DragonWave Inc.

Engineering for the effects of Rain & Fog on the AirPair System

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Overview

This paper is intended to illustrate that the predominant propagation impairment is due to rain fall and that the effects of fog are relatively small in comparison. In addition, this paper will explore how the effects of rain can be engineered against, in order to provide a high availability wireless link.

The deployment of DragonWave *AirPair* wireless links is governed by the estimation of rain loss in a given region, and that the heaviest rains do not occur simultaneously with the heaviest fog conditions. As a result, rain-based link range estimations more than adequately cover impairments due to fog.

Rain-Based Link Range Estimation

The process of estimating radio link ranges is a well understood process and is internationally recognized. Standard, accepted methods for this process are well documented in the form of ITU-530.

ITU-530 defines a process of converting statistical, regionally-based rain data and rain cell extent expectations into path losses which are then designed into a given radio link in the form of a rain fade allowance.

Typically, rain data for 99.99% availability are used in the calculation. The data can be derived from ITU sources (which have been gathering rain data globally for more than 20 years) or where possible from local, trusted sources (such as airports). Availabilities other than 99.99% are estimated by the procedure outlined in ITU-530.

In addition, ITU-530 also includes a “rain cell extent” modifier. This predictive factor is based on the knowledge that rain cell sizes are inversely related to rain intensity (i.e. very heavy thunderstorms are generally physically small, whereas drizzle storms can be very large). The extent of the rain cell then affects longer links differently than it may affect shorter links.

Figure 1 shows typical rain-induced path losses.

- A high rain rate region
  - i.e. ITU rain region K[i]
  - exhibits a rain rate of 42 mm/hr for 0.01% of the time (99.99% design availability)
  - approx 6 dB per km of rain cell
- A light rain region
  - i.e. ITU rain region E[1]
  - exhibits a rain rate of 22 mm/hr for 0.01% of the time
  - approx 3 dB per km of rain cell
- A very heavy rain region
  - i.e. ITU rain region M[1]
  - exhibits a a rain rate of 63 mm/hr for 0.01% of the time
  - approx 10 dB per km of rain cell

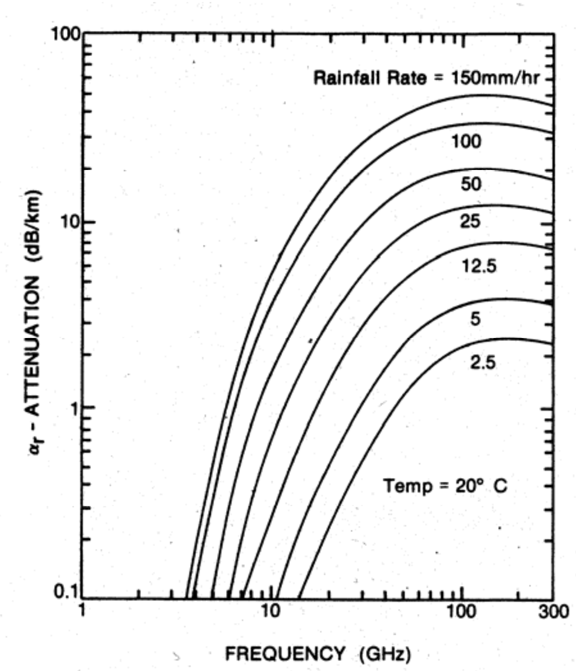

Figure 1 – Typical Rain Attenuation vs Frequency[ii]

(note: this is representative, not exactly as ITU predicts since it does not account for rain cell extent)

Effects of Fog

The effects of fog are generally accepted to be small compared to rain primarily as a direct function of the size of the air-borne water droplets from which fog is made[iii,iv]. These smaller particles tend to be highly absorptive as wavelength increases towards the infra-red and optical spectral regions but are not problematic at the lower millimeter ranges.

