# Voice Signal Analysis and AM Modulation Assignment

Student Name: Sujal Kapoor

Roll Number: 2023UEE0154

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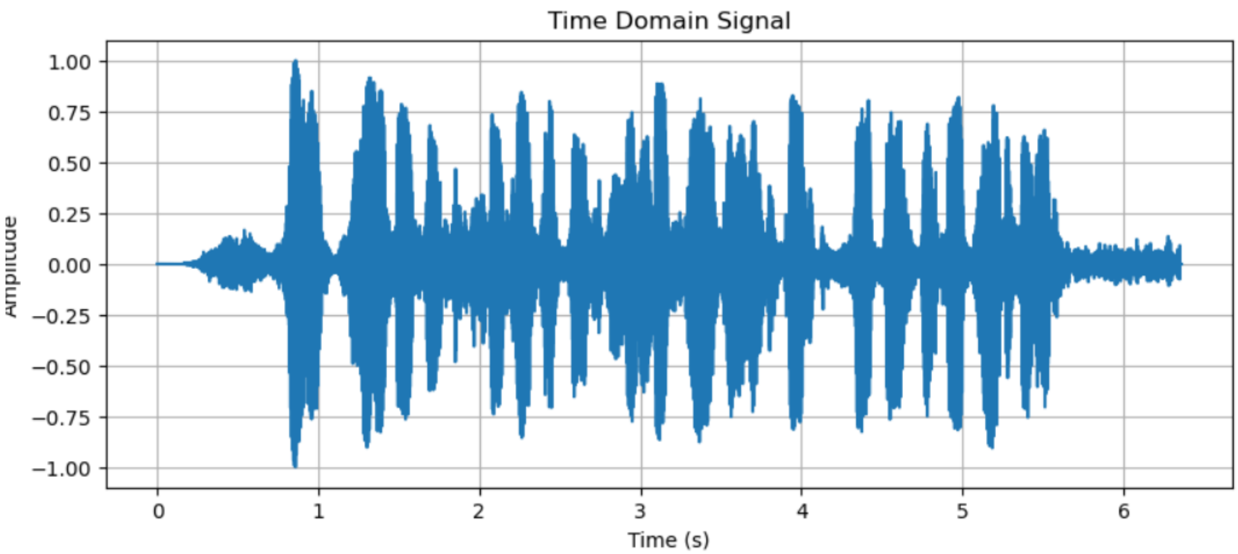
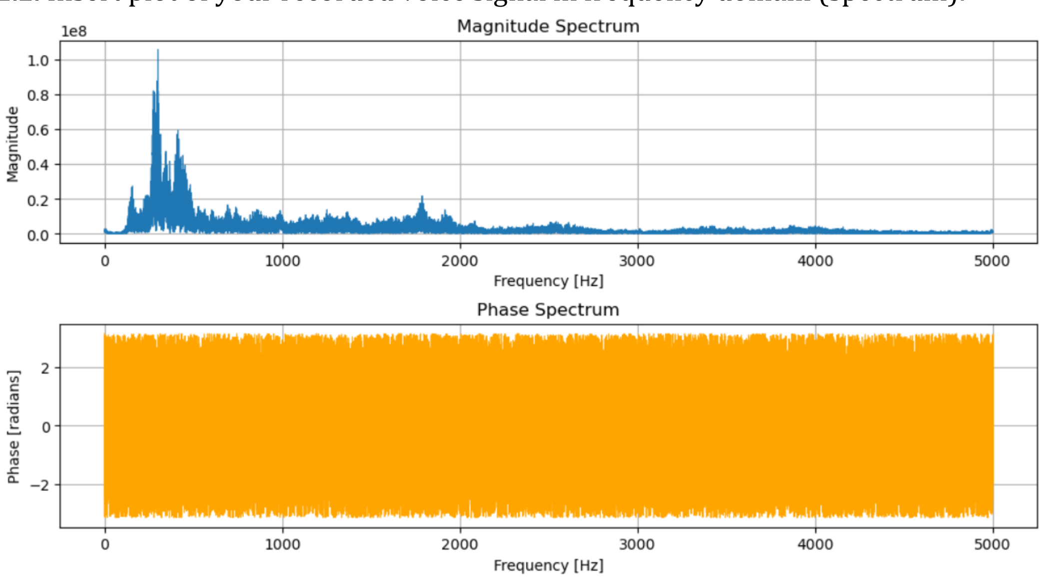
## 1. Time-Domain and Frequency-Domain Analysis of Voice (2 Marks)

