THE UNIVERSITY OF CALGARY

DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

ENEL 471 - Introduction to Communications Systems and Networks
(Winter 2018)

Instructor: Dr. M. Helaoui

FINAL EXAMINATION

Date: April 24, 2018
Time: 7:00 – 10:00 PM
Location: ICT 121/122

Student ID#: _____

Instructions:

1. ***This is a closed-book examination.***
2. ***Answer all questions.***
3. ***Non-programmable calculators are permitted during the examination.***

Marks:

Question	Marks	
1		**/8**
2		**/10**
3		**/10**
4		**/8**
5		**/6**
6		**/8**
TOTAL		**/50**

EXAMINATION RULES AND REGULATIONS

STUDENT IDENTIFICATION

Each candidate must sign the Seating List confirming presence at the examination. All candidates for final examinations are required to place their University of Calgary I.D. cards on their desks for the duration of the examination. (Students writing mid-term tests can also be asked to provide identity proof.) Students without an I.D. card who can produce an acceptable alternative I.D., e.g., one with a printed name and photograph, are allowed to write the examination.

A student without acceptable I.D. will be required to complete an Identification Form. The form indicates that there is no guarantee that the examination paper will be graded if any discrepancies in identification are discovered after verification with the student's file. A Student who refuses to produce identification or who refuses to complete and sign the Identification Form is not permitted to write the examination.

EXAMINATION RULES

(1) Students late in arriving will not normally be admitted after one-half hour of the examination time has passed.

(2) No candidate will be permitted to leave the examination room until one-half hour has elapsed after the opening of the examination, nor during the last 15 minutes of the examination. All candidates remaining during the last 15 minutes of the examination period must remain at their desks until their papers have been collected by an invigilator.

(3) All inquiries and requests must be addressed to supervisors only.

(4) Candidates are strictly cautioned against:

(a) speaking to other candidates or communicating with them under any circumstances whatsoever;

(b) bringing into the examination room any textbook, notebook or memoranda not authorized by the examiner;

(c) making use of calculators and/or portable computing machines not authorized by the instructor;

(d) leaving answer papers exposed to view;

(e) attempting to read other student's examination papers.

The penalty for violation of these rules is suspension or expulsion or such other penalty as may be determined.

(5) Candidates are requested to write on both sides of the page, unless the examiner has asked that the left hand page be reserved for rough drafts or calculations.

(6) Discarded matter is to be struck out and not removed by mutilation of the examination answer book.

(7) Candidates are cautioned against writing in their answer book any matter extraneous to the actual answering of the question set.

(8) The candidate is to write his/her name on each answer book as directed and is to number each book.

(9) A candidate must report to a supervisor before leaving the examination room.

(10) Answer books must be handed to the supervisor-in-charge promptly when the signal is given. Failure to comply with this regulation will be cause for rejection of an answer paper.

(11) If during the course of an examination a student becomes ill or receives word of a domestic affliction, the student should report at once to the supervisor, hand in the unfinished paper and request that it be cancelled. If physical and/or emotional ill health is the cause, the student must report at once to a physician/counsellor so that subsequent application for a deferred examination is supported by a completed Physician/Counsellor Statement form. Students can consult professionals at University Health Services or University Counselling Services during normal working hours or consult their physician/counsellor in the community.

Should a student write an examination, hand in the paper for marking, and later report extenuating circumstances to support a request for cancellation of the paper and for another examination, such a request will be denied.

(12) Smoking during examinations is strictly prohibited.

Question 1 [*8 pts*]

The message signal $m(t)$, whose spectrum is shown in Figure 1 below, is passed through the system in Figure 2 below, where $f_c = 100\,kHz$, $W = 1kHz$, $A_m = \max\left|m(t)\right| = 0.5$, the bandpass filter is ideal and has a bandwidth of $2W$ centered around f_c, the lowpass filter is ideal with a bandwidth of W

a- Sketch the frequency spectra of the signals $y_1(t)$ and $y_2(t)$. **Indicate all the center frequencies, bandwidths, and amplitudes of interest for all the components of these signals**. *[2 pts]*

b- What type of modulation is obtained at the output of System 1? Indicate the modulation index of this modulation. *[2 pts]*

c- Sketch the frequency spectra of the signals $y_3(t)$ and $y_4(t)$. **Indicate all the center frequencies, bandwidths, and amplitudes of interest for all the components of these signals**. *[2 pts]*

d- Propose an alternative for System 2 that does not require a coherent carrier to obtain the message signal $m(t)$ at the output $y_4(t)$. *[2 pts]*

