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INTERNATIONAL CONFERENCE ON COSMIC RAYS AND THE EARTH STORM Part I

I-5-6. Ionospheric Disturbances and Change in Cosmic Radio Noise Absorption on 25 Mc/s at Ahmedabad Associated with Some Solar Events and Geomagnetic Storms in November 1960*

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Summary

The paper describes the results of analysis, of $N(h)$ profiles and the changes in the observed total attenuation of 25 Mc/s cosmic radio noise recorded at Ahmedabad during 10–17 November, 1960, a period of high solar activity.

Using $N(h)$ data and the available models of electron density variation with height above $h_{\max}$ calculations of ionospheric attenuation on 25 Mc/s C. R. noise are made and compared with the observed total attenuation of C. R. noise. It is shown that major attenuation takes place above $h_{\max}$ and that during SC magnetic storms, the attenuations become abnormally low.

The SCNA recorded on 11.11.60 at Ahmedabad is shown to be the likely cause of the SC magnetic storm on 12.11.60.

In a recent paper, Ramanathan *et al.* (1961) have outlined a method of calculating the nondeviative ionospheric attenuation of cosmic radio noise from a knowledge of $N(h)$ profiles calculated from vertical soundings up to $h_{\max}$, electron collision frequencies, and electron distributions above $h_{\max}$ calculated on the basis of models of electron density according to Al'pert *et al.* and Kazantsev. They compared the computed values of absorption of C.R. noise with the observed total attenuation in a disturbed period in August-September 1957. They found that large day-to-day changes in absorption occur above $h_{\max}$ and that on the day following the SC of a magnetic storm the total attenuation became abnormally low. The attenuation increased above its pre-storm value for a period of not less than 24 hours after the end of the storm. They concluded that the major changes in absorption could be explained in terms first of depletion and later of refilling of the F region and above by electrons and ions.

In this communication, we discuss the results of our analysis of ionospheric disturbances from pulsed vertical sounding data and the 25 Mc/s C. R. noise monitor at Ahmedabad during the period 10–17 November, 1960. This period was eventful in that increases in cosmic ray intensities were also reported from high latitudes.

The C.R. noise monitor at Ahmedabad recorded three SCNA'S (Sudden Cosmic Noise Absorption) and associated solar radio noise bursts (See Table I)

Table I. SCNA'S observed on 25 Mc/s at Ahmedabad.

Date	Start time U.T.	Duration, minutes	Max. Absorption db.
11.11.60	0313	90	3
14.11.60	0300	105	1.8
15.11.60	0220	90	4

The hourly $P'(f)$ records for the period under investigation were reduced to true height profiles using Schmerl-ing's coefficients adapted for the dip angle of Ahmedabad (Degaonkar, 1961). The total attenuation from 65 to 1000 km was calculated by evaluating $\int N_e \nu dh$ considering both electron-neutral particle (ν_{en}) and electron-positive ion collisions (ν_{ei}), N_e is the number of electrons per unit volume. The method of calculating the absorption has been explained in our earlier paper. (See Ramanathan *et al.*, 1961). Hourly values of cosmic radio noise attenuation between 06 and 23 hours on each of these days were calculated. As the attenuation was very small between 00 and 06 hours, it was thought unnecessary to show it on the diagram during these hours.

* This paper was read by V. A. Sarabhai.

