Transmitters and Receivers

A Session for
"Electronics and Telecommunications"
A Fairfield University E-Course
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Module: Communication Systems
(in two parts)

- Texts:
  - "Understanding Telephone Electronics," Bigelow, Newnes, 1997, ISBN 0-7506-9944
- References:
  - Electronics Tutorial (Thanks to Alex Pounds)
  - Electronics Tutorial (Thanks to Mark Sokos)
- Part 11 – Broadcast Systems
  - 5 on-line sessions plus one lab
- Part 12 – Transmission & Communications
  - 5 on-line sessions plus one lab
- Mastery Test part 6 follows this Module

Section 11: Broadcast Systems

- Frequency Division Multiplexing
- AM
  - Modulation
  - Demodulation (The Envelope Detector)
- FM
  - Modulation
  - Demodulation (The Phase-Locked-Loop)
- Super Heterodyne Receivers
- Television
- Sampling

Section 12:
Transmission and Networks

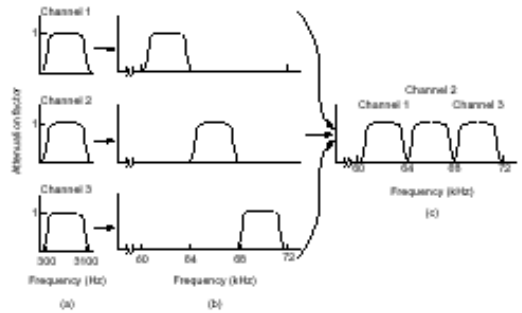
- Transmission Lines
  - Twisted pair
  - Coaxial Cable
  - Optical Fiber
- Microwave Systems
- Satellite Links
- Telephone Systems
- Local Area Networks
- Cellular Phone Systems

Section 11 Schedule

Session 11a	08/25	Time and Frequency Multiplexing	Notes and Web Sites Bigelow: 167-206
Session 11b	08/27	AM Radio	Notes and Web Sites
Session 11c (Labor Day 09/01)	09/03	FM Radio	Notes and Web Sites
Session 11d	**09/08**	**Transmitters & Receivers**	**Notes and Web Sites**
Session 11e (Lab - 09/13, Sat.)	09/10	Television	Notes and Web Sites
Session 11f (Quiz 11 by 09/21)	09/15	Review for Quiz 11	
Session 11g	09/22	Quiz 11 Results	

Frequency Division Multiplexing

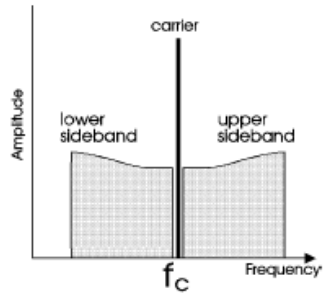
- Here the Bandwidth of the Transmission medium is divided into “Channels” each with enough bandwidth to carry the desired information



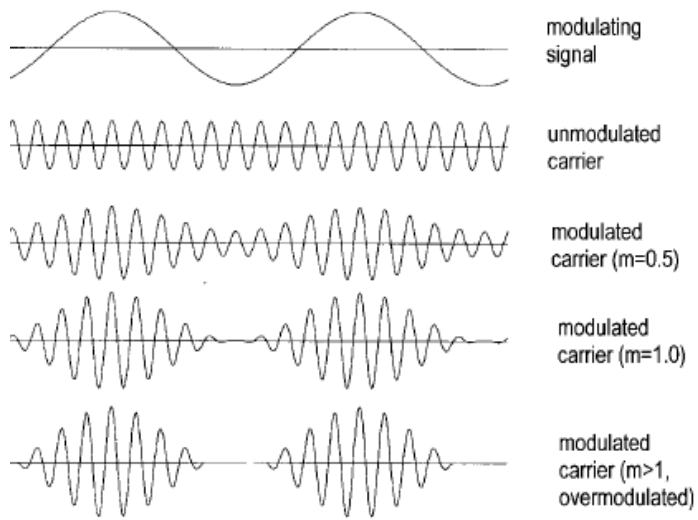
- All Channels are separated by an narrow, unused space in the spectrum called a “Guard Band”
- AM Radio: The RF spectrum from 535 kHz to 1605 kHz is divided into overlapping 20 kHz channels (none overlap in a region)
- FM Radio: the RF spectrum from 88 MHz to 108 MHz is divided into 200 kHz channels (double-width for stereo)
- Broadcast TV: The RF Spectrum from 52 MHz to 88 MHz, 174 MHz to 216 MHz, and 470 MHz to 806 MHz is divided into 6 MHZ channels

