In the Name of God

Communication Systems (25751-4)

Problem Set 04

Fall Semester 1402-03

Department of Electrical Engineering

Sharif University of Technology

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Due on Aban 24, 1402 at 17:00

(∗) starred problems are optional and have a bonus mark!

1 DSB Modulation with Periodic Waveforms

A DSB signal is generated by multiplying the message signal $m(t)$ with the periodic rectangular waveform shown in Figure 2 and filtering the product with a bandpass filter tuned to the reciprocal of the period T_p, with bandwidth $2W$, where W is the bandwidth of the message signal.

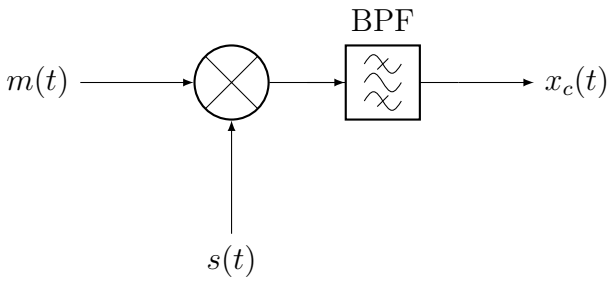

Figure 1: DSB Modulator

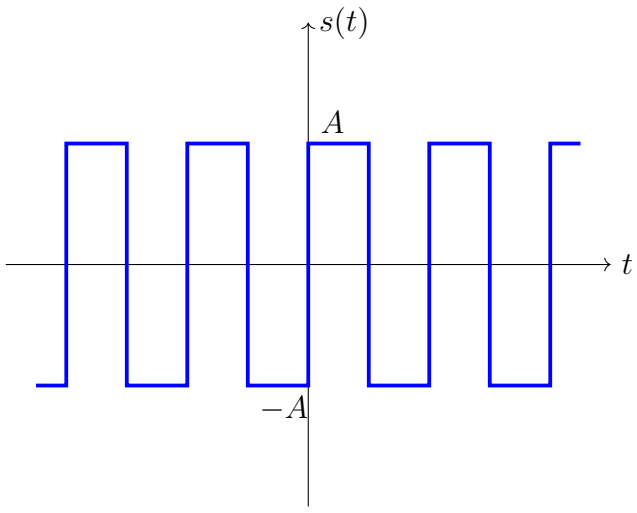

Figure 2: $s(t)$

1. Demonstrate that the output $x_c(t)$ of the BPF is the desired DSB signal

$$x_c(t) = A_c m(t) \sin(2\pi f_c t)$$

where $f_c = \dfrac{1}{T_p}$, and find A_c.

2. Show that it is not necessary that the periodic signal be rectangular. This means that any periodic signal with period T_p can substitute for the rectangular signal in Figure 2.

2 Weaver's SSB Modulator

Weaver's SSB modulator is illustrated in Figure 3. By taking the input signal as $x(t) = \cos(2\pi f_m t)$, where $f_m < W$, demonstrate that by proper choice of f_1 and f_2 the output is a SSB signal.

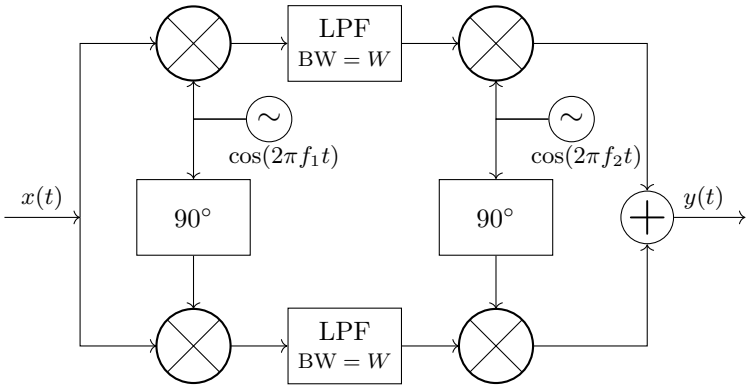

Figure 3: Weaver's SSB Modulator

3 SSB Signal

A USB signal is generated by using the phase shift method.

1. If the input to this system is $\hat{m}(t)$ instead of $m(t)$, what will be the output?
2. Can this signal be demodulated (to get back $m(t)$)? If so, how?

