Student Name: _____________________
Student ID #: ______________________
   (Last 4 digits only)

EE4330 Section 001
Fundamentals of Telecommunications Systems
INSTRUCTOR: Dr. K. R. Rao
Summer 2006, Final
Tuesday, 8 August 2006
3:30 – 5:00 pm (1 Hour and 30 minutes)

INSTRUCTIONS:

1. Closed books and closed notes.
2. Any additional information required is attached to the test, you can only use
   the four-page cheat sheet handout.
3. Choose only one answer from the options given, and show all your work.
4. Please print your name and last four digits of your ID.
(Q1) For direct generation of FM waves using VCO (voltage-controlled oscillator), what is the conclusion on the output when there is **NO** input voltage (message signal) to the VCO?

A. There is no output of the VCO.
B. VCO gives a tone signal at carrier frequency.
C. VCO gives a constant voltage (zero frequency).
D. None of above

(Q2) FM demodulation by direct differentiation given in Fig.1, determine the output of the envelope detector given the input FM signal, \(5 \cos[1000t + 2 \sin(20t)]\), where \(m(t) = \cos(20t)\), \(K_f = 40\), and carrier is \(5 \cos(1000t)\).

\[
\phi_{FM}(t) \xrightarrow{\frac{d}{dt}} \phi'_{FM}(t) \xrightarrow{\text{Envelope detector}} \text{Output}
\]

A. \(5000 + 200 \cos(20t)\)
B. \(1000 + 40 \cos(20t)\)
C. \(1000t + 2 \sin(20t)\)
D. 5

(Q3) Which is **TRUE** about the weak interference in FM, PM and AM systems, (Weak interference is where interference is much less than carrier amplitude),

A. FM and PM systems suppress weak interference better than AM system.
B. Weak interference in AM signal is independent of carrier amplitude.
C. Both A and B are correct
D. None of above

(Q4) Which is **TRUE** about the preemphasis-deemphasis in FM broadcasting,

\[
m(t) \xrightarrow{H_f(\omega)} \text{Freq. modulator} \rightarrow \cdots \rightarrow \text{Freq. demodulator} \xrightarrow{H_f(\omega)} km(t)
\]

A. Preemphasis filter boosts the high frequency components of audio signal.
B. Deemphasis filter attenuates the low frequency components of audio signal.
C. Both A and B are correct.
D. None of above
(Q5) Determine the **Nyquist sampling rate** for the signal \( x(t) = \text{sinc}(10\pi t) + \text{sinc}(50\pi t) \).

A. 10 Hz  
B. 40 Hz  
C. 50 Hz  
D. 60 Hz

(Q6) Determine the **Nyquist sampling interval** for the signal \( g(t) = \text{sinc}^2(5\pi t) \).

A. 0.05 sec  
B. 0.1 sec  
C. 0.2 sec  
D. 10 sec

(Q7) From (Q6), the signal \( g(t) = \text{sinc}^2(5\pi t) \) is sampled at a rate of 5 Hz, 10 Hz, and 20 Hz. What is the conclusion of these sampling processes?

A. \( g(t) \) cannot be reconstructed from \( g(t) \) sampled at 5 Hz.  
B. \( g(t) \) can be reconstructed from \( g(t) \) sampled at 10 Hz.  
C. \( g(t) \) can be reconstructed from \( g(t) \) sampled at 20 Hz.  
D. All of above

(Q8) Which is **TRUE** about a communication channel (noise-free) of bandwidth \( B \) Hz,

A. This channel can transmit a continuous signal of bandwidth \( B \) Hz with error free.  
B. This channel can transmit \( 2B \) pieces of information per second.  
C. 2 pieces of information per second per hertz bandwidth can be transmitted.  
D. All of above

(Q9) What type of pulse modulation can convert an analog signal into a digital signal?

A. PCM  
B. PAM  
C. PWM  
D. PPM
(Q10) A compact disc (CD) records audio signal digitally using PCM. In the quantization process, the audio samples are quantized into 2048 levels. Determine the number of bits required to encode a sample.

A. 1 bit  
B. 11 bits  
C. 10 bits  
D. 20 bits

(Q11) Which is NOT true about the advantages of digital communication over analog communication.

