NATIVE AND IN-DEPTH INNER INTERLEAVING IN DVB-H

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ABSTRACT

This paper presents comparative results of simulation providing two options of the Inner Symbol interleaving in channel coding of digital television of the DVB-T and DVB-H standards. Channel coder of DVB-T/H and model of the disturbances were built in MAT-LAB environment and its simulation results are presented. Comparison between the different Symbol Interleaving possibilities, then QPSK, 16-QAM, 64-QAM inner modulations and 2k, 4k, 8k CCOFDM modes are presented in the paper.

1. INTRODUCTION

The DVB-H (Digital Video Broadcasting – Handheld) [1] is an extension of the DVB-T (Digital Video Broadcasting – Terestrial) [2]. DVB-H offers all Channel coding and Modulation features as the DVB-T and extends them especially by COFDM (Coded Orthogonal Frequency Division Multiplexing) mode 4k and the In-depth Inner interleaving.

Channel coding and Modulation of the DVB-H [1] [2] is composed by Transport Multiplex Adaptation, Randomization for Energy Dispersal, Outer Reed-Solomon Coding, Outer Convolutional Interleaving, Inner Convolutional Coding (possibly punctured), Inner Interleaving (Native or In-depth), Constellations and Mapping to the digital modulation and finally the COFDM symbol creation.

2. NATIVE AND IN-DEPTH MODES OF SYMBOL INTERLEAVING

The Inner Interleaving and its part the Symbol Interleaving is one of the processes offering a choice of channel coding and data protection according to transmission network needs. Native and In-depth Symbol Interleaving used together with COFDM mode 2k, 4k or 8k (only Native) offers flexibility between transmission cell size and mobile reception capabilities.

Symbol Interleaver maps *v*-bit words (symbols formed in Bit-wise Interleaver according to Inner Modulation) onto the active data carriers composing COFDM symbols. The number of data payload carriers depends on used COFDM mode and it can be 1512 (2k mode), 6048 (8k mode) in the DVB-T or both previous and in advance 3024 carriers (4k mode) as an addition of the DVB-H.

Symbol Interleaver acts on data blocks of sizes corresponding to COFDM and Inner Interleaving mode. For the Symbol Interleaving are used permutation functions dedicated to the actual interleaving mode. The length of permutation function and consequently the length of processed data symbols block are following:

- 1512 for 2k mode with Native Symbol Interleaving,
- 3024 for 4k mode with Native Symbol Interleaving,
- 6048 for 8k mode with Native Symbol Interleaving,

and

- 6048 for 2k and 4k mode with In-depth Symbol Interleaving.

The permutation function used for DVB-H In-depth interleaving is same as 8k Native mode permutation function. Interleaved output vectors of size 6048 symbols are then mapped onto four consecutive 2k COFDM symbols or two consecutive 4k COFDM symbols. This data spread over two or four COFDM symbols then provides increased ability of effective error correction by spreading of errors caused by impulsive disturbances in the transmission channel. Details about permutation functions creation are defined in [2].

3. DVB-T/H CHANNEL CODER SIMULATION IN MATLAB

Complete Channel Coding and Modulation with all DVB-T/H features [2] and simplified COFDM modulator with selection of 2k, 4k or 8k modes were built in MATLAB. Also the Channel transmission model with AWGN (Additive White Gaussian Noise) and impulsive noise model were implemented. Impulsive noise is simulated by adding of disturbing time domain signal to the COFDM time domain symbols. Disturbing signal is created in the frequency domain by mapping of random symbols to selected carriers placed over the spectrum and then transformed to the time domain. The impulse character is simulated by affecting of selected COFDM symbols, not the continuing affection of channel. The model allows setting of distance between affected carriers and also COFDM symbols.

4. SIMULATION OF NATIVE AND IN-DEPTH SYMBOL INTERLEAVING

Following section presents MATLAB simulation of the DVB-T/H model with different Inner Symbol Interleaving, QPSK modulation and 2k COFDM mode working in disturbed conditions (this set up is convenient for mobile TV reception).

