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New Channel Coding Methods for Satellite Communication

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Abstract:
This paper deals with the new progressive channel coding methods for short message transmission via satellite transponder using predetermined length of frame. The key benefits of this contribution are modification and implementation of a new turbo code and utilization of unique features with applications of methods for bit error rate estimation and algorithm for output message reconstruction. The mentioned methods allow an error free communication with very low Eb/N0 ratio and they have been adopted for satellite communication, however they can be applied for other systems working with very low Eb/N0 ratio.

Keywords: Turbo code, coding, interleaving, MAP, decoding, bit error rate, bit error rate estimation, satellite communication.

I. INTRODUCTION

The signal transmitted via satellite transponder is affected by many factors. Satellite links are usually designed with extremely low margin of link budget. Therefore low Eb/N0 ratios at the point of receiver are typical and define the basic feature of satellite communications. There are some ways with successful and reliable data message transmission in spite of these adverse conditions. The fundamental method for achievement of reliable message decoding from the signals with very low Eb/N0 ratio is effective channel coding methods. The turbo codes represent an optimal technique due to their unique properties.

II.TURBO CODES

The turbo codes were introduced first in 1993 [4]. At the present time, they are implemented in many modern communication systems above all thanks to their excellent efficiency or more precisely to their high code gain [8]. Therefore they can reach low bit error rates (BER) in the course of extremely low Eb/N0 ratios. The crucial advantage is the fact that turbo codes do not have any marked limit for bit error rate reducing. The principle of an iteration decoding is applied and increasing number of iteration steps allows practically unlimited reduction of bit error rate. In spite of many advantageous properties of turbo codes, they have a few of disadvantages that complicate their implementation. The fundamental handicap of turbo codes is presented by their high latency due to iteration decoding process and relatively complicated decoding algorithm SISO (Soft Input Soft Output).

Moreover a setting of optimal parameters for encoder and decoder is practically insolvable. The project of proper parameters is indeed difficult because the enormous number of combinations of parameters for turbo code design can be applied and it depends on the implementation of given turbo code and objective requirements. Till this time no mathematical tool for turbo code design has been found. A number of algorithms and architectures for turbo codes have been proposed for specific applications [1], [3]. In consequence this, the compromise between turbo code complexity and efficiency is the basic task of turbo code designing with the optimal features for desirable application.

2.1. Decoding of Turbo Codes

The turbo codes provide code gains that reach only several tithes of dB from theoretical maximum channel capacity but with higher encoder complexity. Thus, classical algorithms cannot be used for turbo codes decoding. Therefore a new scheme has been developed with two SISO decoders connected through an iteration loop. The main reason of iterative decoder utilization is a posteriori probability P(uk|y) estimation, where uk is k-th data bit and y is received sequence (code word). The decoder estimates a posteriori ratio for every k-th bit that is determined by (1) (1) y y=−=+ k k P u P u . (1) If the ratio is higher than 1, decoder decides that k-th bit equals to '1'. Vice versa, if the ratio is lower than 1, decoder evaluates k-th bit like '0'. If the logarithmic a posteriori ratio L(uk) will be used the decoding task will be more simplified () . (1) (1) log y y=−=+= k kk P u P u L u (2) In case of the probabilities of data bits are the same, the decision based on a posteriori ratio is equivalent like decision based on LLR – Log-Likelihood Ratio. The decoder does decision based on LLR [](). kk u = sign L u (3) Thus sign of uk is determined by HARD decision and value |L(uk)| designates reliability of this decision.

III. TURBO CODE

Modification Various requirements on turbo code properties are demanded for given application of communication system. The telemetry turbo code has been chosen for short data message transmission like a base code. The telemetry turbo code is determined for short data blocks transmission and it can work with very low Eb/N0 [1]. Therefore it is possible to suppose that a modification of this code is suitable for the development of a proper code for short data message service via satellite transponder. The modification consists in the implementation of an optimum interleaver with appropriate data block length k and code ratio R. The basic operation of thec is a generation of sequences with the smallest mutual correlations. An efficiency of interleaver is given by its proposed parameters. The interleaver quality is pivotal because this element affects in principle the efficiency of turbo code and the approaching to Shannon limit [5].

IV. BER ESTIMATION

The BER cannot be simply determined in real systems without auxiliary pilot signal or training message. However the knowledge of BER is needful for a control of the iteration decoding process and an effective BER estimation method for unknown received message is prerequisite. BER estimation methods presented in the next sections are based on applied methods in publications [12], [13]. These methods have been modified for applications using turbo decoders and they result from the classical turbo code decoding theory. 4.1 The BER Estimation Based on APP The first method for the BER estimation is based on a posteriori probability (APP). Probabilities APPi(+A) and APPi(-A) can be determined in the output of the turbo decoder for each transmission bit xi. Than the BER estimation can be described by the equation ∑()()()==·−+ N iAPPi A APPi A N BER 1 min, 1 (4) where the probability of each term is defined by formulas () LLR e APP A −++= 1 1, (5) () LLR e APP A ++−= 1 1. (6) The resulting BER estimation can be expressed by the equation ∑=+=· N iLLRi N e BER 1. 1 1 1 (7)

4.1 The Modified BER Estimation Method Based on LLR

This method is developed on the basis of theory in [13]. The probability can be calculated for each bit by equation (8), where Λ(n) is a logarithmic likelihood ratio (LLR) ()()()+1 =ΛΛ n n e e P n . (8) This method has been tested by many simulations, but it does not bring good results for the BER estimation of the developed turbo code and this method has been modified. The novel method displayed in Fig. 6 is based on the principle described in the previous text, but total probability as a sum of each bit probability contributions is not calculated. The first step of this method is a decision about correct or incorrect detection of each bit by a set of decision rules. However, the thresholds (t1 and t2) have to be determined correctly. The threshold value (t1 = 2.70805) is specified by formula (8). The threshold t1 is a limiting value, which indicates a high probability when the bit is decoded correctly or not. In case of the threshold t2, the determination of limit is more complicated. If values xHi and xSi are in the interval between -t2 and +t2, it means very high probability of error decision. The resulting limit is established by experimental BER measurements for various turbo codes.

V. 5.1 THE SIMPLIFIED METHOD FOR BIT VALUE CALCULATING

The simplified method for symbol determination used SOFT values from decoder output. The flowchart of this algorithm is shown in Fig. 11. The received packet of message is split in to four parts (sender address, receiver address, message length, data message). The sender and receiver address are divided to 6 x 2 B. The part containing information about message length is divided to 10 x 1 B. The arithmetic mean is calculated for each bit of separated parts. The bit value is determined in basis of the arithmetic mean following by the operation of HARD decision. The sender and receiver address processing is finished by this step. The part of packet specified as a data message carries an information message, which can be divided on n blocks with the same content repeated more than 4 times. The maximum length of message is 160 characters, i.e. 160 B. The arithmetic mean value is calculated for each bit of repetitions and the final bit value is determined by HARD decision. The advantage of this method is a utilization of shorter messages than 160 B resulting in more reliable decoding.

5.2 The Results of Methods for Symbol Value Determining

The relations of the BERsms and number of iteration are shown in Fig. 11, 12 and 13. The graphs display the BERsms characteristics for Eb/N0 = 0.6 dB, Eb/N0 = 0.8 dB and Eb/N0 = 1 dB. The smaller BERsms is achieved by using both methods but for higher redundancy. The bit error rates obtained without application of the methods for BERsms reduction are displayed by blue bars. The green bars represent BERsms values for the probability method and red bars for the simplified method. The zero BER is nearly always achieved for probability method with 10 iterations for Eb/N0 = 0.6 dB. On the other hand, the simplified method does not ever allow to get the zero BER for Eb/N0 = 0.6 dB. For both methods, the zero BER is nearly always achieved for Eb/N0 = 0.8 dB. The probability method gives better results because the BER diminishes to zero after 8 iterations. Also, the probability method is better for Eb/N0 = 1 dB because BER is zero after 4 iterations only.

VI. CONCLUSION

The new progressive channel coding methods for short message transmission via satellite transponder have been developed. The key benefit of this contribution is a design and implementation of new modified turbo code with unique features resulting from application of estimation methods for bit error rate and final forming of the output message. The mentioned methods allow error free communication for very low Eb/N0 ratios and they are suitable for satellite communication however also for other systems working with limiting Eb/N0 ratios.

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