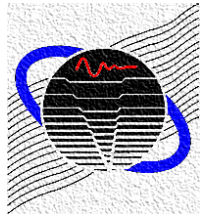
June 17, 2021

# Determination of Octave Band Transmission Loss

David Herrin
University of Kentucky

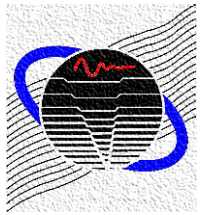




# Motivation

- How can you use simulation data to find the transmission loss in 1/3 octave or octave bands?
- Can you measure the transmission loss in 1/3 octave bands?

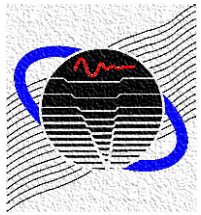




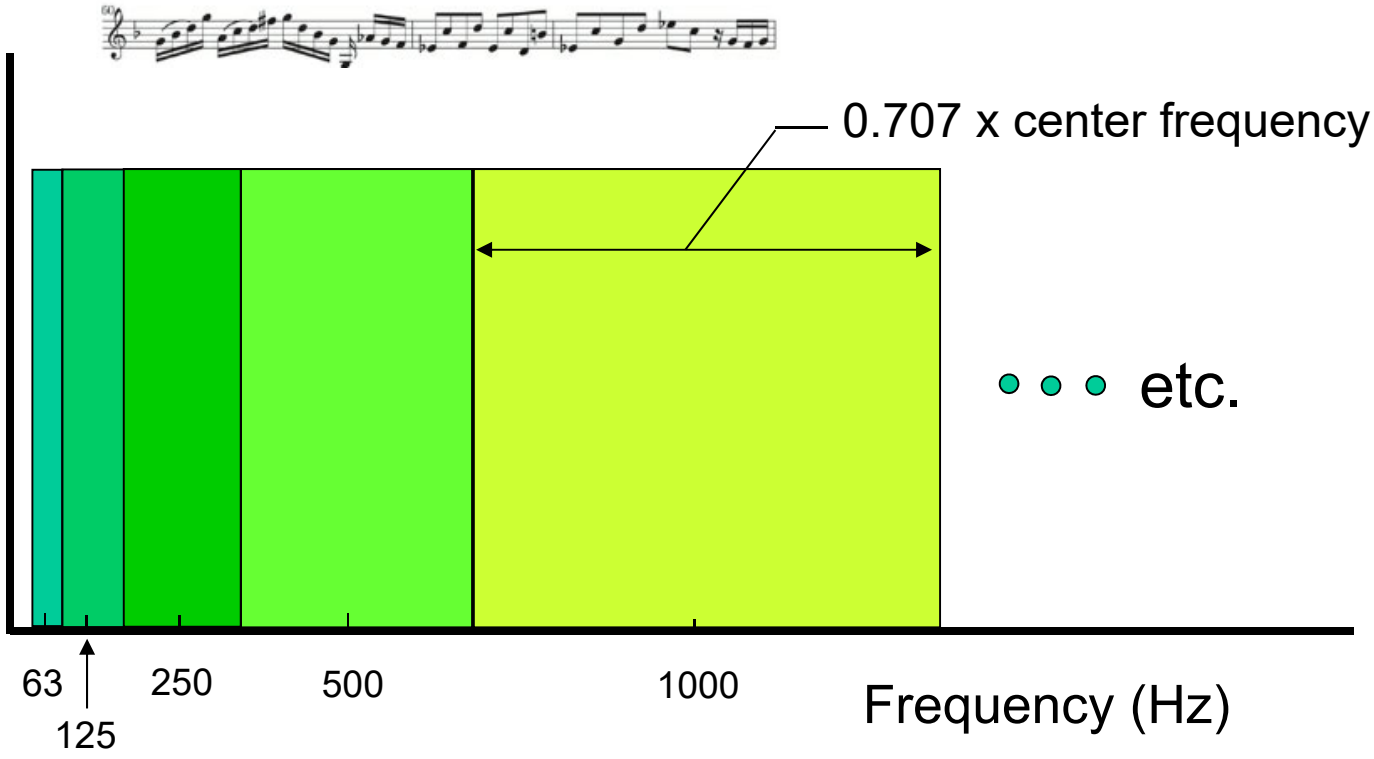
# Overview

- Octave and 1/3 Octave Bands
- Transmission Loss in Octave Bands





# Octave Band Filters




Each octave band filter has a fixed *center frequency* and is twice as wide as the one before it. Each octave band filter may be divided into three one-third octave band filters for more frequency resolution.

