ENEE 420
FALL 2007
COMMUNICATIONS SYSTEMS

TEST # 2:

Please work out the **four** (4) attached problems. **Show** work on provided space and **explain** reasoning; **box** or **circle** your final answers.

Please write your **full name** and **SSN** in the space provided below! Thank you for your cooperation.

Problem #1 . . . . **/40**

Problem #2 . . . . **/20**

Problem #3 . . . . **/30**

Problem #4 . . . . **/30**

Total . . . . **/120**

NAME/SSN: ____

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#1. A communications engineer is asked to generate a modulated signal $s : \mathbb{R} \to \mathbb{R}$ of the form

$$s(t) = Am(t)\cos(2\pi f_c t), \quad t \in \mathbb{R}$$

for some amplitude $A > 0$ and carrier frequency $f_c > 0$, where the information-bearing signal $m : \mathbb{R} \to \mathbb{R}$ is band-limited with cut-off frequency $W < f_c$. For that purpose the product modulator depicted below is made available to the engineer.

1.a. Upon doing some testing, this engineer quickly realizes that the carrier generator used in this product modulator does **not** generate $c(t) = \cos(2\pi f_c t)$ (as advertised in the specs)) but $c(t) = \cos(2\pi f_c t)^3$ instead. Under these conditions, find the Fourier transform of the output $y : \mathbb{R} \to \mathbb{R}$ of the product modulator[1] **(15 pts.)**;

1.b. Use Part **1.a** to determine whether our engineer will be able to complete the task assigned to her with the available equipment (possibly augmented by an appropriate linear filter). In the affirmative give a complete design for doing so. Carefully explain your answer! **(10 pts.)**;

1.c. Repeat Part **1.b** with $c(t) = \cos(2\pi f_c t)^2$ instead **(15 pts.)**.

ANSWER:

[1]**HINT:** Recall the usual trigonometric identities, namely $\cos(2\theta) = \ldots$ so that $\cos(\theta)^3 = \cos(\theta) \cdot \cos(\theta)^2 = \ldots$ for all θ in $\mathbb{R}$.

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#2. The information-bearing signal $m : \mathbb{R} \to \mathbb{R}$ to be transmitted is given by

$$m(t) = 10\cos(1000\pi t) + 5\cos(1500\pi t), \quad t \in \mathbb{R}.$$

This signal will be quantized using Delta-modulation.

2.a. Determine an appropriate sampling interval T_s. Explain your answer **(5 pts.)**;

2.b. Find conditions on Δ and T_s so as to avoid slope overload in this specific example **(15 pts.)**;

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#3. We consider a vestigial-sideband modulation scheme whose shaping filter has frequency response function $H_{\text{VSB}}(f)$ is depicted below. Let $h_{\text{VSB}} : \mathbb{R} \to \mathbb{R}$ denote the corresponding impulse response function.

3.a. Does this shaping filter $H_{\text{VSB}}(f)$ allow for full recovery of any low-pass information-bearing signal with cut-off frequency $W < f_c$? Explain! **(5 pts.)**;

3.b. What is the transmission bandwidth B_T needed for using this modulation scheme? **(5 pts.)**;

Assume now that the information-bearing signal $m : \mathbb{R} \to \mathbb{R}$ is the single-tone signal

$$m(t) = A_m \cos\left(2\pi f_m t\right), \quad t \in \mathbb{R}$$

with $A_m > 0$ and $f_m = cW$ for some $0 < c < 1$.

3.c. Give an expression for the resulting modulated waveform $s_{\text{VSB}} : \mathbb{R} \to \mathbb{R}$ when $\frac{1}{2} < c < 1$ **(10 pts.)**;

3.d. Give an expression for the resulting modulated waveform $s_{\text{VSB}} : \mathbb{R} \to \mathbb{R}$ when $0 < c < \frac{1}{2}$ **(10 pts.)**.

ANSWER:

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#4. Consider the signal $s : \mathbb{R} \to \mathbb{R}$ given by

$$s(t) = A \sin(2\pi(f_c + f_a)t) + B \cos(2\pi f_c t) - A \sin(2\pi(f_c - f_a)t), \quad t \in \mathbb{R}$$

under the conditions $A > 0$, $B > 0$ and $0 < f_a < f_c$.

4.a. Can you interpret s as the modulated signal that results from one of the modulation schemes[2] when the unmodulated carrier is $\cos(2\pi f_c t)$? In the affirmative, identify the modulation technique **(5 pts.)** and give an explicit expression for the corresponding information-bearing signal $m : \mathbb{R} \to \mathbb{R}$ **(5 pts.)**;

4.b. Find the in-phase component s_I and in-quadrature component s_Q of the modulated signal s **(10 pts.)**;

4.c. Give an expression for the envelope a of s **(5 pts.)**. Under what condition will it be possible to extract the original signal m (from s) by means of an envelope detector? **(5 pts.)**;

ANSWER:

[2] You need only consider the schemes studied in ENEE 420.

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