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QUALITY DEGRADATION DUE TO QUADARATURE IMPAIRMENTS IN DVB-T/ DVB-T2 SYSTEMS

BALIAR V. B.

Odessa National Academy of Telecommunications n.a. O.S. Popov
SE "Ukrainian scientific-research institute of radio and television"

УХУДШЕНИЕ КАЧЕСТВА РАБОТЫ СИСТЕМ DVB-T/ DVB-T2 ПРИ НАЛИЧИИ КВАДРАТУРНЫХ ИСКАЖЕНИЙ

БАЛЯР В. Б.

Одесская национальная академия связи им. А. С. Попова
ГП "Украинский научно-исследовательский институт радио и телевидения "

Abstract. *In article study results in direction of quality degradation estimation during DVB-T/ DVB-T2 operation due to quadrature impairments with usage of parameters defined in DSTU ETSI TR 101 290. Obtained estimations will be used as basis during formulation of proposition on corresponding technical norms on such radio-frequency impairments.*

Аннотация. *В статье приведены результаты исследований в направлении оценки ухудшения качества работы систем DVB-T/ DVB-T2 при наличии квадратурных искажений с использованием параметров, определенных в стандарты ГСТУ ETSI TR 101 290. Полученные оценки будут использованы в качестве основания во время формулирования предложений по соответствующим техническим нормам на этот вид радиочастотных искажений.*

INTRODUCTION

Issue on provision of technical operation quality is very important during introduction of digital terrestrial television broadcasting (DTTB). Technical operation quality is complex concept comprising by technical quality of compression, transmission and so on. So provision of technical operation quality is quite complex task that arising before administrations during introduction of digital television broadcasting. Successful solving of this task is possible only with availability of maintenance experience. Simplified approach to solving task of provision of technical operation quality can lead to high "sensitivity" of DTTB service to set of outer factors (e.g., dependence from receiving conditions, receiving locations and so on) and decreasing of attractiveness of transition to digital television broadcasting. In such conditions effective and operative monitoring of technical operation quality is required.

Despite the fact that the DTTB systems have been standardized and implemented in many countries, in most cases their characteristics were normalized for channel with AWGN. However, other types of distortions such as quadrature impairments are not normalized. Presence of such impairments results in significant degradation of digital television broadcasting system characteristics, so it is important to determine the acceptable levels of quadrature impairments, considering the features and characteristics of DTTB systems. Taking in account transition urgency the information on parameters controlled during technical maintenance and corresponding quantitative and qualitative estimations are required.

IMPACT OF QUADRATURE IMPAIRMENTS ON DVB-T AND DVB-T2 SYSTEM PERFORMANCE

Estimation of impact of quadrature impairments on DTTB system performance is performed for DVB-T and DVB-T2 systems [1…5].

For estimation test set-up recommended in ETSI TR 101 290 [6] with some modification is used (see Fig. 1). This set-up meets the case when the measurement was carried out for "out-of-service" mode. In this set-up DVB-T and DVB-T2 transmitters and receivers are referred as DVB transmitter and receiver but measurement was conducted separately for each of the standards. Analysis of the impairment impact was conducted separately for each type of impairments defined above. Results of the studies are presented on Fig. 2−15.

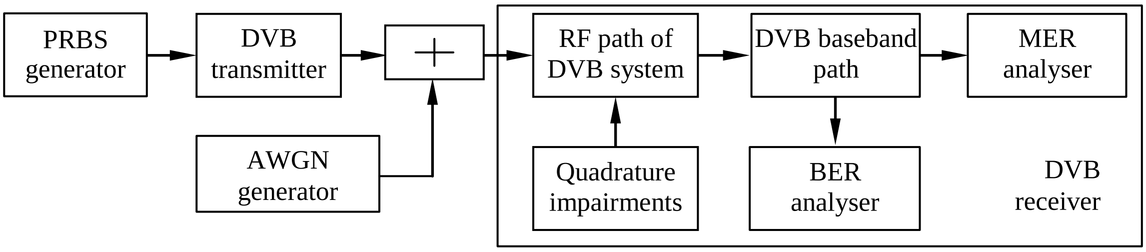


Figure 1 - Test set-up for estimation of impact of quadrature impairments on DVB-T and DVB-T2 performance

Study of the impact of quadrature impairments on the end-to-end path performance of DVB-T and DVB-T2 systems is carried out for four cases that meet the following conditions:

– impact of quadrature impairments of I/Q-signals with only amplitude imbalance at high signal-to-noise ratio (denote such impairment as AI);

– impact of quadrature impairments of I/Q-signals with only amplitude imbalance at signal-to-noise ratio that is higher on 3 dB than the threshold value (denote such impairment as AI + AWGN);

– impact of quadrature impairments of I/Q-signals with only phase error at high signal-to-noise ratio (denote such impairment as PE);

– impact of quadrature impairments of I/Q-signals with only phase error at signal-to-noise ratio that is higher on 3 dB than the threshold value (denote such impairment as PE + AWGN).

For estimation of permissible impairment level of each type it will be used the parameter Δ characterizing the difference between the threshold impairment levels in DVB-T and DVB-T2 at which systems will operate in a QEF mode. This parameter is quite useful for performance comparison of both systems at presence of different impairments. Taking into account the “nature” of BER performance that is characterized by “quasi-vertical” decrease of uncorrected errors in DVB-T2 system the comparison of both systems is possible.

During the analysis of quadrature impairments we will analyze such variants of parameter Δ [7,8]:

1) for case of amplitude imbalance in I/Q-signals:

$$\Delta_{AI} = AI_{T2th} - AI_{Tth} , \quad (1)$$

where

Δ_{AI} is difference between AI threshold values in DVB-T and DVB-T2 systems;

AI_{T2th} is AI threshold value in DVB-T2 system;

AI_{Tth} is AI threshold value in DVB-T2 system.

2) for case of phase error in I/Q-signals:

$$\Delta_{PE} = PE_{T2th} - PE_{Tth} , \quad (2)$$

where

Δ_{PE} is difference between PE threshold values in DVB-T and DVB-T2 systems;

PE_{T2th} is PE threshold value in DVB-T2 system;

PE_{Tth} is PE threshold value in DVB-T2 system.

