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A Comparison of Communication Techniques for Capsule Endoscopes

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Abstract— **In this paper, we present the state of the art of communication technology related to the capsule endoscopes (CEs) and analyze the technologies and characteristics of commercialized CEs on the current global market. The study shows that the communication technology of human body communication (HBC) can reduce the power consumption and have a smaller size of CE compared to radio frequency (RF) communications technology, since the HBC doesn't use power consuming RF components and antenna.**

Keywords-component; Capsule Endoscope; Human Body Communication (HBC); Radio Frequency (RF); Miniaturization

I. INTRODUCTION

Capsule endoscope (CE) is a capsule-shaped electronic device which can examine the digestive tract of human body. Since the conventional endoscope using cables brings great pain and fear to the patients, the orally ingestible CE is receiving great attention to both doctors and patients [1]-[5].

However, compared to conventional cable-typed endoscope, the CE has some missing probability of lesions due to the passive movement of peristalsis. Therefore, CE is usually used in the diagnosis of small bowel abnormalities, where cable-typed endoscopes are difficult to reach.

Since the first development of M2ATM CE by Given Imaging Ltd. in 2000, various CEs are introduced by many companies from different countries. The PillCamTM SB capsule endoscope made by Given Imaging Co. was developed for diagnosis in the small bowel [6]. The EndoCapsule CE made by Olympus Co. was launched in 2005 [7]. The OMOM CE made by CJST(Chongqing Jinshan Science and Technology) Co. was developed in 2004 and received approval by the State Food and Drug Administration (SFDA) of China in 2005 [8]. All of these CEs adopt radio frequency (RF) communication technology to deliver the captured image data from the image sensor like CMOS and CCD in CE. In this case, digital data must be converted to analog RF signal, and RF signal should be radiated out by antenna. This would consume so much power in CE, and integrated circuit (IC) chip size will be increased due to analog components. The small size and low-power consumptions are critical issues when the CE is designed. Furthermore RF frequency interference with users of the same band cannot be neglected. Since the RF signal from the CE inside the human body passes through the channel of various organs, tissues, and spaces, the transmit power of RF signal should be strong enough to communicate with receiver outside the human body. Finally, it can give mutual interferences to the neighboring medical electronic devices. Thus the power control of RF signal should be carefully considered.

On the other hand, MiroCam CE by Intromedic Co. was developed in 2007 [9], based upon human body communication (HBC) technology utilizing the human body as a communication channel. Since the HBC doesn't use RF signal and antenna, it doesn't use RF components. Thus, it can be implemented with small size and low-power consumption.

In this paper we present a comparison study of CE based on the HBC technologies and analyze their technical characteristics.

This paper is organized as follows. The miniaturization concept and characteristics of CE structure using RF communication is described in Section II, Section III presents the HBC technology adopted in CE and its operational procedure. Section IV presents a comparison of commercialized CEs on the global market, and Section V draw some conclusions.

II. RF CAPSULE ENDOSCOPE

When designing and implementing the CE with the concept of miniaturization, ingestible small-size and the various functions same as the conventional endoscope several limitations follow in the development of CE.

The first limitation is miniaturization to obtain an ingestible CE. The high integration of various components and functions to obtain a miniaturization leads to many problems. In addition, if analog components also exist, the noise and power efficiency problem will be critical. The next limitation is low power consumption. Since the CE powered by outside high power electronic magnetic wave is harmful to the human body and operates low data rate [2], the CE which is powered by battery is preferred. Thus, the CE with a built-in battery should be designed to consume as low power as possible to prolong work time. Another limitation relates to communication technology. Since the transmitted data rate, quality of image data (i.e. resolution), bit error rate etc. decide the performance of CE,

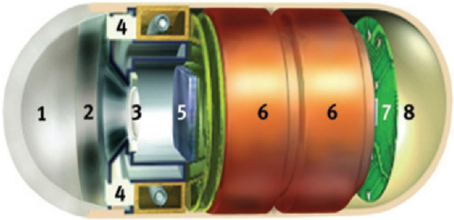


Figure 1. CE strucure of RF communication(1.Optical dome, 2. Lens holder, 3. Lens, 4. LEDs, 5. Image sensor, 6. Battery, 7. ASIC, 8. Antenna)

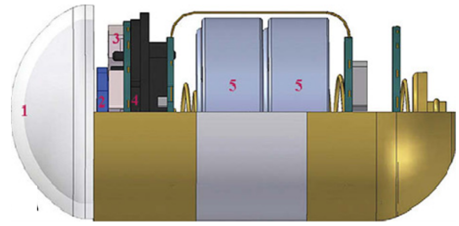
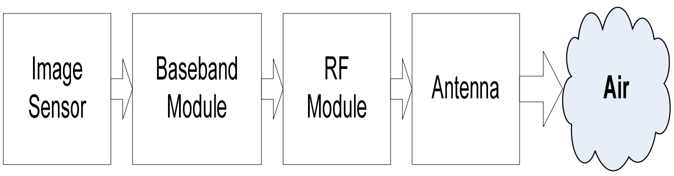


Figure 3. CE strucure of HBC(1. Optical dome, 2. Lens, 3. LEDs, 4. Image sensor, 5. Battery)

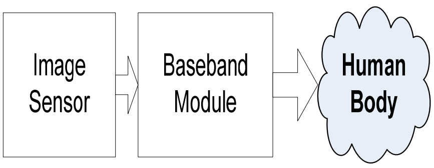
the development of optimized communication technology is also crucial.

