

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

$$c(t) = A_c \times \cos(\omega_c t) \quad (1)$$

and let the (baseband) message be

$$m(t) = A_m \times \cos(\omega_m t) \quad (2)$$

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

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

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

$$s(t) = A_c [1 + m \times \cos(\omega_m t)] \times \cos(\omega_c t) \quad (5)$$

where m denotes the modulation index or modulation depth.

Expand using trig identities (product-to-sum):

$$s(t) = A_c \times \cos(\omega_c t) + A_c \times m \times \cos(\omega_m t) \times \cos(\omega_c t) \quad (6)$$

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

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

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

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

whose maximum and minimum values are:

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

Thus m can be measured from an oscilloscope as

$$m = \frac{V_{max} - V_{min}}{V_{max} + V_{min}} \quad (9)$$

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

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

- 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:

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

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

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

$$= \frac{m^2}{2} \times \frac{2}{2 + m^2} \quad (12)$$

$$\eta = \frac{m^2}{2 + m^2} \quad (13)$$

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/depth
```

%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)');
```

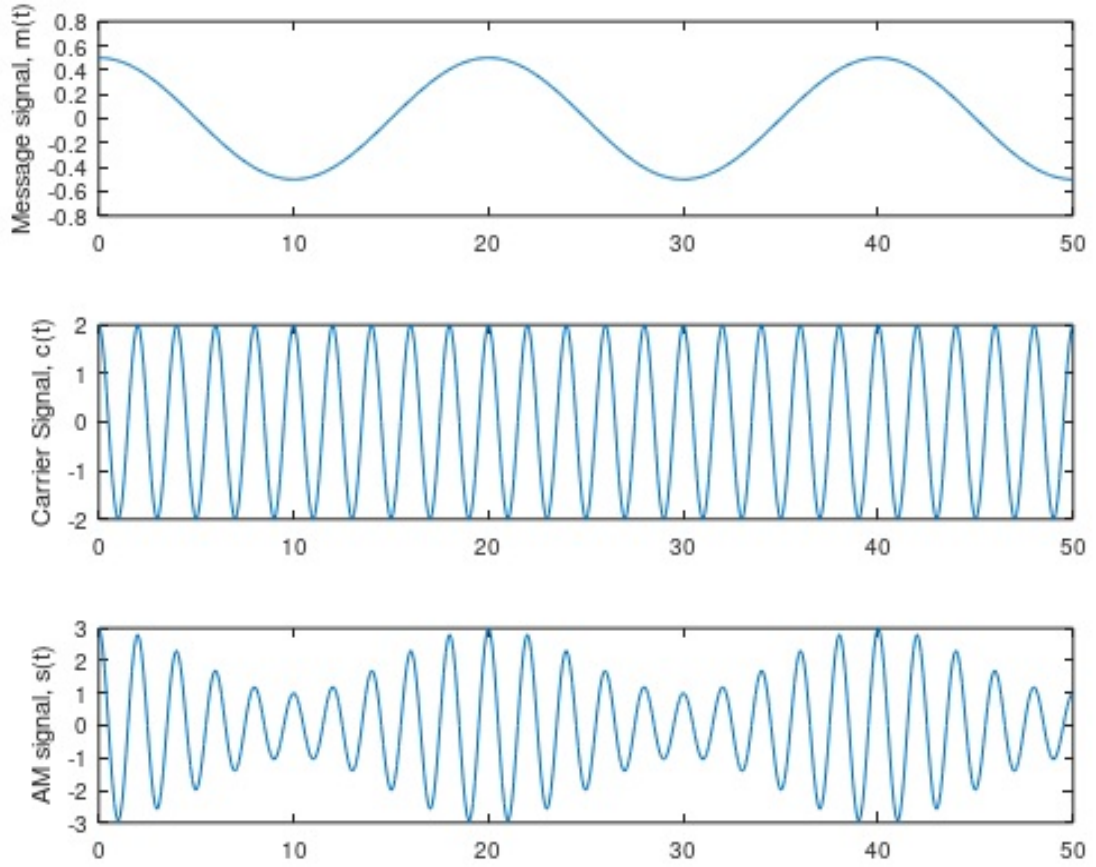


Figure 1: Amplitude Modulation (AM) Wave.

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:

$$s_t = \text{ammod}(m_t, f_c, f_s)$$

- 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	<code>help command_name</code>
Similar to <code>help</code> , however, it shows the information in a more friendly format	<code>doc command_name</code>
Return the number of elements of the vector v	<code>length(v)</code>
Return the number of rows and columns of the matrix A	<code>[row, column]=size(A)</code>
Call <code>ammod()</code> : 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	<code>subplot(m,n,p)</code>
Plot the vector x vs y in a bidimensional graph with the colour <i>color</i> (Use <code>help plot</code> to find the available colours and line styles)	<code>plot(x,y,'color')</code>
Use this command to draw plots in the same axes preserving the former plots	<code>hold on</code>
Draw a grid on the plot area	<code>grid on</code>
Plot the vector x vs y as a discrete sequence (useful for impulse-like sequences)	<code>stem(x,y)</code>
Label the x-axis using the text <i>Message</i>	<code>xlabel('Message')</code>
Label the y-axis using the text <i>Message</i>	<code>ylabel('Message')</code>
Label the graph using the text <i>Message</i>	<code>title('Message')</code>
Create a new figure window	<code>figure</code>

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.