Self-Built AM Radio

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Building a radio by hand is a very important skill to know in emergency situations. A simple radio can be built with an inductor, capacitor, wire, breadboard, diode, and speaker. The radio built in this lab was able to receive a radio frequency of $710kHz$*. Thus, the handmade inductor's inductance is calculated to be* $(3.14 \pm 0.1)\ x\ 10^{-1} mH$*.*

I. INTRODUCTION/THEORY

IN 1865, James Maxwell discovered that electromagnetic waves propagate through empty space at the speed of light and that light is in fact one of these waves [1]. When the frequency of these electromagnetic waves is within a small band, they are visible to the human eye. However, at very low frequencies, these waves can be used to carry audio signals. A simple circuit with an inductor, capacitor and diode can be used to receive these radio waves. The low frequency allows the waves to penetrate through most solid objects. The radio frequency carrier wave can be described by the equation:

$$C(t) = C\cos(w_c t + \phi_c) \tag{1}$$

The wave $C(t)$ has amplitude C, angular frequency w_c and phase ϕ_c. However, the phase is assumed to be 0 as it only changes the time the radio signal starts. The audio message being carried is described

$$m(t) = M_1\cos(w_1 t + \phi_1) + M_2\cos(w_2 t + \phi_2) + ... \tag{2}$$

Each term represents a different tone in the audio message. For a pure tone, only one term exists. The radio carrier wave superimposed with the audio message results in the following equation:

$$V(t) = A\cos(w_c t) + \frac{M}{2}(\cos[(w_c + w_a)t] + \cos[(w_c - w_a)t]) \tag{3}$$

The frequency w_a is the frequency of the pure tone and A is constant offset. It is assumed that $w_c < w_a$ for radio and audio frequencies. This equation represents the signal to captured and analyzed by radio equipment.

In order to analyze the audio message on a radio signal, the signal must first be captured and then demodulated. An LC circuit can be used to select a certain frequency range of signals by using a resonant response. The LC circuit resonates at a frequency of

$$f = \frac{1}{2\pi\sqrt{LC}} \tag{4}$$

Where L is the inductance and C is the capacitance. A diode can demodulate the signal according to the following equation:

$$I_{audio} \propto \cos w_a t + \frac{M}{4A}\cos 2w_a t \tag{5}$$

The first term accurately produces the desired audio signal while the second term is a slight distortion. The coefficient in the second term, $\frac{M}{4A}$ is small enough to be ignored.

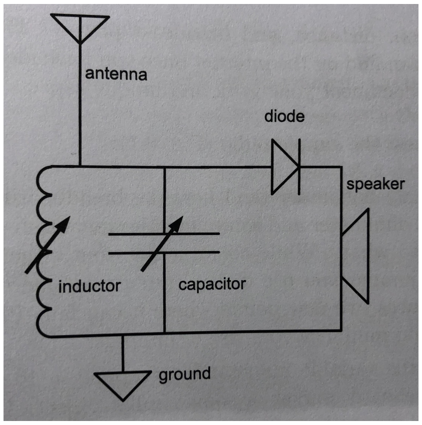

Figure 1: *The breadboard components of the simple radio. [1]*

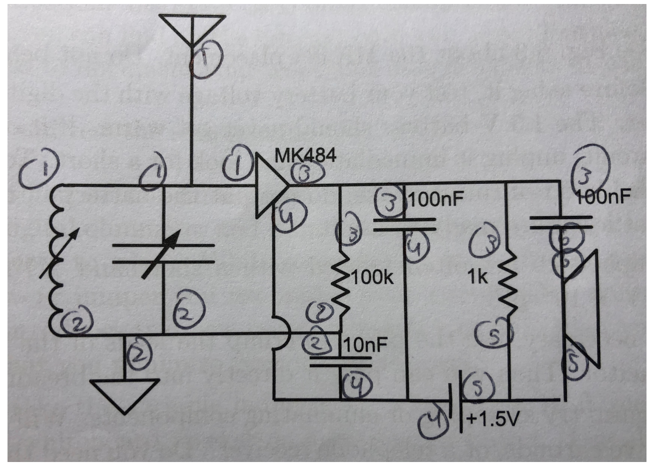

Figure 2: *The breadboard components of the amplified radio. The written numbers correspond to which row those components were placed on the breadboard. [1]*

