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Guidelines on measurements for digital terrestrial television, broadcasting systems

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REPORT ITU-R BT.2389-1

Guidelines on measurements for digital terrestrial television, broadcasting systems

(2016-2024)

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List of abbreviations and acronyms

BL	Base layer
DPB	Decoded picture buffer
EL	Enhancement layer
HDTV	High-definition television
HEVC	High efficiency video code
OTT	Over-the-top
RPR	Reference picture resampling
UHDTV	Ultra-high definition television
VoD	Video on demand
VVC	Versatile Video Coding

1 Introduction

This Report addresses the requirements and methods necessary to maintain the quality of technical operations during the deployment and running of digital terrestrial television broadcasting (DTTB) networks.

This is a vitally important task since neglecting the requirements for maintaining the quality of technical operations over the entire digital broadcasting path will result in significant performance degradation. The detection of failures and the reasons thereof is often quite a difficult problem. That is why the most effective approach is considered to be the application of the technical control of end-to-end path performance with use of the multi-layer open system interconnection (OSI) model to digital broadcasting systems. The control of technical operation quality for digital television broadcasting systems needs to be implemented at the physical, transport, channel, presentation and application levels. This results in the necessity to determine impairment threshold values for the parameters used during monitoring.

Currently, many technical solutions exist for the control of technical operation quality on the different levels of OSI model. However, normative values are practically undefined and limited mainly to specifying permissible input signal levels for digital television broadcasting receivers plus a few other parameters. This leads to sub-optimal operation of the control equipment and may require additional studies to determine the permissible values of those parameters which are subject to control.

Except for direct interference from other stations/services there are other signal impairments (e.g. quadrature impairments, phase noise, non-linear impairments, etc.) which can arise up in the system and which need to be considered in assessing and mitigating degradation over the end-to-end path performance of digital television broadcasting (even in the case where the required signal level is provided). Also it is rather difficult to determine in real time the reasons for signal impairments, which could well be the result of the combined effect of different types of impairments occurring together (e.g. the common influence of average white Gaussian noise (AWGN) and quadrature impairments).

In consideration of the above mentioned factors, the determination of permissible levels of impairments occurring both separately and as a result of common influence is therefore an important task. A further important problem is how to determine the mechanisms involved in signal impairments resulting from separate and common influences of different types and to develop means to limit the adverse impact of these impairments. This also needs to take account of the various technical implementation of digital television broadcasting systems and the various receiving conditions likely to be encountered.

2 Measurement and monitoring principles for digital terrestrial television broadcasting

2.1 Parameters for DTTB performance control

Currently few technical approaches for implementation of control of technical operation quality of DTTB service are defined that mainly differ in layer of OSI model on which the compliance analysis of the received signal to the certain standard structure or values is carried out.

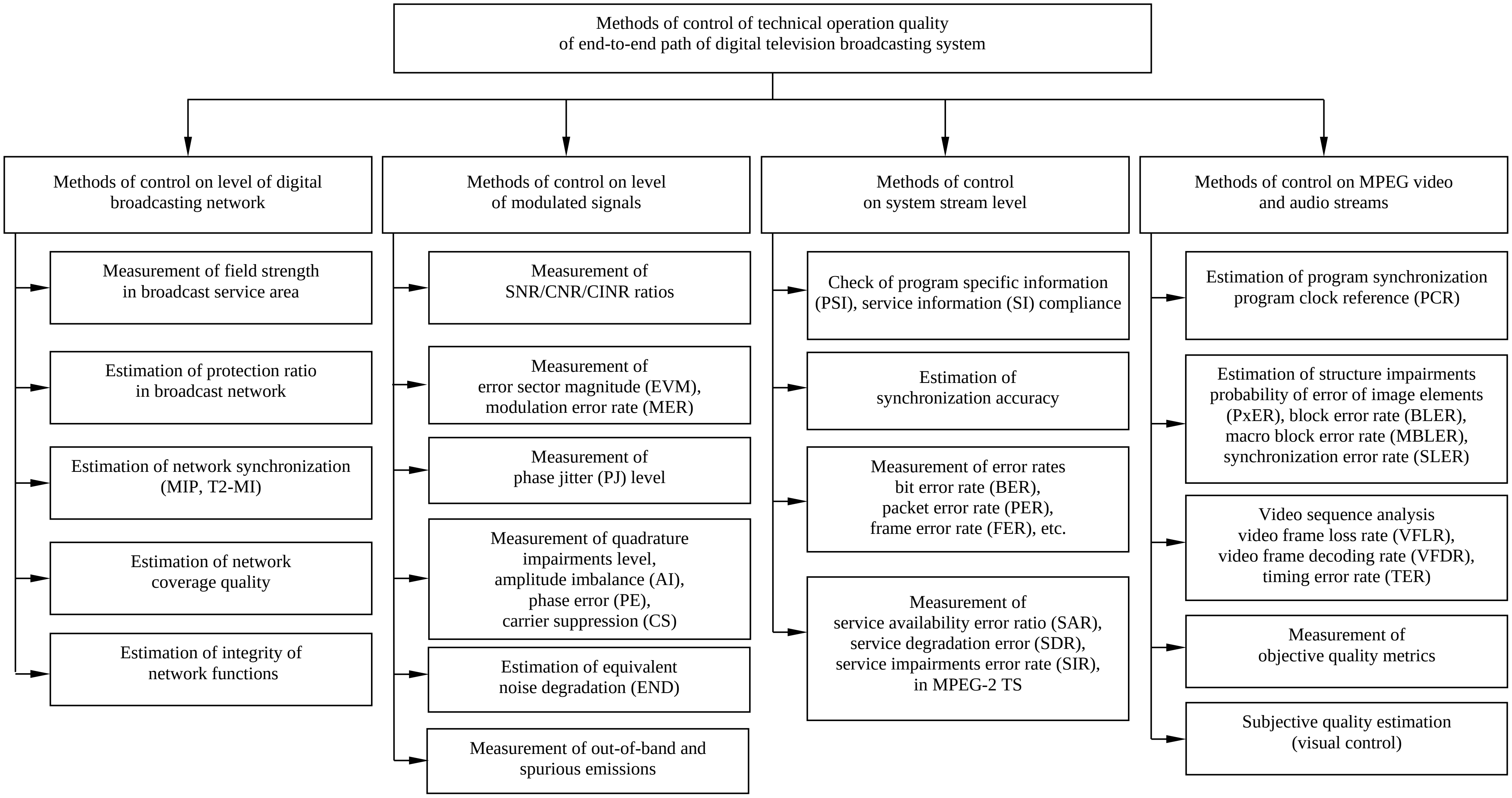
Taking into account complexity of processing of broadcasting program signal in the end-to-end DTTB system path analysis can be carried out on a physical layer (analysis of signal constellation and radio frequency signal), channel/transport layer (analysis of a transport stream of motion picture expert group (MPEG) and/or another type of stream), network layer (analysis of synchronization accuracy of transmitters in a single frequency network, impairment caused by signal interference of transmitters in a network, analysis of coverage quality), presentation layer (analysis of video- and audio streams of MPEG) and at the application layer (visual control or other variants of implementation of control, e.g. automated monitoring).

The result of generalization of existent methods of technical quality control used in DTTB system is given on Fig. 1. According to Fig. 1, methods of technical operation quality control of DTTB system of the digital television broadcasting are divided into four classes:

− methods of control on level of digital broadcasting network;
− methods of control on level of modulated signals;
− methods of control on system stream level;
− methods of control on MPEG video and audio streams.

FIGURE 1

Classification of control methods of technical operation quality of end-to-end path of digital terrestrial television broadcasting system



At the level of DTTB network the control of technical operation quality is commonly implemented as measurement of useful signal field strength in service area with determination to the percent of successful reception points in which a level of signal is within the limits and the signal of DTTB service is decoded are carried out. It is carried out in accordance to procedures with the use of set of measurement equipment that are defined in following ITU-R Recommendations and Reports:

– Recommendation ITU-R BT.1735-1 – Methods for objective reception quality assessment of digital terrestrial television broadcasting signals of System B specified in Recommendation ITU-R BT.1306
– Recommendation ITU-R SM.1875 – DVB-T coverage measurements and verification of planning criteria
– Report ITU-R BT.2035 – Guidelines and techniques for the evaluation of digital terrestrial television broadcasting systems including assessment of their coverage areas
– Report ITU-R BT.2137 – Coverage prediction methods and planning software for digital terrestrial television broadcasting (DTTB) networks
– Report ITU-R BT.2143 – Boundary coverage assessment of digital terrestrial television broadcasting signals
– Report ITU-R BT.2248 – A conceptual method for the representation of loss of broadcast coverage
– Report ITU-R BT.2252 – Objective quality coverage assessment of digital terrestrial television broadcasting signals of Systems A and B
– Report ITU-R BT.2254 – Frequency and network planning aspects of DVB-T2
– Report ITU-R BT.2341 – TV receiver subjective picture failure thresholds and the associated minimum quasi error free levels for good quality reception.

Technical operation quality of DTTB network is also determined by level of interference from other service radio electronic facilities or broadcast transmitters on border of service areas on the receiver input. Interference level is regulated by the corresponding frequency planning and imposing restriction on the technical parameters of radio electronic facilities (radiated power, permissible frequency instability, etc.). ITU-R documents on technical operation quality at this level are following:

– Recommendation ITU-R BT.1368-9 – Planning criteria, including protection ratios, for digital terrestrial television services in the VHF/UHF bands
– Recommendation ITU-R BT.2033 – Planning criteria, including protection ratios, for second generation of digital terrestrial television broadcasting systems in the VHF/UHF bands
– Recommendation ITU-R BT.2052 – Planning criteria for terrestrial multimedia broadcasting for mobile reception using handheld receivers in VHF/UHF bands
– Recommendation ITU-R BT.1895 – Protection criteria for terrestrial broadcasting systems
– Recommendation ITU-R BT.2036 – Characteristics of a reference receiving system for frequency planning of digital terrestrial television systems
– Report ITU-R BT.2382 – Description of interference into a digital terrestrial television receiver.

Another element of control of technical operation quality on network level is estimation of network synchronization that in case of SFN network will determine interference level from the transmitters of nearby service areas.

Documents which determine technical decisions in relation to providing of synchronization of DTTB transmitters are such:

- Report ITU-R BT.2209 – Calculation model for SFN reception and reference receiver characteristics of ISDB-T system
- Report ITU-R BT.2253 – GPS timing receivers for DVB-T SFN application: 10 MHz phase recovery
- Report ITU-R BT.2294 – Construction technique of DTTB relay station network for ISDB-T
- ETSI TS 101 191 – Digital Video Broadcasting (DVB); DVB mega-frame for Single Frequency Network (SFN) synchronization
- ETSI TS 102 773 – Digital Video Broadcasting (DVB); Modulator Interface (T2-MI) for a second generation digital terrestrial television broadcasting system (DVB-T2)
- ETSI TS 102 992 – Digital Video Broadcasting (DVB); Structure and modulation of optional transmitter signatures (T2-TX-SIG) for use with the DVB-T2 second generation digital terrestrial television broadcasting system.

Technical operation quality control of the DTTB systems in all environments of broadcast program distribution (satellite, cable and terrestrial) on the level of modulated signals is defined in ATSC, ISDB, and DVB baseline standards.

