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Some observations on microwave propagation under clear air, fog and cloudy atmospheric conditions in Indian southern region

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Abstract Results on carrier intensity of a microwave communication link situated between Raichur and Adoni having path length 60 km and affected by three different atmospheric conditions *viz* clear air, fog and cloud are presented in this paper The results are mainly related when the performance of the link was not satisfactory under the three different meteorological conditions The low signals associated with deep fades were observed for large percentage of time during foggy and cloudy situations In clear air condition also it has been observed that the carrier intensity was low and associated with large fades The results on the fadings of signals have been discussed in relation to multipath propagation mechanism

Keywords Microwave propagation, clear air, fog, cloud, multipath fading, atmospheric stratification

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1. Introduction

The line of sight microwave communication is affected under varied meteorological situations due to various propagation mechanisms [1]. The different meteorological conditions are clear air, rain, rain bearing cloud, fog *etc.* Among the propagation mechanisms we have scattering, reflection, ducting and multipath [1]. In line of sight communication, multipath phenomena is the most important [2-5]. In multipath propagation several radio rays reach the receiver from transmitter through different paths [6,7]. When the rays are in same phase, the resultant field at the receiver is usually high. But when the rays are out of phases, the resultant field at the receiver is of low level or the instantaneous variation of the signal is large or it can be said that the signal is associated with deep fades. Multipath propagation dominates when the atmosphere is stratified.

In this paper, observations on carrier intensity of a microwave communication link situated between Raichur and Adoni affected by three different atmospheric conditions *viz.* clear air, fog and cloud are presented. The observations are related to when the performance of the link was not satisfactory under the aforesaid three different meteorological conditions. In microwave propagation when the frequency of the radio wave is ≥ 10 GHz, the radio wave is affected by precipitation, cloud, fog *etc.* The radio wave having frequency ≥ 10 GHz is attenuated due to rain, fog and cloud for scattering and absorption [1]. But, it has been seen in the present study that radio signals at 7.2 GHz have suffered deep fades with low signal under fog and cloudy atmospheric conditions. It has been observed that very low signals associated with deep fades were observed for large percentage of time during fog and cloudy conditions. In clear air conditions also deep fades have been found to occur. The results of observations on signals of low level and deep fades have been discussed in the light of multipath propagation mechanisms in this paper.

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2. Source of data

The carrier intensity observations were obtained from an operational agency. The carrier intensity measurements were taken from time to time in the months of December through March during the period 1993-1998 by using a radio link situated between Raichur and Adoni operating at 7.2 GHz with vertical polarization. The carrier intensity observations were taken when the carrier intensity was either low or when the variation of the signal level within one hour was very large. Such observations were taken under clear air conditions and foggy and cloudy situations.

3. Terrain and radio link characteristics

The terrain profile between Raichur and Adoni is shown in Figure 1. The terrain consists of a valley at distance 5 km

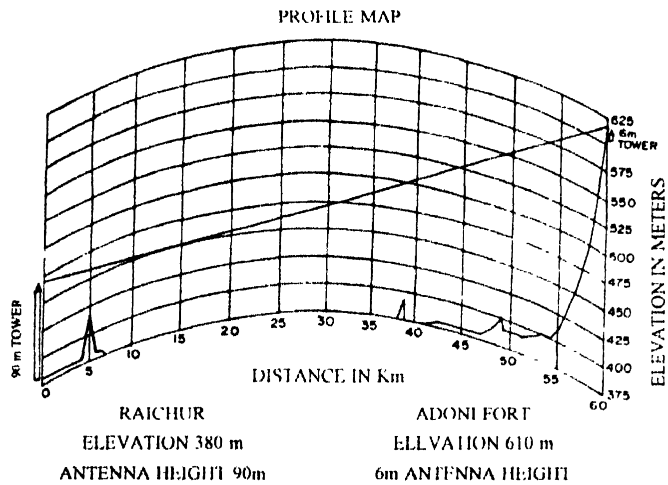

Figure 1. Terrain profile between Raichur and Adoni

from Adoni. The path also consists of rolling plains from 17 km from Adoni upto a distance of 56 km from Adoni. Raichur is situated at an altitude of 380 m above mean sea level while Adoni is situated at an elevation 610 m. The path distance between Raichur and Adoni is 60 km. The heights of antenna at Raichur and Adoni are 90 m and 6 m from the ground respectively.

