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Achievement of Optimum Decoding Characteristics on the Basis of Multithreshold Algorithms.

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Application of multithreshold decoding algorithms both binary, and non-binary digital streams in Gaussian channels with a large noise level was repeatedly considered at four last DSPA conferences.

In the present report the new essentially improved MTD algorithms of error correction in channels with extremely high noise level are considered. Thus the given algorithms remain extremely simple, still possessing the characteristics scarcely distinguished from optimum.

Let's consider the two-channel circuit of data transmission through the Space or other channels with large enough level of Gaussian noise. We shall choose for some signal/noise ratio, originally identical to each of two considered communication channels, such distribution of the common total energy to provide the greatest successful subsequent decoding the accepted information symbols on the basis of multithreshold decoding binary block or convolutional codes [1-3,6]. In other words, criterion of the best redistribution of energy between channels is a choose a minimum level of error propagation effect (EP) at majority decoding. In MTD theory these questions are full enough worked. Decrease in error propagation effect allows to improve considerably convergence of MTD decisions to optimum, that, in turn, creates conditions for more effective work of MTD algorithms at the large noise levels.

At formation such enough simple signal-code design are considered various ways of power balancing. For example, channels can be organized in such a manner that on one of them information symbols of a code, and on another – check symbols are transmitting. In this case analysis EP becomes simpler, that allows to consider quickly enough and full applicability of the maximal number of codes and corresponding to them MTD algorithms in similar coding circuits. Such models of channels have received the name of channels with non-equal power (NEC) [1,5]. They can be simply realized in usual paths of data transmission.

As the detailed analysis of some codes and some updatings МПД of algorithms for channels with various parameters and non-uniform power has shown, moving of border of effective work MTD area aside higher channel noise level in a range of code rates R=1/4 ÷ 3/4 can make up to 1 dB, that is very important, since initial MTD efficiency in channels of usual type appears to be already rather high [1-4,6]. Note that the power ratio in such channels should be within the limits of 1,3 ÷ 3,2.

Necessity of work of the communication equipment at higher noise levels demands increase in number of MTD decoding iterations, but as practice and modeling of algorithms shows, such increase usually appears no more than double, that results in small complexity of MTD realization both in program, and in hardware variants.

The new received results in this area are illustrated by curves at fig. 1 on which opportunities of the offered algorithms and already known methods are submitted. Curves MTD-X corresponds to efficiency of the МПД decoder on PLIS Xilinx, curves MTDmd2, MTD+CC2 and MTD+CC3 are given for MTD application in the elementary concatenated circuits. All these algorithms were in details discussed in [2]. At fig. 1 curves of efficiency for Viterbi algorithm (VA) with a standard code length K=7 and for concatenated circuit VA with Read-Solomon (RS) code, and for a turbo code [7] also are submitted. Vertical C=1/2 defines Gaussian channel throughput, equal 0,5 to which developers aspire at improvement of decoding characteristics for R=1/2. The new result for MTD and channel NEC - dotted line MTD-NEC - corresponds to an opportunity very simple and substantial increase of efficiency of code decoding at a delay of decision-making no more than 400'000 битов at which well-known big enough speed of decoding as in software, and especially in a hardware variant. The specified substantial improvement of multithreshold algorithms efficiency approximately at 1 dB in comparison with others MTD the decoders submitted on fig. 1, is achieved during past period from the moment of carrying out of last conference DSPA. With the account of already achieved closeness of area of effective MTD work to

channel capacity, it is possible to count, that MTD has good prospects on the further of its characteristics approach to the Shannon bound. Thus significant MTD advantage before other algorithms on number of the operations, achieved up to 2 decimal order for various combinations of coding parameters [1,4,6], gives the basis to believe, that MTD must be used actively by development of the modern equipment for the Space and satellite channels.

