Proposed ATSC Recommended Practice: Transport Stream Verification

Advanced Television Systems Committee

1750 K Street, N.W.
Suite 1200
Washington, D.C. 20006
www.atsc.org

The Advanced Television Systems Committee, Inc., is an international, non-profit organization developing voluntary standards for digital television. The ATSC member organizations represent the broadcast, broadcast equipment, motion picture, consumer electronics, computer, cable, satellite, and semiconductor industries.

Specifically, ATSC is working to coordinate television standards among different communications media focusing on digital television, interactive systems, and broadband multimedia communications. ATSC is also developing digital television implementation strategies and presenting educational seminars on the ATSC standards.

ATSC was formed in 1982 by the member organizations of the Joint Committee on InterSociety Coordination (JCIC): the Electronic Industries Association (EIA), the Institute of Electrical and Electronic Engineers (IEEE), the National Association of Broadcasters (NAB), the National Cable Television Association (NCTA), and the Society of Motion Picture and Television Engineers (SMPTE). Currently, there are approximately 140 members representing the broadcast, broadcast equipment, motion picture, consumer electronics, computer, cable, satellite, and semiconductor industries.

ATSC Digital TV Standards include digital high definition television (HDTV), standard definition television (SDTV), data broadcasting, multichannel surround-sound audio, and satellite direct-to-home broadcasting.

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1. SCOPE

This Recommended Practice provides a common methodology for describing Transport Stream conformance criteria. This RP explicitly describes the elements and parameters of A/53 and A/65 that should be verified in an ATSC Transport Stream for it to be considered a proper emission. It does not cover RF, captioning or elementary streams.

While the ATSC standards define strict limits for each parameter, in practice the severity of the error may depend upon the magnitude of the deviation. This document recommends severity levels associated with the ranges of deviation from the standard in these parameters..

2. INTRODUCTION

The ATSC standards define the contents and characteristics of the emission Transport Stream[1]. There may be a large number of interactions and interrelationships amongst various components. Successful tuning and display of programs can be enabled if this Transport Stream adheres to the ATSC standards. The connection between the emission remultiplexer and the 8-VSB modulator is the reference analysis point assumed in this document, as shown in Figure 2.1.

Please note that this diagram shows only a conceptual, functional block view; actual implementations will only share MPEG data with other devices using the MPEG-2 Transport Stream (TS), as Elementary Streams (ES) or Packetized Elementary Streams (PES) cannot tolerate the introduction of any transmission errors and once synchronization is lost the system crashes. Furthermore, real systems may group the functions in different ways and will likely appear different on an electrical or physical block diagram.

This RP uses terms and acronyms defined in ISO 13818-1, A/53 and A/65, and assumes a fair degree of familiarity with MPEG-2 systems as implemented per the ATSC standards. Readers that do not recognize the terms should read A/54 and A/69.

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[1] Note that the initial release of this document does not address Enhanced VSB.
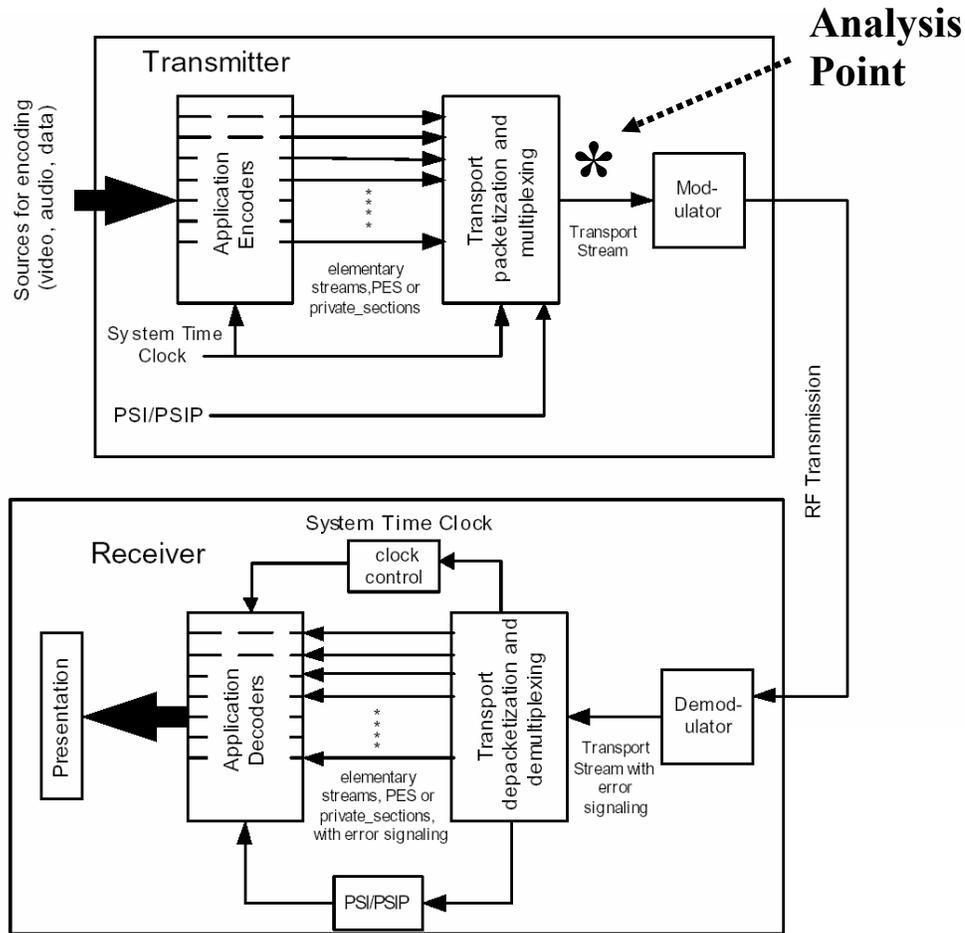
Figure 2.1 Reference analysis point in the DTV system.

