Ionospheric Propagation of Medium Frequencies


Research Department, All India Radio, New Delhi

Received 18 April 1973

The results of a study of the night-time propagation of medium frequencies through the ionosphere are presented. The study concerns the build-up of sky-wave signal through the sunset period, the night-time unabsorbed signal and the decay through the sunrise. The results are based on observations for a period of two years on each of the two frequencies 670 kHz and 1320 kHz for a 1310 km path between Delhi (77° 13' E; 28° 39' N) and Calcutta (88° 23' E; 22° 35' N).

Total absorption is estimated from the signal strength variations around the sunset period and the data are utilized to calculate recombination coefficients of the absorbing layer at different hours after sunset. These values are in general agreement with the ones obtained by other workers. Analysis of the data indicates that the period during which steady sky-wave signals can be received is from about 3 hr after sunset to about 2 hr before sunrise and this fact has to be taken into consideration for frequency planning in the medium frequency band.

1. Introduction

The problems posed by the increasing use of high powered medium frequency (mf) transmissions in frequency planning in that band were realized by the CCIR in the early fifties. Since no reliable data on night-time field strength of medium frequencies were available, field strength measurements of night-time medium frequencies at near and far distances were undertaken by the European Broadcasting Union (EBU) and International Radio and Television Organization (OIRT). The results of a statistical study of these night-time mf field strengths over a period of ten years for a number of paths in the European zone with path distances ranging from 300-3000 km were published by the EBU in a series of articles in the EBU Review1-8. These data have been incorporated in Report No. 264-2 (New Delhi) by CCIR4 for assisting the broadcasting organizations in estimating the median night-time field strength. An empirical formula has also been evolved for determining the field strength, taking into account seasonal, latitude and diurnal variations. However, since the CCIR report was mainly based on propagation data collected at higher latitudes, it was considered necessary that data should be obtained at lower latitudes. With this object in view the Research Department of All India Radio undertook a study of this problem and has conducted since 1968 systematic investigation of the night-time field strength of medium frequencies. The results pertaining to two frequencies, viz. 670 kHz and 1320 kHz, over a path distance of 1310 km from Calcutta (88° 23' E; 22° 35' N) to Delhi (77° 13' E; 28° 39' N) are presented in this paper.

2. Measurements

Continuous recordings of transmissions on 670 kHz from Calcutta were commenced in Aug. 1968 and repeated in Oct. 1968, Dec. 1968, Feb. 1969, April 1969, and June 1969. The recordings were done for about six days in the second and third weeks of each month, from about 1630 hrs to 2400 hrs and from about 0330 hrs the same night to about 0700 hrs the following day, the timings being adjusted in various months with respect to ground sunset and sunrise timings at the mid-point of path. The investigations were continued for one more year from Aug. 1969 to June 1970 on almost the same days as in the previous year for collecting additional data. Similar recordings were done on 1320 kHz transmissions, also from Calcutta, during the period Aug. 1970 to June 1971.

Fig. 1—Variation of annual median of sky-wave field strength with time on Calcutta-Delhi zone for 670 kHz (+, median values; ✴ median values for the Rome-Darmstadt circuit)
Variation of Field Strength with Respect to Sunset and Sunrise and Distribution of Median Field Strength

In order to appreciate better the seasonal effects in the variation of signal strength during sunset and sunrise periods the data were rearranged with respect to ground sunrise and sunset times at the mid-point of the path (lat. 25° 39' N) and graphically shown in Figs. 3 and 4 for the two frequencies. The variations around sunset and sunrise are discussed below.

3.1 Variation of Field Strength with Respect to Sunset and Sunrise

In order to appreciate better the seasonal effects in the variation of signal strength during sunset and sunrise periods the data were rearranged with respect to ground sunrise and sunset times at the mid-point of the path (lat. 25° 39' N) and graphically shown in Figs. 3 and 4 for the two frequencies. The variations around sunset and sunrise are discussed below.

