Comparison of Hydrometeor Attenuation on Parallel Terrestrial Paths at 58 GHz and 93 GHz

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Abstract

The results of 3-year experimental research of attenuation due to hydrometeors at 58 GHz and 93 GHz parallel terrestrial paths are given. The obtained cumulative distributions of attenuation due to all the hydrometeors combined, monthly cumulative distributions of attenuation due to all the hydrometeors combined, cumulative distributions of attenuation due to the individual hydrometeors separately, and cumulative distributions of rain intensities are given. The influence of individual hydrometeors on attenuation is analysed. The obtained cumulative distribution of attenuation due to rain only is compared with the calculated one in accordance with the relevant ITU-R recommendations.

1. Introduction

Demands on the transmission capacity of the terrestrial microwave communications links are rapidly increasing. Terrestrial digital fixed services almost fully occupied frequency bands up to 38 GHz. It is supposed that higher frequency bands will be utilized in the near future. Experimentally obtained statistical characteristics of attenuation due to hydrometeors (rain, hail, snow, fog) will be needed for the realistic assessment of availability performances of new terrestrial digital fixed links operating in frequency bands over 38 GHz.

The Czech Metrology Institute (CMI) and the Institute of Atmospheric Physics of the Academy of Sciences of the Czech Republic (IAP AS CR) have been carrying out joint experimental research in the 58 GHz and 93 GHz frequency bands on terrestrial experimental paths in Prague between IAP AS CR and CMI. This research is focused on the investigation of attenuation due to hydrometeors and of availability performances of terrestrial digital fixed links under real climatic conditions. Experimental results obtained on parallel 58 GHz and 93 GHz terrestrial paths over 3-year period are presented.

2. Experimental Set-up

2.1 Radio Systems

Both 58 GHz and 93 GHz radio systems operate on the same line-of-sight path with the path length of about 853 m. The 58 GHz radio system operates at 57.650 GHz with V polarization. The transmitted power is about 5 dBm and the recording fade margin is about 25 dB. The 93 GHz radio system operates at 93.370 GHz with V polarization. The transmitted power is about 17 dBm and the recording fade margin is about 37 dB.

2.2 Meteorological Measurements

Meteorological conditions are identified both by means of data obtained from a weather observation system located near the receiver sites and from colour video-camera images of the space between the transmitter and receiver sites. The system is equipped with Vaisala sensors for the measurement of temperature, humidity and air pressure, the velocity and direction of the wind. The rain intensities are measured by the dynamically calibrated heated tipping-bucket rain gauge with a collector area of 500 cm^2, and the rain amount per tip is 0.1 mm. The time of the tips is recorded with an uncertainty of 1 second. The Vaisala PWD11 equipment is used for the measurement of visibility in the range from 50 m to 2000 m. The meteorological data is synchronized in time with the measurement of hydrometeor attenuation and is continuously recorded on a computer hard disk.

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2.3 Data Processing

The obtained records of observed attenuation events at 58 GHz and 93 GHz paths were statistically processed over a three year period from December 2007 to November 2010. Data was not available at 58 GHz for the period from January to March 2010 due to a breakdown of the equipment used. The records of attenuation events were compared with the concurrent meteorological situation to identify the reason of the attenuation events. Strictly concurrent attenuation events and hydrometeor occurrences were only processed. Every recorded individual attenuation event was analysed, compared with the concurrent meteorological conditions, carefully identified and was ranked in accordance with the individual types of hydrometeors, i.e. rain (R), a mixture of rain with snow (RS), snow (S), fog (F), a mixture of fog with rain (FR), a mixture of fog with snow (FS), and a mixture of fog with rain and snow (FRS). The obtained time of tips records were processed over the same three-year period and the cumulative distribution of average 1-minute rain intensities was obtained.

3. Experimental Results Obtained

3. 1 Attenuation due to All Hydrometeors

The obtained CDs of attenuation due to all the hydrometeors combined (R, RS, S, F, FR, FS and FRS together) on the 58 GHz and 93 GHz paths for the individual year periods and for the entire 3-year period of observation are given in Figs. 1 and 2.

