011764-512-M

28 November 1973

MEMO TO: File

FROM: E. F. Knott

SUBJECT: Miscellaneous studies of resistive sheets

I. Introduction

A previous memorandum (011764-509-M, 30 October 1973) summarized the results of a sequence of computer runs intended to explore the cross section reducing capabilities of resistive sheets. The sheets were placed at the leading edge of an ogival cylinder three wavelengths wide, and the sheet width was varied from 0.25λ to 1.50λ. Linear, parabolic (square law) and cubic resistance distributions were imposed over the sheet surface, rising to a maximum value (R_{max}) at the leading edge of the sheet. The study showed that, in general, the cross section decreases with increasing R_{max}, provided the rate of change of resistance at the trailing edge of the sheet is small.

The study was incomplete in several respects, however. The maximum leading edge resistance studied was $R_{max} = 4.0$ whereas, based on the results of the performance of a resistive half plane, even greater cross section reductions are theoretically available. Moreover, the study was restricted to the case of edge-on incidence and it is important to know how far in aspect angle a given cross section reduction persists. The possibility of providing greater reduction by the use of multiple sheets was raised during a meeting with AFAL personnel on October 23, 1973 and, although we were convinced that such a procedure would fail, data were obtained via additional computer runs to demonstrate it. Finally, the possibility that a quartic distribution would be

DISTRIBUTION

Hiatt/File Liepa
Knott Senior

11764-512-M = RL-2248

desirable for relatively narrow sheets was suggested.

In order to explore these possibilities, a sequence of 'numerical experiments' was undertaken in November 1973. The computer runs focussed on the following conditions:

1) quartic resistance distributions;
2) $R_{max} = 7.0$ for parabolic distributions;
3) three resistive sheets instead of one;
4) fairing the leading edge of an ogival cylinder.

The effects of these miscellaneous experiments is the topic of this memorandum.

II. Quartic distribution

The results for a quartic distribution are shown for 5 sheet widths in Figure 1*. Sheet widths of 0.5λ and 0.75λ perform better than the resistive half plane used as a standard reference, but only for R_{max} less than about 3.0. This is undoubtedly the result of favorable cancellation, since the performance begins to deteriorate for these two widths and their cross sections begin to rise beyond $R_{max} = 3.0$. The performance of the three remaining sheets tends to be slightly worse than that of the resistive half plane, and in fact is not as good as was found for parabolic and cubic distributions.

The source of the scattering that produces this degradation has not been isolated, but presumably it arises from the trailing edge of the sheet and may also include a contribution (other than the resistive half plane component) at the leading edge. It should be appreciated that a quartic distribution is a quite rapid one in the vicinity of the leading edge of the sheet and because of the finite sampling rate necessary in the computer

*The $\lambda/4$ sheet, which has been one of the widths for other resistance distributions, was inadvertently omitted from the latest (quartic) series.

