Measurement of Electromagnetic Fields in Space by Antenna Effect of Human Bodies. A Study of Safety Control and Risk Management

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Abstract: From a viewpoint of safety control and risk management, electromagnetic fields in space have been studied by the antenna effect of human bodies. The results of the measurement of electromagnetic fields in various places inside and outside of a building are presented. For the interpretation of the results several characteristics as a receiving antenna of a human body, dependence on individuals, dependence on the sort of footwears, and the frequency response are also presented.

Keywords: Antenna effect, human body, electromagnetic field

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]

Our environment is filled with 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 electromagnetic fields are concerned with safety of our life in two aspects. The first is the possible effects on human health of electromagnetic fields in space [3-6] 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 second is the malfunction of electronic instruments including computers caused by the interference of electromagnetic fields emitted from various sources.

The magnitude of the electromagnetic fields in space can be measured as low as several tens of millivolts by an oscilloscope. However, the output voltage from an oscilloscope takes several hundred times higher values when a person touches the metal probe of the oscilloscope. The human body works as a receiving antenna. While this antenna effect of human bodies are concerned with both aspects above, this report mainly addresses the application of the antenna effect to the measurement of electromagnetic fields in our environment. A few properties of the antenna effect of human bodies, however,

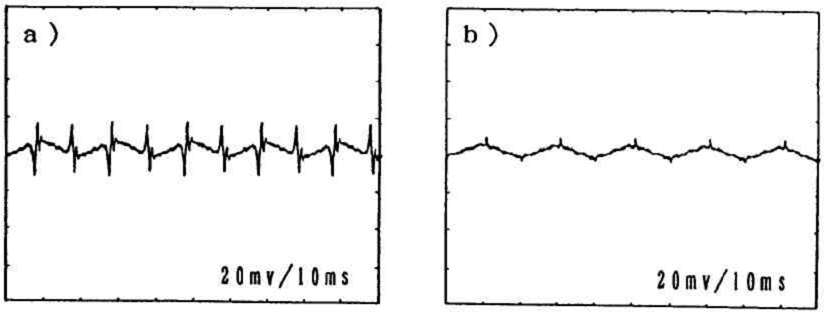

Figure 1. Waveforms of the antenna effect showing an overlap of electromagnetic fields caused by independent sources.

