Exercise 3

The speech intelligibility in a church is bad. The background noise (BGN) is not the reason. The problem is caused by the direct/diffuse field ratio. To improve the speech intelligibility in this church a sound system consisting of a microphone, an amplifier and a single driver loudspeaker box (box with one loudspeaker) is used. The first test of the new system shows no improvement of the speech intelligibility.

A: What is the reason that the use of the sound system is not the solution for the problem?
B: Mention 2 possible practical solutions to improve the speech intelligibility (increasing the 'direct/diffuse ratio') without using a sound system.
C: Mention a solution to improve the speech intelligibility (increasing the 'direct/diffuse ratio') using a sound system. (Describe the sound system!)

A sound field can be described as:

L_p totaal = L_p direct + L_p diffuus

L_p direct = $L_W + 10\lg(Q/4\pi r^2)$

L_p diffuus = $L_W + 10\lg(4/A)$

A: It is all about the 'direct/diffuse' ratio! Increasing the sound power results in an increasement of both $L_p$dir and $L_p$diff. The d/d-ratio doesn't change. So this is not the solution for the BGN problem.

B: Controllable parameters:

- directivity Q
- source receiver distance r
- total sound absorption A.

3 posible practical solutions:

1. improving the directivity (Q>) using reflecting planes near to the sound source
2. decrease the speaker-listener distance (r <)
3. increase of the total sound absorption (A>) using sound absorbing material

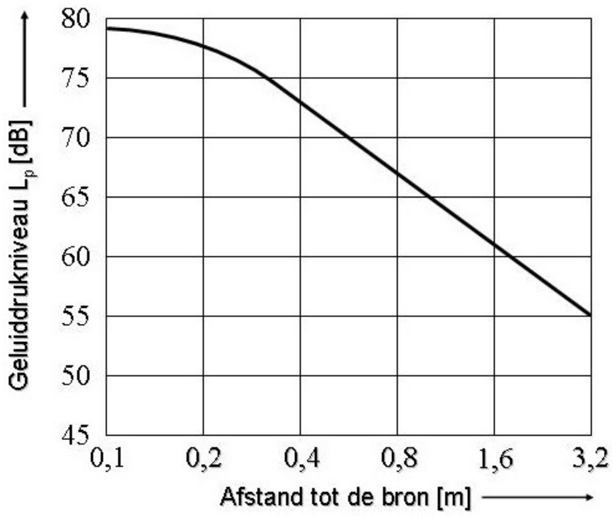
C: Posible solutions using a PA-system (reinforcement system):
Use of:

1. Loudspeaker arrays (columns)
2. Directive mircrophones
3. Headphones (direct output)
4. In ear headset + smartphone + wireless signal

Exercise 4

The graph below is a result of a free field loudspeaker measurement in a large hall.

A: What is the sound power level Lw [dB] of the loudspeaker if the directivity factor Q is equal to 2?
B: At what distance is the sound power of the sound source equal to the sound pressure level?
C: Mention a reason why the line isn't straight for distances less than 40 cm?
D: What is the sound pressure level at the critical distance if the diffuse field sound pressure level is 50 dB? What is the critical distance value?



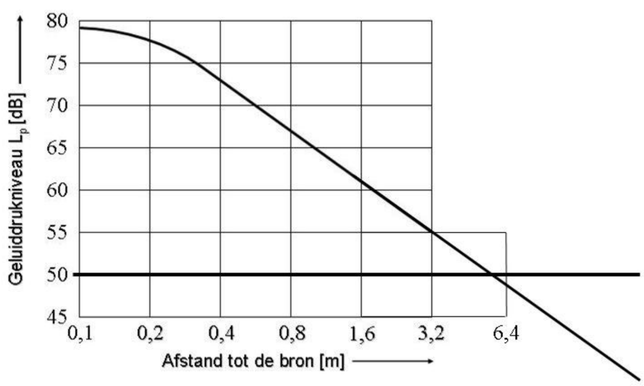
Geluidrukniveau = Sound pressure level
Afstand tot de bron = Source receiver distance

A: Reading the graph: for instance at a distance of 3,2 m → Lp = 55 dB
$L_p = L_W + 10\lg(Q/4\pi r^2)$, $55 = L_W + 10\lg(2/(4 \times \pi \times 3{,}2^2))$ → $L_W = 55 + 18{,}1$ **≈ 73 dB**

