THE MEASUREMENT OF THE EFFECT BETWEEN SHIELDING MATERIAL AND THE SURFACE OF THE REALITY PHANTOM MODEL

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ABSTRACT

We selected a type of shielding sheet and made shielding clothes. Then, we measured the Shielding Effectiveness (*SE*) of a human phantom model that was dressed in the shielding clothes. The measured *SE* for the phantom model with physiological saline and for the phantom model without physiological saline should be close. But the results are different. Therefore, we calculate the effect of the air-gap that exists between the shielding clothes and the human phantom model. From the results of the calculations, we found that the air-gap is 25 mm based on the *SE* from the multiple reflection of the waves. For the case of the distance from the transmitter to the surface of phantom model being 50mm, the *SE* is 3.8 dB, and for the case of the distance from the transmitter to the surface of phantom model being 220 mm, the *SE* is 4.9 dB. Then, we calculate these effect by using the multi-layered model.

INTRODUCTION

Recently, the use of electric devices such as personal computers and mobile phones has dramatically increased in the electronics, information, and communications areas. But these electric devices emit electromagnetic waves, and the waves leaking from some electric devices may have some influence on the human body. In this research, we focus on the electromagnetic shielding for someone who has a pacemaker. There are many types of pacemakers sold commercially that either are pacing from outside the body or are embedded in the body. We focus on the embedded models and the attenuation they require to eliminate electromagnetic waves that come from other places.

In this research, we first measured the Shielding Effectiveness *SE* of several types of shielding sheets, and then we selected one sheet. There was no change in *SE* through the sheet washed. Using this sheet, we made 5 types of shielding clothes. Finally, we evaluated the shielding clothes from calculation and measurement of the *SE*. For calculating the electromagnetic field, we used a multi-layered model that used the Sommerfeld integral that express the spherical waves by a composition of cylindrical waves [1].

MEASUREMENT OF SHIELDING EFFECTIVENESS

Shielding Effectiveness

For evaluation of the attenuation of electromagnetic waves, we usually use the Shielding Effectiveness (*SE*). *SE* is defined as the ratio (expressed in dB) of electric field strength at the observation point without a material (E_0) to that with a material (E_1). *SE* is defined as shown below:

$$SE = 20\log_{10}\frac{|E_0|}{|E_1|} \qquad \text{[dB]} \tag{1}$$

We measured the electric field *SE* for the case of near-field (TR17301A) and far-field (TR17302) by using the Advantest method [2]. We measured the *SE* of some types of materials, and we selected a shielding sheet. The sheet is made from polyester and plated copper (Cu) and nickel (Ni). The thickness is 0.22 mm in average. The *SE* for near-field was 15.3 dB and for far-field was 26.2 dB at 900 MHz.
Next, using this sheet, we made five types of shielding clothes as shown in figs. 1 to 5. Type A in fig. 1 has a crew neck and long sleeves. Type B in fig. 2 has a collar and long sleeves. Type C in fig. 3 has a turtleneck and long sleeves. Type D in fig. 4 has a crew neck and no sleeves. Type E in fig. 5 has a crew neck and short sleeves. These are the characteristics of the clothes which we made. Using these clothes, we measured the *SE* inside of the human phantom model that was dressed with the shielding clothes (ε_r=1, μ_r=1, σ=5.3 $\times$ 10^4 [S/m]) [3].

Table 1: The *SE* of 50 mm points and 220 mm points

Cloth type	Non-saline		With saline		Difference	
	50 mm	220 mm	50 mm	220 mm	50 mm	220 mm
A	27.2 [dB]	15.9 [dB]	43.6 [dB]	37.6 [dB]	16.4 [dB]	21.7 [dB]
B	27.4 [dB]	29.1 [dB]	39.9 [dB]	30.6 [dB]	12.5 [dB]	1.5 [dB]
C	28.1 [dB]	27.4 [dB]	40.9 [dB]	34.3 [dB]	12.8 [dB]	6.9 [dB]
D	25.4 [dB]	18.0 [dB]	38.8 [dB]	37.7 [dB]	13.4 [dB]	19.7 [dB]
E	26.3 [dB]	15.8 [dB]	42.6 [dB]	40.2 [dB]	16.3 [dB]	24.4 [dB]

