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홈 네트워킹을 위한 LED-ID 시스템 성능분석

Performance of LED-ID System for Home Networking Applicaion

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요 약 본 논문은 가시광 통신(Visible Light Communication)시스템에서 고속 데이터 통신을 위한 line coding 기술 동향을 연구하였다. 가시광 통신(Visible Light Communication)기술은 LED를 사용하는 기기에서 나오는 가시광선(RGB)을 이용해서 정보를 전달하는 기술로서 친환경적이고 에너지 절감효과와 유비쿼터스 네트워크 서비스에 응용이 가능하다. 최근에 들어 홈 네트워킹 필요성의 증가와 LEDs (Light Emitting Diode Technologies)의 개선을 통해 가시광 통신 시스템에 관심이 높아지고 있다. 고속의 데이터 전송을 위하고 에러 검출에 효율적인 홈 네트워킹 환경을 위한 LED-ID 시스템 성능분석을 위해 적합한 line coding을 연구하고 NRZ, AMI, 4B5B, HDB3 line coding을 이용하여 홈 네트워킹 LED-ID 모델에 적용하고 LOS환경에서의 성능 비교를 하였다.

Abstract We propose a Z-HBT line coding for a LED-ID system. Z-HBT line coding is defined as follows. First, we apply half bit transition to one bit. Second, we decode encoded bits using difference of bit transition level in one bit duration. As a result, we obtain advantages about synchronization problem and noise effect mitigation at the receiver. We set up outdoor the LED-ID simulation environment. At simulation results, we show 2-3dB gain as compared with existing line coding schemes. The results of the paper can be applied to design and implementation of LED-ID systems for indoor wireless multimedia services.

Key Words : Light Emitting Diode(LED), line coding.

Ⅰ. INTRODUCTION

In the age of the 4th generation communication system, high speed data transmission will play an important part in our life. We will be able to transmit many kinds of information, which are so called multimedia information, at any place and any time. Therefore, the concept of wireless indoor link such as home or office has been proposed and drawn considerable attention. The electrical appliances will be wireless-linked with each other in the future, and using wireless home link, we will be able to access communication each other with these appliances anywhere in indoor environment[1-2]. Specially, a Light Emitting Diode(LED)-ID system can be considered as a candidate for wireless indoor link[3]. The LED-ID is suitable for wireless indoor link because it uses illumination device already installed. Also it is suitable for non-public network because it does not require any licenses. Moreover, light waves are obstructed only by physical obstacles, so it is easy to prevent the interference from adjacent rooms. The LED-ID system occupies no radio frequency spectrum and it can be used where electromagnetic interference is strictly prohibited (hospitals, air planes, and so on). The

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LED-ID system has the above advantages about that the communication throughout the whole room is enabled by high power lighting and lighting equipment with white colored LEDs which are easy to install and have good outward appearance. Therefore, the transmission by light waves is more suitable for indoor wireless networks than that by radio waves[4].

However, there are some problems in the LED-ID system[5]. First, it is easily affected by interferences such as other illumination devices and sunlight. Second, synchronization is a serious problem at the receiver. Even though on off keying (OOK) or non return to zero (NRZ) are already applied to the LED-ID system, it is not desirable solution. For that reason, we research several line coding schemes to obtain its advantages [6]. There are many reasons for using line coding in[7]: 1) Bit clock recovery can be simplified 2) DC component can be eliminated 3) Error detection capabilities 4) bandwidth usage. We focus on high density bipolar 3-zeros (HDB3) line coding. It is a kind of modified alternative mark inversion (AMI) in which bipolar violations may be deliberately inserted to maintain system synchronization and to reduce interference. HDB3 is used in all levels of the European E-carrier system, and it replaces any instance of 4 consecutive 0 bits with one of the patterns "000V" or "B00V". The choice is made to ensure that consecutive violations are of differing polarity. In this paper, we propose a Z-HBT line coding for the LED-ID system and it is defined as follow. First, we apply half bit transition to one bit, and second, decode encoded bits using difference of bit transition level in one bit duration. As a result, we obtain advantages about synchronization and noise effect mitigation and its results are shown in simulation results part.

Therefore, in this paper, we show comparison of performance of the LED-ID system with several line coding schemes and Z-HBT line coding in indoor environment. We set up the indoor environment with 3m*5m*5m size and calculate multi bound area and its impulse response. With computer simulations, we found that these approaches are feasible for the wireless optical link utilizing white LEDs and Z-HBT line coding schemes.

