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UNIVERSITY OF SWAZILAND
FACULTY OF SCIENCE
MAIN EXAMINATION 2004/2005

TITLE OF PAPER : COMMUNICATION SYSTEMS

COURSE NUMBER : E410

TIME ALLOWED : THREE HOURS

INSTRUCTIONS : READ EACH QUESTION CAREFULLY
ANSWER ANY **FOUR** OUT OF **FIVE** QUESTIONS.
EACH QUESTION CARRIES **25 MARKS.**
MARKS FOR EACH SECTION ARE SHOWN ON THE RIGHT-HAND MARGIN.

THIS PAPER HAS 6 PAGES INCLUDING THIS PAGE.

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USEFUL INFORMATION

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

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

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

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

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

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

$m(t) = V_m Sin\omega_m t$

PM signal, $V_{PM}(t) = V_c Sin[\omega_c t + \beta p\, Sin\omega_m t]$

FM signal, $V_{FM}(t) = V_c\, Sin[\omega_c t - M_f\, Cos\omega_m t]$

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

Modulation Index (m_f)	Carrier Frequency J_0	n or order of sidebands 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, N.Y., 1948. Courtesy of the publisher.

QUESTION 1

(a)In Pulse Modulation, a digital carrier signal is modulated by an analogue signal. The technique where the width of a pulse is varied using the modulating signal is called Pulse Width Modulation (PWM). Assume the leading edge of the pulse is maintained constant while the trailing edge is varied in position.

The pulse durations will vary as $\tau(1 + mSin\omega_m t)$

The unmodulated pulse train can be represented by

$$P_T(t) = \frac{V\tau}{T} + 2\frac{V\tau}{T}\sum_{n=1}^{n=\infty}\frac{\sin n\pi \tau/T}{n\pi \tau/T}\operatorname{Cos} n\omega_s t,$$ where τ is the unmodulated pulse width, V = 1 volt.

(i) Derive an expression for the PWM signal, for small values of m (<0.15 rad). (3 marks)

(ii) Analyse your answer to (a) and suggest a method you would employ to recover the modulating signal from the received signal. (3 marks)

(iii) You are required to generate a dual - polarity Pulse Amplitude Modulated signal for use in Pulse Code Modulation transmission. Present a simple circuit diagram which can be used, explaining its operation. (6 marks)

(b) Can a Square - law detector be used to detect a message signal from the received full carrier AM? Include a mathematical analysis. (4 marks)

(c) (i) Design a simple tuned LC circuit for a radio receiver using a minimum of four components. Explain your design. (6 marks)

(ii) Discuss intersymbol interference(ISI) including one effective way of reducing its effects. (3 marks)

QUESTION 2

(a)

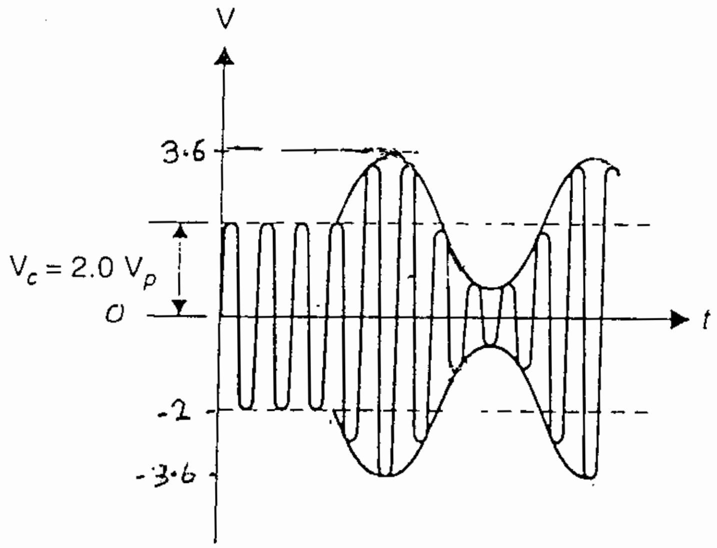
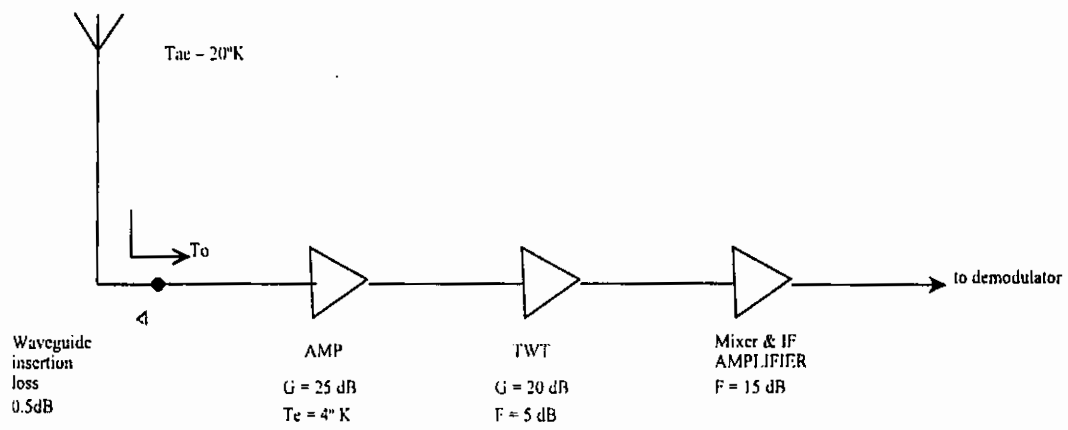


