ELEX 7860 : Wireless System Design
2020 Winter Term

FINAL EXAM
2:30 PM – 5:30 PM
Wednesday, April 17, 2020

This exam has eight (8) questions on three (3) pages. The marks for each question are as indicated. There are a total of twenty-seven (27) marks.
Download this exam and write your answers in a separate document (on paper, using a tablet or word processor). At the end of your document please insert the following text and sign or write your name under it:

> This work is solely my own effort and I understand the consequences of plagiarism and other offences described in BCIT Policy 5104.
>
> Signed: _____

When you are done, convert your document to PDF format (scan it with a phone app such as Genius Scan or Adobe Scan, or export it to a PDF file). Submit your paper before the submission deadline: Friday, April 17 at 5:30 PM. You may submit multiple times. Only the most recent submission will be marked.
Answer all questions. Show your work. Draw a box around your final answer. Numerical answers must include units. Books and notes are allowed. **Show your work.**

This exam paper is for:

Exam 1 A00123456

Each exam is equally difficult.

Answer your own exam.

Question 1 — 4 marks

An app on my phone says the signal received from my 2.4 GHz WiFi router is being received at −46 dBm. Assuming:

- a line-of-sight path between me and the router,
- the router's power output is 100 mW, and
- both the transmit and receive antenna gains are 0 dBi

How far am I from the router?

Question 2 — 2 marks

I measured the received signal level of the BCIT FM radio station at two distances from their Metrotown transmitter site. In Central Park, about 1.25 km away, the signal was −48 dBm. At BCIT, about 2.5 km away the signal was −57 dBm. Assuming a power-law relationship between distance and path loss, what is the path-loss exponent?

Question 3 — 3 marks

At BCIT I measured the average received signal level within each classroom in SW1. This average signal level appears to have a log-normal distribution with a mean of −70 dBm and a standard deviation of 10 dBm. What fraction of the classrooms will have an average received signal level stronger (higher power) than −60 dBm?
Hint: see the Appendix.

Question 4 — 2 marks

A signal received on one antenna is faded about 20% of the time. What is the minimum number of independently-fading antennas required by a receiver using selection diversity so that the signal is only faded 1% of the time?

Question 5 — 5 marks

An OFDM transmitter uses a sampling rate of 4 MHz and an FFT size of 128. Only 100 of the 128 subcarriers are used. A 5 μs guard time is left between each symbol. 16-QAM is used on each subcarrier.

(a) What is the symbol rate (including the effect of the guard time)?

(b) How many bits are transmitted per (OFDM) symbol?

(c) What is the transmitted bit rate?

Question 6 — 6 marks

An $(n, k) = (4, 2)$ FEC code has the generator matrix:

$$G = \begin{bmatrix} 1 & 0 & 1 & 0 \\ 0 & 1 & 1 & 1 \end{bmatrix}$$

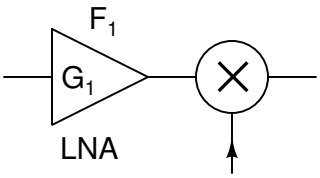
What is the minimum distance of this code? Show your work.

Question 7 — 2 marks

- An RF power amplifier has an OIP3 of 40 dBm. If the output power is 20 dBm, what is the power of the third-order intermodulation product components? Give your answer in dBm.
- If the transmitted signal has two frequency components at 5102 MHz and 5104 MHz, what are the frequency(ies) of the third-order intermodulation components?

Question 8 — 3 marks

The front-end of a receiver consists of an LNA followed by a mixer:



The noise figure of the LNA is $F_1 = 3$ dB with a gain of $G_1 = 6$ dB. The mixer has a loss of 6 dB. What is the overall (cascade) noise figure? Give your answer in dB.

Hint: The noise figure of an attenuator with loss L (gain $\frac{1}{L}$) is L. For example, the noise figure of a 3 dB attenuator (gain $= -3\,\text{dB} = 0.5$) is 2.

Appendix

The values on the line along the bottom give the values of the Gaussian CDF in percent. For example, the probability that a Gaussian random variable has a value *less than* 1 standard deviation below the mean can be obtained from this line as approximately 16% at -1σ.

