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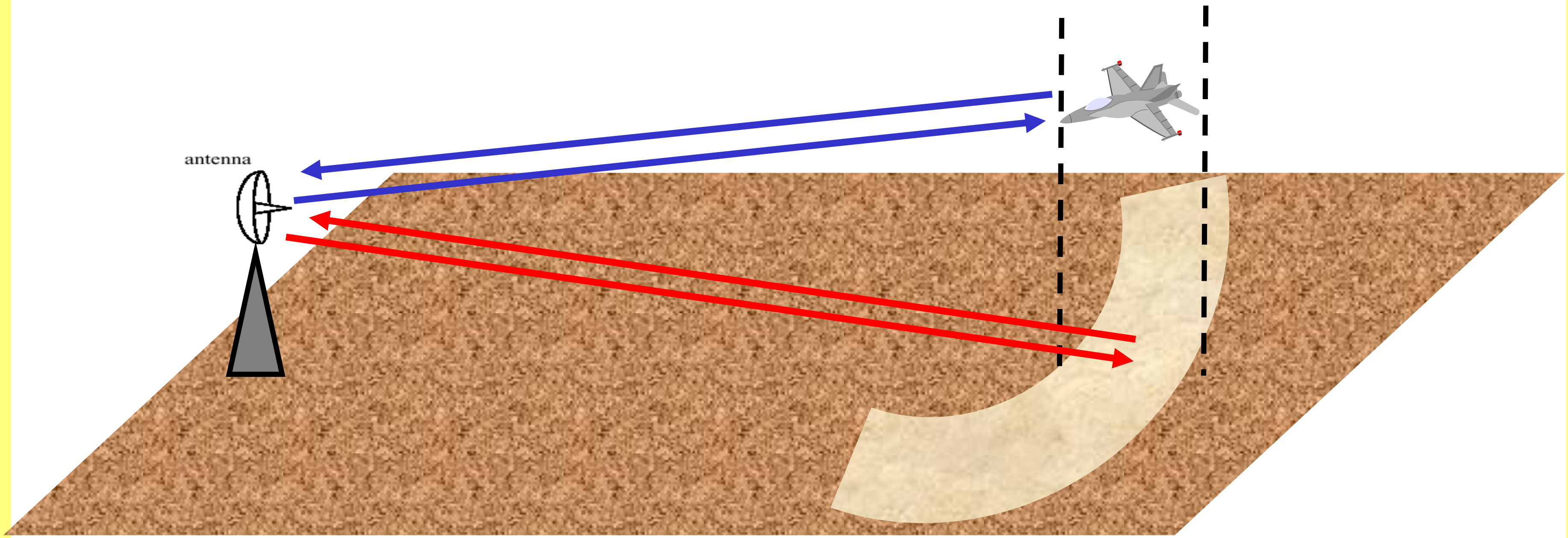
CLUTTER



Area contributing clutter at target's range

To describe the radar return from an extended target, like ground or sea, we define a new parameter:

Radar cross section per unit area of the surface

or

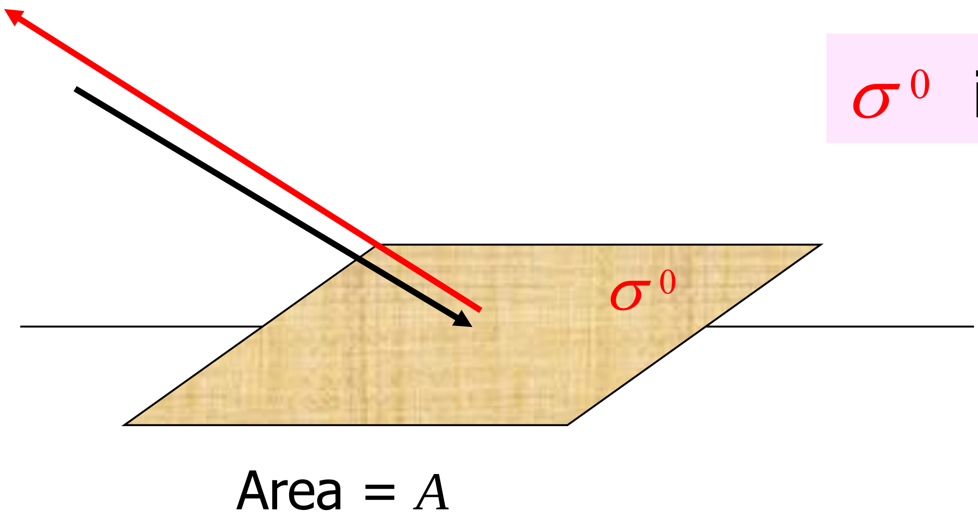
Normalized radar cross section (NRCS)

or

σ^0

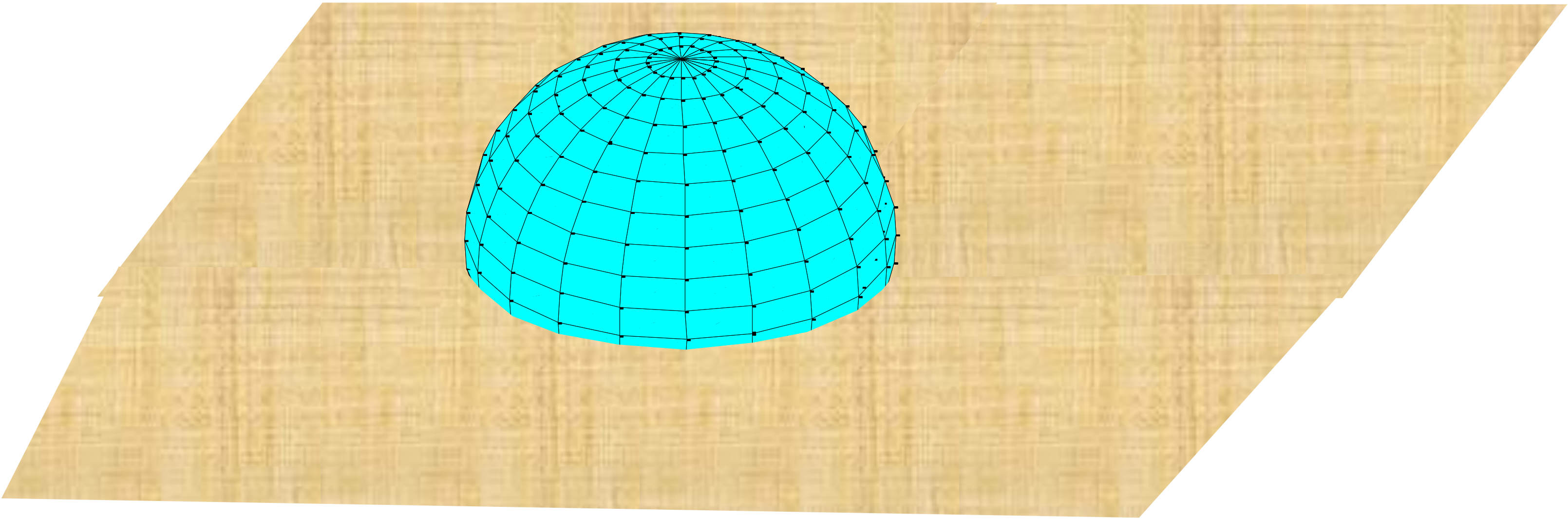
$$\sigma = A\sigma^0$$

σ^0 is dimensionless



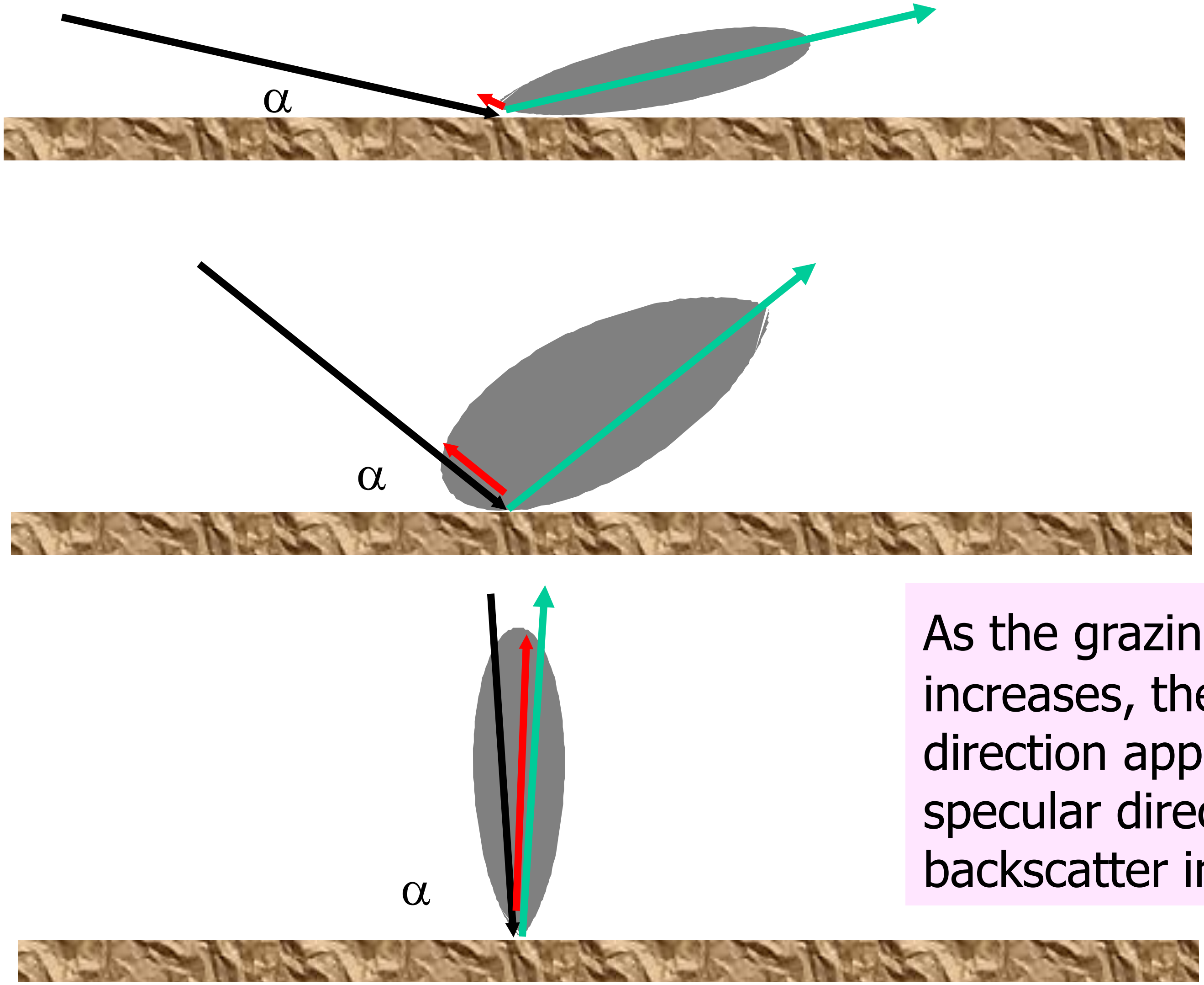
If the surface would have reflected back isotropically, then $\sigma^0 = 1$

If the surface would have reflected back isotropically only above the surface then $\sigma^0 = 2$

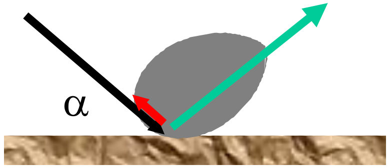


Typical surfaces do not reflect back isotropically.

