Bit error rate calculation model and performance analysis under different atmospheric conditions in laser communication system

HANSHAN LI*, SANGSANG CHEN
School of Electronic and Information Engineering, Xi'an Technological University, Xi'an, 710021, China

In the atmosphere, the channel characteristics of the laser communication system will be influenced by the atmospheric attenuation and turbulence, which restricts the transmission performance of the laser communication information; to scientifically design the laser communication link and improve the reliability of laser communication, based on the principle of laser communication, this paper gives the laser communication model under different atmospheric conditions, analyzes the atmospheric channel characteristics of laser communication system under the conditions without turbulence and with turbulence; derives the mean values and variances of output voltage under corresponding channels, according to the definition of bit error rate (BER) in laser communication system, establishes the BER calculation model of laser communication system under various atmosphere conditions and discusses the effects of different correlation factors on the system BER. Through the calculation and analysis, it can be shown that the BER of the laser communication system decreases with increasing the threshold voltage and the power of laser, when the intensity of laser probability tends to normal distribution, the system BER will remain constant and the reliability of data transmission will achieve the optimal value.

(Received July 21, 2018; accepted November 29, 2018)

Keywords: Atmospheric channel, Laser communication, Bit error rate, Atmospheric turbulence

1. Introduction

Atmospheric laser communication system is based on the atmospheric channel, which is random channel, so it is necessary to fully understand and grasp the characteristics of atmospheric channel, and then excellently estimate and forecast the system transmission performance. Compared with other means of communication, in the quality, the interference of atmospheric channel is more serious, when the atmospheric laser is transmitted in remote distance, because the received laser brightness and coherence will be weakened, the laser beam will lead to jitter and divergence, the superiority of laser transmission has thus been greatly weakened [1]. Therefore, in order to give full play to the advantages of laser transmission, it is essential to first understand the influence of atmospheric channel on laser communication.

Because the laser transfers in the atmosphere, in addition to the atmospheric channel attenuation induced by aerosol, the atmospheric turbulence also have an important impact on the channel. The most important characteristic of the atmosphere is that it is usually in turbulent motion [2]. The random change of atmospheric micro temperature caused by human activities and solar radiation will lead to the random change of atmospheric wind velocity, thus forming the atmospheric turbulent motion. The cumulative of these random changes will generate obvious outline inhomogeneity of atmospheric refractive, which will cause a series of atmospheric turbulence, such as the beam jitter, intensity fluctuation, beam spreading [3]. The flash of beam intensity of laser caused by turbulence reduces the signal to noise ratio and increases BER, which seriously affect the quality of communication, even cause communication failure, so it is necessary to study the effects of atmospheric turbulence.

In this paper, according to the laser communication system model under different atmosphere channels, we derive the expressions of mean and variance of output voltage value under atmospheric attenuation and turbulence conditions by using the basic principle of communication, estimate a complete BER model under different atmospheric channels in laser communication system. By the calculation and analysis of BER model, we get some influences of some factors on BER model, these factors include the emission power of laser, the threshold voltage, the scintillation index, the beam intensity of laser, the atmospheric structure constant of refractive index and the transmission distance. Combining with the trajectory tracking system and tracking platform, we obtain the change rules of laser communication BER under the analysis of the different power of laser, the transmission distance and the velocity of target.

2. Laser communication system

2.1. The laser communication model under different atmospheric conditions

The detection mode of free space optical communications system (FSOCS) can be divided into direct detection system and coherent detection system [4].

The most commonly used digital strength modulation method in direct detection system is on-off keying modulation (OOK), whose symbol detection method is usually threshold detection, that is, when the output of detector is higher than the threshold, the timeslot is considered to be the "1" bit, otherwise it is considered to be the "0" bit [5].

In the FSOCS, after being transmitted by the atmospheric turbulence channel, the signal of laser first focuses on the photoelectric detector by the receiving antenna, then the electrical signal is generated through photoelectric conversion and amplification, and finally the electrical signal is judged by the threshold. In essence, the system error performance depends mainly on the signal to noise ratio. Because of the influence of atmospheric turbulence, not only the signal intensity of the system will generates random fluctuations, but also introduces additional noise to the system, which eventually leads to the error data extracted from the threshold decision.

