Q1

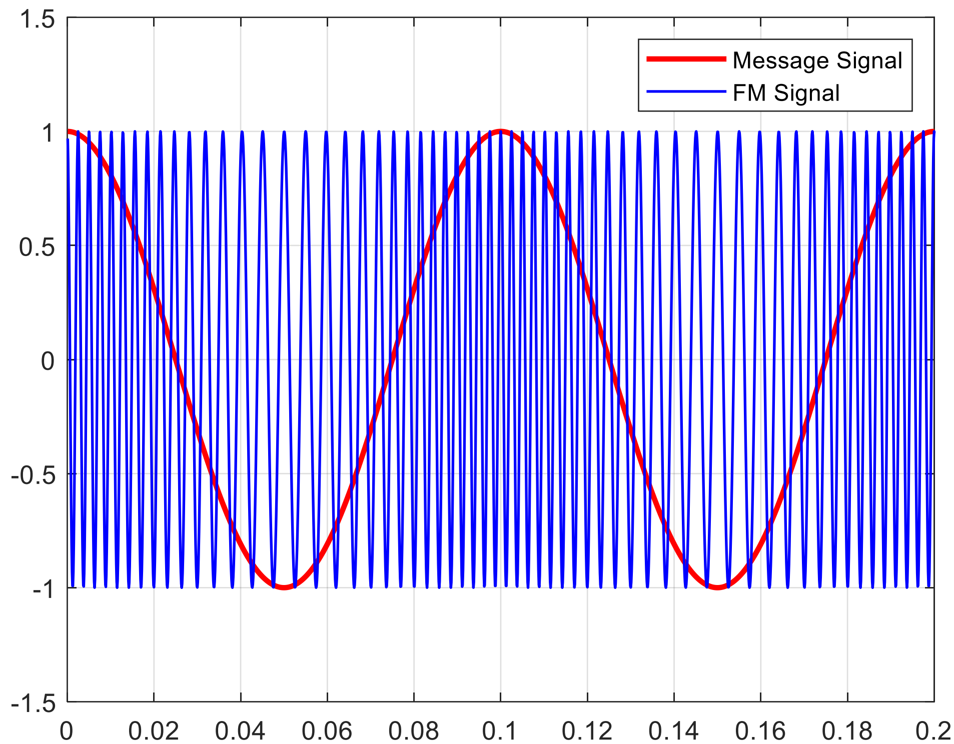

Figure 1 – Message Signal (mp = 1 and 10 Hz) with FM Signal (K_f = 200π and f_c = 300 Hz)

