Comparison of the outage probabilities of some prediction methods with the observed probability of a digital microwave link in western India

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Received 20 November 1997; revised received 26 June 1998

Multipath fading is the major debilitating factor affecting the performance of digital microwave links operating below 10 GHz. The performance of a digital microwave link situated in western India has been investigated and the observed probability of outage deduced from the measurements has been compared with the outage probabilities predicted by various methods to find out a suitable prediction method for this region.

1 Introduction

Clear air phenomena like multipath fading, scintillations, defocussing and reflections from layers affect the performance of digital microwave line-of-sight links operating below 10 GHz. The available data on the effects of multipath fading on digital microwave links from this country are very meagre and the present study tries to fill this gap. Several remedial measures like antenna pattern diversity, adaptive equalizers, switching diversity have been tried by various workers to overcome the fading. In this paper, the performance of a digital microwave link situated in western India has been investigated and the observed probability of outage deduced from the measurements has been compared with the outage probabilities predicted by various methods to find out a suitable prediction method for this region.

2 Experimental details

In the present study propagation measurements were conducted over a high capacity (68 Mb/s) digital microwave link operating at 8 GHz with 8-psk modulation in western India for 44 days. The link is situated on an inclined path with a path inclination of 15.25 m rad over a path length of 48 km. Calculations show that reflection point falls on the Arabian Sea. The system is equipped with adaptive equalizers and has no provision for any type of diversity. The data consist of received carrier level sampled at every second, bit error rates (BERs), severely error seconds (SEs), error seconds and error free seconds. The signal level refers to the carrier level. Measurements of linear amplitude dispersion were also carried out. The amount of dispersion is expressed in terms of linear amplitude dispersion (also known as in-band power difference) which is defined as the peak-to-peak difference in the attenuation measured in decibels across the frequency band. ITU-R (Ref.3) uses this parameter to compare the dispersiveness of various radio hops at different locations. Radiosonde data of India Meteorological Department were also obtained for the same period as that of radio measurements. The radiosonde data correspond to the receiving site, viz. Bombay, and the transmitter is situated in a hilly place known as Matheran.

3 Results

During the period under study, 123 severely errored seconds (SEs) and 181 error seconds were observed. The diurnal variation of SEs shows that the highest number occurred between 0500 to 0600
hrs and 2000 and 2100 hrs. During daytime moderate values were observed. An investigation of meteorological conditions was also carried out by analysing the radiosonde data collected at the receiving site. Initial refractivity gradients deduced from radiosonde data have shown reasonably good correlation with the bit error rates (BERs). An attempt was also made to correlate the diurnal variation of BERs with the diurnal variation of the surface-based layers observed by an acoustic sounder situated at Bombay. Since acoustic sounder data corresponding to the same period of radio measurements were not available, data of the year 1987 were taken. In the absence of concurrent data, it is customary and accepted practice in the field of tropospheric radio wave propagation to compare with statistically significant samples of available data. The good correlation between BERs and surface-based layers and BERs and initial refractivity gradients show that high BERs or a large number of SESs observed are due to surface-based layers prevailing at late evening or early morning hours. Due to high path inclination of the link, elevated layers caused by sea and land breeze did not contribute to the multipath fading.

4 Prediction of outage probability

The total time that BER exceeds the value of $10^{-3}$ is called outage and the probability of BER $>10^{-3}$ obtained from the data is the observed value of outage probability. The outage probability deduced from the experimental data was compared with the predicted probabilities of outage from the methods of Serizawa and Takeshita, Di Zenobio, Campbell et al., Lavergnat et al., Lundgreen and Rummel, general three-path model, and Chao and Lui. This is the first time this type of exhaustive study has been carried out from this region to identify a suitable prediction method.