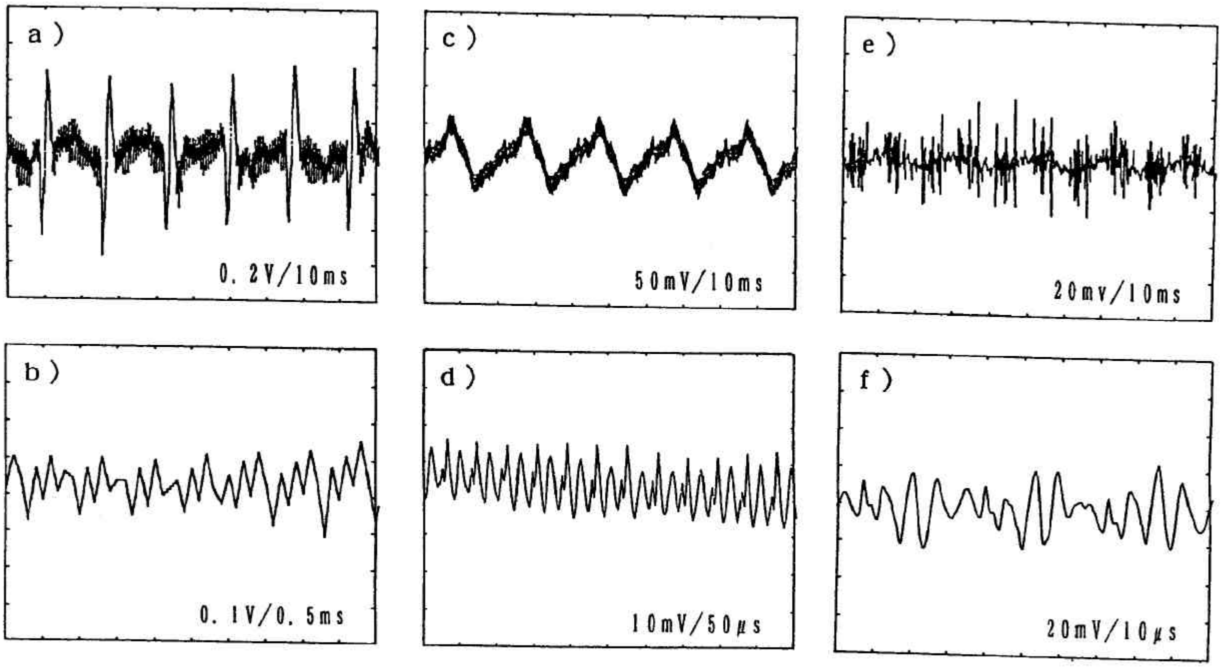

Figure 2. Waveforms of electromagnetic fields caused by several adventitious sources.

Sources of electromagnetic fields. The voltages induced by the antenna effect usually showed complex waveforms. They sometimes showed an overlap of the electromagnetic fields caused by several independent sources. Figure 1a is an example, and is a waveform induced on a man facing a laboratory desk. 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 comparison measurements when fluorescent lamp were turned on and off. Figure 1b shows a waveform recorded when fluorescent lamps were turned off. It does not contain any more the pulse component.

Adventitious sources of electromagnetic fields. The electromagnetic fields near a few other sources than the 50Hz power line. Figure 2a shows the voltage induced on a man in front of a conventional home television set. It was measured at a place0 about 50cm apart from the TV set. Two or three components

Table 1. Voltages induced by the antenna effect at various places

Place	Voltage/mV
Touching instruments	1000
Near instruments	100-400
Near a fluorescent lamp	100
On a corridor	3-5
Center of a sitting room	1-3
Outdoors	1

are described since they allow to interpret the results of the measurement of electromagnetic fields in environments.

Results

Location effect. Table 1 shows the induced voltages measured at several different places by the antenna effect of human bodies. The electric field was strong near installations which carry large electric power, a refrigerator, for example. The signal voltage became higher when one touched the instruments. The electric field was weak on corridors and in sitting rooms where there were few electric instruments. It was strong near a fluorescent lamp on a desk and it contained high frequency components. The electric field was not observable outdoors. These figures can be converted to the usual strength of electric field by dividing the figures by the height of human, ca. 1.7m. The voltage 1V on the top line in Table 1, for example, leads to the electric field strength of 0.59V/m. An oscillosope driven by a battery was necessary for the study of this location effect. A conventional oscilloscope with the 50Hz power line showed little difference in the signals at various places since it picked up the stronger electric field due to the power line connected to itself.

Fluctuation. The fluctuation of the electromagnetic field at one location in a laboratory was studied. 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 place 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 anthlopogenic events. An example of large change was shown in the previous paper.[7)]

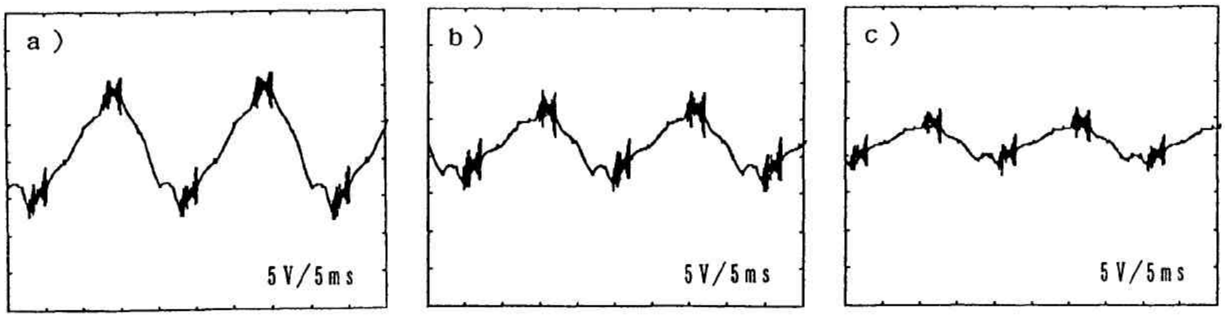

Figure 3. Dependence of the antenna effect on the heights of humans.

can be seen in Fig. 2a. 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 2b is a magnification of Fig. 2a along the time axis. Figure 2c 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. 2d. Finally, Fig. 2e 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. 2f which is a magnification of Fig. 5e along the time axis.

