MULTIPATH FADING IN LINE-OF-SIGHT MICROWAVE LINKS: VARIATION WITH LOCAL TIME AND FADE DURATION STATISTICS

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ABSTRACT

The records from line-of-sight paths have been processed to display variations of the occurrence of selected fade depths with local time. The results show that even the occurrence of shallow fading can vary with local time. However, the variations can be more impressive for deep fading. Data from one space-diversity path have also been processed to show the distributions of the number of events and the exceedance time as functions of the fade depth and the duration. The results indicate that space diversity has only effectively decreased the number and the duration of deep fade events.

INTRODUCTION

Multipath fading measurements were performed in several Brazilian links operated by Empresa Brasileira de Telecomunicações (EMBRATEL) to obtain information on propagation parameters relevant to the design of future line-of-sight microwave links. The specific objectives of the project were to extract the geo-climatic factor from worst-month cumulative distribution functions of single-frequency fading and to investigate the accuracy of available prediction models for the improvement factor of space diversity [1]. The list of selected paths, information on data analysis and the main results from this project are available elsewhere [2].

More recently, the available records from 18 line-of-sight paths have been processed to display variations of the occurrence of selected fade depths with local time. This phenomenon is frequently cited but more rarely quantified in the open literature. The well-accepted model for the prediction of the the percentage of time p_w that fade depth A (dB) is exceeded in the average worst month [1] does not consider possible variations of the occurrence of fade depths with local time.

The same data set has also been processed to display the distributions of the number and the duration of fade events for selected fade depths. This is another aspect of multipath fading inadequately discussed in the open literature, to which no consolidated prediction models are available. The effects of space diversity on these parameters will also be discussed.

It should be observed that the next sections will mainly present the results from data processing. Features that perhaps should be considered in any prediction models will only be indicated. However, results from modeling efforts will be the object of future contributions.

RESULTS

The main features of the analog paths that provided the result to be presented and discussed in this paper are shown in Table 1. Measurements on these paths have been performed for one year only. Due to this limitation on data availability, the full one-year data from each site have been used in the current analysis, instead of only the records contributing to the characterization of the worst month.

Table1. Main features of selected paths

Path	Latitude	Longitude	d (km)	f (MHz)	ε_p (mrad)
Itinga – Entroncamento	04S30’	47W30’	56.4	6123	0.18
Bela Vista – Guará	09S00’	48W30’	46.1	6123	1.20
Tiririca – Guará	09S00’	48W30’	50.4	6123	0.70
Aliança do Tocantins – Gurupi	11S25’	49W02’	49.1	6123	0.75
Toniel – Itiquira	17S13’	54W45’	46.5	6256	2.28
Buriti – Itiquira	17S13’	54W45’	51.1	6256	0.98
Bonsucesso – Jataí	17S46’	51W40’	44.2	4730	0.59 (P) 0.81 (D)

The results from the first four paths in Table 1 are displayed in Figure 1.

