- Envelope detection of AM signals


envelope

- How to recover the envelope?

full-wave rectifier

$$x(t) = f(t) \cos(w_c t) \longrightarrow \boxed{|\cdot|} \longrightarrow |x(t)|$$

- # Envelope detection of AM signals-cont

- **How to recover the envelope?**

$|x(t)| = |f(t)\cos(\omega_c t)| = f(t)|\cos(\omega_c t)| =$

> 0 assume for now
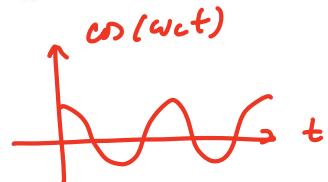
$= f(t)\left[\dfrac{c_0}{2} + \sum_{n=1}^{\infty} c_n \cos(2\omega_c n t + \theta_n)\right] =$

$= \dfrac{c_0}{2} f(t) + \sum_{n=1}^{\infty} c_n f(t)\cos(2\omega_c n t + \theta_n)$

will be filtered out

$\downarrow \mathcal{F}$

$\dfrac{c_0}{2} F(\omega) + \sum_{n=1}^{\infty} c_n \left[\dfrac{F(\omega - 2n\omega_c)e^{j\theta_n} + F(\omega + 2n\omega_c)e^{-j\theta_n}}{2}\right]$

$|a+b| \neq |a| + |b|$
not linear!

$\cos(\omega_c t)$

$|\cos(\omega_c t)|$

periodic
$\omega_0 = 2\omega_c$

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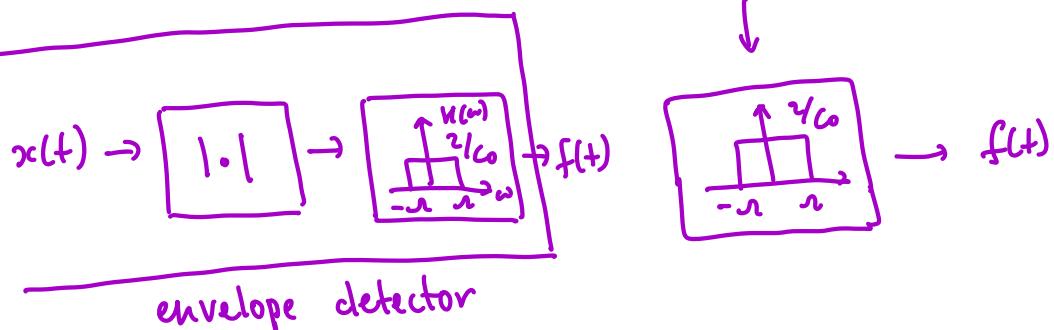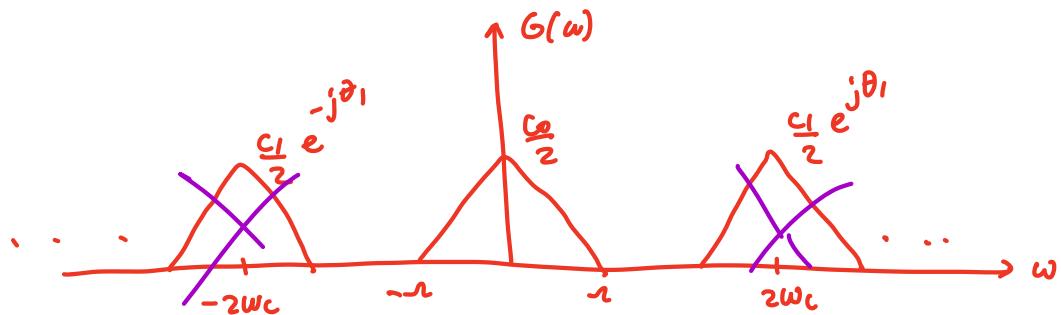
# Envelope detection of AM signals-cont
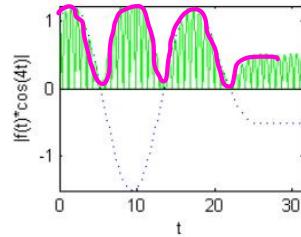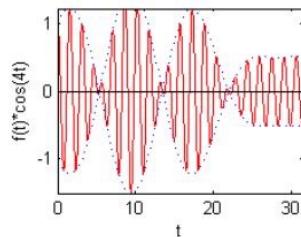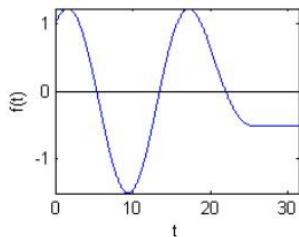
- How to recover the envelope?

