Localization Method Using Received Signal Strength for Wireless Power Transmission of the Capsule Endoscope

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SUMMARY In recent years, capsule endoscopy has attracted attention as one of the medical devices that examine internal digestive tracts without burdening patients. Wireless power transmission of the capsule endoscope has been researched now, and the power transmission efficiency can be improved by knowing the capsule location. In this paper, we develop a localization method wireless power transmission. Therefore, a simple algorithm for using received signal strength (RSS) has been developed so that position estimation can be performed in real time, and the performance is evaluated by performing three-dimensional localization with eight receiving antennas.

key words: capsule endoscope, position estimation, received signal strength, wireless power transmission

1. Introduction

In recent years, capsule endoscopes which are able to observe a wider range than conventional endoscope as one of the medical devices examining the interiors of digestive tracts and without pain in examination have attracted attention. The capsule endoscope is a capsule type medical device having a diameter of about 16 mm and a length of 26 mm, and having an image photographing function and a wireless communication function [11]. As an examination process, the capsule is firstly taken from the mouth, moves through the GI tract by peristaltic exercise, photographs examination regions, and transmits the image data to a sensor array outside the body by wireless communication.

One of the problems of capsule endoscopy is driving power source. Currently, electricity is supplied by the battery built in the capsule. However there are problems such as the limit to the number of images, and the risk that the electrolyte leaked from the battery may adversely affect the human body when the capsule is clogged in the body.

In order to solve these problems, techniques for wireless power transmission from the outside of the body have been developed. Using a sensor array that receives image data from the capsule, electric power is supplied to capsules by transmitting radio waves [2]. With this technology, the capsule can work in the body all the time in examination and transmits the image data to a sensor array outside the body by wireless communication.

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In order to solve these problems, techniques for wireless power transmission from the outside of the body have been developed. Using a sensor array that receives image data from the capsule, electric power is supplied to capsules by transmitting radio waves [2]. With this technology, the capsule can work in the body all the time in endoscopy. Furthermore, the battery is unnecessary to build in the capsule, hence miniaturization can be expected. Here, since the receiving electrodes outside the body are in the form of an array, it is possible to give directionality to the radio wave by controlling the phase [3], [4]. Therefore, in wireless power transmission, it is expected to improve the efficiency of power transmission by limiting the radio waves to a specific position. For that, it’s necessary to specify the position of the capsule endoscope. In this paper, we propose a localization method for wireless power transmission.

There are various methods of localization. The performance of Time of Arrival (TOA) technology is susceptible to the influence of bandwidth and not suitable for position estimation in the human body [5]. And the Angle of Arrival (AOA) technology is difficult to realize inside a complex human body structure [6]. In Received Signal Strength (RSS) localization technology, the received signal strength of the radio frequency wireless signal is measurable at the receiver side during the routine data communication without requiring additional power or occupying extra bandwidth [7]. RSS localization technology is the best choice for in-body localization [8], [9].

In order to enable more accurate localization, various methods for the capsule endoscope have been so far proposed [10]–[13], [19]–[22]. However, there are problems that take a huge amount of time to localize in order to perform complicated calculations according to the living body [14], [15]. In order to realize wireless power transmission, position information needs to be obtained during the endoscopic examination. Therefore, shortening the calculation time is essential. Furthermore, most of these studies have developed algorithms on the assumption that radio waves are radiated from omnidirectional antennas. On the other hand, the wireless power transmission technology in these studies adopts the microwave method [16] which supplies electric power via the antenna, consideration of the directivity of the antenna is required. Among the previous studies, there are no studies that are described with the antenna when transmitting and receiving, and antenna characteristic is not considered.

In the previous study, the purpose is to grasp the position of the capsule in inspection and to consider the directivity of the antenna by a small amount of calculation [17]. In this paper as well, we aim to specify the position information of the capsule endoscope in real time, and localization is performed by a simple algorithm in consideration of the directivity of the antenna in the simulation.

The structure of this paper is shown below. Section 2 shows the system structure of localization and the simulation model created for analysis. In Sect. 3, the investigate result is shown about the parameter for localization. Fur-
thermore, we introduce angle characteristics which cause the error of the parameter and discussed processing on it. In Sect. 4, we assume a capsule endoscope is moving in a three-dimensional space, deal with the tasks obtained in Sect. 3, and propose a localization method under more realistic conditions. Finally, we conclude this paper in Sect. 5.

