EEP3010: Communication Systems Lab

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DEPARTMENT OF ELECTRICAL ENGINEERING
INDIAN INSTITUTE OF TECHNOLOGY JODHPUR

EEP3010: Communication Systems Lab
Lab Project Status Report

On

End-to-end demonstration of audio signal transmission using Amplitude Modulation (AM)

By

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Abstract :

This project aims to construct a simple yet effective system to transmit audio signals using the amplitude modulation (AM) technique. The setup will consist of a transmitter module to modulate the audio signal onto a carrier wave (generated using the function generator available in the lab) and a receiver module to demodulate and reproduce the original audio signal. The project involves understanding the theory behind AM modulation, building the transmitter and receiver circuits, testing the system, and presenting a live demonstration of audio transmission.

Equipments:

- Function Generator
- Potentiometer
- IRF540N NMOS
- Resistors(1K, 10K,470K)
- Capacitor(1uF)
- Speaker
- DSO
- Diode (1N4148)

Detailed Theory Behind the Project:

Amplitude modulation (AM) involves varying the strength of a carrier wave in proportion to the waveform being transmitted. This modulation process encodes the information onto the carrier wave, typically using a transmitter.

Modulation Index in AM represents the ratio of the maximum amplitude of the modulating signal to the amplitude of the carrier signal. It determines the extent of modulation and directly affects the quality of the transmitted signal.
Three types of modulation are categorized based on the modulation index:

- Overmodulation, where the modulation index exceeds 1, leads to distortion.
- Undermodulation, where the modulation index is less than 1, results in inefficient use of bandwidth and decreased signal quality.
- Critical modulation, where the modulation index is precisely 1, optimal for efficient transmission with minimal distortion.

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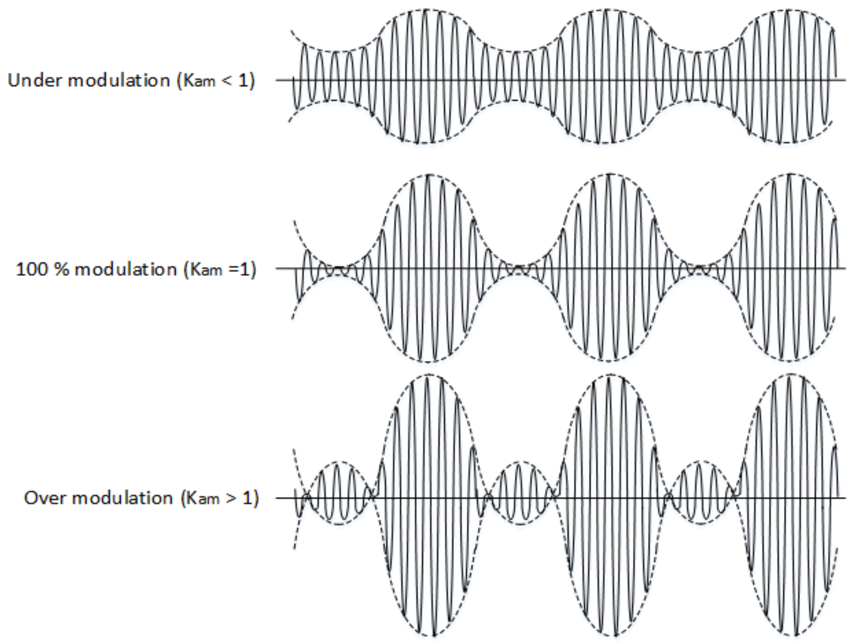


Amplitude Demodulation, specifically through envelope detection, is a method to recover the original modulating signal from the modulated carrier wave. In envelope detection, a diode rectifies the modulated signal, resulting in a signal that represents the envelope of the original modulating waveform.
By extracting the envelope, envelope detection allows for the retrieval of the original modulating signal.

