Reliability of Radio-Relay Systems

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Abstract – **Reliability of radio-relay systems depends on the propagation conditions and the reliability of equipment. The aim of this paper is to analyze transmission parameters such as propagation loss, diffraction fading, attenuation due to atmospheric conditions etc., from the reliability of radio-relay systems point of view. Reliability of radio-relay links, depending on bandwidth channel, digital modulation types and bit rate, is considered using the simulation programme Pathloss. Annual rain and multipath unavailability are analyzed at the frequency of 18 GHz band on two links and four bandwidth channels. These results are particularly important in the design of transmission links over Wireless Internet.**

Keywords – Radio-relay, reliability, rain unavailability, multipath

I. INTRODUCTION

In order to properly plan terrestrial radio-relay line-of-sight systems it is necessary to have accurate propagation parameters or adequate prediction methods. These methods have been developed for the purpose of predicting the most important propagation parameters for radio-relay links [1]. In design of line-of-sights of radio-relay links several propagation parameters must be taken into consideration. These parameters are: diffraction fading due to an obstacle on terrain path, attenuation in the atmosphere, fading due to atmospheric multipath, fading due to multipath arising from the surface reflection, attenuation due to precipitation, variation of the angle-of-launch at the transmitter terminal and the angle-of-arrival at receiver terminal due to refraction, reduction in cross-polarization discrimination in multipath or precipitation conditions and signal distortion due to frequency selective fading and delay during multipath propagation.

The propagation losses on the terrestrial path in the free space consist of losses such as attenuation due to atmospheric gases, diffraction fading due to obstruction or partial obstruction of the path, fading due to multipath, beam spreading and scintillation, attenuation due to variation of the angle-of-arrival/launch, attenuation due to precipitation, dust and storms. The probability of appearance of these events is of great importance in consideration of reliability of line-of-sight radio-relay systems.

All these parameters are calculated in designing of terrestrial radio-relay links to points which are used to provide wireless Internet. From these points wireless Internet is distributed at standardized frequencies to end users.

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II. LINK RELIABILITY

Reliability represents systems ability to operate without outage during a certain period of time. Outage is the loss of ability of a device to perform a required function [2]. The reliability of a radio-relay system depends on equipment and connection availability.

An estimation of the equipment availability is used in order to statistically predict when the equipment or radio-relay system will be unavailable due to unintentional malfunctions on radio-relay devices.

Equipment unavailability Un_{opr} is determined with average time needed for repair (Mean Time To Repair) MTTR(h) and the mean time interval between the appearance of two successive errors (Mean Time Between Failures) - MTBF(h) :

$$Un_{opr} = \frac{\mathrm{MTTR}}{\mathrm{MTTR} + \mathrm{MTBF}} . \tag{1}$$

Since, $\mathrm{MTTR} \ll \mathrm{MTBF}$, the previous expression transforms into:

$$Un_{opr} \cong \frac{\mathrm{MTTR}}{\mathrm{MTBF}} . \tag{2}$$

MTTR and MTBF are stated in the equipment datasheet and the designer of the radio-relay system has no influence on them. Let us consider the influence of connection unavailability on the reliability of the entire system.

The availability objectives, availability ratio (AR) and mean time between outage (Mo), and reciprocal outage intensity (OI) needed for design purposes are given in ref. [3]. The availability objectives applicable to fixed wireless link of length L_{link}, can be derived from the values given in [3]. The variables in equations (3) and (4) are given in ref. [3];

$$AR = 1 - \left(B_j \frac{L_{link}}{L_R} + C_j \right) \tag{3}$$

$$Mo = 1/OI = \frac{1}{D_j \frac{L_{link}}{L_R} + E_j} \tag{4}$$

where the value of j is for section of national portion: j=5, for access network, j=6 for short haul, j=7 for long haul. LR: reference length LR = 2500 km. The lower limit of L*link* used to scale the objectives is L*min* = 50 km. National portion: length 30 km in access portion: The length is shorter than L*min* = 50 km, hence the value of L*link* = 50 km has been used. These values correspond to AR of 99.95% (unavailability of 263 min/year), number of events per year OI = 100 and the mean time between unavailability events Mo = 5257 min.

