

Modernization of DVB-S2 Standard Using Signal-Code Constructions Based on Amplitude Modulation of Many Components

Ivan Horbatyi, and Yevhen Yashchshyn

Abstract—It is proposed to modernize the DVB-S2 standard by using AMMC (amplitude modulation of many components) signals instead of 8PSK (8-phase shift keying) and APSK (amplitude-phase shift keying) signals, and to modernize the DVB-S2 standard equipment by using the AMMC modulator and AMMC demodulator. Usage of AMMC makes it possible to reduce the symbol error rate in communication channel up to 52 times. The satellite digital video broadcast systems that apply signal-code constructions based on AMMC are characterized by a higher energy efficiency from 1 to 2.6 dB compared with signal-code constructions based on 8PSK and APSK.

Keywords—DVB-S2 standard, frequency efficiency, energy efficiency, amplitude modulation of many components

I. INTRODUCTION

THE satellite digital video broadcast systems are developing very dynamically in recent times. This is due to a significant increase in the number and quality of television channels that such systems transmit. The most important indicators of such systems are quality and efficiency. Quality indicators are reliability, authenticity and security. Indicators of efficiency are pragmatic, technical, technological, operational and economic efficiency. The actual task is to increase the quality and efficiency of the satellite digital video broadcast systems, which is conditioned by the demand for increasing the data rate of video broadcast, the need to cover of significant territories by the television signal, the need to ensure the reliable functioning of such systems in conditions of limited frequency and energy resources.

A considerable number of publications are devoted to the issue of improvement the quality and efficiency indicators of satellite video broadcast systems and wireless telecommunication systems. In particular, in [1] the possibility of improving the quality and technical efficiency of the information transmission in the cooperative digital video broadcast systems based on DVB-SH (Digital Video Broadcasting – Satellite Services to Handhelds) standard by rotate the signal constellation of the quadrature phase shift keying (QPSK) signal was investigated. A quality improvement (a bit error rate decreasing) or increasing frequency efficiency of the system by more than 1 dB at

average bit error rate 10^{-2} and about 2 dB at average bit error rate 10^{-4} was achieved.

In [2] an algorithm for designing a signal constellation of a modulated signal for a wavelength-division multiplexing (WDM) channel is proposed. It is shown that it is possible to reduce a bit error rate up to 4.3 times using the proposed 8-ary signal constellation, and it is possible to reduce a bit error rate up to 1.25 times using a 16-ary signal constellation in comparison with the quadrature amplitude modulation (QAM) signal constellation.

In [3] the effect of block interleaving and forward error correction on the bit error rate in WiMAX (Worldwide Interoperability for Microwave Access) systems based on orthogonal frequency division multiplexing (OFDM) is investigated. It is shown that the application of these methods makes it possible to reduce the required signal-to-noise ratio to 2 dB with using 16QAM in the system.

In [4] a general application for television (TV) providers was described, which can measure and monitor in real time the viewer's perceptual video quality (PVQ). PVQ is an important parameter of the quality of the satellite TV system. The PVQ monitor allows the viewer to specify the influences on PVQ score of the transponder broadcasting plan and receiving earth station parameters.

In [5, 6] the development of software for reliable design in order to provide high quality and fault tolerance of complex technical systems is considered.

Among issues that require further resolution, the issue of ensuring the high technical efficiency of satellite video broadcast systems remains important. One of the important ways for increasing the technical efficiency of such systems is the use of high efficiency methods and devices for shaping and processing of signals. The aim of this work is to develop the new high efficiency methods and devices for shaping and processing of signals using a new family of modulation based on amplitude modulation of many components, which makes it possible to increase the quality and technical efficiency of the satellite digital video broadcast systems.

II. THE SATELLITE DIGITAL VIDEO BROADCAST STANDARDS

Satellite broadcast is a reliable and economical way of transmitting a high-quality television signal to any place in a large area of service. One of the features of the use of satellite digital broadcast systems is the limited power of the satellite transponder, therefore, such systems traditionally use signal processing techniques that ensure normal operation at a minimum signal power to noise power ratio at the input of the

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demodulator of the receiving device in exchange for an increase in the band operating frequencies of the system.

