UTILIZATION OF MATLAB FOR THE DIGITAL SIGNAL TRANSMISSION SIMULATION AND ANALYSIS IN DTV AND DVB AREA

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Abstract: *The contribution deals with the utilization of Matlab for simulation and analysis of the digital signal transmission and transmission distortions in DTV (Digital Television) and DVB (Digital Video Broadcasting) area. The simulation model that covers selected phenomena of DVB system signal processing applied in Matlab is presented and phenomena of the transmission protection (channel encoding) is outlined. The digital video signal is represented with the digital data of one non-compressed video frame that is channel encoded and protected against errors with the forward error correction (FEC) codes. The transmission channel model has influence on transmitted digital data and its distortion and the pertubative signals affect on the data decoding. The developed interactive simulation software (Matlab application) features are outlined too.*

Keywords: *digital television, forward error correction, model of the transmission channel*

1 Introduction and approach to simulation and analysis

The DVB in European area deals with the DVB standard [1] and becomes very popular in Czech Republic because of the transition conception to digital broadcasting of television and radio services. The satellite service DVB-S of the czech packet Czechlink is available from satellite Eurobird 1 (GEO 28,5^o E) and terrestrial service DVB-T is available around the capital Prague by two experimental pilot projects (Czech Radiocommunications, Czech Digital Group). The digital television starts and it is important to deal with DVB in research and practical education at the technical universities.

The grant project[1] *"Simulation and analysis of the digital signal transmission and transmission distortions in DTV and DVB area"* aims are simulation and analysis of the digital signal transmission that corresponds to DVB standards. The transmitted digital signal presents the image data information that is source, channel and link coded, digital modulated and transferred by the digital channel model with variable parameters. One project solution task is creation of the experimental simulation model and its application in Matlab. The next paragraphs present selected phenomena of DVB signal processing and at the end of contribution is presented the Matlab application features with one simulation example.

2 Simulation model applied in Matlab

The simulation model is shown in **Fig. 1**. The input video signal is represented with the one non-compressed *RGB* image. The standard image is discretized into raster 720 x 576 picture elements in according to DVB basic resolution. Then the analog transmission signals *RGB* are counted and after analog-to-digital conversions the digital image components YC_BC_R are obtained. The composition of serial digital data multiplex is individual for each sampling format. The digital signal elements sequence is standardized by CCIR ITU R-601 recommendation and generates multiplex of serial image samples [3]. The digital signal is ensured against transmission errors with forward error correction codes (FECs) and

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interleaved. Then the protected serial digital signal is transmitted with the model of the digital transmission channel in baseband. The conversions at the receiver side are vice-versa to described transmitter side. Only the image data interpolation in dependence on used sampling format is added as the last process of analysis.
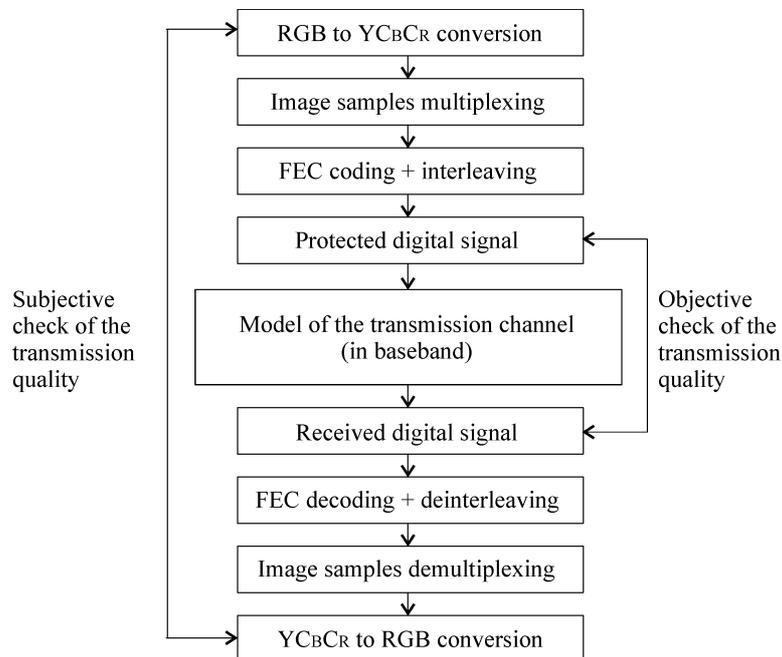

Fig. 1 The simulation and analysis model.

After the transmission with the model of the digital transmission channel the *objective check* (block and bit error rates evaluation) and *subjective check* (comparison of *RGB* images in spatial area) of transmission quality can be figured out. The subjective check of transmission quality is not standardized and the result can be classified into the five level quality scale with decimal graduation (from excellent image to unsufficient image).