This Recommended Practice identifies transport stream issues by type, dividing errors into the following categories:
- Section 5: PSI tables (PAT and PMT)
- Section 6: PSIP tables (MGT, VCT, etc.)
- Section 7: Timing Model and Buffering
- Section 8: Consistency
- Section 9: General Errors

Each error type is also provided with an error severity, as listed below:
- Transport Stream Off Air (TOA)
- Program Off Air (POA)
- Component Missing (CM)
- Quality Of Service (QOS)
- Technically Non-Conformant (TNC)

3. INFORMATIVE REFERENCES

[1]   ATSC A/52B: "Digital Audio Compression (AC-3, E-AC-3) Standard," Advanced Television Systems Committee, Washington, D.C., 14 June 2005.

[2]   ATSC A/53E: "ATSC Digital Television Standard, Revision E," Advanced Television Systems Committee, Washington, D.C., 27 December 2005.

[3]   ATSC A/65C: "Program and System Information Protocol for Terrestrial Broadcast and Cable," Advanced Television Systems Committee, Washington, D.C., 2 January 2006.

[4]   ATSC A/69: "Recommended Practice: Program and System Information Protocol Implementation Guidelines for Broadcasters," Advanced Television Systems Committee, Washington, D.C., 25 June 2002.

[5]   ATSC A/110A: "Synchronization Standard for Distributed Transmission, Revision A," Advanced Television Systems Committee, Washington, D.C., 19 July 2005.

[6]   ETSI TR 101 290 V1.2.1, Digital Video Broadcasting (DVB): Measurement guidelines for DVB systems, May 2001.

[7]   ISO/IEC IS 13818-1:2000 (E), International Standard, Information technology – Generic coding of moving pictures and associated audio information: systems.

[8]   ISO/IEC 13818-4: 2004 (E), International Standard, Information technology – Generic Coding of Moving Pictures and associated audio information: Conformance Testing.

4. ERROR CHARACTERIZATION

As noted earlier, in this document, errors are categorized as:

- Transport Stream Off Air (TOA)
- Program Off Air (POA)
- Component Missing (CM)
- Quality Of Service (QOS)
- Technically Non-Conformant (TNC)

The distinctions between these are important and should be taken into account both by equipment manufacturers of ATSC TS monitoring equipment and the users of that equipment.

Considering these classes of errors, particular attention needs to be paid to the "TNC" or "Technically Non-Conformant" class. In Standards as complex as MPEG-2 and those from the ATSC, situations arise where two "shall" statements collide. At such junctures, the Transport Stream (TS) may be momentarily non-conformant. An example of this might be "PAT repetition error" (see Section 5). If the multiplexer is faced with a choice of outputting a video PID carrying a PTS on the schedule required by Section 7.2 or a repetition of the PAT within the requirements of Section 5, an implementer may choose to output the PTS sample rather than the PAT. Either way, the TS is for a moment non-conformant. Neither choice of non-conformance will affect any real-world receivers. Neither will result in disruption of service. Either will be non-conformant. There is no avoiding these conflicts, and they arise periodically in real-world equipment.

Should a manufacturer of MPEG analysis equipment choose to make either of these errors the cause of an operator alarm, after multiple false alarms the operator may ignore all alarms. That is not desirable.

A number of the possible errors within this Section fall into these categories. While a continuous occurrence of any should constitute an operator alarm, a single occurrence of any should (as indicated by the table) be treated merely as a minor problem, which, unless re-occurring, is not significant.

4.1 Discussion of Error Classification

An explanation of the error classification scheme is as follows:

1) **Transport Stream Off Air (TOA)**: The station is effectively off-air as the Transport Stream errors are severe enough that transport level logical constructs are damaged beyond utility. Receivers will not be able to tune and decode anything within the broadcast. The complete or repeated absence of sync bytes[2] would be an example of this level of error.

2) **Program Off Air (POA):** A main service (virtual channel) is flawed to the point that that service is effectively off air for conformant/reasonable receiver designs. This could involve all of the program elements being improperly constructed or incorrect/missing signaling about elements. The absence of an entry in the VCT for a service would be an example of this type of error.

3) **Component missing (CM):** One of the program components that is signaled by PSIP or the PMT as present is either not present or cannot be found and decoded. One example would be a mismatch between the video PID signaled in the SLD and the actual PID used for the video elementary stream.