There is shown an absolute value of the 2k COFDM symbol spectrum in the Fig. 1 a). Zero carriers are located on the sides of the spectrum. There are 1705 data (1512) and pilot (193) carriers placed in the centre of symbol spectrum.

There is shown an absolute value of the disturbing signal spectrum in the Fig. 1 b). The spectrum has single carriers on the positions with distance of 16 carriers over the entire spectrum of 2048 carriers. This is the spectrum of one symbol used to disturb one of four consecutive 2k COFDM symbols.

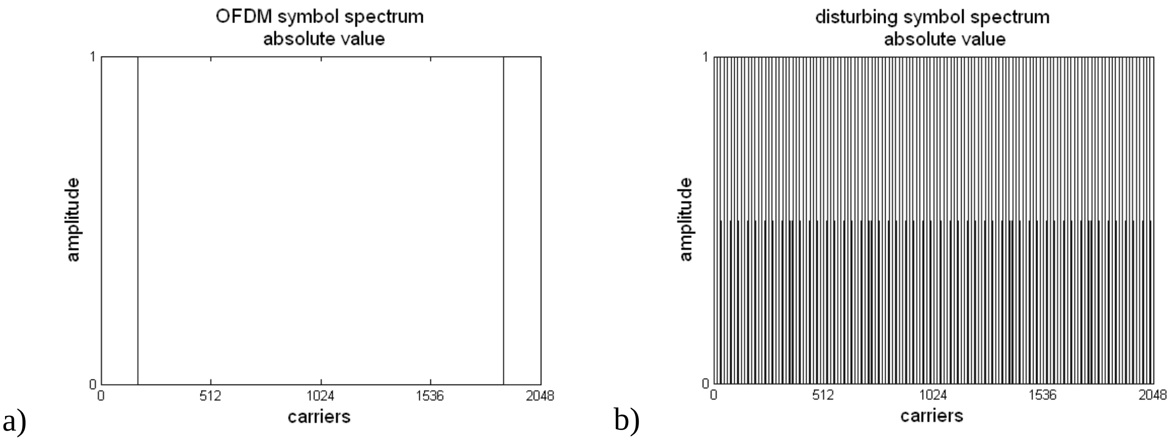

Figure 1: a) Absolute value of 2k mode COFDM symbol spectrum;
b) Absolute value of disturbing 2k mode symbol complex spectrum

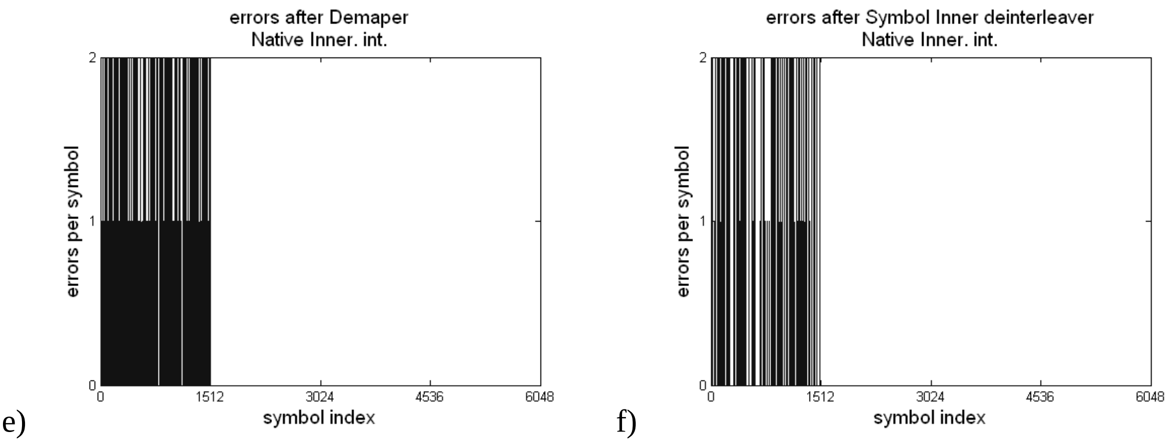

Figure 2: a) Errors location after constellation demapping - Native Inner Interleaved;
b) Errors location after Native Symbol Inner deinterleaving

