0. Introduction/Overview

All sections of this lab will meet in a common lab lecture, occurring on Monday afternoons. At these meetings, we will discuss various radio topics and what you are expected to accomplish in lab. Your memos are to be turned in at this common meeting.

You are expected to read the appropriate chapter in the lab manual prior to your lab section meeting. In many cases, you will be expected to work through a pre-lab assignment that may consist of LTspice simulation and breadboarding a circuit. The manual contains a number of tables and blanks for you to fill in as you work through the lab exercises. This work will be checked by your graduate teaching assistant (GTA) as part of your lab grade. You are encouraged to explore the manual as it contains useful information related to the lab such as data sheets and parts lists.

This lab is a work in a progress. I welcome your feedback (perhaps in your memos) for improving the lab or this manual.

0.1 General Lab Policy

- No food or drinks are allowed in the vicinity of the lab equipment.
- You are expected to be in lab on-time, and to leave your station neat.
- Be considerate to your lab GTA and your colleagues; set you cell phone to "vibrate" and take calls out in the hallway if they are necessary.
- The voltages and currents used in this lab are at relatively safe levels. Still, you should exercise caution with the equipment, especially the dc power supply. Glasses (preferably safety glasses) are recommended as sometimes snipped leads fly in random directions.

0.2 Some General Information

- Sound waves travel at 1100 ft/sec
- The frequency range for a healthy human ear is 20 Hz – 20 kHz. The practical high end is about 15 kHz. The maximum frequency deteriorates with age, especially in men.
- Electromagnetic waves travel at the speed of light.

0.3 Radio's Beginnings

- Heinrich Hertz generated and received the first electromagnetic waves (~1887). He used a spark-gap generator to create microwaves, and on the receiving end, a short distance away, a receiving antenna exhibited a corresponding spark.
- Sir Oliver Lodge improved the *coherer* (the detector) in 1894.
- Guglielmo Marconi transmitted and received radio waves over a 1 km distance in 1896. This marked the infancy of practical radio. The first demonstrated practical use was radio coverage of the Kingston Yacht Regatta in July, 1898.
- About the same time Marconi was developing radio, so was Nikola Tesla, who produced a reliable oscillator for generating radio frequency waves. Tesla demonstrated short range radio wave communication by radio control of a boat. A fire in Tesla's lab delayed his work such that Marconi is generally credited with the invention of practical radio.
- There was an early competition between the Marconi Company and the American Wireless Telegraph Company headed by Lee De Forest. As signals from each company were received, the problem of interference and the need for radio tuning and selectivity was realized.
- 1920s saw the first home entertainment centers: bulky and expensive AM radios.
- 1930s saw introduction of automobile radios. Soon thereafter the first fuzzy dice were employed.

0.4 Basic Radio

- Figure 0.1 shows a block diagram of a basic radio transmitter. A transducer (for instance, a microphone) converts sound waves into electrical waves of the same frequency. It is not practical to transmit these waves for two main reasons. First, efficient antennas have lengths of the order of magnitude of the wavelength. A 1 kHz signal would therefore require a length on the order of 300 km for optimum efficiency.

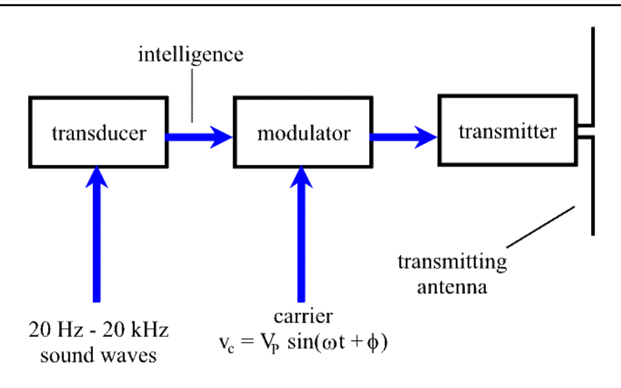

Figure 0.1: Generic radio transmitter

The antennas efficiency would also degrade at wavelengths away from the 300 km design wavelength. The second limitation is that only one station could be broadcast without severe interference.

- The 20 Hz – 20kHz audio signal is referred to as the *intelligence*. It is used to modulate a carrier wave. It can modulate the amplitude (V_p), the frequency (ω) or the phase (ϕ), resulting in, respectively, AM, FM and PM.
- AM: 540-1600 kHz is the designated range, with 10 kHz channel widths, allowing broadcast of audio signals up to 5 kHz.
- FM: 88 – 108 MHz with a 200 kHz channel width allows broadcast of audio signals up to 15 kHz.
- The transmitter may contain power amplifiers, filters and an antenna.
- Figure 0.2 shows a block diagram of a basic radio receiver. The receiver front-end contains the antenna, tuner, filters, and amplifiers.
- The demodulator extracts the intelligence from the high frequency carrier. For AM, the demodulator is mostly referred to as the detector, and for FM, it is referred to as the discriminator.
- FM sounds better than AM for several reasons. First, FM can broadcast higher audio frequencies. Second, noise on the signal (from lightning strikes, static) generally effects the signal amplitude rather than the frequency. Thus, AM tends to be much noisier than FM.

