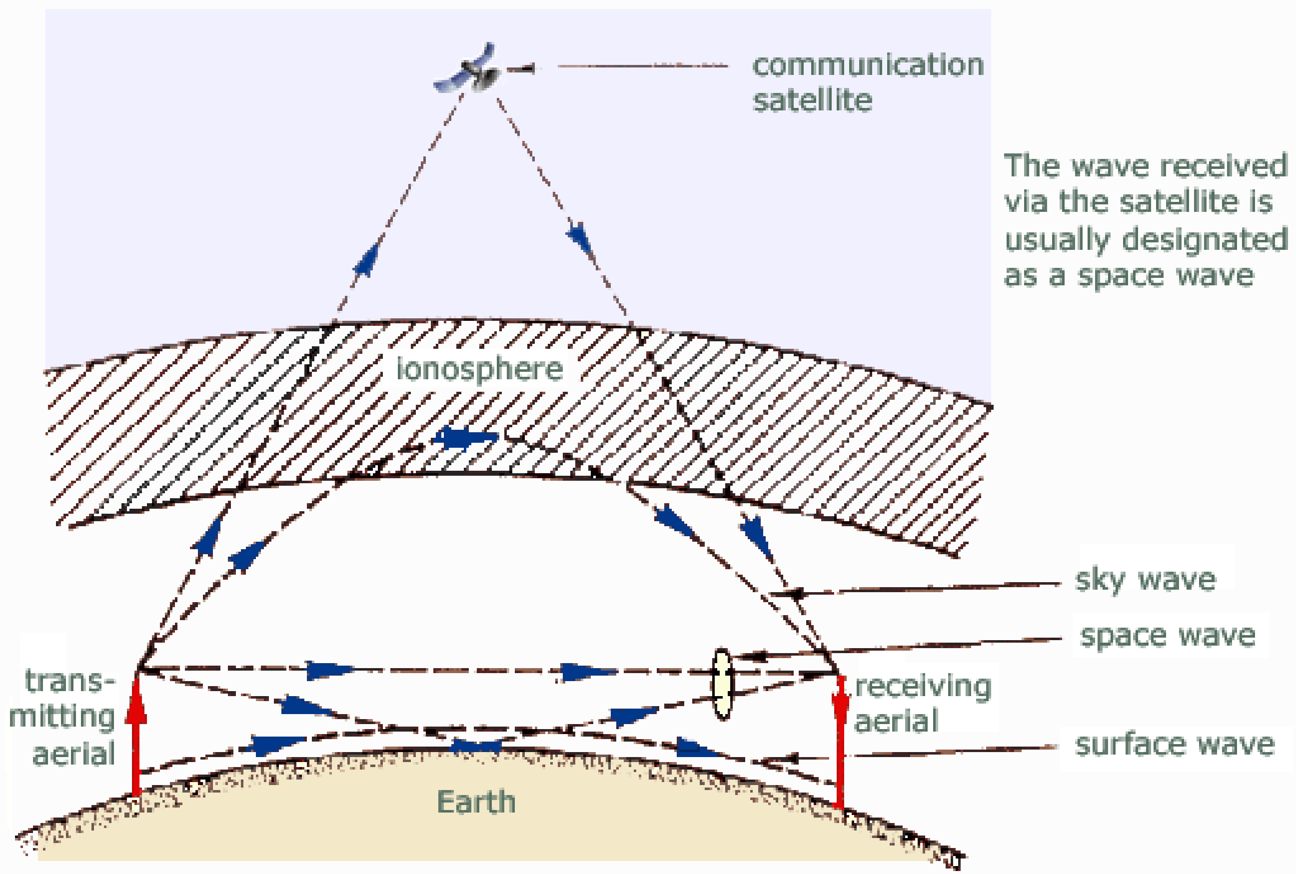
SPACE WAVE PROPAGATION

ECE 516E-ANTENNA & RADIO WAVE

Monday, 29 December 2025

RADIO WAVE PROPAGATION



The transmission paths for radio waves:
surface waves, space waves and sky waves

WHAT IS SPACE WAVE PROPAGATION?

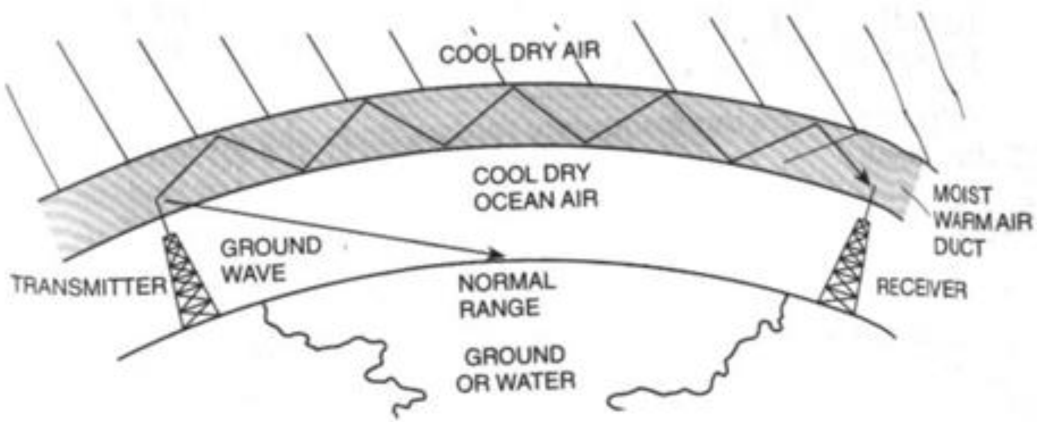
1. The radio waves having high frequencies (over 50MHz or VHF and above) are basically called as s**pace waves**.

2. These waves have the ability to propagate through atmosphere and into space.

3. **Space waves** travel directly or can travel after being reflecting from earth's surface or part of the troposphere.