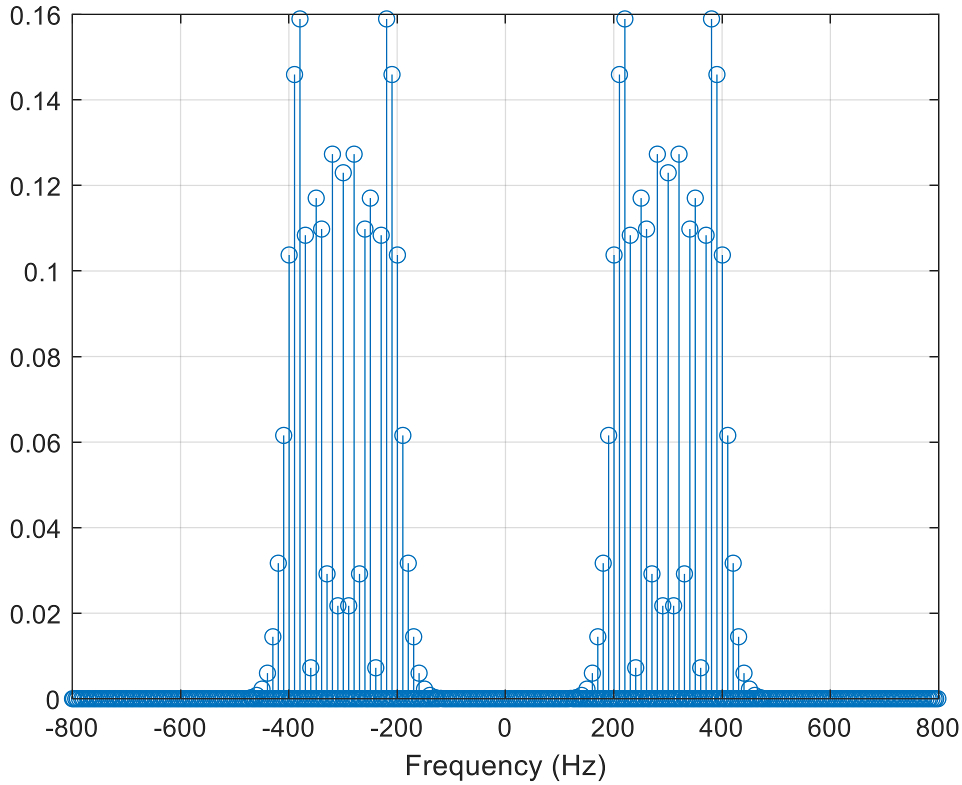

Figure 2 – Important Frequencies (f_{max}, f_{min}, Δf) for Message Signal (Figure 1)

In a time-dependent graph of FM signals, we can observe the frequency variations based on the maximum and minimum values of the original signal. Additionally, an FM signal with a higher modulation index tends to exhibit a broader ripple. The amplitude changes also play a crucial role in the frequency-dependent graph.