4) **Quality of Service (QOS)**: Parameters are out of specification by such a margin that a significant fraction of the receivers can be expected to produce flawed outputs. In many cases, the broadcast is viewable, but may exhibit some form of degradation to the viewer. An example might be the MGT cycle time being somewhat longer than the specification, which would cause slower than normal tuning.

5) **Technically Non-Conformant (TNC)**: Violates the letter of the standard, but in practice will have little effect on the viewing experience. Errors of this type should be corrected, but do not have the urgency of higher severity errors. An example might be a single instance of a 152 ms MGT cycle time (with the remainder of the MGTs coming at less than 150 ms intervals).

In most cases the error threshold for what may appear to be escalating categorization is based on: 1) the official metric to twice the metric, 2) twice the official metric to 5 times the metric, and 3) over five times the metric. The nominal mathematical expression of this is shown below, where Tc is the metric for the cycle time and t is the time since the last arrival (note that for clarity of expression of the time intervals, this document ignores time advances during each millisecond increment):

1) $Tc < t \leq 2Tc$
2) $2Tc < t \leq 5Tc$
3) $5Tc < t$

This scale can prevent "shall-statement collisions" from producing meaningless error alarms, yet provides guidance to equipment makers and users regarding severities.

5. PSI ERRORS

An ATSC transport stream is also required to be MPEG-2 conformant (see Section 5 in reference [8]). Therefore, an ATSC transport stream must include the two mandatory Program Specific Information (PSI) tables. These two tables are known as the Program Association Table (PAT) and the Program Map Table (PMT). The syntax is defined within ISO/IEC 13818-1. The maximum interval for the PAT is specified in the ATSC standards as 100 ms. The maximum interval for the PMT is specified in the ATSC standards as 400 ms. Exceeding the interval on

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[2] Note that A/110A requires inversion of the sync byte value on a periodic basis. Such is compliant with ATSC standards, but is technically MPEG non-compliant.

each of these tables by a small amount should not have a major impact on a receiver, especially since each ATSC conformant receiver should be able to fully tune to any ATSC channel through the use of the ATSC PSIP tables.

5.1 PAT

Error conditions for the Program Association Table are classified in Table 5.1

Table 5.1 PAT Error Conditions

Error Condition	Error Qualifier	TOA	POA	CM	QOS	TNC
PAT repetition error	PAT repetition interval error (found between the last 101 and 200 ms) [1]					X
PAT repetition error	PAT repetition interval error (found between the last 201 to 500 ms)				X	X
PAT absence error	PAT not found for 501 ms (or longer)	X	X	X	X	X
PAT syntax error	Packet with PID 0x0000 doesn't have table_id 0x00	X	X	X	X	X
PAT syntax error	CRC is incorrect for table_id 0x00 within PID 0x0000 [2]					X
PAT syntax error	scrambling_control_field is not '00' for packet within PID 0x0000 [3]	X	X	X	X	X
Legend:						
TOA: TS Off Air, POA: Program Off Air, CM: Component Missing, QOS: Quality of Service, TNC: Technically Non-Conformant						
Notes:						
1) Or over 140 ms with regards to the hard limit of 80 kbps. In A/53, Annex C, Section 5.4 it is noted that in cases where the table section sizes are such that the 100 millisecond repetition rate of the program_association_section() would cause the 80,000 bps maximum rate to be exceeded, the time interval between the byte containing the last bit of the program_association_section() may be increased but in no event shall exceed 140 milliseconds, so that under no circumstances the limit of 80,000 bps is exceeded.						
2) Repeated instances of an incorrect CRC will be interpreted as the table not being present. This case is equivalent to a repetition or absence error.						
3) An error in the setting of the scrambling control field is most likely an indicator of a hard failure or incorrect setting and will persist until corrected.						

5.2 PMT

Error conditions for the Program Map Table are classified in Table 5.2.

Table 5.2 PMT Error Conditions

Error Condition	Error Qualifier	TOA	POA	CM	QOS	TNC
PMT repetition error	PMT repetition interval error (found within the last 401 to 800 ms)					x
PMT repetition error	PMT repetition interval error found between the last 801 to 2000 ms)				x	x
PMT absence error	PMT not found for 2001 ms (or longer)		x	x	x	x
PMT syntax error	Packet with "PMT_PID" doesn't have table_id 0x02		x	x	x	x
PMT syntax error	CRC is incorrect for table_id [1]					x
PMT syntax error	scrambling_control_field is not '00' for packets containing PMT [2]		x	x	x	x
PMT syntax error	"PMT_PID" referenced by PAT not found		x	x	x	x
Legend: TOA: TS Off Air, POA: Program Off Air, CM: Component Missing, QOS: Quality of Service, TNC: Technically Non-Conformant						
Notes: 1) Repeated instances of an incorrect CRC will be interpreted as the table not being present. This case is equivalent to a repetition or absence error. 2) An error in the setting of the scrambling control field is most likely an indicator of a hard failure or incorrect setting and will persist until corrected.						

