MEASUREMENT AND ANALYSIS OF EM PROPAGATION IN AIR RADIATED FROM A SOURCE PUT IN FRESH WATER

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Abstract: In the environmental and civil engineering fields, tracking of the activity of the fish living in the river is expected as one of useful method to realize the improvement of the environmental conditions. If electromagnetic (EM) method is developed for this field, the application of the EM will be significantly increased and hence EMC point of view should be discussed. In this study, propagation of the E-field radiated to the air from the source set in the fresh water is measured and calculated by 2D-FDTD analysis. The folded dipole antenna of 50MHz is used for the source antenna in the water. The E-field radiated to the air is large just over the antenna. Though the distribution of the EM in the air showed in inverse proportion to the square of the distance, detection at 90m from the source was possible. Application to the tracking system at 50MHz can be developed in the future.
Keyword: EM radiation, water, tracking system, FDTD

1. Introduction

The tracking of the location and activity for the animal living in the wild life is necessary to conserve an ecosystem over a long period [1,2]. In particular, the tracking of the activity of the river fish is required for improving or improved the river. The radio telemetry system using the electromagnetic (EM) wave in the water was proposed to track the activity of wild fish. So far, the authors have been investigated propagation of the VHF radio wave in the fresh water to transmit the physiological signal of the fish [3-5]. But, it is not sufficient to use the EM wave for the wide distance due to the electric loss of the water. The simple and automatic radio tracking system that is constructed by source in the water and receiver on the land should be very useful.

The location finding system of the EM noise sources from electric system and a lightning stroke are researched in electromagnetic compatibility and antenna propagation fields [6,7]. However, as the fresh water has a high dielectric constant and large electric loss, the EM propagation from noise source in the dielectric material should be investigated from the aspect of EMC field.

In this study, the propagation of the E-field radiated in the air when the EM source put on the water is measured and calculated for the basic research. The E-field in the air at 50MHz is measured in the natural surrounding. Simulation of the distribution of the E-field is calculated by two-dimensional FDTD.

2. Measurement and calculation method

2.1 Antenna for the source in the water

A folded dipole antenna, which is ultra close-spaced type of array, is able to adjust the terminal impedance without the impedance transformation [8]. The terminal impedance of the 2-wire folded dipole has Z_{air}=280Ω in the vacuum, and Z_{water}=31Ω in the water. After some VHF band frequencies were tested, that will be discussed in Fig. 6, 50MHz was employed because of possibility for long distant range transmission.

Figure 1 illustrates the folded dipole antenna used in water for 50MHz. The length of this antenna is 30cm, which is λ/2 in the water. Figure 2 shows the frequency characteristic of the input impedance of this antenna. Since the impedance at 50MHz is 32Ω, the experimental result coincides with theoretical value.

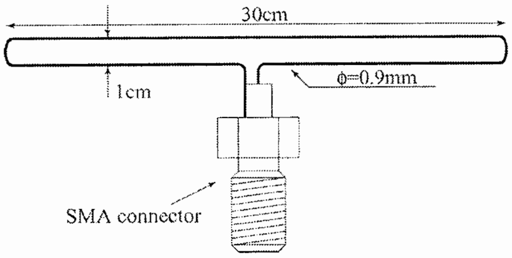

Fig. 1 Folded dipole antenna.

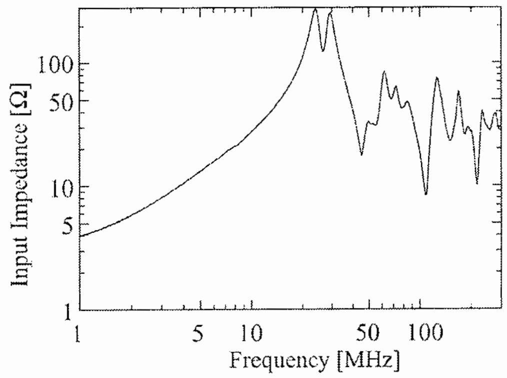

Fig. 2 Frequency characteristic of the input impedance of the folded dipole antenna.

2-2. Measurement site and method

Figure 3 shows a top view of the pond as a test site (Public Works Research Institute, Tsukuba-shi, Ibaragi). There is a bridge made by the steel and the concrete in the center of the pond. As this pond is artificially built, the depth of the pond is about 1.2m constant, and mud accumulates about 30cm on the bottom of the pond. The water of the river flows into the pond. The temperature of the water is 15 to 19 degree centigrade depending on the air temperature. The relative dielectric constant of the sampled water ε_r is measured as 82.3, and that of mud as 75.5, conductivity σ of the water is 0.25 mS and that of mud 0.62 mS at 25 degree centigrade, measured by the method in ref. [5]. The measurements of the distance characteristics were done along on the broken line in the Fig. 3, from the bridge to the opposite shore. There are a small building at the east edge of the bridge and road at the north of the pond. These obstacles had not influenced to the measured results.

