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Proceedings of Symposium on Ultrasonic Electronics, Vol. 36 (2015)
5-7 November, 2015

No-Power-Supply Steerage and Drive for Endoscope Capsule by AC-Added DC Magnetic Field – Investigation of Combination with Ultrasonic Beacon –

交流重畳 DC 磁場による内視鏡カプセル無給電操舵と駆動 – 超音波ビーコンとの併用 –

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1. Introduction

Endoscopy has become a very popular medical-diagnosis method nowadays. Today's capsules include functions of taking photographs of internal organ walls, especially stomach and intestine walls, and store the data into several G-Byte memory in the capsules or send the data directly to external monitor screen.

As the endoscope capsules are brand-new products, there are a lot of demands for performances and addition of new functions. Controllability by external commands, function of manipulation, etc. are the typical requirements that should 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 investigate to achieve both steerage and drive simultaneously. The capsule size is about 11 mm in diameter and 25 to 31 mm in length. The steerage must turn the capsules to right and left and up and down. The drive make them to move forward. We have investigated several methods 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 decided to use magnetic forces to realize compatibility of both no-power-supply steerage and drive.

In order to achieve the steerage in fixed direction and movement of fixed amount, the capsule direction should be notified to an operator. We propose ultrasonic-beacon method to indicate direction of the capsule. DC-steerage currents flow through external X-, Y- and Z-coils. In this paper, we examined a new method that adds driving AC magnetic fields to DC steerage magnetic fields using same external X- and Y-coils. Final target of our this development is to control the capsule by external key-board or joystick commands.

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2. Endoscope capsule with external DC and AC magnetic fields

As shown in Fig. 1, using commercial endoscope capsules, we add functions of no-power-supply steerage and drive 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. DC magnetic fields, Hx^{DC}, Hy^{DC} and Hz^{DC}, are generated by currents through external X-, Y- and Z-coils. After the capsule turns and fixes in a specific direction, AC magnetic fields, Hx^{AC} and Hy^{AC}, make the capsule to vibrate, which drive capsule forward by attached fins. DC magnetic fields and AC magnetic fields are mutually perpendicular, which leads to $\boldsymbol{Hx^{DC}\cdot Hx^{AC} + Hy^{DC}\cdot Hy^{AC} + Hz^{DC}\cdot Hz^{AC} = 0}$. We can set $Hz^{AC} = 0$ without loss of generality.

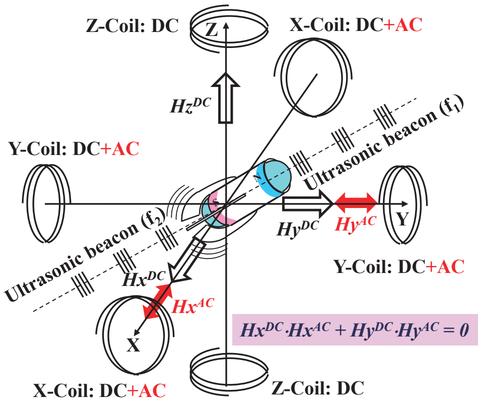
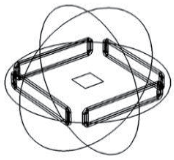


Fig. 1 Endoscope capsule with fins and ultrasonic beacon. External DC and AC magnetic fields steer and drive it respectively.

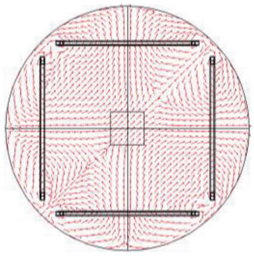
3. DC magnetic fields for steerage

To steer the capsule, arbitrary uniform magnetic fields should be synthesized by external coils. One of the biggest problems is how to take fringing effects of coils into consideration. We simulated magnetic flux density distribution by COMSOL first. Based on above results, fundamental experiments were done.

