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An Experimental Approach to the Electromagnetic Phenomena Associated with Earthquakes

Qinghua Huang and Motoji Ikeya

Department of Earth and Space Sciences, Graduate School of Science, Osaka University, Osaka 560, Japan

Abstract

An experiment using electromagnetic (EM) waves and a model of Greek archipelago is simulated to approach the nature of EM phenomena associated with earthquakes. EM waves with various frequencies were supposed to be propagated between the conductive ionosphere and the Moho plane, which simulated by two aluminum plates. The experimental result indicated that only the EM waves at a certain range of frequencies, e. g., 735-2927 Hz, could show some rippled property of propagation and could propagate over a long distance of hundreds of kilometers from the epicenter.

1. Introduction

The earthquake prediction method by detecting the geoelectric potential changes in Greece is known as the VAN method[1-2]. The observed changes of the geoelectric potential gradient with the amplitude of 10^{-5} V/m are regarded as earthquake precursors and called as seismic electric signals (SES)[2].

There are three types of precursory signals; namely single SES, electrical or SES activity and gradual variation of electric field (GVEF)[2]. Some physical properties of SES can be summarized as following: lead time, empirical relation of SES amplitude and earthquake magnitude, SES polarity and the ratio of SES components and selectivity of SES.

The successful prediction of earthquakes claimed by the VAN group in Greece seems to encourage some optimistic scientists involve in the study of earthquake prediction. However, the unclear physical nature of the generation and propagation of SES led it into a controversial topic recently[2]. Some seismologists, who believe that earthquake prediction would be impossible in principle, don't believe the success of earthquake prediction as claimed by the VAN group[3].

The empirical relation of the SES amplitude and earthquake magnitude was used to predict the earthquake intensity. Such empirical relation was explained using the theory of electromagnetic (EM) waves[4].

The selectivity of SES was used to predict the epicenter of earthquakes. However, the existence of the selectivity of SES and the propagation of SES over a long distance of hundreds of kilometers from epicenter are doubted by those who criticize the VAN method. No consensus theory is given to explain such properties of SES till now. The present paper does not intent to make a claim of earthquake prediction using the VAN method. Instead, an experimental approach of explaining above characteristics of SES was undertaken, i. e., the properties of SES propagation and selectivity are examined based on a simulation experiment using EM waves and a model of Greek archipelago.

2. Experimental method

The Earth's crust (e. g., thickness of 3×10^4 m) was simulated using a granite slab with the thickness of 0.022 m. An aluminum plate simulated the Moho plane was placed against the lower surface of the granite slab as shown in Fig. 1. Another aluminum plate simulated the lower ionosphere (e. g., height of 6×10^4 m) at 0.044 m above the upper surface of the granite slab. The Greek archipelago was modeled in a scale of 1:1,360,000 and the conductive sea surface was covered with aluminum foil.

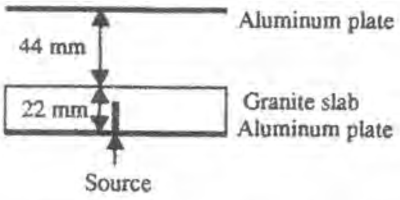


Figure 1. An experimental model

EM waves at different frequencies generated by a microwave generator were emitted from a loop antenna placed in a hole in the center of the granite slab, which simulated the hypocenter. Another loop antenna placed near the surface of the granite slab was used to detect the EM waves. The detector antenna was controlled by a *X-Y* plotter with a sweep range of 0.40 m × 0.28 m and a scan step of 0.01 m and connected with a spectrum analyzer. EM waves at a broad range of frequencies from 10^8 Hz to 10^{10} Hz with a 0.2 increase step of the power index are used, as well as the source power of 15 dBm (0.0316 W).

Considering the relation between the frequency, f and the wavelength, λ, i. e., $f = v/\lambda$, using the propagation speed of EM waves in the medium, v, the scale of the frequency used in this experiment would be 1,360,000:1. Therefore, the EM waves used here would correspond to the frequencies from 73.5 Hz to 7350 Hz.