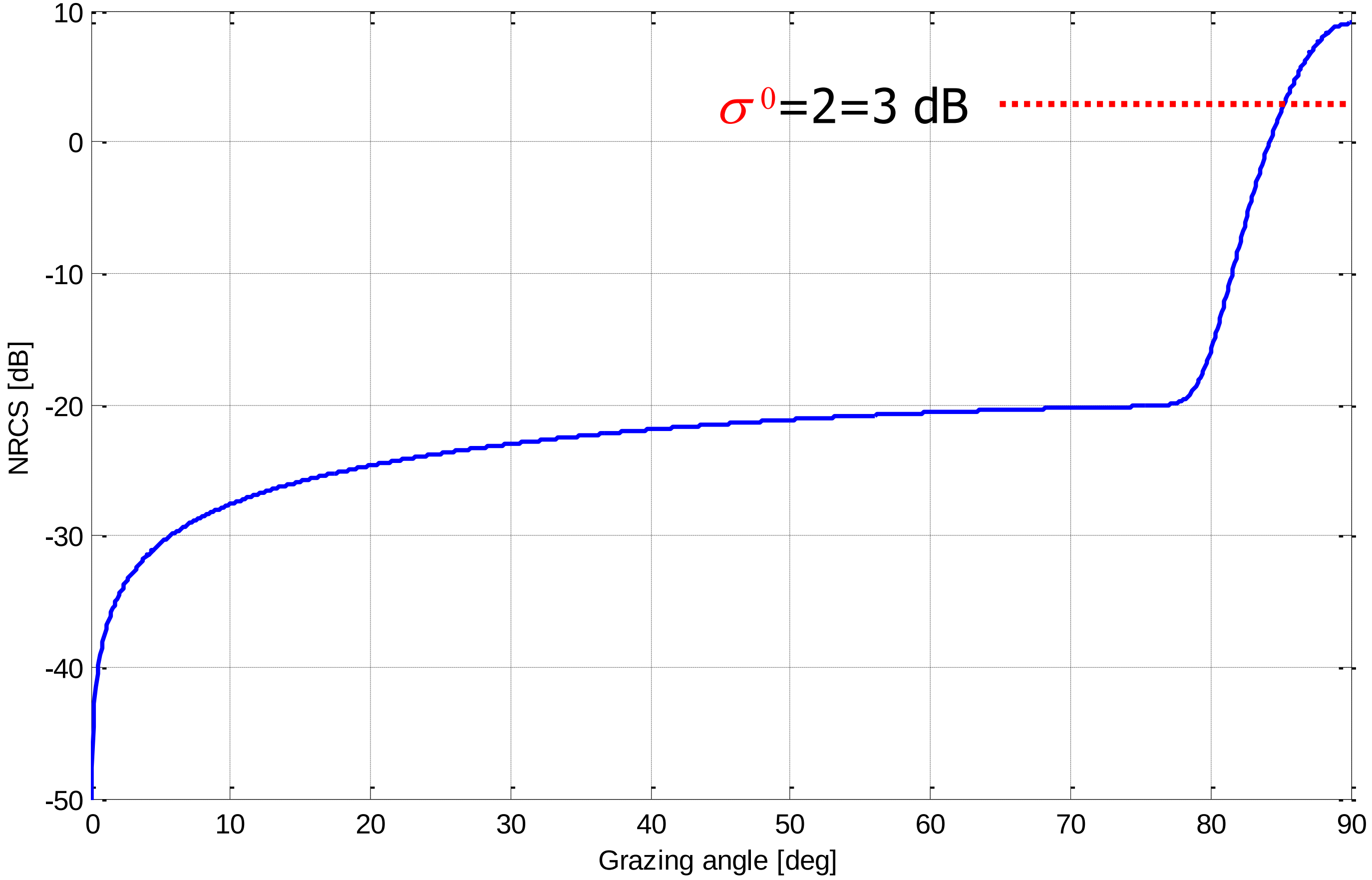
σ^0 depends strongly on the grazing angle and the surface roughness



As the grazing angle α increases, the backscatter direction approaches the specular direction, and the backscatter intensity increases.



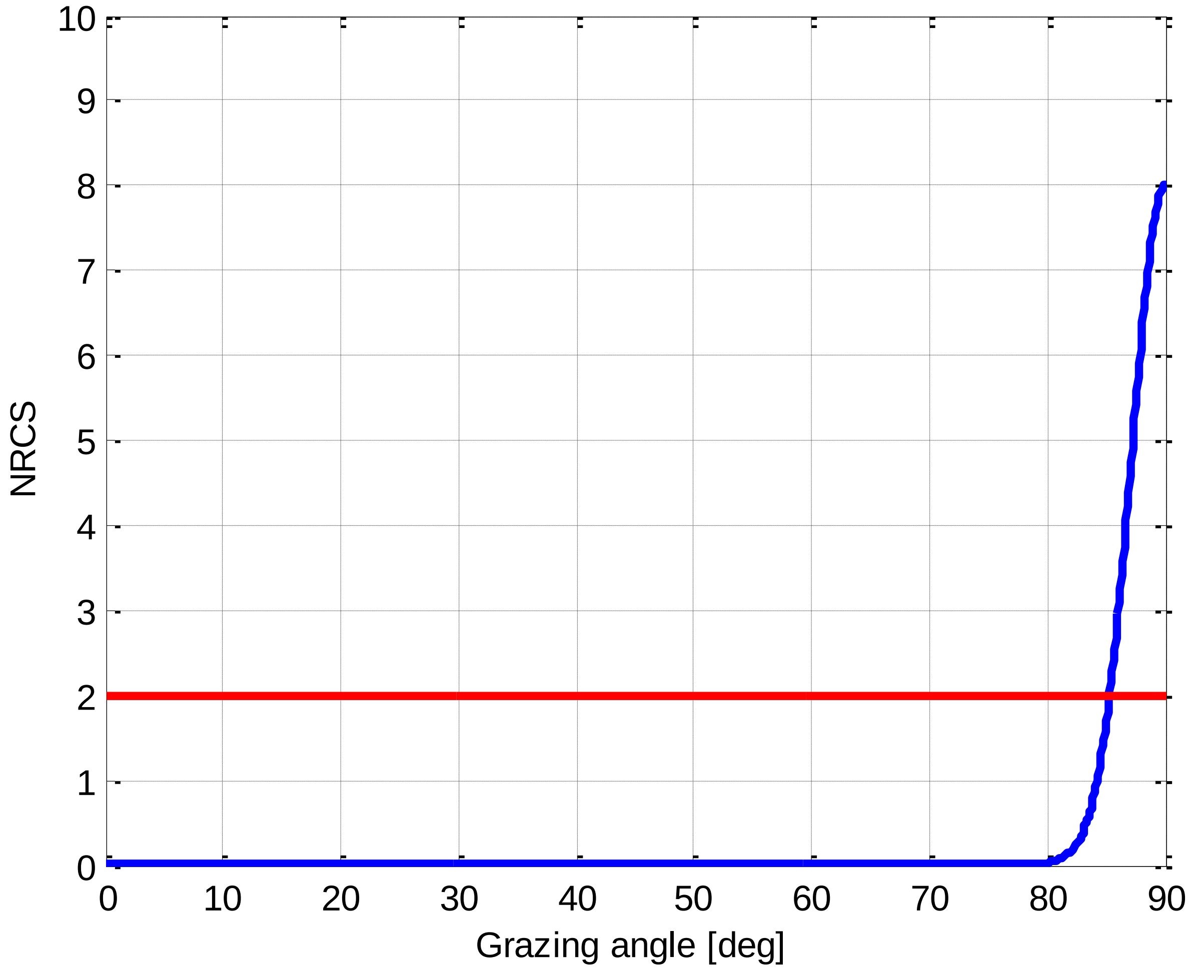
Typical $\sigma^0(\alpha)$ - Normalized radar cross section (NRCS)



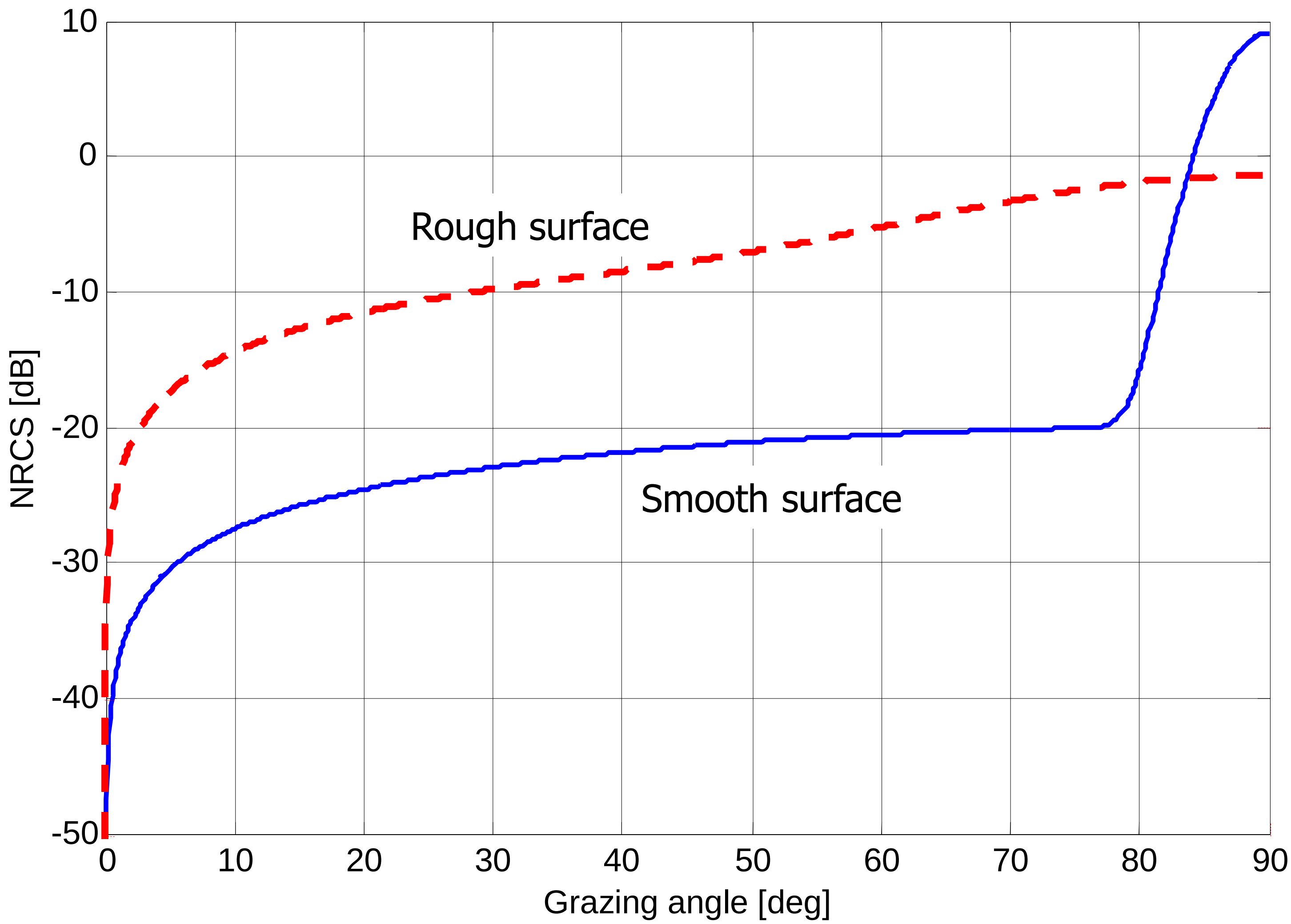
$$\sigma_0(\alpha) = \gamma \sin\alpha + \beta \exp\left[\frac{-\left(\frac{\pi}{2}-\alpha\right)^2}{\delta^2}\right] \quad , \quad \gamma = 0.01, \quad \beta = 8 \; , \quad \delta = \tfrac{\pi}{180}4$$

