THE OCCURRENCE OF HIGH MULTIPLE REFLECTIONS FROM THE F2 REGION OF THE IONOSPHERE BASED ON A STUDY OF THE AHMEDABAD RECORDS

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Introduction

Shortly after the installation of the automatic ionospheric recorder at Ahmedabad in January 1953, it was observed that on certain nights groups of pulses other than the regular ones moved swiftly across the time base on the monitor oscilloscope. On the P′-f records, they produced traces which started from below the ground pulse and crossed the various P′-f traces. Examples of such records are shown in Fig. 1. After the first three months of regular P′-f recording, the phenomenon was not observed for some months, but reappeared clearly in December 1953 and January 1954. A study of the phenomenon was then undertaken.

General Features of the Phenomenon

The following features were noticed about these abnormal traces: (1) They occurred only during night. (2) At any frequency the separation in height between two adjacent abnormal traces appeared to be the same as the virtual height of the first reflection trace at that frequency. (3) They ended at the ordinary critical frequency f_0F_2 of the F_2 layer, and on some occasions, there was another group of pulses ending at the extraordinary critical frequency f_xF_2 of the F_2 layer. (4) The ratio of the slope of an abnormal trace to that of the first reflection trace was found to be the same at any frequency and increased in steps of one from one trace to the next. It was therefore concluded that these abnormal traces represented high order reflections from the ionosphere.

The equipment at Ahmedabad is a British N.P.L. type automatic ionospheric recorder and the pulse repetition frequency is 50 per second. If the delay time of a high order multiple reflection is more than 1/50 second, it will be recorded in the second sweep of the time base, and the equivalent height of the multiply reflected trace will exceed 3000 km. (= 1/50 second). The order of reflection can be determined by dividing the slope or the equivalent height of the trace at any frequency by the corresponding slope or height of the first reflection trace at that frequency.

During regular recording, the duration of the time base is usually adjusted to record echoes of equivalent height upto 1000 km. only. However, the time base duration can be extended to record echoes of equivalent height upto about 2000 km. With such an extended time base, multiples upto the 17th order have been recorded. It was considered that it would be worthwhile to increase the height range still further and arrangements were made on a few occasions to record the echoes in two steps, first showing the reflections upto 1500 km., and then delaying the start of the time base so as to record heights between 1500 and 3000 km. Such a double record is shown in Fig. 2 where all multiple echoes from the first to the ninth can be seen.

An examination of the literature showed that high multiple reflections have been noticed by some previous workers on P′-t records (Pierce and Mimno,[1] Baird[2]). They attributed these to the curved shape of the ionosphere or humped ionisation contours in the ionosphere. These humps produce a mirror-like converging action on the reflected radio beam. Gipps, Gipps and Venton[3] also explained some abnormal traces in P′-f records in terms of humps and concavities in the ionosphere. Munro[4] described certain complexities observed on ionospheric records as the effects of the curvature of the ionospheric surface. Uyeda and Nakata[5] have recently described similar abnormalities observed on h'-t and fct records and explained them on an assumed inclination of the ionosphere and its movement.

ANALYSIS OF AHMEDABAD RECORDS SHOWING HIGH ORDER MULTIPLE REFLECTIONS

A detailed analysis was made of the records showing such abnormal traces and the present note contains a summary of the findings.

The parameters of the F_2 layers were determined by the method of Appleton and Beynon.[6] The virtual heights of the layer at various frequencies were plotted against the corresponding values of Booker and Seaton's function[7]

$$\phi\left(\frac{f}{f_c}\right) = \frac{1}{2}\frac{f}{f_c}\log_e\left|\frac{f_c+f}{f_c-f}\right| - 1$$

where f_c is the critical frequency of the layer and f any frequency less than the critical frequency. It was found that a neat straight line could be drawn through the points showing that the distribution of electrons in the F_2 layer during the night time was approximately parabolic. The values of the virtual heights at $\phi = -1$ and $\phi = 0$ gave respectively the true height of the base h_0F_2 and the height of the level of maximum ion density h_pF_2, the semi-thickness being given by $h_p - h_0$.

f Mc/s	ϕ	h_2 km.	$h_2/2=h_1$ km.	$h(n_1)$ km.	$hn_1/11$ km.	$h(n_2)$ km.	$hn_2/12$ km.	$h(n_3)$ km.	$hn_3/13$ km.	$h(n_4)$ km.	$h(n_4)/14$ km.	Mean h_1 km.
1·9	−0·52	445	223	..	..	..	..	..	..	..	..	223
2·0	−0·47	452	226	..	..	..	..	..	..	..	..	226
2·1	−0·37	460	230	..	..	..	..	..	..	..	..	230
2·2	−0·32	470	235	..	..	..	..	3000	231	..	..	233
2·3	−0·21	480	240	..	..	..	..	3090	238	..	..	239
2·4	−0·12	490	245	..	..	2900	242	3160	243	..	..	243
2·5	0·00	500	250	..	..	2970	248	3250	250	3500	250	250
2·6	+0·14	520	260	..	..	3080	257	3350	258	3640	260	259
2·7	+0·33	540	270	2900	264	3200	267	3450	265	3750	268	267
2·8	+0·54	560	280	3080	280	3360	280	3575	275	..	..	280
2·9	+0·95	615	308	..	..	..	..	..	..	..	..	308

The analysis of a typical record (Fig. 1 *b*) is given in the following table. The value of f_0F_2 was 3·0 Mc/s. $h(n_1)$, $h(n_2)$, $h(n_3)$ and $h(n_4)$ are the virtual heights of observed multiples and are found to be nearly equal to 11, 12, 13 and 14 times h_1. h_pF_2 was found to be 250 km., h_0F_2 to be equal to 198 km. and the semi-thickness of the layer was 52 km.

