N91-32647

THE ELECTRIC FIELD CHANGE CAUSED BY A GROUND FLASH WITH MULTIPLE CHANNELS

Minoru NAKANO
Toyota College of Technology, Toyota, Japan

Nobuyuki TAKAGI, Izumi ARIMA
Gifu University, Gifu, Japan

Zen-Ichiro KAWASAKI
Osaka University, Suita, Japan

Tosio TAKEUTI
Aichi College of Technology, Gamagori, Japan

ABSTRACT

The electric field and the magnetic flux changes caused by a ground flash with multiple channels are measured near the electric power transmission lines during winter thunderstorms. Triggered lightning strokes and the following associated strokes to the transmission line towers produce characteristic waveforms of the field changes. A few examples of the waveforms and a brief discussion are given.

INTRODUCTION

In winter thunderstorms, lightning is often initiated upward almost simultaneouly from several transmission line towers which are distributed along the mountain ridge. This type of lightning is called as 'concurrent flashes', 'a ground flash with multiple channels', or 'a ground flash with multiple striking points'. Hereafter, 'concurrent flashes' is used in this paper. Takagi et al. [1] defined a stroke to the ground which occured within one second after the first return stroke as an associated stroke in concurrent flashes. They summarized the occurrence characteristics of the concurrent flashes. The occurrence rate is 55 % of the ground flashes, the average number of striking points is 5.1, the horizontal distance between striking points is 1.3 km, and the average time intervals between strokes is 6.7 ms for winter lightning. The largest numbers of the striking points are 4 in summer and 17 in winter. Hara et al. [2] also reported that the occurrence rate of the concurrent flashes was 43.3 % and the maximum distance between striking points was 4.7 km in winter.

The concurrent ground flashes may bring multi-conductor and double-circuit tripouts of the electric power transmission line which often occur when winter thunderstorms pass over the transmission lines.

Kawamata et al. [3] discussed the generation mechanism of triggered lightning with multiple striking points. A preceeded cloud flash triggers the first ground flash, and the electric field change caused by the first ground flash is possible to trigger the following ground flashes which strike to other transmission line towers.

we made observations of the electric field and the magnetic flux changes caused by lightning and also recorded lightning channels with video cameras during winter thunderstorms. In this paper, we present a few examples of the electric field changes due to the concurrent ground flashes and give a brief discussion on the characteristics of the field changes.

OBSERVATIONS

We used a fast antenna system and a single-turn loop antenna system for the detections of the electric field and the magnetic flux changes caused by lightning. The bandwidths of the systems are both ranged roughly from 200 Hz to 2 MHz. We set video camera systems at two stations to identify the location of the striking point. We used several video cameras to cover wide view angles at each station.