4 VSB Signal

A VSB signal $y(t)$ is as below. α is a non negative constant less than one.

$$y(t) = \frac{\alpha}{2}\cos(2\pi(f_c + f_m)t) + \frac{1-\alpha}{2}\cos(2\pi(f_c - f_m)t) + \cos(2\pi f_c t)$$

1. Prove that the envelop of the signal can be calculated as below. $d(t)$ represents the distortion.

$$e(t) = \left[1 + \frac{1}{2}\cos(2\pi f_m t)\right] d(t)$$

$$d(t) = \sqrt{1 + \left[\frac{(1-2\alpha)\sin(2\pi f_m t)}{2 + \cos(2\pi f_m t)}\right]^2}$$

2. Find α such that it maximize $d(t)$.

5 VSB Modulation System

A vestigial sideband modulation system is shown in figure 4. The bandwidth of the message signal $m(t)$ is W and the transfer function of the bandpass filter is shown in the figure 5.

1. Determine $h_{lp}(t)$, the lowpass equivalent of $h(t)$, where $h(t)$ represents the impulse response of the bandpass filter.
2. Derive an expression for the modulated signal $x_c(t)$.

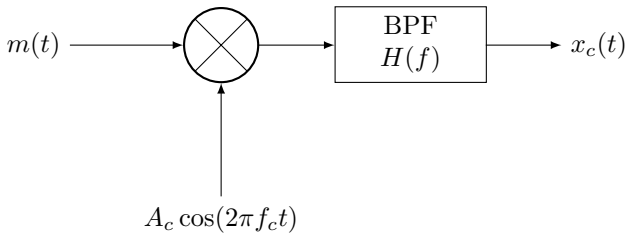

Figure 4: VSB Modulator

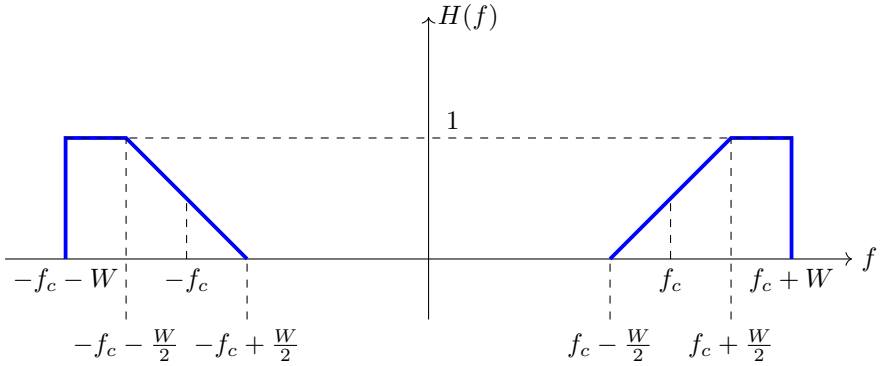

Figure 5: $H(f)$

6 Practical VSB Systems

A vestigial filter $H_i(f)$ in the transmitter of a VSB system has a transfer function as shown in figure 6. The carrier frequency is $f_c = 10$ kHz, and the baseband signal bandwidth is 4 kHz. find the corresponding transfer function of the equalizer filter $H_o(f)$ in the receiver.

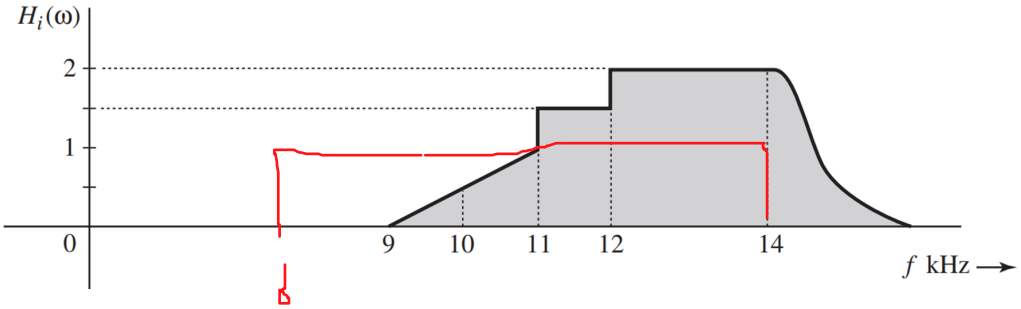

Figure 6: Frequency response of the transmitter filter

7 (∗) Modulation within Nonlinear Channels

Assume that the channel between a transmitter and a receiver has a non-linear characteristic as

$$y(t) = ax(t) + bx^2(t)$$

also we have just oscillator, adder, inverter and tunable band pass filter.(no mixer or multiplier).

1. design a system that can produce the DSB modulated signal at carrier frequency f_c in output.
2. now consider the channel has characteristic of the form

   $$y(t) = ax(t) + bx^2(t) + cx^3(t)$$

   again design a system that can produce the DSB modulated signal carrier frequency f_c in output.