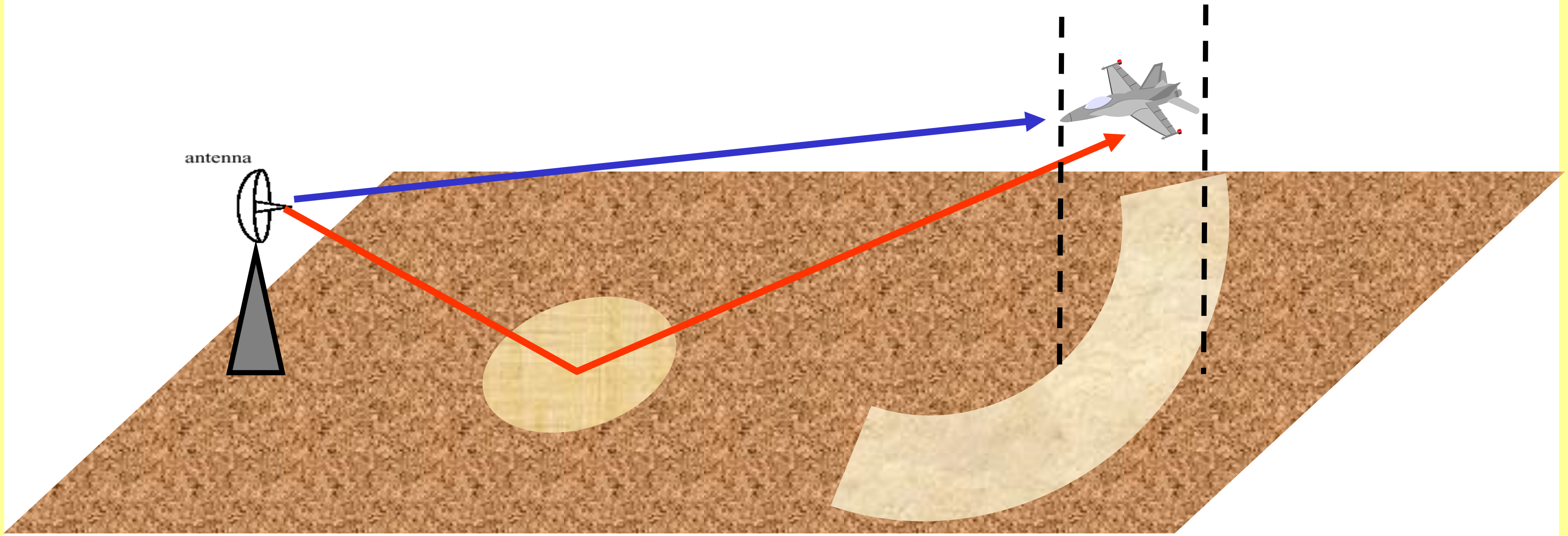
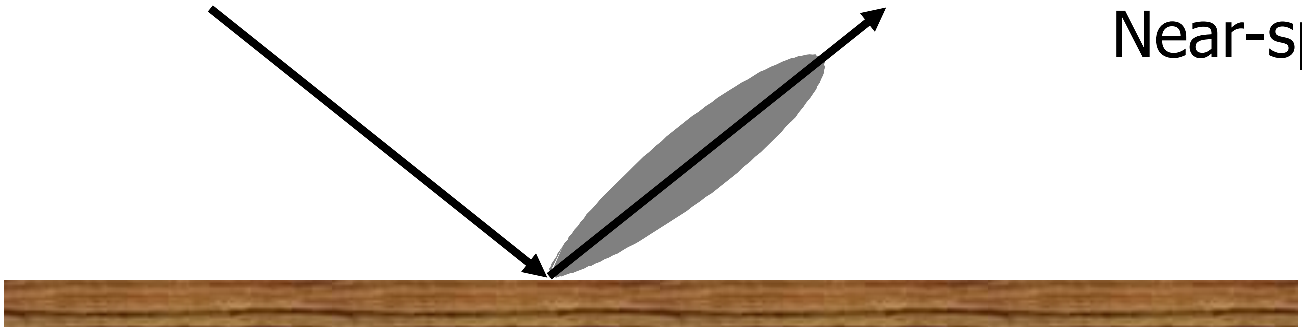
GROUND EFFECTS - MULTIPATH AND CLUTTER

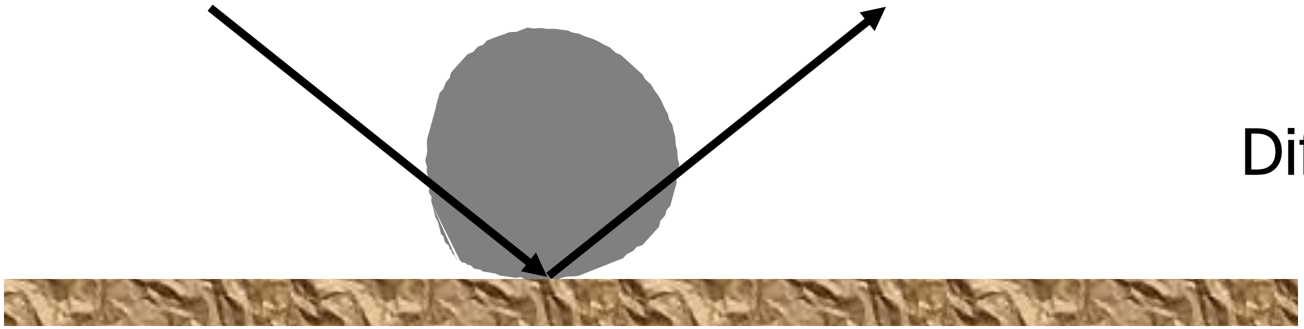


Area contributing to multipath

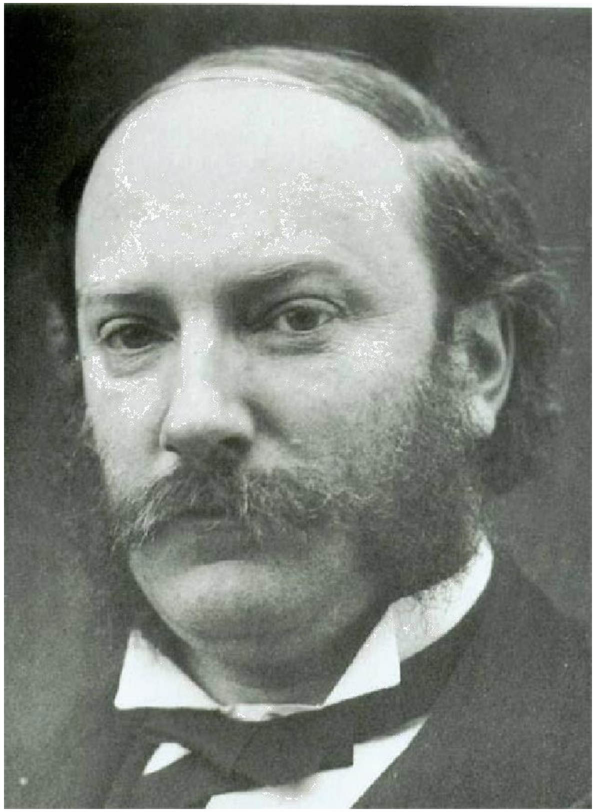
Area contributing clutter at target's range



Near-specular scatter



Diffuse scatter



John William Strutt

3’rd Lord Rayleigh

7/3-82

First Edition printed 1878.

Second Edition revised and enlarged 1896.

THEORY OF SOUND

2

Brown

BY

JOHN WILLIAM STRUTT, BARON RAYLEIGH, Sc.D., F.R.S.

HONORARY FELLOW OF TRINITY COLLEGE, CAMBRIDGE.

IN TWO VOLUMES

VOLUME II.

