University of Pennsylvania
EE206: Electrical Circuits and Systems II – Lab

Amplitude Modulated Radio Frequency Transmission System

Introduction

An Amplitude Modulated Radio Frequency Transmission system consists of a modulator in which a sinusoidal high frequency carrier waveform, f_c, is amplitude modulated (AM) by a lower frequency signal, f_m, containing information to be transmitted. In case of an AM radio transmission, the signal f_m is the voice or music while the carrier frequency f_c is the frequency at which one tunes the radio, e.g. 1060 kHz.

The modulation process requires a multiplication of the two signals. This results in a frequency spectrum composed of the carrier frequency, f_c, and two sideband frequencies at (f_c - f_m) and (f_c + f_m) containing the information. Note that the low frequency information-bearing signal, f_m, has been translated to a much higher frequency range for greater transmission efficiency. Either sideband can be used to recover the modulation signal. The resulting AM signal is shown in Figure 1.

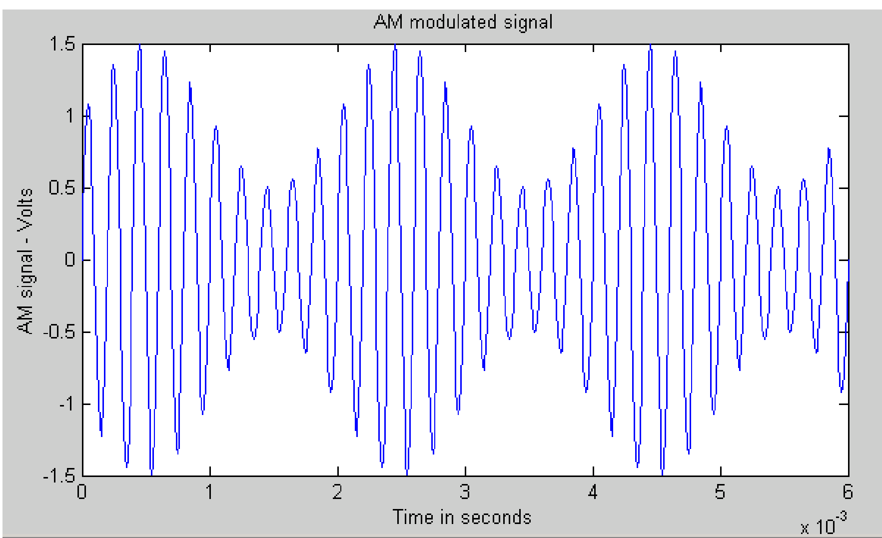

Figure 1: Am Modulated Signal (f_m=500 Hz and f_c=5kHz)

The transmitted radio frequency (RF) signal is received using a tuned filter Followed by an amplifier. A demodulator circuit is then used to extract the information-bearing modulation waveform.

AM Radio Transmission System

In this lab exercise, an AM radio transmission will be designed and tested. The AM system block diagram is shown in Figure 2.

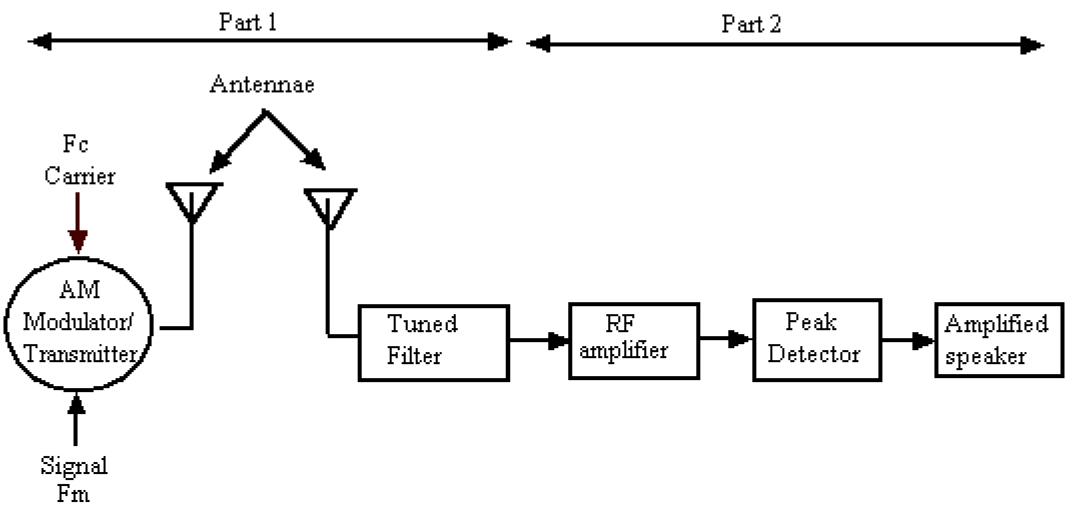

Figure 2 Elements of a Basic AM Radio Transmission System

This exercise will demonstrate some basic principles of AM radio transmission systems. The system elements consist of:

