

COST Action 280

“Propagation Impairment Mitigation for Millimetre Wave Radio Systems”

**Examples of rain gauge data analysis for microwave
rain attenuation estimation****Abstract**

This contribution shows some examples of rain data processing aiming at the radiowave propagation research and fade mitigation technique. The cumulative rain rate distribution, distribution of fade and interfade duration is presented. The mutual correlation, symmetry and excludivity in pairs of measurement sites is shown, new parameters as symmetry and excludivity are defined. The example of the site diversity gain is added. The long term rain rate series stability (63 years) is also studied.

All examples are based on the Czech rain data measurement by the Institute of Atmospheric Physics (IAP) of the Czech Academy whereas the data from the Czech hydrometeorological institute to evaluate the rain rate stability were thankfully used .

1. Introduction

The Institute of Atmospheric Physics Prague measures rain rates at 4 sites over the Czech territory (see Tab.1) using the Tipping-bucket rain gauges. The resolution of used rain gauges was 0.2 mm/tip. All sites are included in the „H“ ITU-R rain zone.

The substantial problem of the Tipping-bucket rain gauges is the varying integration time (no information about the rain rate response between two tips). That’s why sophisticated software to process the Tipping-bucket rain gauge data is required and such software was proposed by the IAP and is described in the contribution being based on:

Author:	O. Fiser
Organisation	IAP AS CR
Department	Dept. of Meteorology
Street Address	Bocni II/1401
Town/City, Postcode	Praha, 141 31
Country	Czech Republic
Tel: +cc-ac-nnnnxxxx	Tel: +420-272016038
Fax: +cc-ac-nnnnyyyy	Fax: +420-272763745
E-mail	E-m: ondrej@ufa.cas.cz

(i) the linearization of the rain amount time response between two tips

(ii) the reading of the rain amount increment using a “moving window” of the length of one minute and with the step of the movement of one second

2. Cumulative distribution (CD) of rain rates, fade and interfade duration

The CDs of rain rates for separate sites and single years for two very close sites Hradec Kralove 1 (H1-astronomic observatory) and Hradec Kralove 2 (H2 - U Nahona Street) were published in [1] and are shown in Fig. 1. While the distributions of both sites are really very close for years 2000, 2001 and 2003, the difference between them is extremely and unexpectedly big in the case of the 2002 year (in 2002 there was a big flood in the Czech Republic). Here we add distribution for particular months in 2004 (Fig. 2)