SECOND EDITION REVISED AND ENLARGED

London

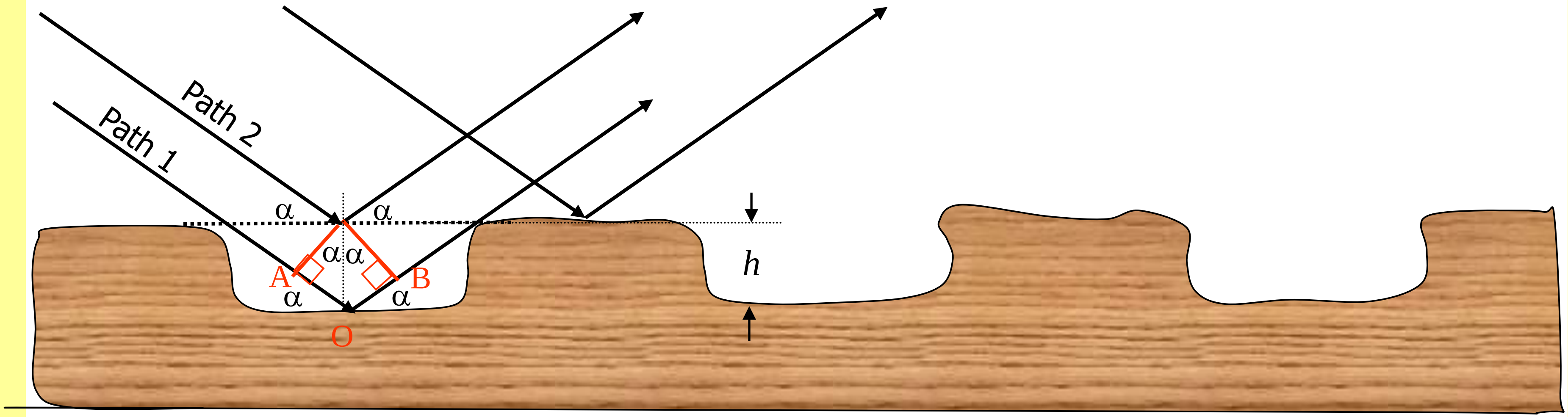
MACMILLAN AND CO., LTD.

NEW YORK: MACMILLAN & CO.

1896

Nadav Levanon, Tel-Aviv University

Rayleigh criterion (for roughness)



$$\Delta R = AO + OB = 2h \sin\alpha$$

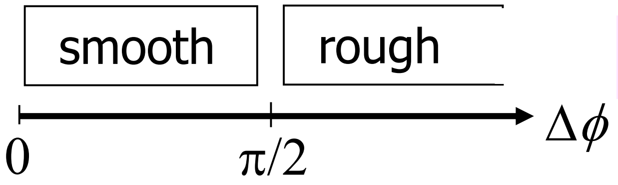
The difference in path length to a distant target

$$\Delta\phi = \Delta R \frac{2\pi}{\lambda} = \frac{4\pi h}{\lambda}\sin\alpha$$

The phase difference between the two paths

$\Delta\phi << \pi \Rightarrow$ specular (mirror like) reflection $\Rightarrow$ **smooth surface**

$\Delta\phi \approx \pi \Rightarrow$ The paths cancel each other $\Rightarrow$ no reflection in the specular direction $\Rightarrow$ reflection diverted to other directions $\Rightarrow$ diffused (or scattered) reflection $\Rightarrow$ **rough surface**