2. Localization Method and Simulation Model

2.1 Localization Method

In this section, the system of localization is explained. As shown in Fig. 1, on the numerical simulation, we assumed that a radio wave was transmitted from a transmitting electrode installed in a human body model to a plurality of receiving electrodes installed on the body surface. Biological tissue is a lossy medium, and RSS at the receiving antennas decreases depending on the thickness of the tissue. Therefore, by measuring RSS, the distance between the transmitting antenna and receiving antennas is able to be calculated backward. Spheres whose radii from the receiving antennas are defined as the distance obtained by back calculation are drawn. By obtaining the coordinates of the intersections of these spheres, the localization result can be calculated.

Next, the theoretical formula is shown. As shown in Fig. 1, the surface of the human body model is set as the x-z plane in the orthogonal coordinate system. The positions of the receiving antennas are grasped in advance, the location of the transmitting antenna is localized by the known receiver location. We assumed that there were \( N \) receiving antennas and the transmitting antenna, and define locations of the \( n \)-th receiving antenna \( R_n (n = 1, \cdots, N) \) and the original transmitting antenna \( T \) as:

\[
R_n = [x_n, y_n, z_n] \quad (1)
\]

\[
T = [x_t, y_t, z_t] \quad (2)
\]

Hence the ideal distance \( d_n \) from the \( n \)-th receiving antenna to the transmitting antenna can be represented as:

\[
d_n = \sqrt{(x_t - x_n)^2 + (y_t - y_n)^2 + (z_t - z_n)^2} \quad (3)
\]

When RSS of the \( n \)-th antenna is defined as \( p_n \), the distance between the transmitting antenna and the receiving antenna \( r_n \) is obtained by:

\[
r_n = Q(p_n) \quad (4)
\]

as a function with \( p_n \). In this case, \( n \) equation of the sphere centered on the \( n \)-th receiving antenna is given.

As shown in Fig. 1, one intersection point is obtainable from three hemispheres centered on the antennas. Therefore, by preparing three formulas, the coordinates \((x, y, z)\) solved as a ternary simultaneous equation are the coordinates of \( I \) in Fig. 1. In this study, the coordinate of \( I \) is calculated as the localization result.

Since there are \( N \) receiving antennas, \( N \times C_3 \) combinations for selecting three antennas are obtained in total. Define \( M \) as:

\[
M = N C_3 \quad (5)
\]

Where the \( m \)-th intersection location \( I_m (m = 1, \cdots, M) \) is represented as:

\[
I_m = [x_m, y_m, z_m] \quad (6)
\]

Consequently, average \( I_m \) is outputted as the localization result. This result is compared with the position of the transmitting antenna \( T \). The distance between them is calculated and used to evaluate the performance of the algorithm.

2.2 Simulation Model

In this section, the simulation model used for numerical calculation is introduced. In electromagnetic field analysis with consideration of the human body, FDTD method is used as an analysis method. Next, the operating frequency is considered. The industrial, scientific and medical (ISM) radio bands are permitted to use for the medical device. Among them, the use of 2.45 GHz band (2.4 to 2.5 GHz), 915 MHz band (902 to 928 MHz, North and South America), and 433.92 MHz band (433.05 to 434.79 MHz, Europe and Africa) is particularly active in the microwave band. In the previous study, the electric field intensity of electromagnetic waves radiated from the power transmitting antenna was calculated by using these three frequency bands and a simple human body model. As a result, the lower the frequency, the smaller the attenuation of radio waves and the higher RSS [17]. Therefore, similarly to the previous research, 433.92 MHz, which is the lowest frequency among the above three bands, is used as the operating frequency.

As a channel model, a simple rectangular parallelepiped model simulating human abdomen is used. Since duodenum contains little air, we treat small intestine as a series of masses rather than tubes, and assume that transmitting antenna is contained in it. The model is shown in Fig. 2. The dimension is 300 × 200 × 300 mm³ to simulate the abdomen. Skin of 2 mm in thickness was placed on the
surface of the body as living tissue, and fat with a thickness of 10 mm was placed inside it. For the sake of simplicity, the inside of the human body was composed of all the muscles, and the size was adjusted so that the size of the entire model was 300 mm. The dielectric constant and conductivity of each tissue of the human body at the frequency of 433.92 MHz used for analysis are shown in Table 1. Compared with this model, the actual human abdomen has a more complicated structure. Therefore, examining the practicality in this model is needed. In Sect. 3.2, the result of the investigation on the influence of human body tissues on RSS is reported.

