Wave Propagation

Communication Systems
Lecture 2

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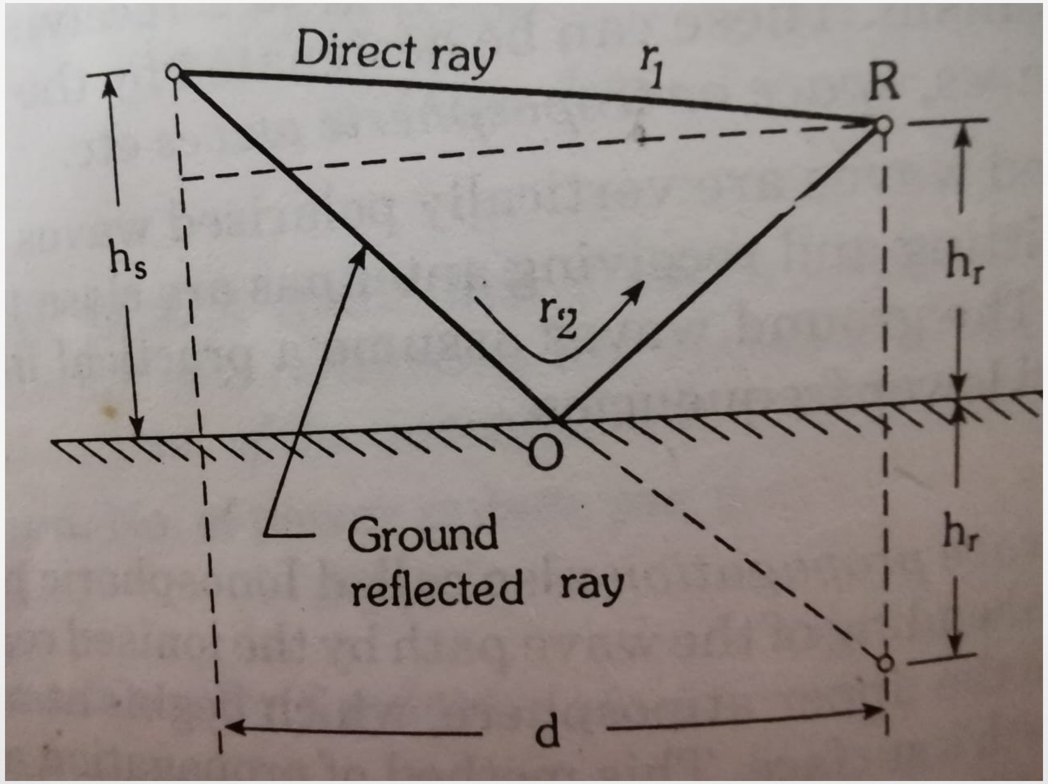
Propagation of Microwave

Mechanisms of Propagation

- Ground Wave propagation
- Sky Wave / Ionospheric propagation
- Space / Tropospheric Wave propagation

Space Wave Propagation over Ideal Flat Earth

Assume Earth to be flat neglecting the curvature.



Two ways of energy reaching the receiver

1. By a ray traveling directly between the transmitting and the receiving antennas over path TR

2. By a ray traveling over path TOR which is due to reflection from the surface of the ground.

Hence the field strength at receiving antenna is a vector sum of the two fields.

The field strength at the receiving antenna R can then be expressed as :

$$E_r = \frac{2E_0}{d} \sin\left(\frac{2\pi h_s h_r}{\lambda d}\right)$$

where E_0 = field intensity produced at a unit distance

[by the tx antenna in the desired direction with the earth absent]

d = Distance between tx & Rx

λ = wavelength (same units as d)

h_s, h_r = Heights of transmitting & receiving antennas (same units as d)

$$r_1^2 = (h_s - h_r)^2 + d^2$$

$$r_2^2 = (h_s + h_r)^2 + d^2$$

Assume that distance $d >>> (h_s + h_r)$

$$r_1 = d + \frac{(h_s - h_r)^2}{2d}$$

$$r_2 = d + \frac{(h_s + h_r)^2}{2d}$$

$2d$

$$r_2 = d + \frac{(h_s + h_r)^2}{2d}$$

The difference between paths of propagation TR & TOR

$$= r_2 - r_1 = \frac{(h_s+h_r)^2 - (h_s-h_r)^2}{2d}$$

$$= \frac{2h_s h_r}{d}$$

The phase difference caused due to this path length

$$= \frac{2\pi}{\lambda}\left(\frac{2h_s h_r}{d}\right) = \frac{4\pi h_s h_r}{\lambda d} \text{ radians.}$$

$\frac{2\pi L}{\lambda}$

Phase difference

E_1 - field strength due to direct wave

E_2 - field strength due to indirect wave.

