HUMAN BODY IMPEDANCE FOR CONTACT CURRENT MEASUREMENT IN JAPAN

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Abstract: The radio-frequency protection guidelines of Japan recommend the limits of contact current for contact hazard due to an ungrounded metallic object under an electromagnetic field in the frequency range from 10 kHz to 15 MHz. To arrange the standard measurement methods of contact current in Japan, the contact body impedance for the Japanese in the frequency range from 75 kHz to 15 MHz is obtained, and the simplified equivalent circuit is determined using nonlinear least squares method. In addition, the human body impedance is obtained from numerical simulation using the impedance method and voxel human model, and compared with measured one.
Key words: contact current, equivalent circuit, impedance method

1. Introduction

In recent years, it has been concerned the potential hazard to human health due to exposure to electromagnetic fields. The direct effects that EM wave radiated from broadcasting stations, base stations of cellular phone and its terminals give directly to human body has been regulated by the enforcement standardization of radio-frequency protection guidelines (RFPG) in many countries. On the other hand, the countermeasure for the indirect effect is insufficient.

For example, RFPG of Japan recommends the limits of contact current for contact hazard due to an ungrounded metallic object under an electromagnetic field in the frequency range from 10 kHz to 15 MHz. However, because the standard measurement methods of contact current have not been recommended yet, the contact current clauses are not adopted as enforcement standards. To arrange the standard measurement methods of contact current in Japan, the measuring of the contact body impedance for the Japanese and the determination of the equivalent circuit are required.

Kanai et al.[1] have reported on the measurement of the contact body impedances in 1984. By following their reports, we have obtained the contact body impedances for eight Japanese adult male in the frequency range from 75 kHz to 15 MHz, and have determined the simplified equivalent circuit using nonlinear least squares method[2][3]. In this report, we add the measurement of the contact body impedances of adult female and children, and compare them with the adult male's. Moreover, to confirm the measurement results, we obtain the human body impedance from numerical simulation using the impedance method and voxel human model.

2. Impedance Measurements

2.1 Materials and Methods

The contact body impedances of eight adult male, five adult female and fourteen children subjects were measured.

Impedances in the frequency range from 75 kHz to 15 (or 10) MHz were measured with an Agilent 4285A Precision LCR Meter. The electrodes which we used were a brass rod of 1.5-cm diameter and a square copper plate of 1.4 cm^2 in the area.

The subjects stood barefoot on a ground plane made of a sheet of aluminum, and their hands were moistened with 0.9-percent physiological solution.

Fig.1 shows the situation of the contact body impedance measurement when grasping contact.

Fig.1 Measurement scenery of contact body impedance (grasping contact)

2.2 Measurement Results

The frequency dependences of averaged contact body impedance of adult subjects are shown in Fig.2. The circles represent the contact body impedance when the finger comes in contact with the square plate, and the squares are that in grasping the rod electrode. The gray plots are male's data, and white plots are female's.

The frequency dependences of averaged contact body impedance of child subjects are shown in Fig.3. The gray plots are data of less than five-year-old, and white plots are from five to nine-year-old.

It is found that the difference of the contact body impedance by the age and the sexuality is not so large.

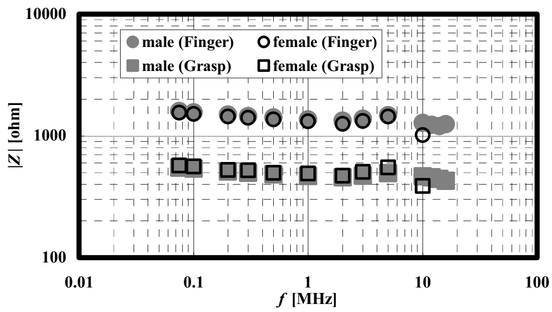


Fig.2 Frequency dependence of contact body impedance for adult male and female

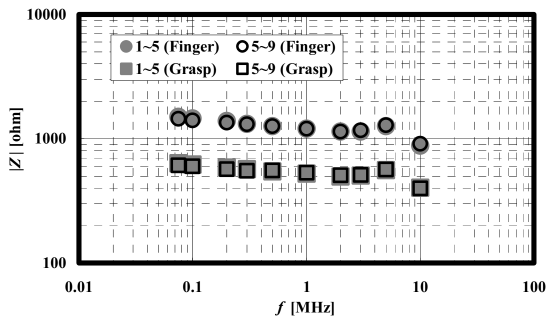


Fig.3 Frequency dependence of contact body impedance for children (1~5 and 5~9)

