Study on Propagation Loss Through Human Body for Wireless Capsule Application

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***Abstract* – The transmission factor of a dipole to dipole and a loop to loop through homogenous human muscle equivalent material is investigated using the FDTD analysis. The transmission factors of the dipole system and the loop system are compared and the optimization of antenna type and the optimal frequency is also discussed. In the case of dipole system, a local maximum of transmission factor is observed at frequency domain. In the case of loop system, the transmission factor decreases as frequency increases monotonously. The transmission factor of loop system is larger than that of the dipole system in the low frequency region, while the performances of both two systems are almost the same in the high frequency region.**

***Keywords* — Capsule antenna; propagation loss; frequency dependence; dipole system; loop system**

I. Introduction

Ingestible capsule antenna systems are expected for healthcare applications [1]. Because the maximum ingestible size of a capsule is very small, the frequency dependence on the transmission characteristics is very important for high data rate communications and high efficiency power transfer through human body.

It is a challenge to increase power transfer efficiency through human body. Transmission factor of a dipole to dipole system was evaluated as an indicator of propagation loss through human boy in previous study [2]. However, it is important to evaluate the maximum received power not only in a dipole to dipole system but also in a loop to loop system. To obtain the maximum received power, the conjugate matching condition in both transmitting and receiving antennas was performed [3, 4].

In this report, the transmission factors of a dipole system and a loop system through a homogeneous material with the same relative permittivity and conductivity as the muscle are studied to demonstrate the frequency dependence on the transmission characteristics for wireless capsule application.

II. Analysis model

A human torso-shaped phantom developed by SPEAG [5] was used as the container of material is shown in Figure 1. Frequency dependent relative permittivity and conductivity of muscle provided by ITIS [6] was filled in the torso-shaped phantom. Two types of antennas, dipole antennas and loop antennas, were used to obtain general conclusions. A wire dipole antenna with a length l_1 and a rectangular loop antenna with a total length L_1 were located in the position of (x_1, y_1, z_1) inside the phantom as the transmitting antennas, separately. The antennas were enclosed by the rectangular column capsule. Dimension of the rectangular column capsules are with length of 30 mm and width of 10 mm. To simplify the investigation, relative permittivity of capsule is set as the air (ε_r=1). A wire dipole antenna with a length l_2 and a rectangular loop antenna with a total length L_2 were located in the position of (x_2, y_2, z_2) outside the torso-shaped phantom as the receiving antennas. In the analysis, the FDTD (Finite-Difference Time-Domain) method was used with considering the dispersive effect. The transmission factor proposed in [4] was used as an indicator of propagation loss.

III. Results and Analysis

Figure 2 shows the transmission factors through torso-shaped phantom. In the case of dipole system, it was found that there is a local maximum at frequency domain, a large value of τ=-25.4 dB was obtained at 495 MHz, corresponding to the half-wavelength resonant frequency ($l_1=\lambda_g/2$) of dipole antenna in human muscle material. In the case of loop system, the transmission factor decreases as frequency increases monotonously, a large value of τ=-13.1 dB was obtained at 80 MHz. This phenomenon is caused by the strong magnetic-coupling between two loop antennas in the near-field region, while this phenomenon was not appeared between two dipole antennas. It is considered that loop system is preferred to realize high efficiency power transfer in the low frequency range, while the transmission factors of both the dipole system and the loop system are almost the same in the high frequency range.

To confirm the phenomena in Figure 2, it is important to consider the transmission factors through torso-shaped phantom under the condition that the transmitting antenna and the receiving antenna are located in an offset position. Figure 3 shows the transmission factors when the position of transmitting antenna is offset from the receiving antenna in the $-z$ direction with the offset value d. Two frequencies of 80 MHz and 402 MHz were observed as lower and higher frequency. The transmission factor decreases as d increases in a broadband frequency range. In the case of 80 MHz, it is found that the transmission factor of the loop system is larger than that of the dipole system, while the transmission factor is reduced in the range of d=30 mm to d=90 mm. In the case of 402 MHz, the transmission factor of the dipole system is almost the same as that of the loop system and the results in Figure 2 are confirmed.

IV. Conclusion

The transmission factors of a dipole system and a loop system through a homogenous human body phantom were compared by the numerical analysis. In the case of dipole system, a local maximum of transmission factor is observed at frequency domain. In the case of loop system, the transmission factor decreases as frequency increases monotonously. The transmission factor of loop system is larger than that of the dipole system in the low frequency region, while the performances of both two systems are almost the same in the high frequency region.

