FORWARD ERROR CORRECTION OF THE STANDARD DVB-SH AND ITS SIMULATION IN MATLAB

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Abstract: This paper deals with the MATLAB implementation of the DVB-SH (Digital Video Broadcasting – Satellite services to Handhelds) FEC (Forward Error Correction) encoder in AWGN (Additive White Gaussian Noise) transmission channel. The application structure and its functions are described. Dependences of *BER* (Bit Error Ratio) and *FER* (Frame Error Ratio) on *C/N* (Carrier-to-Noise Ratio) after turbo decoding as a result of the simulation in AWGN channel are expressed and compared to each other. Finally, obtained results are discussed.

Keywords: DVB-SH-A, turbo encoding, turbo decoding, number of iterations, BER, FER.

1. INTRODUCTION

The DVB-SH standard provides an efficient and flexible mean of carrying broadcast services over an hybrid satellite and terrestrial infrastructure operating below 3 GHz to a variety of portable, mobile and fixed terminals having compact antennas with very limited or no directivity. Target terminals include handheld defined as light-weight apparatus (PDAs, mobile terminals), vehicle-mounted, nomadic (laptops) and stationary terminals [1]. DVB-SH complements and improves the existing DVB-H physical layer standard. DVB-SH specifies two operational modes:

- **SH-A** for OFDM (Orthogonal Frequency Division Multiplexing) terrestrial and OFDM satellite transmission mode,

- **SH-B** for OFDM terrestrial and TDM (Time Division Multiplexing) satellite transmission mode [1], [2].

The S-Band is very demanding in terms of signal coverage. The burden placed on DVB-SH by the high frequency band in which it operates is compensated for by a selection tools that enhanced the signal robustness. For example FEC (Forward Error Correction) scheme, 3GPP2 turbo code is used. Additional code rates with respect to the originally defined 3GPP2 code rates have been introduced to both allow finer granularity in terms of *C/N* adjustment and code combining between OFDM and TDM [3], [4].

This paper contains results of recent development of MATLAB application which allows to simulate FEC and transmission of the DVB-SH-A standard in Gaussian (AWGN) channel. GUI (Graphical User Interface) was also created to make the use of the application and changing settings easier. At the end of this simulation it can show *BER* after turbo decoding and *FER* after turbo decoding. Finally, results of these dependences in Gaussian channel are graphically expressed compared and discussed.

2. TURBO ENCODING

Turbo code caters to the need of achieving higher error correction capability without adding to decoding complexity needed for long codes. Turbo code encodes the same information more then
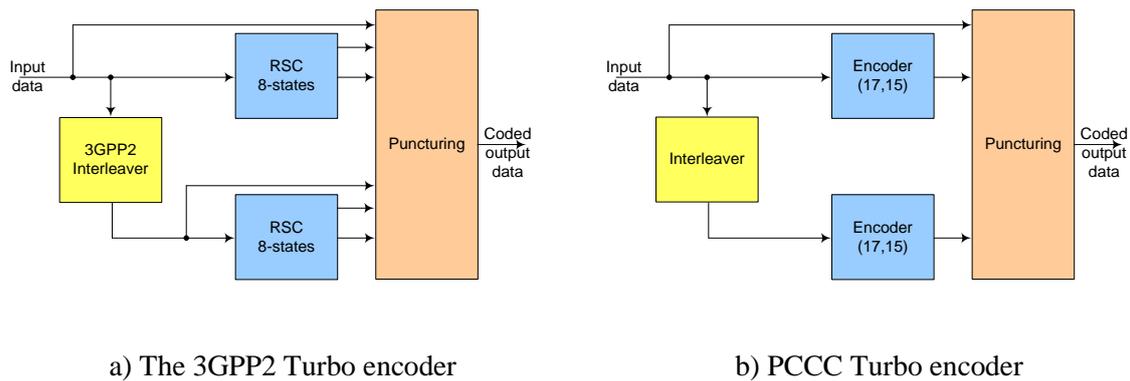
a) The 3GPP2 Turbo encoder　　　　　　　　b) PCCC Turbo encoder

Fig. 1: Turbo encoder of the DVB-SH: a) defined by the DVB-SH and b) modified.

once. The information bits are sent to the encoders (generally 2 encoders) in different order. More precisely, the input information is firstly interleaved and then sent to the second encoder. The decoder in the turbo codes are soft input soft decoder output. The decoding is based on principle iterative decoding [5].

The DVB-SH standard designates the use of the 3GPP2 turbo codes for FEC, e.g. see Fig.1 a). The main features of these codes are e.g. low code rate (from 1/5 to 1/2 and a higher rate of 2/3) and the use of an appropriate puncturing technique to obtain different code rates.

The 3GPP2 turbo encoder employs two systematic and recursive convolutional encoders connected in parallel, with a special interleaver (so called 3GPP2 interleaver). This interleaver precedes the second recursive convolutional encoder. A common constituent code shall be used for all turbo codes. The transfer function for the constituent code and the FEC using 3GPP2 turbo code encoder is described in [4]. After the generating of output symbol sequence is coming the puncturing. Within a puncturing pattern, a *"1"* means that the symbol shall be passed and a *"0"* means that the actual symbol shall be deleted.

