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Study on Light Interference Simulation and Performance Evaluation of Low light Imaging System

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Abstract: For the modern battlefield influence flares, fire and other battlefield equipment shimmer light source for imaging performance, such as reconnaissance capability, through the study of the interference signal response mechanism are low light level imaging equipment, optical equipment, gain characteristics, and quantitative analysis of the battlefield fire and flares affect both light sources of interference imaging reconnaissance system for low light level imaging performance, respectively, to simulate the interference source is located in a different location, after radiation - the output image after the combined effect of shimmer system response system, revealing micro - transmission optical imaging equipment in the imaging light interference conditions under the law, the establishment of a study to assess the effect on image quality and detection distance changes under strong interference.

Keywords: Light Interference; Low light Imaging System; Response Feature; Simulation

INTRODUCTION

Strong light interference is a typical interference way on the modern battlefield. Its impact on photoelectric equipment imaging performance is diverse. Glare may make the features of the target more and more obvious. The imaging optical system gain and brightness self-adaptability may result in a substantial decline in the target imaging quality and imaging contrast; the impact of strong light on the photoelectric equipment detection performance will show different effects due to the different spatial positions of the interference source relative to the target; affected by the same kind of strong light interference, optoelectronic equipment of different band imaging such as visible light, dim light, infrared shows different interference effects[1].

Under the irradiation of interference light generated by interference source, since the light reflected by the target and background is strong, which to some extent will affect the photovoltaic equipment gain coefficient, thus further changing the contrast of target and background; the role of the target and background contrast change in visible light and infrared equipment is not obvious, but that in low light equipment is serious. Next, the paper will analyze the signal response characteristics of low light level imaging system and simulate the impact of two strong light sources such as flares and fire that are often used on the battlefield on low light level imaging system in case of different ranges[2,3].

2. SIGNAL RESPONSE CHARACTERISTICS OF LOW LIGHT LEVEL IMAGING SYSTEM

Low light level imaging system structure is shown in **Figure 1** below: low light level imaging system also includes two types of systems: direct visual system and indirect visual system, both of which are composed of the optical system, optoelectronic cathode, electron lens 1, micro channel plate, electron lens 2, and screen. The direct visual system is to image into the pupil of the human eye by the eyepiece. The indirect visual system is to collect information by CCD and transmit to the monitor, which is judged by the observer.

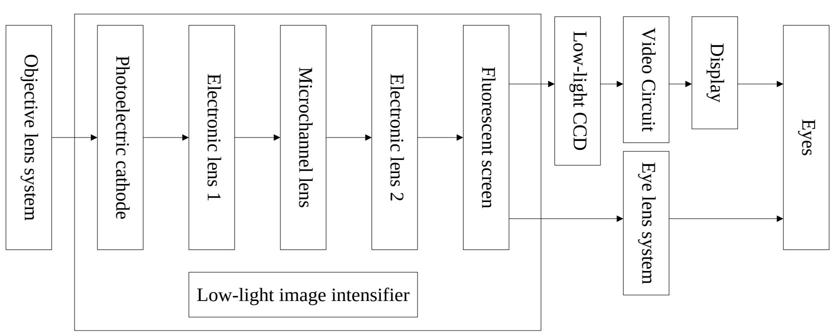

Fig.1: Diagram of low light level imaging system principle

Suppose the radial brightness of the target in the photoelectric scene is Ls:

$$L_s \tau_{atm} \beta = gray_s \qquad (1)$$

In (1), τ_{atm} is the radiation transmittance of the atmospheric environment; β is the conversion coefficient from the scene radial brightness to scene grayscale; grays are the gray value of the scene. According to the rule that the scene reflection energy transfers to each section of low light level imaging system step by step, energy transfer formula of low light level television imaging system is deduced. Suppose illumination at night is Ea and the target is Lambert reflector, brightness Ls after the target reflection is:

$$L_s = \rho_a E_a / \pi \qquad (2)$$

In (2), ρ_a is target reflection coefficient; the target illumination E_k on photocathode input face after atmospheric attenuation and the objective lens imaging system is:

$$E_k = \frac{\pi}{4}\left(\frac{D}{f}\right)^2 \tau_o L_s \tau_{atm} \qquad (3)$$

