BITS Pilani, Dubai Campus

Dubai International Academic City, Dubai, UAE

B.E. Third Year EEE, II Semester, 2012-13

COMPREHENSIVE EXAMINATION

Course No. / Course Title: EEE C383 / COMMUNICATION SYSTEMS

Duration: 2 Hours Max. Marks: 60 Weightage: 30%

Note:- Answer all questions

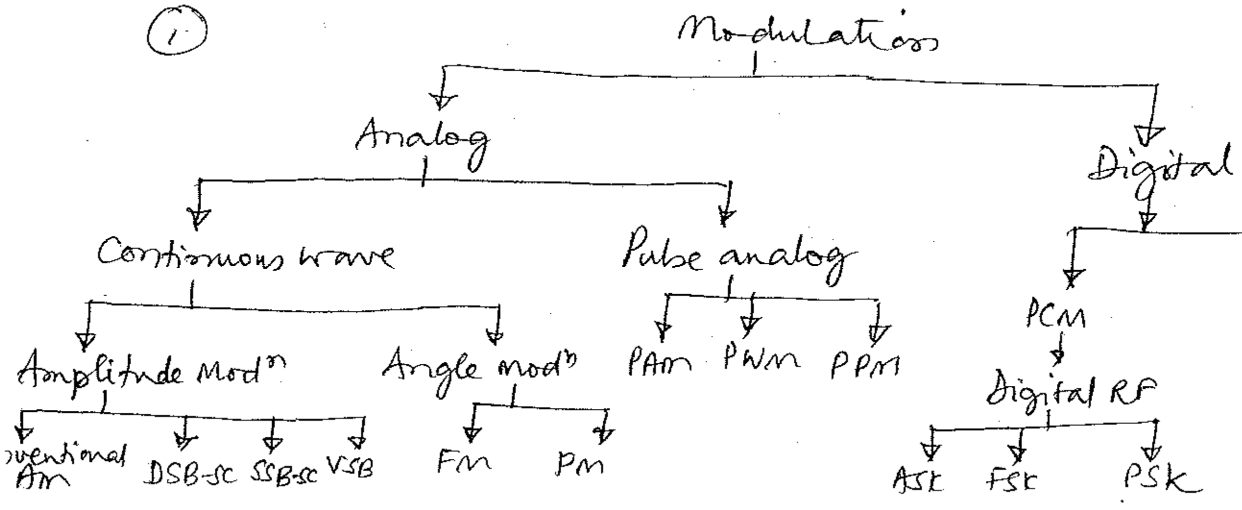
1. Draw a tree diagram indicating the names of all the modulation techniques, both analog and digital, that you have studied in this course. Ensure proper classification. (5)
2. Assuming a quarter-wave antenna, what would be the required antenna height for effective radio communication at 30 MHz? (3)
3. Define the term *multiplexing*. Name and distinguish between the various types of multiplexing that you have come across. (3)
4. You have come across the Hilbert transform during your study of SSB-SC modulation. Obtain the Hilbert transform of the unit impulse function δ(t). (6)
5. Consider a channel whose output-input relationship is given by $v_o(t) = a_1 v_i(t) + a_2 v_i^2(t)$. Show that if an AM signal passes through this channel, it would suffer distortion at the output. On the other hand, show that an FM signal goes through without distortion. Support your answer with appropriate mathematical analyses. (10)
6. Assuming an AWGN channel, sketch the power spectral density of noise at the output of (a) an FM receiver, and (b) a PM receiver. Label the axes correctly. (6)
7. What is *aperture effect* in pulse sampling? How can it be minimized? (5)
8. Name the errors that can be encountered in Delta Modulation. If a sine wave of amplitude A and frequency f_m is passed through a Delta Modulator whose step size is Δ, sketch the approximated signal for the condition $\Delta > 2A$. (6)
9. Define *entropy* of a discrete memory less source. What is the entropy of the English alphabet assuming that all the letters occur with the same probability? (6)
10. With the help of block diagrams and mathematical analysis, show how an FSK signal can be generated and demodulated. (10)

*** Paper ends ***

*** Paper ends ***

SOLUTIONS / MARKING SCHEME

(1)



(5)

(1) ~~f = 30 MHz~~
~~$\lambda = \frac{c}{f} = \frac{}{30 \times 10^{?}}$~~

(2) $f = 30\ MHz$

$\lambda = \frac{c}{f} = \frac{3 \times 10^{8}}{30 \times 10^{6}} = 10\ m$

$\therefore \frac{\lambda}{4} = 2.5\ m$ (3)

(3) Sending a number of signals through the same channel without mutual interference. (3)
TDM & FDM. Elaborate.

