EEEN 322
Communication Engineering

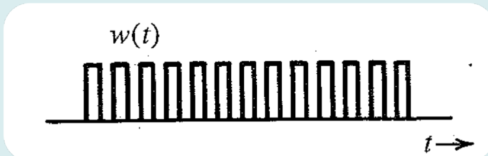
İpek Şen

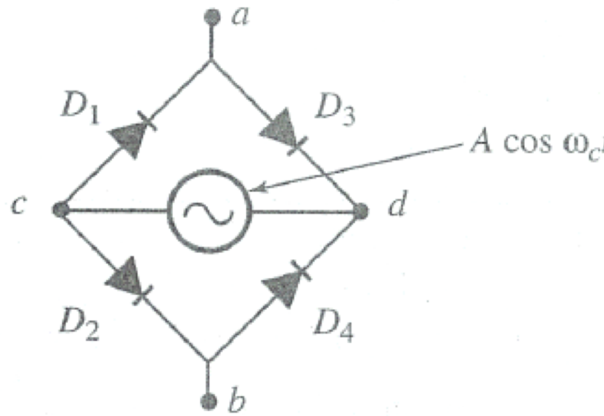
Spring 2019

Week 5

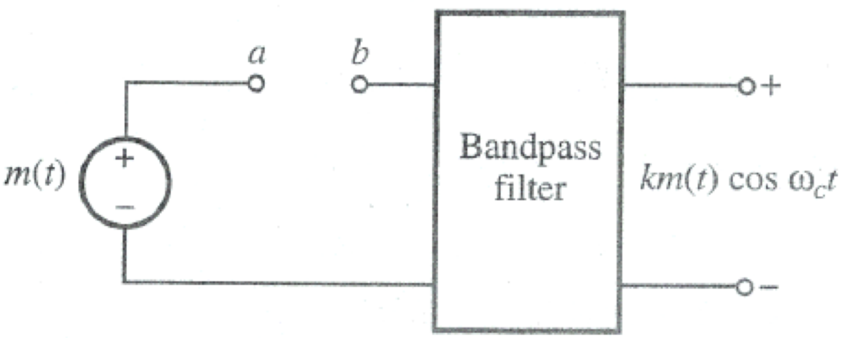
Switching Modulator for DSB-SC Modulation: Diode-Bridge Modulator

Same as multiplying by:

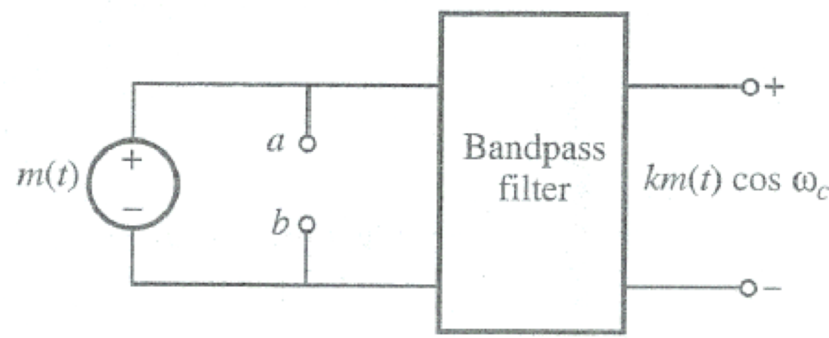




(a)



