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Microwave Propagation Characteristics over Hilly Terrain

D NARAYANA RAO & M J KESAVA MURTHY*
Department of Physics, S V University, Tirupati 517 502
and
S K SARKAR, H N DUTTA & B M REDDY
Radio Science Division, National Physical Laboratory, New Delhi 110 012

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Microwave propagation characteristics over hilly terrain situated in southern India have been presented. Amplitude measurements at 7.6 GHz were made round the clock during Mar. 1981-Apr. 1983 using an operational communication link The daytime signal is characterized with fast and small amplitude fluctuations of the order of 2-3 dB, while during night and early morning large amplitude variations, sometimes as high as 20-25 dB, are observed. High fade rates have been observed to be dominant during premonsoon months. The distribution of fade rates indicates that during monsoon and post-monsoon the fade rate is 30-40 (fades) per hour and the fade rate is 150 per hour in premonsoon, while it is 90 per hour in winter.

1 Introduction

Tropospheric microwave communication is essentially affected by three modes of propagation, namely (i) line-of-sight (LOS), (ii) diffraction and (iii) troposcatter. The LOS propagation mechanism can be explained on the basis of ray optics. The LOS received signal is a geometrical combination of direct ray and ground reflection with a possible contribution from scatter, etc.

A study of the propagation characteristics over hilly areas is particularly important especially in India as it is surrounded by high mountains in the northern and north-eastern borders and the eastern and western ghats cover almost the entire southern coast of the peninsula. Unlike in plain areas, the mathematical formulation due to multiple diffractions and scatter becomes highly complex and one is left with no choice except to use actual propagation data to empirically arrive at the optimum design considerations for new links.

The predominance of any particular microwave propagation mode depends upon the path geometry, radio frequency and the structure of radio refractive index fluctuations of the medium. The characteristics of propagation are determined by the dominant mechanism of propagation. According to homogeneous turbulence theory, field strength relative to free space is characterized by $\lambda^{-1/3}$ laws[1], λ being the wavelength. On the other hand, according to reflection theory, wavelength dependence varies from λ^2 to λ^0 depending upon the layer dimension, wavelength and geometry[2,3]. When the characteristics of propagation in terms of medium field strength, fade depth, fade rate, etc. are known and association of refractive index fluctuations and wind velocity component along the propagation path are determined, it is possible to predict the characteristics of fading patterns from a knowledge of meteorological parameters.

The LOS microwave amplitude measurements at 7 GHz were made round the clock from Mar. 1981 to Apr. 1983 using an operational communication link (of the Posts and Telegraphs Department, Government of India) between Tiruttani and Tirupati situated in the southern part of India. Refractivity and wind information have been obtained from the India Meteorological Department, Madras. The field strength data have been analyzed in terms of hourly median field strength, average fade depth, fade rate, etc.

During daytime the signal is characterized with small amplitude fluctuations while in the late night and early morning rapid and large amplitude variations, sometimes as high as 20-25 dB, are obtained. The deep fades are usually associated with large refractivity gradients. The fade rate determined from the microwave amplitude variation is found to be 300 under turbulent conditions and the fade rate is lower during layered conditions.

2 Terrain Characteristics

The LOS microwave link of Post and Telegraphs Department, Government of India, is situated between Tirupati (lat., 13°39′N; long., 79°22′E) and Tiruttani (lat., 13°11′N; long., 79°38′E) over a path length of 60 km. The field strength measurements of this link were recorded at Tirupati as the receiving terminal. The height of the transmitting antenna at Tiruttani from the ground is 50 m and the receiving antenna at

*Present address: Department of Physics, SVUPG Centre, Kurnool 518 001

Tirupati is situated on a hill of height 900 m. The terrain profile of microwave link is shown in Fig. 1. It is evident from the terrain profile that a major portion of the propagation path falls over hilly area with several hills in between the receiving and transmitting terminals. Some of the major ones are at a distance of 20, 35 and 42 km from the transmitting end (Tiruttani). The system characteristics of Tiruttani-Tirupati microwave link are as follows.

