THE UNIVERSITY OF QUEENSLAND

VENUE:

SEAT NUMBER:

STUDENT NUMBER:

FINAL EXAMINATION

St Lucia Campus

First Semester, 2008

COMS3100 / COMS7100 — Introduction to Communications

PERUSAL TIME	**10mins.**	**During perusal, write on the blank paper provided**
WRITING TIME	**120 minutes**	
EXAMINER	**A/Prof. Vaughan Clarkson and Dr. Aleks Rakic**	

NO. OF PAGES (*include title page and attachments*) 9 Pages - Double-Sided

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Exam Type: **Closed Book - Specified materials permitted**

Permitted Materials:
Calculator - Yes - Non-programmable calculators only
Dictionary - Yes - Any unmarked paper dictionary is permitted
Other – No electronic aids are permitted (e.g. laptops, phone)

Answer: **In writing booklet**

Number of Questions: **7**

Weighting/Marks: **60% / 75 marks**

Special Instructions: **Students must comply with the General Award Rules 1A.7 and 1A.8 which outline the responsibilities of students during an examination.**

ANSWER ALL QUESTIONS

Question 1. (10 marks)

(a) Define the meaning of the terms:

i) instantaneous power,
ii) total energy,
iii) average power,
iv) energy signal,
v) power signal.

(5 marks)

(b) The energy signal $x(t) = \text{sinc}(10\pi t)$ is input to an ideal lowpass filter with cutoff frequency $f_\text{c} = 4$, producing the output signal $y(t)$.

i) Calculate $R_y(\tau)$.
ii) What proportion of the energy in $x(t)$ is dissipated in the filter?

(5 marks)

Question 2. (5 marks)

Consider the message signal $x(t) = \text{sinc}(\pi t)$. Carefully sketch the AM and DSB-SC signals in the time and frequency domains when $f_\text{c} = 5$.

Question 3. (10 marks)

(a) A frequency-sweep oscillator produces a sinusoidal output whose instantaneous frequency increases linearly from f_1 at $t = 0$ to f_2 at $t = T$. Write the expression for the instantaneous angle $\theta_c(t)$ for $0 \leqslant t \leqslant T$. (5 marks)

(b) A circuit whose output equals the time derivative of the input can be used to perform FM-to-AM conversion. Sketch a block diagram of such a circuit, explain the functions of individual blocks, briefly discuss its operation and with the aid of suitable equations demonstrate that it indeed performs the FM-to-AM conversion. (5 marks)

Question 4. **(10 marks)**

(a) In your own words, state the sampling theorem and explain the significance of the Nyquist rate. (5 marks)

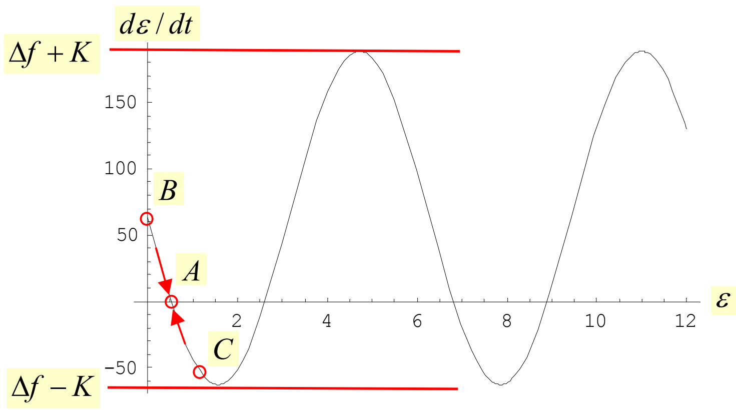

Figure 1: Phase-plane plot for Question 4(b).

(b) A plot of the derivative of a function versus the function is called a phase-plane plot. Figure 1 shows the phase-plane plot of a PLL described by the equation

$$\dot{\varepsilon}(t) = 2\pi[\Delta f - K \sin \varepsilon(t)].$$

Explain the meaning of the parameters $\varepsilon(t)$, K and Δf, the points B and C and why the PLL settles at the stable operating point A provided $K > \Delta f$. (5 marks)

Question 5. (20 marks)

(a) Name and briefly explain four of the parameters that determine the ability of a receiver to successfully demodulate a signal (receiver specifications). (5 marks)

(b) Sketch and briefly discuss the block diagram of a superhet receiver. (5 marks)

