The Influence of Different Phase Function Combinations on Communication Quality in NLOS Communication Model

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Abstract:- Wireless ultraviolet communication is a new type of communication technology, which uses the atmosphere as the transmission medium, and uses the scattering effect of atmospheric molecules and aerosol particles to change the propagation direction of the optical signal carrying information, bypass the blocking obstacles and finally reach the receiving end. The study of the scattering characteristics of ultraviolet light requires the use of scattering phase function. The scattering phase function is the ratio of the scattering energy in the unit solid angle in a specific direction to the average scattering energy in all directions. The scattering of ultraviolet light by the atmosphere is usually divided into two cases : Rayleigh scattering and Mie scattering. Therefore, the scattering phase function is also divided into two cases : Rayleigh scattering phase function and Mie scattering phase function. The scattering phase function in this paper is obtained by the weighted average of the two. There are many empirical formulas for Rayleigh scattering phase function and Mie scattering phase function. In this paper, the ultraviolet light of 266 nm wavelength is taken as an example to simulate and analyze the variation trend of scattering coefficient with wavelength and visibility, and the influence of the combination of different scattering phase functions on the received light power per unit area in the process of ultraviolet atmospheric transmission.

Keywords:- *Free-Space Optical; Scattering Phase Function; Matlab Simulation; Ultraviolet Light; NLOS*

I. INTRODUCTION

Compared with other communication methods, there are many advantages of wireless UV communication, such as the wireless ultraviolet communication has low bit resolution and eavesdropping rate. Ultraviolet light is invisible light, and it is impossible to directly detect the presence of ultraviolet light source by the naked eye. Ultraviolet light propagates signals in all directions through atmospheric scattering, so it is difficult to find out the location of the ultraviolet light source from the scattering signal. Due to the absorption of atmospheric molecules and suspended particles, the intensity of ultraviolet light signal decays exponentially. This intensity attenuation is a function of distance. Therefore, the transmission power of the system can be adjusted according to the requirements of the communication distance, so that the signal outside the transmission range is difficult to be received, and the enemy is difficult to intercept[1]. Then, wireless ultraviolet communication has the advantage of no need to aim and track. Wireless ultraviolet light transmits information through scattering. The transmitter transmits the signal at a certain angle, and the receiving end receives the signal at a certain angle. The transmitter and the receiver will form a common area in space called an effective scatterer. The signal reaches the receiving end after scattering by the effective scatterer. Therefore, as long as the receiving end is within the coverage of the transmitting end, the receiving end can receive the wireless ultraviolet signal. Finally, wireless ultraviolet communication can realize NLOS communication. The collision of ultraviolet signal particles with atmospheric molecules and aerosol particles causes the ultraviolet signal to change the transmission direction, scatter around, and some signals reach the receiving end. Because of its advantages of all-weather operation, strong anti-interference ability and no background noise, wireless ultraviolet optoelectronic devices have emerged, making wireless ultraviolet communication a hot spot in the field of wireless optics[2]. Wireless ultraviolet communication is divided into two working modes : direct-view communication and non-direct-view communication[3]. The direct-view communication means that the optical signal transmitted by the transmitter reaches the receiver in a linear manner. In this way, when the communication link between the transmitter and the receiver is blocked, the information cannot be transmitted. Non-line-of-sight communication refers to the information exchange of ultraviolet light using the scattering characteristics of atmospheric molecules and aerosol particles. The electromagnetic field generated by ultraviolet light causes the oscillation of the self-charge of atmospheric particles and radiates secondary spherical waves. The surface distribution and vibration of the secondary spherical wave will affect the scattering direction of light. Therefore, the ultraviolet light scattering signal has the same information as the light source signal. This working mode overcomes the weakness that other free space optical communication systems must work in the LOS mode[4]. The wavelength range of ultraviolet light is 10nm~400nm. According to the change of wavelength, ultraviolet light is usually divided into four bands : near ultraviolet, medium ultraviolet, far ultraviolet and ultra ultraviolet. The UV spectrum is shown in "Fig.1"[5]. Wireless ultraviolet communication usually uses the mid-ultraviolet band of 200nm ~ 280nm to communicate, which is also known as the ' solar blind ' band. The solar

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radiation in the solar blind ultraviolet band is absorbed by ozone molecules in the stratosphere. There is almost no solar radiation in this band in the low-altitude atmosphere near the ground. The communication is less affected by sunlight, has strong anti-interference ability and can work day and night.

