Modeling and analysis of signal-to-noise ratio and detection probability calculation of laser scanning missile photoelectric detection system

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In order to improve the laser detection ability of intelligent missile guidance, this paper analyzes the space position conversion relation of the intersection between missile and target, and studies the calculation method of target echo energy at the intersection of missile and target based on the laser circumferential scanning missile guidance mechanism. According to the laser reflection characteristics of target itself and the responsivity of photoelectric detection receiver, we deduce and establish the signal-to-noise ratio calculation model of missile guidance photoelectric detection system under the restriction of multiple noise parameters, and analyze the influence of the shot noise, background noise and photoelectric detection receiver noise on the signal-to-noise ratio of the system. The detection probability calculation method of the system is proposed in the aspect of output useful signal and the distribution of system noise. Through quantitative calculation and simulation test, the results show that, under the same detection mechanism, the farther the distance between the missile and the target, the lower the signal-to-noise ratio; under the condition of the same distance, the larger the intersection angle between the missile and the target, the smaller the echo energy and the signal-to-noise ratio.

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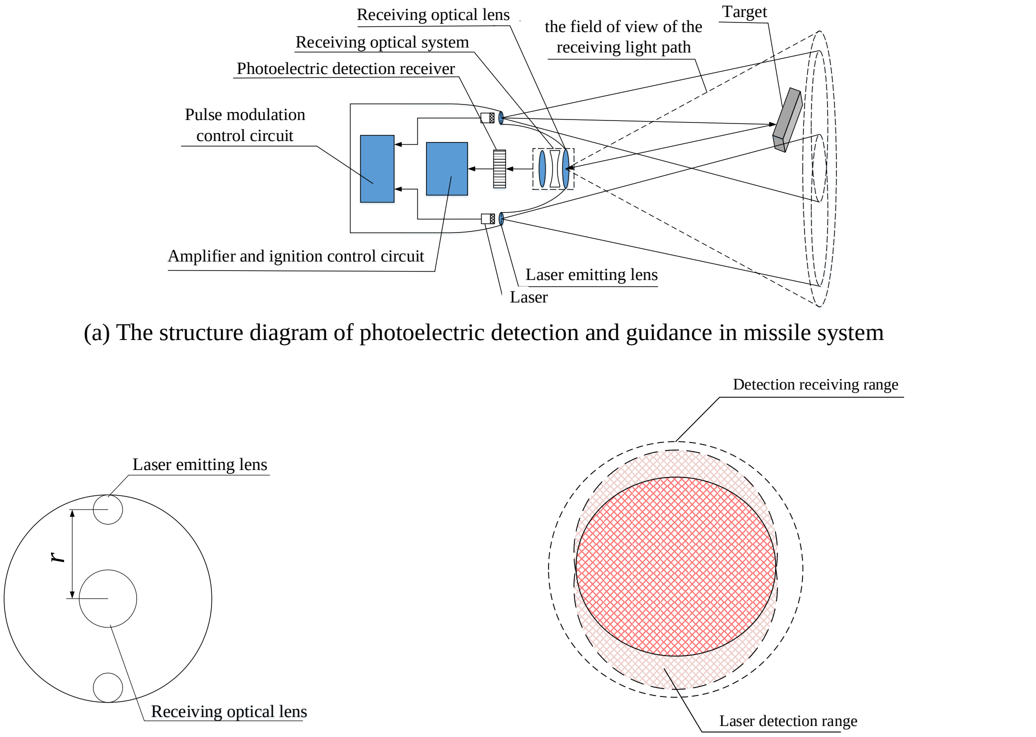
1. Introduction

