Channel Characteristics of Indoor Wireless Infrared Communication System Due to Different Transceiver Conditions

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요 약

In this paper, we consider the diffuse type of indoor wireless optical communication (WOC) system. To find the channel characteristics of indoor wireless infrared communication system, we investigate the simulation process to get the impulse response of diffuse type and analyze the scenario of the indoor structure which we have built. The simulation results of the impulse response include power ratio and time delay due to bounce times. We get and discuss the receiving power distribution according to six configurations which have different transmitter and receiver positions and reflection coefficients of the indoor structure assumed. The results of this paper are useful to design the indoor wireless optical communication systems.

Key Words : Indoor wireless optical communication system, Diffuse type, Channel characteristics

Ⅰ. Introduction

Wireless communication is very important to transfer the information over a distance without the use of electrical conductors or wires. Wireless communication systems can be divided to radio frequency (RF) and wireless optical system. RF communication system has been well developed and popular for several decades. In the long run, people find many insurmountable problems with RF communication such as the demand of wider bandwidth, need of strict laws, interference, fading immunity, high power consumption and so on. However, the drawbacks of RF just can be conquered by wireless optical links. In the meanwhile, wireless optical link outweighs itself for its flexibility, cost effectiveness, and mobility.

Two types of wireless optical communications system have been deposed, and wireless optical communication can be assorted based on distance between transmitter and receiver. Long distance systems are used for outdoor wireless optical links, and always connect different networks. Short distance systems are used for indoor wireless optical link which is suitable for in office and home LANs. Wireless infrared (IR) communications via infrared radiation offer the inexpensive and high speed data links for portable computer networks and have prompted a great interest[1].

The indoor wireless IR links have two main configurations such as diffuse and LOS (line of sight) types. However, LOS type is more prone to blocking as the transmitter and receiver must be able to see each other all the time. On the other hand, diffuse type shows more resistance to blockage due to the availability of more than one path between the transmitter and receiver. Diffuse type (Fig. 1) provides wider area of coverage than LOS type leading to a better mobility support[2].

In this paper, we consider the channel characteristics of the diffuse type of wireless IR communication system. To find its channel

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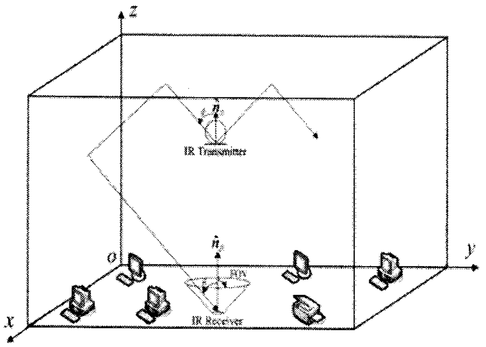

Fig. 1 Room structure and wireless IR diffuse links

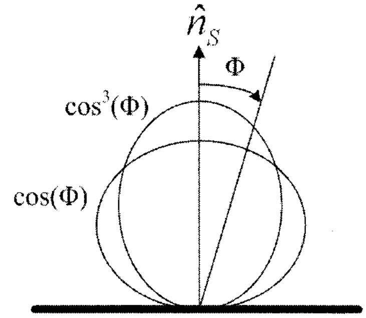

Fig. 2 Normalized shape of the generalized Lambertian radiation pattern

characteristics, we investigate the simulation process to get the impulse response of the diffuse type and analyze the scenario of the indoor structure which we have built.

This paper is organized as follows. Section II develops the simulation model to get the impulse response of the channel in the diffuse type. In Section III, we build the scenario and get its simulation results according to different reflection coefficients, radiation intensity pattern, transmitter height, receiver position, and room size. Section IV shows the discussion and conclusion.

Ⅱ. Simulation Modeling

2.1 Source and receiver models

A wide-beam optical source can be represented by a position vector r_S, a unit length orientation vector $\hat{n}_S$, a power P_S and a radiation intensity pattern $R(\Phi,\Theta)$, defined as the optical power per unit solid angle emitted from the source at position (Φ,Θ) with respect to $\hat{n}_S$.

Following Gfeller[3], the IR radiation pattern model considers that the source has a generalized lambertian radiation pattern (Fig 2), having unaxial symmetry (independent of Θ). The source radiance is given by:

$$R(\Phi)=\frac{n+1}{2\pi}P_S\cos^n(\Phi)\ for$$

$$\Phi\in[-\pi/2,\pi/2] \qquad (1)$$

The pattern mode number for this angle:

$$n=\frac{0.693}{-Ln(\cos(\Phi))}$$

where, n is the mode number of the radiation lobe, which specifies the directionality of the source. This is illustrated in Fig. 2, where sources with higher directionality are seen to have larger mode numbers. The coefficient $(n+1)/2\pi$ ensures that integrating $R(\Phi)$ over the surface of a hemisphere results in the source power P_S which is the total emitted power of the IR transmitter. A mode of $n = 1$ corresponds to a Lambertian emitter, with half power beam width (HPBW) of 60°. To simplify notation, a point source S that emits a unit impulse of optical intensity at time zero will be denoted by an ordered three tuple $S=\{r_S, \hat{n}_S, n\}$ where r_S is its position, $\hat{n}_S$ is its orientation, and n is its mode number. Linearity allows us to consider only unit impulse sources and scale the results for other sources. Similarly, a receiving element R with position r_R, orientation $\hat{n}_R$ area A_R, and field of view (FOV) will be denoted by an ordered four tuple: $R=\{r_R, \hat{n}_R, A_R, \text{FOV}\}$.

