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Ionospheric Absorption on 2·5 MHz at Ahmedabad

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A study is made of diurnal and day-to-day variations of ionospheric absorption on 2·5 MHz measured by Al method at Ahmedabad (23 °N, 72·6 °E; magnetic dip 34 °N) for the year 1973. It is shown that the diurnal variation of absorption follows a law $L = L_0 \cos^n \chi$ where L_0 is absorption when the sun is at zenith. The value of the index n is found to vary from 0·4 to 1·05 during the course of a year, its yearly mean value turning out to be 0·70. The maximum of absorption occurs a little later than noon, the delay being about 45 min in winter and about 12 min in summer. Among the day-to-day variations, the increases in absorption are related to the increases in 1-8 Å solar X-ray flux and the decreases to the occurrences of a reflecting low-type sporadic-E layer. The results are discussed in the context of the roles played by the D- and E- layer ionizations and the atmospheric composition.

1. Introduction

The A1 method of measurement of absorption employs the vertical incidence pulse technique in which radio pulses of short duration are transmitted vertically upwards and the pulse reflections from the ionosphere are received at the same place as that of the transmitter.

The work on absorption done at other places, and the experimental details of the work being done at Ahmedabad were described in an earlier paper by Kotadia *et al.*[1] The absorption is calculated by the formula

$$L \text{ (in } dB) = 20 \log \frac{E_N\, h'_N}{E_d\, h'_d} \qquad \ldots(1)$$

where E is echo amplitude and h' is virtual height of reflection. The subscript N stands for nighttime and d for daytime. The standard reference level $E'_N h'_N$ is obtained for a fixed height of reflection from a large number of nighttime observations free from spread-F and sporadic-E phenomena.

2. Diurnal Variation of Absorption

Observations of ordinary-wave echo amplitudes and heights are usually taken from 0800 to 1800 hrs during daytime and from 2200 to 0200 hrs during nighttime. Fig. 1 gives the diurnal variations for Mar., May, Sep. and Dec. 1973 of (i) monthly median values of absorption on 2·5 MHz, (ii) the 15th day values of cos χ, (iii) normal E-layer critical frequencies f_0E, and (iv) the heights of reflection of the 2·5 MHz pulse. It is observed from Fig. 1 that the absorption reaches its maximum a little later than noon, the noon being defined by the maximum of cos χ where χ is solar zenith angle. This delay is found to be about 45 min in winter and about 12 min in summer. However, on certain days this maximum was observed before noon owing to some unusual phenomena. Very low time-delays observed in Jan. and Feb. 1973 are unusual. There is an indication of a departure in absorption from its smooth diurnal curve near 0800 and 1700 hrs, the departure being in the form of somewhat higher value of absorption. In this context, it may be pointed out that f_0E is very close to the observing frequency 2·5 MHz for absorption and the height of reflection is great. Thus, an appreciable amount of deviative absorption seems to have caused

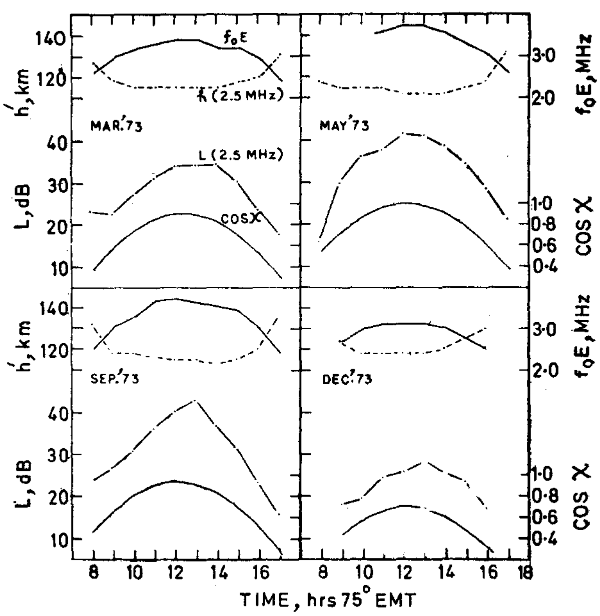

Fig. 1—Diurnal variations of 15th day cos χ, monthly median values of absorption L on 2·5 MHz, virtual height of reflection h' and the E-layer critical frequency f_0E at Ahmedabad during Mar., May, Sep. and Dec. 1973

the departure from the smooth diurnal curve as mentioned above. As the sun goes overhead, h' decreases and f_0E increases, so that the contribution of deviative absorption becomes less; the non-deviative absorption in the D layer below increases sufficiently so as to make the net total absorption increase towards noon, but at a rate depending on the variation of electron density.

3. Dependence of L on cos χ

Under ideal conditions of production and loss of ionization in the D-layer, Appleton[2] showed that absorption would vary as 3/2 power of cos χ. But in practice, the index n of cos χ in

$$L = L_0 \cos^n \chi \qquad \ldots(2)$$

is found to be different from the theoretically expected value, viz. 3/2.

