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EFFICIENCY STUDY OF ALGORITHMS APPLIED IN DVB-T/ DVB-T2 SYSTEMS AT PRESENCE OF PHASE NOISE

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ИССЛЕДОВАНИЕ ЭФФЕКТИВНОСТИ АЛГОРИТМОВ, ИСПОЛЬЗОВАНЫХ В СИСТЕМАХ DVB-T/ DVB-T2, ПРИ НАЛИЧИИ ФАЗОВОГО ШУМА

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Abstract. *In article study results in direction of efficiency estimation of algorithms used in DVB-T/ DVB-T2 systems at presence of phase noise with parameters defined in DSTU ETSI TR 101 290. Obtained estimations will be used as basis during formulation of proposition on corresponding technical norms on permissible phase noise level.*

Аннотация. *В статье приведены результаты оценки эффективности алгоритмов, используемых в системах DVB-T/ DVB-T2, при наличии фазового шума 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 допустимый уровень фазового шума.*

INTRODUCTION

Issue on provision of technical operation quality is very important during introduction of digital terrestrial television broadcasting. 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 phase noise 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 PHASE NOISE ON PERFORMANCE OF DVB-T AND DVB-T2 SYSTEMS

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

Estimation will be carried out for two configurations [7]:

– 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).

For estimation the test set-up (see figure 1) recommended in ETSI TR 101 290 [6] was used with some modification for taking into account the implementation specifics.

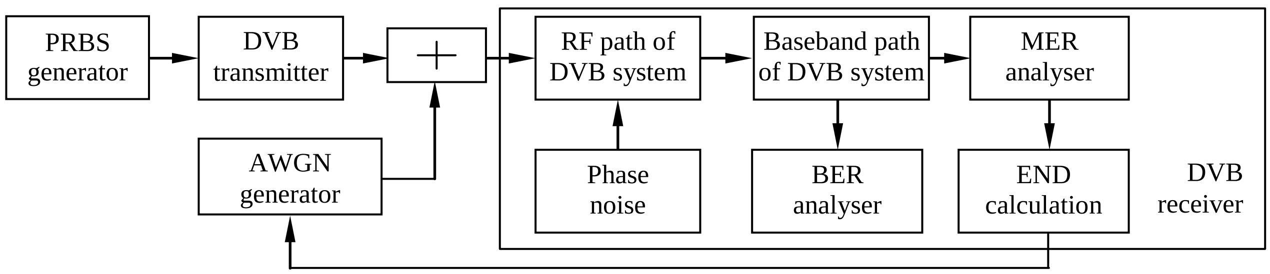

Figure 1 - Test set-up for estimation of phase noise impact on DVB-T and DVB-T2 system performance

The test set-up corresponds to the case of measurement in "out of service" mode. For this set-up a DVB transmitter and a receiver mean the DVB-T or DVB-T2 transmitter and the receiver considering the fact that the measurement was held separately for each of the standards.

In OFDM systems the phase noise can cause Common Phase Error (CPE) which affects all carriers simultaneously. It can be minimized or corrected by using the continual pilots. However the Inter-Carrier Interference (ICI) which is noise-like cannot be corrected.

Phase noise power density is normally expressed in dBc/Hz at certain frequency offset from the local oscillator frequency. There is the recommendation of ETSI TR 101 290 [6] to specify a spectrum mask with at least three points (frequency offsets and levels). Such spectrum mask is shown in figure 2. Frequency off-sets f_a, f_b, f_c are given in table 1.

