ENSC327
Communications Systems
5: Frequency Translation (3.6) and Superhet Receiver (3.9)

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Outline

- Required Background
- Frequency translation (page 128)
- Superhet Receiver (Page 142)

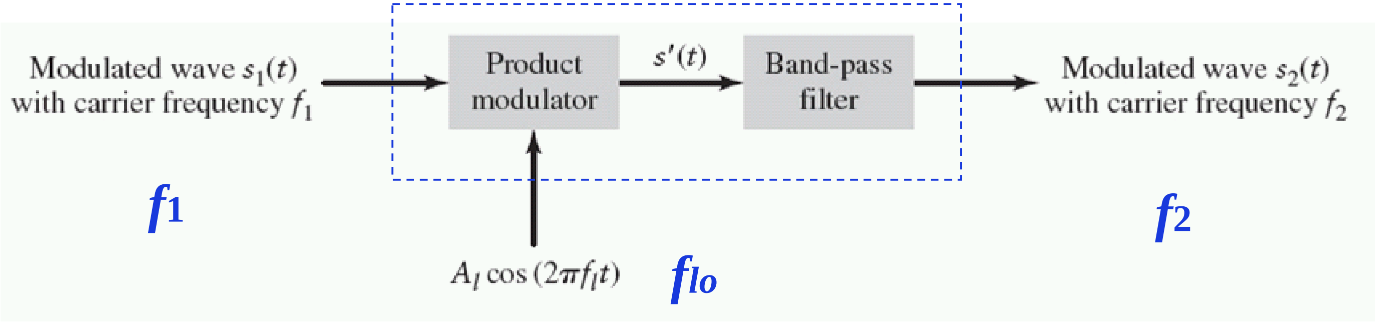
Required Background

- FT of a signal centered around frequency f_1 multiplied by $\cos(2\,\pi\, f_1' t)$.

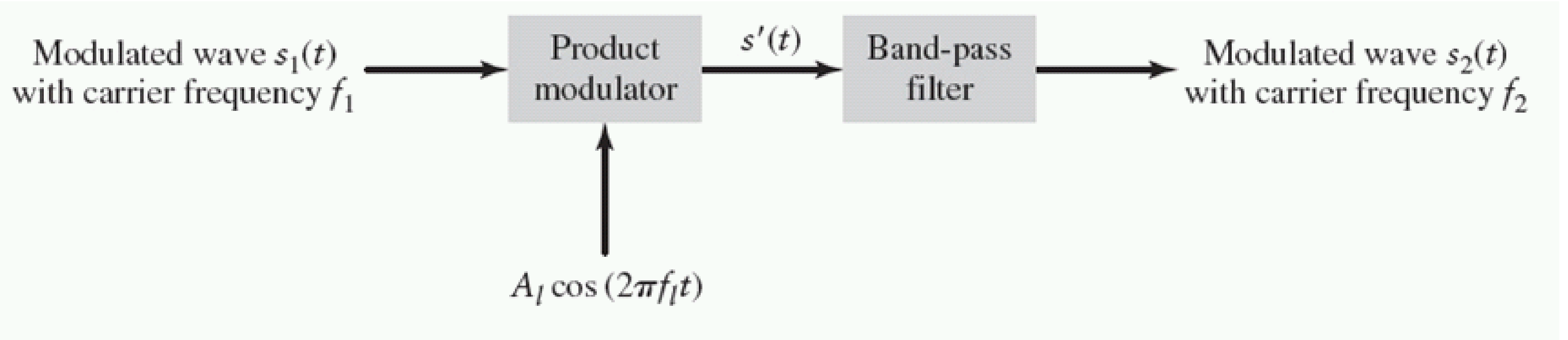
- Spectrum of AM radio broadcast stations and the function of the radio receiver.

Frequency Translation (Page 128)

- Frequency translation:
  - Translate a signal centered around f_1 to a signal centered around f_2 (f_2 is usually lower than f_1).
  - Used in AM & FM radio (to bring signals from different stations to the same intermediate freq f_2 for demodulation)
- Implementation by a mixer:
  - The mixer includes a product modulator and a band-pass filter.
  - How to choose the local frequency (f_{lo}) of the mixer?



High-side tuning and low-side tuning



Assuming $f_1 > f_2$, what are the possible values for f_{lo} ?

Image Signal

- Assume we use $f_{lo} = f_1 + f_2$ to bring (translate) the signal centered at f_1 to f_2 . What other bandpass signal will also be translated to f_2 through this process? This “other” signal is called the “Image Signal”.
- Let’s find the Image Signal through an example: Assume f_1=1000 kHz and f_2= 455 kHz. Use high-side tuning. Find f_{lo} and the center frequency of the image signal.

Image Signal (Summary)

If $f_{lo} = f_1 + f_2$, then an input at freq $f_1 + 2f_2$ can also be moved to f2

(As shown in the previous example.)