Technical operation quality of the DTTB system on level of MPEG video and audio streams is defined by technical quality of transmission and compression of audiovisual information. Among normative documents in this scope it is possible to define the following:

- Recommendation ITU-R BT.1737 – Use of the Recommendation ITU-T H.264 (MPEG-4/AVC) video source-coding method to transport high definition TV programme material
- Recommendation ITU-R BT.1122-2 – User requirements for codecs for emission and secondary distribution systems for SDTV and HDTV
- Recommendation ITU-R BT.1203-1 – User requirements for generic video bit-rate reduction coding of digital TV signals for an end-to-end television system
- Recommendation ITU-R BT.1380-1 – Standards for bit rate reduction coding systems for SDTV
- Recommendation ITU-R BT.1870 – Video coding for digital television broadcasting emission
- Recommendation ITU-R BT.500-13 – Methodology for the subjective assessment of the quality of television pictures
- Recommendation ITU-R BT.813 – Methods for objective picture quality assessment in relation to impairments from digital coding of television signals
- Recommendation ITU-R BT.1676 – Methodological framework for specifying accuracy and cross-calibration of video quality metrics
- Recommendation ITU-R BT.1683 – Objective perceptual video quality measurement techniques for standard definition digital broadcast television in the presence of a full reference
- Recommendation ITU-R BT.1790 – Requirements for monitoring of broadcasting chains during operation
- Recommendation ITU-R BT.1885 – Objective perceptual video quality measurement techniques for standard definition digital broadcast television in the presence of a reduced bandwidth reference

− Recommendation ITU-R BT.1907 – Objective perceptual video quality measurement techniques for broadcasting applications using HDTV in the presence of a full reference signal
− Recommendation ITU-R BT.1908 – Objective video quality measurement techniques for broadcasting applications using HDTV in the presence of a reduced reference signal
− Recommendation ITU-R BT.2073-0 – Use of the high efficiency video coding (HEVC) standard for UHDTV and HDTV broadcasting
− Recommendation ITU-R BT.2021 – Subjective methods for the assessment of stereoscopic 3DTV systems
− Report ITU-R BT.2020 – Objective quality assessment technology in a digital environment
− Report ITU-R BT.2341 – TV receiver subjective picture failure thresholds and the associated minimum quasi error free levels for good quality reception.

As result of conducted analysis it is possible to define such indexes of DTTB technical operation quality on MPEG video- and audio stream level:
− Accuracy of program synchronization (jitter of synchronization signal and error in synchronization signal);
− Temporal parameters of video sequences (video frame loss rate (VFLR), video frame decoding rate (VFDR), timing error rate (TER));
− Objective quality estimation metrics;
− Subjective quality estimation (visual control).

2.2 Monitoring principles for digital terrestrial television broadcasting

Monitoring of DTTB path operation is an important part of technical maintenance. Monitoring allows not only to detect opportunely the origin of failure, degradation of digital quality or status of certain object of monitoring but also to analyse the changes in general status of all broadcasting network on the long time interval and foresee the possible origin of failures or change of the status of monitoring object.

The origin of failure, degradation of digital quality or status for object of monitoring is determined by checking for compliance to the generic standards/specifications with related technical or other norms. The observance of these norms will guarantee the necessary operational quality level of the digital television broadcasting system in most cases.

Depending on the size of digital network the monitoring system can be implemented both as distributed system with separate monitoring centers (in which carry out control of digital network transmitters in a separate region) and as centralized system with control of broadcasting network from one monitoring center.

The automatic hardware monitoring is prevailing approach today. It is increasing efficiency of the monitoring system in terms of operability, amount of objects of simultaneous control and so on. However participation of operator in the process of monitoring remains important and it cannot be fully removed – often there is a necessity of direct co-ordination on failure mitigation and other operations.

Depending on the organizational structure of end-to-end broadcasting path monitoring of digital television broadcasting system operation can be implemented on the output of program stream forming path and also path of primary and secondary distribution of program materials (see Fig. 2). Such monitoring can be conducted by both one organization and several organizations.

Taking into account that a DTTB system model is multi-layered, monitoring can also be implemented on the basis of two approaches – monitoring on one or on several layers. Such layers in most cases are layers of MPEG audio- and video streams (for visual monitoring in most cases but also can be implemented as any other analysis based on the performance estimation of digital video), MPEG transport stream, RF signal and digital network.

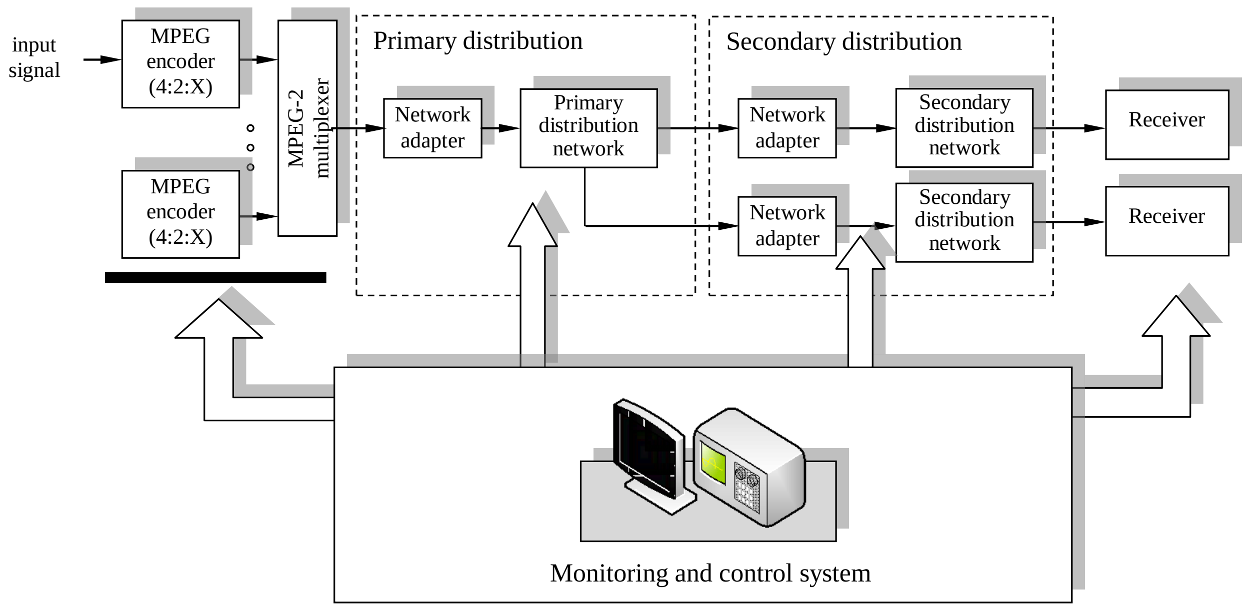
Most effective is approach based on the multi-layered monitoring. It is caused by fact that during processing on the different layers the errors can accumulate and pass from one layer on other and making the detection of reason of their appearing more complicated. Monitoring on several levels can allow to remove this disadvantage of the one-layer monitoring. Parameters that are subject to monitoring on each of layer will be considered in next clauses.

Among ITU-R Recommendations and Reports in direction of implementation of monitoring systems for digital television broadcasting are following:

– Recommendation ITU-R BT.1790 – Requirements for monitoring of broadcasting chains during operation
– Recommendation ITU-R BT.1865 – Metadata to monitor errors of SDTV and HDTV signals in the broadcasting chain
– Recommendation ITU-R BT.2026 – Guidelines on the implementation of systems for in-service objective measurement and monitoring of perceptual transparency for the distribution chain of SDTV and HDTV programmes.

FIGURE 2

Monitoring in different parts of end-to-end path of digital television broadcasting



General requirements to monitoring system are defined in Recommendation ITU-R BT.1790. According to this Recommendation the main requirements for status and quality monitoring, which are essential for reducing the operational burden and realizing advanced and flexible digital broadcasting services, are as follows:

– Capability of in-service monitoring;
– Applicability to the video formats in use such as SDTV, HDTV, UHDTV and 3DTV;
– Applicability to the coding bit rates in use, irrespective of variable bit rate (VBR) or constant bit rate (CBR);

– Applicability to the transmission bit rates in use;
– Applicability to the coding parameters and tools (e.g. profile/level, picture structure, range of motion vectors) in use;
– Applicability to different sources of degradation (e.g. compression ratio and transmission error rate);
– Traceability of the causes of malfunction, failure and degradation;
– Availability of precise information for switching to a reserve system from the monitoring result.

More detailed information on system requirements to system for monitoring of status and quality and to the corresponding equipment is also provided in this Recommendation.

One of the approaches to practical implementation of the system for monitoring of quality in television production path, based on the use of metadata is provided in Recommendation ITU-R BT.1865. It consists in that during passing of audiovisual content in end-to-end production path metadata is inserted in monitoring points. Such metadata contains information on the current results of analysis of content obtained by certain algorithm. In further, by comparing the current and upstream metadata, the audio and video signals are monitored to determine if any problems have occurred. Basic principles of system implementation for in-service objective measurement and monitoring of perceptual transparency for the distribution chain of SDTV and HDTV programmes and guidelines on usage of ITU-R Recommendations/Reports listed in current and previous clauses are provided in Recommendation ITU-R BT.2026.

Out of studio environment, for monitoring of digital television broadcasting system the one of the most widespread technical solutions is simple network management protocol (SNMP). This protocol is based on the use of management information base (MIB) which is a unified tool for exchange of diagnostic and other information on the objects of management. Except that the MIB base can be adapted under the particular user requirements in relation to functionality of the monitoring system. In most cases the MIB base is provided by manufacturers of broadcast equipment or organizations on standardization of broadcasting technologies with the purpose of determination of general principles or compatibility between the management equipment of different manufacturers. As example is ETSI TS 102 032 that contains the SNMP MIB base for test and measurement applications in DVB systems.

Other variant of monitoring implementation is usage of virtual monitoring channel based on MPEG-2 transport stream. This variant uses the special service information tables that contain the special diagnostic information on status of monitoring object and results of the certain measurement which directly specify the quality indicator(-s) (e.g. BER) for digital television broadcasting system. Example of practical implementation of such approach to monitoring is provided in ETSI TR 10 291.

3 Baseband measurements and analysis of MPEG-2 transport streams

3.1 Common measurements and analysis procedures

One of the tasks decided during control of broadcast network operation quality is monitoring of transport stream. Degree of decidability and type of errors in transport stream is a quite reliable indicator of broadcast transmission quality of services that allow to implement monitoring with high level of reliability.

Set of controlled measurement parameters in MPEG-2 transport stream is defined in ETSI TR 101 290. The following assumptions and guiding principles were used in developing these tests:

− the tests are mainly intended for continuous or periodic monitoring of MPEG-2 TSs in an operational environment;

− these tests are primarily designed to check the integrity of a TS at source;

− the tests are consistent with the MPEG-2 Conformance tests defined in ISO/IEC 13818-4.

All measurements related to MPEG-2 transport stream analysis for detection of errors and non-conformity is conducted in transport demultiplexer input. During measurements in MPEG-2 transport stream on receiving side the analysis of its structure compliance to a standard transport stream or compliance to transmitted service information to standard service information is conducted.

Errors depending on importance for MPEG-2 transport stream recovery are classified to three priorities in accordance to ETSI TR 101 290:

− priority 1 – transport stream is not decoded;

− priority 2 – transport stream is partly decoded;

− priority 3 – transport stream contains errors in service information but decodable.

In case of errors with priority 1 the synchronization for processing of received MPEG-2 transport stream becomes impossible and recovery of particular program stream is fail.

Errors with priority 2, unlike errors with priority 1, it is possible to decode the program stream but during this process some errors are appearing or other auxiliary services in MPEG-2 TS will be partly or fully un-decodable.

