Durham University

# Examination Paper

| Examination Session: | Year: | Exam Code: |
|---|---|---|
| May/June | 2020 | ENGI4121-WE01 /ENGI40720-WE01 |

**Title: MEng Engineering**

**Communications Systems Paper 1**

| | | |
|---|---|---|
| Time Allowed: | 2 hours | |
| Additional Material provided: | None. | |
| Materials Permitted: | None. | |
| Calculators Permitted: | | Models Permitted: Those from the Casio fx-83 and fx-85 series. |
| Visiting Students may use dictionaries: | YES | |



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|---|---|
| **Instructions to Candidates:** | Answer ALL questions.<br>All relevant workings must be shown. |

| | |
|---|---|
| Revision: | |

**Question 1**

(a) A baseband transmission system transmits the Manchester code where binary 1 is represented by +V for the first half of the bit duration and -V for the second half.

(i) Give the representation for binary 0.

[5%]

(ii) Determine the correlation coefficient between the two baseband signals representing the one and the zero.

[10%]

(iii) Design a suitable matched filter detector and sketch its output due to an input sequence 1101.

[20%]

(b) A binary frequency shift keying communication system transmits $s_o(t) = 1.414\cos(1000t)$ to represent binary 1 (mark) and $s_1(t) = 1.414\cos(1010t)$ to represent binay 0 (space). Find the probability of error assuming equal probability of transmission of mark and space signals, a single sided noise power spectral density equal to 0.08 W/Hz and bit duration, T=1 second.



[25%]

(c) What is the sampling instant signal to noise ratio in dB at the output of a filter matched to a rectangular pulse of height 10 mV and width 1 ms if the noise at the input to the filter is white with a power spectral density of $1 \times 10^{-9}$ W/Hz?



[30%]



(d) Figure Q.1 shows the correlation detector of a phase shift keying (PSK) signal. Explain its functionality and discuss its synchronisation requirements for optimum performance.

[10%]

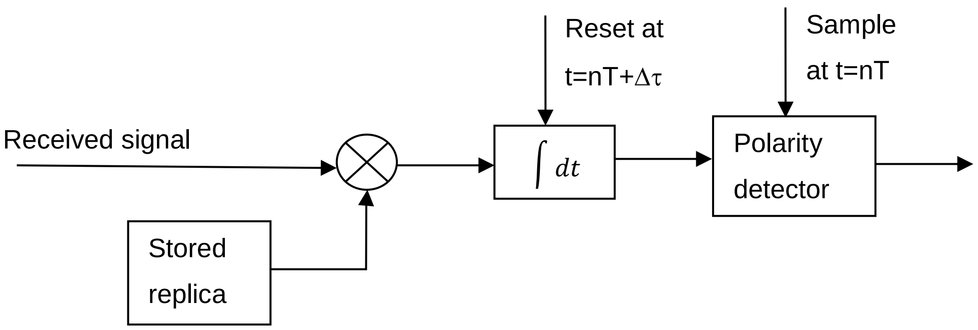


**Figure Q.1**

Use can be made of the following relationships:

**continued**

$$P_e = \frac{1}{2} erfc\sqrt{\frac{E(1-\rho)}{2N_o}} \quad \text{and} \quad \rho = \frac{\int_0^T s_{mark}(t) s_{space}(t)dt}{\sqrt{\int_0^T s(t)^2_{mark}dt \int_0^T s(t)^2_{space}dt}}$$

where $P_e$ is the probability of error, E is the energy per bit and $\rho$ is the correlation coefficient, $s_{mark}(t), s_{space}(t)$ are the mark and space signals, respectively and T is the bit duration.

$$\cos(2\pi f_1 t) . \cos(2\pi f_2 t) = \frac{1}{2}\{\cos(2\pi f_1 + 2\pi f_2)\, t + \cos(2\pi f_1 - 2\pi f_2)\, t\}$$

**Question 2**

(a) A mobile receiver is located 5 km away from a base station and uses a vertical $\lambda/4$ monopole antenna with a gain of 2.55 dB to receive cellular radio signals. The free space E-field at 1 km from the transmitter is equal to $10^{-3}$ V/m. The carrier frequency used for this system is 900 MHz.

(i) Find the length and the gain of the receiving antenna in the linear scale.

[10%]

(ii) Find the received power at the mobile using the 2-ray ground reflection model assuming the height of the transmitting antenna is 50 m and the receiving antenna is 15 m above ground.