Antennas used for analysis are introduced. Originally, these antennas also serve as antennas for wireless power transmission besides transmitting photographed image data. However, the design of antennas with the performance suitable for wireless power transmission is done by others [2], [18]. Therefore, the antennas in this study are assumed to be used for only data transmission (from the capsule to sensor array).

Propagation loss occurs when radio waves pass through living tissue. And the degree of attenuation of RSS is used to calculate the distance between the transmitting and receiving antennas. Therefore, in this paper, in order to confirm the basic operation, antennas fitting within the capsule endoscope and fitting on the human abdomen surface are used without consideration of matching.

- For the transmitting antenna, a 10 mm dipole antenna, which is small enough to install into the capsule endoscope and has a simple structure, is used. The shape of the antenna is shown in the left part of Fig. 3.
- A spiral antenna is adopted as the receiving antenna so that it can be received irrespective of the orientation of the capsule endoscope. The spiral antenna has a wide frequency band and can radiate circularly polarized waves. On the other hand, the directivity is distorted. The directivity of the antenna causes degradation of the localization accuracy due to reasons to be explained later. Therefore, as shown in the right part of Fig. 3, a 4-wire spiral antenna is used.

### Table 1: Electrical constants of each tissue.

<table>
<thead>
<tr>
<th>Tissue</th>
<th>$\varepsilon_r$</th>
<th>$\sigma$ [S / m]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skin</td>
<td>46.1</td>
<td>0.70</td>
</tr>
<tr>
<td>Fat</td>
<td>5.57</td>
<td>0.04</td>
</tr>
<tr>
<td>Muscle</td>
<td>57.7</td>
<td>0.83</td>
</tr>
</tbody>
</table>

3. Calculation of Distance Between Antennas

In this section, the method of calculation of the distance between antennas is explained, which is an indispensable factor in the localization. In addition to the distance between the receiving and transmitting antennas, there are the factors called angle characteristics that affect RSS. Their investigation and the way to process them are considered.

#### 3.1 Attenuation Characteristic for Distance Calculation

In order to obtain the distances $r_n$ used for localization, a function $Q(p_n)$ with $p$ as a variable used in the formula (2) is calculated. As shown in Fig. 4, one receiving antenna is installed in the central part of the human body model, and a transmitting antenna is installed on a straight line perpendicularly crossing the feeding point at the center of the receiving antenna. Then, in the range where the inter-antenna distance $d_n$ is 40 to 160 mm, the transmitting antenna is moved in intervals of 10 mm. And, as receiving radio waves transmitted from the transmitting antenna at each position, RSS was calculated. The simulation results are shown in Fig. 5. For the simulation result, the approximate curve was calculated by the least-squares method, and this function was defined as $Q(p_n)$.

Even at the same distance RSS varies depending on the direction of the transmitting antenna. In this report, we propose an algorithm in one direction, in which the dipole antenna is fixed vertically as a basic algorithm. We plan to solve this problem by proposing a position estimation algorithm using orthogonal antennas in the near future.

#### 3.2 Influence of Human Body Tissues on RSS

This section explains the influence of human organization
on RSS. There are studies reporting a detailed analysis of RSS and distance [23]. This study is described characteristics of nonmonotonicity of human tissues. In comparison with the actual human body, if the value of RSS in the proposed simple model is significantly different, the reliability of the result in the simple human body model is lost. Therefore, it is necessary to investigate the change of the RSS by the organization.

Studies on the effects of changes by tissues have also been conducted in previous studies [17]. We changed the thickness of fat layer and muscle layer while keeping the distance between antennas constant, and investigated the change of RSS value. The results are shown in Table 2. The amount of change in RSS due to the presence of tissue was the largest in fat and was about 3 dB. This is considered to be a major cause of layer reflection. The change amount of RSS due to the thickness of the tissue was about 0.02 dB every 10 mm. The influence on the RSS due to the change in the presence or the thickness of the tissue absence of internal tissue is minimal. From this result, we judged that even if the tissue structure of the medium between the antennas changed, there was hardly any influence on the value of RSS and it can be evaluated with a simple model.

