Propagation Mechanism

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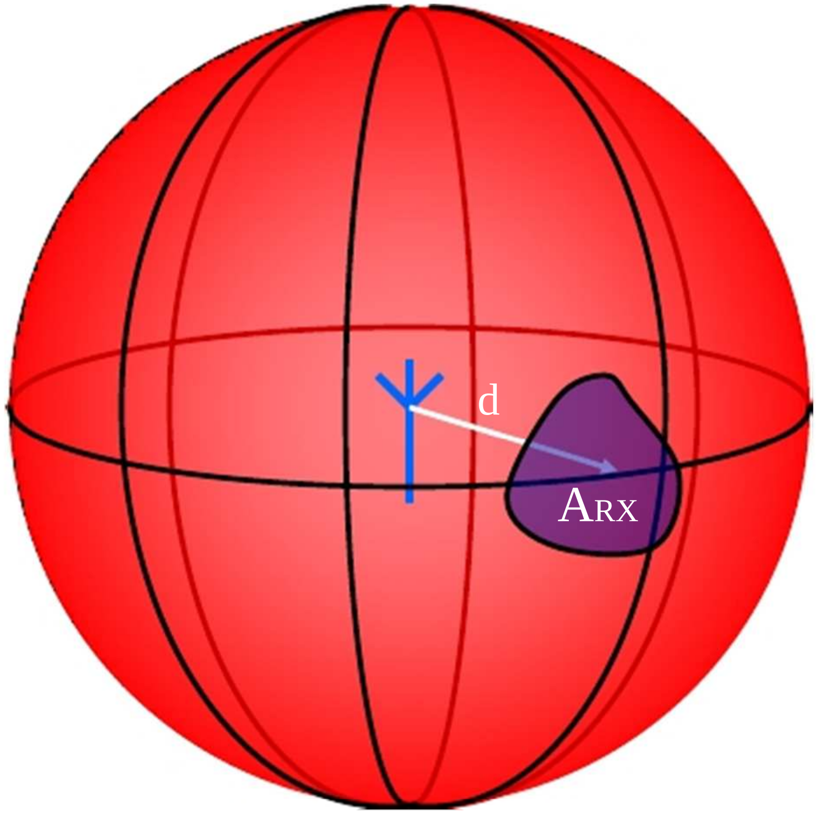
Propagation Mechanism

- **Free-space propagation**
- **Reflection**
- **Diffraction**
- **Scattering**

Free-space loss



If we assume RX antenna to be isotropic:

$$P_{RX} = \left(\frac{\lambda}{4\pi d}\right)^2 P_{TX}$$

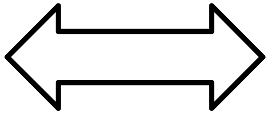
Attenuation between two isotropic antennas in free space is (free-space loss):

$$L_{free}(d) = \left(\frac{4\pi d}{\lambda}\right)^2$$

Free-space loss
Friis' law

Received power, with antenna gains G_{TX} and G_{RX}:

$$P_{RX}(d) = \frac{G_{RX} G_{TX}}{L_{(free)}(d)} P_{TX} = P_{TX} \left(\frac{\lambda}{4\pi d} \right)^2 G_{RX} G_{TX}$$



Valid in the far field only

$$P_{RX|dB}(d) = P_{TX|dB} + G_{TX|dB} - \mathrm{L}_{free|dB}(d) + G_{RX|dB}$$

$$= P_{TX|dB} + G_{TX|dB} - 10 \log_{10} \left(\frac{4\pi d}{\lambda} \right)^2 + G_{RX|dB}$$

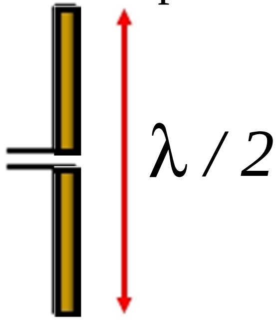
Free-space loss
What is far field?

Rayleigh distance:

$$d_R = \frac{2L_a^2}{\lambda}$$

where L_a is the largest dimension of the antenna.

