THE ECHO TYPE WAVEFORMS WITH OPPOSITE POLARITIES BUT ORIGINATED FROM THE IDENTICAL SOURCE

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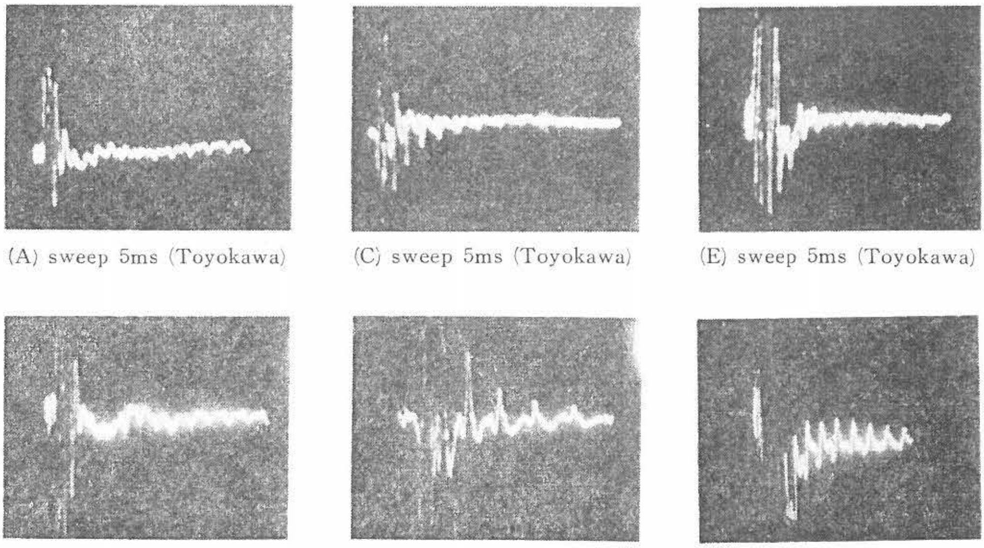
The night-time echo type waveforms consist of a series of pulses traversed to and fro between the ionoshere and the earth. In our laboratory the waveform measurements were carried out at two stations (Toyokawa and Kumamoto; a distance of about 650km) in Aug. 1959, and their origins were located by our usual sferics-fix network. Therefore waveforms originated from the identical source were observed by two separate but similar receivers. The majority of the couples of waveforms show the identical polarities of trains of pulses. But in two cases the exceptional couples of waveforms showing the reverse polarities independent of the orders of reflection were found. It is the object of this paper to give a possible suggestion concerning the above effect.



(A) sweep 5ms (Toyokawa) (C) sweep 5ms (Toyokawa) (E) sweep 5ms (Toyokawa)

(B) sweep 5ms (Kumamoto) (D) sweep 2.2ms (Kumamoto) (F) sweep 5ms (Kumamoto)

Fig. 1

Figs 1 (A) and (B) are the reproductions of typical waveforms with identical polarities. The sweep time represented by them is 5 ms. On the other hand, as shown in Figs 1 (C) (D) (E) and (F), Fig. (C) indicates the opposite polarity to (D), and the same relation can be seen to exist between Figs 1 (E) and (H). Because of the inequality of the sensitivities of the apparata employed in the waveform observations, it is naturel that the magnitude of amplitude in one photo differs from that in another one. However, the fact that the reflected waves of a higher order show the opposite polarlity is demonstrated. As vertical antennae are employed in our waveform observations, we cannot expect the reversed sign of waveform in propagation except for the evidence of such behaviour found in oblique transmissions. Hence a lightning discharge is assumed to be an intercloud one expressed by a horizontal electric dipole. Though the received atmospherics are in general to be radiated from the ground discharge, i. e. a vertical dipole, the author, considering the horizontal lightning discharge in a limited case, derived the expression of the received vertical electric field radiated from a horizontal dipole on a finitely conducting earth.

Suppose the horizontal dipole is put on the origin of the Descartes rectangular coordinate and directed to the x-axis. The electric field of any point in the space is expressed by the next equation (1).

$$E_z = k^2\Pi_z + \frac{\partial}{\partial z}\mathrm{div}\vec{\Pi} \quad \cdots\cdots (1)$$

where k = wave number. Introducing x and z components of the div $\vec{\Pi}$, div $\vec{\Pi}$ becomes

$$\mathrm{div}\,\vec{\Pi} = \frac{\partial \Pi_x}{\partial x} + \frac{\partial \Pi_z}{\partial z}$$

Then the first equation (1) can be written as

$$E_z = k^2\Pi_z + \frac{\partial^2 \Pi_x}{\partial z \partial x} + \frac{\partial^2 \Pi_z}{\partial z^2} \quad \cdots\cdots (2)$$

Next, the refractive index of the earth denoted as n, Π_x and Π_z are expressed as follows.

$$\Pi_x = -\frac{2j}{kn}\frac{\partial}{\partial z}\left(\frac{e^{jkR}}{R}\right) \sim \frac{2}{n} z\frac{e^{jkR}}{R^2} \quad \cdots\cdots (3)$$

$$\Pi_z = \frac{2i}{kn}\cos\varphi\frac{\partial}{\partial r}\left(\frac{e^{jkR}}{R}\right) = -\frac{2\cos\varphi}{n}\left(\frac{r \cdot e^{jkR}}{R^2} + \frac{jre^{jkR}}{kR^3}\right) \quad \cdots\cdots (4)$$

where $\qquad R^2 = z^2 + r^2 = x^2 + y^2 + z^2$

The vertical radiation field Ez at great distances from the dipole is rewritten

$$E_z = k^2\Pi_z = -\frac{2k^2\cos\varphi}{n}\frac{r \cdot e^{jkR}}{R^2} \quad \cdots\cdots (5)$$

If we set the receiving point on the earth surface, z becomes zero and R becomes equal to r. Hence the final form reads

$$E_z = -\frac{2k^2\cos\varphi}{n} \cdot \frac{e^{jkr}}{r} \quad \cdots\cdots (6)$$

As will be seen in equation (6), the vertical electric field at the receiving point is proportional to cos φ, so the difference of polarity of the receiving field may be caused by the factor cos φ. There should be a change of polarity with respect to the direction $\varphi = \frac{2}{\pi}$. We note that the mathematical treatment obtained here is valid for continuous waves. However, it will be seen that this expression can also be applied to the impulsive atmospherics waveforms.

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