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Thoracoscopic surgery support system using passive RFID marker

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Abstract— **This paper proposes a RFID based thoracoscopic surgery support system, which is capable of marking a tumor inside organ tissue. The marker composed of small RFID-tags is implanted in the vicinity of tumor found in the endoscopy test. In the thoracoscopic surgery operation for removing the tumor, an RFID detector determines the accurate position of the implanted RFID-tag markers by measuring the strength of the signal emitted from the target tag. Due to limitation in the size of RFID-tag, the proposed system employs a passive RFID. To activate the passive tag implanted in the organ tissue, this paper designs a saddle-shape efficient power supply antenna. A sensitive and frequency-selective receiver is then designed for detecting the weak signal from the tag. The feasibility test confirms that the proposed method is capable of determining the accurate location of RFID tags implanted in the patient's organ tissue.**

I. Introduction

Recent progress in diagnostic imaging technology enables us to identify lesions that are less than 5 mm in diameter. Although 5 mm accuracy is acceptable for its clinical use as a surgical marker for lung cancer surgery. It was also reported that a surgical margin less than 1 cm was associated with a significantly higher rate of local recurrence. As a result, major centers have adopted a 20-mm margin as a target during resection to minimize local recurrence and improve survival after resection [1],[2]. The excision of the tissue should be minimized to reduce the actual load to a patient, it is difficult to reduce the excision area due to lack of accurate determination of tumor position determination during surgery. The tumor is usually invisible from outside of the tissue because it usually locates inside wall of hollow organ. Furthermore, the shape of organs varies and the tumor position moves according to this variation of the shape.

To solve this problem, many methods have been proposed. Among them, making efficient use of metal clips for marking the lesions is commonly used [3], [4]. This method is efficient in identifying the existence of the tumor in a chosen part of the tissue. However, this method is not good enough to determine the exact position of the marker. Since clips cannot be seen from outside the organ. To determine the accurate tumor position from outside the organ tissue, a magnet marker method has been proposed [5], [6]. In this method, small magnet is placed onto the tumor region. The operator can determine the tumor position by use of magnetic sensor. Although this method is efficient to find the location of tumor, individual markers cannot be identified when two or more magnetic markers are placed.

In this paper, we propose a new tumor localization system based on RFID (Radio Frequency Identification) technology. In the proposed system, the RFID-tag based markers are implanted in the vicinity of lesion site through the endoscopy channel. Then, the position of implanted RFID-tags are determined by measuring the strength of the signals from the tags. The size of RFID tags should be less than of few millimeters because the tags are delivered to the tumor through the narrow endoscope channel. Therefore, the proposed system employs a passive RFID tag having no battery. However, in order to activate the passive RFID tags, the power should be supplied from outside the patient's body. In this paper, we first design efficient power-supply antennas with a simulation software nec2 for sending power to tags implanted in organ tissue. A feasibility test is then carried out in order to confirm the proposed system can determine the accurate position of the RFID tag based marker.

II. RFID System

A. Introduction of RFID system

The RFID system is composed of RFID-tags and corresponding reader-writer. The near field communication between tags and reader-writer is performed using radio waves or inductive coupling. RFID systems have been standardized by the International Organization for Standardization (ISO) [7]. Among the standardized RFID systems, a system operating at the frequency of 13.56 MHz, which is one of the frequency bands for industrial, scientific and medical applications referred to as ISM bands, is widely used for ID card, electric money, automatic turnstile and so on [8], [9]. RFID systems are also used for medical and healthcare purposes such as the patients' identification and management for room entry. [10]-[12].

B. RFID-tags

RFID-tags are classified into three types according the power sources for tags, namely active, passive and semi-active tags. Active tag has a battery and is powered by the battery. In contrast, passive RFID tag has no battery, and power is supplied by the electromagnetic wave or mutual induction. Semi-active one is the combination of active and passive tag, and the power is supplied by both the internal battery and the outer power resource coupled by

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electromagnetic wave or induction. Each RFID-tag has its own UID (Unique IDentifier) and will send the UID to the corresponding reader-writer.

Amongst three types of RFID-tags, passive RFID is most widely used, because of its capability of reducing its size and cost. In the following discussion, we employ a passive tag.