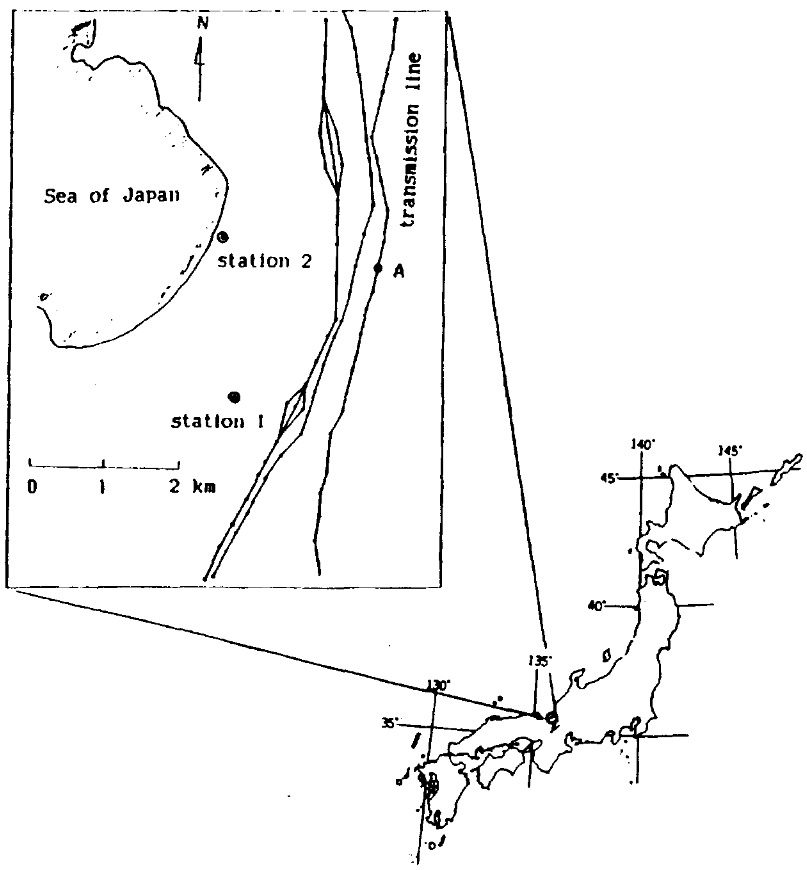

Fig.1. Observation site and transmission lines.

Fig. 1 shows the locations of observation stations where is very close to the electric power transmission lines. Three transmission lines are distributed along low mountain ridge. Small dots on the solid lines show the locations of transmission line towers. The transmission line tower A of 101.7 m height is located at the small peak where is 310 m high above sea level, and a lightning conductor of 4 m length is set on the top of the tower A. So upward streamers often start first from the tip of the lightning conductor.

Fig. 2 shows the electric field and the magnetic flux changes caused by the return stroke of the natural ground flash to a transmissin line tower. Here, 'natural' means that a ground flash starts with a downward streamer from the cloud to the ground. Two traces in Fig. 2 show the same waveforms due to the close return stroke as those in summer lightning. The horizontal distance to the tower struck is 2.1 km.

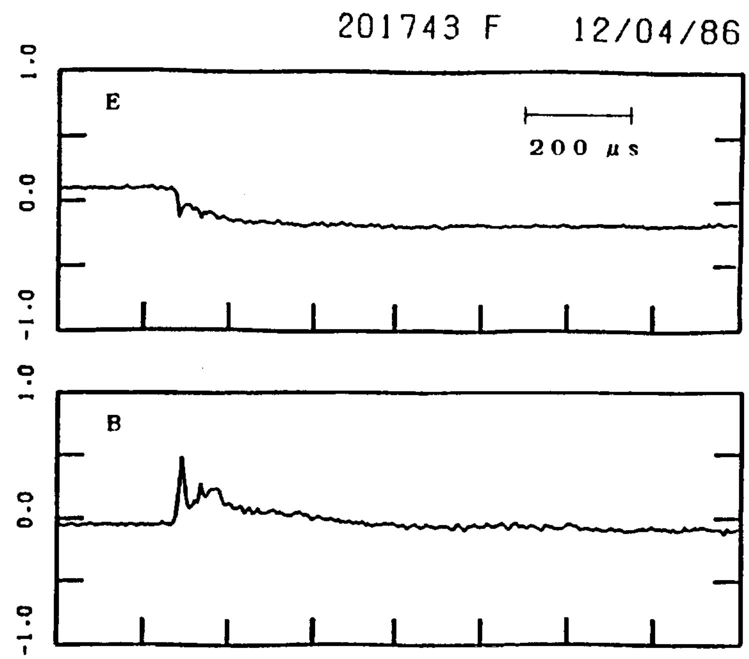

Fig.2. The electric field and the magnetic flux changes caused by a natural lightning to a transmission line tower.

Fig. 3 shows the electric field and the magnetic flux changes caused by triggered lightning flashes. Open circles on the transmission lines in Fig. 3 show the tower to which lightning struck. This was identified with video pictures at two stations. Fig. 4 shows the sketch of video picture of the same triggered flash as one in Fig. 3.

Fig. 5 shows another concurrent flash with several striking points near the tower A. Sketches of video pictures for the same flash are shown in Fig. 6 for different directions. Lightning channels corresponding to striking points given in Fig. 5 are shown in the top sketch in Fig. 6. Fig 7 and Fig. 8 show examples of concurrent flashes