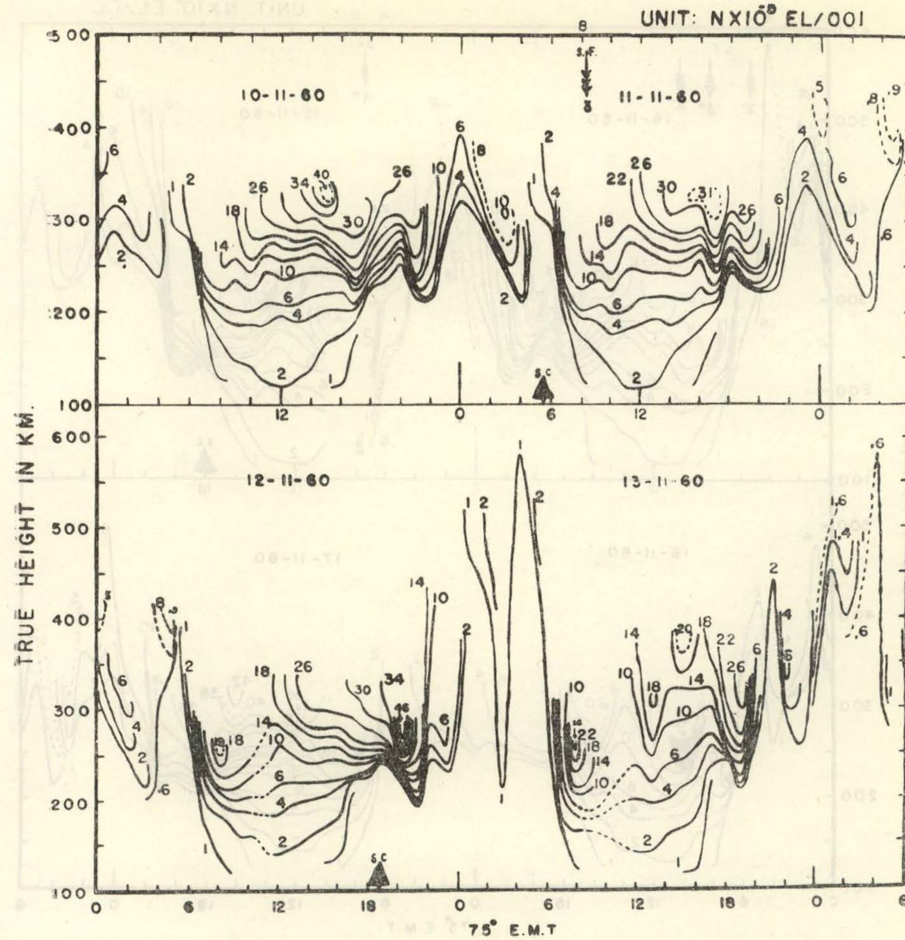

Fig. 1(a). Electron distribution over Ahmedabad during 10-13, Nov. 1960.

In Figs. 1 (a) and 1 (b) are drawn the electron density contours which bring out the main features of the ionospheric disturbances associated with the November 1960 solar events. Five solar flares in this period were reported by the Hiraiso Observatory, Japan and their times of occurrences are shown on the diagram. There were three SC magnetic storms in this period. (See Table II)

If we compare the electron densities on pairs of days, such as, 10 and 11, 12 and 13, and 16 and 17, we find that the electron densities are much lower on the day following the SC storm. It is also seen that the ionosphere is affected much more during dark hours both in respect of height and electron densities.

Table II. SC Magnetic Storms.

Date	SC Starting time, U.T.	ΔH γ	Observatory
11.11.60	0034	132	Hiraiso, Japan
12.11.60	1345	487	Kodaikanal, India
15.11.60	1302	305	Kodaikanal, India

The storm on the 11th being a minor one did not produce any large scale upheavals in the ionosphere. Nevertheless its effect can be detected on the afternoon of that day. The storm which commenced on the 12th was by far the most severe in this series. It is interesting to note that unusually high concentration of electrons (of the order of 46×10^5 electrons/cc) appeared within an hour after SC. This high concentration of electrons disappeared quickly in the next few hours. After midnight, large variations in height were observed ranging from 200 to 600 km. On the 13th, barring the morning peak, the electron densities were low throughout the day. Before the ionospheric condi-