2.3 Equivalent Circuit

Kanai et al.[1] obtained simplified equivalent circuit of body impedance from the measurement results according to the handy procedure. It was difficult to match reactance though resistance was matched well in their methods. Therefore, we determine the equivalent circuit using the nonlinear least square method. Electrode and skin impedance, and spread resistance is used the same values of Kanai et al. Though their circuit includes a variable resistor depended on the frequency, it is not convenient for measuring the contact current. We have improved the circuit with the same frequency dependence using only constant elements. The time constant circuit for muscle is omitted because its beta-dispersion frequency is outside the measuring range of our experiments. Stray capacitance between body and ground is assumed to be 60 pF. Fig.4 shows the equivalent circuit that we obtained.[3]

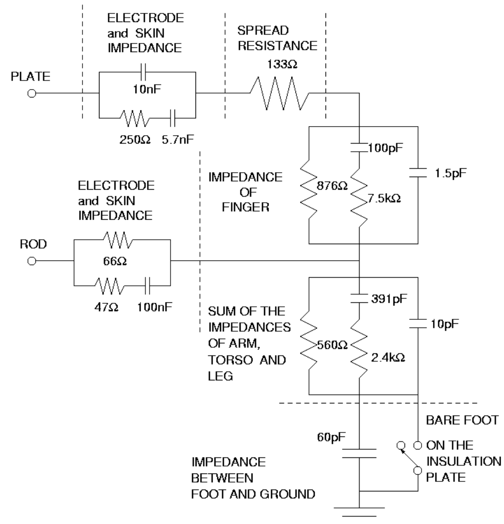
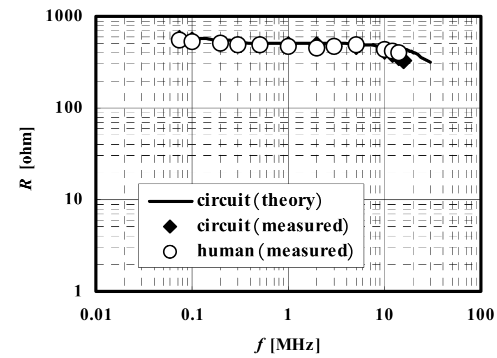
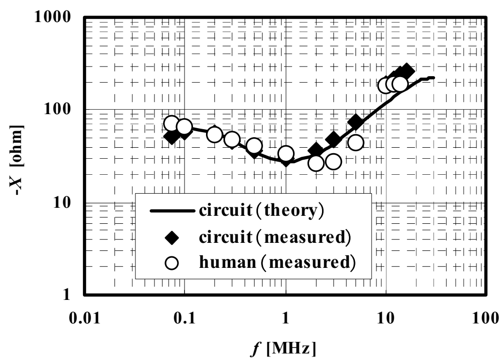


Fig.4 Simplified equivalent circuit for contact body impedance (75 kHz ~ 10 MHz, adult male)



(a) Resistance



(b) Reactance

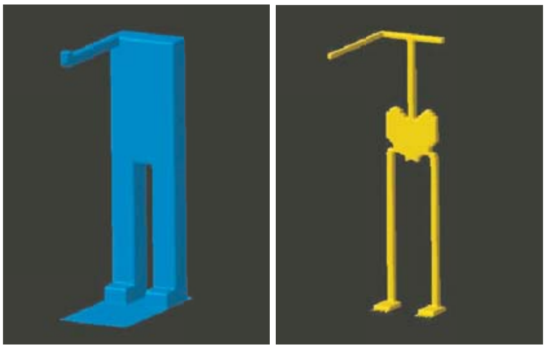
Fig.5 Comparison of human impedance for grasping contact

The frequency dependence of impedance of the equivalent circuit for grasping contact is shown in Fig.5. Solid line represents impedance calculated theoretically, and black diamonds are measurements of the circuit impedance. White circles are measurements of the contact body impedance. In the frequency range from 75 kHz to 15 MHz, the circuit impedance agree with the human body's well.

Notes that this circuit do not simulate frequency dependence from 10 to 75 kHz. Because this equivalent circuit has been determined by data of eight specific Japanese adult men, it is necessary to accumulate more data.

3. Simulation

In the measurement of the human body impedance, the value is disturbed due to subject's individual difference and the contact situation with the electrode. Therefore, we try to confirm it using the computer simulation. The impedance method is used for the electromagnetic field simulation in the low frequency range.



