University of KwaZulu-Natal
School of Engineering
Electrical, Electronic & Computer Engineering

Main Examinations: **December 2016**
Course & code: **Communications: ENEL3CO**

Duration: Three Hours **Total Marks:** 100

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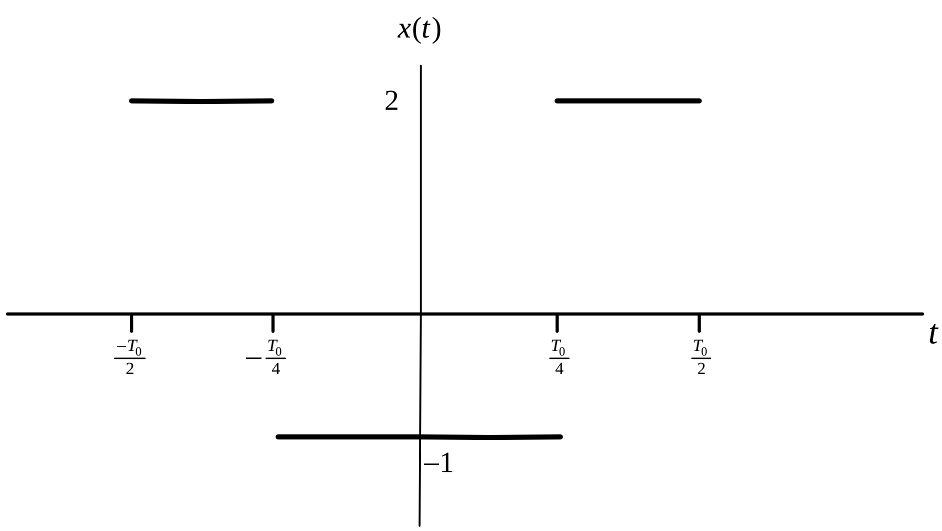
Instructions:

1. This paper consists of **four** questions (Two in Section A and two in Section B). Please answer all questions. ***Use separate answer books for each section.***
2. All questions must be answered in full for part marks to be awarded. **All relevant assumptions must be documented clearly.**
3. Programmable calculators may be used – all memory must be cleared.
4. No notes of any kind are allowed. Useful data is attached at the back of the question paper.

SECTION A
Question 1 **[25]**

1.1 For the waveform shown below, determine the following:



A. The Fourier series coefficients of the first five harmonic frequencies. [8]

B. Plot the single-sided amplitude spectrum of the first five harmonic frequencies. [2]

1.2 The amplitude frequency response of a linear time invariant system is given by:

$$|H(f)| = \begin{cases} 1, & -4f_0 \le f \le 4f_0 \\ \frac{1}{2}, & \text{elsewhere} \end{cases}$$

and the phase response is

$$\angle H(f) = \begin{cases} \dfrac{\pi}{2}, & f \ge 0 \\ -\dfrac{\pi}{2}, & \text{elsewhere} \end{cases}$$

The input signal $x(t)$ is given by

$$x(t) = \frac{1}{2}\sin(\omega_0 t + \frac{\pi}{2}) + \frac{1}{2}\cos(\omega_0 t + \frac{\pi}{2}) + \frac{1}{2}\cos(2\omega_0 t) + \frac{1}{2}\cos(6\omega_0 t)$$

Determine the following:

A. The input power spectral density. [3]

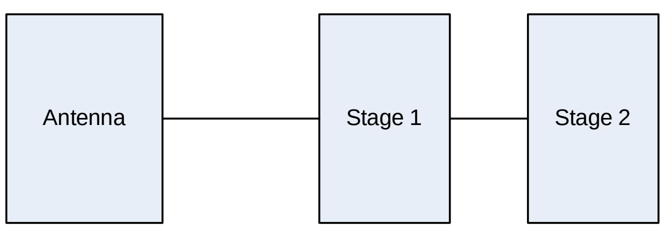
B. The output power spectral density. [4]

C. The signal at the output of the filter. [5]

1.3 Determine the convolution of the signals $x(t) = 2\Pi(t+2)$ and $x(t) = 2\Pi(\frac{t-1}{2})$. [3]

Question 2 **[25]**

2.1 The figure below shows a receiver system for satellite signals and is composed of an antenna, a feeder cable and a two-stage circuitry. The loss factor of the cable connecting the antenna to the first stage of the receiver is 0.4 dB, and each stage has a bandwidth of 27 MHz. The effective noise temperature of the antenna is 50 K.



