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**COMPLEX STUDY OF INFLUENCE OF DIFFERENT FACTORS ON
QUALITY OF SERVICE (QoS) ON DIFFERENT LEVELS OF OSI MODEL
FOR DIGITAL TELEVISION BROADCASTING**

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**КОМПЛЕКСНЕ ДОСЛІДЖЕННЯ ВПЛИВУ РІЗНИХ ФАКТОРІВ НА ЯКІСТЬ
ОБСЛУГОВУВАННЯ (QoS) НА РІЗНИХ РІВНЯХ МОДЕЛІ OSI
ДЛЯ ЦИФРОВОГО ТВ МОВЛЕННЯ**

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**КОМПЛЕКСНОЕ ИССЛЕДОВАНИЕ ВЛИЯНИЯ РАЗНЫХ ФАКТОРОВ НА
КАЧЕСТВО ОБСЛУЖИВАНИЯ (QoS) НА РАЗНЫХ УРОВНЯХ МОДЕЛИ OSI ДЛЯ
ЦИФРОВОГО ТВ ВЕЩАНИЯ**

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Abstract. Article highlights results of complex studies in direction analysis of influence of different factors such as availability of phase noise, quadrature impairments, etc., on quality of service in digital terrestrial television broadcasting system in DVB-T2 standard.

Key words: DVB-T2, impairments, quality of service, MPEG-2 TS, MER, BER.

Анотація. В статті висвітлено результати комплексних досліджень в напрямку аналізу впливу різних факторів, таких як наявність фазового шуму, квадратурних спотворень та інших, на якість обслуговування в системі цифрового наземного телевізійного мовлення в стандарті DVB-T2.

Ключові слова: DVB-T2, спотворення, якість обслуговування, MPEG-2 TS, MER, BER.

Аннотация. В статье отображены результаты комплексных исследований в направлении анализа влияния разных факторов, таких как наличие фазового шума, квадратурных искажений и других, на качество обслуживания в системе цифрового наземного телевизионного вещания в стандарте DVB-T2.

Ключевые слова: DVB-T2, искажения, качество обслуживания, MPEG-2 TS, MER, BER.

Importance of the theme. Currently transition to digital television broadcasting technology is continuing. The important component of successful transition is providing of high technical operational quality of the digital video broadcasting (DVB) systems. One of problems, that it must be solved, is control of technical quality of path operation of television broadcasting systems. Taking into account complexity of current digital television broadcasting systems, such control is carried out on levels of digital broadcasting network, RF signal, transport and video streams.

Series of publications are devoted to the studies in direction of technical quality control of digital TV broadcasting path operation. Among publications it is possible to mention works of A.

Karwowska-Lamparska, D. Wood, Ch. Dosch, M. Krivocheev, V. Dvorkovich and others [1–4]. Research results provided in mentioned above publications is basis for principles of control on different levels of technical operation quality of the analog and digital television broadcasting systems.

During maintenance of transmission and receiving equipment of digital TV broadcasting systems different impairments (quadrature impairments, phase noise and others) can arise up, that will result in technical quality of path operation reducing. Also during combined influence of impairments the reason of system performance degradation not always succeeds to be operatively detected. Technical parameters of the digital TV broadcasting system and their combinations form multi-dimensional factor space of corresponding technical quality. The choice of technical parameters in a certain manner determines the provided technical quality. Therefore during introduction of the digital TV broadcasting systems of choice of such parameter set that will provide the necessary level of technical quality even at presence of one or more types of impairments without the substantial degradation on other factors is important. However, analysis of currently available publications on the digital TV broadcasting systems and corresponding normative documents [5–7], is showed that possibility of such choice is limited. Currently there are many technical solutions in direction of control of technical operational quality at presence of impairments of different types on different levels, but technical regulations on performance are practically not defined and limited mainly only by the possible signal level on the digital TV broadcasting receiver input. It leads to decreasing of control efficiency and causes a necessity for additional researches with the aim of determination of permitted values of parameters that is subject of control. Therefore *actual task* is research of separate and combined influence of impairments on technical operational quality of the digital TV broadcasting system with the appliance of the scientifically-grounded approach on determination of threshold levels of separate and combined impairments and values of parameters used during monitoring on each levels.

The aim and tasks of the research. The aim of thesis is establishing a relationship of technical quality of path operation of digital TV broadcasting systems with levels of separate and combined impairments on the levels of RF signal, transport and video streams with development of propositions on technical norms on parameters that is subject for control.

Tasks of research that must be solved for the achievement of the aim:

- to give description of parameter set that determine the level of technical operational quality of modern digital TV broadcasting systems and systemize methods of multilevel control of technical quality of end-to-end path operation;
- to estimate influence of quadrature impairments, phase noise and additive noise on performance of digital TV broadcasting systems in DVB-T/DVB-T2 standards with determination of their permissible levels and possible scientifically-grounded technical decisions in relation to reduction of influence of separate and combined impairment on resulting technical quality of path operation;
- to define possible consequences of arising of impairments at the level of transport stream and to obtain estimations of impairment influence on technical quality of end-to-end path operation of digital TV broadcasting systems with development of propositions on technical norms for parameters that is subject of control;
- to estimate reasons and consequences of degradation of technical quality of digital terrestrial television broadcasting (DTTB) service operation at the MPEG video stream level and to give corresponding quantitative and qualitative estimations, on the base of it to propose scientifically-grounded solutions in direction of control of technical quality of path operation at this level.

ANALYSIS OF CURRENT STATE OF QUALITY OF SERVICE OF DTTB SYSTEMS CONTROL PROBLEM

The results of the studies in direction of solving the problem of technical quality control of digital TV broadcasting systems on different levels are generalized. Certainly extended set of parameters characterizing technical quality of modern digital TV broadcasting systems are defined. This set of parameters was included in international ITU-R Recommendations on author proposal.

More detailed information on this question is provided in [8–10].

Generalization and classification of existent and proposed methods of estimation of technical quality of digital TV broadcasting systems are realized with the use of multilevel approach (Fig. 1). In accordance to such classification methods of technical quality digital TV broadcasting system path control is divided into four classes. It is found out that such set of methods are quite enough for characterizing impairments at the RF and digital signal levels, and the task of estimation of quantitative and qualitative influence of such impairments with consideration of technical parameters of modern digital TV broadcasting systems is formulated.

Normative base that determines the methods of technical quality control and some normative values on the technical parameters of the digital television broadcasting systems is systematized. The result of this analysis is taken into account during national standardization of the digital television broadcasting systems.

ESTIMATION OF TECHNICAL QUALITY OF OPERATION OF DIGITAL BROADCASTING SYSTEM ON RADIO FREQUENCY LEVEL

Estimation of power performance of digital television broadcasting systems in the DVB-T and DVB-T2 standards is given by a mathematical simulation; as the estimation result the family of dependences of Bit Error Ratio (BER) from Carrier-to-Noise (C/N) ratios for different configurations of transmission-receiving path is obtained. This allowed to estimate authenticity of the results by comparing to the known estimations of such dependences for separate configurations of digital television broadcasting systems, and also additionally gave possibility to define experimentally gain of C/N ratios obtained in DVB-T2 standard comparatively with the DVB-T standard [11].

