Student Number __________ Student Name:______________________

University of Saskatchewan

Dept. of Electrical Engineering

EE325 Communication Systems I

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Final Examination - April 23, 1998

Time: 3 hours

Instructor: D.E. Dodds

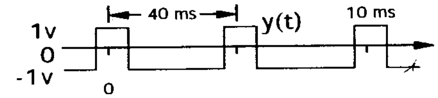
All texts, handout notes and personal notes are permitted.
Photo or electronic copies of problem and exam solutions are not permitted.

Complete 5 (out of 6) questions - all questions have value 12 points

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

1(a) Determine the peak, peak-to-peak, average and rms voltages of the following two signals x(t) and y(t). Also determine the normalized power, fundamental frequency, period and the first six coefficients of the complex "exponential" Fourier series.

$x(t) = 7v \cos 2\pi 400t$



V_p Volts	V_{p-p} Volts	V_{ave} Volts	V_{rms} Volts	P_N Watts	f_0 Hz	T_0 ms	$C_{\pm 5}$ Volts	$C_{\pm 4}$ Volts	$C_{\pm 3}$ Volts	$C_{\pm 2}$ Volts	$C_{\pm 1}$ Volts	C_0 Volts	
7	14	0	4.95	24.5	400	2.5	0	0	0	0	3.5	0	x
1	2	-0.5	1	1	25	40	-0.09	0	.150	0.32	0.45	0.5	y

$c_N = A\left(\frac{\tau}{T_0}\right)\mathrm{sinc}\left(n\pi\left(\frac{\tau}{T_0}\right)\right)$

$= 2\left(\frac{10}{40}\right)\mathrm{sinc}\left(n\pi/4\right)$

(b) Determine a polar "trigonometric" Fourier series approximation to the signal y(t) and verify your calculation using Parseval's theorem.

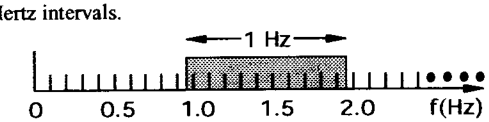
$y(t) = 0.5 + 0.9\cos(2\pi 25t) + 0.64\cos(2\pi 50t) + 0.3\cos(2\pi 75t) - 0.1$

$P_N = (0.5)^2 + \frac{(0.9)^2}{2} + \frac{(0.64)^2}{2} + \frac{(0.3)^2}{2} + \frac{(-0.18)^2}{2}$

$= 0.921$ ✓

(c) A noise-like signal, *v*(*t*), is composed of sinusoidal components each with amplitude 1 mVrms and spaced at one tenth Hertz intervals.

$v(t) = \sum_{n=0}^{n=+\infty} \sqrt{2}\cos(0.2\pi n t)$



(i) The noise-like signal passes through a filter with bandwidth one Hertz. What is the rms voltage and the normalized power of the filter output signal ?

1 µW/peak · 10 peaks = 10 µW $V_{rms} = 3.16$ mV

(ii) What is the filter output rms voltage and normalized power if the filter has 30 Hz bandwidth ?

30 · 10 µW = 300 µW

$V_{rms} = 17.3$ mV

(iii) Determine the power spectral density (PSD) and the amplitude spectral density of the noise-like signal. PSD = 10 µW/Hz ASD = 3.16 mV/√Hz

2(a) Which sampling format is used in commercial systems (i) flat top sampling or (ii) natural sampling ? Explain why.

Flat-top: transmitter needs to send only one value, hold by receiver for pulse duration. In natural sampling, the value changes throughout the sample duration.

(b) A tapeless telephone answering machine records the outgoing message with 8 bit precision at an 8 kHz sampling rate.

(i) How many bytes of memory are required to store a 20 second message ?

8 bits/byte   8 kHz = f_s 1 byte per sample

8 kHz · 20s = 160 000 bytes

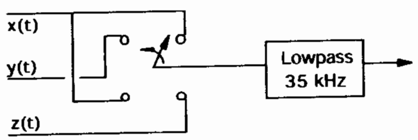
(ii) When playing the outgoing message, stored samples are placed in a digital latch which is connected to an A/D converter followed by an analog lowpass filter. Does this system implement natural or flat top sampling ?

Flat-top → Latch holds digital value

(iii) How can the latch in part (c) be operated to generate 50% duty cycle samples ? What would be the advantage of this ?

Latch must hold for $\frac{0.5}{8000}$ = 62.5 us. then drop to zero for 62.5 us. The advantage would be increased SNR

(c) A three channel PAM system carries signal x(t) which is bandlimited to 7 kHz, signal y(t) which is bandlimited to 5 kHz and signal z(t) which is bandlimited to 4 kHz. Determine the maximum and minimum pulse rate on the transmission line such that all three signals can be reconstructed without distortion.