Presence of errors with priority 3 in MPEG-2 transport stream indicates presence of errors in service information but such errors not so critical for recovery/decoding.

Detailed information on errors with different priorities for ITU-R System B is provided in ETSI TR 101 290. Generalized classification of errors in MPEG-2 TS with indication of impact on recovery/ decoding process is provided in Table 1.

Statistics of errors with different priorities can be used for performance evaluation and monitoring of DTTB service. Such indexes of broadcast network quality of service (QoS) defined in ETSI TR 101 290 are following:

− time interval of service un-availability for correct reception;

− degree of degradation of service reception quality;

− degree of impairment impact to broadcast signal reception and processing.

According to selected criteria and error statistic analysis number of corresponding errors is defined (Service_Availability_Error, Service_Degradation_Error and Service_Impairments_Error). As result of analysis of change in time of such errors the service technical operation quality is evaluated.

Methodology for evaluation is defined in Tables 2 to 4.

TABLE 1

Classification of transmission errors in MPEG-2 transport stream

Error priority	Error type	Impact on recovery/decoding
1	TS_sync_loss	Loss of synchronization during processing of transport stream
	sync_byte_error	Error in sync byte (-s), it is impossible to correctly decode the transport packet. Considering that processing of transport packet payload is based on sync byte successful recovery of any information is practically unreachable.
	PAT_error	Program association table (PAT) contains errors or does not occur at least every 0,5 s (max transmission interval for PAT). Recover of any service stream from MPEG-2 TS is impossible.
	Continuity_count_error	Not valid demultiplexing of elementary streams
	PMT_error	Program map table (PMT) contains errors or does not occur at least every 0.5 s (max transmission interval for PMT). Incorrect configuration of MPEG video and/or audio decoder due to incorrect definition of stream type and compression method can lead to failure of decoding.
	PID_error	Error in PID leads to selection of incorrect elementary stream with “wrong” packet identifier
2	Transport_error	Packet contains uncorrected errors and this leads to failure during recovery of related payload
	CRC_error	PSI/SI table contain errors (according to results of CRC analysis) and corresponding table section or current table is discarded and decoder waits for next repetition of information transmission
	PCR_error	Loss of synchronization in MPEG encoder or decoder
	PCR_accuracy_error	Loss of synchronization during processing in MPEG encoder or decoder that leading to some degradation (jitter in audio/video synchronization, etc.)
	PTS_error	Loss of synchronization during presentation of audio-visual content
2	CAT_error	Conditional access table (CAT) contains errors or does not occur during specified max transmission interval. In case of CA-based systems this leads to loss of access to service-related information during interval between consecutive CA control messages.
3	NIT_error	Network information table (NIT) contains errors or does not occur during specified max transmission interval. Such error leads to loss of network information but this not so critical for MPEG video decoding
	SI_repetition_error	Time for recovery of corresponding PSI/SI table is increased that causes some delay for access to service (sometimes not critical for user).
	Buffer_error	Buffer overload, possible loss of data
	Empty_buffer_error	Receiver buffer filling is insufficient.
	Unreferenced_PID	Decoder can’t access to required elementary stream due to PID unreferenced in any permitted ID set
	EIT_error	Description of events (such information is transmitted in EIT table) becomes unavailable or limited in current or other transport streams
	EIT_actual_error	
	EIT_other_error	
	EIT_PF_error	

TABLE 2

Service evaluation with criteria based on service availability

Purpose	To identify severe distortions and interruptions of the service under certain receiving conditions. The parameter is related to the loss of the service.
Test point	Input of transport demultiplexer
Method	Count the occurrence of error messages for the following parameters over a defined time interval ΔT (e.g. 10 s): 1) TS_sync_loss 2) PAT_error 3) PMT_error For each time interval ΔT, the following differences are calculated (which correspond to the derivation of the increasing function related to the occurrence of the concerned errors): TS_sync_loss (ΔT) = TS_sync_loss (T) – TS_sync_loss ($T - \Delta T$) PAT_error (ΔT) = PAT_error (T) – PAT_error ($T - \Delta T$) PMT_error (ΔT) = PMT_error (T) – PMT_error ($T - \Delta T$) Then Service Availability Error value is calculated: Service_Availability_Error = max{TS_sync_loss (ΔT), PAT_error (ΔT), PMT_error (ΔT)}, or $$\text{SAR} = \max\left(\sum_{i=1}^{N_{T1}} Q_{SAR_i}(T) - \sum_{i=1}^{N_{T2}} Q_{SAR_i}(T - \Delta T)\right),$$ where: $Q_{SAR_i}(T)$ quality index calculated for errors used for estimation of service availability error N_{T1} number of errors during interval T_1 N_{T2} number of errors during interval T_2. Results are displayed over an appropriate period, e.g. 10 minutes, and calculate SAR as the percentage of time for which the parameter exceeds a pre-defined threshold.

TABLE 3

Service evaluation with criteria based on service signal degradation

Purpose	To identify severe degradation under certain receiving conditions. This parameter is related to the level of strong impairments of the service.
Test point	Input of transport demultiplexer
Method	Count the occurrence of error messages for the following parameters over a defined time interval ΔT (e.g. 10 s): 1) CRC_ error 2) PCR_error 3) NIT_error 4) SDT_error For each time interval ΔT, the following differences are calculated (which correspond to the derivation of the increasing function related to the occurrence of the concerned error): CRC_error (ΔT) = CRC_error (T) – CRC_error.($T - \Delta T$) PCR_error.(ΔT) = PCR_error.(T) – PCR_error.($T - \Delta T$) NIT_error.(ΔT) = NIT_error.(T) – NIT_error.($T - \Delta T$) SDT_error.(ΔT) = SDT_error.(T) – SDT_error.($T - \Delta T$)

TABLE 3 (*end*)

	Then Service_Degradation_Error value is calculated: Service_Degradation_Error = max {CRC_error (Δ*T*), PCR_error (Δ*T*), NIT_error (Δ*T*), SDT_error (Δ*T*)}, or $$\mathrm{SDR} = \max\left(\sum_{i=1}^{N_{T1}} Q_{SDR_i}(T) - \sum_{i=1}^{N_{T2}} Q_{SDR_i}(T-\Delta T)\right),$$ where: $Q_{SDR_i}(T)$ quality index calculated for errors used for estimation of service degradation error N_{T1} number of errors during interval T_1 N_{T2} number of errors during interval T_2. Results are displayed over an appropriate period, e.g. 10 minutes, and calculate SDR as the percentage of time for which the parameter exceeds a pre-defined threshold.

TABLE 4

Service evaluation with criteria based on service signal impairment

Purpose	To identify first signs of service degradation under certain receiving conditions. The parameter is related to infrequent impairments of the service.
Test point	Input of transport demultiplexer
Method	Count the occurrence of error messages for the following parameters over a defined time interval Δ*T* (e.g. 10 s): 1) Continuity_count_error 2) Transport_error For each time interval Δ*T*, the following differences are calculated (which correspond to the derivation of the increasing function related to the occurrence of the concerned errors): Continuity_count_error(Δ*T*) = Continuity_count_error(*T*) – Continuity_count_error(*T* − Δ*T*) Transport_error (Δ*T*) = Transport_error (*T*) – Transport_error (*T* − Δ*T*) Then Service_Impairments_Error value is calculated: Service_Impairments_Error = max {Continuity_count_error, Transport_error}, or $$\mathrm{SIR} = \max\left(\sum_{i=1}^{N_{T1}} Q_{SIR_i}(T) - \sum_{i=1}^{N_{T2}} Q_{SIR_i}(T-\Delta T)\right),$$ where: $Q_{SDR_i}(T)$ quality index calculated for errors used for estimation of service impaiment error N_{T1} number of errors during interval T_1 N_{T2} number of errors during interval T_2. Results are displayed over an appropriate period, e.g. 10 minutes, and calculate Service_Impairments_Error_Ratio as the percentage of time for which the parameter exceeds a pre-defined threshold.

For the purpose of these measurements, it may be useful to define several performance classes in relation with the perceived quality-of-service (pQoS). Example that may be used for video and audio services is given in Table 5.

TABLE 5

Examples of perceived quality-of-service

Performance Class	Interpretation
1	High pQoS, no distortions
2	Good pQoS, few impairments.
3	Low pQoS, repeated impairments.
4	Very low pQoS, repeated interruptions of services.
5	Repeated loss of service, impossible to follow any programme

An example for the definition of different reception conditions is provided in Table 6.

The figures in this example are not generally applicable. They may be defined by network operators or service providers to quantify availability and/or performance of a service.

Another method for estimation of performance of digital television broadcasting path is estimation of system availability, link availability, and system error performance for distribution networks such as satellite, cable, terrestrial and microwave systems as well as for contribution networks. ETSI TR 101 290 gives definition for such parameters as defined in Table 7.

TABLE 6

Example of receiving condition classification

Receiving conditions	Criteria
Very good reception quality (pQoS), no visible or audible impairments for several minutes	Service_Availability_Error at Performance Class 1 for 100 % of the time Service_Degradation_Error at Performance Class 1 for 100 % of the time Service_Impairments_Error at Performance Classes 1-2 for 95 % of the time
Very bad reception conditions	Service_Availability_Error at Performance Classes 2-5 for 75 % of the time, Service_Degradation_Error at Performance Classes 2-5 for 95 % of the time, Service_Impairments_Error at Performance Classes 3-5 for 95 % of the time

TABLE 7

Error events according to ETSI TR 101 290

Severely disturbed period (SDP):	A period of sync loss or loss of signal.
Errored block (EB):	An MPEG-2 TS packet with one or more uncorrectable errors, which is indicated by the transport_error_indicator flag set.
Errored time interval (ETI):	A given time interval with one or more EBs.
Errored second (ES):	A specific case of the ETI where the given time interval is one second.
Severely errored time interval (SETI):	A given time interval which contains greater than a specified percentage of errored blocks, or at least one SDP or part thereof.

TABLE 7 (*end*)

Severely errored second (SES):	A specific case of the SETI where the given time interval is one second.
Unavailable time (UAT)	A start of a period of UAT can be defined as: – either the onset of N consecutive SES/SETI events; or – the onset of a rolling window of length *T* in which *M* SES/SETI events occur. These time intervals/seconds are considered to be part of the UAT. A end of period of UAT can be defined accordingly as: – the onset of *N* consecutive non-SES/SETI events; or – the onset of a rolling window of length *T* in which no SES/SETI events occur. These time intervals/seconds are considered to be part of available time. The values *N*, *M* and *T* could differ for different types of service (video, audio, data, etc.).

Considering that set of PSI/SI information is slightly different in current DTTB systems additional error types are defined. System-specific errors (for ITU-R Systems) that mainly errors of third priority are defined in §§ 3.2 to 3.5 of this Report.

3.2 ATSC-specific measurements for transport stream

ATSC-specific service information tables are referred as program and system information protocol (PSIP). During development of ATSC series of standards for cable and terrestrial environments for delivery of digital broadcasting programmes it was decided to define additional service information tables. Such tables are relating to master guide table (MGT), extended text table (ETT), system time table (STT), rating regional table (RRT), cable virtual channel table (CVCT), terrestrial virtual channel table (TVCT). Accordingly, errors in such service information tables will be controlled. Such ATSC-specific errors are provided in Table 8.

