ANTENNA EFFECT OF HUMAN BODIES TOWARDS ELECTROMAGNETIC WAVES IN SPACE. III
FREQUENCY RESPONSE CHARACTERISTICS

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Abstract - As an extension of the previous reports on the antenna effect of the human bodies towards electromagnetic fields in space, various phenomena due to the interaction of the electromagnetic fields with the human bodies, including frequency response characteristics of the human body as a receiving antenna, and dependence of the induced voltages on individuals or on the sorts of footwears are presented. These phenomena are applied to the study of adventitious sources of electromagnetic fields in space such as visual terminals and fluorescent lamps.

Keywords: Antenna effect, human body, electromagnetic waves

The study of safety control and risk management, abbreviated as SCRM, is one of the focal points of the public interest and active efforts are being made for its promotion.¹⁾ In the study information and analytical sciences should play important roles.²⁾

Recently concern about the possible effects on human health of electromagnetic fields in space is increasing.³⁻⁶⁾ Our environment is filled with the electromagnetic fields from various intentional sources including broadcast, telecommunications, radar and navigation systems, and from adventitious sources such as visual displays and computer terminals. The introduction of new sources is ever-increasing. This situation has lead to the provision of exposure guidelines of environmental electromagnetic fields by the international committee. The distribution of the external unperturbed electromagnetic field is altered by the presence of the human bodies. Therefore, the problem of electromagnetic fields in space is first divided into two problems, the external unperturbed electromagnetic field and the interaction of the field with the human body, and then their interconnection is considered. Based on the quantities arising from the interaction of the field with the human body, exposure guidelines are usually set to the external unperturbed electromagnetic field. Theoretical researches are also important in the setting.⁷⁾ Researches on the effects of electromagnetic field on animals and cells, or tissue cultures have been made as a basis to the study of the possible effects on human health.⁸⁾

The antenna effect of the human bodies towards electromagnetic fields in space, which we reported previously, is an approach to the problem of possible effects on human health of electromagnetic fields in space.^{9,10)} The present report is its extension, and it presents the result of the frequency response characteristics of the human body as a receiving antenna, and the construction of an equivalent circuit model of the human body based on the result. It also presents improved measurements of the dependence on individuals.

RESULTS

Frequency response characteristics The frequency response characteristics of the human body as a receiving antenna towards electromagnetic fields in space were measured. Figure 1 shows the comparison of the frequency response of the human body and that of a dipole antenna of copper pipes. The data were obtained in a reactive field zone, at 0.5m from a transmitting antenna. Curve A is the frequency response characteristics of the human body. The response is constant and independent of frequency between 3kHz and 2MHz, but it decreases below 3kHz. Curve C is the response of a dipole antenna of a center input type. These two curves show the same frequency response characteristics. From

this consistency, the equivalent circuit model of pure resistance can be constructed over the frequency range between 3kHz and 2 MHz (from a very low frequency to a medium frequency). Curve B is the frequency response characteristics of the same antenna as used in obtaining curve C. However, in obtaining curve B the minus terminal of the probe of an oscilloscope was not connected with anything. This condition of the measurement is similar to that of the measurement of the human body. Curves B and C show the same frequency response characteristics. This result may justify the arrangement of the measurement of the antenna effect of the human bodies. Comparison of curve A with curve B shows the magnitude of induced voltage on the human body is larger than that of a dipole antenna by about 2.7 times. This observation may be related with the fact that the size of the human body is greater than that of the dipole antenna. It is being pursued that the lowering below 3kHz is the real frequency characteristics of the human bodies.

