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PAPER

Development of RFID Antenna for Detection of Urination

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SUMMARY This paper introduces a radio frequency identification (RFID) tag for urination detection. The proposed tag is embedded into paper diapers in order to detect the patient's urination immediately. For this tag, we designed an RFID tag antenna at 950 MHz, which matches the impedance of the associated integrated circuit (IC) chip. In addition, we calculate the antenna characteristics and measure the reflection coefficient (S_{11}) and radiation pattern of the antenna. The results show that this system can be used to detect urination.

key words: *biological tissue-equivalent solid phantom, paper diaper, radio frequency identification (RFID), urination, finite-difference time-domain (FDTD) method*

1. Introduction

Recently, the declining birthrate and aging population have become serious problems in Japan, as in many developed countries around the world. As a result the workload of nurses and doctors has become heavier. In order to provide a comfortable healthcare environment for elderly patients and improve the quality of medical support, it is very important to build a system to alert medical personnel when a patient's diaper needs to be changed.

At present, a number of ways to detect and measure moisture by using active devices have been reported [1]–[3]. Several ideas for putting extra functionality into a diaper have been presented. In [4] a more automated, but much more complex, self-emptying diaper system has been developed and in [5] a system that also indicates abnormality in the urine with the aid of reagent paper is presented.

Healthcare monitoring systems using radio frequency identification (RFID) technology are expected to be the next stage in medical support due to their great potential in providing low-cost medical services with high patient safety. RFID systems can be divided into two types: active and passive. Active systems offer more stable communications but are large and costly. In contrast, passive RFID devices are small, lightweight, and cheap. For these reasons, passive RFID is a good candidate for medical applications.

In RFID systems the tag is very important. Each RFID tag consists of an antenna and an integrated circuit (IC) chip that transforms the received electromagnetic fields into electrical energy to excite the chip embedded into the antenna and thereby transmit unique digital information back to a Reader/Writer. The communication distance depends on the characteristics of the antenna in this system. In addition, the configuration and the size of the RFID tag depend on the antenna. Hence, the antenna is very important in this system [6]–[8]. However, the characteristics of the antenna are influenced by its environment [9]–[11]. If an antenna is used in new conditions, it needs to be redesigned in order to match the impedance of the IC chip and so achieve adequate gain

We will present a urination detection RFID system in this study. In this system, an RFID tag is embedded into each paper diaper and a Reader/Writer is installed at the end of each bed. If the paper diaper is dry, the RFID tag embedded into it can communicate with the Reader/Writer installed at the end of the bed. On the contrary, if it is wet, the urination prevents communication from the tag. Since the distance between the RFID tag and the Reader/Writer is crucial, it will be discussed in our study. This system allows care personnel to know whether or not a patient has urinated because the urination changes the antenna's characteristics and makes it unable to transmit to the Reader/Writer. As a result, the physical and mental strain of both patients and their care personnel can be reduced.

In previous study, a UHF RFID antenna for detecting incontinence is studied in [12]. It measures the read range of a commercial RFID tag attached in a diaper worn by a person. However, [12] has only been evaluated by experimental data. In addition, the general versatility and repeatability of these results are unclear, because the number of examinees is very small. So, it is necessary to assess a urination detection system quantitatively by a reproducible method.

Our paper is the first study to conduct a quantitative study of urination detection. In addition, it is the first study to design an RFID antenna for a urination detection system. For the urination detection system, we carried out calculations based on numerical human models. Moreover, the antenna characteristics are measured by the use of a human-body-shaped phantom. These quantitative results show that the system can detect urination regardless of individual differences by adjusting the margins.

In this paper, an antenna which can match the impedance of the IC chip for RFID is designed and analyzed by the finite-difference time-domain (FDTD) method

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[13]. This calculation program was written in our laboratory. In addition, this program is compared with commercial software and the validity of the program is confirmed. The operating frequency of the antenna is 950 MHz. Use of this frequency for RFID systems is permitted in Japan. The reflection coefficients and radiation patterns of the proposed antenna are measured with a phantom for comparison with the calculated results.