Detailed Methodology:

I) Amplitude Modulation Circuit:

Consider the below images of the transmitter circuit:

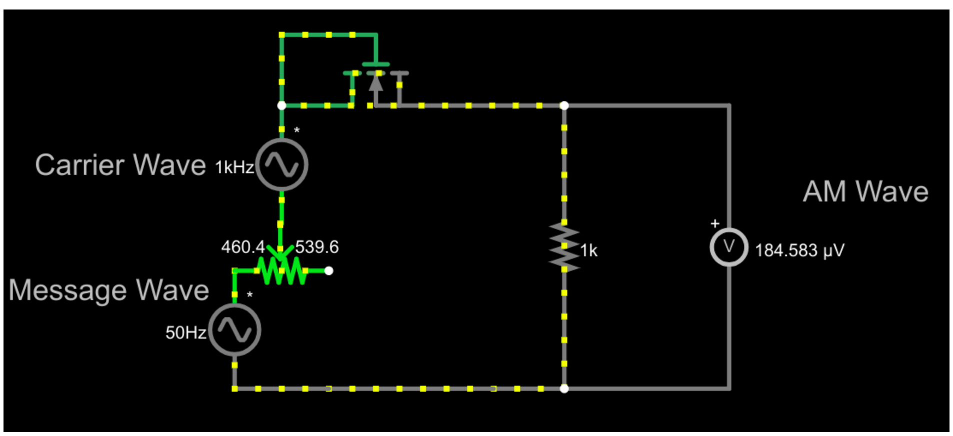


Fig. 1: Amplitude Modulation Falstad Circuit

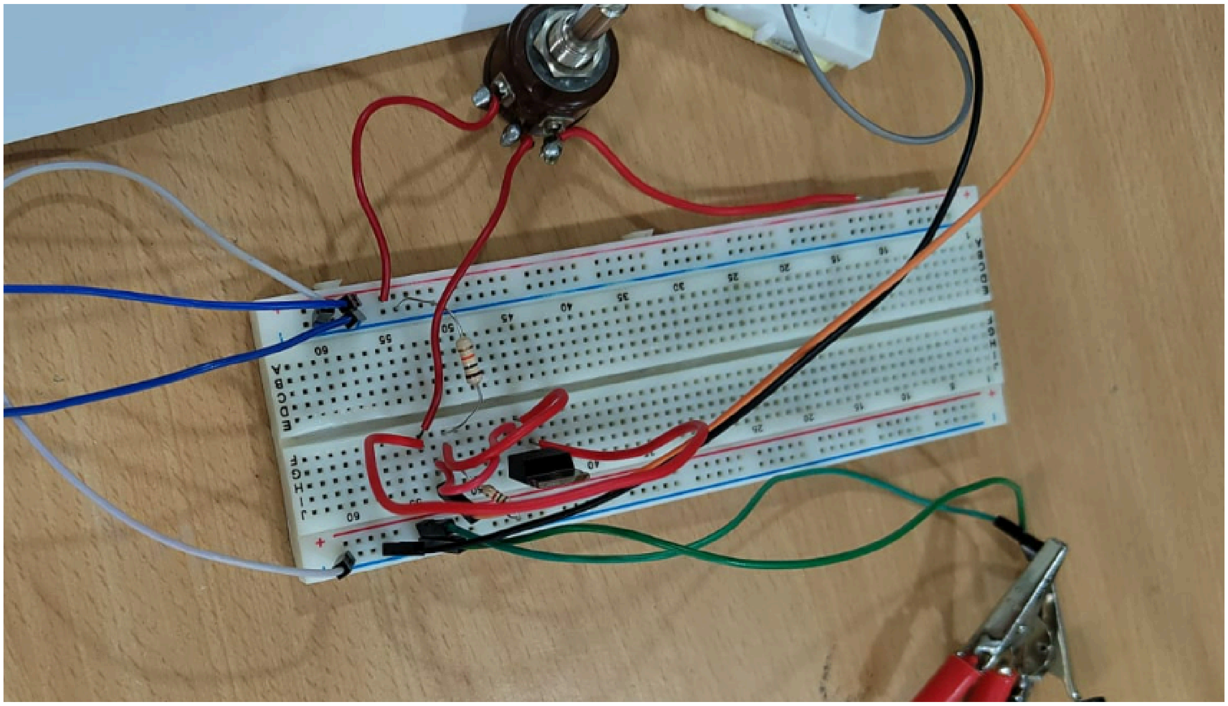


Fig. 2: Amplitude Modulation Circuit on Breadboard

- ❖ **Modulation Control:** Adjustments on the input potentiometer and the introduction of a 100K ohm resistor control modulation. The modulation index is varied using the potentiometer. Potentiometer Rreduces the amplitude of the message wave to prevent over-modulation.
- ❖ **Carrier Signal Path:** Carrier signal fed through the N-channel from drain to source for enhanced modulation.
- ❖ **AM Wave Output:** Output is taken from the drain end of the FET for pronounced modulation by the gate signal.
- ❖ **Inputs Message Signal:** We have done Amplitude Modulation and Demodulation for two different inputs. In the first case, we have given a sinusoidal Wave from the function generator, and in the second case, we have given an audio signal as Input.

II) Amplitude Demodulation Circuit:

Consider the below images of the Reciever circuit:

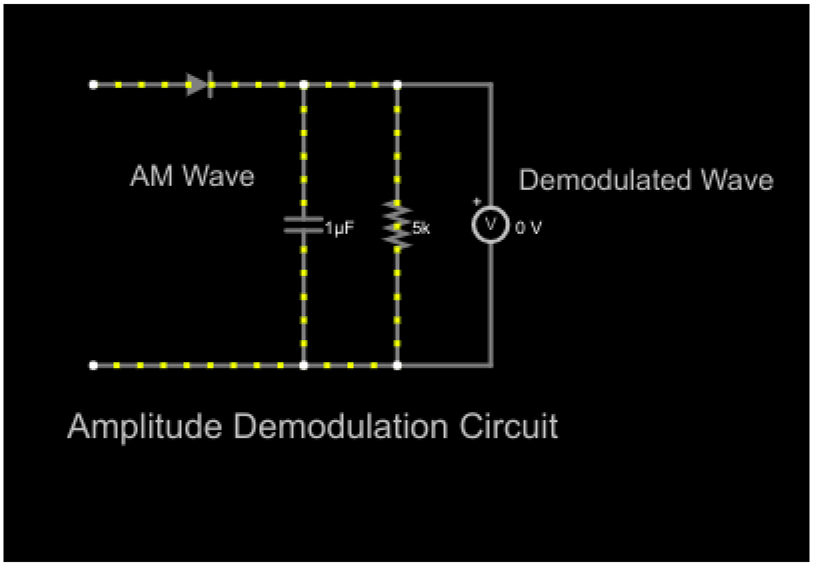


Fig. 3 Amplitude Demodulation Circuit

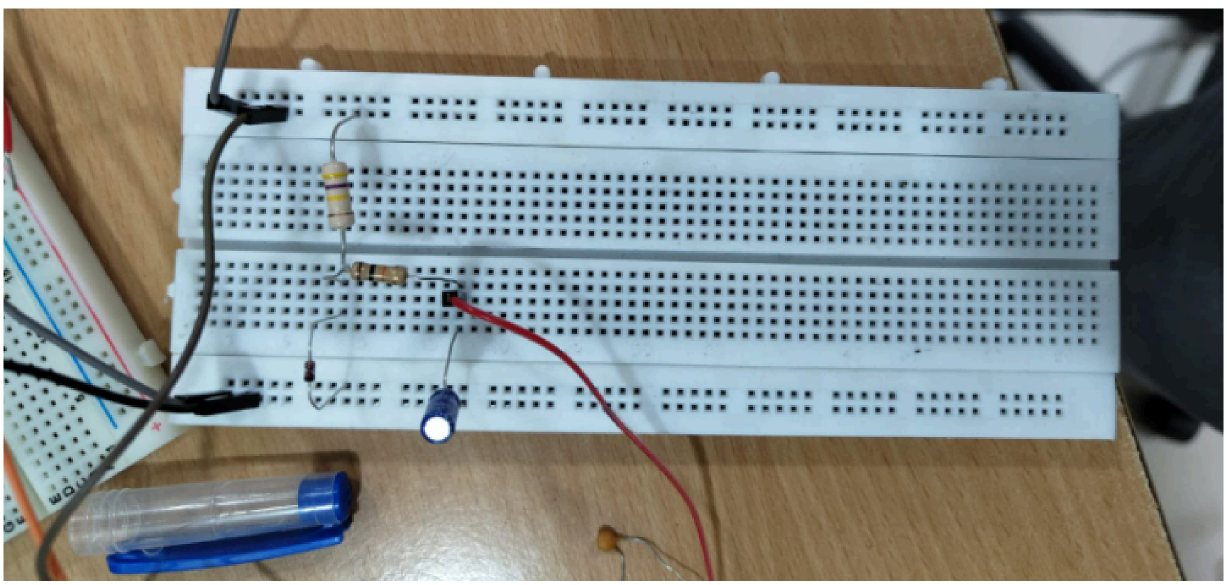


Fig. 4 Amplitude Demodulation Circuit on Breadboard

- **Rectification:**
    - ❖ A germanium diode (1N4148) with a cut-in voltage of 0.3 volts is used for rectification due to its high-frequency response. A high-value resistor (470K) connects the diode to the ground to allow the conduction of

negative half cycles to the ground without affecting amplitude. DC voltage with amplitude-varying high-frequency ripples is obtained across the resistor.

- **Low Pass Filtering:**
