ECE 215 Spring 2025

Objective 3.2: Demodulation

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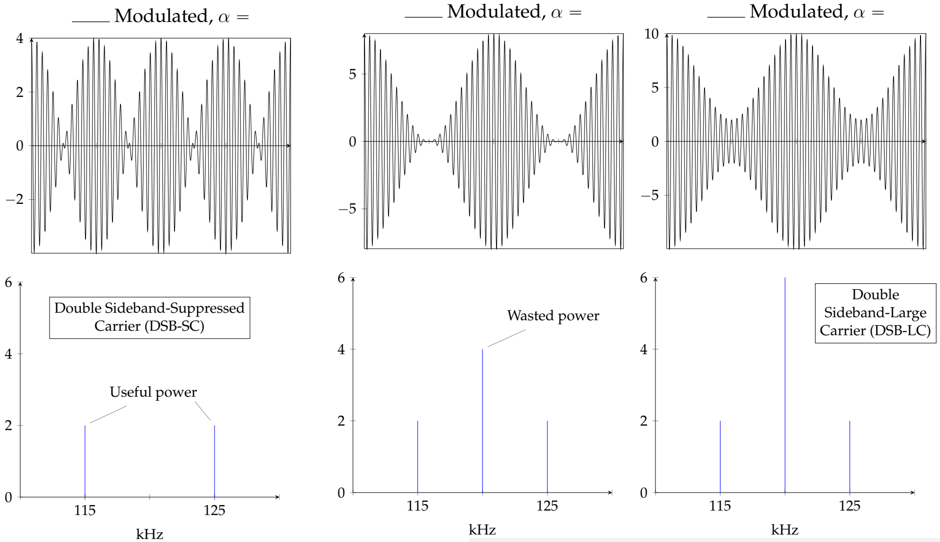
Objective 3.2

I can design a demodulator given a modulated signal for envelope and synchronous detection.

Remember 3 Forms of an AM Signal



Efficiency

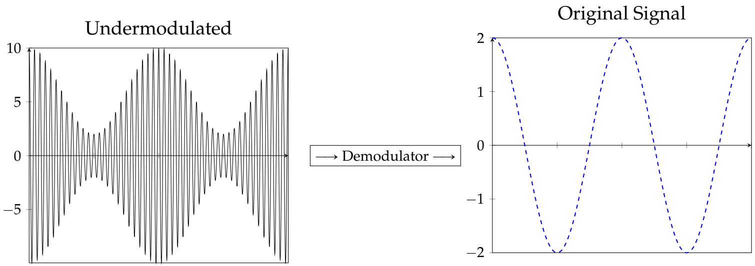
- Recall the definition of efficiency:

$$\eta = \frac{\mathrm{P}_{\text{useful}}}{\mathrm{P}_{\text{useful}} + \mathrm{P}_{\text{wasted}}} = \frac{\mathrm{P}_{\text{upper sideband}} + \mathrm{P}_{\text{lower sideband}}}{\mathrm{P}_{\text{total}}}$$

- With modulation index of α, we have: $\eta = \dfrac{\alpha^2}{\alpha^2 + 2}$
- For bias = 0V : $\eta =$
- For fully modulated signal: $\eta =$
- As α decreases, efficiency decreases
- So why use 100% modulated or undermodulated signals?

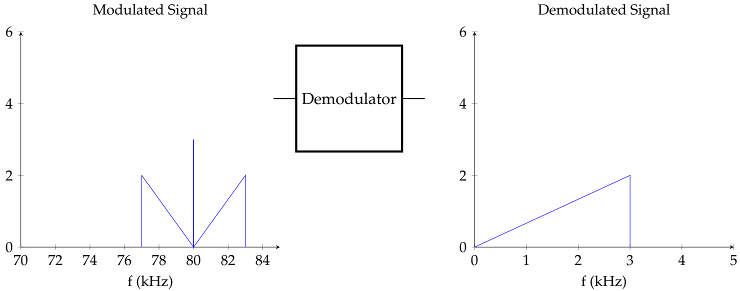
Types of Demodulators

- Demodulators "undo" the modulation we just did
- Synchronus detection (works for all AM signals)
  - Expensive, more complicated
- Envelope detector (works for 100% or undermodulated)
  - Cheap and easy to build



Demodulating Overmodulated Signals

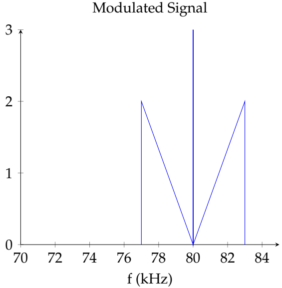
What is the modulation index of the modulated signal?