Min rate		Max Rate	
10 kHz	(theoretical)	70 kHz	(theoretical)
11.5 kHz	(practical)	61 kHz	(practical)

$x(t) = \frac{7kHz}{2}$ = 3.5 kHz   2.35 kHz · 70 kHz

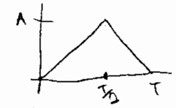
2.5 kHz · control speed   70 · 10%

10 kHz

3(a) What is the peak to rms ratio of a squarewave and a sinewave ?

1:1 Square   Peak : RMS $\frac{1}{\sqrt{2}}$ Sinewave

(b) Determine, from first principles, the peak to rms ratio of a triangular waveform. (Note - integration is required)



RMS = $\frac{2}{T}\int_{T/2}^{0} \left(\frac{4A}{T}\right)^2 dt$

$\frac{2}{T}\int_0^{T/2}\left(\frac{2A}{T}t\right)^2 dt$

$\frac{4}{T}\int_0^{T/2}\frac{4A^2}{T^2}t^2\,dt$

$\frac{2}{T}\left(\frac{4A^2}{T^2}\left(\frac{T}{2}\right)^3\frac{1}{3}\right)$

$\sqrt{\frac{8A^2}{8\cdot 2}}$

$= \frac{A}{\sqrt{2}}$

(c) A 10 bit uniform quantizer has voltage range ±1.024 volts.

(i) What is the bin size in mV ?

$2048/2^{10}$ = 2 mV $P_n = \frac{S^2}{12} = \frac{(2mV)^2}{12}$ = 0.33 mW

(ii) What is the quantizing SNR of a (1/4 load) sinwave with peak - peak voltage 512 mV ?

$P_s = \left(\frac{0.256}{2\sqrt{2}}\right)^2$ = 32.768 mW   SNR = $20\log\left(\frac{0.512}{2.048}\right)$ = −12.04

6.02(10) + 1.77 − 12.04 = 49.73 dB

(iii) What is the quantizing SNR of a complex waveform with peak to peak voltage 512 mV and peak to rms ratio equal to 5 ?

$\frac{P_s}{P_N} = \frac{\left(\frac{1}{4}\cdot\frac{2^{10}S}{2.5}\right)^2}{\frac{S^2}{12}} = \frac{12(655.4)S^2}{S^2}$ = 10 log (12 · 655.4) = 38.96 dB

(d) For the above quantizer, operating at 44.1 kHz, a full load sinewave will have normalized power P_s = $(1.024)^2/2$ = 524 mW.

(i) Determine the total quantizing noise power P_n and calculate 10 $\log_{10}(P_s/P_n)$

$P_N = \frac{(2mV)^2}{12}$ ⇒ $10\log\left(\frac{(1.024)^2}{2}\frac{12}{(0.002)^2}\right)$ = 61.77 dB

(ii) Determine the quantizing noise power in the frequency range 0 - 20 kHz if 100% flat top sampling is used and sin x/x correction has been applied at the system output.

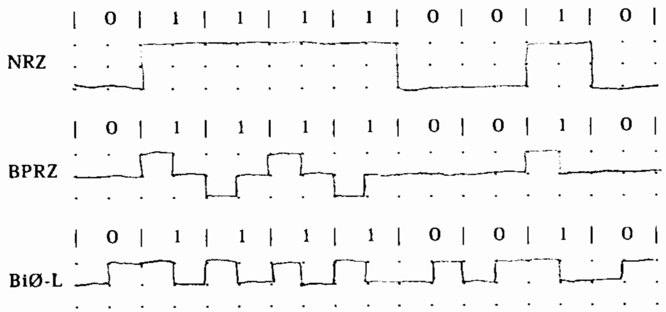
SNR = 6.02 (10) + 1.77 + 10 log$\left(\frac{44.1/2}{20}\right)$

= 62.4 dB

(iii) Determine the quantizing noise power in the frequency range 0 - 20 kHz if the sampling rate is increased by a factor of 8.

SNR = 6.02 (10) + 1.77 + 10 log $\left(\frac{44.1 \times 8 / 2}{20}\right)$ = 71.42 dB

4. (a) Illustrate non-return to zero (NRZ), alternate mark inversion bipolar return to zero (BPRZ) and biphase level (BiØ-L) coding for the following binary sequence.



