Chapter 4

Mobile Radio Propagation : Large Scale loss

General Discussion ☺

- Medium as Filter
- Antenna Size
- Measurement Required
- Channel Models

Propagation Basics

- When electrons moves , they create EM field is created
- By attaching an effective antenna , we can transmit this radiation to space
- Noise

Basics (1)

- VLF , LF and MF bands
- The waves propagate in form of Ground waves
- Example AM
- How ever , at HF the radio waves are not effective (Reason)

Mobile Radio Propagation

- For higher frequency (HF) we use ionosphere reflection (Sky wave)
- Give rise to fading
- **For VHF**
- Uses LOS
- Fading via reflected waves

Antenna Basics

- **Free Space Propagation Model**
- Free space propagation model is used to predict received signal strength when the transmitter and receiver have clear LOS. Satellite communication and Microwave communication (LOS) uses free space propagation typically.
- Predicts that received power decays as a direct function of T—R separation distance .(raised to some power)
- Pt= $\frac{P_t G_1 G_2 \lambda^2}{(4\pi)^2 d^2 L}$ ------------- Friis Free Space Equation

..Friis Free Space Equation..

- P_t= Transmitted power
- G_t= Transmitter Antenna Gain
- G_r= Receiver Antenna Gain
- D= Separation Distance
- L= System Loss Factor (due to remission line loses, antenna losses, filter losses)

$$G=\frac{4\pi Ae}{\lambda^2}$$

GAIN IN MOBILE

Antenna Basics

- Ae is Antenna Aperture and is related physical size of antenna .
- Gain increases as frequency increase
- Isotropic Antenna : An hypothetical antenna , that radiates in all direction
- Effective Isotropic Radiated Power is EIRP = PtGt
- Effective Radiated Power : is radiated power in comparisons to half wave dipole antenna. (Gain 16.4 or 2.15 db)
- ERP=EIRP-2.15dB

Antenna Basics

- Antenna gains are also given in Dbi
- Path Loss Represents attenuation as positive quantity and is measured in dB
- PL(db) =10log(Pt/Pr) or -10log($\frac{G_1 G_2 \lambda^2}{(4\pi)^2 d^2}$)
- Friss Free Space model is only valid In far filed region $d_f = 2D^2/\lambda$
- Where D is largest physical Dimension of antenna

Antenna Basics

- Friss Free Space Equation does not hold for d=0
- So we use a **close in distance** do as as **Received Power reference point**
- The received power is now given as
- $$Pr(d) = Pr(do)\left(\frac{(do)}{d}\right)^2 \text{ or}$$
- $$Pr\ (d)\ dBm = 10\log\left(\frac{Pr(do)}{0.001\ W}\right) + 20\log\left(\frac{(do)}{d}\right)$$

