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ON THE FREQUENCY RESPONSE OF THE BALL ANTENNA FOR MEASURING ELF RADIO SIGNALS

By

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Abstract

The frequency response of the "ball antenna" is calculated for ELF band of 1 c/s to 1 kc/s for the output resistances of 10^9 ohms and 10^8 ohms respectively with various output capacitances. A frequency-response curve is given for the antenna capacitance of 10 $\mu\mu$F. Some discussions are made for the practical use of this antenna.

1. Introduction

Ogawa, Tanaka, Miura and Yasuhara [1966] described a newly developed simple measuring system of natural extremely low frequency (ELF) and very low frequency (VLF) electromagnetic waves by using multi-ball-antenna. With this system long traveled natural ELF signals were measured discriminated from natural local noises. The system can be used even in a large city where not only undesirable natural electrostatic noises but also artificial power-line noises predominate.

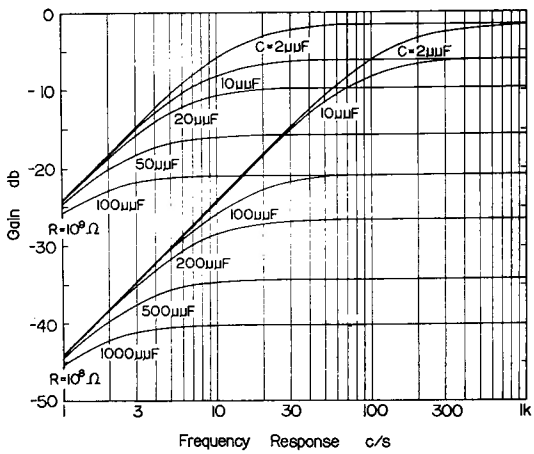
The measuring principle is to measure the potential difference between the conductor antenna of capacitance Co raised in the air to some height h from the ground surface, and the earth. The antenna is connected to the ground through a parallel resistance R and capacitance C. Assuming reasonably the electric field intensity E near the plane ground surface is vertically constant, the output potential difference V across the output resistance R is given by $V=\omega CoREh/\{\omega^2R^2(Co+C)^2+1\}^{1/2}$ where $\omega=2\pi f$, and f is the frequency.

As the size of the conductor antenna which is called the ball antenna cannot practically be far from a few decimeter in the diameter, the value of Co become the order of 10 $\mu\mu$F. In this paper we calculate values of V versus frequencies for the antenna capacitance of 10 $\mu\mu$F, and discuss practical use of this antenna.

2. Result and Discussions

In the figure is given the frequency response curve thus calculated for the

output resistances of $1\times10^{9}\Omega$ and $1\times10^{8}\Omega$ respectively with various values of the output capacitances. It is clear that if we wish to have the higher sensitivity we should use as high value of R and as low value of C as possible. It is also clear that for the wide frequency response in lower frequency range we should use as high values of both R and C as possible.



The frequency response of the ball antenna

In naturally occurring ELF phenomena, reception of the earth-ionosphere cavity resonances is the most interesting subject. Since Schumann [1952a, b, 1957] presented the resonance theory that the ELF electromagnetic energy emitted from the lightning discharges over the world resonates in the cavity between the good conducting earth and the ionosphere, a number of investigators have worked out to find the actual resonant frequencies and to study the associated geophysical effects (Balser and Wagner [1960], Polk and Fitchen [1962], Chapman and Jones [1964], Gendrin and Stefant [1964], Rycroft and Wormell [1964], Hughes [1964]). We have investigated on the same subject and found some interesting phenomena associated with the solar flare event of July 7, 1966 (Ogawa, Tanaka, Miura and Owaki [1966]). In the Schumann resonances the concerned frequencies are from 7 c/s to some hundred c/s while for the phenomena associated with the solar or other non-terrestrial origin the interesting frequencies extend below and above the Schumann resonance region. The reception of such signals requires the use of sufficiently wide frequency-response instrument. The present ball antenna is satisfactorily adopted for such measurement.

There are three major types of measuring methods previously presented. First the magnetic measurement using induction coils is widely made. It has the benefit to measure vector components to study the polarization of the waves. However the induction coil can not be used in a large city because of the interferences of leakage current from nearby streetcars or big factories. The same disadvantage comes in the measurement of earth current (Sao, Jindo and Yamashita [1963]). The third method is to measure the electric component. Balser and Wagner [1960] used the high tower of 37 m in height, while Rycroft

and Wormell [1964] used the horizontal antenna of 190 m in length. It may be considerably difficult to maintain these antennas in good condition. Hughes [1964] used the vertical whip antenna of 10 m in length. Chapman and Jones [1964] used the 3 m vertical rod antenna.

The present ball antenna is the most simple and easy to maintain. In the previous investigation we used an impedance transformer using a cathode follower put into the empty conductor can (the antenna). The grid of the electrometer tube 5886 was directly connected to the inside of the can to minimize the value of C, and the can was supported by a teflon bar which was protected by a metal cover for insulation from the ambient polluted air. A resistor of $1\times10^9\,\Omega$ was used as a grid leakage resistance, which was also put into the can. Thus the output capacitance of the antenna was hold at about $2\,\mu\mu$F. Later we changed the values of R and C to $2\times10^8\,\Omega$ and $200\,\mu\mu$F respectively to get wider frequency responses at low frequencies. In order to receive weak signals as hydromagnetic waves at about 1 c/s to several c/s it is advisable to use as high value of R as possible. It is, however, difficult to keep the high value of the resistance constant in highly damped air especially in the early morning.

In polluted air the atmospheric electrostatic field is highly disturbed and there are ELF range field fluctuations. The power spectrum of such electrostatic fluctuations is not fully investigated in the range of shorter periods than the order of minutes. In the previous investigation we found that the ELF electrostatic noises are localized in the area of some meters. If we use two antennas separated by 15 or more meters, long traveled natural electromagnetic signals can be discriminated from these local electrostatic noises because of their localized distribution.

In order to escape from the artificial noises such as the power-line noises the ball antenna is suggested to be raised from the ground or building surface as high as possible. In the previous investigation we used a mast of 5.5 m in height to hold the antenna. The mast was built on the top of the building of the Geophysical Institute. Thus the undesirable artificial noises are suitably eliminated for the measurement of lower Schumann resonance region of the fundamental mode to the sixth modes.

The present ball antenna is specially suitable for portable use. As it needs simultaneous measurements to investigate on the lightning origin of ELF radio signals, the use of this antenna system is highly recomendable.

The natural radio waves originated from lightning discharges have energy of wide frequency distribution not only in ELF but also in VLF and higher

frequencies. The use of the ball antenna can make possible of the comprehensive study of such natural radio signals. In the study of the phenomena of the hydromagnetic or other non-terrestrial origin not investigated previously the simultaneous measurements of ELF and VLF signals are also highly desirable.

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