Analysis and Simulation of the Transmission Distortions of the Mobile Digital Television DVB-SH

Part 2: Satellite Mode DVB-SH-B with TDM

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Abstract. *This paper deals with the second part of the latest digital TV standard DVB-SH (Digital Video Broadcasting – Satellite to Handhelds) with focus on utilization of its advantages for the next generation of mobile TV broadcasting. In the second part the simulation model of DVB-SH-B, which is using satellite configuration with TDM (Time Division Multiplexing) transmission mode, is presented. The work is especially focused on the description of TDM system configuration. Dependences of BER on C/N ratio for all used types of modulations are compared in the Gaussian (AWGN) channel, which is generally used in DVB-SH/S2 standards for exploring of the transmission distortions. Moreover, in case of QPSK modulation, the data transmission was explored in the Ricean fading channel. Finally, achieved results are evaluated and clearly discussed.*

Keywords

Digital television, mobile TV, DVB-SH-B, TDM, satellite reception, fixed reception, BER

1. Introduction

DVB-SH [1] [2] is defined as a transmission system standard, capable of delivering IP-based media content and data to handheld terminals, like mobile phones and PDAs via satellite, using S-band frequencies. Like DVB-H (Handheld), DVB-SH could be used with the classical terrestrial configuration (OFDM mode) for the transmission of broadcast services [1]. In many cases, mobile operators want to cover large regions or even a whole country. When these situations occur, then classical terrestrial broadcasting, which is used in DVB-T/H and partly in DVB-SH, is not the best choice. However, the options and possibilities of the DVB-SH standard allow the solution of this problem. One of the key features of DVB-SH is the fact that it is a hybrid satellite/terrestrial system that will allow using of satellite to achieve coverage of large areas [2]-[4].

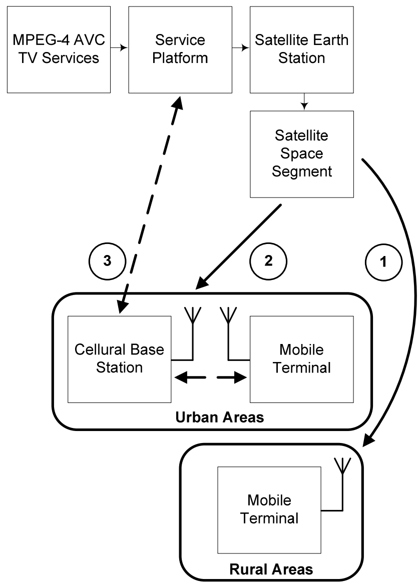


Fig. 1. Overall DVB-SH transmission system reference architecture.

The DVB-SH transmission system and its reference architecture are shown in Fig. 1. The overall solution combines the mentioned hybrid infrastructure of the broadcast system. A space segment, made of high-power geostationary satellites, is suitable for TV broadcast to mobile terminals over nationwide coverage (this situation is presented by number 1 in Fig. 1). The network of medium- and low-power repeaters (number 2 in Fig. 1), co-sited with mobile base stations for TV broadcast to mobile terminals in urban areas, complement satellite coverage for indoor service quality, which may be weakened by walls and terrain obstacles. The system also can interwork at the service level with a cellular network (number 3 in Fig .1) to serve mobile terminals with interactive broadcast [2], [3].

As it was described in [1], standard DVB-SH allows mobile TV transmission in two principle modes: OFDM (for satellite and terrestrial mode) and TDM (for satellite mode). In the TDM transmission mode [2]-[5], the data are broadcasted to mobile terminals on a direct path from a broadcast station via satellite. The TDM signal is partly derived from the DVB-S2 (Satellite 2nd Generation) standard [5]. It allows optimizing transmission through satellite toward mobile terminals. Of course, according to the DVB-S/S2 characteristics, it is used on the direct path only. Moreover, the configuration of the DVB-SH standard allows a combination of TDM and OFDM modes, which is increasing the robustness of the transmission in relevant areas (mainly suburban). Of course, this solution may be of interest in power limited satellite systems [2]-[4].

In the recent years, the research in the area of TDM transmission is mainly focused on the developing of the appropriate satellite channel model for the analysis and simulation of the signal transmission. In case of TDM, a LMS (Land Mobile Satellite) [7] model is usually used. This model describes the narrowband propagation channel in three possible shadowed states: case of line-of-sight, moderate shadow and deep shadow. The main results and their discussion were published in [8], [9]. Measuring of signal level and quality in the hybrid satellite/terrestrial channel model were already done and the results were presented in [10]-[12].