With a view to find out what ionospheric features were associated with high multiples, the parameters h_0, h_p and T obtained from the hourly ionospheric records during the occurrence of the phenomenon were examined.

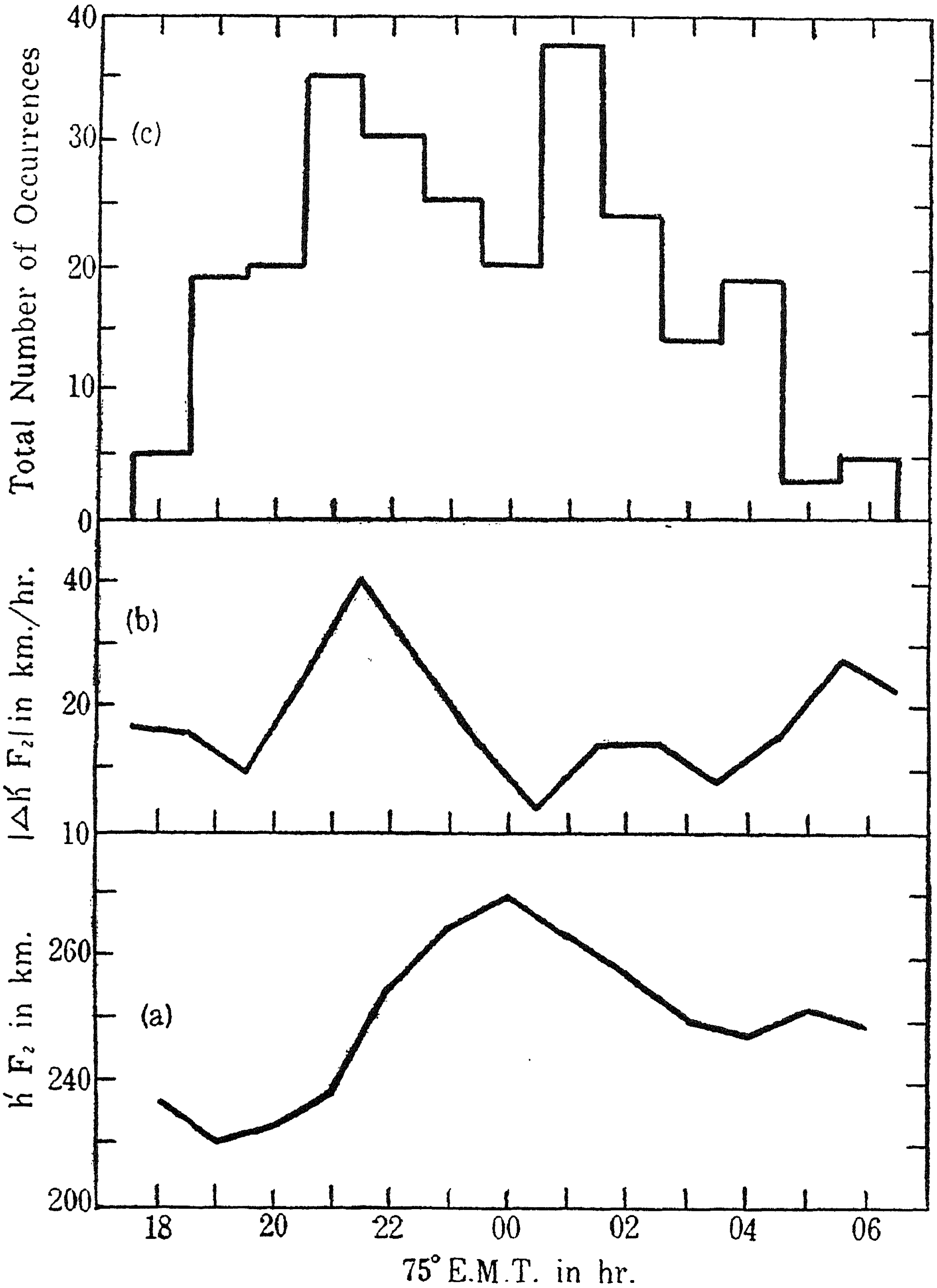

Fig. 3. (*a*) Mean minimum virtual height of the F_2-layer (January 1953 to December 1954). (*b*) Average hour to hour change in $h'F_2$ (January 1953 to December 1954). (*c*) Total number of occurrences of high multiples (January 1953 to December 1954).

