King Fahd University of Petroleum & Minerals
Electrical Engineering Department
EE370: Communications Engineering I (091)

Major Exam II

November 11, 2009
7:00 PM-8:30 PM
Building 59-2002

Serial # 0

Sec #

Name: KEY

ID#

Question	Mark
1	/10
2	/12
3	/8
Total	/30

Instructions:

1. This is a closed-books/notes exam.
2. The duration of this exam is one and half hours.
3. Read the questions carefully. Plan which question to start with.
4. CLEARLY LABEL ALL SIGNIFICANT VALUES ON BOTH AXIES OF ANY SKETCH. There are points for the important numbers.
5. Work in your own.
6. Strictly no mobile phones are allowed.

Good luck

Coordinator & Instructor Sec1 & Sec2 : Dr. Ali H. Muqaibel

Problem 1: (12 points)

A. When the modulating signal is a single-tone sinusoid of 10 kHz, the maximum deviation in an FM broadcast system is 75 kHz, find the bandwidth of the FM signal. **(1 point)**

$BW = 2(\Delta f + B) = 2(75k + 10k) = \boxed{170 \text{ kHz}}$

B. What will be the bandwidth, if the modulating frequency is doubled? **(1 point)**

$BW = 2(75k + 20k) = \boxed{190 \text{ kHz}}$

C. What will be the bandwidth, if both the bandwidth and the amplitude of the modulating signal is doubled. **(1 point)**

Doubling the amplitude results in doubling the freq deviation $\Rightarrow BW = 2(150k + 20)k = \boxed{340 \text{ KHz}}$

D. Which one of the above cases (**A, B, C**) is narrow band FM. Justify your answer **(1 point)**

Non of them because for Narrow band $BW \simeq 2B_{message}$

for Case A $170k \gg 20k$ case B $190k \gg 40k$

Case C $340k \gg 40k$

E. Given the angle modulated signal $x_{EM}(t) = 10\cos(2\pi\times10^5 t + 20\cos 10\pi t)$, is this signal FM or PM signal and what is the message. (k_p=k_f=1) **(2 points)** It could be any

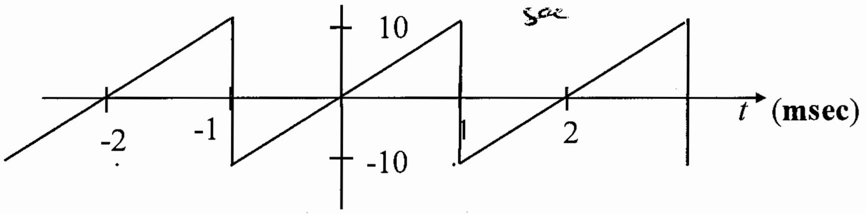
if PM $x_{PM}(t) = A\cos(2\pi(f_c)t + k_p m(t)) \Rightarrow k_p m(t) = 20\cos 10\pi t \Rightarrow \boxed{m(t) = 20\cos 10\pi t}$

if FM $x_{FM}(t) = A\cos(2\pi(f_c)t + k_f \int_0^t m(\alpha)d\alpha) \Rightarrow k_f \int_0^t m(\alpha)d\alpha = 20\cos 10\pi t$

$\Rightarrow \boxed{m(t) = -200\pi \sin 10\pi t}$

F. A baseband signal $m(t)$ is periodic sawtooth signal shown in the figure. **(3+2 points)**

a. Sketch the FM modulated signal if $\omega_c = 2\pi\times10^6$, and k_f=4000π. rad/sec / Volt

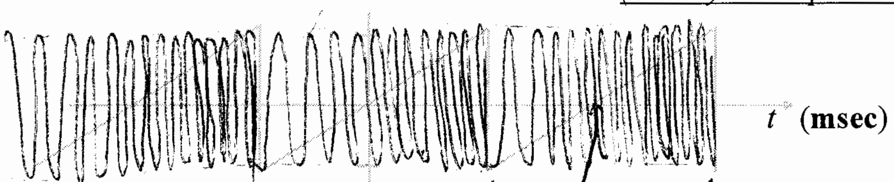


$m_p = 10$

minimum freq = $10^6 + 2000(10) = 10^6 + 20k = \boxed{1.02 \text{ MHz}}$

Similarly minimum freq. $= 10^6 - 2000(10) = \boxed{980 \text{ KHz}}$

(Show your steps & important values)



100.2 MHz

min freq at zero crossing

99.8 MHz

100 MHz

b. If PM is to be used what is the maximum value for k_p.