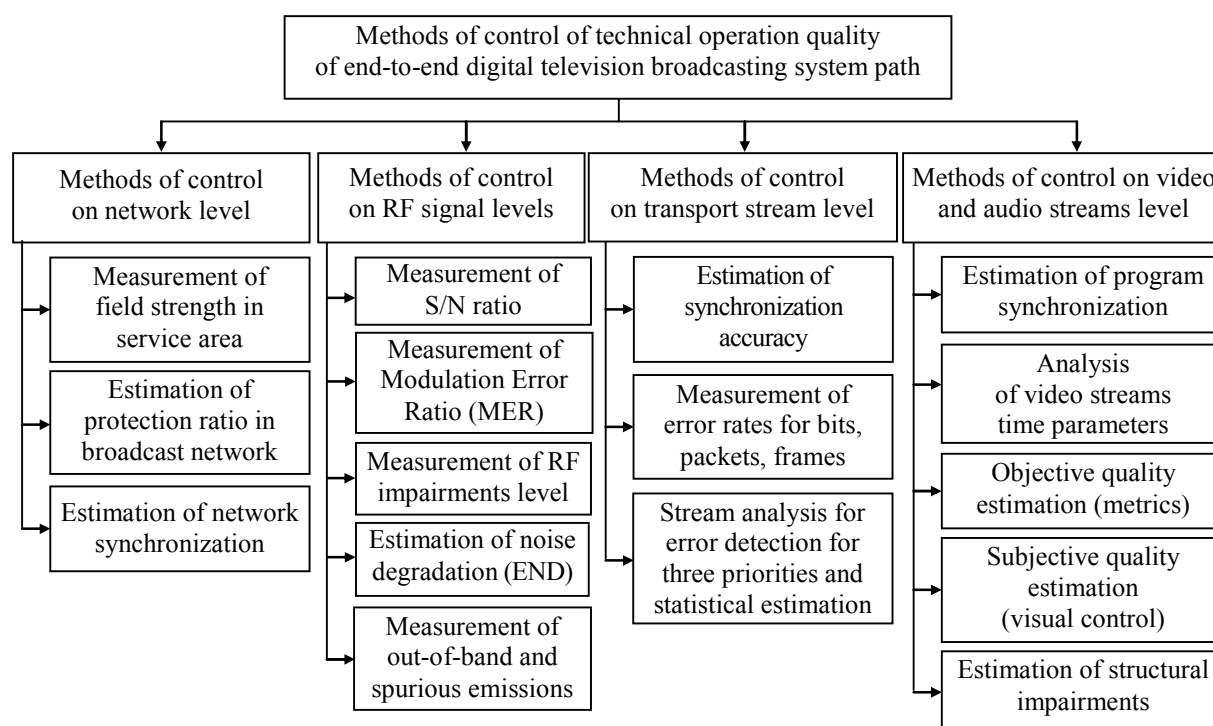


Figure 1 - Proposed classification of methods of technical quality control of service operation of the digital terrestrial television broadcasting

Combined influence of quadrature impairments (Amplitude Imbalance (AI) and Phase Error (PE)) and AWGN on performance of DVB-T and DVB-T2 systems is firstly analysed by mathematical simulation of end-to-end path of the digital television broadcasting systems.

A quantitative and qualitative estimation was carried out at three configurations with equal and different spectral efficiency/correcting capability and two receiving conditions (what characterized by the different levels of additive noise). Except that the additional comparative performance analysis of both digital television broadcasting systems with use of difference value between the threshold levels of AI and PE impairments and permissible values of Modulation Error Ratio (MER) is conducted.

As a study result the family of dependences (part of that is provided on Figs. 2, 3) is obtained and character of influence of quadrature impairments level of each type on BER after inner channel decoder of DVB-T and DVB-T2 systems that characterizes technical operation quality of each of the systems is firstly set.

Based on the results of the dependency analysis the tables with quantitative estimations (one of that corresponds to Table 1 below) are got and that came forward as basis for propositions for technical norms on the possible levels of quadrature impairments of different types in DVB-T and DVB-T2 systems with taking into account the real conditions at that the digital television broadcasting receivers are typically working.

It is found out during the analysis of the obtained dependences that permissible levels of impairments each of types at the insignificant AWGN level in the DVB-T system practically does not depend on internal code rate and increases approximately twice during transition from 16-QAM to 64-QAM (more detailed analysis is given in the text of the Thesis). For the increase of AWGN level this situation changes and the values of threshold levels of impairments begin to depend on configuration, however relation between the permissible levels of impairments during the change of configuration remains approximately the same. However permissible level of quadrature impairments in DVB-T system is less than in DVB-T2 system that it is caused by less efficiency of applicable algorithms in DVB-T system at presence of this type of impairments.

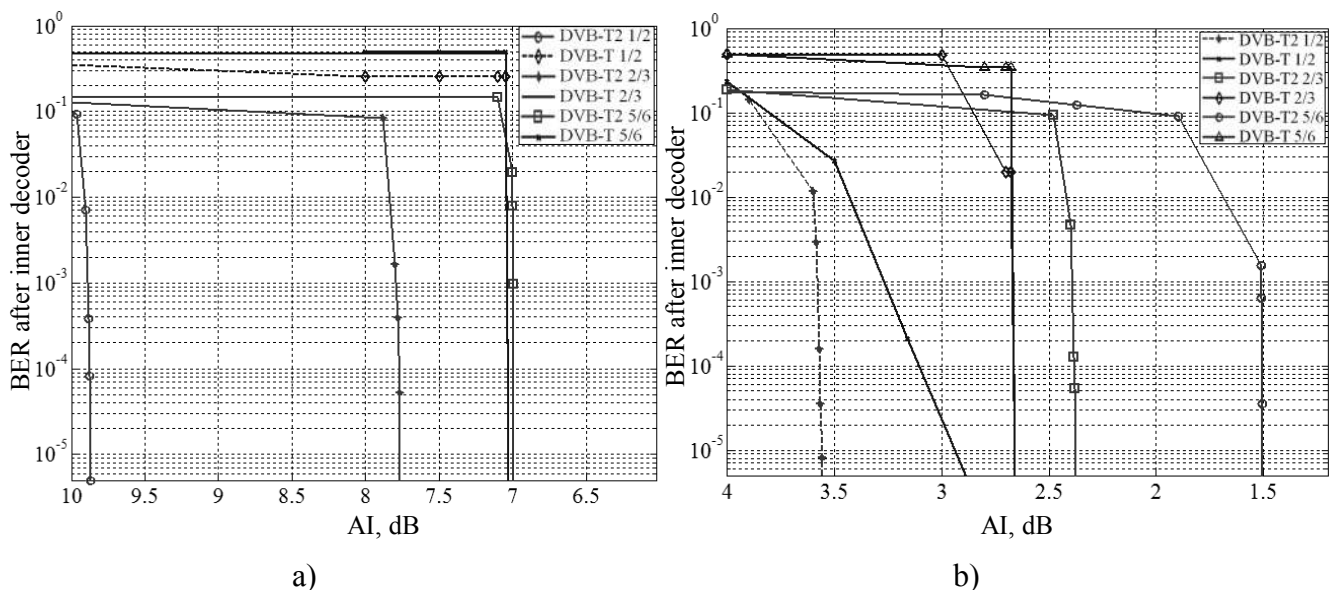


Figure 2 - Dependence of BER after inner decoder from Amplitude Imbalance (AI) at insignificant level of AWGN for: a) 16-QAM in both systems b) 64-QAM (DVB-T) and 256-QAM (DVB-T2)

In DVB-T2 system permissible level of impairments depends on used code rate and modulation method at the insignificant AWGN level and for it's increase. At the increase of code rate the permissible level of impairments decreasing approximately 1,5 times, while at the change of modulation method (from 16-QAM to 256-QAM), at the fixed inner code rate the possible level of impairments decreasing from 2,5 to 5,5 times, that it is shown in the text of dissertation work. Except that, it was defined that difference between the threshold levels of quadrature impairments is different enough and at certain conditions takes negative values. At this case efficiency of algorithms

used in DVB-T2 is lower and DVB-T provides the best performance.

