

# MEASUREMENT OF THE HEIGHT OF IONOSPHERE AT ALLAHABAD.

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(Communicated by Prof. M. N. Saha.)

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## INTRODUCTION.

The study of the Ionosphere is being vigorously carried out in Europe and America with a view to correlate various terrestrial and solar phenomena, such as magnetic disturbances, auroral displays, sunspot activities, etc. An extensive and well organized study of the ionization content and height of the different well recognized ionized layers in the upper atmosphere will throw considerable light on the phenomenon of the propagation of radio waves. It is now a well recognized fact that for point to point successful radio communication different wave-lengths are needed for different seasons and time of the day. The success of the short waves for distant communication is mainly due to refraction of the waves by the ionosphere. There does not seem to be

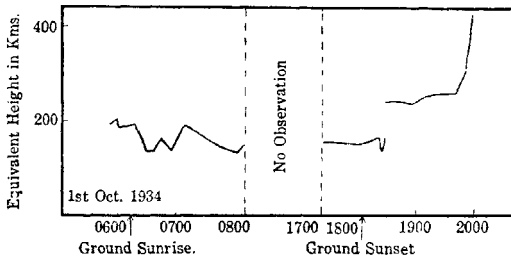


FIG. I.

any doubt that in view of the expected developments of radio communication in India, an extensive study of the ionosphere will be most useful.

The observations reported in this paper were taken at Allahabad (Long.  $81^{\circ} 55' 0''$  E. of Greenwich and Lat.  $25^{\circ} 25' 55''$  N.).

In a previous communication,<sup>1</sup> we have already given a preliminary account of our investigations on the Measurements of the Height of the Ionosphere in the United Provinces of Agra and Oudh. In this investigation, the transmitter was situated at the laboratory and the receiver was kept in the house of a private friend nearly a mile and a half away from the laboratory.

<sup>1</sup> Measurement of the height of the Ionosphere in the U.P. G. R. Toshniwal and Pant—*Nature*—Vol. 133, p. 947, 23rd June, 1934. *Proc. Acad. Sc., U.P.*, Vol. 4, p. 129, 1934.

Since then we have been able to remodel our transmitter and receiver in such a way that both of them are now kept side by side in the same room, and the received pattern remains perfectly stationary for a considerable time.

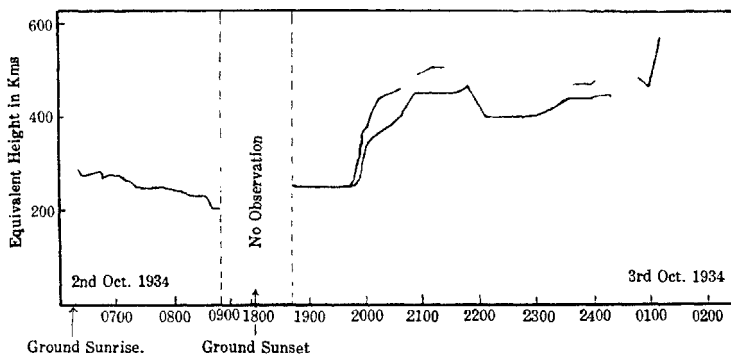


FIG. II.

The main changes have been effected by injecting a small 50 cycle a.c. voltage in the grid circuit of the transmitting tube and by avoiding all condensers in the inter-valve couplings of the receiver.

#### APPARATUS.

The transmitter employed in the experiment consisted of a simple Hartley oscillator. The method of producing pulses was similar to that used by Appleton and Builder.<sup>1</sup> Fifty cycle control voltage was obtained by feeding the filament of the transmitting valve by raw a.c. and connecting the return

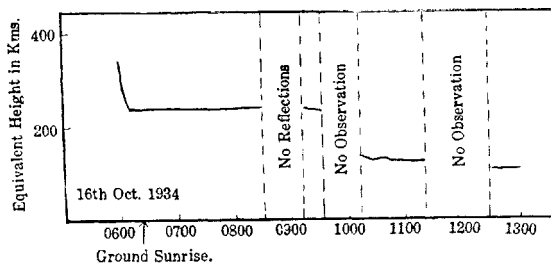


FIG. III.

lead of the grid circuit to one end of the filament instead of the usual method of connecting it to the mid point of the filament transformer. A fixed grid leak of 10 megohms shunted by a variable condenser containing oil dielectric was used for regulating the number of pulses emitted per second.

