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EFFECTIVE HEIGHT OF THE BALL ANTENNA FOR MEASURING ELF RADIO SIGNALS

By

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Abstract

It is necessary to find an effective height of the ball antenna in order to estimate the absolute values of the amplitudes of oscillations and of the power of ELF natural electromagnetic noises. Applying a method of plane reduction for atmospheric electric field measurements the effective height was estimated to be 5.5 m when the ball antenna was set with a supporting rod of 5.5 m in height on the roof of a building 14.5 m in height.

1. Introduction

We have developed a ball antenna for the measurement of ELF and VLF radio signals and demonstrated that it was possible to measure natural ELF and VLF electromagnetic noises propagating around the earth even in a populated area where there might be a number of manmade undesirable noises (Ogawa *et al.* [1966]). We used the ball antenna together with ground antennas to investigate geophysical properties of natural noises in the frequency band of the Schumann resonances in which we have discussed diurnal patterns of relative power in connection with the worldwide thunderstorm activity as signal source, diurnal patterns of resonant frequencies, and Q values in relation to the solar activity. When we discuss the signal amplitude or absolute power it is necessary to refer to the effective height of the antenna. The ball antenna is an entirely new type of antenna for measuring radio signals so that we think it useful to describe a practical method of estimating the effective height of the antenna.

2. Brief description of the ball antenna

The ball antenna which we first used during 1965-1966 was made with an empty milk can with a piece of teflon bar to insulate it from a supporting metal rod which raised the antenna up from the ground. An impedance transformer which is a cathode follower with an electrometer tube of 5886 was included in the empty antenna can and the first grid of the tube was connected to the inside of the can. Later the can was replaced by a hollow copper sphere 22 cm in diameter, which is supported by an iron pipe 5.5 m long and 5 cm in diameter, being separated by a teflon plate with an insulating surface of 100 cm^2 and 1 cm thick. The actual size of this ball antenna is shown in Fig. 1. The

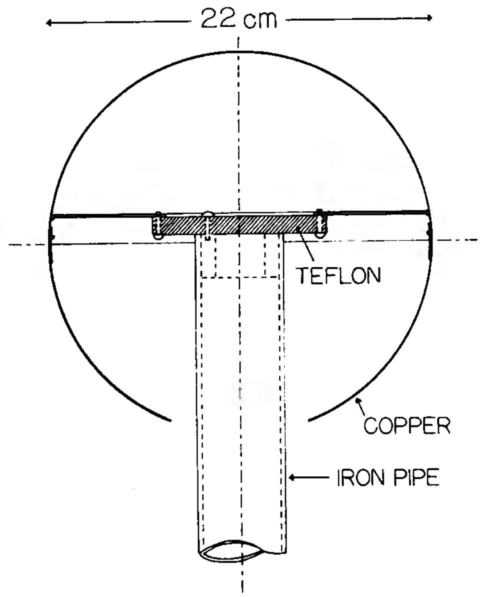

Fig. 1. Ball antenna configuration.

hollow copper sphere with a hole 8 cm in diameter at the lower side is cut into two hemispheres, in the upper half of which is put the impedance transformer described above. The lower half of the antenna plays an role in protecting the insulation of the teflon plate from precipitation and pollution. When it is very humid we can attach an electric heater to warm up the lower side of the teflon plate. Such a ball antenna is raised as high as possible on the roof of a building in order to protect it from various noises near the ground. One of the undesirable noises in the ELF band is that of space charge fluctuations at or below about 6 Hz. It is thought that the origin of its production is at ground level and its drifting level is within a few meters from the ground. The ball antenna suffers little from such a low level noise, while the usual vertical antenna does suffer from the noise. Another undesirable noise which disturbs the measurement of ELF signals is the 60 Hz power line noise which is usually followed by 120, 180, and higher harmonics. These noises may come from nearby power lines and possibly from the surface of the building on which the ball antenna is installed. In this case it is better for the antenna to be raised as high as possible from the ground and also from the building surface. The antenna thus installed at a height level of 5.5 m from the roof surface of the building still receives the 60 Hz noise of 0.3 Vpp in amplitude, in contrast with which natural noises to be measured are of the order of 1 mV so that SN ratio is over 60 db. Thus an amplifier of 60 db gain with two filters of 60 Hz and 120 Hz is used, the rejection ratio at 60 Hz being over −70 db.

