SEA EFFECT DUE TO THE HIGH ALTITUDE NUCLEAR EXPLOSION

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Abstract

Sudden abnormal changes of VLF atmospherics intensities, caused by the very high altitude nuclear explosion over Johnston Island on July 9th 1962, were observed at Toyokawa, Japan. The aspect of this anomalies on records was just the same as SEA caused by solar flares. On the occasion, as the sun was quiet and the onset of the anomalies coincided with the explosion, it seems to me that the anomalies were caused by bomb-induced ionization in the ionospheric D layer. So, it was named "the SEA effect due to nuclear explosion".

In this paper are reported the observation results and a comment on the order of disturbances in the ionospheric D layer.

1. Introduction

The nuclear explosion at altitudes of several tens of kilometers over Johnston Island in the summer of 1958 was observed to produce ionospheric effects at considerable ranges from the burst points. Sudden increase of atmospherics has been observed at Toyokawa and Hiraiso, Japan and discussed by Kimpara[1] and Obayashi.[2]

On July 9th, 1962, sudden abnormal changes of intensities of atmospherics in the VLF range, caused by the very high altitude nuclear explosion over Johnston Island, were observed again at Toyokawa, Japan. However, on this occasion, the sun was quiet and the onset of the anomalies was just the same as SEA caused by solar flares of greater than importance 2. It might be considered that this anomaly was caused by bomb-induced ionization in the ionospheric D layer and this ionization in ionospheric region, shadowed from a high altitude nuclear explosion by earth, was caused by beta particles resulting from the decay of explosion-produced neutrons which was suggested by C. M. Crain and P. Tamarkin.[3]

Here is deduced the order of disturbances in the ionospheric D layer, the observation results and the mode theory on VLF propagation being used.

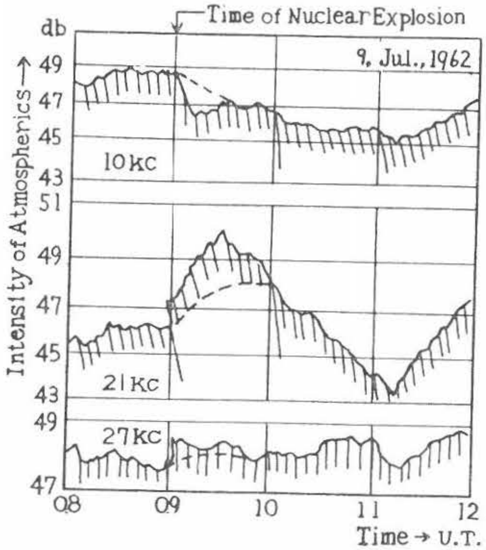

Fig. 1. SEA effect associated with the High Altitude Nuclear Explosion on 9th, Jul., 1962.

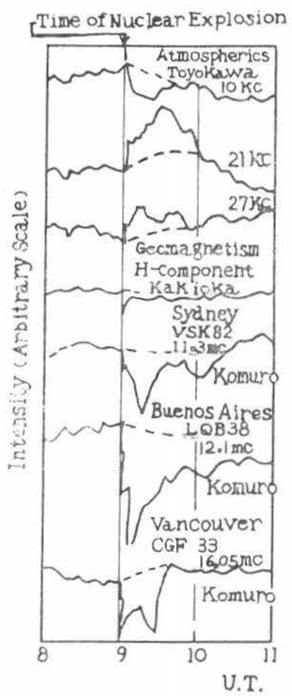

Fig. 2. SID effect associated with the High Altitude Nuclear Explosion on 9th, Jul., 1962.

2. Observations

Fig. 1 shows the SEA effects appearing on the records of the intensities of atmospherics which is associated with the high altitude nuclear explosion on July 9th, 1962 over Johnston Island.

The aspect of this records is just the same as SEA of Mode IV caused by solar flares which has the intensity over the importance 2. The SEA of Mode IV, which has the sudden increase on the component of 21, 27 kc/s and the sudden decrease on 10 kc/s, is statistically classified by the author.

The Kakioka Geomagnetic Observatory in Japan has reported a hook on the horizontal component of the magnetic field of the earth following the explosion. The Komuro Communication Receiving Station in Japan has also reported the short wave fade-out (SWF) on the frequency ranges between 10 to 20 mc/s following the explosion. These results are shown in Fig. 2. Further, f_{min} was blackout in ionogram at the Akita, Kokubunji and Yamakawa Ionosphric Observatories following the explosion.