Dependence on individuals. The antenna effect of human bodies showed dependence on individuals. In this measurement exactly the same footwear, a pair of 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 will be presented next. In the previous paper greater dependence on individuals was reported when an oscilloscope driven by the normal power line was adopted.

Height effect. The dependence of the magnitude of the induced voltage on a human on his height was measured by a power-line driven oscilloscope. A battery-driven one may be preferable as mentioned before. But it could not be used since the bodies tested were children and they could not hang the heavier oscilloscope on the shoulders. Figures 3a-3c show a relation between the voltages induced and the heights of the children. Figures 3a-3c 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 to the measurement by a power-line driven oscilloscope.

Table 2. Dependence on the sort of footwears

Sort of footwears	Voltage/mV
Barefoot	62
Socks	58
Sneakers	44
Shoes	44
Plastic Slippers	42
Sandals(urethan)	38

Footwear effect. The antenna effect of human bodies showed the dependence on the sort of footwears which the subjects put on. The results are summarized in Table 2. There is ca. 1.5 times the difference between the highest value and lowest one. The smaller difference compared with the previous result[8] indicates that 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. In the previous paper[8] greater dependence on the sorts of footwears was reported. 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. The features of change are similar in both experiments.

Frequency response characteristics. The frequency response characteristics of the human body as a receiving antenna towards electromagnetic fields in space were measured. Figure 4 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

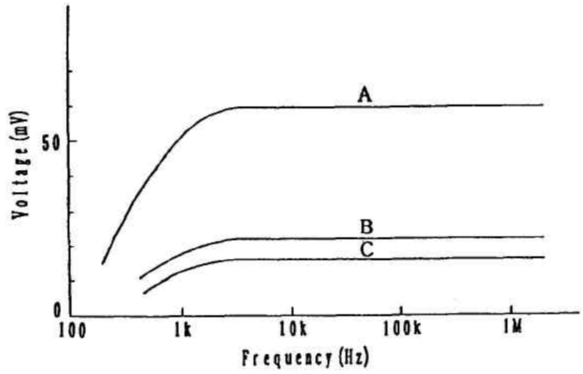

Figure 4. Frequency response characteristics of a human body

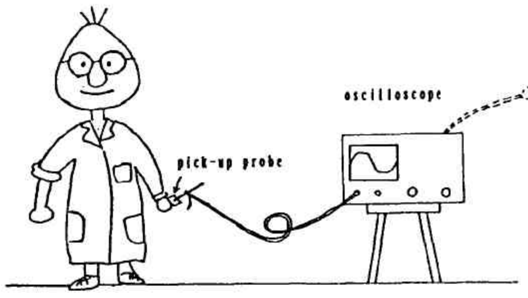

Figure 5. Arrangement of the experiment

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.

Experimental

Arrangement of experiments. The arrangement of experiments is simple and it is illustrated in Fig. 5. It was formed of a metal plate, a copper plate with a size of 20X20X0.5 mm^3 which was electroplated with platinum. This works as the pick-up probe. Two kinds of oscilloscopes were used for the measurements: one, which was driven by the 50Hz normal power line, is from Kikusui Co., model DSS5020A, and the other, driven by a battery, is Kikusui COM3051. Both had the storage function of the electromagnetic waves. The reason why the latter-type of oscilloscope was adopted is that the output of the normal oscilloscope carried a fairly large contribution of the line of the power supply. A recorder, Ohkura DR1200 and a graphics plotter, YHP 7550A, were also utilized for the recording of the output. A signal analyzer, Iwatsu SM2100C, was used for the analysis of the Fourier components of the signal.

Two different configurations were examined in the measurement. In the first configuration, the oscilloscope was placed on the desk and the human stood in a position close to the desk facing the oscilloscope. In the actual measurement, the plus terminal of the probe of the normal oscilloscope was connected to the pick-up probe which was placed on the palm of the human, and the minus terminal was set free not touching anywhere. It is assumed that the output of the oscilloscope in the first configuration refers to the voltage between the human and a point in space close to the human. In the second configuration a battery-driven oscilloscope was adopted. The oscilloscope was hung on the shoulder of the human by a belt. The arrangements of the connection of the probe was the same as in the case of configuration 1.

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.

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