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Recording Apparatuses for Use in Studies of Field-change due to Lightning Discharge

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Abstract

In electrical study of lightning discharge, it is essential to record faithfully the field-change due to a lightning discharge during the whole duration. For this purpose the authors used simultaneously two different methods of observation, i.e. an electrostatic fluxmeter and an amplifier oscillograph. The slower field-change having longer duration than 1 m-sec up to the static field was recorded by an electrostatic fluxmeter, while the faster change having shorter duration than 1 m-sec by an amplifier oscillograph. Operating these apparatuses we can record correctly all the field-changes, whether slow or fast, due to various processes in the lightning discharge, and time of several microseconds can be resolved.

1. Introduction

The field-change due to a lightning discharge generally continues for fractions of a second and contains many fast changes associated with such rapid streamers as a return streamer, a dart leader, each step streamer of a stepped leader, etc., as well as slower changes caused by junction or final processes. In order to record correctly all these changes, it is necessary to use simultaneously two recording methods having different ranges of time correspondence. For the recording of the slower change the authors adopted an electrostatic fluxmeter originally devised by MALAN and SCHONLAND (1950). For the recording of the faster change we constructed an amplifier oscillograph, which records continuously the whole field-change due to a lightning discharge. Using both apparatuses simultaneously we can record all changes due to various processes involved in a lightning discharge with sufficient fidelity.

2. Description of the apparatuses

The apparatuses consist essentially of the electrostatic fluxmeter and the amplifier oscillograph. In recording the field-change, the output of the antenna oscillograph is displayed on the face of a cathode-ray tube with horizontal time-

base and directly photographed upon 16 mm film moving in perpendicular direction to the time-base sweep. The output of the fluxmeter is recorded simultaneously upon a magnetic tape by means of a magnetic recorder, being monitored upon the other cathode-ray tube where it is displayed with horizontal time-base. The playback of the recorded tape is carried out later on, the output of a magnetic-recorder being fed on the horizontal deflection plates of the former cathode-ray tube and photographed upon 16 mm film moving vertically with the same speed as in the case of direct photographing of the amplifier oscillograph. As a marking pulse is impressed manually upon both apparatuses immediately after a lightning discharge, changes recorded in both films can be investigated in correct time correspondence. In producing the marking pulse a rectangular waveform generator is used. The whole apparatuses are shown schematically in Fig. 1.

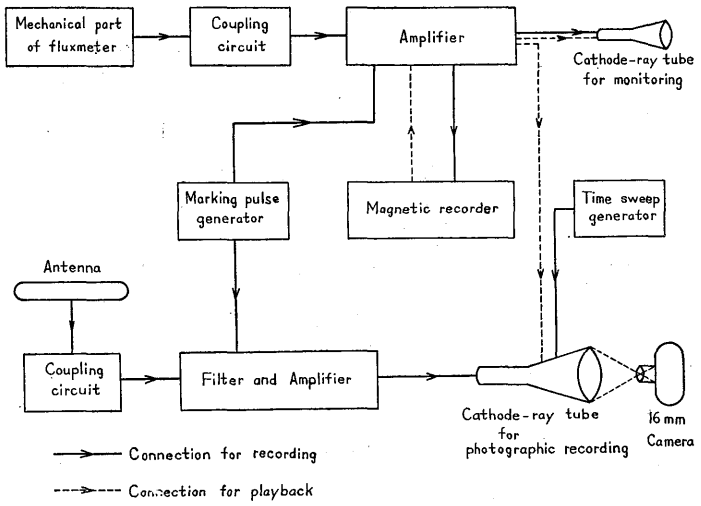

Fig. 1. Block diagram of apparatuses.

3. The electrostatic fluxmeter

The main part of the electrostatic fluxmeter is the same as that constructed by MALAN and SCHONLAND (1950). A head tube is equipped not in the shielding box which covers the mechanical system but separately on the base on which the mechanical system is fixed with a rod, in order to avoid a microphonic noise of the tube caused by mechanical oscillation of rotating parts.