$-\pi \le k_p m(t) < \pi \Rightarrow k_p < \frac{\pi}{10}$

$\boxed{k_{p,max} = \frac{\pi}{10}}$

$\cos x \cos y = \frac{1}{2}[\cos(x+y) + \cos(x-y)]$

$1 \Leftrightarrow 2\pi\,\delta(\omega)$

$\cos \omega_0 \Leftrightarrow \pi[\delta(\omega-\omega_0) + \delta(\omega+\omega_0)]$

Problem 2: (1 points)

The signal $s(t) = 8[1+\cos(120\pi t)\cos(100\pi t)]$ (t is in seconds) is sampled using an ideal sampling function (i.e. a periodic train of impulses) at the rate of 150 samples/sec. Each sample is quantized into the closest integer between 0 and 15. Each of the integer values is encoded using a 4-bit code word according to the usual binary representation of integers, (i.e. 0 = 0000, 1= 0001, …, 15 = 1111).

(a) Is sampling done at, below or above Nyquist rate? Show your work. **(1 point)**

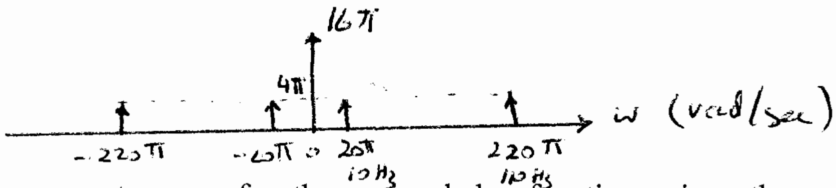
$s(t) = 8\left[1 + \frac{1}{2}(\cos(220\pi t) + \cos(20\pi t))\right]$, max freq = 110 Hz

Nyquist rate = 220 samples/sec

$\Rightarrow$ Sampling is done below Nyquist rate

(b) Sketch the spectrum of $s(t)$ **(2 points)**

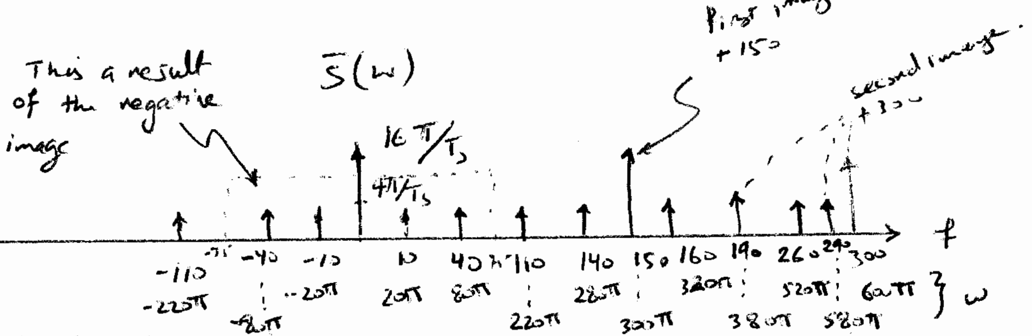
$S(\omega) = 16\pi\,\delta(\omega) + 4\pi[\delta(\omega-20\pi) + \delta(\omega+20\pi)] + 4\pi[\delta(\omega-220\pi) + \delta(\omega+220\pi)]$



(c) Sketch the amplitude spectrum of the sampled function in the range -111 Hz $< f <$ 301 Hz. Label all amplitudes and frequencies. **(3 points)**

$\frac{16\pi}{T_s} = 16\pi f_s = 2400\pi$

$\frac{4\pi}{T_s} = 4\pi f_s = 600\pi$



(d) Determine the sampled value, the quantized value and the binary code for the first three samples, starting from $t = 0$. **(3 points)**

$T_s = \frac{1}{f_s} = \frac{1}{150} = 6.67\text{ ms}$

To get the sampled value substitute the time in the Equation $s(t)$.

Do not forget to use radians.

time	Sampled value	Quantized value	Binary code
0	16	15	1111
6.67 ms	11.23	11	1011
13.33 ms	6.76	7	0111

1 point 1 point 1 point

(e) What is the folding frequency and What would be the recovered signal using ideal lowpass filter. Write the time domain expression? **(3 points)**

The folding frequency $= \frac{f_s}{2} = \frac{150}{2} = 75$ Hz any frequency above 75 will be folded $\frac{f_s}{2} + f_x \rightarrow \frac{f_s}{2} - f_x$ $\Rightarrow$ The 110 Hz $\Rightarrow$ 75 + 35 will be mirrored to 75 - 35 = 40

received signal $= \frac{8}{T_s}\left[1 + \frac{1}{2}[\cos(80\pi t) + \cos(20\pi t)]\right] = 1200 + 600\cos(80\pi t) + 600\cos(20\pi t)$

if the filter has an amplitude that takes care of $\frac{1}{f_s}$ then the amplitude will change.