The conducted analysis allowing to propose technical solutions in relation to minimization of technical quality degradation at presence of quadrature impairments of different types by the scientifically-grounded approach to choice configuration of digital television broadcasting systems, that, except that, allows not to increase implementation complexity of digital television receivers. More detailed analysis of impact of quadrature impairments on QoS for DTTB systems (DVB-T and DVB-T2) is provided in [12, 13].

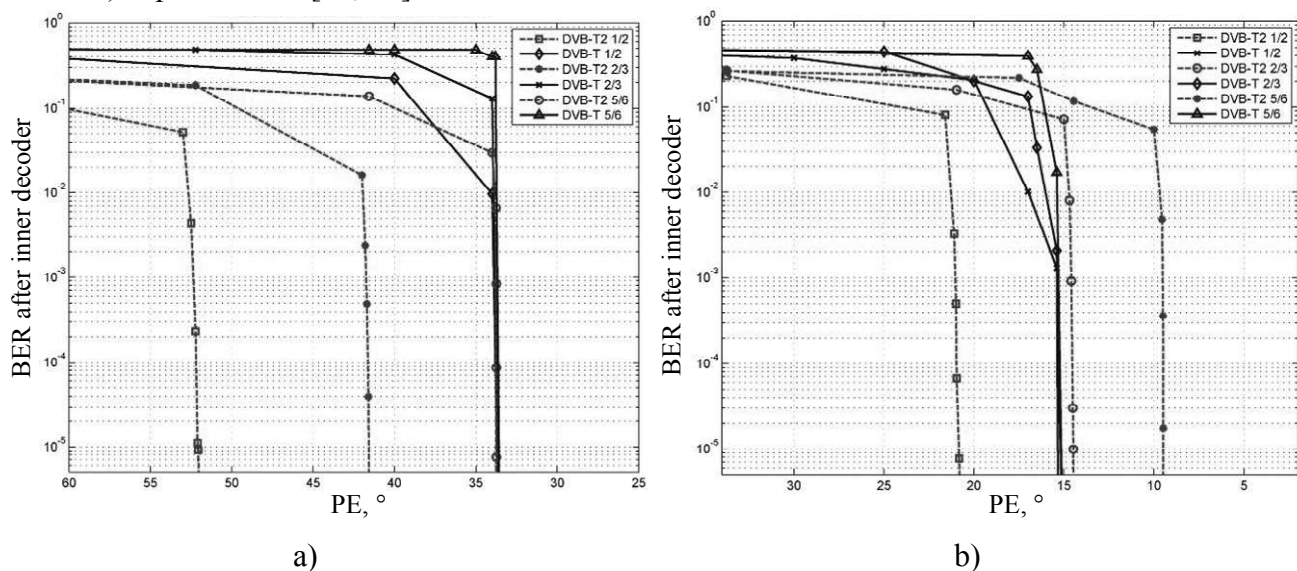


Figure 3 - Dependence of BER after inner decoder from a phase error (PE) at the insignificant AWGN level for:
 a) 16-QAM in both systems b) 64-QAM (DVB-T) and 256-QAM (DVB-T2)

Table 1 - Proposed technical norms on the threshold levels of quadrature impairments of different types in DVB-T and DVB-T2 systems (for 16-QAM)

Parameter	Value					
	1/2	2/3	5/6	1/2	2/3	5/6
	Insignificant AWGN level			Significant AWGN level		
AI_{Th} , dB	7.05			5	4	3.5
AI_{T2th} , dB	9.87	7.7	6.997	6.82	5.7	4.22
Δ_{AI} , dB	2.82	0.65	-0.053	1.82	1.7	0.72
MER_{Th} , dB	7.49					
MER_{T2th} , dB	4.033	6.354	7.5			
PE_{Th} , °	34			23	18.5	15.05
PE_{T2th} , °	50	41.54	33.75	36.2	28.3	22.25
Δ_{PE} , °	16	7.54	-0.25	13.2	9.8	7.2
MER_{Th} , dB	10.71					
MER_{T2th} , dB	6.91	8.838	10.66			

The important index of technical quality of digital television broadcasting path at the radio frequency signal level is a phase noise (jitter) level. During the analysis of combined influence of phase noise (PJ, Phase Jitter) and additive noise of insignificant level in the RF path of DVB-T and

DVB-T2 systems for different configurations by a mathematical simulation family of dependences is obtained, in particular, dependences of BER from PJ level for the set of system configurations on frequency offset 4.464 kHz (part of that is provided on Fig. 4), it's threshold levels there will not be decreasing of technical quality are defined, and corresponding tables are built.

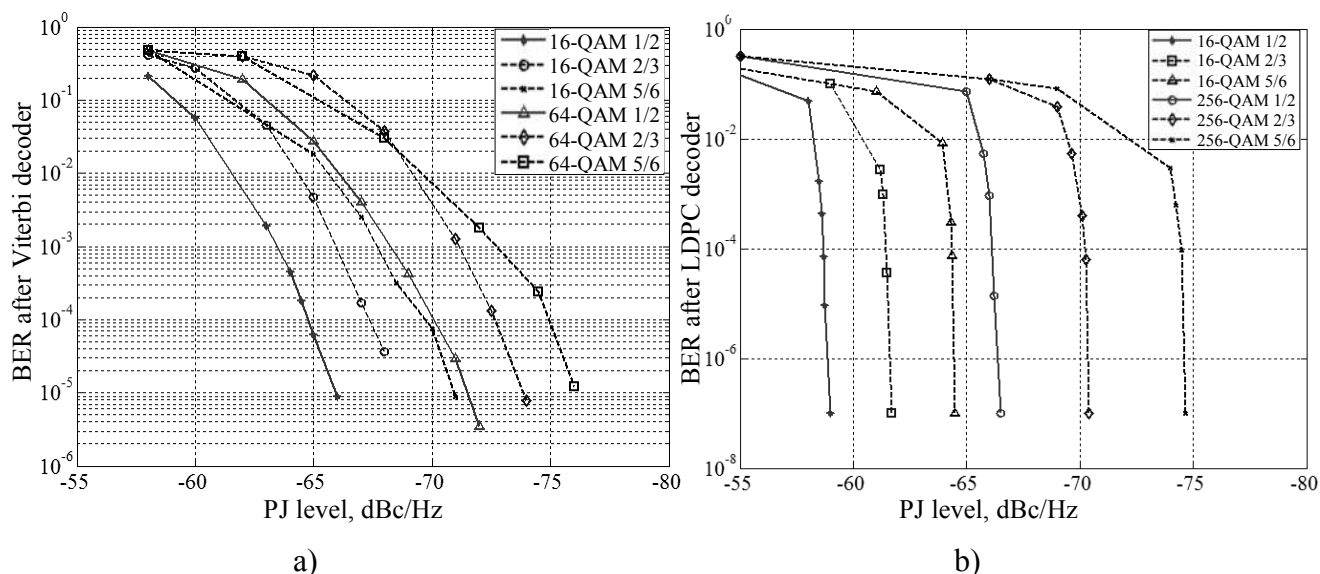


Figure 4 - Dependence of BER after inner decoder from phase noise (PJ) level at frequency offset 4.464 kHz for: a) of DVB-T b) DVB-T2

Threshold levels of impairments are used as basis for propositions in direction of technical norms on the permissible level of phase noise. Except that, the dependence of BER as index of technical quality of digital television broadcasting systems from phase noise level at different offset frequencies from central carrier is studied. The results of this study allow to formulate the propositions on permissible phase noise levels for different configurations of DVB-T and DVB-T2 systems, that it can be used during control of phase noise level in transmitting-receiving equipment.

