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Improvement of aerial image by simulations

Katsunari Ashimine(1), Munemitsu Abe(1), Kazuhiro Wako(2)
(1)R and D Dept. ALPS ALPINE CO., LTD
(2)Department of General Engineering, National Institute of Technology, Sendai College

Abstract

We measured the contrast of standard charts using two different types of retro-reflectors in an AIRR (Aerial imaging by retro-reflection) system, and examined the results to be reproduced by optical simulation. As a result, it became possible to reproduce the effect of retro-reflector diffraction on the Aerial image quality of the AIRR system by optical simulation.

Introduction

Various aerial image display devices have been proposed at present, but the AIRR system has been proposed as suitable for mass production and cost-effective[1,2].In order to evaluate the image quality of the aerial image of this system, it has been reported that the light beam from the original image to the image is re-imaged geometrically optically, and at the same time, the scattering and diffraction of light generated by the retro-reflector structure must also be taken into account[3]. For the purpose of improving the image of the AIRR system, we report how diffracted affects the image quality of aerial images. we have examined the observed measurement and calculation.

Aerial image display system

The aerial image display system is based on the spatial system using retro-reflector, as shown in Fig.1.

Light from Light Source (the original image display) is reflected in the retro-reflector direction in the Reflective polarizer. Retro-reflector's positively reflected light can pass through the λ/4 plate twice to pass through the Reflective polarizer, which can be re-imaged in the air to form an aerial image.

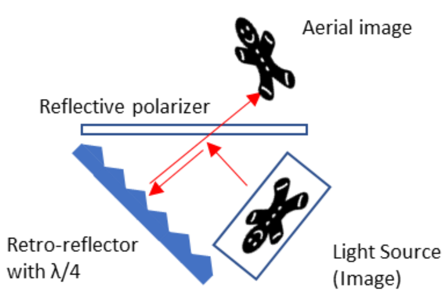


Fig.1 Principle of AIRR

Evaluation and simulation of aerial image display

The observation and evaluation of aerial images were carried out by the measurement system shown in Fig.2.

The optics are arranged so that the aerial image is imaged 200 mm away from the retroreflector. At that time, a camera with an F-value of 5.6 was installed 500 mm away from the retro-reflector to take aerial images and evaluate the images.

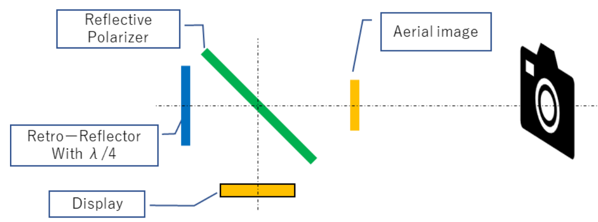


Fig.2 Aerial image observation system

In this evaluation, two retro-reflectors with different recursive pitches, as shown in Fig.3, are used to create a rectangular pattern image of 1LP/mm and 0.24mm square dot shape and an aerial image of the sample image. We take these images.

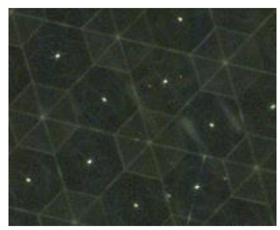
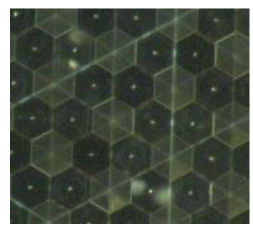
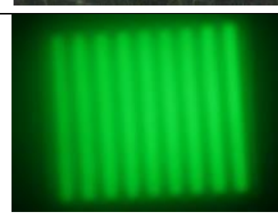
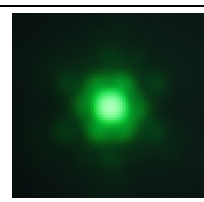
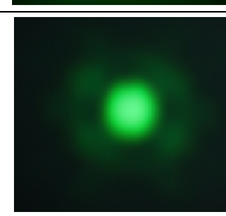
	Sample A 400µm	**Sample B 200µm**
		
		
		

Fig.3 Aerial image observation results

As a result of observation, it was confirmed that the smaller the retro-reflector, the lower the contrast of the chart and the lower the image. In order to confirm this factor, we checked how the image of the dot shape equivalent to 0.24 mm square was imaged in the air. It was confirmed that diffraction light was observed in three directions(hexagon), so we considered reproducing this by simulation.

The simulation was calculated using OpticStudio® and MATLAB® for geometric optical degradation due to ray tracking and wave optical degradation due to diffraction. In both simulations, the same conditions and the same F value as during aerial image evaluation were made. The light beam when the aerial image at a position of 200 mm from the retroreflector was observed.

