G.U. Journal of Science
19(4): 185-189 (2006)

GUJS
www.gujs.org

Spillover Losses in Small Cassegrain Antennas

Nursel AKÇAM♣

Gazi University, Faculty of Engineering and Architecture
Department of Electrical and Electronics Engineering, Maltepe 06570 Ankara, TÜRKİYE
Received: 05.04.2005 Accepted: 10.10.2006

ABSTRACT

In this study, first the radiation properties of a small Cassegrain antenna for 10λ were examined. Next the source of spillover is discussed, and parametric curves showing losses as a function of the Cassegrain design parameters are presented. These results lead to some useful relationships for choosing the design parameters for optimum gain performance.

Keywords: Efficiency, Cassegrain Antennas, Spillover in Cassegrain Antennas.

1. INTRODUCTION

In double reflector antennas; feed, feed support beams and sub-reflector especially cause distribution losses and large blockings in antenna apertures.

In previous studies, the spillover losses due to open-ended rectangular and circular section waveguide feed, which had been mainly used in reflector antennas were studied for TE_{11} and TE_{12} stimulated modes [1].

For the control of the spillover caused by the sub-reflector, the behavior of the field was analitically examined in the region of the sub-reflector reflection limits [2]. For the offset of the Cassegrain and Gregorian antennas, sub-reflector beams were chosen and the spillover losses for these two antennas were compared [3]. In this study, the radiation pattern property of the 10λ Cassegrain antenna and spillover losses were examined for sub-reflector diameter D_S and cosθ main feed mode. In addition, the efficiency for the ratios of various sub-reflector diameters over the main reflector diameters (D_S/D) was calculated. For the efficiency calculation, the integral calculation of the total antenna pattern obtained was examined by a numerical method developed.

2. SPILLOVER LOSSES

The antenna efficiency η_v [4-8] calculates all losses in the system. These losses can be enumerated as spillovers, cross-polarization, phase errors, blockings and non-uniform illuminations.

The main objective of this study was to calculate the efficiency for the ratios of various sub-reflector diameters of Cassegrain antennas over the main reflector diameters (D_S/D). Cassegrain reflector geometry is shown in Figure 1. Here, f is the focal distance, and θ is the radiation angle.

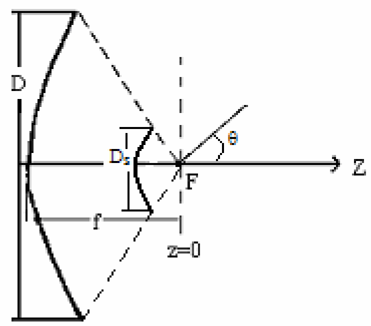

Figure 1. Cassegrain reflector geometry

The directivity for the antenna is given as;

D_0 = (4π x *maximum radiation intensity)* / P_r (1)

where P_r is the total radiated power. In order to obtain the total radiated power, the integral of the radiation pattern is to be taken in one of the following three methods.

(a) Main feed radiation pattern,
(b) Feed system (main feed + sub reflector) radiation pattern,
(c) Total antenna (main feed + sub reflector + main reflector) radiation pattern.

In order for all the methods above to yield the same result, it is enough for the reflector surfaces to be perfect conductors.

The feed pattern functions for an axial symmetric antenna are in the form of $F_E(\theta)=F_H(\theta)=\cos^n\theta$. The total radiated power can be calculated by Eq.2,

$$P_r = 2\pi / [2n(2n+1)] \quad (2)$$

♣Corresponding author, e-mail: ynursel@gazi.edu.tr

and by Eq.3 for a dipole antenna (feed pattern functions $F_E(\theta)=\cos^n\theta$ and $F_H(\theta)=1$),

$$P_r = 4\pi/(6n) \tag{3}$$

The maximum radiation intensity is $|E_{\max}|^2/(2n)$; and from Eq.1, the directivity for an axial symmetric cosine feed becomes

$$D_o = 2(2n+1)|E_{\max}|^2 \tag{4}$$

In case of feed as a dipole, it is found by Eq.5

$$D_o = 3|E_{\max}|^2 \tag{5}$$

If Eq.1 is calculated for a uniform stimulated aperture, the result is

$$D_o = 4\pi A/\lambda^2 \tag{6}$$

If there is no feed and all the power is captured by the aperture; it is possible for the area aperture **A** to have the biggest directivity. The directivity for a random antenna can be stated as in such a form similar to Eq.6 [9].

$$D_o = 4\pi A\eta_v/\lambda^2 \tag{7}$$

where η_v is the antenna efficiency and it calculates all the losses in the system. Thus, η_v can be easily calculated by Eq.1 and Eq.7.

