RADIO ECHO OBSERVATIONS AT TROMSØ DURING THE SOLAR ECLIPSE ON JULY 9TH, 1945

BY

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Considerable interest is attached to the effects of a solar eclipse on the electron densities of the ionized layers. The normal diurnal and annual variations of the critical frequencies of the E- and F_1-layers are solely dependent on the height of the sun. For the F_2-layer, however, the variations are more irregular. It is now generally assumed that the ionisation of the layers are produced by the action of the sun's ultra-violet spectrum, and that the irregular variations of the electron densities of the F_2-layer are secondary effects due to vertical displacements of the air masses at great heights.

An eclipse will thus form an experimental test on this point of view. The electron densities of the E- and F_1-layers are to be expected to follow the eclipse closely, due to the rapid recombination processes in these two lower layers. For the F_2-layer, however, the effect is expected not to be simple, partly due to the slower recombination processes and partly due to vertical movements in this upper part of the atmosphere.

Previous observations during soler eclipses confirm this point of view. Kirby, Berkner, Gilliland and Norton[1] observed during the 90 % eclipse at Washington in 1932 and found that the maximum electron densities of the E- and F_1-layers decreased and increased closely parallel with the obscuration of the sun. On the F_2-layer, however, there seemed to be no noticeable effect of the eclipse. Observation by Henderson in Canada during the same eclipse confirmed these results.

During an eclipse in 1935, Kirby, Gilliland and Judson[1], an effect on the F_2-layer was observed. Observations during the eclipse in 1936 by Minohara and Ito[2] showed, however, no effect on the F_2-layer.

On July 9th, 1945 a partial solar eclipse was to occur at Tromsø ($\varphi = 69°.6$ N, $\lambda = 18.9$ E. Gr.) between $13^h\ 44.5^m$ and $15^h\ 56.9^m$ with maximum at $14^h\ 52.0^m$ MET. The maximum obscuration

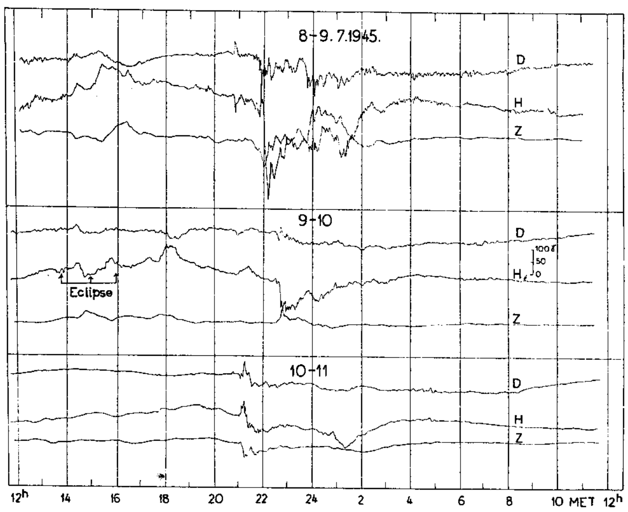

Fig. 1. Earth-magnetic records on the day of eclipse and the previous and following day, recorded in Tromsø.

[1] Radio Observations of the Bureau of Standards during the solar eclipse of August 31st, 1932. Bur. Stan. J. Res. *11*, 829—845 (1933), Proc. Inst. Radio Eng. *22*, 247—264 (1934).

[1] Ionosphere Studies during Partial Solar Eclipse fo February 3th, 1935. Proc. Inst. Radio Eng. *24*, 1027—1040 (1936).

[2] Minohara, Ito, Fujiwhara, and Imamichi. Ionospheric and Magnetic Records in Japan — VI. Rep. Radio Res. Japan, *6* (1936).