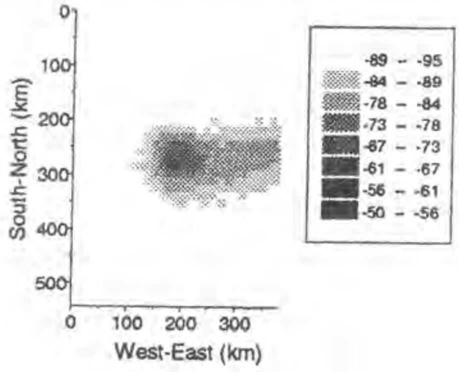
The microwave generator, *X-Y* plotter and spectrum analyzer are controlled by a personal computer.

3. Experimental result

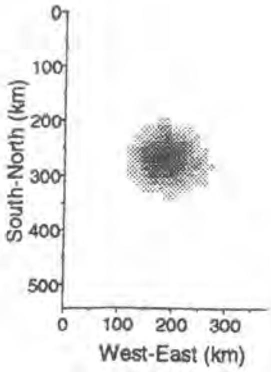
The power distributions of EM waves in the simulating experiment at various frequencies are shown in Fig. 2. The result indicated that the EM waves at extremely low frequency lower than 464 Hz would decay exponentially as a kind of evanescent waves as shown in Fig. 2 (a) – (d). Note that different power scales are used in Fig. 2. An increase tendency of EM waves intensity was found with the increase of frequency.

EM waves also showed some decayed property at the frequency higher than 4639 Hz and an accelerated tendency of evanescence with the increase of frequency. We can conclude, unambiguously, that no EM waves can propagate at the frequency higher than 7353 Hz, based on our experimental result (Fig. 2 (k)).

In a certain range of frequencies, e. g., 735 – 2927 Hz, the EM waves can propagate in some rippled-shape over a long distance of hundreds of kilometers as shown in Fig. 2 (f) – (i).



(a) $10^{8.0}$ Hz (73.5 Hz)



(b) $10^{8.2}$ Hz (116 Hz)

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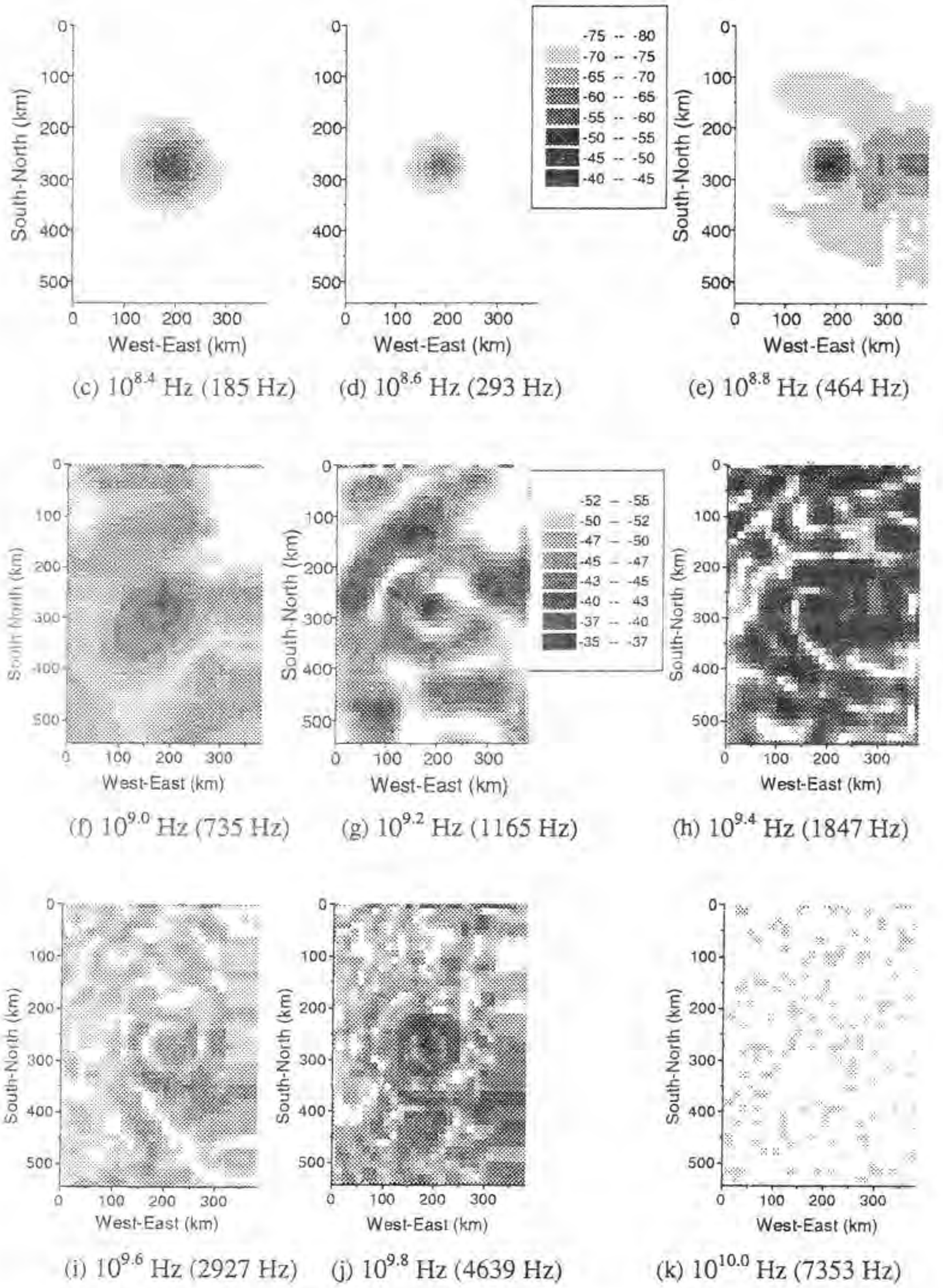