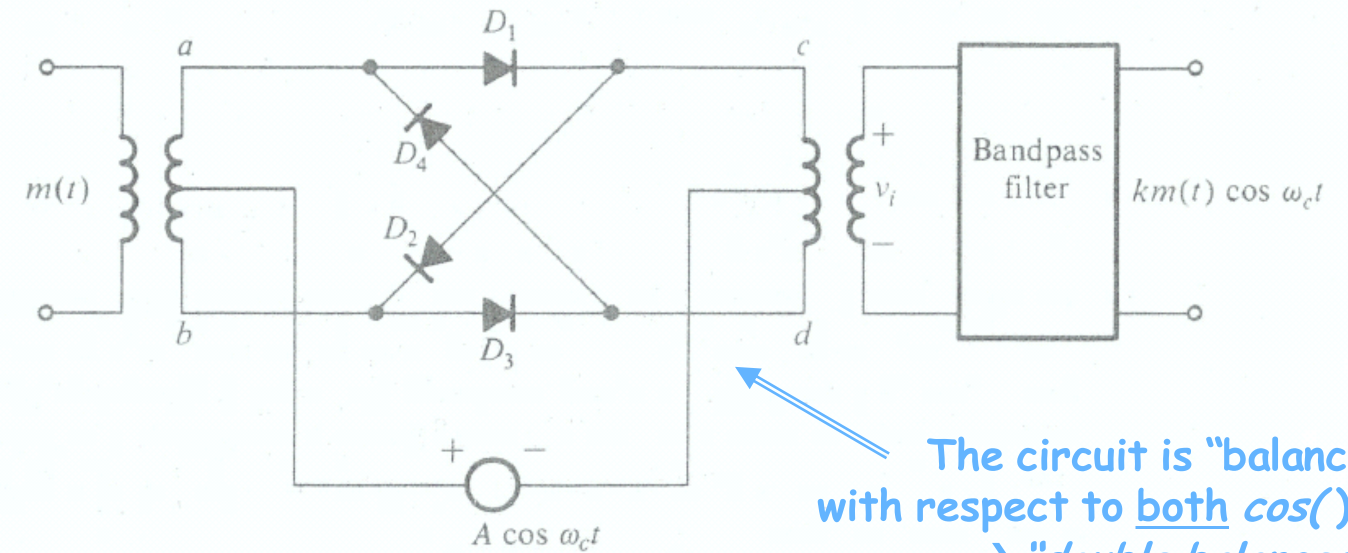
Series-bridge diode modulator



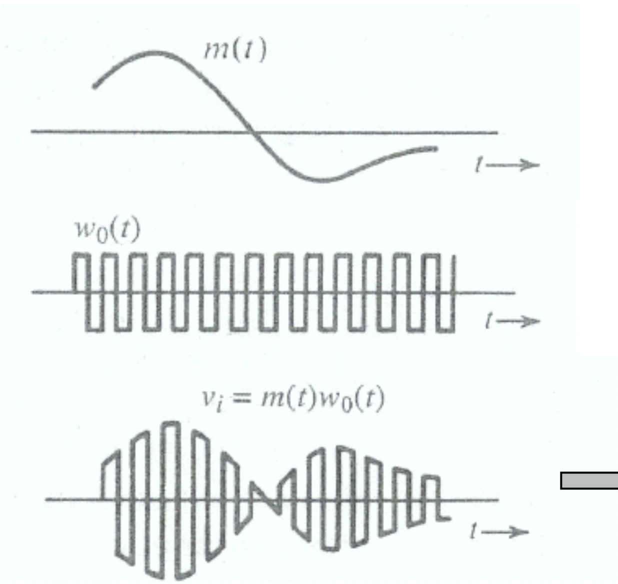
Shunt-bridge diode modulator

Single-balanced modulator

Switching Modulator for DSB-SC Modulation: Ring Modulator



The circuit is "balanced" with respect to both *cos( )* and *m( )* → *"double balanced"*



$$\frac{4}{\pi}\left(\cos\omega_c t - \frac{1}{3}\cos 3\omega_c t + \frac{1}{5}\cos 5\omega_c t - \ldots\right)$$

$$\frac{4}{\pi}m(t)\cos\omega_c t - \frac{4}{3\pi}m(t)\cos 3\omega_c t + \frac{4}{5\pi}m(t)\cos 5\omega_c t - \ldots$$

