LECTURE S22

Modulation

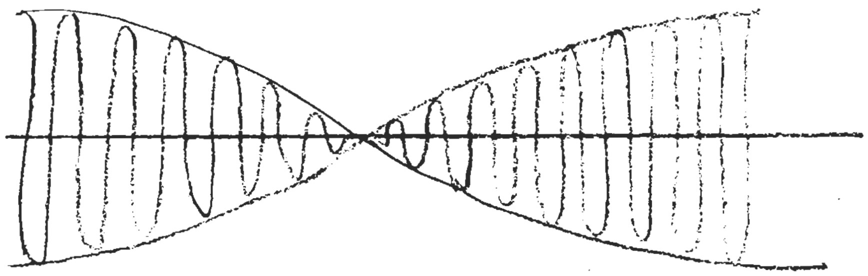
Definition: To vary the amplitude, frequency, phase, or other property of a carrier wave (usually sinusoidal) in proportion to a modulating signal, which contains the information to be carried.

Why modulate a signal?

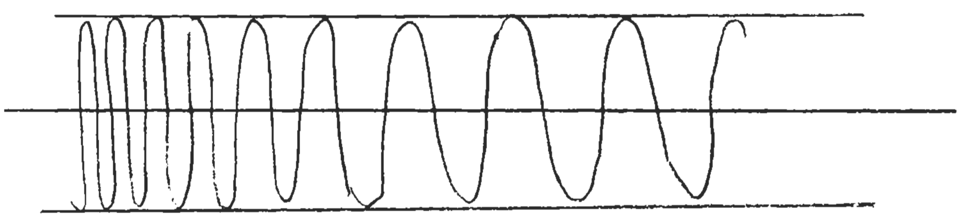
- to allow transmission over a medium
- to share a scarce transmission medium
  - RF spectrum
  - Cable
  - Fiber optics.

Types of modulation:

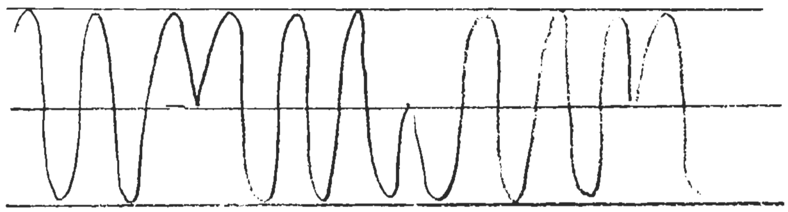
Amplitude modulation



Frequency Modulation:



Phase Modulation: (hard to draw)



Each modulation technique takes up a certain amount of spectrum

Band	Frequencies	BW/station	# stations
AM	530-1630 kHz	10 kHz	110
FM	88-108 MHz	200 kHz	100
VHF (air)	118-136 MHz	25 kHz	720

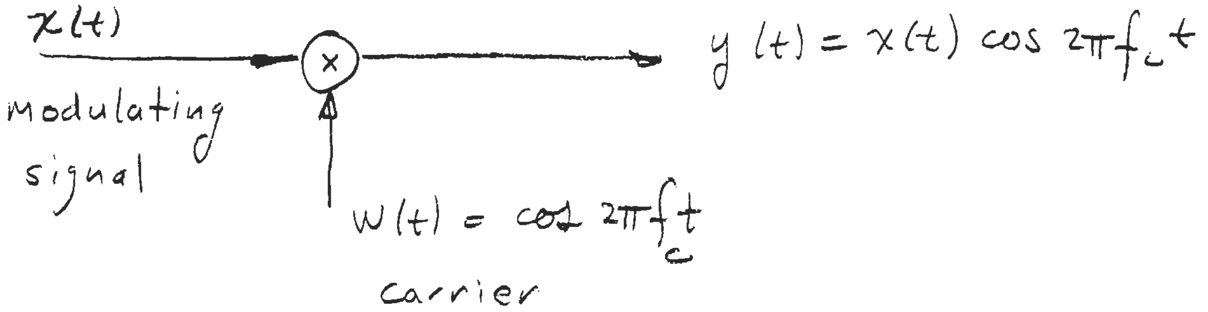
Fundamental Questions:

- why use a particular type of modulation?
- why do some methods take more BW than others?
- what are advantages/disadvantages?
- How do they work?

