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Annual and annual-worst month attenuation statistics at 11 and 18 GHz on an earth-space path over Delhi

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Attenuation data for the period July 1985-Dec. 1989 obtained by 11 and 18 GHz microwave radiometers have been analysed for annual and annual-worst month (July) attenuation statistics. The worst-month cumulative distribution has been given by the envelope of the highest probability for the month of July, the highest rain occurring month and the subsequent conversion ratios determined. It is shown that a factor between 5 and 6 is required to convert from annual-worst month to yearly time percentages. Attenuation for 0.01% of a year (50 min) or 0.1% of the worst month has been evolved as a reliable criterion for communication systems operating at microwave frequencies.

1 Introduction

The design and reliable operation of satellite systems which provide transmission of radio waves for communication and other scientific purposes require knowledge of parameters that give rise to severe signal degradations. Statistical information in respect of attenuation due to precipitation is a parameter of prime concern that has to be taken into consideration especially for communication networks in the microwave region above 10 GHz. Communication engineers commonly consider attenuation for 0.01% of a year or 0.1% of the annual-worst month as a reliable criterion for communication systems operating at microwave frequencies. In this paper, the rain attenuation statistics for the period July 1985 to Dec. 1989 obtained by measuring thermal emission during precipitation using microwave radiometers at 11 and 18 GHz has been analysed.

2 Experimental technique

Attenuation measurements were taken in the emission mode at 11 and 18 GHz (Ref. 1). The antenna system consisted of a paraboloid dish at 11 GHz and of a rectangular horn at 18 GHz.

The radiation received from paraboloid antenna/horn was compared to the radiation from an internal load using a slotted waveguide section in which an absorbing wheel was rotated by a synchronous motor at 45 Hz for X-band system and 95 Hz for K-band system. Block diagram of the radiometric system is shown in Fig. 1. A balanced mixer configuration was used at 11 GHz, whereas a single-ended mixer was used at 18 GHz.

The signal received by the antenna was passed through a modulator, a mixer, an amplifier (60 MHz pre and IF) followed by a detector and a low noise amplifier. The modulated signal was then fed to the phase sensitive detector having an integration time of 6 s. The d.c. output was obtained using a reference signal at the modulation frequency. The output was recorded on a chart recorder where the paper chart was moving at the rate of 30 cm/h. The radiometer was periodically calibrated by a noise source referenced to thermal loads[2]. The noise source, which had an effective temperature of 10,000 K, was varied by a calibrated attenuator connected in series so that different levels of attenuation could be obtained. A known value of attenuation was introduced as a reference value and the records were calibrated with reference to this known value. A 20-dB directional coupler and a 10-dB attenuation would give a convenient calibration signal of 10 K. Calibration was also done using the matched load immersed in liquid nitrogen and noting the change in the output level. The sensitivity of the system was 1 K.

Radiometric observations showed that any change in atmospheric parameters due to precipitation was determined as an enhancement of antenna temperature on the chart recorder. The antenna temperature T_a so obtained was converted to attenuation in dB using the relation

