STUDIES ON RECORDING APPARATA FOR THUNDERSTORM OBSERVATION

Part. I. On the Directive Type Lightning Counter for Thunderstorm Forecast.

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ABSTRACT

We notice the fact that the number of atmospheric pulse per unit time at output of radio-receiver is closely related the thunderstorm activity. Then by use of this fact, we intend to find out some useful apparatus for predicting thunderstorms.

From the results of several preliminary observations, we decide the tuned type lightning counter, which is adjusted to pick up lightning discharges within predetermined radius, to be one of useful auxiliary apparatus in our purpose.

However, the tuned type lightning counter is not yet sufficient for forecasting thunderstorm. Because it indicate neither the direction of the occurrence district of storms nor the direction of storm movement. So as to supply these' weak points, the apparatus combining the pulse counter and the uni-directional C. R. D. F. was designed.

I. Introduction.

Thundersotrm forecast is one of the most important functions of the meteorologist. However, techniques for thunderstorm forecast have mainly depended upon the weather reports and both aural aud visual reports of thunder by many auxiliary observers. There remains the need for some additional methods of detecting and evaluating the thunderstorm activity by the local weather bureau. During our observation of the atmospheric wave-form near their origins, we recognized the fact that the discharge number per unit time seems to be related closely to a developing process of thunder-storm-cell. We expected that it would be possible to forecast thunderstorm by electrically counting the number of lightning discharges. Then, by use of the lighning counter, we intended to replace human observation.

As needed forecast data at local weather bureaus, such an instrument should supply information on the generation of thunderstorms by detecting the discharge number per unit time and on the direction of storm movement during the time it is within about 100 Kilometers from the point of observation. Since 1953 the Research Institute of Atmospherics of Nagoya University developed such an instrument which satisfies these demands. In this paper we first describe the preliminary works which were carried out with the nondirective type lightning counter to determine whether or not the discharge number per unit time is related to the generation of thunderstorm. Then we describe the instantaneous directive type lightning counter under working test, the designe based on the observation data obtained during the last two years.

Although this equipment is now in the preliminary stage, we believe it to be a useful auxiliary apparatus for predicting thunderstorm.

II. Preliminary work.

1. Purpose

Preliminary work was to investigate the following points:

(i) To examine whether the electrical counting of the discharge number per unit time indicates thunderstorm activity within some limited area

(ii) To determine which of two type lightning counters, an untuned or a tuned type, is more suitable to detect thunderstorm activity within about 100 Kilometers

(iii) To decide which frequency band, very low, low, or medium frequency should be selected when using a tuned type lightning counter

(iv) To select a handy and inexpensive instrument with the object of using it for thunderstorm forecast and to keep in mind that it must be understood and easily operated by anybody.

2. Apparatus used.

To select the frequency band, it is necessary to compare the differences in indications of thunderstorm activities using several apparata having variable frequency bands but the same circuit system.

So as not to miscount because of disturbances within the communication system and artificial noises outside, the circuit system employed must have good selectivity. Then it was decided to use a super-heterodyne system as the receiving part.

Block diagram of the nondirective tuned type lightning counter is shown in Fig. 1. Photo. 1. shows this apparatus.

