UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 4 Examination in Engineering: December 2015

Module Number: EE4301 **Module Name: Communication Theory**

[Three Hours]

[Answer **all questions**, each question carries 10 marks]

All the notations have their usual meanings.

Q1 a) i) Illustrate the components in a typical communication system and state their functions.

ii) What is the requirement for modulation in communication systems?

[2.0 Marks]

b) i) Derive the frequency domain expression for a standard Amplitude Modulated (AM) signal under tone modulation.

ii) Sketch the spectrum of the AM signal.

[1.5 Marks]

c) i) Modulation based on switching processes is one method of producing a modulated signal. State two such amplitude modulators.

ii) Describe the functionality of one such modulator mentioned in part i).

[2.5 Marks]

d) Consider a non-linear amplitude modulator. If the output characteristic of the nonlinear element is given by

$$v_{out} = a\, v_{in} + b\, v_{in}^2$$

i) Derive the expressions for $v_{out}(t)$ and $V_{out}(f)$ when

$m(t) = 3\cos(500\,\pi t)$

$c(t) = \cos(5000\,\pi t)$

Hint: Neglect the negative frequency components.

ii) Determine a and b, if the amplitudes of spectral components at 2.5 kHz and 5 kHz are 3 and 4 respectively.

iii) Sketch the frequency spectrum for $v_{out}(t)$.

[4.0 Marks]

Q2 a) The general form of a Single Sideband (SSB) modulated signal can be given as

$$m_{c(SSB)}(t) = m(t)\cos\omega_c t \pm m_h(t)\sin\omega_c t$$

where $m_h(t)$ is the Hilbert Transform of $m(t)$.

i) State the methods that are used to generate SSB modulated signals and describe one of them briefly.

ii) What is the significance of Hilbert transform in SSB systems?

iii) Derive the expressions for Upper Sideband (USB) and Lower Sideband (LSB) for tone modulation condition.

[4.5 Marks]

b) i) How does the Quadrature Amplitude Modulation (QAM) scheme utilize the bandwidth of thee frequency spectrum?

ii) Suggest a scheme to recover the QAM signal

$$m_{c(QAM)}(t) = m_1(t)\cos\omega_c t + m_2(t)\sin\omega_c t$$

[2.5 Marks]

c) Consider the following message signals.

$$m_1(t) = 5\cos(100\pi t) + 10\cos(500\pi t)$$
$$m_2(t) = 10\sin(500\pi t)$$

If these messages are modulated using QAM with a carrier of frequency 2 kHz

i) determine the modulated signal.

ii) sketch the spectrum for the modulated signal.

iii) compute the transmission power of the modulate signal.

[3.0 Marks]

Q3 a) i) What is the difference between narrowband and wideband Frequency Modulation (FM)?

ii) Describe the direct approach of generating FM waves.

iii) State the different demodulation techniques that are used for FM.

[2.5 Marks]

b) i) Explain the functionality of Pre-emphasis and De-emphasis filters.

ii) The received signal at a receiver, the un-modulated carrier and the interference signal are denoted by $R(t), C(t)$ and $I(t)$ respectively. Show that the envelop of the received signal is

$$A_R(t) = (A_C + A_I)^2 + 2A_C A_I(\cos\omega_I t - 1)$$

where, $C(t) = A_C\cos\omega_C t$

$I(t) = A_I\cos(\omega_C + \omega_I)t$

$R(t) = A_R(t)\cos[\omega_c t + \phi_R(t)] = C(t) + I(t)$

[2.5 Marks]

c) A FM modulator with characteristics $A_c = 3$, $f_c = 4\,\text{kHz}$ and $k_f = 80\pi$ is connected to an input $m(t) = 5\cos(80\pi t)$.

i) Determine the modulation index β.

ii) Sketch the frequency spectrum of the modulator output. Use the following third order Bessel function in Table Q3 to obtain this result.

$$m_{FM}(t) = A_c \sum_{n=-3}^{3} J_n(\beta)\cos(\omega_c + n\omega_m)t$$

Hint : $J_{-n}(\beta) = (-1)^n J_n(\beta)$

iii) Compute the power of the modulated signal.

[5.0 Marks]

Q4 a) In Ideal sampling, an analog signal $x(t)$ is multiplied with a periodic impulse train $S_\delta(t)$.

i) Derive the frequency domain expression for the sampled signal $X_\delta(f)$.
Hint : The natural sampled signal is

$$X_S(f) = \sum_{n=-\infty}^{\infty} f_S\,\tau\,\text{sinc}(n f_S \tau)X(f - n f_S)$$

where τ is the duration of the rectangular pulse in natural sampling.

ii) Consider the Ideal Sampled signal with $f_S = 70\,\text{Hz}$ and $x(t) = 1 + 2\cos(2\pi 30t)$. Obtain an expression for the sampled output in frequency domain.

