SITE DIVERSITY GAIN MODEL BASED ON RAIN ATTENUATION MEASUREMENT

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Abstract - *The mobile operators often use point-to-point microwave connections for feeder links in their access network. Applying appropriate diversity techniques we can overcome on the problem of high outage percentage of the feeder links. Diversity gain model based on angular correlation analysis of measured rain attenuation data will be introduced.*

1. INTRODUCTION

In the telecommunication industry mobile operators often use terrestrial point-to-point microwave connections in their feeder networks. This wireless solution has the advantage of rapid and easy deployment and low initial investment. However, microwave links are also highly influenced by meteorological conditions, especially by rain. Site diversity is an efficient countermeasure technique to avoid the effect of rain in the feeder network [1]. The performance of diversity system especially diversity gain will be analysed based on the measured rain attenuation data.

To investigate of millimetre wave propagation phenomenon in different geographic regions a distributed measurement system was realised. Numbers of measuring nodes are installed in different locations of Hungary. Each measuring node collects data from up to eight point-to-point millimetre wave connections realise in star topology around the measuring node. Millimetre wave links operating in the frequency bands of 13, 15, 23 and 38 GHz are under examination. The received IF signal powers are collected together with the meteorological data, using weather station for data collection at different locations. This star topology of the measured links gives an opportunity to investigate joint space and time rain attenuation statistics of the links. To determine such kind of statistics is necessary to optimize diversity systems.

The paper contributes an analysis of a one year (from January to December of the year 2004) measurement at one measuring node (Győr MSC). Based on the measured rain attenuation distribution of point-to-point links the diversity gain and diversity improvement will be presented and parameters of a known diversity gain model will be determinated.

2. TOPOLOGY OF THE INVESTIGATED MEASURING NODE

The transmission access network collects the GSM base station data and generally consists of microwave Plesiochronous Digital Hierarchy (PDH) links, usually forming a star topology. In this paper the investigated node is Győr MSC with three links (**Fig. 3**). All the links operate in the 38 GHz frequency band with vertical polarisation. The link length and angle (according to North) of the links are listed in **Tab. 1.**

3. SITE DIVERSITY

Intense rain shower may cause a deep fade on the microwave link between base station transceiver (BTS) and base station controller (BSC) and cause an outage on the feeder link. Site diversity method can be applied to prevent this event [3]. It use of the fact that intense rain cells usually have quite limited horizontal dimensions, therefore the probability of two or more neighbouring feeder links having simultaneous deep fade is rather small. The degree of improvement afforded by this technique depends on the extent to which the signals in the diversity branches of the system are uncorrelated [4]. The attenuation D(t) time function of theoretical diversity link minimise the link attenuation of the diversity branches [2]:

$$D(t) = \min_{i=1,N}\{a_i(t)\} \tag{1}$$

where $a_i(t)$ is the rain attenuation function of the i^{th} link of the diversity branches.

Fig. 2 illustrates rain attenuation time function caused by a particular rain event on the investigated links. It is a strong correlation between the links. The attenuation occurred at almost the same time, however the attenuations were different on the links. In the case of applying site diversity during this rain event, the attenuation time function depicted on **Fig. 3** can be obtained. Two expressions are used to describe the performance of the site diversity [2]. The diversity improvement factor I_D for fade depth A is defined by:

$$I_D(A) = \min_{i=1,N}\{p_i(A)\} / p_D(A) \tag{2}$$

where $p_D(A)$ and $p_i(A)$ are complement cumulative distribution function of the attenuation measured on the theoretical diversity link and the i^{th} link of the diversity branches, respectively.

The *diversity gain* is the difference between the unprotected A and diversity attenuation A_d values for the same time percentage:

$$G\left(p(A) = p_d(A_d)\right) = A - A_d \tag{3}$$

4. PROCESSING OF THE MEASURED DATA

To be able to determinate the diversity gain and the diversity improvement between a particular link and a theoretical diversity link we should compare point-to-point connections of the same lengths operating at the same frequency and polarisation. We apply a transformation method of rain attenuation time function of a certain link $A(t)$ to the attenuation time function of a reference connection $A_t(t)$ according to the following equation:

$$A_t = L_r \frac{A(t)}{L} \qquad \text{[dB]} \tag{4}$$

where $A(t)$ is the measured rain attenuation time function, L is the length of the link to be transformed to the reference link with L_r=3km length operating at 38 GHz frequency with vertical polarisation. We have to calculate the complement cumulative distribution function to determine the diversity gain and improvement for links.

