Telecommunication Systems

Module 0
Antennas and Propagation

0.3 - Atmospheric Propagation: absorption and refraction

The propagation in the atmosphere differs from that in free space due to:

- ★ Effects of the constituent elements of the atmosphere
- ★ Effects of the terrain and the eventual obstacles present in path of propagation

The relevant physical phenomena connected with constituent elements of the atmosphere:

- ★ Absorption
- ★ Inhomogenity of the path (refraction)

Relevant physical phenomena connected with the presence of terrain and obstacles:

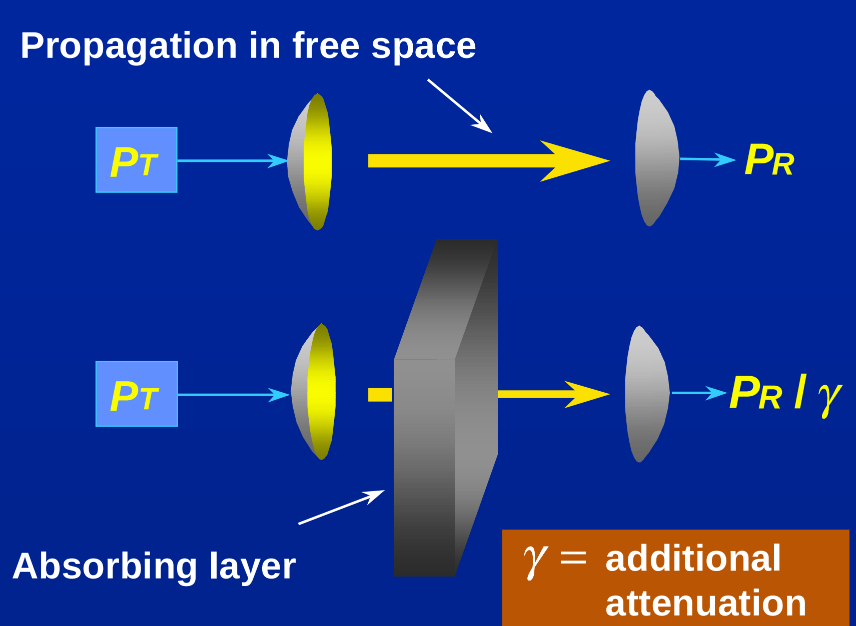
- ★ Diffraction
- ★ Reflection

ABSORPTION

Is due to the interference between the electromagnetic waves and the constituent elements of the atmosphere:

- **gaseous components (molecular resonance)**
- **hydrometeors (water drops)**

In either case, the effect is an attenuation of the electromagnetic wave; the received power shall be less than the case of free space propagation



The additional attenuation is a function of:

- ★ The thickness of the absorbing layer
- ★ The physical interaction mechanism
- ★ The characteristic of constituent components
- ★ The frequency

The phenomena is characterized by a *specific attenuation* (expressed in *dB/km*)

ABSORPTION DUE TO MOLECULAR RESONANCE

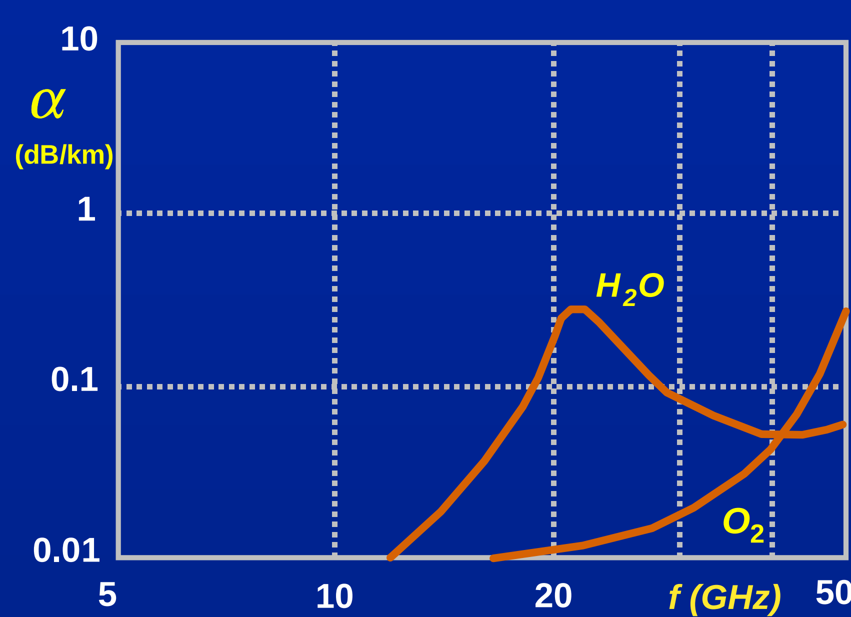
Is connected with the resonance properties of the gas molecules that constitute the absorbing layer.