II. Experimental Arrangement and Procedure

Two radios were built, a simple model and an amplified radio model. Both radios were built using a breadboard for the circuit wiring and basic circuit components. The simple radio model circuit can be seen in Fig. (1).

A variable inductor was built by wrapping 10 feet of AWG enameled copper wire around a 1 inch thick rod. The wire was sanded along the edges so it could connect with the rest of the circuit. The coil was held together by electrical tape. When placed on the circuit board, ferrite rods were placed inside the coil and moved to be partially inside in order to vary the captured frequency. Additionally, the capacitor used was a variable capacitor from $0 - 160pF$. By altering the inductance and capacitance of the circuit, the receiver changes which frequency it is sensitive to. This allows the radio to change radio channels.

The antennae used was $100ft$ of solid single-conductor 22 AWG tinned copper wire, with PVC insulation [1]. The antennae receives the radio signal and relays it to the rest of the circuit board. The speaker was a simple piezo-electric earphone to play the audio. Finally, for both radios, ground was a metal pipe to get as close to an infinite source of electrons as possible. The diode was a 1N34A germanium diode used to demodulate the radio signal into an audio signal via Equation (4).

The amplified radio used the same antennae, variable inductor, variable capacitor, ground connection, and speaker. The new components were two $100nF$ capacitors, a $10nFcapacitor$, a $1k\Omega$ resistor, a $1.5V$ battery, a $1.5V$ battery holder, a $100k\Omega$ resistor and an $MK484 - 1$ AM radio integrated circuit. The circuit build can be seen in Figure (2).

Normally, the myDAQ assistant would be used to record the audio message by replacing the speaker inputs with the myDAQ inputs. However, a PC is needed in order to be able to utilize the myDAQ. Therefore, the audio file was recorded by placing earphones just next to the speaker and recording from there via LabView. This greatly reduces the quality of the audio files.

III. Data, Analysis, and Results

The simple radio was able to capture a faint but audible from the radio station AM710 ESPN-LA. When altering the ferrite core in the inductor, other channels were not able to be accessed.

The amplified radio was able to produce much higher quality audio from the station

AM710 ESPN-LA than the simplified radio. Additionally, after the ferrite cores were moved inside the inductor, a new channel was picked up by the radio. This time it was UCLA radio.

Since the radio picked up ESPN-LA at $710kHz$, the resonant response produced by the inductor and capacitor must be within that range. The capacitor's dial was set to $160 \pm 5pF$. Using Equation (4), the inductance, L, is calculated to be (3.14 ± 0.1) x $10^{-1}mH$.

IV. Conclusion

The amplified radio produced sound quality good enough to use to casually listen to either UCLA radio or ESPN-LA. Using just a few circuit board components, this radio was able to capture a specific frequency of radio waves and demodulate it to receive an audio signal.

This lab can be improved by using a larger inductor. A larger inductor would allow more ferrite cores to be placed inside, and therefore allow more radio channels to be accessed. The inductor used was only capable of holding two ferrite cores. Additionally, the inductor could use more than 10 feet of wire to make it longer and allow more variance. The inductor used was not long enough to cover the ferrite core entirely.

The lab could also be improved by using PC laptops to utilize the myDAQ assistant when recording the audio signals. This would result in much clearer audio signals than recording from the speaker. This easily built radio can be very useful in emergency situations when communication becomes threatened. All one needs is a breadboard, wire, capacitor, inductor, diode, and speaker. Building a radio from these components could prove to be a vital asset in certain situations.

References

[1] G. Wang, Physics 18L Lab Manual (2018).