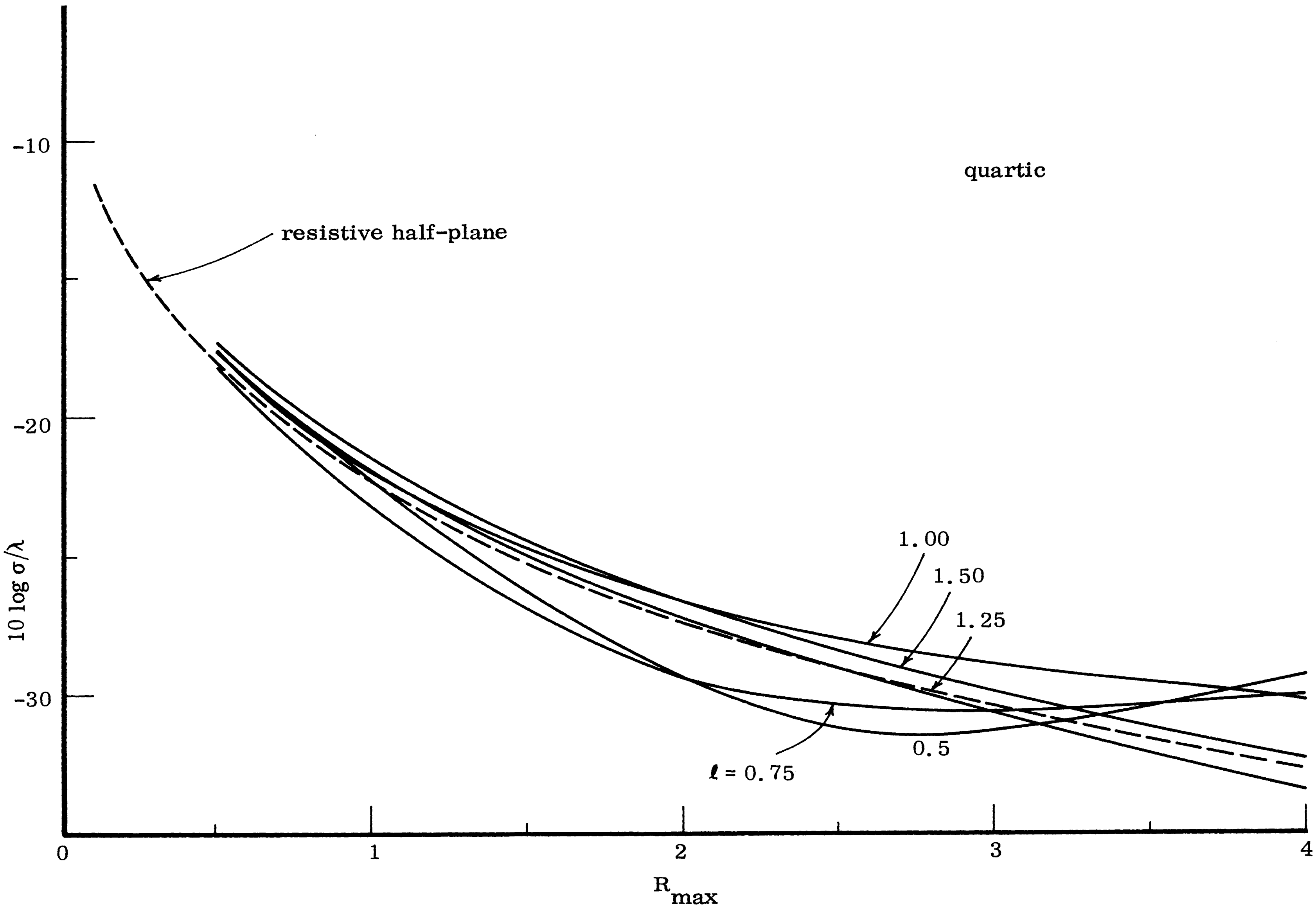

Figure 1. Edge-on cross sections for a quartic resistance distribution.

program, the data may, in fact, be in error. Further studies of this may be implemented, but for the moment it appears that the quartic resistance distribution offers no particular advantage over the parabolic and cubic distributions, at least in a broadband sense.

III. $R_{max} = 7.0$

Previous runs involving parabolic and cubic distributions suggested that the scattering cross sections of a sheet-treated ogival cylinder tend to converge on the theoretical resistive half plane value for large values of R_{max}. These runs had been completed before it had become apparent that the theoretical resistive half plane result represented a good approximation of the net edge-on return, and the highest value used was $R_{max} = 4.0$. However, the theoretical reduction available, as judged from the resistive half plane, was as large as 30 dB, provided by a leading edge value of $R_{max} = 7.0$. Thus, to test the hypothesis, additional data were acquired for this value for parabolic and quartic distributions.

The results are summarized in Figure 2 for the parabolic case. The high terminal value increases the edge-on returns of all except the widest sheets and we believe that, if it were to be increased even more, eventually the cross sections of the widest sheets would also commence rising after bottoming out. The same kind of behavior is true for the quartic distribution, as might be suggested by Figure 1 even though the data for $R_{max} = 7.0$ are not included. Evidently it requires progressively wider sheets to reduce the rapid resistance change imposed by ever higher values of R_{max}, so that a minimum sheet width becomes mandatory for large leading edge resistances.