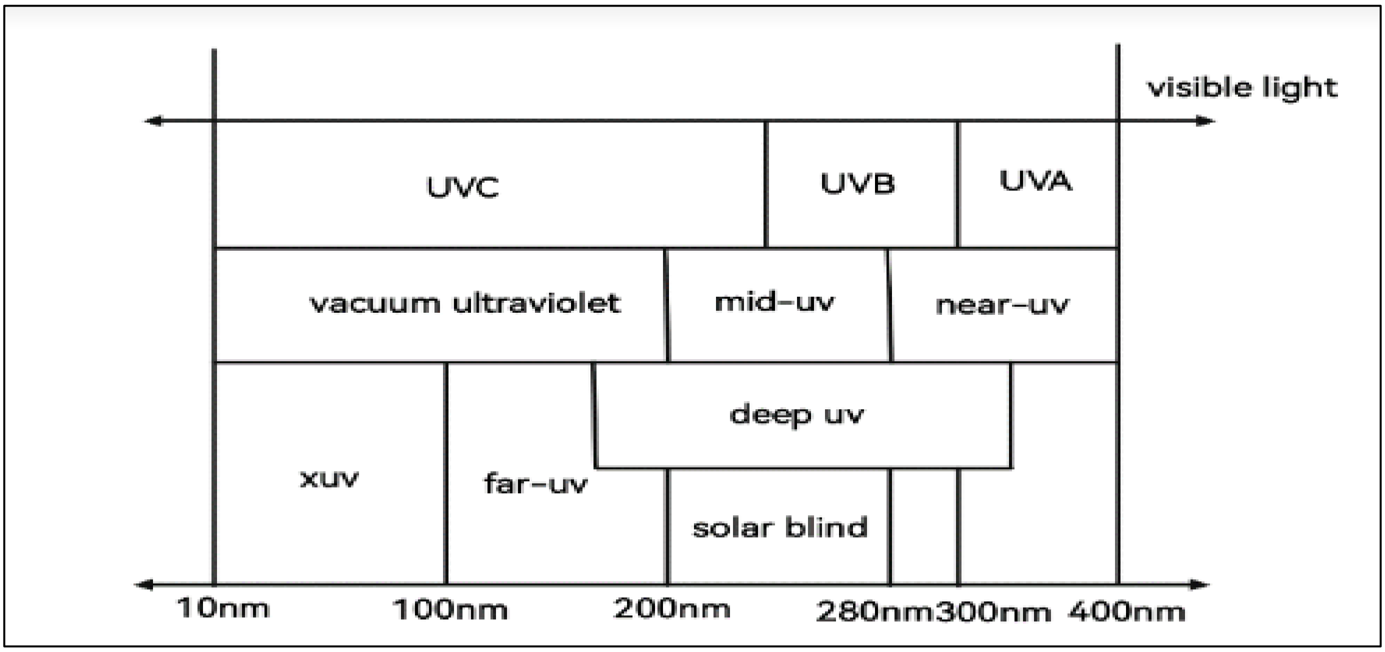

Fig 1: UV Spectra

II. INFLUENCE OF ATMOSPHERE ON ULTRAVIOLET LIGHT

The transmission medium of non-line-of-sight ultraviolet light is the atmosphere. The atmosphere is composed of gas molecules such as oxygen, carbon dioxide, nitrogen and ozone, as well as solid and liquid aerosol particles. Atmospheric attenuation effect is the most basic atmospheric channel characteristics in the process of ultraviolet light transmission, and it is also an important factor leading to optical power attenuation. It is usually expressed by atmospheric absorption coefficient, extinction coefficient and scattering coefficient[6].

A. Absorption of Ultraviolet Light Signal by Atmosphere

The atmosphere has a certain absorption effect on optical signals of all wavelengths. During the transmission of ultraviolet light through the atmosphere, the energy carried by the optical signal will be absorbed by atmospheric molecules. Therefore, wireless ultraviolet communication is a short-distance communication. As the communication distance increases, the energy of the optical signal gradually decreases. Oxygen, carbon dioxide and ozone can absorb the energy of ultraviolet light signal propagating in the air. When the ultraviolet light wavelength is 260nm ~ 280nm, the absorption effect of oxygen can be neglected, and the nitrogen in the air has almost no effect on the absorption problem. Ozone is the main factor of light energy attenuation in solar blind ultraviolet band communication. The higher the concentration of ozone, the stronger the absorption effect of ultraviolet band. The concentration of ozone in the atmosphere is represented by $C(O_3)$, and the absorption coefficient of ultraviolet ozone with a wavelength of 266 nm is :

$$K_a = 0.025 \times C(O_3) \tag{1}$$

Aerosol particles in the atmosphere can also absorb the energy of ultraviolet light signals, and the attenuation degree of light energy is different due to their different types and sizes. Aerosol composition mainly includes inorganic matter, nitrate, sulfate and organic carbon. Carbon-containing aerosol is one of the most complex components, which can be divided into organic carbon and inorganic carbon. Among them, inorganic carbon has strong absorption characteristics for visible light and some infrared spectra, and organic carbon usually reflects the scattering characteristics of solar radiation[7]. Therefore, the aerosol absorption coefficient is characterized by measuring the concentration of inorganic carbon aerosol. The absorption coefficient of black carbon represented by σ, the mass concentration of black carbon is represented by M_{BC}, and the absorption coefficient of aerosol particles is represented by the measured black carbon concentration. The formula is:

$$K_{ap} = \sigma \times M_{BC} \tag{2}$$

B. Scattering Affect of Atmosphere on Ultraviolet Light

NLOS ultraviolet communication is the transmission of information through the scattering of ultraviolet light by particles such as atmospheric molecules and aerosol particles[8]. The scattering effect of the atmosphere on ultraviolet light is divided into Rayleigh scattering and Mie scattering. The scattering effect is related to the size of the scattered particles. Usually, the stronger the scattering effect of the atmospheric particles with the same wavelength of ultraviolet light, the relative size between the particle size and the wavelength determines the degree of scattering and the overall attenuation. When the size of atmospheric particles is

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much smaller than the wavelength of scattered light, the scattering effect of atmospheric particles on ultraviolet light is called Rayleigh scattering, and the scattering intensity is not much different in each scattering direction[9]. Rayleigh scattering is generally considered to play a dominant role in clear sky because the concentration of aerosol particles is very low in clear sky. The expression formula of Rayleigh scattering coefficient of atmospheric molecules is :

$$k_{sca}^{m} = \frac{8\pi^3[n(\lambda)^2 - 1]^2}{3N\lambda^4} \times \frac{6+3\delta}{6-7\delta} \tag{3}$$

