BVRIT HYDERABAD COLLEGE OF ENGINEERING FOR WOMEN

VISHNU
UNIVERSAL LEARNING

MATLAB PROJECT REPORT

TITLE - MODULATION SCHEMES USING MATLAB APP DESIGNER

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1. ABSTRACT

Modulation is a key process in communication systems that enables the transmission of low-frequency information signals over long distances by embedding them into high-frequency carrier signals. This project, “Modulation Schemes using MATLAB GUI”, focuses on the design and simulation of various analog modulation techniques through an interactive graphical interface developed in MATLAB App Designer. The application allows users to input carrier and message parameters such as frequency and amplitude to generate corresponding time-domain waveforms and frequency spectra.

The implemented techniques include Amplitude Modulation (AM), Frequency Modulation (FM), Double Sideband Suppressed Carrier (DSB-SC), Single Sideband Suppressed Carrier (SSB-SC), and Vestigial Sideband (VSB). Each scheme is demonstrated with its unique signal representation, enabling effective comparison and analysis. The GUI-based simulator enhances visualization, eliminates the need for repeated coding, and provides an intuitive platform for understanding modulation concepts. Overall, the project serves as a valuable educational and research tool in Electronics and Communication Engineering.

2. INTRODUCTION

Communication is the backbone of modern technology, enabling the transfer of information across vast distances. However, most real-world signals, such as voice and data, exist in the low-frequency range and cannot be transmitted directly over long distances due to limitations like high attenuation and interference. To overcome this, modulation is employed, a process in which a high-frequency carrier signal is varied according to the information signal. This not only allows efficient transmission but also facilitates multiplexing, improved signal quality, and better utilization of bandwidth.

This project, “Modulation Schemes using MATLAB GUI”, is designed to simulate and visualize various analog modulation techniques in an interactive environment. A Graphical User Interface (GUI) is developed using MATLAB App Designer, where users can input carrier and message parameters such as frequency and amplitude. The simulator then generates the time-domain waveforms and frequency spectra of different modulation schemes, making the study process more intuitive.

The project covers essential modulation schemes such as Amplitude Modulation (AM), Frequency Modulation (FM), Double Sideband Suppressed Carrier (DSB-SC), Single Sideband Suppressed Carrier (SSB-SC), and Vestigial Sideband (VSB). By providing hands-on visualization and comparison, the project enhances conceptual understanding and serves as a practical educational tool in the field of Electronics and Communication Engineering.

3. NEED FOR MODULATION:

In communication systems, most information signals such as voice, music, and data exist in the low-frequency range (typically below 20 kHz). Transmitting these signals directly over long distances is highly inefficient and impractical due to several reasons. To overcome these limitations, modulation is employed, where the information signal is superimposed onto a high-frequency carrier signal. The need for modulation can be understood from the following aspects:

1. High Range Transmission

Low-frequency signals cannot travel long distances effectively because they suffer from high attenuation and distortion. By shifting signals to higher frequencies using modulation, long-distance transmission becomes possible. High-frequency carrier waves propagate more efficiently through antennas and transmission channels, ensuring that signals reach receivers with reduced loss.

2. Quality of Transmission

Direct transmission of baseband signals is highly prone to noise and interference. Modulation improves the quality of communication by placing the signals in frequency bands less affected by external disturbances. This enhances signal-to-noise ratio (SNR) and ensures that the transmitted message is received more clearly.

3. Avoiding Overlapping of Signals

If multiple low-frequency signals were transmitted directly, they would overlap and interfere since their frequency ranges are similar. Modulation solves this by allocating unique carrier frequencies to different signals. For example, in radio broadcasting, each station is assigned a distinct frequency, allowing multiple users to coexist without overlap.

4. IMPORTANCE IN COMMUNICATION SYSTEM

Modulation is essential in communication systems because it allows signals to be transmitted effectively over long distances, ensures efficient utilization of the available bandwidth, and helps minimize the impact of noise and interference. Its importance can be understood in both analog and digital communication domains.