Because the data transmission rate of laser communication is usually achieved Mbps and Gbps magnitude, and the disturbance frequency of atmospheric turbulence is about kHz magnitude, so it can be thought that the level of received beam intensity of laser is independent and stable in each bit slot, if only considering the influence of atmospheric attenuation and atmospheric turbulence, the real-time received power of laser of the FSOCS can be expressed as formula (1).

$$P = I_S M X P_s + P_b \tag{1}$$

In (1), P_s is the average laser power received by detector, P_b is the background light power, M is the atmospheric attenuation coefficient, which is specified in km^{-1}. X is the modulation signal, when the system sends "1" bit, which shows $X=1$; if the system sends "0"bits, which expresses $X=0$. I_S is the intensity scintillation random modulation function, whose the probability distribution is the same as the probability distribution of the normalized light intensity, so $I_S=1$ under the condition of no turbulence influence.

2.2. The atmospheric channel characteristic of laser communication system under the condition without turbulence

When the laser transfers in the atmosphere, the energy attenuation mainly comes from the absorption and scattering of atmospheric molecules and aerosol particles. The atmospheric attenuation coefficient consists of four parts, the absorption coefficient of atmospheric molecules, the absorption coefficient of aerosol particles, the scattering coefficient of gas molecules, and the scattering coefficient of aerosol particles. In the design of laser communication system, as long as the choice of the working wavelength falls within the communication window, the power attenuation caused by atmospheric absorption can be neglected, it can be regarded that atmospheric molecular absorption coefficient is approximated to zero; in addition, because the Rayleigh scattering coefficient is inversely proportional to the biquadrate of wavelength, the Rayleigh scattering coefficient is very small in near infrared band, the gas molecular scattering coefficient can be neglected; the absorption of energy of laser by aerosol is very little, and the absorption coefficient of aerosol particles is negligible. In the horizon transmission of laser, the dominant attenuation of low-level is only Mie scattering [6]. Because the visibility is the macroscopic expression of atmospheric aerosol concentration, based on the empirical formula related to visibility, the atmospheric attenuation coefficient can be expressed by formula (2).

$$M = \frac{3.91}{v}\left(\frac{\lambda}{550}\right)^{-q} \tag{2}$$

In (2), v is the atmospheric visibility, which is specified in km; λ is the communication wavelength of laser, which is specified in nm; q is the wavelength correction factor, which is related to the size and visibility of particles in the atmosphere. When neglecting the atmospheric absorption and Rayleigh scattering, the attenuation coefficient of the laser in the atmospheric channel can be calculated by the empirical formula as follows:

$$q = \begin{cases} 0, & v < 0.5km \\ v - 0.5, & 0.5km < v < 1km \\ 0.16v + 0.34, & 1km < v < 6km \\ 1.3, & 6km < v < 50km \\ 1.6, & v > 50km \end{cases} \tag{3}$$

According to formula (3), the relationship between atmospheric attenuation coefficient and atmospheric visibility under different working wavelengths of laser is given as Fig. 1.

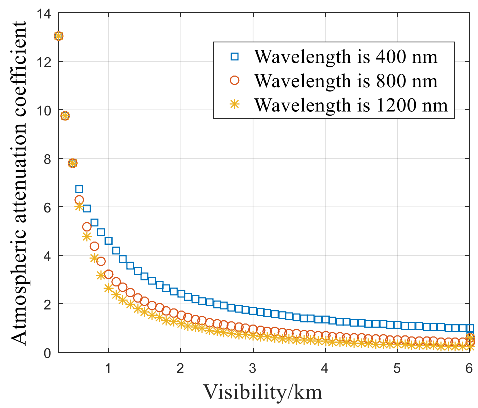

Fig. 1. The relationship between atmospheric attenuation coefficient and visibility under different working wavelengths of laser

Combining formula (3) and Fig. 1, it can be deduced that when the wavelength of laser is a constant, the atmospheric attenuation coefficient is inversely proportional to the atmospheric visibility; when the atmospheric visibility is a constant, the attenuation coefficient increases negative exponentially with the wavelength of laser.