In the field of weapon guidance and detection, the efficiency of these missiles depends on its own detection sensitive unit, especially for armored vehicles, tanks, buildings and other ground targets. Because the radiation characteristics of the ground target are not consistent, the sensitivity of the missile photoelectric detection sensitive unit is also different, which is an important research direction of the strike effectiveness of intelligent missile in the future [1]. The terminal guidance effect of conventional missile is formed by using photoelectric transmitter and receiver with different wavebands. It mainly uses the frequency signal emitted by its own launcher and the echo signal reflected by the missile intersecting the target as the criterion of detonation control, so as to form the target damage effect under the short-range intersection of missile and target [2,3]. For the intersection of the missile and the ground target, the damage to the directional warhead caused by the missile explosion mainly depends on the missile directional warhead system. According to the position of the target relative to the projectile body, it can stimulate the detonating device of the missile detecting and receiving module to strike the target accurately, so as to improve the damage probability of the missile to the ground target. The damage formed by the directional warhead puts forward higher requirements for the detection capability of the missile fuze, which is mainly reflected in the signal-to-noise ratio of the photoelectric detection system of the missile. It is not only required that the photoelectric detection system of the missile has higher detection sensitivity, but also that the anti-jamming ability of the system must meet certain requirements [4]. In order to improve the detection ability of missile, a multi-quadrant high-sensitivity photoelectric detection receiver is introduced into the photoelectric receiving module of the missile. The characteristic of multi-quadrant photoelectric detector is that the receiving aperture of the optical path is larger than the conventional photoelectric detector, which increases the detection field of view. In this way, it is beneficial to receive the reflected echo signal of the target and improve the sensitivity of missile guidance detection. As the size of optical aperture of the detection system increases, the random interference signals from the outside also increase. How to establish the relationship between the sensitivity and the signal-to-noise ratio of the system depends on the signal-to-noise ratio modeling of the system. For the signal-to-noise ratio model of conventional photoelectric detection system, Jie Cao et al. studied the performance of optical communication detection system based on APD [5]. According to the photoelectric detector responsiveness, output photocurrent and target characteristics of the detection system, the signal-to-noise ratio of the system under different bias voltage was given. Based on the characteristics of infrared imaging system, the detecting distance of the system is studied and the mathematical model between the detecting distance and the signal-to-noise ratio is established [6]. Fan Yang et al. studied the signal-to-noise ratio of ground-based infrared detection of space object, analyzed the infrared detection methods of satellites at different transit times, and compared the signal-to-noise characteristics of detection in different infrared bands [7]. Wang Miao et al. studied the photoelectric imaging detection performance and illumination modeling under a strong background light condition, and analyzed the influence of the signal-to-noise ratio of the photoelectric imaging system on the detection sensitivity [8]. Prior works have studied the signal-to-noise ratio of the photoelectric detection system. However, the modeling and analysis of the detection signal-to-noise ratio formed by multi-quadrant photoelectric detectors are still relatively few [9-10]. Meanwhile, the high-speed missile guidance system is a complex comprehensive detection mechanism, which requires the acquisition of target information within a very short intersection time between missile and target, and needs the signal-to-noise ratio of the system to meet the corresponding requirements. This paper uses the laser emission and the photoelectric detection receiver of the missile to compose photoelectric detection system, according to the laser scanning detection mechanism formed by the rotation of the missile itself, established the signal-to-noise ratio model of the system, which provides analytical basis for improving the guidance and detection ability of the missile.

2. Missile laser scanning detection mechanism and echo power calculation modeling

The missile laser scanning detection model, as shown in Fig. 1. The core of the photoelectric detection and guidance system is mainly composed of two laser emission modules and one photoelectric receiving module. In part of laser emission modules, there are pulse modulation control circuit and laser emitting lens; In part of photoelectric receiving module, there are amplifier and ignition control circuit and receiving optical lens. The area covered by the two laser emission modules forms the scanning area. Selecting two laser transmitting modules can enhance the echo power of the target [11]. When the target appears in the scanning area, the target’s surface reflect laser and form laser echo. The photoelectric detection module of the photoelectric receiving system receives and process the laser echo signal. According to the missile detonation control criterion, when the received echo energy is greater than a certain threshold, a detonation control signal is generated to achieve the missile detonation. Two laser emission modules are mainly composed of pulse modulation control circuit, laser and optical components. Because the emitting laser beam exit port has optical components, the optical components form a certain detection field of view, and the combination of two emitting laser fields is the emitting laser scanning region. Photoelectric reception module is mainly composed of optical components of receiving light path, photoelectric detection receiver, amplifier and ignition control circuit, and so on. The receiving field of view formed by the photoelectric detection module covers the emitting laser scanning region. Compared with the detection distance of photoelectric detection system, the distance r between laser emitting lens and photoelectric detection lens is close, so it can be ignored.



(a) The structure diagram of photoelectric detection and guidance in missile system

(b) The distribution diagram of optical lens (c) The schematic diagram of laser emission at a certain distance

Fig. 1. The diagram of missile laser scanning detection mechanism (color online)

Because the missile body rotates in the flight, the laser detection method of the missile body is the rotating scanning detection method in the intersection process between missile and target. As shown in Fig. 2, the region formed by the two laser emission modules is regarded as one laser emission device to form a 360° sector scanning region. Because the field of view of the receiving region is larger than that of the emissive region, when laser and target intersect in the scanning region, the echo from the laser irradiating on the target's surface can incident to the photoelectric receiving module at a certain intersection angle. As can be seen from Fig. 2, when the missile attacks the ground target, the intersection angle is uncertain. In order to establish the echo power model of missile guidance system, it is necessary to obtain the coordinate state of missile body and the relative velocity of target.

