Interleaving Code Symbols in a Low Density Parity Check Code

At the first stage the dithering linear congruental algorithm [Bohorquez R. G., Nour C. A., Douillard C. On the equivalence of interleavers for turbo codes //IEEE wireless communications letters. – 2014. – Т. 4. – №. 1. – С. 58-61.] is used to form interleaver of size N=n1*n2, where n1 the number of memory banks for parallel impleentation of the interleaver. The dithering sequence has the following properties: within the interval S, any difference between the interleaved numbers must be different from any other difference lying in this interval, which prevents the appearance of a cycle in the further linear congruent transformation in which two columns of the interleaver matrix are involved. The sequence can be formed in a way similar to the S-random interleaver, the difference lies in checking the condition: the random candidate number falls into the delay line (sliding window) of length S, where the previous S-1 selected numbers are contained, the differences between them are calculated in pairs, which should differ . When the condition is met, a new candidate number is randomly generated from the remaining valid ones. With a length n1=24, the maximum possible value of the parameter S=3, which is sufficient to provide remote spacing of variable nodes with a repetition degree of 3. In an irregular pattern of nodes with a minimum repetition degree of 3, the majority.

At the next stage of optimization, cyclic rotations of the interleaver matrix columns are performed in order to maximize the minimum value of the “neighborhood” metric in the interleaver row. It is sufficient to perform this optimization for only one interleaver row, since this value is repeated for the rest of the rows. It should be noted that here we perform optimizations based on the minimum degree of the variable node (usually 3), which is equal to the S parameter. It should be noted that the first two stages of optimization are performed focusing only on the minimum degree of repetition, but not on the entire irregular repetition pattern, which makes it possible to form an interleaver with low computational complexity and obtain satisfactory performance in the avalanche-like error reduction mode (“waterfall” region), with the exception of the region "error floor" .

The pattern of irregular repetition is taken into account in the third stage, where to reduce the " error floor" permutations are performed in the memory banks (columns of the interleaver). Each permutation affects only one memory bank (interleaver column) and cannot lead to memory conflicts. For each number in the column from the corresponding variable node, a cycle width search is performed. Also look for cycles with low ACE (number of edges looking out of the cycle), note that cycles with low ACE do not necessarily have low coverage. Each permutation is considered individually according to the following criteria: the total coverage of cycles must be at least 6 (cycles with coverage 2 and 4 must be excluded). Each permutation shall increase the diversity factor, which is the sum of the modules of the difference between numbers before and after interleaving but calculated between the permuted number and any other number in the given interleaver string. The permutation that maximizes the minimum value of the interleaving factor is preferred.The optimization result is a 1032 character long interleaver, which is represented as a 24x43 matrix, the pattern of irregular repetition {Q,P}={[3,6,12,24], [72,68,30,2]} is taken from [Patent RU2708349] for the number of information symbols K=172 with an average number of repetitions of 6. The simulation results are shown in Fig. For the length of the information block K=172 and the coding rate R=1/3, BLER=10^-5 is achieved at Eb/N0=3.8 dB, which corresponds to the signal-to-noise ratio in the transmission channel Esym/N0=-0.97 dB, however, this is followed by the lowering "error floor".

Perfomance is over 2 db gain for block size 172 over known solution:

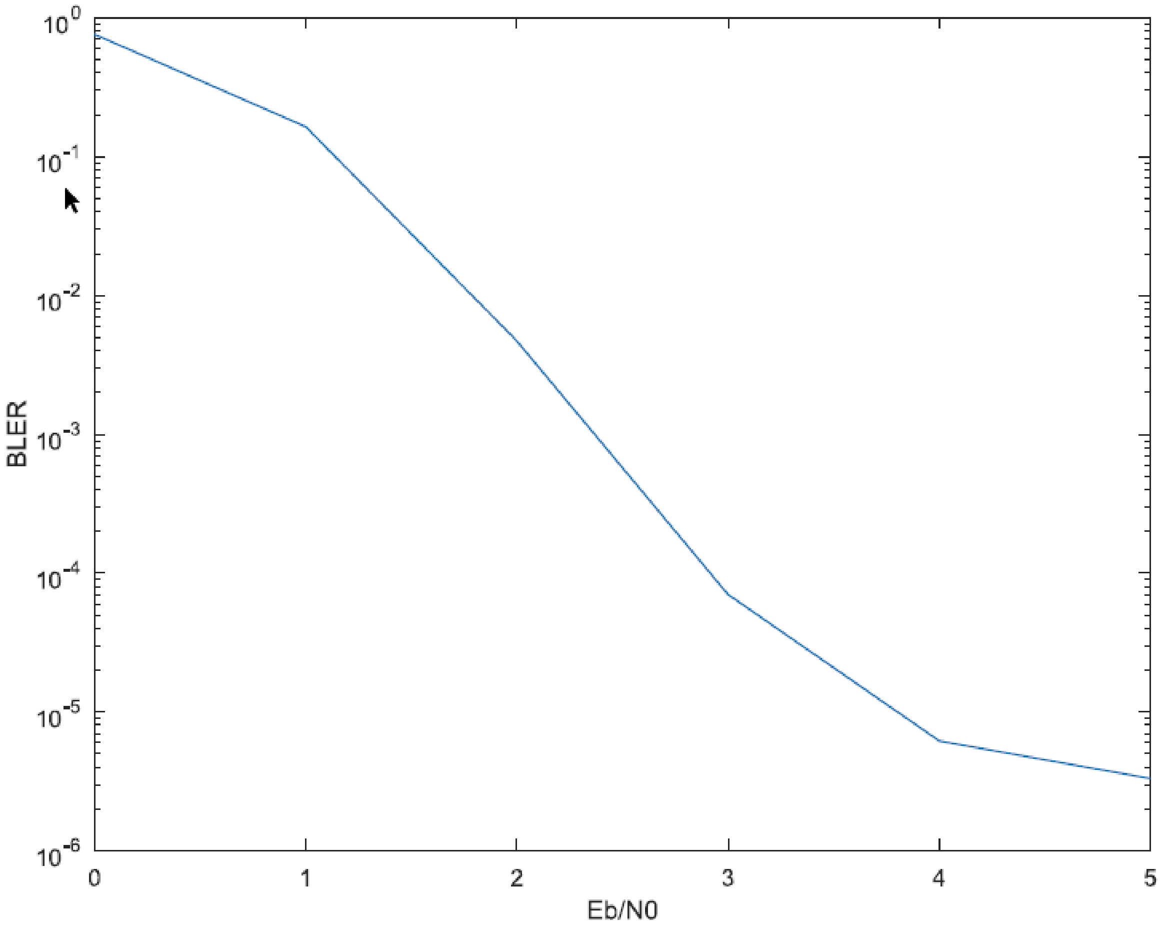

Рис. 3. *BLER* для блока $K = 172$
и $R = 1/3$, *AWGN*, *QPSK*

Fig 1: Proposed solution

[Zhdanov A. E. SIGNAL-CODE DESIGN FOR SUPER-RELIABLE DATA TRANSMISSION BASED ON CODE WITH IRREGULAR REPETITIONS-ACCUMULATION // Theory and technology of radio communication. – 2020. – no. 3. - S. 83-88 URL: https://www.elibrary.ru/item.asp?id=44737213]

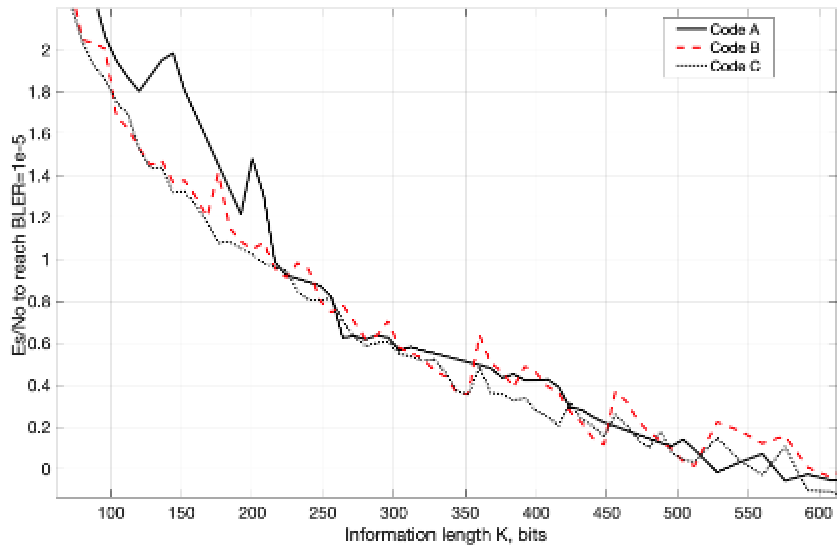

Fig. 2: SNR required for information lengths k to achieve FER level 10^{-5} for MET QC-LDPC codes with rate $1/3$.

Fig 2: Known solution

[Vasiliy U., Sergey E., Svistunov G. Construction of Length and Rate Adaptive MET QC-LDPC Codes by Cyclic Group Decomposition //2019 IEEE East-West Design & Test Symposium (EWDTS). – IEEE, 2019. – C. 1-5.]