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# MULTITHRESHOLD DECODERS FOR HIGH-SPEED SATELLITE COMMUNICATION CHANNELS: NEW OUTLOOKS

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***Abstract.*** The capabilities of multithreshold algorithms of convolutional codes decoding realized on chips PLIS "Xilinx" are described. The characteristics of energetic efficiency and performance of these decoders for high-speed systems satellite and space communication are reviewed. The advanced applications of new method are discussed.

**Introduction.** The development of digit transmission and data processing methods is largely determined by capabilities of high veracity maintenance for the transmitted information systems. The most effective means to increase the digital information veracity is the usage of error correcting coding. The review of the most perspective coding methods by yardstick "efficiency - performance" was made in [1], where it was indicated, that the greatest preference in high-speed satellite channels merit the multithreshold decoders (MTD) [2]. Capabilities of these new methods of error correction, which one were designed by the software and hardware for satellite communications systems created in NIIR at close co-operation with other organizations and the leading specialists in the field of encoders [3,4] are described below.

**Effectiveness criterion of coding applications**. As it is known, the most common parameter for quality evaluation of decoding methods is the code gain (CG). It demonstrates permissible decrease value of energy necessary for transmission of one data bit at some selected mean error probability per bit in case of usage of chosen coding and decoding algorithms, as contrasted to the case, when the coding is not used.

The capabilities of coding for maintenance of demanded efficiency by yardstick CG are shown for coherent binary phase-shift keying (BPSK) in a fig.1. The limit of Shannon is the figure indicated under condition of the code rate R=0 with number of quantizing levels of M great enough, M>> 1, when input signal of the decoder is continuous. It corresponds to minimally possible relation of bit energy transmission $E_0$ to the spectral noise power density $N_0$: $a=E_b/N_0$. This and all other introduced here bounds are obtained from natural conditions R<=C, where C - is a channel capacity. Certainly, at obtaining these limiting estimations it is supposed, that the optimum decoding with necessary high complexity of implementation will be used. Then the given bit error rate $P_b(e)$, rate R and quantizing levels number of the modem M determine in common enough sense a measure of coding effectiveness. At transition from M=2 (case of the "hard decision" modem simply determining, which single bit value has come from a channel) to the "soft decision" modem with M=8, which one estimates the solutions, the obtaining is possible additional CG close to 2 dB. At increase R, to the contrary, the limits of a code even at the best decoding are notably reduced. It is clear, that if the requirements to the transmission accuracy grow, the accessible CG value considerably increases. The economical profit of CG is calculated as tens millions dollars for large system [1,3].

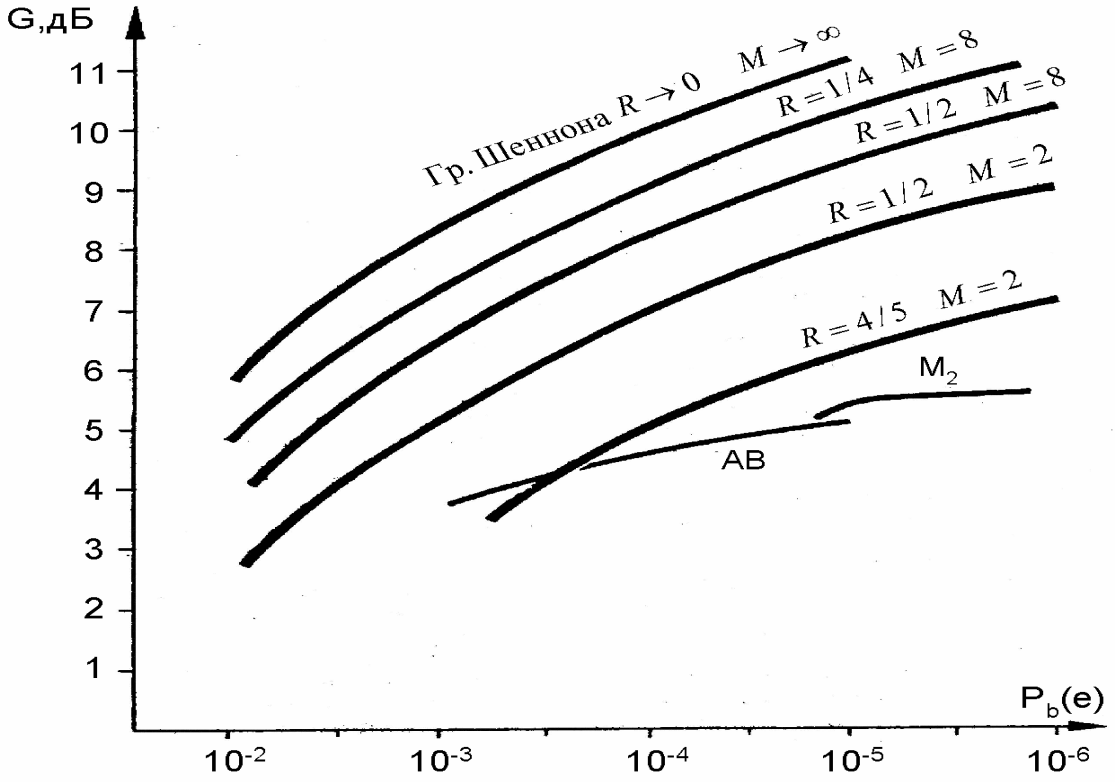


Fig. 1. Maximal levels of CG, accessible for amounts of redundancy as functions of demanded output bit error rate $P_b$ (e).

