MEASUREMENTS OF IONIZATION IN THE IONOSPHERIC LAYERS DURING THE PARTIAL SOLAR ECLIPSE OF JUNE 19, 1936 at SHANGHAI

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ABSTRACT

This is a brief report of the measurements by the method of critical penetration frequency of the maximum intensities of ionization in the ionospheric layers during the partial solar eclipse of June 19, 1936 at Shanghai. The results support the ultra-violet light theory of ionization in the F_1 layer. For the E layer these results suggest that a considerable part of the ionization may be due to agents different from ultra-violet light.

1. *Introduction.*

THE source of ionization in the ionospheric layers is generally attributed to the sun. But for the agency of ionization there are two hypotheses: Appleton[1] is inclined to take the ultra-violet light from the sun as the principal agent in the production of ions, while Chapman[2] is inclined to attribute the cause of ionization to neutral particles shot out from the sun. As the ultra-violet radiation propagates much faster than the neutral particles projected, the phenomena of cutting off and re-establishing the ionizing process would be different, should one or the other be the cause. Solar eclipses offer excellent opportunities of observing such phenomena. The differences to be expected in the effect of an eclipse have been fully discussed by Chapman[3] and by Appleton and Chapman[1]. Should the cause be the ultra-violet radiation or some other radiation of such

1. Nature **129**, pp. 757-758, 1932.
2. Monthly Notices of R,A.S., March 1932.
3. J. Roy. Astronomical Soc. **92**, pp. 413-420, 1932.

high speed, the ionization eclipse would be almost identical both in time and in position with the optical eclipse. Should the cause be corpuscular bombardments, the ionization eclipse would be displaced from the optical eclipse by hours in time and by hundreds of miles in position.

During the total solar eclipse of 1927 Appleton[1] started experimental investigations of this problem by observing radio signal strength. Many experiments[4] were made during the total solar eclipse of August 31, 1932, the annular solar eclipse of August 21, 1933, the solar eclipse of February 14, 1934, and the partial solar eclipse of February 3, 1935. Methods of signal strengths, of retardation times, and of critical penetration frequencies have been used; by far the last is the best for estimating the intensity of ionization[5]. This paper reports the experimental results of measuring the intensities of ionization by the method of critical penetration frequencies during the partial solar eclipse of June 19, 1936, at Shanghai.

2. *Apparatus.*

A special radio-wave transmitter is built to radiate waves of frequencies from 3160 to 6120 kilocycles per second by varying the capacitance of the condenser in the oscillation circuit of the master oscillator. Fig. 1 is the diagram of connections. One 100-watt RCA-852 tube is used for the master oscillator and four more such tubes are used for the radio power amplifier with parallel pairs in push-pull connection. All plate voltages are supplied from one phase of the 3-phase 50-cycle supply of the Shanghai Power Company. The grid bias voltage of the master oscillator is for most of the time highly abnormally negative. The system is turned into normal oscillating conditions only for a fraction of a milli-second each fiftieth of a second by short-circuiting a great part of the bias voltage through a resistance with a specially designed commutator driven by a synchronous motor. A symmetrical horizontal Hertzian aerial of 36 meters total length is used through a feeder of 16 meters with parallel tuning capacitance of from 155 to 1320 micromicro-farads.

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4. Proc. I.R.E. **23**, pp. 658-669, and p. 1356, 1935.
5. Proc. Roy. Soc. A, **137**, pp. 36-54, 1932.

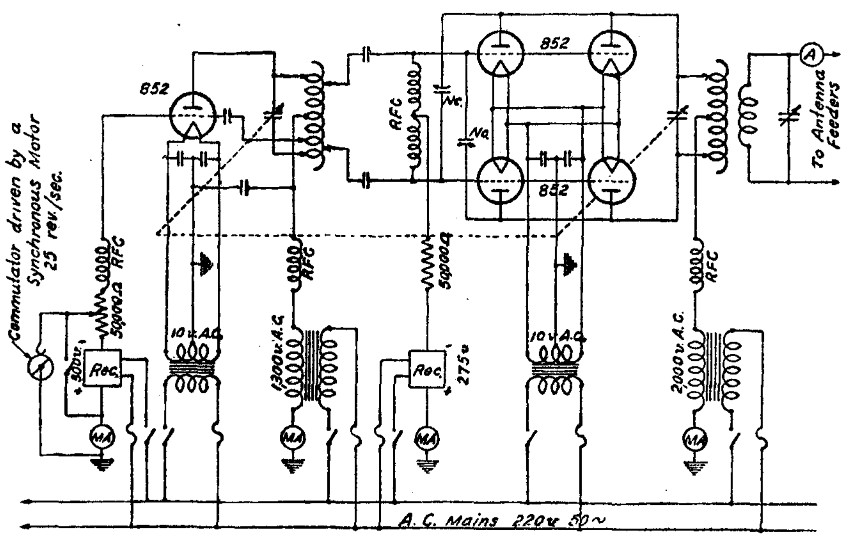


Fig. 1.—Connection Diagram of the Transmitter.

