Design of Organ Phantom for Body-centric wireless System

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***Abstract* – Three organ phantoms (Heart, Liver, Stomach) were designed for experimentally evaluating the performance of implantable and wearable devices. It is necessary to use organ phantoms in body-centric wireless system because the performance of devices is strongly affected by surrounding materials. In order to develop the organ phantom, materials to make phantom were surveyed and the composition was optimized. The optimized organ phantoms were fabricated and electrical properties were measured. The measured relative permittivity and conductivity values are within the error tolerance over the wide frequency range.**

***Index Terms* — tissue equivalent phantom, WBAN, Body-centric wireless system.**

I. INTRODUCTION

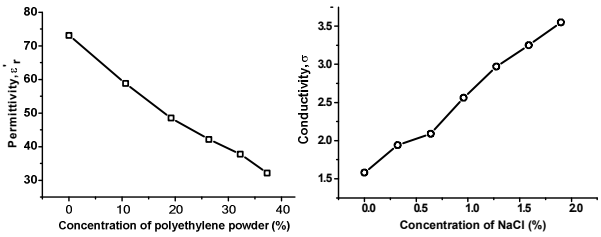
Wireless Body Area Network (WBAN) is a communication system between implantable and/or wearable devices locating off, on, or in body and external devices. The WBAN recently attracts great attention since it can be applicable to variety of areas, especially medical application [1]. Several researches have been conducted on implantable monitoring devices using the Medical Implant Communication Service (MICS) and the industrial, scientific and medical (ISM) band [2], [3]. In these researches, equivalent homogeneous phantoms having average permittivity and conductivity of human body are used to verify the performance of devices [4], [5].

Since, the human body consists of many different organs and they have different permittivity and conductivity, electromagnetic field can be altered differently by each part (organ) of the human body. Therefore using the equivalent homogeneous phantom is not enough to verify the performance of the devices accurately. Several recent researches, showing that the performance of antennas is changed with the location of the devices, support the aforementioned point well [6]-[8].

In this paper organ phantoms (heart, liver, stomach) which have larger volume compared with the other organs are proposed to provide the heterogeneity of human body. To make organ phantoms, we analyze electrical properties of suitable materials and propose the best composition ratio to obtain the electrical properties of human's organ over the wider frequency band.

II. FABRICATION AND MATERIALS

Organ phantom is made of deionized water, polyethylene powder, agar, TX-151, NaCl, and NaN_3. Deionized water is the main ingredient in organ phantom because the main material of tissue is water. Agar helps the phantom to keep self-shaping, served as curing agent. TX-151 makes phantom adhesive so that Polyethylene powder can be well mixed to based mixture (Deionized water + Agar + Tx-151). Polyethylene powder controls the relative permittivity of the phantom. It can lower the relative permittivity, added to the based mixture. Particle size of Polyethylene powder is 35μm, which is important to obtain homogeneity characteristic of the phantom. NaCl is used to control the conductivity of the phantom. NaN3 is preservative. It helps the phantom not to decay easily. Fig.1 shows the electrical properties of the phantom for different concentrations of Polyethylene powder and NaCl, where the values are averaged in the frequency range of 100-6000MHz.



(a) (b)

Fig. 1. Average value of dielectric properties.
(a) Permittivity. (b) Conductivity.

III. MEASUREMENT RESULT

The organ phantoms were fabricated to have electrical property reported in Camelia Gabriel Report [9]. It was written in Table. Ⅰ. Table. Ⅱ shows the composition of materials that are optimized for the organ phantoms to get the value in Table Ⅰ.

To measure electrical property of the phantoms we used Open-Ended Coaxial Line Resonator method. Permittivity probe kit (Agilent 85070E) and Network analyzer (Agilent 8719ES) were used for the measurement system. Measurement is performed in the frequency range of 100~6000MHz and frequency interval is 10MHz. Result comes out as the complex permittivity which can be converted as relative permittivity and conductivity.

Fig. 2 (a) shows measured dielectric properties of each organ phantom. Measured dielectric property of the heart phantom is plotted as square, liver is circle and stomach is

triangle. Percentage errors comparing to the values in Table Ⅰ is illustrated in Fig. 2 (b).