Table 1 - Frequency offsets for 2*k* and 8*k* systems

Mode	f_a, kHz	f_b, kHz	f_c, kHz
2*k*	4.464	8.928	12.392
8*k*	1.116	2.232	3.348

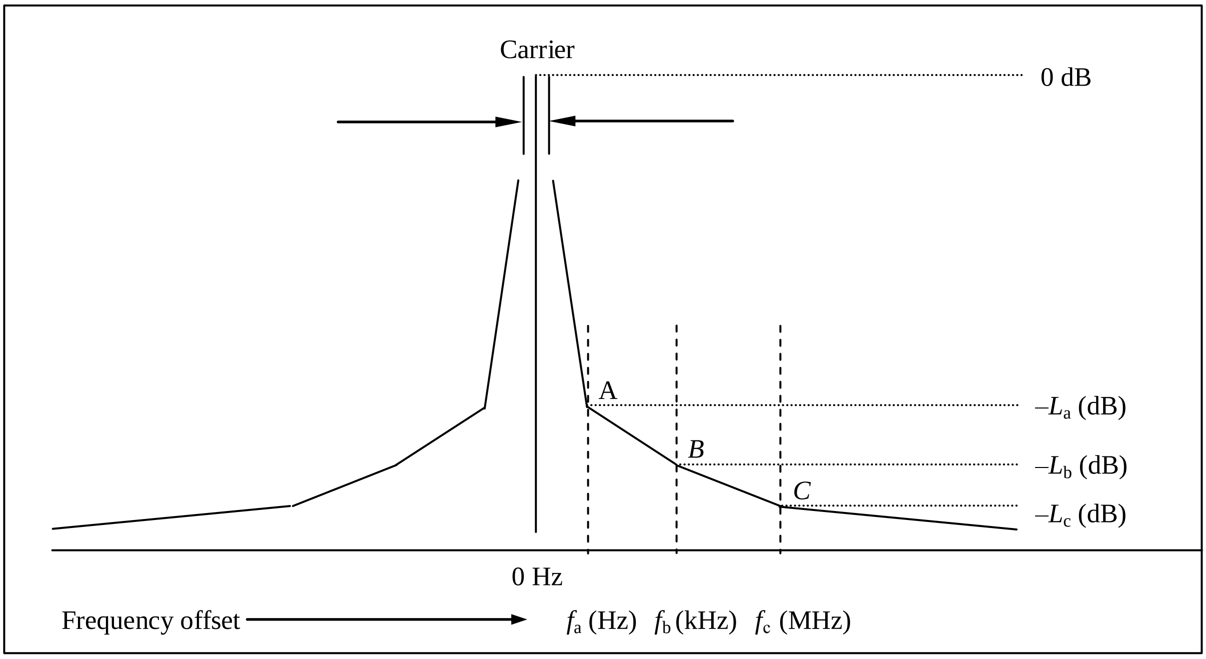

Figure 2 - Spectrum mask for CPE measurement

As well as in the case of quadrature impairments during the tests such two cases were analyzed:

– phase noise impact on technical operation quality for very small AWGN level;

– phase noise impact on technical operation quality for SNR that is on 3 dB higher than threshold value in AWGN channel.

As a result of studies have been obtained dependences (figures 3-18) [8].

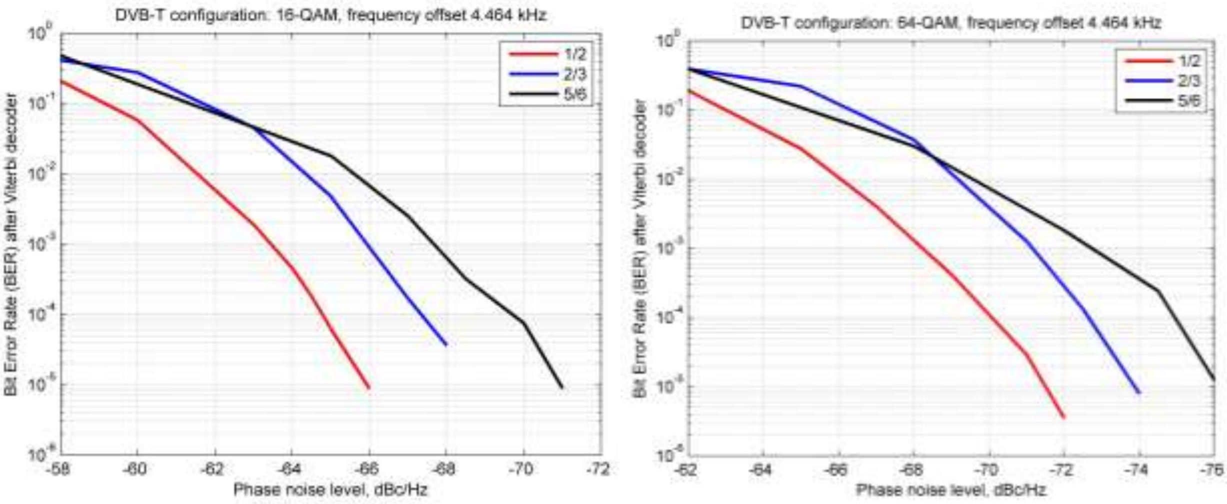

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Figure 3 - Dependence of BER after Viterbi decoder from phase noise level in DVB-T system for 16-QAM (a) and 64-QAM (b) modulations and 4.464 kHz frequency offset