In this sense, an example structure of CE using RF communication is shown in Fig. 1. The CE is a self-contained electronic device which has various functional components. The CE using radio frequency (RF) communication methodology is composed of lens, LEDs, image sensor, battery, RF application-specific integration circuit (ASIC), and antenna. The LEDs(from 4 up to 6) are uniformly placed under the optical dome to illuminate the gastrointestinal tract. The optical dome has the hemisphere shaped window to illuminate light and capture the image.

As the image sensor, complementary metal oxide silicon (CMOS) sensor or charge-coupled device (CCD) are used. The CCD sensor provides better quality of image than the CMOS sensor, but much greater power consumption are required to perform related digital signal processing. The image data captured by image sensor in CE are processed to appropriate digital data and these are transmitted to the outside of human body with the RF module and antenna as shown in Fig 2(a). The power is supplied by 2 batteries. The radiated RF signals is received and recorded by receiver, which can be attached to human body.



(a) RF Communication



(b) HBC

Figure 2. Signal flows of RF communication and HBC

III. HBC CAPSULE ENDOSCOPE

Fig. 3. shows the structure of the CE using the HBC technology from IntroMedic Co. Basic functional components such as LEDs, image sensor, batteries are similar to the CE with RF communication technology, but RF components and antenna do not exist in the CE. Therefore, the CE using HBC technology can achieve a small sized and low power consumption capsule.

The CE transmits data through the human body to a receiver located outside the human body not by using RF signal but by using very low current, so that CE cause no harm to the human body and achieve low power consumption. In addition, all the circuits including the image sensor and other digital circuits can be integrated on one chip without RF components and antenna. Therefore it can be implemented with low cost and low complexity also.

Unlike the CE of RF communications, the data signal flows are simple as shown in Fig 2. (b). The sequentially arranged digital data from parallel-to-serial (P/S) logic propagates as a low-power electric field outside of the human body through the 2 different electrodes(+, -) as shown in Fig 4. That is, a low current generated from the electrodes flows through the human body as a conductor to transmit data to the receiver outside of the human body.

In Fig. 3, the electrodes consist of band type structure and it uses gold plate considering corrosion resistance and no harm to the human body. The CE transmits electrical signal to the outside of human body during passage through the GI tract. The 2 transmitting electrodes should be electrically isolated and separated from each other sufficiently in order to propagate electrical field effectively. And it is preferable that the transmitting electrodes have easy contactable shape for the inside of human body.

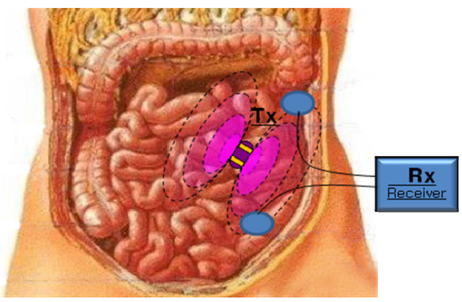


Figure 4. Illustration of HBC CE inside the human body

IV. COPMARISON OF CAPSULE ENDOSCOPES

Based on our research, many companies and research centers throughout the world have proposed technical ideas and prototype of CE, but currently only 4 companies are actively producing CEs. These are Given Imaging in Israel, Olympus in Japan, CJST(Chongqing Jinshan Science and Technology) in China, and IntroMedic in Korea. The reason why only a few CE makers exist is that CE must undergo extensive material toxicity and reliability tests to ensure the safety and receive an approval from certification authority.

Given Imaging first developed CE in the world and stands in the foremost position in the global CE market. "PillCam SB" is the CE for detecting small bowel abnormalities and is the only CE allowed for use in patients two years of age or older. The PillCam SB measures 11mm (Diameter) x 26mm(Length) and weighs 3.45 grams. The PillCam SB can transmit images at a rate of 2 frames/sec, generating more than 50,000 frames during 8 hour procedure. PillCam SB received approval by the U.S. FDA in 2001. In its second-generation, "PillCam SB 2" is produced, which can captures the broadest mucosal area image with the widest field-of-view [6].

