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Quantitative evaluation of high repetition rate laser jamming effect on the pulsed laser rangefinder

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ABSTRACT

Laser may cause disfunction or even damage to laser rangefinder. Based on evaluation rules of high repetition rate laser jam pulsed laser rangefinder, the principles of distance deception and blinding jamming were analysed and the jamming success rate was calculated. We also set up a calculation example for 100 kHz repetition rate laser jam certain type rangefinder. The result showed that we can obtain jamming grade and success rate, accomplish the quantitative evaluation of the laser jamming effect.

1. Introduction

The laser ranging is one of the most mature technologies of laser application in the military. Depending on the working system, laser rangefinder can be divided into two types: the pulsed laser rangefinder and the continuous-wave phase laser rangefinder. Currently, the pulsed laser rangefinder is mostly used [1,2]. Therefore, the evaluation of laser jamming effect on the pulsed laser rangefinder is of great military significance.

The effective laser-based jamming techniques were developed in many countries. Currently, the laser jamming methods to photoelectric system may be divided into soft damage and hard damage: soft damage is using high repetition rate laser to deceptive jam systems with receive wave gate or low frequency work mode, saturate its photodetector to get a wrong output; hard damage is using high peak power laser to blinding jam systems with continuous or high frequency work mode, blind and even damage its photodetector [3–5].

Several studies dealing with countering infrared guided missile threat have been done [6]. The directed infrared countermeasure techniques can be categorized into jamming and damaging countermeasure techniques [7]. Older generation seekers, which are widely deployed and in service, are quite vulnerable to jamming. To jam these kinds of seeker heads, the repetition rate of the jamming source has to be adapted to the seeker head modulation, the jamming power has to be higher than the radiated power of the aircraft. Newer seeker types are often more vulnerable to damage than older generation seekers. The only possibility to counter these seeker head types is to damage or blind the detector with IR laser pulses of sufficient energy. In that case there is no need for high repetition rates like for jamming countermeasure, but for pulse energy that is orders of magnitudes higher than necessary for jamming. Laser may also cause disfunction or even irreversible damage to charge coupled device (CCD). The mechanisms of laser-induced functional damage to CCD have been reported [8–11]. The damage experiments were also developed using continuous laser or pulse laser [9,10], and it was found that the continuous laser can make full-screen saturated or supersaturated easily. However, to make an unrecoverable hard damage to the CCD detector is difficult [11]. However, CCD can be damaged completely after being irradiated by the pulse laser with high energy density, and can not be recovered [10]. A new type laser damaging technology using a combination of high repetition rate laser and high peak power laser have also been reported [12]. Compared with the high repetition rate laser and high peak power laser alone, the combined lasers may cause more serious damages to the CCD.

For laser rangefinder, the high peak power laser can instantly damage its probe in a certain distance space, but repetition frequency is too low to reach the interference effect used alone, so laser warning system needs to cooperate to use. High repetition rate laser (up to 100 kHz), can enter receiver of laser rangefinder and produce a closed signal in advance to lead ranging error.

Based on the principle of high repetition rate laser jamming, the relation between the repetition rate and the jamming effect have been analyzed theoretically, and the working mode was classified as suppressive jamming and deceptive jamming. The mechanism

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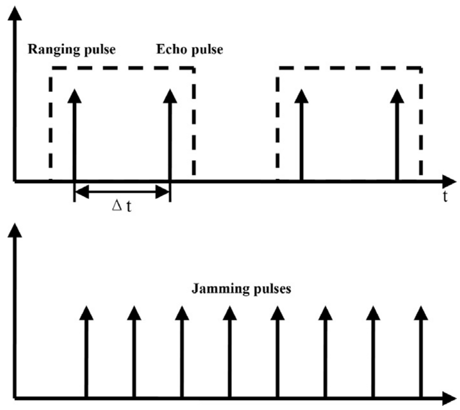

Fig. 1. The principle of jamming.

and characteristic of each mode were discussed [13–16]. But about the quantitative evaluation of high repetition rate laser jamming effect on the pulsed laser rangefinder has no reports. So, in this paper, we mainly study this problem.

2. Evaluation rules for high repetition rate laser jamming effect on pulsed laser rangefinder

The distance from the pulsed laser rangefinder to the target can be calculated exactly as Eq. (1) [17].

$$L = \frac{vt}{2} \tag{1}$$

where v is the propagation velocity of the laser in the atmosphere, t is the propagation time of the laser pulse.

