VE216 Lab 2 Report
AM Radio

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Contents

1 Objectives

- Understand the principle of envelope detector and its relationship with Amplitude Demodulation.
- Review op amp circuits.

2 Theoretical background

2.1 Transimitted Signal

The transmitted AM signal follows form $x(t) = (A+bs(t))cos(\omega_c t+\theta))$, where $cos(\omega_c t+\theta))$ is the carrier. The presense of A and b is important for envelope detection. The efficiency of signal transmitting can be calculated by the following equation

$$\frac{max(bs(t)) - min(bs(t))}{2A} \times 100\%$$

2.2 Pre-built Front-end: Antenna & Tuned RLC circuit

The front-end consists of a tunned RLC circuit, a field effect transistor pre-amplifier and a mixer. The RLC circuit can be modeled by the circuit shown below Figure 1. It is easy to verify that the circuit

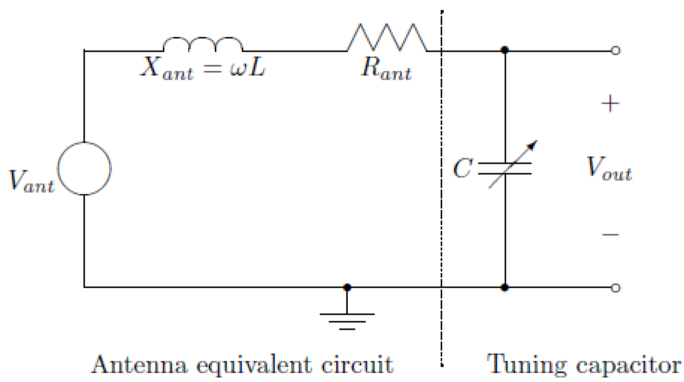


Figure 1: Tuned RLC Circuit diagram

serves as a bandpass filters

$$H(jw) = \frac{\frac{1}{c\omega j}}{\frac{1}{c\omega j} + L\omega j + R} = \frac{1}{LC(j\omega)^2 + RC(j\omega) + 1}$$

where the capacitor is controlled by the radio listener.

2.3 RLC Resonant Circuit

When the current in the circuit is maximized, the circuit is under the situation of resonant. The resonant frequency can be calculated by the following equation

$$f_{res} = \frac{1}{2\pi} \frac{1}{\sqrt{LC}} Hz$$

The 3dB bandwidth

$$BW_{3dB} = \frac{1}{2\pi} \frac{R}{L} Hz$$

The quality factor is

$$Q = 2\pi f_{res} \frac{L}{R}$$

2.4 Amplifier & Mixer in the Front-end

To demodulate the signal, we need to first move the signal to the frequency range where the IF filter works with the mixer. For example, an AM signal has been modulated (shifted) from the baseband

$$x(t) = (A + bs(t))cos(\omega_c t + \phi)$$

the output of mixer is

$$x(t) = (A + bs(t))cos(\omega_c t + \phi)cos(\omega_{LO} t + \theta)$$

We already know that cosine modulation in the time domain means moving in the frequency domain, so the way amplifiers and mixers work can be defined as Figure 2.

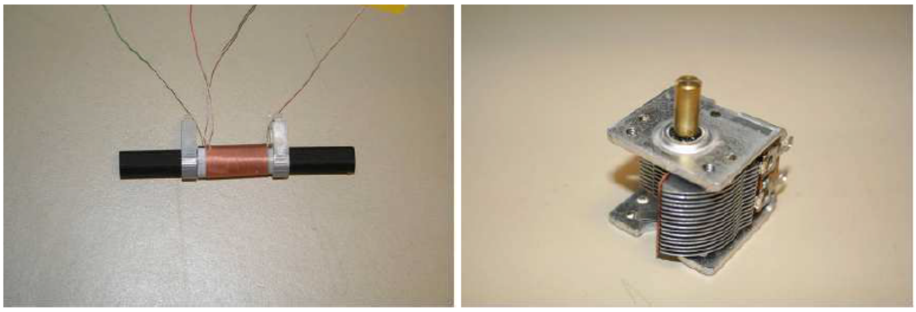


Figure 2: (a) original signal, (b) modulated signal, (c) signal after mixer

2.5 IF Filter

We know that mixers can be used to move the frequency of an AM signal to the desired range. This is especially important for filtering when the filter range is fixed like the IF filter. Usually, we have two choice of f_{LO}

$$f_{LO} = f_c - f_{IF}$$

or

$$f_{LO} = f_c + f_{IF}$$

When $x(t)$ isn't the only signal in the channel. Usually, other signals of different frequencies will also enter this range, interfering with the final demodulation $x(t)$. The situation is shown in Figure 3 & Figure 4