Since the effect of the diffraction of light reflected three times with the retroreflector and toward the aerial image side was considered to be largest. We calculate the diffraction pattern using a Fraunhofer approximation in the effective opening area by simulation.

In order to observe the diffraction pattern, an aerial image of the smallest observable 0.24 mm shape was created, and the observation results and simulation results were compared.

The result is shown in Fig4-1. It was confirmed that the observation result and the simulation result, including diffraction pattern of diffraction light, intensity distribution, and first dark ring diameter, agree well.

Fig.4-2 was compared with the observation results by calculating the contrast ratio when a 1LP/mm chart was used as an aerial image.

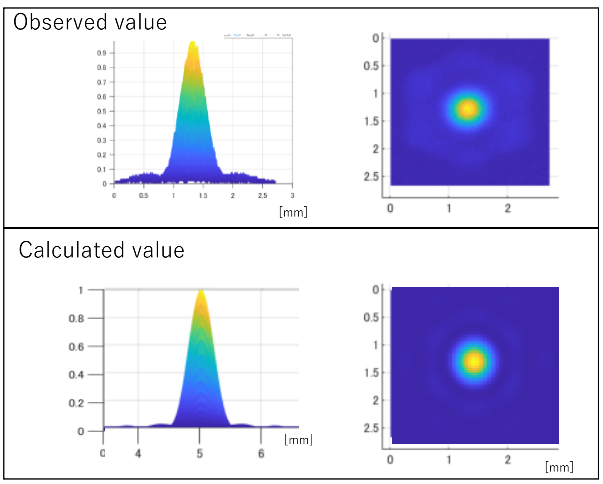


Fig.4-1 Diffraction shape comparison at spots

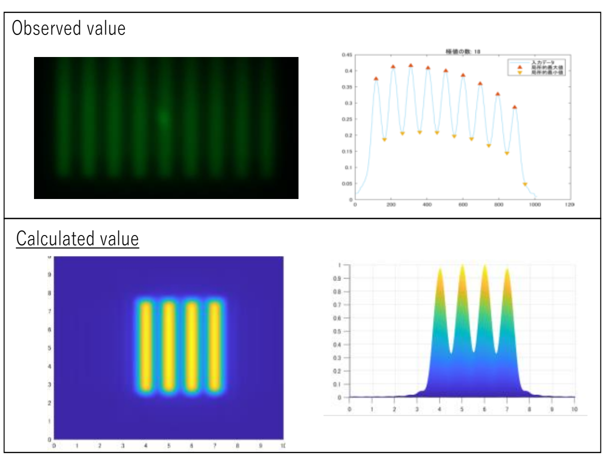


Fig.4-2 Comparison of 1LP/mm chart

As a result, it was confirmed that it was able to reproduce the contrast which were better than the actual one.

In order to confirm whether the effect of the size of the retro reflector can be reproduced in the simulation, the result of checking the diffraction pattern of the dot and the contrast of the chart using two types of retro−reflectors of different sizes under the same conditions is shown in Fig.5.

As a result, it was confirmed that this can reproduce the actual thing well.

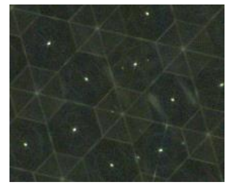
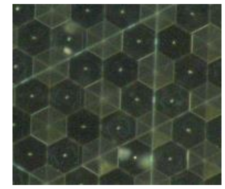
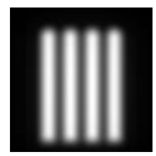
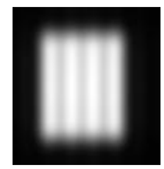
	Sample A Corner prism	Sample B half size of sample A
		
Observed value		
Calculated value		

Fig.5 Differences in retroreflector size

Conclusion

It was shown that the effect of diffraction, which is one of the factors of image degradation of aerial images, could be quantified by optical simulation and the contrast of the chart could be reproduced.

In order to improve the image as a system, it is necessary to add the influence of color, the angle of retro-reflector, tolerance of the actual system, etc., so that evaluation closer to the actual system can be performed by simulation. In order to provide optimal images as a system, we will improve these simulation technologies and improve aerial display images.

References

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Author Biography

Katsunari Ashimine joined Alps Alpine Co., Ltd. (formerly Alpine electronics) in 1999, developed automotive optical−pickups and optical-drives, has developed next-generation display since2019, and has enrolled in a doctoral program at Utsunomiya University since 2020.