# Octave and 1/3 Octave Bands
# Bies et al., 2018

**TABLE 1.2** Preferred octave and 1/3-octave frequency bands

| Band number | Octave band centre frequency | 1/3-octave band centre frequency | Band limits Lower | Band limits Upper |
|---|---|---|---|---|
| 11 | | 12.5 | 11 | 14 |
| 12 | 16 | 16 | 14 | 18 |
| 13 | | 20 | 18 | 22 |
| 14 | | 25 | 22 | 28 |
| 15 | 31.5 | 31.5 | 28 | 35 |
| 16 | | 40 | 35 | 44 |
| 17 | | 5 | 44 | 57 |
| 18 | 63 | 63 | 57 | 71 |
| 19 | | 80 | 71 | 88 |
| 20 | | 100 | 88 | 113 |
| 21 | 125 | 125 | 113 | 141 |
| 22 | | 160 | 141 | 176 |
| 23 | | 200 | 176 | 225 |
| 24 | 250 | 250 | 225 | 283 |
| 25 | | 315 | 283 | 353 |
| 26 | | 400 | 353 | 440 |
| 27 | 500 | 500 | 440 | 565 |
| 28 | | 630 | 565 | 707 |
| 29 | | 800 | 707 | 880 |
| 30 | 1000 | 1000 | 880 | 1130 |
| 31 | | 1250 | 1130 | 1414 |
| 32 | | 1600 | 1414 | 1760 |
| 33 | 2000 | 2000 | 1760 | 2250 |
| 34 | | 2500 | 2250 | 2825 |
| 35 | | 3150 | 2825 | 3530 |
| 36 | 4000 | 4000 | 3530 | 4400 |
| 37 | | 5000 | 4400 | 5650 |
| 38 | | 6300 | 5650 | 7070 |
| 39 | 8000 | 8000 | 7070 | 8800 |
| 40 | | 10000 | 8800 | 11300 |
| 41 | | 12500 | 11300 | 14140 |
| 42 | 16000 | 16000 | 14140 | 17600 |
| 43 | | 20000 | 17600 | 22500 |

# Conversion between Bandwidths

Example:

If the level measured with a 1000 Hz octave band filter is 100 dB, the sound pressure level in narrowband (assuming equal energy across all frequencies) is

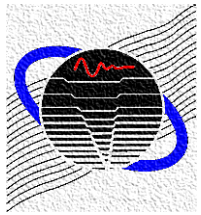
$$L_{p,1\text{ Hz}} = 100 - 10\log_{10}(1400 - 710) = 71.6\text{ dB}$$

The one-third octave band level at the same center frequency is

$$L_{p,1/3} = 71.6 + 10\log_{10}(1120 - 900) = 95\text{ dB}$$

The approximation that the one-third octave band level is 5 dB below the corresponding octave band level is sometimes used in practice.





# Conversion between Bandwidths

## Summing Sound Pressures

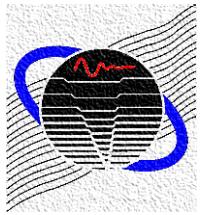
$$L_{p_{tot}} = 10 \log_{10} \left( \sum_{n=1}^{N} 10^{\frac{L_{p_n}}{10}} \right)$$