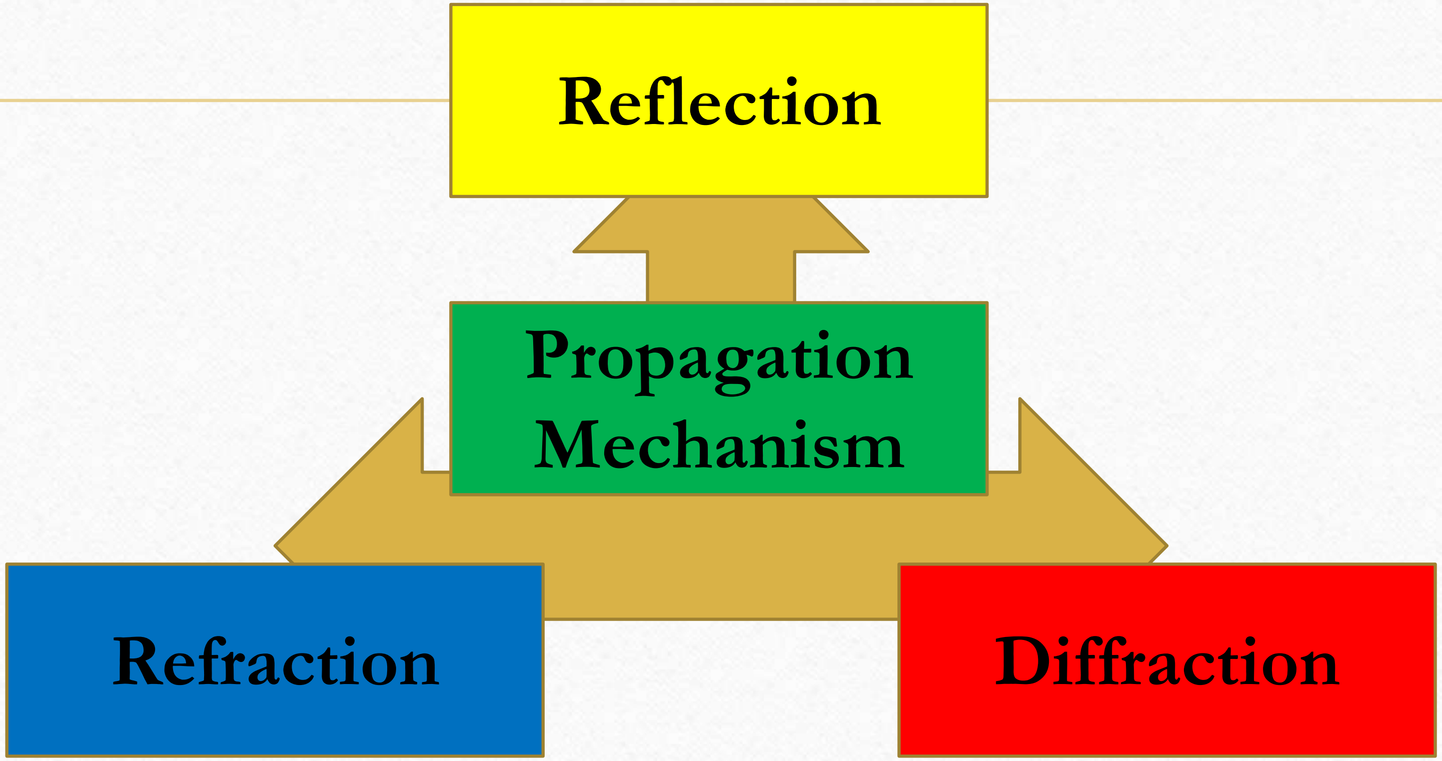
- What will be the far field distance for a BS with
- Largest antenna D= 0.5 m
- F1 = 900 Mhz
- F2=1800 MHz

- **For 900 MHz**

$$\lambda = \left(3\times10^{8}/900\times10^{6}\right) = 0.33\text{m} \qquad d_f = \frac{2D^2}{\lambda} = \frac{2(0.5)^2}{(0.33)} = 1.5\text{m}$$

- **For 1,800 MHz**

$$\lambda = \left(3\times10^{8}/1800\times10^{6}\right) = 0.17\text{m} \qquad d_f = \frac{2D^2}{\lambda} = \frac{2(0.5)^2}{(0.17)} = 3.0\text{m}$$


Reflection
Propagation Mechanism
Refraction
Diffraction

Reflection

- Occurs , when EM wave hits an object which has very large dimension as compared to wavelength .

