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Technical Note

The Anechoic Chamber at the Laboratorio de Acústica y Luminotecnia CIC

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ABSTRACT

This paper describes the new anechoic chamber at the Laboratorio de Acústica y Luminotecnia of the Comisión de Investigaciones Científicas de la Provincia de Buenos Aires (República Argentina) and the evaluation made to establish its performance. The chamber has a free working space of about 7 × 6 × 6 m. The evaluation made shows that the maximum deviation of the free field characteristics in the best path of measurement is less than 1·2 dB throughout the frequency range (80–6300 Hz). The background noise level is about 24 dB (C-weighting).

1 INTRODUCTION

The laboratory contains one anechoic chamber, one reverberant room and four rooms for transmission loss measurements. The anechoic chamber was designed to be free of acoustical reflections from its surfaces and to have high acoustical insulation from external noises. These conditions are required to perform accurate measurements according to international standards.

The anechoic chamber is intended to be used for the following

- determination of directional characteristics of sound transducers;
- measurement of sound levels generated by small equipment (printers, automotive accessories, musical instruments, etc.);

- calibration of electro-acoustic devices;
- performance of hearing and psycho-acoustic tests.

Taking into account these items, it was decided to use, as a model for the building, the anechoic chamber of the Acoustic Laboratory of the Catholic University of Louvain (Belgium). This room provides a free working space of about 7 × 6 × 6 m with sufficient sound insulation for external noise Owing to practical difficulties founded in the construction of wedge absorbers for the lining of the floor, ceiling and walls, a design by Professor Cremer (Berlin University) was chosen. This treatment consists of sound absorbing cubes of different sizes, arranged on four consecutive layers, from the interior of the room to the walls (see section 3). It was decided to design the acoustic treatment to achieve a cut-off frequency of about 100 Hz.

2 THE BUILDING

The room has to be well isolated from external noise, transmitted either by air or through the building. To achieve this it was necessary to build a double structure: the interior one (the inner box) using concrete and the exterior using bricks. The vibration isolation was achieved by mounting the inner box on springs. Figure 1 shows a section of the anechoic room.

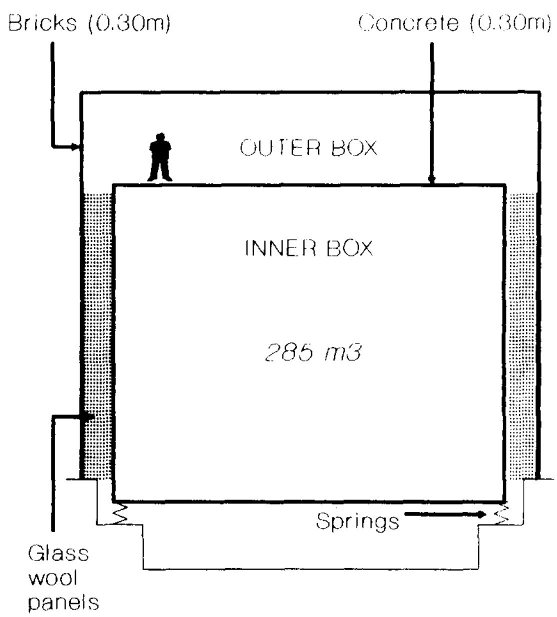


Fig. 1. Anechoic chamber plan.

The inner box is mounted on foundations independent from the rest of the laboratory. Those foundations are vertical concrete walls, 0·80 m in width. The box was built in one piece, isolated from the rest of the building by an air gap and elastic mounts. Those mounts are made of boxes of ten springs each, distributed on the perimeter of the room. In total, 220 springs were placed, each one supporting a weight of 1 t. They were calculated to obtain a resonant frequency of 3–4 Hz. The inner box is enclosed in a second box, 0·30 m thick made of bricks. The space between both boxes is filled with glass wool panels. The access to the room is through two acoustical doors, one mounted on the external wall and the other on the concrete box.

The gross dimensions of the inner room are: $7{\cdot}00 \times 6{\cdot}90 \times 5{\cdot}90$ m, equivalent to 285 m^3 volume. The neat dimensions are: $5{\cdot}40 \times 5{\cdot}30 \times 4{\cdot}30$ m.

3 ACOUSTIC TREATMENT

The lining of the floor, ceiling and walls is made using the design by Professor Cremer, of Berlin University, consisting of sound absorbing cubes of different sizes, arranged in four consecutive layers, from the interior of the room to the walls. The layer next to the wall is made of suspended cubes of 14 cm side and the successive layers, have cubes of 12, 10 and 8 cm respectively. This arrangement forms an spatial quadrille of 15 cm between centers, as seen in Fig. 2. The cubes are made from open pore, non-flammable polyurethane foam (28 kg/m^3 density).