6. PSIP ERRORS

PSIP (A/65) [3] is the glue that holds the digital television (DTV) signal together. PSIP is a voluntary standard of the ATSC and version C has been fully and completely adopted into the regulations of the Federal Communications Commission (FCC), so it is, in fact, a requirement in terms of actual real-world operation[3]. In most locations, multiple DTV stations can be received- and in some cases, from multiple markets. The purpose of PSIP is to describe the information at the system and event levels and to enable an abstract of the collection of programs called a virtual channel. There are two main categories of information in the ATSC PSIP Standard, system information and schedule data. System information allows navigation among and access to the channels currently within the DTV transport stream. It is similar to the PSI data discussed elsewhere in this document. The schedule data provides necessary information for efficient browsing and selection of current and future events.

There are two forms of virtual channel tables defined by the ATSC standards: Terrestrial (TVCT) and Cable (CVCT). A terrestrial broadcast must carry a TVCT and may optionally carry a CVCT.

The ATSC standards require the carriage of up to 12 hours of EIT information (EIT0-3). Carriage of more EITs is recommended, but not required. Because EIT-0 carries signaling information about the current event, a more rapid cycle time has been set for it. EIT1-3, while required to be present, may arrive less frequently. For purposes of this document, the recommendations in the PSIP Recommended Practice (A/69) [4] have been utilized.

The ATSC standards set limits on the cycle times and allowed inaccuracy of the time carried in the System Time Table (STT). While a receiver is tuned to a given station, the STT gives the receiver that channel's current time. If there are differences between the STT times carried by

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[3] The current version of A/65 contains additional features and capabilities that are not covered by this RP.

different stations, then viewers can experience problems such as missing the beginning of programs or incorrect PVR switching.

6.1 MGT

Error conditions for the Master Guide Table are classified in Table 6.1.

Table 6.1 MGT Error Conditions

Error Condition	Error Qualifier	TOA	POA	CM	QOS	TNC
MGT repetition error	MGT repetition interval error (found between the last 151 and 300 ms)					X
MGT repetition error	MGT repetition interval error (found between the last 301 to 750 ms)				X	X
MGT absence error	MGT not found for 751 ms (or longer)	X	X	X	X	X
MGT syntax error	CRC is incorrect for table_id 0xC7 [1]					X
MGT syntax error	scrambling_control_field is not '00' for packets containing MGT [2]	X	X	X	X	X
Legend:						
TOA: TS Off Air, POA: Program Off Air, CM: Component Missing, QOS: Quality of Service, TNC: Technically Non-Conformant						
Notes:						
1) Repeated instances of an incorrect CRC will be interpreted as the table not being present. This case is equivalent to a repetition or absence error.						
2) An error in the setting of the scrambling control field is most likely an indicator of a hard failure or incorrect setting and will persist until corrected.						

6.2 TVCT

Error conditions for the Terrestrial Virtual Channel Table are classified in Table 6.2.

Table 6.2 TVCT Error Conditions

Error Condition	Error Qualifier	TOA	POA	CM	QOS	TNC
TVCT repetition error	TVCT repetition interval error (found between the last 401 and 800 ms)					X
TVCT repetition error	TVCT repetition interval error (found between the last 801 to 2000 ms)				X	X
TVCT absence error	TVCT not found for 2001 ms (or longer)	X [3]	X	X	X	X
TVCT syntax error	CRC is incorrect for table_id 0xC8 [1]					X
TVCT syntax error	scrambling_control_field is not '00' for packets containing TVCT [2]	X [3]	X	X	X	X
Legend:						
TOA: TS Off Air, POA: Program Off Air, CM: Component Missing, QOS: Quality of Service, TNC: Technically Non-Conformant						
Notes:						
1) Repeated instances of an incorrect CRC will be interpreted as the table not being present. This case is equivalent to a repetition or absence error.						
2) An error in the setting of the scrambling control field is most likely an indicator of a hard failure or incorrect setting and will persist until corrected.						
3) PSIP system is off-air. Tuning algorithms based on PSIP will fail. The FCC rules require PSIP (A/65B).						

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6.3 CVCT

Error conditions for the Cable Virtual Channel Table are classified in Table 6.3.

Table 6.3 CVCT Error Conditions

Error Condition	Error Qualifier	TOA	POA	CM	QOS	TNC
CVCT [1]						
CVCT repetition error	CVCT repetition interval error (found between the last 401 and 800 ms)					X
CVCT repetition error	CVCT repetition interval error (found between the last 801 to 2000 ms)				X	X
CVCT absence error	CVCT not found for 2001 ms (or longer)		X [4]	X	X	X
CVCT syntax error	CRC is incorrect for table_id 0xC8 [2]					X
CVCT syntax error	scrambling_control_field is not '00' for packets containing CVCT [3]		X [4]	X	X	X
Legend: TOA: TS Off Air, POA: Program Off Air, CM: Component Missing, QOS: Quality of Service, TNC: Technically Non-Conformant						
Notes: 1) The CVCT is not required to be present in a terrestrial broadcast. 2) Repeated instances of an incorrect CRC will be interpreted as the table not being present. This case is equivalent to a repetition or absence error. 3) An error in the setting of the scrambling control field is most likely an indicator of a hard failure or incorrect setting and will persist until corrected. 4) CVCT generator is off-air. Tuning algorithms based on CVCT will fail.						

6.4 RRT

Error conditions for the Rating Region Table are classified in Table 6.4.