Negative values Δ_{AI} and Δ_{PE} indicate that the threshold value in the DVB-T2 is less than corresponding value in the DVB-T.

Estimation will be carried out for two configurations:

– DVB-T and DVB-T2 configurations with the equivalent spectral efficiency (16-QAM is used in both cases) and inner code rates (1/2, 2/3 and 5/6);

– DVB-T and DVB-T2 configurations for different spectral efficiency (64-QAM and 256-QAM respectively) and equivalent inner code rate (1/2, 2/3 and 5/6).

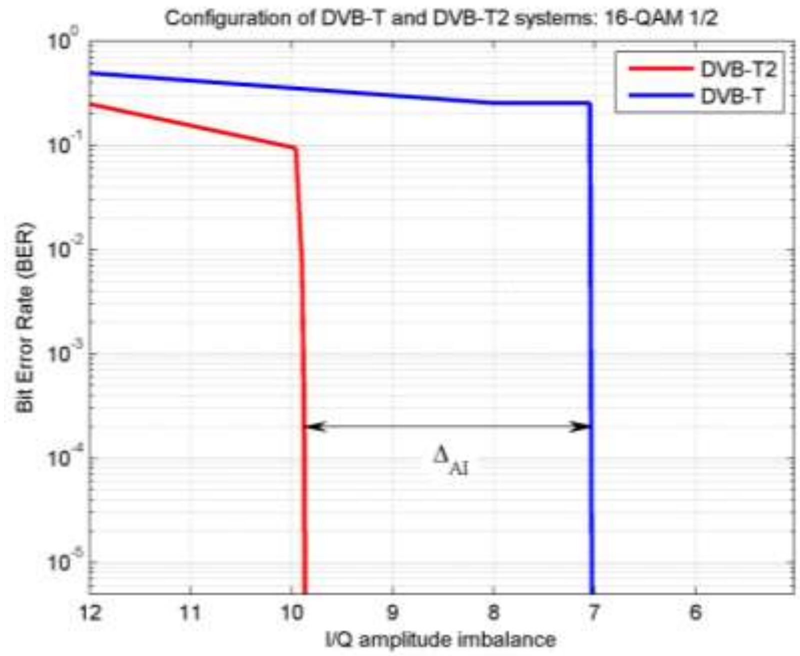


Figure 2 - Dependence of BER at the output of inner channel decoder from I/ Q amplitude imbalance value for 16-QAM 1/2 configuration of DVB-T and DVB-T2 systems

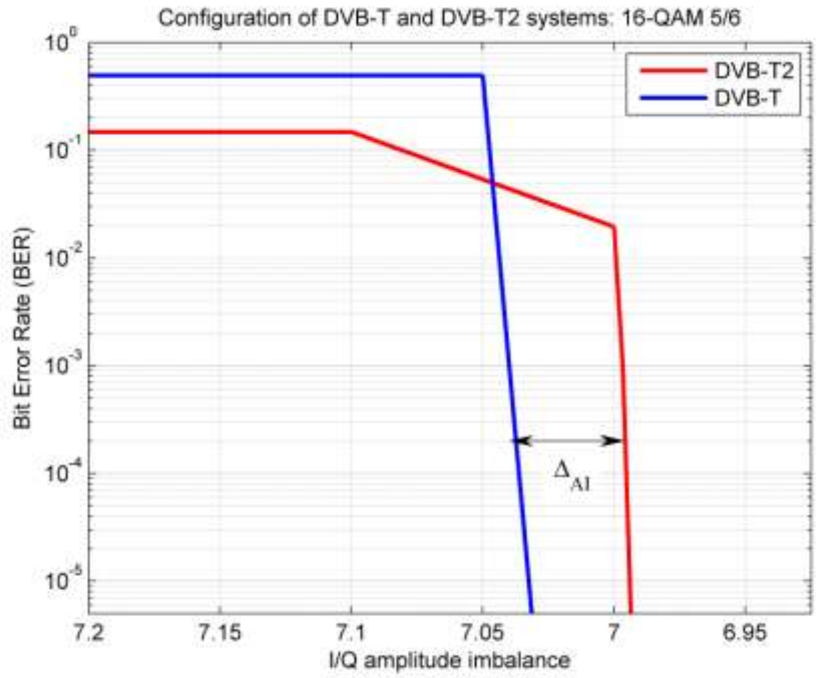


Figure 3 - Dependence of BER at the output of inner channel decoder from I/ Q amplitude imbalance value for 16-QAM 5/6 configuration in DVB-T and DVB-T2 systems

Fig. 2…3 are demonstrating that in DVB-T2 system with 16-QAM greater amplitude imbalance level than in the DVB-T system is permissible. This can be explained by using more powerful corrective coding techniques (LDPC and BCH codes), as well as using multiple stages of interleaving and, in particular, permutation of in-phase and quadrature component of the M-QAM signal. All of this together when applying

16-QAM provides gain on threshold level of amplitude imbalance from 0.83 dB to 2.82 dB, depending on inner code rate (see table 5).

Results for 64-QAM (DVB-T) and 256-QAM (DVB-T2) configurations are presented in table 5. In this case the Δ_{AI} value for inner code rate 1/2 is equal to 0.25. With increasing inner code rate this value is negative and reaches -1.8 dB. This can be explained by the fact that LDPC/ BCH correcting capability with 256-QAM is not enough to correct all errors arising at presence of I/ Q amplitude imbalance. However by increasing the signal-to- noise ratio (SNR) in the channel will allow to obtain gain with this configuration in terms of spectral efficiency is about 4 times compared with the DVB-T configuration (64-QAM 5/6). When using the DVB-T2 system configuration corresponding to 256-QAM 1/2 increase of the SNR is not essential - acceptable impairment levels are approximately the same (the difference is 0.25 dB) [7,8].

Modulation Error Rate (MER) is parameter that additionally used to describe impairments that result in change of signal constellation. Results of MER estimation at presence of I/Q amplitude imbalance are provided on Fig. 4,5. BER corresponding to QEF mode is marked by black dotted line.

Threshold value of MER can be determined by analyzing BER. Result of determining threshold values for MER in DVB-T and DVB-T2 systems is given in tables 1 and 2 respectively.

