# EFFECTS OF RAIN RATE SPATIAL DISTRIBUTION ON POINT-TO-MULTIPOINT SYSTEMS

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## 1. Introduction

Rain gauge records and weather radar data reveal considerable temporal and spatial variations of the rain rate (Fig. 1). Classical point-to-point link design considers only the rain rate statistics for a particular region using the worth month concept [1]. Different approach has to be used for quality and reliability planning of millimeter-wave terrestrial point-to-multipoint systems. Spatial structure of a rainfall event over a specific area has to be taken into account as well. Thanks to the non-uniform spatial distribution of the rain rate a site diversity can be used as one of the propagation impairment mitigation techniques in point-to-multipoint systems (main and diversity links are less likely subjected to the same rain attenuation at the same time).

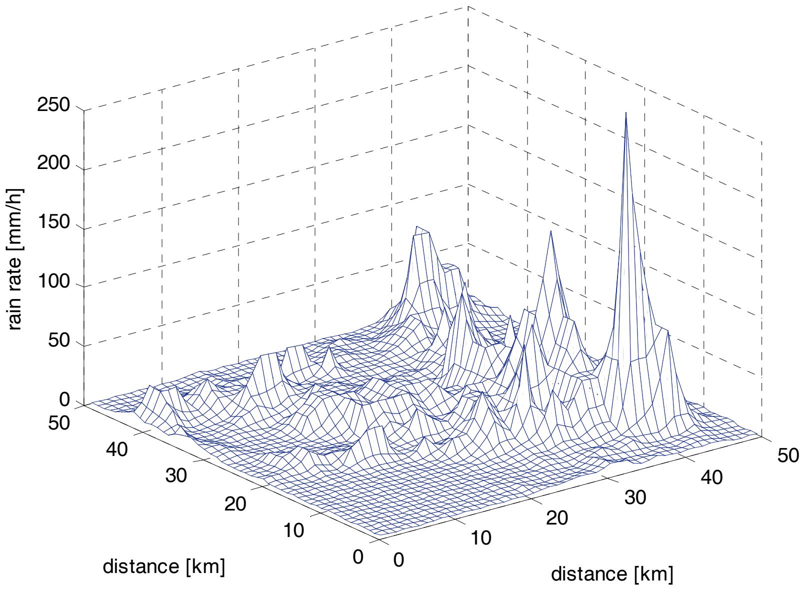


**Fig. 1 - Rain rate spatial distribution [mm/h]**

The improvement of the power balance of the signal reception due to the second diverse link (diversity gain) has been studied in [2] [3] [4]. Rather than studying analytically the two links, the effects of space-time rain distribution on whole millimeter-wave point-to-multipoint MWS (Multimedia Wireless Systems) performance was simulated in a defined area. Instead of investigating diversity gain, the system outage improvement was studied using space-time simulations of a point-to-multipoint system in a specific area during a specific rain conditions.

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## 2. Utilization of Radar Rainfall Data

Radar based rain data [5] have been utilized as an input for system simulations. Large rain event database containing over thousand events for Czech Republic (situated in ITU rain region H) was build for the simulations. Each rain event is represented by a sequence of radar images for 50 x 50 km area with 1 km grid resolution in 1-minute step. The analysis of the statistical variations in spatial organization of precipitation is of great importance. Therefore, the statistical investigation is being performed to obtain description for the occurrence of particular rain structures. Every radar rain scan is described through the spatial structure of rain rate levels. In the Fig. 2, the decomposition of rain intensity in mm/h to particular levels is depicted.

