1. Introduction

The ionospheric absorption of hf radio waves is measured by three methods, namely, (i) vertical incidence pulse technique of A1 method, (ii) cosmic radio noise or A2 method, and (iii) oblique-incidence field-strength of waves transmitted from a distant station or A3 method. Much work has been done on absorption at temperate latitudes particularly in Europe but not at low latitudes. There are some equatorial ionospheric stations at which this work had been carried out for a limited period, the longest of which being at Colombo. However, systematic observations over an extended period are still lacking at low latitudes. A long-term research project was set up in March 1972 at Ahmedabad in collaboration with Prof. E.A. Lauter's group at the German Academy of Sciences, Berlin (GDR) for measurement of ionospheric absorption on different frequencies by the A1 method, and the preliminary results obtained are reported in this paper.

2. Experimental Details

The transmitter delivers a peak pulse power of about 35 kW. The transmitted pulse width is 100 μsec and the pulse repetition frequency is 30 pulse per sec. Three different frequencies are electronically switched in sequence in a time interval of 100 msec and this sequence is repeated at a rate of 5/sec over 5 min. The receiver output is recorded on strip-chart recorder, on punch-paper tape and on photographic film which involves analogue and digital conversion circuits. The movie camera snaps the pictures of echo amplitude and height of reflection at intervals of 1 min giving five snaps for each frequency during one operation. For routine work, the operation is done every hour. In order to avoid interference with other experiments nearby, we have programmed hourly operation at 20 minutes past every hour IST, i.e. UT+5 hr 10 min. A 60 kc/s master oscillator controls a digital clock and other pulse-switching circuits. The equipment can be set either on automatic or manual operation.

The antenna system consists of two vertical delta aerials, oriented at right angles, one for transmitting and the other for receiving. The base of the delta is 120 m long and is at 3 m above the ground level. The top vertex is at a height of 30 m above the ground. It is terminated by a non-inductive resistance of 600 ohms.

The absorption is calculated from the day-time amplitude of the echo and the height of reflection of the pulse relative to those at night-time. A standard night-time reference has to be obtained by observations over several night hours when the ionosphere is free from sporadic-E and spread-F phenomena. Then the absorption is

\[ L \text{ (in dB)} = 20 \log \frac{E_n h'_n}{E_d h'_d} \]

where \( E \) stands for amplitude of the echo and \( h' \) stands for virtual height of reflection. The subscripts \( n \) and \( d \) stand for night-time and day-time. Initial dB setting of the attenuator in the receiver has to be added to the observed amplitude.

3. Results

(i) Diurnal variation of absorption—Observations of the amplitudes of the echo and the heights of reflection are taken from 0800 to 1800 hrs in the day-time daily and usually from 2200 to 0200 hrs in the night-time for 12 to 15 clear ionosphere days. Fig. 1(a) gives the diurnal variation of monthly median values of absorption in April 1972, the time-axis being that for the standard meridian of 75°E. It will be seen...
that the maximum is reached about 40 min after 1200 hrs; however, there were some days on which the maximum occurred even at noon as in August [Fig. 1(b)] or even before noon. The maximum absorption on 1.8 MHz is about 73 dB and that on 2.2 MHz it is 61 dB in April and values are almost the same in August [Fig. 1(b)]. Great caution has to be exercised in selecting the mode of echo (ordinary wave in our case) particularly in the morning and evening hours when formation and disappearance of the E2 and F1 layers complicate the situation of reflection at higher frequencies; one has to take help of the ionograms to ascertain the right mode. It is very likely that the absorption at these times on frequencies close to foE may be slightly higher than shown by the smooth diurnal variation curve.

