Tube Positioning System Designed for Nasogastric Intubation

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***Abstract*—In this paper, a 915-MHz tube positioning system designed for nasogastric intubation has been proposed and demonstrated. The system consists of an in-body transmitting tag and an off-body handheld sensor. The handheld sensor is designed based on the dynamic monopulse radar technique to moderate tissue interference. It can be powered by batteries with an overall power consumption of 1.5 watts. For easy access and display, the MCU and Bluetooth modules are employed to transmit the measurement results to the smartphone. The measurements conducted with ground pork show that the proposed system can successfully detect the tag that is buried 7.5 cm underneath the surface.**

Keywords—nasogastric, sensor, intubation, monopulse radar

I. Introduction

The nasogastric tube (NG tube, NGT) has been commonly used in medical care to provide enteral feeding when patients encounter swallowing disorders. The intubation procedure is inserting a plastic or silicone NGT through the nostrils, down the esophagus, and into the stomach. Even though it is a very regular and safe procedure, it still has some harmful risks, such as injury to the digestive organs during insertion or regurgitation when NGTs are blocked or coiled up. Since the esophagus is right behind the trachea in the neck region, the worse case is that NGTs accidentally enter the trachea instead of oesophagus. Once the tube tip is lying in the lungs instead of stomach, fluid or medication will go into the lung through tube feedings, leading to severe complications such as pneumonia or even death.

To prevent tube displacement, medical professionals use specific guidelines to check tube placement [1]. Color-coded pH paper is usually used to measure the pH of gastric aspirate (pH≤ 5.5). However, those people who have suffered from eating disorders for a certain period of time may not have gastric aspirate to draw. The stomach medicine taken by the patients may also mislead the pH reading of the stomach contents. X-ray radiography is another routinely used procedure, but it is expensive and time-consuming, not to mention unsafe radiation exposure. Even with those checking guidelines, cases of injury and death due to error intubation are still reported every year. It is in demand to have a more efficient and accurate sensing technique to confirm the tube location prior to using NGT for feeding.

There have been several tube-guiding devices available on the market [2-4]. They use different technologies to monitor the intubation process. Although those devices seem promising, they still cannot guarantee 100% successful intubation. In addition, those devices are relatively pricey, making it challenging to promote them to all hospitals or nursing homes.

In this work, a portable wireless NGT position tracking system, which consists of an in-body transmitting tag and an off-body handheld radar-based sensor, is proposed to assist with intubation. As shown in Fig.1, the 915-MHz transmitting tag is attached to the guidewire or NGT and is carried into the human body along with the tube. Outside the body, the handled sensor receiver is used to scan through the skin surface and detect the tag's location. Meanwhile, the measurement results can be sent to the smartphone for easy access and readout. The ultimate aim is to develop a low-cost but reliable intubation aid so that medical professionals can easily carry those devices everywhere in need and assist them in checking tube placement before each feeding.

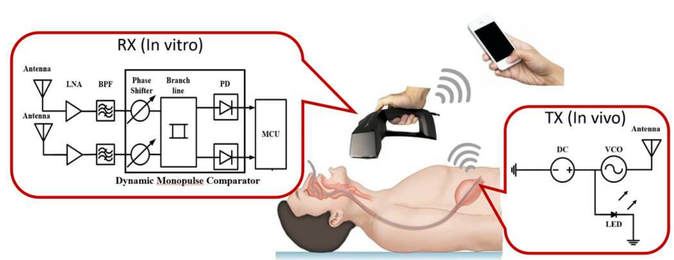


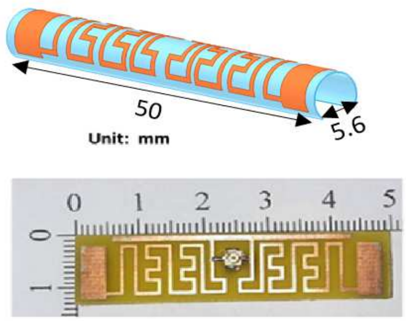
Fig. 1. Scenario of the proposed NGT position tracking system and associated circuit blocks.

II. System Design

A. In-Body Transmitting Tag

[5] has proposed an approach by attaching the transmitting tag to the guidewire. The semi-rigid, steel-core guidewire is placed inside the tube to help increase the force during intubation and can be removed once the tube is correctly positioned. Although the guidewire-assisted technique can be potentially applied to all kinds of invasive medical tubes, the choices and designs of the tag antenna are very confined due to extremely small diameter of the guidewire.

Accordingly, a planar meander-line dipole antenna is chosen in this work, as shown in Fig.2. The size is 50 mm×13 mm, which can be easily wrapped around the NGT. At 915 MHz, the measured return loss is 17.3 dB with 19 MHz bandwidth. The Omni-directional radiation patterns with a peak gain of -0.6 dBi can ensure the signal reception regardless of the tube's orientation.