The length is in the range of 50-250 km. These values correspond to AR of 99.96% (unavailability of 210 min/year),

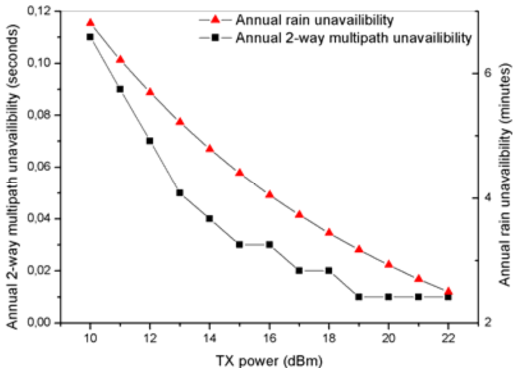

Fig. 1. Unavailability, 7 MHz bandwidth

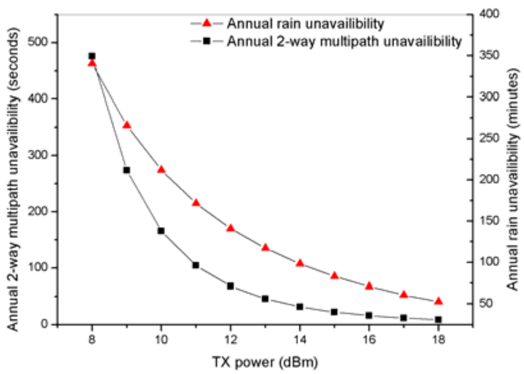

Fig. 2. Unavailability, 56 MHz bandwidth

number of events per year OI = 120 and the mean time between unavailability events Mo = 4381 min.

III. Analysis of the Unavailability

For the purpose of analysis of the influence of radiated power of transmitting antenna on the availability of the link system, two radio-relay routes have been analyzed. The relay routes are used by an internet provider, one is between Niš and Pirot and the other is between Niš and Leskovac. The first route has three hops: Niš-Kamenički vis in the range of 18 GHz, Kamenički vis-Šljivovički vrh in the range of 7 GHz and Šljivovički vrh-Pirot in the range of 18 GHz. The second route has two hops: Niš-Seličevica in the range 18 GHz and Seličevica-Leskovac in the range of 7 GHz. The paper reviews Šljivovički vrh-Pirot and Niš-Seličevica hops only, both in the range of 18 GHz.

The analysis has been performed with Pathloss 5 software packet [4], while NASA SRTM3 digital base has been used in terrain description [5]. The algorithm given in ITU-R P.350-9/14 [1] recommendation has been implemented in Pathloss 5 software. Selective fading is calculated based on equipment signature for a given radio-relay equipment made by Ceragon [6]. The signature parameter definitions and specifications of how to obtain the signature are given in recommendation ITU-R F.1093 [7]. Rain calculation method is ITU-R P.530, and specific attenuation regression coefficients are given in ITU-R P.838 [8].

The results of the analysis are displayed in Figs. 1 and 2, which display the dependencies of annual 2-way multipath and rain unavailability on the transmitter link TX power. In Fig. 1 the above mentioned dependency for 7 MHz bandwidth and QPSK modulation, which correspond to 10 Mbps bit rate can be seen, while fig. 2 displays the same dependencies, but for 56 MHz bandwidth and 256QAM modulation, which correspond to 374 Mbps bit rate.

TABLE I

UNAVAILABILITY VS BANDWIDTH AND BIT RATE

UNAVAILABILITY HOP: NIŠ - SELIČEVICA, 18 GHZ BAND **7 MHZ** BANDWIDTH			
	Mbps	Annual 2-way multipath (sec)	Annual rain (min)
QPSK	10	0.02	3.44
8PSK	15	0.03	4.22
16QAM	20	0.06	5.45
32QAM	25	0.10	6.51
64QAM	31	0.17	8.18
128QAM	36	0.31	10.38
256QAM	42	0.61	14.02
	46	0.97	17.34
14 MHz bandwidth			
	Mbps	Annual 2-way multipath (sec)	Annual rain (min)
QPSK	22	0.03	4.22
8PSK	31	0.06	5.22
16QAM	41	0.12	7.12
32QAM	54	0.17	8.18
64QAM	62	0.31	10.38
128QAM	75	0.61	14.02
256QAM	88	1.22	19.35
	97	1.72	22.93
28 MHz bandwidth			
	Mbps	Annual 2-way multipath (sec)	Annual rain (min)
QPSK	41	0.06	5.45
8PSK	58	0.09	6.22
16QAM	82	0.18	8.18
32QAM	112	0.39	11.45
64QAM	138	0.77	15.57
128QAM	170	1.72	22.93
256QAM	180	2.43	27.37
	200	4.42	37.44
56 MHz bandwidth			
	Mbps	Annual 2 way multipath (sec)	Annual rain (min)
QPSK	82	0.11	6.81
8PSK	123	0.2	8.57
16QAM	165	0.32	10.38
32QAM	222	0.71	14.77
64QAM	275	1.4	20.46
128QAM	330	2.76	29.09
256QAM	374	5.05	39.98
	414	8.71	52.64

It can be concluded from 1 and 2 that the selective fading is more pronounced at wider channel (56 MHz) and higher bit rate, and that by reducing the transmitter power the multipath unavailability increases drastically, as is the case with rain unavailability.