$$\alpha = \frac{A_m}{B} = \frac{2 * \left(\frac{A_c A_m}{2}\right)}{B A_c} =$$

SYNCHRONOUS DETECTOR

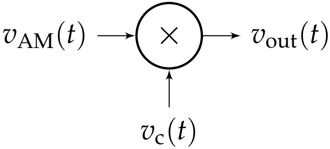
In the frequency domain, we have the following signal:

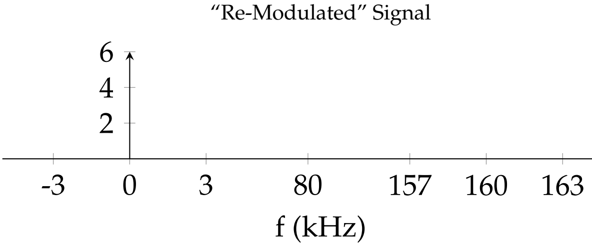


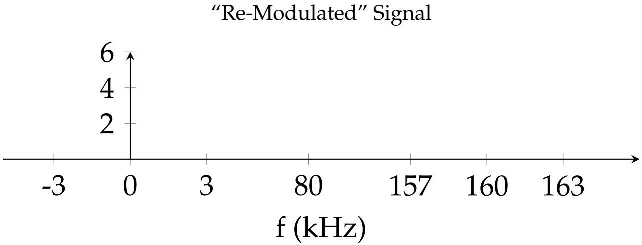
- What is the message signal?
- What is the carrier frequency?

Synchronous Detector

Multiplying the received signal by the carrier frequency...

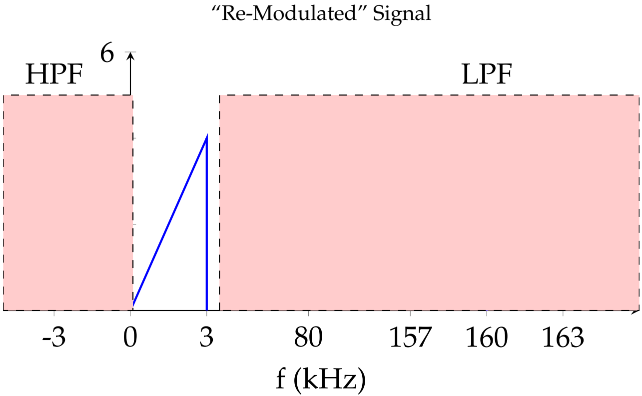






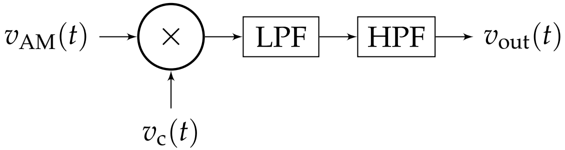
Synchronous Detector (cont'd)

Now we get rid of the stuff we don't want:



Synchronous Detector - Final Form

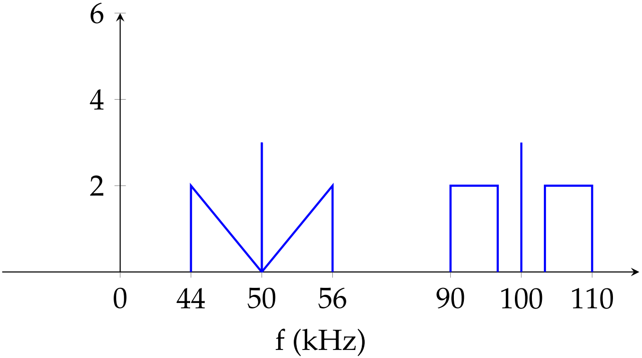
The final form of the synchronus detector is:



- LPF: f_{cut} = value slightly larger than $f_{m,max}$
- HPF: $f_{cut} = 10\text{Hz}$

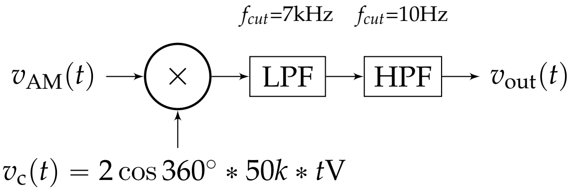
Synchronous Example

Design a synchronous detector to recover the message signal centered at 50kHz.