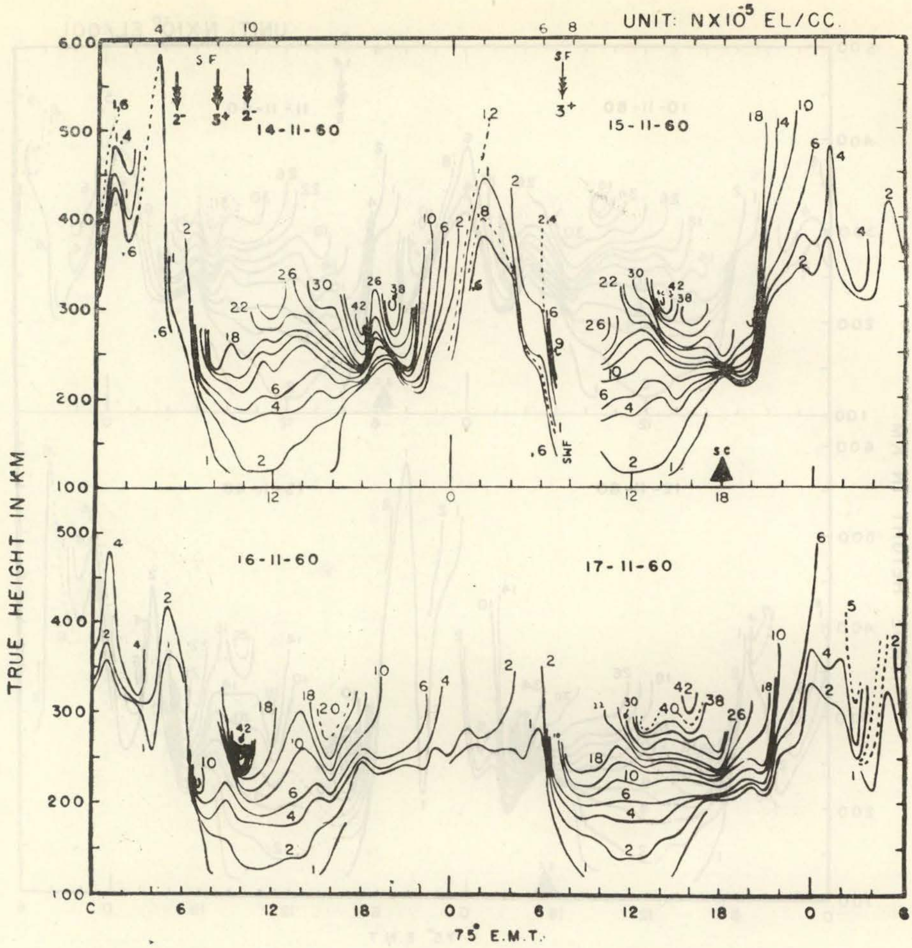

Fig. 1(b). Electron distribution over Ahmedabad during 14–17, Nov. 1960.

tions returned to normal, there was another SC storm on the 15th. This storm caused the iso-dense levels to spread out on the 16th. Here again highly localised concentration of electron densities (of the order of 42×10^5 el/cc) were temporarily formed at about 10 hrs local time on the 16th. The rest of the day showed low electron densities. On the 17th, the electron densities tended to come to normal values.

The effect of the magnetic storms on N_mF (maximum electron density of the F region) n_T (total electron content per cm^2 unit column up to h_{max}) is shown in Fig. 2. N_mF and n_T do not show similar variations because of simultaneous changes in h_{max} and h_0. The changes in N_mF are more rapid than those in n_T. It can be noticed that n_T has undergone reduction on the 13th and 16th after the SC indicating depletion of electrons even below h_{max}.

In Fig. 3 are shown (a) the observed attenuation, (b) the calculated ionospheric attenuation up to h_{max} and (c) the calculated total absorption up to 1000 km assuming three models of electron density variation above h_{max}, one according to Al'pert *et al.*, a second according to Kazantsev and a third according to Garriott (1960). On all these days, irrespective of magnetic disturbance, more ionospheric attenuation seems to have occurred above h_{max} than below that level. This is in conformity with the results arrived at by us previously.