Table I displays a systematic analysis of annual 2-way multipath and rain unavailability dependence on bit rate for bandwidths of 7, 14, 28 and 56 MHz and QPSK, 8PSK, 16QAM, 32QAM, 64QAM, 128QAM and 256QAM modulations.

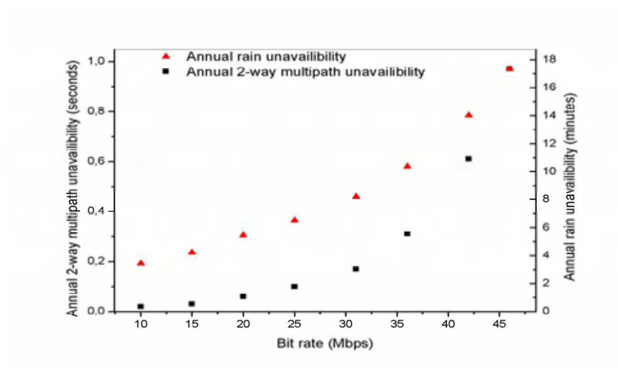

Fig. 3a. Unavailability, 7 MHz bandwidth

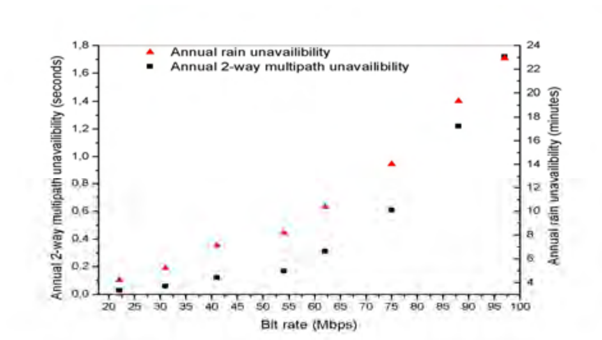

Fig. 3b. Unavailability, 14 MHz bandwidth

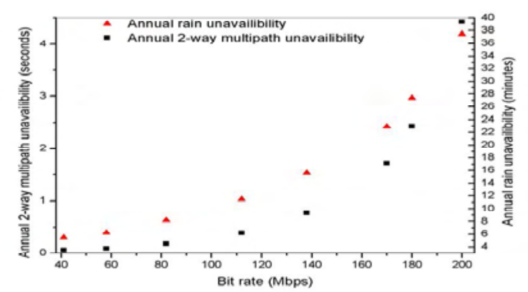

Fig. 3c. Unavailability, 28 MHz bandwidth

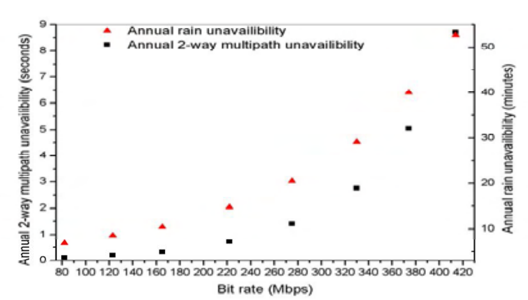

Fig. 3d. Unavailability, 56 MHz bandwidth

TABLE II
UNAVAILABILITY VS BANDWIDTH AND BIT RATE

UNAVAILABILITY HOP: ŠLJIVOVIČKI VRH – PIROT, 18 GHZ BAND **7 MHZ** BANDWIDTH			
	Mbps	Annual 2 way multipath (sec)	Annual rain (min)
QPSK	10	8.59	19.11
8PSK	15	15.27	23.72
16QAM	20	31.22	31.69
32QAM	25	50.14	39.16
64QAM	31	98.92	52.19
128QAM	36	212.57	74.67
256QAM	42	925.26	133.16
	46	885.8	160.26
14 MHz bandwidth			
	Mbps	Annual 2 way multipath (sec)	Annual rain (min)
QPSK	22	7.05	22.92
8PSK	31	16.32	28.93
16QAM	41	36.16	41.03
32QAM	54	54.1	48.67
64QAM	62	81.71	63.84
128QAM	75	202.25	97.15
256QAM	88	602.47	162.18
	97	1607.7	238.05
28 MHz bandwidth			
	Mbps	Annual 2 way multipath (sec)	Annual rain (min)
QPSK	41	8.34	29.21
8PSK	58	12.93	33.62
16QAM	82	41.28	47.21
32QAM	112	82.12	70.23
64QAM	138	224.9	108.86
128QAM	170	518.39	182.21
256QAM	180	890	253.19
	200	2451.09	407.53
56 MHz bandwidth			
	Mbps	Annual 2 way multipath (sec)	Annual rain (min)
QPSK	82	9.6	36.11
8PSK	123	17.06	45.98
16QAM	165	27.32	56.69
32QAM	222	60.4	84.75
64QAM	275	159.2	130.25
128QAM	330	461.47	217.27
256QAM	374	1430.19	371.77
	414	4719.29	643.25

