Target Photoelectric Detection and Laser Countermeasure Game Antagonism Analysis in Laser Detection System

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Abstract
In order to improve the detection capability of laser detection system in sea surface and master Laser countermeasure information. This paper research a detection capability of laser detection system and set up its calculation model in terms of the solar irradiance of optical detection system and target reflection characteristic, build SNR model and give calculation method, analyze the relationship among the background illumination, target caliber and the SNR; research the offensive/defensive problem in an uncertain environment by analyzing the uncertain information of target value and damage probability, and establish an offensive/defensive payoff function in uncertain information and the game payoff matrix, obtain the Nash equilibrium value of the game by combining the particles swarm optimization algorithm and the interval numbers multiple attribute ranking method in the case of uncertain information. Through experiment and calculation, the result shows when the background luminance is stronger, the detection performance will be weaken in photoelectric detection system, and verify the game antagonism is scientific and correct.

Key words: LASER DETECTION, SNR, LASER COUNTERMEASURE, GAME ANTAGONISM, NASH EQUILIBRIUM

1. Introduction

With the diversification of naval combat mission and the widely usage of the shipboard photoelectric sensor devices in navy surface ships, the problem that how to effectively and accurately detect enemy targets and destroy enemy targets is more and more significant. Since the environmental characteristics in sea surface, the detection capability of detection system with the laser detection system to detect the target in sea surface is not satisfactory [1-2]. The performance of detection system is affected by many factors, such as the scattering of the sea background light, the reflected light of the sunlight on targets, the optical system parameters of the photoelectric detection sensor, ever the responsiveness of the laser photoelectric detector, etc., especially the serious decay of the detection capability of the laser photoelectric detector for long-range target under the environment of the sea surface, resulted from the influence of the sea clutter[3]. Currently, the relevant research is just focusing on the analysis of optical turbulence and aerosols, and the influence of the natural phenomena happened in sea surface, such as refraction and diffraction. This paper sets up detection capability model of the sea level laser detection system via solar irradiance and target reflection characteristics of optical detection system, and the expression of the SNR is derived. The variation of background illumination, target diameter and SNR is analyzed. The research on the game theory has already made some valuable research at home and abroad, but in the existing research results, the battlefield environment information is mostly determined, the target value is also the determination value [4]. However, in the actual battlefield environment, the information cannot be obtained accurately [5]. This paper studies on offensive and defensive game under uncertain information environment, the game model on enemy side and on our own under uncertain information is established. A payoff function under uncertain information is established and the game payoff matrix is built via analyzing the uncertain information of target value and damage probability. Using the possibility formula of interval information, the particle swarm algorithm is used to solve Nash equilibrium value, which can implement optimal results of the game strategy in the attack and defense.

2. The mechanism of laser target detection in sea level

Laser detection system in sea surface is composed of two parts which are laser emission part and laser search receiver part [6]. The detection schematic diagram of laser detection system is shown as Fig.1. The shorter the laser pulse duration is, the higher the transmitting frequency is, and the more be propitious to detect the radiation energy of high speed target through the detection field of view. The laser search receiver part mainly adopts photoelectric search receiver which has low noise and high responsivity characteristics, the value of reflective energy on target surface is used to ascertain detection ability target of space target [7]. In this paper, the target detection performance model is effectively set up based on the photoelectric detection SNR of the laser detection system. So the function of the target characteristic, the background illumination and the target reflection of the laser detection region is studied.

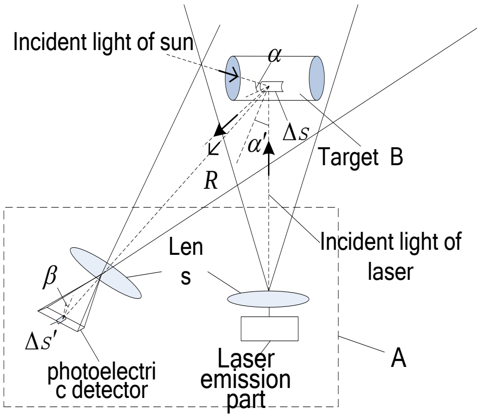

Figure1. Detection schematic diagram of laser detection system

As shown in Figure 1, A is a laser guidance unit, which has two parts, laser detection and laser emission. When A detects the enemy target B, using detection guidance function, A is close to the target B. When the distance between A and B is lower than a certain value, A explodes to damage B to complete the attacking task of target B. Because both A and B are guided by the device, B will also perform the same attack damage task to A at the same time. A and B complete the mission in flight, in order to effectively damage the target B, as far as possible to improve the detection performance of laser detection system.