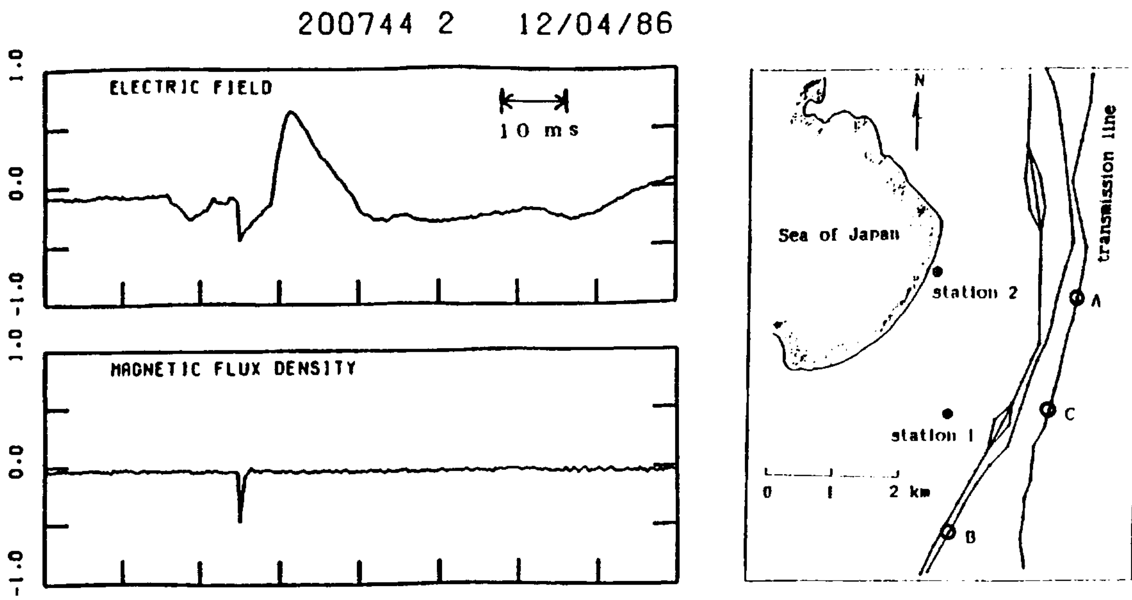

Fig.3. The electric field and the magnetic flux changes caused by a concurrent flash to transmission line towers. Open circles on transmission lines show the towers struck by lightning.

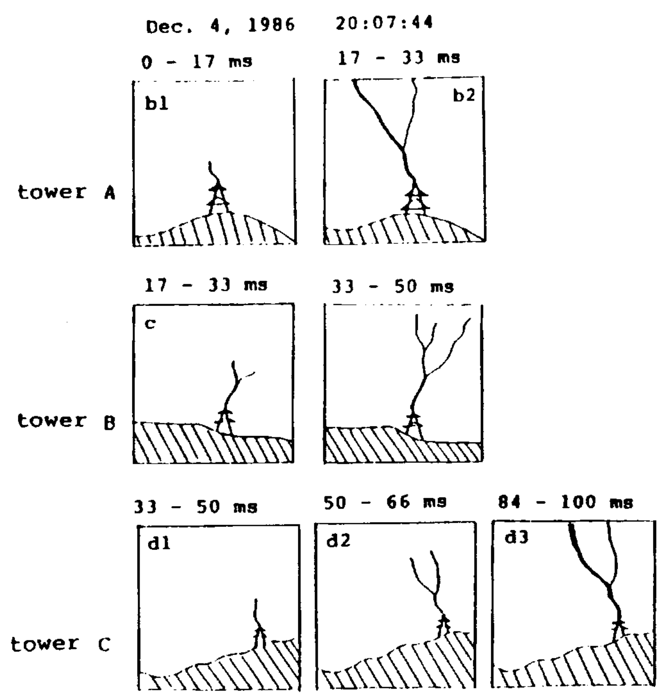

Fig.4. Sketches of video pictures of concurrent flashes to three transmission line towers.