(c) Consider a superhet receiver that receives signals in the 50–54 MHz range with $f_{LO} = f_c + f_{IF}$. Assuming there is little filtering prior to the mixer, what frequency range of image input signals will be received by this system if $f_{IF} = 7$ MHz? (6 marks)

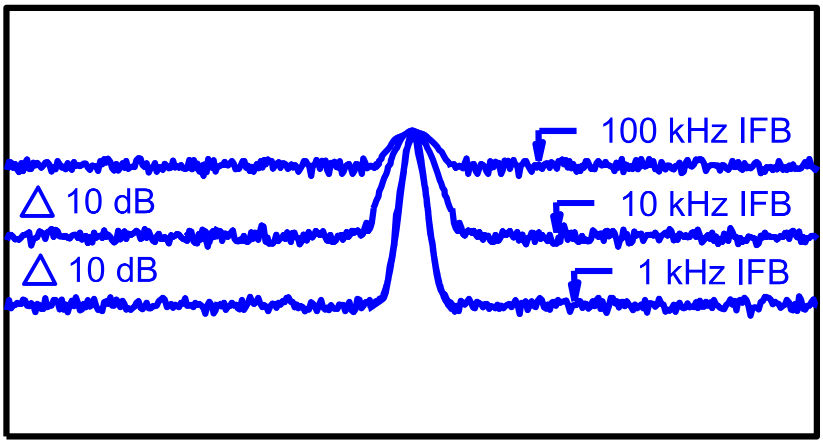

Figure 2: Spectrum analyser signals for Question 5(d).

(d) Figure 2 shows the same signal obtained using three different settings of the IF filter bandwidth on the RF swept frequency spectrum analyser. Explain the difference in the displayed noise levels between these signals and the effect this has on the signal to noise ratio. (4 marks)

Question 6. (10 marks)

(a) i) Sketch the polar NRZ line-coded waveform for the bit sequence 011010.

ii) Repeat i) for unipolar RZ.

iii) Based on your answers to i) and ii), comment briefly on which would be preferred if the objective were to:

- minimise the DC component,
- minimise the bandwidth,
- maximise the timing information,
- achieve robustness against polarity inversion.

(6 marks)

(b) What is the *Open Systems Interconnection (OSI)* model? Name any three layers in the model and explain their significance in one sentence each. (4 marks)

Question 7. (10 marks)

(a) The Bureau of Meteorology records wind direction at its weather stations nationwide at 9am and 3pm daily. The wind direction is classified according to eight points of the compass—N, NE, E, SE, S, SW, W, NW—or 'Calm' if no wind is detectable. At the 'Brisbane Aero' site, the frequencies of wind direction at 9am in June are tabulated in Table 1.

Table 1: Frequencies of wind direction at Brisbane Aero site in June for Question 7(a).

Direction	Frequency
N	0.04
NE	0.01
E	0.01
SE	0.02
S	0.11
SW	0.62
W	0.14
NW	0.04
Calm	0.01

i) Calculate the entropy of wind direction in bits.

ii) Construct a Huffman code for wind direction and calculate its average code length.

(6 marks)

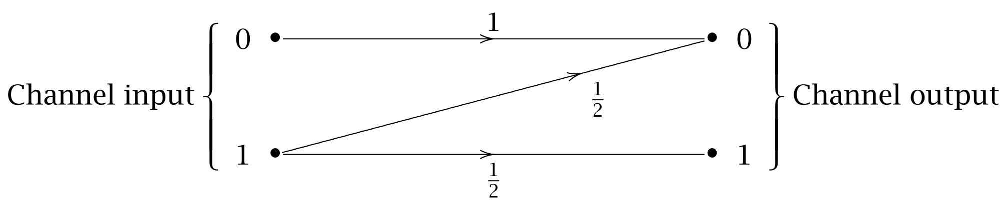

Figure 3: 'Z channel' for Question 7(b).

