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BASEBAND TRANSMISSION QUALITY ESTIMATION FOR DVB-T2 BROADCASTING SYSTEM
(PART 1)

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ОЦІНКА ЯКОСТІ ПЕРЕДАВАННЯ В ОСНОВНІЙ СМУЗІ ДЛЯ СИСТЕМИ МОВЛЕННЯ DVB-T2
(ЧАСТИНА 1)

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ОЦЕНКА КАЧЕСТВА ПЕРЕДАЧИ В ОСНОВНОЙ ПОЛОСЕ ДЛЯ СИСТЕМЫ ВЕЩАНИЯ DVB-T2
(ЧАСТЬ 1)

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Abstract. *The article presents the results of research in the direction of determining the permissible values of parameters that are controlled in the baseband during the evaluation of the quality of the operation of the transmitter-receiver of digital terrestrial television system in DVB-T2 standard at the transport stream level. The main purpose of this study is to obtain quantitative and qualitative assessments of controlled parameters at the level of transport multi-program stream in the base band of digital terrestrial television broadcasting systems that are currently not available in national and international technical literature. In order to achieve the research aim, a mathematical simulation model of the DVB-T2 digital transmission TV transmission system (transmission path, channel with distortion, receiving path with appropriate processing and correction) was implemented in the Matlab / Simulink environment and a computational experiment was carried out, the results of which were analyzed in relevant way of experimental data is the basis for formulating the corresponding requirements to the level of distortions at the level of the base band stream. As a result of the conducted studies, evaluations were made of the appropriate parameters used to control the quality of digital TV system operation at the level of the digital transport multi-program stream. The obtained values can be used for standardizing and monitoring the level of distortion during the technical operation of the receiving and transmitting equipment of the relevant standard, as well as certification and commissioning during the introduction of new equipment, as well as the deployment of digital terrestrial television networks.*

Key words: *digital terrestrial television, DVB-T2, OFDM, transport stream, bit error rate, Matlab.*

Анотація. *У статті надано результати дослідження в напрямку визначення припустимих значень параметрів, що їх контролюють в основній смузі під час оцінки якості роботи передавально-приймального тракту системи цифрового наземного телевізійного мовлення в стандарті DVB-T2 на рівні транспортного потоку. Основною метою цього дослідження є отримання кількісних та якісних оцінок контрольованим параметрам на рівні транспортного багатопрограмного потоку в основній смузі систем цифрового наземного телевізійного мовлення, що відсутні на поточний час у вітчизняній та міжнародній технічній літературі. Для досягнення мети досліджень в середовищі Matlab/ Simulink було реалізовано математичну імітаційну модель наскрізного тракту системи цифрового телевізійного мовлення DVB-T2 (передавальний тракт, канал з спотво-*

реннями, приймальний тракт з відповідним оброблянням та корекцією) та проведено обчислювальний експеримент, результати якого та проведений відповідний аналіз експериментальних даних є основою для формулювання відповідних вимог до рівню спотворень на рівні потоку основної смуги. У результаті проведених досліджень вперше отримано оцінки відповідним параметрам, що використовують для контролю якості роботи цифрового тракту телевізійної системи на рівні цифрового транспортного багатопрограмного потоку. Отримані значення можуть бути використано при нормуванні та контролі рівню спотворень під час технічної експлуатації приймально-передавального обладнання відповідного стандарту, а також сертифікаційних робіт та пусконалагоджувальних робіт під час впровадження нового обладнання, а також розгортання нових цифрових ефірних телемереж.

Ключові слова: *цифрове наземне телебачення, DVB-T2, OFDM, транспортний потік, коефіцієнт помилок бітів, Matlab*

Аннотация. *В статье приведены результаты исследования в направлении определения допустимых значений параметров, которые контролируют в основной полосе при оценке качества работы приёмно-передающего тракта системы цифрового наземного телевизионного вещания в стандарте DVB-T2 на уровне транспортного потока. Основной целью данного исследования является получение количественных и качественных оценок контролируемым параметрам на уровне транспортного многопрограммного потока в основной полосе систем цифрового наземного телевизионного вещания, отсутствуют на настоящее время в отечественной и международной технической литературе. Для достижения цели исследований в среде Matlab/Simulink была реализована математическая имитационная модель сквозного тракта системы цифрового телевизионного вещания DVB-T2 (передающий тракт, канал с искажениями, приёмный тракт с соответствующей обработкой и коррекцией) и проведения вычислительный эксперимент, результаты которого и проведён соответствующий анализ экспериментальных данных является основой для формулирования соответствующих требований к уровню искажений на уровне потока основной полосы. В результате проведённых исследований впервые получены оценки соответствующим параметрам, которые используют для контроля качества работы цифрового тракта телевизионной системы на уровне цифрового транспортного многопрограммного потока. Полученные значения могут быть использованы при нормировании и контроле уровня искажений при технической эксплуатации приёмо-передающего оборудования соответствующего стандарта, а также сертификационных работ и пуско-наладочных работ при внедрении нового оборудования, а также развёртывании новых цифровых эфирных телесетей.*

Ключевые слова: *цифровое наземное телевидение, DVB-T2, OFDM, транспортный поток, коэффициент ошибок битов, Matlab.*

1 INTRODUCTION

Important element of digital terrestrial television broadcasting (DTTB) network maintenance is control of technical operation quality of its separate nodes and whole network. One of tasks that administration will decide during control of technical operation quality of network is monitoring of transport stream performance. Such approach to control allows implementing of technical quality monitoring of DTTB service at high level of reliability.

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. ETSI TR 101 290 is main normative document that defines basic aspects of MPEG-2 TS monitoring and measurement. But this document not defines any threshold values for any parameters controlled during MPEG-2 TS monitoring. Such generalized approach is understandable but this fact leads to some limitation of standard scope and requires for carrying out of additional maintenance and research studies. The last one is provided in this article.

2 DETERMINING OF THE REQUIREMENTS TO OPERATION QUALITY OF DIGITAL BROADCASTING SYSTEM ON TS LEVEL

Basic measurement procedures and parameters controlled on TS level are defined in ETSI TR 101 290 [1]. Although MPEG-2 transport stream analyzer is included in minimal list of measurement equipment for control of technical operation quality of digital terrestrial television broadcasting network the operational and technical regulations for acceptable number of every type errors are absent. The experiment has been carried out to determine the requirements to operation quality of digital broadcasting system on MPEG-2 TS level. Description and the results of the experiment are given below. Estimation of technical operation quality on TS level is carried out for DVB-T2 system with parameters defined in [2–4]. But taking into account that analysis on TS level is substantially not system-depended the results of estimation can be used for any another non-DVB system.

In the DVB-T2 transmitter adaptation to terrestrial channel characteristic has been done at such system configuration: frequency bandwidth – 8 MHz, base bandwidth frame length – 64800 bit, LDPC code rate – 4/5, modulation method – 256-QAM, OFDM mode – 2k, guard interval – 1/4, pilot pattern (PP) – PP1.