$$|x(t)| = g(t) = f(t)|\cos(\omega_c t)| = \frac{c_0}{2} f(t) + \sum_{n=1}^{\infty} c_n f(t) \cos(n2\omega_c t + \theta_n)$$

envelope detector

- # Envelope detection of AM signals-cont
 - What if $f(t) \ngeq 0$?

$$f(t) \rightarrow \widehat{\Sigma} \rightarrow \otimes \rightarrow \; ..$$

DC

$\cos(\omega_c t)$
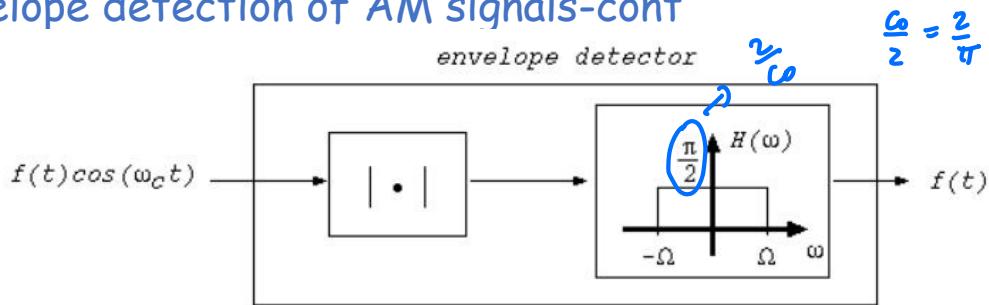
- Envelope detection of AM signals-cont
  - What if the channel is not ideal, e.g. time delay?

• Envelope detection of AM signals-cont

$$\frac{\omega}{2} = \frac{2}{4}$$

$$\frac{2}{\omega}$$
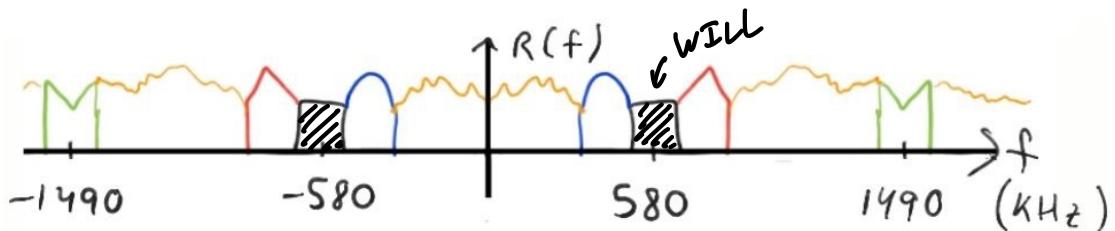
envelope detector

$$f(t)\cos(\omega_c t) \longrightarrow \boxed{|\bullet|} \longrightarrow \boxed{\begin{array}{c} \frac{\pi}{2} \quad H(\omega) \\ -\Omega \quad \Omega \quad \omega \end{array}} \longrightarrow f(t)$$

- • It is not linear!
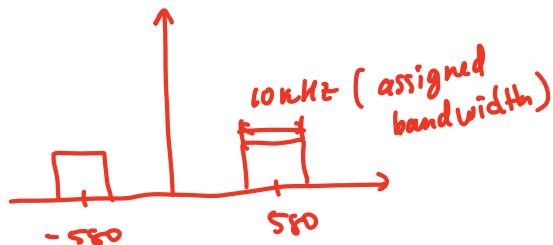
- Superheterodyne AM receiver with envelope detection
  - Real wireless transmission has signals across a broad frequency spectrum:

  - For envelope detection to work, need to isolate signal, how?

Need to get our signal by itself, so that envelope detection works.

A BPF would achieve this, but needs to be selective and tunable ⇒ expensive!