The cubes are suspended using nylon strings from plastic nets on the

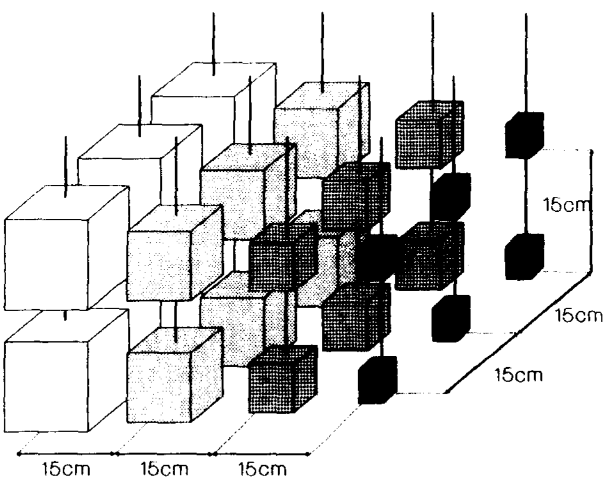


Fig. 2. Absorbing cubes disposition.

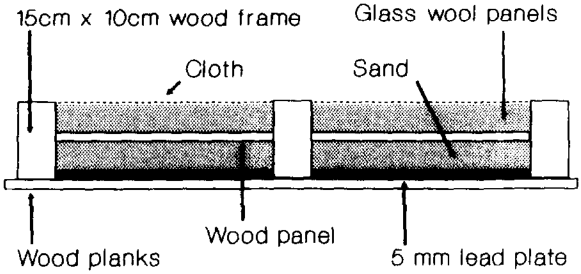


Fig. 3. Outer door.

ceiling and on the floor. The strings cross over the cubes, entering through the center of one face and going out through the other.

On the ceiling there are placed four cube layers hanging from the net. In a similar way, four layers of cubes were suspended from the floor net, 1 m over the bottom of the room.

On the internal surfaces of the walls, ceiling and floor, two successive layers of glass wool, each 5 cm thick, were placed. The density of those layers is 50 kg/m^3.

4 DOORS

The room is accessed through two acoustic doors. One is mounted on the inner box and the other on the external building. The outer door (see Fig. 3) is made of 2 cm wood planks, fixed to a 15 cm $\times$ 10 cm wood frame. The space inside is filled with a 5 mm lead plate and sand. The inner face is finished with glass wool panels, supported by a cloth.

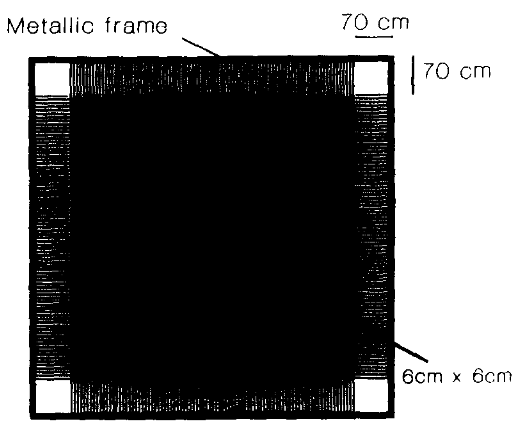


Fig. 4. Floor.

The inner door is built using a metallic frame. The inner face is finished in the same way as the surfaces of the room. In this way, the interior of the room is completely treated.

The two doors are equipped with manual mechanical handles that allow easy opening in both directions.

5 FLOOR

The floor was built using a steel net, fixed to a metallic frame supported on the concrete wall. The net hangs 1 m over the bottom of the room and 0·30 m above the absorbent material. Figure 4 shows the shape of the net.

6 ACCESSORIES

Illumination is provided by four 160 W mercury lamps, that assure excellent illumination, small heat dissipation, low noise level and relatively small reflecting accoustic surfaces. Two holes in the structure of the inner box allow for the entrance of the cables from the control room.

Three metallic structures, fixed to the floor of the room under the steel net, are built for mounting round tables used as bases for equipment under test or measurement instrumentation. There is also a possibility to place steel wires from one corner to the other and from one wall to the opposite one, to support microphones and sources.

No provisions for ventilation were made, because it was considered unnecessary for the work intended.

7 MEASUREMENT OF THE FREE FIELD CHARACTERISTICS

The ideal anechoic room has free field characteristics. That means that for a source placed at any point it is possible to verify that the sound level decays 6 dB for each doubling of the distance and for all frequencies. This can not be achieved in a real anechoic chamber, because:

(a) the absorption of the acoustical materials is reduced in the low frequencies range; and
(b) the existence of hard surfaces (such as the illuminating system, the steel net, etc,) have an important influence at high frequencies.

