OBTAINING THE NUMERICAL RATIO OF CORNERED-SOUND SOURCES

Jose MUJICA[1]
Ramon A. MATA-TOLEDO[2]

Abstract: *The placement of loudspeakers in a room, from home systems to concert rooms, has been studied for many years. As a consequence of this throughout the years audiophiles and professionals have developed rules and methods concerning the placement of cornered-sound sources. There are reasons to choose the best places of a loudspeakers in a room, from getting a better sound quality to avoiding acoustical problems such as resonances, standing waves, reverberation or just the esthetic of the cornered-sound sources. It is well known that placing a loudspeaker on the floor, against a wall or in a corner increase the Sound Pressure Level in varying increasing values. However, audiophiles have different opinions about the sound quality that can be obtained. These extra dBs can help us to increase the Sound Pressure Level in cases when we do not have any more loudspeakers. In this paper we want to establish a numerical relationship between some of the rules and methods mentioned used by audiophiles and practitioners; this relationship will be established by means of a rudimentary experiment placing a loudspeaker in a corner.*

Introduction

Resources must be handled with care in limited or low budget projects. The genesis of this work was the personal experience of the authors when installing the sound sources for a concert using the equipment of a small audio rental company. There were four speakers, two for each side of an open-air acoustic shell. The speakers were to be placed on top of two 6-feet scaffolding towers.

During the initial testing the technicians, at 150 feet from the sources, thought that the speakers on one side of the acoustic shell were not working because they could not hear any sound coming from them. However, when they walked into the shell they were surprised because they could hear sound coming from all speakers in the shell. They were further surprised when they realized that the speakers located at the side of the shell from which they could not hear any sound were place on the scaffolding towers. The speakers located at the side of the acoustic shell from which the technicians could hear a sound were located on the floor.

[1] EE AES Fellow, jmujica@escuelasuperiordeaudio.com.ve, Escuela Superior de Audio y Acústica, Caracas, Venezuela
[2] PhD matatora@jmu.edu, James Madison University, Harrisonburg, VA. U.S.A.

Technicians know the rule-of-thumb that a "loudspeaker on the floor has a Sound Pressure Level gain of +3dB, on the floor and against a wall a gain of +6dB and, in a corner, a gain of + 9 dB." Verifying personally on the field what the theory states was a pleasant experience. However, under the current circumstances and with limited number of speakers, at 150 feet, the sound coming from by the speakers on the scaffolding was missing and it is necessary to produce a satisfactory quantity of sound [1].

After this unexpected and inexplicable event, we wanted to recreate a similar experience in the studio, first, by placing a loudspeaker hanging from the ceiling and, second, placing it at a corner.

From sound theory [2] we know that if we assume that the sound source is at the center of a sphere of a given radius r, the sound energy will travel through the 8 quadrants (right spherical triangles) of the sphere [3]. Now, if we place the sound source at a corner of the room, the area of the sphere is reduced to 1/8 of its area when it was at an elevated position. Due to the configuration of the walls, the sphere is reduced to only one quadrant. However, because the sound energy remains the same the sound intensity travelling through the quadrant will increase an eightfold. According to the dB Power Ratio we know that every time the number of sound sources is doubled this will result in an additional gain of +3dB. This is so because each time you double the power ratio into the formula $Lp = 10*\log(P1/P2)$ you will get +3dB. Likewise, continue doubling of the sound source will result in +6dB, +9dB, etc.

1 Rudimentary experiment cornering a loudspeaker.

We proceeded placing the monitor loudspeaker on a drum throne, taking measurements around a sphere of 1-meter radius. The source signal consisted of a 400Hz tone, getting from an oscillator TEAC model 122A. The amplified loudspeaker was a Thonet &Vander model Vertrac 2.0. The Decibel meters were a portable Radio Shack and application Iphone Decibel X by sky Paw CO. LTD. The hydraulic set of the throne were set to 1-meter height.