The DVB (Digital Video Broadcast) Project consortium developed the European standard for a satellite digital multi-program television broadcasting system – the DVB-S standard [7]. The DVB-S transmission equipment uses the following methods for shaping and processing of signals in forming of a data stream and its adaptation to the communication channel: multiplexing of transport packages and forming of quasi-random sequences for the uniform distribution of energy in time; outer coding using the Reed-Solomon code (RS); interleaving and inner coding using the punctured convolutional code; a signal forming in the main band of frequencies and its modulation.

QPSK is the main modulation type in the DVB-S standard. 8-phase shift keying (8PSK) or 16-ary quadrature amplitude modulation (16QAM) can be further used in Digital Video Broadcasting standard for Digital Satellite News Gathering (DVB-DSNG) [8]. The use of outer RS code and inner convolutional code with coding rates of 1/2, 2/3, 3/4, 5/6, 7/8, and 8/9 enables to significantly reduce the requirements for the ratio E_b / N_0 of the energy of one information bit to the power spectral density of white noise for qualitative demodulation of the modulated signals. Different frequency efficiency from 0.92 to 3.22 bps/Hz can be achieved, depending on the choice of the modulation method and the coding rate.

The second-generation DVB-S2 standard is complementary to the DVB-S Satellite TV standard [9]. In the DVB-S2 system used a wide set of adaptive coding, modulation, and levels of error protection (i.e., coding rates) in the process of forming a signal stream, which increased the data transmission rate by about 30% compared to DVB-S. In such system, outer RS code and inner the low-density parity-check code (LDPC code) with coding rates of 1/4, 1/3, 2/5, 1/2, 3/5, 2/3, 3/4, 4/5, 5/6, 8/9 and 9/10 are used to provide a compromise between the value of the radiated power and the spectral efficiency that can be applied to different modulation methods (QPSK, 8PSK, 16APSK (16-position amplitude phase shift keying) and 32APSK). Different frequency efficiency can be achieved from 0.49 to 4.45 bps/Hz, depending on the choice of modulation method and coding rate.

TABLE I
EFFICIENCY OF SIGNAL-CODE CONSTRUCTIONS BASED ON
M-PSK OR M-APSK, OUTER RS CODE, AND INNER LDPC CODE, WHICH ARE
USED IN THE DVB-S2 STANDARD

Signal-code construction	Frequency efficiency γ [bps/Hz]	Energy efficiency E_s / N_0 [dB]
QPSK 1/4	0.490	-2.35
QPSK 9/10	1.789	6.42
8PSK 3/5	1.780	5.50
8PSK 9/10	2.679	10.98
16APSK 2/3	2.637	8.97
16APSK 9/10	3.567	13.13
32APSK 3/4	3.703	12.73
32APSK 9/10	4.453	16.05

The value of the frequency efficiency and the energy efficiency of the satellite digital video broadcast system when applying some signal-code constructions used in the standard DVB-S2 at quasi error free $PER = 10^{-7}$ (packet error rate) after processing of signals in AWGN (additive white Gaussian noise) channel is given in Table I [9].

Here M-PSK is M-ary phase shift keying, M-APSK is M-ary amplitude phase shift keying, the frequency efficiency γ is equal to the ratio of the data transmission rate to the system bandwidth, the energy efficiency is equal to the minimum required average energy per transmitted symbol E_s to the power spectral density of the white noise N_0 to provide data transmission at a given value PER, and PER is the ratio between the useful transport stream packets correctly received and affected by errors, after forward error correction.

III. VARIETIES OF MODULATION USED IN THE DVB-S2 STANDARD

Varieties of M-PSK are used in the satellite digital video broadcast systems, which is associated with high noise immunity of PSK signals in the radio communication channel and resistance to nonlinear distortions in transponders of artificial satellites of the Earth, which are part of such systems. During the implementation of M-PSK, it is possible to transmit M symbols, while the initial phase of the signal can acquire $M = M_\phi$ discrete values. M-PSK signal has the form:

$$u_{PSK_m}(t) = U_0 \cos(\omega_0 t + \varphi_m(t) + \varphi_0), \quad (1)$$

where U_0 , ω_0 , φ_0 are the amplitude, angular frequency and initial phase of carrier oscillation respectively, $\varphi_m(t)$ is the variable component of the initial phase of the modulated signal during the transmission of m th symbol, and phase number $m = 1, 2, \dots, M_\phi$.

