

Technical Note

Testing of a Device for Positioning Measuring Microphones in Anechoic and Reverberation Chambers

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This paper presents a mechanical positioning system for a measuring microphone designed for acoustic studies in anechoic and reverberation chambers at the Department of Mechanics and Vibroacoustics, AGH. The results are discussed in the context of mechanical positioning and its impact on the outcome of the execution of individual measurement procedures. Moreover, areas for research were identified and solution concepts shown for further development of the automation of acoustic measurements in different research rooms in order to reduce the human involvement in them.

Keywords: positioning system, manipulator, turntable, anechoic chamber.

1. Introduction

The issue of acoustic measurements relating to the identification of sound sources and the study of the acoustic properties of materials and structures made of those materials, requires an accurate positioning of the measuring microphone in the research room. The latter can be either a special acoustic chamber or industrial premises where the machinery and equipment installed are the subject of study. Laboratory acoustic studies are carried out in anechoic and reverberation chambers.

The measurements of the sound power level, sound intensity and the directional characteristics of the electroacoustic transducers are usually performed in anechoic room. Measurements of the sound power level, sound absorption coefficient and sound scattering coefficient are carried out in a reverberation room. In both cases, the microphone must be positioned at many points of the measurement space in order to conduct comprehensive research. According to the standard (EN ISO 3745, 2007), sound power measurements require a big number of measurement points – 20 or 40 if the difference in the individual frequency bands is greater than 10 dB. The number of measurement points is not limited when preparing directional characteristics. Manual positioning is time consuming and tedious as it requires a precise positioning of the measuring microphone (e.g. on a stand) at many measurement points. Therefore the Department of Mechanics and Vibroacoustics began to develop mechanical posi-

tioning systems that meet the requirements necessary for correct measurements.

An automatic measurement system has been developed and implemented in the form of a modular measurement manipulator. Currently, the system makes an automatic positioning of the microphone on the surface of a hemisphere with maximum diameter of 4 m, a resolution of 0.1 mm for the linear modules and of 0.01° for the rotary manipulator. Assuming that the position of the turntable manipulator changes by 1° during the measurements and the position of the microphone for a quarter of a circle in the vertical plane (using linear modules) also changes by 1° , the number of measurements over the hemisphere will be 32,400. Such a large number of measurements is not practically possible by manual positioning. Mechanical positioning means that very accurate directional characteristics of the sound sources can be obtained. Further conceptual and design work is aimed at equipping the currently installed measurement system with new features and developing new systems for the mechanical positioning in order to enhance the measurement capabilities in both types of the acoustic chambers.

2. Positioning of the measuring microphone in the anechoic chamber

A prototype of the mechanical system for positioning the measuring microphone, in the form of a special manipulator for acoustic measurements, was put in 2009 into operation in the anechoic chamber of the

Department of Mechanics and Vibroacoustics, AGH (FELIS *et al.*, 2009). The construction of the mechanical part of the device has been completed in the time of two years, whereas the software has been completed one year later (BATKO *et al.*, 2007).

The manipulator was built as a tool to automate the measurements of sound power, the directional characteristics of sound sources, sound intensity on the surface of a hemisphere, and the diffusion coefficient of acoustic structures (COX, D'ANTONIO, 2009). The modular techniques has been used for this purpose and the manipulator comprises the following elements: a NR-750 Weiss turntable, $L_t = 3300$ mm and $L_s = 700$ mm Rexroth linear modules along with control elements and a drive positioning the microphone's axle. The manipulator's software was written in LabVIEW. The high positioning accuracy of the measuring microphone (in the range below 1 mm) was produced with a relatively small size of the device using a specific configuration of the professional modules. The fundamental technical data are given in Table 1.

Table 1. Technical data of the manipulator.

Workspace	Hemisphere with a diameter of 4 m
The number of degrees of freedom	4
Permissible load on the turntable	35 kN
Turntable torque	1.2 kNm
Resolution of the turntable position	0.01°
Resolution of the linear drives	0.1 mm
Permissible load on the microphone holder	5 N

The main components and the location of the manipulator in the anechoic chamber are shown in Fig. 1.

