CHAPTER - 4 OBSERVATION ON FADES IN THE LOS MICROWAVE LINKS.

[4.1]. INTRODUCTION:
Information on fade depth, fade rate, and fade duration of signals is necessary for designing of a reliable microwave link. So test runs are made over a link to receive these data so that modifications in the system can be introduced after receiving the dynamical variations of these parameters or in case of established links, the fade character data help in the designing of LOS links over a similar terrains and environmental situations (Durkee 1947, Stephansen and Mogensen 1979, Mazumdar et al. 1974) An extensive review on these aspect is made by Stephensen (1981).

The fade data are therefore collected over four links of different terrain conditions as mentioned in the chapter 3. The relevent parameters for such a study are the probability \( P < L \) that the amplitude \( v(t) \) will be below a specified signal level \( L \), the expected number of fades per unit time below a specified signal level and the average duration \( t(L) \) of the fades below \( L \). These parameters are all functions of the specified signal level \( L \).

To characterise the fades occurred over these links, the amplitude data are recorded in recorders with appropriate time constants so that the fast fading over a particular link is recognised. So, the time constant of the recorders are appropriately selected after a few test run and these are set at 100 m sec. for all the four links. The fade data are grouped at hourly interval but when the fade rate is high, this interval is reduced accordingly. The fade depth is coded at intervals of 10 dB level and the duration the signal level
remains below a specified level is found out. Also determined is the number of times the signal envelope crosses the median level in the upward direction. The number of intersections is known as number of fades and this fade number per unit time is called the fade rate. The average fade duration at any fade depth is obtained from the ratio of the total time at or below the fade depth level to the number of fades of this depth.

[4.2] TYPES OF FADING:
The fade character analyses over these links indicate presence of different fade types. Representative fade patterns of Milmilia, Maopet, Laopani and Motapahar links are shown in figs. (4.1 :a,b,c,d,e). The fade characters are basically classified in terms of fade depth and fade rate as shallow and deep, or slow and fast fadings as discussed below.

1. Fig. (4.1a) represents the fast or scintillation type of fading. This type of fading is observed generally over Milmilia, Maopet and Laopani- Habaipur link. In this type of fading, the fade rate varies from 20 to 160 fades per hour. The depth of fades are generally shallow and is always less than 6 to 7 dB. The preferable time of development of this type of fading lies in the post sunrise hours within 9 to 10 hours and fading continues to post midday hours (13 to 14 hours). The probability of occurrence of this type of fading varies with season and will be discussed in the next section.

2. Fig. (4.1b) portrays a slow and shallow type of fading. This type of fading is observed in all the four links and the depth varies from 2dB to 10dB. The pattern is independent of season but is usually seen during pre midnight hours.

3. Fig. (4.1c) shows rapid and deep fades. In this type of
Fig. (4.1a,b,c,d,e) : Photograph of Sample Records of Different Type of Fadings Over The Microwave Links Under Study.
fading, the depth varies from 5 to 40 dB and the signal crosses the median level 4 to 15 times per hour. Fades of this type are detected in all the first links and the preferred time of occurrence is early morning hours.

4. Fig. (4.1d) shows slow and deep fades. In this type of fading the fade depth varies from 5 to 20 dB and the signal crosses the median level 1 to 3 times per hour. Fades of this type are detected in Milmilia, Maopet and Laopani links and preferable time of occurrence is pre or post midnight hours depending on the terrain situations.

5. Fig. (4.1e) shows a typical fade pattern where fast fades are modulated over slow fadings. Such pattern is seen in Milmilia, Maopet and Laopani links.

[4.3] FADE DEPTH DISTRIBUTION AND MULTIPATH OCCURRENCE FACTOR

In the study of signal fades due to multipath interference, the cumulative amplitude distribution \( P(V<L) \) of deep fade is to be determined. Here, fade depths are expressed in dB and probability of fade is expressed on a log scale. The equation which describes the typical distribution is \( P(V<L) = a L^2 \) where \( V \) is the envelope voltage of the randomly fading signal normalised to its non faded signal, \( L \) is any specified signal level and \( a \) is the parameter depending upon fade environment.

