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DEPARTMENT OF PHYSICS  
SCHOOL OF SCIENCES AND HEALTH PROFESSIONS  
OLD DOMINION UNIVERSITY  
NORFOLK, VIRGINIA

Technical Report PTR-81-12

**PROPAGATION OF SOUND THROUGH THE EARTH'S  
ATMOSPHERE**

- I. MEASUREMENT OF SOUND ABSORPTION IN THE  
AIR AND**
- II. DETECTION OF INFRASOUND GENERATED BY  
CLEAR AIR TURBULENCE**

By

Roger Meredith  
Francis Badavi  
and  
Jacob Becher, Principal Investigator



Progress Report  
For the period January 1 - June 30, 1981

Prepared for the  
National Aeronautics and Space Administration  
Langley Research Center  
Hampton, Virginia

Under  
Research Grant NAG1-142  
Harlan K. Holmes, Technical Monitor  
Instrument Research Division



(NASA-CR-165008) PROPAGATION OF SOUND  
THROUGH THE EARTH'S ATMOSPHERE Progress  
Report, 1 Jan. - 30 Jun. 1981 (Old Dominion  
Univ., Norfolk, Va.) 12 p HC A02/MF A01

N82-13828  
THRU  
N82-13830  
Unclass  
08498

CSCL 20A G3/71

August 1981

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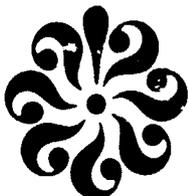
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Submitted by the  
Old Dominion University Research Foundation  
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## PROPAGATION OF SOUND THROUGH THE EARTH'S ATMOSPHERE

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By

Roger Meredith<sup>1</sup>, Francis Badavi<sup>2</sup>, and Jacob Becher<sup>3</sup>

## SUMMARY

This report summarizes work performed under research grant NAG1-142 since January 1, 1981 in the following areas: (I) Measurement of Sound Absorption in Air and (II) Detection of Infrasound Generated by Clear Air Turbulence.

## I. MEASUREMENT OF SOUND ABSORPTION IN AIR

## Cooling System for the Resonant Tube

The large temperature gradient in each tube section resulting from the liquid nitrogen coolant (see ref. 1) necessitated a design modification to the cooling system. The new design incorporates a timer and four solenoid valves so that the liquid nitrogen coolant flow can be reversed periodically. The necessary parts were ordered in mid-January and arrived in early July. When the installation of the valves and timer are completed, the system will be retested.

## Automatic Data-Processing System

The automatic data-processing system centers around the Apple II computer and a 12-bit Datel Intersil model ADC-HC12B analog-to-digital

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converter. The hardware and software for controlling the converter and conversion rate have been completed, and the system is operational. A duty cycle control circuit has been designed and implemented so that on the sixteenth conversion a relay shuts off the vibration exciter used to generate the sound wave. Thus the starting point of each decay curve is exactly known. This information is necessary for evaluating the digital decay information.

It has been found that the slew rate for the digital system is much faster than that of the old analog system and that the digital decay data is of better quality than the same analog signal recorded on the B & K 2305 chart recorder. Most of the decay curves resemble a staircase where each stairstep corresponds to one acoustical round-trip time in the tube (ref. 2). This type of decay curve was previously observed only at the higher frequencies.

The software development has been completed in two stages: (1) data acquisition and (2) digital decay data evaluation. The data-acquisition program controls the conversion rate, depending upon the decay time constant from 6 to 500 Hz, via input from the operator. The decay curve is sampled 252 times at the specified rate to compose the digital decay data. The digital data is displayed on the computer monitor and the operator decides whether to reset the sampling rate and repeat the sampling or save the digital decay data. This is done for all frequencies of the measurement set. The digital data is saved on magnetic floppy disks which can hold 105 frequencies.

Once the data is stored on disk, it can be processed at any time using the digital decay evaluation program. This software reads the data from the disk and plots the decay and the first derivative. The operator chooses the sample points with the minimum value of the first derivative which determine the experimental round-trip time. The average step depth, in decibels, is found from points located an integer number of round trips away from a starting point. This is repeated for several starting points centered around sample number 16, the exact starting point of the decay. Based on these averages, the attenuation in terms of decibels per round-trip time is calculated and converted to nepers/wavelength.