Scheme of the test set-up corresponds to shown in Figure 1. DVB-T2 system input was supplied with multi-program TS that contained data of four television broadcasting services and following Service Information tables – Program Association Table (PAT), Program Map Table (PMT), Time and Date Table (TDT), Time Offset Table (TOT) and Event Information Table (EIT) and others from TS generator.

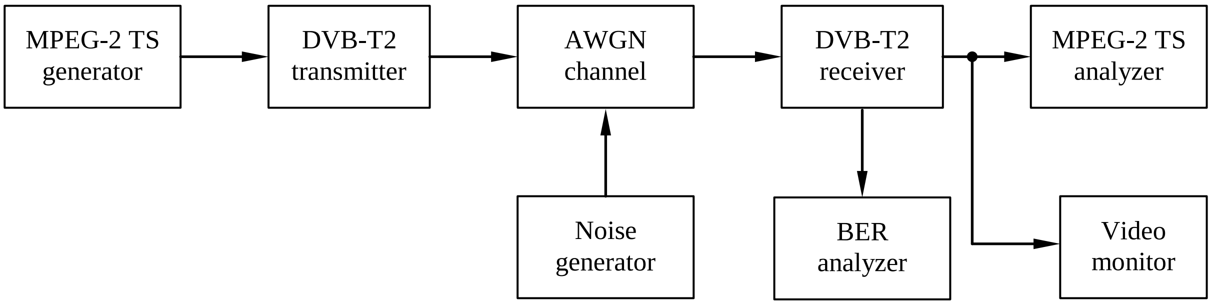
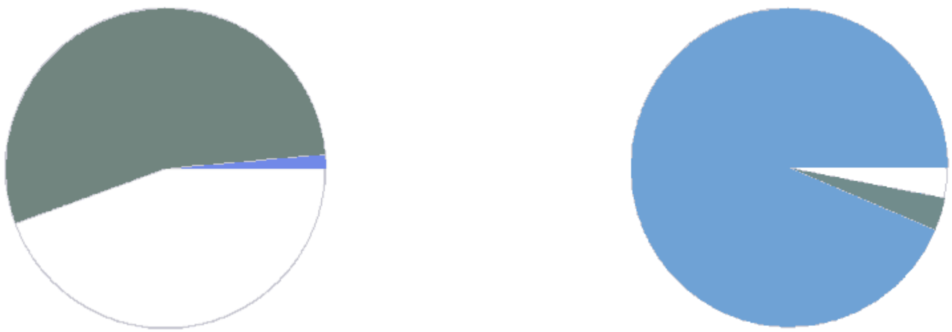


Figure 1 - Test set-up for estimation of impairments on MPEG-2 TS level

The experiment was repeated for four different transport streams. Transport stream parameters used during research are given in Table 1. Distribution of TS resources for PSI/SI data and program streams is shown in Figures 2, 3.

Table 1 - Parameters of transport streams used for experiment

Name	Average bit-rate Mbit/s	Service Information tables
FRANCE	33.189	NIT, SDT, PAT, PMT
TNT	60.964	CAT, NIT, SDT, PAT, TDT, PMT, EIT
DVBT2	33.746	NIT, SDT, PAT, PMT, BAT, TDT, EIT
LUX	20.834	PAT, PMT



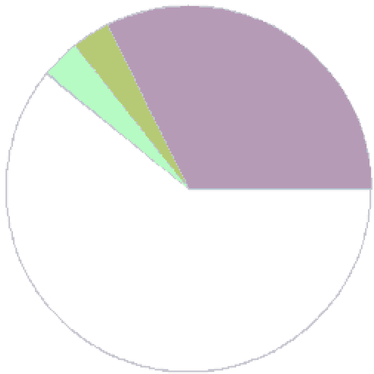
PID = 259 (0×103) (MPEG Layer Audio): 1,42 %
PID = 265 (0×109) (MPEG-4 AVC/ H.264): 54,15 %
Service information: 44,43 %

a) Transport stream France

PID = 101 (0×65) (MPEG-4 AVC/ H.264): 93,61 %
PID = 256 (0×100) (MPEG Layer Audio): 3,35 %
Service information: 3,04 %

b) Transport stream LUX

Figure 2 - Distribution of resource in transport streams France (a) and Lux (b)



PID = 5000 (0×1388) (MPEG-2 Video): 32,32 %

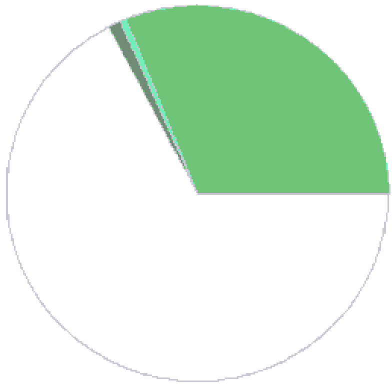
PID = 5001 (0×1389) (MPEG Layer Audio): 3,38 %

PID = 5002 (0×138A) (MPEG Layer Audio): 3,38 %

PID = 5004 (0×138C) (Subtitles DVB): 0,15 %

Service information: 60,77 %

a) Transport stream DVBT2



PID = 120 (0×78) (MPEG-4 AVC/ H.264): 31,07 %

PID = 130 (0×82) (AC3): 0,54 %

PID = 131 (0×83) (AC3): 1,07 %

Service information: 67,32 %

b) Transport stream TNT

Figure 3 - Distribution of resource in transport streams DVB-T2 (a) and TNT (b)

In the channel signal-to-noise ratio (SNR) is changed. In the receiver such operations were made: received stream decoding, analysis of Bit Error Rate (BER) before and after LDPC decoder (in BER analyzer), analysis of error presence in transport streams at system output, visual monitoring of decoded image of one of services on the computer display.

For determining of threshold values for different priority errors it's possible to use criteria of subjective failure point (SFP) during decoding and display of particular program stream contents. Subjective failure point defines border between QEF operation and region with cliff effect on picture. This effect shows itself in appearance of separate elements of MPEG hierarchical video stream structure (pixels, blocks, macro blocks, slices) with incorrectly recovered samples of luminance signal and color-difference signals or their space-temporal shift in adjacent frames of video sequence.

For estimation of technical operation quality of DTTB service the analysis interval corresponds to 8-10 seconds as recommended in ETSI TR 101 290.