Therefore, the human tissue with a complex structure was replaced by a simple model, and concluded that this proposed model is effective in the basically study.

Table 2 Influence of human tissues on RSS.

<table>
<thead>
<tr>
<th>Human tissues</th>
<th>The change in RSS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skin (2 mm)</td>
<td>0.1 dB</td>
</tr>
<tr>
<td>Presence of tissues</td>
<td></td>
</tr>
<tr>
<td>Fat (10 mm)</td>
<td>3.0 dB</td>
</tr>
<tr>
<td>Small intestine (20 mm)</td>
<td>1.5 dB</td>
</tr>
<tr>
<td>Change in fat thickness (per 10 mm)</td>
<td>0.02 dB</td>
</tr>
</tbody>
</table>

3.3 Angle Characteristics

In the process of collecting RSS as changing the position of the capsule endoscope by simulation, it was found that, when the capsule was installed in a portion other than the front, less RSS compared to the position in the front was obtained. This is considered to be due to the angle characteristics of the receiving antenna. Since the directivity exists on the antenna, ease of transmission and reception is different for each direction in transmitting and receiving radio waves. This has an effect on RSS.

As shown in Fig. 6, there are two kinds of elements in the angle characteristic. The first is the depth direction, and the second is the surface direction. In this paper, the angle in the depth direction is referred to as $\theta$, and the angle in the surface direction as $\varphi$. We investigated the details of angle characteristic, and how it affected RSS, by simulation.

First, angle characteristic in the depth direction is explained. Comparing the radio waves receiving from the front direction with receiving from the oblique direction, different RSSs are obtained in spite of the same distance. This is because the directivity in the oblique direction is lower than that in the front. Therefore, when radio waves are received obliquely, longer distances compared to the front are calculated. This causes deterioration of accuracy.

We investigated how much the angle characteristics in the depth direction affected RSS. As shown in Fig. 7, RSS calculation was carried out by moving the transmitting antenna so that the distance between the antennas is fixed at 80 mm on the x-y plane with the z axis fixed, and changing $\theta$. The calculation result is shown in Fig. 8. Compared with the position of $\theta = 90^\circ$ which is a position orthogonal to the receiving antenna, when $\theta$ becomes smaller than $45^\circ$, RSS becomes smaller and RSS attenuates by about 7 dBm at the maximum.
Secondly, angle characteristic in the surface direction is explained. RSS varies depending on the angle $\varphi$ with respect to the direction of the surface of the human body model when a radio wave comes from the diagonal direction. The ease of receiving radio waves varies depending on the corner of the spiral antenna, and RSS varies depending on the angle.

Figure 9 shows the model of the simulation for investigation. A receiving antenna is placed at the center of the human body surface. A transmitting antenna is installed by moving so that the distance between the antennas is 110 mm on a plane 50 mm away in the depth direction. The results are shown in Fig. 10. RSS varies according to angle. Consequently, the difference of about 12 dBm between the maximum value and the minimum value is confirmed.

In this result, note that the results in Fig. 10 are not only due to the angle characteristic in the surface direction. The influence of the angle characteristic of the transmitting antenna is contained in addition to one in the depth direction. In particular, since the dipole antenna which is the transmitting antenna is installed in the vertical direction, RSS becomes extremely small at the position of $\varphi = -90^\circ$, $90^\circ$ where the receiving antenna and the transmitting antenna are just above and below relationship. Hence, RSSs of these positions were corrected by linear interpolation based on surrounding values, and the influence of the angle characteristic of the transmitting antenna was reduced.

3.4 Processing on Angle Characteristics

The angle characteristics in the surface direction have the most effect on RSS. As shown in Fig. 5, when RSS changes by 12 dBm, the distance to be calculated also changes by nearly 40 mm. This is too large error for the distance used for localization accuracy. To solve this problem, correction for angle characteristics is applied as one of the processes of localization algorithm.

A specific correction method is described. First, the processing for angle characteristics in the depth direction is described. As can be seen from Fig. 8, there is almost no change in RSS up to a certain angle. Therefore, we deal with it by reducing the number of receiving antennas used for localization. Accuracy was improved by removing such receiving antennas from localization.

