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Performance Comparison among ASK, FSK and DPSK in Visible Light Communication

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Abstract

We consider the detection of Amplitude-Shift Keying (ASK), Frequency-Shift Keying (FSK) and Differential Phase-Shift Keying (DPSK) in Visible Light Communication (VLC). And their performance is compared according to data rate, transmission distance and incident angle respectively.

Keywords

VLC, ASK, FSK, DPSK

1. Introduction

Nowadays, Light-Emitting-Diodes (LEDs) are widely used and they have a lot of advantages [1], such as high energy and high brightness. In addition to lighting, LED can also be used for communication. Visible Light Communication (VLC) can do better than radio wireless communication in confidentiality and it has no electromagnetic radiation so that it can be used in some special situation.

VLC normally uses the ASK modulation technique, which is simple and widely used. But FSK, DPSK is seldom used in VLC system. As it is almost as simple as ASK, we have done some analyses to FSK and DPSK, as well as compare them to ASK in a line-of-sight (LOS) VLC system, to see whether the performance can be improved when FSK or DPSK is introduced [2].

In this paper, we look into the VLC system and figure out what influences the signal noise ratio (SNR) and bit rate error (BER) in the first section. Secondly, we do some simulation to show the BER influenced by data rate, transmission distance and incident angle respectively. Finally, the performance of OOK, FSK and DPSK is summed up.

2. System Analysis

As shown in **Figure 1**, a general VLC system includes a transmitter and a receiver. The transmitter consists of modulator, LED driver and LED, and the receiver is composed of photo detector (PD), amplifier, demodulator and decision device.

The modulator refers to ASK, FSK and DPSK modulator in this paper, and the demodulator is the corres-

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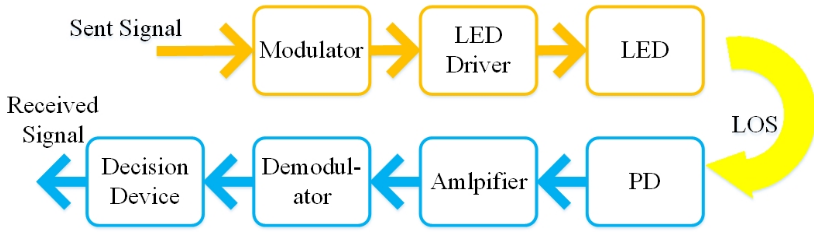

Figure 1. System Scheme

ponding one of the modulator. The PD converts the signal from optical power to electrical current. And then it is amplified and converted to voltage signal.

In a general LOS VLC system as shown in **Figure 2**, we define the parameters as follows. The angle of the LED's half illuminance is $\Phi_{1/2}$, and the irradiance angle is ϕ, The photodiode's (PD) light incident angle is φ, and the field of view of PD is Ψ. Finally, the distance between the LED and the PD is *d*.

The radiation pattern of LED is generally regarded as Lambertian pattern, therefore, the optical intensity at angle ϕ is $I_\phi = I_0 \cos^m(\phi)$. Where I_0 is the perpendicular incidence intensity of the LED, *m* is the order of Lambertian radiation and the relationship between m and $\Phi_{1/2}$ is given by [3]

$$m = \ln(2)/\ln(\cos\Phi_{1/2}) \tag{1}$$

And then we can calculate the received power. It is given by

$$\sigma_{total}^2 = \sigma_{shot}^2 + \sigma_{thermal}^2 = 2qP_rB + 2qI_bI_2B + \frac{8\pi kT_k}{G}\eta AI_2B + \frac{16\pi^2 kT_k\Gamma}{g_m}\eta^2 A^2 I_2 B^2 \tag{2}$$

