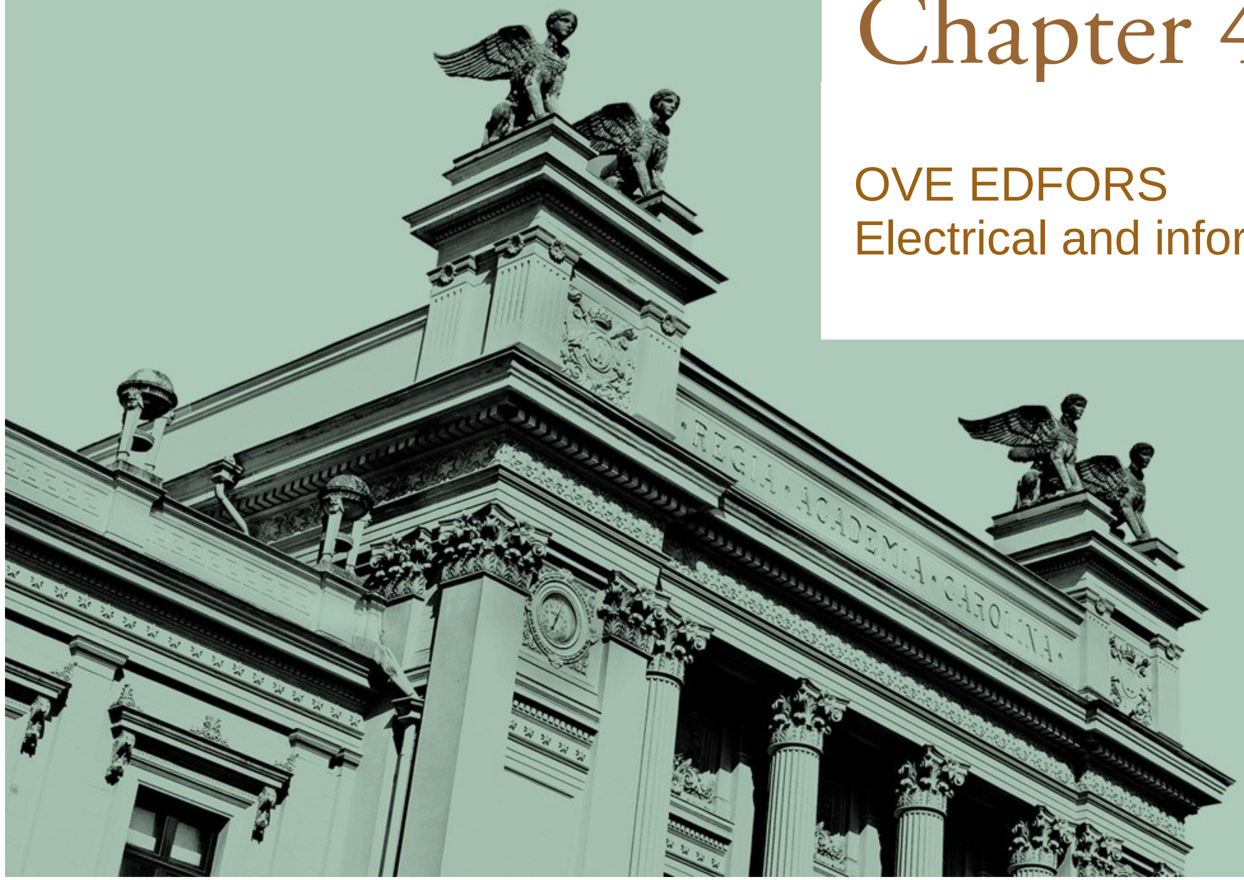
Information Transmission
Chapter 4, Analog modulation