Next, a correction method in the angle characteristic in the surface direction is described. Regarding the surface direction, correction is performed by a method of correcting the calculated distance according to the angle $\varphi$. Without correction, $r_n$ has been calculated differently from $d_n$ due to the influence of angle characteristics. Therefore, it is desirable to calculate $r_n$ as close as possible to $d_n$ as possible. In this study, the method of correction using surface angle is proposed. As shown on the right side of Fig. 10, an approximate function corresponding to the angle is obtained and used as a correction function $C(\varphi)$. Correction is made by multiplying the distance $r_n$ by the value obtained from this function.

Algorithms using these correction functions are explained in Sect. 4.
4. Three Dimensional Localization

4.1 Localization Environment

The arrangement of the antenna is described when performing localization in three dimensions. Figure 11 shows the installation positions of receiving antennas and the moving range of the transmitting antenna. Eight receiving antennas are arranged with the origin at the center of the $x$-$z$ plane of this model surface. These coordinates are based on actual placement in the capsule endoscopy. Positions $R_n$ ($n = 1, \ldots, 8$) of each arrangement are defined as:

$$R_n = \begin{bmatrix} (0, 0) \\ (0, 80) \\ (-60, 60) \\ (60, 60) \\ (-80, -20) \\ (80, -20) \\ (-40, -80) \\ (40, -80) \end{bmatrix} \quad (n = 1, \ldots, 8) \quad \text{[mm]} \quad (7)$$

after defining the center of the model surface as the origin $O$.

The transmitting antenna is placed within the area shown in red in the figure. This area is assumed to be the range where the small intestine exists. The dimension is $200 \times 70 \times 160 \text{mm}^3$. By taking lattice points at regular intervals within this range, the localization of 792 points is performed.

Additionally, in this study, the continuous movement of the capsule endoscopy is considered. In the actual capsule endoscopy, the information of the received RSS is updated at regular time intervals. Therefore, it is assumed that the transmission antenna moves to one adjacent lattice point for each update. As a result, it is possible to know the displacement distance of positions by updating. In this paper, in order to minimize the error, this distance is utilized for localization.

4.2 Procedure of Localization

The flow of localization of per round is shown in Fig. 12.

Localization consists of two steps. The first is calculating temporary position for calculating the angle, and the second is to correct the distance using the obtained angle, to draw spheres again and to obtain the intersection as the localization result.

First, localization is performed using only four of the eight RSS ($p_n$) having large values for the purpose of minimizing of the influence of angle characteristics in the depth direction. Let the four selected RSSs be $p_{n'}$ ($n' = 1, \ldots, 4$) and convert them to the distance $r_{n'}$ using formula (4). Spheres with these distance as a radius is drawn around each receiving antennas and the intersection points $I_{m}$ ($m = 1, \ldots, 4$) of the spheres are calculated. Four intersection points is obtained from the four receiving antennas. In the first step, the average coordinate’s $\bar{I}_m$ are determined as the temporary position.

The second step begins by calculating the angle formed by the temporary position and each receiving antenna. An angle $\theta_{n'}$ in the depth direction and an angle $\varphi_{n'}$ in the surface direction are calculated with the each receiving antenna. Angle correction is performed using them. First, in accordance with the combination of $(r_{n'}, \theta_{n'})$, an appropriate angle correction function $C(\varphi_{n'}, r_{n'})$ is determined from among a plurality of prepared functions. And $r_{n'}'$ is defined as the corrected distance and given by:

$$r_{n'}' = C(\varphi_{n'}, r_{n'}) \times r_{n'}$$

Finally, spheres with radii $r_{n'}'$ are drawn, and the coordinates of the intersection points $I_{m}'$ are calculated. The average value $\bar{I}_{m}'$ of $I_{m}'$ is output as the final position $I'$.

At this time, since there is a limit of the accuracy of the correction function, there is a possibility that correction has not been appropriately applied. Therefore, if there is no way to deal with the distorted distance, the localization error increases. We addressed this problem by considering the weight of intersection points. After four intersection points
are set so that $r_0$. Therefore, the weight at the nearest position is doubled, and the weight at the farthest position is halved. Weights are set so that $\{w_1: w_2: w_3: w_4\} = \{4: 2: 2: 1\}$ in order from the nearest position, and the coordinates obtained by the weighted average are output as the localization result.

