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Rain Fade and Inter-fade Duration Statistics from Two 38 GHz Terrestrial Paths

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1. Introduction

Attenuation due to hydrometeors degrades significantly the quality and availability performance of terrestrial and satellite communication links operating in millimetre wave frequency bands. The influence of rain on these links is often described statistically. The cumulative distribution function of attenuation is widely utilized and is considered as the first order statistics. However, cumulative distribution alone provides no information about fade dynamics that is demanded by system designers.

Fade and inter-fade duration statistics, which are considered as the second order statistics, give basic information about probability distribution of attenuation event durations and of time durations between consecutive attenuation events. In contrast to the first order statistics, there is still a lack of data available on the fade duration statistics in millimetre wave frequency bands [1]. The purpose of this paper is to present results of long term propagation experiments carried out in the 38 GHz frequency band. Empirical fade and inter-fade duration statistics are obtained and suitable models are proposed for their description.

2. Measurement

TESTCOM has measured attenuation due to hydrometeors on the two paths in star configuration operating at 38 GHz with V polarisation. The path length of the path Uvaly – TESTCOM (*path A*) is 9.3 km, the path azimuth is 121.4°. The transmitter is situated in Prague at Strahov (394 metres above sea level), altitude 39 m above ground. The receiver is located at TESTCOM (314 m a.s.l.), altitude 27 m above ground. The transmitting power is 16 dBm, working frequency is 38 319.75 MHz. Antennas having diameter of 0.6 m have been utilized with a gain G = 45 dBi. The fade margin of the link is about 60 dB.

The second path Uvaly – TESTCOM (*path B*) is 15.2 km long, the path azimuth is 254.8°. The transmitter is situated in Prague at Uvaly, altitude 26 m above ground. The receiver is located at TESTCOM, altitude 27 m above ground. The transmitted power is 18 dBm. The link is working on 38 497.25 MHz. Antennas with 0.6 m diameter are used at both end sites. The fade margin achieved is about 50 dB.

The received signal level time series measured on the mentioned paths were processed statistically over a three year period 2003 – 2005. The second order statistics of attenuation due to rain (only rain events selected) were calculated for each individual year and for the whole three year period.

3. Second order statistics

In this section empirical second order statistics obtained from the measured time series of attenuation are presented.

3.1 Fade duration

Figure 1 shows empirical fade duration statistics obtained for three year period January 2003 – December 2005 on the path A and B. Number of fades (i.e. individual attenuation events)

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deeper than an attenuation level and shorter than certain fade duration is expressed as a function of the fade duration. A usual cumulative distribution function can be calculated by means of a total number of fades which value is a limit when the fade duration goes to infinity.

It is often the case that the number of fades is not presented and only probability is given. However, this additional information is very important for designing purposes. The simplest example of it is the outage intensity parameter required in ITU-R Recommendation [2] referring to the availability objectives for the terrestrial fixed wireless links. Thus only fade events longer than 10 seconds are processed here having in mind that an unavailability state duration is longer than 10 seconds by definition.

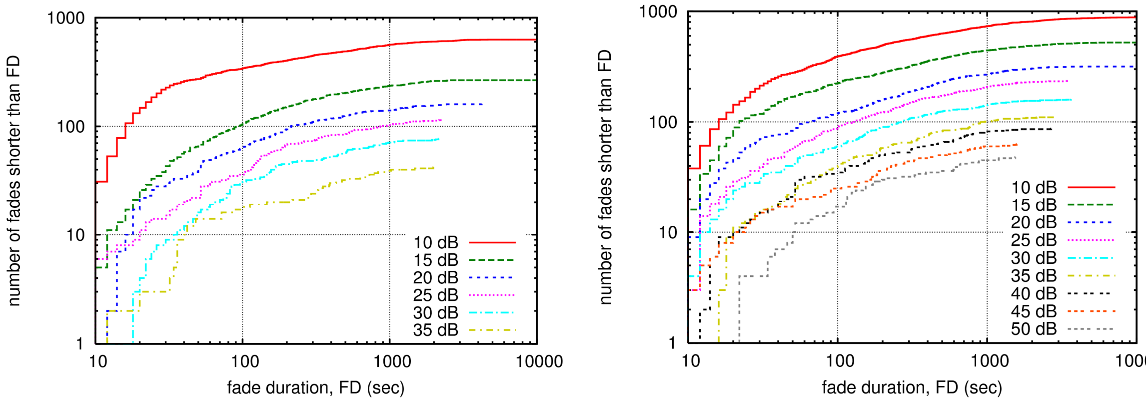

Figure 1: Three year fade duration statistics, 2003-2005, path A - left, path B - right.

A question can arise how many fade events deeper than a given attenuation level will be observed on the link knowing the average number of fade events deeper than a reference level. In order to get a suitable scaling relation, dependencies depicted in Figure 2 were analysed.