For the ground reflection model, the received electric field is given by



$$E = 2E_o \frac{2\pi}{\lambda}\frac{h_T h_R}{d}$$

where $E_o$ is the free space electric field, $h_T, h_R$, are the height of the transmitter and the receiver above ground respectively, and $d$ is the distance between the transmitter and the receiver.



Use can be made of $\frac{E^2}{\eta} = \frac{P_T G_T}{4\pi d^2}$ where d is the distance between the transmitter and receiver, $P_T$ is the transmitted power, $G_T$ is the gain of the transmit antenna, $\eta = 377\ \Omega$ is the free space impedance.

[40%]

(b) The first generation analogue mobile radio system in North America AMPS, was designed for voice communication. It uses the band between 824 to 849 MHz for reverse link and the band between 869 to 894 MHz for the forward link. Using frequency division multiple access FDMA with 30 kHz separation between channels, and two service providers determine the following:

(i) Total number of available channels for each service provider.

[10%]

(ii) Assume that each service provider allocates 21 channels for control. Determine the number of channels per cell for a cluster size of 7.

[10%]

(iii) Explain how the number of users can be increased in such a system.

[5%]

**continued**

(c) Explain the difference between fast and slow fading and how they are modelled.

[25%]

**Table of values of the error function and the complementary error function:**

$$\mathrm{erf}(x) = \frac{2}{\sqrt{\pi}} \int_0^x e^{-u^2}\ du \qquad \mathrm{erf\,c}(x) = \frac{2}{\sqrt{\pi}} \int_x^\infty e^{-u^2}\ du$$

| x | erf(x) | erfc(x) | x | erf(x) | erfc(x) |
|---|---|---|---|---|---|
| 0.00 | 0.0000000 | 1.0000000 | 1.30 | 0.9340079 | 0.0659921 |
| 0.05 | 0.0563720 | 0.9436280 | 1.40 | 0.9522851 | 0.0477149 |
| 0.10 | 0.1124629 | 0.8875371 | 1.50 | 0.9661051 | 0.0338949 |
| 0.15 | 0.1679960 | 0.8320040 | 1.60 | 0.9763484 | 0.0236516 |
| 0.20 | 0.2227026 | 0.7772974 | 1.70 | 0.9837905 | 0.0162095 |
| 0.25 | 0.2763264 | 0.7236736 | 1.80 | 0.9890905 | 0.0109095 |
| 0.30 | 0.3286268 | 0.6713732 | 1.90 | 0.9927904 | 0.0072096 |
| 0.35 | 0.3793821 | 0.6206179 | 2.00 | 0.9953223 | 0.0046777 |
| 0.40 | 0.4283924 | 0.5716076 | 2.10 | 0.9970205 | 0.0029795 |
| 0.45 | 0.4754817 | 0.5245183 | 2.20 | 0.9981372 | 0.0018628 |
| 0.50 | 0.5204999 | 0.4795001 | 2.30 | 0.9988568 | 0.0011432 |
| 0.55 | 0.5633234 | 0.4366766 | 2.40 | 0.9993115 | 0.0006885 |
| 0.60 | 0.6038561 | 0.3961439 | 2.50 | 0.9995930 | 0.0004070 |
| 0.65 | 0.6420293 | 0.3579707 | 2.60 | 0.9997640 | 0.0002360 |
| 0.70 | 0.6778012 | 0.3221988 | 2.70 | 0.9998657 | 0.0001343 |
| 0.75 | 0.7111556 | 0.2888444 | 2.80 | 0.9999250 | 0.0000750 |
| 0.80 | 0.7421010 | 0.2578990 | 2.90 | 0.9999589 | 0.0000411 |
| 0.85 | 0.7706681 | 0.2293319 | 3.00 | 0.9999779 | 0.0000221 |
| 0.90 | 0.7969082 | 0.2030918 | 3.10 | 0.9999884 | 0.0000116 |
| 0.95 | 0.8208908 | 0.1791092 | 3.20 | 0.9999940 | 0.0000060 |
| 1.00 | 0.8427008 | 0.1572992 | 3.30 | 0.9999969 | 0.0000031 |



**continued**

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|---|---|---|---|---|---|
| 1.10 | 0.8802051 | 0.1197949 | 3.40 | 0.9999985 | 0.0000015 |
| 1.20 | 0.9103140 | 0.0896860 | 3.50 | 0.9999993 | 0.0000007 |