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Target Recognition and Accuracy Evaluation of Infrared Radiation Characteristics Measurement Equipment in Dynamic Environment

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Abstract: Infrared radiation characteristic measurement is an important means to obtain information such as target radiation brightness, temperature, and radiation intensity. The measured results can be used to detect and identify targets, and evaluate target stealth effects and other aspects. However, the measurement of infrared radiation characteristics is easily affected by dynamic environments, and it is often difficult to ensure the accuracy of the measured data of infrared radiation characteristics in dynamic environments. Therefore, this article began to study the target recognition and accuracy analysis of infrared radiation characteristics measurement equipment in dynamic environments, testing the calibration results of the medium wave infrared radiation measurement system under different integration times, and the imaging uniformity of the target surface in static and dynamic environments. In the experiment, the imaging uniformity of the target surface in static environments was between 0.9 and 1.1, while the imaging uniformity of the target surface in dynamic environments was between 0.7 and 1.6. The lower the uniformity of target imaging, the smaller the accuracy of infrared radiation measurement. Therefore, dynamic environments can affect the accuracy of infrared radiation measurement.

1. Introduction

Infrared radiation characteristic measurement technology is the most intuitive method to obtain the true spectral characteristics of aviation targets, and has very important significance in the military field. The target infrared radiation characteristic parameters obtained through inversion can be used to evaluate the infrared stealth performance of missiles, and can provide basic data for infrared early warning, antimissile, and infrared stealth technology of various weapons. In the field of equipment, the existing land based, air based, and space based infrared radiation feature measurement systems are important observation equipment for the development and launch of various types of military equipment.

There are many scholars studying infrared radiation. Some scholars believed that using polymer resonators with molecular vibration modes can be used to customize the spectral and angular characteristics of infrared thermal radiation. The resonators are composed of polymer films on reflective substrates [1-2]. Other scholars believed that with the discovery of nanomaterials and nanostructures and the emergence of engineering solutions, building envelopes with glass systems can independently modulate solar radiation in a wavelength band, which is a potential means to improve building energy efficiency and indoor visual comfort, and this approach has become increasingly feasible [3-4]. Other scholars believed that the use of infrared radiation is very widespread because it has recognized biological effects, such as antioxidant, neuroprotective, and anti-tumor effects [5-6].

Due to the increasing activities of people in space, the number of space objects is also increasing in this process, and the requirements for the detection, classification, and feature recognition of space objects are becoming increasingly high, with increasing importance. Infrared detection of targets in space is a kind of all-day detection, and is an important means to obtain the location and infrared radiation characteristics of space objects.

2. Target Recognition and Accuracy Evaluation of Infrared Radiation Characteristics Measurement Equipment in Dynamic Environments

2.1 Overview of Infrared Radiation Characteristics

The characteristics of targets include electromagnetic and optical characteristics, while optical characteristics include infrared radiation. The infrared radiation characteristics of targets and the environment are increasingly used in warfare. The methods of infrared radiation measurement experiments include ground experiments, laboratory simulation experiments, flight experiments, and so on. In these infrared characteristic measurements and studies, ground experiments are necessary because of their high cost performance, but the disadvantage is that they cannot obtain airborne radiation parameters. Jet aircraft experiments on the ground are often subject to various limitations and cannot achieve thermal equilibrium, which can have an impact on infrared measurement. Laboratory simulation experiments are often limited by many conditions and require many simplifications. Theoretical research is completed under many research assumptions, and is the result of theoretical analysis of target radiation sources to obtain characteristics, which often requires actual experiments to obtain. The flight test of military dynamic targets and environmental characteristics is mainly aimed at testing the infrared radiation characteristics of military targets such as aircraft, cruise missiles, ships, tanks, cars, and their backgrounds. It can not only provide true target and infrared characteristic data for the design and development of infrared weapons, but also provide technical services for infrared stealth and anti stealth, infrared simulation, precision guidance, infrared debt detection and surveillance, and other technologies. In addition, it can also be used for survivability testing and evaluation of weapon systems, and as a test tool to verify the infrared radiation characteristics of military aircraft.