We will do it in 3 cheaper steps ☺
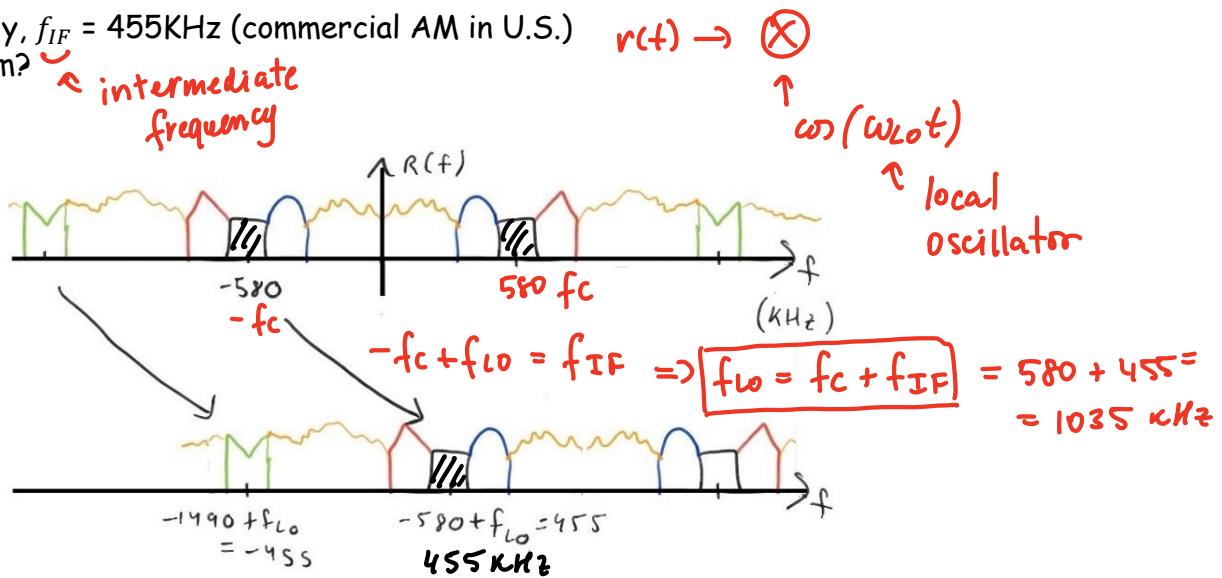
- # Superheterodyne AM receiver with envelope detection-cont
  - ### Heterodyne: demodulate to a lower carrier frequency
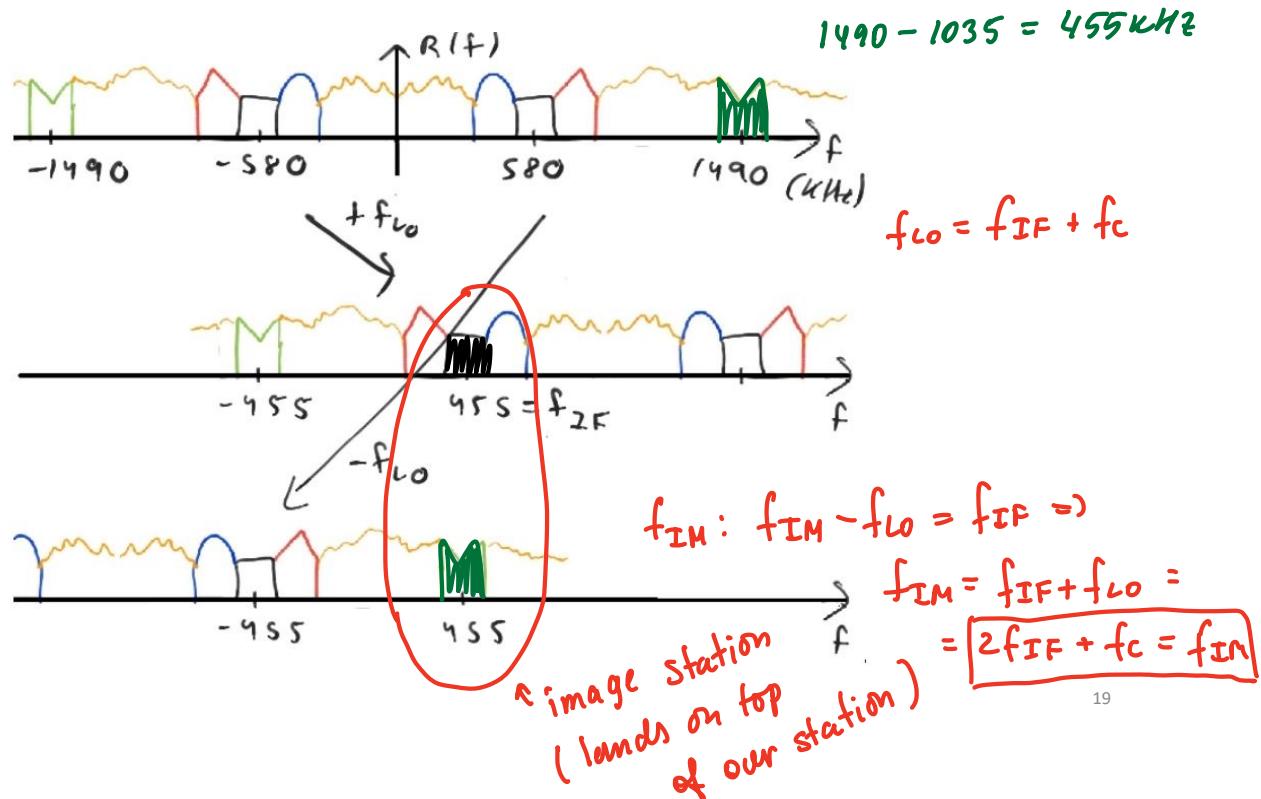
    - Typically, f_{IF} = 455KHz (commercial AM in U.S.)
    - Problem?