In order to calculate the efficiency of a Cassegrain antenna, the feed system (consisting of the main feed and sub-reflector) is stated as one entity.

The spillover losses in four regions for a Cassegrain reflector antenna [10-14] are obtained by examining the amount of the distribution feed system power (Figure 2). The radiated powers in regions of C, I, G and B represent the losses. Because these powers can not be absorbed by the main reflector. The angular limits of the four regions are given in Table 1.

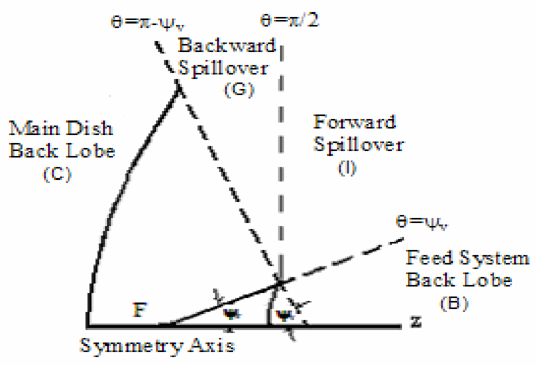

Figure 2. Spillover regions for Cassegrain reflector antenna.

Table 1. Radiation pattern regions for efficiency calculation.

Pattern Region $(\theta_{min},\theta_{max})^*$	Solid Angle	Region
# Main dish (reflector) back lobe $(\pi-\psi_r, \pi)$	Ω_C	C
#Forward spillover $(\psi_r, \pi/2)$	Ω_I	I
# Backward spillover $(\pi/2, \pi-\psi_v)$	Ω_G	G
#Feed system back lobe $(0, \psi_r)$	Ω_B	B

(*In all cases, $0 \langle \phi \langle 2\pi$ due to axial symmetry.)

If the feed system only radiates in free-space, the directivity can be described as in Eq.8,

$$D_{FS} = \frac{(4\pi R^2/2n)|\underline{E}_{FS_{\max}}|^2}{(1/2n)\iint_{4\pi}|\underline{E}_{FS_{\max}}|^2 ds} \tag{8}$$

where $ds = R^2 \sin\theta d\theta d\phi$ and $\underline{E}_{FS}$ (the underscore expresses that the region is phaser) are the distribution region. The pattern integral in terms of space solid angle is described as in the power absorbed by the main reflector.

$$P(\Omega_X) = (1/2n)\iint_{\Omega_X}|\underline{E}_{FS}|^2 ds \tag{9}$$

X= C,I, G or B.

D_{FS} is obtained in the form as in Eq.10,

$$\begin{aligned} D_{FS} &= D_P P(\Omega_X)/P(4\pi) \\ &= D_P\{P(4\pi)-P(\Omega_B)-P(\Omega_I)-P(\Omega_G)\}/P(4\pi) \\ &= D_P\eta_t \end{aligned} \tag{10}$$

where Dp is given as

$$D_P = \frac{4\pi|\underline{E}_{FS_{\max}}|^2}{2nP(\Omega_C)} \tag{11}$$

Thus, the feed system directivity is expressed to be a parabolic directivity D_p and D_p shows all losses except for spillover. η_t is the spillover efficiency and is expressed as in Eq.12,

$$\eta_t = 1 - L_B - L_I - L_G \tag{12}$$

where

L_B :Feed system spillover losses,
L_I :Forward direction spillover losses,
L_G :Backward direction spillover losses.

It is recommended to use main focal feed with high collimator in order to reduce forward direction and backward direction spillover losses. There are two practical limitations of achieving strong feed, to accompany the large apertures. First, if the Cassegrain is small, the sub-reflector may not be placed in a far distance area. Second, the large feed aperture, the sub-reflector causes more blocking losses than itself.