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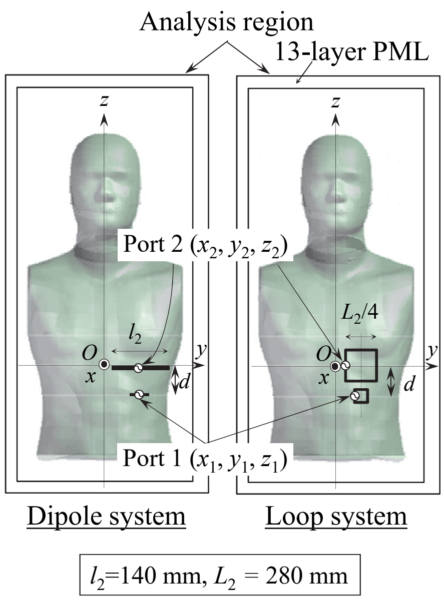


Fig. 1. Analysis model.

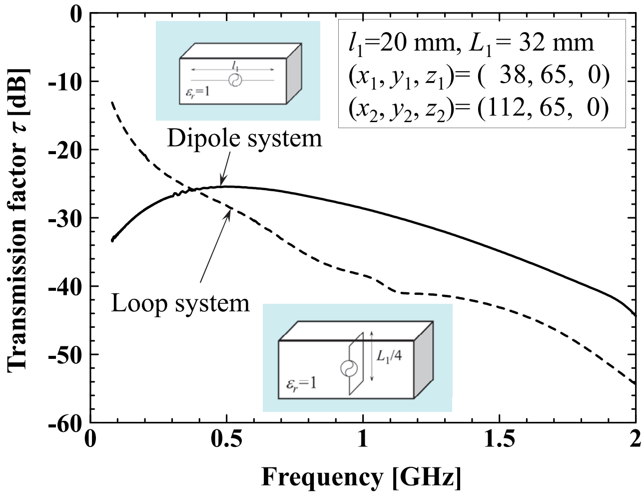
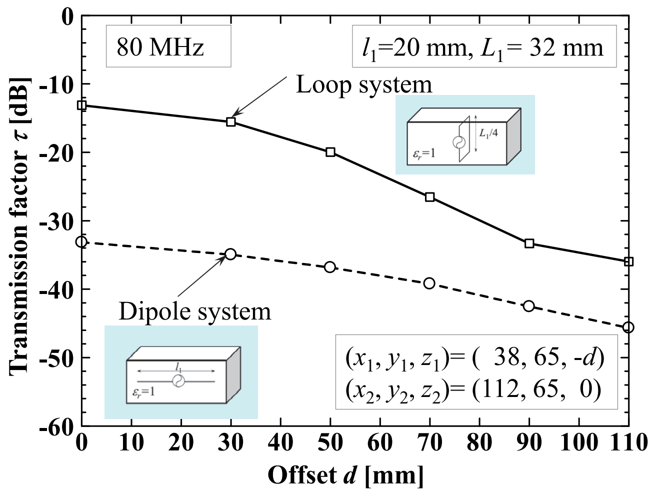
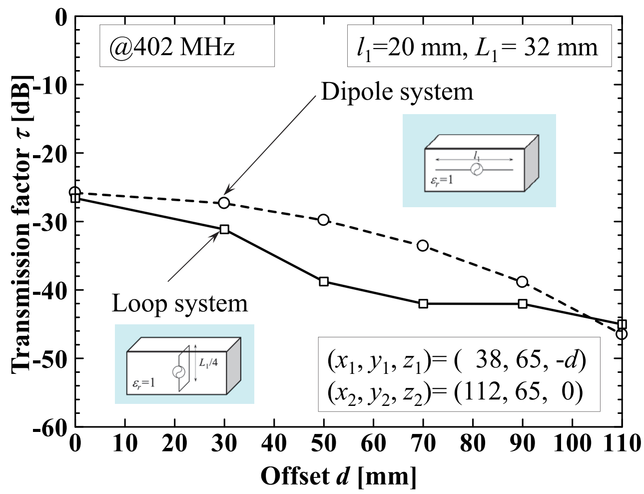


Fig. 2. Transmission factors of dipole system and loop system.



(a) 80 MHz



(b) 402 MHz

Fig. 3. Transmission factors between two antennas when position of transmitting antenna is offset from the receiving antenna in the –z direction.