TROPOSPHERIC PROPAGATION (DUCTING)

1. **Tropospheric propagation/ducting is a special form of space wave propagation.**
2. It represents space wave propagation in relation to the troposphere.
3. The service area from tropospheric propagation extends to just beyond the optical horizon, at which point signals start to rapidly reduce in strength.

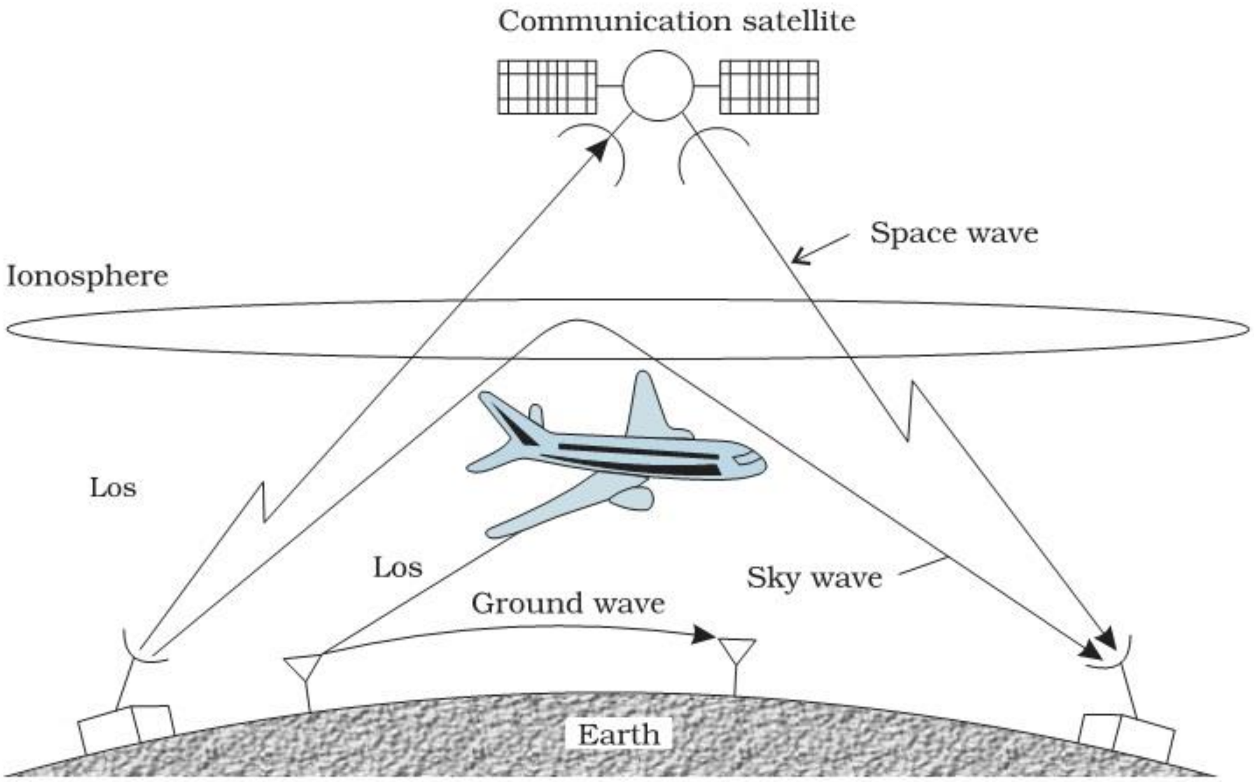


Tropospheric Ducting

DIFFERENCES BETWEEN SPACE WAVE, SKY & GROUND WAVE PROPAGATION

1. Basically the technique of space wave propagation is used in high frequency bands e.g. V.H.F. band, U.H.F band and beyond.
2. At such higher frequencies the other wave propagation techniques like sky wave propagation, ground wave propagation can't work.
3. The other name of space wave propagation is **line of sight propagation**.

GROUND, SKY & SPACE WAVE PROPAGATION

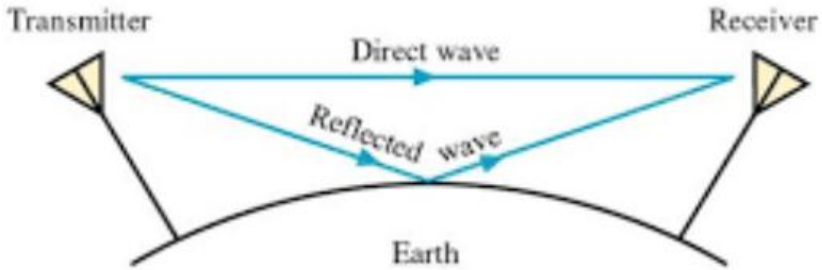


Various propagation modes for em waves.

Sky wave propagation.

