AM - Modulation

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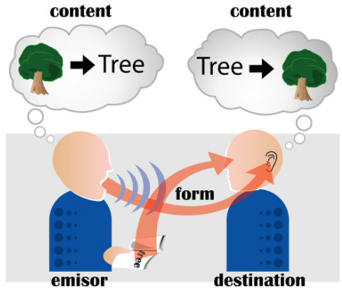
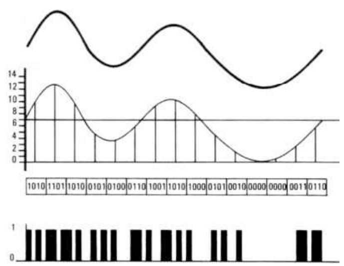
What is Communication?

- Definition: **communication** is a process of transferring information from one entity to another



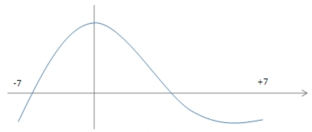
Analog, Discrete and Digital Signals

- An analog signal is a datum that changes over time – continuous
- A discrete-time signal is a sampled version of an analog signal: value of the datum is noted at fixed intervals rather than continuously.
- A digital signal is a quantized discrete-time signal

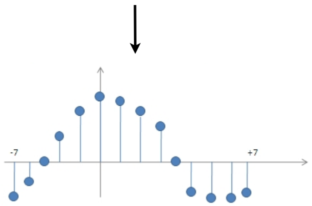


Deleuze's Analog and Digital Communication; Isomorphism; and Aesthetic Analogy

Example - Continuous and Discrete Signals



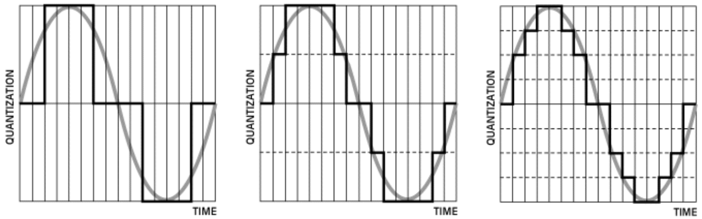
Continuous Signal
(takes values *in the set* [-7,7])



Discrete Signal
(takes values *at the integers* {-7,-6...0...6,7})

- Precision?
- Need Approximation
- Quantization

Example - Quantization



- All of them are discrete signals and digital signals
  - Digital signals with different quantization levels

Pop Quiz #1

Analog vs. Discrete

Pop Quiz #2

Analog vs. Discrete

Pop Quiz #3

Analog vs. Discrete vs. Digital

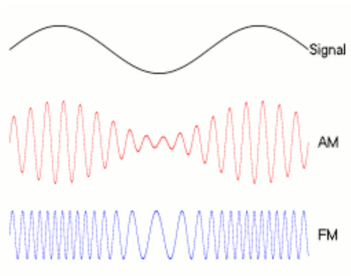
Modulation

- Process of conveying a message signal inside another signal that can be physically transmitted
- Message signals
  - Digital bit stream
  - Analog audio signal
- Alternatively, modulation of a sine waveform is used to transform a baseband message signal to passband signal
  - e.g., FM radio!

Analog and Digital Modulations

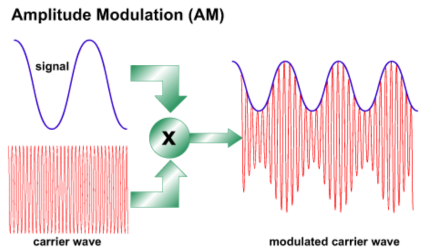
- Analog modulation - applied continuously in response to the analog information signal (first 4 lectures)
  - AM (Amplitude Modulation): amplitude of carrier signal is varied in accordance to instantaneous amplitude of modulating signal
    - Double-sideband modulation (DSB) [including DSB with unsuppressed carrier (DSB-WC), DSB suppressed-carrier transmission (DSB-SC), DSB reduced carrier transmission (DSB-RC)]
    - Single-sideband modulation (SSB, or SSB-AM) [including SSB with carrier (SSB-WC), SSB suppressed carrier modulation (SSB-SC)]
    - Vestigial sideband modulation (VSB, or VSB-AM)
    - Quadrature amplitude modulation (QAM)
  - Angle modulation
    - FM (Frequency modulation): frequency of carrier signal is varied in accordance to instantaneous value of modulating signal
    - Phase modulation (PM): phase shift of the carrier signal is varied in accordance to the instantaneous phase shift of the modulating signal)
- Digital modulation - analog carrier signal is modulated by a digital bit stream (from 5th lectures).

Illustration



Revisit: AM

- Amplitude of carrier signal is varied in accordance to instantaneous amplitude of modulating signal



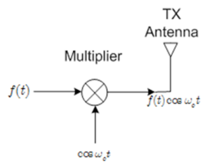
More detail,

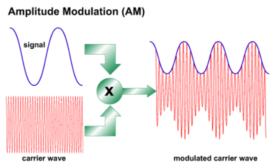
Time-varying amplitude (Envelope)

- General sinusoidal signal: $\phi(t) = \boxed{f(t)}\cos\boxed{\theta(t)}$
- Moreover, $\theta(t) = \omega_c t + \gamma(t)\,;\, \gamma(t) \leftarrow 0$ for AM

Time-varying angle

- So that, $\phi(t) = f(t)\cos(\omega_c t)$





- We call $\phi(t)$ modulated signal

Q: What happens in frequency domain?