As long as the temperature of any object is higher than absolute zero, infrared radiation would be generated. Therefore, it is possible to detect objects by receiving infrared radiation from the object. This method has many advantages. Infrared radiation properties are often used on advanced materials [7]. Infrared radiation characteristics are key data for target characteristics. The radiation of military equipment such as missile exhaust radiation requires a large amount of experiments and infrared radiation characteristics analysis. Infrared radiation can guide flight routes, which can improve target recognition capabilities and greatly help military equipment tracking and interception [8]. Infrared radiation also has certain risks. Infrared radiation irradiation of the skin can produce reactive oxygen species and cause mutations in the protease. Although not as severe as ultraviolet radiation, repeated infrared radiation exposure can cause skin photoaging [9-10]. Solar radiation is classified by wavelength, including visible, infrared, and ultraviolet light. Infrared radiation is the largest solar radiation that causes oxidative stress and aging of human skin [11].

2.2 Introduction to Infrared Radiation Characteristics Measurement System

The infrared radiation characteristic measurement system includes a tracking turntable electronic control system. The overall design of this system is based on the structural design, through the combination design of various subsystems and unit modules of the electronic control system, to complete the functions of the infrared tracking turntable.

The electronic control system in the infrared radiation characteristic measurement system has the functions of digital image processing, measurement data acquisition, and system management. It can identify and track the target, thereby measuring the trajectory and radiation characteristics of the target. Infrared radiation can be used not only in the military, but also in the detection of food enzyme activity [12-13].

The infrared radiation characteristic measurement system also includes a tracking turntable optical mechanical system, in which the visible light band function is to identify and record the visible targets in space, and the main functions of the long, medium, and short bands are to obtain the infrared images and radiation characteristics of the targets. The composition of the infrared radiation characteristic measurement system is shown in Figure 1:

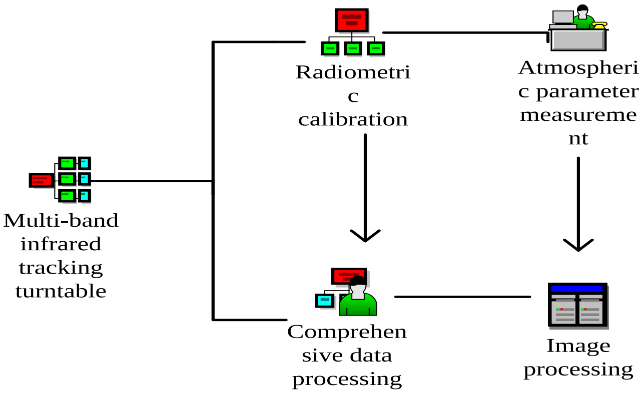

Figure 1: Infrared radiation characteristics measurement system composition

2.3 Measurement Principle of Infrared Radiation Characteristics and Infrared Sensor Principle

The measurement of infrared radiation characteristics is to convert the received thermal radiation into the radiation temperature of the object being measured through infrared thermal imaging. By using the radiation temperature, the infrared radiation intensity of the target can be calculated [14-15]. The infrared radiation algorithm is based on measuring data, then fitting the data into the output response curve of the imaging system, and then calculating the radiation temperature of the target through the gray value of the system. Because different infrared imaging systems have different gray values, it is necessary to calibrate the infrared radiation characteristic system.

The methods of infrared radiation measurement include close range imaging and remote imaging, which use the ground to calibrate the radiation of an infrared detection system to obtain indicators such as radiation distribution characteristics and radiation intensity. After correction by the infrared measurement system, calculations can be made based on the stored temperature of the thermal imaging system, so that the radiation temperature and radiation intensity of the target can be obtained.

High precision infrared sensors mainly include optical systems that use convex and concave lenses for imaging, mapping remote target images onto focal plane detectors; detector module: it is mainly composed of an array of sensitive components, wherein the sensitive unit is mainly composed of vanadium oxide, amorphous silicon, titanium, yttrium barium copper oxide, and other materials. It can convert the intensity of infrared radiation into the size of resistance. Under infrared radiation with a specific wavelength range, crystals can be obtained, and infrared radiation can be used for food drying [16-17]. Data processing module: generally, new modules are used to minimize system error using signal conditioning circuits. Subsequently, based on timing circuits, reference sources, and control circuits, the output voltage of sensitive units is detected one by one through scanning to achieve infrared target detection.

