

IMPLEMENTATION OF 16APSK MODULATION IN MATLAB USED FOR THE DVB-SH-B TRANSMISSION

Ladislav Polák, Ondřej Kaller, Tomáš Kratochvíl
Department of Radio Electronics, Brno University of Technology
Purkyňova 118, 612 00 BRNO

Abstract

This paper deals with the implementation of the 16APSK modulation in MATLAB and its simulation model verification. This type of modulation can be used in the DVB-SH standard, when the satellite transmission mode (mode SH-B) is used. Brief description of this standard features and example of transmission in Gaussian (AWGN) channel are presented in the paper. Dependences of BER on C/N ratio for all types of payload modulations are compared with focus on satellite TV services and their availability. Finally, obtained results are evaluated and discussed.

1 Introduction

DVB-SH (Digital Video Broadcasting - Satellite to Handhelds) is a relatively new standard that provides an efficient and flexible broadcast services over the hybrid terrestrial and satellite infrastructure operating in S-band, (2.17 - 2.2) GHz, to a variety of portable, mobile and fixed terminals. The key feature of DVB-SH is the fact that it is a hybrid satellite/terrestrial system that will allow the use of a satellite to achieve coverage of large regions. In areas where direct reception of the satellite signal is not possible, terrestrial gap filler can be used to provide coverage. Target terminals, include handheld, defined as light-weight and battery-powered apparatus (e.g. PDAs, mobile terminals), vehicle-mounted, (e.g. laptops) and stationary terminals (set-top-boxes) [1]-[4].

DVB-SH complements and improves the existing DVB-H (Handheld) physical layer standard. This improvement pushes the limits on the possibilities of DVB broadcasting to handheld terminals. DVB-SH specifies two operational modes [1]-[4]:

- **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.

The overall DVB-SH system architecture is shown in the Fig. 1.

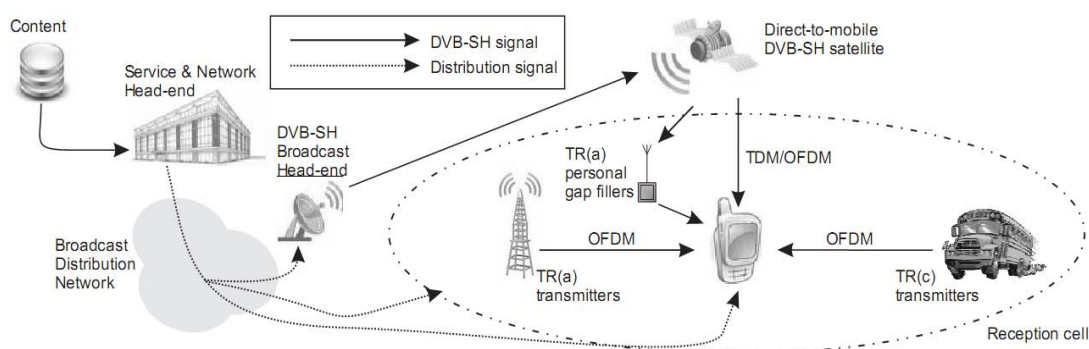


Figure 1: DVB-SH network architecture [2].

This paper especially deals with the implementation of the 16APSK (Amplitude Phase Shift Keying) modulation in MATLAB. Resources for the modeling and simulation of the 16APSK modulation and demodulation are included in the Communication Toolbox. This toolbox also includes many adjustable parameters for settings of the modulation (symbol mapping, phase shift, e.g.). However, in case of 16APSK modulation, MATLAB can not enable set the symbol mapping used in DVB-SH [8]. Moreover, in the DVB-SH standard, the positions of the symbols in constellation diagram are defined by special way. Therefore, for the analysis and modeling of data transmission

in DVB-SH-B system, this type of modulation should be implemented in MATLAB by other way. This paper also contains results of recent development of MATLAB application, which allow simulating complete transmission of the DVB-SH-B in Gaussian (AWGN) transmission channel. At the end of this simulation, it can show *BER* (Bit Error Ratio) after turbo decoding. Finally, results of these dependences in Gaussian channel are graphically expressed, compared and discussed.