The result of fade depth distribution analyses in terms of probability distribution, diurnal and seasonal character for all the three links are described in the following section. It is observed that signal over Motapahar link suffers practically no fades and therefore this link is normally not taken in to account for indepth studies.

(1) Milmilia -Durgasarovar Link -
A. Probability Of Fade Distribution:
For this analyses, the fade depth distribution is plotted by
taking all the data collected over the study periods. The probability distribution plot so obtained at various fade depth level is shown in fig. (4.2) and the distribution follows the log normal pattern as is seen from fig. (4.2). The value of $\varepsilon$ (the multipath occurrence factor) for this link is then determined and fixed at 0.609. So the fade distribution over this link can be defined by $P = 0.609 L^2$. The slope of this line is found out to be 11 dB/decade of occurrence of fades.

B. Diurnal And Seasonal Variation Of Fade Occurrence:
The temporal variation pattern of fade depth occurrence is then determined by making a morphological study of the same. For this purpose fades of depth within 1 to 45 db have been taken.

Fig. (4.3) shows that the probability of fade occurrence is maximum during winter season where fadings are detected over 30% of winter periods. It is followed by summer months where 20% of the total summer data show fadings. The fading is less in other seasons. Fades over this link show a clear diurnal character (fig 4.4) and the fade patterns too are different at different times of the day. Deep fades are detected more in the early morning hours (type c & d as shown in fig. (4.1), during all the seasons except for summer when fades are more abundant in premidnight hours and when midday fades are often seen. It is also to be noted that midday fades are fast with low depth whereas the early morning fades are rapid and deep.

C2D. Maopet-Durgasarovar Link:
This link runs over hilly terrain and this terrain is covered by ever green as well as by the desidious forest. The fade probability pattern over this link follows log normal distribution fig. (4.5). To receive the multipath occurrence factor (ie. $\varepsilon$), the procedure adopted in Milmilia link as mentioned above, is followed on this link too. The curve then received by using the $\varepsilon$ value follows $P = 0.714 L^2$. The slope of
MILMILIA-DURGASAROVAR LINK

EQUATION OF BEST FITTING CURVE: \( P = 0.609 L^2 \).

\[
\text{PC OF TIME FADE DEPTH IS } \geq \text{ ABCISSA.}
\]

\[
\text{FADE DEPTH IN DB}
\]

\[
0.001 \quad 0.01 \quad 0.1 \quad 1 \quad 10
\]

\[
0.00 \quad 20.00 \quad 40.00 \quad 60.00
\]

Fig.(4.2) : Probability Occurrence Of Fade Depth Over MILMILIA - DURGASAROVAR Microwave Link
Seasonal Variation Of Fade Occurrence.

Over Milmilia, Maopet & Laopani Links.

Fig. (4.3) : Seasonal variation of PC of Fade occurrence over Milmilia, Maopet and Laopani links.
Diurnal Variation Of Fade Occurrence
Milmilia Durgasarovar Link

**Fig.(4.4)**: Diurnal Variation Of PC Of Fade Occurrence At Different Seasons Over Milmilia - Durgasarovar Link.
this curve is 11 dB/decade of probability fig. (4.5). This factor indicates that attenuation decrease rate though is same over a marshy (Milmilia) and a hilly link (Maopet), the probability of receiving fadings over the hilly terrain is much higher than that of Milmilia link. The seasonal variation of fade occurrence over this link is shown in fig. (4.3). It shows that maximum fades occur during the winter months with 34% of occurrence, followed by the premonsoon months.

The diurnal variation of fading at different seasons over this link is shown in fig. (4.6). Here too, we have taken fades of depths ranging between 2 to 45 dB. A clear diurnal variation in the occurrence of fades has been received. Figure shows that the fading is generally a nocturnal phenomenon with preferential period of occurrence during early morning hours except for summer months when the fades are seen more often in premidnight hours.