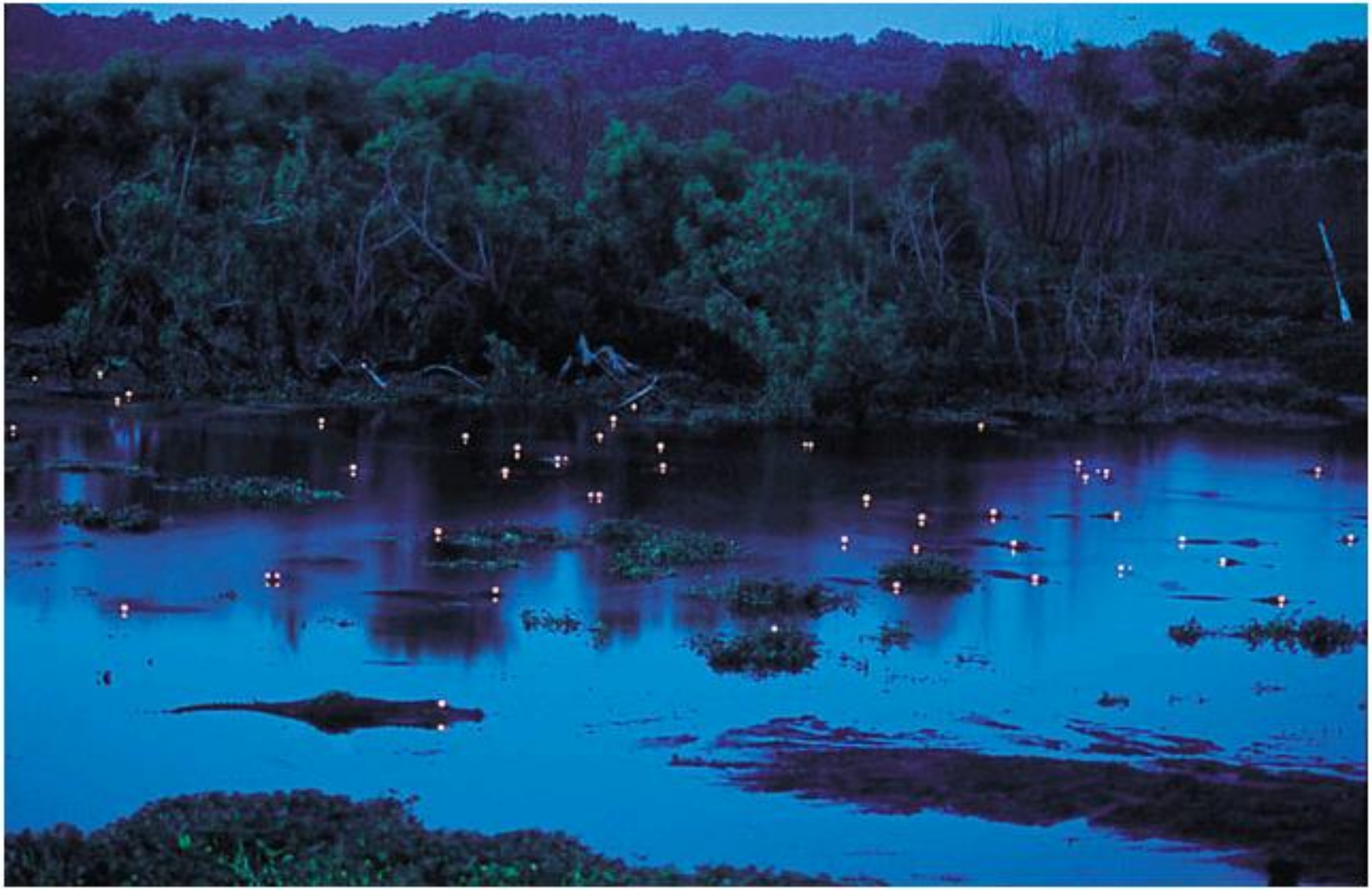


Smooth surface $\Rightarrow \Delta\phi < \pi/2 \Rightarrow$

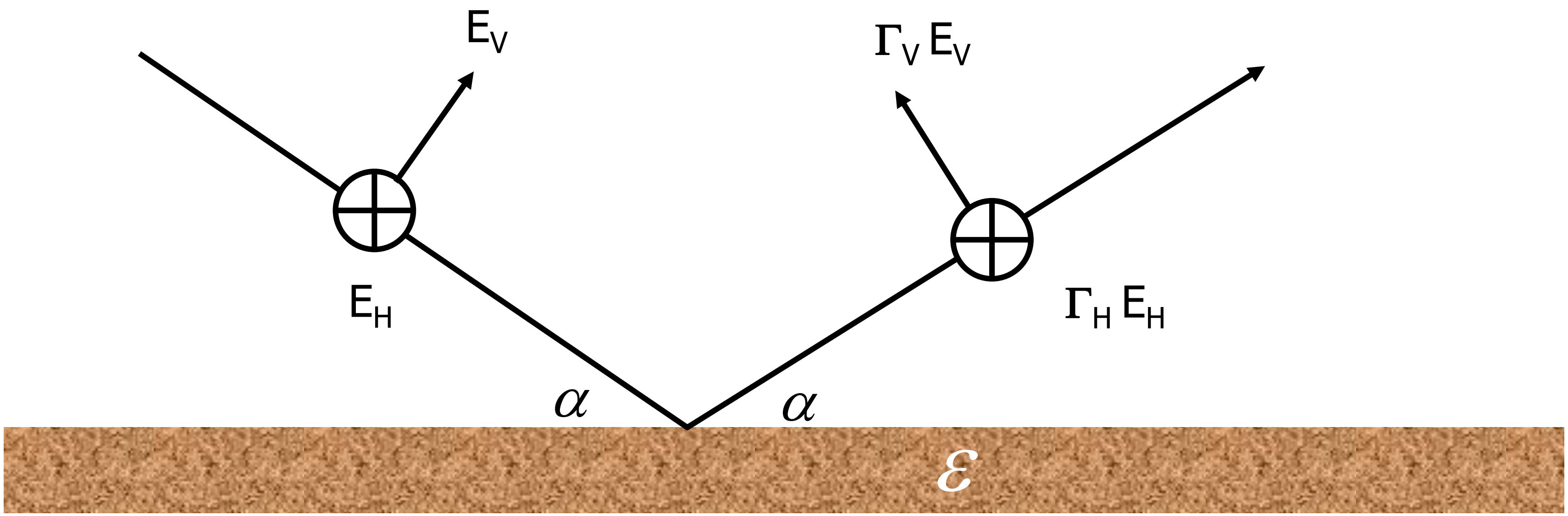
$$h < \frac{\lambda}{8\sin\alpha}$$

At small grazing angle α, almost any surface is smooth!

Alligators at dusk, Payne's Prairie State Preserve, Florida.



Courtesy John Moran, The Gainsville Sun ©



$$\varepsilon = \varepsilon' + j\varepsilon'' \approx K/\varepsilon_0 - j60\lambda\sigma$$

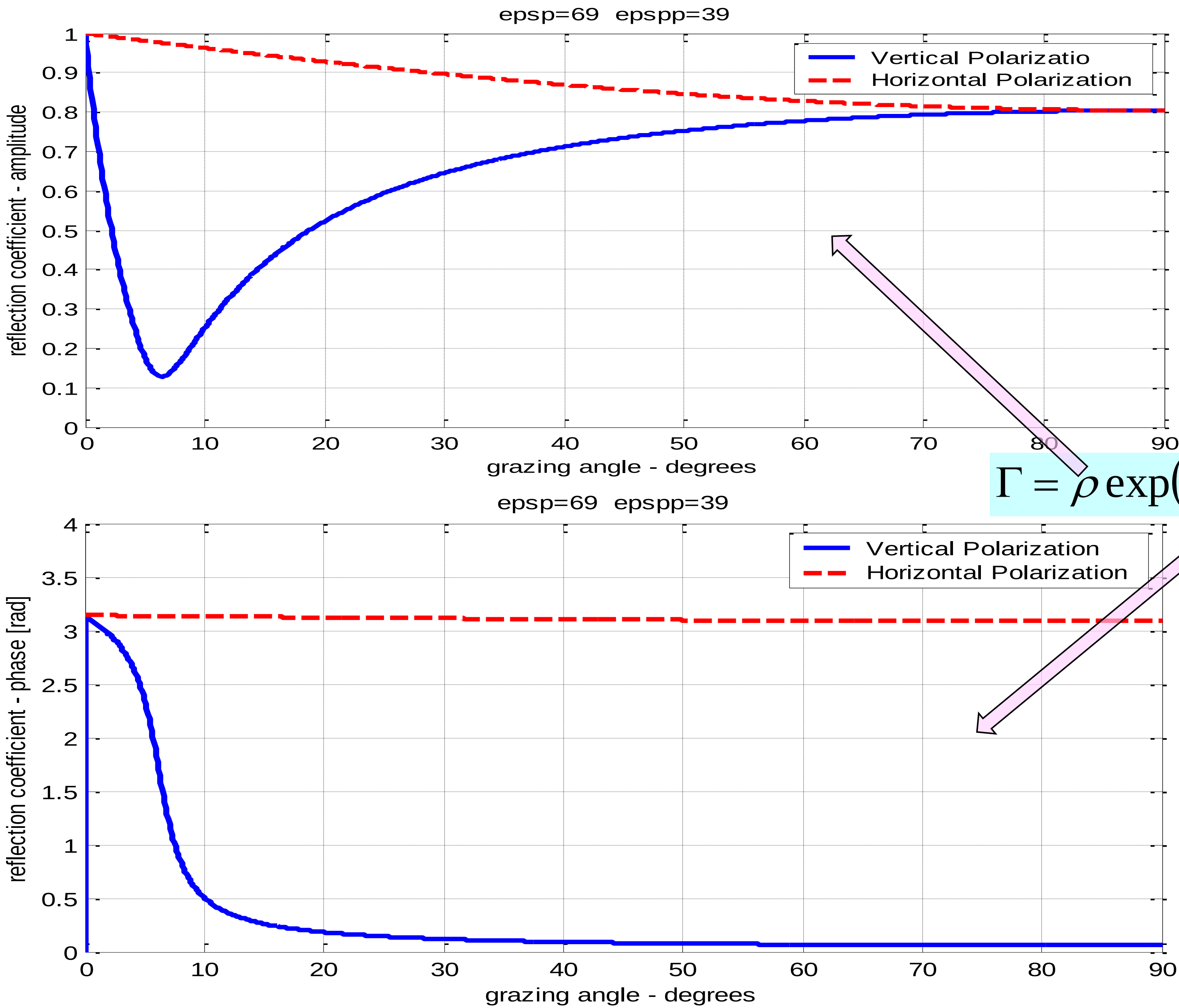
ε - complex dielectric constant of the surface
K - permittivity of surface
σ - conductivity of surface

ε_0 - dielectric constant of free space
λ - signal wavelength

$$\Gamma_H = \frac{\sin\alpha - \sqrt{\varepsilon - \cos^2\alpha}}{\sin\alpha + \sqrt{\varepsilon - \cos^2\alpha}}$$

$$\Gamma_V = \frac{\varepsilon\sin\alpha - \sqrt{\varepsilon - \cos^2\alpha}}{\varepsilon\sin\alpha + \sqrt{\varepsilon - \cos^2\alpha}}$$

$\varepsilon_0 = 8.8541878\text{x}10^{-12}$ farad/meter



$$\Gamma = \rho \exp(-j\phi)$$

ref_coef

$$\Gamma_H = -\Gamma_V = \frac{1-\sqrt{\varepsilon}}{1+\sqrt{\varepsilon}} \quad , \quad \alpha = 90^0$$

$$\Gamma_H = \Gamma_V = -1 \quad , \quad \alpha = 0^0$$

At very small grazing angle α:

1. The surface behaves like a mirror
2. There is a polarity change without attenuation (ρ=1)

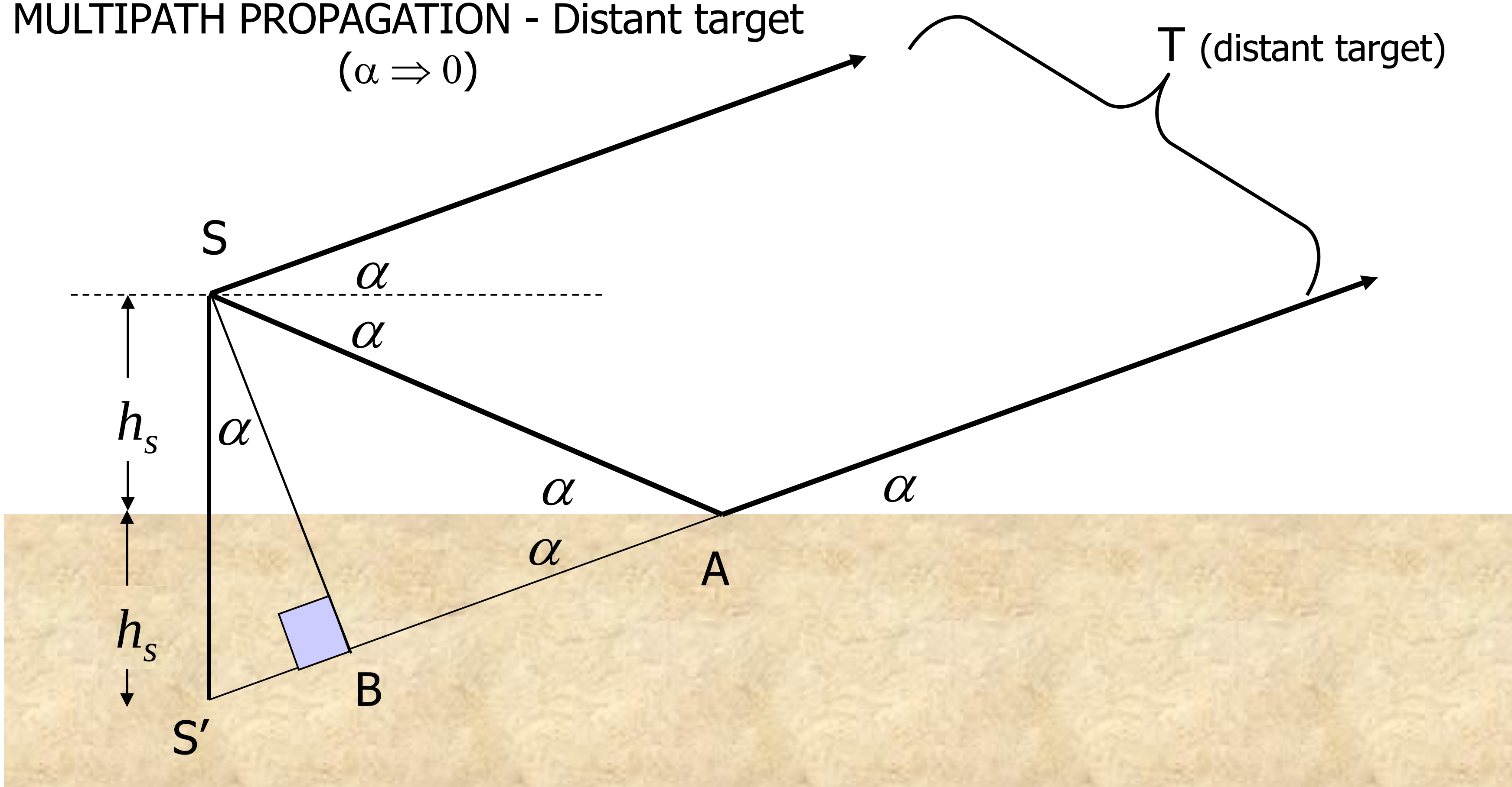
At larger grazing angle multiply ρ by "specularity" coefficient ρ_s

$$\overline{\rho_s^2} = \exp\left[-\left(\frac{4\pi\sigma_h \sin\alpha}{\lambda}\right)^2\right]$$

Surface roughness STD (σ_h)

MULTIPATH PROPAGATION - Distant target

$(\alpha \Rightarrow 0)$



$$\overline{\mathrm{SAT}} - \overline{\mathrm{ST}} = \Delta R = \overline{\mathrm{S'B}} = 2h_s \sin\alpha$$

$$\Delta\phi_1 = \frac{2\pi}{\lambda}\Delta R = \frac{4\pi}{\lambda} h_s \sin\alpha$$

$$\Delta\phi = \pi + \Delta\phi_1 = \pi + \frac{4\pi}{\lambda} h_s \sin\alpha$$

Polarity change due to reflection

$$F = \frac{\text{Field at target in the presence of surface}}{\text{Direct field at target}} = 1 + \rho \exp(-j\Delta\phi)$$

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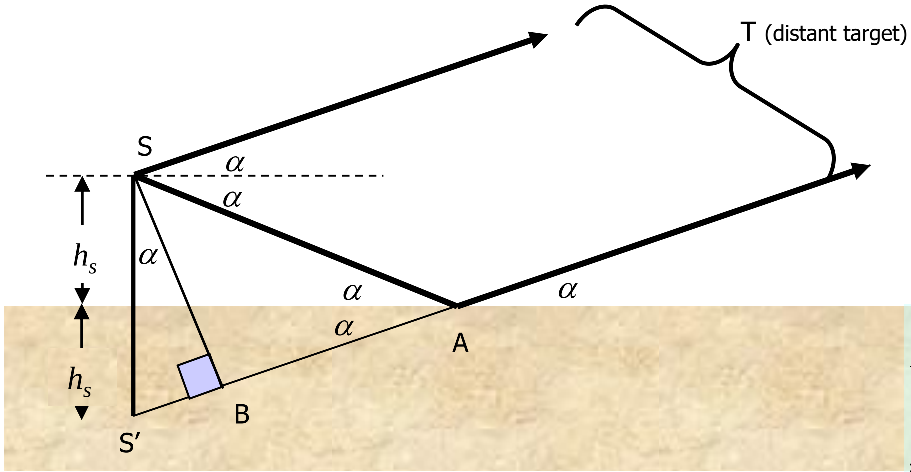


$$F = \frac{\text{Field at target in the presence of surface}}{\text{Direct field at target}} = 1 + \rho \exp(-j\Delta\phi)$$

$$\Delta\phi = \pi + \Delta\phi_1 = \pi + \frac{4\pi}{\lambda} h_s \sin\alpha \qquad \rho = 1$$

$$F = 1 + \exp(-j\pi)\exp\left(-j\frac{4\pi}{\lambda} h_s \sin\alpha\right)$$

$$= 1 - \exp\left(-j\frac{4\pi}{\lambda} h_s \sin\alpha\right)$$

$$= \exp\left(-j\frac{2\pi}{\lambda} h_s \sin\alpha\right)\left[\exp\left(+j\frac{2\pi}{\lambda} h_s \sin\alpha\right) - \exp\left(-j\frac{2\pi}{\lambda} h_s \sin\alpha\right)\right]$$

$$= \exp\left(-j\frac{2\pi}{\lambda} h_s \sin\alpha\right) 2j \sin\left(\frac{2\pi}{\lambda} h_s \sin\alpha\right)$$

