# Measuring Acoustics Wave Analysis In Rigid Walls

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***ABSTRACT:*** *In this paper, we studied the analysis of acoustic waves and how they move theoretically. This process is applicable inside the rigid walls. The values of sound waves in the cylindrical box are measured, and calculated, and modal frequencies are drawn. The results are presented with graphics and also in table forms.*

**Keywords:** Acoustic Standing Waves, Closed Cylindrical Enclosures

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**1. Acoustic Standing Waves**

In the paper are discussed the acoustic processes in a closed cylindrical volume (Figure 1). As a result of multiple reflections of the sound waves from the walls of the volume threedimensional sound field arises [1], an example of which is given in Figure 2. Depending on the shape, dimensions and their ratios in the enclosed volume fluctuations occur with a different set of natural frequencies [2, 3].

The acoustic processes in a closed cylindrical volume can be represented by the wave equation in cylindrical coordinate system $(r, \phi, z)$ [4]:

$$\nabla^2 p = c \cdot \left[ \frac{1}{r} \frac{\partial}{\partial r} \left( r \frac{\partial p}{\partial r} \right) + \frac{1}{r^2} \frac{\partial^2 p}{\partial \phi^2} + \frac{\partial^2 p}{\partial z^2} \right] \tag{1}$$

where: ϕ - azimuth angle of the source.

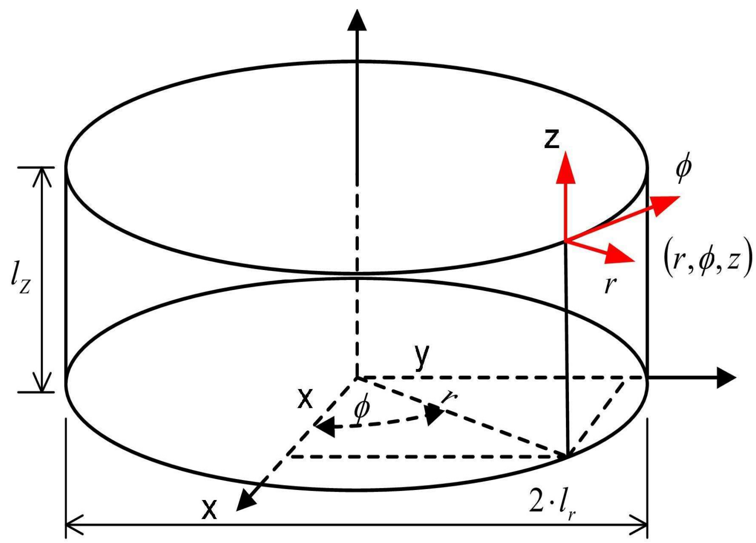


Figure 1. Cylindrical acoustic volume [5]

The solution of the wave equation is [6, 7]:

$$p = \begin{cases} \cos(j \cdot \theta) \\ or \\ \sin(j \cdot \theta) \end{cases} \cdot \cos\left(\frac{n_z \cdot \pi \cdot x}{l_z}\right) \cdot J_j \cdot \left(\frac{\lambda_{j,k} \cdot r}{l_r}\right) \quad (2)$$
$$n_Z, j, k = 0, 1, 2, ...$$

where: $J_j$ - Bessel function.