From the results of Fig. 1, with increment of atmospheric visibility, atmospheric attenuation coefficient will decrease. When the atmospheric visibility is constant, the wavelength of laser is bigger; the atmospheric attenuation coefficient is smaller. At the same time, when the transmission distance is constant, the velocity of target is bigger, the system BER is higher. Therefore, in the data transmission of ballistic target tracking system, in order to improve the stability of the target tracking, we select the wavelength of laser according to the characteristics of target and the atmospheric conditions.

2.3. Atmospheric characteristics of laser communication system under considering with turbulence

In the FSOCS, the intensity scintillation is one of the most important turbulence effects. It can cause the random fluctuation of the output current of the receiver, thus increasing the detection noise of the system. When atmospheric turbulence is strong, the scintillation noise may causes sudden communication errors and even interrupts communication [7]. When the internal and external scale effects are neglected, the scintillation index of Gauss beam is written as formula (4).

$$\sigma_t^{\,2} = \exp\left[\frac{0.49\sigma_r^{\,2}}{(1+1.12\sigma_r^{\,12/5})^{7/6}} + \frac{0.51\sigma_r^{\,2}}{(1+0.69\sigma_r^{\,12/5})^{5/6}}\right] - 1 \tag{4}$$

In (4), $\sigma_r^{\,2} = 1.23 C_n^2 K^{7/6} L^{11/6}$, which expresses the Rytov variance, K is the wave number, L is the transmission distance, C_n^2 is refractive-index structure constant of atmosphere. Fig. 2 indicates the relationship between the scintillation index and the Rytov variance. When the Rytov variance is equal to 1, the scintillation index reaches the maximum value.

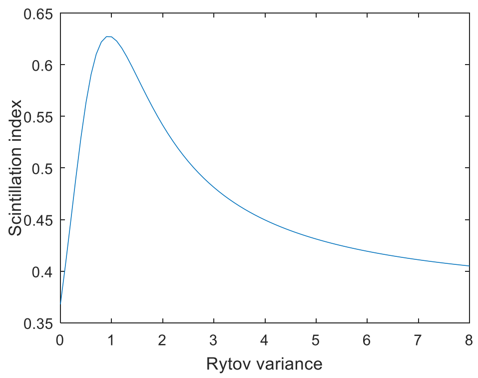

Fig. 2. The relationship between scintillation index and Rytov variance

In addition to the scintillation index, the probability distribution of intensity of laser is also an important description method of its statistical characteristics. Due to small scale fluctuations are modulated by large scale fluctuations, based on this assumption, we can obtain the Gamma-Gamma distribution model applied to the from weak to strong fluctuation region, the probability density distribution of normalized intensity of laser can be showed as formula (5).

$$p(I_S) = \frac{2(\alpha\beta)^{(\alpha+\beta)/2} I_S^{\,(\alpha+\beta-2)/2} K_{\alpha-\beta}(2\sqrt{\alpha\beta I_S})}{\Gamma(\alpha)\Gamma(\beta)} \tag{5}$$

In (5), I_S is the intensity modulation function of laser, $K_{\alpha-\beta}(\cdot)$ is the dual modified Bessel function, $\Gamma(\cdot)$ is the Gamma function. When the transmitted light wave is a plane wave, α, β are respectively expressed as formula (6).

$$\begin{cases} \alpha = \left[\exp\left(\dfrac{0.49\sigma_r^{\,2}}{(1+1.12\sigma_r^{\,12/5})^{7/6}}\right) - 1\right]^{-1} \\ \beta = \left[\exp\left(\dfrac{0.51\sigma_r^{\,2}}{(1+0.69\sigma_r^{\,12/5})^{5/6}}\right) - 1\right]^{-1} \end{cases} \tag{6}$$

If we use the skewness to describe the asymmetry of probability distribution for mean, use the kurtosis to describe the concentration degree of probability distribution for the normal distribution, combining (5) and (6), it can be showed that the similarity of the practical intensity probability distribution and the lognormal distribution can be describe by skewness and kurtosis.