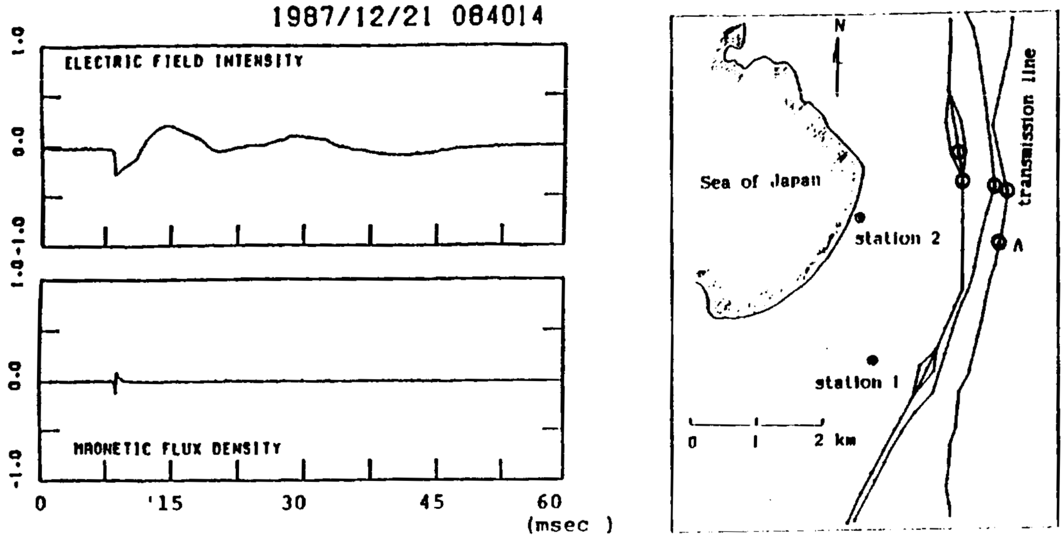

Fig.5. Same as Fig.3 except for date.

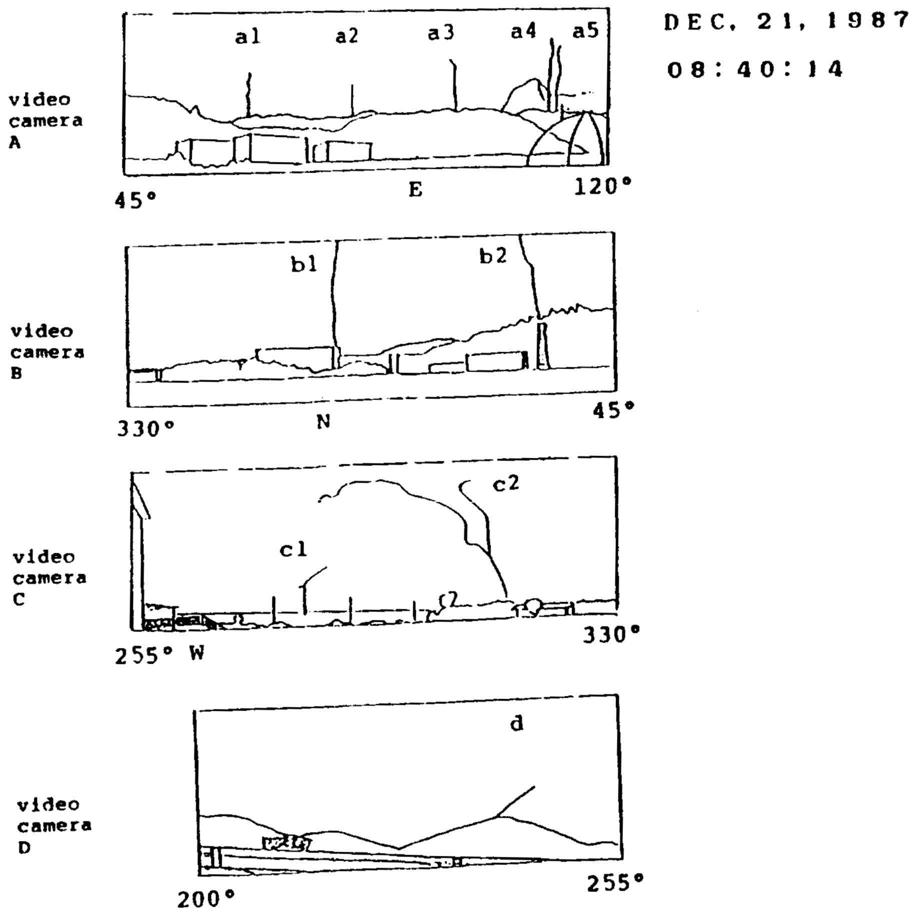

Fig.6. Sketches of video pictures of concurrent flashes to transmission line towers and other structures for different directions. Direction angles show in each sketch.