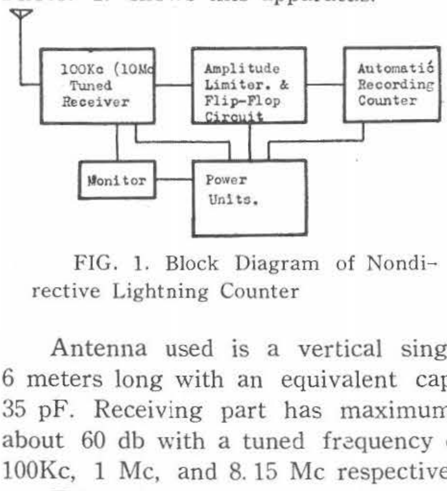
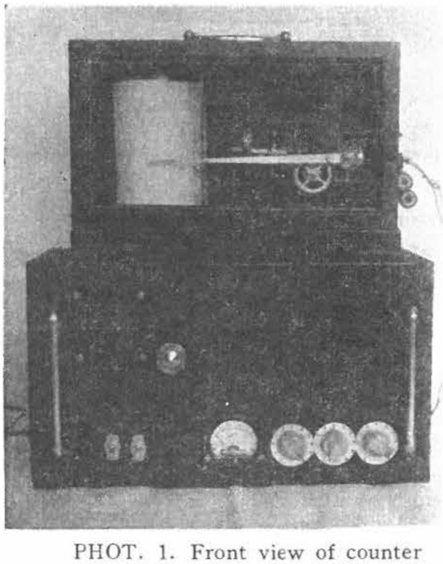


FIG. 1. Block Diagram of Nondirective Lightning Counter



PHOT. 1. Front view of counter

Antenna used is a vertical single wire, 6 meters long with an equivalent capacity of 35 pF. Receiving part has maximum gain of about 60 db with a tuned frequency of 28Kc, 100Kc, 1 Mc, and 8.15 Mc respectively.

Triggering level is set so as to work when the equivalent intensity of thunder discharge pulse is over 0.1 v/m. The output of counter circuit is connected with the self-recording counter run by clockwork. A pen-point records every time there is a discharge.

3. Preliminary observation and results obtained

Preliminary observations for the purpose of investigating those points mentioned above were carried out during the summer seasons of both 1953 and 1954 at the city of Maebashi which is known to be one of the districts with the most frequent occurrences of thunderstorms in Japan.

At time of observation, the gain and the triggering level of counters were first adjusted to work by atmospherics having only amplitudes over 0.1 v/m. After such adjustment, it was found that when the frequency curves of the discharge number per unit time of counters were flat, thunderstorms were not reported within about 100 Kilometers of the observation point.

From such results, it may be said that the adjustment of counter was suitable to serve our purpose. Now we shall give some suitable examples which seem to explain the basic relation between the thunderstorm activity and its discharge number per unit time.

(i) August 22, 1953. (See Figs. 2 and 3)

Fig. 2 represents the time variation of the thunderstorm discharge frequency per unit time. Fig. 3 shows the thunderstorm observation reports for the same day in districts surrounding the observation point.

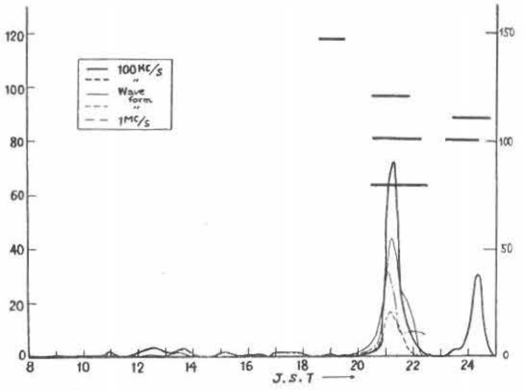


FIG. 2. Thunderstorm discharge frequency curve on August 22, 1953

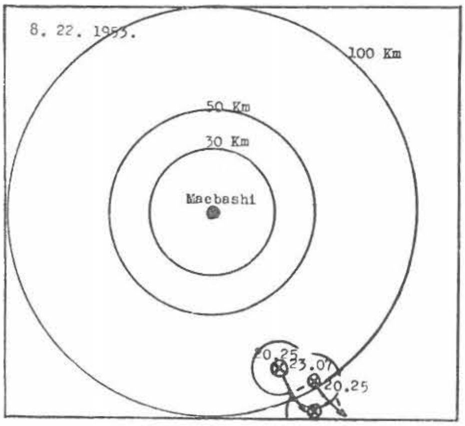


FIG. 3. Thunderstorm report within 100 Km of Maebashi on August 22, 1953

In Fig. 2, two remarkable peaks are indicated in the frequency curve. From Fig. 3 it can be assumed both the first and second peaks are caused by thunderstorms occurring in the vicinity of Tokyo from 80 to 110 Km away from Maebashi, because there was no count of the number of discharges from thunderstorms occurring at 18 h 35 m and 01 h 40 m 120 Km distant from Maebashi. These results, as mentioned above, prove there is a limitation of the receiving distance.