Figure 4 shows the cross-sectional view of pond to measure the distribution of the E-field in the air. The half wavelength dipole antenna is set on the bridge to receive the E-field. The transmission folded dipole antenna and its driver circuit are sunk under the water. The depth of the antenna in the water is 60cm from the water surface. The excitation amplitude is $2.5V_{p\text{-}p}$ when the folded dipole antenna is connected and put in the water.

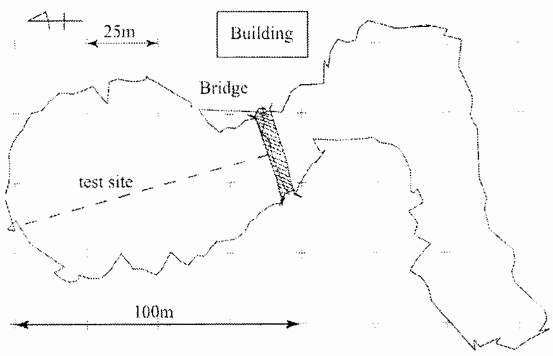

Fig. 3 Top view of the pond used as test site.

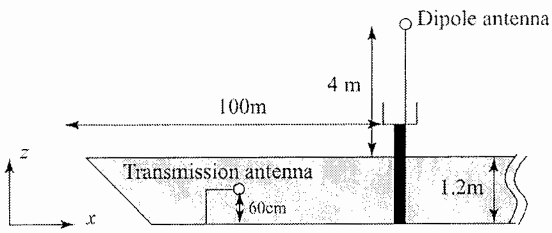

Fig. 4 Cross-sectional view of measurement site.

2.3 FDTD simulation method

Figure 5 shows the two-dimensional FDTD analysis model for the calculation of E-field distribution. The cell size of the FDTD analysis is $\Delta x=\Delta z=1$cm. Time step Δt is 23.5ps by Courant stability condition. To calculate the distribution until 100m, the analysis space is x=20,000 cell and z=20,000 cell, and an excitation point is set on the center of the analysis space. The Mur's absorbing boundary condition is used. The measured relative dielectric constant ε_r and conductivity σ is used for simulation.

To determine the EM frequency of this study, the electric radiation from water to air for some frequency are calculated. Figure 6 shows the E-field distributions for z-direction just over driving source at each frequency. In the VHF range, the radiation for 50MHz seems to be relatively larger than other frequencies.

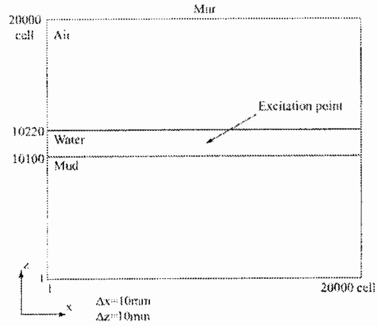

Fig. 5 2D-FDTD analysis model for the E-field distribution.

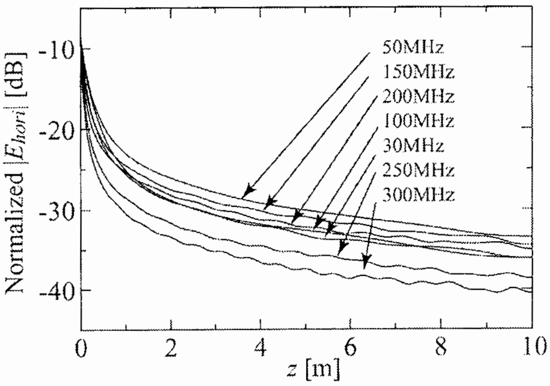

Fig. 6 The spatial distribution of radiated E-field at each frequency. (x-axis: excitation point.)

4. Results of the propagation of the E-field radiated in the air

Figure 7 shows the calculated spatial distribution of the E-field in the water, mud and air. Both source and receiver antennas were assumed to horizontally set. The amplitude is normalized by the E-field at the excitation point. The E-field emission to the air is large just over the antenna. On the other hand, the E-field along with the water surface is small. Since relative dielectric constant of the air and water is different drastically, it is expected that the EM wave reflects on the boundary between air and water. The EM wave radiated from the excitation point reflects on the boundary between air and water, and makes the standing wave.

