

# 11.2 Amplitude modulation

Name: \_\_\_\_\_ Class: \_\_\_\_\_ Date: \_\_\_\_\_

Total: 24 marks

KEY WORDS amplitude modulation • envelope detector

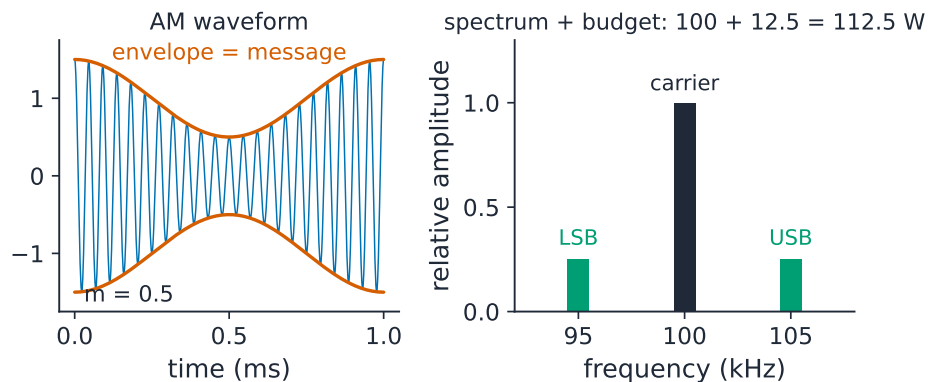
## Objective

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

$P_c = 100W$ ,  $m = 0.5$ : 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  $f_c = 100kHz$ ,  $f_m = 5kHz$ : 1.6  $\mu s$  to 31.8  $\mu s$ ;  $\tau = 10 \mu s$  sits comfortably inside.

## 2 Practice

2.1 A transmitter runs  $P_c = 200W$  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  $f_c = 500kHz$  and  $f_m = 10kHz$ , give the envelope detector's  $\tau$  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  $\tau$  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  $\tau$  and verify it fits BOTH modulation depths; if it cannot fit  $m = 0.9$ , state the failure mode and the standard fix. [7]

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## Solutions

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### 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  $\tau$  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.