III. THORACOSCOPIC SURGERY SUPPORT SYSTEM USING RFID

A. Principle of Proposed RFID System

Fig.1 illustrates the configuration of the proposed thoracoscopic surgery support system using the RFID tag. In this figure, we assume the lung tumor case. Bronchoscope is used to detect a tumor. When tumor are found, miniature RFID tags are implanted near the lesions in order to mark their positions. Thoracoscopic surgery is then carried out in order to remove the tumor. In the surgery, a small antenna, which detects radio signals from the implanted RFID tags, are inserted in order to determine the position of the markers. The received signal is applied to the signal detector to measure the received signal strength. Since the signal strength is inversely proportional to the distance between the tag and the antenna, the operator can find the position of the marker tag by making use of signal strength information.

In order to inform operators the measured signal strength, the measured signal strength information is applied to the audio interface. The audio interface converts the signal strength information into corresponding beep tone. The operator find the accurate position of marker tags by sweeping the detection antenna near the tumor area, and searching for the positions corresponding to high tone beep.

B. Design of power supply antenna

In our application, the size of RFID tag is strictly limited. In order to deliver the tags to tumor through the bronchoscope channel, the size should be less than a few millimeters. Therefore, we employ a passive RFID tag without battery. In order to run the passive RFID tag, we have to supply power from the outside. The conventional passive RFID tag systems share a single antenna for power supply and detection. This shared antenna is, however, too large to use for our application. Since the detection antenna should be delivered through the thoracoscope channel, its size is also limited less than 10 mm in diameters.

To solve the problem, we use two antennas for energy supply and detection. The miniature size antenna is used for detecting the signal from the RFID tags. The size of the detection antenna is less than 10 mm in diameter in order to go through the thoracoscope channel.

As a power supply antenna, we use a large size loop antenna, which sends the power from outside of the patient body. In order to activate the RFID tags, the magnetic field strength at the tag is higher than 12 A/m. On the other hand, since the power supply antenna is located outside of the patient's body, the distance between each RFID tag and power supply antenna reaches 50 mm. The conventional power supply antenna is not efficient for supplying enough power to the targeting tag. To supply enough power to the tag, we assume a saddle shaped antenna attached to the patients.

The system configuration for designing the antenna is shown in Table I. The parameters are followed by the RFID device fabricated by Star Engineering Co. Ltd.

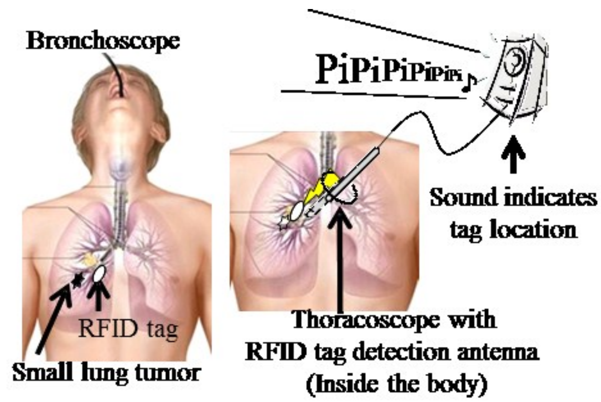

Fig. 1. RFID-tag based thoracoscopic surgery support system.

TABLE I
RFID SYSTEM PARAMETERS (TAGS AND READER WRITER DEVICE ARE FABRICATED BY STAR ENGINEERING CO. LTD.)

Standard	ISO 15693
Frequency	Antenna→tags 13.56 MHz tags →Antenna 13.56+/-0.423 MHz
Coding Pattern	Antenna→tags ASK 10% tags →Antenna FSK 10%
Size	10.5×2.2×1.2 mm
Transmission Rate	26 kbit/s
Magnetic field strength	Max 12 A/m

C. Saddle- Shaped Power Supply Antenna

Fig. 2 shows the shape of the antenna surface was designed. Saddle-shaped antenna is 280 mm long side, 240 mm short side and 137 mm height. In the design two types of antennas are shown, one is single-loop saddle-shaped antenna (Saddle 1A), and the other is six-loop saddle-shaped antenna (Saddle 6A). As a reference, a conventional six-loop antenna (Flat 6A) is examined. The wireline used in the antenna is supposed to be 1.8 mm in radius. Measurement point was set to be 50 mm in depth from the body surface, which corresponds to the location of the lung tissue. The input power for each antenna is assumed to be 16 W, 20 W, and 30 W, respectively. TableII. shows that the magnetic field strength generated by the power suppply antenna. Saddle 1A has reached 12 A/m the upper limit of normal operation of the RFID tag 16 W. Saddle 6A and Flat 6A cannot meet the requirement even if the power supplied to the antenna reaches 30 W.