AM Facts

- AM audio has a maximum frequency of less than 10 kHz
- An AM radio channel needs ~18 kHz bandwidth
  - Two sidebands
    - Upper from fc+fmin to fc+fmax (fc+fm simple tone)
    - Lower from fc-fmin to fc-fmax (fc-fm simple tone)
  - channel spacing in each geographical region is 20 kHz

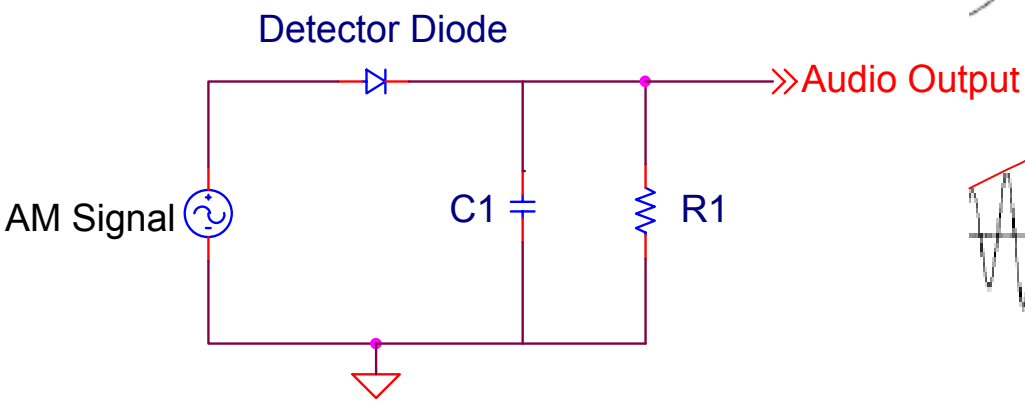


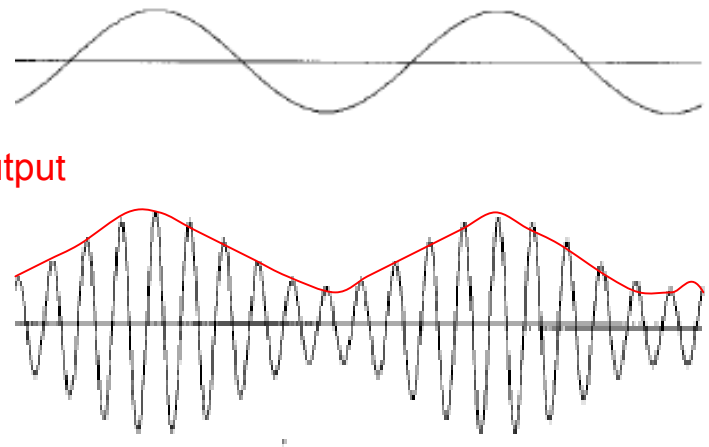
- The AM Radio band is from 535 kHz to 1605 kHz
- Carrier amplitude varies in proportion to the audio signal
- AM transmitters average about 70% modulation
  - avoid over modulation
  - The carrier amplitude cannot go to zero or the spectrum gets very broad and interferes with other channels



AM Demodulation

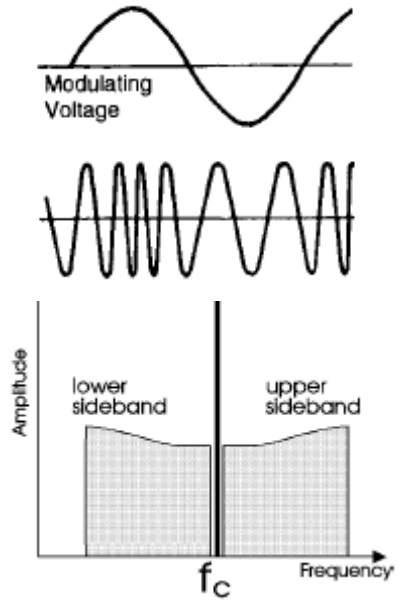
- Two methods for AM demodulation
  - Mixing (multiplying by) a reproduced carrier wave
    - Requires locally generating a sine wave at the same frequency and in phase with the signal.
    - Then pass the result through a low-pass filter to get the audio
  - Envelope Detection (used in almost all AM receivers)
    - Use a diode and a RC filter to "follow" the envelope of the AM signal (which is the audio)





