Information Transmission
Chapter 4, Analog modulation

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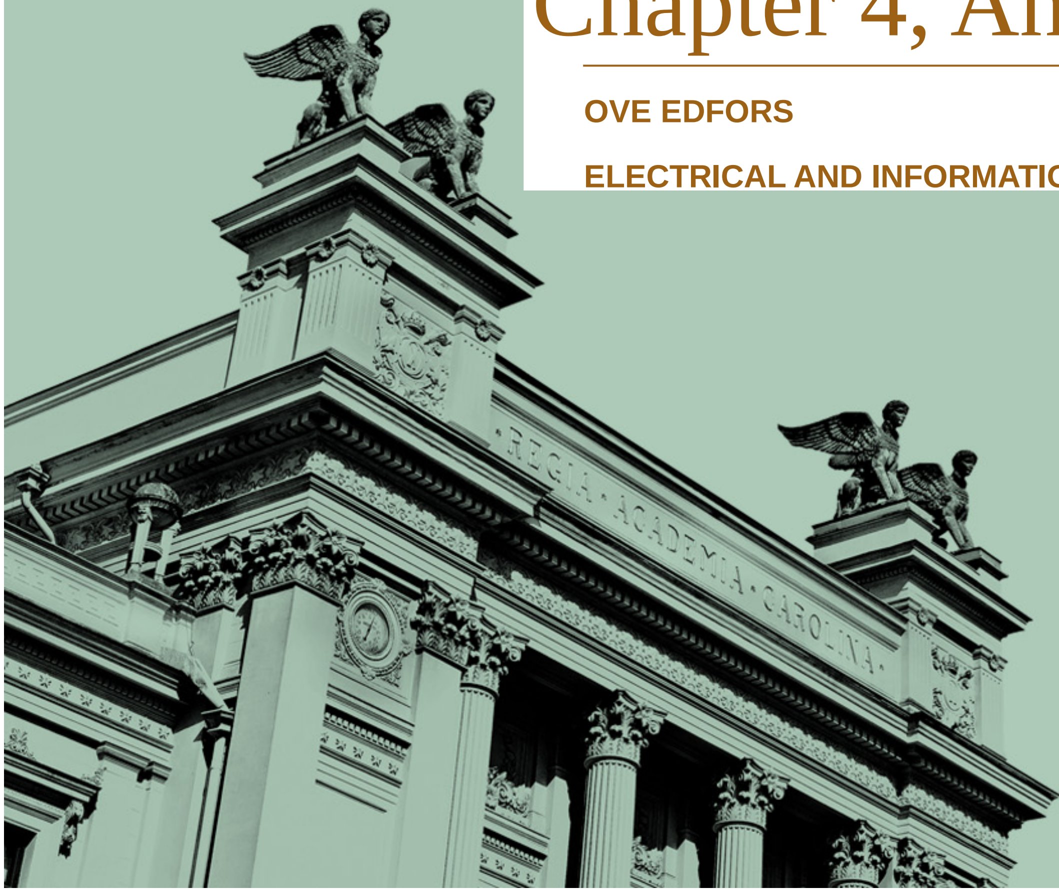
ELECTRICAL AND INFORMATION TECHNOLOGY



Analog modulation

- Shift the frequency to an appropriate frequency for transmission

$$s(t) = A(t)\cos[\omega_0 t + \phi(t)], \qquad \omega_0 = 2\pi f_0$$

- Vary the amplitude or phase to represent the information
  - Phase slope (derivative) = frequency shift
- The original signal $A(t)$ is often called the ***baseband*** signal