In the case of atmosphere, the principle contributions come from:

★ Oxygen (O_2), that has a maximum absorption level at 60 GHz

★ Water vapor (H_2O), with a maximum absorption level at 22.5 GHz

The power absorbed causes an increase in the vibration of the molecules *(temperature)*

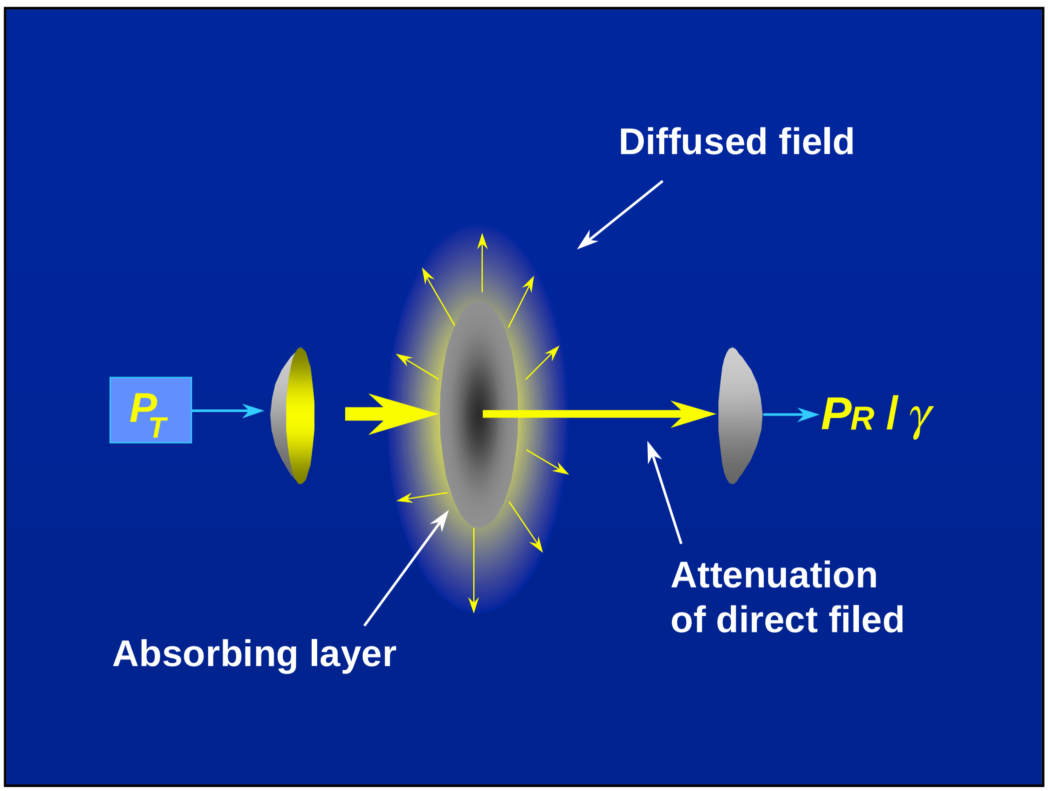


ABSORPTION WITH DIFFUSION

Is due to the interference of the electromegnetic wave with the particles present in the absorbing layer and in particular with *water drops* present in the case of:

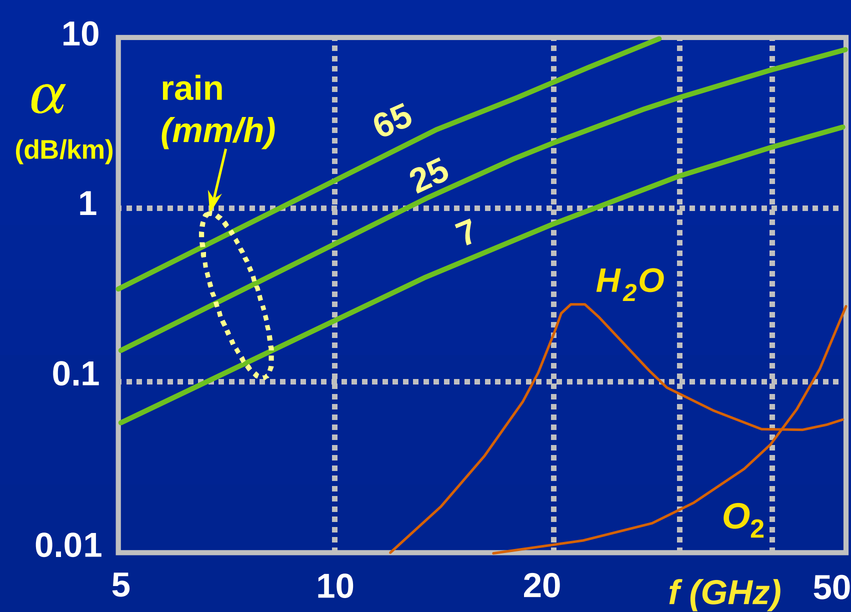
- rain
- fog

Part of the field energy incident on the layer is diffused around the region of interaction



ABSORPTION DUE TO RAIN

- The specific attenuation is a function of the intensity of the precipitation (measured in *mm/h*)
- In addition the specific attenuation is a function of frequency



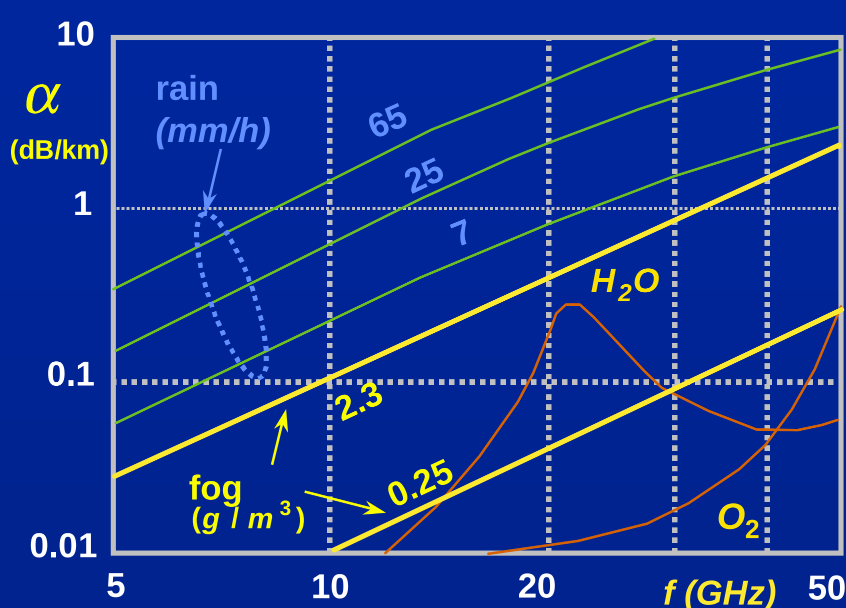
ABSORPTION DUE TO FOG

- The overall attenuation is a specific function of the concentration of fog (measured in $g\ /\ m^3$)
- Concentration is connected with *visibility*:

$$0.25\ g\ /\ m^3 \approx 150\ m$$

$$2.3\ g\ /\ m^3 \approx 30\ m$$

- Also in this case, the specific attenuation is a function of frequency



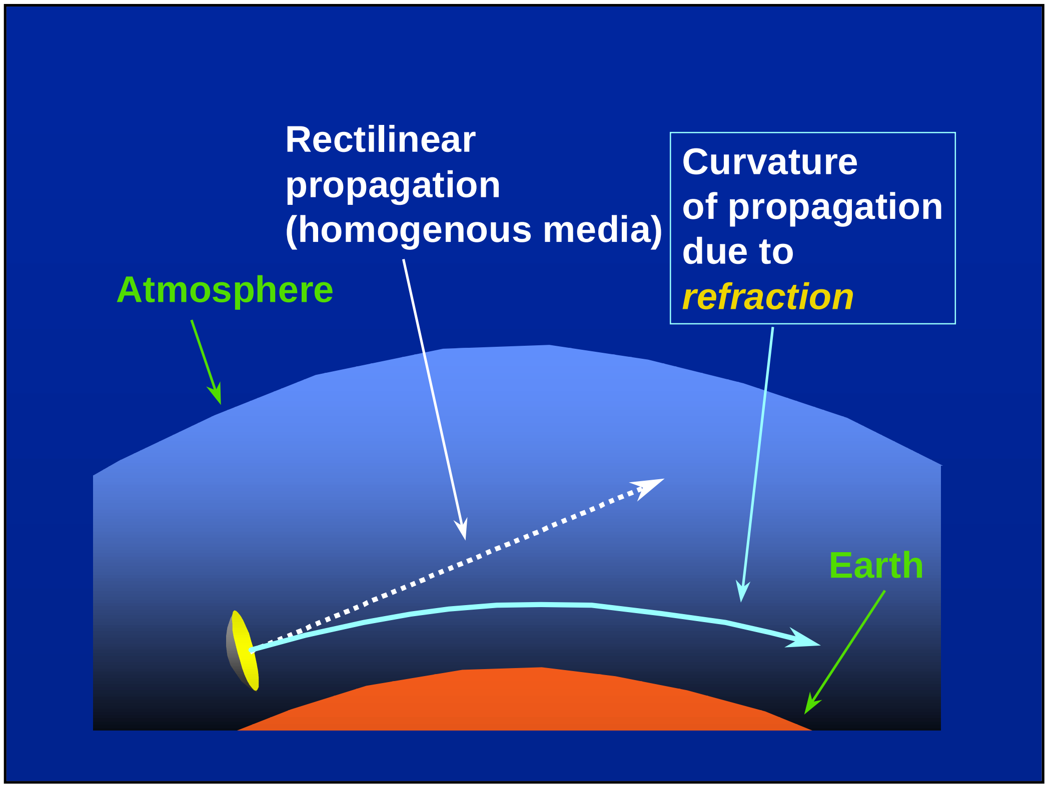
REFRACTION

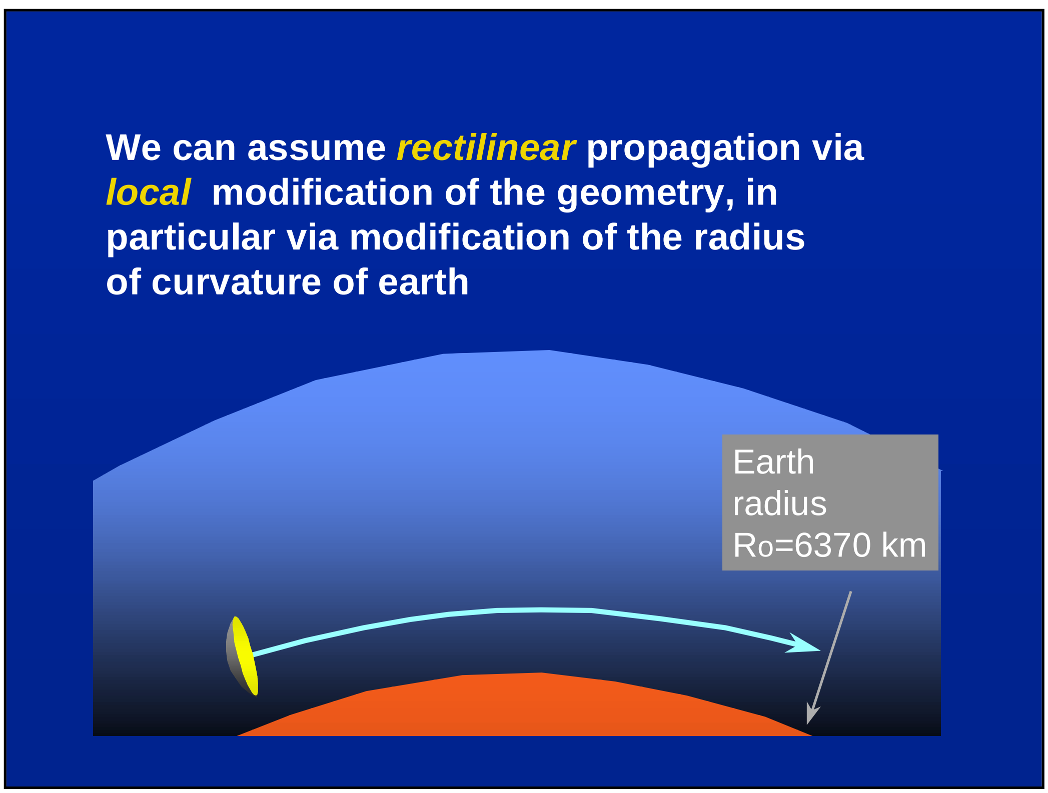
- ★ The mode of propagation of the electromagnetic wave in a medium is dependent on the *index of refraction n* of the medium
- ★ In the case of a *homogeneous* medium (that is with *constant* index of refraction) the propagation is governed by laws of geometric optics (*rectilinear* propagation)
