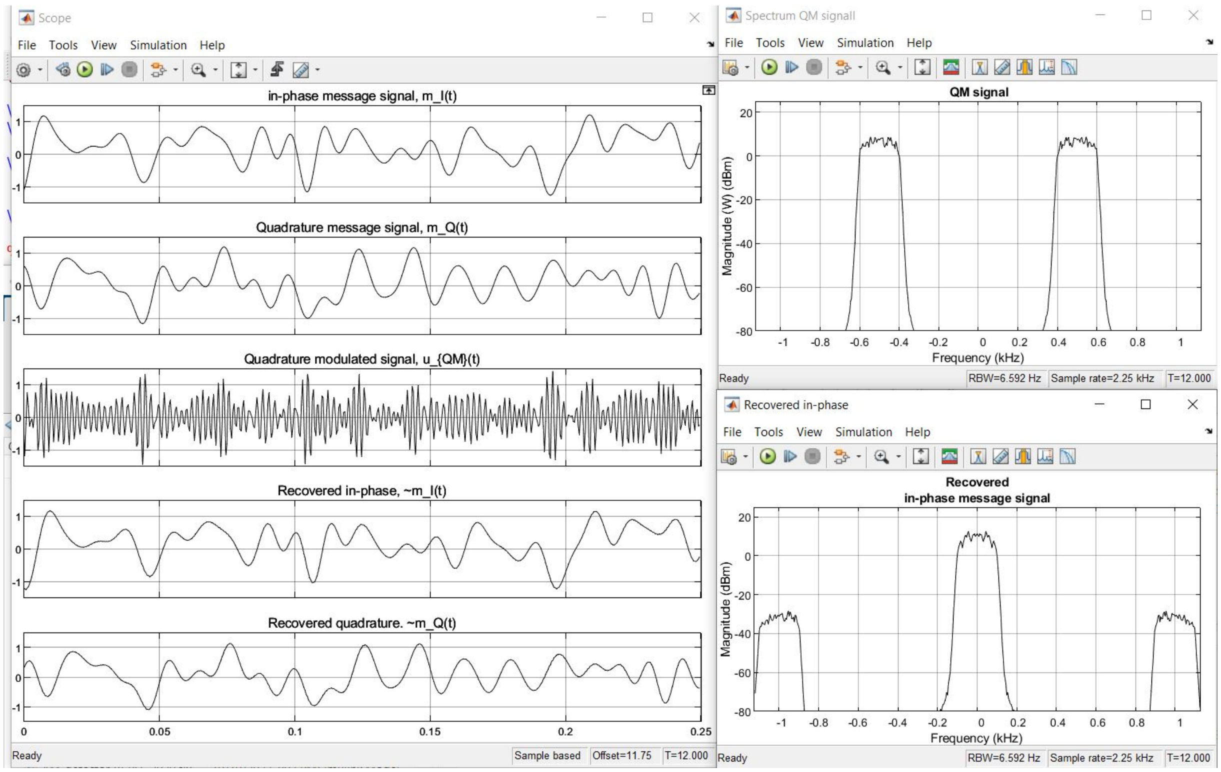
Solution of Homework # 6

1. Quadrature modulation



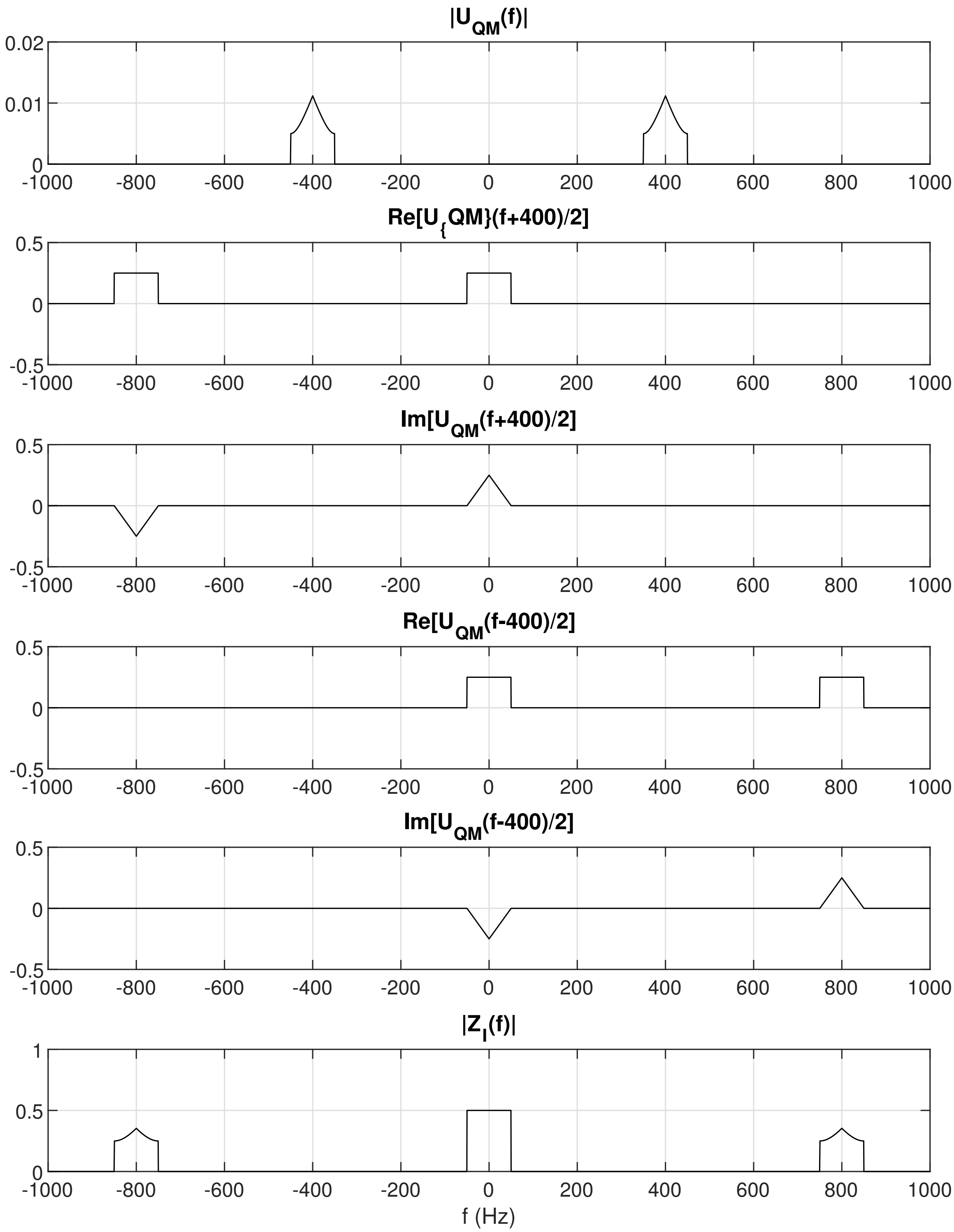
The shapes of the demodulated signals are very close to those of the message signals.

2. QM signal with $m_I(t) = \text{sinc}(100t)$, $m_Q(t) = \text{sinc}^2(50t)$ and $f_c = 400$ Hz

   (a) The amplitude spectrum $|U_{\text{QM}}(f)|$ is shown in the top of the figure below.

   (b) Real and imaginary parts of the spectrum of $u_{\text{QM}}(t)$ multiplied by $\cos(400\pi t)$ are shown in the four plots in the middle of the figure above. The amplitudes are normalized and depend on the amplitude of the local oscillator (LO) signal.