nrcs

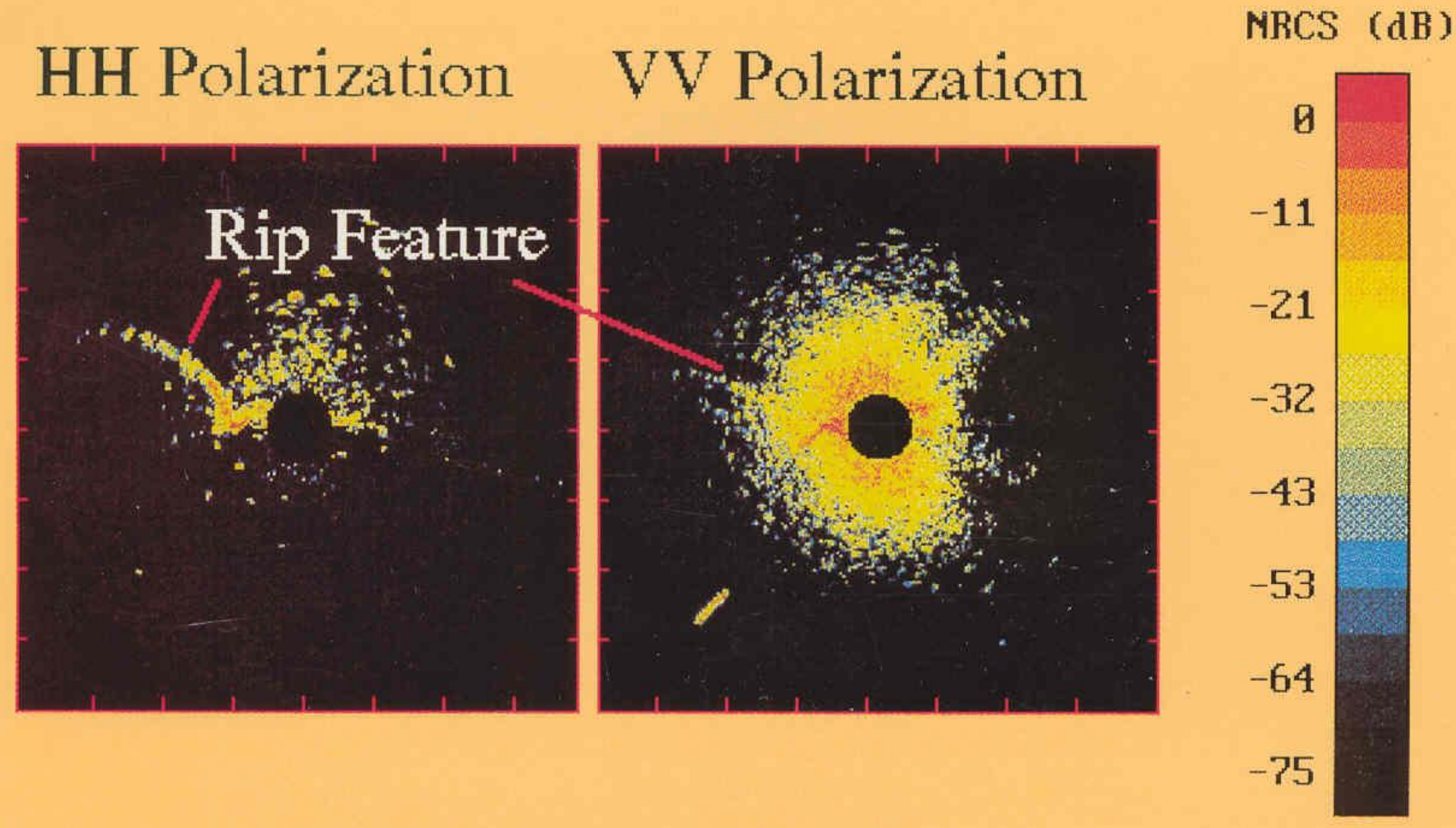
Linear scale



nrcs


10
0
-10
-20
-30
-40
-50
NRCS [dB]
0
10
20
30
40
50
60
70
80
90
Grazing angle [deg]
Rough surface
Smooth surface