At the conditions of presence of phase noise and increase of level of Additive White Gaussian noise the technical quality of the digital television broadcasting system path is significantly decreasing. For minimization of influence of such combined impairment on resulting technical quality of DVB-T and DVB-T2 path the technical decisions are presented. In this work two technical solutions allowing without additional complication of receiver to compensate degradation of performance of digital television broadcasting systems that arises up as a result of increase of AWGN level are proposed: a) to increase requirements to minimum the C/N ratio on the input of digital television receiver; b) to increase requirements to the minimum permissible level of phase noise.

During the analysis of the first proposed technical solution the level of the equivalent noise degradation (END) is used and this parameter that determines, as far as it is necessary to increase the CNR, that performance of digital TV broadcasting system corresponding to quasi-error free mode. It was defined by mathematical simulation, that for minimization of influence of phase noise on technical quality of DVB-T and DVB-T2 paths at presence of AWNG with high level the END value changes from 4.6 to 15 dB depending on configuration of digital TV broadcasting system. In this case for providing of permissible level of technical quality of digital TV broadcasting system service area size will be reduced or output power of DVB-T and DVB-T2 transmitters will be increased.

In the case of increase of requirements to the minimum of phase noise level the correction coefficients that must be added to the threshold values of phase noise level at the insignificant AWGN level with the aim of compensating of worsening of receiving conditions (in particular, increase of additive noise level) are defined. For this purpose dependences of END from level of phase noise on frequency offset from central carrier of 4.464 kHz are obtained (Fig. 5).

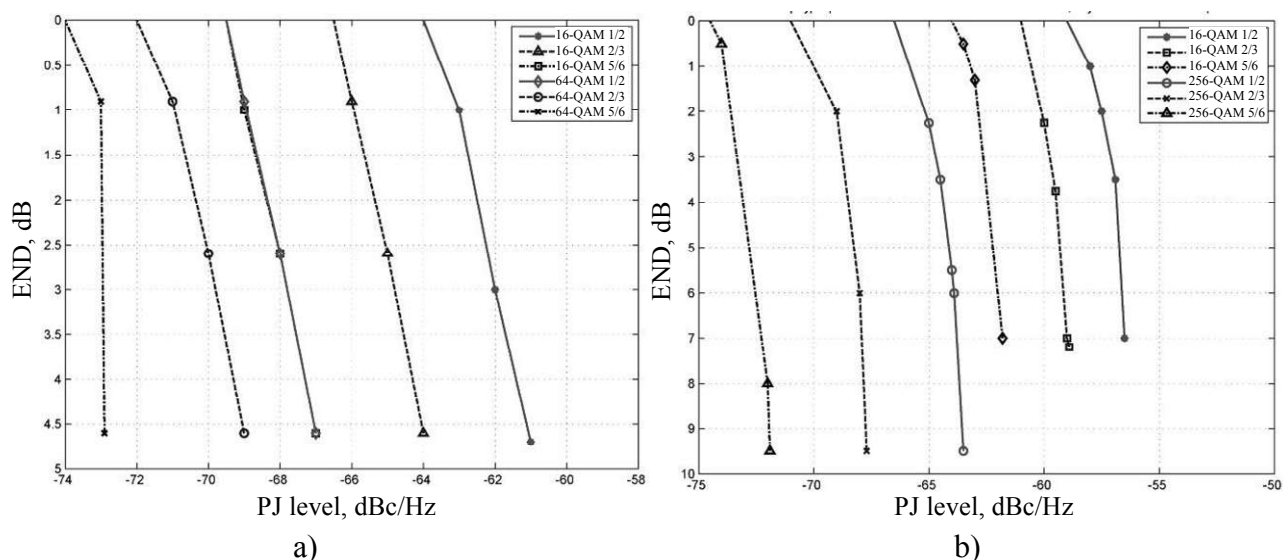


Figure 5 - Dependence of END from level of phase noise for: a) DVB-T, b) DVB-T2

Studies showed that in the case of reduction of requirements to the threshold levels of phase noise from 1 to 3 dBc/Hz maybe it is possible to compensate degradation of technical quality of digital TV broadcasting system path caused by the combined impairment (combination of phase noise and AWGN with a level that is greater on 3 dB than threshold value). It allowed to formulate propositions for technical norms for the level of phase noise with consideration of possible technical quality degradation as result of degradation of receiving condition of digital TV of broadcasting signals. In more detail all results are highlighted in [14, 15].

TECHNICAL QUALITY ESTIMATION OF DIGITAL BROADCASTING SYSTEM FUNCTIONING AT THE TRANSPORT STREAM LEVEL

The results of analysis of methods for technical control of impairment level are presented and the quantitative and qualitative estimations of influence of impairments on technical quality at the transport stream (TS) level with determination of character of influence on integrity and possible failures on the different stages of decoding are given. On the base of obtained results propositions related to technical norms on the parameters controlled at this level during the operative monitoring are formulated.

The appearance of impairments at TS stream level is estimated by means of stream analysis for appearing of errors in service information that have different criticality to the different processing stages and in accordance with it different priority is appropriated. Time distribution for error events with different priorities at different BER values characterizing the different receiving conditions of digital TV broadcasting signals is obtained by mathematical simulation for four TS streams with different parameters. It was defined that time distribution of error events and it's amount differ for the different TS streams that it is caused by differences in structure and forming. However, approximate relationship of errors with different priorities and types is kept and with the increase of error priority it's amount (both absolute and relative) decreasing. It is set that effective is the use approach proposed by an author, that consists in that during the analysis of TS stream the calculation of cumulative and instantaneous threshold amount of errors with different priorities is expedient. It will allow to increase of system efficiency during monitoring of technical quality of digital TV broadcasting system at TS stream level. Part of results obtained during the analysis of transport streams titled as France, Lux, DVBT2 and TNT during 8 seconds, is provided on Fig. 6.