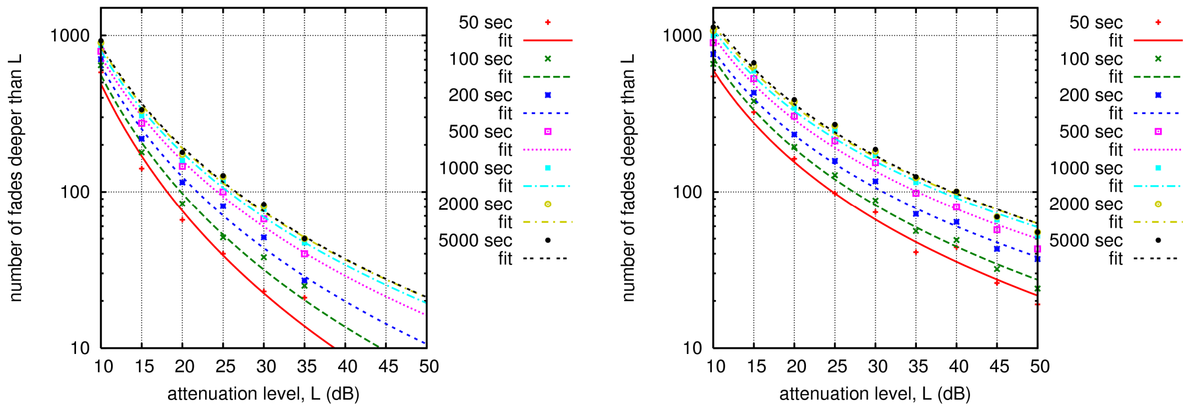

Figure 2: Number of fades versus attenuation level, path A - left, path B - right.

From above Figures, a number of fades N_L (-) deeper than an attenuation level L (dB) decreases with this level. It was found that this dependence can be well estimated by the equation:

$$N_L = \exp\left(a - (\ln(L))^b\right) \tag{1}$$

where a and b are parameters. Besides the measured points, Figure 2 also shows fitted curves according to (1). Path A parameters range in the intervals $a \sim (9.87, 10.05)$, $b \sim (1.42, 1.56)$ and path B parameters range in the intervals $a \sim (9.52, 10.11)$, $b \sim (1.30, 1.37)$. Clear difference is seen between the paths A and B. As the paths are almost in the same location and, it seems the path length and path azimuth affect the number of fades. However, more studies would be needed to establish suitable path length relation.

3.2 Inter-fade duration

Figure 3 shows empirical inter-fade duration statistics obtained from a three year period 2003 – 2005 on the paths A and B. Both path statistics exhibit unexplained similar shift at inter-fade duration values of about 10^6 seconds.

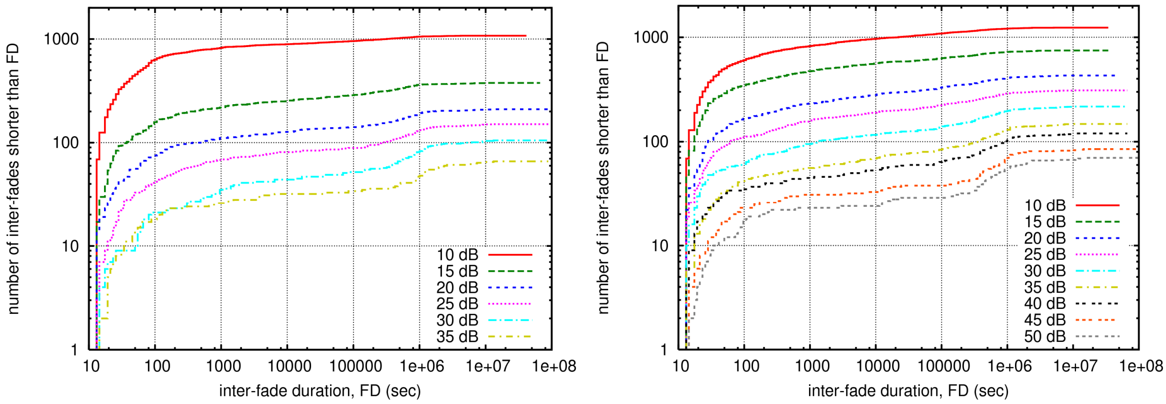

Figure 3: Annual inter-fade duration statistics for the period 2003-2005, path A - left, path B - right.

4. Fade duration modelling

Three possible models of the fade duration cumulative distributions are compared in Figures 4, 5 and 6. Cumulative distributions for the path B were fitted by log-normal, ITU-R composite [3] and gamma distribution respectively. Table 1 summarizes the root mean square errors of fitted models.