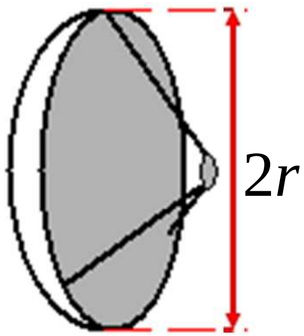
$\lambda/2$ -dipole



$L_a = \lambda/2$

$d_r = \lambda/2$

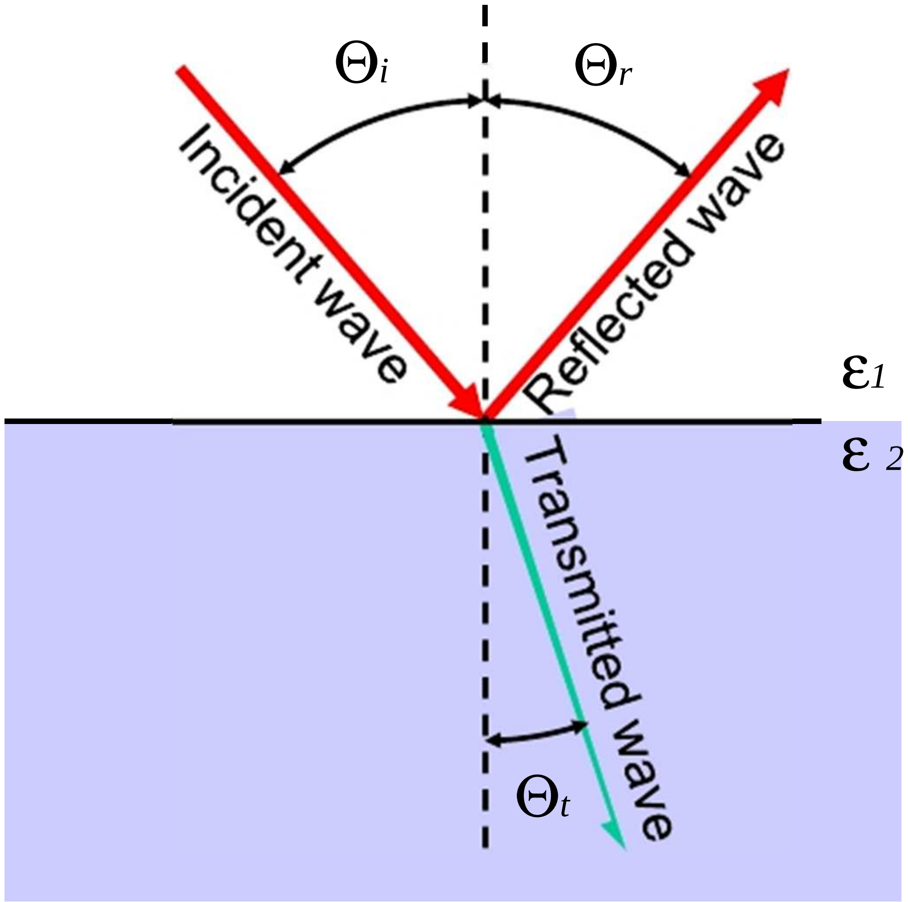
Parabolic



$L_a = 2r$

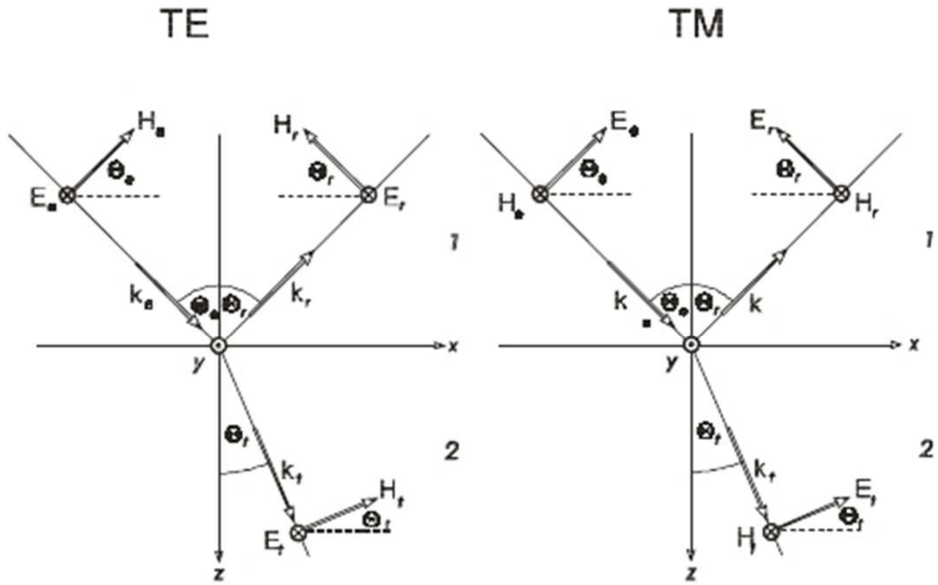
$$d_R = \frac{8r^2}{\lambda}$$

Reflection and transmission (1)

