CARLETON UNIVERSITY

Department of Systems and Computer Engineering

SYSC4700 Telecommunications Engineering Winter 2017

Term Exam SOLUTIONS – 15 February 2017

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		30
2		25
3		40
4		30
Total		125

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.

Q1 [30 pts] – Short Questions:

a) **[5 pts]** Compare IoT and M2M communications from the TCP/IP perspective.

Applications layer must be present in IoT. Therefore, IoT requires TCP/IP. But M2M does not require TCP/IP.

b) **[5 pts]** State two main difference between circuit switching (TDM) and packet switching.

- Fixed speed vs speed conversion
- Dedicated vs shared bandwidth
- Call set up vs IP routing
- Separate vs integrated switching and multiplexing
- Fixed delay vs variable delay

c) **[5 pts]** What does "data analytics" refer to?

Data Analytics refers to the extraction of knowledge from large data sets.

d) **[5 pts]** What is the difference between a "standard" and a "regulation"?

Mandatory standards are called regulations

e) **[5 pts]** Given two examples of highly successful standards developed by the IEEE.

- 802.11
- 802.16
- 802.3 Ethernet
- 802.15 Bluetooth/ZigBee

f) **[5 pts]** Standards play an important role in the wireless industry.

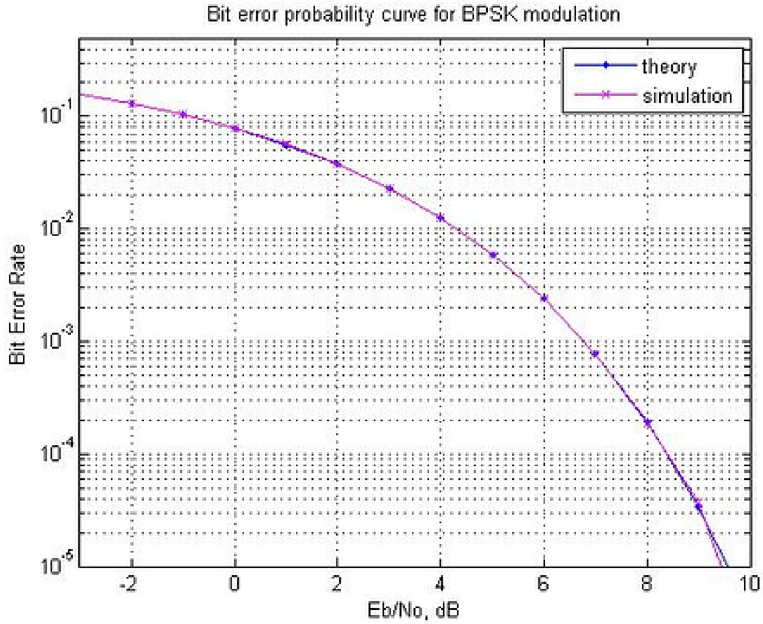
- Write one benefit of the standards to the vendors.

  Global market

- Write one benefit of the standards to the operators.

  Multiple sources of supplies

Q2 [25 pts] – Power Calculations: In the 4G LTE wireless networks, the bandwidth is assigned to applications in terms of "resource blocks (RBs)". The bandwidth of one RB is 200 KHz.



Consider an LTE application that uses BPSK modulation; the corresponding BER versus SNR (E_b/N_0) relation is given in the above figure. This application requires a BER of 10^{-4} and it is assigned one RB.

The AWGN power spectral density is N_0 = -174 dBm/Hz, and the receiver noise figure is 6 dB. Find the necessary received signal power, P_{RX}, in Watts.

$P_N = N_0 + B + F = -174$ dBm/Hz + $10\log_{10}(200*10^3) + 6 = -114.9$ dBm

BER = 10^{-4} → SNR = 8.5 dB

SNR = $P_S - P_N$

P_S = SNR + P_N = 8.5 dB + -114.9dBm = -106.48 dBm = -136.48 dBW = $2.25*10^{-14}$ W

Q3 [40 pts] – Short Questions:

a) **[10 pts]** 4G LTE promises rates up to 1 Gbps. On the other hand, the rates wireless users experiences are substantially less. Describe the two main reasons for this situation.

- The advertised rates are "shared" rates by all the users served by a BS; as such, each user gets only a small fraction of this sum-rate. (In other words, each user gets a small amount of bandwidth).

