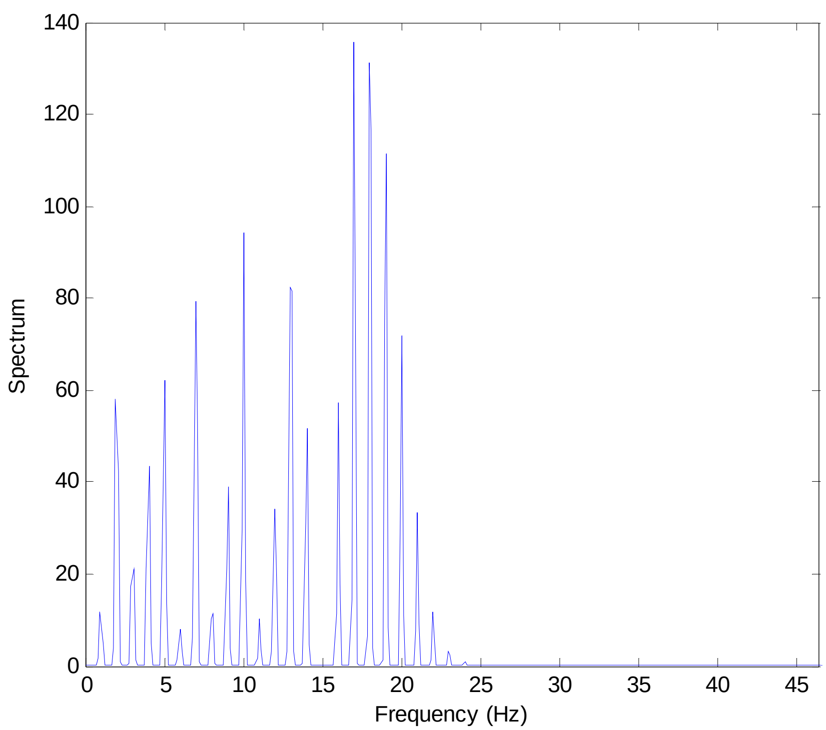
Problem 9.27. In this computer experiment, we investigate the performance of FM in noise. Using the Matlab script for the FM experiment provided in Appendix 8:
(a) Plot the spectrum of the baseband FM phasor.
(b) Plot the spectrum of the band-pass FM plus noise.
(c) Plot the spectrum of the detected signal prior to low-pass filtering.
(d) Plot the spectrum of the detected signal after low pass filtering.
(e) Compare pre-detection and post-detection SNRs for an FM receiver.

In the following parts (a) through (d), set the initial CNdB value to 13 dB in order to be operating above the FM threshold.

(a) By inserting the following statements after the definition of FM, we obtain the baseband spectrum

```
[P,F] = spectrum(FM,4096,0,4096,Fs);
plot(F,P(:,1))
xlabel('Frequency (Hz)')
ylabel('Spectrum')
```

An enlarged snapshot of the spectrum near 0 Hz is shown here. It shows the tones at the regular spacing that one would expect with FM tone modulation. Note that initial plot shows the "negative frequency" portion of the spectrum just below F_s = 500 Hz. This is due to the nature of the FFT and the sampling process.



