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Active Infrared Night Vision System of Agricultural Vehicles

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Abstract

Active infrared night vision system was significant for night driving and it has been greatly used on limousine car. Design active infrared night vision system for agricultural vehicles greatly improved the night vision of them and it was an inevitable trend. Comparing parameters of various night vision systems and designing active infrared night vision system of agricultural vehicles was significant for improving active security of agricultural vehicles working at nighttime. By analyzing the infrared night vision system basic parameters determined the structure form and basic parameters, calculated the infrared light wave width and emission power to choose each components, designed active infrared night vision system's structure and determined parameters of agricultural vehicles.

Keywords*: agricultural vehicles, infrared night vision system, active security*

1. Introduction

According to the statistics by Nation Highway Traffic Safety Administration Bureau of United States, though nighttime only occupies a quarter of the whole highway transportation, but the death by car accident occupies half percent reach to 55% [1]. The reason is the night vision has been greatly shortened; only 80 metres through the lamps. The car with shorting vision distance and ineffective condition on rain, snow night or heavy mist are the main reasons of security [2]. Although the night vision system has been used widely on limousine car and bus, but still be blank in the application of agricultural vehicles. The agricultural vehicles work at nighttime most of the time, doing research works on installing night vision system of agricultural vehicles, and raising its active security are very important. Most of the time agricultural vehicles work only at a certain area, closing headlight when it's necessary and leaving its night vision system working can lower consuming of electricity and prolong the life of battery, and reduce disturbing civilians. According to different circumstances, driver can see 3-5 times far more than lamp vision, and be safe in special weather. It is a safety active system with great merit in use [3]. By analyzing the infrared night vision system basic parameters determined the structure form and basic parameters, calculated the infrared light wave width and emission power to choose each components, designed active infrared night vision system structure and parameters of agricultural vehicles.

2. Choose Categories of Night Vision System

Night vision is the ability to see things in the dark. No matter biological or technological method, night vision system needs to satisfy two conditions: enough spectrum scope and enough spectral density. Eye is an optical system, but only responds to 380~780 nm visible light. In the night, 70% spectra are in infrared scope [4]. The infrared spectrum occupies majority, and in starlight night spectrum is less, therefore the eyes have not night vision functions. Agricultural vehicles work often in the night, choosing appropriate night vision system is necessary.

In principle, infrared night vision system consists of passive infrared night vision system and active infrared night vision system. Passive infrared night vision system use thermo imaging camera to receive infrared rays radiating by animal and human beings, and magnified to

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display. Things with thermo are special in the image and with clear contrast, but road information in detail such as traffic lane line and bounders, are vague due to little thermo [5].

2.1. Active Infrared Night Vision System.

Active infrared night vision system use near infrared light to light objects and CCD or CMOS camera catch the light reflected by the objects. After the processing of ECU, the image shows on monitor clearly and naturally, even the object with little heat, its principle as Figure 1. The active infrared image needs infrared radiator, especially in long-distance the power of radiator should be strong enough, and detect distance shouldn't be too long, most of the time its a few hundred meters. Active infrared night vision system is suitable for agricultural vehicles too.

From the structure, infrared lamp gives off special wave of rays and illuminating 0-200m in front of the car and meantime objects give off infrared rays in the area included, the infrared ray reflected by the objects will be absorbed by the black-white camera and becoming the resource of image. In preventing disadvantageous influence, infrared filter should be put before black-white camera to prevent other rays, only near infrared rays can go through. When the rays reflected by objects filtered by the infrared filter, the infrared image signal goes into the black-white camera. The black-white camera can transfer the infrared signal into electrical signal, electrical signal processed by video circuit and displayed in the car to provide observing [6].

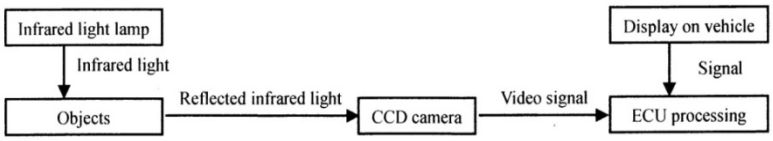

Figure 1. Principle of Active Infrared Night Vision System

2.2. Passive Infrared Night Vision System.

Passive infrared system need no radiator source, it depends on target itself. It depends on the temperature and radiance differences among objects, namely heat camera receive the far infrared light of human being or animal and output after processing, the image includes the heat information, so the passive infrared night vision system come into being. The passive infrared system image include target and its background, the difference is the foundation of passive infrared system, the radiation of target and its background passes through atmosphere after being absorbed and spread then goes into heat camera. So it is unsuitable a little.