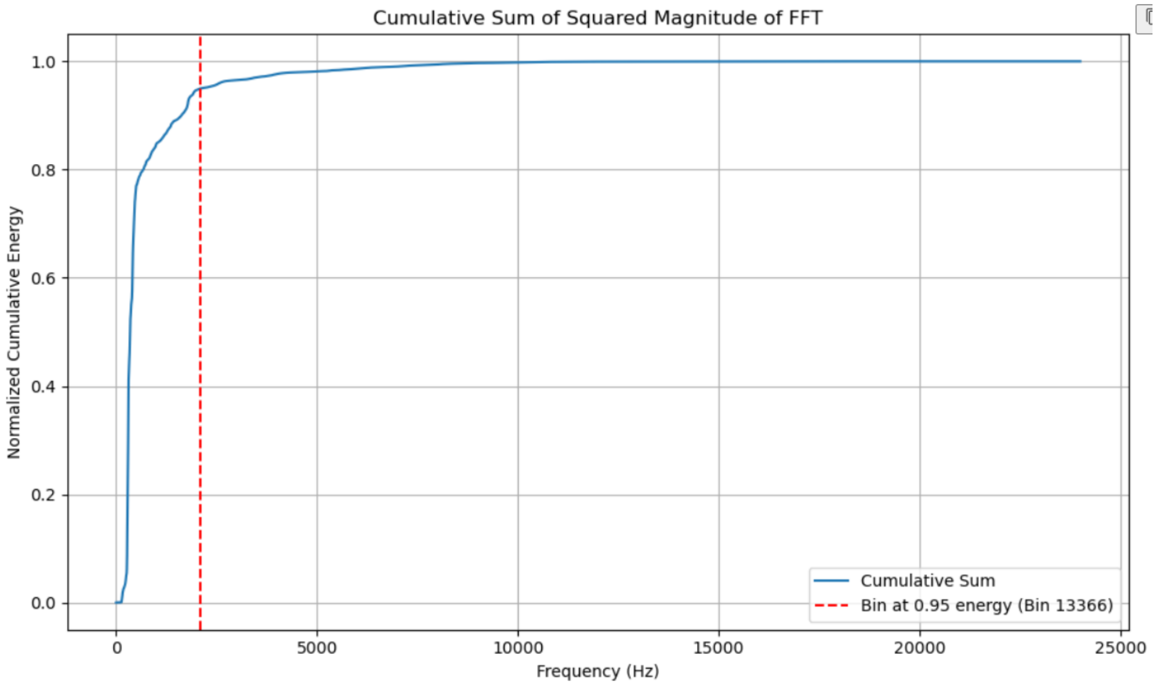
1.1. Insert plot of your recorded voice signal in time domain:




1.2. Insert plot of your recorded voice signal in frequency domain (spectrum):



1.3. Estimate the bandwidth of the voice signal (in Hz):
2102Hz




1.4. Briefly describe the dominant frequency components you observe:

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Estimated Voice Bandwidth: 1790.06 Hz
Frequency Range: 134.65 Hz to 1924.71 Hz
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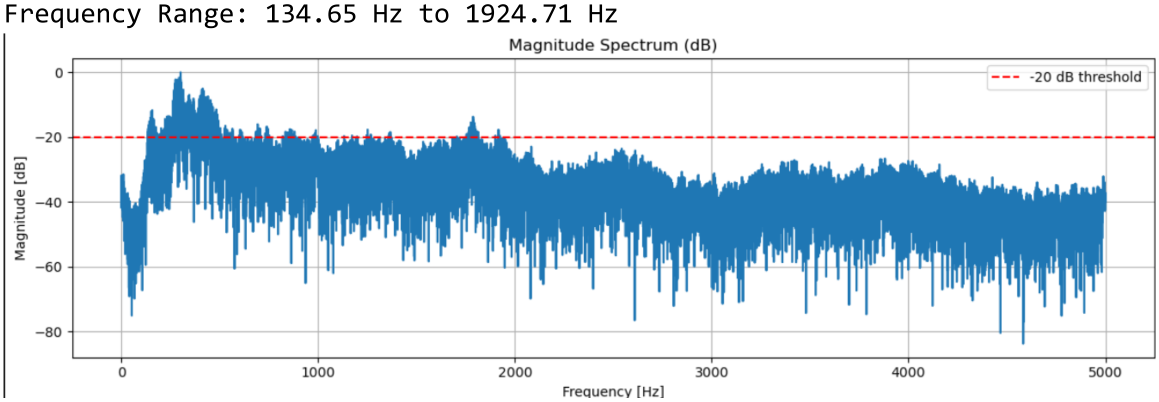