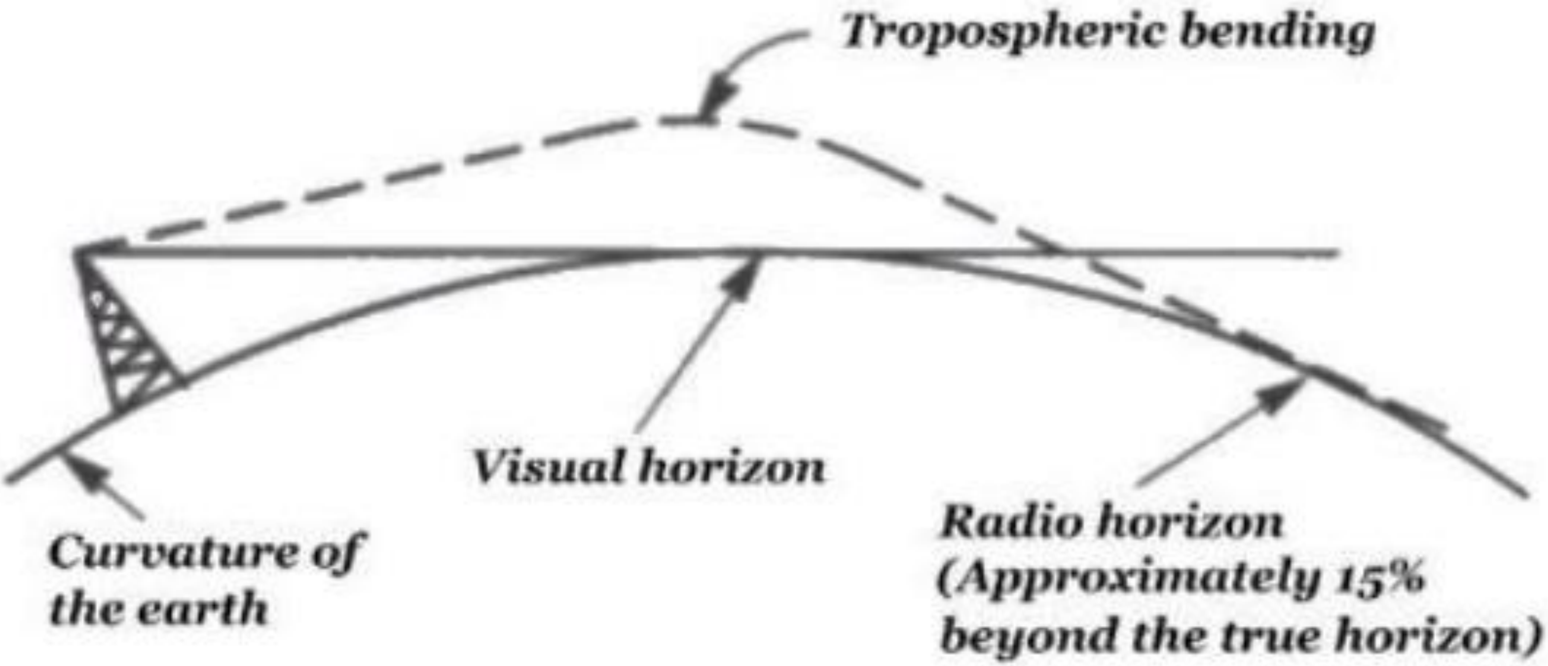
GROUND, SKY & SPACE WAVE PROPAGATION

1. The space wave follows two distinct paths from the transmitting antenna to the receiving antenna, i.e
   1. Through the air directly to the receiving antenna, and
   2. Reflected from the ground to the receiving antenna.
2. The primary path of the space wave is directly from the transmitting antenna to the receiving antenna.
3. To receive the signal through the primary path, the receiving antenna must be located within the radio horizon of the transmitting antenna.



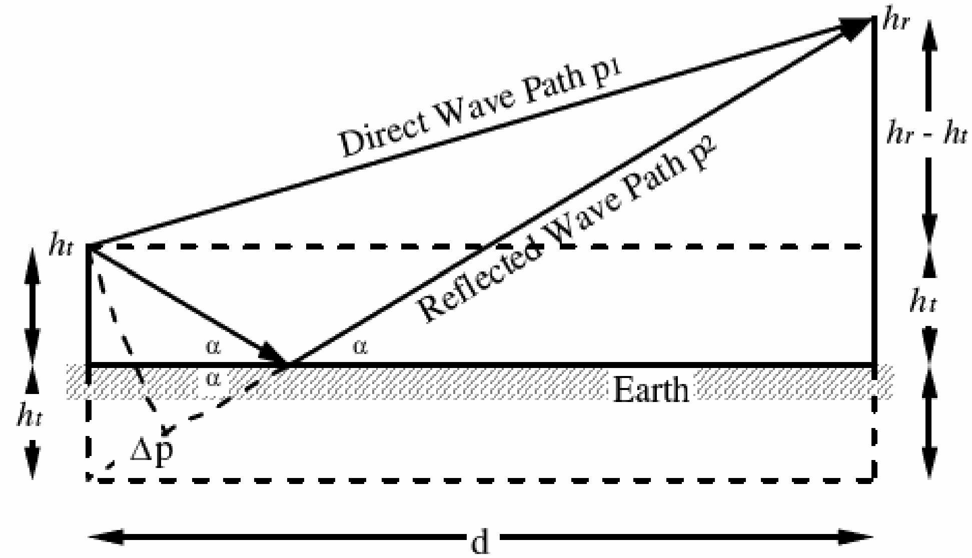
RADIO HORIZON

Because space waves are refracted slightly when propagated through the troposphere, the radio horizon is actually about one-third farther than the line-of-sight or natural horizon.



FADING OF SPACE WAVES

1. Although space waves suffer little ground attenuation, they are susceptible to fading.
2. This is because space waves actually follow two paths of different lengths (direct path and ground reflected path) to the receiving site and, therefore, may arrive in or out of phase.
3. If these two component waves are received in phase, the result is a reinforced or stronger signal.
4. Likewise, if they are received out of phase, they tend to cancel one another, which results in a weak or fading signal.



LIMITATIONS OF SPACE WAVES

1. As a form of electromagnetic radiation, like light waves, radio waves are affected by the following phenomena reflection,
    a) refraction,
    b) diffraction,
    c) absorption,
    d) polarization, and
    e) scattering.

EFFECT OF CURVATURE OF EARTH

1. When the distance between the transmitting and receiving antennas is large, curvature of earth has considerable effect on Space Wave Propagation.