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Modulation property

- Shifting the frequency does not modify the information content

$$g(t)\cos 2\pi f_0 t \leftrightarrow (1/2)[G(f+f_0)+G(f-f_0)]$$

- There are two replicas, one at positive frequencies and one at negative

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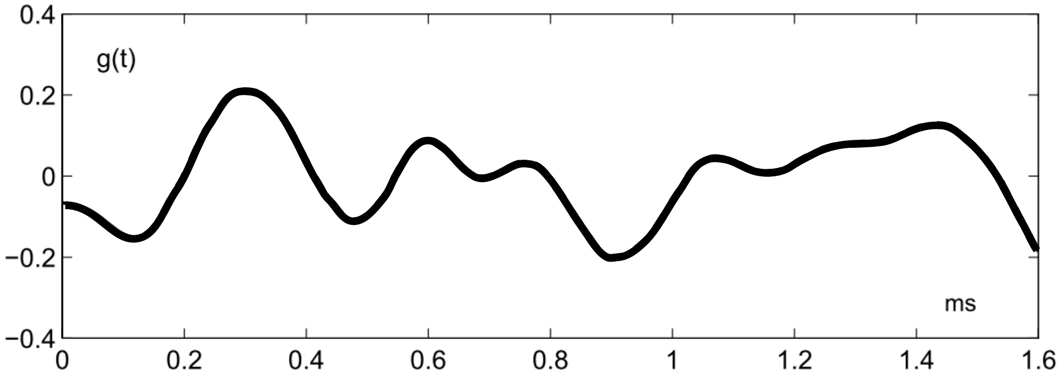
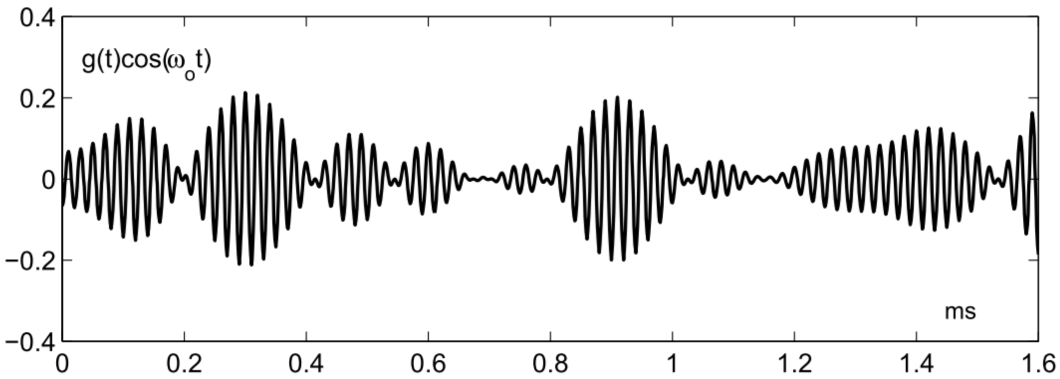
Example, a modulated bandpass signal

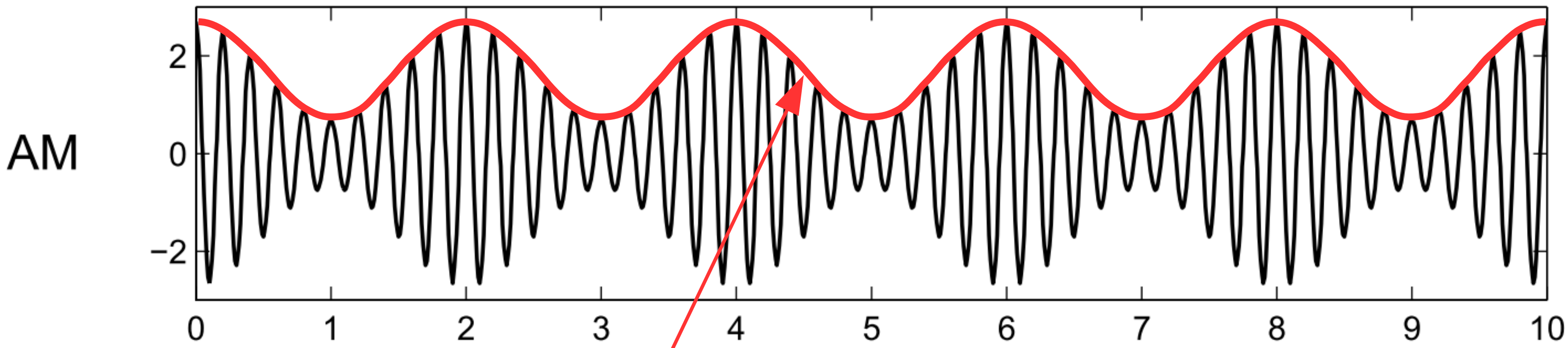
- A 5 kHz bandpass signal modulated with a 50 kHz carrier