$$|F| = \left|2\sin\left(\frac{2\pi}{\lambda} h_s \sin\alpha\right)\right|$$

$|F|^2$ = power ratio at target

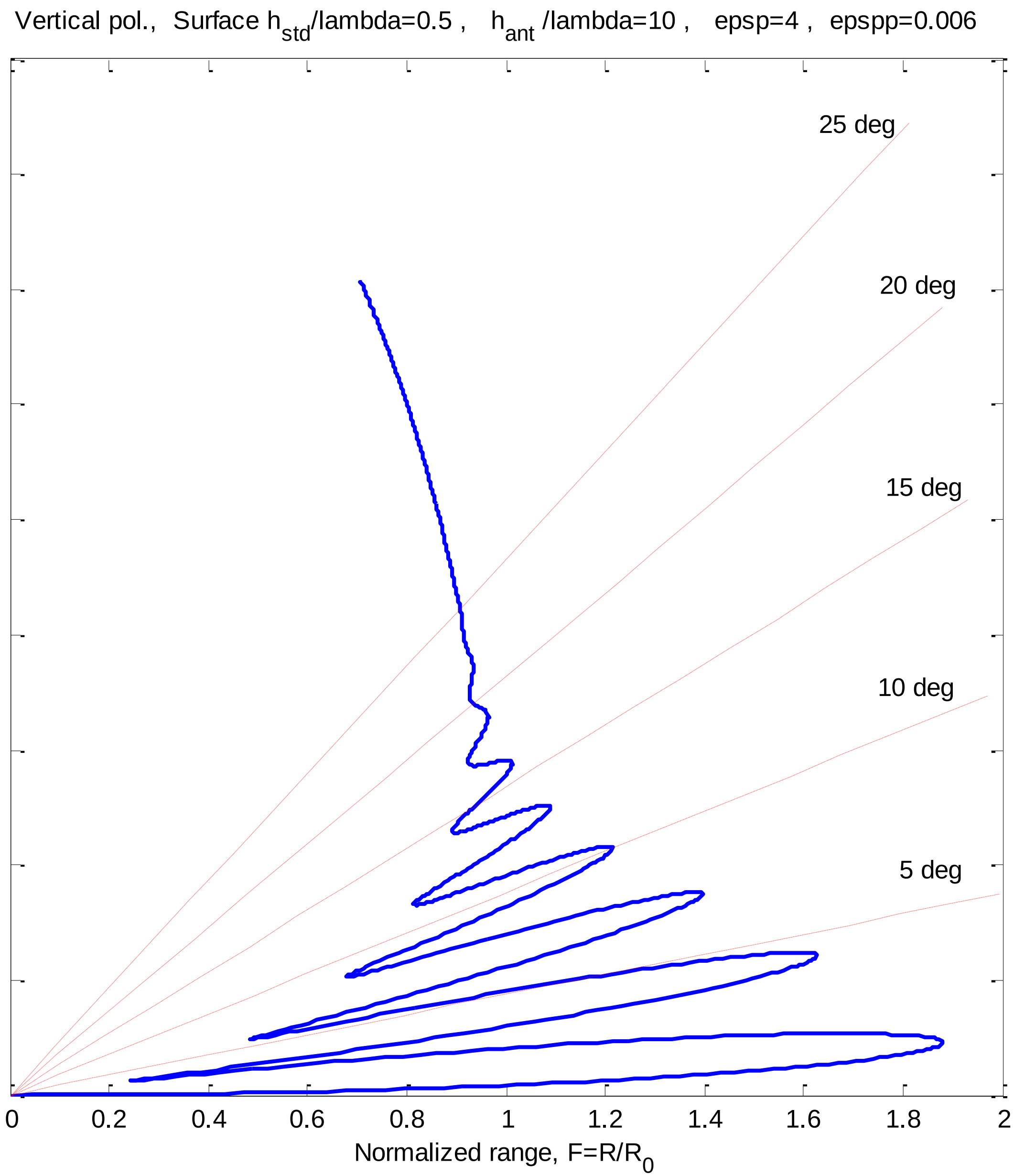
$|F|^4$ = power ratio back at radar

$$|F|^4 = 16\sin^4\left(\frac{2\pi h_s \sin\alpha}{\lambda}\right)$$

$$\left.\begin{array}{l} P_R \;\alpha\; |F|^4 \\ P_R \;\alpha\; R^4 \end{array}\right\} \qquad R \;\alpha\; |F|$$

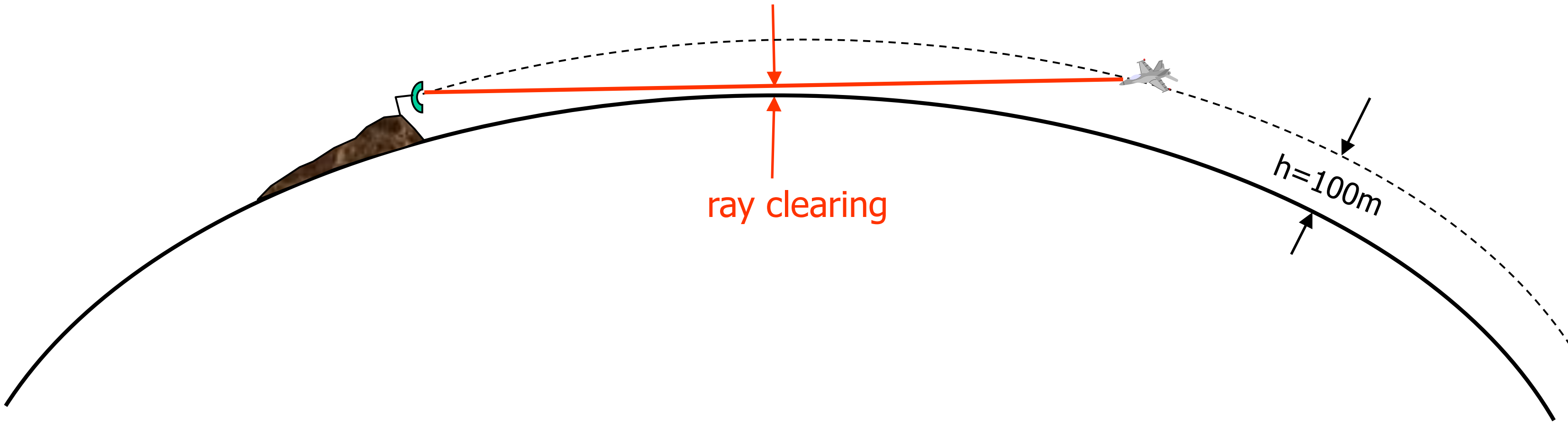
Assumes that the direct-path and the surface-reflected path are subject to the same antenna gain.

