Use of a Sailplane in Measuring Acoustic Attenuation in the Atmosphere

By D. W. Beran* and J. T. Gething,
Meteorology Department, University of Melbourne

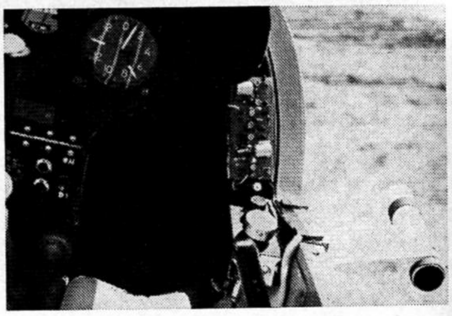

Fig. 3. Pilots view of instrument panel and controls used for sending the acoustic and radio signals.

Introduction

Acoustic sounders have recently come into use for the study of boundary layer meteorological parameters which are identified by the backscatter from turbulent region inbedded in them [McAllister, 1968]. To quantitatively assess the backscattering cross section of the turbulence the atmospheric attenuation of the acoustic waves must be known [Little, 1969].
Under the direction of the senior author an experiment [Beran, 1970] was conducted at Benalla, the base of the Gliding Club of Victoria, during November 1969 to measure acoustic attenuation in the free atmosphere.
A Slingsby Dart 17R was used as a silent platform to carry an acoustic source whose output was measured at the ground. The distance to the glider was calculated and from a comparison of the successive sound levels received at the ground, as the glider descended from heights up to 3,000 m, a profile of the atmospheric attenuation was derived.

Theory of Acoustic Attenuation

For a hemispherically spreading sound wave the intensity, I, at a distance, r, from the source is

$$I = \frac{P}{2\pi r^2} \exp(-a r)$$

where P is the acoustic power and a the total attenuation coefficient.
In the free atmosphere the total attenuation coefficient can be represented as

$$a = a_c + a_m + a_s,$$

where a_c is the so-called classical attenuation, a_m the molecular attenuation and a_s the miscellaneous or excess attenuation, due to factors such as scattering and focussing of the wave. The classical attenuation, due to viscosity, heat conduction, molecular diffusion and radiation of heat, can generally be neglected in comparison with the molecular attenuation. This component, a_m, of the absorption is due to the relaxation process involving a lag in the adjustment of the vibrational energy of O_2 molecules during the passage of the sound wave. It is frequency and humidity dependent. Little work has been done on the nature of a_s, however, Delsasso and Leonard [1953] found that it accounted for a significant portion of the total attenuation. This is borne out by our measurements.

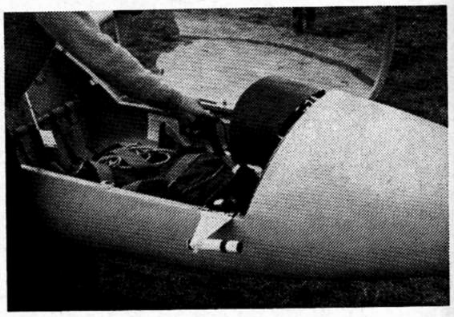

Fig. 4. Slingsby Dart 17R cockpit showing the pilots push button control; the control panel and radiation shield for wet and dry bulb thermisters.

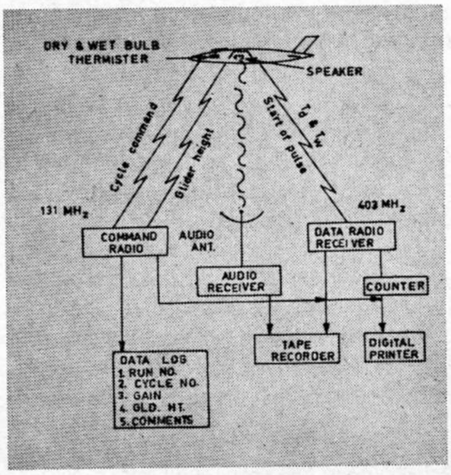

Fig. 1. Schematic of ACATHA data collection system.

