ALMA Memo 329

Scattering of Solar Flux by Panel Grooves: Update

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Abstract— **Fine grooves machined into the surface panels of an antenna help to scatter solar radiation. In an earlier memo it was concluded that a circular profile for the grooves was superior to a triangular. After correcting some errors in that note the triangular grooves appear to be more effective. The corrected formulation and some additional comments are presented here.**

I. Introduction

In a previous memo [1] the efficacy of different geometries of grooves in panel surfaces for scattering solar radiation was evaluated. It was concluded that a circular groove profile was significantly better than a triangular one. However Richard Hills [2] has pointed out an error in the original expression for the circular groove scattering which we correct here. We also add some comments about a more realistic expectation for the triangular grooves.

II. Groove Scattering

Fig. 1 shows the two groove geometries with the appropriate parameters.

A. Triangular Grooves

In the original memo it was assumed that the axis of the triangular cross-section was normal to the surface of the panel or secondary mirror. In a practical case it is more likely that this axis will be at the same absolute angle across the whole panel (possibly normal to the panel at the mid-radius). In that case the scattered radiation will cover an anular region in the plane of the secondary with a width given by the convolution of the secondary diameter and the panel size. Since the panel is likely to be a similar size to the secondary, or somewhat larger, this will reduce the flux by a factor of about two compared to the original calculation.

The decrease in flux originally derived was

$$\eta = \frac{d_s}{16\alpha f}, \tag{1}$$

With a further factor of two this would give an attenuation of about $\eta = 0.05$, reducing the solar flux at the secondary to

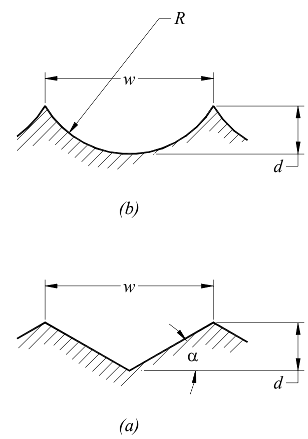

Fig. 1. Parameters used to characterize the groove cross-sections for *(a)* a triangular groove, and *(b)* a circular groove which is approximated as a parabolic curve.

11–14 kW m^{-2}.

At the most focused region, which could be close to a secondary support strut, the reduction could be much more significant.

B. Circular Grooves

Cutting grooves with a tool of radius R to a depth d produces a pitch of

$$w = 2\sqrt{2Rd} \; . \tag{4}$$

The slope angle is uniformly distributed over a range

$$0 \le \alpha \le \alpha_{\max} \qquad \alpha_{\max} \approx \frac{4d}{w} \tag{5}$$

which is twice that of a triangular groove having the same aspect ratio. The Ruze criterion now gives

$$d \le \frac{\varepsilon}{0.298}, \tag{6}$$

essentially the same as for triangular grooves.

Now the solar energy is distributed within a cone, and at the secondary this is a circle of radius

$$r = 2\alpha_{\max} f \; . \tag{7}$$

19 October, 2000

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Note that this is about twice the size for the triangular groove, and the energy is distributed within a circle rather than being in an annular region. However, the distribution will have a peak in the central region and the corresponding reduction in solar flux when the sun is on-axis will be approximately

$$\eta = \frac{d_s}{4\alpha_{\max} f}\,, \tag{8}$$

which gives $\eta = 0.23$ for the same width and depth of groove used for the calculation of the triangular groove, only a four-fold reduction in flux density. (The original memo [1] had errors in the numerical calculation as well as the formula.) At the secondary the average flux density is reduced to 45–55 kW m^{-2}. This varies as d/w, as it does for the triangular grooves. Since the distribution is peaked at the center, however, the actual flux densities would be higher. The most focused region is at the prime focus, so at the secondary mirror the distribution will be more diffuse, but when the sun is off-axis there is the possibility that the strongly focused region is near one of the secondary support struts.

It is clear that, in contrast to the original conclusion, the triangular grooves are (probably significantly) superior to the circular ones.

III. SCATTERING TO OTHER REGIONS

Although the solar heat load should be removed from the secondary it should also be directed away from the secondary support struts. This means trying to avoid caustics[1] in a volume round the antenna. This is not a trivial proposition. If a reflecting surface which produces caustics is slightly altered the caustics will be displaced rather than destroyed [3]. Larger changes in the surface may cause the caustics to merge or divide but not necessarily reduce them.

It would seem that the surface finish should be as random as possible without violating the Ruze requirement. This would produce a large number of caustics, but none with large concentrations of energy.

ACKNOWLEDGEMENT

I wish to thank Richard Hills for taking the time to go through the original memo and point out the errors.

REFERENCES

[1] J. W. Lamb, “Scattering of solar flux by panel grooves,” *ALMA Memo Series*, No. 256, Mar. 1999.
[2] R. E. Hills, Private communication, 10 Nov. 1999
[3] J. F. Nye: *Natural Focusing and Fine Structure of Light*, Bristol: IoP Publishing, 1999.

[1] Note that he coinage of the word *caustic* for regions where light is concentrated reflects its burning effects.