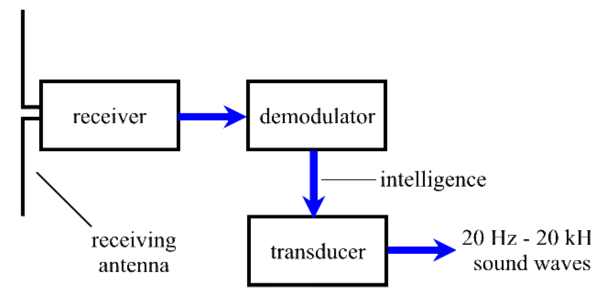

Figure 0.2: Generic radio receiver

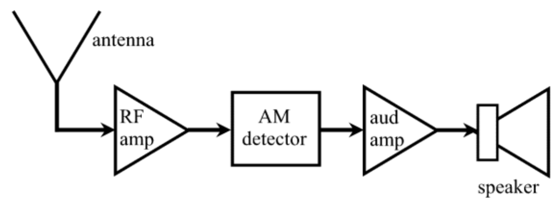

Figure 0.3: Single station AM radio

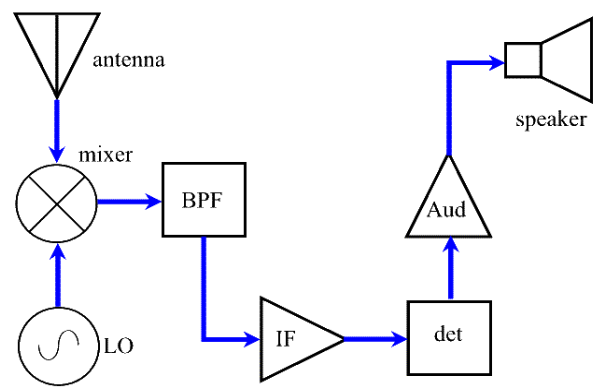

Figure 0.4: Generic AM radio

0.5 Part I. The single-station AM radio

The first part of this course will consist of studying and assembling the different components that make up a single-station AM radio as shown in Figure 0.3. We will begin construction of the radio at the output end, developing a simple audio amplifier to drive a speaker. A weak audio signal will be fed to this stage to see how well it amplifies and emits sound from the speaker. Then, the AM detector circuit will be studied and tested prior to adding it to the radio. At this point a weak amplitude modulated signal will be fed to the detector. If acceptable sound exits the speaker, then the RF ("Radio Frequency") amplifier stage will be studied, tested and added. Finally, an antenna will be studied and added to the radio for picking up a single AM station.

0.6 Part II. Heterodyne AM radio

A more advanced radio design will allow the user to tune the radio to pick up different stations. This is done using a *heterodyne* approach, as indicated in Figure 0.4. Here, the amplitude modulated RF signal is mixed with a tunable oscillator frequency. The output of the mixer is filtered to leave behind only the intermediate frequency (aka difference frequency), which is then amplified. This frequency conversion process of mixing two sinusoidal signals to produce a third sinusoidal signal is called heterodyning. The amplitude modulated IF signal is then passed through a detector to extract the audio signal. The audio signal is then amplified and passed to the speaker. Heterodyning is frequently used in communication systems to down-convert a received signal to a more manageable frequency, or to up-convert a signal to a higher frequency, perhaps so it can then be broadcast.

0.7 Part III. AM radio enhancement

In the final part of this course, students and their instructor will agree on a project topic that involves modifying your radio to enhance its performance. Possibilities include reducing power consumption, building a different version of a block such as the audio amplifier, adding feedback to stabilize the output for different levels of station strength, adding a circuit for adjusting bass/treble of the output, adding a signal strength meter, or adding a received frequency display.

0.8 Tips

Here are some general tips to help you in this class.

- Often what you breadboard one week will be used the next week, so do not be too quick to disassemble!
- Consider checking out a free Green Room locker (1st floor of Broun) to store your parts so they don't receive backpack damage.
- When you begin antenna construction, you will likely find it very convenient to have electrical tape (or duct tape) and a knife (or box cutters). You may also want to procure an all-plastic small flat head screwdriver for tuning your trimming capacitors (contact with metal greatly influences its performance). Some students get by quite well with a plastic guitar pick.
- Get a jump on your radio enhancement project by communicating with your project partner. This person is easy to identify: they are sitting at the table adjacent to yours. Brainstorm early with your partner to get some ideas.