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DISTORTION OF VLF RADIO WAVE FIELD BY VERTICAL METAL POLES

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Abstract

As the first step towards solving the problem of the distortion of the VLF radio wave field, the intensity of 17.4 kHz signals propagating about 110 km has been observed around the vertical metal poles of 12m height. Three kinds of field intensity have been measured simultaneously; one is the vertical electric field intensity (E_v) detected by a whip antenna, and the other two are the maximum and the minimum field intensity (E_{max} and E_{min}) measured by a loop antenna. The field intensity, E_v, increases with distance from a pole while E_{min} decreases and E_{max} is approximately constant or slightly decreases. At a distance of more than 10–20 m, E_v becomes constant and equal to E_{max}. Thus the effects of a pole seem to extend over a distance nearly equal to its height.

1. Introduction

It is well known that the relative phase and the field intensity of VLF radio waves reflected from the lower region of the ionosphere are very sensitive to small ionization changes in this region. By receiving VLF signals at various propagation distances many researchers have investigated propagation characteristics of this wave and time-variations of the lower ionosphere, for example, variations during sunrise and sunset, and disturbances associated with solar flares, PCA and geomagnetic storms. We are now in a position to start an investigation on detection of local ionization changes in the lower ionosphere by the use of VLF signals propagating a short distance (NDT (17.4 kHz, Yosami, Aichi Pref.) — Kyoto, about 110 km). The most difficult problem in detecting ionization changes in the lower ionosphere by short path VLF signals is how to eliminate the overwhelming ground wave and derive information about the ionosphere involved in the weak sky waves. A new method has been developed by which it is possible to estimate the field intensity and the relative phase of the ground wave and the sky waves with two polarizations (TM and TE) separately (Kikuchi and Araki, [1972]). This method assumes that the magnetic field of the ground wave and the sky wave of TM mode is perpendicular to the plane determined by the propagation path and the vertical line at a receiving point and that the magnetic field of the TE mode sky wave is parallel to this plane. It is therefore necessary that the wave field is not distorted by reflections from obstacles such as buildings, trees, electric poles and so on. Though distortion of VLF radio-waves is generally considered to be small because of their long wave-length, our preliminary observation shows that a slight displacement of a receiving point causes a great difference in the field intensity near and in a building. Thus more detailed knowledge on field distortion of VLF signals becomes necessary. As the first step in approaching this problem, measurements of VLF wave field distortion due to vertical metal poles of simple geometry were made. This paper is a brief report of the results and the interpretation of the measurements.

2. Description of the Experiment

The experiments were made on the university athletic ground which is shown in Fig. 1. Six vertical metal poles (A–F) for illumination were chosen as obstacles

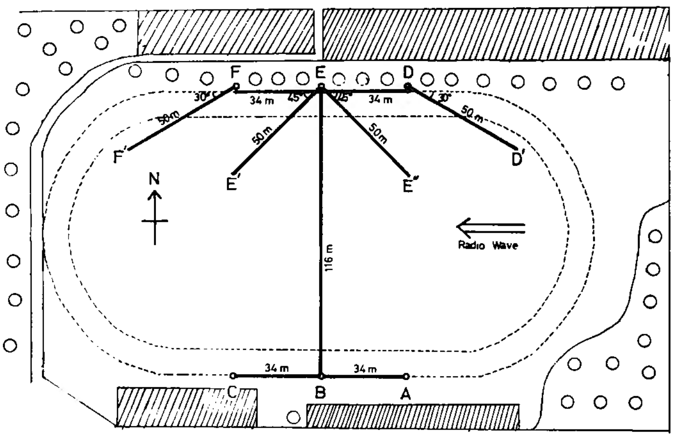

Fig. 1. The experimental field. The vertical metal poles of 12m height are denoted by A–F. The measurements of the field intensity were made along thick lines. Hatched regions and open circles show buildings and trees, respectively.

making distortion of the VLF radio wave field. The height of the poles is about 12 m. Houses and trees around the ground are lower than the poles except for two trees at the southside of the pole B.

The following three kinds of field intensity were measured;

1) E_v; the vertical electric field intensity measured by a whip antenna.
2) E_{max}; the maximum field intensity measured by a loop antenna. Usually this is measured when the plane of the loop antenna is set parallel to the propagation plane (the plane determined by the propagation path and the vertical line at a receiving point).
3) E_{min}; the minimum field intensity measured by setting the plane of the loop antenna perpendicular to the propagation plane.