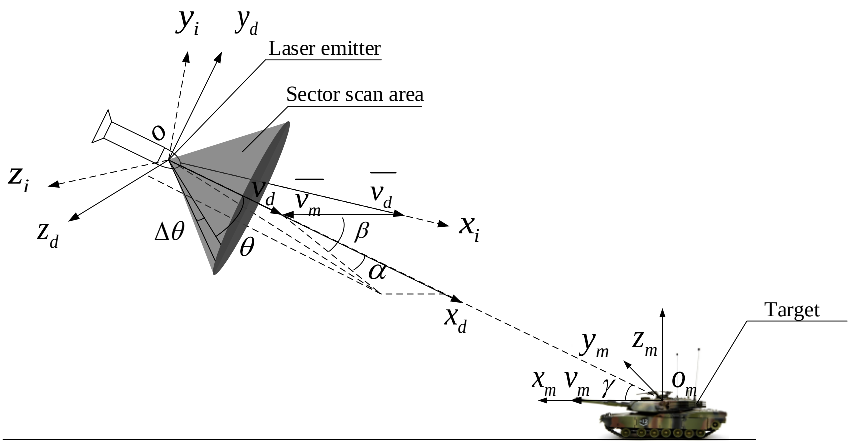


Fig. 2. The coordinate system of missile and target

The laser beam emitted by the missile detection system is scanned in a conical circumferential scanning at a forward rake θ, gap $\Delta\theta$. It is assumed that during the intersection, the missile photoelectric detection system and the target all keep moving in uniform rectilinear motion along their respective axes. Taking the starting point o of the detection beam emission as the origin of the missile body coordinate system, the axis ox_d is selected as the axis of the detection system, and the movement direction of the missile system is positive. Make the axis oy_d perpendicular to the axis ox_d, the axis ox_d, oy_d and oz_d compose a right-handed coordinate system $ox_d y_d z_d$. The target coordinate system $o_m x_m y_m z_m$ is established with the target's geometric center as the origin. The origin of the missile relative velocity coordinate system is also set at the starting point o of the detection beam emission. The positive direction of axis ox_i is the relative velocity vector direction, the axis oy_i is perpendicular to the axis ox_i, and the relative velocity coordinate system $ox_i y_i z_i$ between missile and target is established. In the coordinate system of the missile system, the velocity of the missile detection system is denoted as v_d, and the relative motion velocity is denoted as $\overline{v_d}$. In the target coordinate system, the target velocity is denoted as v_m, and the relative motion velocity is denoted as $\overline{v_m}$. Assuming that the yaw angle of the target is α and the pitch angle is β, then the transformation matrix between the target coordinate system and the missile coordinate system is:

$$N_m = \begin{bmatrix} \cos\alpha\cos\beta & \sin\beta & -\sin\alpha\cos\beta \\ -\cos\alpha\sin\beta & \cos\beta & \sin\alpha\sin\beta \\ \sin\alpha & 0 & \cos\alpha \end{bmatrix} \quad (1)$$

In the missile coordinate system, the relative velocity of the target is:

$$\overline{v_d} = v_d - N_m \cdot v_m \quad (2)$$

The echo energy reflected from the target which relative to the missile itself intersect with relative velocity $\overline{v_d}$ based on (1) and (2). Therefore, the echo energy generated by the target is determined by the scanning time corresponding to $\overline{v_d}$. The laser emission power is P_0, the laser echo pass through the optical devices of the photoelectric receiving module, and the echo power that can be obtained on the photosensitive surface of the photoelectric receiver is $P(t)$. It can be obtained as follows:

$$P(t)=\frac{P_0\cdot\tau_0\cdot\eta\cdot\rho_0}{t_0\sqrt{2\pi}}\exp\left[-\frac{1}{2t_0^2}\left(t-\frac{2R}{c}\right)^2\right] \tag{3}$$

In (3), t_0 is the time that the missile can continuously reflect echoes on the target's surface. τ_0 is the optical efficiency of the optical path system of the photoelectric detector. η is quantum efficiency. ρ_0 is the reflectance of target's surface. R is the distance between the missile photoelectric detection system and the target. c is the speed of light [12].