  - ❖ A simple capacitor filter is employed to filter out low-frequency amplitude variations from the rectified AM wave. A capacitor allows high-frequency ripples to pass through to the ground, leaving low-frequency component voltage across it. Filtering out low-frequency components matches to the envelope of the AM wave thus enabling envelope detection.
- **Output:** We are able to successfully de-modulate the waveform for both sinusoidal and audio signals. Results are shown in the next section.

<u>Experimental Results:</u>

For Sinusoidal Signal:

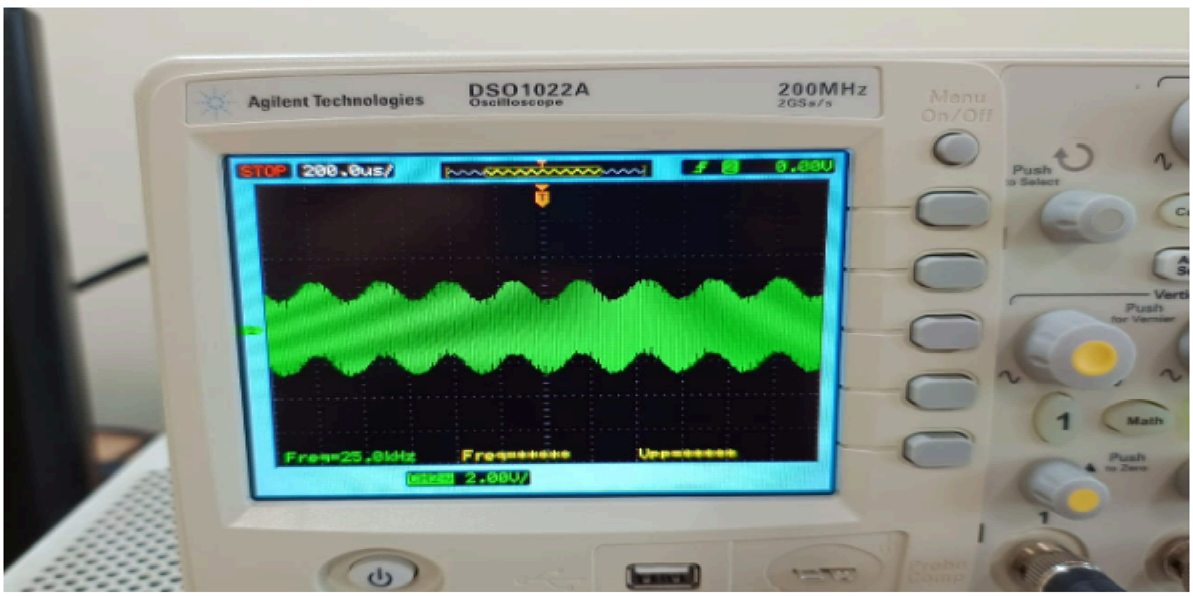


Fig. 5 Amplitude modulation Wave for Sinusoidal Input

Carrier Wave		
V_{pp} = 2.5V	Freq = 85 kHz	Offset = 0
Message Wave		
V_{pp} = 10V	Freq = 3.5 kHz	Offset = 0