(3) Laopani - Habaiipur Link:
The probability of occurrence of fades over this link is shown in fig. (4.7). Here also, the fade distribution curve follows the log normal pattern. Similarly, the multipath occurrence factor $\varepsilon$ is calculated for this link and is found to be .774 and then the equation of the distribution curve is received by using this parameter as $P = .774 L^2$. The slope of the curve is 10 dB/decade of probability of occurrence as shown in the fig. (4.7). The seasonal variation of fadings over this link is shown in fig. (4.3) which gives that the probability of occurrence is highest during summer months. While computing this figure, all fades up to -45 dB have been considered.
The diurnal variation of occurrence probability of fadings is shown in the fig. (4.8), which indicates that nocturnal fadings are more often detected over this link. Well developed fadings, with fade depth $> 45$ dB, are present during midnight.
MAOPET-DURGASAROVAR LINK
EQUATION OF BEST FITTING CURVE: \( P = 0.714 \, L^2 \).

\[ \text{PC OF TIME FADE DEPTH IS} \geq \text{ABCISSA.} \]

\[ \text{FADE DEPTH IN DB} \]

\[ \text{Fig.(4.5): Probability Occurrence Of Fade Depth Over} \]
\[ \text{MAOPET - DURGASAROVAR Microwave Link.} \]

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Diurnal variation Of Fade Occurrence
Maopet - Durgasarovar Link

% Of Fade Occurrence

Time (in Hours)

Fig.(4.6) : Diurnal Variation Of Fade Occurrence At Different Seasons Over Maopet - Durgasarovar Link.
Equation of Best Fitting Curve: $P = 0.774 - L^2$

Fig. (4.7): Probability Occurrence of Fade Depth over Laopani - Habaipur Link

PC of Time Fade Depth is $\geq$ Abscissa.
Diurnal Variation Of Fade Occurrence
Over Laopani—Habaipur link.

Seasons
+ Summer + Pre Monsoon
• Monsoon • Winter

Fig. (4.8): Diurnal Variation of Fade Occurrence at Different Seasons Over Laopani—Habaipur Link.
hours and we detect only few cases of day time development of fadings as can be seen from the fig. (4.8). In diurnal variations, there is a marked difference between the P&T links and the railway link. Here premidnight occurrence of fading is more than the early morning fade events.

[4.4] FADE RATE CHARACTERISTIC:
Fade rate of a signal is as important a parameter as the fade depth. Comprehensive analyses of such parameters help in understanding the dynamical behaviour of the system. The fade rate of microwave signal may vary from 1 fade/hour to 120 fades/hour. The fade rate also has a diurnal as well as seasonal variation. The fade rate distribution pattern with respect to these aspects for the three links are described in the following section.

MAO PET - DURGASAROVAR LINK:
Fig. (4.9) shows the probability of occurrence of different fade rate levels for a complete season. This shows that probability of occurrence of fades of rate 5-10 fades/hour is maximum. The fade rate as high as 120 fades/hour shown in fig.(4.1a) has also been observed during summer with a fairly low occurrence probability (.5% only).

The cumulative distribution of average fade rate also reflects this pattern of seasonal dependence of fade rate value fig.(4.10). Here, we see that for 50% probability level, winter favours 5 fades/hour while during summer it goes to 10 fades/hour.

Fig.(4.11) represents the average diurnal variation of fade rate. This shows that fade rate is maximum during daytime and minimum during night hours. The average fade rate is highest in summer months with 18 fades/hour and is minimum during winter months with 8 fades/hour. During post monsoon and pre-monsoon periods, average fade rate is 15 fades/hour.
MILMILIA - DURGASAROVAR LINK:
The analyses on fade rate for this link have also been done following the procedure adopted for Maopet link. Fig. (4.12) represents the probability of occurrence of fade rate of a particular level over Milnilia Durgasarovar path. Here too, we note that the fade rate varies with season and probability of occurrence is highest during winter months with 5 fades/hour which is detected 34% of the total winter period. However the maximum fade rate is observed in summer when 80 fades/hour is noted with .1% occurrence of probability. The maximum fade rate for pre/post monsoon and winter season is limited at 40 fades/hour.

