UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 4 Examination in Engineering: November 2016

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

[Three Hours]

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

Q1 a) i) Define the term modulation.

ii) Explain the phenomena of over modulation in Amplitude Modulation (AM).

[2 Marks]

b) i) Non-linear elements are also used to construct AM modulators. State two such non-linear modulators.

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

[2.5 Marks]

c) Explain the synchronous or coherent demodulation process for Double Sideband Suppressed Carrier (DSB-SC) modulation scheme using diagrams and mathematical expressions.

[1.5 Marks]

d) The output of a standard AM modulator is given by,

$$150\cos(3100\pi t)+30\cos(3000\pi t)+150\cos(2900\pi t)$$

where $m_c(t), c(t)$ and $m(t)$ represent modulated signal, carrier signal and baseband signal respectively.

i) Convert the above expression to the form of a standard AM modulated waveform $m_c(t)=A_c\left[1+\mu A_m\cos(2\pi f_m t)\right]\cos(2\pi f_c t)$ and determine the expressions for $m(t)$ and $c(t)$, if the ratio between the amplitudes are $A_c : A_m = 2:1$.

Hint :

$$\cos(\theta+\phi)=\cos(\theta)\cos(\phi)-\sin(\theta)\sin(\phi)$$
$$\cos(\theta-\phi)=\cos(\theta)\cos(\phi)+\sin(\theta)\sin(\phi)$$

ii) Determine the modulation index (μ) and compute the power efficiency (η) of this modulator.

iii) From the results obtained in ii), show that the power efficiency is independent of the carrier signal amplitude.

[4 Marks]

Q2 a) i) State the main drawback in Double Sideband (DSB) modulation schemes.

ii) Derive expressions for Upper Sideband (USB) and Lower Sideband (LSB) for tone modulation condition in Single Sideband (SSB) modulation scheme, if the modulated waveform takes the form,

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

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

iii) State the significance of Quadrature Amplitude Modulation (QAM) and illustrate the modulation process.

[5 Marks]

b) Consider the following message signals which are being modulated using the standard QAM with a carrier of frequency 3 kHz.

$$m_1(t) = 15\cos(300\pi t) + 10\cos(50\pi t)$$

$$m_2(t) = 20\sin(500\pi t)$$

i) Determine the modulated signal.

ii) Sketch the spectrum for the modulated signal.

[3 Marks]

c) 12 signals each band limited to 6 kHz are multiplexed leaving a 1 kHz guard band between the channels and the main carriers. The modulation scheme used for the main carrier is AM. Determine the bandwidth of the composite signal, if the sub-carrier modulation is

i) SSB Suppressed Carrier

ii) Vestigial Sideband (VSB) with a 15% extension to the sideband.

[2 Marks]

Q3 a) i) State the main characteristics of linear and non-linear carrier wave modulation schemes.

ii) Compare the instantaneous phase and instantaneous frequency of Frequency Modulation (FM) and Phase Modulation (PM) techniques.

iii) State the different demodulation techniques that are used for FM and explain one of them.

[5 Marks]

b) A FM modulator with characteristics $A_c = 4$, $f_c = 6\,\text{kHz}$ and $k_f = 100\pi$ is connected to a baseband signal $\cos(40\pi t)$.

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 Marks]

Q4 a) i) Use diagrams to distinguish the main sampling techniques in digital communication.

ii) Explain the process of Ideal reconstruction using the interpolation filter.

[4 Marks]

b) i) Mention three analog pulse modulation techniques.

ii) Illustrate and explain the generation of Pulse Width Modulated (PWM) and Pulse Position Modulated (PPM) waves.

[3 Marks]

c) Sketch the transmitted signal corresponding to the bit stream 1, 1, 0, 1, 1, 0, 1, 0 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) Unipolar Return to Zero (RZ)

ii) Bipolar Non Return to Zero (NRZ)

iii) Manchester coding

[3 Marks]

Q5 a) i) What is the requirement of 'Encoding' stage in Pulse Code Modulation (PCM)?

ii) Derive an expression for the signal to noise ratio (S/N) in terms of normalized signal power and step size of the quantization levels Δ.

[2 Marks]

b) i) Explain the phenomena of Inter Symbol Interference (ISI) with an approach taken for remedying it.

ii) Draw the 8 - QAM waveform for the following bit stream with the appropriate constellation diagram.
001 111 010 001 101 110

[4 Marks]

c) A sinusoidal signal with the highest frequency component of 2.5 kHz is modulated using PCM. The sampling frequency selected is 20% higher than its Nyquist rate. The signal to noise ratio required for this modulation process is 30 dB.

i) Extend the answer obtained in a) ii) to a logarithmic expression in terms of number of bits in the code word (n), assuming the normalized signal power for a sinusoidal signal is $\frac{1}{2}m_p^2$ where m_p is the peak amplitude and $\left(\frac{S}{N}\right)_{dB} = 10\log_{10}\left(\frac{S}{N}\right)$.

ii) Using the results in i), determine the minimum number of bits required for the code word to satisfy the given (S/N) ratio.

iii) Calculate the minimum bandwidth required for the considered transmission process.

[4 Marks]

Table Q3

x	n OR ORDER																
	(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.