The organization of this paper is as follows. Section 2 briefly describes the functional block diagram of the DVB-SH-B transmitter. The implementation of the 16APSK modulation and the process of modulation and demodulation are described in Section 3. The parameters for the analysis and simulation are presented in Section 4. Section 5 contains graphical dependences of the *BER* after turbo decoding on *C/N* (Carrier-to-Noise Ratio) for the DVB-SH-B performance analysis in Gaussian channel. Finally, the results are evaluated and discussed in Section 6.

2 Block diagram of the standard DVB-SH-B

The structure of the DVB-SH-B transmitter block diagram is shown in Fig. 2.

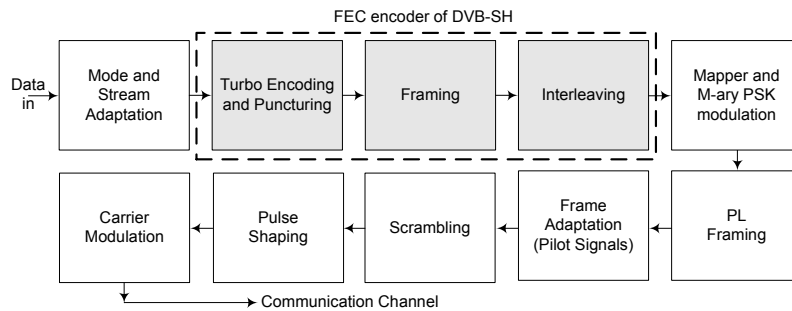


Figure 2: Block diagram of the DVB-SH-B transmitter.

How it can be seen in the Fig. 2, the first functional block is the Mode and Stream Adaptation. 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 transmitted frame and performs scrambling, which the same that was used in DVB-H standard [1]-[6].

The next step contains the turbo encoder and puncturing. The turbo code (3GPP2) is used for the FEC (Forward Error Correction) encoding of the input data stream. Additional code rates have been introduced to both DVB-SH modes (OFDM and TDM) allow better granularity in terms of *C/N* adjustment [1]-[5].

The interleavers are introduced to enhance the resistance of the waveform to short-term fading and medium-term shadowing impairments in communication channels. The DVB-SH, as a DVB-H, is using bit-wise interleaving. The output of the turbo encoder shall be bit interleaved using a block interleaver [1]-[3].

After the FEC process (FEC Encoding, Framing and Interleaving), the output of channel interleaver is mapped into the constellation of the selected type of modulation. In contrast with DVB-SH-A, QAM modulations are not used in DVB-SH-B system. Instead of QAM modulations, PSK modulations (Phase Shift Keying) are preferred. DVB-SH-B mode uses QPSK, 8PSK and 16APSK modulations. These modulations constellations and the associated mapping, as defined by DVB-S2 in [2], shall be used.

The transmitted mobile TV signal 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 2 016 bits. CU number is depending on the number of modulated symbol and it is transmitted in 476 PL slots, which make the entire frame. From the perspective of the signal transmission the division of SH frame is important on the PL slots [2] [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 $1.e^{j45^\circ}$ [2]. Finally, one TDM slot has a fixed length equals to L_{TOT} . The complete structure of the DVB-SH-B frame with the pilot organization in the PL slot is shown in Fig. 3.

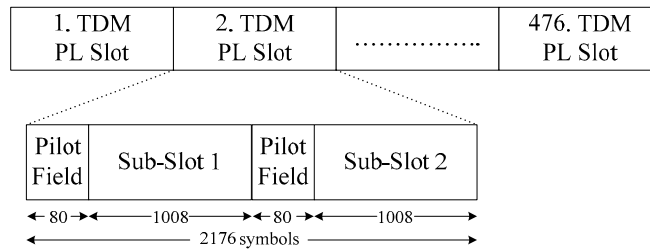


Figure 3: The structure of one DVB-SH-B frame in the PL slot (mode TDM).

