Fade Dynamics Investigation applying Statistics of Fade Duration and Level Crossing Rate

Balázs Héder, Róbert Singliar, and János Bitó

***Abstract*—**The impact of rain attenuation on wireless communication signals is predominant because of the used high frequency (above 10 GHz). The knowledge of statistics of attenuation is very important for planning point-to-point microwave links operating in high frequency band. Describing the statistics of attenuation is possible for instance with fade duration or level crossing rate. In our examination we determine these statistics from one year measured data for a given microwave link, and we are going to make an attempt to transform the level crossing rate statistic to fade duration statistic.

***Keywords*—**Rain Attenuation Measurement, Fade duration, Level Crossing Rate.

I. Introduction

To investigate wave propagation phenomena a rain attenuation and weather data measurement system was established. Currently in Hungary a number of point-to-point millimetre wave links operating in the frequency bands of 13, 15, 23 and 38 GHz. The received IF signal powers are collected with the meteorological data together using weather stations at different locations for data collection.

This paper investigates the dynamics of rain attenuation. Different statistics such as fade duration, number of events and level crossing rate are important for analysis of wave propagation phenomena, because they are indicating important information about the dynamics of the received signal. These statistics can be derived from our available measured data.

To prepare these second-order statistics a one year period data measured on one 38 GHz link in Hungary in 2004 is considered. Fade duration and level crossing rate statistics will be compiled for attenuation exceeding different attenuation levels (fade thresholds) from 3 up to 8 dB. The parameters of the investigated link are described in Table I.

The paper is organized as follows: Section 2 presents the fade duration and level crossing rate, Section 3 describes our data processing method while Section 4 shows our fade duration estimation from LCR, concluding remarks are given in Section 5.

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TABLE I
Parameters of the Investigated Link

Links	Site name	Freq. [GHz]	Pol.	Length [km]	Azimuth [deg]
HU11	Kondorosi út	38	H	1.5	238.3

II. Fade Duration and Level Crossing Rate

Fade duration and level crossing rate (LCR) are used to present dynamic, time-varying characteristics of the propagation channel [1].

Fade duration indicates the time length how long the attenuation will exceed a certain threshold value. This parameter is important in communication systems where length of outage time is a critical parameter. The fade duration depends on the attenuation level, frequency and elevation angle. In this paper fade duration Cumulative Distribution Functions (CDF) will be analysed. The CDF of fade duration shows how much percent of all occurred fade events have shorter or equal duration than a given duration.

Level crossing rate defines how often the signal envelope crosses a certain threshold with positive (or negative) fade slope [2][3]. It is an important dynamic characteristic of the communication channel. Level crossing rate will be investigated by using the CCDF (Complement Cumulative Distribution Function). The CCDF of level crossing rate shows how much is the probability that the number of crosses during a certain time interval (for instance a day) is higher than a given number, if there was at least one cross in the interval.

III. Data Processing

The measured AGC data of the investigated PDH links are processed at the central measuring node located in Budapest University of Technology and Economics. Using the conversion table the received RF power level can be determined from the measured AGC voltage. Defining the zero dB attenuation, the instantaneous attenuation of any microwave link can be determined from the RF signal level.

Level Crossing Rate statistics**:** In case of level crossing rate we have been investigating only the crosses in a positive direction (positive fade slope) because in a given period of time the number of crosses in a positive going direction is almost equal (assumed to be equal) with the crosses in a negative going direction. The level crossing rate CCDF was calculated from one year measured data and gives information about the number of crosses in one day for 3 different threshold values (3, 5 and 8 dB). We split the one year time interval to 24 hour intervals so we can investigate the number of crosses (e.g. in our case it is about 600 for a given threshold at 8dB) in one day. From the number of crosses we can calculate the CCDF curve for each threshold value. We also investigated the worst and the best month of the LCR CCDF statistic.

Fig. 1 presents the LCR CCDF, which for a given probability (if occurred any level crossing on a given day) gives the minimum number of crosses in one day for each threshold value.

Fig. 2 shows the LCR CCDF calculated for January (best month), June and October (worst month) of the year 2004 (for the link HU11) for the 3 dB threshold value.

Fade duration statistics have been compiled for attenuation exceeding the 3, 5 and 8 dB levels [4]. The data are retrieved from the database files for a one year period (2004).

