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Multipath effects on a line-of-sight microwave link

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The effects of multipath in relation to the deteriorated performance of a microwave communication link situated between Guntakal and Adoni over the Indian southern region have been investigated. The received signal level under normal condition is usually found to be around −60 dBm. The performance of the link is satisfactory when the signal level is equal to and greater than −74 dBm, which is the satisfactory level of the signal. It has been seen that the link performance starts deteriorating when the signal level reduces to as low as around −75 dBm. The most problematic months during which the performance of the radio link is not up to the satisfactory level are found to be from November to May. The peaks of the disturbances are in the months of February through May. The performance of the link has been found to be disturbed during 2300-0800 hrs LT. On the basis of low signal level (multipath fading), causes of deterioration in relation to meteorological conditions have been determined. In order to counter multipath fading, some techniques have been discussed in this paper. In future this study can also be taken as a reference for designing the microwave communication systems located in the Indian southern region. It is suggested that the link should be equipped with some diversity system.

1 Introduction

In recent studies it has been found that the performance of communication links located over Indian southern region are affected due to the varied meteorological conditions[1,2]. The performance estimation of deterioration in another microwave communication link situated between Adoni and Guntakal and operating at 7 GHz has also been carried out and presented in this paper. The normal received signal level under clear air condition has been found to be −60 dBm. The performance of the link is satisfactory when the received signal level is equal to or more than −74 dBm, but it has been found to be deteriorated when the signal level reduces to −75 dBm from normal level of −60 dBm and is in worst condition when the signal level is around −80 dBm. It has also been observed that the low signal levels are associated with low fade depth (2-4 dB), moderate fade depth (4-10 dB) and large fade depth (10-20 dB). The meteorological conditions prevailing around the link site have been derived from the ground based meteorological observations and radiosonde data. It has been found that the fall of ground temperature causes temperature inversion and gives rise to super-refraction and ducting situations. The multipath fading is found to be more under super-refraction and ducting conditions[3,4]. The deterioration in link performance is due to interferences among direct rays, ground reflected rays, rays scattered/ reflected from atmospheric irregularities/glints, etc. Such interferences give rise to multipath fading and fall of signal level. The operational link is not equipped with any diversity system. Space diversity[5] with antennae separated vertically may be utilized to counter the multipath fading to increase the signal level. Another technique is antenna tilting[6,7] which may also be utilized to counter the multipath fading.

2 Source of data

The field strength observations were provided by an operational agency. The field strength measurements were made by using a microwave communication link operating at 7 GHz during 1990-1997. The transmitting power is 1 Watt. The transmitting and receiving antennae are parabolic dish with horn feed. The transmitting and receiving antennae gain are 40 dB. The fade margin is 30 dB. The sensitivity of the receiver is −90 dBm. The ground based meteorological observations and radiosonde data around the link sites were obtained from the India Meteorological Department (IMD).

The ground based meteorological observations over four locations and upper air data over two locations, which are nearer from the link site, were

taken for this study. On the basis of the meteorological observations monthwise meteorological condition was deduced for the link site.

3 Terrain characteristics

The terrain profile between Guntakal and Adoni is shown in Fig. 1. The terrain consists of a valley at a distance around 10 km from Adoni. The path also consists of rolling plains from 25 km, from Adoni up to Guntakal. Guntakal is situated at an altitude of 460 m above mean sea level (msl), while Adoni is situated at an elevation of 610 m above mean sea level. The path distance between Adoni and Guntakal is 52.7 km. The height of antenna at Adoni and Guntakal is 6 m and 60 m, respectively, from the ground.

4 Results and discussion

The signal level larger than −75 dBm is considered to be good for radio link performance. The performance of the link situated between Guntakal and Adoni has been found to be affected when the signal level is equal to or less than −75 dBm. The non-performance of the link has been determined by analyzing the measured signal levels when the signal levels are equal to and less than −80 dBm. The carrier intensity was recorded during January-December. The performance of the link deteriorated during the months of November through May, which are considered to be the problematic months in the present study. The total duration during which the signal level is equal to or less than −80 dBm are 20 h, 60 h, 120 h, 75 h, 55 h, 25 h and 25 h in January, February, March, April, May, November and December, respectively. This is illustrated in Fig. 2.