The paper is organized as follows. Section 2 introduces the proposed system model and Section 3 shows the simulation results and discussions. Finally, Section 4 draws some conclusion of the paper.

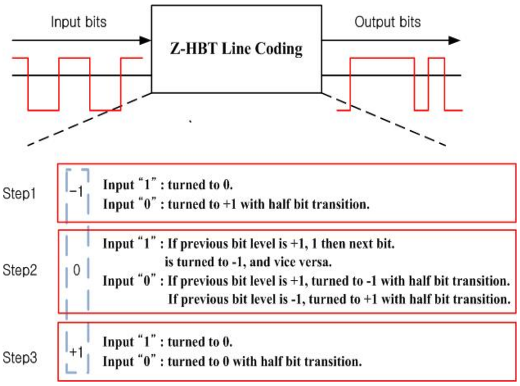

Fig. 1. Block Diagram of Z-HBT Line Coding
그림 1. Z-HBT Line Coding의 블록도

Ⅱ. SYSTEM MODEL

1. System Model

Fig. 1 shows a block diagram of a proposed line coding scheme for the LED-ID system. Random input binary bits are digitally modulated by modified line coding module block. In this paper, we handle AMI, 4B5B and HDB3 line coding schemes and find suitable line coding scheme for the LED-ID system.

HDB3 line coding is the best among above line coding schemes in aspects of error performance and DC component elimination, so we Z-HBT line coding for the LED-ID indoor environment. HDB3, based on the AMI code, limits the maximum number of consecutive zeros transmitted to three. The basic idea consists of replacing series of four bits that are to equal to "0" with a code word "000V" or "B00V", where "V" is a pulse that violates the AMI law of alternate polarity and is rectangular or some other shape. The rules for using "000V" or "B00V" are as follows. First, "B00V" is used when up to the previous pulse, he coded signal presents a DC component that is not null (the number of positive pulses is not compensated for by the number of negative pulses). Second, "000V" is used under the same conditions as above when up to the previous pulse the DC component is null. And third, pulse "B" ("B" for balancing), which respects the AMI alternately rule, has positive or negative polarity, ensuring that two successive V pulses will have different polarity. HDB3line coding has the following characteristics. The timing information is preserved by embedding it in the line signal even when long sequences of zeros are transmitted, which allows the clock to be recovered properly on reception. And the DC component of a signal that is coded in HDB3 is null. Fig. 2 shows the OOK line encoding graph at input binary bits stream is "11000010000000000000".

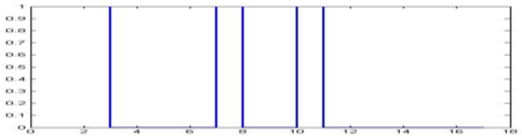

Fig. 2. Encoding Graph of input data
그림 2. 입력 신호의 인코딩 그래프

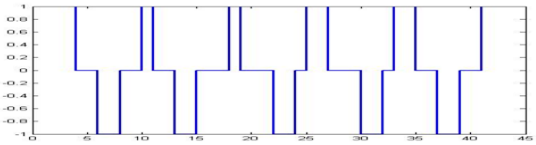

Fig. 3. Encoding Graph of Z-HBT
그림 3. Z-HBT 의 인코딩 그래프

As high signal transmission rate is being more important thing, however, synchronization and bit error rate (BER) are sensitive problem at the receiver. So, in this paper, we apply half bit transition at the middle of bit to one bit for good synchronization performance at the receiver. As shown in Fig. 3, when the bits stream is same in Fig. 2, bit transition is occurred at the middle of bit. For example, when have a current bit "0", if input bit is "1", Z-HBT line encoder changes bit position from high to low with half bit transition. Similarly, if input bit is "0", Z-HBT line encoder changes bit position from low to high during half bit duration.

2. Transmitter and Receiver Model

A transmitter can be represented by a position vector rS, a power PS, and a radiation intensity pattern $R(\phi)$, defined as the optical power per unit solid angle emitted from the transmitter. Following in [8], we model a transmitter using a general Lambertian radiation pattern as follow (1).

$$R(\phi) = \frac{n+1}{2\pi} P_S \cos^n(\phi) \qquad \phi \in [-\pi/2, \pi/2], \tag{1}$$

where, n is the mode number of the radiation robe, which specifies the directionally of the transmitter. As shown in Fig. 4, transmitter has higher directionality with lager mode number.