As it can be seen, thank to the new features and innovations in the transmission modes, which DVB-SH incorporates, the options of signal transmission are several in comparison of classical DVB-T/H (OFDM only). However, the study of sufficient signal strength and quality, represented by *C/N* vs. *BER* (Bit Error Ratio) is not finished in DVB-SH-B and is worth to be explored.

A short introduction on to the mobile digital TV DVB-SH standard and related last work review was made in [1]. The first part of this paper especially focused on the description of the performance of DVB-SH-A mode. In the second part the attention is devoted to the performance of the DVB-SH-B mode (TDM configuration). To explore the performance of DVB-SH-B and its transmission distortions Gaussian and fixed fading transmission channel (without Doppler shift) and its model [6] were used.

The organization of the paper is as follows. Section 2 briefly describes the functional block diagram of the transmitter DVB-SH-B. Attention is devoted mainly on the "new" modulation types and scrambling processing and their implementation in MATLAB. The parameters and typical scenarios for the analysis and simulation are presented in Section 3. Section 4 contains graphical dependences of the *BER* after turbo decoding on *C/N* ratio for the DVB-SH-B performance analysis in Gaussian and fixed TV fading channels. Finally, the results are evaluated and discussed in Section 5.

2. Block Diagram of the DVB-SH-B

The structure of the transmitter follows common DVB-SH-B transmitter block diagram, as shown in Fig. 2. The structure of the FEC (Forward Error Correction) of the

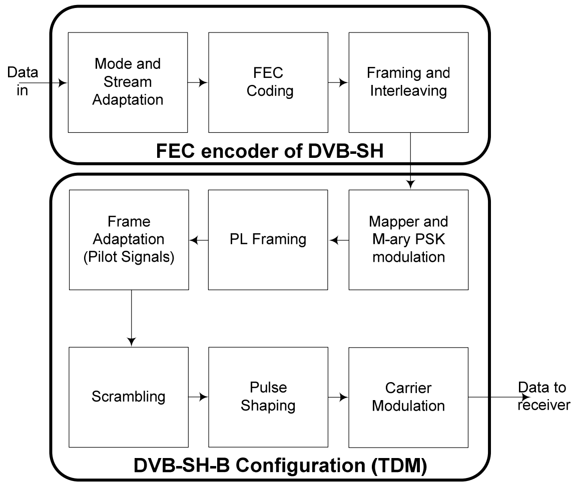


Fig. 2. Block diagram of the DVB-SH-B transmitter (satellite configuration with TDM).

DVB-SH standard was presented in [1]. This part of the DVB-SH transmitter is same for both modes (SH-A and SH-B). Therefore, the description of each block is not given here. The following part of the paper is focused only on the description of TDM configuration and its signal processing. Details of the following blocks are briefly described below.

2.1 Mapper and M-ary PSK Modulation

After the Mode and Stream Adaptation and FEC encoding process, the output of channel interleaver is mapped into the constellation diagram of the selected type of modulation. In contrast with DVB-SH-A, QAM modulations are not used in DVB-SH-B. Instead of QAM, PSK (Phase Shift Keying) modulations are preferred. DVB-SH-B mode used QPSK, 8PSK and 16APSK modulations. These modulations constellations and the associated mapping, as defined by DVB-S2 in [5], shall be used.

MATLAB functions and tools support some functions for the modulation and demodulation. In the developed application the, `modem.pskmod(M)` function was used from Communication Toolbox. This function also enables set up symbols to be mapped. However, the symbol order does not match the mapping in the DVB-SH specification [4]. Moreover, the 16APSK modulation constellation is created in a special way [4], [5]. Therefore, the 16APSK modulation was implemented in the created application in another way. The reason is that the function `modem.pskmod` does not allow changing the properties of `psk.SymbolOrder` and `psk.SymbolMapping`.

The final MATLAB code, performing symbol mapping and modulation for QPSK and 16APSK, is given below:

```
% QPSK mapping (according to ETSI EN 302 583)
 modulator = modem.pskmod(4);        % QPSK
 modulator.PhaseOffset = (-pi/4);% TDM mode: DVB-SH-B
 modulator.SymbolOrder = ('user-defined');
 modulator.SymbolMapping = [1 0 2 3];
% Modulation - QPSK
```

```
modulation = modulate(modulator, modulation_state);

% 16APSK mapping (according to ETSI EN 302 583)

% IQ points positions in the constellation diagram
R1 = [0.267+0.267i -0.267+0.267i -0.267-0.267i…
0.267-0.267i]; % „Circle 1"with radius R1

R2 = [1.095+0.293i 0.802+0.802i 0.293+1.095i -0.293+1.095i…
-0.802+0.802i -1.095+0.293i -1.095-0.293i -0.802-0.802i…
-0.293-1.095i 0.293-1.095i 0.802-0.802i 1.095-0.293i];
% „Circle 2"with radius R2

xlength = length(bit_interleaving_output);

for  k=1:xlength; % xlenght is a length of interl. stream

     if bit_interleaving_output(k,:)== [0 0 0 0];

        modulation(1,k)= R2(2);

     elseif bit_interleaving_output(k,:)== [0 0 0 1];

        modulation(1,k)= R2(11);

        ...
        ...

     elseif bit_interleaving_output(k,:)== [1 1 1 0];

        modulation(1,k) = R1(2);

     elseif bit_interleaving_output(k,:)== [1 1 1 1];

        modulation(1,k) = R1(3);

     end
end
```