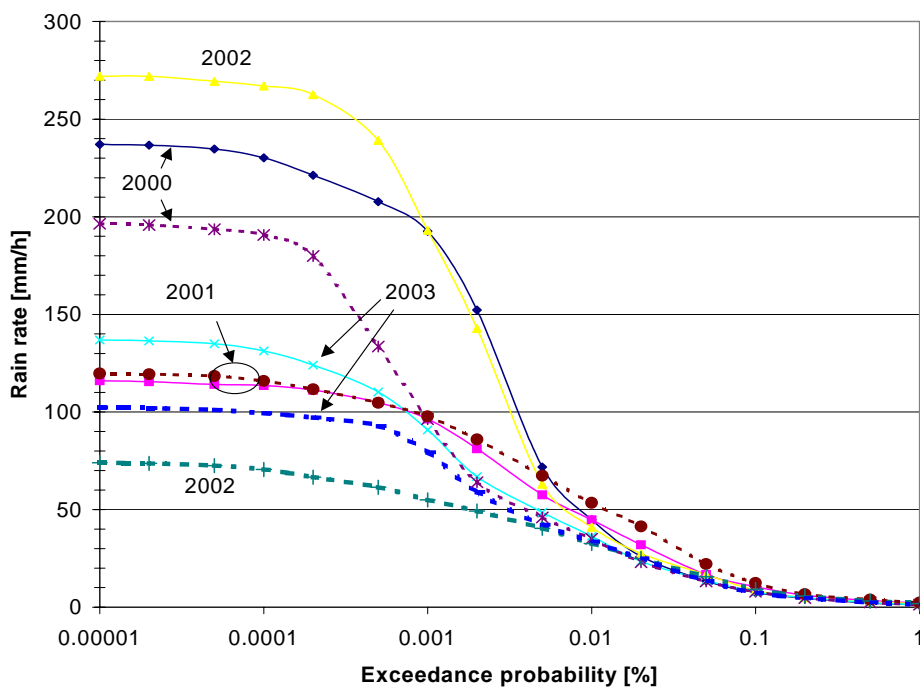


Fig. 1 Cumulative distribution of rain rates for single years and for sites Hradec Kralove 1 (solid line) and Hradec Kralove 2 (dashed line)

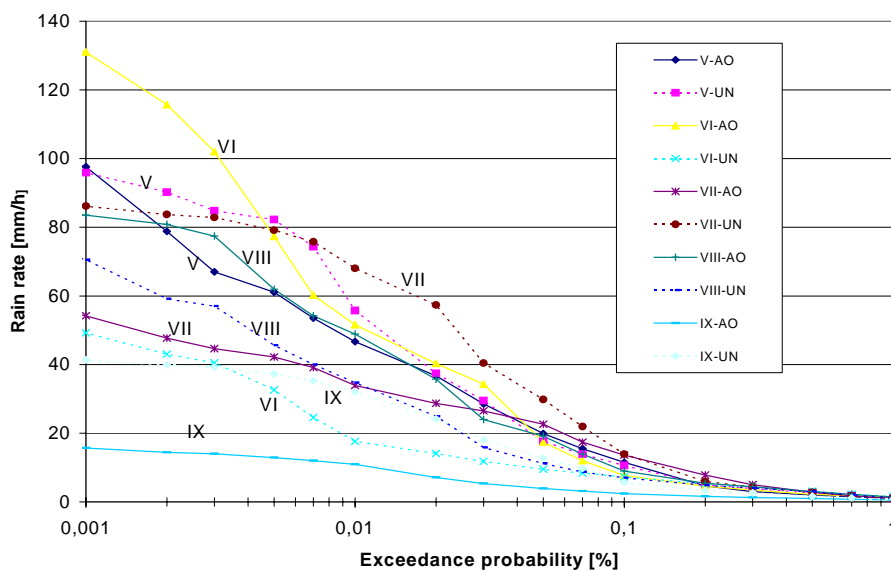


Fig. 2 Cumulative distribution of rain rates for particular months of the 2004 year and for sites Hradec Kralove 1 (solid line, labelled AO=astronomic observatory) and Hradec Kralove 2 (dashed line, labelled UN=U Nahona Street)

Fig. 3 shows the distribution of the interfade duration and rain event duration derived from data from 4 years of rain rate measurement from all four sites in the Czech Republic that was published in [1].

