ENCLOSURE FOR LOW-FREQUENCY ASSESSMENT OF ACTIVE NOISE REDUCING CIRCUMAURAL HEADSETS AND HEARING PROTECTORS

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1.0 Introduction

Active Noise Reduction (ANR) technology is currently being employed in commercially available communication headsets [4]. ANR is most effective at frequencies below 1 kHz and complements the passive attenuation characteristics of conventional circumaural earcups.

Commonly used acoustic test fixtures (such as KEMAR), however, fail to provide sufficient sound isolation of the measuring microphone below 100 Hz for measuring the performance of these devices [2][3]. This can produce erroneous measurements of sound transmission. Even if adequate isolation could be achieved, there would remain the problem of generating a high-intensity sound field within a room at low frequencies.

To overcome these difficulties, an acoustic test cell has been designed for measuring the performance of ANR circumaural headsets and hearing protection devices (HPDs) at frequencies below 1000 Hz.

2.0 Design of a Low-Frequency Test Cell

The test cell is similar to that used by Shaw and Thiessen for research into passive HPDs [1]. This version, however, consists of two equal-sized chambers mounted vertically and excited by a moving-coil loudspeaker (see figure 1). The lower chamber contains the device under test while the upper chamber encloses the sound source.

To develop high sound pressure levels, the volume of the test cell must be kept as small as possible. The practical lower limit of the test cell's size is imposed by the device under test, in this case, one circumaural earcup. The maximum outer dimensions of the earcups that will be tested are approximately 110 to 120 mm. The upper and lower chambers, therefore, are constructed from aluminum tubing with an inside diameter of 200 mm and a wall thickness of 9.5 mm. Each chamber is 200 mm in length giving a total volume of 6.28×10^{-3} m^3. These dimensions allow sufficient internal space for the device under test, the clamping hardware and damping material required for the reduction of cross-modes.

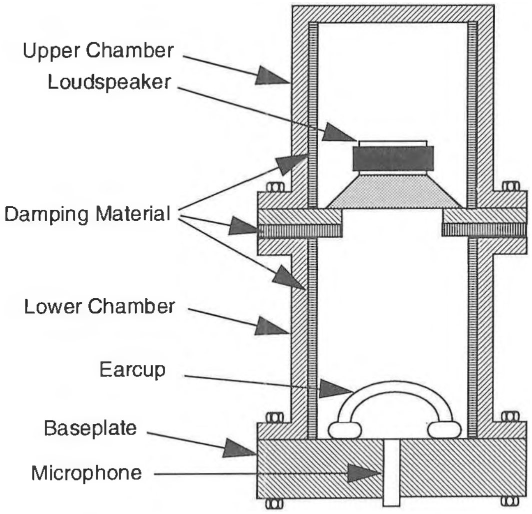

Figure 1. Low Frequency Test Cell (not to scale).

The enclosed volume is excited by a commercially available polypropylene woofer cone with an outer diameter of 150 mm. It is mounted in a rigid, 9.5 mm thick aluminum plate and is located between the upper and lower chambers of the test cell. The woofer's suspension provides a compliance equivalent to a 29.5×10^{-3} m^3 volume of air. Together with the driver's effective mass, this yields a free-air resonance of approximately 36 Hz. When the driver is mounted in the test cell (volume of 6.28×10^{-3} m^3), the test cell's compliance dominates, and the mounted resonant frequency changes to approximately 80 Hz.

The upper chamber is rigidly coupled to the loudspeaker mounting plate and the lower chamber is rigidly coupled to a massive (4 kg) baseplate using 1/4" bolts. The upper and lower chambers, however, are isolated from each other by a 1/4" layer of damping material. This reduces the transmission of vibration from the loudspeaker to the baseplate.

Measurements are performed by sealing the earcup cushion against the baseplate. The earcup contact force is controlled by a spring mechanism inside the test chamber. Sound pressure inside the earcup is measured by a 1/2" B&K 4133 microphone flush mounted in the baseplate. The earcup's transmission loss is determined by calculating the difference between the sound pressure level inside and outside the earcup. It is therefore important to ensure that the test cell does not produce any pressure nodes on the outer surface of the earcup and that adequate isolation of the microphone is provided.

3.0 Performance

The sound pressure levels measured in this test cell are quite high. For 1W electrical power input to the speaker at a frequency of 100 Hz, a sound pressure level of 134 dB re 2×10^{-5} Pa was recorded. The maximum attainable sound pressure level is determined by the maximum power rating of the loudspeaker, in this case 40W. At this power level, the sound pressure inside the test cell is 150 dB.

A measurement of sound pressure level versus frequency was made with the microphone mounted in the baseplate. The results are shown in Figure 2. The fractions shown below the plot indicate the length of the test chamber in wavelengths of various frequencies.