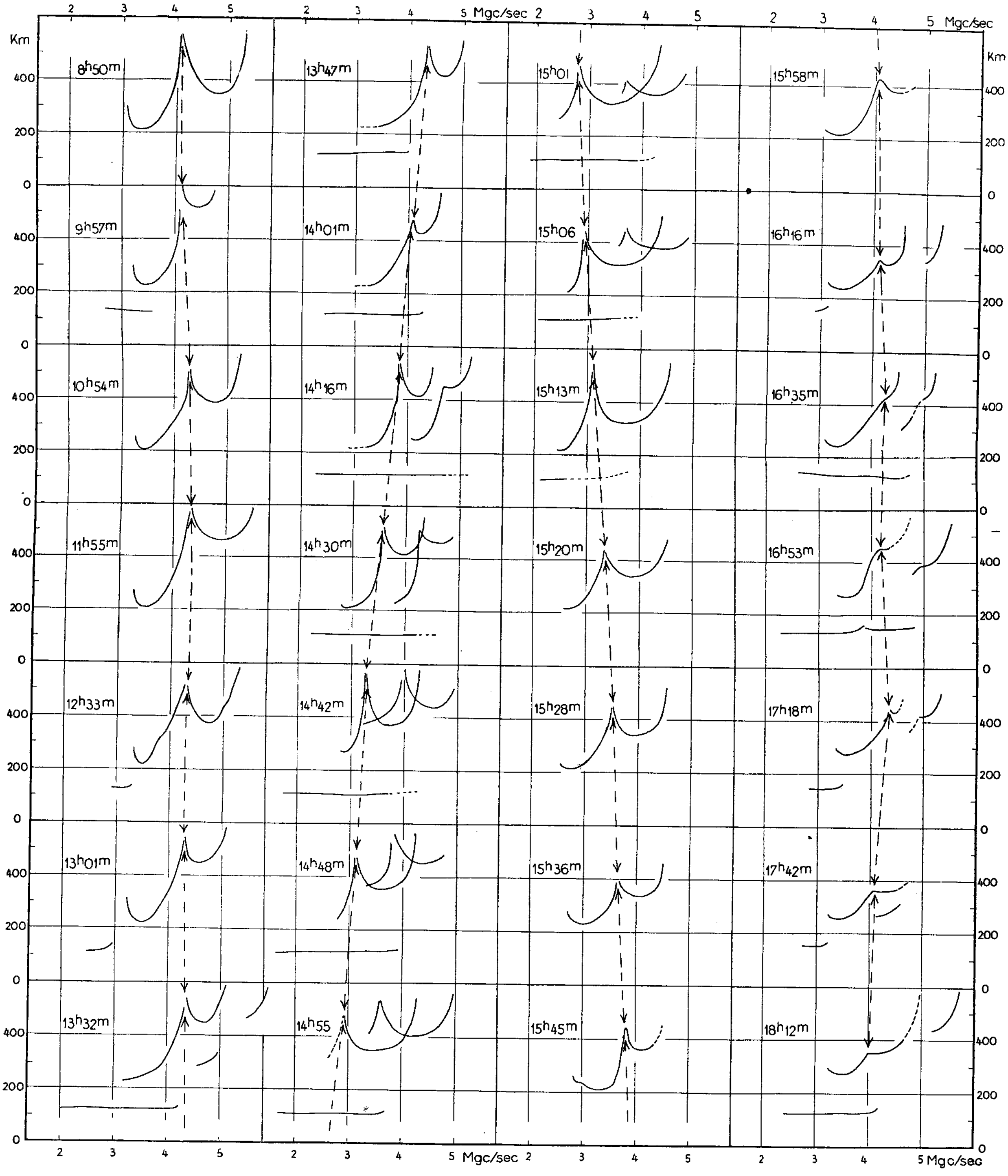

Fig. 2. P′, f-curves recorded on 9th July 1945 at Tromsø. The changes in the critical frequencies of the F_1-layer are especially pronounced.

was 92.9 %. At an earthmagnetically highly disturbed place as Tromsø, there will always be a chance for a magnetic storm to appear which would completely obscure or destroy the eclipse effects expected. On the days of 7th and 8th July considerable earth-magnetic activity was present and it was sufficient to produce a strong absorption which made echo observation on these