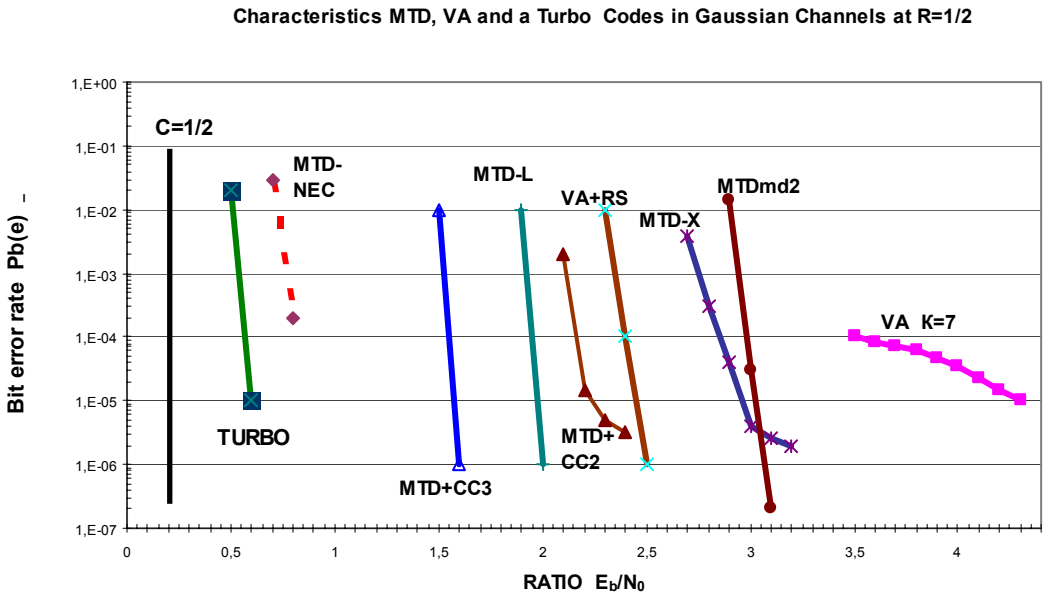

Fig. 1.

Further we shall note, that during forty years of majority algorithms in binary channels development in the theory of coding there were no attempts of generalization of these algorithms on non-binary symbolic codes and threshold decoders corresponding to them. Now long-term development of the full theory for not binary majority methods of correction of mistakes [1,4,6] is completed. Simple codes in realization for non-binary digital streams are offered and effective multithreshold algorithms of their decoding with rather small number of operations per a data symbol are created.

These algorithms also provide aspiration of non-binary MTD decisions to decisions of the optimum decoder (OD) as it takes place and in case of binary codes and their decoders. Analytical estimations for traditionally calculated error probabilities in the first symbol of a code are received at threshold decoding block and convolutional codes, and also the low estimations of error probabilities for OD and other important characteristics of codes and algorithms. All achieved results in the field of non-binary majority algorithms are unique and have no analogues in the world literature on error correcting codes.

Theoretical results, estimations of characteristics and great volume of MTD non- binary algorithms modeling in channels with the a large noise level show, that opportunities of these algorithms essentially, on many decimal powers surpass values of achievable levels of reliability on the basis RS - codes of any length. In conditions when for codes with the big alphabets construction of VA with good characteristics appears impossible, and characteristics of RS codes are rather low, non-binary MTD opportunities appear practically unlimited at all. Thus complexity of the symbolical data decoding appears rather small. The volume of statistics of decoding near 1E9 (billion) can be received approximately during a one hour of the general purpose personal computer work on the usual software without any optimized.

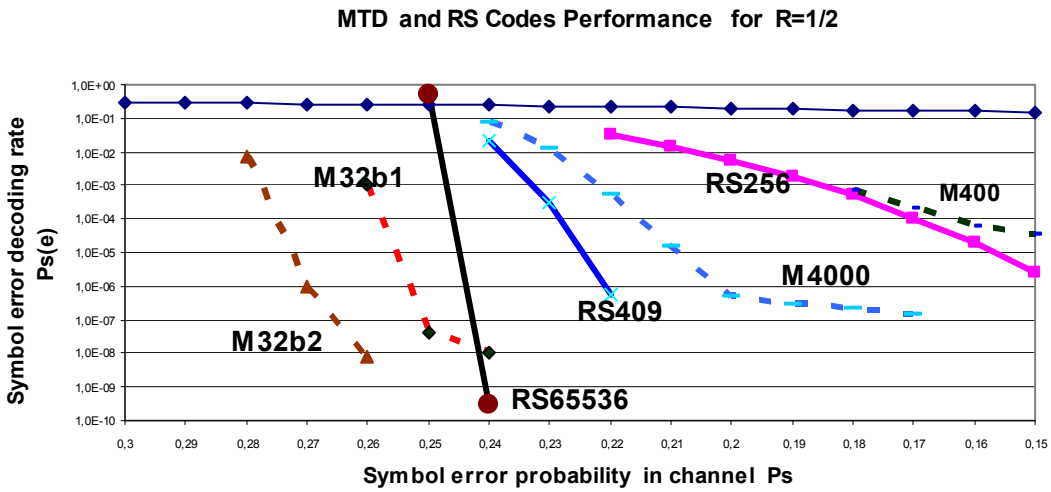

Fig. 2.