General amplitude modulation

- The simplest form of AM is where the information can be found in the envelope of the bandpass signal

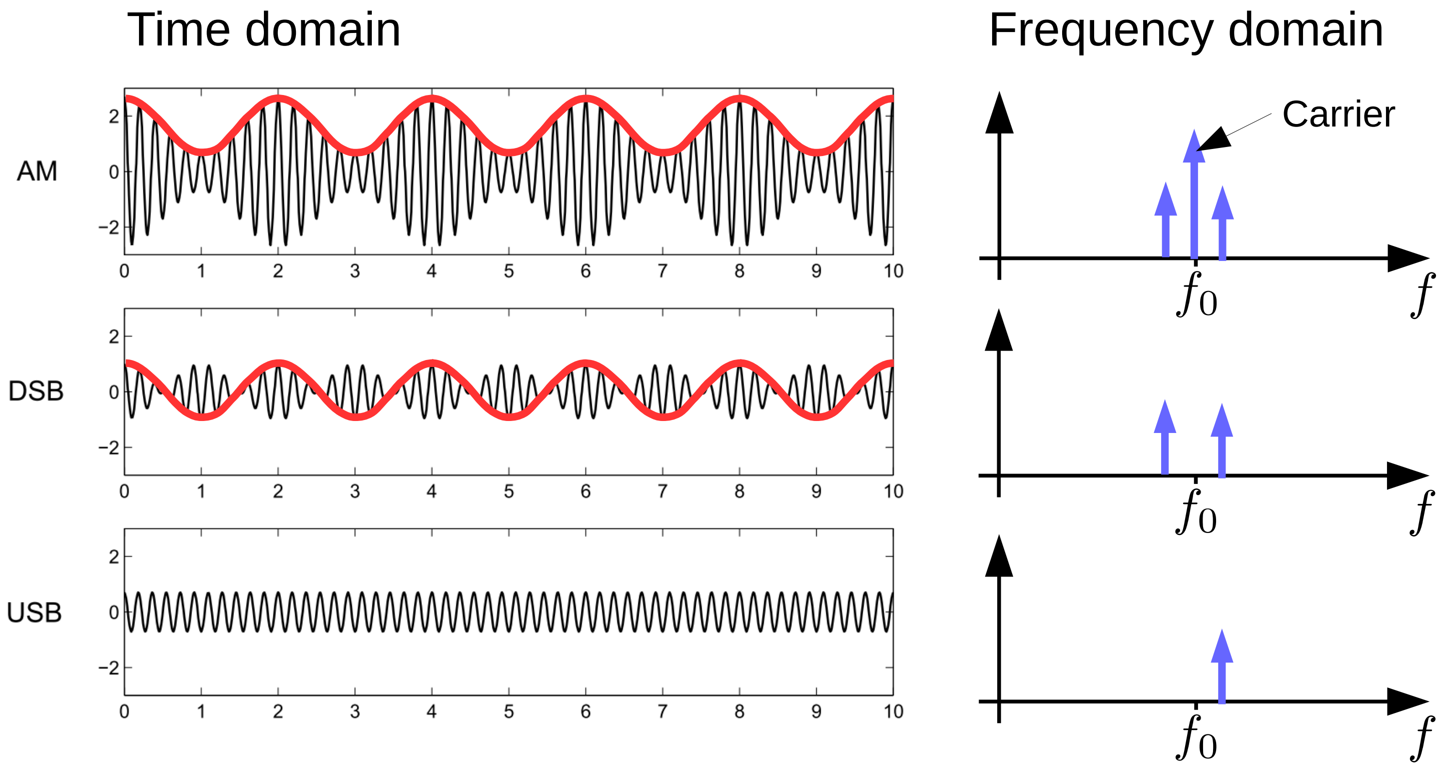


$$s(t) = A[1 + m_{AM}\, g(t)] \cos 2\pi f_0 t$$

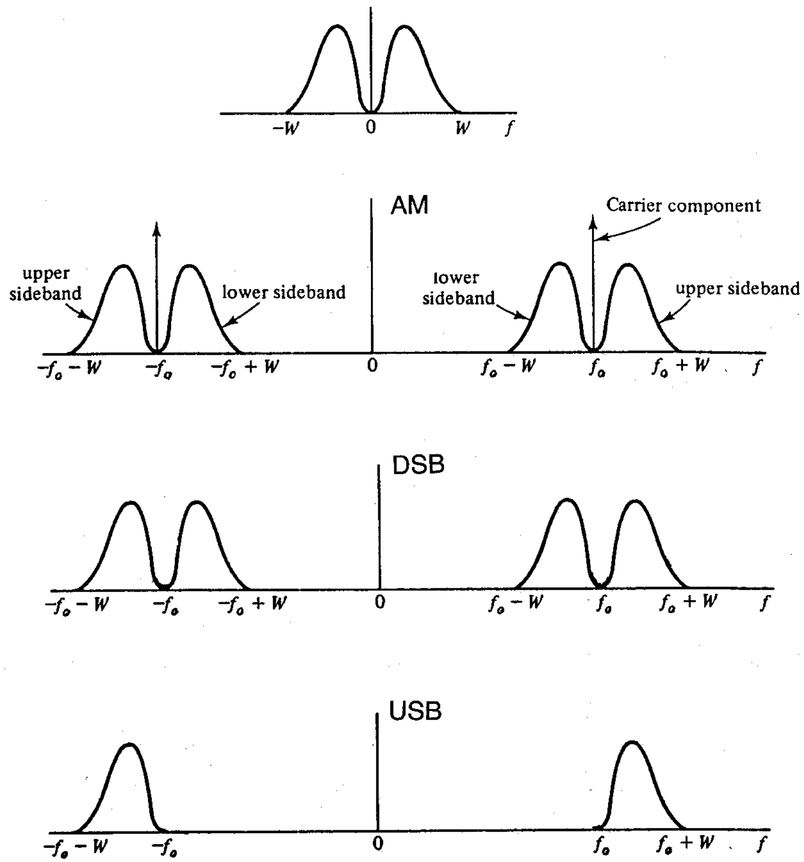
- m_{AM} is the so-called modulation index

Carrier supression

- The carrier signal contains no information and can be supressed



Different amplitude moldulation tech.



Frequency modulation

Frequency modulation intro.

- Shift the frequency to an appropriate frequency for transmission

$$s(t) = A(t)\cos[\omega_0 t + \phi(t)], \qquad \omega_0 = 2\pi f_0$$

- Phase slope (derivative) = frequency shift
- Let the baseband signal change the frequency of the bandpass signal
  - High amplitude (baseband signal) – high frequency
  - Low amplitude (baseband signal) – low frequency