## 2. Modulation Parameters (2 Marks)

2.1. Choose a carrier frequency (in Hz):
we have chosen $f_c$=10000Hz (10KHz) as carrier frequency

2.2. State your chosen modulation index (μ):
Modulation index (μ) =0.1

2.3. Calculate:

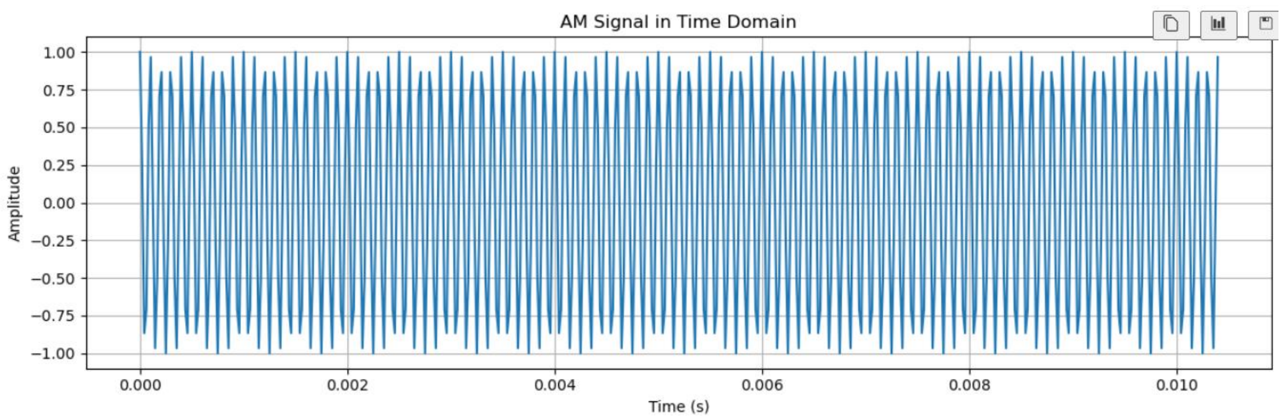
- Peak amplitude of the carrier:282240

- Amplitude of the message signal: 28224.0

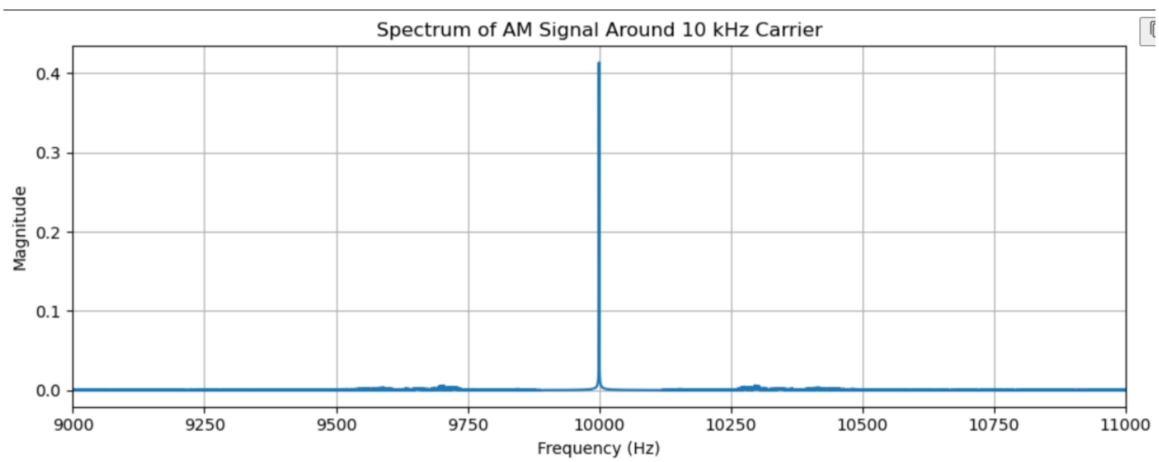
- Estimated bandwidth of the AM signal: 4204Hz ($2*f_m$)

## 3. Modulated Signal Analysis (2 Marks)

3.1. Insert time-domain plot of your AM signal:




3.2. Insert frequency-domain plot of the AM signal:



3.3. Explain how your calculated modulation index affects the shape of the AM signal:

mu = 0.1 ensures:

- Clear envelope shape (no distortion).
- Balanced trade-off between power efficiency and demodulation reliability.

