ICT-3104: Electronic Communication and Microwave Engg.

Lab session 1: Amplitude Modulation (AM)

Academic Year 2021-2022

Objectives

In this lab session the student will learn to

- To understand how a high-frequency carrier wave can be varied in amplitude by a low-frequency message signal.
- To generate an AM signal using a carrier and modulating signal.
- To observe the AM waveform on an oscilloscope and analyze its characteristics (modulation index, envelope, frequency components).
- To verify the effect of modulation depth on the AM signal quality.
- To implement AM using Matlab.

Rules and submission of the lab report

- The lab report must be done in pairs.
- It will contain the matlab code (including explaining comments), as well as the corresponding figures, generated by solving the sections (1) to (4).
- The deadline is two weeks after the lab session. Late submissions will imply a penalty.
- The report and the code will be submitted via google drive.
- Please, generate a .zip file including report and code. The file name must contain the name of both authors. (Example: sohel_rana_and_shamim_hossain.zip)

1 Single-tone message (classical derivation)

Let the carrier be

$$c(t) = A_c \times cos(\omega_c t) \tag{1}$$

and let the (baseband) message be

$$m(t) = A_m \times cos(\omega_m t) \tag{2}$$

The standard AM is formed by making the carrier amplitude vary linearly with the message:

$$s(t) = [A_c + A_m \times cos(\omega_m t)] \times cos(\omega_c t) \tag{3}$$

$$s(t) = A_c \left[1 + \frac{A_m}{A_c} \times cos(\omega_m t)\right] \times cos(\omega_c t) \tag{4}$$

$$s(t) = A_c \left[1 + m \times cos(\omega_m t)\right] \times cos(\omega_c t) \tag{5}$$

where m denotes the modulation index or modulation depth which defined as $m = \frac{A_m}{A_c}$.
Expand using trig identities (product-to-sum):

$$s(t) = A_c \times cos(\omega_c t) + A_c \times m \times cos(\omega_m t) \times cos(\omega_c t) \tag{6}$$

Using $cos\alpha \times cos\beta = \frac{1}{2}[cos(\alpha + \beta) + cos(\alpha - \beta)]$,
Again, rewrite the Eq. (6) as

$$s(t) = A_c \times cos(\omega_c t) + \frac{A_c m}{2} \times cos[(\omega_c + \omega_m)t] + \frac{A_c m}{2} cos[(\omega_c - \omega_m)t] \tag{7}$$

Interpretation: the modulated signal consists of three spectral components:

- **Carrier** at ω_c with amplitude A_c,
- **Upper sideband (USB)** at $\omega_c + \omega_m$ with amplitude $\frac{A_c m}{2}$,
- **Lower sideband (LSB)** at $\omega_c - \omega_m$ with amplitude $\frac{A_c m}{2}$,
- **Bandwidth** is $[(\omega_c + \omega_m) - (\omega_c - \omega_m)]$

2 Envelope and modulation index (practical measurement)

For the time waveform $s(t) = A_c[1 + m \times cos(\omega_m t)] \times cos(\omega_c t)$, the envelop is defined as

$$Envelop(t) = A_c[1 + m \times cos(\omega_m t)] \tag{8}$$

whose maximum and minimum values are:

$$V_{max} = A_c(1 + m), \qquad V_{min} = A_c(1 - m),$$

Thus m can be measured from an oscilloscope as

$$m = \frac{V_{max} - V_{min}}{V_{max} + V_{min}} \tag{9}$$

Interpretation: the modulation index (m) has three conditions:

- If $m = 1$, the envelope dont crosse zero (perfect-modulation (no distortion).
- If $m < 1$, the envelope dont crosse zero (under-modulation (no distortion).
- If $m > 1$, the envelope crosses zero (over-modulation (distortion).