The coefficient $(n+1)/2\pi$ ensures that integrating $R(\phi)$ over the surface of a hemisphere results in the source power PS. A mode number n=1 corresponds to a traditional Lambertian source.

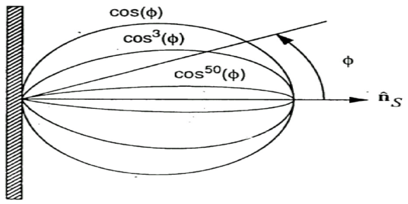

Fig. 4. General Lambertian Radiation Pattern
그림 4. General Lambertian Radiation Pattern

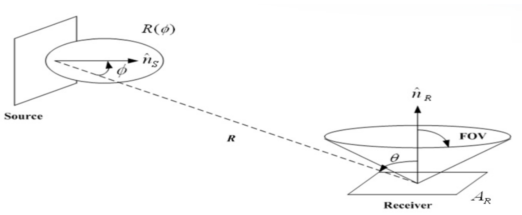

Fig. 5. Geometry of Transmitter and Receiver
그림 5. 전송단과 수신단의 신호

To simplify notation, a point transmitter S that emits a unit impulse response of optical intensity at time zero will be denote by an ordered three-tuple in,

$$S = \{\mathbf{r}_S . \hat{\mathbf{n}}_S, n\}, \quad (2)$$

where, rS is its position, $\hat{\mathbf{n}}_S$ its orientation, and n is its mode number. Similarly, a receiver element R with position rR , orientation $\hat{\mathbf{n}}_R$, area AR, and field of view (FOV) is denoted by an ordered four-tuple,

$$R = \{\mathbf{r}_R . \hat{\mathbf{n}}_R, A_R, FOV\}. \quad (3)$$

Fig. 5 shows geometry of transmitter and receiver in (2) and (3). The scalar angle FOV is defined such that a receiver only detects light whose angle of incidence is less than FOV.

3. Channel Model

Consider a transmitter and receiver, as represented above (1) and (2), in indoor environment with guarantee line of sight (LOS) condition. If the distance R between transmitter and receiver is much larger than are a AR, then the received irradiance is approximately constant over the surface of the receiver, and also, all of the signal is considered that arrive at the sametime at the receiver. As following above approximation, the impulse response is simple a scaled and delayed Dirac delta function as follow in[9].

$$h(t : S, R) = \frac{n+1}{2\pi} \cos^n(\phi) d\Omega rect(\theta / FOV) \delta(t - R/c), \quad (4)$$

where, $d\Omega$ is the solid angle subtended by receiver's differential area,

$$d\Omega = \cos(\theta) A_R / R^2. \quad (5)$$

R is the distance between the transmitter and receiver,

$$R = \|\mathbf{r}_S - \mathbf{r}_R\|. \quad (6)$$

θ istheanglebetween $\hat{\mathbf{n}}_R$ and(rS-rR),

$$\cos(\theta) = \hat{\mathbf{n}}_R \cdot (\mathbf{r}_S - \mathbf{r}_R) / R. \quad (7)$$

ϕ is the angle between $\hat{\mathbf{n}}_S$ and(rR -rS),

$$\cos(\phi) = \hat{\mathbf{n}}_S \cdot (\mathbf{r}_R - \mathbf{r}_S) / R. \quad (8)$$

And the rectangular function is defined as follow,

$$rect(x) = \begin{cases} 1 & for \ |x| \le 1 \\ 0 & for \ |x| > 0 \end{cases}. \quad (9)$$

In (4), c is denoted by speed of light.

Using above impulse response of LOS condition, multi bounce impulse response can be calculated easily by as follow.

$$h(t; S, R) = \sum_{k=0}^{\infty} h^{(k)}(t; S, R). \quad (10)$$

where, $h^k(t)$ is the response of the light under going exactly k reflections. Using LOS impulse response $h^{(0)}(t)$ in (4), higher order term (k>0) $h^k(t)$ in (10) is represented as follow.

$$h^{(k)}(t; S, R) = \int_S h^{(0)}(t; S, \{\mathbf{r}, \hat{\mathbf{n}}, \pi/2, dA_R\}) \otimes h^{(k-1)}(t; S, \{\mathbf{r}, \hat{\mathbf{n}}, 1\}, R), \quad (11)$$

where, $\otimes$ is denoted convolution sum. Moreexactly, substituting (4) for (11) and performing the convolution sum results in

$$h^{(k)}(t; S, R) = \frac{n+1}{2\pi} \int_S \frac{\rho_r \cos^n(\phi) \cos(\theta)}{R^2} \cdot rect(2\theta/\pi) h^{(k-1)}(t - R/c; \{\mathbf{r}, \hat{\mathbf{n}}, 1\}, R) dA_R. \quad (12)$$

