Development of a Transcutaneous Information Transmission System using Transmitted Light for the Total Artificial Heart

Dong Woo Kang*, Hee Chan Kim, Byoung Goo Min

Dept. of Biomedical Engineering, College of Medicine
Seoul National University

Abstract

A transcutaneous information transmission system using transmitted infrared light for an implantable total artificial heart(TAH) was developed and the performance of the system was tested. In an *in vitro* test, transmittance of the developed system was measured through various thicknesses of pig skins. In an *in vivo* test, a loopback test using a personal computer was performed to determine the error rate and an experiment using a mock system was taken. In this experiment, within acceptable lateral and vertical displacements, the error rate of at least 3.8E-6 was guaranteed. Monitoring signals from the internal controller(Intel 87C196) of the mock system were successfully transmitted to the external controller(IBM PC) and the operating commands from the external controller were successfully conducted by the mock system. Communication was done in half duplex mode according to RS-232 protocol at the speed of 4800 bps.

1. Introduction

Biotelemetry is a method of transmitting signals containing various information of a living body to a remote place by wire or wireless. In artificial organs, it enables us to communicate with an implanted organs. Infrared light is often used in optical biotelemetry because an electromagnetic radiation having a wavelength of 1μm is reported to have the best transmittance through human skin[1]. The merits of infrared biotelemetry over the traditional FM telemetry are: First, it is free from radio regulation. Second, it is immune to electromagnetic surroundings[2][3]. Besides, infrared light is invisible.

A biotelemetry system using transmitted infrared light for an implantable Total Artificial Heart(TAH) was developed in our laboratory. The main purposes of this paper are to introduce the developed system and to test its performance. This paper is organized as follows. In section 2, the developed system is introduced. In section 3, some of the results of *in vivo* and *in vitro* test are presented.

2. Materials and Methods

The schematic block diagram of our biotelemetry system is shown in Fig. 1.

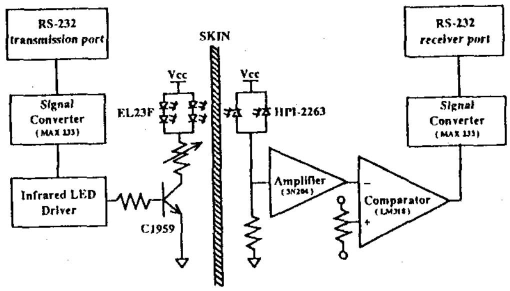

Fig. 1. Schematic block diagram of biotelemetry sytem

The binary data from the internal controller of the TAH(Intel 87C196)(or operating commands from the external controller(IBM PC)) are amplitude modulated to drive the Infrared Emitting Diode(IED)s.

The light emitter/receiver module is composed of 1 photodiode located at the center of 4 IEDs. As the light emitters, 4 IEDs(EL23F, Japan) having a peak emission wavelength of 940nm which is in the infrared light range are used. As a light receiver, a PIN type photodiode(HPI-2263, Japan) having a peak wavelength of 900nm is used.

Comparator generates precise square pulses of the received signals. These pulses are appropriately converted to be transferred to the external controller(or the internal controller of the TAH).

3. Results

To examine the performance of the developed biotelemetry system, several experiments including an *in vitro* and an *in vivo* test were performed.

3.1 *In vitro* test

In the *in vitro* test, the transmittance of our biotelemetry system was examined using various thicknesses of pig skins. The peak-to-peak voltage levels of the received signals were plotted in Fig. 2. Since the threshold of the comparator circuit is 40mV, error free operation is possible theoretically up to 22mm of skin thickness.

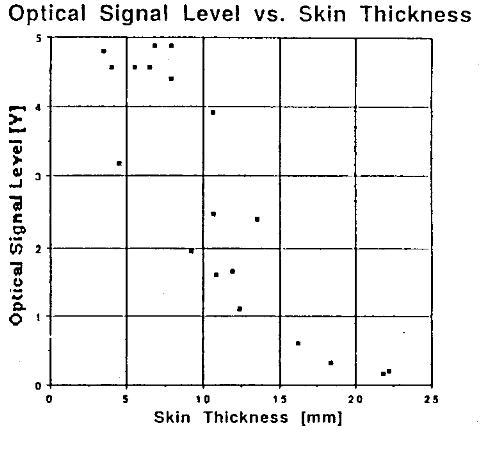

Fig. 2. Optical signal level vs. skin thickness

3.2 *In vivo* test

In the *in vivo* test, the internal light emitter/receiver module with a TET(Transcutaneous Energy Transmission) coil was implanted in the back of a 20 kg dog. Then a loopback test was executed with the TET in action. Digital binary data from 0 to 255 were generated from a serial port of a personal computer according to RS-232 protocol. They were transmitted and received through our biotelemetry system and then compared with the original data. When the TET was activated, noise ripple of about 1.4V was detected in our biotelemetry system, but it did not cause errors in communication. This test was repeated 1000 times and no error was detected. Based on these experimental results, it can be concluded that our biotelemetry system guarantees the error rate of at least 3.8E-6. In this case, the acceptable range of the lateral displacement of the external transmitter/receiver module was up to 4.52mm and the vertical displacement, up to 28.45mm, respectively.

In operation with a mock system, our biotelemetry system worked satisfactorily. Monitoring signals from the mock system were successfully received and plotted on the monitor of PC and the stroke length and velocity of the brushless DC motor were successfully controlled.

4. Conclusion

A transcutaneous information transmission system using transmitted infrared light was developed. Throughout *in vivo* and *in vitro* test, it was shown that the desired performance could be obtained with a relatively simple circuit configuration. When the TET was in action, it was observed that noise ripples which might cause errors in communication were introduced into the system. The reduction of the noise ripples from the TET and the decrease of power dissipation are under investigation.

References

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