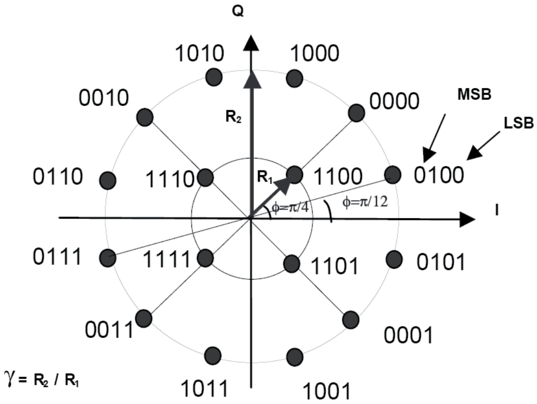


Fig. 3. Bit mapping into 16APSK signal constellation [4].

As it can be seen from the presented source code, 16APSK modulation has special features (see Fig. 3). The 16APSK modulation constellation shall be composed of two concentric rings of uniformly spaced 4 and 12PSK point, respectively in the inner ring (radius R_1) and outer ring (radius R_2). The ratio of the outer circle radius to the inner circle radius shall be equal to 3 [3], [4].

In case of deep interest on the full version of the MATLAB code, the code is available on request.

2.2 PL Framing and Pilot Insertion

The transmitted mobile TV is organized in frames. The SH frame to be transmitted in TDM mode consists of a number of PL (Physical Layer) slots of length L_{TOT}= 2176 symbols, each of them comprising of 2 (QPSK), 3 (8PSK) or 4 (16APSK) CU (Capacity Units) of 2016 bits. CU number is depending on the number of modulated symbol and it is transmitted in 476 PL slots, which make the entire frame [4].

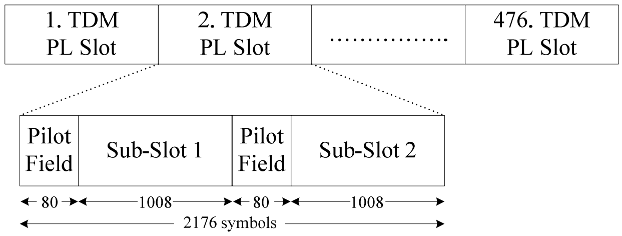


Fig. 4. The structure of one DVB-SH-B frame in the PL slot (mode TDM).

The complete structure of the DVB-SH-B frame with the pilot organization in the PL slot is shown in Fig. 4.

From the perspective of the signal transmission, the division of SH frame on the PL slots is important (see Fig. 4). One PL slot is divided into two equally long sub-slots with a length of 1008 symbols. A PF (Pilot Field) shall be inserted before each sub-slot. In each PL slots there are two PF of equal duration L_{PF} = 80 symbols. Each pilot symbol shall be an un-modulated symbol, on the position $1.e^{j45°}$ [4]. Finally, one TDM slot has a fixed length equal to L_{TOT}.

2.3 Physical Layer Scrambling

Prior to modulation, each PL slot including the PF, shall be randomized for energy dispersal by multiplying the I and Q modulated baseband signal symbol samples by a unique complex randomization sequence [4]:

$$C(i) = C_I(i) + jC_Q(i) \quad i = 1,...L_{TOT}, \tag{1}$$

The final scrambled I and Q components from (1) will therefore be expressed as [5]:

$$I_{SCR}(i) = I(i)C_I(i) - Q(i)C_Q(i) \quad i = 1,...L_{TOT}, \tag{2}$$

$$Q_{SCR}(i) = I(i)C_Q(i) + Q(i)C_I(i) \quad i = 1,...L_{TOT}. \tag{3}$$

In the DVB-SH-B, concretely in TDM mode, the scrambling code sequence shall be constructed by combining two real m-sequences into a complex sequence. In this case, the Gold sequences are used. These sequences are a combination of two generator polynomials and their exact form can be found in [4]. The first sequence (x) has set its first variable to one and the others are equal to zero. In case of the second sequence (y), all initial variables are set to one [4], [5]. Only one complex sequence $C_I(i) + jC_Q(i)$ is required for DVB-SH-B. A possible block diagram for PL scrambling sequences generation is shown in Fig. 5.