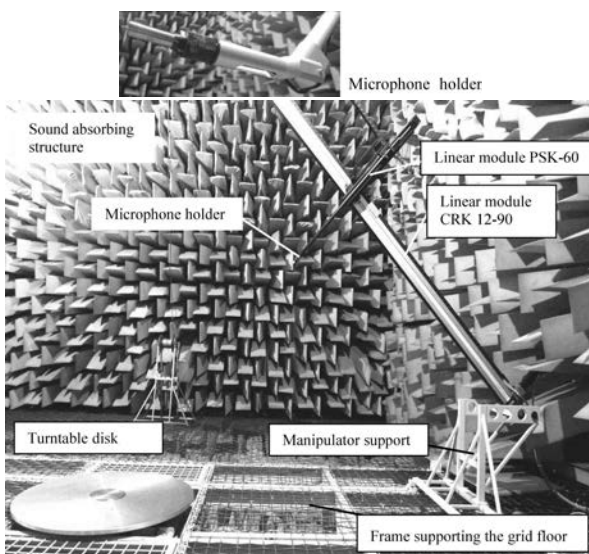


Fig. 1. The location of the manipulator in the anechoic chamber.

3. Operational tests of the measurement manipulator

In order to verify the correct operation of the manipulator in the anechoic chamber, preliminary studies have been performed including:

- tests of the components and control software,
- the determination of the sound power level of the sound source on the surface of the hemisphere with a radius of 2 m,
- the determination of the directional characteristics of the sound source.

The tests demonstrated that the mechanical and electrical systems' components and the control software operated correctly and showed also further possibilities and needs for improving their performance. The sound level measurements made by a Bruel&Kjaer isotropic sound source showed the correctness of the positioning system and turned out to be a great convenience in doing research. The measurements of planar directional characteristics were made at a fixed position of the linear modules using only the turntable (one degree of freedom), whereas the spatial directional characteristics were obtained using all the modules of the manipulator. An omnidirectional speaker set of the author's own design was used as the sound source. The objective of the study was to determine the effect of the resolution of the angle of rotation of the sound source (turntable) on the accuracy of the directional characteristics being determined.

The studies have shown that in this type of measurements, it is reasonable to use a resolution of the source rotation angle not greater than 1 degree. For such a resolution, it is possible to obtain reproducible directional characteristics – both planar and spatial – where changes in the sound pressure level (local extremes) can be observed. Thus far, it had not been possible to record them due to an insufficient number of measurements on the surface of the hemisphere. Examples of planar directional characteristics obtained with the manipulator are shown in Figs. 2 and 3. Planar di-

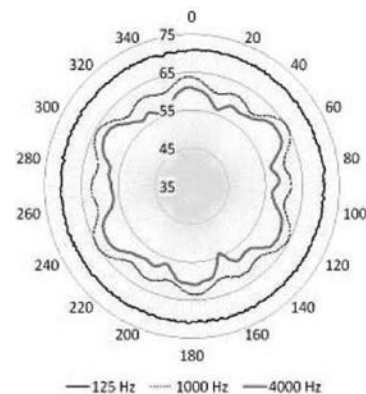


Fig. 2. Directional characteristics of a twelve-speaker sound source for frequencies of 125, 1000 and 4000 Hz.

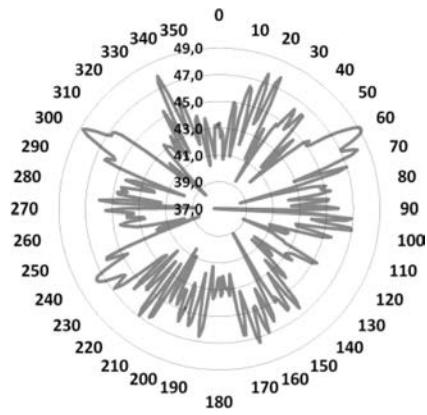


Fig. 3. Directional characteristics of a twelve-speaker sound source for a frequency of 16 kHz.

rectional characteristics were obtained from measurements made at points lying on a circle with a radius of 2 m, on the horizontal plane passing through the centre of the sound source.

An example of spatial directional characteristics of a sound source is shown in Fig. 4. The measurement

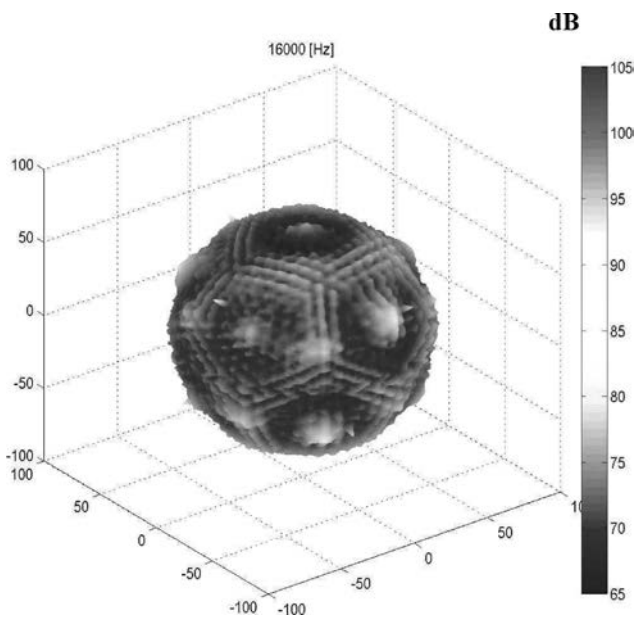
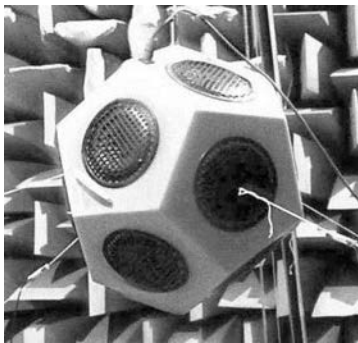