We have been calculated the length of each fade event, the number of events, than we calculated the cumulative distribution function (CDF) curve for the 3 investigated threshold values.

The CDF of fade duration is plotted in Fig. 3. Shown is the probability of events for which duration exceeds abscissa at the given level (3, 5 and 8 dB threshold level). Please observe that according the measured data almost all events have shorter duration than 1000 s. We can observe that for higher thresholds belong a shorter duration.

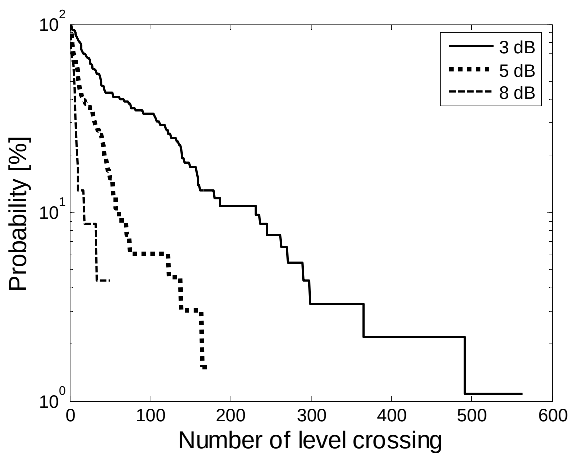

Fig. 1 The CCDF of level crossing rate for the investigated 3 threshold values calculated from one year data

IV. Fade Duration Estimation from LCR

By next step we made an attempt to derive the CDF of fade duration from the LCR CCDF. For example if in a given day (corresponding to 86400 sec) the number of crosses (for a given threshold) is 3, than the assumption can be drown that the number of fade events is 3 too. Furthermore, if we made the rough assumption also that the fade and nonfade events are equally distributed with the same duration, hence all of the 3 fade events have equal length (corresponding to 14400 s in our

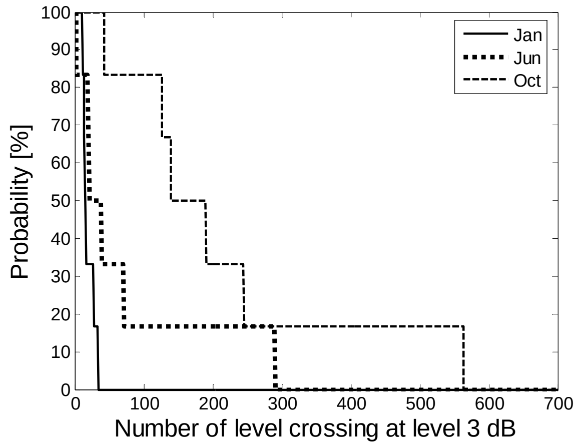

Fig. 2 The CCDF of level crossing for 3 dB threshold value calculated from monthly data

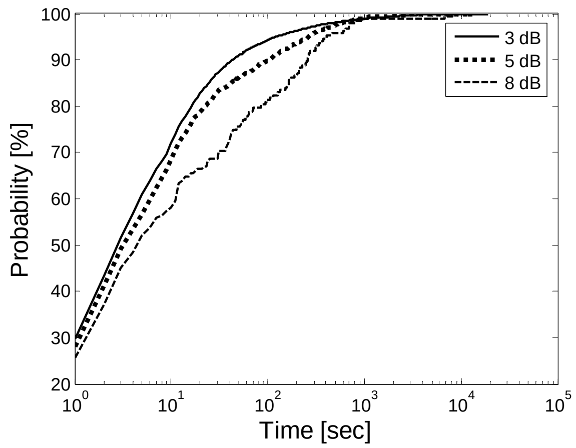

Fig. 3 CDF of fade duration calculated from measured data for different threshold values

example) calculated according to (1). In (1) b represents the number of crossing in a day and its value is 3.

$$\frac{86400}{2 \cdot b} = 14400 \sec \qquad (1)$$

At the 8 dB level there is high probability that the number of crosses is 20 or higher in a day. If the number of crosses is exactly 20, we assume that the duration of one event is 2160 s. Compared to our measured data this interval is very long, because according to our statistical fade duration analysis the most of fade events at this level have duration of 1-15 sec. This remarkable difference in fade duration is caused by the rough assumption of fade duration distribution and length explained above. So by the transformation we must assume shorter durations. The CDF curve of fade duration must have zero value at zero duration, because if there is a fading, the probability that this fading have zero duration is zero. Therefore we made an improved assumption that at the maximum number of crossing in a day the fade events in the given day have the shortest duration which is one sec, according to our fade duration statistical investigations. This leads us to modify (1) by inserting a coefficient *a* to be able to calculate the fade duration with this improved assumption from the measured LCR values.

$$\frac{T}{b_{\max}\cdot a}=1\sec,\quad a=\frac{T}{b_{\max}} \tag{2}$$

Where *T* is the investigated time interval (in case of one day it is 86400 s), b_{max} is the maximum number of crosses in a given day and *a* is a coefficient which depends on maximum number of crosses.