In the case of the September 1957 events, we had found that the Al'pert and Kazantsev models were satisfactory on high and low absorption days respectively. In the present investigation, we have tried the models of Al'pert, Kazantsev and Garriott for the electron density distribution above h_{max}. Al'pert's and Kazantsev's models served as two extremes, Al'pert's showing a slow rate of fall of electron density with height above h_{max} and Kazantsev's showing a much faster rate. Garriott's model strikes a mean between these two extreme models. It was found that on any single day, the calculated attenuations based on these models did not give complete hour to hour agreement with the observed attenuations. The discrepancies were most pronounced when there were sudden increases or decreases of concentration of electrons above the level of h_{max}. To

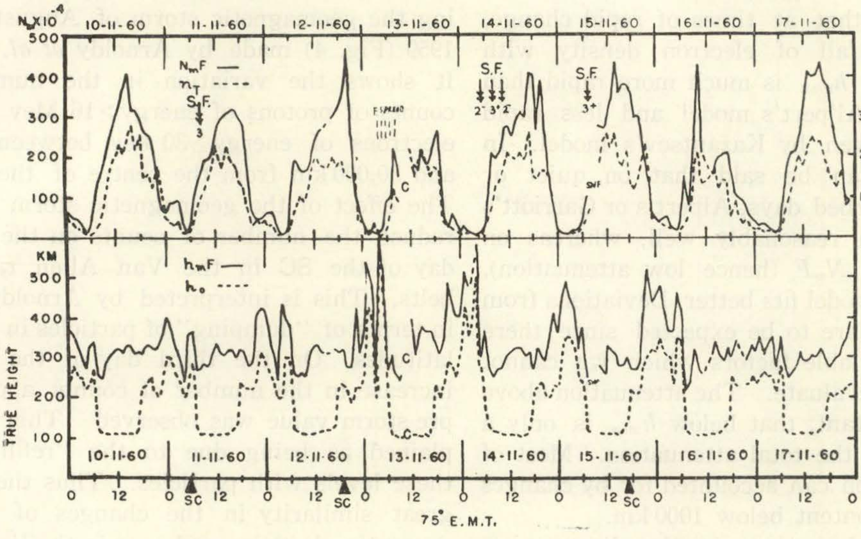

Fig. 2. N_mF, n_T, h_mF and h_0 over Ahmedabad during 10–17, Nov., 1960.
SC magnetic storm at 0034 U.T. on 11-Nov-60
SC magnetic storm at 1348 U.T. on 12-Nov-60
SC magnetic storm at 1303 U.T. on 15-Nov-60