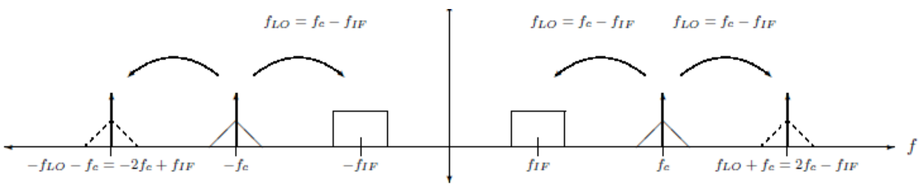


Figure 3: when $f_{LO} = f_c - f_{IF}$

So, before we mix the signals, we should add a band-pass tunable signal to the AM signal that is wider than the IF signal, but narrow enough to filter out those potentially interfering signals.

2.6 A simple Butterworth Filter Realization of the IF Filter

In the lab, we will construct an op amp-based IF filter, which is not optimal, but is easy to obtain.

It is shown in prelab that the frequency response is

$$H_{IF}(s) = \frac{a_1 s}{a_2 s^2 + a_3 s + a_4}$$

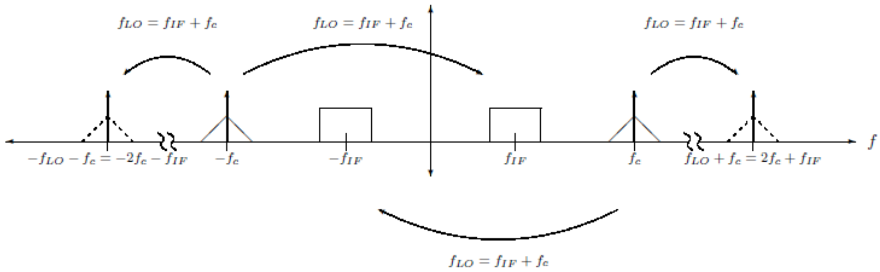


Figure 4: when $f_{LO} = f_c + f_{IF}$

where

$$a_1 = -R_2R_3C/(R_1+R_2)$$
$$a_2 = R_1R_2R_3C^2/(R_1+R_2)$$
$$a_3 = 2R_1R_2C/(R_1+R_2)$$
$$a_4 = 1$$

and through educated approximation, we can easily verify that

$$f_{res} = \frac{1}{2\pi}\sqrt{\frac{R_1+R_2}{R_1R_2R_3C^2}}$$
$$H_{max} = R_3/R_1$$
$$BW = 1/R_3C\pi$$

3 Experiment Procedures

3.1 Modulated Sine Wave

- Set the load of the function generator to be 50 Ohm
- Use the function generator to generate a modulated sine wave withe baseband frequency 1kHz and modulating frequency 100kHz.

  The original signal should have 4V Vpp.

  The carrier signal should be sine wave as well.

  The modulation index should be 0.5
- Directly connect the generator to the oscilloscope to verify the generated waveform. Store the images with time division 200μs and 20μs

3.2 Modulated Triangular Wave

- Repeat Part 1, with the only different that the original signal should have triangular shape.