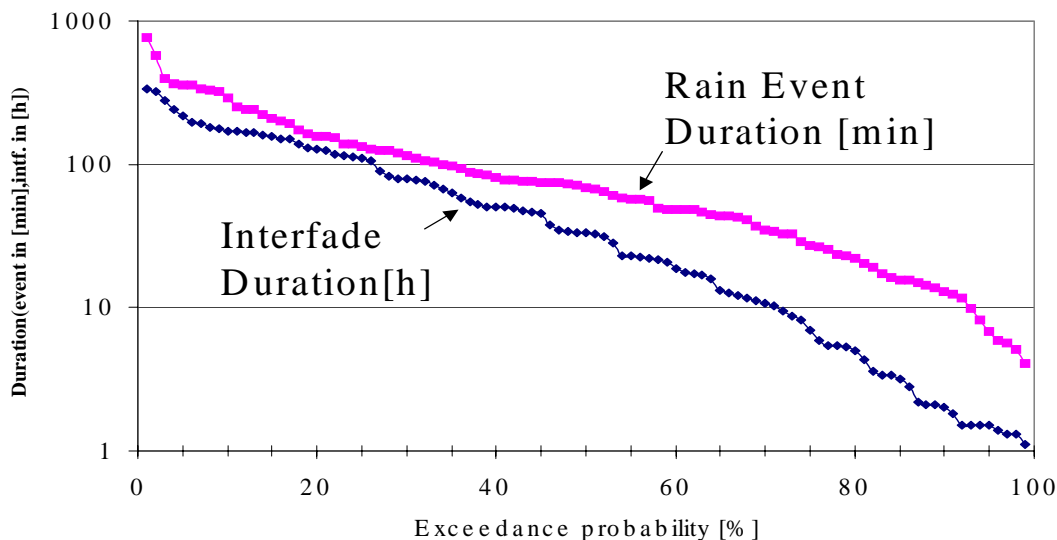


Fig. 3 Distribution of the interfade duration and rain event duration having been derived from measurement corresponding to the four-year period 2000-2003 and to the four sites in the Czech Republic (Prague, Hradec Kralove 1, Hradec Kralove 2 and Borislav)

3. Stability of rain rate series

A relative error of a x-year rain-rate CD ($x=1,2,\dots,62$) related to the long-term rain-rate measurement ($N=63$) was studied. The long-term (63 years) data from the Czech Republic are used.

The important question was established: how many years is a sufficiently representative period? Is 5 years enough? Or 10 years? Or even 30 years? To answer this question we had to investigate the stability of rain-rate distribution. A similar study based on 24-year rain-rate data from 27 stations in UK was performed in [2].

It is concluded that a period of 10 – 20 year measurement is required to limit the rain-rate RMSE under 5%.

Description of method to evaluate rain rate stability: To determine the rain-rate stability we use the RMSE (root mean square error) which expresses the relative difference between the rain-rate derived from x-year measurement and the rain-rate derived from long-term (N -years, $N>x$) measurement on the given exceedance probability P .

$$RMSE(P, x) = 100 \cdot \sqrt{\frac{1}{n} \sum_{i=1}^n \left(\frac{R_x(P) - R_{LT}(P)}{R_{LT}(P)} \right)^2} \quad (1)$$

where P is the exceedance probability in [%] ($P= 1,0.3,0.1,\dots, 0.001$ % in our case)

$R_x(P)$ is the rain-rate exceeded for P [%] in one of x -years period ($x=1,2, \dots, 62$)

$R_{LT}(P)$ is the long -term (in our case $N=63$ years) rain-rate exceeded for P [%]

n is the number of x -year consecutive periods

The parameter $RMSE(P, x)$ shows the results for single exceedance probabilities P . For quick estimation of the stability of the long-term rain-rate measurement we define an average $RMSE(x)$ as

$$RMSE(x) = \frac{1}{n} \sum_i RMSE(P_i, x) \quad (2)$$

where n is the number of selected exceedance probabilities P_i .

Evaluating the rain data and the formulas above we plotted a curve of the average $RMSE$ in the Fig 4. One can see that the accuracy of the distribution of a several years statistics is low (high value of $RMSE$) when compared to the long-term distribution. Taking the 10 – 20 year measurement we can observe that the average $RMSE$ is under 6% and this could be recommended as a good estimation for the long-term rain-rate CD (cumulative distribution).

Generally speaking, the RMSE is increasing with the decreasing exceedance probability, as it is seen from Fig.5. If one requires the accuracy for 0.01% exceedance probability he should use at least the 15-year measurement. For the exceedance probability of 0.001% and RMSE below 5% the 40-year period of measurement should be required.

