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Diurnal Variability of Rainfall Rate in the Amazon Region and its Effect on the Performance of Low Availability Satellite Systems

#Jorge L. Cerqueira[1], Mauro S. Assis[2]
[1]Military Institute of Engineering, Rua Pinto Guedes 140 apt. 303 – Rio de Janeiro – RJ, 20511-320, Brazil. jlcerq@ime.eb.br
[2]Fluminense Federal University, Rua Coelho Neto 17 apt. 301 – Rio de Janeiro – RJ, 22231-110 – Brazil. msassis@openlink.com.br

1. Introduction

The evaluation of fade margin due to rain is normally based on the annual cumulative distribution of precipitation rate corresponding to the area under study. This distribution is adequate for planning high availability systems with high fade margins. The same is not true for low availability links, such as broadcast satellite services (DTH – Direct To Home) or VSAT (Very Small Aperture Terminal) systems. In a digital satellite system, the basic parameter of the link budget is the carrier-to-noise ratio (C/N) at the receiver input, which is related to the bit error rate (BER) and modulation scheme. Due to random variability of propagation factors, the C/N relation of a satellite link has to be expressed in terms of a given percentage of time it is exceeded. In general, two indicators of service performance are considered: quality and availability [1]. In the case of low availability systems these two levels can be defined as:

a) the percentage of the year or of the worst month during which the quality objective is maintained;

b) the percentage of the year or of the worst month during which the service is still acceptable (service availability).

This paper does not intend to go further into the discussion of the above performance criteria. The objective here is to highlight the importance of a deep knowledge of the rain phenomenon when planning low availability systems. In this context, based on measurements carried out in the Amazon region (equatorial climate), this paper discusses the diurnal variability of rainfall rate and its effect on the performance of satellite links.

2. Diurnal variability

Figure 1 shows the annual clock hourly rain accumulation for Belém [1^0 23’S, 48^0 26’W], Macapá [0^0 02’N, 51^0 05’W] and Cruzeiro do Sul [7^0 36’S, 72^0 40’W]. It is observed that the rain accumulation varies along the day from one location to another. At the site of Belém there is a large accumulation in the afternoon, with almost no rain during morning and night periods, while at the site of Macapá the rain is more or less uniformly distributed during the day. At the site of Cruzeiro do Sul the diurnal variability has an intermediate behaviour between Belém and Macapá, with more than one concentration peak along the day.

Depending on the service being planned, this variability may be quite important. For instance, intense rain in the morning or afternoon periods (business hours) affects commercial services. On the other hand, if the concentration of rain occurs in the evening, the prime time of TV broadcasting will be damaged. It should be pointed out that at the other sites in the region the rain distribution along the day has shown a similar behaviour.

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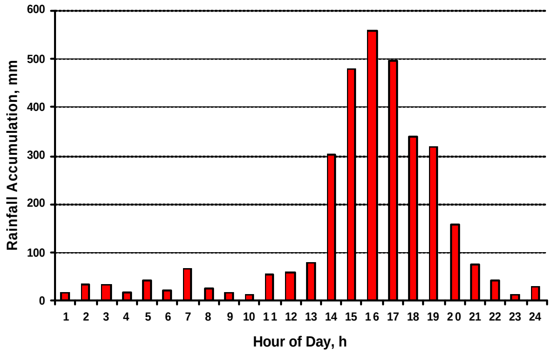
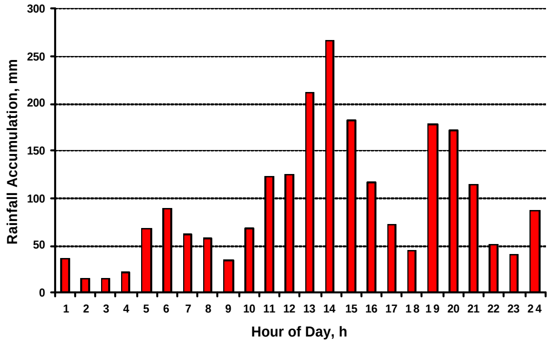


(a)



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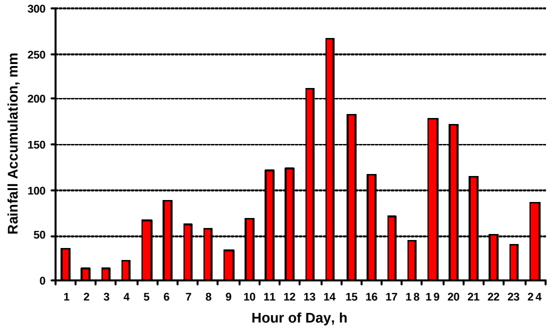