Fig (4.13) shows the cumulative distribution of the fade rate on the seasonal basis. At 50% probability level, fade rate is 5 fades/hour in winter and 10 fades/hour in premonsoon and postmonsoon months while in summer for 50% probability level, the fade rate is 12 fades/hour.

Fig (4.14) gives the diurnal variation of average fade rate. It shows that the fade rate with 22 fades/hour is maximum during midday in summer months.

LAOPANI HABAIPUR LINK:
The fade rate analyses over this link have been carried out in a similar way as described for other two links and the maximum fade rate is observed during summer as we have seen for the other two links. Fig. (4.15) shows the probability of occurrence of fade rate at various levels and at different months of the year. The fades with 160 fades/hour are more often detected during summer. But these fast fades are very less during winter, while fade rate up to 140 fades/hour are present during pre/post monsoon period.
Fig.(4.9) : Probability occurrence of Fade Rate at Different Seasons over Milmilia - Durgasarovar Link.
Fig.(4.10) : Cumulative distribution of fade rate at different seasons over Maopet - Durgasarovar link.
Fig.(4.11) : Diurnal Variation Of Average Fade Rate At Different Seasons Over Maopet - Durgasarовар Link.
Fig (4.12): Probability Occurrence Of Fade Rate At Different Seasons Over Milmilia - Durgasarovar Link.
Fig.(4.13) : Cumulative Distribution Of Fade Rate At Different Seasons Over Milmilika-Durgasarovar Link.
Diurnal Variation Of Average Fade Rate

Fig.(4.14) : Diurnal Variation Of Average Fade Rate At Different Season Over Milmilia-Durgasarovar Link.
Fig.(4.15) : Probability Occurrence Of Fade Rate At Different Seasons over Laopani-Habaipur Link.
Fig.(4.16) : Cumulative Distribution Of Fade Rate At Different Seasons Over Laopani-Habaipur Link.
Diurnal Variation Of Average Fade Rate

Laopani—Habaipur Link

Average Fade Rate (Fades/Hour)

Seasons:
- Summer
- Pre Monsoon
- Winter
- Post Monsoon

Fig.(4.17) : DIURNAL VARIATION OF FADE RATE AT DIFFERENT SEASONS OVER LAOPANI-HABAIPUR LINK.
This picture is also reflected in the cumulative distribution of fade rate (fig 4.16). The fade rate which is high during summer with 20 fades/hour at 50% probability level, goes down to 8 fades/hour during winter.

We then examine the presence of diurnal variation, if any, of the fade values. A clear preferential developmental time of fast fade is noted. The fast fades start developing after 3/4 hours of local sun rise and fade rate increases till prenoon hours, fig. (4.17). The average fade rate goes up to 12/14 fades/hour during summer and premonsoon pre midday hours.

[4.5] FADE DURATION:
The average fade duration at any fade depth level is obtained from the ratio of total time at or below the fade depth to the number of fades at that fade level (Vigantis 1970). The average fade duration for Milmilia- Durgasarovar link is shown in fig. (4.18). The curve represents the plot of average fade duration against each fade depth level for this link. From this observations an average fade duration distribution curve is defined by \( t = 550 L \) and is best fitted for the deep fade region. For the Maopet - Durgasarovar Link the distribution curve for the average fade duration is shown in fig. (4.19). For this link too an equation for best fitting of the curve is found out and is defined by \( t = 514 L \). Similarly the average fade distribution plot for Laopani- Habaiipur link is shown in fig 4.20. The best fitted equation for this case is \( t = 246 L \).

This analysis shows that Milmilia and Maopet links experince fades of large durations with the coefficient factors 550 and 514 respectively, while the Laopani- Habaiipur link suffers fades of small durations with coefficient factor 246. This study indicates that fading mechanisms over two districts of Assam valley may not be the same.
Fig.(4.18) : Distribution Curve For Average Fade Duration Over Milmilia - Durgasarovar Link.
Fig.(4.19) : Distribution Curve For Average Fade Duration Over Maopet - Durgasarovar Link.
Fig.(4.20) : Distribution Curve For Average Fade Duration Over Laopanil-Habaipur Link.
The results are presented in the following table

### TABLE-4.1
Summary of characteristic features of fade depth, fade rate and fade duration as observed over the microwave links.