In the records of the period January 1953 to December 1954 there were 256 such occurrences. It was found that in general high multiple reflections were associated with a hump in the ionospheric surface over the place of observation. High multiples occurred more or less continuously for many hours in certain periods of the night in some months. Near the critical frequency the multiples are generally weaker, due no doubt to increased absorption as well as to increased slope of the P′-*f* traces.

The distribution of the occurrence of high multiples with the hour of the night is shown in Fig. 3 (*c*). In Fig. 3 (*a*) and 3 (*b*) are shown the mean

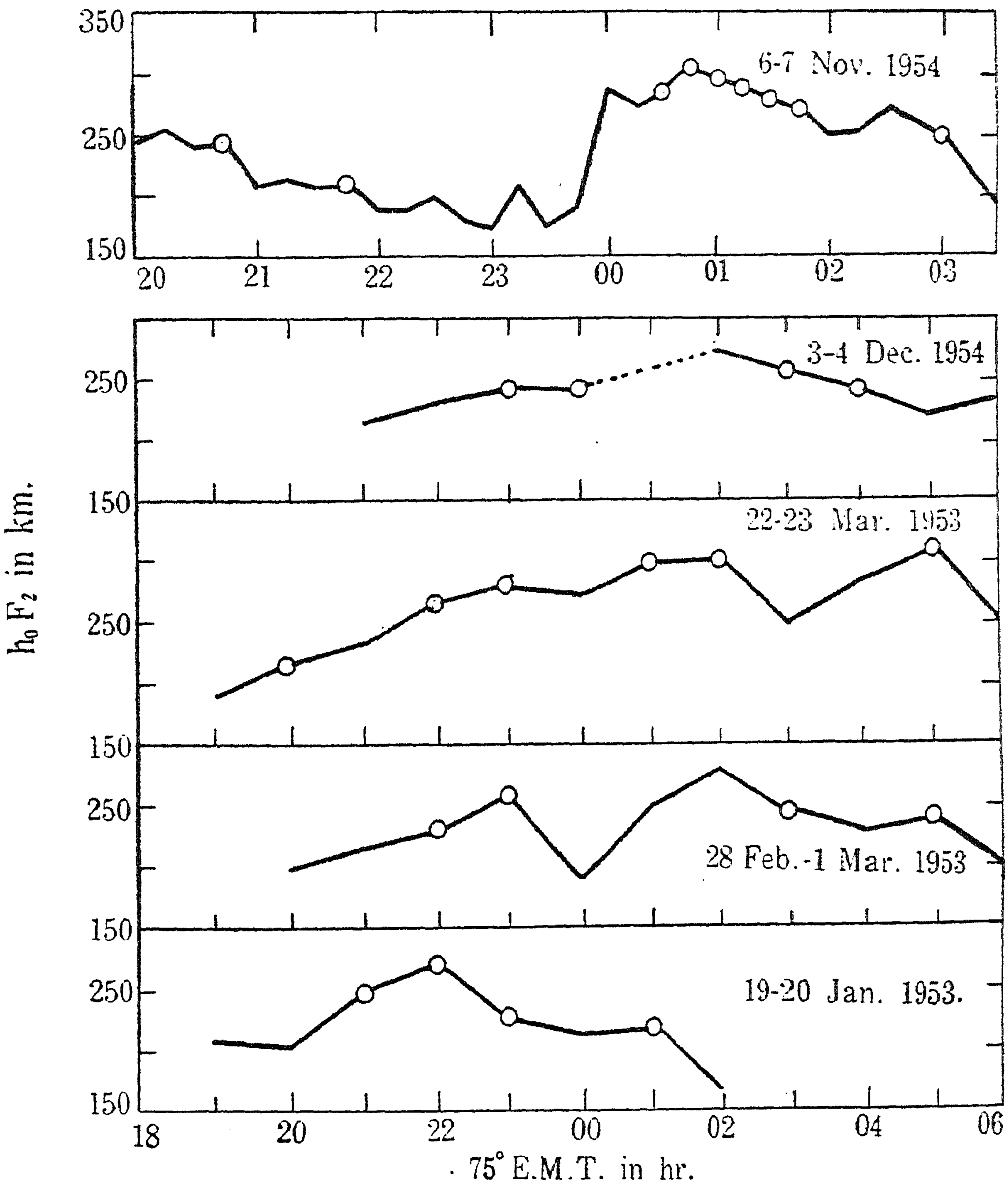

FIG. 4. Variation of h_0F_2 and the occurrence of high multiples on a few nights.

virtual height ($h'F_2$) and the average hour-to-hour change in virtual height ($h'F_2$) during the period January 1953 to December 1954.

It will be seen that the hour of maximum occurrence of high multiples are round about 21 hours, 01 hour and 04 hour. The times of maximum frequency of occurrence of high multiples nearly coincide with or precede the times of maximum rate of change of $h'F_2$. The strength of the peak at 01 hour in Fig. 3 (*c*) is abnormal due to the large number of occurrences of high multiples at that hour in one month only, namely in November 1954.

Figure 4 gives the analysis of the heights of the F_2 layer on a number of individual nights at times when high multiples were observed. The circles represent the times at which high multiples were observed.