Those observation results indicate that the onset of the phenomena observed at the time of the explosion coincided with the explosion and the aspects of all the phenomena were just the same as SID caused by solar flares. Hence, it is clear that such geophysical disturbances were directly related to the nuclear explosion.

3. Ionization mechanism

To consider the ionization mechanism in ionospheric regions, for example, about 5000 km from burst-point, shadowed from a high altitude nuclear

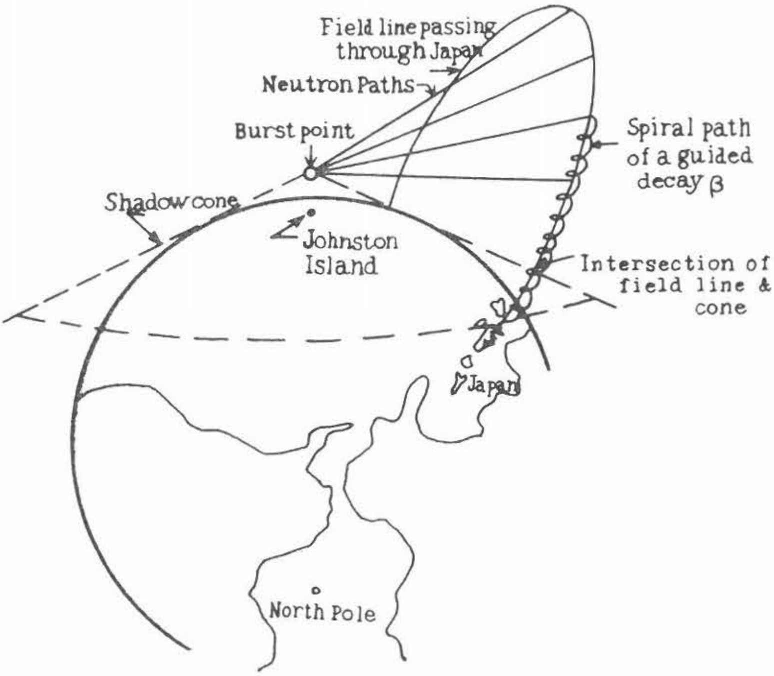

Fig. 3. Model for ionization resulting from Neutron decay.

explosion by earth, it is useful to review how energy is released from the high altitude nuclear explosion.

First, I considered that X-rays produced from the nuclear bursts can produce penetrating electrons by Compton scattering and by photoelectric emission. However, those processes for production of electrons are very small, because the atmospheric density is too low to support a sufficient number of collisions. Then, I agree to the Crain and Tamarkin's mechanism(3) by neutron decay model. This mechanism is outlined in the followings. That is, Fig. 3 indicates how ionization is produced, for example, over Japan, by neutrons originating from the Johnston Island bursts. The bomb-produced neutrons, emitted nearly isotropically and with a rather wide velocity spectrum from the point of detonation, flood through the earth's magnetic field. As they propagate out they decay exponentially in time and produce β particles which are emitted isotropically. β particles so produced, spiral around and along the magnetic field lines passing through the region where they are produced (Spitzer, 1956).(4) Hence the geomagnetic field lines guide these β particles toward the earth. Depending on the point and angle of injection of given β particles, they will immediately travel sufficiently deep into the atmosphere to lose their energy by ionizing collisions. Thus, any given ionospheric region is ionized by β particles that have come down field lines from regions of space along these field lines where β particles were produced by neutron decay (Crain and Tamarkin, 1961).(3)

4. Ionospheric D layer's disturbances deduced from the SEA effects

To discuss to what degree the ionospheric D layer is disturbed by nuclear explosion, it is useful to adopt the wave guide mode theory in VLF propagation. Then, first, the wave guide mode theory by Wait[5] is described briefly.

