TT3010 - Audio technology and room acoustics. Exercise 4 - Loudspeakers in rooms Solutions

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Tasks

1

Remember that the speed of sound c, the frequency f and wavelength λ. have the following relation.

$$c = f\lambda \tag{1}$$

If we rearrange the expression and insert the diameter d, of the woofer, we get the frequency:

$$f_{woofer} = \frac{c}{d_{woofer}} \approx 900\ Hz \tag{2}$$

The same thing can be done for the tweeter.

$$f_{tweeter} = \frac{c}{d_{tweeter}} \approx 6860\ Hz \tag{3}$$

2

The acoustic power output W_{Ac} of the sound system is equal to the product of the electrical input power W_{ele} and the efficiency of the sound system η. Then $W_{Ac} = \eta W_{ele} = 0.5$ kW.

Now we can express the sound power level radiated by the speaker in terms of decibel using the following expression.

$$L_W = 10 \log \frac{W_{Ac}}{W_0} \tag{4}$$

where $W_0 = 10^{-12}$ W. This gives us a sound power level of $L_W \approx 147$ dB.

We can now calculate the free field sound pressure level at 90 m and with a Q-factor that is 4.

$$L_p = L_w + 10 \log \frac{Q}{4\pi r^2} \tag{5}$$

This gives $L_p \approx 103$ dB.

3

For an octave band, the upper cut-off frequency is twice the lower cut-off frequency. Therefore, if f_{up} and f_{low} represent the upper and lower cut-off frequencies,

$$f_{up} = 2f_{low} \tag{6}$$

Furthermore, the center frequency of an octave filter is $f_{center} = \sqrt{f_{up} f_{low}}$. We can then substitute $2f_{low}$ in the equation to get

$$f_{center} = \sqrt{2f_{low} f_{low}} = \sqrt{2} f_{low}$$

Knowing this, we can express f_{low} in terms of f_{center}.

$$f_{low} = \frac{f_{center}}{\sqrt{2}} \tag{7}$$

So, the lower cut-off frequency will be $f_{low} = \frac{500}{\sqrt{2}} \approx 354\ Hz$. and the upper cut-off frequency will then be $f_{up} = 2f_{low} \approx 707\ Hz$

4

Oscillations, or howling, due to acoustic feedback will occur if the distance between the microphone and the loudspeaker is equal to the wavelength of sound or a integer multiple thereof (and if the gain is high enough). Thus, the condition for oscillation due to acoustic feedback can be expressed as $n\lambda = d$, where n is an integer, λ is the wavelength and d is the distance between microphone and loudspeaker.

Substituting λ with $\frac{c}{f}$, we get the following expression for the frequencies that experience maximally strong acoustic feedback.

$$f = \frac{n \cdot c}{d} \tag{8}$$

The minimum frequency f_{min} can be found by inserting $n = 1$.

$$f_{min} = \frac{1 \cdot 343}{5} = 69 \text{ Hz}$$

which is the lowest frequency for which oscillation could take place. If one inserts positive integers for n (e.g 1,2,3,4,...), one will find the harmonics of f_{min}, which is the frequencies where you might experience oscillation due to (positive) feedback.

5

When speaking at a normal conversational level, an average speaker emits about 10^-5 W sound power. If there are n speakers, each radiating a power P, then the time needed to generate an amount of energy E can be calculated realizing that energy is equal to the product of power and time.

$$E \cdot P \cdot t \rightarrow t = \frac{E}{nP} \tag{9}$$

It takes around 1050 J energy to increase the temperature of water (tea) by 1°C. Consider tea to be at room temperature, 25 °C, which is to be raised to 100 °C. The total energy needed to boil a cup of tea, will then be $E = 1050 \cdot 75$ J $\approx 7.875 \times 10^4$ J. The time to generate this amount of energy is then

$$t = \frac{E}{nP} = \frac{7.875 \times 10^4}{50 \cdot 10^-5} 1.575 \times 10^8 \text{ s} =\approx 5 \text{ years} \tag{10}$$

So, the statement is valid.

6

a

We can use the x-axis $r/\sqrt{Q}$ to find the related difference $L_p - L_W$.

$$\frac{r_5}{\sqrt{Q}} = \frac{5}{\sqrt{2}} \approx 3.5 \rightarrow L_p - L_W \approx -18\text{dB} \rightarrow L_p = 80 - 18 = 62\text{dB} \tag{11}$$

$$\frac{r_{15}}{\sqrt{Q}} = \frac{15}{\sqrt{2}} \approx 10.6 \rightarrow L_p - L_W \approx -21\text{dB} \rightarrow L_p = 80 - 21 = 59\text{dB} \tag{12}$$

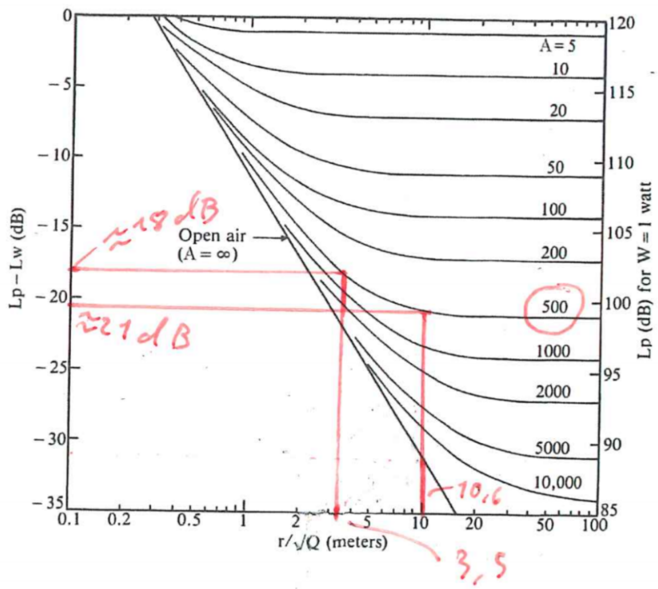

Figure 1: Illustration for task 6a

b

$$L_{p,5} = L_W + 10\log(\frac{Q}{4\pi r_5^2} + \frac{4}{A}) \approx 60.6\text{dB} \quad (13)$$

$$L_{p,15} = L_W + 10\log(\frac{Q}{4\pi r_5^2} + \frac{4}{A}) \approx 59.4\text{dB} \quad (14)$$