Dependence of the BER after inner channel decoder from I/ Q amplitude imbalance in channel with AWGN for different configurations of DVB-T and DVB-T2 systems is given on Fig. 6, 7. Dependencies are obtained with noise level that exceeds threshold on 3 dB in the AWGN channel [7, 8].

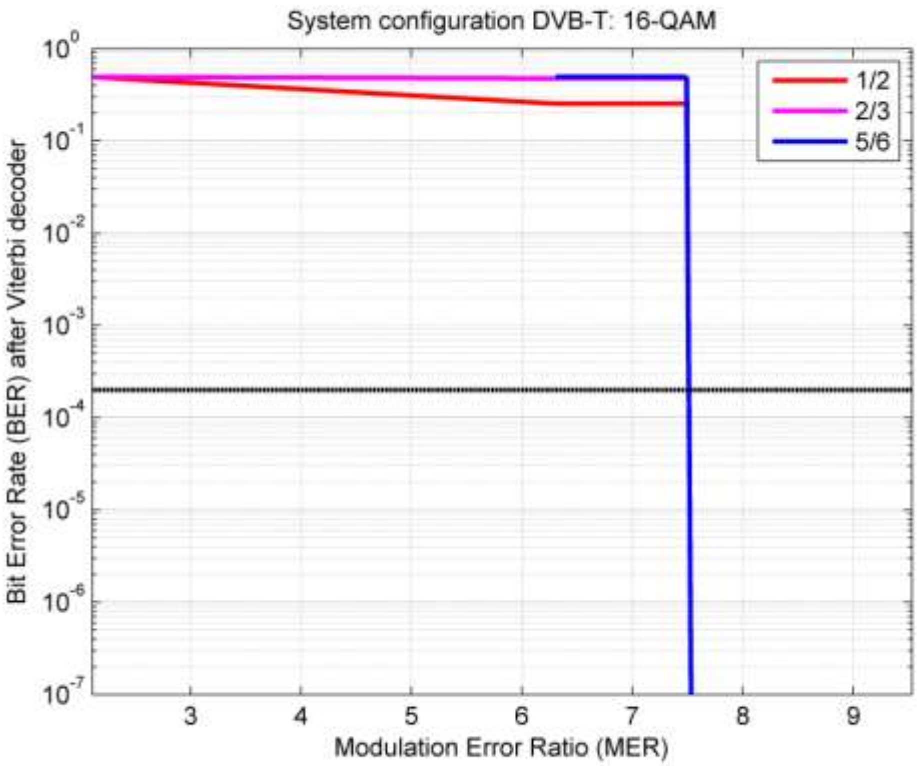


Figure 4 - Dependence of BER after Viterbi decoder on MER for 16-QAM configuration in the DVB-T system at presence of I/ Q amplitude imbalance

Table 1 - Result of determination of raw threshold values for MER in DVB-T system at $\mathbf{BER \approx 2 \times 10^{-4}}$ (QEF) at presence of I/ Q amplitude imbalance

Parameter	Value		
Code rate	1/2	2/3	5/6
MER, dB (16-QAM)	7.49		
MER, dB (64-QAM)	14.75	16.2	

The nature of dependence differs from previous cases where the noise level is low. This can be explained by fact that at presence of quadrature impairments additive white Gaussian noise is to some extent a positive factor that ensures diversity of signal constellation points so that they fall to valid decision boundary boxes in the demodulator or close to it.

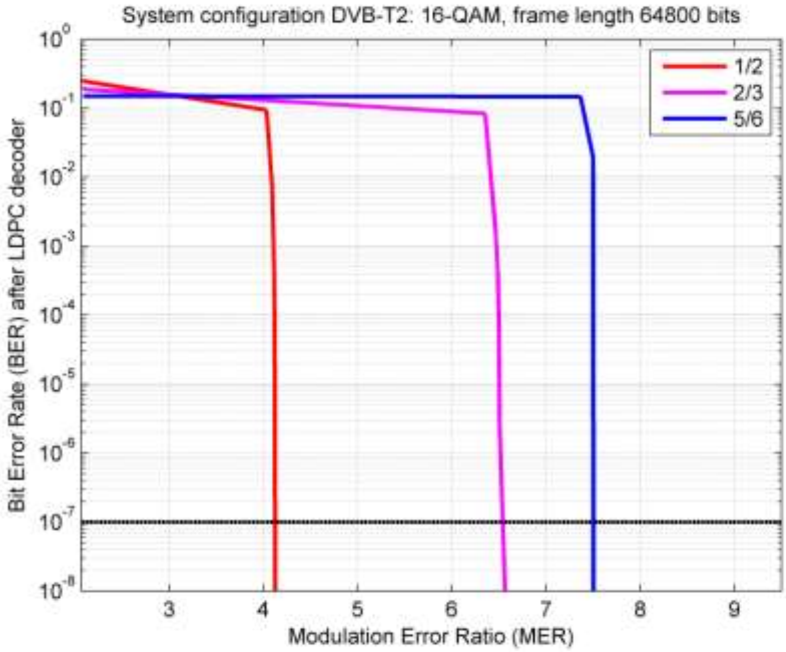


Figure 5 - Dependence of BER after LDPC decoder on MER for 16-QAM configuration in the DVB-T2 system at presence of I/ Q amplitude imbalance

Table 2 - Result of determination of raw threshold values for MER in DVB-T2 system at $\mathbf{BER \approx 1 \times 10^{-7}}$ (QEF) at presence of I/ Q amplitude imbalance

Parameter	Value		
Code rate	1/2	2/3	5/6
MER, dB (16-QAM)	4.033	6.354	7.5
MER, dB (256-QAM)	13.56	17.15	21.2