2.4 Basic Principles of Infrared Radiation Calibration

The foundation of infrared calibration is to achieve infrared radiation measurement, and the purpose of calibration is to establish the relationship between radiation amount and gray value, so that the quantitative relationship between radiation energy and imaging electronics components can be obtained, and the radiation brightness, radiation temperature, and radiation intensity of the target can be calculated. The process of infrared radiation calibration is shown in Figure 2:

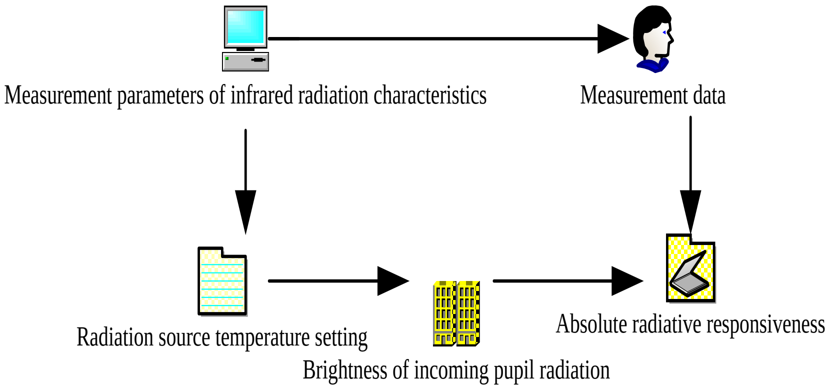

Figure 2: The process of infrared radiation calibration

2.5 Key Technologies of Infrared Radiation Characteristics Measurement Equipment

The key technology of infrared radiation characteristic measurement equipment includes infrared image fast processing and recognition. Infrared image processing technology can identify the target from the image signal through the infrared characteristics of the object, and then calculate the spatial position to achieve the purpose of automatic tracking. The key technology also includes system model identification technology. Through neural network technology, an appropriate model can be selected to approximate the actual system. Then, by analyzing the input and output data in the system, a suitable set of parameter errors can be found within a satisfactory range, enabling the system to complete the task of model identification.

2.6 Target Recognition and Measurement Accuracy of Infrared Radiation Characteristics in Dynamic Environments

Infrared radiation has the function of observing atmospheric temperature. In target recognition of infrared radiation characteristics measurement equipment in dynamic environments, infrared imaging seekers would separate the target from complex scenes after acquiring infrared images.

Among the various features separated, the edge is the most basic feature, and the edge contains a large amount of image information. Therefore, it is necessary to preprocess the edge information, which is the foundation of target recognition and target tracking. Many infrared image guidance systems are non zoom imaging systems, which is not conducive to the expression and recognition of multiscale targets. Therefore, it is necessary to find an adaptive multiscale wavelet edge detection method for target detection and recognition.

Materials and systems that statically reflect electromagnetic spectrum infrared radiation support the performance of many inherent technologies, including building insulation, energy-saving windows, spacecraft components, electronic shielding, container packaging, protective clothing, and camouflage platforms [18]. Various photoreduction conversion devices under infrared radiation utilize the photophysical process of fusion conversion to convert two low-energy photons into high-energy photons [19].

Instability of the platform in a dynamic environment can affect the accuracy of infrared radiation measurement. Due to the relative shaking of the measuring device and the measured target, this can lead to inaccurate pixel measurements in the image, and the data may be the average value of thermal radiation from multiple locations. The integration and thermal response time of an infrared measurement system can also have an impact on the accuracy of infrared measurement. The shorter the integration and thermal response time, the higher the measurement accuracy. For example, the integration time of a medium wave cooled infrared detector is a few milliseconds, while that of a long wave cooled infrared detector is a hundred microseconds, and the thermal response of a non cooled infrared detector is several tens of milliseconds. Due to the short integration time, the platform shake of the long wave cooled detector is relatively small, and the measured distance is also twice that of the non cooled detector. With the same measurement distance, cooled detectors have higher resolution, making them more suitable for use in situations with large temperature differences [20].

