Faculty of Science
Department of Electrical and Electronic Engineering
Main Examination 2015

Title of Paper : Communication System Principles

University of Swaziland

Course Number : EE442

Time Allowed : 3 hrs

Instructions :

1. **Answer any four (4) questions**
2. **Each question carries 25 marks**
3. **Useful information is attached at the end of the question paper**

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The paper consists of six (8) pages

Question 1 [25]

a) With reference to the basic elements of a digital communication system, answer the following questions:

   i. What is source coding? [2]

   ii. What is the purpose of the digital modulator and digital demodulator? [4]

   iii. What is the purpose of the channel encoder and channel decoder [4]

b) What are the dominant sources of noise limiting performance of communication systems in the Very High Frequency (VHF) and Ultra High Frequency (UHF) band? [2]

c) Figure 1.1 below shows a pulse signal which is a half-cosine function.

   i. Express this pulse signal by a mathematical formula. [3]

   ii. Find its Fourier transform. [10]

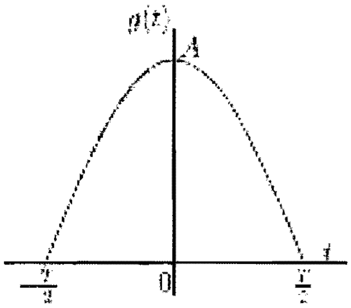


Figure 1.1

Question 2 [25]

a) Find the 3-dB bandwidth of the following signal [10]

$$g(t) = \begin{cases} e^{-20\pi t}, & t > 0 \\ 0, & t \leq 0 \end{cases}$$

i. What would you say about the 3-dB bandwidth of the following bandpass signal [5]

$$g(t) = \begin{cases} e^{-20\pi t}\cos(2\pi f_c t), & t > 0 \\ 0, & t \leq 0 \end{cases}$$

Note that frequency $f_c \gg 0$

b) Consider the modulation system whose system diagram is shown in Figure 2.1. The modulation scheme is not mentioned. Instead, you are to figure it out. In the system diagram, the -90^0 phase shifter is a device that can perform -90^0 phase shifts to any incoming signal.

Suppose that $m(t) = \cos(2\pi f_1 t)$

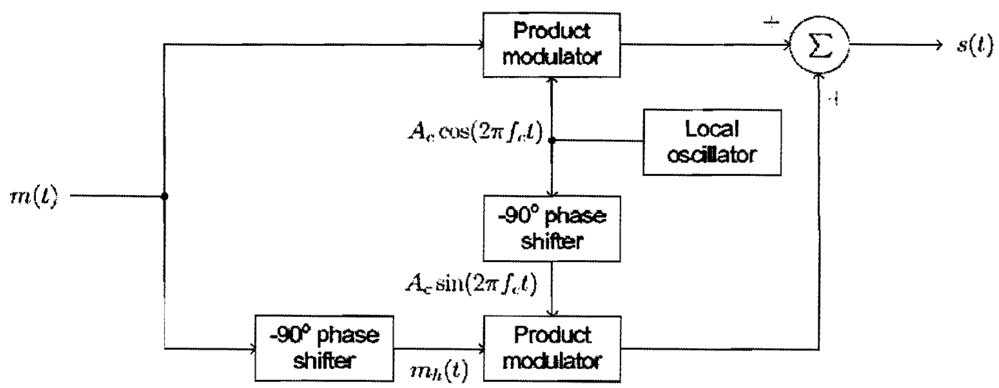


Figure 2.1

For some tone frequency f_1

i. Determine the corresponding modulated signal $s(t)$ of the system in Figure 2.1. [7]

ii. Based on your answer in b. (i), discuss what the modulation scheme should be. [3]

Question 3 [25]

a) Determine the Fourier transform of the resulting Amplitude Modulated (AM) signal, sketch the corresponding AM amplitude spectra and determine its transmission bandwidth. [18]
Given the following message signal:
$m(t) = \cos(2\pi f_1 t)\cos(2\pi f_2 t), \quad where\ f_1 = 10KHz\ , f_2 = 20KHz\ and\ f_c = 100KHz$

b) Consider the QAM system. Suppose that at the receiver, the local oscillator is subjected to phase error; i.e., the carrier wave generated by the local oscillator is $2\cos(2\pi f_c t + \varphi$, where φ is the phase error. The situation is illustrated in Figure 3.1. Show that this phase error will cause crosstalk between the two demodulated signals. [7]

