

CALCULATION OF RADIO SIGNAL ATTENUATION USING LOCAL PRECIPITATION DATA *

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According to the peculiarities of climatic conditions of Lithuania the change in Chebil's model was made. For the first time the rain rate values for 13 localities in Lithuania have been calculated using this model. This data has shown that the definition of Rain Zone E does not describe the Lithuanian climatic conditions. The values of rain attenuation have been calculated as well. The Flavin's relationship for calculations of rain attenuation was used. The dependences of rain attenuation on the frequency for both locations of Ukmergė and Laukuva have been calculated. A review of the results on the rain rate and rain attenuation can be entered into total attenuation prediction or system-planning tools.

Keywords: rain attenuation, Flavin's relationship, Chebil's method

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1. Introduction

The electromagnetic waves are seriously affected by the atmosphere environments, in which the rainfall is the most important factor. At frequencies of 10 GHz and higher heavy rain seriously attenuates radio transmissions because raindrops absorb and scatter radio waves [1]. Knowledge of the rain attenuation in this frequency range is desirable while planning a reliable communication system at any location. Rain attenuation is the major variable in the calculation of the total attenuation. Rain attenuation prediction similarly as weather prediction is not an exact science.

Several methodologies exist for the prediction of rain attenuation on radio waves paths [1]. These methodologies can be grouped into two classes: empirical methodologies based on measurement databases from stations in different climatic zones within a given region and physical models attempting to reproduce the physical behaviour involved in the attenuation process. The propagation characteristics in rain and melting snow are calculated in [2] by treating these media as artificial dielectrics. Computed values of attenuation and phase

shift in rain, obtained by this approach, are compared with those derived by using Mie scattering theory over a frequency range of 1–100 GHz and for rain rates up to 100 mm/h. Empirical procedures have tended to be used most often and with usually the best results. One of the most accepted methods for rain attenuation A prediction is an empirical procedure based on the approximation relation between A and the rain rate R [3]:

$$A = aR^b, \quad (1)$$

where a and b are functions of frequency f and rain temperature T .

As shown in (1), attenuation due to rain depends on the rainfall intensity, or rain rate R . Rain rate data is presented in units of length per unit time (millimetres per hour), but in practice it is measured with a tipping bucket rain gauge over intervals of typically one minute [4] or five minutes [1]. The prediction of rain rate is the most important step when analysing rain attenuation. Rainfall rate is highly variable, both in terms of location and time (includes diurnal, seasonal, and yearly variations). Therefore the rain rate and rain attenuation are analysed for concrete climatic conditions, e. g., in Colombia [1], in Malaysia [4], in India [5], and in North America [6]. The rain attenuation and attenuation dis-

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tribution have been obtained in [5] by using the measured rain drop size distribution and the ITU-R (International Telecommunication Union – Radio Regulations) model [7] of rain rate distribution, over the frequency range of 10–200 GHz at three locations in the Indian region, to indicate the variability in the rain attenuation pattern in the tropical region. Considering that the raindrop size distribution and rain rate change with geographical location and this can strongly influence rain attenuation, [8] recommends the usage of an expanded set of power-law parameters for various raindrop distributions in calculating the specific attenuation. However, as far as we know, there are no data about the calculation of rain rates in Lithuania.

Lithuania, being in the transition geography zone from the Baltic Sea climate to Atlantic and continentals East Europe climate, may be distinguished for its variable climate. Continuous circulation of the air masses is one of the most important factors forming the Lithuania climate. Humid weathers predominate in Lithuania all over the year. It is often raining in spring, summer, autumn, and even in winter. There are 20–30 thaw days even in the very mid-winter. The relative humidity is 85–90% in spring and it is about 70% in summer. 60% of annual precipitation falls out in the warm period of the year [9]. The annual precipitation in rainy wet year is twice higher as compared to dry year. The distribution of precipitation is not uniform in Lithuania. The most humid location in Lithuania is Laukuva (in the Šilalė region), where the annual average precipitation is about 820 mm [9]. The named peculiarities of Lithuanian climatic conditions are valid reasons to use local Lithuanian meteorological data in rain attenuation calculation.

The main goals of this paper were to apply the known models to calculate the rain rate as well as the rain attenuation using local meteorological data of Lithuania.

2. Calculation of rain rate and rain attenuation

One method of predicting rain attenuation at a particular location is by using the relationship derived by Flavin [10] from analysis of measurements taken in Australia. This relation is given by the expression

$$A = (0.0308f - 0.1872)R, \quad (2)$$

where A (dB) is rain attenuation, f (GHz) is the operating frequency, R (mm/h) is the rain rate.

