AMERICAN UNIVERSITY OF BEIRUT
Department of Electrical and Computer Engineering
EECE340 Signals and Systems -Summer 2011

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Problem Set 4

Out: Thursday July 21, 2011 Due: Wednesday July 27, 2011

Work individually and write your complete solutions on clean paper. Start early, no extensions will be allowed.

Problem 1

In this problem, we will consider an AM modulation scheme called Single Side Band (SSB -AM). Here we transmit only a single side of the signal, knowing that it can be completely recovered at the receiving end. This will free up a wider area in the frequency spectrum, and thus allow for more signals to be multiplexed on the frequency axis.

Consider the SSB generation scheme shown in figure 1. Assume that $x(t)$ has the (real) Fourier transform shown.

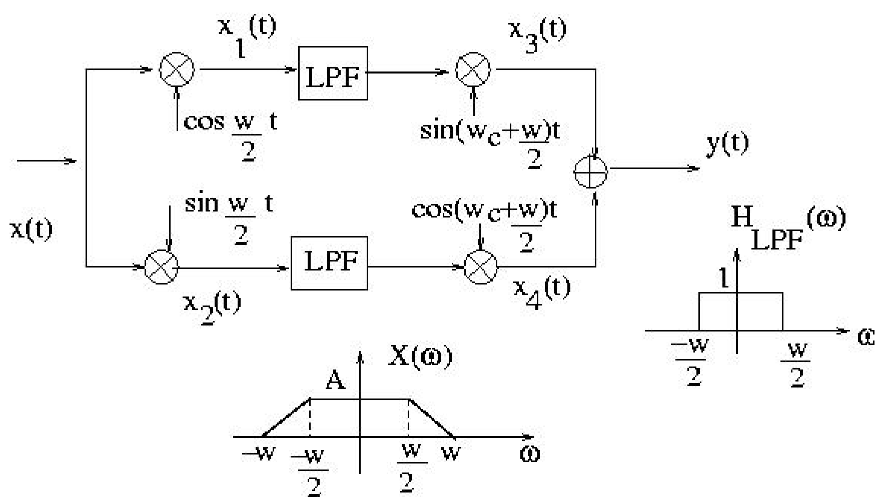

Figure 1: problem 1

a) Sketch the Fourier transform of $x_1(t)$, $x_2(t)$, $x_3(t)$, $x_4(t)$, and $y(t)$. This should demonstrate that $y(t)$ is in fact single-side band modulated version of $x(t)$ modulated on the carrier w_c.

b) Suggest a scheme for recovering the original signal $x(t)$ from the SSB-AM signal $y(t)$.

Problem 2

Consider the AM demodulation scheme shown in figure 2. As we discussed in class, a common problem with AM synchronous demodulation is the phase shift in the carrier signal, that is trying to demodulate $y(t) = (A + x(t))\cos(w_c t + \theta)$ using a local oscillator $\cos w_c t$.