From formula (3), in order to improve the detection capability of laser scanning missile photoelectric detection system, there are mainly two measures. One is to increase the aperture diaphragm of the photoelectric detection receiving optical path, and the other is to increase the power of the transmitting laser.

3. Calculation method of signal-to-noise ratio of missile photoelectric detection system

The signal-to-noise ratio of the missile photoelectric detection system is the ratio between the signal and the total noise received by the photoelectric receiving device. The signal-to-noise ratio can represent the ratio of the signal current or voltage to the noise current or voltage, or the ratio of the number of optical electronic generated by the signal and the noise [13]. The signal-to-noise ratio is defined as:

$$S_{NR}=V_d/N_n \tag{4}$$

In (4), V_d is the number of the useful echo signal electrons reflected by the target in the laser scanning region of the missile, which can be approximately expressed as:

$$V_d=\frac{t_0\cdot s_m\cdot\eta\cos\alpha\cos\beta\int_{\lambda_1}^{\lambda_2}L(\lambda)\tau(\lambda)\tau_o\lambda d\lambda}{hcR^2} \tag{5}$$

In (5), h is Planck's constant and c is the speed of light. $L(\lambda)$ is the radiation brightness of the target. s_m is the detector area. $\tau(\lambda)$ is the atmospheric transmittance. R is the distance between the target and the imaging system. τ_o is the transmittance of the optical system.

As for the missile photoelectric detection system, the system noise mainly includes the shot noise caused by target radiation, the background radiation noise and the noise of the photoelectric detection receiver, which can be expressed by (6):

$$N_n=\sqrt{N_1^2+N_2^2+N_3^2} \tag{6}$$

The shot noise caused by target radiation is a random process of absorbing photons and generating charge by photosensitive surface of photoelectric receiving device. Under certain incident light radiation, the number of optical electronic produced by the photosensitive surface in any same, instantaneous interval is not exactly the same. Instead, the number of optical electronic fluctuates around a certain average value, and the fluctuation of the number of optical electronic forms optical electronic shot noise. Shot noise is proportional to the square root of the total charge number of the signal. It is the inherent noise of the photoelectric device and cannot be suppressed or balanced out by the subsequent circuit [14]. The target signal shot noise is mainly determined by the number of the target radiation electrons, and the mean of shot noise can be calculated by (7):

$$N_2=\sqrt{\frac{t_0\cdot s_m\cdot\eta\cdot\cos\alpha\cdot\cos\beta\int_{\lambda_1}^{\lambda_2}L_b(\lambda)\tau(\lambda)\tau_o\lambda d\lambda}{hcR^2}} \tag{7}$$

In (7), $L_b(\lambda)$ is the brightness of background radiation. For the background radiation noise of the target radiation, it is caused by the incident photon of the background radiation. Background radiation includes the background radiation of the sun, the moon and other stars and the sky background radiation. Sky background radiation is caused by the scattering and reflection of radiation by the atmosphere to the sun and the radiation emitted by the atmosphere itself. The background radiated noise can be calculated by (8).

$$N_2=\sqrt{\frac{t_0\cdot s_m\cdot\Omega\cdot\eta\cdot\int_{\lambda_1}^{\lambda_2}L_b(\lambda)\tau(\lambda)\tau_o\lambda d\lambda}{hc}} \tag{8}$$

In (8), Ω is the field of view of the photoelectric detection system.

The noise of photoelectric detection receiver itself is mainly the thermal noise of photoelectric detection device. It can be expressed as:

$$N_3=\sqrt{4kT_0t/q^2R_0} \tag{9}$$

In (9), T_0 is the absolute temperature of the detector. k is the Boltzmann constant. q is the response electric quantity of the photoelectric detector. And R_0 is the effective load resistance value of photoelectric detection receiver [15].