The transmitted power of the radio link is 1 watt. The transmitting antenna gain is 40 dB and the receiver antenna gain is 40 dB.

The meteorological observations over Raichur, Kurnool and Hyderabad were obtained from the India Meteorological Department. The over all on an average meteorological conditions over these locations are almost same.

4. Results and discussion

Signal levels under different atmospheric conditions were obtained for the present study provided to us. The different conditions were clear air, foggy and cloudy. Such atmospheric conditions were ascertained from visual inspection. The occurrence percentage of various class of signal level under three atmospheric conditions are presented in Figure 2. Even though the measurements were taken during clear air conditions. The signal levels were recorded only when the signal level was low or the variation in signal within one hour was very large for example, from –50 dBm to –72 dBm or from –60 dBm to –80 dBm *etc*. Figure 2 depicts that under the clear air condition, the signal levels lying in the range

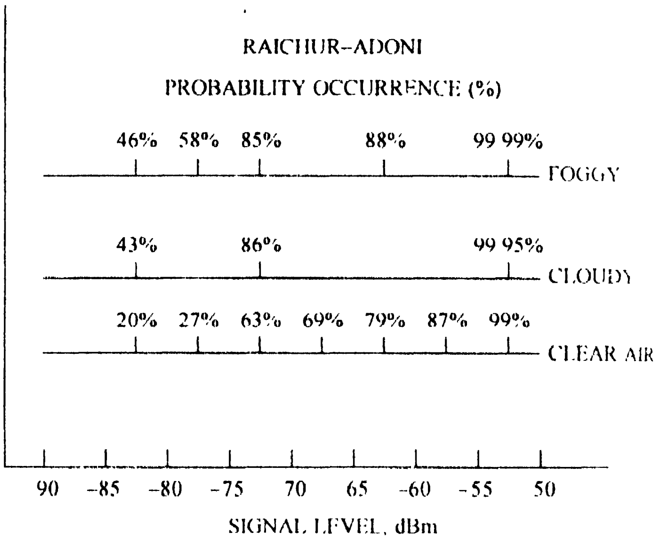

Figure 2. Occurrence percentage of signal levels under different atmospheric conditions

from –75 dBm to –70 dBm, have been found to occur for 36% while the signal levels lying in the range from –85 dBm to –80 dBm occurred for 19%. Therefore, the signal level has been found to be associated with the signals less than –75 dBm even under clear air condition for more than 60% of the total observations (100%).

We have observed that there is wide variation in signal level under foggy condition. The low signals lying between 75 dBm and –70 dBm have been found to occur for 28% while the signals lying between –85 dBm and –80 dBm occurred for 27% and signals lying from –90 dBm to –85 dBm were found to occur for 19% under foggy situation. The low signal associated with less than –70 dBm was found to occur for 74% out of total observations (100%) under foggy situation. The fog always occurs near the earth's surface upto a height 150 m or 200 m. The meteorological situations during fog are associated with both saturated water vapour and some amount of liquid water. The change of meteorological situation (temperature or water vapour or liquid water content) from normal condition (level) leads to change in atmospheric condition. Such change on atmospheric condition gives rise to change in signal level with fades. The foggy condition too also has been found to affect the microwave communication in this case.

The result on signal level under cloudy condition shows that signal level from -75 dBm to -70 dBm occurs for 45.5% and the signal level between -85 dBm and -80 dBm occurs for 45.5%. It indicates that under cloudy condition, the most of the time the signal was of low order. The low signal 70 dBm has been found to occur for around 91% out of the total observations (100%). The observed result on carrier intensity suggests that even cloud can affect the performance of a microwave link. It is well established that for line of sight microwave communication the low signal associated with deep fades are due to multipath fading In case of cloudy condition also it has been seen that there is a change in atmospheric condition. Such change in atmospheric condition causes a change in microwave signal characteristics. The low signal characterized with fades as it has been seen in cloudy condition,can only be explained on the basis of multipath propagation as it is explained for microwave signals under clear air condition. Some details on carrier intensity in different months when carrier intensity measurements were made under varied meteorological situations are presented in Table 1.

