Experimental Study of Transmission Factor Through Conducting Human Body Equivalent Liquid

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Abstract – **The transmission factor from a 20 mm dipole antenna immersed in the human body equivalent liquid (HBEL) and the deionized water to the outside are investigated using the FDTD analysis and the measurement. Both calculated and measured transmission factor using the mixed-mode S-parameter method are shown good agreement. It is observed that the transmission factor increases as the frequency decreases in case of the water but there is a peak value in the frequency characteristics of transmission factor in case of HBEL. It is found that the input resistance under the conjugate matching condition increases as the frequency decreases only in the case of highly conducting HBEL and the optimum frequency appears.**

Index Terms — **Capsule endoscope, Conjugate matching condition, Transmission factor, Dipole antenna.**

1. Introduction

Ingestible capsule endoscope systems are expected for healthcare applications [1]. Maximum ingestible size of a capsule endoscope are with the length of around 20 mm and the selection of the operating frequency and the evaluation of the maximum received power through a conducting human body are quite important for high data rate communications.

Recently the wireless power transfer (WPT) system has been studied by many researchers. WPT system realizes quite small power transmission loss using the near-field coupling between transmitting and receiving antennas. In order to maximize the received power, the conjugate matching condition in both transmitting and receiving antenna systems were performed and the transmission factor was evaluated [2].

In this report, the transmission factor from a dipole antenna immersed in a homogeneous conducting liquid as a human body equivalent liquid (HBEL) phantom and a receiving antenna outside has been studied by the measurement and the numerical analysis. Input impedances under the conjugate matching conditions in cases of both HBEL and the deionized water were compared in order to explain why the transmission factor has a peak value only in the case of highly conducting HBEL.

2. Analysis and Experimental Setup

The torso shape phantom as a container of liquids is shown in Fig. 1. The deionized water and the human body equivalent liquid (HBEL) with temperature of 18°C are filled in the torso phantom. The origin of coordinates was located at the top of a torso phantom. A y-polarized transmitting dipole antenna with the length of l_1=20 mm was located in the position of (x_1, y_1, z_1)=(38, 65, -540) and a y-polarized receiving antenna with the length of l_2=140 mm was located in the position of (x_2, y_2, z_2)=(112, 65, -540). The FDTD method was used with considering the dispersive effect of liquids. Fig. 2 shows the relative permittivity and the conductivity of both deionized water and HBEL measured by using the coaxial probe method. In order to obtain S-parameters in broadband frequency range, the mixed-mode S-parameter method [6] with 4-port VNA N5224A was used.

3. Results

Fig. 3 shows the transmission factor τ when a torso phantom was filled with the deionized water or HBEL. Almost good agreements between calculated and measured values were observed. In the case of deionized water, τ increases as frequency decreases. Only in the case of HBEL with higher conductivity compared with the deionized water, a peak value with level of -25.3 dB was observed at 675 MHz corresponding to the half-wave resonance ($l_1=\lambda_g/2$) of transmitting dipole antenna. Fig. 4 shows the input impedance of transmitting dipole antenna in case of the deionized water and HBEL. It is observed that resistance increases as frequency decreases only in the case of HBEL. From the maximum power transfer theorem, the input power is expressed as $P_{in}=V^2/4R_{in}$ under the conjugate matching conditions of $Z_s=Z^*_{in}$ and $Z_L=Z^*_{out}$ and it is considered that large R_{in} cause to the small value of transmission factor in lower frequency range. Fig. 5 shows the calculated τ when the length of transmitting antenna changes as l_1=20 mm, 54 mm and 140 mm. The half-wavelength resonant frequencies corresponding to each length were observed and high τ has been obtained as the length of antenna increases. However, the length of transmitting antenna is limited around 20 mm for a capsule endoscope and the maximum transmission factor will be considered around -25 dB.

4. Conclusion

The transmission factor from a 20 mm transmitting antenna to a receiving antenna was investigated in a homogenous conducting liquid phantom. It is observed that there is a peak value of transmission factor corresponding to the half-wavelength resonant frequency in case of highly conducting liquids such as human body tissues.

