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Student Number ____________ (Print) **Student Name:**______________________

The solutions provided here are my own work → **Signature:**______________________

University of Saskatchewan

Dept. of Electrical Engineering

EE 352 Communication Systems I

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Final Examination - April 20, 2006 9:00 am

Time: 3 hours

Instructor: D.E. Dodds

All texts, handout notes and student's own handwritten notes are permitted.
Photocopied and laser printed problem and exam solutions are not permitted.

Complete all questions
The exam has 60 points.

Where possible, use the space below each question for your answer.
Use the reverse side of the pages for additional work.
Hand in your entire question paper; do not separate the pages.

1a. i) **Signals** – Describe (in words) the difference between a *power signal* and an *energy signal*. Give an example of each with a mathematical expression describing the time waveform. (2 pts)

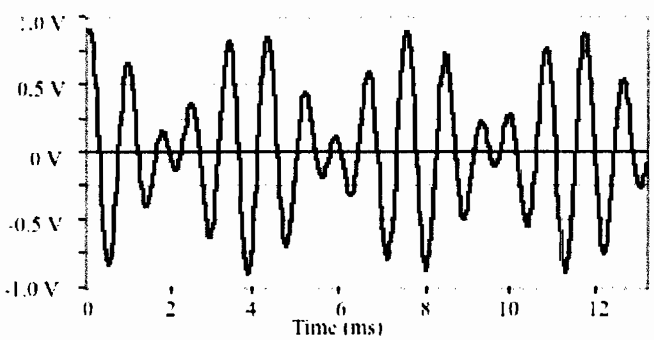
ii) Describe (in words) the difference between *periodic* and *aperiodic signals*. Show the difference with waveform illustrations. (1 pt)

iii) Describe (in words) the difference between *deterministic* and *probabilistic signals*. (1 pt)

1b. **Signals** (3 pts) – A telephone set generates two tones at 941 Hz and 1204 Hz when the "*" button is pressed. The expression $v(t) = 0.4\cos(2\pi * 941t) + 0.5\cos(2\pi * 1204t)$ describes the generated voltage (in volts) and the waveform is illustrated below.

Calculate the *normalized* average power (in watts) of:

i) the 941 Hz signal component,
ii) the 1204 Hz signal component and
iii) the total combined signal.



Assuming 600-ohm load impedance and the combined signal, calculate the following:

iv) the average power in dBm,
v) the peak envelope power in dBm and
vi) the instantaneous peak power in dBm..

2a. **AM Sideband Efficiency** (3 pts) - An AM broadcast transmitter with 40 kW carrier power is broadcasting a sinusoid with 30% modulation index. Calculate

i) the power in the upper sideband,
ii) the total power transmitted and
iii) the power efficiency of the transmission.

2b. **AM Superheterodyne** (3 pts) - A heterodyne receiver is tuned to a station at 3.7 MHz. The local oscillator frequency is 7 MHz and the IF is 10.7 MHz.

i) make a sketch showing the spectral translation to the IF frequency.
ii) What is the image frequency?
iii) If the LO has appreciable second-harmonic content, what two additional frequencies are received?

2c. **AM-SSB** (4 pts) – The energy signal $m(t) = 5\text{V}\sin(2\pi f_c t)/2\pi f_c t$ has a rectangular baseband spectrum in the frequency range $\pm f_c$ with amplitude $5\text{V}/(2f_c)$. When this signal modulates a carrier, the resulting signal is $s(t) = 5\,\text{V}\cos 2\pi f_0 t\left(\sin(2\pi f_c t)/2\pi f_c t\right)$. Assuming $f_0 = 10000$ Hz and $f_c = 1000$ Hz, then

i) Sketch the "rectangular" spectrum of the modulated signal.

ii) If the upper sideband (above 10000 Hz) is removed, mathematically describe the time waveform resulting from the inverse Fourier transform.

3a. **FM Transmission** (2 pts) – There is a noise advantage in using ***preemphasis*** in FM broadcasting. Explain why.

3b. **FDM and TDM** (4 pts) – i) What is the reason for using frequency division multiplexing (FDM)? (Time division multiplexing (TDM) serves a similar purpose). ii) Assuming 6 voice signals each with bandwidth 300 – 3700 Hz and assuming realistic filters and other components, estimate the required bandwidth for QAM transmission and then for PAM transmission.

3c. **Sampling** (4 pts) – A PAM transmission channel is to carry a 20-20kHz music signal.

a) what is the minimum sampling rate required in theory?
b) assuming filters with 200 dB per decade (60 dB per octave) roll-off rate, what sampling rate is required to ensure that, for the output frequency range 20-20kHz, all alias components are reduced in amplitude by 30 dB.

4a. **PCM Coding** (4 pts) - A 12 bit uniform quantizer has voltage range ±4.096 volts and operates at 44.1 kHz. A full load sinewave has normalized power $P_S = (4.096)^2/2 = 8.388$ W.

(i) For this full load sinusoid, determine the step size, the total quantizing noise power P_n and calculate SNR in dB, i.e. $10 \log_{10}(P_s/P_n)$

(ii) Determine normalized quantizing noise power (in watts) in the frequency range 0-15 kHz.

4b. **PCM Coding** (6 pts) - We are given a high quality baseband audio signal, $m(t)$ with bandwidth 20 kHz and power $A^2/16$ where A is the maximum amplitude of signal. (Recall that $P = A^2/2$ for a sinusoid).