Software is being developed so that the computer can process a complete measurement set (~ 80 frequencies) without operator assistance. Background data has been collected at 30° C and is being used to verify and modify the aforementioned software. The bottled air supplied under contract to NASA does not meet composition requirements for "standard" air, and consequently special cylinders of standard air have been ordered.

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## II. DETECTION OF INFRASOUND GENERATED BY CLEAR AIR TURBULENCE (CAT)

### Introduction

The experimental procedures for this experiment have been divided into four phases, which are described below. This report focuses on phases 1 and 2.

#### (1) Detection of Atmospheric Infrasound

This will be accomplished through instrumentation developed under two previous NASA grants (NGR 36-028-004 and NAS1-11707-29). This is a unified acoustic data-acquisition system which is an AM carrier system consisting of a converter signal, conditioning electronics, and peripheral equipment. This phase of the experiment also includes calibration and instrumentation checkout and installation of a microphase array system.

Instrumentation checkout and calibration.--The unified system had to be checked and calibrated prior to any field testing, and hence it was extensively tested in the lab. The procedures for calibration are described in the paragraphs which follow.

The distortion measurements were done by using an HP Model 334A Distortion Analyzer. The procedure was carried out for three different cable lengths. The data for the distortion level and the system dynamic range is given in table 1 (see ref. 3). The standard 4 percent distortion level occurred at approximately 135 dB for all 4 microphone systems. A typical distortion graph is shown in figure 1.

The amount of crosstalk of the zero-drives due to the leakage of electronic noise between different channels was measured by exciting one channel with an acoustical signal of 1 kHz/120 dB and measuring the SPL of the

adjacent channels. In all cases it was decided the amount of crosstalk was virtually insignificant in the entire system.

A piston-type infrasonic calibrator, driven at an equivalent SPL of 90 dB, was used to determine the frequency response of the system. Table 2 gives the particular frequency at which the amplitude of the SPL fell below the standard -3 dB over the entire operating frequency range of 0.1 to 10 Hz. Figure 2 shows the frequency response of all 4 channels with a 457-m (1500-ft) long cable as a means of signal transmission (ref. 4).

Installation of microphone array.--An area north of the Lunar Landing Facility was selected to install the microphone array in the shape of a 244-m (800-ft) equilateral triangle with a microphone at the center and one at each apex. The data-acquisition system was installed in a mobile van near the center microphone. Due to the local terrain, 457-m (1500-ft) long cables were used to connect the microphones to the data-acquisition system.

## (2) Signal Processing

This phase of the experiment includes

(a) design and construction of an A/D converter and development of necessary software to be incorporated with an APPLE II computer as a means of digital analysis of the data; and

(b) development of digital correlation techniques to extract the direction of an infrasonic source from the phase information contained in the signal received in the microphone array.

An A/D converter has been procured and the proper software was written to carry out the conversion. Due to the slow rate of conversion, all of the software was written in BASIC language. At present, work is being carried out to develop a multi-channel correlation technique to be used in the near future as a means of input-signal phase studies.

## (3) Interpretation of Infrasonic Signature

A prime goal of the experiment is, through experiment, to differentiate between CAT and other sources of infrasound.

(4) Corroboration with Other Methods

Once patches of CMB are located in the atmosphere, corroboration can be achieved through test flights of aircraft into the suspected region.

## REFERENCES

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2. Zuckerwar, Allan J.; and Griffin, W.A.: J. Acoust. Soc. Am., Vol. 68, 1980, pp. 218-226.
3. Zuckerwar, Allan J.; and Holmes, Harlan N.: A Verified Acquisition System for Acoustic Data. NASA TND 8327, Mar. 1977, pp. 14-18.
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Table 1. System distortion and dynamic range.

Mic Channel	Cable Length (ft) <sup>a</sup>	Range Setting of Zero-Drive Amplifier	Noise Floor (dB) <sup>b,c</sup>	SPL at 4% Distortion (dB) <sup>d</sup>	Dynamic Range (dB) <sup>e</sup>
1	1,000 <sup>c</sup>	34	58	134	71
	1,500		59	130	66
			60	126	61
2	1,000 <sup>c</sup>	34	57	132	70
	1,500		58	130	67
			59	126	62
3	1,000 <sup>c</sup>	30	56	135	74
	1,500		57	132	70
			58	126	63
4	1,000 <sup>c</sup>	32	57	136	74
	1,500		58	131	68
			59	126	62

<sup>a</sup>1 ft = 0.3048 m

<sup>b</sup>Bandwidth of noise floor measurement: 22.4 Hz - 22.4 kHz.