(a) shape of body (b) skeleton

Fig.6 Simple voxel model of human body for grasping contact

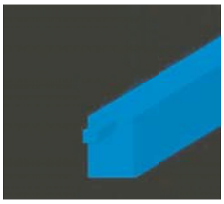
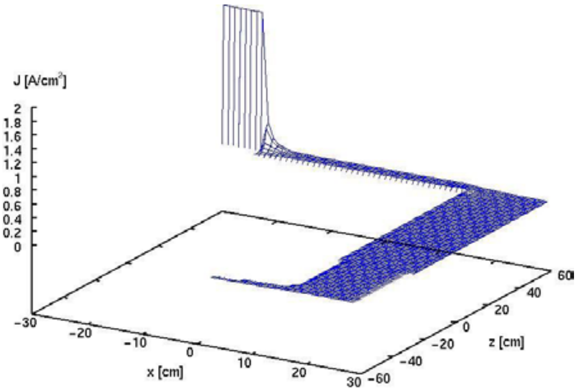


Fig.7 Voxel model of right hand for finger contact

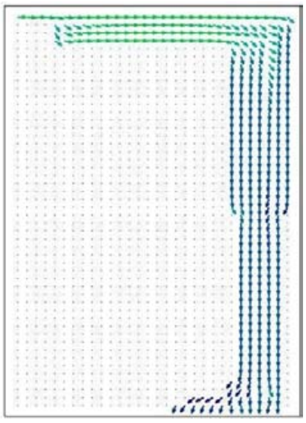
Figs.6 and 7 show the simple voxel model of human body which we used. The size of the cell is 1 cm. The head and the left arm are omitted. The contact situation with the metallic object assumes the finger contact. It is assumed that this model consists of the bone and the mixture of 1:1 of muscle and blood. Conductivity of each tissue is quoted from Gabriel's report[4].

Fig.8 shows the current density distribution obtained by the impedance method, where the injection current is 2 ampere. It is found that the current has concentrated on the tip of a finger.

According to the result of Fig.8, the impedance is calculated by obtaining complex voltage drop from the tip of a finger to the ground, and dividing it by the injection current.



(a) magnitude



(b) direction

Fig.8 Current density distribution (finger contact)

Figs.9 and 10 show the frequency dependence of impedances. White circles are measurement values of contact body impedance, gray diamonds are values obtained from the impedance method, and the solid line is the measured value of the impedance of equivalent circuit. Triangle are measured values of Ref.[1]. In the range of frequency 1 MHz or less, the simulated values and measurements are corresponding very well. On the other hand, in the range of frequency 1 MHz or more, the trend of frequency dependence of simulation values is similar to measurements of Kanai et al. The cause might be presence of the inductance of the lead wire.

4. Conclusion

The human body impedance of 27 Japanese subjects (eight adult male, five adult female and fourteen children) from the frequency 75 kHz to 15 (or 10) MHz was measured. According to these results, a simple equivalent circuit (for adult male) is determined.

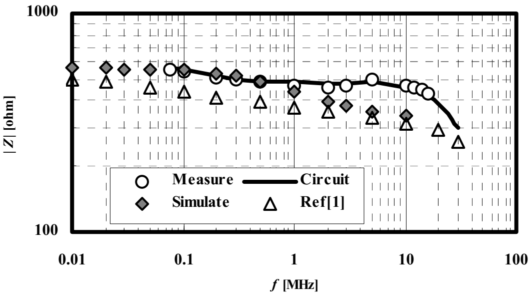


Fig.9 Frequency dependence of contact body impedance for grasping contact

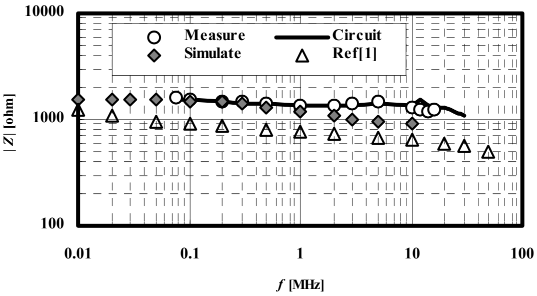


Fig.10 Frequency dependence of contact body impedance for finger contact

The experiment in the range of the frequency from 10 kHz to 75 kHz, and the construction of the equivalent circuit excluding effects of the lead wire are present problems. To obtain a standard equivalent circuit of the contact body impedance, we should acquire subject's more data by using a high-speed measurement technique.

We have obtained the human body impedance according to the computer simulation, and compared it with measurements. If we use a more realistic human model, we will be able to obtain an exact finding for human body impedance.

We are producing a prototype of the contact current meter based on current findings.

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