Experimental Estimation and Correction of the Methods for Radio Waves Attenuation Prediction in Rain

Boncho Bonev[1], Kliment Angelov[2] and Emil Altimirski[3]

Abstract – **An experimental estimation of main methods for prediction of rain attenuation of radio waves is presented. Data for attenuation values and rain rates from real radio links, worked in Bulgaria are used for the study. Then the real and predicted attenuations are analyzed by using existing methods. Corrections in existed methods for increase their precision for the territory of Bulgaria are suggested.**

Keywords – **Rain attenuation, gaseous attenuation, microwave, prediction methods.**

I. INTRODUCTION

The human race progress sets new challenges to the communication technologies, related mainly with transfer of much more information. The radio links that work in frequency band from 2,4 to 5,6 GHz are not able to respond to these challenges. This requires the usage of higher frequencies in the present-day communication systems. In this case the other problems, like hydrometeors and atmospheric gaseous attenuation exist. The losses caused by atmospheric gases and hydrometeors are the main reason for link distance limitation when frequencies over 10 GHz is used [1]. This influence is significant especially for frequencies above 45-50 GHz when the link distance can reach only 1-2 km with the link availability of 99,99% or greater [1].

This paper presents an analysis of calculated and measured rain attenuation and suggests a correction of coefficients used in rain prediction models [2]. The experimental data for radio wave attenuation are from 4-year measurements over radio link that has worked in Sofia region [3].

II. THEORETICAL ANALYSIS

The radio waves with frequencies above 10 GHz are significantly absorbed and scattered by hydrometeors like rain, snow, fog, clouds etc. The attenuation when the heavy rain occurs is so great, that sometimes the connection can interrupt completely even if the link distance is short.

The rain attenuation L_{rain} is caused mainly by rain absorption and is expressed as [4]

[1]Boncho Bonev is with the Faculty of Telecommunications at Technical University of Sofia, 8 Kl. Ohridski Blvd, Sofia 1000, Bulgaria, E-mail: bbonev@tu-sofia.bg.

[2]Kliment Angelov is with the Faculty of Telecommunications at Technical University of Sofia, 8 Kl. Ohridski Blvd, Sofia 1000, Bulgaria, E-mail: kna@tu-sofia.bg.

[3]Emil Altimirski is with the Faculty of Telecommunications at Technical University of Sofia, 8 Kl. Ohridski Blvd, Sofia 1000, Bulgaria.

$$L_{rain} = L_{sp\_rain}.r.d/1000, \qquad (1)$$

where L_{sp_rain} is the specific rain attenuation in dB/km and can be calculated by using the ITU model [4] as follows

$$L_{sp\_rain} = k(f).RR^{\alpha(f)}. \qquad (2)$$

In Eq. (2) RR is the rain rate in mm/h, $k(f)$ and $\alpha(f)$ are the frequency and polarization dependent constants.

In Eq. (1), the distance d is in meters and r is a correction, what renders an account of the fact that the rain falls only on part of the link distance and can be calculated by the expression [4, 5]

$$r = \left(1 + d/35000\exp(-0.015RR)\right)^{-1}. \qquad (3)$$

In our analysis we use these formulas to calculate theoretical rain attenuation for examined radio link. We also use them to obtain the value of specific rain attenuation based on experimental data. Then by using of the smaller squares method we obtain new coefficients for rain attenuation prediction model.

III. RESULTS AND ALALYSIS

We examine two radio links working at frequencies 11,15 GHz and 19,15 GHz with vertical polarization on distance of 7,1 km in Sofia region. For our study we use statistical data for rain rate in Sofia region based on 4-year measurement. By using this data we calculate theoretical rain attenuation with Eq. (1) – (3). The values of $k(f)$ and $\alpha(f)$ are obtained from [2] and are given in Table I.

TABLE I

Frequency, GHz	$k(f)$	$\alpha(f)$
11,15	0,018396	1,155685
19,15	0,0878735	0,991755

We also use the statistical data of rain attenuation for these radio links and compare and analyze theoretical and experimental rain attenuation – yellow and red drawing on Fig. 1 and Fig. 2.

