

## EE334 Superheterodyne Receivers

In the AM Demodulation notes we covered the core of an AM radio receiver. We left out several parts that modern radios have such as the tuner and automatic gain control (evens out the volume of stations). In this set of notes, we will learn about the Superheterodyne technique of tuning a radio (yes, all radios not just AM).

### A simple, but flawed tuner

- To listen to a radio station, your radio must pick out (isolate) the station you desire from all the other stations in your area. We could use a bandpass filter to do this as the illustration below shows.
  
  - However, a static bandpass filter is no good. To be useful as a tuner the filter would need to have an adjustable center frequency so that we can move it around to pick out different stations. Unfortunately there is a problem with adjusting the center frequency as Problem #1 illustrates.
1. Mad scientist O. Idar has built a RLC bandpass filter with the following components: resistor = 100 ohms, inductor = 1.59 mH, capacitor = 44.2 pF. What are the bandwidth, center frequency, and Q of the filter?

$$f_c = \frac{1}{2\pi\sqrt{LC}} =$$

$$BW = 2\pi f_c^2 CR =$$

$$Q = \frac{f_c}{BW} =$$

Will the filter accept a standard US AM broadcast (BW = 10 kHz)?

O. Idar changes the capacitor to 7.07 pF which changes the center frequency of the filter. Oddly, the Q value doesn't change because the real (non-complex) resistance of the inductor is frequency dependent ("skin effect"). The net effect is that the BW of the filter is different. What is the center frequency and BW of the filter? Does the filter have enough BW to tune in an AM station at the new center frequency?

The superheterodyne (superhet) tuner was developed in response to bandwidth problems of the variable bandpass filter. The typical superhet AM receiver is the AM receiver covered in AM Receiver packet with a few additions. A superhet AM receiver is shown in Figure 1 below. The bullets after the figure explain important info about the new components.

- The RF Filter (aka “Phat Philter”) is an adjustable bandpass filter with a very wide bandwidth (very low Q). The job of the Phat Philter is to prevent the reception of frequencies that can cause problems for the superheterodyne radio. These problem frequencies are called “image frequencies” and will be dealt with later when we understand enough to know why they’re a problem.
- The Local Oscillator (LO) is a sub-circuit that generates Sine waves. The frequency of the Sine waves is adjustable. Adjusting the LO frequency enables us to tune the superhet radio. In U.S. radios, the common practice is for the LO to be set to a frequency that’s higher than the carrier frequency of the station that you want to listen to.
- The Mixer has two inputs: A which gets signals from the antenna and B which is hooked to the LO. Neither input has priority over the other. **The Mixer combines each frequency on input A with the LO wave from input B in the following manner to produce the following output frequencies:**
  - $f_A$
  - $f_{LO}$
  - $|f_{LO} - f_A|$
  - $f_{LO} + f_A$
- The IF Filter stands for “intermediate frequency filter.” The IF Filter is a bandpass filter with a center frequency of 455 kHz and a BW = 10 kHz (standard AM broadcast bandwidth). The IF has a very high Q-value. In fact the IF Filter is almost ideal.
- The LO and Phat Philter are ganged together so that adjusting the frequency of one adjusts the other up or down by the same amount. The reason for this will become clear shortly.

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Let's learn how the superhet AM receiver works by doing a problem together.

2. Make a copy of the superhet receiver below but leave out the Phat Philter for now.
  - a. Assume that there are three stations in your local area: AM 680, AM 760, and AM 1420. List the frequencies present at the A input of the mixer. Remember that AM broadcasts in the USA have a BW of 10 kHz.
  - b. Suppose that the LO is set to 1215 kHz. Referencing the action of the mixer on the previous page, list the frequencies appearing at the output of the mixer.
  - c. List the frequencies at the output of the IF Filter. IOW, what frequency or range of frequencies passes through the IF Filter?
  - d. The frequencies passing through the IF Filter is a lower frequency version of which radio station?
  - e. Which radio station is being listened to?