Fig. 4. Spatial directional characteristics of a twelve-speaker sound source for a frequency of 16 kHz.

points were located on a hemisphere with a radius of 2 m. The resulting characteristics are a graphical representation of 32,400 measurements approximated using the Matlab software.

4. A new concept of microphone positioning in the anechoic chamber

The study showed the benefits of developing techniques for the automatic positioning of the microphone during acoustic measurements (PILCH, KAMISIŃSKI, 2011). Therefore, the development of a conceptual design for a new microphone positioning system has been undertaken. The main advantage over the old one, is the possibility to use it for studies requiring the entire space of the measurement chamber under conditions of small perturbations of the free field. The new system would complement the existing one.

The fundamental dimensions of the anechoic chamber are given in Table 2.

Table 2. The fundamental dimensions of the anechoic chamber.

Dimension	Height [m]	Width [m]	Length [m]
Outside	10.39	10.17	9.70
Inside (wall to wall)	9.64	9.60	9.12
Inside (wedge to wedge)	7.34	7.20	6.65
Working space	6.90	7.20	6.65

The following values have been assumed:

- 1) the source would be located on the existing NR-750 Weiss turntable,
- 2) the working space would take the form of a cylinder with the height of $H = 600$ mm and the diameter of $D = 600$ mm,
- 3) in the working space, the microphone would be suspended with small diameter ropes to minimize the interference of the free field,
- 4) the accuracy of the positioning for a linear displacement of the microphone will be 1 mm,
- 5) the axis of the measuring microphone can be re-oriented relative to the sound source,
- 6) the number of degrees of freedom of the whole positioning system with the turntable is 4.

The developed concept of the positioning system is shown in Fig. 5. The main feature of the system is a cylindrical measurement space in which any microphone position based on the coordinates (x, y, φ_1) can be determined.

The measuring microphone is moved in the vertical direction by means of two vertical linear drives working synchronously and placed on two opposite walls in the zone of the sound-absorbing wedges. Between

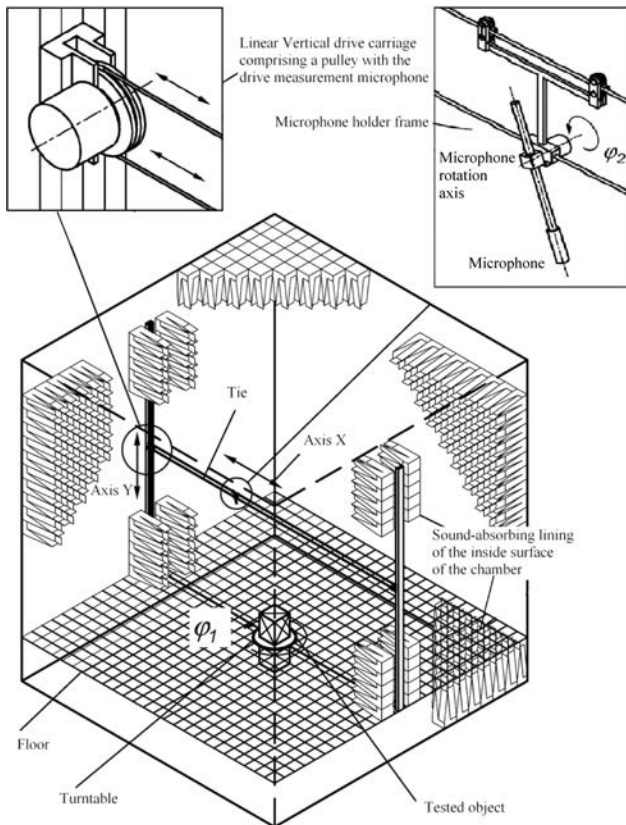


Fig. 5. A new concept of positioning the measuring microphone in the anechoic chamber.