The jamming principle is shown in Fig. 1. By making one or more jamming pulse enter the receiving circuit of rangefinder ahead of the backward wave, the high repetition rate laser will lead the distance calculation false or confused.

So the repetition rate of the jamming laser must satisfy Eq. (2).

$$f \geq \frac{v}{2L} \tag{2}$$

Evaluation rules include evaluation index and separation of jamming grade. In this paper, we mainly research on the below evaluation indexes: the probability of the jamming laser pulse enter the receiving circuit, the power of the jamming pulse that the receiving system gets, the minimum detectable power of the rangefinder, the saturation threshold and damage threshold of the rangefinder detector. The jamming grade can be separated into 4 levels as shown in Table 1.

In military application, the jamming grade must reach two or above, so we mainly analyze the distance deception jamming and blinding jamming.

Table 1
The jamming grades of high repetition rate laser on pulsed laser rangefinder.

Grade	Rangefinder state	Reason
0 (jamming failure)	Normal ranging	No jamming pulse enters the rangefinder receiving system or the power of jamming pulse entered is far less than the minimum detectable power of the rangefinder.
1 (ranging accuracy jamming)	Ranging accuracy decreased	The power of jamming pulse entered is slightly less than minimum detectable power, and this leads a delay to the counting circuit of the photoelectric detector.
2 (distance deception jamming)	Ranging results error	The power of jamming pulse entered is greater than the minimum detectable power of rangefinder.
3 (blinding jamming)	Can not ranging, temporary or permanent damage	The power of jamming pulse entered is greater than the saturation threshold or damage threshold of the detector.

3. Principles of distance deception jamming and blinding jamming

3.1. Principle of distance deception jamming

Two cases were treated to show how the laser jams rangefinder. Assuming that L_1 is the distance from the rangefinder to target, L_2 is the distance from the laser jammer to the rangefinder, L_{false} is the false ranging result, t_0 and t_1, respectively, are the launching times of ranging signal and jamming signal, and we assumed that $t_0 < t_1$.

Case 1: $L_2 > L_1$
The case 1 is illustrated in Fig. 2.
In this case, the ranging result is L_1. That means, the laser jammer cannot make any interference to laser rangefinder.
Case 2: $L_2 < 2L_1$
The case 2 is illustrated in Fig. 3.

The ranging result can be calculated as Eq. (3):

$$\begin{cases} L_{false} = \frac{1}{2} \cdot \left(t_1 - t_0 + \frac{L_2}{c} \right) \cdot c \\ t_0 < t_1 < \frac{L_1 - L_2}{c} + \frac{L_1}{c} + t_0 \\ L_{false} < L_1 \end{cases} \tag{3}$$

Fig. 4 shows the ranging results as the function of delay time between jamming signal and ranging signal when L_1 is 5000 m and L_2 is 4000 m, 5000 m or 7000 m. From the figure, when $L_2 < L_1$, the time dynamic range $(t_1 - t_0)$ is greater than that when $L_1 \leq L_2 < 2L_1$. This means that when the distance between the rangefinder and target is fixed, the closer the laser jammer to the rangefinder, the

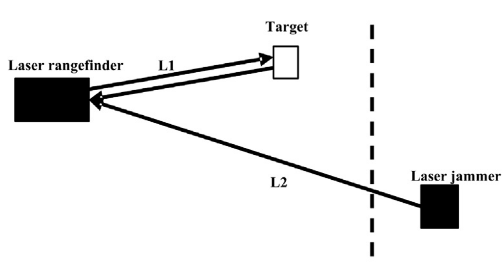

Fig. 2. Jamming case 1 ($L_2 > 2L_1$).

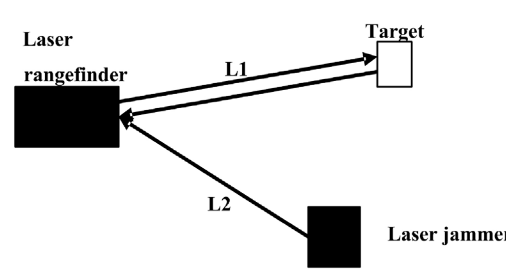

Fig. 3. Jamming case 2 ($L_2 < 2L_1$).