FM Facts

- Carrier Frequency varies in proportion to the audio signal
- FM audio has a maximum frequency of less than 15 kHz
- An FM radio channel needs extra bandwidth
  - Monaural: 200 KHz
  - Stereo: 400 KHz
- The FM Radio band is from 88 MHz to 108 MHz (in the middle of the VHF TV Band, between channels 6 and 7)

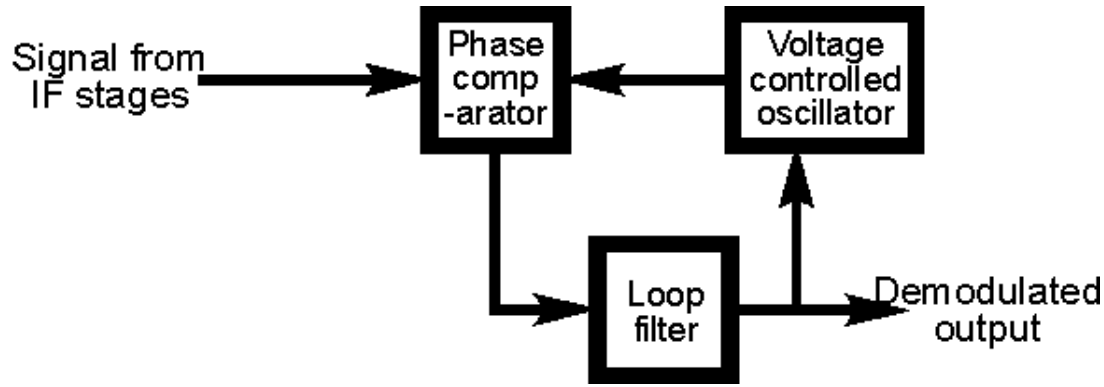


- Broadcast FM transmitters are limited to 75 KHZ maximum deviation
- The FM Modulation Index is the ratio $k = \Delta f / fm$
  - Narrow Band FM ($k < 1$) BW approaches AM
  - Wide Band FM ($k > 1$, broadcast FM is Wide-Band) has good noise immunity
- FM Demodulators include:
  - Limiters followed by one of: Ratio Detector, Discriminator, or Zero Counter
  - Phase-Locked-Loop PLL (VCO, Phase Detector, Loop Filter)