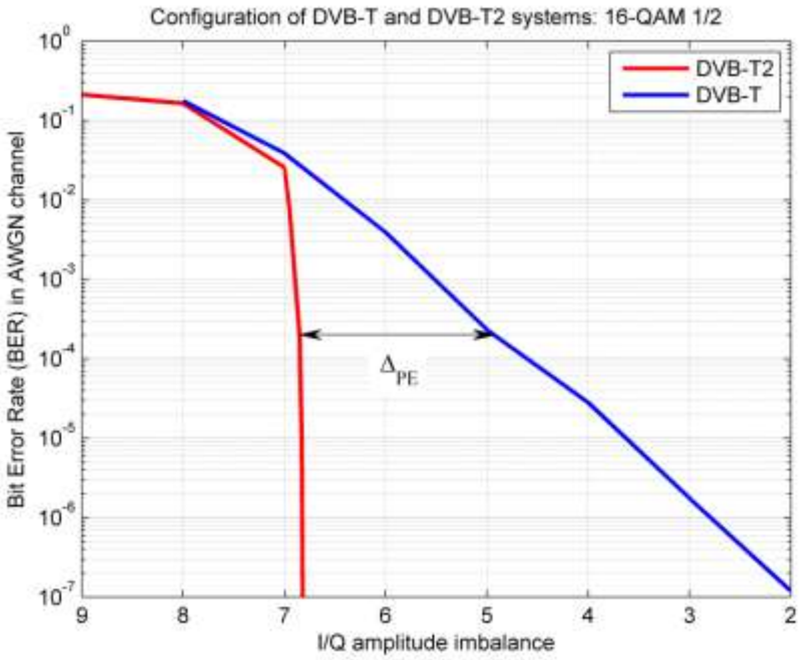


Figure 6 - Dependence of the BER after inner channel decoder on I/ Q amplitude imbalance value in the AWGN channel for 16-QAM 1/2 configuration in DVB-T and DVB-T2 systems

The above is demonstrated on Figures 5. In contrast then the level of AWGN is negligible, difference between the threshold values of AI + AWGN impairment at 16-QAM with different code rates in DVB-T and DVB-T2 systems is changed in range from 0.72 to 1.82 dB.

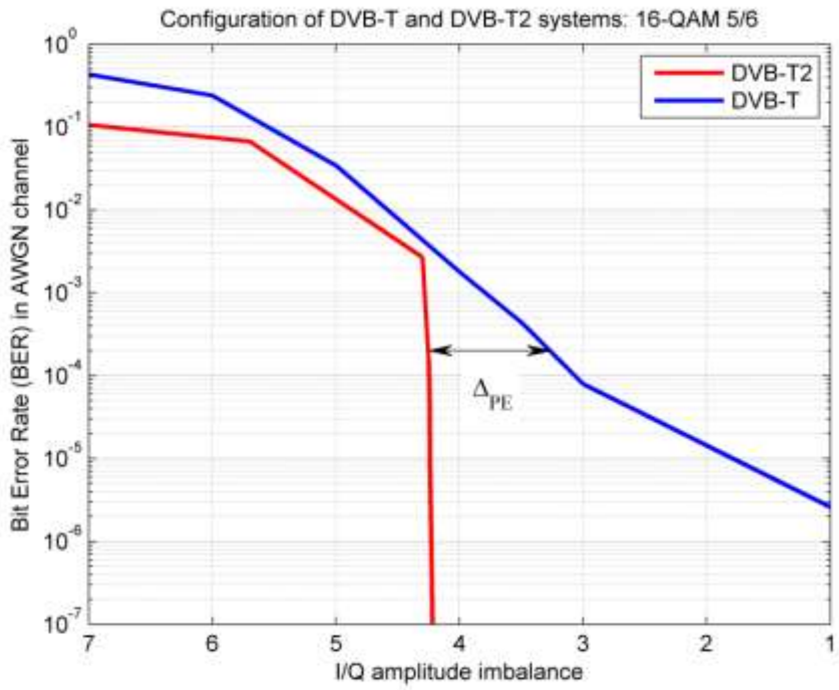


Figure 7 - Dependence of the BER after inner channel decoder on I/ Q amplitude imbalance value in the AWGN channel for 16-QAM 5/6 configuration in DVB-T and DVB-T2 systems

With such a difference with a small increase of DVB-T2 system signal strength required level of noise immunity is provided even at the presence of quadrature impairments.

Dependence of the BER after inner decoder for different configurations of DVB-T and DVB-T2 systems at presence of I/ Q phase error is given on Fig. 8…9.

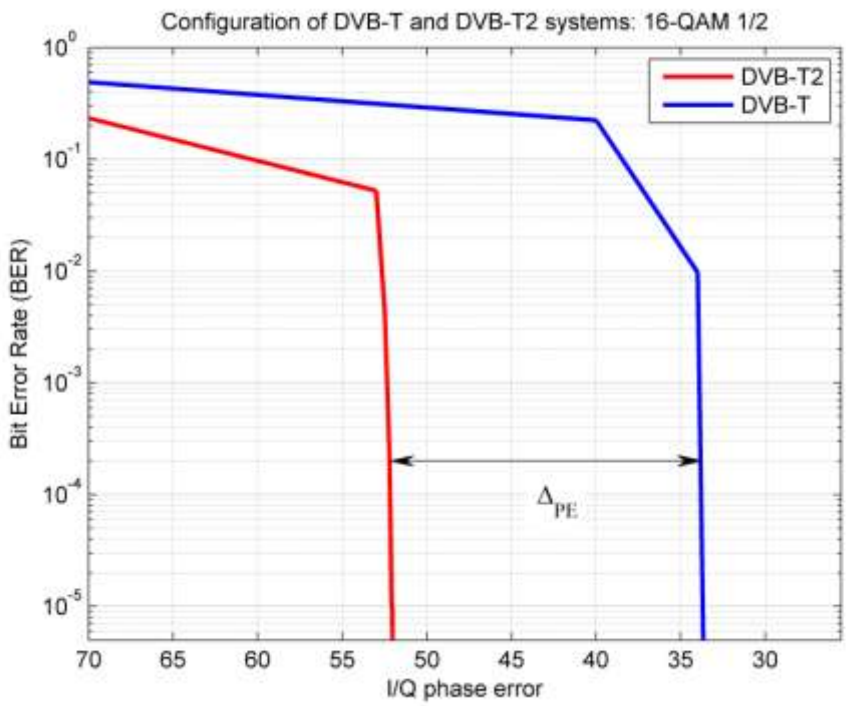


Figure 8 - Dependence of the BER after inner channel decoder from I/ Q phase error value for 16-QAM 1/2 configuration in DVB-T and DVB-T2 systems