<sup>1</sup> Appleton and Builder—*Proc. Phys. Soc.*, Vol. 44, p. 76, (1932).

The receiver consisted of two screen-grid transformer coupled high frequency amplifiers followed by an anode bend triode detector and a single stage d.c. amplifier. Thus it was possible to avoid the use of condensers for interstage coupling purposes and, therefore, even when the receiver was directly coupled to the tank circuit of the transmitter, there was no blocking and the echoes could be easily seen on a cathode ray oscillograph.

In the initial stages of the experiment, a Hertzian half wave horizontal antenna fed by means of a tuned two wire feeder was used; but later on it was found more convenient to use a single wire feed system as outlined by Everitt and Byrne.<sup>1</sup> The latter arrangement was extremely easy and convenient.

The whole equipment—the transmitter as well as the receiver—now in regular use is contained in a small room about 15 ft. by 12 ft., and does not need more than one observer. The output of the last stage of the receiver

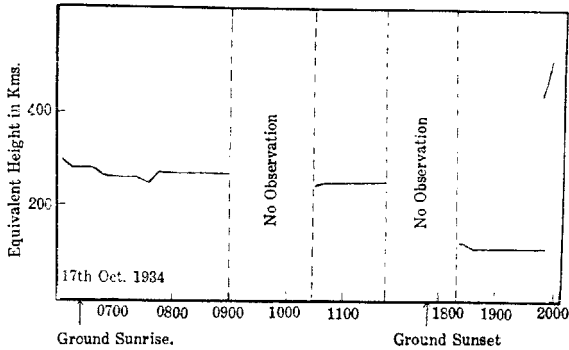


FIG. IV.

was fed in an oscillograph and the stationary pattern was visually observed. A thyatron circuit was used for a linear time base. In order to make the pattern very stable it was found necessary to inject a small 50 cycle voltage in the grid circuit of the thyatron.

This arrangement proved very satisfactory. The pattern became unsteady only when there were fluctuations in the frequency of the a.c. generator, which seldom happened.

Occasionally photographs of the echo patterns were taken and a few typical photographs are reproduced to show the variations of the equivalent height of the ionosphere with time (Plate II).

## RESULTS.

The present paper deals with the observations taken between the period—1st October, 1934 to 12th November, 1934. (Appendix I.)

<sup>1</sup> Everitt and Byrne—*Proc. Inst. Radio Eng.*, Vol. 17, p. 1840, (1929).

The normal behaviour of the Ionosphere as deduced from these observations can be described as follows :—

Echoes from F-layer were observed normally for the 75 metre wave that was used for these experiments.

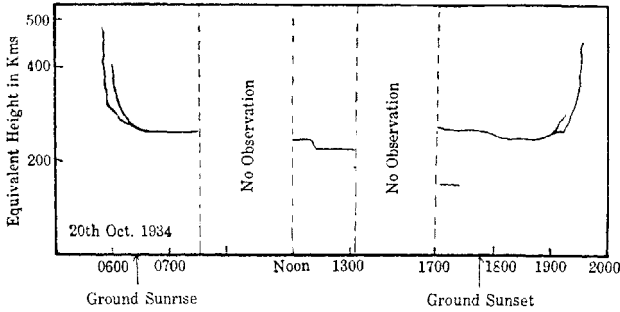


FIG. V.