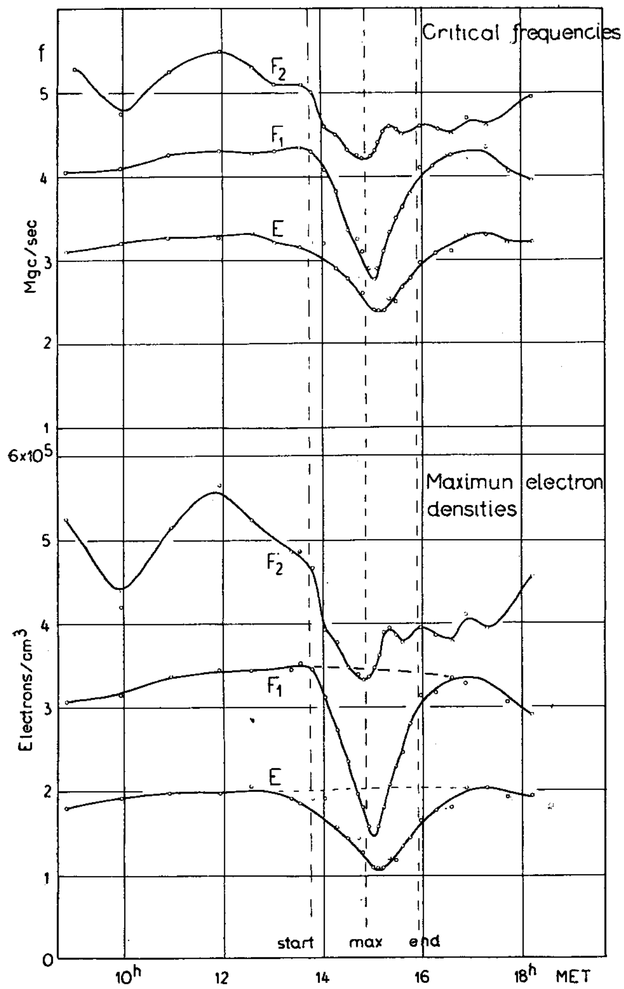

Fig. 3. Variation of the critical frequencies, ordinary ray, and maximum lectron densities of the ionized layers during the solar eclipse on 9th July, 1945 at Tromsø.

days difficult. On the 9th, however, the earth-magnetic activity had declined, and the day was fairly quiet. Echoes of medium strengths were recorded during the whole day. An abnormal E-layer occurred, however, during the greater part of the day, with critical frequencies exceeding by far the critical frequencies of the normal E-layer. This abnormal E-layer, however, was always penetrated by the signals, and F_2-echoes could always be obtained. Also the characteristic P′, f-curves for the F-layer could be drawn, permitting the critical frequencies of the F_1- and F_2-layers to be determined. For the normal E-layer, however, we could on almost all the P′, f-curves determine the critical frequency from the well-defined group-retardation effect on the F-echoes appearing just where the signals penetrate the normal E-layer at the critical frequency.

Fig. 2 shows the P', f-curves drawn up from the records on the day of eclipse.

In Table 1 are given the critical frequencies, ordinary component, of the E-, F_1, and F_2-layers.

Table 1.