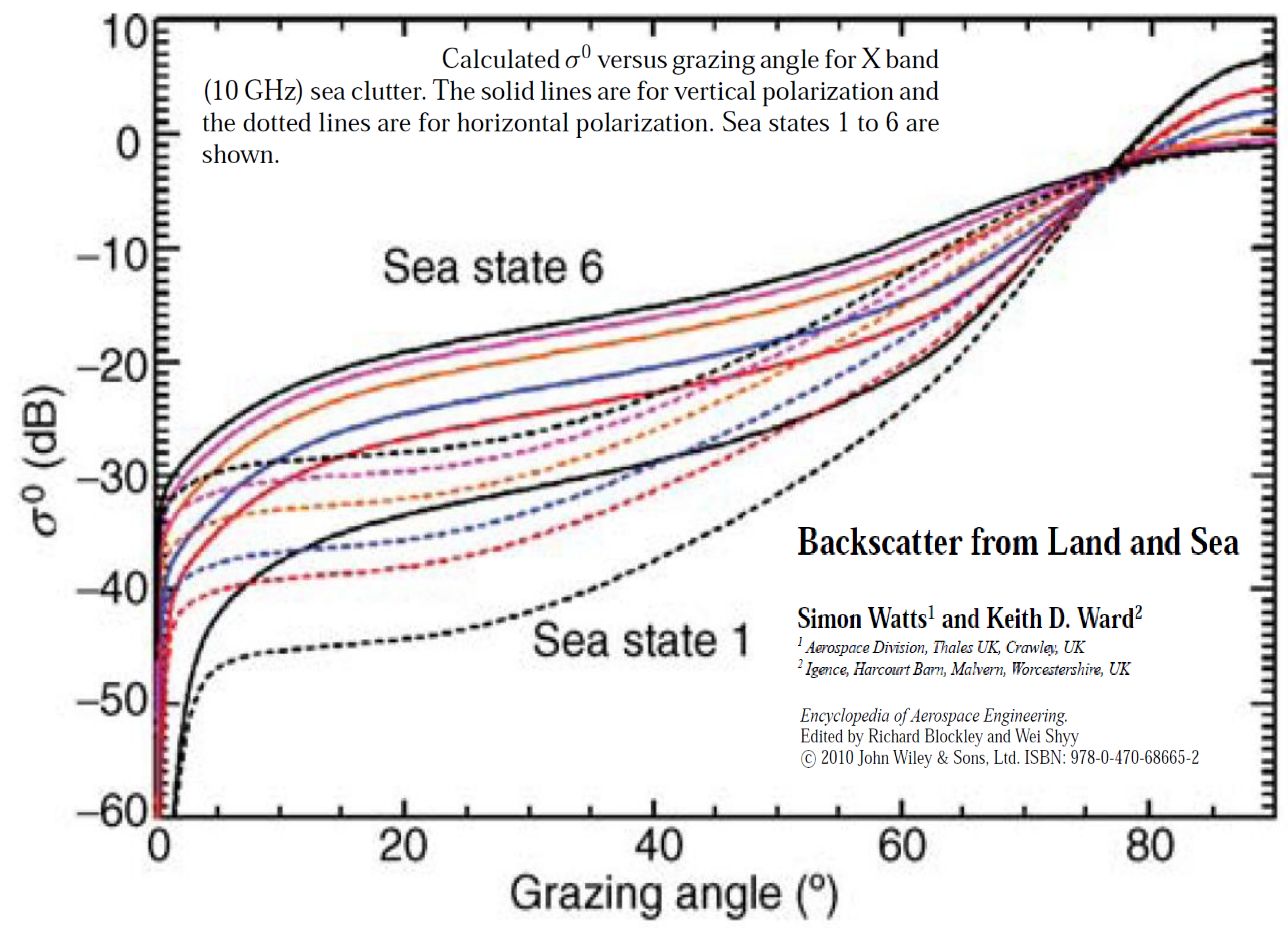
nrcs_1

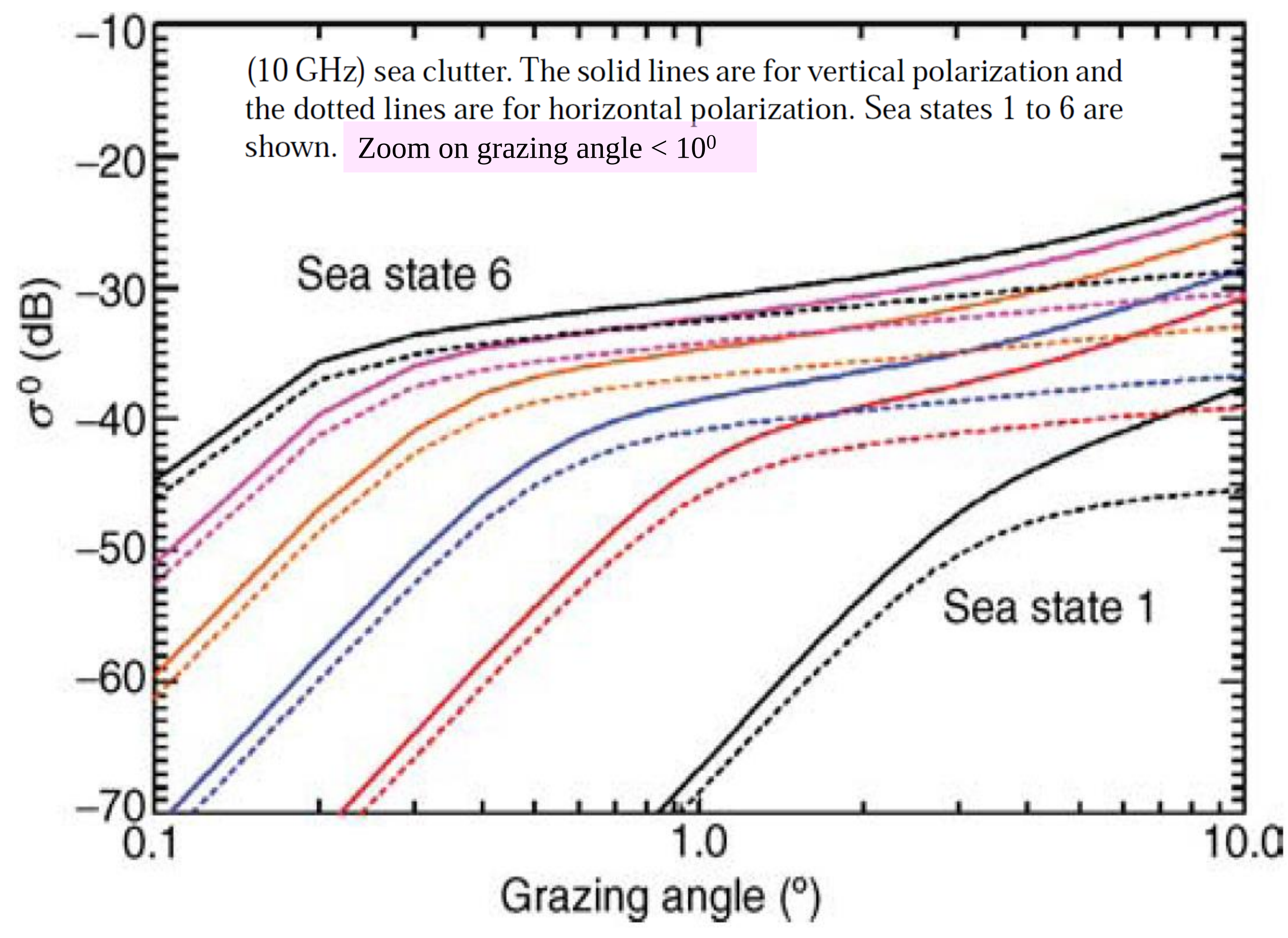


Horizontally (left) and vertically (right) polarized X-band marine radar images collected during the joint ONR/NRL High Resolution Experiment show polarization effects due to different scattering mechanisms associated with wave breaking along a convergence front under study

From: D.B. Trizna: "A model for Brewster angle damping and multipath effects on the microwave radar sea echo at low grazing angle", *IEEE Transactions on Geoscience and Remote Sensing*, Vol. 35, No. 5, Sept. 1997, pp. 1232-1244.

Rip - a piece of rough water where two currents meet


Calculated σ^0 versus grazing angle for X band (10 GHz) sea clutter. The solid lines are for vertical polarization and the dotted lines are for horizontal polarization. Sea states 1 to 6 are shown.
Sea state 6
Sea state 1
Backscatter from Land and Sea
Simon Watts[1] and Keith D. Ward[2]
[1] Aerospace Division, Thales UK, Crawley, UK
[2] Igence, Harcourt Barn, Malvern, Worcestershire, UK
Encyclopedia of Aerospace Engineering.
Edited by Richard Blockley and Wei Shyy
© 2010 John Wiley & Sons, Ltd. ISBN: 978-0-470-68665-2
σ^0 (dB)
10
0
−10
−20
−30
−40
−50
−60
0
20
40
60
80
Grazing angle (°)


(10 GHz) sea clutter. The solid lines are for vertical polarization and the dotted lines are for horizontal polarization. Sea states 1 to 6 are shown.
Zoom on grazing angle < 10^0
Sea state 6
Sea state 1
–10
–20
–30
–40
–50
–60
–70
σ^0 (dB)
0.1
1.0
10.0
Grazing angle (°)

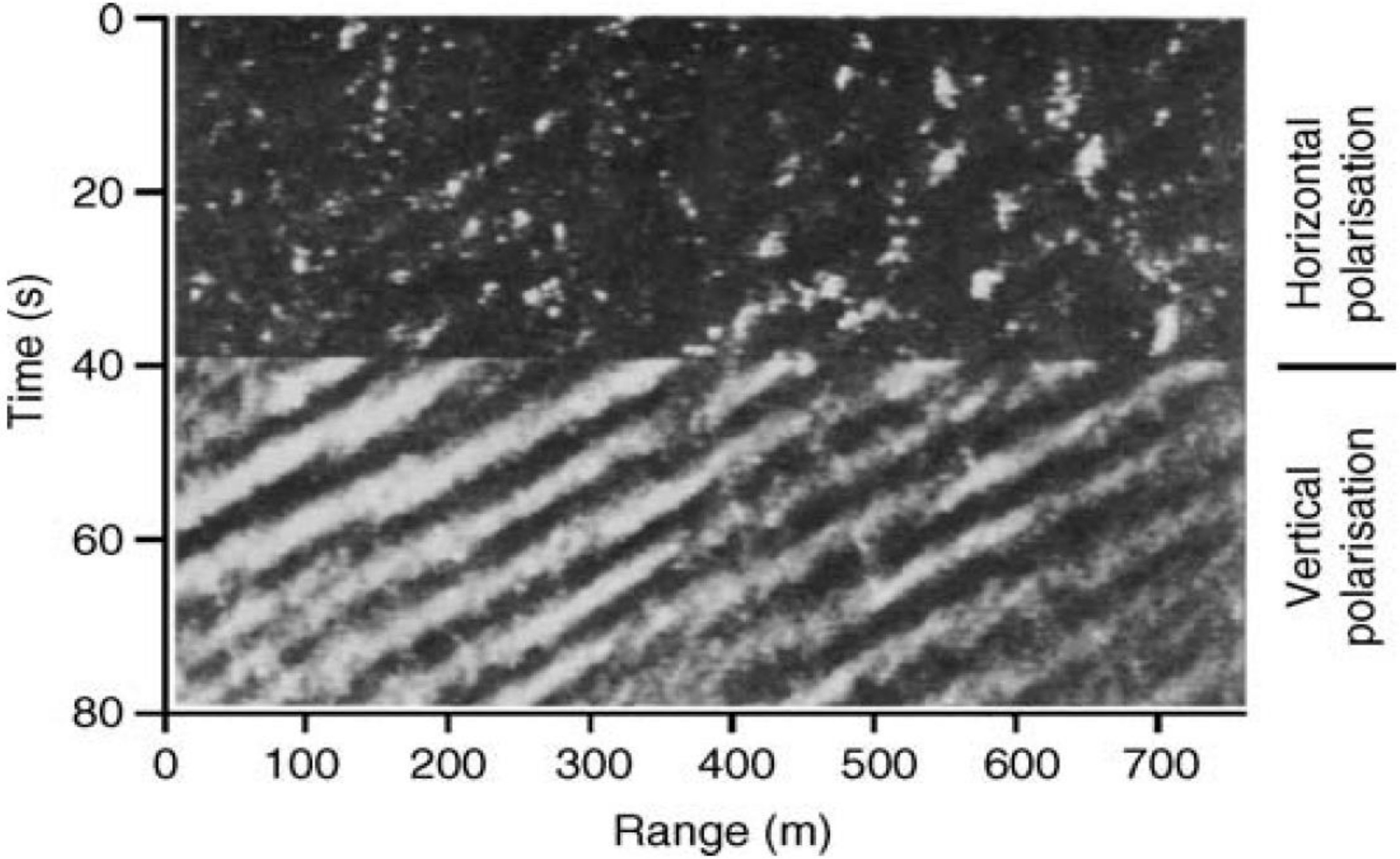
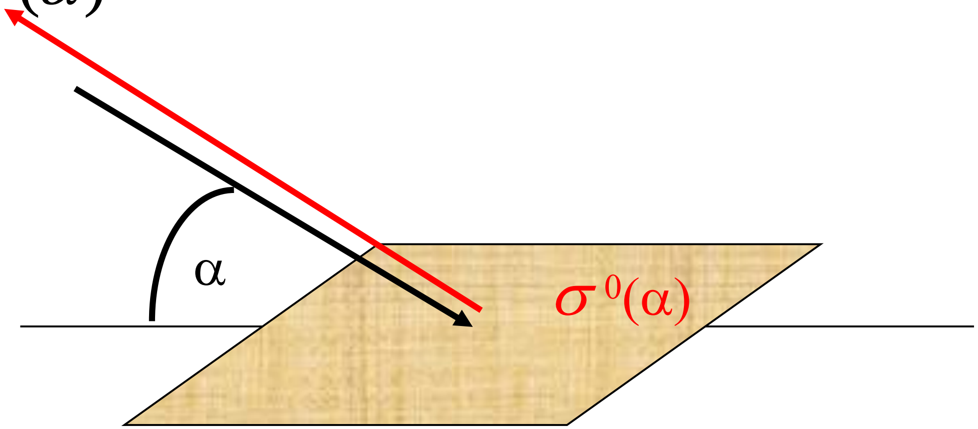


Figure 8. Range-time intensity plot of sea clutter averaged over 250 successive pulses to remove the speckle component, revealing the underlying mean level. After 60 s, the radar was switched from vertical to horizontal polarization.