Revisit: Fourier Transform Pair

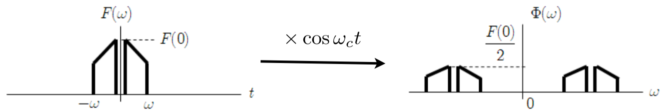
- Definition:

$$f(t) = \frac{1}{2\pi}\int_{-\infty}^{\infty} F(\omega)e^{j\omega t}d\omega \longleftrightarrow F(\omega) = \frac{1}{2\pi}\int_{-\infty}^{\infty} f(t)e^{-j\omega t}dt$$

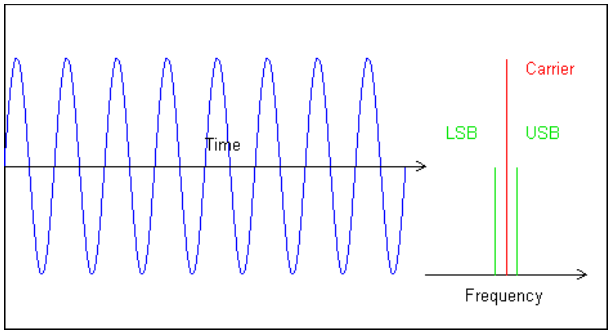
Inverse Fourier Transform   Fourier Transform

- Modulation Property: $f(t)e^{j\omega_c t} \longleftrightarrow F(\omega - \omega_c)$
- Euler's relationship: $\cos x = (e^{jx} + e^{-jx})/2$
- Therefore, for modulated signal : $\phi(t) = f(t)\cos(\omega_c t)$

$$\Phi(\omega) = \frac{1}{2}F(\omega + \omega_c) + \frac{1}{2}F(\omega - \omega_c)$$



Illustrative Animation



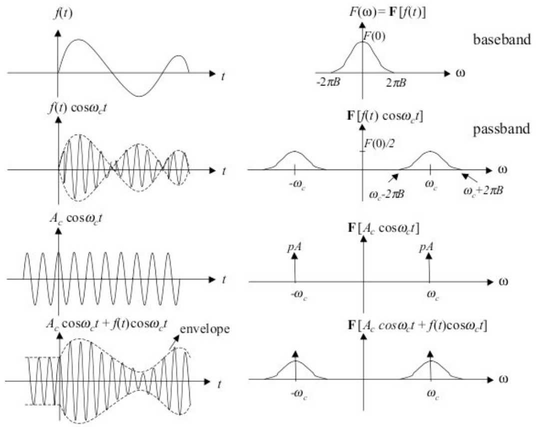
Commercial Broadcast Stations use...

- Double-sideband large-carrier (DSB-LC)
  - Simply adding a carrier term: $\phi_{AM}(t) = f(t)\cos(\omega_c t) + A\cos\omega_c t$
  - Spectral density:

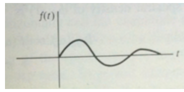
$$\Phi_{AM}(\omega) = \frac{1}{2}F(\omega+\omega_c) + \frac{1}{2}F(\omega-\omega_c) + \pi A\delta(\omega+\omega_c) + \pi A\delta(\omega-\omega_c)$$

$\rightarrow$ The same as $\Phi(\omega)$ except two impulses!

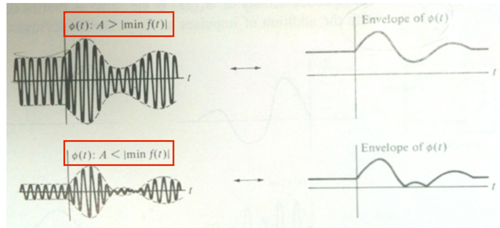
Spectral Density of DSB-LC



Modulation Index



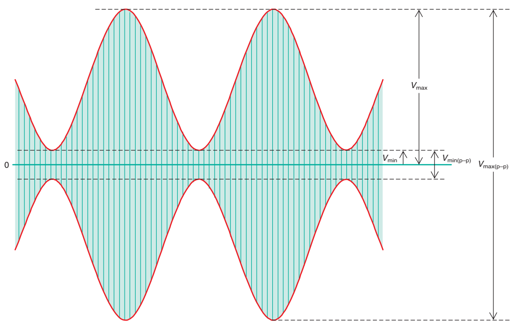
$f(t) = \cos\omega t$



- Define modulation index: $m = \dfrac{\text{peak DSB}-\text{SC amplitude}}{\text{peak carrier amplitude}} = \dfrac{\max(\cos\omega t)}{A} = \dfrac{1}{A}$
- So that $\phi_{AM}(t) = A(1 + m\cos\omega t)\cos\omega_c t \to 1 + m\cos\omega t \geq 0 \Rightarrow m \leq 1$
- Hence, to be correctly demodulated, $m \leq 1$