$$A\ (\mathrm{dB}) = 10 \log_{10} (T_m - T_{bb})/(T_m - T_a)$$

where

T_m Mean medium temperature of atmosphere obtained from radiosonde measurements

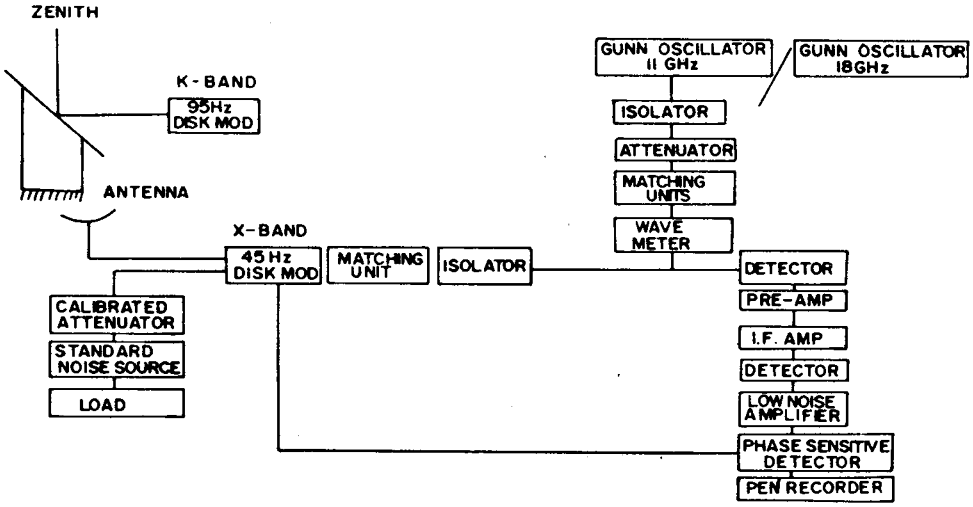

Fig. 1—Block diagram of the radiometric system.

T_{bb} Cosmic background radiation (~2.9 K)

Variation of antenna temperature for different values of T_m is shown in Fig. 2, from where attenuation can be obtained directly.

The mean medium temperature of atmosphere was obtained from radiosonde data available for two firings per day at 0000 hrs and 0012 hrs GMT. For long-term data analysis it is usually difficult to calculate the values of T_m for each data point. Therefore a mean value of T_m as 290 K was taken between 280 K at the rainfall ceiling of 3.5 km and 300 K at the surface. Using this mean value, calculations were made and error, if any, was not found to be significant.

Results and discussion

The errors involved in the attenuation measurements using radiometer technique depend upon the uncertainity of waveguide physical temperature, fluctuations in the mean medium temperature, and calibration of the radiometer system[3]. Considering all the above factors, attenuations have been predicted with an error of not more than 5%. However, one of the limitations of the observations in the emission mode is that we cannot measure more than 14 dB at which the radiometer gets saturated, in which case, the antenna temperature equals the mean medium temperature[4].

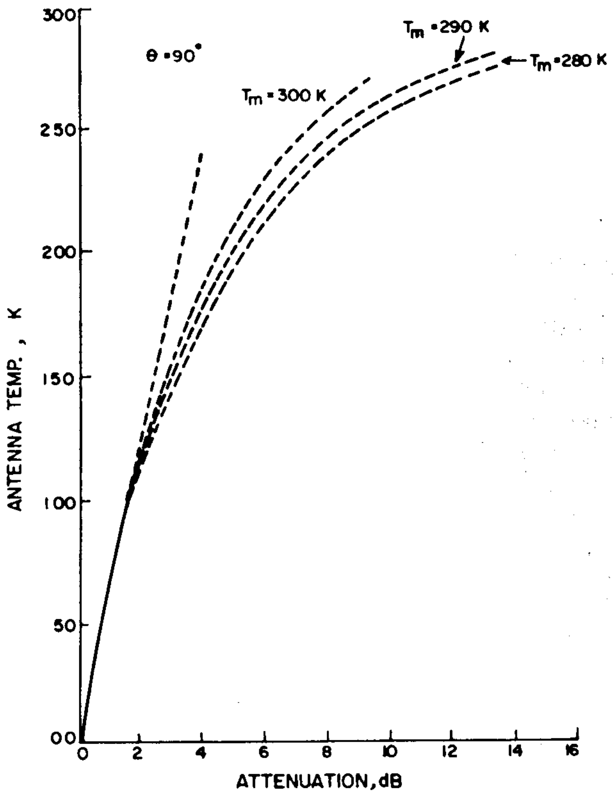

Fig. 2—Variation of antenna temperature for different values of T_m for elevation angle (θ) of 90°.

The analysis of the attenuation data has been concentrated on the worst-month statistics. The worst month for a pre-selected attenuation threshold is the month with the highest probability of exceeding a chosen threshold. The worst month cumulative distribution for a particular year is then given by the envelope of the highest monthly probability distribution statistics from that year. At 11 and 18 GHz, the worst month envelopes are determined by the cumulative distribution for the month of July. The comparison of the yearly attenuation statistics for the period July 1985-December 1989 with the cumulative worst-month attenuation for the month of July for each year of the above period at 11 and 18 GHz are presented in Figs 3 and 4 respectively. The plotted results

