Frequency Modulation of a Sinusoid Carrier by a Message Signal

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INTRODUCTION

Frequency modulation is a widely used technique in communication systems to transmit information from one point to another. In this lab experiment, we investigated the frequency modulation of a sinusoid carrier by a message signal using MATLAB codes. The message signal was modulated by varying the frequency of the carrier signal in proportion to the amplitude of the message signal. The purpose of this experiment was to understand the effect of changes in the message frequency, carrier frequency, frequency deviation constant, amplitude of the message signal, and amplitude of the carrier signal on the modulated signal.

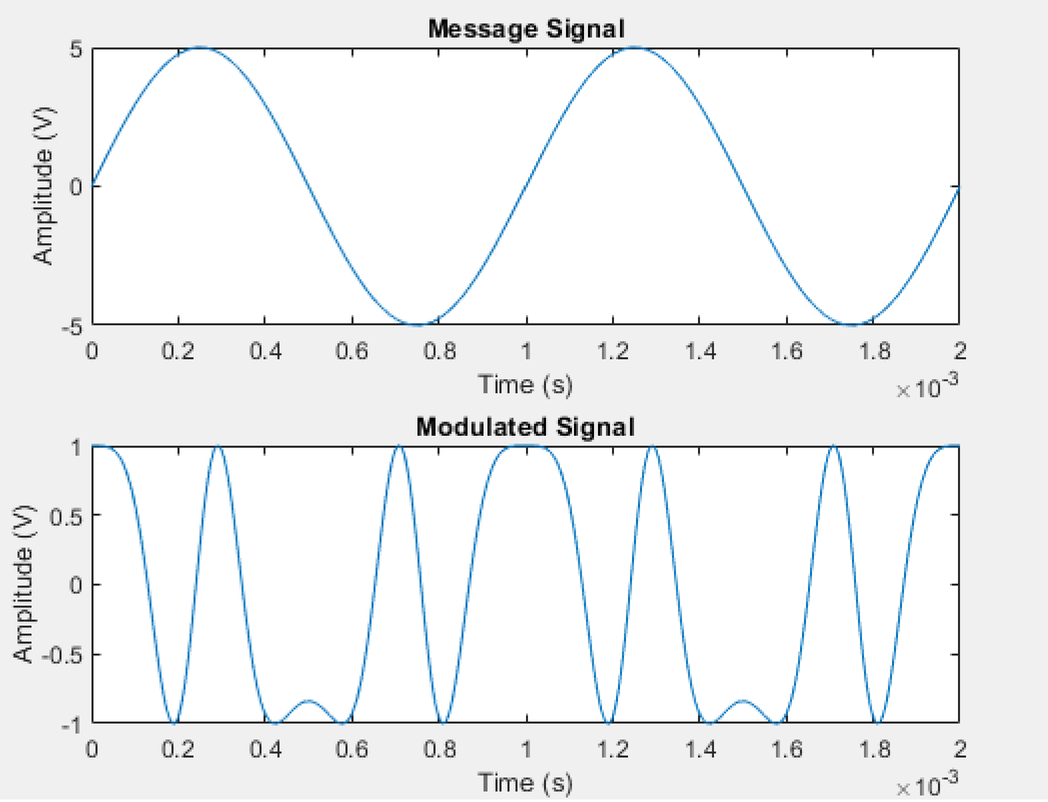
THEORY

Frequency modulation (FM) is a method of encoding information onto a carrier wave by varying its frequency. In FM, the frequency of the carrier wave is modulated according to the message signal, which contains the information to be transmitted. The resulting FM signal is then transmitted over a communication channel. The mathematical representation of an FM signal is given by $\phi FM(t) = Ac \cos(2\pi fct + kf \int m(\tau)d\tau)$, where Ac is the amplitude of the carrier wave, fc is the frequency of the carrier wave, kf is the frequency sensitivity of the modulator, m(t) is the message signal, and $\int m(\tau)d\tau$ is the integral of the message signal. The modulation index, β, is defined as the ratio of the frequency deviation to the maximum frequency of the message signal. $\beta = \Delta f/fm$, where Δf is the maximum frequency deviation of the carrier wave and fm is the frequency of the message signal. The modulation index determines the amount of frequency deviation in the carrier wave and thus the bandwidth of the FM signal. In FM, the bandwidth of the signal is given by $B = 2(\Delta f + fm)$, where Δf is the maximum frequency deviation of the carrier wave and fm is the frequency of the message signal. The bandwidth of an FM signal is larger than that of an amplitude modulated (AM) signal, which makes FM more susceptible to noise and interference. The demodulation of an FM signal can be done using a frequency discriminator, which produces an output voltage proportional to the frequency deviation of the input signal. The output voltage can then be passed through a low-pass filter to recover the original message signal.