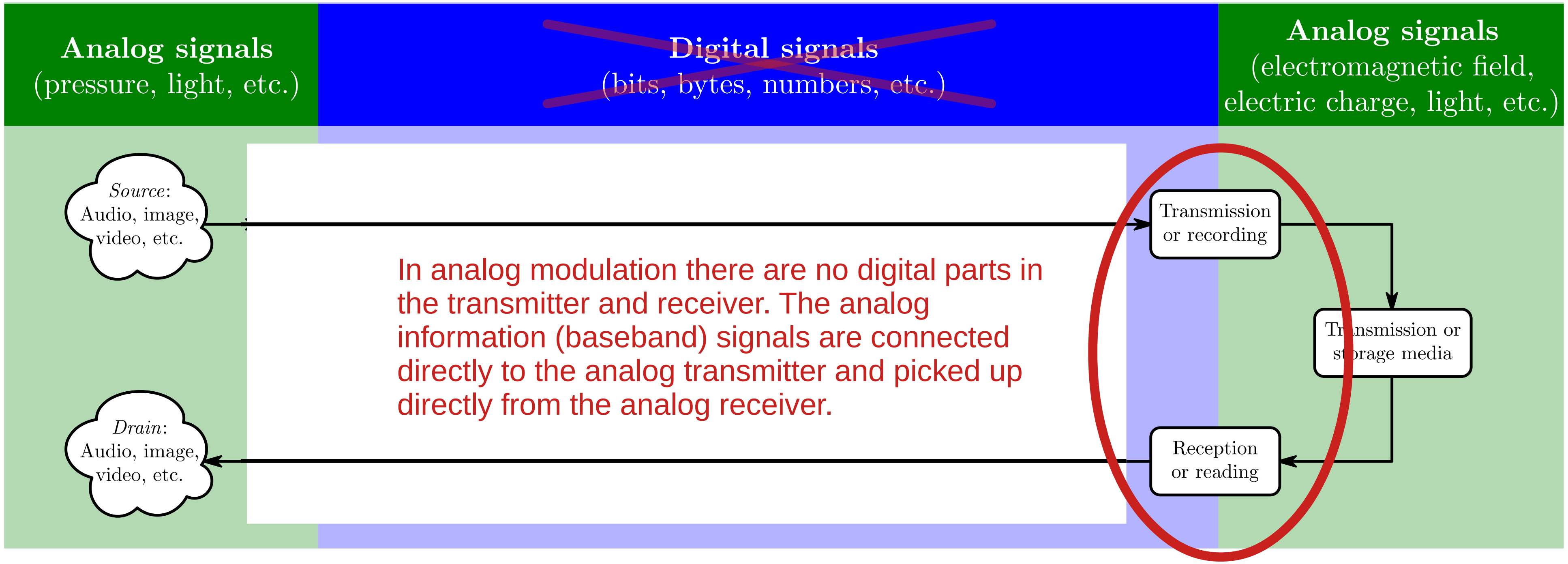
OVE EDFORS
Electrical and information technology



Learning outcomes

- After this lecture the student should:
  - Know the basic principles of analog modulation techniques
  - Understand how amplitude modulation is performed and which basic variants there are
  - Understand how frequency modulation is done and how an increased bandwith leads to gains in quality (SNR)
  - Understand why FM radio broadcasting is transmitted the way it is

Where are we in the BIG PICTURE?



Lecture relates to pages 117–127 in textbook.

Analog modulation/ transmission techniques

Analog modulation – basic principles

- 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 (time derivative of phase) = frequency shift
- The original signal $A(t)$ is often called the ***baseband*** signal