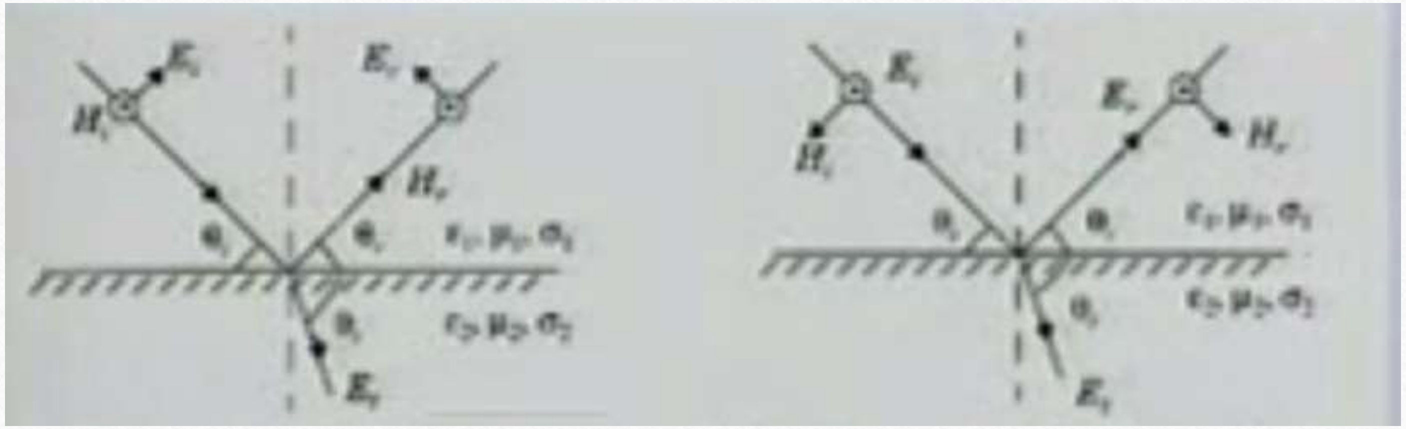
Diffraction

- Behavior of EM waves , when EM faces a obstacle
  - Wrap Up Behavior
  - Explain how signals can travel in urban and rural areas environment without LOS

Scattering

- Occurs when medium through which waves travel has small obstacles (as compared to wavelength)

Reflection from Dielectric

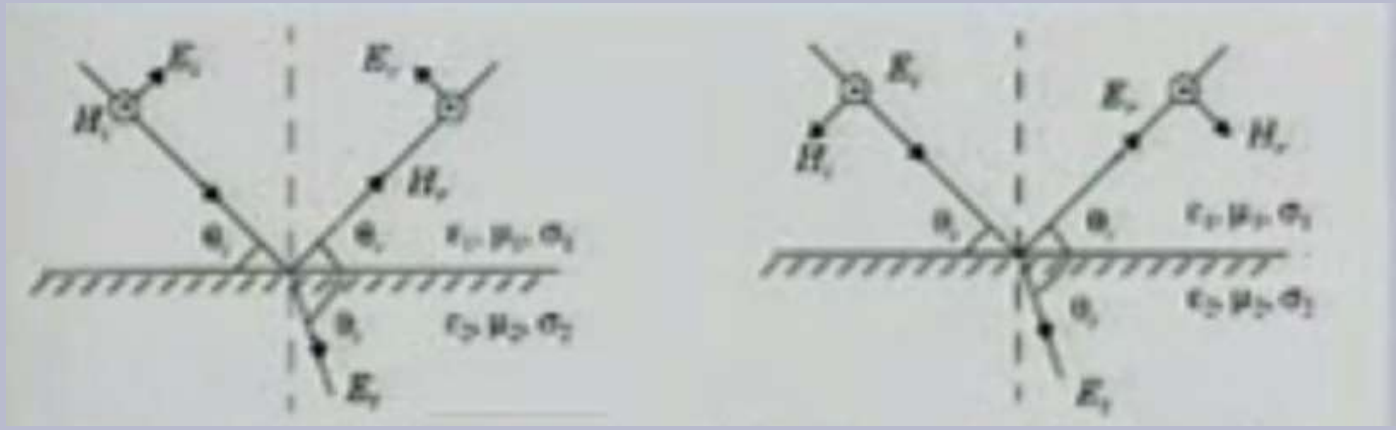


The plane of incidence : Can be defined as plane containing the incident m reflected and transmitted rays .

- The dielectric constant of a perfect dielectric ϵ is given as $\epsilon = \epsilon_o \epsilon_r$

- Where ϵ_o is constant and its value is given as 8.85×10^{-12} and ϵ_r is relative value of permittivity
- If dielectric is lossy , it will absorb some energy and some will be reflected .

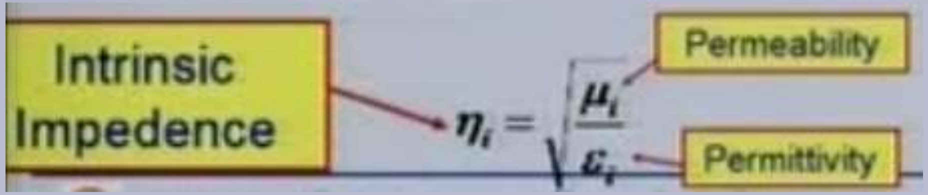
$$\epsilon = \epsilon_o \epsilon_r - J \epsilon'$$



