C 4　空間周波数を用いた速度測定技術

Velocity Measurement Techniques Using Spatial Frequency

李　樹栄　　　有賀　規
Shu Wing Li　　　*Tadashi Aruga*
郵政省通信総合研究所
Communications Research Laboratory

Abstract

Two different velocity measurement techniques using spatial frequency are studied in this paper.

First, the spatial filtering effect of a transmission grating placed at the image plane of an optical system for velocity measurement is studied theoretically and experimentally. Experimental results of application of this technique are shown.

A new, and mathematically equivalent, technique for velocity measurement by illumination of the moving object with a periodical laser beam will then be discussed. Experimental results of velocity measurement using this technique will also be presented.

I. Introduction

A common velocity measurement technique is Doppler velocimetry. An alternative technique is by using spatial frequency, which can be due to a transmission grating or a periodical laser beam pattern.

II. By Spatial Filtering

In transmission grating velocimetry, a periodical transmission grating is placed at the image plane of an optical system. For an object moving across the latter's field of view, its image is spatially filtered as it moves across the grating, producing a periodically ampiltude-modulated output signal from a photon detector placed behind the grating.

The spatial filtering effect of the grating can be shown to produce a signal, I(t), given by

$$I(t) = a \exp(i 2\pi u \mathrm{v} t)\, F(u) \tag{1}$$

where $F(u)$ is the Fourier component of the brightness distribution function of the object at the spatial frequency of the grating, u. That is, the detected signal is proportional to the magnitude of the Fourier component of the object spectrum at the spatial frequency of the grating, and it is a periodical time function of frequency

$$f = u \mathrm{v} \tag{2}$$

where v is the velocity of the image.

Using the experimental setup shown in Fig. 1, the proportional relation of Eq. (1) is verified for the picture shown in Fig. (2) as the moving object. a set of gratings with square wave transmittance of different spatial frequencies is used. The gratings are placed at the image plane in turn, and the detector outputs are fed into the spectrum analyzer. The signal amplitude obtained is measured in each case. A plot of the relative signal amplitudes so obtained versus the spatial frequencies of the gratings used is shown in Fig. 3(a). The Fourier spectrum of the object, obtained by a FFT of the brightness distribution of the object, is shown

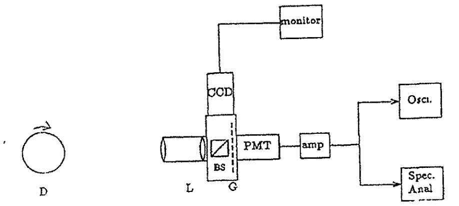
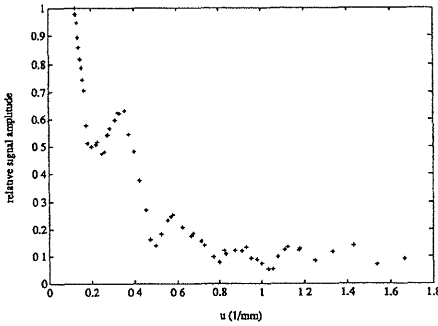


Fig. 1



(a)

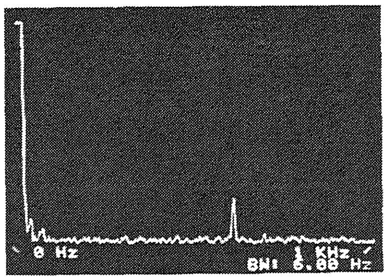
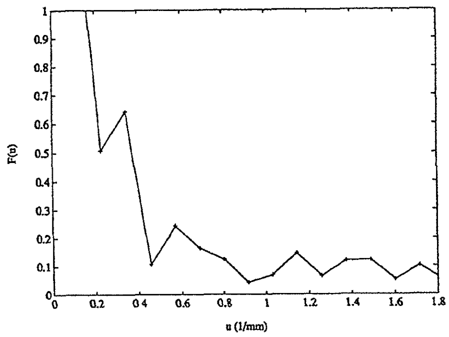


Fig. 4

Fig. 2



(b)

Fig. 3

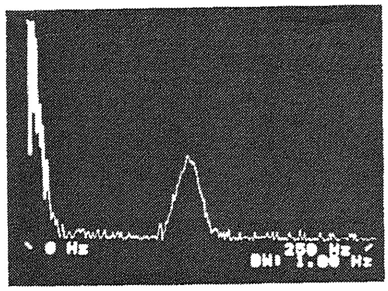


Fig. 5

in Fig. 3(b) for comparison. The good agreement between the two results verifies Eq. (1) experimentally.

As an example of application of this method to measure the velocity of a moving object, Fig. 4 shows the signal generated by a car moving in the street. The signal is obtained from a distance of 17 m with a 200 mm lens and a 5 lines/mm grating. This signal of 624 Hz corresponds to a velocity of 39.4 km/h.

III. Illumination With a Laser Beam Pattern

Instead of using a transmission grating to modulate the input to the photon detector, an alternative, and mathematically equivalent, method to generate a periodical output signal from the detector is by active illumination of the object with a periodical laser beam pattern. This technique would be particularly useful in nighttime or outer space applications.

By placing a beam expander and a grating with square wave transmittance in the path of the output of a He-Ne laser, a laser beam pattern with an intensity profile that changes periodically is experimentally realized. Fig. 5 shows the signal obtained from a car with a laser beam pattern of period 10 cm generated in the middle of a street. The 320 μV signal at 119 Hz corresponds to a velocity of 42.8 km/h.

IV. Conclusion

These several examples of experiments indicate that the optical velocimetry principle/technique we demonstrated above is applicable to common moving objects in one pass through the detector's field of view. The method is applicable for the measurements of the velocities of a variety of objects, including vechicles, clouds, air pollution bulks and spacecrafts. It can be used for single-ended remote sensing of outdoor objects as well as for non-contact velocity measurements in production processes. High accuracy velocity determination can be expected.