## Example:

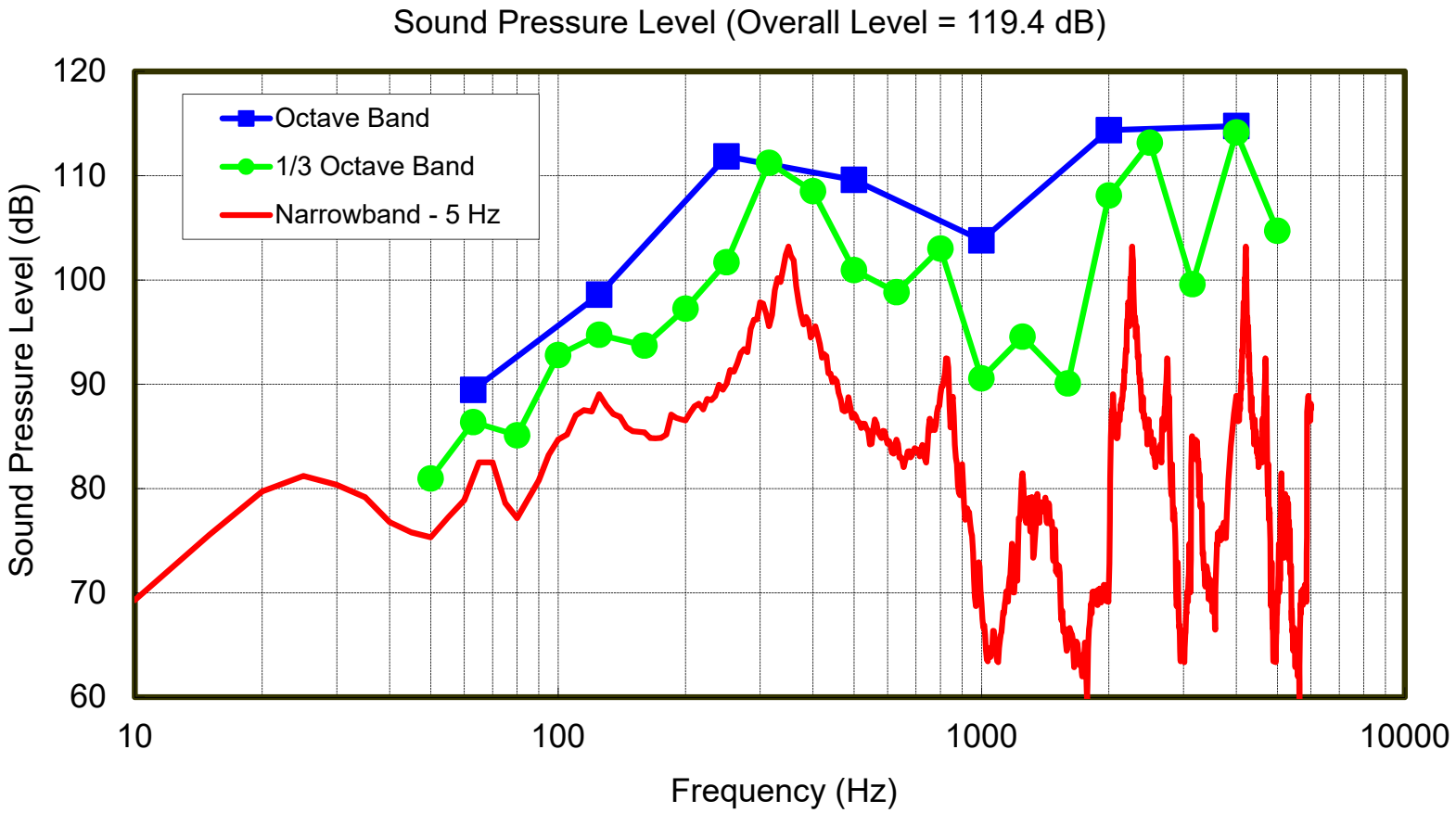
The 1000 Hz octave band includes the 800, 1000, and 1250 Hz third-octave bands. Determine the octave band level if the 1/3-octave band levels are 86, 86 and 86 dB, respectively.

$$L_{p_{tot}} = 10 \log_{10} \left( 10^{86/10} + 10^{86/10} + 10^{86/10} \right) = 91 \text{ dB}$$