3. Target characteristic analysis of laser detection system

The space target is not luminous by itself, but the target will radiate from the solar energy when the target is irradiated by the sun. Then, the light energy received by the laser photoelectric detector will have a portion of the energy that comes from the reflective energy from sunlight. The schematic diagram of the target irradiated by the sun is shown in Figure 2. $\vec{n}$ is the normal direction on the surface element ds of target, and the angle between the incident sunlight and the normal direction is α and $\alpha \in \left(-\pi/2,\ \ \pi/2\right)$, and β stands for the angle from connecting the laser photoelectric detector to the center of the target and the normal direction $\vec{n}$ and $\beta \in \left(-\pi/2,\ \ \pi/2\right)$.

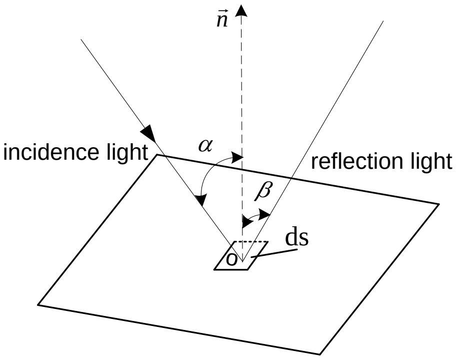

Figure2. Schematic diagram of the sunlight on the target

Assumed the solar spectral irradiance is $E_{sun}(\lambda)$, and the area irradiated is S_1, then the solar radiation received by the target is:

$$d\Psi = \int S_1 \cos\alpha E_{sun}(\lambda) d\lambda \tag{1}$$

In formula (1), α is the angle between the incident sunlight and the normal direction, which is shown in Fig.2.

Due to the difference of wrapping material, the dielectric constant, and the surface roughness of the targets, different targets exhibit different reflection characteristics [8]. Assuming an average reflectance from the target surface is $\tilde{\rho}$, and then the reflected luminous flux of the target is:

$$d\Phi = \int \tilde{\rho} S_1 \cos\alpha E_{sun}(\lambda) d\lambda \tag{2}$$

When the effective reflection area of spatial objects is S_2, and β stands for the angle from connecting the laser photoelectric detector to the center of the target and the normal direction $\vec{n}$, which is shown as Fig.2. When the target is illuminated by sunlight, the illumination of the space target on the photosensitive surface in the laser receiving detector is:

$$E_1 = \frac{\tilde{\rho} E_{sun} S_1 S_2 \cos\alpha \cos\beta}{\pi R^2} \tag{3}$$

In formula (3), E_{sun} is the illumination of the target from the sunlight.

In addition to the influence of the solar spectrum on the laser photoelectric detector and the reflection characteristic of the emission laser on the target will influence the energy of laser photoelectric detector. Supposing the angle between the incident laser and the normal direction of surface element ds' illuminated by laser is α', which is shown as Fig.1. The angle between the connection of the detector and the center of the surface element ds' illuminated by laser and the normal direction of surface element ds' illuminated by laser is β', and ρ' is an average reflectance from the target surface illuminated by laser. E' is illumination from the laser to target. The laser energy reflected by target acts on photosensitive surface of photoelectric detector, Illumination expression is shown as:

$$E_2 = \frac{\rho' E' S_1' S_2' \cos\alpha' \cos\beta'}{\pi R^2} \tag{4}$$

In formula (4), S_1' is the area irradiated by laser, and S_2' is the effective reflection area of target irradiated by laser.

