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No-Power-Supply Steerage for Endoscope Capsule by Combination of DC Magnetic Field and Ultrasonic Beacon

直流磁場と超音波ビーコン併用による内視鏡カプセル等の無給電操舵の研究

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1. Introduction

Given Image Ltd. and Olympus Medical Systems Ltd. are providing endoscope capsules and several other companies are catching up with them. Endoscopy has become a very popular medical diagnosis method nowadays. Today's capsules have functions of taking photographs of internal organ walls, especially stomach and intestine walls, and store the data into several G-Byte memory included in the capsules or send the data directly to external monitor screen. However they cannot be controlled to turn and move by external key-board or joystick commands.

As the endoscope capsules are brand-new products, there are a lot of demands for improving their performances and adding new functions to them. Controllability by external commands, farther miniaturization and battery-less, addition of manipulation functions, etc. are the typical requirements necessary to be investigated. We have been studying no-power-supply steerage to fix the direction of capsule and also no-power-supply drive to propel the capsule. In this paper we focus on the former item, while the other paper will treat the latter.

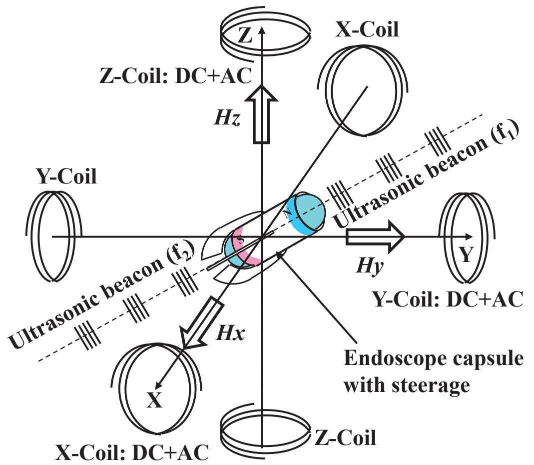

Fig. 1 Endoscope capsule with magnetic thin cylinder and ultrasonic beacon.

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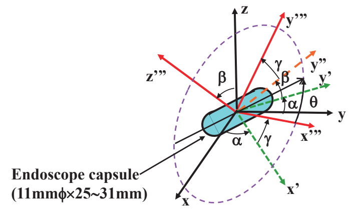


Fig. 2 Direction of capsule and coordinates to determine Hx^{DC}, Hy^{DC} and Hz^{DC}.

2. No-power-supply steerage for endoscope capsule

The endoscope capsule has no motor to move independently, so no-power-supply steerage is crucial for turning. As shown in Fig. 1, the size is a diameter of about 11 mm and a length of 25 to 31 mm. It must turn to right and left on a given plane (Fig. 2). We have studied a method using magnetic force as no-power-supply steerage and ultrasonic-beacon method to indicate direction of the capsule.

A thin cylinder-type magnet with fins is attached to the capsule. Magnetic fields, *Hx*, *Hy* and *Hz*, are generated by external X-, Y- and Z-coils. They are given as follows:

$$Hx = H\sqrt{\cos^2\alpha + \sin^2\alpha\cos^2\beta}\ \cos(\theta + \gamma + \varphi_x) \quad (1a)$$

$$\varphi_x = \arctan(\tan\alpha\cos\beta) \quad (1b)$$

$$Hy = H\sqrt{\cos^2\alpha\cos^2\beta + \sin^2\alpha}\ \sin(\theta + \gamma + \varphi_y) \quad (2a)$$

$$\varphi_y = \arctan\left(\frac{\tan\alpha}{\cos\beta}\right) \quad (2b)$$

$$Hz = H\sin(\theta + \gamma)\sin\beta \quad (3)$$

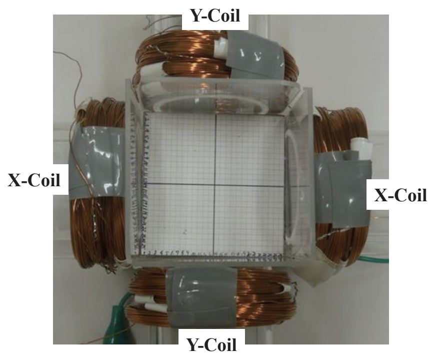


Fig. 3 Experimental no-power-supply steerage system.