The relationship between Rayleigh scattering coefficient and wavelength is shown in "Fig.2". It can be seen from the simulation image that as the wavelength increases, the value of the Rayleigh scattering coefficient gradually decreases. where $n(\lambda)$ represents the refractive index of the atmosphere. For the standard atmosphere, the molecular number density $N = 2.54743 \times 10^{19} cm^{-3}$ in sunny weather, and the depolarization term $\delta = 0.035$, where the unit of λ is micron, and N represents the particle number density of the scatterer. The refractive index of standard air is expressed as follows, where the unit of λ is nanometer.

$$[n(\lambda) - 1] \times 10^8 = \frac{5791817}{238.0185 - \lambda^{-2}} + \frac{167909}{57.362 - \lambda^{-2}} \tag{4}$$

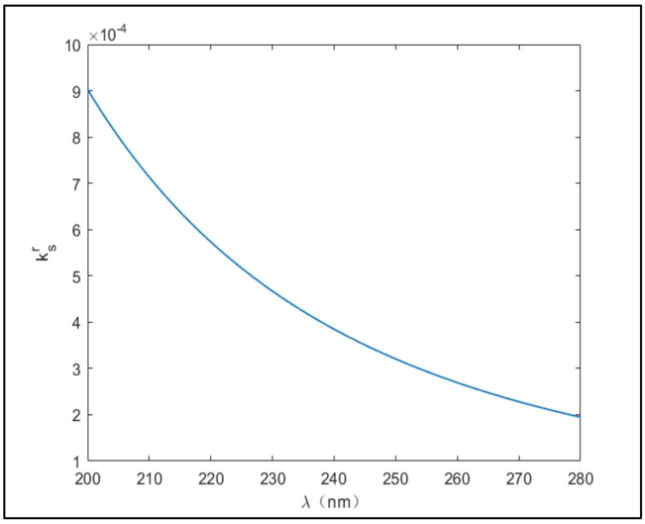

Fig 2: The Relationship between Rayleigh Scattering Coefficient and Wavelength

- ***The Commonly Used Classical Formulas for Calculating the Rayleigh Scattering Coefficient are:***

$$k_s^{ray} = 2.677 \times 10^{-17} \times \frac{P}{T} \times \gamma^4 \tag{5}$$

T is the absolute temperature, T = 300K in the standard atmosphere, P is the atmospheric pressure, γ is the ultraviolet wavenumber. When the proportion of aerosol particles in the air is large, Mie scattering plays a leading role, and the wavelength size of aerosol particles is generally larger than the wavelength of ultraviolet light or slightly different from it. Mie scattering is very complex, and its scattering coefficient is usually expressed by an empirical formula[10]:

$$k_s^{min} = \frac{3.91}{R_V} \times \left(\frac{\lambda_0}{\lambda}\right)^q \tag{6}$$

Where R_V is the visibility, λ is the ultraviolet wavelength, $\lambda_0 = 550nm$, q is the correction factor related to the visibility value, and its value is as follows. The relationship between the Mie scattering coefficient and the visibility is shown in "Fig.3". It can be seen from the formula that when the visibility is fixed, the Mie scattering coefficient decreases gradually with the increase of wavelength. It can be observed from the simulation image that when the wavelength is fixed, the Mie scattering coefficient in the ultraviolet solar-blind band decreases with the increase of visibility.

$$q = \begin{cases} 1.6 & R_V > 50km \\ 1.3 & 6km < R_V < 50km \\ 0.16R_V + 0.34 & 1km < R_V < 6km \\ R_V - 0.5 & 500m < R_V < 1km \\ 0 & R_V < 500m \end{cases}$$

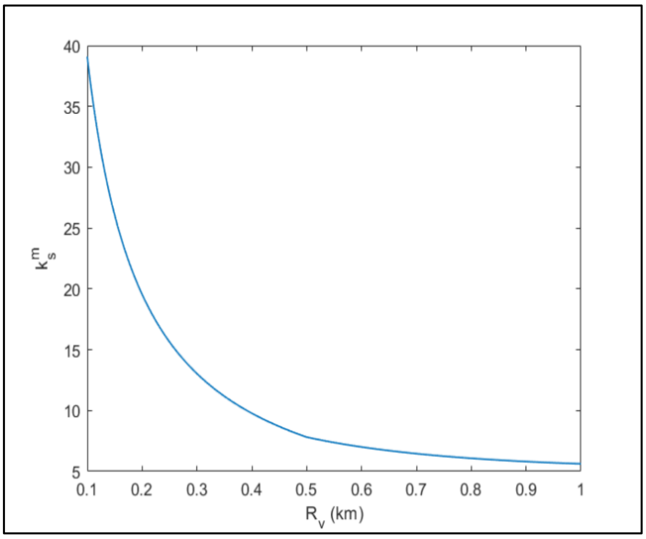

Fig 3: Relationship between Mie Scattering Coefficient and Visibility

III. SCATTERING PHASE FUNCTION

The scattering phase function is an important parameter for the study of non-line-of-sight wireless ultraviolet light scattering communication. The Rayleigh scattering phase function has two basic expressions. The Mie scattering phase function commonly used includes the Henyey-Greenstein phase function, the H-G1 phase function given by Cronette and Shanks, and the modified H-G2 function considering the forward and backward scattering conditions. These three types of scattering phase functions all add an asymmetry factor g.

