

11.2 Amplitude modulation

Name: _____ Class: _____ Date: _____

Total: 24 marks

KEY WORDS amplitude modulation • envelope detector

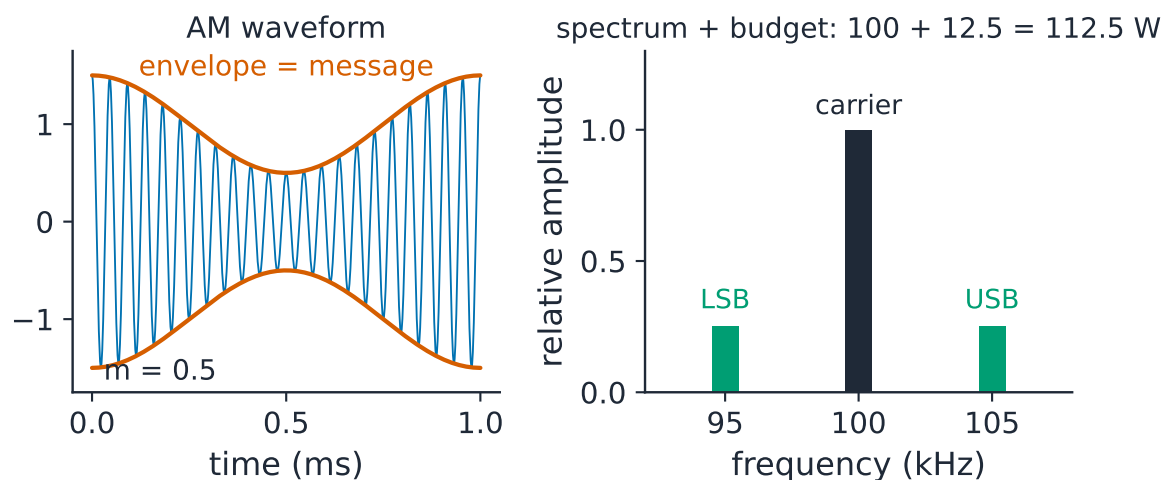
Objective

Derive DSB and SSB spectra and power shares, design an envelope detector within its distortion limits, and close a full AM power budget.

1 Key knowledge and worked examples

■ The power budget

$s = A[1 + m \cdot x]\cos(\omega_c t)$: carrier power $P_c = A^2/2$, sidebands $(m^2/2)P_c$, total $P_c(1 + m^2/2)$. Efficiency $\eta = (m^2/2)/(1 + m^2/2) = 33\%$ at best ($m = 1$).



The envelope is the message; the budget bars show the carrier taking most of the power.

■ Worked example: two budgets

$P_c = 100$ W, $m = 0.5$: sidebands 12.5 W, total 112.5 W, $\eta = 11.1\%$. At $m = 1$: 50 W, 150 W, 33.3% – two-thirds of the transmitter heats the antenna carrying a carrier that holds no information.

■ The envelope detector window

The RC time constant must satisfy $1/\omega_c \ll \tau \ll 1/\omega_m$, tightened by deep modulation to $\tau \leq \sqrt{1 - m^2}/\omega_m$. For $f_c = 100\text{kHz}$, $f_m = 5\text{kHz}$: $1.6\text{ }\mu\text{s}$ to $31.8\text{ }\mu\text{s}$; $\tau = 10\text{ }\mu\text{s}$ sits comfortably inside.

2 Practice

2.1 A transmitter runs $P_c = 200\text{W}$ at $m = 0.6$. Compute the sideband power and the total radiated power. [3]

2.2 Compute the transmission efficiency at $m = 0.8$. [3]

2.3 For $f_c = 500\text{kHz}$ and $f_m = 10\text{kHz}$, give the envelope detector's τ bounds. [3]

3 Exam-style questions

3.1 A 10 kW AM transmitter (carrier power) operates at $m = 0.7$.

Compute the power in each sideband, the total sideband power, and the total radiated power. Compute the efficiency and check the budget closes (carrier + sidebands = total). The station engineer proposes suppressing the carrier entirely (DSB-SC): compute the sideband power the SAME total transmitter power would then deliver, and state what the receiver must add. [8]

3.2 An envelope detector uses a diode and RC on a signal with $f_c = 100kHz$, message bandwidth to $f_m = 5kHz$.

Derive the two τ bounds (carrier ripple; envelope following). Compute the upper bound at $m = 0.5$ and at $m = 0.9$, keeping the lower bound fixed at its carrier-ripple value. Choose τ and verify it fits BOTH modulation depths; if it cannot fit $m = 0.9$, state the failure mode and the standard fix. [7]

Solutions

2.1

- Sidebands $(0.36/2) \times 200 = 36W$.
- Total $200 \times (1 + 0.18) = 236W$.

2.2

- $\eta = (0.64/2)/(1 + 0.32) = 0.32/1.32 = 24.2\%$.

2.3

- Lower $1/(2\pi \times 500k) = 0.32\mu s$; upper $1/(2\pi \times 10k) = 15.9\mu s$.

3.1

- Each sideband $m^2/4 \times P_c = 0.49/4 \times 10k = 1225W$.
- Total sidebands 2450 W; total power $10000 \times 1.245 = 12450W$.
- Efficiency $2450/12450 = 19.7\%$.
- Budget: $10\,000 + 2450 = 12\,450$ ✓ closes.
- DSB-SC with the same 12 450 W total: ALL of it is sidebands – 12 450 W of message-bearing power, $5.1\times$ more than before.
- The receiver must regenerate the carrier coherently (a local oscillator at exactly f_c and phase) – an envelope detector no longer works, which is why broadcast stayed with full AM.

3.2

- Carrier ripple: $\tau \gg 1/\omega_c = 1.6\,\mu s$.
- Envelope following: $\tau \ll 1/\omega_m = 31.8\,\mu s$ at small m , tightened to $\sqrt{1-m^2}/\omega_m$ for depth m .
- $m = 0.5$: upper bound $\sqrt{0.75}/(2\pi \times 5000) = 27.6\mu s$.
- $m = 0.9$: upper bound $\sqrt{0.19}/(2\pi \times 5000) = 13.9\mu s$.
- $\tau = 5\,\mu s$ fits both ($1.6 \ll 5 \ll 13.9$) ✓.
- If τ were chosen at, say, $20\,\mu s$ it would fit $m = 0.5$ but fail $m = 0.9$: diagonal clipping on the envelope's fastest falls; the standard fixes are to cap m at the transmitter or switch to synchronous detection.