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CALIBRATION AND ANALYSIS FOR A 0.53 μm INCOHERENT DOPPLER LIDAR

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I. Introduction

A ground based, prototype Doppler lidar is being developed to demonstrate the feasibility of an incoherent detection technique to remotely measure winds in the atmosphere. This prototype system consists of a narrow-band, single-frequency laser transmitter, a high-resolution, Fabry-Perot Interferometer (FPI) utilizing a multichannel Image Plane Detector (IPD) and a data acquisition system. A description of the prototype Doppler lidar hardware is given in Rosenberg and Sroga, 1985. This paper will describe the calibration and analysis procedures for this system. Preliminary results from data obtained with the system pointed vertically will be presented.

II. Instrument Calibration

The signal intensity measured in each channel of the FP1-IPD Doppler lidar is the convolution of the spectral distribution of the source (e.g. laser or atmospheric backscatter) with the instrument transmission function for that particular channel. The instrument functions, which contain information of the spectral broadening effects and the relative IPD channel sensitivities, are obtained by a wavelength scan of the instrument across a narrow-band, single-frequency source. Fig. 1 illustrates the transmission function of the 12-channel Doppler lidar FPI obtained by pressure scanning the etalon chamber while illuminating the FPI entrance aperture with diffuse light from a stabilized, single-frequency helium neon laser. The periodic nature of the FPI transmission function suggests that a Fourier series decomposition can be used to completely describe the instrumental broadening effects. Killeen and Hays, 1984 describe a procedure for calculating a Fourier series of such data and translating these Fourier coefficients computed at a calibration source wavelength to other operating wavelengths. Fig. 2 shows the magnitude of the channel #1 Fourier coefficients as a function of the harmonic term at the calibration source wavelength (a, 0.6328 μm) and translated to the Doppler lidar operating wavelength (b, 0.532 μm). The Fourier calibration coefficients for each FPI-IPD channel are calculated in a similar manner.

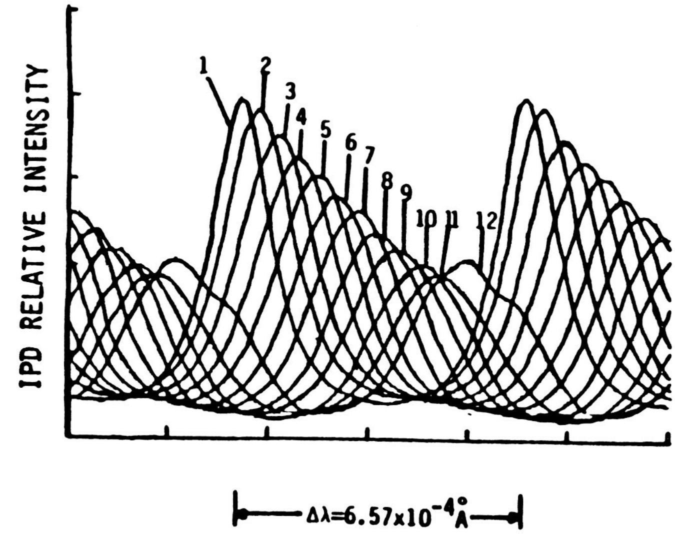

Fig. 1. Relative transmission function of the 12-channel FPI obtained during a pressure scan of the FPI etalon chamber using a stabilized, single-frequency helium Neon laser as the calibration source.