The Expression of the Rayleigh Scattering Phase Function of the First Kind is:

$$P_R(\cos\theta_S) = \frac{3}{4}(1 + \cos^2\theta_S) \tag{7}$$

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The Second Kind of Rayleigh Scattering Phase Function is:

$$P_R(\cos\theta_S) = \frac{3[1 + 3\gamma + (1-\gamma)\cos^2\theta_S]}{4(1+2\gamma)} \qquad (8)$$

γ is the model parameter related to the ultraviolet wavelength, when $\lambda = 266nm$, $\gamma = 0.017$. The relationship between Rayleigh scattering phase function and scattering angle is shown in "Fig.4". It can be seen from the simulation image that the forward scattering and backward scattering are symmetrically distributed. The scattering phase function takes the minimum value at 90°, and the symmetry axis of the whole image is 90° at the scattering angle.

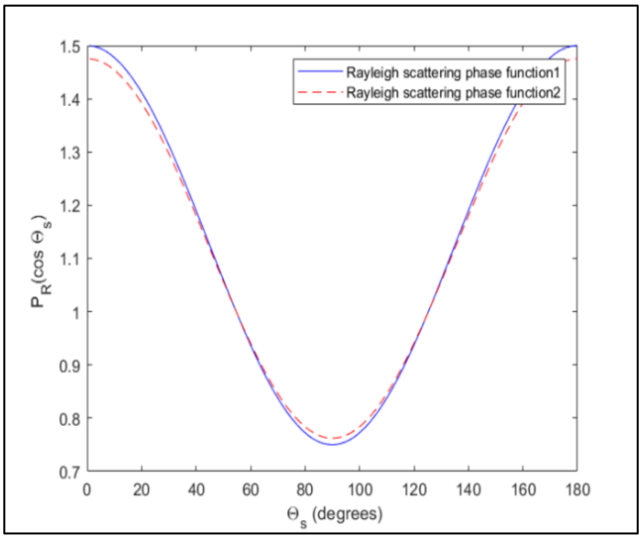

Fig 4: The Relationship between Rayleigh Scattering Phase Function and Scattering Angle

There are three kinds of Mie scattering phase functions. The expression of the Mie phase function H-G considering only forward scattering is [11]:

$$P_{HG}(\cos\theta_S) = \frac{1-g^2}{(1+g^2-2g\cos\theta_S)^{\frac{3}{2}}} \qquad (9)$$

Cronette and Shanks used the Rayleigh phase function and the H-G phase function to derive the improved H-G Mie scattering phase function H-G1, whose expression is :[12]

$$P_{H-G1}(\cos\theta_S) = \frac{3}{2}\times\frac{1-g^2}{2+g^2}\frac{1+\cos^2\theta_S}{(1+g^2-2g\cos\theta_S)^{\frac{3}{2}}} \qquad (10)$$

The modified H-G2 Mie scattering phase function can be expressed as :

$$P_{H-G2}(\cos\theta_s) = (1-g^2)\left[\frac{1}{(1+g^2-2g\cos\theta_s)^{3/2}} + f\frac{0.5(3\cos^2\theta_s - 1)}{(1+g^2)^{3/2}}\right] \qquad (11)$$

The relationship between the three types of Mie scattering phase functions and the scattering angle is shown in "Fig.5". The value of g is related to the weather. Under the conditions of sunny, haze, fog and rain, g is 0.72, 0.8, 0.9 and 0.93 respectively[13]. Taking the modified H-G2 phase function as an example, the relationship curve between the scattering phase function and the asymmetry factor is shown in "Fig.6", and the value of the model parameter f is 0.5.

It can be seen from the simulation image that the scattering phase function has the maximum value when the scattering angle is 0°, but it is not a strictly decreasing function with the increase of the scattering angle. After 90°, the H-G2 phase function has a tendency to decrease and then increase. It is demonstrated that the modified H-G2 phase function can take into account the backscattering. There are some differences in the values and changes of the three Mie scattering phase functions. Taking the modified H-G2 function as an example, under different weather conditions, the value of g is different, and the simulation curve of scattering phase function has different changes. The value range of scattering phase function in harsh environment is larger than that in sunny weather.

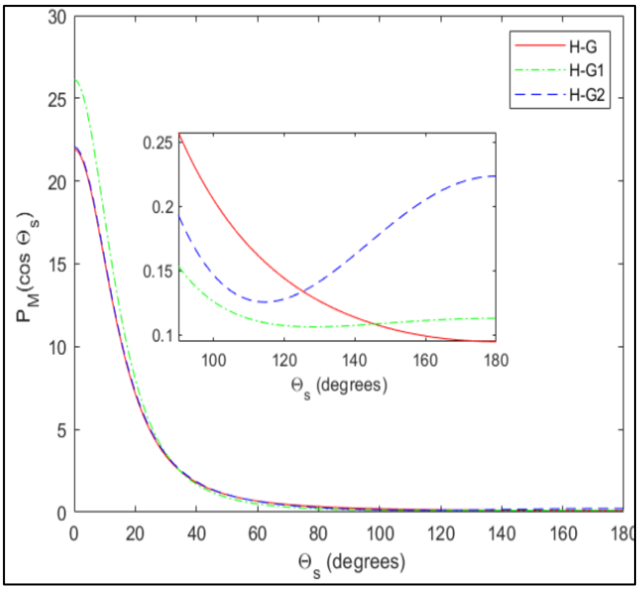

Fig 5: The Relationship between Three Kinds of Mie Scattering Phase Functions and Scattering Angle