(4) Derive and show that (6)

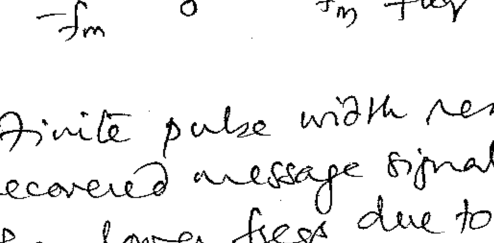
$$\delta(t) \xrightarrow{H.T.} \frac{1}{\pi t}$$

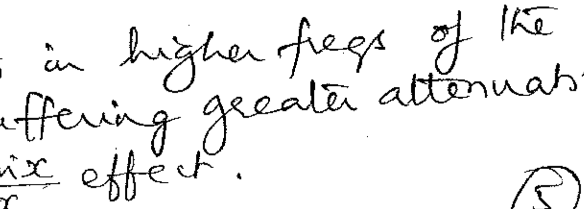
(5) For AM, $v_i(t) = A_c[1 + k_a m(t)] \cos \omega_c t$

For FM, $v_i(t) = A_c \cos[\omega_c t + k_f \int m(t)\, dt]$

Substituting for $v_o(t)$, it can be shown that for the AM case we have distortion components in the receiver input signal.
For FM, it is seen that $v_i(t)$ component is present at receiver input without any distortion components. (10)

(6)



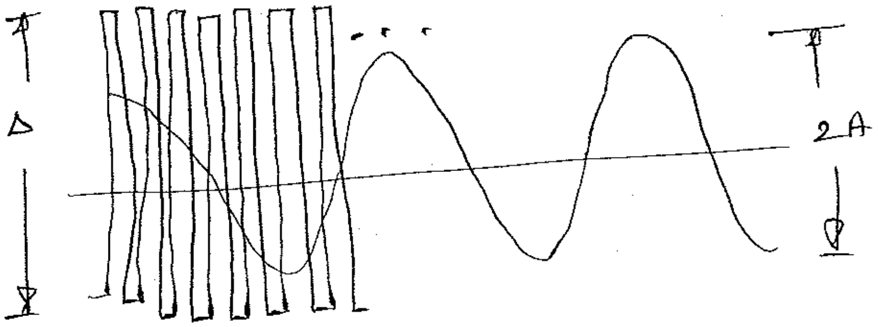


(6)

(7) Finite pulse width results in higher freqs of the recovered message signal suffering greater attenuation than lower freqs due to $\frac{\sin x}{x}$ effect. (5)

Keep pulse width $\Delta < 0.1\, T_s$.

(8) - Slope overload distortion
- "Hunting" ⇒ Granular noise
- Start-up error } (1½)



"Step-size limiting" occurs. (4½)

(2)

(9) Average info/message of the source.

$H(S) = -\log_2\left(\frac{1}{26}\right)$ bits/message ~ 4.7 bits/message (4)

(10) As discussed in class.
Should include both coherent detection (5)
and non-coherent detection (5)
with mathematical analysis.

