URSI AP-RASC 2019, New Delhi, India, 09 - 15 March 2019

Tri-band Wireless Capsule Endoscopic Communication System for Low Frequency Real-time Image Transmission

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Abstract

Wireless capsule endoscope (WCE) is a device that can realize real-time image transmission without cables. In this paper, a tri-band WCE communication system is proposed for low frequency real-time image transmission. The system consists of two transmitting antennas and a receiving antenna, with three frequency bands (38.5, 48.2 and 57.6 MHz band). Simulated results show that the path loss is 51, 30.6 and 54.4 dB at 38.5, 48.2 and 57.6 MHz with the distance of 50 mm between the capsule and the receiving antenna, and indicating that the communication system is possible to be used for WCE real-time image transmission.

1. Introduction

For patients requiring small bowel diagnosis, wireless capsule endoscope (WCE) a good option as it can realize real-time image transmission without cables and can inspect the entire small intestine area [1]. The transmitting antenna inside the capsule and the receiving antenna attached to the body surface are indispensable devices for real-time image transmission, usually realized by inductively coupled coils [2] - [4]. Optional operating band includes 400 MHz and 2.4 GHz bands, with the 400 MHz band usually for data transmission and the 2.4GHz band usually for device wake-up and control.

However, due to the absorption of the human body, high frequency signals are not a good choice for human body communication. The measurement results in [5] show that the path loss of the 2.4 GHz communication system is about 80dB with the antenna distance of 50 mm. On the contrary, using low frequency signals can effectively reduce signal absorption. In [6], the path loss is only about 40 dB at 30 MHz with the antenna distance of 50 mm. Unfortunately, the antenna bandwidth at low frequencies is usually narrow, and resulting in a lower data rate. In general, real-time image transmission requires a data rate of 2.4 Mbps [7], which is a huge challenge for low frequency antennas.

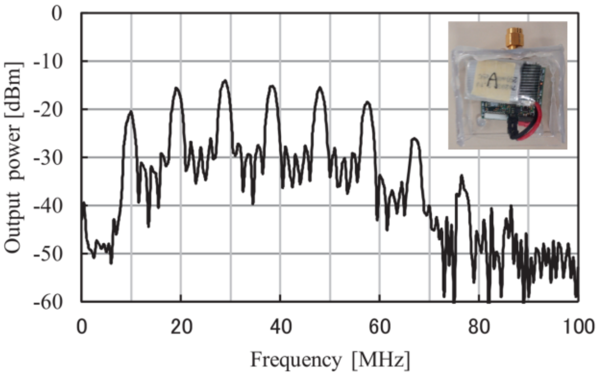

Figure 1. IR transceiver and signal spectrum [8].

J. Wang, et al. developed a 10 - 60 MHz impulse radio(IR) based transceiver with corresponding antennas for human body communication [6], [8]. The transceiver can generate pulses of 10 ns width with a maximum output of -15 dBm, as shown in Fig. 1 [8]. There are five signal strong frequencies between 10 - 60 MHz (19.3, 28.9, 38.5, 48.2, and 57.6 MHz), and up to five frequency bands can be used for multi-band communication. Data rate of 1.25 Mbps can be realized in [6], but still not enough for real-time image transmission. If other signal peaks of the transceiver can be used, the data rate can be further improved, and therefore real-time image transmission is possible to be realized.

2. Antenna structure and simulated result

Two transmitting antennas and a receiving antenna in [3] and [4] are used for performance evaluation. For convenience of description, the transmitting antenna operating at 48.2 MHz is called as Tx_1 (width: 0.2 mm; pitch: 0.4 mm; copper thickness: 0.017 mm), the transmitting antenna operating at 38.5 and 57.6 MHz is called as Tx_2 (width: 0.1 mm; pitch: 0.2mm; copper thickness: 0.017 mm), and the receiving antenna operating at 38.5, 48.2 and 57.6 MHz is called as Rx (width:0.4 mm; pitch: 1 mm; copper thickness: 0.017 mm), as shown in Figs. 2 (a) - (c). All antennas are designed by FR-4 substrates ($\varepsilon_r = 4.3$, tan $\delta = 0.035$), and optimized by CST STUDIOSUITE 2018. Fig. 2 (d) shows the simulation environment. Two transmitting antennas are placed at two ends of a polyetheretherketone (PEEK) capsule ($\varepsilon_r = 3.2$, tan $\delta = 0.01$), with a PEC cylinder as the battery and transceiver. The receiving antenna is attached at the bottom center of a muscle phantom ($\varepsilon_r = 76.4$, $\sigma = 0.7$ S/m at 50 MHz [9]) with dimensions of 100 × 100×100 mm^3, with a