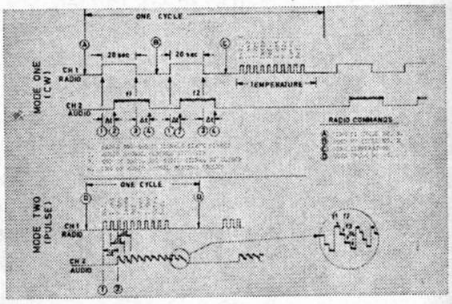

Fig. 5. Schematic of the records collected on magnetic tape for the CW mode (top) and the pulse mode (bottom).

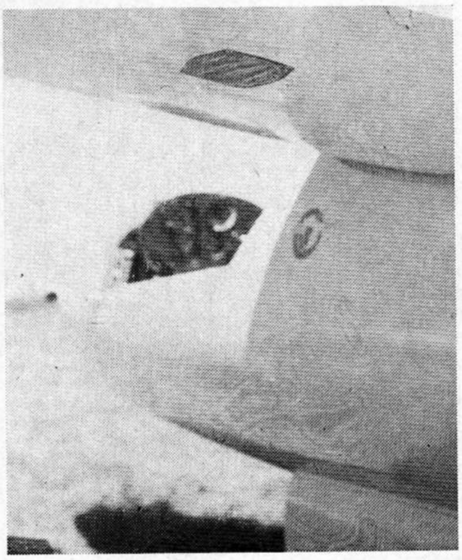

Fig. 2. Detail of speaker mounting in wing of Dart.

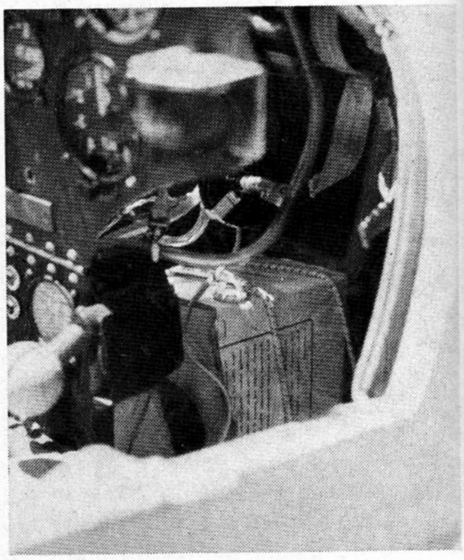

Fig. 6. Placement of data link radio transmitter in front of the Dart instrument panel and between the pilot's feet.

* D. Beran is now with the Wave Propagation Laboratory, NOAA, Boulder, Colorado.

The Experiment

If the distance of a sound source from a fixed receiver changes from r_1 to r_2 then the attenuation coefficient of the medium between r_1 and r_2 is given by

$$a = \frac{0.23\ (\text{db loss} - \text{db spread})}{(r_2 - r_1)}$$

where $\text{db loss} = 20 \log \frac{P_2}{P_1}$,

$\text{db spread} = 20 \log \frac{r_1}{r_2}$,

and P_1 and P_2 are the pressure amplitudes of the sound wave received from the source at distances r_1 and r_2. A schematic of the AGATHA (Assessment by Glider of Attenuation, Temperature, Humidity and Altitude) measuring system used in this experiment is shown in figure 1. This system was comprised of both glider mounted and ground based equipment which included an acoustic source and receiver, temperature and humidity sensors, along with radio links and recorders. The acoustic signal was generated by an oscillator, a 5 w amplifier and a 7″ × 4″ oval cone speaker flush mounted in the innermost fabric panel of the wing just behind the spar and approximately 1.5 m from the fuselage (see fig. 2). The pilot could transmit either 20 second CW tones at any one of four frequencies (750 Hz, 1,060 Hz, 1,600 Hz, 2,500 Hz), temperature information, or a continuous cycle of approximately 1 second pulses at each of the frequencies. This was done using the control panel mounted on the side of the cockpit and the push button on the control column (fig. 3 and 4). The distance to the glider was determined by measuring the difference in time between receiving a signal sent over the data radio link and the acoustic tone. The lag in arrival at the ground of the radio and acoustic pulses and the speed of sound profile computed from the measured temperature profile provided the information necessary for calculating the distance to the glider within ±1%. Figure 5 details the CW and pulse modes illustrating the use of coincident radio and acoustic signals and the method of sending temperature information. Figure 6 shows the data link transmitter (a modified 403 MHz radiosonde) on the cockpit floor between the pilot's legs.