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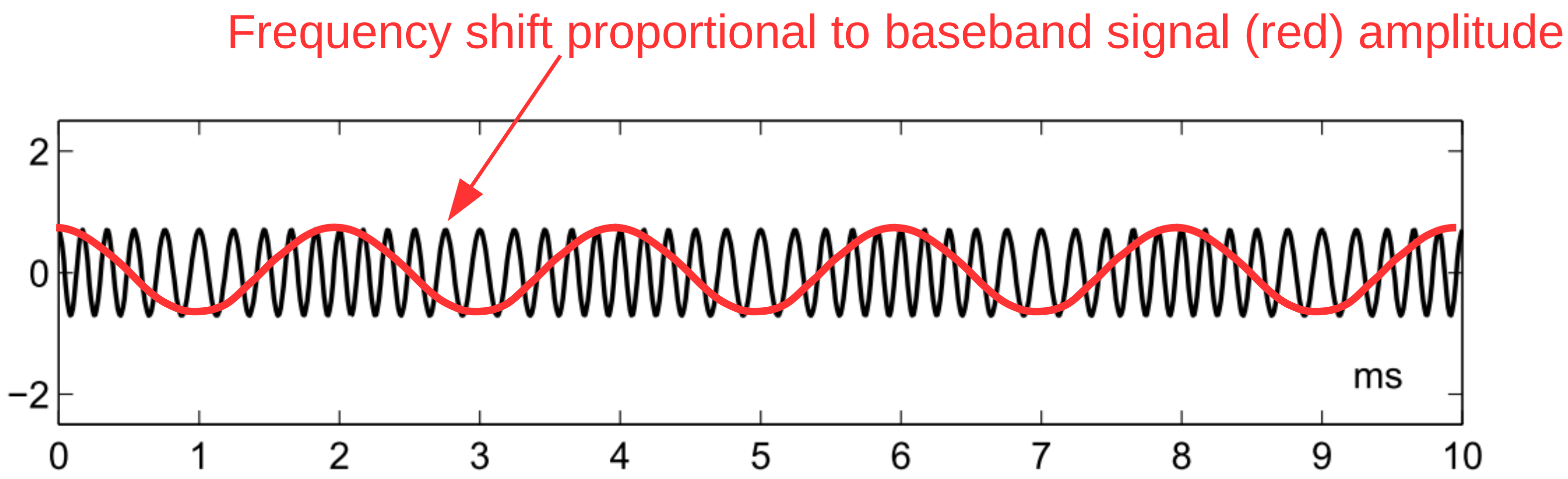
FM signal with sinusoidal baseband sig.