The total radiant illumination on photosensitive surface received by the laser detection receiver is:

$$E = E_1 + E_2 \tag{5}$$

Then the light energy reflected from the space target acting into the pupil on the detector is:

$$\mathrm{E}_L = \frac{\eta \varepsilon S_3 (E_1 + E_2)}{\pi R^2} \tag{6}$$

In formula (6), η stands for the attenuation factor of the light energy in the communication process disturbed by the refraction, scattering and attenuation. ε is the transmittance of the optical system, S_3 is the area enter the system, $S_3 = \pi (D/2)^2$, D is the effective aperture of the optical system[9].

Then, the photoelectron number of the detector outputting is:

$$N_S = \frac{\kappa \varpi t E_L}{(hc/\vec{\lambda})} \tag{7}$$

In formula (7), κ is the response rate of the laser photoelectric detector, ϖ is the average quantum efficiency, and t is the minimum detection time when the detector has output signal, $\vec{\lambda}$ is the average wavelength.

The photoelectron number from background optical signal of detector outputting is:

$$N_B = \frac{\kappa \varpi_B t \eta \varepsilon A_B E_B}{(hc/\vec{\lambda})} \tag{8}$$

In formula (8), ϖ_B is the average quantum efficiency from background optical signal, A_B is area on the detector from background optical signal, E_B is the energy on the pupil of the detector from background optical signal. Then SNR of laser detection system is expressed as:

$$SNR = \frac{N_S}{N_{NOISE}} = \frac{N_S}{\sqrt{N_B}} = \frac{\kappa\varpi t E_L}{(hc/\vec{\lambda})} \Bigg/ \sqrt{\frac{\kappa\varpi_B t\eta\varepsilon A_B E_B}{(hc/\vec{\lambda})}}$$

(9)

According to formula (9), it can be calculate to the relationship between the photoelectron number on the surface from target radiation and SNR.

For the adversarial system, in order to effectively damage the enemy target, firstly, it is need to accurately detect the enemy targets, which requires laser photoelectric detection system taken on good detection performance.

4. The analysis of laser countermeasure model based on Game Theory

Under the condition on ensuring the premise of signal-to-noise ratio, due to enemy side and on our own both have the function to detect and attack each other, it is need to attack using strategy. The strategy is used to minimize our loss, and to maximize the damage of enemy target. In the actual battlefield environment, the information often cannot be accurately obtained, which often can be described as interval information in mathematics.

4.1. The establishment of payment functions under uncertain information

Supposing our assemblage is $\{A1, A2,...An\}$, and $a_{ij}(i=1,2,\cdots,n,\ j=1,2,\cdots,m)$ stands for our confrontation states. $a_{ij}=1$ stands for the attack from our laser fuze whose number is i to energy laser fuze whose number is j; $a_{ij}=0$ stands for abandoning attack of our laser fuze whose number is i and it is in defense state. The enemy also will find our laser fuze. Through the assessment of battlefield situation, the enemy laser fuze chooses whether to implement the counterattack to our laser fuze, or to be in defense state. Enemy assemblage is $\{B1, B2,...Bm\}$, $b_{ji}(i=1,2,\cdots,n,\ j=1,2,\cdots,m)$ stands for enemy confrontation states. $b_{ji}=1$ stands for the attack from enemy laser fuze whose number is j to our laser fuze whose number is i; $b_{ji}=0$ stands for abandoning attack of enemy laser fuze whose number is j and it is in defense state. Our strategy set is $\{a_1, a_2,...a_n\}$ and the enemy strategy is $\{b_1, b_2,...b_m\}$. The strategy set of enemy side and on our own can be summarized as follows {attack and task allocation, abandoning attack into defense} [10].

