Lecture 7: More AM Modulation Methods

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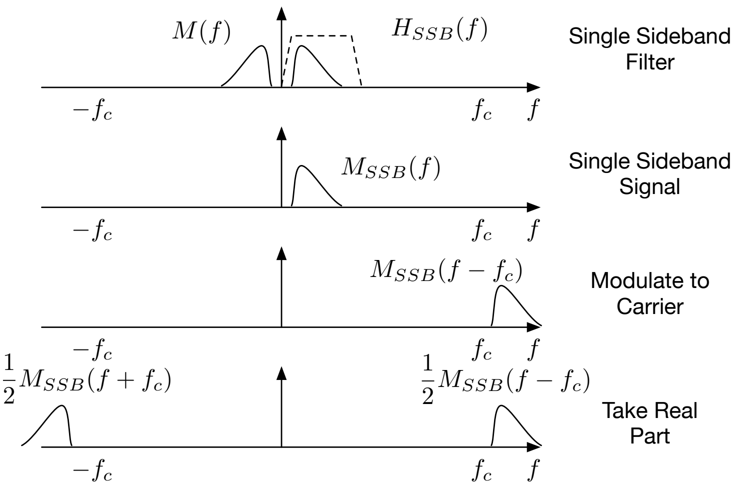
More AM Modulation Methods

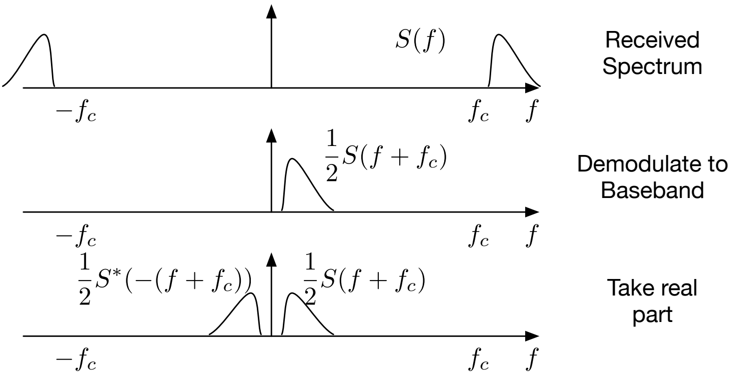
- Vestigial sideband modulation (VSB)
  - VSB spectrum
  - Modulator and demodulator
  - NTSC TV signsals
- Quadrature modulation
  - Spectral efficiency
  - Modulator and demodulator

SSB Modulation



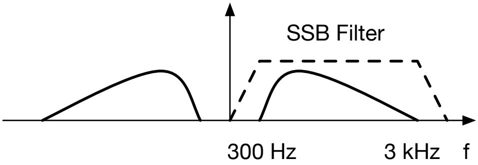
SSB Demodulation

To decode the SSB signal, we just reverse the operations



Vestigial Sideband Modulation (VSB)

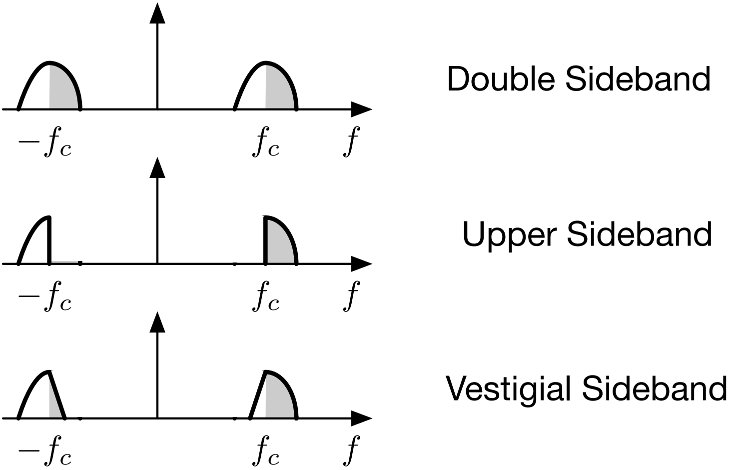
- SSB relies on being able to filter out one sideband. For audio this is possible because the voice spectrum drops off below 300 Hz, allowing space for a transition band



- This is not possible for other signals, like video, that have strong components at low frequencies.