The absolute value of skewness and kurtosis are smaller, the practical probability distribution and the normal distribution are closer, the deviation between calculated results and the measured results are smaller; when the skewness is a negative, the probability of the measured laser beam intensity lower than the threshold is greater than the normal distribution, obviously the measured leakage alarm probability also is greater than distribution calculation results.

3. The new bit error rate model of laser communication system

In the atmosphere, laser transmission mainly affected by the atmospheric attenuation and atmospheric turbulence, In order to make the research universal and practical, we establish the bit error model considering the influences of both atmospheric attenuation and atmospheric turbulence, and use laser Gauss beam by taking into account the practical communication system.

3.1. The parameters of bit error rate model

The output noise of detector mainly includes shot noise and background noise. Since the laser system ultimately needs to judge the voltage threshold, it is necessary to convert the current signal into voltage signal through the subsequent amplifier circuit [8]. The output voltage signal can still be considered as a Gauss random variable.

Assuming that the receiver of laser is photodiode type, since the electrons randomly produced by thermal excitation can cause some fluctuations, which result in the formation of shot noise [9], and the voltage variance of shot noise can be written by formula (7).

$$\sigma_{SN}^2 = 2eBGi_s R_f{}^2 = 2eBGP_s R_i R_f{}^2 \tag{7}$$

In (7), R_f is the load impedance, B is the bandwidth of the filter, G is the circuit amplification, e is electronic charge, i_s is the average signal current, here, $i_s = P_s R_i = \eta e \lambda P_s/(hc)$, R_i is characterizes the sensitivity of the detector, η is the quantum efficiency of the detector, h is the Plank constant, c is the velocity of light, P_s is the power of laser. Similarly, the voltage variance of background noise can be showed by formula (8).

$$\sigma_{BN}^2 = 2eBGP_b R_i R_f{}^2 \tag{8}$$

In (8), P_b is the background radiant power. According to the formula (1), when $I_S = 1$ and $X = 0$, in other words, if the system sends "0"bits and without having to consider the influence of atmospheric turbulence, the real-time received power of laser is express as $P_s = P_b$, so the mean and variance of the output voltage are indicated as follows.

$$U_0 = P_b R_i R_f \tag{9}$$

$$\sigma_0^2 = \sigma_{BN}^2 = 2eBGP_b R_i R_f{}^2 \tag{10}$$

In (9) and (10), U_0 and σ_0^2 are respectively the mean and variance of the output voltage when $I_S = 1$ and $X = 0$. Similarly, if $I_S = 1$ and $X = 1$, the real-time received power of laser by system is express as $P_s M + P_b$, the mean and variance of the output voltage are written by formula (11) and (12).

$$U_1 = (P_s M + P_b) R_i R_f \tag{11}$$

$$\sigma_1^2 = \sigma_{SN}^2 + \sigma_{BN}^2 = 2eBG(P_s M + P_b) R_i R_f{}^2 \tag{12}$$

In (11) and (12), U_1 and σ_1^2 are respectively the mean and variance of the output voltage when $I_S = 1$ and $X = 1$.

3.2. The bit error rate model without considering the influence of turbulence

In the FSOCS, the method of demodulating signal is the threshold detection. The output voltage of the detector includes the signal voltage and the noise voltage, after sampling and the receiver compares it with the threshold [10]. If the sampling value is greater than the threshold, it is considered to be "1" bit; if the sampling value is less than the decision threshold, it is considered to be "0" bit. Due to the noise interference, the system will produce two kinds of bit error: when we send "0" bit, the sum of signal voltage and noise voltage is less than the threshold, that is mistaken for "1" bit, this is called false alarm; if we send "1" bit, the noise voltage and signal voltage could cancel out, that is mistaken for "0" bit, this is called miss detection [11]. The bit error rate refers to the probability of receiving bits are misjudged, which includes the false alarm probability and miss detection probability [12]. Without considering the influence of atmospheric turbulence, it can be thought that the system obeys the Gauss random process, we use U_T to express the threshold, the distributions of the false alarm probability and miss detection probability can be shown as Fig. 3.

