ЎЗБЕКИСТОН РЕСПУБЛИКАСИ АХБОРОТ ТЕХНОЛОГИЯЛАРИ ВА КОММУНИКАЦИЯЛАРИНИ РИВОЖЛАНТИРИШ ВАЗИРЛИГИ

МУҲАММАД АЛ-ХОРАЗМИЙ НОМИДАГИ ТОШКЕНТ АХБОРОТ ТЕХНОЛОГИЯЛАРИ УНИВЕРСИТЕТИ УРГАНЧ ФИЛИАЛИ

## МУҲАММАД АЛ-ХОРАЗМИЙ ИЗДОШЛАРИ

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# PROBLEMATICS OF USING A MULTI-THRESHOLD DECODER

*Rakhimov T.G., Reypnazarov E.N.*
*Tashkent University of Information Technologies named after Muhammad al Khwarizmi*

This article proposes the use of multi-threshold decoders of self-orthogonal codes in such systems that provide high correcting ability with low implementation complexity. The tasks are set, which must be solved before using the multi-threshold decoders as part of high-speed digital data transmission systems, including digital television systems.

Requirements for the speed and reliability of the transfer of information from year to year increase significantly [1]. As a result, the use of error correction algorithms can be problematic because of the high complexity of the decoder, which will not be able to cope with the processing of high-speed information flow [2], [3]. This leads to the need to search for new methods of error correction, which, with high decoding efficiency, will have a low implementation complexity [4]. One of the most effective solutions to the described problems of noise-immune coding with high correcting power is the use of the multi-threshold decoder (MTD) of self-orthogonal codes (SOC).

This decoder is the development of the simplest threshold decoder and allows you to decode very long codes with linear length of code execution complexity [5], [6], [7]. At the heart of the MTD is iterative decoding, which allows you to come close to solving the optimal decoder in a sufficiently large range of code rates and noise levels in the channel. At the same time, MTD preserves the simplicity and speed of a conventional threshold decoder, which meets the requirements for existing and future high-speed information transmission systems [8] and digital broadcasting systems [9]. It is the combination of these qualities that should allow MTD to fill in the shortcomings of the described methods of noise-immune coding [10].

In operation, the MTD searches for the most plausible codeword by performing a comparison of the codeword that is in the decoder and a codeword different from it in the decoded symbol [11]. In this case, MTD, unlike a conventional threshold decoder, can always calculate the total distance between the received message and the contents of the decoder. This allows the MTD with each change of the decoded symbol to be strictly approximated to the solution of the optimal decoder, since this distance necessarily decreases with each change of the decoded symbols [12]

Note that in order to obtain the best performance when using MTD, its developers proposed a number of approaches [13], [14]. One of them is the choice of codes that are least susceptible to the effect of multiplication errors in multi-threshold decoding. In this case, optimization is performed to minimize the number of identical second differences between the positions of non-zero elements of the generating polynomial [l5]. Another approach involves the use of cascading encoding schemes in which external codes, such as codes with parity, Hamming codes and short SOCs, are also used in conjunction with SOC decoded by MTD [16]. The application of the proposed approaches allowed both to bring the MTD performance efficiency closer to the channel capacity, and to reduce the probability of an error in the area of effective MTD performance.

MTD is one of the best methods of error correction in terms of the ratio of efficiency and complexity of implementation and is therefore suitable for use in high-speed digital data transmission systems, including in advanced digital television systems [17]. At the same time, before the practical use of the MTD under specific conditions, when it is necessary to obtain the best probabilistic-energy characteristics, it is necessary to do a huge amount of work.

First, it is necessary to choose or build the applied SOC. This code, as shown in [18], should be least susceptible to the error propagation effect, which is manifested in the fact that when the decoder commits the first error, the probability of occurrence of subsequent errors substantially increases. This significantly degrades the characteristics of the iterative decoding scheme, which includes MTD. Note that when constructing a “good” in terms of the resistance to propagation errors of the SOC, it is necessary to perform a number of optimization procedures, in particular, to choose the best code structure with parallel cascading. One of the algorithms of choice is the algorithm for obtaining the best codes involves carrying out computer simulation of a huge volume, which may take weeks to run a normal personal computer.

After building the code, you need to adjust the parameters of the decoder, for which the optimization procedure [19] is again performed, during which dozens are configured, and in some cases even hundreds of MTD parameters. It is also quite costly from a computational point of view operation.

At the final stage, it is necessary to make sure that the developed MTD meets the requirements, assessing its probabilistic and energy characteristics. In case the target BER is not very small (>$10^{-10}$), such an estimate is easily accomplished by computer simulation within several hours of operation of the personal computer [20]. Note that the known analytical estimates of MTD efficiency are strongly underestimated at a high noise level and are poorly suited for this purpose. In the case if the target BER, as in modern and prospective digital television systems, is very small ($10^{-11}$ or less), then the process of obtaining such estimates with acceptable accuracy can be delayed for weeks, months and even years of work of the personal computer. All this makes the task of reducing the time for obtaining estimates of the effectiveness of MTD relevant. This task can be solved both by increasing the speed of work of computer models of MTD, and by developing more effective analytical methods for evaluating its characteristics [21].

In addition, in a number of transmission systems of various kinds of information, especially in digital television systems, so-called adaptive coding and modulation are often used to improve the efficiency of the communication channel, when code with one or another code rate is used depending on the channel state and modulation of a larger or of a smaller order. For the MTD, the questions of its application in such schemes were not solved before. Another complexity of the use of self-orthogonal codes in such systems is due to the fact that they do not have a very large code distance and, therefore, they are characterized by the presence of the so-called saturation region of the error probability. This complicates the task of obtaining very low error probabilities required in modern digital information transmission systems. Therefore, the problem of reducing the probability of error when using self-orthogonal codes in the area of their suboptimal decoding is also topical

In this article is shown that one of the best in terms of ef6ciency and complexity is the multi-threshold decoder of self-orthogonal codes that сап be used in advanced digital television systems. The main problems arising in this process are identified and directions for their solution are formulated.

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