2. Required Communication Distance for Urination Detection

Communication between the tag in each diaper and the Reader/Writer at the end of the bed is very important in order to detect whether the paper diaper is dry or wet in this system. Therefore, the reading range will be estimated. The reference system for the heights of Japanese people is shown in Fig. 1. The average height of Japanese people (B + C) is about 1.7 m for men and 1.6 m for women, and the average inseam (C) is about 0.70 m for men and 0.65 m for women, respectively [14]. In addition, the length of beds is usually 2.0 m to 2.2 m in hospitals and care homes in Japan. The distance between the end of the bed and the head (A) is assumed to be 50 mm, and the distance for communication r (C + D), including a margin, was calculated using these figures. The distance r is 1.3 m for men and 1.4 m for women. On this basis, the required RFID antenna gain (G_r) for communication was calculated by following the Friis Transmission Formula [15].

$$r = \frac{\lambda}{4\pi}\sqrt{\frac{P_t G_t G_r}{P_r}} \tag{1}$$

where r is the communication distance, λ is the wavelength, G_t and G_r are the antenna gains of the Reader/Writer antenna and the tag antenna, respectively, P_t is the RF output power of the Reader/Writer, and P_r is the power necessary to excite the IC chip. The values of G_t and P_t are taken from the Reader/Writer on sale. The requirements of the system are shown in Table 1. The RF output power of the Reader/Writer (Pt) is 24.0 dBm. This is equal to the maximum power of a third-generation mobile phone. Use of mobile phones in hospital rooms is now allowed in many hospitals, because the radiated power of mobile phones is becoming small and mobile phones have almost no effect on medical devices. The radiated power of our presented system is equal to the maximum radiated power of a third-generation mobile phone. So, our presented system could be safely used in hospital rooms. The results showed that the target gains of the RFID antenna are more than −16.5 dBi for men and −15.9 dBi for women. Therefore the antenna needs to be designed to exceed those gains.

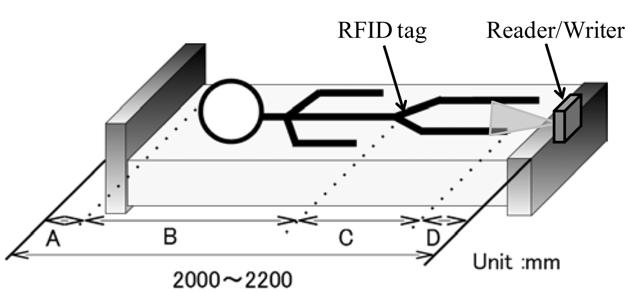


Fig. 1 Reference system.

Table 1 Designed values of the RFID antenna.

Frequency f	950 MHz
Wavelength λ	0.32 m
Gain of Reader/Writer G_t	6.8 dBi
RF output power of Reader/Writer P_t	24.0 dBm
Power of IC chip P_r	−20.0 dBm

3. Experimental Evaluation

3.1 Antenna Structure

The structure of the proposed RFID antenna is shown in Fig. 2. The operating frequency of the antenna is 950 MHz. The antenna has a form similar to [16] and a UHF RFID tag like this is commonly used. The requirements for the RFID antenna in each paper diaper are that it must be compact and flat. Due to the size limitation for RFID tags, the proposed antenna has a meandering structure. The lengths and widths of the meandering trace can be varied to obtain the desired resistance and reactance values. For impedance matching, a loop structure is used in our antenna design. Moreover, in our study, the capacitance of the antenna can be adjusted by the parallel structure near the IC chip.

The impedance of the antenna does not match the IC chip in free space or the each dry diaper. However, the impedance of the antenna matches that of the IC chip in each dry paper diaper worn on a human body. The results are shown in Fig. 8 and will be discussed later. In addition, From [17], we found the communication distance of an antenna becomes very short by urination. Thus, the characteristics of the antenna in the each dry diaper are very important.

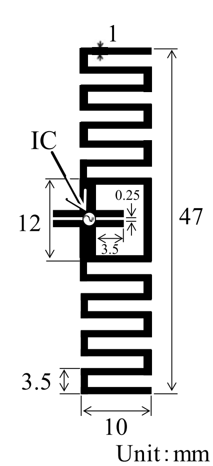


Fig. 2 Structure of antenna.