Measurement of the *SE* using the human phantom model

There are many phantom models available commercially. For measurement, we used a woman lay model. We drilled through the surface and waterproofed the inside of the model. This phantom model was made of FRP and filled with physiological saline (ε_r=49, μ_r=1, σ=0.9 [S/m]) [4]. If the human phantom model itself has a *SE*, we can not measure the true *SE*. Therefore, we measured the near-field *SE* and far-field *SE* of the phantom model at 900MHz using Advantest methods. The phantom model structure had no influence on the measured value of *SE*. Therefore, we can ignore the thickness of the phantom model.
Our *SE* measurement setup is shown in fig. 6. For measurement, we used a dipole antenna with a length of 171 mm for the transmitter and a length of 40 mm for the receiver, and the emitted frequency was 900 MHz. The receiver was located at the position (under a breast) of the current line of a pacemaker inside the phantom model. We measured in a shield room and wave absorber was pasted over all the walls. We used a spectrum analyzer (Advantest, R3361B) whose Tracking Generator (TG) output (1mW) was connected to the transmitter (Schwarzbeck, UHF9105). The receiver was connected to the 30 dB pre amp (Advantest, R14601) and that was connected to the input of the spectrum analyzer.
We changed the distance from the inside surface of the phantom model to the transmitter, and we measured *SE* for the cases of the distance d being 50 mm and 220 mm. The reasons for which we chose 50 mm and 220 mm are that 50 mm is near-field, 220 mm is far-field, and the guidance for using a mobile phone near a pacemaker. At first we measured the *SE* of a non-physiological saline model, and then we filled the phantom model with physiological saline. The results of the measured *SE* using the five types of clothes are shown in table 1. The average of the non-physiological saline model of *SE* at the near-field point was 26.9 dB, and for the case of the far-field point was 21.2 dB. The average of the physiological saline filled model of *SE* at the near-field point was 41.2 dB, and for the case of the far-field point was 36.1 dB. The difference between the non-physiological saline model and the physiological saline model at the near-field point is 14.3 dB. For the case of the far-field point the difference is 14.8 dB. *SE* is the amount of interception of the electric field, and the values should be close to 0 dB under normal circumstance. But the difference is about 15 dB. Therefore, we confirmed this result with numerical calculations using a multi-layered model.

CALCULATION OF ELECTROMAGNETIC FIELD

In calculating an electromagnetic field, we have to consider the location of the observation point, because the calculations of an electromagnetic field for a near-field point and that for a distant point are quite different. For an electric dipole, the electromagnetic field is expressed by eq. (2) and eq. (3) by using a Hertz vector $\boldsymbol{\Pi}$.

Eq. (4) shows the Hertz vector $\boldsymbol{\Pi}$ related to the electric dipole.

$$E = \nabla\nabla \cdot \boldsymbol{\Pi} + k^2\boldsymbol{\Pi} \tag{2}$$

$$H = j\omega\varepsilon\nabla \times \boldsymbol{\Pi} \tag{3}$$

$$\boldsymbol{\Pi} = \frac{Il}{j4\pi\omega\varepsilon}\frac{e^{-jkR}}{R}\boldsymbol{i}_z \tag{4}$$

Here E is the electric field, H is the magnetic field, k is wave number, j is complex, ω is angular frequency, ε is dielectric constant, I is the current, l is the antenna length, R is the distance from the source, and $\boldsymbol{i}_z$ is the unit vector of z. For numerical analysis, we use the same parameters as used for the measurements. We can calculate the electromagnetic field by applying the continuity of the H_r and E_θ component to eqs. (2) and (3), where the x–y plane is the horizontal element in Cartesian coordinates.

The coordinate system of the multi–layered model which we use to calculate the electromagnetic field is shown in Fig. 7. A electric dipole source is assumed at $z = h$ with homogeneous layers above and below the dipole extending to infinity in the horizontal directions. The axial direction of the dipole source is located vertically perpendicular to each layer. The Hertz vector for the up–going wave is expressed as $\boldsymbol{\Pi}_i^u$, the Hertz vector for the down–going wave is expressed as $\boldsymbol{\Pi}_i^d$, and the Hertz vector for the direct wave is expressed as $\boldsymbol{\Pi}_0^p$, where the subscript i indicates the layer.

EVALUATION OF THE LENGTH OF THE AIR-GAP

For calculation, we assumed the source to be an electric dipole. Each homogeneous layer extends to infinity in the horizontal direction, so we can express the electromagnetic field with the Sommerfeld integral. The multi-layered modeling of the phantom model is shown in fig. 8. The right side of fig. 8 is the phantom model dressed in a shielding cloth. The phantom model has an air-gap between the shielding cloth and the inside surface of the phantom model at under the breast (We can assume the phantom model to be free space). Therefore, we modeled the dressed phantom model as shown in the circle on the left side of fig. 8. We assumed the distance from the source to the surface of the shielding cloth is 25 mm. This distance is the same as for the measurement setup. The thickness of the shielding cloth is 0.22 mm. For calculating the electromagnetic field, we used the electric parameters that were estimated in section 3. Fig. 9 shows the relation of the length of an air-gap and *SE*. In fig. 9, d expresses the distances from the source to the inside surface of the phantom model, that is 50 mm and 220 mm. For calculation, we vary the length of the air-gap from 0 mm to 50 mm. From this figure, we found that as the length of the air-gap becomes larger, the *SE* becomes larger. For the case of the length of air-gap being 25 mm which is the same as the experimental setup, the multiple reflection wave effect is 3.8 dB in the situation d=50 mm, and the multiple reflection wave effect is 4.9 dB in the situation d=220 mm.