→ Interpretation: how much modulated variable varies around its 'original' level

Modulation Index - Alternative Definition



Peak value of modulating signal :

$$V_m = \frac{V_{max} - V_{min}}{2}$$

Peak value of carrier signal :

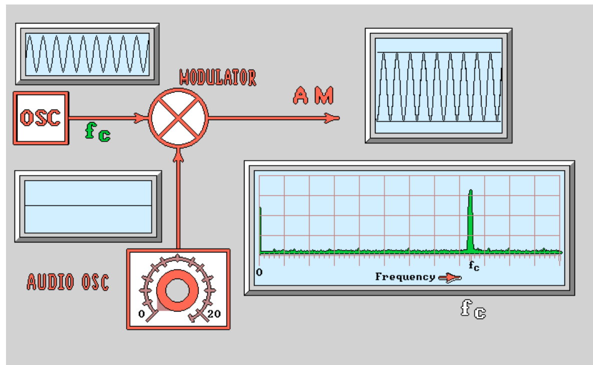
$$V_c = \frac{V_{max} + V_{min}}{2}$$

Modulation index:

$$m = \frac{V_{max} - V_{min}}{V_{max} + V_{min}}$$

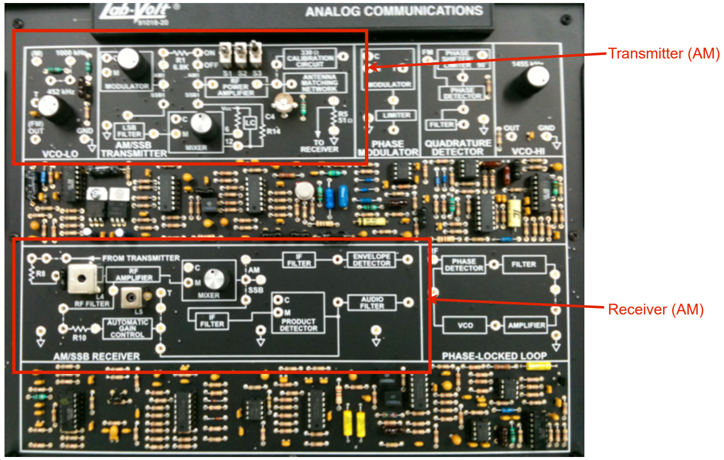
*See slide 13 for illustration

Animation

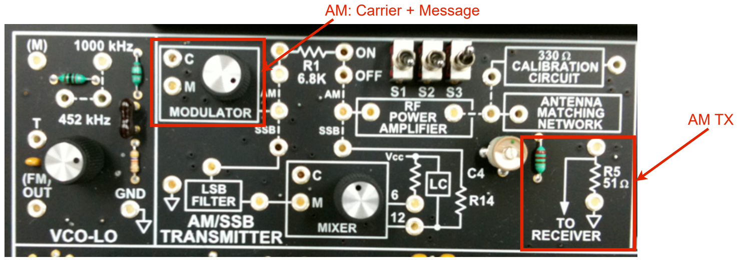


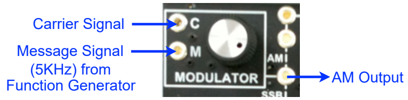
Local file: Lec_AM_animation.gif

Your experiments...



AM Transmitter

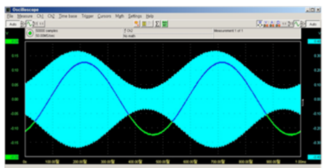




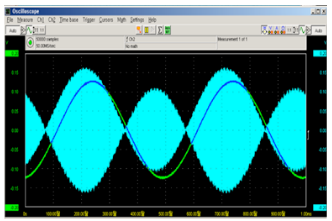
- You may play by changing
  - carrier frequency, modulation index, AM/SSB modes, etc.

Illustrative results

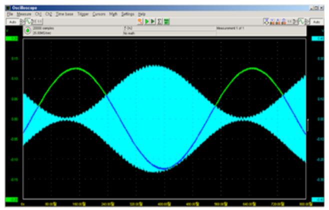
- Modulated Signals



index < 1



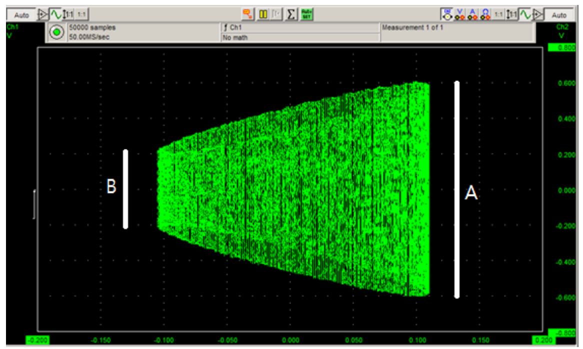
index > 1



index = 1

Illustrative results

- Try to change modulation index and observe results in X-Y plot



Case of m<1