Table 6.4 RRT Error Conditions

Error Condition	Error Qualifier	TOA	POA	CM	QOS	TNC
RRT [1]						
RRT repetition error	RRT repetition interval error (found between the last 60001 and 120000 ms)					X
RRT repetition error	RRT repetition interval error (found between the last 120001 to 300000 ms)				X	X
RRT absence error	RRT not found for 300001 ms (or longer)			X [4]	X	X
RRT syntax error	CRC is incorrect for table_id 0xCA [2]					X
RRT syntax error	scrambling_control_field is not '00' for packets containing RRT [3]			X [4]	X	X
Legend: TOA: TS Off Air, POA: Program Off Air, CM: Component Missing, QOS: Quality of Service, TNC: Technically Non-Conformant						
Notes: 1) RRT is not required to be present for Rating Region 1. If the RRT is signaled in the MGT, then these error conditions apply. 2) Repeated instances of an incorrect CRC will be interpreted as the table not being present. This case is equivalent to a repetition or absence error. 3) An error in the setting of the scrambling control field is most likely an indicator of a hard failure or incorrect setting and will persist until corrected. 4) PSIP component missing.						

6.5 EIT and ETT

Error conditions for the Event Information Table and Extended Text Table are classified in Table 6.5.

Table 6.5 EIT and ETT Error Conditions

Error Condition	Error Qualifier	TOA	POA	CM	QOS	TNC
EIT-0 repetition error	EIT-0 repetition interval error (found between the last 501 and 1000 ms)					X [3]
EIT-0 repetition error	EIT-0 repetition interval error (found between the last 1001 to 2500 ms)				X [4]	X [3]
EIT-0 absence error	EIT-0 not found for 2501 ms (or longer)		X [4]	X [4]	X [4]	X [3]
EIT syntax error	CRC is incorrect for table_id 0xCB [1]					X
EIT syntax error	scrambling_control_field is not '00' for packets containing EIT [2]			X [5]	X	X
EIT-1 repetition error	EIT-1 repetition interval error (found between the last 3.01 to 6 seconds)					X [6]
EIT-1 repetition error	EIT-1 repetition interval error (found between the last 6.01 to 15 seconds)				X [6]	X [6]
EIT-1 absence error	EIT-1 not found for 15.01 seconds (or longer)			X [6]	X [6]	X [6]
EIT-2, EIT-3 repetition error	EIT-2, EIT-3 repetition interval error (found between the last 1.01 and 2 minutes)					X [6]
EIT-2, EIT-3 repetition error	EIT-2, EIT-3 repetition interval error found between the last 2.01 to 5 minutes)				X [6]	X [6]
EIT-2, EIT-3 absence error	EIT-2, EIT-3 not found for 5.01 minutes (or longer)			X [6]	X [6]	X [6]
ETT syntax error	CRC is incorrect for table_id 0xCB [1]					X
ETT syntax error	scrambling_control_field is not '00' for packets containing ETT [2]			X [5]	X	X

Legend:

TOA: TS Off Air, POA: Program Off Air, CM: Component Missing, QOS: Quality of Service, TNC: Technically Non-Conformant

Notes:

1) Repeated instances of an incorrect CRC will be interpreted as the table not being present. This case is equivalent to a repetition or absence error.

2) An error in the setting of the scrambling control field is most likely an indicator of a hard failure or incorrect setting and will persist until corrected.

3) This condition is technically compliant, but violates the A/65 recommended interval (in the U.S., the FCC recommended interval).

4) EIT-0 is required. Certain receivers may have difficulty tuning and EPG display may be affected.

5) PSIP component missing – may or may not affect behavior of receiver.

6) EIT1–3 are required. EPG display may be affected if missing. Recommended timings for EIT1–3 are given in A/69 (PSIP Recommended Practice).

6.6 STT

Error conditions for the System Time Table are classified in Table 6.6.

Table 6.6 STT Error Conditions

Error Condition	Error Qualifier	TOA	POA	CM	QOS	TNC
STT repetition error	STT repetition interval error (found between the last 1001 and 2000 ms)					X
STT repetition error	STT repetition interval error (found between the last 2001 to 5000 ms)				X	X
STT absence error	STT not found for 5001 ms (or longer)			X [2]	X	X
STT syntax errors	CRC is incorrect for table_id 0xCD [1]					X
STT time value error	STT time value is more than 30 seconds away from current correct GPS second_count (including GPS_UTC_offset impact)			X [2,3]	X	X
Legend: TOA: TS Off Air, POA: Program Off Air, CM: Component Missing, QOS: Quality of Service, TNC: Technically Non-Conformant						
Notes: 1) Repeated instances of an incorrect CRC will be interpreted as the table not being present. This case is equivalent to a repetition or absence error. 2) PSIP component missing. 3) This error is considered large enough to have a noticeable impact on users who tune/record by time of day.						

7. TIMING AND BUFFER ERRORS

Timing is the key to the MPEG-2 encoding and decoding processes. MPEG-2 Systems (ISO/IEC 13818-1) [7] defines a model for the system timing, adherence to which allows independent design of encoders and decoders that can interoperate. An MPEG-2 decoder's 27 MHz reference clock needs to be synchronized with the equipment that is creating the encoded stream. In order to achieve this synchronization, PCR (Program Clock Reference) 27 MHz clock timestamps are sent within the stream at a rate frequent enough to re-synchronize the decoder with the encoder clock.