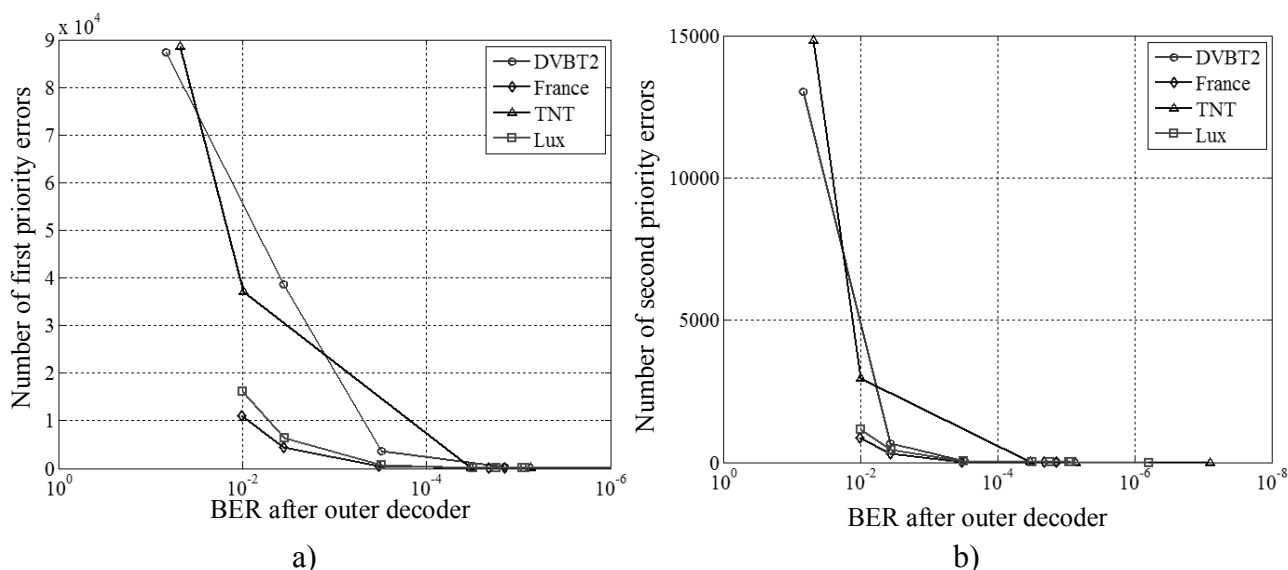


Figure 6 - Results of statistical analysis during 8 seconds for appearing in transport streams of errors with: a) first priority b) second priority

With the use of statistical and subjective estimations the task of determining the amount of errors with different priorities greater of that technical quality (both during the reproduction of video signal and at the level of service) will substantially degraded is decided. Such results provided in the text of the Thesis is used as basis for propositions on norms for technical quality of digital TV broadcasting path in the case of control at the TS stream level by the calculation of amount of errors. Another approach for technical quality control of digital TV broadcasting path also is possible - estimation of parameters that characterize quality of digital TV broadcasting system operation at transport stream level, in particular *relative time for absence of service signal reception (SAR)*, *relative time for impairment of service signal (SIR)*, *relative time for service degradation (SDR)*. On the base of mathematical simulation the quantitative and qualitative estimations of SAR, SDR and SIR are obtained, that it is provided on Fig. 7 for four transport streams (France, TNT, DVBT2, Lux).

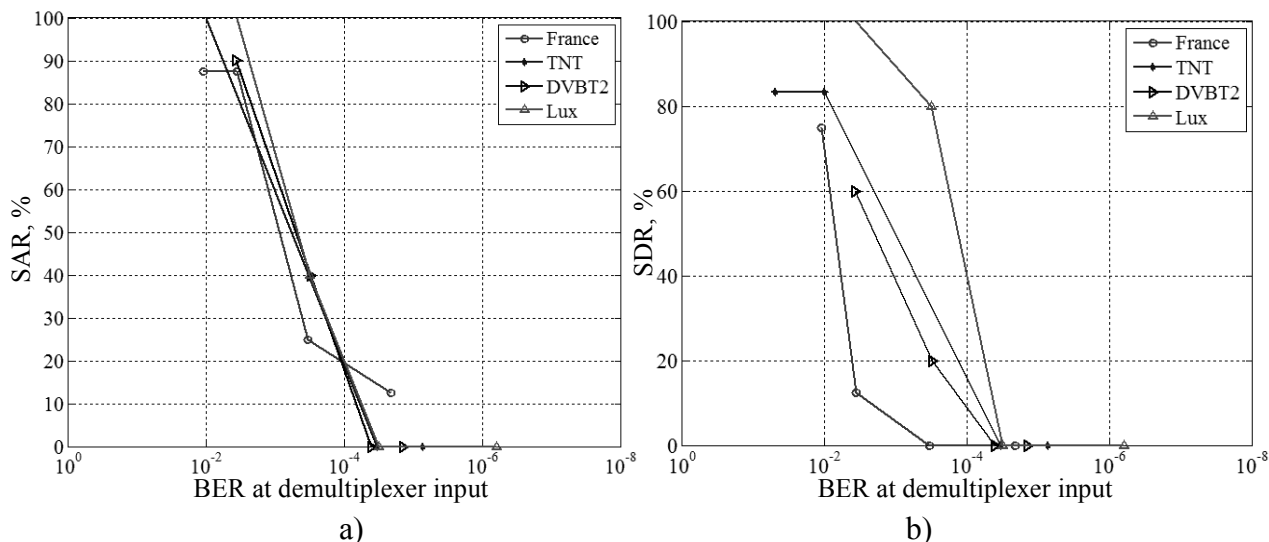


Figure 7 - Dependence of quality indexes at transport stream level from BER:
a) SAR b) SDR

Additionally, dependences of SAR, SDR and SIR from BER allowed to estimate influence of TS stream structure on technical quality of digital television broadcasting service at presence of impairments. It is set that SIR value is in dependency from average TS rate - with rate reduction at fixed BER the damage of TS stream is less and accordingly damage of video is less. Except that, there is dependence of SDR from qualitative composition of service information - at the same re-

ception conditions in TS streams with different structure different immunity to impairments is provided.

For establishment of technical norms on SAR, SDR and SIR parameters that will allow to control technical quality of digital TV broadcasting system, the limit levels of impairments at that there will not be considerable subjective failures during the reception of digital broadcasting signals are estimated. Based on generalization of the results provided on Fig. 7 and visual control of recovered video for analysed transport streams, the permissible values of SAR, SDR and SIR at the different BER and classes of technical quality are defined (see table 2).

Table 2 - Proposed technical norms on SAR, SDR and SIR

Technical quality class	Character of influence on decoding process of transport stream	Parameters of technical quality at transport stream level			
		BER	SAR, %	SDR, %	SIR, %
1	Impairments are absent	$\approx 1 \cdot 10^{-11}$	0	0	0
2	insignificant degradation	$\approx 1 \cdot 10^{-7}$	0	0	0
3	periodic degradation	$\approx 1 \cdot 10^{-5}$	≈ 5	≈ 5	1-2
4	frequent breaking of decoding	$\approx 1 \cdot 10^{-4}$	≈ 20	10-40	50-85
5	considerable part of stream is not decodable	$\approx 1 \cdot 10^{-3}$	≈ 60	40-90	90-95
		$\approx 1 \cdot 10^{-2}$	≈ 100	90-100	100

Detailed analysis of QoS for DTTB systems (DVB-T and DVB-T2) in presence of errors in TS stream are provided in [16, 17].

**STUDY AND ESTIMATION OF INFLUENCE OF AUDIOVISUAL SERVICES
BASED ON MPEG STANDARD SIGNAL IMPAIRMENTS DURING
DISTRIBUTION THROUGH A BROADCASTING CHANNEL**

Such studies are devoted to the analysis of appearance of impairments and development of methods of estimation of performance degradation during transmission of MPEG video streams. As a result of researches reasons and consequences of appearance of impairments at the level of encoding/decoding and multiplexing/demultiplexing of audiovisual service signals at MPEG video stream level with consideration of features of processing and transmission are defined. Based on study results classification (Fig. 8) is firstly built.

For estimation of structural impairments of video signals the set of parameters is proposed that is determined on different levels of the MPEG encoding hierarchy (metrics for measure of structural impairments). By mathematical simulation the estimation of structural and other impairments of video signals encoded with different configurations of MPEG encoder is given by means of this set. Part of obtained results for Pixel Error Ratio (PxER) for different parameters of inter-frame encoding determined by structure of Group of Pictures (GOP) is provided on Fig. 9. An estimation was carried out for GOP structures with 1 and 45 pictures with unidirectional prediction (it is marked as I1P and I45P), and also with 2 and 75 pictures with a bi-directional prediction (it is marked as I2BP and I75BP).