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B.E. (Hons.) EEE Third Year, Second Semester, 2012-13

Test 1 (Closed Book)

EEE C383 Communication Systems

Duration: 50 min Max. Marks: 30 Weightage: 15%

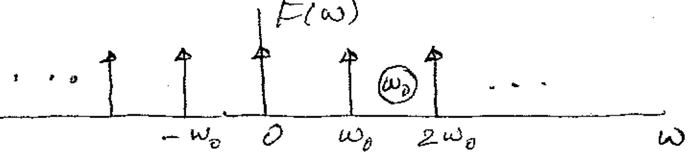
Note: *Answer all questions. All questions carry equal marks.*

1. Obtain and sketch the Fourier transform of a periodic train of unit impulses. Assume that the period is T_0.
2. An unmodulated carrier wave has a normalized power P_C. When the carrier is amplitude modulated to a depth of μ by a sinusoid, the power increases to P_T. Obtain the relationship between μ, P_C, and P_T.
3. Obtain the Hilbert transform of the function $\cos\omega_0 t \cos\omega_1 t, \omega_1 > \omega_0$.
4. Recall the square-law modulator for AM that was discussed in the class. If the input is now a conventional AM signal and the bandpass filter is replaced by a lowpass filter, we obtain a square-law demodulator. Show, with appropriate mathematical analysis, that this demodulator allows distortionless recovery of the baseband signal only if the AM wave has a low percentage modulation.
5. Obtain the expression for modulation index of a single-tone phase-modulated signal.

SOLUTIONS / ANSWERING SCHEME

1. Using Fourier series approach it can be shown that

$$\sum_{k=-\infty}^{\infty} \delta(t-kT_0) = \omega_0 \sum_{n=-\infty}^{\infty} \delta(\omega - n\omega_0) \quad \text{where } \omega_0 = \frac{2\pi}{T_0}$$ (4)



(2)

2. $s(t) = A_c[1+\mu \cos\omega_m t]\cos\omega_c t$

$$P_c = \frac{A_c^2}{2}; \quad P_{SB} = \overline{[A_c \mu \cos\omega_m t \cos\omega_c t]^2} = A_c^2\mu^2 \cdot \frac{1}{2}\cdot\frac{1}{2} = \frac{1}{4}A_c^2\mu^2$$

$$P_T = P_c + P_{SB} = \frac{A_c^2}{2} + \frac{1}{4}A_c^2\mu^2 = \frac{A_c^2}{2}\left(1+\frac{\mu^2}{2}\right)$$

$$\therefore \boxed{P_T = P_c\left(1+\frac{\mu^2}{2}\right)}$$ (6)

(3) Using the definition of Hilbert transform, it can be shown that $\cos\omega_0 t \cos\omega_1 t \xrightarrow{H.T.} \cos\omega_0 t \sin\omega_1 t$ for $\omega_1 > \omega_0$. (6)

(4) $v_i(t) = A_c[1 + k_a m(t)] \cos\omega_c t$

$v_o(t) = a_1 v_i(t) + a_2 v_i^2(t)$

Output of LPF can be shown to be

$y(t) = \frac{a_2 A_c^2}{2} + a_2 A_c^2 k_a m(t) + \frac{a_2 A_c^2 k_a^2}{2} \cdot LPF\{m^2(t)\}$

Desired component: $a_2 A_c^2 k_a m(t)$

Distortion component: $\frac{a_2 A_c^2 k_a^2}{2} \underset{[0,\omega_m]}{LPF} \{m^2(t)\}$

Ratio of desired to distortion component:

$$\frac{2}{k_a m(t)}$$

Ideally, this should be infinite.

Possible if $|k_a m(t)| \ll 1 \Rightarrow$ small percentage modulation. (6)

(5) Single tone PM:

$\theta(t) = \omega_c t + k_p m(t)$

$= \omega_c t + k_p A_m \cos\omega_m t$

$\omega_i(t) = \frac{d\theta(t)}{dt} = \omega_c + k_p A_m \omega_m(-\sin\omega_m t)$

$|\Delta\omega| = k_p A_m \omega_m$ (6)

$\beta_{pm} = \frac{\Delta\omega}{\omega_m} = k_p A_m$

(8 marks)

*** Paper ends ***

SOLUTIONS / MARKING SCHEME

(1) $\frac{S_o}{N_o} = \frac{S_i}{\eta f_m}$ $\quad S_i = -80\,dBm$ $\quad 10\log_{10}\left(\frac{S_i}{10^{-3}}\right) = -80$

$\Rightarrow \frac{S_i}{10^{-3}} = 10^{-8}$ or $S_i = 10^{-11}\,W$

(10)

$\therefore \frac{S_o}{N_o} = \frac{10^{-11}}{2\times2\times10^{-17}\times4\times10^{3}} = \frac{10^{3}}{16}$

(2) Probability of selecting one word from 10,000 words is $\frac{1}{10,000}$

$\therefore$ Info/word $= -\log_2\left(\frac{1}{10000}\right)$ bits

No. of words used to describe picture is 1000.