*Morning Hours* :—The echoes were always absent in the early morning hours, and would make their appearance about 20 minutes before ground sunrise. A single  $F_1'$ -echo of very small intensity from the F-layer (height 400 Kms. approximately) was first observed, which later increased in intensity and in a few minutes was followed by the  $F_1''$ -echo. The doublet separation, i.e., the distance between the two magneto-ionic components,  $F_1'$ , and  $F_1''$  to begin with was about 100 Kms. The  $F_1''$ -echo continuously approached the  $F_1'$ -echo, the shorter delay echo and within about 10 minutes was super-

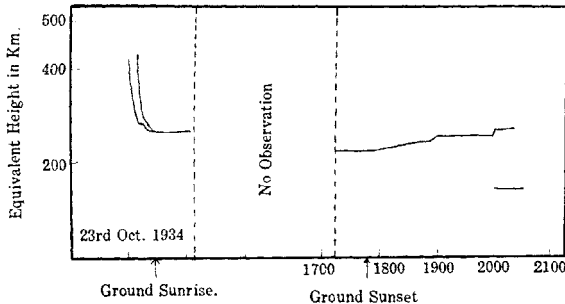


FIG. VI.

imposed upon the latter. Then a violent fluctuation in the intensity of the echo pattern would usually take place and multiple echoes would be observed. The superimposition of the two echoes took place from 5 to 10 minutes before ground sunrise. The equivalent height of the Ionosphere went on continuously and rapidly falling and in about half an hour after sunrise a steady state was reached after which there was very little variation in the equivalent height throughout the day.

*Noon and Afternoon hours* :—The equivalent height was very nearly constant, and usually one echo from F-layer was observed, which was rather weak and at times from 10 to 15 minutes nothing could be observed.

*Evening and night hours* :—The equivalent height gradually increased from its afternoon minimum value to about 500 km. During the period beginning from about an hour before ground sunset and about half an hour after sunset several multiple echoes were observed,—sometimes as many as twelve. The intensity of the echoes was sometimes very great, so much so that it would shoot beyond the oscillograph screen. The peculiarity was that at times some one of the higher order echoes was extremely stronger than the first. In about three quarters of an hour after ground sunset the  $F_1'$  and  $F_1''$ -echoes would separate, and appear at first as a close doublet, the separation usually increased quite rapidly, and within about 15 to 30 minutes the longer delay echo would disappear and shortly afterwards the shorter delay echo would also disappear, and no trace of reflection was observable till a little before ground sunrise. Plate II, figs. *a*, *b*, etc., give an idea of one evening's normal behaviour.

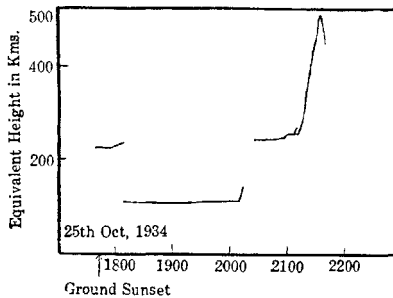


FIG. VII.

*Abnormal behaviour.*—In addition to the phenomena already described above, at times the echoes from both the E-layer and the F-layer would appear simultaneously.

Reflections from the E-layer were visible during the morning hours on the 1st October and 9th October.

Fig. I. 1st October, 1934.—No observations could be taken between 0810 and 1721 hours. Reflections from about 140 km. were observed in the morning as well as the evening.

Fig. II. 2nd October, 1934.—No observations between 0848 and 1846 hours. The figure shows occasional rise and fall of F-layer height between 2000 and 0115 hours next morning.

Fig. III. 16th October, 1934.—It was a cloudy day. There was no reflection between 0830 and 0915 hours. Due to breakdown in the a.c. supply no observations could be taken between 0930 and 1015 hours. Strong E multiple echoes appeared however at 1015 and remained possibly up to

1300 hours, when the observations were closed down due to intense electrical disturbances. No observations could be taken due to the same reason between 1120 and 1230 hours. No observations were taken after 1300.

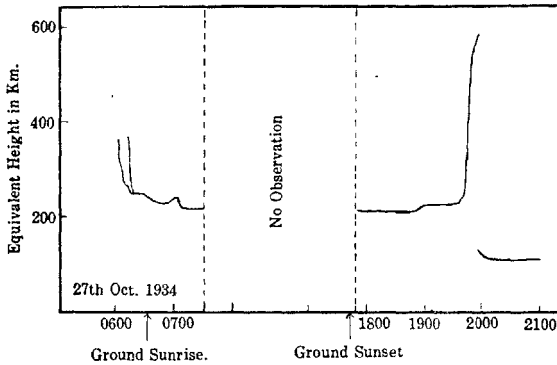


FIG. VIII.