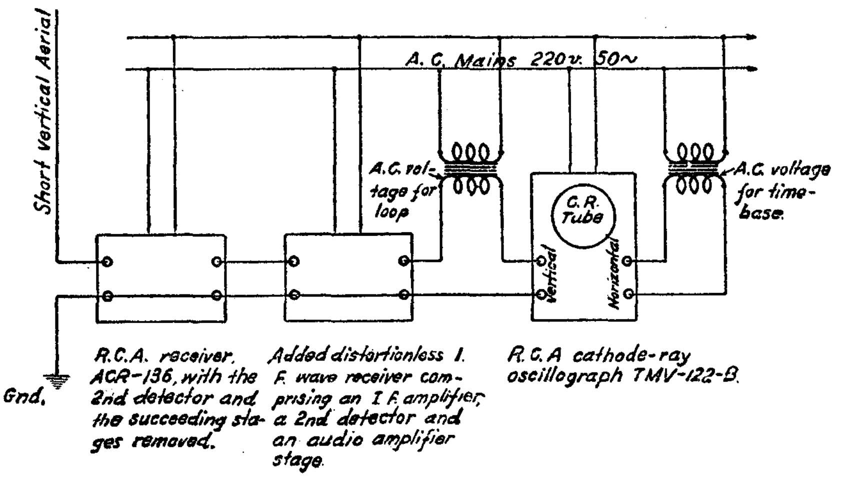


Fig. 2.—Connection Diagram of the Receiver.

The receiving station is located about one kilometer to the north of the transmitting station (121° 30′ E, 31° 14′ N). To minimize local interferences a short vertical antenna is used. The radio part and the one intermediate stage of a RCA's ACR-136 superheterodyne receiver is used with an additional intermediate stage, a special second detector and a special audio amplifier designed to suppress transients in order to get faithful reproduction of sharp pulses. (See Fig. 2) The received pulses are shown in cathode-ray oscillographic patterns with a R.C.A.'s TMV-122-B cathode-ray oscillograph or rather with a type RCA-906 tube, for its audio amplifier and linear time base are not used. The time base is sinusoidal in the form of a narrow loop, obtained from the 50-cycle city power supply. A cinematographic camera, with the lens changed to take near views, is geared to a synchronous motor to take five pictures of the cathode-ray oscillograms per minute.

3. *Procedure.*

Fifteen frequencies were chosen according to the settings of the variable condenser in the oscillation circuit of the master oscillator, namely at 5 to 50 scale divisions by intervals of 5 divisions and at 60 to 100 divisions by intervals of 10 divisions. One frequency was pre-assigned to each minute, starting with the highest frequency at half past eleven o'clock Shanghai time (1130), taking decreasing steps to the lowest at 1144, keeping the extreme frequency for another minute, and then taking increasing steps, and so on till 1630.

A four-day program covering June 18 to 21, 1936 was carried out. Three operators were busy. One at the transmitter was to re-set the ganged condensers of the master oscillator and the power amplifier and the condenser for feeder tuning, according to their respective pre-determined values at the beginning of each minute. A second operator at the receiver re-tuned it each minute and note the presence of various reflected pulses in a well prepared notebook. The third operator took care of the photographic recording of the cathode-ray patterns and inserted notes for the time, for the frequency and sometimes for the date, during the repeating minute of the extreme frequencies at the beginning of each fifteen minutes.

4. *Experimental Results.*

The fifteen frequencies chosen according to the settings of the condenser of the master oscillator are given in Table 1. The pulse sent out by the transmitter had a duration not more than one fifth of a millisecond, but the ground pulse received was two or three times wider, probably due to the condenser-and-leak type of the first detector. The reflected pulse from the E layer combined with the ground pulse made the appearance of a still wider pulse. However, with the decrease in sensitivity of the receiver, separate pulses could be clearly seen. As it was the presence or absence of the reflections rather than their retardation times we desired to acertain, and as the time of the eclipse drew near, we did not try to remove this lack of refinement. Often the receiver's sensitivity was first reduced to acertain the presence or the absence of reflection from the E layer, and then immediately increased to acertain that from F_1 or F_2 layers. Full importance was given to the visual observations, while the photographs were taken as checking and supplementing records. Out of the four day's experiments, only two day's photographic records were obtained, viz. on the day of eclipse and the day after the next, a part of which as sample is shown in Table 2.

Table 1.