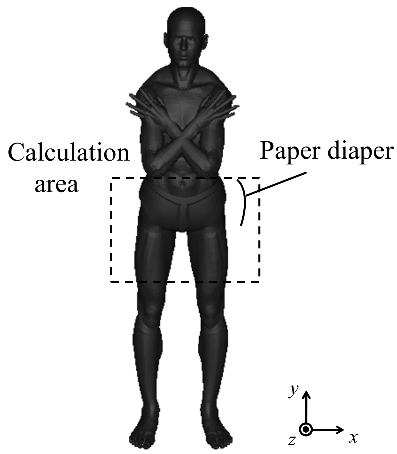


Fig. 3 Model of human with diaper.

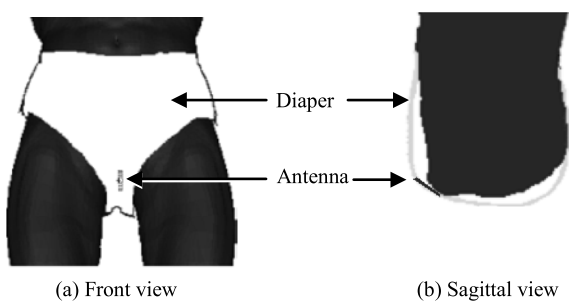


Fig. 4 Antenna position.

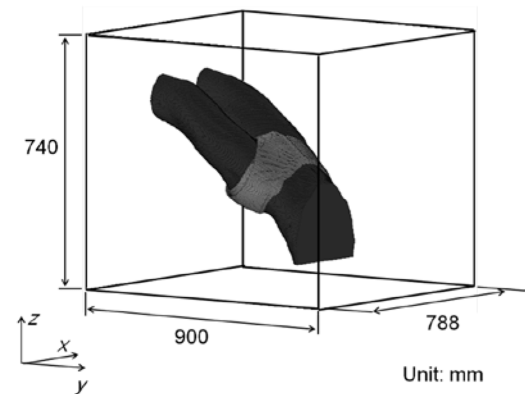


Fig. 5 Analytical region.

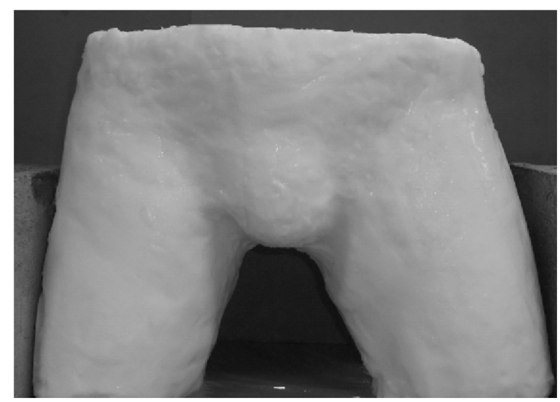


Fig. 6 Phantom between the abdomen and the femoral without a diaper.

Table 2 Recipe of the phantom.

Material	Amount[%]
Glycerin	53
Deionized water	37
Sodium chloride	5
Agar	5

3.2 Analytical Models

Figure 3 presents a numerical human model with a paper diaper. This model is made by the three-dimensional computer graphics (3DCG) software "poser®". The dashed line shows the calculation area. In our calculation models, the reflection coefficients and radiation patterns of the antenna in the dry and wet diapers are analyzed. In the calculation, the wet diaper is defined by changing the electrical properties from the dry diaper.

Figure 4 shows the human body wearing the paper diaper with the proposed antenna shown in Fig. 2. The proposed antenna is embedded into the paper diaper. The thickness of the paper diaper is 6 mm and the depth of the antenna in the diaper is 3 mm. The position of the antenna is in the wet area. In addition, the position of the antenna makes it easy to communicate with the Reader/Writer. In our research, all the characteristics of the antenna were calculated by the finite-difference time-domain (FDTD) method. The analytical region using the FDTD method is shown in Fig. 5. The human model is obliquely positioned in order to prevent the antenna from being a stair-step approximation. The dimensions of the computational domain are 788 mm × 900 mm × 740 mm, and an eight-layer perfectly matched layer (PML) surrounds the domain. The cell size of x, y, and z is 0.25 mm around the antenna. It increases gradually with the distance, and the maximum size of each cell is 2.0 mm. In addition, free space of more than 1/4 λ surrounds the human model and the radiation patterns are calculated on the five cells from the absorbing boundary.