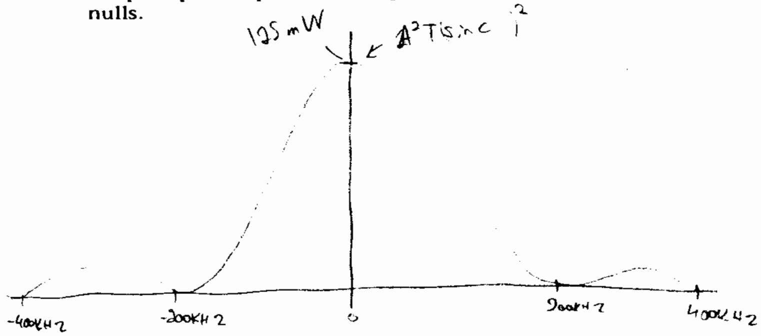
(b) Random data is transmitted using NRZ coding, 200 kb/s rate and ±5 volt amplitude.

i) Calculate the normalized power in the data signal.

$P_n = 5V^2 = 25W$

$5V = V_{RMS}$

ii) Sketch the power spectrum on a 2 sided frequency scale and indicate the peak power spectral density and the frequency of any spectral nulls.



iii) Estimate the data signal power in the audio bandwidth of 20 Hz -20 kHz through (approximate) integration of the power spectral density.

$125\ mW/Hz \cdot 20000\ Hz$

$= 2.5\ W$

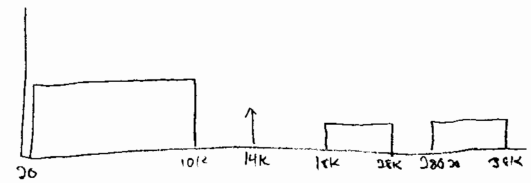
5. Assume that two audio signals with constant amplitude spectral density from 20 Hz to 10 kHz are to be multiplexed into one composite signal using a method similar to FM and TV stereo. One of the signals remains at baseband while the other signal is sent using DSB-SC modulation. Note that a pilot tone at one half the carrier frequency is transmitted and used to synthesize a receiver carrier for DSB-SC demodulation.

(a) What is the result of demodulation with 45 degree receiver carrier phase error and with 90 degree phase error ?

Demodulation with 45° degree error → $\cos 45° = 0.707$

90° → 0 output ⇒ $\cos 90° = 0$

(b) Assuming that the pilot frequency is 14 kHz, sketch the one sided composite signal spectrum and indicate all important frequencies.



(c) Why is the pilot tone NOT sent at the DSB-SC carrier frequency ?

must be selected filtered, and amplified. Ease of filter construction

(d) What would be the advantage and disadvantage of using a pilot frequency of 11 kHz ?

Hard to extract carrier from narrow range

Less Bandwidth required

(e) The pilot tone is generated from the DSB-SC carrier at the transmitter by using a frequency divide by two (counter) circuit. The receiver carrier is generated from the pilot tone by using a multiply frequency by two logic circuit (a transition detector is one method). Illustrate waveforms for pilot signal generation and carrier regeneration and explain how the receiver carrier can be synthesized with the same phase as the transmitter carrier.

6 (a) A television receiver is tuned to channel 6 which has video carrier at 83.25 MHz and audio carrier at 87.75 MHz. The TV uses a superheterodyne receiver with video IF at 45.75 MHz and sound IF at 41.25 MHz.

(i) What is the local oscillator frequency when tuned to channel 6 ?

Lo = 83.25 + 45.75

= 129 KHz

(ii) What are the video and sound image frequencies ?

Vid → 129 + 45.75 = 174.75 MHz

Sound → 129 + 41.25 = 170.25 MHz

(iii) Repeat i) for a sub-heterodyne receiver with the same IF frequencies. Do you see any problems ?

i) LO_{vid} = 83.25 − 45.75 = 37.5 MHz

LO_{vid} = 87.75 − 41.25 = 46.5 MHz

Not Same

(b) An AM transmitter is tested with a dummy resistive load. The modulated output is expressed as $\phi(t) = [1+\mu m(t)]A_c\cos\omega_c t$ where m(t) is the program signal with zero average value and m_p = 1.0. With no modulation, m(t) = 0, the output power is 10 kW. Typical programming signals have peak/rms ratio of 4. The modulation index is set at 85% (i.e. μm_p = 0.85). Find the average transmitter power when a program signal is broadcast.

$\langle m^2(t)\rangle = \frac{(0.85)^2}{0.4^2}$ = 0.045156

$\frac{(A_c)^2}{2} = 1000$

A_c = 141.4 V

$P_{av} = (1 + \langle m^2(t)\rangle)\frac{A_c^2}{2} = (1 + 0.045156)\frac{(141.4)^2}{2}$

= 10.45 KW

END