Varieties of M-APSK are used to increase the data transmission rate and frequency efficiency of the system. During the implementation of M-APSK, it is possible to transmit M symbols, while the amplitude of the signal can acquire M_U discrete values, and the initial phase can acquire M_ϕ discrete values. M-APSK signal has the form:

$$u_{APSK_m}(t) = U_{mu} \cos(\omega_0 t + \varphi_{m\phi}(t) + \varphi_0), \quad (2)$$

where U_{mu} is the amplitude of the modulated signal during the transmission of m th symbol, the number of discrete amplitude levels $mu = 1, 2, \dots, M_U$, $\varphi_{m\phi}(t)$ is the variable component of the initial phase of the modulated signal during the transmission of m th symbol, and the phase number $m\phi = 1, 2, \dots, M_\phi$.

The 16APSK modulation constellation composed of two concentric rings of uniformly spaced 4 and 12 PSK points, respectively in the inner ring of radius R_1 and outer ring of radius R_2 in the DVB-S2 Standard. The 32APSK modulation constellation composed of three concentric rings of uniformly spaced 4, 12 and 16 PSK points, respectively in the inner ring of radius R_1 , the intermediate ring of radius R_2 and the outer ring of radius R_3 . The standard applies certain values of ratio R_2 / R_1 and ratio R_3 / R_1 depending on the chosen type of coding method. The signal constellations of some M-PSK and M-APSK signals used in the DVB-S2 standard are shown in Fig. 1. Signal constellation of 16APSK signal is shown in Fig. 1(c) at the value of radius ratio $R_2 / R_1 = 2.57$, and signal constellation of 32APSK signal is shown in Fig. 1(d) at the values of radius ratios $R_2 / R_1 = 2.53$, $R_3 / R_1 = 4.30$.

IV. AMPLITUDE MODULATION OF MANY COMPONENTS

It is advisable to apply a new varieties of APSK – a new family of modulation based on amplitude modulation of many components (AMMC) to improve the technical efficiency of satellite video broadcast systems or telecommunication systems.

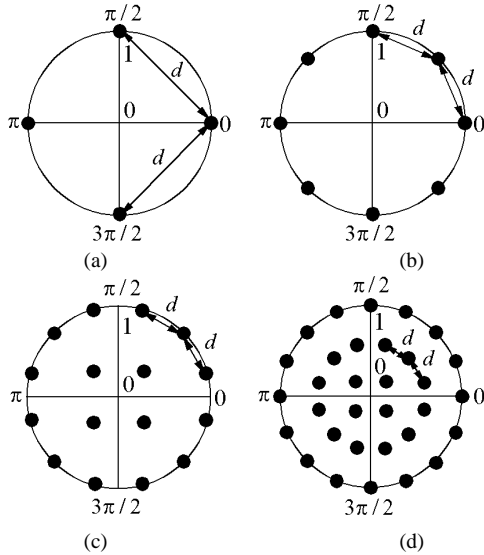


Fig. 1. Signal constellations: (a) QPSK, (b) 8PSK, (c) 16APSK, (d) 32APSK.

During the implementation of AMMC, the modulated signal is formed as the sum of its N components which modulated by the amplitude and differing in the initial phases $\varphi_0 + \varphi_n$. It has the form [10]:

$$u_{AMMC}(t) = \sum_{n=1}^N U_0 a_n u_{m_n}(t) \cos(\omega_0 t + \varphi_0 + \varphi_n), \quad (3)$$

where a_n are the coefficients of proportionality for n th sub-channels of the modulator, and u_{m_n} are the modulating signals at the inputs of the multipliers in the n th sub-channels of the modulator.