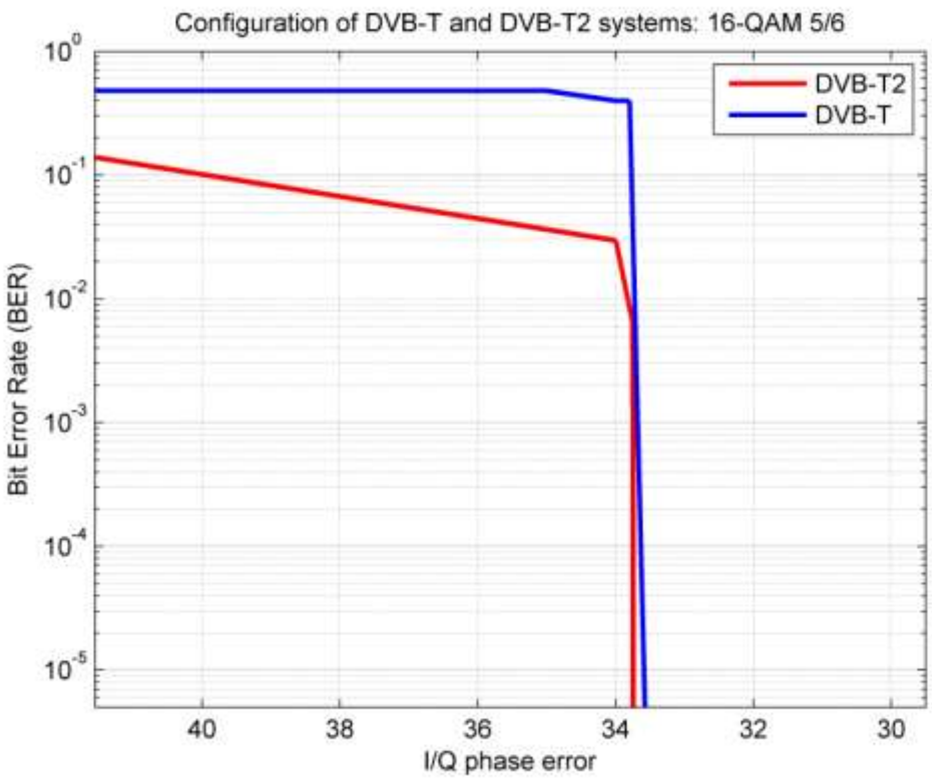


Figure 9 - Dependence of the BER after inner channel decoder from I/ Q phase error value for 16-QAM 5/6 configuration in DVB-T and DVB-T2 systems

Difference between the PE impairment threshold values is from -0.25^0 to 16^0 for the case of 16-QAM and from -5.94^0 to 5.25^0 for the case of 64-QAM (DVB-T) and 256-QAM (DVB-T2). Thus with negligible level of AWGN a situation is similar to the case of I/ Q amplitude imbalance.

Dependence of the BER after inner channel decoder on modulation error ratio (MER) at presence of I/ Q phase errors for different configurations of DVB-T and DVB-T2 systems is given on Fig. 10-11. Result of determination of threshold values for MER in DVB-T and DVB-T2 systems is given in Tables 3 and 4 respectively [7, 8].

Table 3 - Result of determination of Raw threshold values of MER at $\mathbf{BER \approx 2 \times 10^{-4}}$ (QEF) at presence of I/ Q phase error in DVB-T system

Parameter	Value		
Code rate	1/2	2/3	5/6
MER, dB (16-QAM)	10.71		
MER, dB (64-QAM)	17.48		

Table 4 - Result of determination of Raw threshold values of MER at $\mathbf{BER \approx 1 \times 10^{-7}}$ (QEF) at presence of I/ Q phase error in DVB-T2 system

Parameter	Value		
Code rate	1/2	2/3	5/6
MER, dB (16-QAM)	6.91	8.838	10.66
MER, dB (256-QAM)	14.84	17.99	21.66

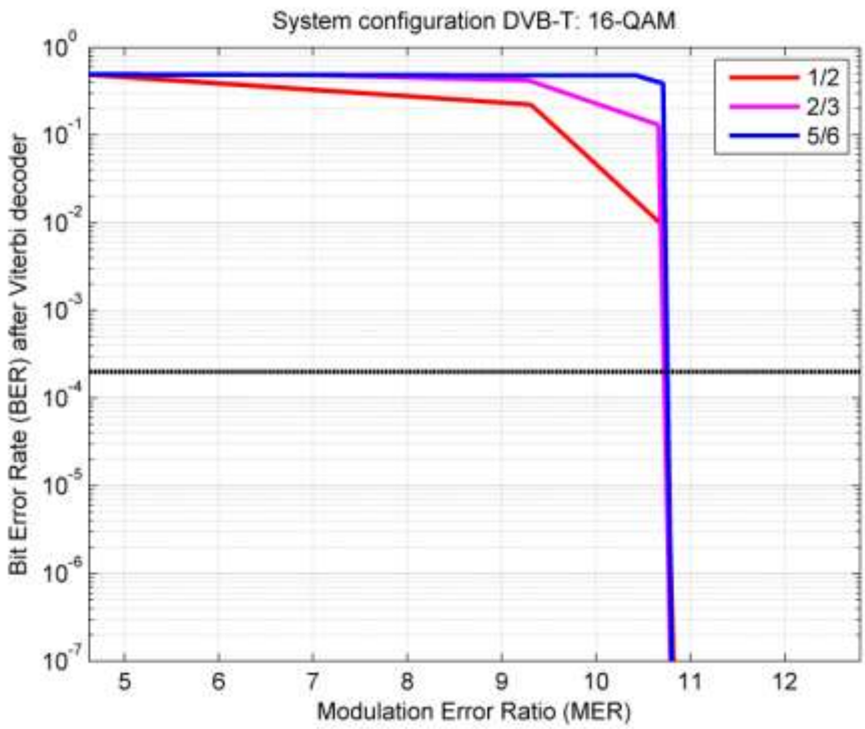


Figure 10 - Dependence of BER after Viterbi decoder on MER for 16-QAM configuration in the DVB-T system at presence of I/ Q phase error