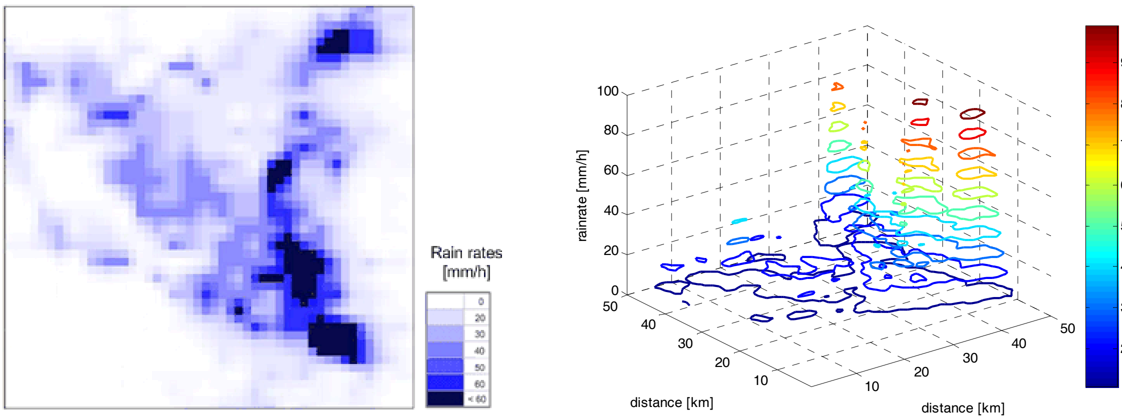


**Fig. 2 - Rain intensity [mm/h] during rainfall a) spatial distribution (50 x 50 km area); b) decomposition to particular levels**

Simulation tool was developed to evaluate various aspects of the system performance under different conditions. Utilizing the simulation tool, a network of hubs in an urban environment can be generated and the environment can be read from realistic GIS input or generated randomly using statistical models. Finally, terminal stations are randomly generated based on user-defined rules. Each link between a hub and terminal station can be simulated separately, so that overall statistics of the system performance can be generated for different conditions, network arrangements, etc. Outputs can be generated as time-series as well as statistical distributions. More information about simulation tool can be found in [6].

## 3. Outage Improvement Probability

Site diversity improvement is highly dependent on the actual spatial distribution of the rain rate. Different results can be expected for different rain patterns. The rain rate distribution in both time and space is given by the rain type and geographical region. At first, we concentrate on the site diversity improvement probability function definition using the simulation tool introduced above.

During simulations for each rainfall radar scan the position of the hypothetical terminal station was changed in 1 km step grid. Position of the main hub was changed in a circle around the terminal station with fixed radius. The receiving signal strength was calculated for every azimuth of the hypothetical main link. If the signal strength dropped below the chosen threshold, the diversity links for angular separation from 1 to 359 degrees and diversity link length ranging from 2 to 6 kilometers were investigated. This way the outage improvement statistics dependence was obtained.

The outage improvement probability determines the ratio between the successful trials to establish the diversity link and total number of all main link outages. Based on our simulations we derived an empirical formula for the outage improvement probability as a function of rain fade margin, angle separation $\vartheta$, and a ratio of the main and diverse link lengths ($d_{main}/d_{div}$):

$$P = a_{const} \cdot \left( 1 - \left( \frac{\vartheta - \pi}{\pi - b_{const}\sqrt{1 - \frac{d_{main}}{d_{div}}}} \right)^2 \right) \cdot \left( \frac{d_{main}}{d_{div}} \right)^{c_{const}} \quad (1)$$

where $a_{const}$ is constant dependent particulary on maximal rain rates and $b_{const}$, $c_{const}$ are rain rate spatial distribution and rain fade margin dependent parameters. Genetic algorithms were used to derive the empirical parameters for each case.