The general form of recursive definition of subsequent symbols and Gold code sequence are available in [4], [5]. The equations from (4) to (10), presented below, serve for easy orientation in the created MATLAB code.

The output from y sequence is marked as an *output_y* and it is defined by equations (4) and (5):

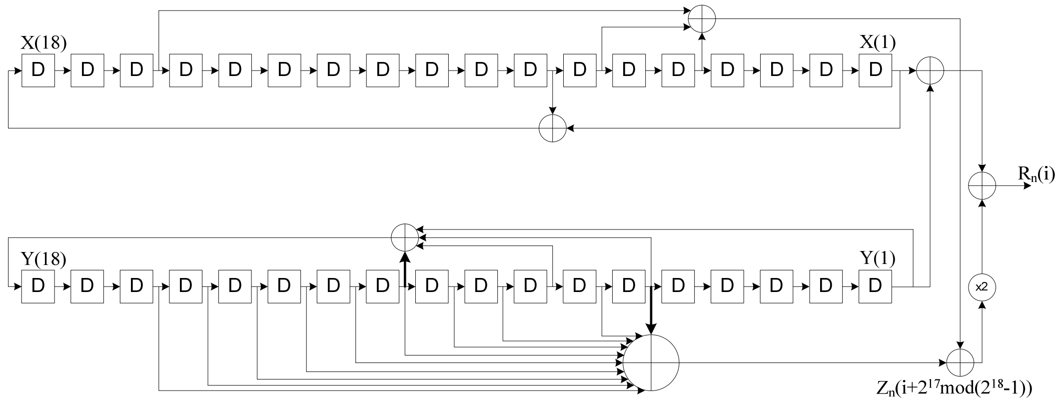


Fig. 5. Configuration of the PL scrambling code generator.

$$output\_y_1(i) = y(6) \oplus y(7) \oplus y(9) \oplus \oplus y(10) \oplus y(11) \oplus y(12) \quad i = 1,...L_{TOT}, \tag{4}$$

$$output\_y(i) = output\_y_1 \oplus y(13) \oplus y(14) \oplus \oplus y(15) \oplus y(16). \quad i = 1,...L_{TOT} \tag{5}$$

Equations (6) and (7) come from recursive loop and are used in scrambling process:

$$input\_x(i) = x(1) \oplus x(8), \quad i = 1,...L_{TOT} \tag{6}$$

$$input\_y(i) = y(1) \oplus y(6) \oplus \oplus y(8) \oplus y(11). \quad i = 1,...L_{TOT} \tag{7}$$

With the combination of (4) and (5), the Gold code sequence (9) is then defined as:

$$output\_x(i) = x((i)\mathrm{mod}(2^{18})) \oplus y(i), \tag{8}$$

$$z\_n(i) = x(5) \oplus x(7) \oplus x(16) \oplus output\_y(i), \tag{9}$$

$$R\_n(i) = 2.z\_n((i+2^{17})\mathrm{mod}(2^{18}-1)) \oplus \oplus output\_x(i), \tag{10}$$

where i is again from 1 to L_{TOT}.

Finally, it is necessary to ensure the bit shift of the both m-sequences from the highest to the lowest bit (see Fig. 5). The binary sequence is also converted to integer valued sequence R_n (R_n assuming values 0, 1, 2 and 3) by the transformation, defined by (10). Therefore, using (10), the final complex scrambling code sequence is defined as:

$$C(i) = C_I(i) + jC_Q(i) = e^{(jR\_n(i)\pi/2)}. \tag{11}$$

All possible examples of sequence scrambling are available in [4].