<table>
<thead>
<tr>
<th>Parameter to be studied</th>
<th>Link 1 Milmilia</th>
<th>Link 2 Maopet</th>
<th>Link 3 Laopani</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Type of fades</td>
<td>1. Fast Shallow</td>
<td>1. Fast, shallow</td>
<td>1. Fast, shallow</td>
</tr>
<tr>
<td></td>
<td>2. Slow, shallow *</td>
<td>2. Slow, shallow</td>
<td>2. Slow, shallow</td>
</tr>
<tr>
<td>5. Fast fading modulated over slow fading</td>
<td>5. Fast fading modulated over slow fading</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>5. Fast fading modulated over slow fading</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* indicates the dominating feature of the fading.

2. **FADE DEPTH**

- Equation for the probability distribution of fade depth:
  - Link 1: \( P = .609 L^2 \)
  - Link 2: \( P = .714 L^2 \)
  - Link 3: \( P = .714 L^2 \)

- Slope for equation of the best fit for the fade distribution curve:
  - 11 dB/decade
  - 11 dB/decade
  - 10 dB/decade

- Link cutoff:
  - Link 1: 0.003 %
  - Link 2: 0.005 %
  - Link 3: 0.008 %

- Seasonal variation of fade occurrence:
  - Winter maximum
  - Winter maximum
  - Summer maximum

- Diurnal variation of fade occurrence:
  - Early morning maxima
  - Early morning maxima
  - Premidnight maxima

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3. FADE RATE
At 50% probability level, 10 Fades/hour, 15 Fades/hour, 20 Fades/hour

Seasonal variation: Summer Maximum, Summer maximum, Summer maximum
Diurnal variation: Pre Midday maximum, Pre Midday maximum, Pre Midday maximum

FADE DURATION
Equation for the best fitted straight line:
- \( t = \frac{550}{L} \) indicating presence of slow fades.
- \( t = \frac{514}{L} \) indicating presence of slow fades.
- \( t = \frac{246}{L} \) indicating presence of fast fades.

[4.6] COMPARATIVE STUDY ON MICROWAVE FADINGS WITH OTHER STATIONS:
Results of seasonal and diurnal variations of fade depth/fade rate observed over the above mentioned links are compared with those reported from some other stations. The geographical configuration of the stations are given below:

1. Low latitude interior region of American Continents (Palmetto, Ottawa and Omaha).
2. Low latitude coastal region of American Continents (Jacksonville).
3. Low latitude tropical region of India (Delhi, Tirupati).

(1) FADE DEPTH:
Seasonal Variations: From the earlier discussions and analyses it is clear that fade occurrence over Milmilia and Maopet links reaches maximum during winter months fig.(4.2) and the fade occurrence over Laopani link reaches maximum...
during summer. We now compare these patterns with those reported by other groups.

It is to be noted that while analysing these features as shown in Table 4.1 (and also in our figures) we take into account fades of all depth (negative excursion) up to -45 dB. But over Palmetto link, fades up to only -20 dB are considered. The threshold level of fading considered over Jacksonville and Ottawa are not well defined. Fig. (4.21) shows the seasonal variation pattern over Jacksonville while Fig. (4.22) represents the fading character over Palmetto and Ottawa links. The winter summer and equinoxial variations in % occurrence of fades for Jacksonville, Ottawa, Palmetto, Milmilia, Maopet, Laopani are shown in the Table 4.2