The turbo code as standardized by the 3GPP2 organization shall be used for the DVB-SH. However, this type of turbo encoder has several disadvantages from the perspective of simulation:

- complexity (the transfer function of the constituent code of the 3GPP2 RSC encoders is complex),

- complicated turbo interleaver (computation of interleaving address for the input data payload),

- turbo decoding method (the DVB-SH turbo encoding process, based on 3GPP2 is well specified in [5], on the other hand, turbo decoding process is not describing).

The disadvantages of implementation of 3GPP2 turbo encoder were mentioned above. For the simulation, therefore, was used a modified type of this turbo encoder. The created application used PCCC (Parallel Concatenated Convolutional Code) turbo encoder (see Fig. 1 b). This type is preferred mainly for its very low BER [5].

The PCCC turbo encoder, as well as the 3GPP2 turbo encoder, consists of two recursive convolutional encoders. These encoders, more precisely, their structure are defined by generator polynomials $G_1 = 17_{OCT}$ and $G_2 = 15_{OCT}$. The constituent encoders code the same data stream that for different encoders is interleaved. One of the main differences between these two encoders is that in the PCCC turbo coder the systematic bits are transmitted only once. It is very important in terms of time consumption of whole simulation. The process of the puncturing after the PCCC turbo coding is that same in the case of 3GPP2 turbo coder.

3. TURBO DECODING

How it was mentioned in the previous chapters, the turbo decoding process for the standard DVB-SH is not defined. For the decoding data stream in this simulation (after the demodulation and depuncturing) SISO-MAP (Soft Input Soft Output Maximum A Posteriori) method was used. An iterative structure of SISO-MAP detection and SISO decoder is proposed for differential turbo coded systems. The turbo decoder, which was used in the simulation, is shown in Fig. 2.
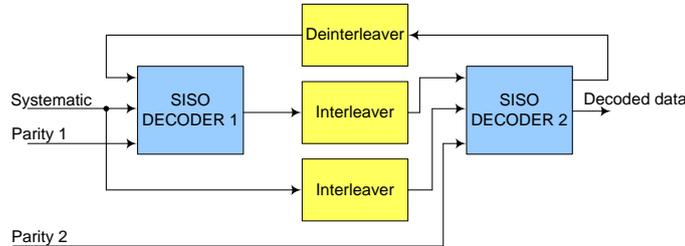

Fig. 2: SISO-MAP turbo decoder

How it can be seen in the Fig. 2, two soft decision decoders are employed. SISO Decoder 1 provides soft output which is a measure of the reliability of each decoded bit from the reliability. From the reliability information the extrinsic information is extracted. The extrinsic information is independent of the current decoder input. The extrinsic information after interleaving is passed to the SISO Decoder 2. The second decoder uses this information to decode the interleaved bit sequences. From the soft outputs of SISO Decoder 2 the new extrinsic information is fed back to the input of SISO Decoder 1 and so on. If the error occurs due to noisy input of the first decoder, it may be corrected by the second decoder. More detail description and mathematical algorithm can be found in [5]. The repeating of this turbo decoding processing is dependent on the number of iteration. For example, when the number of iterations is equals five, then the turbo decoding is repeated five times.

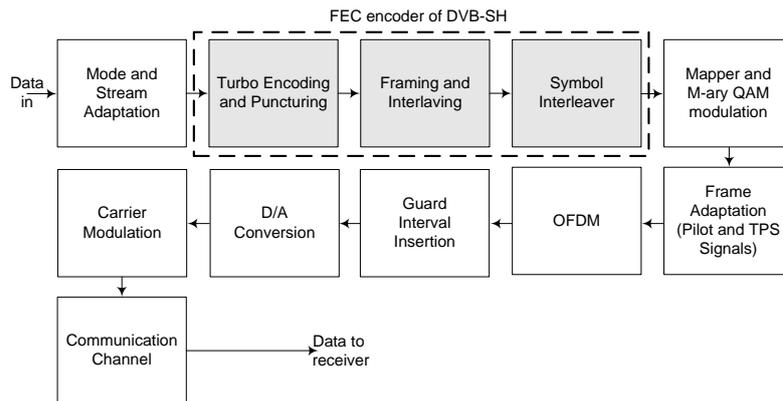## 4. BLOCK DIAGRAM OF THE STANDARD DVB-SH

Fig. 3: Block diagram of the transmitter of the DVB-SH-A

The structure of the transmitter follows common DVB-SH-A transmitter block diagram, as shown in Fig. 3. Each block is represented by one m-file function. The receiver is programmed as inverted transmitter.