Fig. IV. 17th October, 1934.—No observation period—0900 to 1030 hm. and 1145 to 1820. Reflection from the F-layer was observed during midday period, but when the observations were again started in the evening the E-echoes alone were present. However at 1950 the E-echoes suddenly disappeared and reflections from the F-layer alone were seen. There were no echoes after 1956 hours.

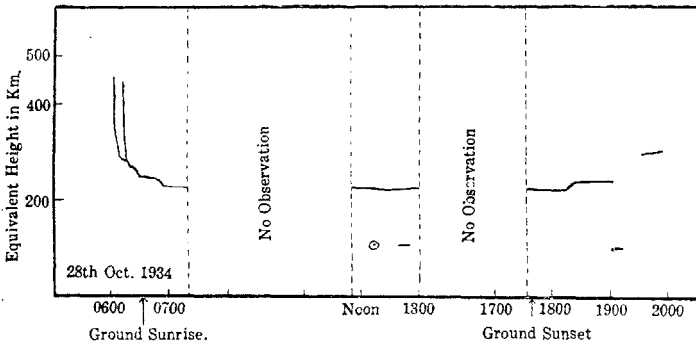


FIG. IX.

Fig. V. 20th October, 1934.—No observation period—0730 to 1202 and 1305 to 1705 hours. Reflections from the F-layer were visible during morning as well as noon. But multiple reflection from both E and F-layers was visible between 1705 and 1727 hours. E-layer reflections were comparatively stronger than the F-layer reflections.

Fig. VI. 23rd October, 1934.—No observation period—0715 to 1715 hours. Between 2003 and 2032 strong multiple reflection from E-layer and

reflections from F-layer were both visible. The observations had to be closed at 2032 hours.

Fig. VII. 25th October, 1934.—F-layer echoes were visible up to 1810 hours, when E-echoes also appeared. After 1810 F-layer echoes entirely disappeared and E-echoes were visible up to 2024 when F-echo again appeared.

Fig. VIII. 27th October, 1934.—No observation period—0730 to 1750 hours. F-layer height was fairly constant between 1750 and 1935 hours, after which it rapidly rose to 596 Km. within 20 minutes. At 1956 occasional reflections from E-layer were seen and between 1956 and 2100 hours E-echoes were visible. Reflections from E-layer disappeared at 2100 hours, and shortly afterwards the observations had to be discontinued.

Fig. IX. 28th October, 1934.—No observation period—0720 and 1150 and 1300 to 1735 hours. F-layer echoes were coming throughout, but reflections from E-layer were occasionally visible.

Fig. X. 7th November, 1934.—Observations were taken in the evening only, F-echoes which were present in the beginning disappeared and E-

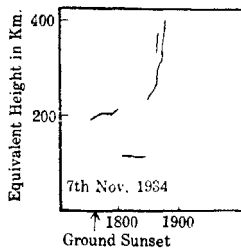


FIG. X.

echoes alone were seen between 1803 and 1827 hours, when F-echo again appeared.

Fig. XI. 8th November, 1934.—No observation period—0730 to 1220 and 1351 to 1745 hours. When the observations were started at midday, the E-echoes alone were visible, but at 1245 reflections from the E-layer disappeared and that from F-layer appeared. F-echo was visible up to 1252 when it disappeared and reflection from E-layer again appeared. E-echo again disappeared at 1330 hours and reflections from F appeared. At 1334 E-echo again appeared and F-echo disappeared. At 1343 hm. E and F echoes were simultaneously coming and at 1345 E-echo disappeared and F-echo alone was present.

Fig. XII. 15th and 16th December, 1934.—Continuous observations were taken from 1600 hours on 15th December to 2200 hours on 16th December. The magneto-ionic splitting was visible at 1600 and again at 1850. It was rather remarkable that F-layer echoes were visible at 0311 and could be seen right up to 0339 on 16th December. The average F-layer equivalent height was about 240 km.

On a few occasions the first F-echo was seen to be a distinct triplet (Appendix I). A strong central echo was usually preceded and followed by a weak component on each side. The triplet has been observed by independent observers in this laboratory and several attempts were made to photograph it but due to the sudden appearance and short duration of these echoes it was not possible to secure a good photograph.