In the region of 23 GHz, heavy fog presents a propagation impairment which is of similar magnitude to normal atmospheric gases (see Figure 2). A much more significant factor is Heavy and Excessive rain. In contrast, when considering the Infrared and Visible light regions on the right side of this figure, it can be seen that Free Air Optical (FAO) equipment is severely impacted by both rain and fog. In fact fog is a crippling propagation element for FAO systems due to the fact the fog water droplet sizes end to be comparable to the FAO system operating wavelengths.

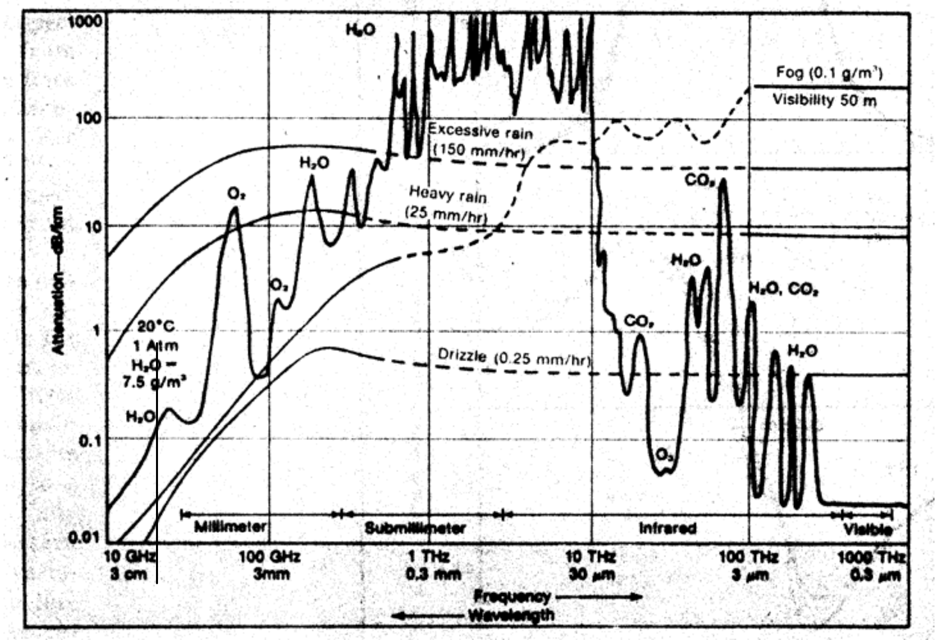

Figure 2 – Comparative Propagation Impairments Due to Rain, Drizzle, Fog and Atmospheric Gases[v]

When considering the losses associated with fog at 23 GHz, a starting point is the definition of "visibility" in fog. Very dense fog[vi] provides a visibility of < 50m and exhibits a water vapour density of 0.4 – 1 g/m^3. At 1 g/m^3 , visibility is very low….on the order of 10m or so. Using this extreme case (1 g/m^3) and the propagation loss prediction method employed by Althshuler[vii], it is possible to estimate the path loss in fog using;

$$\text{Fog Path Loss [dB/km/g/m}^3\text{]} = -1.347 + 0.0372\lambda + (180/\lambda) - 0.22T$$

Where: λ = wavelength in meters
T = Temp, deg C

$\therefore$ Path Loss [dB/km] @ 1 g/m^3 fog @ 20^{o}C and 23 GHz = ~ 0.3 dB/km.

This is closely supported by data pertaining to clouds[2], very light rain and or drizzle[viii]. Figure 3 shows a summary view of loses associated with Fog (and clouds). Note that very heavy fog exhibits a density of 0.5 – 1 g/m^3 of air.

