Laboratory 03

ECE 478/ECE 570 – Principles of Communication Systems

Date: 02/17/2025
Section: Amplitude modulation
Policy: No make-up labs will be given.

Amplitude modulation

Amplitude modulation is the process in which the amplitude of carrier wave $c(t)$ is varies about a mean value linearly with the baseband signal $m(t)$.
The sinusoidal carrier wave $c(t)$ is given by

$$c(t) = A_c \cos(2\pi f_c t), \tag{1}$$

where A_c is the carrier amplitude and f_c is the carrier frequency.
Then, the amplitude modulated signal can be written as

$$s(t) = A_c \left[1 + k_a m(t)\right] \cos(2\pi f_c t), \tag{2}$$

where, k_a is a constant defined as the amplitude sensitivity of the modulator.
The envelope of $s(t)$ is given by $A_c \left[1 + k_a m(t)\right]$.
Let the information baring baseband signal $m(t)$ be a single-tone (another sinusoidal signal) given by

$$m(t) = A_m \cos(2\pi f_m t), \tag{3}$$

Therefore, bu substituting (3) into (2), the modulated wave can be written as

$$s(t) = A_c \left[1 + k_a A_m \cos(2\pi f_m t)\right] \cos(2\pi f_c t) \tag{4}$$

The condition $|k_a m(t)| < 1$ ensures that the function $1 + k_a m(t)$ is always positive. Recall that the envelope of AM signal is given by $A_c \left[1 + k_a m(t)\right]$. When the amplitude sensitivity k_a of the modulator is large enough to make $|k_a m(t)| > 1$ for any t, the carrier wave becomes over-modulated. Over-modulation results in carrier phase reversals whenever the factor $1 + k_a m(t)$ crosses zero. The modulated wave then exhibits envelope distortions. Note that by avoiding over-modulation, a one-to-one relationship can be maintained between the envelope of the AM signal and modulating baseband signal for all values of t.
Let the message bandwidth be W. Then the carrier frequency f_c should be much larger than the message bandwidth W; i.e., $f_c >> W$. If the above condition is not satisfies, then the envelope cannot be detected satisfactory.
The AM modulated wave can be rewritten in as a function of modulation index μ as follows:

$$s(t) = A_c \left[1 + \mu \cos(2\pi f_m t)\right] \cos(2\pi f_c t), \tag{5}$$

where $\mu = k_a A_m$ is the modulation index.

0.1 Example 01: Single-tone Amplitude modulation

```
%Defining AM modulation Index
mu=input(' Enter the value of modulation index (mu) = ');

%Defining frequency of message signal
fm=input('Enter frequency of message signal (fm) (e.g. fm = 50) = ');

%Defining frequency of carrier signal
fc=input('Enter carrier frequency (fc) (fc>>fm) (e.g. fc = fm*10) = ');

N = 1024;    %N point FFT N>fc to avoid freq domain aliasing
fs = 4096; % sample frequency
t = (0:N-1)/fs;

%Generating modulating signal (message signal)
Am=5; % Amplitude of message signal
mt=Am*cos(2*pi*fm*t); %  generating the message signal
figure(1)
subplot(4,1,1);
plot(t,mt), grid on;% A plot for the message signal
title ('Message Signal');
xlabel ('time');
ylabel ('Amplitude');

%Generating carrier signal
Ac= 10;% Amplitude of carrier signal
%Tc=1/fc;% Time period of carrier signal
ct = Ac*cos(2*pi*fc*t);% generation of  carrier signal
subplot(4,1,2);
plot(t,ct), grid on;% A plot for the  carrier signal
title ('Carrier Signal');
xlabel ('time');
ylabel ('Amplitude');

%Generating AM Modulated signal
st=Ac*(1+mu*cos(2*pi*fm*t)).*cos(2*pi*fc*t); %  AM wave
subplot(4,1,3);
plot(t,st);% a plot for the AM signal
title ('Amplitude Modulated signal');
xlabel ('time');
ylabel ('Amplitude');

%Generating spectrum of AM wave
Sf = 2/N*abs(fft(st,N));
f = fs * (0 : N/2) / N;    %fft  is symmetric, only the positive half ...
    is sufficient
subplot(4,1,4);
plot(f(1:256),Sf(1:256));    % a plot for the AM signal
title ('Spectrum of AM signal');
xlabel ('frequency');
ylabel ('Amplitude Spectrum');

grid on;
```

Exercise:

- Vary the modulation index and observe the phase reversals and amplitude distortions.
- Vary the frequencies of carrier and message signal.
- Plot/observe the resulting AM wave and its frequency spectrum.
- Evaluate the bandwidth of the resulting AM signals via the corresponding frequency spectrum.

Design Question 01

Let the message signal to an AM modulator be a multi-tone sinusoidal signal given by

$$m(t) = A_1 \cos(2\pi f_1 t) + A_2 \cos(2\pi f_2 t) + A_3 \cos(2\pi f_3 t)$$

The carrier signal is given by $c(t) = A_c \cos(2\pi f_c t)$.

Develop a Matlab script design the AM modulator below:

(a) By choosing appropriate values for the amplitudes and carrier frequencies, plot the AM modulated wave in time-domain for

  (i) 50% modulation

  (ii) 100% modulation

  (ii) 125% modulation

(b) Plot the amplitude spectra of the corresponding AM waves.

(c) Evaluate the bandwidth requirement of the channel that this AM modulated signal would be transmitted over.

(d) Determine the transmit power requirements of the AM modulated output signal of your design.

(e) Discuss the trade-offs among the bandwidth, transmit power and implementation complexity of your AM modulator design. In answering this question, as an design engineer of a communication system, you must pay a special attention to bandwidth, power, and complexity trade-offs in the context of global, social, and economic factors.