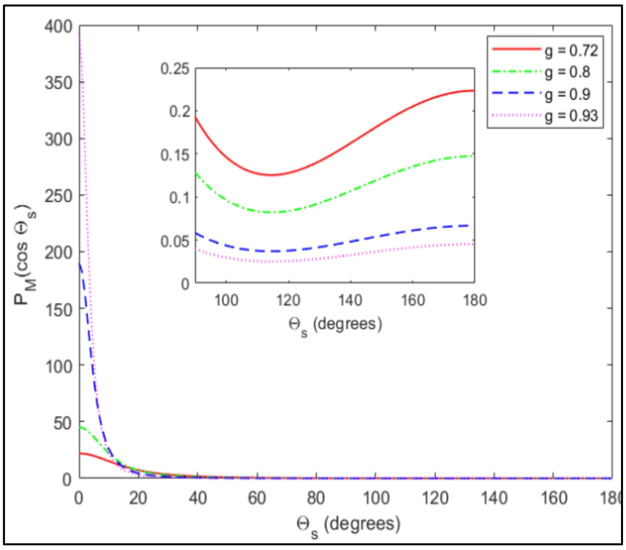

Fig 6: Mie Scattering Phase Function (H-G2) under Different Weather Conditions

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IV. THE ESTABLISHMENT OF COMMUNICATION MODEL

The study of wireless ultraviolet communication channel model is the basic work to study the influence of different scattering phase function combinations on the performance of non-line-of-sight ultraviolet communication. Firstly, the non-line-of-sight ultraviolet single scattering channel model based on the long spherical coordinate system is introduced. The ultraviolet NLOS single scattering communication system model is shown in “Fig.7”[14]. In the single scattering transmission model, the transmission of ultraviolet light only considers the occurrence of single scattering, the ultraviolet light signal is transmitted to the scattering body through the atmosphere after being transmitted by the transmitter, after scattering by the scattering particles, part of the ultraviolet light particles are received by the receiving end, ignoring the occurrence of multiple scattering, thereby reducing the difficulty of analyzing the communication process. The long spherical coordinate system is applied to the ultraviolet single scattering channel model, the transmitter and receiver are placed at two endpoints of the long spherical coordinate system. In the figure, the emission end F_1 emits ultraviolet light signal at the emission elevation angle β_T, and β_T is the angle between the central axis of the emission cone and the positive direction of the x-axis. The horizontal distance between the transmitter and the receiver is set to r, and r_1 and r_2 are the distances from the transmitter and the receiver to the common scatterer, respectively. The receiving end F_2 receives the ultraviolet light signal by receiving the elevation angle β_R.V is the common part of the intersection of the transmitting cone and the receiving cone, which is called the common scatterer. This area is the scattering effective area that enables the optical signal to reach the receiving end. P is a point in both the emission region and the receiving region. When the ultraviolet light signal reaches this point, it scatters, and a part of the light signal passes through the scattering to the receiving end. θ_S is the scattering angle, θ_T and θ_R are the emission half-field angle and the receiving half-field angle, and the scattering angle $\theta_S = \beta_T + \beta_R$. The long spherical coordinate system used in the single scattering channel model of ultraviolet light is shown in “Fig.8”. Any point on the ellipsoid can be uniquely determined by the radial coordinate ξ, the angular coordinate η, and the azimuth angle ϕ. Any point in the three-dimensional space rectangular coordinate system composed of xoy can also be transformed into the point coordinates in the long spherical coordinate system.

