Characteristics Comparison of Three Different WCE Implanted Antennas in UWB Low Band

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ABSTRACT

This paper proposes and compares three different kinds of implanted antenna designs operating in ultra-wide band (UWB) low band 3.1-4.8 GHz to meet the demand of deep implantation and larger bandwidth for medical wireless capsule endoscope (WCE) application. The proposed antennas can be accommodated in the capsule dome and are characterized by light weight, low profile, low cost, small size. Antenna characteristics are compared in terms of input impedance matching, impedance bandwidth, axial ratio, radiation power, front-to-back ratio, peak gain, as well as near-field E field. Measurement results will be shown in presentation also with different TX orientations and receiving antennas.

Keywords

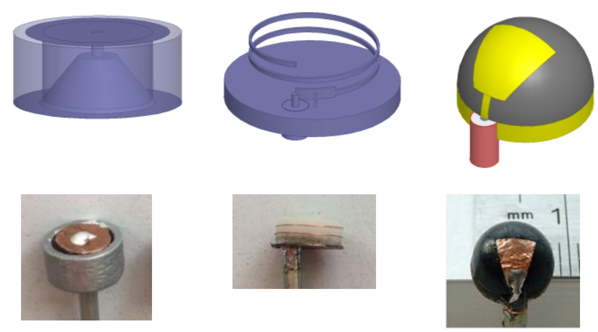
Implanted antenna; dielectric resonator antenna (DRA); WCE; UWB.

1. INTRODUCTION

Wireless capsule endoscope (WCE) capsule can take pictures/videos and then transmit the real-time biological data from the inside of the gastrointestinal tract to exterior medical instruments. The current technical challenges for WCE communications lies in the demands of deep implantation and larger bandwidth for higher-resolution video transmission. RF frontend antennas of the TX/RX system play a critical role in the high performance of the high frequency and larger bandwidth for deep implantation communication. In the previous work, we have proposed a conformal trapezoid strip excited broadband hemispherical dielectric resonator antenna (DRA) design in ultra-wide band (UWB) low band 3.1-4.8 GHz [1]. In this paper, we propose other two designs for implanted WCE capsule and compare the antenna characteristics of all the three designs.

2. ANTENNA CHARACTERISTICS

Figure 1 summarizes the proposed three antenna types, which are all accommodated in half sphere of the capsule end with dimension 11x6mm. In UWB low band, the surrounding medium of the capsule antenna can be approximately determined as one homogeneous medium with average muscle tissue at 4GHz which has dielectric constant of 51.5 and average conductivity of 3.2 S/m [1]. Figure 2 shows the return loss comparison in average muscle tissue phantom. All of the three antennas can be tuned to have a good matching performance within UWB low band in spite of different impedance bandwidths.



(a) discone (b) helix (c) DRA

Figure1. Three proposed antenna designs operating in UWB low band, (a) discone antenna with back cavity and shorting wall; (b) helix antenna with matching stub; (c) conformal trapezoid strip excited hemispherical DRA.

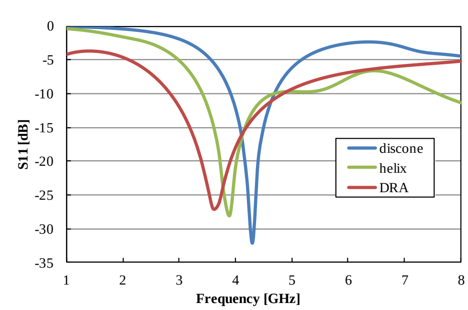


Figure 2. Comparison of the simulated return losses in tissue-simulating fluid phantom.

The conformal trapezoid strip excited broadband hemispherical DRA has been described in detail in [1]. The discone antenna can increase bandwidth with introduction of the back cavity and achieve good impedance matching with shorting wall between disc and cone. Figure 3 shows the impedance improvement and as expected [2] largely declined impedance of the implanted antenna has been enhanced and matched to 50 Ohm. The resonance frequency of the proposed discone antenna can be tuned easily via shorting wall position as well as the cone slope.

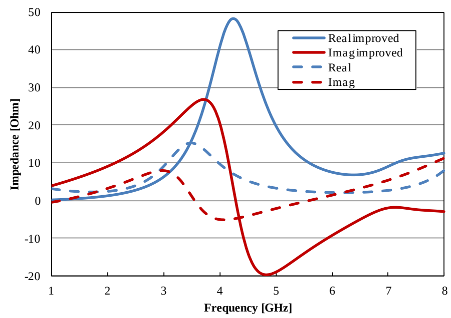


Figure 3. Impedance of discone antenna with back cavity; improved impedance matching with shorting wall.