- ★ In the atmosphere the index of refraction is *not* homogenous, therefore the propagation experiences curvature (refraction phenomena)

The index of refraction *n* of atmosphere depends on:

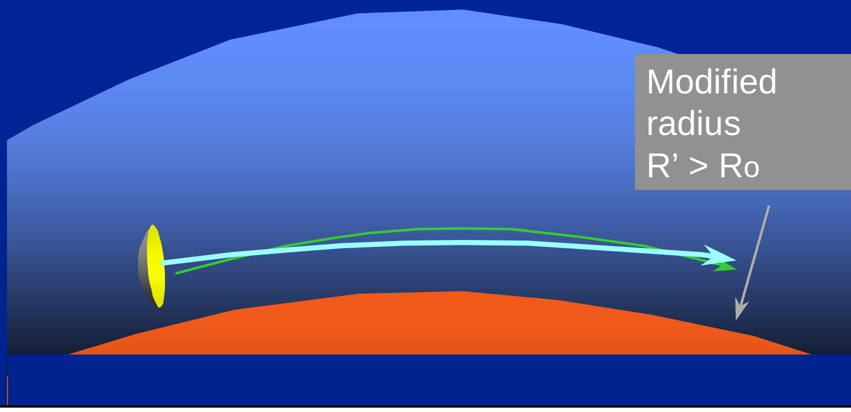
- ★ the *temperature*
- ★ the *pressure*
- ★ The partial pressure (concentration) of *water vapor*.

Such parameters vary with *elevation*; the index *n* generally decreases (tending to 1) as elevation is increased