Those facts make a room anechoic for only a limited frequency range, for some directions and for some source–receiver distances.

TABLE 1
Different methods for the measurement of the Free Field Characteristics of Anechoic Chambers

Method	*Description*	*Advantages*	*Disadvantages*
1	Fixed source, receiver with continuous displacement, frequency by steps[3 7]	Continuous register of the deviation	Complex equipment
2	Fixed source, displacement of the receiver in steps[8]	Simpler equipment than method 1	Arduous measurement
3	Module source receiver rotating in the axis of the source and different source–receiver distances[9]	Easy to implement	Measurements are limited to horizontal planes and source in the center of the room[5]
4	Module source receiver in different places in the room and different source–receiver distances[2,7]	Simple instrumentation	No idea of the measurement paths, problems in low frequencies[5]

The measurement of the free field characteristics of the room can be made using different methods. Those methods are summarized in Table 1, with their advantages and disadvantages.

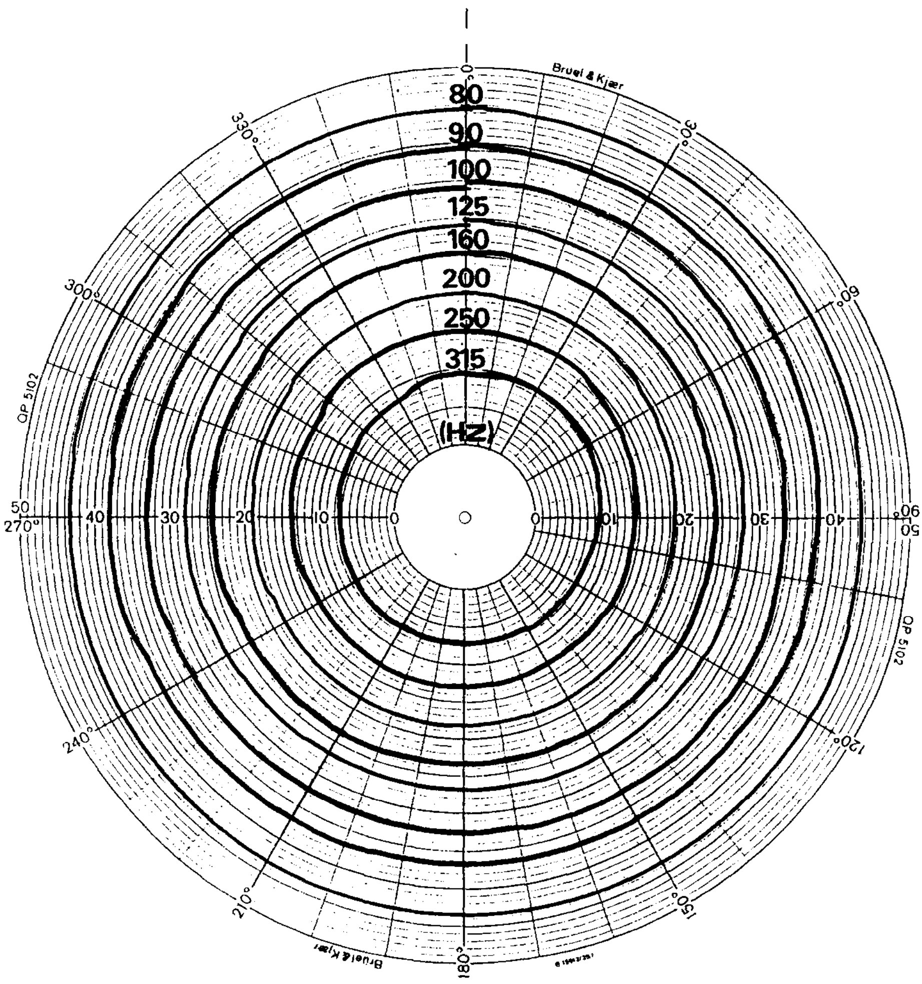
Method 1 provides the more comprehensive results. However, because of its technical difficulties, method 2 was chosen since it is considered as the next best. This measurement method requires the use of a fixed acoustical source and a moving microphone, placed at locations spaced 0·10 m in between.

