Radiocommunication Study Groups

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PROPOSED MODIFICATION TO RECOMMENDATION ITU-R P.530-13

Outage intensity in terrestrial links due to rain

1 Introduction

Recommendation ITU-R F.1703 [1] provides availability objectives for real digital fixed wireless links, taking into account Recommendation ITU-T G.827 [2]. Among these objectives, limits are specified for the outage intensity, defined as the number of unavailability events per year. For a digital radio link, an unavailability event occurs whenever a specified bit error rate is exceeded for periods over 10 seconds.

Document 3M/27 (2010 meeting) presented a tentative empirical model for the prediction of outage intensity due to rain, based on 26 year-station data of number of fades measured in 16 terrestrial line-of-sight links in Brazil [3], Japan [4], Hungary and Norway [5]. The document is mentioned in the WP 3M Chairman's Report (Annex 3 to Document 3M/174) as a reference for future work towards the inclusion of such a method in Recommendation ITU-R P.530.

Since then, additional information was gathered from recent publications in the technical literature, including measured data from 11 year-stations (4 links) in Norway [6] and 4 year stations (4 links) in Malaysia [7].

With the now available data from different climates, including 41 year-stations from 24 links in 5 countries, the previously proposed model was refined and its inclusion in Recommendation ITU-R P.530 is proposed. This document presents the experimental data available, describes the process used to derive the experimental prediction method and examines the link margins required to comply with Recommendation ITU-R F.1703. Finally, the step-by-step procedure proposed for inclusion in Recommendation ITU-R P.530 is presented.

2 Experimental measurements

The measured results correspond to the yearly number of fades due to rain exceeding several attenuation thresholds. The main characteristics of the links where the measurements were performed are given in Table 1. The value of point rainfall rate exceeded during 0.01% of the year ($R_{0.01}$) in the link area are also given, as it is used in the modeling. For links 1 to 16 the value of $R_{0.01}$ was derived from measurements of rainfall rate at one point (usually the link reception point), concurrent in time with the rain attenuation measurements the provided the number of fades.

For links 17 to 24, from which measured data of point rainfall rate is not available, the value was obtained from Recommendation ITU-R P. 837-5.

TABLE 1

Experimental links characteristics

Country	#	Site	f (GHz)	d (km)	R0.01 (mm/h)	Pol	years
JP	1	Yotsuya	33,40	2,3	50,1	V	3
	2	Akasaka	32,60	2,1	50,1	V	3
	3	Koenji	23,20	1,2	84,4	V	2
	4	Karagasaki	15,25	9,1	66,3	V	3
	5	YRP	18,58	6,37	63,0	V	1
BR	6	Barueri	14,53	21,69	73,9	V	1
	7	Bradesco	14,55	12,79	73,9	V	2
	8	Cenesp	14,55	12,78	73,9	H	2
	9	Cenesp	18,61	12,78	73,9	H	1
	10	Parana	14,52	42,99	73,9	H	2
	11	Scania	14,50	18,38	73,9	V	2
	12	Shell	18,59	7,48	78,2	V	1
HU	14	V2	37,85	0,315	77,3	H	1
	15	Budafok	39,11	2,4	77,3	V	1
NO	16	Eidsvag	38,25	3,8	31,3	V	1
	17	Ahus	42,10	5,6	28,3	V	3
	18	Rælinger	42,10	4,9	28,3	V	3
	19	Lillestrøm	42,10	2,4	28,3	V	3
	20	Fornebu	83,50	3,45	36,0	V	2
MY	21	UTM1	15,00	0,3	101,7	H	1
	22	Indah Villa	15,00	3,96	93,6	V	1
	23	UTM2	23,00	0,3	101,7	H	1
	24	KDU	23,00	0,91	94,1	V	1