(c)

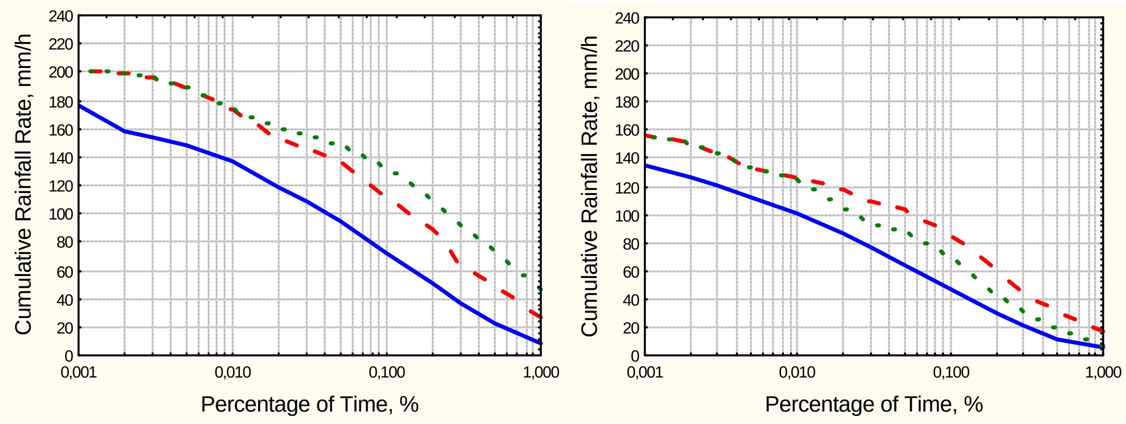
Figure 1: Annual clock hourly rainfall accumulation: (a) Belém; (b) Macapá ; (c) Cruzeiro do Sul

3. The concept of worst 2-hours period

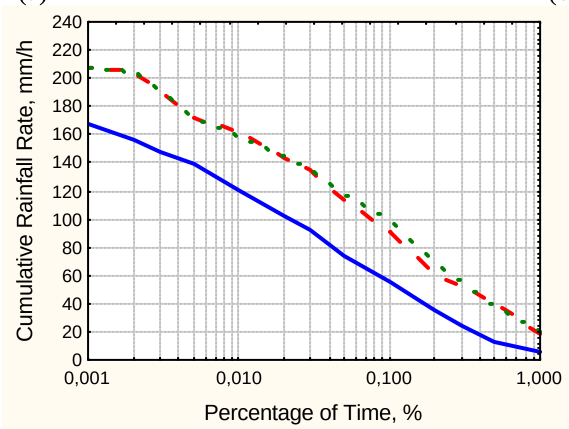
Based on the results presented in the previous Section, it seems to be advisable that, in addition to annual and worst month cumulative rainfall rate distributions, statistics of diurnal variations should be also taken into account when implementing low availability satellite systems in regions of heavy precipitation. In this context, it will be firstly introduced the concept of worst hour period. This concept is defined in a similar way as the worst month [2]: for a period of 12 months, the annual worst hour period statistics is obtained by selecting the worst performance (highest rainfall rate) among all hour periods of day at each annual occurrence level. Let X(i,j) be the rainfall rate that is exceeded in jth percentage of time in the ith hour period. Then the worst hour at level *j* (percentage of time) is determined by the highest rainfall rate X(i,j) among all 24 hours.

However, it should be mentioned that when comparing worst month and worst hour cumulative distributions, besides the rainfall distribution, the result is also affected by the number of reference intervals used in the analysis. In the worst hour analysis 24 intervals are considered, while in the case of worst month this number is reduced to 12. In order to avoid this effect, it is proposed to introduce the concept of worst 2-hours period, for which the cumulative distribution is based on 12 intervals.

Figure 2 shows the annual, worst month and worst 2-hours period cumulative distributions for Belém, Macapá and Cruzeiro do Sul. At the site of Belém (Fig. 2a), for time percentages higher than 0.01%, the worst 2-hours period cumulative distribution shows rainfall rate levels higher than the corresponding worth month levels. The opposite is observed at the site of Macapá (Fig. 2b), where higher levels of rainfall rates occur on the monthly cumulative distribution. Finally, as expected from the behaviour commented in Section 2, at the site of Cruzeiro do Sul (Fig. 2c) there is no difference between worth month and worth 2-hours period cumulative distributions.