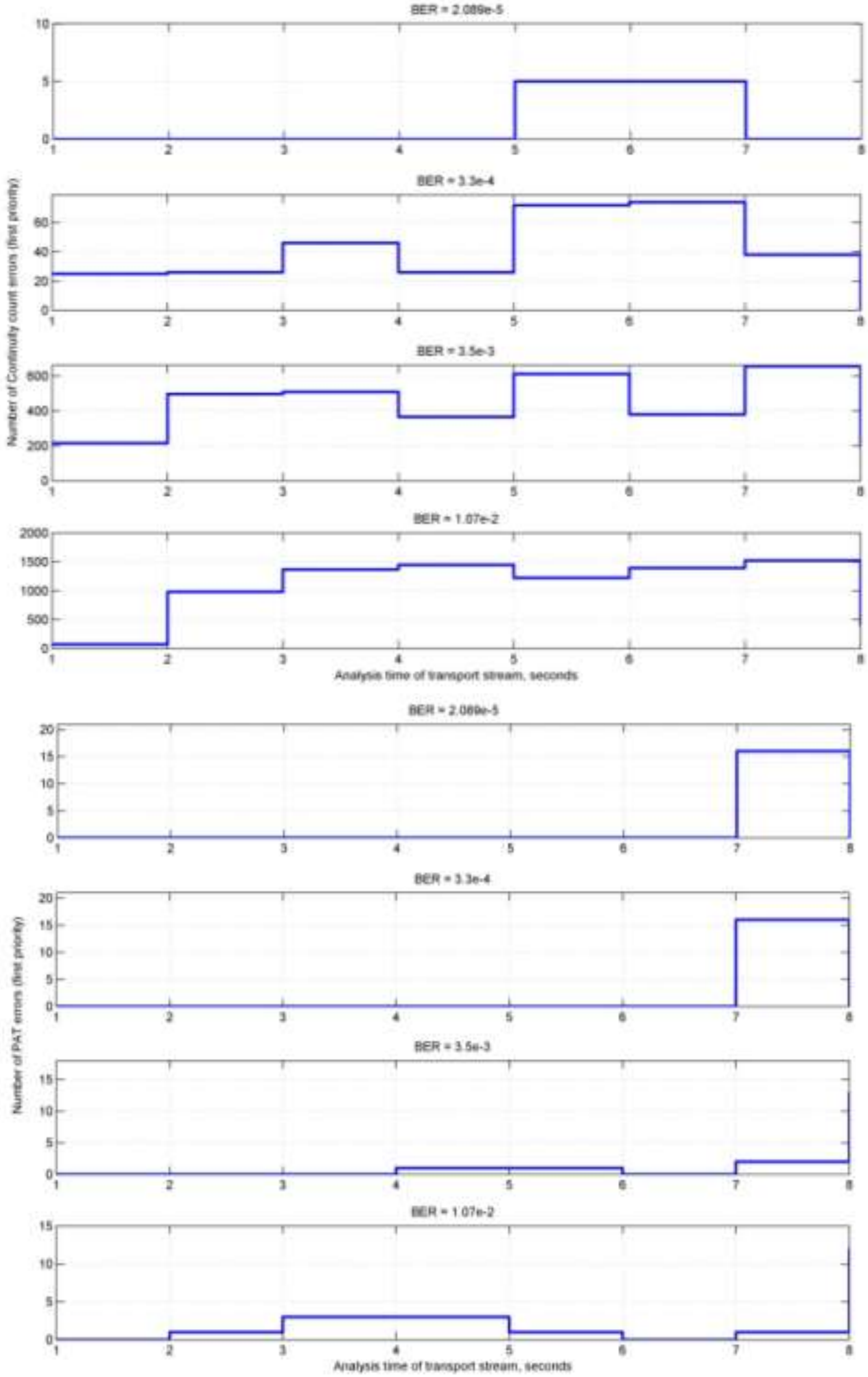
Measurements were made at six SNR (21 dB, 21.05 dB, 21.125 dB, 21.175 dB, 21.188 dB, 21.190 dB) corresponding to different values of BER after BCH decoder (10^{-2} to 10^{-7}) [5].

Study results are presented on graphic dependencies in Figures 4-11 that describe operation quality of system on MPEG-2 TS level [6].

Figures 4-5 show distributions in time of error with different priority in FRANCE transport stream for different BER values at the input of MPEG demultiplexer. From diagrams it can be seen that with BER increasing number of errors with different priorities increases that will cause interruption in receiving and decoding of television broadcast service signals. In a case of direct interruption of information concerning separate video frames decoding some regions or even all the picture of one or more frames will be impossible.

Total error number of every type (see Table 2) will decrease with decreasing BER in the channel. From temporal diagrams for Continuity_count_error, PAT_error and TS_sync_error it can be seen that maximum value of every type errors is different (from about 1500 errors to 1–2 errors). It's explained by periodicity of transmission for corresponding service information element. For example, continuity counter value is transmitted in every TS packet. So such type errors appear more often than others of mentioned above types. Errors PAT_error appear rarely but it doesn't mean they are not important – in a case of such error recovering of any program stream from transport stream becomes impossible or difficult. Frequency of such error events relates to the fact that PAT is transmitted over some time intervals (not often than once in 0.5 s).

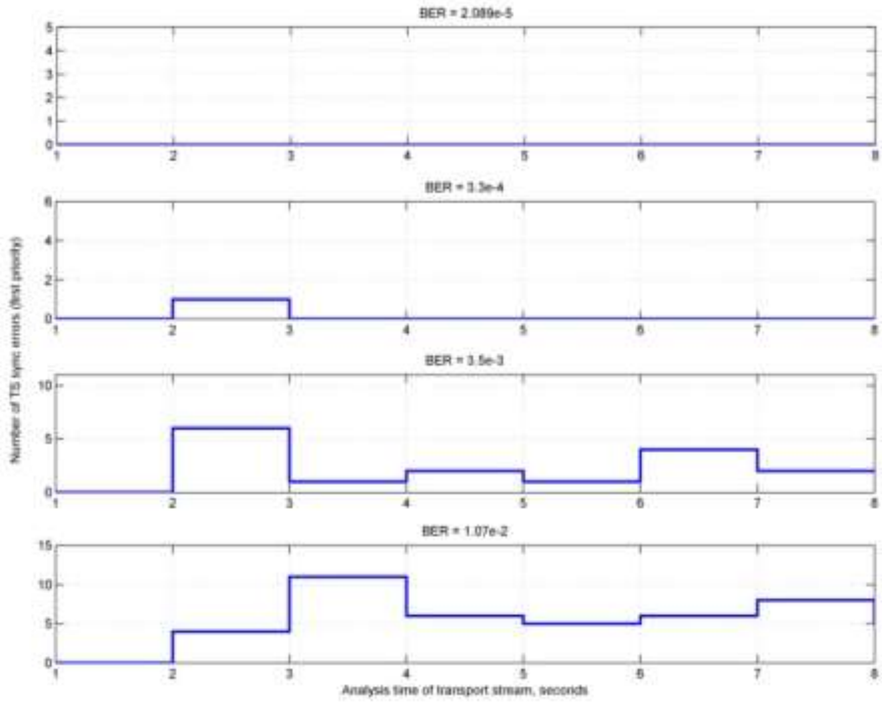
During experiment practically there were no third priority errors what conformed to provision of ETSI TR 101 290 - such priority errors appear extremely rarely (see Table 2).



