# 7.3A ANTENNA SIZE FOR MST RADARS

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The purpose of this note is to point out that it is possible to make the antenna of an MST radar too large (unless some sort of focussing scheme is used). And it is not just that the signal ceases to become stronger beyond some critical antenna size; the received scattered signal actually becomes weaker as the antenna size is increased whenever the target is in the near field (Fresnel region) of the antenna. The Arecibo antenna is a case in point; for MST work it would be worthwhile to use a feed which illuminated only a portion of the dish, as we shall see.

The radar equation for a monostatic radar (single antenna for transmitting and receiving) can be written as

$$P_r = \frac{P_t G \, \Sigma \, A_{eff}}{(4\pi R^2)^2} \qquad (1)$$

where $P_r$ and $P_t$ are the received and transmitted power, G is the antenna gain, $A_{eff}$ is the antenna effective area, $\Sigma$ is the total radar scattering cross section of the target, and R is the range to the target. (The radar equation should really be written as an integral over the antenna pattern, but we omit this complication here.) The gain and effective area of an antenna are related by the well-known relation

$$G = 4\pi A_{eff}/\lambda^2 \qquad (2)$$

where $\lambda$ is the wavelength. It is important to note that this result follows directly from the reciprocity theorem for antennas (identical transmitting and receiving patterns) and that this theorem holds for any antenna separation (e.g., STUTZMAN and THIELE, 1981); i.e., it applies in the near field as well as the far field of an antenna. Next we assume that the target is 'soft' (fills the beam) and so

$$\Sigma = \sigma V_s \qquad (3)$$

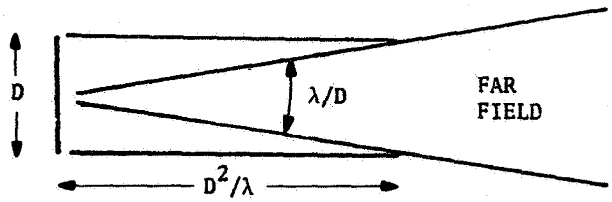
where $\sigma$ is the scattering cross section per unit volume and $V_s$ is the scattering volume defined by the pulse length and the beam, i.e.,

$$V_s \cong \Omega R^2 \Delta r \cong \frac{4\pi}{G} R^2 \Delta r \qquad (4)$$

where $\Omega$ is the beam solid angle and $\Delta r$ is the pulse length. Combining (1)-(4) and dropping proportionality constants gives

$$P_r/P_t \sim \frac{\lambda^2 \sigma \Delta r}{R^2} G \sim \frac{\sigma \Delta r}{R^2} A_{eff} \qquad (5)$$

Now all we need to do is express G in terms of the antenna size and the range. The relationship depends upon whether we are in the near or far field of the antenna (Fresnel or Fraunhofer region). As shown in the sketch below, the beam will be more or less cylindrical out to a distance of 1-2 x $D^2/\lambda$, where D is the diameter of a circular (say) aperture, and will spread out with a beam




width of roughly $\lambda/D$ for larger distances (the far field). Hence we can write, very approximately,

$$
\begin{aligned}
G &= 4\pi R^2/(\text{Beam area}) \\
&\cong 4\pi R^2/A \qquad\qquad\qquad \text{(near field)} \\
&\cong 4\pi R^2/(\lambda R/D)^2 \cong 4\pi A/\lambda^2 \quad \text{(far field)}
\end{aligned}
\tag{6}
$$

Expressed in another way, using (2)

$$
\begin{aligned}
A_{eff} = \lambda^2 G/4\pi &\cong \lambda^2 R^2/A \quad \text{(near field)} \\
&\cong A \qquad\qquad \text{(far field)}
\end{aligned}
\tag{7}
$$

The optimum antenna size for receiving the scattered signal from a given range R would be very roughly $A \cong \lambda R$. Note that $A_{eff}$ and hence the received signal strength decreases with increasing antenna size A in the near field, and that this result has been obtained using only the most basic principles of antenna theory. Of course, in the near field (Fresnel region) the antenna could be focussed in some way to give a much stronger return, but in many cases focusing will not be practical.

As an example of how the numbers can work out, consider the Arecibo Observatory antenna, with a diameter D of 300 m and a wavelength of 0.7 m for the 430-MHz radar. The near field in this case extends beyond 100 km even though the dish is not uniformly fed (see SHEN and BRICE, 1973, for detailed calculations of the Arecibo case), and at a range of 20 km, say, (7) gives $A_{eff} \cong 3 \times 10^3$ m$^2$ vs $A \cong 7 \times 10^4$m$^2$. A feed which fed only a fraction of the dish should actually improve the signal-to-noise ratio for MST experiments at Arecibo. These effects are less important for VHF radars, but may still need to be considered for observations in the troposphere and lower stratosphere.

REFERENCES

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