Rain Attenuation and Fading on a Line-of-sight Microwave Link

D K SINHA*, S K CHATTERJEE & P BANDYOPADHYAY
Institute of Radiophysics & Electronics, University of Calcutta, Calcutta 700 009
and
D K NATH
Eastern Region Telecommunication Maintenance, Calcutta

Received 21 January 1987; revised received 15 July 1987

Signal strength fluctuations on 11 GHz over the P & T microwave link between Calcutta and Kulpi with a repeater at Sherakul (Calcutta-Sherakul distance, 38 km) have been recorded since December 1984. These records show two prominent effects, namely, (i) rain attenuation, and (ii) fading. The rain rate in this location, measured with a fast response rain-gauge, often exceeds 200 mm/hr and causes deep fades (exceeding 30 dB). The total rain attenuation has been fitted with a relation of the form, $a_1 R^b$, where $R$ is the point rain rate and $a_1$ and $b$ are constants. The fading effects, particularly noticeable at night during the winter months, can be classified into three distinct types. The first is characterized by slow fading of small amplitudes, the second is also slow fading with deep fades superposed, and the third is characterized by fast fading. The results presented will be useful in the design of LOS microwave links.

A line-of-sight microwave link on 11 GHz between Kulpi (near Diamond Harbour) and Calcutta (Tireratnabazar Telephone Kendra) is run by the P & T Department. The link has a repeater near the path mid-point at Sherakul, the Calcutta-Sherakul path length being about 38 km. Signals transmitted from Kulpi using a steady power of about 10 W undergo tropospheric fluctuations during propagation over the Kulpi-Sherakul path. These fluctuations are removed by the repeater at Sherakul and a steady signal (fluctuation within 1%) is transmitted once again towards the Calcutta end. The tropospheric fluctuations of this signal over the Sherakul-Calcutta path are recorded by connecting a chart recorder at the AGC point within the receiver at Calcutta. Calibrations are made using attenuators and a steady signal source. Although the absolute signal level of the source is not known, the tropospheric fluctuations of the signal strength can be measured, using the calibration, to an accuracy of about 1 dB. A preliminary examination of the recorder charts shows two prominent tropospheric effects, namely, (i) rain attenuation, and (ii) fading. The purpose of this communication is to report the major features of these two effects.

Attenuation due to rain arises from absorption and scattering of radio energy by the rain drops. The observed attenuation $A$ in an extended volume of rain covering a line-of-sight (LOS) path length $L$ (in km) can be expressed as

$$A = \frac{L}{a d l}$$

where $\alpha$ is the specific attenuation in dB/km due to the rain. The relationship between $\alpha$ at a point along the path at any instant and the rain rate $R$ (in mm/hr) at that point and at the same instant can be expressed as

$$\alpha = a R^b$$

where $a$ and $b$ are constants dependent on frequency, temperature and dropsize distribution. This simple expression was obtained empirically by early workers\(^1\), and discussed in detail, including its analytical basis, by Olsen et al.\(^2\) Obviously, the observed attenuation $A$ for a microwave link is dependent on the spatial and temporal structure of rainfall which is difficult to characterize.

---

* UGC Teacher Fellow from B N College, Hooghly, West Bengal

---

Fig. 1—Cumulative distribution of rain attenuation
to determine. Although, conceivably one can attempt this by placing a large number of raingauges along the path, such a detailed picture of rain structure at different instants is not necessary for the designer of a line-of-sight communication system. The system engineer is primarily interested in predicting the excess attenuation margin for given percentages of time over the link. This information has been obtained from our signal strength records and is given in Fig. 1 which shows the cumulative distribution of attenuation associated with the rain events recorded during the year 1985 (continuous-line curve). A similar distribution obtained by the Telecommunication Research Centre, New Delhi, for the LOS link between Telephone Bhavan and Cossipore Telephone Exchange (6.4 km) on 13 GHz is also included (broken-line curve). The latter distribution is an average curve averaged over a four-year period (1979-83). The generally higher values of attenuation for the Calcutta-Sherakul path (38 km) is obviously due to its greater path length.

A fast response raingauge (integration time, 10 s) was located at the Institute of Radiophysics and Electronics (some 2-3 km north-east of Tirettabazar Telephone Kendra) and from the data collected during a one-year period (Jan.-Dec. 1985) a cumulative distribution of rain rate has been obtained; it is shown by the continuous-line curve in Fig. 2. Two other curves are also included in Fig. 2 for comparison. The broken-line curve is an average curve of 5-min rain rate, averaged over a four-year period (1979-83), based on data obtained at Calcutta in collaboration with Telecommunication Research Centre, New Delhi, using ordinary raingauges mostly tipping bucket type. The dash-and-dot curve in Fig. 2 shows clock minute surface rainfall rates for CCIR rain climate region 1 which includes India. The three curves show close agreement except for the fact that the continuous-line curve extends to about 240 mm/hr, much above the values (140-160 mm/hr) where the other two curves terminate, and shows higher occurrences for rainfall rates above about 80 mm/hr. This is ascribed to the differences in the integration times of the three curves, being 10 s for continuous-line curve, 1 min for dash-and-dot curve, and 5 min for broken-line curve. It is known that smaller integration times tend to accentuate higher rain rates. The opposite tendency below the 80 mm/hr level is probably not significant, being due to year-to-year differences. As regards the CCIR curve, considering that it is a kind of average derived for a wide region of the globe, the agreement should be considered satisfactory.

One may wish to relate the rain attenuation statistics (Fig. 1) to the rainfall statistics obtained at a point (Fig. 2). A rough way of doing it would be as follows: We may put \( \alpha = a \bar{R}_p \), where \( \bar{R} \) may be taken as a path average rain rate. This may be related to point rain rate \( R_p \) through a reduction coefficient \( K \), where \( \bar{R} = K \bar{R}_p \). Analytic expression for the reduction coefficient as given by Lin is

\[
K = [1 + \frac{0.6}{\bar{R}_p - 6.2}]/2636
\]

We may then put total attenuation as \( A_t = a_1 \bar{R}_p^b \). We have read values of \( A_t \) and \( \bar{R}_p \) for the same percentage occurrences from the continuous-line curves in Figs 1 and 2 respectively, and when these values are fitted into the above relation, we obtain a straight line as shown in Fig. 3. The points fit the straight line satisfactorily, and the values of \( a_1 \) and \( b \) obtained from the graph are: \( a_1 = 1.65 \) and \( b = 0.817 \).

The fading effects observed in our records, particularly during winter nights, can be classified into three distinct types (Type-1, Type-2 and Type-3). Typical records are shown in Fig. 4. Type-1 is slow fading (15-20 fades per hr) with small amplitudes (2-6 dB). Type-2 is slow fading but with deep fades (20-30 dB) superposed, giving the records a spiky appearance. Type-3 is characterized by fast fading (50-100 fades per hr).
Fig. 4—Typical records illustrating the three types of fading observed over the Calcutta-Sherakul path [Calcutta-Kulpi microwave link (17 GHz)]
of large amplitudes (20-30 dB). The occurrences of the three types for the months Nov. 1984-May 1985 are shown in Fig. 5. Type-1 has the highest occurrence and is most frequent during the winter months. Type-2 is rather rare (about 6%) and occurs only in winter. The occurrences of Type-3 are more or less constant (about 17%) over the months December through April. The hourly occurrences of the three types at night during winter (Dec. 1984-Feb. 1985) are shown by three histograms in Fig. 6. While Type-1 appears shortly after sunset and shows nearly equal incidence between pre-midnight and post-midnight hours, the other two types seem to have some preference for the post-midnight hours. We have also examined their day-by-day occurrences during the winter months and found that the incidence of Type-1 is fairly regular. Type-3, however, has a tendency to recur on groups of nights. Sarkar also reported somewhat similar fades at night over the New Delhi-Sonepat link (7 GHz, 40 km) which he tried to explain on the basis of Ikegami's concept of attenuation and of interference regions formed with different M-profiles. We know that fading arises from changes in the transmission medium. The fact that Type-1 occurs regularly in winter near sunset indicates that it is probably related to the rapid cooling of the ground and the temperature inversion that results. The atmosphere under such conditions is quite stable and allows only small movements which produce the slow fading of small amplitude characteristic of Type-1. The deep fades of Type-2 are likely to be due to multipath effects. For Type-3, we suggest two possible explanations: either it is due to multipath effects involving three or more ray paths as explained by Ikegami or it is due to scintillation effect produced by the presence of small blobs of inhomogeneities in the troposphere.

The data presented in this communication may be taken as characteristic of the Eastern region of India and should be of use to system designers.

We are indebted to Prof. A K Sen of the Institute of Radiophysics & Electronics for giving us the fast response raingauge records. Our grateful thanks go to Mr Y Kumar of the Telecommunication Research Centre, New Delhi, for allowing us to use some of his results.

References
6 Ikegami F, IRE Trans (USA), AP-7(3), (1959) 252.