The detrimental effect of an excessive rate of change seems to persist away from the edge-on value, as illustrated in Figure 3. This is a plot of the backscattering pattern of an ogival cylinder having a 1λ sheet joined to the leading edge, and a parabolic distribution is assumed across the sheet. The

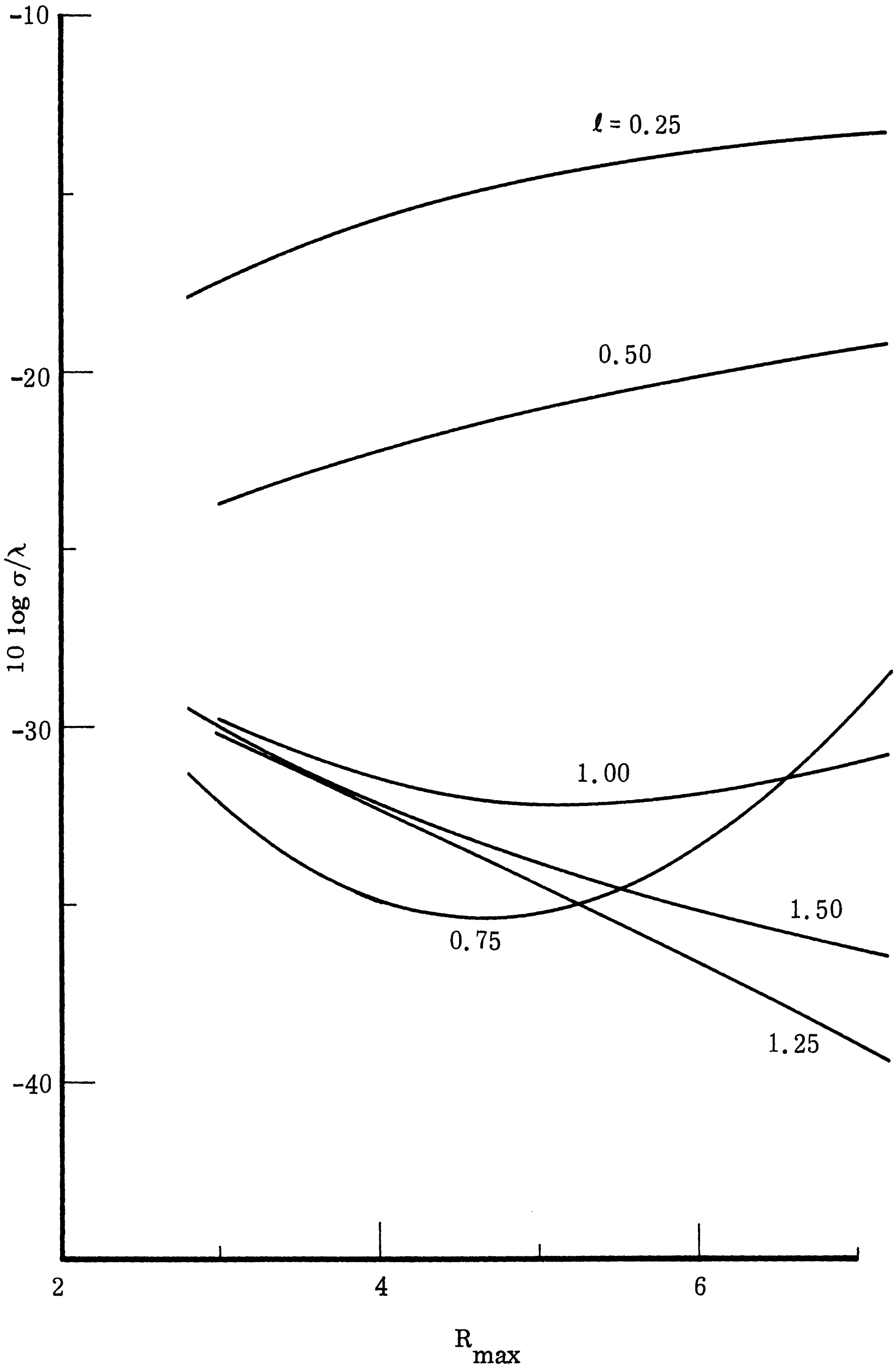

Figure 2. Increasing R_{max} to a value of 7.0 increases the edge-on returns of all except the widest sheets. These data are for a parabolic distribution.