As the thunderstorm occurs in only one district within about 100 Km from the observation point, it is possible by the above facts to get a general idea of the thunderstorm activity from generation to extinction as is indicated in the frequency curve obtained by the counter.

Considering the counting rate per unit time, the activity within a thunderstorm area seems to be intermittent and not continuous. That means that the group of cumulonimbus in a thunder area has many thundercells and that these cells become successively active at random intervals.

A sudden increase in the counting rate occurs when thunderstorm is reported within the limited receiving distance. Then the envelope of the frequency curve indicates the peak, as shown in Fig. 2, which rises sharply and desends rather more slowly. It may be considered that in the growing stage the thunder-cell rapidly accumulates electrical energy from the meteorological force and both the charge-up and the discharge are frequently carried out into the cloud and then the discharge number per unit time increases sharply. After the active stage, the cloud rapidly loses its energy both through discharge and by rainfall and then the number of discharges decreases. The only differece found in the indications in frequency bands was a difference in the number of discharge per unit time which may be caused chiefly by the difference in the intensity of frequency spectrum of atmospherics in origins and also by the attenuation on the way of propagation. At this point, we shall explain in detail by giving the following example.

(ii) **August 13, 1954**

To decide the frequency band most adequate for representing the occurrence of the thunderstorm and also to make sure of the relation between the number of discharges per unit time and the thunderstorm activity, we used the tuned type lightning counters having the same circuit, the same band width and the gain. Adjustment has settled the suitable gain and triggering level to count the discharge number occurring within about 100 Km from the observation station. Throughout the observation period, the limitation of receiving distance gave satisfactory results. Then, to interpret the results obtained, we shall turn our attention to the thunderstorms within 100 Km.

Fig. 4 gives the thunderstorm reports in districts surrounding the city of Maebashi. The Roman numerals represent the order of occurrence. In order to make clear the relation between the time of occurrence and the distance from the occurring place, diagram of the distance to the time of occurrence is shown in Fig. 5.

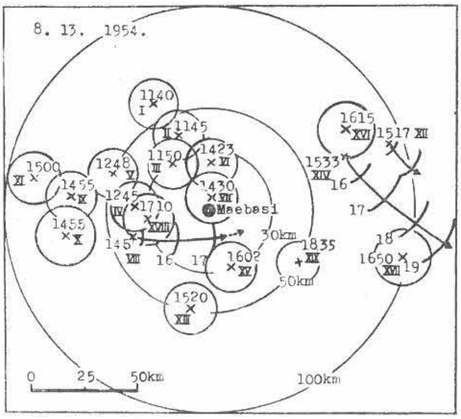


FIG. 4. Thunderstorm report within 100 Km of Maebashi on August 13, 1954

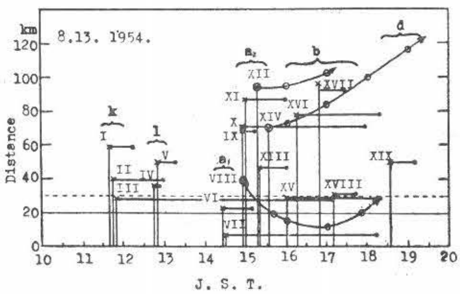


FIG. 5. Diagram of the distance to the time of occurrence in thunderstorm on August 13, 1954

In Figs. 4 and 5, symbol X represents the suspention thunderstorm which is active only in one district, symbol ⊗ represents the traveling thunderstorm which traverses a thunderstorm area in some direction. The Arabic numerals are the time of occurrence and the Roman numerals the order of occurrence. The direction of the traveling thunderstorm is specially indicated by an arrowhead. It is convenient to consider these thunderstorms in groups and we have indicated them as *k* (covering 3 storms), *l* (covering 2 storms), *a* (covering 9 storms), and *b* (covering 7 storms) group. In all of these groups the thunderstorms occurred at almost the same time.