$$\Delta f = \frac{K_f}{2\pi} * mp = \frac{200\pi}{2\pi} * 1 = 100\ Hz$$

$$f_{max} = f_c + \Delta f = 300 + 100 = 400\ Hz$$

$$f_{min} = f_c - \Delta f = 300 - 100 = 200\ Hz$$

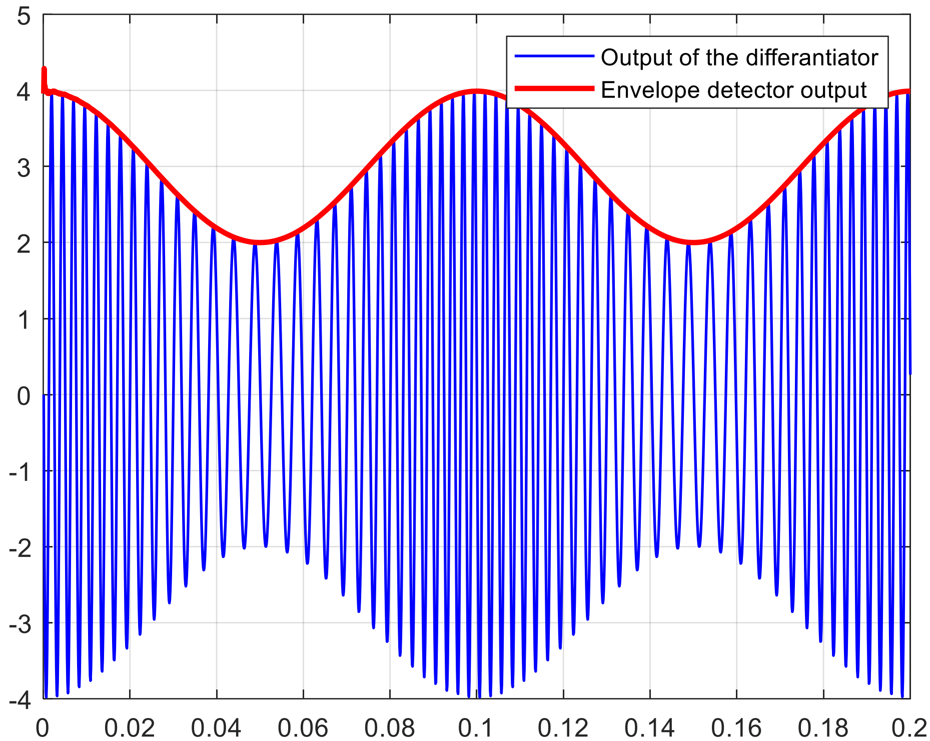

Figure 3 – Envelope Detector Output after FM Demodulation

$$B = f_0 = 10\ Hz$$
$$W = 2 * (\Delta f + B) = 2 * (100 + 10) = 220\ Hz$$

Q2

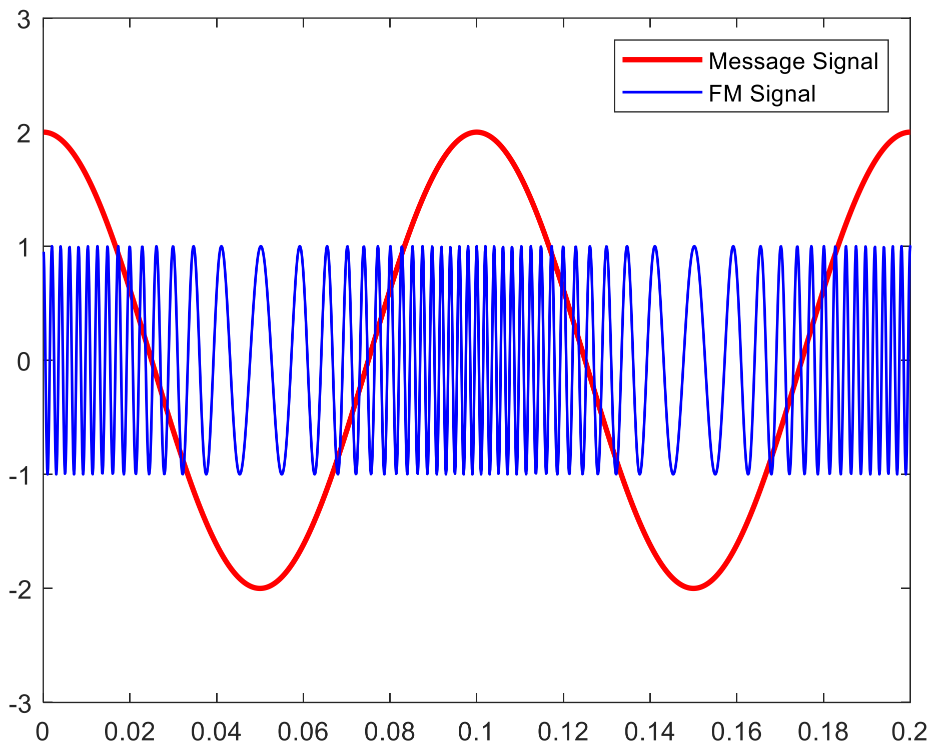

Figure 4 - Message Signal (mp = 2 and 10 Hz) with FM Signal (K_f = 200π and f_c = 300 Hz)

