Phys 1402 2017-11-14 Lec 21

What are decibels (dB)?

Relative scale of Energy, Power, Intensity, Loudness, Brigtness, Signal Strength.

Energy is often streamed over time

This is measured as Power:

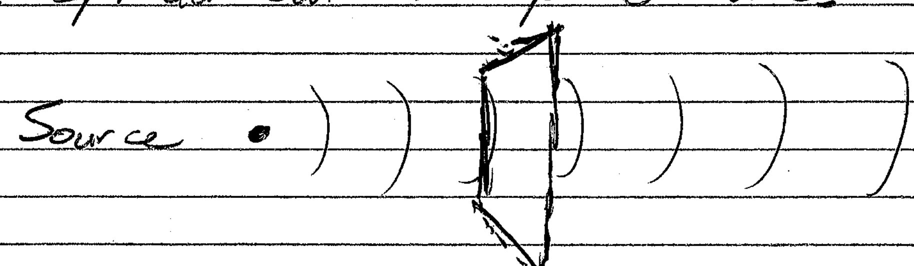
$$\boxed{P = \frac{\Delta Energy}{\Delta t}}$$

Ex: $1\,W = 1\,J / 1\,s$

$$Energy = P \Delta t$$

Ex: $1\,kWh = (1\,kW)(1\,hour)$
$= (1000\,J/s)(3600\,s)$
$= 3.6\ MJ$

Waves spread out in space also.



"Catcher" to grab and measure waves.

Since Power scales w/ size of receiver

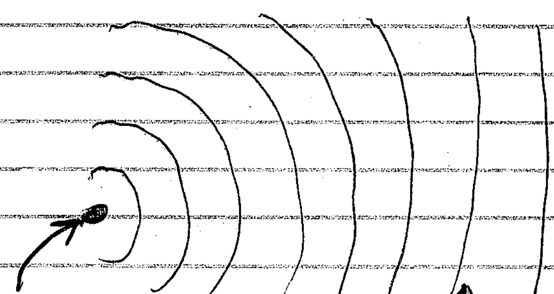
$$P = \underline{I}\,A$$

Area of receiver

Intensity

Intensity is $\boxed{I = \frac{P}{A}}$

The most spread-out wave is a spherical wave from a point source.



Source generates Power

Wave intensity decreases with distance.

$$P = IA = I\left(4\pi R^2\right)$$

Use sphere because all points receive the same intensity of waves.

$$I = \frac{P}{4\pi R^2} \quad \text{(Point Source)}$$

These units have a huge <u>Dynamic Range</u>

$$\text{Dynamic Range} = \frac{\text{Strongest Energy}}{\text{Weakest Energy}}$$

Ex: Hearing $\dfrac{1\ W/m^2}{10^{-12}\ W/m^2} = 10^{12}$

Our perception scales with the power of 10. This is a <u>logarithmic scale</u>.

Ex: $I = 3 \times 10^{-5}\ W/m^2$

Power of 10 is -5

Minor adjustment is $3\times$

(3)

decibels provide a number system where the power of 10 comes first, then the minor adjustment.

$$3\times10^{-5} = 10^{x} \quad \text{for some } x.$$

$10^{-5} = 1\times10^{-5}$ Too small
$10^{-4} = 10\times10^{-5}$ Too big

$10^{-4.5} = 3.16\times10^{-5}$ Very close

$10^{-4.4} = 3.98\times10^{-5}$ Even worse

$10^{-4.6} = 2.5\times10^{-5}$ Too small

$10^{-4.52} = 3.02\times10^{-5}$ Closest w/ 2 decimal

To interpret as decibels, just use the power of 10.

$$3\times10^{-5} \rightarrow -4.52 \text{ bels}$$
$$-45.2 \text{ decibels}$$
$$\sim -45 \text{ dB}$$

Easy way: $\log(3\times10^{-5}) = -4.52$

$$10\log(3\times10^{-5}) = -45.2$$

To turn a number (x) into dB: $10\log(x)$

What do we use as x?
Every quantity is a scaling factor of a unit.
numerical part is x.
dB measurements are always relative to some reference quantity.
The dB level corresponds to a scaling factor.

level (dB)	Factor
10 dB	$10^{1.0} = 10$
20 dB	$10^{2.0} = 100$
30 dB	$10^{3.0} = 1000$
1 dB	$10^{0.1} = 1.258 \approx 26\%$ increase
3 dB	$10^{0.3} = 2$
6 dB	$10^{0.6} = 4$
9 dB	$10^{0.9} = 8$
Increase by adding 3 dB	Increase by doubling

(*) As energy scales by multiplication, decibel levels increase by addition.

0 dB $10^{0} = 1$

Zero dB is not nothing, it is a factor of one. 0 dB means no change from the reference.

-3 dB $10^{-0.3} = 0.5$ (Decrease by factor of 2)

~~3x10~~

+5 dB -50 dB 3×10^{-5}

$= -45$ dB

$10 \log 3 = 10(0.5) = 5$

$10 \log(10^{-5}) = 10(-5) = -50$

3 dB $\Rightarrow$ 2

5 dB $\Rightarrow$ 3

7 dB $\Rightarrow$ 5

③

What does 86 dB mean?

$$\left.\begin{matrix}10\text{ dB}\\+10\text{ dB}\\\vdots\end{matrix}\right\}8\text{ times}\qquad\left.\begin{matrix}10\\\times 10\\\vdots\end{matrix}\right\}8\text{ multiplications}$$

$$\begin{matrix}+3\text{ dB} & & \times 2\\+3\text{ dB} & & \times 2\end{matrix}$$

$$= 2\cdot 2\cdot 10^8$$
$$= 4\times 10^8$$

What reference levels are used?

Sound: Quietest Audible sound $I_0 = 10^{-12}\ W/m^2$

Typical conversation ~ 70 dB

What intensity is this?

Scaling Factor $= 10^7$

$$I = (10^7)(10^{-12}\ W/m^2) = 10^{-5}\ W/m^2$$

<u>Dynamic Range</u>

$$\text{Ratio} = \frac{I_{max}}{I_{min}} \text{ or } \frac{P_{max}}{P_{min}}$$

Vision: 90 dB

LCD TV: 1000:1 $\quad 10\log(1000) = 30$ dB

Hearing: 120 dB

CD: 16-bit voltage $\quad 90\text{dB} + 6\text{dB} = 96$ dB

$$\frac{2^{16}}{2^0} = 65536 \text{ Voltage Ratio}$$

$$P = IV = \frac{V}{R}V = \frac{V^2}{R}$$

Power Ratio $= 65536^2 =$
$= 4.3\times 10^9$