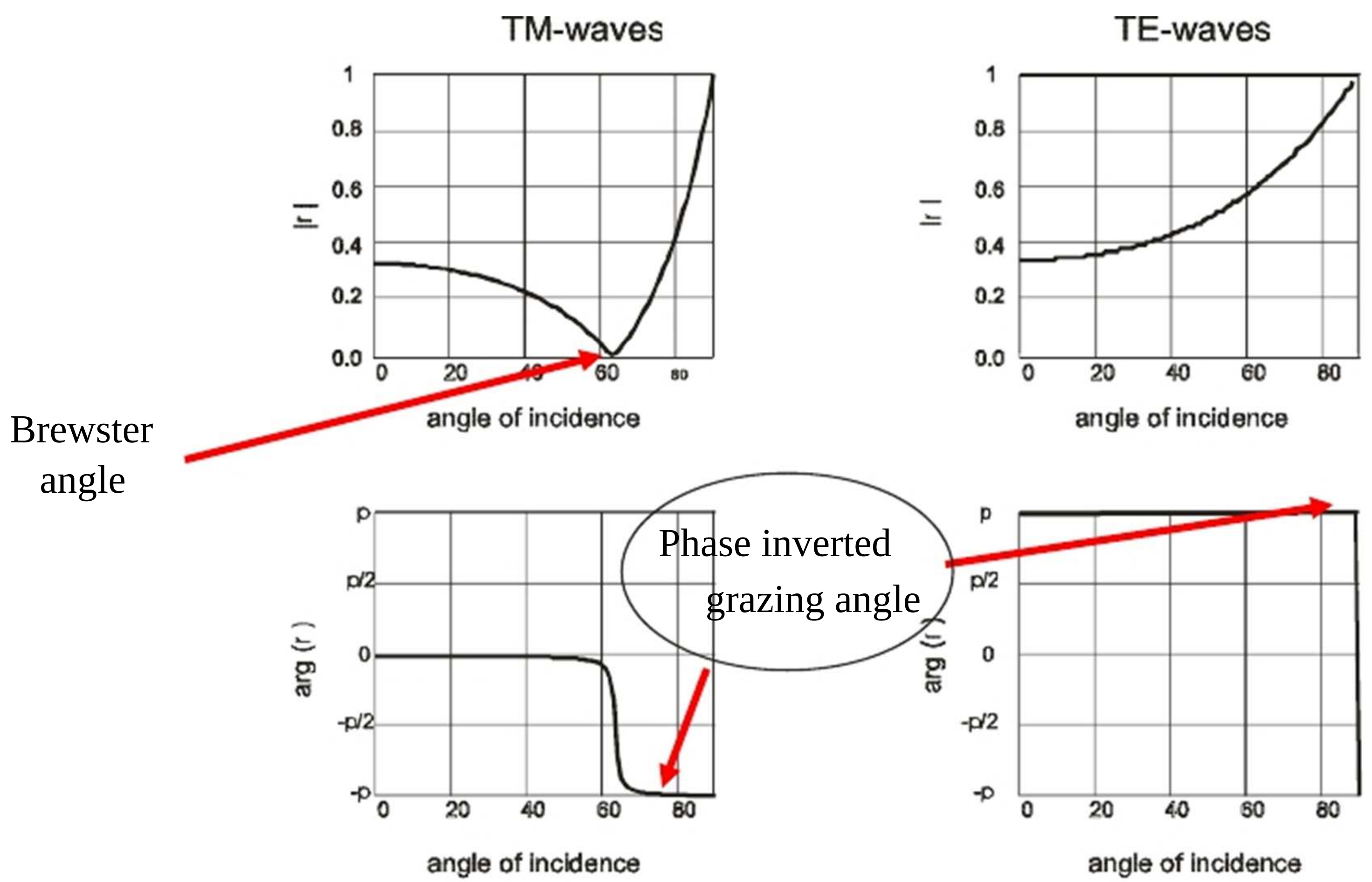


Reflection and transmission (2)