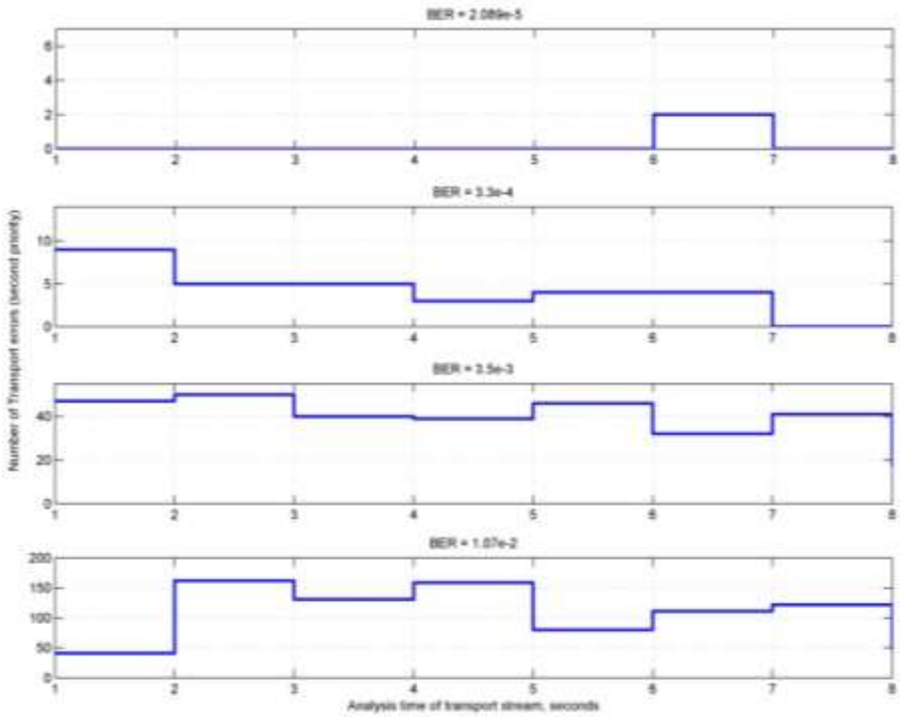
a) b)

Figure 4 - Time distribution of Continuity_count_error (a), PAT_error (b) events for different BER in broadcasting channel for FRANCE transport stream

Figures 6-7 show time distributions of errors with different priorities in TNT transport stream for different BER at the input of MPEG demultiplexer. Time distribution of error events and corresponding numbers differ from values obtained for FRANCE transport stream because of the difference in transport stream structure. However approximate relation of different priority and type errors remains same and with error priority increasing error number (as absolute so relative number) decreases.

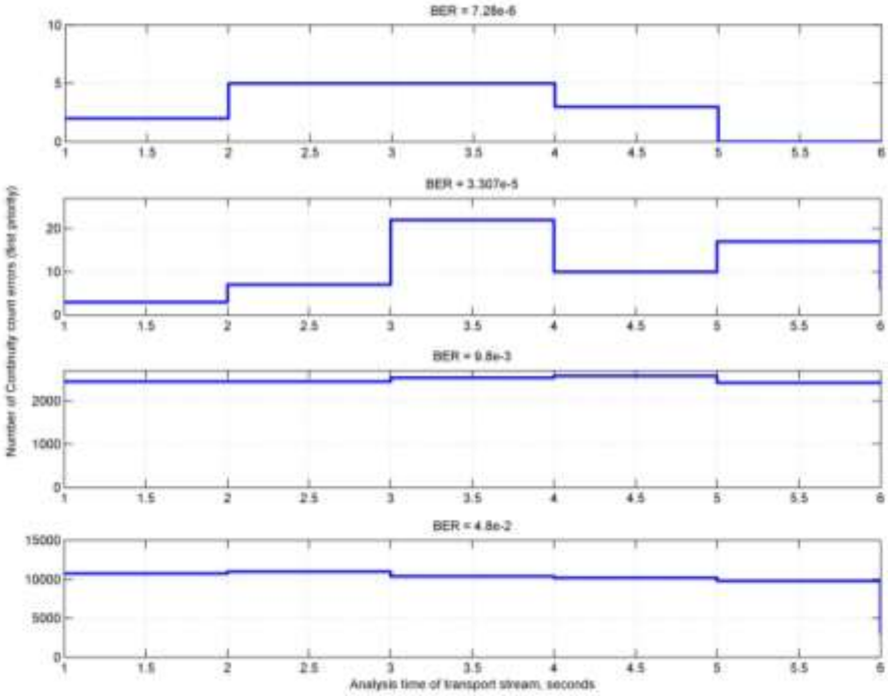


a)

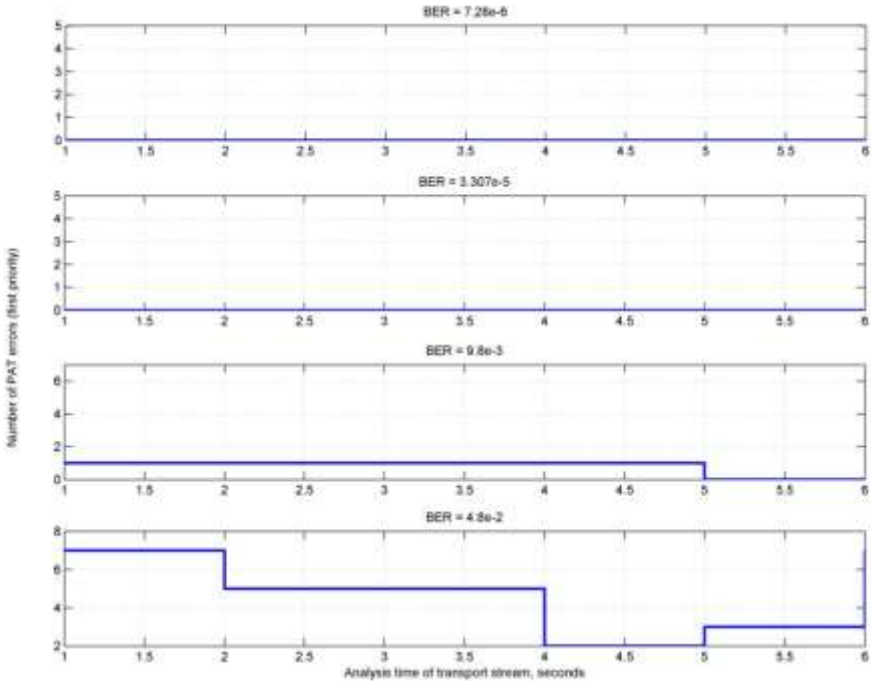


b)