CCDFs of the transformed rain attenuations of the three microwave links and of the theoretical diversity links (between HU52 and HU55, HU55 and HU56, HU52 and HU56) in case of applying one year measured data are shown on **Fig. 4** and **Fig. 5.**

The calculated diversity improvement curves are shown on **Fig. 6.** The curves depict the diversity improvement calculated between two particular links and a theoretical diversity link (defined between this two particular links) (2). In the legend it is signed just with the names of the particular links. The calculated diversity gain values at different attenuation probability regarding to the CCDFs are shown on **Fig. 7** for the one year period. The curves depict the diversity gain between a two particular links considering the theoretical diversity between them.

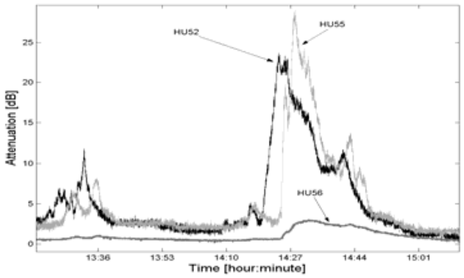

Fig. 1. *Rain attenuation time functions on the investigated link caused by the rain event occurred on 5th of April in 2004*

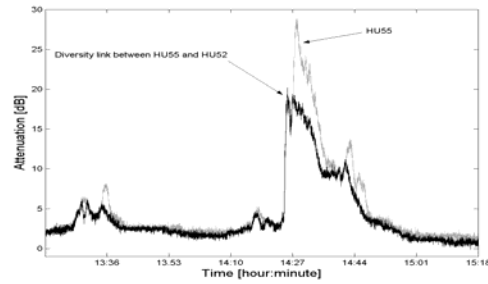

Fig. 2. *Rain attenuation time functions on HU55 link and on the theoretical diversity link between HU55 and HU52 caused by the rain event occurred on 5th of April in 2004*

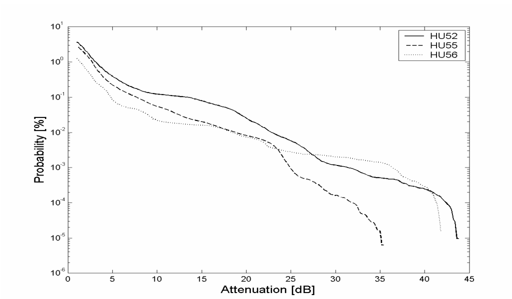

Fig. 4 . *Cumulative distributions of the transformed rain attenuation for the links around Győr MSC in case of considering one year measured data*

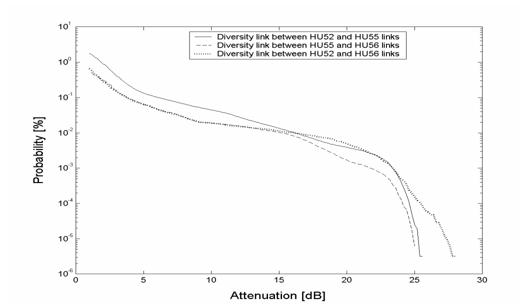

Fig. 5. *Rain attenuation time functions on HU55 link and on the theoretical diversity link between HU55 and HU52 caused by the rain event occurred in 2004*