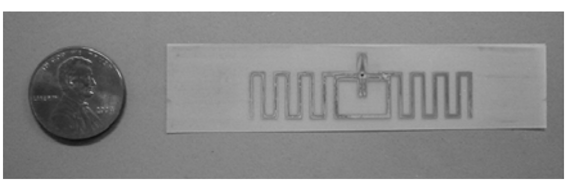
Figure 6 illustrates a fabricated phantom. This phantom is the area between the abdomen and the femoral of the human body. The recipe of the phantom is shown in Table 2. Details of how the phantom is made are given in [18].

The electrical properties of the numerical human body, the phantom, and the paper diaper in dry and wet conditions are listed in Table 3. In our research, a 2/3 muscle-equivalent phantom is used for the human model. The electrical properties of the proposed phantom at 950 MHz were found to be $\varepsilon_r = 36.6$ and $\sigma = 0.64$ S/m [19]. These are common values for the average electric constants of the human body [20], [21]. In addition, the relative permittivity and conductivity of the phantom and the diaper are measured by an HP-85070B dielectric-probe measurement system (Agilent Technology Company, Palo Alto, CA). In our measurements, the open-ended coaxial probe was pressed fitly against the measured object and the reflection coefficient was measured [22]. From the results, the difference in the electrical constants between the numerical human body and the phantom is less than 5%.

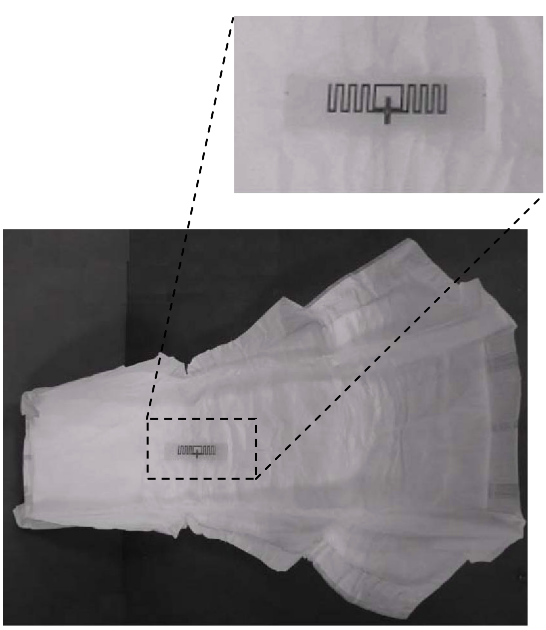
In order to measure the antenna characteristics using the network analyzer, the IC chip was removed from the RFID tag. In order to feed the antenna, a coaxial cable with a $\lambda/4$ balun, which is embedded to change the unbalanced line into a balanced line, is connected to the feeding point. The feeding point was at the position of the IC chip. Figure 7 shows the embedded position of the proposed antenna. The antenna characteristics are measured in the diaper. In the measurement, the urination is defined as an aqueous solution. The aqueous solution has the same electric constant as urine. The electric constant of urination is derived from [23]. The aqueous solution is made from water, glycerin, and sodium chloride. The reflection coefficients and radiation patterns were measured with the phantom in an anechoic chamber and the results will be discussed in Sect. 4.

Table 3 Electric constants.

	Relative permittivity	Conductivity [S/m]
Numerical human body (2/3 muscle)	36.6	0.64
Phantom	34.9	0.67
Paper diaper (dry)	1.3	0.01
Paper diaper (wet)	61.4	1.54



(a) Manufactured antenna



(b) Manufactured antenna on a paper diaper. The antenna characteristics are measured in the diaper.

Fig. 7 Embedding position of the antenna.