In Eq. (2), L_0 is absorption at χ=0. Fig. 2 shows the plot of L and cos χ on a log-log graph paper for the months representative of winter, equinoxes and summer conditions. Lines are fitted by least square method. Values of absorption affected appreciably by deviative effect in the E layer, near sunrise and sunset in some months are neglected when fitting the regression line. The values of n and L_0 determined from the above lines are given in Table 1. It may be noted that n is generally high in summer with the exception of that determined for Feb. 1973. It was so again in the case of frequencies of 1·8 and 2·2 MHz. The mean value of n for ten months of the year turned out to be 0·70 on 2·5 MHz. The values of L_0 show dependence on season as well as sunspot number.

The scatter of points in Fig. 2 is slightly reduced if time-delay correction is applied. The mean value of

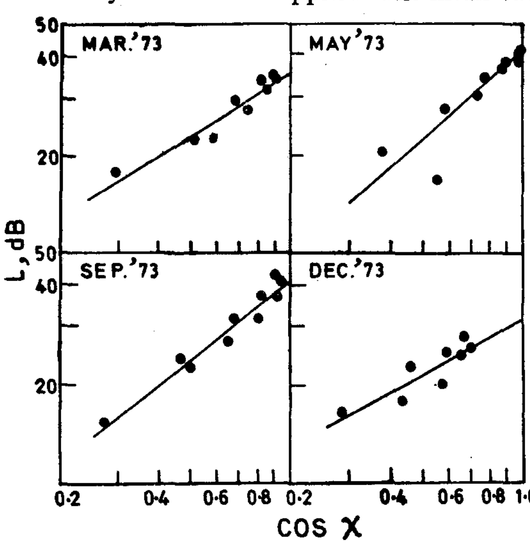

Fig. 2—Dependence of absorption L on the cosine of the solar zenith angle (The plot is done on log-log paper without applying time-delay correction)

Table 1—Values of n and L_0 in $L = L_0 \cos^n \chi$ on 2·5 MHz in 1973

Month	n	L_0 dB	Time delay min	R_s
Jan.	0·85	38·8	0·0	43.1
Feb.	1·05	37·6	−2·0	42·9
Mar.	0·63	35·9	25·0	46·0
Apr.	0·73	42·3	20·8	57·7
May	0·86	40·7	18·1	42·4
June	—	(39·5)*	—	39·5
July	—	(23·1)*	—	23·1
Aug.	0·68	26·7	15·2	25·6
Sep.	0·79	40·8	21·3	59·3
Oct.	0·41	35·4	30·0	30·7
Nov.	0·46	35·5	25·0	23·9
Dec.	0·55	31·4	44·3	23·3
Mean	0·70	36·5	19·8	38·2

* Note : Values in brackets are doubtful.

n is then found to be 0·78. Values of n obtained at several other places were given in our earlier paper.[1] Owing to the equipment and power supply failures, no observations could be taken in the months of June and July 1973.

4. Alternate Representation of Diurnal Variation of L

An alternate way of representing the diurnal variation of absorption as a linear function of the solar zenith distance is that used by CRPL (Central Radio Propagation Laboratory), now called NOAA (National Oceanic and Atmosphere Administration). It is given as

$$L = A + B \cos \chi \qquad \ldots(3)$$

where B represents sensitivity of absorption to solar control and A gives absorption at χ=90° or at night. The constants A and B are determined from the plot of L against cos χ on a linear graph paper. The sensitivity B is found to be high in summer and equinoxes. Table 2 gives the values of B and A obtained by linear extrapolation. It is likely that A may turn out to be negative in one or two months when the slope B is very high and that it may have high positive values when B is small. Such variations in the values of A are only mathematical and they may not have much practical significance. From some direct measurements with the echo obtained from strong E_s layer at about 110 km near sunset time when the D- and E-layer ionizations practically disappear or reduce to very small amounts, the absorption was found to be approximately 4 dB; and this nighttime

Table 2—Values of A and B in the Equation $L = A + B \cos \chi$ on 2·5 MHz in 1973

Month	A	B
Jan.	2·85	27·02
Feb.	−1·19	38·66
Mar.	8·05	29·08
Apr.	7·30	35·81
May	3·25	38·06
June	—	—
July	—	—
Aug.	5·09	22·44
Sep.	4·35	37·58
Oct.	16·59	19·91
Nov.	14·08	22·92
Dec.	8·72	25·09
Mean	6·91	30·66

value is not going to change much with the season. So the extrapolation of the line to get the value of A is just intended for mathematical computation of absorption. Eq. (3) may be written in another form to take into account the diurnal variation of ionization and the height of reflection as

$$L = A + B \cos^n \chi$$

or,

$$(L - A) = L' = B \cos^n \chi \qquad \ldots(4)$$

which is of the form similar to Eq. (2) except that in Eq. (4), the observed nighttime absorption is subtracted from the total observed daytime absorption. But when the value of n is close to unity, the observed absorption will obey satisfactorily any of the above three relations viz. Eqs. (2), (3) and (4) within the limits of experimental error.