Olympus Co. launched "EndoCapsule" in Europe in 2005. EndoCapsule can display a clear and bright field of view with the fine observation of a variety of small bowel abnormalities, since it uses CCD image sensor. However, due to the power consumption problem, Most of the CEs are using CMOS sensor, since it ensures lower power consumption than CCD sensor. EndoCapsule measures 11mm (Diameter) x 26mm (Length) and weighs 3.8 grams[7].

CJST developed "OMOM" in 2004. CJST is a Chinese national enterprise and develops the CE, capsule robots, Ph capsules, and so on. OMOM capsule endoscope was approved by Chinese State Food and Drug Administration (SFDA) for clinical application in March 2005. The OMOM capsule has a size of 13mm (Diameter) x 27.9mm (Length) and weighs 6 grams. Images are generally taken at a rate of 2 frames/sec, though the rate can be varied according to the type of image. There are 14 receiver elements placed close to the surface of the abdomen and waist in the recorder jacket. The duration of the battery of the OMOM capsule is about 8 hours, similar to the PillCam and EndoCapsule. The image format is adjustable between VGA: 640 × 480 and QVGA: 320 × 240 [8].

(a) PillCam

(b) EndoCapsule

(c) OMOM

(d) MiroCam

Figure 5. Pictures of various CEs

IntroMedic developed MiroCam in 2007, based on a novel HBC technology. The new technology reduces the power consumption compared with existing CEs that use RF communication technology, which contain power-consuming RF components, such as local oscillator, LNAs (Low Noise Amplifiers), and Antenna. The MiroCam capsule has the smallest size and weight according to our research. The size is 10.8mm (Diameter) x 24mm (Length) and weight is 3.4 grams. It has also a wider field of view (FOV) of 150 and longer battery life of 11 hours than other CEs. The MiroCam transmits images with resolution of 320 × 320 and at a rate of 3 frame/sec, generating more than 118,800 frames [9].

V. CONCLUSIONS

In this paper, we compared between RF communication and human body communication as the representative communication technologies for capsule endoscopes. According to our study, in terms of working principles, HBC can reduce the power consumption and have a smaller size of CE compared to radio frequency (RF) communications technology, since the HBC doesn't use power consuming RF components and antenna. In the future, we think that the quality of images obtained by two communication technologies should be also compared.

TABLE I. COMPARISONS OF CEs

Items	***Small Bowel Capsule Endoscope***			
	Given Imaging SB/SB2	***Olympus EndoCapsule***	***CJST OMOM***	***IntroMedic MiroCam***
Size(Diameter×Length)	11 26mm	11 × 26mm	13 × 27.9mm	11 × 24mm
Weight	3.45g	3.8g	<6g	3.4g
Resolution	256×256	N/A	320×240, 640×480	320×320
Frame rate	2 fps	2 fps	2 fps(1fps, 0.5fps)	3 fps
Working Time	8 hr	8 hr	8 hr	11 hr
Field of view	140°/156°	145°	140°	150°
Communication Tech.	RF	RF	RF	HBC
Real Time Viewer	No/Yes	Yes	Yes	Yes

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REFERENCES

[1] C. McCaffrey, O. Chevalerias, C. O'Mathuna, K. Twomey, “Swallowable-Capsule Technology,” IEEE Pervasive Computing, vol. 7, pp. 23-29, January 2008.

[2] B. Chi, J. Yao, S. Han, X. Xie, G. Li, and Z. Wang, “Low-power transceiver analog front-end circuits for bidirectional high data rate wireless telemetry in medical endoscopy applications,” IEEE Trans. On Biomedical Engineering, vol. 54, no. 7., pp. 1291-1299, July 2007.

[3] A. Moglia, A. Menciassi, M. O. Schrr, and P. Dario, “Wireless capsule endoscopy: from diagnostic devices to multipurpose robotic systems,” Biomedical Microdevices, vol. 9, no. 2, pp. 235-243, December 2006.

[4] S. H. Woo, Z. Mohy-Ud-Din, and J. H. Cho, “Duodenum identification mechanism for capsule endosopy,” IEEE Trans. On Biomedical Engineering, vol. 58, no. 4., pp. 905-912, April 2011.

[5] S. Bang, .J. Y. Park, S. Jeong., Y. H. Kim, H. B. Shim, T. S. Kim, D. H. Lee, and S. Y. Song, “First clinical trial of the ‘‘MiRo’’ capsule endoscope by using a novel transmission technology: electric-field propagation,” Gastrointestinal Endoscopy, vol. 69., no. 2, pp. 253-259, 2009.

[6] http://www.givenimaging.com/en-us/HealthCareProfessionals/ Products/ Pages/PillCamSB.aspx.

[7] http://www.olympus-europa.com/endoscopy/2001_5491.htm.

[8] http://english.jinshangroup.com/Products/Endoscopycapsule/tabid/64/Default.aspx.

[9] http://www.intromedic.com/en/product/productInfo.asp.