4. Calculated and Measured Results

4.1 Reflection Coefficients

The calculated and measured reflection coefficients (S_{11}) of the proposed antenna are shown in Fig. 8. The results are the characteristics of the antenna both in free space and embedded in a paper diaper on the phantom. From the results, this antenna has good impedance matching at 950 MHz when the paper diaper is dry. On the other hand, this antenna does not resonate at 950 MHz when it is in free space or the paper diaper is wet. Both the calculated and measured results are in good agreement. As those results, in the wet diaper, it is not possible to match the impedance between the antenna and the IC chip, so that the power is not supplied to the IC chip from the antenna.

4.2 Radiation Pattern

Figure 9 indicates the radiation patterns in the y-z planes. They are absolute gains. The radiation patterns were measured by the network analyzer, whose impedance is 50 Ω, so that it does not match the impedance of the proposed antenna. Therefore, they were converted to absolute gains. The measured gains were corrected by the mismatch loss due to the difference between 50 Ω and the impedance of the IC chip. The gain of the $-y$ direction is important because the Reader/Writer is installed in this direction. From Sect. 2,

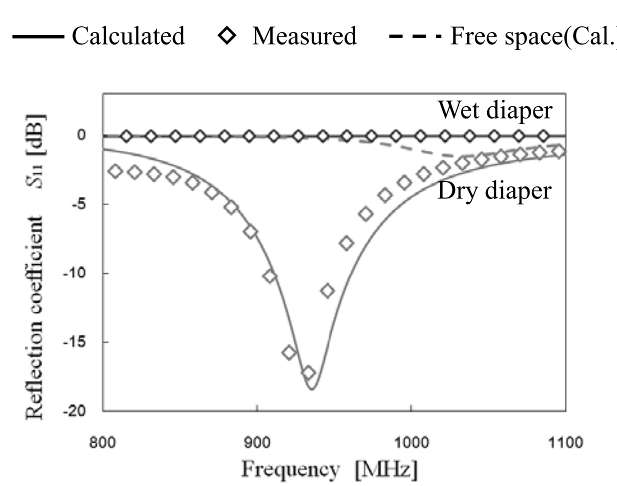
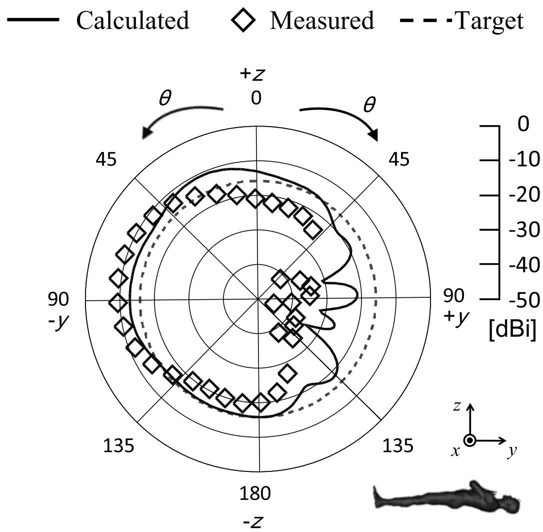
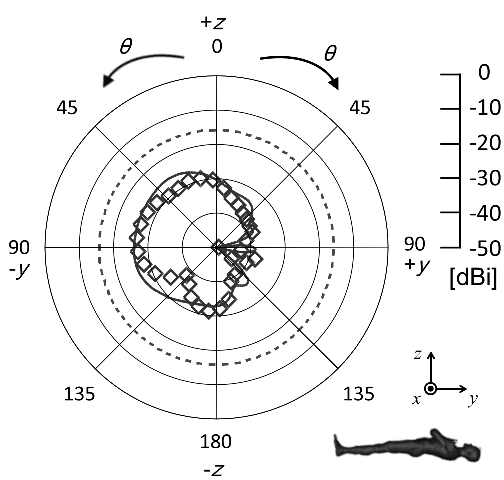


Fig. 8 Reflection coefficient.



