Dealing with Roughness & Irregular Geometries

$$P_R = P_T \left(\frac{\lambda}{4\pi}\right)^2 G_T G_R \frac{1}{\left[2\left(h+\frac{z}{n}\right)\right]^2} T^2 L^2 B^2 \rho \Gamma$$

Somewhat rough surface

$$P_R = P_T \frac{\lambda^2}{(4\pi)^3} G_T G_R \frac{1}{\left(h+\frac{z}{n}\right)^4 n^2} T^2 L^2 B^2 \sigma^0 A$$

Very rough surface,
irregular geometry

Coherent vs. Incoherent Scattering

Coherent:

Reflected component of the incident wave that follows Snell's Law.
Phase is very important for understanding how coherent wave interact.

Incoherent:

Component of the incident wave that "randomly" scatters in all directions.
No long worried about phase because the phase is effectively random

Usually dealing with these three regimes for radar sounding

Smooth Surface = mostly coherent scattering

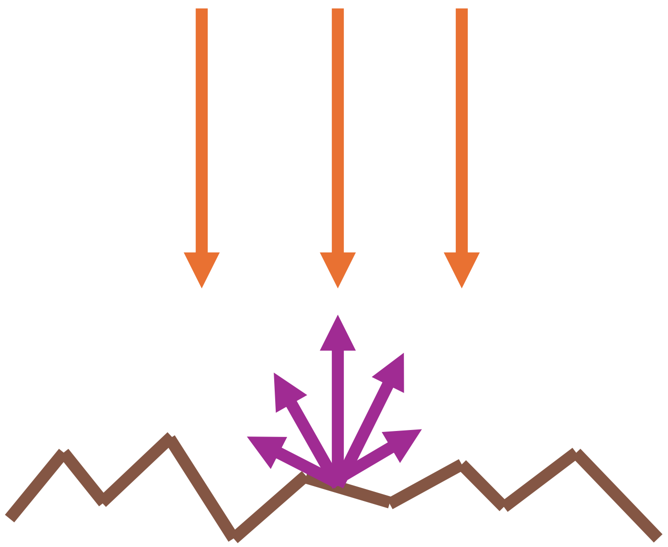
Moderately Rough Surface = mix of coherent and incoherent scattering

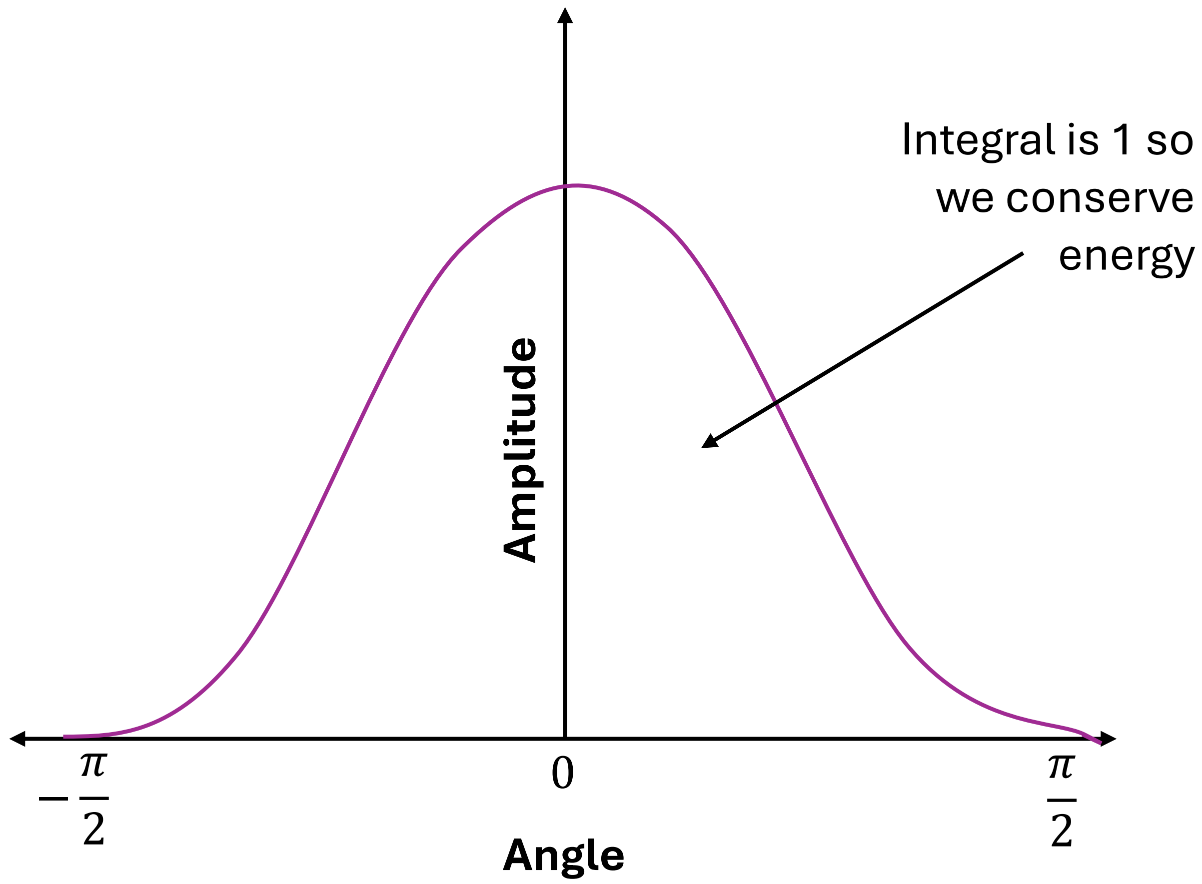
Very Rough Surface = only incoherent scattering

Volume Scattering = only incoherent scattering

Angular Scattering Function

How much of the incident power does an object reflect in each direction?





