EEELE445 Lab 8: AM Superheterodyne Receiver

Purpose

The purpose of this lab to look at the functions performed by the super heterodyne AM receiver. A block diagram of the receiver is shown below. The principal functions of the receiver are frequency conversion (by the mixer), image rejection, signal amplification and filtering by the IF amplifier, signal demodulation by an envelope detector, and audio amplification.

Reference Sources

Couch section 4-11 frequency converters, 4-16 superheterodyne receivers and 4-13 for AM demodulation by envelope detection, 5-2 for AM broadcast standards (table 5-1). Lecture 28 class notes.

Prelab:

Describe the function corresponding to the following terms as related to the super-heterodyne receiver:
- RF amplifier
- Mixer
- LO
- IF amplifier
- envelope detector, slope overload
- AGC
- image signal

Be able to answer for the questions:
- What is the occupied bandwidth of a Commercial AM station as defined by the FCC?
- What is the frequency range of the AM broadcast band?
- Why is AGC necessary in a practical AM receiver?
- How do you calculate the image frequency given the LO frequency, the desired RF frequency, and the IF frequency? (Couch example 4-6)
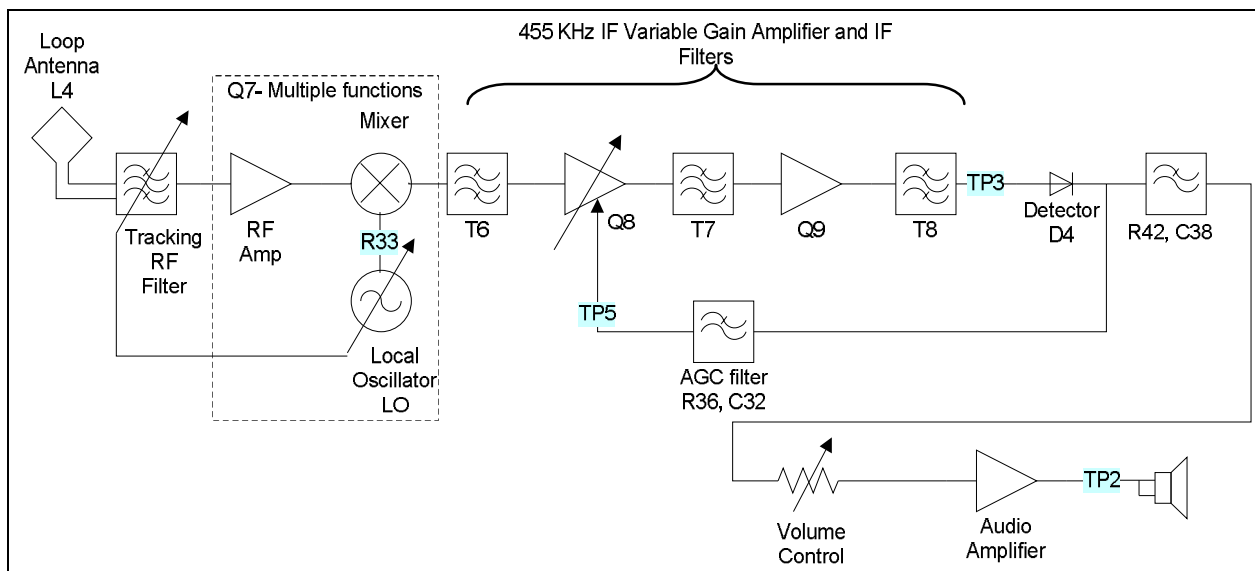
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Method:

Antenna, Local Oscillator, Mixer:
1. The output of the **local oscillator** is on the right hand side of R33. Note that the frequency of the sinusoid changes as the tuning is changed. The several mechanically variable capacitors on the back of the receiver cause it to change frequency as the tuning knob is changed. Tune the receiver to a strong, clear signal and identify its broadcast frequency. Remember that the receiver antenna is directional and you may improve the signal strength by repositioning the radio.
   - Sketch the signal LO at R33 and determine the frequency of the local oscillator. Note that ground is TP15
   - What is the IF frequency given $f_{IF} = f_{lo} - f_{radio\ station}$?