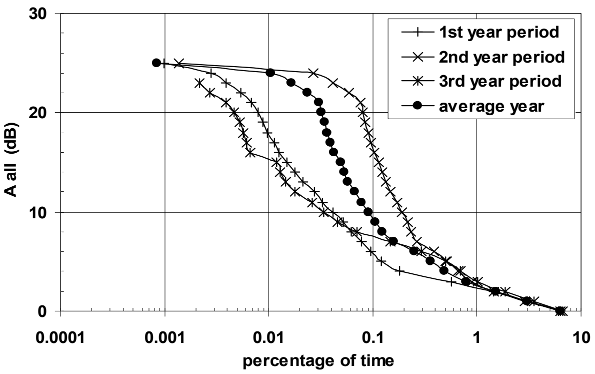

Fig. 1. Obtained CDs of attenuation due to all the hydrometeors combined at 58 GHz

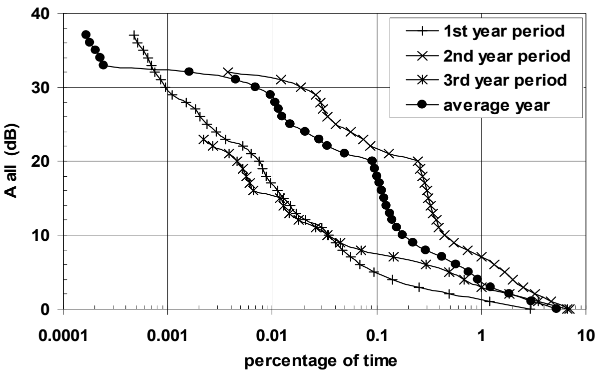

Fig. 2. Obtained CDs of attenuation due to all the hydrometeors combined at 93 GHz

The large year-to-year variability of the CDs of attenuation due to all the hydrometeors combined can be seen at both frequencies.

The obtained monthly CDs of attenuation due to all the hydrometeors combined over the 3-year period of observation are given in Figs. 3 and 4.

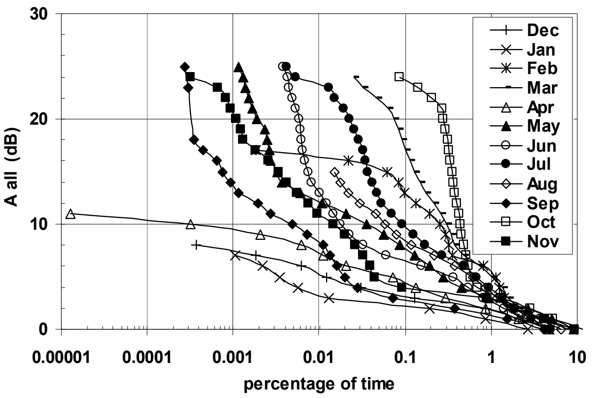

Fig. 3. Obtained monthly CDs of attenuation due to all the hydrometeors combined at 58 GHz

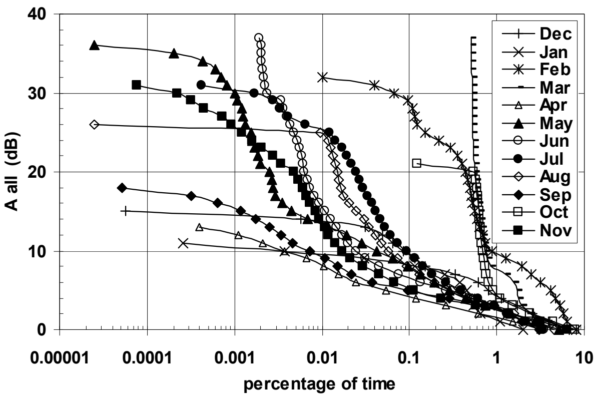

Fig. 4. Obtained monthly CDs of attenuation due to all the hydrometeors combined at 93 GHz

It can be seen that the cumulative distribution of attenuation due to all hydrometeors together for 58 GHz for the worst month over the three-year period is formed by pertinent parts of the cumulative distributions for October, February, and March.

