The purpose of this laboratory exercise is to obtain overview of the block structure of encoder/decoder and modulator/demodulator in systems DVB-H/SH and DVB-S2/C2/T2. BER (Bit Error Ratio) before and Viterbi decoding (DVB-H), after turbo decoding (DVB-SH) and before and after LDPC decoding (DVB-S2/C2/T2) as well as after all error corrections is examined during simulated transmission. These parameters illuminate the purpose of functional blocks and influence of their settings on resulting errors in the DVB-H/SH/S2/C2/T2 transmissions.

Theoretical Background

Standard DVB-H

DVB-H (Digital Video Broadcasting –Handheld) is a technical specification for the transmission of digital TV to handheld receivers such as mobile telephones and PDAs and was formally adopted as ETSI standard EN 302 304. DVB-H has been developed from the DVB-T (Terrestrial) standard. Thank to the FEC (Forward Error Correction), which is used in DVB-H system, the transmission is much easier in unfavorable conditions (mobile and portable scenarios). Depending on the currently transmission scenario (multipath propagation, Doppler’s shift), DVB-H system allows wide possibilities of parameter settings for the needs of requirements for service operator:

- 3 possibilities of modulation (QPSK, 16QAM, 64QAM)
- 5 different FEC rates (1/2, 2/3, 3/4, 5/6, 7/8)
- 4 possibilities of guard interval (1/32, 1/16, 1/8, 1/4)
- 3 OFDM carrier modes 2k (1705), 4k (3409) a 8k (6817)
- 3 possible channel bandwidth (8, 7, 6, 5) MHz
- Hierarchical/non-hierarchical modulation
- Native / In-depth (In-Depth) interleaving.

**Block diagram** of the DVB-H coder and modulator is shown in Fig. 1. Coder consists of outer FEC block, performed by Reed-Solomon (on level MPE-FEC) coder and outer interleaving on byte level, inner FEC, using convolutional encoder with possibility of puncturing and outer interleaving, acting on two levels (bit and symbol interleaving). The purpose of interleaving is the elimination of burst errors. These four blocks, serve as FEC, providing the transmission error protection.
The structure of the demodulator and decoder is not defined in the ETSI specification, so it leaves the implementation on the manufacturer of the end devices (set-top boxes). It is obvious, that the receiver will consist of blocks performing reversed operations to the transmitter and block performing synchronization and correction of the received signal.

The main window of application that will be used for the simulation of data transmission in DVB-H standard can be seen in Fig. 2. The application includes blocks of coder and modulator as they are in Fig. 1. It is also includes transmission channel simulator and blocks of demodulator and decoder of received signal and also enable the BER (before and after Viterbi decoding) and MER (Modulation Error Ratio) enumerations. There are constellation diagrams of the last finished simulation displayed in the right side of the window. Moreover, created application enable shows the OFDM spectrum (transmitted and received). Application does not enable option for the hierarchical modulation.
Standard DVB-SH

The DVB-SH system provides an efficient and flexible mean of carrying broadcast services over a hybrid satellite and terrestrial infrastructure operating at frequencies below 3 GHz (generally around 2.2 GHz) to a variety of portable, mobile and fixed terminals having compact antennas with very limited or no directivity. This configuration of system is optimal for the battery-powered devices (PDAs and mobile phones), vehicle-mounted (laptops) and stationary terminals (set-top boxes). One of the main innovations of the DVB-SH standard is in the ensuring FEC of the transmitted data. DVB-SH standard uses 3GPP2 (3rd Generation Partnership Project 2) turbo codes as a FEC. OFDM (Orthogonal Frequency Division Multiplexing) is the natural choice for the terrestrial modulation as it has been already selected for DVB-T/H systems. For the satellite transmission, two modulations have been selected, which leads to two reference architectures within the variety of possible hybrid satellite/terrestrial system architectures: SH-A (for OFDM terrestrial and OFDM satellite transmission mode) and SH-B (for OFDM terrestrial and TDM satellite transmission mode). Depending on the currently transmission scenario (multipath propagation, Doppler’s shift), DVB-SH system allows wide possibilities of parameter settings for the needs of requirements for service operator:

- 4 possibilities of modulation (QPSK, 8PSK, 16APSK, 16QAM)
- 8 different FEC rates (1/5, 2/9, 1/4, 2/7, 1/3, 2/5, 1/2, 2/3)
- 4 possibilities of guard interval (1/32, 1/16, 1/8, 1/4)
- 4 OFDM carrier modes 1k (853), 2k (1705), 4k (3409) and 8k (6817)
- 3 possible channel bandwidth (8, 7, 6, 5, 1.7) MHz
- TDM mode (for satellite transmission)
- Hierarchical/non-hierarchical modulation.

![Block diagram of the DVB-SH transmitter.](image)

Fig. 3: Block diagram of the DVB-SH transmitter.
Block diagram of the DVB-SH coder and modulator, for both system configurations, is shown in Fig. 4. Coder consists of outer FEC block, performed by 3GPP2 turbo coder and channel and time interleaving on byte and bit level. These blocks are ensured the error protection of the transmitted data.

The structure of the demodulator and decoder is not defined in the ETSI specification, so it leaves the implementation on the manufacturer of the end devices (set-top boxes). It is obvious, that the receiver will consist of blocks performing reversed operations to the transmitter and block performing synchronization and correction of the received signal.

The main window of application that will be used for the simulation of data transmission in DVB-SH standard (for both system configurations) can be seen in Fig. 4. The application includes blocks of coder and modulator, as they are in Fig. 3. It is also includes transmission channel simulator and blocks of demodulator and decoder of received signal and also enable the BER (after turbo decoding) and MER enumerations. There is constellation diagram of the last finished simulation displayed in the right side of the window. Moreover, created application enable shows the OFDM spectrum (in case of OFDM transmission mode). Application does not enable option for the hierarchical modulation.

Standard DVB-S2

DVB-S2 (2nd Generation Digital Satellite Television Broadcasting) is the second-generation specification for broadband satellite applications and was formally adopted as ETSI standard in 2005. The DVB-S2 standard has been specified around three key concepts: best transmission performance, total flexibility and reasonable receiver complexity. These concepts are achieved thanks to the new source coding method MPEG-4 AVC (Advanced Video Coding) and new FEC coding methods, so called LDPC (Low-Density Parity Check) and BCH (Bose-Chaudhuri-Hocquenghem) codes. In common, DVB-S2 standard uses three significant stages of FEC: outer coding (BCH), inner coding (LDPC) and bit interleaving. DVB-S2 system configuration enables used 4 types of PSK modulations, concretely QPSK, 8PSK, 16APSK and 32APSK. Nowadays, standard
DVB-S2 is oriented for the supporting the TV broadcasting in HDTV (High Definition Television) quality. Depending on the currently transmission scenario, DVB-S2 system allows wide possibilities of parameters settings:

- 4 possibilities of modulation (QPSK, 8PSK, 16APSK, 32APSK)
- 11 different FEC rates (1/4, 1/3, 2/5, 1/2, 3/5, 2/3, 3/4, 4/5, 5/6, 8/9, 9/10)
- 3 different values of „roll-off“ factors (0.35, 0.25, 0.20)
- 3 different frequency bands (VHF, UHF, SHF).

**Block diagram** of the DVB-S2 coder and modulator is shown in Fig. 5. Coder consists of the combination of BCH and LDPC coder and as an addition, a bit interleaver is used. These blocks are ensured the error protection of the transmitted data.