3.3 Envelop Detector

- Assemble the circuit using $R = 75k\Omega$ and $C = 2.2nF$
- Use the envelope detector to "demodulate" the two signals in Part 1 and 2. Store images at 200μs and 20μs and be sure to display both CH1 and CH2

3.4 Amplifier

- Use the function generator to generate a 5kHz sine wave with 500 mV Vpp
- Assemble the circuit using $R_1 = 15k\Omega$, $R_2 = 5.6k\Omega$, $R_3 = 82k\Omega$ and $C = 220\mu F$

4 Experimental Results

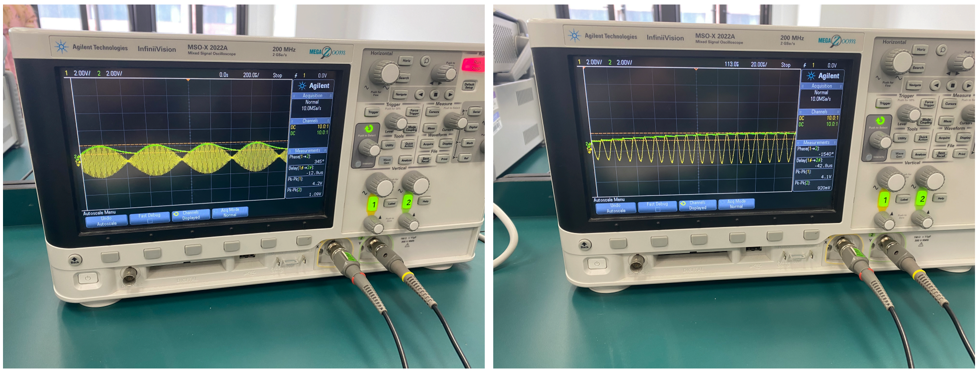
4.1 Modulated Sine Wave

The original sine wave is $s(t) = 2cos(\omega t + \theta)$. With index=0.5, the amplitude is 4Vpp. And the carrier should be

$$y(t) = (2cos(\omega t + \theta) + 4)cos(\omega_c t + \theta_c)$$

where $\omega = 1kHz/2\pi$ and $\omega_c = 100kHz/2\pi$

The generated wave is shown as the yellow part



(a) Time Division $20\mu s$ (b) Time Division $200\mu s$

Figure 5: Modulated Sine Wave

4.2 Modulated Triangular Wave

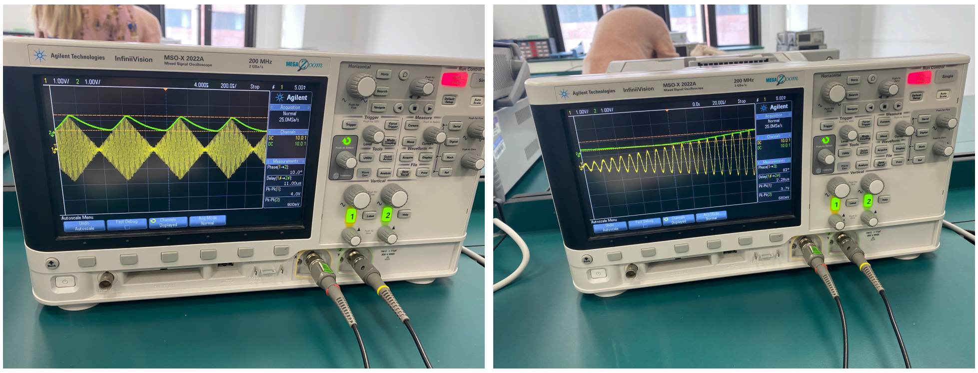
The original triangular wave is

$$s(t) = 2\sum_{n=-\infty}^{\infty} tri(4ft - 1 + 4n) - tri(4ft + 1 + 4n)$$

With index=0.5, the amplitude is 4Vpp. And the carrier should be

$$y(t) = (2\sum_{n=-\infty}^{\infty} tri(4ft - 1 + 4n) - tri(4ft + 1 + 4n) + 4)cos(\omega_c t + \theta_c)$$

where $f = 1kHz$ and $\omega_c = 100kHz/2\pi$
The waveform is shown in picture(yellow part) The generated wave is shown as the yellow part

