Modeling and Investigation of the LDPC Immunity Code to Provide Increased Immunity in the Dvb-T2 Standard Digital Television System

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Abstract. In this paper, an error-correcting LDPC code has been investigated and modeled to provide an increase in noise immunity in a digital television system of the DVB-T2 standard. The algorithm of functioning of the noise-correcting LDPC codec was studied theoretically and practically. The noise-correcting LDPC code in the digital television system of the DVB-T2 standard with the developed interactive computer simulation program in the Matlab/Simulink programming language, the dependence of the number of errors on the error probability for the noise-correcting LDPC code was modeled and investigated.

Keywords: LDPC code, error-correcting code, DVB-T2 standard, encoder and decoder, noise immunity, interference, noise, error probability, syndrome, codeword length.

With the development of telecommunication technologies, interest in transmitting information with a minimum number of errors has grown again. Low-density parity codes have become part of the DVB-S2 satellite data transmission standard for digital television and have entered the IEEE 802.3 an Ethernet 10G network standard. A replacement has also taken place in the DVB-T2 standard for digital television broadcasting. Low-density parity codes are a powerful error correction technique that outperforms many well-known coding schemes. The codes can be used in any communication system where energy savings are significant or the signal-to-noise ratio is very low [1].

Low Density Parity Codes (LDPCs) are linear block codes whose parity matrix is sparse, i.e. contains a small number of zeros. Depending on the type of LDPC code and the method of its synthesis, the number of zero elements in the check matrix will vary. In addition to the matrix description, LDPC codes can also be described using a bipartite undirected Tanner graph. It is called bipartite because the nodes of the graph are divided into two different types. This representation makes it possible to more clearly describe the decoding algorithm [2].

Information processing using noise-correcting coding procedures allows to provide the required error probability, however, the use of coding requires encoder, decoder, interleaved devices, and, consequently, additional processing costs. In conditions where it is required to maintain a high transmission rate while ensuring a given noise immunity, it is necessary to have codes that can effectively deal with occurring errors and have fast encoding/decoding procedures [3].

In 1948, Claude Elwood Shannon published his work on the theory of information transmission. One of the key results of the work is the information transmission theorem for a noisy channel, which indicates the possibility of minimizing the probability of transmission error over the channel by choosing a sufficiently large length of the keyword - a unit of information transmitted over the channel. When transmitting information, its stream is divided into blocks of a certain (most often) length, which are converted by the encoder (encoded) into blocks called keywords. Key words are transmitted over the channel, possibly with distortion. On the receiving side, the decoder converts the keywords into a stream of information, correcting (if possible) transmission errors. Low Density Parity Check (LDPC) codes are a class of linear block codes that provide excellent performance with relatively low computational cost to decode them. These codes were proposed by Robert Gallagher back in 1963, but were forgotten for forty years due to the complexity of the implementation of their decoding algorithms [4].

In practice, in a digital television system, Bowes-Chowdhury-Hokvingham (BCH) codes are used for outer coding, and a low-density parity check (LDPC) code for inner.

It should be noted that the efficiency of irregular LDPC codes is higher than the efficiency of regular codes. This is explained by the fact that in irregular codes, due to the different number of ones in rows and columns, information symbols are protected differently. As a result, during decoding, the so-called wave effect appears, when more secure bits are decoded faster and then, as it were, help in decoding less secure bits [4].

To study and simulate the noise-correcting LDPC code in a digital television system of the DVB-T2 standard, an interactive computer simulation program was developed in the Matlab/Simulink programming language. The program is designed to simulate and calculate the dependence of the number of errors on the error probability for the error-correcting LDPC code.

To study and simulate the noise-correcting LDPC code in the digital television system of the DVB-T2 standard using the Matlab / Simulink software environment, we use the following parameters (Fig. 1,2,3,4,5) and set the characteristics of the blocks for the code (32400) of the digital television system DVB-T2 standard (Table 1).