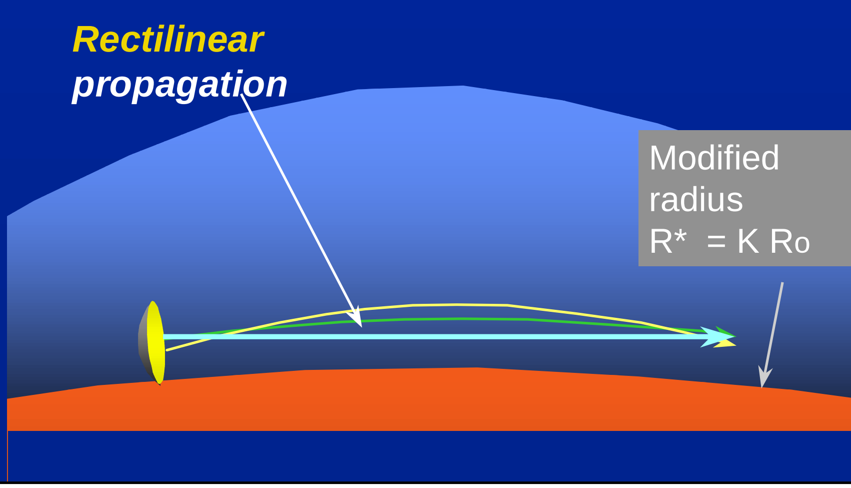

Rectilinear
propagation
(homogenous media)
Curvature
of propagation
due to
refraction
Atmosphere
Earth


We can assume *rectilinear* propagation via
local modification of the geometry, in
particular via modification of the radius
of curvature of earth
Earth
radius
R_0=6370 km

We can assume ***rectilinear*** **propagation via** ***local*** **modification of the geometry, in particular via modification of the radius of curvature of earth**



We can assume ***rectilinear*** **propagation via** ***local*** **modification of the geometry, in particular via modification of the radius of curvature of earth**



The parameter *K* is the ratio between the modified earth radius leading to rectilinear propagation and the true radius of earth *Ro*.

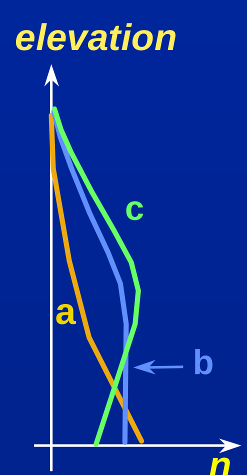
The value of *K* depends on:

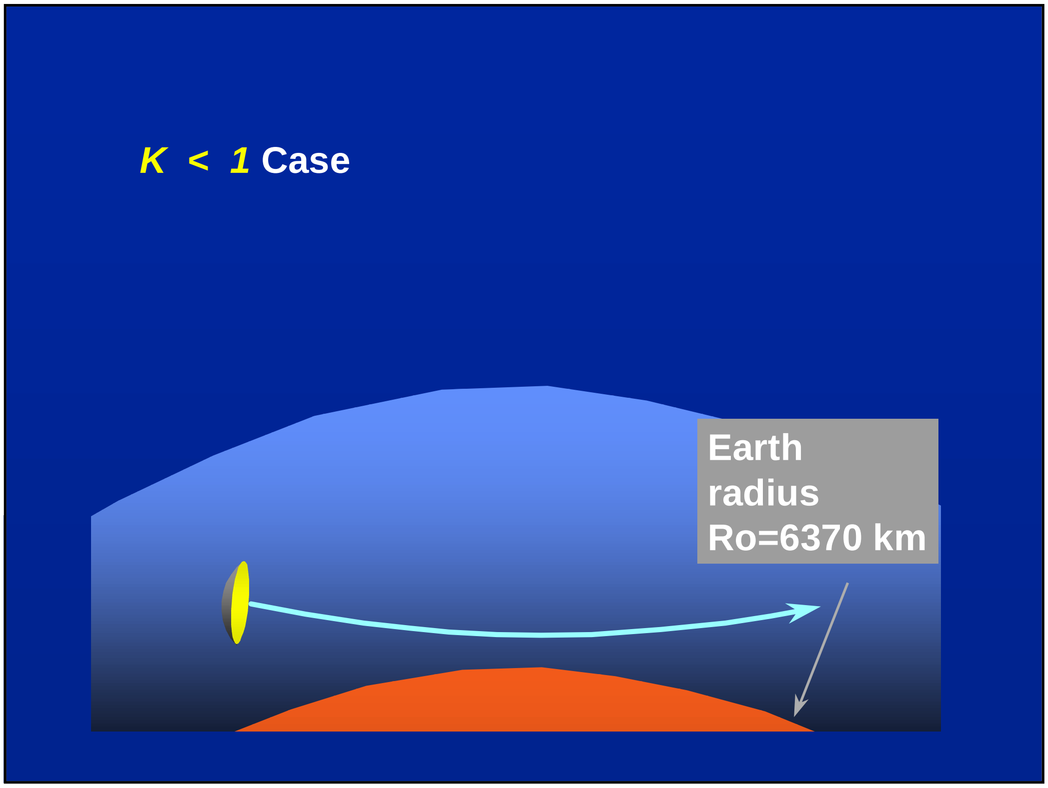
- the type of atmosphere, that is, on how the index of refraction varies with elevation
- the meteorological conditions