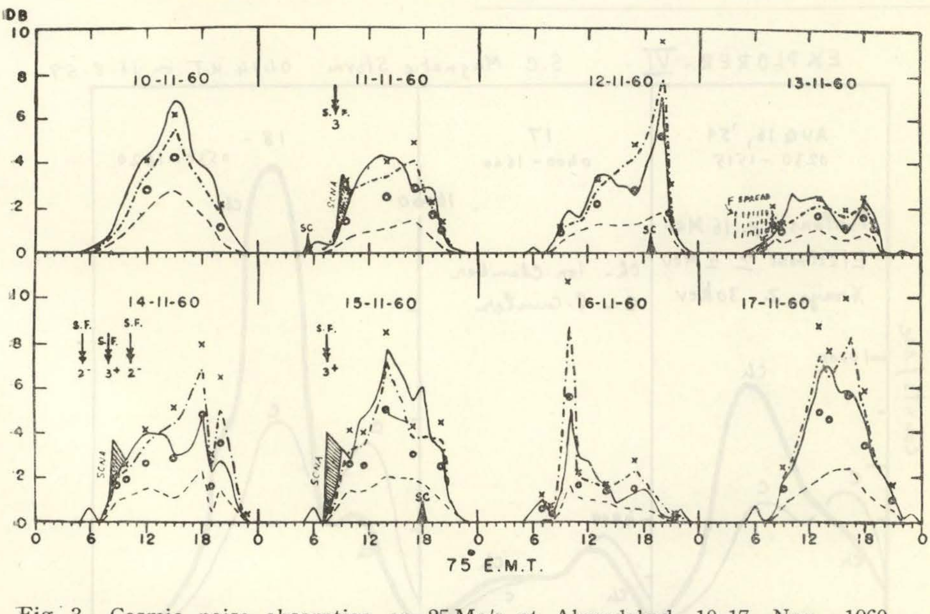

Fig. 3. Cosmic noise absorption on 25 Mc/s at Ahmedabad, 10–17, Nov., 1960. Observed ——; calculated absorption up to h_{max} – – –; calculated total absorption up to 1000 km with Al'pert model above h_{max} ×××; Kazantsev ooo; Garriott –·–·–.

take a few examples, we find that the calculated absorptions based on the Al'pert model are too high between 16–20 hrs on the 12th, 14–20 hrs on the 14th, 08–10 hrs on the 16th and 12–18 hrs on the 17th, whereas the calculated absoption based on the Kazantsev model are gnenerally lower than the observed ones. There is agreement at some hours. This means that at times of rapid change, the rate of fall of electron density with height above h_{max} is much more rapid than according to Al'pert's model and less rapid than that given by Kazantsev's model. In general, it can be said that on quiet or slightly disturbed days, Alpert's or Garriott's model fits in reasonably well, whereas on days of low N_mF (hence low attenuation), Kazantsev's model fits better. Deviations from these models are to be expected since there are many variable factors which we cannot yet properly evaluate. The attenuation above h_{max} is important; that below h_{max} is only a small part of the total attenuation. Most of the attenuation can accounted for by changes in electron content below 1000 km.

The hatched portions in the diagram indicate three SCNA's caused by absorption occurring mainly in the lower ionosphere. These absorptions as can be seen from the diagram are but small effects compared to the diurnal F region attenuation. The late evening peaks in absorption observed during winter and equinoxes in high sunspot years has almost vanished in November 1960.

It is interesting to compare these results with the radiation measurements made with an integrating ion chamber and a Geiger counter in U.S.A. satellite Explorer VI during the geomagnetic storm of August 16–18, 1959 (Fig. 4) made by Arnoldy *et al.* (1960). It shows the variation in the number of counts of protons of energy $\geq$16 Mev and of electrons of energy $\geq$30 kev between 10,000 and 30,000 km from the centre of the earth. The effect of the geomagnetic storm was to reduce the number of counts on the second day of the SC in the Van Allen radiation belts. This is interpreted by Arnoldy *et al.* in terms of "dumping" of particles in auroral latitudes. On the third day of the SC, an increase in the number of counts above the pre-storm value was observed. This was explained as being due to the "refilling" of these levels with particles. Thus there is a great similarity in the changes of flux of energetic electrons and ions in the Van Allen radiation belts and low energy electrons in the ionosphere below 1000 km.

Fig. 5 (a) shows an interesting solar event which was recorded by the 25 Mc/s cosmic