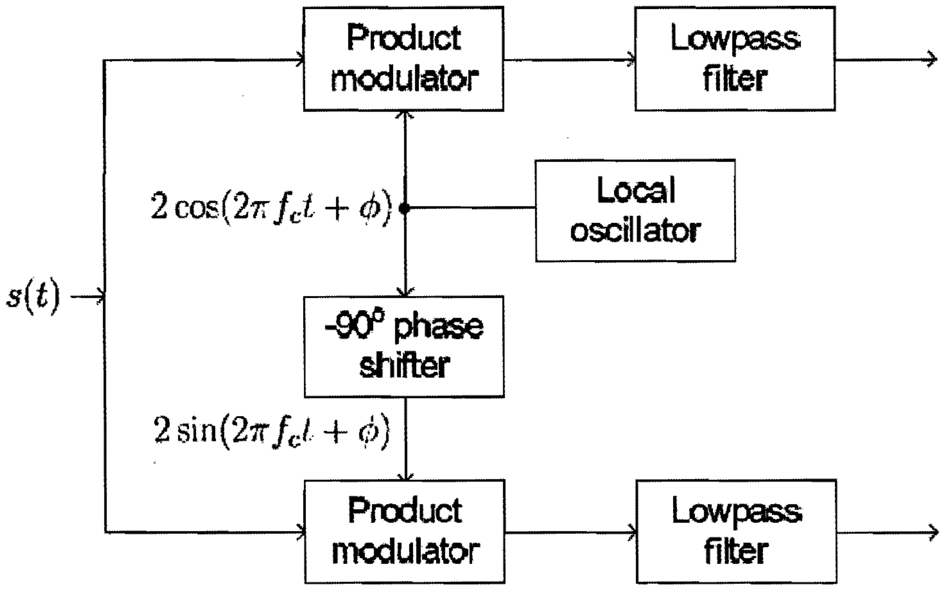


Figure 3.1

Question 4 [25]

a) A carrier wave of frequency 100 MHz is frequency-modulated by a sinusoidal wave of amplitude 20 volts and frequency 100 KHz. The frequency sensitivity of the modulator is 25 KHz per volt.

i. Determine the approximate bandwidth of the FM signal, using Carson's rule. [3]

ii. Determine the bandwidth by transmitting only those side frequencies whose amplitudes exceed 1 percent of the unmodulated carrier amplitude. Use figure 4.1, the universal curve for this calculation. [3]

iii. Repeat your calculations, assuming that the amplitude of the modulating signal is doubled [3]

iv. Repeat your calculations, assuming that the modulation frequency is doubled. [3]

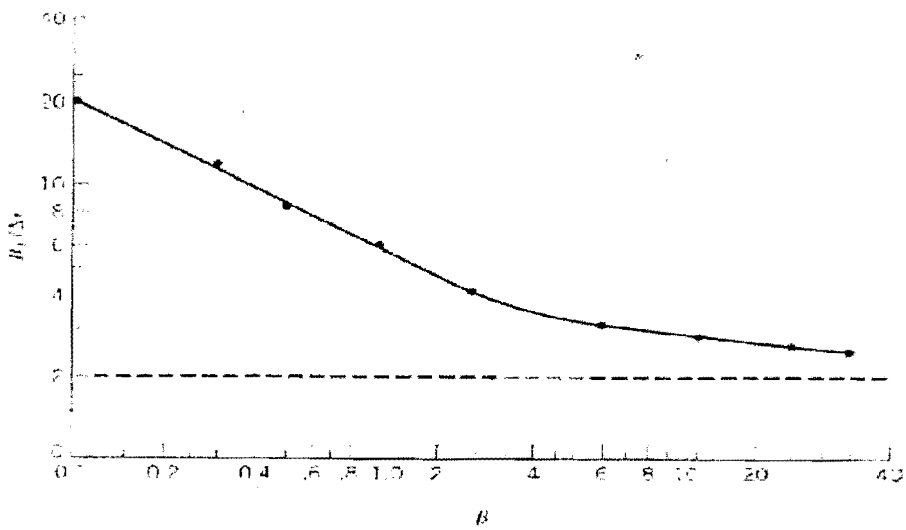
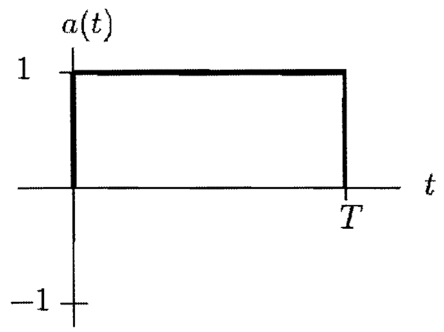


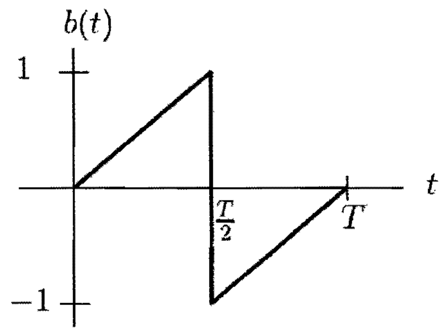
Figure 4.1

b) Determine the correlations of the following signal pairs. [13]

i.