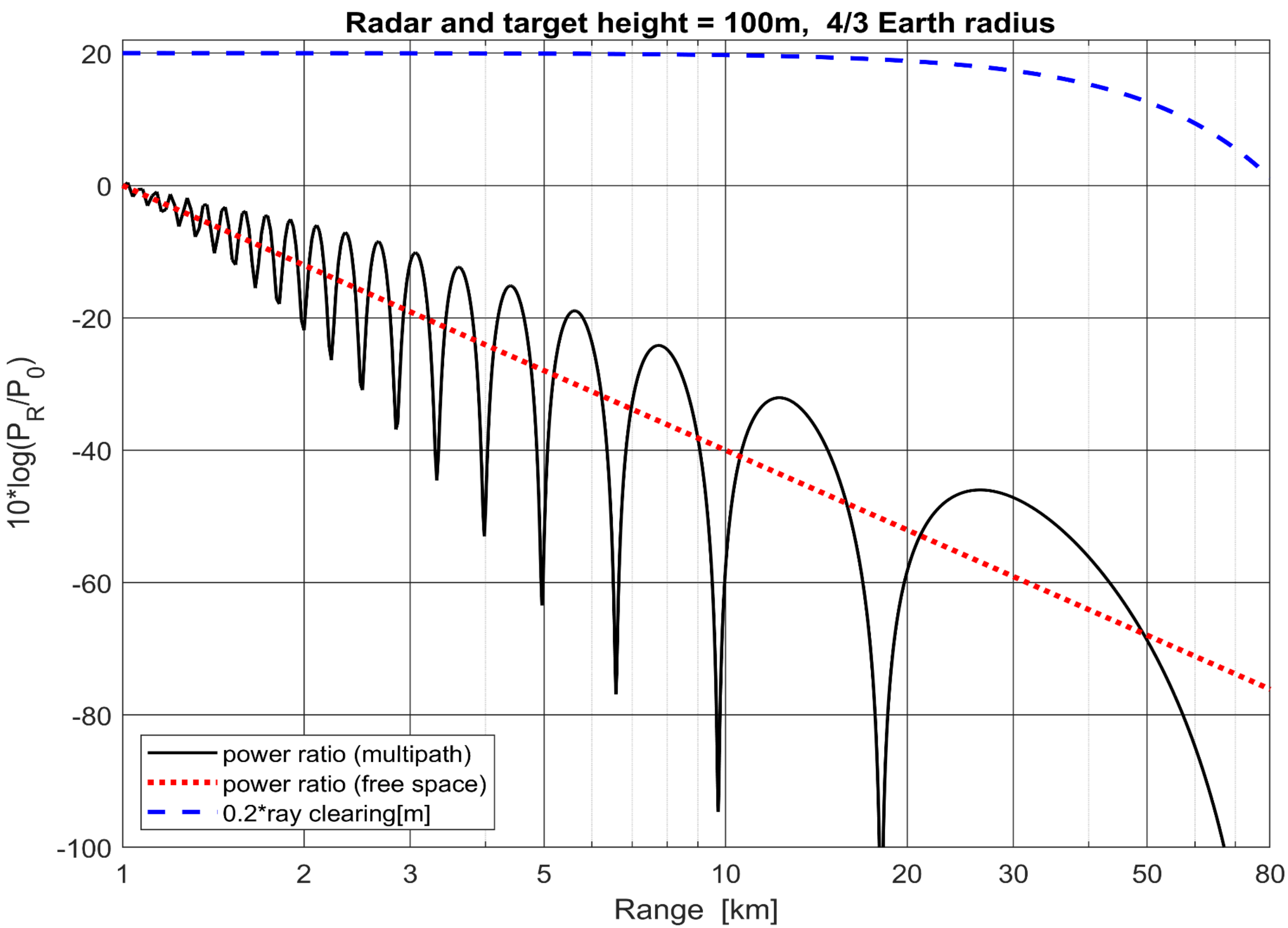
Nadav Levanon, Tel-Aviv University



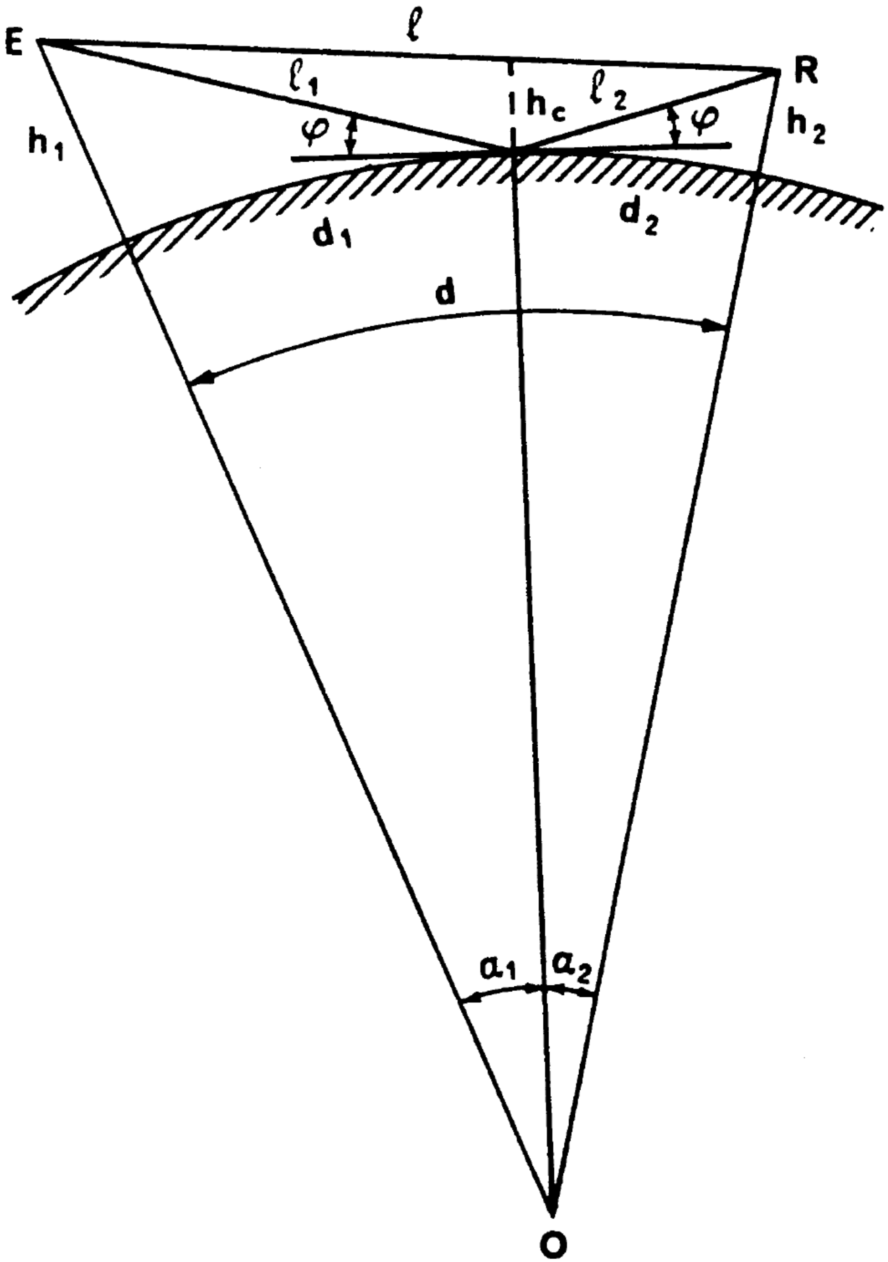
Multipath induced null pattern

grnd_ref


ray clearing
h=100m



Relative received power from a target approaching at a fix height


E
ℓ
R
ℓ1
hc
ℓ2
φ
φ
h1
h2
d1
d2
d
α1
α2
O

3.2 *Reflection geometry*

An analysis of surface reflections requires a determination of the geometrical specular reflection point located at some distance, d_1, from one of the terminals. This is not easy to determine as an exact solution exists only for a flat Earth. Approximate solutions are available for small angular distances for terminals near the surface of the Earth and for very large distances between terminals such as the case of an earth terminal and a geostationary satellite [Boithias, 1984; Kerr, 1965].

In the first case, it is convenient to define two intermediate quantities, m and c:

$$m = \frac{d^2}{4\,a_e(h_1 + h_2)} \tag{3}$$

$$c = (h_1 - h_2)/(h_1 + h_2) \qquad h_1 > h_2 \tag{4}$$

where a_e is the effective radius of the Earth and the other quantities are those shown in Fig. 2. Then one finds a third quantity, b:

$$b = 2\sqrt{\frac{m+1}{3m}} \cdot \cos\left[\frac{\pi}{3} + \frac{1}{3}\arccos\left(\frac{3c}{2}\sqrt{\frac{3m}{(m+1)^3}}\right)\right] \tag{5}$$

and the quantities of interest, namely the distance d_1, the path length difference Δ, and the grazing angle φ (rad) are given by:

$$d_1 = \frac{d}{2}(1 + b) \tag{6}$$

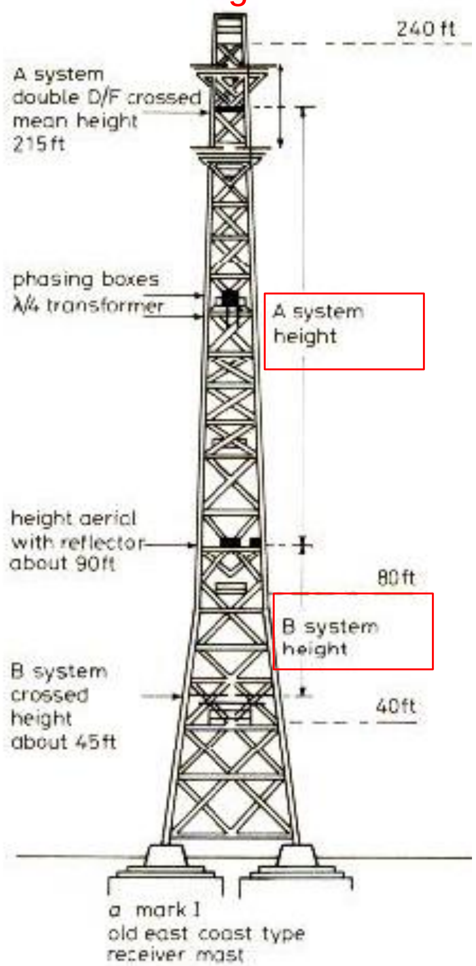
$$\Delta = \frac{2 d_1 d_2}{d}\,\varphi^2 \tag{7}$$