In practice, it is advisable to use AMMC signals in which the variable components of the initial phases of n th components are calculated according to such equation:

$$\varphi_n = \varphi_{in} + \frac{\pi n}{N}, \quad (4)$$

where φ_{in} is certain initial phase.

The types of AMMC include the proposed M-ary AMMC (M-AMMC) under which the modulation signals are discrete, M-AMMC with symmetric constellation, which do not contain signal points with zero power, and M-AMMC having the shift of amplitude levels of modulating signals. The signal constellations of the some proposed M-AMMC signals are shown in Fig. 2. The number of unique AMMC signals with 3 components that can be unambiguously demodulated is

$$M_{eff} = 3M_U(M_U - 1) + 1, \quad (5)$$

where M_U is the number of evenly distant levels of modulating signals what are used during shaping components of AMMC signals.

The total number of symbols that can be obtained using N components and all possible combinations of modulating signals at arbitrary initial phases of the components is equal to

$$M_{tot} = (M_U)^N. \quad (6)$$

The signal constellations of 8AMMC signal with 3 components having the shift of amplitude levels of modulating signals (Fig. 2(a)), 16AMMC signal with 3 components (Fig. 2(b)) and 32AMMC signal with 3 components (Fig. 2(e)) characterized by symmetry of constellation relative to the origin of coordinates of the amplitude-phase plane and absence of a signal points with zero power.

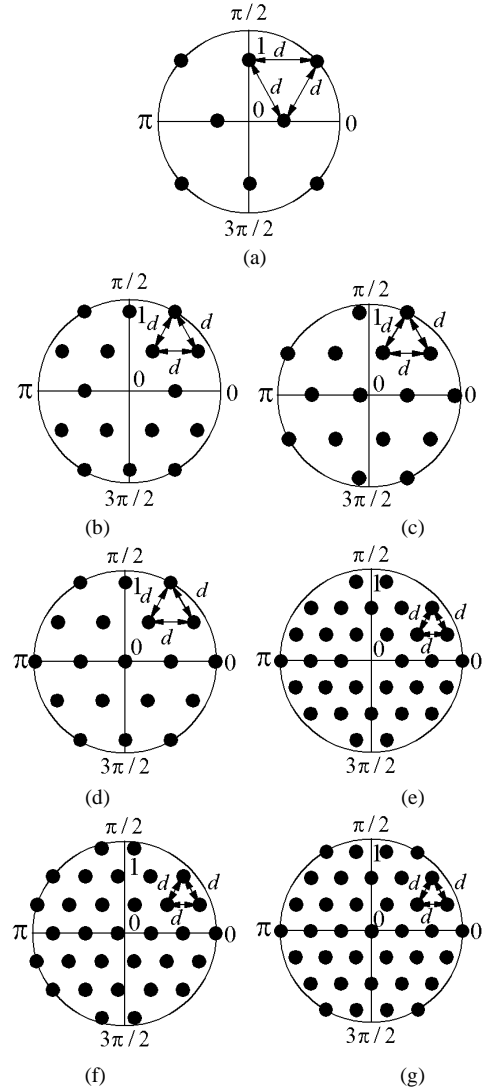


Fig. 2. Signal constellations: (a) 8AMMC with 3 components having the shift of amplitude levels of modulating signals, (b) 16AMMC with 3 components with symmetric constellation, (c) 16AMMC with 3 components having the shift of amplitude levels of modulating signals, (d) 19AMMC with 3 components, (e) 32AMMC with 3 components with symmetric constellation, (f) 32AMMC with 3 components having the shift of amplitude levels of modulating signals, (g) 37AMMC with 3 components.

Also interesting from a practical point of view are the signal constellations of 16AMMC signal with 3 components having the shift of amplitude levels of modulating signals (Fig. 2(c)) and 32AMMC signal with 3 components having the shift of amplitude levels of modulating signals (Fig. 2(f)).