According to (7)-(9), the total system noise N_n can be calculated. With the definition of signal-to-noise ratio, the total signal-to-noise ratio of missile photoelectric detection system can be calculated:

$$S_{NR}=\frac{t_0\cdot s_m\cdot\eta\cdot\cos\alpha\cos\beta\int_{\lambda_1}^{\lambda_2}L(\lambda)\tau(\lambda)\tau_o\lambda d\lambda}{hcR^2\sqrt{N_1^2+N_2^2+N_3^2}} \tag{10}$$

4. Detection probability calculation and analysis of missile photoelectric detection system

Missile photoelectric detection system has many kinds of noise sources. The main noise comes from the detector noise, which conforms to the Gaussian distribution. When a specific external input signal and the noise signal input at the same time, the output signal of the photoelectric receiving module still conforms to the Gaussian distribution. And its probability density can gain by formula (11).

$$P(V)=\frac{1}{\sqrt{2\pi}V_n}e^{-\frac{(V-V_m)^2}{2V_n^2}} \tag{11}$$

In (11), V is the amplitude of the target signal. V_m is the mean value of the target signal. And V_n is the root mean square value of the noise of the photoelectric detection receiver. The probability that the input signal-to-noise ratio of photoelectric detection receiver exceeds the threshold signal-to-noise ratio is the detection probability of the system. By (11), the detection probability can gain by formula (12).

$$P'(t)=\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{S_{NR}-T_n}e^{-\frac{t^2}{2}}dt \tag{12}$$

In (12), S_{NR} is the signal-to-noise ratio of the photoelectric detection system. $T_n=(V-V_m)/V_n$ is the threshold signal-to-noise ratio of the photoelectric detector. When T_n is fixed, the target detection probability of the photoelectric detection system is a single increasing function of the input signal-to-noise ratio S_{NR}.When the input signal-to-noise ratio is determined, the lower the threshold signal-to-noise ratio, the higher the detection probability [16-17]. Based on the formula (12), to the missile laser scanning detection system, the main factors to consider when setting the threshold voltage are the average value of the background illuminance noise that generated by the photoelectric detection receiving circuit and the inherent noise of the detection circuit itself. These two noises are the main factors affecting the signal-to-noise ratio of the entire system. Generally speaking, we set the threshold voltage in the missile laser scanning detection system, the criterion of the threshold voltage is choose the half of the peak value in the total output signal that target reflect, in fact, When we design the detection circuit, the threshold voltage can follow the background illumination to make appropriate adjustments, avoid the problem of insufficient detection ability caused by the use of a fixed threshold voltage.

In the missile photoelectric detection system, the input signal-to-noise ratio of the system is related to the echo energy of the target laser, the background radiation and the distance between the system and the target. Therefore, the relation between the input signal-to-noise ratio of the missile photoelectric detection system can be derived by formula (13).

$$S_{NR}(R)=\frac{\omega[L_1(\lambda)-L_b(\lambda)]s_n\tau(\lambda)}{N_0R^2} \tag{13}$$

In (13), s_n is the target reflection cross-sectional area, ω is the responsiveness of the photoelectric detector, and N_0 represents the noise equivalent temperature difference of the system, which can be calculated by formula (14).

$$N=\frac{\sqrt{s_m\Delta f}}{s_o\tau_o D^*} \tag{14}$$

In (14), s_o is the effective area of the optical system. Δf is the equivalent noise bandwidth. D^* is the detection degree. In general, $D^*=2.5$.

From the above analysis, it can be seen that the effective detection distance of the missile photoelectric detection system is related to the detection probability, signal-to-noise ratio, environmental background, target reflection echo power and other factors of the photoelectric detection system. Formula (3) shows that the main core parameter of laser reflected energy obtained by the photoelectric detection system of the missile is the projectile target intersection distance. In order to fully reflect the echo energy obtained by the photoelectric detection system under different intersection conditions, we set up the detection distance model according to the deduced signal-to-noise ratio function, background illumination, target transmitting laser cross-sectional area and other parameters, which can be expressed by formula (15).

$$R=\sqrt{\frac{\omega[L(\lambda)-L_b(\lambda)]s_ns_o\tau_o\tau(\lambda)D^*}{(s_m\Delta f)^{1/2}\cdot S_{NR}}} \tag{15}$$

From (15), the detection distance is inconsistent with the signal-to-noise ratio, which is mainly reflected in two aspects. One is that the emitted laser has energy attenuation during the propagation process. The longer the distance, the more obvious the attenuation. Therefore, when the detected target is far away, the target's own reflection laser energy will be weakened. It can be seen from formula (15) that the energy weakening is not proportional to the detection distance; second, the signal-to-noise ratio is affected by the background illuminance and the inherent noise of the detection circuit, when the detection distance changes, the inherent noise will not change significantly, which is also the reason for the inconsistency between the detection distance and the signal-to-noise ratio.