3 Power relations (assuming load, $R = 1\Omega$ for simplicity)

- **Carrier Power:** $P_c = \frac{A_c^2}{2R} = \frac{A_c^2}{2}$
- Each sideband amplitude $= \frac{A_c m}{2}$, so **power in one-sideband** as

$$P_{SB} = \frac{\left(\frac{A_c m}{2}\right)^2}{2} = \frac{A_c^2 m^2}{8}$$

- **Power in two-sideband** as

$$P_{TSB} = 2 \times P_S B = \frac{A_c^2 m^2}{4}$$

- **Total power in AM** as

$$P_t = P_c + P_{TSB} = \frac{A_c^2}{2} + \frac{A_c^2 m^2}{4} = \frac{A_c^2}{2}\left(1 + \frac{m^2}{2}\right)$$

4 The efficiency of AM

The transmission efficiency η is the fraction of total transmitted power that actually carries the message information - i.e., the sideband power fraction:

$$\eta = \frac{P_{TSB}}{P_t} = \frac{\frac{A_c^2 m^2}{4}}{\frac{A_c^2}{2}\left(1 + \frac{m^2}{2}\right)} \tag{10}$$

Cancel the common factor $\frac{A_c^2}{2}$:

$$\eta = \frac{\frac{m^2}{2}}{\left(1 + \frac{m^2}{2}\right)} \tag{11}$$

$$= \frac{m^2}{2} \times \frac{2}{2 + m^2} \tag{12}$$

$$\eta = \frac{m^2}{2 + m^2} \tag{13}$$

5 MATLAB code for AM

MATLAB is a high-level programming and numerical computing environment widely used for data analysis, simulation, and algorithm development. It provides powerful built-in functions and toolboxes for areas such as signal processing, image processing, machine learning, and control systems. With its easy-to-use syntax and visualization capabilities, MATLAB is popular in both academic research and industry applications.

5.1 Approach I

%At the start of a script to ensure a clean workspace before running code:

```
clc;        % Clears the Command Window
clear all;  % Removes all variables from the workspace (frees memory)
close all;  % Closes all open figure windows
```

%To setup simulation parameters as

```
A_c=2;     % Carrier amplitude
f_c=0.5;   % Carrier frequency
A_m=0.5;   % Message signal amplitude
f_m=0.05;  % Message signal frequency
F_s=100;   % Sampling rate/frequency
m=1;       % Modulation index/deepth
```

%Defining the time range, carrier signal, message signal, and AM wave as

```
t=[0:0.1:50];                % defining the time range & disseminating it into samples
c_t=A_c*cos(2*pi*f_c*t);     % defining the carrier signal wave
m_t=A_m*cos(2*pi*f_m*t);     % defining the message signal
s_t=c_t.*(1+m*m_t);          % Amplitude Modulated wave, according to the standard definition
```

%This snippet is MATLAB code for plotting message, carrier, and AM signals in one figure using **subplot** as

```
subplot(3,1,1);             % Divide the figure into 3 rows, 1 column, and use the 1st section
plot(t, m_t);                % Plotting the message signal wave
ylabel('Message signal, m(t)');

subplot(3,1,2);             % Divide the figure into 3 rows, 1 column, and use the 2nd section
plot(t, c_t);               % Plotting the carrier signal wave
ylabel('Carrier Signal, c(t)');

subplot(3,1,3);             % Divide the figure into 3 rows, 1 column, and use the 3rd section
plot(t,s_t);                % Plotting the amplitude modulated wave
ylabel('AM signal, s(t)');
```