Using a shield cable of large diameter in connecting studs and a head tube, the total capacity of studs system can be made less than 120 $\mu\mu$ F. As the system is grounded by a resistance of 500 kilo-ohm, the time constant is approximately 0.06 m-sec. The cycle of generated electromotive force is 1000 c/s and consequently time longer than 1 m-sec can be resolved. The head circuit is designed so as not to be saturated in any strong field caused by thunderclouds overhead. Recording range of the field is from 30 to 10^5 volts/m.

4. The amplifier oscillograph

The recording apparatus of this type was originally devised by WATSON-WATT and APPLETON (1923), and has been improved by many scientists for investigations of the waveform of atmospherics.

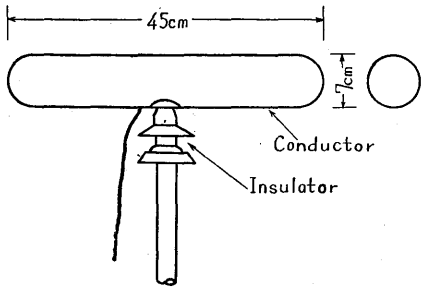

Fig. 2. Elevated conductor.

The apparatus constructed by the authors consists of an antenna (an elevated conductor), a head circuit, an amplifier, a cathode-ray oscillograph and recording devices. The elevated conductor is a brass cylinder both ends of which have semispherical forms. The dimensions of the conductor are shown in Fig. 2 and its capacity is some 20 $\mu\mu$ F. The height of the equipped conductor is about 8 m. The time constant of the antenna system is 0.2 μ-sec, the value being sufficiently small for a potential of the system to follow any fast change in the field. The potential proportional to the electric field is fed to the head circuit.

The amplifier shown in Fig. 3 is of resistance-capacity coupled design. In order to obtain a wide level frequency response, some feedback technique is

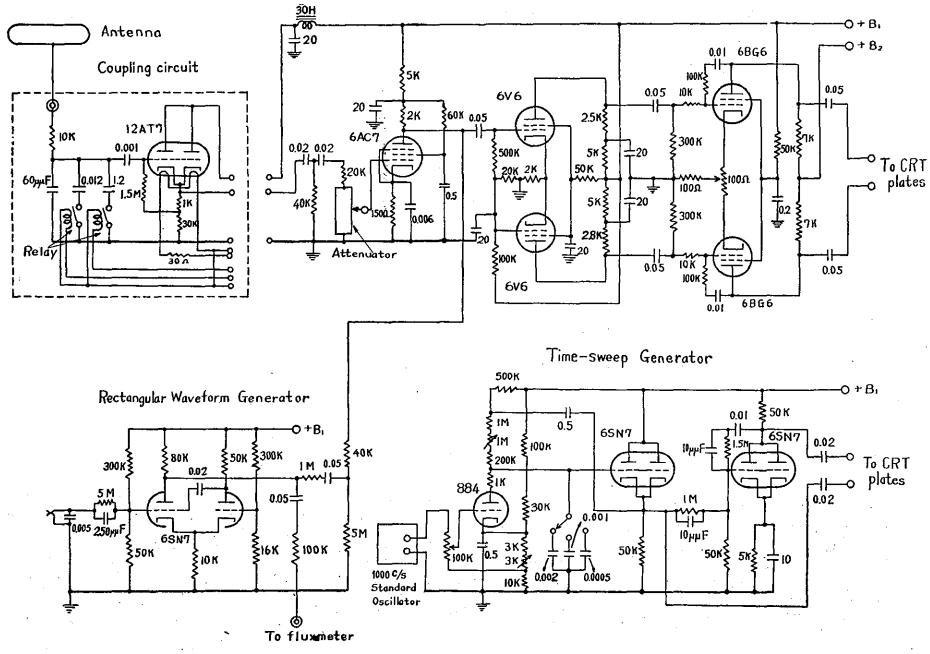

Fig. 3. Circuits used in the amplifier oscillograph.

