Large Scale Propagation Model

Propagation Model

- Propagation models are used for:
  - Predicting the average signal strength at a given distance from the transmitter
  - Estimating the variability of the signal strength in close spatial proximity to a particular locations

- Can be categorized into two types:
  1. Large-scale propagation models
  2. Small-scale propagation models

Large Scale Propagation Model:

- Predict the mean signal strength for an arbitrary transmitter-receiver(T-R) separation.
- Estimate radio coverage of a transmitter
- Characterize signal strength over large T-R separation distances (several 100's to 1000's meters)

Small Scale Propagation Model:

- Characterize rapid fluctuations of received signal strength over
  - Very short travel distances (a few wavelengths)
  - Short time durations (on the order of seconds)

Multipath Propagation Mechanism

- There are three basic propagation mechanisms in addition to line-of-sight paths:
  1. Reflection
  2. Diffraction
  3. Scattering

- **Reflection** - occurs when signal encounters a surface that has large dimension relative to the wavelength of the signal.

- **Diffraction** – occurs at the edge of an impenetrable body that is large compared to the wavelength of the radio wave. When a radio wave encounters such an edge, waves propagate in different directions with the edge as the source.

- **Scattering** – occurs when incoming signal hits an object whose size in the order of the wavelength of the signal or less.

Multipath Propagation

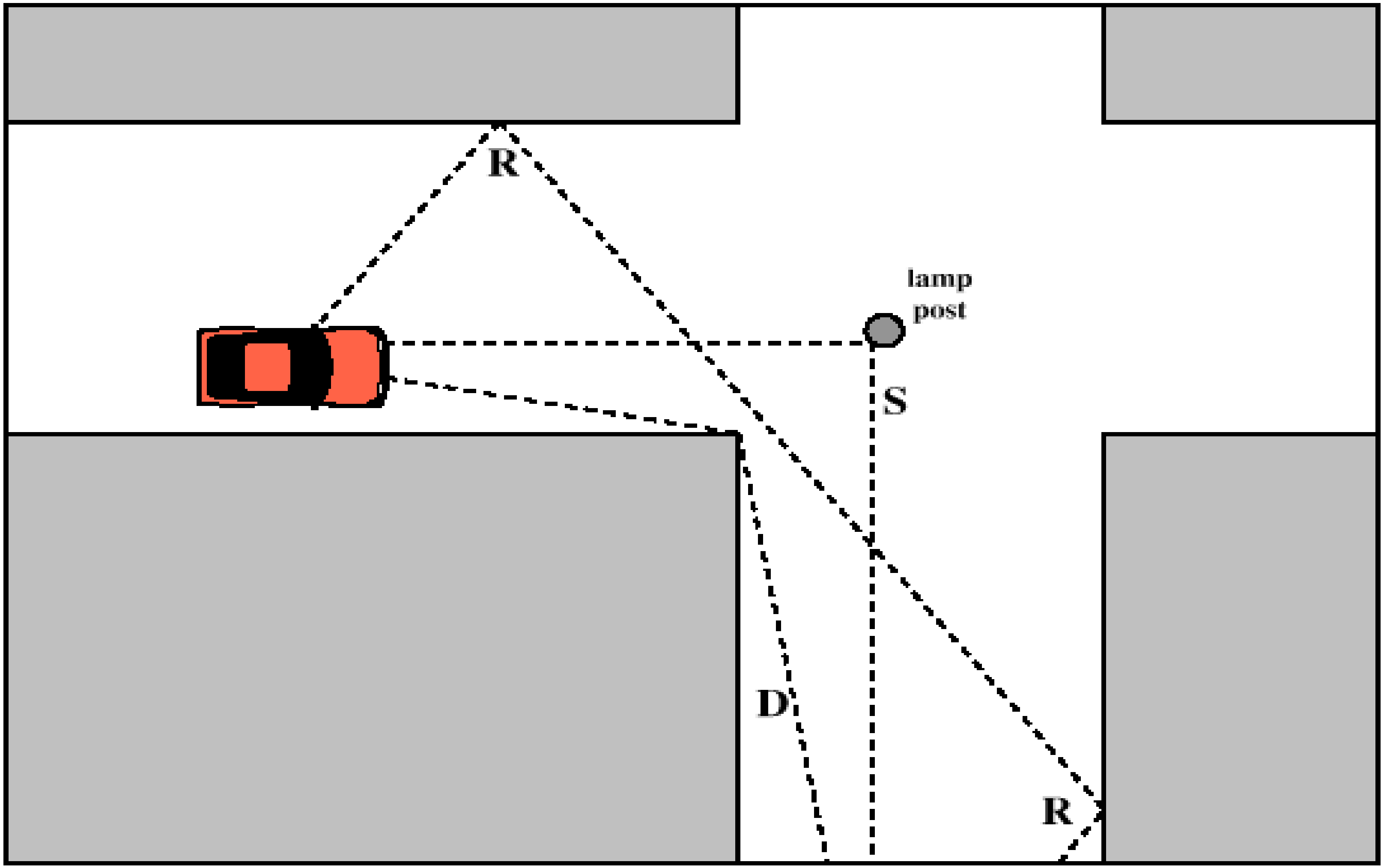
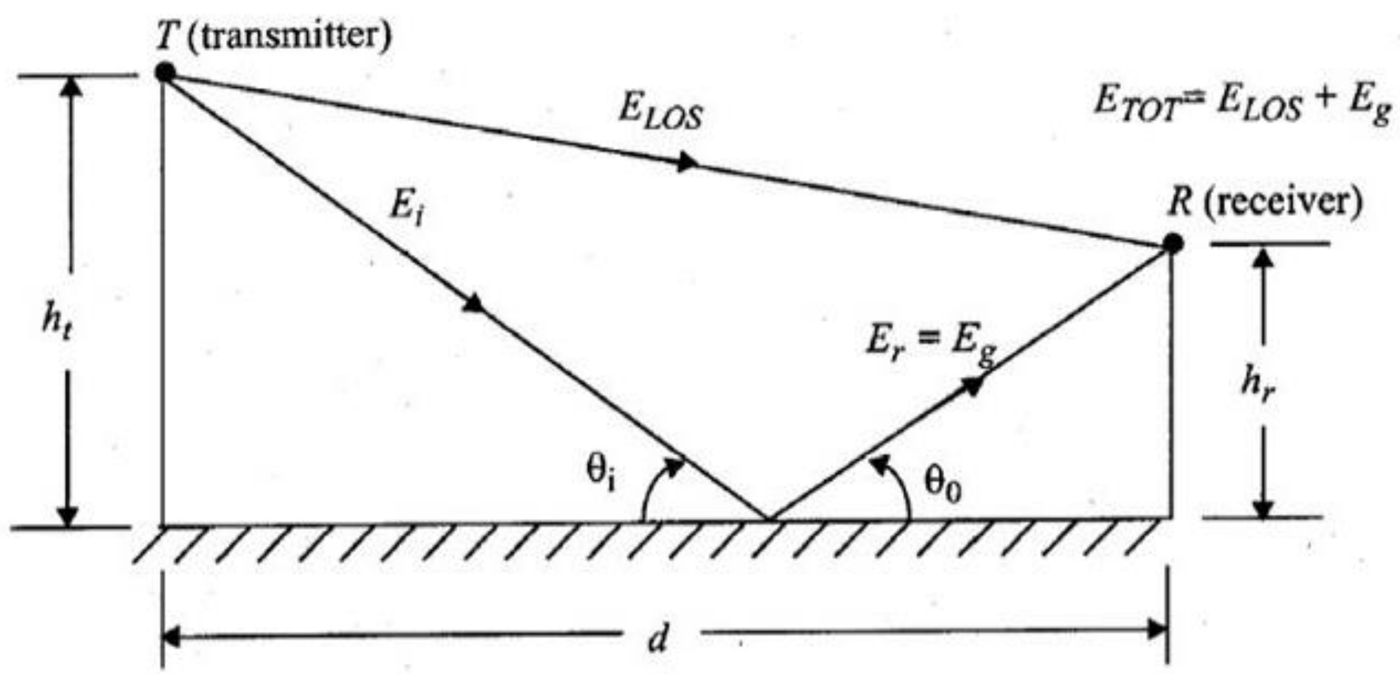