The methods of Serizawa and Takeshita and Di Zenobio are based on the linear amplitude dispersion. The former method takes into account the linear amplitude dispersion, whereas the latter method is an extension of the former method as it takes into account the quadratic dispersion as also the occurrence of a notch frequency lying strictly within the band. It is then combined with the formulae of Serizawa and Takeshita and a final formula is developed by incorporating the multipath fade occurrence factor. Campbell et al. have used a two-ray model which has found wide application in narrow band channel modeling. The outage is calculated on the basis of equipment signature concept. In the three-ray model the amplitude of direct ray is taken as unity with zero delay. The amplitudes and delays are used to find frequency correlation coefficient between powers at two frequencies which in turn is utilized to find probability of outage with the help of threshold value of linear amplitude dispersion. In the method of Lavergnat et al., a statistical two-ray propagation model with the parameters and the associated joint probability distribution of these parameters is employed to account for the selectivity of atmospheric medium. The physical parameters that are considered to influence multipath are path length, frequency, bandwidth, altitude and slope of radio path, roughness, antenna lobe aperture, and other meteorological parameters grouped under the heading "climatic factor". The method of Lundgreen and Rummel is based upon a statistical channel model developed from measurements on a 6 GHz unprotected link operating on 8-psk system due to selective fading. The method of Chao and Lui, in which Jakes approach is modified for calculating outage probability, is based on a two-ray model in terms of carrier frequency, path length, modulation scheme, etc.

Table 1 shows the comparison of the observed probability of outage with the outage probabilities predicted by different methods. The table depicts that outage probability calculated by Di Zenobio's method comes closest to the observed value followed by that calculated by the method of Campbell et al. The method of Serizawa and Takeshita deviates by two orders of magnitude.

<table>
<thead>
<tr>
<th>Method</th>
<th>Outage probability</th>
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<tbody>
<tr>
<td>Di Zenobio</td>
<td>$1.627 \times 10^{-6}$</td>
</tr>
<tr>
<td>Serizawa and Takeshita</td>
<td>$3.855 \times 10^{-4}$</td>
</tr>
<tr>
<td>Campbell et al.</td>
<td>$1.291 \times 10^{-7}$</td>
</tr>
<tr>
<td>Chao and Lui</td>
<td>$6.086 \times 10^{-10}$</td>
</tr>
<tr>
<td>Lundgreen and Rummel</td>
<td>$1.600 \times 10^{-3}$</td>
</tr>
<tr>
<td>General 3-path model</td>
<td>$4.320 \times 10^{-4}$</td>
</tr>
<tr>
<td>Lavergnat et al.</td>
<td>$3.170 \times 10^{-3}$</td>
</tr>
<tr>
<td>Observed value</td>
<td>$5.560 \times 10^{-6}$</td>
</tr>
</tbody>
</table>
from the observed value. The outage probabilities deduced from other methods deviate appreciably from the observed value. It seems the methods based on linear amplitude dispersion are more suitable in this climatic zone. This is explained as follows. Digital systems are affected by frequency-dependent attenuation (amplitude dispersion) leading to what is known as dispersive fading. The ability to estimate the seasonal and geographical variation of dispersive fading and the accurate knowledge of the meteorological causes of dispersive fading help not only in improving the performance of existing digital radio systems but also in designing more reliable systems. As mentioned earlier, the occurrence of elevated layers and ground-based layers in this region is very high due to various meteorological phenomena like advection, subsidence, etc. These layers lead to dispersive fading. Since dispersiveness is accounted by linear amplitude dispersion, methods based on this concept are more suitable in this climatic zone. The advantage of this method is simplicity and easy applicability.

The LOS links situated in this zone, both analog and digital, are mostly affected by dispersive fading and are not degraded by flat fading. The outage values deduced from the Lundgreen and Rummiller's method are not even closer to the observed values in this link. In fact most of these methods have overestimated the outage probability and one reason for this deviation could be that they are more suitable for estimating outage probability in high capacity digital systems.

5 Conclusions
The high BERs and high SESs occurring in the early morning and late evening hours are due to ground-based super-refractive layers occurring in the region. The outage probability deduced from the Di Zenobio's method is in close agreement with the observed probability followed by that deduced by the method of Campbell et al. This study is based on whatever data are available and gives some insight into the selection of outage prediction methods for designing digital microwave links in this region. The accuracy of these methods can be improved if the multipath fade occurrence factor used in the methods of Serizawa and Takeshita and Di Zenobio can be replaced by the equation developed from the data of line-of-sight links operating in the same climatic conditions. This parameter is dependent on frequency, path length and meteorological conditions. Large data base of LOS links operating in the same region with similar characteristics is required for the development of this parameter. At present such large data base is not available with any group in the country and its generation can be done by the operating agencies of line-of-sight microwave links like Department of Telecommunications, Railways, etc.

References