**Table 4.2**

<table>
<thead>
<tr>
<th>Stations</th>
<th>Summer</th>
<th>Post monsoon</th>
<th>Winter</th>
<th>Pre Monsoon</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Jacksonville</td>
<td>09</td>
<td>07</td>
<td>12</td>
<td>4.6</td>
</tr>
<tr>
<td>2. Ottawa</td>
<td>14*</td>
<td>08</td>
<td>02*</td>
<td>05</td>
</tr>
<tr>
<td>3. Palmetto</td>
<td>20</td>
<td>05</td>
<td>01*</td>
<td>05</td>
</tr>
<tr>
<td>4. Milmilia</td>
<td>26$</td>
<td>10</td>
<td>34*</td>
<td>16</td>
</tr>
<tr>
<td>5. Maopet</td>
<td>26*</td>
<td>27</td>
<td>33*</td>
<td>29</td>
</tr>
<tr>
<td>6. Laopani</td>
<td>40*</td>
<td>26</td>
<td>19*</td>
<td>28</td>
</tr>
</tbody>
</table>

- Maximum Occurrence
- Minimum Occurrence

It is clear from the table [4.2] that over Jacksonville the maximum occurrence of fading is observed during winter months like that observed over Milmilia and Maopet links. However the
fade events are more or less evenly distributed over Maopet link for the whole season.

On the other hand the fade occurrence character over Laopani-Habaipur is more akin to those detected over interior continental stations like Ottawa and Palmetto as shown in the fig. (4.22). The similarity in all these three links a summer maximum in fade occurrence is clearly detected. This is a significant observation because we generally do not expect to receive coastal region effect over these two land locked stations. But we must point out here that these links are located very near to the mighty river Brahmaputra fig. (3.1). Where the river width may go up to 8 km at places.

8. Diurnal variation Of Fade Depth:
In this section an attempt has been made to compare the diurnal variation pattern of fade occurrence of the links over Assam valley with different stations as given in the table 4.3.

<table>
<thead>
<tr>
<th>Stations</th>
<th>Path Length</th>
<th>Geographical Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Omaha-Palmetto</td>
<td>57 Km</td>
<td>Hilly</td>
</tr>
<tr>
<td>2. Palmetto</td>
<td>31 Km</td>
<td>Hilly</td>
</tr>
<tr>
<td>3. Delhi-Meerut</td>
<td>63.5 Km</td>
<td>Plain Terrain</td>
</tr>
<tr>
<td>4. Tiruttani-Tirupati</td>
<td>60 Km</td>
<td>Hilly Terrain</td>
</tr>
<tr>
<td>5. Milmilia-Durgasarovar</td>
<td>41 Km</td>
<td>Marshy</td>
</tr>
<tr>
<td>6. Maopet-Durgasarovar</td>
<td>64 Km</td>
<td>Hilly &amp; Forest</td>
</tr>
<tr>
<td>7. Laopani-Durgasarovar</td>
<td>55 Km</td>
<td>Marshy &amp; Forestry</td>
</tr>
</tbody>
</table>

Our earlier observation on diurnal fade occurrence character shows that all the study links follow the same pattern of maximum occurrence of fades during post midnight and early morning hours (up to prenoon period in many cases) except during summer months when more events are detected during pre
Seasonal Variation Of fade Occurrence.
Over Coastal Region (Jacksonville)

Fig.(4.21) : Seasonal Variation Of PC Of Fade Occurrence Over Low Latitudes Coastal Region Stations (Jacksonville).
Seasonal Variation Of Fade Occurrence.

Palmetto & Ottawa (Interior Region)

Fig. (4.22) : Seasonal Variation Of PC Of Fade Occurrence Over Low Latitude Interior Region Stations (Palmetto & Ottawa)
midnight hours. It is to be noted that though Laopani-Hbaipur experiences a totally different seasonal fade occurrence patterns, the diurnal variation features are same as observed for the other two links. We will now examine the diurnal fade occurrence character over some other links in relation to those observed by us. It is seen from the fig. (4.23) that probability of fade occurrence over Omaha- Palmetto link (path length 57 Km) shows the pattern similar to that observed over Assam valley. They have also received a summer time high pre midnight occurrence in fade as shown by Milmilia & Maopet links. The Palmetto Link (path length 31 Km) also shows the same pattern, fig.(4.24).