Observations at short period intervals taken on a few nights showed fair correlation between the highest order multiple and the curvature of the

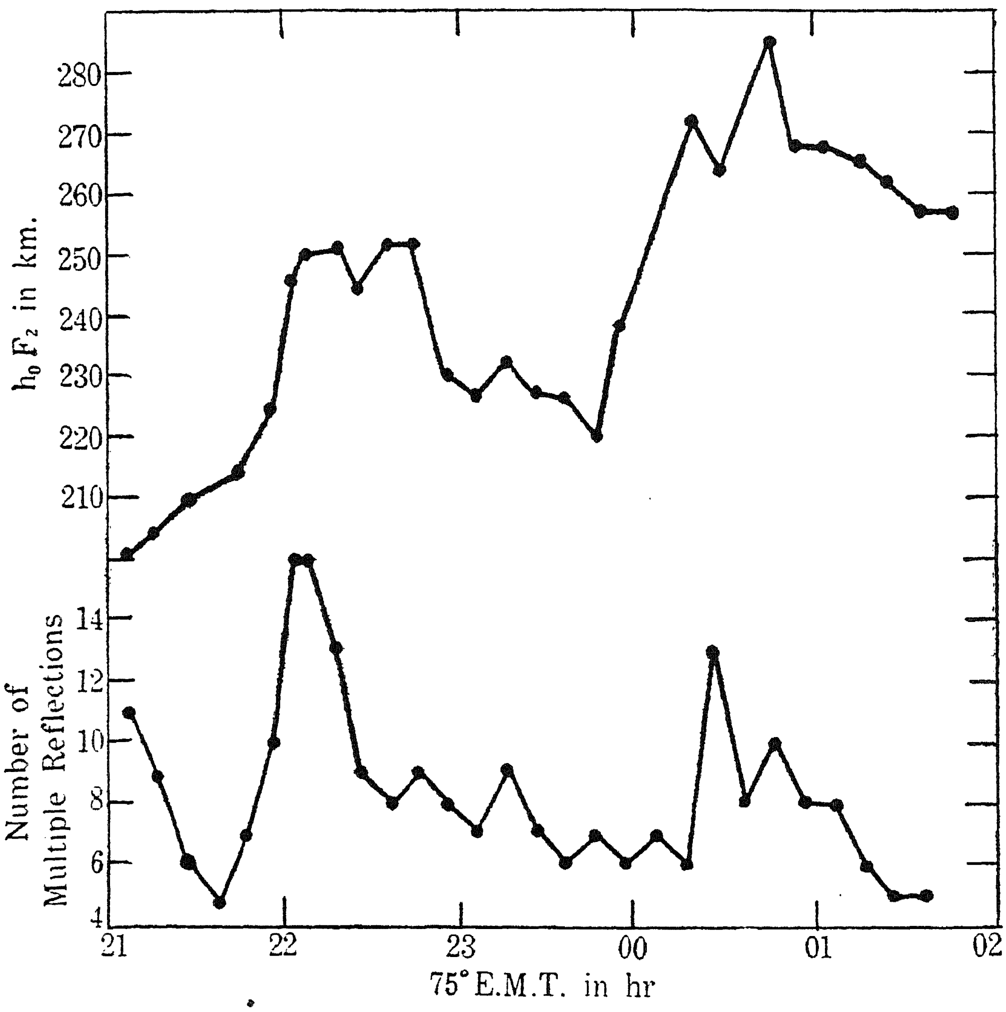

FIG. 5. The variation of the total number of multiple reflections and the height of base of the F_2 layer on the night of 10 to 11 March 1955.

ionospheric surface. Figure 5 shows the results of observations taken on the night of 10–11 March 1955.

It was found that sporadic E does not affect the high multiples except when it blankets the normal reflections. Sometimes high multiples of F_2 and sporadic E can be seen simultaneously recorded over the same frequency range (Fig. 1*b*).

1 F scatter usually reduces the number of multiple reflections but there are some exceptions to this also (Fig. 1 *c*).

Seasonal Variation of Multiple Reflections

It appears from Fig. 6 that high multiples are least frequent in the summer months May to July and most frequent in November to March or