In this formula, *A* is the receiving area of PD, *R* is the PD sensitivity. And a PD can't receive any signal if φ is larger than the field of view (FOV) of PD marked as Ψ. So we can see that

$$SNR = p_r^2 / \sigma_{total}^2 \tag{3}$$

In order to decrease the system complexity, we choose to use noncoherent demodulation, the bit error rate (BER) of ASK, FSK and DPSK is given by [4] [5]:

$$BER_{2ASK} = \frac{1}{2}\exp(-SNR/4) \tag{4}$$

$$BER_{2FSK} = \frac{1}{2}\exp(-SNR/2) \tag{5}$$

$$BER_{2DPSK} = \frac{1}{2}\exp(-SNR) \tag{6}$$

3. Simulation Results and Discussion

Now the performance of ASK, FSK and DPSK is given out according to data rate, transmission distance and incident angle respectively, whose model is the LOS model I mention above. And the bandwidths of these modulations are calculated according to the feature of the modulation. The parameters used in the simulation are shown in **Table 1** [6].

In ASK modulation, the bandwidth is equal to the data rate Rb, in FSK modulation, the bandwidth is equal to abs (f2 − f1)/2 + Rb, where f1 and f2 are the carrier frequencies of FSK, and in DPSK modulation the bandwidth is also equal to Rb.

AS shown in **Figure 3**, we assume the incident angle is 0 degree, the carrier frequencies of FSK are 1 MHz and 2 MHz, the transmission distance is 100 m, and the data rate ranges from 100 Kbps to 1 Mbps. We can see that DPSK performs best, and ASK is better than FSK when data rate is low, when data rate goes high, FSK can finally exceeds ASK.

As shown in **Figure 4**, the incident angle is set to 0 degree, the carrier frequencies of FSK are 1 MHz and 2 MHz, the transmission distance ranges from 10 m to 200 m. We can see that the BER increase significantly for

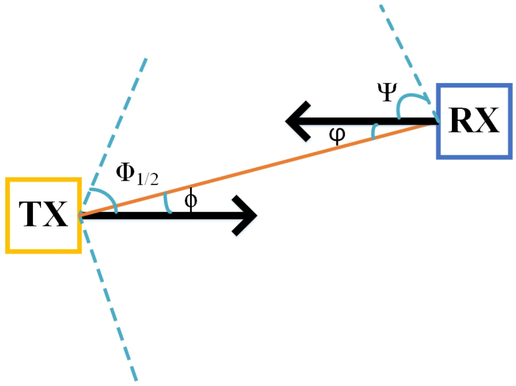

Figure 2. LOS VLC scheme diagram.

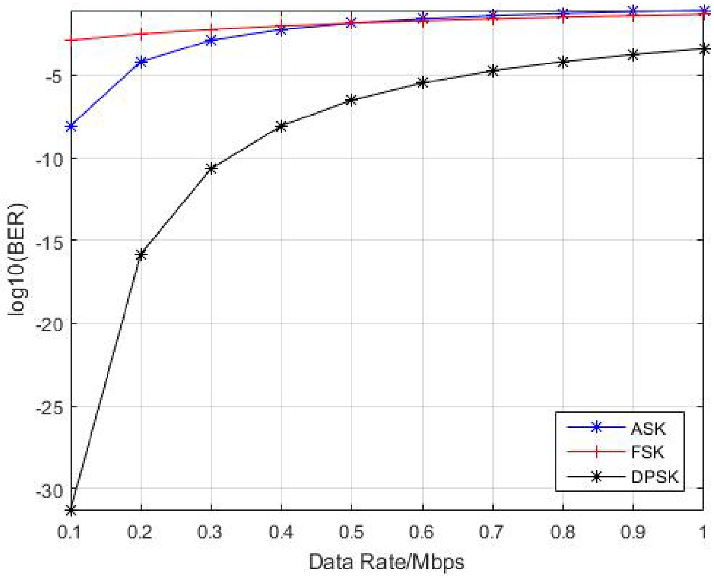

Figure 3. BER vs. data rate.

Table 1. Simulation parameter.