When applying M-AMMC, a $\log_2 M_{eff}$ bit of information may be transmitted within the duration of one information symbol. So, applying of 19AMMC signal with 3 components (Fig. 2(d)) allows to transmit more information by 6.2% when using a certain number of symbols or reduce the number of symbols in the information package by 6.2% when transmitting information through the communication channel comparatively with 16QAM or 16AMMC, and 37AMMC signal with 3 components (Fig. 2(g)) allows to transmit more information by 4.18%. However, the signal constellations of 19AMMC signal with 3 components and 37AMMC signal with 3 components contain signal points with zero power, which can complicate the operation of the phase-locked loop in the receiving device.

The feature of AMMC signals with N components is that they are demodulated in the N -dimensional demodulation space. Each point of the AMMC signal in such a space has coordinates equal to the amplitudes of signals at the outputs of each n th sub-channels of the modulator. Unlike demodulation of AMMC signals, each signal point can be depicted on the demodulation plane in the Cartesian coordinate system with coordinates equal to the amplitudes of signals at the outputs of the two sub-channels of the quadrature demodulator during demodulation of PSK or QAM signals.

To implement M-AMMC signals, it is proposed to use the AMMC modulator and AMMC demodulator [11], the block diagrams for which are shown in Fig. 3 and Fig. 4 respectively.

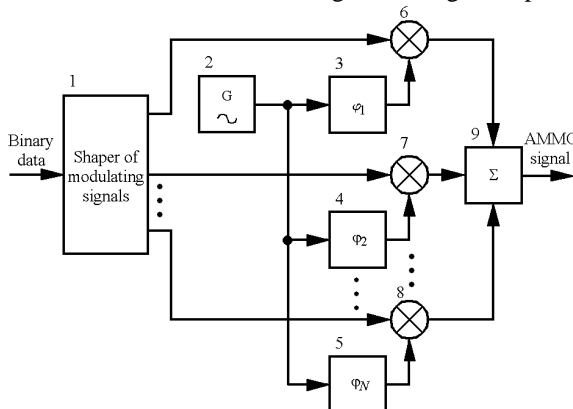


Fig. 3. AMMC modulator: 1 – shaper of modulating signals, 2 – generator of harmonic carrier oscillation, from 3 to 5 – phase shifters, from 6 to 8 – multipliers, and 9 – adder

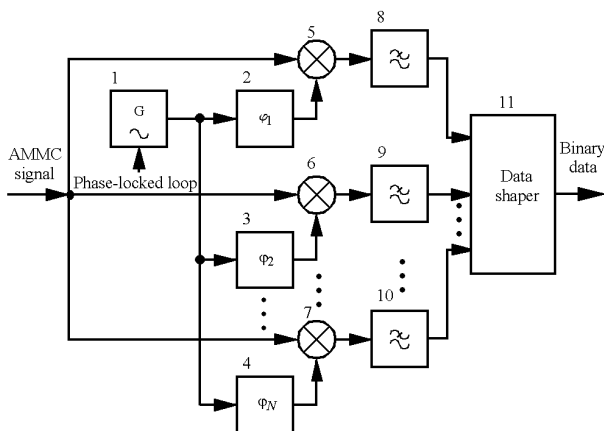


Fig. 4. AMMC demodulator: 1 – generator of harmonic carrier oscillation with phase-locked loop, from 2 to 4 – phase shifters, from 5 to 7 – multipliers, from 8 to 10 – low pass filters, and 11 – data shaper

The AMMC modulator comprises shaper 1 of modulating signals with N outputs, generator 2 of harmonic carrier oscillation of transmission, from first to N th phase shifters 3–5 for angles φ_n , where n is a number of the shaped modulating signal, from first to N th multipliers 6–8 and adder 9 having N inputs. The AMMC demodulator comprises generator 1 of harmonic carrier oscillation synchronized by frequency and phase with the oscillation of generator of harmonic carrier oscillation of transmission, from first to N th phase shifters 2–4 for angles φ_n , from first to N th multipliers 5–7, from first to N th low pass filters 8–10 and a data shaper 11 having N inputs. The AMMC demodulator includes the phase-locked loop (PLL), which can be constructed on the basis of known or new proposed methods and devices of phase synchronization [12].