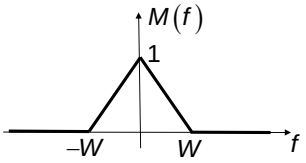

Figure 1

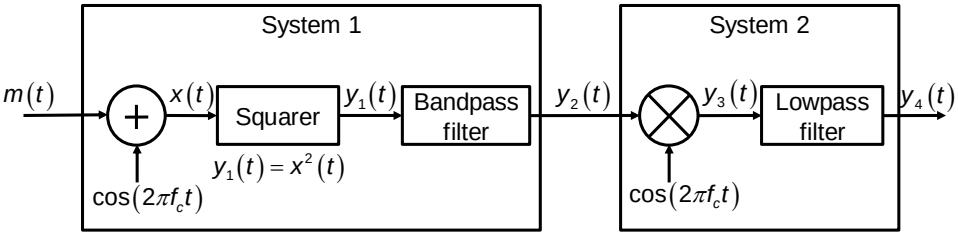

Figure 2

Question 2 [*10 pts***]**

A conventional AM signal is given by:

$$s(t) = 5\cos(1800\pi t) + 20\cos(2000\pi t) + 5\cos(2200\pi t)$$

a- Determine the modulating signal $m(t)$ and the carrier $c(t)$. *[2 pts]*

b- Determine the modulation index and the ratio of the power in the sidebands to the power in the carrier. *[2 pts]*

This signal is fed to a conventional AM receiver using an envelope detector. The average noise power per unit bandwidth measured at the input of the receiver front-end is 10^{-3} watt per Hertz.

c- Assuming an input resistor of $1\,\Omega$, calculate the input signal-to-noise ratio of the system. *[2 pts]*

d- Determine the output signal-to-noise ratio at the output of the receiver. *[2 pts]*

e- By how many decibels is this system inferior to a DSB modulation system? *[2 pts]*

Question 3 [*10 pts*]

An angle-modulated signal around a carrier frequency $f_c = 10\,MHz$, has the form

$$s(t) = 100\cos\left(2\pi f_c t + 4\sin\left(2000\pi t\right)\right)$$

The modulating message has a maximum amplitude $A_m = \max\left|m(t)\right| = 1$.

a- Determine the peak-phase deviation and peak-frequency deviation of $s(t)$. *[2 pts]*

b- Determine $m(t)$ and k_f if $s(t)$ is an FM signal *[2 pts]*

c- Determine $m(t)$ and k_p if $s(t)$ is a PM signal *[2 pts]*

d- Determine the approximate bandwidth of $s(t)$ using Carson's rule. *[2 pts]*

e- Sketch the spectrum of the modulated signal $s(t)$. **Show only the sidebands within the approximate bandwidth calculated in d-. Indicate all the frequencies and amplitudes of interest**. (Use the table below) *[2 pts]*

	$\beta = 1$	$\beta = 2$	$\beta = 3$	$\beta = 4$	$\beta = 5$
$n = 0$	0.7652	0.2239	-0.2601	-0.3971	-0.1776
$n = 1$	0.4401	0.5767	0.3391	-0.066	-0.3276
$n = 2$	0.1149	0.3528	0.4861	0.3641	0.04657
$n = 3$	0.0196	0.1289	0.3091	0.4302	0.3648
$n = 4$	0.0025	0.034	0.132	0.2811	0.3912
$n = 5$		0.007	0.043	0.1321	0.2611
$n = 6$		0.0012	0.0114	0.0491	0.131
$n = 7$			0.0025	0.01518	0.05338
$n = 8$				0.004	0.01841
$n = 9$					0.0055

Question 4 [*8 pts***]**

A FM modulation system has a modulation index $\beta = 4\ rad$.

a- The SNR at the input of the FM receiver is equal to 30 dB. What is the SNR at the output of the FM receiver if no pre-emphasis and de-emphasis filters are used. *[2 pts]*

This FM modulation system uses a pair of pre-emphasis and de-emphasis filters defined by:

$$H_{pe}(f) = 1 + j\frac{f}{f_0} \quad \text{and} \quad H_{de}(f) = \frac{1}{1 + j\frac{f}{f_0}}$$

where $f_0 = 2.1kHz$, the message bandwidth $W = 15kHz$.