2.3. Comparison with Passive and Active Infrared Night Vision System.

Passive infrared night vision system receives the infrared radiation coming from different objects with different energy and amplifies the signal to show on display finally. In passive infrared night vision system the object such as pedestrian with heat display obviously and with high contrast, but vague when show the objects of circumstance with heatless. Passive infrared night vision system requires much in hardware, and the quality of image has shortcomings. The ratio of performance to price is low, and it cannot satisfy the needs of night vision system [7]. Because of agricultural vehicles in a certain area, the circumstance of periphery is the main target of its observation. In addition, the noise of agricultural vehicles is higher, the hearing of driver cannot reach it and vision is its only information source, so that passive night vision system is obviously not suitable. Active night vision system has the clear information of periphery and its cost is lower, and it should be chosen for agricultural vehicles.

3. Components and Calculations

3.1. Camera Type

Receiver of infrared night vision system is camera. Currently the key of night vision system is the two parameters of image sensors and they determine the whole function of system. They determine the system performance. Sensitivity determines the visible areas and signal-to-noise determine the ability to prevent dizzy when in front of another night vision system. The most popular image sensor is a CCD with sensitivity 50 V/(lxs) and limited signal-

to-noise, only 50 dB. In contrast, the CMOS image sensors appeared last few years have more advantage, with sensitivity 5 V/(lxs) and signal-to-noise of 120 dB. The low power, integrated and small physical appearance can be expected only from CMOS image sensors. CMOS image sensors can be made into the button size, in addition to infrared minimized products and high-performance battery, the security of agricultural vehicles in nighttime will be improved greatly.

Night vision system adopts camera with lower illumination in black-white series usually reach 0.003lux-0.001lux. Meantime in determining minimum illumination the F in aperture should be determined, as it and minimum illumination are impottant parameters. F is the ratio of focus of camera to caliber gap, namely F=d/D. When F decreases, the caliber of gap increases and the brightness of imaging also increases. Active infrared night vision system has to chose camera lens with active aperture to fit for circumstance with great change of beam brightness. In Engineering most of the time F=1.2-1.6 active aperture lens can be expected. Target dimension is the important factor to determine effect of night vision system imaging. With the increases of target dimension the clearness of imaging becomes more and more clear, and the area of active increase also. In engineering 1/3 inch CCD is the first choise though luminous flux and angle of view can't reach 1/2 inch CCD, but it has good cost performance. Depth-width ratio of camera picture is 4:3, 1/3 inch CCD with width of 8.47mm and depth 6.35mm. To avoid the vague in image due to focus changing, the focus doesn't change most of the time, vision is from 15m to infinite distance. Focus of camera may determine by f=H1×L/H2, H1 is the hight of target dimension, H2 the actual hight and L the distance between objects and camera. In case from 15m to camera, image of object with height 2m occupies 90% the whole height of target then f=6.35×0.9×15/2≈43mm we can get through calculation.

3.2. Monitor Type

Surroundings are more complicated at nighttime, change of clair-obscure and the limit of infrared light may lead to low signal-to-noise and contrast. For the follow-up picture processing and display, need to boost the picture. Low contrast is the most important character, often adopt an ash degree pull and stretch to boost the infrared picture, improve picture contrast degree. Gray-scale value adjustment decreases its low value and increases its high value.