Fig.(4.25) shows the diurnal variation of hourly fade depth over Delhi- Meerut link (Prasad et.al.1990). This figure however does not speak the occurrence character of fades. We may bring here our figure on diurnal variation of fade depth fig.(4.26) over Milmilia link. It is however to be noted that this picture on fade depth is true for other links too. We note from the figure that the fade depth is always high during night to morning hours and reaches the heighest value within 5- 6 hours in the morning. We also note a similar feature on fade depth variation over Delhi- Meerut link fig.(4.25) where average fade depth varies between 2 db in midday to 13 db in the early morning hours. The fade depth variation patterns over this link and also those over our links show that average fade depth is always low during daytime and high during post mid night and early morning hours.

However, for some links where cutoff or fade out conditions are very often generated, it is worthwhile to analyse the fade character in terms of link cut off events. Fig.(4.27) shows fade out time over Tirupati- Tirutanni link (path length 60 Km) where fade out conditions are very often detected. (Rao et. al. 1993). Fig. (2.27) shows that link cut off events
Diurnal Variation Of Fade Occurrence.
Over Omaha—Palmetto Link (57 km Path)

Fig. (4.23): Diurnal Variation Of Fade Occurrence Over Omaha—Palmetto Link.
Diurnal Variation Of Fade Occurrence
Over Palmetto Link Path (31 km).

Fig.(4.24): Diurnal Variation Of Fade Occurrence
Over Palmetto Link (31 km).
Fig. (4.25): Diurnal variation of average fade depth over Delhi-Meerut link.
Diurnal Variation Of Fade Depth

Fig.(4.26) : Diurnal Variation Of Average Fade Depth Over Milmilia-Durgasarovar Link.
Diurnal Variation Of Fade Out
Tiruttani - Tirupati Link (60 Km)

Fig. (4.27) : Diurnal Variation Of Fade Out
Over Tiruttani - Tirupati Link (60 Km)
are highest during early morning hours of pre monsoon period and fade out condition is lowest during post monsoon period.

This comparative study indicates that the diurnal fade character with large fade events during night to prenoon is basically well maintained over different link paths irrespective of the frequency and path lengths. However, season to season variation in fade events may be different depending on the local environment and terrain situations.

[2]. Fade Rate:
In the above article we have described the fade occurrence and fade depth variation at different seasons and at different hours of the day. Another important associated parameter that needs analysis is the fade rate variations. So this parameter will now be examined over different link paths.

It is seen from our earlier discussion in this regard that the fade rate varies from 2 fades/hour to 25 fades/hour at various hours of the day depending upon seasons. While during this analysis we have taken into consideration of all types of fading including the multipath types. It is also to be noted that fade rate pattern that have been described corresponds to average fade rate for a particular period. However there are instances of getting more than 100 fades/hour during summer Fig.(4.2a). It is seen from the figs. (4.11) (4.14) (4.17) that fades with high fade rate start developing in the morning hour, generally after 3 - 4 hours of sun rise. This fade with fast rate continues up to 2-3 hour of local noon. This type of fading is very rarely detected during night hours, when multipath fadings are often developed. It is to be mentioned that deep fades are developed during late night or early morning hours and these features are maintained at different seasons. Fig.(4.28) that gives a diurnal fade rate variation pattern over Delhi - Sonepat path carries the same
Diurnal Variation of Average Fade Rate

Delhi—Sonipet Link

Fig.(4.28) : Diurnal Variation of Average Fade Rate at Different Seasons over Delhi—Sonipet Link.
Fig.(4.29) : Probability Occurrence Of Fade During The Worst Month Period Of Nov.
features of the fade rate variations over the links studied by us.

**[4.7] Conclusion:**
Microwave propagation characteristics in terms of fade depth distribution, fade occurrence, fade rate and fade duration are extensively studied over the three LOS links of Assam valley and the observations related to these aspects have been presented in this chapter along with a few comparative analyses of the features with those received from various workers of the globe.