1. AM modulator/transmitter
2. Tuned circuit receiver
3. RF amplifier
4. Peak (or envelope) detector
5. Audio frequency transistor amplifier

During the first lab you will build and test the first part (modulator with tuned filter) of the AM Radio Transmission system (Fig. 1). The second part will be done in a few weeks after you have discussed transistor circuits in EE216.
Design of an AM Modulator

Pre-lab assignment

1. Read the first part of section 12.3 in the textbook by D. Irwin on Resonance circuits.
2. Design a parallel LC circuit so that the resonance frequency is 200 kHz. This will be used as the tuned filter that detects the career frequency. You can use one of the following values for the inductance L:

47 µH
82 µH
100 µH
680 µH

In-lab experiments

Parts:

1 – 2N5457 n-channel JFET (used as a variable resistor)
1 – LF356 Op-Amp
1 – Inductor (TBD)
1 – Capacitor (TBD)
1 – Resistor of 15kOhm
1 – Resistor of 1kOhm

Note: Construct this circuit in one corner of your protoboard and save it. In the second part of this project an AM receiver will be designed. After completion of the two circuits the combination will be tested to see if you have a working AM transmit/receive system.

Procedure:

1. Tuned LC circuit

   a. Build the LC circuit that has a resonance of about 200 kHz. Use the values of L and C that you calculated as part of the prelab.
   b. To test the circuit, connect a resistance of 1 kOhm between the function generator and the LC circuit as shown in the Fig. 3 below.

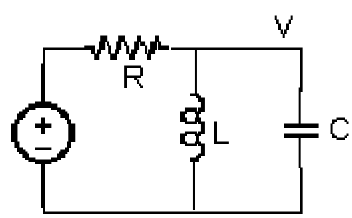

Figure 3: LC circuit.

Apply a sinusoidal signal to the circuit with amplitude of 5Vpeak-to-peak and vary the frequency from 10kHz to about 500 kHz. Measure the voltage over the LC circuit as a function of the frequency. Find the frequency at which the voltage is a maximum (resonant frequency). Find also the bandwidth and quality factor of this resonant circuit.

2. Modulator/Transmitter

The circuit of Fig. 4 shows how to build a modulator. It consists of a non-inverting amplifier in which the carrier V_i, with frequency f_c, is applied to the non-inverting input terminal. The gain of the amplifier (1 + R1/Rds) can be varied through a voltage-controlled resistor Rds. This resistor is implemented with a JFET (Junction Field Effect Transistor) transistor. This JFET can be considered as a variable resistor, as is shown in

Fig. 5. The voltage applied to the gate input terminal, V_G, determines the value of the resistor. The resistance is proportional to the applied gate voltage. The gate terminal is connected to the modulating signal V_S, with frequency f_m. This signal will thus change the amplification of the amplifier in relation to the value of the modulating signal, as schematically indicated in Fig. 4. This result in an AM modulated signal.