3. Fundamental experimental model for no-power-supply steerage

In order to confirm our proposal, we developed a simple two-dimensional no-power-supply steerage system shown in Fig. 3. The active area can be modified from 5×5 cm^2 to 10×10 cm^2. Supply DC voltages for X- and Y-coils are variable from 0 to 12 [V]. Fundamental operations required to steer the capsule have been confirmed using this system.

4. Magnetic field distributions by DC steerage voltages

To develop more functional systems based on the Fig. 3's model, we precisely measured magnetic field distributions. We measured two types of distributions shown in Fig. 4 and 6. In the former, magnetic field is parallel to X- or Y-axes and measurement was done along the lines perpendicular to the field. Three lines at center and at ±2 cm offset from the center respectively were arranged. In the latter, magnetic field is slanted by about 45° from the axes. Same three lines perpendicular to magnetic field were arranged.

Measured magnetic field distributions of the former and latter are shown in Fig. 5 and Fig. 7 respectively. Perpendicular components to measurement lines are shown in Fig. (a) of each figure. Parallel components to measurement lines are shown in Fig. (b) of each figure. To control steerage of the capsule, exact magnetic field distributions should be determined at any place of access area. By physical consideration of experimental results, we will improve the structure to obtain more uniform magnetic field.

5. Conclusion

We have been investigating new no-power-supply steerage and drive for endoscope capsules. Fundamental experiment was done for the former.

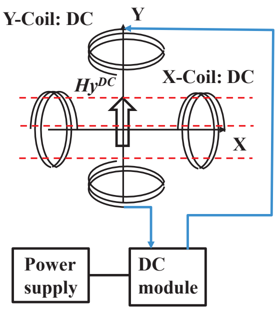
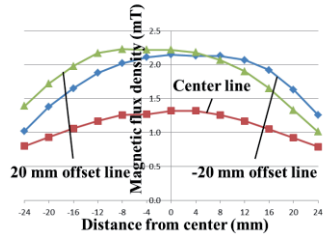
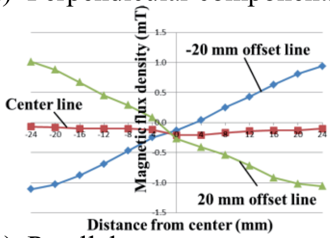


Fig. 4 Measurement of magnetic field distributions. Magnetic field is parallel to axis.



(a) Perpendicular components



(b) Parallel components

Fig. 5 Measured magnetic field distributions in Fig. 4.

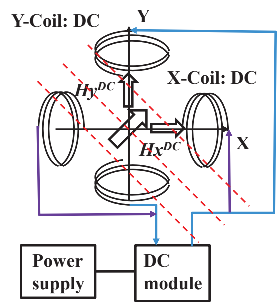
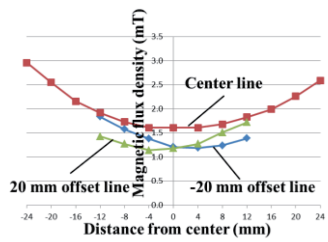
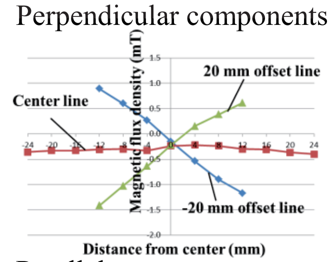


Fig. 6 Measurement of magnetic field distributions. Magnetic field is slanted by 45°.



(a) Perpendicular components



(b) Parallel components

Fig. 7 Measured magnetic field distributions in Fig. 6.

References

1. Home page of Given Image Ltd., http://www.givenimaging.com/.

2. T. Sakata and M. Hikita, in Proc. of Symp. on Ultrason. Electron. Vol.34, pp.127-128, 2013.