Figure 5 - Time distribution of TS_sync_error (a) and Transport_error (b) events for different BER in broadcasting channel for FRANCE transport stream

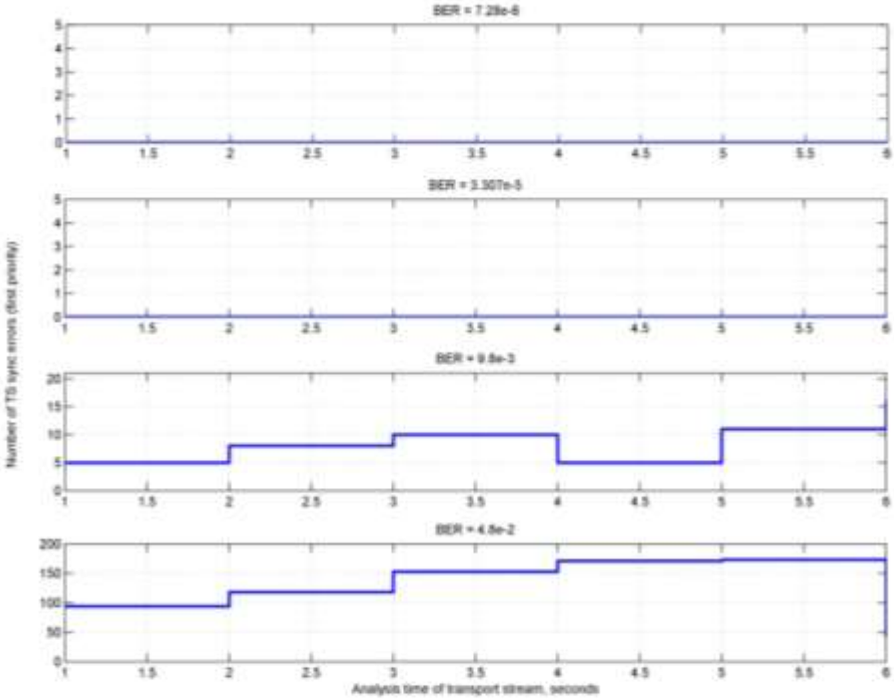


a)

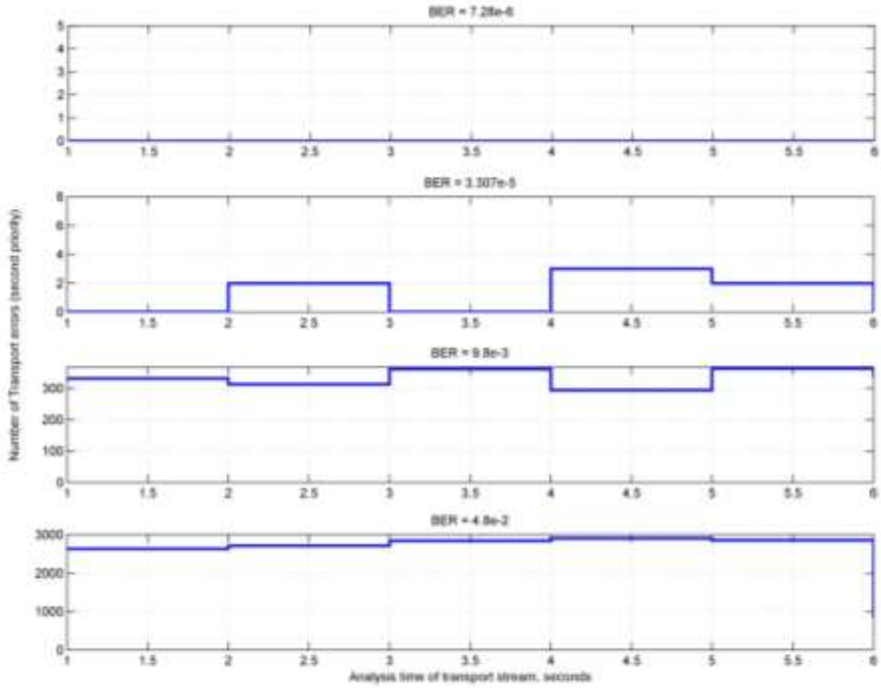


b)

Figure 6 - Time distribution of Continuity_count_error (a) and PAT_error (b) events for different BER in broadcasting channel for TNT transport stream

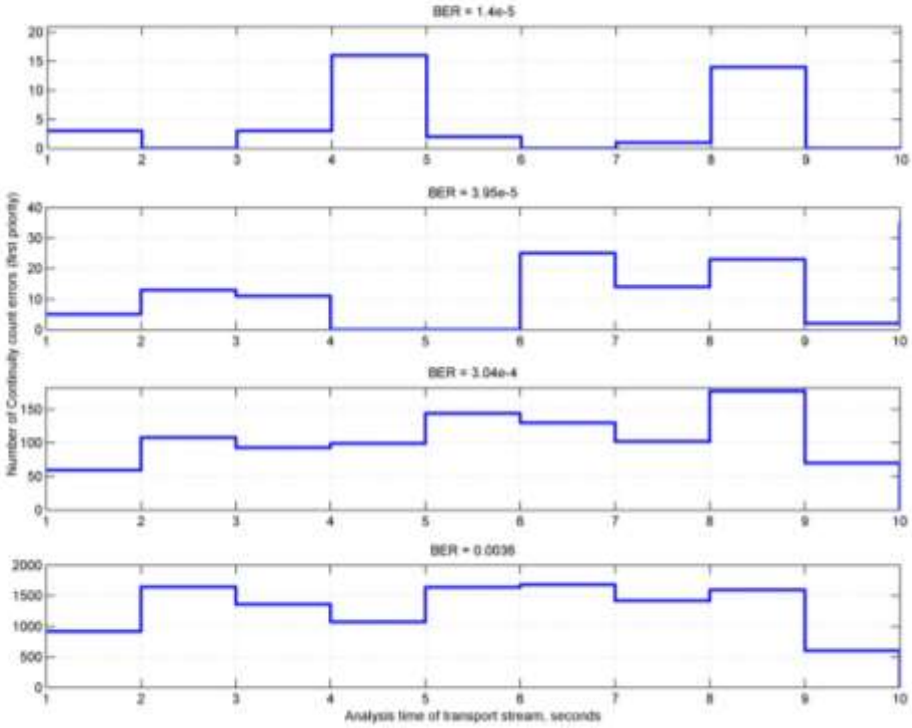


a)

