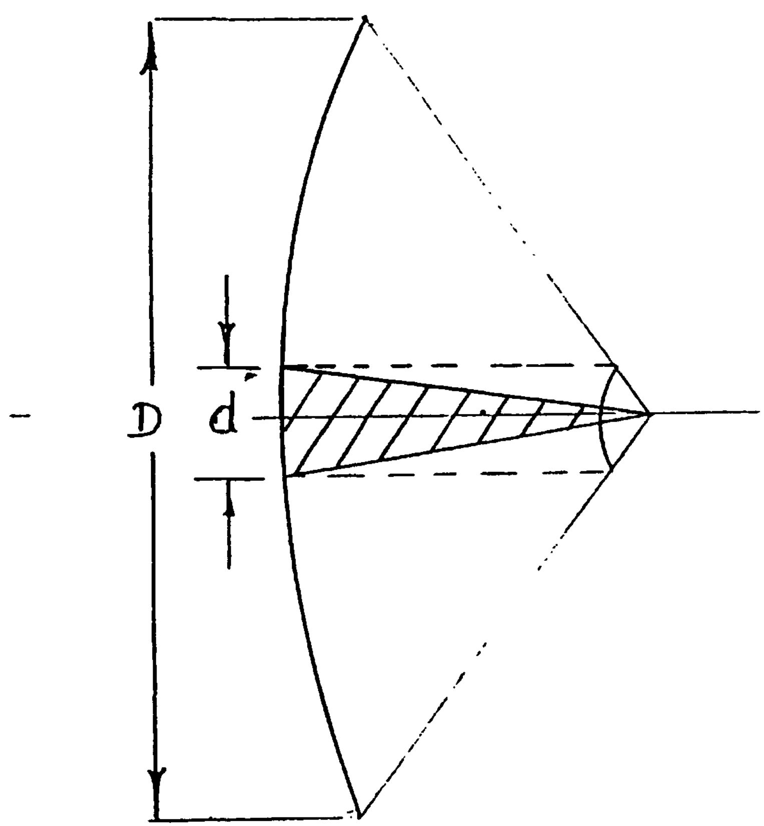

Figure 3.

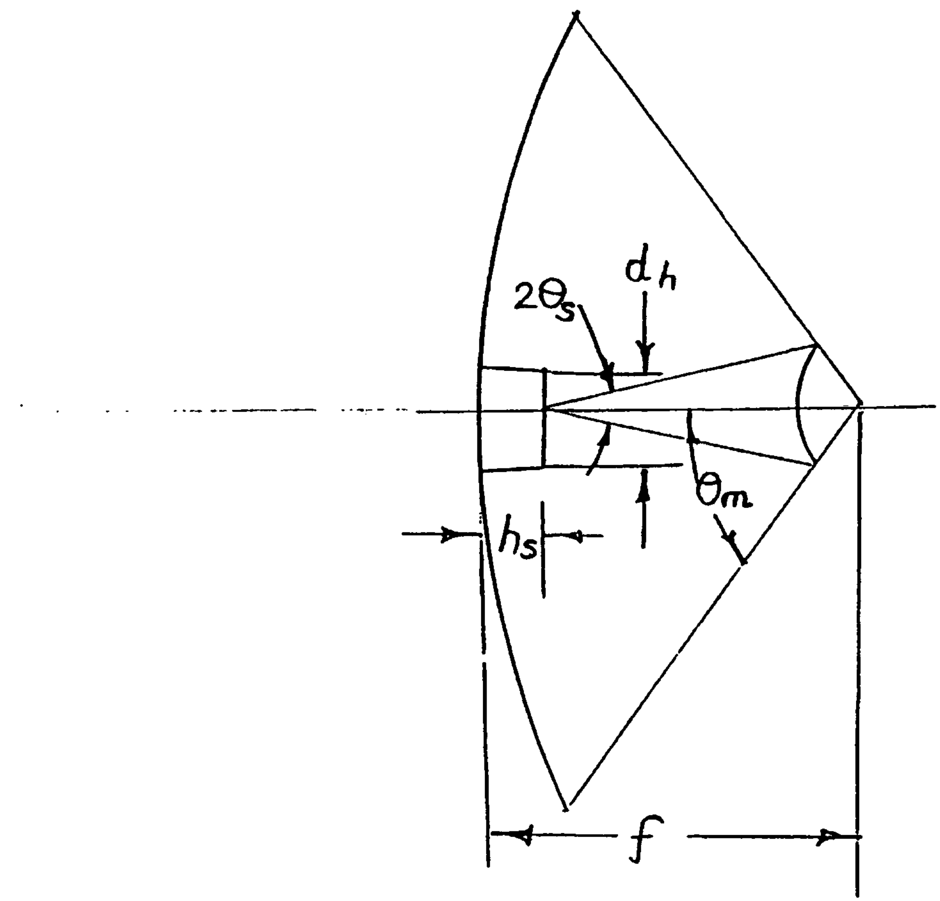

Figure 4.