Area integration of $\sigma^0(\alpha)$

$$d\sigma = dA\sigma^0(\alpha)$$



Area element = dA

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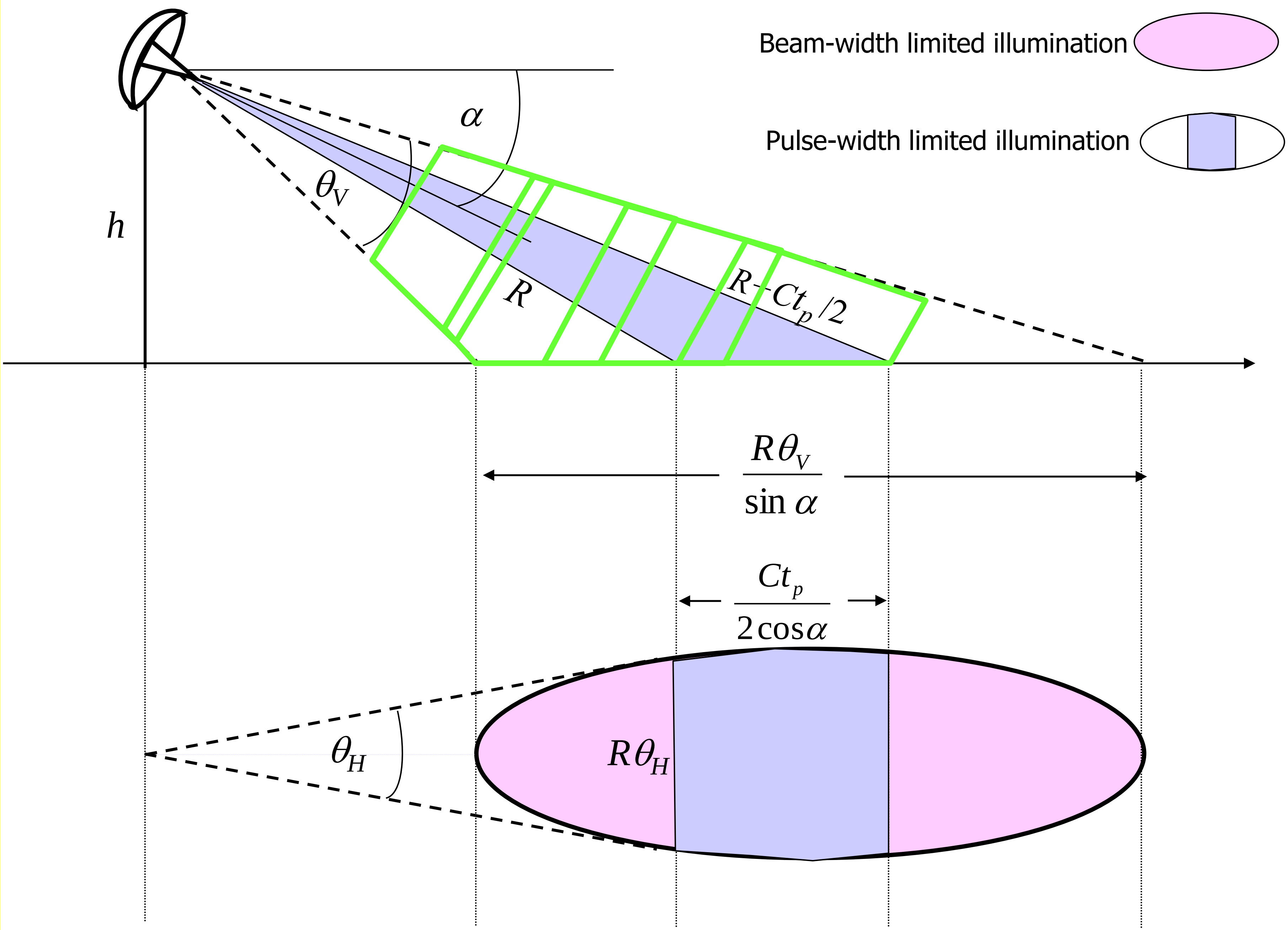
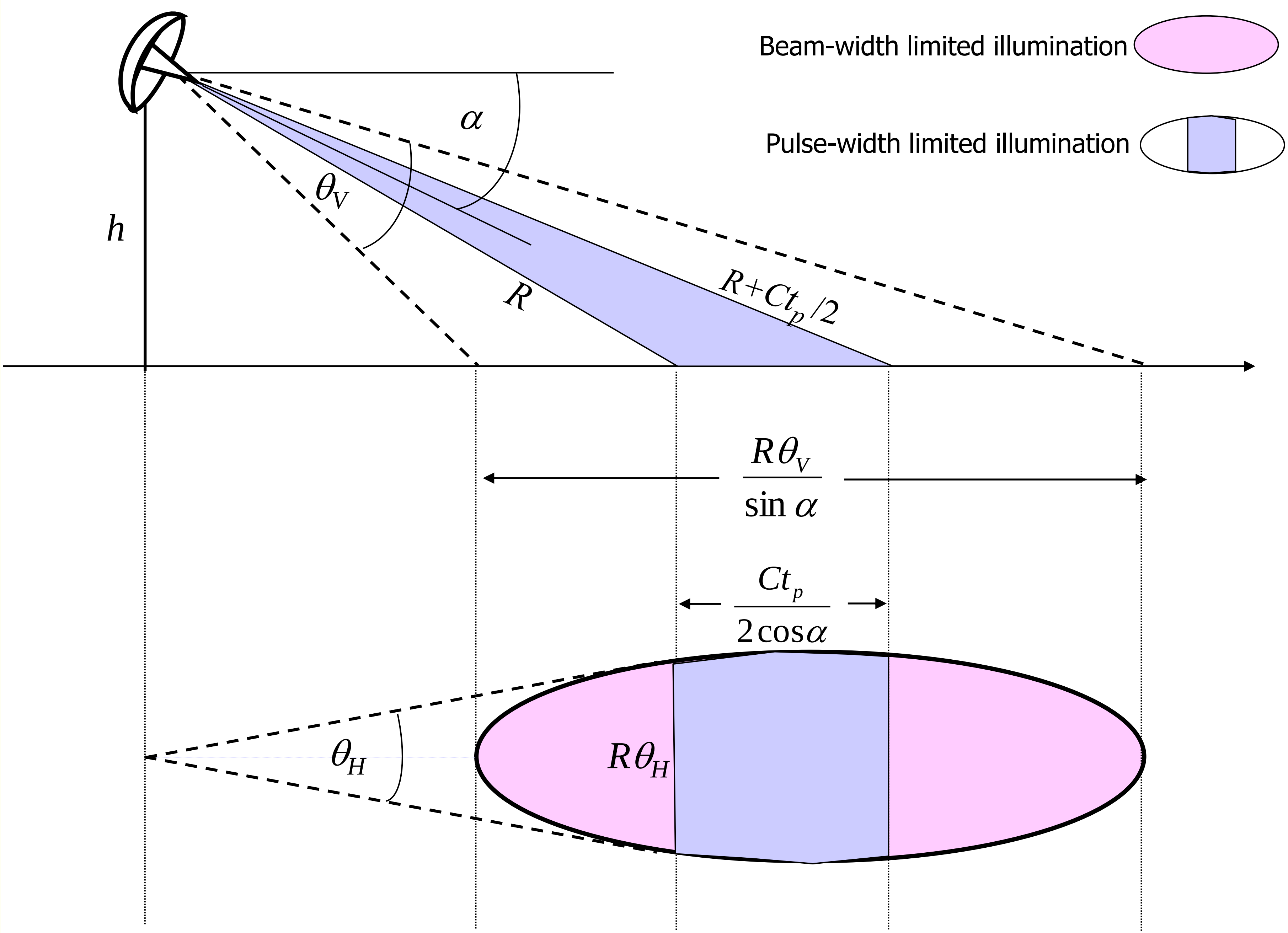
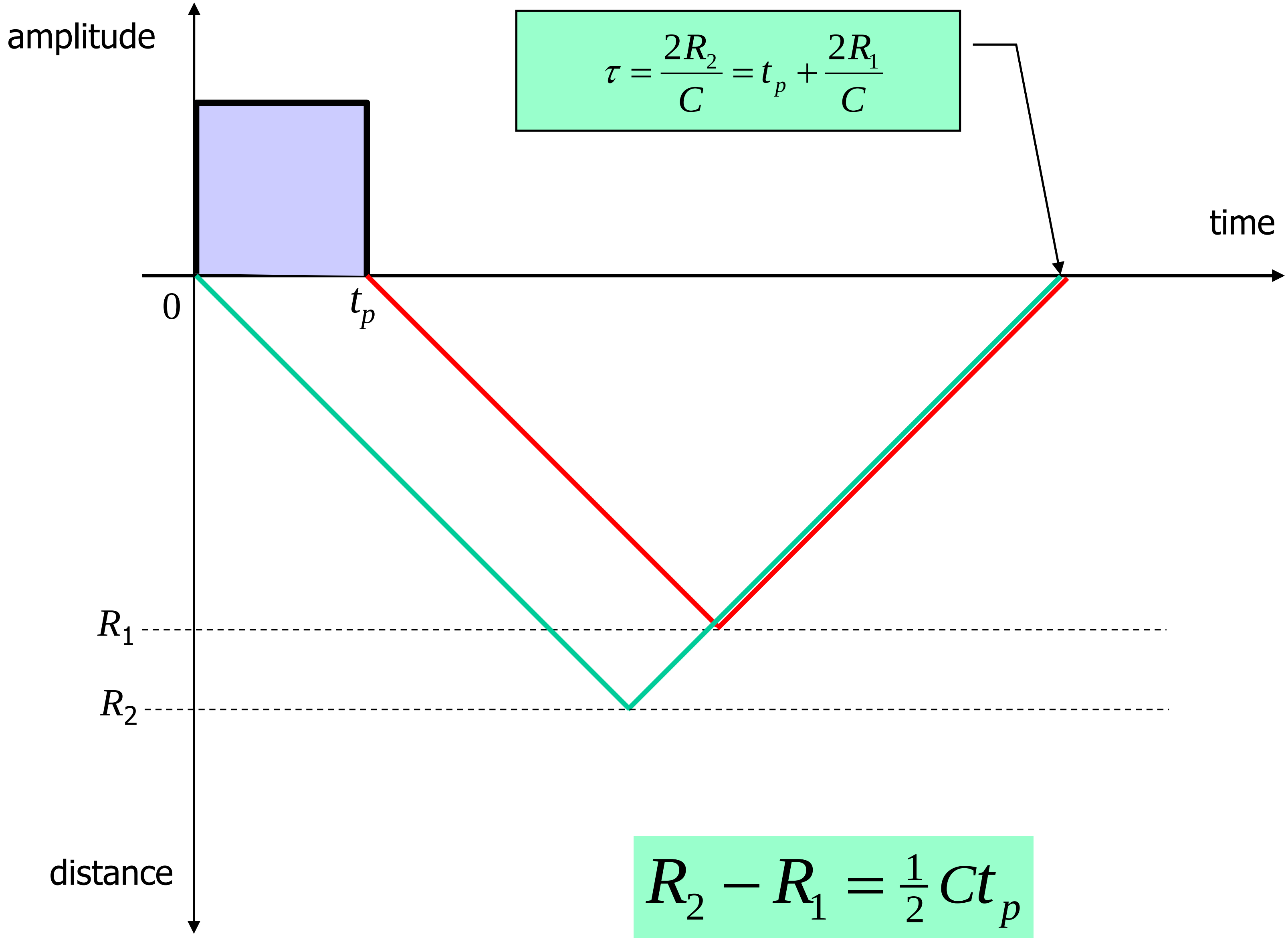
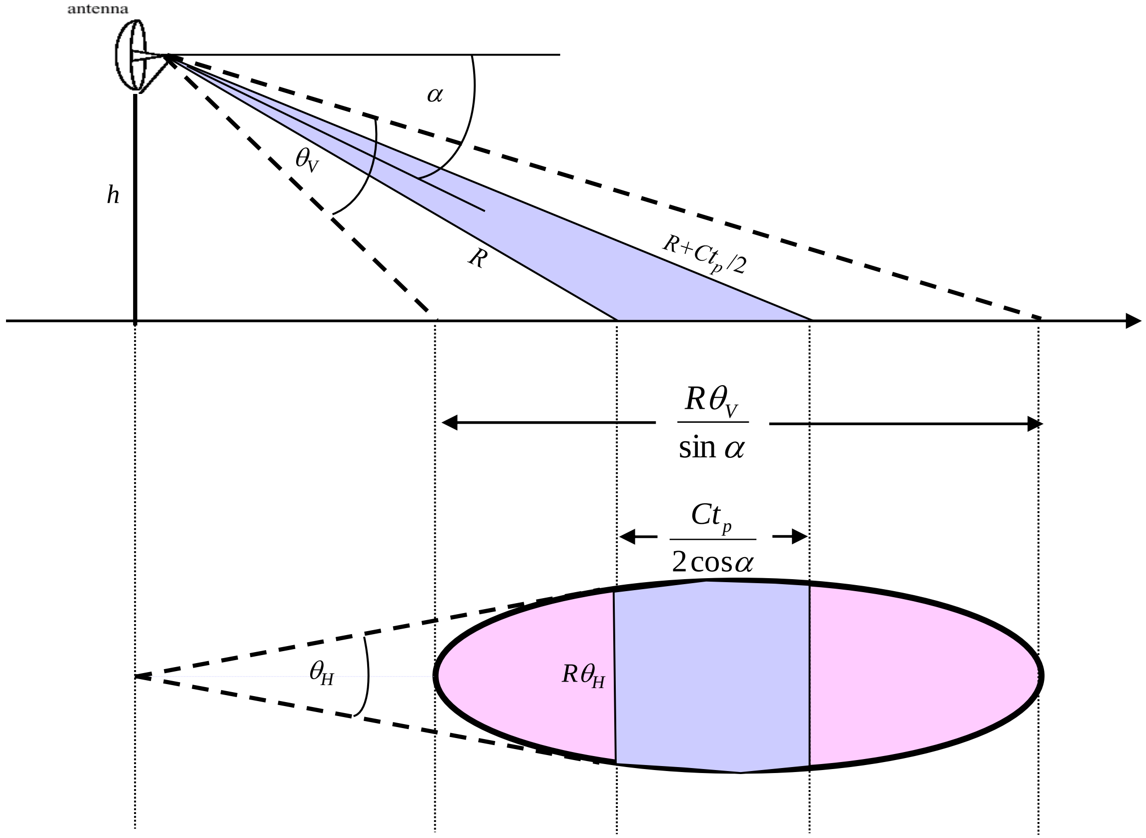