Demodulating FM

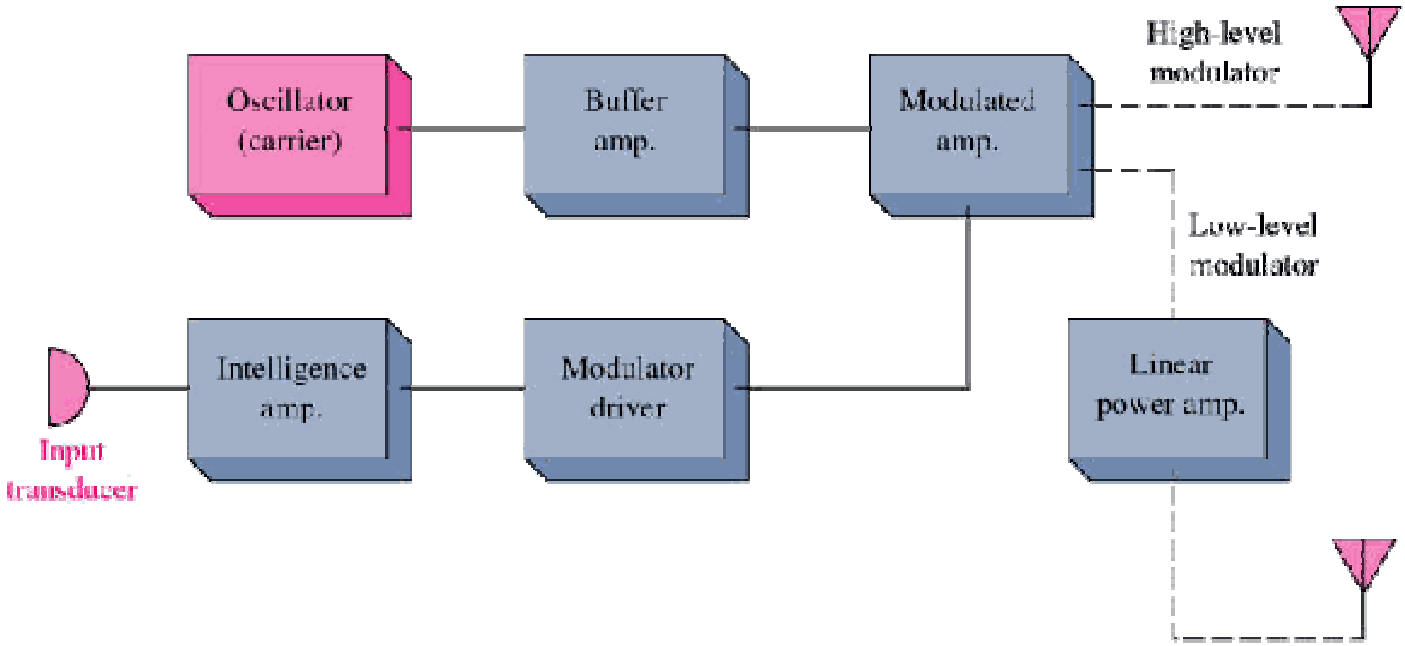
- Limiter
  - An FM signal has no Amplitude variation
    (any that is there is either from noise or interference)
  - Amplify the signal and put it through a Limiter
    (Clipper – creates an almost square wave)
    to remove any AM
  - Filter out the created harmonics (odd multiples of the carrier in the square wave) to get back a clean FM Modulated Sine Wave
- Detector
  - Use the slope of a filter to create AM that is proportional to the FM and use an envelope detector (Ratio Detector, Discriminator)
  - Count zero crossings per second
  - Use a Phase-Locked-Loop (PLL) to track the time-varying carrier

The Phase-Locked-Loop



- A PLL has three primary components
  - **Phase Comparator**: outputs a voltage proportional to the phase difference between two sine waves
  - **VCO** (Voltage-Controlled-Oscillator): A sine wave generator whose frequency increases (or decreases) when an input voltage increases (or decreases … zero input → fc)
  - **Low-Pass (loop) Filter** : Lets DC and Audio through but filters out any high frequency components
- The PLL locks onto the carrier and tracks the frequency variation. The voltage into the VCO is the original audio

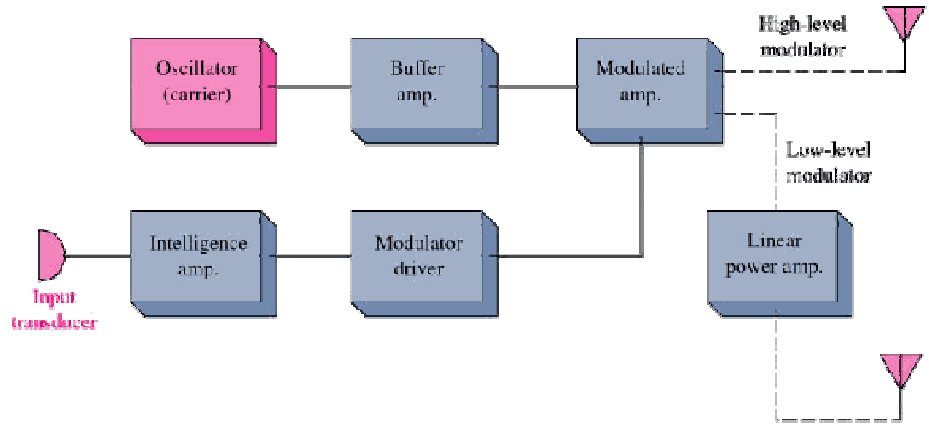
RF Transmitters



- High-Level: Directly modulates the RF high power output stage with the audio. The information signal and the carrier sine wave are mixed after the carrier is amplified
- Low-Level: Uses a "Linear Amplifier" stage after modulation to produce the required RF output power level. The information signal and the carrier sine wave are mixed before the carrier is amplified