G = 20 dB G = 10 dB

F = 1.5 dB F = 4 dB

A. Determine the effective noise temperature of the system. [5]

B. To guarantee a successful reception of the signal from the satellite, a minimum signal-to-noise ratio of 25 dB is required. Determine whether there would be a successful reception if the input signal power at the receiver is -90 dBW. [2]

2.2 A downlink satellite communication system has the following parameters.

Frequency	10 GHz
Received power	-116 dBW
Receiver Gain	40 dB
Transmitter Gain	30 dB
Distance	36000 km
System losses	5 dB
Receiver noise temperature	200 K
Bandwidth	10 MHz

A. Determine the transmit power level of the satellite station. [5]

B. Determine the EIRP. [1]

C. Determine the carrier-to-noise ratio. [4]

2.3 The autocorrelation function of the random process is given by $R(\tau) = 1 + \cos(\tau) + e^{-|\tau|}$. Determine the mean and variance of the random process. [8]

SECTION B

Question 3 [25]

3.1 Draw and label the spectrum of the composite baseband signal of stereophonic FM. A diode-bridge modulator is used to yield the DSB-SC component. Draw the circuit and show that the output is in fact DSB-SC. (You do not need to perform a Fourier analysis from first principles). [3+5]

3.2 Derive the direct method of generation for FM. Give an expression for the maximum capacitance deviation. [4+2]

3.3 In a binary pulse code modulation system, the output SQNR is to be held to a minimum of 40 dB. The uniform quantizer has L levels.

A. Prove that the SQNR is given as $\frac{3}{2}L^2$. [4]

B. Determine the number of required levels for the quantizer. [3]

3.4 VSB-AM is employed in analogue television to preserve spectrum space. Sketch the transmitter filter response and the relative demodulator output for such a system, where the baseband signal has a bandwidth of 4.5 MHz. [4]

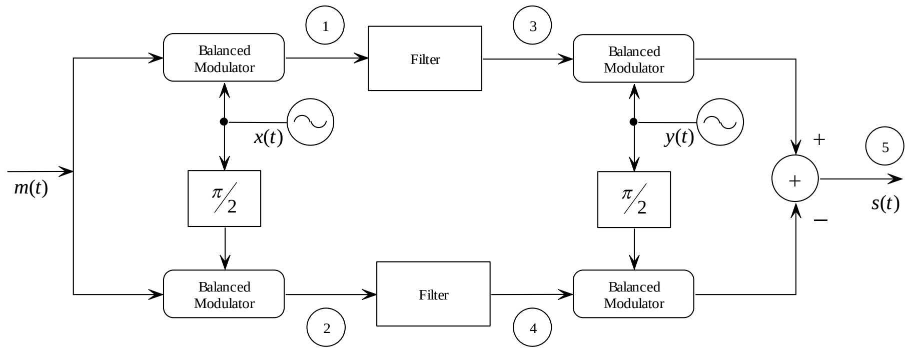
Question 4 [25]

4.1 A carrier is angle modulated by the sum of two sinusoids, $\beta_1 \sin w_1 t$ and $\beta_2 \sin w_2 t$, where the message frequencies are not harmonically related.

A. Write an expression for the modulated signal. [1]

B. Find the spectrum of the signal. [6]

4.2 Consider the following system:



A. Given the message signal $m(t) = 0.5\cos(2\pi 10^4 t)$, design the above system to achieve a single-sided spectral component of $10^6 + 10^4$ Hz at the output with amplitude 2 Volts. Draw the complete system and write out the signals at Points 1, 2, 3, 4 and 5. The carriers are not specified. [10]

B. A student is able to design a quadrature phase shifter, signal summer, envelope detector, frequency doublers and quadruplers. Suggest a possible option for recovery of the message. Prove the method. [8]

DATASHEET

Propagation loss factor $= \left(\frac{\lambda}{4\pi d}\right)^2$ where λ is the transmission wavelength and d is the distance of the satellite from the earth station.

$G_R = \frac{4\pi}{\lambda^2} A_R$, where A_R is the effective antenna aperture area.