Radar Cross-Section

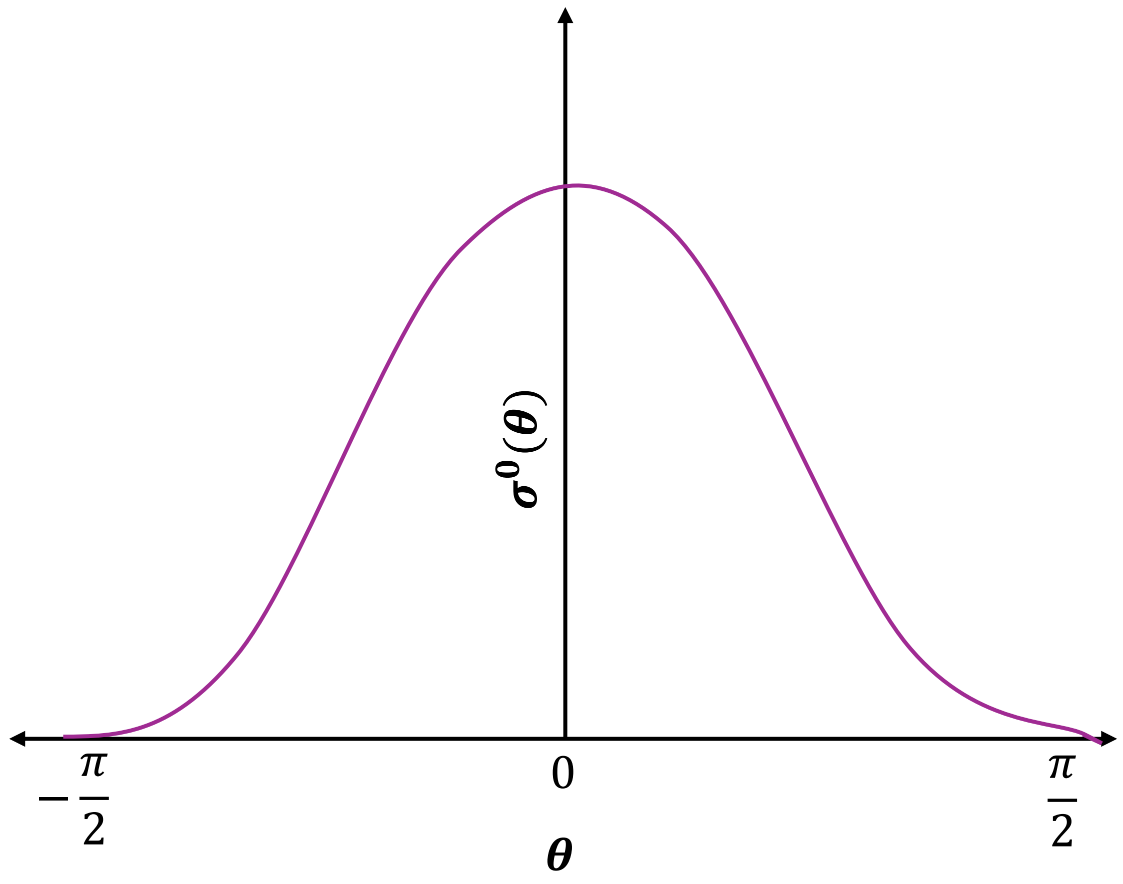
A more unintuitive way to define the angular scattering function…

Formal Definition:

$$\sigma = \lim_{R\to\infty}\left(4\pi R^2 \frac{P_R}{P_T}\right)$$

Normalized Radar Cross-Section:

$$\sigma^0 = \frac{\sigma}{A}$$



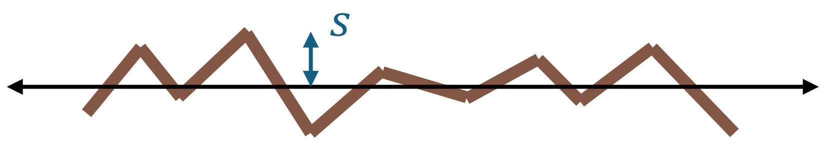
Reflection from a Smooth Surface "Specular Reflection"

What does smooth mean?

$$s < \frac{\lambda}{32 \cos \theta}$$

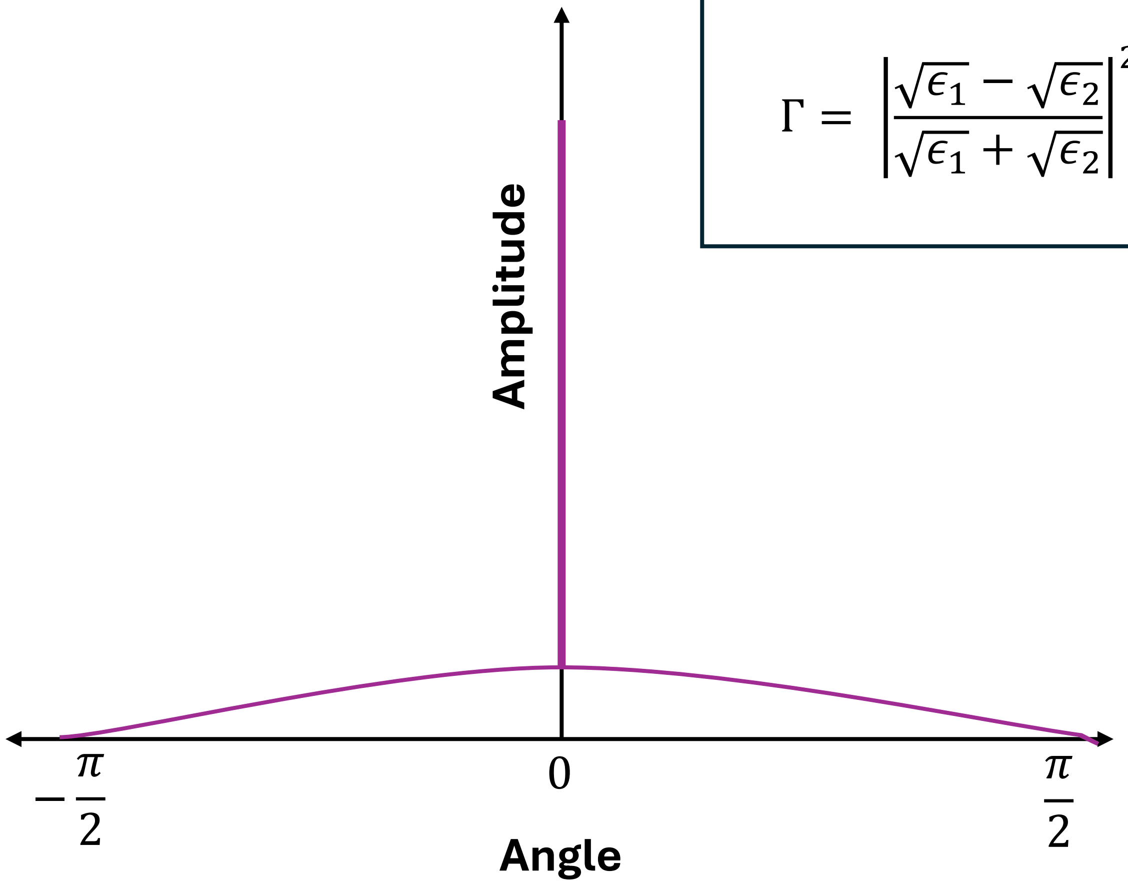
"Fraunhofer Roughness Criterion"

s = mean deviation from a smooth surface
λ = radar wavelength
θ = incidence angle



Use Snell's Law and Fresnel reflectivity.

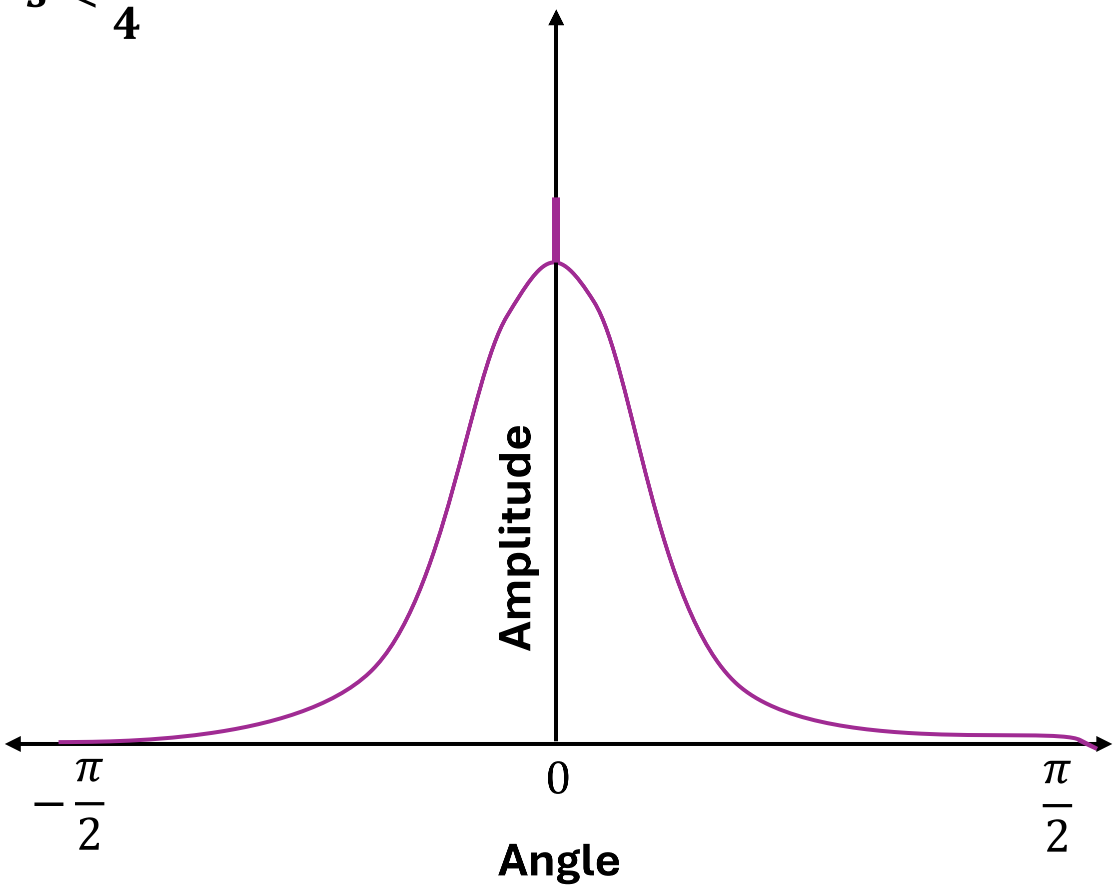
$$\Gamma = \left| \frac{\sqrt{\epsilon_1} - \sqrt{\epsilon_2}}{\sqrt{\epsilon_1} + \sqrt{\epsilon_2}} \right|^2$$



Reflection from a Semi-Smooth Surface

What does semi-smooth mean?