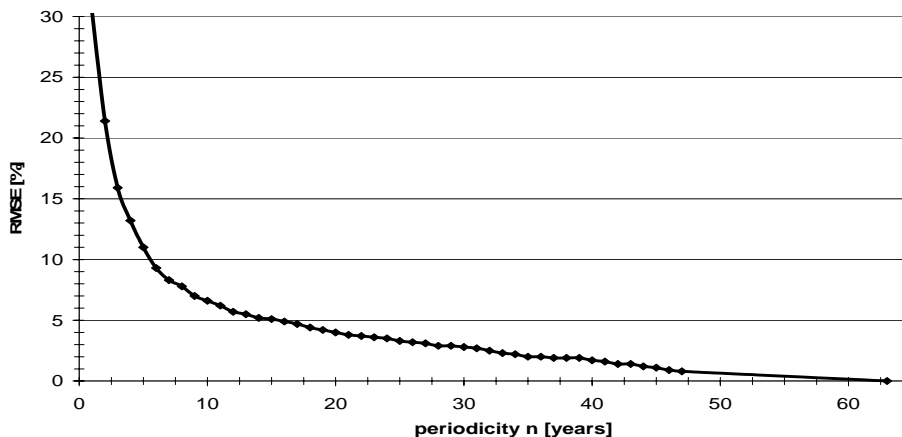


Fig.4 Average RMSE of rain-rate distribution related to the periodicity of measurement

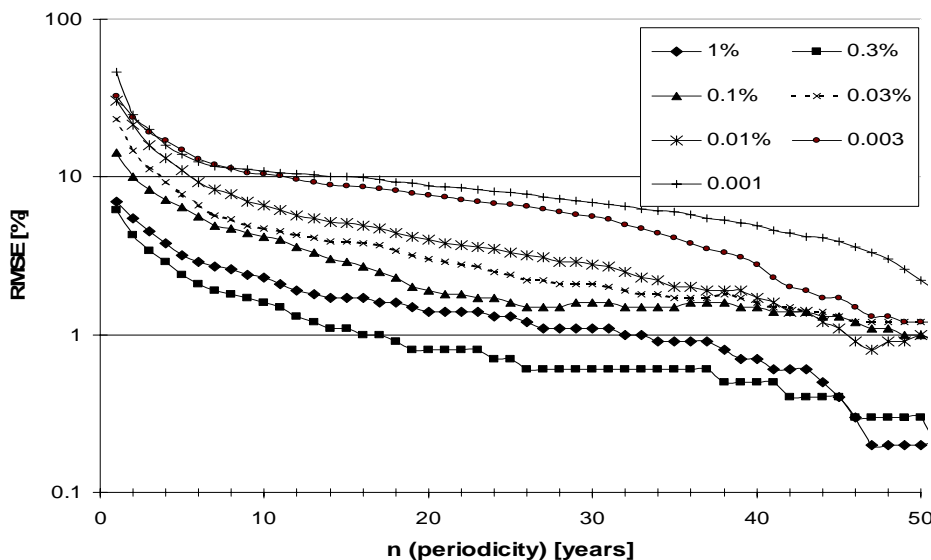


Fig.5 RMSE of rain-rate distribution for particular exceedance probabilities related to the periodicity of measurement

4. Correlation between stations (in pairs)

The correlation coefficients between pairs of measurement sites were published in [1], see also Tab.1 . It corresponds to the period 2000-2003.

Tab. 1 Mutual correlations computed from one-minute rain rate records. The summer period June-September for separate years 2000, 2001, 2002 and 2003 was selected

Site	Code	H1	H2	IAP	BOR
Hradec Kralove 1	H1	X	8km	100km	141km
Hradec Kralove 2	H2	32.10%	X	97km	139km
Prague	IAP	3.30%	3.60%	X	70km
Borislav	BOR	3.20%	4.40%	5.00%	X

For the site diversity - one of the mitigation techniques - the low value of correlation is welcome. We can see from Fig.6 that its value is decreasing with the distance (as expected) and also from Tab.1, that its value is lower in the east-west distance (prevailing direction of the front lines, here it is H1 and H2 against IAP and BOR) than in the north-south direction (BOR-IAP).

