International Journal of Engineering

Journal Homepage: www.ije.ir

Research on Acquisition Probability of the Visible Light Reconnaissance Equipment to Ground Targets

Z. Liwen*[a], S. Ming[b], L. Na[a], Z. Qipeng[b], C. Xiangzheng[b]

[a] *School of Electrical Engineering, Henan University of Science and Technology, Henan, Luoyang , P.R. China*
[b] *Key Laboratory of Electro-Optical Countermeas ures Test & Evaluation Technology, Henan, Luoyang, P.R.China*

PAPER INFO

Paper history:
Received 15February 2016
Received in revised form 01April 2016
Accepted 14 April 2016

Keywords:
Visible Light Reconnaissance Equipment
Detection Probability
Intercept Range
Target-background Contrast

ABSTRACT

The detection probability of visible light reconnaissance equipment is one of key indexes to assess the performance of the system. The detection probability is determined by many factors, such as atmospheric visibility, target-background contrast, target size and distance, solar elevation angle etc. Based on the detection probability model of the visible light reconnaissance equipment to gain targets, chief factors affecting the reconnaissance capability of the visible light reconnaissance equipment are analyzed. With the simulation calculation of the model, the relations between the detection probability model of the visible light reconnaissance equipment and the parameters, which including the contrast between the target and background, atmospheric visibility, the solar elevation angles, the optical system magnification and intercept range, are analyzed. All these are beneficial to further evaluate the reconnaissance capabilities of the visible light reconnaissance equipment.

***doi**: 10.5829/idosi.ije.2016.29.04a.08*

1. INTRODUCTION

Modern military reconnaissance activities is done to obtain the intelligence information of the enemy operational activities, and to supply the intelligence for right decision-making or belligerent command adjusting. Military reconnaissance is the important guarantee for war victory. Especially in a war under the condition of information, once the objectis discovered and then destroyed, which gives higher demand for real-time battle field perception ability. So, the effects of military reconnaissance are more remarkable. To find a target and determine its position, basing on the nature of the target and characteristics of the environment, the reconnaissance equipment is used to search the targets in the possible area [1-5]. Owing to the influence of various factors, the results of the reconnaissance are always uncertain, random, so the statistical rule is usually described with the digital features of random events or random variables, and the most basic and the most commonly used method of which is the detection probability [6-10]. The detection probability is usually expressed with the value between 0-1.

There are many surveillance reconnaissance methods; one of the most common methods is visible light optical detection. Visible light reconnaissance equipment is an important means for acquiring battle field targets information in modern war, which is more and more widely used in the application of the photo electric reconnaissance equipment. The acquisition probability of the visible light reconnaissance equipment to ground targets at different environmental conditions and different meteorological conditions reflects the reconnaissance capacity of the visiblelight reconnaissance equipment [11-16]. Basing on the theory model of discovery probability of visible light reconnaissance device, this paper mainly studies the influences on visible light reconnaissance capability of the contrast between the target and background, atmospheric visibility, the solar elevationangles, the optical system magnification, intercept range and other factors. The results of study providean important basis for the performance evaluation and capacity prediction of visible light reconnaissance system.

*Corresponding Author's Email: zhangliwen97@163.com (Z. Liwen)

Please cite this article as:Z. Liwen, S. Ming, L. Na,Z. Qipeng, C. Xiangzheng,Research on Acquisition Probability of the Visible Light Reconnaissance Equipment to Ground Targets, International Journal of Engineering (IJE), TRANSACTIONS A: Basics Vol. 29, No. 4, (April 2016) 500-504

2. THEORY MODEL

The formula describing the probability of detection for ground targets is given by Bailey [17]:

$$P_D \approx \frac{1}{2} \pm \frac{1}{2}\sqrt{1-\exp[-4.2(\frac{C}{Ct}-1)^2]} \quad (1)$$

where, the plus sign is used when $C_t < C$. Ct is the threshold contrast, where the eye just distinguishing the objects from the background, which is the function of the view angle α of an object to human eye and the background natural illumination, just as the follow expression:

$$\log_{10} C_t \approx (\log_{10}\alpha + 0.5)^{-1} - 2 \quad (2)$$

where, α is given the average angular subtense, in minutes of arc at the eye of an object, which is defined here with the characteristic scale of an object H and the distance to the object R as:

$$\alpha = 3.44\frac{MH}{R} \quad (3)$$

Here, the unit of H is m, the unit of R is km, M is the magnification of the visual optical devices, such as the telescope. M equals 1, when the object is observed with the naked eye.