According to studies [11], the use of other known modulators and demodulators, such as a quadrature modulator and a quadrature demodulator, is not feasible for the shaping and processing of AMMC signals, as it does not achieve the potential noise immunity of AMMC signals. A significant advantage of the AMMC demodulator is the ability to provide higher resistance to zero drift in the sub-channels of the AMMC demodulator when processing AMMC signals with a non-rectangular signal constellations compared to a quadrature demodulator.

It has been established that the distance between centers of instability zones caused by zero drift in the sub-channels of the demodulator on the demodulation plane along one axis is less by 1.25 dB compared to the distance along the other axis when attempting to demodulate the 19AMMC signal with 3 components by the quadrature demodulator in contrast to the AMMC demodulator, in which these distances are identical. Let the symbol error rate on the output of the decisive device, which is located on the output of the demodulator, will be $P_s = 10^{-5}$ when the zero drift in the demodulator sub-channels does not yet cause errors in the symbol recognition using the AMMC demodulator to demodulate such signal at the ratio of the average energy of one information symbol to the power spectral density of white Gaussian noise $E_s/N_0 = 20.26$ dB. Under the same conditions, a 1.25 dB decrease in the distance between centers of instability zones along one axis caused by zero drift in the sub-channels in case of use of the quadrature demodulator to demodulate such signal results in increase of symbol error rate to the value $E_s/N_0 = 0.1$, hence such satellite video broadcast system or telecommunication system becomes unsuitable for use.

The AMMC modulator and the AMMC demodulator are universal devices that are suitable for shaping and processing of M-ary amplitude shift keying (M-ASK), M-PSK, M-APSK, M-QAM and M-AMMC signals. These devices contain N channels, so they are a little more complicated to implement than two-channel quadrature modulator and quadrature demodulator. However, this disadvantage can be eliminated in the case of production the AMMC modulator and the AMMC demodulator in the form of integrated circuits.

V. MODERNIZATION OF DVB-S2 STANDARD

Let's explore the effect of using AMMC instead of other types of modulation applied in the DVB-S2 standard.

The symbol error rate on the output of the decisive device of the ideal demodulator with the use of AMMC and other varieties of amplitude-phase modulation can be calculated by applying the following proposed equation, which is obtained from the previously proposed equation [10, 11]:

$$P_s \cong n_m \cdot Q_1 \left(\sqrt{K_E \cdot \frac{E_s}{2N_0}} \right), \quad (7)$$

where $Q_1(x) = 1 - \Phi(x)$ is the probability density function, $\Phi(x)$ is the cumulative distribution function, n_m is the coefficient equal to the average number of adjacent points that are located around one of the points of the signal constellation, K_E is the coefficient equal to the ratio of the minimally possible energy of the difference between two symbols corresponding to adjacent points to the average energy of all symbols corresponding to unique signal points, E_s is the average energy of one information symbol, and N_0 is the power spectral density of white Gaussian noise.

The adequacy of (7) is confirmed by the coincidence of calculation results of the PSK symbol error rate and the QAM symbol error rate obtained by using a well known relationships [13, 14].

The study results of dependence of symbol error rate P_s on ratio E_s/N_0 of average energy of one information symbol to the power spectral density of white Gaussian noise for varieties of PSK, QAM and AMMC using (7) are shown in Fig. 5.

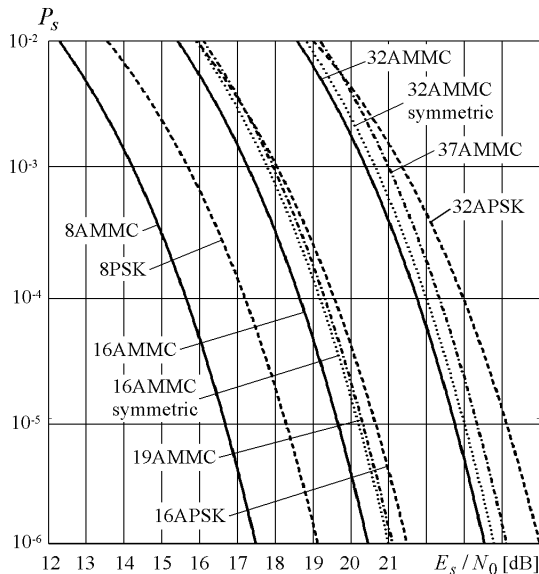


Fig. 5. Dependence of symbol error rate P_s on ratio E_s/N_0 for varieties of M-PSK, M-QAM and M-AMMC

