Design of Miniaturized Telemetry Module for Bi-Directional Wireless Endoscopy

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Abstract: A bi-directional and multi-channel wireless telemetry capsule, 11mm in diameter, is presented that can transmit video images from inside the human body and receive a control signal from an external control unit. The proposed telemetry capsule includes transmitting and receiving antennas, a demodulator, decoder, four LEDs, and CMOS image sensor, along with their driving circuits. The receiver demodulates the received signal radiated from the external control unit. Next, the decoder receives the stream of control signals and interprets five of the binary digits as an address code. Thereafter, the remaining signal is interpreted as four bits of binary data. Consequently, the proposed telemetry module can demodulate external signals so as to control the behavior of the camera and four LEDs during the transmission of video images. The proposed telemetry capsule can simultaneously transmit a video signal and receive a control signal determining the behavior of the capsule itself. As a result, the total power consumption of the telemetry capsule can be reduced by turning off the camera power during dead time and separately controlling the LEDs for proper illumination of the intestine.

1. Introduction

In the medical field, several types of miniaturized wireless telemetry capsules have recently been designed, such as endoscopes, that can take pH and pressure measurements in the intestine and send biomedical signals from inside the human body.

At the beginning of biomedical telemetry, Beenken and Dunn developed a technique for the short distance radio telemetry of physical information [1]. Further research on biomedical telemetry was performed by R. S. Mackay, including several discrete electronic devices and short wavelength EM wave techniques [2]. Meanwhile, modern wireless telemetry, as introduced by Uchiyama and Saito, uses a wireless telemetry capsule to monitor the gastric pH based on an iridium oxide electrode mounted on the telemetry capsule [3].

In particular, in relation to monitoring gastrointestinal disease, a new type of video-telemetry capsule has been developed that is swallowed and journeys down the gastrointestinal tract while transmitting images [4]. As such, the capsule, 11 mm in diameter and 30 mm long, i.e. about the size of a pill, provides a kind of inside view at a rate of two frames per second. Its video images are transmitted using UHF-band telemetry to aerials taped to the body. This development of miniaturized telemetry capsules is expected to eliminate the problems related to fiber-optic endoscopes, including patient discomfort and the limitations on how far endoscope tips can advance into the small bowel.

However, while being moved by peristalsis, the capsule can only transmit images one-way from inside to outside the human body. Consequently, it is impossible to control the camera behavior, including the ON/OFF power functions and effective illumination inside the intestine. Furthermore, for the detection of reliable and correct information, the telemetry capsule should be designed to transmit several biomedical signals, such as pH, temperature, and pressure etc.

Accordingly, the current paper presents the design of a bi-directional and multi-channel wireless telemetry capsule, 11mm in diameter, which can transmit video images from inside the human body and receive control signals from an external control unit. The proposed telemetry capsule includes transmitting and receiving antennas, a demodulator, decoder, four LEDs, and CMOS image sensor, along with their driving circuits. The receiver demodulates the received signal that is radiated from the external control unit. Next, the decoder receives this serial stream and interprets five of the binary digits as an address code. Thereafter, the remaining signal is interpreted as four bits of binary data. As a result, the proposed telemetry module can demodulate the external signals to control the behavior of the camera and four LEDs during the transmission of video images.

In a miniaturized wireless telemetry capsule, it is important to make the antenna size as small as possible. Therefore, the current study used a small loop antenna as it has a simple structure and its properties are insensitive to construction details. The RF carrier frequencies were 433 MHz for the transmission of the external control signals and 315 MHz for transmission of the biomedical signals from inside the body.

The proposed telemetry capsule can simultaneously transmit a video signal and receive a control signal determining the behavior of the capsule. As a result, the total power consumption of the telemetry capsule can be reduced by turning off the camera power during dead time and separately controlling the LEDs for proper illumination in the intestine. Accordingly, the proposed telemetry module for bi-directional and multi-channel communication has potential applications in many other fields as well as medical diagnosis.

2. Structure

2.1 Miniaturized Telemetry Module

The proposed miniaturized wireless telemetry capsule consists of a CMOS image sensor, lighting LED, transmitter and receiver circuits, two antennas, and battery, as shown in Fig. 1.