those drives, two thin steel ropes are stretched to support the microphone. The horizontal movement of the measuring microphone is effected by pulling the ropes that pass over the pulleys attached to the vertical linear drives. At the same time, the microphone holder is attached to the lower rope and moves along with it, while the upper rope is used to stabilise the position of the microphone. The microphone holder moves relative to the rope on the pulleys. Two variants of measuring the microphone axis rotation in the direction of the source have been used:

- a) in one, the rotation drive is attached to the microphone holder and moves along with it,
- b) in the other one, the microphone rotates by a relative motion of the ropes moving the microphone in the horizontal direction. It is enough to block the movement of the upper part of the microphone holder relative to the rope and thus, using an appropriate yoke, cause the rotation of the microphone mounted on a swivel pin to the lower rope.

Another concept involves the measuring microphone moving in the horizontal direction by a self-propelled carriage moving along the two steel ropes; a drive will also be mounted on the carriage to rotate the axle of the microphone. The control of the positioning system with ropes suspending the microphone needs to take into account the deflection of the

ropes under the weight of the microphone. The system allows for the possibility of verification and correction of positioning by determining the coordinates of the microphone relative to fixed points of the chamber using the phonometric system described in the patent claim No. P-393 868 dated 07 February 2011. Further conceptual and design work will also address the issue of damping the vibration of the ropes while they move the microphone between the measurement points.

5. Positioning of the tested object in the reverberation chamber

The reverberation chamber is a research room whose walls are not parallel. All the surfaces of the chamber are hard and smooth with a very low sound absorption coefficient. The approximate dimensions of the chamber are: length 6.8 m, height 6.0 m, width 5.6 m. Such a design enables the production of a diffuse sound field, which is fundamental to its operation.

Many standard measurement procedures for the reverberation chamber require averaging the acoustic pressure over time and space, which is usually done by moving the microphone or using a multi-microphone system. The study of the sound scattering coefficient requires a precise positioning of the measured sample, which was done using a Weiss turntable (Fig. 6). The studied sample can be placed on the

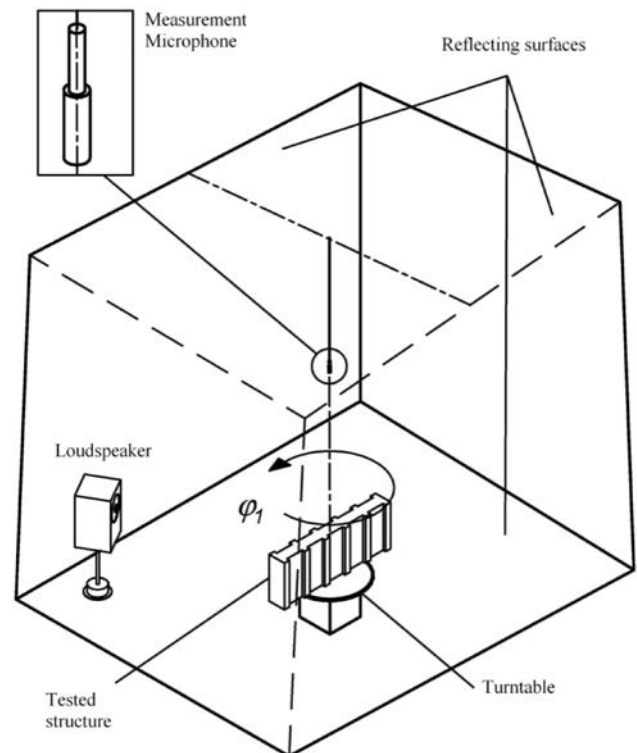


Fig. 6. A new concept of positioning the measuring microphone in the reverberation chamber.