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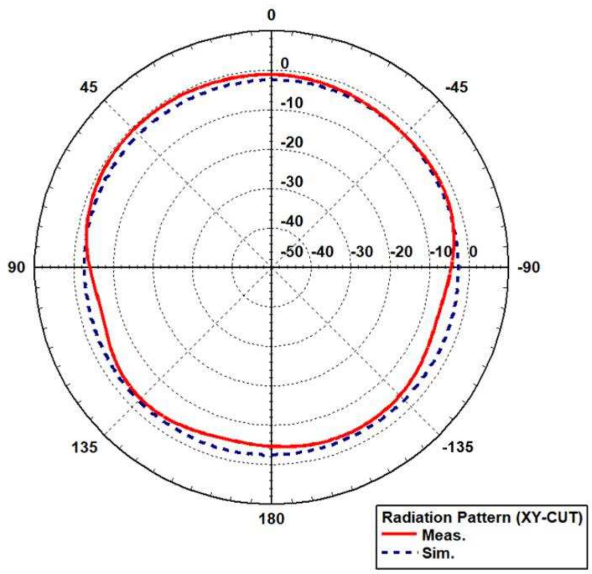

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Fig. 2. (a) The proposed tag antenna and implemented circuit photo, (b) The comparison of measured and simulated radiation patterns.

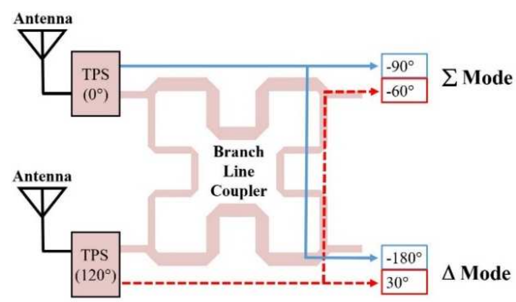
B. *Off-Body Sensor Receiver*

For off-body sensing, a 915-MHz amplitude-based monopulse radar system is chosen as the sensor receiver. Monopulse radar is mainly used for target angle measurement and tracking. The information on the target angular position is determined by comparison of signals received in two or more simultaneous beams. According to the concept of conventional monopulse comparator, the received signals can result in sum and difference patterns. Target's angular position can be estimated using a sum-difference power ratio curve. In this application, the signals propagate from the inside out through the human body, which will encounter significant attenuations due to tissue effects. Using power ratio instead of absolute power strength can moderate the impact, which becomes beneficial for this application.

Furthermore, a pair of tunable phase shifters are added to the monopulse comparator to form a dynamic monopulse receiver. The literature has already proven its feasibility in improving positioning accuracy [6]. By electrically adjusting the phase difference of those phase shifters, the radiation beam can be steered and thus distribute numerous power ratio curves in the desired field-of-view, as shown in Fig.3. The target's angular position is thus estimated by the power detector readings. Since the positioning data is averaged from several power ratio curves, positioning error can be reduced.

The monopulse comparator is integrated with chip antennas, low-noise amplifiers, and bandstop SAW filters. In addition, an Arduino pro-mini module is employed to control the circuit as well as process the data. Note that the antennas are surrounded by a soft foam to increase the comfort level so that the sensor can be close to the skin surface during scanning. In order to easily access and read out the data, a Bluetooth module (HC-05) and a LCD display are also added to this handheld device. Figure 4 shows the photos after all components are assembled in a customized handheld case. Overall the power consumption is 1.5 watts. Since the required supply voltage is only 5 volts, it can be powered by batteries or a USB power bank, making it more portable and convenient to use.

The Bluetooth module is used to transmit data to a smartphone for data storage or serve as a control panel. To make it more practical, a user interface program running on the Android system is also developed using App Inventor.



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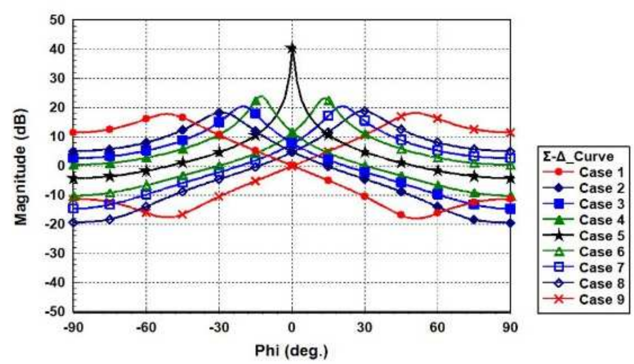

(b)

Fig. 3. (a) Schematic of proposed dynamic monopulse radar receiver, (b) The resultant power ratio curves by phase sweeping.

III. Measurement Results

The measurement is performed using ground pork. An 8.3-cm-thick ground pork is stacked in a plastic container, where the tag antenna is placed inside the ground pork. According to our application, the intubation pathway is relatively confined so that the maximum positioning area along the pathway should be less than 16 cm × 16 cm. Therefore, the handheld sensor is moved on a 16×16 grid in increments of 1 cm along both x and y directions, resulting in a total number of 256 measurement points.

