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OPTICAL DESCRIPTION OF CONVECTION TURBULENCE FROM THE MEASUREMENT WITH HARTMANN WAVEFRONT SENSOR AND SINGLE APERTURE SENSOR

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ABSTRACT

The feature of coherent length r in a convection turbulence cell is deduced from data of arrival-angle statistic using a Hartmann wavefront sensor of an adaptive optics system and single aperture sensor. The outer scale of the turbulence is inversed. A normalized logarithm distribution of r is suggested.

INTRODUCTION

The effectiveness of an adaptive optics system correcting image degradation is depended on atmospheric turbulence parameters. Hence, the methods for measuring turbulence parameters are important for both application and experiment research of adaptive optics. In the paper, parameters (coherent length r [1] and outer scale L) in convection turbulence cell are deduced from data ststistic of Hartmann wavefront sensor of an adaptive optics system and single aperture sensor.

EXPERIMENT AND RESULTS

A convection turbulence cell, heated from bottom and cooled on top with controlled temperature differences, is built here in AIOFM for experiment research of adaptive optics. The convection turbulence in the cell is Von-Karman type, shown in figure 1. Hence, for a single aperture of diameter D, the variance of arrival-angle (two dimensional image motion) is [2]:

$$\sigma^2=0.358\lambda^2 r^{-5/3}D^{-1/3}(1-0.822A^{1/6}+0.053A^{0.84}\exp(-A/55.6)) \qquad (1)$$

$$A=D^2/L^2 \qquad (0<A<1)$$

Data processing rate is 6(frames/sec) for a civil video signal of the single aperture sensor. Data statistic is done during the time of 15 minutes. Figure 2 shows the statistical distribution of arrival-angle in the turbulence cell as a normalized type both in x and in y directions, which indicates that the turbulence is isotropic. Figure 3 and 4 show the relationship of arrival-angle and average value of coherent length for numbers of 15-minute to the different sizes of the single aperture respectively. In figure 3, the experiment results are well fitted from (1) in the sense of the least variance as L chosen to be 90mm, which means that the turbulence outer scale is about 90mm. In figure 4, the average value of r keeps unchanged in small size of aperture and becomes longer as the aperture size increases. this shows the smoothing effect of the receiving aperture.

Parameters of the Hartmann wavefront sensor are 37-element, sampling rate 380 frames/second, 8bit A/D convertor with 128x128 pixels. The data processing rate is 40 frames/second. Each subaperture size is 5.2mm with subwindow of 16x14 pixels.

Since $D<<L$ for Hartmann wavefront sensor, (1) is reduced to

$$\sigma^2=0.358\lambda^2 r^{-5/3}D^{-1/3} \qquad (2)$$

One group of r for 37-element subaperture is statistcally obtained in time interval 75 seconds (300 frames). The groups of r are measured many times for 30 minutes. The statistical distribution of r for all groups of 37-subaperture is shown in the figure 5. This distribution has the mean value exactly same as that in figure 4 at small size of single aperture and is well fitted by normalized logarithm curve. The interesting thing is that for any time interval (within the range of experiment allowance) longer than 75 seconds and any repeating times, such distribution stays in the same way. This suggests us that the coherent length r of turbulence (possibly in the real atmosphere) obeys some distribution with a typical value, as conventionally described for turbulence intensity, being the average of large statistic scale. Therefore, the distribution of coherent length of turbulence sounds more reasonable than its average value in a finite statistic scale for most of apllicatiobns.

CONCLUSION

Since the Hartmann wavefront sensor measures the dynamic wavefront variation (image motion) in a speed faster than single aperture sensor and provides both spatial and temporal informations about the varying wavefront, it is a good tool for measuring turbulence parameters. However, the conventional measurements, such as single aperture sensor, are sometimes limited by the sampling speed and by the aperture size itself because of the smoothing effect of aperture. The coherent length of the atmospheric turbulence possibly obey a normalized logarithm distribution in a finite statistic scale properly chosen.