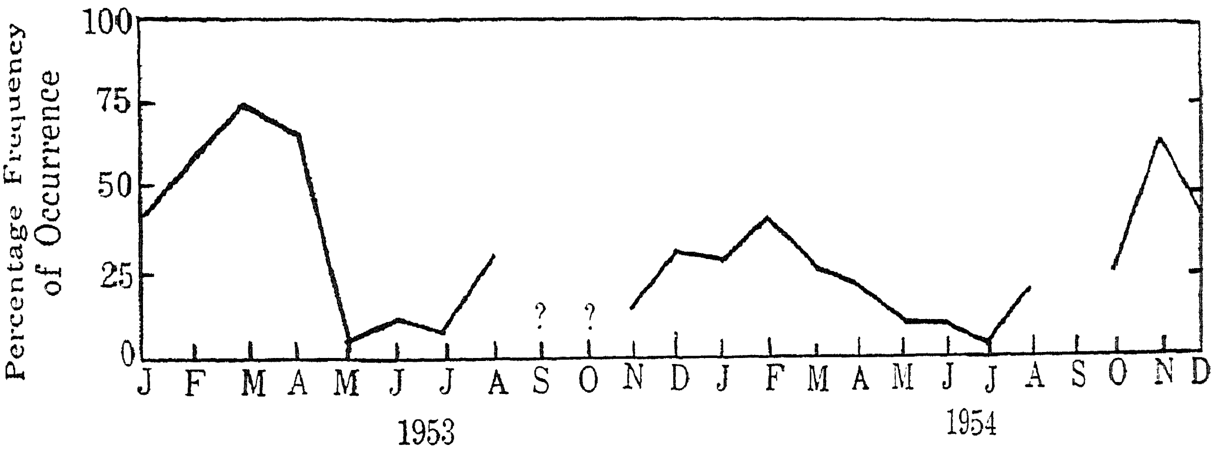

FIG. 6. Percentage of nights on which high multiple reflections were recorded in various months January 1953 to December 1954.

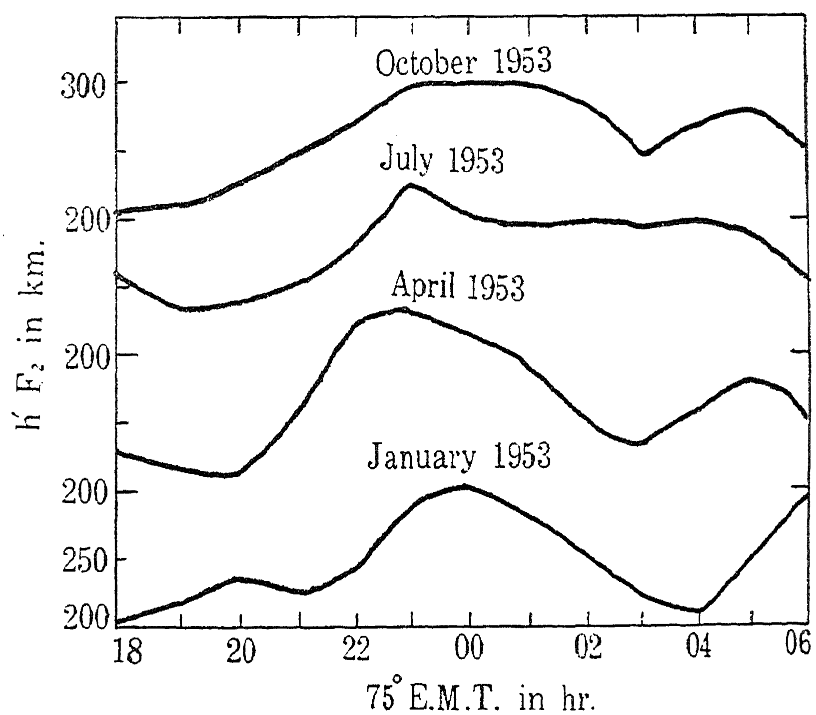

FIG. 7. Variation of $h'F_2$ during night time in different months of the year.

April. This accords with the fact that the daily variations of $h'F_2$ are least pronounced in the summer months and most pronounced in autumn and spring. During summer, E_s and 1 F—scatter are rather more frequent and these no doubt contribute partly to the rarity of high multiples in that season.

IRREGULARITIES IN THE INTENSITIES OF THE MULTIPLE REFLECTIONS

A phenomenon related to the above is the anomalous and varying distribution of intensity of multiple echoes. This phenomenon can be seen clearly on many occasions on the monitor oscilloscope and generally occurs on multiples higher than the third. It is difficult to determine quantitatively intensity ratios of the various multiples from the P'-f records but approximate estimates of their intensity can be obtained in some cases.

At times, depending upon the position of the hump with respect to the place of observation, a higher multiple may be formed by combination of waves leaving the transmitter at different angles and arriving at the receiver after being reflected from off-vertical points in the ionosphere. The intensity of some particular multiple may then be greater than that of the lower ones depending upon the curvature, height, and reflection coefficient of the F_2 layer, as well as on the radiation patterns of the transmitting and receiving antennæ.

CONCLUSION

These observations show clearly that even at night, the F_2 layer can by no means be considered as a simple plane reflecting surface and that there are dynamic changes going on in it most of the time. Determination of the reflection coefficient of the layer and of the absorption of the atmosphere below it is rendered particularly difficult because of these changes.

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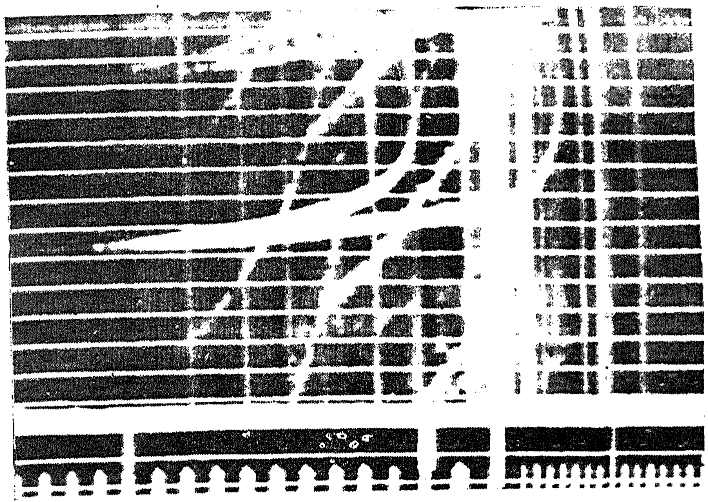


FIG. 1(*a*). P′-*f* record at 01 hr. on 28-10-1954.