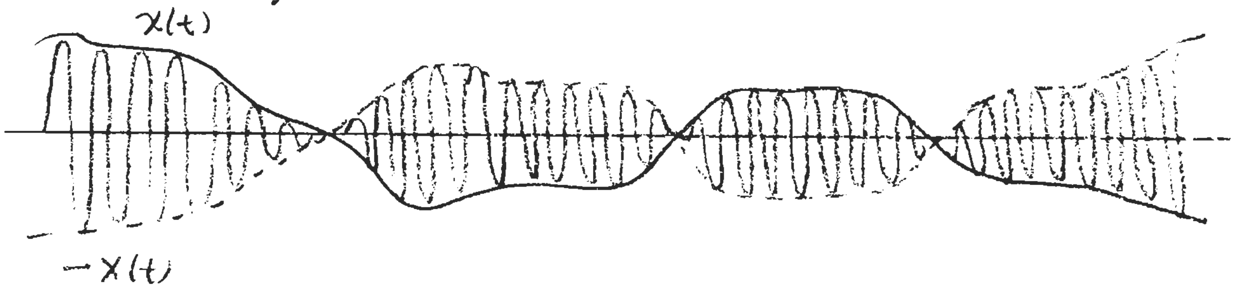
Amplitude Modulation (AM)

AM is the most common form of modulation, and the easiest to understand.

AM-DSB/SC (double side band, suppressed carrier)



Typical signal:

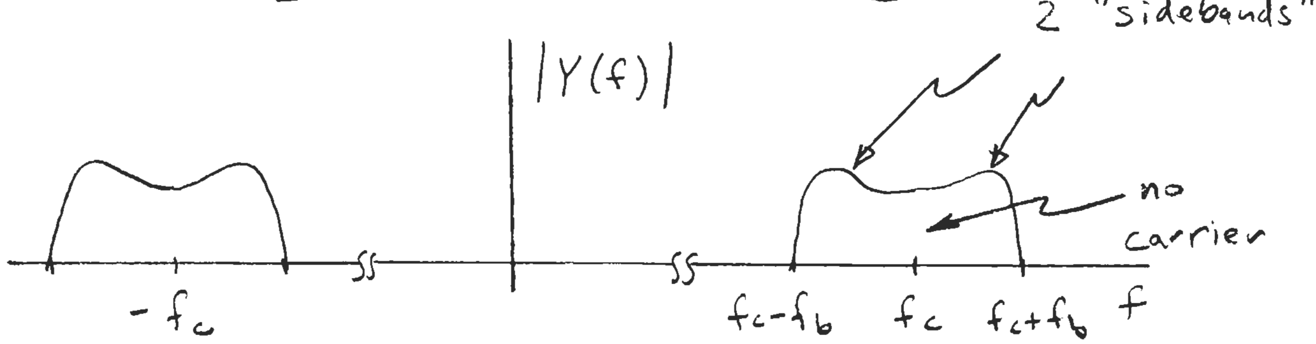


There is not too much to be said about the time domain signal.