MET	Echo observations during the eclipse 9. 7. 1945					
	Critical frequencies f: Mgc/sec			Maximum electron density N: 10^5 electrons /cm³		
	E	F_1	F_2	E	F_1	F_2
h m						
8 50	3.10	4.05	5.30	1.80	3.06	5.24
9 57	3.20	4.10	(4.75)	1.91	3.14	4.20
10 54	3.25	4.25	5.25	1.97	3.37	5.15
11 55	3.25	4.30	5.50	1.97	3.45	5.65
12.33	3.32	4.28	5.30	2.06	3.42	5.24
13.01	3.20	4.30	5.10	1.91	3.45	4.86
13.32	3.15	4.35	5.10	1.86	3.53	4.86
13.47	(3.20)	4.30	5.00	(1.91)	3.45	4.67
14.01	(3.20)	4.08	4.60	(1.91)	3.11	3.95
14.16	2.90	3.82	4.50	1.57	2.73	3.78
14.30	2.78	3.55	4.32	1.44	2.35	3.48
14.42	2.78	3.25	4.27	1.44	1.97	3.40
14.48	(2.60)	3.10	4.23	(1.26)	1.80	3.34
14.55	—	2.90	4.25	—	1.57	3.37
15.01	(2.40)	2.77	4.32	(1.08)	1.43	3.48
15.06	2.40	2.90	4.40	1.08	1.57	3.62
15.13	2.40	3.10	4.57	1.08	1.80	3.90
15.20	2.55	3.33	4.60	1.19	2.07	3.95
15.28	2.50	3.50	4.55	1.17	2.29	3.86
15.36	2.68	3.63	4.50	1.34	2.46	3.78
15.45	2.78	3.80	—	1.44	2.70	—
15.58	2.97	4.10	(4.60)	1.65	3.14	(3.95)
16.16	3.08	4.13	4.55	1.77	3.18	3.86
16.35	3.10	4.25	4.50	1.80	3.36	3.78
16.53	3.30	4.20	4.70	2.03	3.29	4.12
17.18	3.30	4.35	4.60	2.03	3.53	3.95
17.42	3.20	4.05	—	1.91	3.06	—
18.12	3.22	3.95	4.95	1.94	2.91	4.57

[1] One must be aware that the prediction of the eclipse mentioned above is computed for the earth's surface. The time of commencement and end as well as the degree of obscuration will be slightly changed i the niveau of the ionosphere. From a paper by Grönstrand (Stockholm Observatorium Annaler, Vol. 14, No. 7, 1944) we compute that the degree of obscuration at 120 km height at Tromsø will be 2.2 % less than on the ground. The degree of obscuration for the E-layer we thus may assume to be 90.7 %. For the F_1- and F_2-layers the degree of obscuration will be even less. Concerning the time of beginning and end, the changes from the earth's surface to the height of the E-layer will be less than one minute, and, therefore, without importance.

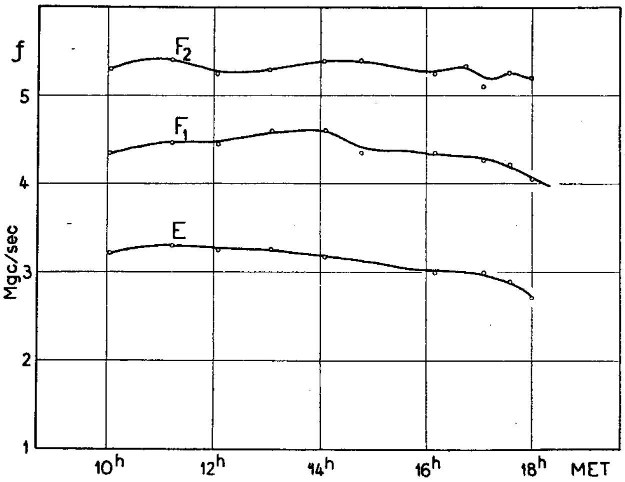

Fig. 4. Variation of the critical frequencies, ordinary ray, on 10th July, 1945 — the day after the eclipse.

In some cases where the determinations are less defined, the values are given in brackets. In the same table the corresponding maximum electron densities are computed using the formula for the ordinary ray:

$$N = (3\,\pi\,\mathrm{m}/2\mathrm{e}^2)\cdot f^2 = 1.87\cdot 10^{-8}\cdot f^2 \text{ electrons/cm}^3$$

The results are shown in fig. 3, and the results of the observations taken on the following day as control are demonstrated in fig. 4.