TABLE 8

ATSC-specific errors in transport stream

Type of error	Impact on recovery/decoding
MGT_error	MGT contains PID's for some of ATSC-specific tables, so error in MGT leads to lack of such information
STT_error	STT contains information that define difference GPS time and time difference between GPS time and UTC so any timing information becomes unavailable
RRT_error	RRT contains information about permitted audience age or region so in case of error such information becomes unavailable
TVCT_error & CVCT_error	TVCT and CVCT tables are containing information about program streams referred as virtual channels in multiplexed streams. So if error condition appearing such information becomes unavailable or limited
ETT_error	Detailed description of TV channels and events becomes unavailable

For more details on ATSC-specific measurements in MPEG-2 transport stream see ATSC Recommended Practice A/78: Transport Stream Verification.

3.3 DVB-specific measurements for transport stream

In DVB systems the additional set of service information tables such as network information table (NIT), service description table (SDT), bouquet association table (BAT), running status table (RST), time and date table (TDT), time offset table (TOT) and stuffing table (ST) are defined. Measurements based on integrity estimation of such service information tables are specific to DVB systems. Information about DVB-specific errors in service information is provided in Table 9.

TABLE 9

DVB-specific errors in transport stream

Type of error	Impact on recovery/decoding
SDT_error	Description of services available to the viewer becomes unavailable or limited in current or other transport streams
SDT_actual_error	
SDT_other_error	
RST_error	Quick updating mechanism for the status information carried in the EIT is unavailable or limited
TDT_error	Error in current UTC time and date information

Besides some errors related to basic set of errors of Table 1 is standard-specific in case of DVB (or ISDB or ATSC or DTMB). For example, Unreferenced_PID error is appearing either due to error in table ID of SDT, EIT or other table, or due to error ID corresponds to ID of any service information table used only in corresponding broadcasting standard.

3.4 ISDB-specific measurements for transport stream

Series of ISDB standards is defining specific service information tables. Such tables are local information table (LIT), event relation table (ERT), index transmission table (ITT), partial content announcement table (PCAT), stuffing table (ST), broadcaster information table (BIT), network board information table (NBIT), linked description table (LDT), download control table (DCT), download table (DLT), selection information table (SIT), software download trigger table (SDTT). ISDB-specific errors in transport stream are defined in Table 10.

TABLE 10

ISDB-specific errors in transport stream

Type of error	Impact on recovery/decoding
LIT_error	Loss of information related to the local event (program segment event) included in each event (program).
ERT_error	Loss of information related to ERT that describes the relation among the events (programs) and/or local events (program segment events).
ITT_error	The index transmission information table describes information to be used for transmission of program index of an event (program). Error leads to loss of such information

TABLE 10 (*end*)

Type of error	Impact on recovery/decoding
PCAT_error	PCAT includes starting time and continuing time of partial content in accumulated data broadcasting. This error leads to loss or limiting access to services of data broadcasting
ST_error	the ST is used to invalidate existing sections, for example at delivery system boundaries. This error leads to situation where such operations are impossible.
BIT_error	the BIT includes broadcaster unit comprising network or SI transmitting parameter information for each broadcaster. Corresponding error leads to situation where such information is unavailable.
NBIT_error	the NBIT includes board information in network and reference information for acquiring the board information. Corresponding error leads to situation where such information is unavailable.
LDT_error	the LDT includes various collected data for reference from other tables. Due to error such references are lost.

3.5 DTMB-specific measurements for transport stream

DTMB systems define the service information tables such as network information table (NIT), service description table (SDT), event information table (EIT), time and date table (TDT). The information about DTMB-specific errors in service information are provided in Table 11.

TABLE 11

DTMB-specific errors in transport stream

Type of error	Impact on recovery/decoding
NIT_error	NIT contains errors or does not occur during specified max transmission interval. Such errors lead to loss of network information
NIT_actual _error	
NIT_other _error	
SDT_error	Description of services available contains errors or does not occur during specified max transmission interval. Such errors lead to unavailable description of services to the viewer in current or other transport streams.
SDT_actual_error	
SDT_other_error	
EIT_error	Description of events in EIT table contains errors or does not occur during specified max transmission interval. Such errors lead to unavailable description of events or limited in current or other transport streams.
EIT_actual_error	
EIT_other_error	
TDT_error	Error in current UTC time and date information.

In Table 11, NIT_other, SDT_other and EIT_other are transmitted and measured alternatively only when they occur in the transport stream. Time offset table (TOT) representing local time offset can be also transmitted besides TDT and measured only when it is occurred in the transport stream.

3.6 Set of measurement equipment

For analysing performance of digital television broadcasting in different parts of end-to-end path on MPEG-2 transport stream portable (mainly for field tests) or full-size transport stream analyser is needed.

In most cases as input such analysers are using asynchronous serial interface (ASI) input or directly RF signal input but in case that transport stream analyser is a part of measurement receiver with corresponding demodulator (satellite, cable or terrestrial).

Besides due to some differences in MPEG-2 transport stream structure for DVB, ATSC and ISDB systems the support of corresponding broadcasting standard is needed for providing full range of measurements.

3.7 Examples of technical quality evaluation

Examples of technical quality evaluation on MPEG transport stream level that can be useful for Administrations are provided in Annex 1 to this Report.

4 Baseband measurement and analysis of non-MPEG streams

Baseband measurement and analysis specific for non-MPEG streams (e.g. GSE, T2-MI streams) may be provided.

5 System measurement and analysis for digital terrestrial television broadcasting

5.1 Common RF/IF measurements

During control at the level of digital modulated signals the basic parameters of technical operational quality of DTTB systems are:

- signal-to-noise ratio (SNR), carrier-to-noise ratio (CNR) and carrier-to-(interference + noise) ratio (CINR);
- error vector magnitude (EVM) and modulation error ratio (MER);
- level of quadrature impairments characterized by amplitude imbalance (AI), phase error (PE) (also called quadrature error (QE)) and degree of carrier suppression (CS) of I/Q -components in M-QAM signal;
- phase jitter (PJ);
- equivalent noise degradation (END);
- level of out-of-band and spurious emission (shoulder attenuation).

After estimation of SNR, CNR and CINR in broadcasting channel the measured value is compared with a necessary (threshold) value at which the DTTB system will work in quasi-error-free mode (QEF). Besides not only absolute value is important but also difference between measured and necessary value. The threshold values of CNR and SNR for different DTTB systems are defined corresponding normative documents.

Common modulation quality is estimated by two parameters:

- modulation error ratio (MER);
- error vector magnitude (EVM).

MER is computed to include the total signal degradation likely to be present at the input of a receiver's decision circuits and so give an indication of the ability of that receiver to correctly decode the signal. Estimation of MER is based on information about N pair of received (Ij, Qj) coordinates. Ideal position of the symbol (centre of decision block) is represented as vector (Ij, Qj).

A vector $(\delta I_j, \delta Q_j)$ is determined as distance between ideal and measured position of received symbol. In other words, a received vector $(\bar{I}_j, \bar{Q}_j)$ is the sum of ideal vector (*Ij*, *Qj*) and error vector (Fig. 3).

The sum of the squares of the magnitudes of the ideal symbol vectors is divided by the sum of the squares of the magnitudes of the symbol error vectors. The result, expressed as a power ratio in dB, is defined as the modulation error ratio (MER):

$$MER = 10 \times \log_{10}\left\{\frac{\sum_{j=1}^{N}(I_j^2+Q_j^2)}{\sum_{j=1}^{N}(\int \delta I_j^2+\delta Q_j^2)}\right\} \tag{1}$$

$$MER = \sqrt{\frac{\sum_{j=1}^{N}(I_j^2+Q_j^2)}{\sum_{j=1}^{N}(\delta I_j^2+\delta Q_j^2)}} \tag{2}$$

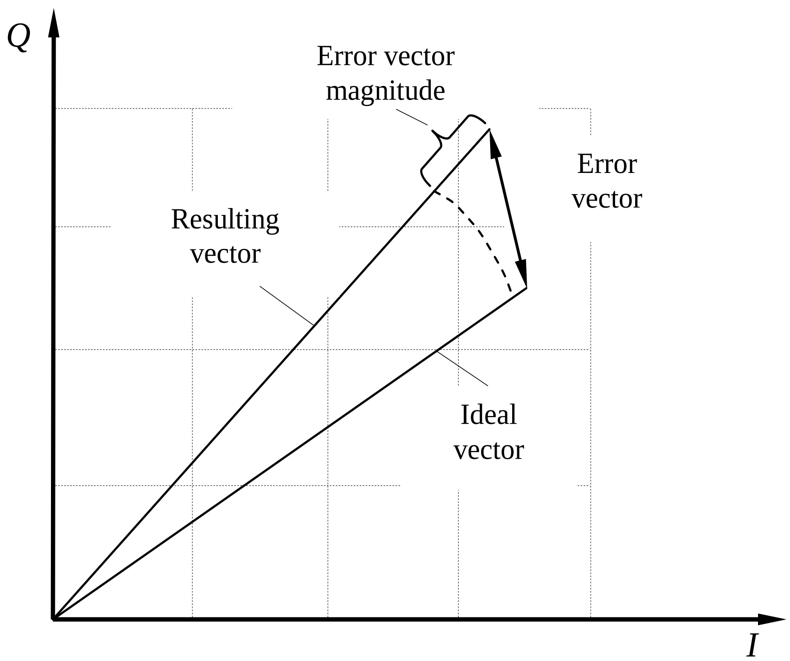
$$EVM = \frac{1}{S_{max}}\sqrt{\frac{1}{N}\sum_{j=1}^{N}(\delta I_j^2 + \delta Q_j^2)} \tag{3}$$

where:

S_{max}: maximal value of absolute value of vectors (*Ij*, *Qj*).

FIGURE 3

Error vector calculation



Since higher-order QAMs (e.g. 256 or higher QAMs) have shorter symbol distances than lower-order QAMs, ideal vectors may be detected erroneously as shown in Fig. 4, which leads to calculation of incorrect MER as shown in Fig. 5. The linearity of MER against *C*/*N* deteriorates for higher-order QAMs, and MER becomes larger than the actual signal quality. Some methods that address the problem for higher order QAMs are described in Annex 1.