From figures 3-4 it's obvious that phase noise in DVB-T system causes performance degradation at lower levels of noise than in DVB-T2 system. It allows reducing to some extent the requirements for acceptable values of phase noise for the second generation digital terrestrial television broadcasting system (DVB-T2) [8].

On the basis of relations represented in figures 3-4 it's possible to determine phase noise threshold value for DVB-T and DVB-T2 systems to operate in quasi error-free (QEF) mode. In this mode BER after Viterbi decoder will correspond $\mathrm{BER} \approx 2 \cdot 10^{-4}$ for DVB-T system and $\mathrm{BER} \approx 1 \cdot 10^{-7}$ after LDPC decoder for DVB-T2 system.

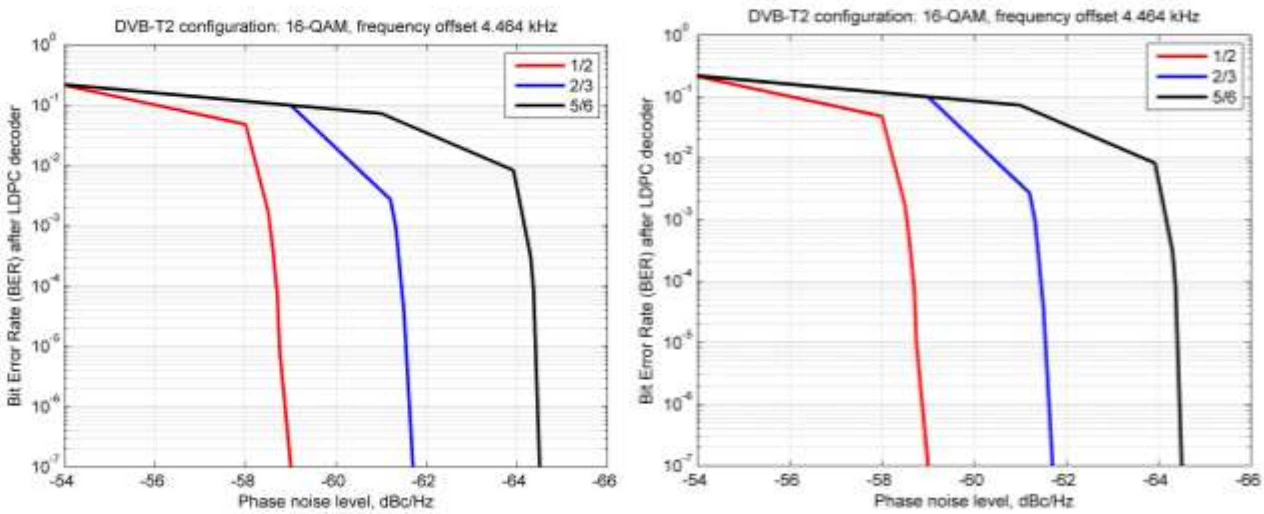

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Figure 4 - Dependence of BER after LDPC decoder from phase noise level in DVB-T2 system for 16-QAM (a) and 256-QAM (b) modulations and 4.464 kHz frequency offset

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. Threshold values at different frequency offsets from central carrier are given in tables 2-3 and in figures 5-6.

Gain in terms of acceptable phase noise level provided with DVB-T2 system corresponds to the value about 4 to 5.75 dBc/Hz for 16-QAM modulation.

From tables 2-3 it's obvious that higher phase noise level is acceptable for DVB-T2 system. At lower error protection and higher information bit-rate (configuration DVB-T2: 16-QAM 5/6) phase noise level corresponding to DVB-T configuration (16-QAM 1/2) is acceptable.