Modulation property

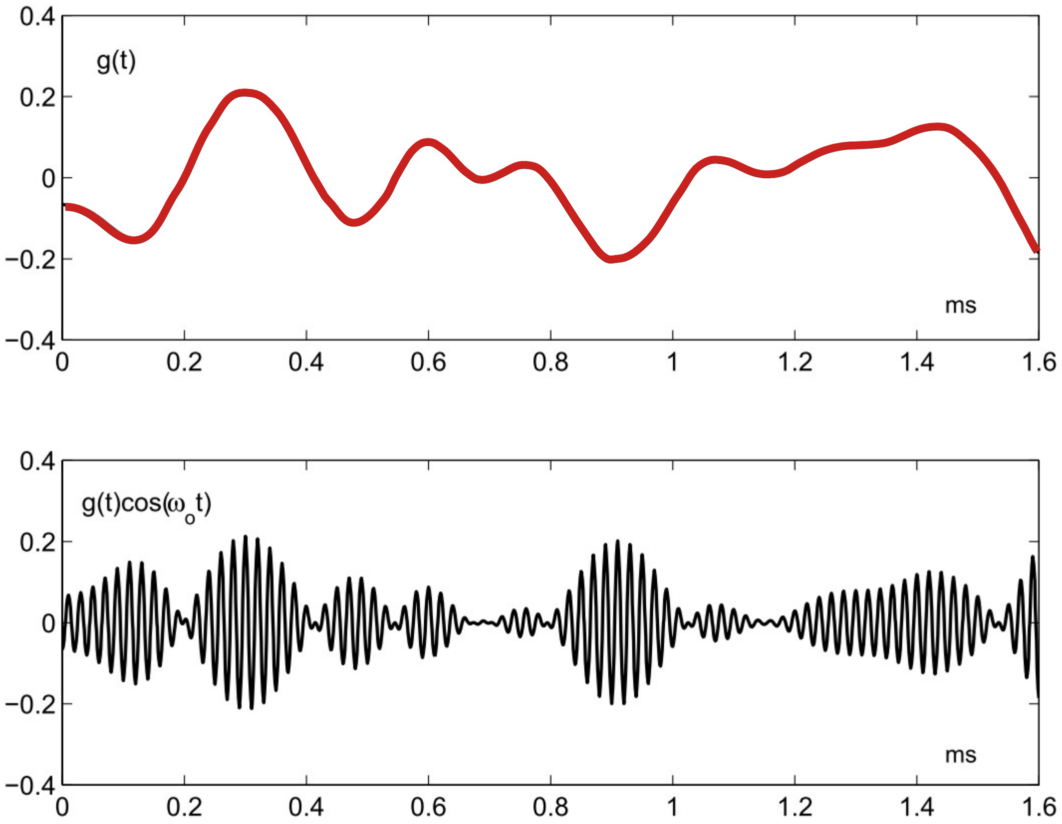
- Shifting the frequency does not modify the information content

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

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

Example, a modulated bandpass signal

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



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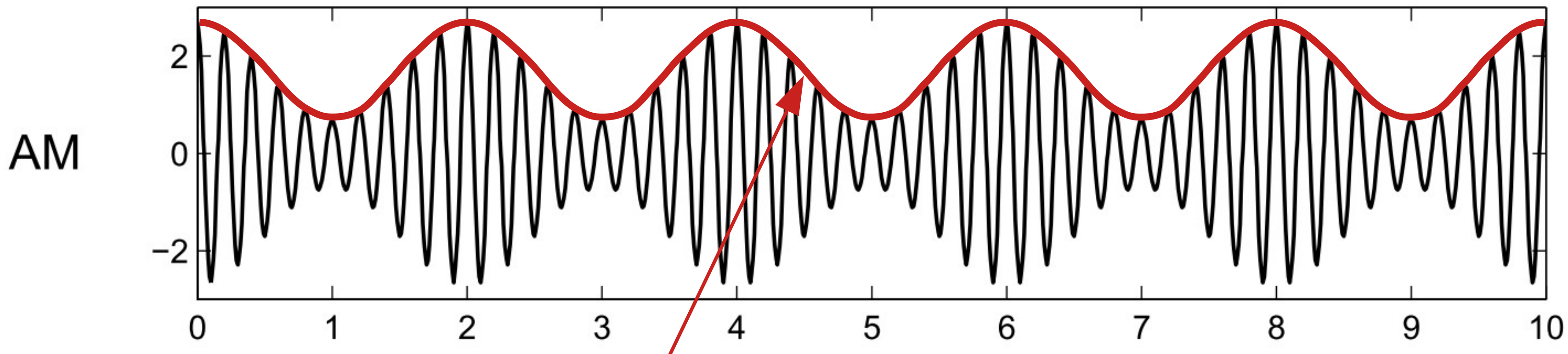
AMPLITUDE MODULATION

General amplitude modulation

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



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

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

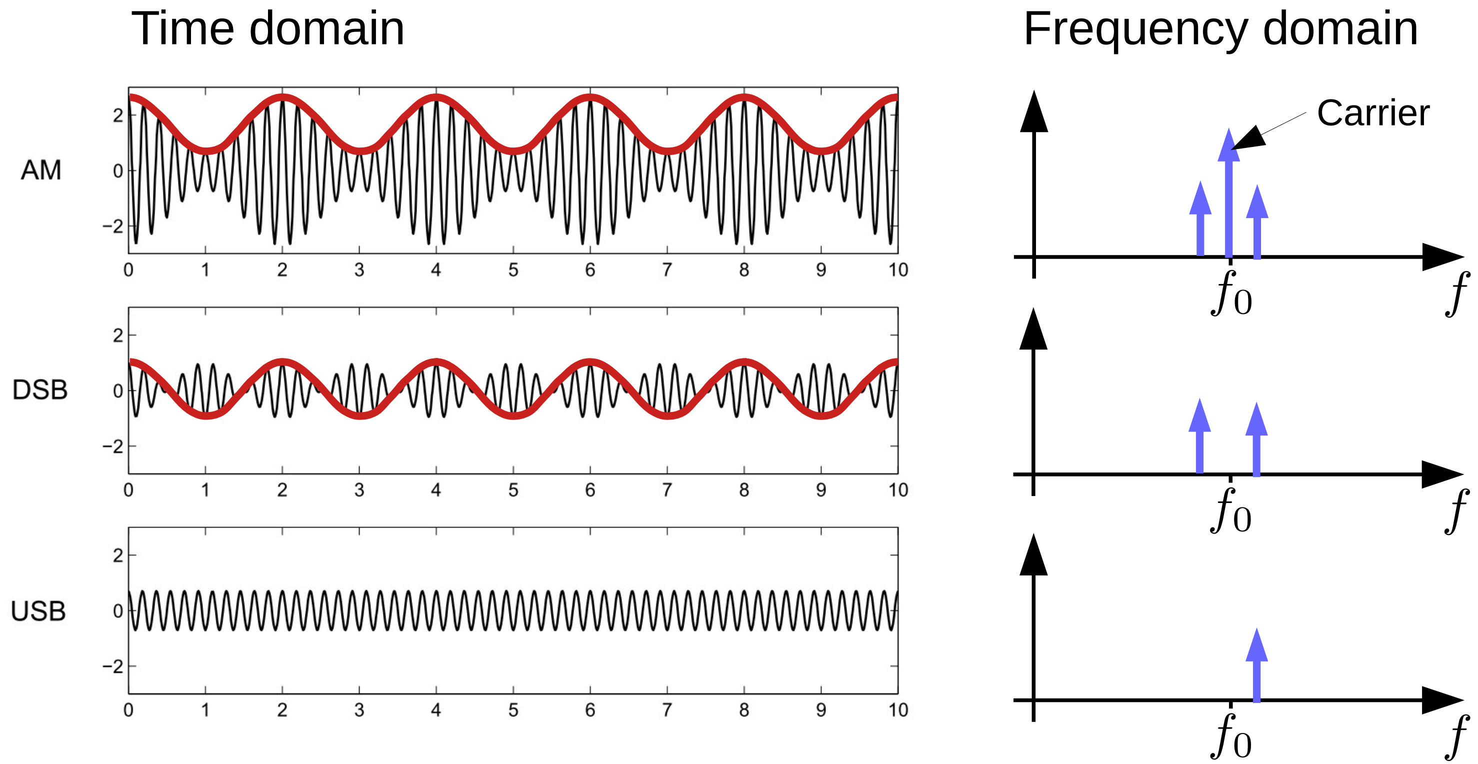
Carrier supression

- The carrier signal contains no information and can be supressed

AMPLITUDE MODULATION (WITH CARRIER)