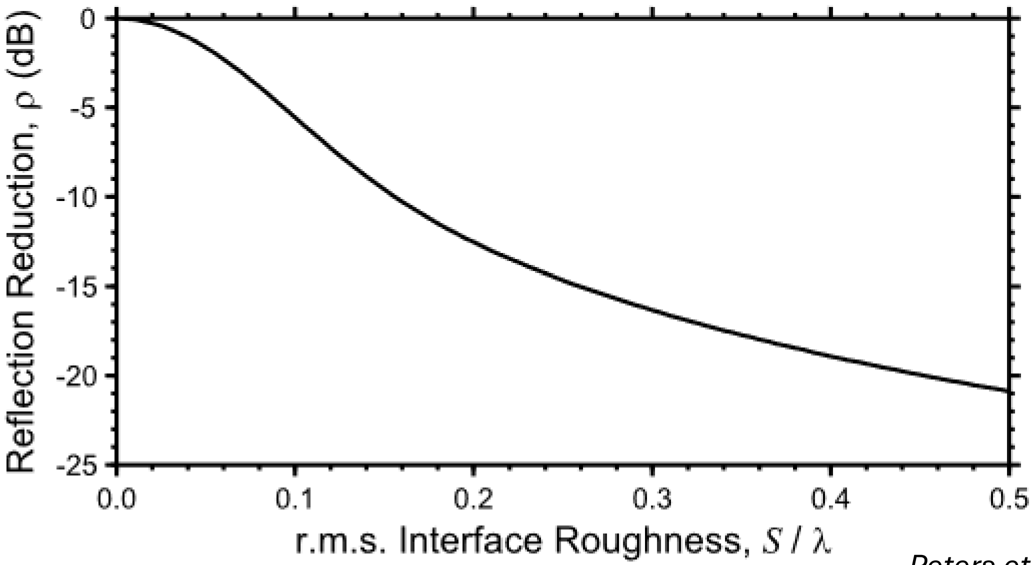
$$\boldsymbol{s < \frac{\lambda}{4}}$$



Add a "roughness modifier" to the smooth surface radar equation.

