EE4330 Section 001
Fundamentals of Telecommunications Systems
INSTRUCTOR: Dr. K. R. Rao
Spring 2006, Test 2
Thursday, 6 April 2006
3:30 – 4:50 pm (1 Hour and 20 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.

4. Please print your name and last four digits of your ID.
(Q1) Determine the basic block components (i), (ii), and (iii) of the given PLL operation diagram,

\[ A \sin(\omega_c + \theta) \to (i) \to (ii) \to (iii) \]

(i), (ii), (iii)
A. \( \otimes \), Loop filter, VCO
B. \( \oplus \), Loop filter, VCO
C. \( \otimes \), VCO, Loop filter
D. \( \oplus \), VCO, Loop filter

(Q2) Which part is included in superheterodyne AM receiver?
A. Frequency modulator
B. Local oscillator
C. Phase detector
D. Voltage control oscillator

(Q3) Consider a super heterodyne receiver designed to receive the frequency band 20 to 50 MHz with IF frequency 10 MHz. What is the range of frequencies generated by local oscillator for this receiver? (Note: Receiver frequency converter uses down-conversion)

\[ A + m(t) \cos \omega_c t \]

\[ [A + m(t)] \cos \omega_c t \]

RF amp., and BPF tunable to \( \omega_c \)

Local Oscillator

A. 30 to 60 MHz
B. 10 to 60 MHz
C. 10 to 40 MHz
D. 30 to 40 MHz
(Q4) Find the average power of PM signal (phase modulation),
\[ u(t) = U \cos(2\pi f_c t + V \sin(2\pi f_1 t) + W \cos(2\pi f_2 t)) \], where \( f_c \) is the carrier frequency.

A. \((W^2 + V^2 + U^2)/2\)
B. \(W^2 + V^2 + U^2\)
C. \(U^2\)
D. \((U^2)/2\)

(Q5) Find instantaneous frequency (in Hz) of FM signal,
\[ u(t) = \cos(2\pi f_1 t + 2\pi g \int x(\tau) d\tau) \] and PM signal,
\[ v(t) = \cos(2\pi f_2 t + 2\pi h y(t)) \]. Where \( x(t) \) and \( y(t) \) are message signals, \( g \) and \( h \) are constants.

FM  ,    PM
A. \(f_1 + g x(t)\), \(f_2 + h y(t)\)
B. \(f_1 + g \int x(\tau) d\tau\), \(f_2 + h y(t)\)
C. \(f_1 + g\), \(f_2 + h\)
D. \(f_1\), \(f_2\)

(Q6) Message signal \( m(t) = M \cos(2\pi f_m t) \) is FM modulated using \( k_f = \pi \).

Determine frequency deviation (in Hz). \( \phi_{FM}(t) = A \cos[\omega_0 t + k_f \int m(\alpha)d\alpha] \)

A. \(\frac{1}{2} M \cos(2\pi f_m t)\)
B. \(\pi M \cos(2\pi f_m t)\)
C. \(\frac{1}{2\pi} M \sin(2\pi f_m t)\)
D. \(\frac{1}{2\pi M} M \sin(2\pi f_m t)\)

(Q7) From (Q6), find peak frequency deviation (in Hz) and modulation index.

<table>
<thead>
<tr>
<th>Peak freq dev</th>
<th>Modulation index</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. (M/(2\pi)), (M/(2\pi f_m))</td>
<td></td>
</tr>
<tr>
<td>B. (M/2), (M/(2f_m))</td>
<td></td>
</tr>
<tr>
<td>C. (M), (M/(f_m))</td>
<td></td>
</tr>
<tr>
<td>D. (\pi M), (\pi M/(f_m))</td>
<td></td>
</tr>
</tbody>
</table>

(Q8) Message signal \( m(t) = W \cos(2\pi f_m t) \) is FM modulated by a carrier, \( \cos(2\pi f_c t) \).

Find the FM signal, given \( k_f = 2\pi \).