3. The effective height and its estimation

The output voltage of the above amplifier equals the product of the field intensity and the effective height of the antenna, so that it is necessary to find the value of the effective height in order to estimate the field intensity. The effective height of the ball antenna is much smaller than when the ball is located at that level over perfectly level ground without the supporting pipe and the building. The actual height of the ball antenna is 20 m from the ground ; the antenna is installed on the roof of the building 14.5 m in height. In the previous papers (Ogawa *et al.* [1966] and Ogawa *et al.* [1967]) we used 20 m for the antenna height to evaluate the amplitude of the ELF oscillations. It is however clear that the presence of the post and the building seriously disturb the electric field and make it impossible to obtain absolute values of the field from measurements made ; thus the value is not correct, so that it is also a purpose of this paper to correct this value by estimating the effective height of the antenna on an experimental basis.

The method of estimation of the effective height of the ball antenna which we used is the same as a method of plane reduction of the atmospheric potential gradient measured (refer to, for example, Chalmers [1967]). The cathode follower is disconnected from the inner surface of the ball and a potential equalizer such as a radio active substance or other is attached to the surface of the ball antenna. We used burning mosquito coils as a potential equalizer. A fine wire connects the antenna and an electrometer with which the antenna potential is measured in a time series, for example, of each period of one minute.

During the same period another group of the experimenters install two supporting posts of about 4 m length separated horizontally by about 5 m on flat level ground about 150 m away from the building with the ball antenna. Two copper wires 1 mm in diameter are stretched at two different height levels on the posts. The center parts of the wires are insulated by teflon bars and connected to two different electrometers respectively. The potential equalizer is also used to equalize the potential of these wire antennas to the potentials of the same levels of the atmosphere, and the potentials are read by the electrometers in the same time series as those of the ball antenna. The adjacent parts of the wire to the antenna used are also separated from the supporting posts by teflon bars and used as guards with potential equalizers. The potential difference between two center wire antennas is observed and divided by the separation of both antennas, which gives the field intensity of the atmospheric static field. Or simply we use one wire antenna and its potential is divided by the height of the antenna. Such a situation of plane reduction of the ball antenna is shown in Fig. 2. One example of the camparison of the ball antenna potential and the electric field on a flat surface is shown in Fig. 3, from which we can estimate the effective height of the ball antenna to be 5.5 m. The ball antenna potential is divided by the effective height thus obtained and the time variations at the place of ELF measurement is compared with those on the flat surface. The result is shown in Fig. 4. In the initial

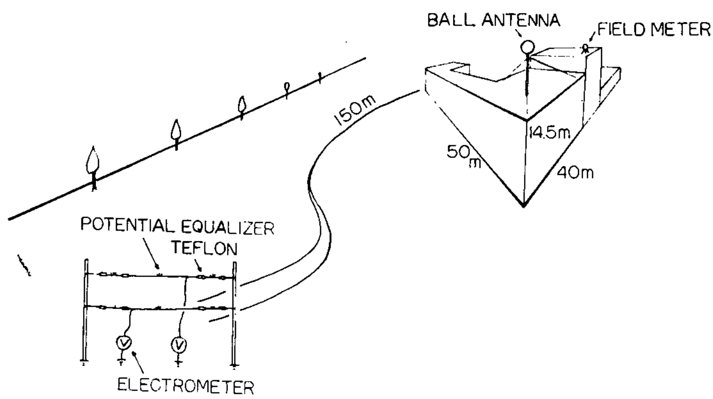

Fig. 2. Situation of plane reduction of the ball antenna.

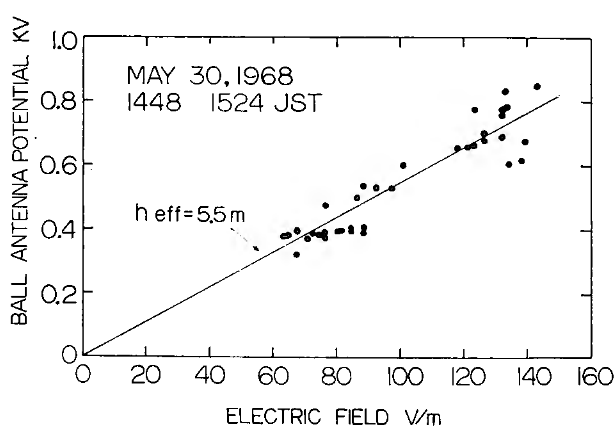

Fig. 3. Deduction of the effective height from the plane reduction experiment.