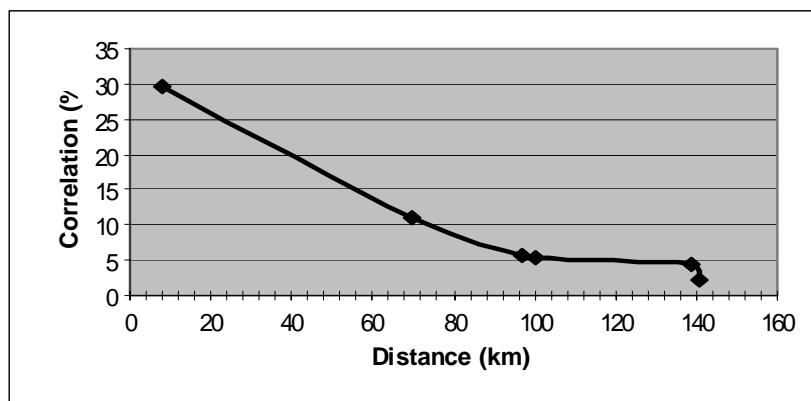


Fig. 6 Correlation between rain rates at various sites as a function of the distance

We evaluated also the correlation between sites H1 and H2 (8 km distance) from the 2004 year data (1 second rain rate series was used while the integration time being 1 minute). The resulting correlation coefficient is 27%. To see the influence of the time shift between rain events at H1 and H2 sites we computed the correlation coefficient as a function of the time shift of rain rate series from -12 minutes to +12 minutes. The step of computation was 2 seconds. The results for separate months as well as for the whole year 2004 are shown in Fig.7. One can observe that the rain event at station H2 occurs by 6 minutes earlier (in average) than at station H1. The similar situation occurs also in particular months except the month of July. This fact well founds the site diversity technique utilisation at sites H1 and H2.

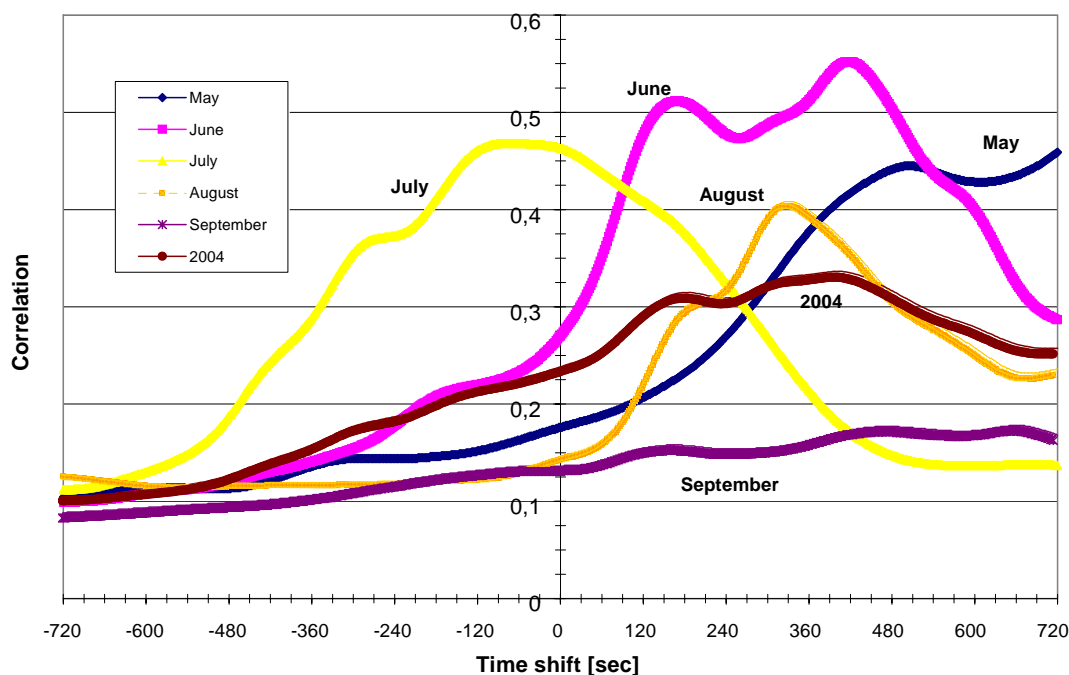


Fig. 7 Correlation between rain rates at various sites as a function of the distance

The results were described in [3]. The corresponding diversity gain (first row of Tab. 2) is about 7 dB at the 0.01% exceedance probability level and for frequency 12 GHz, elevation 7.5 deg of a hypothetical satellite link. The site diversity gain was estimated using the model Assis-Einloft [4] and our rain rate distribution (CD) data.