Multiple conditions can cause the decoder clock to get out of sync with the encoder:
- Incorrect PCR timestamps inserted in the TS. This condition can send the decoder reference clock out of sync with the encoder clock.
- PCR not inserted often enough. This condition could cause the decoder reference clock to drift away from the encoder clock as it does not receive resynchronized timestamps often enough.
- Jitter introduced during the delivery process (packets arriving early or late, which creates drift of the decoder clocks and causes buffer underflow or overflow).

A referenced clock is used during the decoding process to indicate when to move data between buffers and to indicate when a frame should be decoded and presented to the stream.

Null packets are used to maintain a constant bit rate transport stream for the 8-VSB modulator. Some facilities see these Null packets as opportunistic packets and replace them with private data packets. This process should not impact a normal ATSC receiver. Although, physically dropping a Null packet prior to modulation, or replacing one Null packet with two private data packets, will negatively impact the PCR timing, and possibly the 8-VSB modulator

also. This is why re-multiplexers must take great care to accurately restamp all PCR, PTS, and DTS values whenever transport packets are shifted in time.

The PTS (Presentation Time-Stamp) and DTS (Decoding Timestamps) are based on the PCR and are used by the decoder to sequence the decoding process, and to manage the decoding buffer.

If the local decoder clock is not synchronized with the encoder, it may affect the decoding process by providing incorrect timing. The consequences of de-synchronization can be buffer overflow or underflow, or presentation timing mismatch. The result of this error can lead to freeze or missing frames on the display. Another result of this scenario could be poor audio/video lip-synchronization.

Buffer, PTS, and DTS errors can also be introduced by encoders and multiplexers outside of PCR errors (see Section 5 in reference [8] for timestamp accuracy and consistency). They can also create some timing errors, resulting in missing or out of sync decoded elements.

> Note: Actual decoders may have a larger buffer than the minimum required by MPEG-2, therefore are capable of absorbing some effects of timing errors and buffer overflow. The standard provides a minimum amount of RAM so that a theoretical model will never underflow or overflow. Some receivers may provide more memory than is required by the standard. Therefore, it is possible to have some receivers working well while others fail. A model using the minimum amount of RAM as specified by the standard may fail, while another model with 50 percent more RAM works flawlessly. This is a sign that the T-STD buffers in the encoder are either underflowing or overflowing. Meeting these buffer requirements does not guarantee a high quality program, but it does mean that the program can be decoded by any receiver that complies with the ATSC standard.

A maximum data rate for PSI and PSIP has been defined to keep the receiver microprocessor from overflowing. A maximum data rate of 250 kbps is defined for each of the following:

1) PSIP Base PID (0x1FFB)

2) EIT PIDs

3) ETT PIDs

The upper limit for the PSI is 80 kbps, but this is only applicable to the PAT PID and the PMT PID of the program being decoded.

7.1 PCR

Error conditions for the Program Clock Reference are classified in Table 7.1.

Table 7.1 PCR Error Conditions

Error Condition	Error Qualifier	TOA	POA	CM	QOS	TNC
PCR [1]						
PCR error	Unsignaled PCR discontinuity				X	X
PCR repetition error	PCR repetition interval error (found between the last 101 and 200 ms)					X
PCR repetition error	PCR repetition interval error (found between the last 201 to 500 ms)				X	X
PCR absence error	PCR not found for than 501 ms (or longer)		X	X	X	X
PCR error	PCR inaccuracy (greater than +/– 500 ns and less than or equal to +/- 2500 ns)					X
PCR error	PCR inaccuracy (greater than +/– 2500 ns)				X	X
PCR related parameters	PCR frequency offset (greater than 810 Hz and less than or equal to 4050 Hz)					X
PCR related parameters	PCR frequency offset (greater than 4050 Hz)				X	X
PCR related parameters	PCR frequency drift (greater than 75 milliHerz/second (mHz/s) and less than or equal to 375 mHz/s)					X
PCR related parameters	PCR frequency drift (greater than 375 mHz/s)				X	X
PCR related parameters	PCR overall jitter (greater than 25 μS and less than or equal to 125 μs)					X
PCR related parameters	PCR overall jitter (greater than 125 μS)				X	X
Legend: TOA: TS Off Air, POA: Program Off Air, CM: Component Missing, QOS: Quality of Service, TNC: Technically Non-Conformant						
Notes: 1) ETSI TR 101 290 v1.2.1 Section 5.3 and Annex I [6] provide measurement techniques for these PCR-related parameters. The thresholds therein are explicitly not part of this recommendation and should be ignored in favor of those in the table..						

7.2 PTS

Error conditions for the Presentation Time-Stamp are classified in Table 7.2.