(a) (b)



(c)

Figure 2: Annual *(full line)*, worst month *(broken line)* and 2-hours period *(dotted line)* cumulative distributions: (a) Belém; (b) Macapá ; (c) Cruzeiro do Sul

4. Practical considerations

Based on the previous results, a new concept seems to be necessary when planning low availability satellite systems in equatorial (and probably tropical) areas. An example is given in Fig. 3 for the site of Belém, having as reference the percentage of 0.3% of the worst month, corresponding to a rainfall rate of 64 mm/h (see Fig. 1a). Assuming that the evaluation of system availability is based on this rainfall rate, it can be noted in Fig. 3 that outages could be expected, in average, between 4 and 6 p.m. Increasing the fade margin of the link it is possible to avoid this problem. In the implementation of this solution, new criteria for the evaluation of system availability must be defined. The present paper proposes the introduction of the concept of worst 2-hours period and relating the system outage to the cumulative distribution of this new reference. In the above example and according to Fig. 3a, the percentage of 0.3% of the worst 2-hours period corresponds to a precipitation rate of 92 mm/h. Figure 4 shows the 2-hours period rainfall rate exceedance for Belém with this new reference (92 mm/h), being clear now that there is no outage all day long. For a typical satellite link in the 12 GHz band with an elevation angle around 50 to 70°, this rainfall rate implies in increasing the fade margin evaluated for 64 mm/h by 3 to 5 dB [3]. However, it should be pointed out that caution must be exercised when implementing this solution. Depending on system parameters, it may be proved unfeasible due to the transmitter power required. On the other hand, with this higher fade margin, the link will produce unnecessary interference most of time. An alternative is the use of some kind of fade countermeasure, such as ULPC (uplink power control) or site diversity [1]. The range of power in the ULPC device and the diversity gain will be referred to this additional fade margin.

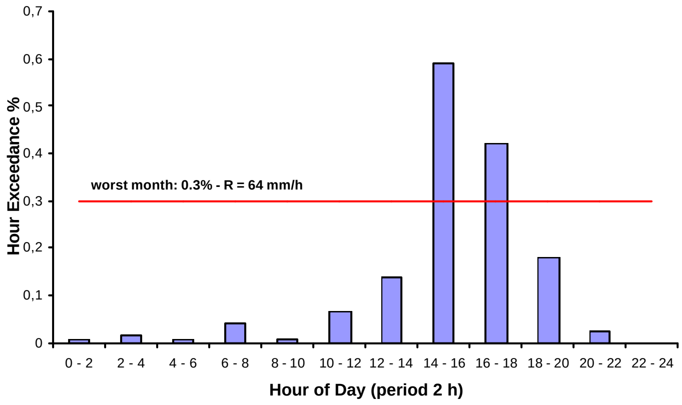


Figure 3: Annual 2-hours period exceedance for Belém (64 mm/h)

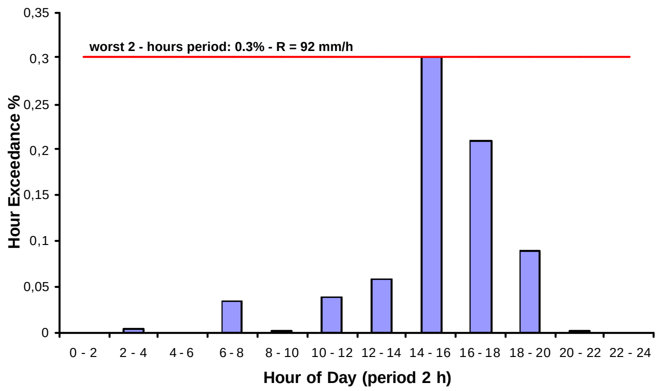


Figure 4: Annual 2-hours period exceedance for Belém (92 mm/h)

On the other hand, in the sites of Macapá and Cruzeiro do Sul the worth month cumulative distribution is adequate for evaluating system performance. Fig. 2 can be used to justify this affirmative. In Macapá it is clear that the worth month cumulative distribution is much more restrictive than the corresponding worth 2-hours period, while in Cruzeiro do Sul there is no difference between the two criteria.

5. Concluding remarks

This paper has introduced the concept of worst 2-hours period in the planning of low availability satellite systems located in regions of heavy precipitation. This means that, in addition to annual and worst month cumulative rainfall rate distributions, statistics of diurnal variation of rainfall rate should be also taken into account. On the practical point of view, the decision about the use of the worst 2-hours cumulative distributions must be based on the annual clock hourly exceedance. This point is clarified in the examples based on Belém, Macapá and Cruzeiro do Sul data. If the worst 2-hours cumulative distribution is used other mitigation techniques as UPLC and diversity gain can also be employed to improve system availability.

References:

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