The scalar angle FOV is defined such that a receiver only detects light whose angle of incidence (with respect to the detector normal $\hat{n}_R$) is less than FOV (in Fig. 3). A limited field of view may be an inadvertent effect of detector packaging, or it may be used intentionally to reduce unwanted reflections or noise[4].

2.2 Reflector model

A reflector model for diffuse channel is shown in Fig. 3. The components are: an IR transmitter as practical source, a reflecting surface and a photodiode as a IR receiver. In this study, we consider neither the border effect nor diffraction. In all cases the size of the reflecting cell is supposed to be infinite, compared with the width of wavelength. We have simulated an optical link on an empty flat walls, white paint, rectangular room, with constant reflectivity[5].

The receiver is characterized by its FOV. The reflector model considers that all the surfaces are Lambertian reflectors. It means that the reflected signal is independent from the incident signal[6]. So, the channel transfer function as follows for FOV in equation (2).

$$h(t) = \frac{n+1}{2\pi} cos^n(\Phi) \cdot \cos(\theta) \frac{A_R}{R^2} \cdot \delta(t - \frac{R}{c}) \quad (2)$$

The received signal is then a delayed $\delta(t)$ function, the delay is proportional to the distance ***R*** and the light speed *c*. For the bounces after the first reflection, we use the recursive model proposed by Barry et al. that is given by[7]:

$$h^k(t) = \frac{n+1}{2\pi} \cdot \sum_{i=1}^{n} \frac{\rho_j \cdot \cos^n(\Phi) \cdot \cos(\theta)}{R^2} \cdot h^{k-1}(t) \quad (3)$$

where ρ_j is the reflection coefficient of the cell.

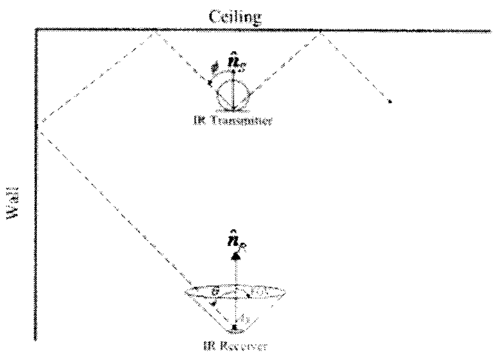

Fig. 3 Reflector model for diffuse links

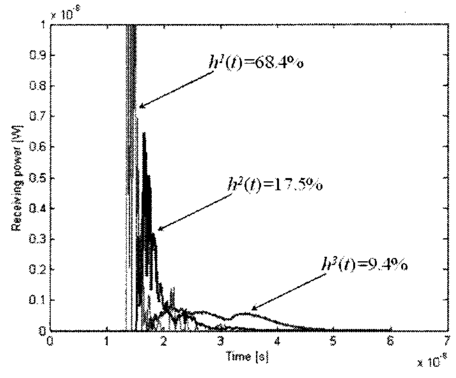

Fig. 4 Impulse response of configuration A in Table 1

By defining a practical size of a room and simulation conditions like configuration A in Table 1, we get the impulse response include power ratio and time delay due to bounce times (Fig. 4). Assuming a one watt source, each of the response is labeled by the total power it would carry. From the results shown in Fig. 4, we can estimate the total receiving power from once reflected light is 68.4%. The power seems to decrease for each of the higher order impulse response.

Ⅲ. Scenario and Similation

Diffuse type links are subjected to multipath propagation due to reflections from walls, ceiling, and other surfaces. In order to investigate the effects of diffuse transmission on indoor wireless optical propagation characteristics, a simulation was conducted in a room with floor dimensions of 6 m (length) × 4 m (width), and ceiling height of 3 m.

To make different simulation conditions we have changed the reflection coefficients of the room, transmitter parameters (position, mode pattern), and receiver parameters (position, FOV) as shown in configurations B to G in Table 1. The orders of the simulation are from configuration B to configuration G in Table 1. In configuration B, we have changed the reflection coefficients of the room from 0.1 to 0.8 as shown in Fig 5. The simulation result in configuration B shows that the higher reflection coefficient is the more power is received