- In Analog Communications:

1. Efficient Transmission – Modulation makes it possible to transmit low-frequency signals such as speech and music over long distances by shifting them to higher frequency ranges.
2. Bandwidth Utilization – It ensures that the limited spectrum is used efficiently by adapting the signal to available frequency bands.
3. Noise Reduction – Modulation places signals in frequency ranges that are less affected by external interference, improving clarity.
4. Multiplexing – Different carrier frequencies can be assigned to multiple signals, enabling simultaneous transmission without interference (e.g., radio and TV broadcasting).

- In Digital Communications:

1. Data Integrity – Digital modulation techniques ensure reliable and accurate transfer of binary data.
2. Spectral Efficiency – Modulation maximizes the amount of information transmitted within limited bandwidth.
3. Error Correction – Advanced digital modulation supports error detection and correction, improving communication reliability.
4. Security – Techniques like spread spectrum and encryption-based modulation enhance signal security and privacy.

5. Components / Software Used

To develop this project, both software tools and basic hardware setup are required:

- Software Requirements

1. MATLAB:
   - Primary software for coding and GUI development.
   - Provides built-in functions for signal generation, plotting, and spectral analysis.
2. MATLAB App Designer:
   - Used to design the graphical user interface.
   - Allows drag-and-drop creation of buttons, labels, edit fields, and axes.

- Toolboxes Used:

1. Signal Processing Toolbox – for Fourier Transform and spectral analysis.
2. Communications Toolbox – for functions like ssbmod and signal visualization.

- Hardware Requirements

1. A PC/Laptop with the following specifications:
2. Minimum 4 GB RAM (8 GB recommended).
3. Processor: Intel i3 or higher.
4. Operating System: Windows/Linux/MacOS.

6. CLASSIFICATION

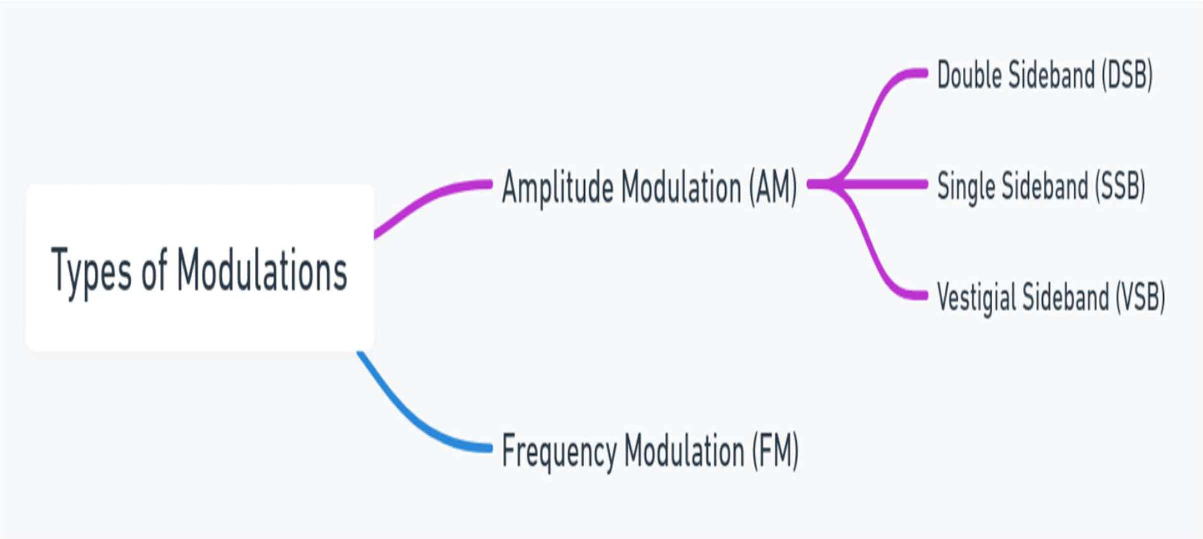

Fig: TYPES OF MODULATIONS

6.1 AMPLITUDE MODULATION

- Amplitude modulation is the process by which amplitude of the carrier signal is varied in accordance with the instantaneous value of the modulating signal, but frequency and phase of carrier wave remains constant.
- Modulating signal frequency is lower than that of the carrier frequency.
- The carrier and modulating signals are represented by