In Equation (1), C is the actual contrast available at the eye at the distance R to the object after atmospheric effects and equipment gains and display setting are accounted for, which can be expressed as:

$$C = C_0\frac{1}{1+\overline{SG}(e^{\sigma R}-1)} \quad (4)$$

where, C_0 is the actual contrast available at the eye at the zero distance to the object, which depends on the visible light reflectivity of the objects, r_t, and the visible light reflectivity of the background of objectives, r_b, just as the follow equation [18, 19]:

$$C_0 = \left|\frac{r_t - r_b}{r_b}\right| \quad (5)$$

And $\overline{SG}$ is the background luminance ratio of the sky to the ground. The equation used to predict $\overline{SG}$ is given by Huschke [20] with the visible light reflectivity of the ground background, r_b, the visibility V, the solar elevation angle h and the observation pitch angle F:

$$\overline{SG} \approx \frac{1}{3}[(SG)_{r_b} + (SG)_h + (SG)_V]F \quad (6)$$

where,

$$\begin{cases} (SG)_{r_b} = e^{(-1.15\ln r_b - 0.75)} \\ (SG)_h = e^{(-3.4\sin h + 2.7)} \\ (SG)_V = e^{(-0.5\ln V + 1.5)} \end{cases} \quad (7)$$

the observation pitchangle F changes with h:

$$\begin{cases} F = 2 & (h \le 10^\circ) \\ F = 1.5 & (10^\circ < h \le 55^\circ) \\ F = 1 & (h > 55^\circ) \end{cases} \quad (8)$$

In Equation (4), σ is the extinction coefficient of the visible light, which is usually expressed with the visibility:

$$\sigma = \frac{3.912}{V} \quad (9)$$

3. SIMULATION RESULTS AND ANALYSIS

3. 1. Effects of the Target-to-background Contrast on the Detection Probability Basing on the formula describing the probability of detection, at different detected distances, the relations of the detection probability with the target-to-background contrast are given in Figure 1. Here, the solar elevation angle is 45°, the visibility is 5 km, the magnification of the visual optical devices is selected as 8, and the characteristic scale of objects is 3 m. With the present parameters, obviously, the variation of the detection probability presents increasing trend with the increasing target-to-background contrast. It is noticing that the detection probability rapidly reduces with increase of the detected distance.

3. 2. Effects of Different Visibilities on the Detection Probability Figure 2 illustrates the change tendency of the detection probability with the increasing visibilities at different detected distances. Where, the visible light reflectivity of the object is 0.1, the visible light reflectivity of the background is 0.2, the target-to-background contrast is 0.5, the solar elevationangle is 45°, and the magnification of the visual optical devices is selected as 8.

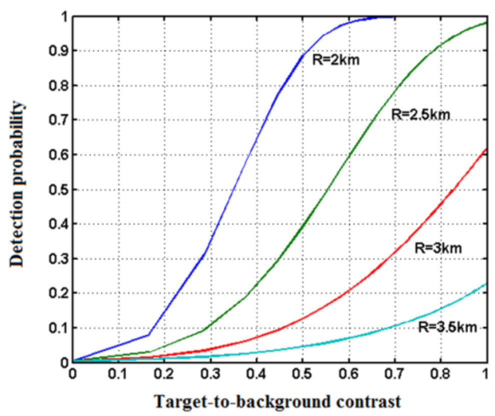

Figure1. The detection probability changes with the target-to-background contrast at different detection distances.

From Figure 2, it is seen that the detection probability increases with the increasing visibility, and the detection probability is about 3 km, as the visibility is 9 km. What is more, at the same visibility, the detection probability is much lower with the larger detection distance.

3. 3. Effects of the Solar Elevation Angle on the Detection Probability While other parameters remain the same, varying one parameter of the solar elevation angle (the different detecting time), the detection probability under different detection distances is shown in Figure 3. Obviously, the detection probability of the targets with larger solar elevation angle at noon is much larger than that with smaller solar elevation angle at dawn or dusk. With the rise of the solar elevation angle, the detection probability increases, but it has different increasing rates during different solar elevation angles. During the solar elevation angles from 10 to 50 degrees, the detection probability increases rapidly, rises sharply at near 55 degrees, then increases slowly after 55 degrees. And at the same solar elevation angle, the higher detection probability with the smaller detection distance.

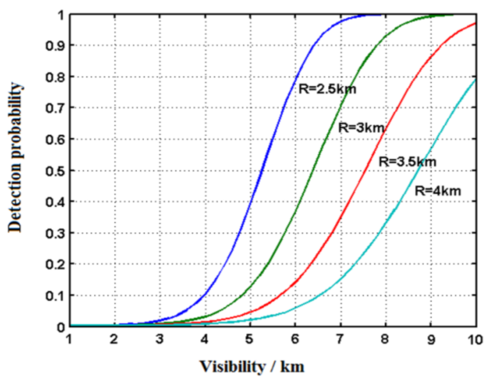

Figure 2. The detection probability changes with the visibility at different detection distances.

