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Rain Intensity Influence on to Microwave Line Payback Terms

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Introduction

Transmission of microwave signals above 10 GHz is vulnerable to precipitation. Rain, snow, sleet, ice particles and hail may attenuate and scatter microwave signals and thus result in reduced availability from a system quality point of view. The energy is attenuated due to radiation (scatter) and absorption (heating).

The attenuation due to absorption is larger than attenuation due to scatter for wavelengths that are small compared with the drop size. For wavelengths that are long compared to drop size, the attenuation due to scatter is larger than attenuation due to absorption.

Also rain events produce unavailability of microwave link, which sometimes lead operators to economical and sometimes license loosing. Our article it is attempt to look on to microwave line planning from economical point of view and to identify the risks, which can be met during microwave line planning.

Characteristics of precipitation

Orographic precipitation. The terrain in the area of interest determines orographic precipitation. Forced uplift of moist air over high ground gives precipitation when the dew point is reached. Figure 1 shows a typical weather condition in north part of Latvia (Latgale). Moist air from the Baltic Sea approaches the coastline and is forced up by the mountains and hills close to the shore. The clouds have much smaller water content after passing the mountains and reaching Latgale. This is clearly reflected in the regional rainfall statistics of Latvia.

Convectional precipitation. During the hot summer days, heavy clouds may build up in the afternoon due to convection of hot humid air. These clouds may give intense rain with thunder. See Fig. 2.

Cyclonic precipitation. Characterized by large scale vertical motions associated with synoptic features such as depression and fronts. See Fig. 3.

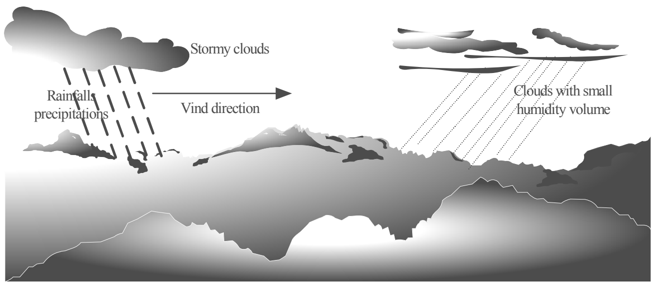

Fig. 1. Orographic precipitation

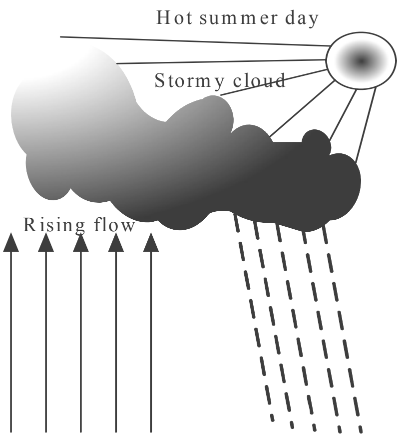

Fig. 2. Convectional precipitation

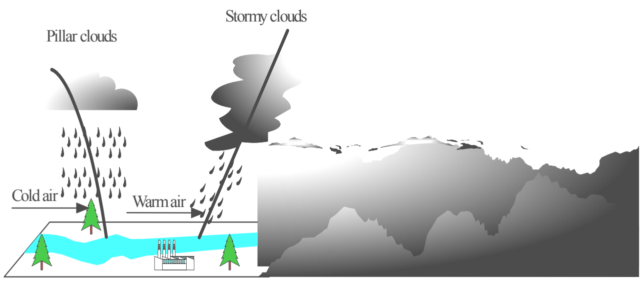

Fig. 3. Cyclonic precipitation

Tropical cyclone storms. In tropical areas moving circular storms with intense convective rain may occur with heavy rain 50 - 200 km in diameter. The monsoon rain is a typical example. This is characterized by intense stratiform rainfall for several hours a day and extended over several hundreds of kilometers.

How precipitation affects radio wave propagation

As mentioned earlier, microwave transmission at 10 GHz or above may be seriously affected by precipitation. Fig. 4 shows a radio relay path where the Fresnel zone is partially filled with rain droplets from a shower. Each particular raindrop will contribute to the attenuation of the wanted signal. The actual amount of fading is dependent on the frequency of the signal and the size of the raindrop.

