UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 4 Examination in Engineering: November 2017

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

[Three Hours]

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

Q1 a) i) Illustrate the components in a typical communication system and state the function of two of such components.

ii) What is the envelope of a standard Amplitude Modulated (AM) wave?

iii) Show that more than 50% of the transmitted power of a standard AM signal is wasted by the carrier components using usual notations.

[3.5 Marks]

b) Explain the function of a non-linear standard AM modulator using illustrations.

[1.5 Marks]

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

$$v_{out} = a\, v_{in} + b\, v_{in}^2$$
$$v_{in} = m(t) + c(t)$$

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

$m(t) = 2\cos(200\,\pi t)$

$c(t) = \cos(4000\,\pi t)$

Hint: Neglect the negative frequency components.

ii) Determine a and b, if the amplitudes of spectral components at 0 Hz and 2 kHz are 10 and 3 respectively.

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

[5 Marks]

Q2 a) i) Compare the bandwidth efficient AM techniques by sketching the formation of sidebands in the modulated spectrum.

iii) Model the coherent demodulation process of Single Sideband (SSB) modulation scheme and state the significance of the residue, 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 $m(t)$.

iv) Briefly explain the operation of a SSB modulator.

[4 Marks]

b) The transfer function of a de-emphasis filter in a frequency modulated (FM) receiver is given by,

$$H_d(f) = \frac{1}{1 + j\,2\pi\,RC\,f}$$

where R and C represents the resistance and capacitance of the filter circuit.

i) Explain the operation of pre-emphasis and de-emphasis filters.

ii) Show that the 3dB (half power) bandwidth of the above filter is given by $f_{3dB} = \dfrac{1}{2\pi\,RC}$.

iii) If the modulating signal bandwidth is W, the carrier amplitude is A and the single sided power spectral density for Gaussian noise N_0 is given by,

$$S_d(f) = N_0 \frac{f^2}{A^2} \frac{1}{\left[1 + \left(f/_{f_{3dB}} \right)^2\right]}.$$

obtain an expression for output noise power $P_{N(d)}$ of the de-emphasis filter from the following formula.

$$P_{N(d)} = \int_{-W}^{W} S_d(f).df$$

[Hint: $\int \frac{x^2}{a^2 + x^2}.dx = x - a\tan^{-1}\left(\frac{x}{a}\right)$]

iv) If the output noise power without the de-emphasis filter is given by $P_N = \dfrac{2N_0 W^3}{3A^2}$, determine the Improvement, $I = \dfrac{P_N}{P_{N(d)}}$ (ratio between the output noise powers) caused by the de-emphasis filter in dB, if the parameter values are $RC = 5 \times 10^{-5}$ and $W = 30$ kHz.

[6 Marks]

Q3 a) i) Explain the 'capture effect' in FM.

ii) State the two bands available in FM spectrum and briefly explain how they are approximated using Carson's rule.

iii) Explain a FM modulation and a demodulation technique briefly.

[5 Marks]

b) A FM modulator with characteristics carrier amplitude $A_c = 2$, carrier frequency $f_c = 4$ kHz and $k_f = 50\pi$ is connected to a baseband signal $2\cos(20\,\pi t)$.

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) What are the advantages of digital communication systems compared to analog communication systems that made them popular?

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

[4 Marks]

b) i) Explain the requirement and the process of non-uniform quantizing method.

ii) Consider a sinusoidal message signal of $4\cos(2\pi t)$ being sampled at a frequency 10 Hz. If the encoding scheme being used is the signed representation with a 3 bit code word and quantizing levels are uniformly spaced, determine the encoded outcome using a table which includes sample values, quantized levels and the corresponding codeword.

[3 Marks]

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

ii) Bipolar Return to Zero (RZ)

iii) Manchester coding

[3 Marks]

Q5 a) i) State the main issue in Pulse Code Modulation (PCM) in terms of transmission efficiency.

ii) Briefly explain a method which has been adopted to overcome the issue mentioned in i).

[2 Marks]

b) i) Explain why Digital Carrier Wave Modulation schemes are more popular than Pulse Modulation techniques.

ii) Draw the 8 – QAM waveform for the following bit stream with the appropriate constellation diagram.
011101110001111100

[4 Marks]

c) A sinusoidal signal with the highest frequency component of 4 kHz is modulated using PCM. The sampling frequency selected is 25% higher than its Nyquist rate. The signal to noise ratio required for this modulation process is 45 dB.

i) Derive a logarithmic expression for signal to noise ratio in terms of number of bits in the code word (n). Assume 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

		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.