(A) *k* **group**

This group seems to be a comparatively solitary thunder group because these thunderstorms occur in almost the same districts and at the same time with the same time interval. These storms occurred about an hour before the *l* group thunderstorms. Figs. 6, 7 and 8 show the frequency variation curve of the thunderstorm discharge number per unit time. The curve in Fig. 6 was obtained by the static field meter which was used simultaneously with the counter to observe the static field change in the thunderstorm, in Fig. 7 by the mean intensity meter of atmospherics (tuned in 28 Kc), and in Fig. 8 by the lightning counter tuned in 100 Kc and 8.15 Mc.

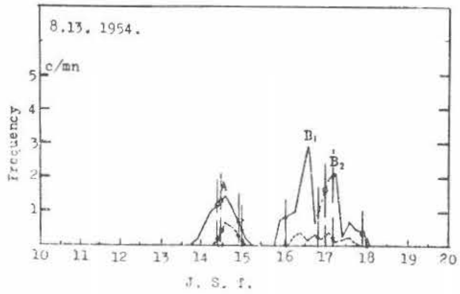


FIG. 6. Frequency variation curve of the thunderstorm discharge number per unit time by the static field meter

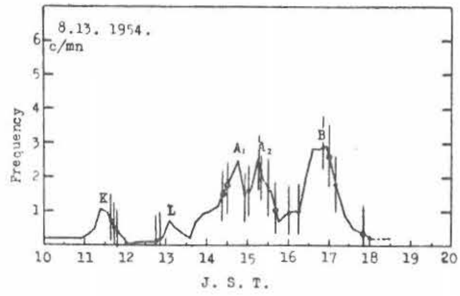


FIG. 7. Frequency variation curve of the thunderstorm discharge number per unit time by the mean intensity meter

The effects in *k* group are not seen in Fig. 6, but are represented by a small distinct peak K in the records of 28 Kc and 100 Kc (See Figs. 7 and 8). However, in the records of 8.15 Mc, only some variation of which is barely recognizable is found. These facts show that the variation of static field is attenuated below 1 v/m when thunderstorm area is over 30 Km from the observation point and only the electromagnetic variation accompanied by the thunder-discharge remains the component of the radiation field. The difference in the frequency curve between 100 Kc and 8.15 Mc may be considered to depend only upon the difference of attenuation by the propagation, because both instruments have the same gain and triggering level. In Figs. 7 and 8, each frequency curve formed by the *k* group begins to rise about an hour earlier than the occurring time of K peak. This tendency is often but not always seen in the frequency curve and is one of the convenient me-

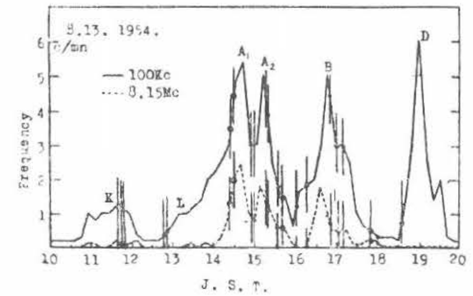


FIG. 8. Frequency variation curve of the thunderstorm discharge number per unit time by the lightning counter

asures for forecasting thunderstorms.

(B) *l* group

This also seems to be a solitary group because the storms occur about fifty-five minutes after the occurrence in *k* group and ninty-five minutes before the following *a* group, lasting for only a short time, about thirty minutes. In *l* group, the relation between the appearance time of peak L in the frequency curve and the occurrence time of thunder is contrary to the occurrence in *k* group. That is, the frequency of the discharge number per unit time increases after the report of thunder. On this occasion it seems that the thunder activity began abruptly at high intensity and then discharged gradually changing to small intensity.