A. Quantization error in the digital communication cannot be reduced.  
B. Digital signal can be coded to yield low error rates and high fidelity.  
C. Noise and distortion within limits cause no effects to digital communication.  
D. Regenerative repeater makes digital communication more reliable over longer distance communication.

(Q12) Non uniform quantization can be realized by using compander in Fig. 2.

\[
\begin{array}{ccc}
  u & \rightarrow & (i) \\
  w & \rightarrow & \text{Uniform quantizer} \\
  v & \rightarrow & \text{Nonuniform quantized of } u \\
  & \rightarrow & (ii) \\
  & \rightarrow & \hat{u}
\end{array}
\]

Determine these functional blocks, (i) and (ii), of a compander.

(i) ,  (ii)  
A. Expander , Expander  
B. Expander , Compressor  
C. Compressor , Expander  
D. Compressor , Compressor

(Q13) 8-bit PCM signal using a \(\mu\)-law quantizer with \(\mu = 255\). Calculate the SNR in dB of this PCM system. Hint: SNR using \(\mu\)-law quantization is \(\frac{3L^2}{[\ln(1+\mu)]^2}\)

A. 13.98 dB  
B. 15.57 dB  
C. 38.05 dB  
D. 39.65 dB
(Q14) Given a block diagram of DPCM (differential pulse code modulation), select blocks \((i)\) and \((ii)\).

\[
\begin{align*}
&\sum \quad \rightarrow \quad (i) \quad \rightarrow \quad \text{To channel} \\
&\quad \downarrow \quad (ii) \quad \leftarrow \quad \sum
\end{align*}
\]

\((i)\), \((ii)\)

A. Delay, Quantizer
B. Quantizer, Predictor
C. Predictor, Quantizer
D. Lowpass filter, Predictor

(Q15) In DM (delta modulation), a message signal \(m(t)\) is approximated and gives the output as a staircase approximation \(\hat{m}_q(t)\) in Fig. 3. Identify two types of noise \((i)\) and \((ii)\) that occur at the output.

\[
\begin{align*}
&m(t) \quad \rightarrow \quad (i) \quad \rightarrow \quad \hat{m}_q(t) \\
&\quad \downarrow \quad (ii) \quad \leftarrow \quad m(t)
\end{align*}
\]

\((i)\), \((ii)\)

A. Granular noise, Slope overload noise
B. Slope overload noise, Granular noise
C. Aliasing noise, Quantization noise
D. Quantization noise, Interference noise

(Q16) Which is TRUE about the distortion in communication system.

A. Temporal dispersion (signal spreading in time) is undesirable in TDM systems.
B. Nonlinearities of channel cause the spectral dispersion (signal spreading in frequency).
C. Spectral dispersion causes serious problems in FDM systems.
D. All of above
(Q17) A nonlinear channel output is given by \( y(t) = x(t) + 0.001x^2(t) \), where \( x(t) \) is an input to the channel. Given \( x(t) = (1000/\pi) \text{sinc}(1000t) \). Find the spectrum of the output, \( Y(\omega) \).

A. \( \text{rect}(\omega/2000) + (1/\pi)\Delta(\omega/4000) \)
B. \( \pi\text{rect}(\omega/2000) + \pi\Delta(\omega/4000) \)
C. \( 2\pi\text{rect}(\omega/2000) + 2\pi\Delta(\omega/4000) \)
D. \( \pi\text{rect}(\omega/2000) + \Delta(\omega/4000) \)

(Q18) Which is NOT the radio propagation path that causes multipath distortion in the radio systems,

A. Sky wave
B. Reflected wave
C. Both A and B
D. None of above

(Q19) Find the energy of signal \( g(t) = 2 \text{sinc}(\pi t) \).

Hint: use Parseval’s theorem, \( E_g = \int_{-\infty}^{\infty} g^2(t)dt = \frac{1}{2\pi} \int_{-\infty}^{\infty} |G(\omega)|^2 d\omega \). (Define, \( \text{sinc}(\chi) = \frac{\sin(\chi)}{\chi} \)

A. 1
B. 2
C. 3
D. 4

(Q20) Find the energy spectral density of \( x(t) = \text{rect}(t - 1) \) in Fig. 4.