Acknowledgment

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References

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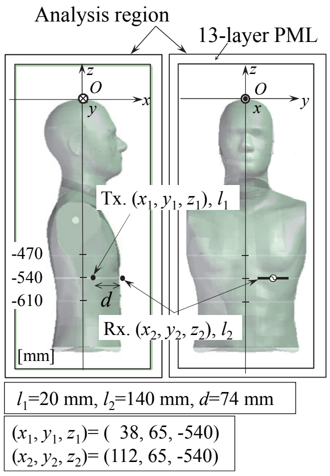


Fig. 1. Analysis model.

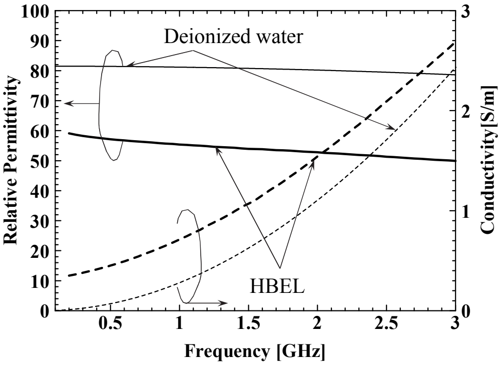


Fig. 2. Relative permittivity and conductivity of deionized water and HBEL.

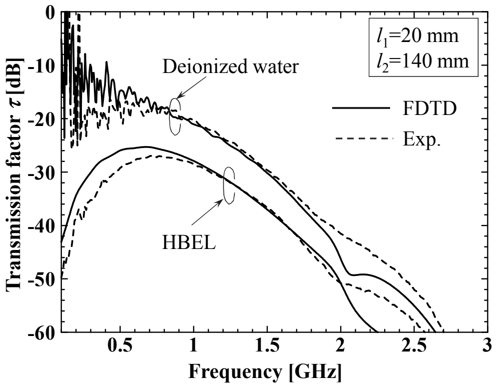
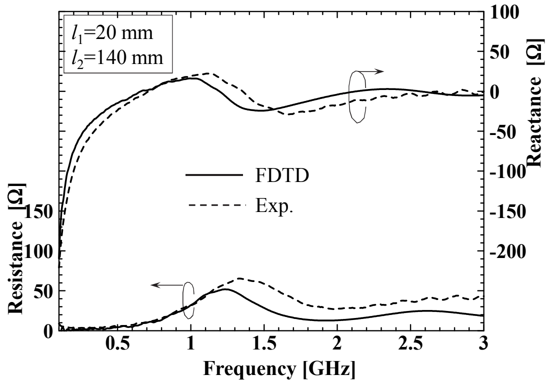
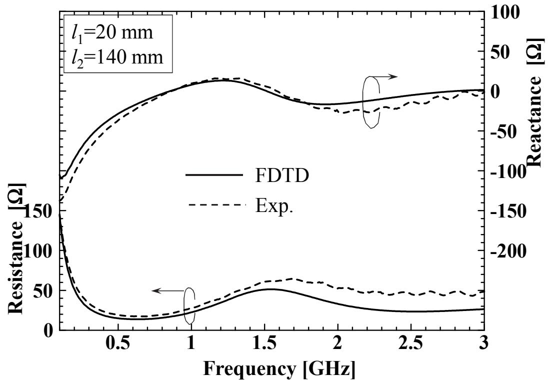


Fig. 3. Transmission factor.



(a) Deionized water.



(b) HBEL.

Fig. 4. Input impedance Z_{in}.

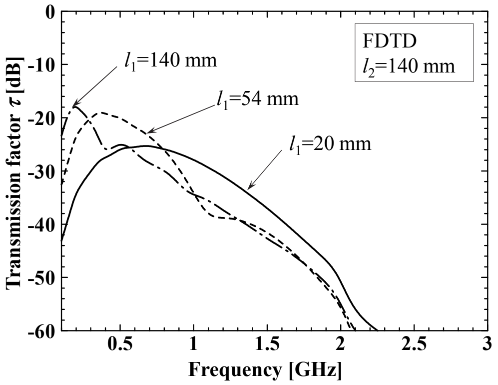


Fig. 5. Calculated transmission factor by changing length of transmitting antenna as l_1=20, 54 and 140 mm.