The University of Scranton

Physics and Electrical Engineering Department

Electromagnetics Laboratory Amplitude Modulated Radio

Author:
Thomas Swartz
Department of Physics
University of Scranton
Scranton, PA 18505

Instructor:
Dr. Argyrios Varonides
College of Arts and Sciences
University of Scranton
Scranton, PA 18505

May 2, 2011

Abstract

This experiment demonstrates the procedures and theoretical background of Amplitude Modulated radio broadcasts. The primary part of the experiment pertains to the creation and utilization of an AM reciever, as well as an AM transmitter using active components. The secondary part of the procedure involves the hand-made creation of an AM receiver with a bipolar junction transistor amplifier.

Contents

List of Tables

1 Introduction

This project will examine the usage of AM (Amplitude Modulated) radio transmission. The main topics covered by this experiment are; the creation of an AM transmitter, the creation of an active AM receiver, and the creation of a passive AM receiver.

AM radio transmissions were the dominant method of broadcasting information throughout much of the 20^{th} century. AM receivers detect amplitude variations of radio waves from a specifically tuned frequency and converts it into a signal that could be amplified and heard.

The setup for this experiment will not use any amplification.

1.1 Operation of AM Broadcasts

In order to adequately understand how to create a proper AM transmitter and receiver, one must understand how AM radio operates. Much of the experiment relies on local AM radio station broadcasts, although this prerequisite may ignored; as will be discussed in Section 3.

In North America, the transmitter power for commercial AM stations range from 250 Watts to 50,000 Watts. Naturally, the larger power transmitters cover a much greater distance.

Medium-wave and short-wave AM radio signals act differently during daytime and nighttime. During the day AM signals travel by ground wave; the signals reflect off of the surface of the Earth and the ionosphere, diffracting around the curve of the Earth for a few hundred kilometers. However, at night, changes in the ionosphere allow the signals to travel for distances up to a factor of 3 to 4 times their daytime distance. Because of this susceptibility to atmospheric and electrical interference, AM broadcasting mainly attracts talk radio and news broadcasts, as music broadcasts lose much of the fidelity from such interference.

2 Procedure

The experiment consists of three distinct apparatus; a 'tank-radio' kit, a transmission kit, and a hand-built receiver. The parallel configuration of an inductor and capacitor is often referred to as a 'tank' circuit because of its ability to store electrical energy in the circuit.

The primary concern of the experiment involves the induction of currents in conductors. A current can be induced into a wire by either moving a loop of wire in a constant magnetic field or by exposing the loop of wire to a changing magnetic field.

Faraday's Law effectively describes the generation of electromagnetic fields. Faraday's Law states that the induced EMF in the circuit is numerically equal to the rate of change of the magnetic flux through it.

For a coil of many turns, Faraday's Law is:

$$E = -N\frac{d\Phi}{dt} \tag{1}$$

Where N is the number of turns in the coil of wire. The equation says that the EMF is the time rate of change of the magnetic flux through the coil.

2.1 Creating an LRC AM Receiver

Using the provided circuit schematic, a simple circuit is created and attached to a large length of wire to be used as an antenna. For this experiment, two wires to be used as an antenna were used; a short wire of about 15 feet, and a wire of about 300 feet in length stretched from The University of Scranton's St. Thomas Hall 5^{th} floor to the Physics Lab on the 2^{nd} floor. The short antenna was tested in separate configurations. The antenna was oriented horizontally across the laboratory, and then at a $45°$ angle with respect to the setup. The setup of the large antenna prohibited testing directional antenna configurations. However, given the large distance of the antenna, the effect could largely be ignored as the antenna is much greater than the average wavelength of the signals that will be received. If the antenna was shorter than the average wavelength of the signals received, then it would be necessary to test directional antennas. A LED was bridged from the leads of the receiver coil and the attached capacitor was tuned until the the LED began to illuminate. A capacitive ear-piece was attached in the appropriate place on the circuit and the properly tuned AM radio broadcast was heard.

Next, a transmitter was created using a similar schematic and attached to a variable signal generator. The extremely simplified transmitter circuit consists of an inductor, capacitor, and the signal generator. The signal created by the variable signal generator is transmitted through the open loops of the inductor. The tank radio's ear-piece was replaced with the leads to an oscilloscope and placed in front of the transmitter's inductor coil. The received signal was measured from the oscilloscope and the receiver's placement in reference to the transmitter was varied. Three separate positions were noted and logged; one at $0°$, one at $-45°$, and one at $45°$.

2.2 Creating a Passive AM Receiver

Creation of a Passive Crystal Radio, similar to the 'trench radios' used during World War II, is slightly more complex. Fortunately, using a schematic greatly aided the construction. Figure 1 shows the circuit diagram for a 'tank radio'. A large variable inductor was wired to the antenna signal, a capacitor, and a capacitive ear-piece. Once the variable inductor was tuned, a radio broadcast was discernible from the background noise of the circuit. In order to "clean up" the signal, a diode was attached and a variable resistance apparatus was attached across the leads of the inductor. This increased the volume of the received signal significantly. The received signal was then passed to the oscilloscope and measured.