5. Calculation and analysis

According to the above theoretical modeling and analysis, the capture rate of missile photoelectric detection system affects the damage efficiency of missile detonation in the missile target intersection. As can be seen from Fig. 1, on the one hand, the longer the distance between the missile and the target is, the larger the area of the missile's firing and killing is. However, the ratio of the killing power that can be affected effectively on the target is small, and the damage effect of the target may be reduced. On the other hand, the longer the distance between the missile target intersection, the smaller the laser echo energy actually reflected by the target. According to formula (11) and (12), the echo energy obtained by the photoelectric detection module may be lower than the mean value of the target signal, which lead to a low probability of missile detection of the target and make the detonating device of the missile system fail. Therefore, the missile can produce a certain lethality to the target only on the basis of a certain detection distance. According to the coordinate relationship between the missile and the target, if the missile and target are placed in the same coordinate system, there is a certain intersection angle between them. It can be seen from formula (5) that the change of intersection angle also affects the number of target-reflected laser electrons obtained by the photoelectric detection module. If the detection output generated by the number of electrons reflected from the target laser does not reach the threshold value of detonation control, the missile is not able to achieve explosive killing efficiency. In order to comprehensively analyze the effectiveness of the missile detection system on the target, according to formula (3), when the transmitting pulse laser power is 40W and the intersection angle is constant, the change relationship between the detection distance and the output echo power is calculated, as shown in Fig. 3.

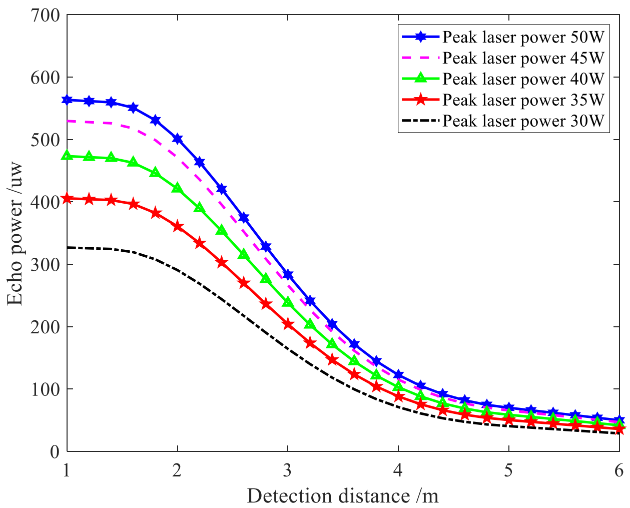


Fig. 3. The echo power distribution curve at different detection distances

When the detection distance increases, the echo power obtained by the photoelectric detection and receiving module gradually decreases. It indicates that the detection distance is inversely proportional to the echo power to some extent. Fig. 4 shows the change curve of echo power under the condition of the same detection distance and the intersection angle between the missile and the target. It is not difficult to find that the larger the intersection angle is, the smaller the energy reflected by the target is. It fully reflects that the change of the intersection angle is also the main parameter affecting the performance of the missile detection target, the calculated result is consistent with the coordinate transformation relation.

