# (BUILDING A SIMPLE AM RADIO RECEIVER)

**Introduction:**

In earlier exercises you studied impedance that an inductor and a capacitor exhibit in an AC circuit. Since the voltage across one leads the current by $\pi/2$ while the voltage across the other lags it by $\pi/2$, it is possible to choose values of L and C such that at some frequency, with the same current flowing through each (as when they are connected in series), the total impedance can be made negligibly small. This only occurs at one frequency as the frequency dependence of the impedance of L and C are different. The frequency at which the impedance of the two elements just cancel one another is called the 'resonant' frequency. Such a circuit at resonance can pass a large current, with large instantaneous voltages across each element (L and C), but with a very small voltage across the two of them together.

A single loop containing one inductor in series with one capacitor is sometimes called a 'tank circuit'. Driving such a circuit at its resonant frequency with a small signal can build up large currents as the capacitor and inductor pass energy back and forth. This is like giving a pendulum a small push each time it passes through its lowest position. The energy stored in the pendulum (potential or kinetic) increases with each push until it is swinging wildly. In this way, the phenomenon of resonance can be used to detect an AC signal of one frequency in the presence of a jumble of signals at other frequencies. This has many uses, including that of a radio (or TV) receiver, and the principle remains relevant also in our era of digital TV.

The technical information that is given here about radio transmission and reception is included to satisfy the curiosity of those of you who want to know why the circuit works.

During this laboratory, you will:

1. Build an LC circuit, making use of your experience in past labs to find the inductance and capacitance from the geometry of the devices.
2. Investigate resonance in an LC circuit.
3. Use an LC circuit to build a simple amplitude modulation (AM) radio receiver.

**Introduction:**

In the 1920's, during the infancy of radio communication, it was not uncommon for hobbyists to build AM radio receivers from crude components. Wrapping any household tube such as a 'Quaker Oatmeal' container with wire could make one of these, the inductor. Other parts, such as the diode (made with crystals of galena – lead ore) which was needed to rectify the signal, could be obtained at hobby shops. The crystal was used with a fine curl of wire called a 'cat's whisker' to construct a crude diode (diodes are electronic components that allow current to flow in only one direction). Built around the galena, these receivers became known as 'crystal radios'.

In this exercise, you will investigate some of the physics involved in such a radio receiver. Specifically, you will investigate how a simple circuit consisting of an inductor L and a capacitor C can be adjusted (tuned) to resonate at a desired frequency, select a particular radio station from what is now a broad spectrum of communication channels, and convert the energy received into comprehensible information.

To understand the function of a radio receiver, you need to know some basic properties of a radio signal. Almost all wireless (and fiberless) communications (including radio – AM/FM/short wave/CB, cellular phones and television) use electromagnetic waves (same as light, but with longer wavelengths) as the transport medium. Radio communication consists of two parts: 1) sending an electromagnetic wave that has been coded with information in the form of a modulated signal; 2) receiving the signal and decoding the information and expressing it in a form that can be detected by the human senses.

The radio signal itself can be considered as having two parts, the carrier wave and the information modulation. The carrier wave is a sinusoidal electromagnetic signal that is used to carry the energy. High frequencies are used because they offer better properties for propagation and detection of the signal. You may have noticed in the induction experiment that a high frequency wave induces a higher voltage in the transformer's secondary winding than a low frequency wave of the same amplitude. The carrier wave should have a much higher frequency than its modulation (information) to avoid confusion in the decoding process. This established a convention for separating signal frequencies into two categories: Radio Frequency (RF) for higher frequencies and Audio Frequency (AF) for low frequencies. Check your text for a chart showing the range of the electromagnetic spectrum.

The second part of the transmission signal is the information modulation. The two common analog (as opposed to digital) types of modulation are Amplitude Modulation (AM) and Frequency Modulation (FM). In AM radio, the sound information is superimposed onto the carrier wave by increasing and decreasing the amplitude of the carrier wave in proportion to the audio. This could be accomplished at the transmission station by sending an electrical signal of the same frequency as the carrier wave through a microphone. The microphone would change its resistance in proportion to the pressure of the sound. This would change the amplitude of the signal. (In reality, radio stations use more elaborate devices.) The resulting signal had a modulated amplitude (see Figure 22), thus the name AM (Amplitude Modulation). The signal is then broadcast by an antenna.