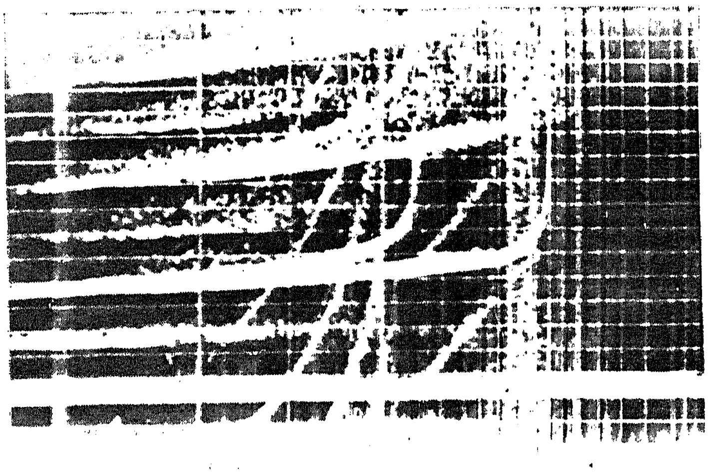


FIG. 1(*b*). P′-*f* record at 02 hr. on 31-1-1953.

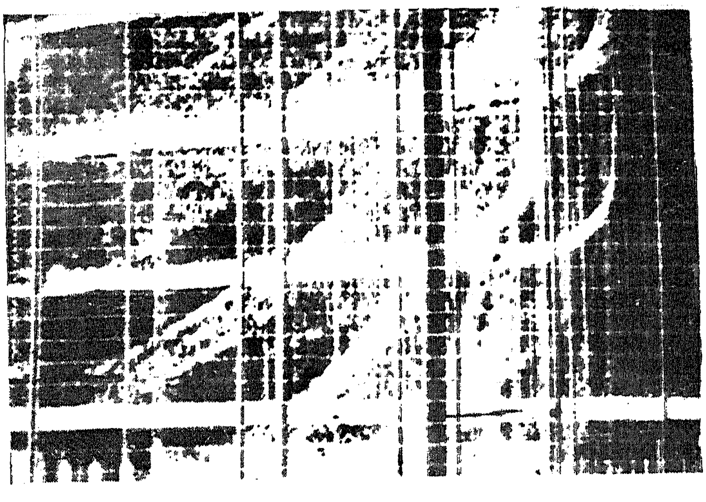


FIG. 1(*c*). P′-*f* record at 00 hr. on 17-3-1953.

FIG. 1. P′-*f* records showing abnormal traces crossing the lower order reflection traces.

