SOME RESULTS OF THE WAVE FORM OF ATMOSPHERICS

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Summary—The observations of atmospherics were made in September 1952 and in September 1953. The wave forms were recorded and the fixing of sources was conducted by triangulation at Toyokawa, Akita and Kumamoto. Waveforms of the regular peaked type at night were analysed on the reflection theory, and the reflection height of the ionosphere and the distance of the source were calculated.

Several waveforms from the same sources received at Toyokawa and Akita were discussed. Some examples were shown, indicating that the quasi-period of the second half cycle of the oscillatory component increases with distance, and its rough explanation was given.

1. Introduction

In our Institute, observations of direction finding of atmospherics at three stations were carried out a few years ago, but each distance of base line was so nearer that the triangulation of original sources was too difficult to locate the sources of atmospheries. Last year we provided the other stations that are around six hundred kilometres apart, so we might expect more accurate results than ever. The observations of direction finding at three stations, Toyokawa (137°22′ E, 34°50′ N), Kumamoto (130°46′ E, 32°56′ N) and Akita (140°08′ E, 39°44′ N) as well as of wave form at two stations were carried out in Sep. 1952, Feb. 1953, and Sep. 1953. The present paper represents the results of the two kinds of typical wave forms concerning the regular smooth day time type and the regular peaked type, but it is not possible to deduce some final results because of few observational records.

2. Wave Form Observed at Night

The observations at night were made in September 1952 and in September 1953. Several hundreds of wave forms were recorded. But, only a very small proportion of these total wave forms were suitable for analysis on the reflection theory. Then, the distance deduced by wave form analysis was compared with the corresponding distance of the source determined by direction finding method. But, the number of wave forms available in the following discussion was reduced to fourteen cases, and this is due to the following reasons, *i.e.*, the accurate fixing of source is hardly obtained by the present direction finding techniques liable to the bearing error caused by the polarization in the atmospherics at night, and moreover the good fixing of source does not correspond to the accurate wave form frequently.

For evaluating h the reflection height of the ionosphere and d the distance of the source, a reference pulse is selected on the wave forms and the time intervals between this and the successive pulses of the same sign are usually measured. But in our case, the ground pulse and the first sky pulse are selected on the wave forms in the following manner.

(α type) This type occurs in the case that the ground pulse is less attenuated, and follows the successive sky pulses $s_1, s_2, \ldots$ on the wave forms. And the first sky pulse s_1 appears to correspond to the first pulse of the opposite sign to the ground pulse.

(β type) This type occurs in the case that the ground pulse is much attenuated and disappears on the wave forms. Then, the first excursion from the base line appears to correspond to the first sky pulse s_1.

For evaluting the reflection height of the ionosphere and the distance of the source, wave forms were examined by graphical method (this graphical method has been given by Dr. Caton and Dr. Pierce (1935)).

The wave form analysis yields the value for d_W the distance of the source, and its comparison with the value of d_D the distance determineded by direction finding method is shown in Table 1.

TABLE 1

Atmospheric	Time and date	d_D ($\times 10^3$ km)	d_W ($\times 10^3$ km)	$\frac{d_D - d_W}{d_D}$ (%)	Type of selection of the order of reflected pulses	h (km)
N- 1	Sep. 5, 1953. 21 hr.	1.6	1.50	3	α	90
N- 2	Sep. 7, 1953. 0 hr.	2.2	2.12	4	α	85
N- 3	Sep. 15, 1952. 20 hr.	1.0	0.92	5	β	85
N- 4	Sep. 17, 1952. 20 hr.	3.0	3.15	− 5	β	90
N- 5	Sep. 6, 1953. 0 hr.	2.9	3.05	− 5	α	90
N- 6	Sep. 9, 1953. 0 hr.	2.4	2.65	−10	β	90
N- 7	Sep. 6, 1953. 0 hr.	*ca.* 0.4	0.47	−18	α	80
N- 8	Sep. 22, 1952. 2 hr.	1.3	1.03±0.13	20	β	90
N- 9	Sep. 5, 1953. 21 hr.	3.0	2.40	20	β	90
N-10	Sep. 5, 1953. 21 hr.	3.2	2.47	22	β	90
N-11	Sep. 15, 1952. 20 hr.	1.1	0.84	22	α	90
N-12	Sep. 22, 1952. 2 hr.	2.0	1.42±0.10	27	β	90
N-13	Sep. 9, 1953. 0 hr.	0.9	1.22	−36	α	90
N-14	Sep. 10, 1953. 21 hr.		2.40±0.10		β	90