$\therefore$ No. of bits/picture $= -1000 \times \log_2\left(\frac{1}{10000}\right)$

$= 13.29 \times 10^3$

$= 1.33 \times 10^4$ bits

Info/pixel $= -\log_2\left(\frac{1}{16}\right) = 4$ bits

No. of pixels/picture $= 0.1 \times 10^6$

$\therefore$ Info/picture $= 0.4 \times 10^6 = 4 \times 10^5$ bits

Ratio $= \dfrac{4 \times 10^5}{1.33 \times 10^4} = \dfrac{40}{1.33} = 30:1$ (6)

(3) Minimum sampling rate is

$2f_m$ samples/sec

Assume n bits/sample

$\Rightarrow 2nf_m \frac{\text{bits}}{\text{sec}}$

Here $n = 8$

$2 \times 8 f_m \leq 48 \times 10^6$

$\therefore f_m \leq \frac{48}{16} \times 10^6$ (4½)

$\Rightarrow f_{max} = 3$ MHz

$m(t)$ → AAF → Sampler → Quant. → Encoder → ... R ... → D/A → LPF → (1½)

(4)

$f_m = 3$ kHz

$f_s = 20$ kHz

$A_m = 1$ V

$A_m \leq \dfrac{\Delta \cdot f_s}{2\pi f_m}$

$\Delta \geq \dfrac{A_m \cdot 2\pi f_m}{f_s} \geq \dfrac{1 \times 2\pi \times 3 \times 10^3}{20 \times 10^3}$ (8)

$\Rightarrow \Delta \geq \frac{3\pi}{10}$ V.

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Course No. / Course Title: EEE C383 COMMUNICATION SYSTEMS

Quiz 2

Duration: 20 min Max. Marks: 10 Weightage: 5%

Name: ____

ID No.: _______________________

Answer all questions in the blanks provided against each question. Numerical answers should be supported with appropriate rough work in the space provided; otherwise, credit will not be given for the answer, even if correct.

1. White noise is applied as the input to a filter having the transfer function $H(\omega)$. The power spectral density (PSD) of the output is ____________________. (1)
2. For a channel to be distortionless, its magnitude response must be _______________ over the entire frequency range and the phase response must be ____________ with frequency. (1)
3. AWGN stands for ____. (0.5)
4. A 10 kHz bandwidth signal is transmitted using DSB-SC modulation. Noise with two-sided PSD of 10^{-9}W/Hz is encountered in the channel. For an output SNR of 40 dB, the required signal power at the input of the demodulator is ___________. (2)
5. Coherent detection is preferred over envelope detection for conventional AM under low input SNR condition for the following reason: ____(1)
6. In FM, for every doubling of the transmission bandwidth, the output *SNR* increases by a factor of ____. (0.5)
7. The PSD of noise at the output of an FM receiver has a ______________ spectrum. (1)
8. In order to reduce the effect of noise in the higher frequency region of the message signal, FM systems employ a __________________ filter at the transmitter and a ________________ filter at the receiver. (1)
9. DPSK stands for ____. At the output of a DPSK receiver errors tend to occur in ____________. (1)
10. In an FSK receiver using coherent detection, the filter is a _________ filter. (1)

(Space for rough work. Use other side too, if necessary.)

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Quiz 2

Duration: 20 min Max. Marks: 10 Weightage: 5%

SOLUTIONS

Name: ____

ID No.: ____

Answer all questions in the blanks provided against each question. Numerical answers should be supported with appropriate rough work in the space provided; otherwise, credit will not be given for the answer, even if correct.

