NOAA Technical Memorandum ERL WPL-88

A CALIBRATOR FOR OPTICAL INSTRUMENTS THAT MEASURE C_n^2 AND CROSSWIND

B. W. Guderian
G. R. Ochs

Wave Propagation Laboratory
Boulder, Colorado
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Partial support for this project was provided by the U.S. Army Electronics Command, Atmospheric Sciences Laboratory, White Sands, N.M. 88002, under Contract ASL 81-8030.

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UNITED STATES
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ABSTRACT

This report describes a calibrator for optical instruments that measure C_n^2 and crosswinds. Operating instructions, alignment procedures, and circuit diagrams are included.

1. INTRODUCTION

The optical systems[1,2,3] that have been designed and built by the Wave Propagation Laboratory to measure average crosswind and the refractive-index structure parameter C_n^2 may be calibrated without special test instruments. A specialized test instrument is useful, however, in that it can perform a rather complete check of the receiver and its calibration, and do so, if desired, without removing the receiver from its mount. The calibrator described here provides two LED sources, which are 100% modulated at the carrier frequency. Two lower frequency square waves, always 90° out of phase, and with adjustable modulation depth, are available to amplitude modulate the carriers. Procedures for calibrating C_n^2 and wind are contained in Sections 2 and 3; the Appendix contains the circuit diagram and layout of the instrument, and derivations of the calibration techniques.

2. C_n^2 CALIBRATION

Place the calibrator in front of the receiver and check to make sure that signals are being received in both channels. Set the digital pot on the C_n^2 meter for the path length to be used. Observe the signals at the microdot test points on the C_n^2 meter with an oscilloscope. The square wave modulation on the carriers, with maximum amplitude a and minimum amplitude b is related to the C_n^2 meter readings (see Appendix) as follows:

$$\log(a/b) = \sqrt{\frac{C_n^{\;2}\; L^3}{1.48\; k_1\; D^{7/3}}} \tag{1}$$

where D is the $C_n^{\;2}$ meter aperture diameter, L is the path length, and k_1 is a constant which depends upon the aperture geometry of the $C_n^{\;2}$ system.

Calculate the ratio a/b for $C_n^{\;2} = 1 \times 10^{-12}$ and, while observing the signals on the scope, adjust the bias pots on the calibrator to obtain this ratio at both $C_n^{\;2}$ meter test points. Other scale points can be checked by calculating a/b for other $C_n^{\;2}$ values although it is difficult to set small a/b ratios accurately.

3. WIND CALIBRATION

Again, place the calibrator in front of the receiver and check to make sure that signals are being received in both channels. The relationship between the calibrator modulation frequency f and the wind speed reading v is

$$f = \frac{v}{2\; k_2 d} \tag{3}$$

where d is the separation of the centers of the receiving apertures and k_2 is a constant determined by the diameters of the transmitter and receivers. The value of k_2 is 1.00 for the 5 cm system and 1.06 for the 15 cm system.

To check the calibration, calculate f for full scale readings on each scale setting. Set the module to the proper full scale with the test signals illuminating the receiver. Then switch to + or - and quickly back to RUN. If this is not done, the wind computer may lock up on a subharmonic of the correct wind speed, because the test signal, unlike real signals, is a single frequency. Set the calibrator to the calculated modulation frequency by setting the RANGE to either LO (5-50 Hz) or HI (50-250 Hz) and adjusting the MODULATED FREQ pot for the desired frequency at the MOD OUT connector.

4. ALIGNMENT PROCEDURE

The initial circuit alignment consists of adjusting the bias of the carrier square wave. This is accomplished by observing the signal at either of the SIGNAL microdots and adjusting the trim pot between op amps 3 and 10 so that the bottom of the carrier square wave is at 0.0 volts. When this is done properly only the top of the signal should show any modulation.

