Propagation Effects & their Impact

- Many phenomena causes lead signal loss on through the earths atmosphere:
  - Atmospheric Absorption (gaseous effects)
  - Cloud Attenuation (aerosolic and ice particles
  - Tropospheric Scintillation (refractive effects)
  - Faraday Rotation (an ionospheric effect)
  - Ionospheric Scintillation (a second ionospheric effect)
  - Rain attenuation
  - Rain and Ice Crystal Depolarization
- The rain attenuation is the most important for frequencies above 10 GHz
  - Rain models are used to estimate the amount of degradation (or fading) of the signal when passing through rain.
  - Rain attenuation models: Crane 1982 & 1985; CCIR 1983; ITU-R p,618-5(7&8)

Propagation Effects and their Impact II

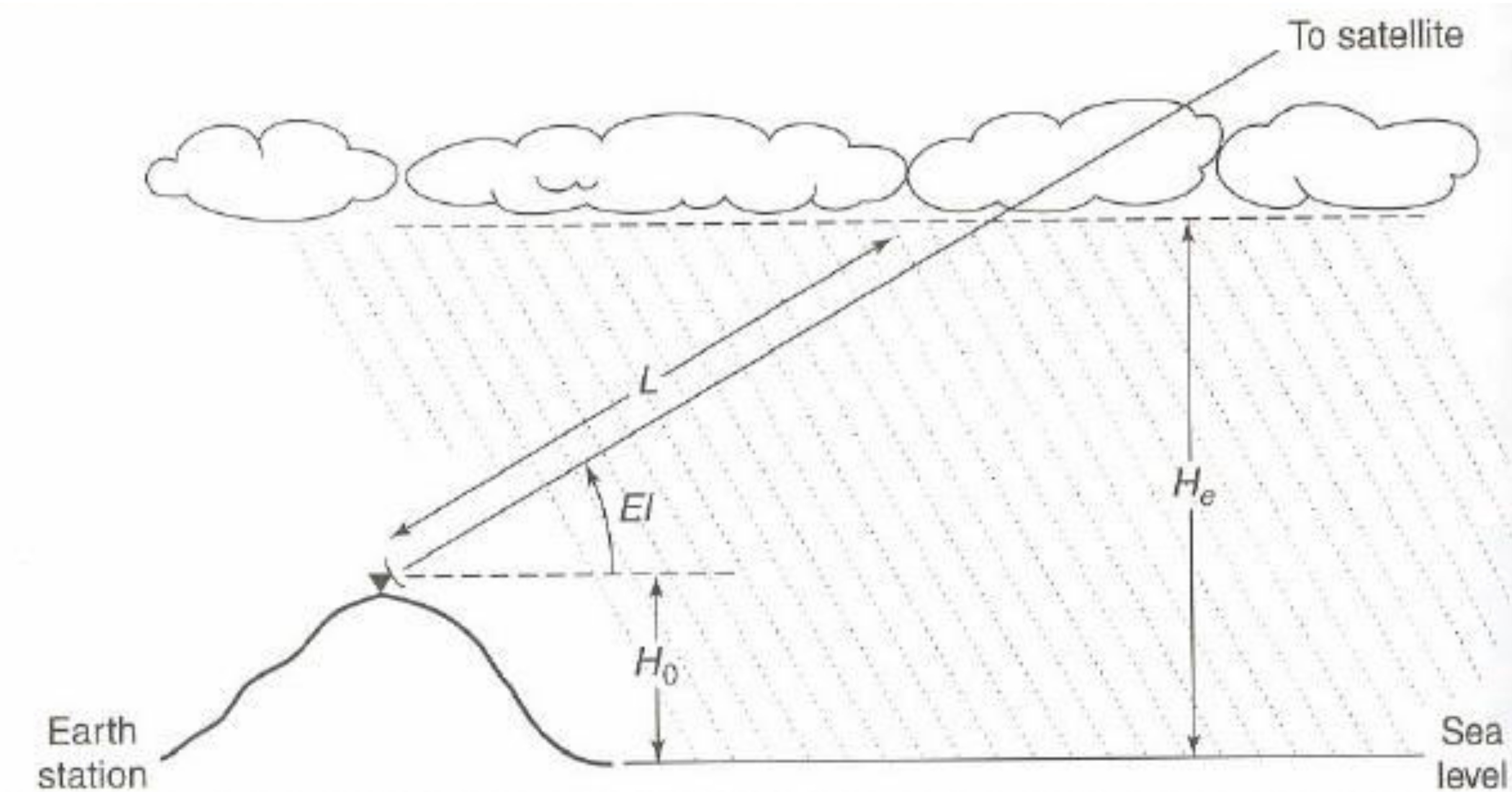


Figure 3. Geometry of satellite path through rain [1]