Table 1. Indoor structure scenario for simulation

Parameter \ Configuration		A	B	C	D	E	F	G
room	length(x)	6	6	6	6	6	6	variable
	width(y)	4	4	4	4	4	4	variable
	height(z)	3	3	3	3	3	3	variable
	ρ (4walls, ceiling, floor)	0.5	variable	0.5	0.5	0.5	0.5	0.5
transmitter	mode	1	1	variable	1	3	3	3
	x	3	3	3	3	3	3	3
	y	2	2	2	2	2	2	2
	z	2.5	2.7	2.7	variable	variable	2.5	2.5
receiver	area	1cm^2	1cm^2	1cm^2	1cm^2	1cm^2	1cm^2	1cm^2
	FOV	70°	70°	70°	70°	70°	70°	70°
	x	0.5	3	3	3	3	variable	3
	y	0.5	2	2	2	2	variable	2
	z	0.5	1	1	1	1	variable	1

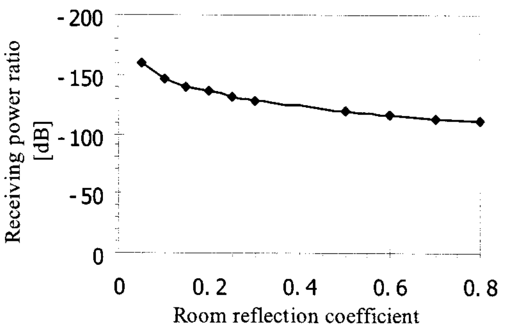

Fig. 5 Receiving power ratio versus different reflection coefficient of the room (4walls, ceiling, floor)

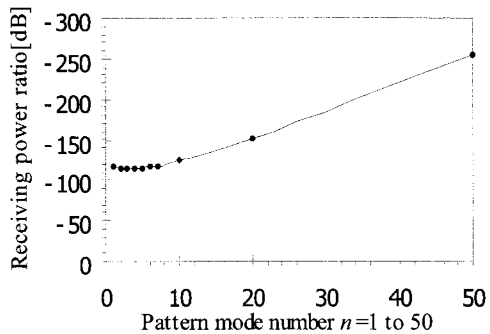

Fig. 6 Receiving power ratio versus different mode number of radiation pattern

as we have expected. In this case, we have assumed that the reflection coefficients of four walls, the ceiling, and the floor are same.

In configuration C, the source radiation pattern mode is varied from 1 to 50 and the proper reflection coefficients of 0.5 have been chosen based on the simulation result on configuration B and practical sense. The simulation results show that the highest receiving power is at n=3 and the bigger n (over n=3) is the lower receiving power will be as shown in Fig. 6.

In configuration D and E, we have got the receiving power ratio according to the radiation patterns and different heights of transmitter as

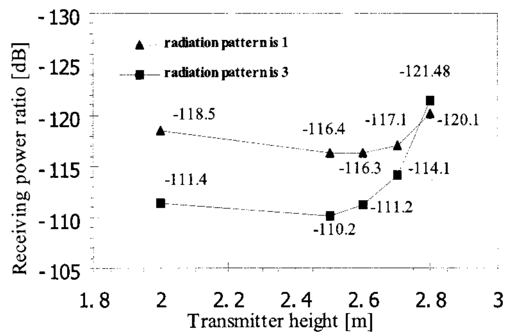

Fig. 7 Receiving power ratio versus different transmitter height for two pattern modes (n=1, 3)

shown in Fig. 7. The results show that the highest receiving power level is at the radiation pattern of

Table 2. Receiving power ratio versus different receiver position and room size change

	Receiver position [x, y, z]				Room size [x y z]		
	[3,2,1]	[1,2,1]	[2,2,1]	[1,1,1]	[6 4 3]	[10 6 3]	[14 8 3]
Receiving power ratio [dB]	-107.0	-122.9	-111.8	-125.9	-107.0	-110.1	-113.2

n=3 and height of 2.5 m.

In configuration F, we have evaluated the receiving power ratio in the view of 4 different receiver positions and room size change, which is shown in Table 2. The ceiling and the walls of the room are modeled as ideal Lambertian reflectors with the reflection coefficient of 0.5 for the walls, floor and ceiling. In all the cases we have studied, a mobile transmitter is located at four different points [x, y, z] = [3, 2, 1], [1, 2, 1], [2, 2, 1] and [1, 1, 1] on the floor, 1 m above the floor and pointed upwards. It also emits 1 watt optical power totally with an ideal Lambertian radiation pattern.

Simultaneously, in order to see how the room size affects to the receiving power we have chosen three different sizes of the room. The result in Table 2 shows that the smaller the room size is the bigger the receiving power ratio. From Table 2, we can see the highest power has been given at the center of the smallest room.

Ⅳ. Conclusion

We have obtained the channel impulse response due to different reflection coefficients and transmitter and receiver positions for the given room. The simulation results show that the bigger reflection coefficient is the more receiving power ratio. Moreover, the receiving power ratios have been given for 6 different scenarios including reflection coefficient change, mode pattern change of the source, receiver position change, and room size change. These results are useful to design the indoor wireless optical communication systems.

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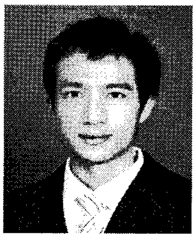

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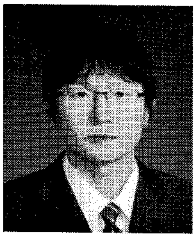

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