N⁰	Parameter name	Parameter value						
1.	Frequency range:	(474-858) MHz with 8MHz						
	DMV	channel bandwidth						
2.	Modulation type	16-QAM						
3.	Constellation position	16						
4.	Bandwidth	8 MHz						
5.	Error-correcting code	LDPC						
6.	Code word length	32400						
2. 3. 4. 5. 6.	DMV Modulation type Constellation position Bandwidth Error-correcting code Code word length	channel bandwidth 16-QAM 16 8 MHz LDPC 32400						

Below are the parameters of the model (Fig.1,2,3,4,5).

🛅 Source Block Parameters: Bernoulli Binary Generator 🛛 🗙							
Bernoulli Binary Generator							
Generate random Bernoulli distributed binary numbers. <u>Source code</u>							
Parameters							
Probability of zero:	0.2						
Source of initial seed:	Parameter 🔹						
Initial seed:	61						
Sample time:	1						
Samples per frame:	32400						
Output data type:	double 👻						
Simulate using: Interpreted execution							
OK Cancel Help Apply							

Fig.1. Parameters of Bernoulli Binary Generator

Function Block Parameters: LDPC Encoder							
LDPC Encoder (mask) (link)							
Encode a message using a binary low-density parity-check code. The parity-check matrix specifies the code.							
(N-K) and N are the number of rows and columns in the parity-check matrix. This block accepts a column vector input signal with K elements. The output is a binary column vector with N elements. It is a solution to the parity-check equation, with the first K bits equal to the input.							
The last (N-K) columns of the parity-check matrix must form an invertible matrix in GF(2). If they form a triangular matrix, the parity-check equation will be solved by forward or backward substitution; otherwise, matrix inverse will be used (which may cause delays when updating or starting the model).							
Parameters							
Parity-check matrix (sparse binary (N-K)-by-N matrix):							
dvbt2ldpc(1/2)							
ОК Cancel Help Apply Fig.2. Parameters of LDPC Encoder							
🔁 Function Block Parameters: Binary Symmetric Channel 🛛 🗙 🗙							
Binary Symmetric Channel (mask) (link)							
Add binary errors to the input signal.							
Parameters							
Error probability:							
0.2							
Initial seed:							
71							
Output error vector							
Output data type: double							
OK Cancel Help Apply							

Fig.3. Parameters of Binary Symmetric Channel

 Function Block Parameters: LDPC Decoder LDPC Decoder (mask) (link) Decode a binary low-density parity-check code using the message-passin algorithm. The parity-check matrix specifies the code. (N-K) and N are the number of rows and columns in the parity-check matrix. This block accepts a column vector input signal with N elements. Each element is the log-likelihood ratio for a received bit (more likely to b'0' if the log-likelihood ratio is positive). The first K elements correspond the information part of a codeword. Parameters Parity-check matrix (sparse binary (N-K)-by-N matrix): 	× Ig					
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Parity-check matrix (sparse binary (N-K)-by-N matrix):						
	arity-check matrix (sparse binary (N-K)-by-N matrix):					
dvbt2ldpc(1/2)						
Output format: Information part	•					
Perior trace Used decision	_					
Decision type: Hard decision	•					
Output data type: double	•					
Number of iterations:						
50						
Stop iterating when all parity-checks are satisfied						
Output number of iterations executed						
Output final parity-checks						
Fig.4. Parameters of LDPC Decoder						
Nunction Block Parameters: Error Rate Calculation1						
Error Rate Calculation (mask) (link)						
Compute the error rate of the received data by comparing it to a delayed version of the transmitted data. The block output is a three-element vector consisting of the error rate, followed by the number of errors detected and the total number of symbols compared. This vector can be sent to either the workspace or an output port.						
input is a scalar or a vector. The inputs to the 'Tx' and 'Rx' ports must be scalars or column vectors.						
scalars or column vectors.						
The 'Stop simulation' option stops the simulation upon detecting a target number of errors or a maximum number of symbols, whichever comes first.						
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The 'Stop simulation' option stops the simulation upon detecting a target number of errors or a maximum number of symbols, whichever comes first. Parameters Receive delay: 0 Computation delay: 0						
Input is a scalar of a vector. The inputs to the 'Tx and 'tx' ports must be scalars or column vectors. The 'Stop simulation' option stops the simulation upon detecting a target number of errors or a maximum number of symbols, whichever comes first. Parameters Receive delay: 0 Computation delay: 0 Computation mode: Entire frame						
Input is a scalar or a vector. The inputs to the 'Tx and 'tx ports must be scalars or column vectors. The 'Stop simulation' option stops the simulation upon detecting a target number of errors or a maximum number of symbols, whichever comes first. Parameters Receive delay: 0 Computation delay: 0 Computation mode: Entire frame Vulput data:						
Input is a scalar or a vector. The inputs to the 'Tx and 'tx' ports must be scalars or column vectors. The 'Stop simulation' option stops the simulation upon detecting a target number of errors or a maximum number of symbols, whichever comes first. Parameters Receive delay: 0 Computation delay: 0 Computation mode: Entire frame Output data: Port						