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

Standard temperature T_o = 290 K

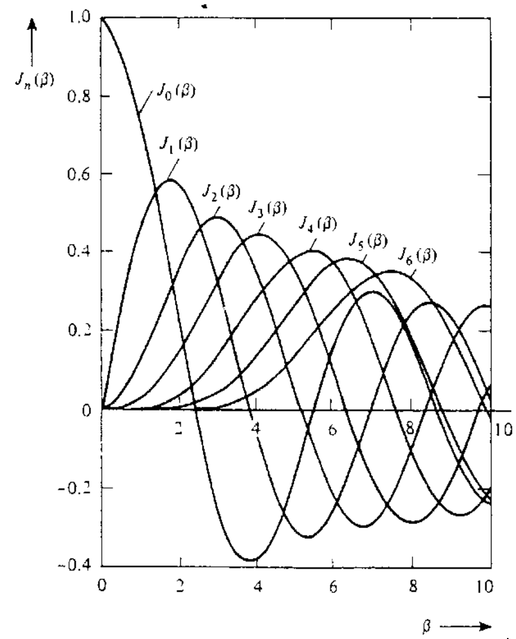
Speed of light = 3×10^8 m/s

TABLE OF FOURIER TRANSFORMS

Time Domain	Frequency Domain
$\delta(t)$	1
1	$\delta(f)$
$\delta(t-t_0)$	$e^{-j2\pi f t_0}$
$e^{j2\pi f_0 t}$	$\delta(f-f_0)$
$\cos(2\pi f_0 t)$	$\frac{1}{2}\delta(f-f_0)+\frac{1}{2}\delta(f+f_0)$
$\sin(2\pi f_0 t)$	$-\frac{1}{2j}\delta(f+f_0)+\frac{1}{2j}\delta(f-f_0)$
$\Pi(t)$	$\mathrm{sinc}(f)$
$\mathrm{sinc}(t)$	$\Pi(f)$
$\Lambda(t)$	$\mathrm{sinc}^2(f)$
$\mathrm{sinc}^2(t)$	$\Lambda(f)$
$e^{-\alpha t}u_{-1}(t), \alpha>0$	$\frac{1}{\alpha+j2\pi f}$
$te^{-\alpha t}u_{-1}(t), \alpha>0$	$\frac{1}{(\alpha+j2\pi f)^2}$
$e^{-\alpha\|t\|}$	$\frac{2\alpha}{\alpha^2+(2\pi f)^2}$
$e^{-\pi t^2}$	$e^{-\pi f^2}$
$\mathrm{sgn}(t)$	$1/(j\pi f)$
$u_{-1}(t)$	$\frac{1}{2}\delta(f)+\frac{1}{j2\pi f}$
$\delta'(t)$	$j2\pi f$
$\delta^{(n)}(t)$	$(j2\pi f)^n$
$\frac{1}{t}$	$-j\pi\,\mathrm{sgn}(f)$
$\sum_{n=-\infty}^{n=+\infty}\delta(t-nT_0)$	$\frac{1}{T_0}\sum_{n=-\infty}^{n=+\infty}\delta(f-\frac{n}{T_0})$

n \ β:	0.5	1	2	3	4	5	6	7	8	9	10
0	0.9385	0.7652	0.2239	−0.2601	−0.3971	−0.1776	0.1506	0.3001	0.1717	−0.09033	−0.2459
1	0.2423	0.4401	0.5767	0.3391	−0.06604	−0.3276	−0.2767	−0.004683	0.2346	0.2453	0.04347
2	0.03060	0.1149	0.3528	0.4861	0.3641	0.04657	−0.2429	−0.3014	−0.1130	0.1448	0.2546
3	0.002564	0.01956	0.1289	0.3091	0.4302	0.3648	0.1148	−0.1676	−0.2911	−0.1809	0.05838
4		0.002477	0.03400	0.1320	0.2811	0.3912	0.3576	0.1578	−0.1054	−0.2655	−0.2196
5			0.007040	0.04303	0.1321	0.2611	0.3621	0.3479	0.1858	−0.05504	−0.2341
6			0.001202	0.01139	0.04909	0.1310	0.2458	0.3392	0.3376	0.2043	−0.01446
7				0.002547	0.01518	0.05338	0.1296	0.2336	0.3206	0.3275	0.2167
8					0.004029	0.01841	0.05653	0.1280	0.2235	0.3051	0.3179
9						0.005520	0.02117	0.05892	0.1263	0.2149	0.2919
10						0.001468	0.006964	0.02354	0.06077	0.1247	0.2075
11							0.002048	0.008335	0.02560	0.06222	0.1231
12								0.002656	0.009624	0.02739	0.06337
13									0.003275	0.01083	0.02897
14									0.001019	0.003895	0.01196
15										0.001286	0.004508
16											0.001567

Table of Bessel values



Bessel Plots

Table of Useful Trignometric formulae

$\sin a \cos b = 0.5[\sin(a+b) + \sin(a-b)]$
$\cos a \sin b = 0.5[\sin(a+b) - \sin(a-b)]$
$\cos a \cos b = 0.5[\cos(a+b) + \cos(a-b)]$
$\sin a \sin b = 0.5[\cos(a-b) - \cos(a+b)]$
$\sin a + \sin b = 2\sin\left(\frac{a+b}{2}\right)\cos\left(\frac{a-b}{2}\right)$
$\cos a + \cos b = 2\cos\left(\frac{a+b}{2}\right)\cos\left(\frac{a-b}{2}\right)$
$\sin(a \pm b) = \sin a \cos b \pm \cos a \sin b$
$\cos(a \pm b) = \cos a \cos b \mp \sin a \sin b$