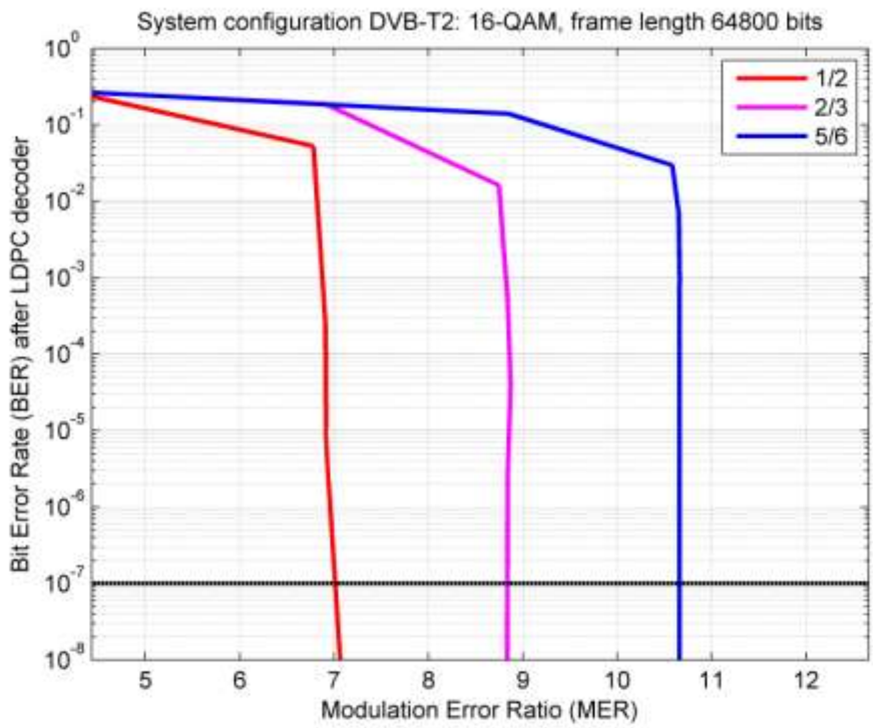


Figure 11 - Dependence of BER after LDPC decoder on MER for 16-QAM configuration in the DVB-T2 system at presence of I/ Q phase error

Dependence of the BER after inner channel decoder from I/ Q phase error in AWGN channel for 16-QAM and different inner code rates in DVB-T and DVB-T2 systems, is given on table 1. Analysis of the difference between PE + AWGN impairment threshold values for this case shows that difference value is changed in range 7.2^0 to 13.2^0. In other case this difference is -0.82^0 to 1.15^0.

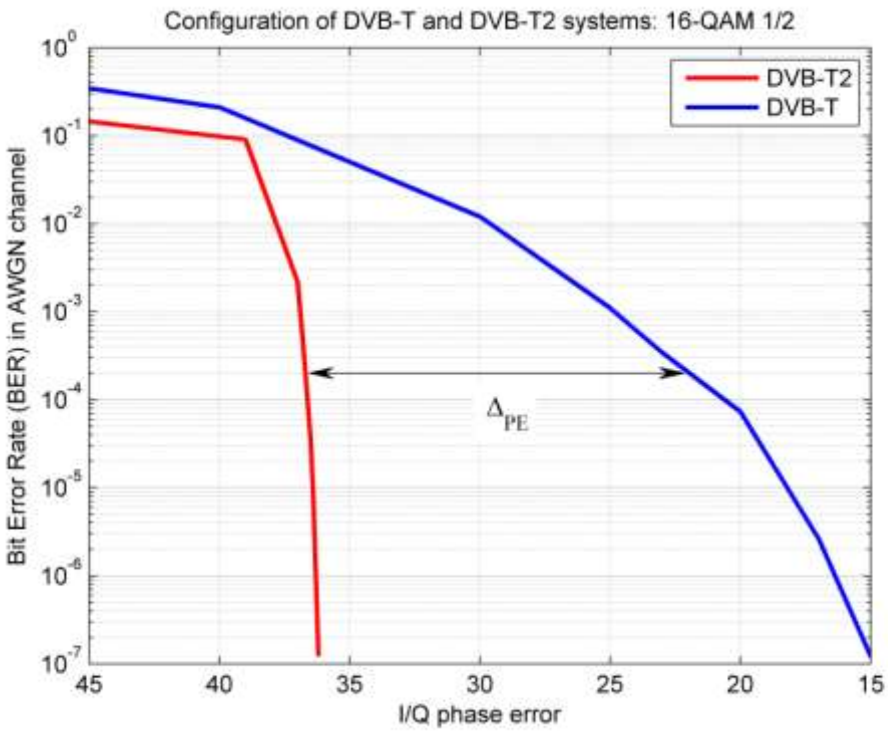


Figure 12 - Dependence of BER at the output of inner channel decoder from I/ Q phase error in AWGN channel for 16-QAM 1/2 configuration in DVB-T and DVB-T2

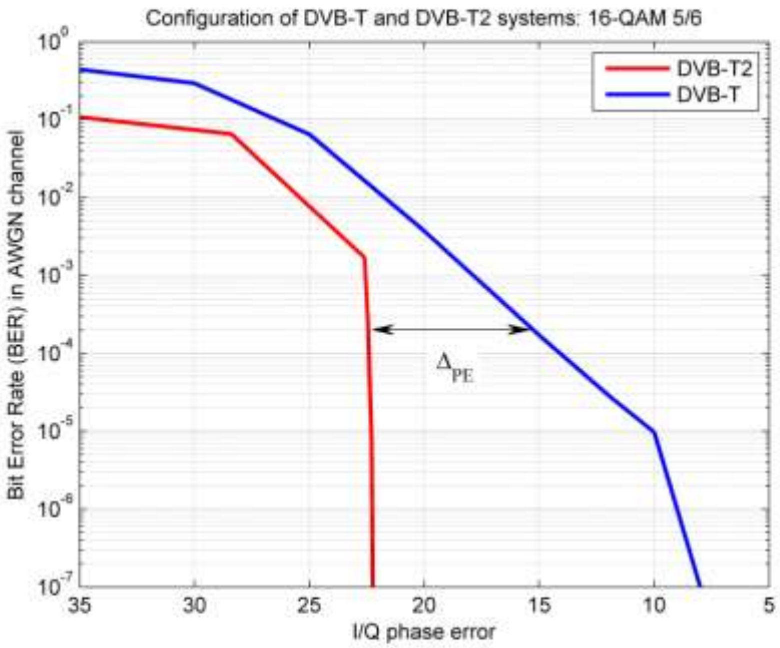


Figure 13 - Dependence of BER at the output of inner channel decoder from I/ Q phase error in AWGN channel for 16-QAM 5/6 configuration in DVB-T and DVB-T2

