Training Program : Point-to-Point Radio Link Design

Course : Rain Attenuation

COMPLEMENTS to Lesson 1 : Absorption and Scattering

Use of the 60 GHz frequency band

Millimeter microwave signals in the frequency band around 60 GHz suffer strong attenuation due to oxygen molecule (O_2) absorption. This poses significant limits to the use of this frequency band.

On the other hand, applications have been identified to take advantage of signal attenuation. One example are inter-satellite links, with specific interest in military communications, where attenuation through the atmosphere guarantees total protection to eavesdropping from the earth.

Over the 57–71 GHz FCC unlicensed band, the IEEE 802.11ad (WiGig) standard was issued in 2009 and allows up to 7 Gbit/s capacity over a limited range. The new standard 802.11ay (second generation WiGig) supports 8.64 GHz maximum bandwidth, with up to 100 Gb/s and 300 - 500 meters of extended range for various applications.

More generally, the attractive aspect of the 60 GHz band is that strong attenuation, while limits the possible transmission range, allows intense frequency re-use in the same area, providing high immunity to interference.

Let us consider that the EM Spectrum extends in the three domains of frequency, physical space, and time, and it is "used" when it is "denied to other potential users". This is a very general definition of "EM Spectrum Use", useful to evaluate spectral efficiency of a given radio system [1].

Therefore, the "space" occupied by a 60 GHz system is reduced by the limited propagation range, so that other users of the same band can co-exist and operate at a reduced distance. This increases Spectral Efficiency, compared with other frequency bands.

Rain Attenuation in different climates

Following the development of new radio links in the 30 - 40 GHz range, or even above the 60 GHz band, it is clear that reliable models for rain attenuation are more and more important.

One significant aspect is that, according to the present ITU-R model, rain events are characterized exclusively by rain intensity. On the other hand, other factors may be relevant to correctly evaluate rain attenuation. Much effort has been devoted to theoretical studies about statistical Drop Size Distributions (DSDs), raindrop shape, etc.

Different climatic conditions, in different world regions, lead not only to different rain intensities, but also to different experimental outcomes about DSDs and other rain parameters.

As an example, relevant comments are reported in [2], where measurements in England and in Singapore are compared. One conclusion is that ". . . the distributions measured . . . are very different, which strongly suggests that drop size distributions differ under different climatic conditions".

While the general relationship for specific rain attenuation $\gamma = k R^{\alpha}$ (R = rain intensity, k and α coefficients depending on frequency) is generally agreed, specific estimates for k and α are probably required for different climates. Such a conclusion applies particularly for frequencies above the 60 GHz band.

This topic is likely to require further study in the next future, while interest increases in the use of millimeter frequencies.

Other particles in the atmosphere

Clouds and Fog: The ITU model can be applied in the range between 5 and 200 GHz [3]. Specific attenuation is computed as a function of water vapor density in the atmosphere and of a specific attenuation coefficient K (depending on temperature and frequency).
Reference values can be derived for the K coefficient in the range 0.5 to 1.0 at 30 GHz and between 4 and 5 at 80 GHz. As an example, assuming thick fog conditions (50 m visibility), corresponding to $0.5 g/m^3$ water vapor density , then specific attenuation is estimated as 0.25 - 0.5 dB/km at 30 GHz and to 2.0 - 2.5 dB/km at 80 GHz.

Snow and Hail : Attenuation is basically governed by the water content and (in the case of hail) by the size of the hailstones relative to the wavelength. In some cases, equivalence with rainfall with similar water content can be of help for a rough attenuation estimates. Wet snow is taken into account in the ITU-R model as an "Attenuation multiplying factor". Note that snow accumulation on antennas and radomes is a separate phenomenon from the effect of falling snow and should be limited with suitable maintenance countermeasures.
Dust and Sand : Again, attenuation is mainly a function of the moisture content of the particles. Specific models are not available or sufficiently reliable. Field results [4] at 37 GHz show that attenuation is less than 0.6 dB/km in humid climates.

Useful References

[1] Moreno L., " Spectrum Utilization in a Digital Radio-Relay Network", IEEE Transactions on Electromagnetic Compatibility, 1982

[2] Asen W., Gibbins C.J., "A comparison of rain attenuation and drop size distributions measured in Chilbolton and Singapore", Radio Science, 2002

[3] ITU-R Rec. P.840-8, "Attenuation due to Clouds and Fog", 2019

[4] Al-Rizzo H.M. et al., "Particle-Size Distribution of Iraqi Sand and Dust Storms and Their Influence on Microwave Communication Systems", IEEE Tr. Antennas and Propagation, 1988