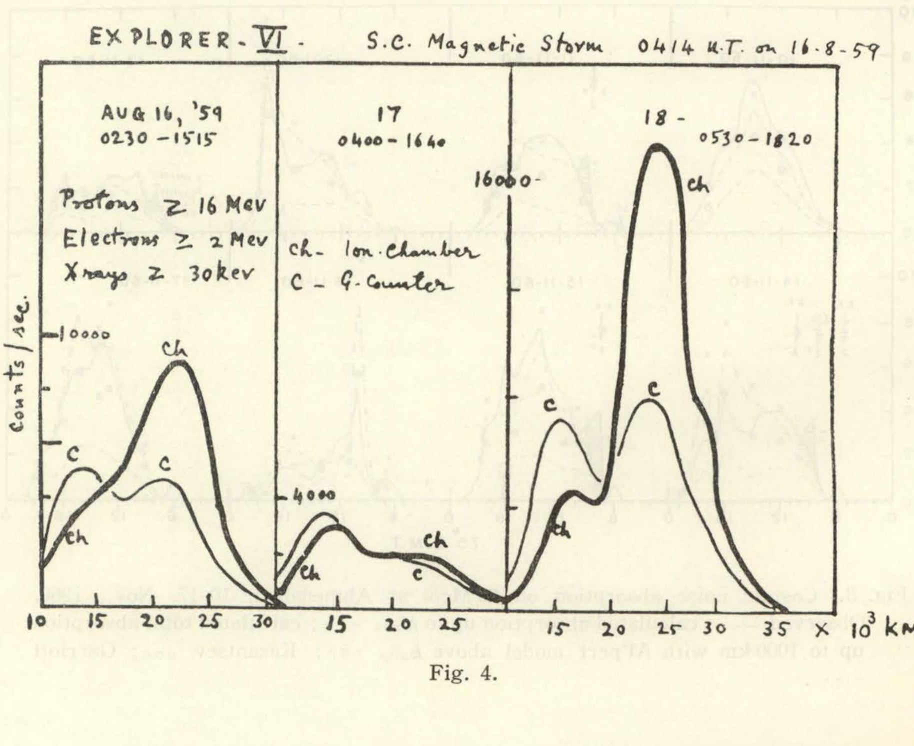

Fig. 4.

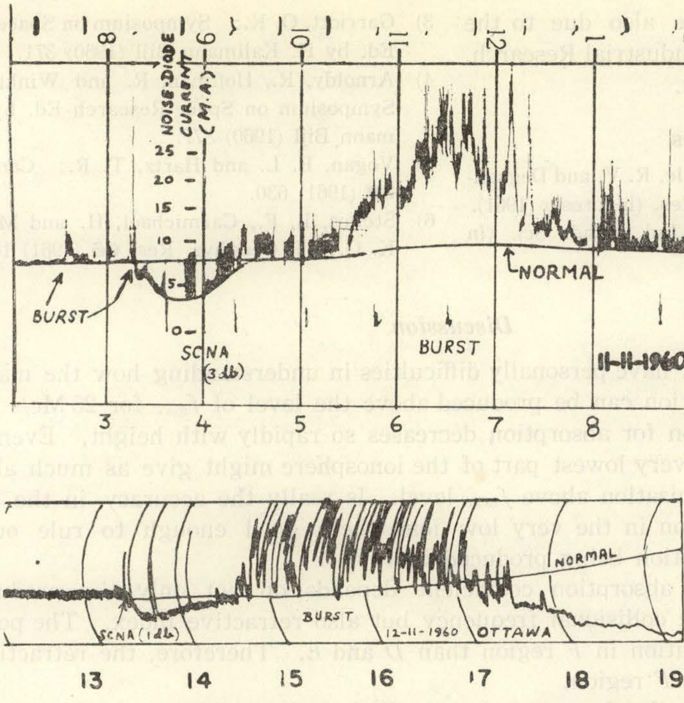

Fig. 5. (A) SCNA and solar bursts on 25 Mc/s, Ahmedabad.
(B) SCNA and solar bursts on 30 Mc/s, Ottawa.

radio noise monitor at Ahmedabad on 11.11. 1960. The SCNA started at 0313 U.T. It was gradual in development with duration of about 90 minutes. It caused maximum absorption of about 3 db. About two hours after the start of the SCNA, a long duration burst of solar noise of highly variable intensity lasting for nearly three hours was recorded. The normal trend of the C.R. noise for a quiet period is also shown in the diagram. The C.R. noise intensity returned to normal by about 08 U.T. It is likely that the severe magnetic storm which started at 1345 U.T. on the 12th was an effect of this solar flare and the subsequent intense solar radio bursts since the time delay between the occurrence of the SCNA on 11.11.60 at Ahmedabad and the SC on the 12th is about 35 hours.