From fig. 3 it is evident that the eclipse had a pronounced effect on the maximum electron densities of the F-$_1$ and E-layers. Drawing the broken line in fig. 4 indicating the undisturbed conditions of the E- and F_1-layers, we may say that on the F_1-layer the effect of the eclipse was to decrease the maximum electron density from 3.47 to $1.48\cdot 10^5$ electrons/cm^3, *i. e.* with 57 %. For the E-layer the corresponding decrease was from 2.04 to $1.04\cdot 10^5$ electrons/cm^3, *i.e.* with 49 %. Further we notice that there seems to be a slight asymmetry in the curves for E- and F_1-ionisation with respect to the eclipse, the minima in the E- and F_1-curves appearing about 10 minutes a f t e r the time of maximum obscuration.

For the F_2-layer the changes are less simple. The commencement of the eclipse is followed by a sudden decrease in the ionisation curve, the latter having a minimum at about the time of maximum obscuration. But after the eclipse the previous condition of the F_2-layer does not seem to have been restored. From the observations it seems to be evident that the eclipse has an effect, but that this effect is masked by vertical movements and the slower recombination process.

Berkner[1] expresses the view that when the F_1- and F_2-regions are widely separated, which occurs in summer, there should be no significant changes in the electron density of the F_2-layer to be observed, but when the layers are merged together as in winter time, a definite decrease during the eclipse is to be expected. We see, however, that during this last eclipse, allthough the F_1- and F_2-layers were well separated, there seems to be a definite eclipse effect. The effect is, however, considerably smaller and more irregular than for the F_1- and E-layers.

APPENDIX

During the war an ionospheric station was erected by the German forces at Kjeller, north of Oslo. Together with a similar station in Tromsø the ionosphere, through these two stations, was kept under continuous control, and the observations were used for selecting the most convenient frequency bands for radio communication during the war. After the capitulation on May 8th 1945, the station Kjeller was taken over by allied forces and at the same time the German personnel was ordered to continue the observations. Spesial instructions were given for the observations during the solar eclipse on July 9th.

The results of the echo-observations are of considerable interest, especially on account of the simultaneous observations in Tromsø. The results from Kjeller will therefore be given below and compared with the results from Tromsø.

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The geographical coordinates for Kjeller are $\varphi = 59°.98$ N, $\lambda = 11°.04$ E. Gr. The eclipse started at Kjeller at $13^h\,48.0^m$, had its maximum at $15^h\,1.0^m$ and ended at $16^h\,10.0^m$ MET. The degree of maximum obscuration at ground level was 86.7 %. Compared with Tromsø, the obscuration was less; further, Kjeller lies south of the zone og maximum obscuration whereas Tromsø lies north of the zone.

[1] Terrestrial Magnetism and Electricity, edited by Fleming, N. Y. 1939, p. 462.

As in Tromsø, an abnormal *E*-layer occurred which happily was not sufficiently dense to cut off the *F*-echoes. The critical frequencies of the normal *E*-layer were assumed to be where the cusp of the *F*-echoes started.

The results of the echo-observations are illustrated in fig. 5, where the critical frequencies for the ordinary ray are given. From these, the maximum electron densities are computed. Further, the heights of the minimum values of the F_2-echoes, determined from the P′, f-curves, are given. Below are given the highest recorded frequencies of the abnormal *E*-echoes which are to be regarded as the critical frequencies of the abnormal *E*-layer.

Fig. 5. shows that the eclipse was accompanied by an almost symmetrical dip in the electron density curve for all three layers. For Tromsø we have a symmetrical dip in the electron density curve for the F_1 and *E*-layers, whereas the values for the F_2-layer show a more irregular decrease. The virtual heights for the *F*-layer at Kjeller show a decrease during and after the eclipse which must be interpreted as a contraction and sinking of the layer as a whole. The eclipse seems to have no influence on the reflections from the abnormal *E*-layer, which indicates that the ionizing agency for this layer cannot be a radiation which is propagated rectilinearly from the sun.

The results from Kjeller and a comparison with the results from Tromsø are summed up in Table 2. The undisturbed values for the electron densities are determined from the position of the broken lines in fig. 5.