As can be seen from Fig. 5, the use of 8AMMC with 3 components having the shift of amplitude levels of modulating signals instead of 8PSK ensure reduction of symbol error rate in the communication channel in 52 times at ratio $E_s/N_0 = 17.47$ dB, the use of 16AMMC with 3 components having the shift of amplitude levels of modulating signals instead of 16APSK ensure reduction of

symbol error rate in 14 times at ratio $E_s/N_0 = 20.45$ dB, and the use of 32AMMC with 3 components having the shift of amplitude levels of modulating signals instead of 32APSK ensure reduction of symbol error rate in 30 times at ratio $E_s/N_0 = 23.53$ dB.

Usage of 16AMMC with 3 components with symmetric constellation and 16AMMC with 3 components with symmetric constellation also makes it possible to reduce the symbol error rate, but the benefits from their use are less than the modulations mentioned above. Usage of 19AMMC with 3 components and 37AMMC with 3 components provide even fewer improvements.

The use of the best varieties of M-AMMC ensure reducing the necessary value of ratio E_s/N_0 at the input of the decisive device for the correct recognition of the received symbols, in particular the use of 8AMMC ensure reducing the required ratio E_s/N_0 by 1.65 dB, 16AMMC by 1.04 dB, and 32AMMC by 1.46 dB at the symbol error rate 10^{-6} .

To study the expediency of using M-AMMC at modernizing the DVB-S2 standard, a mathematical modeling of the satellite digital video broadcast system was performed in the event that some varieties of the proposed M-AMMC are included in the signal-code constructions. The simulated system consisted of a transmitting device, a radio channel with AWGN, and a receiving device. During the simulation, the effects of modulation, coding, and the data transmission protocols in accordance with the DVB-S2 standard were taken into account. The results of calculating the frequency efficiency and the energy efficiency of such system which apply signal-code constructions based on the outer noise immunity RS code, inner LDPC code with a number of coding rates and M-AMMC using mathematical modeling in the Mathcad program are given in Table II.

As can be seen from Table II, the constructions based on 8AMMC with 3 components having the shift of amplitude levels of modulating signals (Fig. 2(a)), 16AMMC with 3 components having the shift of amplitude levels of modulating signals (Fig. 2(c)), and 32AMMC with 3 components having the shift of amplitude levels of modulating signals (Fig. 2(f)) ensure the highest system energy efficiency among the considered signal-code constructions.

Also noteworthy are signal-code constructions based on 16AMMC with 3 components with symmetric constellation (Fig. 2(b)) and 32AMMC with 3 components with symmetric constellation (Fig. 2(e)) that are characterized by symmetry of constellation relative to the origin of coordinates of the amplitude-phase plane and absence of a signal points with zero power. The system which apply signal-code constructions based on 19AMMC with 3 components (Fig. 2(d)) and 37AMMC with 3 components (Fig. 2(g)) are characterized by higher frequency efficiency and high energy efficiency, but the signal constellations of such signals contain a signal points with zero power, which may be their disadvantage. Thus, it is expedient to apply the considered signal-code constructions based on AMMC signals in order to increase the noise immunity of the satellite digital video broadcast systems.

