ECE 4705 Lab
Experiment 6 – Amplitude Modulation
Julio Ortiz Guzman
ECE4705L_03

ECE 4705L **EXPERIMENT 6**

AMPLITUDE MODULATION[1]

INTRODUCTION

The objective of this experiment is to become familiar with amplitude modulation (AM modulation). With AM modulation, the amplitude of the sinusoidal carrier is used to amplify the message signal. Proper AM modulation requires a modulation index, which can be thought of as the extent to which the carrier modulates the message, that is large enough for the message to be contained within the carrier without going through any phase reversals. To perform this type of modulation, a circuit known as a square law diode modulator can be created following the circuit in Figure 1.

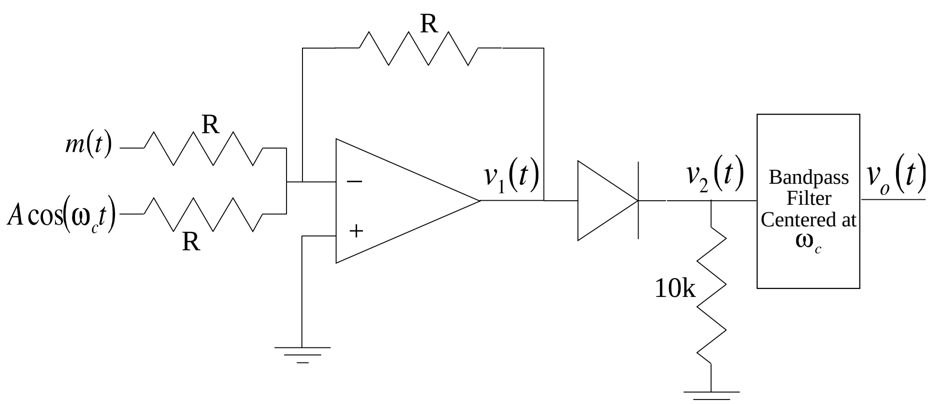

Fig. 1 – Square Law Dioide Modulation Circuit

For the given square law diode modulator, if we assume that

$$m(t) = A_m \cos(2\pi \times 5000t) \text{ and } carrier = A\cos(\omega_c t), \ where\ \omega_c = 2\pi \times 80000 \text{ rad/sec.}$$

and the diode characteristics are assumed to be

$$v(t) = av_1(t) + bv_1^2(t),$$

we can show that $v_2(t)$ is given by

$$v_2(t) = am(t) + bm^2(t) + bA^2\cos^2(\omega_c t) + aA\left[1 + \frac{2b}{a}m(t)\right]\cos(\omega_c t).$$

Finally, since the bandpass filter is centered at ω_c, only values within the given filter's frequency range will pass, resulting in a $v_o(t)$ given by

$$v_o(t) = aA\left[1 + \frac{2b}{a}m(t)\right]\cos(\omega_c t).$$

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[1] Based on a lab from Dr. James Kang

LAB

By substituting $m(t) = A_m \cos(2p \times 5000t)$ and $w_c = 2p \times 80000$ rad/sec, we can solve for the voltages at $v_1(t)$, $v_2(t)$ and $v_o(t)$, and sketch the two-sided amplitude spectrum of $v_2(t)$.

1. $m(t) = A_m\cos(2\pi 5000t)$ carrier $= A\cos(2\pi \underbrace{80000t}_{\omega_c t})$

characteristics

$$v(t) = av_1(t) + bv_2(t)$$

$$v_2(t) = am(t) + bm^2(t) + bA^2\cos^2(\omega_c t) + aA\left[1 + \tfrac{2b}{a}m(t)\right]\cos(\omega_c t)$$

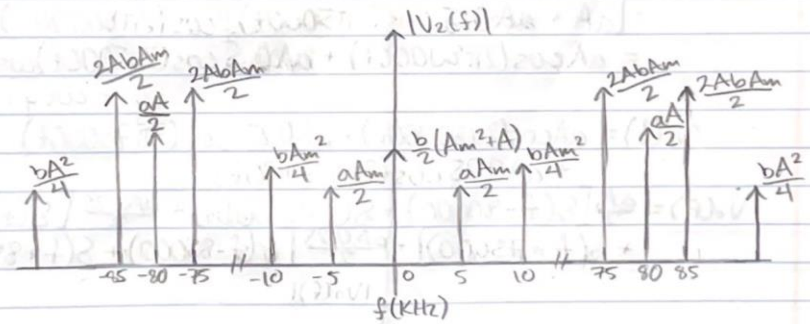
$$v_o(t) = aA\left[1 + \tfrac{2b}{a}m(t)\right]\cos(\omega_c t)$$

a) $$v_2(t) = aA_m\cos(2\pi 5000t) + bA_m^2\cos^2(2\pi 5000t) + bA^2\cos^2(2\pi 80000t) + aA\left[1 + \tfrac{2b}{a}A_m\cos(2\pi 5000t)\right]\cos(2\pi 80000t)$$

$$v_2(t) = aA_m\cos(2\pi 5000t) + \frac{bA_m^2}{2} + \frac{bA_m^2}{2}\cos(2\pi\cdot 2\cdot 5000t)\Big] + \frac{bA^2}{2} + \frac{bA^2}{2}\cos(2\pi\cdot 2\cdot 80000t)\Big] + aA\cos(2\pi 80000t) + A2bA_m \cos(2\pi 5000t)\cos(2\pi 80000t)$$