A. \(\cos[2\pi f_c t + \frac{W}{f_m} \sin(2\pi f_m t)]\)
B. \(\cos[2\pi f_c t + \frac{W}{f_m} \cos(2\pi f_m t)]\)
C. \(\cos[2\pi f_c t + W f_m \cos(2\pi f_m t)]\)
D. \(\cos[2\pi f_c t + W f_m \sin(2\pi f_m t)]\)
(Q9) Find the difference between bandwidth of FM signal with message signal $2m(t)$ (amplitude of $m(t)$ is doubled), and bandwidth of FM signal with message signal $m(t)$ in Hz.

Given $\phi_{FM}(t) = A \cos[\omega_c t + k_f \int_{-\infty}^{t} m(\alpha) d\alpha ]$ and $m_p$ is the peak value of $m(t)$.

Hint: use Carson’s rule to find bandwidth of both FM signals.

A. $k_f m_p$
B. $k_f m_p / \pi$
C. $2k_f m_p / \pi$
D. $k_f m_p / (2 \pi)$

(Q10) Given Bessel function table of $J_n(\beta)$,

What is the value of $\frac{[J_2(\beta)]^2}{2} + \frac{[J_2(\beta)]^2}{2}$.

A. 0
B. $Y$
C. $(Y^2)/2$
D. $Y^2$

(Q11) Tone modulated FM signal is given by $u(t) = \cos[2\pi f_c t + \beta \sin(2\pi f_m t)]$.

We can write this signal in combination terms of Bessel functions,

$$u(t) = \sum_{n} J_n(\beta) \cos(2\pi f_c t + 2\pi nf_m t), \text{ where } n \in \{\ldots,-1,0,1,\ldots\}, \beta \text{ is modulation index.}$$

Find the average power of $v(t) = \sum_{n=-\infty}^{\infty} J_n(\beta) \cos(2\pi f_c t + 2\pi nf_m t)$

Given Bessel function table,

<table>
<thead>
<tr>
<th>$n$</th>
<th>$J_n(\beta)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>$W$</td>
</tr>
<tr>
<td>1</td>
<td>$X$</td>
</tr>
<tr>
<td>2</td>
<td>$Y$</td>
</tr>
<tr>
<td>3</td>
<td>$Z$</td>
</tr>
</tbody>
</table>

A. $(W^2 + X^2 + Y^2)/2$
B. $(W^2)/2 + X^2 + Y^2$
C. $W^2 + X^2 + Y^2$
D. $W^2 + 2X^2 + 2Y^2$

(Q12) From (Q11), find bandwidth (in Hz) of this modulated signal $v(t)$

A. $f_m$
B. $2f_m$
C. $4f_m$
D. $6f_m$
(Q13) FM signal with modulating signal \( m(t) \) is NBFM when,
A. \( |k_f m(t)| < 1 \)
B. \( |k_f m(t)| > 1 \)
C. \( |k_f m(t)| = 1 \)
D. None of the above

(Q14) What is the main purpose of using PDE (preemphasis-dephasis) in FM broadcasting?
A. To reduce the bandwidth of the modulated signal.
B. To reduce interference by channel noise at higher frequencies.
C. To attenuate the lower frequency components of the message signal.
D. None of the above

(Q15) The amplitude variations of the angle modulated carrier can be eliminated by a,
A. Band pass Limiter
B. Band pass filter
C. Differentiator
D. DC blocker

(Q16) Given message signal \( m(t) \) has no jump discontinuities, determine the function names in the blank blocks (i) and (ii).

\[ m(t) \rightarrow (i) \] Phase modulator \[ \rightarrow \] FM signal \[ \rightarrow (ii) \] PM demodulator \[ \rightarrow m(t) \]

(i) , (ii)
A. Integrator, Integrator
B. Integrator, Differentiator
C. Differentiator, Integrator
D. Differentiator, Differentiator
(Q17) Given an analog signal spectrum \( G(f) \), find the **Nyquist interval** (in sec.) of this signal.

\[ f \]

\[ -B \quad B \]

A. \( \frac{1}{2B} \)
B. \( B \)
C. \( 2B \)
D. \( 4B \)

(Q18) A compact disc (CD) records audio signals digitally by using PCM. Assume the audio signal bandwidth to be 15 kHz. What is the **Nyquist rate** (in kHz)?