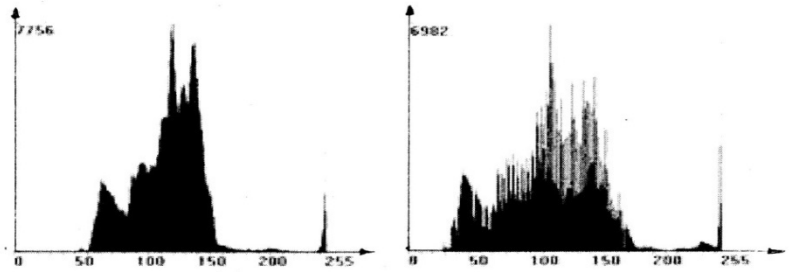

Figure 2. Contrast of Image Gray-scale Value after Boosted

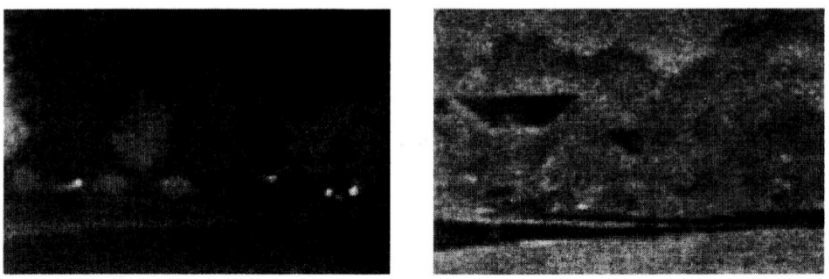

Figure 3. Contrast of Image Definition after Boosted

Figure 2 and Figure 3 are the contrast of gray-scale value and definition. It is clear that the more clear picture boosted, the better of layer, pedestrian and driveway line is also brighter, easy to observe. According to image before and after, the boosted image distributing gray-scale

value equality. And also by narrowband filter prevents visible light and cancel environment influence to the definition. Use infrared filters to filter non-image wavelength light of environment and the light from another vehicle in front. Strengthen the anti- interference that the night vision system ability. Use polarization to fix polarizer and test plate in front of laser projector and CCD camera, to illuminate the influence from the same kind night vision system [8].

3.3. Calculation of Infrared Light Wave Width

The design of infrared lamp is the nucleus of active night vision system; it can directly influence the distance in effective and clearness of image etc. directly. The infrared lamp is the key part of the night vision system; its quality directly influences the function of the whole system. Now three kinds are in use: halogens lamp, laser beam lamp and infrared light-emitting diode (LED). The halogens infrared lamp includs infrared filter, absorbing visible light and sending out near infrared light. Most of car illuminate lamp is halogens lamp, it sends out of ray including continuous spectrum of visible light and near infrared light, and the near infrared exportation greatly and take up 1/3 percent of the total energy around. We choose the infrared ray filter of different wave-length and different bandwidth according to needs. Active infrared night system mostly adopts halogens light as infrared light source currently; it has the characters of far light distance, continuous wave-length, small physical volume and uniformity etc. and disadvantage of short life, about 8000 hours. Common infrared LED has little cost, high reliability, wide light beam and short projecting distance characteritics, mostly is used for short distance night vision system, just accords with characteristics of agricultural vehicless. But laser beam lamp has the strong brightness, correct direction, narrow beam (about 0.1-0.2 degrees) and long projecting distance, but more expensive, applicable to long vision system. This kind system currently only has minority domestic at the development factory, and mostly use foreign semi-conductor laser LED and isn't suitable for the use of agricultural vehicles. For the beam is very concentrated, therefore it expand the ray through dissipating equipment to spread with a certain angle. When choice the sector angle the disturbing among system has to be cleaned. For the agricultural vehicles infrared night vision system being visible in 20 m should be needed, so we define 15 m from vehicle 4 m wide beam is needed. From Figure 4 we can get the infrared sector angle [9].

$$2\varphi = 2\arctan\frac{2}{15} \approx 2\times 7.55 = 15.1^{\circ}$$

So the beam width at 20 m is $w = 2\times 20\times \tan 7.55^{\circ} = 2\times 2.65 = 5.3$. According to the experience of current night vision system some reach to 200 m; it can satisfy the infrared night vision system needs.

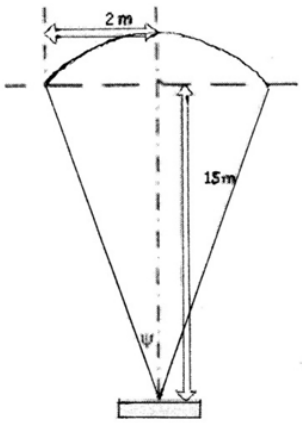

Figure 4. Calculation of Infrared Sector Angle

3.4. Calculation of Infrared Light Emission Power

Power of infrared light source is related to minimum illumination. Minimum illumination in theory stand for CCD sensor sensitivity of circumstance light. The value decrease with the light, and the sensitivity incease. The laser radar functional distance can get from the follow equation [10-12]:

$$P_r = \frac{4P_t T_{A1}\eta_t}{\pi R_1^2 \theta_T^2}\Gamma\frac{T_{A2}}{4\pi R_2^2}\frac{\pi D_r^2 \eta_r}{4} \tag{1}$$

In equation, P_r -power of echo signal, P_t -emmition power of infrared light source, T_{A1} -air transmission ratio of transmitter to objects, η_t -transmission ratio of infrared light source opstacle system, θ_T -width angle of infrared light source, R_1 -distance from objects to infrared light source, Γ - section of objects reflection, T_{A2} -air transmission ratio of transmitter to objects, R_2 - distance from objects to receiver, D_r -aperture of camera lens, η_r - air transmission ratio.