The integral in (11) and (12) can be calculated numerically by discontinuous reflecting surfaces into numerous small reflecting elements, each with ΔA Therefore, (11) and (12) can be represented as follow.

$$h^{(k)}(t;S,R)=\frac{n+1}{2\pi}\sum_{i=1}^{N}\frac{\rho_r\cos^n(\phi)\cos(\theta)}{R^2}\cdot rect(2\theta/\pi)h^{(k-1)}(t-R/c;\{\mathbf{r},\hat{\mathbf{n}},1\},R)\Delta A_R\cdot \tag{13}$$

Ⅲ. Simulation Result

Table 1 is represented simulation parameters for calculation LOS and multi bounce received signal. We set up the indoor room size with 5m length (x-axis), 3m width (y-axis) and 3m height (z-axis) where it is designed in rectangular coordinate system. Position of transmitter and receiver are (2.5m, 2.5m 3m) and (1m, 1m, 0m) as illustrated in Fig. 6. Mode number of transmitter in (1) is fixed by “1”, FOV of receiver in (5) is 60 degree and received area AR is 1cm. So, using above parameters of mode number, FOV and received area, we can calculate valid reflecting area from ① to ④ which illustrated in Fig. 6. Receiving signal which bounced outside of valid reflecting area are not considered. We control the power of transmitted signal is 1W and it is transmitted to all direction and the attenuation coefficient of each reflecting walls is fixed 0.9 (0.9 is concrete’s attenuation coefficient). And the parameter “T” is the bin width of the power histogram that approximates the impulse response, so, receive dsignals with in time “T” are just summed at the receiver.

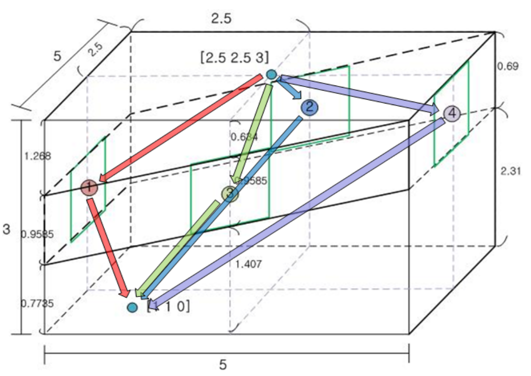

Fig. 6. Simulation Environment with Multi Bounce
그림 6. Multi Bounce의 시뮬레이션 환경

Table 1. Simulation parameters
표 1. 시뮬레이션 파라미터

	Parameter	A	
Space	Length(x)	5m	
	Width(y)	5m	
	Height(z)	5m	
Source	Mode	1	
	X	2.5	
	Y	2.5	
	Z	3	
Receiver	Area	1cm	
	FOV	60	
	X	1	
	Y	1	
	Z	0	
Transmitted optical power	1W		
Reflection index	wall : 0.9		
Resolution	T	2ns	
	bounces	1	2
	Nx	500	100
	Ny	500	100
	Nz	300	60

In this paper, we consider only the first order reflected signal, that is $h^{(1)}(t)$, because of, the calculation complexity of higher order (k>1)impulse response is very high and received power of higher order (k>1) impulse response is very low.

Fig. 7 shows the impulse response of $h^{(1)}(t)$ based simulation parameters. X-axis represents simulation time and y-axis represents power of received signal. A reason of existing four impulse responses is that each impulse is affected by different time delay and power attenuation due to difference of distance between the transmitter / receiver and reflecting point at four vertical walls. The dominant impulse response is the reflected signal at reflecting region ③ and the last impulse response is the reflected signal at reflecting region ④. Using the impulse response in Fig. 7, the final received signal is obtained by convolution sum between.