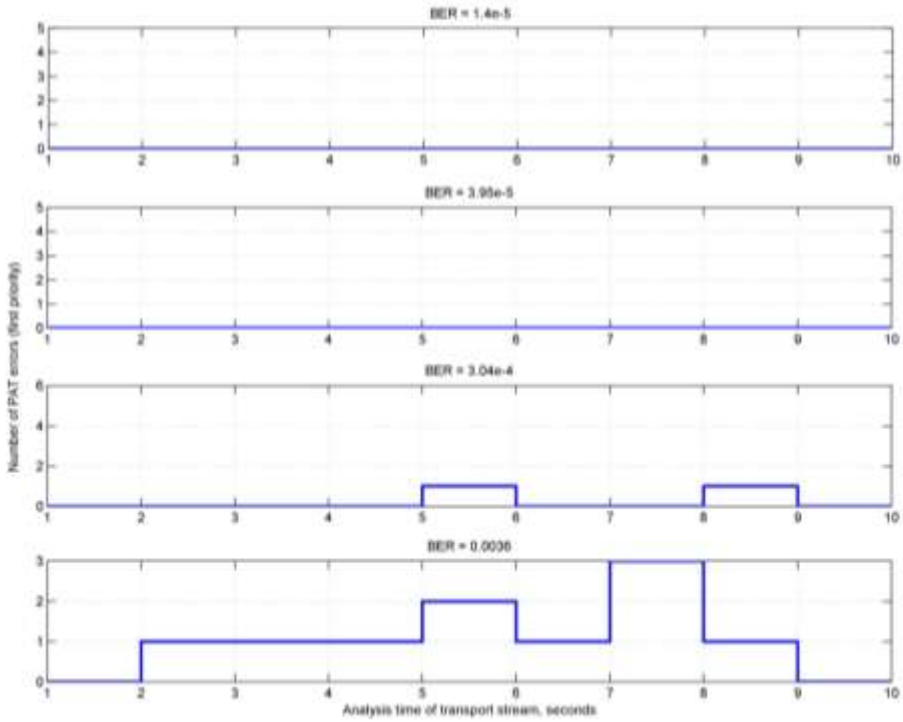


b)

Figure 7 - Time distribution TS_sync_error (a) and Transport_error (b) events for different BER in broadcasting channel for TNT transport stream

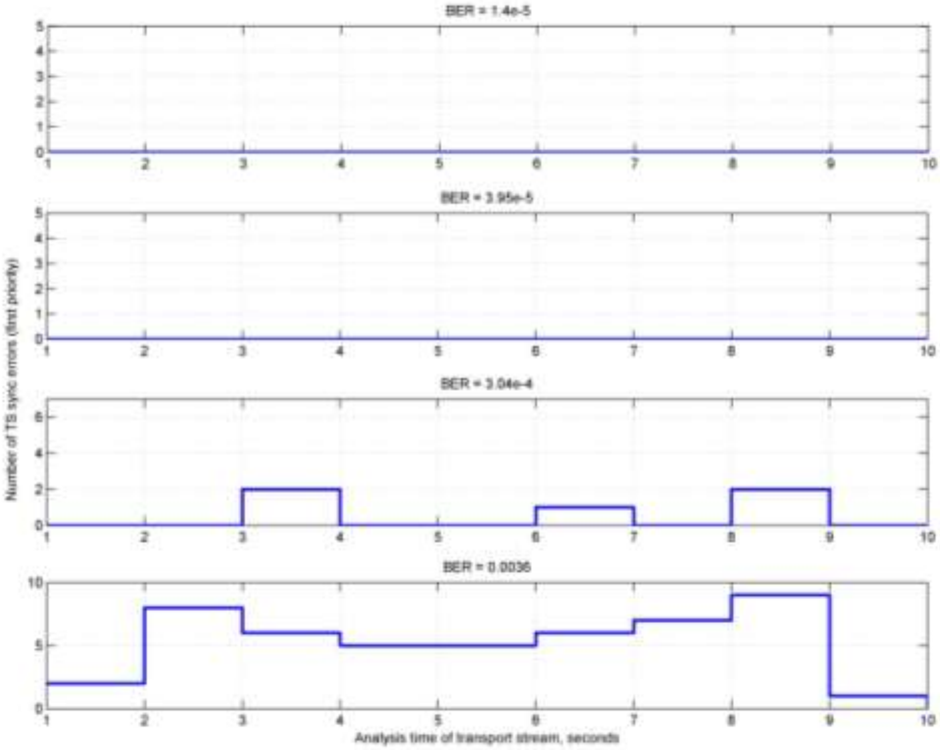


a)

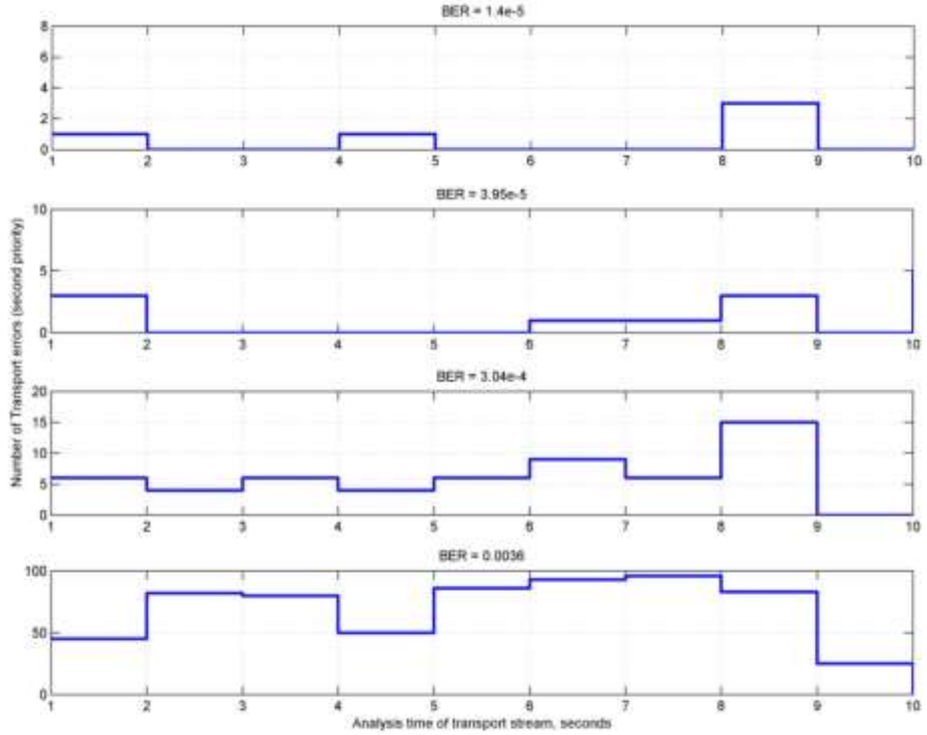


b)

Figure 8 - Time distribution of Continuity_count_error (a) and PAT_error (b) events for different BER in broadcasting channel for DVBT2 transport stream

