Problem Set X

The **due date** for this homework is **Tue 2 Apr 2013 12:59 AM EDT -0400**.

In this problem set, you will be given a total of ten attempts. We will accept late submission until the fifth day after the due date, and late submission will receive half credit. Explanations and answers to the problem set will be available after the due date. Since the homework problems will become gradually more challenging as the course proceeds, we highly recommend you to start the habit of printing out the problems and working on them with paper and pencil. Also, please be sure to read the problem statements carefully and double check your expressions before you submit.

A pdf version of this problem set is available for you to print. Note: all mathematical expressions have to be exact, even when involving constants. Such an expression is required when a function and/or a variable is required in the answer. For example, if the answer is $\sqrt{3}x$, you must type `sqrt(3)*x`, not `1.732*x` for the answer to be graded as being correct.

Question 1

Digital Amplitude Modulation

Two students disagree about a homework problem. The issue concerns the discrete-time signal $s(n)\cos(2\pi f_0 n)$, where the signal $s(n)$ has no special characteristics and the modulation frequency f_0 is known. Sammy says that he can recover $s(n)$ from its amplitude-modulated version by the same approach used in analog communications. Samantha says that approach won't work.

What is the spectrum of the modulated signal in terms of the spectrum of $s(n)$? Fill in the blank corresponding to the gain of the spectrum (write your answer as a fraction).

____$[S(\cdot)+S(\cdot)]$

Preview Help

Question 2

Digital Amplitude Modulation

What is the spectrum of the modulated signal in terms of the spectrum of $s(n)$? Fill in the blank corresponding to the **smallest** frequency.

$?[S(\_\_\_\_) + S(\cdot)]$

NOTE: to enter f_0, type `f0`

Preview Help

Question 3

Digital Amplitude Modulation

What is the spectrum of the modulated signal in terms of the spectrum of $s(n)$? Fill in the blank corresponding to the **largest** frequency.

$\cdot[S(\cdot) + S(\_\_\_\_)]$

NOTE: to enter f_0, type `f0`

Preview Help

Question 4

Sammy says that he can recover $s(n)$ from its amplitude-modulated version by the same approach used in analog communications. Samantha says that approach won't always work. Who is correct?

- Sammy
- Samantha
- Not enough information has been given.

Question 5

The teaching assistant does not want to take either student's side. Instead, he tells them that if $s(n)\cos(2\pi f_0 n)$ and $s(n)\sin(2\pi f_0 n)$ were both available to be combined to create an "interesting" signal, $s(n)$ can be recovered. Can you determine what he has in mind? What is the spectrum of this "interesting" signal expressed in terms of the spectrum of $s(n)$?

$S(\_\_\_\_)$

NOTE: to enter f_0, type `f0`

Preview Help

Question 6

AM Stereo

Stereophonic radio transmits two signals simultaneously that correspond to what comes out of the left and right speakers of the receiving radio. While FM stereo is commonplace, AM stereo is not, but is much simpler to understand and analyze. An amazing aspect of AM stereo is that both signals are transmitted within the same bandwidth as used to transmit just one. Assume the left and right signals are bandlimited to W Hz.

$$x(t) = A(1 + m_L(t))\cos(2\pi f_c t) + A m_R(t)\sin(2\pi f_c t)$$

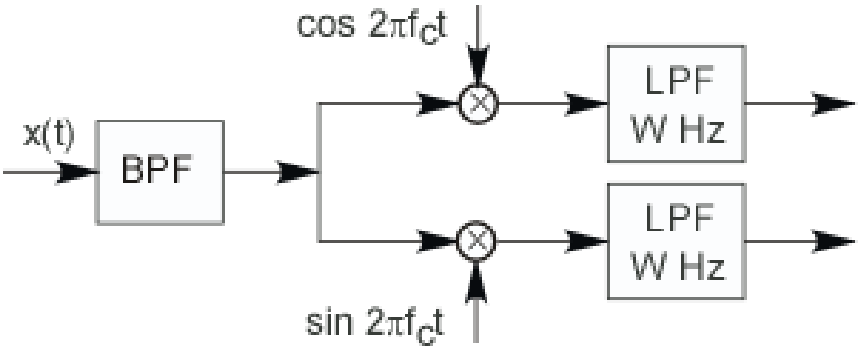
Find the Fourier transform of $x(t)$ related to the message signals $m_L(t)$ and $m_R(t)$.
$X(f) = ?$

NOTE: Due to limitations in the automatic grader please use the following conventions:
To enter $M_L(f - f_c)$, type `M1`. To enter $M_L(f + f_c)$, type `M2`. To enter $M_R(f - f_c)$, type `M3`. To enter $M_R(f + f_c)$, type `M4`.

Preview Help

Question 7

Let us use a coherent demodulator as the receiver, shown below.



We need to show that this receiver indeed works: It produces the left and right signals separately.

The output of the upper "rail" (the top path) is ?
NOTE: to enter $m_L(t)$, type `mL` and to enter $m_R(t)$, type `mR`

Preview Help

Question 8

The output of the lower "rail" (the bottom path) is $?$

NOTE: to enter $m_L(t)$, type `mL` and to enter $m_R(t)$, type `mR`

Preview Help

Question 9

Assume the channel attenuates and adds white noise to the transmitted signal. Find the signal-to-noise ratio of the receiver's output for the left signal.

$\mathrm{SNR} = ?$

For the power in the left channel, $\mathrm{power}[m_L]$, type `Pm`, to enter the attenuation parameter α, enter `a`, and to enter N_0 type `N0`.