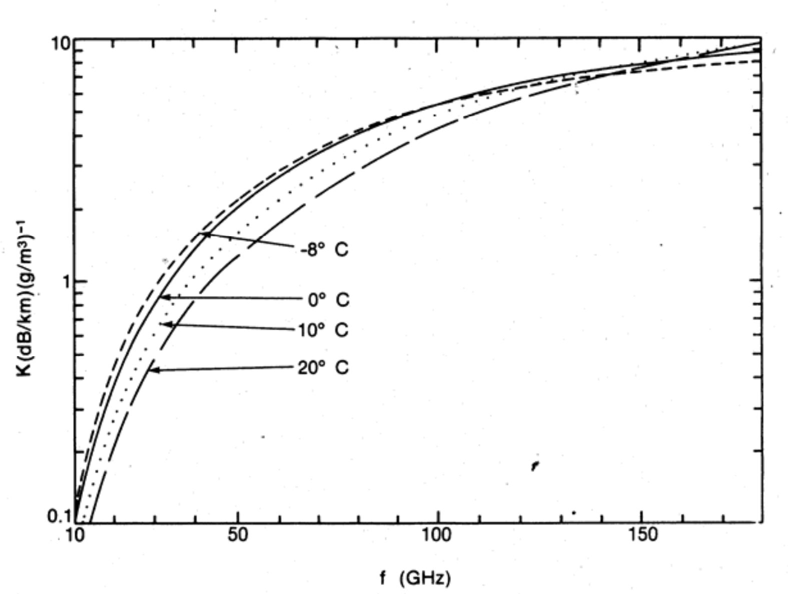

Figure 3 – Summary of Fog/Cloud Induced Losses[2]

Engineering for Rain and Fog

The data presented in this paper shows that rain is the major factor effecting link availability, therefore a microwave link is engineered for rain conditions rather than for fog conditions. Given the rain for a specific region, and the length of a link, the ITU-530 standard can be used to calculate how many db of propagation loss will be experienced for a desired % of time due to rain. Once this loss is calculated, a link can then be engineered to the desired availability, by allocating the margin required for that service level. The link can be engineered by adjusting the antenna size, choosing a high-power option, or changing the frequency which is used (which in turn causes the required link margin to change). The AirPair link tool uses the ITU-530 standard, the AirPair performance, all other propagation effects and regional rain data to provide accurate equipment engineering for desired link availabilities.

Summary

The predominant propagation factor affecting millimeter wave propagation links is rainfall. Although fog has an impact, this impact is very small in comparison to rain at frequencies in the 20 – 30 GHz range. Therefore, designing a link to accommodate the required rain-induced link fade inherently addresses any impairments related to fog. In addition, the well-known rain properties and effects, as well as the AirPair engineering tool, allow a very a link to be easily engineered to a desired level of availability.

In contrast, Free Air Optic (FAO) systems are highly impacted by both rain and fog. The degree of impairment can easily render these links useless (i.e. the fades are so large that the electronic equipment can not compensate). Therefore, in practice, FAO links tend to be limited to very short range links (i.e. < 500m).

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Footnotes:

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[i] ITU rain data available in ITU-R 837

[ii] Bhartia, Bahl, Millimeter Wavelength Engineering and Applications, Wiley 1984

[iii] Dudzinski, "Atmospheric Effects on Terrestrial Millimeter-Wave Communications, Reprinted by IEEE press

[iv] Lane, Norbury, "Propagation Factors and Communications Systems in the Band 30 – 300 GHz", IEE Radio Spectrum Conservation Techniques Conference, July 1980

[v] Tiffany, "Most Reliable Messenger: MM-Waves Get Through", Microwaves & RF, Sept. 1983

[vi] Koester, Kosowsky, Sparacio, " Millimeter Wave Propagation", Millimeter Wave Radar Applications to Weapon Systems, Vol 1.

[vii] Altshuler, "A Simple Expression for Estimating Attenuation by Fog at Millimeter Wavelengths", IEEE Trans. On Antennas and Propagation, Vol AP-32, NO. 7, July 1984

[viii] Frey, "The Effects of the Atmosphere and Weather on the Performance of a mm-Wave Communications Link", Applied Microwave and Wireless