National Technical University of Athens, School of Electrical and Computer Engineering
Introduction to Telecommunications
2nd Laboratory Exercise, Academ. Year 2019-20

Question 1
Generate a random sequence of 36 bits with an equal probability of 0 or 1. For the following consider that the bit length is Tb = 0.2 sec.

a) Modify the generated bits sequence according to B-PAM width A (Volts) and present the resulting signal. Width A is expressed as the sum of the last three digits of each student's Registry Number. If the sum exceeds 9 then the sum of the digits continues until a one-digit number is obtained.

b) Present the constellation chart of the above B-PAM signal.

c) Generate AWGN noise and add it to the B-PAM signal you created in sub-query a for two Eb / N0, 6 and 12 dB values respectively. Show the resulting signals in different diagrams (three diagrams along with 1aa). Compare and comment on the differences you notice.

d) Show the constellation diagrams for the signals that appeared in subsection c΄.

e) Generate a sufficient number of random bits and AWGN noise of sufficient power to calculate and plot the probability of erroneous digit (BER) as a function of Eb / N0 for values of 0-15 dB with a step of 1 dB. Compare the resulting experimental diagram with the corresponding theoretical one.

Note 1: In the diagrams of sub-questions a and c the horizontal axis should express time (sec).

Note 2: Noise is simulated as a complex random variable Z = X + jY, where the real random variables X and Y are independent and each follows a normal distribution with mean 0 and standard deviation such that its one-sided spectral power density be N0 / 2.

Note 3: In sub-question c΄ use only the real part of the noise. In subsection d΄ use the complex random noise variable.

Question 2
Configure the sequence of digits (36 bits) of the 1st query against BPSK, QPSK and 8-PSK. Assume a carrier frequency fc equal to 2 Hz if the sum of the digits of your Register Number is a even number or 3 Hz if it is an unnecessary number, A amplitude (Volts) similar to the 1st query and mapping coded Gray.

a) Write the resulting sequence of symbols for each configuration scheme.
b) Present the corresponding transmission waveform for each configuration scheme (three individual diagrams).

Question 3
Configure the sequence of digits (36 bits) of the 1st query by QPSK with Volts A symbols (similar to the 1st query). QPSK to be considered in the base zone and not on the carrier.
a) Present the resulting constellation diagram by considering a coded image (p / 4) Gray. Note the corresponding symbols in the diagram.

b) Generate AWGN noise as in question 1c΄ (see Note 2) and present the resulting constellation diagram for two Eb / N0, 6 and 12 dB values respectively.

c) Generate a sufficient number of random bits and AWGN noise of adequate power to calculate and plot the probability of erroneous digit (BER) as a function of Eb / N0, for values from 0-15 dB with step 1 dB. Compare the resulting experimental diagram with the corresponding theoretical one. Compare and comment on QPSK performance with a corresponding BPSK system.
d) A text file will be used within this query (excerpts from Arthur C. Clarke's "Extra-Terrestrial Relays" article published in the Wireless World Magazine in October 1945. If the sum of the last three digits of each student's Registry (separately) is an odd number the clarke_relays_odd.txt file should be used, otherwise (if it is a even number) the clarke_relays_even.txt file should be used. The files are available on the course page at mycourses.ntua.gr.

(i) Read this text file converting the code binary (bits) ASCII string. For convenience, you can use commands from the Python binascii library.

(ii) Quantize the signal using a uniform 8-bit quantizer and plot the resulting signal. Use pieces of code from the 1st Laboratory Exercise if you modify them appropriately.

(iii) Configure the quantized signal using QPSK modulation by mapping with Gray coding and 1 Volt symbols.

(iv) Generate AWGN noise and add it to the QPSK signal you created for two Es / N0 values, 6 and 12 dB respectively.

(v) Demodulate and present the constellation diagrams for the signals that appeared in subsection (iv).

(vi) Calculate the probability of an incorrect BER digit for the two Es / N0 cases you missed and compare it with the theoretical one.

(vii) After remodeling the signals in subsection (v), reconstruct the text file for both Es / N0 cases. Reconstructed text files should be included in the submission of the work. Note any differences (errors) with the original text.

Question 4 (optional - bonus)
The query will use a .wav signed 16-bit PCM Mono 44100 Hz audio file. If the sum of the last three digits of each student's Registry Number (separately) is an unnecessary number to use the sound fi le1_lab2.wav file, otherwise (if it is a even number) use the sound fi le2_lab2.wav. The files are available on the course page at mycourses.ntua.gr.

a) "Read" the .wav file and diagram the signal waveform it represents. You can use commands from Python's scipy.io wavfile library.

b) Quantize the signal using a uniform 8-bit quantizer and plot the resulting signal. For quantization you can also use pieces of code from the 1st Laboratory Exercise if you modify them appropriately.

c) Configure the quantized signal using QPSK configuration by considering Gray coding mapping and 1 Volt symbols.

d) Generate AWGN noise and add it to the QPSK signal you created for two Es / N0, 4 and 14 dB values respectively.

e) Demodulate and present the constellation diagrams for the signals that appeared in subsection d4/.

f) Calculate the probability of an incorrect BER digit for the two Es / N0 cases you missed and compare it with the theoretical one.

g) Having demodulated the signals in subsection e΄, reconstruct the audio signal for both Es / N0 cases and listen to it. You can use commands from Python's scipy.io wavfile library. Reconstructed audio signals must be in .wav unsigned 8-bit PCM Mono 44100 Hz format and included in the submission of the work. Notice the difference in sound quality. Aside from the bugs in the demodulation, what else has undermined the sound quality in the procedure you followed;

Note: This query is optional and its full implementation will result in a 25% increase in total laboratory grade.

General Instructions
1 All required graphics should be accompanied by a title, a memorandum and the corresponding captions on the axes. 2 The work will be submitted by uploading a .zip file per group of 2 people which should include: a) The single source code that will execute all queries (must be legible and with comments) and produce the requested diagrams (without external intervention). The file will be either Python (.py) or MATLAB / Octave (.m) b) Two .pdf / .doc text files (one for each Registry Number) that will answer the queries thoroughly and include all charts.
3 The code should faithfully reproduce the diagrams embedded in the submitted .pdf / .doc files, otherwise the work will not be considered. 4 For clarifications / questions you may email at telecomshmmyntua@gmail.com after the holidays.