Frequency	7.659 GHz
Transmitting antenna	Parabolic dish with horn feed
Gain of transmitting antenna	40 dB
Receiving antenna	Parabolic dish with horn feed
Gain of receiving antenna	40 dB
Transmitted power	1 W
Recorder time constant	300 msec

3 Data Base

The data analyzed for this study comprise a total of 11864 hr during the period Mar. 1981-Apr. 1983. The data have been studied for both diurnal and seasonal behaviour. The seasons have been classified as pre-monsoon (March, April and May), monsoon (June, July, August and September), post-monsoon (October and November) and winter (December, January and February) for the purpose of the present analysis. The microwave field strength observations used in this study were recorded using a pen recorder with a time constant of 300 msec. Radiosonde observations were also obtained from the India Meteorological Department, Madras. The radiosonde observations are available for 0000 and 1200 hrs GMT corresponding to early morning and late evening hours of local time.

4 Distribution of Field Strength

The average signal level is expressed in terms of median field strength. It is defined as that which is exceeded during a half of the reception time. The median field strength gives an idea about the average level of the signal but does not show how deep the fading is. The median field strength is measured in dBμV.

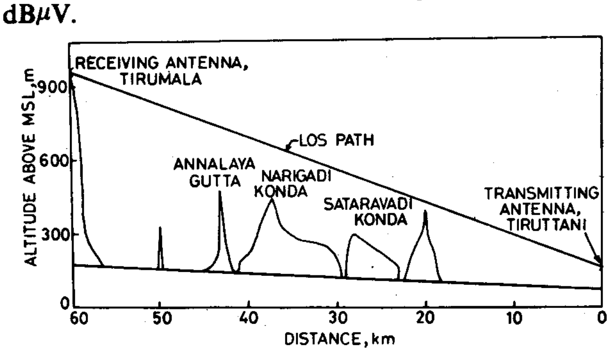

Fig. 1—Terrain profile of the microwave link between Tiruttani and Tirupati

The average diurnal variation of median field strength for Tiruttani-Tirupati microwave link for all the months is shown in Fig. 2. It is seen that the field strength is of the order of 35 dBμV from 0600 to 0800 hrs IST, and during 1200-1800 hrs IST, the field strength is steady at 40 dBμV. During nighttime, the median signal level is found to decrease marginally by 2 dB from the daytime steady level of 40 dBμV.

The behaviour of the median signal level for different seasons has been studied and is shown in Fig. 3. It is seen that in post-monsoon both during day and nighttime there is no appreciable change in the signal level. However, in the premonsoon months appreciable difference has been found to exist between daytime and nighttime signal levels. During nighttime the signal level is of the order of 35 dB and it reaches a value of 40 dB around noon. The median signal level, however, is the lowest around early morning hours (0600-0800 hrs IST) and is of the order of 32 dB. The high noontime values usually persist up to 1800 hrs LT.

The cumulative probability distribution of median field strength is shown in Fig. 4. At 90% probability level, the signal strength is 27 dB in the pre-monsoon months while for other seasons it is 35-36 dB.

5 Fade Rate Characteristics

Fade rate of microwave signal is an important characteristic to define the size of atmospheric

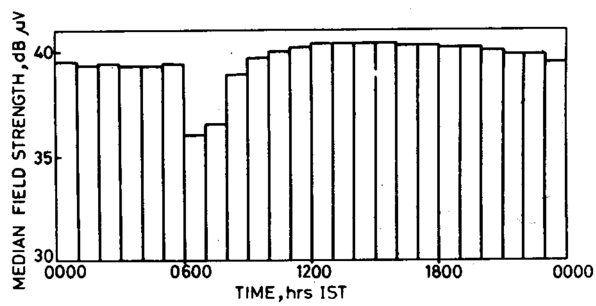

Fig. 2—Diurnal variation of median field strength observed during all the months (1981-83)