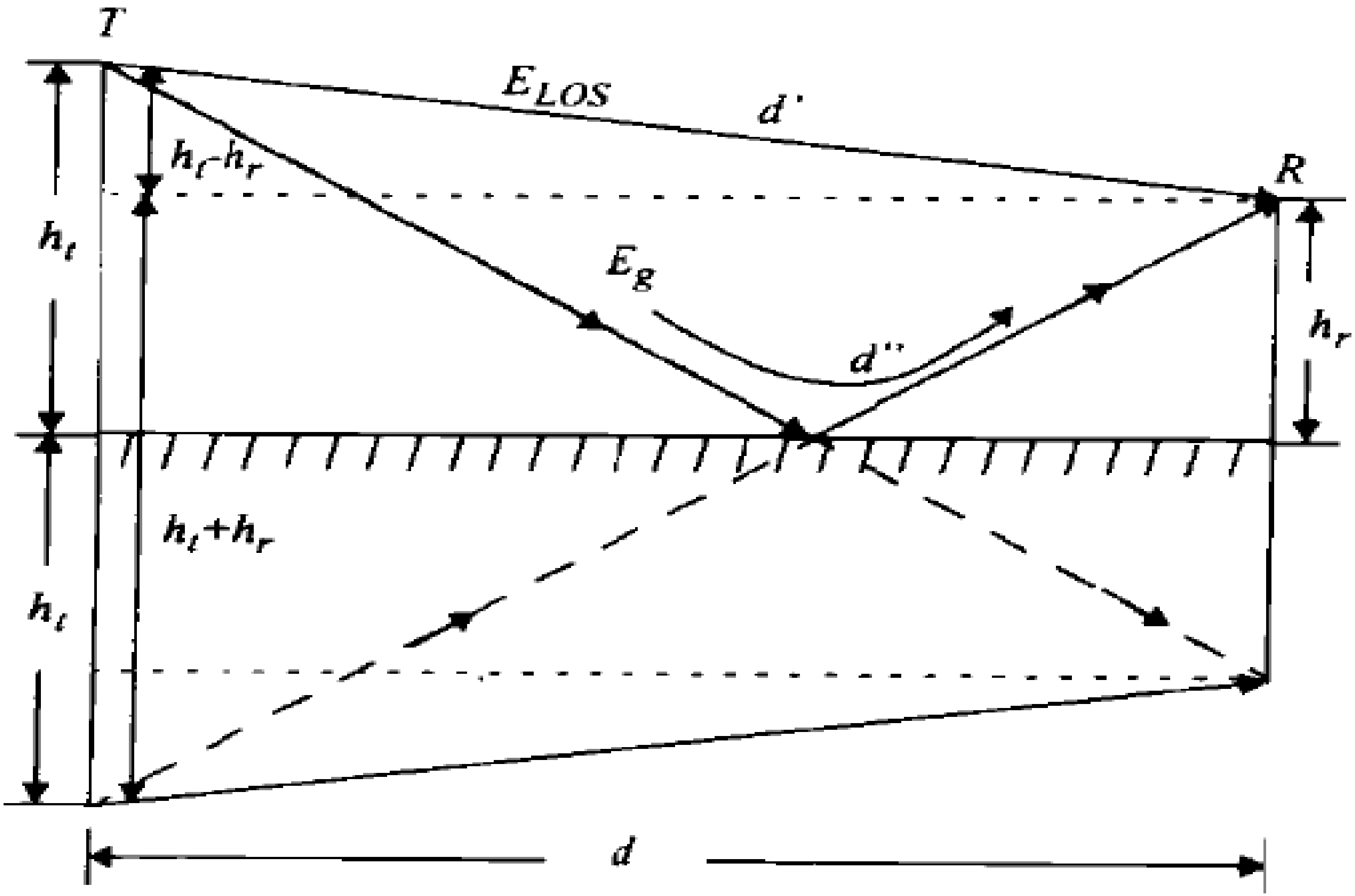
Figure 5.10 Sketch of Three Important Propagation Mechanisms: Reflection (R), Scattering (S), Diffraction (D) [ANDE95]