The results from the calculations showed us that the reason for the difference was due to the effect of multiple reflected waves between the shielding sheets and the phantom model. In fact, we used a female phantom model, and the shielding cloth and the surface of the phantom model were not connected at the point under the breast. The air-gap between the cloths and the phantom model affect strongly the *SE*, and as the length of the air-gap becomes larger, the *SE* becomes larger. Electromagnetic waves coming from the cloth neck opening are one of the reasons the measured value of *SE* and the calculated value of *SE* are different.

CONCLUSION

In this research, in order to suggest the electromagnetic shielding cloth for a pacemaker holder, we measured the *SE* and calculated the *SE*. At first, we selected a type of shielding sheet and made five styles of shielding clothes. These clothes have several shapes. We measured the *SE* using a human phantom model that was dressed in the shielding clothes for the cases of without physiological saline and with physiological saline. *SE* is the amount of interception of the electric field, and the values should be close to 0 dB under normal circumstances. But the difference is about 15 dB. Therefore, we calculated the *SE*, and we tried to find the relation between the air-gap and the *SE*. From the results of the calculations, we found that as the length of the air-gap becomes larger, the *SE* becomes larger. Using our methods, we easily found the relation of the air-gap and the *SE*. The results of our measurements and calculations show that we can avoid the risk of electromagnetic waves that come from other places by using the shielding clothes.

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FIGURES

Figure 1: Type A

Figure 2: Type B

Figure 3: Type C

Figure 4: Type D

Figure 5: Type E

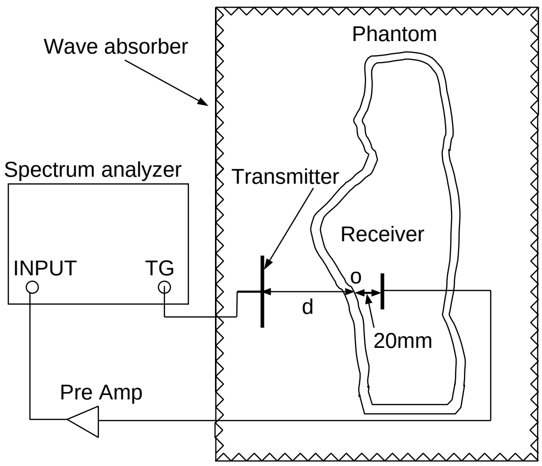

Figure 6: The measurement setup

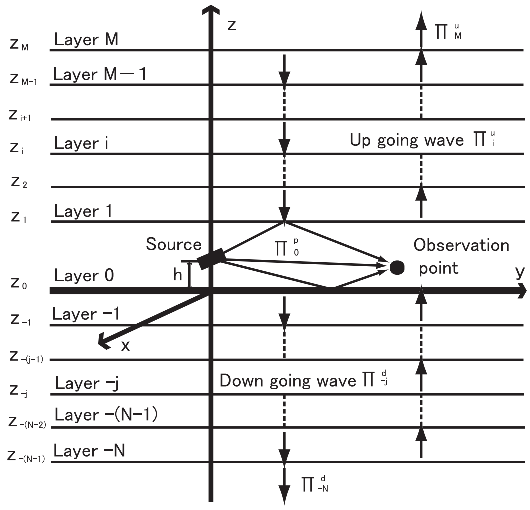

Figure 7: Multi–layered model.

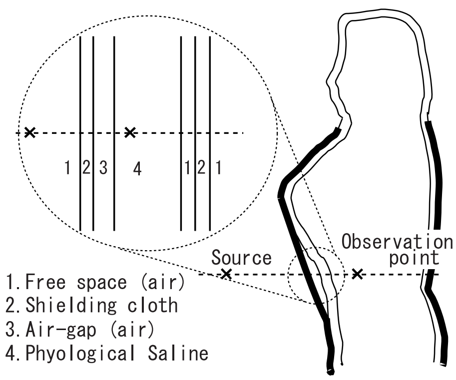

Figure 8: Multi-layered modeling

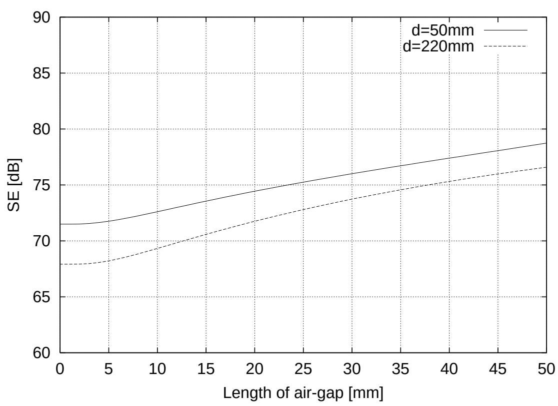

Figure 9: The length of air-gap VS *SE*