Measurement of Dipole Antenna in Deionized Water

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***Abstract*—Measurement result of dipole antennas in deionized water is compared with numerical analysis. The results of FDTD simulation and measurement are shown good agreement. Maximum transmission coefficient of -25 dB through the 74 mm thick deionized water was obtained.**

Keywords—ingestible, dipole; capsule endoscope; water

I. INTRODUCTION

Ingestible capsule endoscope systems is expected for healthcare applications [1, 2] and high efficiency antenna for capsule endoscope is studied by many researchers [3-5].

Generally, maximum ingestible size of a capsule endoscope are with the length of 20 mm and with the width of 10 mm [1], respectively, and it is considered that the efficiency of antennas has a limitation which is caused by the electrical size. Also the surrounding environment of a capsule changes as the capsule pass through various internal organs of a human body with different dielectric permittivity, and the size of antenna compared with the wavelength of operating frequency changes from moment to moment.

Furthermore, the absorption of electromagnetic waves by the internal organs is quite large and the transmitting power from a capsule antenna becomes quite week as frequency increase, which is caused by high conductivity, and selection of the operating frequency is of important for low loss wireless communications between transmitting antenna with capsule and a receiving antenna located in the near field.

In the previous work, use of inside a capsule with limited volume was firstly selected in [1, 3] for fabricating area of an antenna and outside (interface) a capsule is used in limited paper such as [4], however, comparison of the antenna characteristics between them has not been clarified.

In order to evaluate an antenna characteristics inside the human body, it is necessary to evaluate both the input impedance of antennas and the transmission characteristics inside and outside of a human body. However, there are few researches which compares the results of EM-analysis and measurements by the reasons that the ambiguity of dielectric permittivity of body tissue and human body phantom made of liquid with the volatility and/or the temperature change [5].

Recently, the S-parameter method [6] using two port Vector Network Analyzer is widely used to obtain input impedance of the unbalanced antennas in a wide band frequency range. In this report, a dipole antenna located inside and outside of a capsule is measured using S-parameter method and compared with numerical analysis. As an equivalent body tissue, the deionized water is used and the transmission characteristics between transmitting dipole antenna with a capsule and receiving dipole antenna was investigated.

II. EXPERIMENTAL SETUP

The experiment setup is shown in Fig. 1. The water with temperature of 18℃ is filled in a cubical acrylic case. A transmitting dipole antenna with length of l_1=20 mm is located in the center of the acrylic case and a receiving dipole antenna with length of l_2=140 mm is located near the acrylic case with distance of D=2 mm. In order to obtain the reflection and the transmission characteristics in broadband frequency range, the S-parameter method [8] was used with two port of VNA. The FDTD method is used for simulation without considering the acrylic cube case. The complex permittivity of deionized water was measured by using the coaxial probe method and is used for FDTD analysis as a curve fitted Debye dispersive material (ε_∞=4.9, ε_s=81.5, τ=1.05e-11[s]) [7].

III. COMPARISON BETWEEN EXPERIMENT AND ANALYSIS

The reflection coefficient and transmission coefficient of a dipole antenna located in deionized water is shown in Fig. 2. Almost good agreement between calculated and measured values was observed. The resonant frequency of dipole antenna was 7.5 GHz in vacuum, which was changed to almost 1.4 GHz when the antenna was located in the water. However, several resonances below 1 GHz were observed. This phenomena was caused by the multiple reflection of the cubical water structure. A relatively high transmission with levels of around -25 dB through the 74 mm thick deionized water with wideband characteristics below 1 GHz was observed. Above all, frequency use of below 1 GHz is a better selection for the communication of capsule endoscope systems with background of low conductivity, causing multiple reflections, result in higher transmitting signal levels.

IV. FDTD ANALYSIS OF DIPOLE ANTENNA WITH CAPSULE

The validity of the FDTD analysis was confirmed in Sec. III and the analysis of the dipole antenna inside or interface of a capsule was performed. As a liquid phantom, the body tissue liquid (produced by SPARG) shown in Fig. 3 with dielectric constant of around 50 and with larger conductivity compared with the ionized water have been used to obtain more realistic case. Geometry of a dipole antenna with a capsule are shown in Fig. 4. Size of a capsules are with the length of 30 mm and with the width of 10 mm. In order to compare the cases with and without the capsule filled by air (ε_r=1), 4 kind of configurations were considered. Fig. 4(a) shows the case without a capsule, Fig. 4 (b) shows the case when dipole antenna is located at the center axis of a capsule and Fig. 4(c) shows the case when dipole antenna was located at the interface of a capsule.

Calculated reflection and transmission coefficient of a dipole antenna located in body tissue liquid is shown in Fig. 5. In case of dipole antenna located at interface of capsule, reflection coefficient decreased and high transmission coefficient of -32 dB was obtained which is considered that the effective dielectric permittivity increase up to that without the capsule case.

V. Conclusion

In this paper, the measurement of a dipole antenna located in deionized water was studied. The results of FDTD simulation and measurement are shown good agreement. Maximum transmission coefficient of -25 dB through the 74 mm thick deionized water was obtained. Also it is found that a dipole antenna located at the interface of a capsule has good performance compared with the case of dipole antenna located in a capsule.