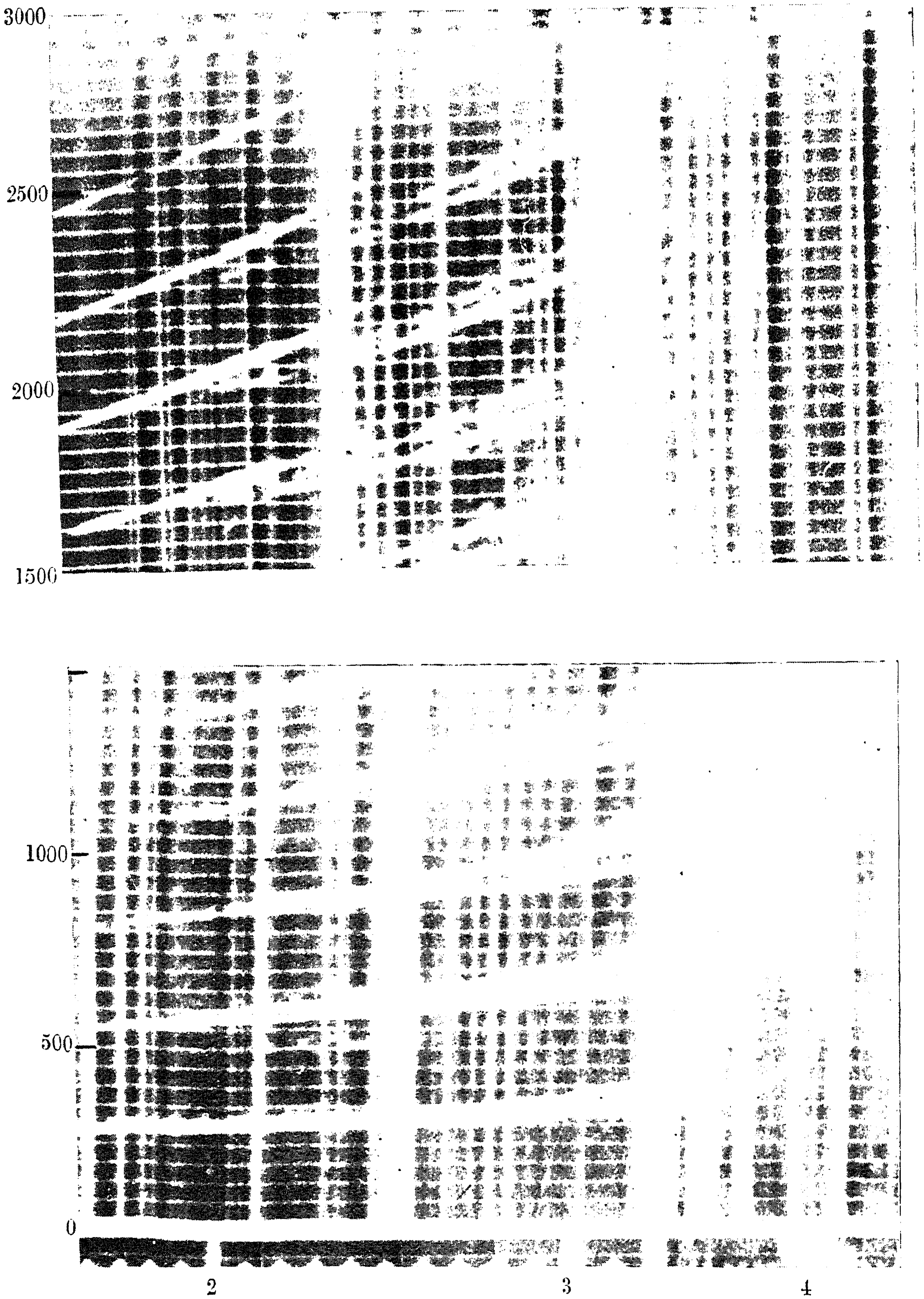


FIG. 2. P′-f record at 22 hr. on 10–3–1955 recorded in two steps, one recording echoes upto 1500 km. and the second immediately after, from 1500 km. to 3000 km.

(a)

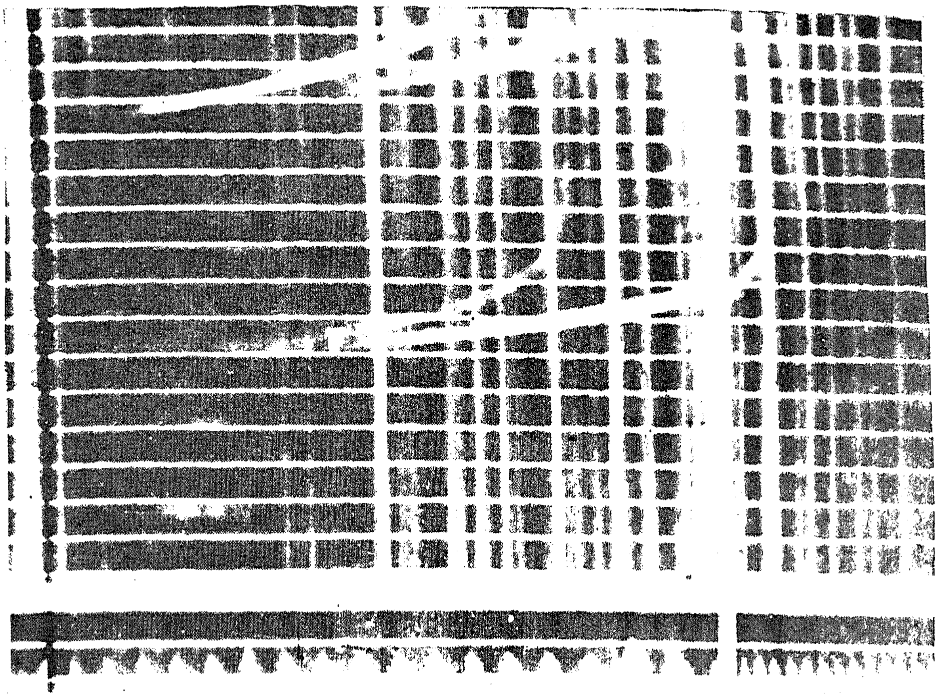


FIG. (a) P′-f record at 00 hr. on 18-3-1954.

(b)