It is interesting to compare a similar event which was recorded on the 30 Mc/s riometer at Ottawa on 12.11.1960. This is shown in Fig. 5(b) after Vogan and Hartz (1961). There the SCNA started at 1325 U.T. and produced maximum absorption of 1 db. As can be seen from the diagram, this SCNA was also followed by irregular long duration solar bursts. The Ottawa record shows in addition the presence of a polar cap type of absorption. These are now attributed to the bombardment of the upper atmosphere by low energy cosmic ray particles.

The field strength recordings of 164 kc/s transmissions from Tashkent Radio Station which are regularly made at Ahmedabad (unpublished) have shown sudden enhancements corresponding to the solar flare on 11, 14 and 15 November 1960. But the solar flare on 12.11.60 which was recorded by the 30 Mc/s riometer at Ottawa could not be recorded here as it was night time. This flare had caused nearly 210% increase in the neutron monitor intensity over its pre-flare intensity at Deep River, Canada. However, the flare which occurred at 0220 hrs U. T. on 15.11.60 could be recorded at Ahmedabad by both the low frequency and high frequency monitors. This caused nearly 175% increase in the neutron monitor intensity over its pre-flare value at Deep River within 10 minutes of the start of the flare (see Steljes *et al.*, 1961).

Acknowledgement

The authors wish to express their grateful thanks to Professor K. R. Ramanathan for guidance. The thanks are also due to the Council of Scientific and Industrial Research, India, for financial support.

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Discussion

Hultqvist, B. K. G.: I have personally difficulties in understanding how the majority of non-deviative absorption can be produced above the level of f_{max} for 25 Mc/s radiation, as the cross section for absorption decreases so rapidly with height. Even very small ionization in the very lowest part of the ionosphere might give as much absorption as attributed to ionization above f_{max} level. Is really the accuracy in the knowledge about the ionization in the very low ionosphere good enough to rule out the possibility of the absorption being produced there?

Piggott, W. R.: The absorption coefficient depends on not only the product of electron density and the collisional frequency but also refractive index. The point is very much denser ionization in *F* region than *D* and *E*. Therefore, the refractive index is relatively low in *F* region.

Sarabhai, V. A.: Yes, the frequency is not all that above the critical frequency.

Knecht, R. W.: Regarding Dr. Hultqvist's comment, I should think one would expect a greater amount of deviative absorption to occur in the region just above the *F* layer maximum compared to the region just below because of the considerably lower electron density gradient on the topside.

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INTERNATIONAL CONFERENCE ON COSMIC RAYS AND THE EARTH STORM Part I

I-5-7. Vertical Travelling Disturbances in the Ionosphere*

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An attention of a number of ionosphere investigators[1)-5)] has long ago been drawn to the appearance on *h'f* records of unusual separations, which begin near critical frequencies of *F2* layer and then displace to the low frequency end of *F*-trace. The presence of such separations shows the appearance of ionospheric irregularities of electron concentration. This paper considers some preliminary results of investigation of vertical travelling disturbance in the ionosphere, obtained by the data of the Moscow station of vertical sounding for 1958.

While investigations ionograms for RWD and SWI for winter, summer and equinox months were considered. For the days where they observed evident vertical travelling disturbances, *f*- and *h*-graphs were built. As a rule, ionograms, recorded in five minute interval, were used. Consider the case of the appearance of travelling disturbances, observed on 25 March 1958 at the Moscow station. Fig. 1 gives *f*- and *h'* -graphs for

* This paper was read by N. V. Pushkov.