Table 2 - Threshold values of phase noise for 16-QAM in DVB-T and DVB-T2 systems

System	Code rate	Threshold value for phase noise, dBc/Hz		
Frequency offset, kHz		4.464	8.928	12.392
DVB-T	1/2	-61	-64.5	-66
	2/3	-64	-67	-69
	5/6	-67	-70	-72
Frequency offset, kHz		4.464	8.928	12.392
DVB-T2	1/2	-57	-58.9	-60.9
	2/3	-59	-61.6	-63.4
	5/6	-61.5	-64.5	-66.25

Table 3 - Threshold levels of phase noise for 64-QAM (DVB-T) and 256-QAM (DVB-T2) modulations

System	**Code rate**	**Threshold value for phase noise, dBc/Hz**		
Frequency offset, kHz		4.464	8.928	12.392
DVB-T (64-QAM)	1/2	-67	-69	-72
	2/3	-69	-72.5	-74
	5/6	-73	-76	-78
Frequency offset, kHz		4.464	8.928	12.392
DVB-T2 (256-QAM)	1/2	-64	-66.5	-68.1
	2/3	-67.5	-70.4	-72.2
	5/6	-72	-74.65	-76.5

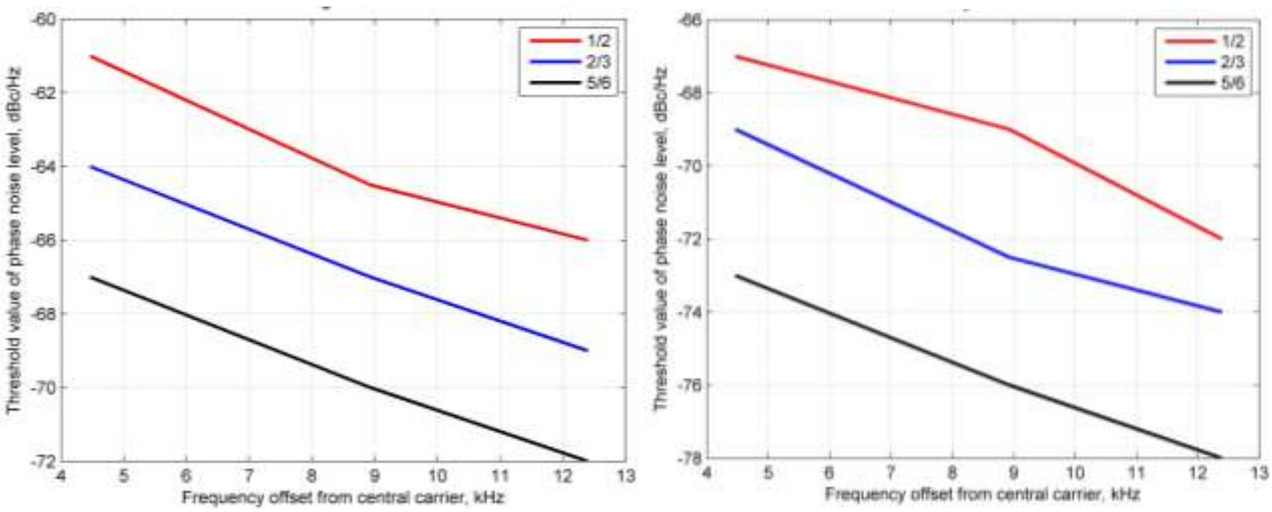

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Figure 5 - Dependence of threshold level of phase noise from frequency offset
for 16-QAM (a) and 64-QAM (b) modulations in DVB-T system