2-Ray Ground Reflection Model

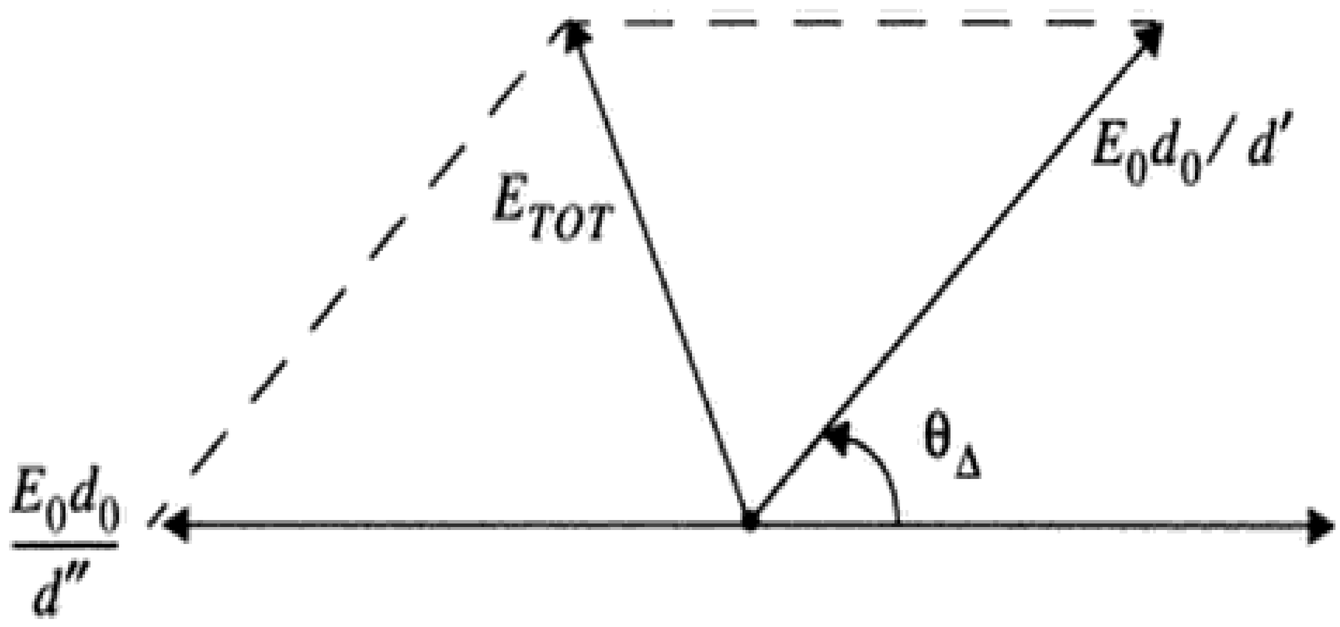
- Reasonably accurate for predicting
  - the large-scale signal strength over long distances (» km) for mobile systems that use tall towers (heights > 50 m)
  - line-of-sight microcell channels in urban environments



The method of images is used to find the path difference between the line-of-sight and the ground reflected paths.



Phasor diagram showing the electric field components of the line-of-sight, ground reflected, and total received E-fields, derived from equation



Example 3.6:

A mobile is located 5 km away from a base station and uses a vertical $\lambda/4$ monopole antenna with a gain of 2.55 dB to receive cellular radio signals. The E-field at 1 km from the transmitter is measured to be 10^{-3} V/m. The carrier frequency used for this system is 900 MHz.

(a) Find the length and the gain of the receiving antenna.

(b) Find the electric field and received power at the mobile using the 2-ray ground reflection model assuming the height of the transmitting antenna is 50 m and the receiving antenna is 1.5 m above ground.

Diffraction

- Diffraction allows radio signals to propagate around the curved surface of the earth and to propagate behind obstructions.
- Based on Huygen's principle, which says that all points on a wave front can be considered as point sources for the production of secondary wavelets.