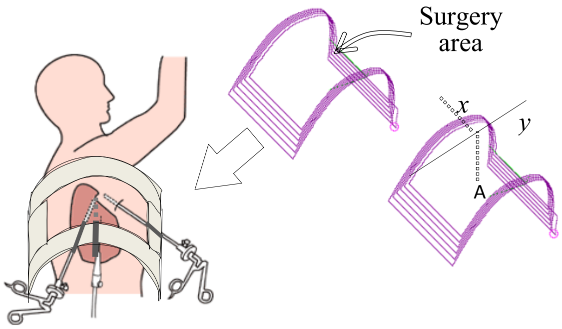

Fig. 2. Intraoperation of Saddle –Shaped Power Supply Antenna and signal level Measurement point

TABLE II
SIGNAL POWER MEASUREMENT RESULT A (MEASUREMENT POINT Y= - 50 MM)

Measurement Point	16 W	20 W	30 W
Saddle 6A Magnetization [A/m]	7.5	8.39	10.24
Saddle 1A Magnetization [A/m]	12.06	13.42	16.52
Flat 6A Magnetization [A/m]	7.541	8.43	10.33

IV. EXPERIMENT ON MARKING SYSTEM

A. *RFID tag signal Extraction*

Fig.3 and Fig.4 show the proposed method was implemented. In this experiment, we employ the RFID device fabricated by Star Engineering Co., Ltd. (RFID Reader Writer: TR3-LD003C).

A passive RFID tag is placed between a power supply antenna (A) and a sensor antenna (B). As shown in Fig.4, the tag is implanted in the patient's organ tissue.

In the experiment, the distance between the power supply antenna and RFID tag was set to be 10 mm. The signal strength against the distance between the sensor antenna and an RFID tag is then examined.

The received signal from the sensor antenna is the sum of the signal from the RFID-tag, whose frequency is 13.56 +/- 0.423 MHz, and the signal from the power supply antenna at the frequency of 13.56 MHz. In order to extract the signal from the RFID-tag from the detected signal, we employ frequency converter and narrowband filter as shown in Fig.5. Firstly, the received signal is applied to the DBM (Double Balanced Mixer). Frequency conversion is performed by mixing the carrier frequency of 13.56 MHz. The received signal after frequency conversion is then fed into the digital signal processing block. In the digital signal processing block, the signal is fed into FFT (fast Fourier transformation) part, after Hann window operation. FFT output is applied to the band pass filter (BPF) to extract only the frequency components near 0.423 MHz from the frequency domain received signal to extract the response signal from the RFID tag. In this way, it get the the received signal power.

B. *Result*

We performed the experiment five times and calculated the average for results. Fig. 6 shows the average value result of measurement 5 times. In less than 30 mm, the received signal amplitude was inversely proportional to the distance between the tag and sensor antenna. This result implies that the proposed scheme is capable of estimating the distance in 5 mm accuracy by measuring the signal amplitude.