<sup>c</sup>Reference SPL: 20  $\mu$ Pa.

<sup>d</sup>Frequency of distortion measurement = 1 kHz.

<sup>e</sup>5 dB above noise floor to SPL at 4 percent distortion

Table 2. System cutoff frequency of -3 dB.

<u>Microphone Channel</u>	<u>-3 dB point</u>
1	$f_c = 0.5 \text{ Hz}$
2	$f_c = 0.2 \text{ Hz}$
3	$f_c = 0.5 \text{ Hz}$
4	$f_c = 0.2 \text{ Hz}$

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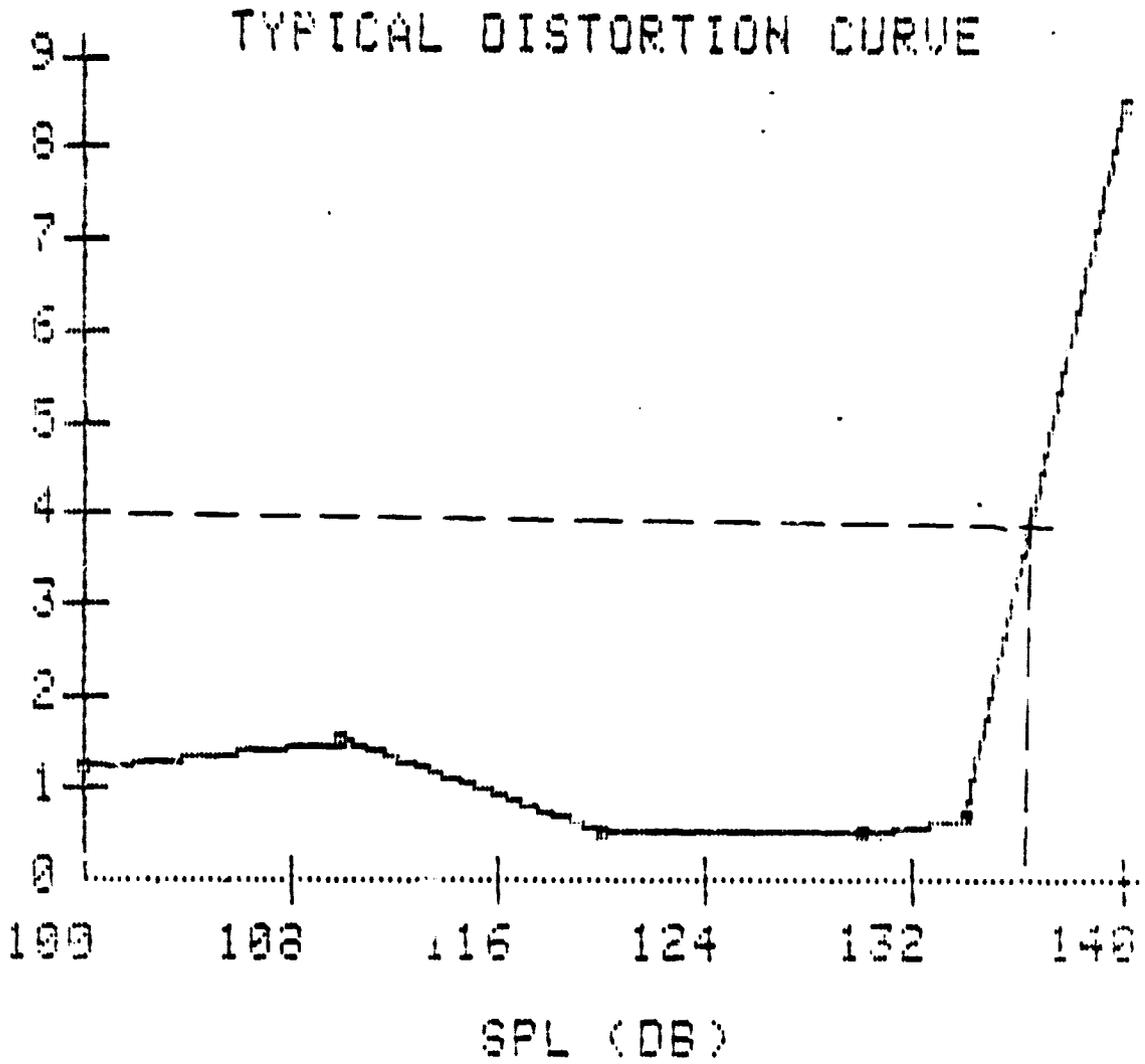


Figure 1. Typical distortion curve of the microphone with 4 percent distortion level at approximately 135 dB.