2. The field strength at the receiver becomes small as the direct ray may not be able to reach the receiving antenna.

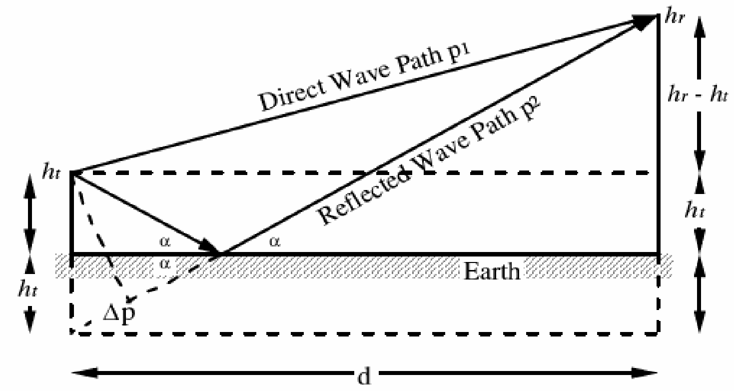
3. The earth reflected rays diverge after their incidence on the earth. The curvature of earth therefore creates shadow zones.

EFFECT OF IMPERFECTION OF EARTH

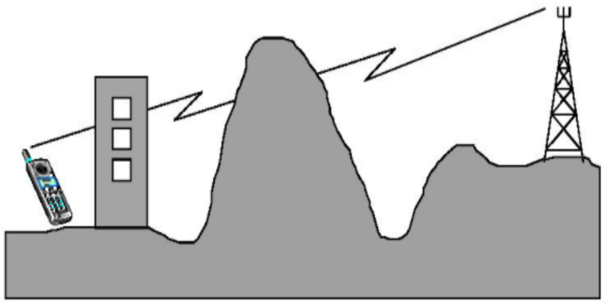
- Earth is basically imperfect and electrically rough.
- When a wave is reflected from perfect earth, its phase change is 180̊ .
- But actual earth makes the phase change different from 180̊ .
- The amplitude of ground reflected ray is therefore smaller than that of direct ray.
- The field at the receiving point due to space is reduced by earth's imperfection and roughness

LINE OF SIGHT CONSTRAINTS

- The line of sight distance is that exact distance at which both the sender and receiver antenna are in sight of each other.
- Therefore if we want to increase the transmission distance then we must extending the heights of both the sender as well as the receiver antenna. This type of propagation is used basically in radar and television communication.
- The frequency range for television signals is between **470 and 840 MHz** while GSM band is between **880 – 1880 MHz**. These waves are not reflected by the ionosphere.
- So, for the propagation of such signals, several transmitters have to be used each overing a specific area.
- In GSM, these areas are called cells.
- For TV, geostationary orbits can be used as reflectors in the sky.

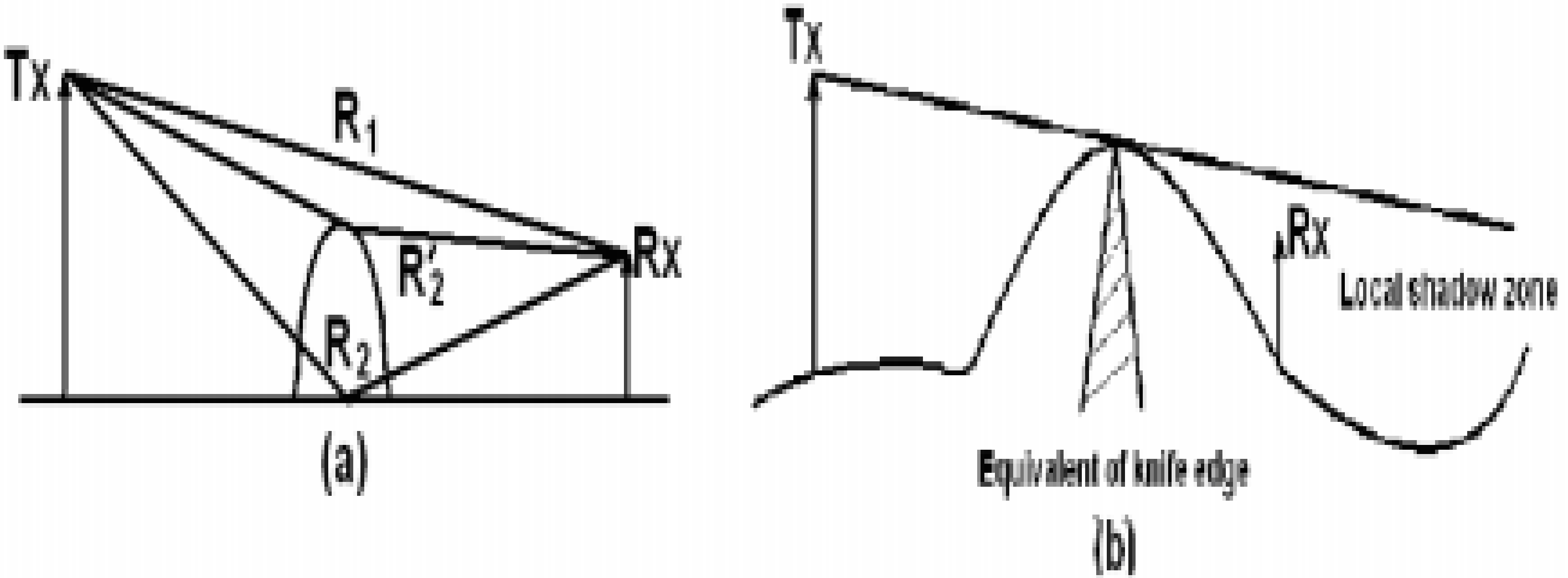


SHADOWING EFFECT OF HILLS AND BUILDINGS (1)