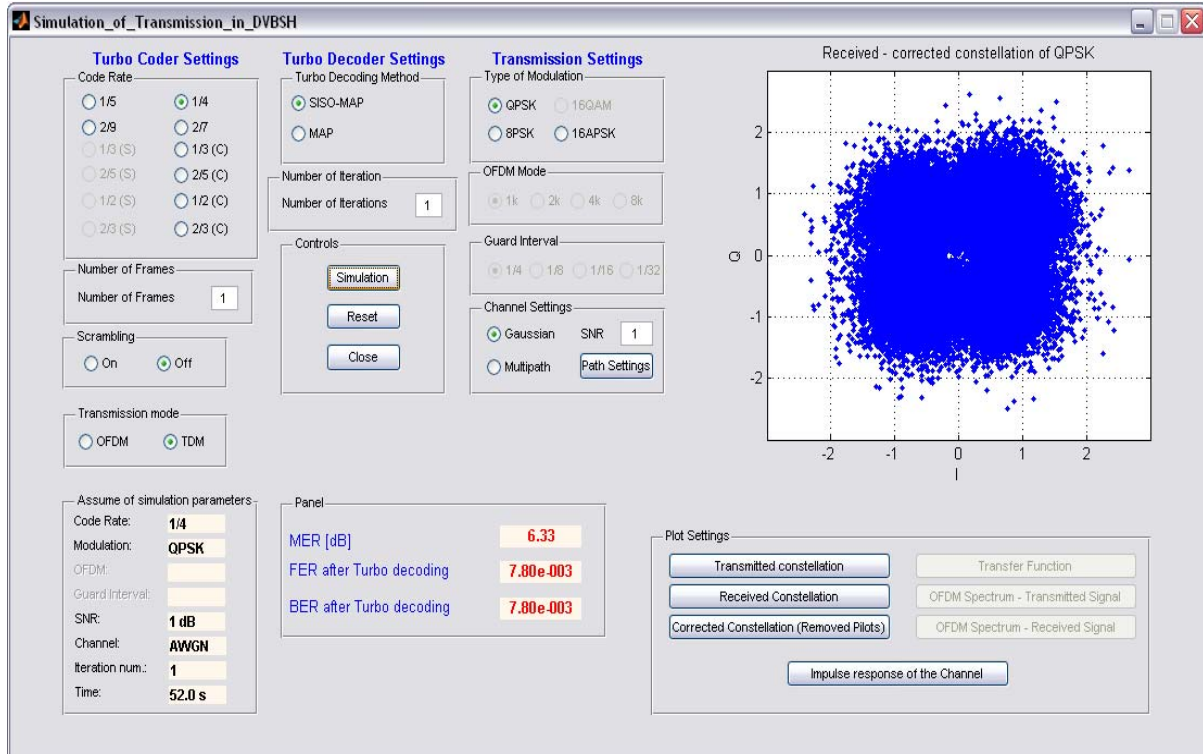


Figure 4: Main window of the MATLAB application for the DVB-SH simulation.

In the DVB-SH-B and in the TDM mode, the scrambling code sequence shall be constructed by combining two real m-sequences into a complex sequence. The general form of recursive definition of subsequent symbols and Gold code sequence are available in [2].

Now, complete SH frame (in TDM mode) signal is available in the time domain. After the scrambling, the signals shall be filtered with RRC (Root Raised Cosine). The roll-off factor shall be $\alpha = 0.35$; 0.25 and 0.20, depending on the service requirements [1]-[4]. In our analysis and simulation the parameter α was set on 0.35.

The carrier modulation shall be performed by multiplying 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 to 2.2 GHz, as recommended in [1]-[4].

The created application (and its GUI), which was used for the analysis and simulation of signal transmission in DVB-SH-B standard, is shown in Fig. 4. Details are available on request.

3 Implementation of the 16APSK modulation into MATLAB

MATLAB functions and tools support several solutions for the modulation and demodulation. In our developed application, the `modem.pskmod(M)` function was used from Communication Toolbox. This function also enables set up that which symbols are be mapped. However, the symbol order does not match the mapping in the DVB-SH specification [2]. On the other hand, the 16APSK modulation was implemented by another way. Reason is that function `modem.pskmod` can not allow

changing the properties of `psk.SymbolOrder` and `psk.SymbolMapping` [7]. Moreover, the 16APSK modulation constellation is created by special way [2]. Therefore, the modulation 16APSK was implemented in the application manually.

