Study on Modeling of Visible Light Communication in Indoor Furniture Scene

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***Abstract*—The environmental information of the indoor scene has great influence on the prediction of the indoor visible light communication channel and the optimal layout of the light source. This article mainly introduces a modeling method for predicting the optical power distribution of indoor visible light communication when a simple furniture is arranged in the room. The method is based on the Lambertian model, which meshes the surface of a wall surface or an indoor object to obtain a small surface element. The microelement is used as a receiver or a secondary light source, and the optical power distribution of indoor visible light communication is simulated and analyzed. It provides a feasible modeling method for indoor visible light communication channel prediction and optimal layout of light sources.**

Keywords—visible light communication; Lambertian model; channel modeling

I. INTRODUCTION

This article assumes that both the light source and the diffuse reflection are based on the Lambertian radiation model. First, all the surfaces in the room are meshed to obtain tiny facets, which can then be divided into two steps in the case of non-line-of-sight links: The tiny facet is used as a receiver to calculate the received optical power. In the second step, the tiny facet is used as a light source to perform Lambert radiation. Finally, the total optical power received by the receiver is calculated.

With the development of information technology, the demand for data volume in wireless communication is increasing day by day. The previous communication technology has not been able to meet the requirements of the information age. Visible Light Communications (VLC) is an emerging optical wireless communication technology developed in white LED technology. Compared with traditional RF communication and other optical wireless communications. VLC has high transmission power, ultra-high speed data transmission, harmless to the human body, no electromagnetic interference, ubiquitous, energy saving and other advantages [1]-[3].

The LED lamp compared to the conventional incandescent lamp has many advantages such as small size, low energy consumption, long life, quick reaction speed and the like. Therefore, in the indoor visible light communication system, most of the light sources are LED light sources [4].There are two types of indoor visible light communication links, one is the line-of-sight link and the other is the non-line-of-sight link[5].

II. CHANNEL MODELING

A. Lambertian Model

In the channel model of this paper, the Lambertian model is applied in the light emission mode of the light source and the diffuse reflection mode of the object surface.

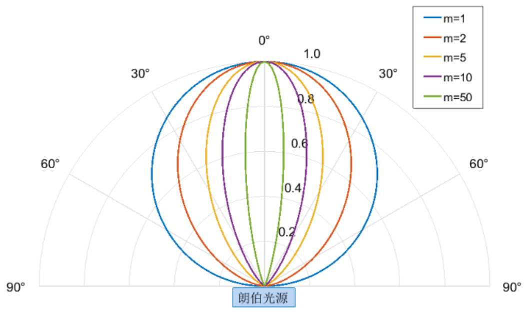

Fig. 1. Normalized Lambertian radiation pattern.

As shown in Fig.1, assuming that the light emitting mode of the LED light source is a Lambert radiation model and the luminous intensity at the center of the light source is I_0 , the luminous intensity of the light source is expressed as [6]:

$$I(\phi) = I_0 \cos^m(\phi) \tag{1}$$

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In the formula, ϕ is the emission angle, which is the angle between the emission direction and the normal direction of the light source, and m is the parameter of the directionality of the light source, which is called Lambert's emissivity and is determined by the half-power angle $\phi_{1/2}$ of the light source.

$$m = -\frac{\ln 2}{\ln\cos(\phi_{1/2})} \tag{2}$$

When m=1, the light source is an ideal Lambertian light source.

B. Geometric Modeling of Indoor Scenes

In order to facilitate the calculation and simulation, the indoor furniture and other objects are simplified and the cylinder is used to represent the indoor objects. For the room's doors, windows, or appendages on the wall, it is represented by the attached surface on the wall. At the same time, record and save the reflection coefficient corresponding to each surface of the indoor object or wall surface. As shown in Fig. 2, a simple indoor scene model of the $10m\times6m\times4.6m$ room is shown. There are two indoor objects and one subsidiary surface in the model.

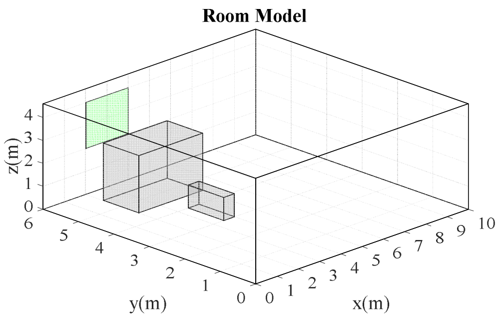

Fig. 2. Indoor simple scene three-dimensional model.

C. Optical Power Calculation

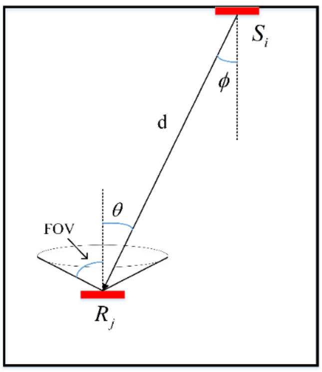

Fig. 3. Optical power transmission and reception schematic.