Table 7.2 PTS Error Conditions

Error Condition	Error Qualifier	TOA	POA	CM	QOS	TNC
PTS interval error [2]	Interval between coded PTS values is 701 to 1400 ms [3]					X
PTS interval error	Interval between coded PTS values is 1401 to 3500 ms [3]				X	X
PTS absence error	Interval between coded PTS values exceeds 3501 ms [3]			X	X	X
PTS increment error	PTS time not incrementing at the reciprocal of the frame rate [1]					X
Legend:						
TOA: TS Off Air, POA: Program Off Air, CM: Component Missing, QOS: Quality of Service, TNC: Technically Non-Conformant						
Notes:						
1) Any discrepancy in the correlation of the timing between the PTS time and the frame rate could result in decoding buffer overflow or underflow. This could be manifested by the display of missing or frozen frames at an interval that depends on the size of the offset between the reciprocal of the PTS time and the frame rate. This could also contribute to changes in the apparent audio/video synchronization ("lip synch").						
2) A/53 places tighter constraints on video PES construction; see the section on PES constraints in A/53.						
3) PTS values are required with intervals not exceeding 700 ms in each elementary audio and video stream. These time intervals are measured in presentation time, that is, in the same context as the values of the fields, not in terms of the times that the fields are transmitted and received.						

7.3 Buffer Errors

Buffer errors are classified in Table 7.3

Table 7.3 Buffer Error Conditions

Error Condition	Error Qualifier	TOA	POA	CM	QOS	TNC
Buffer errors	Overflow of transport buffer					X
Buffer errors	Underflow of transport buffer				X	X
Buffer errors	Overflow of system information buffer					X
Buffer errors	Overflow of MPEG-2 Video buffer					X
Buffer errors	Underflow of MPEG-2 Video buffer				X	X
Buffer errors	Overflow of AC-3 Audio buffer					X
Buffer errors	Underflow of AC-3 Audio buffer				X	X
PSIP bandwidth	A/65 maximum PSIP bandwidth (250kb/s for base, 250kb/s for EIT and 250kb/s for ETT) [1]				X	X
Legend:						
TOA: TS Off Air, POA: Program Off Air, CM: Component Missing, QOS: Quality of Service, TNC: Technically Non-Conformant						
Notes:						
1) Exceeding this limit may result in degradation of other services.						

8. CONSISTENCY ERRORS

Before a receiver can decode a transport stream, it must identify the relationship between components in the stream. Some components contain audio and video (Elementary Streams), and other components contain information describing the relationship between them (Metadata). The receiver uses metadata to identify each component, determine its function and select an appropriate set of components when the user selects a virtual channel for decoding. Conflicts and problems within the structure of metadata are called 'consistency errors.' Consistency errors can result in broken decoding, missing system components (such as closed captioning), and/or missing program guide information. This section covers the types of errors that can cause these problems.

Broadcasters need to concern themselves with two kinds of metadata. Metadata defined by the ATSC is called 'Program and System Information Protocol' (PSIP), and Metadata defined by MPEG is called 'Program Specific Information' (PSI). Some of the functions of PSI are duplicated by PSIP. The duplication creates alternative means of locating system components; problems arise if they conflict.

There are three categories of metadata consistency errors: external, internal, and collision errors.

External consistency errors occur when the PSIP and PSI information do not agree with one another. These errors typically occur when more than one device in the system is configured to generate metadata. If the PSIP is generated by one system device, and the PSI is generated by another system device, then it is possible for the two devices to get out of 'sync' with each other. For example, the PMT is a PSI table, and the TVCT is a PSIP table. Both tables contain the program_number field. Suppose the PMT (generated on a multiplexer) lists one value for the program_number, and the TCVT (generated in a PSIP generator) contains a different one. The receiver is forced to decide between the PSIP and the PSI, and cannot determine which one is correct. The response of a receiver to a specific external consistency error depends upon the receiver implementation. Two receivers from different vendors will frequently react differently to the same external table inconsistency.

Internal consistency errors occur when metadata contains references that are wrong but do not cross the boundary between PSI and PSIP. For example, the Program Map Table (PMT) is a PSI table. One of the data fields in the PMT is the PCR_PID. If the value of the PCR_PID field is incorrect, then receivers may have difficulty displaying video and audio. This is an internal constancy error because the PCR_PID value is found in a PMT (a PSI table) and not carried in any PSIP table.

Internal consistency errors are not limited to PSI tables; they can occur in PSIP tables too. Consider the Master Guide Table (MGT) and the Channel Extended Text Table (Channel ETT), both of which are PSIP tables. Correctly formatted PSIP requires an MGT, but the Channel ETT is an optional PSIP table. If the MGT (required table) contains a reference to the Channel ETT (optional table), but the Channel ETT does not exist in the stream, then the resulting stream has a PSIP internal consistency error. Internal consistency errors can cause receivers to search for absent stream elements, or fail to find existing elements. Program guide information, closed captioning, and secondary audio channels are examples of program elements that may be affected by internal consistency errors.

Collision errors are the third kind of consistency error. They occur when similar metadata is generated on different devices in a system, and then multiplexed together into the same output. For example, multiplexers and PSIP generators are frequently capable of generating PSI. Consider the case where PSI is generated on a multiplexer, and also generated by a PSIP generator. Unless steps are taken to consolidate the PSI from these two sources, the two different

versions of PSI will collide at the output of the multiplexer. The output will contain alternating versions of PSI from each source (in this case the multiplexer and PSIP generator version). Many receiver implementations will simply fail to decode in the presence of a collision error.

Consistency errors are classified in Table 8.1.