(i) Signal build-up after sunset: (a) 670 kHz—It can be seen from Fig. 3 that in general the night-time

---

Fig. 2—Variation of annual median of sky-wave field strength with time on Calcutta-Delhi zone for 1320 kHz (● median values; ○, median values for Monte Carlo-Jurbise circuit)

Fig. 3—Seasonal variation with time of signal strength of the field across Calcutta-Delhi sky-zone for 670 kHz

---
steady state is reached at about the same time, 3 hr after sunset, throughout the year but the absorption at sunset, and consequently the rate of growth of the signal, differs from month to month being generally more in summer than in winter. The standard deviation of the 2-yr values at midnight, midpoint sunset at ground and at reflecting layer are observed to be 3.7, 7.6 and 6 dB respectively. The seasonal difference in
the sunset absorption is presumably due to the difference in the noon altitude of the sun and consequent difference in the residual ionization of the D-layer at sunset. The latter fact would also account for the rapid growth of a signal around sunset in summer as the rate of fall in D-layer ionization after sunset may be assumed to be proportional to $N^2$ at sunset, where $N$ is the electron density.

(b) 1320 kHz—It would be seen from Fig. 4 that the seasonal changes in the growth of the signal for 1320 kHz after sunset are less than those for 670 kHz. The standard deviations are 5.6 dB at midpoint ground sunset and 40 dB at sunset + 45 min. As in the case of 670 kHz these are also more than the nighttime standard deviation which is about 2.8 dB. The absorption at sunset is also considerably less for 1320 kHz than for 670 kHz. The stable value of field strength is reached 1 hr earlier than that for 670 kHz.

(ii) Decay of signal around sunrise—From Figs. 3 and 4 it is to be observed that the rate of fall in the signal from the night-time value is understandably more than the rate of growth after sunset, the fall commencing from about 45 min before ground sunrise for both frequencies. In both cases the post-midnight field strength tends to be lower. The monthly curves are more closely grouped for 1320 kHz than for 670 kHz.

The annual median field strength variations of the two frequencies with respect to sunset and sunrise are shown in Fig. 5.

3.2 Field Strength Distribution, Recombination Coefficient in the Evening

Notwithstanding any possible seasonal causes, an attempt was made to detect any recognizable distribution of the median field strengths. The results of this analysis are shown in Figs. 6 and 7 where the distributions of median field strengths in logarithmic units (dB above 1 $\mu$V) are compared with normal distribution. The observed distributions are shown for three different times: (i) ground sunset at midpoint, (ii) ground sunset + 45 min (corresponding to D-layer sunset) and (iii) ground sunset + 4 hr when the steady state had been reached. From Figs. 6 and 7 it would be seen that at all times there is close agreement with the normal distribution. No significance can, therefore, be attached to the monthly variations of the field strength value at a particular time as being due to seasonal effects.

From the annual median curves of Fig. 5 an attempt has been made to estimate the recombination coefficient of D-layer after sunset. To facilitate this and also to show graphically the possible variation of $\alpha$ with time, Fig. 8 has been drawn which shows the reciprocal of relative absorption as a function of time for both frequencies. The slope of this curve can be considered as proportional to the recombination coefficient under certain simplified assumptions. From the curve for 670 kHz it would appear that the recombination coefficient remains fairly constant till about 1 hr 15 min after ground sunset. With an assumed value of $N=200$ at sunset and a relative absorption of 21.4 dB, the recombination coefficient calculated from the slope of the curve comes out to be $2.4 \times 10^{-8}$ cm$^2$/sec, which is in agreement with the values obtained by other workers. $\alpha$ as calculated from the curve for 1320 kHz at sunset comes out to be $1.5 \times 10^{-8}$ cm$^2$/sec.

4. Conclusions

(1) Observations made at lower latitudes regarding variations of median frequency field strength, around sunset and sunrise, generally agree with those made at higher latitudes.

(2) The half-hourly median field strengths at all times seem to be distributed log-normally as has been found by other workers.

(3) The recombination coefficient of the D-layer estimated from the growth of the signal after sunset compares favourably with that obtained from other methods.

Acknowledgement

This work forms part of 'propagation research' of the Research Department of All India Radio and is published with the kind permission of the Research Engineer, All India Radio.

References