b- What is the value of the improvement factor *I* in the output signal-to-noise ratio of the FM receiver produced by using this pair of pre-emphasis and de-emphasis filters? *[2 pts]*

c- What is the SNR at the output of the FM receiver taking into account the effect of the pre-emphasis and de-emphasis filters. *[2 pts]*

d- By how many decibels this FM system is superior to a DSB system? *[2 pts]*

Question 5 [*6 pts***]**

a. Plot the spectrum of a PAM wave produced by the modulating signal:

$$m(t) = 2\sin(2\pi f_m t)$$

Assuming a modulation frequency of $f_m = 1\ kHz$, sampling period $T_s = 200\ \mu s$ and pulse duration $T = 100\ \mu s$ *[2 pts]*

b. Using an ideal reconstruction filter, plot the spectrum of the filter output. *[2 pts]*

c. What should be the expression of the amplitude spectrum of the equalizer required to compensate for the aperture effect. *[2 pts]*

For the spectrum plots, indicate all the frequencies and amplitudes of interest.

Question 6 [*8 pts*]

For practical considerations, a pulse $g(t)$ in a PAM signal is assumed to have the shape shown in Figure 3. The amplitude is $A=1$, and the pulse duration is $T=3$ *ms*.

a. Determine the impulse response $h(t)$ of a filter matched to this signal and sketch it. *[2 pts]*

b. What is the peak value of the matched filter output? *[2 pts]*

c. What is the expression of the peak-pulse signal-to-noise ratio if a white noise with double-sided power spectral density of $N_o/2=10^{-4}\ W/Hz$ is added to the signal before the matched filter? *[2 pts]*

d. Compare the peak-pulse signal-to-noise ratio in this case to the ideal case where the pulse has zero rising and falling times, the same amplitude ($A=1$), and the same pulse duration ($T=3$ *ms*). *[2 pts]*

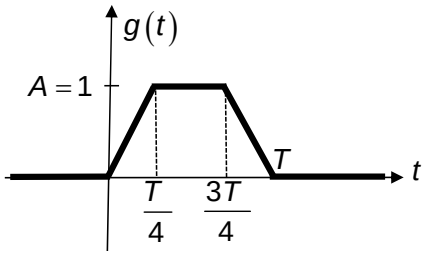

Figure 3

Trigonometric Identities

$$\cos(a+b)=\cos(a)\cos(b)-\sin(a)\sin(b)$$
$$\cos(a-b)=\cos(a)\cos(b)+\sin(a)\sin(b)$$
$$\sin(a+b)=\sin(a)\cos(b)+\cos(a)\sin(b)$$
$$\sin(a-b)=\sin(a)\cos(b)-\cos(a)\sin(b)$$
$$\cos(a)\cos(b)=\frac{1}{2}\left[\cos(a-b)+\cos(a+b)\right]$$
$$\sin(a)\sin(b)=\frac{1}{2}\left[\cos(a-b)-\cos(a+b)\right]$$
$$\sin(a)\cos(b)=\frac{1}{2}\left[\sin(a+b)+\sin(a-b)\right]$$
$$\cos\left(a+\frac{\pi}{2}\right)=-\sin(a)$$
$$\cos\left(a-\frac{\pi}{2}\right)=\sin(a)$$
$$\sin\left(a+\frac{\pi}{2}\right)=\cos(a)$$
$$\sin\left(a-\frac{\pi}{2}\right)=-\cos(a)$$

Properties of the Bessel Functions of the First Kind

$$J_n(\beta)=\frac{1}{2\pi}\int_{-\pi}^{\pi}\exp\left(j\beta\sin(\theta)-jn\theta\right)d\theta$$
$$J_{-n}(\beta)=(-1)^n J_n(\beta)$$

Fourier Transform Pairs

$$\text{rect}\left(\frac{t-T/2}{T}\right)\xrightarrow{\mathcal{F}}T\,\text{sinc}(\pi fT)\,\text{e}^{-j\pi fT}$$

Indefinite Integrals

$$\int\frac{x^2dx}{a^2+b^2x^2}=\frac{x}{b^2}-\frac{a}{b^3}\tan^{-1}\left(\frac{bx}{a}\right)$$