FIGURE 4

Calculation error in higher order modulation

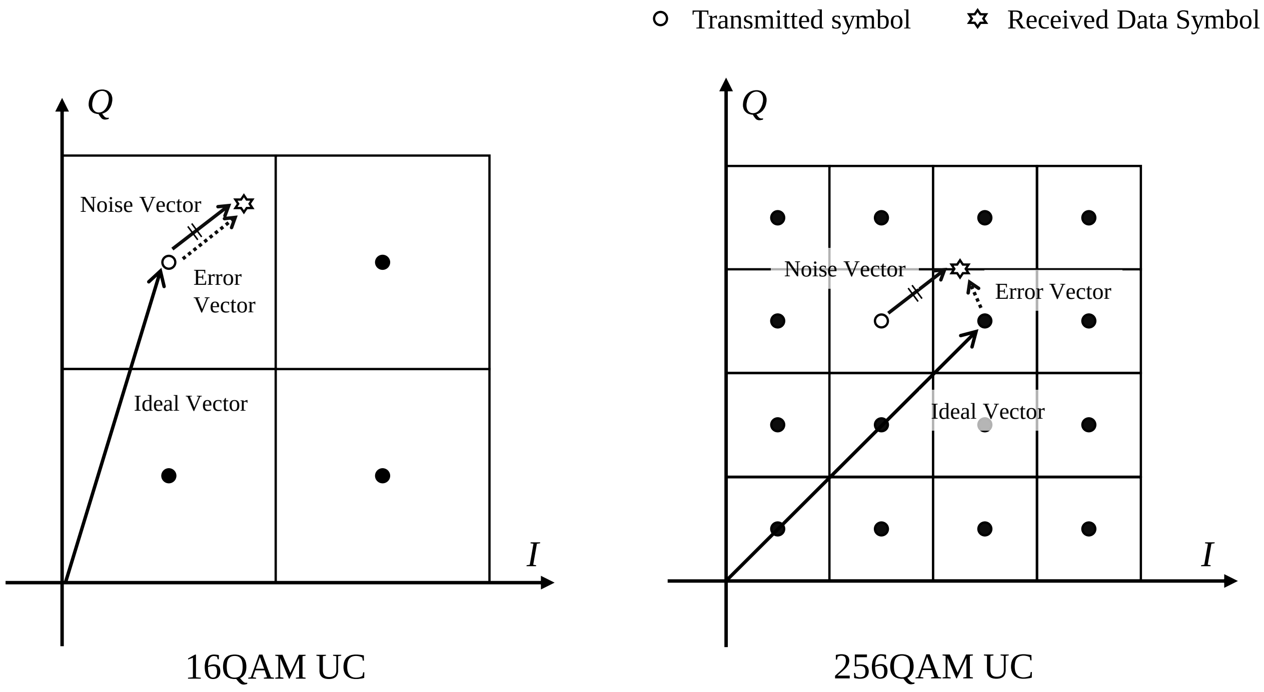
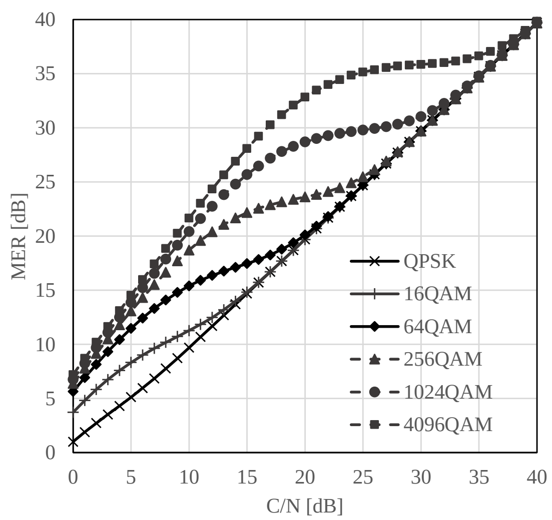


FIGURE 5

Relation of *C*/*N* vs. MER with conventional calculation method



Except an instantaneous value of MER the root-mean-square (RMS) and percentile (e.g. at 99% of observation time) values are also used.

Amplitude imbalance of *I*/*Q* signals is appearing in quadrature modulator/demodulator. In case of amplitude imbalance length of vectors of modulated signal vector on constellation diagram are different and partly compensated in quadrature modulator/demodulator. This leads to variation of constellation point location with some trajectory from nominal position and demodulation errors are appearing.

At presence of amplitude imbalance the M-QAM constellation is "compressed" along one of axes (In-phase or Quadrature) of *I*/*Q* complex plane. Example of this ideal and distorted constellation for DVB-T is provided on Fig. 6.

Magnitude of amplitude imbalance of *I*/*Q*-signals is estimated as follows:

$$AI = \left| \frac{v_2}{v_1} - 1 \right| \cdot 100\ \% \tag{4}$$

where:

ν_1 length of rectangle side formed by constellation points which is located along an I-axis

ν_2 length of rectangle side formed by constellation points which is located along an Q-axis.

The phases of the two carriers feeding the *I* and *Q* modulators have to be orthogonal. If their phase difference is not 90° a typical distortion of the constellation diagram results. The receiver usually aligns its reference phase in such a way that the 90° error ($\Delta\varphi$) is equally spread between φ_1 and φ_2 (Fig. 7).

FIGURE 6

Constellation diagram for 64-QAM in DVB-T system
a) ideal constellation b) constellation with amplitude imbalance

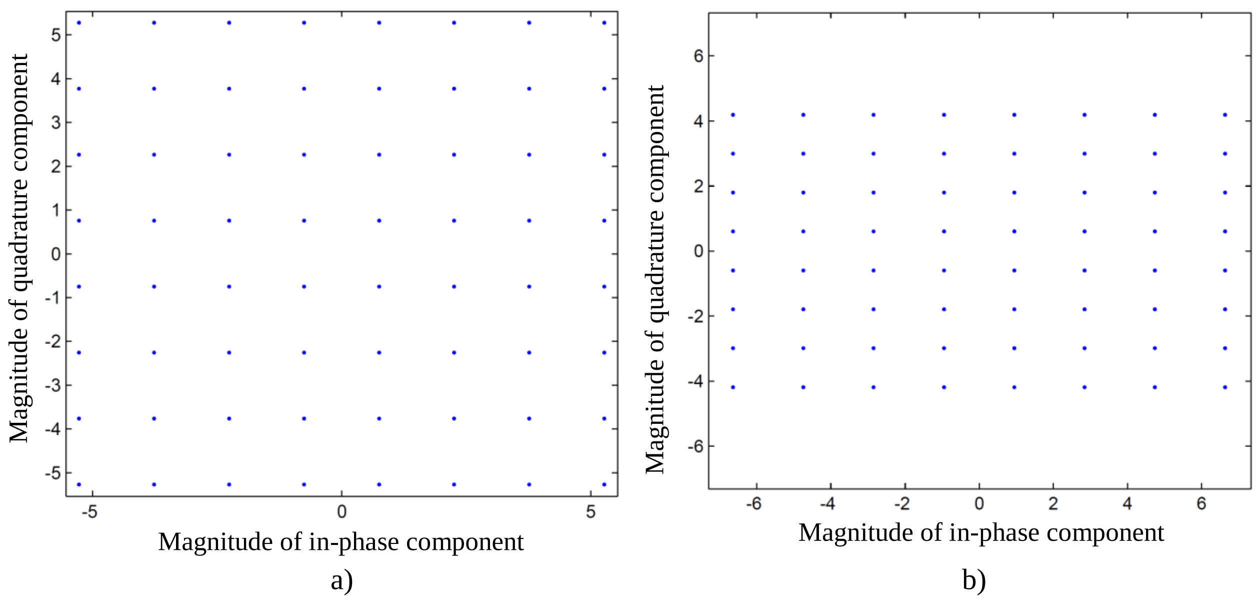
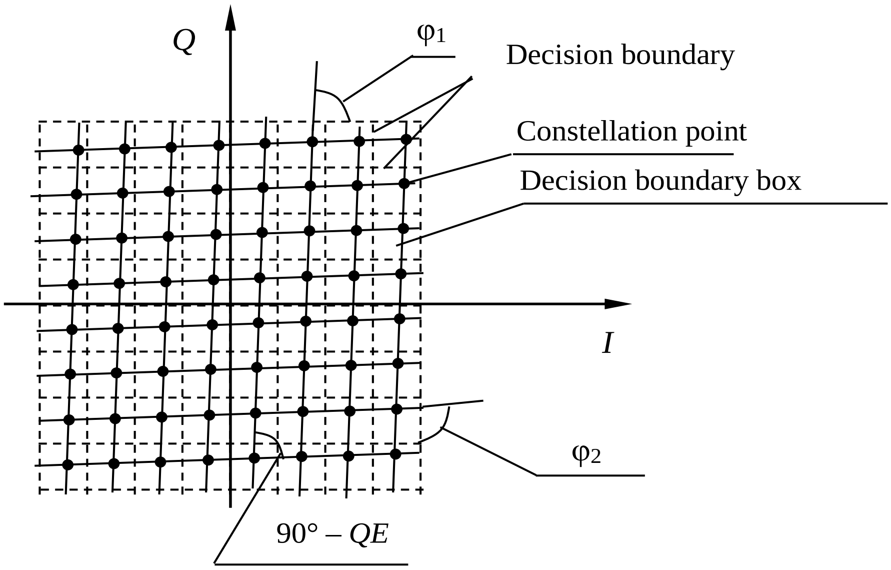


FIGURE 7

Distortion of constellation diagram resulting from *I*/*Q* quadrature error (QE)



Absolute value of quadrature error $\Delta\varphi = |\varphi_1 - \varphi_2|$ is defined as following:

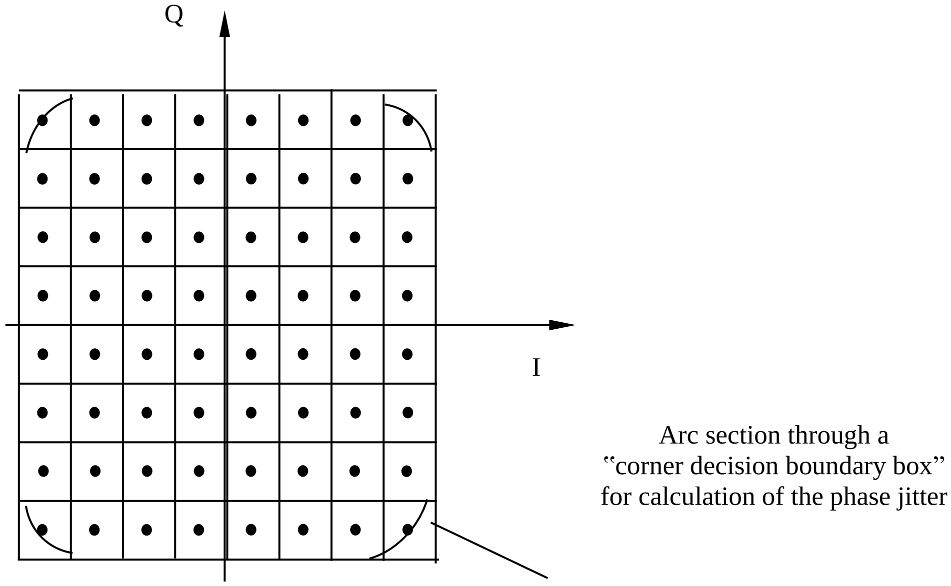
$$QE = \frac{180^\circ}{\pi} \sum |\varphi_1 - \varphi_2|, \text{ degrees} \quad (5)$$

The phase jitter (PJ) of an oscillator is due to fluctuations of its phase or frequency. Using such an oscillator to modulate a digital signal results in a sampling uncertainty in the receiver, because the carrier regeneration cannot follow the phase fluctuations.

The signal points are arranged along a curved line crossing the centre of each decision boundary box as shown in Fig. 8 the four "corner decision boundary boxes".