7.1 Sound sources

To minimize errors in the free field determination, it is necessary for the sound source to have an omnidirectional characteristic within the frequency range. The use of a non-omnidirectional source generates optimistic results because it avoids the contribution of the room surfaces. This error in the measurement increases as the free field condition of the room decreases. It is possible to draw curves that quantify those errors.[1]

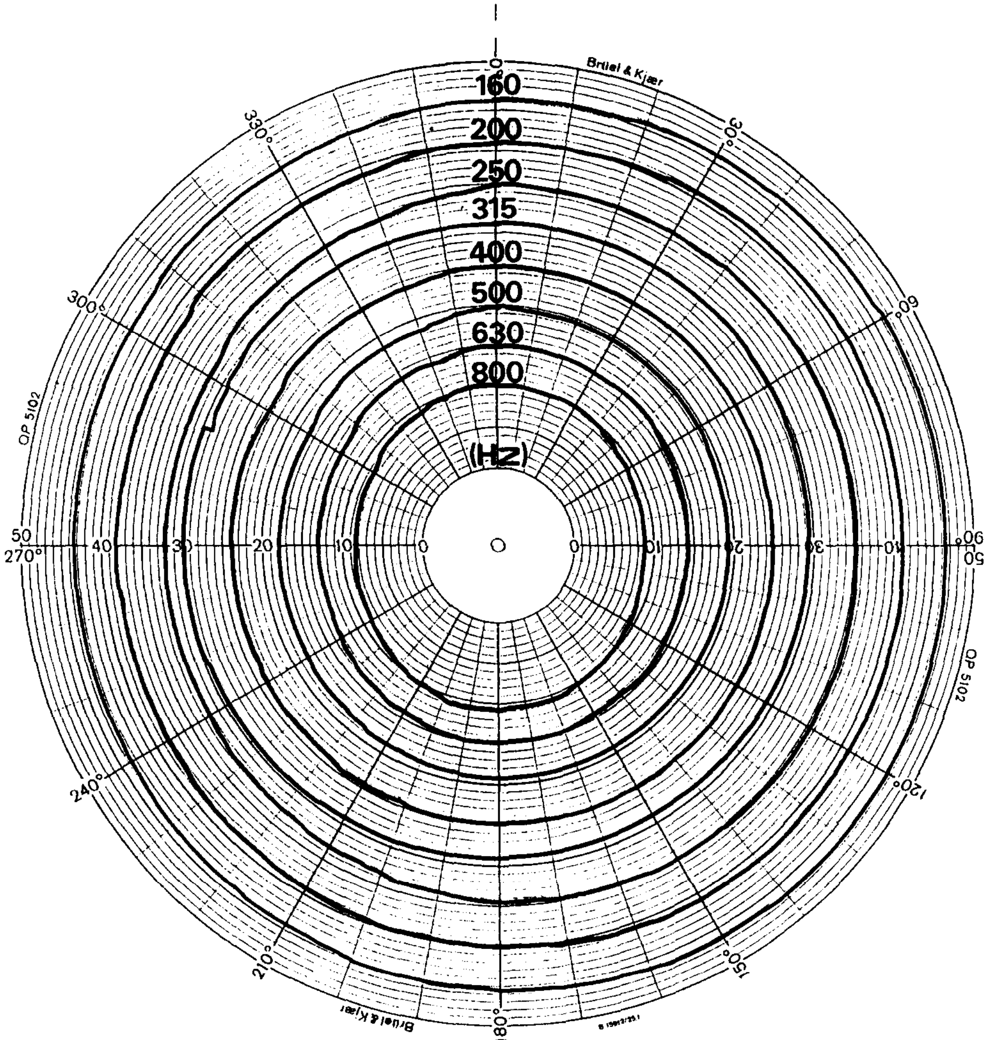
Based on those considerations the following sources were chosen:

(1) From 80 to 250 Hz: an electrodynamic loudspeaker, 4 in in diameter, mounted in one 2 litre baffle, with acoustic suspension, with a maximum deviation from a spherical characteristics of ±1 dB.



(a)

Fig. 5. Directional characteristics. (a) Sound source 1 (used from 80 Hz to 250 Hz); (b) sound source 2, 160 Hz to 800 Hz (used from 315 Hz to 6300 Hz); (c) sound source 2, 1000 Hz to 3150 Hz (used from 315 Hz to 6300 Hz); (d) sound source 2, 4000 Hz to 6300 Hz (used from 315 Hz to 6300 Hz).