Let's look at the frequency domain:

What is $Y(f)$?

$$Y(f) = X(f) * \frac{1}{2}\left(\delta(f-f_c) + \delta(f+f_c)\right)$$
$$= \frac{1}{2}\left[X(f-f_c) + X(f+f_c)\right]$$

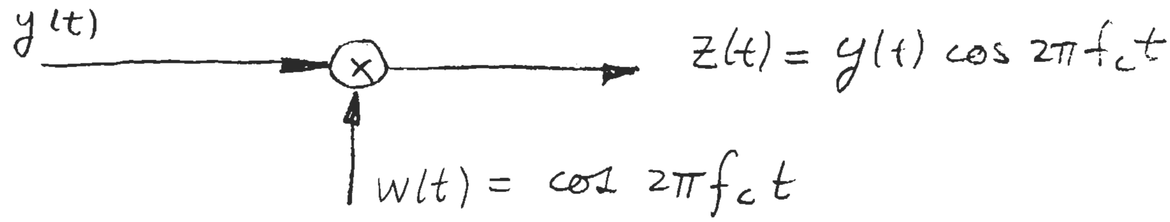


Because there are 2 sidebands, no carrier, this is called AM-DSB/SC.

How do we recover signal?

Demodulation of AM-DSB/SC

To recover $x(t)$, multiply by carrier



Analyze in frequency domain:

$$Y(f) = \mathcal{F}[y(t)]$$

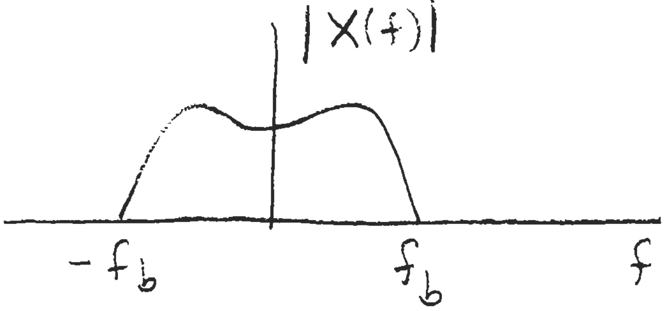
$$= \mathcal{F}[x(t)\,w(t)]$$

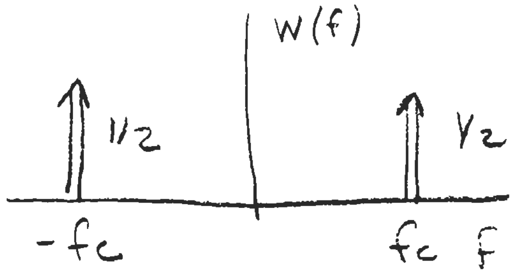
$$= X(f) * W(f)$$

$X(f) = \; ? \; =$ whatever information is on signal

$$W(f) = \mathcal{F}[\cos 2\pi f_c t]$$

$$= \frac{1}{2}\left(\delta(f - f_c) + \delta(f + f_c) \right)$$





"bandwidth" of signal

Typically, $f_c \gg f_b$.

AM radio:

$f_c \approx 1$ MHz
$f_b \approx 5$ kHz

$$Z(f) = Y(f) * \frac{1}{2}\left(\delta(f-f_c) + \delta(f+f_c)\right)$$

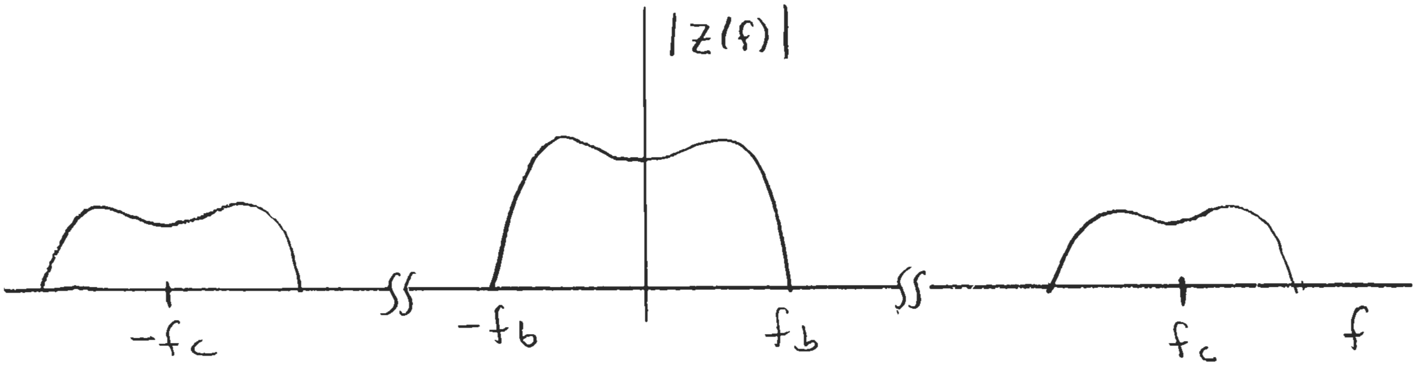
$$= \frac{1}{2}\left(Y(f-f_c) + Y(f+f_c)\right)$$