(C) *b* group

It is convenient to divids this group into two smaller ones, i. e. 'a_1' and 'a_2', the former consisting of two suspension thunderstoms which occurred within about 25 Km north of the observation point. As the thunder area is near the observation station, a remarkable change is seen in all records. The time indicated the maximum frequency of discharge number occurs simultaneously in all observed bands within statistical error. The relation between the time appearing at peak 'A_1' and reported time of the thunder is the same as the *l* group thunder. Peak 'A_2' shown in Figs. 7 and 8 seem to be the same as indicated by 'a_2' sub-group thunder over 30 Km away from the observation station. Because 'A_2' peak does not appear in the record of staticfield meter it is shown in Fig. 6. In this case, the maximum frequency of discharge number occurs simultaneously on all observed frequency bands. But the reason why the appearance time of maximum frequency of discharge number is not the same as that of thunderstorm report seems to be differences in the objects observed and observing methods, i. e. the former records the thunderstorm electrically and the latter aurally and visually.

(D) *b* group

The peak of the frequency curve by thunderstorms was also shown in the same way like other groups. In this group, the thunder area is distributed at various distances between 10 Km and 100 Km. Then the difference in the aspect of the frequency curve depends mainly upon the difference in the distances. Because the static field meter indicates only the effect of thunder within 20 Km, but on the other hand, the counter indicates the effect of all thunder included in *b* group.

Based on Fig. 8, we outline the difference of the frequency component of atmospherics. Table. 1 is a comparison of the distance from the thunder area with the mean height of the peak in the frequency curve. The mean height of each peak shown in the data of 8.15 Mc is taken to a unity.

From this table, it would seem that the ratio value of the mean height has a tendency to increase with the distance from the observation point. It may be said that the frequency component of 8.15 Mc is more quickly attenuated than that of 100 Kc in proportion to the di-

TABLE. 1.

Group	Distance from Thunder area (Km)	The mean height of peaks in the discharge frequency per unit tim	
		100 Kc	8. 15 Mc
a_1	7 - 23	3.5	1
k	29 - 60	7.8	1
l	36 - 50	27	1

stance increase.

Some conclusions may be deribed from the above as to the relation between the frequency of discharge number per unit time and the occurrence of thunder.

4. Conclusions

(i) When a thunder area exists within 20 Km of observation point, the frequency of the discharge number per unit time increases sharply and peaks are formed simultaneously in the frequency curves of 28 Kc, 100 Kc and 8.15 Mc under some limitation of the receiving distance

(ii) When a thunder area exists between 30 Km and 60 Km, peaks in the frequency curves are also formed in all observed frequency bands but lower than peaks in the 20 Km distance

(iii) When a thunder area exists over 60 Km, peaks are found only in the frequency curves of 28 Kc and 100 Kc but these are very low and do not appear in the records of 8.15 Mc

(iv) Generally speaking, the height of peaks shown in frequency curves of the discharge number per unit time decreases in propotion to the distance between the observation point and the thunder area

(v) It is possible to set some desired limit to the receiving distance when both the gain of the receiver and the triggering level for pulse are selected properly

(vi) It seems that the shape of the peak in the frequency curve is related to the time variation of electrical energy in the thunder-cell. The height of the peak in the frequency curve of the discharge number per unit time may be considered a rough estimations of thunderstorm activity

(vii) The nondirective tuned type lightning counter having the proper gain and triggering level for the output pulse, can indicate some thunderstorm activity within 100 Km from the observation point and therefore it would be possible to forecast thunderstorms at the period when the discharge number per unit time starts to increase sharply.

III. Instantaneous direction divided type lightning counter

By the results obtained in the preliminary observation, we recognize that the direction divided type lightning counter would be a more useful apparatus for forecasting thunderstorms, making thunderstorm distribution charts and locating local sources of atmospherics. This apparatus instantaneously count the number of discharges caused by lightning on the azimuth divided in four or more. Then the apparatus combining the pulse counter and the uni-directional C. R. D. F. was designed. A block diagram of this apparatus is show in Fig. 9.