(ii) Dependence of absorption on zenith distance of the sun —The diurnal variation of absorption at a place is a function of the zenith distance of the sun and the absorption $L$ can be expressed as

$$L = L_0 \cos n\chi,$$

where $\chi$ is zenith angle of the sun at the place of observation and $L_0$ is the subsolar value of absorption, i.e. when $\chi=0$. A plot of log $L$ against log (cos $\chi$) gives the value of the exponent $n$ from the slope of the expected straight line and the value of $L_0$ is obtained from the intercept on the log $L$ axis. This is shown in Fig. 2 for April 1972. The values of cos $\chi$ at different hours are those for the fifteenth day of the month and those of $L$ are monthly median values. It is to be noticed that the points lie very close to a straight line drawn through the points by the method of least squares. Fig. 3 gives a similar plot for August 1972. The values of $n$ and $L_0$ for April and August 1972 on the two frequencies are given in Table 1.

It may be seen that both $n$ and $L_0$ have a tendency to change with season. Since the solar activity in April and August is practically the same, the values of $L_0$ do not differ much in these months. The values of $n$ obtained here are somewhat higher than those observed on 2.5 MHz in 1957-58 by Shirley; however, the values of $L_0$ seem to be consistent. Table 2 gives a comparison of the mean values of $n$ obtained from diurnal variation at different places.

It will be seen from Table 2 that the value of $n$ lies in the range 0.7 to 1.0 as against 1.5 expected under ideal solar control of ionization (Appleton). However, Dieminger18 reported $n = 1.5$ from seasonal variation of absorption at Tsumeb. The change in $L_0$ with season is ascribed to the changes in solar activity, gas composition and temperature in the ionosphere, which affect the production and loss rates of ionization.

(iii) Day-to-day variation of absorption—Fig. 4 gives the day-to-day variations of the noon value of absorption.
absorption in April 1972. The sunspot number $R_z$ and magnetic activity index $ΣK_p$ are also shown in Fig. 4. It is to be noted that day-to-day variations in absorption on 2.2 MHz are larger than on 1.9 MHz although the absorption on the higher frequency is generally less than on the lower frequency. Further, there is an indication of reduction in absorption on magnetically disturbed days, but there is no clear correlation between the day-to-day variations of $L$ and $R_z$.

The earlier part of the fortnight in August 1972 was much disturbed, and this forms a part of the Retrospective World Interval, viz. July 26 to August 14, 1972. The day-to-day variations of $L$ in August 1972 shown in Fig. 5 indicate that the absorption is reduced to some extent on days of increased magnetic activity as also found in April. The variations in absorption at the higher frequency are larger than on the lower frequency, and on one or two days, the absorption on higher frequency was even larger than on lower frequency, an observation which is unusual. These features may be due to greater penetration of the wave into the ionosphere at higher frequency and to the response of the ionizable gas to perturbations at greater heights. There are some reports showing increase in absorption at midlatitudes following the day of magnetic disturbance with a lag of 3 to 5 days$^{15-16}$.

Fig. 4—Day-to-day variations of ionospheric absorption on 1.8 MHz and 2.2 MHz at Ahmedabad in April 1972. (Sunspot number $R_z$ and magnetic activity index $ΣK_p$ are also shown for comparison)

Fig. 5—Day-to-day variations of ionospheric absorption on 1.8 MHz and 2.2 MHz at Ahmedabad in August 1972 compared with those of $R_z$ and $ΣK_p$.

Acknowledgement
The authors wish to express their gratitude to Prof. E. A. Lauter and his group at the German
Academy of Sciences, Berlin (GDR) for generously presenting as gift a very sophisticated equipment for measurement of ionospheric absorption at different frequencies under a protocol signed between the Governments of India and the German Democratic Republic for scientific cooperation. The authors are also thankful to Dipl. Ing. H. Kober, Dr K. G. Jani and Mr B. M. Patel for their assistance in the installation and maintenance of the equipment. Two of the authors (J.C.P. and G.M.C.) thank the CSIR, New Delhi, for the grant of research fellowships.

References
3. SCHWENTEK, H., Nachrtech. Z., 18 (1965), 94.