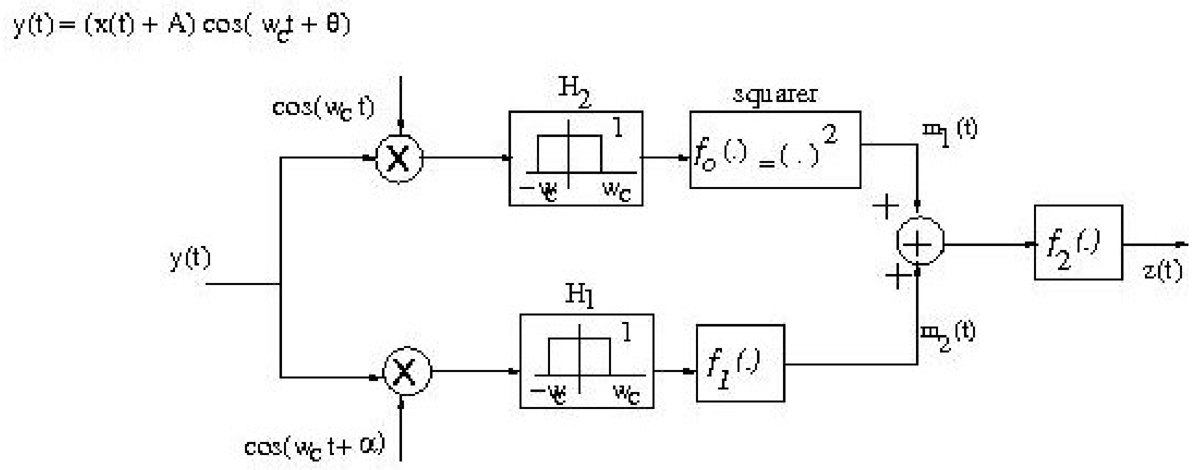

Figure 2: Problem 2

In this problem you will design a demodulator which can get rid of phase shift problems.

As shown in the figure, the received signal is $y(t) = (A + x(t))\cos(w_c t + \theta)$ where $x(t)$ is band limited $X(w) = 0$,$|w| > w_m$, and $w_m < w_c$.

Over the upper path, $y(t)$ is multiplied by the oscillator $\cos w_c t$, low-pass filtered up to w_c and then passed through a nonlinear squarer device $f_o(x) = x^2$ (symbol $(.)^2$).

In the lower path, a similar operation occurs, except for a phase shift α in the oscillator $(\cos(w_c t + \alpha))$ and the use of the nonlinear device $f_1(.)$. Finally, the sum is passed through $f_2(.)$ which is also a nonlinear device that you have to determine.

(a) Find the output $m_1(t)$ of the upper path after the squarer. *Hint:* use trigonometric identities.

(b) Based on the result you obtained in (a), determine the phase shift α and the nonlinear functions $f_1(.)$ and $f_2(.)$ such that the output $z(t)$ DOES NOT depend on the phase shift θ. (i.e., it contains no terms like $\cos\theta$ or $\sin\theta$).

Problem 3

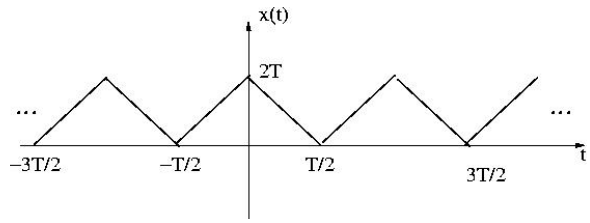

Figure 3: Sawtooth waveform for problem 3

(a) Find the Fourier transform for the periodic sawtooth waveform $x(t)$ shown in figure 3.

(b) Now find the exponential Fourier Series expansion for $x(t)$.

(c) Discuss the results obtained in parts (a) and (b).

Problem 4

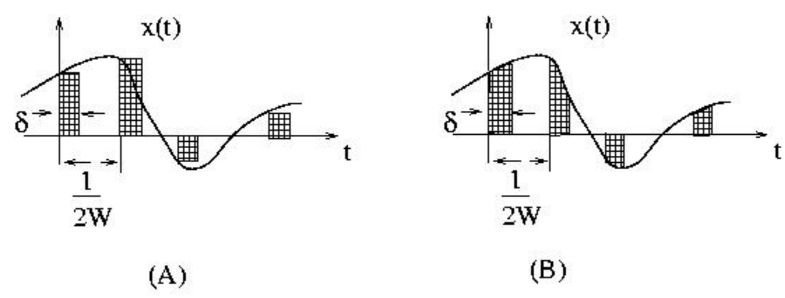

Figure 4: problem 4

In any real communication or control system employing sampled waveforms, finite pulses must be used instead of the ideal impulses we have been discussing in lectures. Two ways of generating finite pulses are illustrated in figure 4. On the left in (A) , the value of $x(\frac{n}{2W})$ is sampled and held for the pulse duration δ. On the right (B), sections of the signal $x(t)$ of duration δ are gated out every $\frac{1}{2W}$ seconds.