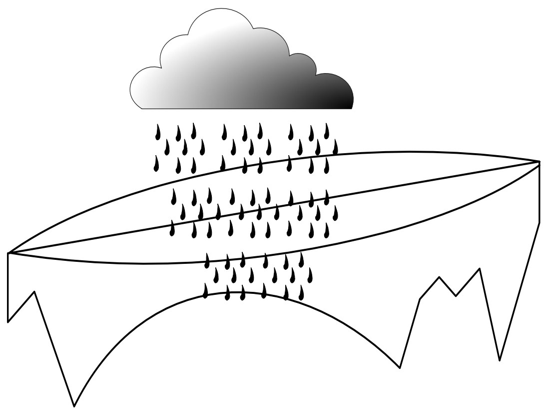

Fig. 4. Rain shower

The two main causes to attenuation are scattering and absorption. When the wavelength is fairy large relative to the size of raindrop, scattering is predominant. Conversely, when the wavelength is small compared to the raindrop size, attenuation due to absorption is dominating.

Scattering. Since the radio waves are a time varying electromagnetic field, the incident field will induce a dipole moment in the raindrop. The raindrop dipole will have the same time variation as the radio waves and will therefore act as an antenna and re-radiate the energy. A raindrop is an antenna with low directivity and some energy will be re-radiated in arbitrary directions giving a net loss of energy in the direction towards the receiver.

Absorption. When the wavelength becomes small relative to the, more and heating of the raindrop absorbs more energy. The radio waves will vary too much infield strength over the raindrop to induce a dipole effect. Calculated attenuation for one precipitation particle at 10 GHz.

Total rain attenuation for a radio path. In order to calculate the rain induced outage we must know the total amount of raindrops within the Fresnel zone as well as their individual size. The attenuation may be found using

$$A \approx \int_0^\infty N(D) \bullet Q(D,f)dD\,. \qquad (1)$$

In this formula ***N*** is the raindrop size distribution and ***Q*** is the attenuation of one particle at a given frequency f. Determining the attenuation using formula (1) is not a very easy task since it is hard to actually count the number of raindrops and measure their individual sizes. An easier method is to measure the amount of rain that hit the ground in some time interval. This is denoted rain rate. The connection between rain rate *R* and *N(a)* is given by the number of raindrops and measure their individual sizes. An easier method is to measure the amount of rain that hit the ground in some time interval. This is denoted rain rate. The connection between rain rate *R* and *N(a)* is given by raindrop size distribution

$$N(D) = N_0 \bullet e^{(-aR^b D)}\,, \qquad (2)$$

where a=41; b=-0,21; D = drop diameter [cm].

Higher rain rate, larger raindrops

$$R = 0{,}6 \bullet 10^{-3} \bullet \pi \int_0^\infty D^3 V(D) N(D) dD\,, \qquad (3)$$

where *V(D)* denote the terminal velocity of the raindrop.

Both the terminal velocity and typical raindrop distributions have been studied thoroughly and are well known. So it is possible to estimate the attenuation by considering the rain rate only.

Rainfall is measured in millimeters [mm], and rain intensity in millimeters pr. hour [mm/h]. Different measurement principles are for *R* > 100 mm/h: *R* = 100 ram/h.

Rain measurements. Rainfall is measured in millimeters [mm], and rain intensity in millimeters pr.hour [mm/h]. Different measurement principles are shown in Fig. 5.

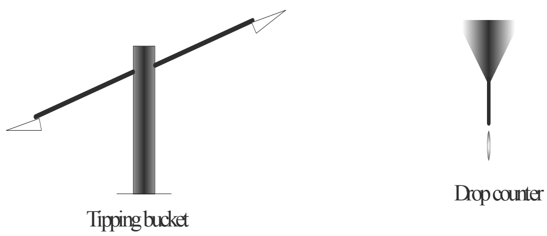

Fig. 5. Rain gauges

An important parameter is the integration time, e.g. the time between readings of the rainfall. Typical values for integration time are 1 min, 5 min, 10 min, 1 hour, 1 day. An integration time of 1 minute should be used for rain intensity in link calculation. To illustrate the importance of the integration time, let us look at the example shown in Fig. 6.

