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Conversion of power estimation in Audacity to real Sound Pressure Level in ear phones

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In Audacity (version 3.3.3), it is possible to tune the amplitude of the output signal. In the menu under *Effect../ Volume and Compression/ Amplify*, the signal amplitude can be defined by the root mean squared error (RMSE) of the signal. However, Audacity does not provide this value **rmse**, but gives this value in decibel (dB) with respect to an internal reference value p_o . Let us call this amplitude value (in dB) as amplitude p_{Au} , which then relates to the real RMSE of the output by

$$p_{Au}^1 = 20 \log \left(\frac{\mathbf{rmse}^1}{p_o} \right) \quad (1)$$

$$p_{Au}^{ref} = 20 \log \left(\frac{\mathbf{rmse}^{ref}}{p_o} \right) \quad (2)$$

Here \mathbf{rmse}^1 is the RMSE of the signal under study and \mathbf{rmse}^{ref} is the RMSE of the signal at the audition threshold, i.e. the audible signal with the lowest intensity. We note that then Eqs. (1), (2) yield

$$\mathbf{rmse}^1 = p_o 10^{\frac{p_{Au}^1}{20}} \quad (3)$$

$$\mathbf{rmse}^{ref} = p_o 10^{\frac{p_{Au}^{ref}}{20}} . \quad (4)$$

The sound pressure level p_{ear} generated in the ear phones can be supposed (in a good approximation) to be proportional to the amplitude in the

generated signal, i.e. the RMSE, and hence¹

$$p_{\text{ear}}^1 = a \cdot \mathbf{rmse}^1 \quad (5)$$

$$p_{\text{ear}}^{\text{ref}} = a \cdot \mathbf{rmse}^{\text{ref}} \quad (6)$$

where $a \neq 0$ is any proportionality factor capturing the properties of the devices and cables between the Audacity output signal and the ear-phone signal.

The Sound Pressure Level (SPL) is defined as

$$SPL = 20 \log \left(\frac{p_{\text{ear}}^1}{p_{\text{ear}}^{\text{ref}}} \right) \text{ dB}, \quad (7)$$

where p_{ear}^1 and $p_{\text{ear}}^{\text{ref}}$ is the sound pressure of the heard signal under study and the sound pressure of the heard reference signal with the lowest intensity, respectively. Then inserting Eqs. (3), (4), (5) and (6) into Eq. (7) yields

$$\begin{aligned} SPL &= 20 \log \left(\frac{\mathbf{armse}^1}{\mathbf{armse}^{\text{ref}}} \right) \text{ dB} \\ &= 20 \log \left(\frac{\mathbf{rmse}^1}{\mathbf{rmse}^{\text{ref}}} \right) \text{ dB} \\ &= 20 \log \left(\frac{p_o 10^{\frac{p_{Au}^1}{20}}}{p_o 10^{\frac{p_{Au}^{\text{ref}}}{20}}} \right) \text{ dB} \\ &= 20 \log \left(10^{(p_{Au}^1 - p_{Au}^{\text{ref}})/20} \right) \text{ dB} \\ &= 20(p_{Au}^1 - p_{Au}^{\text{ref}})/20 \text{ dB} \\ SPL &= (p_{Au}^1 - p_{Au}^{\text{ref}}) \text{ dB}. \end{aligned}$$

For instance, for a single subject $p_{Au}^1 = -18.177$ and $p_{Au}^{\text{ref}} = -93.177$ yielding to $SPL = 75\text{dB}$.

¹Bies, David A., and Hansen, Colin. (2003). Engineering Noise Control.