Outline

- huge issue —only dealing with decibels today
  —not much biology
- evidence of confusion
- acoustical units
- the decibel family
- audio demonstration

Decibel Confusion

"[The sonar] has a maximum output of 230 decibels, compared with 100 decibels for a jumbo jet."
The Economist, 1998 March 7.

"This system generates extremely loud low-frequency sound (maximum output of ≥ 230 decibels as 1 micropascal broadband waveforms...)."
Nature, 1998 March 5.

"...clicking noises of shrimp registered more than 80 decibels. Oil rigs can ring out about 180 decibels."
Victoria Times-Colonist, 1998 March 21.

Acoustical Units: Pressure

What is sound?

Sound is a vibration that travels as a wave in a fluid.

Several variables: pressure, displacement, density.

Pressure is the usual measure of sound amplitude.

ANSI reference pressure: • 1 µPa in liquids (water)
• 20 µPa in gases (air)

1 Pa is one newton per square metre
1 µPa = 10^{-6} ≈ 10^{-11} of atmospheric pressure

Acoustical Units: Intensity

Sound intensity *(I)* is acoustic power per unit area.

It is the product of pressure *(p)* and particle velocity *(v)*.

For a single wave propagating freely away from boundaries,

$$\langle I \rangle = \frac{\langle p^2 \rangle}{\rho c}.$$

ANSI reference intensity: 10^{-12} W/m² or 1 pW/m².

The Decibel

The decibel (abbreviated dB) is used to compare level differences of *like* quantities, usually intensity, power, etc.

It is logarithmic:

multiplication of intensity ⁄ *addition* to the decibel level

x 10 ⁄ 1 bel or 10 decibels

x 10 ⁄ +10 dB
x 100 ⁄ +20 dB
x 1000 ⁄ +30 dB
etc.

Sound Pressure Level (SPL)

sound pressure level $= 10\log_{10}\left[(p/p_0)^2\right]$

$= 20\log_{10}\left[p/p_0\right]$

units are dB re p_0

typical received sound levels:

15 m from automobile: 74 dB re 20 µPa
100 m from ship: 134 dB re 1 µPa

It is essential to include the reference pressure when specifying a sound pressure level.

Intensity Level (IL)

intensity level $= 10\log_{10}\left[I/I_0\right]$

units are dB re 1 pW/m²

in air
SPL of 0 dB (re 20 µPa) ⁄ IL of 0 dB (re 1 pW/m²)

in water
SPL of 0 dB (re 1 µPa) ⁄ IL of -62 dB (re 1 pW/m²)

Intensity level and sound pressure level should not be confused, especially when comparing results for different acoustic media.

"Air" Decibels vs. "Water" Decibels

justification for the air-borne sound standard

20 µPa/ 0 dB

The quietest sound a healthy person can hear.

2 Pa/ 100 dB

A very loud sound.

however...

The same sound pressure that acousticians would label 0 dB in air would be labelled 26 dB in water.

Source Level

Source level is one measure of the ouput of a transducer.

It is the SPL at a reference distance, usually 1 metre.

Typically, it is measured at a larger distance and the number corrected (upwards) for spreading loss.

e.g. 230 dB re 1µPa at 1 m

It is essential to include the reference distance as well as the reference pressure when specifying a source level.

Typical Sound Pressure Levels

Sources in Water	dB//1µPa	p [Pa]	dB//20µPa	Sources in Air
airgun (a)	**200**	**10k**	**174**	
NATO LFAS (a)	**190**		**164**	
Beluga call (a,b)	**180**	**1k**	**154**	
	170		**144**	sonic booms
large ship (a)	**160**	**100**	**134**	*OUCH!*
	150		**124**	rock concert
fin whale call (a)	**140**	**10**	**114**	jet at 500 m
	130		**104**	jackhammer (d)
	120	**1**	**94**	factory
	110		**84**	vacuuming (d)
Beluga threshold (c)	**100**	**0.1**	**74**	busy traffic
	90		**64**	conversation
seal threshold (c)	**80**	**0.01**	**54**	pillow talk

(a) at range of 100 m (b) at frequency of 100kHz (c) at frequency of 1 kHz (d) at operator's

Source Levels: dB (re 1µPa at 1m)

	240 dB	seismic airgun
	230 dB	NATO LFAS
Beluga call	220 dB	Heard Island
	210 dB	Vibroseis
jet take-off	200 dB	seismic profilers
supertanker tonal	190 dB	ATOC
fin whale call	180 dB	depth sounders
icebreaker breaking ice	170 dB	
helicopter	160 dB	
various whale calls	150 dB	oil drilling from ships
snowmobile	130 dB	

Other Issues

- impulsive vs. continuous sources
- spectrum levels: dB re 1 $\mu Pa^2/Hz$

  dB re 1 $\mu Pa/\sqrt{Hz}$

  1/3-octave band dBs
- weighting of SPL for human hearing: the dBA
- reaction threshold curves for marine mammals
- directivity of transducers, sidelobe levels

Summary

- Check reference pressures, especially when comparing in-air and in-water levels.
- Check for confusion between source levels and received levels.
- Sound pressure and sound intensity are not the same.
- Human hearing standards do not necessarily hold for aquatic animals.

Any acoustic level specified in decibels without reference quantities is suspect.