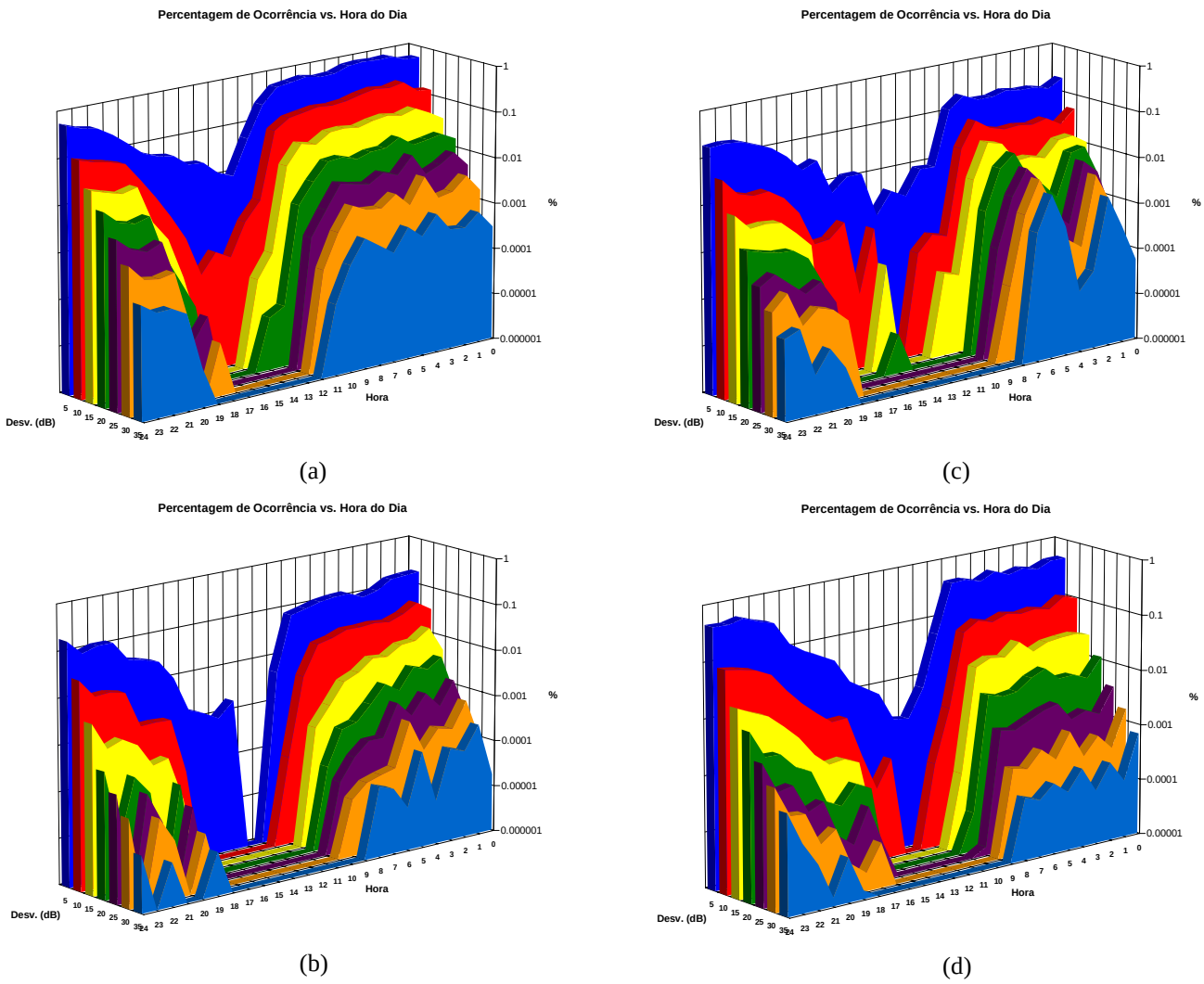

Fig 1. Percent occurrence of fade depths as a function of local time on the following paths: (a) Aliança do Tocantins – Gurupi; (b) Itinga – Entroncamento; (c) Bela Vista – Guará; and (d) Tiririca – Guará. Front scale: local time in 1h intervals from 0 h (right) to 24 h (left). Depth scale: fade depth in 5 dB intervals from 5dB (back) to 35 dB (front). Vertical logarithmic scale: percentage in powers of 10 from 1.0 (top) to 0.000001 (bottom).

These results show that even the occurrence of the more frequent shallow fading (5 dB to 10 dB) can vary with local time (decrease of one order of magnitude or more around noon as compared with the occurrence during late night hours). The variations of the occurrence of deep fading (25 dB or more) with local time are more dramatic (decrease of several orders of magnitude around noon as compared with the occurrence during late night hours). It is also interesting to observe the features of two distinct periods. The first period, characterized by high occurrence of multipath fading, begins around sunset and lasts from 14 hours to 18 hours. Consequently, the second period, characterized by low occurrence of multipath fading, is relatively shorter. It also seems that two transitions between these periods could be asymmetric. Indeed, the results corresponding to shallow fading and those corresponding to the path Tiririca–Guará in Fig.1(d) shows the transition around sunrise is sharper than the one around sunset. In addition to the main behavior describer above, one should observe the possibility of short-term fluctuations in the dependence of the occurrence of deep fading (25 dB or more) with local time, such as those in the post-midnight hours in Fig. 1(c) (Bela Vista–Guará path).

It is also important to note that the features indicated in the previous paragraphs are not present in the data from all the paths. For example, the results from the paths Toniel–Itiquira and Buriti–Itiquira in Fig. 2 show a relatively flat variation of the percentage of occurrence of fade depths (less than or equal to 25 dB) with local time. The features indicated in Fig.1 are only present for deeper fades, but in a less evident way. Therefore, it necessary to identify the causes for the different behaviors displayed in Figs. 1 and 2 before a successful model can be developed.

