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Study on No-Power-Supply Drive for Endoscope Capsule by AC Magnetic Field – Investigation of Addition to No-Power-Supply Steerage –

交流磁場による内視鏡カプセル等の無給電駆動の基礎研究 –
超音波ビーコン併用無給電操舵への重畳の検討 –

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1. Introduction

Endoscope capsules have been developed and provided by several companies, i.e. Given Image Ltd. and Olympus Medical Systems Ltd. [1]. Since endoscope capsules are brand-new products, there are a lot of demands for improving their performances and adding new functions to them. Real-time observation, controllability from external commands, farther miniaturization and battery-less, addition of manipulation functions, etc. are the typical demands necessary to be devised.

The size is a diameter of about 11 mm and a length of 25 to 31 mm. We have been studied no-power-supply steerage for endoscope capsules [2]. In this paper, we investigate addition of drive function to them. The steerage must turn the capsules to right and left on a given plane. The drive make them to move forward. We investigate a couple of method to move the capsules. Recently-proposed wireless power transfer technique using LC space-resonant phenomenon is one of promising methods, but a motor is necessary in this case. In order to achieve both turning and movement, we decide to use a method with magnetic force to realize compatibility of both no-power-supply steerage and drive. However, in order to achieve the steerage in fixed direction and movement of fixed amount, direction of the capsule should be notified. We propose ultrasonic-beacon method to indicate direction of the capsule.

As illustrated in the other paper, DC-steerage currents are used to flow through external X-, Y- and Z-coils. We also use same coils to produce AC magnetic fields to drive the capsule. There are several methods to add AC-drive currents to DC-steerage currents. In this paper, first we study direction of AC magnetic field to drive the capsule effectively, which also determine AC-drive currents to flow through external coils. To achieve simultaneous steerage and drive, we propose time-division method to add DC and AC currents within same coils.

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2. Proposed endoscope capsule structure

Schematic illustration of the proposed structure to achieve both no-power-supply steerage and drive is shown in Fig. 1. Using commercial endoscope capsules, we add functions of no-power-supply steerage and drive functions and ultrasonic beacon to notify the direction of the capsule. The former can be achieved by a thin cylinder type magnet with fins, while the latter by conventional ultrasonic technique. As shown in Fig. 2, magnetic fields, *Hx*, *Hy* and *Hz*, are generated by currents through external X-, Y- and Z-coils. If making the capsule to turn and fix in a specific direction and move on an arbitrary plane, magnetic fields produced by coils should be controlled.

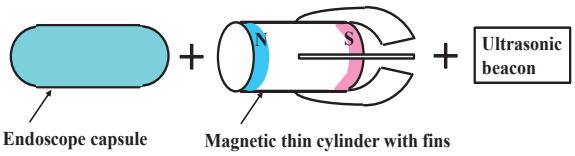

Fig. 1 Endoscope capsule structure joining magnetic thin cylinder with fins and having ultrasonic beacon.

3. Addition of AC-drive and DC-steerage magnetic field

3.1 Direction of AC magnetic field

The DC magnetic fields to steer the capsule are already determined (Fig. 2) [2]. To drive the capsule efficiently, i.e. vibrations or swings, AC-drive magnetic field should be provided perpendicularly to the capsule. The DC magnetic fields are represented by a 3-dimentional vector (Hx^{DC}, Hy^{DC}, Hz^{DC}). AC magnetic fields are also represented by (Hx^{AC}, Hy^{AC}, Hz^{AC}). The perpendicular condition between them leads to

$$Hx^{DC} \cdot Hx^{AC} + Hy^{DC} \cdot Hy^{AC} + Hz^{DC} \cdot Hz^{AC} = 0 \quad (1)$$

It is possible to set $Hz^{AC} = 0$, because there are three variables for a single restriction condition, which reduces the number of external coils. As shown in Fig. 3, this illustrates that AC magnetic

fields are not only on the plane perpendicular to capsule but also on X-Y plane. They are given as follows:

$$(Hx^{AC}, Hy^{AC}) = \text{Const}\cdot(1, -Hx^{DC} / Hy^{DC}) \quad (2)$$

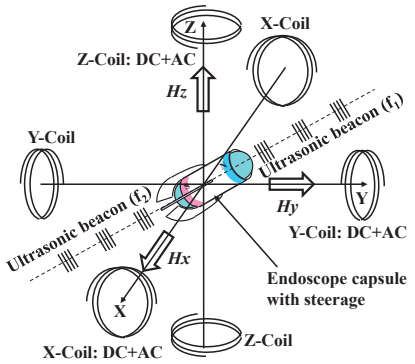

Fig. 2 Endoscope capsule and DC-steerage / AC-drive magnetic fields produced by external coils.

