DIFFERENCING BETWEEN DECIBEL (DB) ADDITION IN ROOM ACOUSTIC DESIGN AND LINE ARRAY LOUDSPEAKERS DESIGN

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Abstract: *Historically, in the textbooks and based on the physical formula of the decibel, audio authors and practitioners have stated that "if we double the number of equal-sound sources we get an increase of sound output of + 3 Decibels." However, since the line array loudspeakers (LAS) boom, we have seen correlated source systems where audio engineers stated that if these sources were also doubled, it was possible to obtain + 6* ***dB****. This conclusion has been presented in many professional forum, conferences, and professional papers. When asked why this is so, in general, presenters justify this result as a direct consequence of the Sound Pressure Level Formula (****dBspl****). Although this justification is true for correlated sources, among the audio profession, the concept of dBspl has always been used undistinguishable with that of the Intensity of the Sound in dB. For this reason, in the acoustic design of a room, it is necessary to use a different value, namely, the Root Mean Square of the Sound Pressure Level. That in some system is possible to obtain one result but not in others has created confusion among practitioners. In this paper, the authors attempt to shed some light on the confusion on the use the concept of the* ***dBspl*** *as it relates to room acoustic and the loudspeakers design.*

Introduction

It is generally assumed that in the design of an acoustic system, if the number of equal-sound sources is doubled, there is an increase in the audio output of + 3dB. With the advent of line array loudspeakers (LALs) in correlated source systems, according to some practitioners, the output should be + 6dB. The latter result is justified by using the Sound Pressure Level formula where its logarithmic factor is multiplied by 20 instead of 10, as it is done when calculating Sound Intensity. These two results have brought confusion in room-acoustic design among practitioners and technicians. In the opinion of the authors, this topic has been treated lightly; as a matter of fact, Eargle and Foreman [1], state that "…we can construct a new scale [table of values] in which a doubling of sound pressure corresponds to a 6 dB increase in sound pressure level (SPL)."

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The acoustic principles used in the installation of LAS are not new [2]. They have been known and used since first installed as column loudspeakers in big reverberation environments such as those encountered in traditional Christian churches. Here, engineers took column loudspeakers principles and combined them with the Neodymium magnets. The result of this new technology was a system of stackable small and light boxes with an amazing output power and accuracy between components as it was never experienced. In addition, as a consequence of this development, an old acoustical concept has reemerged, namely, that of correlated sources [3]. The application of this concept, under certain conditions, has made possible to get the equal sound pressure level at different positions from the same sound sources.

But again, you keep finding the mingling of the concepts of sound pressure level and sound intensity as can be seen in figure I which reproduces that of [4].

If the sound pressure level stated in dB this information can be use in calculations.
For instance, a loudspeaker datasheet provides us with information for the
Characteristic sound pressure level (1W/1m):95 dB. This means that at 1 watt of power,
The loudspeaker generates a sound pressure level of 95 dB at a distance of 1 meter. The
Following table indicates by how many decibels the sound pressure level of the
Loudspeakers increases at a given power.

Power (w)	1	2	5	6	10	15	20	30	50	100
Increase in the sound pressure level	0	3	7	8	10	12	13	15	17	20

The table shows that at 6 watts you need to add 8 dB to the 95 dB. Consequently, at 6
Watts of power we obtain 103 dB SPL at a distance of 1 meter. There is also a Mathematical formula for this calculation that yields the same result.

$$P1 = pn + 10 \times \log (p)$$

P1: Sound Pressure level (dB) pn: Characteristic sound pressure level (dB) P: supplied Power (w)

Each doubling of power gives us an additional of 3 dB spl

Figure I. The Sound Pressure Level and the Power. TOA Page.

The confusion, previously mentioned, with regard to the difference in the number of **dB** that can be outputted from a sound system arises during the acoustical design of a room where the Root Mean Square of the Sound Pressure Level (in dBspl) should be used as oppose to traditionally used of the value of Level Pressure Sound at a point.

1. Ratio between the sound intensity and the sound pressure level

1.1. Sound Intensity

The sound intensity (Acoustic Power per unit of area) that goes through an imaginary spherical Surface around a punctual source (See Figure II), can be expressed as shown next [5]:

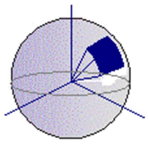

Figure II. Spherical Surface

$$I = \frac{W}{A} = \frac{W}{4\pi r^2} \quad (\mathrm{W/m^2})$$

The sound intensity can be calculated with a sound wave as follows:

$$I = \frac{W}{A} = \frac{p^2}{\rho c} \quad (\mathrm{W/m^2}) \quad \textbf{(F1.1)}$$

where
I = Sound Intensity (W/m^2)
W = power (Watts)
A = area (m^2)
r = Spherical Surface radius (m)
p = Pressure Root mean Square (N/m^2)
ρ = Density (kg/m^3)
c = Sound velocity (m/s)