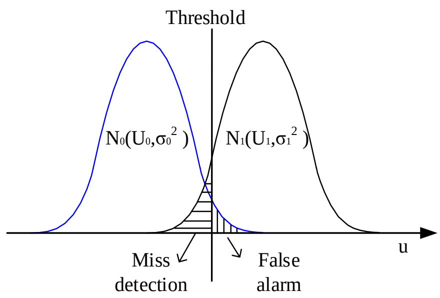

Fig. 3. The distributions of false alarm probability and miss detection probability

In Fig. 3, "0" bit curve and "1" bit curve obey normal distribution with mean values U_0 and U_1, and variances σ_0^2 and σ_1^2, respectively. From Fig. 3, we can observe that the threshold is bigger, the false alarm probability is smaller, the miss detection probability is higher; on the contrary, the false alarm probability is bigger, the miss detection probability is lower. In the target tracking system, we set the threshold based on the required false alarm probability and miss detection probability of the laser communication system, and make the bit error rate low. So according to Fig. 1, the false alarm probability and miss detection probability can be expressed as

$$P_f(u > U_T) = \int_{U_T}^{\infty} \frac{1}{\sqrt{2\pi\sigma_0^2}} \exp\left[-\frac{(u-U_0)^2}{2\sigma_0^2}\right] du = \frac{1}{2} erfc\left(\frac{U_T - U_0}{\sqrt{2\sigma_0^2}}\right) \tag{13}$$

$$P_m(u < U_T) = \int_{-\infty}^{U_T} \frac{1}{\sqrt{2\pi\sigma_1^2}} \exp\left[-\frac{(u-U_1)^2}{2\sigma_1^2}\right] du = \frac{1}{2} erfc\left(\frac{U_1 - U_T}{\sqrt{2\sigma_1^2}}\right) \tag{14}$$

In (13) and (14), $erfc(\cdot)$ is the complementary error function, where, $erfc(z)=\frac{2}{\sqrt{\pi}}\int_z^{\infty}\exp(-t^2)dt$. when the atmospheric turbulence is not taken into account, we assume the "0" and "1" bits are equal probability transmitting, so the total bit error rate (BER_{total})of the system can be deduced by formula (15).

$$BER_{total}=\frac{1}{2}P_f+\frac{1}{2}P_m=\frac{1}{4}erfc\left(\frac{U_T-U_0}{\sqrt{2\sigma_0^2}}\right)+\frac{1}{4}erfc\left(\frac{U_1-U_T}{\sqrt{2\sigma_1^2}}\right)$$
$$=\frac{1}{4}erfc\left(\frac{U_T-P_bR_iR_f}{2\sqrt{eBGP_bR_iR_f^{\,2}}}\right)+\frac{1}{4}erfc\left(\frac{(P_sM+P_b)R_iR_f-U_T}{2\sqrt{eBG(P_sM+P_b)R_iR_f^{\,2}}}\right) \tag{15}$$

3.3. The bit error rate model with considering the influence of turbulence

Under the influence of atmospheric turbulence, the power of laser and received intensity by the detector will produce random fluctuations, which not only affect the mean value of the signal voltage, but also make the noise variance change [13]. When system sends "0" bit, because the signal power is equals to 0, the fluctuations of intensity of laser can be ignored, then the output voltage variance $\sigma_0^{'2}=\sigma_0^{\,2}$; When system sends "1" bit, the fluctuation of intensity of laser not only modulate received power of laser, but also introduces additional flicker noise to system, therefore the mean and variance of output voltage can be indicated by formula (16) and (17).

$$U_1^{'}=(P_sI_SM+P_b)R_iR_f \tag{16}$$

$$\sigma_1^{'2}=\sigma_1^{\,2}+P_sMR_i\sigma_t^{\,2} \tag{17}$$

Due to the atmospheric disturbance frequency is far less than the rate of data transmission, bit error rate between each bits can be regarded as statistically independent, which can be considered as the conditional probability about I_S, so combining formula (5), (16) and (17), we obtain the BER calculation function of laser communication system as formula (18).