(b) Consider the 'Z channel' depicted in Figure 3. Given that $I(X; Y)$ is maximum when the probability of selecting a '0' at the channel input is $p = 3/5$, evaluate the channel's capacity. (4 marks)

Some Useful Formulae

Power Relationships in FM and PM Modulations

$$S_T = \tfrac{1}{2}A_c^2$$
$$P_c = \tfrac{1}{2}A_c^2 J_0^2(\beta)$$
$$P_1 = A_c^2 J_1^2(\beta)$$
$$P_2 = A_c^2 J_2^2(\beta)$$
$$\beta = \begin{cases} f_\Delta (A_m / f_m) & \text{FM} \\ \phi_\Delta A_m & \text{PM} \end{cases}$$

Transmission Bandwidth of FM

$$B_T = 2M(\beta) f_m \quad \text{with} \quad \frac{|J_M(\beta)|}{|J_0(\beta)|} \geqslant 1\%$$
$$B_T = 2(\beta + 2) f_m$$
$$B_T = 2(f_\Delta + W) = 2(D+1)W \quad \text{where} \quad D = \frac{f_\Delta}{W}$$

Nyquist Sampling Rate

$$f_s \geqslant 2W$$

PAM Transmission

$$B_T \geqslant \frac{1}{2\tau} \gg W$$
$$\tau < 0.1 T_s = 0.1 / f_s$$
$$r = M f_s \geqslant 2MW$$

Table 2: Comparison of Fourier representations.

Time Domain	***Periodic***	***Non-periodic***	
Discrete	***Discrete-Time Fourier Series*** $\tilde{X}[k] = \frac{1}{N}\sum_{n=0}^{N-1} \tilde{x}[n]e^{-j2\pi kn/N}$ $\tilde{x}[n] = \sum_{k=0}^{N-1} \tilde{X}[k]e^{j2\pi kn/N}$	***Discrete-Time Fourier Transform*** $X(e^{j\omega}) = \sum_{n=-\infty}^{\infty} x[n]e^{-j\omega n}$ $x[n] = \frac{1}{2\pi}\int_{-\pi}^{\pi} X\left(e^{j\omega}\right)e^{j\omega n}\,d\omega$	***Periodic***
Continuous	***Fourier Series*** $X[k] = \frac{1}{T}\int_{-T/2}^{T/2} \tilde{x}(t)e^{-j2\pi kt/T}\,dt$ $\tilde{x}(t) = \sum_{k=-\infty}^{\infty} X[k]e^{j2\pi kt/T}$	***Fourier Transform*** $X(j\omega) = \int_{-\infty}^{\infty} x(t)e^{-j\omega t}\,dt$ $x(t) = \frac{1}{2\pi}\int_{-\infty}^{\infty} X(j\omega)e^{j\omega t}\,d\omega$	***Non-periodic***
	Discrete	***Continuous***	***Freq. Domain***

Table 3: Properties of the discrete-time Fourier series.

Property	Time domain	Frequency domain
Linearity	$a\tilde{x}_1[n] + b\tilde{x}_2[n]$	$a\tilde{X}_1[k] + b\tilde{X}_2[k]$
Duality	$\tilde{X}[n]$	$\frac{1}{N}\tilde{x}[-k]$
Time-shift	$\tilde{x}[n-n_0]$	$e^{-j2\pi kn_0/N}\tilde{X}[k]$
Frequency-shift	$e^{j2\pi k_0 n/N}\tilde{x}[n]$	$\tilde{X}[k-k_0]$
Convolution	$\tilde{x}_1[n] \circledast \tilde{x}_2[n]$	$N\tilde{X}_1[k]\tilde{X}_2[k]$
Modulation	$\tilde{x}_1[n]\tilde{x}_2[n]$	$\tilde{X}_1[k] \circledast \tilde{X}_2[k]$
Time-reversal	$\tilde{x}[-n]$	$\tilde{X}[-k]$
Conjugation	$\tilde{x}^*[n]$	$\tilde{X}^*[-k]$
Symmetry (real)	$\mathfrak{Im}\{\tilde{x}[n]\} = 0$	$\tilde{X}[k] = \tilde{X}^*[-k]$
Symmetry (imag)	$\mathfrak{Re}\{\tilde{x}[n]\} = 0$	$\tilde{X}[k] = -\tilde{X}^*[-k]$
Parseval	$\sum_{n=0}^{N-1} \lvert\tilde{x}[n]\rvert^2 = N\sum_{k=0}^{N-1} \left\lvert\tilde{X}[k]\right\rvert^2$	

Table 4: Properties of the discrete-time Fourier transform.

