EEEN 462 – ANALOGUE COMMUNICATION

MEASUREMENTS IN DECIBELS – STUDY GUIDE/REVISION

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1. INTRODUCTION TO DECIBELS (DB)

1. **What are decibels?**

   Decibels (dB) are a logarithmic unit used to express **ratios** of power, voltage, current, or intensity. Unlike linear scales, dB compresses large ranges into manageable numbers.

2. **Origin**

   Developed from the **bel** (B), named after Alexander Graham Bell. 1 bel = 10 decibels.

3. **Why logarithmic?**

   Human perception (e.g., sound loudness, signal strength) is logarithmic, not linear.

2. WHY USE DECIBELS?

- **Advantages**
  - Simplifies multiplication/division of ratios into addition/subtraction.
  - Handles extremely large/small values (e.g., antenna gain: 0.001 to 100,000 → −30 dB to 50 dB).
  - Matches human sensory perception (e.g., +10 dB ≈ "twice as loud").
  - Standardizes comparisons across devices (amplifiers, filters, antennas).

3. CORE FORMULAS

All dB calculations express a **ratio** relative to a **reference**.

1. **Power Ratio (dB)**

$$\text{dB} = 10\log_{10}\left(\frac{P_2}{P_1}\right)$$

- P_2 is Measured power, and P_1 is Reference power.
- Example: Amplifier output is 100× input power → $10\log_{10}(100) = 20$dB

2. **Voltage/Current Ratio (DB)**

$$\text{dB} = 20\log_{10}\left(\frac{V_2}{V_1}\right) \quad (\text{or } \frac{I_2}{I_1})$$

- Applies when voltages/currents are measured across **identical impedances**.
- Derives from:

$$P \propto V^2 \rightarrow 10\log_{10}(V^2/V_1^2) = 20\log_{10}(V_2/V_1).$$

- Example: Voltage doubles → $20\log_{10}(2) \approx 6$ dB

4. ABSOLUTE DB UNITS (REFERENCE VALUES)

Add a suffix to denote the reference value:

- **dBm:** Power relative to **1 milliwatt** (mW).

$$P_{\text{dBW}} = 10\log_{10}\left(\frac{P}{1\ \text{W}}\right)$$

  - Example: 1 mW = 0 dBm; 1 W = 30 dBm.

- **dBW:** Power relative to **1 watt** (W).

$$P_{\text{dBW}} = 10\log_{10}\left(\frac{P}{1\ \text{W}}\right)$$

  - Example: 1 W = 0 dBW; 1 kW = 30 dBW.

- **dBV:** Voltage relative to **1 volt** (V).

$$V_{\text{dBμV}} = 20\log_{10}\left(\frac{V}{1\ \mu\text{V}}\right)$$

- **dBμV:** Voltage relative to **1 microvolt** (μV).

$$V_{\mathrm{dB\mu V}} = 20\log_{10}\left(\frac{V}{1\ \mu\mathrm{V}}\right)$$

- **dBi:** Antenna gain relative to an **isotropic radiator** (theoretical lossless sphere).
- **dBrn:** Power relative to noise floor level (usually -90dBm)

5. Key Applications

- **Gain/Loss:**
  - **Positive dB:** Gain (amplifier).
  - **Negative dB:** Loss (filter, cable).
  - Example: A −3 dB filter halves input power

$$(10^{-3/10} \approx 0.5).$$

- **Signal-to-Noise Ratio (SNR):**

$$\mathrm{SNR_{dB}} = 10\log_{10}\left(\frac{P_{\mathrm{signal}}}{P_{\mathrm{noise}}}\right)$$

  - Critical for communication systems (e.g., SNR > 20 dB for clear audio).
- **Cascaded Systems:**

  Total gain = Sum of individual gains (in dB):

$$G_{total}=G_1+G_2+G_3 \text{ (dB)}$$

  - Example: Amplifier (+10 dB) → Cable (−2 dB) → G_{total}=8 dB
- **Noise Figure (NF):**

$$\mathrm{NF_{dB}} = 10\log_{10}(F) \quad (F = \text{noise factor})$$

  - Quantifies degradation of SNR by a device (lower NF = better).

6. CALCULATIONS & EXAMPLES

- **Power Example:**

  Transmitter power = 20 W → Convert to dBm:

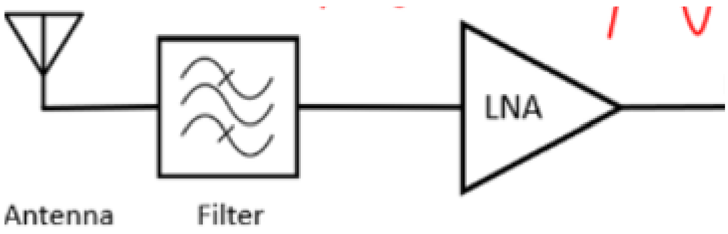
$$P_{\text{dBm}} = 10\log_{10}\left(\frac{20\text{ W}}{0.001\text{ W}}\right) = 10\log_{10}(20,000) \approx 43\text{ dBm}.$$

- **Voltage Example**

  Microphone output = 0.01 V → Convert to dBV:

$$V_{\text{dBV}} = 20\log_{10}(0.01) = -40\text{ dBV}.$$

- **Gain Chain**
  - Antenna: −1 dB (loss), Filter: -2 dB, LNA: +20 dB , Cable: −6 dB.
  - Total gain: −1 -2 +20−6 =11 dB.



7. COMMON MISTAKES & TIPS

- **Mistakes**
  - Using 10 log for voltage ratios (should be 20 log).
  - Ignoring impedance mismatches (voltage dB assumes same impedance).
  - Confusing dB (ratio) with dBm/dBW (absolute).
- **Tips**
  - **Check suffixes:** dBm ≠ dBW ≠ dBV.
  - **Negative dB ≠ loss:** e.g., negative gain = attenuation.
  - **Use dB for quick math:**
    - +3 dB ≈ 2× power, +6 dB ≈ 2× voltage.

      −10 dB = 0.1× power.
  - **Verify with linear values** when troubleshooting.

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8. PRACTICE PROBLEMS

1. Convert 46 dBm to watts.
2. An amplifier has 15 dB gain. If input is 2 mW, what is output (in dBm and mW)?

3. A 20 dB attenuator is followed by a 30 dB amplifier. What is the overall gain?
4. SNR at receiver input is 15 dB. Noise power is 1 nW. What is signal power (in dBm)?

9. SUMMARY

Decibels simplify engineering calculations by converting multiplicative relationships into additive ones, enabling efficient analysis of gains, losses, and signal quality. Mastery of dB is essential for RF, communications, audio, and signal processing.