CARLETON UNIVERSITY

Department of Systems and Computer Engineering

SYSC4700 Telecommunications Engineering Winter 2016

Term Exam – 10 February 2016

1. **NO CELL PHONES. Closed-book exam (with one-page aid-sheet).**
2. **Write answers in the spaces provided on the question sheet.**
3. **5 pages including this cover page.**
4. **Duration: 75 minutes**

Name: **Student Number:**

Question	Mark	Max possible mark
1		**110**
2		**40**
3		**40**
Total		**190**

USEFUL EXPRESSIONS:

Received power: $P_{RX} = P_{TX} + G_{TX} - PL + G_{RX}$ (dB scale)
Received power: $P_{RX} = P_{TX}\, G_{TX}\, G_{RX} / PL$ (linear scale)

Noise power: $P_N = k\, T\, B\, F$ Watts (linear scale)
where $k = 1.38 \times 10^{-23}$ (Boltzmann's constant); T = 273+°C
Noise power: $P_N = -228.6 + 10\log_{10}(273 + C°) + 10\log_{10}(B) + F$ dBW (dB scale)
where °C: temp. in degrees centigrade; B: bandwidth in Hz; F: noise figure

SNR = $P_{RX} - P_N$ (dB scale)
SNR in linear: P_{RX} / P_N (linear scale)

Free space path loss: FSPL = $(4\pi d/\lambda)^2$ (linear scale)
FSPL = $-147.6 + 20 \log_{10}(f) + 20 \log_{10}(d)$ (dB scale)
where frequency *f* is in Hz and distance *d* is in m.

PL is terrestrial radio links: PL = $A + 20 \log_{10}(f) + 10n \log_{10}(d)$
where *n* (>2) is the propagation exponent.

Question 1 – Short Questions [110 points]

a) [5 pts] Briefly explain why the concept of "dynamic routing" is used in telephone networks.

b) [5 pts] Who is the engineer/mathematician known as the father of information theory?

c) [5 pts] What does power spectral density (power spectrum) describe?

d) [5 pts] In analog-to-digital conversion through the PCM approach, no matter how carefully the PCM parameters are chosen, there is always an irrecoverable loss of information during a particular operation. What is that operation?

e) [10 pts] What is the bit rate used to transmit digital voice,

- in wireless cellular networks (approximate value)?
- in wired telephone networks?
- in CD quality (approximate value)?

f) [5 pts] Define spectral efficiency.

g) [10 pts] How many dBs should the SNR be increased in order to increase the spectral efficiency from m to m+1 (use Shannon's formula, and assume that SNR is high)?

h) [10 pts] In a wireless system, the path loss is given as PL = -150 + 20 $\log_{10}(f)$ + 35 $\log_{10}(d)$. Assume that the carrier frequency in this system is increased from 800 MHz to 2.4 GHz. What will be the impact on the following (decrease or increase by how much):

- wavelength:
- speed of light:
- path loss:

i) [5 pts] The noise power in a 10 MHz channel centered at 5.4 GHz is measured as -98 dBm. How much will the noise power be in a 10 MHz channel centered at 900 MHz.

j) [10 pts] The noise power in a channel is measured as -103 dBm when the temperature is 20 ^{O}C. How many dBs will the noise power increase or decrease when the temperature increases to 25 ^{O}C?

k) [10 pts] DVB-C2 (Digital Video Broadcasting -- Cable) is a European standard for the broadcast transmission of digital television over cable networks (approved in 2009). The future extensions of this standard will allow modulation levels up to 65536-QAM. At such a modulation level, what will be the bit rate in an 8 MHz channel.

l) [10 pts] What do the following acronyms stand for?

- ADSL:
- PCM:
- FTTH:
- What is the popular acronym for the 4G wireless standard?:

m) [5 pts] Who invented telegraph, in which century?

- Inventor:
- Century:

n) [15 pts] The data rate can be calculated as $R = n\ B\ SE$ [bits/sec], where n is the MIMO gain, SE is the spectral efficiency [bits/sec/Hz], and B is the bandwidth [Hz].

In a wireless system these parameters are given as follows: n = 100, B = 300 MHz @ 1 GHz carrier, SE = 30 bits/sec/Hz.

- Calculate R using the above values.
- Discuss how realistic the given n, W, and SE values are (justify your answer).

Question 2 [40 marks] – ADC and TDM Hierarchy

A PCM-based analog-to-digital converter (ADC) for voice uses the following specifications:

- The ADC captures the detail in the voice signal up to 15 kHz.
- 256 levels are used for quantization.

Consider a time-division multiplexing scheme (TDM) which combines the digital output from users whose analog data is digitized through the above described ADC scheme. A TDM frame consists of samples from 12 users plus 2 bits for synchronization purposes.

Next, 20 of the above described frames are combined together, another 6 bits are added for synchronization, and thus a super-frame is formed (note that each frame in a super-frame carries data from different sets of users).

Calculate the required line speed to transmit these super-frames.

Question 3 [40 marks] – Link Budget

Consider a cellular user who is walking towards one BS (base station) to another, denoted as BS_A and BS_B, which are 100 meters apart.

The path loss between the user and the BSs is given as $PL = 105 + 10n \log_{10}(d)$ dB, where n is the propagation exponent.

The transmit power of both BSs is the same; however the n values are different: $n_A = 2$ and $n_B = 4$.

At what point, the received signal powers from both BSs will be the same? (That is, when the received powers are the same, how far will the user be away from BS_A?)