EECS 216 SPECTRA FOR MODULATION METHODS

Def: *Modulation* of a message signal $m(t)$: Multiplies $m(t)$ by a sinusoid.
So: Modulated signal: $x(t) = m(t)\cos(2\pi f_c t)$ where f_c=*carrier* frequency.
Why? So why do we modulate signals $m(t)$ for communications purposes?

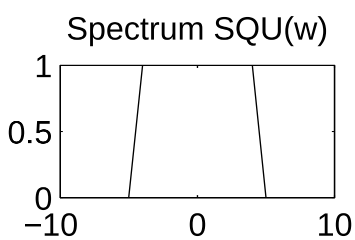
1. *Transmission:* $m(t)$ can't be radio broadcast; $x(t)$ can (higher freqs).
2. *Freq. multiplexing:* Transmit several messages $m_i(t)$ using one $x(t)$.

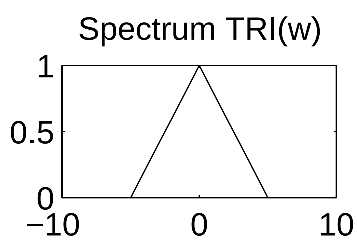
Recall: $\mathcal{F}\{m(t)\cos(\omega_c t)\} = \frac{1}{2}M(\omega-\omega_c)+\frac{1}{2}M(\omega+\omega_c)$ where $\mathcal{F}\{m(t)\} = M(\omega)$.
Huh? Multiply $m(t)$ by $\cos(\omega_c t)$ shifts spectrum $M(\omega)$ up and down by ω_c.
Below: $\mathcal{F}\{squ(t)\} = SQU(\omega); \mathcal{F}\{tri(t)\} = TRI(\omega); \mathcal{F}\{bowl(t)\} = BOWL(\omega)$.

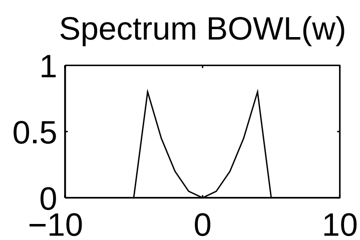
DSBSC: Send 3 signals at once by modulating them at different carrier freqs.
Each: Maximum freq.=5, bandwidth=10; total signal has bandwidth=100.
Note: 3 modulated signals separated by bandwidth=2(maximum frequency)!

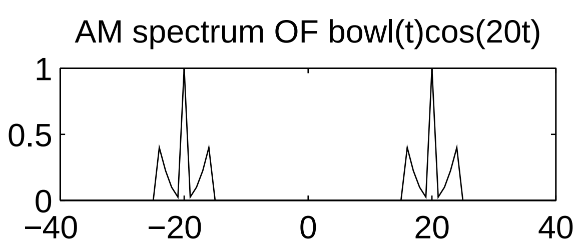
AM: Amplitude Modulation; adds in *carrier* $\cos(20t)$: $[(1+m(t))\cos(20t)]$.
Why? Receive AM using envelope detector (1+m(t)>0); easy to find signal.
DSBSC: Double SideBand Suppressed Carrier (excludes carrier): $[m(t)\cos(20t)]$.
Why? Don't waste power transmitting carrier; still use envelope if $m(t) > 0$.

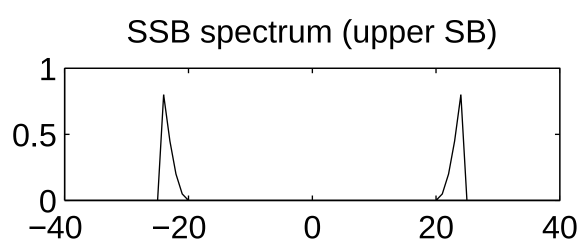
Goal: Send two signals left(t) and right(t) as one single signal stereo(t).
So: Can recover mono signal left(t)+right(t) directly from baseband.
Soln: stereo(t)=[left(t)+right(t)]+[left(t)–right(t)]$\cos(2\pi 38000t)$ works.