The effects of rain attenuation have been extensively studied over many years and the values of rain rates are available in ITU-R recommendations. The world has

been divided into rain climatic zones marked from A to Q [11]. The rainfall rate is not uniform throughout the rainy area. In fact, the higher the rain rate the smaller area is affected. Therefore, when predicting the attenuation a path length reduction factor is introduced. This factor is dependent on R . As shown in [11], Lithuania is in Zone E, where the rain rate for 0.01% of time is 22 mm/h. However, for providing the objective additional information on rain rates for Lithuania we used local climatic data. The rain rate data are not always readily available from local weather agencies. Only the average annual precipitation is available in many cases. The use of Chebil's model appears suitable as an alternative for the sites where thunderstorm occurrence data are unavailable [1]. This model was verified against data from several localities resulting in the best estimate of measured data. It is exemplified by the following expression:

$$R_{0.01\%} = \alpha M^\beta, \quad (3)$$

where $\alpha = 12.2903$, $\beta = 0.2973$, M is the average annual precipitation.

The averaged annual precipitation in several localities of Lithuania [12] and the values of rain rates calculated using (3) for 13 towns of Lithuania are presented in Table 1. The values of rain attenuation calculated using Flavin's relationship are presented in Table 1 as well. We obtained the difference of about 10% in the values of rain rates for different localities of Lithuania. The values of $R_{0.01\%}$ calculated for Ukmergė and Laukuva using (3) differ from the value ascribed to Rain Zone E by 73% and 76%, respectively. The values of $R_{0.01\%}$ in different localities of Lithuania calculated using Chebil's model differ from the value ascribed to Rain Zone K by starting from 49% (in Ukmergė) up to 54% (in Laukuva). So the calculated data of rain rate in Lithuania are closer to the value ascribed to Rain Zone K (which is near from Zone E) than to the value ascribed to Rain Zone E.

The dependences of rain attenuation on the frequency for localities of both Ukmergė and Laukuva have been calculated in the frequency range from 10.5 to 40 GHz (Fig. 1, straights 1 and 2) using (2). Rain attenuation increases at higher frequencies when wavelengths are close to the size of the raindrops.

Chebil's model was verified against data from several tropical localities with an average annual accumulation of 500–2000 mm. The average annual precipitation varied from 588 to 821 mm in several investigated localities of Lithuania (see Table 1) and these values were from the named range. It is important to note that a

Table 1. Average annual precipitation M (mm) in several localities of Lithuania (data is taken from [12]), values of rain rates $R_{0.01\%}$, (mm/h) calculated using (3), values of rain rates $R'_{0.01\%}$ (mm/h) calculated using (4), and rain attenuation calculated using relation (2).

Locality	M , mm	0.6M, mm	$R_{0.01\%}$, mm/h	$R'_{0.01\%}$, mm/h	A , dB	
					$f = 10.5$ GHz	$f = 26$ GHz
Biržai	605	363	82.52	70.9	11.24	50.63
Klaipėda	735	441	87.44	75.12	11.91	53.65
Laukuva	821	492.6	90.36	77.63	12.31	55.44
Kaunas	630	378	83.52	71.76	11.38	51.25
Kybartai	613	367.8	82.85	71.17	11.28	50.84
Šiauliai	600	360	82.32	70.72	11.21	50.51
Telšiai	788	472.8	89.27	76.69	12.16	54.78
Raseiniai	682	409.2	85.52	73.47	11.65	52.48
Šilutė	737	478.2	89.57	76.95	12.2	54.96
Utena	650	390	84.3	72.42	11.48	51.73
Varėna	658	394.8	84.61	72.69	11.52	51.92
Ukmergė	588	352.8	81.83	70.3	11.15	50.21
Vilnius	683	409.8	85.55	73.5	11.65	52.49

part of the annual precipitation in Lithuania is snowfall. Only 60% of the annual precipitation falls in the warm period of the year [9]. It is noted in [13] that the values of snow attenuation are much lower than the rain attenuation values and therefore it is recommended to neglect this type of attenuation in super high frequency (SHF) range. According to this peculiarity of Lithuanian climatic conditions we made a change in (3). For such mixed meteorological conditions, if there is no annual rain data and only annual precipitation data is available, this equation can be written as

$$R'_{0.01\%} = \alpha(\gamma M)^\beta, \quad (4)$$

where $\gamma \leq 1.0$ is a coefficient of warm period in a year.

Then the relation (2) can be written as

$$A' = (0.0308f - 0.1872) \alpha(\gamma M)^\beta. \quad (5)$$

The values of rain rates R' for investigated localities of Lithuania calculated using (4) are given in Table 1. Even in this “improved” case the obtained values of rain rates vary from 70.3 mm/h (in Ukmergė) to 77.6 mm/h (in Laukuva) and are higher than the values ascribed to Rain Zone E according to ITU Radio Regulations [11]. It is worth to emphasize that in ITU Radio Regulations of 1990 five different Rain Zones have been used [14]. According to that data Lithuania was ascribed to Rain Zone 2 with rain rate of 55 mm/h that is much closer to local meteorological values presented in this paper. These values are from 3.7% to about 13% higher than the value $R_{0.03\%} = 67.7$ mm/h calculated using the data on the longest heavy rain measured in Sartai [15]. The value $R_{0.03\%} = 67.7$ mm/h is only 4% higher than the value ascribed to Rain Zone N and it is 82.3% higher than the one ascribed to Rain Zone E for 0.03% of time.

Table 2. Values of rain attenuation calculated using relation (5).