3. RESULTS

The simplest feed member in this category is dipole. In Figure 3, using n=1 main feed cosine and dipole, the power rate for feed systems is drawn as a function of the diameter of the sub-reflector. The reference powers (P_r) are given for the cosine curve and the dipole curve by Eq.4 and Eq. 5, respectively.

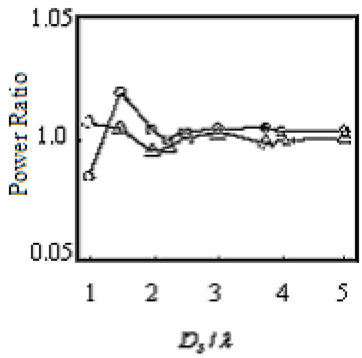

Figure 3. Radiated power rations from antenna (o→for dipol and Δ →n=1 for cosinüs main feed pattern)

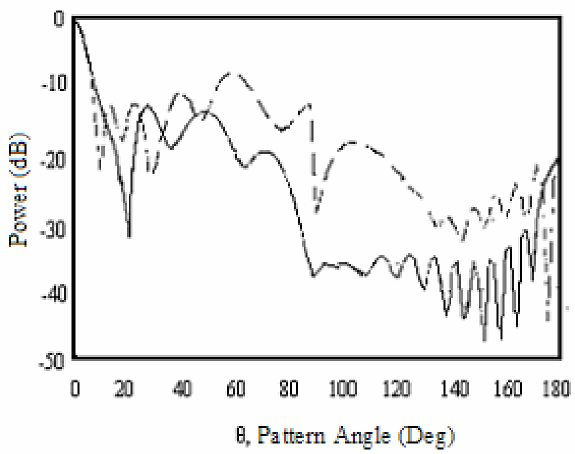

Figure 4. Radiation pattern for the dipole which has been calculated by applying the MOM. — $\phi = 0^o$ (E-plane),– – $\phi = 90^o$ (H-plane), $F_E = \cos\theta$, $F_H = 1$, D=10λ, D_s=2.5λ, f/D = 0.4, c = 1.5λ, E_{max}=3.7V/m co-polarized.

When the total antenna radiation pattern is calculated, a problem occurs for the dipole feed. In Figure 4, the dipole which has been calculated by applying the MOM (Method of Moment) to the EFIE (Electrical Field Integral Equation) seemed as if it would have a wide pattern on the H-plane. Here, the wide angle radiation level is only 8dB lower than the main beam peak (in the back hemisphere, there is a big discontinuity at 90° due to the cut of the top of the feed). The same situation also exists on the E-plane of the main beam shape.

The following spillover loss calculations are presented in form $\psi_r = 28^o$, $\psi_v = 64^o$ and only n=1 cosine feed patterns. The forward direction spillover losses L_I is almost the same for all configurations (Figure 5). The slight drops in small D_S values is due to the cancellation of the sub-reflector distribution field pattern. The backward direction spillover losses L_G (Figure 6) are completely in the sub-reflector distribution field. The fact that the directivity is very good is a result of keeping the big sub-reflector diameters small (D_s/D=0.25 λ - D_s/D=0.1 λ).

The power loss for the rear beam region of the feed system displays a similar behavior at L_B (Figure 7). The rear beam region of the main reflector (Figure 8) is the measurement of the power absorbed by the main reflector. It shows small increases by the sub-reflector diameter. The spillover losses, for all cases, were placed on the basis of high freqency techniques and far-field approaches; and they showed the expected behaviors.

For different feed cases, the efficiency is given based on the main dish diameter in Figure 9. Figure 9 shows the ratio of the power which has been calculated by the numerical integral of the total antenna pattern by using Eq. 2. This ratio must be always one, however, in reality it varies based on the feed and antenna configurations. Because the sub-reflector is not always in the far field of the feed. Its ratio is the highest for the first case. Here, the feed is 1λ less than the sub-reflector.