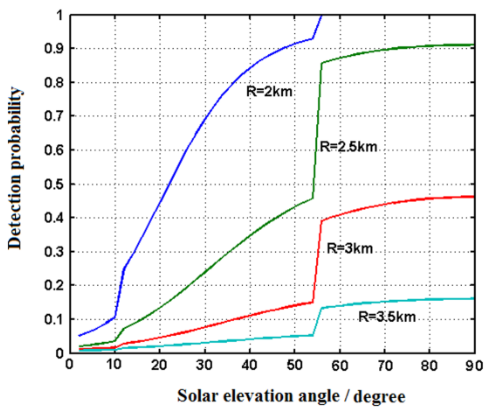

Figure 3. Detection probability with the visibility the solar elevation angle under different detection distances.

3. 4. Relation between the Detection Probability and the Magnifications of Optical System When other parameters remainthe same, the detection probability of the different magnification under different detection distance is presented in Figure 4. Here, the magnification M =1, which means that the target is observed with the naked eye. The detection probability increases more with a higher magnification than that with the naked eye. However, when the detection distance increases, at the low visibility, the effect of the approach to improve the detection probability through increasing the magnification of optical system is not very obvious.

3.5. Effects of the Detected Distance on the Detection Probability at Different Conditions Figure **5** (a~d) give the detection probability with the detected distance at different backgrounds, different visibilities, different solar elevationangles, and different surveillance equipments. From Figure **5**, it can be concluded as follows: (1) The higher contrast of target and background, the detection probability of ground target with visible light reconnaissance equipment is larger, and the reconnaissance distance is more far. (2) Under the condition of low visibility, the detection probability of ground target with visible light reconnaissance equipment decreases rapidly with increasing reconnaissance distance, while at high visibility, this change becomes slow. (3) At noon with larger solar elevation angle, the detection probability of ground target with visible light reconnaissance equipment is much larger, and the reconnaissance distance is also farther than in other time. Adoption of optical amplifying system is helpful to improve the detection probability, but only by increasing the magnification of the optical system, the reconnaissance distance cannot effectively increase.

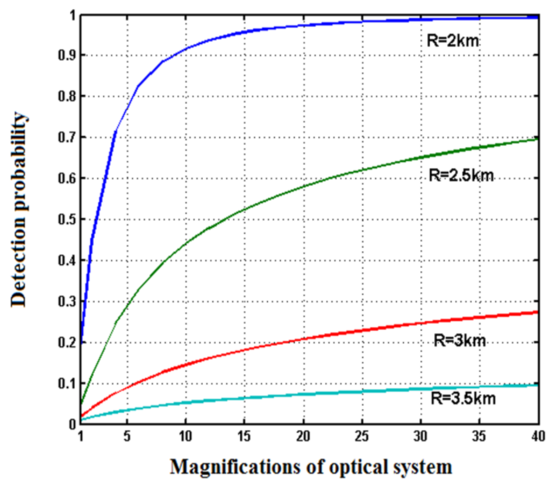

Figure4. Detection probability with the magnifications of optical system under different detection distances.