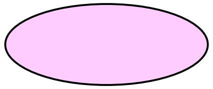

Beam-width limited illumination
Pulse-width limited illumination
α
θ_V
h
R
$R+Ct_p/2$
$\frac{R\theta_V}{\sin\alpha}$
$\frac{Ct_p}{2\cos\alpha}$
θ_H
$R\theta_H$



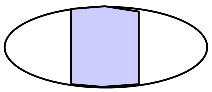
$$\tau = \frac{2R_2}{C} = t_p + \frac{2R_1}{C}$$

$$R_2 - R_1 = \tfrac{1}{2} C t_p$$



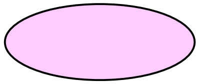
Beam-width limited illumination 

$$A_{bwli} = \frac{\pi R^2 \theta_H \theta_V}{4\sin\alpha}$$

Pulse-width limited illumination 

$$A_{pwli} = \frac{Ct_p R\theta_H}{2\cos\alpha}$$

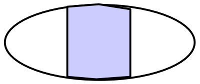
Beam-width limited illumination



$$A_{bwli} = \frac{\pi R^2 \theta_H \theta_V}{4 \sin \alpha}$$

$$P_R = \frac{P_T G^2 \lambda^2}{(4\pi)^3} \frac{\pi \theta_H \theta_V \sigma^0(\alpha)}{4 \sin \alpha} \frac{1}{R^2}$$

Pulse-width limited illumination



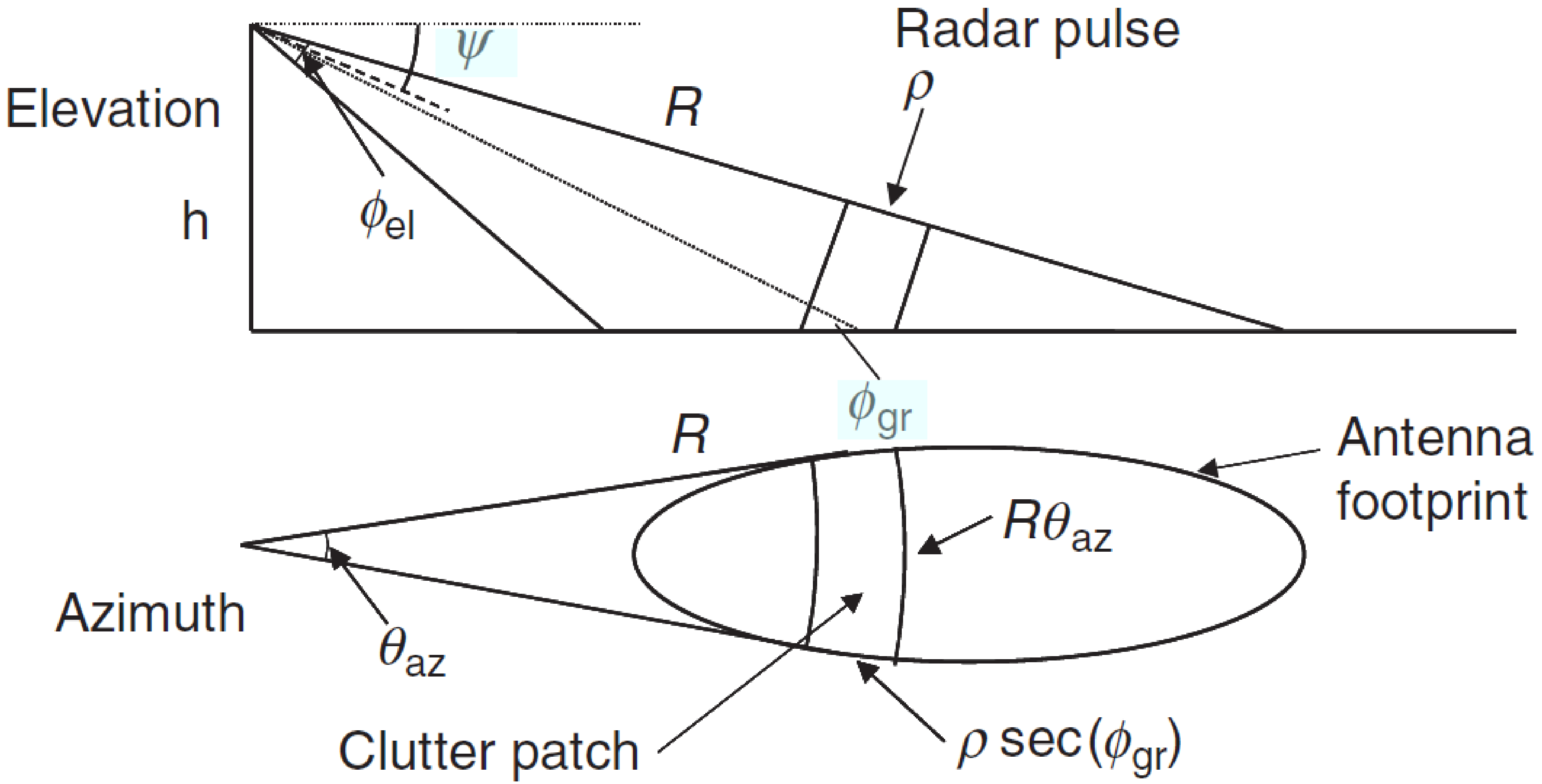
$$A_{pwli} = \frac{C t_p R \theta_H}{2 \cos \alpha}$$

$$P_R = \frac{P_T G^2 \lambda^2}{(4\pi)^3} \frac{C t_p \theta_H \sigma^0(\alpha)}{2 \cos \alpha} \frac{1}{R^3}$$

Taking into consideration the Earth curvature

$$\psi = \sin^{-1}\left(\frac{R^2 + h^2 + 2r_E h}{2R(r_E + h)}\right)$$

$$\phi_{\text{gr}} = \sin^{-1}\left(\frac{h}{R} + \frac{h^2}{2r_E R} - \frac{R}{2r_E}\right), \quad r_E \approx \tfrac{4}{3}\,\text{Earth radius}$$



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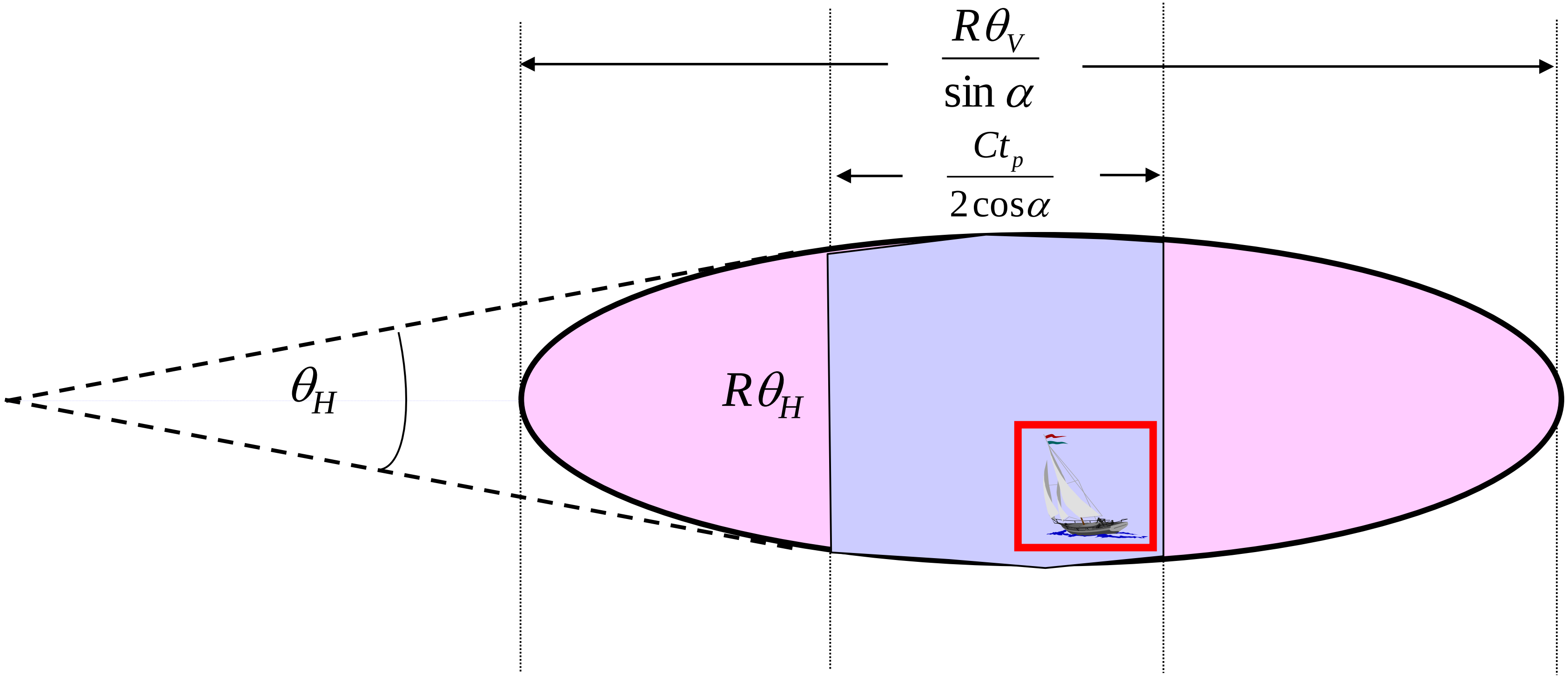
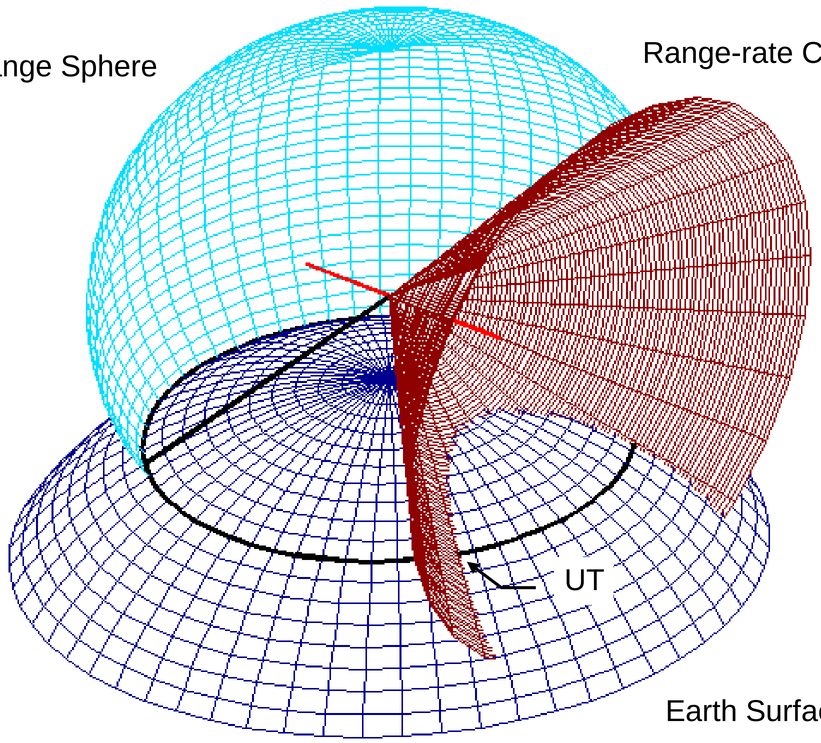