- Where ϵ’= σ/2*Pi*f

$$\Gamma_{\parallel} = \frac{E_r}{E_i} = \frac{\eta_2 \sin\theta_t - \eta_1 \sin\theta_i}{\eta_2 \sin\theta_t + \eta_1 \sin\theta_i} \quad \text{(E field in plane of incidence)}$$

$$\Gamma_{\perp} = \frac{E_r}{E_i} = \frac{\eta_2 \sin\theta_i - \eta_1 \sin\theta_t}{\eta_2 \sin\theta_i + \eta_1 \sin\theta_t} \quad \text{(E field normal to plane of incidence)}$$



$$\eta_i = \sqrt{\frac{\mu_i}{\varepsilon_i}}$$

Remember

- Statistical models fail after 10 GHz, For frequency above 10 Ghz , we use deterministic models .(like ray tracing)

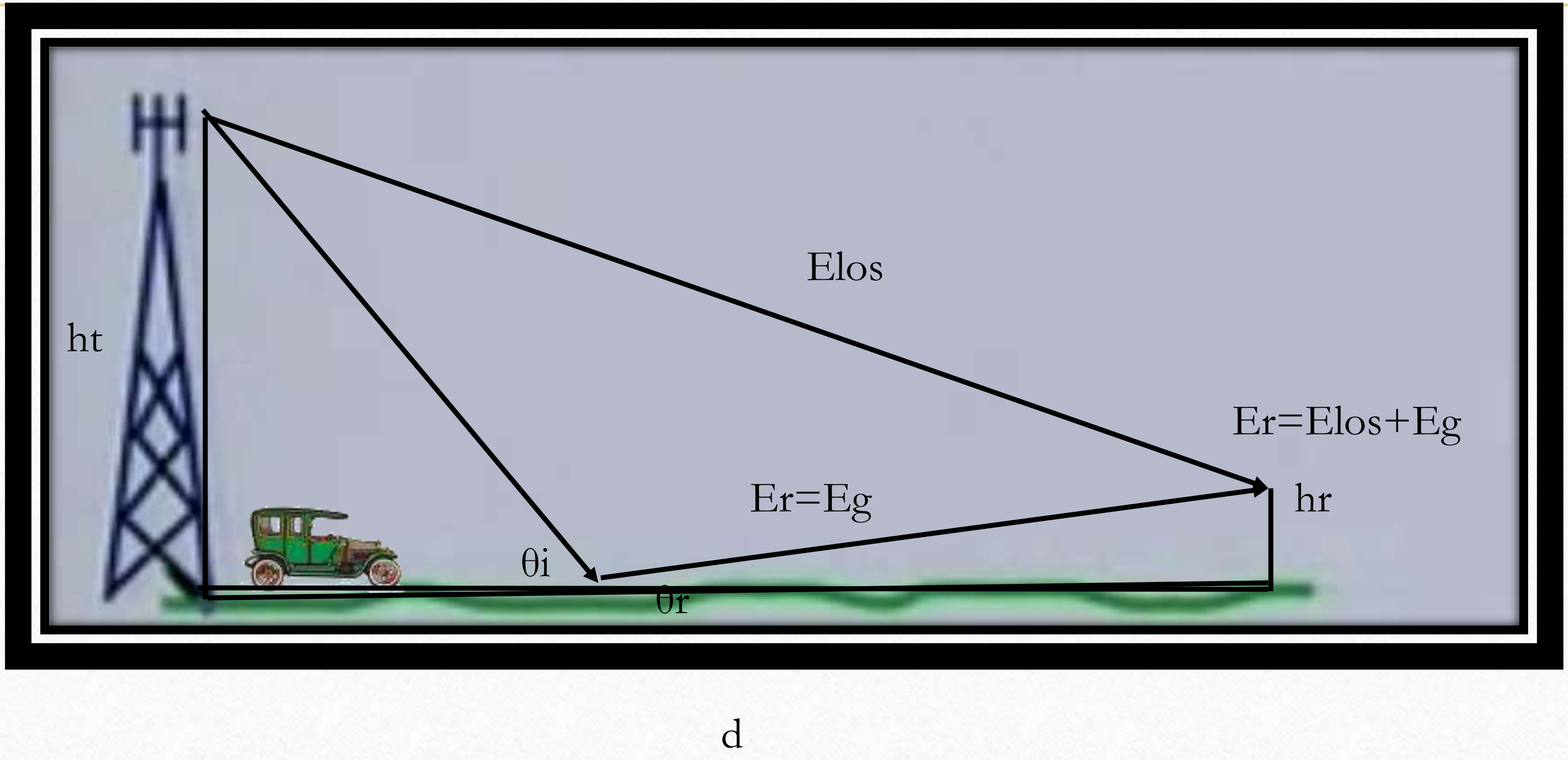
Reflection from Conductors

- EM energy cannot pass through perfect conductors.
- All the energy is reflected back
- So
- $\theta i=\theta r$
- Ei= Er (E field in Plane of incidence)
- Ei=-Er (E field normal to Plane of incidence)
- $\Gamma_{\perp=}1$
- $\Gamma\|=-1$