We can achieve high diversity gain using the theoretic diversity link. The angular dependence of diversity gain is shown on **Fig. 8** and on **Fig. 9**. The used diversity gain model similar to the model in [5]:

$$G(\alpha) = A \cdot sin\left(\alpha/2\right)^{x} \tag{5}$$

where $G(\alpha)$ is an angle α dependent diversity gain, A and x are the model parameters. Curve fitting to the calculated diversity gain data is applied the minimum squared error algorithm to determine the model parameters [2]. The less diversity gain shown on **Fig. 9** is because of the less rain event occurred around the HU55 link unlike around HU52. It can be obtained from the **Fig. 8** that the approximately 8 dB diversity gain between the links HU55 and HU52 is very similar to the attenuation difference (approx. 10 dB) between these two links during the rain event shown on **Fig. 2.** The one year statistic is quite reliable to predict diversity gain. We can predict the diversity gain not only for a given degree but for an optional as well, so it is useful for network planning. The model parameters for a given probability are listed in **Tab. 2.**

CONCLUSION

Measured rain attenuation data of one year period of PDH links connected in star network are processed to investigate site diversity performances. These configurations enable to analyze time and space correlation statistics of rain attenuation. We have proposed a simple angular dependent site diversity gain model to predict diversity gain by network planning process. However, rain is very stochastic in time and space, therefore to get appropriate results it is necessary to investigate more than one year statistics of data to predict diversity gain and improvement.

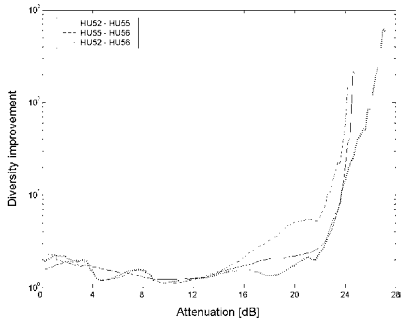

Fig. 6. *Diversity improvement curves for one year measured data*

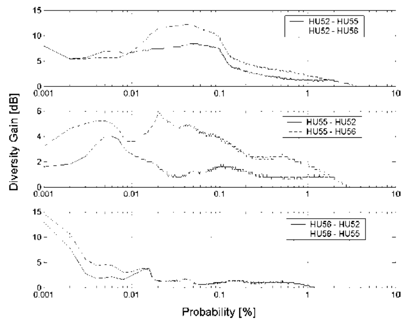

Fig. 7. Diversity gain vs. time percentage curves for the one year measured data

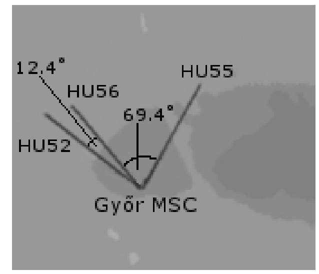

Fig. 3. The PDH link topology around the measurement node Győr MSC

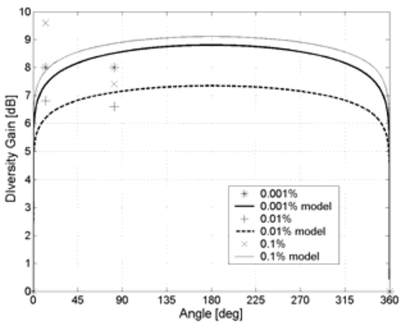

Fig. 8. Angular dependence of diversity gain between HU52 and the diversity paths between HU52 and the other links for different attenuation probability

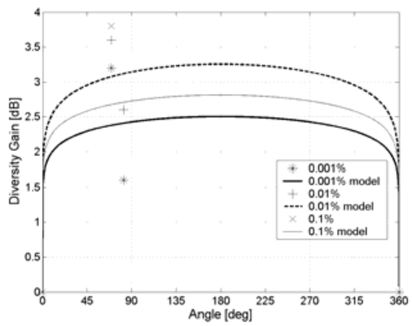

Fig. 9. *Angular dependence of diversity gain between HU55 and the diversity paths between HU55 and the other links for different attenuation probability*

Tab. 1. *The investigated links around measuring node Győr MSC*

Link node	Length [km]	Azimuth [deg]
HU52	2.97	307.7
HU55	2.93	29.5
HU56	2.64	320.1

Tab. 2. *Model parameters*

A / x	Probability [%]		
	0.001	0.01	0.1
HU52	8.8 / 0.079	7.344 / 0.0772	9.11 / 0.0656
HU55	2.504 / 0.092	3.254 / 0.0101	2.812 / 0.089

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