An Optical Blockage Illumination Correction Factor for Circular Reflectors

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Introduction

In this paper we present a simple, practical, and accurate method of estimating the gain reduction of large circular dish reflector antennas caused by central blockage, edge blockage, and plane wave blockage from the struts. The resulting blockage gain loss of the main reflector, usually expressed as a blockage factor [1], is:

$$\eta_b = (1 - \frac{1}{\eta_i}\frac{A_b}{A_0})^2 \tag{1}$$

where, η_i is the illumination efficiency, A_b is the area of the aperture blockage, and A_0 is the total aperture area.

It should be noted that for the case of uniform illumination, the blockage factor given by (1) is based on a quasi-optical aperture approach. However, when this illumination is non-uniform, (1) is only correct qualitatively, and not quantitatively, for the central and strut blockage cases. To correct this situation, we propose in this work to slightly modify (1) as follows:

$$\eta_b = (1 - c_i^c \frac{A_b^c}{A_0} - c_i^e \frac{A_b^e}{A_0} - c_i^s \frac{A_b^s}{A_0})^2 \tag{2}$$

where we refer to c_i as the illumination correction factor, which is still equal to 1 for a uniform aperture illumination. The superscripts *c, e,* and *s* in the illumination correction factors and blockage areas refer to central, edge, and strut blockages, respectively. Using the quasi-optical aperture approach we can express the illumination correction factor for each particular type of blockage as follows:

$$c_i = \frac{A_0}{A_b} \times \frac{\int_{A_b} E_s dA}{\int_{A_0} E_s dA} \tag{3}$$

where E_s is the surface field distribution over the dish aperture. For a general case, the value of c_i can only be computed numerically. However, for convenience, in this paper we graphically present the results of numerical computations in a form that allows one to calculate the blockage factor by using the simple formula in (2), without having to perform a numerical simulation.

The Illumination Correction Factor for Central and Strut Blockages, and for the Case of an Under-Illuminated Edge

All the results presented in this paper have been obtained under the assumption that the aperture field distributions were either the "Polynomial-on-Pedestal" or Gaussian types.

The illumination correction factor has been computed by using (3) for the case of central blockage and an under-illuminated edge for both types of aperture illuminations, and is plotted in Figs. 1–4. Different values of edge taper were used as parameters to generate the plots. As it can be seen from these plots, for heavily tapered Cassegrainian or Gregorian reflectors, making the subreflector diameter slightly less than is necessary for the full main dish illumination can cause the gain to increase because the second term in (2) decreases faster than the increase of the third one.

Unlike the central blockage and the under-illuminated edge cases, where the axially-symmetric blockage can be described in terms of a single parameter - the percentage of blockage, for example - the strut blockage depends on many parameters instead. Thus, in order to produce a set of general plots for the strut blockage case, we need to impose some constraints on the considered strut design.

First of all, we typically neglect the spherical wave type of strut blockage, because it depends on a large number of design parameters. However, when the spherical wave blockage occurs near the dish edge, the plots in Figs. 3 – 4 can still be used. Also, when the strut blockage is largely spherical in nature, it can be considered as being the blockage of a sectorial shape on the aperture disk, and we can set the illumination correction factor equal to 1.

In this paper we concentrate, instead, on the plane-wave type of strut blockage. Furthermore, we assume that the strut thickness t, number of struts n, and the central blockage diameter D_c satisfy the relationship:

$$b = \frac{\pi D_c}{nt} = const \geq 1 \tag{4}$$

Figs. 5 and 6 plot the optical blockage illumination correction factor computed by using (3), for the case of plane-wave strut blockage, and for both types of aperture illuminations, with different values of edge tapers as parameters. In contrast to the previous plots, the plane wave strut blockage illumination correction factor is shown in these figures as a function of the normalized area of strut blockage.