For small Cassegrain antennas (the main reflector diameter of 10λ – 20λ) the efficiency of 50% is considered to be a good level. In the cases shown in Figure 9, it is observed that the efficiency level is approximately in the neighborhood of 30%. In this case, the antenna losses need to be reduced.

If the forward direction and backward direction spillover losses are desired to be reduced, a front focal feed with very good collimator must be used. Also the problem of the forward direction spillover losses in Cassegrain antennas can be reduced by using a dielectric guide structure between the feed and the main feed including the feed field. The backward spillover losses are related to the dimensions of the sub-reflector and can be controlled upto a (certain) degree [18].

In today's use, most of the symmetric dual reflector antennas are based on the traditional Cassegrain reflector system. In the design used, the limitation ratio D_s/D is generally 0.1 or less in order to avoid distribution losses and large blockings. If the main reflector diameter is 10 λ - 20 λ , the sub-reflector diameter is to be 1λ or 2λ .

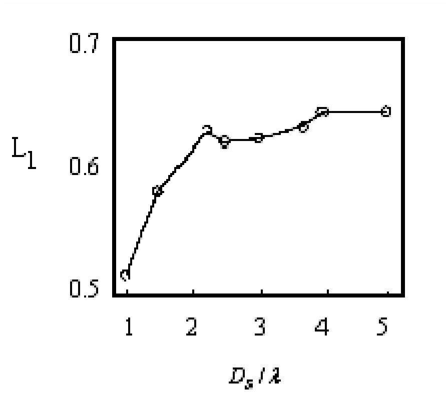

Figure 5. Feed system forward direction spillover losses.

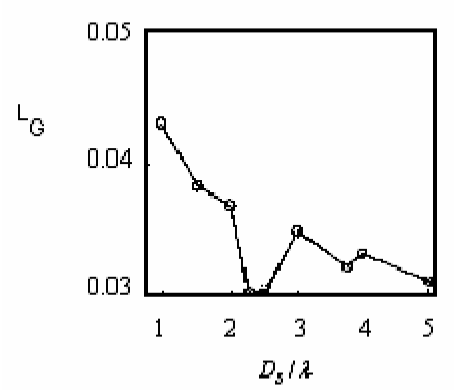

Figure 6. Feed system backward direction spillover losses.

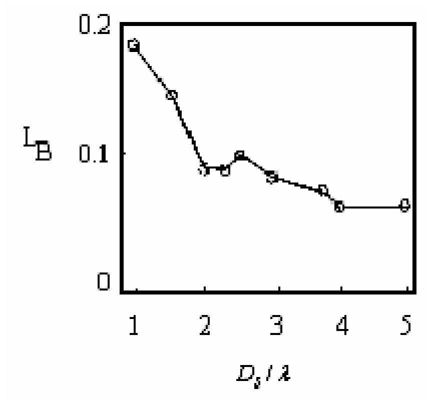

Figure 7. Feed system back lobe spillover losses.

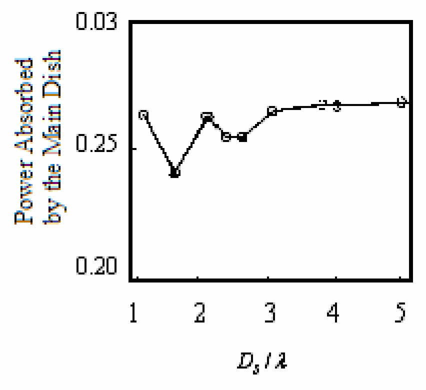

Figure 8. Feed system C region spillover losses.

The symbols and feed cases in Figure 9 are as follows.