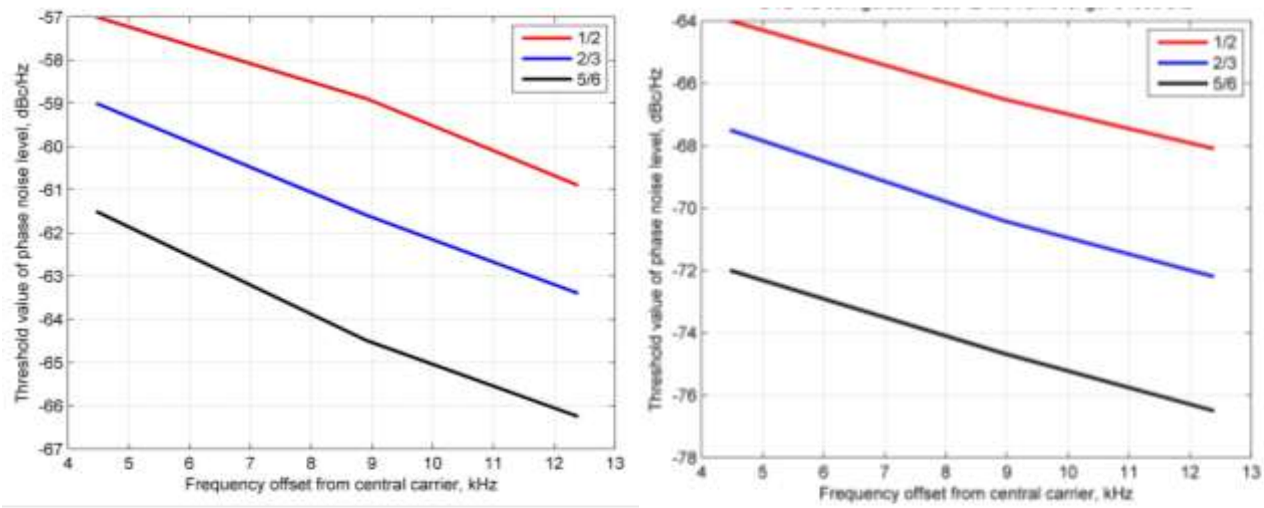

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Figure 6 - Dependence of threshold level of phase noise from frequency offset
for 16-QAM (a) and 256-QAM (b) modulations in DVB-T2 system

Similar dependences are also observed at other modulation methods – 64-QAM (DVB-T) and 256-QAM (DVB-T2). But in these cases the benefit is observed at different inner code rates as well as because of using of more effective digital modulation method. It's confirmed by the fact that higher phase noise threshold level is acceptable at DVB-T2 configuration 256-QAM 5/6 than at DVB-T 64-QAM 1/2. In a case of using DVB-T2 system gain in terms of phase noise threshold level is 1 to 3.9 dBc/Hz at all inner code rates.

Above estimated gains may be achieved only when AWGN level is very small. But if SNR at the input of DVB receiver is only on 3 dB (typical receiver implementation margin) higher than threshold level there will be significant technical operation quality degradation. 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 article 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) [6] 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 (see tables 4-6 and figures 7-10).

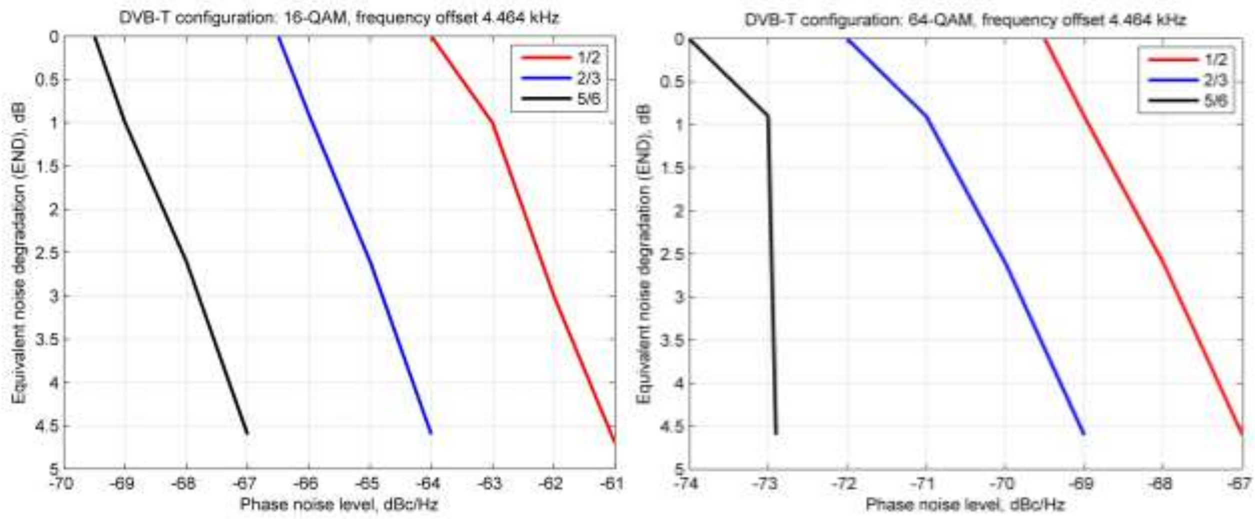

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Figure 7 - Dependence of equivalent noise degradation value from phase noise level for 16-QAM (a) and 64-QAM (b) in DVB-T system

