Aim ↬ To study the concept and fundamentals of Amplitude Modulation.

Software Required ↬ MATLAB

Theory ↬

Amplitude Modulation [AM] is a widely used technique in communication systems where the amplitude of a carrier signal is varied in proportion to the instantaneous amplitude of the message or baseband signal. The carrier signal is typically a high-frequency sinusoidal wave, and its amplitude modulation allows for efficient transmission of the message over long distances via radio waves.

In AM, the modulated signal s(t) is expressed as:

$$s(t) = [A_c + m(t)] \cdot cos\ (2\pi f_c t)$$

where:

- A_c is the amplitude of the carrier signal,
- m(t) is the message signal,
- f_c is the frequency of the carrier signal.

The modulation index μ is defined as the ratio of the message signal amplitude to the carrier amplitude:

$$\mu = \frac{A_m}{A_c}$$

where A_m is the peak amplitude of the message signal. For effective modulation, $\mu \leq 1$ is required, meaning the message amplitude should not exceed the carrier amplitude to avoid distortion in the transmitted signal.

Generation of AM Signal ↴

The generation of an AM signal can be achieved through several methods, including direct modulation or using modulator circuits. The modulated signal contains the carrier frequency, upper sideband (USB), and lower sideband (LSB). These sidebands carry the information from the message signal. The bandwidth of an AM signal is twice the bandwidth of the baseband signal m(t), as the total transmitted bandwidth is:

$$B_T = 2B_m$$

where B_m is the bandwidth of the message signal.

Demodulation of AM Signal ↴

To recover the original message signal from the modulated signal, demodulation is required. One common method for AM demodulation is envelope detection, where the envelope of the modulated signal is extracted. The output of the demodulator provides a signal proportional to the message, which can then be further filtered to remove any residual carrier frequency or noise.

Frequency Spectrum of AM Signal ↴

The AM signal in the frequency domain shows the carrier component at f_c, along with the upper and lower sidebands at f_c+f_m and f_c-f_m, respectively, where f_m is the highest frequency present in the message signal. The total power of an AM signal is distributed among the carrier and sidebands, and the sidebands contain helpful information.

The frequency domain representation of an AM signal can be expressed as:

$$S(f) = A_c[\delta(\mathrm{f} - \mathrm{f}_c) + \delta(\mathrm{f} + \mathrm{f}_c)] + \frac{\mu A_c}{2}[\delta(\mathrm{f} - (\mathrm{f}_c + \mathrm{f}_m)) + \delta(\mathrm{f} - (\mathrm{f}_c - \mathrm{f}_m))]$$

where $\delta(f)$ represents the Dirac delta function, indicating the presence of discrete frequency components.

Applications of AM ↴

AM is used in various applications, including radio broadcasting (AM radio), aviation communication, and two-way radio systems. Although it has been largely replaced by more advanced techniques like Frequency Modulation (FM) and digital modulation in some areas, AM is still preferred for certain types of long-range communication due to its simplicity and ease of implementation.

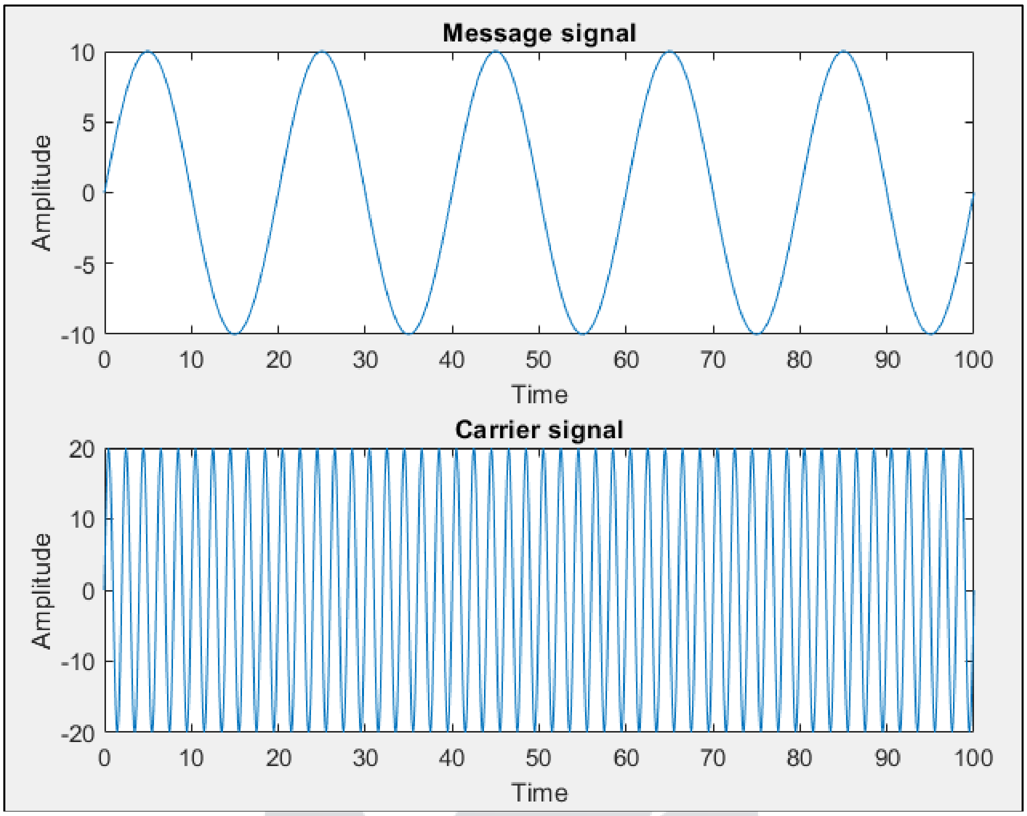
In modern communication systems, modulation techniques like AM are crucial for ensuring efficient transmission of information over diverse channels.