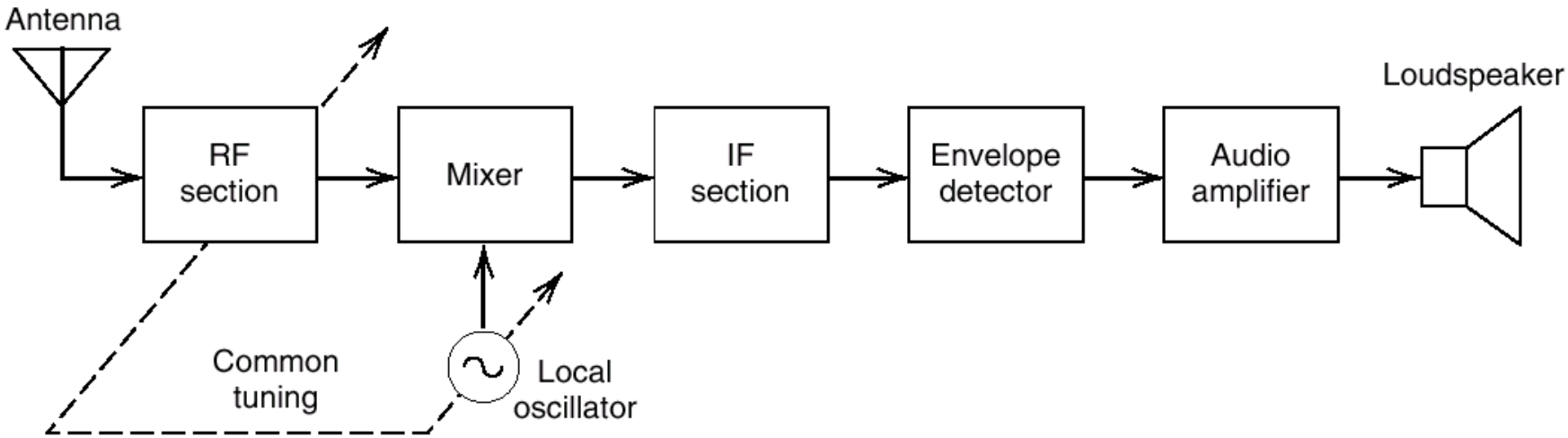
Transmitter Subsystems

- **Oscillator**: Produces a sine wave at the carrier frequency
- **Buffer Amplifier**: Increases the RF power level and isolates the oscillator from being affected by the modulator



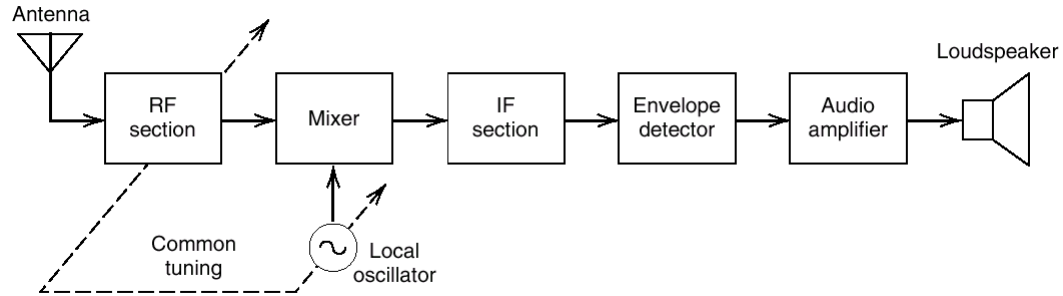
- **Modulator**: produces either an AM or FM signal centered at the carrier frequency.
  - The AM modulator is sometimes called **mixing** (the two signal interact or mix in a non-linear component to create sum and difference frequency signals)
  - FM is often done by directly modulating the Oscillator (a VCO)
- **Linear Amplifier**: Used in a low-level modulated transmitter to amplify the modulated carrier to the desired power level