According to the results of the research, it was proposed to modernize the DVB-S2 standard by using the 8AMMC signal with 3 components having the shift of amplitude levels of modulating signals instead of 8PSK signal, the 16AMMC signal with 3 components having the shift of amplitude levels of modulating signals instead of 16APSK signal and the

TABLE II
EFFICIENCY OF THE SATELLITE DIGITAL VIDEO BROADCAST SYSTEM WHICH
APPLY SIGNAL-CODE CONSTRUCTIONS BASED ON M-AMMC,
OUTER RS CODE, AND INNER LDPC CODE

Signal-code construction	Frequency efficiency γ [bps/Hz]	Energy efficiency E_s/N_0 [dB]
8AMMC with 3 components having the shift of amplitude levels of modulating signals 3/5	1.780	3.789
8AMMC with 3 components having the shift of amplitude levels of modulating signals 9/10	2.679	9.269
16AMMC with 3 components having the shift of amplitude levels of modulating signals 2/3	2.637	6.672
16AMMC with 3 components with symmetric constellation 9/10	3.567	12.559
16AMMC with 3 components having the shift of amplitude levels of modulating signals 9/10	3.567	11.998
19AMMC with 3 components 9/10	3.788	12.624
32AMMC with 3 components having the shift of amplitude levels of modulating signals 3/4	3.703	10.147
32AMMC with 3 components with symmetric constellation 9/10	4.453	14.668
32AMMC with 3 components having the shift of amplitude levels of modulating signals 9/10	4.453	14.406
37AMMC with 3 components 9/10	4.640	14.979

32AMMC signal with 3 components having the shift of amplitude levels of modulating signals instead of 32APSK signal, and to modernize the DVB-S2 standard equipment by using the AMMC modulator and AMMC demodulator in their composition instead of quadrature modulator and quadrature demodulator. The results of studies on the frequency efficiency γ and the energy efficiency E_s/N_0 of the satellite digital video broadcast systems based on DVB-S, DVB-DSNG, DVB-S2 and modernized DVB-S2 standards depending on the applied signal-code constructions using mathematical modeling in the Mathcad program are shown in Fig. 6.

As can be seen from Figure 6, the use of M-AMMC instead of 8PSK and M-APSK during the formation of signal-code constructions allows to increase the energy efficiency of the satellite digital video broadcast system from 1 to 2.6 dB at the same frequency efficiency.

CONCLUSION

According to results of the performed researches, it is proposed to modernize the DVB-S2 standard by using the M-AMMC signals instead of 8PSK and M-APSK signals, and to modernize the DVB-S2 standard equipment using devices for shaping and processing of M-AMMC signals instead of devices for shaping and processing of 8PSK and M-APSK signals. Usage of M-AMMC makes it possible to reduce the symbol error rate in communication channel up to 52 times or to reduce the required ratio of average energy of one information symbol to the power spectral density of white Gaussian noise compared to the modulation varieties used in this standard. The satellite digital video broadcast systems that apply signal-code constructions based on M-AMMC, outer RS code and inner LDPC code are characterized by a higher energy efficiency from 1 to 2.6 dB compared with signal-code constructions based on 8PSK and M-APSK, therefore the proposed modernization of DVB-S2 standard will allow to

increase the noise immunity and the energy efficiency of such systems.

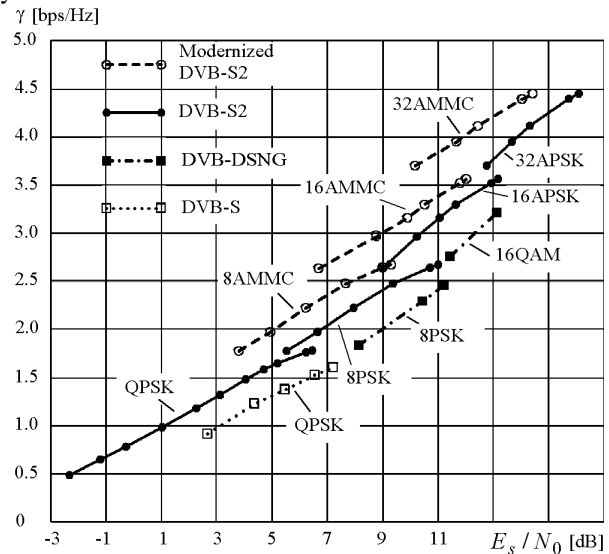


Fig. 6. Efficiency of the satellite digital video broadcast systems based on DVB-S, DVB-DSNG, DVB-S2 and modernized DVB-S2 standards

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