In night vision system, area reached by infrared light source may image in camera. For the light rays distribution function is equality, object is equivalent to expand object form. According to width light rays, calculated radius of area from infrared light source is R =200×tan(7.55°)≈26.5m. From target demention and lens focus, the maximum imaging radius from 200m is c=19.7m. For the difference between objects of imaging system and Langbo objects of normal expansion. To increase the video luminous flux matching coefficient C is:

$$C = \frac{\pi \times 19.7^2}{\pi \times 26.5^2} \approx 0.55 \tag{2}$$

Actual irradiation power in imaging equipment $P_t^{'} = P_t C$, According analysis above, in (1) predigest:

$$P_r = \frac{P_t C T_A^2 \rho D_r^2 \eta_t \eta_r}{4R^2} \tag{3}$$

ρ - spectrum reflectivity of object, factory of camera only provide minimum illumination Lmin to reference, power of light source and luminous flux can transfer through spectrum luminous efficacy characteristics. For the maximum of luminous efficacy is a function of adapting standard changing, chosing 550nm spectrum luminous efficacy maximum K_m =683lm/W. CCD camera matching parameter with 850nm infrared light source δ is 0.35 about, so the calculation is:

$$P_r = \frac{L_{\min} S}{K_m \delta} \tag{4}$$

In equation S =6.35×8.47×10-6=0.0000538 m^2 is the CCD image target dimension. (2) and (4) put into (3):

$$P_t = P_r \frac{4R^2}{CT_A^2 \rho D_r^2 \eta_t \eta_r} = \frac{L_{\min} S}{K_m \delta}\frac{4R^2}{CT_A^2 \rho D_r^2 \eta_t \eta_r} \tag{5}$$

Put R =200m, T_A =0.9, ρ =0.5, D_r =0.01m, $\eta_t = \eta_r$ =0.8, C =0.55, δ =0.35, $L_{\min}$ =0.001lux and K_m =683lm/W into (5):

$$P_t = \frac{0.001 \times 5.38 \times 10^{-5}}{683 \times 0.35} \times \frac{4 \times 200^{2}}{0.55 \times 0.9^{2} \times 0.5 \times 0.01^{2} \times 0.8^{2}} \approx 2.53W$$

To determine the power of infrared light source is P=3W [13-15].

4. Installation on Agricultural Vehicle

Infrared camera equipment fixed at middle rearview mirror of the cab, in this way the good sight distance and visual angle could be expected, and no influence or damage from atmosphere such as rain and fog. Installation side elevation in Figure 5(a), camera longitudinal direction angle with horizontal line is γ, the hight is h from the earth, aim sweep angle of camera is α. Infrared camera equipment fixed planform in Figure 5(b), camera longitudinal direction horizontal sweep angle is β, and Φ with the middle line of vehicle. All the installation parameters are different among vehicles, and they should be modulated many times then made certain.

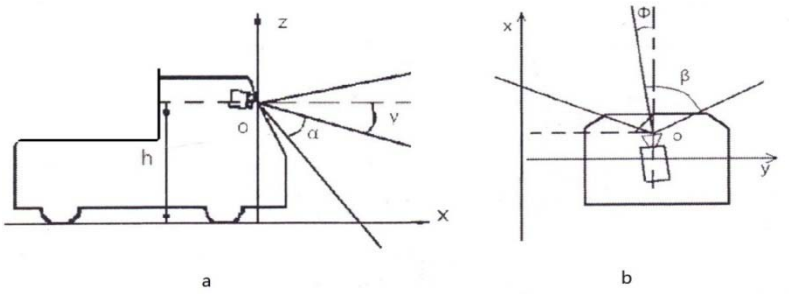

Figure 5. Fixing Parameters on Agricultural Vehicles

5. Conclusion

Currently, more and more car manufacturers developed various infrared night vision system to improve security. But for the cost reason, large manufacturer just adopted luxurious car with night vision system. Comparing parameters of various night vision systems and designing active infrared night vision system of agricultural vehicles was significant for improving active security of agricultural vehicles working at nighttime. By analyzing the infrared night vision system basic parameters determined the structure form and basic parameters, calculated the infrared light wave width and emission power to choose each components, designed active infrared night vision system structure and installation parameters on agricultural vehicles, modulated many times till made them certain. In the trial vehicle, the infrared night vision system worked well and conform to the requirement of project. Adopting active infrared night vision system for agricultural vehicles is an inevitable trend and significant.

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