(a) Dry diaper



(b) Wet diaper

Fig. 9 Radiation pattern (y-z plane).

the dotted line shows that the target gain is −15.9 dBi. When the paper diaper is dry, the calculated gain is −13.7 dBi and the measured gain is −9.2 dBi. In other words, the calculated gain is 2.2 dB higher and the measured gain is 6.7 dB higher than the target gain in the dry diaper. When the paper diaper is wet, the calculated gain is −26.0 dBi and the measured gain is −27.5 dBi. Compared to these, the calculated result is about 10.1 dB below the target and the measured result is about 11.6 dB below the target in the wet diaper condition.

4.3 Discussion

The communication distances in the $-y$ direction are shown in Table 4. They are calculated from the Friis Transmission Formula shown in Sect. 2. The read range is obtained in an anechoic chamber. From Sect. 2, the required communication distance was 1.3 m for men and 1.4 m for women, respectively. From the above subsections *A* and *B*, in the case of the wet diaper, the characteristics of the antenna are worse than in the case of the dry diaper. In addition, the measured radiation patterns are close to the calculated results, although there are some differences due to the volume of the human phantom and the cable. Although the communication distance exceeded the target in the case of the dry diaper, it fell below the target in the case of the wet diaper. Hence, when the paper diaper is dry, the RFID tag can communicate with the Reader/Writer. On the contrary, when it is wet, the urination prevents the tag from communicating. In addition, there is sufficient margin between the target and the result. Therefore the difference between a real situation and the results calculated by Eq. (1) is included in the margin. Thus, the results indicate that urination can be detected from the change in the antenna characteristics.

Table 4 Communication distance between RFID tag and Reader/Writer.

	Calculation	Measured
Dry diaper	1.97 m	3.30 m
Wet diaper	0.48 m	0.40 m

5. Conclusion

This paper has presented a urination sensing system in which an RFID tag is embedded into each paper diaper and a Reader/Writer is installed at the end of each bed. Failure of the tag to respond to the reader indicates that the diaper is wet.

A tag antenna which can match the impedance of a specific IC chip was designed and the characteristics of the antenna were calculated by the FDTD method. In addition, the reflection coefficient and radiation pattern of the antenna when mounted on a phantom were measured. When the paper diaper was dry, the reflection coefficient (S_{11}) of the antenna was sufficient for the impedance matching at 950 MHz. The reflection coefficient of the proposed antenna is lower than −10 dB from 911 MHz to 960 MHz. However, the S_{11} of the proposed antenna worsened when the paper diaper was wet. In addition, the gain in the direction of the legs is important because the Reader/Writer is installed in this direction. Although the antenna gain exceeded the target in the case of the dry diaper, it fell below the target in the case of the wet diaper in this direction. The results show that urination changes the antenna characteristics considerably and therefore that the system can be used to detect urination. Moreover, people sleep in various poses. So, in a further study, we will consider variations in pose.

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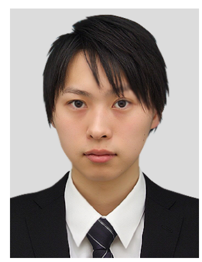
References