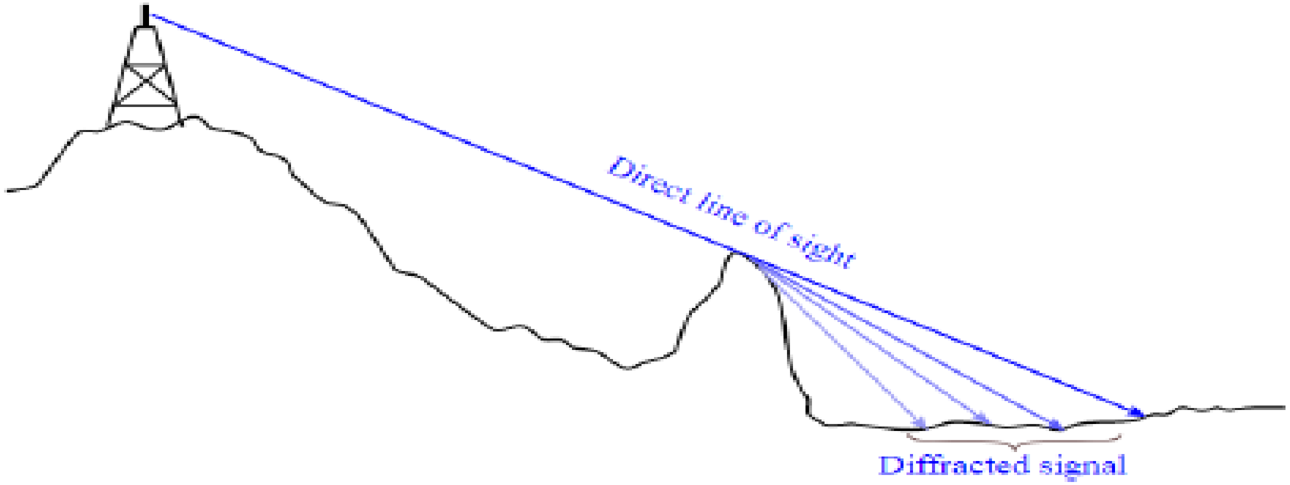
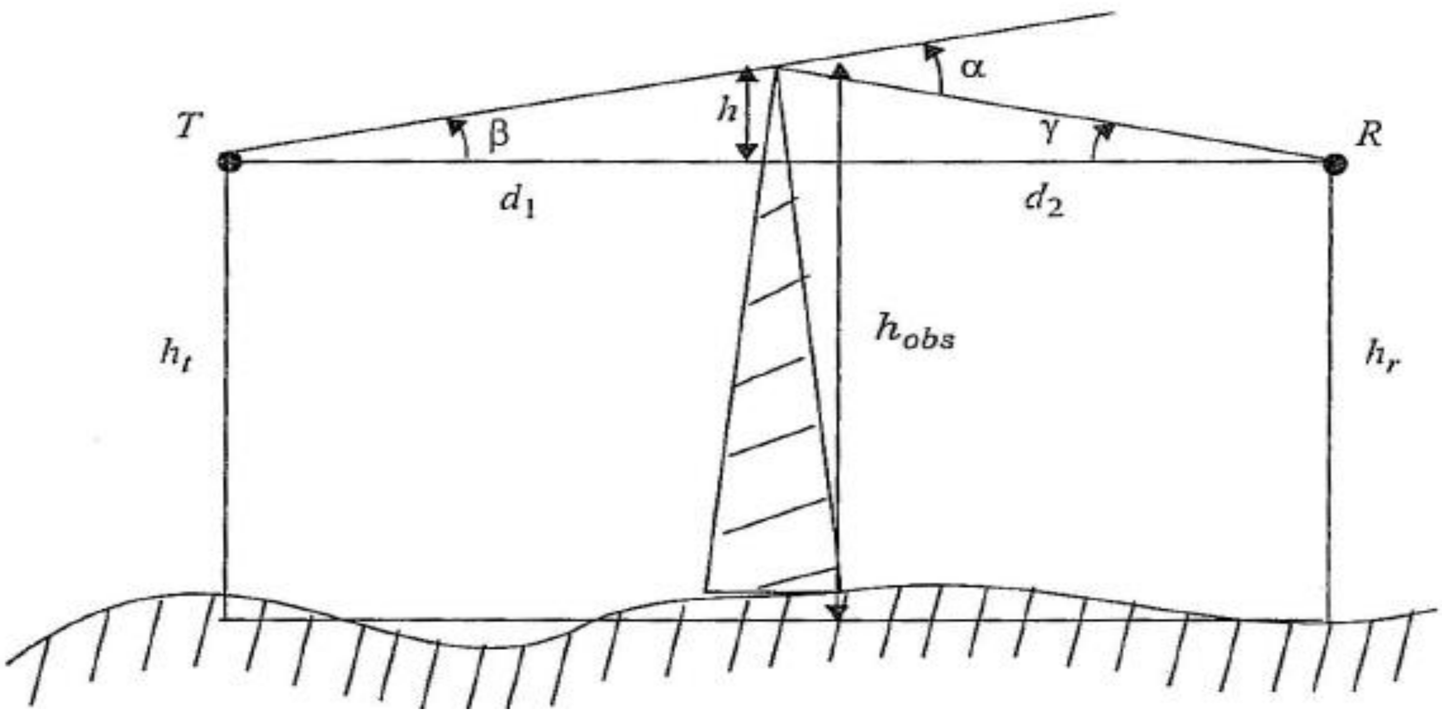