symbol	**$\cos^n\theta$ feed**
Δ	for n = 1
□	for n = 4.76

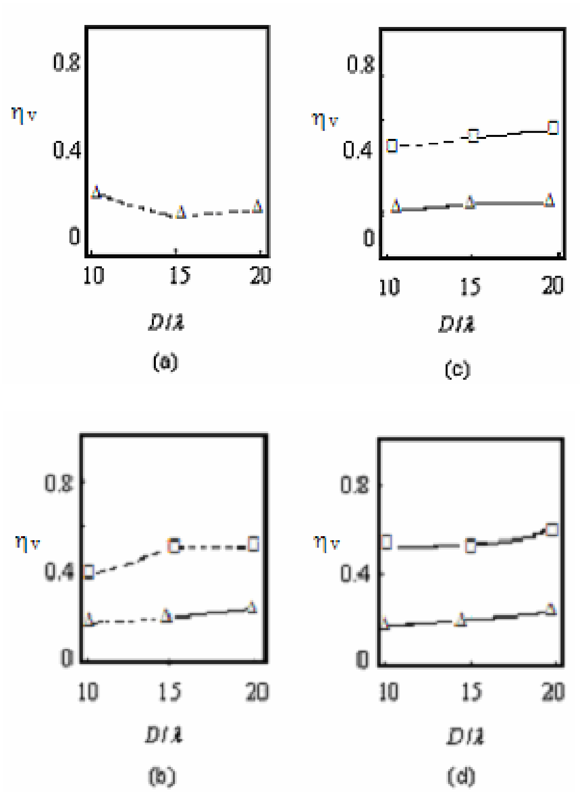

Figure 9. Efficiency for different feed cases

REFERENCES

[1] Lee S. W. and Zimmerman M. L., "Reflector spillover loss of an open-ended rectangular and circular waveguide feed.", IEEE Trans. Antennas Propagat., 38(6): 940-942, (1990).

[2] Morcira F. J. S. and Prata A., Jr., "Design of axially–symmetric Cassegrain and Gregorian configurations with reduced spillovers.", IEEE Antennas and Propagat. Society International Symposium, 2: 820-823, (1998).

[3] Srikanth S., "Comparison of spillover loss of offset Gregorian and Cassegrain antennas.", IEEE Antennas and Propagat. Society, AP-S International Symposium (Digest), 1: 444-447, (1991).

[4] Collin R. E., "Aperture efficiency for paraboloidal reflectors.", IEEE Trans. Antennas Propagat., 32(9): 997, (1984).

[5] Clarricoats P. J. B. and Poulton G. T., "High efficiency microwave reflector antennas- a review.", Proc. IEEE, 65(10): 1470, (1977).

[6] Collins C. W., "Shaping of subreflectors in Cassegrain antennas for maximum aperture efficiency.", IEEE Trans. Antennas Propagat., 21(3): 309, (1983).

[7] Williams W.F., "High efficiency antennas with arbitrary phase and amplitude distributions, reflector., Microwave J., 8:(7), 79, (1965).

[8] Kildal P. S., "Factorization of the feed efficiency of parabolic and Cassegrain antennas.", IEEE Trans. Antennas Propagat., 33(8): 903, (1985).

[9] Syrigos H., "Backfire feed antenna beats Cassegrain design.", Microwave System News, 13(10): 164, (1983).

[10] Rao R. L. J. and Chen S. N. C., "Illumination efficiency of a shaped Cassegrain design.", IEEE Trans. Antennas Propagat., 18(3): 411, (1970).

[11] Green K. A., "Modified Cassegrain antenna for arbitrary aperture illumination.", IEEE Trans. Antennas Propagat., 11(2): 589, (1963).

[12] Viggh M., "Designing for desired aperture illuminations in Cassegrain antenna.", IEEE Trans. Antennas Propagat., 11(3): 198, (1963).

[13] Galindo V., "Design of dual reflector.", IEEE Trans. Antennas Propagat., 12(4): 403, (1964).

[14] Galindo-Israel,Victor; Verruttipong, Watt; Norrod, Roger D.; Imbriale, William A. "Scanning properties of large dual-shaped offset and symmetric reflector antennas.", IEEE Trans. Antennas Propagat., 40(4): 422-432, (1992).

[15] Harrington R. F., Field computation by Moment methods., MacMillan, NewYork, 1982.

[16] Harrington R. F., "Matric methods for field problems.", Proc. IEEE, 55(2): 136, (1967).

[17] Mautz J. R. and Harrington R. F., "An improved E-field solutions for conducting bodies of revolution.", Syracuse Univ. Syracuse, NY, Tech. Rep. TR-80-1.

[18] Jenn D. C., Application of integral equation theory to reflector antenna analysis, A Dissertation Presented to the Faculty of the Graduate Scholl University of South California, (1987).