Signal at IF amplifier:
2. The **IF frequency** for all AM radios is set by the FCC to be <u>455 kHz</u>. TP3) shows the AM modulated IF after amplification and filtering to reject other AM stations. Connect a scope probe to TP3.
   - Measure the frequency of the IF signal. (The horizontal sweep of the scope <=50 μs/div.)
   - While observing the IF, put another probe on the bottom of resistor R47, (TP2) which has the **detected IF signal** present. Compare the two signals.
   - Ask for help from instructor to show that the detected audio signal follows the negative envelope of the IF. Sketch the two signals. Can you see any distortion (slope overload) caused by the envelope detector time constant? Describe it.
   - Sketch the spectrum of the signal at IF, TP3 and identify the carrier and the sidebands. Estimate the bandwidth of the signal.

AGC:
3. Test point TP5 is the **AGC-automatic gain control**. The DC voltage from the AM detector output is proportional to the tuned station signal strength. The DC is used to control the gain of the IF amplifiers so that the recovered audio amplitude is not dependent on the received signal strength.
   1. Re-tune the radio. Note how the dc level at TP5 varies as the input signal level changes.
   2. Does the voltage at TP5 increase, or decrease when the input signal strength increases?
   3. Re-position the radio while watching the voltage at TP5. Is the ferrite coil AM antenna directional?
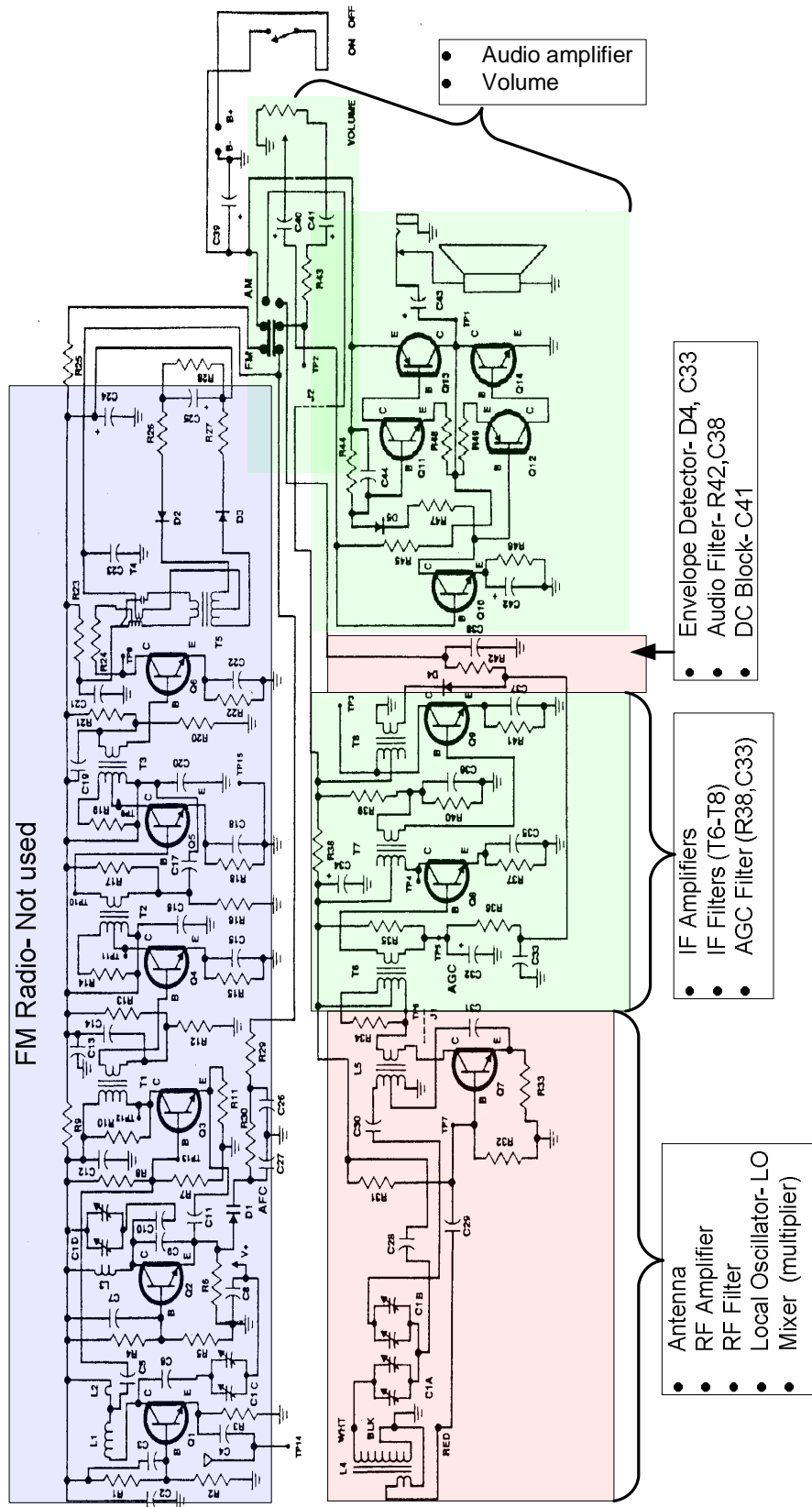
Audio Spectrum:
4. Look at the spectrum of the audio signal at TP1 with a frequency span of 0 Hz to 10 KHz, linear amplitude.
   - Can you observe discrete frequencies being present? Can you observe harmonically related frequencies in the spectrum?
   - While observing the audio spectrum as in (5), check the signals at 1090, 1230, and 1450 kHz and give an estimate of the highest frequency that is being allowed in m(t) by each station.
   - Are any of the stations exceeding the 5 kHz FCC bandwidth limit on m(t)?