(i) If we use PCM encoding with a uniform (linear) quantizer having $L = 2^N$ levels, what is the minimum number of bits N we need to encode $m(t)$ without clipping and ensure SNR of at least 52 dB?

(ii) What is the minimum rate for sampling $m(t)$ to avoid aliasing? As an engineer, what rate would you specify?

(iii) In the frequency range 0 - 20 kHz, there is a reduction in quantizing noise power if the sampling rate is increased to 32 times the minimum rate. This will improve the output SNR by ________dB.

5a. **Baseband Coding** (3 pts) - Illustrate the waveform when the sequence 010 1110 0110 is transmitted with the following code schemes. Assume ±10 volt amplitude and 100 kb/s rate.
NRZ (non return to zero) BPRZ (bipolar return to zero) BiØ-L (biphase level)

| 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 |

NRZ

| 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 |

BPRZ

| 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 |

BiØ-L

5b. **NRZ Random Data Spectrum** (3 pts) –Random data bits are transmitted using NRZ coding, 200 kb/s rate and ±5 volt amplitude.

a) Calculate the normalized power in the data signal.
b) Sketch the power spectrum, indicating the peak power spectral density and the frequency of any spectral nulls.
c) Determine the data signal power through integration of the spectral density from minus infinity to plus infinity. (Parseval's theorem)

5c. **PN Sequence Scrambler** (2 pts) – A self-synchronized scrambler uses a 9 bit shift register with taps at shift register positions 4 and 9. Assume that there is an isolated single bit error in the transmission channel. How many errors will occur in the descrambled output data?

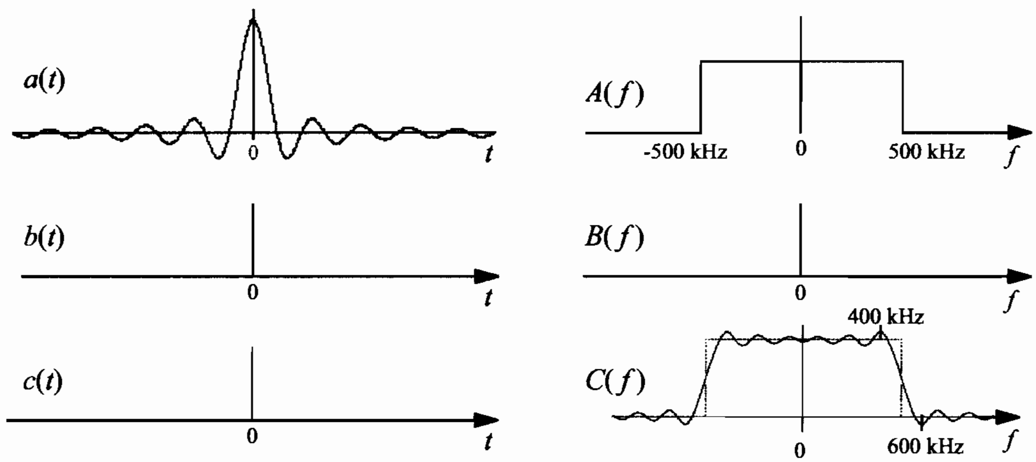
5d. **PN Sequence Spectrum** (2 pts) – A length = 15 PN sequence has amplitude ±2 volts (4 Vp-p). The sequence generator is clocked at 30 kHz.

a) What is the spectral amplitude at 0 Hz? ___________ volts
b) What is the spectral amplitude at 2 kHz? ___________ volts.
c) What is the spectral amplitude at 30 kHz? ___________ volts

6a. **Fourier Transform, Convolution and Digital Transmission** (6 pts) - A digital transmission system could be designed with "Nyquist" pulse signaling so that the transmission bandwidth is strictly limited. The ideal bandlimited amplitude spectrum is illustrated as $A(f)$ and the Nyquist pulse (unlimited in time) is illustrated in $a(t)$. It is convenient to synthesize Nyquist pulses using a transversal filter, however, the synthesized pulse duration is limited by the length of the filter. Truncation of the ideal Nyquist pulse is modeled as multiplication by a rectangular gating "window" of duration equal to the length of the transversal filter.

Since multiplication of time functions results in convolution of their spectra, the resulting spectrum $C(f)$ is the convolution of the ideal Nyquist pulse spectrum $A(f)$ and $B(f)$, the spectrum of the rectangular gating window.

(a) For positive time, calibrate (in us) the second and fourth zero crossing of $a(t)$.
(b) To the best of your ability, sketch the spectrum $B(f)$.
(c) Based on your estimate of $B(f)$, illustrate the rectangular gating window $b(t)$.
(d) Circle the portion of $a(t)$ that is synthesized by the transversal filter (i.e. $c(t)$).



6b. **Matched Filter and Eb/No** (4 pts) - Rectangular pulses of amplitude ± 900 mV and duration 10 ns are received in the presence of white noise spectral density $N_0/2 = 2$ nW/Hz. A correlator based matched filter multiplies by a correctly timed unit pulse of duration 10 ns. i) Determine the detected signal energy and the detected noise energy. ii) Also determine the signal to noise ratio at the detector and the probability of error in the binary transmission system.).

END

Have a good summer!