The complete description of the features of 16APSK modulation (with symbol mapping) it can be found in [2]. The final MATLAB code, performing symbol mapping and modulation for 16APSK, is given below:

```
% 16APSK mapping (according to ETSI EN 302 583)
% IQ points in the constellation diagram

R1 = [0.267+0.267i -0.267+0.267i -0.267-0.267i 0.267-0.267i];
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];

xlength = length(bit_interleaving_output); % Length of input values

for k=1:xlength

    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,:) == [0 0 1 0];
        modulation(1,k) = R2(5);

    elseif bit_interleaving_output(k,:) == [0 0 1 1];
        modulation(1,k) = R2(8);

    elseif bit_interleaving_output(k,:) == [0 1 0 0];
        modulation(1,k) = R2(1);

    elseif bit_interleaving_output(k,:) == [0 1 0 1];
        modulation(1,k) = R2(12);

    elseif bit_interleaving_output(k,:) == [0 1 1 0];
        modulation(1,k) = R2(6);

    elseif bit_interleaving_output(k,:) == [0 1 1 1];
        modulation(1,k) = R2(7);

    elseif bit_interleaving_output(k,:) == [1 0 0 0];
        modulation(1,k) = R2(3);

    elseif bit_interleaving_output(k,:) == [1 0 0 1];
        modulation(1,k) = R2(10);

    elseif bit_interleaving_output(k,:) == [1 0 1 0];
        modulation(1,k) = R2(4);

    elseif bit_interleaving_output(k,:) == [1 0 1 1];
        modulation(1,k) = R2(9);

    elseif bit_interleaving_output(k,:) == [1 1 0 0];
        modulation(1,k) = R1(1);

    elseif bit_interleaving_output(k,:) == [1 1 0 1];
        modulation(1,k) = R1(4);

    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
```

How it can be seen in the presented source code, 16APSK modulation has special features (see Fig. 5). The 16APSK modulation constellation shall be composed of two concentric rings of uniformly spaced 4 and 12PSK points, 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 [2], [3].

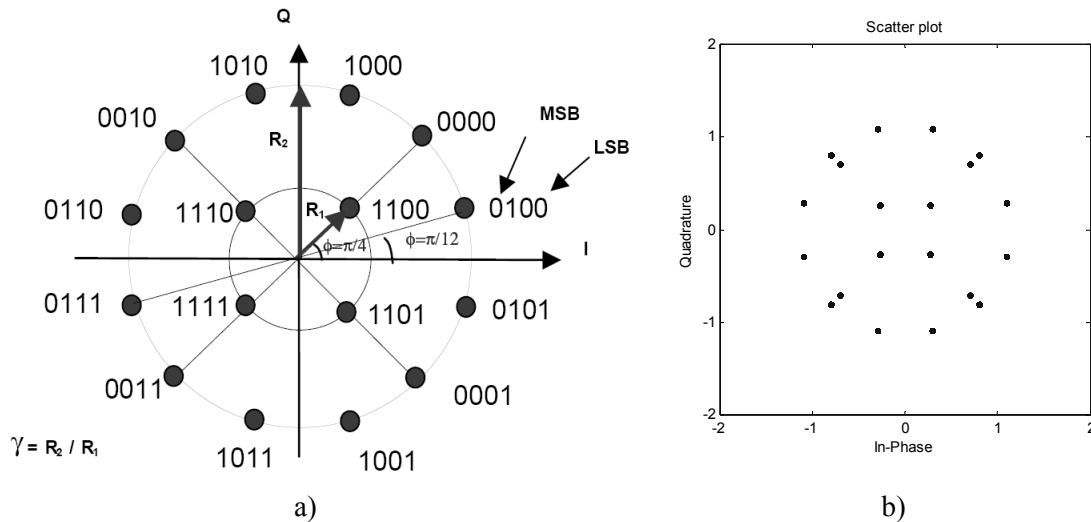


Figure 5: Bit mapping into 16APSK signal constellation: a) recommended for the DVB SH-B standard [2]; b) realized in MATLAB (with pilots).

