## Digital Communications 2 (6 CFU): 4th of July, 2018 [Prof. P. Migliorati, Univ. of Brescia]

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Surname, Name, Matr.: ............................................................................... Signature: ..................................................

Answer to the questions carefully, and according to the order assigned in the text. An answer consisting of ONLY FEW LINES of text will be considered NOT sufficient. Therefore, try to describe the considered topic with a bit of details (it is expected an average value of (circa) one page for every question, including diagrams and figures). If the hand written text and the general organization of the answers on the paper will not be CLEAN and CLEARLY written, and therefore difficult to be properly read and interpreted, the answer would NOT BE TAKEN into account in the final evaluation. Any NOT GIVEN or COMPLETELY WRONG answer will be taken into account negatively (i.e., producing a penalty (negative marks)) in the overall evaluation.

**Questions: Part1 (Exercises)**

1. - A (7,4) cyclic linear block code is described by the generator polinomial $g(D) = D^3 + D^2 + 1$. Indicate the possible code-words. Determine the generator matrix of this code, in its systematic shape.
   - Indicate the values assumed by the "sindrome" associated to a possible single bit error, a possible two bits error, a possible three bits error.
   - Consider the Hamming code with $N = 127$. Determine the error probability in case of both hard (use the more precise estimation) and soft decoding.
2. Consider the BCH code of length $N = 31$ and generator polynomial (in octal description) 107657. In this code there is 1 word composed by all zeros, 155 words with 7 ones, 465 with 8 ones, 5208 with 11 ones, ...
   - What is the generator polynomial of this code (g(D)= ...) ? Determine the number of possible codewords, and the probability of error (in case of hard and soft decision).
   - The code is extended adding a final parity check bit (imposing an even number of "1").
     - (a) Determine the new probability of error (in case of hard and soft decision).
     - (b) What is the minimum required bandwidth (in case of binary modulation) if the information bit-rate is equal to 1 Mbit/s.
   - Consider the following possible codewords.
     - (c) 0000000000000100011111010111100 1 is a valid codeword ?
     - (d) 0000000000000111101011111000100 1 is a valid codeword ?
3. Convolution Codes
   - Consider a convolutional code with $R = 1/3$, and octal generators $(1, 3, 2)$. Determine and draw the tree and the state diagrams of the code.
   - Determine the code word associated to the information sequence: 010101100.
   - Determine the bit-error probability (considering at least 3 non zero terms in the union bound), and the minimal bandwidth required in case of an information bit-rate equal to 10 Mbit/sec.

**Questions: Part2 (Theoretical Description)**

4. Turbo-LDPC Codes
   - Describe the curves that represents the performance (P(E) as a function of Eb/No) of a turbo code, indicating the role of the iterations, and the role of the inter-leaver.
   - Describe the basic idea of the tanner graphs and the bit-flipping algorithm for the decoding of an LDCP code.
   - Describe the basic idea and the motivation of the EXIT charts.
5. OFDM
   - Describe the analytical expression of an OFDM symbol and the block diagram of an OFDM encoder and decoder.
   - Describe the channel equalization procedure performed in the OFDM modulation systems.
6. DSSS
   - Describe why and when a DSSS modulation system is robust against multi-path fading.
   - Describe the basic idea of the Rake Receiver, indicating also why this is working properly in the case of DSSS modulation.
7. CPM
   - Draw the phase-tree in the case of MSK modulation.
   - Determine the analytical expression of the likelihood function that should be maximized by the optimal receiver in the case of MSK modulation.