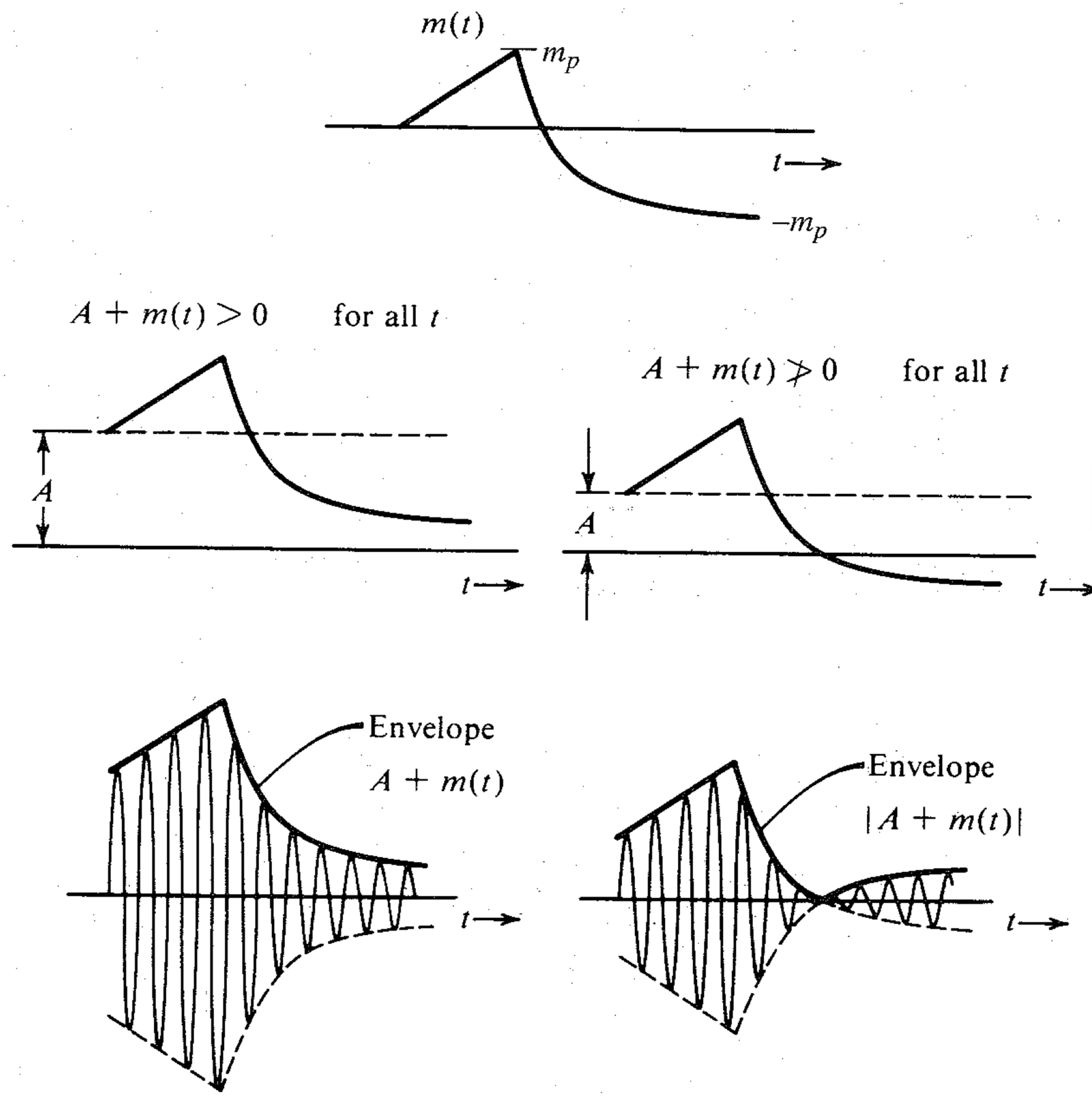
Band-pass filtering gives: $\frac{4}{\pi}m(t)\cos\omega_c t$

Double-balanced modulator

$$\varphi_{AM}(t) = [A + m(t)]\cos\omega_c t$$

Amplitude Modulation (DSB+C)