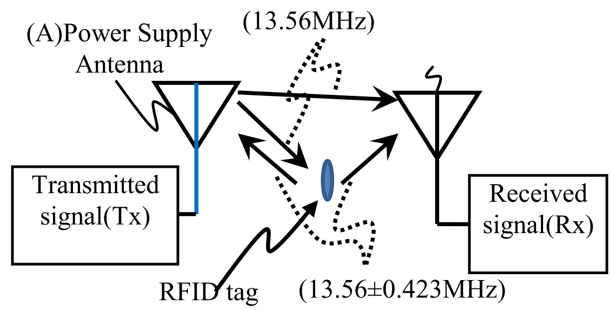

Fig. 3. Block Diagram of the signal from the RFID-tag

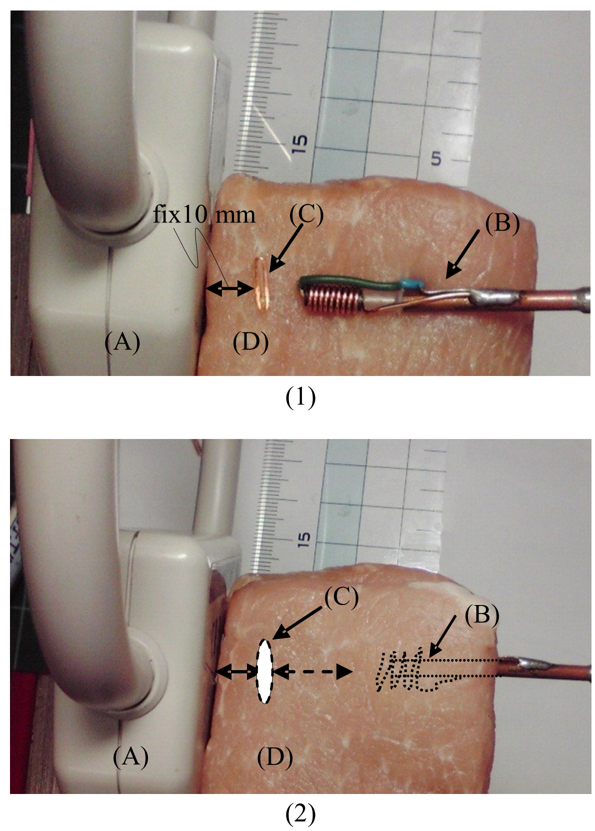

Fig. 4. Photographs showing actual measurement setup with phantom. Distance of the RFID-tag and the sensor antenna are variable. (1) using phantom measurement , (2)inside of phantom (A):Power Supply Antenna, (B) RFID-tag Signal Sensor Antenna, (C) RFID-tag, (D) Phantom(Pig)

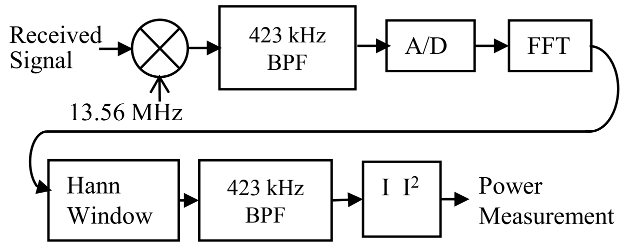

Fig. 5. RFID tag Signal Extraction Diagram

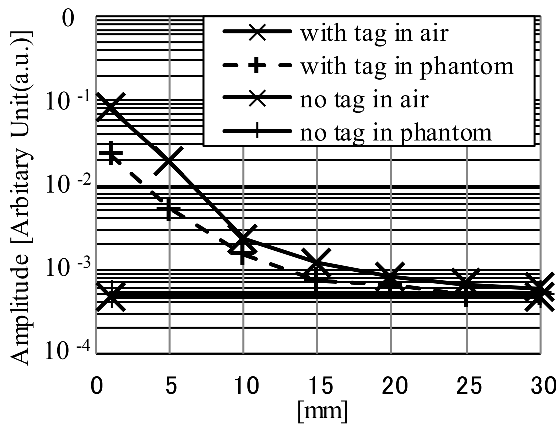

Fig. 6. Signal Level of RFID-tag between RFID-tag Signal Sensor Antenna. (a.u. is Arbitary Unit)

V. Conclusion

We have proposed an RFID-based thoracoscopic surgery support system, which is capable of marking the small lung tumor position. First we have designed the power supply antenna for supplying power to RFID-tags implanted near the tumor region. The designed antenna is saddle-shaped along the surface on the patient's body. Computer simulation result showed that the proposed antenna satisfies the required magnetic field strength at 50 mm away from the wire line. The designed "Saddle 1A" antenna can generate 12 A/m of the magnetic field when the input power is 16 W. This is considered to be a problem of impedance matching. We are now struggling to solve impedance matching of the designed antenna in order to improve the power efficiency.. This improvement may contribute to minimize power consumption of an power amplifier. The feasibility test in measuring the strength of the received signal from the tag implanted in the phantom is carried out. Although the power loss due to phantom medium was observed, the loss is negligible in estimating the distance. The proposed system is capable of estimating the position of the targeting tag in 5 mm accuracy. The paper also proposed the audio interface to indicate the estimated distance to the surgery operator.

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