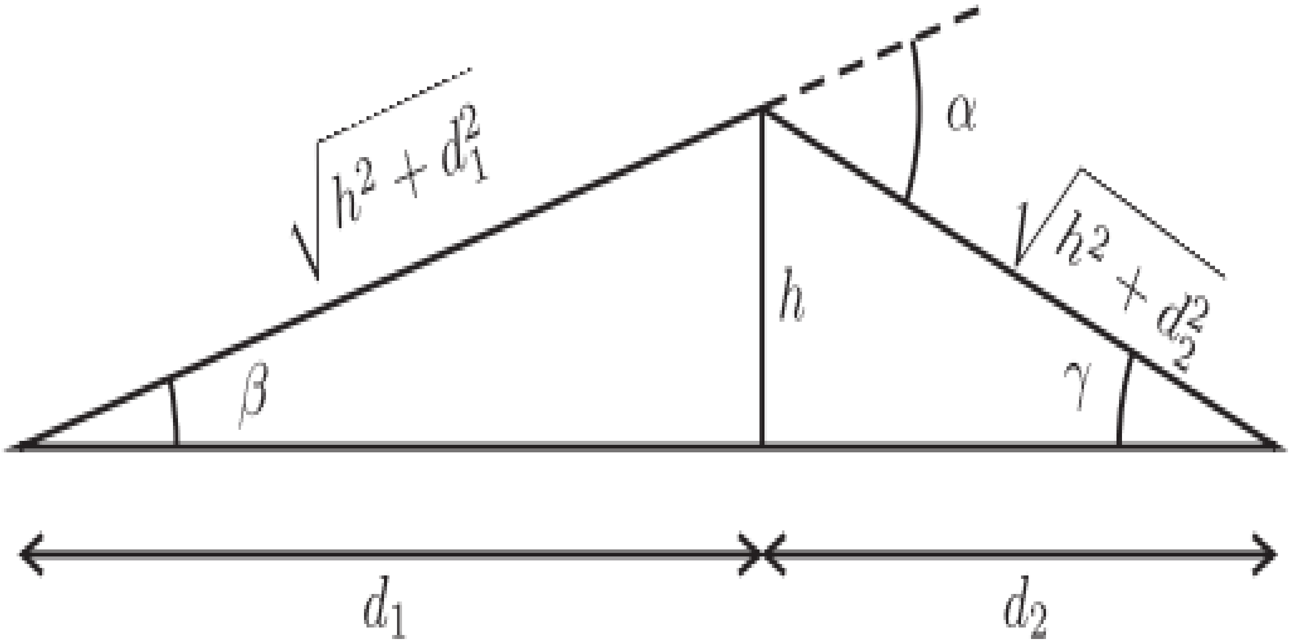
Fig. Radio wave diffraction.

Knife Edge Diffraction Model

- Estimating the signal attenuation caused by diffraction of radio waves over hills and buildings.
- Consider a receiver at point R, located in the shadowed region (also called the diffraction zone). The field strength at point R is a vector sum of the fields due to all of the secondary Huygen's sources in the plane above the knife edge.



Knife Edge Diffraction Geometry ($h_t = h_r$)