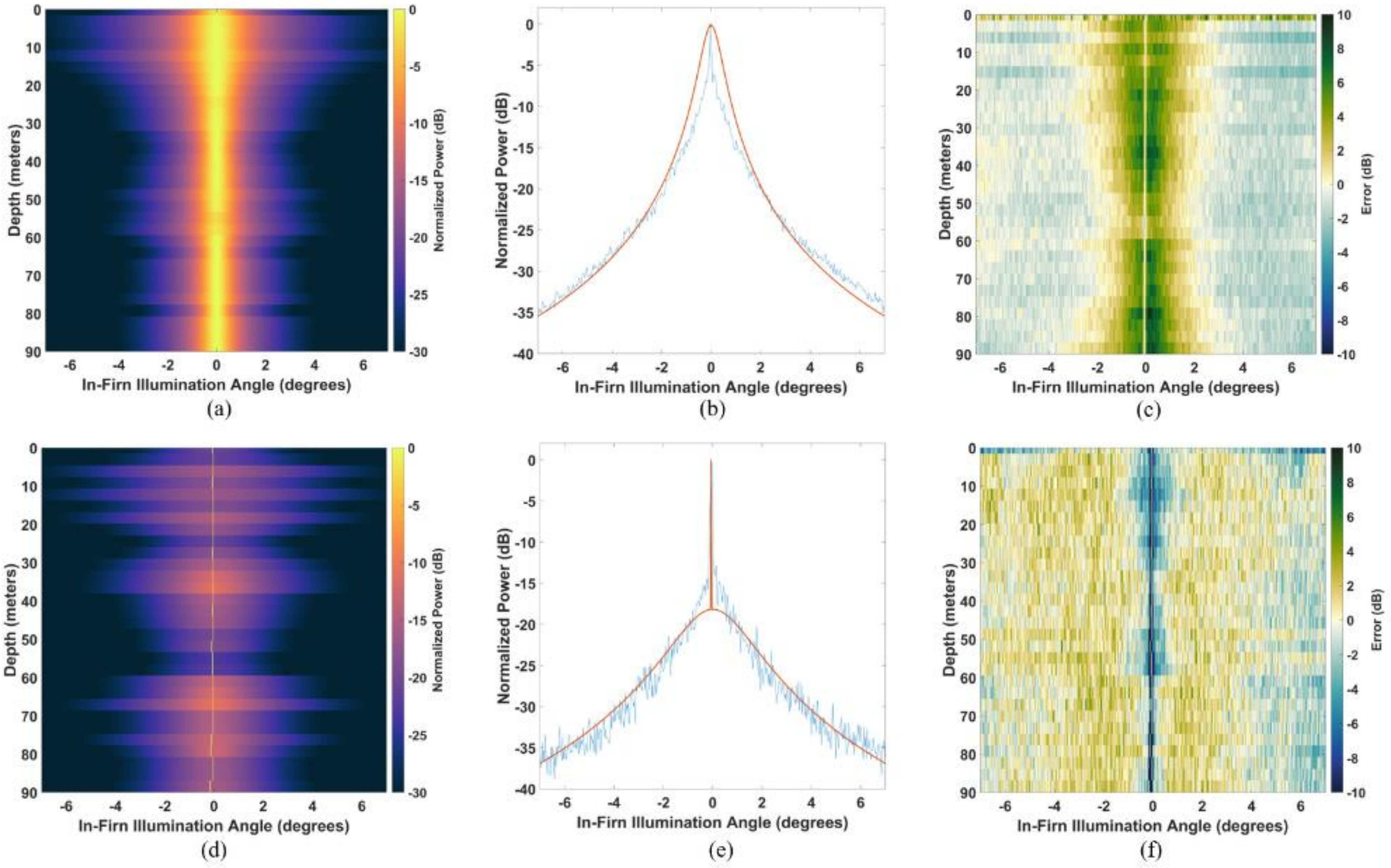
$$g = \frac{4\pi s}{\lambda}$$

$$\boldsymbol{\rho = e^{-g^2} I_0^2\left(\frac{g^2}{2}\right)}$$

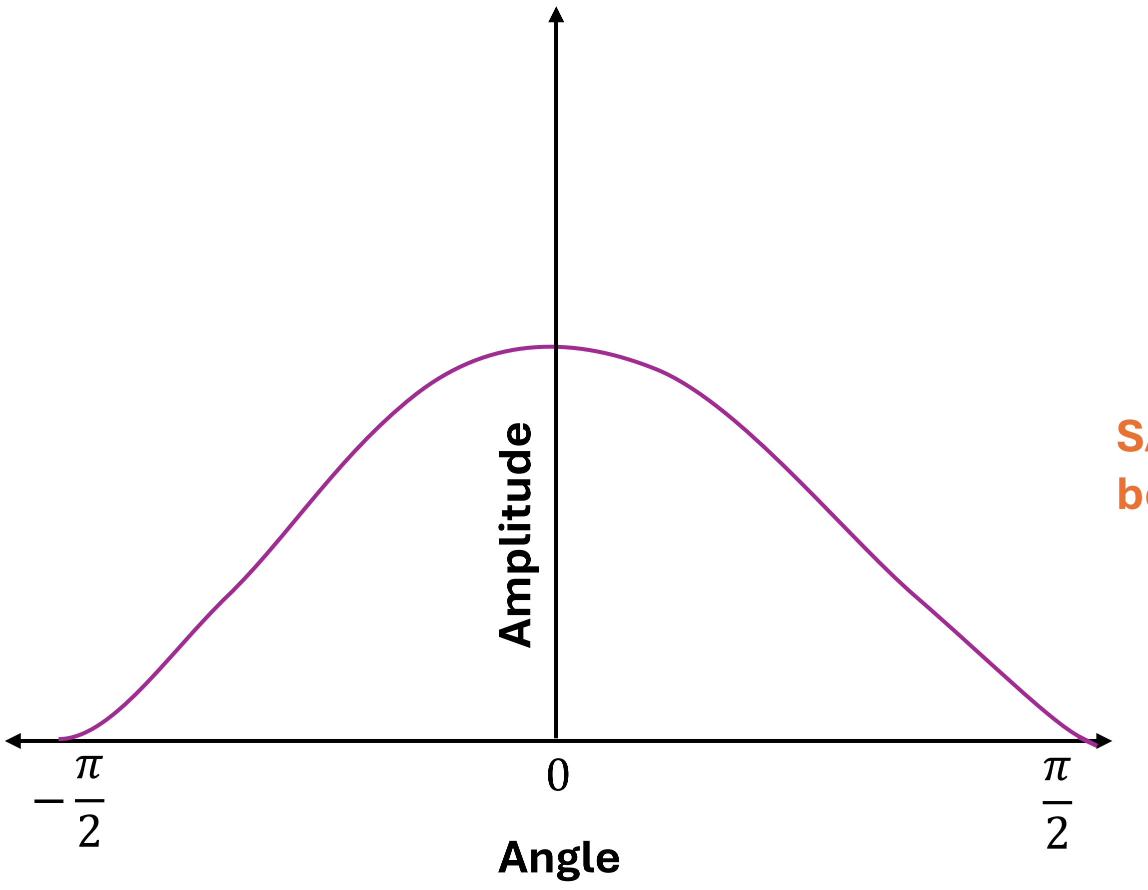


Peters et al. (2005)

Real Radar Example!