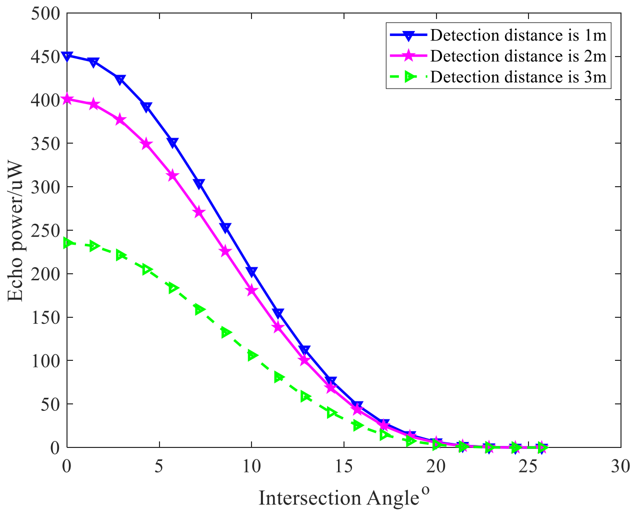


Fig. 4. Echo power distribution curve under different intersection angles

From the point of view of detection signal-to-noise ratio and detection probability, the signal-to-noise ratio of the system is affected by the target radiated shot noise, the background radiated noise and the noise of the photoelectric detection receiver. The influence of these noises is mainly restricted by the optical aperture diaphragm of the photoelectric receiving system and the thermal noise of the photoelectric receiver. For the same missile, the size of the optical aperture diaphragm of the photoelectric detection system and the thermal noise of the photoelectric detection device are determined. Therefore, the signal-to-noise ratio and detection probability of missile system are mainly determined by the illumination of environmental background and the laser echo energy reflected from the target. The output of the laser echo energy is affected by the reflectivity of the target, the cross-sectional area of the laser reflection and the detection distance. It can be seen from formula (11) and (12) that the detection probability is established on the basis of a certain detection signal-to-noise ratio. The amplitude and mean value of the target signal are proportional to the root mean square value of the noise of the photoelectric detection receiver. Fig. 5 shows the relationship between detection probability and signal-to-noise ratio under different threshold signal-to-noise ratio. From the Fig. 5, when the threshold signal-to-noise ratio is constant, the larger the signal-to-noise ratio, the higher the detection probability. For the same photoelectric detection system, there is a certain relationship between signal-to-noise ratio and detection distance. Fig. 6 shows the relationship between the signal-to-noise ratio and the detection distance under two atmospheric transmittance conditions. The results show that the system conforms to the rule that the longer the detection distance is, the lower the signal-to-noise ratio is. It also shows that the longer the detection distance is, the lower the laser echo energy reflected by the target is, and the lower the detection probability is.

Through the above calculation and analysis, the correlation calculation between the echo power formed by the missile and target intersection and the signal-to-noise ratio of the system is made. The missile photoelectric detection system needs certain echo energy to form initiation and control function. The position of the target in the missile coordinate system reflects the detection of the target in different space positions. In order to effectively verify the relationship between the signal-to-noise ratio of the missile photoelectric detection system and the target echo power, static simulation test was carried out. The two emitting lasers on the missile are fired forward to form an overlapping detection area. The emitted power of each laser is 25 W, and the optical field of view emitted is 16°. The power supply voltage of the detection circuit is 5V, the optical field of the photoelectric detection receiver is 20°. Because the distance between the emitting laser point and the photoelectric receiving and detecting optical center is relatively short, the distance can be ignored for the entire photoelectric detecting system of the missile. Therefore, the field of view of the photoelectric receiving system is sufficient to cover two laser emitting regions. Taking missile photoelectric detection system as fixed coordinate system, the simulation experiment is carried out with cylindrical target. According to the principle in Fig. 2, the target and missile form different intersection angles in different ways. When the coordinate of the target is orthogonal to the coordinate ox_d of the missile and the center of the target is on ox_d, the amplitude of echo signal of different detection distances is collected at an interval of 0.3 m. Since the direction of the missile cannot be kept completely horizontal with the ground in the launching process, the detection distance interval in the measured data is approximately equal to 0.3 m. Table 1 shows the output voltage peak value of the photoelectric detection module and the average amplitude value of the inherent noise of the corresponding detection system.

