

R&S® A/V DISTORTION ANALYSIS

Inspecting Output Quality of Audio and Video Devices

Products:

- ▶ R&S®VTC
- ▶ R&S®VTE
- ▶ R&S®VTS
- ▶ R&S®BTC

Harald Ibl, Anna Sachs | 7BM87 | Version 1e | 08.2020

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1 Introduction

For A/V devices such as smartphones, tablet PCs, Blu-ray players, set-top boxes and TV sets, the perceived video quality must satisfy very high standards. A/V devices need to hold their own in three main areas:

- ▶ **Stability**
(environmental influences, response to source signal disturbances, etc.)
- ▶ **Performance**
(switching times, delays)
- ▶ **Compliance with standards**
(input and output formats)

Any deviations from the expected video and audio output can be automatically and precisely detected with R&S® A/V distortion analysis on all common analog and digital interfaces such as HDMI™ and MHL™.

This document examines the relevant setups and configurations

This chapter begins by discussing the basic concept of R&S® A/V distortion analysis. This is followed by a list of the supported A/V interfaces and test instruments. Then, the typical application areas are described.

Chapter 2 examines technical considerations related to the test sequence and measurement results. This information can be used to derive the proper configuration for any application. Chapter 3 contains practical examples.

1.1 Basic concept

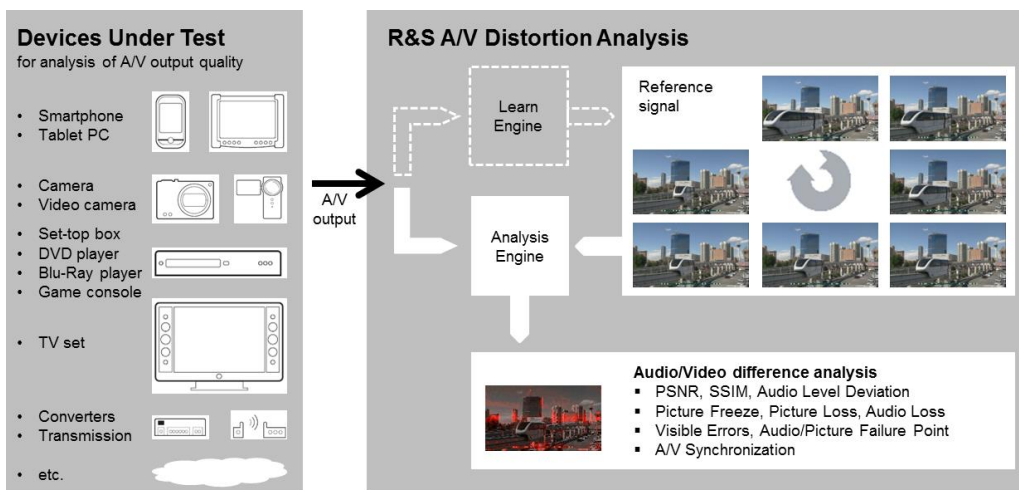


Figure 1-1: Basic concept of R&S® A/V distortion analysis

The R&S® A/V distortion analysis measurement option compares the video and audio output of a device under test (DUT) in real time with a previously recorded reference. For the reference recording, the same video processing chain and the same A/V material must be used. R&S® A/V distortion analysis measures the deviations with respect to a recorded reference (as opposed to absolute A/V quality). Using this recorded reference has the advantage that all video scaling applied to the signal in the video processing chain is excluded from the test. Instead, the DUT performance is evaluated to allow reliable identification of influences related to faulty DUT behavior or other disruptions.

The left half of the R&S®A/V distortion analysis user interface (see [Figure 1-2](#)) clearly shows the result of the comparison (middle image: "Difference") between the applied A/V signal (left image: "Signal") and the reference sequence (right image: "Reference") in real time. On the right half of the screen, individual measurement results can be formatted in various ways, e.g. tables, graphs, detailed log entries (see [2.4](#)).