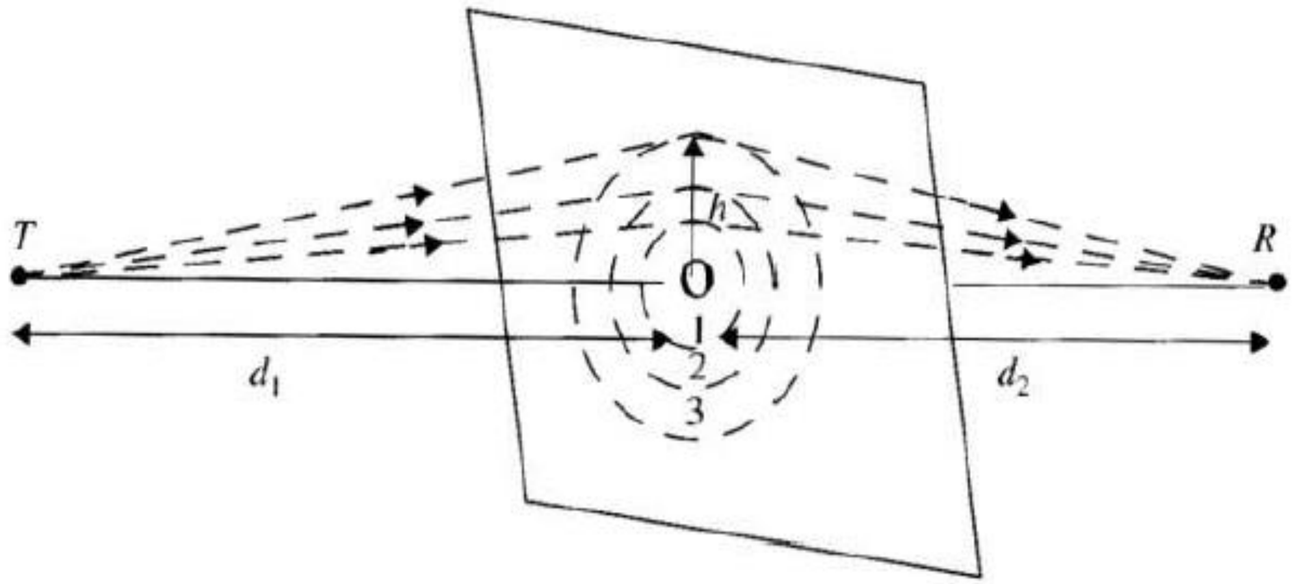


Diffraction Loss For Various Value of V

$G_d(dB)$	v
0	≤ -1
$20 \log(0.5-0.62v)$	[-1,0]
$20 \log(0.5\, e^{-0.95v})$	[0,1]
$20 \log(0.4-(0.1184-(0.38-0.1v)^2)^{1/2})$	[1, 2.4]
$20 \log(0.225/v)$	> 2.4

Fresnel zones

- Fresnel zones represent successive regions where secondary waves have a path length from the TX to the RX which are $n\lambda/2$ greater in path length than of the LOS path.



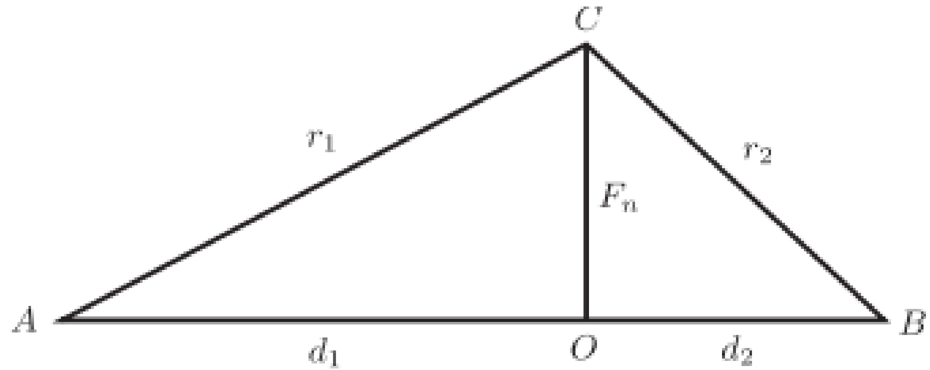


Figure : Fresnel zone radius illustration

The radius of the nth Fresnel zone circle can be found as follows. Consider the triangle below which shows a cross-section of the nth Fresnel zone. Path AB is teh direct path and path ACB is the indirect path. The condition that will locate point C on the nth Fresnel zone is

$$r_1 + r_2 = d_1 + d_2 + n\lambda/2.$$

Hence,

$$\sqrt{d_1^2 + F_n^2} + \sqrt{d_2^2 + F_n^2} = d_1 + d_2 + n\lambda/2,$$

and since $F_n \ll d_1,\ F_n \ll d_2$, we can approximate this as

$$d_1 + \frac{F_n^2}{2d_1} + d_2 + \frac{F_n^2}{2d_2} = d_1 + d_2 + n\lambda/2.$$