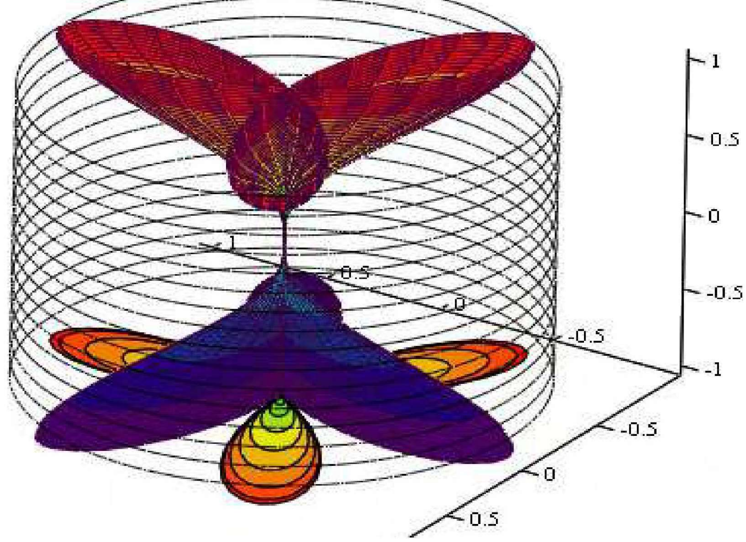


Figure 2. Distribution of the magnitude of sound pressure in a cylindrical box: *j* axial sound wave, $f = 3.538$ kHz, $j = 3$, $k = 0$, $\lambda_{j,k} = 4.201189$, $\cos(j.\theta)$, mode (0, 3, 0)

The natural frequencies for the corresponding values of $n_z$, $j$ and $k$ can be found by [5]:

$$f = \frac{c}{2} \cdot \sqrt{\left(\frac{n_z}{l_z}\right)^2 + \left(\frac{\lambda_{j,k}}{\pi \cdot l_r}\right)^2}, \text{ Hz} \quad (3)$$
$$n_Z, j, k = 0, 1, 2, ...$$

The natural frequency of the cylindrical box, calculated in accordance with mathematical dependence (3) is presented in Figure 3 and Table 1.

| № | Mode | $n_z$, j, k | Frequency, *kHz* |
|---|---|---|---|
| 1 | j axial | 0, 1, 0 | 1.551 |
| 2 | j axial | 0, 2, 0 | 2.573 |
| 3 | z axial | 1, 0, 0 | 2.774 |
| 4 | z, j tangential | 1, 1, 0 | 3.178 |
| 5 | k axial | 0, 0, 1 | 3.227 |
| 6 | j axial | 0, 3, 0 | 3.538 |
| 7 | z, j tangential | 1, 2, 0 | 3.784 |
| 8 | z, k tangential | 1, 0, 1 | 4.256 |
| 9 | j axial | 0, 4, 0 | 4.479 |
| 10 | j, k tangential | 0, 1, 1 | 4.491 |
| 11 | z, j tangential | 1, 3, 0 | 4.497 |
| 12 | z, j tangential | 1, 4, 0 | 5.268 |
| 13 | z, j, k oblique | 1, 1, 1 | 5.278 |
| 14 | j axial | 0, 5, 0 | 5.404 |
| 15 | z axial | 2, 0, 0 | 5.548 |
| 16 | j, k tangential | 0, 2, 1 | 5.648 |
| 17 | z, j tangential | 2, 1, 0 | 5.761 |
| 18 | k axial | 0, 0, 2 | 5.909 |

Table 1. The eighteen lowest normal modes and their natural Frequencies for a cilindrical box with rigid walls.

**2. Enclosure Response Measurements in Model Closed Cylindrical Box**

The measured characteristics of the sound pressure in cylindrical enclosure with the application software Realtime Analyzer [8] are presented in graphical form in Figure 4.

Measurements were made in a cylindrical box with dimensions: height 6.2*cm*, diameter 13*cm* and wall thickness 0.1*cm*. The program allows the data from the measured values of sound pressure in dB to be stored in tabular and text format for further analysis.