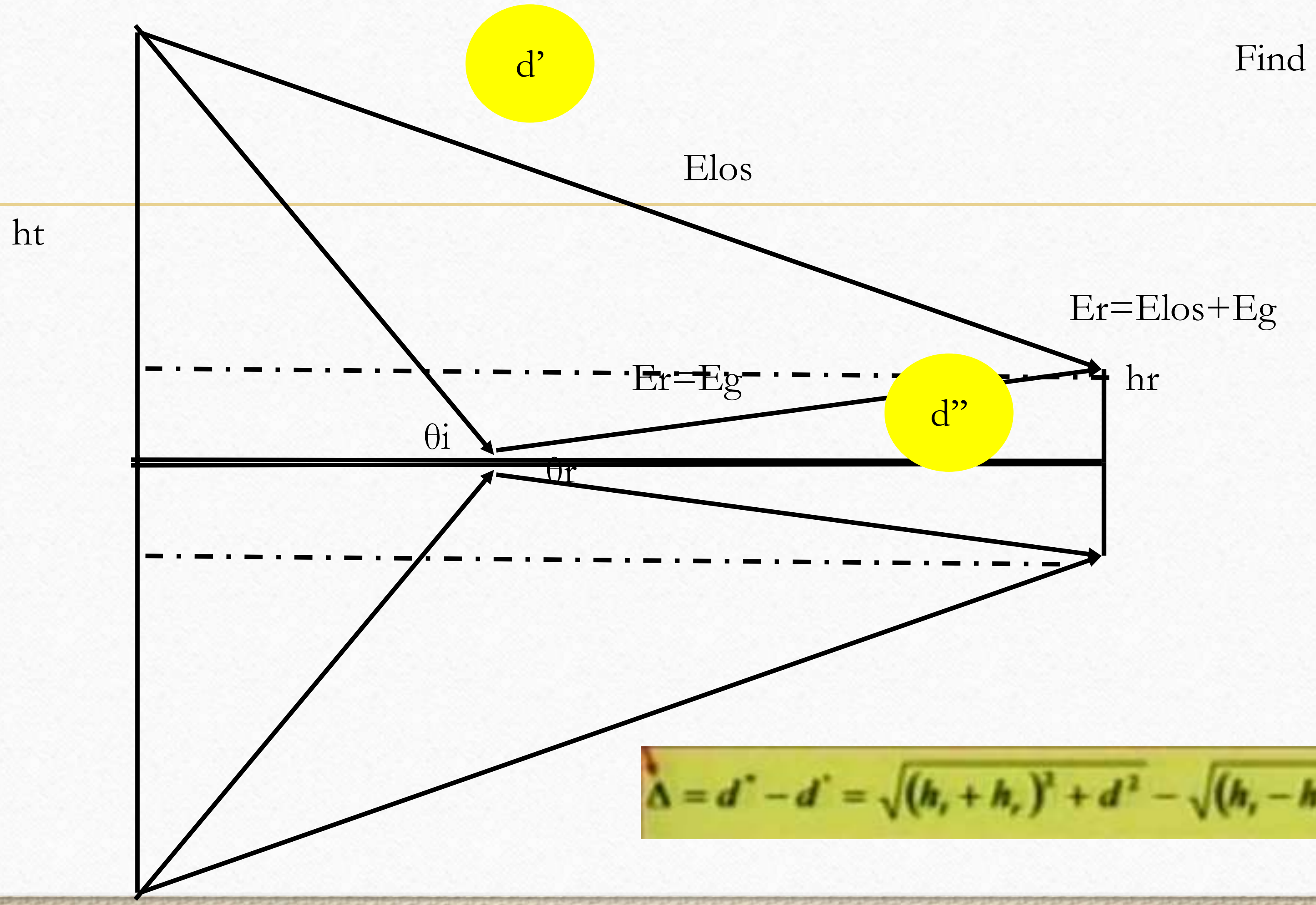
Ground Reflection Model

- Reflection to ground
- Normally and strongest when we have LOS
- A two ray ground reflection model is used
- The model is reasonably accurate for predicting large scale signal strength over several Kilometers .
- Assumption : he height of Antenna >50 meters