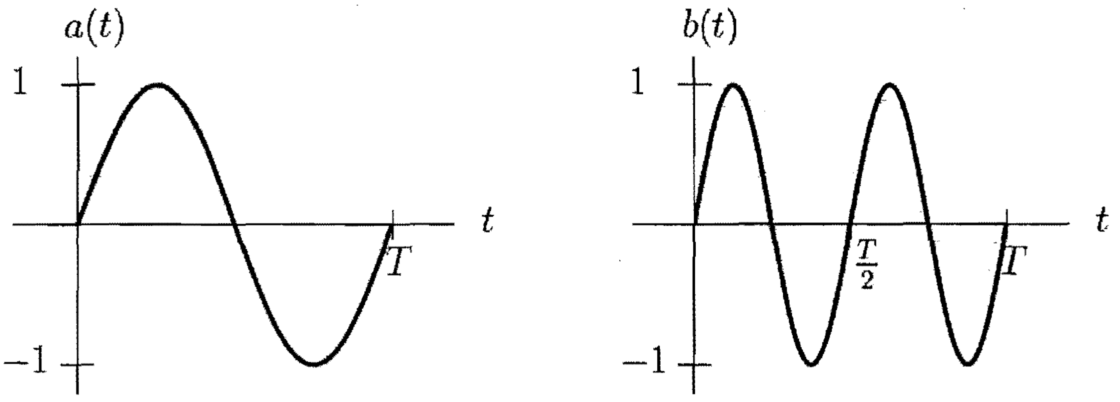


(a)



(b)

ii.



(a) (b)

Question 5 [25]

a) Define the following terms:

i.	Inter-symbol Interference	[1]
ii.	Sampling	[1]
iii.	Quantization	[1]
iv.	Bandwidth	[1]
v.	Communication System	[1]

b) Assume uniform quantization. Design the quantization levels $\{v_i\}$ when the number of quantization levels is 8 and the maximum signal amplitude is $|m|max = 4$. Also, design the encoding table, with the smallest possible binary codeword length. [7]

c) For Question 5. (b), determine the bit rate, that is, the number of bits transmitted per second, when the message signal bandwidth is $W = 3\ kHz$. Note that the smallest possible bit rate under the requirement of the sampling theorem is desired. [3]

d) Determine the bit rate, symbol rate and transmission bandwidth of the PCM system under the following settings. Message bandwidth $W = 4kHz$, the Nyquist sampling rate, $256 - level$ quantization.

i.	The line code is 2-ary PAM with full-width rectangular pulse.	[3]
ii.	TDM is applied and the number of multiplexed message signals is 12.	[3]
iii.	The 16-ary PAM is employed.	[2]
iv.	The half-width rectangular pulse is employed for line coding.	[2]

Type of Modulation	Mapping Functions $g(m)$	Corresponding Q
		$x(t)$
AM	$A_c[1+m(t)]$	$A_c[1+m(t)]$
DSB-SC	$A_c m(t)$	$A_c m(t)$
PM	$A_c e^{jD_p m(t)}$	$A_c \cos[D_p m(t)]$
FM	$A_c e^{jD_f \int_{-\infty}^{t} m(\sigma)\,d\sigma}$	$A_c \cos\left[D_f \int_{-\infty}^{t} m(\sigma)\,d\sigma\right]$
SSB-AM-SC[b]	$A_c[m(t) \pm j\hat{m}(t)]$	$A_c m(t)$
SSB-PM[b]	$A_c e^{jD_p[m(t) \pm j\hat{m}(t)]}$	$A_c e^{\mp D_p \hat{m}(t)} \cos[D_p m(t)]$
SSB-FM[b]	$A_c e^{jD_f \int_{-\infty}^{t} [m(\sigma) \pm j\hat{m}(\sigma)]\,d\sigma}$	$A_c e^{\mp D_f \int_{-\infty}^{t} \hat{m}(\sigma)\,d\sigma} \cos\left[D_f \int_{-\infty}^{t} m(\sigma)\,d\sigma\right]$
SSB-EV[b]	$A_c e^{\{\ln[1+m(t)] \pm j\hat{\ln}[1+m(t)]\}}$	$A_c[1+m(t)] \cos\{\hat{\ln}[1+m(t)]\}$
SSB-SQ[b]	$A_c e^{(1/2)\{\ln[1+m(t)] \pm j\hat{\ln}[1+m(t)]\}}$	$A_c\sqrt{1+m(t)} \cos\{\frac{1}{2}\hat{\ln}[1+m(t)]\}$
QM	$A_c[m_1(t) + jm_2(t)]$	$A_c m_1(t)$