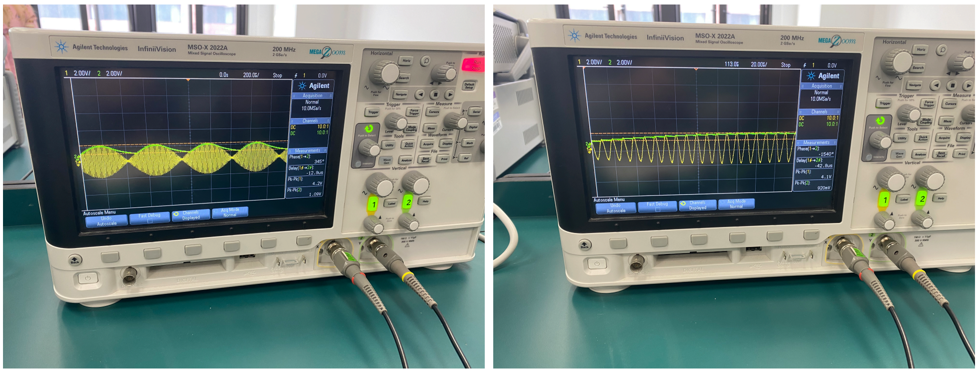


(a) Time Division 20μs (b) Time Division 200μs

Figure 6: Modulated Triangular Wave

4.3 Envelope Detector

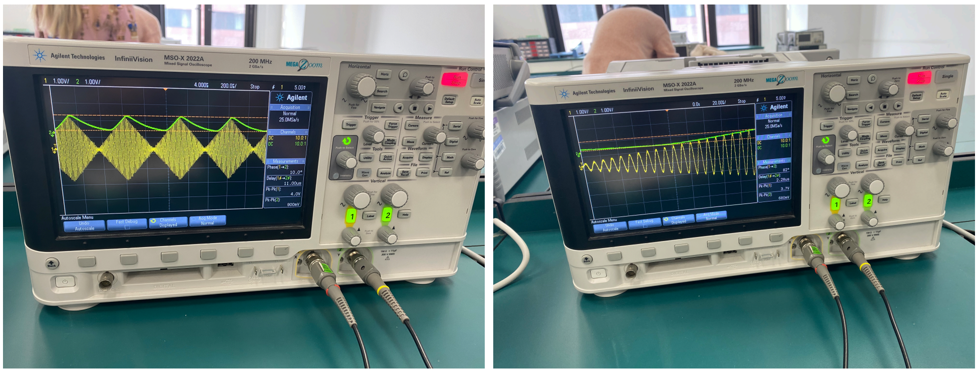
Sine wave Shown in the figure:



(a) Time Division 20μs (b) Time Division 200μs

Figure 7: Modulated Sine Wave with envelope

Triangular Wave Shown in the figure



(a) Time Division 20μs (b) Time Division 200μs

Figure 8: Modulated Triangular Wave with envelope

4.4 Amplifier

The measured input and output are shown in the figure

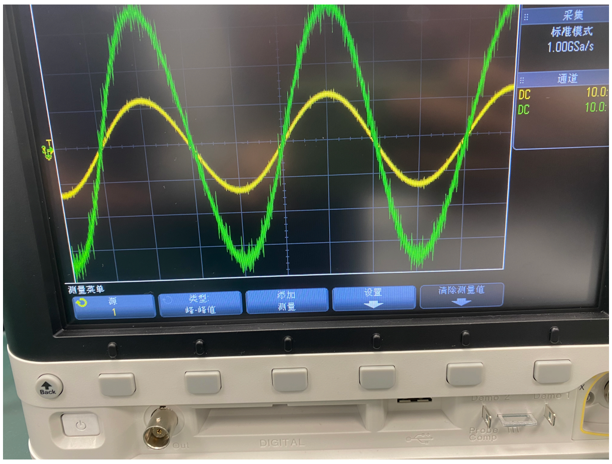


Figure 9: Input and Output with amplifier

Experimentally, we get the output $\frac{V_o}{V_i} = \frac{960mV}{250mV} = 3.84$
Theoretically, we get that

$$\frac{V_o}{V_i} = |\frac{(R_1 + R_2)c\omega j}{R_2(c\omega j + \frac{1}{R_3})}| = 3.68$$

Experimental outcome fit the theoretical outcome.

5 Conclusion

In this lab we

- Learn about resonance phenomena and simple RLC bandpass filters.
- Learn about the mechanism of antennas
- Learn basic superheterodyne receiver operating principles
- Construct a operational superheterodyne

And the error may cause by the resist of wire. Also, there may exist simulation error of the appliance. In the amplifier part, the error may caused by the unstable cursor.