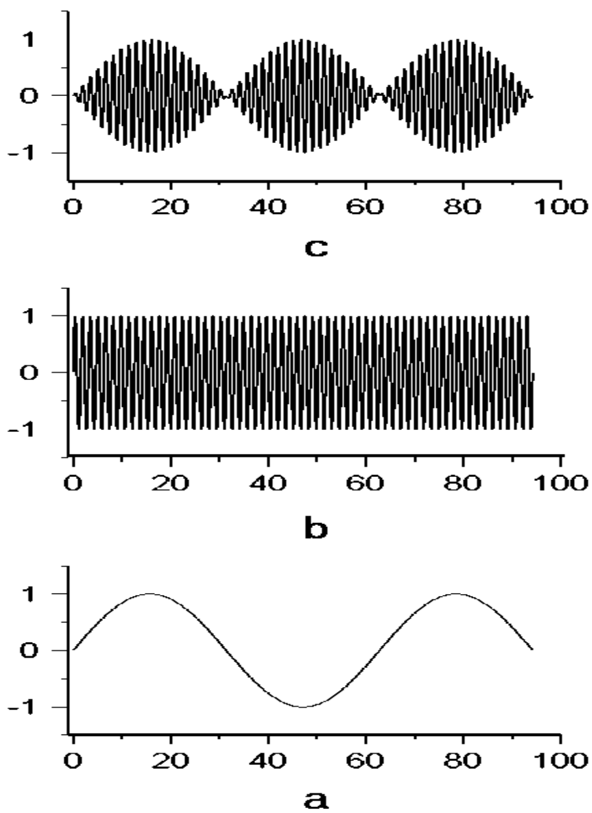



**Figure 17: a) Low frequency sound wave, b) High frequency carrier wave, c) Carrier wave with amplitude modulated by the sound wave**

In this lab, the LC circuit will be tuned to the carrier signal, and a diode and earphone will demodulate the signal, that is, separate the audio frequency from the carrier wave radio frequency. The LC circuit, adjusted to resonate at the frequency of the carrier wave, captures a little of the energy of the wave to produce a forced harmonic oscillation of current (and potential) in the circuit. The audio modulation causes the peak to peak voltage in the circuit to increase and decrease. A simple earphone in series with a diode can detect these changes in amplitude and convert them back into sound waves that you can hear.

This radio receiver is powered purely by the energy of the radio signal it receives. It needs no batteries, or other sources of power. The sound volume it produces is rather low, however. To amplify it, as is done in more practical radio receivers, would require power from another source.

**Experiment:**

**A Resonant circuit:**

You have used all of the components used in this lab with the exception of the diode and inductor. You worked with the same adjustable capacitor when studying 'Capacitance, Geometry, and Ohm's Law'. Look back in your notebook for the expressions for the value of C and recalculate if necessary.

The inductance of a solenoid of length Y, number of turns N, and cross sectional area A is given by: $L = \mu_0 A N^2/Y$ Henries (H). Once again, $\mu_0$ is the permeability of free space. In your case, something like (check with TA) Y = 13.1 cm, N = 120 turns, and the radius of the form on which the coil is wound is 3.6 cm. The uncertainty of both the length and radius is 0.1 cm.

- **Calculate L, the inductance of this solenoid.**
- **Calculate $\Delta L$, the uncertainty of this number.**

The circuit contains an inductor L, a capacitor C and an oscilloscope. If you are not familiar with the symbols, please review figure 23. Remember that the resonant frequency of such a circuit is:

$$f = 1/[2\pi(LC)^{1/2}].$$

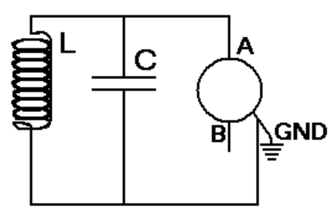
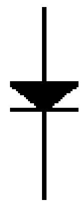
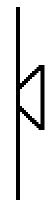



**Figure 18: Resonant LC circuit**

- The diode and headset should not be part of the circuit for the first part of the lab.
- By adjusting the capacitor, tune the circuit to obtain the strongest signal (largest amplitude on the 'scope) (Please read "*Appendix VI Leybold Parallel Plate Capacitor*" at the end of the chapter. Note: If you feel resistance while turning the large knob, stop turning it. **Do NOT force either of the knobs.**)
- From the dimensions of the components, calculate the theoretical resonant frequency $f_t$ and its uncertainty $\Delta f_t$.

- Record the frequency of the carrier wave $f_{cw}$. Estimate its uncertainty, $\Delta f_{cw}$.
- Compare the observed and calculated resonant frequencies with a linear comparison graph. Do they agree? Can you think of any reason why they might not be in agreement?

**A Crystal Radio:**

Adding a diode: , and an earphone: , you can complete the crystal radio, shown in figure 24.

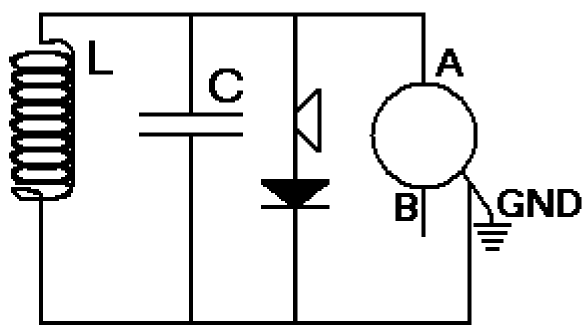



**Figure 19: Crystal radio with oscilloscope**

- **Adjust the capacitor to obtain resonance in the circuit. Use the 'scope and earphone to determine the conditions for highest amplitude (loudest signal).**
- **Record the frequency in your notebook with an estimate of its uncertainty.**

The carrier wave's peak to peak amplitude will not be well defined. It oscillates with the sound wave modulation. The sound will be faint (all the power to drive the earphone must come entirely from the carrier wave). Please help keep the room as quiet as possible so that you and others will be able to hear it.