Table 8.1 Consistency Errors

Error Condition	Error Qualifier	TOA	POA	CM	QOS	TNC
TSID values in PAT and VCT (transport_stream_id) do not match [1]		X	X	X	X	X
PAT/VCT mismatch [2]	Different number of programs found in VCT than signaled in PAT [3]		X		X	X
VCT/PMT mismatch	SLD/PMT mismatch (number of services)			X	X	X
VCT/PMT mismatch	SLD/PMT element mismatch (different "parameters" for matching program elements)			X	X	X
PMT/EIT-0 descriptor mismatch [4]	Mismatch in duplicated descriptors for current event between PMT and EIT-0			X	X	X
ETT syntax errors	ETT has invalid ETM_ID or ETM_ID does not match existing event_id in EIT (excludes channel ETT)			X [5]	X	X
ETT syntax errors	ETT has ETM_ID of channel ETT, but MGT does not flag channel ETT on this PID				X	X
Multiple sources of PSI	Version numbers for particular PSI tables should never decrease (except at wraparound) [6]	X	X	X	X	X
Daylight Savings time settings	STT contains invalid values for Daylight Savings time switchover					X
Service Location Descriptor missing from VCT	No Service Location Descriptor in VCT		X	X	X	X
Dangling source_id	source_id mismatch (either source_id in VCT does not have a corresponding source_id in EIT or source_id in EIT does not have a corresponding source_id in VCT)		X	X	X	X
MGT mismatch	Version number and/or size of tables signaled in MTG does not match with actual table [7]				X	X
MGT mismatch	PSIP table found in stream, but not signaled in MGT					X
Legend:						
TOA: TS Off Air, POA: Program Off Air, CM: Component Missing, QOS: Quality of Service, TNC: Technically Non-Conformant						
Notes:						
1) Receivers may not tune if these fields do not agree.						
2) While some receivers may operate correctly, others may not display the program in this case.						
3) Conditional on the state of the hidden flag in the VCT, whether the virtual channel is digital or analog and whether the virtual channel is in another transport						
4) This error condition may cause captioning to not work.						
5) The text description of the event is the missing component.						
6) This condition is indicative of multiple sources of PSI tables (from both multiplexer and PSIP generator).						
7) Tables signaled differently than the actual parameters can lead to variable behavior, dependant on the receiver and the actual table.						

9. GENERAL ERRORS

The errors listed within this Section cover a variety of types of problems (typically transport-related). For those listed in only the QOS and TNC columns, a single occurrence should be treated merely as a minor problem, which, unless periodically re-occurring, is not of concern. A

repeated occurrence should warrant investigation, as it might be indicative of a device approaching total failure.

If the station is using Distributed Transmission systems (as defined by A/110A [5]), then test equipment not equipped for A/110A can be expected to indicate a TS Synch Loss error every 624 packets, as the synch byte is altered at that time per A/110A.

Some types of errors do occur which are not listed in the following table. Specifically, they are:

- One or more transport packets were detected with a PID value that was not part of a properly signaled service. This situation is sometimes referred to as an "orphan PID".
- Some TS may also contain DVB or ARIB system tables in addition to PSIP. All of these tables have fixed PID assignments and do not appear in the PMT. User notification of such occurrences in a given TS may need to be conditioned by user expectations rather than treated as errors.

  Note: Multiple MPEG-2 Registration Descriptors within a loop may be a commonly encountered error as the rules for usage were originally unclear and only clarified after significant amounts of equipment were deployed.

General errors are classified in Table 9.1.

Table 9.1 General Errors

Error Condition	Error Qualifier	TOA	POA	CM	QOS	TNC
TS Synch Loss [1]	Two or more sync bytes are corrupt (not 0x47)	X	X	X	X	X
Sync Byte Error [1]	Single Sync byte is not 0x47				X	X
Cadence Sync byte error [2]	One or more Cadence Sync bytes corrupt				X	X
Cadence Sync byte error [2]	Cadence Sync byte has not been found in 624 packets				X	X
Cadence Sync byte error [2]	Cadence Sync byte has not been found in 3120 packets	X	X	X	X	X
Continuity Count Errors	Packets have been lost				X	X
Transport error [3]	transport_error_indicator in TS packet header is set					X
Multiple registration descriptors	Multiple registration descriptors in any given iteration of a descriptor loop [4]					X
PID values below 0x30 are used in the TS	PID values below 0x30 are reserved for specific applications as defined in the relevant standards. Any other use of these PID values is an error.					X
Missing Descriptors	One or more required descriptors were not found in the stream [5]			X	X	X
Legend:						
TOA: TS Off Air, POA: Program Off Air, CM: Component Missing, QOS: Quality of Service, TNC: Technically Non-Conformant						
Notes:						
1) See also special case of Distributed Transmission Adapter (Cadence Sync Byte) [5].						
2) Only of significance if Distributed Transmission (A/110A [5]) is in use and looking at the output of the Distributed Transmission Adapter.						
3) Transport sync errors are indicative of missing packets. Missing packets are treated elsewhere in this document.						
4) The error may be more severe, depending upon the situation.						
5) The following descriptors are required to be present in the stream: AC-3 Audio Descriptor, Program Smoothing Descriptor, ISO-639 Language Descriptor (until March 2008) and Service Location Descriptor.						

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