Sound Intensity expressed in dB:

According to [6] the Sound Intensity can be expressed as

$$L_i = 10 * \log \frac{I}{I_{ref}}$$

where

$$Iref = Reference\ Intensity\ \left(\frac{W}{m^2}\right)$$

According to ISO 3740:2019 the Reference Level of the Sound Intensity is:

$$10^{-12}\frac{W}{m^2}$$

1.2. Sound Pressure Level.

Sound Pressure is the square root of the Sound Intensity. The Sound Pressure level is the root mean square pressure of a sound. From F1.1., given that

$$I = \frac{p^2}{\rho c}$$

Results

$$L_I = 10 * \log\left(\frac{\frac{p^2}{\rho c}}{\frac{p^2{}_{ref}}{\rho c}}\right)$$

Simplifying

$$L_I = 10 * \log\frac{\cancel{\rho c}p^2}{\cancel{\rho c}p^2{}_{ref}}$$

We get

$$L_{spl} = 10 * \log\left(\frac{p^2}{p^2{}_{ref}}\right)$$

Using a property of the exponents, we have

$$L_{spl} = 10 * \log\left(\frac{p}{p_{ref}}\right)^2$$

By the logarithm exponential law, we have that:

$$L_{spl} = 2 * 10 * \log\frac{p}{p_{ref}}$$

Sound Pressure Level expressed in dB

According to ISO 3740:2019 we have that the Sound Pressure Level can be expressed as:

$$L_{spl} = 20 * \log \frac{p}{p_{ref}}$$

Where

P: is The Root Mean Square of the Pressure (N/m2)

The standard reference level p_{ref} is 20 x10^{-6} N/m^2.

2 Ratio between power and the sound pressure level

2.1 The Decibel Power law

If we double the power ratio of sound sources of the Sound Intensity, we will get an increasing of +3dB.

So, if we have

$$dB = 10 * \log \frac{P_1}{P_2}$$

Where P_1 is the power and P_2 the reference power.

Doubling the relation P_1/P_2 we get

$$10 * \log(2) = 10 * 0.3 = \ +3\text{dB}$$
$$10 * \log(4) = 10 * 0.6 = \ +6\text{dB}$$
$$10 * \log(8) = 10 * 0.9 = \ +9\text{dB}$$

But if we use the formula for Sound Pressure Level (spl) with a correlated source as we do with a line array, we would get the values shown below.

$$L_{spl} = 20 * \log \frac{\mathrm{p}_1}{\mathrm{p}_2}$$

Doubling the relation p1/p2 we get

$$20 * \log(2) = 20 * 0.3 = \ +6\text{dB}$$
$$20 * \log(4) = 20 * 0.6 = \ +12\text{dB}$$
$$20 * \log(8) = 20 * 0.9 = \ +18\text{dB}$$

The last relation shows that doubling the sound sources will increase the total Sound Pressure Level in +6dB. However, this is only true in correlated sources of sound.

2.2 Using the Root Mean Square into Room acoustic design

When we work in acoustic design for rooms, we must use the Root Mean Square (rms) of the Sound Pressure level because the behavior of the sound waves may be affected by many factors such as reverberation, reflections, diffusion, standing waves, source position, etc. Also, the type of source can give us different responses according to the geometrical characteristic of the room.

If we work with software of Acoustic Prediction like
EASE [7] or CATT [8] to design the acoustic of a room, we can observe the values we get when doubling the number of sources would be that of the corresponding Root Mean Squares.

2.2.1 Using JBL Software Simulator to get the Sound Pressure Level.

The graphs shown in Figure III were obtained using the JBL Line Array Calculator II to compare the Sound Pressure Level when sources were doubled; the result we obtained was +3dB when compared two traditional loudspeakers.

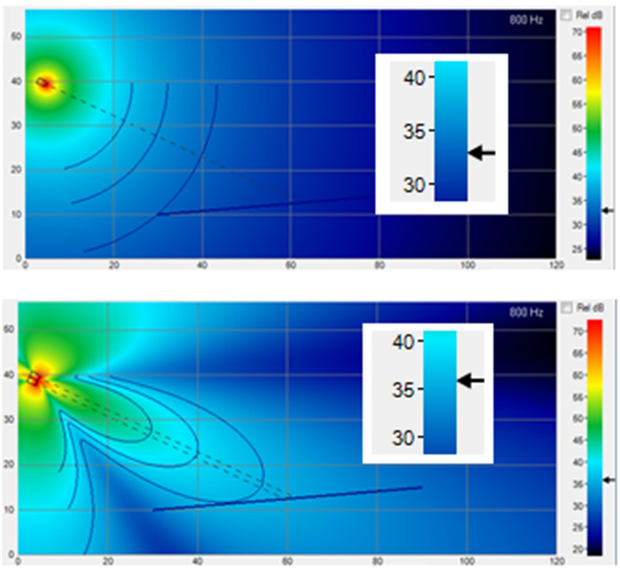

Figure III. Using the JBL Line Array Calculator II to double the number of sources. As can be seen, we got +3dB of increasing.