The room was a studio recording isolated to 60 dB of attenuation. The reverberation time of the room was 0.6 seconds. The Sound Intensity obtained was 81 dB

Testing 8 points over the front hemisphere, the sound variations were under 2 dB as shown in Figure 1. (Video available at YouTube: Acoustic Prediction Loudspeaker suspended Vs. Cornered)

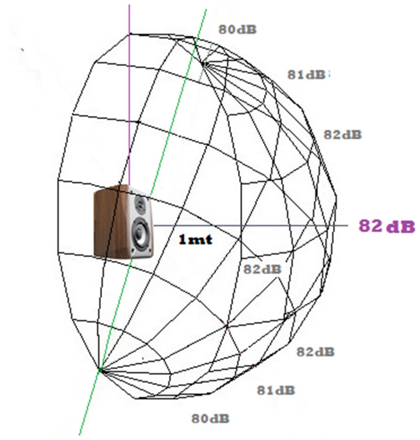

Figure 1. Measurements over the front hemisphere

The step was to place the loudspeaker at a corner (See Figure 2) to test the dB variations while maintaining the same control settings. As we can be seen in the video, uploaded on Youtube, the result was the one we expected according to the rule-of-thumb previously mentioned; an increment of +9dB when compared to the initial suspended position.

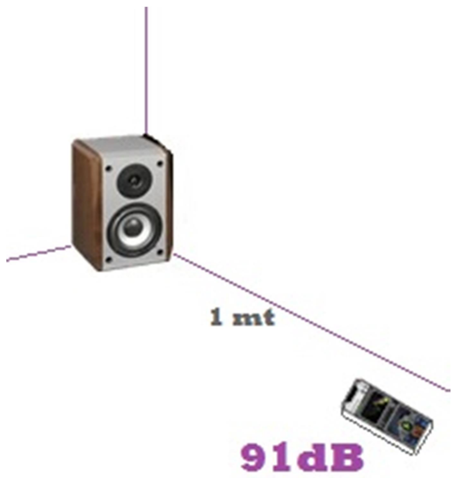

Figure 2. Measurement over the cornered loudspeaker

2.-Calculating the relation.

Knowing that the intensity of the sound is the acoustic power per unit of area in a direction perpendicular to that area, we calculated the area of a 1-meter radius sphere. This area multiplied by the sound intensity will produce the corresponding acoustic power (Expressed in W).

The rest of this paper aims to justify mathematically the result of the experiment already described.

2.1.-Calculating the surface of a sphere of radius 1.

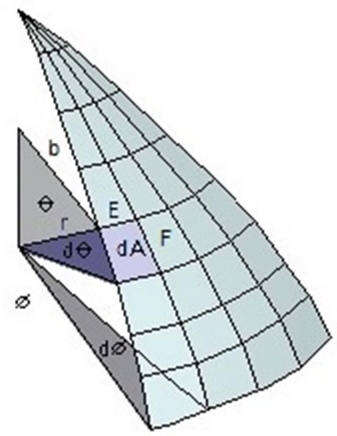

Figure 3. Source of radiation [4]

From the Figure above we can get the following relations. [5]

$$b = r * \sin(\theta)$$

$$E = b * d\emptyset$$

$$F = r * d\theta$$

$$dA = E * F$$

Then we get

$$dA = r * \sin(\theta) * d\emptyset * r * d\theta$$

or its equivalent

$$dA = r^2 * \sin(\theta) * d\theta * d\emptyset$$

Now we can write the integral like

$$\int_0^{\emptyset} \int_{\theta 1}^{\theta 2} r^2 * \sin\theta * d\theta * d\emptyset$$

Solving the integral for dθ for one hemisphere

$$r^2 \int_0^{2\pi} (-\cos\theta \Big|_0^{\pi}) \, d\emptyset$$

$$r^2 \int_0^{2\pi} (-\cos\pi - (-Cos(0)) d\emptyset$$

$$r^2 \int_0^{2\pi} \big(-(-1) - (1)\big) d\emptyset$$

$$2 * r^2 \int_0^{2\pi} d\emptyset$$

The formula for the area of the sphere is given by

$$A = 4\pi r^2$$

Knowing that its radius 1 meter, the total area is

$$A = 4\pi$$

2.2 Getting the Sound Power on both measurements.

2.2.1 Sound power for 82 dB.

For 82 dB we can use the following formula to get the Sound power expressed in Watts. [6]

$$Lp = 10 * \log(\frac{P1s}{P2r})$$

Where Lp is Power the level in dB.
P1s is the Sound Power measured with the loudspeaker suspended.
P2r is the Reference Power in Watts.

We must find P1s, using the measurement of 82dB as Lp and the reference Level $1*10^{-12}$ Watt as P2.

$$82 = 10 * \log(\frac{P1s}{10^{-12}})$$

$$10^{\frac{82}{10}} = \cancel{10}^{\cancel{\log}(\frac{P1s}{10^{-12}})}$$

$$P1s = 10^{8.2.} * 10^{-12}$$

$$P1s = 10^{-3.8}W$$

2.2.2 Sound power for 91 db.

For 91 dB we can use the following formula to get the Sound Power expressed in Watts.

$$Lp = 10 * \log(\frac{P1c}{P2r})$$

Where Lp is Power the level in dB.
P1c is the Sound Power measured with the loudspeaker cornered.
P2r is the Reference Power in Watts.