Payment is the final gain or loss of player in game. In the game, the enemy loss must be our gain. The sum of enemy side and on our own is zero. Assuming the formation value information matrix of our one laser fuze is $W_a = \left[w_1^a, w_2^a,..., w_n^a\right]$, and w_i^a is the value information of our laser fuze whose number is i. Damage probability for whole enemy target of our laser fuze, whose number is i, is $P_i^a = \left[(p_{i\min}^{a1} p_{i\max}^{a1}), (p_{i\min}^{a2} p_{i\max}^{a2}),..., (p_{i\min}^{am} p_{i\max}^{am})\right]$. $(p_{i\min}^{aj} p_{i\max}^{aj})$ stands for damage interval probability from our NO.i laser fuze to enemy NO.j laser fuze. The formation value information matrix of enemy one laser fuze is $W_b = \left[w_1^b, w_2^b,..., w_m^b\right]$, and w_j^b is the value information of enemy laser fuze whose number is j. Damage probability for whole our target of enemy laser fuze, whose number is j, is $P_j^b = \left[(p_{j\min}^{b1} p_{j\max}^{b1}), (p_{j\min}^{b2} p_{j\max}^{b2}),..., (p_{j\min}^{bn} p_{j\max}^{bn})\right]$. $(p_{j\min}^{ai} p_{j\max}^{ai})$ stands for damage interval probability from our NO.j laser fuze to enemy NO.i laser fuze. The attack value of our laser fuze is $W_a' = \left(w_{\min}^a w_{\max}^a\right)$, the value of enemy counterattack our is $W_b' = \left(w_{\min}^b, w_{\max}^b\right)$. The payoff function of our laser fuze is

$$Z_a = \sum_{i=1}^{n} a_{ij}\left(P_i^a W_b - W_a'\right) - \sum_{j=1}^{m} b_{ji}\left(P_j^b W_a - W_b'\right) \quad (10)$$

In formula (10), a_{ij} and b_{ji} are both two valued decision variable.

Because of the information is uncertain, each element in the payoff matrix is an interval number. Each row vector of the matrix responds to our pure strategy a_i, each column vector responds to a pure strategy b_j of the enemy, the payoff matrix in game is shown as follows:

$$\begin{array}{cc} & \begin{array}{cccc} b_1 & b_2 & \cdots & b_m \end{array} \\ \begin{array}{c} a_1 \\ a_2 \\ \vdots \\ a_n \end{array} & F_a = \begin{bmatrix} F'_{a11} & F'_{a12} & \cdots & F'_{a1m} \\ F'_{a21} & F'_{a22} & \cdots & F'_{a2m} \\ \vdots & \vdots & \vdots & \vdots \\ F'_{an1} & F'_{an2} & \cdots & F'_{anm} \end{bmatrix} = \begin{bmatrix} \left(f_{\min}^{a11} f_{\max}^{a11}\right) & \left(f_{\min}^{a11} f_{\max}^{a11}\right) & \cdots & \left(f_{\min}^{a1m} f_{\max}^{a1m}\right) \\ \left(f_{\min}^{a21} f_{\max}^{a21}\right) & \left(f_{\min}^{a22} f_{\max}^{a22}\right) & \cdots & \left(f_{\min}^{a2m1} f_{\max}^{a2m}\right) \\ \vdots & \vdots & \vdots & \vdots \\ \left(f_{\min}^{an1} f_{\max}^{an1}\right) & \left(f_{\min}^{an2} f_{\max}^{an2}\right) & \cdots & \left(f_{\min}^{anm} f_{\max}^{anm}\right) \end{bmatrix} \end{array} \quad (11)$$

In formula (11), $F'_{ai1}, F'_{ai2}, \cdots, F'_{aim}$ are the different payment values of our laser fuse, when our strategy is a_i and the enemy takes tactics $b_1, b_2, \cdots, b_m$ separately. In the paper, the payment values of our laser fuze are the interval number: $\left(f_{\min}^{ai1}\, f_{\max}^{ai1}\right), \left(f_{\min}^{ai2}\, f_{\max}^{ai2}\right), \cdots, \left(f_{\min}^{aim}\, f_{\max}^{aim}\right)$ [11].