In both the cycle mode and on command from the controller, temperature and humidity information was transmitted. The length of the radio pulse was a function of temperature determined by the wet and dry bulb thermistors mounted in a radiative shield outside the canopy of the aircraft as shown in figure 4. Figure 7 shows the installation of the batteries, SW amplifier and frequency and pulse length generating electronics in the wing root. A gimbal-mounted parabolic dish and microphone were used to receive the acoustic signal on the ground. An operator tracked the glider through a sighting mechanism (see fig. 8) having an aperture equal to the beam width of the dish (2½° at 2,500 Hz). The narrow beam width together with a wind screen of fine mesh reduced the effect of ambient noise.

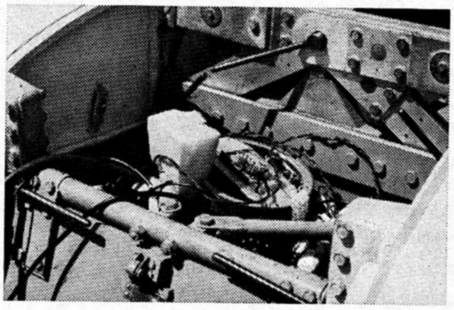

Fig. 7. Placement of batteries, SW amplifier and frequency and pulse length generating electronics in the wing root behind the pilot.

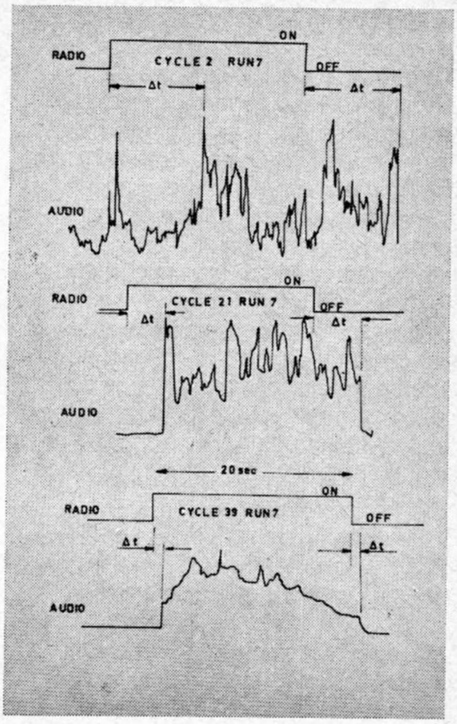

Fig. 10. Raw data collected during a CW run. The traces identified as «RADIO» indicate the time duration of the signal at the aircraft. The «AUDIO» traces represent the signal as it was recieved at the ground. The top trace was from an altitude of about 2,000 meters, the center one from about 1,200 meters and the lower one from about 500 meters.

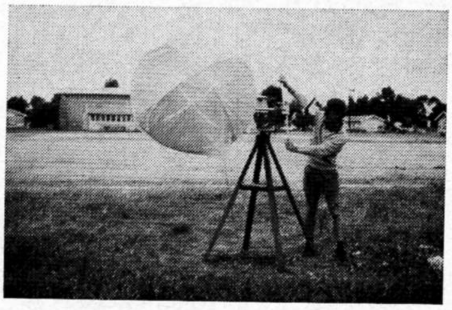

Fig. 8. Acoustic signal receiving antenna in operation. Note the use of netting over the parabolic dish to reduce ambient noise, the counter weight, sighting mechanism and gimbal mounting to facilitate tracking the glider.

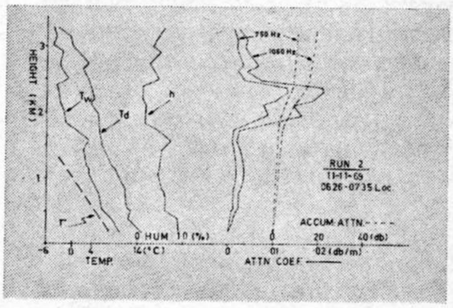

Fig. 11. Measured values of wet (Tw) and dry (Td) bulb temperatures and derived valves of himidity (h), molecular plus classical attenuation coefficient at each level (solid lines on right) and accumulated molecular plus classical attenuation (dashed lines).