- Snell's law
  - Reflection angle $\Theta_r = \Theta_e$
  - Transmission angle $$\frac{\sin \Theta_t}{\sin \Theta_e} = \frac{\sqrt{\varepsilon_1}}{\sqrt{\varepsilon_2}}$$
- Transmission and reflection: distinguish TE and TM waves

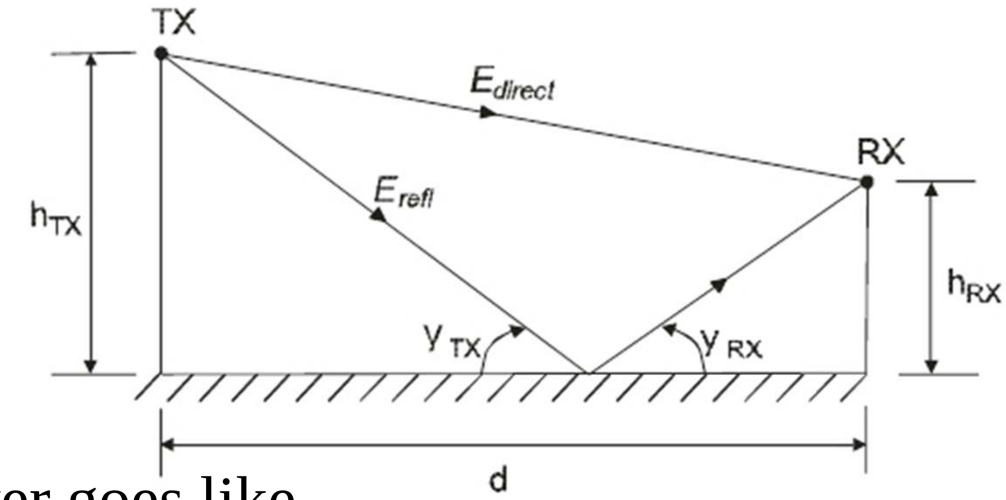


Reflection and transmission (3)



The d-4 law (1)

- For the following scenario



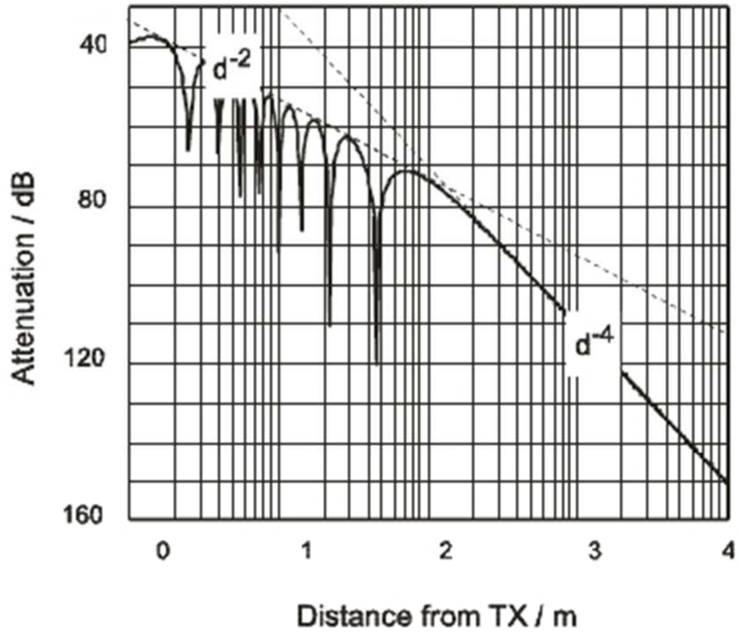
- the power goes like

$$P_{RX}(d) \approx P_{TX} G_{TX} G_{RX} \left(\frac{h_{TX} h_{RX}}{d^2} \right)^2$$