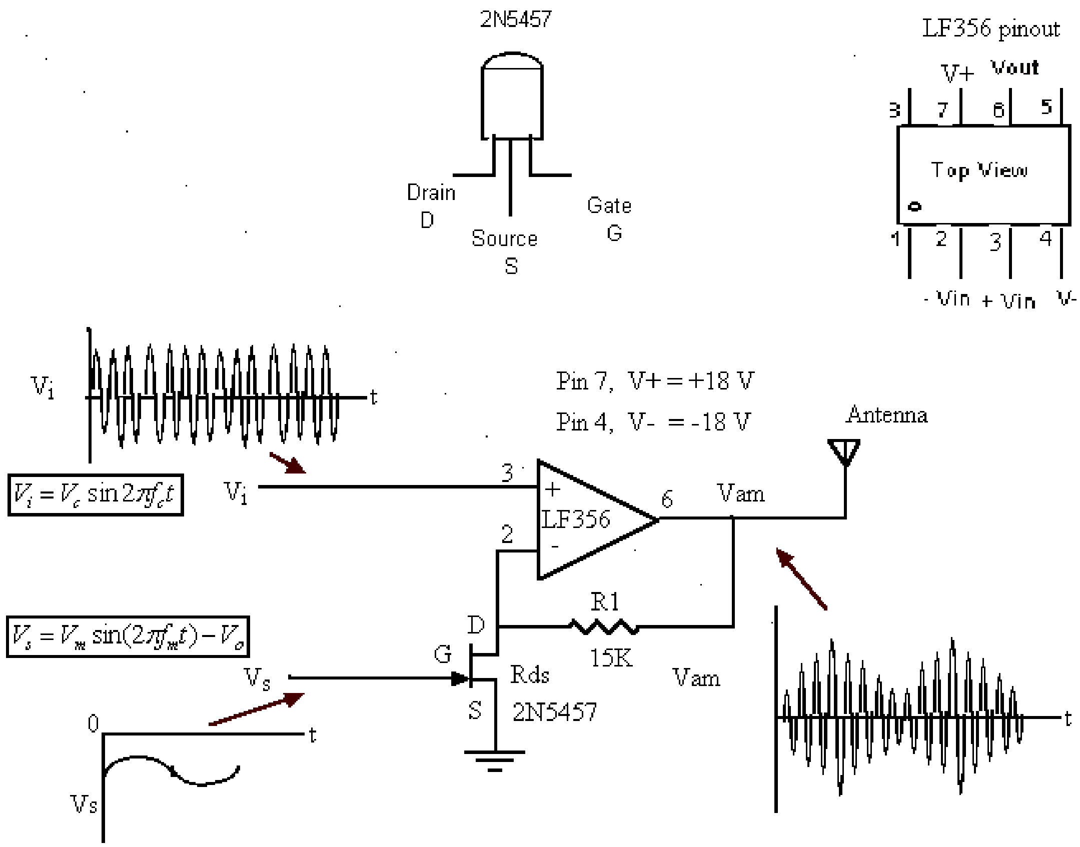

Figure 4: A Simple AM Modulation/Transmitter Circuit

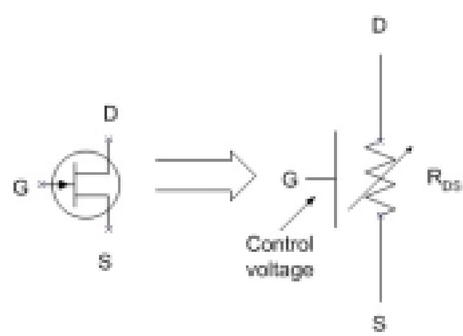

Figure 5: A JFET used as a voltage-controlled resistor.

a. Assemble the circuit shown in the Fig. 4. Pin 3 signal will be the carrier signal that should be in the 180 - 200 KHz range (supplied from a function generator). The exact frequency will be determined in the design of the tuned LC circuit at the receiver end (see previous section). Use the HP 33120A generator for the carrier waveform.

$$V_i = 0.5\sin 2\pi f_c t$$

The modulation waveform, Vs, requires approximately a – 1V off-set voltage to provide a quiescent operating point in the linear range of the R_{ds} vs. V_g. Use the Krohn-Hite 1200A function generator to provide this off-set to the modulation waveform. Check the waveform on the oscilloscope before connecting it to your circuit.

$$V_s = 0.2 \sin 2\pi f_m t - 1$$

b. Using a modulation frequency of 500 Hz, observe the modulator output V_{am} as V_m is increased. Make adjustments to the amplitude and off-set voltage of V_s to produce a maximum linear output waveform. (Approximately 2 Vp-p of modulation.)

c. The modulator will also act as the transmitter by connecting a 1-ft length of wire (you could use wire with clips or banana plugs) to the output terminal.

3. Modulator/Receiver

The goal is to transmit an AM signal and receive it using the tuned LC circuit.

a. After connecting a 1-ft antenna to the output of the transmitter, connect also a 1-ft antenna to the LC circuit (you do not need the 1kOhm resistor or function generator). This antenna will receive the transmitted waves and convert them in a voltage over the LC circuit.

b. Place the antenna from the modulator and from the receiver approximately 4-5 inches apart. Measure the voltage over the LC circuit using a oscilloscope probe. Display the received AM modulated signal on the oscilloscope. Measure the amplitude of the transmitted and received signals.

c. Place the antennas at different lengths from each other and measure the amplitude of the transmitted signal and the amplitude of the corresponding received signal. Do this for antenna distances of 1, 2, 4, 8 inches, 1, 1.5 and 2 ft apart.

4. <u>Report</u>

Under the Experimental Results section, discuss:

a. Tuned filter:
    i. Design, component values
    ii. Measured characteristics: resonant frequency, bandwidth, quality factor
b. Modulator:
    i. Show the measured modulated output signal and give the value of the amplitude Vm and off-set voltage of Vs that gives you a maximum linear output waveform.
    ii. What is the modulation index of your signal?
c. Modulator/Receiver:
    i. Show a oscilloscope trace of typical received signal. Indicate the amplitude of the overall signal and compare it with the amplitude of the transmitted signal
    ii. Show in table of graph form the ratio of the received over the transmitted signal as a function of the antenna distance.

March 24, 2002.