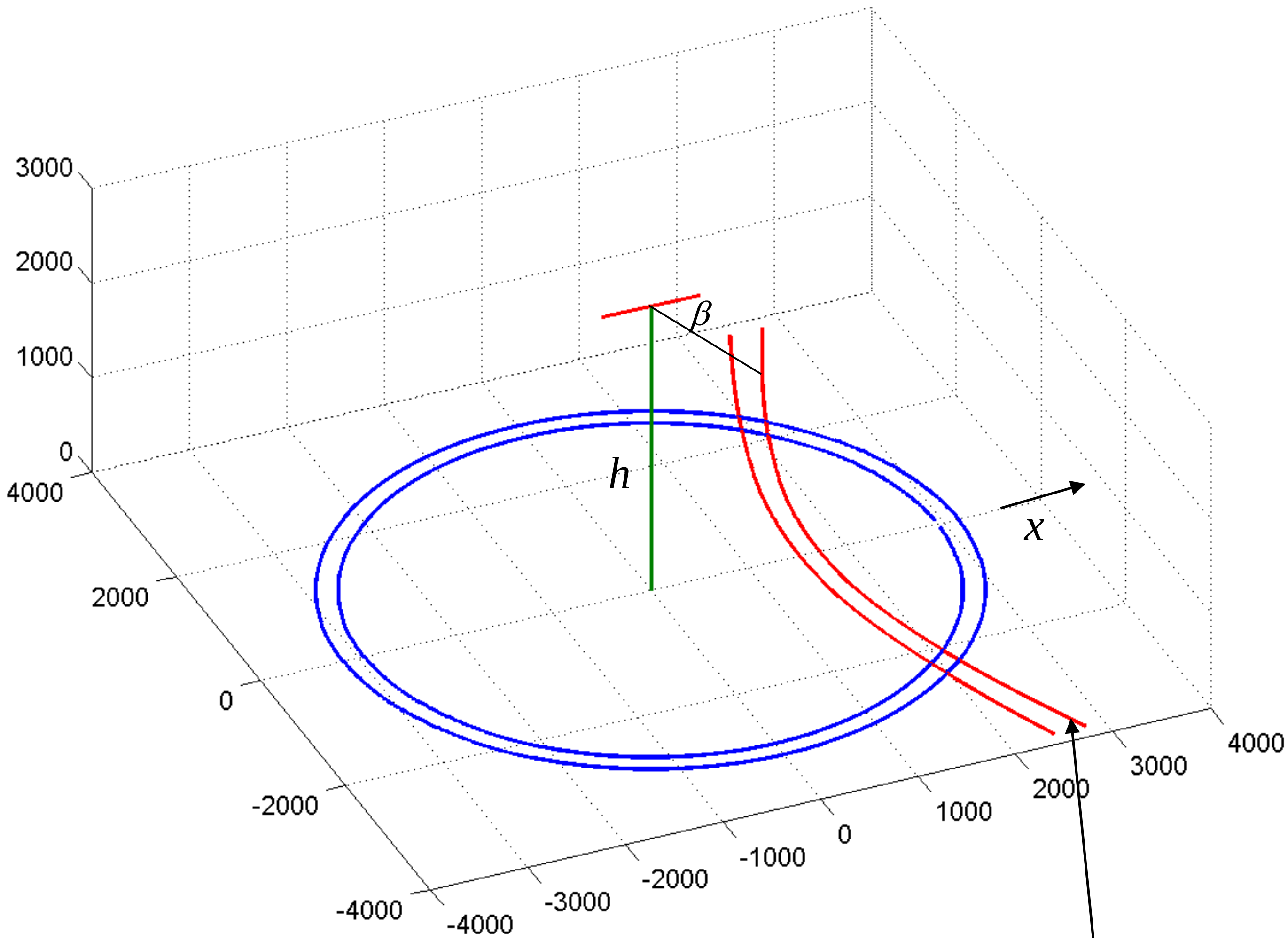
A major challenge in radar design:

Reduce the illuminated clutter area in order not to obscure the target.

How?

- Reduce effective pulse-width (pulse compression)
- Reduce horizontal beamwidth (SAR in airborne radar)
- Utilize the difference in Doppler between clutter and moving targets (in stationary radar)
- Utilize Doppler processing (in airborne radar)