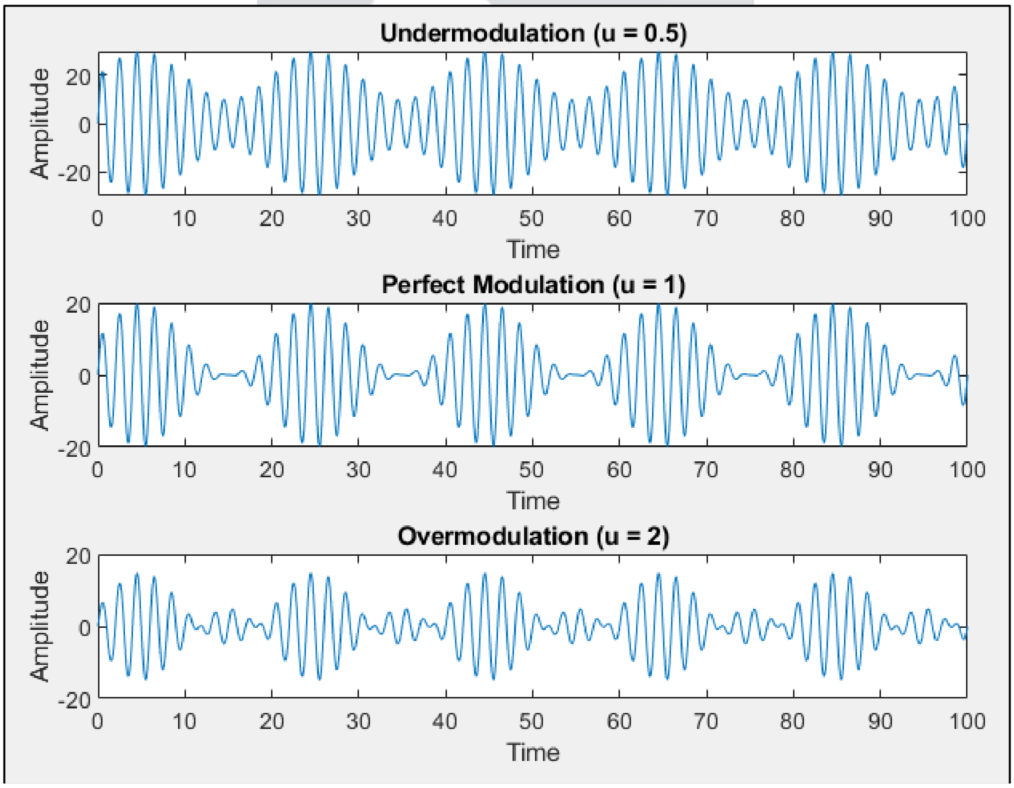
Code ↬

```
% Amplitude Modulation
clc;
clear;
close all;

Am = 10;
Fm = 0.05;
```

```
Fc = 0.5;
u = [0.5, 1, 2];
t = 0:0.1:100;

mt = Am * sin(2*pi*Fm*t);
ct = cell(1,3);
A = cell(1,3);

for i = 1:length(u)
   Ac = Am / u(i);
   ct{i} = Ac * sin(2*pi*Fc*t);
   A{i} = ct{i} .* (1 +u(i)*sin(2*pi*Fm*t));

   if u(i) < 1
      mod_type = 'Undermodulation';
   elseif u(i) == 1
      mod_type = 'Perfect Modulation';
   else
      mod_type = 'Overmodulation';
   end

   subplot(3,1,i);
   plot(t, A{i});
   xlabel('Time');
   ylabel('Amplitude');
   title([mod_type ' (u = ' num2str(u(i)) ')']);
end

figure;
subplot(2,1,1);
plot(t, mt);
xlabel('Time');
ylabel('Amplitude');
title('Message signal');

subplot(2,1,2);
plot(t, ct{1});
xlabel('Time');
ylabel('Amplitude');
title('Carrier signal');
```

Output ↬


Message signal
Amplitude
Time
Carrier signal
Amplitude
Time


Undermodulation (u = 0.5)
Amplitude
Time
Perfect Modulation (u = 1)
Amplitude
Time
Overmodulation (u = 2)
Amplitude
Time

Result ↬

The experiment successfully generated Amplitude Modulated signals for different modulation indices

1. **Undermodulation** ($u = 0.5$): The signal is weak, and the carrier is not fully modulated.
2. **Perfect Modulation** ($u = 1$): The signal is ideal, with the carrier fully modulated without distortion.
3. **Overmodulation** ($u = 2$): The signal shows distortion due to overmodulation.

These observations demonstrate how varying the modulation index affects signal quality and clarity.

Conclusion ↬

The experiment shows that the modulation index significantly impacts AM signal quality. Undermodulation leads to weak signals, overmodulation causes distortion, and perfect modulation ensures optimal transmission without distortion. Maintaining an appropriate modulation index is crucial for clear communication.

Precautions ↬

- Ensure the carrier amplitude is properly chosen to avoid overmodulation and signal distortion.
- Maintain the modulation index within the acceptable range to prevent information loss.
- Use appropriate sampling rates to avoid aliasing during signal generation and analysis.