$r(t) \rightarrow \otimes$
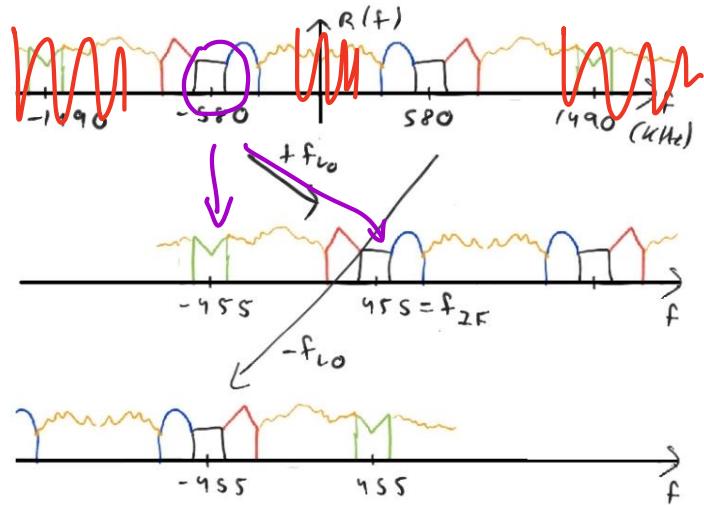
← *intermediate*
frequency

$\cos(\omega_{LO}t)$

↖ local
oscillator

$R(f)$

-580
- fc

580 fc

(kHz)

$-fc + f_{LO} = f_{IF} \Rightarrow \boxed{f_{LO} = fc + f_{IF}} = 580 + 455 = $

$= 1035 \, kHz$

$-1490 + f_{LO}$
$= -455$

$-580 + f_{LO} = 455$

455 KHz

- Superheterodyne AM receiver with envelope detection-cont

$1490 - 1035 = 455\,kHz$

$f_{LO} = f_{IF} + f_C$

$f_{IM}: \quad f_{IM} - f_{LO} = f_{IF} \Rightarrow$

$f_{IM} = f_{IF} + f_{LO} =$

$= \boxed{2f_{IF} + f_C = f_{IN}}$

↖ image station
(lands on top
of our station)

- Superheterodyne AM receiver with envelope detection-cont
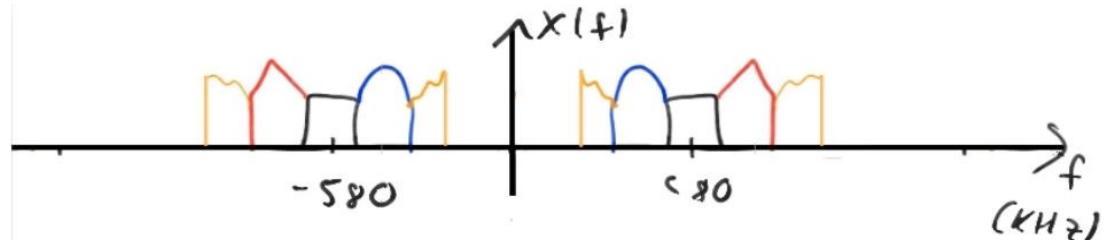

- Image station problem
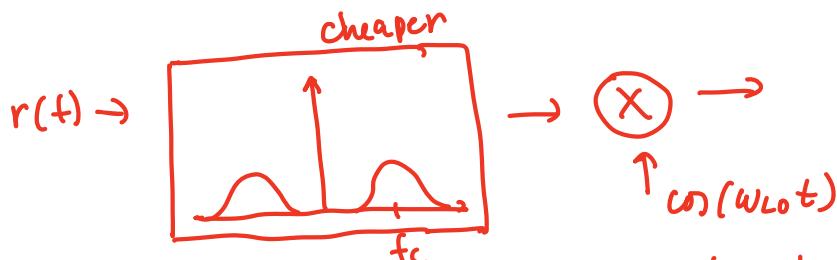
  How to fix it? Preselector BPF