$$BER=\frac{1}{4}erfc\left(\frac{U_T-U_0}{\sqrt{2\sigma_0^{'2}}}\right)+\int_0^{\infty}\frac{1}{4}erfc\left(\frac{U_1^{'}-U_T}{\sqrt{2\sigma_1^{'2}}}\right)P(I_S)dI_S$$
$$=\frac{1}{4}erfc\left(\frac{U_T-P_bR_iR_f}{2\sqrt{eBGP_bRR_f^{\,2}}}\right)$$
$$+\int_0^{\infty}\frac{1}{4}erfc\left(\frac{(P_sI_SM+P_b)R_iR_f-U_T}{\sqrt{4eBG(P_sI_SM+P_b)R_iR_f^{\,2}+P_sI_SR_i\sigma_t^{\,2}}}\right)P(I_S)dI_S \tag{18}$$

According to (18), it can be shown that the BER of laser communication system will be affected by some factors which mainly include power of laser, the threshold voltage, the scintillation index, the intensity of laser, the structure constant of atmospheric refractive index and the transmission distance. In order to effectively improve the data transmission efficiency and reduce the bit error rate, we try to change these factors for obtaining the minimum BER under a certain transmission distance. Based on the target tracking platform, to enhance the system detection rate, such measures can be taken as improving the power of laser, changing the threshold voltage, which can reduce the bit error rate of the system in a targeted way, and then correctly make better the performance of laser communication system.

4. Calculation and testing analysis

4.1. Calculations and discussions

According to the BER calculation model of the laser communication system, it can be known that the bit error rate of laser transmission system is affected by multiple factors. In order to effectively verify the feasibility of the BER model, we make some qualitative calculation analysis. Assume that $P_b=2\times10^{-4}W$, $B=1GHZ$, $R_f=1K\Omega$, $G=2\times10^3V/A$, $R_i=0.9$, the power of laser is 30mW, 50mW and 90 mW respectively. According to formula (15), without considering the influence of atmospheric turbulence, the relation of the system BER and the threshold voltage and the power of laser is shown in Fig. 4.

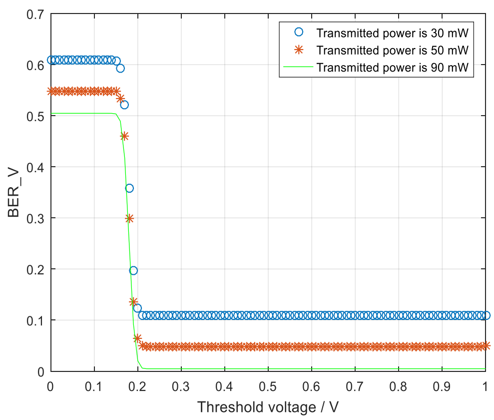

Fig. 4. The relation of the system BER and the threshold voltage and the power of laser without considering the influence of atmospheric turbulence

According to Fig. 4, it can be obtained that without considering the effect of atmospheric turbulence, the threshold voltage increases, the system BER becomes smaller. When the threshold voltage is less than 0.2V, the system BER is more than 0.5; when the threshold voltage is greater than 0.2V, the system BER is not only less than 0.12, but relatively keep stable, which reflects the change of threshold voltage can improve effectively the communication performance. In addition to the threshold voltage, the power of laser also has a certain impact on the system BER performance. From Fig. 4, it can be indicated that with the power of laser increases, the system BER decreases, under the condition of same threshold voltage, when the difference of the power of laser is 60*mW*, the BER of system differs 0.1; but when the threshold the voltage is greater than 0.2*V* and the power of laser is equal to 90*mW*, the bit error rate is close to zero, now the detection performance of system is best.