In the code presented below the example is focused on the implementation of the configuration of PL scrambling code generator to the MATLAB:

```
% PL scrambling - Gold sequence

% Definition of the input parameters
output_x = zeros(1,2^18);
z_n = zeros(1,2^18);
[rows columns] = size(SH_Frame);
R_n = zeros(1,columns);

% Initial conditions of m-sequences
seq_x = [1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0];
seq_y = [1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1];

% The PL scrambling process
for k = 1:2^18

    input_x = xor(seq_x(1), seq_x(8));
    output_xy = xor(seq_x(5), seq_x(7));
    output_xy = xor(output_xy, seq_x(16));
    output_y = xor(seq_y(6), seq_y(7));
    output_y = xor(output_y, seq_y(9));
    output_y = xor(output_y, seq_y(10));
    output_y = xor(output_y, seq_y(11));
    output_y = xor(output_y, seq_y(12));
    output_y = xor(output_y, seq_y(13));
    output_y = xor(output_y, seq_y(14));
    output_y = xor(output_y, seq_y(15));
    output_y = xor(output_y, seq_y(16));
    input_y = xor(seq_y(1), seq_y(6));
    input_y = xor(input_y, seq_y(8));
    input_y = xor(input_y, seq_y(11));
    output_x(k) = xor(seq_x(18), seq_y(18));
    z_n(k) = xor(output_xy, output_y);
    seq_x = circshift(seq_x,[0 -1]);
    seq_y = circshift(seq_y,[0 -1]);
    seq_x(18) = input_x;
    seq_y(18) = input_y;

end

for k = 1:length(R_n)

    R_n(k) = 2*z_n(mod(k+2^17,2^18-1)) + output_x(k);

end

% The final complex scrambling code sequence

for k = 1:Number_of_PL_slots

    for l = 1:length(R_n)

        if R_n(l) == 1

            a = real(SH_Frame(k,l));
            b = imag(SH_Frame(k,l));
            SH_Frame(k,l) = -b + 1i*a;

        elseif R_n(l) == 2

            SH_Frame(k,l) = SH_Frame(k,l) * (-1);

        elseif R_n(l) == 3

            a = real(SH_Frame(k,l));
            b = imag(SH_Frame(k,l));
            SH_Frame(k,l) = b - 1i*a;

        end

    end

end
```

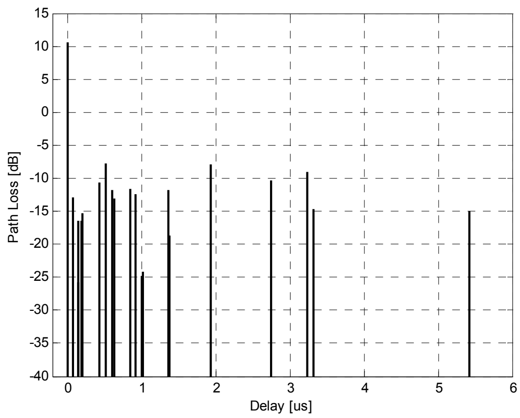


Fig. 6. Impulse response of the RC20 (Ricean) channel.

2.4 Pulse Shaping and Carrier Modulation

Now, the complete SH frame (in TDM mode) signal is available in the time domain [4]. After the scrambling, the signals shall be filtered whit RRC (Root Raised Cosine). The roll-off factor shall be $\alpha = 0.35$; 0.25 and 0.20, depending on the service requirements [4], [5]. In our analysis and simulation the parameter α was set to 0.35.

The simulation (and also example of implementation) of the DVB-T/H/SH modulator in detail is described in [1] and [13]. The same modulator was used in this paper and slightly modified to the DVB-SH-B operation (S-band).The carrier modulation shall be performed by multi-plying the in-phase and quadrature samples by $\sin(2\pi f_0 t)$ and $\cos(2\pi f_0 t)$, respectively (f_0 is the carrier frequency of course). Of course, the signal transmission is realized in the S-band. Therefore, in the simulation, the carrier frequency equals 2.2 GHz, as recommended in [3], [4].

2.5 Channel Simulation

At this point, DVB-SH-B signal is prepared and it can be transmitted by using transmission channel model. As it was mentioned, TDM signal is partly derived from the DVB-S2 and it is used on the direct path only. Therefore, for the analysis and simulation of the performance of the DVB-SH-B RC20 channel model [6], [13] was used. The RC20 channel profile and its typical impulse response, which was used for this simulation, are shown in Fig. 6.

3. Simulation of the DVB-SH-B Transmission in Gaussian and RC20 Channels

A brief description of the block diagram of the DVB-SH-B was presented in the previous chapter. This chapter contains a brief description of the transmission channel models, which were used for the simulation and analysis of the satellite TV transmission. The Gaussian (AWGN) channel as a general and reference channel was used.

When reflected signals are added to a direct signal then the quality of the reception get worse. This event makes situations, when several reflected signals are present simultaneously with the direct signal at the receiver side. These situations are modeled in channel, which is defined as a Ricean channel. In this type of channel, the Gaussian channel and its characteristics also exist. This is theoretical channel profile without Doppler shift. In case of Ricean channel in fact we have 20 indirect paths and 1 direct path [6], [11]-[14]. This path has zero delay and phase shift.