As an example a curve the AB in a fig. 1 demonstrates capabilities of standard Viterbi algorithm (VA) for convolution codes with code rate R=1/2 and length of the encoding register K=7, which one is widely used now. The VA provides CG about 5,2 dB at $P_b$ (e) $=10^{-5}$, that is possible to recognize as significant achievement for the beginning 70-th years of XX-th, when this algorithm was realized in hardware. Let's mark, that almost 2 dB from full 5,2 dB of CG, as mentioned above, are obtained by "soft decision " modem. The chart M2 is adduced for a case of multithreshold decoder (MTD) usage with the hard modem [4]. The characteristics of so simple MTD are better, than for VA because of its applications for much more lengthy codes and practically optimum decoding with the MTD algorithm.

**Implementation of software MTD.**. Designed in NIIR software MTD versions [5] have reached very high throughput level. To the present time it was possible essentially to lower an average of decoding operations N per a bit of a code. Software MTD should execute N=50-400 operations depending on a noise level and redundancy of a used code. As contrasted to the other algorithms with efficiency that is closed to MTD they all are on two decimal powers more complex in operations than MTD [6,7]. The similar difference in complexity of applied algorithms now is in general extremely rare. So large advantages of any similar method should be used in the conforming areas in the greatest possible degree. Such approaches in MTD capabilities has allowed to realize extremely fast and simple software MTD for digital television systems built in NIIR for usual processors. MTD for these systems has a coding gain (CG) approximately on 3 dB higher, than for algorithm Viterbi (VA), in particular, at code rate R=3/4, appearing simultaneously approximately in 4 times more throughput, than VA.

The development of this perspective direction in NIIR will be proceeded.

The application of signal processors and specialized microprocessors allows to reach software MTD throughput of tens megabits per second [6-8].


**Implementation MTD. The hardware version.**

Chipset of the designed with NIIR of versions of implementation MTD in PLIS Xilinx is showed at the photo in fig. 2. This MTD is further development since 1975 of a series of convolutional code decoders based on multithreshold decoders (MTD) and can be considered as an example of their fifth generation in NIIR.

The characteristics of convolution MTD at code rate R=1/2 are shown in a fig. 3. In this convolution MTD all algorithms capabilities of this class on multisequencing operations of decoding at a hardware level completely realized. Therefore performance of the decoder limits only by running speed of the data in its shift registers, which one fall into to the most fast members of circuitry PLIS. It also determines very much high efficiency MTD on PLIS, which one makes in the different realized versions of this decoder from 160 up to 480 Mbits/s and can be essentially increased.

As follows from a view of the charts, introduced in a fig. 3, very simple convolution MTD with response about 200 Mbits/s and the decoding delay about 10000 bits is supposed. MTD is on 1,5 dB better than standard Viterbi algorithm (VA) with a code register length K=7. Let's remind, that the improvement CG even on 0,1 dB is considered very much serious as achievement. Therefore such large difference in CG between an AB and MTD at actually unlimited performance last allows to assert, that the creation in NIIR of modern versions of MTD algorithms on the new element base is major scientific and technological achievement in the field of error correcting coding methods.

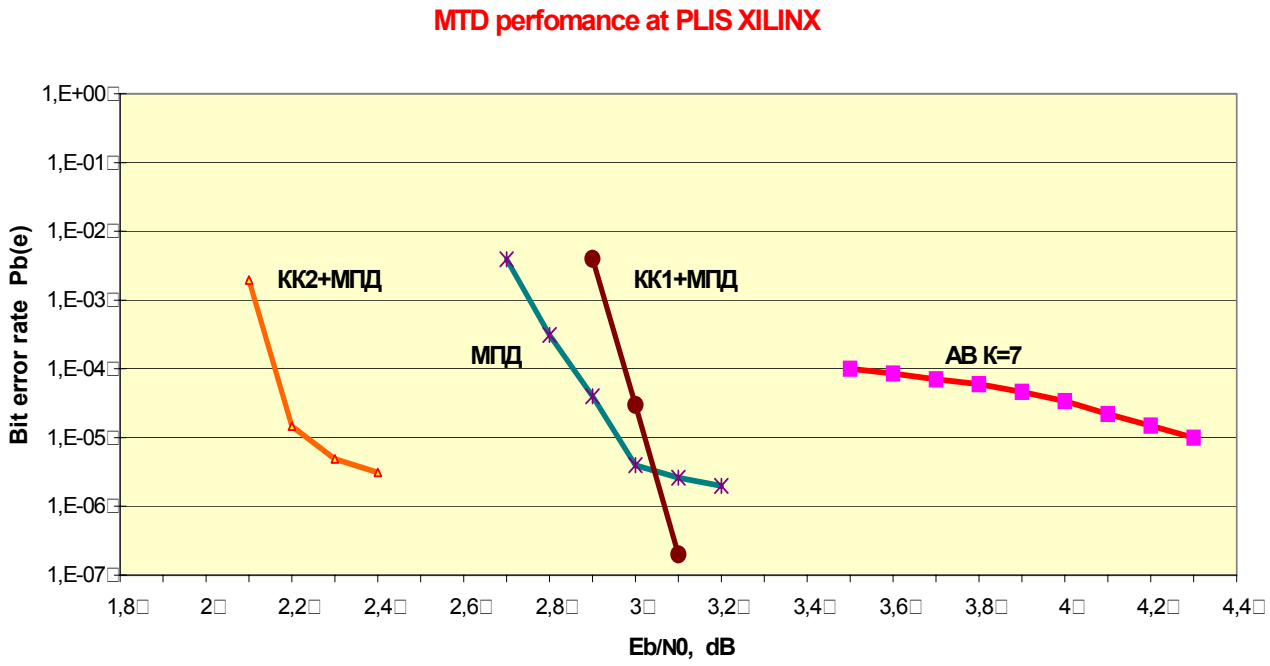


Fig. 3. The characteristics of decoders built on the basis PLIS Xilinx

It is well-known, that most effective by CG yardstick are the miscellaneous concatenated codes. In a fig. 3 the charts КК1 and КК2 demonstrate capabilities of concatenated circuits with MTD, operating with an external code parity check codes. Common code rate of these concatenated circuits is close to R~1/2. In the case of the MTD for КК1 delay of decoding makes about 10000 bits, in the second one, for КК2, it is close to 40'000 bits. In both versions of implementation of concatenated circuits the performance of decoders exceeds 150 Mbits/s and it also can be considerably increased. Let's point out, that realized in MTD the concatenating with parity check codes, for what in the scheme of coding one half-adder is added only, appears incomparably easier, than in concatenated circuit of VA with Reed-Solomon codes. Thus the concatenated circuits with MTD appear more effectiveness both on CG, and on code rate [7-8].

**Advanced application of algorithms MTD.**

The application of more highly-packed chips PLIS "Spartan" of the "Xilinx" corporation allows to proceed to decoding circuits based on MTD, which one provide a level of power engineering $a=E_b/N_0$~1,6 dB, saving extremely high MTD performance. For more high requirements to response MTD he will supply a~1,0 dB at delay about 400 thousand bits and response about 20 Mbit/s.

The refinement of technological capabilities PLIS of new types at implementation MTD in NIIR as soon as possible will be finished also achievement of the extreme possible power characteristics of coding, close to introduced in a fig. 1, it is envisioned within the nearest two years at preservation rather high efficiencies MTD not less than 10 Mbit/s.

The large volume of the new scientific and educational-methodical information about algorithms of the MTD class can be found on the web-site about MTD algorithms: www.mtdbest.iki.rssi.ru .

Conclusions. Huge advantage MTD before all other decoding circuits on number of operations and capability of their full multisequencing at a hardware representation allow to consider, that as a result of 30-year's researches in NIIR the broad class of multithreshold algorithms is designed, which one can be recognized by the main compact coding method for many modern high speed systems of communication with extreme possible levels of a coding gain and very much by fast response time.

The methods MTD in the field of high noise of a channel already now allow supplying a demanded level of power engineering of a channel with the more simple ways. Decoders MTD there are a lot of years successfully work in already designed in NIIR satellite communications systems.

The capabilities of modern technology allow even for high-speed channels to elaborate hardware-software versions of MTD decoders, which ones will have time to execute large enough number of operations with each decoding bit. It creates conditions for implementation of more and more composite code designs. The high characteristics of MTD decoder very visually illustrate that apparent true, that those algorithms, that use non-rationally computing resources, always will lose considerably to much more simple methods, which use more effective decoding.

It is doubtless, that **the problems of complexity** of coding implementation will be kept in the foreseeable future, and in connection with increase of speeds of information exchange of the requirement of simpler implementation of decoders will be more urgent. Cheap at all versions of implementation will appear those algorithms, which one execute only very simple, homogeneous and fast operations. MTD is better for this requirement content. And the conformity of its capabilities to the characteristics of the most composite algorithms makes MTD by even more attractive.

Thus, last decade has created conditions for achievement in an actual channel forming equipment of communications systems of a level of power engineering, rather close to idealized limits for channels space and communications by satellite. The high characteristics, except for MTD, can supply all some methods. But the count of a problem of complexity at comparable levels CG demonstrates, that in this case algorithms on the basis MTD save affinity on the complexity of implementation to the elementary threshold decoder and consequently in most cases applications of coding are most procedures of decoder choice for high speed systems, reasonable on the cost, in communication.

The introduced capabilities MTD demonstrate a high level of the Russian elaborations in an orb of communications systems of different assigning advanced foreign researches of this type approximately for 5-7 years. The achievements, reviewed in this article, NIIR provide effective increase of transmission accuracy in digital satellite, the Space and other communication channels for the most broad assigning.

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