Mode Adaptation consists of CRC (Cyclic Redundancy Check) encoding, to provide detection every MPEG packet. Stream Adaptation provides padding to complete a constant length of one trans-

mitted frame and performs scrambling [4]. For the simulation of the data transmission this block is omitted, because the scrambling of input data stream has not significant effect on the error correction. The program, therefore in the first step is generated the input data sequence. The length of one data frame, which was used in simulation, is 2048 bits.

The next stage contains the turbo encoding and puncturing. The process of coding and puncturing was described in previous chapter.

The interleavers are introduced to enhance the resistance of the waveform to short-term fading and medium-term shadowing impairments in satellite and terrestrial channels. The DVB-SH, as a DVB-H, used bit-wise interleaving. The output of the Turbo encoder shall be bit interleaved using a block interleaver. The values for block interleaving are given in [4]. Practically, each code rate has own bit-wise interleaver function.

Before the symbol interleaving, the input stream is demultiplexed (mapped to output modulation symbols) into v sub-streams, depending of the modulation used: $v = 2$ for QPSK and $v = 4$ for 16QAM. Each sub-stream from the demultiplexer is then interleaved in the interleaver with own interleaving sequence called permutation function.

The FEC encoder of the transmitter of the standard DVB-SH was described. The following blocks provide modulation and OFDM framing. These blocks are similar as blocks, which are used in DVB-H and they are described in [6] and [7].

5. SIMULATION

Application for the simulation of the transmission of DVB-SH-A has been implemented in MATLAB. For the simulation of the DVB-SH-A transmission following settings was used:

- mode: 1k (satellite reception)
- code ratio: 1/5 (robust transmission)
- modulation: QPSK, 16QAM
- transmission channel: Gaussian (AWGN)
- turbo decoding: SISO-MAP
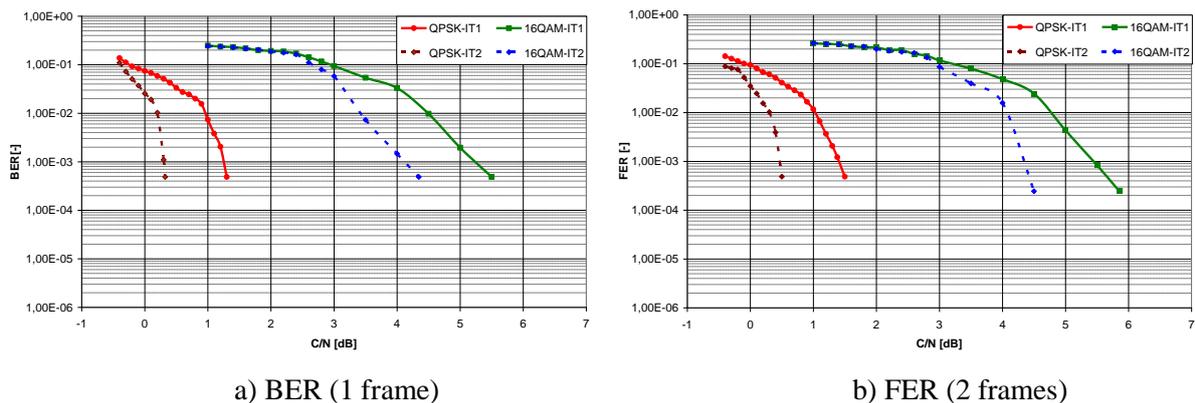- number of iterations (IT number): 1 and 2.

a) BER (1 frame)	b) FER (2 frames)

Fig. 4: Simulated dependences of BER and FER on C/N ratio after turbo decoding in AWGN channel

6. RESULTS

Dependence of the *BER* on *C/N* ratio as a result of the simulation in the Gaussian channel is graphically expressed. The Fig. 4 a) and b) illustrate *BER* and *FER* ratio after turbo decoding. In both

figures the solid lines present the case, when iteration number is equal to one. Dotted lines present the case, when iteration number is equal to two. From the results it is easy to see that the multistate modulations with less number of states are more robust than the modulation with higher number of states. The *BER* and *FER* are better thanks to the increasing number of iterations. For achieving the same *BER* and *FER* ratio for the various types of modulation as in Gaussian channel we do not need to increase the value of *C/N*. For example, to achieve a very low *BER* (approximately 3.10^{-4}) for QPSK modulation it is needed *C/N* = 1.3 dB, for 16QAM it is *C/N* = 5.6 dB. But when the IT number equals two, for QPSK modulation it is needed *C/N* = 0.3 dB, for 16QAM it is approximately *C/N* = 4.35 dB.

7. CONCLUSIONS

The application that allows simulation of the DVB-SH standard (precisely DVB-SH-A) transmission was developed and described. Dependence of the bit error rate and frame error ratio on carrier-to-noise ratio after turbo decoding was explored. Differences between the numbers of iterations in turbo decoding processing were also investigated and discussed. Results for all type of DVB-SH modulations were obtained and discussed.

Future work will be focused on a channel estimation block to provide reliable simulation results in fading transmission channels. This work will be also continuing to improve turbo decoding algorithm (SISO-MAP) and add another type algorithms (Log-Map, Map).

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