TRANSFER EFFICIENCY OF THE COMPACT RANGE

R. W. Kreutel

Scientific-Atlanta, Inc.
4357 Park Drive, Suite E, Norcross, GA 30093

Over the years formulations have been developed which provide an implicit measure of transfer efficiency of the compact range. Reasonable accuracy has been demonstrated for both antenna and RCS measurement applications. In general, however, these formulations require specific design details pertaining to the collimating reflector. In this note a more general formulation is examined in which efficiency is explicitly expressed in terms familiar to antenna engineers and which do not directly involve reflector parameters. Applications of this formulation are presented.

Keywords: Antenna, RCS, and Compact Range

Introduction

An early form of the radar equation applicable to the compact range was derived some years ago by Hess and Johnson,[1].

$$\frac{P_R}{P_T} = \frac{G_F^2 \lambda^2 \sigma}{(4\pi)^3 R_o^4}$$

where G_f is the feed gain measured in the direction of the principal ray passing through the center of the quiet zone and R_o is the distance from the feed horn to the reflector measured along the principal ray. Equation (1) has generally been proven valid and gives useful results. However, the form of (1) does not permit its general applicability to all compact range configurations, nor does it give an easily identifiable range efficiency factor.

In this note a simple form of the radar equation, equivalent to equation (1) is examined. This form is completely general in its applicability and explicitly contains efficiency factors which are readily identifiable.

ANALYSIS

In a compact range a flat wavefront is created in the close in near field of a collimating reflector or system of reflectors. The flat wavefront is a useful approximation to a plane wave over a region generally referred to as the quiet zone or the plane wave zone. One measure of the performance of a compact range is the efficiency with which power is delivered from the terminals of the collimator feed to the quiet zone. If the transverse area of the quiet zone is A_o and P_o watts are input at the feed terminals then the power density in the quiet zone is given by

$$(PD)_{QZ} = \eta \frac{P_o}{A_o}$$

where η is the efficiency defined above.

η can be readily factored into the product of two terms which we will call η_1 and $\eta 2$. $\eta 1$ is defined as the fraction of power input to the feed that is actually collimated by the collimating reflector. It is identical to the "spillover efficiency" factor familiar to antenna engineers. The second factor, η_2 is defined as:

$$\eta \overset{\Delta}{=} \frac{\text{Power Delivered to Quiet Zone}}{\text{Power Collimated by Reflector}}$$

In terms of these efficiency factors the radar equation for the compact range can be written as:

$$\frac{P_R}{P_T} = (\eta_1 \eta 2)^2 \frac{\lambda^2 \sigma}{4 \pi A_o^2}$$

where λ is the wavelength and σ is the target RCS.

It is instructive to examine typical values of η_1 and η_2 encountered in practice. In order to do that we broadly group compact range designs into two groups: (1) those that treat edge diffractions with actual edge treatment such as serration or rolled edges (Figure 1) and (2) the 'shaped', two reflector designs (Figure 2). While the implementation approaches are quite different, the purpose is the same - namely, to create an aperture field in the compact range reflector which is fairly uniform over the central section of the reflector and which tapers to a low level at the edges. The relationship between the rate of taper and the amplitude ripple in the quiet zone is fundamental and analogous to similar relations in filter theory.

If we make the assumption that both groups are more or less equally successful in controlling the aperture fields, then it follows that the factor η_2 will be about the same for both cases. In Figure 3 the high frequency limit of η_2 is plotted vs. the ratio of quiet zone dimension to reflector size. For most practical system (i.e. those which must operate over wide bandwidths including low frequencies), η_2 will have a value of about 0.5.

The use of a 'shaped' subreflector to create the aperture field is generally accompanied by high spillover efficiency. This statement follows from the fact that the subreflector can be designed to intercept the feed energy at very low levels while achieving the desired aperture field variation by means of the subreflector shaping. The front fed reflector system on the other hand requires that the main reflector intercept the feed radiation at relatively high level in order to create the proper aperture field.

Note that in the subreflector system there are two sources of spillover: (1) the feed horn spillover around the subreflector and (2) spillover around the main reflector. Spillover around the main reflector will be significant at low frequencies where the subreflector is electrically small. At frequencies at which microwave optics is applicable main reflector spillover can generally be neglected. At these frequencies, assuming a well designed multi-mode or corrugated horn type feed, spillover efficiencies exceeding 90% are achievable.

Spillover efficiency for the front fed system is typically in the 35 to 40% range. These values were obtained by direct integration of standard feed patterns.

RESULTS

Based on the foregoing estimates the overall one way efficiency of the compact range will fall in the range 15% to 45%. Typical data for the generic collimator types are plotted in Figure 4 as a function of the rates of quiet zone size to reflector size.

REFERENCES

Hess, D.W. and Johnson, R.C. 'Compact Ranges Provide Accurate Measurement of Radar Cross-Section', Microwave Systems News, September 1982.