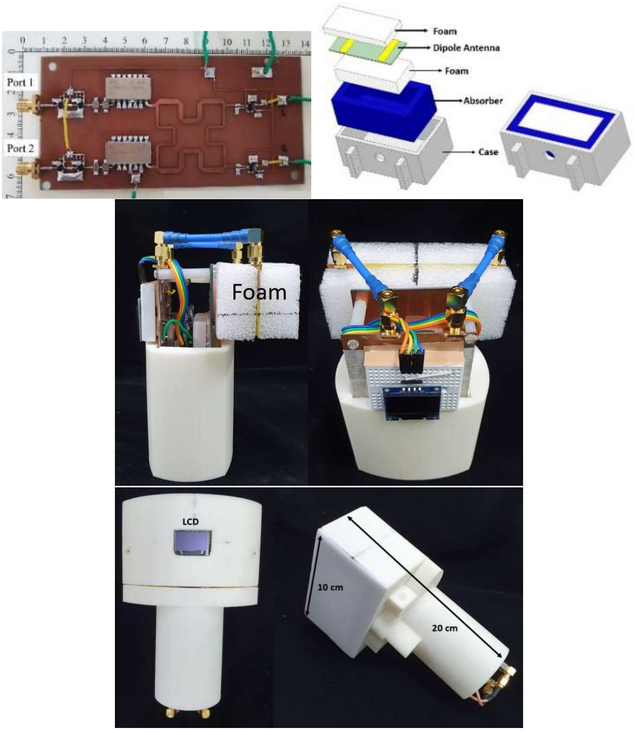

Fig. 4. Photos of the proposed handheld system assembling.

Measurement results from two burying depths of the tag antenna are shown in Fig.5. For the case where the tag is placed 4.5 cm underneath the surface, the position of the tag (indicated by a dash-line box in the figures) can be clearly identified. When the burying depth is increased to 7.5 cm, the tag antenna can still be detected even though the received power is reduced due to more propagation loss. The position error is increased as well when the depth is increased. Fortunately, our application for NGT intubation doesn't require precise positioning accuracy since NGT is theoretically inserted into the upper digestive tract. Therefore, it can allow a certain error tolerance along the pathway but still should pay extra attention to some risky areas, such as intersections of the epiglottis, bronchi, and cardia. The system should be able to determine whether the NGT is passing through those areas instead of detouring to the wrong pathway.

IV. Conclusion

This work designs and demonstrates a tube positioning system designed for nasogastric intubation. Although the feasibility of the proposed concept has been proved, the research is still very primary, and further improvements are currently under development; and also continue to try deeper measurements to ensure it fits each patient's body type. This tube positioning technology can be applied to other types of medical tubes, such as an endotracheal tube or urinary catheter, to help prevent tube misplacement. The ultimate goal of this project is to develop a low-cost, portable, yet convenient guiding device serving as an intubation aid. Hopefully, someday in the future, it can help improve patient care as well as reduce healthcare costs.

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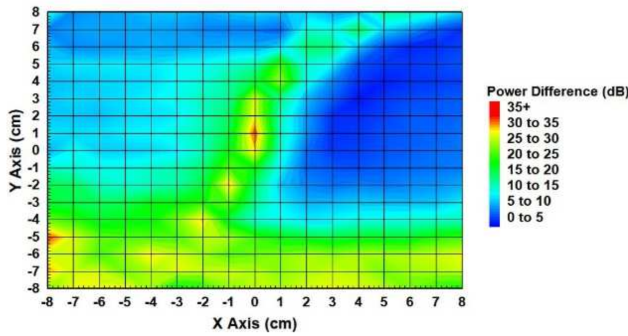

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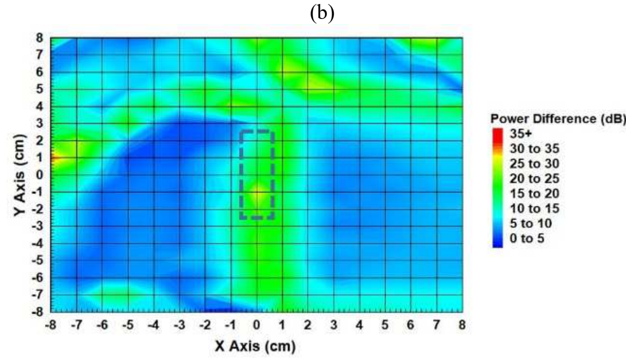

(c)

Fig. 5. (a)Experimental setup, Measured results with antenna burying depths (b)45-mm and (c)75-mm in ground pork.

Acknowledgment

The authors would like to express their gratitude the supported in part by the Ministry of Science and Technology of Taiwan under Grants MOST 110-2221-E-194-013-.

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