Scattering from a Rough Surface

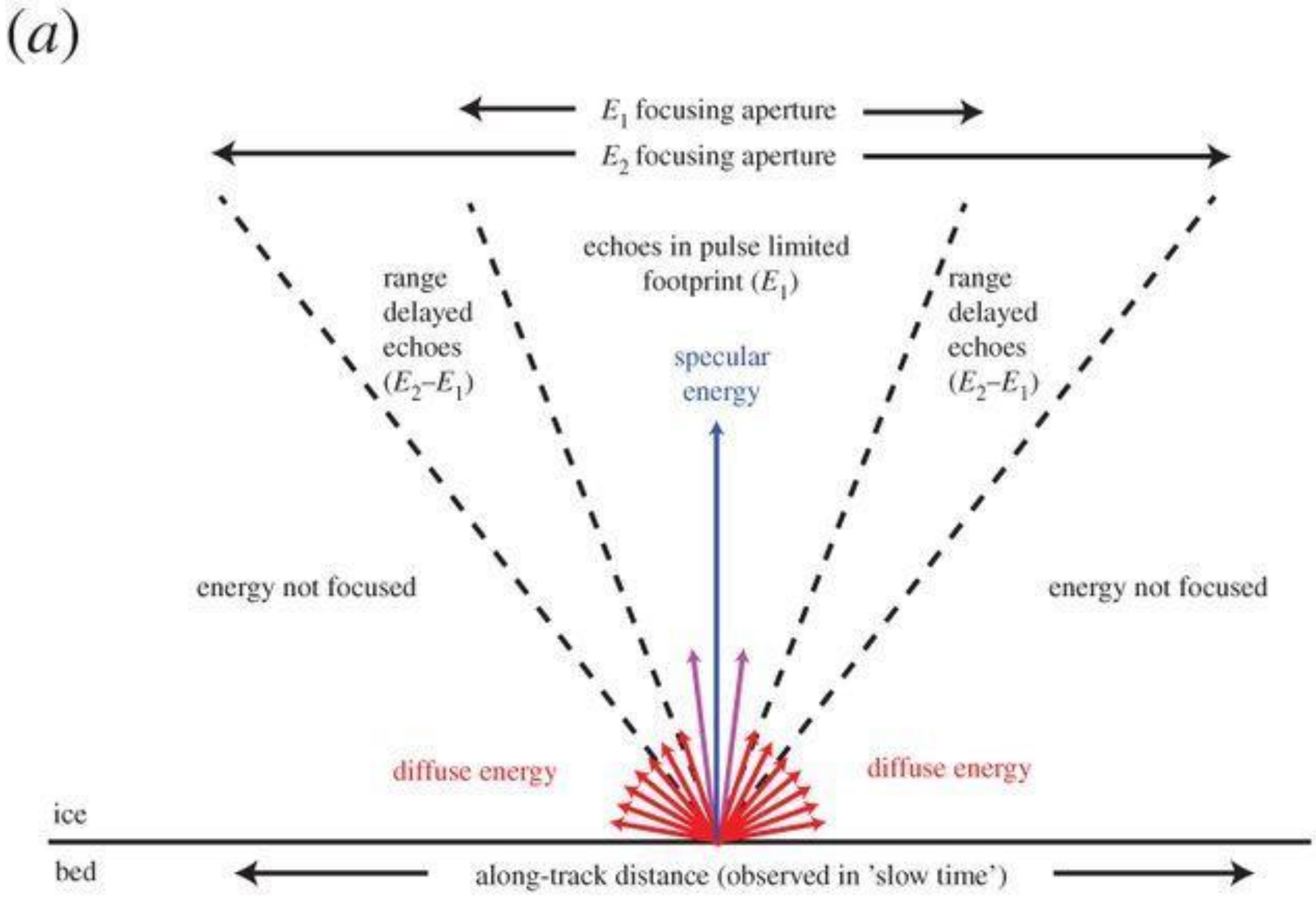


Lots of models for the radar cross-section, some work better than others in various situations. A simple one is given below just as an example...

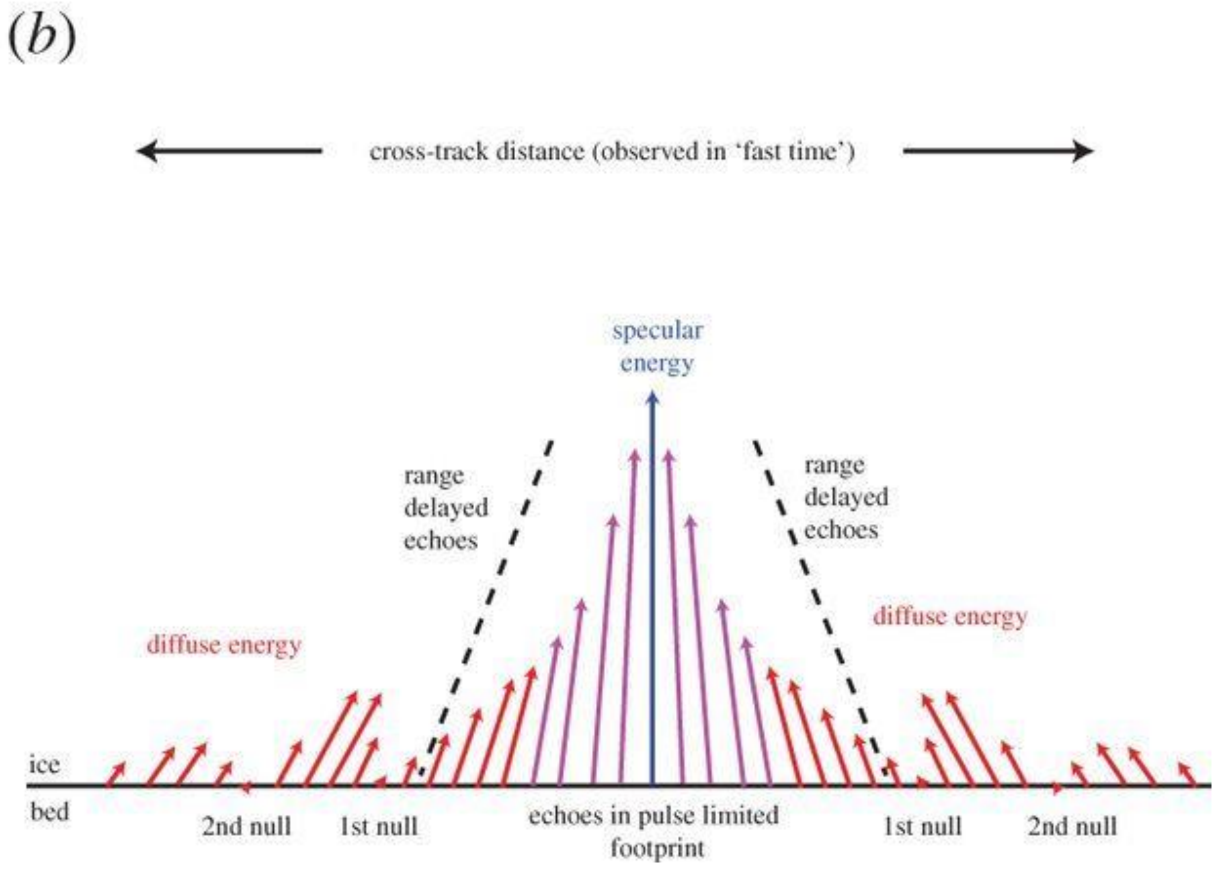
$$\sigma^0 = \frac{\Gamma e^{-\frac{\tan^2\theta}{2s^2}}}{2s^2\cos^4\theta}$$