In general, there is a reasonably good agreement between the d_W's and d_D's, as seen in Table 1, though we should not overestimate the accuracy. While, of the $\frac{d_D - d_W}{d_D}$'s, several cases indicate the unreasonable values and these data might require further investigations. But, it might be thought that these cases would correspond to the results of the distortion caused by the reflection in the ionosphere, mainly due to the relative phase change of the component wave. Finally the d_W's were plotted against the d_D's in Fig. 1. And for the reflection height h, most of the cases indicated the value of 90 km.

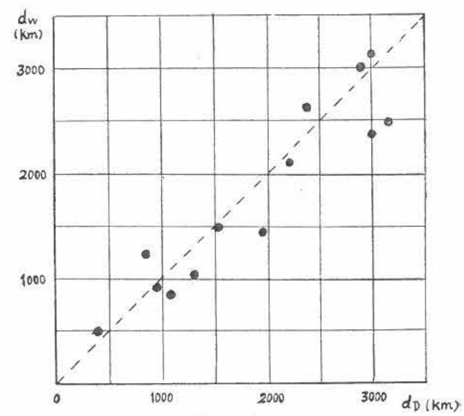

FIG. 1

3. Wave Form Observed in the Daytime

It is clearly of interest to compare the typical wave form results obtained in the daytime with the results from triangulation. We deduced the frequency of the second quasi-half cycle from each wave form, and in Fig. 2 the ordinary is drawn by this frequency and abscissa by the distance of original source obtained from triangulation.

We might be able to deduce that the frequency would increase with distance.

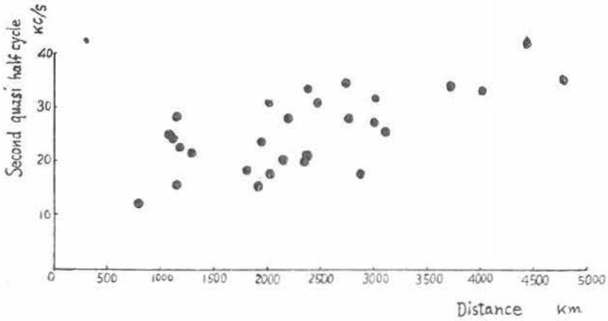

FIG. 2

Because of the character of our wave form measuring apparatus, the first half cycle cannot be fully photographed; so we measured the second half cycle. In other words the wave form appears to be concentrated to the origin of the figure as distance increases. This can be roughly explained by the fact, recently reported by Bowe, that the low frequency component of the wave form originated from distant source decreases with distance.

Further we investigated the two wave forms of the same origin received simultaneously at two different stations. The photographed wave forms are shown in Fig. 3, and from these we can deduce the following conclusions, as would be expected.

(I) The atmospherics radiated from the same origin have rather similiar wave forms, and the intrinsic character of the wave form radiated from a discharge is reserved after a long travelling.

(II) The wave form varies with distance travelled.

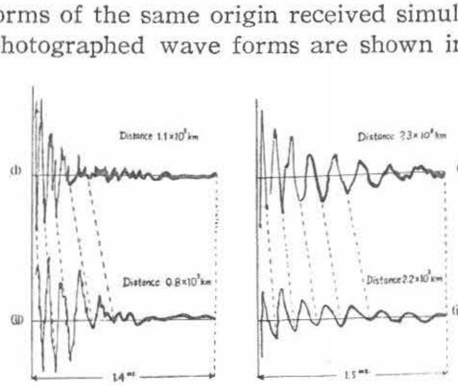

FIG. 3. Observed wave forms (i) at Akita (ii) at Toyokawa.