$8 + 4\cos(80\pi t) + 4\cos(20\pi t)$

Problem 3: (8 points)

A speech signal has a total duration of 20 s. It is sampled at the rate of 12 kHz and then encoded. The signal-to-(Quantization) noise ratio is required to be at least 45 dB. Calculate **the minimum storage capacity** needed to accommodate this digitized speech signal.
Assume the output signal-to-(Quantization) noise is given by the following:

$$(SNR)_O = \frac{3}{2}(2^{2n}),\text{ where } n \text{ is the number of bits/sample}$$

Hint: Do not forget to convert the SNR from dB to normal scale.

(3 points)

Storage = data rate * duration.

$45\,dB = 10\log_{10} x \Rightarrow x = 31622.777$

$\frac{3}{2}(2^{2n}) = 31622.777 \Rightarrow n \simeq 7.18 \Rightarrow n = 8$ bits minimum.

# of bits cannot be non integer.

Storage $= 20\,\text{sec} \cdot 12\,K\,\frac{\text{Samples}}{\text{Sec.}} \cdot 8\,\frac{\text{bits}}{\text{Sample}} = 1920\,M$ bits

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If non-uniform quantization is to be implemented using the μ-law with μ=100. And m_p=8V.

1. If the input signal to the compander is 2V what will be the output voltage. **(1 point)**

The normalized input $= \frac{2}{8} = 0.25$, The normalized output is 0.7

$\Rightarrow$ The output $= 0.7\,(8) = 5.6$ V

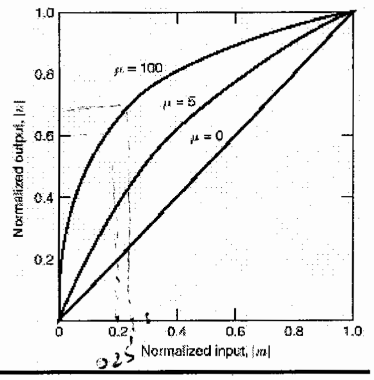
2. For a 7-bit quantizer, how many levels (approximately) are going to represent the signal up to 20% of the maximum possible input. **(2 points)** $\mu = 100$

20% input results in 60% output

# of levels $\simeq 0.6 * 2^7$

$= 0.6 * 128 = 76.8$

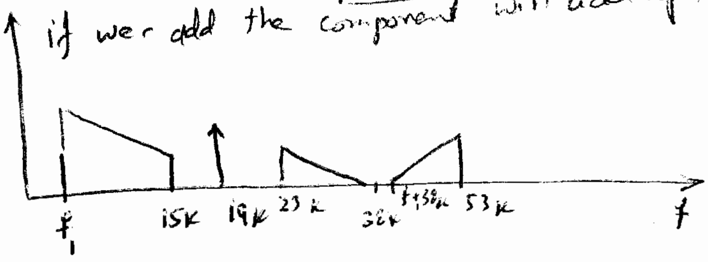
$\simeq 77$

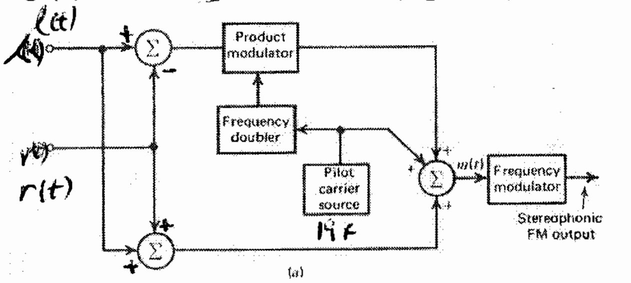


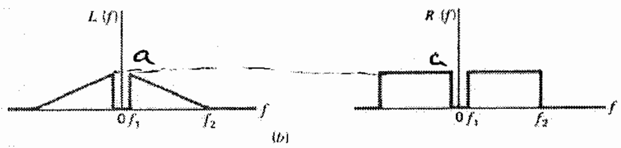
The block diagram of the figure below shows the modulation system for transmitting *stereophonic FM waves.* The input signals *l(t)* and *r(t)* represent the left-hand and right-hand audio signals, respectively. **Sketch** the single-sided amplitude spectrum of the composite signal *m(t),* assuming that the input signals *l(t)* and *r(t)* have the spectra shown in Fig.(*b*), and that f_2= 15 kHz. **(2 points)**

assuming that l(t) & R(t) have the same spectrum phase

if we add the component will add up.







assume