In (3), D is the effective aperture of the optical system; f is the focal length of the optical system; τ_0 is optical system transmittance; τ_{atm} is the atmospheric transmittance, which is related to the distance between the target and the imaging system. After photoelectric-electro-optical conversion, imaging device screen output target brightness Lp is:

$$L_p = GE_k \qquad (4)$$

In (4), G is the gain of device brightness. Supposing the device's electro-optical magnification is m; photocathode sensitivity is S_k; The working voltage of electron lens 1 and electron lens 2 are respectively V1, V2; the gain of micro channel plate (MCP) is G_{mcp}; luminous efficiency of the phosphor screen is ηp, which can prove that:

$$G = S_k (V_1 + V_2) G_{MCP} \eta_p / m^2 \qquad (5)$$

(5) The target brightness Le of transferring to the pupil of the human eye through eyepiece (coupling lens) is:

$$L_e = \tau_e L_p \qquad (6)$$

In (6), □τe is the transmittance of eyepiece or the coupling lens; and then through the low light CCD response, amplifying circuit, video circuit processing, the output voltage is:

$$V_{sys} = L_e \frac{\pi}{4}\left(\frac{D_e}{f_e}\right)^2 R_{ccd} A_{CCd} G_v \qquad (7)$$

In (7), De is the effective aperture of the eyepiece; fe is the focal length of the eyepiece; R_{ccd} is the detector response rate; G_v is video signal amplification. According to (1)-(6), it can be obtained:

$$V_{sys} = \left(\frac{\pi}{4m}\right)^2 L_s \left(\frac{D}{f}\right)^2 \tau_0 \tau_{atm} S_k (V_1 + V_2) G_{MCP} \eta_p \tau_e \left(\frac{D_e}{f_e}\right)^2 R_{ccd} A_{ccd} G_v$$

Then, after the output voltage of the system is quantified, the system output image gray scale is as follows:

$$Gray = \frac{255}{V_{max} - V_{min}} V_{sys}$$

Ion barrier membrane voltage and system noise in the actual low light level television system limit the minimum detectable signal. The CCD saturation limits the maximum detectable signal. The typical low light level television signal response function curve is "S" shape, as shown in 2. EMax and EMin respectively represent the illumination received by the system image intensifier photocathode surface when the system exactly reaches saturation and SNR (Signal-to-Noise Ratio) is 1, respectively corresponding to the system output image grayscale maximum $Gray_{Max}$ and minimum $Gray_{Min}$. Although infrared and low light level imaging systems have some differences in the imaging principle, this kind of photoelectric imaging system signal response degree function curve is basically the same in shape[4,5].

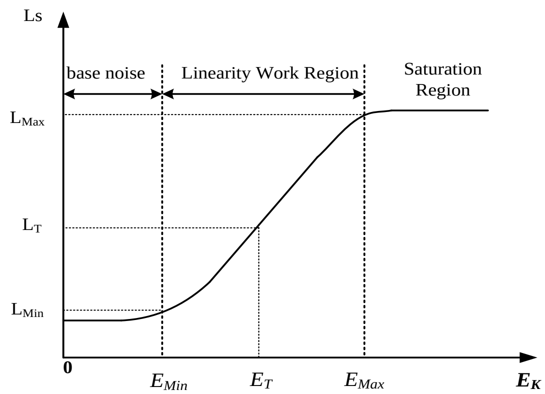

Figure 2: Typical low light level system signal response degree function curve

3. MODELING OF STRONG LIGHT SOURCE INTERFERING LOW LIGHT LEVEL IMAGING SYSTEM GAIN CHARACTERISTIC

Different from that of the infrared imaging system, the gain characteristic of strong light interference low light level imaging system is mainly gain characteristic of low light level system by influencing low light automatic brightness control circuit: when the incident light intensity change is small, the role of automatic brightness control circuit is small; when the incident light intensity change is big, the automatic brightness control circuit can reduce the gain of micro channel plate, so that image tube screen can maintain the proper brightness values [6].

To achieve this model building, first assuming that the maximum brightness of a typical scene is L_{Max}, the minimum brightness is L_{Min}, the brightness of a local area of the scene is L_{ij}, strong light source brightness is L_{Light}, the maximum gradation quantitative voltage is V_{Max}, the minimum gradation quantitative voltage is V_{Min}, micro channel plate gain value is G_{mcp} when there is no strong light. According to system signal response function, when there is no strong light interference, infrared imaging conversion voltage and the gray scale can be expressed as:

$$V_{ij} = \left(\frac{\pi}{4mf_o f_e}\right)^2 \tau_e R_{CCD} A_{CCD} G_V S_k \left(V_1 + V_2\right) G_{mcp} k_p \tau_0 \tau_{atm} L_{ij}$$

$$Gray_{ij} = \frac{255}{V_{max} - V_{min}} V_{ij}$$

When strong light interference source appears in the visual field, the voltage conversion gain of observing scene radiation in the entire field changes; in order to meet high dynamic range display of the scene, automatic brightness control circuit automatically adjusts the system micro channel gain gear. Its adjustment range and strong light brightness are closely related to the brightness value contributed by the system photocathode surface.