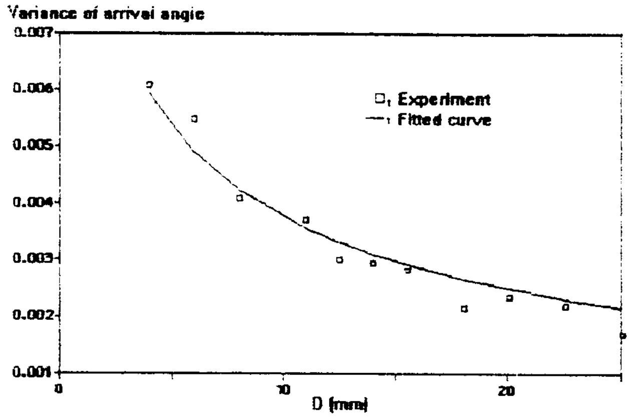

Fig. 3 Variance of arrival angle vs aperture size

REFERENCES

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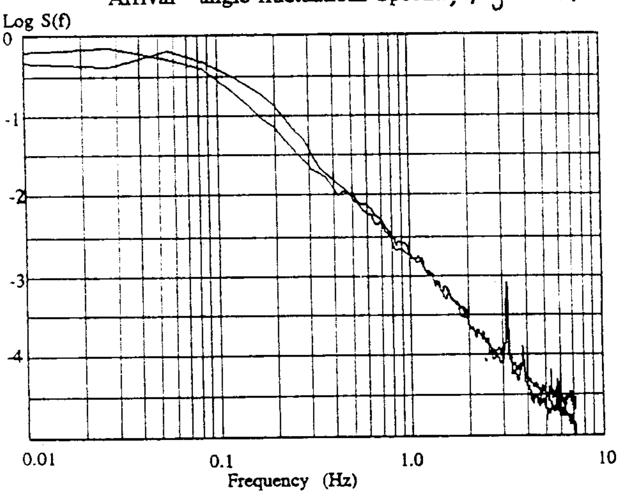
2. D.H.Tofsted, Appl.Opt.,Vol.31,No.27, p5865.

Arrival - angle fluctuations Spectra, Figure 1.



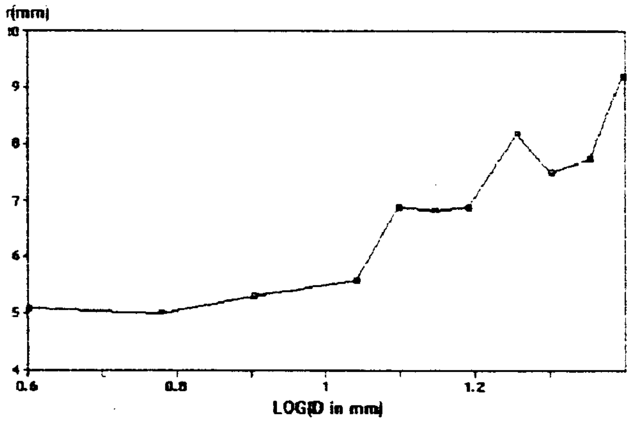


Fig.4 Coherent length r vs receiving aperture size

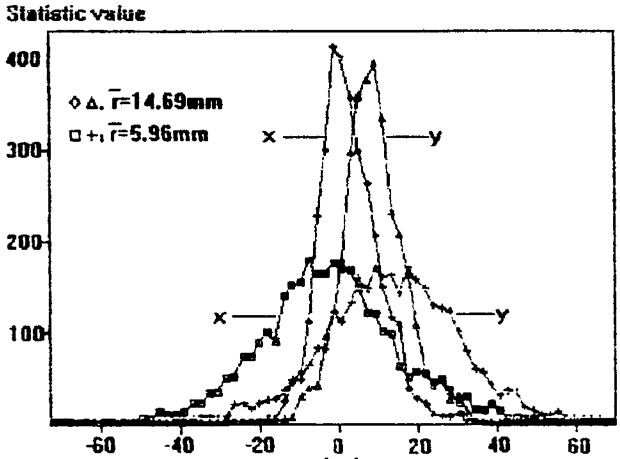


Fig. 2 Distribution of arrival-angle in the cell

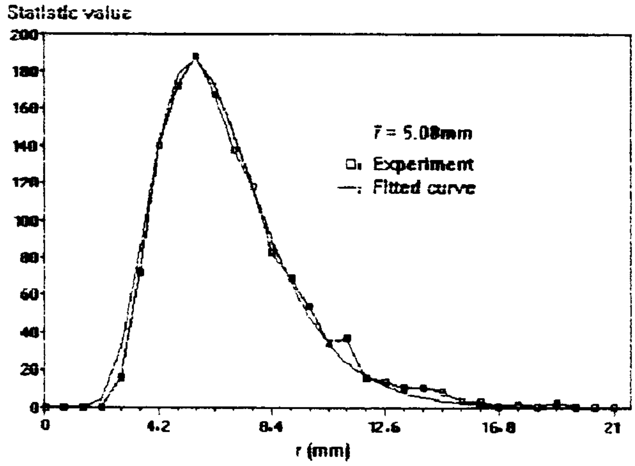


Fig. 5 Distribution of coherent length