Therefore the transformation is made for each point of LCR CCDF with equation (3).

$$\frac{T}{a\cdot b}=t \tag{3}$$

Where *T* is the investigated time interval (in case of one day it is 86400 s), *b* is the number of crosses in a given day, *a* is the coefficient which depends on maximum number of crosses, *t* is the assumed time interval of one event in the given day.

With these assumptions, the duration of one event at level 8 dB is 2.5 sec., if there were 20 crosses in a given day (*a*=1728, b_{max}=50).

The CDF curves of fade duration which are derived from the CCDF curves of level crossing rate with this method is depicted on Fig. 4-Fig. 6 for different threshold levels.

From the figures we can observe that for the 3 dB level determined CDF curve of fade duration is the most identical to the calculated curve (determined from measurement). Please observe that from the LCR derived CDF curves significantly underestimate the fade duration CDF curves derived from the measured data, especially by short fade durations. The main possible reason is that we made an assumption that all the events in a day have equal durations. From the measured data we can realize that the different fade events could have very different durations, and the fade duration statistics is carrying this information.

If we try to split the one year data to shorter periods, this assumption might be more correct. So we split the one year data to one hour intervals. In this case the CCDF of level crossing rate is depicted in Fig. 7 for different threshold levels, while the derived CDF of fade duration and the original CDF of fade duration for 3 dB level are shown in Fig. 8. Please observe that neither in this case the derived CDF curves significantly underestimate the fade duration CDF curves derived from the measured data.

Comparing Fig. 4 with Fig. 8 we can observe that in case of splitting the one year data to one hour intervals for 10 s belongs probability under 40% and in case in case of splitting the one year data to one day intervals above 40%. Please observe that the time axis of the two curves has a different resolution.

If we decrease the examined time interval which the one year data is split to, we can derive only a part of the CDF of fade duration (only from 1 sec up to the length of the examined interval).

If we apply one hour splitting, there is a high probability that we find some events, which are longer than one hour. In this case in that hour wasn't any level crossing, but the fade duration statistic contains this hour too (Fig. 9). In Fig. 9 the number of level crossing (in positive direction) is depicted beside the LC contraction.

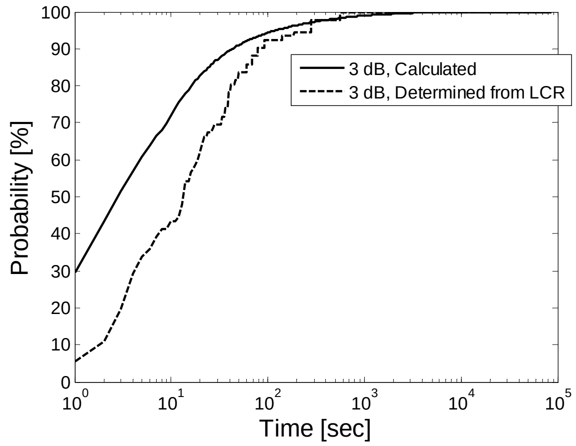

Fig. 4 The calculated and from the LCR determined CDF of fade duration for 3 dB threshold value

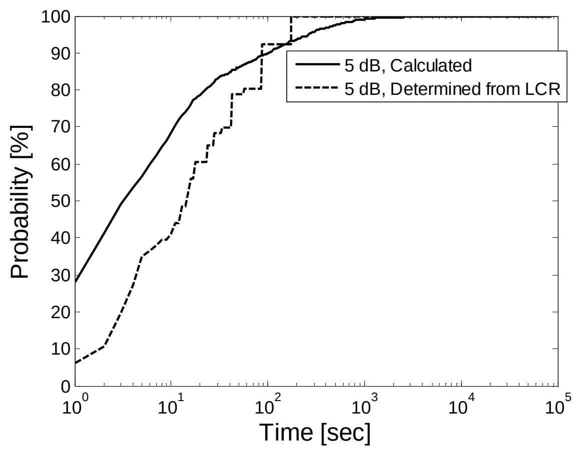

Fig. 5 The calculated and from the LCR determined CDF of fade duration for 5 dB threshold value