The cumulative distribution of attenuation due to all hydrometeors together for 93 GHz for the worst month over the three-year period is formed by pertinent parts of the cumulative distribution for March, and February.

3. 2 Attenuation due to Individual Hydrometeors

The obtained CDs of attenuation due to all the hydrometeors combined and the individual hydrometeors separately, i.e. due to R, RS, S, F, FR, FS, FRS and F+FR+FS+FRS, over the 3-year period of observation at 58 GHz and 93 GHz are shown in Figs. 5 and 6.

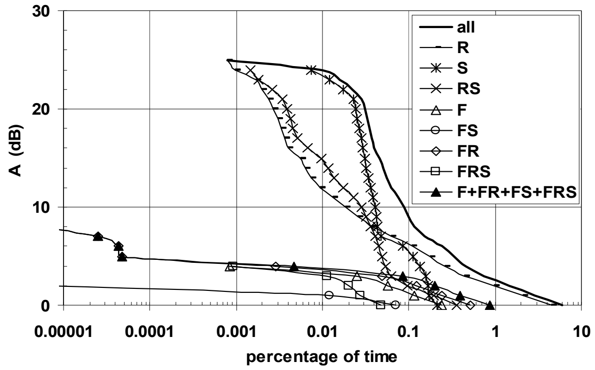

Fig. 5. Obtained CDs of attenuation due to all the hydrometeors combined and the individual hydrometeors separately at 58 GHz

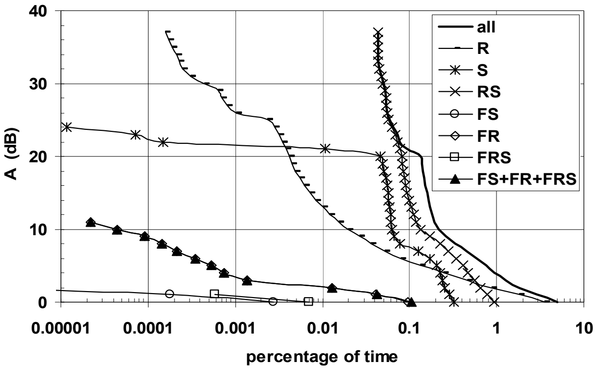

Fig. 6. Obtained CDs of attenuation due to all the hydrometeors combined and the individual hydrometeors separately at 93 GHz

It can be seen that the dominant attenuation events at 58 GHz were caused by snow and at 93 GHz were caused by a mixture of rain with snow. Dominant attenuation due to rain with snow on 93 GHz path occurred in March. It was caused by a heavy snow thunderstorm. Snow was settled down on antennas about 11 hours while the thunderstorm took about 2 hours. Unfortunately, as it was mentioned above, data was not available at 58 GHz for the period from January to March 2010. Both CDs of attenuation due to snow at 58 GHz and 93 GHz were dominantly caused by snow events occurred in March and October 2009. Attenuation events due to fog only were not observed at 93 GHz. Dominant attenuation events due to a mixture of fog and rain at both frequencies occurred in October 2009. The influence of F, FS, FR and FRS on attenuation is insignificant at both frequencies.

3.3 Rain Intensity Distribution

The obtained CD of the average 1-minute rain intensities (*R(1)*) over the three-year period as well as the calculated CD of *R(1)* in accordance with the ITU-R recommendation [1] are given in Fig. 7.