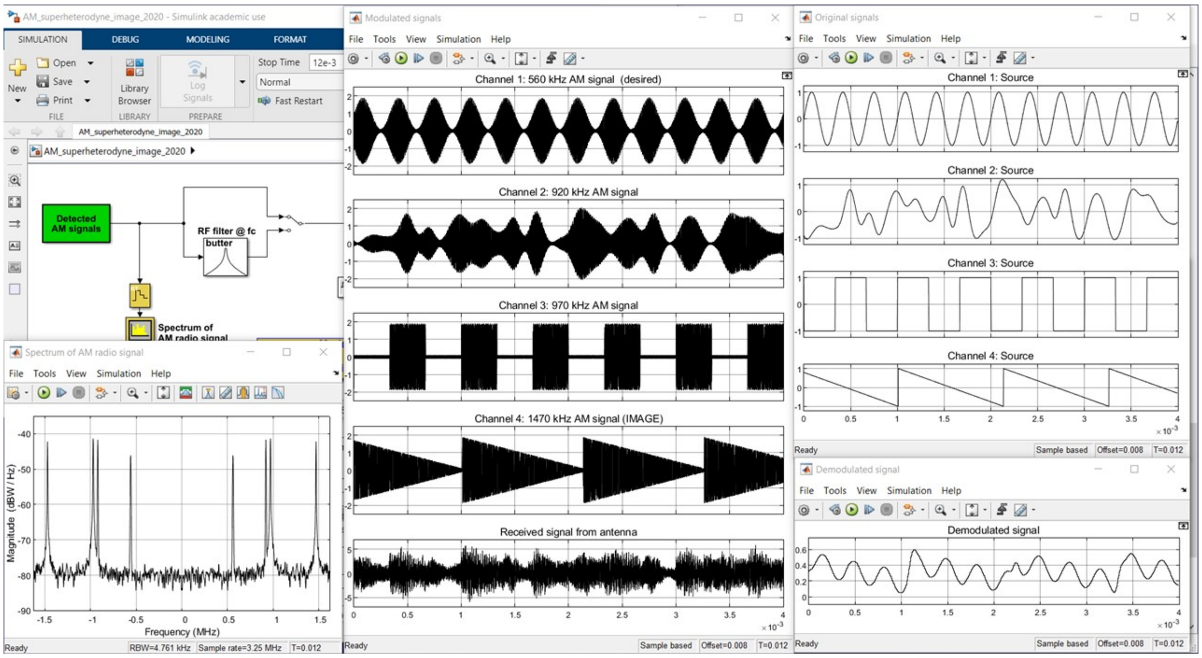
   The resulting spectrum of $z_I(t) = u_{\text{QM}}(t)\,\cos(400\pi t)$ is shown in the bottom plot. After lowpass filtering the in-phase signal $\text{sinc}(100t)$ will be obtained.



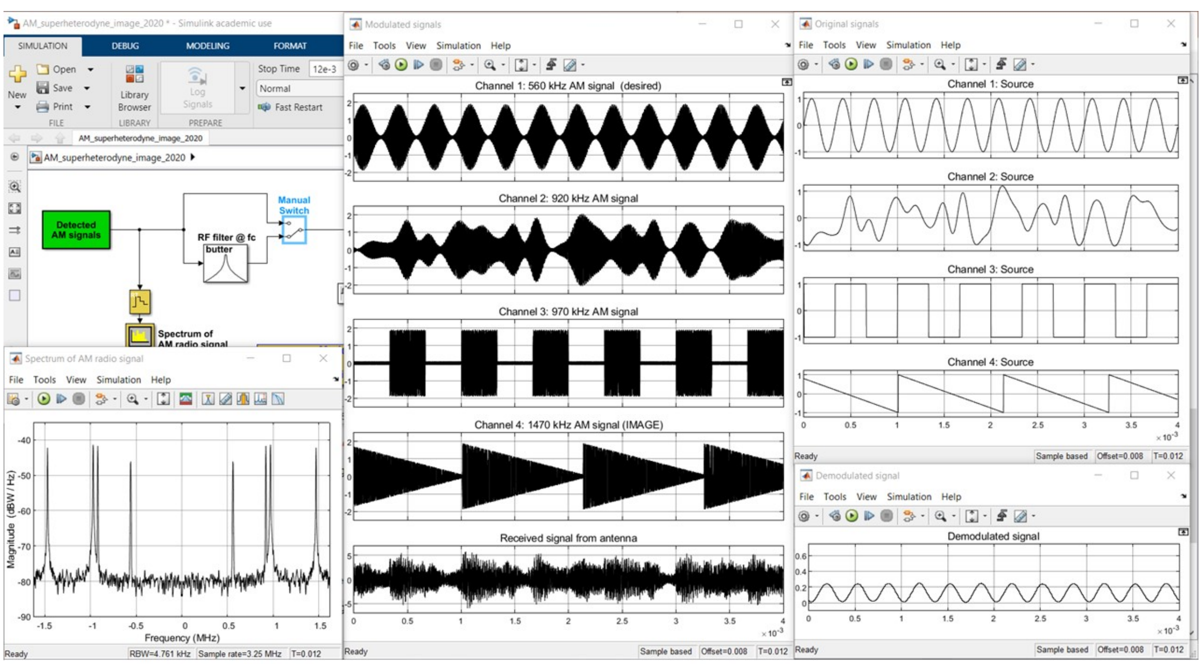
$|U_{QM}(f)|$
$\mathrm{Re}[U_{\{}\mathrm{QM}\}(f+400)/2]$
$\mathrm{Im}[U_{QM}(f+400)/2]$
$\mathrm{Re}[U_{QM}(f-400)/2]$
$\mathrm{Im}[U_{QM}(f-400)/2]$
$|Z_I(f)|$
f (Hz)

3. Computer model of a superheterodyne receiver

(a) No channel filter: Desired channel 1 (sine) and image channel 4 (ramp) demodulated signals overlap.