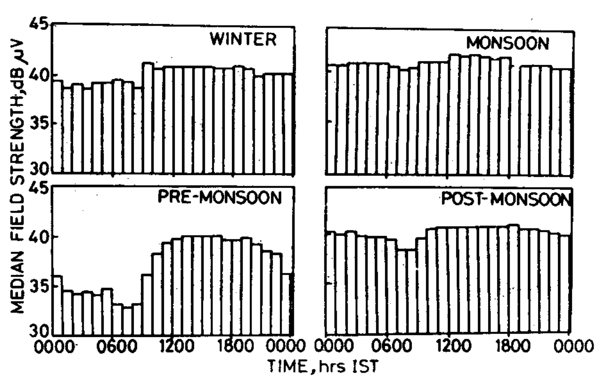

Fig. 3—Diurnal variation of median field strength observed during different seasons

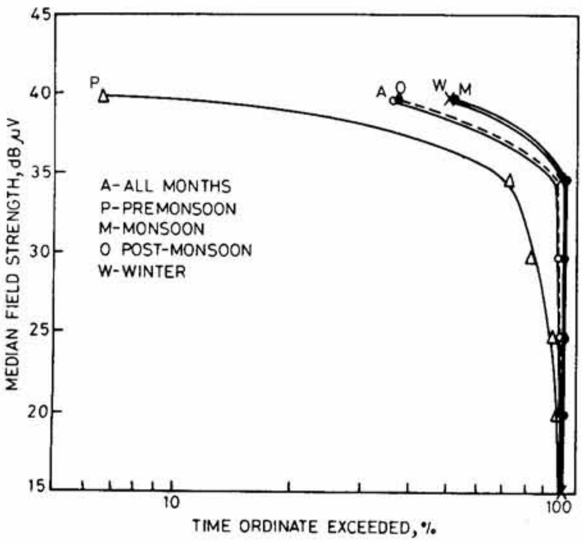

Fig. 4—Cumulative distribution of median field strength

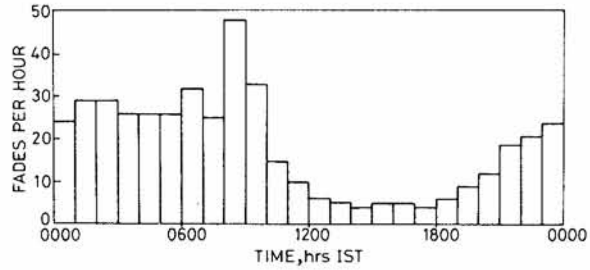

Fig. 5—Diurnal variation of fade rate observed during all months

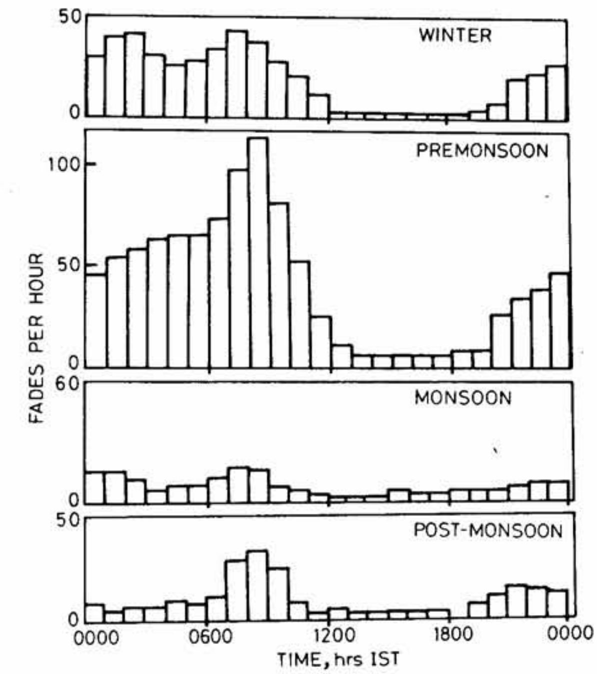

Fig. 6—Diurnal variation of fade rate observed during different seasons

irregularities since it limits the digital data transmission rate[4,5]. The rate of fading is usually determined by counting the intersections of the median signal level and is expressed as number of fades in a desired time interval. The fade rate observed over Tiruttani-Tirupati LOS microwave link at 7.6 GHz has been found to vary from 1 to 500 fades per hour.