- Unless a user is very close to the BS, its SNR will be low; in turn, its spectral efficiency will also be low [remember, $SE_{max} = \log_2(1+SNR)$].

Rate comes from the product of bandwidth and spectral efficiency. If both of them are low, the rate is also low.

b) **[15 pts]** Consider a high-quality analog-to-digital converter (ADC) for voice signals with the following specifications:

- The ADC captures the detail in the voice signal up to 15 KHz.
- 1024 levels are used for quantization.

Next, consider a time-division multiplexing scheme (TDM) which combines the digital output from 13 users whose analog data is digitized through the above described ADC scheme. A TDM frame consists of samples from 13 users plus three bits for synchronization purposes.

Find the line speed (in bits/sec) to carry this TDM traffic.

$\log_2(1024)$ =10 bits per sample

Sampling rate = $30*10^3$ sample per second

$(13*10+3) *30*10^3$=3.99 Mbit/sec

c) [**5 pts**] Which one of the following numbers is a typical path-loss value in a wireless network, if a user is about 1 km away from BS: -1000 dB, -100 dB, -10 dB, 0 dB, 10 dB , 100 dB, 1000 dB?

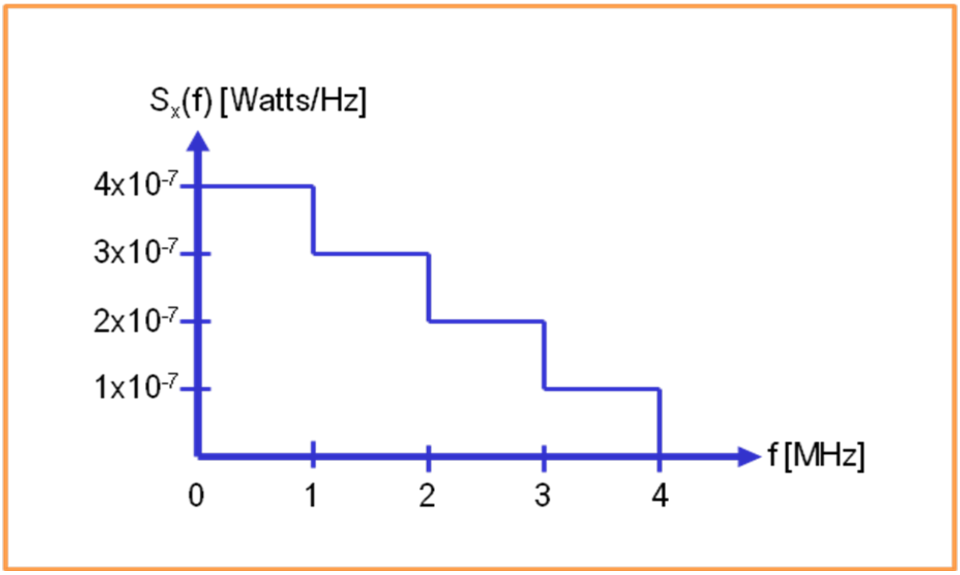
100 dB

d) **[10 pts]** What is the highest bit-rate achievable in a system with the following parameters?

- SNR = 20 dB
- Number of transmit antennas = 6
- Number of receive antennas = 4
- Bandwidth = 20 MHz

$\min(6,4)*20*10^6*\log_2(1+100)$ = 532.65 Mbps

Q4 [30 pts] – Power Spectral Density: The power spectral density, $S_x(f)$, for a digital signalling scheme is given below. PSD is symmetric with respect to the vertical axis; the left part is not shown.



a) Find the total power of this signalling scheme.

2*[(4*1) +(3*1) +(2*1) +(1*1)] $*10^{-7}*10^{-6}$= 2 Watts

b) How much power does this signalling scheme has between 2 MHz and 3 MHz?

0.2 x 2=0.4 Watts

c) How much power does this signalling scheme has at 3 MHz?

0 Watts

d) Find the absolute bandwidth of this signalling scheme.

4 MHz

e) $BW_{90\%}$ (90%-bandwidth) is defined as the frequency below which 90% of the total power is confined to. Find $BW_{90\%}$ for this signalling scheme.

Total power = 2 Watts

2*0.9=1.8 Watts → 3 MHz