Then, the value of the variance of the four coordinates is calculated. A large variance suggests that the incorrect distance (outliers) is included in intersections. As a method of detecting outliers, the localization result before updating introduced in Sect. 4.1 is utilized. Specifically, it is assumed that localization has performed $i$-th update ($i \geq 3$). At this time, by calculating the inclination and the displacement distance in the traveling direction from $i$-1 th and $i$-2 th positions, the $i$-th position can be estimated. As the highly reliable position, this position is compared with the four intersection obtained from the spheres.

At the four intersections, it is assumed that the closest point from this estimated position has the smallest error. Therefore, the weight at the nearest position is doubled, and the weight at the furthest position is halved. Weights are set so that $\{w_1: w_2: w_3: w_4\} = \{1: 1: 1: 1\}$ in order from the nearest position, and the coordinates obtained by the weighted average are output as the localization result.

Then, the value of the variance of the four coordinates is defined as $V$. When $V$ is extremely large or small, another weight is set. When $V < 0.5$, it can be judged that the dispersion of the error is small, and it is assumed that $\{w_1: w_2: w_3: w_4\} = \{1: 1: 1: 1\}$ assuming that weighting is unnecessary. When $V > 10$, it can be determined that the error is large, and $\{w_1: w_2: w_3: w_4\} = \{2: 1: 1: 0\}$ is weighted as the farthest coordinates lead to the cause of the error.

In the case of update count $i < 3$, since there is no localized position before updating, the weighting is determined using the distance from the temporary position. Although the error is not necessarily small as it is closer to the temporary position, at least since there is a tendency to move away from the temporary position when correction is failed, $\{w_1: w_2: w_3: w_4\} = \{2: 2: 2: 1\}$, and outputs the weighted average coordinates as the localization result.

### 4.3 The Performance of Localization

First, we show to the time required for localization. At all 792 points, it was judged that the time from the input of RSS to the output of localized coordinate is extremely small ($< 0.1$ s), and the real time property which is the condition for use in the wireless power transmission is sufficient. The error between the localization result and the original position was obtained. Then, colors are separately displayed in each magnitude of the error. A part of the result is shown in Fig. 13. Since it is difficult to show all the points in three dimensions, results at 50 mm from the front surface ($y = 50$) and at 50 mm from the right surface are displayed. As shown in the figure, an error within 40 mm was achieved at all points. Furthermore, the number of points within 20 mm of error was more than 70%. At present, the study to impart directionality by phase control in wireless power transmission is still in the development stage, and there is no decision as to how much error is specifically tolerated. However, in this paper, we confirmed that the error range could be within 2 capsules (40 mm) within all area, hence we judged that the position information was able to be tracked sufficient accuracy by the proposed algorithm.

### 5. Conclusion

In the paper, a localization method for wireless power transmission to the capsule endoscope is developed. Real-time localization has been required, and the position has been estimated by a simple algorithm using RSS. We have developed a method including algorithms that take antenna directivity into consideration by setting transmitting and receiving antennas respectively in the simulation.

Considering the angle characteristic of the antenna, in this paper, the localization was performed in two steps of calculating the temporary position and calculating the final position. By calculating the temporary position, the influence of the angle characteristic of the antenna was corrected. In addition, considering the position was updated at certain time intervals, localization was also performed using the estimated position before updating. As a result, it was possible to estimate the position within an error of 40 mm while maintaining real time property.

As a future task, it is important to consider the direction of the transmitting antenna. As shown in Sect. 3.1, the RSS changes according to the direction of the transmitting antenna even at the same distance. Therefore, based on this algorithm, we aim at localization independent of orientation by combining the localization results when the transmitting antenna is horizontal and vertical.

Furthermore, we are planning to estimate the position using a model with a complex structure close to the human body, using an antenna for wireless power transmission. Specifically, the techniques in localization such as antenna characteristics are also required to practical models. Therefore, we plan to try to adapt processing of angle characteristic to a complex body model. In fact, factors such as the curvature of the abdomen are left behind in the error of localization. However, as discussed in the weighting discus-
sion, discussion of RSS with neighboring external elements can be considered locally, and we think that a plane model is sufficient. This area is thought to be a degradation factor of positional accuracy, but we plan to discuss it in verification with a real model to be carried out in the future.

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References


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