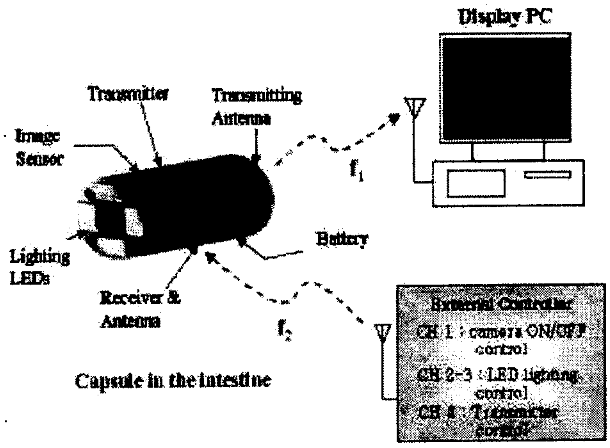


Fig. 1. Conceptional diagram of bi-directoinal wireless endoscopy system

As such, a bi-directional and multi-channel wireless telemetry capsule, 11 mm in diameter, was designed and implemented, which can transmit video images from inside the human body and receive control signals from external control units. The capsule also includes two 10mm diameter loop antennas, one for transmitting the video signal and the other for receiving the external control signal.

The CMOS Image sensor is a single-chip 1/3 inch format video camera, OV7910, which can provide a high level of functionality within a single small-footprint package. The image sensor supports an NTSC-type analog color video signal and can directly interface with a VCR TV monitor or other display devices with a 75 ohm terminated input. In addition, the image sensor has a very low power consumption as it only requires a single 5-volt DC supply.

Fig. 2 shows a transmitter and receiver circuit block diagram of inside the capsule. In the block diagram, one SMD type transistor amplifies the video signal for efficient modulation using a three biasing resistor and one inductor. In the bottom block, a tiny SAW resonator oscillates at 315 MHz for AM modulation of the video signal. This modulated signal is then radiated by the transmitting antenna from inside to outside the body.

Since 315 MHz is the commercial cable channel frequency for cable TV broadcasting systems, users can watch the images of the intestine on a TV using CH 39, which is a hyperband cable channel.

The receiver circuit block diagram is illustrated in Fig. 3. For the RF receiver, a commercialized ASK/OOK (ON-OFF Keyed) superhetrodyne receiver with an 8-pin SMD

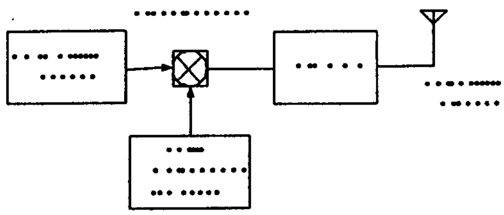


Fig. 2. The video signal transmitter of capsule inside.

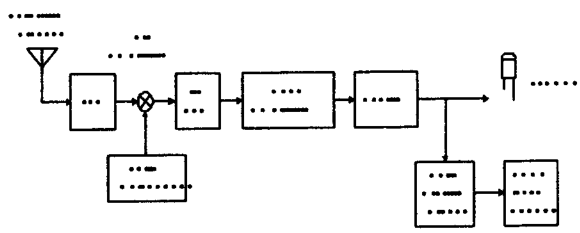


Fig. 3. Receiver circuit inside capsule.

size was used. This single chip receiver IC for remote wireless communications, which includes an internal local oscillator fixed at a single frequency, is based on an external reference crystal or clock. Plus the decoder IC receives the serial stream and interprets the serial information as four bits of binary data. Each bit is used for channel recognition of the control signal from outside the body. Since the CMOS image sensor module consumes most of the power compared to the other components in the telemetry module, controlling the ON/OFF of the CMOS image sensor is very important. Moreover, since lighting LEDs also use a significant amount of power, the individual ON/OFF control of each LED is equally necessary. As such, the control signal is divided into four channels in the current study. A high output current amplifier with a single supply is utilized to drive the loads in the capsule.

2.2 External Control Circuits

A schematic diagram of the external control unit is illustrated in Fig. 4. (a), where the ON/OFF operation of the switch in the front of the unit is encoded into 4 channel control signals. These digital signals are then transferred to a synthesizer (HM8134-2,HAMEG) and modulated into an RF signal using an OOK transmitter with a carrier frequency of 433 MHz.

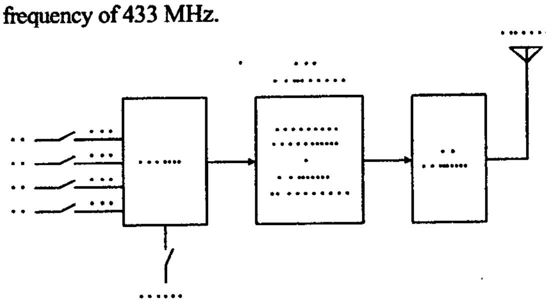


Fig. 4. External control circuit

3. Experiments and Results

A miniaturized telemetry capsule, consisting of a transmitting and receiving antenna, RF transmitter, demodulator, decoder, four LEDs, and CMOS image sensor,along with their driving circuits, was designed and implemented.