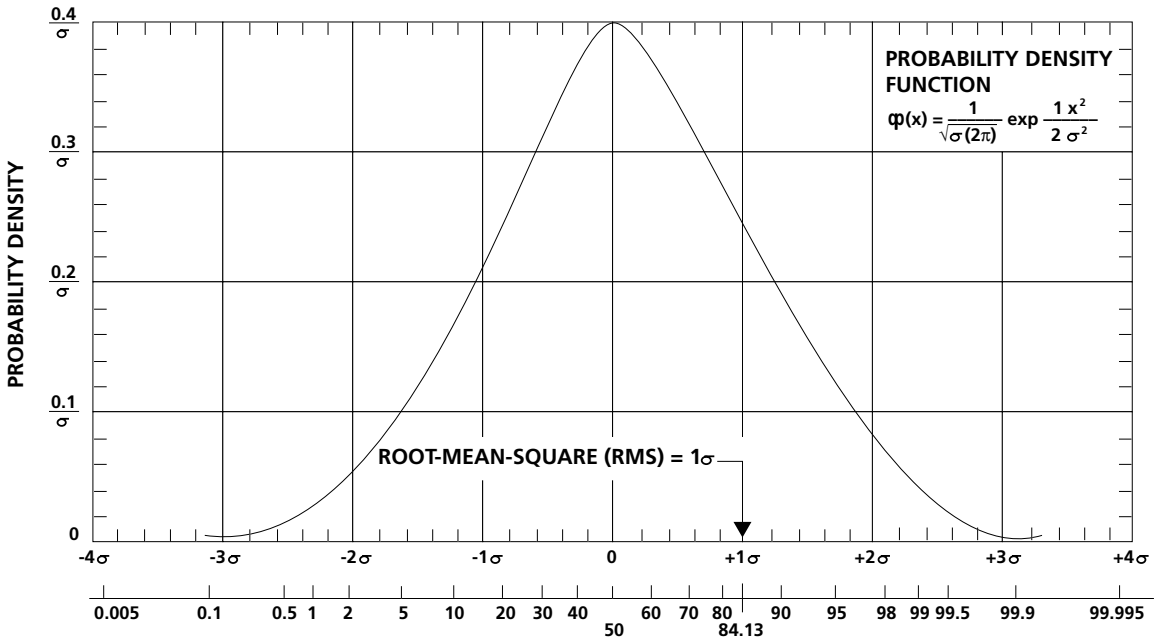


Figure 1. Gaussian Voltage Distribution

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Exam 2 A00123456

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Answer your own exam.

Question 1 — 4 marks

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- a line-of-sight path between me and the router,
- the router's power output is 100 mW, and
- both the transmit and receive antenna gains are 0 dBi

How far am I from the router?

Question 2 — 2 marks

I measured the received signal level of the BCIT FM radio station at two distances from their Metrotown transmitter site. In Central Park, about 1.25 km away, the signal was −51 dBm. At BCIT, about 2.5 km away the signal was −60 dBm. Assuming a power-law relationship between distance and path loss, what is the path-loss exponent?

Question 3 — 3 marks

At BCIT I measured the average received signal level within each classroom in SW1. This average signal level appears to have a log-normal distribution with a mean of −66 dBm and a standard deviation of 6 dBm. What fraction of the classrooms will have an average received signal level stronger (higher power) than −60 dBm?
Hint: see the Appendix.

Question 4 — 2 marks

A signal received on one antenna is faded about 20% of the time. What is the minimum number of independently-fading antennas required by a receiver using selection diversity so that the signal is only faded 1% of the time?

Question 5 — 5 marks

An OFDM transmitter uses a sampling rate of 4 MHz and an FFT size of 256. Only 200 of the 256 subcarriers are used. A 5 μs guard time is left between each symbol. 16-QAM is used on each subcarrier.

(a) What is the symbol rate (including the effect of the guard time)?

(b) How many bits are transmitted per (OFDM) symbol?

(c) What is the transmitted bit rate?

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An $(n, k) = (4, 2)$ FEC code has the generator matrix:

$$G = \begin{bmatrix} 1 & 0 & 0 & 1 \\ 0 & 1 & 1 & 1 \end{bmatrix}$$

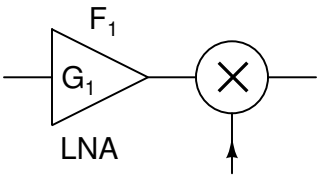
What is the minimum distance of this code? Show your work.

Question 7 — 2 marks

- An RF power amplifier has an OIP3 of 30 dBm. If the output power is 10 dBm, what is the power of the third-order intermodulation product components? Give your answer in dBm.
- If the transmitted signal has two frequency components at 2406 MHz and 2407 MHz, what are the frequency(ies) of the third-order intermodulation components?

Question 8 — 3 marks

The front-end of a receiver consists of an LNA followed by a mixer:



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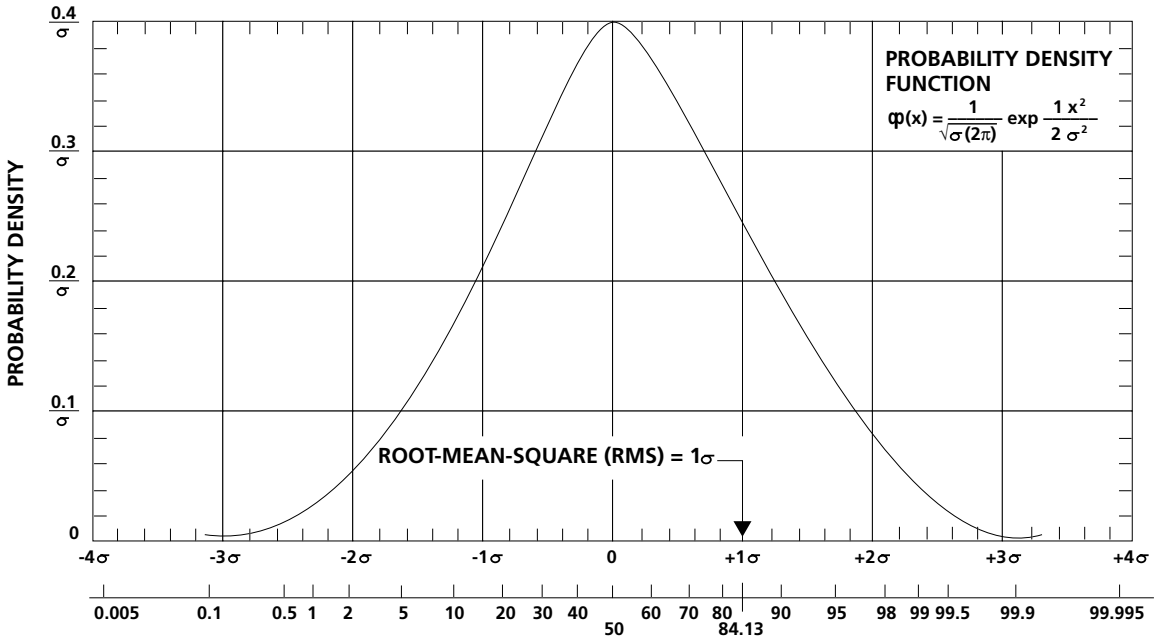

Figure 1. Gaussian Voltage Distribution