Journal of Physics: Conference Series

Research on laser Link performance of UAV-based platform based on reverse modulation

Research on laser Link performance of UAV-based platform based on reverse modulation

Bo Yang[1], Guoce Huang[2], Yequn Wang[2] and Guisheng Wang[1]

[1]Graduate school, Air Force Engineering University, Xi'an, Shannxi, 710051, China

[2]Information and Navigation school, Air Force Engineering University, Xi'an, Shannxi, 710051, China

[*]Corresponding author's e-mail: rzhang_17@stu.xidian.edu.cn

Abstract. In order to solve the problem of UAV-based optical communication under the constraints of low load, high transmission rate and low bit error rate, this paper studies the alternative scheme and the possibility of optical communication system based on reverse modulation. Based on the study of atmospheric effect, alignment error, and reverse modulator performance, the light intensity propagation model is constructed. Through MATLAB simulation, it is found that under weak turbulence, the link communication distance can reach 7-12km.Good communication effect when turbulence intensity is below 0.4; Increasing the receiver size can improve the communication chain performance effectively.

1. Introduction

Free Space Optical communication [1] (Free Space Optical, FSO) is a hot problem in the Optical communication system in recent years, with the further study in the field of Optical communication, airborne communications platform as an important node of Optical communication network become a consensus, in view of the airborne platform is small volume, less weight, flexible movement, jitter stronger and other characteristics, there are different solutions. At the same time, the development of UAV airborne platform is mature, as a communication node is also more and more extensive. Compared with ordinary optical communication, airborne platform is more unstable, emitting and receiving laser beam has larger atmospheric attenuation effect, turbulence effect and greater jitter error.

Laser communication link system based on reverse-modulation is just for the consideration of load and power, using reverse-modulated Reflector [2] (MRR) to replace the transmitting and receiving system of receiving terminal, so that it reduces system complexity, reduces power consumption and weight, and can be used in scenarios such as satellites, onboard platforms, etc.

Reverse modulation is one of the key technologies in optical communication. The RESEARCH on MRR FSO technology in the United States started early. In 1996, Utah State University and Phillips Laboratory jointly carried out the high-altitude balloon semi-duplex MRR test to earth, with the communication distance and speed of 31km and 20KB /s, respectively [3]. NRL tested the Trident Warrior2008 surface to build ship-to-ship MRR links using the dual-mode Light Launch System (DMOI) and MRR modules, which proved the feasibility of applying them to navy ships [4].

2. Airborne platform MRR FSO optical link propagation model

Using the current 1550nm laser emitter with mature technology, the link is divided into two terminals (interrogation terminal and reverse modulation terminal), equipped with a transmitter and a receiver.

Journal of Physics: Conference Series **1738** (2021) 012039 doi:10.1088/1742-6596/1738/1/012039

The retrograde modulation end is equipped with a "cat eye" reverse modulator. Due to the principle of optical reflection, when the transmitter is on time, the light is reflected and then the communication is carried out, which saves the complex tracking and sighting system.

When information is uploaded, the transmitter transmits the light wave that loads the information, and the reverse modulator demodulates the information. When the information is transmitted downward, the beam containing no information is transmitted by the transmitter, which is verified after receiving by the reverse modulator, and the transmitted information is added, and then reversely transmitted back to the receiver to complete the down transmission of the information.

3. Analysis of light intensity propagation model

3.1. Laser field intensity distribution

According to the Principle of Huygens-Fresnel, the laser field intensity distribution of the semiconductor laser has obvious regularity. It is assumed that when the distance is 0, it is the beam waist of the laser beam, and it is perpendicular to the receiving plane of the propagation direction. Therefore, the light intensity of any point received on the receiver can be expressed as:

$$I(r,z) = I_0 \left(\frac{w_0}{w(z)} \right)^2 \exp\left(\frac{2r^2}{w^2(z)} \right) \tag{1}$$

$$E(I) = E[I_{beam} \exp(2X - E(X))] = I_{beam} \exp(-2\sigma_R^2) \tag{2}$$

$I(r,z)$ denotes the distance from the transmitter is z, the distance from the center of the circle is r; I_0 represents the intensity of light at the center of the beam at a distance of 0; w_0 denotes the beam waist of the beam at point 0; $w(z)$ is the beam waist of the beam at the distance.