On fig 2 results of non-binary MTD algorithm modeling and characteristics decoding estimations of RS codes in non-binary channels with independent errors for code rate R=1/2 are submitted. Continuous lines are for RS codes of the corresponding length n, and dotted – non-binary MTD with the basis (the size of the alphabet) q=256 (symbol – 1 byte).. The choice such q, corresponding to byte structure of symbolical streams of the information, is very convenient for realization of data processing algorithms at standard computing means. From the submitted diagrams follows, that characteristics of MTD decoding for enough short (on modern measures) codes length n=32000 bytes are unattainable for RS codes with arbitrary large length. We shall note thus, that real application was found till now only with RS codes of length no more n=256. It is possible to assert also, that RS codes of length about 4000 will not be realized at all in the foreseeable future. At the same time MTD byte decoders (with alphabet 256) for majority decoding non-binary codes have rather high characteristics which for a code with n=32000 are unattainable for RS codes of any length with R=1/2. We shall note, that choice the alphabet q with greater volume will increase MTD efficiency without some appreciable increase in complexity of decoding whereas for long RS codes the increase in the size of the code basis occurs automatically, but characteristics of coding do not improve in the same degree, as for MTD, which in case of need simply uses longer codes with the fixed unchanged alphabet.

Thus, it agrees fig. 2, MTD realizes good characteristics as at rather simple software means (that it was already marked above), and (as it has shown preliminary designing) in a hardware form.

Certainly, if It is not need the MTD work in so heavy noisy conditions as it is submitted in the above-stated figures, redundancy of codes for non-binary MTD may be reduced in any degree even to several percents. In particular, great volume of non-binary MTD algorithm modeling at R=7/8 has shown, that at small redundancy multithreshold decoding remains very simple, and characteristics of resulting reliability differ from corresponding characteristics of the same RS code on redundancy of length about 4000 symbols quite a little. But at R=7/8 creation the fast decoder for RS code of such length more than is very problematic, whereas MTD remains and for low redundant codes rather fast and very simple.

On the basis of comparison of long non-binary codes efficiency with MTD decoding and a very long RS codes, it is possible to draw a conclusion on occurrence of an opportunity of simple realization with the MTD on basis of majority decoding non-binary codes great volume extra reliable superarchives with very long periods of storage of video-, audio- and other special types data. It is determined by insignificant complexity of coding, simplicity of decoding and very easy control of the current reliability over total storage period.

So conveniently also it is simply possible to apply non-binary MTD to coding CDs - disks and other digital production of wide application.

Set of the received results for decoding the binary and symbolical data allows to consider, that the given researches confirm an opportunity of successful decoding on MTD base at more and more high

noise levels of the channel. Complexity of the most difficult stage of coding – MTD procedures of decoding on the reception side always appears a lot of smaller, than for other algorithms comparable with MTD on efficiency.

The literature (in Russian)

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P.S.

You can find detail information about non-binary MTD (QMTD) for R=7/8 and R=0,95 in our new article “Обобщение алгоритма МПД на недвоичные коды» in Russian magazine “Мобильные системы» №2, 2007, this paper is at our web-site also at page «Метод» (in Russian).

Trans.: “Generalization MTD algorithms at non-binary codes“, magazine “Mobile systems” N0.2, 2007.

You can write to your computer also special demo program for non-binary MTD. It is at the page “Education” of our web-site together with short instruction for this program.

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Have you any interest to translate and publish our monograph [1]?:

V.V. Zolotarev. The Theory and Algorithms of Multithreshold Decoding. - Under scientific edition of the member-correspondent of the Russian Academy of Sciences U.B.Zubarev, M.,«Radio and communications», «Hot Line - Telecom», 2006, 270p. See information about this book at first page “Metod” of our web-site.