Table 2.

Place	Degree of max. obscuration at ground level	Layer	Electron densities in 10^5			Decrease in per cent.
			Undisturbed values	Minimum values	Decrease	
Tromsø	0.927	F_1	3.47	1.48	1.99	57
		E	2.04	1.04	1.00	49
Kjeller.....	0.867	F_2	4.30	2.60	1.70	39
		F_1	3.10	1.80	1.30	42
		E	1.77	1.20	0.57	32

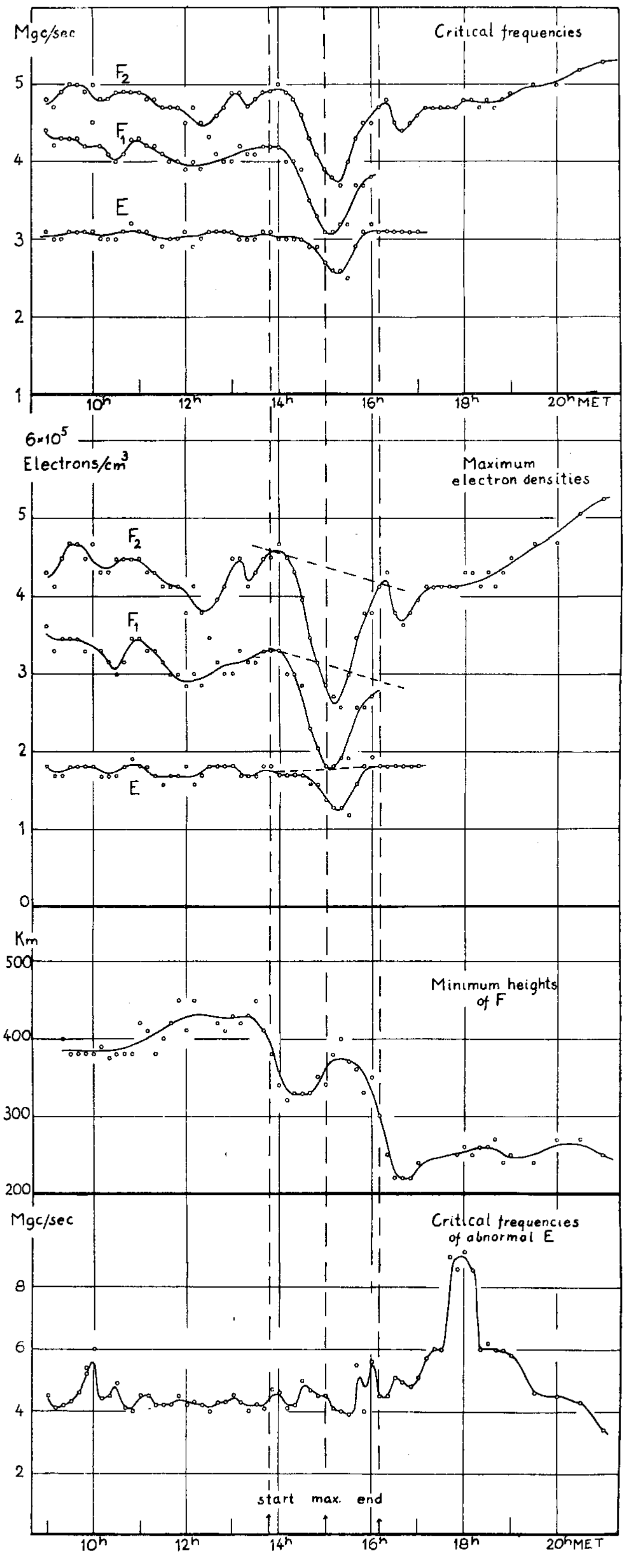

Fig. 5. Results of radio echo-observations at Kjeller during the eclipse in July 9th, 1945. The variation of the critical frequencies, ordinary component, electron densities, minimum virtual heights of the *F*-reflections and critical frequencies of the abnormal *E*-layer, are shown.

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