The main window of application that will be used for the simulation of data transmission in DVB-S2 standard can be seen in Fig. 6. The application includes blocks of coder and modulator, as they are in Fig. 5. It is includes only AWGN transmission channel simulator. Application also includes blocks of demodulator and decoder of received signal and also enables the BER (before and after LDPC decoding). There are constellation diagrams of the last finished simulation displayed in the down side of the window.
Standard DVB-C2

DVB-C2 (2\textsuperscript{nd} Generation Digital Transmission System for Cable Systems) is the second-generation specification for broadband cable applications, developed on the first generation specification, DVB-C standard. It was formally adopted as ETSI standard in 2010. The system is primarily designed for new services for broadcasting, such as VOD (Video on Demand) and HDTV. DVB-C2 standard, in comparison with DVB-C, offers a wide range of adjustable parameters for broadcasting and advanced FEC (BCH+LDPC), which is used for ensuring of the transmitted data. An important novelty in the DVB-C2 is the presence of OFDM technique (only 4K mode). Therefore, DVB-C2 standard is not backward compatible with DVB-C. Depending on the currently transmission scenario, DVB-C2 system allows wide possibilities of parameters settings for the needs of requirements for service operator:

- 5 possibilities of modulation (16QAM, 64QAM, 256QAM, 1024QAM, 4096QAM)
- 6 different FEC rates (2/3, 3/4, 4/5, 5/6, 8/9, 9/10)
- 2 possibilities of guard interval (1/64, 1/128)
- 1 OFDM carrier mode 4k (3409)
- 2 possible channel bandwidth (8, 6) MHz.

Block diagram of the DVB-C2 coder and modulator is shown in Fig. 7. Coder consists of the combination of BCH and LDPC coder and as an addition, a bit, time and frequency interleaver are used. These blocks are ensured the error protection of the transmitted data.

The main window of application that will be used for the simulation of data transmission in DVB-C2 standard can be seen in Fig. 8. The application includes blocks of coder and modulator, as they are in Fig. 7. It is includes only AWGN transmission channel simulator. Application also includes blocks of demodulator and decoder of received signal and also enables the BER (before and after LDPC decoding and after BCH coding) and MER. There are constellation diagrams of the last finished simulation displayed in the up side of the window.

![Block diagram of the DVB-C2 transmitter.](image-url)
Standard DVB-T2

DVB-T2 (2nd Generation Digital Terrestrial Television Broadcasting) is the second-generation specification for broadband terrestrial applications, developed on the first generation specification, DVB-T standard and was formally adopted as ETSI standard in 2009. DVB-T2 is the world’s most advanced digital terrestrial transmission (DTT) system offering higher efficiency, robustness and flexibility. It introduces the latest modulation and coding techniques to enable highly efficient use of valuable terrestrial spectrum for the delivery of audio, video and data services to fixed, portable and mobile services. Thank to the advanced FEC coding (BCH+LDPC) and interleaving techniques DVB-T2 enables the transmission of data at very low C/N ratio. Moreover, thank to the new technique, so called rotated constellation, can to improve the robustness of transmitted data, mainly in the selective fading channels. Depending on the currently transmission scenario, DVB-T2 system allows wide possibilities of parameters settings:

- 4 possibilities of modulation (QPSK, 16QAM, 64QAM, 256QAM)
- 6 different FEC rates (1/2, 3/5, 2/3, 3/4, 5/6)
- 7 possibilities of guard interval (1/128, 19/128, 19/256, 1/32, 1/16, 1/8, 1/4)
- 6 OFDM carrier modes 1k (853), 2k (1705), 4k (3409), 8k (6817), 16k (13 633) and 32k (27 841)
- 6 possible channel bandwidth (10, 8, 7, 6, 5, 1.7) MHz
- SISO (Single Input Single Outpu) a MISO (Multiple Input Single Output) mode.
Fig. 9: Block diagram of the DVB-T2 transmitter (without blocks ensuring of the rotated constellation and PAPR reduction).

Block diagram of the DVB-T2 coder and modulator is shown in Fig. 9. Coder consists of the combination of BCH and LDPC coder and as an addition, a bit, time and frequency interleaver are used. These blocks are ensured the error protection of the transmitted data.

