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Electro Optic Methods in Intra-body Communication System

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Abstract

Intra-body communication is proposed by Zimmerman in 1995 and the galvanic coupling has been observed to be the best method for data transmission. With the increasing transmission requirements and the development of optical fiber communication, a high speed system is possible to be designed based on the Electro optic methods. In this paper, the characteristics of the intra-body communication system are introduced. Principles and structures of optic modulation for intra-body communication are reviewed. Internal and external modulation methods are introduced and discussed. A system of the electro optic modulation is recommended and discussed.

1. Introduction

Intra-body communication was originally proposed by Zimmerman of MIT (Massachusetts Institute of Technology) in 1995. Intra-body communication is a technology that involves using the human body as a transmission medium for electrical signals [1, 2]. With the increasing of the population around the world, it is urgent to create a modern nursing technology to provide service for human being [2]. The sensor technology and the intra-body communication technology provide a good blueprint for the new medical monitoring system which has been gradually released from the traditional human-labor nursing. Intra-body communication uses a human body as a

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communication channels in the terminals. Therefore, the importance of intra-body communication is increasing as a valid tool for communication among mobile terminals. Over the past few years, many researchers have devoted themselves to the problem.

Intra-body communication has the characteristics of high transmission quality, high security, easy network access and high data rates, etc. It is believed to be a novel and promising technology for wireless body area networks [1, 3], biomedical monitoring [4, 5] and supplying power for implants [5], etc. The galvanic coupling intra-body communication is an important method for attaining the signals transmitted within in the human body [6-8]. In this approach, signal transmission is achieved by coupling signal currents galvanically into the human body. The information signals were usually obtained in the galvanic coupling method and it has been known as the best way in testing the signal. Few attempts have been made in enhancing the signal transmission speed of the intra-body communication system. The development of the optical fiber communication has changed our life much in its high speed and wide bandwidth. A high speed intra-body communication system is needed.

In this paper, the characteristics of the intra-body communication system are introduced. Principles and structures of the optic modulation for intra-body communication were reviewed. Internal and external modulation methods are introduced and discussed. An electro-optic modulation system which is usually adopted in the intra-body communication is introduced here in detail.

2. Characteristics of the Signal

Due to the dielectric properties of human tissues [9-11], devices to detect the signal have to be designed for the specific object. At the same time, the safety of human has to be ensured. The induced currents should not be too high to stimulate nerve or interfere with the body signals located in the frequency range of operation. Signals with frequencies below 10 kHz have to be avoided.

Figure 1 shows the schematic diagram of intra-body communication model. In the intra-body communication system, human body acts as a medium [12]. The electric field is coupled into the body to implement data communication with human tissue. If an electrode is placed in the electric field, the induced electrostatic charge may be generated on the electrode surface. The electric charge quantity may change with the electric field varying. Therefore, the physical quantity variation of the electric field can be detected to obtain relevant information through some method. The galvanic coupling method is widely used in the electrostatic detection technology. If the information to be transmitted is modulated in the quasi electrostatic field and coupled to human body, a weak electric field will be produced around the human body. A receiver is applied to detect the variation of the weak electric field. The signal was then modulated and extracted. In the electro optic modulation, the signal is introduced into the electro optic modulator and the modulated laser is obtained. Then the modulated light signal transmits the fiber at high speed.

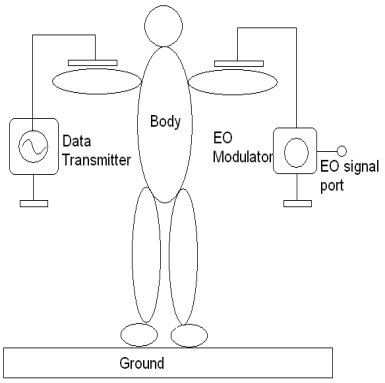

Fig. 1 Schematic diagram of Intra-body Communication model.

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3. Electro Optic coupling methods for intra-body communication system

The invention of laser makes it possible to realize passing information by laser. To obtain the modulated laser, many methods can be adopted. The laser can be modulated in intensity, in amplitude or in frequency etc. The modulation methods can also be divided into internal modulation and external modulation. External modulation includes electro optic modulation, sound optic modulation and magnetic optic modulation, where the signal modulation process is completed outside the laser diode (LD). Internal modulation, also called direct modulation, where the signal is introduced into the producing process of the LD or light emitting diode (LED).