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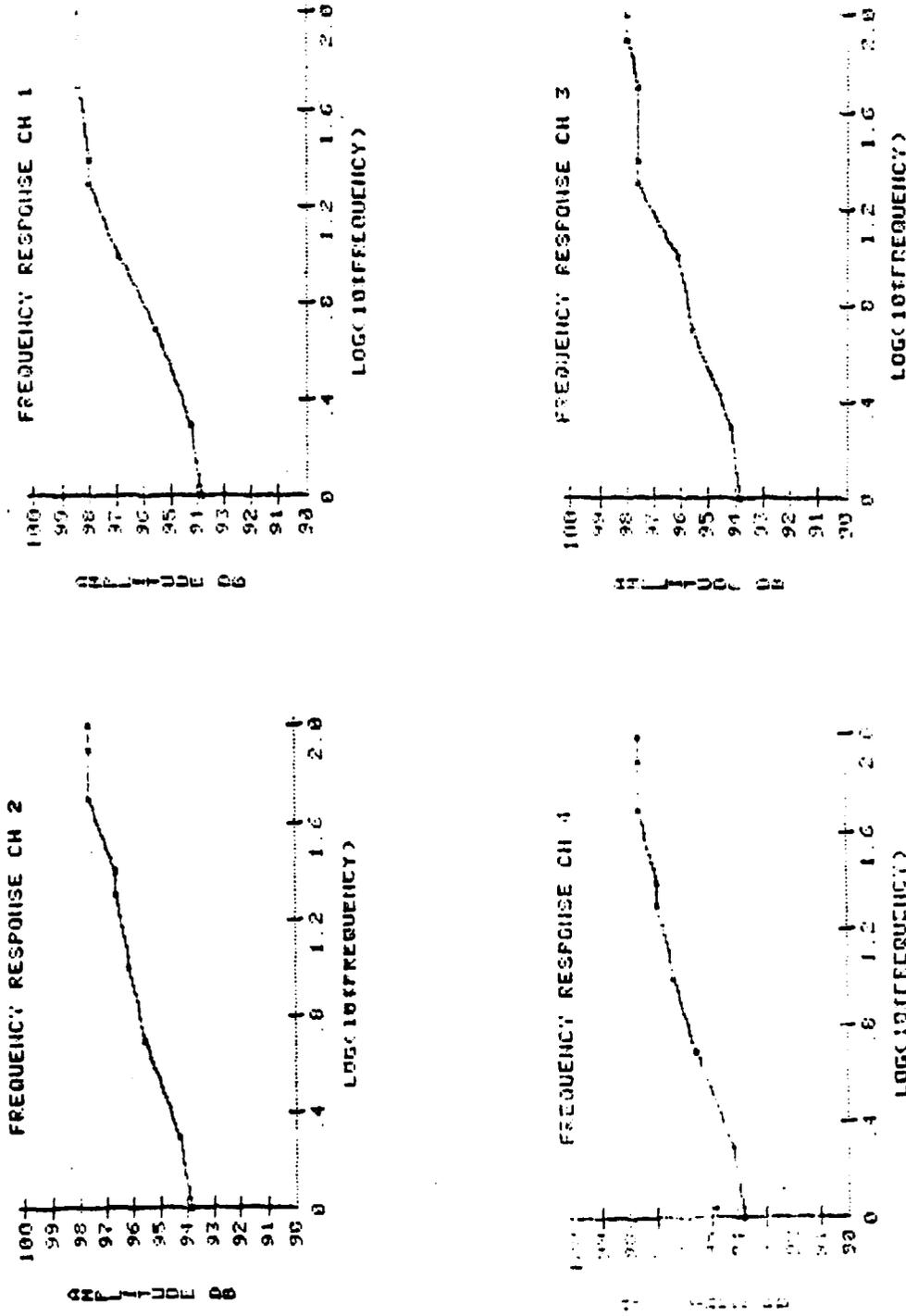


Figure 2. Frequency response of microphone with -3 dB cutoff point.