4.2. An analysis method of solving the Nash equilibrium value based on the possibility of interval degree

When $f'_1 = \left(f_{\min}^{1}\, f_{\max}^{1}\right) > f'_2 = \left(f_{\min}^{2}\, f_{\max}^{2}\right)$, it can be concluded that the probability formula via possible degree definitions based on comparing two interval numbers:

$$p_{f'_1 > f'_2} = \begin{cases} 1, & f_{\max}^2 \le f_{\min}^1; \\ \dfrac{f_{\max}^1 - f_{\max}^2}{f_{\max}^1 - f_{\min}^1} + \dfrac{f_{\max}^2 - f_{\min}^1}{f_{\max}^1 - f_{\min}^1} \cdot \dfrac{f_{\min}^1 - f_{\min}^2}{f_{\max}^2 - f_{\min}^2} + 0.5 \dfrac{f_{\max}^2 - f_{\min}^1}{f_{\max}^1 - f_{\min}^1} \dfrac{f_{\max}^2 - f_{\min}^1}{f_{\max}^2 - f_{\min}^2}, & f_{\min}^2 < f_{\min}^1 < f_{\max}^2 \le f_{\max}^1; \\ \dfrac{f_{\max}^1 - f_{\max}^2}{f_{\max}^1 - f_{\min}^1} + 0.5 \dfrac{f_{\max}^2 - f_{\min}^2}{f_{\max}^1 - f_{\min}^1}, & f_{\min}^1 < f_{\min}^2 < f_{\max}^2 \le f_{\max}^1. \end{cases} \tag{12}$$

Correspondingly, when $f'_2 > f'_1$, the probability formula is shown as follows:

$$p_{f'_2 > f'_1} = \begin{cases} 0, & f_{\max}^2 \le f_{\min}^1; \\ 0.5 \dfrac{f_{\max}^2 - f_{\min}^1}{f_{\max}^1 - f_{\min}^1} \dfrac{f_{\max}^2 - f_{\min}^1}{f_{\max}^2 - f_{\min}^2}, & f_{\min}^2 < f_{\min}^1 < f_{\max}^2 \le f_{\max}^1; \\ \dfrac{f_{\min}^2 - f_{\min}^1}{f_{\max}^1 - f_{\min}^1} + 0.5 \dfrac{f_{\max}^2 - f_{\min}^2}{f_{\max}^1 - f_{\min}^1}, & f_{\min}^1 < f_{\min}^2 < f_{\max}^2 \le f_{\max}^1. \end{cases}$$

(13)

Supposing

$F'_{ai1} = \left(f_{\min}^{ai1}\, f_{\max}^{ai1}\right), F'_{ai2} = \left(f_{\min}^{ai2}\, f_{\max}^{ai2}\right), \cdots, F'_{aim} = \left(f_{\min}^{aim}\, f_{\max}^{aim}\right)$ are the different payment values of our laser fuse, when our strategy is a_i and the enemy takes tactics $b_1, b_2, \cdots, b_m$ separately. According to formula (12), the interval values compare by pairwise, the possibility degree matrix can be obtained:

$$\begin{array}{cc} & \begin{array}{cccc} F'_{ai1} & F'_{ai2} & \cdots & F'_{aim} \end{array} \\ \begin{array}{c} F'_{ai1} \\ F'_{ai2} \\ \vdots \\ F'_{aim} \end{array} & P = \begin{bmatrix} - & p_{12} & \cdots & p_{1m} \\ p_{21} & - & \cdots & p_{2m} \\ \vdots & \vdots & \vdots & \vdots \\ p_{m1} & p_{m2} & \cdots & - \end{bmatrix} \end{array} \tag{14}$$

In formula (14), p_{xy} is the possibility degree when $F'_{aix} > F'_{aiy}$. $p_{yx} = 1 - p_{xy}$, $x, y \in \{1, 2, \cdots, m\}, x \ne y$, $p_{xx} = ('-')$ stands for any information need not be given for comparing the interval number F'_{aix}. $\forall x \in \{1, 2, \cdots, n\}$. The matrix P is a complementary judgment matrix and the value of p_{xy} is used to describe the extent of interval payment F'_{aix} excelling over F'_{aiy}. When $p_{xy} = 1, F'_{aix}$ is absolutely superior to F'_{aiy}; when $p_{xy} = 0$, F'_{aiy} is absolutely superior to F'_{aix} [12]. The possibility of the interval number is obtained by comparing the value of the interval objective function by pairwise. The scheme is sorted via the sorting method of complementary judgment matrix to obtain the optimal scheme.