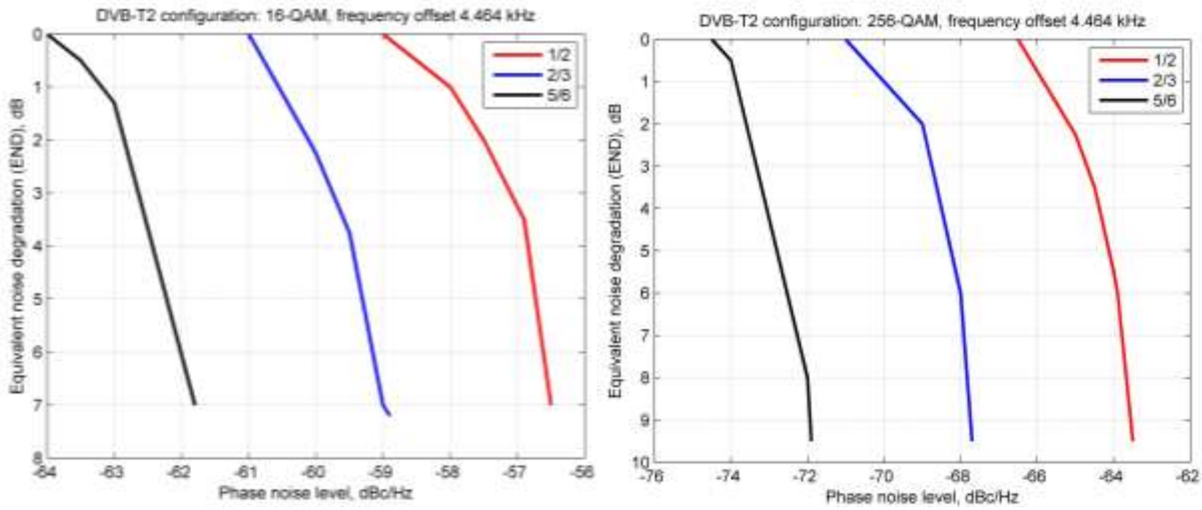

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Figure 8 - Dependence of equivalent noise degradation value from phase noise level for 16-QAM (a) and 256-QAM (b) in DVB-T2 system