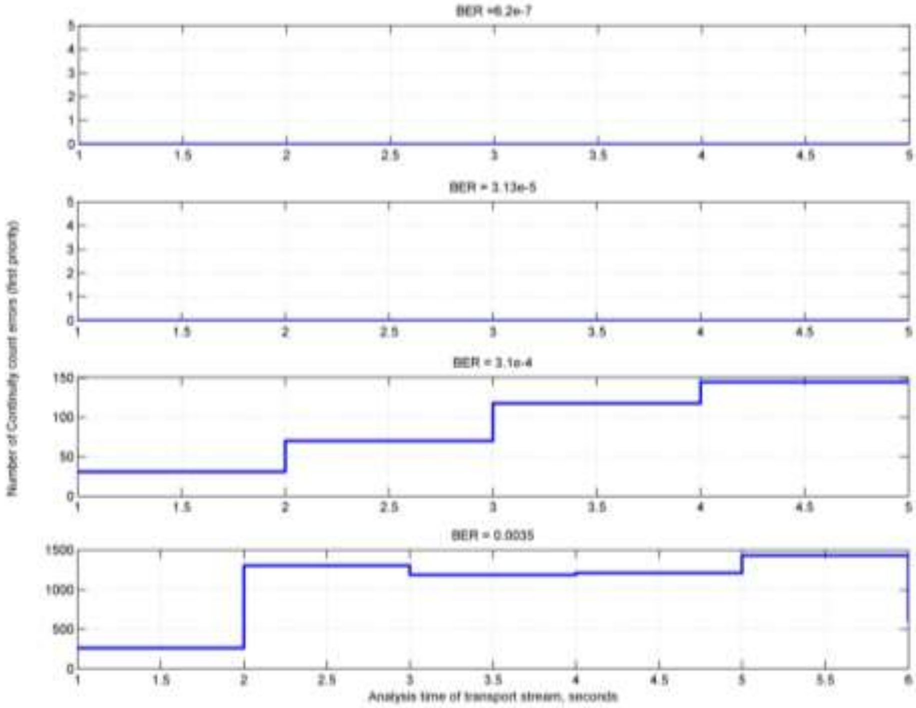


a)

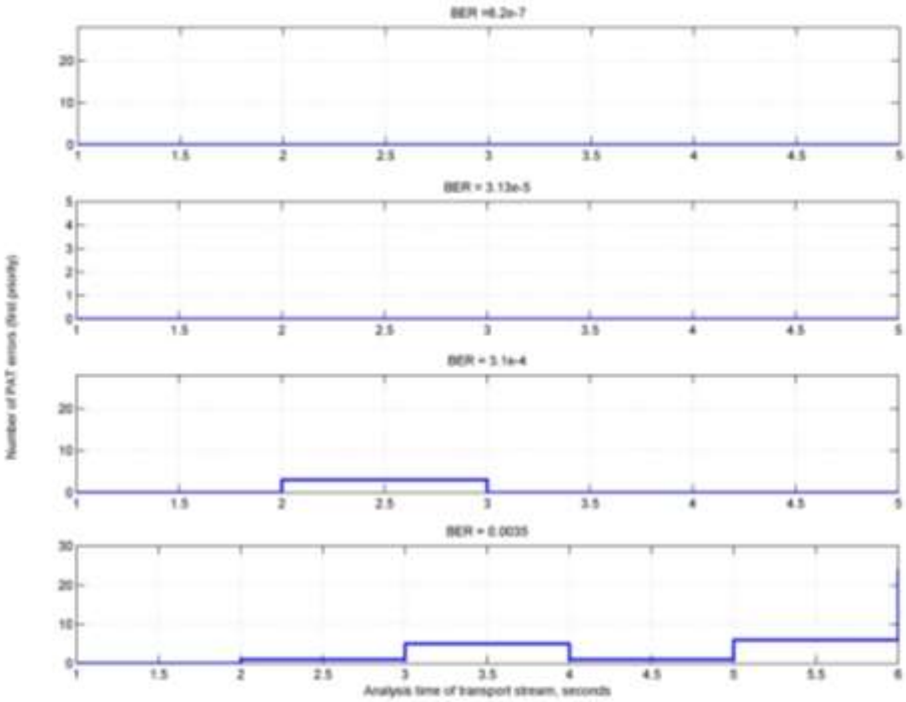


b)

Figure 9 - Time distribution of TS_sync_error (a) and Transport_error (b) events for different BER in broadcasting channel for DVBT2 transport stream

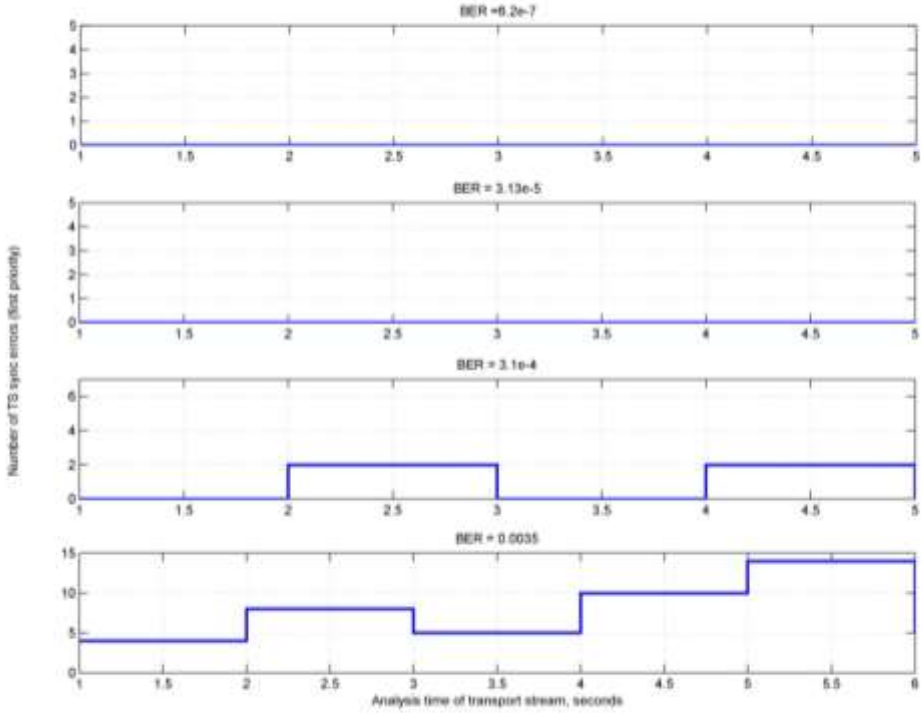


a)