4.3. Solving Nash equilibrium value based on particle swarm optimization algorithm

According to payoff matrix under uncertain information, using the possibility formula of interval information, the particle swarm algorithm is used to solve Nash equilibrium value, which can implement optimal results of the game strategy in the attack and defense.

Assuming our strategy set is $\{a_1, a_2, \ldots a_n\}$, Nash equilibrium value can be obtained:

$$w = \max \min_{1 \le y \le m} \sum_{i=1}^{n} F'_{aiy} a_i \tag{15}$$

The solution on Nash equilibrium of single matrix can be transformed into linear programming problem. The yield values of each solution in uncertain information environment are interval numbers. Assuming $w'(a) = \min\limits_{1 \le y \le m} \sum\limits_{i=1}^{n} F'_{aiy} a_i$, the formula (15) can be converted into the following mathematical programming problems:

$$w = \max w'(a) \tag{16}$$

$$s.t. \quad \begin{cases} \sum\limits_{i=1}^{n} F'_{aiy} a_i > w'(a), & y = 1, 2, \cdots, m; \\ a_1 + a_2 + \cdots + a_n = 1, & \\ a_i > 0, & i = 1, 2, \cdots, n. \end{cases} \tag{17}$$

The solution Nash equilibrium of a single matrix is the optimal solution for linear programming of formula (16) and formula (17). In this paper, the game problem of single matrix whose yield values are interval numbers is solved by using particle swarm optimization [13-14].

Each individual optimal particle means the best place for the individual particle arrived, and the update is described as follows: Assuming $Y_i(t)$ is the optimal particle of last generation, the present optimal particle is $Y_i(t+1)$, the new particle is $N_i(t+1)$. $g(x)$ stands for adaptive value function, when particles satisfy the following: $Y_{g(N_i(t+1))>g(Y_i(t+1))} > 0.5$, $Y_i(t+1) = N_i(t+1)$; if $Y_{g(N_i(t+1))>g(Y_i(t+1))} \le 0.5$, $Y_i(t+1) = Y_i(t)$.

The global optimal particle is the best position for all particles. The possibility matrix is obtained by comparing the interval fitness value of present optimal particle by pairwise. According to the complementary possibility matrix ranking method to sort the interval fitness, the particle, whose ranking is first, is the global optimal particle.

5. Calculation and experiment analysis

5.1. Analysis on the detection capability of the system

We chose that the peak value emission power of emitting laser is 50W; the laser impulse frequency is 600Hz. The focal length of the emission laser lens is 20mm, the focal length of the receiving laser lens is 20mm. Receiving lens's transmission efficiency is 0.88 [15], the photosensitive surface area of photoelectric detection receiver is $3mm \times 3mm$, and the conversion response rate of the photoelectric detector is (2-6) $\times 10^{-6}$μs. Based on the SNR's formula of the laser detection system, the detection SNR change curve of the photoelectric detection system in different sky background luminance can be obtained under the condition of the unchanged solar altitude angle in the laser detection area.

Based on the SNR's formula of the laser detection system, under the condition of the unchanged solar altitude angle in the laser detection area, the detection SNR change curve of the laser detection system in different sky background luminance can be obtained. Fig.3 shows the change curves of SNR under different sky background luminance.