Conclusion is made that during worsening of reception conditions the level of structural impairments is increasing and this results in the substantial degradation of subjective quality. At condition of increase of error amount in video sequences only with I- and P-pictures structural impairment metrics are increased and it's levels depend on the amount of the predicted frames.

During increase of interval between reference frames this error is increased and, accordingly, error probability at corresponding level of MPEG encoding hierarchy is also increasing. At bi-directional prediction at high BER in video sequences with the small amount of B-frames the structural impairment metrics is more than in case of sequences with large amount of frames. However with BER reduction than the amount of the damaged reference frames is reduced, it maybe more effectively to recover the frames.

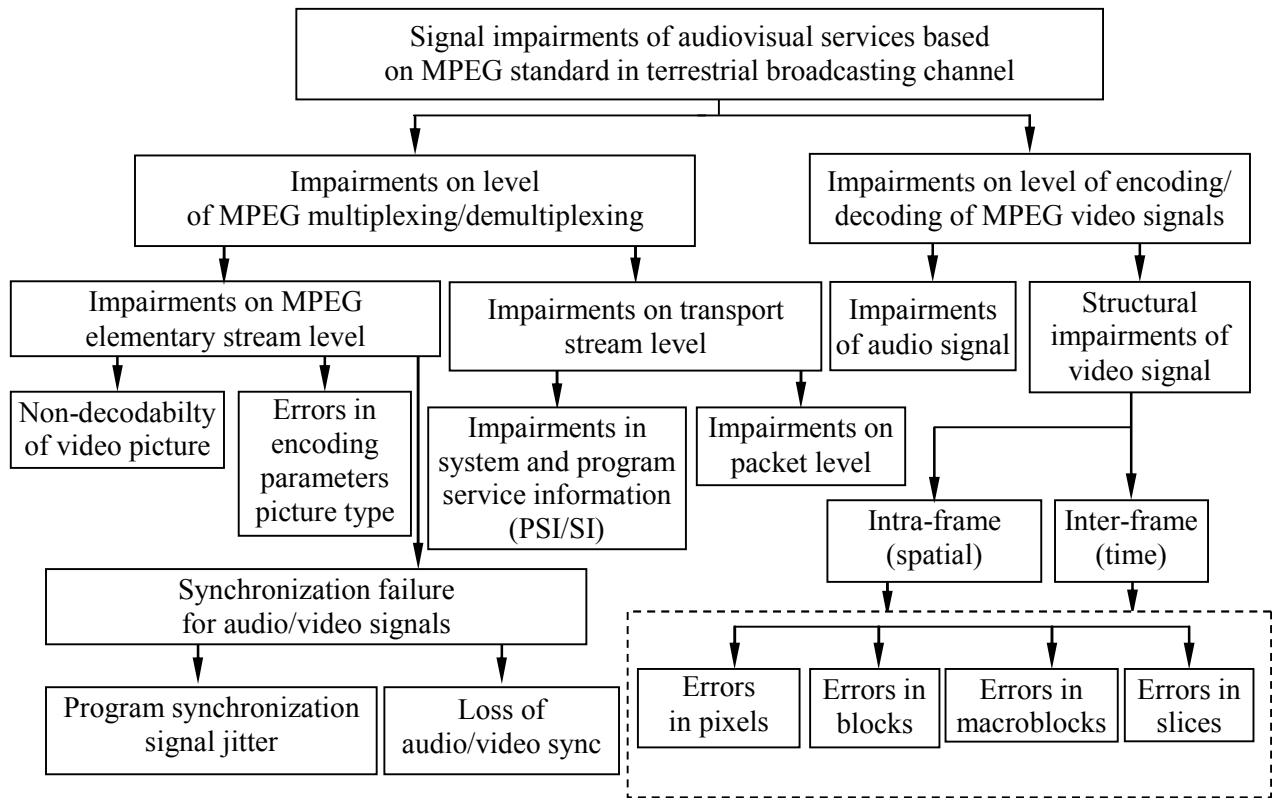


Figure 8 - Classification of impairments during distribution of MPEG streams

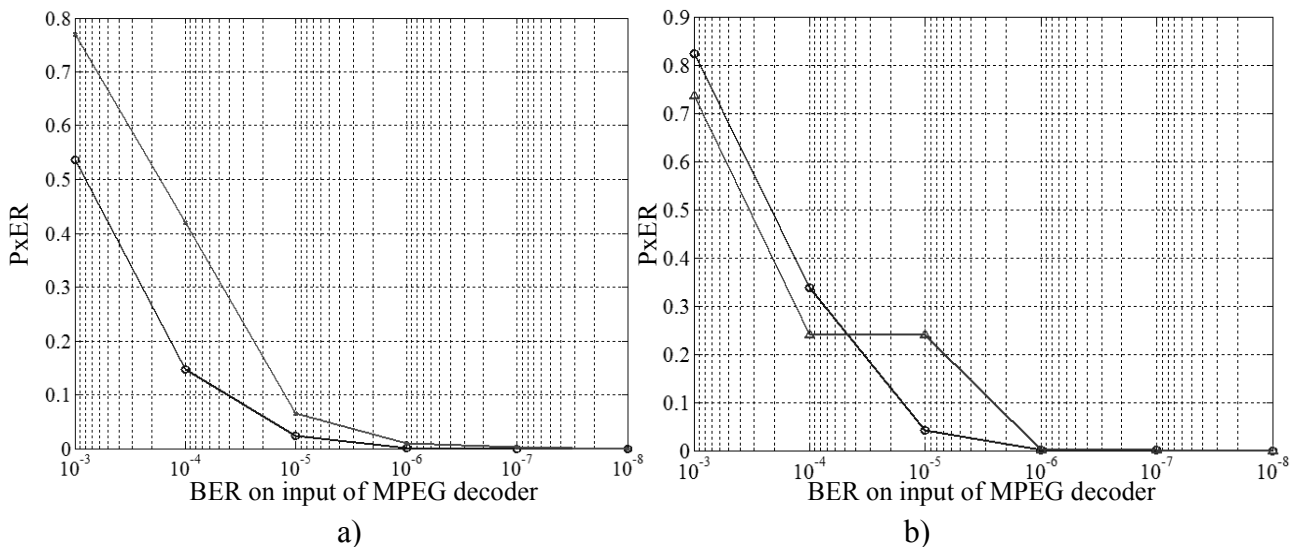


Figure 9 - Dependence of PxER from BER for GOP structures: I1P, I45P (a) and I2BP, I75BP (b)

For estimation of impairments during MPEG multiplexing the set of parameters is proposed, including probability of correct decoding of video frame, probability of video frame loss and other. By mathematical simulation quantitative and qualitative estimations to such parameters are given and it was found out that during increase of amount of errors the amount of correctly decoded video frames is decreasing, thus for sequences only with unidirectional prediction at the increase of interval between reference frames the amount of the decoded frames is increasing, and in sequences with small number of B-frames the probability of video frame decoding is more than at the large amount of frames with a bidirectional prediction (Fig. 10).