Property	Time domain	Frequency domain
Linearity	$ax_1[n] + bx_2[n]$	$aX_1(e^{j\omega}) + bX_2(e^{j\omega})$
Differentiation (frequency)	$nx[n]$	$j\frac{dX(e^{j\omega})}{d\omega}$
Time-shift	$x[n-n_0]$	$e^{-j\omega n_0}X(e^{j\omega})$
Frequency-shift	$e^{j\omega_0 n}x[n]$	$X(e^{j(\omega-\omega_0)})$
Convolution	$x_1[n] * x_2[n]$	$X_1(e^{j\omega})X_2(e^{j\omega})$
Modulation	$x_1[n]x_2[n]$	$\frac{1}{2\pi}X_1(e^{j\omega}) \circledast X_2(e^{j\omega})$
Time-reversal	$x[-n]$	$X(e^{-j\omega})$
Conjugation	$x^*[n]$	$X^*(e^{-j\omega})$
Symmetry (real)	$\mathfrak{Im}\{x[n]\} = 0$	$X(e^{j\omega}) = X^*(e^{-j\omega})$
Symmetry (imag)	$\mathfrak{Re}\{x[n]\} = 0$	$X(e^{j\omega}) = -X^*(e^{-j\omega})$
Parseval	$\sum_{n=-\infty}^{\infty} \lvert x[n]\rvert^2 = \frac{1}{2\pi}\int_{-\pi}^{\pi} \left\lvert X(e^{j\omega})\right\rvert^2 d\omega$	

Table 5: Properties of the Fourier series.

Property	Time domain	Frequency domain
Linearity	$a\tilde{x}_1(t) + b\tilde{x}_2(t)$	$aX_1[k] + bX_2[k]$
Differentiation (time)	$\frac{d\tilde{x}(t)}{dt}$	$\frac{j2\pi k}{T}X[k]$
Time-shift	$\tilde{x}(t-t_0)$	$e^{-j2\pi k t_0/T}X[k]$
Frequency-shift	$e^{j2\pi k_0 t/T}\tilde{x}(t)$	$X[k-k_0]$
Convolution	$\tilde{x}_1(t) \circledast \tilde{x}_2(t)$	$TX_1[k]X_2[k]$
Modulation	$\tilde{x}_1(t)\tilde{x}_2(t)$	$X_1[k] \circledast X_2[k]$
Time-reversal	$\tilde{x}(-t)$	$X[-k]$
Conjugation	$\tilde{x}^*(t)$	$X^*[-k]$
Symmetry (real)	$\mathfrak{Im}\{\tilde{x}(t)\} = 0$	$X[k] = X^*[-k]$
Symmetry (imag)	$\mathfrak{Re}\{\tilde{x}(t)\} = 0$	$X[k] = -X^*[-k]$
Parseval	$\frac{1}{T}\int_{-T/2}^{T/2} \lvert\tilde{x}(t)\rvert^2 dt = \sum_{k=-\infty}^{\infty} \lvert X[k]\rvert^2$	

Table 6: Properties of the Fourier transform.

Property	Time domain	Frequency domain
Linearity	$a\tilde{x}_1(t) + b\tilde{x}_2(t)$	$aX_1(j\omega) + bX_2(j\omega)$
Duality	$X(jt)$	$2\pi x(-\omega)$
Differentiation	$\frac{dx(t)}{dt}$	$j\omega X(j\omega)$
Integration	$\int_{-\infty}^{t} x(\tau)\, d\tau$	$\frac{1}{j\omega}X(j\omega) + \pi X(j0)\delta(\omega)$
Time-shift	$x(t - t_0)$	$e^{-j\omega t_0}X(j\omega)$
Frequency-shift	$e^{j\omega_0 t}x(t)$	$X(j(\omega - \omega_0))$
Convolution	$x_1(t) * x_2(t)$	$X_1(j\omega)X_2(j\omega)$
Modulation	$x_1(t)x_2(t)$	$\frac{1}{2\pi}X_1(j\omega) * X_2(j\omega)$
Time-reversal	$x(-t)$	$X(-j\omega)$
Conjugation	$x^*(t)$	$X^*(-j\omega)$
Symmetry (real)	$\mathfrak{Im}\{x(t)\} = 0$	$X(j\omega) = X^*(-j\omega)$
Symmetry (imag)	$\mathfrak{Re}\{x(t)\} = 0$	$X(j\omega) = -X^*(-j\omega)$
Scaling	$x(at)$	$\frac{1}{\lvert a\rvert}X\left(\frac{j\omega}{a}\right)$
Parseval	$\int_{-\infty}^{\infty} \lvert x(t)\rvert^2\, dt = \frac{1}{2\pi}\int_{-\infty}^{\infty} \lvert X(j\omega)\rvert^2\, d\omega$	