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

EE4330 Section 001
Fundamentals of Telecommunications Systems

INSTRUCTOR: Dr. K. R. Rao

Summer 2006, Test 2
Tuesday, 11 July 2006
3:30 – 5:20 pm (1 Hour and 50 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) Given a tone message signal \( m(t) = \cos(\omega_m t) \), the result from VSB + C envelope detection is approximately, \( E(t) = 1000 \cdot \left[ 1 + \frac{m(t)}{1000} \right] \). Pass this signal \( E(t) \) to the DC blocking.

Determine output of the DC blocking.

A. \( \cos(\omega_m t) \)
B. \( 1000 \cos(\omega_m t) \)
C. \( 1000 + \cos(\omega_m t) \)
D. No output signal

(Q2) Determine the basic block components (i), (ii), and (iii) of the given PLL (Phase-Locked Loop) operation diagram,

\[ A \sin(\omega_c t + \theta_i) \]

(i) , \( \oplus \), (ii) , (iii)

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

(Q3) Which is NOT true about the PLL?

A. PLL tracks the phase and frequency of the carrier component of the received signal.
B. PLL can be used for synchronous demodulation of AM signal.
C. Loop filter in PLL is a low-pass filter with narrow-band.
D. PLL amplifies the signal and suppresses noise at the input.

(Q4) Which component is NOT included in a superheterodyne AM receiver?

A. Voltage control oscillator
B. Radio-frequency amplifier
C. Frequency converter
D. Envelope detector
(Q5) Superheterodyne receiver is designed to receive the frequency band 540 to 1300 kHz with IF frequency 260 kHz. Receiver frequency converter uses down-conversion. Determine the range of frequencies generated by local oscillator for this receiver.

A. 280 to 1560 kHz
B. 280 to 1040 kHz
C. 800 to 1040 kHz
D. 800 to 1560 kHz

(Q6) Given message signal \( m(t) \),

Determine the function names in blank blocks (i) and (ii).

(i) , (ii)
A. Integrator, Differentiator
B. Integrator, PLL
C. Differentiator, Integrator
D. Differentiator, PLL
(Q7) Find the instantaneous phase of an angle modulated signal $x(t)$, where $x(t) = 3 \cos[200\pi t + \sin(10t) - 5\cos(4\pi t)]$

A. $200\pi t + \sin(10t) - 5\cos(4\pi t)$
B. $200\pi + 10\cos(10t) + 20\pi\sin(4\pi t)$
C. $100 + \frac{5}{\pi}\cos(10t) - 10\sin(4\pi t)$
D. $100 + \frac{1}{2\pi}\sin(10t) - \frac{5}{\pi}\cos(4\pi t)$

(Q8) From (Q7), find the instantaneous frequency deviation (in Hz), given $3\cos(200\pi t)$ is the carrier.

A. $\sin(10t) - 5\cos(4\pi t)$
B. $10\cos(10t) - 20\pi\cos(4\pi t)$
C. $\frac{1}{2\pi}\sin(10t) - \frac{5}{2\pi}\cos(4\pi t)$
D. $\frac{5}{\pi}\cos(10t) + 10\sin(4\pi t)$

(Q9) Given an FM signal $y(t) = 10\cos[200\pi t + 2\sin(30\pi t)]$, and $10\cos(200\pi t)$ is the carrier. Find the peak frequency deviation (in Hz).

A. 100
B. 60
C. 30
D. 15

(Q10) From (Q9), find the modulation index, given the bandwidth of message signal is 15 Hz.

A. 1
B. 2
C. 4
D. 8

(Q11) From (Q9) and (Q10) estimate the bandwidth (in Hz) of this FM signal using Carson’s rule.

A. 60
B. 90
C. 150
D. 270
(Q12) Message signal \( m(t) = 10 \sin(20\pi t) \) is phase modulated by a carrier, \( \cos(1000\pi t) \). Find the PM signal, given \( k_p = 0.1 \).