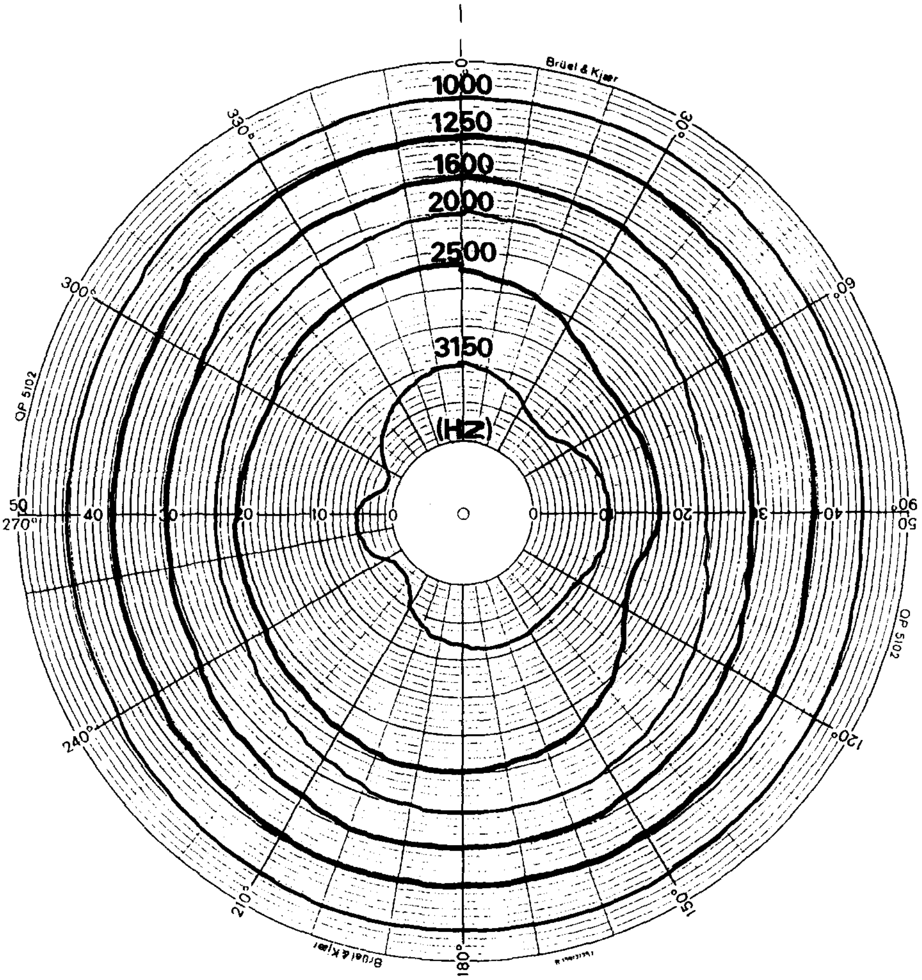


(b)
Fig. 5—*contd.*

(2) From 315 to 6300 Hz, a configuration of two electrodynamic loudspeakers, 5 in in diameter, placed face to face and electrically connected to obtain an acoustic source of order zero. The maximum deviation from 315 to 1250 Hz was ±1·5 dB. Above 1250 Hz the deviations increase, however, the better characteristics of the chamber over this range produce small errors. Figure 5 shows the directional characteristics of the sound sources used.

7.2 Measurement microphone

The 13 mm capacitor microphone used for the measurement has omnidi-



(c)