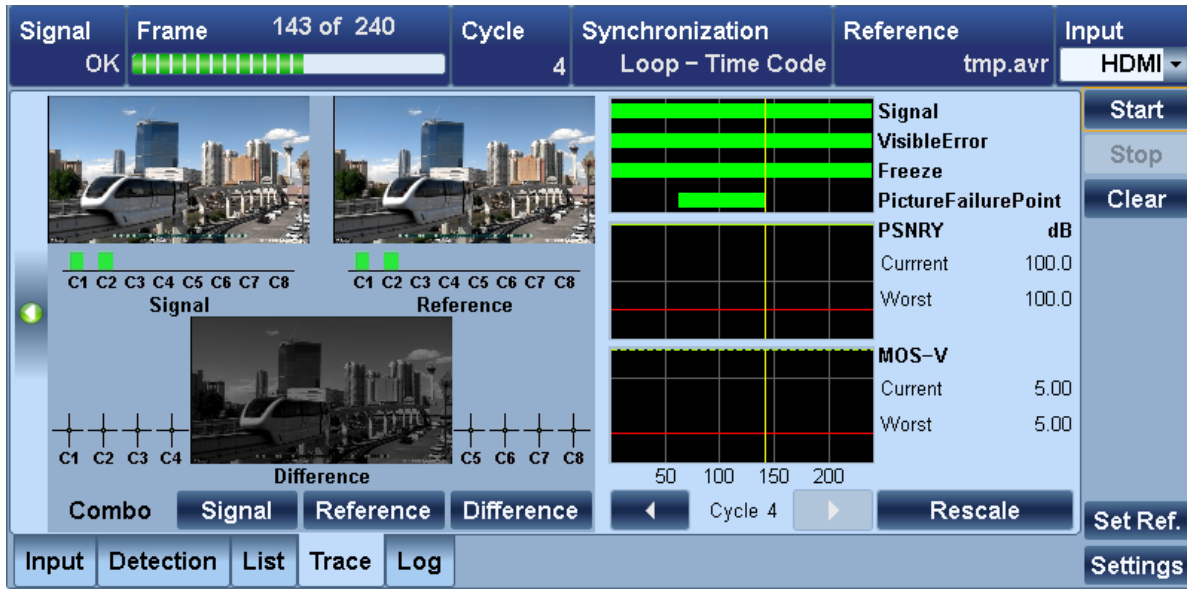


Figure 1-2: User interface for the R&S®A/V distortion analysis measurement option

Using R&S®A/V distortion analysis, there are three different basic possibilities for the reference:

- ▶ **Self Referenced:** Each transmitted frame is compared with the previously transmitted frame. In this case, no reference needs to be recorded. "Self Referenced" is used, for example, during tests on image stabilizers. In addition, the picture freeze and black frame measurements can be used to detect errors in the video output without having to first record a reference. In this manner, video sequences of any length can be analyzed.
Example: Testing whether an HD recorder handles video without judder and dropouts.
- ▶ **Still Picture:** The DUT plays back a stationary pattern in an endless loop. This image is stored once as the reference. This method is useful, for example, for identifying pixel errors or checking whether the specified menu screen is actually present after executing a certain command sequence.
- ▶ **Loop – APL / Loop – APL Section / Loop – Time Code:** Here, any A/V sequence can be used as the reference. Depending on the refresh rate, the sequence can have a maximum length between 15 seconds and 60 seconds. During the analysis process, this reference is saved in the test instrument's RAM. For continuous tests, the DUT plays back the A/V sequence in an endless loop. This Application Note focuses mainly on the Loop – APL / Loop – APL Section and Loop – Time Code reference methods and examines various uses thereof.

A faulty DUT can deviate from the content of the reference sequence in various ways. Every case is reliably detected:

- ▶ Faulty pixels within a frame
- ▶ Unexpected frame
 - Frame not updated ("picture freeze")
 - Black frame
 - Dropped frames
- ▶ Incorrect audio level

- ▶ Incorrect synchronization
 - Fluctuating frame rendering rate
 - Changes in offset between video and audio (A/V delay)

Besides allowing quantification of deviations, R&S®A/V distortion analysis can perform subjective picture assessment measurements. Such measurements reveal how strongly the errors that occur would be perceived by a human.