Figure 2.0

(i) Write an expression for the waveform shown on Figure 2.0. (4 marks)
(ii) Determine the amplitude and phase of the additional carrier which must be added to the waveform to attain a modulation index m = 0.2. (4 marks)

(b)An earth station receiver for a satellite-to-ground Super High frequency communication link is as shown below.



The various stages may be considered matched for maximum power transfer. Compute

(i) the overall noise figure of the system at the waveguide input and (10 marks)

(ii) the signal-to-noise power ratio at the input to the demodulator when the available signal power from the aerial is 7×10^{-13} W and the equivalent noise bandwidth of the receiver is 10 MHz. (8 marks)

QUESTION 3

(a) A waveform $x(t) = 10\cos\left(1000t + \pi/3\right) + 19.9\cos\left(2000t + \pi/6\right)$ is to be uniformly sampled for digital transmission.

(i) What is the maximum allowable time interval between sample values that will ensure perfect signal reproduction? (4 marks)

(ii) If x(t) is to be transmitted using PCM with quantisation interval width of about 0.087 V, compute the required transmission rate. (10 marks)

(b) Delta Modulation is used to quantize an audio signal $m(t) = 3Cos(1000\pi t)$. Compute the signal - to -quantization noise ratio. Assume a sampling rate eight times the Nyquist rate. (11 marks)

QUESTION 4

(a) (i) Present a simple circuit design where a varactor diode is used for FM generation. Discuss its operation. (5 marks)

(ii) A narrow band FM receiver has an input SNR of 3:1. What peak frequency deviation will the noise produce, given that the maximum frequency in the audio signal is 3 kHz? Assume there is no other noise contribution to the system. (4 marks)

(b)A 10^5Hz carrier signal is angle - modulated by a 15 kHz message signal. The available channel for transmission of the modulated waveform is 40 kHz.
Design a phase - modulator which can be used for the generation of the desired signal, whose frequency spectrum matches the available channel. Show all derivations, block diagrams etc. (7 marks)

(c) A 100 W carrier is frequency modulated by a sinusoidal signal of 5 kHz and unit amplitude. If the peak frequency deviation of the transmitter is carefully increased until the 8^{th} order side frequency component of the Bessel functions of the first kind, just begins to appear for the first time, compute

(i) the frequency deviation (3 marks)
(ii) the bandwidth of the signal (3 marks)
(iii) the average power in the 5^{th} order side frequency. (3 marks)

QUESTION 5

a) A 2- sec video shows 3 poles vertically placed in a straight line, 5 cm apart, with the grey one between the black and white ones. The black and white poles are 3 times the height of the grey one. Present a translation of a single scan of this scene into an electrical signal which can be used to convey the information to a receiver. (7 marks)

(b) An FM radio receiver is tuned to Channel 4 in the Citizens Band (RF signal at 27.005 MHz). The output of the first IF amplifier is at 10.695 ±.005 MHz. Give a detailed description of the detection process. Show calculations and diagrams. (8 marks)

(c)The output stage of an AM radio transmitter can deliver a maximum of 12 kW mean rf power into an aerial when modulated to a depth of 100 %. Determine

(i) the power output when the carrier is unmodulated. (3 marks)

(ii) Compare the possible power outputs when after modulation to a depth of 60 %, one sideband is suppressed, with when the SSB-SC system is employed. (7 marks)