Table 1. Some details of signal levels during different period under varied meteorological situations

Atmospheric condition	Months	Signal levels	
Clear air	December		
	January	Moderate	(-60 to 70) dBm
	February	Low	(70 to 82) dBm
	March		
Foggy	December		
	January	Low	(-70 to -90) dBm
	February		
Cloudy	December	Low	(70 to -90) dBm

The results on variations of signal levels within an hour have been presented in Figure 3. It is important to mention here that the measurements of carrier intensity were made under disturbed conditions even during clear air conditions. During foggy and cloudy situations, when most of the occasions the signal level was of low level, the variation of the signal within an hour was also low in most of the cases. The variation was from 5 dB to 10 dB for 68% of the time and from 15 dB to 20 dB for 16% of the time under cloudy condition. In case of foggy situation, the variation of signal within an hour was from 5 dB to 10 dB for 16% of the time and from 10 dB to 15 dB for 37% of the time and from 15 dB to 25 dB for 10% of the time and from 20 dB to 25 dB for 16% of the time under foggy condition. In case of foggy condition, even from 35 dB to 40 dB variation was also observed for 15% of the time. Such percentage is not acceptable in case of tactical communication where we look forward for 99.99% of reliability of link performance. Under foggy condition also, the propagation mechanism is dominated by multipath propagation phenomena in case of

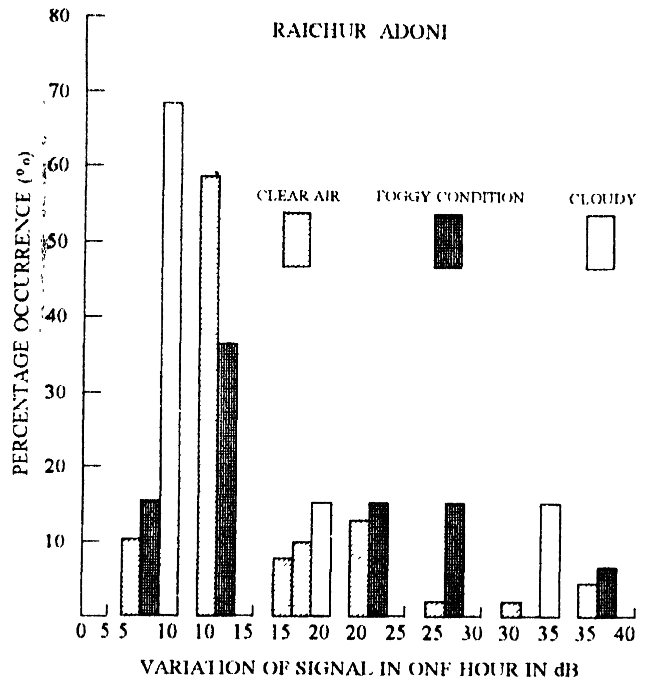

Figure 3. Variation of signal levels within an hour under different atmospheric conditions.

foggy situation we have temperature inversions. In turn, such temperature inversion gives rise to stratified atmospheric conditions. The line of sight microwave communication is dominated by multipath propagation in stratified atmosphere and the refractivity gradient is more negative than -100 N/km [8-10]. In multipath propagation, the radio rays travel through different paths and give rise to variations in signals. The large range of signal variation has been observed under foggy situations. Even during clear air condition, particularly during December, January, Fabruary and March, low signals characterised with deep fades are observed. But the frequency of such occurrence was low in clear air as compared to foggy condition. The ground based meteorological characteristics around link path is presented in Table 2.

Table 2. Ground based meteorological characteristics over communication link path during 0000 UT and and 1200 UT.

Months	Temperature (°C)	Humidity (%)
December	21.5	63
	(27.9)	(34)
January	21.6	64
	(29.0)	(32)
February	23.6	54
	(32.2)	(29)
March	27.1	50
	(35.6)	(28)

The results within brackets pertain to 1200 UT.

The large variation of signal level within an hour and the low order signal level observed under three different meteorological conditions are due to multipath propagation mechanism. It is seen in Table 2 that the fall of temperature from day time to night time in the months from December to March, when the signals were of low order was 8-9°C. The fall of ground temperature is responsible for the earth's surface cooling. Such cooling causes temperature inversion and produces stratified atmosphere conditions with high refractivity gradient. The degree of stratification increases when the refractivity gradient is of large order. The large order of degree of stratification supports atmospheric layers formation The radio rays travel through different paths because of these layers. It has been seen whenever there is de-focussing effect, there is fall in signal level and whenever there is focussing effect there is an increase in signal level. The radio rays travelling through different paths under such stratified atmospheric situations give rise to fades, which are termed as multipath fadings.

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