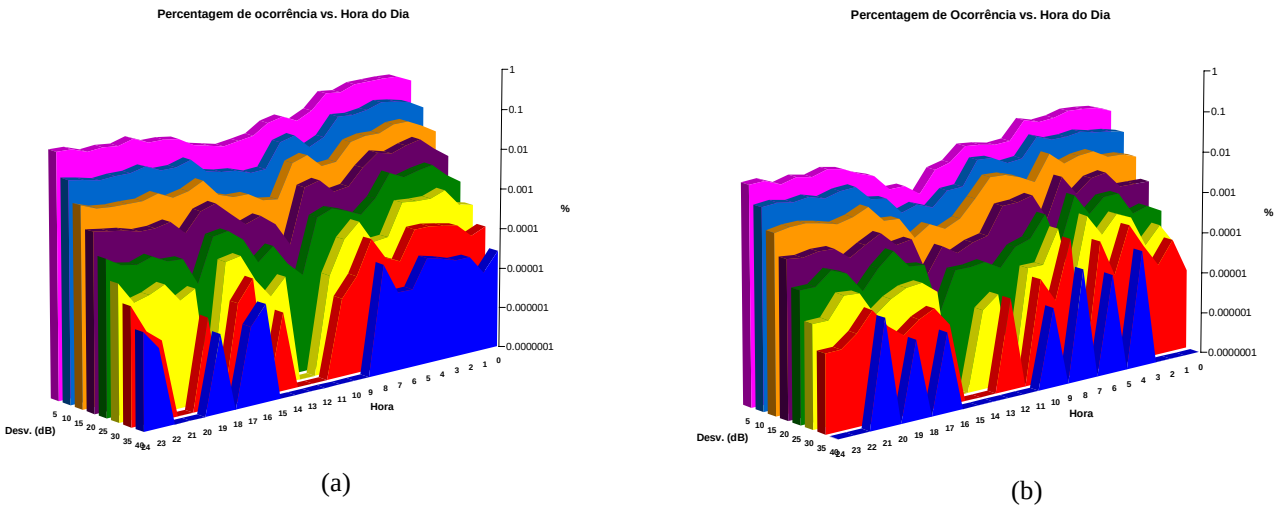

Fig 2. Percent occurrence of fade depths as a function of local time on the following paths: (a) Toniel–Itiquira; (b) Buriti–Itiquira. Same scales as in Fig. 1, with the additional fade depth of 40 dB.

Fig. 3 shows the distributions of the number of events and the exceedance time (s) as functions of the fade depth (dB) and the duration (s) [3] on the path Bonsucesso-Jataí indicated in the last line of Table 1, which operates with space diversity. The decrease of the number of events and the exceedance time with both the fade depth and the duration is evident, particularly for fade depths greater than or equal to 10 dB. A comparison between Figs. 3(a) and 3(c), as well as between Figs. 3(b) and 3(d), respectively, indicates that, in this particular example, space diversity has only effectively decreased the number and the duration (consequently, also the exceedance time) of fade events deeper than 20 dB. This is an indication that shallower fades simultaneously affected the principal and the diversity paths.

CONCLUSION

The records from line-of-sight paths have been processed to display variations of the occurrence of selected fade depths with local time. The results have show that even the occurrence of shallow fading can vary with local time, but that the observed variations can be more impressive for deep fading. It is important to note that these variations are not present in the data from all the paths. Therefore, successful models for this phenomenon should be able to predict the results displayed in both Figs. 1 and 2 from the path parameters, as well as from terrain and climatic information. Data from one space-diversity path have also been processed to investigate how fast do the number of events and the exceedance time decrease as functions of the fade depth and the duration. The results have also indicated that space diversity has only effectively decreased the number and the duration of deep fade events.

It may be important to have results such as these incorporated into prediction models of multipath fading. These models could be useful in the design of new microwave line-of-sight paths and in interference calculations. It should be noted that these paths would be more robust to interference during hours when they do not experience fading. Therefore, models that are able to predict the features described in this paper would have a potential to facilitate sharing between systems in the fixed service and new systems in other services with busy hours coinciding with the unfaded hours line-of-sight paths. One such new system is the short-message satellite communication system between vehicles and central stations operating in the C band.