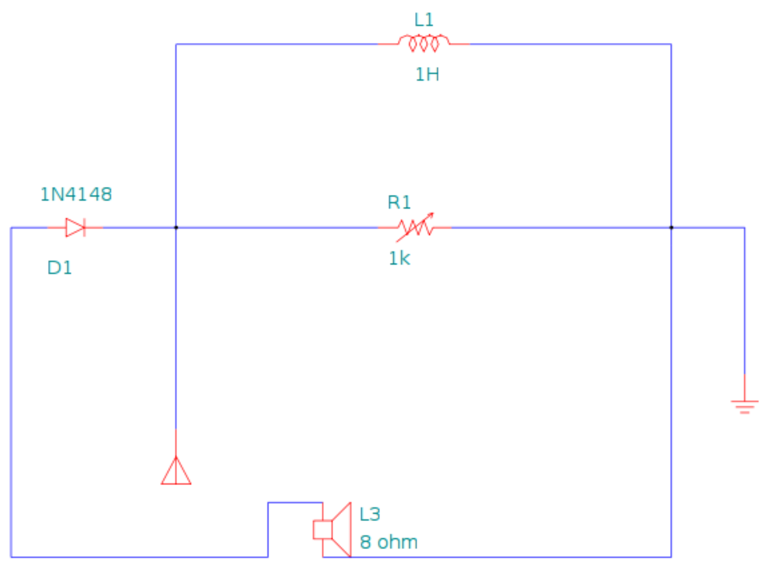

Figure 1: Receiver Coil Wiring Diagram for a Crystal Radio

2.3 Hand-Built AM Receiver

In addition to the kits provided for this experiment, a hand-made AM receiver was created using a breadboard and a large variable inductor. Reverse-engineering the passive crystal receiver and recreating it on a breadboard allows for much more customization of the circuit, such as the introduction of a digital amplifier and even a digital signal processor. Neither of these were used in this experiment but may be revisited at another time, if time permits. The hand built receiver was customized using transistors to boost the received signal. This configuration is referred to as a bipolar junction transistor amplifier, or a BJT receiver, as seen in Figure 2.

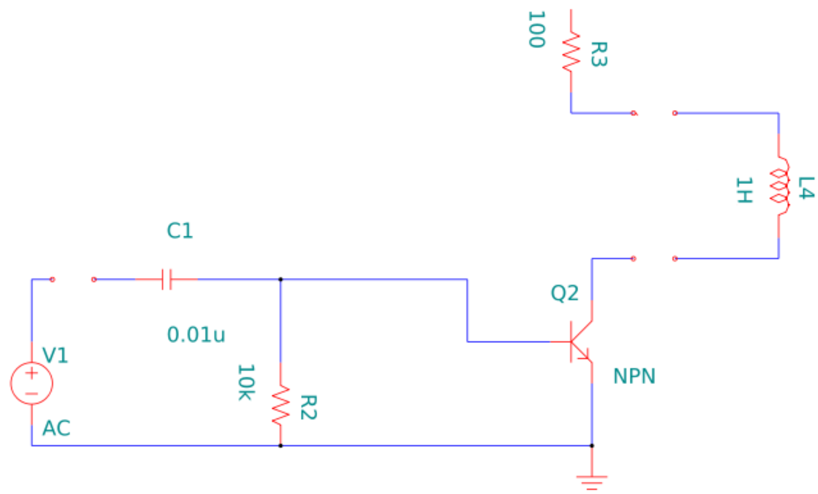

Figure 2: Schematic diagram of a BJT amplifier

3 Discussion

The hand-built and crystal radios had the ability to tune to 2 stations, which were subsequently referenced on a Radio Shack SW-100 Multi-band Radio. The first station was ESPN Radio (AM 630 kHz) and a Scranton News Radio station (900 kHz)

Using the crystal radio kit, it was observed that upon attaching a "decade box" (a variable resistor bridge) and increasing the resistance to $\sim 40k\Omega$ the audio signal heard from the earpiece would increase. After the resistance on the radio increased above $50k\Omega$, the observed audio would decrease in intensity. Upon further investigation it was noted that the resistance of the earpiece was $10k\Omega$. Once the resistance of the circuit became much greater than the resistance of the earpiece, the audio intensity began to decrease.

It is also important to address the effect of directional antennas. Given many small-apparatus AM radio sets (such as the Radio Shack SW-100 used in this experiment) the attached AM antennas are mounted in such a way that they could be oriented in the X-Y plane. This feature is very important on small sized antennas, as noted in Section 2.1.

The following data was collected:

	Capacitive Earpiece	Circuit
Resistance	82.5 pF	115 nF
Inductance	195 μH	215 nH

Table 1: Calculated Values of Apparati

References

[1] "Operating Instructions", The Science Source, 1996. Waldoboro Maine.

[2] Newkirk, David and Karlquist, Rick (2004). Mixers, modulators and demodulators. In D. G. Reed (ed.), The ARRL Handbook for Radio Communications (81st ed.), pp. 15.115.36. Newington: ARRL. ISBN 0-87259-196-4.