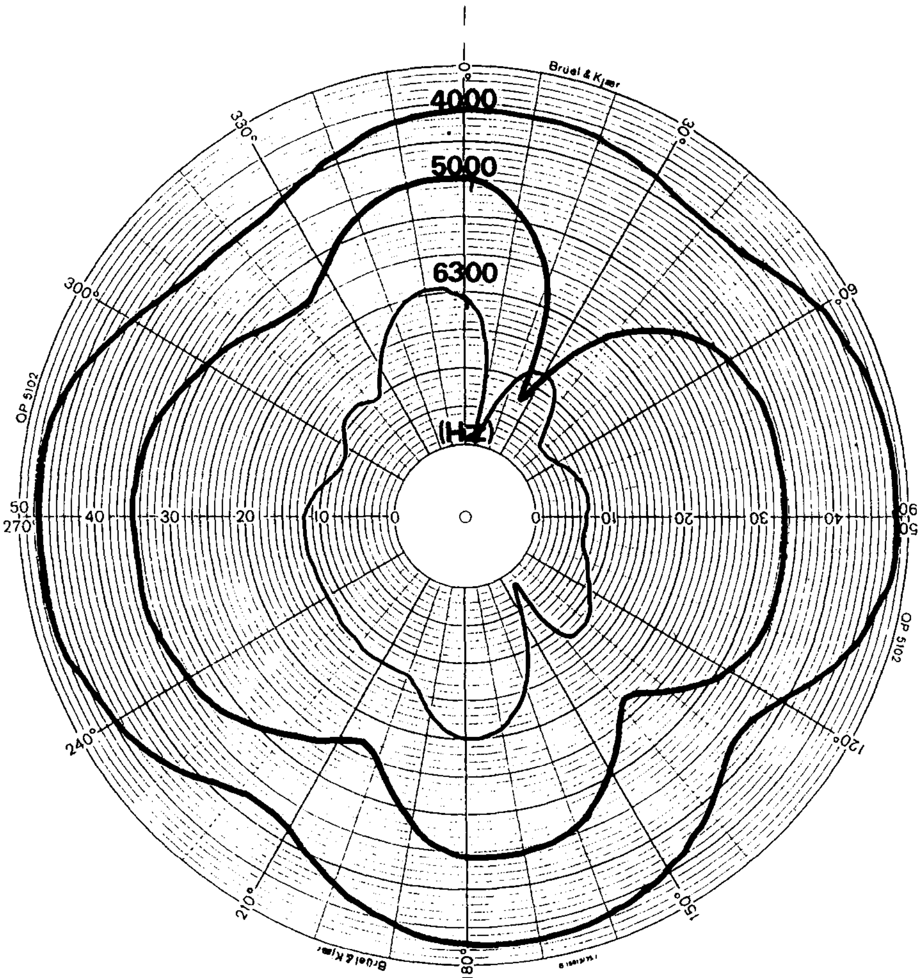
Fig. 5—*contd.*

rectional characteristics within ±1 dB across the measurement range. A Bruel & Kjaer model 4165 was used.

7.3 Measurement paths

The room was measured along three different paths, which are shown in Fig. 6.

Path 1, following the principal diagonal east–west, at 1·8 m height above the floor net. The sound source was placed at 1·10 m from the west corner. The useful path was of approximated 6 m length.



(d)

Fig. 5—*contd.*

Path 2 as above, but with the sound source half-way between corners. The useful path was about 2·80 m length.

Path 3, following a straight line between the middle points of the southwest and northeast walls (1·80 m height from the floor net), with the sound source in the center of the room. The useful path was about 2·50 m length.

7.4 Measurement method

Figure 7 shows the instruments used for the measurement of the free field characteristics. A sinusoidal signal of the desired frequency is generated

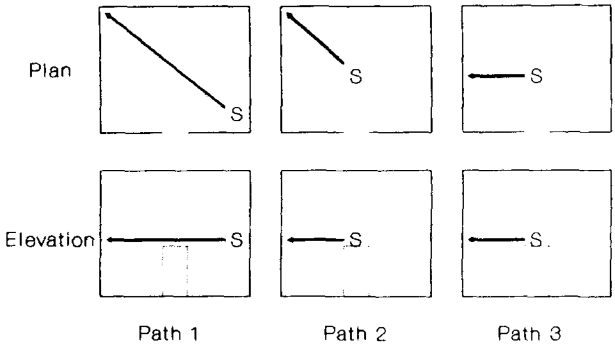


Fig. 6. Measurement paths.

by the oscillator (Brüel & Kjaer type 1022) connected to the sound source. The microphone signals are amplified and the corresponding sound level is determined by the measuring amplifier (Brüel & Kajer type 2120). The switch allows selection between the reference and measuring microphone signals.

The reference microphone remained fixed during the measurement of the path. It was used to verify that the sound level delivered by the source remains constant during the measurement. The measuring microphone (or 'traveller' microphone) was used to measure the sound levels along the paths. This microphone was moved in 10 cm steps.

The measurement methodology was as follows:

(a) For each measurement path, the reference microphone was located

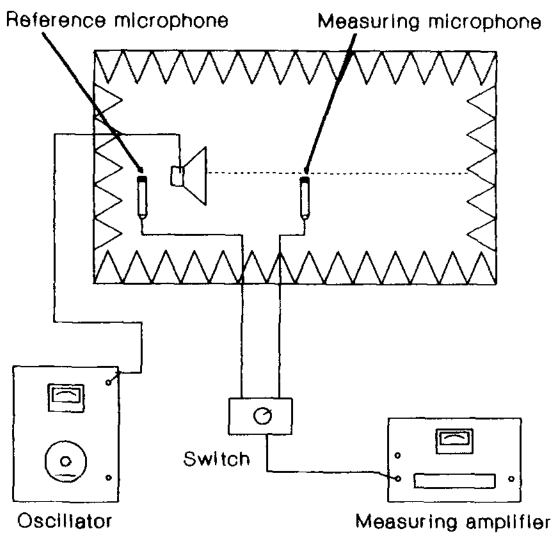


Fig. 7. Measurement instrumentation.

so that it would not interfere with the measurement. The second microphone was placed at the first measurement point (46 cm from the acoustic centre of the source).

(b) Sound levels from the two microphones were recorded, for all frequencies within the first range (80, 90, 100, 125, 160, 200 and 250 Hz).

(c) The measuring microphone was then moved to the next position (56 cm from the source). It was verified that the level measured by the reference microphone remained the same as in step (b). This procedure was repeated for all the frequencies of the range.

(d) Step (c) was repeated for all the different positions of the path under test.

(e) The sound source was then changed for the second one corresponding to the frequency range (315, 400, 500, 630, 800, 1000, 1250, 1600, 2000, 2500, 3150, 4000, 5000 and 6300 Hz). All the steps as in (b), (c) and (d) were repeated.