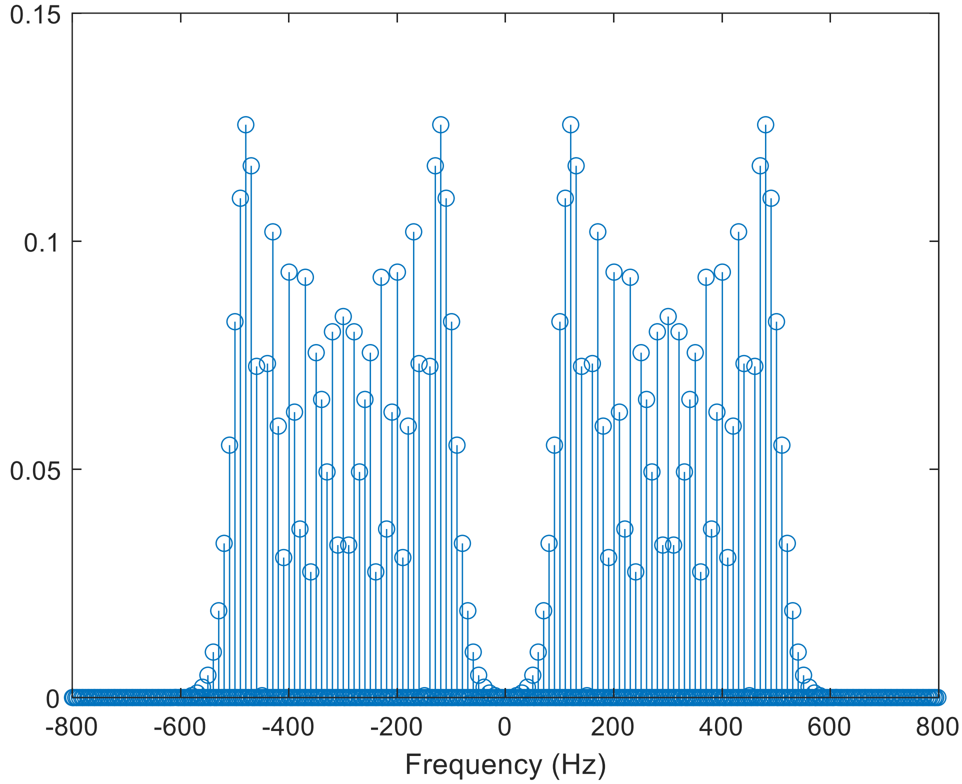

Figure 5 - Important Frequencies (f_{max}, f_{min}, Δf) for Message Signal (Figure 4)