FIGURE 8

Position of arc section in the constellation diagram to define the PJ (example: 64-QAM)



The PJ can be calculated theoretically using the following algorithm:

For every received symbol:

1) Calculate the angle between the I-axis of the constellation and the vector to the received symbol ($\tilde{I}$, $\tilde{Q}$)

$$\varphi_1 = \arctan\frac{\tilde{Q}}{\tilde{I}} \tag{6}$$

2) Calculate the angle between the I-axis of the constellation and the vector to the corresponding ideal (I, Q)

$$\varphi_2 = \arctan\frac{Q}{I} \tag{7}$$

3) Calculate the error angle:

$$\varphi_E = \varphi_1 - \varphi_2 \tag{8}$$

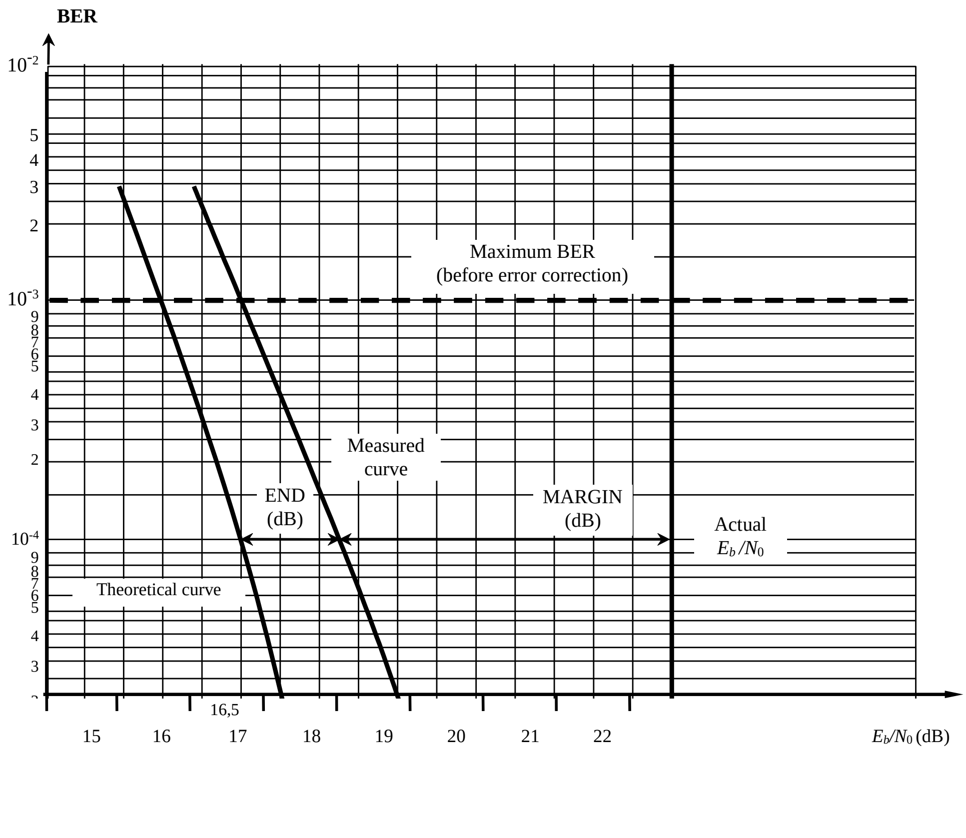
From these N error angles calculate the RMS phase jitter:

$$PJ = \sqrt{\frac{1}{N}\sum_{i=1}^{N}\phi_{E_i}^2 - \frac{1}{N^2}\left(\sum_{i=1}^{N}\phi_{E_i}\right)^2} \tag{9}$$

Equivalent noise degradation (END) is another parameter used for system performance estimating. Figure 9 is not the true theoretical curve representing BER for some abstract system. The END is obtained from the difference in dB of the C/N or E_b/N_0 ratio needed to reach a BER corresponding to QEF mode and the C/N or E_b/N_0 ratio that would theoretically give a BER corresponding to QEF mode, for a Gaussian channel. Considering that phase noise, interference and other noise-like processes this parameter can be used for impact estimation of any type of noise.

FIGURE 9

Measurement of equivalent noise degradation



Important parameters which characterizes technical operational quality of DTTB systems is a BER. BER is defined for all stages of error correction for estimation of FEC performance using equation (10):

$$\text{BER} = \frac{1}{N}\sum_{i=1}^{N}\left|b_i - b_i'\right| \qquad (10)$$

where:

b_i sequence of bits of transmitted stream

b_i' sequence of bits of received stream.

Usually BER is estimated before and after an internal channel decoder. Such approach provide short-term estimation and commonly used in broadcast practice.

Example of BER requirements for DVB systems is provided in Table 12.

TABLE 12

BER requirements in DVB systems of the first and second generations

System	BER		
	Before Viterbi decoder	**Before Reed-Solomon decoder**	**After Reed-Solomon decoder**
DVB-C	–	$\leq 1 \cdot 10^{-4}$	$\leq \left(1 \cdot 10^{-11}..1 \cdot 10^{-12}\right)$
DVB-S	$7 \cdot 10^{-2}..7 \cdot 10^{-3}$	$\leq 2 \cdot 10^{-4}$	
DVB-T			
	Before LDPC decoder	**Before BCH decoder**	**After BCH decoder**
DVB-C2	$1 \cdot 10^{-2}..1 \cdot 10^{-3}$	$\leq 1 \cdot 10^{-7}$	$\leq \left(1 \cdot 10^{-11}..1 \cdot 10^{-12}\right)$
DVB-S2			
DVB-T2			

Currently for DTTB systems the generally accepted practice is to estimate the packet error ratio (PER) and the frame error ratio (FER).

5.2 ATSC-specific measurements

In general practically all measurements defined in previous clause are applicable to ATSC system because of maximum commonality (not full) between digital terrestrial television systems. Estimation of impact for AWGN, multipath components, amplitude and phase distortions, non-linearity and interference are basic measurements during technical maintenance for ATSC system equipment. But there are some differences in such basic measurements due to ATSC-specific processing. Such differences are related to measurements of BER (due to trellis-coded modulation), analysis of spectrum (due to frequency parameters applied for ATSC and VSB modulation), constellation-based measurements (impact estimation of AWGN, *I*/*Q* amplitude and phase errors, phase noise, etc.).

More information for measurements in ATSC system is provided in following documents:

– ATSC Recommended Practice A/64B: Transmission measurement and compliance for digital television;

– ATSC Recommended Practice A/74: Receiver performance guidelines;

– IEEE Std 1631-2008: IEEE Recommended practice for measurement of 8-VSB digital television transmission mask compliance for the USA.

5.3 DVB-specific measurements

Differences in measurements related to DVB-T system are practically the same that in ATSC system. COFDM is used in DVB-T system so there are some measurements specific to this multicarrier modulation and structure of RF signal with parameters applied in European countries. Some measurements require estimation of impairments on single or all carriers (for example, MER measurement is often applied on all carriers for interferer impact estimation).

Basic measurements for DVB-T system are including of AWGN impact estimation, constellation-based analysis (phase jitter, *I*/*Q* errors), spectral mask analysis, RF frequency measurements (RF frequency accuracy, RF channel width, Symbol Length measurement at RF). Measurement of amplitude, phase and group delay is based on reference pilots in OFDM signal. Another DVB-specific measurement in comparison to ATSC is crest factor estimation due to high Peak-to-Average Ratio (PAR) of COFDM signal.

As for DVB-T2 system, measurements include (additionally to measurements in DVB-T system) additional power measurements (MISO group power ratio, signal to interference noise ratio, etc.), error ration estimations (P1 symbol error rate, BER before LDPC and before BCH decoders, baseband frame error rate), and T2-MI tests. Also there are some additions to parameters of basic measurements that considering additional OFDM modes and so on.

For more information for measurements in DVB-T system see ETSI TR 101 290 digital video broadcasting (DVB); Measurement guidelines for DVB systems and Amendment A14-2 to this standard that providing measurements for DVB-T2 system.

5.4 ISDB-specific measurements

ISDB measurements are practically the same as in DVB system because of both COFDM systems. But due to some difference in transmission principles (e.g. layered transmission in segments and differential modulation usage) there are some differences in measurements. Measurements for ISDB systems include BER calculations, constellation tests, *I*/*Q*-related measurements, OFDM-related measurements, and spectrum analysis.

5.5 DTMB-specific measurements

DTMB measurements are practically the same as that in DVB system as both are OFDM systems. Basic measurements for DTMB system include AWGN impact estimation, constellation-based analysis (phase jitter and *I*/*Q* errors), spectral mask analysis, RF frequency measurements (RF frequency accuracy, RF channel width, etc.), and peak-to-average ratio (PAR) of OFDM signal.

For more information for measurements in DTMB system, see GB/T 26683-2011 General specification for digital terrestrial television receiver.

5.6 Set of measurement equipment

Set of measurement equipment includes:

– spectrum analyser;

– test receiver with constellation analyser, response estimations (amplitude, phase, group delay and impulse responses analysis) and BER calculations;

– test transmitter for measurements on DTTB receivers;

– MPEG-2 TS and noise generators;

– MPEG test decoders and TV monitor.

All mentioned above measurement equipment support corresponding broadcast standard.

6 Network measurement and analysis for digital terrestrial television broadcasting

6.1 Basic network measurements

All measurements carried out at the level of network broadcasting transmitters, can be classified by:

– periodicity (periodic measurements and measurements carried out during failures or during the initial network deployments);
– measurement mode (in service and out of service measurements);
– stage of the technical maintenance of digital television broadcasting network (during network deployment, during the technical operation or another stage).

During the initial deployment of a network of digital television broadcasting transmitters the main objectives are:

– control of broadcasting coverage quality (as a process of validation of the results of frequency planning, or as a routine procedure for evaluating the reception quality at various points in the service area in order to further improve coverage). Techniques for such measurements, as well as some practical examples and results of measurements of coverage quality are summarized in § 2.1 of this Report;
– influence assessment of other transmitters in broadcasting network (existing or newly introduced) or radio electronic facilities that operate in co-channel or adjacent channel combined with the broadcast transmitter. The norms on the measured parameters in this case are considered in § 2.1 of this Report.

Among the parameters that are measured during the initial network deployment for broadcast transmitters are typically considered:

– field strength at the receiving locations;
– *C/N* ratio or other equivalent ratios (SNR, E_s/N_0, E_b/N_0), and also its extended versions that taking into account other factors (e.g. SINR);
– Protection ratio (PR) in the receiving locations on the service area border;
– intensity of digital image cliff effect (visual control of decodability) using various criteria such as, for example, subjective failure point (SFP);
– BER for testing of reception mode of digital television broadcasting signal (QEF or non-QEF mode).

All these parameters together determine the resulting coverage quality for broadcasting network, as well as characterize the operational quality at the broadcasting network level in the presence of interfering signals of other transmitters.

The measurement principle is the same when new transmitter in the network of broadcast transmitters (e.g. to improve coverage or increase the capacity of the existing broadcast network). The main difference is a minimum set of parameters that measured and reduced set of measurements. During this the coverage quality for signal of newly introduced transmitter using main parameters and criteria defined above for step initial deployment are controlled and compliance to the protection ratios to minimize interference from other broadcast transmitters/transmitters of other services.

Periodic quality monitoring for broadcasting signal coverage to identify white gaps in the primary coverage, which were not found during the initial inspection can be made during the technical maintenance of transmitters of broadcasting network. But still the main type of control is the periodic monitoring of the integrity and performance of part of the digital stream, which is responsible for the broadcasting network functions (usually control the integrity of the digital auxiliary streams carrying information on network synchronization and other network functions and evaluation of the accuracy for network synchronization).

Parameters that are controlled in the auxiliary digital stream at this stage was partially considered above in clause on quality control in the transport stream (e.g. control of network information table NIT), and partly will be discussed further in § 6.2 in relation to the specific digital broadcasting systems. Detection of white gaps in the coverage is produced using the same parameters as in the initial network deployment, but may be smaller number of measurements, and possibly with a limited set of parameters.

Estimation of the synchronization accuracy on level of system streams for systems based on the use of different modifications of the MPEG-2 TS system transport stream, basic set of parameters for the measurements in the network includes:

– estimation of synchronization accuracy with program clock reference (PCR) for streams with certain packet identifier (PID) and system clock in a transport stream in the presence of jitter. Usually frequency shift in clock, drift rate, overall jitter, the accuracy of PCR (accuracy PCR) are estimated;
– estimation of the transport stream rate which can vary due to a failures of the buffer multiplexer/re-multiplexer.