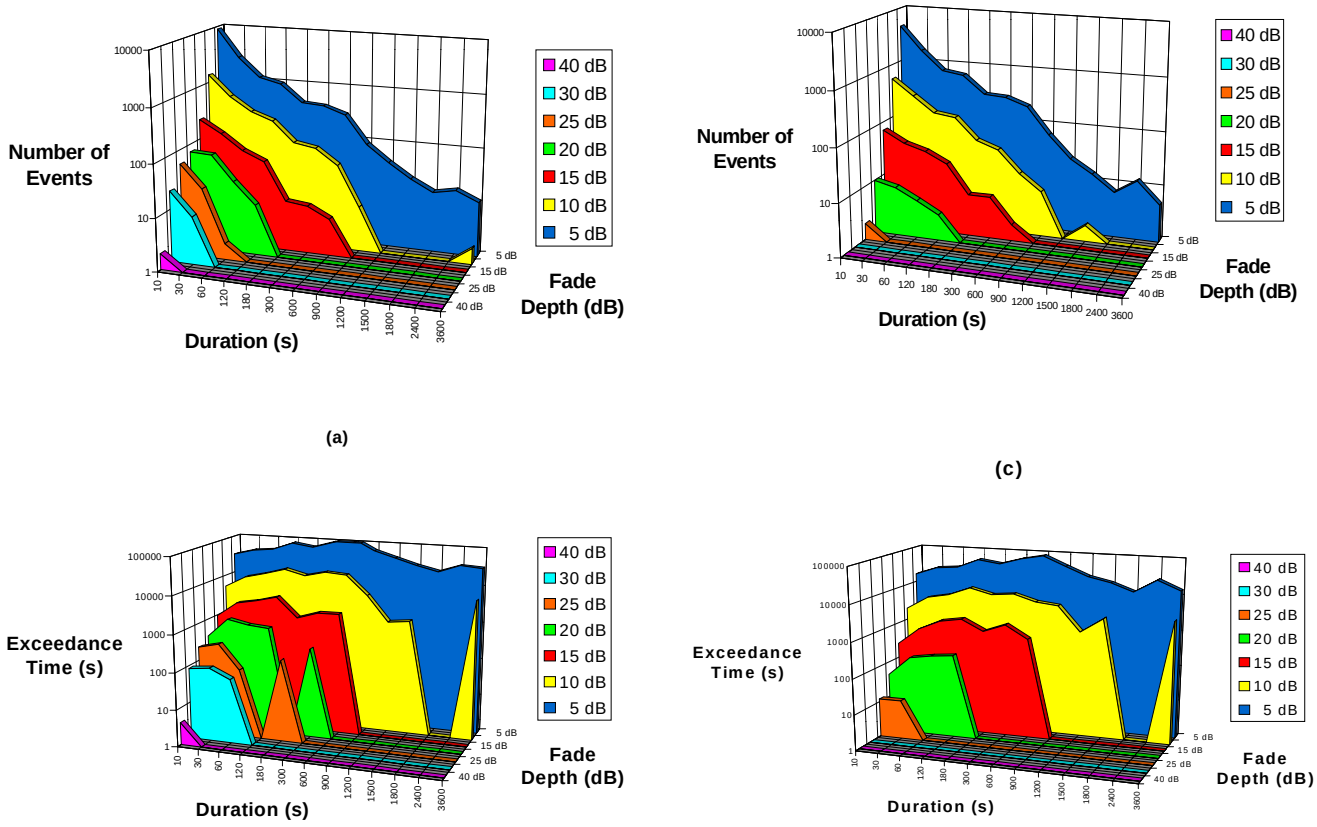

Fig 3. Number of events and exceedance time as functions of fade depth (dB) and duration (s) on the path Bonsucesso-Jataí: (a) number of events in the principal channel; (b) exceedance time in the principal channel; (c) number of events resulting from space diversity; and (d) exceedance time resulting from space diversity. Front scale: duration of 10 s, 30 s, 60 s, 120 s, 180 s, 300 s, 600 s, 1200 s, 1500 s, 1800, 2400 s, and 3600 s (left to right). Depth scale: fade depths (dB) also shown in the legends. Vertical logarithmic scales: number of events in powers of 10 from 1 (bottom) to 10000 (top) and exceedance time in powers of 10 from 1 s (bottom) to 100000 s (top)

REFERENCES

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