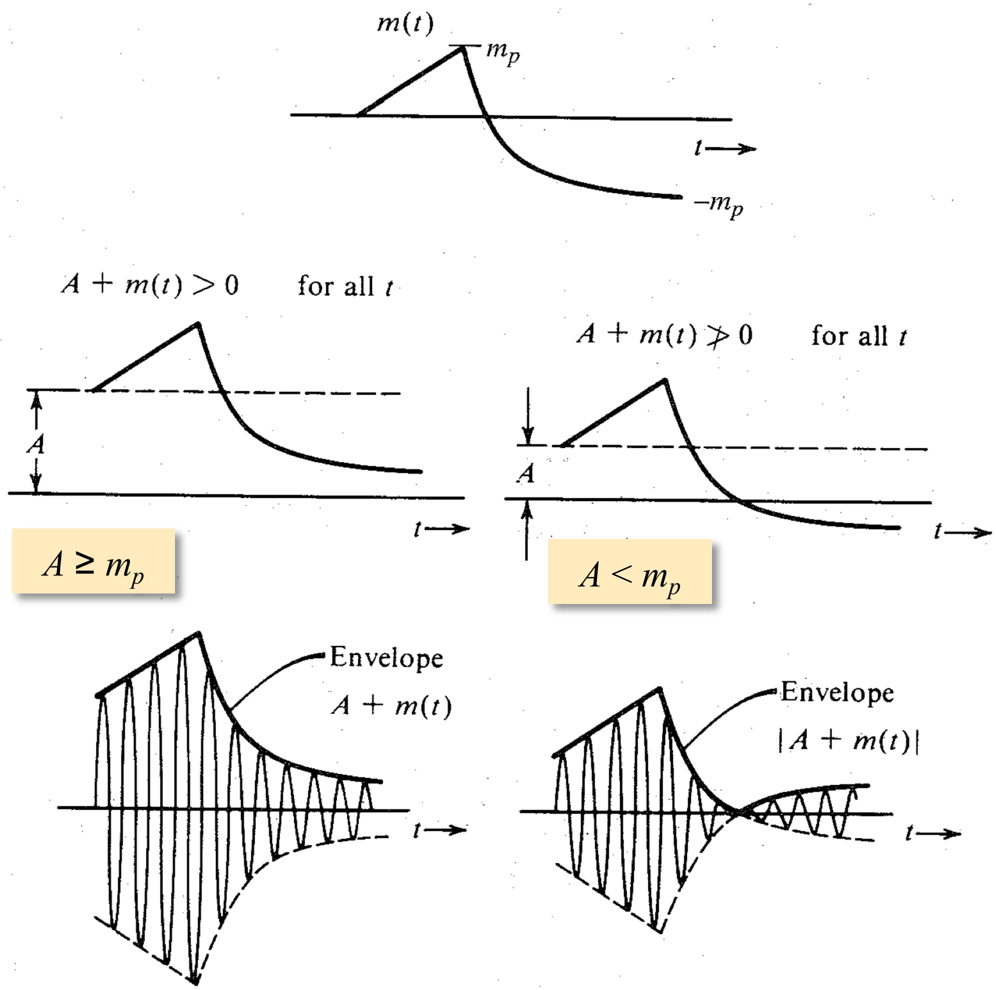
$A \geq m_p$



$A < m_p$

$$\varphi_{AM}(t) = [A + m(t)]\cos\omega_c t$$

Amplitude Modulation (DSB+C)



Modulation index

$$\mu = \frac{m_p}{A}$$

Condition for envelope detection:

$$\boxed{A \geq m_p}$$

or

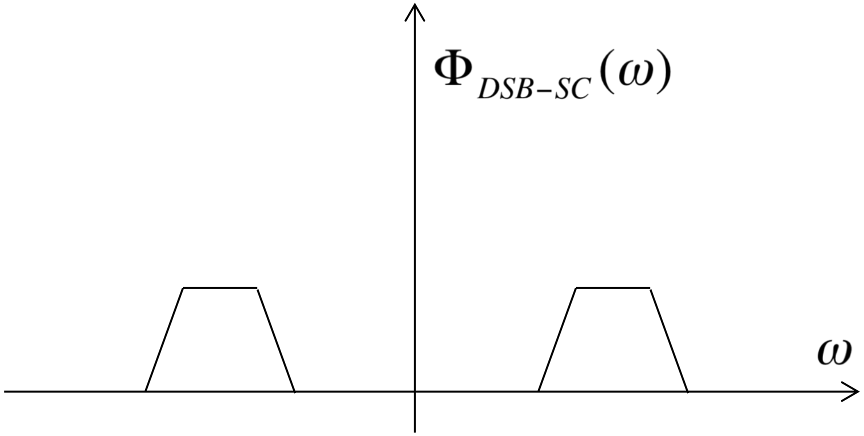
$$\boxed{0 \leq \mu \leq 1}$$

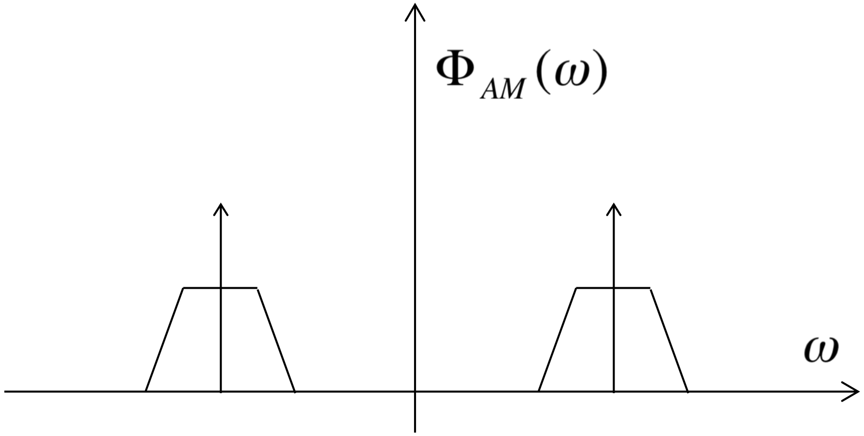
Spectrum of Amplitude-Modulated Signal

$$\varphi_{AM}(t) = [A + m(t)]\cos\omega_c t \;\Leftrightarrow$$

$$\frac{1}{2}[M(\omega+\omega_c) + M(\omega-\omega_c)] + \pi A[\delta(\omega+\omega_c) + \delta(\omega-\omega_c)]$$

The spectrum of $\varphi_{AM}(t)$ is the same as the spectrum of $m(t)\cos\omega_c t$, but in addition there are two impulses at $\pm\omega_c$.





when $m(t)$ itself is a cosine as well (with angular frequency ω_m)

Tone Amplitude-Modulation

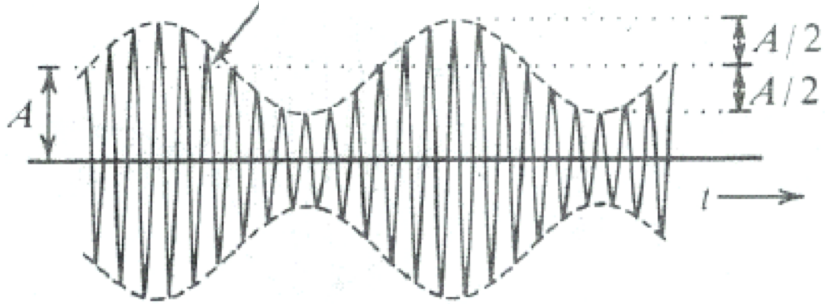
$$m(t) = B\cos\omega_m t \qquad \Rightarrow \varphi_{AM}(t) = [A + m(t)]\cos\omega_c t = [A + B\cos\omega_m t]\cos\omega_c t$$

$$\Rightarrow m_p = B \Rightarrow \mu = \frac{B}{A} \Rightarrow B = \mu A \qquad \Rightarrow \varphi_{AM}(t) = A[1 + \mu\cos\omega_m t]\cos\omega_c t$$