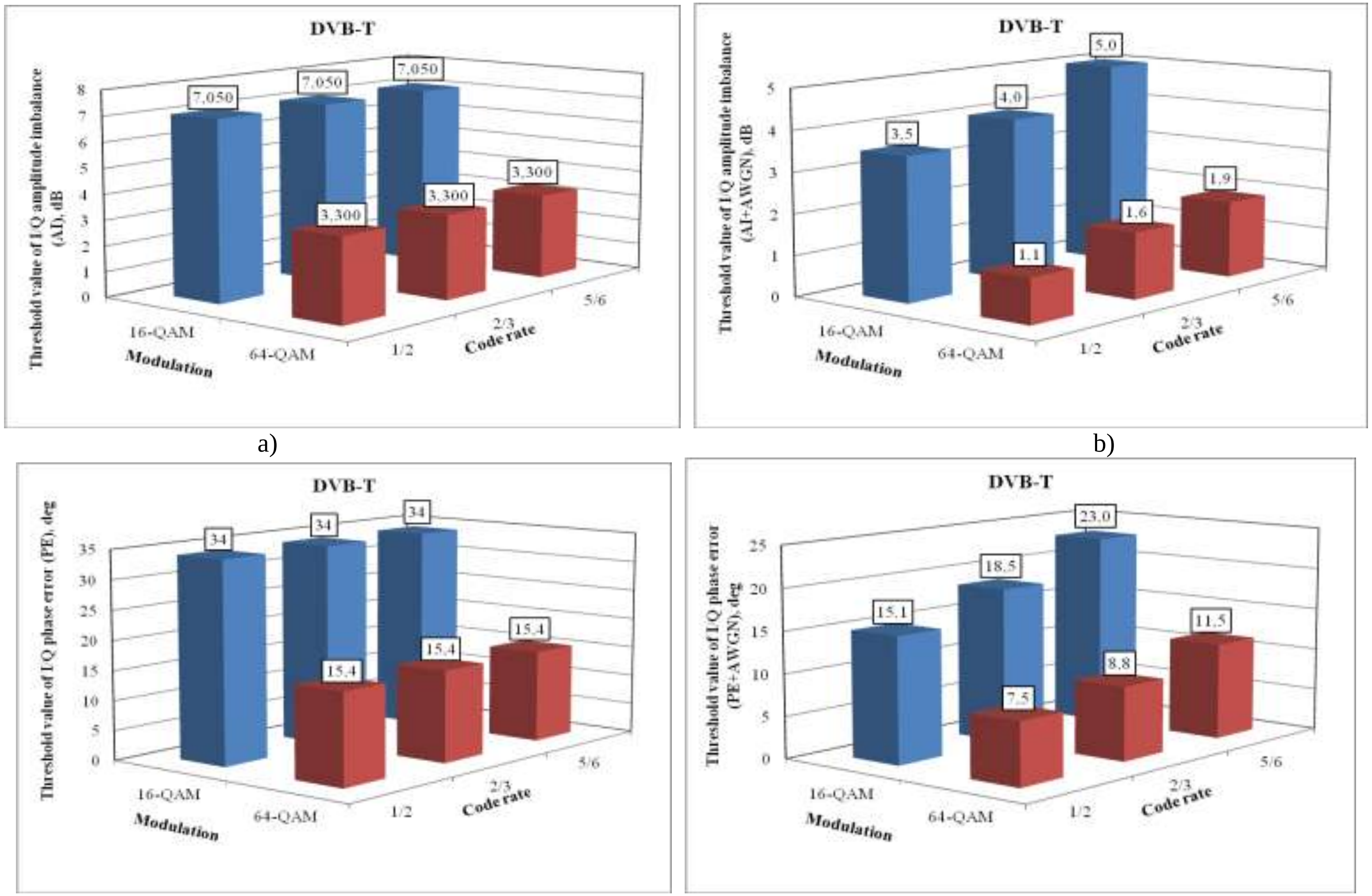
Based on the analysis of figures and also on a previous results it was formed the tables 5, 6 containing threshold values of quadrature impairments under two conditions - small level of AWGN and AWGN level which is higher on 3 dB than the permissible level.

Analysis results of Table 5 regarding impairment acceptable level dependence from modulation method and inner code rate are presented on Fig. 14…15. These figures show that acceptable levels of each type of impairments in the DVB-T practically does not depend on inner code rate and increased approximately twice during transition from 16-QAM and 64-QAM.

Table 5 - Raw threshold levels of impairments for 16-QAM in DVB-T and DVB-T2 systems

Parameter	Value		
Code rate	1/2	2/3	5/6
AI and PE impairments			
AI_{Tth} , dB	7.05		
AI_{T2th} , dB	9.87	7.7	6.997
Δ_{AI} , dB	2.82	0.65	-0.053
MER (DVB-T), dB	7.49		
MER (DVB-T2), dB	4.033	6.354	7.5
PE_{Tth} , ^{0}	34		
PE_{T2th} , ^{0}	50	41.54	33.75
Δ_{PE} , ^{0}	16	7.54	-0.25
MER (DVB-T), dB	10.71		
MER (DVB-T2), dB	6.91	8.838	10.66
AI+AWGN and PE+AWGN impairments			
AI_{Tth} , dB	5	4	3.5
AI_{T2th} , dB	6.82	5.7	4.22
Δ_{AI} , dB	1.82	1.7	0.72
PE_{Tth} , ^{0}	23	18.5	15.05
PE_{T2th} , ^{0}	36.2	28.3	22.25
Δ_{PE} , ^{0}	13.2	9.8	7.2