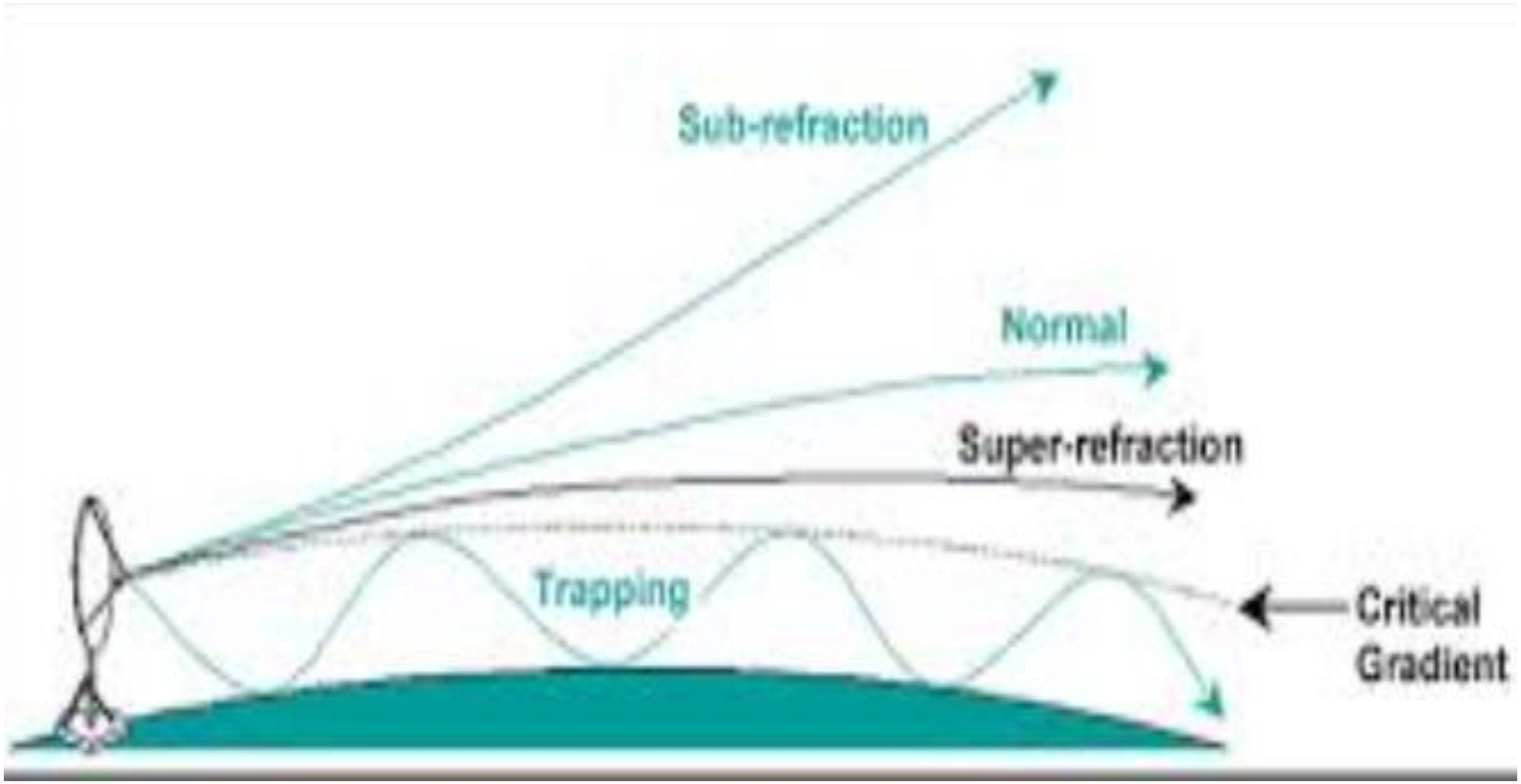
1. At VHF and above, serious disturbances in space wave propagation are caused by trees, buildings, hills and mountains.
2. They cause reflection, diffraction and absorption. Losses caused by absorption and scattering increase with the increase of frequency up to 3 GHz.
3. Beyond 3 GHz, building walls and wood become opaque to the waves. At these higher frequencies the received signal strength is considerably reduced at position on the shadow side of any hill.

SHADOWING EFFECT OF HILLS AND BUILDINGS (2)



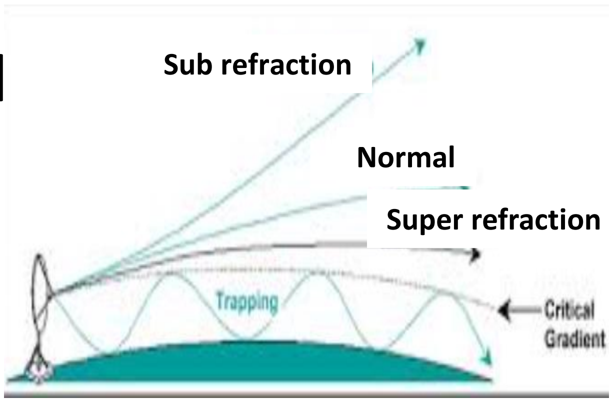
To estimate real impact of hills, the analysis is normally carried out by replacing the actual obstruction by an equivalent knife edge