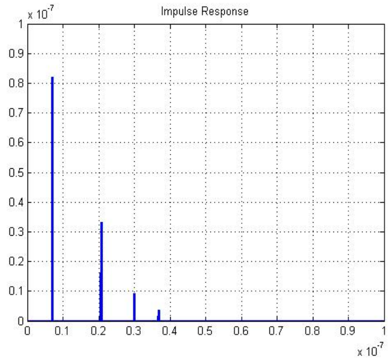

Fig. 7. Impulse response of Multi Bounce
그림 7. Multi Bounce 임펄스 결과

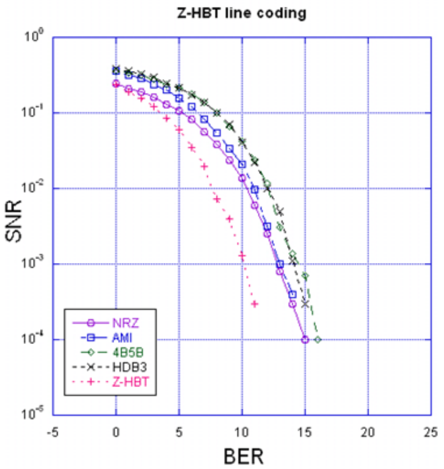

Fig. 8. BER Performance
그림 8. BER 결과

impulse response and line coded signal at the receiver and it is represented in mathematical form as follow.

$$y(t) = \hat{x}(t) \otimes h(t) + n(t), \qquad (14)$$

where, $y(t)$ is received signal, $\hat{x}(t)$ is line coded input signal, $h(t)$ is impulse response and $n(t)$ is the additive white Gaussian noise (AWGN).

Fig. 8 shows BER performance between 4B5B, HDB3 and Z-HBT line coding. As shown in above BER graph, we obtain 2 – 3dB SNR gain comparison with conventional line coding in indoor environment.

Ⅳ. Applications of The Proposed Scheme

In Table 2, LED-ID can provide cable free communication at very high bit rates as high as 100Mbps. In addition, it has a major advantage that it causes no interference to RF. This made wireless communication possible in RF hazardous areas such as hospital and space station.

Table 2. Different of LED-ID and RF
표 2. LED-ID와 RF의 비교

Property	LED-ID Comm.	RF Comm.
Bandwidth	Unlimited, 400nm~ 700nm	Regulatory, BW Limited
EMI	No	Yes
Line of sight	Yes	No
Standard	Beginning	Matured
Power consumption	Relatively low	Medium
Visibility security	Yes	No
Intra-structure	LED Illumination	Access Point
Mobility	Limited	Yes
Coverage, Distance	Narrow, short	Wide, Medium

These LEDs are becoming the most promising candidate for future general illumination, due to some important advantage, which they offer over the traditional light sources. These include long life expectancy and the continually increasing power efficiency. Another distinct characteristic that distinguishes LEDs from other light sources is their considerable modulation bandwidth, which enables wireless high-speed LED-ID. Figure 9 shows the LED-ID application of the home network. It is suitable for wireless home link which requires high speed wireless link. The LED-ID is suitable for a non-public network, or a consumer communication network, such as wireless home link which is the topic here because they do not require any licenses. Moreover, light waves are obstructed only by physical obstacles, and it is easy to prevent the interference from adjacent rooms. Existing wiring could carry data to smart illumination, providing easy network access points throughout home or office.

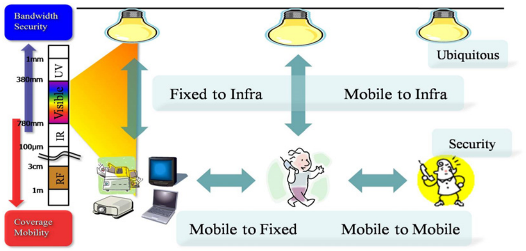

Fig. 9. LED-ID application of home network
그림 9. 홈 네트워크의 LED-ID 응용

There are many promising indoor applications including the transmission of television and multimedia signals using the ceiling lamp or the desk lamp, the use of LED light spots in cars, trains, buses and airplanes as Internet access points and the realization of local information points in shops, airports, train stations and museums. Therefore the transmission by light waves is more suitable for indoor wireless networks than the one by radio waves.

V. Conclusions

The LED-ID offers the advantage of unlicensed part of the spectrum and security property. Also, line coding offers good synchronization and error detection properties. So, in this paper, we handled some line coding for indoor the LED-ID system and Z-HBT line coding. We obtained good synchronization and error correction properties. From simulation results, we confirmed difference of the BER performance between convention line coding and proposed one. At the same BER (10-4), proposed line coding scheme obtained SNR gain of 2-3dB as compared with HDB3 and 4B5B line coding.

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