$$\varphi = \frac{h_1 + h_2}{d}\left[1 - m(1 + b^2)\right] \tag{8}$$

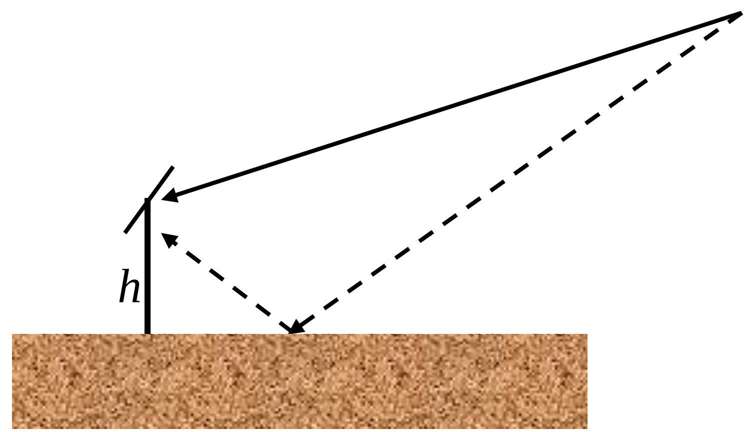
Chain Home Radar

Typical operating conditions:
FREQUENCY: 20 to 30 MHz (15 to 10 meters).
PEAK POWER: 350 kW (later 750 kW).
PULSE REPETITION FREQUENCY: 25 and 12.5 pps.
PULSE LENGTH: 20 μs.

Receiving antenna



$$h_{S1} = 29\text{m},\ h_{S2} = 65.5\text{m}$$
$$\lambda = 10\text{m}$$



$$h_{S1} = 29\text{m},\ h_{S2} = 65.5\text{m}$$

$$\lambda = 10\text{m}$$

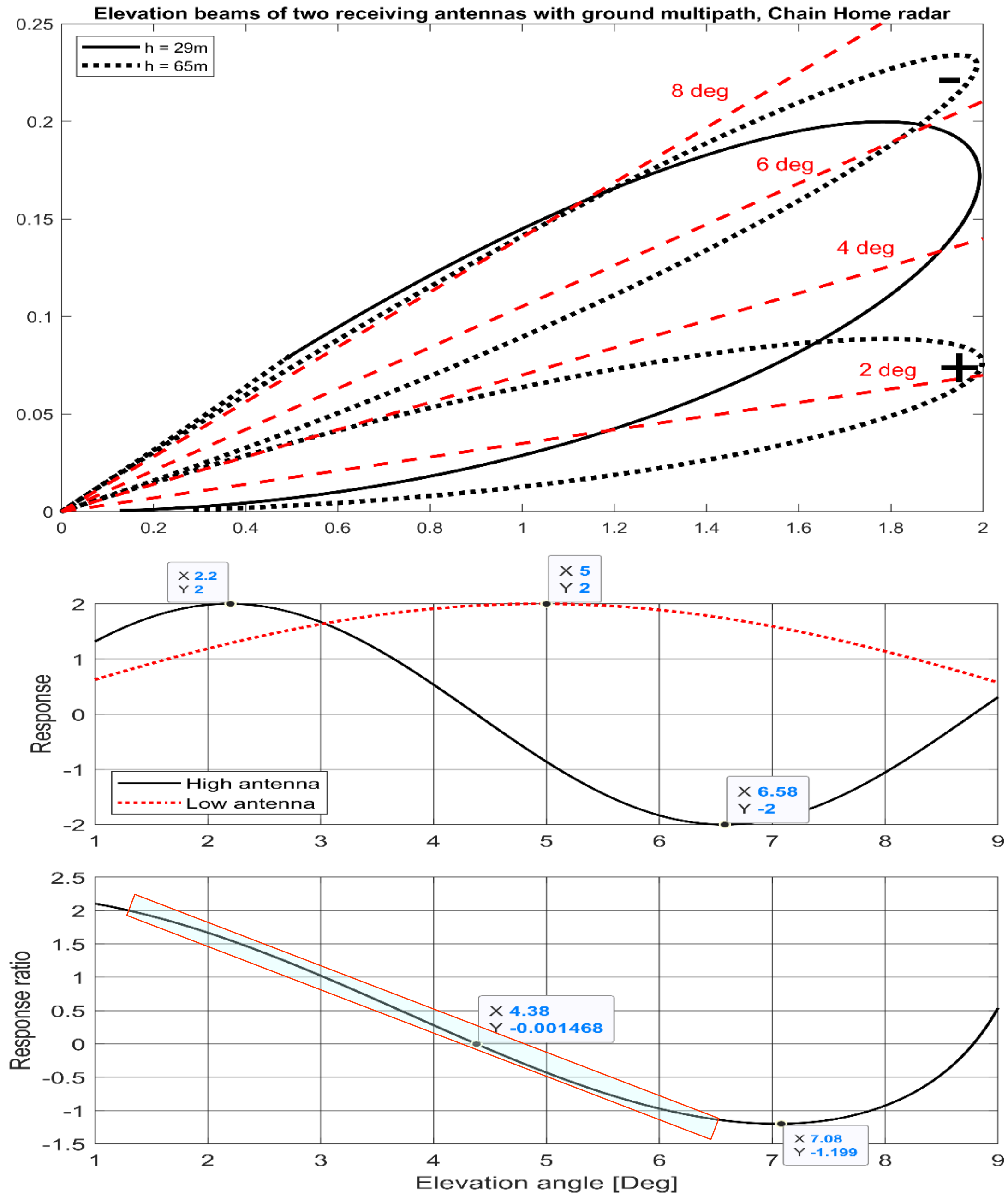
$$|F| = \left| 2\sin\left(\frac{2\pi}{\lambda} h_s \sin\alpha\right) \right|$$