SUB, NORMAL, SUPER REFRACTION & DUCTING



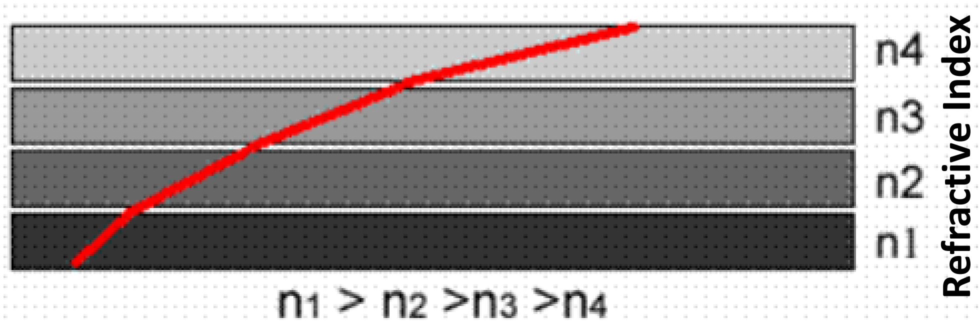
SUB-REFRACTION

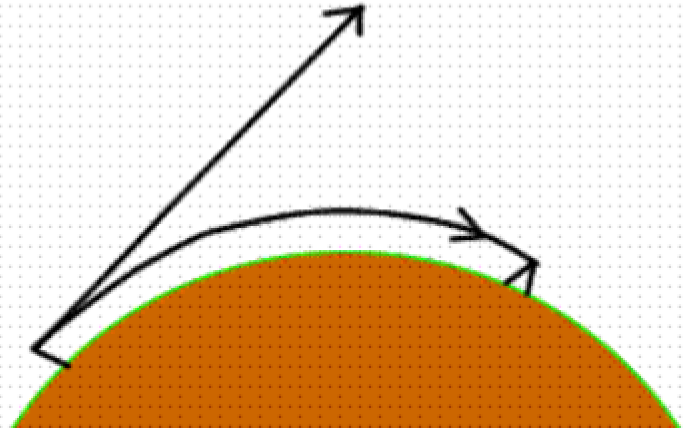
1. Sub-refraction occurs when atmospheric conditions cause the radar beam to bend less compared to the standard atmosphere.
2. It occurs when the atmosphere is unstable relative to the Standard Atmosphere.
3. Sub-refraction has the following effects:
   a) causes the radar to overshoot targets that would ordinarily be observed under standard atmospheric conditions
   b) results in a reduction in the operational range of the radar.
   c) reduces ground clutter in the lowest elevation cuts.



SUPER-REFRACTION

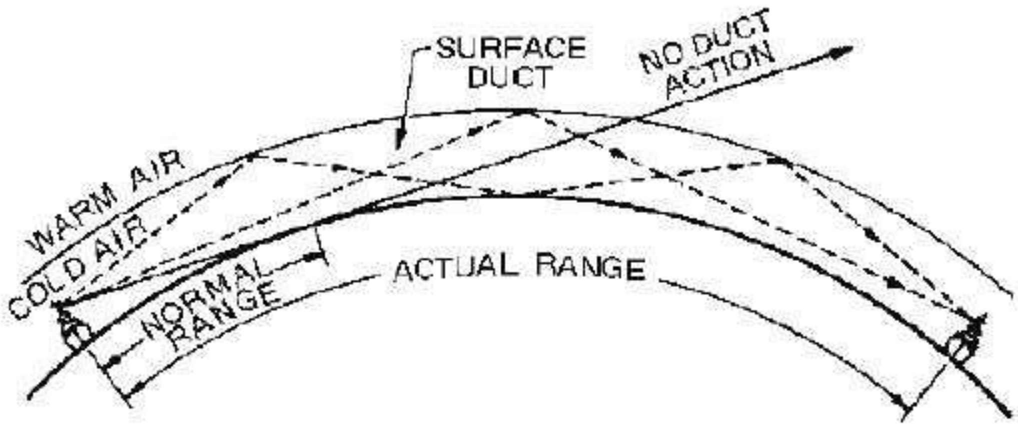
1. In cold, rough weather lower temperature of atmosphere is usually well mixed and the refractive index is more or less standard.
2. When day is warm, land and air both become warm. After sunset if sky is clear, land radiates its heat and its temperature falls rapidly.
3. As a result earth and lower layer of atmosphere cool down but upper layer remains unchanged.
4. It results in temperature inversion. If this inversion is sufficiently intense it results in super refraction.
5. Though this effect is common over deserts, it can also occur anywhere if sky is clear and land is dry.
6. It is maximum in early morning and disappears after sun rise.
7. Such conditions frequently exist over sea particularly near coasts where air close to sea tends to be damp and cool while upper layer is dry and warm.





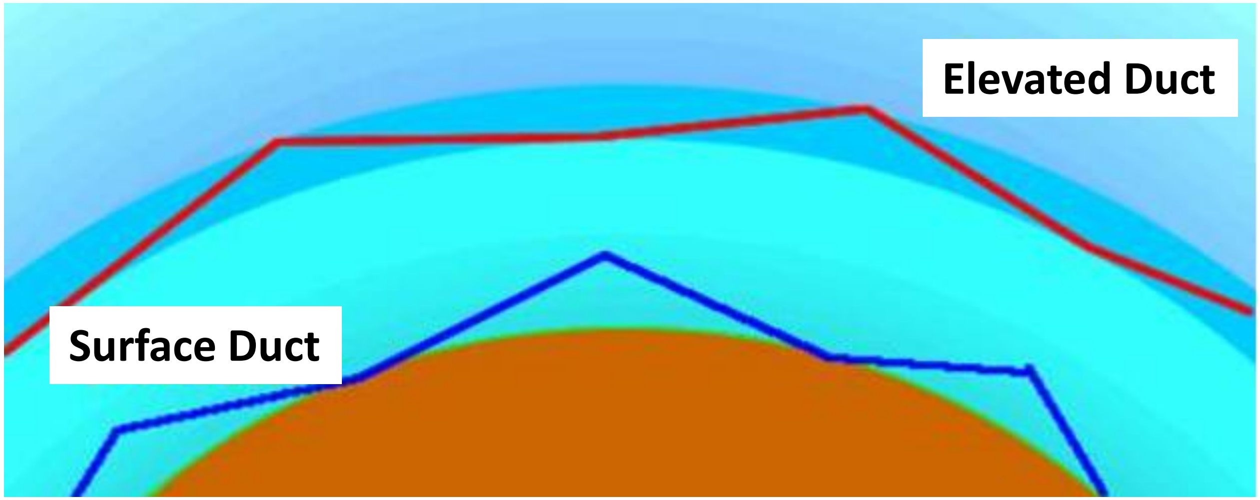
DUCTING

- Ducting is a special form of super-refraction where the EM wave is trapped between two atmospheric layers of different refractive index