$$\Delta f = \frac{K_f}{2\pi} * mp = \frac{200\pi}{2\pi} * 2 = 200\ Hz$$

$$f_{max} = f_c + \Delta f = 300 + 200 = 500\ Hz$$

$$f_{min} = f_c - \Delta f = 300 - 200 = 100\ Hz$$

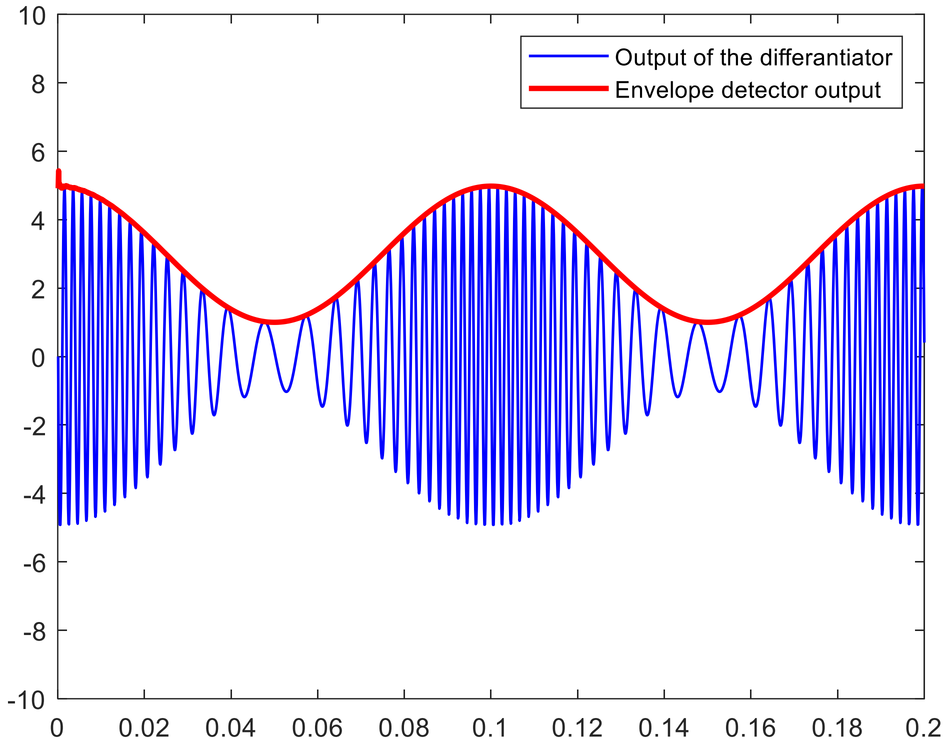

Figure 6 - Envelope Detector Output after FM Demodulation

$$B = f_0 = 10\ Hz$$

$$W = 2 * (\Delta f + B) = 2 * (200 + 10) = 420\ Hz$$

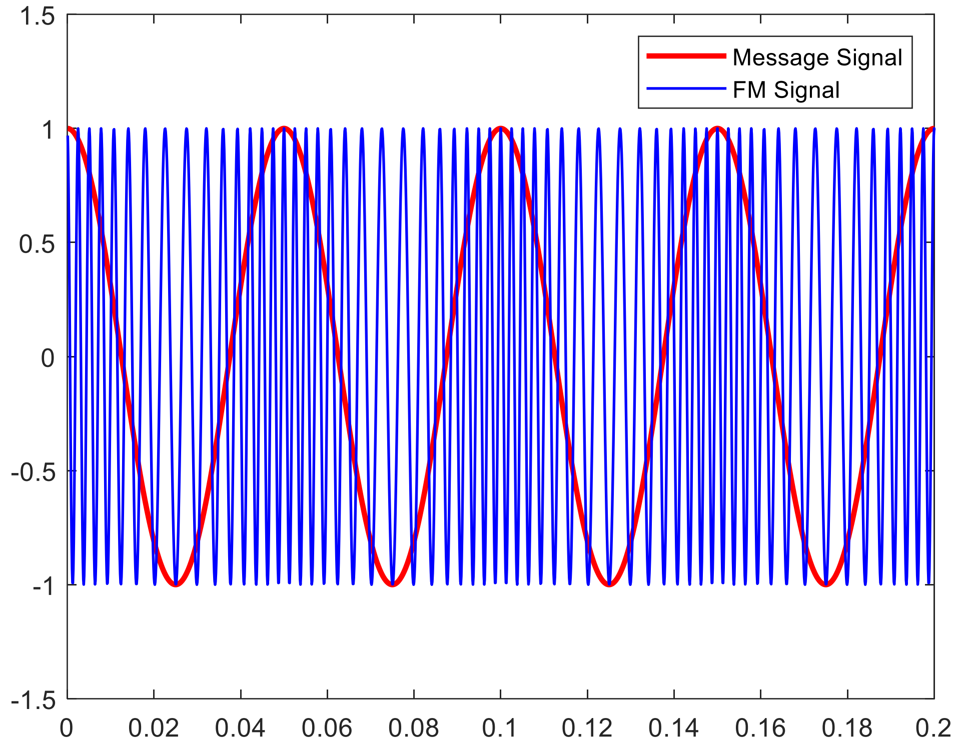

Figure 7 - Message Signal (mp = 1 and 20 Hz) with FM Signal (K_f = 200π and f_c = 300 Hz)