used. The overall frequency characteristic is shown in Fig. 4. As to the fast response of the amplifier VALLEY and WALLMAN (1948) showed the following relation between a bandwidth and the rise time:

$$\tau \cdot B = 0.35,$$

where B is the bandwidth of -3db range in c/s, and τ the rise time in sec. As the bandwidth of the present apparatus is 300 kc/s, the rise time of output voltage corresponding to the step input is some 1 μ-sec. This value is sufficiently small compared with the velocity of time sweep on the cathode-ray tube. A low cut filter is devised between head circuit and amplifier so as to cut down the slower change having longer duration than 1 m-sec. The decay constant of the apparatus in reproducing the flat portion of the step input is about 0.3 m-sec. By using this filter, inversion of successive horizontal time-bases on the film can be avoided.

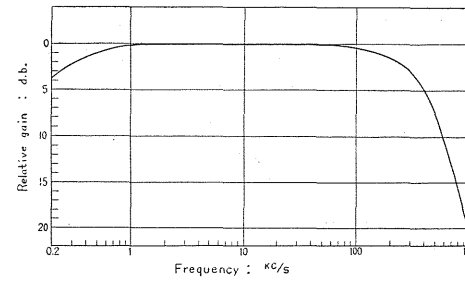

Fig. 4. Overall frequency characteristic of the amplifier ascillograph.

In order to obtain continuous recording, a simllar method to that of PIERCE (1957) is used. A time-base deflecting horizontally on the cathode-ray tube, is combined with a camera in which a 16 mm film moves vertically. Vertical deflections of the tube are due to field. Recording range of the field is from 1 to 10^5 volts/m. The available periods of the time-base are 4, 3 and 1 m-sec and the speeds of film are 20, 30 and 40 cm/sec. In observation in 1955, the horizontal time-base was deflected at the period of 4 or 3 m-sec, the film speed of 20 cm/sec being combined. In observation in 1956, the time-base of 1 m-sec and the film speed of 40 cm/sec were used in order to confirm the results concerning the very fast changes recorded in 1955.

5. Concluding remarks

Recording the field-change by using the apparatuses above described has brought us many new and valuable informations concerning the mechanism of

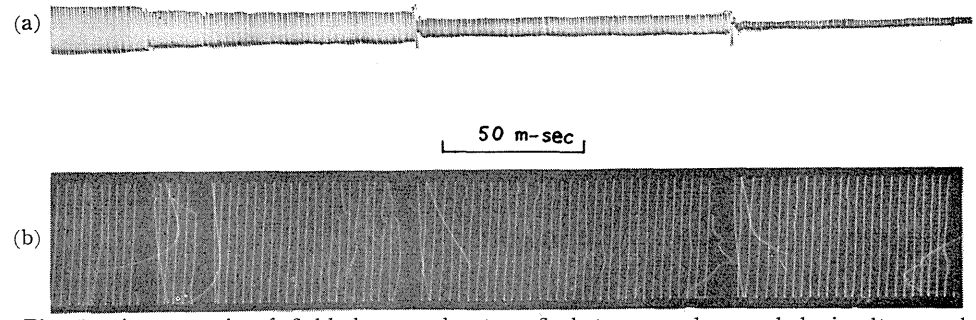

Fig. 5. An example of field-changes due to a flash to ground recorded simultaneously by the electrostatic fluxmeter (a) and by the amplifier oscillograph (b). In both records time increases from left to right, the same position along the horizontal direction representing the same time.

the lightning discharge as are stated by KITAGAWA (1957 a, b). The results of recording in two different thunderstorm seasons also show that the following operation is the fittest for the investigation of the lightning discharge:

1) The period of time-base of 3 m-sec being combined with the film speed of 20 cm/sec for the amplifier oscillograph.
2) The film speed of 20 cm/sec for the playback of the output of the electrostatic fluxmeter recorded upon a magnetic tape.

An example of simultaneous recording obtained in this operation is shown in Fig. 5.

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