Preview Help

Question 10

Multi-tone digital communication

In a so-called multi-tone system, several bits are gathered together and transmitted simultaneously on different carrier frequencies during a T second interval. For example, B bits would be transmitted according to

$$x(t) = A\sum_{k=0}^{B-1} b_k \sin(2\pi(k+1)f_0 t),\ 0 \le t < T$$

Here, f_0 is the frequency offset for each bit and it is harmonically related to the bit interval T. The value of b_k is either -1 or $+1$. This is a variation of FSK.

A student likes digital systems so much that he decides to produce a discrete-time version. He samples the received signal (sampling interval $T_s = \frac{T}{N}$). How should N be related to B, the number of simultaneously transmitted bits?

$N >?$

NOTE: To enter f_0 type `f0`

Preview Help

Question 11

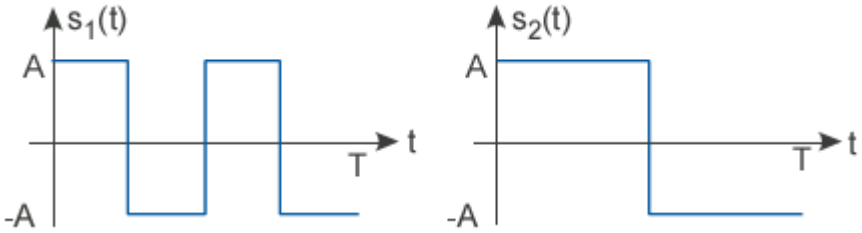
The student wanted to sample the transmitted signal because the transmitter can take on a particularly elegant form. In particular, his software implementation can run very efficiently. What does he have in mind?

Question 12

Downlink Signal Sets

In digital cellular telephone systems, the base station (transmitter) needs to relay different voice signals to several telephones at the same time. Rather

than send signals at different frequencies, a clever engineer suggests using a different signal set for each data stream. For example, for two simultaneous data streams, she suggests BPSK signal sets that have the depicted basic signals.



Thus, bits are represented in data stream 1 by $s_1(t)$ and $-s_1(t)$ and in data stream 2 by $s_2(t)$ and $-s_2(t)$, each of which are modulated by a 900 MHz carrier. The transmitter sends the two data streams so that their bit intervals align. Each receiver uses a matched filter for its receiver. The requirement is that each receiver **not** receive the other's bit stream.

What is the transmission bandwidth required by the proposed system?

Preview Help

Question 13

Does the fact that the two data streams are transmitted in the same bandwidth at the same time mean that the receiver for one bit stream is affected by the other bit stream? Will the proposal work?

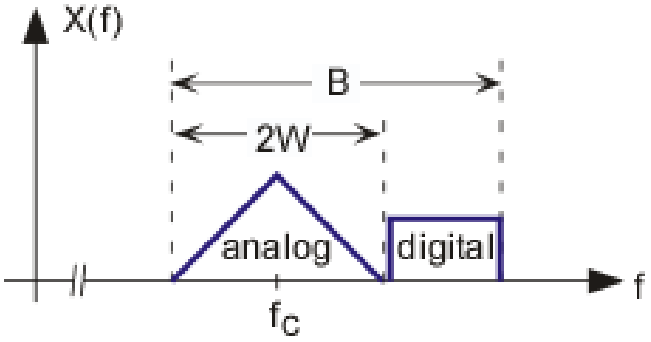
- Yes, the proposal will work.
- No, the proposal will not work.
- Interference between bit streams can occur in some situations.

Question 14

Mixed Analog and Digital Transmission

A signal $m(t)$ is transmitted using amplitude modulation in the usual way.

The signal has bandwidth W Hz, and the carrier frequency is f_c. In addition to sending this analog signal, the transmitter also wants to send ASCII text in an **auxiliary band** that lies slightly above the analog transmission band. Using an 8-bit representation of the characters and a simple baseband BPSK signal set (the constant signal +1 corresponds to a `0`, the constant -1 to a `1`), the data signal $d(t)$ representing the text is transmitted at the same time as the analog signal $m(t)$. The transmission signal spectrum is as shown and has a total available bandwidth B.



Write an expression for the time-domain version of the analog portion of the transmitted signal in terms of the analog signal $m(t)$, the digital signal $d(t)$, and the pulse of duration T, $p_T(t)$.

In other words, fill in the blank in the expression

$$x(t) = \_\_\_\_\_ + \sum_n \{\dots\}$$

NOTE:

To enter f_c, type `fc`. To enter $b(n)$, type `bn`. To enter $m(t)$, type `m`. To enter $d(t)$, type `d`. To enter $p_T(t - nT)$, type `pnT`.

Preview Help

Question 15

Mixed Analog and Digital Transmission

Write an expression for the time-domain version of the digital portion of the transmitted signal in terms of the analog signal $m(t)$, the digital signal $d(t)$, and the pulse of duration T, $p_T(t)$.

Fill in the blank in the expression

$$x(t) = \ldots + \sum_n \{\_\_\_\_\_\}$$

NOTE:

To enter f_c, type `fc`. To enter $b(n)$, type `bn`. To enter $m(t)$, type `m`. To enter $d(t)$, type `d`. To enter $p_T(t - nT)$, type `pnT`.

Preview Help

Question 16

What is the maximum datarate the scheme can provide in terms of the available bandwidth B?

$R_{\max} = ?$

Preview Help

In accordance with the Honor Code, I certify that my answers here are my own work.

Submit Answers Save Answers