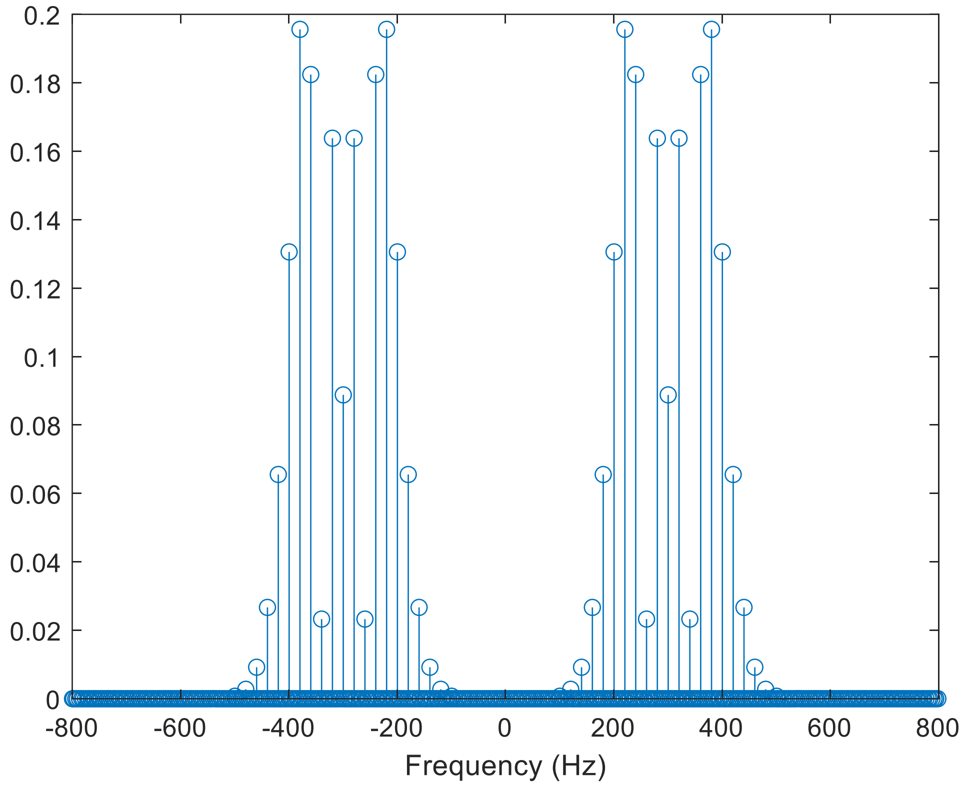

Figure 8 - Important Frequencies (f_{max}, f_{min}, Δf) for Message Signal (Figure 7)

$$\Delta f = \frac{K_f}{2\pi} * mp = \frac{200\pi}{2\pi} * 1 = 100\ Hz$$

$$f_{max} = f_c + \Delta f = 300 + 100 = 400\ Hz$$

$$f_{min} = f_c - \Delta f = 300 - 100 = 200\ Hz$$

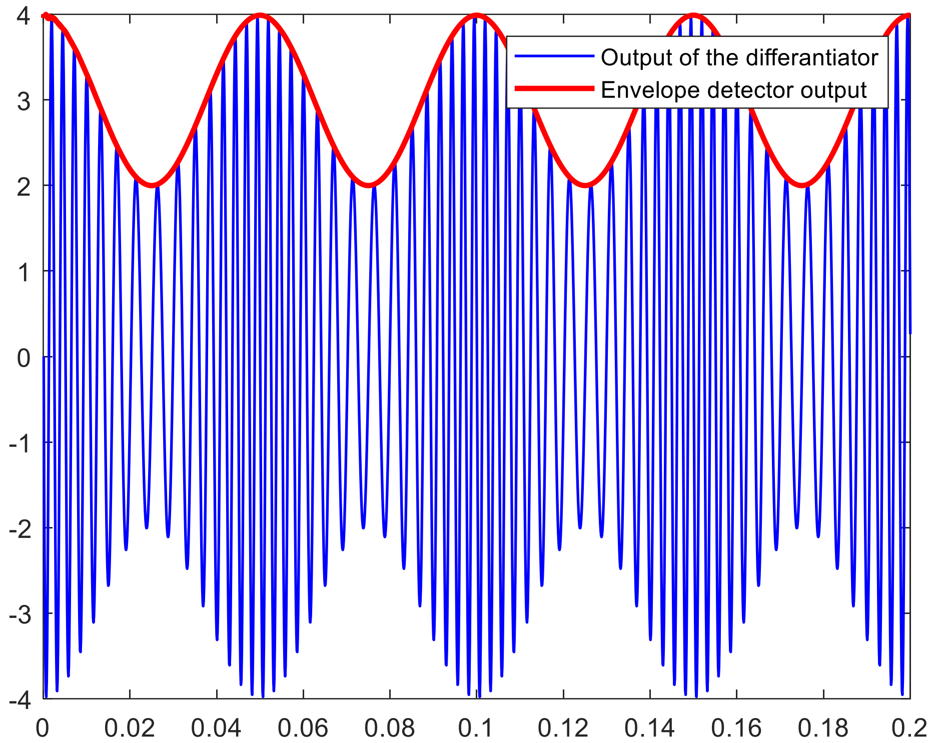

Figure 9 - Envelope Detector Output after FM Demodulation

$$B = f_0 = 20\ Hz$$

$$W = 2 * (\Delta f + B) = 2 * (100 + 20) = 240\ Hz$$

CASES	W_{FM} (Hz)
mp = 1 and f_0 = 10 Hz	220
mp = 2 and f_0 = 10 Hz	420
mp = 1 and f_0 = 20 Hz	240

When the mp is doubled, the bandwidth nearly doubles as well.
If the mp remains constant, the bandwidth doesn't change significantly.