ATTENUATION

- The first, and most well known, effect of rain is that it attenuates the signal. The attenuation is caused by the scattering and absorption of electromagnetic waves by drops of liquid water. The scattering diffuses the signal, while absorption involves the resonance of the waves with individual molecules of water. .
- Absorption increases the molecular energy, corresponding to a slight increase in temperature, and results in an equivalent loss of signal energy.
- Attenuation is negligible for snow or ice crystals, in which the molecules are tightly bound and do not interact with the waves.
- The standard method of representing rain attenuation is through an equation of the form $Lr = \alpha R\beta L = \gamma L$

ATTENUATION

where Lr is the rain attenuation in decibels (dB)

R is the rain rate in millimeters per hour

L is an equivalent path length (km)

α and β are empirical coefficients that depend on frequency and to some extent on the polarization.

The factor γ is called the specific rain attenuation, which is expressed in dB/km. The equivalent path length depends on the angle of elevation to the satellite, the height of the rain layer, and the latitude of the earth station.

DEPOLARIZATION

- Rain also changes the polarization of the signal somewhat. Due to the resistance of the air, a falling raindrop assumes the shape of an oblate spheroid. Wind and other dynamic forces cause the raindrop to be rotated at a statistical distribution of angles.Consequently, the transmission path length through the raindrop is different for different signal polarizations and the polarization of the received signal is altered.
- For a satellite communication system with dual linear polarizations, the change in polarization has two effects. First, there is a loss in the signal strength because of misalignment of the antenna relative to the clear sky orientation given by

$$L = 20 \log(\cos \tau)$$

DEPOLARIZATION

- where, τ is the tilt angle relative to the polarization direction induced by the rain. Second, there is additional interference noise due to the admission of a portion of the signal in the opposite polarization.The average canting angle with respect to the local horizon can be taken to be 25°.
- It is an interesting property of earth-satellite geometry that a LP signal is not oriented with the local horizontal and vertical directions, even though a horizontally polarized signal is parallel to the equatorial plane and a vertically polarized signal is perpendicular to the equatorial plane
- when transmitted from the satellite. Thus the optics of the earth station antenna must be correctly rotated in order to attain the appropriate polarization alignment with the satellite.