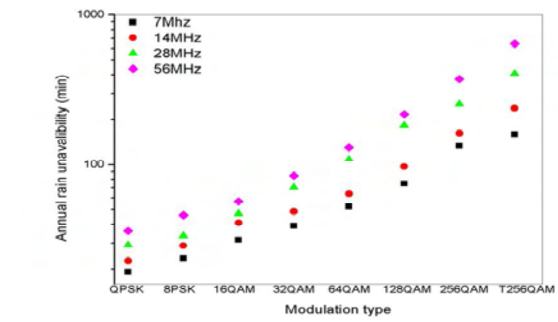

Fig. 4a. Unavailability vs. modulation

The analysis has been performed on Niš-Seličevica hop at 19 GHz frequency with vertical polarization. Hop length was 10.76 km. The results from Table I are displayed in Figs. 3a-d, and it can be noticed from them that there is a high dependency of unavailability on the bandwidth and modulation type, i.e. bit rate. These dependencies must be taken into consideration in order to enable reliable operation when links capacity is designed, since it is obvious that radio-relay availability strongly affects the operation routine. This is particularly the case with QAM modulation at high bit rates.

Table II displays the results of the analysis of multipath and rain unavailability for Šljivovički vrh-Pirot hop of length 18,76 km. The calculations have been performed at 19 GHz frequency with vertical polarization. Multipath and rain unavailability dependence on bandwidth, modulation type and

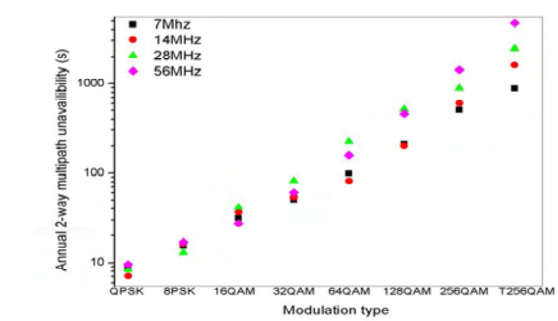

Fig. 4b. Unavailability vs. modulation

bit rate have been analyzed. Figures 4a and 4b show plots of unavailability dependence on modulation type for different bandwidths. It can be seen that by increasing bandwidths multipath and rain unavailability also increase. Multipath unavailability increase is significant at 256QAM modulation, i.e. at bit rates of several hundred Mbps, where unavailability is three orders of the magnitude higher than at QPSK modulation. As a consequence of this problem, special care must be taken when designing link connections of large capacities. The analysis of unavailability of both hops considered in this paper has shown the same dependence on bandwidth, modulation type and bit rate. This means that QPSK modulation has a lesser multipath and rain unavailability for the same bit rate, even though it uses a wider channel. This fact has to be taken into proper consideration when radio-relay connections of high reliability are designed.

IV. Conclusion

The reliability of radio-relay system due to the unavailability of link connection as a function of emitting antenna TX power, bit rate, bandwidth and modulation type has been analyzed, in purpose of study data transmission. Two link connections in the range of 18 GHz with vertical polarization have been discussed. The calculations were performed based on the algorithm defined in ITU-R recommendations with the use of a commercial software packet, while the characteristics of radio-relay equipment were given by manufacturer Ceragon for each bandwidth and modulation. During calculations of selective fading equipment signature has been used in order to determine precisely the 2-way multipath unavailability. The dependence of unavailability on the emitter TX power has been analyzed and it was shown that the unavailability drastically increases when TX power is reduced. Based on tables and figures displayed in the paper a large dependence of rain and multipath unavailability on the bandwidth can be noticed. The unavailability is significantly depended on the modulation type. The unavailability at QPSK modulation for the same bit rate and different bandwidths is considerably lesser than is the case with other types of modulation. Unavailability increases by three orders of the magnitude at 256QAM modulation in comparison to QPSK modulation. In conclusion, based on presented tables and figures, optimal equipment, which satisfies international standards, for a specific radio-relay internet connection can be designed. This can be useful for internet providing to the distance places.

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