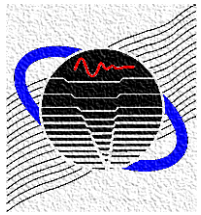
# 1/3 and Octave Band Sound Pressures



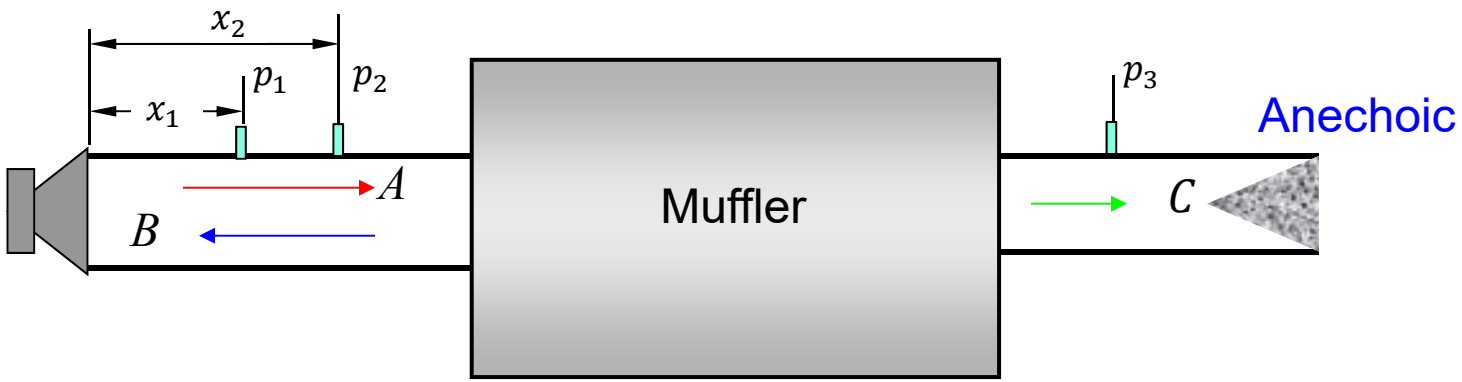
# Overview

- Octave and 1/3 Octave Bands
- Transmission Loss in Octave Bands





# Method 1 Wave Decomposition



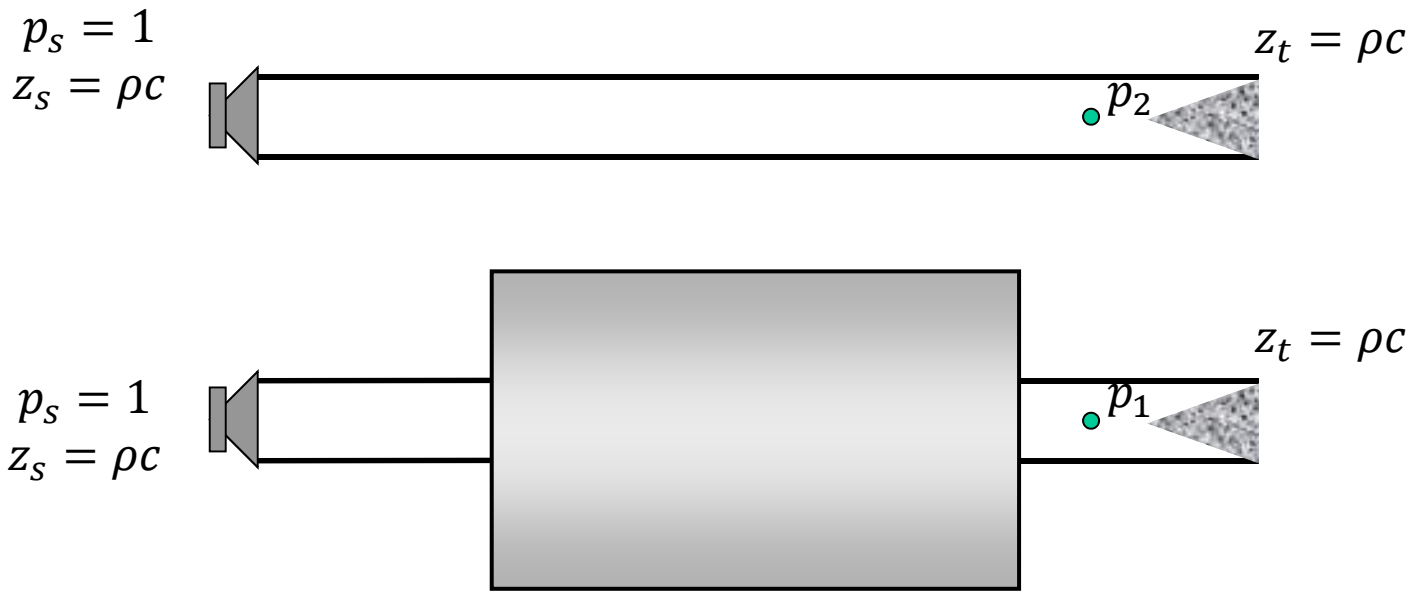

$$TL = 10\log_{10}\left(\frac{W_i}{W_t}\right) \qquad W_i = |A|^2\frac{S_1}{\rho c} \qquad W_t = |C|^2\frac{S_2}{\rho c}$$

With anechoic termination,

1. $A$ and $C$ are simulated directly in narrowband.
2. $W_i$ and $W_t$ can be calculated in narrowband and then convert to octave bands.

# Method 2 Equivalent Insertion Loss

Insertion loss is equal to transmission loss if source and termination are both anechoic.

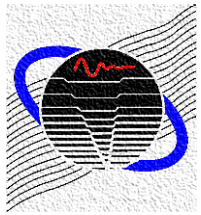



$$TL = IL = SPL_2 - SPL_1$$

# Method 2 Equivalent Insertion Loss

1. Calculate the sound pressures $p_1$ and $p_2$ at the termination of the straight tube and the muffler separately in narrowband.
2. Convert $p_1$ and $p_2$ to octave (or 1/3 octave) bands and find the difference as transmission loss.