A. 15
B. 30
C. 44.1
D. 64

(Q19) In telephone communication, conversational signal bandwidth is 4000 Hz. The signal is sampled at a rate of 8000 samples per second (8 kHz). Each sample is quantized into 256 levels (\( L = 256 \)). Determine the number of **bits per second** required to encode the signal.

A. 4,000
B. 8,000
C. 32,000
D. 64,000

(Q20) The \( \mu \)-law and \( A \)-law quantizers are generally non-uniform,

\text{\( \mu \)-law quantizer,} \quad y = \frac{1}{\ln(1+\mu)} \ln \left( 1 + \frac{\mu m}{m_p} \right), \quad 0 \leq \frac{m}{m_p} \leq 1

\text{\( A \)-law quantizer,} \quad y = \begin{cases} \frac{A}{1 + \ln A} \left( \frac{m}{m_p} \right), \quad 0 \leq \frac{m}{m_p} \leq \frac{1}{A} \\ \frac{1}{1 + \ln A} \left( 1 + \ln \frac{4m}{m_p} \right), \quad \frac{1}{A} \leq \frac{m}{m_p} \leq 1 \end{cases}

What are the values of \( \mu \) and \( A \) that make both quantizers uniform?

A. \( \mu = 0, \quad A = 1 \)
B. \( \mu = 1, \quad A = 0 \)
C. \( \mu = 100, \quad A = 87.6 \)
D. \( \mu = 255, \quad A = 1 \)
1. A  textbook p.185
2. B  textbook p.189
3. C  class notes Ch.4 part2 p.48-49  \( L_0 = [20, 50] - 10 = [10, 40] \)
4. D
5. A  \( \frac{d \theta(t)}{dt}, \frac{d \theta(t)}{dt} \)  \( (u(t)) = \cos \theta(t), (v(t)) = \cos \theta(t) \)
6. A  \( \frac{k_f m(t)}{2 \pi} = \frac{\pi M \cos 2\pi f_m t}{2 \pi} = \frac{M}{2} \cos 2\pi f_m t \)
7. B  peak freq = Max \( \left| \frac{k_f m(t)}{2 \pi} \right| = \frac{M}{2} \),  \( \beta = \frac{\Delta f}{2 \pi f_m} = \frac{k_f m_p}{2 \pi f_m} = \frac{M}{2 f_m} \)
8. A  \( F_m = \cos [2\pi f_c t + k_f \int W \cos 2\pi f_m t dt] = \cos [2\pi f_c t + \frac{2\pi W}{2 \pi f_m} \sin 2\pi f_m t] \)
9. B  \( BW_{\text{m}(t)} - BW_{\text{m}(t)} = 2 \left( \frac{k_f m_p}{2 \pi} + f_m \right) - 2 \left( \frac{k_f m_p}{2 \pi} + f_m \right) = \frac{k_f m_p}{2 \pi} \)
10. D  \( Y^2 + \frac{Y^2}{e} = Y^2 \)
11. B  \( \frac{J_x^2}{2} + \frac{J_y^2}{2} + J_z^2 + J_z^2 = \frac{W^2}{e} + X^2 + Y^2 \)
12. C  \( BW = (f_c + 2f_m) - (f_c - 2f_m) = 4f_m \)
13. D  textbook p.216
15. A  textbook p.234
16. B
17. A
18. B  Nyquist rate = 2 \times 15 \text{kHz} = 30 \text{kHz}
19. D  8000 \text{ samples} \times \log_2 256 \text{ bits} = 64,000 \text{ bit/sec} , textbook p.263
20. A  textbook p.270 , class notes Ch.6 p.6-2d