10.7 Communication Systems Laboratory Experiment

Purpose: MATLAB and Simulink ([5], see also Appendix D) are convenient tools for studying flows of signals in any system, including communication systems. This is particularly important when analytical expressions for signals either become cumbersome or are not available due to the complexity of operations performed on signals. In this laboratory experiment, we will use MATLAB to study some basic problems related to the material presented in this chapter. In addition, we will use Simulink to simulate the switching modulator and the envelope detector, that is, to simulate the entire modulation-demodulation process.

Part 1. Consider the signal $x_1(t) = x(t)$ given in Figure 3.22. Find analytically its Fourier transform and plot its magnitude frequency spectrum. Present this signal in MATLAB, using the signal representation considered in Example 2.11. Take `t=-2:0.01:3`. This signal is basically sampled with $T_s = 0.01$. Compare the obtained results with the frequency magnitude spectrum obtained using `X=Ts*fft(x)` and `plot(abs(X))`, a method used in MATLAB for numerical calculation of the Fourier transform.

Part 2. Find the Hilbert transform of the signal considered in Part 1. Use the MATLAB statement `hx=imag(hilbert(x))`. Form the amplitude modulated signal using `xmod=x.*cos(wc*t)` with `wc=100`. Find and plot the frequency magnitude spectrum of `xmod`. Form the amplitude modulated SSB signals defined in (10.54) and (10.57) and find their frequency magnitude spectra. Compare these frequency magnitude spectra with the frequency magnitude spectrum of the double-sideband modulated signal.

Part 3. Use Simulink to make block diagrams for the switching modulator and the envelope detector (demodulator) whose schemes are presented in Figures 10.9 and 10.10. Connect them into a communication system. Note that you must use a relatively large value for the carrier signal amplitude A_c (as a matter of fact, it is required that $A_c >> |x(t)|$). Under such a condition, the output voltage of the switching modulator is equal to

$$v_{\text{out}}(t) = [x(t) + A_c \cos(\omega_c t)] p_{T_c}^{\text{train}}(t), \quad T_c = \frac{2\pi}{\omega_c} \tag{10.61}$$

where $p_{T_c}^{\text{train}}(t)$ is a periodic pulse train of duty cycle $0.5T_c$ and magnitude 1 (it is presented in Figure 3.18 with $T_c = T$ and $E = 1$). The Fourier series of such a pulse train is given by

$$p_{T_c}^{\text{train}}(t) = \frac{1}{2} + \frac{2}{\pi} \sum_{n=1}^{\infty} \frac{(-1)^{n-1}}{2n-1} \cos(\omega_c (2n-1) t) \tag{10.62}$$

Show from (10.61) and (10.62) that the output component of the first harmonic is given by

$$\frac{A_c}{2} \left[1 + \frac{4}{\pi A_c} x(t) \right] \cos(\omega_c t) \tag{10.63}$$

which represents the DSB-TC signal.

Part 4. Pass the signal defined in Part 1 through the modulator-demodulator configuration developed in Part 3. Observe on an oscilloscope the signal at the output of the modulator (modulated signal) and the signal at the output of the envelope detector (demodulated signal). Note that the parameters of the envelope detector must satisfy

$$(r_d + R_s)C << \frac{2\pi}{\omega_c} << R_l C << \frac{1}{f_{x\max}} \tag{10.64}$$

where r_d is the diode resistance in the forward biased region and $f_{x\max}$ approximately denotes the largest frequency in the original signal frequency magnitude spectrum (the capacitor charging time constant must be short and the discharging time constant must be long). Plot the waveform of the modulated signal. Plot the waveform of the demodulated signal and compare it with the original signal.

Part 5. Perform modulation-demodulation operations defined in Part 4 using the MATLAB functions `modulate` and `demod`. Compare the results obtained in Parts 4 and 5.

Comment: Reference [6] represents a very comprehensive guide to the use of MATLAB in communication systems.

SUPPLEMENT:

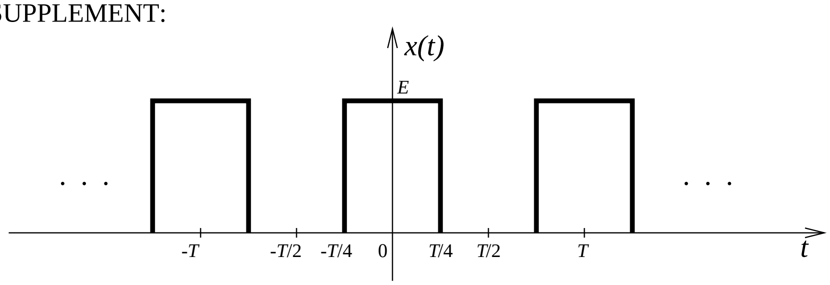

FIGURE 3.18: A square wave signal

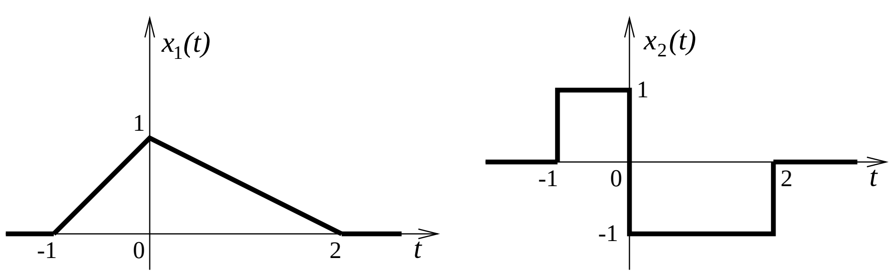

FIGURE 3.22: Two Fourier transformable signals

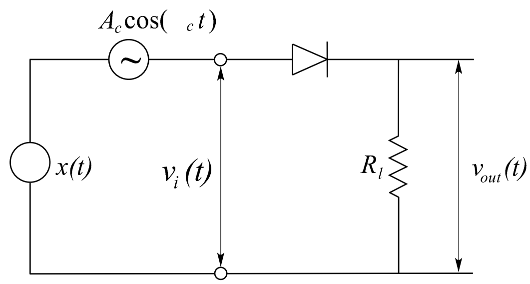

Figure 10.9: Switching modulator

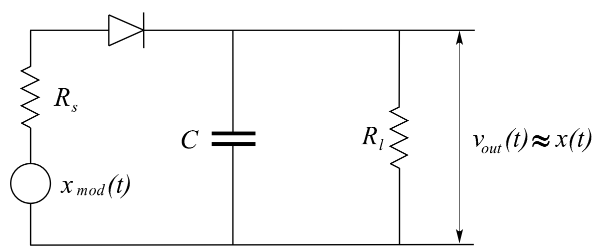

Figure 10.10: Envelope detector

$$s_{mod}(t) = \frac{1}{2}s_{mod}^{cos}(t) - \frac{1}{2}\hat{s}_{mod}^{sin}(t) \tag{10.54}$$

$$\frac{1}{2}s_{mod}^{cos}(t) + \frac{1}{2}\hat{s}_{mod}^{sin}(t) \tag{10.57}$$

where

$$s_{mod}^{cos}(t) = x(t)\cos(\omega_0 t) \leftrightarrow \frac{1}{2}X(j(\omega - \omega_0)) + \frac{1}{2}X(j(\omega + \omega_0))$$

$$\hat{s}_{mod}^{sin}(t) = \hat{x}(t)\sin(\omega_0 t) \leftrightarrow \frac{j}{2}\hat{X}(j(\omega + \omega_0)) - \frac{j}{2}\hat{X}(j(\omega - \omega_0))$$