AM Super Heterodyne Receiver



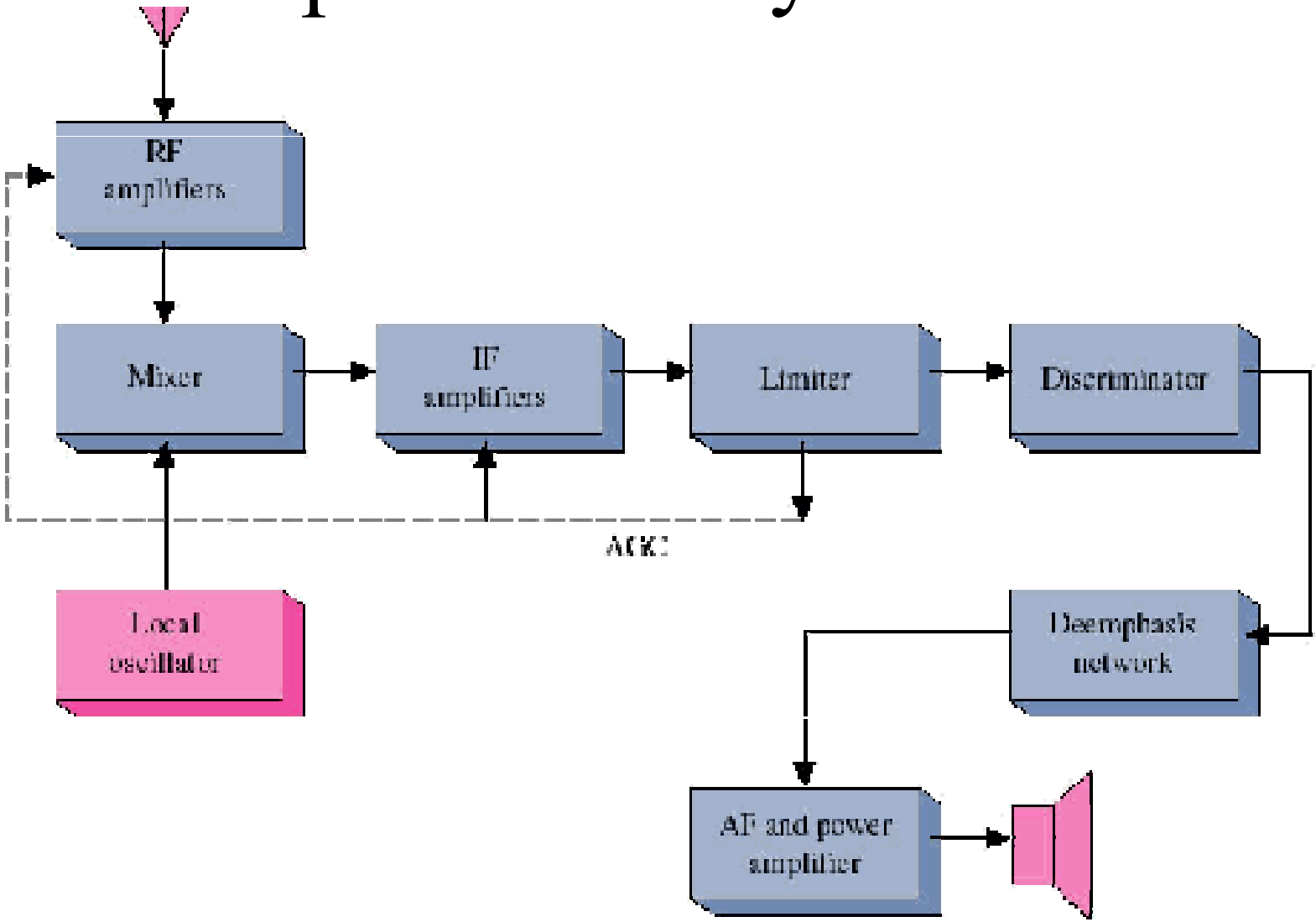
- The original carrier is “Mixed” with a local oscillator that is offset in frequency by a fixed amount (the Intermediate Frequency or IF).
- This produces a copy of the original spectrum centered at the IF frequency where it is filtered and amplified.

