

Phys 2426

2017-11-14

Lec 21

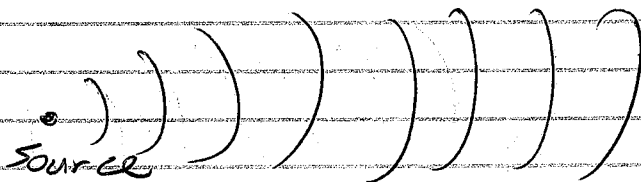
Goal today: Understand decibels

Background: Energy is always streamed over time.

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

$$\Delta \text{Energy} = P \Delta t$$

Waves involve spreading in space as well.



generates Power

↑ Power spreads over a large Area.

Power Detected = (Wave strength) (Area)

$$(\text{Wave Strength}) = \frac{P}{\text{Area}} \leftarrow \text{Intensity}$$

Examples: $I = 3 \times 10^{-5} \text{ W/m}^2$ (Loud Voice)

$I = 1360 \text{ W/m}^2$ (Sunlight above atmosphere)

~~There~~ There is a wide dynamic range of values here.

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

$$\text{Hearing Ratio} = \frac{1 \text{ W/m}^2}{10^{-12} \text{ W/m}^2} = 10^{12}$$

Our perception is logarithmic.

②

When we usually measure things:

$$\text{Quantity} = (\text{Scaling Factor}) \text{ Unit}$$

Scaling Factors are the numbers we use
and scientific notation helps deal w/ wide ranges

$$7.8 \times 10^4 \quad \text{vs} \quad 1.2 \times 10^9$$

Since the power of 10 is the most important part, let's just use that.

$$7.8 \times 10^4 = 10^x$$

$$\log(7.8 \times 10^4) = x = 4.9 = 49 \text{ dB}$$

This power of 10 is called a "bel".

To create decibels, use $10 \text{ dB} = 1 \text{ bel}$

Interpretation: 49 dB means $\sim 8 \times 10^4$ units

Reverse process:

$$91 \text{ dB} \rightarrow \text{Scaling Factor} = 10^{9.1} = 1.26 \times 10^9$$

decibels measure a level of energy relative to some reference unit.

$$\text{Sound Level: } I_0 = 10^{-12} \text{ W/m}^2$$

$$\text{WIFI Power: } P_0 = 1 \text{ mW}$$

③

Example dB Levels

Level (dB)

Factor

⊗

10 dB	$10^{1.0} = 10$
20 dB	$10^{2.0} = 100$
30 dB	$10^{3.0} = 1000$
Increase by adding	Increase by Multiplying

⊗

As energy scales by multiplication, decibel level increases by addition.

$$3 \text{ dB} \quad 10^{0.3} = 2$$

$$5 \text{ dB} \quad 10^{0.5} = \sqrt{10} \approx 3$$

$$7 \text{ dB} \quad 10^{0.7} = 5$$

$$\text{Ex: } 84 \text{ dB} = 90 \text{ dB} - 3 \text{ dB} - 3 \text{ dB} \\ \text{or} = 80 \text{ dB} + 7 \text{ dB} - 3 \text{ dB}$$

$$\text{Factor} = 10^{9 \cdot \frac{1}{2} \cdot \frac{1}{2}} = 0.25 \times 10^9 = 2.5 \times 10^8$$

$$(\text{or}) \quad 10^{8 \cdot 5 \cdot \frac{1}{2}} = 2.5 \times 10^8$$

Ex: 84 dB sound level

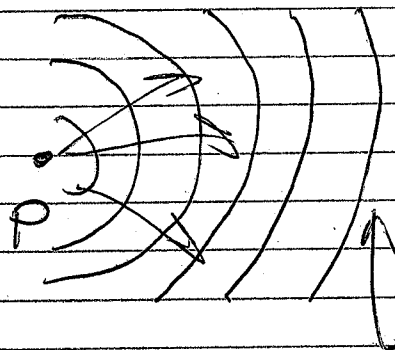
$$I = I_0 (\text{Factor}) = (10^{-12} \text{ W/m}^2) (2.5 \times 10^8) \\ = 2.5 \times 10^{-4} \text{ W/m}^2$$

Ex: -84 dBm Wifi signal

$$P = P_0 (\text{Factor}) = \frac{(1 \text{ mW})}{2.5 \times 10^8} = 4 \times 10^{-12} \text{ W}$$

4

Spherical Waves - spread as much as possible.



Catch all energy at this radius,

$$P = \iint \vec{I} \cdot d\vec{A} = \iint I dA = I_{avg} \iint dA$$

$$P = I A = I 4\pi R^2$$

$$I = \frac{P}{4\pi R^2}$$

As it turns out, All sources have $I \propto \frac{1}{R^2}$

If you're far enough away.

What happens if you double your distance from the source?

Intensity will decrease by a Factor of 4.

Level will decrease by 6 dB.

8)

Dynamic Range - usually in dB

Hearing: 120 dB

CD: 16-bit voltage

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

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

$$\text{Power Range} = 65536^2 = 4.3 \times 10^9$$

$$\text{Corresponding level: } 90 \text{ dB} + \lg(4.3) \cdot 10$$

96 dB

Vision: 90 dB

LCD TV: 1000:1 Contrast ratio

$$1000 = 10^3 \Rightarrow 30 \text{ dB}$$

Summary:

$$\text{Scale Factor} = 10^x$$

$$x = \lg(\text{Scale Factor})$$

$$\text{dB Level} = 10 \times x$$

$$x = \frac{\text{dB level}}{10}$$

$$(\text{dB level}) = 10 \lg(\text{scale factor})$$

$$(\text{Scale Factor}) = 10^{(\text{dB level} / 10)}$$