VSB Idea

The solution is *Vestigial Sideband Modulation, VSB* where a small portion (a vestige) of the unneeded sideband. This reduces DC distortion.



- VSB signals are generated using standard AM or DSB-SC modulation, then passing modulated signal through a sideband shaping filter.

- The signal can be designed so that demodulation uses either standard AM or DSB-SC demodulation, depending on whether a carrier tone is transmitted.

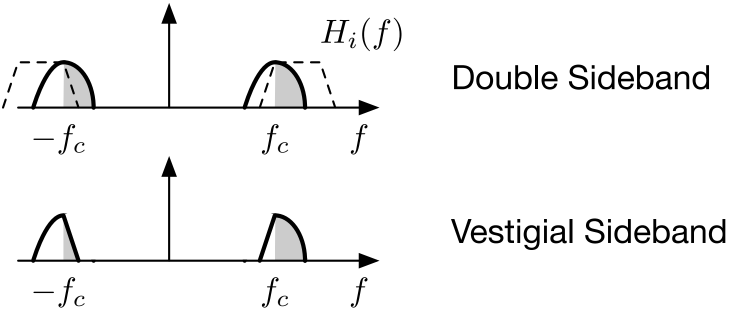
- VSB modulation with envelope detection are used to modulate image in analog TV signals. (The audio signal is modulated using FM.)

VSB Modulator

The transmitted signal has spectrum

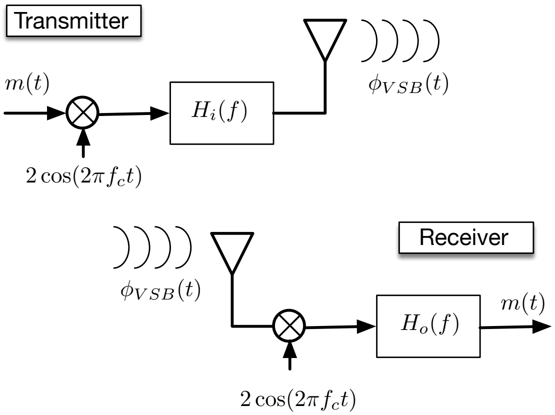
$$\Phi_{\mathrm{VSB}}(f) = \big(M(f+f_c) + M(f-f_c)\big)H_i(f)$$

where $H_i(f)$ is the *shaping filter* for the VSB modulator.



VSB System

We transmit the VSB signal $\phi_{VSB}(t)$,



How do we choose the receiver filter $H_o(f)$ so that we get the original message back?

VSB Receiver

- The intermediate signal after the demodulator is

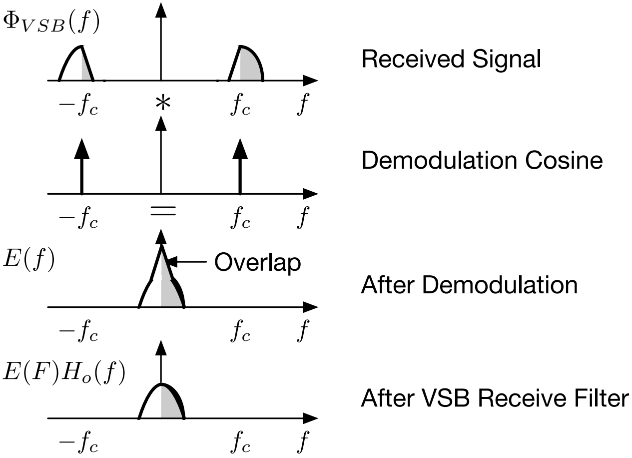
$$e(t) = \phi_{\mathrm{VSB}}(t) \cdot 2\cos\omega_c t$$

  has spectrum

$$\Phi_{\mathrm{VSB}}(f + f_c) + \Phi_{\mathrm{VSB}}(f - f_c)$$

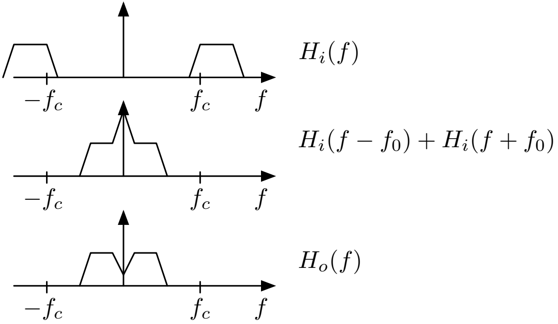
- This has two copies of the signal that are shifted to baseband, but unfortunately they overlap!
- This is then filtered by $H_o(f)$.