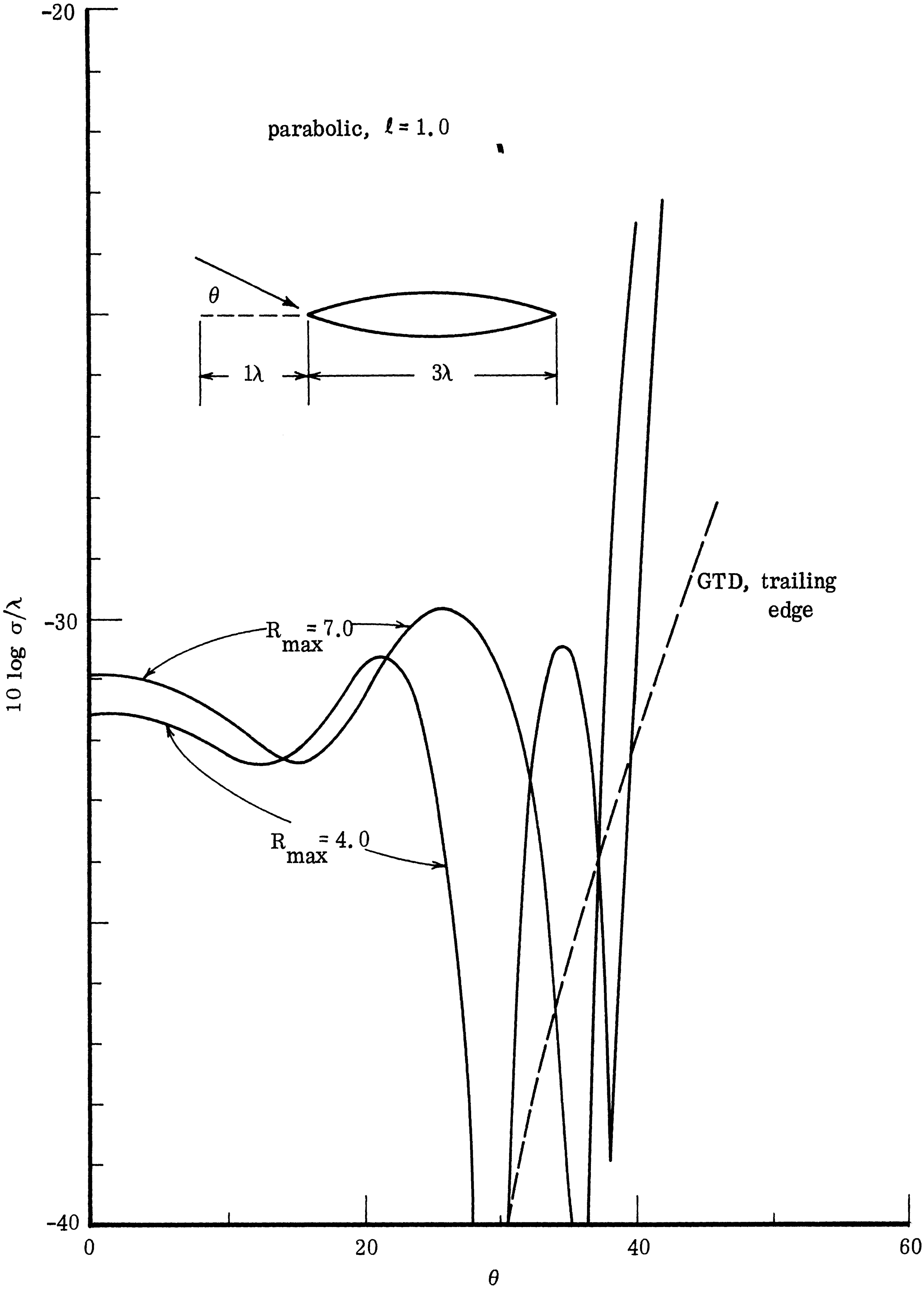

Figure 3. Comparison of backscattering patterns for R_{max} = 4.0 and 7.0.

higher value of R_{max} (7.0 as compared with 4.0) increases the edge-on return by 0.5 dB and the enhancement does not diminish as the aspect angle swings away from edge-on. Thus if the edge-on return cannot be reduced to an acceptable level by increasing R_{max}, neither can the returns away from edge-on.