![Fig. 4.](image)

A. \( \text{sinc}^2(\omega/2) e^{-j2\omega} \)
B. \( \text{sinc}^2(\omega/2) \)
C. \( \text{sinc}^2(\omega/2) e^{j2\omega} \)
D. None of above

END OF THE TEST QUESTIONS
1. B  Lecture p.p. 5-23  Chapter 5 - part 1

2. A  \[ \frac{d \phi_{FM}}{dt} = 5 \left( 1000 + 40 \pi \cos 20t \right) \cdot \cos \left[ 1000t + 2 \sin 20t \right] \]  
   (Lec pp. 5-26)  
   (chapter 5)

3. C  Lecture pp. 5-38, 5-39  Chapter 5 - part 2

4. A  Lecture pp. 5-41, 5-43  Chapter 5 - part 2

5. C  \[ x(t) = \text{sinc}(10\pi t) + \text{sinc}(50\pi t) \]  
   Consider the max freq of \( x(t) \)

   \[ X(\omega) = \frac{1}{10} \text{rect} \left( \frac{\omega}{20\pi} \right) + \frac{1}{50} \text{rect} \left( \frac{\omega}{100\pi} \right) \]

   \[ \text{max freq of } x(t) \text{ is } 25 \text{Hz} \]
   \[ \therefore \text{Nyquist rate } = 50 \text{ Hz} \]

6. B  \[ g(t) = \text{sinc}^2(5\pi t) \]

   \[ G(\omega) = \frac{1}{5} \Delta \left( \frac{\omega}{20\pi} \right) \]

   \[ \text{max freq of } g(t) \text{ is } 5 \text{Hz} \]
   \[ \text{Nyquist rate } = 10 \text{ Hz} \]
   \[ \therefore \text{Nyquist interval } = 0.1 \text{ sec} \]
\( D \) g(t) has Nyquist rate at 10 Hz
(Sampling at 5 Hz is called undersampling)
(Sampling at 20 Hz is called oversampling)

\( D \) Textbook p. 260

\( A \) Textbook p. 262

\( B \) #Levels = \( 2^n \) (quantization)
#bits = \( \log_2 2048 = 11 \) bits

\( A \) Textbook p. 263-264

\( C \) Lecture p. 6-7C chapter 6 -part 1

\( C \) SNR (dB) = 10 \log \left( \frac{3 \cdot (2^8)^2}{\left[ \ln(1+255) \right]^2} \right) = 38.05 \text{ dB}

\( B \) Lecture p. 6-16 chapter 6 -parte

\( A \) Lecture p. 6-19 chapter 6 -parte

\( D \) Lecture p. 3-3 , 3-4 chapter 3

\( y(t) = \frac{1000}{\pi} \text{sinc}(1000t) + 0.001 \cdot \frac{1000^2}{\pi^2} \text{sinc}^2(1000t) \)

\( y(\omega) = \frac{1000}{\pi} \cdot \frac{\pi}{\omega} \text{rect}\left(\frac{\omega \pi}{2\pi \cdot 1000}\right) + 0.001 \cdot \frac{1000^2}{\pi^2} \Delta \left(\frac{\omega \pi}{4\pi \cdot 1000}\right) \)

\( D \) Lecture p. 3-6 (b) chapter 5

\( E_g = \int_{-\infty}^{\infty} (2 \text{sinc} \pi t)^2 \, dt = 2^2 \cdot \frac{1}{2\pi} \int_{-\infty}^{\infty} \left| \text{rect}\left(\frac{\omega \pi}{2\pi}\right) \right|^2 \, d\omega \)

\( \text{rect}\left(\frac{\omega \pi}{2\pi}\right) \rightarrow \frac{1}{\pi} \longmapsto \frac{1}{2\pi} \)

\( = 4 \)

\( B \) ESD of \( x(t) = |X(\omega)|^2 = X(\omega) \cdot X^*(\omega) \)
\( = \text{sinc}\left(\frac{\omega}{2}\right) e^{-j\omega} \cdot \left(\text{sinc}\left(\frac{\omega}{2}\right) e^{j\omega}\right)^* = \text{sinc}^2\left(\frac{\omega}{2}\right) \)