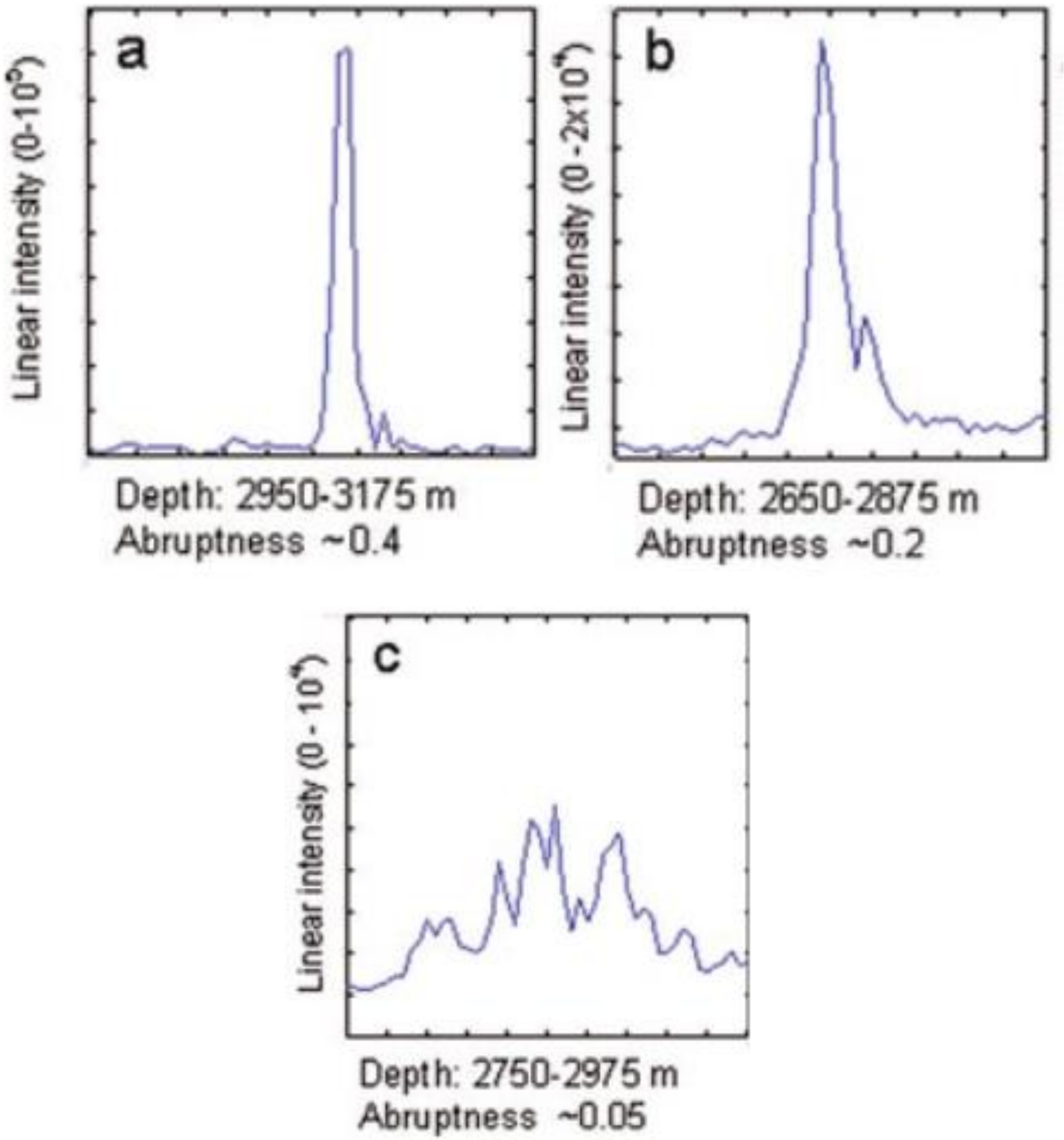
SAR instruments are very often operating in this regime, because the typical wavelength is only 5 cm.