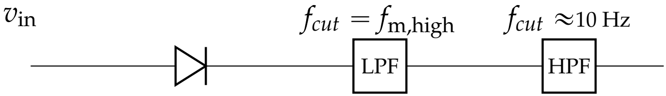


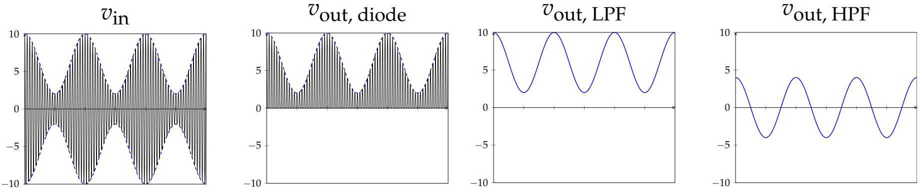
Synchronous Example Solution

The final form of the synchronus detector is:



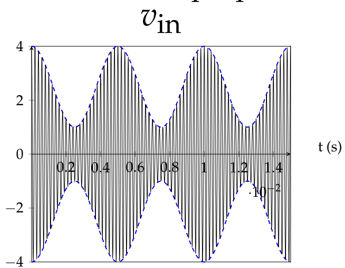
Demodulating 100%/Undermodulated Signals





Envelope Detection Example

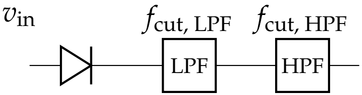
Determine the proper filter cutoff frequencies.

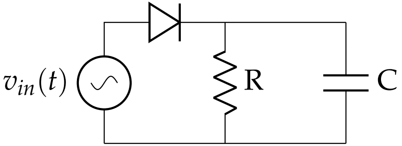


$$T_{\text{m}} = 5\text{ms} \implies f_{\text{m}} =$$

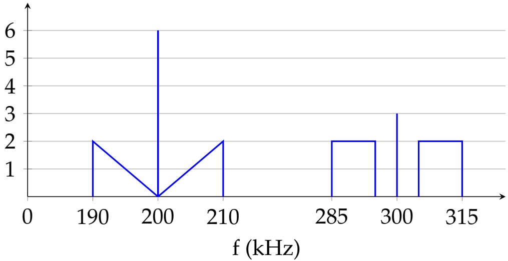
$$f_{\text{cut, LPF}} =$$

$$f_{\text{cut, HPF}} =$$





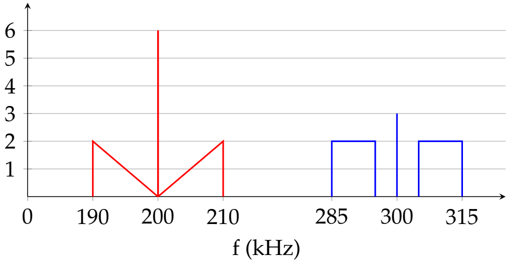
Demodulation Example



For $A_c = 2\text{V}$:

- What is the modulation index for each signal?
- What is the efficiency?
- Is the signal over-, under-, or fully-modulated?
- What demodulator(s) can you sue for each signal?
- Design a demodulator for each signal

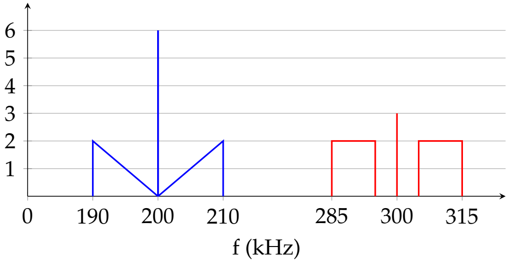
Demodulation Example



For $A_c = 2\text{V}$: (Signal centered at 200kHz)

- What is the modulation index for each signal? $\alpha_1 = \dfrac{2+2}{6} = 0.667$
- What is the efficiency? $\eta_1 = \dfrac{0.667^2}{0.667^2 + 2} = 18.2\%$
- Is the signal over-, under-, or fully-modulated?
- What demodulator(s) can you sue for each signal? Synchronous or Envelope
- Design a demodulator for each signal Envelope, LPF @ ~11kHz, HPF @ 10Hz

Demodulation Example



For $A_c = 2\text{V}$: (Signal centered at 300kHz)

- What is the modulation index for each signal? $\alpha = \dfrac{2+2}{3} = 1.333$
- What is the efficiency? $\eta_1 = \dfrac{1.333^2}{1.333^2 + 2} = 47\%$
- Is the signal over-, under-, or fully-modulated?
- What demodulator(s) can you sue for each signal? Synchronous
- Design a demodulator for each signal Synchronous, multiplier @ 300kHz, LPF @ ~16kHz, HPF @ 10Hz

Tradeoffs

Detector Type	Applicability	Receiver Complexity	Efficiency
• Envelope	• Fully modulated • Under modulated	• Cheap • Easy to build	• Wasted power due to required bias
• Synchronous	• All types	• Expensive • Complex to build	• Very efficient (up to 100%!)