In the following example we use one Linea Array Loudspeaker (Figure IV)

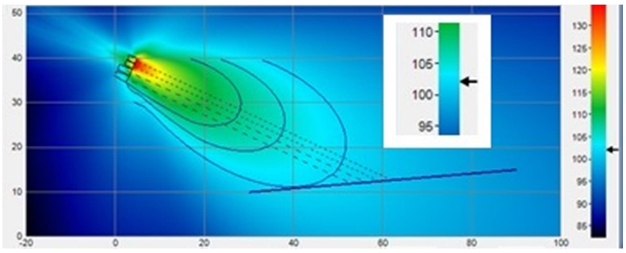

Figure IV. Four boxes

Then we doubled the number of speakers to get +6dB. But when we added two boxes of subwoofers to get the complete broadband, we got +4dB. This result tells us that, in fact, the Line Array technology achieves +1dB over the value we expected, but no the +6dB sales engineers are talking about. (Figure V).

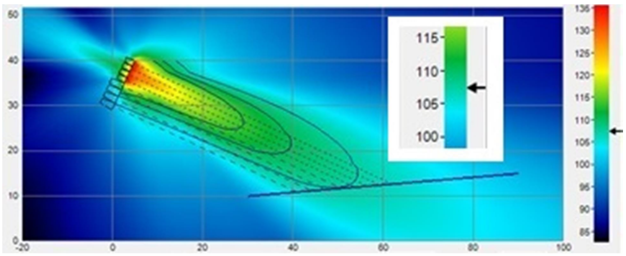

Figure V. Eight boxes.

2.2.2 Using the EASE Software simulator to get the Sound Pressure Level.

We then proceed placing one traditional loudspeaker into the acoustic simulator software EASE as shown in Figure VI, getting 76dB of Sound Pressure Level.

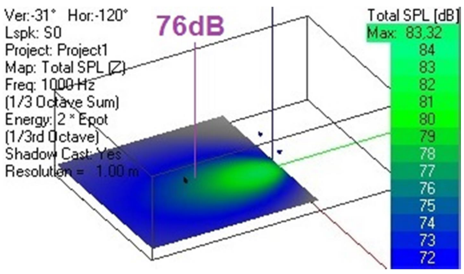

Figure VI. Placing one traditional loudspeaker we get 76dBspl.

Then we placed two traditional loudspeakers running the simulation again and got 79dB. We obtained an increment of +3dB as expected because the software uses the Root Mean Square and not a punctual sound pressure. Figure VII.

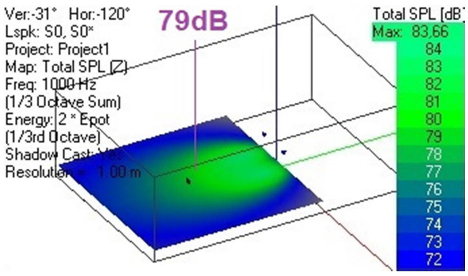

Figure VII. Placing two traditional loudspeakers we get 79dBspl.

2.3. Calculating the Sound Pressure Level using the rms. [10]

If we double a unity pressure under the rms formula, we will have

$$L_{spl} = 20 * \log \sqrt{\frac{(1^2 + 1^2)}{1}}$$

This can be expressed as

$$L_{spl} = 20 * \log \sqrt{2}$$

$$L_{spl} = 20 * \log(2)^{\frac{1}{2}}$$

Using logarithms

$$L_{spl} = \frac{1}{2} * 20 * \log(2)$$

$$L_{spl} = 10 * 0.3 = 3\ dB$$

Another way to express the rms is

$$L_{spl} = 20 * \log \frac{2}{\sqrt{2}}$$

$$L_{spl} = 20 * \log(2 * 0{,}707)$$

In any case we can show that

$$L_{spl} = 20 * \ 0.150 = 3dB$$

Therefore, we can then prove easily that

$$\text{Lspl} = 20 \text{ Log } (2)^{1/2} = 3$$
$$\text{Lspl} = 20 \text{ Log } (4)^{1/2} = 6$$
$$\text{Lspl} = 20 \text{ Log } (8)^{1/2} = 9$$

3. Conclusion

You Can talk about that doubling the numbers of sound source will increase +6dB when you work with correlated sources. But when you are working in the Acoustics field you must work with Root Mean Square of the Pressure and in this case the increasing value will be +3dB.

Because the number of papers and speeches are most about Line Array loudspeakers, today, it must be desirable that sales engineers mention this difference to avoid confusing members of the audience not aware of this subtle difference.

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