Using (4), we can relate the normalized strut blockage area $a_{sb\ norm}$ and the strut blockage area a_{sb} (both expressed as percentages) through the ratio b as follows:

$$a_{sb\ norm} = a_{sb} \times b \tag{5}$$

This approach to describing the strut blockage area enables us to use the plots in Figs. 5 and 6 for different values of the ratio b.

Conclusion

In this paper, we have introduced an illumination correction factor for the optical blockage that improves the approximate formula (1), published previously for optical blockage gain loss of a circular dish, by replacing it with the more accurate expression appearing in (2). The optical blockage illumination correction factor (3) can be found by using the plots appearing in Figs. 1 – 6 for different types of blockage and aperture illumination functions, solely from the knowledge of percentage of blocked area, and using the illumination function and its taper as a parameter. This enables one to compute the optical blockage gain loss for circular dish antennas with excellent accuracy (tolerance of a few hundredths of a dB), without having to run computer codes.

Solid Red - No Taper
Long Dashed Dark Blue - 5dB Taper
Short Dashed Green - 10dB Taper
Long Dash-Dotted Light Blue - 15dB Taper
Long Dash-Double-Dotted Yellow - 20dB Taper
Long Dash-Triple-Dotted Purple - 60dB Taper

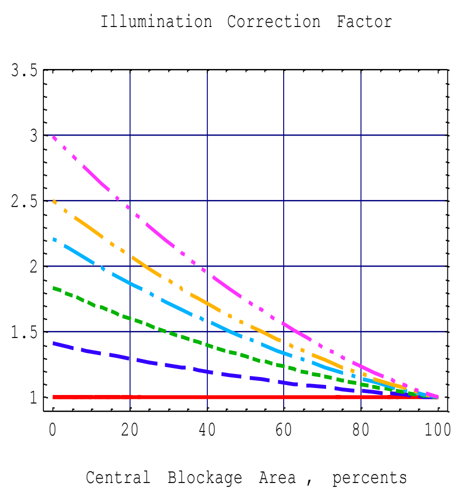

Fig. 1. "Polynomial-on Pedestal" Aperture Illumination.

Solid Red - No Taper
Long Dashed Dark Blue - 5dB Taper
Short Dashed Green - 10dB Taper
Long Dash-Dotted Light Blue - 15dB Taper
Long Dash-Double-Dotted Yellow - 20dB Taper
Long Dash-Triple-Dotted Purple - 25dB Taper

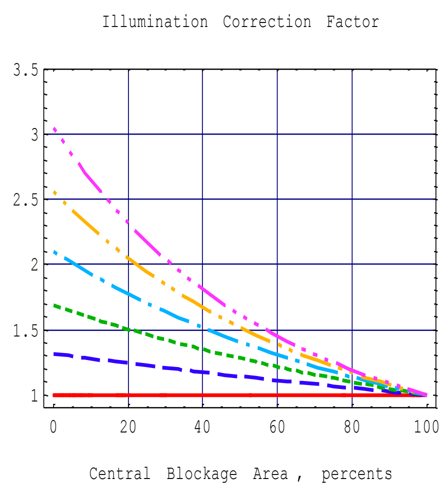

Fig. 2. Gaussian Aperture Illumination.

Solid Red - No Taper
Long Dashed Dark Blue - 5dB Taper
Short Dashed Green - 10dB Taper
Long Dash-Dotted Light Blue - 15dB Taper
Long Dash-Double-Dotted Yellow - 20dB Taper
Long Dash-Triple-Dotted Purple - 60dB Taper

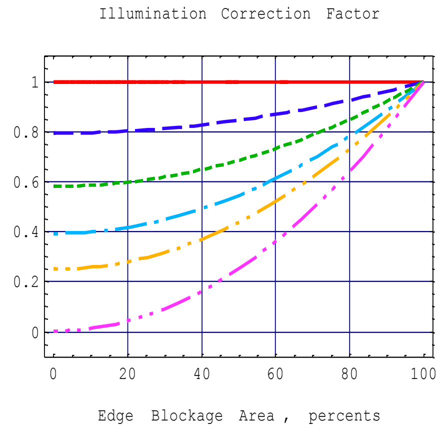

Fig. 3. "Polynomial-on Pedestal" Aperture Illumination.

