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Infrared decoys recognition method based on dual-band information fusion

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HIGHLIGHTS

- Difference in different aspects between targets and decoys.
- Simulation of decoys.
- Fusion of information from dual-band imaging system.

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ABSTRACT

Targets recognition is an important and difficult task in infrared guidance technology. But with the development of different kinds of infrared decoys, it is difficult to recognize targets from decoys only by information from single-band detectors. In order to improve targets recognition ability from decoys, more information should be used. In this paper, infrared radiation features of targets, infrared decoys and background are analyzed. Research shows that targets and decoys have differences in the thermal energy distribution in different bands because of their difference in material composition. Based on this difference, this paper proposes an information fusion method that fuses information from dual-band detectors to detect and recognize targets. Experimental results show that this method has a better performance compared to the method which only use information from single-band.

1. Introduction

Infrared flares and decoys are commonly used to prevent the missile seeker from locking on and lure the missile away from target platform [1,2,12]. So the ability of distinguishing targets from decoys and flares is an important performance indicator of guided systems. But the development and improvement of all kinds of infrared decoys have made a severe challenge to infrared guided missiles. Several algorithms for recognition between targets and decoys have been proposed and different information is utilized for distinguishing between targets and decoys in recent years. Chen and Shen [1] proposed a decoy recognition method for long wave infrared imaging seeker which uses the differences in materials and radiation characteristics between decoys and target aircrafts. This algorithm is simple and has less calculation, and it can be implemented in hardware easily. But the ability of anti-interference is poor in the case of close-distance imaging. For the non-point source infrared decoys which are made of new materials, some recognition methods using motion characteristics difference of targets and decoys which includes differences of centroid, principal axis, projection statistics, aspect ratio, etc. are proposed [3,4,14].

Almost all methods mentioned above recognize targets and decoys by using information acquired from single-band detector and they did not work for some infrared decoys which are made of new materials.

Currently, many countries are devoting themselves to the research of new type decoys, and have achieved good results [16]. Non-point decoys, aerodynamic decoys and towed decoys have appeared to counter infrared guided missiles. In a single band, these decoys not only can simulate the infrared radiation characteristics of targets, but also have similar kinetic characteristic with targets. So these recognition methods in a single band are difficult to get a good result. In addition, because of the heat exchange between target and background, atmospheric absorption, scattering and so on, thermal energy is attenuated in the process of transmission [5,6]. Therefore, the information acquired from

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infrared detection system is weak, which makes it difficult to distinguish targets from decoys if we only use the information acquired from single-band detector. For these reasons above, it is necessary to improve the performance of infrared detection system by using multi-band information. Now, some researchers have focus on the research of how to utilize information acquired from different band detectors [7,8].

The infrared radiation characteristics of different types of radiation sources in different bands are different essentially. In this paper, these differences of thermal energy distribution of targets, infrared decoys and other background noise in different bands are analyzed firstly by using Planck's Law and Wien's Displacement Law. Then a targets detection and recognition approach based on dual-band information fusion is proposed in this paper. Comparing with existing methods, fusing the information acquired from different bands can make full use of redundant or complementary information, and the probability of target recognition and anti-interference performance are improved.

2. The principle of dual-band anti-interference

To achieve the purpose of anti-interference by dual-band detection, all kinds of information acquired from detection system must be analyzed by seeker from different views. Then the target can be recognized by using the differences in different aspects between target and interference to achieve the purpose of anti-interference [15]. Although the radiation characteristics of target aircrafts can be simulated by infrared decoys in a certain extent, there are still many differences between targets and decoys.

2.1. Infrared radiation characteristics of targets

The main targets studied in this paper are aircrafts. Infrared radiation of aircrafts mainly includes the thermal radiation of engine nozzle, exhaust plume radiation caused by its high temperature, thermal radiation of aircraft skin caused by aerodynamic heating when aircrafts fly at a high speed and the reflection to environment radiation by aircraft skin. The nozzle of aircraft engine can be regarded as a gray body resource. Then its radiant intensity can be computed by using its temperature.