[1] M. Kent, “The use of stripline configurations in microwave moisture measurements II,” J. Microwave Power, vol.8, pp.194–198, 1973.
[2] M. Kent and T.E. Price, “Compact microstrip sensor for high moisture content materials,” J. Microwave Power., vol.14, pp.363–365, 1979.
[3] N. Boules and T.W. Nehl, “Design optimization of glassembedded capacitive-type water sensors,” IEEE Trans. Ind. Appl., vol.24, no.3, pp.402–410, May-June 1988.
[4] T. Fujimoto, T. Hashimoto, H. Sakaki, Y. Higashi, T. Tamura, and T. Tsuji, “Automated handling system for excretion,” Engineering in Medicine and Biology Society, 1998. Proc. Annual Int. Conf. of the IEEE, vol.4, pp.1973–1976, Oct.-Nov. 1998.
[5] T. Ejaz, T. Nakae, T. Takemae, C. Egami, O. Sugihara, and H. Ikeda, “A sensing system for simultaneous detection of urine and its components,” IEEE APCCAS 1998, The 1998 IEEE Asia-Pacific Conference on Circuits and Systems, pp.221–224, Nov. 1998.
[6] T. Nakajima, M. Takahashi, K. Saito, and K. Ito, “Evaluation on characteristics of wristband type RFID antenna using a layer structural arm model,” Proc. Int. Conf. Applicat. of Electromagnetism and St. Innovation Competition Awards (AEM2C 2010), pp.125–128, Taipei, Taiwan, Aug. 2010.
[7] K. Finkenzeller, RFID Handbook, Wiley & Son, New York, 2000.
[8] R. Want, “An Introduction to RFID Technology,” IEEE Pervasive Computing, vol.5, pp.25–33, Jan.-March 2006.
[9] R.Y.-S. Tay, Q. Balzano, and N. Kuster, “Dipole configurations with strongly improved radiation efficiency for hand-held transceivers,” IEEE Trans. Antennas Propag., vol.AP-46, no.6, pp.798–806, June 1998.
[10] K. Uesaka and M. Takahashi, “Antennas for contact-less IC card/RFID tag systems,” IEICE Trans. Commun. (Japanese Edition), vol.J89-B, no.9, pp.1548–1557, Sept. 2006.
[11] C. Cho, H. Choo, and I. Park, “Design of planar RFID tag antenna for metallic objects,” IEEE Antenna Wireless Propag., Lett., vol.10, 2011, pp.1010–1014, 2008.
[12] H.-E. Nilsson, J. Siden, and M. Gulliksson, “An incontinence alarm solution utilizing RFID based sensor technology,” RFID-Technologies and Applications (RFID-TA), 2011 IEEE Int. Conf. on, pp.359–363, Sept. 2011.
[13] D.M. Sullivan, Electromagnetic Simulation Using the FDTD Method, Wiley–IEEE Press, New York, 2000.
[14] AIST (National Institute of Advanced Industrial Science and Technology) (http://riodb.ibase.aist.go.jp/dhbodydb/index.php.ja).
[15] S. Promwong, “Optimum template receiver of ultra wideband transmission network for short-range wireless communication systems,” Inform. Networking, ICOIN, pp.1–5, 2009.
[16] M. Michishita and Y. Yamada, “A novel impedance matching structure for a dielectric loaded 0.05 wavelength small meander line antenna,” Antennas and Propagation Society International Symposium 2006, IEEE, pp.1347–1350, July 2006.
[17] H. Nakajima, K. Saito, M. Takahashi, and K. Ito, “Fundamental study of RFID antenna for detection of an urination,” 2011 IEICE General Conference, p.88 March 2011 (in Japanese).
[18] K. Ito, K. Furuya, Y. Okano, and L. Hamada, “Development and characteristics of a biological tissue-equivalent phantom for microwaves,” Electronics and Communications in Japan, vol.84, no.4, pp.67–77, April 2001.
[19] S. Gabriel, R.W. Lau, and C. Gabriel, “The dielectric properties of biological tissues: II. Measurements in the frequency range 10 Hz to 20 GHz,” Phys. Med. Biol., vol.41, pp.2251–2269, April 1996.
[20] W. Xia, K. Saito, M. Takahashi, and K. Ito, “Performances of an implanted cavity slot antenna embedded in the human arm,” IEEE Trans. Antennas Propag., vol.57, pp.894–899, April 2009.
[21] W. Xia, K. Saito, M. Takahashi, and K. Ito, “Implanted cavity slot antenna for 2.45 GHz applications,” Antennas and Propag. Society Int. Symp., 2008. AP-S 2008. IEEE., vol.57, pp.1–4, 2008.
[22] T. Onishi, R. Ishido, T. Takimoto, K. Saito, S. Uebayashi, M. Takahashi, and K. Ito, “Biological tissue-equivalent agar-based solid phantoms and SAR estimation using the thermographic method in the range of 3-6 GHz,” IEICE Trans. Commun., vol.E88-B, no.9, pp.3733–3781, Sept. 2005.
[23] C. Gabriel, “Compilation of the dielectric properties of body tissues at RF microwave frequencies,” Brooks Air Force Technical Report AL/OE-TR-1996-0037, 1996.



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