FDTD Analysis of Capsule Dipole Antenna In Digestive System of Human Body

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Abstract - **The transmission factor from a capsule dipole antenna located in a digestive system of human body to the outside are investigated using the FDTD analysis. It is found that the peak values of the transmission factor are observed in a frequency range of 400-600 MHz for different organs of digestive system. High received power was obtained when a transmitting antenna and a receiving antenna have the same polarization. Received power was compared with different impedance matching conditions.**

Index Terms — **Capsule endoscope, Dipole antenna, Digestive system, Transmission factor, Polarization.**

1. Introduction

Ingestible capsule endoscope systems are expected for healthcare applications [1]. The capsule endoscope pass through the digestive system of a human body composed of the esophagus, the stomach, the small intestine and the large intestine. In the previous work, the path loss through a human body has been studied by some researchers and many kinds of path loss expression were used [2-3]. The surrounding dielectric permittivity and conductivity changes as the capsule pass through the digestive system and the characteristics of the path loss changes. The size of antenna compared with the wavelength of operating frequency also changes from moment to moment. However, few researches are focus on the received power from a capsule dipole antenna located in different parts of the digestive system.

In this report, the transmission factor [4] was used as the path loss and was evaluated with changing the organs of a digestive system. Furthermore, the capsule dipole antennas with different impedance matching conditions including the conjugate matching conditions were compared.

2. Analysis model

The FDTD analysis model of a human body developed by SPEAG was used which is constructed by using MRI images. It includes 76 kinds of organs and the relative permittivity and conductivity of each organs provided by ITIS [5] were used. The torso part of a human body was used in the FDTD analysis. Lumina of digestive system were filled with deionized water. The cross sections of an analysis model in *xz*-plane and *xy*-plane were shown in Fig. 1. The origin of coordinates was located at the top of the head. A transmitting dipole antenna (Tx.) with the length of l_1=20 mm was located at (x_1, y_1, z_1) in the digestive system of a human body and a receiving dipole antenna (Rx.) with the length of l_2=140 mm was located at (x_2, y_2, z_2) outside of a human body. The position of Tx. changes along the digestive system as z=-470, -540, -610 and -700 mm which corresponds to the cases when the Tx. was located the esophagus, the stomach, the small intestine and the large intestine. The FDTD method with considering the dispersive effect of complex dielectric permittivity was used for numerical analysis.

3. Transmission Factor Through Digestive System

An example of the conductivity distribution in *xz*-plane was shown in Fig. 2 (Left). The color indicates the magnitude of conductivity at 1 GHz. It is observed that the conductivity of the heart is larger than the other organs. When Tx. antenna passes through the esophagus, the polarization of Tx. antenna is considered vertical direction because its narrow structure, and polarizations of both Tx. and Rx. antennas were selected as z-direction. The position of Tx. antenna is (x_1, y_1, z_1)=(20, 0, -470) in the esophagus and two cases of the position of Rx. antenna located in front (x_2, y_2, z_2)=(112, 0, -470) and back (x_2, y_2, z_2)=(-116, 0, -470) of a human body, respectively, were calculated. The transmission factor τ of each case were shown in Fig. 2 (Right). The peak value of τ was observed at 600 MHz corresponding to the half-wavelength resonant frequency of Tx. antenna, while τ decreases as the frequency increases as the conductivity of surrounding organs increases. It is observed that higher τ in case when Rx. antenna is located back of a human body compared with the case when Rx. antenna is located front of a human body which will be considered that the heart with higher conductivity compared with other organs absorbs EM-wave.

When the capsule endoscope is in the stomach, the Tx. antenna will rotate and it is necessary to consider the polarization of Tx. antenna. An example of τ when Tx. antenna was located in the stomach was shown in Fig. 3. The polarizations of Tx. antenna in *x*, *y* and *z* directions were calculated at (x_1, y_1, z_1)=(20, 65, -540), while the polarization of Rx. antenna was settled in z-direction at (x_2, y_2, z_2)=(112, 65, -540). It is observed that relatively higher τ was obtained when the Tx. and Rx. antennas have same polarization.