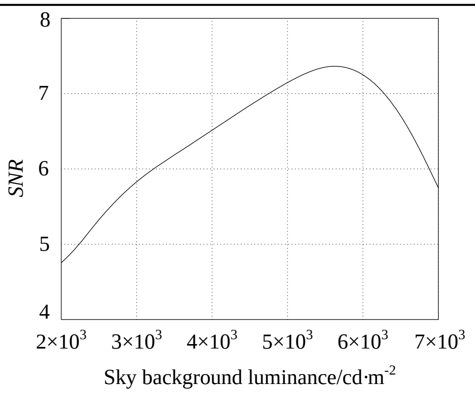

Figure 3. The change curves of SNR under different sky background luminance

It is known from Fig.3 that the laser detection SNR increases with the increase of the background luminance in the beginning, but afterwards it will decrease with the increase of the background illumination, when the laser optical detection system design parameters are unchanged. Because when the background illumination reaches a certain value, the amplitude of the target signal changes small, at the same time the inherent noise of the system still increases. According to the definition of SNR, the SNR of the laser detection system will decrease. As shown as Fig.3, the SNR reaches maximum value 7.3 when the sky background luminance is 5.5×10^3cd/m^2, and when the sky background luminance is 2.5×10^3cd/m^2, the SNR just is 5.4, which is cannot meet the SNR value of the laser detection system. The laser detection system cannot detect and recognize the target information.

For the laser detection system in sea surface, the higher the SNR is, the stronger the detection capability of the system is, while the SNR threshold is an important index for signal detection. In order to quantitatively research the system maximum detection range varies with the SNR threshold; it is to do the simulation study with changing SNR threshold value. As shown in Figure 4, when the SNR threshold is constant, the maximum detection range presents an inverse relationship with the incident angle. When the incident angle is constant, the maximum detection range decreases with the increase of the SNR threshold value. When the SNR threshold value is less than 2.5, the maximum detection range gets a sharp decrease with the increase of the SNR threshold. When the SNR threshold value is greater than 2.5, the maximum detection range changes slightly with the increase of the SNR threshold value, while the change of the incident angles don not impact the maximum detection range much. When selecting the parameter, the SNR threshold value is generally 4 or more, although has certain effect on the R, but the effect is not obvious. Thus, within a certain range, reducing the SNR threshold value can significantly improve the detection capability of the system.

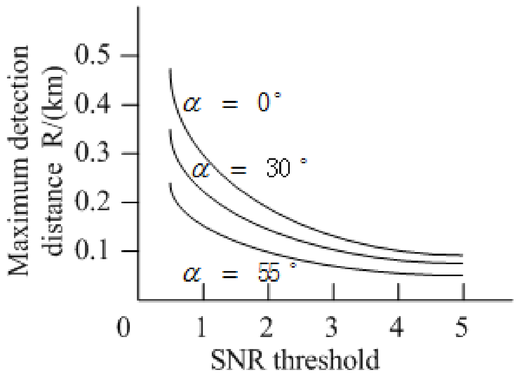

Figure 4. Relationship between maximum detection range and SNR threshold value

5.2. Experiment and analysis

To check the detection capability of the photoelectric sensor optical system in near sea surface, a photoelectric sensor detection system platform is established according the solar radiation characteristic of the target, the reflection properties, and the noise characteristics, even the computing formula of the maximum detection range, which means using high-speed acquisition card in a different sea background illumination to collect output analog signals from the photoelectric sensor under different distances, and take comparative analysis between analog signal amplitude of the output signal and the amplitude of the noise inherent. Usually the pulse signal of the dynamic target is obtained commonly by use comparing conversion processing methods in the detection circuit of the analog output signal, which can be used to measure whether there is a target in photoelectric detection sensor system. It is often to use more than a certain threshold voltage value as the critical state of the signal converting in comparison conversion processing circuit, and this threshold voltage value should be greater than the maximum amplitude of the currently background inherent noise in the circuit. According to this recognition principle, an experiment is taken in the sea surface for a simulated target.

The size of the simulated target is 2.1m × 0.3m, the optical lens is 85-125mm, the relative aperture is 1: 1.8, the distance from the photoelectric sensor to the target is 100m and 200m, which for dynamic testing in this two location points, and with the background illumination from 2.0×10^3cd / m^2 to 6.0×10^3cd / m^2 , we collect the target signal. The normal of the reflective surface of the target parallels to the axis of the optical detection system. Table 1 shows the output signal and the inherent noise signal of the photo sensor.