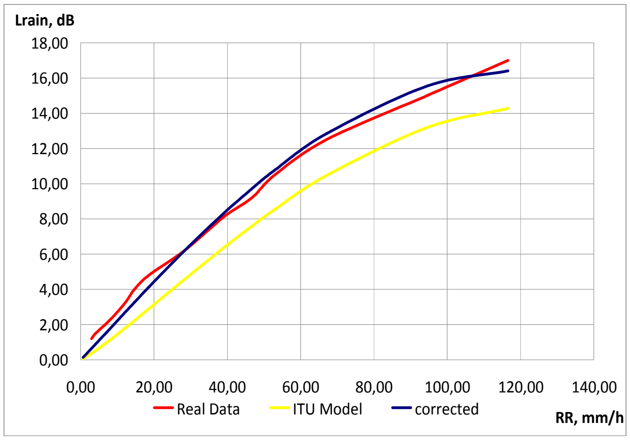

Fig. 1. Rain attenuation for 7,1 km radio link, *f*=11,15 GHz

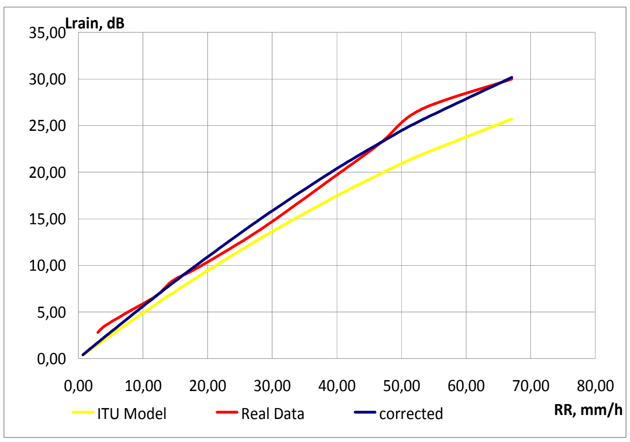

Fig. 2. Rain attenuation for 7,1 km radio link, *f*=19,15 GHz

We assume the rain rate statistic is the same for the every part of link distance, because the measurement period is long enough.

Fig.1 and Fig. 2 show the similar disposition of the drawings for theoretical and real rain attenuation of studied radio link. Obviously the real attenuation is 1 dB for light rain and 3-4 dB for heavy rain bigger than the theoretical for two studied frequencies. The correction obtained from Eq. (3) is not the frequency dependent and the difference can be searched out in the specific rain attenuation calculation – Eq. (2). One of the possible reasons can be found in the rain drops size distribution that is different for the rainfalls occur in different time but with the same rain rate. That for example causes serious differences in optical wave attenuation [6] and also can lead to different specific attenuation for the given frequencies. That give us the ground to precise the coefficients $k(f)$ and $\alpha(f)$ in Eq. (2).

First it is calculated the specific attenuation value according the real measured rain attenuation and then by using the same model based on Eq. (2) is obtained the new values of $k(f)$ and $\alpha(f)$. The smallest squares method is used [7].

The corrected values of rain attenuation are calculated and are shown with the blue line on Fig. 1 and Fig. 2. The corrected values of the coefficients are given in Table II.

TABLE II

Frequency, GHz	$k(f)$	$\alpha(f)$
11,15	0,03485	1,04390
19,15	0,096502	1,00477

IV. CONCLUSIONS

From applied drawings can be viewed that in a heavy rain conditions the calculated by ITU model rain attenuation and the real one are rather different. This can cause mistakes in the link budget calculation. One of possible reasons is the rain drops size distribution that can be different for the different regions of a given country what is in some of climate regions according ITU prediction model [8]. Therefore there is a need of specifying the rain attenuation prediction models and one of possible ways is by defining more accurately the coefficient in these models. Another way is to divide the climate regions on sub-regions according to the specific meteorological conditions. This demands more experimental data for rain attenuation and rain rate in the typical regions like flat country, mountain etc. and is the object of our further studies.

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