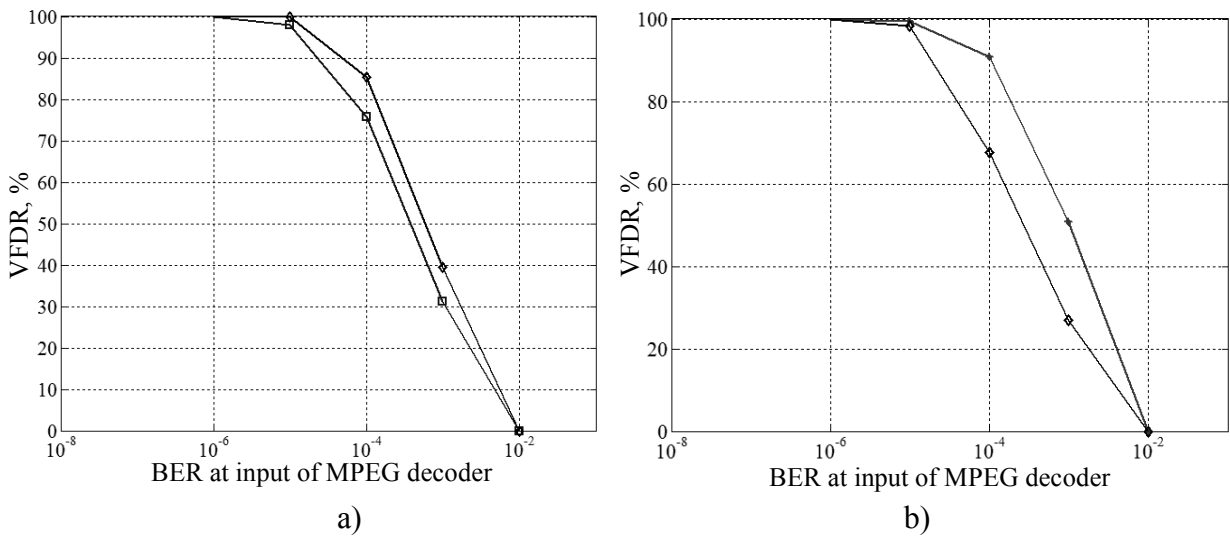


Figure 10 - Dependence of probability of video frame decoding (VFDR) from BER on an input of MPEG decoder for the video sequences I1P, I45P (a) and I2BP, I75BP (b)

Probability of loss (non-decodability) of reference I-frame, probability of loss of P- and B-frames, probability of incorrect determination of video frame type and amount of program timing errors at different configurations of inter-frame encoding and receiving conditions for video signal and corresponding analysis is carried out. As estimation result the relationship between choice of performance of inter-frame encoding and level of structural impairments is set; that can be used for minimization of such impairments during choice of corresponding configuration and further analysis/development of methods for compensation of cliff effect on video picture.

Metrics used in video compression systems are analyzed for solving of task of increase of operability and efficiency of monitoring of technical quality at level of MPEG video streams. On criteria of complexity minimum, most commonality and efficiency following metric are selected: average peak signal to noise ratio (A-PSNR), video quality metrics (VQM), structural similarity (SSIM). For such metrics dependences from BER at input of MPEG decoder with different configurations and parameters of inter-frame encoding are obtained and relationship with level of visual damage of video sequence is set. Part of the obtained results for mode of MPEG encoder with unidirectional prediction and for Y-SSIM metric (SSIM for luminance signal) is provided on Fig. 11.

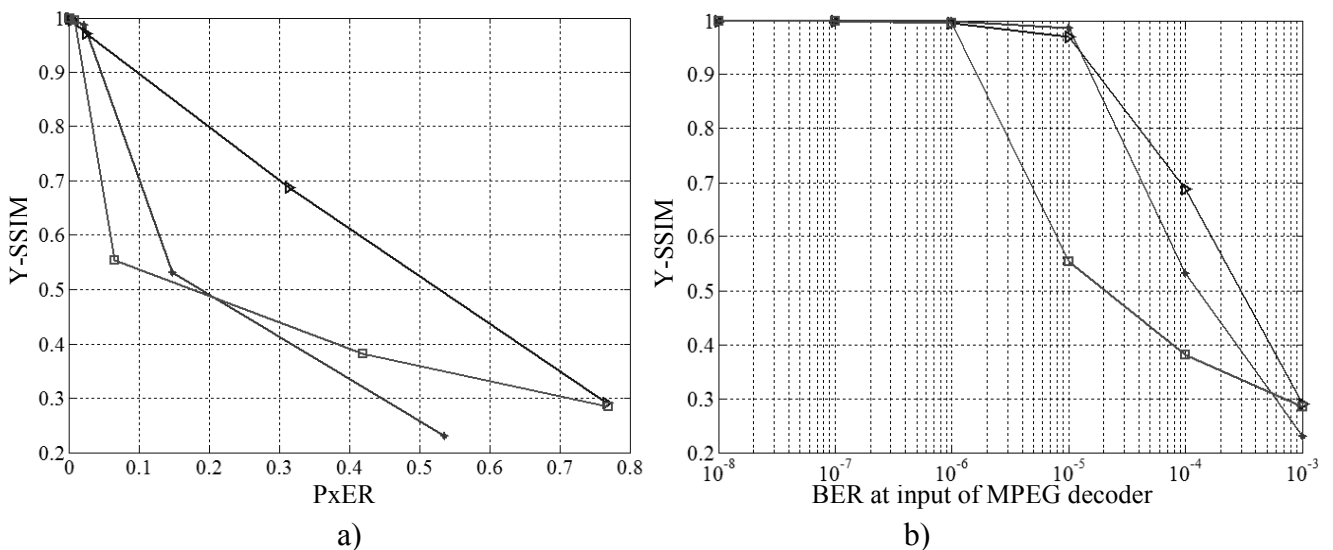


Figure 11 - Dependence of Y-SSIM for I1P, I9P, I45P video sequences from:
a) PxER b) BER

As result it is found out that during the estimation of algorithms applied in the system of quality monitoring of digital TV broadcasting networks, is effective approach that takes into account the features of impairment influence on resulting quality estimated during decoding and reproduction of video signal. Objective quality estimation metrics is providing sufficient efficiency not only for estimation of compression algorithms but also for the operative monitoring of technical quality of digital TV broadcasting networks. Most effective among the studied metrics is SSIM metrics for luminance signal that provides the maximum Pearson correlation coefficient ($r_{\text{aver}} > 0.95$) averaged for different configurations of MPEG inter-frame encoding.

On results analysis two variants of system for operational monitoring of technical quality, based on analysis of structure of video stream and use of objective quality estimation metrics are proposed. In the text of dissertation work advantages and disadvantages of proposed approach in terms of efficiency, commonality and complexity of implementation are analysed.

More detailed analysis of study results on level of MPEG video stream is provided in [18-22].

CONCLUSIONS

As study result the estimation of single and combined influence of impairments on performance of digital TV broadcasting systems taking into account the features of it's implementation is given; on base of this the propositions on technical norms for technical quality of digital TV broadcasting system on the level of RF signal, transport and video streams are formulated and corresponding technical decisions in relation to minimization of negative influence of impairments are proposed. In process of scientific studies following basic scientific and practical results are obtained:

1. The system of factors that define the level of technical quality of digital TV broadcasting systems and corresponding methods of control are characterized and on base of this it's classification with application of multi-level approach is proposed.

2. A task on research of influence of quadrature impairments, phase noise and additive noise on performance of DVB-T/DVB-T2 systems is decided. Thus the estimation of technical quality degradation in such systems at different conditions to non-ideality of quadrature modulator/demodulator performance with different ratio of each impairment in combined impairment is first given. The obtained values are used for development of technical norms on level of impairments of this type proposed in this work.