3.2. Models under turbulent flow conditions

The lognormal model is only applicable to the case of weak turbulence. When the turbulence intensity is low, the light intensity distribution tends to gaussian distribution. However, with the increase of turbulence intensity, the phenomenon of trailing tail and the weakening of light intensity will occur.

$$f(I) = \frac{1}{I\sqrt{2\pi\sigma_R^2}} \exp\left(-\frac{\left(\ln I + \sigma_R^2/2\right)^2}{2\sigma_R^2} \right) \tag{3}$$

σ_R^2 is the variance of logarithmic fluctuation; $I = A / A_0$, A is the light intensity received by the receiving end, A_0 is the light intensity emitted by the transmitting.

3.3. A transmission model of reflected light

According to existing studies, part of diffuse light and diffracted light are also received at the receiving end. However, six beams of reflected light play a major role in receiving light intensity. Considering the transmission model of reflected light, the light intensity expression of CCR reflected light can be obtained as follows:

$$I_{fs}(r,z) = \mu \frac{2P_r}{\pi w^2(z)} \exp\left(-\frac{2r^2}{w^2(z)} \right) \left[\exp\left(-2\left(\frac{\chi(z)}{w(z)} \right)^2 \right) \psi\left(\frac{4r\chi(z)}{w^2(z)} \right) + \frac{2P_r}{\pi w_0^2} \right] \tag{4}$$

μ is the reflection efficiency of CCR; P_r is the total power received by CCR; $\chi(z)$ is the divergence distance of CCR.

3.4. Field intensity reception model

In this paper, a Gaussian beam is adopted, and its beam waist means that the radius of its waist spot is always greater than a minimum value in the direction of the optical axis. The propagation of Gaussian beam in space satisfies the following relation:

$$w_z = w_0\left(1+\varepsilon\left(\frac{\lambda z}{\pi w_0^2}\right)^2\right)^{\frac{1}{2}} \tag{5}$$

z is the propagation distance, w_0 is the girdle waist of the spot when distance z is 0, and $\varepsilon = (1+2w_0^2/\rho_0^2(z))$, $\rho_0(z) = \left(0.55C_n^2k^2z\right)^{-\frac{3}{5}}$ is the coherence length.

Assuming that the radius of the reverse detector is a and the aiming error is r. Then the received optical power can be expressed as:

$$h_p(r,z) = \iint_A I(\rho - r, z)d\rho \tag{6}$$

Integrate the above equation,

$$h_p(r,z) \approx A_0 \exp\left(-\frac{2r^2}{w_{zeq}^2}\right) \tag{7}$$

$A_0 = \left[erf(v)\right]^2$, $v = \left(\sqrt{\pi}a\right)/\left(\sqrt{2}w_z\right)$, $w_{zeq}^2 = \dfrac{2w_z^2A_0}{\sqrt{\pi}erf(v)\left[v\exp\left(-v^2\right)\right]}$, w_{zeq} is the equivalent beam radius of the receiving end.

The expression of the light intensity of the receiver:

$$I_{sr}(r,z) = \mu\frac{2P_r}{\pi w^2(z)}\exp\left(-\frac{2r^2}{w^2(z)}\right)\left[\exp\left(-2\left(\frac{\chi(z)}{w(z)}\right)^2\right)\psi\left(\frac{4r\chi(z)}{w^2(z)}\right)+\frac{2P_r}{\pi w_0^2}\right]$$
$$\exp(-2\sigma_R^2)A_0\exp\left(-\frac{2r^2}{w_{zeq}^2}\right) \tag{8}$$

4. Link performance simulation

The mathematical tool MATLAB is used for the numerical simulation of MRR FSO link. According to the communication requirements, the performance of the link is comprehensively analyzed from the change of optical intensity at the receiving end. The performance of the communication link under different influencing factors is discussed respectively, and the corresponding optimal solution is given theoretically to guide the engineering practice and application.

4.1. Different communication distances

When the communication distance is increasing, the optical intensity distribution radius of the receiver is increasing, and the optical intensity amplitude is decreasing.