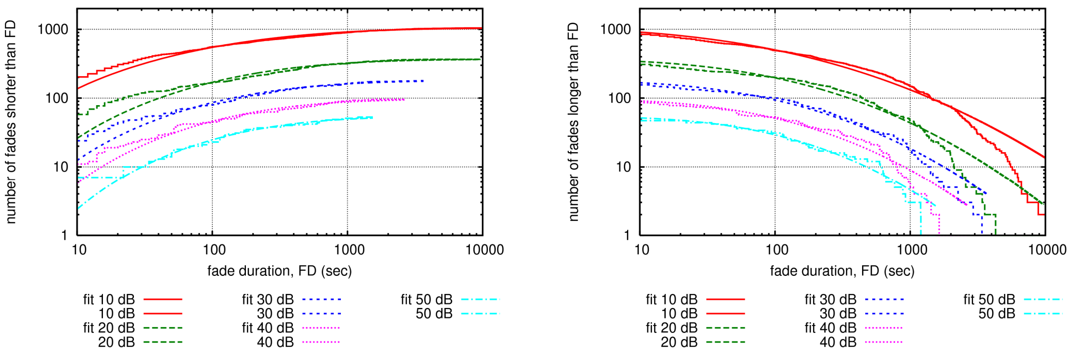

Figure 4: Fade duration statistics for the period 2003-2005, path B, *Log-normal* distribution fit.

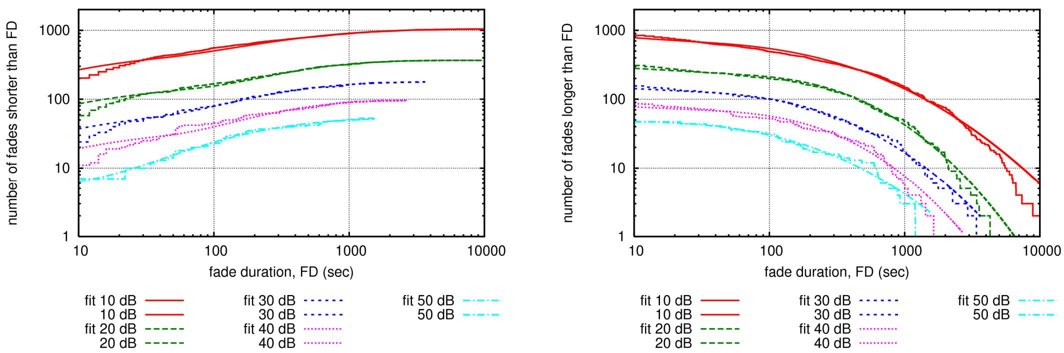

Figure 5: Fade duration statistics for the period 2003-2005, path B, *ITU-R composite* distribution fit.

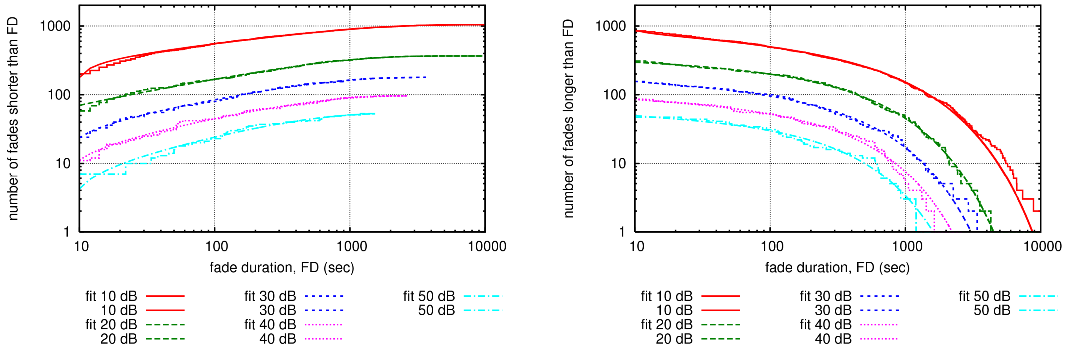

Figure 6: Fade duration statistics for the period 2003-2005, path B, *Gamma* distribution fit.

Table 1: Root mean square errors of model distributions

Model distribution	Attenuation level (dB)				
	10	20	30	40	50
Log-normal	0.0132	0.0197	0.0207	0.0343	0.0327
ITU-R [3]	0.0064	0.0065	0.0105	0.0231	0.0299
Gamma	0.0032	0.0044	0.0092	0.0158	0.0261

Gamma distribution function was found to be the most suitable one for modelling rain fade duration statistics. As the errors given in Table 1 confirm, the ITU-R composite distribution function model developed primarily for Earth-space paths has a slightly worse performance and often used the log-normal model was found to be the worst one.

Discrete fade events are often modelled as Poisson distributed random events. It is known that random waiting times between Poisson distributed events are gamma distributed [4]. From this one can expect that inter-fade duration statistics can also be modelled in a similar way.

5. Conclusion

Rain fade and inter-fade duration statistics obtained from two long term terrestrial propagation experiments in 38 GHz band were presented. The dependence of the number of fade events on the attenuation level was analysed and a new model was proposed based on the measured data. Three fade duration distribution models were compared showing the gamma distribution is particularly well suited for fade duration statistics modelling.

Acknowledgments

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[4] http://mathworld.wolfram.com/GammaDistribution.html