A. \( \cos[1000\pi t + \sin(20\pi t)] \)
B. \( \cos[1000\pi t + 20\pi \cos(20\pi t)] \)
C. \( \cos[1000\pi t - \frac{1}{20\pi} \cos(20\pi t)] \)
D. \( \cos[1000\pi t + 100 \sin(20\pi t)] \)

(Q13) Message signal \( m(t) = \cos(t) - 2 \sin(t) \) is frequency modulated. Carrier frequency is 100 rad/sec. The FM signal is given by \( x(t) = \cos[100t + \sin(t) + 2 \cos(t)] \). Find the average power of the message signal and the average power of the FM signal.

Message signal, FM signal
A. 3, 4
B. 5, 1
C. 3/2, 2
D. 5/2, 1/2

(Q14) FM signal with modulating signal \( m(t) \) is NBFM, where \( a(t) = \int_{-\infty}^{t} m(\alpha) d\alpha \), when,

A. \( |k_f a(t)| < < 1 \)
B. \( |k_f a(t)| > > 1 \)
C. \( |k_f a(t)| = 1 \)
D. None of the above

(Q15) Narrowband FM signal is given by \( x_{NBFM}(t) = A [\cos(\omega_c t) - B \cos(\omega_m t) \sin(\omega_c t)] \). Where message signal bandwidth is \( \omega_m \) rad/sec, carrier frequency is \( \omega_c \) rad/sec. Determine the bandwidth of NBFM signal in rad/sec.

A. \( \omega_c + 2 \omega_m \)
B. \( \omega_c + \omega_m \)
C. \( 2 \omega_m \)
D. \( \omega_m \)

(Q16) From (Q15), determine the average power of the NBFM signal.

A. \( (A^2)/2 + (A^2 B^2)/8 \)
B. \( (A^2)/2 + (A^2 B^2)/4 \)
C. \( (A^2)/2 + (A^2 B^2)/2 \)
D. \( (A^2)/2 + (A^2 B^2) \)
(Q17) Given Bessel function table of $J_n(\beta)$, where $\beta_1$ is a constant.

<table>
<thead>
<tr>
<th>$n$</th>
<th>$J_n(\beta_1)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>L</td>
</tr>
<tr>
<td>1</td>
<td>M</td>
</tr>
<tr>
<td>2</td>
<td>N</td>
</tr>
<tr>
<td>3</td>
<td>P</td>
</tr>
</tbody>
</table>

Determine the value of $\sum_{n=-2}^{2} J_n(\beta_1)$

A. $L$
B. $L + 2N$
C. $L + M + N$
D. $L + 2M + 2N$

(Q18) Tone signal $m(t)$ with peak value $m_p$ and bandwidth $B$ Hz, is both phase and frequency modulated. Carrier frequency is $f_c$ Hz.

Tone signal, $m(t) = m_p \cos(2\pi B t)$

$x_{PM}(t) = A \cos[\omega_c t + k_p m(t)]$, $k_p$ is a constant

$x_{FM}(t) = B \cos[\omega_c t + k_f \int_{-\infty}^{t} m(\alpha) \, d\alpha]$, $k_f$ is a constant

Find the peak frequency deviation (in Hz) of PM signal.

A. $k_p m_p B$
B. $k_p m_p$
C. $k_p m_p / 2$
D. $k_p m_p / B$

(Q19) From Q(18), find the peak frequency deviation (in Hz) of FM signal.

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

(Q20) From (Q18) and (Q19), find the difference in Hz between bandwidths of PM signal and FM signal using Carson’s rule, $(BW)_{PM} - (BW)_{FM}$

$Hint: Bandwidth of angle modulation = 2[peak frequency deviation + message signal bandwidth] = 2[\Delta f + B]$
1. A
2. C
3. D
4. A
5. B
6. C
7. A
8. D
9. C
10. B
11. B
12. A