$$V_C = V_C \sin\omega_m t$$

$$V_m = V_m \sin\omega_m t$$

- Expression for AM

$$V_{AM} = V_c\ (1+m\sin\omega_m t)$$

Where m $=\frac{V_m}{V_c}$=modulation index or depth of modulation or amplitude sensitivity. m lies between 0 and 1.

- There are three key conditions to understand: under modulation, critical modulation, and over modulation.

- ✓ Under Modulation: Modulation index < 1; carrier amplitude is dominant, resulting in less effective signal representation.
- ✓ Critical Modulation: Modulation index = 1; modulation is optimal, providing clear signal representation without distortion.
- ✓ Over Modulation: Modulation index > 1; modulating signal amplitude exceeds the carrier amplitude, leading to distortion.

6.1.1 DOUBLE SIDE BAND SUPPRESSED CARRIER (DSB-SC):

- In the process of Amplitude Modulation, the modulated wave consists of the carrier wave and two sidebands.
- The modulated wave has the information only in the sidebands. Sideband is nothing but a band of frequencies, containing power, which are the lower and higher frequencies of the carrier frequency.
- If this carrier is suppressed and the saved power is distributed to the two sidebands, then such a process is called as Double Sideband Suppressed Carrier system or simply DSBSC.
- The carrier and modulating signals are represented by

$$V_C = V_C \sin\omega_m t$$

$$V_m = V_m \sin\omega_m t$$

- Expression for DSB-SC

$$V_{DSB-SC} = V_c * V_m$$

6.1.2 SINGLE SIDE BAND SUPPRESSED CARRIER (SSB-SC):

- The process of suppressing one of the sidebands along with the carrier and transmitting a single sideband is called as Single Sideband Suppressed Carrier system or simply SSBSC.

- This SSBSC system, which transmits a single sideband has high power, as the power allotted for both the carrier and the other sideband is utilized in transmitting this Single Sideband.
- The carrier and modulating signals are represented by

$$V_C = V_C \cos\omega_m t$$

$$V_m = V_m \cos\omega_m t$$

- Expression for DSB-SC

s(t)=AmAc2cos[2π(fc+fm)t]$s(t)=AmAc2\cos[2\pi(fc+fm)t]$ for the upper sideband

Or

s(t)=AmAc2cos[2π(fc−fm)t]$s(t)=AmAc2\cos[2\pi(fc-fm)t]$for the lower sideband

6.1.3 VESTIGIAL SIDE BAND:

- To avoid the loss of information, a technique is chosen, which is a compromise between DSB-SC and SSB, called as Vestigial Sideband (VSB) technique.
- The word vestige which means “a part” from which the name is derived.
- Vestigial Sideband Modulation or VSB Modulation is the process where a part of the signal called as vestige is modulated, along with one sideband.
- The modulating signal m(t)$m(t)$ and carrier signal Accos(2πfct)$Ac\cos(2\pi fct)$ are applied as inputs to the product modulator. Hence, the product modulator produces an output, which is the product of these two inputs.Therefore, the output of the product modulator is

p(t)=Accos(2πfct)m(t)$p(t)=Ac\cos(2\pi fct)m(t)$

Apply Fourier transform on both sides

P(f)=Ac2[M(f−fc)+M(f+fc)]$P(f)=Ac2[M(f-fc)+M(f+fc)]$

The above equation represents the equation of DSBSC frequency spectrum.