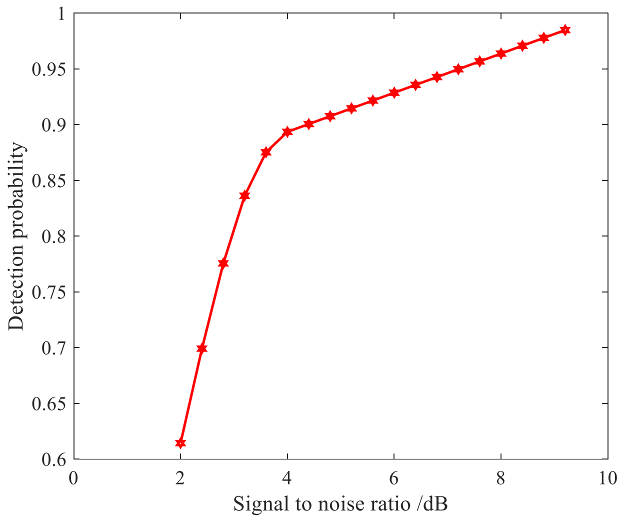


Fig. 5. Detection probability distribution curves under different SNR conditions

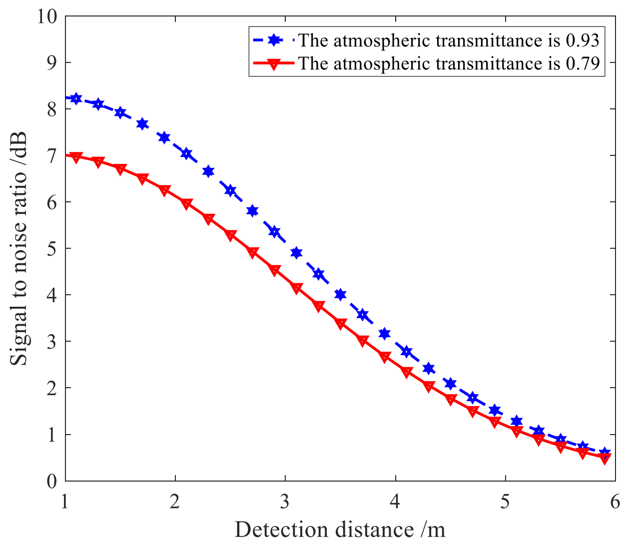


Fig. 6. Signal-to-noise ratio distribution curves at different detection distances

Table 1. The test data of echo signal at different detection distances

No.	*R/m*	*V/mV*	V_n/mV
1	2.32	4805	465
2	2.57	4115	459
3	2.91	3217	467
4	3.23	2610	460
5	3.56	2157	458
6	3.90	1823	466
7	4.22	1598	455
8	4.49	1456	458

It can be clearly seen from the data in Table 1 that, under the condition that the missile is orthogonal to the target, the shorter the distance between the target and the missile, the greater the output signal peak value. When the detection distance is 2.3 m, the target peak signal output by the detection system reaches 4.805 V, the average value of the inherent noise of the detection circuit system is about 0.465 V, and the signal-to-noise ratio reaches 10.33. With the increase of the distance, when the detection distance is 4.5 m, the inherent noise of the detection circuit remains unchanged, but the output signal peak value formed by the target echo is only 1.456V, and the signal-to-noise ratio is only 3.18.

In order to observe the influence of the intersection angle on the target, the center line between the target and the missile is assumed to remain unchanged, but the angle formed between the target and ox_d is adjusted. Adjusting the angle between the target and ox_d at a distance of 3.2 m. Table 2 shows that the data of the peak of the tested target echo signal.

Table 2. The test data of target at different intersection angles

No.	γ	*V/mV*	V_n*/mV*
1	0.2	4820	465
2	2.3	4817	459
3	5.5	4065	467
4	7.2	3508	460
5	10.2	2439	458
6	12.7	1645	466
7	15.5	1022	455
8	19.1	683	468

It is not difficult to find when the intersection angle increases, the energy incident from the laser echo energy reflected by the target into the optical aperture of the photoelectric receiving system have obvious changes. If the intersection angle between the target and the missile is between 5.5° and 15.5°, the signal-to-noise ratio of the photoelectric detection system can reach 2.25 to 8.7. However, when the distance between the target and the missile increases and the intersection angle exists, the signal-to-noise ratio is very smaller. Especially, when the intersection angle between the target and the missile reaches 19.1°, the laser echo energy output reflected by the target is only 0.683V. This value is basically close to the value of the inherent noise of the detection system. The signal-to-noise ratio is less than 1.46, so the detection probability is basically 0.

According to the above quantitative simulation test results, the detection capability of the missile optical detection system is mainly reflected by the signal-to-noise ratio of the whole detection system. Only when the signal to noise ratio is satisfied, the detonation derive of the detection system can be worked, then the damage effect is achieved. At the same time, from the principle of laser scanning missile photoelectric detection system, we know that the photoelectric receiving system for laser emission and target laser reflection energy has a certain field of view. For the same target, at the same distance, if the target is at the edge of the field of view of the receiving light path, compared with the distance from the center of the field of view, the distance at the edge of the field of view is slightly longer, according to formula (10) and (15), If the detection distance is long, the reflected energy will be weakened.

6. Conclusions

This paper establishes the calculation model of the distance between missile and target, the signal-to-noise ratio of photoelectric detection system and the detection probability of the photoelectric detection system, and analyzes the influence of the change of the space relationship between missile and target on the missile photoelectric detection ability based on the missile photoelectric detection mechanism and the space position relationship between missile and target. Combined with the established mathematical model, quantitative calculation and quantitative simulation test, the relationship between the missile photoelectric detection performance and the signal-to-noise ratio of the system is analyzed. The results of calculation and test show that under the same detection mechanism, the farther the distance between the target and the missile, the lower the signal-to-noise ratio is detected. Under the condition of the same distance, the greater the intersection angle between the target and the missile, the smaller the echo energy and signal-to-noise ratio is. The research results of this paper provide a theoretical basis for improving the design of missile photoelectric detection system.

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