Raindrop shape. the spherical shape. This deviation from the spherical shape results that the raindrops are more extended in the horizontal direction and consequently will attenuate horizontal polarized waves more than vertical polarized. This means that vertical polarization is favorable at high frequencies where outage due to rain predominates.

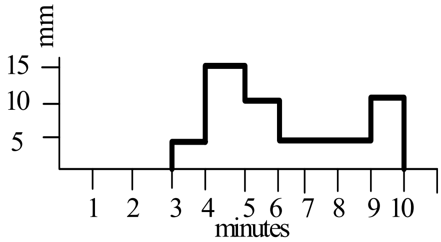

Fig. 6. Rain rate and integration time: 1 *min*. Integration time: 30, 90, 60, 30, 30, 30, 60 mm/h; 5 *min*. integration time 48, 18 mm/h; 10 *min* integration time: 33 mm/h; 1 *hour* integration time: 5,5 mm/h

Unavailability due to rain

Effective path length. Since rain has a tendency to cluster (especially at high rain rates), only parts of typical radio link path will affected by rain. The effective path length containing rain cells is given by:

$$\psi = \frac{d}{1 + \left(\dfrac{d}{35 \bullet e^{-0,015 \bullet R}} \right)}, \tag{4}$$

where d is the path length in km for R>100 mm/h: R=100 mm/h.

R is the rain intensity in mm/h for 0.01% of the time. and the rain zone contour maps. If you do not have local information on the rain intensity, this may be found using in Table 1.

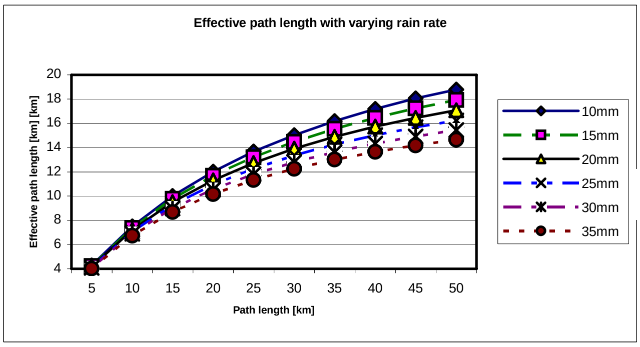

Fig. 7. Effective path length depending on rain intensity

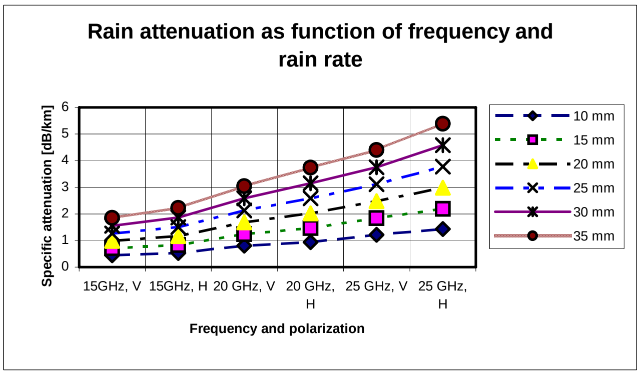

Fig. 8. Rain attenuation versus frequency

Table 1. Rainfall intensity exceeded [mm/h]

Percentage of time	*A*	*B*	*C*	*D*	*E*	*F*	*G*
1.0	<0.1	0.5	0.7	21	0.6	1.7	3
0.3	0.6	2	2.8	4.5	2.4	4.5	7
0.1	2	3	5	8	6	8	12
0.03	5	6	9	13	12	15	20
0.01	8	12	15	19	22	28	30
0.003	14	21	26	29	41	54	45
0.001	22	32	42	42	70	78	55

Table 1 (cont.). Rainfall intensity exceeded [mm/h]

Percentage of time	*H*	*J*	K	*L*	*M*	*N*	*P*	*Q*
1.0	2	8	1.5	2	4	5	12	24
0.3	4	13	4.2	7	11	15	34	49
0.1	10	20	12	15	22	35	65	72
0.03	18	28	23	33	40	65	105	96
0.01	32	35	42	60	63	95	145	115
0.003	55	45	70	105	95	140	200	142
0.001	83	55	100	150	120	160	250	170

Fade depth due to rain. As seen earlier, the rain rate R was connected to the drop size distribution and the terminal velocity of the rain drops. Knowing R, it is possible to calculate the amount of raindrops and their size within the Fresnel zone. The specific attenuation (dB/km) is given by precipitation:

$$\gamma_r = k \bullet R^{\alpha}, \tag{5}$$

where k and α are given in Table 2 and vary with radio frequency and polarization.