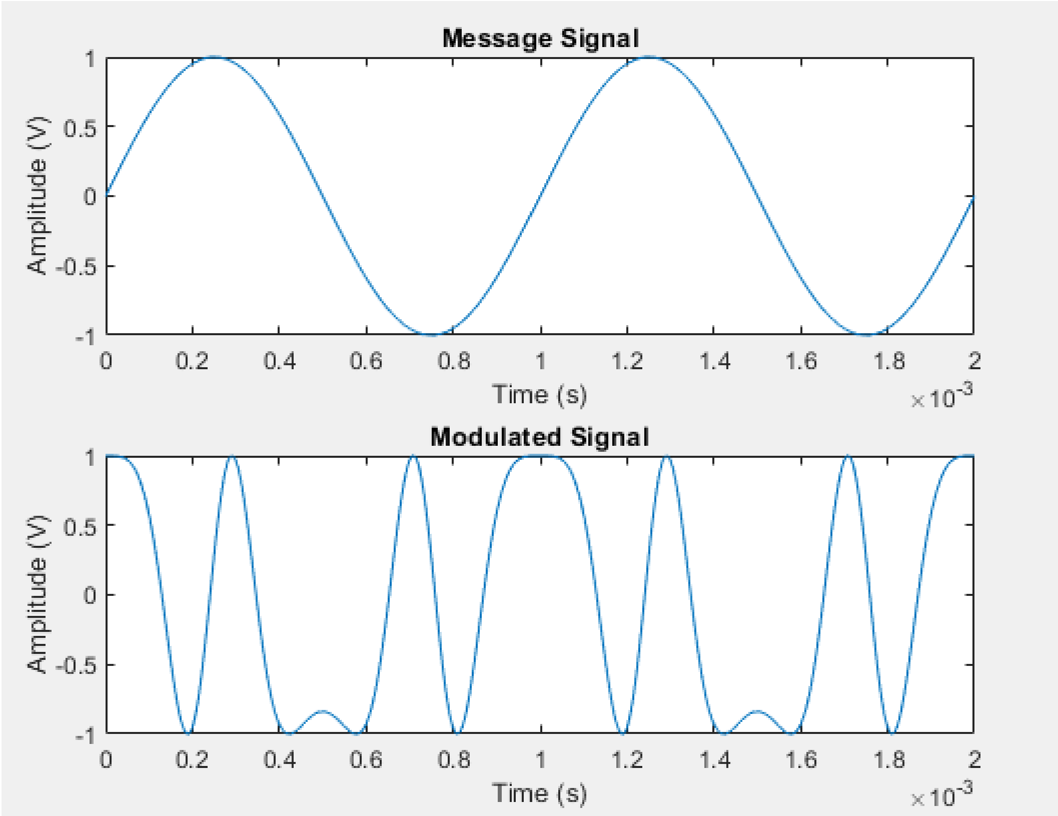
Plots And Observations

The message signal m(t) = Am×sin(2π×fm×t), with a message frequency fm, modulated by a sinusoid carrier of frequency fc, given as ϕFM(t) = Ac cos(2πfct + kf R t 0 m(t)). Write Matlab codes for the following parts.