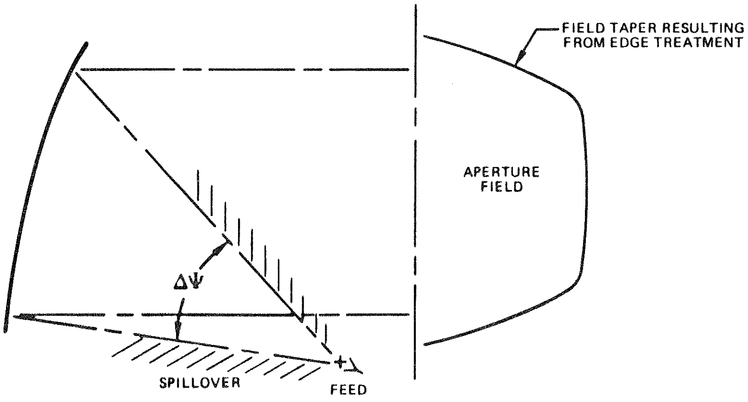

FIGURE 1

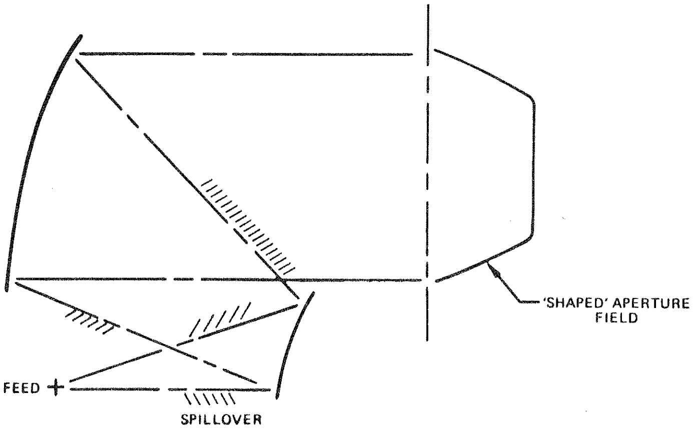

FIGURE 2

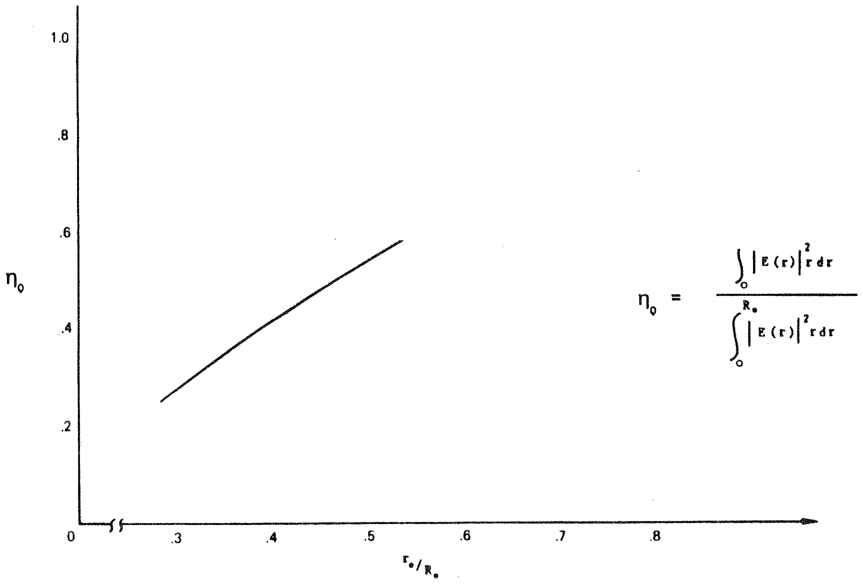

FIGURE 3

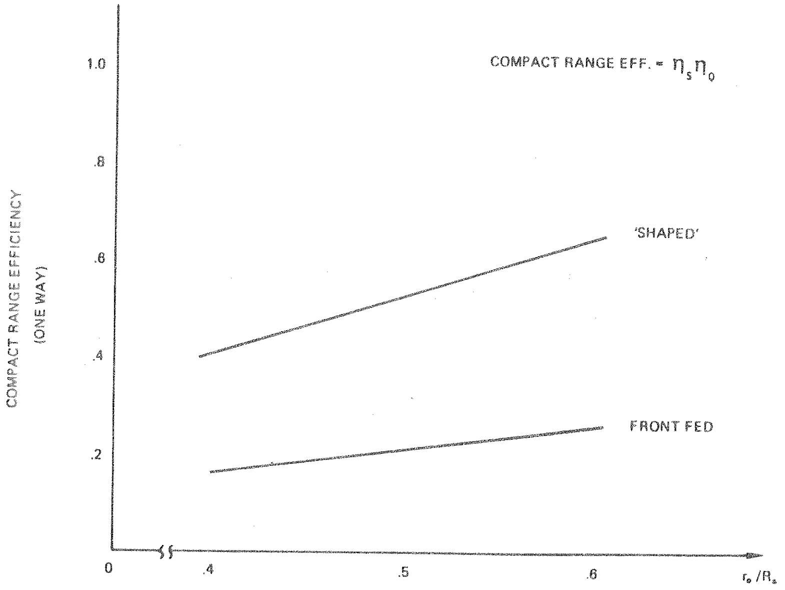
COMPACT RANGE EFF. = $\eta_s \eta_0$
'SHAPED'
FRONT FED
COMPACT RANGE EFFICIENCY (ONE WAY)
1.0
.8
.6
.4
.2
0
.4
.5
.6
r_o/R_s

FIGURE 4