Generator input signal
5. Connect a function generator to a coax with clips on it. <u>Do not</u> connect the clips to any of the circuitry; do not allow the clips to touch each other. Lay the clips near the radio antenna. Set the generator for AM, $f_c = 900$ kHz, 50% modulation, and $f_m = 400$ Hz. Tune the radio to receive this signal and adjust the generator output level until you hear a clear audio tone from the speaker. (the output amplitude of the generator will have to be quit large!)
   - Observe the audio output spectrum and time waveform at TP1. The scope should display a clean 400 Hz sinewave.
   - Record the amplitude of the tone as you vary the modulating frequency, f_m, from 100 Hz to 1 kHz in 100 Hz steps and from 1 Khz to 10 Khz in 1 Khz steps. Make a plot of $|H(f)|$ vs f_m. How well does this look like a perfect lowpass pass filter with $f_{cut-off} = 5$ kHz?
   - With the receiver tuned to the 900 kHz signal as above, set the carrier frequency of the AM signal from the generator to the image frequency of the radio. You may have to do some experimenting to find the proper frequency. Remember that the IF bandwidth is only 10 KHz wide! Have the modulating frequency at 400 Hz so you can recognize the audio. Is the image frequency at 900 kHz plus twice the IF frequency as found in (1)?

SCHEMATIC DIAGRAM - AM FM RADIO

FM Radio– Not used

Audio amplifier
- Audio amplifier
- Volume

Envelope Detector- D4, C33
- Envelope Detector- D4, C33
- Audio Filter- R42,C38
- DC Block- C41

IF Amplifiers
- IF Amplifiers
- IF Filters (T6-T8)
- AGC Filter (R38,C33)

- Antenna
- RF Amplifier
- RF Filter
- Local Oscillator- LO
- Mixer (multiplier)

EELE445 - LAB 8 Student Report

Section_____   **Name**_____

Date: _____   **Lab Partner:** _____

Attach your pre-lab answers to your report

1. Antenna, Local Oscillator, Mixer:
- Sketch the signal LO at R33 and determine the frequency of the local oscillator.
- What is the IF frequency given $f_{IF} = f_{lo} - f_{radio\ station}$?

2. Signal at IF amplifier:
- Measure the frequency of the IF signal:
- Ask for help from instructor to show that the detected audio signal follows the negative envelope of the IF. Sketch the two signals. Can you see any distortion (slope overload) caused by the envelope detector time constant? Describe it.
- Sketch or plot the spectrum of the signal at IF, TP3 and identify the carrier and the sidebands. Estimate the bandwidth of the signal.

3. AGC-automatic gain control:
- Re-tune the radio. Note how the dc level at TP5 varies as the input signal level changes. Does the voltage at TP5 increase, or decrease when the input signal strength increases?
- Re-position the radio while watching the voltage at TP5. Is the ferrite coil AM antenna directional?

4. Audio Spectrum:
- Can you observe discrete frequencies being present? Can you observe harmonically related frequencies in the spectrum?
- Observe the audio spectrums of signals at 1090, 1230, and 1450 kHz and give an estimate of the highest frequency that is being allowed in m(t) by each station.
- Are any of the stations exceeding the 5 kHz FCC bandwidth limit on m(t)?

5. Generator input signal
- Record the amplitude of the tone as you vary the modulating frequency, f_m , from 100 Hz to 1 kHz in 100 Hz steps and from 1 Khz to 10 Khz in 1 Khz steps.
- Make a plot of $|H(f)|$ vs f_m . How well does this look like a perfect lowpass pass filter with $f_{cut-off} = 5$ kHz?
- Is the image frequency at 900 kHz plus twice the IF frequency as found in (1)? Actual image frequency: