PROPAGATION CONSIDERATION

The channel affects the electro-magnetic waves in several ways, through:

- Path attenuation
- Polarization
- Noise

The factors to be considered are:

- Gaseous absorption
- Absorption and scattering by clouds, fog,...etc.
- Atmospheric turbulence
- Ionospheric effects

Statistical techniques are used in modelling these effects because of their random nature.

Most significant impairments of radio wave propagation occur in the troposphere and the ionosphere.

Troposphere → first few 10’s km, ~ 50-60 km
(clouds & rain)

Ionosphere → Ionized region from ~ 80 – 1000 km

Frequencies used or under consideration are:

100 MHz – 30 GHz

Frequency range 3 – 10 GHz is least affected and is used heavily.

Ionospheric effects are significant at 30 MHz – 700 MHz
> 10 GHz  Tropospheric effects are significant.

Mobile systems require additional considerations

- Multi-path effects
- Scattering by buildings, trees,…etc.

Tropospheric Effects

Gaseous absorption is a function of temperature, pressure, humidity, elevation angle of the satellite.

Estimated one-way attenuation for a vertical earth-space path as a function of frequency.
The first absorption band at ~22.2 GHz is caused by water vapour.

The second band at ~60 GHz is caused by oxygen.

Absorption increases as elevation angle is reduced.

\[ \propto \frac{1}{\sin(El)} \]

From the chart we can obtain the following:

In the frequency range 1 – 18 GHz

Zenith one way absorption is in the range 0.03 – 0.2 dB

For elevation angle $El = 5^\circ$, it becomes $0.35 – 2.3$ dB

These figures become (100% humidity) $0.03 – 0.5$ dB

For elevation angle $El = 5^\circ$, it becomes $0.35 – 5.7$ dB

**Attenuation due to hydrometers**

Condensed water vapours existing in the atmosphere. e.g. rain, hail, ice, fog, cloud, snow,.....

Rain drops produce the maximum attenuation.

**Attenuation by Rain**

Assumptions:

1. RF wave decays exponentially through rain
2. Rain drops are spherical
3. Attenuation due to each drop is independent and additive.
Over length $L$ of path, \[ A_R = \int_{0}^{L} \alpha \, d\alpha \]

Where $\alpha$ is the specific attenuation of rain in dB/km

The specific attenuation can be determined by integrating the attenuation cross section $Q_t$ over all drop sizes

\[ \alpha = 4.343 \int Q_t(r, \lambda, m) n(r) \, dr \]

where $r \rightarrow$ drop radius

$\lambda \rightarrow$ wavelength

$m \rightarrow$ complex refractive index

and $n(r) \rightarrow$ drop size distribution

Substituting in the overall attenuation we get,

\[ A_R = 4.343 \int_{0}^{L} \left[ N_o \int Q_t e^{-N_t} \, dr \right] d\alpha, \text{ where } N_o \& \Lambda \text{ are empirical constants.} \]

These calculations show that rain attenuation increases with frequency and rain rate.

Rain attenuation become significant for $f > 10$ GHz

Rain attenuation can be estimated by:

\[ \alpha = a R^b \]

a and b are constants and R is the surface rain rate.

Rain Attenuation Prediction
Measurements are time consuming and expensive. Several rain attenuation prediction methods were proposed. e.g.

\[ A = a R^b L(R) \]

where \( L(R) = \text{effective path length} = \frac{2636}{R - 6.2 + \frac{2636 \sin(\theta)}{4 - G}} \)

\( \theta = \text{elevation angle} \)

\( R = 5 \) minutes average rain rate in mm/h

\( G = \) earth station height above sea level

**Attenuation by clouds and Fog**

Similar to rain with cloud liquid content of 0.05 to 5 g/m³

Largest attenuation from clouds is equivalent to light rain ~ 10 mm/h.

Liquid content of fog is ~ 0.4 g/m³ and extends from 2 – 8 km,

Attenuation due to fog is negligible for satellite communications.