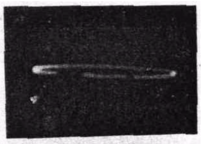
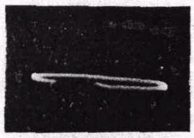
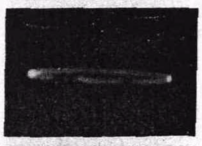
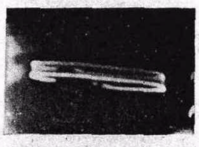
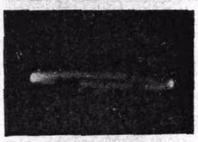
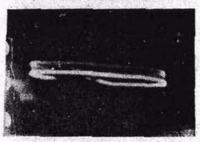
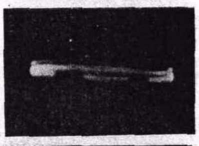
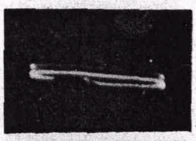
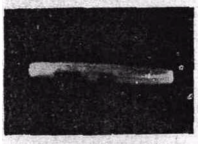
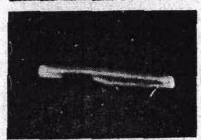
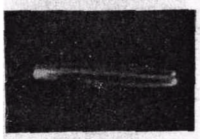
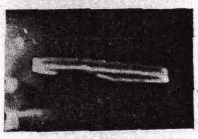
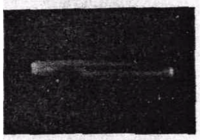
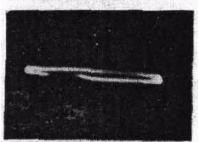
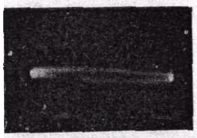
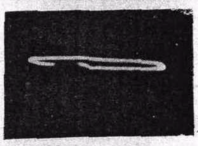
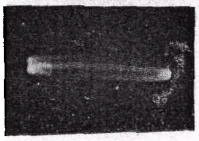
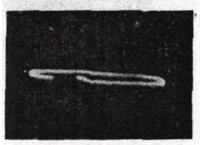
Condenser scale divisions	Frequency in kc/sec.
5	6120
10	5770
15	5450
20	5160
25	4890
30	4665
35	4460
40	4300
45	4150
50	4010
60	3790
70	3585
80	3410
90	3260
100	3160

Taking as the critical penetration frequency for the E layer the frequency between that with reflection from the F_1 layer and the adjacent one without it, and taking as the critical penetration frequency for the F_1 layer the frequency between that with reflection from the F_2 layer and the adjacent one without it, we obtain the curves in Fig 3 which are plotted against Shanghai time.

5. *Deductions.*

The critical penetration frequency in kilo-cycles per second, f, is related to the maximum number of ionic carriers or electrons per cubic centimeter in the layer penetrated, N, by the formula

Table. 2. Sample Photographic Records.

Shanghai time	Frequency in kc/sec.	*June 19, 1936* Record	Remark	*June 21, 1936* Record	Remark
1405	4890				
1406	4665				critical frequency of F_1 layer =4460 kc.
1407	4460				
1408	4300				
1409	4150		critical frequency of F_1 layer =4080 kc.		
1410	4010				critical frequency of E layer =3790 kc.
1411	3790		critical frequency of E layer =3688 kc.		
1412	3585				
1413	3410				

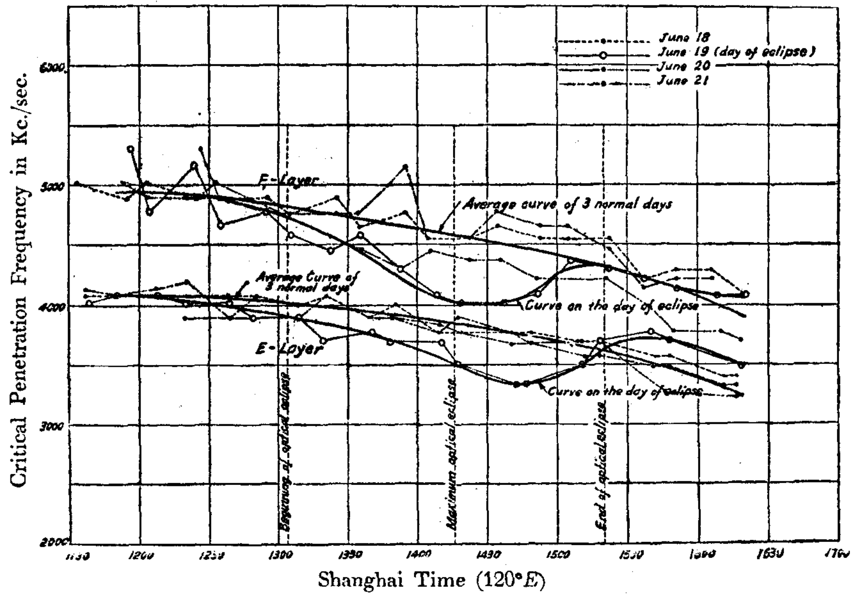


Fig. 3.—Critical Frequencies for E and F_1 Layers Plotted against Time.