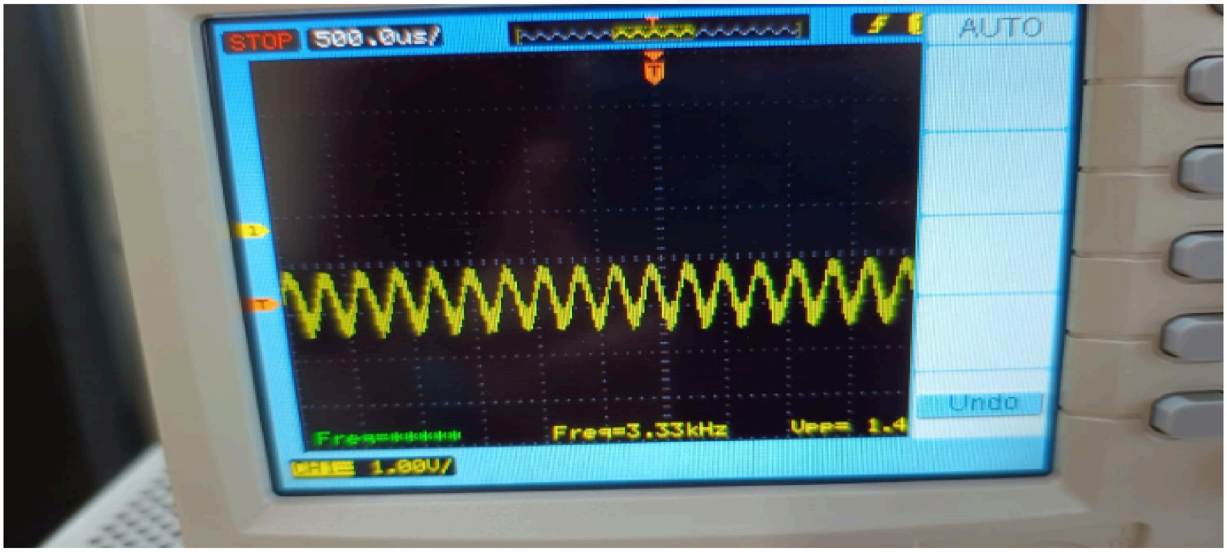


Fig. 6: Amplitude Demodulation Wave for Sinusoidal Input

For Audio Signal:

Carrier Wave		
V_{pp} = 5V	Freq = 25 MHz	Offset = 0
Message Wave		
Audio Input from Laptop		