IV. Shape control and multiple sheets

Previous results suggested that a high leading edge resistance may substantially reduce the edge return but that the return from the junction between the sheet and the leading edge of the metallic body may increase if the sheet is narrow enough. An attempt can be made to reduce the junction return by changing the shape of the metallic body, as suggested in Figure 4(b). In order to produce this faired effect, the leading edge of the cylinder was replaced with concave sections so that the opposite sides of the body are tangent where they join at the edge.

As shown by the backscattering patterns of Figure 5, the fairing is beneficial for aspects out to 20 degrees or so, beyond which the 'ordinary' shape of Figure 4(a) performs better. The benefit of the fairing tends to be greater for larger values of R_{max}, but is never much more than 1 dB. Since the experiment was performed for only one sheet width (1λ), the benefits for other widths are not known. The improvement is marginal and the fairing may be difficult to justify in a practical application.

Since our previous analyses have suggested that the leading edge of the sheet is the dominant source of scattering, applying additional sheets could serve no useful purpose. They would merely increase the scattering by virtue of the additional scattering. The configuration used is shown in Figure 4(c), in which a total of three sheets were used, all 1λ wide. The spacing was such that the three leading edge returns were nearly all in phase. A typical scattering pattern is included in Figure 5 along with that of the single-sheet configuration for a value of $R_{max} = 4.0$. The amplitude of the

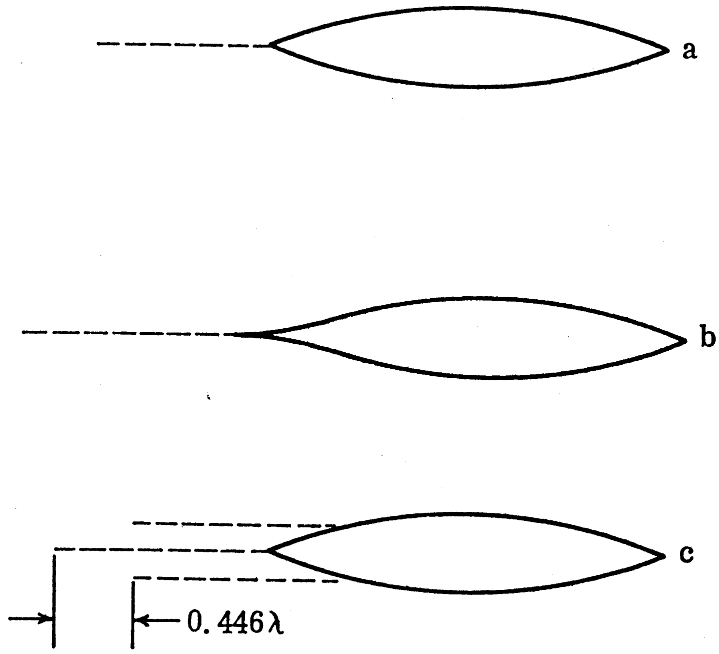

Figure 4. a) ogival cylinder, b) concave faired cylinder,
c) ogival cylinder with three resistive sheets.

scattering from the 3-sheet treatment is virtually a steady 6 dB greater than that of the single-sheet version, thus bearing out our original notions.

Interestingly enough, the cross section of the multiple treatment is nowhere near being a factor of $3^2 = 9$ greater than that of the single sheet treatment. The reason is apparently due to the change in the currents, as shown in the surface current distributions plotted in Figure 6 for edge-on incidence. The currents are stronger on a single sheet than on the center sheet of a 3-sheet array; the currents on the outer sheet are much weaker than on the center sheet. Thus, on the basis of these distributions, one ought not necessarily expect the edge-on cross section to rise as n^2, where n is the number of sheets used. As was anticipated, of course, the use of