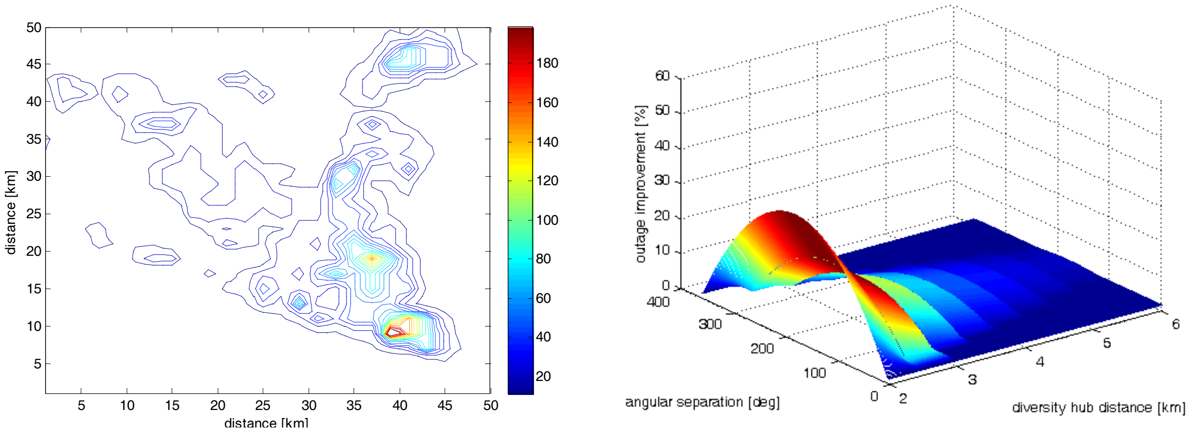


**Fig. 3 – Rain no.1 a) rain intensity [mm/h]; b) calculated outage improvement probability for rain fade margin 17 dB using (1)**

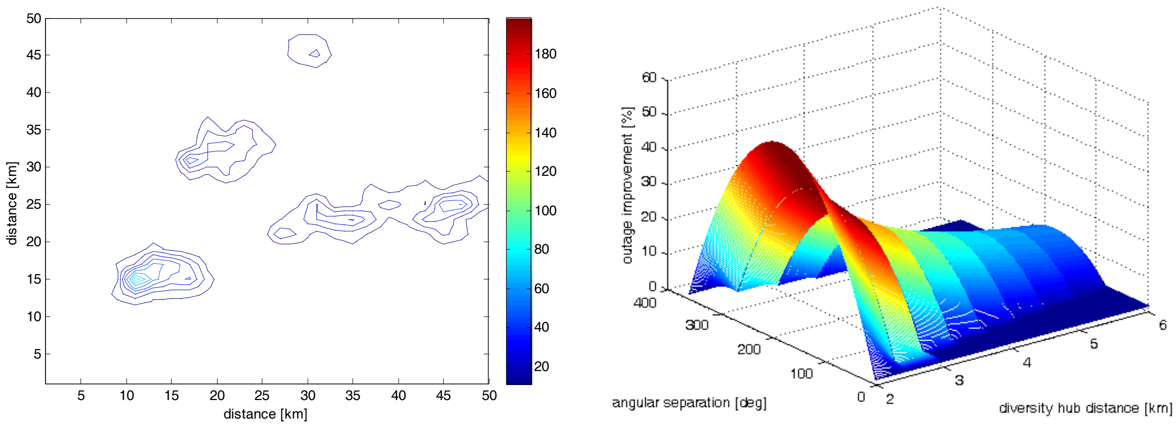


**Fig. 4 – Rain no.2 a) rain intensity [mm/h]; b) calculated outage improvement probability for rain fade margin 17 dB using (1)**

The results for particular rain rate distributions Fig. 3a (Fig. 4a) for the rain fade margin 17 dB are demonstrated in Fig. 3b (Fig. 4b). The first radar scan is taken from rain event in Czech Republic in 2002 (an extreme rainstorm causing local flash floods). The functions approximate the actual simulation results with an average error less than 1%. It should be noted that the line-of-sight is considered for all of the hypothetical links within the studied area. The systems parameters used during the simulations: transmitter power 15 dBm, hub antenna gain 21 dBi, terminal station antenna gain 37 dBi, frequency 42 GHz.

## 4. Summary

The analysis of the statistical variations in spatial organization of precipitation and its influence on point-to-multipoint systems were presented. A simulation tool was developed to evaluate various aspects of the point-to-multipoint system performance in millimeter-wave band. Large rain event database for Czech Republic was build for the simulation using time sequences of rainfall radar images.

System outage improvement probability for millimeter-wave MWS was derived as a function of rain fade margin, angle separation, and distances of main and diversity hubs. This function approximates the actual simulation results with an average error around 1%. Based on the outage improvement statistics, the rain types will be classified and corresponding occurrence probabilities from rain rate spatial distribution point of view and its impact on MWS will be investigated in subsequent work.

## 5. Acknowledgment

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