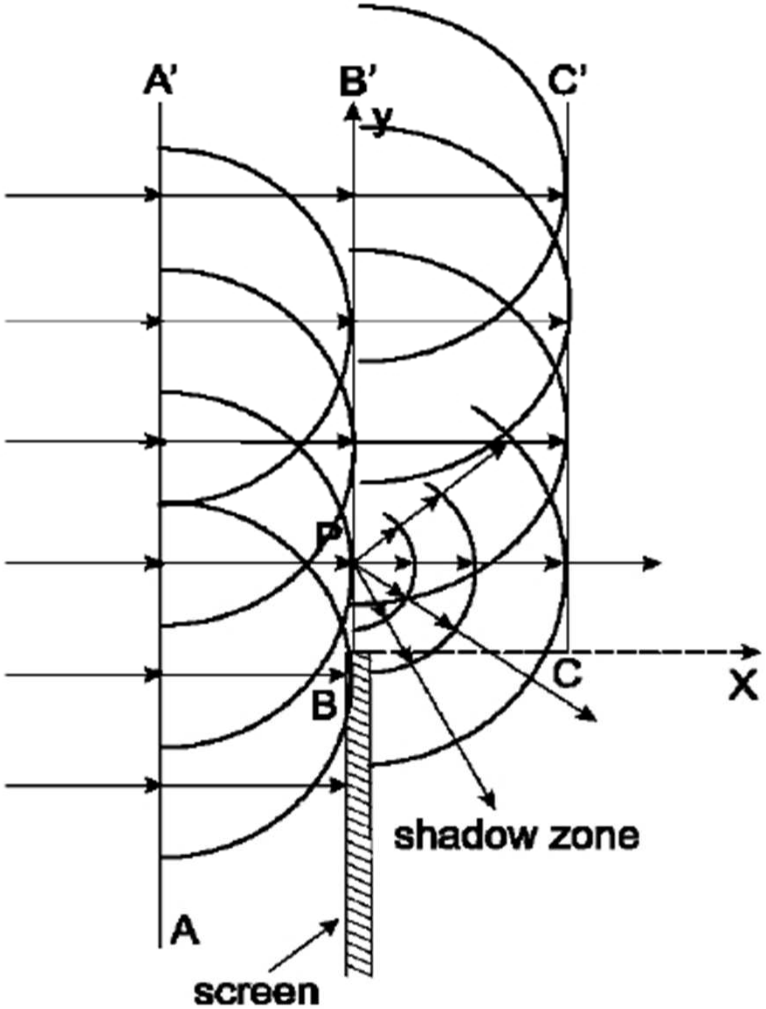
- for distances greater than

$$d_{break} \geq \frac{4 h_{TX} h_{RX}}{\lambda}$$

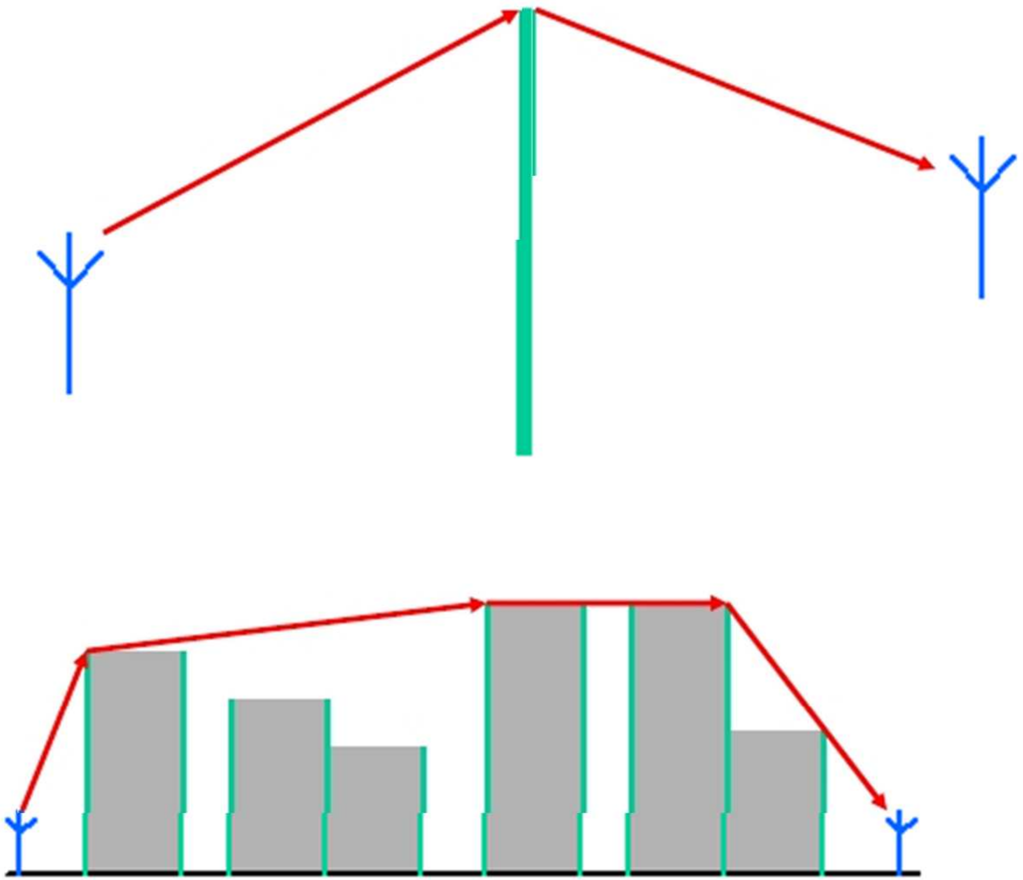
The d^{-4} law (2)