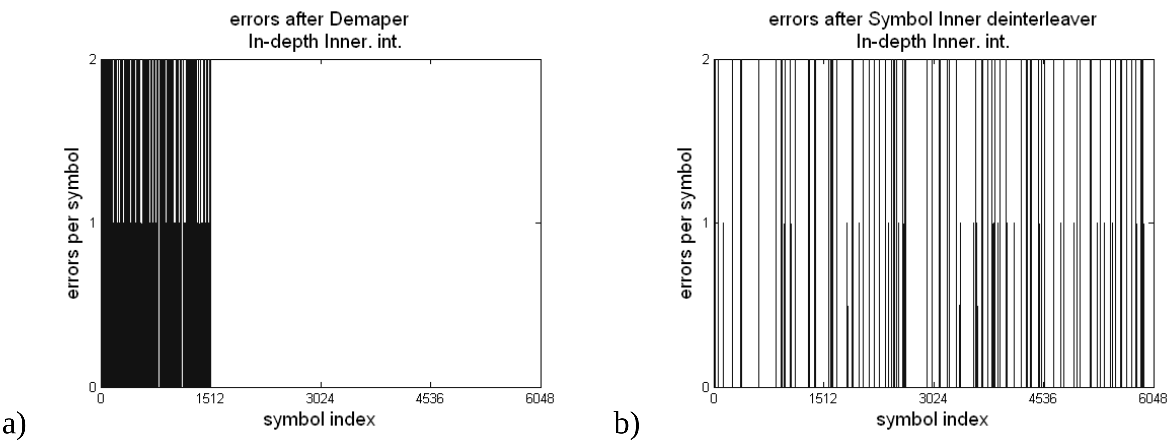

Figure 3: a) Errors location after constellation demapping - In-depth Inner Interleaved;
b) Errors location after In-depth Symbol Inner deinterleaving

The next Fig. 2 and Fig. 3 present errors location on the data sequence of size 6048 data symbols. Errors were caused by affecting of each 4^{th} COFDM symbol by disturbing signal with each 16^{th} carrier disturbed. Symbol indexes are on the *x*-axis of the graph. The size of sequence is given by four consecutive 2k COFDM symbols processed by In-depth Symbol Interleaver with permutation function of corresponding 6048 length. There are numbers of errors per one symbol on the *y*-axis. Number of possible errors per symbol corresponds with used Inner QPSK Modulation and is 2 therefore.

There is presented errors location over the sequence after constellation demapping in the Fig. 2 a) and the Fig. 2 b) presents errors location after the Native Symbol Inner deinterleaving. Errors are concentrated only in affected region of size 1512 carriers never mind before or after Native Symbol Inner deinterleaver processed.

The next Fig. 3 a) presents errors location over the sequence after constellation demapping and the Fig. 3 b) presents errors location after the In-depth Symbol Inner deinterleaving. It is obvious the effective spread of errors, originally concentrated only in affected region of size 1512 carriers, over the overall 6048 data symbols.

Simulated error rates of DVB-T/H model using QPSK, 16-QAM and 64-QAM Inner modulation with different COFDM modes are compared in the following Tab. 1 to Tab. 3:

Inner modulation	2k COFDM mode		4k COFDM mode		8k COFDM mode
QPSK	Native	In-depth	Native	In-depth	Native
Demaper SER	$3.50 \cdot 10^{-2}$	$3.27 \cdot 10^{-2}$	$3.96 \cdot 10^{-2}$	$3.04 \cdot 10^{-2}$	$4.35 \cdot 10^{-2}$
Viterbi BER	$6.94 \cdot 10^{-2}$	$2.94 \cdot 10^{-4}$	$7.88 \cdot 10^{-2}$	$6.70 \cdot 10^{-3}$	$8.08 \cdot 10^{-2}$
RS BER	$7.05 \cdot 10^{-2}$	0	$7.16 \cdot 10^{-2}$	$4.57 \cdot 10^{-4}$	$7.11 \cdot 10^{-2}$