(f) The path was changed and the procedure repeated.

8 RESULTS

After more than 2000 measurements the deviations for each path and frequency (21 frequencies on each path) were obtained. Figures 8–12 show the absolute values of the maximum deviations with respect to the

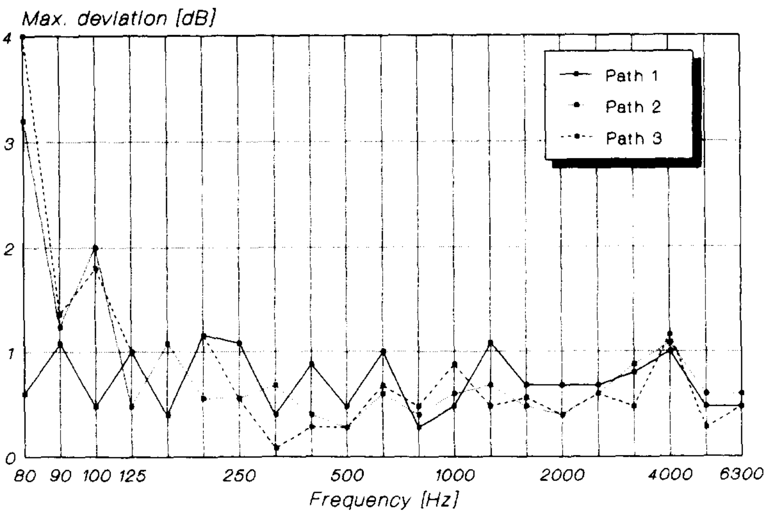


Fig. 8. Absolute values of the maximum deviations to the $1/r^2$ law, interval from 0·5 to 1·5 m.

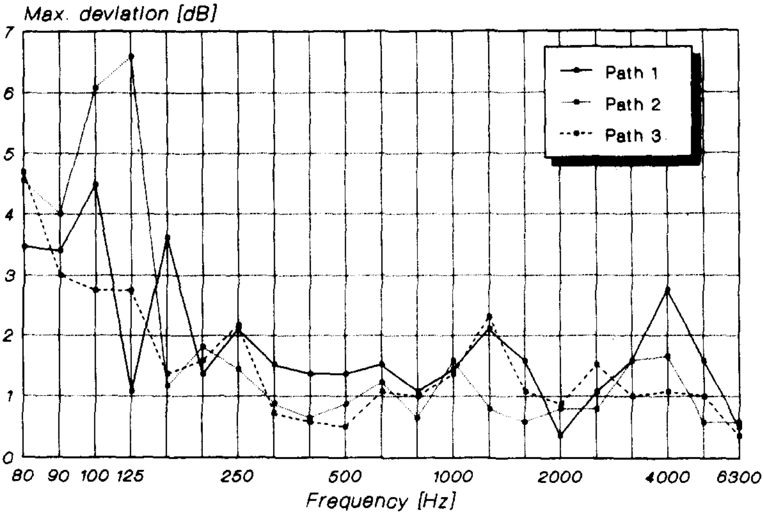


Fig. 9. Absolute values of the maximum deviations to the $1/r^2$ law, interval from 1·5 to 2·5 m.

inverse square law as a function of the frequency for each source-receiver interval and using the different paths as a parameter. It is important to take into account that these graphs represent the worst case, because only the maximum error of each interval is shown.

The differences in measuring techniques and directional characteristics of the sound sources do not allow close comparisons between this cham-

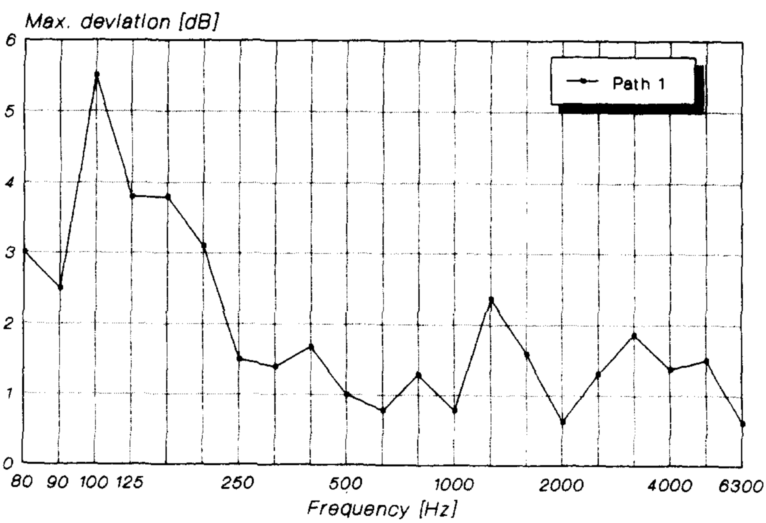


Fig. 10. Absolute values of the maximum deviations to the $1/r^2$ law, interval from 2·5 to 3·5 m.

