BRITISH ACOUSTICAL SOCIETY: Meeting on "Infrasound and low frequency Vibrations" at Salford University on 26th November, 1971.

- -

Instrumentation for Infrasound -

H. G. Leventhall and R. A. Hood,

Chelsea College, London.

Infrasound covers the range from about 20Hz down to 0.002Hz, or lower. The first decade, from 20Hz to 2Hz, is of special interest since this is the region where most man-made infrasound at appreciable levels occurs.

Two aspects of instrumentation are dealt with (a) apparatus for the detection recording and analysis of infrasound (b) apparatus for production of controlled levels of infrasound for subjective experiments.

(a) The detection, recording and analysis of infrasound requires basically the same apparatus as at audio frequencies, but there are some differences which must be taken into account if the apparatus is to function correctly at the lower frequencies.

The microphone. A number of specialised microphone systems have been developed for the lower frequency infrasounds (e.g. hot wire, thermistor, electrolytic) but piezoelectric and condenser microphones may also be used. The low frequency limit of a microphone employing a diaphragm depends on the pressure equalisation hole connecting the rear of the diaphragm to the atmosphere. If this hole is blocked or omitted and the capsule sealed, the diaphragm will, ideally, respond to static pressure changes. The diaphragm deflection is transmitted by the sensing element (piezoelectric material or capacitor), which may not be able to maintain its response down to very low frequencies because of charge leakage through external resistance during the period of the exciting pressure. High input impedance amplifiers must be used to reduce charge leakage. For example, we have used a piezoelectric microphone adapted to operate down to about 0.1Hz(1). This is the B & K type 4117 which has a normal low frequency limit of 3Hz, but by blocking the equalisation hole and using a high input impedance amplifier the low frequency response was extended by over an octave. The microphone capacitance is nominally 4000 pF which, in combination with a 10^9 ohm input impedance amplifier, gives the electrical 3dB point at about 0.04Hz. Residual air leakage raises the acoustic low frequency cut-off to 0.1Hz. The result is an inexpensive, easy-to-use microphone system with a frequency response of over 5 decades. A condenser microphone with a capacitance of, say, 60 pF could also be used with a suitable high input impedance amplifier, but the impedance which may be employed is limited by any resistive paths within the microphone itself. The condenser microphone also lends itself to use in a high frequency (MHz) tuned circuit or balanced bridge. Diaphragm movement in the tuned circuit causes a frequency modulation which is subsequently demodulated to regain the low frequency. Diaphragm movement in the balanced bridge causes an amplitude variation which is detected.

Commercial frequency modulation systems are available e.g. the B & K type 2631 carrier system with either one inch or half inch microphones and the Sennheiser MK4 110-1.

These microphones respond over the audio as well as the infrasonic region. If interest is only in infrasound it may be advantageous to limit the high frequency response. This may be done with a "front leak" obtained by enclosing the capsule in a chamber with a small opening which is of too high resistance to transmit high frequencies, thus combining low pass filtering of the airborne acoustic waves with wind-shielding.

An infrasonic microphone should be calibrated at low frequencies. A simple method is the pistonphone which uses constant peak displacement of a diaphragm to produce constant pressure changes. However, difficulties arise at low frequencies since heat loss to the walls of the pistonphone causes a reduction in pressure during the period of the diaphragm displacement. This occurs when the pressure changes are turning from adiabatic to isothermal and can cause an error of up to 3dB (2), (3). The effect is minimised by using a large volume compared with the surface area of the pistonphone cavity. For example a cavity of dimensions 5cm diameter and 10cm length has less than a 0.5dB error at 1Hz and a 1dB error at about 0.2Hz. We have found a hand operated pistonphone to be useful for field calibrations (1). An alternative method of calibration is to use constant force, rather than constant displacement, excitation of the pistonphone by employing a vibrator fed with constant current to excite the diaphragm. The pistonphone volume should be small to ensure that the stiffness of the system is due to the air rather than to the vibrator suspension and then, when the pressure tends to drop due to heat conduction, the deficit is made up by the constant force of the vibrator.

Recording Apparatus. A visual record of the infrasonic region may be obtained with an ultraviolet recorder but it is more useful to tape record. A direct recording tape recorder, no matter how expensive it is, will not cover the infrasonic region. A modulation system must be used. Frequency modulation is the commonest of these. F.M. recorders respond down to D.C. and are usually costly, multi-channel systems. However, it is possible to construct external frequency modulation/demodulation units to use with an audio tape recorder (1). There are limitations on dynamic range because the tape recorder's flutter and wow frequencies fall within the infrasonic region. The system described in reference (1) had major inherent noise peaks at 6Hz and 12Hz of magnitude equivalent to an input level of about 70dB and could be used only for input noise levels above about 80dB.

Analysis. Conventional octave and one-third octave filters have been extended into the infrasonic region using active filters. However, much infrasound tends to have narrow band components (e.g. engine firing rates or chimney resonances) and this may require a narrow band analysis. Narrow band analysers are usually of constant percentage bandwidth or constant bandwith and low frequency versions are manufactured for vibration analysis. A Dawe Instruments type 1461 analyser extending down to 2Hz with approximately 3% bandwith has been adapted for use with a level recorder(1)

There are difficulties in using a heterodyne analyser (constant bandwith) at low frequencies since this system produces sum and difference components by multiplication of the input with a high frequency, subsequently filtering out either the sum or the difference frequency. For an input at 2Hz the sum and difference frequencies are separated by 4Hz and the selection of one of these requires a narrower filter than is usually available in heterodyne analysers, which use filters at high frequencies. For example the

the B & K 2010 analyser extends down to 2Hz, but with a bandwidth of 3.16Hz and will be in error at its lower frequencies. The homodyne system permits very narrow band filtering at low frequencies. In this the input is mixed with an oscillator of the same frequency as the input giving a low frequency difference component tending to D.C. Filtering is by narrow band low pass active filters. A commercial version (Fenlow SP4 spectrum analyser) has a narrowest bandwidth of 0.06Hz and lowest frequency limit of 0.3Hz.