3 Number of fades and outage intensity

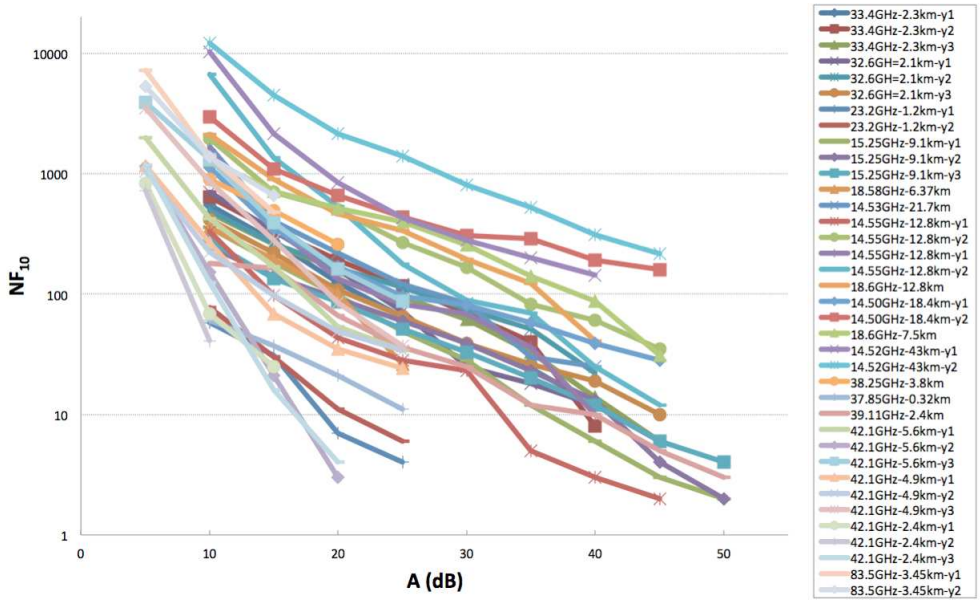
The number of fades exceeding an attenuation threshold (A) with durations longer than 10 seconds $NF_{10}(A)$ can provide an estimation of the outage intensity (OI). If the margin (M) of the link associated to a given bit error rate or block error rate (BER) is known, then

$$OI(M) = NF_{10}(A = M) \quad (1)$$

Figure 1 shows the measured values of NF_{10} *(A)* for all 41 year-station data available, just to give an idea of how of the number of fades behavior.

FIGURE 1

Yearly number of fades with duration longer than 10 s



Inspection of the plots indicates that a first degree exponential or a power-law can be used to describe the variation of the number of fades with the attenuation threshold. In the tentative model proposed previously (Doc. 3M/27) an exponential function was used. Considering the additional data now available, a power-law provides slightly better results:

$$NF_{10}(A) = aA^{-b}. \quad (2)$$

Based on the existing knowledge of the behavior of rain attenuation, it is reasonable to assume that NF_{10} depends on path length, operating frequency and polarization. Also, some statistical quantity representative of the rainfall rate characteristics in the region should be included in the prediction model.

Following these considerations, multivariable non-linear regression was used to obtain a simple empirical expression for the number of fades exceeding a given attenuation threshold. Using NF10 as the dependent variable, the independent variables included in the model were: exceeded attenuation (*A*), path length (*d*), and specific attenuation for the rainfall rate exceeded for 0.01% of the time (γ_R). The resulting expression is given below:

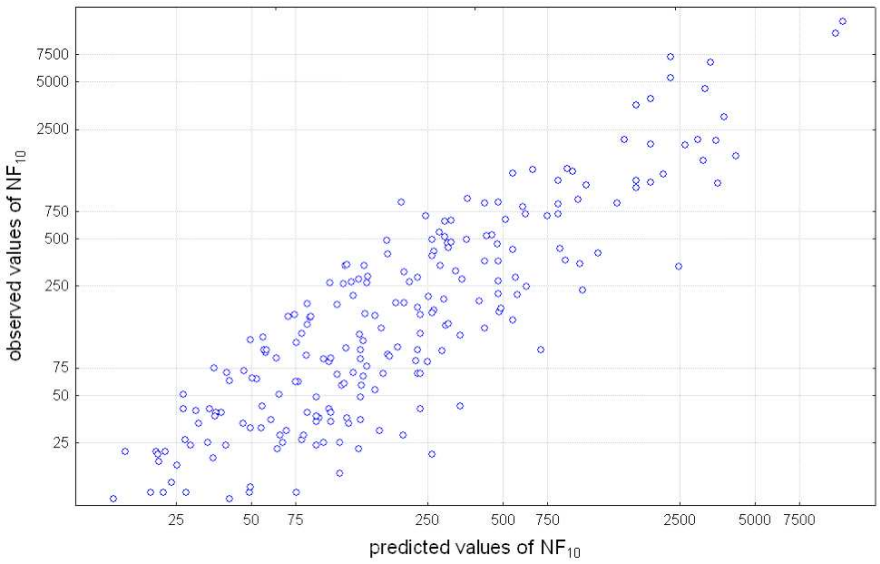
$$NF_{10}(A) = 850\,\gamma_R A^{-1.82} \quad (3)$$

The values of γ_R, which depend on operation frequency and polarization, can be obtained from Recommendation ITU-R P.838.