### CONCLUSIONS.

The observations reported above cover the autumn period and conclusively show that the 75 metre waves are normally reflected during this period by the F-layer which exists at an average height of 240 Km. during most part of the day. Occasionally reflections from the E-layer have also been observed. The reflections are entirely absent during most part of the

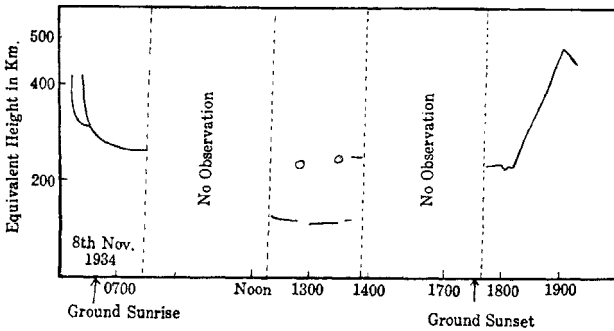


FIG. XI.

night due to electron limitation. During the day, due to high absorption in the lower regions, the F-layer echoes are rather weak. There is violent intensity fluctuations in the reflected echoes during the sunset period, when multiple echoes are also observed. Magneto-ionic splitting has also been observed a few minutes before sunrise and about an hour after sunset. At times this splitting of the echoes has also been noted during the day.

Sudden drop in the equivalent height during the evenings as reported by Rakhshit<sup>1</sup> is not generally obtained and, therefore, it is not possible to say anything about the so-called 'evening concentration'<sup>2</sup> of ionization.

In view of the meagre data that has so far been collected and also in the absence of other meteorological data, correlation has not been attempted in this paper. A detailed study of the ionosphere is being carried out in this laboratory and will be reported later.

<sup>1</sup> Rakhshit—*Phil. Mag.*, Vol. 8, p. 695, (1934).

<sup>2</sup> Ranzi—*Nature*, Vol. 130, p. 545, (1932).



Our hearty thanks are due to Prof. M. N. Saha, F.R.S., for many useful suggestions and his keen interest in these investigations and also for the

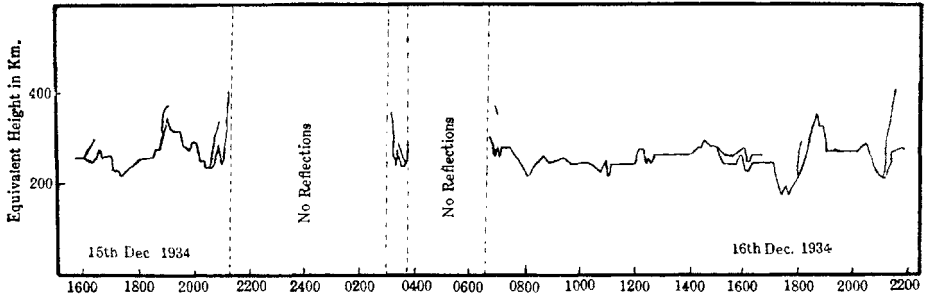


FIG. XII.

facilities that he gave us. We have to thank Messrs. R. R. Bajpai and T. D. Bansal, students of the M.Sc. class, for graph No. XII.

## APPENDIX.

N.B.—Twenty-four hour convention has been used and the time has been given in Indian Standard Time, which is 5½ hours ahead of Greenwich Mean Time.