Assuming that the source is a vertical electric dipole radiating P kilowatts, the vertical electric field in millivolts per meter at a great circle distance, d, in km from transmitter is given by the mode sum

$$E = E_0 W \quad \cdots\cdots\cdots\cdots \quad (1)$$

where

$$W \cong \left[\frac{d/a}{\sin d/a}\right]^{1/2} \cdot (d/\lambda)^{1/2}/(h/\lambda) \cdot \left|\sum_{n=0}^{\infty} \delta_n S_n^{3/2} e^{-i2\pi S_n (d/\lambda)}\right|$$

$$E_0 = 300\sqrt{P}/d$$

$$S_n = (1 - C_n^2)^{1/2}$$

C_n is a solution of

$$\frac{(L-i)C_n - \sqrt{C_n^2 L^2 - iL}}{(L-i)C_n + \sqrt{C_n^2 L^2 - iL}} = e^{4\pi i H C_n} \cdot e^{-2\pi i n} \quad \cdots\cdots\cdots \quad (2)$$

where the earth is assumed the perfect conductor, and

$$L = \omega/\omega_r, \qquad H = h/\lambda, \qquad n = 0, 1, 2, \cdots\cdots$$

$$\delta_n = \left[1 + \frac{\sin 4\pi H C_n}{4\pi H C_n}\right]^{-1} \sim \begin{cases} 1 \cdots\cdots & n = 1, 2, 3, \cdots\cdots \\ 1/2 \cdots\cdots & n = 0 \end{cases}$$

a = radius of earth in km
λ = wavelength in km
ω = angular frequency in radians per second
ω_r = (plasma frequency)^2 / collisional frequency = $(2\pi f_0)^2/\nu$
f_0 = plasma frequency
N = electron density
ν = collisional frequency
h = separation in km between ionospheric reflecting layer and ground

The complex values of C_n satisfying (2) have been obtained from an automatic computer using a program devised by Howe.[6] Here these results are used.

To simplify the problem, it is assumed that both the distance to the source of atmospherics and its intensity are constant before or after the nuclear explosion. Then

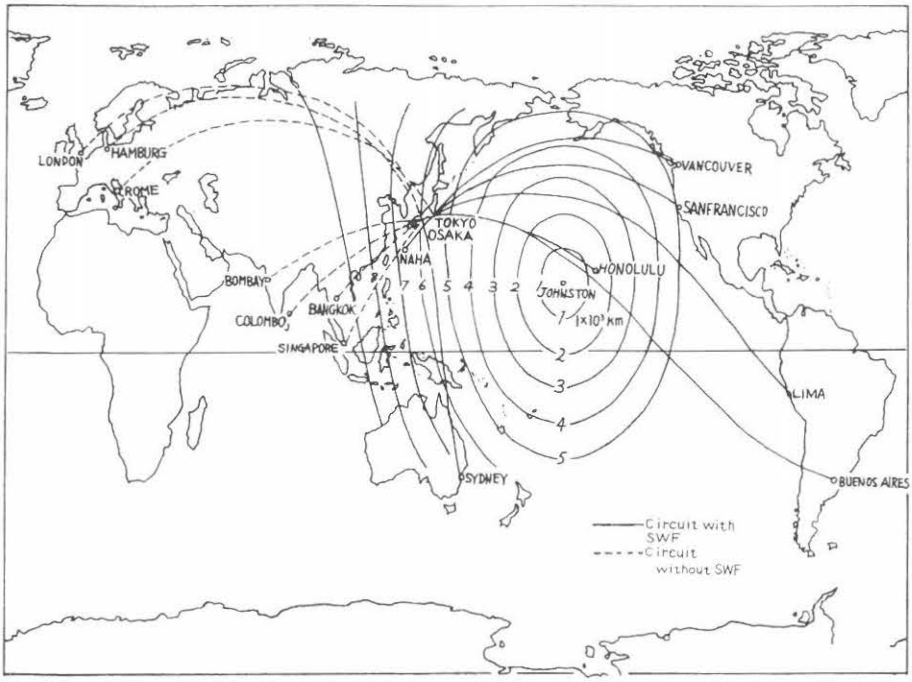

Fig. 4. SWF on the international short wave circuits at 0900 U.T. on 9th, Jul., 1962.

E_0 in (1) becomes constant.

Denoting that E_1 is the receiving intensity of atmospherics before the nuclear explosion and E_2 is that of after, then, from (1)

$$E_1 = E_0 W_1$$

$$E_2 = E_0 W_2$$

It can be written as follows

$$E_2 / E_1 = W_2 / W_1$$

where E_2/E_1 is obtained from the observing data, but for W_1, it is necessary to know the distance, d, to the source of atmospherics, the receiving frequency, the height, h, of the ionosphere, the electron density, N, in the height of h and the collisional frequency, ν, in the height of h.