DOUBLE SIDE-BAND MODULATION

UPPER SIDE-BAND MODULATION

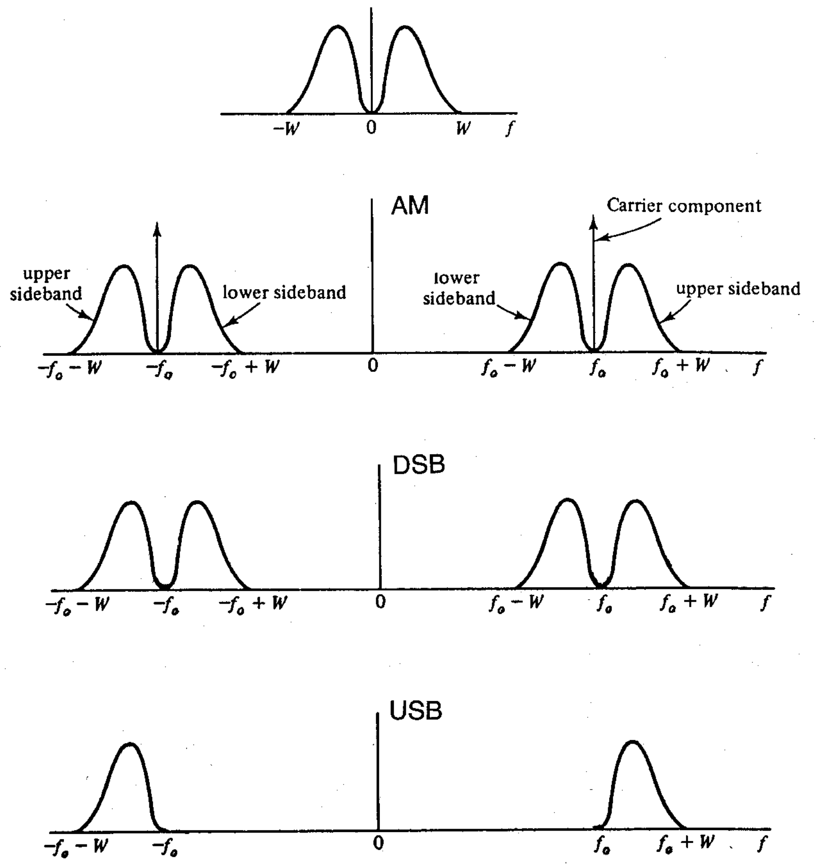


Different amplitude moldulation tech.

AMPLITUDE MODULATION
(WITH CARRIER)