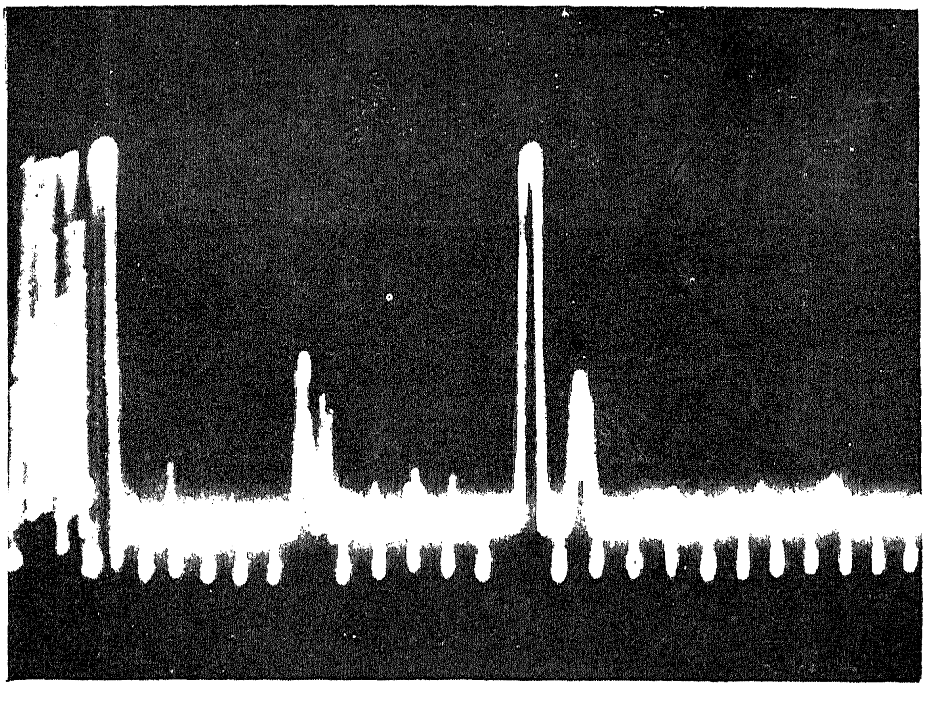
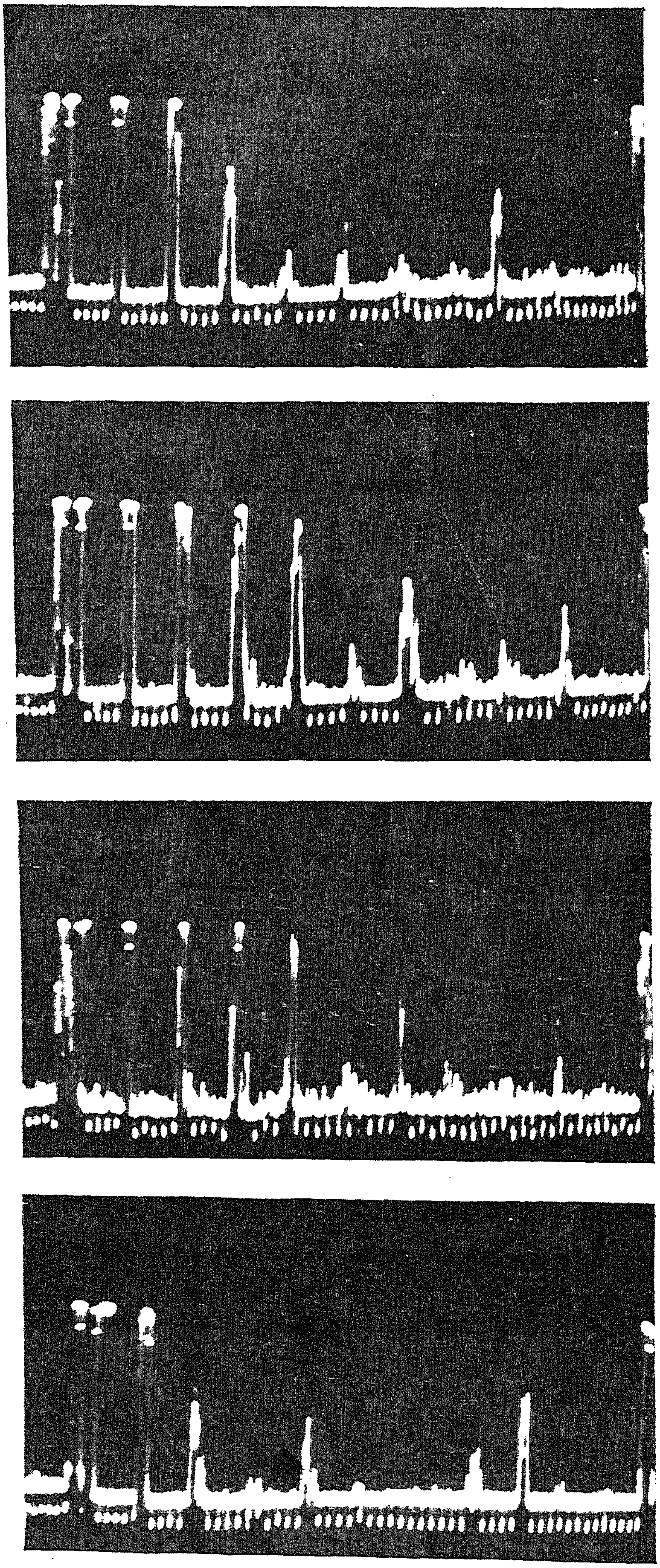


FIG. (b) Photo at 2230 hr. on 28-3-1955.

FIG. 8. Records showing second order reflection stronger than the first order reflection



(*a*) 2125 hrs.

(*b*) 2126 hrs.

(*c*) 2127 hrs.

(*d*) 2128 hrs.

FIG. 9. Multiple echoes at intervals of one minute on 24-3-1955.

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