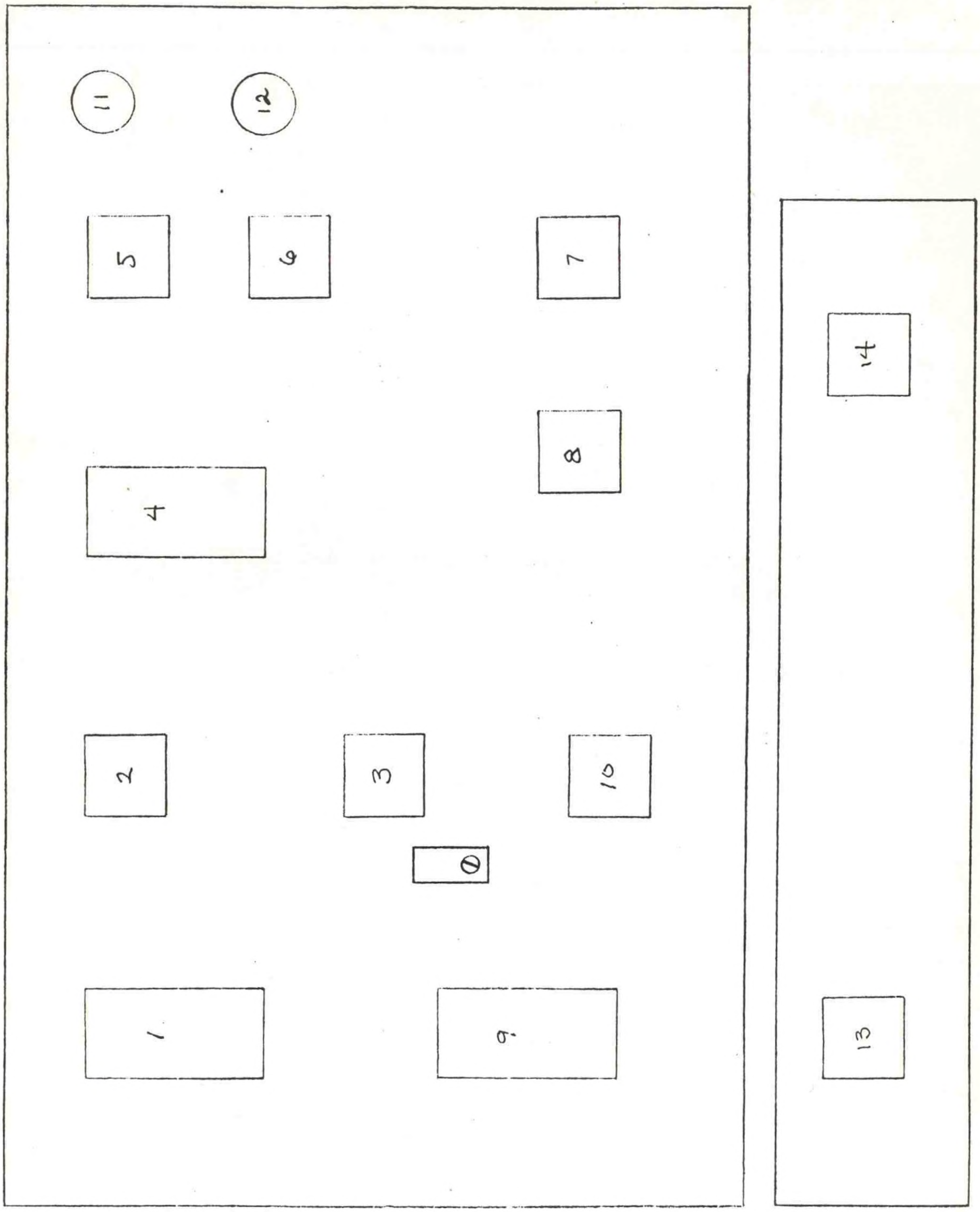
5. REFERENCES

1. Ochs, G.R., W.D. Cartwright, and D.D. Russell (1980): Optical C_n^2 instrument model II, NOAA Tech. Memo. ERL WPL-51.

2. Ochs, G.R., and W.D. Cartwright (1980): A crosswind measurement module for the model II optical C_n^2 instrument, NOAA Tech. Memo. ERL WPL-53.