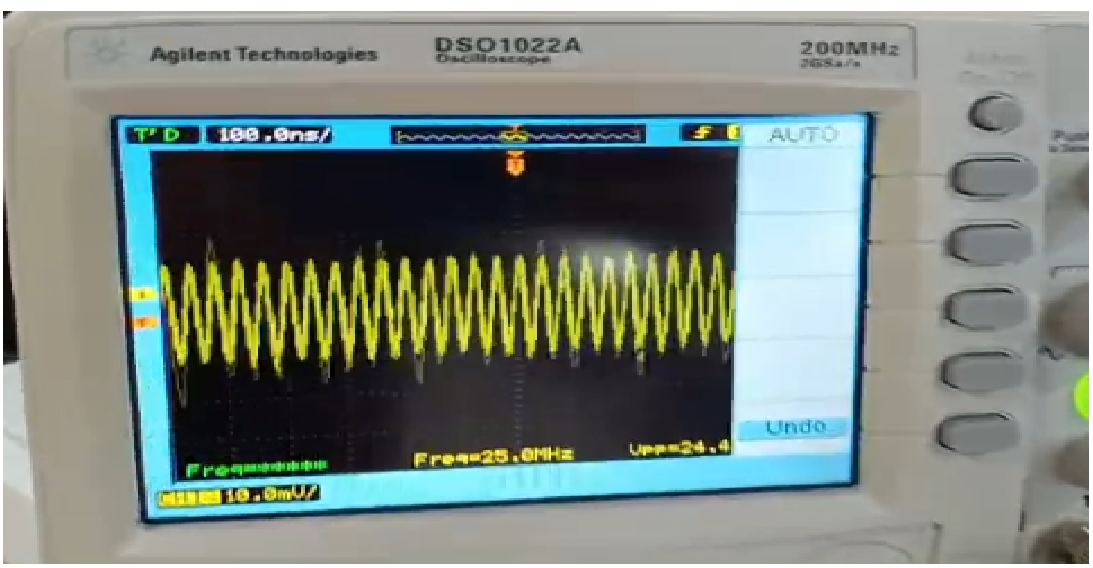


Fig. 7: Amplitude Demodulation for Audio Signal as Input

Results Discussion:

- In the case of sinusoidal wave input, we could also notice different levels of modulations i.e. under-modulation, critical modulation, and over-modulation. However, when it comes to transmitting an audio signal, we couldn't see these differences as clearly.
- In the case of sinusoidal wave input, we could clearly notice the envelope but, when it comes to transmitting an audio signal, we couldn't observe it properly.
- In amplitude demodulation using an envelope detector, a diode and capacitor work together to extract the message signal. The diode rectifies the modulated signal, allowing only the positive envelope to pass through. The capacitor then smooths out the rectified signal, resulting in an approximation of the original message signal. Further filtered by a low-pass filter to eliminate any remaining high-frequency noise.

Challenges Faced:

1) The microphone module procured from the lab was not able to properly retrieve the sound. The output of the microphone was very noisy even after passing through the Low pass filter.
2) The maximum available carrier wave frequency was 10 MHz, which would require a larger antenna.
3) We did not do wireless transmission because the frequency range of IRF540N nMOS transistor is 100 MHz--168 MHz which gives rise to the necessity of a very long antenna (>3metres). To procure such an antenna or construct it, was thus not taken up by us.
4) We were required to bias the NMOS IRF540N as per the datasheet. At first, without giving offset but only Vpp, the AM wave used to get half rectified in the beginning only as the condition Vgs>Vth won’t be satisfied without offset. However, giving an offset voltage of 2.5V helped mitigate this issue.

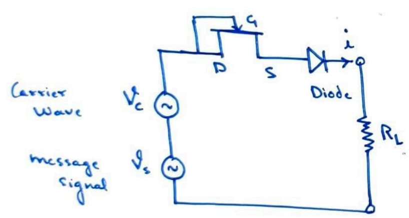
Conclusion:

The project successfully implemented a wired audio transmission system using amplitude modulation (AM) by constructing transmitter and receiver modules. By using lab equipment such as function generators we effectively modulated audio signals onto carrier waves as amplitude modulation(AM), demodulate it and were able to hear the output audio signal on the speaker, achieving reliable transmission.

Appendix:

Calculations & Derivations:

Derivation of the expression for the output voltage (AM voltage) produced by the circuit:-



As $V_D = V_G$, we have $V_{DS} > V_{GS} - V_{th}$

Hence the MOSFET is in saturation

Using square law, we have

$i = Av^2$

$i = A(v_c + v_s)^2$

$i = A(v_c^2 + v_s^2 + 2v_c v_s)$

As v_c & v_s are small v_s^2 & $v_c^2 \longrightarrow 0$

$i \approx 2Av_c v_s$

But incorporating in accuracies in the square law, we have

$i = a_1 v + a_2 v^2 \underbrace{\cdots}_{\text{other higher order terms}}$

$i = a_1(v_c + v_s) + a_2(v_s^2 + v_c^2 + 2v_s v_c) + \underbrace{---}_{\text{Higher order terms are ignored}}$

$i = \underbrace{a_1 v_c + a_2 2v_s v_c}_{\downarrow} + a_1 v_s + a_2 v_s^2 + a_2 v_c^2$

Similar to amplitude modulation

Hence we can approximate

$V_{AM} \approx R_L i$