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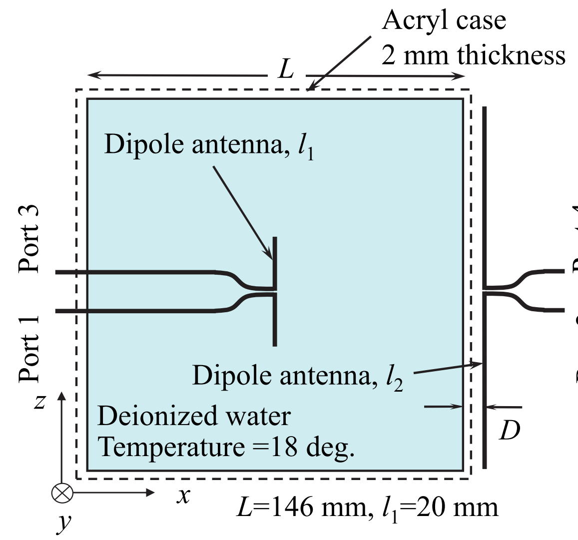

Fig. 1 Experimental setup of transmitting and receiving of dipole antennas in deionized water.

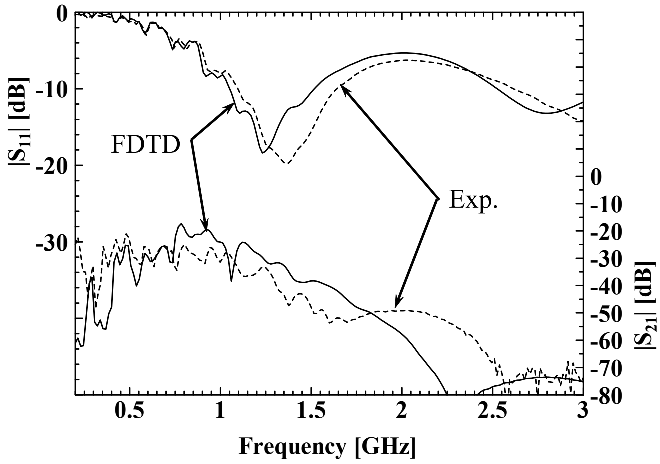

Fig. 2 Reflection and transmission coefficient of dipole antennas in deionized water.

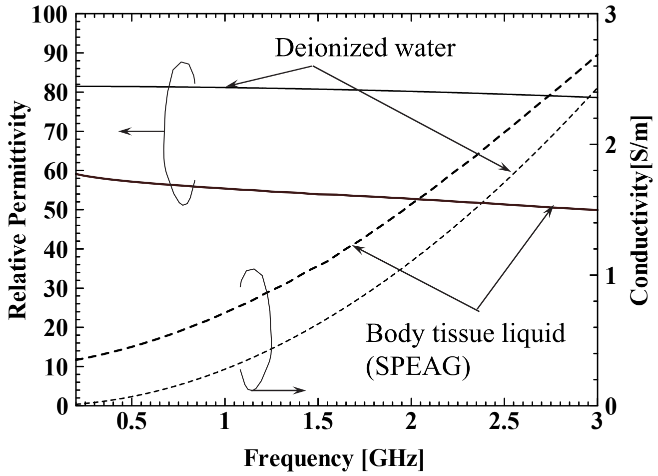

Fig. 3 Complex permittivity of deionized water and body tissue liquid phantom.

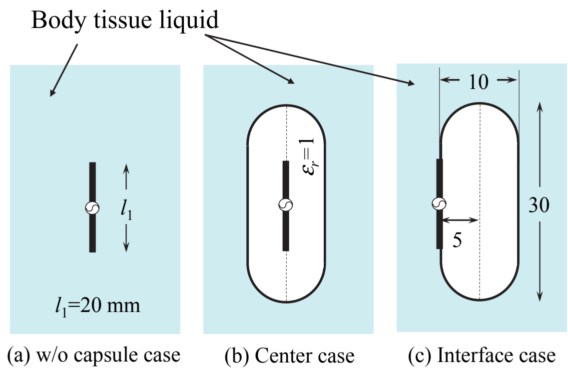

Fig. 4 Geometry of dipole antenna with capsule.

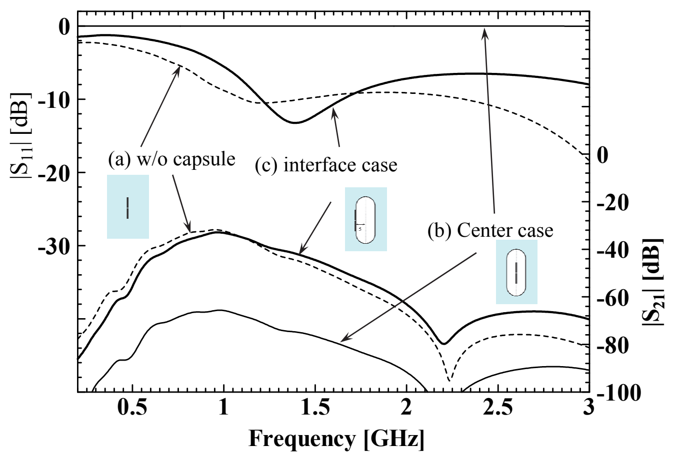

Fig. 5 Reflection and transmission coefficient in body tissue liquid phantom.

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