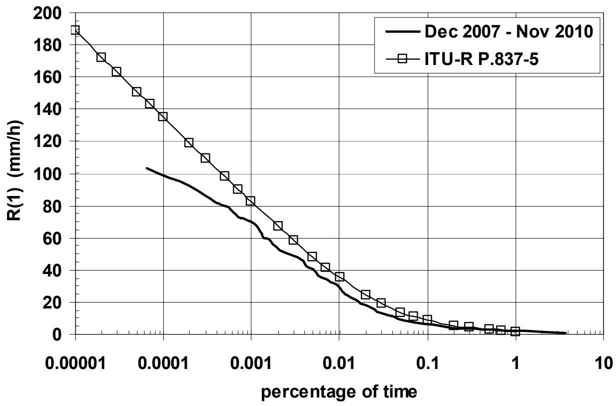

Fig. 7. Obtained and calculated CDs of *R(1)*

The obtained *R(1)* for 0.01% of time of year ($R(1)_{0.01}$) was 28.7 mm/h while the ITU-R recommendation [1] gives $R(1)_{0.01}$ = 35.2 mm/h. It can be seen that the measured *R(1)* are generally lower than the calculated *R(1)* in accordance with ITU-R recommendation. It might be due to great year-to-year variations of CDs of rain intensities due to different weather conditions in individual years.

3.4 Comparison with ITU-R

The obtained CDs of attenuation due to rain only at 58 GHz and 93 GHz are compared with the calculated CDs of attenuation due to rain for the average year in accordance with the relevant ITU-R recommendations [2],[3] in Figs. 8 and 9. Two different $R(1)_{0.01}$ were used for calculations: a) $R(1)_{0.01}$ = 28.7 mm/h obtained from measurement at CMI over 3-year of observation, and b) $R(1)_{0.01}$ = 35.2 mm/h given in [1].

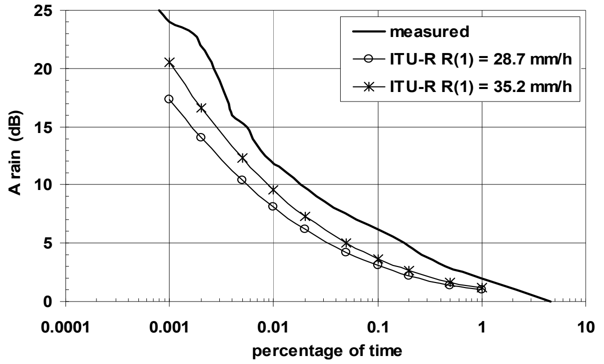

Fig. 8. Comparison of obtained CD of attenuation due to rain only and calculated CD of attenuation due to rain according to ITU-R at 58 GHz

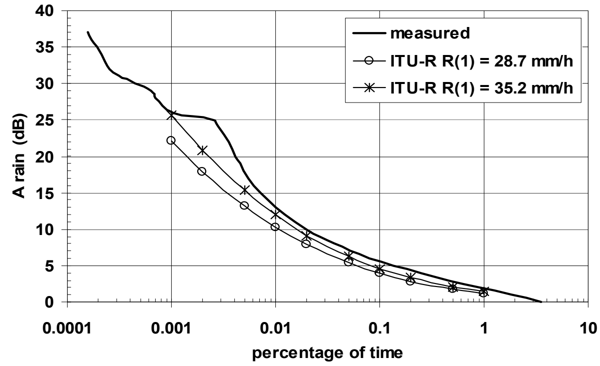

Fig. 9. Comparison of obtained CD of attenuation due to rain only and calculated CD of attenuation due to rain according to ITU-R at 93 GHz

It can be seen that the measured values of attenuation due to rain only are slightly higher than the calculated ones for both frequencies. It might be due to the large year-to-year variability of CDs due to rain as well as by the fact that the relevant ITU-R recommendation [3] is advised for use up to 40 GHz only and for path lengths up to 60 km.

4. Conclusion

The experimental results obtained on two parallel terrestrial paths at 58 GHz and 93 GHz and the obtained cumulative distributions of rain intensities were presented. The obtained results were analysed and can be used for the assessing of the availability performances of both terrestrial links.

5. Acknowledgments

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6. References

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3. *Propagation data and prediction methods required for the design of terrestrial line-of-sight systems*, Rec. ITU-R P.530-12, ITU-R Recommendations and Reports, ITU, Geneva, Switzerland, Edition 2, 2009.