$\cos(2\pi f_c) \to \frac{1}{2}\delta(f - f_c) + \frac{1}{2}\delta(f + f_c)$

$$DC - \frac{bA_m^2}{2} + \frac{bA^2}{2} = \frac{b}{2}(A_m^2 + A^2)$$



Here we can see that the amplitude spectrum of the signal at $v_2(t)$ contains the spectra of both the message signal and the carrier signal, and only it's magnitudes are affected by the modulation index. Modulation index can also be though of as the ratio of the message amplitude to the carrier amplitude, where the ratio must be less than one to properly recover the signal when it comes time for demodulation. Solving for the modulation index of the output voltage in terms of a, b, and A_m results in a modulation index of,

b) $$v_o(t) = aA\left[1 + \tfrac{2b}{a}A_m\cos(2\pi 5000t)\right]\cos(2\pi 80000t)$$

$\mu = k_a A_m$ where $s_{AM}(t) = A_c[1 + k_a A_m\cos(2\pi f_m)]\cos(2\pi f_c)$

$$\mu = \frac{2bA_m}{a}$$

The final output $v_o(t)$ is obtained after passing the signal through the bandpass filter centered at the carrier frequency, so only the magnitudes within the bandpass range will be outputted. A sketch of $v_o(t)$ as a function of time and the corresponding amplitude spectrum showing magnitude in terms of A, a, b, A_m assuming a modulation index of 0.5 can be drawn.

c) $v_o(t) = aA[1+\frac{2b}{a}A_m\cos(2\pi 5000t)]\cos(2\pi 80000t)$

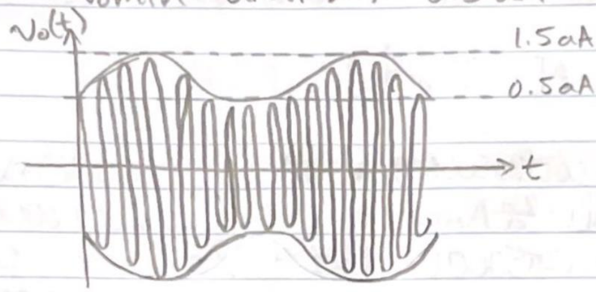
where $\mu = \frac{2b}{a}A_m = 0.5$

$\therefore$

$v_o(t) = aA[1+0.5\cos(2\pi 5000t)]\cos(2\pi 80000t)$

$v_{o\,max} = aA[1+\mu] = 1.5aA$

$v_{o\,min} = aA(1-\mu) = 0.5aA$



With modulation index, when Ac > Am, the signal can be modulated without any loss of the message but when Ac < Am there will be loss of data when the signal is recovered.

d) $v_o(t) = aA[1+0.5\cos(2\pi 5000t)]\cos(2\pi 80000t)$

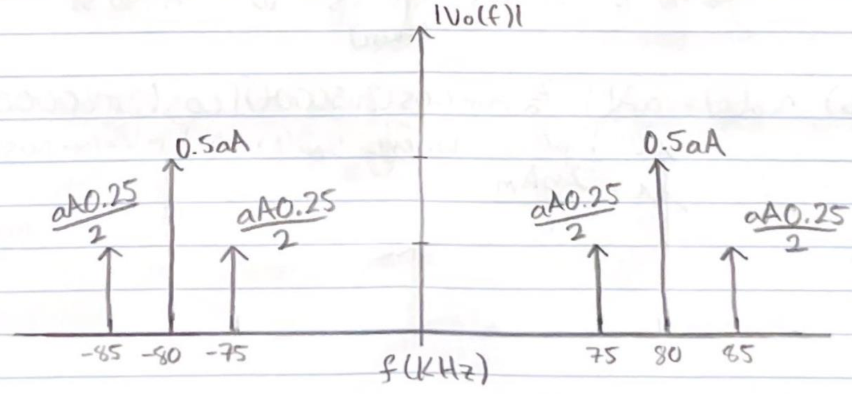
$= [aA + aA0.5\cos(2\pi 5000t)]\cos(2\pi 80000t)$

$= aA\cos(2\pi 80000t) + aA0.5\cos(2\pi 5000t)\cos(2\pi 80000t)$

$\cos x\cos y = \frac{1}{2}\cos(x+y) + \frac{1}{2}\cos(x-y)$

$v_o(t) = aA\cos(2\pi 80000t) + aA0.25\cos(2\pi 75000t) + aA0.25\cos(2\pi 85000t)$

$V_o(F) = \frac{aA}{2}[\delta(f-80000)+\delta(f+80000)] + \frac{aA0.25}{2}[\delta(f-75000) + \delta(f+75000)] + \frac{aA0.25}{2}[\delta(f-85000)+\delta(f+85000)]$



CONCLUSION

Amplitude Modulation can be effectively used to transmit signal messages by enveloping the message signal within a higher amplitude, and normally higher freuency, carrier wave. Here the carrier wave is varied in proportion to the message signal to establish the modulation index. It is important when choosing a carrier signal to have Ac >= Am to avoid loss of information in the message signal. It was seen that the modulation index value was multiplied by the magnitude of the message signal's amplitude spectrum to produce the modulated amplitude spectrum..