3.1 Implementation of the 16APSK demodulation into MATLAB

How it was described, the implementation of 16APSK modulation into MATLAB was made by manual way. Therefore, the demodulation of the received signal (in case of 16APSK) must be done again by manual way. The implementation of the 16APSK demodulation process into MATLAB is given below:

```

demodulation = zeros(length(Received_sequence),length(sequence));

for k = 1:length(Received_sequence)

    if (abs(Received_sequence(1,k))>=0 && abs(Received_sequence(1,k))<0.535) &&
        (angle(Received_sequence(1,k))>=0 && angle(Received_sequence(1,k))<(pi/2))
        demodulation(k,:) = [1 1 0 0];
    elseif(abs(Received_sequence(1,k))>0 && abs(Received_sequence(1,k))<0.535) &&
        (angle(Received_sequence(1,k))>=(pi/2) && angle(Received_sequence(1,k))<(pi))
        demodulation(k,:) = [1 1 1 0];
    elseif(abs(Received_sequence(1,k))>0 && abs(Received_sequence(1,k))<0.535) &&
        (angle(Received_sequence(1,k))>=-pi && angle(Received_sequence(1,k))<-(pi/2))
        demodulation(k,:) = [1 1 1 1];
    elseif((abs(Received_sequence(1,k))>0 && abs(Received_sequence(1,k))<0.535) &&
        (angle(Received_sequence(1,k))>=-pi/2 && angle(Received_sequence(1,k))<0))
        demodulation(k,:) = [1 1 0 1];
    elseif(abs(Received_sequence(1,k))>=0.535 && abs(Received_sequence(1,k))<20) &&
        (angle(Received_sequence(1,k))>=0 && angle(Received_sequence(1,k))<(pi/6))
        demodulation(k,:) = [0 1 0 0];
    elseif(abs(Received_sequence(1,k))>=0.535 && abs(Received_sequence(1,k))<20) &&
        (angle(Received_sequence(1,k))>=(pi/6) && angle(Received_sequence(1,k))<(pi/3))
        demodulation(k,:) = [0 0 0 0];
    elseif(abs(Received_sequence(1,k))>=0.535 && abs(Received_sequence(1,k))<20) &&
        (angle(Received_sequence(1,k))>=(pi/3) && angle(Received_sequence(1,k))<(pi/2))
        demodulation(k,:) = [1 0 0 0];
    elseif(abs(Received_sequence(1,k))>=0.535 && abs(Received_sequence(1,k))<20) &&
        (angle(Received_sequence(1,k))>=(pi/2) &&
        angle(Received_sequence(1,k))<(2*pi/3))
        demodulation(k,:) = [1 0 1 0];
    elseif(abs(Received_sequence(1,k))>=0.535 && abs(Received_sequence(1,k))<20) &&
        (angle(Received_sequence(1,k))>=(2*pi/3) &&
        angle(Received_sequence(1,k))<(5*pi/6))
        demodulation(k,:) = [0 0 1 0];

```

```

elseif(abs(Received_sequence(1,k))>=0.535 && abs(Received_sequence(1,k))<20) &&
    (angle(Received_sequence(1,k))>=(5*pi/6) && angle(Received_sequence(1,k))<pi)
    demodulation(k,:) = [0 1 1 0];
elseif(abs(Received_sequence(1,k))>=0.535 && abs(Received_sequence(1,k))<20) &&
    (angle(Received_sequence(1,k))>=-pi && angle(Received_sequence(1,k))<-(5*pi/6))
    demodulation(k,:) = [0 1 1 1];
elseif(abs(Received_sequence(1,k))>=0.535 && abs(Received_sequence(1,k))<20) &&
    (angle(Received_sequence(1,k))>=-(5*pi/6) && angle(Received_sequence(1,k))<-(
    2*pi/3))
    demodulation(k,:) = [0 0 1 1];
elseif(abs(Received_sequence(1,k))>=0.535 && abs(Received_sequence(1,k))<20) &&
    (angle(Received_sequence(1,k))>=-(2*pi/3) && angle(Received_sequence(1,k))<-(
    pi/2))
    demodulation(k,:) = [1 0 1 1];
elseif(abs(Received_sequence(1,k))>=0.535 && abs(Received_sequence(1,k))<20) &&
    (angle(Received_sequence(1,k))>=-(pi/2) && angle(Received_sequence(1,k))<-(
    pi/3))
    demodulation(k,:) = [1 0 0 1];
elseif(abs(Received_sequence(1,k))>=0.535 && abs(Received_sequence(1,k))<20) &&
    (angle(Received_sequence(1,k))>=-(pi/3) && angle(Received_sequence(1,k))<-(
    pi/6))
    demodulation(k,:) = [0 0 0 1];
elseif(abs(Received_sequence(1,k))>=0.535 && abs(Received_sequence(1,k))<20) &&
    (angle(Received_sequence(1,k))>=-(pi/6) && angle(Received_sequence(1,k))<0)
    demodulation(k,:) = [0 1 0 1];
end
end

```

4 Simulation parameters

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

- mode: TDM (for the satellite transmission)
- code ratio: 1/4 (robust protection)
- modulation: QPSK, 8PSK, 16APSK
- transmission channel: Gaussian (AWGN)
- turbo decoding method: SISO-MAP (Soft Input Soft Output – Maximum A Posteriori)

The number of iterations (number of repeated decoding processes) is equal to eight (8), as it is recommended in [3]. The limit of the error-free reception – QEF (Quasi Error Free) is considered for C/N , where the BER is equal to 1.10^{-5} after turbo decoding, as recommended in [2], [3].

5 Simulation Results

Simulation of the satellite TV transmission in the DVB-SH-B standard, for a varying C/N ratio in the Gaussian channel (AWGN), are in the Fig. 5. Results of BER after turbo decoding vs. C/N ratio in Gaussian channel model are illustrated.

Figure 6 shows the dependences of the BER after turbo decoding on C/N ratio in Gaussian (AWGN) channel for all type of modulations. There were obtained three dependences: the first for QPSK, the second for 8PSK and the third for the 16APSK modulation. How it can be seen, modulation QPSK is the most robust to noises. For the achieving of QEF it is needed a very low value of C/N . In case of 8PSK and 16APSK modulations the value of C/N in the channel must be higher. That means that the higher number of states in multistate modulations (in this case 8PSK and 16APSK) is needed for higher C/N for smaller BER . Moreover, PSK modulations are less robust to the noises. The QEF can be achieved at 4.0 dB in case of 8PSK and at 6.0 dB in case of 16APSK modulation.

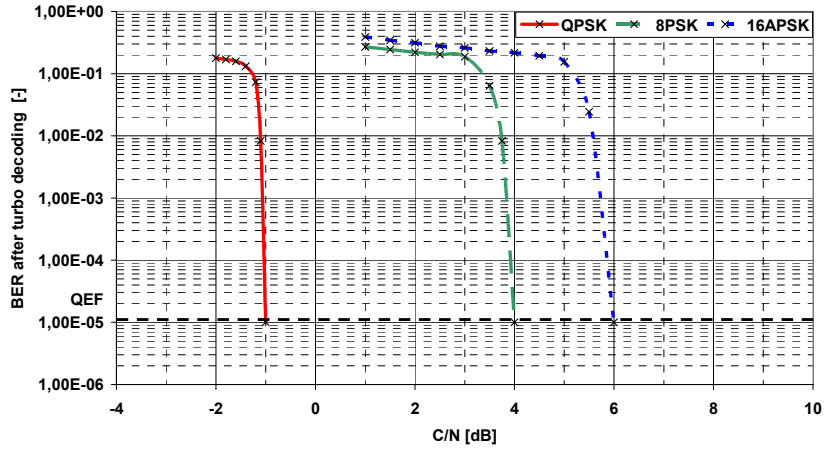


Figure 6: Satellite reception scenario (QPSK, 8PSK, 16APSK, mode TDM, CR 1/4) and DVB-SH-B performance (BER after turbo decoding with 8 iterations as a function of C/N) in AWGN channel.