$$F = 2\sin\left(\frac{2\pi}{\lambda} h_s \sin\alpha\right) e^{j\phi}$$

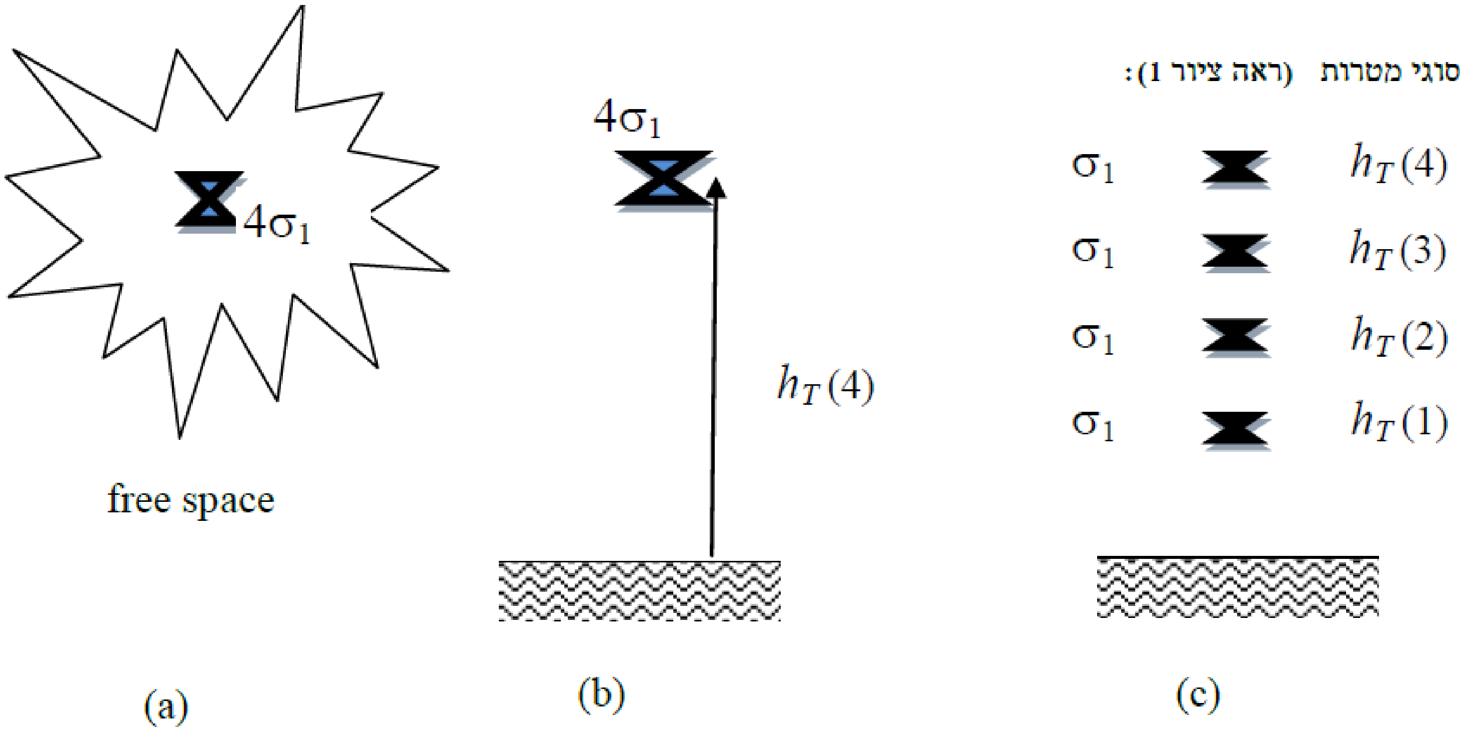
$$f_1 = 2\sin\left(\frac{2\pi}{10} 65.5 \sin\alpha\right) e^{j\phi_1}$$

$$f_2 = 2\sin\left(\frac{2\pi}{10} 29 \sin\alpha\right) e^{j\phi_2}$$

$$\frac{f_1}{f_2} \underset{\phi_1 \approx \phi_2}{\approx} \frac{\sin(41.155 \sin\alpha)}{\sin(18.22 \sin\alpha)}$$



יש להשוות בין שלושה סוגי מטרות (ראה ציור 1):



ציור 1

בכל שלושת המקרים המטרה נמצאת בטווח R ממכ"ם ימי שהאנטנה שלו בגובה $h_S = 8\text{m}$ מעל פני הים.

(a) מטרת נקודה במרחב חופשי עם שח"מ $= 4\sigma_1$.

(b) מטרת נקודה בגובה $h_T = 12\text{m}$ מעל פני ים חלק, עם שח"מ $= 4\sigma_1$.

(c) ארבע מטרות נקודה בגבהים $h_T = [3,\ 6,\ 9,\ 12]\text{m}$ מעל פני ים חלק, כשלכל אחת שח"מ $= \sigma_1$.
ההספק החוזר במקרה זה הוא <u>סכום ההספקים</u> החוזרים מ 4 המחזירים.

נתון: $\sigma_1 = 50\,\text{m}^2$, $G = 160$, $\lambda = 0.033\text{m}$

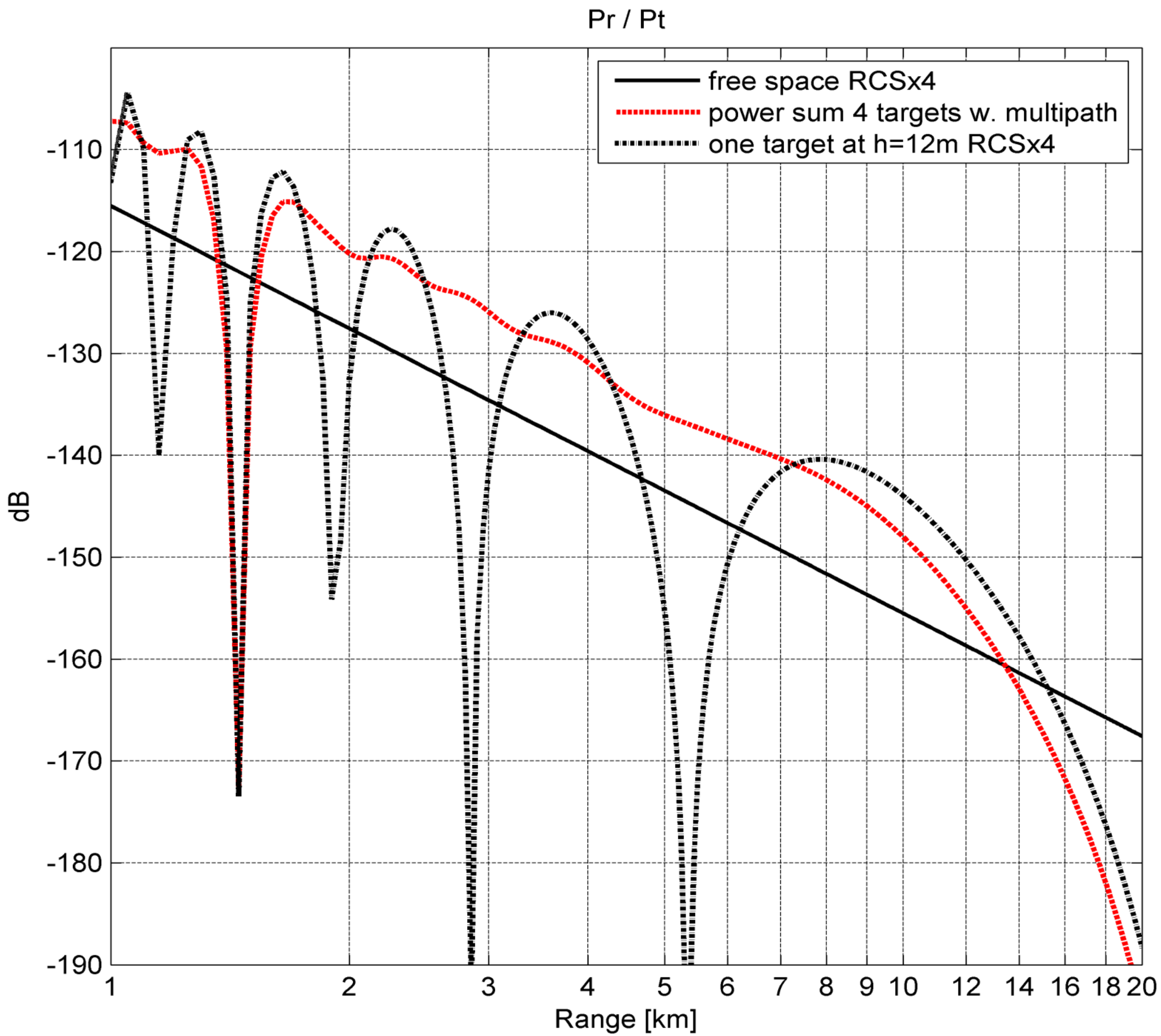

Pr / Pt
free space RCSx4
power sum 4 targets w. multipath
one target at h=12m RCSx4
dB
-110
-120
-130
-140
-150
-160
-170
-180
-190
1
2
3
4
5
6
7
8
9
10
12
14
16
18
20
Range [km]

Figure 9.10 Echo strength comparison. Extended target compared with point of same RCS, calculated by sum-of-ten and Eq. (9.16)