$B = A/2$

$\boxed{\mu = 0.5}$

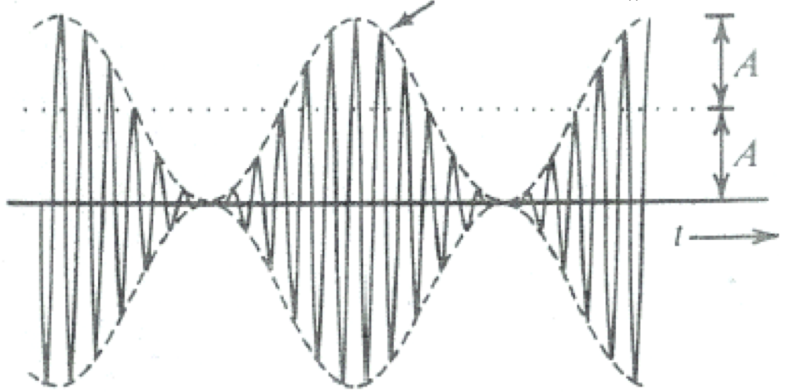
$A(1+0.5\cos\omega_m t)$



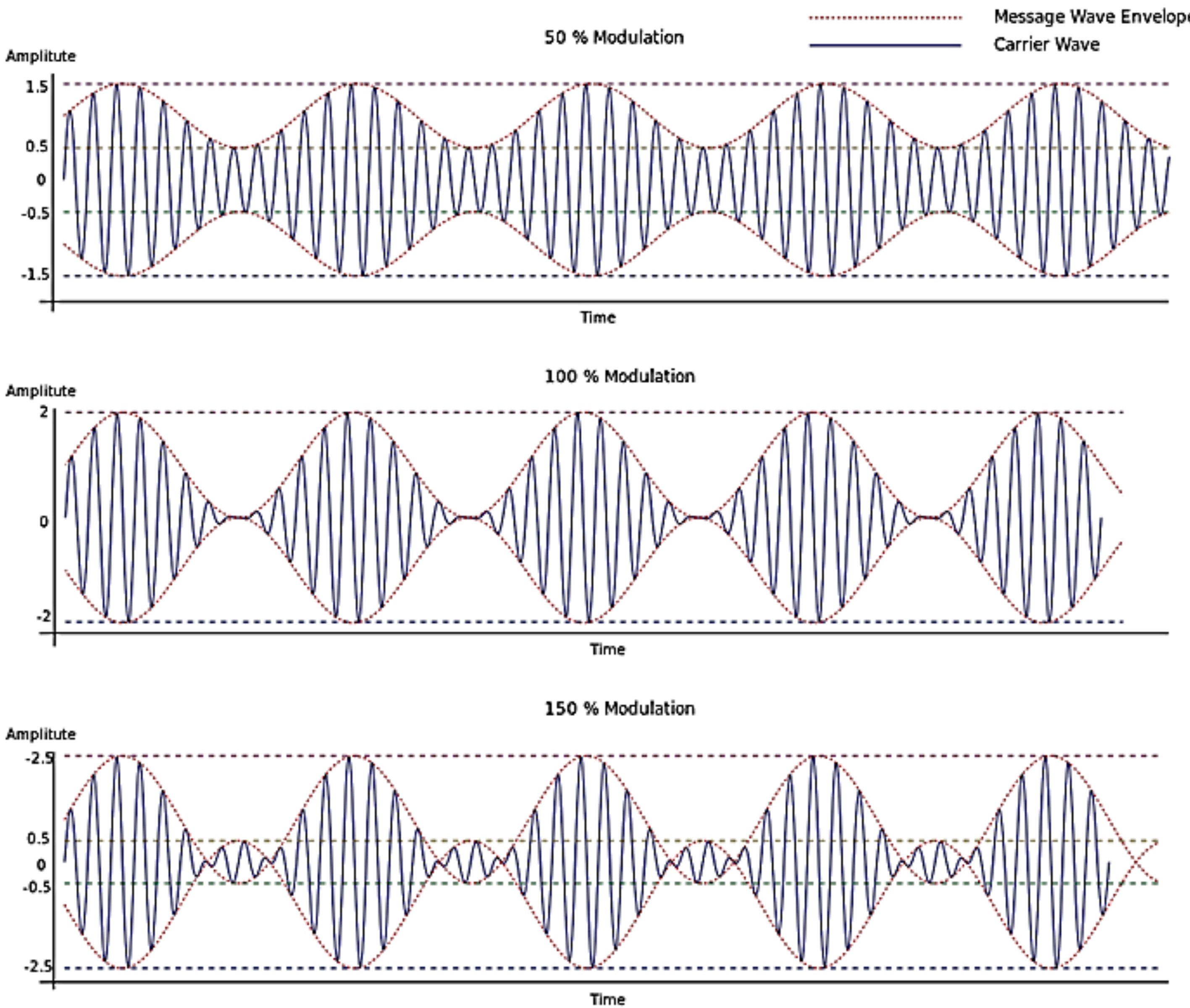
$B = A$

$\boxed{\mu = 1}$

$A(1+\cos\omega_m t)$



Effect of Modulation Index μ in Amplitude Modulation (DSB+C)



$\mu = 0.5$

$\mu = 1$

$\mu = 1.5$

Sideband Power and Carrier Power

The carrier is a non-message-carrying component of the AM signal. Therefore power spent for its transmission is (in some sense) wasted.

$$\varphi_{AM}(t) = \underbrace{A\cos\omega_c t}_{\text{carrier}} \quad + \quad \underbrace{m(t)\cos\omega_c t}_{\text{sidebands}}$$

Power: $P_c = \dfrac{A^2}{2}$ $\qquad P_s = \dfrac{1}{2}P_m$

Power efficiency: $\boxed{\eta = \dfrac{useful\ power}{total\ power} = \dfrac{P_s}{P_s + P_c} = \dfrac{P_m}{A^2 + P_m}}$

Note that for tone modulation:
(with $0 \le \mu \le 1$)

$$m(t) = \mu A\cos\omega_m t \qquad P_m = \frac{(\mu A)^2}{2}$$

$$\eta = \frac{\mu^2}{2+\mu^2} \qquad \Rightarrow \eta_{max} = 33\% \quad (\mu = 1)$$