The output signal of each amplifier adds to the Recording C. R. T which is newly designed. The Recording C. R. T. shown in Photo. 1 consists of an electric gun, a twin deflection plate and a collector plate divided on the azimuth into eight sections. The output of the collector plate is connected to the counter parts and the output of the counter parts operates the automatic recording instrument.

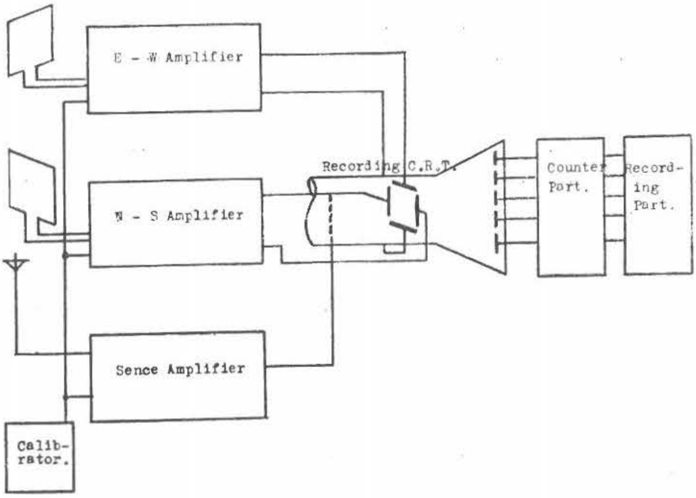


FIG. 9. Block diagram of the instantaneous direction divided lightning counter

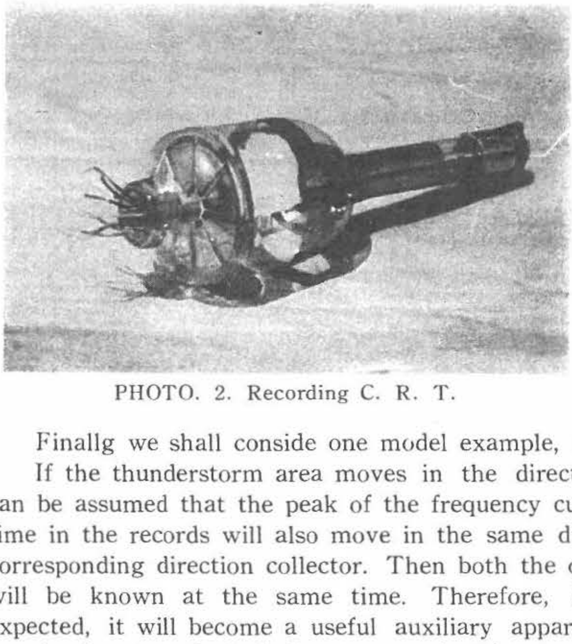


PHOTO. 2. Recording C. R. T.

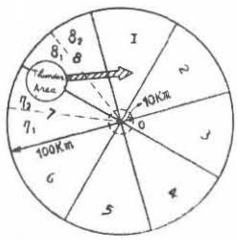


FIG. 10. One model thunderstorm example to explain the action of the direction divided type counter

Finallg we shall conside one model example, shown in Fig. 10.

If the thunderstorm area moves in the direction indicated by the arrowhead, it can be assumed that the peak of the frequency curve of the discharge number per unit time in the records will also move in the same direction, i. e. toward the output of corresponding direction collector. Then both the occurrence and the traveling direction will be known at the same time. Therefore, if this apparatus operates as can be expected, it will become a useful auxiliary apparatus for forcasting thunderstorms in any local meteorological observatory. A trial production of this distinctive apparatus has been made and after any necessary adjustments, it will be used in preliminary observations planned for the summer of 1955.

IV. Acknowledgement

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