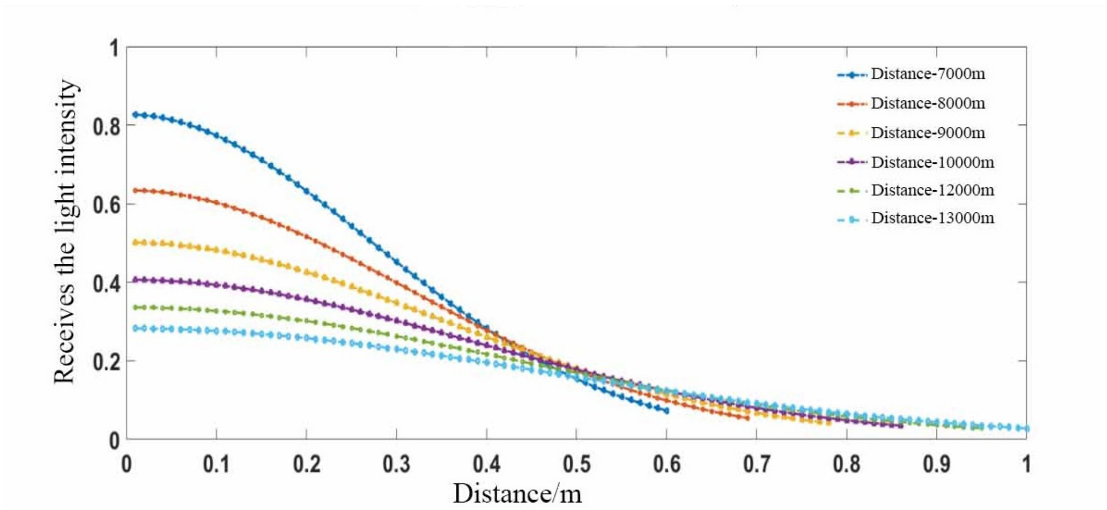

Figure 1. The relationship between communication distance and receiving light intensity

4.2. Different turbulence intensities

The range data used in the simulation was 6km and the reflection error of the reversely adjusted reflector was 0.001rad. With the change of turbulence intensity, the distribution of light intensity is basically stable, mainly distributed within 0.5m from the center. Meanwhile, the intensity at the center of light intensity varies greatly, and the farther the distance is, the smaller the turbulence intensity changes.

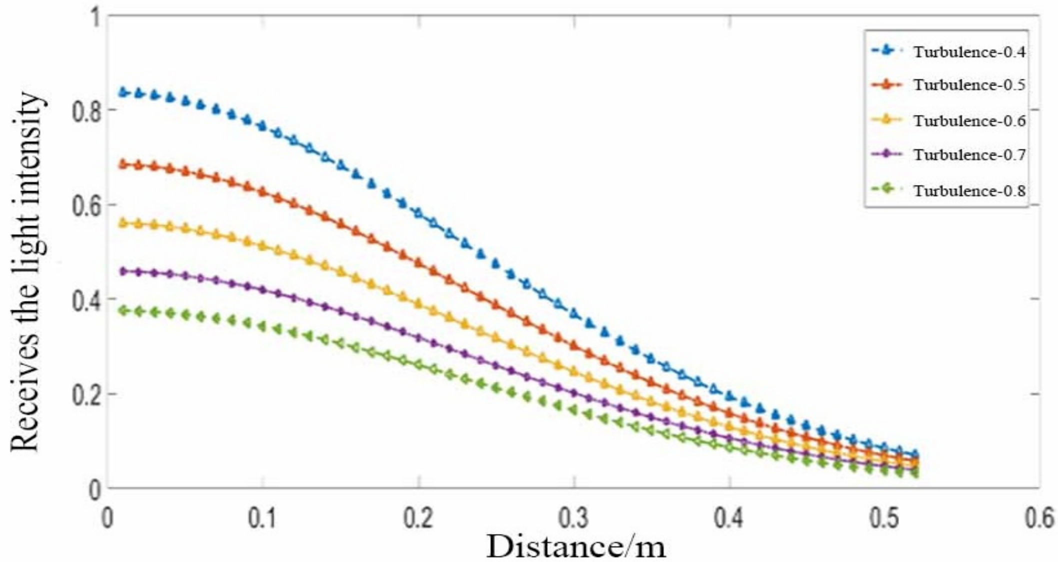

Figure 2. Relationship between turbulence intensity and receiving light intensity Different receiver radii

5. Conclusion

Through the establishment of the reverse-modulation communication link model and the numerical simulation of the closed expression using MATLAB, it can be known that the optical intensity receiving effect can be improved by increasing the radius of the receiving end, and in the case of turbulence, the size of the receiving end radius should be greater than 50mm.

References

[1] Chen, S., Zhang, Z., Cai, S.(2018)High power budget coherent free space optical communication system based on fiber laser phased array.In:2018 Asia Communications and Photonics Conference (ACP).Hangzhou. pp. 1-3.
[2] Ding,D,Q., Ke X,Z.(2010) Performance of asymmetric response reflection free space optical communication link .J. Journal of Applied Science,.pp. 337-341.
[3] Zeng Z.L., Huang,H.Y. (2017)Research progress of inverse modulation spatial laser communication technology .J. Optical communication technology.pp.16-19.
[4] Qiu,H., Wang,J.Y.(2015) Reverse modulation optical communication technology .J. Military communication technology.pp.29-33.