The fading patterns are first classified into five major groups after defining the pattern on the basis of fade rate and fade depth. The analyses indicates that terrains features though have a role to play towards controlling the fade pattern, these are to a large extent dependent on the Fresnel zone clearance factor and atmospheric situations. This we have clearly seen in Laopni - Habaipur link, where first fresnel zone is 50% obstructed in $K = 2/3$ condition leading to link cutoff events with probability of $0.008\%$. The multipath occurrence factor is also high as $0.774$. I must add here, at the same breath that this can not be the sole factor for receiving the large fade events because we have seen that event with large fresnel zone clearance, Maopet link shows the probability of black-out to be appriciably high ($0.005\%$). Here we may considere the experimental observation by *Barnet (1972)*, where it is shown that coefficients in probability of multipath fading increases by a factor of 1.2 when operating frequency changes from 6 to 7 GHz. This will no doubt increase the fade events at 7 GHz compared to what will be seen at 6 GHz. However, there may be two or three factors working simultaneously (like multipath fading / scattered signal from small scale irregularities) for generating fades in these links. Because we have seen that when short duration, large number of black- out events dominate in the Laopani -
Habaipur link, the maopet and Milmilia links show only a few events with relatively large black-out periods.

It is worth mentioning here that in Motapahar link, the fresnel zone clearance though is 24 meters, the link suffers practically no fading. This is a hilly cum builtup area and it is not passing over a big water expouse. So in such a terrain we don't expect the atmosphere to generate a conditions that may result to large fades. So even if the fresnel zone clearance is very low we have not observed any significant fades over this link.

Further, the seasonal and diurnal variations in fade occurrence over Kamrup Links (Milmilia & Maopet Links) and those Nagaon districts (Laopani link), are to be noted with interest, because when Maopet and Milmilia link suffer maximum fades during winter and early morning hours, the Laopani Link experience maximum fades during summer and pre midnight hours. We may here point out the generation of thick fogs during winter over Maopet link because of height factor. Similar is the situation over Milmilia where fog condition during winter is generated by river Brahmputra.

The large winter time fades can be explained by temperature inversion (as dealt in chapter 5) seen through radiosonde observation and sodar echogram. The effect of temperature inversion, thunderstorm or front wave on microwave fades are discussed by many workers (Webster 1983, Schivone 1982). The effect of temperature inversions on microwave fades during winter night have been received from Indian stations too (Das et.al. 1989).

But we do not have sodar observation over Laopani link to relate these events with temperature structures. However large fade events during summer night have also been reported (Ruthroff 1971), when RRI gradient is negative.
This factor have been further examined where we have seen that Milmilia and Maopet links behave like a low latitude coastal region stations whereas Laopani link shows the fade character of the low latitudes interior regions of American continents. So the large scale variations in fade occurrence are mostly controlled by the local environments. But so far the diurnal variation is concerned, the fades are basically night time events, preferential time of development varying between pre midnight to early morning hours.

It is also seen that the mode of scattering of the signals from irregular medium that results to fade occurrence at different hours of the day. We have seen that after 2/3 hours of sunrise to pre midday hours, the signal suffers relatively fast fades with average 10 to 15 fades/hour (instant fade/ratemay go up to 160 fades/hour) and this type of fading is seen in all links irrespective of their terrain situations. However, the magnitude of fluctuations and number of events vary from a place to another. The large rapid variations of the RRI in the atmosphere and its association with fast fades have been reported by Tukuji (1957), Troleselg (1955) Sarkar et al. (1982) etc. The analysis of such fades with respect to boundary layer structures has been dealt in chapter 5.

The whole exercise leads to a result that probability of development of fades over the Kamrup links are high during the winter early morning periods. But the significant part to be highlighted is the worst period for the communication is not the winter months but is during the post monsoon period. The worst month statistics, during the month of November over the Milmilia link is shown in fig.(4.29) where the link cutoff is 0.007 % of the total data of the month, which is 0.004 % higher than the average value of the year. This large occurrence of fade black out events can be correlated with large occurrence of ducting condition during the post monsoon months.