$$V_{Light} = \left(\frac{\pi}{4mf_o f_e}\right)^2 \tau_e R_{CCD} A_{CCD} G_V S_k \left(V_1 + V_2\right) G_{mcp} k_p \tau_0 \tau_{atm} L_{Light}$$

Assuming $(V_{Light}-V_{Min}) / (V_{Max}-V_{Min}) = n$, after the strong light interference source plays role, the gain of micro channel plate is automatically adjusted to $G'_{mcp} = G_{mcp} / n$. The image voltage of different pixel conversion is:

$$V'_{ij} = \left(\frac{\pi}{4mf_o f_e}\right)^2 \tau_e R_{CCD} A_{CCD} G_V S_k \left(V_1 + V_2\right) G'_{mcp} k_p \tau_0 \tau_{atm} L_{ij}$$

4. THE SUBJECTIVE EVALUATION METHOD OF INTERFERENCE EFFECT

4.1 Subjective evaluation method: There are many existing image quality evaluation methods. One of the most simple is the subjective evaluation method. Subjective evaluation method means that according to some pre-defined evaluation criteria or their own experience, the observer puts forward the quality judgment according to the visual effect and gives the quality scores. The scores given by all the observers are weighted average, and the result is the subjective quality of image. Subjective evaluation generally chooses two types of observer. One is experienced specialists, and the other is ordinary observers. These two types have different experience, so their angle of care may be different. Considering their last evaluation results are more convincing.

There are two scales for subjective quality evaluation, namely relative scale and absolute scale. The so-called absolute scale is to give absolute quality score results to known image. The relative scale is to determine the relative quality scale of an image in a group of images. Although subjective quality evaluation method better reflects the subjective quality of the image, the results are greatly influenced by the observer's subjective perception and behavior, and cannot be described with a mathematical model, and thus subject to certain restrictions in practical applications[7].

4.2. Quantitative evaluation method: A reliable image quality evaluation method can be used to correctly evaluate the image quality, the level of processing technology and the system performance. This section will analyze the simulation results through quantitative evaluation of interference image quality. Common objective image evaluation indicators are divided into two categories according to its applicable conditions. One is direct statistical calculations of a single image. These indicators include mean, variance, information entropy, average gradient, etc. The other is MSE（MSE，Mean Square

Error） and PSNR（PSNR,Peak Signal-to-noise Ratio） widely used in image compression and restoration to compare the original image and the interference image[8].

5. COMPREHENSIVE EFFECT OF STRONG LIGHT SOURCE ON LOW LIGHT LEVEL IMAGING SYSTEM

Strong light sources that affect low light level imaging system reconnaissance performance include battlefield fire and flares. According to the impact of strong light interference source on the target surface space radiation characteristics, the influence of the photoelectric system gain characteristic and saturation effect, the output image of low light level system after the combined effect of radiation-transmission-system response is simulated when interference source is in different positions, which provides experimental data base for studying the impact of interference sources in different locations on low light level system image quality and reconnaissance performance[9,10].

Low light level television system parameters are as follows: optical system f number fo is 1.7, optical system transmittance τ_0 is 0.9; photocathode sensitivity S_k is 700□A/lm; screen luminous efficiency K_p is 40lm/W; electron optics magnification m is 0.85; eyepiece f number f_e is 3, eyepiece transmittance τ_e is 0.78; video signal amplification G_V is 5 multiplied by 104; detector response rate R_{CCD} is 5 multiplied by 104V/W, system's effective photosensitive area A_{CCD} is 100μm^2; system voltage signal quantization range V_{min} is 0V, V_{max} is 5V.

Fig. 3 (a) indicates the system output image simulation results when the low light level system imaging is not interfered by flame light; Fig. 3 (b) represents the system output image simulation results when the flame is in the system view field and 40m in front of the target; Fig. 3 (c) represents the system output image simulation results when the flame is in the system view field and 40m behind the target; Fig. 3 (d) represents the system output image simulation results when the flame is in the system view field and 20m on the left of the target; Fig. 3 (e) represents the system output image simulation results when the flame is in the system view field and 20m on the right of the target; Fig. 3 (f) indicates the system output image simulation results when the flame is in the system view field and 900m away from the target.