3. Ochs, G.R., and W.D. Cartwright (1980): Optical system model IV for space-averaged wind and C_n^2 measurements.

APPENDIX A -- CIRCUIT DIAGRAM AND LAYOUT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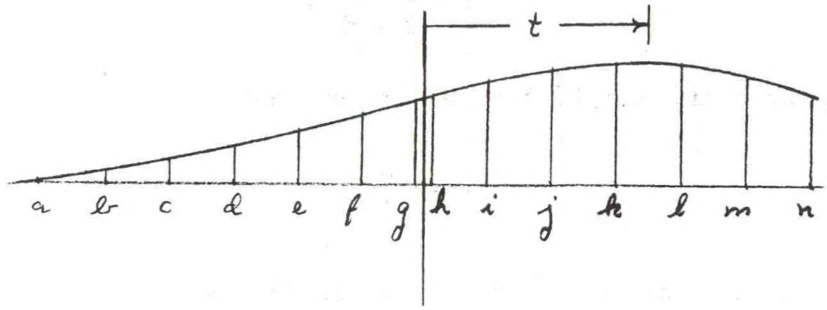
Derivation of the test signal and windspeed relationship.



The crosswind module determines wind speed by examining the time-delay correlation function of the fluctuations of irradiance of the two separated apertures. A servo system adjusts time delay t so that the correlation at a through n satisfies the relationship

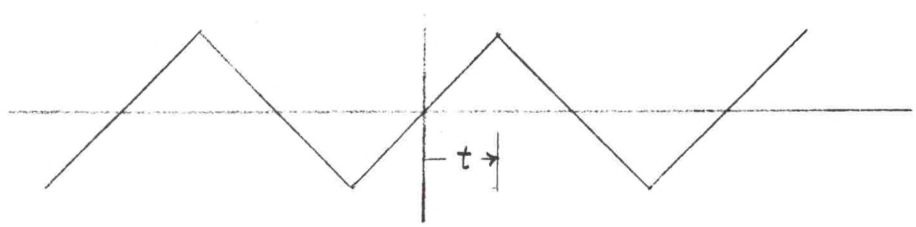
$$(\ell+m+n) - (h+i+j+k) + (d+e+f+g) - (a+b+c) = 0 .$$

Then windspeed v is

$$v = \frac{k_2 d}{2t} \qquad (2)$$

where d is the center separation of the sensors and k_2 is a constant determined by the diameters of the transmitter and receivers.

Two square waves, 90° out of phase, have a correlation function as follows:



where the frequency, f = 1/4t. The velocity reading corresponding to test signals of frequency f can be found by combining with (2) so

$$f = \frac{v}{2\ k_2 d} \quad . \tag{3}$$

In the 5 cm instrument, k = 1, d = .066 m, so that

$$f = \frac{v}{.132} \quad .$$

(For the 15 cm instrument which has nearly tangent apertures, k = 1.06.)

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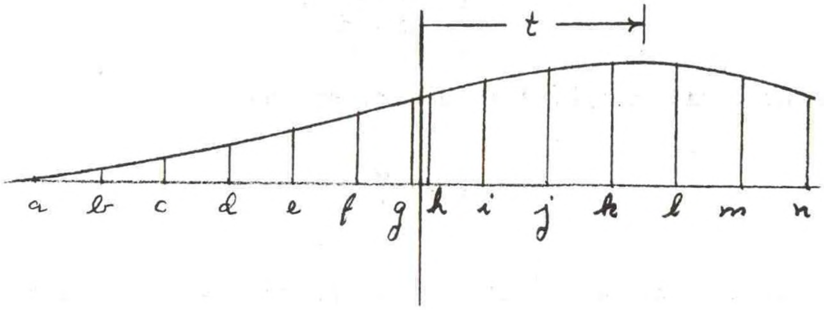

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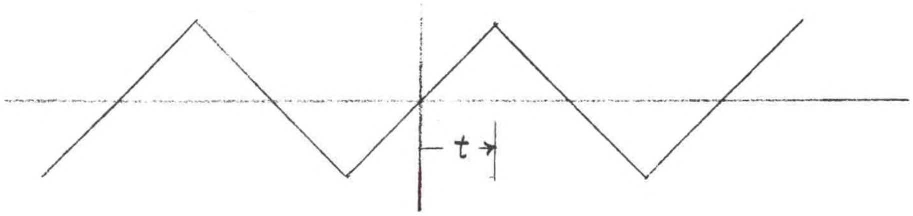

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