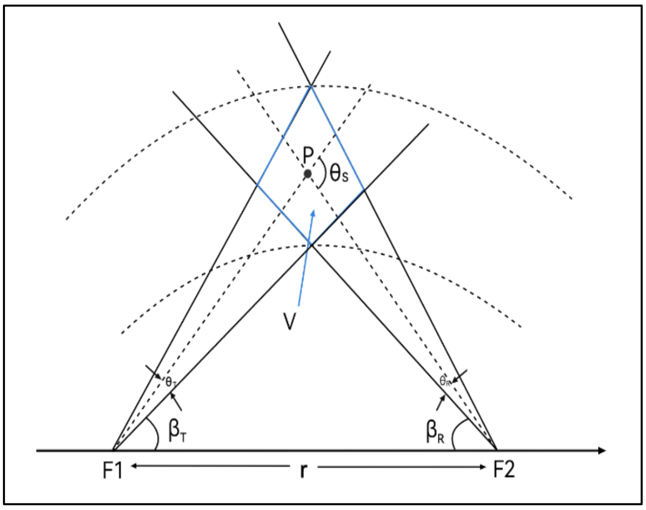

Fig 7: NLOS Ultraviolet Single Scattering Communication Link Diagram

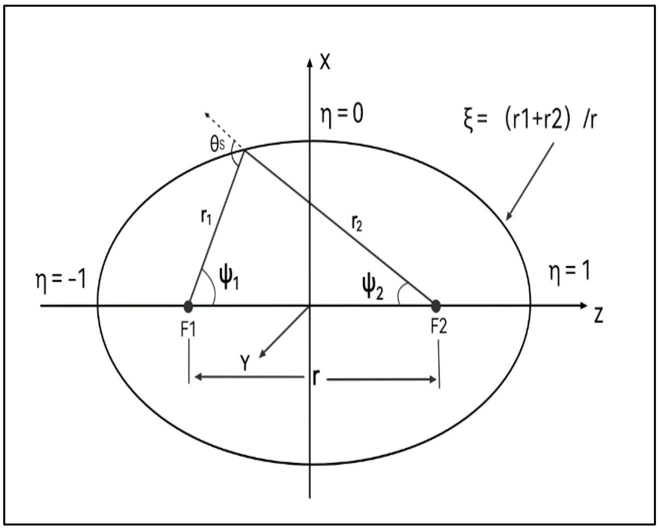

Fig 8: Long Spherical Coordinate System

Assuming that the atmospheric channel is a linear time invariant system. At t=0, the emitting end emits an ultraviolet light signal with an energy of E_t and reaches the effective scatterer at the divergence angle θ_T. The energy per unit solid angle is $\frac{E_t}{\Omega}$, The solid angle $\Omega = 4\pi \sin^2 \frac{\theta_T}{2}$ corresponding to the emission cone. Photons pass through the emission cone and reach point P in the scattering body after a transmission time of $t = r_1/c$. The energy per unit volume at point P is $H_p = \frac{E_t e^{-k_e r_1}}{\Omega {r_1}^2}$, where k_e is the extinction coefficient of the atmosphere, $k_e = k_s + k_a$. $k_s$is the scattering coefficient, and k_a is the absorption coefficient. Photons interact with atmospheric molecules and aerosol particles at point P, and the volume derivative dv of the scatterer containing point P can be regarded as a spherical secondary point light source. The energy of this point light source in space is $dE_p = k_s H_p dv$. After introducing the scattering phase function. The energy contained in the volume differential dv of the scatterer containing the P point is $dR_P = dE_p \frac{P(\cos\theta_S)}{4\pi}$, where $P(\cos\theta_s)$ is the scattering phase function. Considering that both Rayleigh scattering and Mie scattering occur when ultraviolet light signals are transmitted in the atmosphere, the scattering phase function is determined by both Rayleigh scattering phase function and Mie scattering phase function. The weighted average is expressed as[15] :

$$P(\cos\theta_s) = \frac{k_s^{ray}}{k_s} P_R(\cos\theta_s) + \frac{k_s^{min}}{k_s} P_M(\cos\theta_s) \qquad (12)$$

Part of the energy scattered by dv is received by the receiving end at time $t = (r_1+r_2)/c$. The receiving power per unit area received by the receiver is $dE_r = dR_P \frac{e^{-k_e r_2}}{{r_2}^2}\cos(\zeta)$, When the effective scattering volume in space is not large, $\cos(\zeta)$ can be considered as 1, resulting in $dE_r = \frac{k_s E_t p(\cos\theta_s) e^{-k_e(r_1+r_2)}}{4\pi\Omega({r_1}^2{r_2}^2)} dv$. The expression for the scattering volume differential in the long spherical coordinate system is $dv = \frac{r^3}{8}(\xi^2-\eta^2)d\xi d\eta d\phi$, substituting dv、$\xi = \frac{r_1+r_2}{r}$ and $\eta = \frac{r_1-r_2}{r}$ into dE_r, the energy per unit area of the receiving end can be obtained as $dE_r = \frac{k_s E_t p(\cos\theta_s) e^{-k_e\xi(r_1+r_2)}}{2\pi r\Omega(\xi^2-\eta^2)} d\xi d\eta d\phi$, because $\xi = \frac{r_1+r_2}{r}$, then $\xi = \frac{ct}{r}$ and $d\xi = \frac{cdt}{r}$ can be obtained. Substituting them into the above equation and integrating each parameter, the received light power per unit area at the receiving end is obtained as:

$$E(\xi) = \begin{cases} 0 & \xi < \xi_{min} \\ \frac{E_t c k_s e^{-k_e\xi(r_1+r_2)}}{2\pi\Omega r^2}\int_{\eta_1(\xi)}^{\eta_2(\xi)}\int_{\phi_1(\xi,\eta)}^{\phi_2(\xi,\eta)} \frac{P(\cos\theta_s)}{\xi^2-\eta^2} d\phi d\eta & \xi_{min} \le \xi \le \xi_{max} \\ 0 & \xi > \xi_{max} \end{cases} \qquad (13)$$

V. THE INFLUENCE OF DIFFERENT SCATTERING PHASE FUNCTION COMBINATIONS ON THE PERFORMANCE OF NON-LINE-OF-SIGHT WIRELESS OPTICAL COMMUNICATION

In this paper, the first and second types of Rayleigh scattering phase functions and different Mie scattering phase functions are weighted and combined, and the received power per unit area received by the single scattering channel model receiver is used for simulation analysis. Taking the solar-blind ultraviolet wavelength of 266 nm as an example, the transmission power is set to 1W, and the simulated scattering coefficient and absorption coefficient are obtained from Reference[16]. Considering the combined effect of Rayleigh scattering and Mie scattering on the light particles transmitted in the air, the absorption coefficient of ultraviolet light transmitted in the atmosphere is set to $k_a = 0.74 \times 10^{-3}m^{-1}$, and the scattering coefficient is $k_s = 0.49 \times 10^{-3}m^{-1}$. The Rayleigh scattering coefficient is $k_s^{ray} = 0.24 \times 10^{-3}m^{-1}$, and the Mie scattering coefficient is $k_s^{min} = 0.25 \times 10^{-3}m^{-1}$.