Figure 2. Experimental result of the detected power (unit: dBm) of electromagnetic waves at different frequencies. Scales in (b), (c) and (k) are the same as that in (a); (e), (f), (i) and (j) are the same as (d); (h) is the same as (g).

The EM waves at the frequencies of 464 Hz and 4639 Hz showed some kinds of complicated characteristics, i. e., both propagation tendency and decay tendency to some extent as shown in Fig. 2 (e) and (j).

4. Discussion

EM waves may propagate in a certain mode if they are constricted within two parallel conductive planes, according to the theory of propagation of EM waves. The cut-off frequency, f_m of a given mode, m, e. g., $m = 1$, can be determined using the distance of two parallel planes, d from the relation $f_m = mv/2d$, where v is the propagation speed of EM waves within the two parallel planes[5]. The EM waves with the frequency lower than the cut-off frequency, f_m would be cut off (evanescent) rather than propagate over a long distance.

Considering the propagation of EM waves between the lower ionosphere layer and the Moho plane, a tentative estimation of the cut-off frequency of the EM waves leads to $f_m = v/2d = (\varepsilon/\varepsilon_0)^{-1/2}c/2d = 589$ Hz, using the propagation speed of EM waves, $c = 3\times10^8$ m/s, the distance between the ionosphere and the Moho plane, $d = 9\times10^4$ m and the dielectric constant of earth, $\varepsilon = 8\ \varepsilon_0$, where ε_0 is the dielectric constant in vacuum.

The natural propagation of EM waves between the ionosphere and the Moho plane would be complicated, considering the different media inside. The simulation result does not confirm the cut-off frequency is the same as the present estimation value, i. e., f_m = 589 Hz. However, we are sure that the EM waves can be propagated in a certain range of frequency, e. g., 735-2927 Hz.

At some certain frequency, e. g., 464 Hz and 4639 Hz, complicated properties of propagation were found. Such frequency seems to be located in a transitional range with different characteristics of propagation. Hence, the EM waves at such frequency may elicit some EM phenomena to a region with a certain distance from the epicenter.

This simulation experiment also seems to support the existence of the selectivity effect of SES. At the two SES observatories (IOA and VOL), which recorded SES and predicted an earthquake successfully by the VAN group, the detected signals are at least one order intensive than another two observatories (ASS and KER), which did not record any SES. The detailed discussion of the selectivity of SES and the estimation of SES amplitude based on our simulation experiment will be undertaken elsewhere.

5. Summary

An experimental approach to the electromagnetic (EM) phenomena associated with earthquakes was simulated using EM waves and a scaling model of Greek archipelago. The experimental result indicated that the EM waves both at the frequency lower than 464 Hz and at the frequency higher than 4639 Hz would evanesce quickly and hence both could not be propagated over a long distance. However, the EM waves at a certain range of frequencies, e. g., 735-2927 Hz, showed some rippled property of propagation and could be propagated over a long distance of hundreds of kilometers from the epicenter. The selectivity of SES was also discussed.

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