AM/FM Receiver

Communication Systems

- We have studied the basic blocks of any communication system
 - Modulator
 - Demodulator
- Modulation Schemes:
 - Linear Modulation (DSB, AM, SSB, VSB)
 - Angle Modulation (FM, PM)

• Principles:

- Frequency Spectrum Sharing (many transmitters using one medium)
- Demodulating desired signal and rejecting other signals transmitted at the same time

- The source signal is audio
- Different sources have different spectrum
 - Voice (speech)
 - Music
 - Hybrid signals (music, voice, singing)

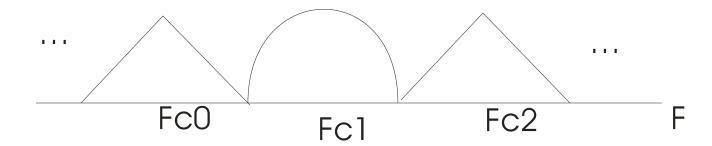
- Different audio sources have different bandwidth "W"
 - Speech- 4kHz
 - High quality music- 15kHz
 - AM radio limits "baseband" bandwidth W to
 5kHz
 - FM radio uses "baseband" bandwidth W to
 15kHz

- Radio system should be able to receive any type of audio source simultaneously.
- Different stations with different sources transmit signals simultaneously.
- Different listeners tune to different stations simultaneously.

- The different radio stations share the frequency spectrum over the air through AM and FM modulation.
- Each radio station, within a certain geographical region, is designated a carrier frequency around which it has to transmit
- Sharing the AM/FM radio spectrum is achieved through <u>Frequency Division Multiplexing (FDM)</u>

Example of AM Radio Spectrum

• Different radio stations, different source signals



- Carrier spacing- 10kHz (AM)
- Bandwidth (3-5kHz)

- For AM radio, each station occupies a maximum bandwidth of 10 kHz
- Carrier spacing is 10 kHz
- For FM radio, each station occupies a bandwidth of 200 kHz, and therefore the carrier spacing is 200 kHz

- Transmission Bandwidth: B_T
- B_T is the bandwidth occupied by a message signal in the radio frequency spectrum
- B_T is also the carrier spacing
- AM: $B_T = 2W$
- FM: $B_T = 2(D+1)W$ (Carson's Rule)

- Design of AM/FM radio receiver
- The radio receiver has to be cost effective
- Requirements:
 - Has to work with both AM and FM signals
 - Tune to and amplify desired radio station
 - Filter out all other stations
 - Demodulator has to work with all radio stations regardless of carrier frequency

• For the demodulator to work with any radio signal, we "convert" the carrier frequency of any radio signal to

Intermediate Frequency (IF)

- Radio receiver design can be optimized for that frequency
- IF filter and a demodulator for IF frequency

AM/FM Radio Spectrum

- Recall that AM and FM have different radio frequency (RF) spectrum ranges:
 - AM: 540 kHz 1600 kHz
 - FM: 88 MHz 108 MHz
- Therefore, two IF frequencies
 - AM: 455 kHz
 - FM: 10.7 MHz

- A radio receiver consists of the following:
 - A Radio Frequency (RF) section
 - An RF-to-IF converter (mixer)
 - An Intermediate Frequency (IF) section
 - Demodulator
 - Audio amplifier



- This is known as the "Superheterodyne" receiver
- Two stages: RF and IF
 (filtering and amplification)
- The receiver was designed by Armstrong

RF Section

- Tunes to the desired RF frequency, f_c
- Includes RF bandpass filter centered around fc
- The bandwidth B_{RF}
- Usually not narrowband, passes the desired radio station and adjacent stations

• The minimum bandwidth of RF filter:

$$B_{RF} > B_T$$

 Passes the desired radio channel, and adjacent channels

- RF-IF converter:
 - Converts carrier frequency → IF frequency

• How can we convert signals with different RF frequencies to the same IF frequency?

- Local oscillator with a center frequency fio
- fio is a function of RF carrier frequency

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



- RF-to-IF receiver includes:
 - An oscillator with a variable frequency five
 (varies with RF carrier frequency)
 - By tuning to the channel, you are tuning the local oscillator and RF tunable filter at the same time.

• All stations are translated to a fixed carrier frequency for adequate selectivity.



Local Oscillator

• Two frequencies are generated at the output of product modulator:

$$f_{LO}+f_c=2f_c+f_{IF}$$

 $f_{LO}-f_c=f_{IF}$

- The higher frequency component is eliminated through filtering
- We are left with IF frequency

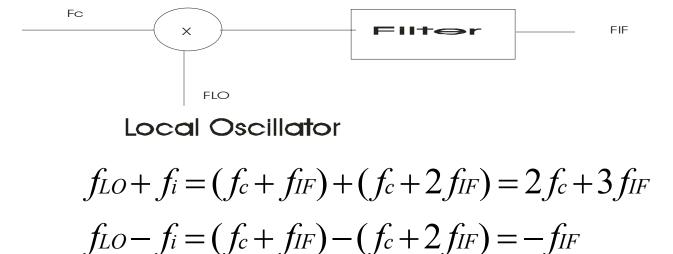
One problem with this receiver:

"Image Signal"

• Image signal has a center frequency:

$$f_i = f_c + 2 f_{IF}$$

• If an "image signal" exists at the input of the "RF-to-IF" converter, then the output of the converter will include the desired signal + image signal



- Example: Incoming carrier frequency 1000 kHz,
- Local oscillator = 1000+455=1455 kHz
- Consider another carrier at 1910 kHz
- If this is passed through the same oscillator, will have a 1910-1455=455 kHz component
- Therefore, both carriers will be passed through RF-to-IF converter

- Therefore, RF filter should be designed to eliminate image signals
- The frequency difference between a carrier and its image signal is: 2 *f*_{IF}
- RF filter doesn't have to be selective for adjacent stations, have to be selective for image signals
- Therefore,

$$B_T < B_{RF} < 2 f_{IF}$$

- IF filter:
 - Center frequency fir
 - Bandwidth approximately same as transmission bandwidth, B_T
 - For AM: $B_T = 2W$
 - For FM: $B_T = 2(D+1)W$

- Depending on the type of the received signal, the output of "IF filter" is demodulated using AM or FM demodulators.
- For AM: envelope detector
- For FM: frequency discriminator