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Ultra-wideband Conical Helix for Capsule Endoscope System

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Abstract

In this paper, the ultra-wideband (UWB) conical helix antenna for the implantable micro-systems is proposed. To transmit the diagnostic real-time image data with high resolution at high speed, the system with the larger bandwidth is needed. A wideband antenna suitable for such systems is required. The proposed antenna can be designed to satisfy the ultra-wide bandwidth in a capsule endoscope system. The bandwidth enhancement of the small-sized antenna is significant in a restricted volume. To realize this, the conical shaping is applied to the normal mode helical antenna (NMHA). The conical helix is considered as 3-dimensional structure of the meander line with Bowtie shape holding a wide bandwidth performance. The designed antenna covered with a capsule is simulated in the body equivalent material released by FCC. The antenna has the bandwidth of 385~500 MHz for VSWR<2 and the fractional bandwidth of 25.9%. The antenna has the omni-directional radiation pattern to transmit signals independent of capsule position and orientation. The antenna size is 8mm in diameter and 7mm in height. The proposed structure provides the ultra-wideband performances within the implantable micro-systems at the biomedical frequency band, and can be viable for the UWB systems of the biomedical telemetry.

1. Introduction

In recent years, the implantable micro system, which is a kind of wireless systems for biomedical applications, has been introduced [1]. This system transmits internal image data to an external receiver. The system contains a camera module, batteries, associated circuitry, and an antenna, and these devices are encased in a capsule module. Since the capsule endoscope system is very small and works inside the body, several considerations are required. The electromagnetic properties of human body tissues, which have effects on the antenna performances and propagation channel, are considered first. Secondly, a very small-sized antenna is required. For a receiver to detect the transmitted signal independent of capsule positions and orientations, the proposed antenna needs to have an omni-directional radiation pattern. Lastly, in order to transmit diagnostic real-time image data with high resolution at high speed, an ultra-wideband (UWB) antenna suitable for the UWB implantable system is required. Existing systems for the wireless capsule endoscope nearly have a narrow bandwidth in the operating frequency band, which leads to low resolution of medical image data [2, 3]. Therefore, in this paper, the UWB antenna viable for UWB implantable telemetry is proposed.

2. Antenna Design

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Basically, since the capsule endoscope system is implanted inside the body, design of the antenna is based on the study of the materials and the propagation characteristics in the body [4]. The human body consists of many parts, which have frequency dependent material properties such as dielectric constant and conductivity. As in [3], the multilayered human body can be simplified as one equivalent layer. According to the document released by FCC, the average values of the body tissue parameters are 56 in permittivity and 0.83 in conductivity [5]. For the implantable medical devices, the magnetic antenna is profitable in the body [1]. Thus, the antenna proposed in this paper is a broadband helical antenna which operates on normal mode at the biomedical band. Generally, the NMHA has the narrow bandwidth. However, by applying the conical structure to the NMHA as shown in Figure 1, the broadband characteristics can be obtained [6]. The conical helix is considered as 3-dimensional structure of the meander line with Bowtie shape holding a wide bandwidth performance. The total length of the conical helix is a quarter wavelengths, differently from the conical spiral antenna. The antenna has the diameter of 8 mm and the height of 7 mm. It is located at the right side of the capsule in Figure 1.

3. Simulated Results and Discussion

The simulated return losses of the proposed conical helix and the conventional helical antennas are shown in Figure 2. As shown in figure, while the bandwidth for VSWR<2 of the conventional NMHA is 21 MHz of 443 ~ 464 MHz and the fractional bandwidth is 4.6 %, the bandwidth of the proposed conical helical antenna is 115 MHz of 385 ~ 500 MHz and the fractional bandwidth is 25.9 %, which is larger than, 20 %, the reference of the UWB fractional bandwidth. The values are obtained within capsule in the tissue-simulating fluid with relative permittivity of 56 and conductivity of 0.83. Figure 3 shows the radiation patterns of the proposed antenna. The elevation pattern is depicted in solid line, and the azimuth in dotted line. The radiation patterns are omni-directional likely as the conventional one. The proposed antenna within a capsule sample is positioned in the center of the container filled with tissue-simulating fluid with permittivity of 56 and conductivity of 0.83. The receiving loop antenna is adhered to the outer surface of the container. Figure 4 illustrates the measurement setup using tissue-simulating fluid for the scattering matrix and the received power on azimuth plane. Measurement on elevation plane is taken by bending the coaxial cable to a right angle. Experimentally observed results will be presented at the conference.

4. Conclusion

The UWB conical helix antenna for the biomedical telemetry is proposed to support the capsule endoscope system using ultra-wide bandwidth. To achieve the bandwidth enhancement of the NMHA, the conical shaped structure is applied to the NMHA. The proposed antenna has the bandwidth of 385 ~ 500 MHz for VSWR<2 and the fractional bandwidth of 25.9 %, covered with capsule in the tissue-simulating fluid with relative permittivity of 56 and conductivity of 0.83. The antenna has the omni-directional radiation pattern to transmit signals independent of capsule position and orientation. The antenna size is 8mm in diameter and 7mm in height. The proposed structure provides the ultra-wideband performances within the implantable micro-systems at the biomedical frequency band, and can be viable for the UWB systems of the biomedical telemetry.