As can be seen from Table 1, under the same condition of detection distance, the amplitude of the output target signal is increased gradually with the increase of the background illumination, while a slight change in the inherent noise. When the background noise is less than 4.4×10^3, the signal amplitude of the target output change obviously, with an increasing trend, while the inherent noise almost unchanged. According to the definition of SNR, at 4.4×10^3 background illumination conditions, most of SNR are greater than 6.0. With a greater than 4.4×10^3 and less than 5.8×10^3 background illumination conditions, SNR is close to 5.5, which indicates that the contrast is clear with the 2.0×10^3 ~ 4.8×10^3 E/cd·m^{-2} background illumination, and the detection ability of photoelectric sensor detection system is relatively stable, even can improve the detection capabilities. Further, when the distance increases, under the same background illumination conditions, the inherent noise signal of photoelectric sensor detection system is almost constant, however the output signal of the target slightly decreased, and when the distance is increased. For the same target, the increase of the distance means the decrease of effective area from imaging to the photoelectric sensor photosensitive surface.

Table 1. Output signal and inherent noise signal under different illumination conditions

Num	Illumination conditions（$\times10^3$/cd·m^{-2})	110m detect distance(R/m)		130m detect distance (R/m)	
		Output signal with target（V/mV)	Inherent noise（V/mV）	Output signal with target（V/mV）	Inherent noise（V/mV）
1	2.0	3221	502	3044	509
2	2.3	3452	515	2986	516
3	2.6	3908	453	2876	515

4	3.0	3477	572	3115	602
5	3.7	3643	568	3009	565
6	4.4	3679	546	3245	498
7	4.8	4231	633	3315	552
8	5.2	3876	678	2988	608
9	5.8	3781	783	3102	765

At the same laser detection system, the decrease of effective area result in the attenuated intensity of the output signal, which substantially coincide the above theoretical analysis of the definition of SNR. When background illumination is greater than 4.8×10^3 /cd·m^{-2}, the output signal amplitude do not change significantly, but the inherent noise signal has a significant increase. This is mainly under the strong background illumination conditions, the influence of stray light outside on photoelectric detection system causes the photoelectric sensor to detect more spurious signals, according to the superposition principle of spurious signal in the photoelectric sensor detection system, the inherent noise signal output increases, which is easy to drown useful target signal in the background signal, result in it is hard to recognize the real target signal for photoelectric sensor detection system. Therefore, detection performance of the detection system is relatively poor under strong background illumination. In order to eliminate the influence of the strong background illumination, there is a need to use the filter technology to eliminate the influence, which at the same time improves the detection capability of photoelectric sensor detection system.

From the analysis of the detection capability and experiment situation, based on laser countermeasure model, in the confrontation between the two sides, firstly, it is need to ensure that we can identify the enemy, which requires that our detection system has good detection performance. Secondly, in the confrontation, we need to optimize our strategy, so that the smallest to lose, the greatest to damage enemy. If both of these points can be assured in the war, then our victory will be guaranteed.

6. Conclusions

The theoretical model of detection ability is established to analyze the detection ability and the affecting factors of the laser detection system on the basis of working principle of laser detection system and space targets characteristics. The calculation and analysis shows that the laser detection ability is closely related to the space targets characteristics and background. The detection ability is affected by the strong background light. We can use the appropriate spectral filter technology to improve laser detection capability under the strong background light in sea level detection system. The theoretical model of SNR and the calculation method in this paper provide a reliable basis for improving design laser detection system, which can improve detection ability of shipboard general purpose photoelectric detector in sea surface. The offensive/defensive problem in an uncertain environment was presented via analyzing the uncertain information of target value and damage probability. According to the attack value of information on both sides, payoff function in uncertain information was established and the game payoff matrix was built. The Nash equilibrium value of the game was obtained via combining the particles swarm optimization algorithm and the interval number multiple attribute ranking method in the case of uncertain information, which can provide the theoretical basis for the optimal strategy of offensive and defensive game in the uncertain environment.

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