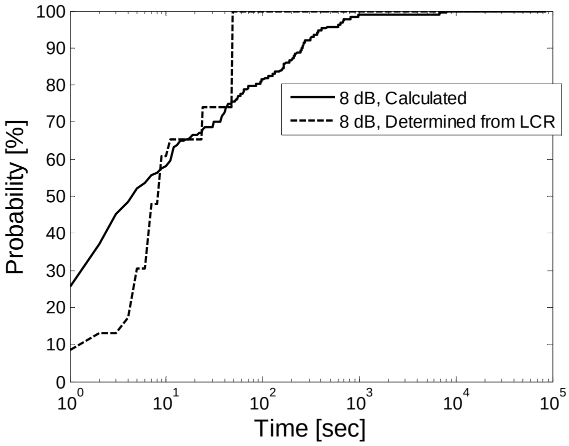

Fig. 6 The calculated and from the LCR determined CDF of fade duration for 8 dB threshold value

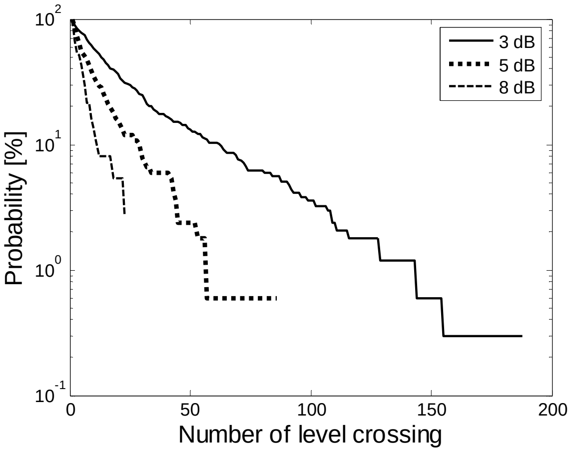

Fig. 7 The CCDF of level crossing rate for the investigated 3 threshold values calculated for one our

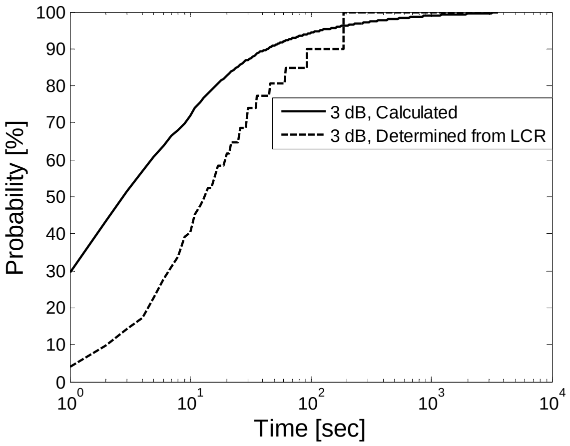

Fig. 8 The calculated and from the LCR determined CDF (calculated for number of crosses in one hour) of fade duration for 3 dB threshold value

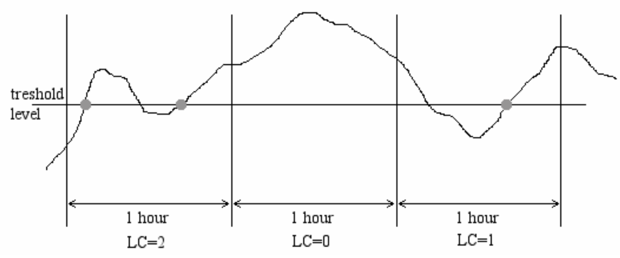

Fig. 9 The representation of a 3 hour rain attenuation event

V. Conclusions

We have been investigating fade duration and level crossing rate statistics of a one year measured data for one point-to-point microwave link operating in 38 GHz frequency band. From the results we can draw the conclusion that the transformation of LCR to fade duration is not obvious because the rain is a highly stochastic event. The assumption to decrease the examined time interval failed.

As a future work we can investigate level crossings with considering different threshold levels for different crossing directions.

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URL: http://www.telenor.no/broadwan/

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