The transient response time of the filter may need to be considered. For example, a low pass filter of 0.06Hz bandwidth will have a rise time of about 8 seconds. If a frequency sweep analysis is to be used with these narrow bands the sweeps must be very slow to give a sweep time through the pass band greater than the transient time.

Analysis may also be carried out by sampling followed by computation. This is the best method for the very low infrasounds since analogue instruments are not practical in these ranges.

The components of a portable infrasonic detecting, recording and analysing system used by the authors are shown in Fig. 1.

(b) The production of infrasound for laboratory investigation of subjective response has been achieved with a pressure chamber of dimensions 3ft by 4ft by 6ft constructed from 1 inch blockboard. An adjustable neck at the side enables the chamber to operate as a Helmholtz resonator which can be tuned over the range 3Hz to 18Hz. The chamber is driven by four 15 inch high-power loudspeakers mounted in the walls and fed from a 300 watt power amplifier. The chamber is ventilated by a fan through the resonator neck so that the subjects may be inside for long periods without vitiation of the atmosphere which would occur with a completely closed chamber. An automatic cut-out is incorporated to remove the excitation if the sound rises accidentally above a pre-set level. A cut-out button is also provided for use by the subject and the door handles operate from both inside and outside. The subject and operator maintain contact through an intercommunication system and there is also a 1.5 ft by 1.5 ft window in the door. The chamber is fitted with apparatus for a number of subjective tests. Sound pressure levels of 126dB can be obtained for the noise band from 2Hz to 20Hz and levels of up to 145dB for single frequency excitation when the chamber is tuned. Higher levels can be obtained by driving hard but this introduces distortion and causes excessive vibration of the chamber walls.

References

(1) Hood, R. A. and Leventhall, H.G. Acustica, Vol. 24, No. 7, 1971

(2) Delany, M. E. J.A.S.A., Vol. 44 No. 2, 637-638, 1969

(3) Beranek, L. L. Acoustic Measurements.

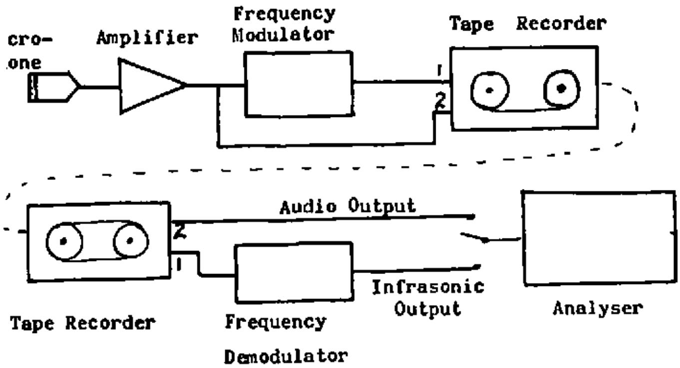

Fig. 1. RECORDING AND ANALYSING APPARATUS.

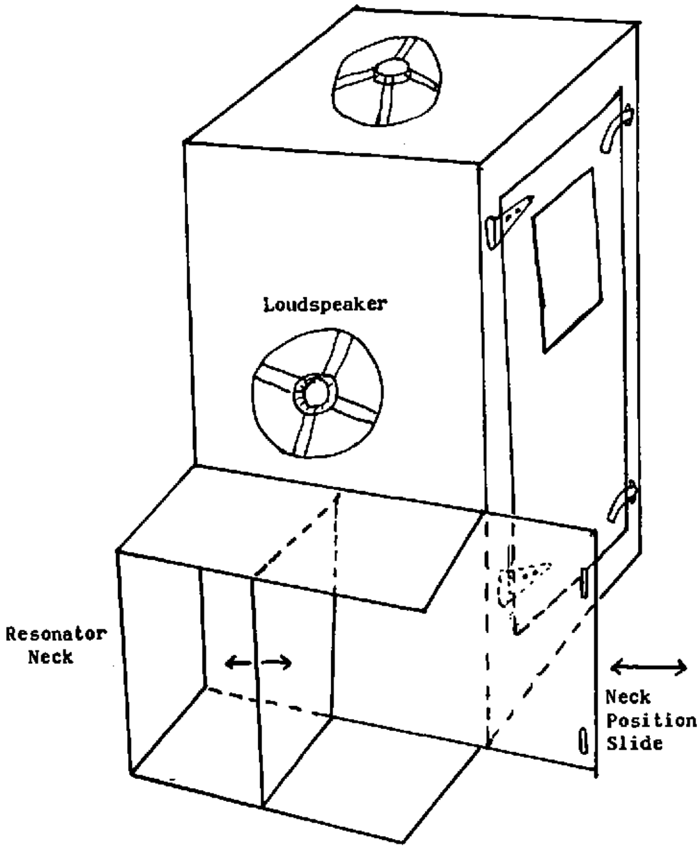

Fig. 2. INFRASONIC CHAMBER SHOWING RESONATOR NECK