The nozzle of aircraft engine is assumed as a gray body resource, according to the Planck's Law:

$$M_{\lambda g} = \varepsilon M_{\lambda bb} = \varepsilon \times \frac{2\pi hc^2}{\lambda^5 (e^{hc/k\lambda T} - 1)} \tag{1}$$

where $M_{\lambda g}$ indicates spectral radiant exitance of gray body, its unit is W cm^{-1} μm^{-1}, ε is the emissivity of gray body, h represents Planck constant, c is the velocity of light, λ is the wavelength whose unit is μm, and T indicates absolute temperature whose unit is K.

When the aircraft is flying, the temperature of aircraft skin will rise because of aerodynamic heating, so the skin can produce a strong infrared radiation. The relation between skin's temperature and velocity of aircraft can be determined by the following formula.

$$T = T_0 \left[1 + \gamma \left(\frac{v - 1}{2}\right) Ma^2\right] \tag{2}$$

where T is the temperature of aircraft skin, T_0 is the temperature of the surrounding atmosphere whose value is between 200 K and 300 K, γ represents the coefficient of restitution whose value is 0.82 in laminar flow and 0.87 in turbulent flow. v is 1.4 and it indicates the ratio of heat capacity at constant pressure and heat capacity at constant volume of air. Ma is mach number which represents the velocity of aircraft. For the aircraft in laminar flow and stratosphere (above 11.3 km), formula (2) can be simplified as the following.

$$T = T_0(1 + 0.164\ Ma^2) \tag{3}$$

By substituting formula (3) into Planck's Law, the infrared radiant exitance of skin can be derived. In paper [6], the author proposed that most of skin's infrared thermal radiation is in long-wave infrared band when the aircraft is flying at a low speed. With the increasing of flight speed, the peak wavelength of skin infrared radiation moves towards the middle-wave infrared band, but the long-wave infrared radiation still retains a lot of radiation energy.

2.2. Radiation characteristics of infrared decoy

Infrared decoys are the most commonly interference mean used to counter against infrared guidance missiles in modern combat aircrafts. Most of the fighters, fighter bombers and helicopter gunships have been equipped with a number of decoys.

The main technical metrics of infrared decoys include radiant intensity, the ignition time, the spectral characteristics, the burning time, the speed of ejection, aerodynamic characteristics and so on [9,10].

(1) Radiant intensity. Generally, radiant intensity of decoys must be stronger than the radiant intensity of target protected, and the radiant intensity value of decoys is about between 10 kW/sr and 100 kW/sr.
(2) Ignition time. The ignition time of airborne infrared decoys is usually a few tenths of a second. It is defined as the time spending on the process from starting ignition to the radiant intensity up to 90% of the nominal value.
(3) Spectral characteristics. Most of infrared decoys are chemical heat source, and their radiant characteristics can be approximated as the radiation of blackbody or gray body. When airborne infrared decoys are burning, the infrared radiation is mainly in the band of 1–3 μm and 3–5 μm.
(4) Burning time. In order to ensure the targets cannot be recaptured, the burning time must be long enough. Generally, the burning time of airborne infrared decoys is more than 4.5 s.
(5) Speed of ejection. In general, the speed of ejection is 15–30 m/s.
(6) Aerodynamic characteristics. It is mainly influenced by the aerodynamics of decoys and the relative speed of wind when the decoys is releasing.

2.3. Comparison and analysis of spectral characteristics between targets and decoys

From their respective infrared radiation characteristics of targets and decoys, it is known that targets have a continuous infrared thermal radiation, and its thermal radiation changes little since the temperature of targets are stable with time. But the infrared radiation of decoys lasts a short time. When the radiant intensity is large, the equivalent temperature of decoy's surface may be higher than the temperature of target, but the intensity changes rapidly. According to Wien's Displacement Law, the relation between λ_m (peak wavelength of spectral radiation) and T (temperature) can be formulated as follows.

$$\lambda_m T = 2898 \tag{4}$$

From the formula (4), we can know that target's infrared radiation characteristics determine that the peak wavelength of its spectral radiation changes little with time and decoy's characteris-