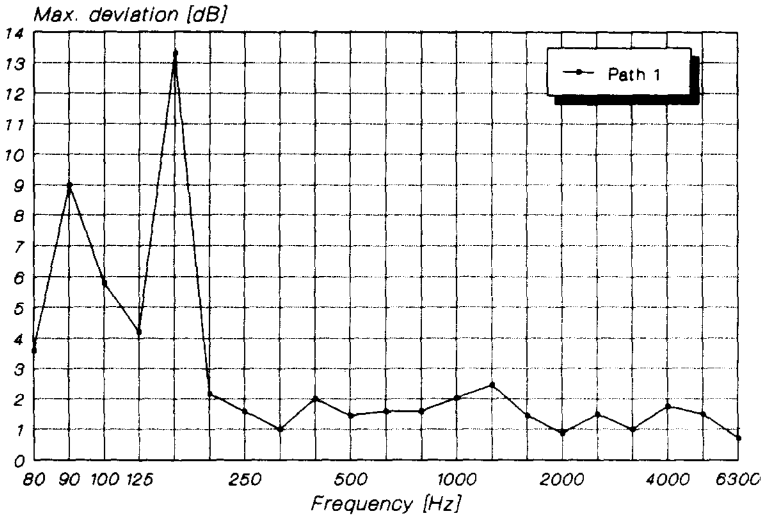


Fig. 11. Absolute values of the maximum deviations to the $1/r^2$ law, interval from 3·5 to 4·5 m.

ber and those presented in the references. For example, the chamber presented in Ref. 2 obeys the inverse square law within ±1 dB throughout the frequency range, but neither the directional characteristics of the sound sources, nor the path of measurements are given. Our chamber, as seen in the figures, fulfils the free field characteristics within ±1.2 dB throughout the frequency range of measurements in path 1 near the

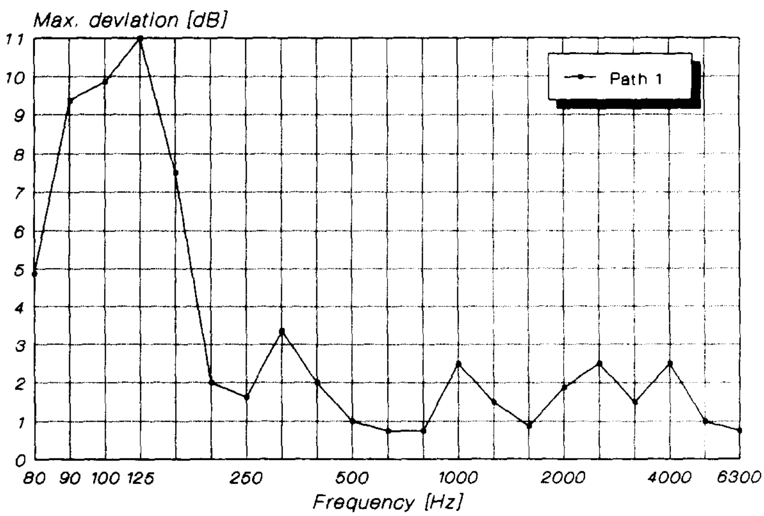


Fig. 12. Absolute values of the maximum deviations to the $1/r^2$ law, interval from 4·5 to 5·5 m.

sound source, having this source, with very omnidirectional features below 1250 Hz.

The results presented by Maekawa and Marimoto in Ref. 3 have similar free field properties as the present chamber. In this case both measurement methods are similar, although the sound sources used in that evaluation seems to have less omnidirectional characteristics than presently used.

As regards the background noise level, it was measured under realistic conditions of ambient noise. The value obtained was less than 24 dB (C-weighting).

9 CONCLUSIONS AND COMMENTS

The object of those measurements was to characterize the behaviour of the anechoic room, in order to discover its performance.

The results obtained show a poor performance at low frequencies, probably because of the lining thickness. However, based on these measurements it is possible to understand the necessary corrections, and the measurement errors and the best paths to be used during the measurements.

The chamber would increase its performance if, at least, one additional layer of cubes is added in order to enhance the absorption of the lining. Furthermore, the glass wool layers which are fixed on the internal surfaces (walls, ceiling, floor and door) should be displaced a few centimetres to enhance the low frequency behaviour.

The measurements show that the anechoic room is suitable above 80 Hz for strictly free field measurements in path 1 for distances to the sound source less than 1·5 m though it is important to take into account that when directional sources are used the measurement errors introduced by the chamber decrease. Finally, the background noise level is low enough to make the room useful for the designed purposes.

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