Based on the variation results of Fig. 4, the threshold voltage is assumed to be 0.3*V* and the power of laser is 90*mW*, when considering the atmospheric turbulence, the relation of the system BER and the scintillation index and the beam intensity of laser as shown in Fig. 5.

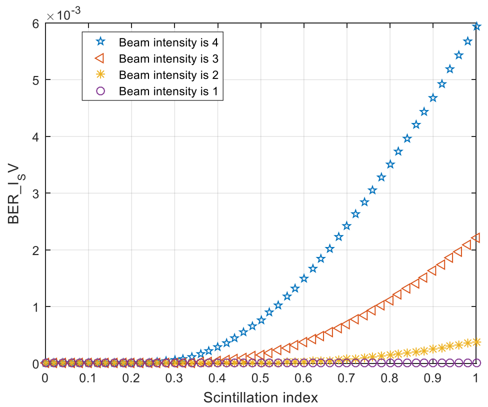

Fig. 5. The relation of the system BER and scintillation index and the beam intensity of laser with considering the influence of atmospheric turbulence

Considering the atmospheric turbulence, when the scintillation index is less than 0.3, the system BER is close to zero, when the scintillation index is greater than 0.3, the change of the system BER is need to fully consider the beam intensity of laser, such as when the scintillation index is equal to 0.8, if the beam intensity of laser is 4, the system BER is 3.5×10^{-3}; if the beam intensity of laser is 3, the system BER is 1.2×10^{-3}, if the beam intensity of laser is 2, the system BER is 0.3×10^{-3}. Thus it can be seen that the beam intensity of laser is smaller, the system BER is smaller, the performance of data transmission system is better. Especially, when the beam intensity of laser is 1, that is the intensity probability tends to normal distribution, the system BER is kept constant, the reliability of data transmission is optimal in the communication system. From Fig. 4 and Fig. 5 can found that the threshold voltage and the power of laser are determined according to the required bit error rate of communication system.

In order to study the influence of atmospheric refraction and the transmission distance on the system BER, we calculate and discuss by combining formula (4) and (18), Fig. 6 shows the influences of the system BER on the transmission distance under various atmospheric refractive index structure constants.

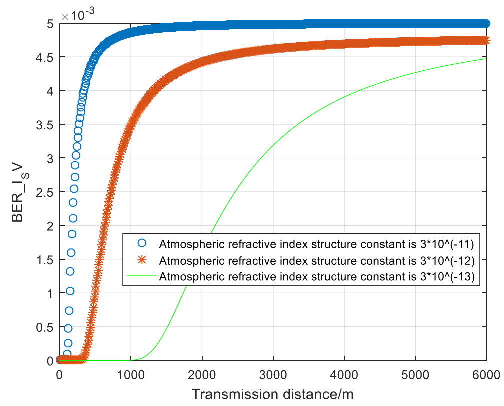

Fig. 6. The relation of the system BER and the transmission distance and atmospheric refractive index structure constant with considering the influence of atmospheric turbulence

According to Fig. 6, we can see the system BER increases rapidly with the increase of transmission distance, and when the transmission distance is a constant, the BER increases rapidly with the increase of the refractive index structure constant. Assume it is necessary to meet the requirement of BER identically equal to 3×10^{-3}, when the atmospheric refractive index structure constant is 3×10^{-13}, the effective communication distance is close to 2.8 Km; with the increase of atmospheric refractive index structure constant, and the effective distance of transmission becomes closer; when the atmospheric refractive index structure constant reaches 3×10^{-11}, the effective transmission distance has been reduced to below 100m, which shows that under a certain distance, it is advantageous to the data transmission efficiency as the atmospheric refractive index structure constant decrease.

4.2. Testing and analysis

Due to the complexity of the practical engineering and the limitation of the theoretical analysis, it is very important to carry out the outdoor laser transmission testing to further analyze the importance of laser transmission characteristics on the FSOCS. In this paper, we design and implement a testing platform combining the ballistic tracking system and laser information communication system to verify and analyze the effectiveness and accuracy of the final BER calculation model of laser communication system. The testing platform is shown in Fig. 7.