Tab. 2 Diversity gain (DG) of the studied measurement site pairs (left column corresponds to the first site of the pair on given exceedance probability). Frequency 12 GHz and elevation $\Theta=7.5^\circ$ were chosen. For site codes see Tab. 1.

Pairs	Diversity Gain (dB)					
	P=0.1%		P=0.01%		P=0.001%	
	DG(X)	DG(Y)	DG(X)	DG(Y)	DG(X)	DG(Y)
H1-H2	1.5	2.0	6.3	7.8	9.2	9.7
PRG-BOR	1.2	1.9	6.8	7.2	7.6	10.2
PRG-H2	2.7	1.7	10.4	7.5	15.8	12.7
PRG-H1	2.3	1.8	9.1	7.6	15.3	12.7
BOR-H2	1.3	2.9	6.9	10.3	6.3	12.1
BOR-H1	1.3	2.5	7.1	9.0	9.9	15.1

To see the differences in concurrent rain rate occurrence at various pair of measurement sites we defined and computed the following parameters:

- T11 ratio of rain time (R >1 mm/h on both sites concurrently) to the total time [%]
- T00 ratio of rain time (R <1 mm/h on both sites concurrently) to the total time [%]
- T10 ratio of rain time (R>1 mm/h on site 1 and R<1 mm/h on site 2) at same instants to the total time [%]
- T01 ratio of rain time (R<1 mm/h on site 1 and R>1 mm/h on site 2) at same instants to the total time [%]
- T-1 ratio of the rain time (R>1 mm/h) on site 1 to the total time [%]
- T-2 ratio of the rain time (R>1 mm/h) on site 2 to the total time [%]

- Excludivity1 ratio of the time when R>1 mm/h on site 1 only to the time when R>1 on both sites concurrently [1]
- Excludivity2 ratio of the time when R>1 mm/h on site 2 only to the time when R>1 on both sites concurrently [1]
- Symmetry percentage expression of the difference between time T01 and T10(T10=100%) mathematically: $Symmetry=100*(T01/T10-1)$

In Tab. 3 there are shown values of mentioned parameters having been derived from one year measurement (2000).

Tab.3 Parameters describing the pair concurrent differences in the rain rate measurements. See Tab.1 describing the codes (BOR,PRG,H1 and H2) for sites

Site1-Site2		Total observation time [min]
T11	T10	T-2
T01	T00	Excludivity1
T-1	Excludivity2	Symmetry

BOR-PRG			296334.0			H1-H2			272716.0		
0.3	1.4	1.7				1.6	0.6	2.2			
1.4	97.0	4.7				0.7	97.1	0.4			
1.7	4.7	0.0				2.3	0.4	16.7			
BOR-H2			273367.0			PRG-H2			273367.0		
0.2	1.4	1.6				0.3	1.4	1.7			
2.2	96.2	7.0				2	97.2	4.7			
2.4	11.0	57.1				2.3	6.7	42.9			
BOR-H1			272716.0			H1-PRG			272716.0		
0.1	1.4	1.5				0.3	1.9	2.2			
2.1	96.4	14.0				1.4	96.4	6.3			
2.2	21.0	50.0				1.7	4.7	-26.3			

5. Conclusion

This study should show the elected important possibilities concerning the utilisation of rain rate measurement to describe the radiowave propagation through the atmosphere and especially to predict the rain attenuation. Also one method enabling the estimation of the site diversity gain is included. Dynamical properties were described in [1] in details and are not included in this contribution.

The IAP is continuing in the rain rate measurements on one hand as well as in the development of effective methods processing the rain data for radiowave propagation purposes.

6. Acknowledgement

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6. References

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