The attenuation due to rain in 0.01% of the time for a given path may be found by

$$A_{0,01} = \psi \bullet k \bullet R^{\alpha} \text{ [dB].} \tag{6}$$

Table 2. Regression coefficients for estimating specific attenuation in equation (6)

Frequency [GHz]	k_h	k_v	α_h	α_v
1	0.0000387	0.0000352	0.912	0.880
2	0.0001540	0.0001380	0.963	0.923
4	0.0006500	0.0005910	1.121	1.075
6	0.0017500	0.0015500	1.308	1.265
7	0.0030100	0.0026500	1.332	1.312
8	0.0045400	0.0039500	1.327	1.310
10	0.0101000	0.0088700	1.276	1.264
12	0.0188000	0.01 S8000	1.217	1.200
15	0.0367000	0.0335000	1.154	1.128
20	0.0751	0.0691	1.099	1.065
25	0.124	0.113	1.061	1.030
30	0.187	0.167	1.021	1.000
35	0.263	0.233	0.979	0.963
40	0.350	0.310	0.939	0.929

The relation between fading margin and unavailability for the path is given by

$$F = 0{,}12 \bullet A_{0,01} \bullet P^{-(0{,}546+0{,}043 \bullet \lg P)}, \qquad (7)$$

where$P$ is the unavailability in percent.

Formula 7 is used to scale to other percentages of time than 0.01%. The unavailability may be found solving equation 7 with respect to P.

$$P = 10^{11{,}628(-0{,}546+\sqrt{0{,}29812+0{,}172\lg(0{,}12 \bullet A_{0,01}\ /F))}}. \qquad (8)$$

To avoid imaginary values, use $A_{0,01} / F = 0{,}155$ in cases where $A_{0,01} / F < 0{,}154023$.

Economical calculation of 50 km long microwave transmission line

We can connect those two points using two 70 m or three 50 m towers

$$h = \frac{d_1 \bullet d_2}{12{,}74 \bullet k}, \qquad (9)$$

where **k**-factor which define refractivity gradient we will take 1,33.

So, earth bulge in case of 50 km long hop will be 37 m height in the middle and only 9 m in case of 25 km long hop

Then we calculate Fresnel ellipsoid radius in the middle of 50 km hop and 25 km hop for 15 GHz microwave using formula

$$F_1 = 17{,}3\sqrt{\frac{d_1 \bullet d_2}{f \bullet d}} \qquad (10)$$

and we will get 16 m for 50 km hop and 11 m for 25 km hop than we will consider some 15 m high obstacles in the middle of the hop and the final result is that we need two 70 m tower for connection two points situated 50 km away each from other or three 35 m towers for the same 50 km points connection. The building and mast prices we will mark ac B expenditures.

The expenditures for two 70 m towers and three 35 m tower building are almost the same and the question is only that for two points communication we shall purchase one additional 15 GHz SDH microwave complex of equipment which current market price with 1,2 m antennas is about 30 000 EUR.

And so we have two cases:

1) First case expenditures are 30 000 EUR.
2) Second case expenditures are 60 000 EUR.

Now we shall define which case is preferable, from first point of view first one is better because it 30 000 EUR less. But we shall consider that we build 63E1-leased line with certain QoS demand from potential customers. Current market price for E1 leased line in Latvia is 300 EUR/month so during the eyar our leased line will bring in house 300x12x63=226 800 EUR in gross.

But we shall remember that microwave line can have unavailability due to rain. In the table you can see attenuation values dB/km for different rain rates in mm and vertical and horizontal polarized 15 GHz microwave systems.