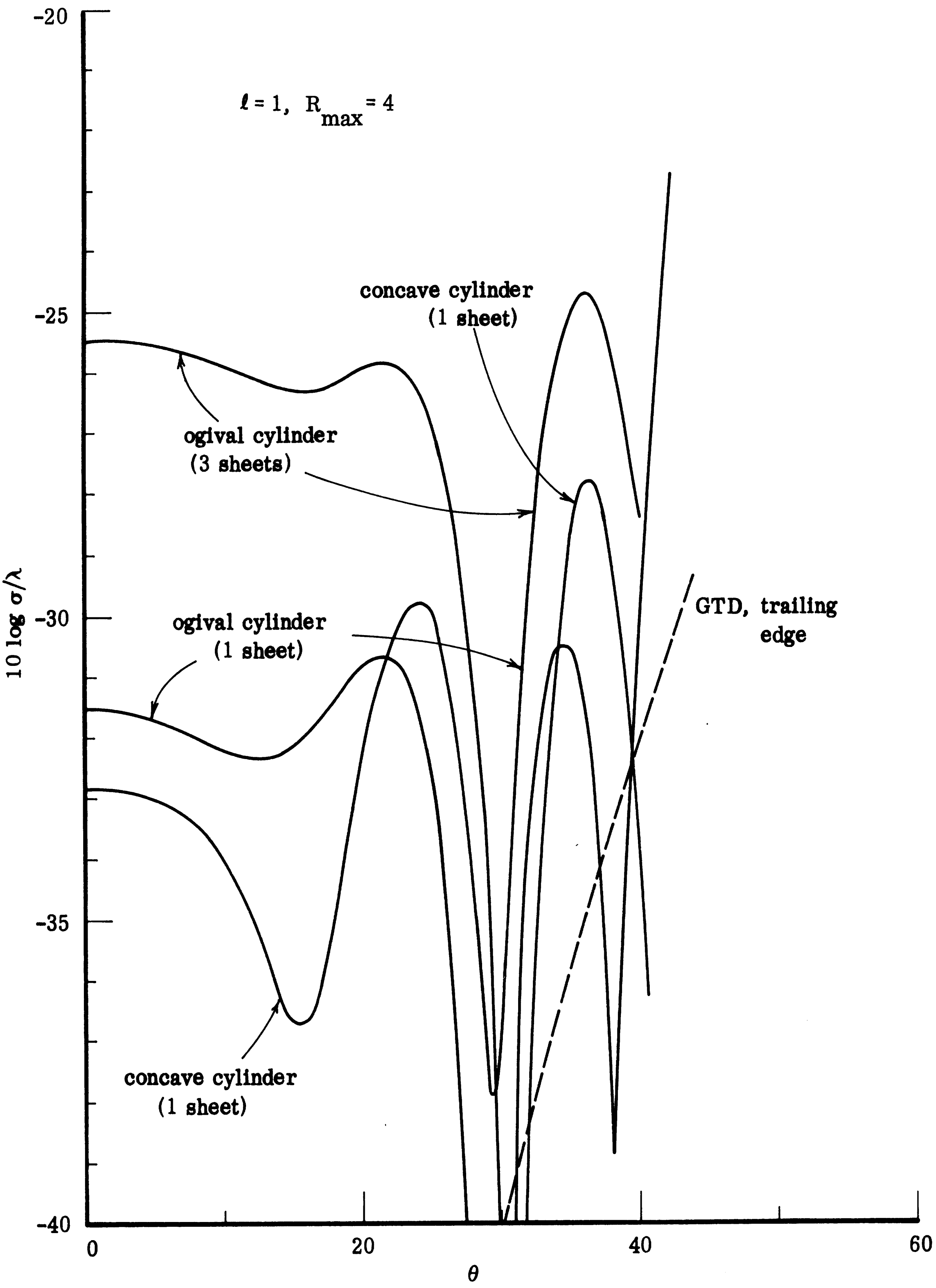

Figure 5. Cross section patterns of the three edge-treated shapes of Figure 4.