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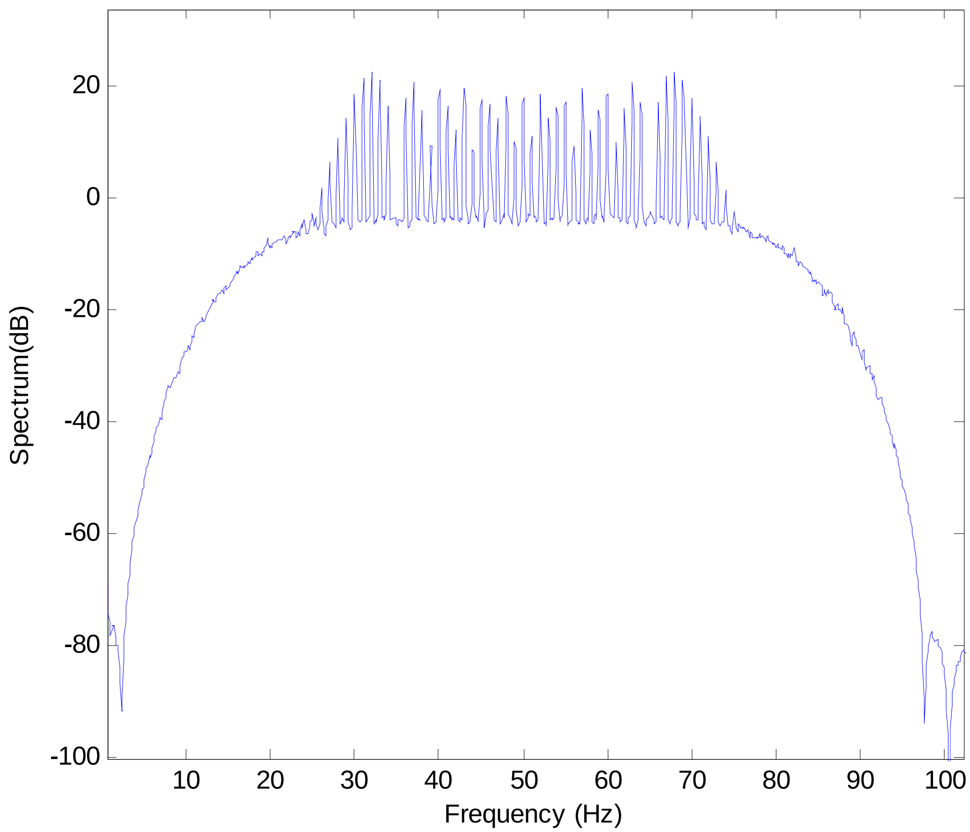
Problem 9.27 continued

(b) The spectrum of the bandpass FM plus noise is obtained by inserting the statements

*[P,F] = spectrum((FM+Noise).*Carrier,4096,0,4096,Fs);*
*plot(F,10*log10(P(:,1)))*
xlabel('Frequency (Hz)')
ylabel('Spectrum')

An expanded view of the result around the carrier frequency of 50 Hz is shown below. The spectrum has been plotted on a decibel scale to show both the FM tone spectrum and the noise pedestal.



(c) To plot the spectrum of the noisy signal before low-pass filtering, we insert the following statements in the FM discriminator function, prior to the low pass filter

[P,F] = spectrum(BBdec,1024,0,1024,Fsample/4)
*plot(F,10*log10(P(:,1)))*
xlabel('Frequency (Hz)')
ylabel('Spectrum(dB)')

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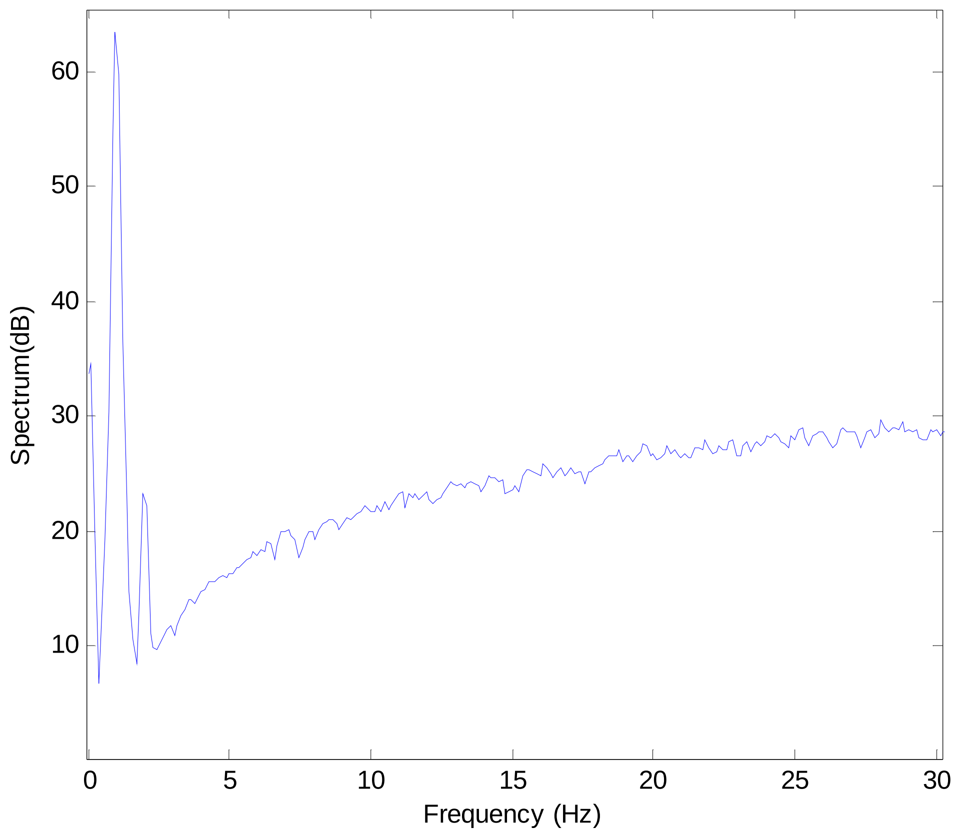
Problem 9.27 continued