- ## Superheterodyne AM receiver with envelope detection-cont
  - Real wireless transmission has signals across a broad frequency spectrum:

$\uparrow X(f)$

-580 ≤ 80

$\rightarrow f$

(KHz)
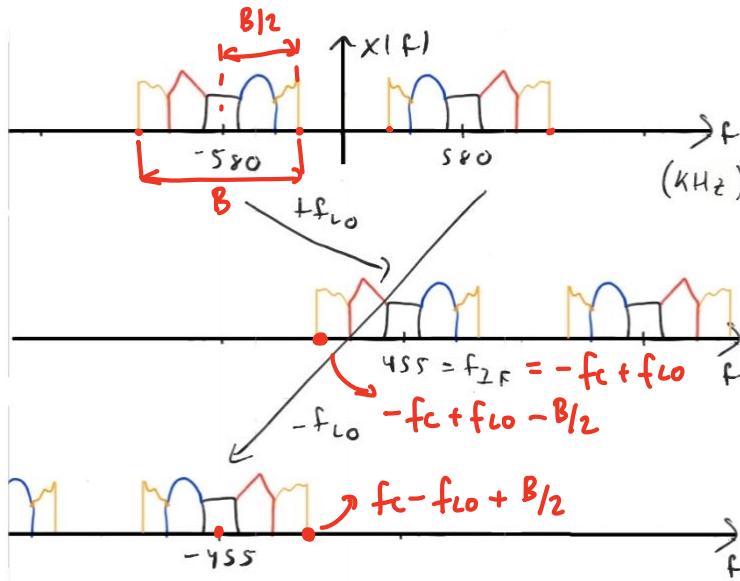
  - Bandwidth of filter?

cheaper

$r(t) \rightarrow$

$\boxed{X}$ $\rightarrow$

$\uparrow \cos(w_{LO} t)$

f_c

Preselector BPF: tunable, not selective (so wide)

- Superheterodyne AM receiver with envelope detection-cont

$B/2$

$X(f)$

-580

B

580

(kHz)

$+f_{LO}$

$-f_{LO}$

$455 = f_{2F} = -f_c + f_{LO}$

$-f_c + f_{LO} - B/2$

$f_c - f_{LO} + B/2$

-455

$f_c - f_{LO}$

$f_c - f_{LO} + \dfrac{B}{2} < -f_c + f_{LO} - \dfrac{B}{2} \implies B < 2(f_{LO} - f_c) =$

$\underbrace{\phantom{f_{LO} - f_c}}_{f_{IF}}$

$= 2f_{IF}$

$B \approx 1 \, MHz \gg 10 \, kHz$

- Superheterodyne AM receiver with envelope detection-cont
  - Should we use $f_{LO} = f_c + f_{IF}$ or $f_{LO} = f_c - f_{IF}$?

  high-LO standart

    - If we use $f_{LO} = f_c + f_{IF}$ ← cheaper!
      $f_{LO} \in [995, 2155]$ KHz

      $\dfrac{f_{LO,max}}{f_{LO,min}} \approx 2$
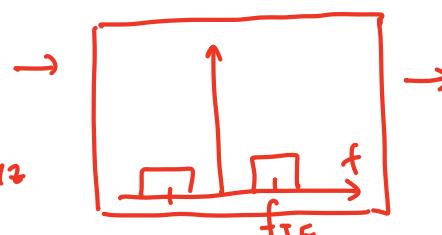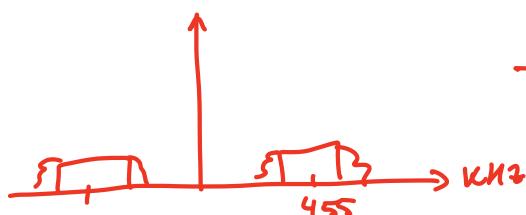
    - If we use $f_{LO} = f_c - f_{IF}$
 $f_{LO} \in [85, 1245]$ KHz , $\dfrac{f_{LO,max}}{f_{LO,min}} \approx 15$ ← more demanding design

Now, signal is at 455 KHz

IF filter

→

ready for the envelope detector :)

KHz

455

f_{IF}

BPF : not tunable, but very selective

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