The pulse waveform in A can be considered as the result of ideal impulse sampling followed by a filter whose impulse response is short square pulse of duration δ. The pulse waveform in (B) is simply the result of multiplying $x(t)$ by a periodic rectangular wave. Assuming that $X(w)$ is bandlimited to $|w| < W$, describe in detail the spectra of these two pulse waveforms for $|w| < W$ and show how in each case $x(t)$ can be recovered exactly.

Problem 5

Consider the system shown in figure 5 where the input signal $x(t)$ is multiplied by periodic pulse train $s(t)$ of period T. Assume that $x(t)$ is band limited to $w \leq w_m$.

(a) Assume that $\Delta = T/3$. Determine the maximum value of T (in terms of w_m) such that no aliasing occurs in $z(t)$.

(b) Now assume that $\Delta = T/4$.Determine the maximum value of T (in terms of w_m) such that no aliasing occurs in $z(t)$.

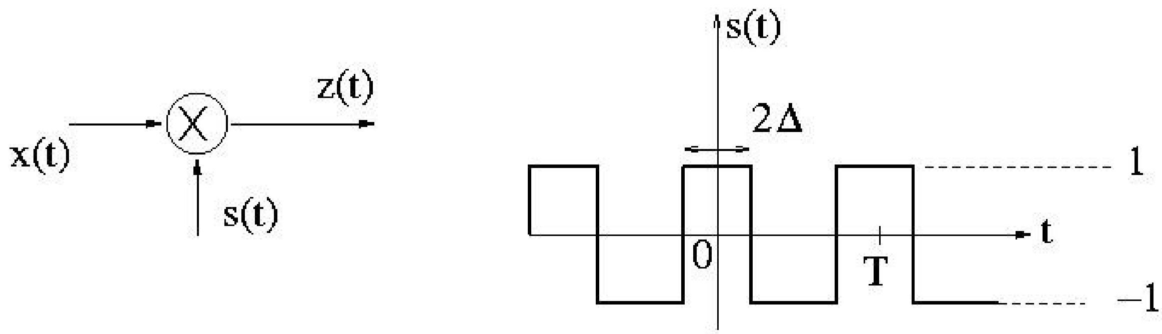

Figure 5: Problem 5

Problem 6

The periodic waveform $x(t)$ shown in figure 6 is the input to an LTI system with the frequency response $H(w)$ as shown in the same figure. Find the output waveform $y(t)$ in the form of the sum of cosines with the appropriate amplitude and phase angles.

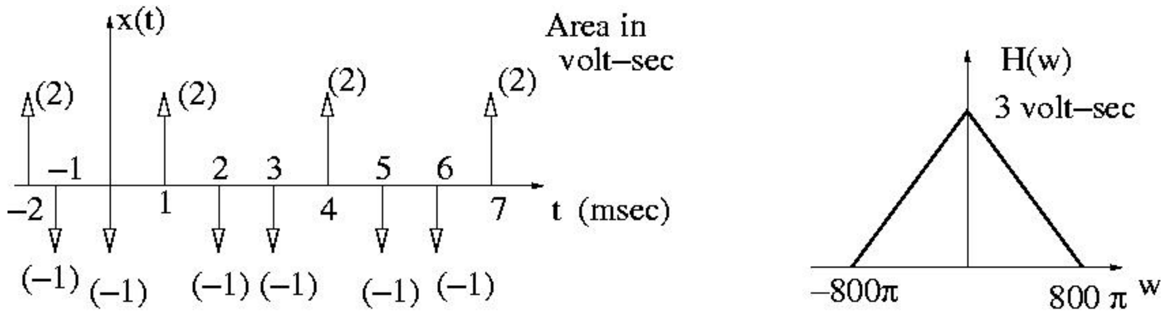

Figure 6: Problem 6