ECE 447 Fall 2025

Lesson 13
Angle Modulation,
Part 3

UNITED STATES
AIR FORCE
ACADEMY

SCHEDULE AND ADMIN

- Schedule
- Admin
  - **Lab 3 Assignment**. Due Lesson 14 - specifically 15 Sep by 2359 via Gradescope upload.

  - **HW2**. Posted on course website. Due Lesson 15 (17 Sep)

  - HW1 Lathi solutions posted to Teams - getting your submissions graded...

  - GR1 is a week from this Friday. Review day the Wednesday prior. Topics will primarily be from Chapter 4 of the textbook, though topics from Chapters 2-3 are fair game.

REVIEW

- If $m(t)$ has $m_p = 2V$ and a bandwidth of 50kHz, what is the deviation ratio β, assuming $k_f = 2{,}000\pi$? What is the FM signal bandwidth using Carson's Rule?

- Which attributes of $m(t)$ most influence the bandwidth of an FM signal? Of a PM signal?
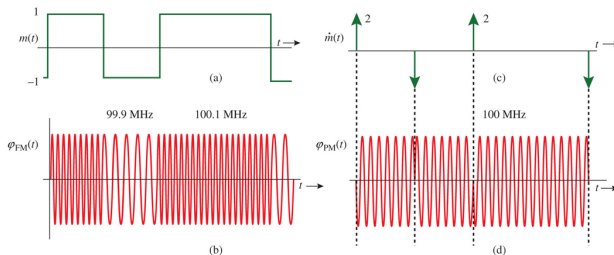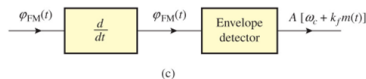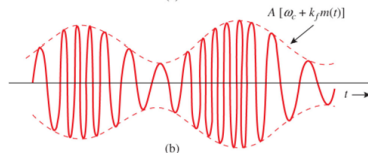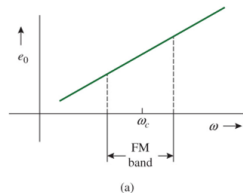
FM DEMODULATION

- Basic idea: make FM look like AM and use an envelope detector

- Need output amplitude to vary as a function of input frequency

- Info of FM signal located in $\omega_i = \omega_c + k_f m(t)$

- Use ideal differentiator:
  $$\dot{\varphi}_{FM}(t) = \frac{d}{dt}\left(A\cos[\omega_c t + k_f \int_{-\infty}^{t} m(\alpha)d\alpha]\right) = ?$$

- Even though differentiator output is combo of FM and AM, envelop detector won't care if $\Delta f \ll f_c$ (typically true)

(a)

(b)

(c)

FREQUENCY MIXING, AKA HETERODYNE*

- Problem: generally filters can either be tunable without a sharp rolloff OR fixed with a sharp rolloff (i.e., high Q, or quality, factor)
- Solution: use both to get the best of both worlds
- Frequency mixer block diagram:
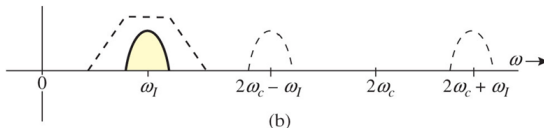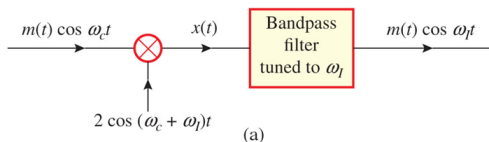
*The word "heterodyne" comes from Greek roots, combining hetero- ("other" or "different") and -dyne (from dynamis, meaning "power" or "force"). Reginald Fessenden coined the term around 1901 to describe his principle of mixing two different radio frequencies to create an audible "beat" frequency in a wireless communication receiver.

SUPERHETERODYNE RECEIVER

- Invented by Edwin Armstrong (see Section 4.8.4!)

- Widely used for broadcast receivers (AM, FM, TV)

- Uses a local oscillator (LO) with a frequency exactly f_{IF} above f_c, or $f_{LO} = f_c + f_{IF}$

- Simultaneous tuning of both the LO and RF tunable filter (one knob does both)
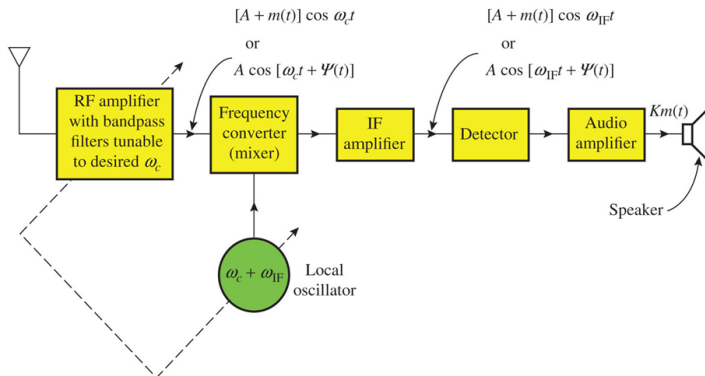
IMAGE STATIONS AND FDM

- Image Stations

- Frequency Division Multiplexing (FDM) Steps