6.2 FREQUENCY MODULATION:

- In frequency modulation, the frequency of the carrier signal is varied in accordance with the instantaneous values of the modulating signal. Thus the amplitude of the carrier doesn't change due to frequency modulation.
- The frequency variation in the carrier called the frequency deviation is proportional to the instantaneous value of modulating voltage.
- The carrier and modulating signals are represented by

$$m(t) = A_m \cos(2\pi f_m t)$$

$$c(t) = A_c \cos(2\pi f_c t)$$

Expression for FM

$$f_m(t) = f_c + k A_m \cos(2\pi f_m t)$$

$$f_m(t) = f_c + k\, m(t)$$

- The modulation index is the ratio of maximum deviation in frequency of the modulating signal.

$$\mu = \frac{\Delta f_{\max}}{f_m} = \frac{K_{A_m}}{f_m}$$

7. WORKING

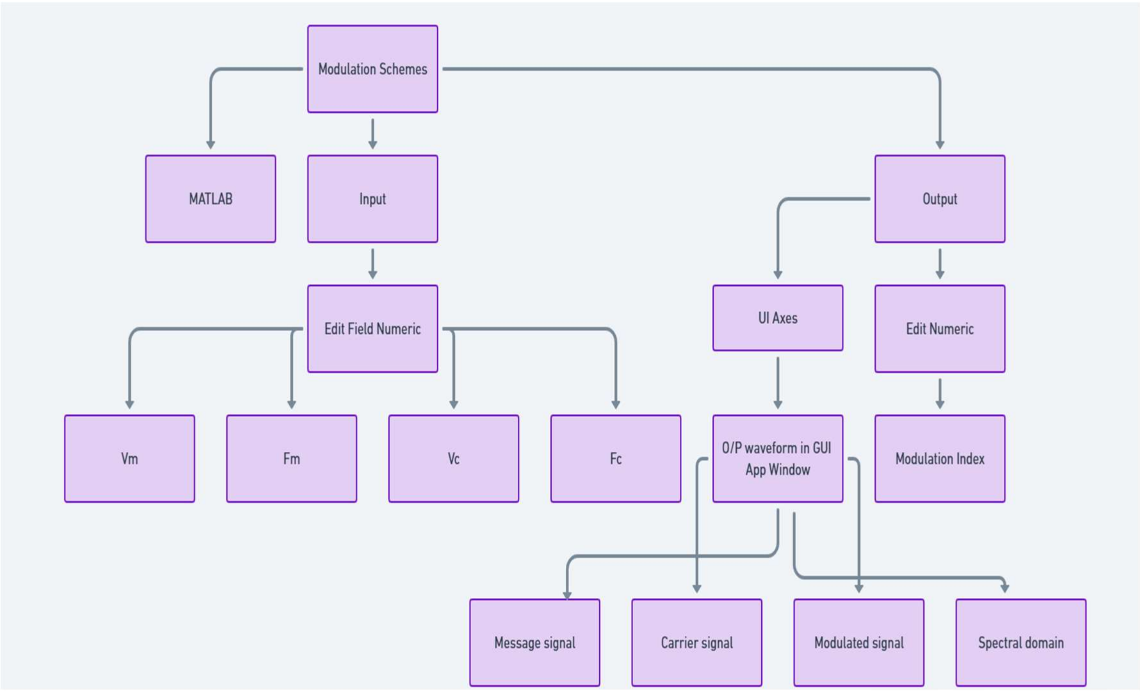

Fig: Flow Chart

This flowchart explains the working of modulation schemes using MATLAB with a GUI. The user provides input parameters such as message amplitude (Vm), message frequency (Fm), carrier amplitude (Vc), and carrier frequency (Fc) through numeric fields. Based on these inputs, the system generates the message signal, carrier signal, and the modulated signal. The GUI displays the output waveforms and also calculates the modulation index. Results can be viewed in both time and spectral domains for better analysis.

