UNIVERSITY OF TORONTO
DEPARTMENT OF ELECTRICAL & COMPUTER ENGINEERING

ECE 416F
Communication Systems I
Final Exam

December 13, 2000
Time: 2:00 - 4:30 PM

Examiner: Prof. Elvino S. Sousa

Instructions:

1. **Type A exam: No aids allowed except for a non-programmable calculator.**
2. **Answer all of the 6 questions.**
3. **All 6 questions are of equal value.**
4. **Begin the answer to each question on a new page.**
5. **Answer questions 1,2,3 on one book and questions 4,5,6 on a second book.**

1) In an AM communication system the power of the transmitted signal is equal to 2 Watts. The modulation index is equal to 50%, the modulating signal (the message signal, $m_1(t)$) is a sinusoidal signal with frequency 5 KHz, and the carrier frequency is equal to 1 MHz.

a) Give an expression for the AM signal in the time domain, clearly specifying numerical values for all parameters.

b) Sketch the AM signal in the time domain (approximate).

c) Give an expression for the spectrum of the AM signal.

d) Sketch the spectrum of the AM signal.

e) If a second (independent) message signal ($m_2(t)$), with 5KHz bandwidth, is required to be transmitted, is there a way to do this without using any extra bandwidth? If so, give the expression for the total signal (i.e. the signal that carries the two information signals).

2) A random process is created by generating an infinite sequence of independent zero mean Gaussian random variables G_k with variance 2, and inputing the signal $X(t) = \sum_k G_k \delta(t - kT)$ to a filter with transfer function $H(\omega) = 1 - \left|\frac{\omega T}{\pi}\right|$, for $|\omega| \le \frac{\pi}{T}$ and zero elsewhere.

a) Give the power spectral density of the output process, $Y(t)$.

b) If the process $Y(t)$ is input to an ideal low-pass filter with bandwidth $B_L = \frac{1}{4T}$ Hz, sketch the power spectral density of the output process $Z(t)$.

c) Determine the average power of the process $Z(t)$.

d) Now we would like to produce a bandlimited white noise process by filtering the process $Z(t)$. Give the transfer function of the required filter.

e) Give the auto-correlation function for the resulting bandlimited white noise process.

3) A PCM system is used to transmit a 10 KHz message signal. The required SNR for the system is equal to 30 dB. Assume that a uniform quantizer is used and that the signal level can be assumed to be random with a uniform distribution.

a) Determine the bit rate for the digitized message signal.

b) Determine the bandwidth required to transmit this signal assuming the use of minimum bandwidth pulses and a binary baseband transmission scheme.

c) Determine the minimum bandwidth required assuming the use of quaternary minimum bandwidth pulses and DSB modulation, i.e. the transmitted pulses have one of 4 possible amplitudes (-3, -1, 1, 3).

4) A DSB transmission system utilizes a carrier frequency of ω_c. The transmitted signal has the form $Am(t)\cos(\omega_c t)$ where the message signal has bandwidth B. The channel is affected by noise with power spectral density $S_n(\omega) = N_0(|\omega| - \omega_c)^2$.

a) Give the block disgram for a receiver.

b) If the demodulated signal is equal to $m(t) + \eta(t)$ give the power spectral density of the noise process $\eta(t)$.

c) Determine the SNR of the demodulated signal.

5) An FM signal has carrier frequency ω_c and message signal $m(t) = A_m \sin(\omega_m t)$ where $\omega_m \ll \omega_c$. The power of the signal is equal to 4 Watts. The modulator is such that if a 2 volt d.c. signal is applied to the message signal input then the output signal has a frequency equal to $\omega_c + 50$ KHz.

a) Give a time domain expression for the signal.

b) Sketch the spectrum of the signal. Give the approximate shape.

c) If $\omega_m = 20\pi$ Krad/s give an approximate value for the bandwidth of the FM signal.

d) Give the block diagram for a demodulator for the FM signal.

6) Two independent message signals of bandwidth 10 KHz are required to be multiplexed over a common channel with center frequency 1 MHz.

a) Give the block diagram of a system that utilizes QAM modulation.

b) Give the block diagram of a system that utilizes DSB modulation.

c) Give the block diagram of a system that utilizes SSB modulation (with lower sideband).

d) Which of the above methods is the most efficient for the use in a cellular system for transmission from the mobile to the base station?

e) Assume that a cellular system uses the above modulation scheme and that the system transmits voice signals with baseband bandwidth equal to 4 KHz. Determine the number of calls that we may have per cell assuming a system bandwidth of 5 MHz (for mobiles to transmit) and a frequency re-use cluster size equal to 7 cells.