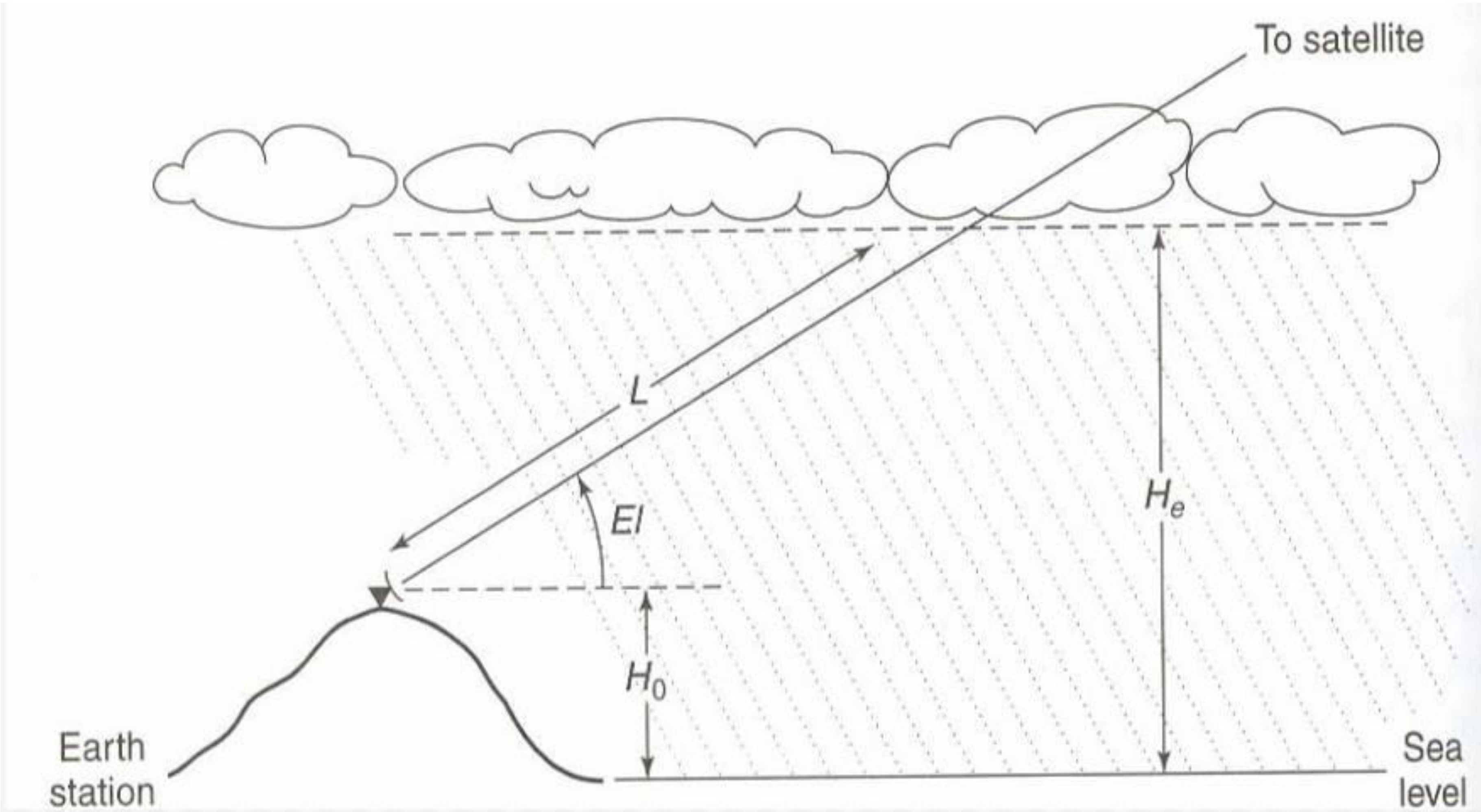
Atmospheric absorption,

- The propagation are primarily due to the effects of the Earthâ€™s atmosphere and their impact on system availability and margin. Distortions due to multipath propagation do not affect the millimeter wave. However, some atmospheric effects at the millimeter wavelengths are gaseous absorption, cloud attenuation, rain attenuation, and tropospheric scintillation. Gaseous absorptions are mainly due to atmospheric gaseous components (predominantly oxygen and water vapor) and typically have a small contribution to the total path attenuation in the W/V band . Cloud attenuation at the W/V bands can contribute to significant loss (> 10 dB). Rain attenuation has the most dominant contribution to the total propagation loss when dealing with higher frequencies . Troposphere scintillation is the rapid fluctuations in the refractive index of owing to turbulence and produces random fades and enhancements of the received signal amplitude . This phenomenon can seriously affect satellite-earth links at frequencies above 10 GHz and at very low elevation angles (<=5 degrees).