Field strength at the receiver

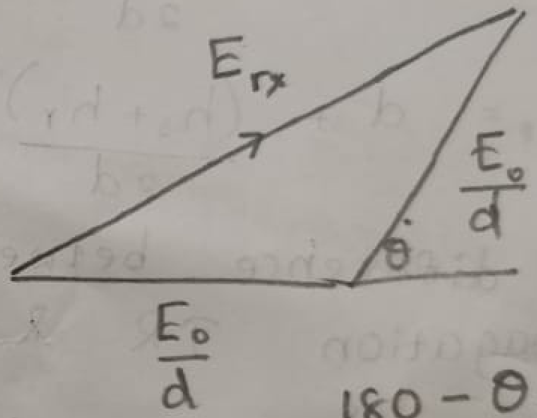
$$= \sqrt{E_1^2 + E_2^2 - 2E_1E_2 \cos \frac{4\pi h_s h_r}{\lambda d}}$$

E_0 = Field strength at unit

E_0 = Field strength at unit distance

* Field strength at a distance d, $= \frac{E_0}{d}$

- Assume the magnitudes of fields at receiver due to direct & indirect wave to be same, $E_1 = E_2 = \frac{E_0}{d}$



$180 - \theta = \frac{4\pi h_s h_r}{\lambda d}$

∴ Field strength at the receiver $= \sqrt{\left(\frac{E_0}{d}\right)^2 + \left(\frac{E_0}{d}\right)^2 - 2\left(\frac{E_0}{d}\right)^2 \cdot \cos\left(\frac{4\pi h_s h_r}{\lambda d}\right)}$

$= \sqrt{2}\,\frac{E_0}{d}\sqrt{1 - \cos\left(\frac{4\pi h_s h_r}{\lambda d}\right)}$

$= \frac{2E_0}{d} \sin\frac{2\pi h_s h_r}{\lambda d}$

When $\frac{2\pi h_s h_r}{\lambda d}$ is less than 0.5

[when d is large]

Then sine of the angle can be replaced by the angle itself

$$E_r = \frac{2E_0}{d} \times \frac{2\pi h_s h_r}{\lambda d}$$

$$= \frac{4\pi h_s h_r}{\lambda d^2} \cdot E_0$$

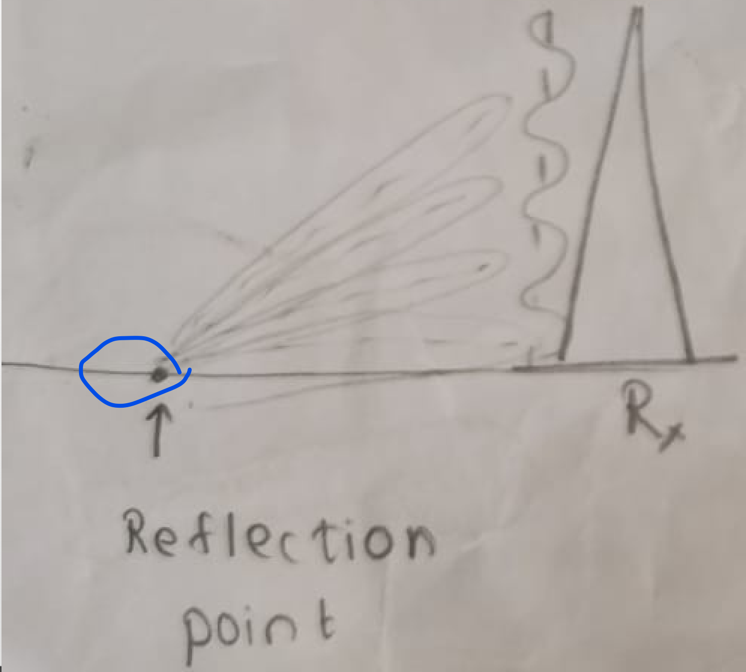
- E_0 depends upon the directivity of the antenna & tx power
- The field strength inversly propotional to the square of the distan...

propotional to the square of the distance.

$E \alpha \frac{1}{d^2}$

- Increase of $\frac{h_s h_r}{\lambda}$ results in an increase field strength at large distance.

∴ Along the tower Sinusoidal field strength



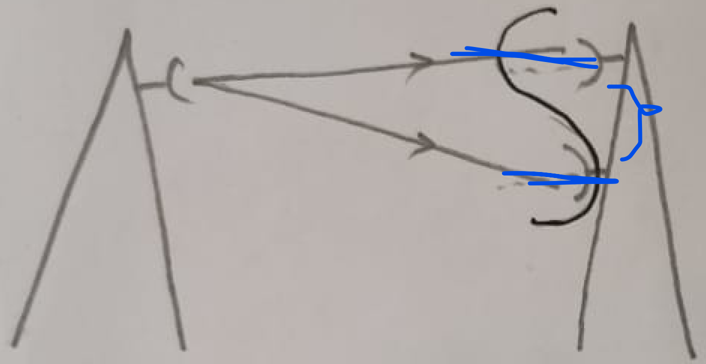
* Tower is not uniformly illuminated.

* Depends on the Soil conductivity of the reflection point.

* soil conductivity depends on the weather condition.