The Rice factor K [4], [14] denotes the ratio of the signal in the direct path to the sum in all echo paths (12):

$$K = \frac{\rho_0^2}{\sum_{i=0}^{N_e} \rho_i^2}, \tag{12}$$

where ρ_0 is the attenuation in the direct signal path N_e is the certain number of echoes and ρ_i is the attenuation in echo path i.

Usually, in the Ricean channel model, factor K equals 10. However, in [4] examples are available, when this value is different. Therefore, for better exploring of the signal distortions in Ricean channel model, 2 different K-factors were used. For the analyzing and simulation of the performance of the direct path, this value was set to 10 and 5. More details about the implementation (and again with examples of source codes) of the mentioned transmission channel model can be found in [13].

For the simulation of the DVB-SH-B fixed-satellite TV transmission the following settings were used:

- 1/4 (robust protection) code rate of turbo codes,
- QPSK (satellite and fixed) 8PSK and 16APSK (both satellite) modulation,
- TDM mode (for the satellite and fixed transmission),
- Gaussian (AWGN) and RC20 (fixed) transmission channel models,
- K-factor of RC20 channel model set to 10 (strong direct path) and 5 (weak direct path),
- SISO-MAP (Soft Input Soft Output - Maximum A Posteriori) turbo decoding,
- 8 iterations of turbo decoding (recommended in [3]).

The limit of the error-free reception is considered for C/N, where the BER is equal to 1.10^{-5} after turbo decoding. This BER operation has not been standardized yet, but most of the recent papers deal with this value [1], [4].

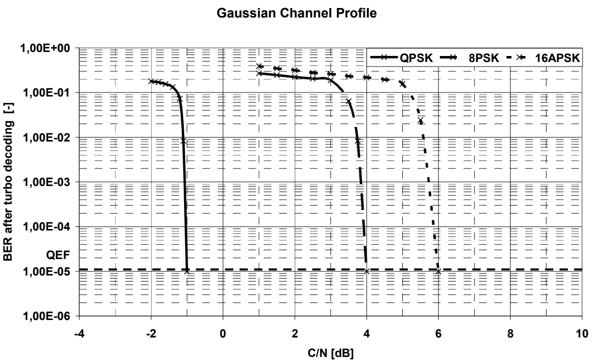


Fig. 7. Satellite reception scenario (QPSK, 8PSK, 16APSK, mode TDM, CR 1/4) and DVB-SH-B performance (*BER* after turbo decoding with 8 iterations as a function of *C/N* ratio) in the Gaussian channel.

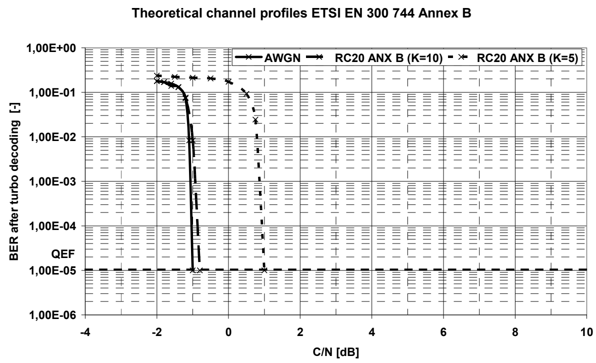


Fig. 9. Fixed reception scenario (QPSK, mode TDM, CR 1/4) and DVB-SH-B performance (*BER* after turbo decoding with 8 iterations as a function of *C/N* ratio) in RC20 channel with different K-factors.

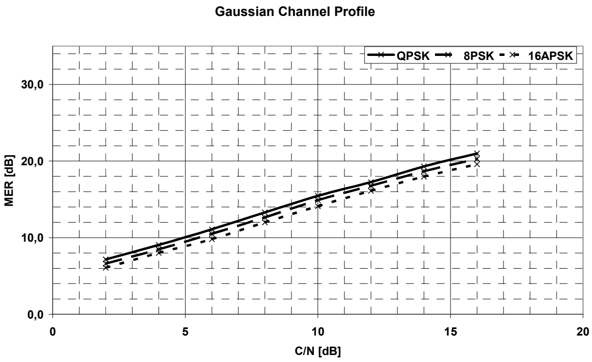


Fig. 8. Modulation error ratio *MER* in the DVB-SH-B satellite scenario as a function of *C/N* ratio in the Gaussian channel model (QPSK, 8PSK, 16APSK, mode TDM, CR 1/4).