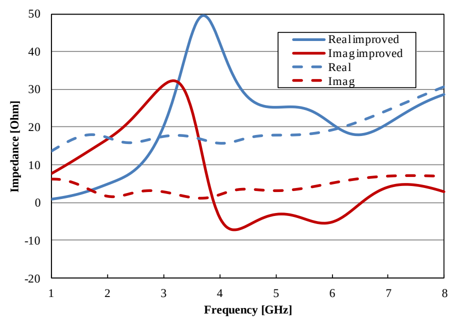


Figure 4. Impedance of helix antenna; improved impedance matching with short shunt stub and flattening feeding.

The proposed helix antenna operates in quasi-axial mode with fair cross-polarization ratio. The terminal impedance of a helix radiating in the axial mode in free space is nearly resistive with values 100–200 ohms. When the helix is implanted inside biological tissue, the impedance will be as expected largely reduced as shown in Figure 4 [2]. In order to provide a better matching inside biological tissue, a short stub between the first helix pitch and ground plane as well as a wider flat strip at the feeding start are employed. The improved impedances are shown in Figure 4, from around 20 ohm up to around 50 ohm. The resonance frequency of the helix antenna can be tuned easily changing the short stub distance from the coaxial transmission line as well as the feeding height.

Table 1 and Table 2 compare the far-field and near-field characteristics of the proposed three antennas respectively. DRA can cover the full UWB low band, nearly 3-5 GHz and bandwidth of the helix is 1.5 GHz, while discone has relatively narrow bandwidth, i.e., 0.8 GHz. Both DRA and discone antenna have relatively good linear polarization characteristics with high axial ratio. Helix antenna works in the axial mode and possesses elliptical polarization. The radiated power is integrated over a far-field sphere with 80 mm radius. In terms of the radiation ability, DRA exceeds helix and helix further exceeds discone. DRA explicitly shows higher power radiating outwards than the helix and discone antennas. This characteristic plays an important role in WCE

Table 1. Far-field characteristic comparison

	Discone	Helix	DRA
Bandwidth [GHz]	0.8	1.5	2.0
Axial ratio [dB]	50	6	48
Radiated power [dBW]	-88.8	-68.1	-59.1
Front-to-back ratio [dB]	2.33	3.9	6.2
Peak gain [dBi]	-79.6	-55.8	-49.3

Table 2. Near-field characteristic comparison

Max near field E field [V/m]	Discone	Helix	DRA
20mm Sphere	0.88	13.5	33.8
40mm Sphere	0.09	1.14	3.1

communications. On the other hand, obviously, due to the high lossy characteristics of the biological tissue in UWB, path loss is much larger than that in free space. That is why the radiated power seems relatively low. Front-to-back ratio can represent partly the directivity of the implanted antenna. DRA exceeds the other two in terms of the front-to-back ratio and transmitting power can be more directed. In fact, when the receiving antenna locates in the near-field region of the transmitting implanted antenna, the radiating/coupling front-to-back ration may be distance-dependent. About the gain at the maximum radiation direction, the peak gain of DRA also shows better performance than the other two antennas.

In the near-field comparisons, two near-field spheres with radius of 20 mm and 40 mm are set up to measure the maximum E field. The capsule antenna accommodation half sphere has a diameter around 11mm and the effective wavelength at 4 GHz inside biological torso tissue is around 10 mm. Therefore 20 mm and 40 mm sphere can be approximately regarded in near-field region of the implanted antenna in ideal case (with ideal transmitting source and same-aperture receiving antenna). The maximal near-field coupled E field of DRA is still higher than helix and discone.

In words, DRA can have good impedance bandwidth, good linear polarization, high radiated power and good directivity compared with the other two proposed helix and discone. In terms of communication with wearable receiving antenna, if the transmitting implanted antenna with strong linearized directivity, the wearable receiving antenna array will undertake more performance responsibilities, since the transmitting implanted antenna will randomly move inside the gastrointestinal tract. However, on the other hand, strong radiating/coupling capability will lead a dominant role rather than the other characteristics, such as circular polarization or omni-directional radiation characteristics.

3. ACKNOWLEDGMENTS

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4. REFERENCES

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