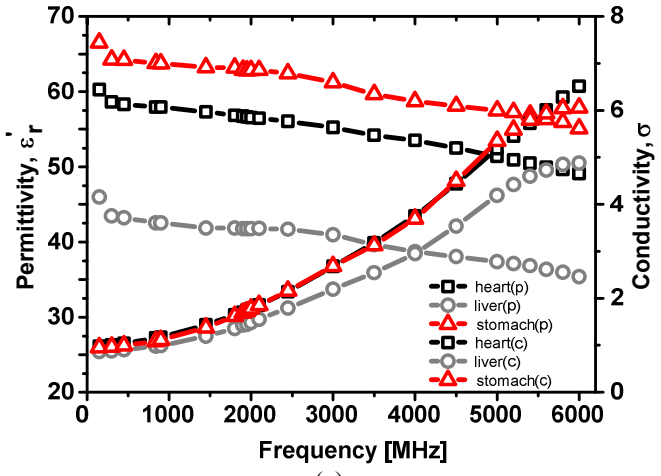
TABLE Ⅰ
DIELECTRIC PROPERTIES OF HEART, LIVER AND STOMACH

Frequency (MHz)	Real part of the complex relative permittivity, ε′			Conductivity, σ (S/m)		
	HEART	LIVER	STOMACH	HEART	LIVER	STOMACH
150	60.26	45.95	66.51	0.98	0.86	0.95
450	58.31	43.20	64.20	1.04	0.90	1.00
900	57.94	42.55	63.73	1.17	0.99	1.11
1450	57.32	41.84	63.26	1.44	1.19	1.38
1800	56.84	41.84	63.19	1.65	1.36	1.62
2450	56.07	41.68	62.41	2.14	1.79	2.16
3000	55.22	40.95	61.24	2.68	2.19	2.69
4000	53.51	38.72	58.72	3.76	2.95	3.70
4500	52.50	38.05	58.10	4.44	3.54	4.50
5000	51.39	37.38	57.48	5.19	4.19	5.35
5400	50.46	36.84	56.92	5.73	4.60	5.80
6000	49.10	35.37	55.07	6.51	4.88	6.06

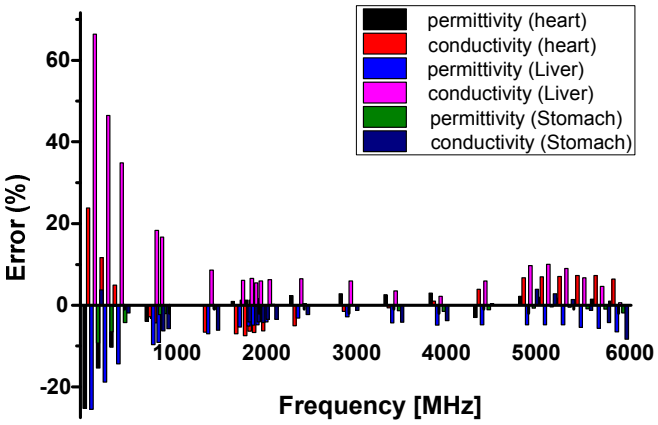
Fig. 2 shows that Heart and Stomach phantoms have error less than 10% in the most of frequency range except 100~450 MHz. On the other hand, Liver phantom has a relatively narrow 10% error frequency band (900MHz to 6000MHz). The electrical properties in low frequency band can be made fit into 10% allowable error limit by using lower composition ratio of Polyethylene powder and NaCl. However, the 10% error frequency band becomes narrow.

TABLE Ⅱ
INGREDIENTS AND COMPOSITION RATIO OF THE FABRICATED PHANTOMS

Ingredients	Composition ratio [%]		
	Heart	Liver	Stomach
Deionized water	82.17	71.12	85.4
Polyethylene powder	13.15	24.89	9.82
Agar	2.67	2.31	2.78
TX-151	1.44	1.24	1.49
NaCl	0.49	0.36	0.43
NaN3	0.08	0.07	0.09



(a)



(b)

Fig. 2 Electrical properties of organ phantoms. (a) Permittivity and conductivity. (b) Error.

IV. Conclusion

Three organ phantoms (Heart, Liver, Stomach) have been designed and fabricated in order to conduct more precise experiment. Heart and Stomach phantoms can electrically act as human's organ in the frequency between 450~6000MHz and Liver phantom can be used over the frequency range between 900~6000MHz.

Acknowledgment

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