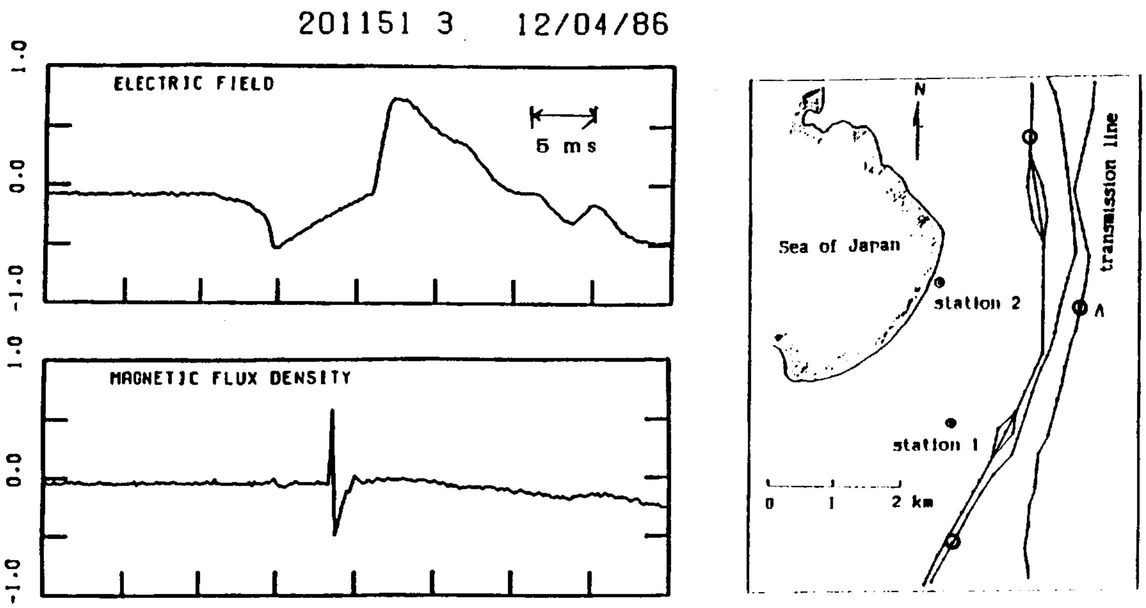

Fig.7. Same as Fig.3 except for date.

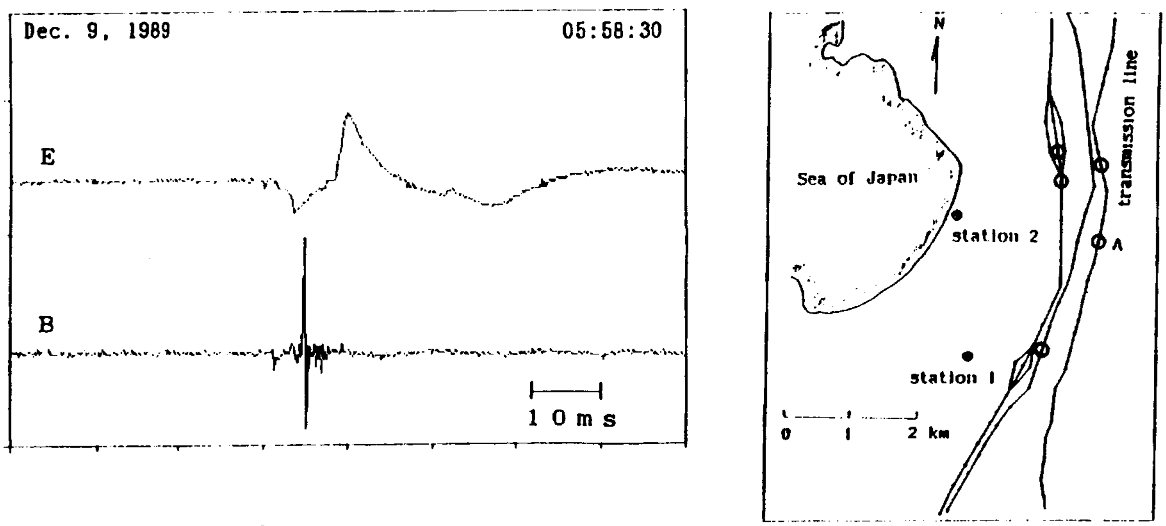

Fig.8. Same as Fig.3 except for date.

