EARTH-ORIGIN ELECTRIC NOISES AND ELECTRICAL PARAMETERS OF THE EARTH CRUST

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ABSTRACT

Inserting an electric field sensor into an electrically non-conductive bore-hole measuring 100 m in length, we had detected earth-origin electric pulses. In order to clarify the relation between the wave electric behavior in the earth and the electrical parameters of the earth crust, we measured the specific dielectric coefficient and conductivity of the earth crust. An increasing trend of the measured specific dielectric coefficient in accordance with depth has the same trend as that of intensity of the background electric noise in the earth crust.

INTRODUCTION

In order to elucidate the property of electromagnetic (EM) waves in the earth, we developed a new system [1] for measuring EM waves in the earth, which can distinguish noises in the earth from those above the ground. The new system consists of a specific deep bore-hole (10 cm in diameter and 100 m in depth) made of electrically non-conducting materials, co-axial linear dipole field sensors, and a frequency-analyzing equipment whose CRT can display frequency dynamic spectra of the detected EM noises on real-time basis. Through observations of electric noises in both regions, above and under the ground, we found earth-origin electric pulses whose intensity was stronger than those detected above the ground. Furthermore, the frequency dynamic spectra of the detected noises showed clear lower frequency cutoffs at 200 ～ 300 Hz. The clear lower frequency cutoffs in the spectra suggest that the earth-origin electric pulses might have been propagating in a kind of wave-guide formed by electrically conductive boundary, which is similar to the phenomena of atmospherics reflecting between the ionosphere and the ground [2,3]. Since the ground surface, including the sea, is regarded as the upper conductive boundary of the wave-guide, we attempted to estimate the depth of bottom conductive boundary. From the observed lower frequency cutoffs, we derived the depth to be 250 ～ 167 km for waves with the observed cutoff frequency of 200 ～ 300 Hz when we assumed the specific dielectric coefficient of the earth crust to be 9. The validity of the estimated scale depth can be supported by the result of the electrical conductivity of the earth derived from the geomagnetic field data by Rikitake [4], in which he showed that the electrical conductivity in the earth near the ground surface steeply decreases with depth and keeps its value to be ～ 10^{-3} [S/m] down to about 200 km in depth, then it upturns with the depth. The conductivity around 500 km in depth was the same order of magnitude (～ 1 [S/m]) as that of the ground surface (the sea). From our observational results, we can expected that the electric pulses detected in the earth were generated in the deep earth and were propagating in the wave-guide formed between the ground surface and the electrically high conductive region at the depth below few hundreds km in the earth, and the noises detected above the ground were regarded to be leaked components from the ground. We reported the observational result on the earth-origin electric pulses at AP-RASC 2001 in Tokyo [5], and its detailed discussion will be published in GRL [6]. In order to clarify the validity of the propagation of the earth-origin electric noises in the deep earth, we attempted to clarify a relation between the intensity of electric noises in the earth and the electrical parameters of the earth crust.

MEASUREMENTS OF ELECTRICAL PARAMETERS OF THE EARTH CRUST

The most suitable way to know the electrical parameters of a medium is to measure the impedance (or admittance) of electric antenna in the medium, because, in the low frequency range, the equivalent circuit of the antenna admittance is generally expressed as a conductance and a capacitance connected in parallel, and the electrical conductivity and the dielectric coefficient of the medium around the antenna easily change the values of the antenna conductance and capacitance. The ordinary way of obtaining the antenna admittance, which is reciprocal to the antenna impedance, is to measure AC currents flowing into the medium through the dipole elements when a voltage was applied to the the feeding point of the dipole, and to take a ratio of the current to the applied voltage. A complex function of the antenna admittance was obtained by an FFT servo-analyzer connected to the dipole antenna, in which frequency-swept voltages were applied to the dipole element. The real and imaginary parts of the function provide an antenna conductance and capacitance, respectively. From these values, we can derive values of conductivity and dielectric coefficient of the medium, respectively.

We carried out their measurements in the earth from 5 to 95 m in depth at every 2.5 m, inserting the dipole antenna into the bore-hole. We have obtained a depth-dependence of the specific conductivity and the specific dielectric coefficient in the earth. Figure 1 shows a depth-dependence of the measured antenna conductance. Although the values of the antenna conductance are dispersed from depth to depth, most of their values are in a range less than 10^{-7} [1/Ω]. Using these values, we can derive the conductivity of the earth crust using a roughly estimated effective