DOUBLE SIDE-BAND
MODULATION

UPPER SIDE-BAND
MODULATION



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FREQUENCY MODULATION

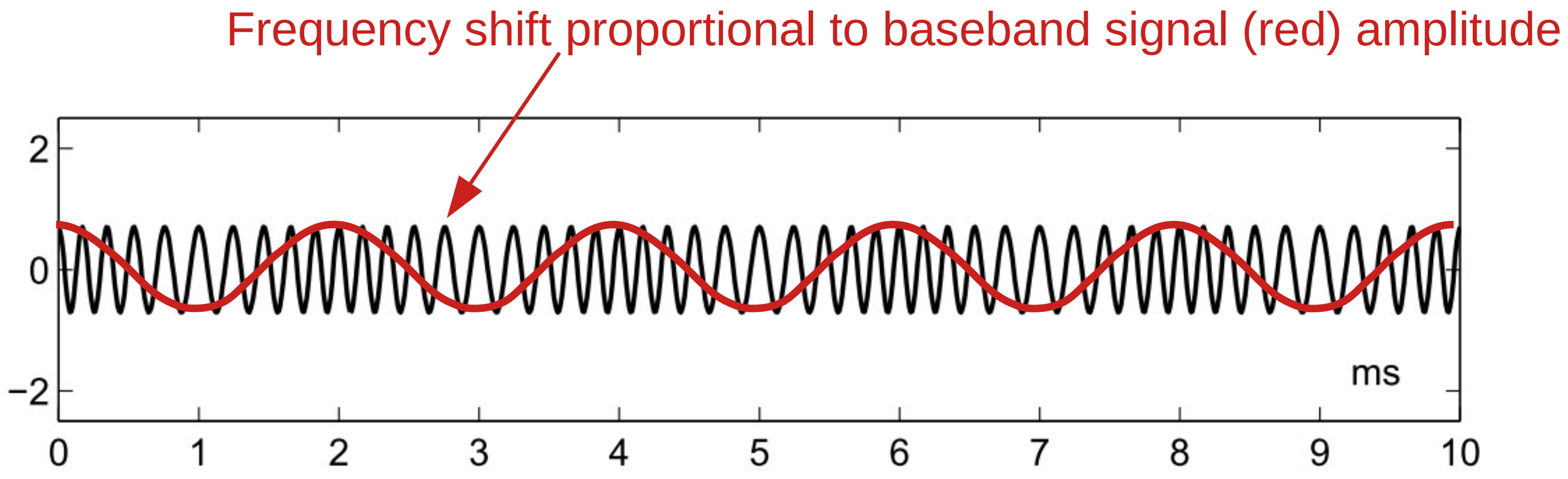
Frequency modulation introduction

- 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

FM signal with sinusoidal baseband sig.



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

Frequency modulation

- Let the signal be

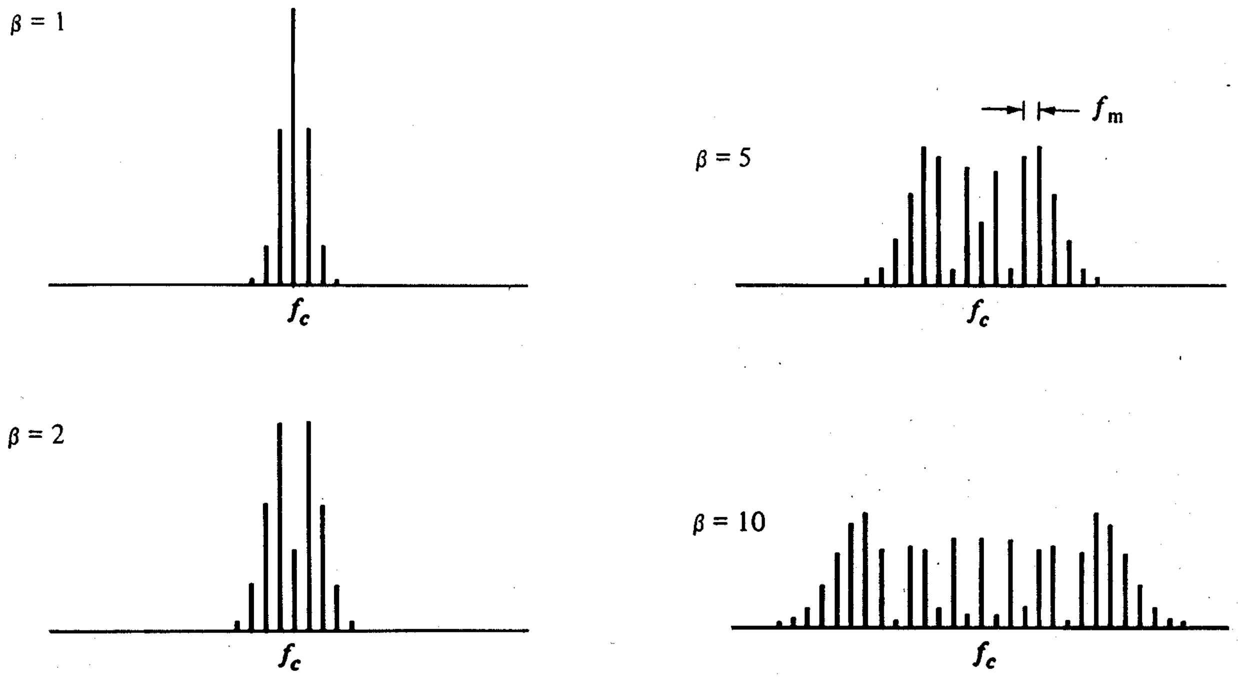
$$s(t) = A\cos[2\pi f_0 t + m_{FM}\int_{t_o}^{t} g(\tau)\, d\tau]$$