The variation of fade rate observed during 24 hr is shown in Fig. 5. By presenting the average fade rates the short term fluctuations are smoothed out. Fig. 5 shows that the nighttime fade rate from 2100 hrs to about 0700 hrs is much higher than the daytime fade rate. However, during transition hours, i.e. during 0700-1000 hrs the fade rate is very high exceeding the nighttime fade rate. A rapid fall in fade rate starts at about 1000 hrs and from 1900 hrs the fade rate again rises steadily. The fade rate during nighttime reaches a maximum at around 0100 hrs and continues to be high till sunrise. The high fade rate observed during morning transition hours is due to unstable atmospheric conditions that prevail in those hours[6]. The layered structures that dominate during nighttime start depleting as the solar radiation heats the earth's surface. During nighttime fade rates are high which may be due to multipath propagation modes that are present because of the layer structure of the atmosphere[7-12]. The low fade rate observed during daytime is due to the well mixing of the atmosphere.

Seasonal distribution of fade rate is presented in Fig. 6, which reveals that there is not much variation in the fade rate during the monsoon and post-monsoon months when the atmosphere is supposed to have a low degree of stability. During these periods the diurnal variation in the fade rates is between 2 and 35, the maximum fade rate being around 0800 hrs and minimum during 1200-1900 hrs. During premonsoon months, the diurnal variation is much higher, the fade rate around 0800 hrs being of the order of 120 fades per hour and from 1200 to 1900 hrs being 5 fades per hour. The difference between the fade rates occurring during daytime and nighttime is appreciably large during the premonsoon months. The results indicate that during premonsoon in the nighttime, the atmosphere is fairly stable while during daytime it seems that the plume structure is dominant. In winter months, the fade rate observed during nighttime is 40 per hour while during daytime it is only 2 per hour. The fade rates observed in the winter season are considerably higher than both during monsoon and post-monsoon, but lower than during the premonsoon.

Seasonal cumulative distribution of fade rate is shown in Fig. 7. At 10% probability level, the fade rate is 150 per hour for the pre-monsoon season and 90 per hour for the winter months while during the monsoon and post-monsoon periods the fade rate is of the order of 30 to 40 per hour.

6 Fade Depth

Fade depth is defined as the difference between the maximum and minimum field strengths over a very small interval of time. The atmospheric conditions vary diurnally and also from season to season. It is, therefore, evident that fading of different magnitudes exists during different seasons. The diurnal variation of fade depth observed during different seasons is presented in Fig. 8. Fig. 8 shows that during winter, the fade depth observed from 1000 to 2000 hrs is almost of negligible magnitude while the fade depth is 3 dB in the early hours of the day. An average fade depth of about 2 dB is observed in the nighttime.

During the premonsoon months, average fade depth of 5 dB is observed from 0600 to 0700 hrs while fade depth of the order of only 1 dB is observed between 1200 and 2000 hrs. During nighttime, the average fade depth is 3-4 B. However, fade depth as large as 25 dB has been observed on several occasions during morning transition hours especially in the months of February and March. A few records with such large fade depth are shown in Fig. 9.

Diurnal variation of average fade depth observed during the monsoon period (Fig. 8) indicates that from 0700 to 0900 hrs the average fade depth is 2 dB and during the rest of the day, the average fade depth is almost negligible. The fade depth observed during nighttime in the post-monsoon is found to be 1 dB while it is almost negligible during the daytime.

The cumulative distribution of fade depth observed during all the months and in different seasons presented in Fig. 10 reveals that during premonsoon and winter seasons, for 1% of time, the