3. The choice of configurations of DVB-T/DVB-T2 systems with the aim of reduction of requirements to permissible level of quadrature impairments in case of simultaneous appearance of I/Q-signal amplitude imbalance, quadrature error or phase noise at presence of AWGN is firstly grounded. It became basis for development of technical decisions in relation to minimization of negative influence of RF impairments without increasing complexity of digital television receiver.

4. Statistical and other estimations of errors with different priorities in transport streams with a different structure and different number broadcasting programs is firstly given, on the base of results the dependences of relative time for absence of service signal reception, relative time for impairment of service signal and relative time for service degradation at different reception conditions and system configurations are firstly obtained.

5. Norms on technical quality of digital TV broadcasting systems at transport stream level for the different approaches for monitoring with establishing relationship between time indexes of technical quality of digital TV broadcasting service and subjective quality estimation of path work are developed.

6. Characterization of impairments at MPEG video stream level that can arise up during transmission through path of digital TV broadcasting systems is first given, and classification with determination of consequences of impairments is built.

7. The system of parameters that characterize the degree of impairments of MPEG video stream in spatial and time domains during transmission through the path of digital TV broadcasting

system is proposed. The quantitative and qualitative estimations of structural and other impairments with the use of such parameters at different performance and prediction modes during inter-frame encoding of video sequences are firstly given.

8 Propositions on technical decisions in relation to system implementation for monitoring of digital TV broadcasting path performance at video stream level based on objective quality estimation metrics and structural impairment estimations are developed.

Scientific and practical results can be the basis for further researches in direction of development of international normative base in part of increase efficiency of technical quality control for digital TV broadcasting paths on video application, physical, transport and network levels. Studies of author are related to the programs of researches conducted in the Study Group 6 “Broadcasting services” of Radiocommunication Sector of International Telecommunication Union (ITU-R SG 6) and defined by ITU-R Questions. Study results are presented at an international level as contributions of Ukraine to ITU-R SG 6 and most of them are included ITU-R Recommendations and in draft international handbook on digital TV broadcasting implementation. In co-authorship the results obtained during dissertation researches are included in national normative base as national standards and technical reports in direction of introduction of digital TV broadcasting systems and control of technical operational quality. Researches of author are also related to the work on development of educational methodological base for training and retraining of specialists in digital television, sound and multimedia broadcasting within the framework of ONAT n.a. A.S. Popov. During work in international program framework on “Digital television and sound broadcasting” of ITU-D Center of Excellence for the CIS countries operating on a base of ONAT n.a. A.S. Popov, author study results are widely used during international workshops and distance learning courses.

REFERENCES

1. Eriz, Berjon, G. Eizmendi, I. Velez, M. Prieto, G. Correia, S. Arrinda, and A. Angueira. "Laboratory Tests for Testing DVB-T2 Mobile Performance." *IEEE International Symposium on Broadband Multimedia Systems and Broadcasting (BMSB)* (2010): 1-5. Print.
2. Cornillet, Nicolas, Matthieu Crussiere, and Jean-Francois Helard. "Performance of the DVB-T2 System in a Single Frequency Network: Analysis of the Distributed Alamouti Scheme." *IEEE International Symposium on Broadband Multimedia Systems and Broadcasting* (2011): 1-4. Print.
3. Castreuil, Anthony, Kevin Pelkmans, Jeroen Doggen, and Kevin Moolenschot. "A Study of MPEG-2-streaming Simulation Methods." *E-LAB Master Theses* (2007): 8. Print.
4. Méry, Dominique, Dominique Cansell, Cyril Proch, Denis Abraham, and Patrick Ditsch. "The Challenge of QoS for Digital Television Services." *EBU Technical Review* (2005): 1-11. Print.
5. *Error-correction, data framing, modulation and emission methods for second generation of digital terrestrial television broadcasting systems*: Recommendation ITU-R BT.1877. Switzerland: ITU, 2010.
6. *Digital Video Broadcasting (DVB); Frame structure channel coding and modulation for a second generation digital terrestrial television broadcasting system (DVB-T2)*: ETSI EN 302 755. – Sophia, France: ETSI, 2009.
7. *Digital Video Broadcasting (DVB); Implementation guidelines for a second generation digital terrestrial television broadcasting system (DVB-T2)*: ETSI TR 102 831. – Sophia, France: ETSI, 2010.
8. Baliar, V.B., and O.V. Gofaizen. "Digital Terrestrial Television Broadcasting Systems of Second Generation: Aspects of Introduction and Contribution of Ukraine in International Standardization." *Zviyazok* № 1/11 (2011): 7-12. Print.
9. Baliar, V.B., and O.V. Gofaizen. "Technical aspects of introduction of second generation terrestrial digital television broadcasting systems in Ukraine on national, regional and local levels". *Digital technologies* № 10 (2011): 63–69. Print.
10. Baliar, V.B., and O.V. Gofaizen. *Proceedings of International Scientific-technical Conference “Technology of Digital Broadcasting: Strategy of Introduction in Ukraine (DBT-2009)*. International Standardization in ITU-R of Second Generation Terrestrial Digital Television Broadcasting System, ONAT N.a. A.S. Popov, Ukraine. Odessa: n.p., 2009. 21-34. Print.
11. Baliar, V.B., and O.V. Gofaizen. "Comparative analysis of digital terrestrial television broadcasting systems in DVB-T/T2 standards". *Digital technologies* № 11 (2012): 31–46. Print.
12. Baliar, V.B. "Performance of DVB-T/DVB-T2 Digital Broadcasting Systems in the Presence of

Quadrature Impairments." *Eastern-European Journal of Enterprise Technologies* № 1/2 (61) (2013): 68-71. Print.

13. Baliar, V.B. "Quality degradation due to quadrature impairments in DVB-T/ DVB-T2 systems." *Digital technologies* № 14 (2013): 81-94. Print.

14. Baliar, V.B. "Impact of phase noise on technical operational quality of DVB-T/ DVB-T2 systems." *Eastern-European Journal of enterprise technologies* № 2/9 (62) (2013): 4-7. Print.

15. Baliar, V.B. "Study of algorithms applied in DVB-T/ DVB-T2 systems at presence of phase noise." *Digital technologies* № 15 (2014): 73-83. Print.

16. Baliar, V.B. "Estimation of technical quality of DVB-T2 system on MPEG-2 TS stream level ." *Measuring and computing devices in technological processes* № 1 (2013): 85-90. Print.

17. Baliar, V.B. "Subjective-statistical estimation of technical quality of DVB-T2 system operation on transport stream level." *Bulletin of national university "KPI . – № 11 (2013): 57-63. Print.*

18. Baliar, V.B. "Estimation of failure performance on level of MPEG video stream for digital television broadcasting system." *Digital technologies* № 10 (2011): 70-78. Print.

19. Baliar, V.B., and O.V. Gofaizen. "Impact analysis of mobile channel impairments on system performance with MPEG compression". *Scientific works of ONAT n.a. A.S. Popov* № 1 (2012): 122-131. Print.

20. Baliar, V.B. *Operation Quality Estimation of End-to-end Path of Digital Television Broadcasting*. Proc. of Proceedings of International Scientific-technical Conference "Technical Aspects of the Quality of Tele-communication Services", Odessa. N.p.: n.p., 2013. 16. Print.

21. Baliar, V.B. "Impairments in MPEG digital streams during technical quality reduction of audiovisual system operation." *Digital technologies* № 15 (2014): 113-120. Print.

22. Baliar, V.B. "Efficiency analysis of operational monitoring of DTV chains on base of objective quality estimation metrics." *Digital technologies* № 12 (2012): 84-95. Print.