Parameter	Value	Parameter	Value
Transmitted optical power	900 mW	Fixed capacitance per unit area	112 pF/cm^2
Semi-angle at half power	70 degree	Open-loop gain	10
Effective area in PD	1 cm^2	Temperature	298 K
FOV of PD	60 degree	FET trans-conductance	30 mS
PD sensitivity	0.2 A/W	FET noise factor	1.5
Back ground current	0.0051 A	I_3	0.0868
Noise bandwidth factor	0.562		

all the modulation methods. We can derive above result from that the optical power is proportional to the square of the transmission distance. And DPSK is the best, FSK is better than ASK at every point of fixed distance.

We set the transmission distance to 100 m, the carrier frequencies of FSK are 1 MHz and 2 MHz, the incident angle varies from 0 degree to 60 degree. And we can learn that all of the modulation methods could not demodulate correctly when the angle is larger than 15 degree. Among these three methods, DPSK performs best. (**Figure 5**)

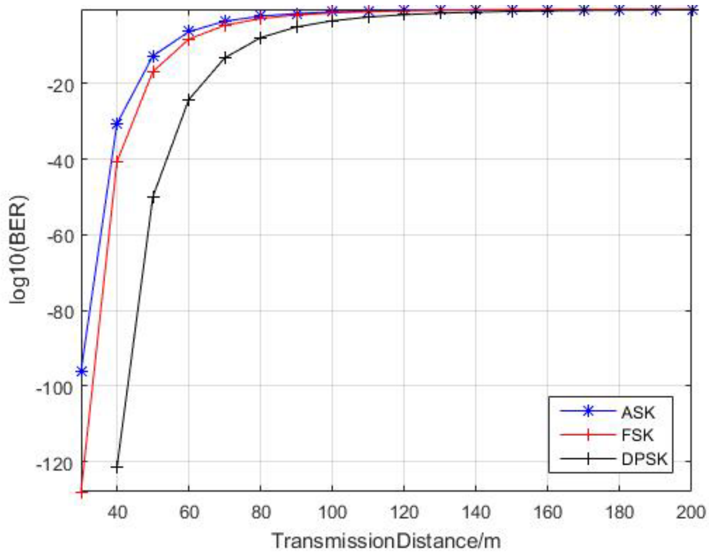

Figure 4. BER vs. distance.

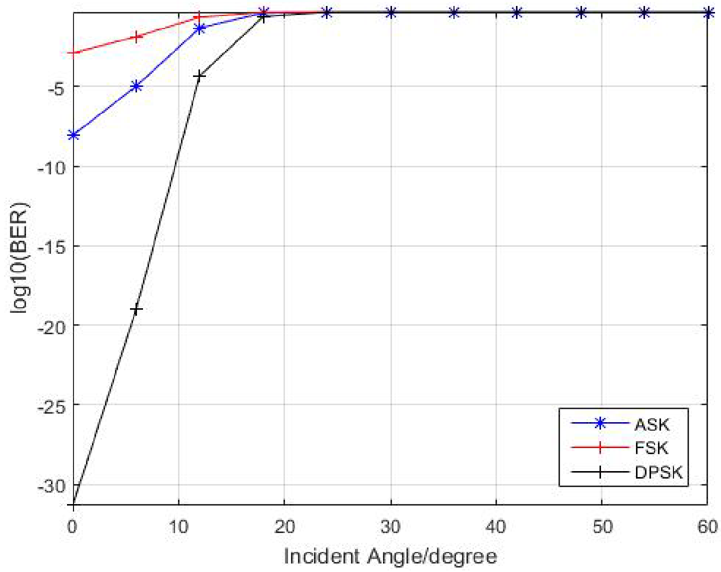

Figure 5. BER vs. incident angle.

4. Conclusion

In this paper, we have done some analyses to the LOS VLC transmission system and compared the noncoherent detection performance of ASK, FSK and DPSK according to different data rate, transmission distance and incident angle. DPSK always performs best, and FSK can beat ASK when the ratio of data rate to carrier frequencies difference is large.

Acknowledgements

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