1. White noise is applied as the input to a filter having the transfer function $H(\omega)$. The power spectral density (PSD) of the output is $\frac{\eta}{2}|H(\omega)|^2$. (1)
2. For a channel to be distortionless, its magnitude response must be constant over the entire frequency range and the phase response must be linear with frequency. (1)
3. AWGN stands for Additive White Gaussian Noise. (0.5)
4. A 10 kHz bandwidth signal is transmitted using DSB-SC modulation. Noise with two-sided PSD of 10^{-9}W/Hz is encountered in the channel. For an output SNR of 40 dB, the required signal power at the input of the demodulator is 0.2 W. (2)
5. Coherent detection is preferred over envelope detection for conventional AM under low input SNR condition for the following reason: it does not exhibit threshold effect. (1)
6. In FM, for every doubling of the transmission bandwidth, the output *SNR* increases by a factor of 4. (0.5)
7. The PSD of noise at the output of an FM receiver has a parabolic spectrum. (1)
8. In order to reduce the effect of noise in the higher frequency region of the message signal, FM systems employ a pre-emphasis filter at the transmitter and a de-emphasis filter at the receiver. (1)
9. DPSK stands for Differential phase shift keying. At the output of a DPSK receiver errors tend to occur in pairs. (1)
10. In an FSK receiver using coherent detection, the filter is a notch filter. (1)

(Space for rough work. Use other side too, if necessary.)

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B.E. (Hons.) EEE Third Year, Second Semester, 2012.2013

Quiz 1

EEE C383 Communication Systems

Duration: 20 min   Max. Marks: 10   Weightage: 5%

Name: ____ *ID No.:* ____________________

Note:- For numerical answers, indicate the calculations in the space for rough work in order to get full credit.

1. Consider a source *X* that produces five symbols with probabilities ½, ¼, 1/8, 1/16, and 1/16. The source entropy *H*(*X*) is _______________ bits/symbol. (1.5)
2. An analog signal having 4 kHz bandwidth is sampled at 1.25 times the Nyquist rate. The sampling rate is _________ samples/sec. Each sample is quantized into one of 256 equally likely levels. Assume that the successive samples are statistically independent. The entropy of the source is ________ bits/sample and the information rate of this source is ____________ kilobits/sec. (0.5+0.5+1)
3. Sampling theorem states that: (1.5+0.5)
   ____
   ____
   ____
   ____
   _____________________. Undersampling a signal would result in ________________.
4. In Delta Modulation, the consequences of choosing a small step size are to experience _______________ ___________________________ and that of large step size is _______________________. (0.5x2)
5. PCM stands for ____ and it involves the operations of _________________, ________________________, and ________________. (0.5x4)
6. Name the three analog pulse modulation schemes: ______________________________________, ____________________________________, ____________________________________. (0.5x3)

(Space for rough work. Show all numerical calculations for full credit. Use other side too, if necessary)

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Quiz 1

EEE C383 Communication Systems

Duration: 20 min   Max. Marks: 10   Weightage: 5%

Name: SOLUTIONS   ***ID No.:*** ____

Note:- For numerical answers, indicate the calculations in the space for rough work in order to get full credit.

1. Consider a source *X* that produces five symbols with probabilities ½, ¼, 1/8, 1/16, and 1/16. The source entropy *H*(*X*) is 1.875 bits/symbol. (1.5)
2. An analog signal having 4 kHz bandwidth is sampled at 1.25 times the Nyquist rate. The sampling rate is 10 K samples/sec. Each sample is quantized into one of 256 equally likely levels. Assume that the successive samples are statistically independent. The entropy of the source is 8 bits/sample and the information rate of this source is 80 kilobits/sec. (0.5+0.5+1)
3. Sampling theorem states that: (1.5+0.5) Given a signal bandlimited to f_m Hz, it can be reconstructed from its samples provided that the sampling rate $f_s \geq 2f_m$. Undersampling a signal would result in Aliasing.
4. In Delta Modulation, the consequences of choosing a small step size are to experience Slope-overload distortion and that of large step size is "Hunting". (0.5x2)
5. PCM stands for Pulse-code modulation and it involves the operations of Sampling, Quantization, and Encoding. (0.5x4)
6. Name the three analog pulse modulation schemes: PAM, PWM, PPM. (0.5x3)

(Space for rough work. Show all numerical calculations for full credit. Use other side too, if necessary)