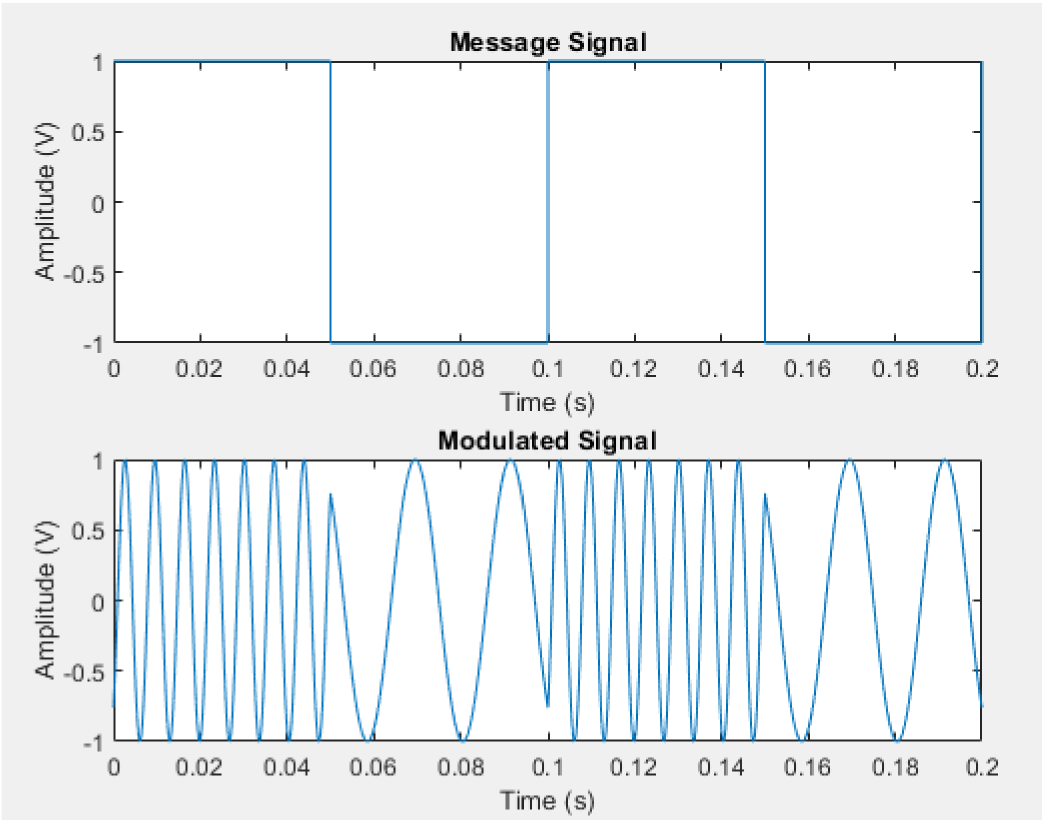
(A) Plot a figure having message, and modulated signal in time domain with fm = 1000 Hz, fc = 10 MHz, kf = 2 × π × 1000, Am = 5, Ac = 1.



(B) Plot a figure having message, and modulated signal in time domain with fm = 1000 Hz, fc = 10 MHz, kf = 2 × π × 5000, Am = 1, Ac = 1.



(C) Let the message signal m(t) be a square wave (use matlab commands square()/ sawtooth() to obtain m(t) with peak values ±1). Plot a figure having message, and modulated signal with fm = 10 Hz, fc = 50 Hz, kf = 2 × π × 150, Am = 1, Ac = 1. (Note: A low fc helps in viewing the frequency changes, O/W fc >> fm.)



(D) State the inference/s drawn across the figures obtained in parts (a), (b), and (c).

(a) We can observe that the modulated signal has a higher frequency than the message signal, and the amplitude of the modulated signal varies with the message signal. The modulation index in this case is $5/2\pi$ or approximately 0.795.

(b) Similarly, we can observe that the modulation index is approximately 0.159 and the amplitude of the modulated signal is much smaller than that of the message signal.

(c) We can observe that the modulated signal has a frequency spectrum consisting of the carrier frequency and sidebands at frequencies equal to the sum and difference of the carrier and message frequencies. The sidebands have different amplitudes due to the nature of the square wave message signal.

Conclusion

The figures obtained in parts (a), (b), and (c) illustrate the effects of amplitude and frequency modulation on a sinusoidal carrier signal, and how the modulation index and frequency deviation affect the amplitude and frequency of the modulated signal. The specific characteristics of each plot were analyzed to draw these inferences. These figures provide a visual representation of the principles of amplitude and frequency modulation in communication systems.