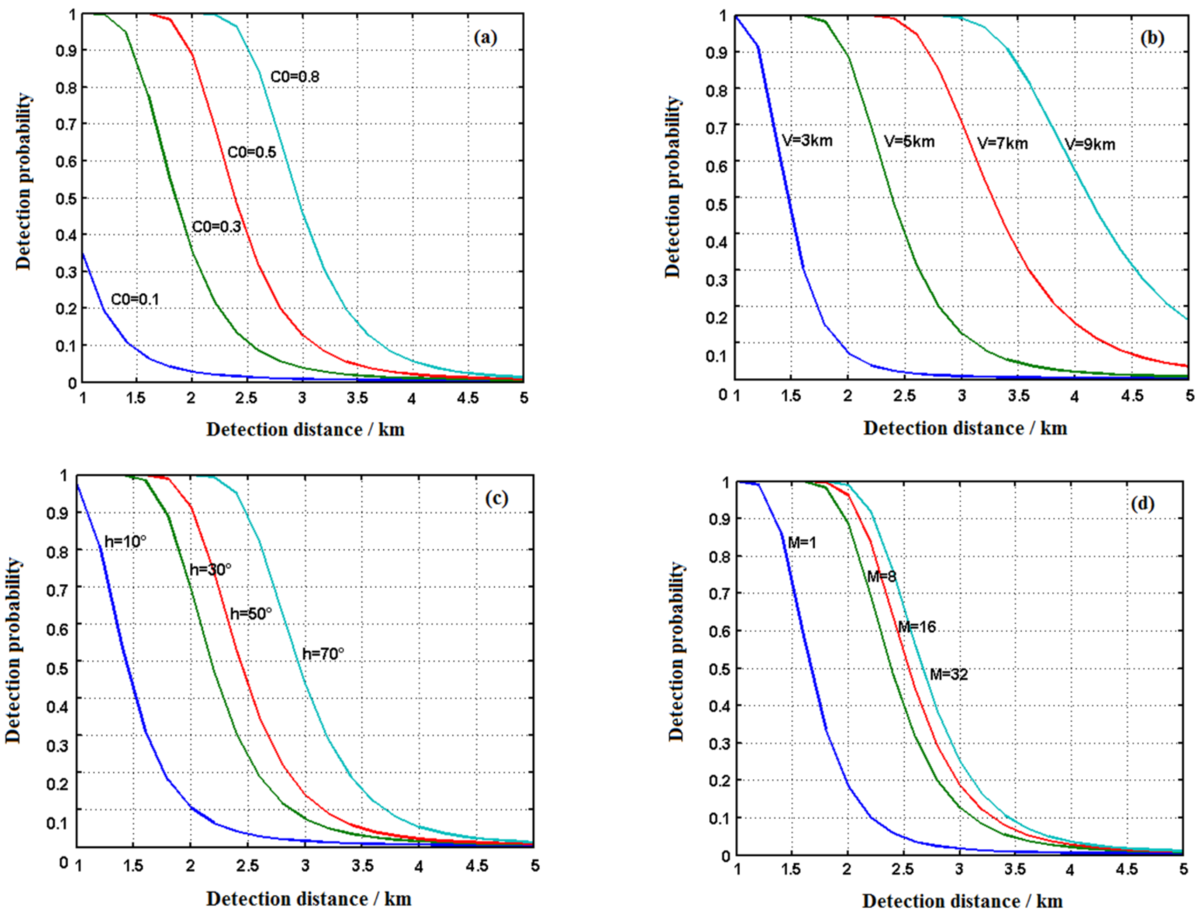

Figure 5. Detection probability with detected distance at different conditions: (a) different backgrounds, (b) different visibilities, (c) different solar elevation angles, and (d) different surveillance equipments

4. CONCLUSIONS

Through the simulation calculation, the influences on the detection probability of visible light reconnaissance equipment are analyzed under the different target and background contrasts, different visibilities, different solar elevationangles, different surveillance equipments, and different reconnaissance distances. The simulation results show the detecting probability has been massively affected by the meteorological conditions and environmental factors, and it varies regularly with such factors as visibility, the target-to-background contrast and the solar elevation angle. The conclusions are important to military detecting applications.

5. ACKNOWLEDGEMENTS

This work was financially supported by Foundation of Educational Commission of Henan Province (No. 14A510003).

6. REFERENCES

1. Han, W.H., Bai, Z.P. and Wang, J.Y., "Exploration of calculation methods for target detection probability", ***Electro-optic Technology Application***, Vol. 22, No. 2, (2007), 25-27.
2. Kouba, J.T. and Bose, S.C., "Terminal seeker pointing-angle error at target acquisition", ***Aerospace and Electronic Systems, IEEE Transactions on***, Vol., No. 3, (1980), 313-319.
3. Han, G.X., He, J. and Qi, J.Q., "Fused detection probability model of nrcs based on rank k criterion", ***Journal of Naval University of Engineering***, Vol. 26, No. 1, (2014), 64-70.
4. Feizi, A., Aghagolzadeh, A. and Seyedarabi, H., "Using combined local object based features and cluster fusion for the behaviors recognition and detection of abnormal behaviors", ***International Journal of Engineering*** Vol. 28, No. 11, (2015), 1597-1604.
5. Mardia, H., "New techniques for the deinterleaving of repetitive sequences", in Radar and Signal Processing, IEE Proceedings F, IET. Vol. 136, (1989), 149-154.
6. Milojevic, D. and Popović, B., "Improved algorithm for the deinterleaving of radar pulses", in Radar and Signal Processing, IEE Proceedings F, IET. Vol. 139, (1992), 98-104.