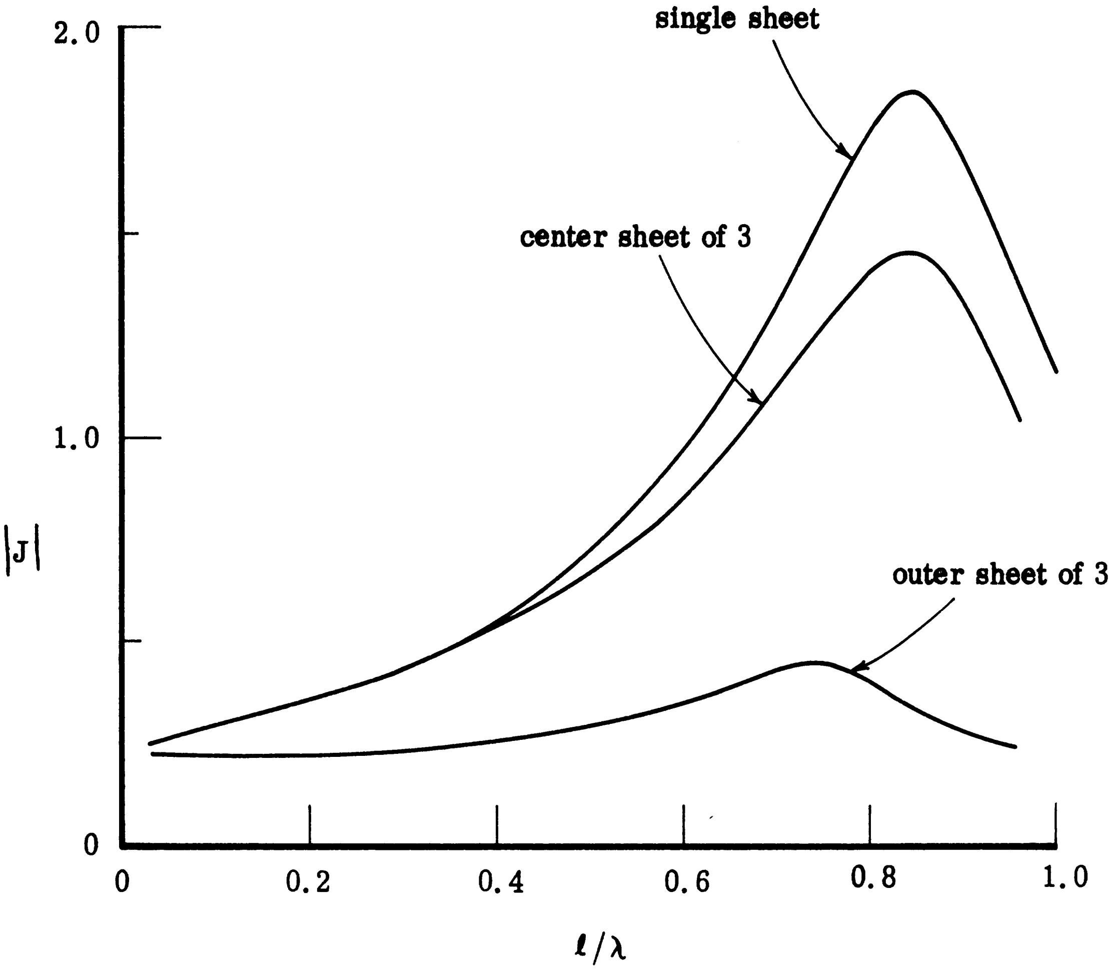

Figure 6. Current distributions on single and multiple sheets.

multiple sheets should be avoided, at least when configured as in Figure 4(c).

V. Comparison of distribution laws

A display of the scattering patterns obtained for four resistance distributions is shown for reference in Figure 7. Included in the diagram is a dashed line representing the trailing edge contribution of the metallic ogival cylinder, as well as the parabolic sheet treatment for the faired cylinder discussed above. The sheet width was fixed in all cases at 1λ and R_{max} was held at a value of 4.0.

Note that the linearly loaded sheet imparts the least cross section reduction, its pattern lying considerably above those of the other distributions. The parabolic loading is best and, in particular, when applied to the 'standard' ogival cylinder, has the lowest side lobe of any of those centered near 35 degrees. The precise reason for the superiority of the parabolic case has yet to be determined. Both the quartic and the cubic distributions produce poorer results than the parabolic, presumably because, as mentioned earlier, such rapid rates of change cannot be supported by a sheet only 1λ wide. Although it may be found that these higher order distributions prove better for wider sheets, our main interest is in accomplishing the reduction with sheets as narrow as possible. This being the case, the parabolic distribution seems optimum.