Dependence on individuals In the previous paper the dependence on individuals of induced voltages on the human bodies was reported. In the present study we improved the following two points in the measurements. First, an oscilloscope driven by a battery was used. An oscilloscope driven by the normal power line picks up a signal due to the power line leading to itself. Second, exactly the same footwear, slippers of plastics, was employed. The subjects put on the same plastic slippers with bare feet. Records of 12 persons of 19 and 20 in age are 125, 125, 125, 125, 130, 135, 135, 135, 140, 145, 150, 155mV, and the average and the standard deviation are 135mV and 9.89mV respectively. Partial correlation of the induced voltages on the persons with their heights was observed. Another example supporting the correlation is presented next.

Height effect The dependence of the magnitude of the induced voltage on a human on his height was measured by configuration 2. Configuration 1 may be preferable where there is no pick-up of the electric field by the 50Hz power line leading to the oscilloscope employed. But it could not be used since the bodies tested were children and they could not hang the heavier oscilloscope on the shoulders. Figures 2a-2c show a relation between the voltages induced and the heights of the children. Figures 2a-2c are data for children 152, 145, and 140cm tall and the voltages are 19.5, 14.0, 8.0V respectively. The voltage becomes high as the height of a child. It is remarkable that the voltages vary by more than 2 times though the heights differ only by 12 cm. The high voltages observed in the figures are characteristic values to the measurements by configuration 2.

Footwear effect It was shown in our second paper that the voltage induced by the antenna effect of human body depended very much on the sorts of footwears of a test body. There were about 4 times the difference between the highest value and the lowest one. The large difference was obtained by using a conventional type oscilloscope driven by the normal power line. When a special type oscilloscope driven by a battery was employed (configuration 1), only smaller difference was noted. But it was not investigated quantitatively. Recently, we have investigated the footwear effect by configuration 1. The results are summarized in Table 1. The change of the voltage is much smaller and there is

Table 1. Dependence on the sort of footwears

Footwears	Voltage/mV
Barefeet	62
Socks	58
Sneakers	44
Shoes	44
Plastic Slippers	42
Sandals(urethan)	38

only 1.5 times the difference between the highest value and lowest one. The smaller difference indicates that by this configuration the antenna of the

human body forms a nearly closed system. But looking at the details, we see that the voltage is the highest when the subject is barefooted and that it is the lowest when the subject puts on sandals with urethan soles or slippers made of plastics. This change accords with the previous one obtained by using a normal power-line-driven oscilloscope in the second paper.

Sources of electromagnetic fields The voltages induced by the antenna effect usually show complex waveforms. They sometimes show an overlap of the electromagnetic fields caused by several independent sources. Figure 3a is an example, and is a waveform induced on a man facing a laboratory desk. It was obtained by configuration 2. At least two components are seen, one, a sinusoidal component of 50Hz due to the power line and the other, a pulse component of 50Hz repetition rate. The pulse component is caused by fluorescent lamps for illumination in a laboratory. This was confirmed by the measurements where fluorescent lamp were turned off. Figure 3b shows a waveform recorded when fluorescent lamps were turned off. It does not contain any more the pulse component.

Antenna effect of other bodies than the human bodies It may be natural to inquire how the voltage induced by the antenna effect depends on the size and the material of the antenna. We have studied the voltages induced by the antenna effect of several other bodies than the human bodies. Configuration 2 was used. The results are shown in Figs. 4a-4f. Figure 4a shows the voltage induced when the electrode was put on a upper surface of a laboratory desk of dimension of 1.5 0.75 0.8m³.