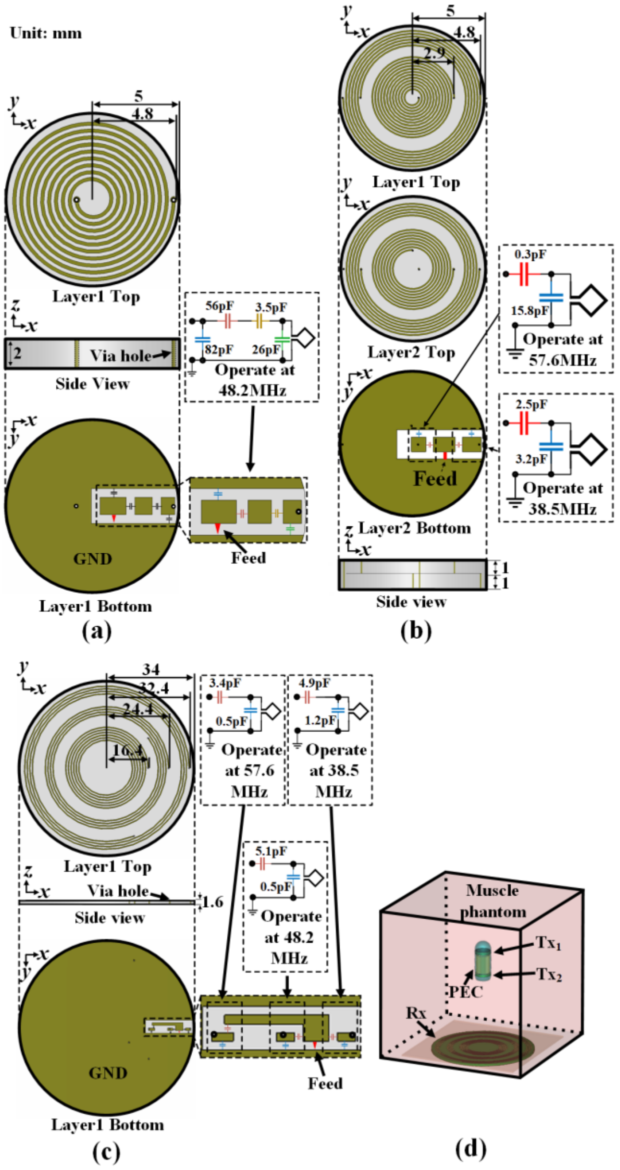

Figure 2. Structure and dimensions of three antennas and simulation environment. (a) Structure of Tx₁. (b) Structure of Tx₂. (c) Structure of Rx. (d)Simulation environment.

80 × 80 × 1 mm^3 Teflon pad ($\varepsilon_r = 2.1$, tan $\delta = 0.0002$). Fig. 3 shows the simulated reflection and transmission coefficients. The -10-dB bandwidth of two transmitting antennas are 39.3 - 39.4 MHz, 48.1 - 48.2 MHz and 57.3 - 57.7 MHz, respectively, and the -10-dB bandwidth of the receiving antenna are 38.5 - 38.9 MHz, 47.8 - 48.4 MHz, and 57.8 - 58.5 MHz, respectively. Due to the position adjustment of the antenna, the resonant frequency is slightly different from results in [3], [4]. The simulated transmission coefficient is -51, -30.6 and -54.4 dB at 38.5, 48.2 and 57.6MHz, respectively. Since it is possible to receive the data from the transceiver with attenuation of 85 dB [6], it can be roughly assumed that the system can realize a data rate of 1.25 Mbps of each frequency band, and can realize a total data rate of 3.75 Mbps to meet the requirements of real-time image transmission.

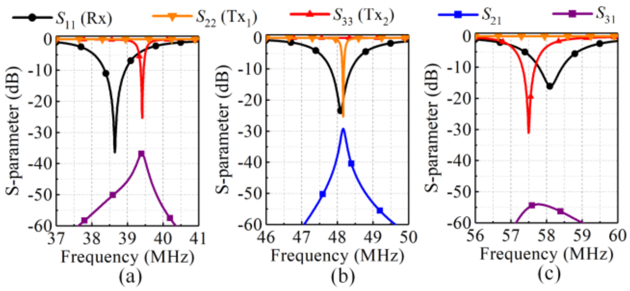

Figure 3. Simulated reflection and transmission coefficients. (a) Tx_1 and Rxfrom 37 to 41 MHz. (b) Tx_2 and Rx from 46 to 50 MHz. (c) Tx_1 and Rx from 56 to 60 MHz.

3. Conclusion

In this paper, a low frequency tri-band WCE communication system is proposed with two transmitting antennas and are receiving antenna for WCE real-time image transmission. Simulated results show that the system can meet the data rate requirements of real-time image transmission and can realize tri-band communication.

4. Acknowledgements

Authors thank Prof. Jianqing Wang from Nagoya Institute of Technology for their valuable advice and the fund support by the MIC/SCOPE #185006005, and the Otsuka Toshimi Scholarship Foundation.

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