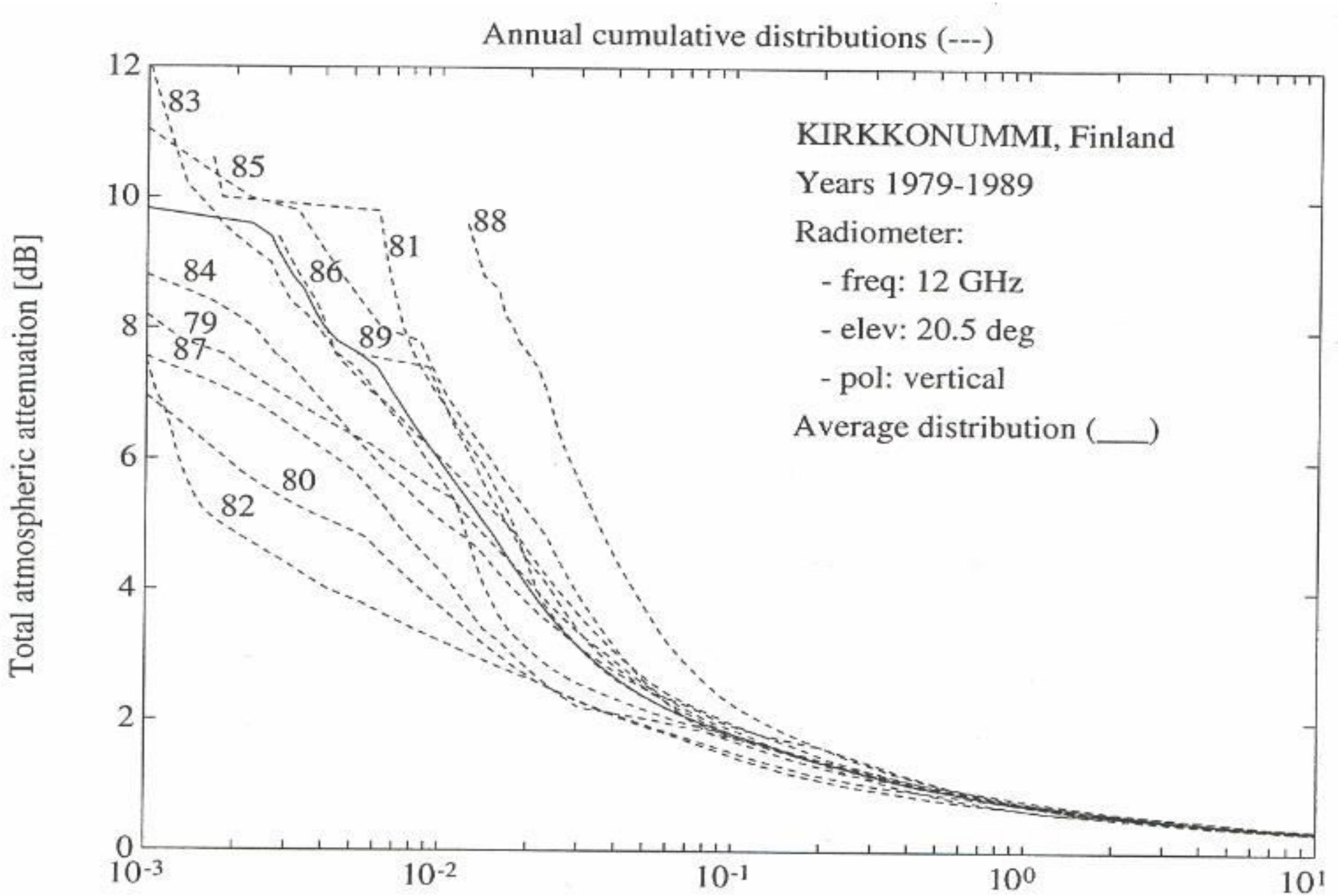
Rain & Ice effects

- Rain affects the transmission of an electromagnetic signal in three ways: (1) It attenuates the signal (2) it increases the system noise temperature (3) it changes the polarization. All three of these mechanisms cause a degradation in the received signal quality and become increasingly significant as the carrier frequency increases. As the wavelength decreases and approaches the size of a typical rain drop (approximately 1.5 mm), more scattering and absorption occurs and the attenuation increases. Also, as the rain rate increases during a heavy downpour, the size of the rain drops, and hence the attenuation, increases.

Geometry of satellite path through rain



attenuation



Cloud Effects

- Cloud attenuation becomes increasingly important to consider for reliable satellite communications at frequencies above 10 GHz . For clouds or fog consist of small droplets, less than 0.01 cm, the Rayleigh approximation is valid for frequencies below 200 GHz and it is possible to express the attenuation in terms of the total water content per unit volume . The following equation can be used to obtain the attenuation due to clouds for a given probability:

$$A = L K l \sin\theta \quad dB \ for \ 90° \geq \theta \geq 5°$$

where L is the total columnar content of liquid water (kg/m^2),

Kl is the specific attenuation by water droplet

and θ is the elevation angle.