We must find P1c, using the measurement of 91dB as Lp and the reference Level $1*10^{-12}$ Watt as P2.

$$91 = 10 * \log(\frac{P1c}{10^{-12}})$$

$$10^{\frac{91}{10}} = \cancel{10}^{\cancel{\log}(\frac{P1c}{10^{-12}})}$$

$$P1c = 10^{9.1} * 10^{-12}$$

$$P1c = 10^{-2.9}W$$

2.3 Obtaining the Intensity of the Sound.

Now we will proceed to dividing the Sound Power values previously obtained ($P1s= 10^{-3.8}$ W and $P1c= 10^{-2.9}$W) by the total sphere's area and 1/8 of this total respectively [6].

$$Is = \frac{10^{-3.8}}{4\pi} \; 1.26 * 10^{-5}$$

$$Ic = \frac{10^{-3.8}}{\frac{\pi}{2}} = 1 * 10^{-4}$$

Where Is is Intensity of the sound suspended
Ic I Intensity of the sound cornered

3. Solving the numerical ratio

We can now introduce the sound intensity into the dB formula to get the numerical ratio related to the area of radiation. The level (L) in dB will be

$$L = 10 * \log(\frac{1 * 10^{-4}}{1.26 * 10^{-5}})$$

$$L = 9\ dB$$

Conclusion

In the sound reinforcement field, understanding the behavior of the sound reflection within the acoustical environments can help us to get the maximum efficiency of our resources. Contrary to the empirical studies on this topic by audiophiles, the authors believe that there are situations where it is necessary to increase the dBs based on theoretical foundations.

While the motivation for this paper was open-air and real-life project, it is important to take into account that in closed rooms, we must consider acoustic laws related to phenomena such as early reflection effects, passing through delays, to intelligibility.

As indicated before, keeping constant the sound source power on an imaginary sphere and then concentrating that density over an octant will increase the power ratio eightfold. When this result is calculated by mean of the decibel power formula, we will get 9 dB of gain as it was demonstrated theoretically.

References

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THE AUTHORS

 

Jose Mujica Ramon A. Mata-Toledo

Jose Mujica holds an Electrical Engineering degree from the Universidad Central de Venezuela. He is also an AES Fellow and author of several books including Audio Engineering (1990-2006), Audio Dictionary (1990 in Spanish), Infinitesimal Calculus with Analytic Geometry and Computing Applied to Audio (1993 in Spanish), and The Master handbook of P.A. (1993 In Spanish). He has written software for the electroacoustic Hewlett-Packard HP-41CV calculator (1984) using Constant Voltage 70.7V Software for Hewlett-Packard 86B (1988) and Q-Basic (1989). Mr. Mujica developed the software Audio Utilities with 20 applications (dB, RT60, Mass Law, 70.7V, filters, electroacoustic, etc.) in Visual Basic (1992). He has worked too as an Electroacoustic Consultant dedicated to acoustic prediction software such as EASE and CATT. In addition, Mr. Mujica is co-founder and Director of the School of Audio and Acoustics in Caracas, Venezuela. He is also author of several papers including Discrete Fourier Transform: two examples steps by step. Since 2015 he has been working on Audio Engineering Historical interviews and the Acoustic Prediction Channel on YouTube.

Ramon A. Mata-Toledo holds a PhD in Computer Science from Kansas State University. He also holds an MS in Computer Science and MBA degrees from the Florida Institute of Technology. In addition, he holds a Professional master's in business Intelligence from Villanova University and a Master in Oracle Administration from the Oracle Corporation. His bachelor's degree is in mathematics and physics from the Instituto Pedagogico of Caracas, Venezuela. Currently he is a Professor of Computer Science and an Affiliate Professor of Mathematics and Statistics at James Madison University. Dr. Mata-Toledo is a Distinguished Professor of the College of Integrated Sciences and Technology at James Madison University and a U.S. Fulbright Scholar. He has published over 100 refereed papers in national and International conferences and is co-author of four books all published with the Schaum's Outline Series of the McGraw-Hill. He is also the Computer Science Editor of AccessScience of the McGraw-Hill. Dr. Mata-Toledo recently co-authored the book, still unpublished, Logic for Computer Scientists with Dr. Daniel Flage of the JMU Department of Philosophy and Religion.