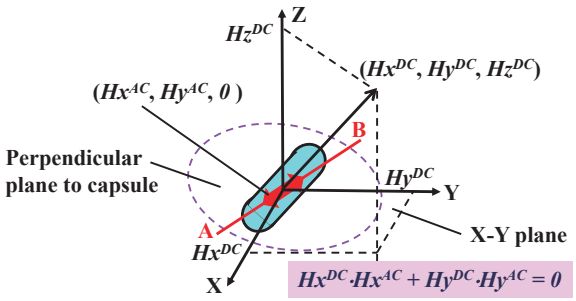

Fig. 3 AC-drive magnetic fields are on both plane perpendicular to capsule and X-Y plane.

3.2 Time-division method to add AC and DC

To drive the capsule keeping its specific direction, we propose a time-division method to apply DC-steerage currents and AC-dive currents alternatively as shown in Fig. 4. Each current should be determined to satisfy Eq. (2).

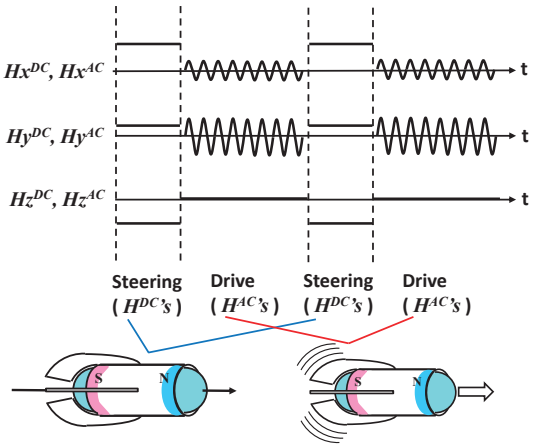

Fig. 4 Time-division method to add DC and AC magnetic fields.

4. Fundamental experiment to confirm proposal

To confirm our proposal, we did fundamental experiment using simple two-dimensional model. As the block diagram is shown in Fig. 5, only Y-coil is used to provide Y-directional DC-steerage magnetic field. X-coil is used to produce perpendicular AC-drive magnetic field. Experimental set-up is illustrated in Fig. 6. Experimental results showed possibility of achieving both steerage and drive.

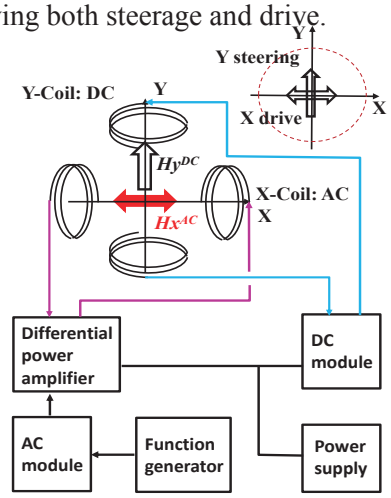

Fig. 5 Block diagram of two-dimensional model to check our proposal (addition of DC and AC).

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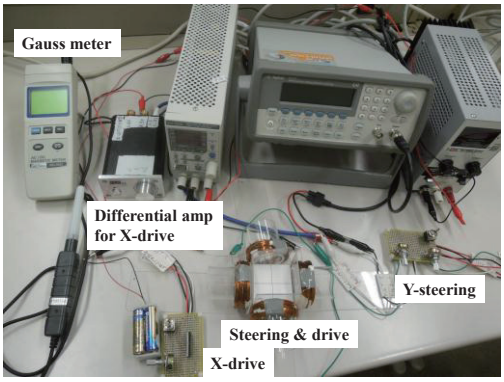

Fig. 6 Fundamental experimental set-up of Fig. 5 to achieve steerage and drive simultaneously.

5. Conclusion

We proposed no-power-supply steerage and drive for endoscope capsules using thin cylinder type magnet with fins. Fundamental experiment using two-dimensional model are conducted.

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.