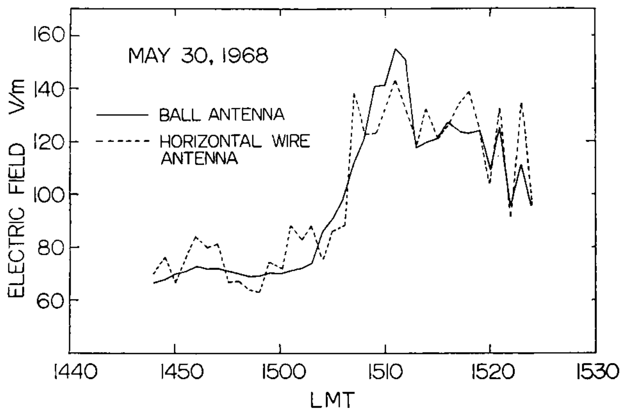

Fig. 4. Simultaneous records of the atmospheric electric field measured with the ball antenna and the horizontal wire antenna.

part of the record for about 15 minutes the time response of the ball antenna does not seem quick enough to follow the variation but it is not very serious in estimating the effective height.

We used several kinds of antennas before establishing the final ELF receiving system ; i. e., we changed the shape of the ball, the length of the supporting pipe, and the horizontal position of the antenna. In each occasion we did not make plane reduction of the antenna directly but we compared the ball antenna potential with the record of the field mill which is set near the ball antenna on the same building. The field mill is calibrated beforehand, and from this the effective height of the ball antenna can be estimated. Such an example

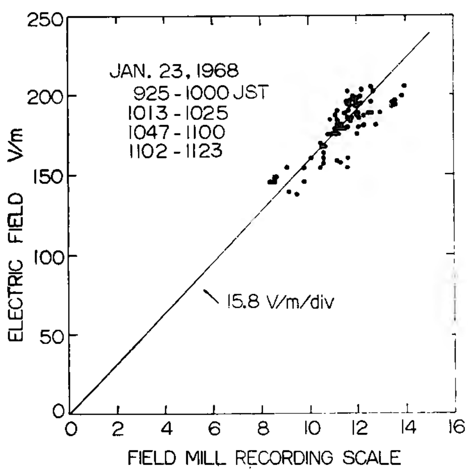

Fig. 5. Calibration of the field mill recording.

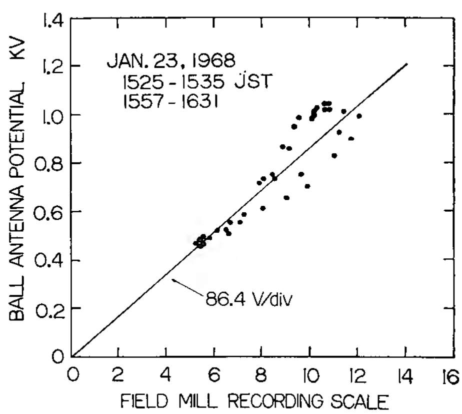

Fig. 6. Calibration of the ball antenna by comparing with the field mill recording.

using the same ball antenna is shown in Figs. 5 and 6. Plots in Fig. 5 give the value of field mill plane reduction 15.8 V/m/div. Plots in Fig. 6 give 86.4 V/div which is the ratio of the ball antenna potential and the field mill recordings. Using the two values we obtain the effective height of the ball antenna as 5.5 m. The value of the effective height thus estimated in two different ways and at different times agree with each other and are the same value as the length of the supporting pipe of the ball antenna. This is, however, entirely accidental and the value 5.5 m is the effective height of the ball antenna including all effects of both the supporting pipe and the building.

References

Chalmers, J. A., 1967; *Atmospheric Electricity*, Pergamon Press, Oxford.

Ogawa, T., Y. Tanaka, T. Miura, and M. Yasuhara, 1966; Observations of natural ELF and VLF electromagnetic noises by using the ball antennas, J. Geomag. Geoelectr., 18, 443-454.

Ogawa, T., Y. Tanaka, M. Yasuhara, A. C. Fraser-Smith, and R. Gendrin, 1967; Worldwide simultaneity of occurrence of a Q-type ELF burst in the Schumann resonance frequency range, J. Geomag. Geoelectr., **19**, 377-384.