A capsule container filled by air (ε_r=1) with the length of 30 mm and with the width of 10 mm was considered as shown in Fig. 4. In our previous work, it was found that the impedance matching to the internal impedance of 50 Ω is easy when a dipole antenna is located at the interface of a capsule compared with the case located inside a capsule [6]. Fig. 4 shows the received power under the three kinds of match conditions. (a) is the case when conjugate match conditions $Z_s=Z^*_{in}$ and $Z_L=Z^*_{out}$ are applied to the whole frequency band and (b) is the case when Z_S= 30.8+j435 Ω and Z_L= 4.65+ j42 Ω, optimum internal impedances at the frequency of 450 MHz, and (c) is the case when Z_L= Z_S= 50 Ω. It is observed that high received power of -25 dB was obtained in case (b) compared with the case (a). Cases when the capsule dipole antenna passes through the small intestine and large intestine were not shown in this report. However, it is found that the position of Rx. should be placed at the sides of human body in order to obtain high received power.

4. Conclusion

The transmission factor from a capsule dipole antenna located in the digestive system of a human body was investigated. It was found that the peak values of transmission factor were observed in a frequency range of 400-600 MHz for different organs of digestive system when the Tx. and Rx. antennas have the same polarization.

Acknowledgment

This work was partly supported by COI STREAM (Center of Innovation Science and Technology based Radical Innovation and Entrepreneurship Program) and by JSPS KAKENHI Grant Number 26289122.

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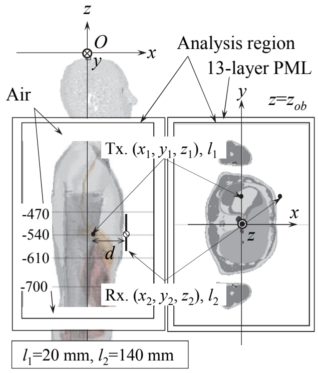

Fig. 1. Analysis model.

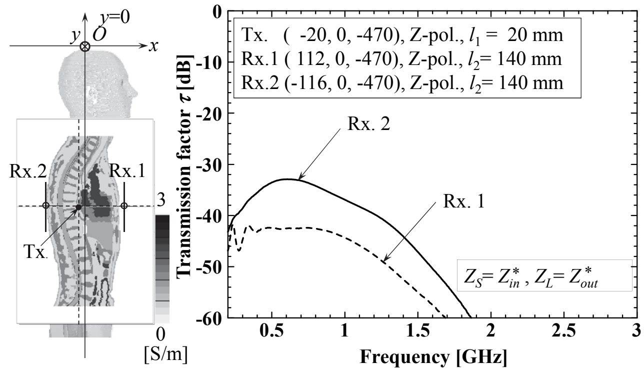

Fig. 2. Transmission factor when Tx. dipole antenna is located in esophagus.

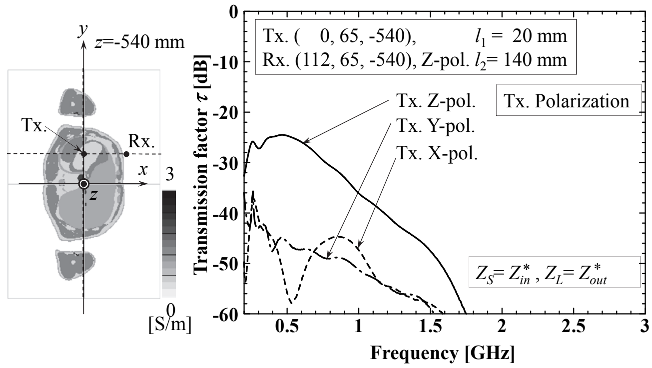

Fig. 3. Transmission factor when Tx. dipole antenna is located in stomach.

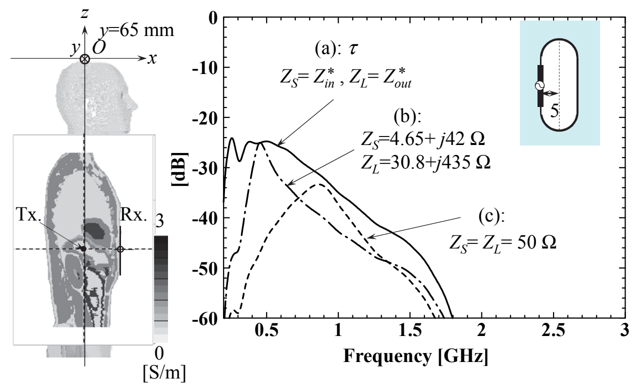

Fig. 4. Received power with different impedance matching conditions.