Figure 8 shows the E-field distribution radiated from horizontal source antenna to the air by measurement and calculation. The horizontal component with the water surface is larger than vertical component. The amplitude is normalized to 0dB for the value at 3.5m from the source. The difference between the calculated and the measured results is about 15dB at the distance of 90m. The measured E-field decreased almost in inverse proportion to the square of the distance. On the other hand, the calculated result indicates that the E-field decreases in inverse proportion to the 1.5th power of the distance.

Figure 8 also shows the measurement results of the distributions of vertical E-field component when the source antenna sets on horizontal with the water surface. The vertical E-field is almost constant through 20m, and decreases from 20 to 40m. Since the date of the vertical for the distance is dispersed wider than horizontal, the spatial distribution of the horizontal has stable characteristic. It means that horizontal E-field will be suitable to use in this situation.

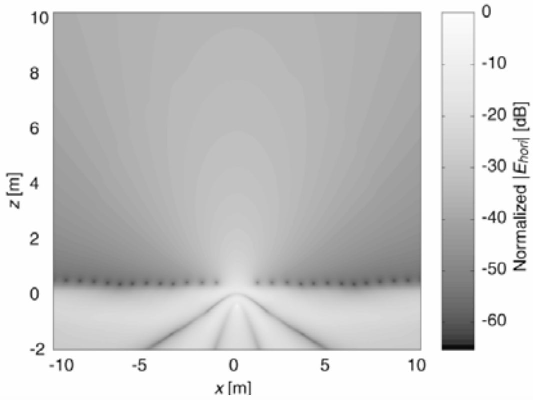

Fig. 7 The E-field spatial distribution radiated from water.

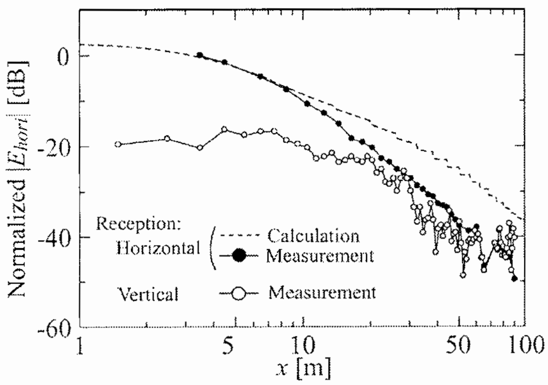

Fig. 8 Horizontal and vertical E-field distributions in the air at the height of 4m from water surface (calculation and measurement).

Figure 9 shows the angle pattern of the source antenna put at horizontally. The source antenna is set at 3.5m from the receiving antenna. Assuming the angle when the source and receiving antennas set parallel is indicated as 0 degree, the source antenna is turned from –90 to 90 degree. The amplitude is normalized to 0dB for the value at 0 degree. The characteristic of angle pattern is bilateral symmetry. The variation of the amplitude in the angle pattern is less than 10dB.

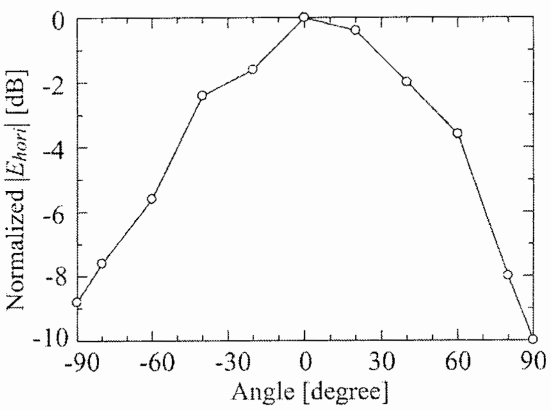

Fig. 9 Angle pattern of the source antenna in the water (measurement at x=3.5m and z=4m).

5. Discussions

As the water has a high dielectric constant and conductivity, this estimation corresponds to the EM propagation for the boundary between a high dielectric material and the air. As E-field near the water surface is small, at higher than 2m may be detectable. The distribution of the horizontal E-field along with the water surface is the function with the distance. The E-field at 90m from the excitation point can be detected. From the angle pattern, if the receiving and source antennas set in the perpendicular to each other, the detection of the E-field can be possible.

It is expected that the radio tracking system can be used to track the activity of the river fish living the river which have about 100m.

6. Conclusions

The distribution of the E-field radiated from water is measured and calculated by 2D-FDTD analyses. The E-field radiated to the air is large just over the antenna at 50MHz. The distribution of the horizontal E-field with the water surface is the function of the distance. The EM strength at 90m from the excitation point can be detected. It is expected to apply to the source tracking system using the radio wave at 50MHz for the activity measurement of the river fish. The development of the useful system for the location of the EM source is future study.

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