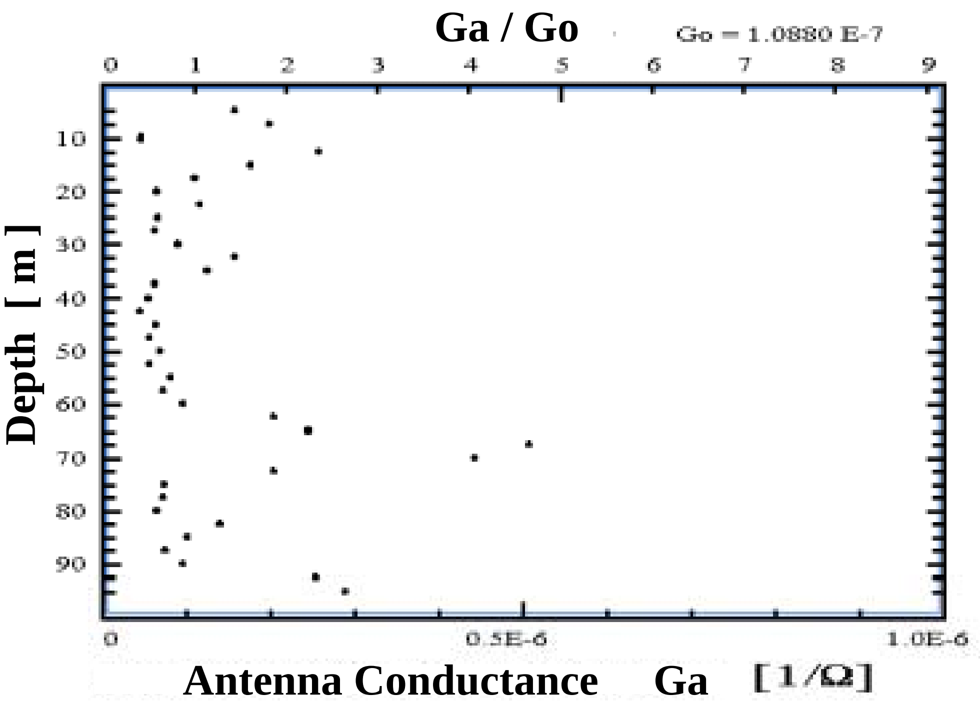

Fig. 1 Depth-dependence of the antenna conductance in the earth (bottom scale), and their ratios to the value measured in the air (top scale).

volume where electric lines of force from one elements to another one are effectively penetrating. We obtained the conductivity of the earth as 10^{-5} [S/m]. This value is extremely small compared to the value (10^{-3} [S/m]) given by Rikitake [4]. The obtained lower value means important information on EM wave attenuations in the earth. The frequency-derivative to the imaginary part of the measured complex function for the antenna admittance can provide the antenna capacitance. Figure 2 shows a depth-dependence of the measured antenna capacitance (the bottom scale) and of the derived specific dielectric coefficient (the top scale).

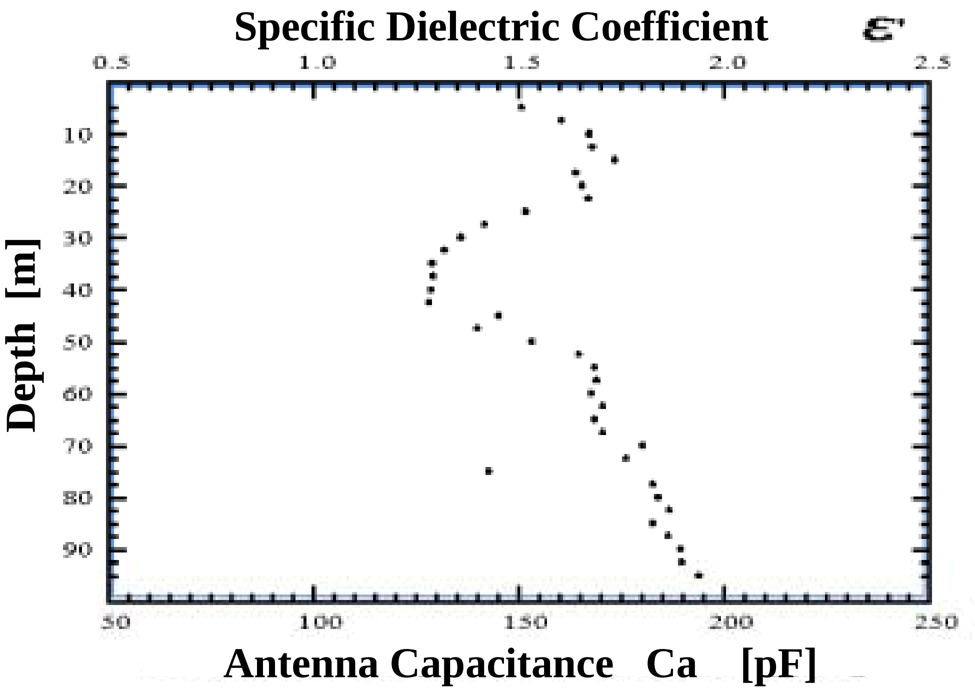

Fig. 2 Depth-dependence of antenna capacitance (bottom scale), and specific dielectric coefficient (top scale).