Fig.5. Parameters of Error Rate Calculation

On (Fig.6,7,8) the investigated scheme of the model of the noise-correcting code LDPC in the digital television system of the DVB-T2 standard is shown. The model scheme under study consists of the following blocks: Bernoulli Binary Generator (generator), LDPC Encoder (encoder), Binary Symmetric Channel (transmission channel), LDPC Decoder (decoder), Error Rate Calculation (error analyzer) and Display.



Fig.6. Scheme of the LDPC error-correcting code model in a DVB-T2 digital television system (error probability is 0.2)

The displays of the model demonstrate: a transmission line using the LDPC code. Input combination, encoded sequence, output combination, errors (error probability is 0.2).



Fig.7. Scheme of the model of the noise-correcting code LDPC in the digital television system of the DVB-T2 standard (error probability is 0.8)

The displays of the model demonstrate: a transmission line using the LDPC code. Input combination, encoded sequence, output combination, errors (error probability is 0.8).



Fig.8. Scheme of the LDPC error-correcting code model in a DVB-T2 digital television system (error probability is 1.0)

The displays of the model demonstrate: a transmission line using the LDPC code. Input combination, encoded sequence, output combination, errors (error probability is 1.0).

The simulation results and calculated values are summarized in Table 2.

I able 2.							
N⁰	Probability of errors	Frequency error	Number of detected	Total number of			
			errors	characters compared			
	0	0	0	3,24e+4			
	0,1	0,0991	3211	3,24e+4			
	0,2	0,1989	6445	3,24e+4			
	0,3	0,2995	9672	3,24e+4			
	0,4	0,3986	1,296e+4	3,24e+4			
	0,5	0,5008	1,623e+4	3,24e+4			
	0,6	0,6007	1,946e+4	3,24e+4			
	0,7	0,7003	2,269e+4	3,24e+4			
	0,8	0,7959	2,759e+4	3,24e+4			
•	0,9	0,9011	2,916e+4	3,24e+4			
•	1	1	3,24e+4	3,24e+4			

A study was made using the model (Fig.6,7,8), the dependence of the number of errors on the error probability for the noise-correcting LDPC code in the digital television system of the DVB-T2 standard.

Figures 9 and 10 show the simulation results: the dependence of the error rate, the number of detected errors on the error probability for the LDPC code (32400).



Fig.9. Graph of error rates versus error probability for LDPC code



Fig.10. Graph of the number of detected errors versus the error probability for the LDPC code

The results of research and modeling show that low-density parity codes are a powerful error correction technique that outperforms many well-known coding schemes. The codes can be used in any communication system where energy savings are significant or the signal-to-noise ratio is very low [1].

In practice, in a digital television system, *Bose-Chowdhury-Hokvingham* (BCH) codes are used for outer coding, and a low-density parity check (LDPC) code for inner.

It should be noted that the efficiency of irregular LDPC codes is higher than the efficiency of regular codes. This is explained by the fact that in irregular codes, due to the different number of ones in rows and columns, information symbols are protected differently. As a result, during decoding, the so-called wave effect appears, when more secure bits are decoded faster and then, as it were, help in decoding less secure bits [4].

Produced and modeled the dependence of the number of errors on the error probability for errorcorrecting LDPC code, the results show that such codes provide a high degree of error correction. The lower the probability of the influence of interference on the communication channel, the less will be the erroneous reception of binary symbols.

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