From AMS Glossary

radar equation

An equation expressing the power of a radar echo at the input of the receiving antenna of a radar as a function of the range and radar cross section of a target.

For a point target and plane-polarized radiation, it is written

$$P_r = P_t \frac{G^2 \lambda^2 \sigma}{64 \pi^3 r^4},$$

where P_r is the received power, P_t the peak power transmitted by the radar, G the gain of the antenna, λ the wavelength, r the distance to the target, and σ the radar cross section of the target. For a distributed target such as precipitation, which fills the radar beam, the radar equation may be written

$$\overline{P_r} = P_t \frac{G^2 \lambda^2 \theta \phi h}{1024 \pi^2 \ln 2} \frac{\eta}{r^2},$$

where θ and ϕ denote the antenna beamwidths in the horizontal and vertical planes, h is the pulse length of the transmitted signal, and η is the radar reflectivity of the target. This equation assumes that the antenna pattern has a Gaussian shape and that the scattering volume is uniformly filled. The radar signals received from distributed targets fluctuate; the overbar on P_r indicates that it is a time average over a period equal to several multiples of the coherence time of the received signal. From the radar equation, the fundamental measurable property of precipitation is the radar reflectivity η, which depends on the sizes and concentration of the hydrometeors and their thermodynamic phase. For hydrometeors small enough for the Rayleigh scattering approximation, it is given by

$$\eta = \frac{|K|^2 \pi^5}{\lambda^4} Z,$$

where
$|K|^2$
is a dielectric factor, approximately equal to 0.93 for water and 0.21 for ice. The factor Z is called the radar reflectivity factor of the precipitation. It equals the sum of the sixth- powers of the diameters of the water drops in a unit volume of space or of the melted diameters of the snow and ice particles in a unit volume. It may be expressed in terms of the drop-size distribution as

$$Z = \int_0^\infty N(D) D^6 dD,$$

where $N(D)\ dD$ is the number of drops per unit volume with diameters in the interval dD. (For ice-phase precipitation, $N(D)$ is the distribution of melted diameters.)

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