7. Jain, M., Agrawal, S. and Preeti, C., "Fuzzy reliability evaluation of a repairable system with imperfect coverage, reboot and common-cause shock failure", ***International Journal of Engineering***, Vol. 25, No. 3, (2012), 231-238.
8. Nishiguchi, K.I. and Kobayashi, M., "Improved algorithm for estimating pulse repetition intervals", ***Aerospace and Electronic Systems, IEEE Transactions on***, Vol. 36, No. 2, (2000), 407-421.
9. FAN, W., WANG, Y. and RAO, R.-z., "Wavelength band selection method for taget detection based on character of atmosphere radiation [j]", ***Infrared and Laser Engineering***, Vol. 2, (2005), 177-189.
10. Khakpour, F. and Ardeshir, G., "Using a novel concept of potential pixel energy for object tracking", ***International Journal of Engineering-Transactions A: Basics***, Vol. 27, No. 7, (2013), 1023-1032.
11. DENG, J., GAO, F. and ZHANG, L., "Equivalent test of optical camouflage effectiveness by reducing observation distance", ***Journal of Detection & Control***, Vol. 3, (2012), 19-22.
12. XU, H., ZHANG, J.-j., YUAN, Y.-h., ZHANG, P.-h. and HAN, B., "Detection probability of infrared and visible image fusion system", ***Optics and Precision Engineering***, Vol. 12, (2013), 3205-3213.
13. LI, S.-g., NIE, J.-s. and LI, H., "Effectiveness analysis on eyeballing optical reconnaissance under a typical atmospheric condition [j]", ***Infrared and Laser Engineering***, Vol. 5, No., (2010), 915-919.
14. Toloei, A. and Niazi, S., "Estimation of los rates for target tracking problems using ekf and ukf algorithms-a comparative study", ***International Journal of Engineering-Transactions B: Applications***, Vol. 28, No. 2, (2014), 172-179.
15. Yi, W., Wei, F. and Ruizhong, R., "The analysis of the target—background contrast undera typical atmospheric condition", ***Laser&Infrared***, Vol. 34, No. 5, (2004), 467-471.
16. Liang, D.M., Zhang, M.J. and Zhang, Y.X., "Equivalent calculation anaiysis for operating range of visible light reconnaissance system", ***Modern Electronics Technique***, Vol. 36, No. 1, (2013), 25-27.
17. Bailey, H., *Target detection through visual recognition: A quantitative model*. 1970, DTIC Document.
18. TANG, H. and JIN, W., "Testing conditions of visibility distance and their effects on results [j]", ***OPTICAL TECHNOLOGY***, Vol. 1, (1999), 80-84.
19. Xie, Q.-F., "Ground-target model of radar detection based on stochastic theory", ***Huoli yu Zhihui Kongzhi***, Vol. 36, No. 10, (2011), 131-133.
20. Huschke, R., "Atmospheric visual and infrared transmission deduced from surface weather observations, Rand, (1976), 9-12.

Research on Acquisition Probability of the Visible Light Reconnaissance Equipment to Ground Targets

Z. Liwen[a], S. Ming[b], L. Na[a],Z. Qipeng[b], C. Xiangzheng[b]

[a]*School of Electrical Engineering, Henan University of Science and Technology, Henan,Luoyang , P.R. China*
[b]*Key Laboratory of Electro-Optical Countermeas ures Test & Evaluation Technology, Henan, Luoyang, P.R.China*

P A P E R I N F O

Paper history:
Received 15 February 2016
Received in revised form 01April 2016
Accepted 14 April 2016

Keywords:
Visible Light Reconnaissance Equipment
Detection Probability
Intercept Range
Target-background Contrast

چکید

احتمال تشخیص تجهیزات شناسایی نور مرئی یکی از شاخص های کلیدی برای ارزیابی عملکرد سیستم است .احتمال تشخیص توسط عوامل بسیاری مثل دید اتمسفر، کنتراست هدف- پس زمینه، اندازه هدف و فاصله، زاویه ارتفاع خورشیدی و غیره تعیین می شود. بر پایه مدل احتمال تشخیص برای تجهیزات شناسایی نور مرئی و به دست آوردن اهداف، عوامل مهم تاثیرگذار بر قابلیت شناسایی تجهیزات شناسایی نور مرئی مورد تحلیل قرار گرفت. با محاسبات شبیه سازی مدل، روابط بین مدل احتمال تشخیص برای تجهیزات شناسایی نور مرئی و پارامترها، شامل کنتراست بین هدف و پس زمینه، دید اتمسفر، زوایای ارتفاع خورشیدی، بزرگنمایی سیستم نوری و طیف وسیعی رهگیری، تجزیه و تحلیل شد. همه این ها برای بررسی بیشتر قابلیت شناسایی تجهیزات شناسایی نور مرئی مفید است.

doi*: 10.5829/idosi.ije.2016.29.04a.08*