$$s(t) = A(t)\cos[\omega_0 t + \phi(t)], \qquad \omega_0 = 2\pi f_0$$

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Frequency modulation

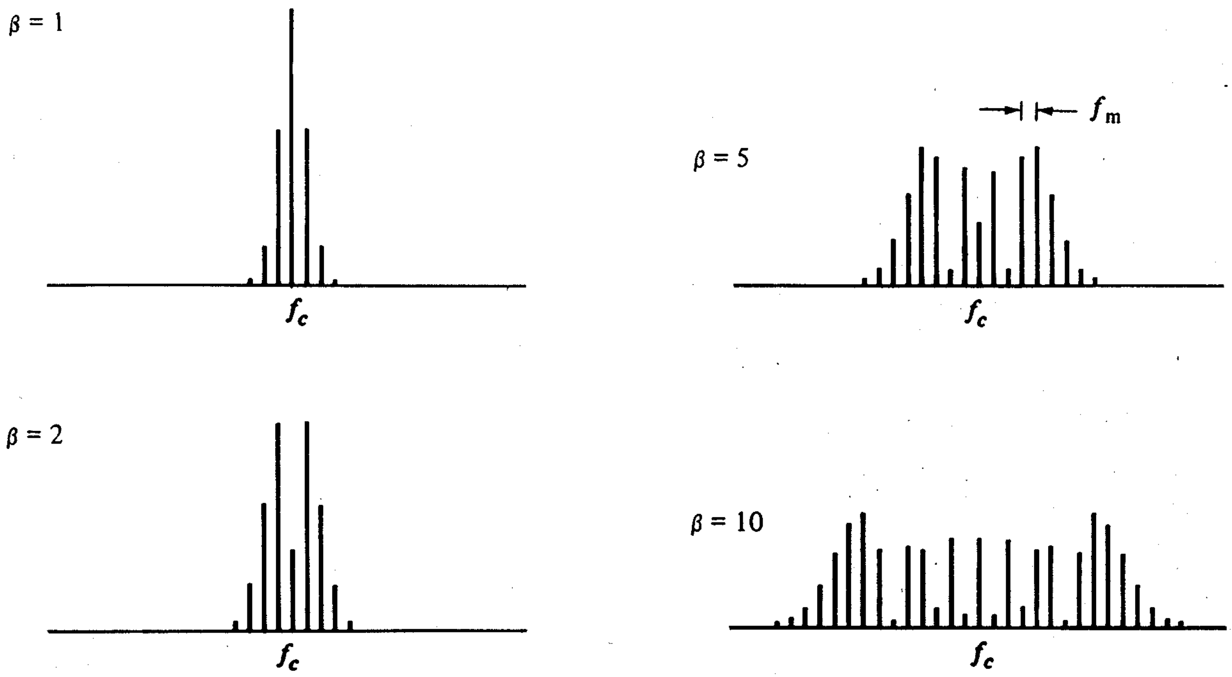
- Let the signal be

$$s(t) = A\cos[2\pi f_0 t + m_{FM} \int_{t_o}^{t} g(\tau)\, d\tau]$$

- Where m_{FM} is scaling constant and the instantaneous frequency is given by $f_0 + m_{FM} g(t)/2\pi$
- The larger modulation index and baseband amplitude the larger is the frequency deviation Δf
- Modulation index: $\beta = \Delta f / f_m$

Derived for: $g(t) = \cos(2\pi f_m t)$

Spectrum of an FM signal with sinusoidal baseband signal



Larger modulation index β, larger bandwidth

Bandwidth

- Approximate bandwidth by **Carson's rule**

$$
\begin{aligned}
W_{RF} &\approx 2(\Delta f + f_m) \qquad \text{(Deviation Form)} \\
&= 2 f_m (1 + \beta) \qquad \text{(Index Form)}
\end{aligned}
$$

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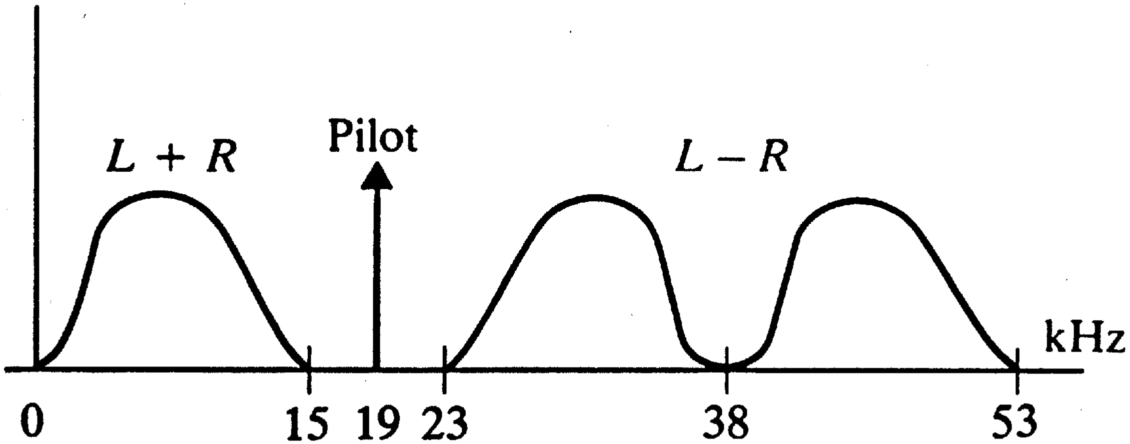
Bandwidth expansion – gain in SNR

- The SNR after demodulation is determined by the modulation index

$$(S/N)_{\text{out}} \approx \frac{3\beta^2}{2} (S/N)_{\text{in}}$$

- We can trade bandwidth with SNR

FM stereo broadcasting signal



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