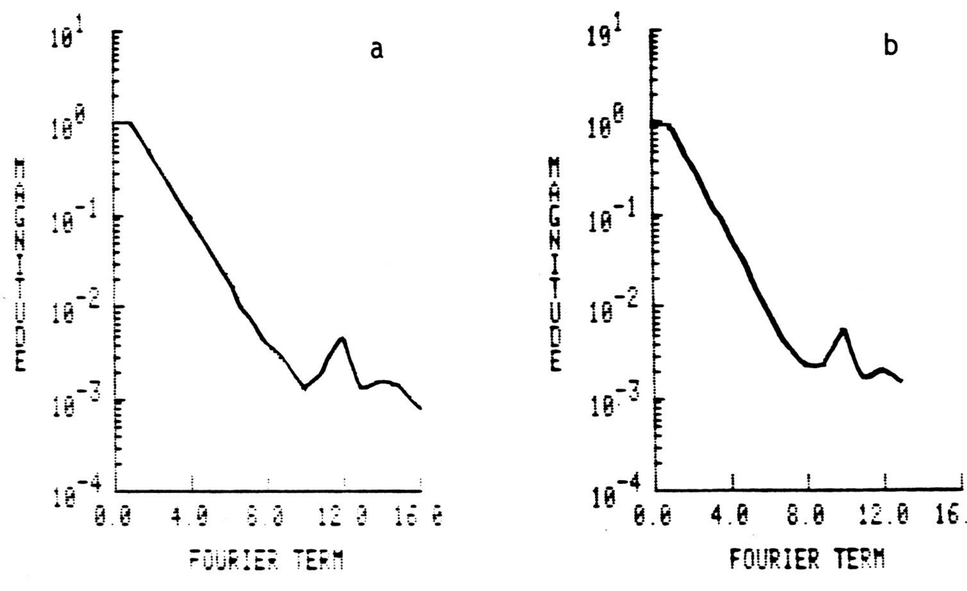

Fig. 2. Magnitude of the Fourier coefficients for channel #1 at the calibration source wavelength (a, 0.6328 μm) and translated to 0.532 μm (b).

III. Data Analysis

The Fourier calibration coefficients calculated from the above procedure are combined with an analytical description of the FPI and the atmospheric backscatter spectra to form a model of the Doppler lidar backscattered signals. This instrument model is a nonlinear function of the system design parameters and the Fourier calibration coefficients, which are the system constants, and variable parameters as the total aerosol and molecular backscatter intensities and the mean atmospheric Doppler shift velocity. A nonlinear regression technique (Draper and Smith, 1981), which is similar to the matrix technique of Killeen and Hays, 1984, is used to adjust these variable model parameters to yield a "best fit" of the model to the measured FPI-IPD intensities, and therefore optimum values for these parameters.

Preliminary atmospheric testing with the 0.53 μm Doppler lidar has been conducted to demonstrate the system capabilities. The calibration and analysis procedures have been applied to this data to derive the mean Doppler shift and separate the total aerosol and molecular backscatter contributions. Fig. 3a illustrates an example of data for a single shot obtained on 3 September, 1985 with the system pointing vertically. The sample labeled 1 is a measurement of the transmitted laser pulse spectrum and the subsequent samples represent the atmospheric backscatter spectra sampled at 300m intervals (2 = 300m, 3 = 600m). Fig. 3b shows the least-squares regression fit of the instrument model to this data. Fig. 4 is an average of approximately 10 shots along with the regression fit to this averaged data. A discussion of these results and error analysis will be presented.

References

Draper, N. R., and H. Smith, 1981, Applied Regression Analysis, Second Edition, John Wiley and Sons, Inc., New York, NY, pp. 709.

Killeen, T. L. and P. B. Hays, 1984, "Doppler Line Profile Analysis for a Multichannel Fabry-Perot Interferometer", Appl. Opt., V23, pp. 612-620.

Rosenberg, A. and J. Sroga, 1985, "Development of a 0.5 μm Doppler Lidar for Space Applications" in Global Wind Measurements, W. E. Baker and R. J. Curran (Eds.), H. Deepak Publishing, Hampton, VA.

