

## 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  $m_c(t) = A_c[1 + \mu A_m \cos(2\pi f_m t)] \cos(2\pi f_c t)$  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  $(\mu)$  and compute the power efficiency  $(\eta)$  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  $A_c = 4$ ,  $f_c = 6$  kHz and  $k_f = 100\pi$  is connected to a baseband signal  $\cos (40 \pi t)$ .
  - i) Determine the modulation index  $\beta$ .
  - 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  $\Delta$ .

[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  $\left(\frac{S}{N}\right)_{pp} = 10\log_{10}\left(\frac{S}{N}\right)$ .
  - 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

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Source: E. Cambi, Bessel Functions, Doves Publications, Inc., New York, 1948. Coursesy of the publisher.