The optical power at the receiver can be expressed as [7]:

$$P_r = H(0)P_t \tag{3}$$

Where $H(0)$ is the DC gain of the channel, P_t is the transmit power and P_r is the receive power. The channel DC gain can be expressed as [8]:

$$H(0;S_i,\mathrm{R}_j) = \begin{cases} \frac{(m+1)A_r}{2\pi d^2}\cos^m(\phi)\cos\theta\,\mathrm{T}_s(\theta) \\ \cdot\mathrm{g}(\theta)V(S_i,R_j,E), & 0\le\theta\le FOV \\ 0, & \theta\ge FOV \end{cases} \tag{4}$$

Where S_i is the ith light source, R_j is the jth receiver, ϕ is the radiation angle of the transmitter, θ is the incident angle of the light at the receiver, A_r is the receiver area of the photodetector, d is the distance between the light source S_i and the receiver R_j, FOV is the angle of view of the receiver. $\mathrm{T}_s(\theta)$ is the gain of the optical filter, which is not considered in this paper, so let $\mathrm{T}_s(\theta)=1$. $V(S_i,R_j,E)$ is the visual function of the light source S_i and the receiver R_j under the environment E. If there is no occlusion between the direct paths between them, then $V(S_i,R_j,E)=1$, otherwise it is 0. $g(\theta)$ is the optical concentrator gain. Assuming its internal refractive index is n, it can be expressed as:

$$g(\theta) = \begin{cases} \frac{n^2}{\sin^2(FOV)}, & 0\le\theta\le FOV \\ 0, & \theta > FOV \end{cases} \tag{5}$$

Where $0\le FOV\le\frac{\pi}{2}$.

III. SIMULATION

The optical power simulation in this paper is based on the indoor scene model in Figure 2. The four light sources are located at (3, 2, 4.6), (3, 4, 4.6), (6, 2, 4.6), (6, 4, 4.6). Assuming that the reflection coefficient of the four walls of the room wall, the ceiling, and the floor are all 0.8, the reflection coefficient of the surface of indoor surfaces and small objects is 0.2, and the surface reflection coefficient of large objects is 0.5. The maximum number of reflections of the optical signal in the room is one, that is, the received optical power can be expressed as the sum of direct and one-time diffuse optical power. The relevant simulation parameters are shown in Table 1.

TABLE 1. Simulation Related Parameter Setting

Half-power angle	60°
Radiation powe	1W
Physical area of photo-detector	$1cm^2$
FOV of receiving units	60°
Refractive index	1.5
Object surface grid step	0.1m
Receiving surface grid step	0.125m
Receiving surface height	0.85m

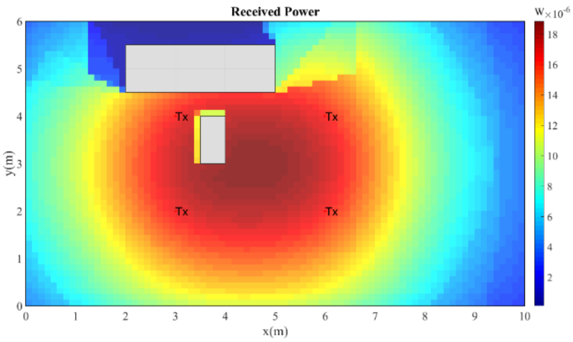

Fig. 4. Two-dimensional view of optical power distribution.

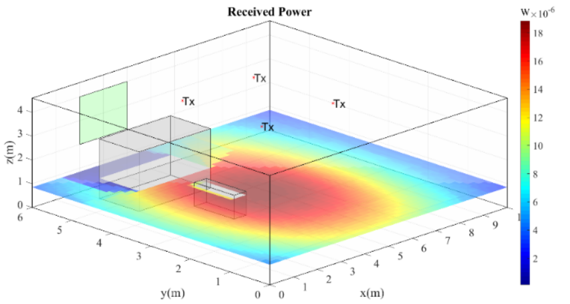

Fig. 5. Three-dimensional view of optical power distribution.

Fig. 4 and Fig. 5 show the simulation results of the optical power at the receiving surface. It can be seen from the figure that the optical power has been greatly reduced when the propagation loss of the light source has passed through the path to the receiver. With the increase of the propagation distance, the optical power also decreases. Therefore, the optical power received at the position directly below the light source is greater than other positions, and the optical power decreases from just below the light source to the surrounding light. In addition, because the indoor objects block the direct light, the optical power in some locations is provided by only one diffuse reflection. Therefore, the optical power received by these locations is much lower than the optical power that can receive the direct light. In addition, the grid step size of the internal object surface is greatly related to the final simulation result. The smaller the grid step size is, the more accurate the result is, but it also increases the calculation time. It is necessary to carefully weigh the proportions of both precision and calculation time, and choose the appropriate grid step size.

IV. CONCLUSION

This article describes the scene modeling method of indoor visible light communication based on Lambertian model. Under the condition of simple furniture and accessories in the room, the simulation results of the optical power distribution of the four light sources are given. The simulation results show that The obstruction of the object results in a significant drop in the optical power in some receiving areas. The research in this paper provides a feasible method for channel prediction of indoor visible light communication and optimal layout of light sources.

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