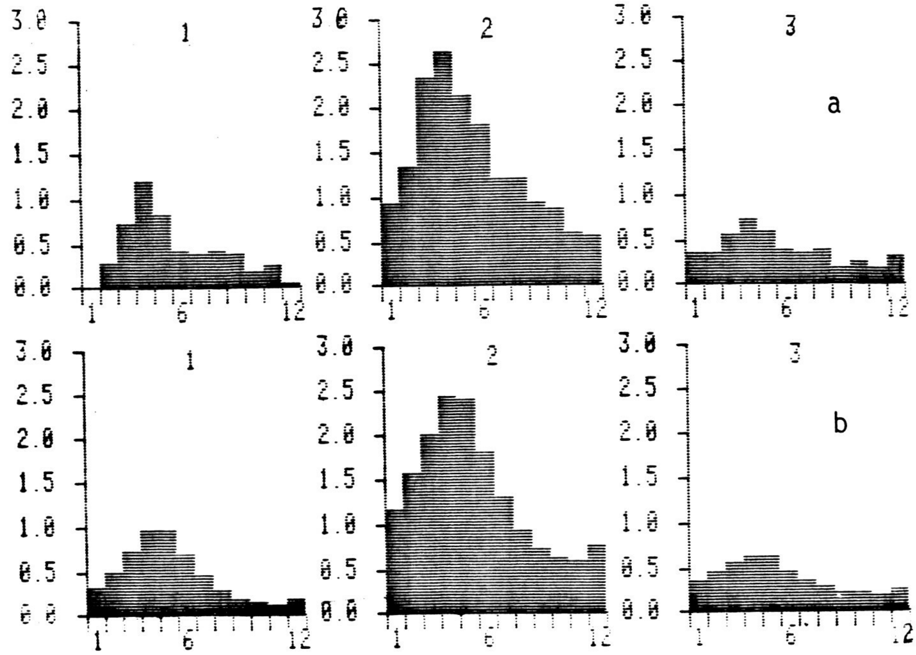

Fig. 3. Doppler lidar data obtained for a single laser pulse (a) and a regression fit of model to above data (b). See text for further description.

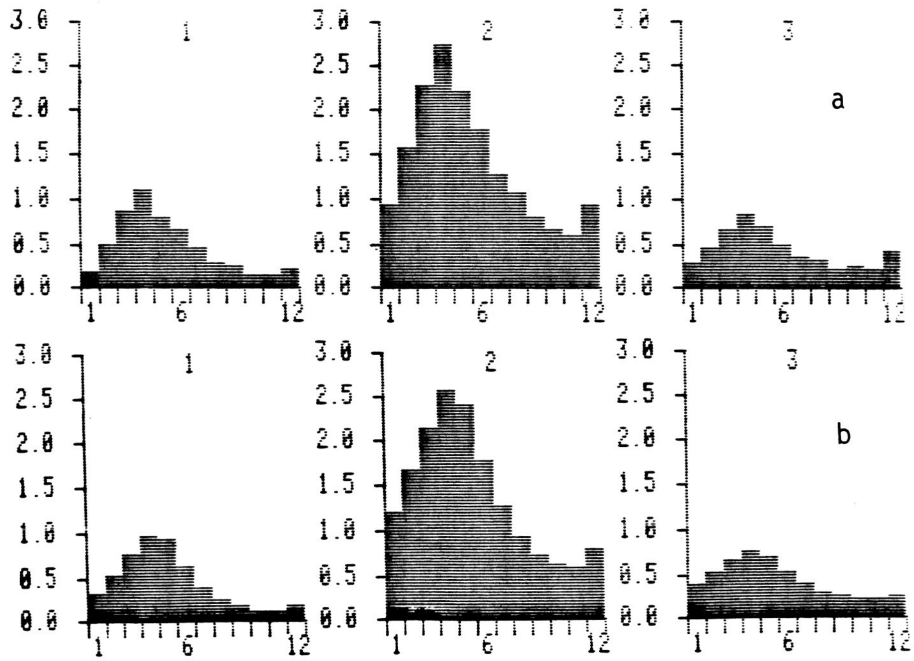

Fig. 4 Same as Fig. 3 except an average of ~ 10 shots.