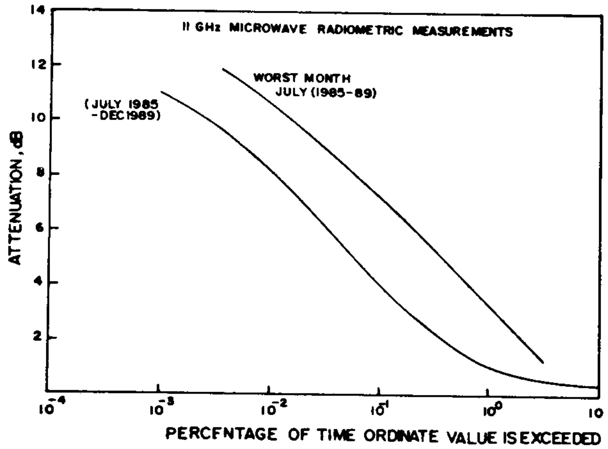

Fig. 3—Comparison of the worst-month attenuation with the whole year attenuation at 11 GHz.

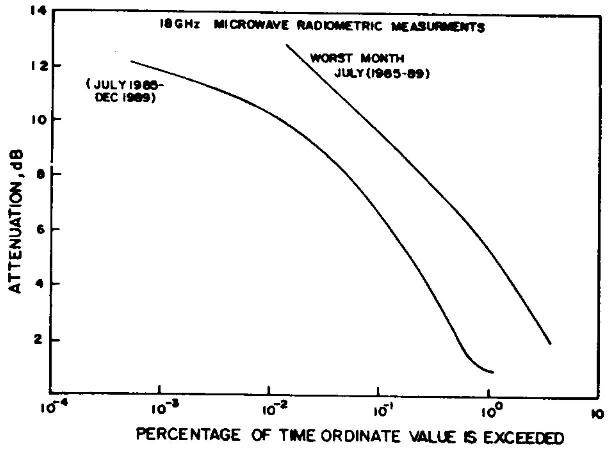

Fig. 4—Same as Fig. 3 but at 18 GHz.

Table 1—Cumulative annual and worst-month attenuation statistics at 11 GHz

Attenuation dB	Percentage of year given attenuation is exceeded (July 1985-Dec. 1989)	Percentage of worst-month given attenuation is exceeded July (1985-1989)	Ratio between worst-month and yearly values
2	3.5×10^{-1}	2.2	6.3
4	9.8×10^{-2}	5.8×10^{-1}	6.0
6	3.6×10^{-2}	2.1×10^{-1}	5.8
8	1.1×10^{-2}	6.2×10^{-2}	5.6
10	2.8×10^{-3}	1.6×10^{-2}	5.7

Table 2—Cumulative annual and worst-month attenuation statistics at 18 GHz

Attenuation dB	Percentage of year given attenuation is exceeded (July 1985-Dec. 1989)	Percentage of worst-month given attenuation is exceeded July (1985-1989)	Ratio between worst-month and yearly values
2	5.3×10^{-1}	3.8	7.1
4	3.0×10^{-1}	1.8	6.0
6	1.4×10^{-1}	7.8×10^{-1}	5.6
8	5.1×10^{-2}	2.8×10^{-1}	5.5
10	1.3×10^{-2}	7.6×10^{-2}	5.8

show that annual and worst-month attenuations for 0.5% of the time are 1.6 and 4.6 dB at 11 GHz and 2.4 and 6.8 dB at 18 GHz.

The ratios between worst month and yearly values for different attenuation levels are presented in Tables 1 and 2 for 11 and 18 GHz respectively.

From Tables 1 and 2, it is seen that the ratios of the worst month and yearly values vary between 5.6 and 6.3 at 11 GHz and between 5.5 and 7.1 at 18 GHz, with the mean ratios being 5.8 at 11 GHz and 6.0 at 18 GHz. This indicates that the rainfall is spread over to 5-6 months and this contributes to fading with dominant period of about 2 months covering July and August. The rest of the period has dry weather including the long spell of intense summer.

From the above discussion, it is clear that it is possible to generate a prediction curve from attenuation values over Delhi based on the average worst-month conditions, and such a curve should find application for other parts of the country as well. These results can be used to arrive at a confident margin for operation of communication systems. The confident margin can be obtained in terms of attenuation plotted against percentage time the ordinate value is exceeded which in turn depends on the outage time.

References

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