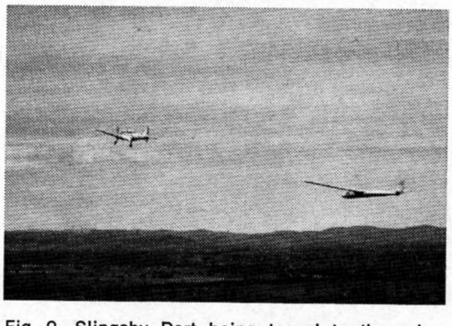

Fig. 9. Slingsby Dart being towed to the release altitude by a Chipmonk tug aircraft.

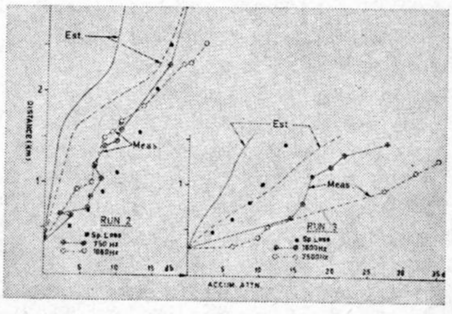

Fig. 12. Measured valves of accumulated total attenuation ($a_m + a_c + a_s$) (curves through data points) and calculated valves of $a_m + a_c$ (as in fig. 11). The difference between the two curves is the excess attenuation a_s.

The field procedures were as follows: The glider was towed by a Chipmunk aircraft to about 3,000 m (see fig. 9) and after release began a spiral descent with straight runs at minimum sinking speed, back and forth over the dish. It was possible to make about 10 level passes per 1,000 m and the runs were terminated at 200 m. Temperature information was sent during the turns and acoustic pulses on the level runs. Temperatures were also sent during the climb to altitude and all temperature information was displayed on line by a digital printer. Pibal wind soundings were made during the climb and also immediately after the glider landed.

Data Analysis and Results

An example of some of the raw CW data is shown in figure 10. Note the decrease in variance of the signal at lower altitudes, a result of reduced scintillation over shorter path lengths. An electronic computer was used to calculate the theoretical and excess attenuation coefficients from distance, temperature, humidity and frequency. Preliminary results from some of the flights are shown in figures 11 and 12. The dependence of the attenuation on frequency and on humidity is demonstrated in figure 11 and the relative magnitudes of the spreading loss, the classical and molecular attenuation (represented by the estimated attenuation curve) and the excess attenuation (shown by the difference between the estimated and measured values) are shown in figure 12.
The results suggest that the excess attenuation coefficient, α_s, varies from 0.01 to 10 times the molecular plus classical coefficients. The excess attenuation is roughly represented by linear relationships of the form

$$\alpha_s = \frac{\xi - A}{B}$$

where ζ is the wind shear squared and A and B are frequency dependent constants determined from the various regressions shown in figure 13. The presence of influences other than the shear (which is an indication of the intensity of inertial turbulence) is demonstrated by the non-zero value of the coefficient at zero shear. This is most probably due to thermal turbulence and refraction effects.
A fuller account of this experiment will be given in forthcoming publications of the Meteorology Department, University of Melbourne [Beran, Reynolds and Gething, 1971].

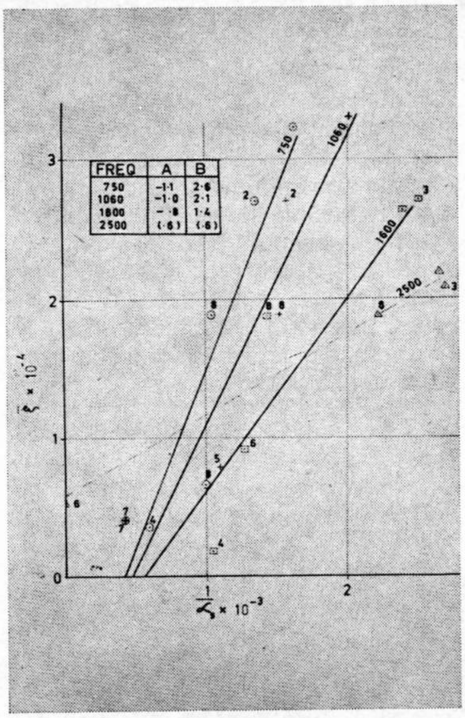

Fig. 13. Regression curves showing the dependence of excess attenuation (α_s) on wind shear squared (ζ).

References

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