The following plot is obtained when expanded near the origin. We plot the spectrum in decibels in order to show the noise and the non-flat nature of its spectrum more clearly. The decibel scale also illustrates some low-level distortion that has been introduced by the demodulation process as exhibited by the small second harmonic at 2 Hz and the low dc level.



(d) To plot the spectrum of the noisy signal before low-pass filtering, we insert the following statements in the FM discriminator function, after the low-pass filter

[P,F] = spectrum(Message,1024,0,1024,Fsample/4)
*plot(F,10*log10(P(:,1)))*
xlabel('Frequency (Hz)')
ylabel('Spectrum(dB)')

The following plot is obtained when expanded near the origin. Again we plot the spectrum in decibels in order to show the noise and, in this case, the effect of the low-pass filtering. The low-pass filtering does not affect the distortion introduced by the demodulator in the passband.

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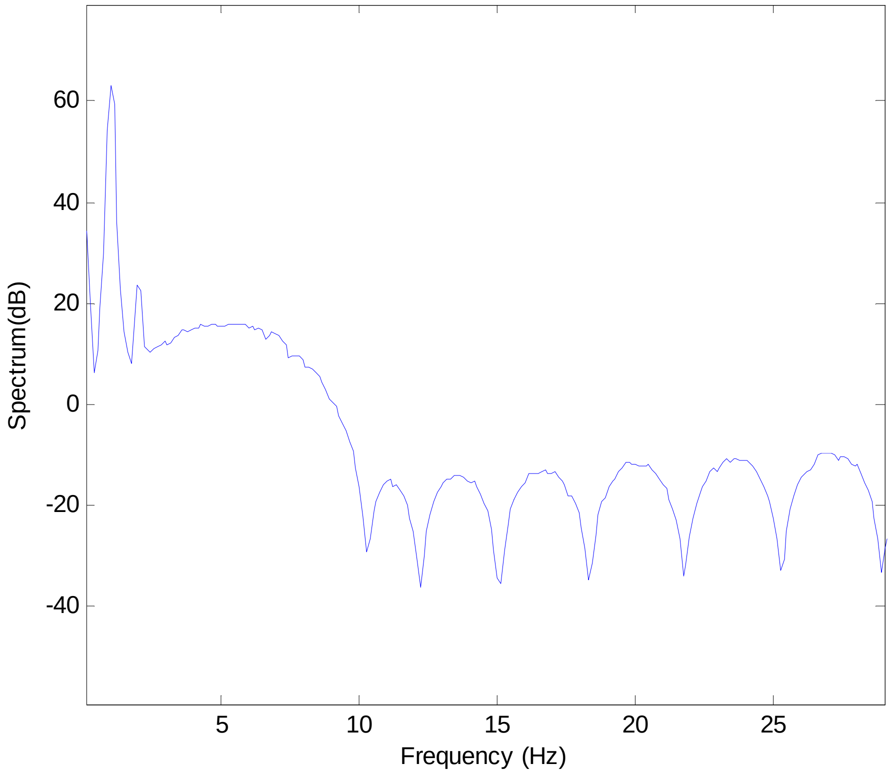
Problem 9.27 continued



(a) Running the code as provided produces the following comparison of the post-detection and pre-detection SNR.