Basics of Noise and Its Measurement

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Adding Decibels

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Decibels

$$L_p = 20 \log \frac{p}{p_0} \text{ dB re } 20\ \mu\text{Pa}$$

$$(p_0 = 20\ \mu\text{Pa} = 20 \times 10^{-6}\ \text{Pa})$$

$p \;\; = 1$ Pa

$$L_p = 20\log_{10} \frac{1}{20 \times 10^{-6}}$$

$= 20 \log 50{,}000$

$= 94$ dB

Example 1

$p \;\; = 31.7$ Pa

$$L_p = 20\log_{10} \frac{317}{20 \times 10^{-6}}$$

$= 20 \log (1.58 \times 10^6)$

$= 124$ dB

Example 2

Adding Decibels

- Three ways
  - Adding dBs
    - 40 dB + 40 dB = 80 dB
  - Adding powers
    - “40 dB + 40 dB = 43 dB”
  - Adding signals
    - ??

Adding Decibels

L_{p1}	L_{p2}	P_1 (mW)	P_2 (mW)	P_1+P_2 (mW)	L_{12}
120	120	1000.0	1000	2000.0	123.0
119	120	794.3	1000	1794.3	122.5
118	120	631.0	1000	1631.0	122.1
117	120	501.2	1000	1501.2	121.8
116	120	398.1	1000	1398.1	121.5
115	120	316.2	1000	1316.2	121.2
114	120	251.2	1000	1251.2	121.0
113	120	199.5	1000	1199.5	120.8
112	120	158.5	1000	1158.5	120.6
111	120	125.9	1000	1125.9	120.5
110	120	100.0	1000	1100.0	120.4
109	120	79.4	1000	1079.4	120.3
108	120	63.1	1000	1063.1	120.3
107	120	50.1	1000	1050.1	120.2
106	120	39.8	1000	1039.8	120.2
105	120	31.6	1000	1031.6	120.1
104	120	25.1	1000	1025.1	120.1
103	120	20.0	1000	1020.0	120.1
102	120	15.8	1000	1015.8	120.1
101	120	12.6	1000	1012.6	120.1
100	120	10.0	1000	1010.0	120.0

Adding Decibels

- With multiple sources, add powers not decibels
  - $W_i = [10^{(L/10)}]*10^{-12}$
  - $W_{total} = W_1 + W_2 + ... + W_n$
  - The level of total sound is:
    - $L_{total} = 10*\log_{10}(W_{total}/ 10^{-12})$
  - Reference power is 10^{-12} Watts.

Example

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  - What is the sound power level of two sources together?

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  - Answer: 56.5 dB

Remember

Increase in dB	Power Increase	Pressure Increase
3	2X	1.4X
10	10X	3.2X
13	20x	4.5X
20	100X	10X

Decrease in dB	Power Decrease	Pressure Decrease
-3	0.5X	0.71X
-10	0.1X	0.32X
-13	0.05X	0.22X
-20	0.01X	0.10X

Example

- A wall attenuates sound by 20 dB. If the sound level in absence of wall is 90 dB, what will be the sound level in presence of wall?
  - $L_{\text{with wall}} = L_{\text{without}} - 20 = 70$ dB

Adding Signals

- Signals - pressure, voltage, acceleration, velocity, force

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- If we want to find the decibel level due to two individual signals, then we must first add them, and then find the resulting level.
  - $v_1 = a_1 \sin(\omega_1 t + Ø_1)$, $v_2 = a_2 \sin(\omega_2 t + Ø_2)$

- Correlated or uncorrelated signals

Adding Correlated Signals

- Given two signals with same frequency,
  - $v_1 = a_1 \sin(\omega t + Ø_1)$, $v_2 = a_2 \sin(\omega t + Ø_2)$
  - $v_{1\text{-}rms} = a_1/1.414$
  - $v_{rms} = [(a_1^2/2 + a_2^2/2 + a_1 a_2 \cos(Ø_1 - Ø_2)]^{0.5}$

Vrms when $a_1 = a_2$		
Phase Diff. (deg.)	v_{rms}	Final dB
0	$1.414a_1 = 2a_{rms}$	+6
90	$a_1 = 1.414a_{rms}$	+3
120	$0.707a_1 = a_{rms}$	0
180	0	??

Adding Uncorrelated Signals

- Given two signals with same frequency,
  - Here we use the energy or power approach.
  - Two signals of rms strengths A and B
  - Final signal's strength: $(A^2 + B^2)^{0.5}$
  - Decibels add like power
- Always assume that signals are uncorrelated unless known otherwise.

Example

- A lathe is generating 76 dB of sound, while a blower is generating 70 dB of sound. What is the combined sound power level in the room?

  - $L_{total} = 10 \log_{10}(10^{7.6} + 10^{7.0}) = 77 \text{ dB}$

Example

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  - $L_{total} = 10 \log_{10}(10^{5.8} - 10^{5.1}) = 57$ dB

Perception of dBs

Change in Sound Level (dB)	Change in Perceived Loudness
3	Just perceptible
5	Noticeable difference
10	Twice (or 1/2) as loud
15	Large change
20	Four times (or 1/4) as loud

References

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