① Phys 1402 2016-11-15 Lec ~~[illegible]~~ 24

Decibels – Why?

- Huge range of strengths.
  Can use sci. notation, but cumbersome.
- Dynamic Range – mix strong & weak
  Ex: Hearing Loudest = (10^{12}) (Quietest)
- Signal-to-noise is usually a ratio.
- Wave strength often <u>scaled</u> by
  <u>mult</u> or <u>div</u> the <u>power</u> or <u>energy</u>.

  Ex: Shaded glass may absorb 50% of light.
- Commonly used in sci. & medical equipment.

How? Decibels are exponents, and multiplication turns into addition.

$$(x^2)(x^3) = (x \cdot x)(x \cdot x \cdot x) = x^5$$

$5 = 2 + 3$

As the physical quantity is <u>mult.</u> or <u>div.</u> the exponent is <u>added</u> or <u>subtracted</u>.

Details: Use powers of 10.
<u>deci</u> is small, so the number of dB is larger than the exponent.

~~Factor~~ $\text{Ratio} = 10^{\beta/10}$

(2)

$$\text{Ratio} = {}^{\beta/10}$$

Ratio = comparing two energies by dividing.

β = measure of ratio in decibels

Ex:

β	Ratio	
1 dB	$10^{0.1} = 1.26$	26% increase
3 dB	$10^{0.3} = 2$	
5 dB	$10^{0.5} \approx 3$	
7 dB	$10^{0.7} = 5$	
10 dB	$10^{1.0} = 10$	
20 dB	$10^{2.0} = 100$	
0 dB	$10^{0} = 1$	

Can use as an absolute scale with a reference val.

$$\frac{P}{P_{ref}} = \text{Ratio} \qquad P = P_{ref}(\text{Ratio})$$

↖ Power, energy, or intensity

Energy ⟷ Buckets

Power ⟷ Stream — Spread in Time

Intensity ⟷ Rain — Spread in Area, Time

Examples:

Sound: $I_{ref} = 10^{-12} \frac{J}{m^2 \cdot s}$

$I_{ref} = 10^{-12}$	Ratio = 1.0	$\beta = 0$ dB
Normal Conversation:		
$I = 10^{-6}$	10^{6}	60 dB
Power Tools:		
$I = 10^{-2}$	10^{10}	100 dB

What happens to sound with distance?

$$I \propto \frac{1}{r^2}$$

If the distance (r) to a source is doubled, the intensity decreases by $2^2 = 4$.

How can we turn this into dB?

$$4 = (2)(2) \Rightarrow (3\,dB) + (3\,dB) = (6\,dB)$$

A decrease is a negative β value.

Conclusion: The sound level decreases by 6 dB.

Spherical Waves $I = \frac{P}{4\pi r^2}$ ← power

↑ Intensity

$$I = I_{ref}\, 10^{\beta/10}$$

Ex: Radio Waves

Ref Value is $P_{ref} = 1\ mW$

If the ref is 1 mW, the units are dBm.

This is the power in a wire.

My phone, on the 2100 MHz band, can deal with a signal of −100 dBm.

$$P = P_{ref}\ 10^{B/10} = (1\ mW)(10^{-10})$$

$$= 10^{-13}\ W$$

How week is an equivalent signal from Mars?

Distances: 10 km → 50×10^6 km

Distance Ratio: 5×10^6

Power Ratio: 25×10^{12}

2.5×10^{13}

(4dB) — 13 is 130dB/10

Total: 134 dB

The signal from mars would be −234 dB

How do we compensate?

- Antenna gain 70-100 dB
- More Power 60 dB
- Better Receiver

Signal to Noise Ratio

38 dB $\quad 10^{3.8} = 6300$

Signal is ~6000x more powerful than noise

Received Power

0 dBmV $\quad 10^{0} = 1$

Received signal is 1 mV

Upstream Power

48 dBmV $\quad 10^{4.8} = 63000$

Transmitted signal is 63000x more powerful than 1 mV signal.

Recall: $P = IV = \frac{V^2}{Z}$ $\quad$ Power ratio = 63000
Voltage ratio = 250

$V_{ref} = 1$ mV $\quad V_{sig} = 250$ mV

How many dB is a voltage ratio of 10?

power ratio = 100 $\Rightarrow$ 20 dB