Another factor affecting infrared radiation measurement is the temperature change of the lens and hood. Due to the fact that the infrared radiation characteristic measurement device not only receives radiation from the target, but also receives radiation from the lens and hood, the initial temperature of the infrared radiation measurement device lens cannot be fully determined. Therefore, during the operation of the device, due to changes in the radiation of the lens and hood, the temperature of the lens and hood would also change.

2.7 Infrared Radiation Characteristics Measurement Technology

In infrared radiation characteristic measurement technology, the field of view of a single pixel of a detector is e, the detection area of the detector for a single pixel is r, and the distance between the target and the detector is l. The calculation method for the actual effective field of view of the target for a single pixel of the detector is shown in Formula 1:

$$h = \frac{r}{l^2} \tag{1}$$

The irradiance of the target background received on a single pixel is shown in Formula 2:

$$Z(X) = T(X) \cdot h + J(e - h) \tag{2}$$

In Formula 2, T(X) is the average radiant brightness of the target's response in the detector band, and J is the average radiant brightness of the background film.

When the optical system focuses on the infrared focal plane, the spectral radiation power on the photosensitive surface is shown in Formula 3:

$$M(X) = [Z(X) \cdot P + T(X) \cdot h] \cdot Z(X) \tag{3}$$

P in Formula 3 represents the effective luminous area of the optical system.

3. Dynamic Environment Infrared Radiation Characteristics Measurement Experiment

This article has experimented with the impact of platform swing on the measurement results. Using a long wave uncooled infrared thermometer to perform platform swing, it can be found that the imaging of the edge of the blackbody source is relatively clear through the temperature measurement results of the imaging of the blackbody source under static state using the thermometer. When measuring the temperature of the image in the swing situation, it can be found that the edge image of the blackbody source is relatively blurred, but the central image does not change much compared to the static image. The reason may be that the center of the blackbody source receives relatively uniform radiation, so the swing has little impact on the central image of its blackbody source. However, when the edge of a blackbody source is shaking, it would receive a relatively weak energy of background radiation compared to blackbody radiation, which would cause the measured temperature to decrease, resulting in a deviation in the measured value of infrared radiation characteristics.

In this experiment, this paper also tested the accuracy of radiation measurement for point and area sources using a medium wave infrared radiation measurement system with an aperture of 700 mm. In this experiment, this paper also conducted radiation calibration for the system of area source blackbody, which allows the effective radiation surface of the blackbody to completely cover the entrance pupil and field of view of the system. The calibration results of the medium wave infrared radiation measurement system at different integration times are shown in Figure 3:

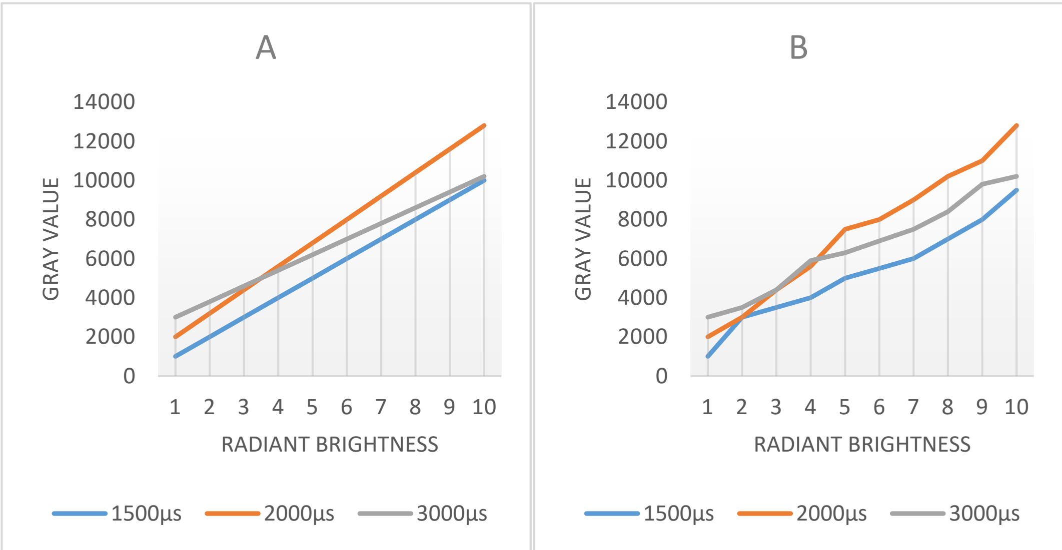

Figure 3: Radiometric calibration results

Figure 3A represents the calibration results of the system under static state. The experimental fitting results show that the radiation brightness and gray level values are proportional under different medium waves, indicating that the system has good linearity at various integration times. Figure 3B represents the results of system calibration in a dynamic environment. It is found that the radiation brightness is not proportional to the gray value, which would create obstacles to the measurement of infrared radiation characteristics.

This article analyzes the target surface of the entire system. The imaging uniformity of the target surface under static conditions and the imaging uniformity of the target surface under dynamic environments are shown in Figure 4:

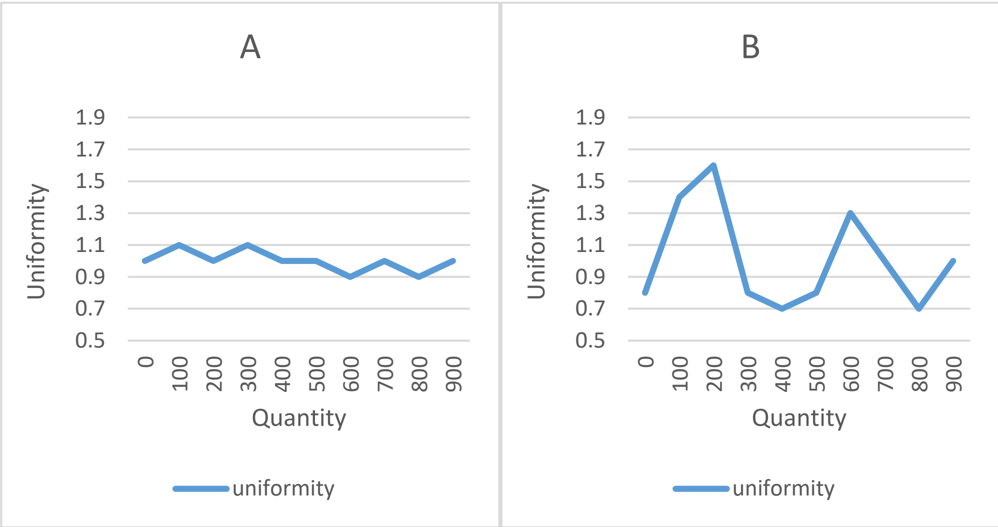

Figure 4: The uniformity of the calibrated image

Figure 4A represents the imaging uniformity of the target surface under static conditions, while Figure 4B represents the imaging uniformity of the target surface under dynamic conditions. The experimental results in Figure 4 show that the uniformity of the target surface under static conditions is concentrated between 0.9 and 1.1, indicating that the system has good uniformity and is conducive to improving the accuracy of target extraction. However, the uniformity of the dynamic target surface ranges from 0.7 to 1.6, indicating that the uniformity of the target surface is poor in dynamic environments, which can easily affect the measurement accuracy of infrared radiation characteristics.

4. Conclusions

Nowadays, various military powers in the world attach great importance to the measurement technology of infrared radiation characteristics. In the field of military target radiation measurement technology, research focuses on target recognition and optical radiation characteristics measurement in multi band and complex combat environments. However, infrared radiation characteristics measurement technology is often affected by dynamic environments. Therefore, this article focuses on target recognition and accuracy analysis of infrared radiation characteristics measurement equipment in dynamic environments, aiming to study the impact of dynamic environments on target recognition and accuracy analysis of infrared radiation characteristics measurement equipment. This paper experimentally tests the calibration results of a medium wave infrared radiation measurement system at different integration times and the imaging uniformity of the target surface in static and dynamic environments. Through the experimental data results, it can be clearly understood that the dynamic environment has a significant impact on the measurement of infrared radiation characteristics. Due to space reasons, the number of experiments conducted in this article is not enough. People would continue to explore the field of infrared radiation in the future.

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