6.2 Network type-specific measurements

6.2.1 General

A set of measurements for a particular digital terrestrial broadcasting system may be different depending on its implementation and in recent years these differences are increasing. In general, this class of measurements is carried out for single frequency networks (SFN) of transmitters in which an important object is to provide radiation synchronization of transmitters in the broadcasting network in accordance with different geographic locations and other factors. If current network do not meet the requirements for synchronization of transmitters in the network this may lead to a significant reduction in the operational quality of the broadcast network, the increasing of the interference level, reducing the network gain and other negative consequences.

Set of measurements is determined by processing a particular broadcasting system and approach to providing the synchronization of SFN transmitters.

In general, for OFDM-based broadcasting systems it is important to ensure stability of the carrier frequency and the sampling frequency of the modulator output signal, which is important for the SFN operation. So accuracy of these two frequencies is estimated. The estimation of these parameters for compliance with normative values is part of the process to ensure bit and frequency synchronization for signals at the transmitter outputs in single frequency network.

For VSB based systems the increased resistance to echoes with the overall concept of synchronization of the transmitters in a single frequency network is considered. This approach is discussed in more details in § 6.2.4 and ATSC Document A/110.

Also measurement of the overall delay in the digital television broadcast path for adjustment of signal emission time for SFN transmitters is important. Such adjustments are ensuring the time synchronization for emissions. A typical approach for providing this synchronization is to use the universal reference clocks (e.g. GPS signal).

6.2.2 DVB-specific measurements

Depending on the system generation (DVB-T or DVB-T2) estimation of the different components of the link/network layers (at the levels of special synchronization packet in DVB-T system and the special stream in DVB-T2) is carried out.

Characteristics of special packet used to synchronize the transmitters in a single frequency network called mega-frame initialization packet (MIP) are estimated in the DVB-T system. In particular, the following parameters are evaluated:

– checking the integrity of MIP packets (test on syntax compliance and test of contents/periodicity of MIP pointer);
– checking the insertion rate of MIP packets into the transport stream;
– accuracy of synchronization time stamp (STS) that are inserted into MIP packets.

Basics and methods of such measurement are given in the ETSI TR 101 191 and ETSI TR 101 290 standards.

Special stream called Modulator Interface (T2-MI) stream is used for implementing of SFN mode in DVB-T2 system. In this case, assessment of compliance of syntax and stream characteristics of the T2-MI to standards is carried out, in particular:

– measurements of the syntax of T2 MI packets;
– checks on the T2-MI MIP;
– check on consistency of T2-MI signalling information;
– measurements at T2-MI transport layer.

6.2.3 ISDB-specific measurements

The ISDB standard (see ARIB B-31, Appendix 5) defines several approaches to the synchronization of transmitters in a single frequency network. Approaches are following: complete synchronization, slave synchronization, reference synchronization, synchronization conversion (quasi-synchronization). For transmission of synchronization information for transmitters in single frequency network ISDB-T uses Information Packet, containing network synchronization information, information on multiplexing for calculating the delays and frame boundaries for bit synchronization. Control of integrity and syntax of this packet, as well as the insertion rate is main purpose of network synchronization measurements.

6.2.4 ATSC-specific measurements

ATSC A/110 defines a standard for synchronization of multiple transmitters emitting trellis coded 8-VSB signals in accordance with ATSC A/53 Part 2 and of both single and multiple transmitters emitting Mobile DTV (ATSC-M/H) signals in accordance with ATSC A/153 Part 2. It also describes the concept of an SFN and the types of transmission methods that can be used to construct an SFN in ATSC environment. It explains the requirements for transmitters and receivers to make an SFN work, and it describes the characteristics of the 8-VSB system that must be considered when synchronizing transmitters in the distributed transmission form of SFN. Finally, it explains the mechanisms to be used in the synchronization processes for single-transmitter M/H and both conventional 8-VSB SFN and M/H SFN operations.

During ATSC or ATSC-M/H operations it is needed to control the packet timing and PCR accuracy to maintain frequency, time and data synchronization. So related measurements of transmitter synchronization accuracy and time delays in SFN mode are needed. These are including measurements of syntax and contents of transmitter control packets, field-rate side channel and/or dummy data bytes channel (for M/H system) used for synchronization of SFN transmitters.

6.2.5 DTMB-specific measurements

The DTMB series standards (GB/T 28433-2012 Technical requirements for single frequency network of DTTB and GB/T 28434-2012 Technical requirements and measurement methods of DTTB single frequency network adapter) define several approaches to the synchronization of transmitters in a single frequency network.

Characteristics of special packet used to synchronize the transmitters in a single frequency network called second frame initialization packet (SIP) are estimated in the DTMB system. In particular, the following parameters are evaluated:

The transmitters in SFN get the maximum delay time T_{delay_max} and the distribution network delay $T_{delay\_transmitted}$ by detecting SIPs contained in received TS streams.

– T_{delay_max}: maximum delay time, which is the transmission time of all transmitters related to 1pps from GPS.

– $T_{delay\_transmitted}$: distribution network transmission delay time, which is the transmission time in distribution networks after TS stream being launched by SFN adapters.

The maximum delay time which can be handled by transmitters in SFN is 0.9999999 second.

6.3 Set of measurement equipment

Set of measurement equipment or its functionality may vary depending on the stage of the technical maintenance (initial network deployment, monitoring during operation, introduction of the new transmitter to an existing network, etc.) on which measurements are carried out. Thus, two sets of equipment or functionalities (basic and extended sets) can be considered for measurement of network parameters.

The basic set includes equipment sufficient for the measurement and estimation of the main characteristics of the synchronization signals (see § 6.2.1):

– calibrated antenna;

– GPS or GLONASS receivers;

– the spectrum analyser and the analyser for echo signals;

– protocol analyser with measurement of basic parameters such as BER, MER, C/N, etc.;

All of the mentioned above analysers (spectrum and protocol analysers) may be implemented based on a single portable device with basic functionality.

Extended set of equipment in addition to the basic set can include analysers for synchronization signals and protocols (e.g. T2-MI, DVB-T MIP, ATSC TCP) used in digital television broadcasting. Furthermore, the extended set of equipment generally has extended functionality (e.g. recording and analysis of transport stream in real-time and other special streams for detection of errors in the syntax).

7 References

1 ETSI TR 101 290 Digital Video Broadcasting (DVB); Measurement guidelines for DVB systems;

2 ETSI TR 101 291 Digital Video Broadcasting (DVB);Usage of the DVB test and measurement signaling channel(PID 0x001D) embedded in an MPEG-2 Transport Stream (TS);

3 ETSI TS 102 032 Digital Video Broadcasting (DVB); SNMP MIB for test and measurement applications in DVB systems;

4 DVB Document A14-1 Digital Video Broadcasting (DVB); Measurement guidelines for DVB systems; Amendment for T2-MI (Modulator Interface);

5 ATSC Recommended Practice A/64B: Transmission Measurement and Compliance for Digital Television;

6 ATSC Standard A/53: Digital Television Standard Part 2 – RF/Transmission System Characteristics;

7 ARIB STD-B31 Transmission System for Digital Terrestrial Television Broadcasting;

8 ARIB STD-B46 Transmission System Based on Connected Segments for Terrestrial Mobile Multimedia Broadcasting;

9 ABNT NBR 15601 Brazilian Standard: Digital terrestrial television – Transmission System;

10 JEITA handbook: Methods of Measurement for Digital Terrestrial Broadcasting Transmitters;

11 Tektronix Multi-layer Confidence Monitoring in Digital Television Broadcasting;

12 Tektronix Guide to MPEG Fundamentals and Protocol Analysis (Including DVB & ATSC);

13 Rohde & Schwarz Fundamentals of Spectrum Analysis;

14 Recommendation ITU-R SM.329 Unwanted emissions in the spurious domain;

15 Recommendation ITU-R SM.1541 Unwanted emissions in the out-of-band domain;

16 ATSC A/110:2011 Standard for Transmitter Synchronization;

17 IEEE Std 1631-2008: IEEE Recommended Practice for Measurement of 8-VSB Digital Television Transmission Mask Compliance for the USA.

8 List of Acronyms

3DTV	Three dimensional television
AI	Amplitude imbalance
ASI	Asynchronous serial interface
ATSC	Advanced Television Systems Committee
AWGN	Average white Gaussian noise
BAT	Bouquet association table
BCH	Bose-Chaudhuri-Hocquenghem
BER	Bit error rate
BIT	Broadcaster information table
BLER	Block error rate
CAT	Conditional access table
CBR	Constant bit rate
CINR	Carrier to interference plus noise ratio
CNR	Carrier to noise ratio
COFDM	Coded orthogonal frequency division multiplexing
CRC	Cyclic redundancy check
CS	Carrier suppression
CVCT	Cable virtual channel table
DCT	Download control table

DLT	Download table
DTMB	Digital terrestrial multimedia broadcast
DTTB	Digital terrestrial television broadcasting
DVB	Digital video broadcasting
EB	Errored block
EIT	Event information table
END	Equivalent noise degradation
ERT	Event relation table
ES	Errored second
ETI	Errored time interval
ETSI	European Telecommunications Standards Institute
ETT	Extended text table
EVM	Error vector magnitude
FER	Frame error rate
GLONASS	GLObal NAvigation Satellite System
GPS	Global Positioning System
GSE	Generic stream encapsulation
HDTV	High definition television
I/Q	In-phase/quadrature
ID	Identification
ISDB	Integrated Services Digital Broadcasting
ITT	Index transmission table
LDPC	Low density parity check
LDT	Linked description table
LIT	Local information table
M/H	Mobile/Handheld
MBLER	Macro block error rate
MER	Modulation error rate
MGT	Master guide table
MIB	Management information base
MIP	Mega-frame initialization packet
MISO	Multiple Input Single Output
MPEG	Motion picture expert group
M-QAM	M-ary quadrature amplitude modulation
NBIT	Network board information table
NIT	Network information table

OFDM	Orthogonal frequency division multiplexing
OSI	Open system interconnection
PAR	Peak-to-average ratio
PAT	Program association table
PCAT	Partial content announcement table
PCR	Program clock reference
PE	Phase error
PER	Packet error rate
PID	Packet identifier
PJ	Phase jitter
PMT	Program map table
pQoS	Perceived quality of service
PR	Protection ratio
PSI	Program specific information
PSIP	Program and system information protocol
PTS	Presentation time stamp
PxER	Probability of error of image elements
QAM	Quadrature amplitude modulation
QE	Quadrature error
QEF	Quasi-error free
QoS	Quality of service
RF	Radio frequency
RMS	Root mean square
RST	Running status table
RRT	Rating regional table
SAR	Service availability error ratio
SDP	Severely disturbed period
SDR	Service degradation error
SDT	Service description table
SDTT	Software download trigger table
SDTV	Standard definition television
SES	Severely errored second
SETI	Severely errored time interval
SFN	Single frequency network
SFP	Subjective failure point
SI	Service information

SIE	Service impairments error
SINR	Signal to interference noise ratio
SIP	Second frame initialization packet
SIR	Service impairments error ratio
SIT	Selection information table
SLER	Synchronization error rate
SNMP	Simple network management protocol
SNR	Signal to noise ratio
ST	Stuffing table
STS	Synchronization time stamp
STT	System time table
T2-MI	Modulator interface (for DVB-T2)
T2-MI MIP	Modulator information packet (T2-MI)
TCP	Transmission control protocol
TDT	Time and date table
TER	Timing error rate
TOT	Time offset table
TS	Transport stream
TVCT	Terrestrial virtual channel table
UAT	Unavailable time
UHDTV	Ultra high definition television
VBR	Variable bit rate
VFDR	Video frame decoding rate
VFLR	Video frame loss rate

Annex 1

Calculation of MER for higher-order modulated signals

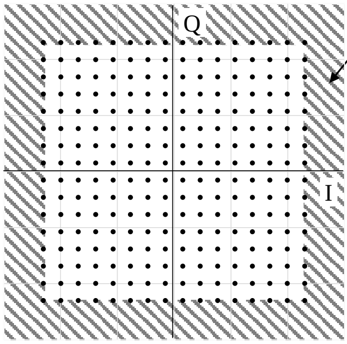
This Annex describes MER calculation methods suitable for higher order modulated-signals.