If $f_{lo} = f_1 - f_2$, then an input with freq $\left| f_1 - 2f_2 \right|$ will be moved to f2

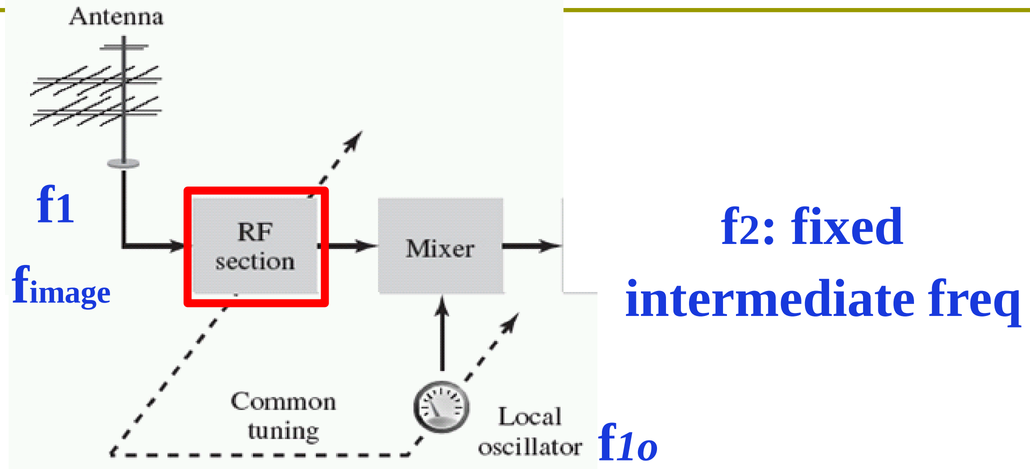
Consider two cases:

$f_1 > 2f_2$:

$f_1 < 2f_2$:

The signal at f_1 is the desired signal and the one at "image frequency" is the undesired signal which should be removed (by filtering) before frequency translation.

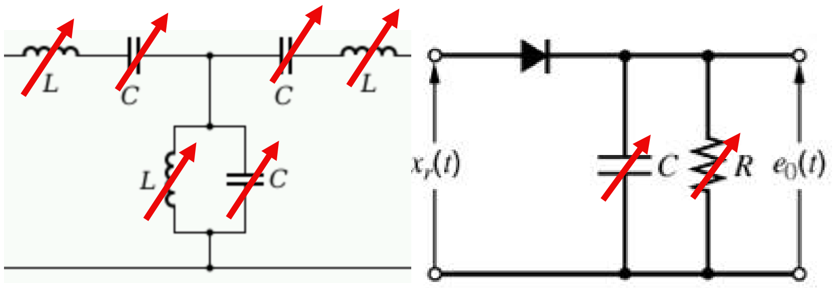
Remove Image Signal by RF Filter



- Solution: Apply a bandpass RF filter before the mixer:
  - The center of the RF filter is at the desired frequency:
    - Example: the radio channel we want to listen to.
  - The unwanted image signal is thus filtered out.
  - The local frequency is changed together with the RF filter freq.
    - The freq after the freq translation is the same intermediate freq.
  - The passband of the RF filter is about 40-50 kHz for AM
    - Wider than the 10kHz AM bandwidth (cheaper to build)

Superheterodyne Receiver

- Early AM receivers:
  - Tune the receiver to capture the desired input signal
  - Expensive to build narrow-band filters at high frequencies
  - Also, this filter must be tunable over a wide AM range



Bandpass filter envelope detector

Superheterodyne Receiver

- Superheterodyne: supersonic heterodyne receiver
  - Heterodyne: mix or translate frequency
- Short name: superhet
- A breakthrough in radio broadcast history
- Invented by Edwin H. Armstrong in 1918

- The idea: Translate the input signal to a fixed frequency at the receiver. The majority of the circuits can be fixed.

- Example of creative thinking!

Superheterodyne Receiver (Cont.)

Desired: f_{RF}

Local Freq:

$$f_{lo} = f_{RF} + f_{IF}$$

Image Freq:

$$f_{RF} + 2 f_{IF}$$

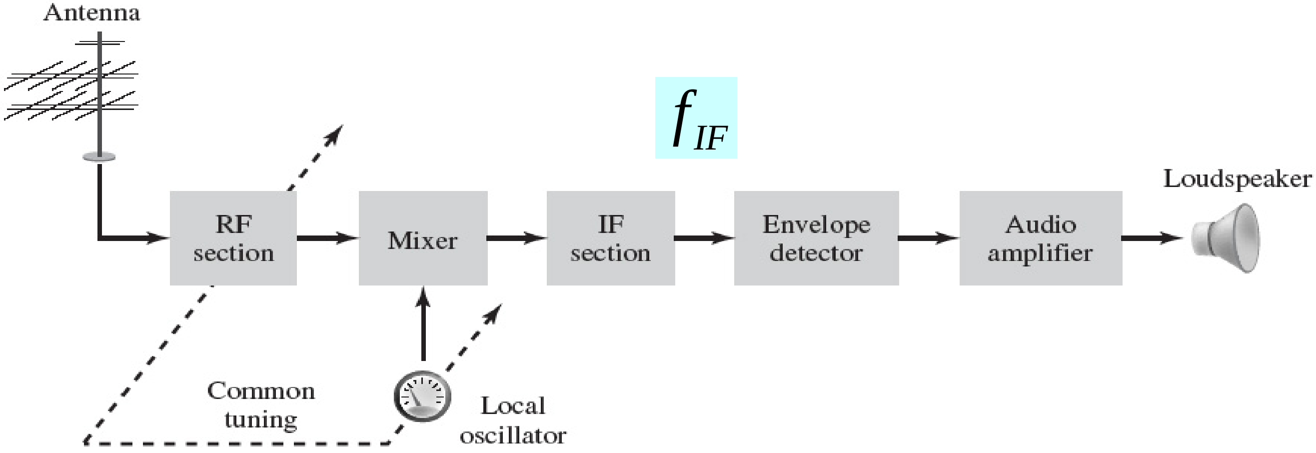


FIGURE 3.27 Basic elements of an AM radio receiver of the superheterodyne type.

- The input signal is translated to a fixed intermediate frequency (IF) by a mixer.
- Only the Local Oscillator (LO) freq is changed when we tune the radio.
- The fixed intermediate frequency (IF):
  - 455kHz for AM radio, 10.7MHz for FM radio
  - Bandwidth: 10kHz in AM radio, and 200k Hz for FM radio.
  - The IF filter is not tunable, can be made to have good selectivity
  - Usually made of quartz crystal. Example: Monolithic crystal filters
  - Can be implemented digitally

- The RF filter at the front has wider bandwidth (cheaper) and is tunable.

Superheterodyne Receiver (Cont.)

- Correction to the book:
- Equation (3.46) on Page 143 should be:

$$f_{lo} = f_{RF} + f_{IF}$$

Because high-side tuning is used in superheterodyne AM radio receiver.

Superheterodyne Receiver (Cont.)

- Why use high-side tuning?

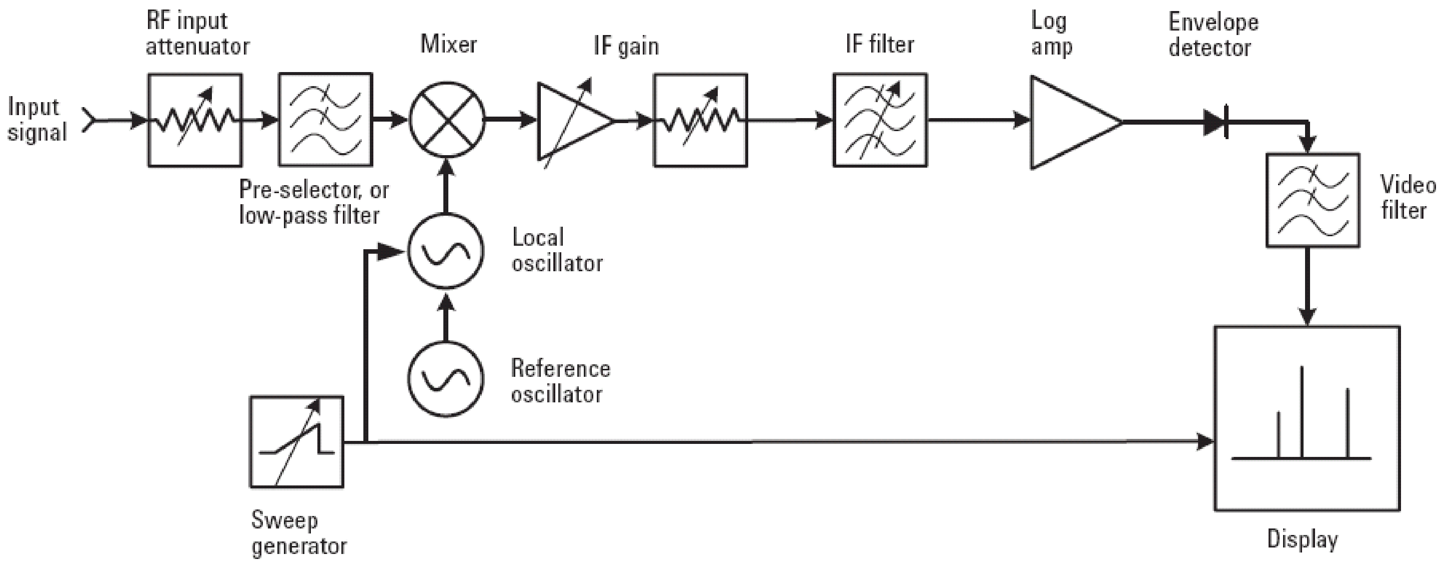
  High-side tuning leads to smaller tuning ratio for local oscillator.
  This is easier to implement (by variable capacitor).

- AM station frequency: 540 kHz ~ 1600 kHz (BW is 10 kHz)
- The IF freq: 455kHz
- The range of local frequency for low-side tuning:

- The range of local frequency for high-side tuning:

Applications of the Superhet Receiver

- Already saw the application in Radio receivers.
- The Spectrum Analyzer is essentially an electronically tuned Supherhet receiver



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