Ground Reflection Model



Find Path Difference



$$\Delta = d'' - d' = \sqrt{(h_t + h_r)^2 + d^2} - \sqrt{(h_t - h_r)^2 + d^2} = \frac{2h_t h_r}{d}$$

- Now we can easily Compute phase difference and time difference

$\theta\,\Delta = 2\pi\,\Delta/\lambda$

$\tau d = \Delta/c = \theta\,\Delta/2\pi\, fc$

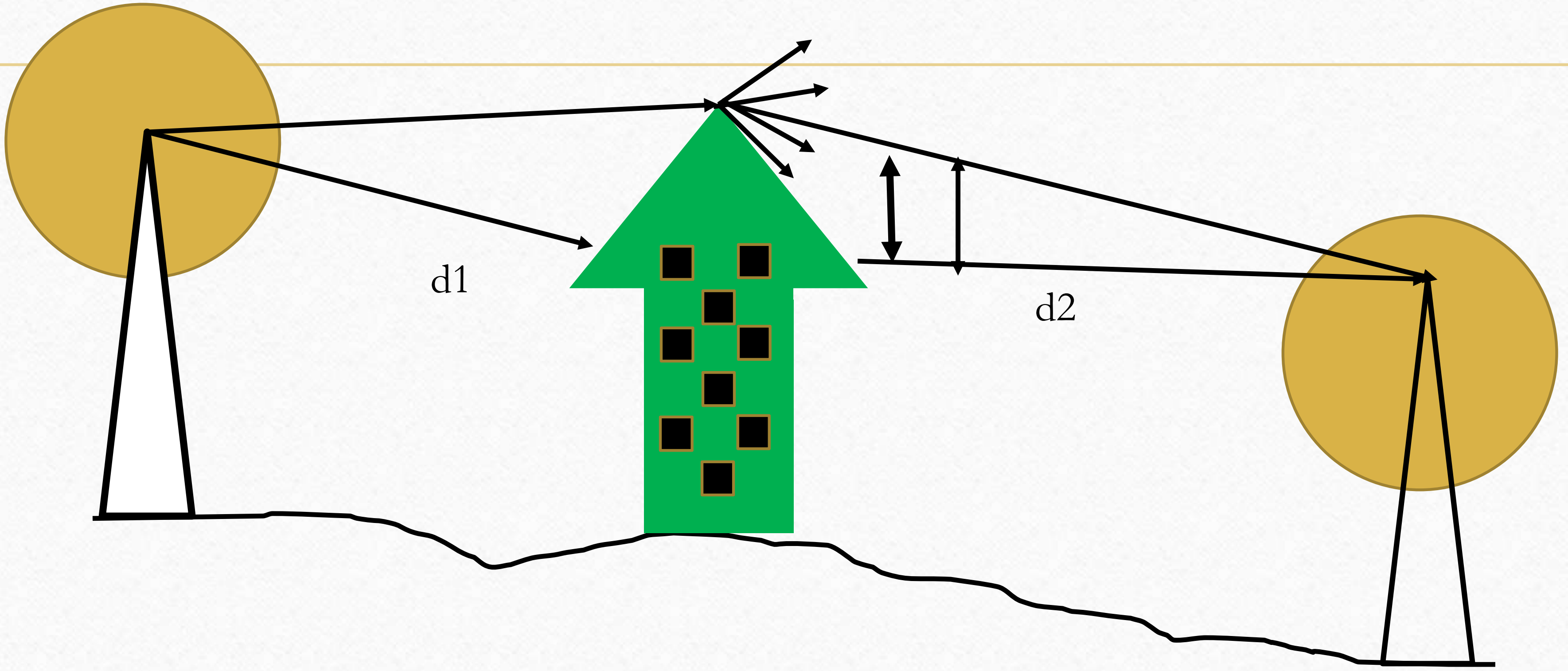
As the distance increase, the distance between the d' and d" becomes small

$$\text{Ptotal} = \frac{2E.d.2\pi h\,t\,h\,r}{d(\lambda d^2)}$$

Diffraction

- Obstruction occurred at sharp edges.
- Explains , why we can use mobile communication without LOS
- Phenomena : Huygen Principle : All points , on a wave front can be considered as point sources for the production of secondary wavelets.
- Causes , propagation of secondary wavelets in to shadowed regions .