The two types of Rayleigh scattering phase functions and the H-G, H-G1 and H-G2 Mie scattering phase functions are weighted and combined to form six types of scattering phase functions. The range of communication distance is set to 200m~1000m. The elevation angle and the receiving elevation angle are set to 40°, and the transmitting half-field angle and the receiving half-field angle are set to 15°. The influence of different scattering phase function combinations on the received power per unit area of the receiving end is simulated and analyzed, as shown in "Fig.9". The results show that under the combination of different scattering phase functions, the power density received by the receiver gradually decreases with the increase of the path. When the Mie scattering phase function is the same, the corresponding curves of different Rayleigh scattering phase functions almost coincide, so the influence of different Rayleigh scattering phase functions on the received power is very weak. By selecting the H-G Mie scattering phase function, the power density of the receiving end of the ultraviolet communication system can be significantly increased.

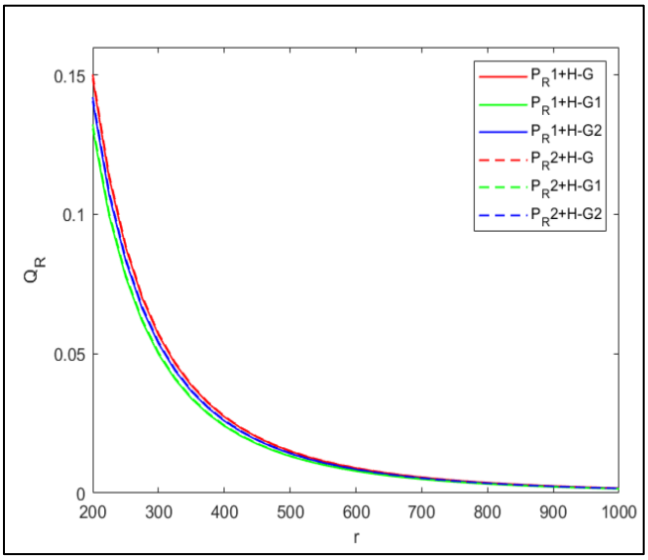

Fig 9: Simulation Curves of Received Power Per Unit Area with Distance under Different Combinations of Scattering Phase Functions

The receiving elevation angle is set to 40°, the transmitting elevation angle is set to 10°~90°, and the transmitting half field angle and the receiving half field angle are set to 9°. The relationship between the receiving power per unit area and the transmitting elevation angle under different scattering phase function combinations is simulated and analyzed, as shown in "Fig.10". As the receiving elevation angle decreases, the optical power received by the receiving end increases. Similarly, the transmitting elevation angle is set to 40°, the receiving elevation angle is set to 10°~90°, and the transmitting and receiving half field of view angle remains unchanged. The simulation results are shown

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in “Fig.11”. With the decrease of the emission elevation angle, the optical power received by the receiving end increases. When the emission elevation angle is less than 25°, the increase is very large. Under the same Mie scattering phase function, the image almost coincides. Under the same Rayleigh scattering phase function, the selection of H-G2 and H-G phase functions makes the value of the received power per unit area larger than that of H-G1. Under normal weather conditions, H-G and modified H-G2 scattering phase functions can better simulate the scattering of aerosol particles to ultraviolet light and improve the performance of communication.

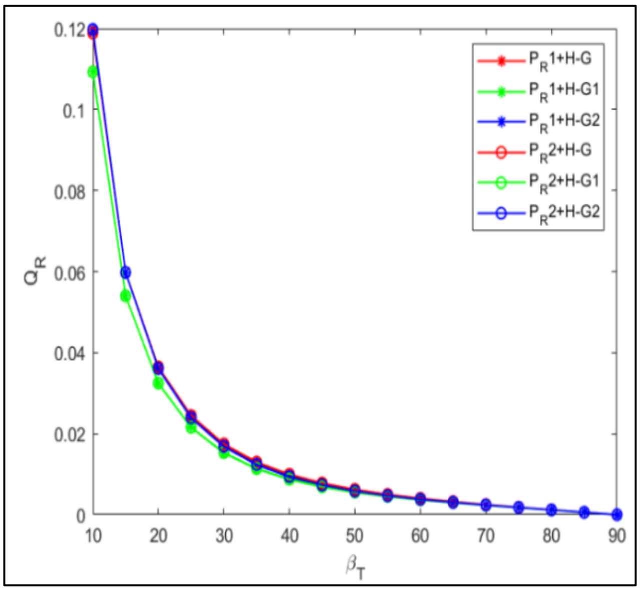

Fig 10: The Simulation Curve of the Received Power Per Unit Area with the Change of the Transmitting Elevation Angle Under Different Scattering Phase Function Combinations

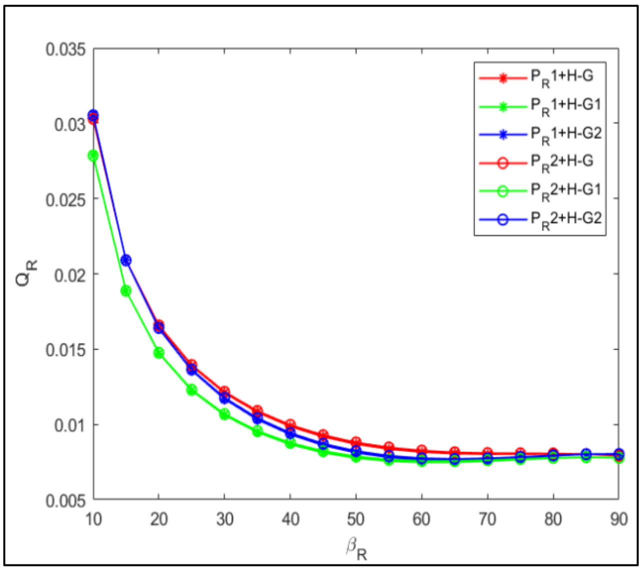

Fig 11: The Simulation Curve of the Received Power Per Unit Area with the Change of the Receiving Elevation Angle under Different Scattering Phase Function Combinations