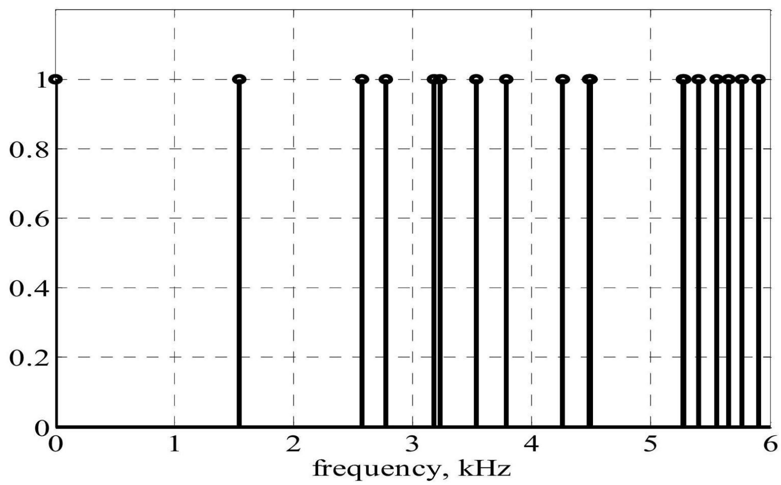


Figure 3. Plot of mode distribution

To examine the modal structure of the enclosure box response at the center of the volume was measured.

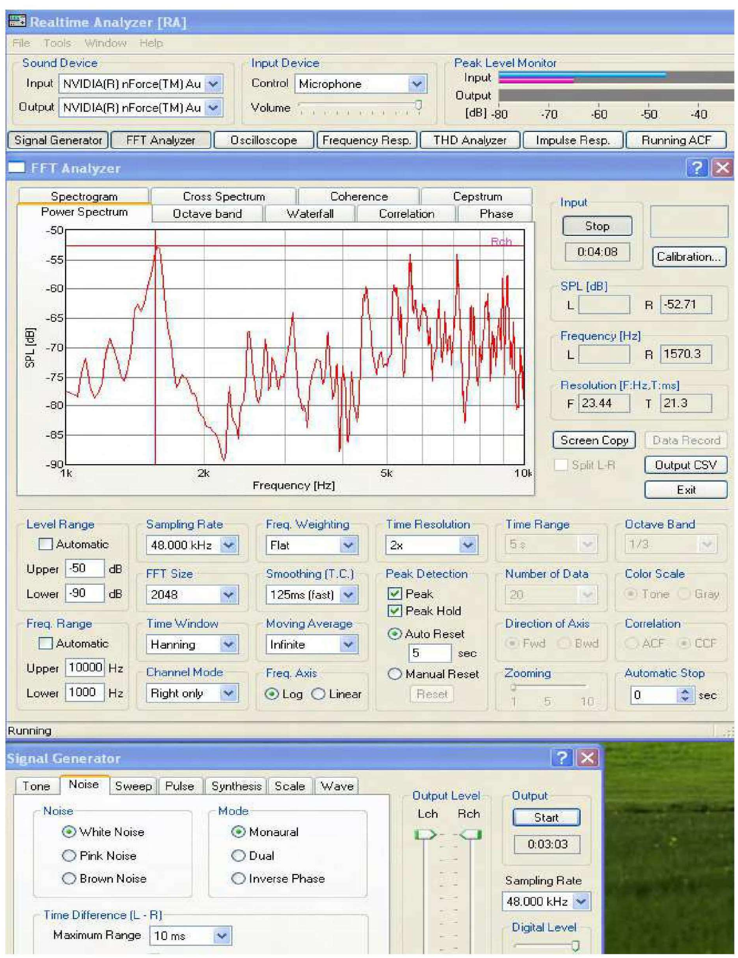


Figure 4. The measured sound pressure in the closed cylindrical enclosure (dimensions: height 6.2*cm*, diameter 13*cm* and wall thickness 0.1*cm*)

## 3. Conclusion

In the cylindrical acoustic volumes as with rectangular [2] “axial” and “tangential” natural frequencies can be defined. The *z* -axial natural frequency for $j = k = 0$ is given in Table 1, № 3 and № 15. When $n_z = 0$ by analogy with the rectangular speaker enclosure *z*, ϕ-tangential natural frequencies can be defined – Table 1, № 10 and № 16. If $n_z = 0$ and $j = 0$ the sound is focused along the axis of the cylinder, the sound wave propagates radially and the natural frequencies are *r*-axial – Table 1, № 5 and № 18. When $n_z = 0$ and $k = 0$ the natural frequencies can be called - axial [4] (perpendicular to *z* and *r* ) as shown in Table I, № 1, 6, 9 and № 14.

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