$$= \frac{1}{4}\left[X(f-2f_c) + X(f) + X(f) + X(f+2f_c)\right]$$

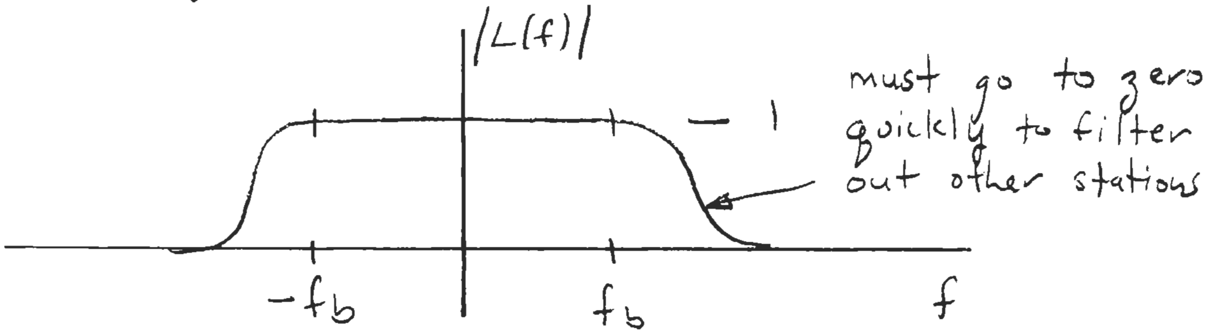
$$= \frac{1}{2}X(f) + \frac{1}{4}X(f-2f_c) + \frac{1}{4}X(f+2f_c)$$

signal of interest

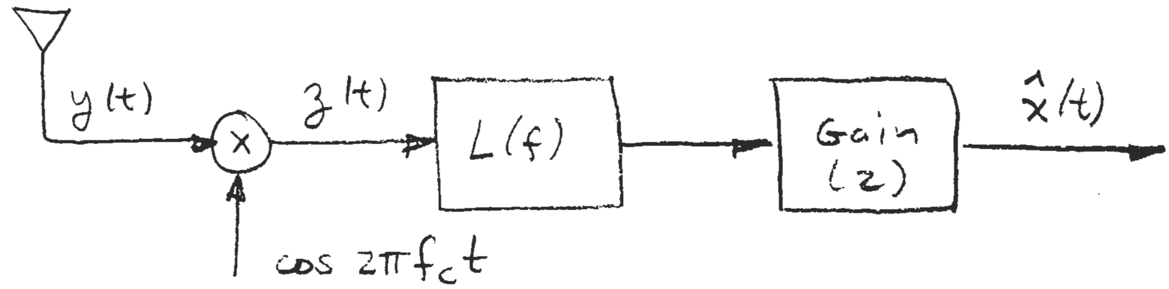
spurious high frequency signals



To eliminate high frequency copies, pass $y(t)$ through a <u>low-pass filter</u>, $L(f)$:



So demodulation looks like:



$\hat{x}(t) = x(t)$ if $L(f)$ is "ideal" and there is no noise.