Locality	A' , dB		
	$f = 10.5$ GHz	$f = 26$ GHz	$f = 40$ GHz
Biržai	9.66	43.5	74.07
Klaipėda	10.23	46.09	78.48
Laukuva	10.57	47.64	81.11
Kaunas	9.77	44.03	74.97
Kybartai	9.69	43.67	74.36
Šiauliai	9.63	43.39	73.89
Telšiai	10.44	47.06	80.13
Raseiniai	10.01	45.08	76.76
Šilutė	10.48	47.22	80.4
Utena	9.86	44.44	75.67
Varėna	9.9	44.6	75.94
Ukmergė	9.58	43.14	73.45
Vilnius	10.01	45.1	76.79

It is worth to mention that the review of Lithuanian climatic conditions and the obtained data about the rain rates in towns investigated here show that the definition of Rain Zone E does not describe the Lithuanian climatic conditions correctly.

The values of rain attenuation calculated by using relation (5) for 13 towns of Lithuania are presented in Table 2. The conditions of the radio signal propagation due to rain in Laukuva are worse than in other here investigated localities of Lithuania. The dependences of rain attenuation on the frequency for Laukuva (straight 3) and Ukmergė (straight 4) calculated using relation (5) are presented in Fig. 1. The rain attenuation values decrease 1.16 times when the change in the relation (5) is made.

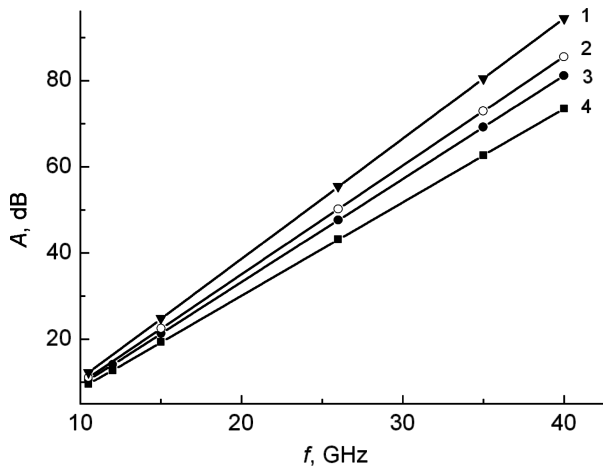


Fig. 1. Dependences of rain attenuation on the frequency for Laukuva (straights 1 and 3) and Ukmergė (straights 2 and 4). Straights 1 and 2 were obtained using relation (2). Straights 3 and 4 were calculated using relation (5).

3. Conclusions

The conditions of the radio signal propagation due to rain in Laukuva are worse than in other here investigated localities of Lithuania. Considering that the rain rate is changing with geographical location and that it can strongly influence the rain attenuation, we recommend the usage of local meteorological data.

The definition of Rain Zone E does not describe correctly enough the Lithuanian climatic conditions and there is a need to specify this Rain Zone ascription.

The maximum difference of the values of rain attenuation in the investigated localities is about 8 dB when the signal frequency $f = 40$ GHz.

Investigation of meteorological data shows the necessity to modify Chebil's model.

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RADIJO SIGNALO SILPNINIMO SKAIČIAVIMAS, NAUDOJANT VIETINIUS DUOMENIS APIE KRITULIUS

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Santrauka

Projektuojant radijo stotis Lietuvoje, tenka atsižvelgti į radijo signalo silpninimą lietuje, o norint jį apskaičiuoti, reikia žinoti lietaus intensyvumą, tačiau dažnai žinomas tik vidutinis metinis kritulių kiekis. Taikant Chebil'io modelį, kuris naudojamas kaip alternatyva, kai nėra tikslių duomenų apie lietingas dienas, pirmą kartą apskaičiuotas lietaus intensyvumas 0,01% metų laiko $R_{0,01\%}$ (mm/h) trylikoje Lietuvos miestų. Pasinaudojus šiomis vertėmis, pagal Flavin'o sąryšį apskaičiuotas signalo silpninimas dėl lietaus Biržuose, Klaipėdoje, Laukuvoje, Kaune, Kybartuose, Šiauliuose, Telšiuose, Raseiniuose, Šilutėje, Utenoje, Varėnoje, Ukmergėje ir Vilniuje. Priklausomai nuo ištirtos vietovės geografinės padėties, silpninimas

lietuje gali skirtis iki 3 dB, kai signalo dažnis $f = 10,5$ GHz, o kai $f = 40$ GHz, silpninimas lietuje skiriasi net 8 dB.

Skaičiuojant lietaus intensyvumą Lietuvos sąlygomis, Chebil'io modelyje rekomenduota įvesti koeficientą, kurio skaitinė vertė parenkama atsižvelgus į tai, kurią metinio kritulių kiekio dalį sudaro lietaus krituliai.

Lietuvos klimato ypatumų analizė bei šiame darbe apskaičiuotų lietaus intensyvumo verčių palyginimas su Tarptautinės radijo ryšių sąjungos rekomenduota verte rodo, kad E lietaus zonos, kuriai priskiriama Lietuvos teritorija, apibrėžimas netiksliai apibūdina Lietuvos klimato sąlygas.