The acoustic behaviour of the test cell can be described in terms of lumped parameters up to a frequency at which the largest dimension approaches $\lambda/(2\pi)$. For a maximum dimension of 200 mm, this corresponds to a frequency of approximately 270 Hz.

In the lumped parameter region (frequencies below 270 Hz), the test cell exhibits a distinct low-pass filter characteristic. The cutoff frequency is determined by the driver's mounted resonance frequency of approximately 80 Hz. Above this frequency, the response exhibits a second-order, 12 dB/octave roll-off.

For frequencies above 400 Hz, wave behaviour begins to occur. The test chamber's first resonance frequency appears at approximately 650 Hz. Note that the length of the test chamber at this frequency corresponds to a standing wave between $\lambda/4$ (425 Hz) and $\lambda/2$ (850 Hz). This is because the driver's acoustic impedance is neither zero (corresponding to a pressure anti-node) nor infinite (corresponding to a pressure node).

To examine the variation of sound pressure with height above the baseplate, a probe microphone was inserted through the opening in the baseplate. The sound pressure level was recorded at heights above the baseplate from 0 to 80 mm. This range includes the maximum earcup height of 60 mm.

The measurements of sound pressure level versus height for four different frequencies are shown in figure 3. At 100 Hz, there is no change of sound pressure level with height; in fact, there is only a slight change (less than 1.5 dB) at 300 Hz. This is expected since the lumped parameter region extends to about 270 Hz.

The change in sound pressure level with height is higher for frequencies of 650 Hz and 1000 Hz; however, the reduction is still less than 15 dB up to a height of 60 mm (maximum height of typical earcup).

A final important characteristic is a measurement of indirect sound paths to the measuring microphone. To measure this, two swept-frequency measurements were made at the baseplate microphone, one with the microphone exposed to the sound field in the cavity and the other with the microphone covered by a rigid aluminum cap sealed with putty. The difference between the two measurements indicates the amount of sound which reaches the microphone indirectly. For the above configuration, indirect sound pickup was more than 60 dB below the direct sound pickup from 10 Hz to1 kHz.

4.0 Conclusions

A test cell has been constructed for low-frequency measurements of ANR circumaural headsets and HPDs. Sound pressure levels up to 150 dB at frequencies below 100 Hz may be generated within this test cell. The small dimensions of the test cell ensure that no sound pressure minima occur over the surface of the earcup. The completely sealed acoustic chamber provides sound isolation which permits the measurement of earcup attenuation to the bone conduction limit. The test cell is thus suitable for transmission loss measurements up to a frequency of 1000 Hz.

5.0 Acknowledgements

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6.0 References

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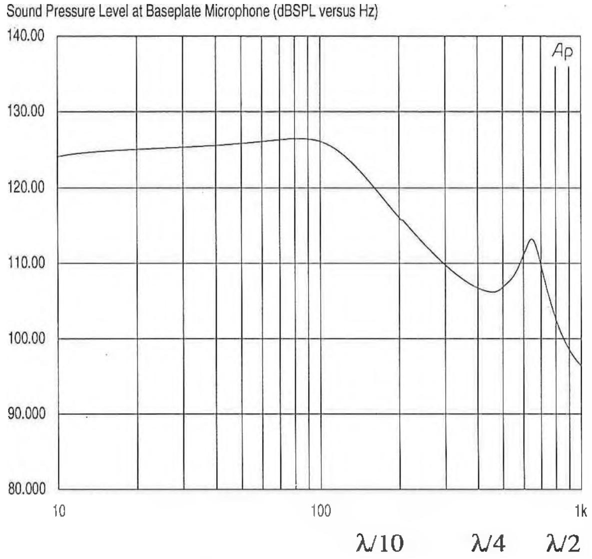

Figure 2. Sound pressure produced at baseplate for 1 Vrms input to loudspeaker.

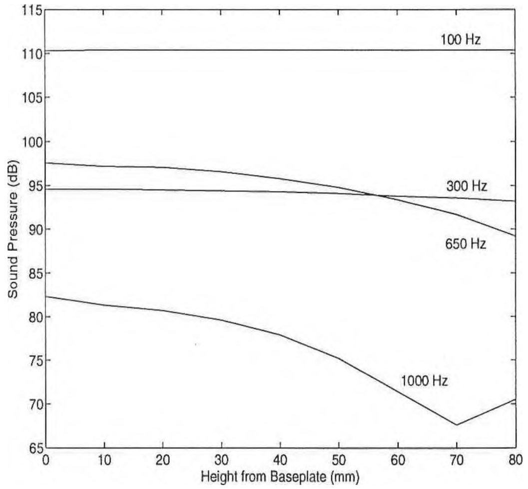

Figure 3. Variation of sound pressure with height above baseplate.