The scatter plot of measured versus observed values is shown in Figure 2.

FIGURE 2

Predicted vs. measured values of number of fades longer than 10 s

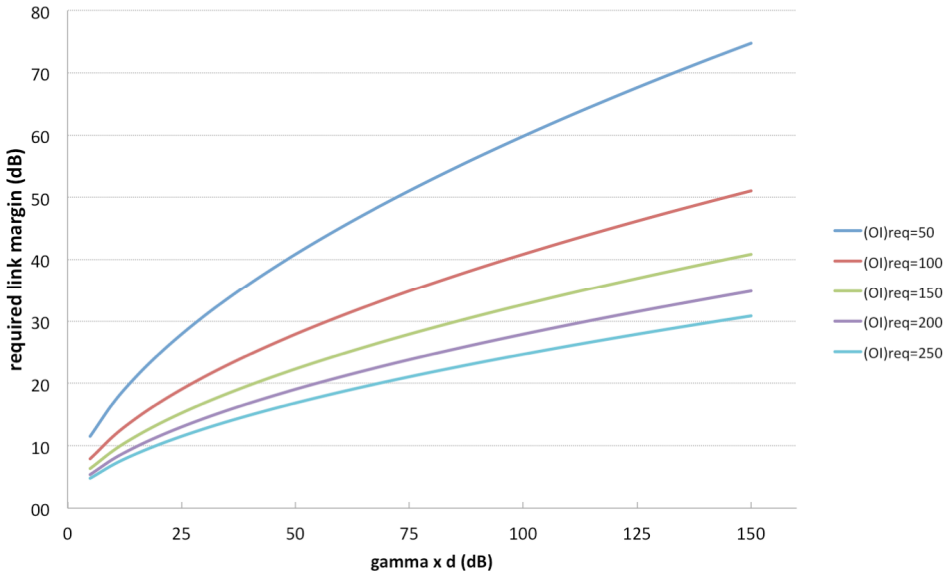


4 Single-hop link margins (example calculation)

The required margin for a single-hop link to meet the availability objectives can be easily obtained from (1) and (2):

$$M = \left(\frac{850 \gamma_R d}{OI} \right)^{0.55} \quad (4)$$

Figure 3 shows the required margin as a function of *OI* for single-hop links with different values of $\gamma_{\square} d$.



5 Proposed modification to Recommendation ITU-R P.530-13

1) Include a new Section 2.4.8 with the following:

2.4.8 Prediction of outage intensity due to rain

The outage intensity (*OI*) is defined as the number of unavailability events per year. For a digital radio link, an unavailability event occurs whenever a specified bit error rate is exceeded for periods over 10 seconds. The following method should be used for the prediction of outage intensity due to rain attenuation in a single-hop link:

Step 1: Obtain the rain rate $R_{0.01}$ exceeded for 0.01% of the time (with an integration time of 1 min). If this information is not available from local sources of long-term measurements, an estimate can be obtained from the information given in Recommendation ITU-R P.837.

Step 2: Compute the specific attenuation, γ_R (dB/km) for the frequency, polarization and rain rate of interest using Recommendation ITU-R P.838.

Step 3: An estimate of the outage intensity due to rain is given by:

$$OI(M) = 850\gamma_R M^{-1.82} \quad (58)$$

where M(dB) is the link margin associated to the bit error rate or block error rate of interest.

2) Renumber all following equations and figures properly.

References

[1] Availability objectives for real digital fixed wireless links used in 27 500 km hypothetical reference paths and connections, Recommendation ITU-R F.1703, 2005.

[2] Availability performance parameters and objectives for end-to-end international constant bit-rate digital paths, Recommendation ITU-T G.827, 2003.

[3] ITU-R input Document 3M/87, Brazil, 2009.

[4] ITU-R input Document 3M/196, Japan, 2007.

[5] ITU-R input Document 3M/171, Telenor AS, 2000.

[6] Michael Cheffena, Terje Tjelta, Tor Ove Breivik, “Fade Duration Statistics of Millimetre Wavelength Terrestrial Line-of-Sight Links”, Proceedings of the Fourth European Conference on Antennas and Propagation (EuCAP), Barcelona, Spain, 2010.

[7] Al-Hareth Zyoud, Hassan Dao, Md. Rafiqul Islam, Jalel Chebil and Khaled Al-Khateeb, “Fade Dynamics Analysis for Terrestrial Microwave Links”, International Conference on Computer and Communication Engineering, Kuala Lumpur, Malaysia, 2010.

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