Fig.3 (a):

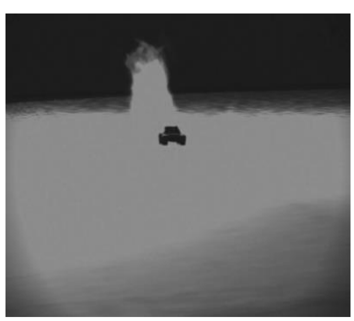

Fig.3 (b):

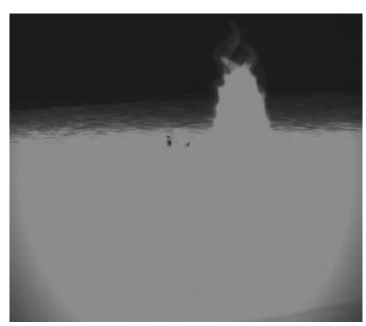

Fig.3 (c):

Fig.3 (d):

Fig.3 (e):

Fig.3 (f):

Fig. 4 (a) represents the system output image simulation results before flare is launched; Fig. 4 (b) indicates the system output image simulation results when the flare rises to a certain height H1; Fig. 4 (c) represents the system output image simulation results when the flare rises to a certain height H2(H2>H1). Fig. 4 (d) represents the system output image simulation results when the flare rises to a certain height H3 (H3> H2).

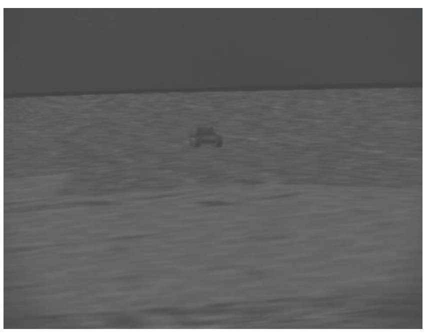

Fig.4(a):

Fig.4(b):

Fig.4(c):

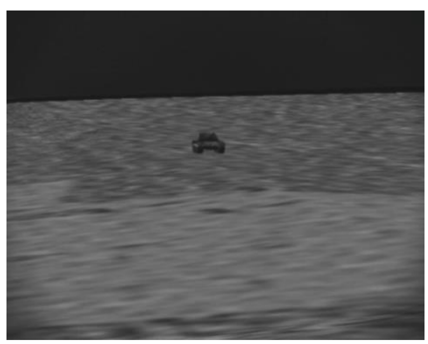

Fig.4(d):

6. RESULTION

Centering around the photoelectric equipment operating distance and evaluation method under strong light interference as well as energy transfer characteristics of low-light and infrared equipment, it has established low-light and infrared operating distance calculation model under strong light interference, subjective evaluation method of interference effects, and objective evaluation method of interference effects based on the average method, variance, average gradient method, mean square error, and peak signal-to-noise ratio method.

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REFERANCE

1. Zhang Fang-fang,Ruan Jiang-yang,Wang Xiao-rui.Research on the Performance Prediction of Infrared Imaging System Based on Laser Interference[J].Electronic Science&Technology. 2011.24（9）：149-153.
2. Wang Xiao-rui,Zhang Jian-qi,Feng Zhuo-xiang,Xie Wei-bo.Characterization method for low-light-levelTV imaging system[J].High power laser ang particle beams. 2004.16(9):
3. Liu Xin.Research on the Methods of Multispectral Infrared Imaging System Performance Characterization [D].Xi Dian University. 2012.
4. Liu Xin,Zhang Jian-qi,Wang Xiao-rui.Method for predicting the operation range of multispectral thermal imaging systems[J].Journal of Xi Dian University. 2013.40(2).
5. Tian Si.Key Technologies of Infrared and loe-level-light Image Real-time Fusion [D].Nanjing Universityof Science&Technology. 2010.
6. LUO Yuan,WANG Ling-xue,JIN Wei-qi. Developments of Image Processing Algorithms and Systems for LLL (Vis.)/IR Color Night Vision [J]. Infrared Technology. 2010.32(6).337-344.
7. Zhang Jun-ju,Chang Ben-kang,Zhang Bao-hui,Min Chao-bo,Yuan Yi-hui,Jiang Bin.Long-distance image fusion system for infrared and LLL/visible bands[J].Frared and Laser Engineering.2012.41(1).20-24.
8. Gu Qi. Cooled infra and low-light-level mixed reconnasossance technique—long distance low-light-level imaging system [D].Beijing Institute of Technology. 2015.
9. Guo Bing-tao, Wang Xiao-rui, Jing Wei-guo, Wang Xiao-bing,Chen Yu-jiao. Feature Quantitative and Simulation Analysis of Low-Light-Level TV Imaging under Highlight Disturbance at Different Locations [J].Acta Photonica Sinica. 2014.43(12).1024002-1一1024002-6.

10. Ru Zhibing,Liu Bing,Li Shuangquan. Design and experiment for polarization imaging system of low-light-level image imntensifier[J].Journal of Applied Optics. 2015.36(3).435-441

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