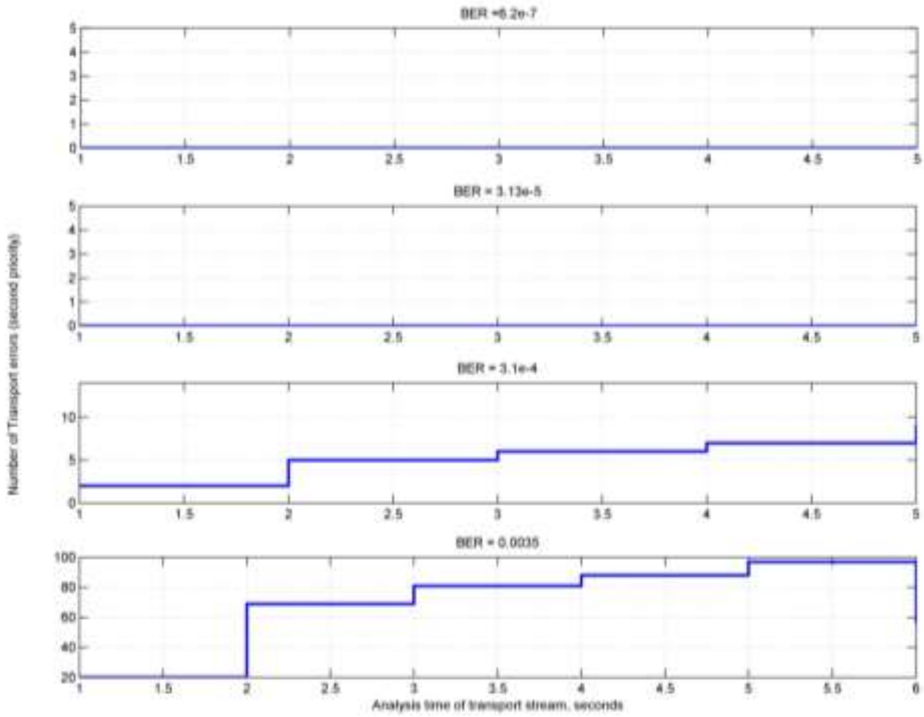


b)

Figure 10 - Time distribution of Continuity_count_error (a) and PAT_error (b) event for different BER in broadcasting channel for LUX transport stream



a)



b)

Figure 11 - Time distribution of TS_sync_error (a) and Transport_error (b) events for different BER in broadcasting channel for LUX transport stream

Figures 8-9 show time distributions of errors with different priorities in DVBT2 transport stream for different BER at the input of MPEG demultiplexer.

Time distribution of error events and corresponding numbers differ from values obtained for previous transport streams, however approximate relation of different priority and type errors remains constant and with error priority increasing their number (as absolute so relative) decreases.

Unlike the other transport streams third priority errors have been found during DVBT2 transport stream analysis.

Figures 10-11 show time distributions of some types of errors with different priorities in LUX transport stream for different BER at the input of MPEG demultiplexer. A pattern of their occurrence is changed at different BER corresponds to previous results for other transport streams but quantitative measures differ.

Using a video analysis it may be determined the approximate number of errors of each priorities at which technical operation quality reducing of the digital television broadcasting network will be in acceptable. In this case presence of errors of a particular type will indicate the end-to-end path point where failures could potentially take place. The last may be realized by built-in test sub-stream, which is transmitted together with program streams in the transport stream [7].

During analysis it will be determined two types of threshold values – cumulative and instantaneous threshold error number of each priority.

Instantaneous threshold error number will mean error number at which considerable impairments during decoding/picture displaying of control video monitor are appeared that results in subjective quality degradation.

Cumulative threshold error number that will be determined by addition of number of different type errors of the same priority during certain analysis time interval will characterize general technical operation quality of digital television broadcasting network during analysis time interval. It can be used to monitor the overall dynamics of technical operation quality change for prevention of failures.

Fro determination the instantaneous threshold error number it will be used time distribution diagrams and for the cumulative threshold error number – with dependence for number of errors of corresponding priority from BER.

If the cumulative number of second priority errors over interval of 8 seconds is greater than or equal to 500-700 errors at average (e.g., priority 2.1), then it points to a significant degradation of the technical operation quality of digital television broadcasting service and $\mathrm{BER} \geq 1 \cdot 10^{-3}$ - the image will be practically un-decoded. If the number of errors over analysis interval is not more than 2-7 errors of second priority (see Table 2) - this indicates interruption of digital television broadcasting signal reception over small time period of and, in principle, is permissible and such error number is threshold. However, in the case of even a slight excess of this threshold it should be carried out a detailed analysis for detection of possible causes of this type errors appearing.

For errors of first priority thresholds are slightly different - the presence of about $8.2 \cdot 10^{4}$ errors of priority 1.4 indicates to $\mathrm{BER} \geq 1 \cdot 10^{-3}$ and about 10-50 errors is permissible (see Table 2).

Greater permissible number of errors (threshold) in the latter case does not indicate their lower importance when assessing the quality of digital television broadcasting service – presence of errors of first and second priorities leads to different consequences during recovery of program and/ or transport streams.

Furthermore it should be noted that a slight excess of the threshold for the error number of priority 1 probably will be lead to the impossibility of any successful processing of multi-program transport stream (i.e., all sub-streams simultaneously) while at the same situation for priority 2 errors - only to decoding disability of certain program streams or separate elementary streams.

Priority 3 errors can not be used for the operational detection of significant degradation of the reception quality or maintenance of digital television broadcasting network. This can be explained by fact that over almost the entire analysis interval for all transport stream this priority errors were absent.

As regard instantaneous threshold number of errors, on the average, permissible number of first priority errors is 5-20 errors per single analysis interval, and for the second priority errors - 2-3 errors. For these values substantial degradation of perceived quality will be not observed and cliff effect will be absent for a long time.

Table 2 - Statistics of different priorities error appearance

Parameter	Value							
Instantaneous threshold number of errors of corresponding priority								
TS name	France		TNT		DVBT2		Lux	
BER	$1{\cdot}10^{-3}$	$1{\cdot}10^{-5}$	$1{\cdot}10^{-3}$	$1{\cdot}10^{-5}$	$1{\cdot}10^{-3}$	$1{\cdot}10^{-5}$	$1{\cdot}10^{-3}$	$1{\cdot}10^{-5}$
priority 1.4	658	5	2574	20	1685	16	1433	0
priority 1.3	2	16	1	0	3	0	6	0
priority 1.1	6	0	11	0	9	0	14	0
priority 2.1	50	2	361	3	96	3	97	0
priority 2.2	1	0	2	0	4	0	12	0
priority 2.6	1	0	2	0	4	0	0	0
Cumulative threshold number of errors of appropriate priority								
priority 1.4	3243	10	12404	59	11956	39	5395	0
priority 1.3	3	16	4	0	10	0	13	0
priority 1.1	16	0	40	0	49	0	41	0
priority 2.1	295	2	1663	7	640	5	355	0
priority 2.2	1	0	7	0	2	0	38	0
priority 2.6	1	0	6	0	2	0	0	0

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