Date.	Hours of Observation.	Reference.	REMARKS.
34. 10. 1	0555-0810 1721-2015	Graph I. ....	1823.—Echoes from 137 Km. were very strong. 1824.—Echoes from three heights were seen (168 Km. 242 Km. 337 Km.). 1834.—Twelve multiple echoes from F-layer (244 Km.) were seen. 1855.—Several multiple echoes of which 1st, 2nd, and 3rd were close doublets. 1940.—Multiple echoes of which fourth was very strong. 1956.—Very feeble echoes after which there was no trace of reflection. 0848.—The echoes were very feeble after which they could not be detected. 1950.—F <sub>1</sub> ' and F <sub>1</sub> "-echoes separated and the distance between them gradually increased.
34. 10. 2	0620-0900	Graph II. ....	2131.—Only F <sub>1</sub> '-echo remained.
34. 10. 3	1840-2215	....	2208.—F-layer height diminished which later gradually increased. 2338.—F <sub>1</sub> ' and F <sub>1</sub> "-echoes again separated. 0113.—F-echo last observed at 555 Km. height. No trace before 0615 hours. Echoes disappeared at 2002 and there was no trace up to 2215 hours when the observations were closed.
34. 10. 4	0515-0750	....	0515-0550.—No trace. 0707.—F-layer very feeble. Height 265 Km. No trace hereafter. 1900.—Multiple echoes from 260 Km. <i>The first was a triplet.</i> 1920.—F <sub>1</sub> ' and F <sub>1</sub> "-echoes just separated. 2012.—F-echo last visible. Height 550 Km.
34. 10. 5	0555-0815 1925-2030	....	0810.—Echoes became very feeble, and no trace after 0815. F-echoes alone were present. No reflections after 1945.
34. 10. 6	0530-0900 1705-2100	....	0558.—F-echo appeared. Height 440 Km. 0828.—F-echoes were last seen. 1705-1725.—No trace of any reflection. 1725.—Reflection from E-layer. Height 101 Km.
34. 10. 7	0530-0801	....	1908.—F-echo appeared. Several photographs were taken which are reproduced in Plate II; the F-echo was last seen at 593 Km. height.
34. 10. 9	0557-0715	....	0559.—First appearance of F-echo. Height 451 Km. 0801.—The observations had to be closed. F-layer echoes were present throughout, but between 0708 and 0715 reflections from E-layer (87 Km.) were also seen.