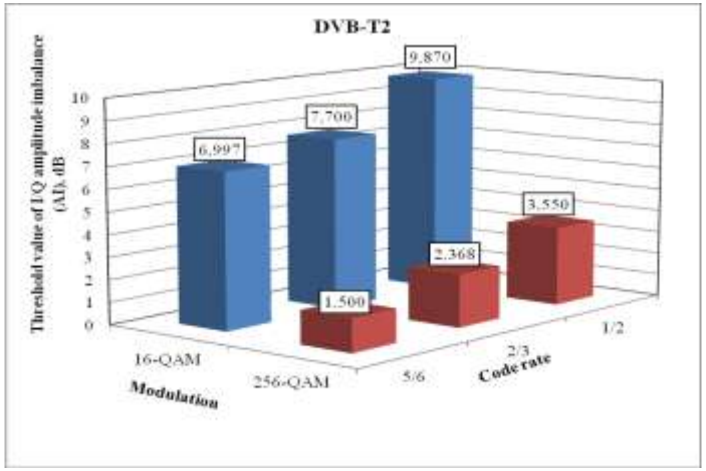
Acceptable impairment level in the DVB-T2 system depends on chosen inner code rate and modulation method. Thus, with increasing inner code rate acceptable impairment value is reduced by approximately 1.5 times, while when changing modulation method (from 16-QAM to 256-QAM) at a fixed inner code rate acceptable impairment level is reduced by the value of 2,5 to 5.5 times [7, 8].



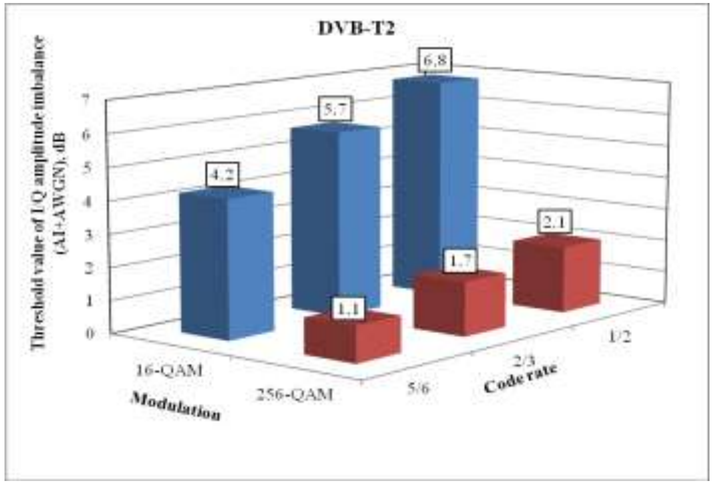
a) b) c) d)

Figure 14 - Dependence of acceptable levels of I/ Q quadrature impairments from modulation method, inner code rate and receiving conditions in DVB-T system

a) AI b) AI + AWGN c) PE d) PE+ AWGN



a)



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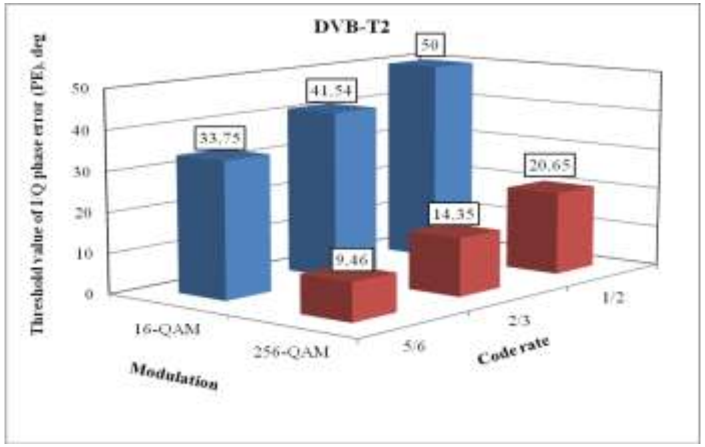

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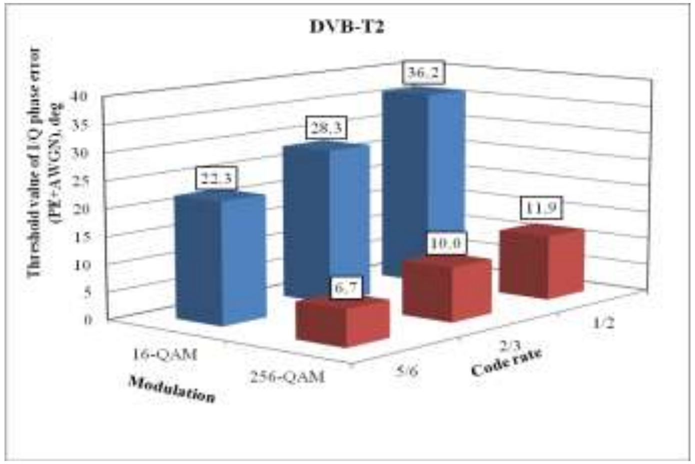

d)

Figure 15 - Dependence of acceptable threshold levels of I/ Q quadrature impairments from modulation method, inner code rate and receiving conditions in DVB-T2 system:

a) AI b) AI + AWGN c) PE d) PE+ AWGN

Table 6 - Raw threshold levels of impairments in DVB-T (64-QAM) and DVB-T2 (256-QAM) systems

Parameter	Value		
Code rate	1/2	2/3	5/6
AI and PE impairments			
AI_{Tth} , dB	3.3		
AI_{T2th} , dB	3.55	2.368	1.5
Δ_{AI} , dB	0.25	-0.93	-1.8
MER (DVB-T), dB	14.75	16.2	
MER (DVB-T2), dB	13.56	17.15	21.2
PE_{Tth} , ^{0}	15.4		
PE_{T2th} , ^{0}	20.65	14.35	9.46
Δ_{PE} , ^{0}	5.25	-1.05	-5.94
MER (DVB-T), dB	17.48		
MER (DVB-T2), dB	14.84	17.99	21.66
AI+AWGN and PE+AWGN impairments			
AI_{Tth} , dB	1.87	1.62	1.1
AI_{T2th} , dB	2.05	1.65	1.094
Δ_{AI} , dB	0.18	0.03	-0.006
PE_{Tth} , ^{0}	11.5	8.8	7.5
PE_{T2th} , ^{0}	11.9	9.95	6.68
Δ_{PE} , ^{0}	0.4	1.15	-0.82

CONCLUSIONS

Based on the analysis results of the obtained dependencies the tables with quantitative estimations are got and that came forward as basis for propositions for technical norms on the permissible 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 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. 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.

In DVB-T2 system permissible level of impairments depends on used code rate and modulation method at the insignificant AWGN level and for its 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. 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.

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