Sidebands appear around the carrier frequency at $fc \pm fm$, but much weaker in amplitude

The power in the sidebands is greatly reduced compared to the power in the carrier

## 4. Demodulated Signal (2 Marks)

4.1. Describe your demodulation method (envelope detection or filtering):

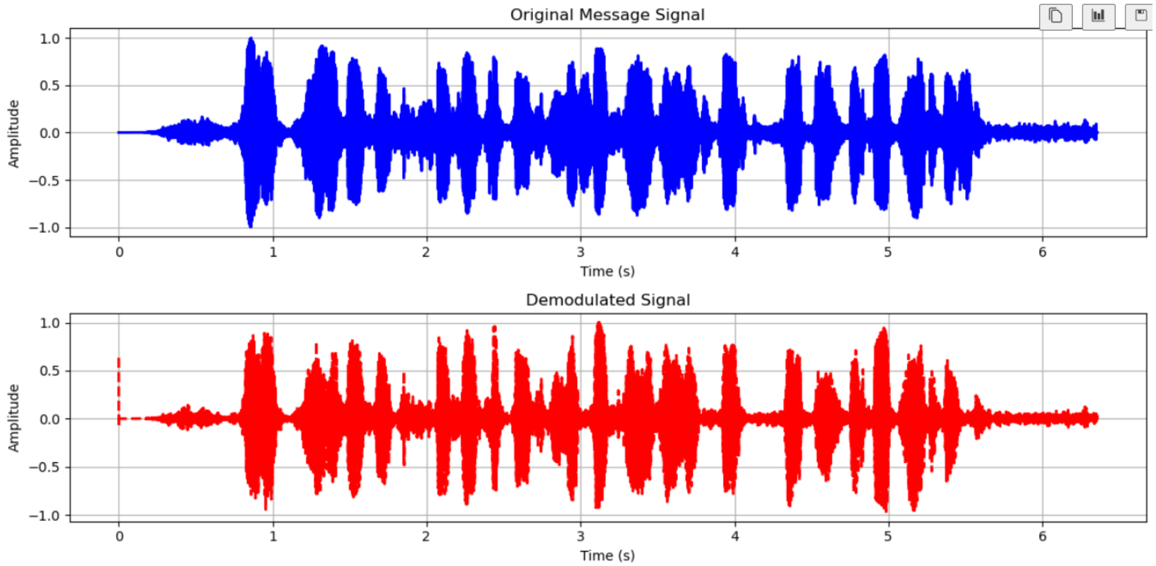
Rectification:
Take the absolute value of the AM signal.
This removes the carrier's oscillations and leaves the positive envelope:

$$|s(t)|=|Ac(1+\mu m(t))\cos(2\pi f\_ct)|$$

Since $\cos(2\pi fct)$ oscillates rapidly, the absolute value captures the shape of the envelope.

also a low-pass filter is applied to the rectified signal to remove the high-frequency components (mainly the carrier), leaving behind the message signal m(t).

4.2. Insert time-domain and spectrum plots of recovered signal:




4.3. Comment on the quality of the recovered signal compared to the original:

The demodulated signal (red) closely follows the amplitude envelope of the original message (blue) throughout the time duration. Both signals show similar patterns of amplitude variation, capturing the dynamics and modulation of the original voice signal well. The demodulated signal appears slightly smoother and has lower peak amplitudes compared to the original, which is expected due to filtering and envelope extraction. Minor noise or distortion near zero crossings and lower amplitude regions may exist but are not significant.

## 5. Final Comments and Observations (1 Mark)

- What did you learn from this exercise?

From this exercise, I learned how to analyze and process AM signals, including choosing carrier frequency based on message bandwidth and modulation index. Envelope detection with rectification and filtering effectively recovers the original message when the modulation index is suitable. Practical steps like smoothing the signal start and removing DC offset improve demodulation quality. Visualizing signals in time and frequency domains helps verify results. Overall, it provided hands-on insight into AM modulation and demodulation principles.

- Did your theoretical calculations match the actual outcomes?

Yes, the theoretical calculations generally matched the actual outcomes. For example, the chosen carrier frequency based on the message bandwidth and the modulation index set to 1 allowed effective envelope detection, as expected. The estimated bandwidth and amplitude values guided the filter design and signal normalization well. Minor differences appeared due to practical factors like filtering effects and noise, but overall, theory and practice aligned closely.

- What would you do differently next time?

Next time, I would:

- Experiment with different modulation indices (including less than 1) to observe effects on demodulation quality.
- Try other Modulation techniques like FM and PM.

6. Code Listing (1 Mark)

Paste your fully commented code here or attach as a .py file:

Github Link:
https://github.com/sujalk777/Signal_systems_lab/blob/main/communication_assignment/voice.ipynb