VI. Conclusion

These miscellaneous studied of resistive sheets have, first of all, confirmed that multiple sheets should best be avoided. A parabolic distribution of sheet resistance seems to be optimum, at least for sheets 1λ wide, and fairing the cylinder to provide a smoother junction between sheet and cylinder is helpful, but only of marginal value. It appears that rapidly changing distributions, such as the cubic and quartic rates, are useful only if sufficiently wide sheets can be tolerated.

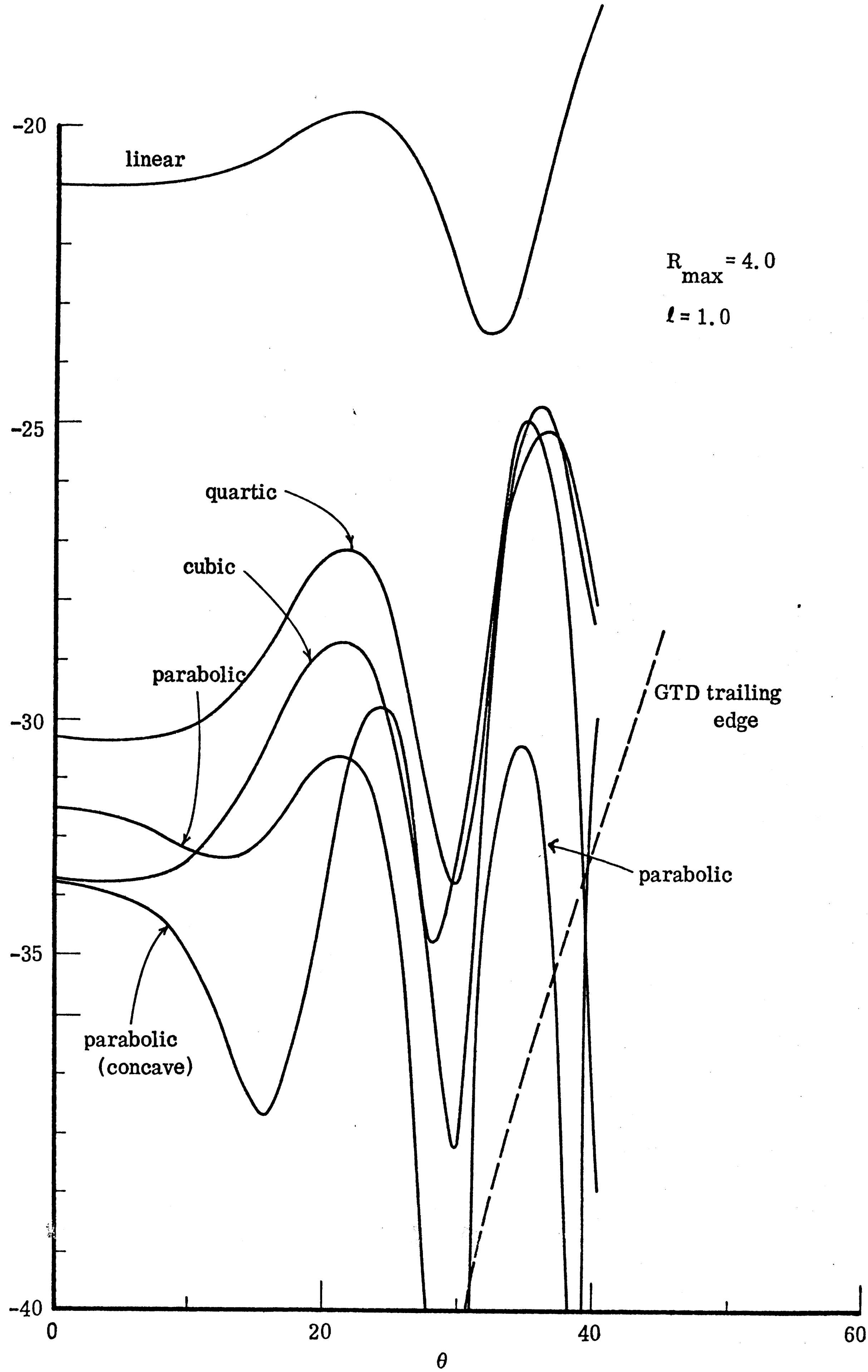

Figure 7. Comparison of backscattering for the four distributions studied.