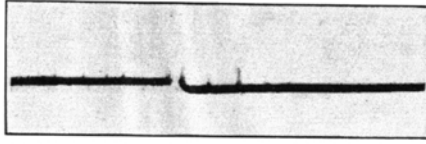
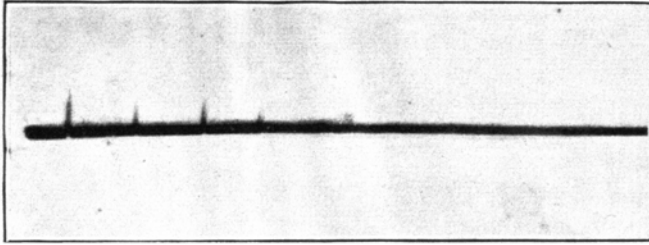
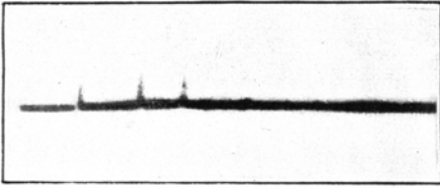
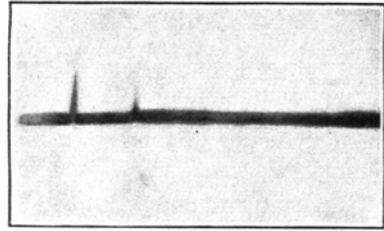
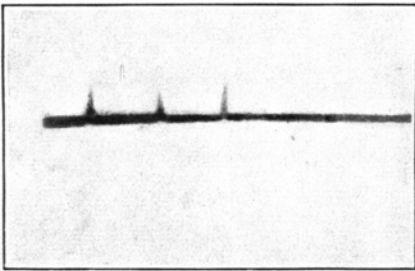
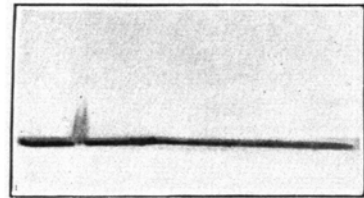
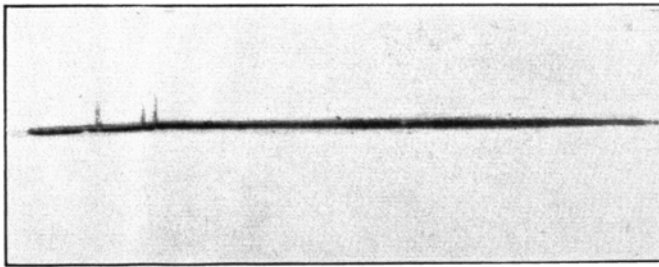
Date.	Hours of Observation.	Reference.	REMARKS.
34. 10. 14	0530-0635 1755-2100	.....	0602.—First F-layer echo appeared. 0635.—Observations closed. Very strong multiple echoes were obtained from 1755 onwards. At 1830 the first echo was a <i>triplet</i> , the middle one was very strong and there were two very close components on the two sides.
34. 10. 16	0530-1300	Graph III	1940-2025.—E-layer echoes were observed. 0556.—F-echoes were first observed. 0830-0900.—No reflection. 0930-1015.—No observations could be taken due to trouble in the a.c. generator. 1015.—Strong reflections from an intermediate layer (135 Km.). There were very strong multiple reflections throughout up to 1300. The F-layer height at 1300 was 104 Km., observations were closed at 1300.
34. 10. 17	0600-1145 1820-2030	Graph IV	F-layer was throughout present up to noon, but when the observations were started at 1820 strong reflections (E-layer) from a height of 123 Km. were observed, at 1835 there were as many as twelve multiple-reflections. 1950.—E-layer disappeared, when F-layer appeared. 1956.—F-layer was last observed. The equivalent height was 509 Km. F-layer alone was present throughout the morning hours. 1015.—Occasional reflection from E-layer.
34. 10. 18	0720-1115 1715-2000	.....	1830-1845.—E and F-echoes were both present. 1925.—F-layer echo disappeared. The F-echoes were alone observed throughout the day.
34. 10. 19	0530-1100 1645-2200	.....	F-layer echo was present throughout. But at 1705 and 1725 echoes from an intermediate layer (152 Km.) and F-layer echoes (274 Km.) were simultaneously coming.
34. 10. 20	0530-0730 1202-1305	Graph V	There were multiple echoes from both the layers, however at 1718 the E-layer echoes were stronger than the F-layer echoes. 1938.—F-layer echo was last seen at 453 Km. 0600.—F-echo first appeared. Height 398 Km. 0552.—F-echo appeared. Height 438 Km. 1954.—A close triplet for the first echo was seen.
34. 10. 21	0542-0735	.....	2024.—The F <sub>1</sub> <sup>*</sup> component was last seen at 494 Km.
34. 10. 22	0530-0715 1735-2100	.....	2030.—A close triplet was again visible.
34. 10. 23	0530-0715 1715-2032	Graph VI	2003-2032.—Echoes from (145 Km.) were observed along with F-layer echoes (274 Km.).
34. 10. 24	0545-0730 1915-2030	.....	0605.—F-layer echo first appeared. Height 458 Km. 1958.—F-echo last seen. Height 584 Km.

Date.	Hours of Observations.	Reference.	REMARKS.
34. 10. 25	1740-2155	Graph VII	1810.—Both E- and F-echoes were present. 1825-2010.—F-echo absent. E-echoes (111 Km.) alone were present. During this interval there were at times nine multiple echoes and they were at times extremely strong, shooting far beyond the oscillograph screen. 2014.—E-echo height 142 Km. 2025.—E-echo disappear and F-echo only present—height 242 Km.
34. 10. 26	0530-0705 1805-2150	.....	0602.—F-echo height 423 Km. first appeared. F-layer alone was present throughout. 2148.—F-echo suddenly disappear. Height at 2145 was only 243 Km. 0620.—F-echo height 364 Km. first appeared.
34. 10. 27	0530-0730 1750-2100	Graph VIII .....	1845.—Multiple F-echo height 213 Km. The first echo was extremely intense for over two minutes. 1956.—F-echo height 596 Km. Occasional reflections from E-layer were visible. Height 126 Km.
34. 10. 28	0530-0730 1155-1300 1735-2000	Graph IX	2000.—F-layer disappeared. Strong echoes from E-layer. Height 112 Km. 2100.—E-layer echoes disappeared. 0601.—F-echo first appeared. Height 470 Km. When the observations were started at 1155, only F-echo (231 Km.) was present. But at 1215 E-echo (108 Km.) was also seen. 1240.—Both E- and F-echoes were observed. F-layer echoes were always stronger. 1255.—F-echoes alone were present. 1907-1912.—E-echoes were observed. Height 105 Km. 0612.—F-echo appeared. Height 434 Km.
34. 10. 29	0545-0730 1755-1900	.....	0607.—F-echo appeared. Height 424 Km.
34. 10. 30	0545-0720 1350-2015	.....	1957.—Echoes disappeared.
34. 11. 1	1705-2015	.....	1950.—F-echoes disappeared.
34. 11. 2	0545-0725 1805-1825	.....	0607.—F-echo appeared. Height 379 Km. F-echoes were observed throughout.
34. 11. 3	0545-0725 1755-1955	.....	0611.—F-echo appeared. Height 497 Km.
34. 11. 4	1115-1143	.....	F-echoes were present. Height 251 Km.
34. 11. 5	0600-0705 1800-1915	.....	0613.—F-echo appeared. Height 582 Km. It was raining since 1500 and the sky was overcast with thunder clouds during the evening observations. 1815.—Multiple echoes appeared which were rather feeble. 1853.—Echoes disappear. F-echoes were throughout present.