The receiving elevation angle and the transmitting elevation angle are set to be 50°, the receiving half-field angle is 30°, and the transmitting half-field angle is 1°~48°. The variation of the optical power received by the receiving end per unit area with the emission half-field angle under different phase function combinations is simulated and analyzed, as shown in “Fig.12”. The simulation values of the receiving half-field angle and the transmitting half-field angle are interchanged, and the variation of the power density received by the receiving end with the receiving half-field angle under different phase function combinations is observed and analyzed. The result is shown in “Fig.13”. Since the phase functions used are empirical formulas, they may differ from the actual situation. The results show that the energy received by the receiving end per unit area under the combination of six scattering phase functions increases with the increase of the receiving half-field angle. This is because the increase of the receiving half-field angle leads to the increase of the receiving area and the received energy. However, the influence of the emission field angle on its value change is not fixed, which needs to be analyzed in detail. The energy of the emitted light remains unchanged. The increase of the emission half-field angle will lead to the decrease of the signal intensity, but it will also increase the volume of the effective scatterer. The former leads to the decrease of the scattering energy density, and the latter leads to the increase of the scattering energy density. The combined effect of the two determines the change of the energy at the receiving end. It can be seen from the image that the combination of H-G Mie scattering phase function and arbitrary Rayleigh scattering phase function in normal weather has obvious advantages in improving the quality of communication, followed by H-G2 phase function, and H-G1 is the worst.

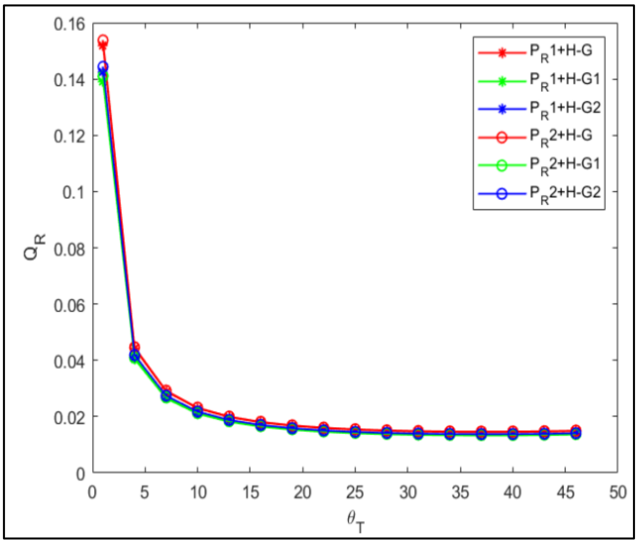

Fig 12: The Simulation Curve of the Received Power Per Unit Area with the Change of the Transmitting Half Field Angle Under the Combination of Scattering Phase Function

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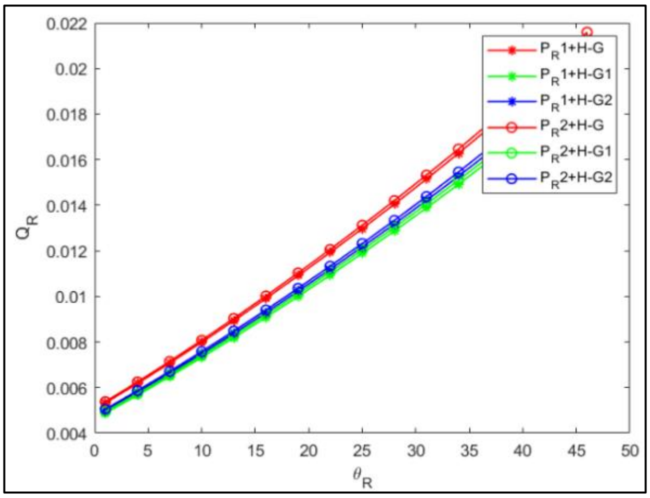

Fig 13: The Simulation Curve of Receiving Power Per Unit Area with the Change of Receiving Half Field Angle Under the Combination of Scattering Phase Function

VI. CONCLUSION

With the rapid development of ultraviolet optoelectronic devices and the popularization in military and civilian fields, non-line-of-sight ultraviolet communication technology is becoming more and more popular. This paper mainly discusses the unique advantages of the solar blind ultraviolet band and the scattering and absorption of ultraviolet light by the atmosphere. The non-line-of-sight ultraviolet single scattering coplanar communication model is established by using matlab simulation software. Three important parameters of scattering coefficient, absorption coefficient and scattering phase function are introduced. The influence of wavelength and visibility on scattering coefficient and the influence of six kinds of weighted combination of Rayleigh scattering phase function and Mie scattering phase function empirical formula on the receiving power density of NLOS ultraviolet communication system are simulated and analyzed. The results show that by changing the geometric parameters of the communication link such as transmitting elevation angle and receiving elevation angle and the half field of view of the transceiver, the performance of the ultraviolet communication system can be changed to flexibly adapt to the needs of different scenarios. Two different types of Rayleigh scattering phase functions have little effect on the quality of ultraviolet communication. Under normal weather conditions, the H-G Mie scattering phase function can better simulate the scattering of ultraviolet light by aerosol particles. The simulation results of this paper can provide theoretical guidance for the selection of the scattering phase function in the process of designing the NLOS ultraviolet communication system under normal weather.

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