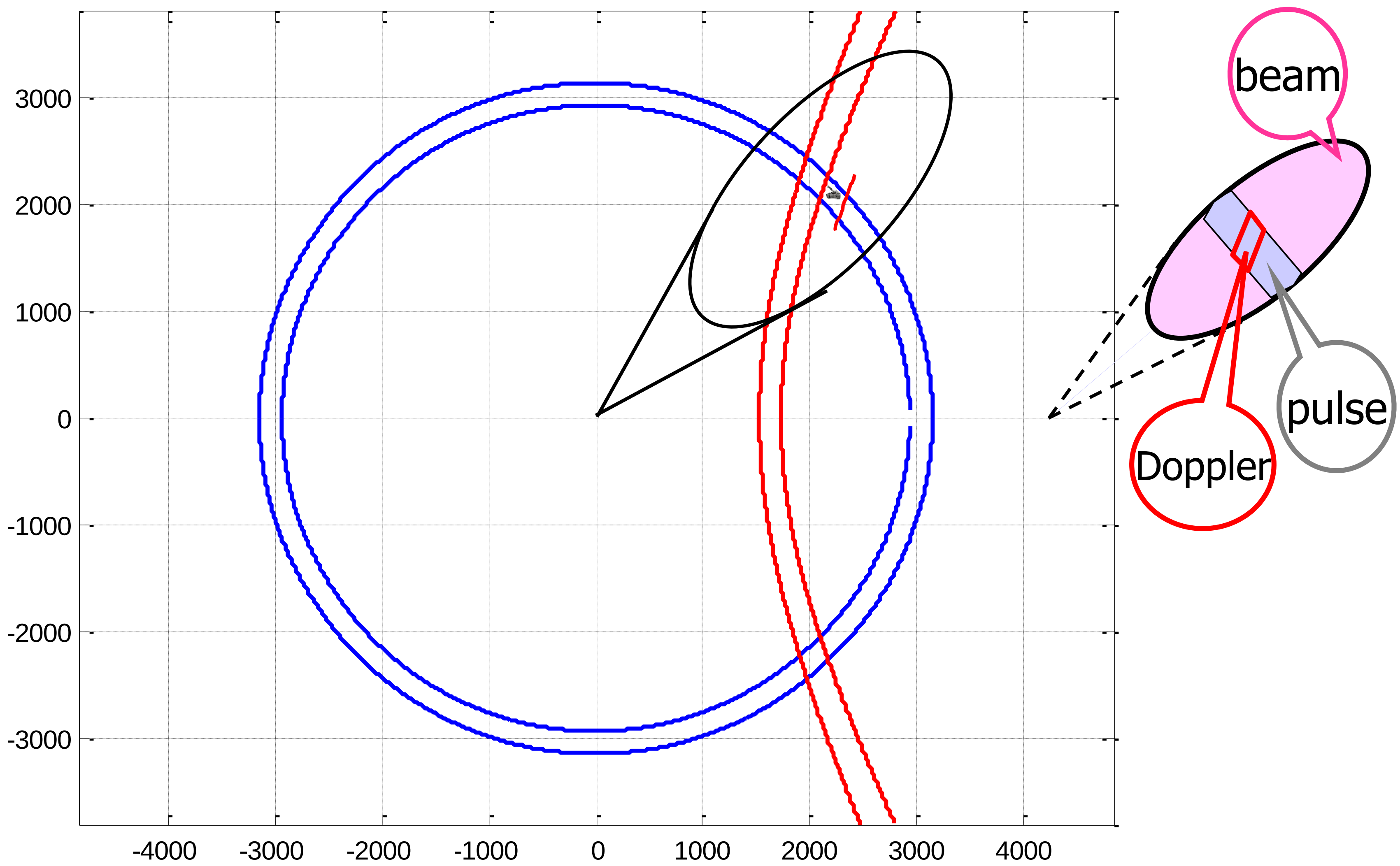

Range Sphere
Range-rate Cone
UT
Earth Surface



$$x^2 = \left(y^2 + h^2\right)\cot^2 \beta$$

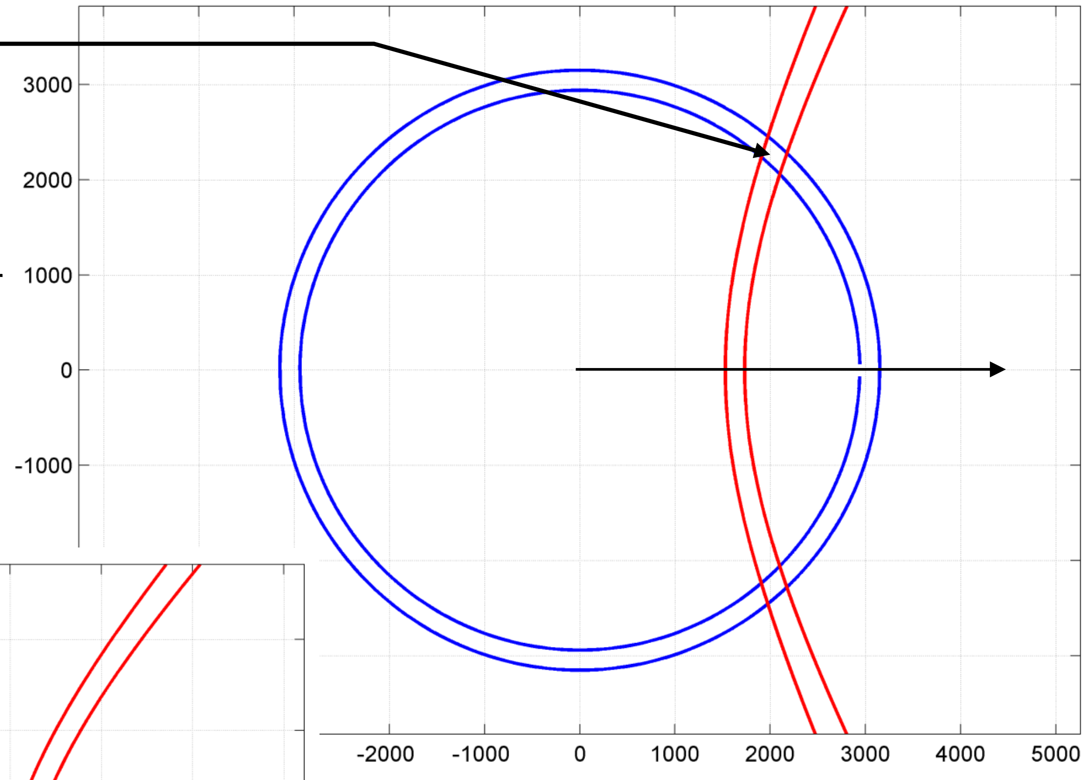
*Doppler processing involves a coherent pulse <u>train</u>. Hence more circles and hyperbolas.

ilumin3

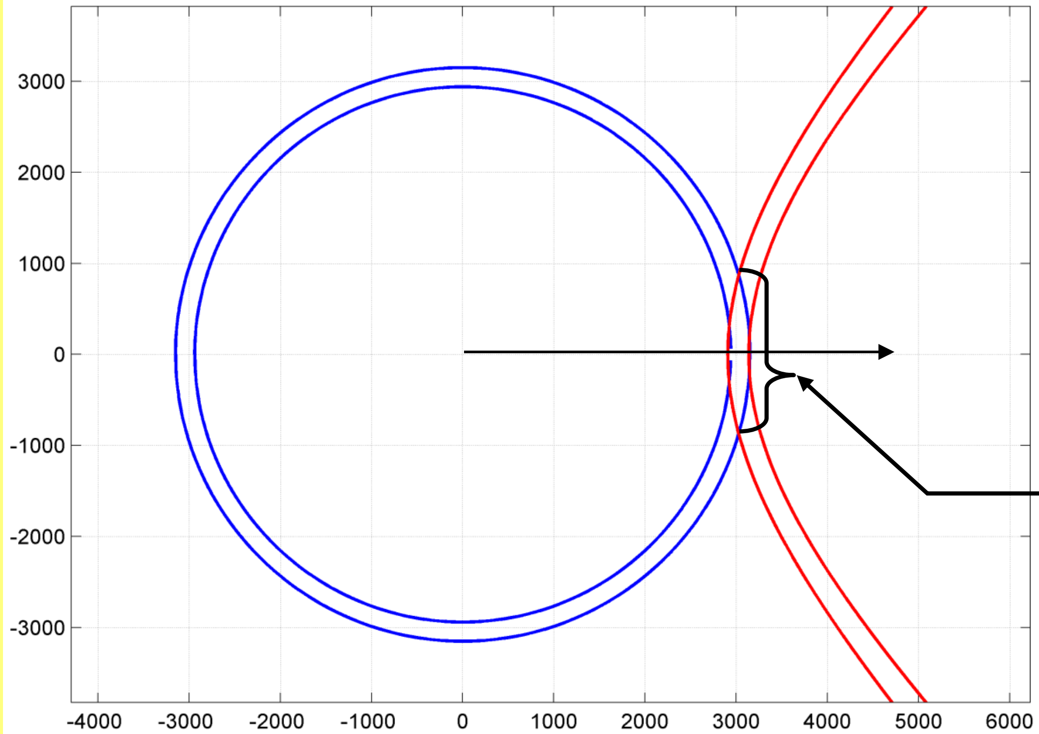

3000
2000
1000
0
-1000
-2000
-3000
-4000
-3000
-2000
-1000
0
1000
2000
3000
4000
beam
pulse
Doppler

ilumin3

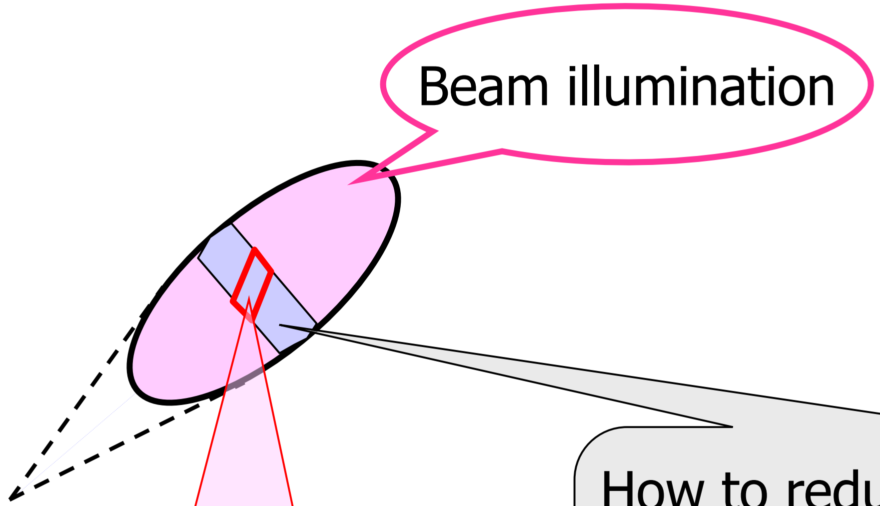
Off subtrack illumination
→ good azimuth resolution



In addition to range resolution and Doppler resolution, the size of the reflecting ground patch, is affected by the geometry. This result belongs to the topic of:
Geometric **D**ilution **O**f **P**recision (**GDOP**)



Near subtrack illumination
→ poor azimuth resolution.
Iso-Doppler and iso-range cells coincide.



How to reduce pulse width is covered by the topic "pulse compression", which requires first to learn about the "matched filter"

The behavior of the compressed pulse in the presence of Doppler is covered by the topics "Ambiguity function" and "Coherent pulse train"

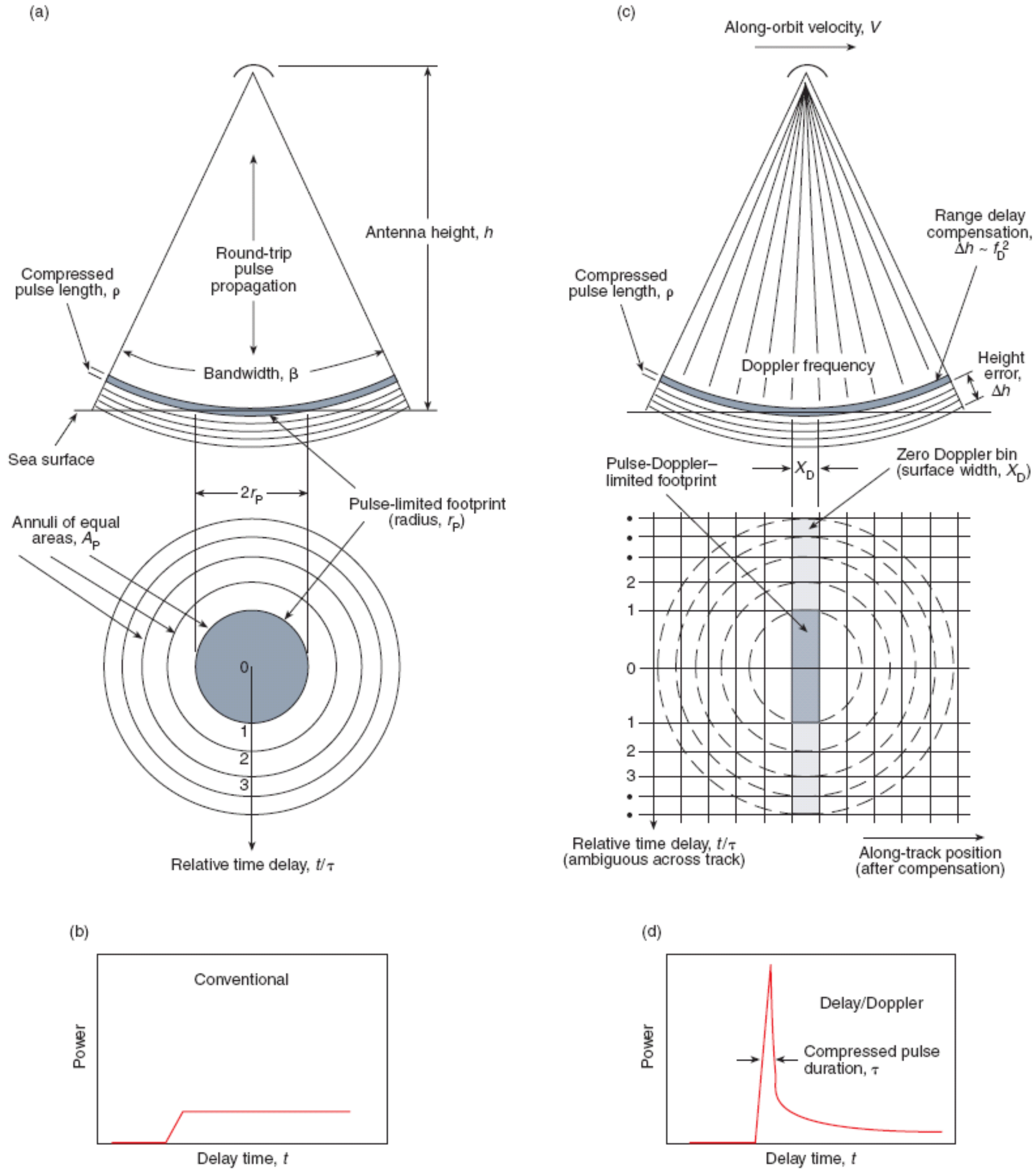


Figure 1. Comparison of a conventional pulse-limited radar altimeter's (a) illumination geometry (side view) and footprint (plan view) and (b) impulse response, with a delay/Doppler altimeter's (c) illumination geometry and footprint and (d) impulse response.

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