Table 1: Error rates in DVB-T/H using QPSK Inner modulation

Inner modulation	2k COFDM mode		4k COFDM mode		8k COFDM mode
16-QAM	Native	In-depth	Native	In-depth	Native
Demaper SER	$3.55 \cdot 10^{-2}$	$3.57 \cdot 10^{-2}$	$3.93 \cdot 10^{-2}$	$3.47 \cdot 10^{-2}$	$3.45 \cdot 10^{-2}$
Viterbi BER	$6.79 \cdot 10^{-2}$	$7.52 \cdot 10^{-4}$	$7.19 \cdot 10^{-2}$	$8.80 \cdot 10^{-3}$	$6.75 \cdot 10^{-2}$
RS BER	$7.57 \cdot 10^{-2}$	0	$7.90 \cdot 10^{-2}$	$1.80 \cdot 10^{-3}$	$7.19 \cdot 10^{-2}$

Table 2: Error rates in DVB-T/H using 16-QAM Inner modulation

Inner modulation	2k COFDM mode		4k COFDM mode		8k COFDM mode
64-QAM	Native	In-depth	Native	In-depth	Native
Demaper SER	$3.30 \cdot 10^{-2}$	$2.94 \cdot 10^{-2}$	$3.33 \cdot 10^{-2}$	$3.34 \cdot 10^{-2}$	$3.42 \cdot 10^{-2}$
Viterbi BER	$5.99 \cdot 10^{-2}$	$2.45 \cdot 10^{-4}$	$5.56 \cdot 10^{-2}$	$7.20 \cdot 10^{-3}$	$6.16 \cdot 10^{-2}$
RS BER	$6.39 \cdot 10^{-2}$	0	$5.84 \cdot 10^{-2}$	$2.10 \cdot 10^{-3}$	$6.72 \cdot 10^{-2}$

Table 3: Error rates in DVB-T/H using 64-QAM Inner modulation

There are visible the differences between the Native and In-depth Symbol interleaving results in the Tab. 1., Tab. 2 and Tab. 3. Symbol error rates after demapping process are similar for both modes whereas the error rates after Viterbi decoder and consequently after Reed-Solomon decoder are considerably better for the In-depth interleaving. Viterbi decoder and Reed-Solomon decoder damage the data even more when the concentration of errors is excessive. By comparison of results across different used Inner modulations is visible that the disturbances model results in similar error rates regardless of modulation.

5. CONCLUSION

Presented simulation results confirmed the In-depth Symbol Interleaver capability to spread the errors caused by impulsive disturbances of COFDM symbols. Disturbances model with each 16^{th} carrier disturbed was used for the explanation of the Native and In-depth Symbol interleaving function in order to simplify the graphs readings. Graphical differentiation of presented graphs would become difficult when higher concentration of disturbed carriers is used. Disturbances model with each 4^{th} carrier disturbed was used for the numerical comparison of Native versus In-depth Symbol interleavers capabilities.

When the Native Symbol Interleaving is used, errors concentration over the affected region remains significant and Viterbi decoder is not capable to repair damaged symbols. In-depth Symbol Interleaver spreads the errors over four (2k mode) or two (4k mode) times longer symbols sequence and decrease the local errors concentration. This helps the Viterbi decoder to effectively repair some of the errors.

Disturbances model used in presented simulation provides significant injure of disturbed COFDM symbols. Used approach disturbs each 4^{th} or 16^{th} carrier of each 4^{th} symbol, without reference to used COFDM mode. This means that the ratio of damaged constellation symbols and number of carriers remains constant in affected COFDM symbol for all modulation modes.

Simulated results are influenced by used finite data length of 8730 bytes what is in opposite to continuous data stream in real broadcasting. Presented results should be therefore considered as relative for the comparative use only.

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