3   Forward Error Correction FEC in Digital Television Transmission

The principal of the transmission with error-protection coding in digital television deals with the redundancy information that is added to the source-coded digital signal in the channel encoder. This enables the channel decoder in the receiver to correct any errors. The addition of the redundancy information leads to an increase in the data volume to be transmitted. The task of channel coding in the receiver is to find the position of the incorrect bits by the evaluation of the redundancy that is also possibly affected by the transmission errors. The added redundancy is then removed. Therefore channel coding is required which provides for forward error corrections (FECs). Two relevant methods of error protection in the transmission of digital television are forward error corrections by block Reed-Solomon code (FEC1) and convolution code (FEC2) with interleaving (see **Fig. 2**).

For the transmission of digital TV over satellite and via terrestrial transmission networks the RS (n, m) code - $n = m + k$ where m is the number of information symbols and k is the number of correction symbols - is concatenated with the convolution code by means of an interleaver. The RS code is based on the Galois field GF (2^8), and therefore has a symbol size of 8 bits. The RS (255, 239) was chosen which processes a data block of 239 symbols and can correct up to 8 symbol errors by calculating 16 redundant correction symbols. As an MPEG-2 packet is 188 bytes long, the code was shortened, i.e. the first

51 information bytes were set to zero and not transmitted at all. In this way the RS (204, 188) code is generated. After the outer code a convolution interleaver with depth I = 12 is used. From the frame length of the outer code with n = 204 the base delay results as $M = n/I$ = 17. Finally a convolution code is applied to the interleaved symbols. Its rate $R = m/n$ - where m is the number of input bits and n is the number of output bits - is equal to 1/2, the constraint length is K = 7. Optionally the 2/3, 3/4, 5/6 and 7/8 rates are possible. Coding for error correction by transmission over cable is similar, only the convolution code is not required as the signal-to-noise performance in the cable channel is very much better than in the satellite channel [2].
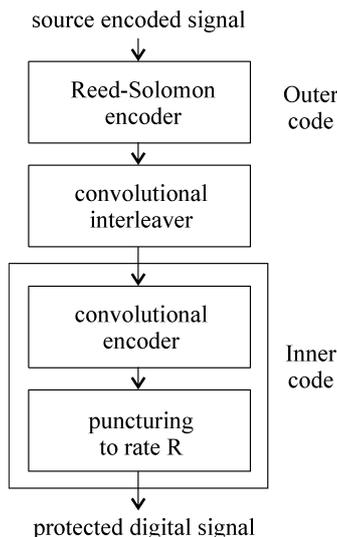
source encoded signal

```
          ┌──────────────┐
          │ Reed-Solomon │   Outer
          │   encoder    │   code
          └──────────────┘
          ┌──────────────┐
          │ convolutional│
          │  interleaver │
          └──────────────┘
       ┌─────────────────────┐
       │ ┌─────────────────┐ │
       │ │  convolutional  │ │
       │ │     encoder     │ │   Inner
       │ └─────────────────┘ │   code
       │ ┌─────────────────┐ │
       │ │    puncturing   │ │
       │ │    to rate R    │ │
       │ └─────────────────┘ │
       └─────────────────────┘
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protected digital signal

Fig. 2 Forward error correction codes in the transmission of the DVB.

4   Matlab application for interactive simulation overview