3.1 Internal modulation

Internal modulation operates in the lamps. LD and LED are usually used in the internal modulation of the intra-body communication. The information to be transmitted is converted into current signal, which is injected into the semiconductor lamps, e.g. LD or LED. Thus the modulated light signal can be obtained. It is widely used in the fiber communication system and the intra-body communication system concluded.

LD and LED are usually used in the internal modulation, which is also called direct modulation. Figure 2 shows the electro optic properties of LD and LED. For LD, the light output power is linear when the current is above or below a definite value at about 180 mA. For LED, the light output power is almost linear with the current. The linear relationship between the light output power and the current make it possible to covert the signal current into modulated light output. In the intra-body communication, it is possible to use the internal modulation of LD or LED light in obtaining the information and transmitting at high speed. To obtain the linear modulation, the working point should be at the linear part of the output curves.

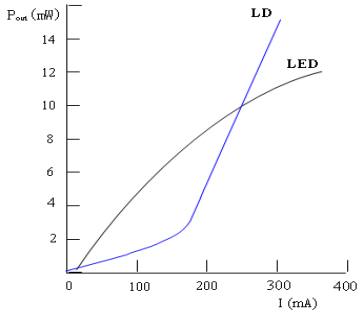
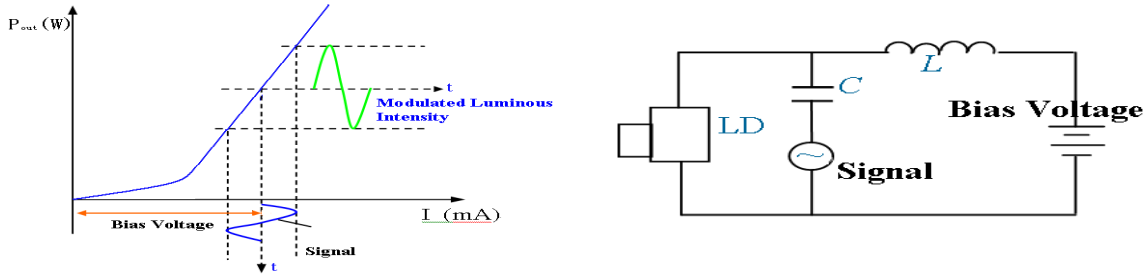


Fig. 2 Electro optic properties of Laser Diode and Light Emitting Diode.

In figure 3 (a) and (b), the modulation principle circuit and the schematic diagram of LD modulation properties are shown. To make the working point be at the linear part of the output curve, a direct bias voltage is needed for the device. At the linear part, the signal is converted into the modulated luminous intensity and the internal modulation will be realized.



(a) (b)

Fig. 3 Internal Modulation of Laser Diode: (a) Modulation principle circuit; (b) Schematic Diagram of Laser Diode Modulation properties.

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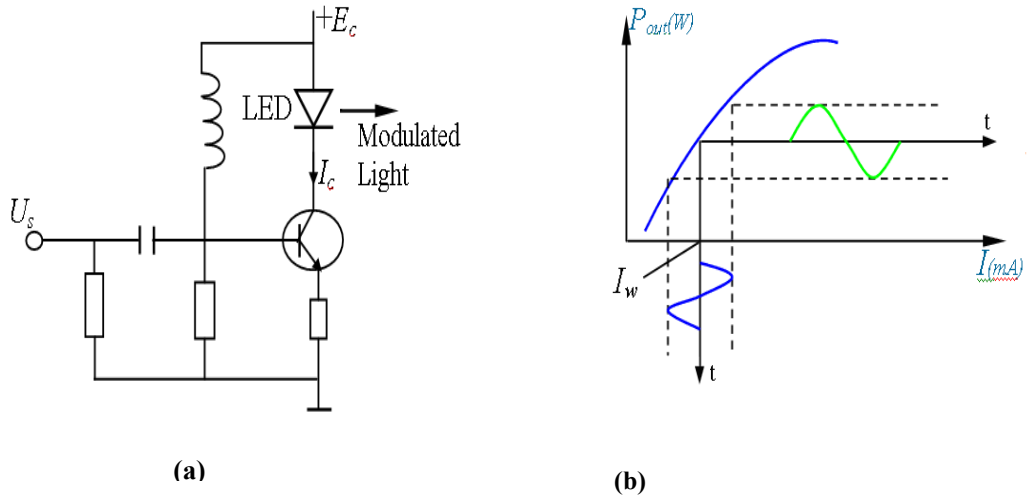
In figure 4 (a) and (b), the modulation principle circuit and the schematic diagram of LED modulation properties are shown. From figure 2, the light output properties are nearly linear at almost the whole curves. A better working point should be selected at the relatively linear part of the output curves. A direct bias voltage is not necessary here for the device. At the linear part, the signal is converted into the modulated luminous intensity and the linear modulated laser can be attained.