Specularity, Abruptness, and RSR

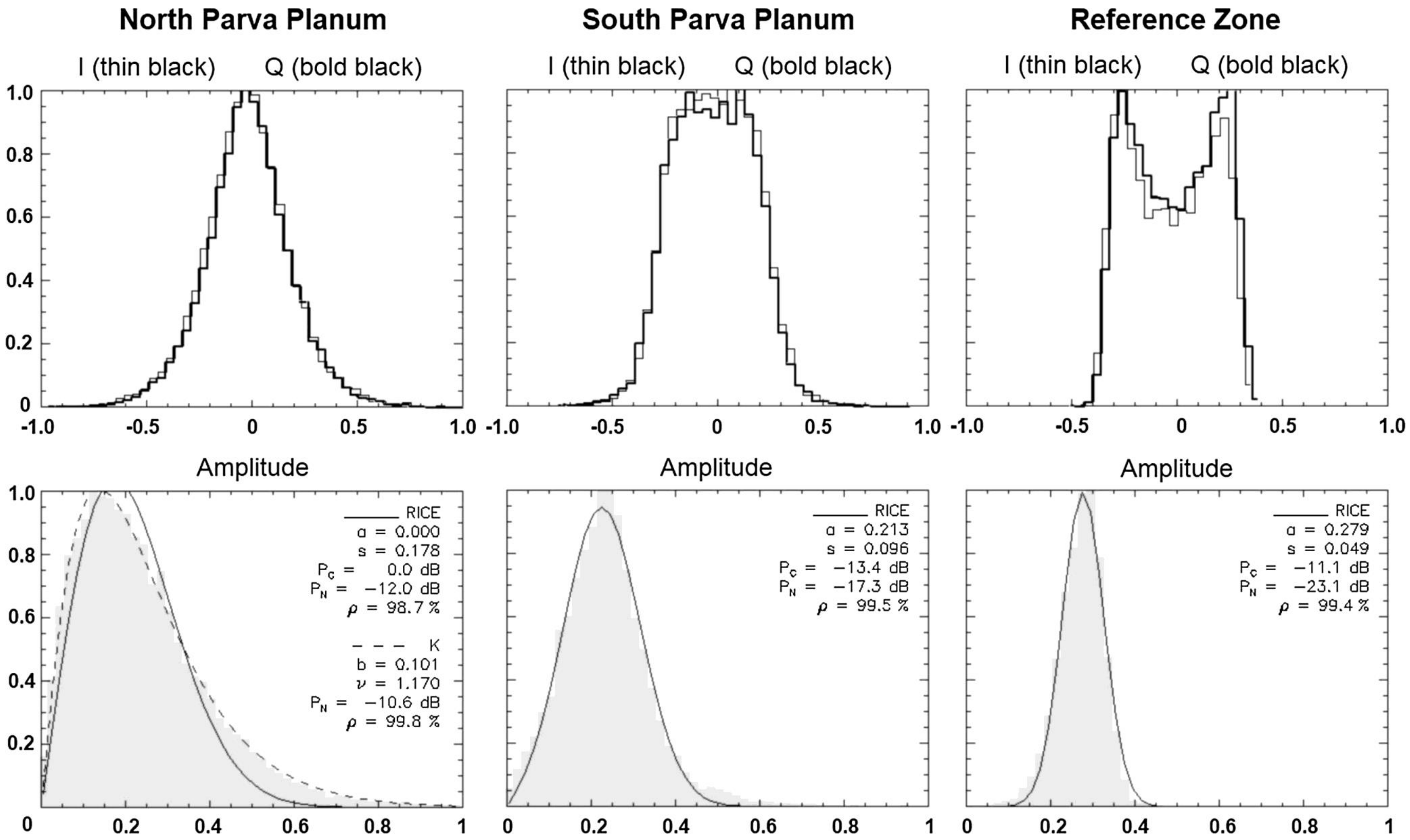


Specularity, Abruptness, and RSR





Specularity, Abruptness, and RSR



Scattering from Large Irregular Geometries

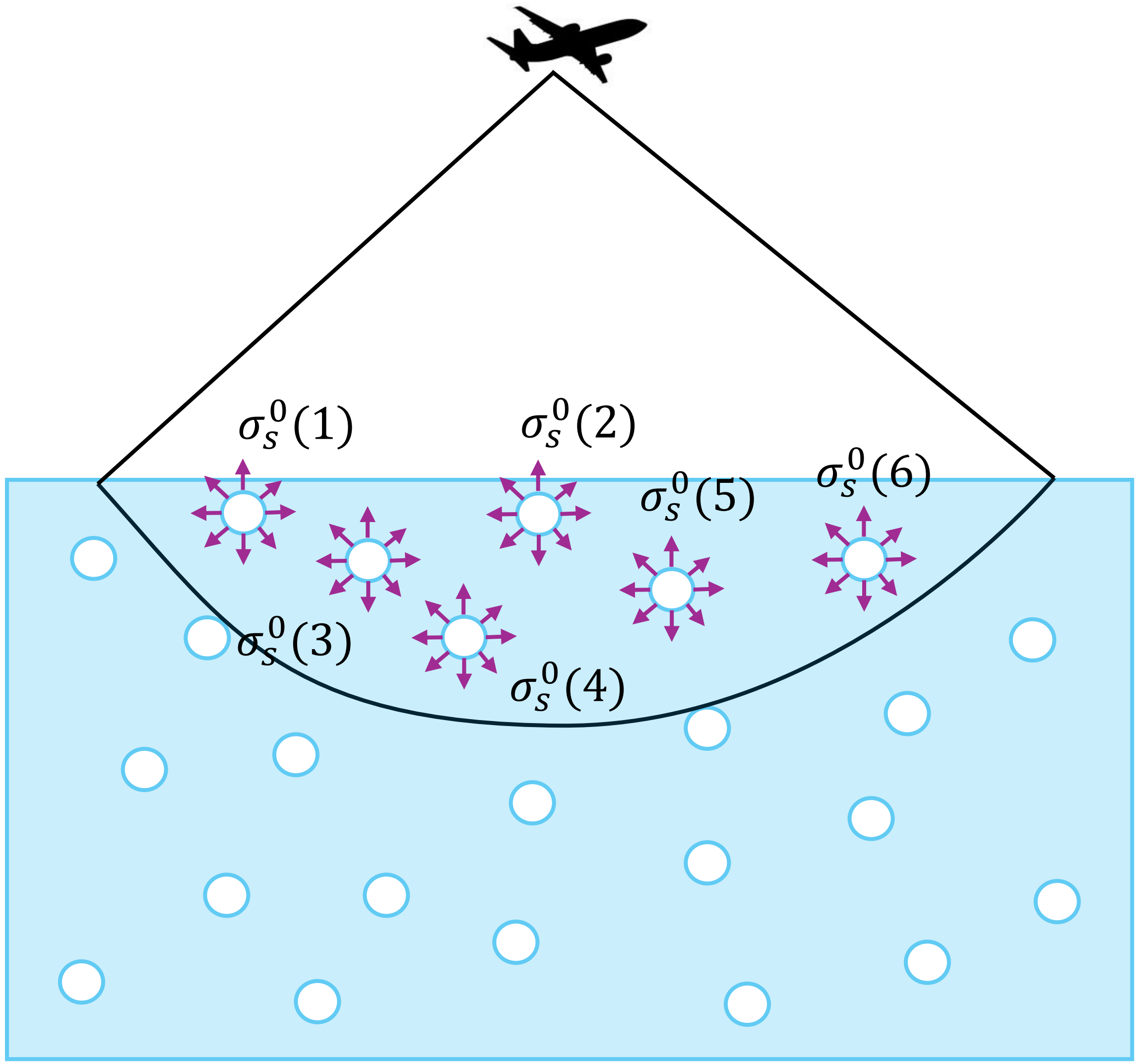
Look up the radar cross-section in a book and hope that someone either measured it or came up with an analytic formula… ☹

Cylinders, spheres, cubes, etc you can find.

Large = 1 or more radar wavelengths across

Volume Scattering

Aggregate return from many small, independent scattering objects within the radar footprint



$$\sigma = \sum_{i=1}^{N} \sigma_s^0(i)$$