The number of days during which the performance of the link was not up to the mark and the signal which was characterized with low signal level for 14 days, 26 days, 54 days, 38 days, 26 days, 16 days and 16 days in January, February, March, April, May, November and December, respectively, are also shown in Fig. 2. The diurnal variation, when there was deterioration in the performance of the link and the received signal level as recorded was equal to or less than −80 dBm, is shown in Figs 3 and 4. It has been found that the low signal level was observed more number of times during 2300-0800 hrs LT in January, February, March and April and the low signal level was observed moderate number of times during 2200-0800 hrs LT in November and December. The low signal level was characterized for maximum period during 0000-0800 hrs LT in March.

A fade is the difference of the two ends (precisely, maxima and minima) of an instantaneous signal level. The fade depth also has been estimated when the signal level is of low order, i.e. one end of the signal level is equal to or less than −80 dBm. For example,

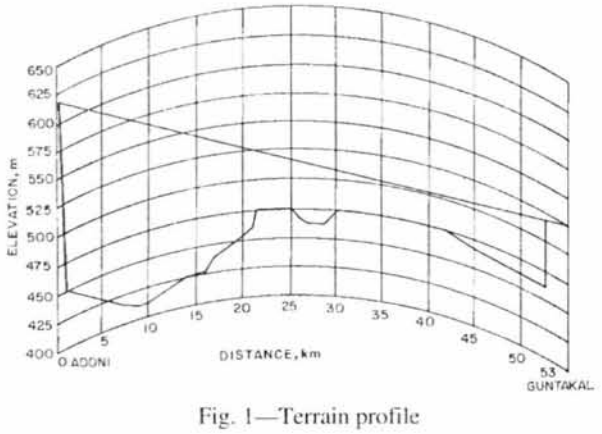

Fig. 1—Terrain profile

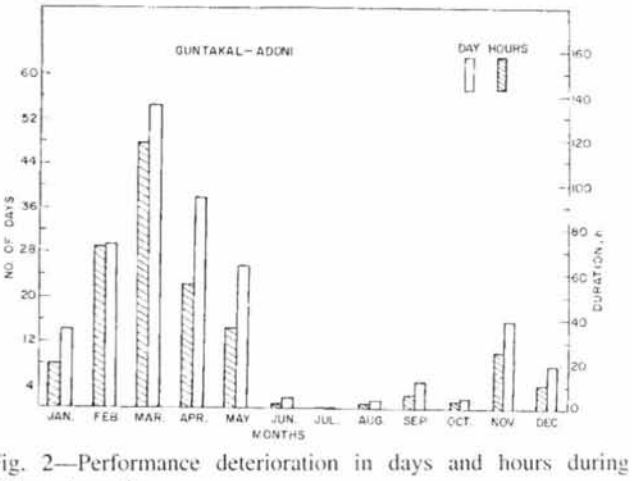

Fig. 2—Performance deterioration in days and hours during different months

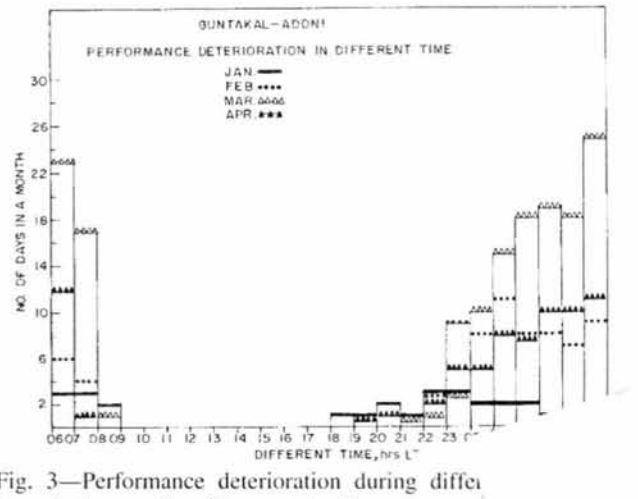

Fig. 3—Performance deterioration during diffe hours in the months of January-April