B: $L_p = L_W + 10\lg(Q/4\pi r^2)$, $L_p = L_W$ indien $10\lg(Q/4\pi r^2) = 0$, $Q/4\pi r^2 = 1$, $Q = 4\pi r^2$
$r = (Q/4\pi)^{1/2}$, **r ≈ 0,4 m**

C: A reduction of 6 dB per distance doubling only applies if the source-receiver distance is approx. 5 x the largest dimension of the sound source. Only then the source can be considered as a point source. In this case a S-R distance of 40 cm is relatively small related to the dimensions of the sound source.

D: At the critical distance the direct field sound pressure level is equal to the diffuse field sound pressure level. The total sound pressure level at the position of the critical distance is '50 + 50' = 53 dB. De critical distance is approx. 5.5 à 6 m (see intersection graph lines).



Exercise 5

The proud owner of a new set of loudspeakers claims that, according to him, one box can "produce 100 watts of sound energy". The boxes are in his living room. This room has a volume of 100 m^3 and a reverberation time is 0.5 s for all frequency bands. The presumed directivity factor Q = 1 (omnidirectional).

A: What is the sound pressure level at a distance of 5 m from that box if the sound power is really 100 watt,? Discuss the calculated result.
(sound power level $L_W = 10\lg(W/W_0)$ dB, $W_0 = 10^{-12}$ watt)

The just noticeable difference (JND = Just Noticeable Difference) between two sound pressure levels of noise-like sounds is 1 dB.

B: How many extra power do you need to produce 1 dB more sound at the same listener position?

In the same listening room another loudspeaker box of 40 watt produces the same sound level as the 100 watt box. Source position, listener position and level knob (amplifier) position are equal comparing the first situation.

C: Mention 2 reasons!

A: $L_W = 10\lg(W/W_0)$ dB, $10\lg(100/10^{-12}) = 140$ dB
$L_p = L_W + 10\lg(Q/4\pi r^2 + 4/A)$ dB, Q = 1, r =5 m, A = V/6T = 100/(6 x 0,5) = 33,33 m^2,
$L_p = 150 + (-9,1)$ **≈ 131 dB** (level of a starting jet fighter, far above the pain trteshold, in your living room… no way. This should have something to do with the conversion of electrical energy to sound energy (efficiency, effectiveness ore something).

B: $L_{Wnew} - L_W = 1 \rightarrow 10\lg(W_{new}/10^{-12}) - 10\lg(100/10^{-12}) = 10\lg(W_{new}) - 10\lg(100) = 10\lg(W_{new}/100) = 1 \rightarrow \lg(W_{new}/100) = 0{,}1 \rightarrow W_{new}/100 = 10^{0,1} = 1{,}26$
$W_{new} = 1{,}26 \times 100 = 126$ Watt. This means **26 watt** (> 25 %) extra power.

In other words: (targeted) 1 dB difference: $10\lg(x) = 1 \rightarrow \lg(x) = 0{,}1 \rightarrow x = 1{,}26$
Extra power for 1 dB more sound: 1,26 x 100 =126 watt. This means **26 watt** extra power.

C:
1. the efficiency of the 40-watt box is much higher
2. the Q (directivity in the direction of listener position) of the 40-watt box is higher than the directivity of the 100-watt box.

FORMULAS (without explanation and without dimension)

$$c = \lambda f = 340$$

$$L_p = 10\lg\frac{p_{eff}^2}{p_0^2}$$

$$L_W = 10\lg\frac{W}{W_0}$$

$$L_I = 10\lg\frac{I}{I_0}$$

$$L_{pdir} = L_W + 10\lg\left(\frac{Q}{4\pi r^2}\right)$$

$$L_{pdiff} = L_W + 10\lg\left(\frac{4}{A}\right)$$

$$L_p = L_W + 10\lg\left(\frac{Q}{4\pi r^2} + \frac{4}{A}\right)$$

$$A = \sum\left(\alpha \cdot Opp\right)$$

$$T = \frac{V}{6A + 4mV}$$

$$r_k = \sqrt{\frac{QA}{16\pi}}$$

ref. values:
$p_0 = 2 \times 10^{-5}$
$W_0 = 10^{-12}$
$I_0 = 10^{-12}$