Solid Red - No Taper
Long Dashed Dark Blue - 5dB Taper
Short Dashed Green - 10dB Taper
Long Dash-Dotted Light Blue - 15dB Taper
Long Dash-Double-Dotted Yellow - 20dB Taper
Long Dash-Triple-Dotted Purple - 25dB Taper

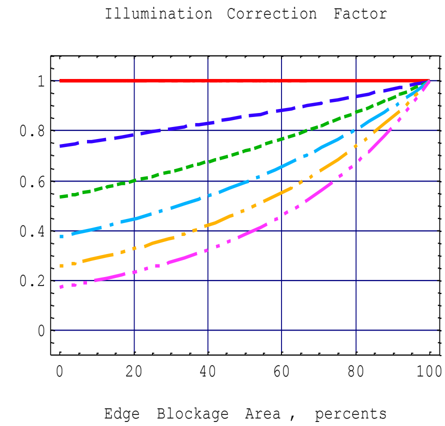

Fig. 4. Gaussian Aperture Illumination.

Solid Red - No Taper
Long Dashed Dark Blue - 5dB Taper
Short Dashed Green - 10dB Taper
Long Dash-Dotted Light Blue - 15dB Taper
Long Dash-Double-Dotted Yellow - 20dB Taper
Long Dash-Triple-Dotted Purple - 60dB Taper

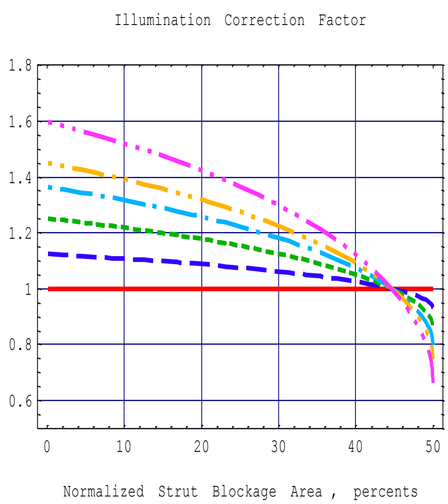

Fig. 5. "Polynomial-on Pedestal" Aperture Illumination.

Solid Red - No Taper
Long Dashed Dark Blue - 5dB Taper
Short Dashed Green - 10dB Taper
Long Dash-Dotted Light Blue - 15dB Taper
Long Dash-Double-Dotted Yellow- 20dB Taper
Long Dash-Triple-Dotted Purple - 25dB Taper

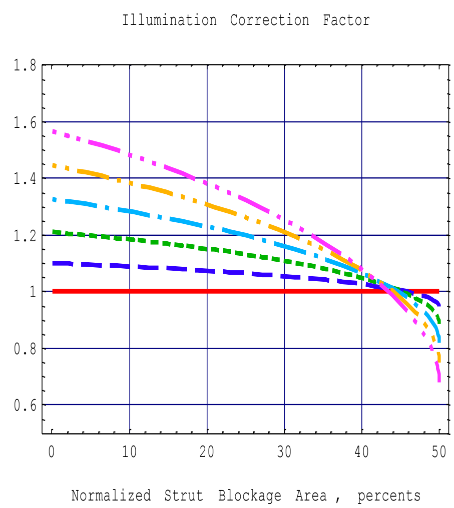

Fig. 6. Gaussian Aperture Illumination.

References:

[1] W. V. T. Rusch, T. S. Chu, A.R. Dion, P. A. Jensen and A. W. Rudge, "Quasi-optical antenna design and applications", in *The Handbook of Antenna Design*, vol. 1, A. W. Rudge, K. Milne, A.D. Olver and P Knight, Ed., London: Peter Peregrinus Ltd., 1982, p. 179.