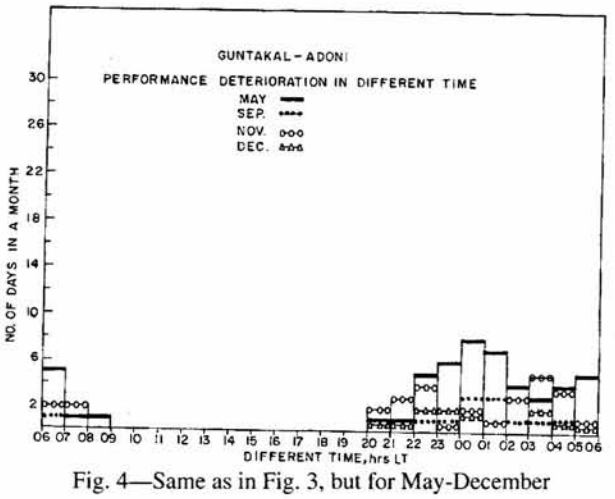

Fig. 4—Same as in Fig. 3, but for May-December

suppose the signal level has varied from −60 dBm to −80 dBm, it indicates that the fade depth is {−60 dBm−(−80 dBm)} = 20 dB. The maximum fading of the order of 15-20 dB was observed during February, March, April and May and the moderate order fading of 10 dB in November, December and January during 2300-0800 hrs LT. Large fades of the order of 20 dB are found to occur for around 6% of the time. The operating radio system has a fade margin 30 dB. Therefore, there is no problem in the performance of the communication link due to fades, but the low order of signal levels cause problem in the performance of the link. The performance of the link has been found to be deteriorated when the signal level is low due to multipath fading[1,2]. In order to achieve high reliability level, extra gain in the system, preferably, by deploying techniques of antenna tilting at both the ends is needed. The antenna is to be fixed wherever maximum signal is obtained.

The ground based meteorological characteristics around the radio path is presented in Table 1. It is seen that the fall of temperature from daytime to nighttime is appreciable during December-May when there is deterioration in the performance of the link. The fall in temperature is maximum around 9°C in the month of March. The deterioration in the link performance has also been found to be quite frequent in March. The fall of ground temperature is responsible for the fast cooling of the earth's surface due to radiative cooling. The cooling causes temperature inversion and hence produces stratified situations in the atmosphere with high refractivity gradient. The degree of stratification increases when the refractivity gradient is of large order and in turn supports layers formation. It has been observed by acoustic sounder that ground based and multiple elevated layers are formed during these months in this region[8]. The radio rays travel through different paths through these layers. It has been seen that whenever there are interferences among the travelling rays through different layer, there is fall in signal level.

Table 1—Ground based meteorological conditions around link site

Months		Meteorological conditions over							
		Bellary (15.09°N, 76.51°E)		Anantpur (14.41°N, 77.37°E)		Kurnool (15.50°N, 78.04°E)		Raichur (16.12°N, 77.21°E)	
		Temp. (°C)	Relative Humidity (%)	Temp. (°C)	Relative Humidity (%)	Temp. (°C)	Relative Humidity (%)	Temp. (°C)	Relative Humidity (%)
Nov.	I	23	69	23	70	23	72	24	64
	II	28	45	28	47	29	44	29	41
Dec.	I	21	69	21	72	20	72	21	63
	II	28	38	27	44	29	37	28	34
Jan.	I	23	51	21	69	20	70	22	64
	II	29	31	29	36	30	32	29	32
Feb.	I	23	51	23	54	23	57	24	54
	II	32	25	32	26	33	24	32	29
Mar.	I	27	45	26	47	27	48	27	50
	II	35	22	35	19	36	21	36	28
Apr.	I	29	53	29	52	30	49	30	54
	II	36	28	37	23	37	24	37	30
May	I	29	58	29	62	30	54	30	60
	II	36	33	36	32	38	27	38	33

Note: I—0530 hrs IST
II—1730 hrs IST

The radio rays travelling through different paths under such stratified atmospheric situations give rise to multipath fading. The observed fall of ground temperature from day to night in November, December, January, March, April and May are 6°C-10°C. In fact, the fall of temperature during February, March and April, when the non-performance of the link is maximum, is very high (8-10°C). The fall of temperature in other months, when there is no problem with the performance of the link, is of low order (3°C). The radiosonde observations from nearest available observatory are taken at 0.5 km and 1 km. These observations have been analyzed to obtain the ground based ducting and super-refraction frequency across 0.5 km-1 km around the radio link for different months.

The local meteorological conditions prevailing around and over the link location and other nearby radiosonde stations have also been considered. The super-refractive and ducting conditions have been found to be more in January, February, March, April and May. The average refractivity gradient of the five months (February-May) has been found to be –60 N/km which is considered to be high and is a favourable condition for multipath fading. The super-refractive and ducting frequency are around 10% during March when the deterioration in the link performance is maximum due to multipath fading.

5 Conclusions

The deterioration in the performance of the communication link has been ascertained for multipath fading. Such multipath fading causes total fadeouts in the link. The link performance during the time of deterioration can be improved by employing either some diversity systems such as space/frequency or remedial techniques preferably tilting of antennae.

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