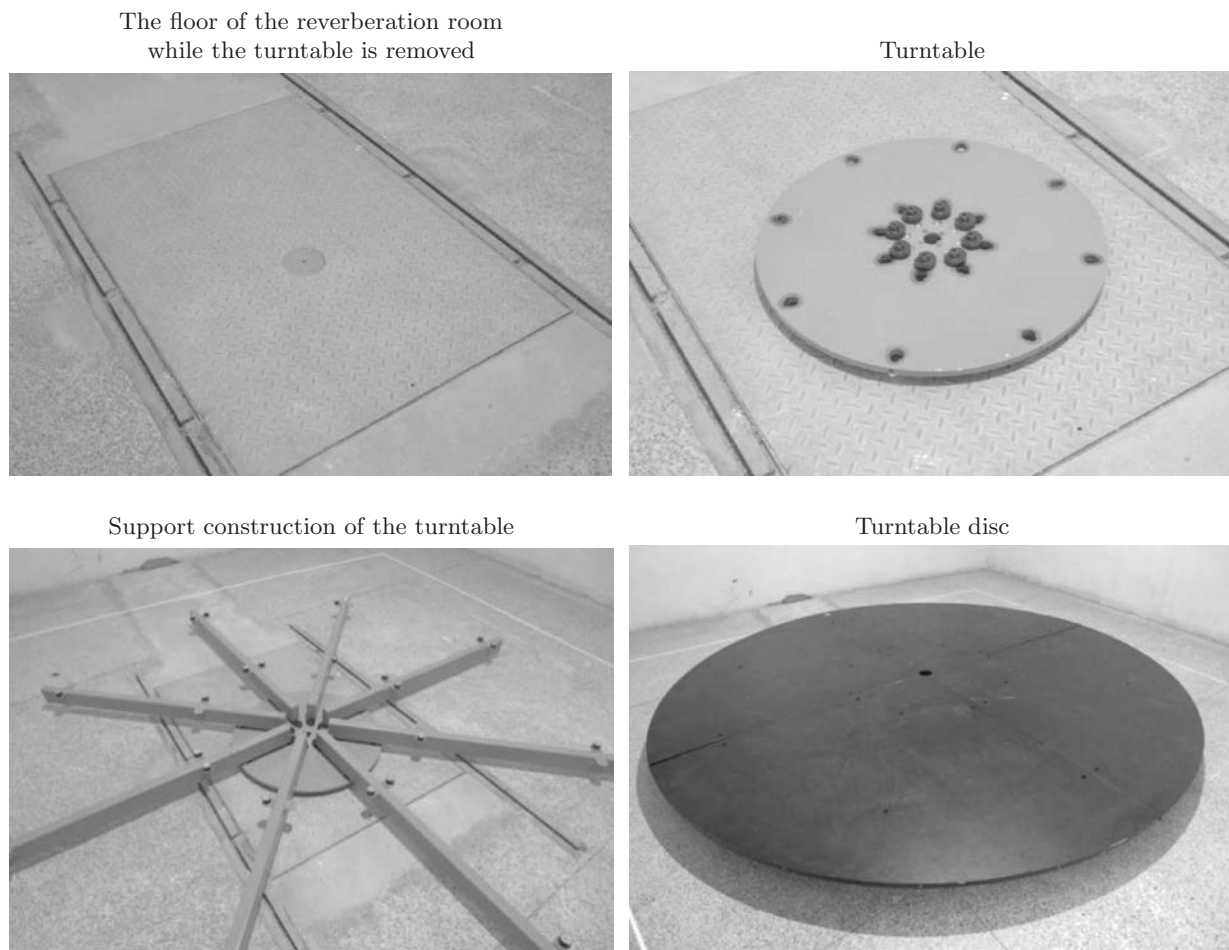


Fig. 7. The turntable in the reverberation chamber at the Department of Mechanics and Vibroacoustics.

turntable, while the sound source and measuring microphones are positioned manually (KAMISIŃSKI *et al.*, 2010). A prototype system described here is in operation at the Department of Mechanics and Vibroacoustics.

6. Summary and conclusions

The studies conducted so far demonstrate several benefits of the mechanical positioning of the microphone during acoustic measurements. The main benefit is the possibility of performing a large number of measurements in a short time with virtually no human intervention after proper preparation and programming of the manipulator position. A vision system is used to observe the process of measuring. The duration of acoustic measurements is mainly determined by the time it takes to move the microphone between the measurement points. The measurement of sound power with the use of the manipulator takes up to 10 minutes, whether by manual positioning it takes about 2 hours. For measurements of the spatial directional characteristics at an angular resolution of 1° , the measurement lasts 30 minutes, whereas the corresponding

measurements with manual positioning take about 30 hours.

Preliminary studies showed that the manipulator fully satisfied its basic design and construction principles. The actual positioning accuracy and the load-bearing capacity of the turntable was greater than planned. The study also demonstrated the possibility of further improvement to the measurement capability of the structure.

One problem with testing in an anechoic chamber, which does not require the use of the keypad, is the lack of rapid movements of the modules outside the measurement. Therefore we began work by a method allowing for a quick positioning of the manipulator modules in the zone of wedges in the anechoic chamber, and by modifying the actuators. This problem is also associated with a reduction of the impact of elements of the manipulator on the sound field of the chamber. Further work toward the gradual improvement of the software controlling the measurement procedures is also underway. A new concept of positioning the measuring microphone in the anechoic chamber, shown in Fig. 5, reduces these nuisances and increases the research capabilities of the device.

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