TYPES OF DUCTING

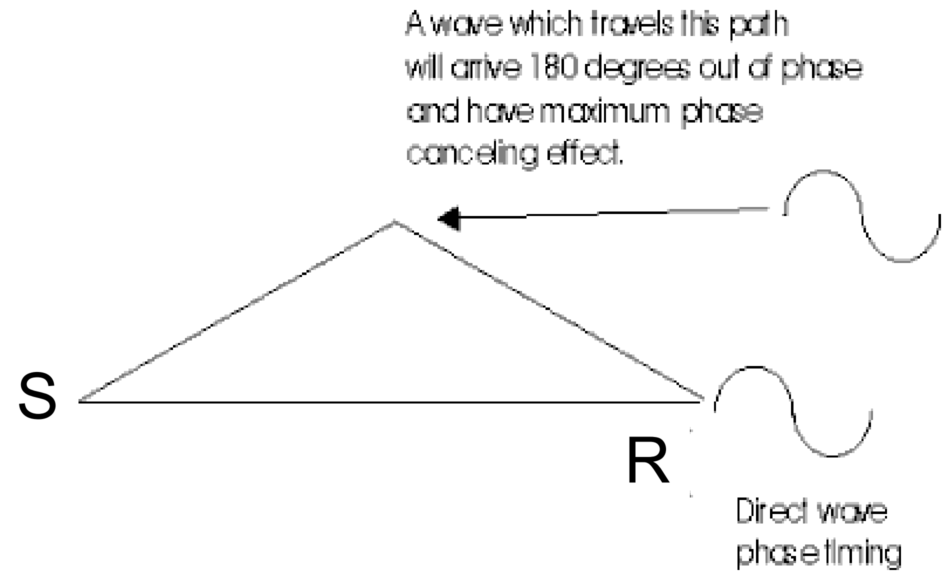
- **Ducting** can occur either at ground level or it can be elevated.



- **Ducting** has the effect of increasing the radar range.

FERSNEL ZONE (1)

1. Consider a direct wave traveling in a straight line from the source, S, to the receiver, R.
2. Other waves that travel slightly off the direct path may still arrive to the same receiver if they bump into “something”.



3. If they are out of phase with the direct wave they will have wave canceling effect.

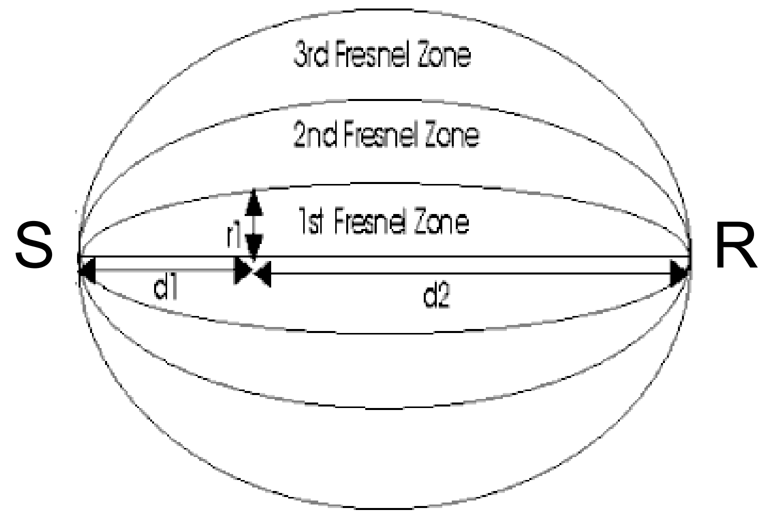
FRESNEL ZONE (2)

Each Fresnel zone is an ellipsoidal shape as follows:

Zone 1: the signal is 0 to 90 degrees out of phase

Zone 2: the signal is 90 to 270 degrees out of phase

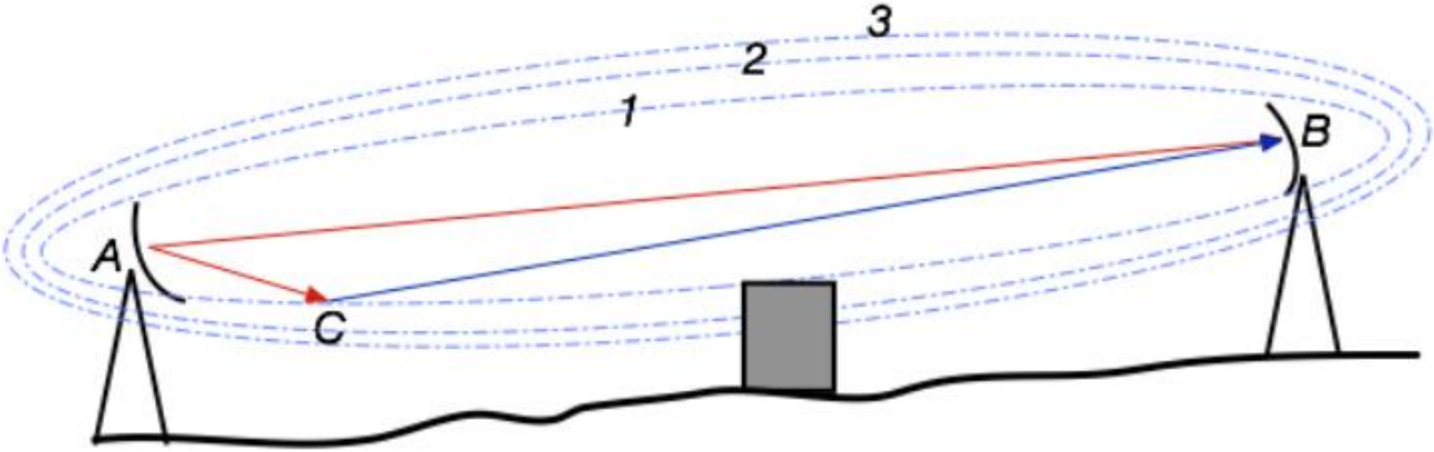
Zone 3: the signal is 270 to 450 degrees out of phase