(a) (b)

Fig. 4 Internal Modulation of Light Emitting Diode: (a) Modulation principle circuit; (b) Schematic Diagram of Light Emitting Diode Modulation properties.

3.2 External modulation

External modulation includes electro optic modulation, acoustooptic modulation and magneto-optic modulation. The signal coupling process is realized outside the laser. Electro optic modulation is popular in the intra-body communication because of wider bandwidth, better stability and higher efficiency.

In the electro optic modulation, the laser may be modulated when the laser transmits the electro optic crystal, whose refraction index changes with the signal voltage because of Pockels Effect and Kerr Effect. The output modulated light can be produced and transmit in optic fiber with high speed and wide bandwidth. Electro optic modulation can be divided into intensity modulation, amplification modulation and angle modulation. Usually the intensity modulation is adopted because of it simple design principle. The intensity modulation can be realized using longitudinal electro-optic modulation and transverse electro-optic modulation [13-15].

Figure 5 shows the longitudinal modulation principle of the electro optic modulation structure. Here KDP (KH_2PO_4) crystal is used as the example. The electro optic crystal is placed between two orthotropic polarizers. The polarizer P1 is parallel to axis x and the polarizer P2 is parallel to axis y. A quarter wave polarizer (QWP) is inserted between P2 and the crystal. When the electric field is added to the crystal, the inductive axis x' and y', which locate at 45 degree angle with x and y, are produced. The polarized laser enter the crystal and be divided into two components at x' and y'.

The transmissivity can be obtained:

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$$T = \frac{I_o}{I_i} = \sin^2\left(\frac{\Delta\varphi}{2}\right) \quad . \tag{1}$$

$$\Delta\varphi = \frac{2\pi}{\lambda} n_o^3 \gamma_{63} V \quad . \tag{2}$$

γ_{63} is the linear electro optic coefficient of KDP crystal, λ is the laser wavelength and V is the signal voltage. The signal voltage can be coupling into the electro optic crystal, the laser will be modulated when it gets across.

In the electro optic modulation: the structure is simple; the modulation process is stable; the natural birefringence can be avoided. The modulation bandwidth is wide enough for intra-body modulation. Therefore, it can be adopted in this field.

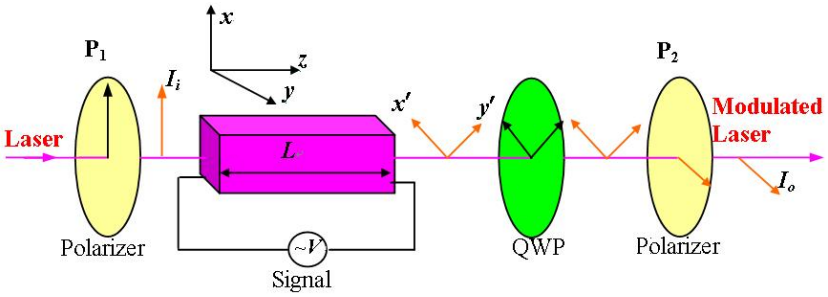

Fig. 5 Principle and structure of the longitudinal Electro Optic Modulation Device.

In the electro optic modulation, electro optic crystal is important. In intra-body communication, the device usually works at the daytime. To eliminate the influence of visible light, the infrared laser is preferred. The LD wavelength can be 850 nm, 930 nm or 1310 nm. In the electro optic modulation, the corresponding electro optic crystal is needed. Table 1 shows the properties of GaAs and CdTe. The CdTe crystal has better properties in electro optic modulation and is usually chosen for the intra-body communication.

Table 1 Properties of Electro Optic Crystals: GaAs and CdTe

Properties	*GaAs*	*CdTe*
Electro optic coefficient γ_{41} (cm/V)	1.6×10^{-10}	7.0×10^{-10}
Half-wave voltage (1310nm) (kV)	11.12	5.55
electrical resistivity ($\Omega \cdot m$)	4.0×10^{-6}	2.1×10^{-9}

4. Conclusion

High speed sensor systems for intra-body communication are reviewed. The characteristics of the intra-body communication system are analyzed and introduced. Principles and structures of the internal and external optic modulation for intra-body communication were reviewed. The electro optic modulation system, which is usually adopted are introduced and discussed. The electro optic crystals for infrared LD are listed and discussed.

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