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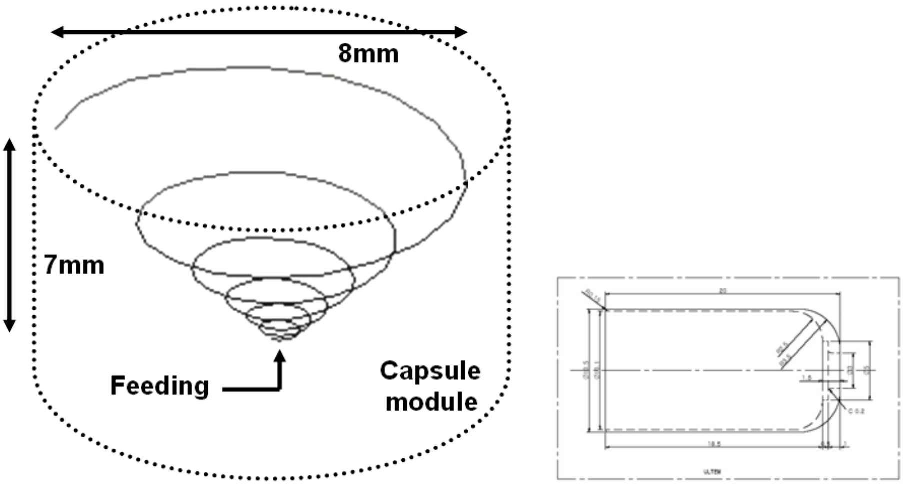

Fig. 1 Configuration of the conical helix and the layout of the capsule endoscope

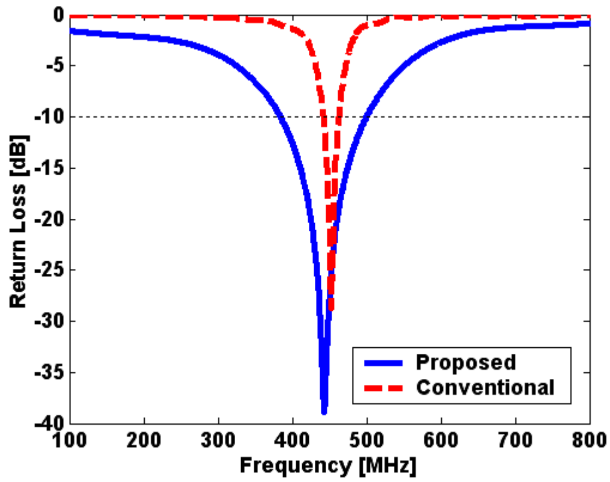

Fig. 2 Simulated return losses of the proposed and conventional helical antennas

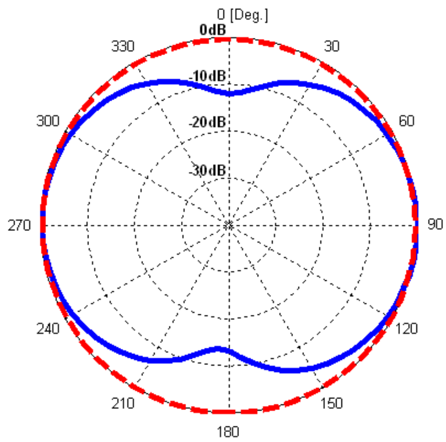

Fig. 3 Radiation patterns of the elevation and the azimuth plane

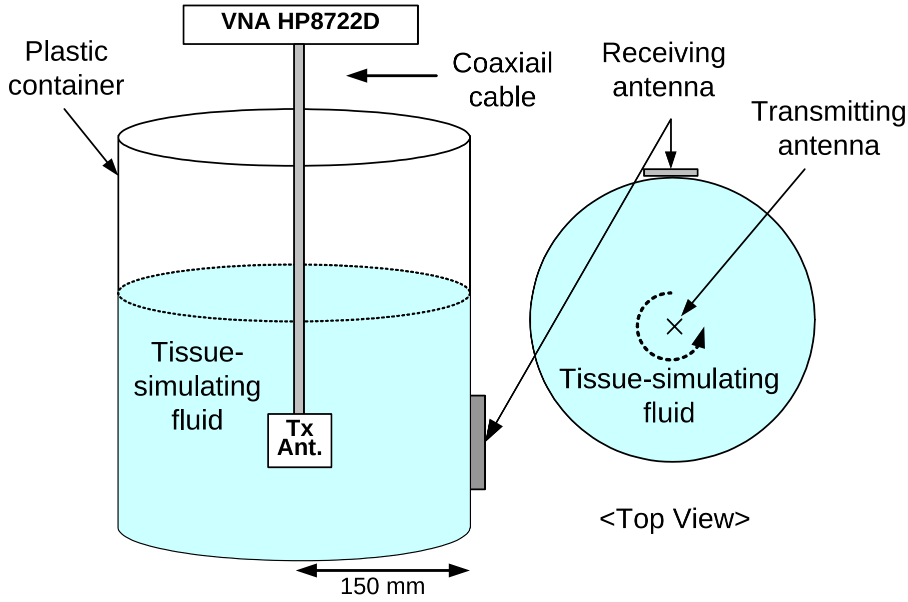

Fig. 4 Measurement setup using tissue-simulating fluid for the scattering matrix and the received power on azimuth plane

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