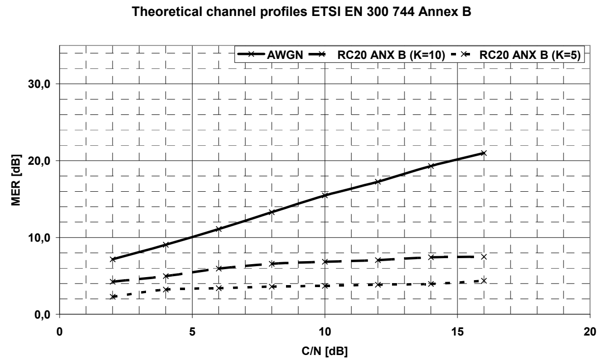


Fig. 10. Modulation error ratio *MER* in the DVB-SH-B fixed scenario as a function of *C/N* ratio in the Gaussian channel and in RC20 channel with different K-factors (QPSK, mode TDM, CR 1/4).

4. Simulation Results and Their Evaluation

Simulation results of the satellite TV transmission in the DVB-SH-B standard for a varying C/N ratio in the Gaussian channel (AWGN) and fixed reception (RC20), represented by the fading channel and its model, are in Fig. 7 to 10, where *BER* after turbo decoding vs. *C/N* ratio in Gaussian and Ricean fading channel model is illustrated. The results for modulations that are using QPSK, 8PSK and 16APSK in various types of transmission scenarios are different based on higher requirements on *C/N*.

The simulation parameters and configuration for the satellite reception scenario has been chosen with respect to satellite and fixed channel model parameters.

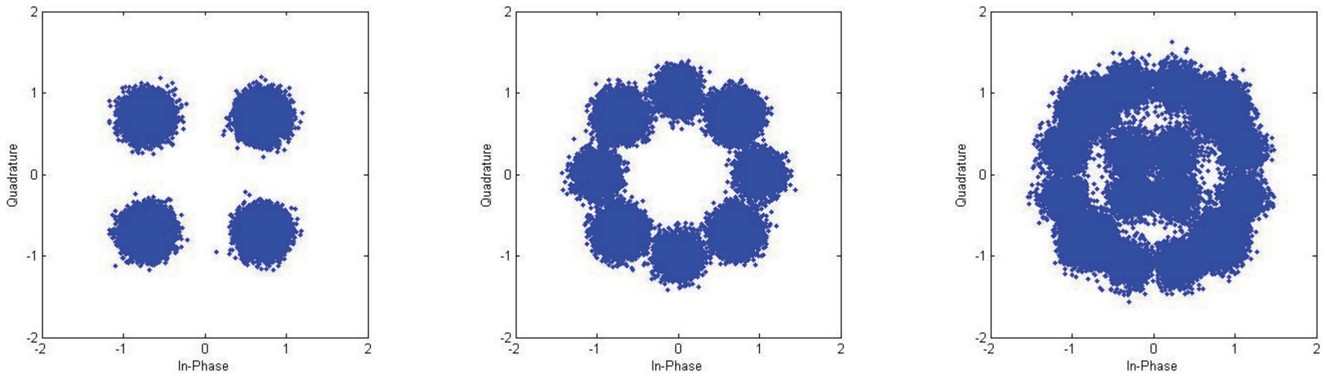
As it was mentioned, RC20 is a fixed channel model without of Doppler's shift (the receiver is in a fixed position). The maximum relative delay of the signal echo is equal to 5.42 μs (see Fig. 6), which is not critical in terms of level of signal quality.

Channel	K-factor [-]	Modulation	C/N [dB]
AWGN	-	QPSK	-1.0
	-	8PSK	4.0
	-	16APSK	6.0
RC 20	10	QPSK	-0.8
	5		1.0

Tab.1. Comparison of the simulation results of minimal *C/N* for *BER* equal to $1\cdot10^{-5}$ in standard DVB-SH-B.

Moreover, thank to the direct signal path between the transmitter and receiver, the transmitted signal is more resistant to the short term fadings. These are main reasons, why the conditions of signal reception are better in RC20 channel model than other fading channel models [11]-[14].

For the better exploration of the transmission distortions in RC 20 channel model, two possible values of K-factor were used. As it can be expected, the lower level of the direct path ($K = 5$) means that, for the achieving a good signal quality, the min. value of *C/N* ratio must be higher (see Fig. 9).