AGGREGATE EFFECT OF CONTRIBUTIONS FROM DIFFERENT ZONES

1. Since the phase of the wave propagating through adjacent high order Fresnel zones differ by 180^o, the sum of these waves tend to cancel.
2. Adjacent higher order zones cancel each other, cancellation being more complete for the higher order zones.
3. The aggregate effect of all higher order zones after pairwise cancellation is only about half the contribution from the first zone.
4. Therefore, the first Fresnel zone bounds the volume contributing significantly to wave propagation and if the first Fresnel zone is clear of any obstacles, LOS propagation can be assumed.

IMPORTANCE OF FRESNEL ZONES (1)



1. If unobstructed, radio waves will travel in a straight line from the transmitter to the receiver.
2. If there are reflective surfaces along the path, such as bodies of water or smooth terrain, the radio waves reflecting off those surfaces may arrive either out of phase or in phase with the signals that travel directly to the receiver.
3. Waves that reflect off of surfaces within an **even Fresnel zone** are out of phase with the direct-path wave and reduce the power of the received signal.
4. Waves that reflect off of surfaces within an **odd Fresnel zone** are in phase with the direct-path wave and can enhance the power of the received signal.

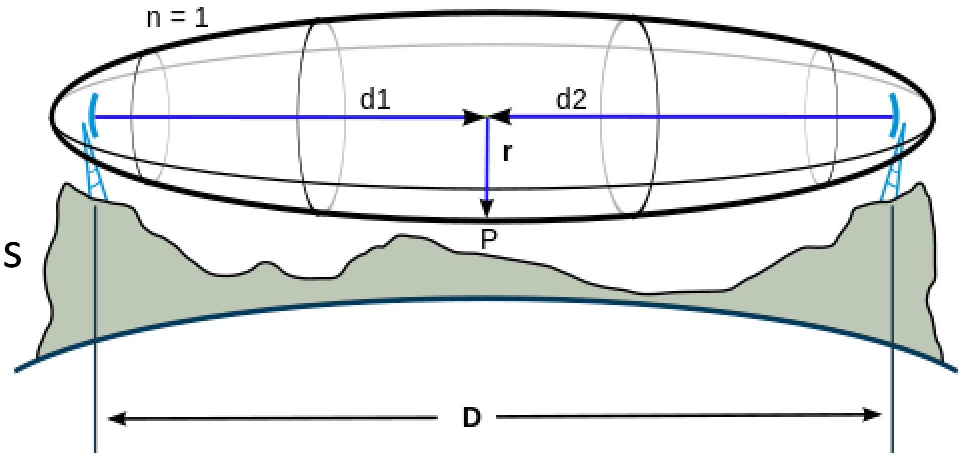
IMPORTANCE OF FRESNEL ZONES (2)

- Fresnel Zones provide a means to calculate locations where a given obstacle will cause in phase or out of phase multipath interference.

CALCULATING FRESNEL RADIUS

The general equation for calculating the Fresnel zone radius at any point P in between the endpoints of the link is the following:

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



Where

F_n is the n^{th} Fresnel Zone radius in metres

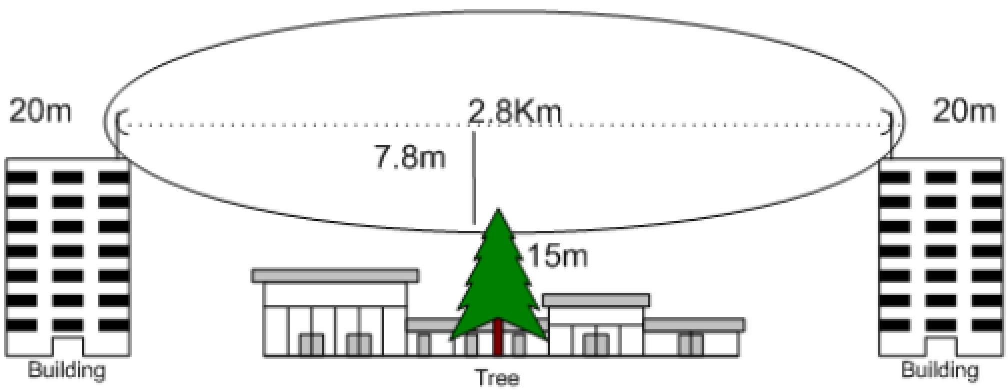
d_1 is the distance of P from one end in metres

d_2 is the distance of P from the other end in metres

λ is the wavelength of the transmitted signal in metres

GENERAL RULE OF THUMB

1. The first Fresnel zone must be kept largely free from obstructions to avoid interfering with the radio reception.
2. Some obstruction of the Fresnel zones can be tolerated.
3. As a rule of thumb the maximum obstruction allowable in the first zone is 40%, but the recommended obstruction is in practice 20% or less.



REVIEW QUESTIONS

1. How often do you see this kind of tower in the big cities like Nairobi?

2. Why are Mobile operators busy laying fibre optic cables in all major towns?