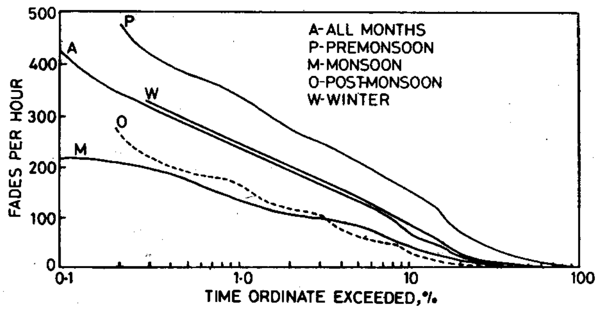

Fig. 7—Cumulative distribution of fade rates

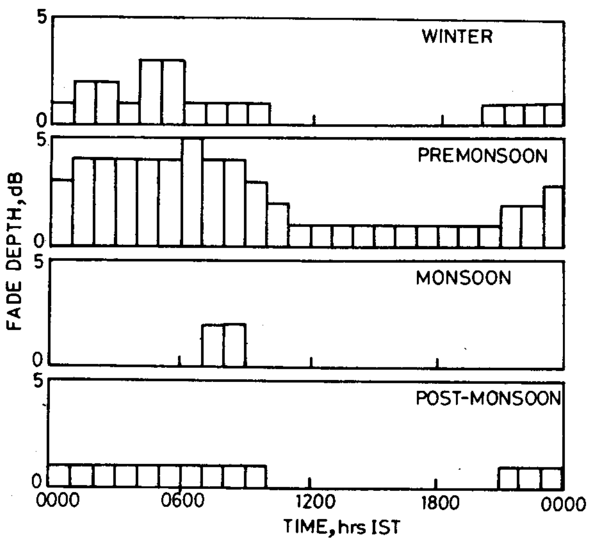

Fig. 8—Diurnal variation of fade depth observed during different seasons

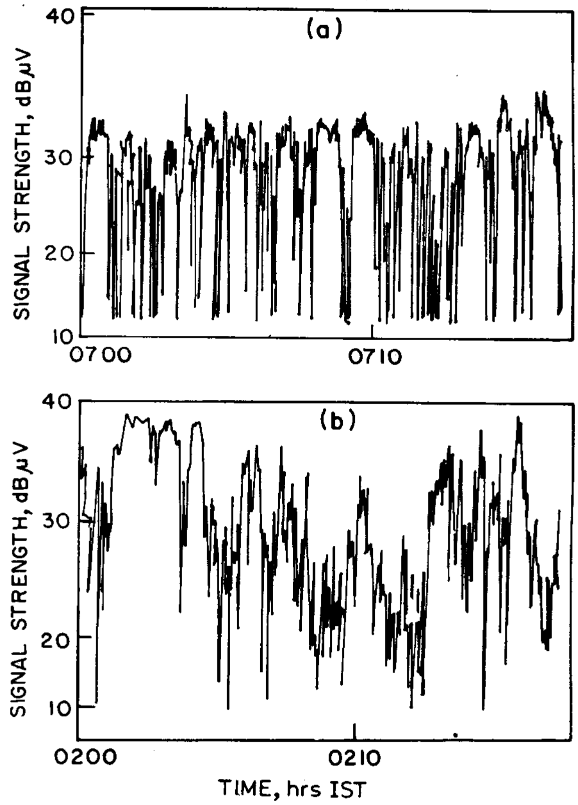

Fig. 9—Typical records of large fade depth observed [(a) for 3 Mar. 1983 and (b) for 16 Feb. 1982]

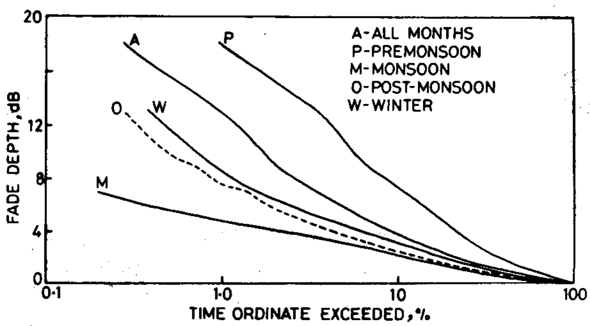

Fig. 10—Cumulative distribution of fade depths

fade depth is more than 18 and 10 dB, respectively, while for the monsoon and post-monsoon months, at 1% level, the fade depth is 5 and 7 dB, respectively. At 90% level, the fade depth is more than 1 dB for all the seasons. Fig. 10 also indicates that the variation of fade depth between 90 and 10% is more in the premonsoon and winter months than in the monsoon and post-monsoon seasons. During the entire period of observation fades with a depth of 1 dB were observed for 90% of time, while for 1% of time fades with 13 dB and more were observed.

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