- 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 $\Delta f = m_{FM}\, g(t)/2\pi$
- Modulation index: $\beta = \Delta f / f_m$

Derived for information signal:

$$g(t) = \cos(2\pi f_m t)$$

Spectrum of FM (sinusoidal baseband)



Larger modulation index β, larger bandwidth

Spectrum of FM (sinusoidal baseband)

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

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

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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

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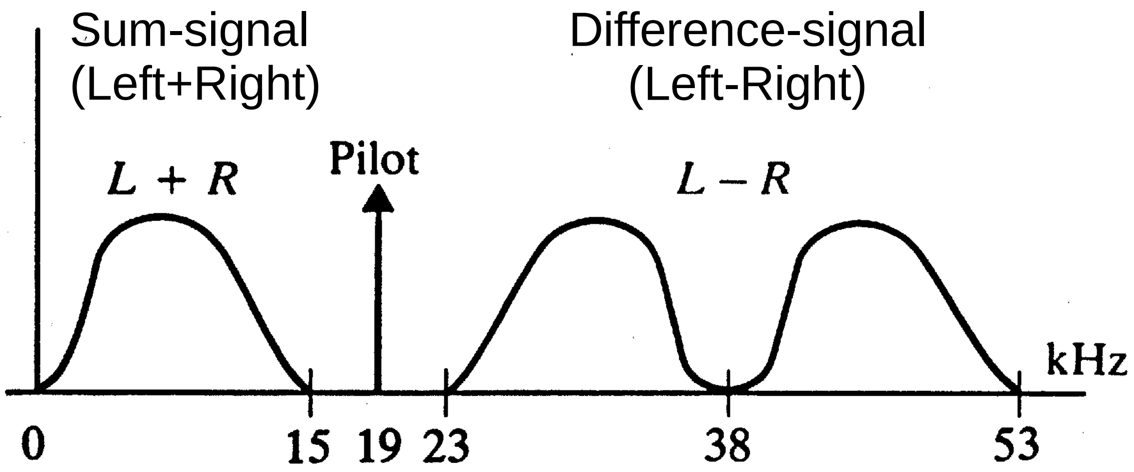
FM stereo broadcasting signal



Mono receivers listen to this part only

Stereo receivers listen to this part too

But, how do you get proper stereo, with correct left and right?

Summary

- Analog modulation does not use any "digital" part of the transmitter/receiver chains
- Modulation is typically done by influencing amplitude or frequency of a carrier signal
- Amplitude modulation comes in several forms, with and without carrier component, and the radio bandwidth is "the same" as the baseband signal bandwidth
- Frequency modulation expands the bandwidth, compared to the baseband signal, and the larger the expansion the better the quality (trading bandwidth and SNR)
- Stereo FM broadcasting transmit the sum and difference signals (of left/right), to allow for simple mono receivers.

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