The main window of application that will be used for the simulation of data transmission in DVB-T2 standard can be seen in Fig. 10. It also includes transmission channel simulator and blocks of demodulator and decoder of received signal and also enable the BER (before and after LDPC decoding) and MER enumerations. There is constellation diagram of the last finished simulation displayed in the right side of the window.
RF Channel Models

User interface “Channel Environment” (it is not available at DVB-S2/C2 applications) for the setting of the channel parameters is available for DVB-H/SH/T2 standards (see Fig. 11). This application allows to set of parameters (Path Loss, Delay and Phase Shift), depending on the type of the communication channel model. It is enable set parameters of 20 different channel paths. Of curse, the validity of the actual path can be set by its checkbox. The value of the C/N ratio (and also the AWGN channel) it can be set individually in the main window of each application.

The created user interface “Channel Environment” enables chose one of the follow channel models (each of them have specific properties):

- Ricean channel – 1 direct path and 20 in-direct paths,
- Rayleigh channel – only in-direct path or echoes (20),
- TU6 (Typical Urban) – 6 in-direct paths; the speed of the receiver is equals to 50 km/h,
- RA6 (Rural Area) – 1 direct and 6 in-direct paths; the speed of the receiver is equals to 100 km/h,
- VU (Vehicular Urban) – 12 in-direct paths; the speed of the receiver is equals to 30 km/h,
- MR (Motorway Rural) – 12 in-direct paths; the speed of the receiver is equals to 100 km/h,
- PI (Pedestrian Indoor) – 1 direct and 11 in-direct paths (high delays and low path loss of paths); the speed of the receiver is equals to 3 km/h,
- PO (Pedestrian Outdoor) – 1 direct and 11 in-direct paths (high delays and low path loss of paths); the speed of the receiver is equals to 3 km/h.

Fig. 11: Main window for the settings of the parameters of fading channel models.
Objectives and Instructions


2. Run Mathworks MATLAB (R2007b) and open „Simulation_of_Transmission_DVB-H“ simulator application for the simulation of the transmission of portable scenario in DVB-H system. For the simulation of this scenario use these settings: 16QAM modulation, mode OFDM 4K, 2/3 code rate, guard interval 1/8 and PI and PO fading channel models. As a first, perform simulation for the Gaussian (AWGN) channel. The noise sweep set from 1 to 23 dB with step 1 dB. Note values of BER (before and after Viterbi decoding) and values of MER. Make a graph containing all three dependences of BER (before and after Viterbi decoding) and MER on the C/N ratio.

**Settings of the parameters of the communication channels:** At first, you must select a *Multipath* option in the main window of the application, and then press the *Path Settings* button. After that the “Channel Environment” interface should be appeared (see Fig. 11). From the Type of Channel select *Pedestrian Indoor (Outdoor)* channel model. When you selected the type of channel model, then the parameters of channel paths should be set automatically. Therefore, as a last step, you must confirm the settings by the *Done* button.

**In case, when you do not used the option for the stepping of S/N parameter, then you must give all new value manually into the field From (below the checkbox Batch of SNR)!!**

3. Run Mathworks MATLAB (R2007b) and open „Simulation_of_Transmission_DVB-SH“A simulator application for the simulation of the transmission of mobile scenario in DVB-SH-A system. For the simulation of this scenario use these settings: QPSK modulation, mode OFDM 2K (select the OFDM mode), 2/3 code rate, guard interval 1/16 and RA6 and TU6 fading channel models. As a first, perform simulation for the Gaussian (AWGN) channel. The noise sweep set from -2 to +3 dB with step 0.5 dB. The number of iterations (number of turbo decoding processes) set on number 8. Note values of BER (after turbo decoding) and values of MER. Make a graph containing all dependences of BER (after turbo decoding) and MER on the C/N ratio.

**Settings of the parameters of the communication channels:** see point 2.

4. Run Mathworks MATLAB (R2010b) and open „Simulace přenosu DVB-S2“ simulator application for the simulation of the in DVB-S2 system. Simulate the satellite transmission scenario for 8PSK and 16APSK modulations. Use these settings: code rates 2/5 and 5/6 and AWGN channel. The noise sweep set from 0 to 18 dB with step 0.5 dB. Perform simulations for 8PSK and 16APSK simulations. Note values of BER (before and after LDPC decoding) and values of MER. Make a graph containing dependences of BER on C/N ratio before („Kanálová chybovost“) and after („Celková chybovost“) LDPC decoding and marked the frontier of the QEF (Quasi Error Rate) limit.