1 Method 1

In this method, MER is calculated only if a received symbol is outside of the outermost symbols as shown in Fig. A1-1. Since the outermost symbols have fewer adjacent symbols, the probability of symbol detection error is lower. This method reduces the impact of the error vector calculation error and improves the accuracy of MER calculation.

FIGURE A1-1

MER calculation only for outermost symbols



2 Method 2

In this method, soft-decision is used to determine the ideal symbol position. $(I_k + \delta I_{j,k}, Q_k + \delta Q_{j,k})$ are the coordinates of the received data point j, and (I_k, Q_k) are the coordinates of the k-th ideal symbol position: S_k (in the case of 1024-QAM, S_k is within the range of S_1 to S_{1024}). $(\delta I_{j,k}, \delta Q_{j,k})$ denotes the error vector between the received data point j and S_k. It is assumed that the probability density function, $P(j,k)$, of S_k coinciding with the transmission signal point follows a normal distribution depending on the noise variance "σ^2." Accordingly, $P(j,k)$ can be expressed as:

$$P(j,k) = \frac{1}{\sqrt{2\pi\sigma^2}} \exp\left(-\frac{\delta I_{j,k}^2 + \delta Q_{j,k}^2}{2\sigma^2}\right) \qquad \text{(A1-1)}$$

$P(j,k)$ and the Euclidean distance between the received data point j and S_k have a negative exponential relationship. The noise is derived from thermal noise in the receiver. The mean of $\delta I_{j,k}$ and of $\delta Q_{j,k}$ is assumed to be 0, where the number of received data points is sufficiently large. The noise will be represented by a normal distribution using σ^2.

In general, the summation of the probability density function of each received data point must be equal to 1. $\tilde{P}(j,k)$ is described as follows to normalize the $P(j,k)$:

$$\tilde{P}(j,k) = \frac{1}{\sum_{k=1}^{2^M} P(j,k)} P(j,k) \qquad \text{(A1-2)}$$

where $1/\sum_{k=1}^{2^M} P(j,k)$ is the normalizing constant and M is the modulation order; e.g. for QPSK and 4096-QAM, M = 2 and 12, respectively.

MER calculation with soft-decision is as follows:

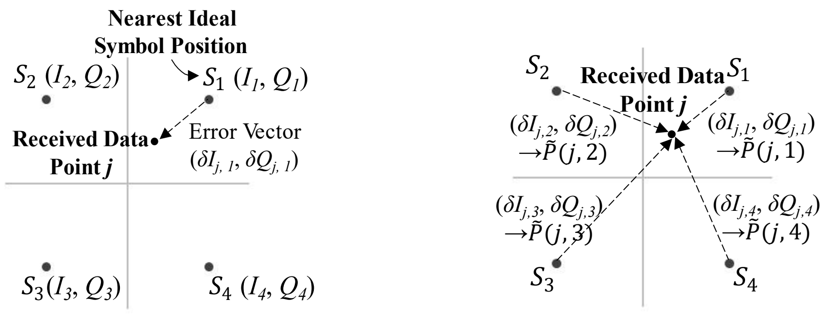
$$\text{MER} = 10\log_{10}\left(\frac{\sum_{j=1}^{N}\sum_{k=1}^{2^M}(I_k^2 + Q_k^2)\cdot\tilde{P}(j,k)}{\sum_{j=1}^{N}\sum_{k=1}^{2^M}\left(\delta I_{j,k}^2 + \delta Q_{j,k}^2\right)\cdot\tilde{P}(j,k)}\right) \quad \text{(dB)} \qquad \text{(A3)}$$

While the conventional MER is calculated with the nearest ideal symbol position, the MER with likelihood is calculated with every ideal symbol position using likelihood. This eliminates decision errors from the MER calculation in the low C/N range and provides correct evaluation values of the received signal.

Figure A1-2 shows the MER calculations. For simplicity of explanation, QPSK is used as an example. The conventional MER is calculated only with the nearest ideal symbol position: S_1. When S_1 does not coincide with the transmission signal point, this error vector is not equivalent to the actual value. In contrast, the MER with soft-decision is calculated from all four ideal symbol positions. $\tilde{P}(j,1)$–$\tilde{P}(j,4)$ is computed from each error vector: the Euclidean distance between the received data point j and S_1–S_4. The MER with soft-decision is calculated with each probability: $\tilde{P}(j,1)$–$\tilde{P}(j,4)$, each magnitude of S_1–S_4 and each error vector. The MER with soft-decision is calculated by each data carrier, i.e. it can be shown in the frequency domain. For example, it can detect frequency selective interferences in the frequency.

FIGURE A1-2

MER calculation comparison



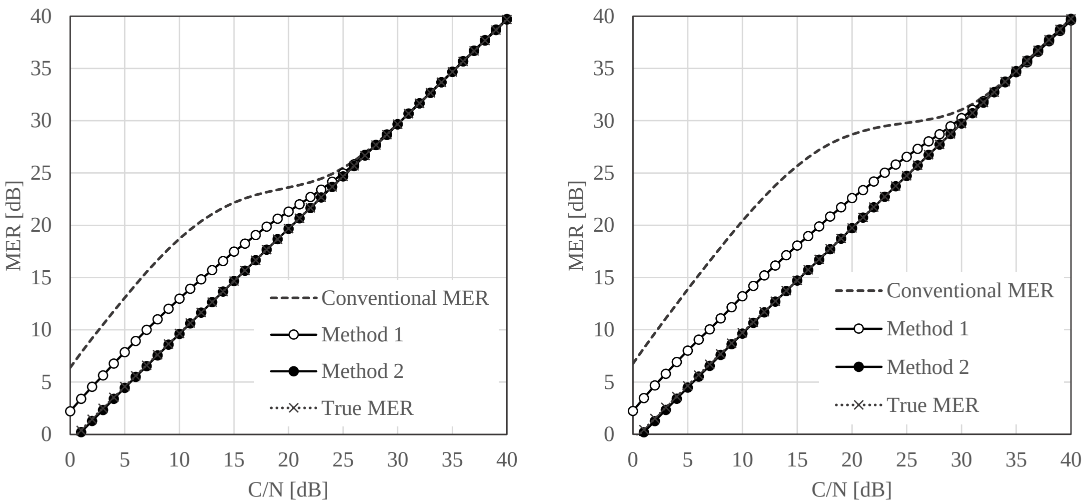
(a) Conventional MER (hard-decision) (b) Method 2 (soft-decision)

Figures A1-3 and A1-4 compare different MER calculation methods. MER calculated by the method with soft-decision is almost the same as true MER.

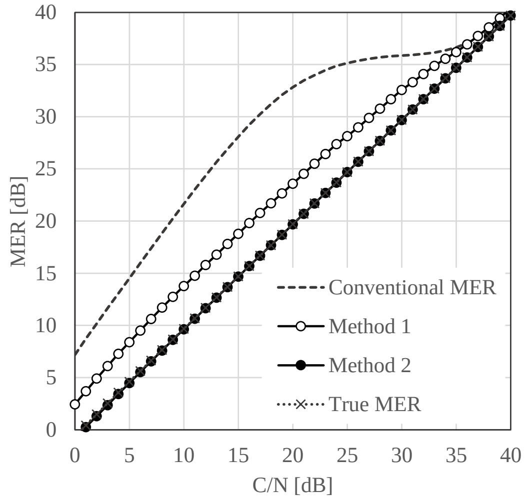
Note that the methods differ in terms of computational complexity. Since the method with soft-decision calculates probabilities from all symbols, its complexity is larger than that of the MER calculation using the outermost symbols only.

FIGURE A1-3

Comparison of MER calculation methods with uniform constellations



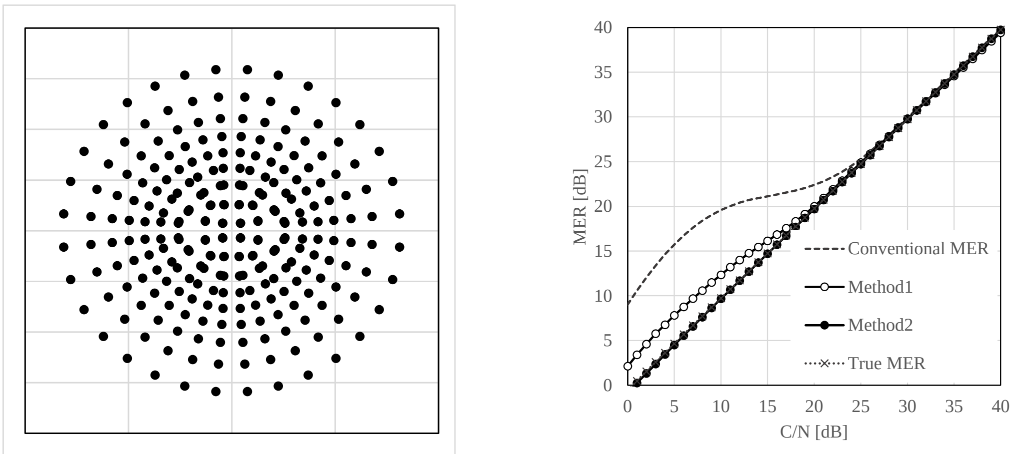
(a) 256-QAM (b) 1024-QAM



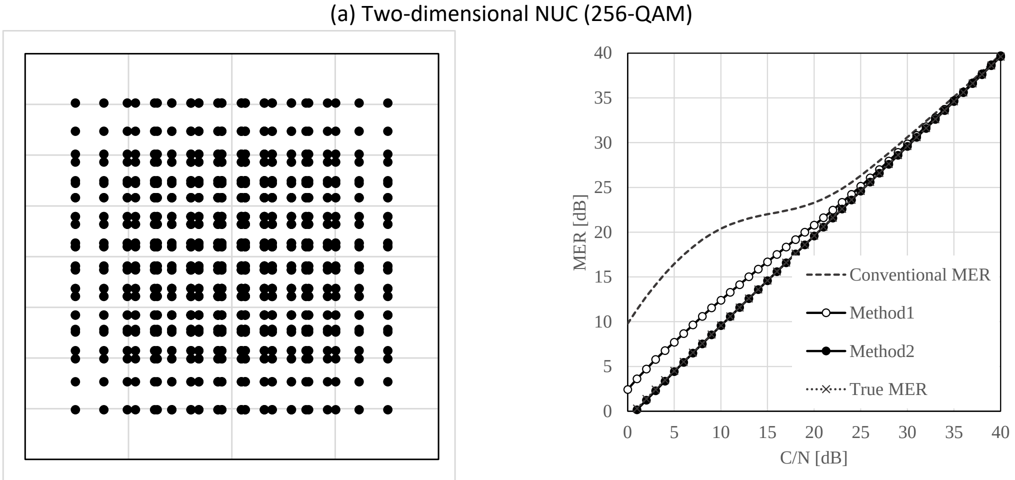
(c) 4096-QAM

FIGURE A1-4

Comparison of MER calculation methods with non-uniform constellations (NUCs)



(a) Two-dimensional NUC (256-QAM)



(b) One-dimensional NUC (1024-QAM)