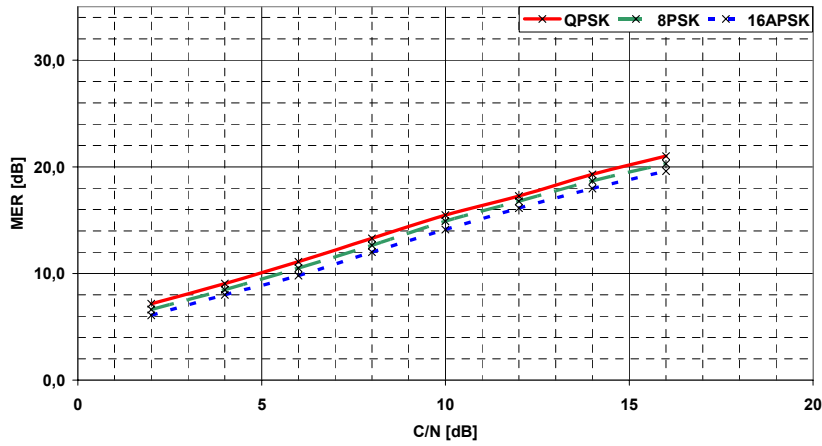


Figure 7: Modulation error ratio MER in the DVB-SH-B satellite scenario as a function of C/N in the AWGN channel (QPSK, 8PSK, 16APSK, mode TDM, CR 1/4).

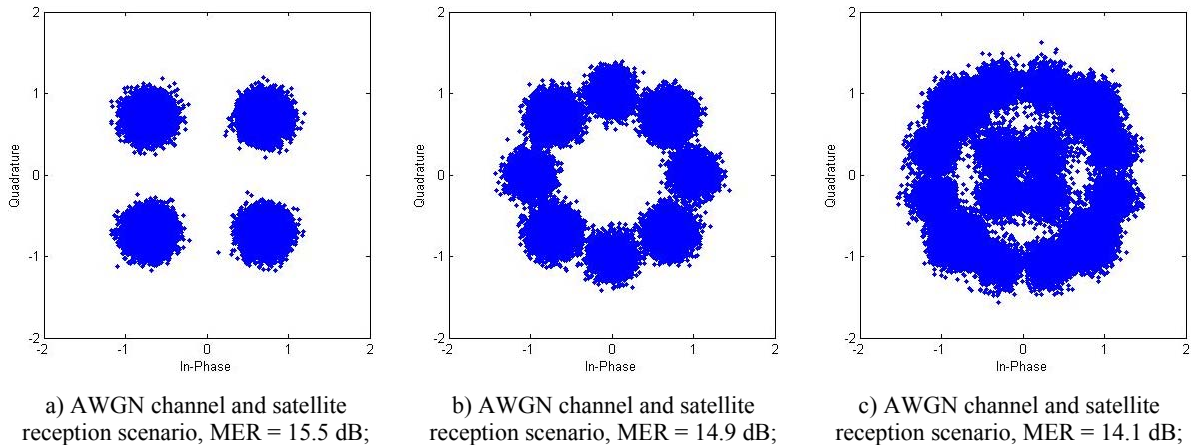


Figure 8: Simulation: I/Q constellation in AWGN channel and satellite reception scenario and MER equal to: a) 15.5 dB (with QPSK), b) 14.9 dB (with 8PSK), c) 14.1 dB (with 16APSK) - all the constellations includes channel correction and $C/N = 10$ dB.

Dependences of the *MER* (Modulation Error Ratio) on *C/N* in the DVB-SH-B system were obtained to. The value of *MER* is depending on the selected type of modulation. How it can be seen in the Fig. 7, for all types of modulations, the shape of curve has a linear form, because the communication channel has only Gaussian character.

Typical examples of the constellation diagrams for all types of modulations are also easy to see in the Fig. 8.

6 Conclusions

In this paper the implementation of the 16APSK modulation and demodulation processing in MATLAB was presented. Presented method allows simulation of the DVB-SH transmission, when TDM mode is used (DVB-SH-B). Dependences of the *BER* after turbo decoding on *C/N* ratio were explored for the Gaussian channel for all available of modulations (QPSK, 8PSK, 16APSK).

Presented results can be used for the transmission distortion analysis and evaluation of the DVB-SH system parameters influence on transmitted signal of the satellite/mobile TV.

Acknowledgement

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