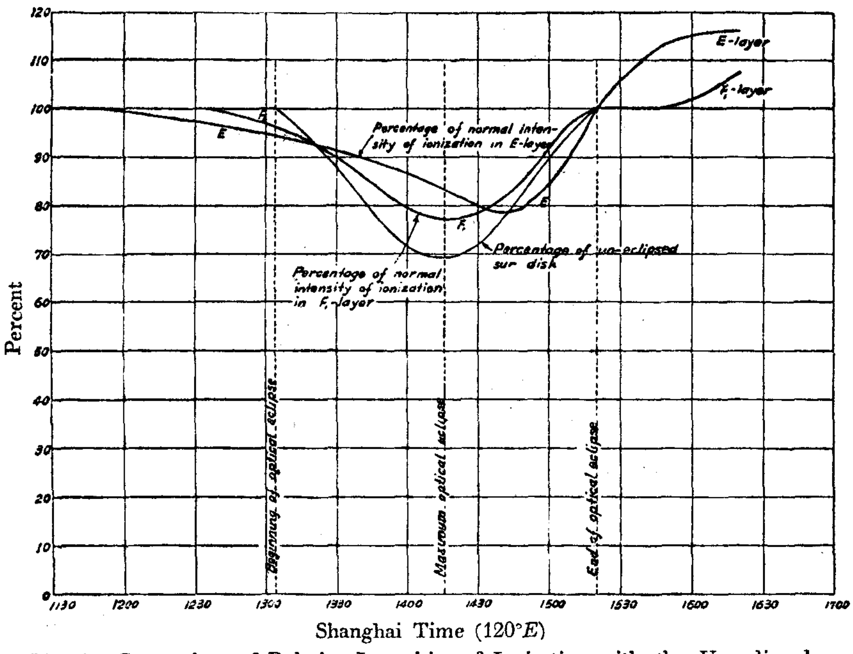


Fig. 4.—Comparison of Relative Intensities of Ionization with the Un-eclipsed Sun Disk

$$N = 0.0184 f^2.$$

The theory and the assumptions involved in the above formula have been discussed by Appleton and Naismith[5].

Comparison of the relative intensities of ionization in the E layer and in the F_1 layer with the optically un-eclipsed sun disk are plotted against time in Fig. 4, from which the following are deduced:—

(a) The ionization eclipse of the F_1 layer was almost entirely in synchronism with the optical eclipse.

(b) The ionization eclipse of the E layer is only roughly in synchronism with the optical eclipse, deviating from it in four respects:

(1) the ionization noticeably began to decrease an hour before the beginning of the optical eclipse, and at the beginning of the optical eclipse reached a decrease amouting to one-third of the maximum decrease;

(2) the maximum ionization eclipse occurred about fifteen minutes after the maximum optical eclipse;

(3) the time rate of re-establishing the ionization was about twice as great as the time rate of cutting it off, while there was only a slight difference in these rates of the optical eclipse;

(4) at the end of the optical eclipse the ionization had only achieved about two-thirds of its re-establishment, which was finished about an hour later with an excess ionization amounting to about one-half of the maximum decrease.

These phenomena were observed with the E layer. However, with the F_1 layer, the first and third phenomena appeared to be very slight, while the second and the fourth seemed to be entirely absent.

6. *Discussions.*

These experimental results and the deductions thereof seem to indicate: (a) the ionization of the F_1 layer may be almost entirely due to ultra-violet light or such high-speed radiation, agreeing with Appleton; (b) the ionization of the E layer can not be explained by this hypothesis alone, a considerable part of it being due to some other agent, probably corpuscular bombardments in accordance with Chapman. These are in general agreement with the experimental evidences obtained during previous solar eclipses by various experimeters, as collected by Appleton and Chapman[4].

This experiment was made primarily as preparations for more extensive and better planned experiments during the total solar eclipse of September 21, 1941 in China. One more comfirmation of the previous results by this experiment alone may have only a very limited value. But to those such as the International Union for Scientific Radiotelegraphy who collect all sorts of data about this subjects from various localities under various conditions, the results of this experiment may be useful.

7. *Acknowledgments.*

Thanks are due to the Telegraph Administration and the broadcast stations in Shanghai for their cordial coorporation in minimizing the local interferences. The writers wish also to thank the members of the Institute of Astronomy, Academia Sinica, for informations concerning both optical and corpuscular eclipses. They are much indebted to the Director of this Institute Mr. S. L. Ting and to our colleague Mr. S. L. Yang for generous facilities and hearty encouragement. Finally they wish to express their thanks to Mr. C. C. Woo and Mr. F. Y Chu for assistance in operating the transmitter.