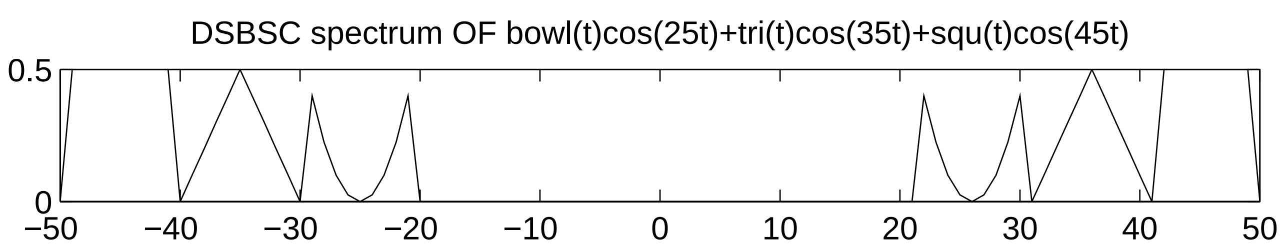










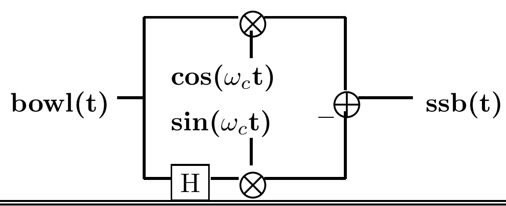


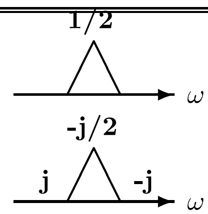
EECS 216 SINGLE SIDEBAND (SSB)

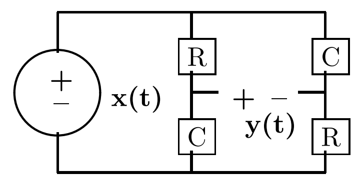
What: Transmit only upper sidebands of the modulated $m(t)$ (see overleaf).
Why? Half the bandwidth & half the power; has half the noise (same SNR).
Where: Digital TV (vestigial sideband); DSL modems; CB and ham radios.
How? A *really* sharp filter would clip the sidebands! Is there an easier way?

Def: The *Hilbert transform* of $x(t)$ is $\mathcal{H}\{x(t)\} = \int_{-\infty}^{\infty} \frac{x(\tau)}{\pi(t-\tau)} d\tau = x(t) * \frac{1}{\pi t}$.
Huh? $\mathcal{F}\{\frac{1}{\pi t}\}$=–jSGN($\omega$)=–j if $\omega > 0$; j if $\omega < 0$. -90^o phase shift for $\omega > 0$.
How? Circuit below right: $|H(\omega)|$=1 and $\angle H(j\omega)$=-90^o at ω=1/(RC).

So? Let ssb(t)=bowl(t)cos($\omega_c t$)–$\mathcal{H}$\{bowl(t)\} sin($\omega_c t$) for bowl(t) overleaf.
Then: ssb(t) has the spectrum shown overleaf: Only upper sidebands appear!
Since: Lower sidebands of bowl(t)cos($\omega_c t$) and $-\mathcal{H}$\{bowl(t)\} sin($\omega_c t$) cancel.







So? Only use half as much bandwidth to transmit $m(t)$; more efficient.
Hence: Can transmit twice as many messages using the same bandwidth!
And: Use half the power. Smaller bandwidth→half the noise (same SNR).

ENVELOPE RECEIVERS & HETERODYNE DEMODULATORS

Goal: Recover $m(t)$ from (1+m(t))cos($\omega_c t$) (AM) or $m(t)\cos(\omega_c t)$ (DSBSC).

AM: If $|m(t)| < 1$ then 1+m(t)> 0 and we may use an *envelope detector*:
1.) Pass signal through a diode: keeps only positive parts of the signal.
2.) Then a capacitor smoothes out the carrier oscillations, leaving $m(t)$.

AM: **Superheterodyne** receiver (most transistor radios; goes back to 1920):
Use: 2[(1+m(t))cos($2\pi f_c t$)] cos($2\pi(f_c - 455000)t$)=(1+m(t))cos($2\pi 455000 t$) +(1+m(t))cos($2\pi(2f_c - 455000)t$). Latter term is the *image*–filter out.
Then: Intermediate filter centered at 455 kHz and then envelope detector.
Why? More selective; avoids carrier phase problem noted below; history.

DSBSC: Can't use envelope detector: $m(t) < 0$ →phase reversals at those times.
So: Send: y(t)=m(t)cos($\omega_c t$). Rcvr: y(t)cos($\omega_c t$)=$\frac{1}{2}$m(t)+$\frac{1}{2}m(t)\cos(2\omega_c t)$.
Then: Latter term is *image* frequency component; filtered by earphone/speaker.

But: Carrier *phase* unknown to receiver; received $m(t)\cos(\Delta\text{phase})$ may=0!
Why? $\underbrace{2[m(t)\cos(\omega_c t+\theta)]\cos(\omega_c t)}_{\text{UNKNOWN CARRIER }\theta} = \underbrace{m(t)\cos(\theta)}_{\text{FADING}} + \underbrace{m(t)\cos(2\omega_c t+\theta)}_{\text{IMAGE(filtered out)}}$.

SSB: Rcvr∼xmitter except sign: bowl(t)=ssb(t)cos($\omega_c t$)+$\mathcal{H}$\{ssb(t)\} sin($\omega_c t$).
Why? Keep upper/lower sideband when shift down/up for freqs > / <0.
Mix: Compute 4x(t)y(t)=$[x(t)+y(t)]^2$–$[x(t)-y(t)]^2$ using square-law device.