The size of the multi-channel receiver block was 11mm in diameter and 7mm in length. To verify the proposed design, bi- directional and multi-channel transmission experiments were carried out.

A four-channel miniaturized telemetry module was fabricated for the multi-channel trnasmission experiments. To verify to the operation of the external control unit and telemetry capsule, CH 1 was used to control the ON/OFF of the CMOS image sensor and CHs 2~4 to control the LED lighting. The four switches in front of the control pannel were able to make 16 different control signals (4 bit, 2^4 = 16).

To verify the bi-directional operation of the telemetry module, all experiments were carried out while a video signal was being transmitted from the CMOS image sensor. This image data was then displayed on a computer with a cable TV receiving card.

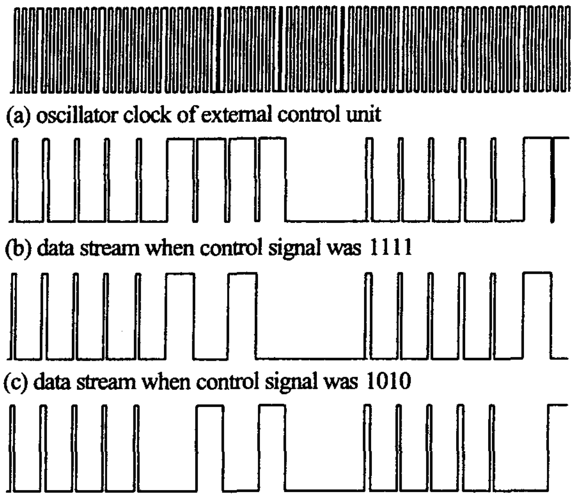
Fig. 5 shows the patterns of the control signals. (a) is the oscillator clock of the external control unit and (b) is the data stream when the pattern of the control bits is 1111, the condition when the CMOS image sensor and all lighting LEDs are in an ON-state. (c) is the data stream when the patern of the control bits is 1010, the condition when the CMOS image sensor and only one of the LEDs are in an ON-state. (d) shows another example of the data stream when the pattern of the control bits is 0101.

Accordingly, the experiemental results verified that the proposed miniaturized telemetry module could operate accurately as a bi-directional and multi-channel telemetry module and that its operation could be controlled by an external signal while transmitting a video signal. The data rate was 100 bps in the experiments. Fig. 7 shows the external control uint manufactured for the experiments. The size of the control unit was 20 cm(L) x 30 cm(W) x 15 cm(H).

4. Discussion

The current paper presented and implemented a bi-directional and multi-channel wireless telemetry capsule, 11mm in diameter, which can transmit video images from inside the human body and receive control signals from an external control unit. The proposed telemetry capsule includes an RF transmitter, transmitting and receiving antenna, demodulator, decoder, four LEDs, and CMOS image sensor, along with their driving circuits. As such, the proposed telemetry module is able to demodulate external signals to control the behavior of the camera and four LEDs during the transmission of video images.

Since the proposed telemetry capsule can simultaeously transmit a video signal and receive a control signal determining the behavior of the capsule itself, the total power consumption of the telemetry capsule can be reduced by turning off the camera power during dead time, and



(a) oscillator clock of external control unit

(b) data stream when control signal was 1111

(c) data stream when control signal was 1010

(d) data stream when control signal was 0101

Fig. 5. Patterns of diferrent control signals

Fig. 6. Photograph of external control unit

separately controlling the LEDs for proper illumination in the intestine. Accordingly, it is expected that the proposed telemetry module can be utilized as a base for further multi-channel bidirectional video telemetry developments.

5. Acknowledgement

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References

[1] Beenken. H. G. and Dunn. F. L. "Short distance radio telemetring of physiological information", *IRE Trans. Medical Electronics,* Telemetry Set 2;82 , 1959.

[2] R.S.Mackay, "Biomedical Telemetry", *IEEE press,* pp.225-231, 1993.

[3] K.Saito, A. Uchiyama et al, "Telemetry Capsule for Gastric pH Monitoring", *Proceeding of 12th International Symposium on Biotelemetry,* Nov., 1992.

[4] J. Paul, M2A Swallowable Imaging Capsule , *ELE282 Biomedical Engineering Seminar I,* Feb 26, 2001.

[5] J. Everard, Fundamentals of RF Circuit Design with Low Noise Oscillators , *JOHN WILEY & SONS, LTD,* pp-179-201, 2001.