Further close examination was made to investigate the latter conclusion. The intervals between adjacent corresponding parts of these figures near the origin are rather shortened than that far from the origin.

In order to clarify the relation, it is convenient to consider the intervals in relation to the distance travelled d. Let us introduce s to represent the interval between two corresponding parts.

Subscript 1 denotes the result obtained at one station, and subscript 2 refers to another station.

It might be thought that there might be a rough linear relation between $\frac{d_1}{d_2}$ and $\frac{s_2}{s_1}$ as shown in Table 2.

The agreement s_2/s_1 computed from the recorded wave form and the inverse ratio of distance travelled shows that there is some relation between the distance and the frequency of wave form in the range of frequencies here considered.

TABLE 2

Atmospheric	Results from triangulation			Results from wave form analysis		
	Distance from Akita d_1 ($\times 10^3$ km)	Distance from Toyokawa d_2 ($\times 10^3$ km)	Ratio of two distances $\frac{d_1}{d_2}$	Interval between two corresponding parts near origin: Akita s_1	Toyokawa s_2	Inverse ratio of two intervals $\frac{s_1}{s_2}$
D-1	2.4	2.0	1.2	7.0	8.5	1.2
D-2	2.3	2.2	1.1	8.5	9.5	1.1
D-3	1.5	1.2	1.3	5.0	6.2	1.2
D-4	1.1	0.8	1.4	4.0	5.5	1.4
D-5	1.1	0.8	1.5	4.1	6.0	1.5
D-6	1.1	0.9	1.3	4.1	7.9	1.9
D-7	5.4	4.9	1.1	5.7	8.0	1.4
D-8	very distant	very distant	*ca.* 1	7.9	7.9	1.0

It is possible to apply the results shown in Table 1 to the Budden's 'wave guide' theory of very low frequency propagation, so as to derive the above relation. If it is assumed that the atmospheric travels in a 'wave guide' formed between a perfectly conducting earth and a perfectly conducting sharply bounded ionosphere, the received e.m.f. in one mode of nth order is approximately proportional to

$$\cos\frac{\pi nX}{h}+\frac{\pi nX}{h}\sin\frac{\pi nX}{h}$$

$$X=\sqrt{c^2t^2-\rho^2}$$

where,

h: the height of ionosphere

c: light velocity

ρ: distance of source

t: time

Now, if the oscillatory wave form computed from the received e.m.f. due to the mode of nth order intersects with time axis at $t_1, t_2, \ldots, t_m, \ldots$, and we put $\frac{\pi nX}{h}=x$, then solving $\cos x+x\sin x=0$, $x_1, x_2, \ldots$ may be obtained as solutions.

Hence,

$$\frac{\pi n}{h}\sqrt{c^2t_m{}^2-\rho^2}=x_m$$

$$t_m=\frac{1}{c}\sqrt{\rho^2+\frac{h^2x_m^2}{n^2\pi^2}}\fallingdotseq\frac{\rho}{c}\left(1+\frac{1}{2}\,\frac{h^2x_m^2}{\rho^2n^2\pi^2}\right)$$

Then the intervals between two adjacent intersections Δt_m may be written as

$$\Delta t_m=t_m-t_{m-1}=\frac{h^2}{2\,cn^2\pi^2}\,\frac{1}{\rho}(x_m^2-x_{m-1}^2)\propto\frac{1}{\rho}$$

From above expression we have thus shown that the intervals between two adjacent intersections are inversely proportional to the distance travelled.

But it must be remembered, however, that real daytime propagation is different from the above condition, because of, mainly, the perfect conducting ionosphere.

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