The individual tests are:

- ▶ MOS-V (2.3.2.8)
- ▶ Visible error (2.3.4.1)
- ▶ Picture failure point (2.3.4.2)
- ▶ Audio failure point (2.3.4.3)

In this manner, it is possible to automate test sequences that are specified based on visible errors/audio dropouts.

Another special feature provided by R&S®A/V distortion analysis is the ability to detect "overlays" while recording a reference sequence. Overlays can be the player's control bars, status information or logos which cover parts of the video content during output. In this manner, the measurement focuses on the actual video content and cannot be disrupted by unexpected overlay content (see 2.1.1.2).

Analysis of the individual pixels in the frame always uses the same format with R&S®A/V distortion analysis: namely, 720 x 576 pixels in the color range YCbCr and 4:2:0. If the video signal is in a different format, it is converted to this format prior to analysis. This ensures constant speed during the subsequent analysis process regardless of the number of input pixels. Since the reference is recorded via the same processing path, this transformation does not influence the identification of picture errors.

1.2 Supported A/V Interfaces and Test Instruments

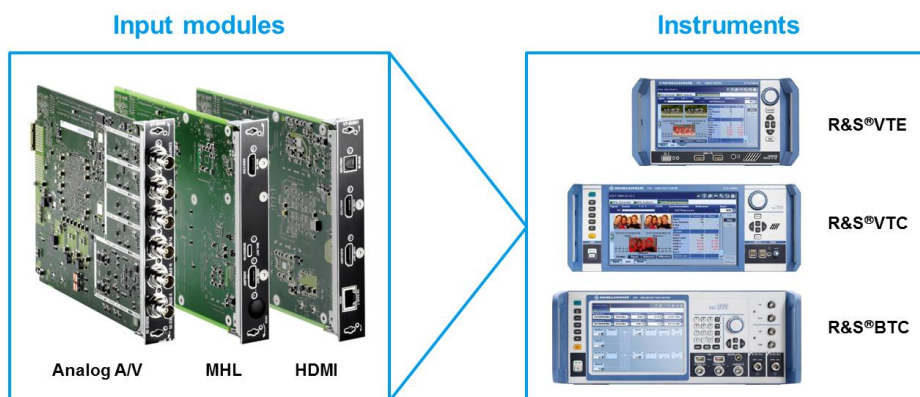


Figure 1-3: A/V interfaces and test instruments supported by R&S®A/V distortion analysis

R&S®A/V distortion analysis can be used with all common A/V interfaces and corresponding signal formats in conjunction with the following input modules:

- ▶ Analog A/V:
 - Composite (SD), component (SD/HD), VGA
- ▶ MHL™
 - Version 1.2 & 2.0, resolution up to 1920x1080, 8x audio (PCM up to 48 kHz)

► **HDMI™**

Version 1.4 & 2.0 (3G), resolution up to 4k (4096x2160), 8x audio (PCM up to 48 kHz)

Other digital interfaces such as SDI, DVI, LVDS and DisplayPort can be accommodated using external signal converters that support HDMI™. In this manner, the LVDS output of a TV set mainboard can be analyzed, for example. If this TV interface is not accessible, it is recommended to use the A/V signal on the SCART output.

The input modules can be used in the R&S®VTE compact video tester as well as the R&S®VTC video test center. These two instruments differ primarily in terms of the size of the built-in display and the number of module slots.

If the A/V device under test (DUT) has a TV/broadcast receiver that requires comprehensive stress testing with all relevant interference types (e.g. fading, adjacent channel occupation), the R&S®BTC broadcast test center is recommended since it can also accommodate the "Analog A/V" and HDMI™ input modules.