Date.	Hours of Observations.	Reference.	REMARKS.
34. 11. 6	0600 0708 1810-1902	.....	0613.—F-echo appeared. Height 410 Km. 1810.—Strong multiple echoes all very close doublets were observed. 1902.—Owing to supply breakdown observations were closed. F-layer at 202 Km. was present in the beginning but at 1803 E-echo appeared. Height 104 Km.
34. 11. 7	1731-1900	Graph X	1827.—E-echo disappeared. 1849.—F-echo last visible. Height 642 Km. 0613.—F-echo appeared. Height 419 Km.
34. 11. 8	0600 0730 1220 1351 1745-1920	Graph XI ..... .....	0730.—Observations were discontinued, but they were begun at 1220. The F-echoes were absent; the E-echoes alone were present up to 1245. Before the E-echoes disappeared the echoes became very unsteady, sometimes shooting beyond the oscillograph screen and sometimes disappearing entirely. 1245.—F-echo appear. Height 237 Km. 1252-1330.—F-echo absent and E-echo visible and remained till 1330. The echoes were very strong and steady. Height 113 Km. 1332.—E-echo disappeared and F appeared. Height 244 Km. 1334.—F-echo disappeared and E-echo appeared again. 1343.—Both the E and F echoes were seen. 1345.—E-echo disappeared and F-echoes alone were seen. 1155.—E-layer echo height 115 Km. 1227.—F-layer. Height 312 Km. 0613. F-echo appeared. Height 383 Km. 1130-1230.—There was no trace of any reflection. Only the E-layer was present in the evening. 0612.—F-echo first appeared. Height 435 Km. At noon there were some indications of E-echo. But from 1212-1245 only the F-echo was present. Height 238 Km. 1815.—Momentary reflections from E-layer. Height 117 Km. 1839.—F-echo last seen. Height 494 Km. 0615.—F-echo first appeared. Height 538 Km.
34. 11. 9	1155 1940	.....	
34. 11. 10	0600 0722 1130 1230 1837 1915	..... ..... .....	
34. 11. 11	0600 0720 1155-1245	..... .....	
34. 11. 12	1800-1900 0600 0720	..... .....	

N.B.—Prior to the 16th October, the receiver was a little bit insensitive and hence no reflections were visible during the day, but later the receiver was properly adjusted and it was possible to observe reflections throughout the day. The Electric Noise Level at the laboratory was always high when the Laboratory was open, therefore at times the observations had to be discontinued suddenly.



*a**b**c**d**e**f**g*

The photographs of F-echoes were taken on the 6th October, 1934, between 1905 and 2009 Indian Standard time.

Fig. *a*, 1905 ; Fig. *b*, 1908 ; Fig. *c*, 1915 ; Fig. *d*, 1929 ; Fig. *e*, 1942 ; Fig. *f*, 2006 ; Fig. *g*, 2009.

*N.B.*—Ground pulse is present in Fig. *a* and is absent in the other figures.