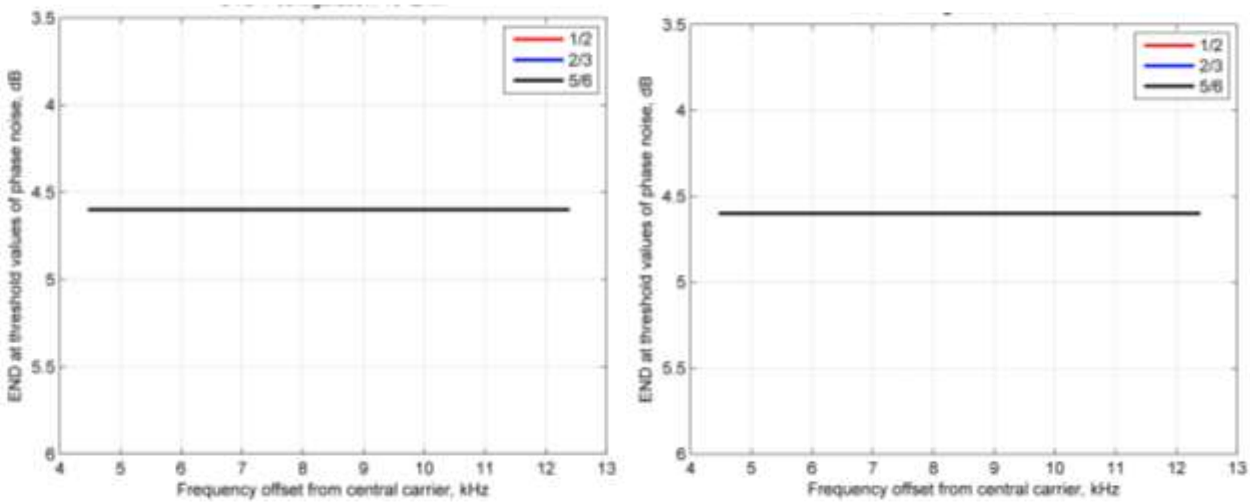

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Figure 16 - Dependence of equivalent noise degradation value from frequency offset at presence of phase noise for 16-QAM (a) and 64-QAM (b) in DVB-T system

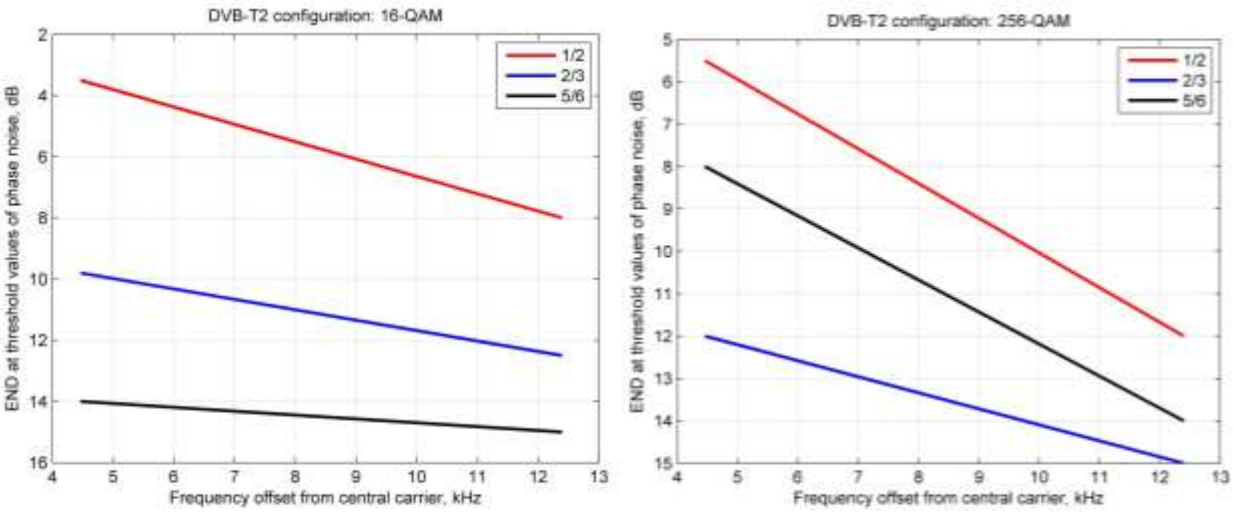

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Figure 18 - Dependence of equivalent noise degradation value from frequency offset at presence of phase noise for 256-QAM in DVB-T2 system

From the figures and the tables it's clear that at presence of AWGN with high level DVB-T2 system provides worse performance than DVB-T system. It can be explained by the fact that under condition of phase noise impact and presence of AWGN with small level DVB-T2 system does operate on the edge of its capabilities because of lower value of phase noise threshold level. But under condition of increasing of AWGN level a necessity of increasing receiver input signal power level or changing phase noise threshold value appears.

Table 4 - Dependence of equivalent noise degradation value from frequency offset at presence of phase noise

Frequency offset, kHz	**END, dB**		
Code rate	1/2	2/3	5/6
DVB-T (16-QAM)			
4.464	4.6	4.6	4.6
12.392	4.6	4.6	4.6
DVB-T2 (16-QAM)			
4.464	3.5	9.8	14
12.392	8	12.5	15
DVB-T (64-QAM)			
4.464	4.6	4.6	4.6
12.392	4.6	4.6	4.6
DVB-T2 (256-QAM)			
4.464	5.5	12	8
12.392	12	15	14

From Table 4 it's clear that for DVB-T system it's necessary SNR in AWGN channel to be 0.9 to 10.4 dB more to provide the same performance as in DVB-T2 system.

The results of the tests for estimation END value depending on phase noise level are given in Tables 5-6.