Diffraction, Huygen’s principle

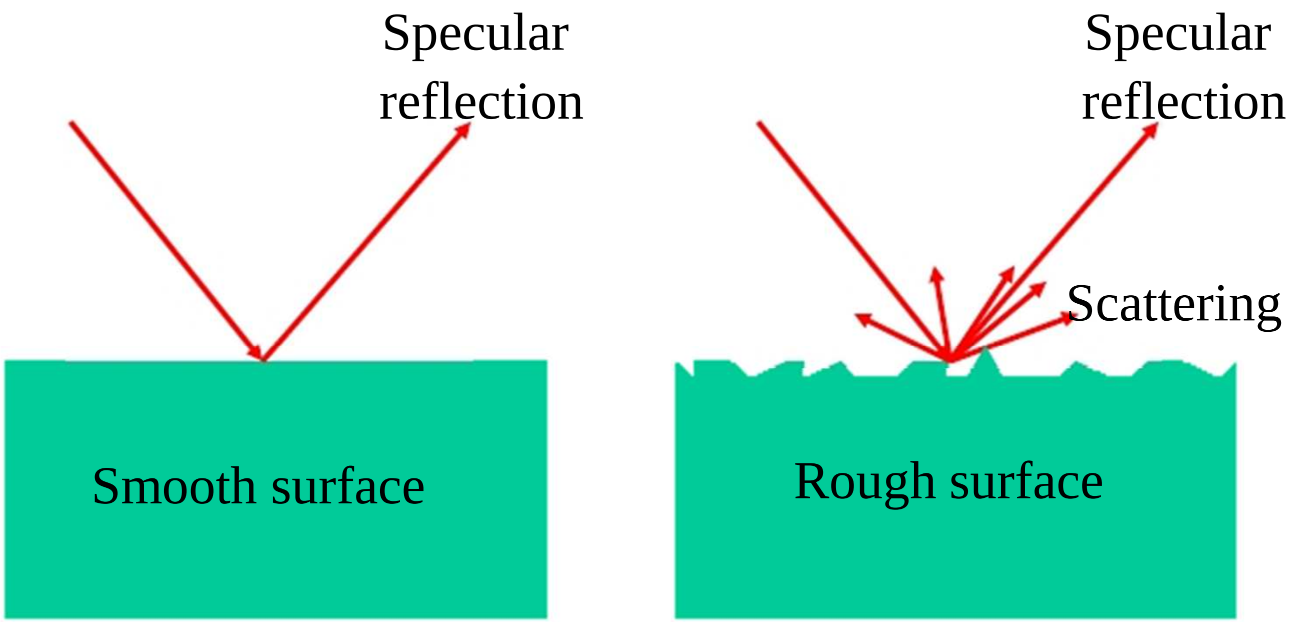


Diffraction

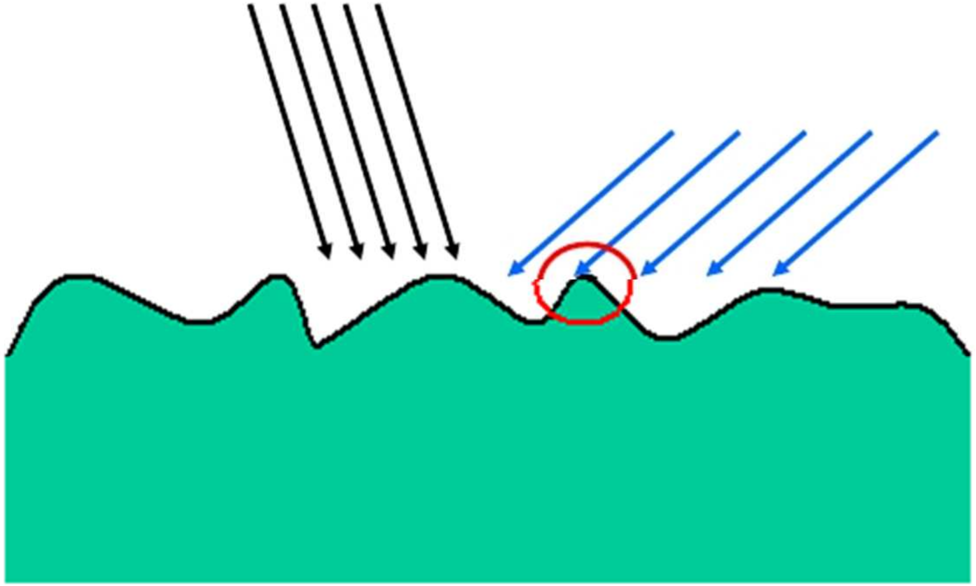


- Single or multiple edges
- makes it possible to go behind corners
- less pronounced when the wavelength is small compared to objects

Scattering


Specular
reflection
Specular
reflection
Scattering
Smooth surface
Rough surface