**Settings of parameters for the simulation:** As an input data type, chooses a random (*Náhodná data*). In this case, a random data sequence (ones and zeros) will be generated. After then, click on the *FEC dekódování* button. In the opening window use these settings: length of frame (Délka rámců) 64 800 bits, code rates (Kódový poměr) 2/5. After the setting of all parameters, click on the “Uložit a zavřít” button. Click on the *Mapování* button and choose the type of modulation – 8PSK. And again, the settings should be finished by the button “Uložit a zavřít”. As a last, you must define the value of the S/N ratio. If you click on the button *AWGN kanál*, then you can set...
this value (SNR [dB]) and confirm that with the Nastav button. The whole operation you can finished by the button Uložit a zavřít. The whole simulation you should be repeat by the code rate 5/6 and modulation 16APSK.

5. Run Mathworks MATLAB (R2007b) and open „Simulation_of_Transmission_DVB-T2“ simulator application for the simulation of the transmission of fixed scenario in DVB-T2 system. For the simulation of this scenario use these settings: 64QAM modulation, mode OFDM 8K, 2/3 code rate, guard interval 1/8 and RL20 ANX B and RC20 ANX B fading channel models. As a first, perform simulation for the Gaussian (AWGN) channel. The noise sweep set from 4 to 25 dB with step 0.5 dB. Note values of BER (before and after LDPC decoding) and values of MER. Make a graph containing all three dependences of BER (before and after LDPC decoding) and MER on the C/N ratio.

Settings of the parameters of the communication channels: The setting of the parameters of the mentioned fading channels is possible in the main window of the created application. In field “Výběr kanálu”, you should be selected a Riceův (Rayleighův) kanál. After that you should be see the “Channel Environment” interface (see Fig. 11). When you selected the type of channel model, then the parameters of channel paths should be set automatically. Therefore, as a last step, you must set the settings by value of the C/N ratio (in field C/N [dB]).

In case, when you do not used the option for the stepping of S/N parameter, then you must give all new value manually into the field Jeden (below the radiobutton Krokovat)!!

6. Voluntary exam: Run Mathworks MATLAB (R2010b) and open „DVB-C2“ simulator application for the simulation of the transmission in DVB-C2 system. As an input data type, chooses a picture (Obrázek). Perform simulations for 256QAM and 1024QAM simulations. Use these settings: code rate 3/4 (256QAM) and 5/6 (1024QAM), channel AWGN. The noise sweep set from 16 to 39 dB with step 0.5 dB. Perform simulations for 256QAM and 1024QAM simulations. Note values of BER (before and after LDPC decoding) and values of MER. Make a graph containing all three dependences of BER (before and after LDPC decoding) and MER on the C/N ratio.

Notes to the measurements

1. Log to the laboratory computer as „Workstation only“, login „student“, password „student“. It is prohibited to brose www pages and/or connects to the FTP servers during the excersise. If actualization of software will offered, call the teacher or cancel it.

Measurement devices used

PC Personal Computer
SIM Applications for the simulation of mobile TV (DVB-H/SH) transmission and 2nd Generation DVB Systems (DVB-S2/C2/T2)
Conclusions

It is necessary for each student to comment every point of measurement in detail, all results and measured characteristics have to be commented. Individual conclusion should also include important technical and professional findings from the measurement.

Questions

1. What are advantages and disadvantages of the “new” coding techniques (turbo code, LDPC+BCH codes)?
2. How are reflected the fadings in the constellation diagrams, which are caused by the communication channel?
3. Which transmission channel causes the worst error rate? (AWGN, RC 20ANX B, RL20 ANX B, RA6, TU6, PI, PO)?

Used and recommended literature


Fig. 12: Laboratory workstation – exercise no 9.