Table 3. Attenuation dB/km versus rain intensity and polarization

Rain rate	15GHz, V	15GHz, H
10 mm/h	0,45	0,52
15 mm/h	0,71	0,84
20 mm/h	0,98	1,16
25 mm/h	1,26	1,51
30 mm/h	1,55	1,86
35 mm/h	1,85	2,22

The link budget for 15 GHz SDH microwave line we will calculate using formula

$$FM = P_r - P_{th}, \qquad (11)$$

where P_t – system threshold for SDH usually for BER 10^{-6} threshold is –75dBm

$$P_r = P_t + G_t + G_r - 20\lg F - 20\lg L - 92{,}4, \qquad (12)$$

where P_t – system transmit power we will take as 20 dBm; G_t – transmitting antenna gain we will take 42 dBi; G_r – receiving antenna gain we will take also 42 dBi; F – frequency GHz; L – distance km.

For 50 km hop we will have P_r= - 46dB and consequently FM = 29 dB.

For 25 km hop we will have P_r= - 40 dB and consequently FM = 35 dB

Attenuation due to rain, which those hop, can have during the rain events during the 0,01% of a year you can see in the Table 4.

Table 4. Total attenuation for 50 and 25 km long 15 GHz microwave hops

	Attenuation in dB due to rain for 50 km long hop		Attenuation due to rain in dB for 25 km long hop	
Rain rate	15GHz, V	15GHz, H	15GHz, V	15GHz, H
10mm/h	8	10	6	7
15mm/h	13	15	9	11
20mm/h	17	20	13	15
25mm/h	21	24	16	18
30mm/h	24	29	18	22
35mm/h	29	33	21	25

You can see that 50 km long hop will have unavailability due to the rain in case of 30 mm/h rain for vertical polarization and in case of 30 mm/h rain for horizontal polarization.

Usual discount for 0,01% link unavailability per year is 5% of yearly fee which is in our case 226 800 EUR x5% = 11 340 EUR/year which during 3 year will lead us to spent 34 020 EUR for compensation towards our customers. It is more than 4 020 EUR which we would pay for additional microwave SDH hop.

Conclusion

1) During the microwave line planning we shall consider unavailability which can happened during the rain, snow, and fog events.

2) In order to meet customer requirements better we shall have local statistic about rain intensity and apply this statistic to engineering calculations.

3) Strong knowledge about market prices for leased lines and discount rates for the region where we plane to build microwave line also necessary.

4) In some countries (as Russia) also GSM operators have certain QoS figures, which they shall meet according to the license. If operator doesn't meet those requirements his GSM license can be terminated.

References

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G. Ivanovs, D. Serdega. Rain Intensity Influence on to Microwave Line Payback Terms // Electronics and Electrical Engineering. – Kaunas: Technologija, 2006. – No. 6(70). – P. 60–64.

There is presented investigation of rain intensity influence on to microwave line building investments. Rain intensity research in Latvia lead us to conclusion that ITU-R proposed data not suitable for microwave line planning in Latvia and can cause additional expenditures which operator will pay as a poor quality compensation to end user. Il. 8, bibl. 5 (in English; summaries in English, Russian and Lithuanian).

Г. Ивановс, Д. Сердега. Влияние интенсивности дождя на сроки окупаемости РРЛ линии // Электроника и электротехника. – Каунас: Технология, 2006. – №. 6(70). – С. 60–64.

Представлены исследования влияния интенсивности осадков на инвестиции в строительство РРЛ линии. Исследования интенсивности дождя в Латвии привели нас к выводу, что данные предлагаемые МККР не могут быть использованы для планирования РРЛ линий в Латвии. Найдено, что их использование может привести к дополнительным затратам в виде выплаты компенсаций операторами оконечным пользователям за плохое качество связи и перерывы в работе РРЛ линий. Ил. 8, библ. 5 (на английском языке; рефераты на английском, русском и литовском яз.).

G. Ivanovs, D. Serdega. Lietaus intensyvumo įtaka ML atsipirkimo terminams // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2006. – Nr. 6(70). – P. 60–64.

Išnagrinėta kritulių intensyvumo įtaka ML linijos tiesimo investicijoms. Lietaus intensyvumo Latvijoje tyrimai leido padaryti išvadas, kad ITU-R pateikti duomenys negali būti panaudoti ML linijoms planuoti Latvijoje. Be to, jas naudojant galima patirti papildomų išlaidų, kurios pasireiškia kaip operatoriaus kompensacija galutiniams abonentams už blogą ryšio kokybę bei ML linijos darbo pertrūkius. Il. 8, bibl. 5 (anglų kalba; santraukos anglų, rusų ir lietuvių k.).