Solution Test 2 Summer 2006 (EE 4330)

\[ f_{LO} = f_{RF} + f_{LF} = [540, 1300] - 260 = [280, 1040] \]

\[ x(t) = A \cos (\phi_c + \phi_m), \text{ instantaneous phase } = \phi_c + \phi_m \]

\[ \text{freq deviation (Hz) = } \frac{1}{2\pi} \frac{d}{dt} (\sin 30t - 5 \cos 4\pi t) \]

\[ \text{peak freq deviation (Hz) = } \max \left| \frac{1}{2\pi} \frac{d}{dt} (2 \sin 30\pi t) \right| = \frac{8 \times 30}{2\pi} = \frac{30}{15} \]

\[ \text{modulation index } \beta = \frac{\text{peak freq dev(Hz)}}{\text{message signal BW(Hz)}} = \frac{30}{15} = 2 \]

\[ \text{Carson's BW}_{FM} = 2(\text{peak freq. + msg BW}) = 2(\beta + 1) \text{ msg BW} \]
\[ = 2(30 + 15) = 2(2 + 1) \cdot 15 = 90 \]

\[ \psi_{PM}(t) = \cos \left( 1000\pi t + 0.1 \cdot 10 \sin 20\pi t \right) \]
\[ = \frac{1000\pi}{\text{carrier k}_p \text{ m(t)}} \]
\[ m(t) = \cos t - 2\sin t \quad \Rightarrow \quad x(t) = \cos \phi \]

\[ P_m = \frac{L^2}{2} + \frac{A^2}{2} = \frac{5}{2} \quad \Rightarrow \quad P_x = \frac{L^2}{2} \]

14. A
\[
\Psi_{FM} = \text{Re} \left[ e^{j \frac{k_f}{2} a(t)} e^{j \omega t} \right], \quad a(t) = \int_0^t m(\alpha) d\alpha
\]

\[
= \text{Re} \left[ (1 + j \frac{k_f}{2} a(t) - \frac{k_f^2}{2!} a^2(t) + ... ) (\cos \omega t + j \sin \omega t) \right]
\]

With assumption \( |k_f a(t)| < 1 \), then Higher order terms \( \rightarrow 0 \)

\[ \therefore \Psi_{FM} \rightarrow \Psi_{NBFM} = \cos \omega t - k_f a(t) \sin \omega t \]

15. C
\[ x_{NBFM}(t) = \frac{A \cos \omega t - AB \cos \omega t \sin \omega t}{\omega t \cos \omega t} = \frac{B}{2} \cos \omega t, \text{center at } \omega_c \]

16. B
\[ x_{NBFM}(t) = A \cos \omega t - \frac{AB}{2} \sin(\omega_c + \omega_c) t - \frac{AB}{2} \sin(\omega_c - \omega_c) t
\]

\[ P_x = \frac{A^2}{2} + \frac{(AB)^2}{2} + \frac{(AB)^2}{4} = \frac{A^2}{2} + \frac{A^2 B^2}{4} \]

17. B
\[ \sum_{n=2}^L J_n(\beta_e) = J_0(\beta_e) + J_1(\beta_e) + J_{-1}(\beta_e) + J_{-2}(\beta_e) + J_2(\beta_e)
\]

\[ = L + (-1)^M M + (-1)^N N \quad \Rightarrow \quad L + 2N \]

18. A
Peak freq dev (Hz) of \( x_{FM} \) = \( \max \left| \frac{1}{2\pi} \frac{d}{dt} k_p m(t) \right| = k_p m_p B \]

19. D
Peak freq dev (Hz) of \( x_{FM} \) = \( \max \left| \frac{1}{2\pi} \frac{d}{dt} k_f \int_0^t m(\alpha) d\alpha \right|

\[ = \max \left| \frac{1}{2\pi} k_f m(t) \right| = \frac{k_f m_p}{2\pi} \]

20. A
Using Carson's
\[ BW_{PM} - BW_{FM} = 2 \left[ k_p m_p B + B \right] - 2 \left[ \frac{k_f m_p}{2\pi} + B \right]
\]

\[ = 2 k_p m_p B - \frac{k_f m_p}{\pi} \]