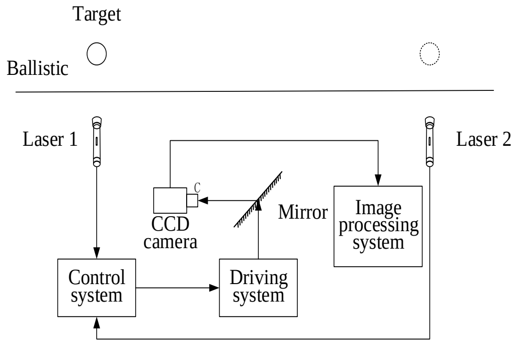

Fig. 7. A testing platform combining the ballistic tracking system and laser information communication system

In Fig. 7, shows, the laser 1 is the starting point, when it detects a signal, the CCD camera and mirror will are triggered to acquire and track the target images; the laser 2 is the ending point, when it detects a signal, the CCD camera will be closed and the target tracking is stopped. To ensure the target can be tracked reliably on a predetermined orbit, it is need to improve the control precision of rotating mirror for making target imaging information can reliable locate in the effective pixel area of CCD camera, which requires the low BER of laser communication system. With the coordination of the rotating mirror control system and laser communication system, it reduces the abrasion of CCD camera in the process of high velocity rotation, overcomes the own defect of small detection viewing field and increases the detection viewing field, which makes the whole tracking becomes more stable, at the same time, it also provides credible data for the subsequent information fusion of target image. Table 1 gives the BER of the laser communication system under the same power of laser and different transmission distances; Table 2 gives the BER of the laser communication system under the same transmission distance and different velocities of target.

Table 1. The BER of the laser communication system under the same power of laser and different transmission distances

laser power/mW	transmission distance/m	BER
90	100	0
90	800	2.5×10^{-2}
90	1000	6×10^{-2}

Table 2. The BER of the laser communication system under the same transmission distance and different velocities of target

transmission distance/m	velocity of target/（m/s）	BER
200	40	0
200	100	2×10^{-3}
200	300	5.4×10^{-3}

In Table 1, when the power of laser is 90*mW*, with the increment of the transmission distance, the BER increases. In Table 2, when the transmission distance is 200*m*, the velocities of target is bigger, the BER is higher. From Table 1 and Table 2, it can be seen that when the power of laser is certain, the changes of transmission distances lead to the changes of the target imaging in the detection photosensitive surface, the transmission distance is closer, the imaging plane is larger, the BER is lower; on the contrary, the BER is higher. This result is basically consistent with the formula (18). When the transmission distance is determined, we increase the power of laser to reduce the BER.

In addition, under the condition of a certain transmission distance, the higher velocity of target has less information of the target imaging in the detection photosensitive surface, the sensitivity of the laser communication becomes lower, which reflects the choice of threshold voltage in the laser communication system, in order to reduce the system BER, we can appropriate adjust the threshold voltage.

The testing and analysis show that under different atmosphere conditions, the BER of the laser communication system is restricted the tracking accuracy of rotating mirror. Based on the theory calculation model, we can improve the system control performance by changing the related parameters of laser communication BER model.

5. Conclusions

This paper establishes a BER calculation model of laser communication system under different atmospheric conditions, analyzes atmospheric channel characteristics of the laser communication system with atmospheric turbulence and without atmospheric turbulence, gives the means and variances of output voltage value for two cases; according to the definition of BER, derives the BER calculation model in laser communication system under different atmospheric conditions. Theoretical analysis and practical testing results show that the change regulations of system BER is affected by these factors which mainly include with the power of laser, the threshold voltage, the scintillation index, the intensity of laser, the atmospheric structure constant of refractive index and the transmission distance, which is not only conducive to the simulation researches of the BER of laser communication system, but also provide some references for engineering design evaluation.

Acknowledgements

This work has been supported by Project of the National Natural Science Foundation of China (No. 61773305) and the Key Programs of Shaanxi science and Technology Department (No.2017GY-037). The Program for Innovative Science and Research Team of Xi'an Technological University.

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*Corresponding author: lihanshan269@163.com