8. OUTPUTS

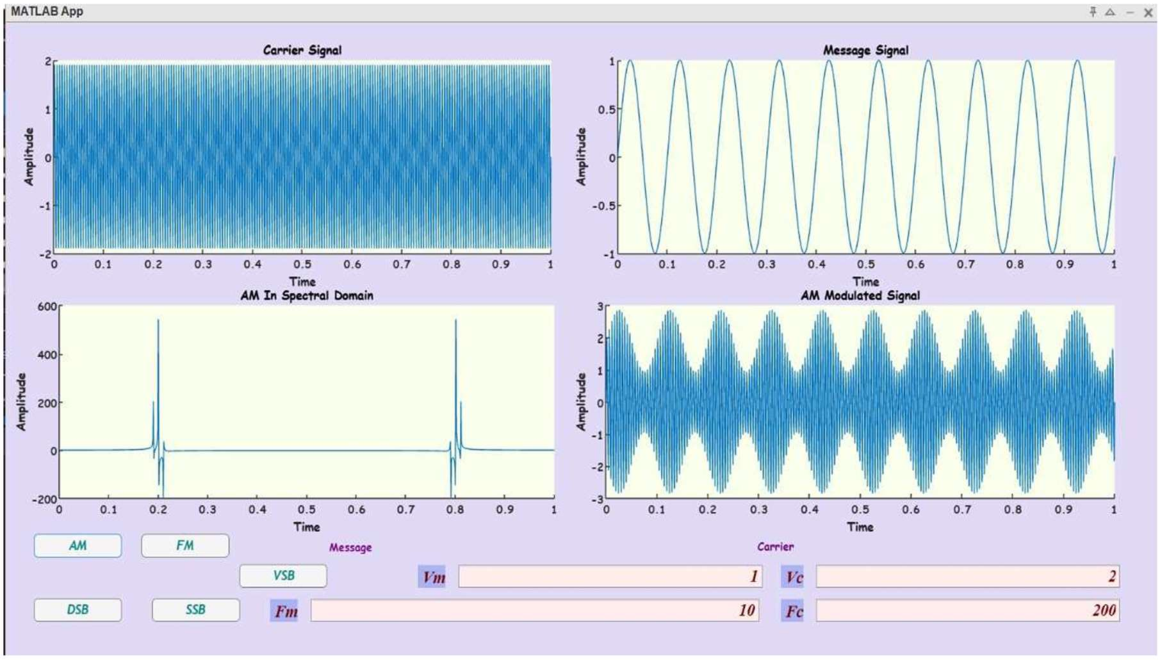

Fig: 8.1 – AMPLITUDE MODULATION

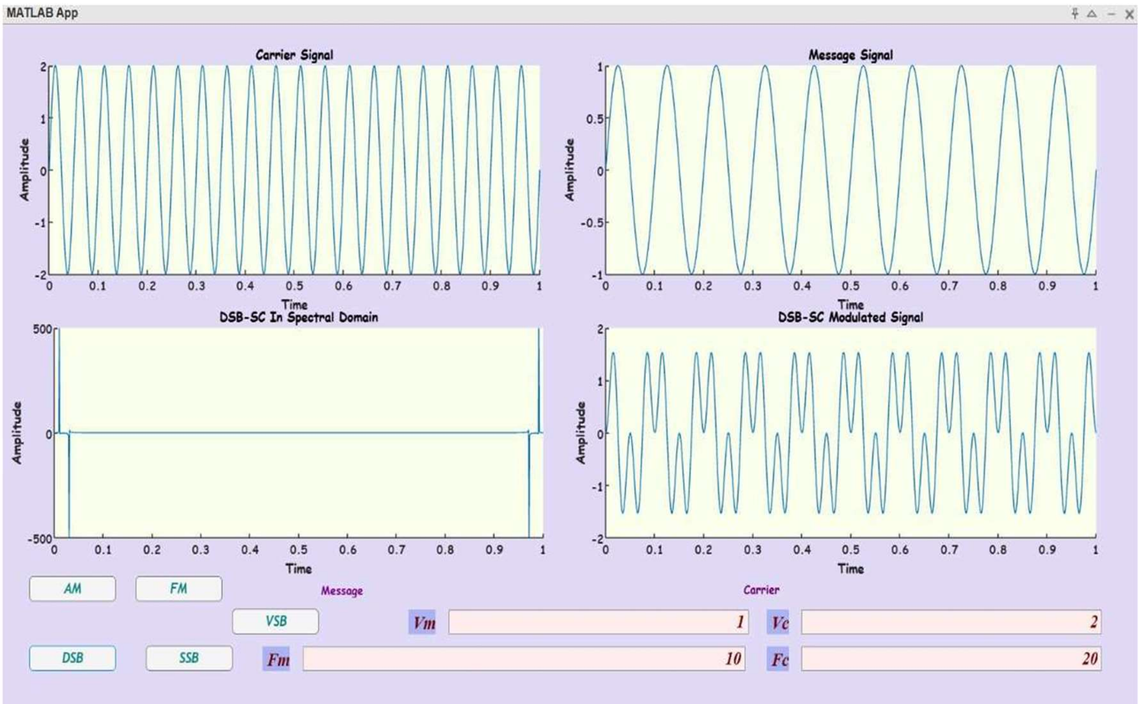

Fig: 8.2 – DSB-SC MODULATION

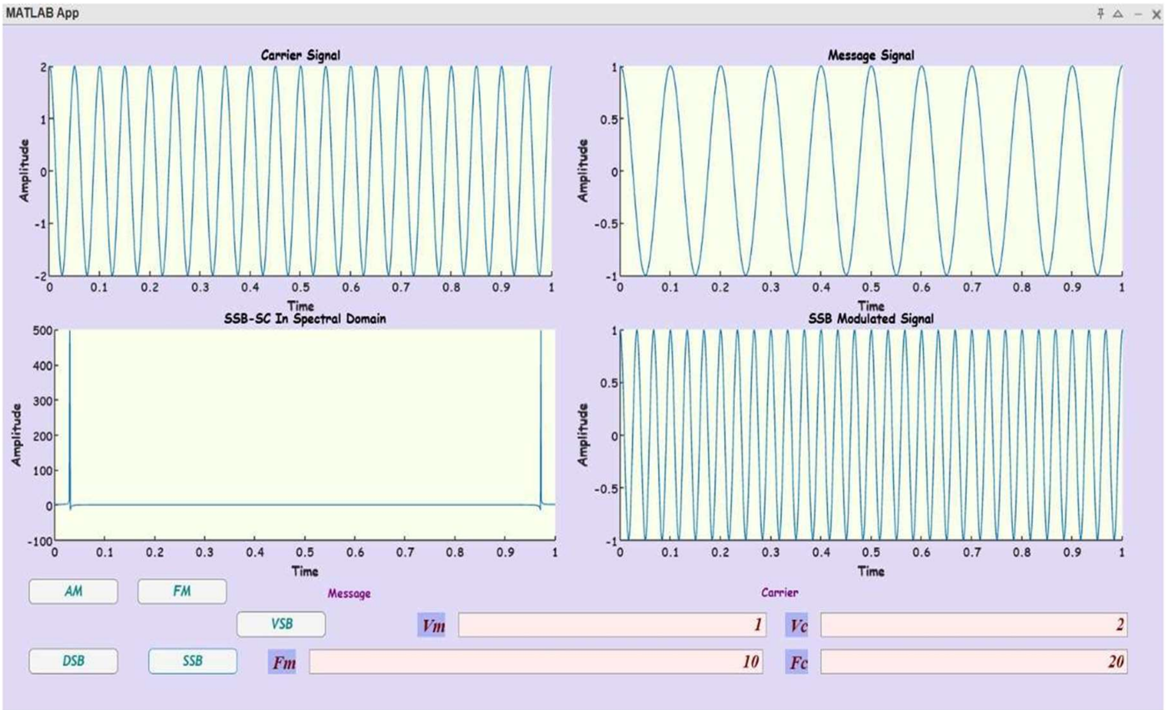

Fig: 8.3 – SSB-SC MODULATION

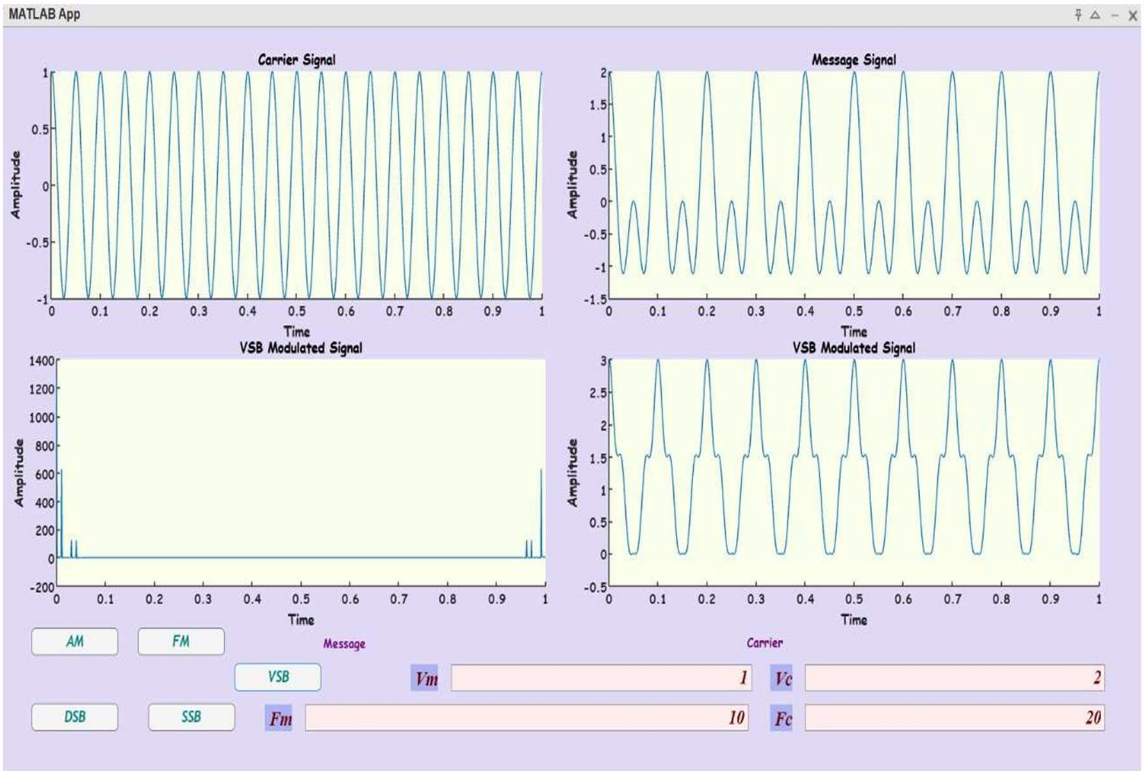

Fig: 8.4 –VSB MODULATION

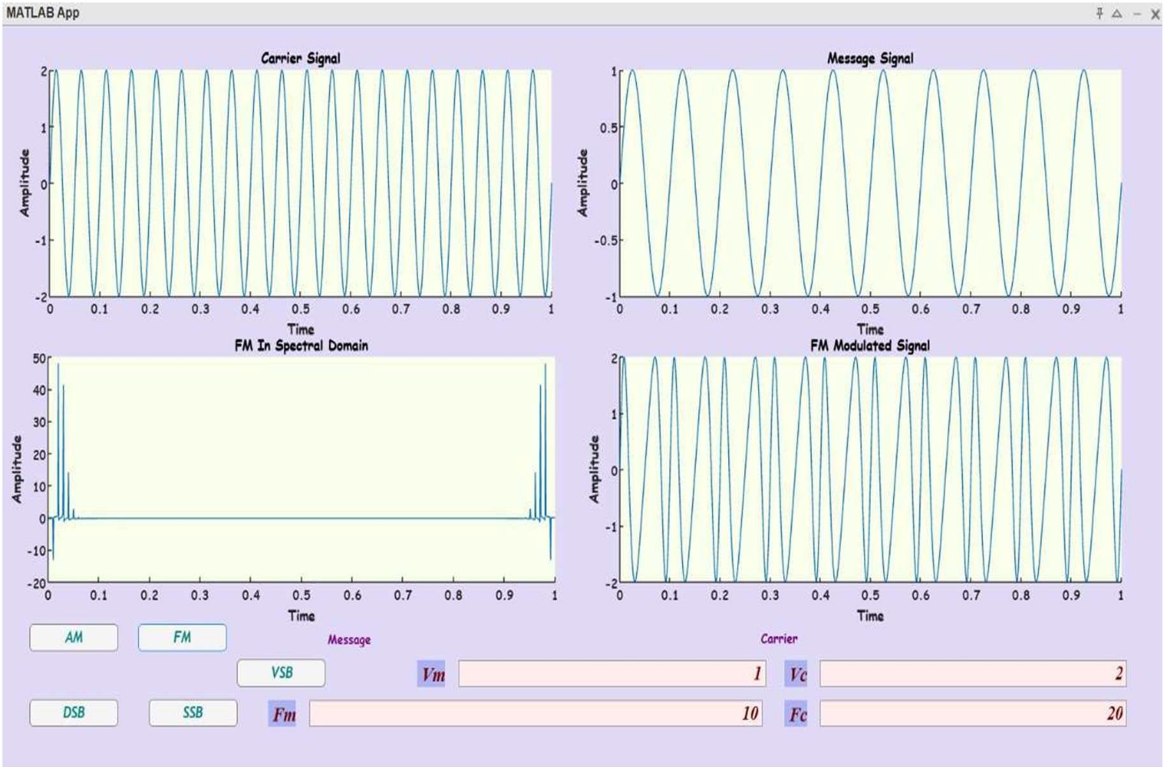

Fig: 8.5 –FREQUENCY MODULATION

9. APPLICATIONS

- Radio Broadcasting (AM & FM) – AM is used for long-distance communication, while FM provides better sound quality and noise resistance.
- Television Transmission (VSB) – VSB modulation is used in TV broadcasting for efficient bandwidth use and easy demodulation.