[3.5 Marks]

b) A signal $x(t)$ is band limited to f_m Hz. It can be reconstructed completely from its samples by passing the sampled signal through an ideal low pass filter. The cutoff frequency of the low pass filter is greater than f_m Hz.

i) Derive an expression for the Interpolation filter output in time domain. Assume that the interpolation filter is an ideal low pass filter with a Gain k and a cutoff frequency B Hz.

ii) Explain the method of reconstructing the message signal using the derived expression in part i).

[3.5 Marks]

c) Sketch the transmitted signal corresponding to the bit stream 1, 0, 1, 1, 1, 0, 0, 1 for each of the following line coding scheme. Assume that the channel is a low-pass linear time invariant system with a larger bandwidth.

i) Bipolar Non Return to Zero (NRZ)

ii) Polar Return to Zero (RZ)

iii) Unipolar NRZ

iv) Split-phase Manchester

[3.0 Marks]

Q5 a) AT & T multiplexing hierarchy used in a digital telecommunication has four levels T1, T2, T3 and T4 lines. The signals of T1 line consists of Pulse Code Modulated (PCM) voice and multiplexed digital data.

i) Draw the frame structure of T1 line and briefly explain it.

ii) If the PCM / Time Division Multiplexing (TDM) system uses a sampling frequency of 8 kHz, determine bit rate of T1 line.

iii) Explain why the output bit rate at a given level exceeds the sum of the input bit rate in the AT & T hierarchy.

[4.0 Marks]

b) Consider an analog signal with values ranging from (-1.5) to (1.5) volts bandwidth of the signal is 6 kHz. This signal is sampled, quantized and binary coded to generate the PCM signal.

i) Determine the step size of the quantized signal, if the samples are quantized into 16 uniform levels.

ii) Determine the number of digits in the codeword and design binary codewords for each quantization level.

iii) Determine the binary pulse rate (in bits per second) of the binary coded signal and the minimum bandwidth that requires to transmit the signal.

iv) If the signal is transmitted as a 4-ary PSK carrier modulated PCM signal, what is the minimum number of 4-ary pulses required to encode each sample?

v) What is the bandwidth of the signal after 4-ary PSK carrier modulation?

[6.0 Marks]

Table Q3

		n OR ORDER															
x	(CARRIER)	(- - - - - - - - - - Sidebands - - - - - - - - - -)															
(m_f)	J_0	J_1	J_2	J_3	J_4	J_5	J_6	J_7	J_8	J_9	J_{10}	J_{11}	J_{12}	J_{13}	J_{14}	J_{15}	J_{16}
0.00	1.00	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
0.25	0.98	0.12	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
0.5	0.94	0.24	0.03	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1.0	0.77	0.44	0.11	0.02	—	—	—	—	—	—	—	—	—	—	—	—	—
1.5	0.51	0.56	0.23	0.06	0.01	—	—	—	—	—	—	—	—	—	—	—	—
2.0	0.22	0.58	0.35	0.13	0.03	—	—	—	—	—	—	—	—	—	—	—	—
2.5	−0.05	0.50	0.45	0.22	0.07	0.02	—	—	—	—	—	—	—	—	—	—	—
3.0	−0.26	0.34	0.49	0.31	0.13	0.04	0.01	—	—	—	—	—	—	—	—	—	—
4.0	−0.40	−0.07	0.36	0.43	0.28	0.13	0.05	0.02	—	—	—	—	—	—	—	—	—
5.0	−0.18	−0.33	0.05	0.36	0.39	0.26	0.13	0.05	0.02	—	—	—	—	—	—	—	—
6.0	0.15	−0.28	−0.24	0.11	0.36	0.36	0.25	0.13	0.06	0.02	—	—	—	—	—	—	—
7.0	0.30	0.00	−0.30	−0.17	0.16	0.35	0.34	0.23	0.13	0.06	0.02	—	—	—	—	—	—
8.0	0.17	0.23	−0.11	−0.29	−0.10	0.19	0.34	0.32	0.22	0.13	0.06	0.03	—	—	—	—	—
9.0	−0.09	0.24	0.14	−0.18	−0.27	−0.06	0.20	0.33	0.30	0.21	0.12	0.06	0.03	0.01	—	—	—
10.0	−0.25	0.04	0.25	0.06	−0.22	−0.23	−0.01	0.22	0.31	0.29	0.20	0.12	0.06	0.03	0.01	—	—
12.0	0.05	−0.22	−0.08	0.20	0.18	−0.07	−0.24	−0.17	0.05	0.23	0.30	0.27	0.20	0.12	0.07	0.03	0.01
15.0	−0.01	0.21	0.04	−0.19	−0.12	0.13	0.21	0.03	−0.17	−0.22	−0.09	0.10	0.24	0.28	0.25	0.18	0.12

Source: E. Cambi, *Bessel Functions*, Dover Publications, Inc., New York, 1948. Courtesy of the publisher.