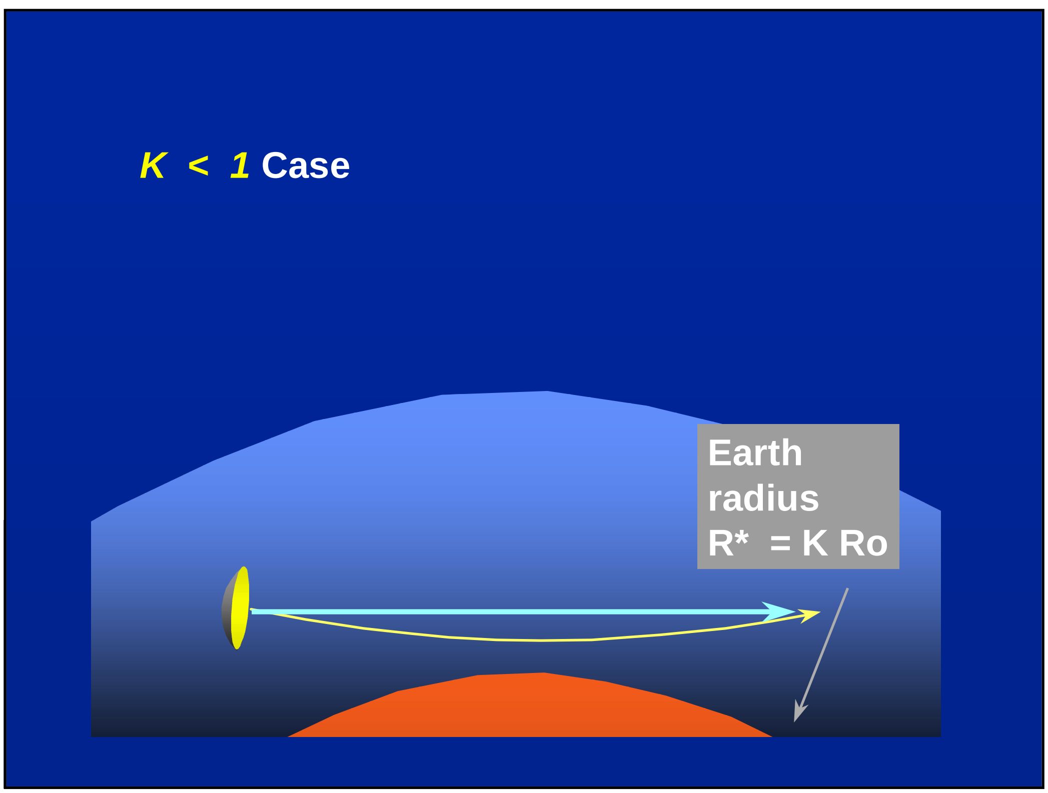
The previous case assumes that the index *n* *decreases* uniformly with elevation (a)

If *n* remains *locally* constant as elevation varies, we have rectilinear propagation, with *K=1* (b)

If *n* increases *locally* as elevation varies, the propagation path curves downward, and the “modified” earth radius will be *R* < Ro*, and *K < 1* (c)




K < 1 Case
Earth
radius
Ro=6370 km


K < 1 Case
Earth
radius
R* = K Ro

K	Zone	Weather
1.33	temperate	Without fog
1 - 1.33	arid mountainous	Without fog
0.66 - 1	temperate	Light fog
0.5 - 0.66	litoranee	Heavy fog
0.4 - 0.5	tropical, water	Fog an rain

End 0.3