The surface was coated with plastics which is an insulator of electricity. The component due to the 50Hz power line is higher by more than 2 times of magnitude than that induced on a human body, but the pulse component due to fluorescent lamps is unobservable. It is remarkable that an insulator induces such a high voltage. We think that it may be due to the large dimension of the desk. On the other hand, for the cause to the absence of the pulse component due to fluorescent lamps, one could think the frequency characteristics of the desk. But we think that it is due to the directionality of the antenna. In the second paper we showed that the antenna effect of the human bodies had strong directionality. Figures 4b and 4c show the directionality of an antenna of a copper pipe (2m in length and 8mm in diameter). In Fig. 4b the pipe was put vertically to the floor and in Fig. 4c it was put in parallel with the floor. The pulse component can be seen in Fig. 4b but it cannot be seen in Fig. 4c. We speculate that the pulse component cannot be seen when antennas are put in parallel with the floor. The waveform shown in Fig. 4d was recorded when the pick-up electrode was put on a painted wooden part of the same desk. The different surfaces of a body give different voltages and waveforms. The antenna effect generally depends on the state of the surface, which was shown in our first paper. Figure 4e shows the waveform induced when the pick-up electrode was put on the floor of a laboratory. In spite of its large dimension the voltage is rather small. Finally, Fig. 4f shows the voltage induced when the electrode was put on metal part of a gas bomb made of steel (47l in volume). Both components, one due to the 50Hz power line and the other due to fluorescent lamps, are a little lower in magnitude than those on the human bodies. It is surprising that the voltage induced by a metal antenna is low.

Dependence on times of measurements As an application of the antenna effect of the human bodies, we have investigated how the electromagnetic field at one location in space varies with the time. We measured by configuration 1 the induced voltage on a man standing in a laboratory. The measurements were carried out at 9 a.m., 12 a.m., and 6 p.m. for 8 days. The total times of the measurements are 12. The voltages are 32, 34, 38, 40, 42, 42, 45, 50, 50, 50, 50, 54mV. The mean value is 44mV and the standard deviation is 6.8mV. The electromagnetic field at one location in space may vary generally with the

condition of sources of electromagnetic fields. In the above example the change of the electromagnetic fields is small, but the statistical distribution implies some anthropogenic events. An example of large change was shown in the first paper.⁹⁾

Adventitious sources of electromagnetic fields

As an application of the antenna effect we have measured the electromagnetic fields near a few other sources than the 50Hz power line. Figure 5a shows the voltage induced on a man in front of a conventional home television set. It was measured at the location about 50cm apart from the TV set. Two or three components can be seen in Fig. 5a. The voltage is higher by more than one order of magnitude than that measured in a laboratory, and the pulse component of 50Hz repetition amounts to 1V. A high frequency component looked like a noise has a frequency of about 4kHz. Figure 5b is a magnification of Fig. 5a along the time axis. Figure 5c shows a waveform recorded in front of a personal computer. Its magnitude is comparable to that in a laboratory, but the component of 50Hz mainly due to the power line is severely distorted. The frequency of a noise-like component is about 40kHz as shown in Fig. 5d. Finally, Fig. 5e shows a waveform taken in a terminal room of our main frame computer. The magnitude is not so high compared with that in a laboratory, but the frequency is high. It is about 150kHz, as shown in Fig. 5f which is a magnification of Fig. 5e along the time axis.

EXPERIMENTAL

Dipole antennas A transmitting and a receiving antenna have been constructed. The transmitting antenna is a serial arrangement of two copper pipes of 8mm in diameter and 1m in length. The total length is 2m. A gap between the two pipes is about 0.5mm. The antenna is set vertically on a laboratory stand. Two holes are drilled about the center of the antenna for the connection of a current input device, one at 5mm above and the other at 5mm below the gap. Sinusoidal waves of 20V_{p-p} were put through the holes from a function generator. The structure of a receiving antenna is nearly the same as the transmitting antenna, with the exception of the total length of 0.6m. A signal picked up from electromagnetic fields in space was measured by an oscilloscope. The probe of the oscilloscope was connected to the two holes about the center of the antenna.

Arrangements of the experiment Arrangements of the experiment are nearly the same of those in the previous work. Two different configurations were examined in the measurements. In configuration 1, the oscilloscope worked in a battery-driven mode and it was set on a chair in front of the desk. In configuration 2, the oscilloscope worked in a power-line-driven mode and it was placed on a laboratory desk and the human stood in a position close to the desk facing the oscilloscope. The arrangement of the connection of the probe was the same as those in configuration 1.

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