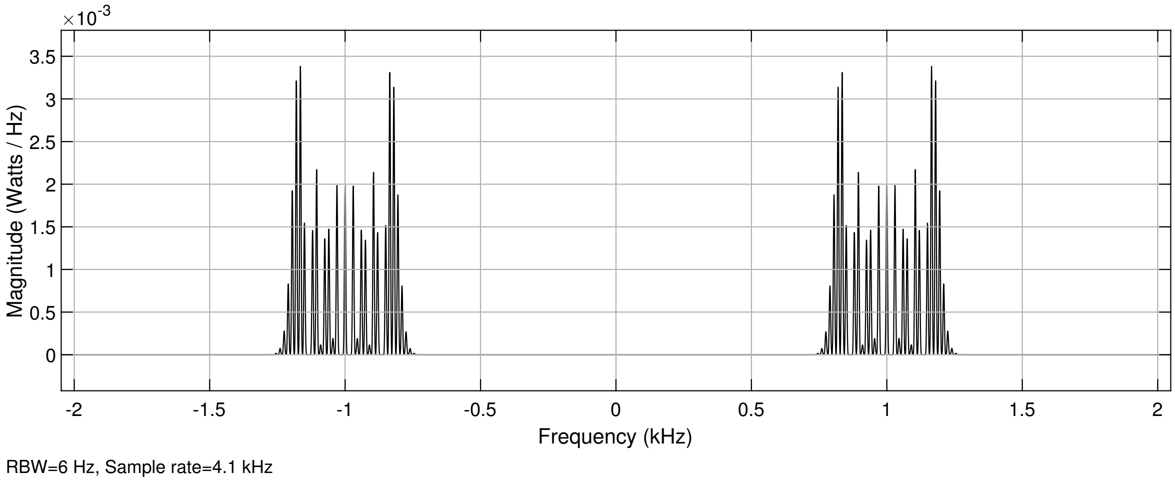


(b) Channel filter enabled: Image channel (ramp) signal is removed. The demodulated signal is the sine waveform from channel 1.



4. Computer model of an FM system using a phase-locked loop receiver

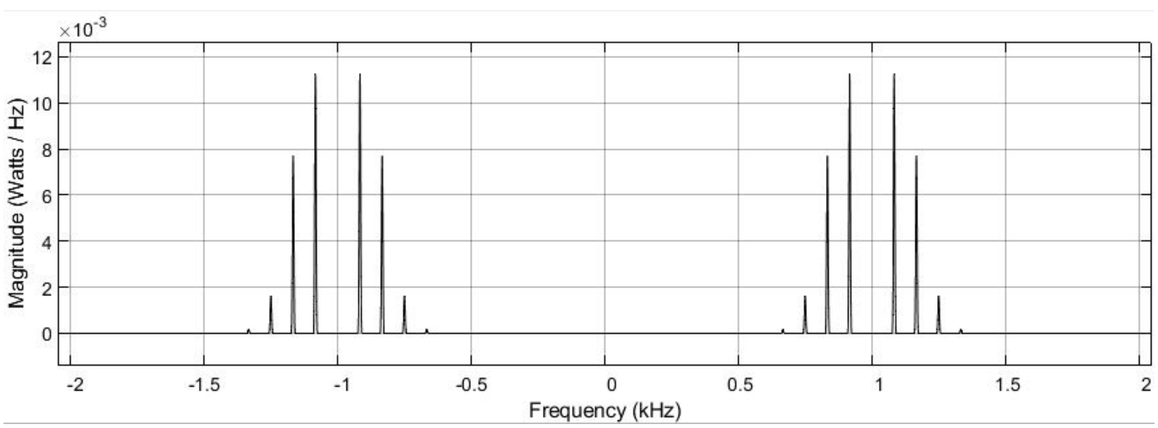
(a) $f_m = 15$ Hz: $\beta_f = \frac{\Delta f_{\max}}{W} = \frac{200}{15} = 13.33$. Result:



(b) Modulating frequency valu for $\beta_f = 2.4$:

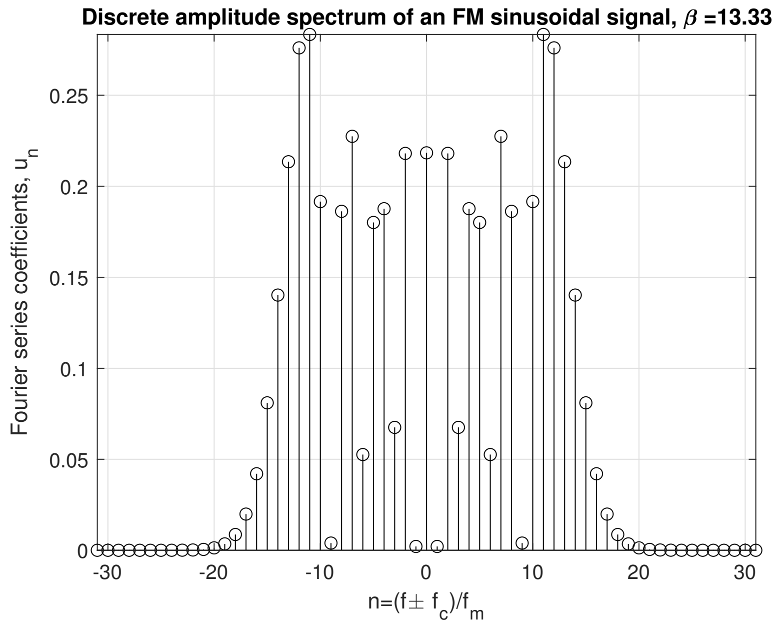
$$\beta_f = \frac{\Delta f_{\max}}{f_m} \quad \longrightarrow \quad f_m = \frac{\Delta f_{\max}}{\beta_f} = \frac{200 \text{ kHz}}{2.4} = 83.33 \text{ kHz}.$$

Result:



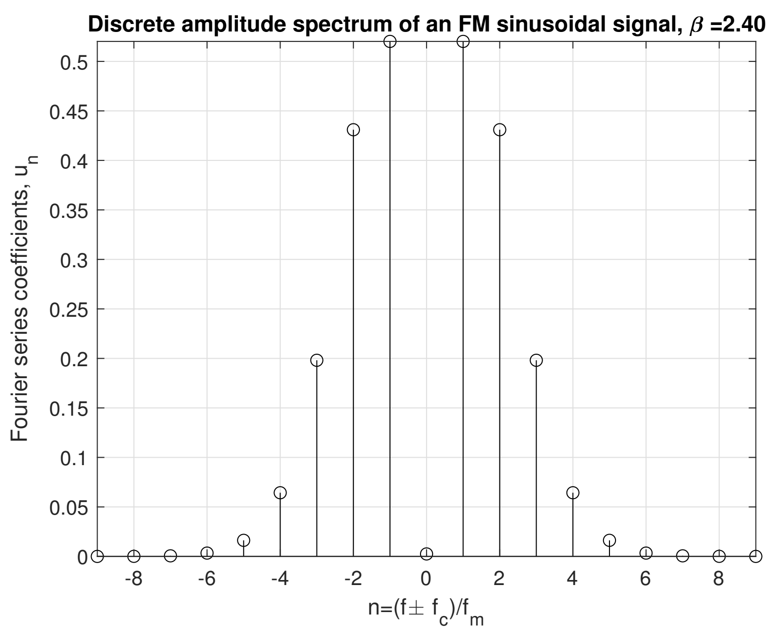
5. Spectrum and bandwidth of a sinusoidal modulated FM signal

(a) $\beta_f = 13.33$:



Carson's bandwidth: $B_c = 28.7 f_m$.

(b) $\beta_f = 2.4$:



Carson's bandwidth: $B_c = 6.8 f_m$.

Compared with the computer model results, the spectra are remarkably similar. In part (b), note that there is no carrier because the corresponding Fourier series coefficient $c_0 = J_0(2.4) = 0$. (See also slide 5 of presentation `12_FM_and_noise.pdf`)