The specific dielectric coefficient (the top scale) is largely fluctuating from 1.3 to 1.7 in a range down to 45 m in depth where is a sedimentary layer. However, their values in the region below 50 m in depth clearly shows a monotonically increasing trend, where is the base rock region. Judging from the increasing trend, it is expected that the specific dielectric coefficient would become large for the deeper earth.

Using the values of conductivity and dielectric coefficient in the earth crust, we can examine the propagation property of EM waves in the earth.

MEASUREMENTS OF ELECTRIC NOISES IN THE EARTH

In addition to the measurements of the electrical parameters in the earth crust, we also measured wave electric noise in the earth. Figure 3 shows the depth-dependence of electric noise intensity in the earth. In the figure, one vertically thin rectangle shows a frequency-time (f-t) diagram (frequency dynamic spectra) of electric noises measured at a depth in the earth. The color corresponds to the predefined noise intensity as shown by the color bar scale. Thirty six f-t diagrams obtained at every 2.5 m from 5 m to 95 m in depth are placed horizontally from left to right. We can clearly see an increasing trend of electric noise intensity in accordance with the depth. Two increasing trends in accordance with depth between the specific dielectric coefficients and the electric noise intensities suggest that the wave attenuation might become small in the region with large dielectric coefficients, and that the dielectric coefficient strongly affects to the property of EM wave propagations in the earth.

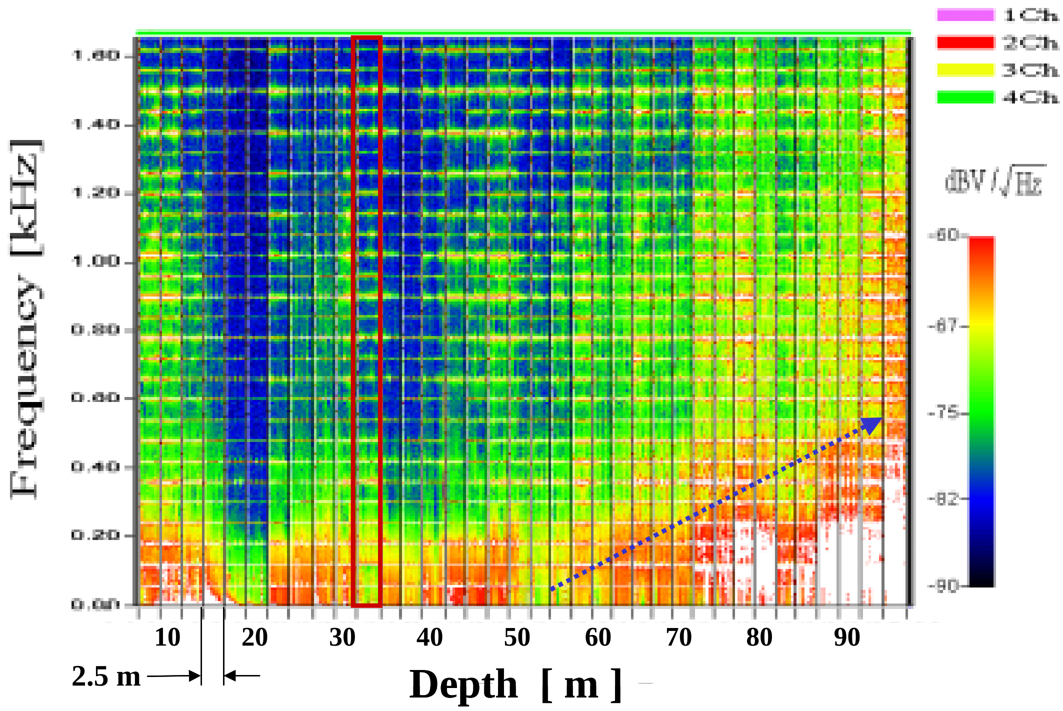

Fig. 3 Depth-dependence of electric noise intensity. Each vertically thin rectangle indicates frequency dynamic spectra (f-t diagram) of electric noise measured at each indicated depth. Colors indicate noise intensity.

DISCUSSION

From some situations clarified in the present study, we have been convinced of the formation of a wave-guide in the earth. We can speculate that the region with high dielectric coefficient would be sandwiched by the electrically high conductive layers, and that EM waves could propagate there with rather weak attenuation.

We have estimated a propagation distance (the Skin-depth) of EM waves in the earth, using the electrical parameters obtained in the present study. The Skin-depth which is reciprocal to the attenuation constant became 7 km when we used the conductivity of 10^{-5} [S/m] obtained in the present measurement, although its value becomes as 200 m for using the conductivity of 10^{-3} given by Rikitake [4] in the deep earth. If the dielectric coefficient is larger than the value obtained in the present measurements, the EM waves could propagate for a longer distance.

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