TABLE 4-1 COMPLEX ENVELOPE FUNCTIONS FOR VARIOUS TYPES OF MODULATION *(cont.)*

Type of Modulation	Corresponding Amplitude and Phase Modulation		Linearity
	$R(t)$	$\theta(t)$	
AM	$A_c\lvert 1+m(t)\rvert$	$\begin{cases} 0, & m(t) > -1 \\ 180^\circ, & m(t) < -1 \end{cases}$	L[c]
DSB-SC	$A_c\lvert m(t)\rvert$	$\begin{cases} 0, & m(t) > 0 \\ 180^\circ, & m(t) < 0 \end{cases}$	L
PM	A_c	$D_p m(t)$	NL
FM	A_c	$D_f \int_{-\infty}^{t} m(\sigma)\,d\sigma$	NL
SSB-AM-SC[b]	$A_c\sqrt{[m(t)]^2 + [\hat{m}(t)]^2}$	$\tan^{-1}[\pm\hat{m}(t)/m(t)]$	L
SSB-PM[b]	$A_c e^{\pm D_p \hat{m}(t)}$	$D_p m(t)$	NL
SSB-FM[b]	$A_c e^{\pm D_f \int_{-\infty}^{t} \hat{m}(\sigma)\,d\sigma}$	$D_f \int_{-\infty}^{t} m(\sigma)\,d\sigma$	NL
SSB-EV[b]	$A_c\lvert 1+m(t)\rvert$	$\pm\hat{\ln}[1+m(t)]$	NL
SSB-SQ[b]	$A_c\sqrt{1+m(t)}$	$\pm\frac{1}{2}\hat{\ln}[1+m(t)]$	NL
QM	$A_c\sqrt{m_1^2(t) + m_2^2(t)}$	$\tan^{-1}[m_2(t)/m_1(t)]$	L

$\text{Cos}(A \pm B) = \text{Cos}\,A\,\text{Cos}\,B \mp \text{Sin}\,A\,\text{Sin}\,B$

$\text{Sin}\,A\,\text{Sin}\,B = \frac{1}{2}[\text{Cos}(A - B) - \text{Cos}(A + B)]$

$\text{Sin}\,A\,\text{Cos}\,B = \frac{1}{2}[\text{Sin}(A + B) + \text{Sin}(A - B)]$

$\text{Sin}(A \pm B) = \text{Sin}\,A\,\text{Cos}\,B \pm \text{Cos}\,A\,\text{Sin}\,B.$

$\text{Cos}\,A\,\text{Cos}\,B = \frac{1}{2}[\text{Cos}(A + B) + \text{Cos}(A - B)]$

Boltzmann constant $k = 1.38 \times 10^{-23}$ J/K

$$\int Sinax\,dx = -\frac{1}{a}Cosax \qquad \int Cosax\,dx = \frac{1}{a}Sinax$$

TABLE A
Bessel functions of the first kind

m	$J_0(m)$	$J_1(m)$	$J_2(m)$	$J_3(m)$	$J_4(m)$	$J_5(m)$	$J_6(m)$	$J_7(m)$	$J_8(m)$	$J_9(m)$	$J_{10}(m)$
0.0	1.000	—	—	—	—	—	—	—	—	—	—
0.2	0.990	0.099	0.005	—	—	—	—	—	—	—	—
0.4	0.960	0.196	0.019	0.001	—	—	—	—	—	—	—
0.6	0.912	0.286	0.043	0.004	—	—	—	—	—	—	—
0.8	0.846	0.368	0.075	0.010	0.001	—	—	—	—	—	—
1.0	0.765	0.440	0.114	0.019	0.002	—	—	—	—	—	—
2.0	0.223	0.576	0.352	0.128	0.034	0.007	0.001	—	—	—	—
3.0	-0.260	0.339	0.486	0.309	0.132	0.043	0.011	0.002	—	—	—
4.0	-0.397	-0.066	0.364	0.430	0.281	0.132	0.049	0.015	0.004	—	—
5.0	-0.177	-0.327	0.046	0.364	0.391	0.261	0.131	0.053	0.018	0.005	0.001
6.0	0.150	-0.276	-0.242	0.114	0.357	0.362	0.245	0.129	0.056	0.021	0.006
7.0	0.300	-0.004	-0.301	-0.167	0.157	0.347	0.339	0.233	0.128	0.058	0.023
8.0	0.171	0.234	-0.113	-0.291	-0.105	0.185	0.337	0.320	0.223	0.126	0.060
9.0	-0.090	0.245	0.144	-0.180	-0.265	-0.055	0.204	0.327	0.305	0.214	0.124
10.0	-0.245	0.045	0.254	0.058	-0.219	-0.234	-0.014	0.216	0.317	0.291	0.207