The developed Matlab application (see **Fig. 3**) for the simulation and analysis creates the tool for experimental simulation with GUI and interactive help (see **Fig. 4**). The *input image* can be selected from file (*.BMP, *.JPG etc.), the digital video signal *sampling format* (4:4:4, 4:2:2, 4:2:0), *transmission multiplex* (serial or parallel) and *transmission quality* (8 or 10 bps) selection corresponds to ITU R-601 recommendation. The *forward error correction* uses the standard block RS code (RS (255, 239), RS (255, 235), RS (255, 223), RS (255, 205)), interleaver with depth up to 20 and convolution code with rate 1/2, 2/3, 3/4, 5/6 or 7/8. The developed model of the transmission channel [4] can change the *character of the transmission* (low-pass, high-pass, band-pass, band-stop, multiband filters), possibility of *design method* selection and it has *variable parameters* (filter order, cut-off frequencies, attenuations and allowed ripples of transmission module in passband and stopband, interactive design using the tolerant fields of the digital transmission channel model) (see **Fig. 5**). The *additive noise* pertubation and *reflected signal* with variable parameters can affect transmitted signal too. The receiver tasks are *decision level* setting, *channel encoding*, *correction of the transmission errors*, *digital-to-analog conversion* and *visualisation* of received images in spatial domain (*RGB* image).

The results of the simulation process are window for subjective evaluation that includes input and output images (*RGB* and Grayscale) and the window of block and bit error rates of transmission (see **Fig. 6**). The protected and non-protected transmission can be evaluated separately and the influence of protection on transmitted image and efficiency of the protection is obvious that way [5].
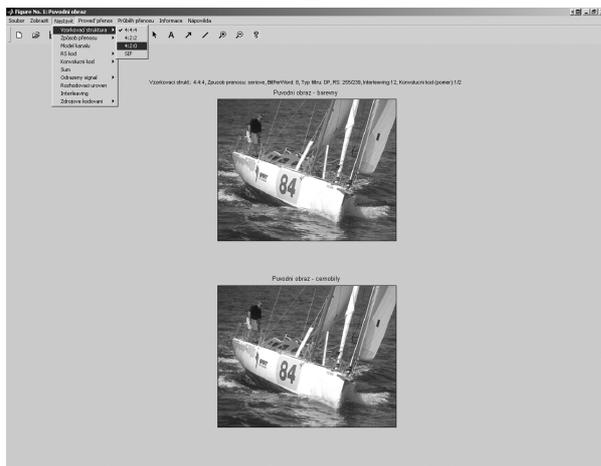
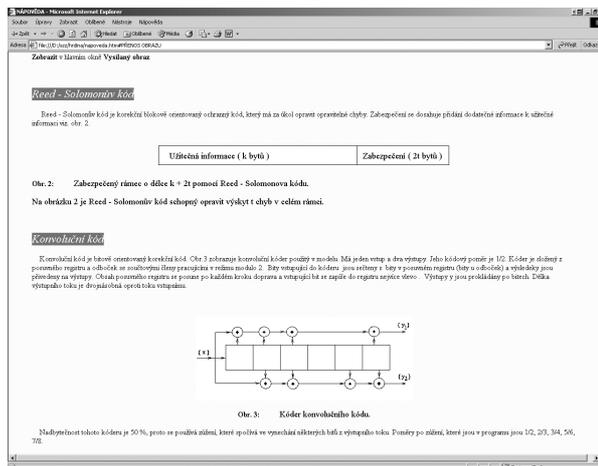**Fig. 3** Input screen with the original Grayscale and *RGB* images and setup menu.

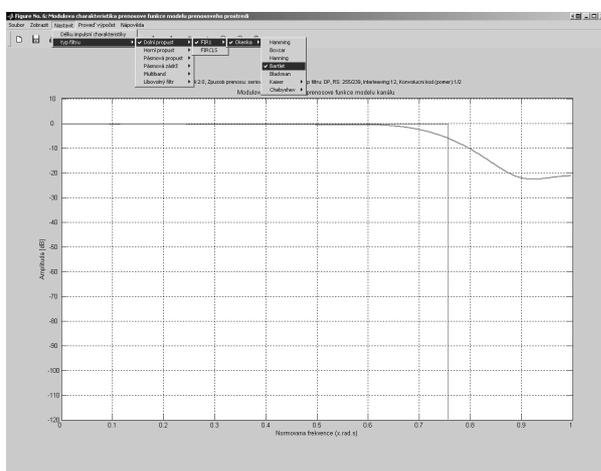**Fig. 4** Interactive help and tutorial available for education.

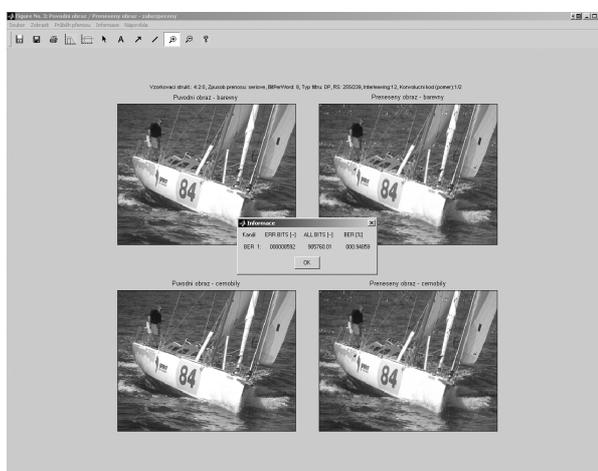**Fig. 5** Interactive design of transmission channel parameters and design method setup.

Fig. 6 Comparison of transmitted images including the window of *BER* evaluation.

Tab. I Setup and results of the simulation example.

Parameter	Setting
Sampling format	4 : 2 : 0
Transmission multiplex	serial 27 MHz 8 bits per sample
Transmission channel model	low-pass character, $f_{LP} = 0.84\, f_s/2$
FEC1 – RS code	RS (255, 239)
Interleaving depth	12
FEC2 – convolution code rate	1/2
Noise character and level	white noise, 0,3V
Reflected signal level / delay	0V / 0 samples
Decision level	0V
Source coding	NRZ unipolar
Bit error rate (without correction codes)	1.49 %
Bit error rate (with correction codes)	0.77 %
Block error rate (without correction codes)	46.39 %
Block error rate (with correction codes)	26.12 %

5   Simulation example results

The **Fig. 3 to 6** outline together the example of the practical design and set up of the digital image transmission simulation using the developed application. The **Tab. I** presents the setup parameters and objective results of the simulation example (block and bit error rates of protected and non-protected transmissions). Each simulation experiment results can be saved into the file and directly compared with the results of the new simulation. The output images, models of the transmission channels and models of the distortions can be saved into files too.

6   Conclusion

Described approach to simulation and analysis and software implementation in Matlab is the partial solution of the mentioned grant project and gives some general results for baseband digital transmission channel simulation and analysis of digital television transmission. The developed Matlab GUI application can be used for the illustrative modeling and experimental education of the digital television technique area. This work presents the open modular application that can be ensemble with the other transmission phenomena of the DVB standard signal processing (digital modulation techniques, transmission in RF band etc.)

Acknowledgement

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