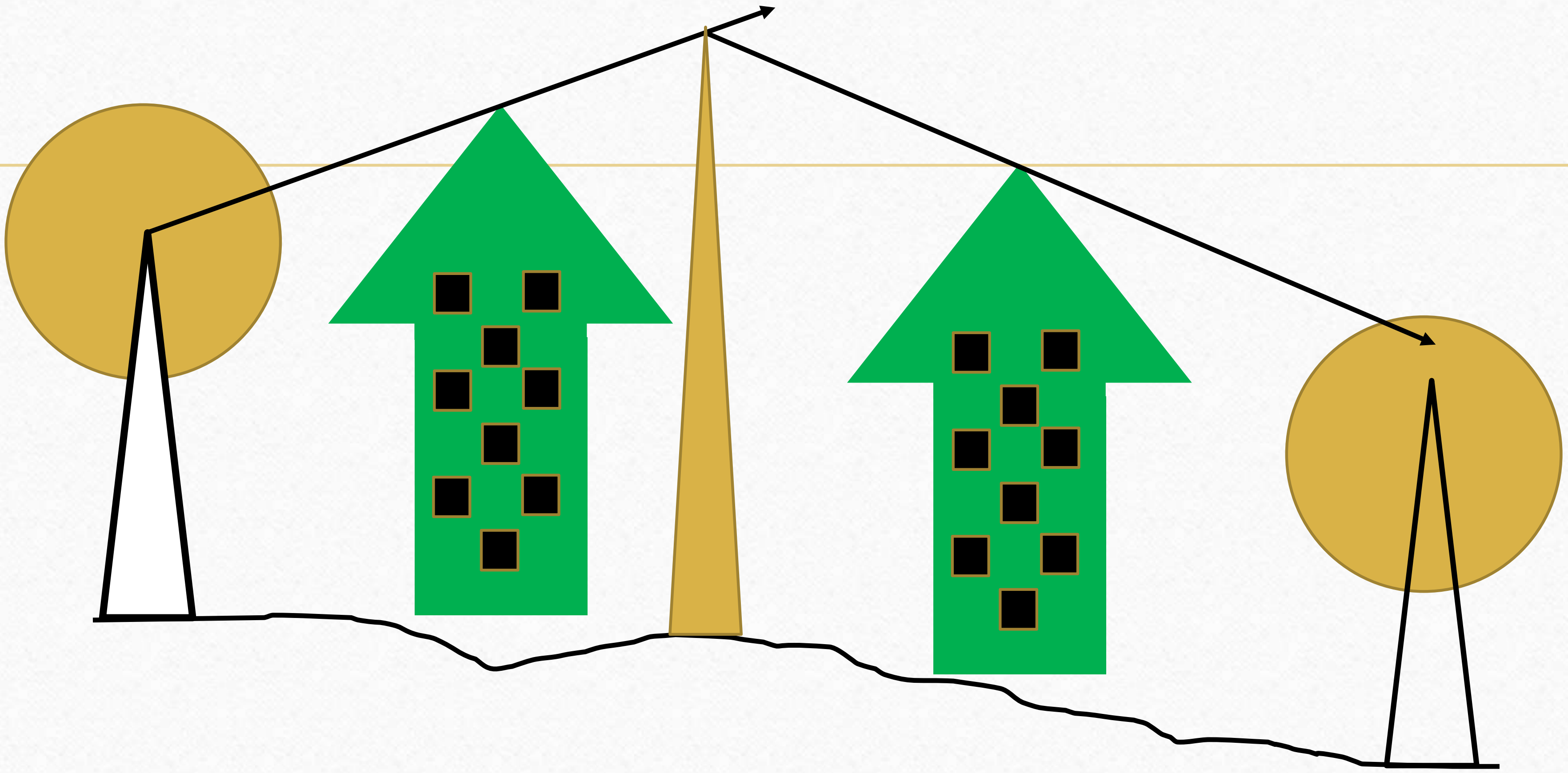
Knife Edge Diffraction Model



Diffraction Gain

- The Fresnel Kirchhoff Diffraction diffraction is given by v=h $\sqrt{\frac{2(d1+d2)}{(lambda)*d1*d2}}$
- Book Page 131

Multiple Knife Edge Diffraction Model



Scattering

- Causes the energy t be radiated in many direction
- Eg. Follage , boards