Research of Limit Performance of Infrared Seeker Based on Image Information

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Abstract: For mastering the limit performance of weapon. Picked the main factors, used MORTARN, analyzed relations between them and atmospheric transmission, taken images of infrared seeker, calculated error, then got limit performance of the infrared seeker. Provides support for test and use of infrared seeker, and improves test design.

1. Introduction
Infrared imaging guidance has been widely used in countries since its birth in the 1970s [1] due to its all-weather work, strong anti-interference ability and good concealment [2]. It has been widely used in various military combat systems such as precision guidance, fire control, alarms and investigation. Infrared seeker mainly takes the infrared radiation difference between target and background obtained by the CCD sensor to pick the target [3], but on the way of Infrared radiation’s atmospheric transmission [4], many factors such as visibility [5], temperature [6] and relative humidity [7] can make a certain degree of influence which include the maximum capture distance of infrared seeker or unclear imaging of the captured target or small targets be can’t detected at normally distance. In the paper, the influence of different factors on infrared radiation transmission is analyzed combined with MODTRAN [8]. And based on the test image, the influence of different factors on infrared seeker is analyzed and then the limit performance of the infrared seeker, while it can provide technical support for the subsequent test design.

2. Infrared Radiation Detector Received
The attenuation of infrared radiation by atmosphere is mainly reflected in transmittance of infrared band and atmospheric path radiation [9]. Taking the anti-ship missile in the sea battlefield environment as an example, the infrared radiation received by the infrared seeker detection system includes the ship and environmental radiation; it can be considered unchanged for ship itself. The attenuation is caused by is caused by environmental factors, including solar radiation, sky radiation, sea surface radiation, and path heat radiation.

When target is far away from missile, its imaging as a point target in the infrared subsystem, and it has a so low probability of detection that may not be considered. However, when it is an area target, and occupies more than several pixels in image, the target's brightness equation is [10]:

$$L = c \cdot \int_{\lambda_{1}}^{\lambda_{2}} [N_{t}(\lambda) \cdot \tau_{a}(\lambda) + N_{a}(\lambda)] \cdot \alpha_{p} \cdot A_{o} \cdot \tau_{p}(\lambda) \cdot R(\lambda) d\lambda + B_{o}$$

Where: $c$ is gain coefficient, $N_{t}(\lambda)$ is spectral radiance of target, $\tau_{a}(\lambda)$ is atmospheric spectral transmittance, $N_{a}(\lambda)$ is path spectral radiance, $A_{o}$ is effective light-passing area of optical system, $\tau_{p}(\lambda)$ is spectral transmittance of the optical system, $R(\lambda)$ is voltage response rate of detector, $B_{o}$ is
When the environment changes, transmittance and contrast between target and environment are caused to decrease, so that imaging distance of the seeker is reduced, and imaged is blurred, and then found distance is to be reduced.

3. Influences of Main Factors
Due to the existence of atmospheric window, infrared seeker generally works in medium and long bands. Analyzes transmission of infrared radiation in medium band for different seasons (summer and winter) and main factors (visibility, temperature and humidity) according with MODTRAN. Results are as follows.

![Relation of infrared radiation and visibility](image)

**Figure 1.** Relation of infrared radiation and visibility
It can be seen from the figure that infrared radiation which be received increases exponentially as visibility increased, and the trend becomes gradually slowly while visibility reaching a certain value; and decreases logarithmically as temperature increased, especially at a certain temperature, the falling speed severe increased while at low and high temperature, it decreases slowly. At the same time, infrared radiation gradually decreases as relative humidity increases, when relative humidity is low, the speed is more slowly, but the downward trend is sharply accelerated while it is close to saturation (>80%). What’s more, it also can be seen that the attenuation of long band is smaller than middle band attenuation under the same conditions.

4. Image Information Mining

4.1. Model Check
MODTRAN is an atmospheric model established by the US Air Force Physics Laboratory based on years of meteorological data and experience. It has a certain use-error in different regions and climatic conditions. Collecting the test data and take a correction is necessary for get accurate seeker
performance indicators. Images of missile by infrared seeker under different distances are shown in figure 4.

![Image of different distances](image)

**Figure 4.** Images of different distances

It receives the infrared radiation of target for imaging, ignore influence of detection system's error and noise, and pixel value of image can be used in calculation as the infrared radiation received by detector. In the condition on the day of test, the transmittance at different distances be calculated by MODTRAN. Taking the infrared image obtained at 0.1km as the reference (ignoring the atmospheric attenuation), transmittance get by image and its calculated error by MODTRAN are calculated and shown in Table 1.

| number | distance/km | MODTRAN's transmission rate | image’s transmission rate | error |
|--------|-------------|------------------------------|---------------------------|-------|
| 1      | 0.1         | --                          | 1                         | --    |
| 2      | 7           | 0.6536                      | 0.6163                    | 6.0%  |
| 3      | 11          | 0.5226                      | 0.4830                    | 8.1%  |
| 4      | 13          | 0.3947                      | 0.3479                    | 13.4% |

Take mean value under different distances as calculation error of MODTRAN, and get the error is 9.2%. According to this error, it is possible to mine the change of maximum capturing distance of infrared seeker caused by parameters’ alter, and then obtain the limit performance of infrared seeker.

4.2 Analysis of Limit Performance

Combines the influence of main factors which act a role on the atmospheric transmission process of infrared radiation with image information, limit performance of infrared seeker under different environmental can be studied.

(1) On some test day, visibility is 12 km, relative humidity is 70%, temperature is 25°C, and the maximum distance of infrared seeker is 7 km. Assume the visibility alters from 5km to 40km, and other factors are unchanged. According to the relationship between infrared radiation transmission and visibility, the maximum capture distance of infrared seeker can be calculated. And result is shown in figure 5.
It can be seen that maximum capture distance increases as the visibility increases. Because of aerosol content decreases and atmospheric transmittance increases as visibility increases and the attenuation of infrared radiation decreases during transmission. At the same time, it can be foreseen that when visibility reaches a certain value, maximum capture distance will not change, and it has been reached the limit of infrared seeker.

(2) Another test day: cloudy, visibility is 15km, relative humidity is 60%, temperature is 10°C.
The infrared seeker captures target at 12km in test. According to the relationship between infrared radiation and temperature, the maximum capture distance of infrared seeker can be extended under different temperature while other conditions are unchanged. Relation between max-capture distance and temperature is shown in figure 6.

It can be seen that when temperature changes to 30°C, the calculated maximum capture distance is 1.1 km, and the capture distance becomes smaller as temperature increases. Subject to the objective environment, it should be cautious to take use when temperature is higher than 40°C, especially when visibility is also not ideal.

According to the relationship between infrared radiation and relative humidity, while others are unchanged, and the maximum capture distance can be extended under different relative humidity conditions. The result is shown in figure 7. As relative humidity increases, the capture distance decreases exponentially. The theoretical value of maximum capture distance is 5.3km when relative humidity reaches 90%, but when relative humidity reaches a certain value (95%), the infrared seeker is nearly unusable, and the theoretical value is 0.9km, which represents the limit performance of infrared seeker.
5. Conclusion
During the atmospheric transmission process, many factors such as visibility, relative humidity and temperature have a certain influence on target detection of the infrared seeker. Based on the analysis of variation of infrared radiation transmission by main factors, this paper analyzes image information of infrared seeker, and extends the limit performance of infrared seeker; it provides reference for infrared seeker’s using in different conditions. The test technical support and is of great significance for assessing missile performance and operational effectiveness.

6. References
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