# Method 3 Direct TL Conversion

If transmission loss in narrowband is available,

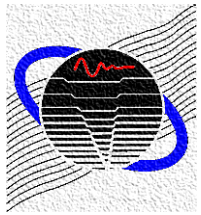
1. Set the incident sound power $W_i$ as a constant.
2. Calculate the corresponding transmitted sound power $W_t$ at each frequency.

$$L_{W_t} = L_{W_i} - TL$$

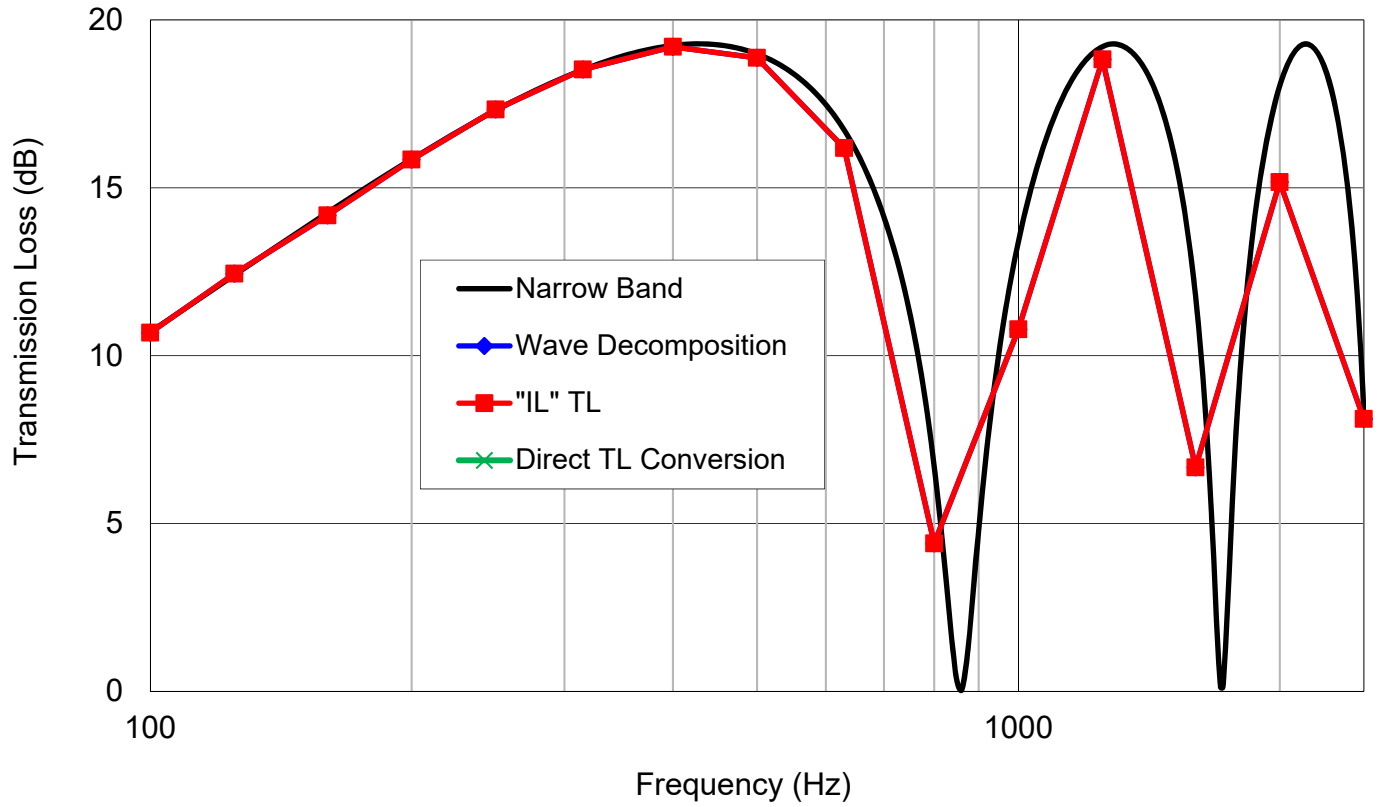
3. Then $W_i$ and $W_t$ then can be converted into octave bands and the difference taken in dB.

$$TL = L_{W_i} - L_{W_t}$$





# Test Case Simple Expansion Chamber



# Summary

- There is no standard procedure for determining transmission loss in 1/3 or octave bands using measured data or simulation.
- Three methods are proposed. The underlying assumption is that the source is broadband.
- Direct transmission loss conversion is the simplest method.

Wang, P., Hua, X., Wu, T., and Herrin, D., "Methods for Determining Muffler Transmission Loss in Octave Bands," SAE Technical Paper 2016-01-1317, 2016, doi:10.4271/2016-01-1317.