3.1 Simulation of magnetic flux density distribution produced by rectangular coils



(a) Schematics for simulation



(b) Distribution of magnetic flux density, B

Fig. 2 Results of COMSOL simulation for rectangular coils.

Simulation schematics and simulated magnetic flux density distribution are shown in Fig. 2(a) and (b). We assumed 30×30 cm^2 area surrounded by 30×6 cm^2 rectangular coils and aimed to obtain uniform magnetic fields within center 6×6 cm^2 area.

3.2 Experimental magnetic flux density distribution by rectangular coils

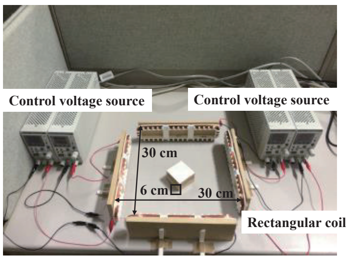
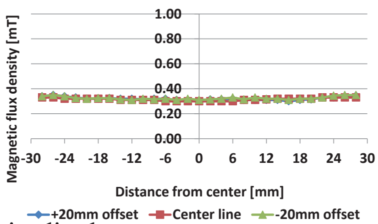
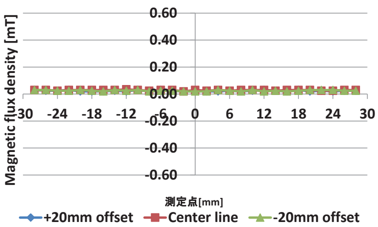


Fig. 3 Experimental setup. 30×6 cm^2 coils are used.



(a) Longitudinal components



(b) Transversal components

Fig. 4 Measured magnetic flux density distribution in center 6×6 cm^2 area.

As experimental setup is shown in Fig. 3, same coil structures as assumed in simulation are used. Longitudinal and transversal components of measured magnetic flux density distributions in center area are shown in Fig. 4(a) and (b). Uniform distributions almost same as simulation results are obtained.

4. Addition of driving AC magnetic fields to DC fields

We should drive the capsule keeping its direction fixed. We have proposed a new driving method to add AC magnetic fields to DC fields. As shown in Fig. 5, after the direction of the capsule is determined by Hx^{DC}, Hy^{DC} and Hz^{DC}, $Hx^{DC} + Hx^{AC}$ and $Hy^{DC} + Hy^{AC}$ propel the capsule to move forward. Addition of AC current to DC current is rather difficult problem. We have proposed combining circuits, where AC currents from X- and Y-AC-modules are added to DC main currents from X-, Y- and Z-DC-modules via transformers as block diagram is shown in Fig. 6.

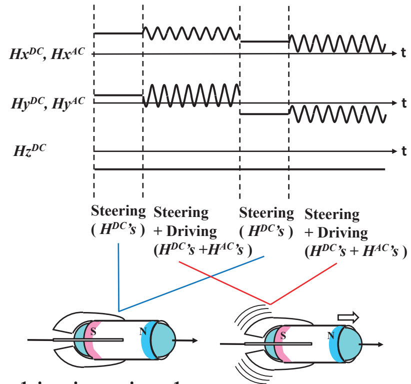


Fig. 5 Achieving simultaneous steerage and drive by addition of DC and AC magnetic fields.

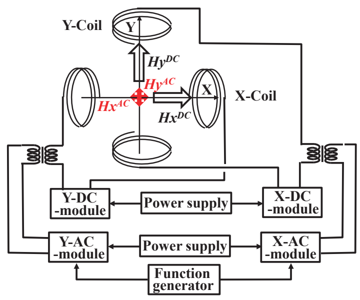


Fig. 6 Block diagram of DC/AC combining circuits. Only DC-module is used for Z direction.

5. Conclusion

We proposed no-power-supply steerage and drive for endoscope capsules with thin cylinder magnet and fins. Simulation, experiment and proposal of new combing circuits are presented.

References

1. K. Miyazaki, T. Sakata and M. Hikita, in Proc. of USE Vol.35, pp.47-48, 2014.