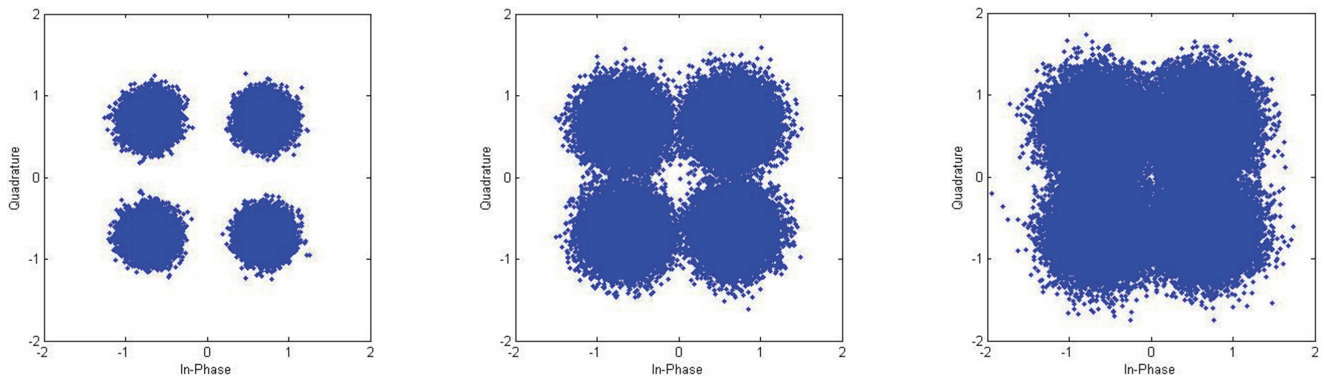


a) AWGN channel and satellite reception scenario, MER = 15.5 dB;

b) AWGN channel and satellite reception scenario, MER = 14.9 dB;

c) AWGN channel and satellite reception scenario, MER = 14.1 dB;

Fig. 11. Simulation: I/Q constellation in AWGN channel and satellite reception scenario and MER equal to: a) 15.5 dB (with QPSK), b) 14.9 dB (with 8PSK), c) 14.1 dB (with 16APSK) - all the constellations include channel correction and *C*/*N* = 10 dB.



a) AWGN channel and fixed reception scenario, MER = 15.5 dB;

b) RC20 channel (K=10) and fixed reception scenario, MER = 6.8 dB;

c) RC20 channel (K=5) and fixed reception scenario, MER = 3.7 dB;

Fig. 12. Simulation: I/Q constellation with QPSK modulation in RC20 fading channel and satellite reception scenario and MER equal to: a) 15.5 dB (AWGN), b) 6.8 dB (K=10), c) 3.7 dB (K=5) - all the constellations include channel correction and *C*/*N* = 10 dB.

The difference in *BER* results for the various transmission parameters and channel types is also easy to compare in Tab. 1. The results with *C*/*N* below zero dB (below noise level) seem to be quite promising. Typical results and the example or illustration constellation diagrams for the various transmission scenarios and channel types are also easy to see in Fig. 11 and 12.

5. Conclusions

In this paper, the one of the latest DVB-SH standard for the hybrid satellite/mobile TV broadcasting was analyzed and simulated.

The paper was especially focused on the model DVB-SH-B, which is using configuration with TDM transmission mode. Detailed description of the DVB-SH-B system configuration (transmitter side) with comprehensive examples of MATLAB scripts was presented too. The performance of the DVB-SH-B mode was analyzed in Gaussian and fixed (RC20) fading channels and their models (different K-factors).

As it can be seen from the graphs (see again Fig. 7 to Fig. 10), there are principle differences between the results. Especially, there are significant differences between the results in the case, when the Gaussian and RC20 channel models were used. This is caused by the features of the PSK modulations, which have lower resistance to noises and fadings compared to QAM modulations [14]. This disadvantage is also available in the Gaussian channel, where for achieving of a good signal quality, the differences between a required *C*/*N* are higher (see again Tab. 1). On the other hand, thank to the number of iterations (8 iterations), the results are much better than in the DVB-S/S2. As it can be seen, the higher number of turbo decoding can mean higher demand on the *C*/*N* for a good signal quality.

The DVB-SH-B mode represents very good possibilities for the next generation of mobile TV broadcasting. However, this solution is optimal only for the satellite (and also fixed) reception conditions. One solution of this problem can be found in the option of TDM/OFDM mode combination, which allows increasing the robustness of the transmission in communication channels with bad reception conditions. However, for equivalent capacity, the TDM/OFDM mode requires a higher bandwidth in frequency spectrum than the OFDM/OFDM mode. Therefore, TDM/OFDM mode is not frequently used [2].

Despite all the mentioned disadvantages, DVB-SH standard offers a very good solution for the future mobile TV broadcasting. On the other hand, mobile phones, which are available on the market (with capability of mobile TV decoding and tuner for DVB-H standard), should be innovated. Therefore, the development of smart and fast hardware mobile TV terminals (mainly for fast signal processing) is unavoidable.

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