The wave field of VLF signals transmitted from a vertical electric dipole is composed of three component waves, i.e., the TM-mode ground wave, the TM-mode sky wave and the TE-mode sky wave. Though the intensity of the ground wave decreases rapidly in accordance with distance from the transmitter, it is still much greater than that of the TM- and TE-mode sky waves at a short distance. The TE-mode sky wave converted from TM-mode during ionospheric reflection is weaker than the TM-mode sky wave. Therefore E_{max} should be equal to the intensity of the ground wave slightly modified by the TM-mode sky wave. Since E_v is also almost entirely determined by the ground wave, it should be equal to E_{max} if there is no field distortion. If obstacles distort the wave field, E_v does not always be equal to E_{max}. For example, let us consider a case shown in Fig. 2. In an undisturbed

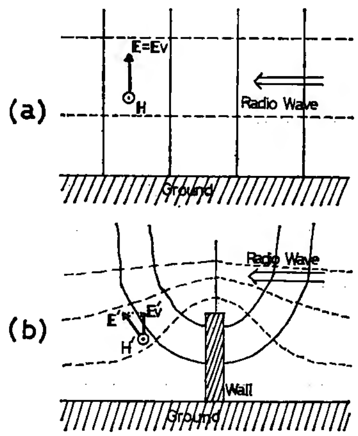

Fig. 2. Electric field line (solid line) and equipotential line (dashed line) in undistorted (a) and distorted (b) condition.

condition, the electric field, E, of TM-mode radio wave propagating from the right is assumed to be upward and the magnetic field, H, perpendicular to the plane of the paper (Fig. 2a). A loop antenna set parallel to the plane of the paper detects H and gives the field intensity equal to E. If the wave field is distorted by a vertical thin wall of finite height and infinite width as shown in Fig. 2b, the wave electric field (E') would incline in the plane of the paper. A vertical component of E', E'_v, is not generally equal to the field intensity, E'_{max}, which is derived from a measurement of H' by the loop antenna. A degree of the field distortion might therefore be estimated by comparing E_v and E_{max}. If the loop antenna has directivity of a perfect eight figure shape, E_{min} would be the intensity of the TE-mode sky wave. Practically E_{min} shows the TE-mode sky wave mixed with the reduced TM-mode sky and ground waves due to imperfect directivity and it would also change by distortion of the wave field.

The measurements were made along the lines drawn in Fig. 1. The lines FF′ and DD′ were taken obliquely southward because branches stretching out from the trees at the north boundary of the ground might distort the wave field. In Fig. 3 are plotted the values of E_{max} and E_v measured along the four lines A–B, B–C, D–E

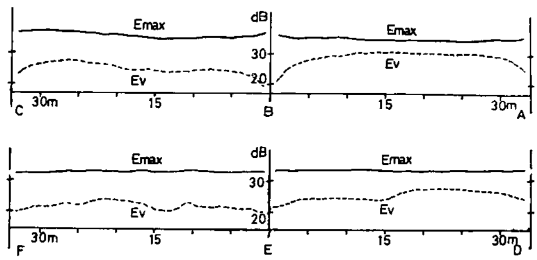

Fig. 3. Field intensity between two vertical metal poles.

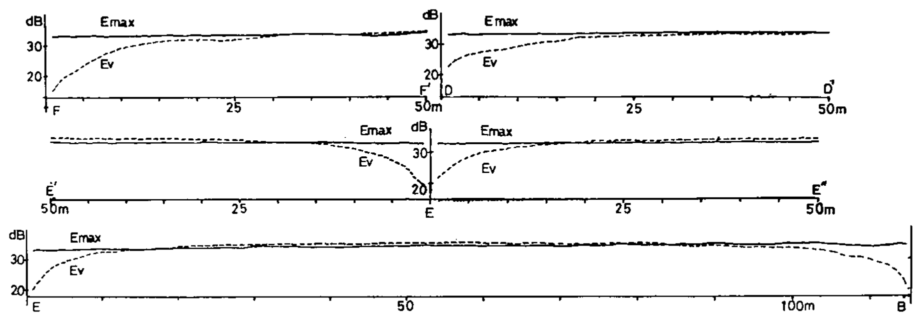

Fig 4. Field intensity versus distance.

and E–F. The field intensity E_v along F–E and the west half of ED is somewhat smaller and fluctuates. This seems to be caused by branches of the trees overhanging from the north side of the line F–D to the height of the whip antenna. Near the line BC there are also several obstacles such as automobiles, rocks and iron pipes, and the field are disturbed. The values of E_{max} and E_v along the line A–B seem to show a typical pattern of the field distortion between two metal poles. This shows that E_v decreases towards the poles while E_{max} is relatively constant or slightly increases. Fig. 4 shows the field intensity along DD', EE', EE'', FF' and BE. The field pattern near the poles is similar to that in Fig. 3. From Fig. 4 we can read that E_v becomes nearly equal to E_{max} at a distance of 10–20 m from the pole. Though the measured values of E_{min} are widely scattered about the averaged value, they show an overall tendency to increase toward the poles (for example, difference between E_{max} and E_{min} is 31 *dB* at the central part of the line B--E and 27–28 *dB* at one meter distance from the poles B and E). Decrease of E_v might be caused by bending of the electric field lines which should be vertical in an undisturbed condition. The reason for constancy or slight increase of E_{max} and increase of E_{min} is not clear at present, but the answer seems to lie in the fact that E_{max} and E_{min} are the field intensity measured by the loop antenna through the horizontal magnetic field of the wave while E_v is obtained by direct measurement of the electric field.

Reference

Kikuchi, T. and T. Araki, 1972; Analysis of Variations of Short Path VLF Radio Waves during Sunrise and Sunset, Preprint for the lecture at Spring Meeting 1972 of the Japanese Society of Geomagnetism and Geoelectricity.