in which the magnetic flux changes are different from those in Fig. 3 and Fig. 5. In Fig. 3 and Fig. 5, the rapid changes of the electric field and the magnetic flux occur simultaneously, as well as the return stroke in summer lightning. On the other hand, in Fig. 7 and Fig. 8, the occurrence time of the large changes in the magnetic flux is not corresponding to the rapid changes in the electric fields. The horizontal extents of the striking points in the flashes shown in Fig. 3 to Fig. 8 are 4.1 km, 1.5 km, 6.3 km and 3.0 km respectively. All cases, upward streamers start from the lightning conductor at the top of the tower A, as shown in the figures.

RESULTS AND DISCUSSION

Continuing currents

Seven ground flashes which starts with upward developing streamers show very similar electric field changes to those shown in Fig. 3 to Fig. 8. The slow field change preceeds the negative rapid changes corresponding to return strokes or M-components. The slow field change may due to some electrical activities within clouds. Since the propagation direction of the electric current pulses was not measured, the electrical processes of the rapid field changes are not discussed further. After rapid changes, the electric fields vary almost linearly to the positive direction, and are followed by slow changes with large amplitudes. As the time constant of the input circuit is 1 ms, the response of the system to the slow field changes is rather poor. The electric field changes corresponding to the linear changes is actually increasing to the negative direction with time. Thus the field changes are interpreted as caused by the continuing currents. The electric field changes always show rapid changes which are followed by slow changes caused by the continuing currents flowing through the lightning channel to the ground.

Table 1 shows the time of the duration of the continuing currents and the horizontal extents of striking points. The horizontal extents of the electric charge in clouds may influence on above two parameters, and they correlate positively. Table 1 shows the tendency of positive correlation between two parameters. The electric field changes by the continuing currents, as well as first return stroke, may trigger lightning strokes to other transmission line towers, when the streamer develops into the deep clouds.

Magnetic flux change pulses

As mentioned previously, any rapid change of the electric field is not detected at the time when the rapid change of the magnetic flux is detected. Small changes of the magnetic flux are found at the time of the negative fast changes of the electric fields. We used a disk antenna for the electric field change meters and measured only the vertical electric field changes. Thus, horizontal lightning channel may responsible to the results that no rapid electric field changes are detected at the time corresponding to the large pulses of the magnetic

Table I Duration of the continuing current and the maximum distance between striking points.

Duration of C.C. (ms)	Maximum distance (km)
7.5	6.3
6.2	3.0
6.0	4.1
2.3	1.5
1.3	1.0

flux changes. In winter lightning, long horizontal channels often observed below the cloud base. Small current pulses which produce large changes of the magnetic flux may superimpose on the continuing currents through the horizontal channels.

Concluding remarks

The electric field changes caused by a concurrent lightning flash have continuing current components. The electric field changes due to the continuing currents is possible to trigger the associated strokes. Quantitative analysis of the data is remained as further study. Simultaneous measurements of the occurrence time of each lightning stroke to the tower and the electric field change are very important for the discussion on the mechanism of the concurrent lightning flash. We designed optical measuring system with 1 us time resolusion and 4 degrees spatial resolusion by using horizontal photodiode array to measure the time interval between stroke to different towers. Data obtained by new system will be helpful for further quantitative discussion on the mechanism of the concurrent lightning with multiple channels.

The observations were partly supported by Technical Research Center, Kansai Electric Power Co., Inc.. M. Nagatani and H. Nakada of Nagoya University are very helpful for the instrumentations and the observations.

REFERENCES

[1] Takagi, N., et al., Lightning flash with multiple strikes to the ground, Trans. IEE, Japan, 111-B, 93-98, 1991.

[2] Hara, T., Y. Takahashi and M. Yasui, Observation of winter lightning on a 500 kV line on the Japan Sea coast, Trans. IEE, Japan, 108-B, 289-296, 1988.

[3] Kawamata, Y., T. Takeuti, M. Nakano and Z-I Kawasaki, A case study on triggered lightning in winter, IEE Tech. Report, HV-89-50, 31-38, 1989.