This looks like:



The filter $H_o(f)$ needs to compensate for the fact that the two sidebands overlap when demodulated to baseband.

VSB Receive Filter



We can recover $m(t)$ by using a filter $H_o(f)$ defined by

$$H_o(f) = \frac{1}{H_i(f + f_c) + H_i(f - f_c)}, \quad |f| \leq B$$

Note that the division is only done over the signal bandwidth!
How could we design $H_i(f)$ to make our lives easier?

VSB Encoding and Decoding

- There are lots of other ways to encode and decode VSB, especially if we are using SDR's.
- You'll see one in the next homework that uses complex modulation, a different filter, and a neat Fourier transform symmetry trick.
- VSB signals turn up in many different places
- The analog TV system NTSC used VSB to save bandwidth
- VSB is widely used in Magnetic Resonance Imaging (MRI) to reduce the amount of data you need to collect

Quadrature Amplitude Modulation (QAM)

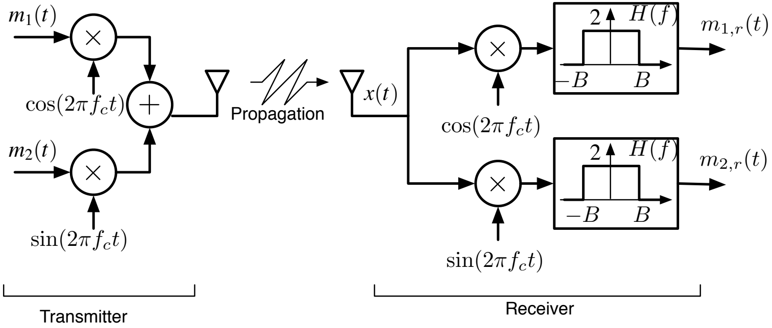
- DSB-SC modulates a signal with bandwidth B to a transmitted signal with bandwidth $2B$
- SSB reduces the transmitted bandwidth to B, but
  - requires more complex modulator
  - reduces SNR (for a fixed carrier amplitude)
- Quadrature amplitude modulation uses the $2B$ transmitter bandwidth to send two independent (real) signals:

$$m_{QAM,c}(t) = m_1(t)\cos(2\pi f_c t) + m_2(t)\sin(2\pi f_c t)$$

- QAM has the same *spectral efficiency* as SSB but does not need sharp band-pass filters
- QAM is used in almost all digital communication methods, including telephone modems, cable TV, satellite TV

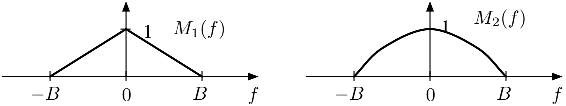
QAM Modulator and Demodulator

Two real messages, $m_1(t)$ and $m_2(t)$. m_1 is modulated on a cosine, and $m_2(t)$ is modulated on a sine.

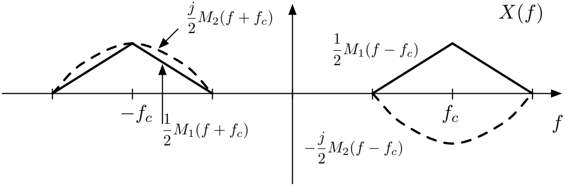


Note that we need a synchronous receiver, or the two channels will interfere. What happens with a 90° phase shift?

If the input spectra look like



Then the transmitted spectrum looks like



Then demodulating with a cosine will give me $M_1(t)$ at baseband, and demodulating with a sine will give me $M_2(t)$.

QAM

- One way to think about this system is that we send $m_1(t)$ on the real, or in phase channel (modulate and demodulate with $\cos(2\pi f_c t)$)
- The second message $m_2(t)$ is sent on the imaginary, or quadrature channel (modulate and demodulate with $\sin(2\pi f_c t)$)
- There are generalizations that use many phases and amplitudes to send lots of digital bits at once.
- This is widely used for cable TV, such as QAM-64. We'll see this later in the course.

AM Modulation

- Many different ways to encode information as amplitude
  - AM
  - DSB-SC AM
  - SSB
  - VSB
  - QAM
- Common issues
  - Synchronization
  - Bandwidth
- Next: Encoding information in frequency