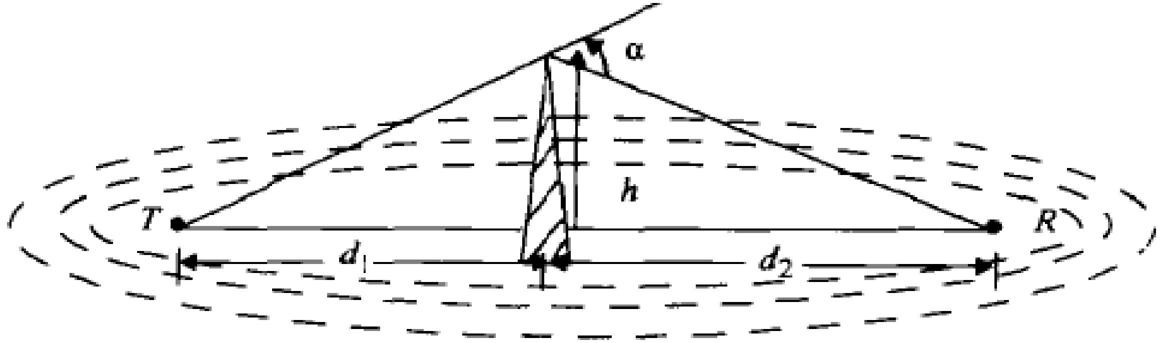
Therefore,

$$\frac{F_n^2}{2}\left[\frac{1}{d_1} + \frac{1}{d_2}\right] = F_n^2 \frac{d_1 + d_2}{2d_1 d_2} = n\lambda/2$$

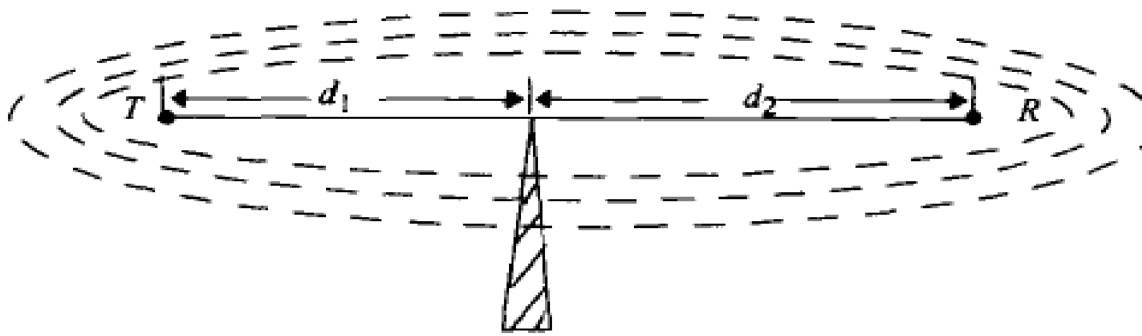
yielding

$$F_n = \sqrt{\frac{n\lambda d_1 d_2}{d_1 + d_2}}$$

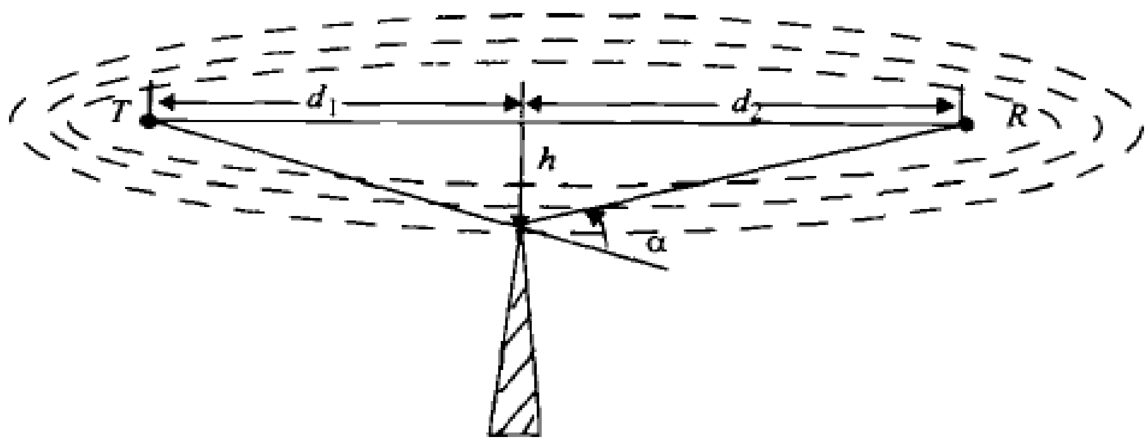
Three Cases:



(a) α and ν are positive, since h is positive



(b) α and ν are equal to zero, since h is equal to zero



(c) α and ν are negative, since h is negative

Example 3.7

- Compute the diffraction loss for the three cases. Assume λ=1/3m, d1 =1 km, d2 =1 km and (a)h =25m, (b)h =0, (c)h =-25m. For each of these cases, identify the Fresnel zone within which the tip of the obstruction lies.

Example 3.8

Given the following geometry, determine (a) the loss due to knife-edge diffraction, and (b) the height of the obstacle required to induce 6 dB diffraction loss. Assume $f = 900$ MHz.