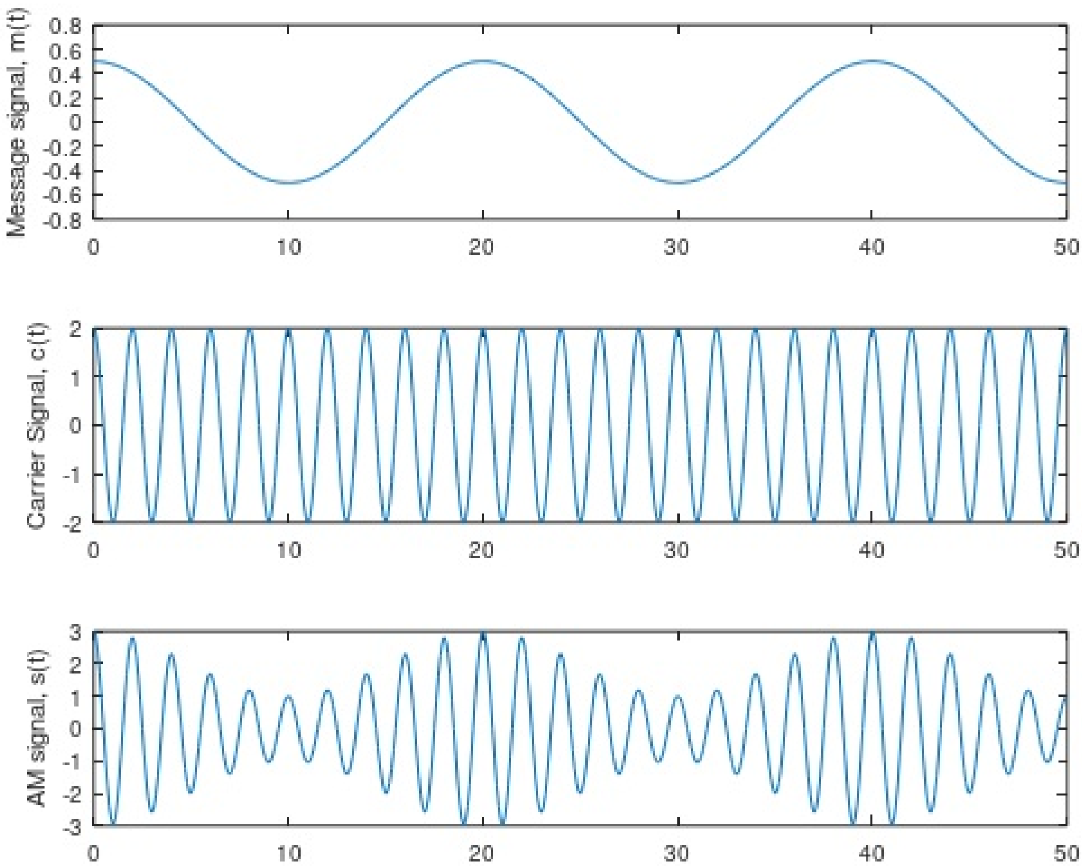

Figure 1: Amplitude Modulation (AM) Wave.

5.2 Approach II

MATLAB has a built-in function **ammod()** in the Communications Toolbox that directly generates an Amplitude Modulated (AM) signal.
Here is the general syntax:

$$s_t = ammod(m_t, f_c, f_s)$$

- m_t: message signal;
- f_c: carrier frequency (Hz);
- f_s: sampling frequency (Hz)

6 Appendix

	Matlab Functions
Display help text in the command window	`help command_name`
Similar to `help`, however, it shows the information in a more friendly format	`doc command_name`
Return the number of elements of the vector v	`length(v)`
Return the number of rows and columns of the matrix A	`[row, column]=size(A)`
Call **ammod()**: Use the function to modulate the message signal	$s_t = ammod(m_t, f_c, f_s)$
Break the Figure window into m rows and n columns and generate one axes at position p	`subplot(m,n,p)`
Plot the vector x vs y in a bidimensional graph with the colour *color* (Use `help plot` to find the available colours and line styles)	`plot(x,y,'color')`
Use this command to draw plots in the same axes preserving the former plots	`hold on`
Draw a grid on the plot area	`grid on`
Plot the vector x vs y as a discrete sequence (useful for impulse-like sequences)	`stem(x,y)`
Label the x-axis using the text *Message*	`xlabel('Message')`
Label the y-axis using the text *Message*	`ylabel('Message')`
Label the graph using the text *Message*	`title('Message')`
Create a new figure window	`figure`

Table 1: Matlab Commands

$\sin(A)\sin(B) = \frac{\cos(A-B)-\cos(A+B)}{2}$
$\cos(A)\cos(B) = \frac{\cos(A-B)+\cos(A+B)}{2}$

Table 2: Trigonometric Relationships.