AM Receiver Facts



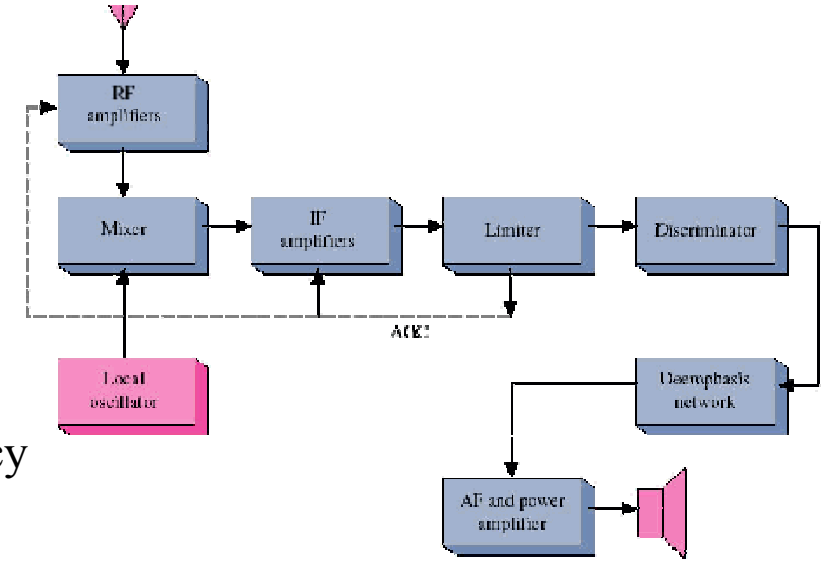
- RF Amplifier
  - Provides high voltage gain
  - "Tuned" to only amplify the desired RF signal and reduce the strength of other signals
- Local Oscillator
  - Frequency is adjusted to be 455 kHz above (the "super" in super heterodyne) the desired signal's carrier frequency
- Mixer
  - The Local Oscillator and amplified signal interact or mix in a non-linear component to create sum and difference frequency signals
  - Since the L.O. frequency is higher than the carrier by 455 kHz, the difference signal is centered at the 455 kHz IF frequency
- IF: Amplifies and selectively filters the difference AM signal (now centered at 455 kHz)
- Envelope Detector: Recovers the original audio from the AM signal
- Audio Amplifier: provides audio power to the speaker

FM Super Heterodyne Receiver



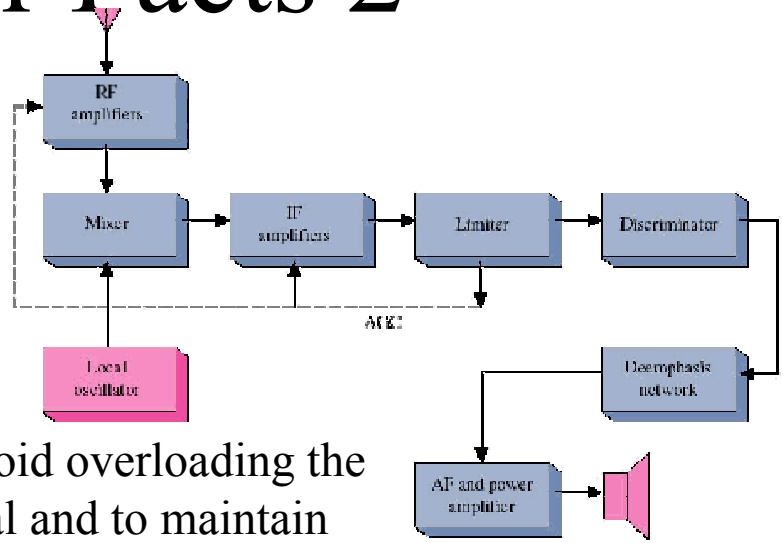
FM Receiver Facts

- RF Section
  - Amplifier that provides high voltage gain
  - "Tuned" to amplify the FM Band and reduce the strength of other signals
- Local Oscillator
  - Frequency is adjusted to be 10.7 MHz above the desired signal's carrier frequency
- Mixer
  - The Local Oscillator and amplified signal interact (mix) in a non-linear component (often a diode) to create sum and difference frequency signals
  - Since the L.O. frequency is higher than the carrier by 10.7 MHz , the difference signal is centered at the 10.7 MHz IF frequency
- IF Amplifier: selectively filters and amplifies the difference FM signal (now centered at 10.7 MHz)
- Limiter: Reduces any residual AM on the IF signal by "clipping" it
- Discriminator: Recovers the original audio from the FM signal



FM Receiver Facts 2

- De-Emphasis: Reduces the higher frequency audio components (they were boosted at the transmitter) for accurate reproduction. (this reduces the FM hiss)



- AGC: Automatic Gain Control
  - Used in most radio and TV receivers to avoid overloading the amplifiers in the presence of a strong signal and to maintain more uniform audio volume from station to station
- AFC: Automatic Frequency Control (not shown)
  - Used in FM receivers to lock in to the desired signal's carrier frequency.
  - The DC voltage from the FM Detector is fed back to the local oscillator to "pull" it back to the nearest signal

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