5. Day-to-day Variations in Absorption

Hour-to-hour and day-to-day fluctuations in absorption are observed to the extent of $\pm$ 12 to 15 dB around midday during the course of a month as compared to its monthly median value. The reasons for such fluctuation can be traced back to the changes in ionization in a particular height range; these changes themselves might have been caused by the changes in the ionizing radiation intensity and the occurrences of sporadic irregularities or changes in the atmospheric composition. An example of such day-to-day fluctuations in noon absorption is shown in Fig. 3 for Jan. and Feb. 1973. Fig. 3 also shows the daily mean sunspot number and the day-to-day (0700 hrs UT) 1-8 Å solar X-ray flux observed by the satellites Solrad 10 and Explorer 44, and published in the *Solar Geophysical Data* bulletin of NOAA.

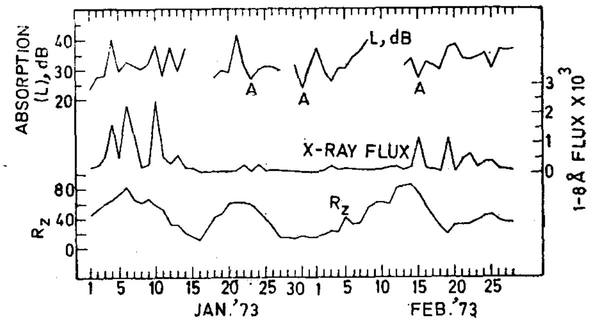

Fig. 3—Day-to-day variations in noon-time absorption compared with 1-8 Å solar X-ray flux and sunspot number during Jan.-Feb. 1973 (A indicates the presence of blanketing low-type E_s)

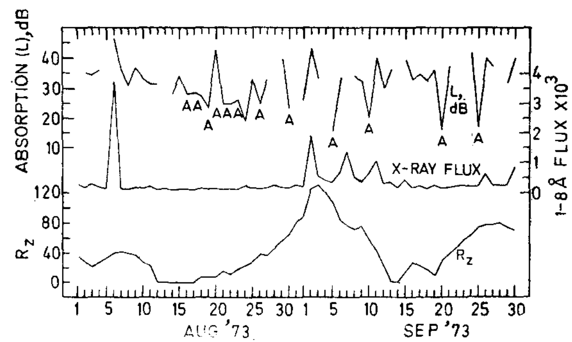

Fig. 4—Day-to-day variations in noon-time absorption compared with 1-8 Å solar X-ray flux and sunspot number during Aug.-Sept. 1973

It may be seen that on some days, the absorption was found to be very low. The letter A marked against such low values of absorption indicates that a strong reflecting or blanketing low-type E_s occurred on those days at the time of recording the echo amplitudes. Further, there were some occasions of increases in absorption which corresponded to solar X-ray bursts. The X-ray flux is usually maintained at an undisturbed value of about $0 \cdot 4 \times 10^{-3}$ ergs/cm^2/sec, but sometimes burst-type increases occur. In contrast to this, the daily variation of R_z is rather smooth and it is hard to find a good correlation between L and R_z on a daily basis.

Another example of day-to-day fluctuations in absorption is given in Fig. 4 for Aug. and Sep. 1973. It is clearly seen that most of the decreases in absorption are caused by the presence of blanketing low-type E^s and some of the increases in absorption seem to be associated with the increases in solar X-ray flux. It may, however, be pointed that there are some cases of increase in absorption, which are not related in any way with the X-ray flux, and also do not maintain any proportionality between the related increases of L and X-ray flux on different occasions. Once again, we find that there is no good correlation between the daily changes of L and R_z.

6. Discussion and Conclusions

(i) The index n of $\cos \chi$ for solar diurnal variation of monthly median absorption is found to vary from 0·41 to 1·05 during the course of a year, with the absorption being generally high in summer. The annual mean value of n turns out to be 0·70. This compares well with those obtained by other workers on a similar frequency at different latitudes.[3-8] The seasonal variation of n is probably due to the changes in the atmospheric composition and electron density distribution profiles; this variation, in turn, involves the changes in the refractive index and the loss-rate of ionization. The value of n is also affected by the frequency of occurrence of sporadic-E layer and other unusual solar events.

(ii) The relaxation effect in absorption is determined by the quantity $1/2\alpha N$ where α is the effective recombination coefficient and N is the electron density. Since N in the D- and E-regions at low latitudes is reduced at different levels in winter as compared to that in summer, and there is a seasonal variation of height of these ionized layers so as to give decreased α in winter, the integrated relaxation effect would be larger in winter than in other seasons.

(iii) The reflecting low-type E_s causes reduction in absorption, because the radio wave is reflected abruptly at a low sharp boundary of the intense ionization. The reduction in absorption is approximately a measure of deviative absorption which would be suffered by the wave in the normal E-region when there is no E_s and the observed absorption for reflection from the blanketing E_s gives roughly the non-deviative absorption of the wave in the D-region. Reference is also made to the work of Purkait and Datta[9] in this connection.

(iv) The occasional increases in absorption seem to be associated with the increases in 1-8 Å solar X-ray flux. The lack of proportionality between changes in absorption and the X-ray flux on different occasions is probably due to the changes in the atmospheric composition which affect the production and loss rates of ionization as well as the N-h profile.

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