* This impact is minimized by having 2 antennas.

* Angle diversity.



No horizontal seperation only vertical seperation.

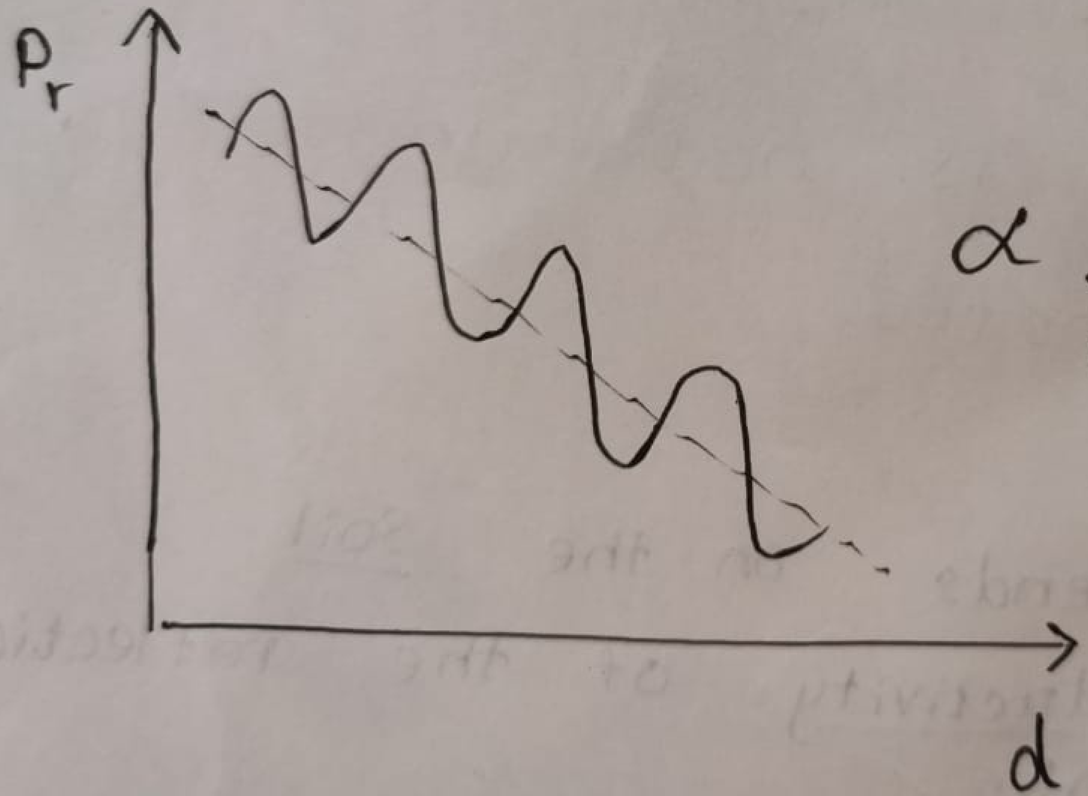
* Seperation between the 2 antennas should be such that when one is at a peak, the other should be at null.

To ensure that, $\Delta h = \left(\frac{n \lambda d}{4 h_s}\right)$

$$E_r = \frac{2E_0}{d} \sin(k h_r)$$

$$k = \frac{2\pi h_s}{\lambda d}$$

* Relative Field Strength



$\propto \frac{1}{d_4}$

- Assumptions

  - The distance between transmitting and receiving antennas to be considerably greater than antenna heights. $h_t + h_r \ll d$
  - The angle of incidence of the ray TO at the surface of the earth will then be small.
  - The reflection from the point O, can be assumed to take place with no change in magnitude but with reversal phase.

Effect of Earth Imperfection and Roughness

- With the perfect earth, the reflection on the ground takes place without changing the **amplitude and with phase reversal**. With the roughness of the earth this will not be true resulting an impact of the distance.

Shadowing Effect of Hills and Buildings

The local shadow zone refers to an area where the radio waves from a transmitting antenna are obstructed or blocked by the irregular terrain features.

In this zone, the radio waves are blocked, and the signal cannot reach the receiving antenna directly.
The signal strength becomes weaker or attenuated as it encounters obstacles, such as hills or valleys, along its path.

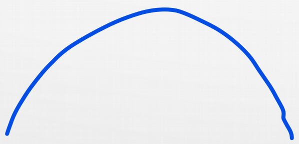
- Any irregularity in the terrain such as hills, valleys can result in the receiving antenna falling in the local shadow zone.
- The field strength at the receiver antenna decreases.

Variation of Field Strength with Height

$E \rightarrow h$

$E_r = 2E_0$

- In case of flat earth the field strength varies with the height of the receiver.
- The maximum that can be obtained from this is twice as the free space value.
- With the curved earth, the maximum is lesser than the twice of free space wave.



$E_r < 2E_0$

Atmospheric Effects in Space Wave Propagation

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Reference

- Sanjeeva Gupta, “Microwave Engineering”