Kirchhoff theory – scattering by rough surfaces



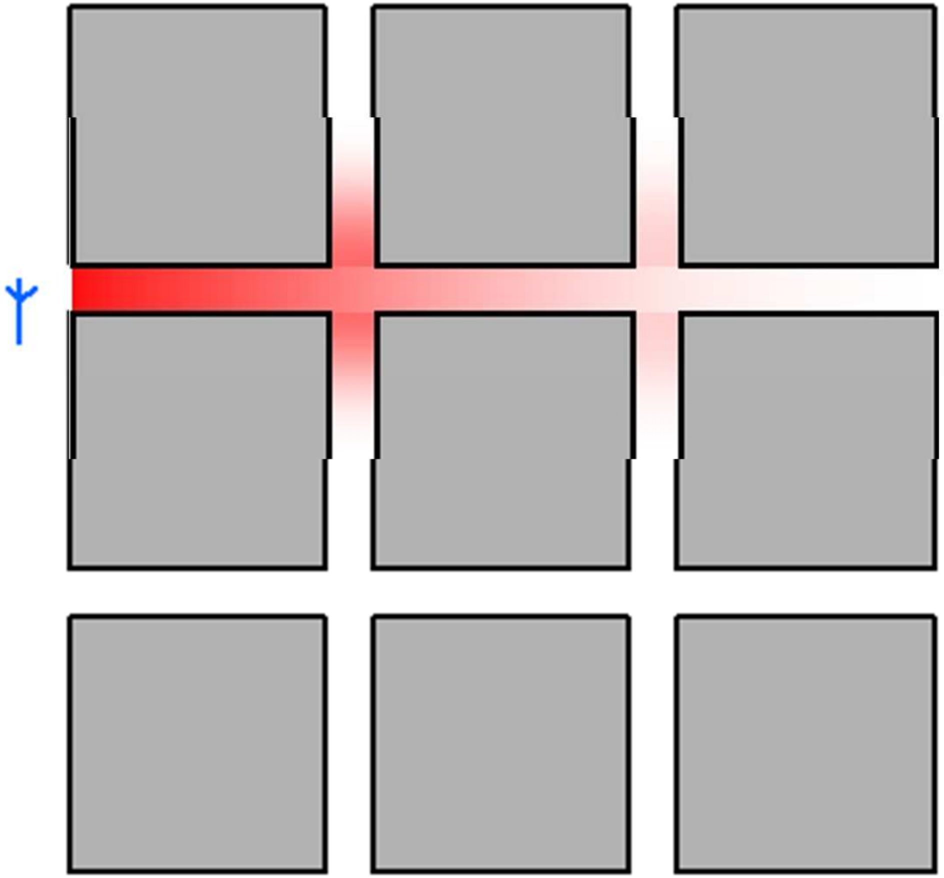
for Gaussian surface distribution

angle of incidence

$$\rho_{rough} = \rho_{smooth} \exp[-2(k_0 \sigma_h \sin\psi)^2]$$

standard deviation of height

Waveguiding



Waveguiding effects often result in lower propagation exponents

n=1.5-5

This means lower path loss along certain street corridors