(1) Receiving frequency —— It is 10, 21 and 27 kc/s respectively.

(2) The distance to the sources —— On that day, the records of the intensity of atmospherics were not disturbed by the local sources within about 1000 km and so they were almost controled by the seasonal sources, which are distributed between about 2000 km and about 6000 km, at tropical zone such as the Philipines and Borneo. And what is more, it is deduced by the data of the SWF, which is shown in Fig. 4, in the national communication circuits that the regions of the disturbances in the

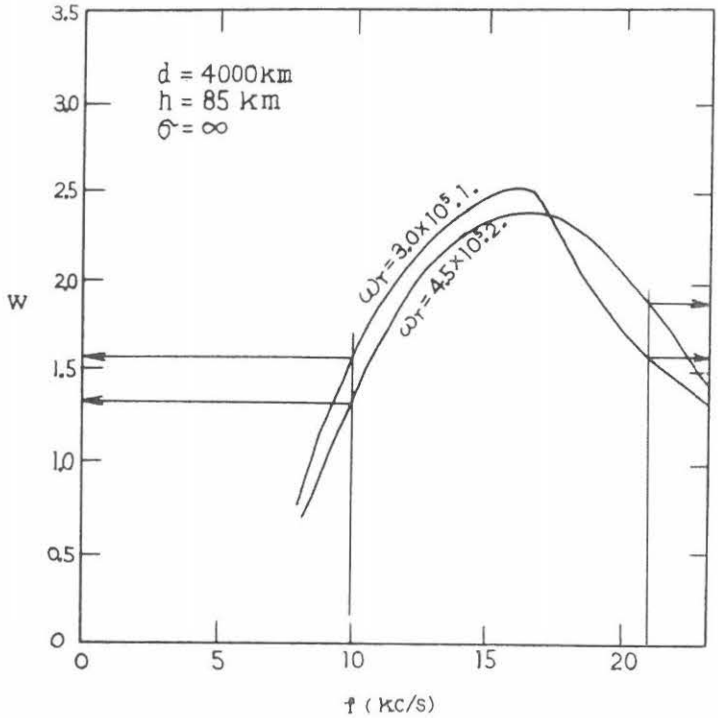

Fig. 5. Spectrum function for d=4000 km, h=85 km, $\sigma=\infty$.

ionosphere suffered by the nuclear explosion are about within 5000 km from the burst-point. Then the mean distance to the sources of atmospherics is assumed to be about 4000 km.

(3) The height of the ionosphere —— 85 km is assumed for the VLF waves.

(4) The electron density at 85 km near sunset —— It is adopted $N=2-3\times10^2$ cm^{-3} from the results of Nicolet (1953).[(7)]

(5) The collisional frequency at 85 km near sunset[(8)] is adopted 1.4×10^6 sec^{-1}.

Then the spectrum function, W_1, for d=4000 km, h=85 km and $\omega_r=3\times10^5$ are indicated on the curve in Fig. 5.

Assuming that the electron density in the ionospheric D layer is increased by the bomb-produced neutrons and the value of the variation on 10 kc/s takes standard, as E_2/E_1 is 0.8 from the data, then W_2 is 0.8 W_1.

From among the calculated spectrum function curves for d = 4000 km, h = 85 km and various values of ω_r, the curve which goes across the 0.8 W_1 point on 10 kc/s component can be found out. Its curve is shown in Fig. 5 (2). It is shown that such an aspect explains satisfactorily the observed data. Then the increase of the electron density in the ionospheric D layer by the bomb-produced neutrons is the order of one and half times as much as before the nuclear explosion.

5. Conclusion

In this paper, the SEA effect on the intensity of atmospherics associated with the high altitude nuclear explosion is reported. The aspect of the records is just the same as SEA caused by the solar flares.

The SEA effect was caused by the bomb-induced ionization in the ionospheric D layer. The ionization in ionospheric region shadowed from the high altitude nuclear explosion by earth is one caused by the decayed particles guided by the earth's magnetic field.

The order of the increase of the electron density in the ionospheric D layer may be deduced by using the data of the SEA effect in VLF atmospherics and the wave guide mode theory in VLF propagation.

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