- Satellite Communication (SSB & DSB-SC) – These schemes save bandwidth and power, making them ideal for long-distance satellite links.
- Mobile and Wireless Communication – Modulation enables efficient spectrum use, higher data rates, and reliable mobile/wireless communication.
- Radar and Navigation Systems – Used in radar for target detection and in GPS for accurate positioning over long distances.
- Military Communication – Secure and bandwidth-efficient modulation schemes are used for defense and tactical communication systems.
- Data Communication (Modems) – Modems use modulation to convert digital data into analog signals for transmission over telephone lines.
- Marine and Aviation Communication – Modulation ensures reliable long-distance communication for ships and aircraft navigation.
- Remote Sensing and IoT Devices – Many IoT sensors and remote monitoring devices rely on modulation for wireless data transfer.

10. CONCLUSION

The project successfully demonstrates the implementation of analog modulation schemes using a MATLAB-based GUI. By providing interactive controls for signal parameters and generating real-time waveforms and spectra, the GUI offers an effective and user-friendly learning tool.

- Key conclusions drawn from the project are:

1. Visualization improves understanding: By observing waveforms and spectra, students gain better insights compared to theoretical study.
2. Efficiency: The GUI reduces the need for repetitive coding, saving time and effort.
3. Comparison of Schemes: The tool enables easy comparison of AM, FM, DSB-SC, SSB-SC, and VSB.
4. Educational Value: It provides an excellent platform for students and educators in the field of communication engineering.

Overall, the project highlights the importance of modulation in communication systems and demonstrates how modern tools like MATLAB GUI can simplify complex concepts. It serves as a foundation for further research and development in advanced modulation and communication techniques.