Threshold level of phase noise for two cases – AWGN with very small and high levels – are represented in Table7. Difference in threshold levels of phase noise is determined for estimation phase noise level by which it's necessary to decrease threshold value in a case of high AWGN level.

Table 5 - Dependence of equivalent noise degradation value from phase noise level for 16-QAM

Parameter	Value			
DVB-T (16-QAM 1/2)				
Phase noise level, dBc/ Hz	-61	-62	-63	-64
END, dB	4.7	3	1	0
DVB-T (16-QAM 2/3)				
Phase noise level, dBc/ Hz	-64	-65	-66	-66.5
END, dB	4.6	2.6	0.9	0
DVB-T (16-QAM 5/6)				
Phase noise level. dBc/ Hz	-67	-68	-69	-69.5
END. dB	4.6	2.6	0.9	0
DVB-T2 (16-QAM 1/2)				
Phase noise level, dBc/ Hz	-56.5	-57.5	-58	-59
END, dB	7	2	1	0
DVB-T2 (16-QAM 2/3)				
Phase noise level, dBc/ Hz	-58.9	-59.5	-60	-61
END, dB	7.2	3.75	2.25	0
DVB-T2 (16-QAM 5/6)				
Phase noise level, dBc/ Hz	-61.8	-63	-63.5	-64
END, dB	7	1.3	0.5	0

Table 6 - Dependence of equivalent noise degradation value from phase noise level for 64-QAM (DVB-T) and 256-QAM (DVB-T2)

Parameter	Value			
DVB-T (64-QAM 1/2)				
Phase noise level, dBc/ Hz	-67	-68	-69	-69.5
END, dB	4.6	2.6	0.9	0
DVB-T (64-QAM 2/3)				
Phase noise level, dBc/ Hz	-69	-70	-71	-72
END, dB	4.6	2.6	0.9	0
DVB-T (64-QAM 5/6)				
Phase noise level, dBc/ Hz	-72.9	-72.95	-73	-74
END, dB	4.6	2.6	0.9	0
DVB-T2 (256-QAM 1/2)				
Phase noise level, dBc/ Hz	-63.5	-64	-65	-66.5
END, dB	9.5	3.5	2.25	0
DVB-T2 (256-QAM 2/3)				
Phase noise level, dBc/ Hz	-67.7	-68	-69	-71
END, dB	9.5	6	2	0
DVB-T2 (256-QAM 5/6)				
Phase noise level, dBc/ Hz	-71.9	-72	-74	-74.5
END, dB	9.5	8	0.5	0

From Table 7 it's clear that it's possible to compensate impact of AWGN increasing by insignificant decreasing of phase noise threshold level (from 1 dBc/ Hz to 3 dBc/ Hz). At the same time benefit of transition to DVB-T2 system remains – for this system acceptable phase noise level is higher than for DVB-T system. This benefit is achieved due to DVB-T2 system signal processing that provides higher efficiency in terms of information bit-rate, SNR and permissible levels of different types of distortions [8].

Table 7 - Threshold values of phase noise for two cases – AWGN with very small and high levels

System	Code rate	Threshold level of phase noise, dBc/ Hz		Difference, dBc/ Hz
		AWGN with very small level	AWGN with high level	
DVB-T (16-QAM)	1/2	-61	-64	3
	2/3	-64	-66.5	2.5
	5/6	-67	-69.5	2.5
DVB-T2 (16-QAM)	1/2	-57	-59	2
	2/3	-59	-61	2
	5/6	-61.5	-64	2.5
DVB-T (64-QAM)	1/2	-67	-69.5	2.5
	2/3	-69	-72	3
	5/6	-73	-74	1
DVB-T2 (256-QAM)	1/2	-64	-66.5	2.5
	2/3	-67.5	-71	3.5
	5/6	-72	-74.5	2.5

CONCLUSIONS

Thus the estimation of technical quality degradation in such systems at different conditions to non-ideality of quadrature modulator/demodulator performance (in particular phase noise) 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 article. 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.

Currently, provided above results were included in preliminary draft new report ITU-R BT.[DTTBMEASUREMENT] originated from contribution of Ukraine in work of Study Group 6 "Broadcasting services".

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