	R&S®VTE	R&S®VTC	R&S®BTC
Display size	7"	11.6"	8.4"
Module slots	3	8	8

Figure 1-4: Comparison of module slots and display formats

The modular design of the test instruments allows installation of analysis modules as well as modules to generate suitable test signals:

- **HDMI™ generator:**
Version 1.4 and 2.0(3G). Resolution up to 4k x 2k, 8 audio channels.
- **Broadcast modulator (R&S®VTE/VTC only):**
Generates RF broadcast signals in line with all common standards and allows easy execution of RF tests, e.g. with different levels and C/N values.

All of the test instruments presented here support a comprehensive set of remote control commands for automation of R&S®A/V distortion analysis.

1.3 Application Areas

R&S®A/V distortion analysis is useful in any application involving processing of video and audio signals that are output on a suitable interface.

It does not matter whether the signal reaches the DUT via a transmission path or is played back directly from memory or generated in the DUT itself.

Typical applications are as follows:

Stability

- Effect of environmental influences such as temperature, EMC¹, shock and humidity
- Resource handling (e.g. memory leaks, processor load, memory management)
- Hardware and firmware reliability under long-term conditions
- Boosting software quality through increased test depth with automated software tests

¹ Rohde & Schwarz offers special solutions for EMC testing (see 5.1).

- ▶ Reducing test times through automated picture inspection in series production

Performance

- ▶ Switching time between different transmission channels
- ▶ Delay between signal request and signal arrival
- ▶ Missing video images due to faulty decoder implementation
- ▶ Audio to video synchronization ("lip sync")
- ▶ Coverage issues

Compliance

- ▶ Behavior in the presence of defined transmission disruptions such as weak signal levels, low signal-to-noise ratio or strong adjacent channels

2 Basic Operation

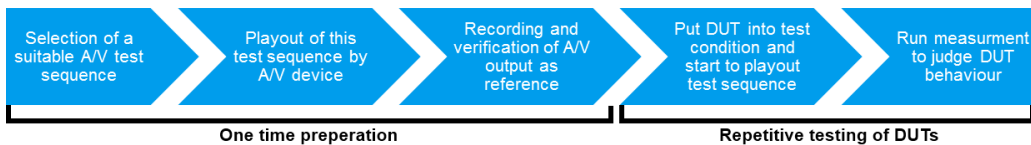


Figure 2-1: Operating steps with R&S® A/V distortion analysis

As shown in [Figure 2-1](#), the A/V reference sequence must first be recorded in a one-time preparatory step. This includes verification of whether usage of the recorded reference leads to error-free measurement results. [Section 2.1](#) discusses the prerequisites that impact the selection of the A/V content in the sequence.

After the reference has been recorded, it can be saved for subsequent use with all DUTs with identical A/V nominal output in terms of the content and format.

Once the reference is selected, testing of the DUTs can begin. The DUTs are configured such that the test sequence is played back under the desired test conditions at the A/V output in an endless loop. Then, the actual test process begins as discussed in [section 2.2](#). Finally, the measured values and presentation of results are considered in [section 2.3/2.4](#).

2.1 Recording the Reference

In order to successfully record the reference, the DUT must play back the test sequence in an endless loop such that the A/V content can be clearly identified in each repetition. This depends on three factors:

- ▶ Synchronization method
- ▶ Content of test sequence
- ▶ DUT configuration

The following subchapters take a detailed look at the settings required for each application case. Then, the precise steps required to record the reference are presented.

2.1.1 Synchronization Method

The purpose of the synchronization method is to quickly identify each video frame to be analyzed based on a unique identifier. This identifier allows the following:

- Detection of when the A/V content of the test sequence has been fully acquired during recording of the reference
- Determination of the associated reference content during the measurement

2.1.1.1 APL/ALP Section

The average picture level (APL) method uses the behavior of the average brightness values of all frames as a unique identifier. An algorithm then determines the start and end of the sequence in the recording. During the measurement, the algorithm allows identification of individual images in relation to the reference.

Almost any test sequence content can be directly used. However, the APL value must exhibit sufficient fluctuations. Ideally, the sequence should contain scene cuts as shown in the following example.

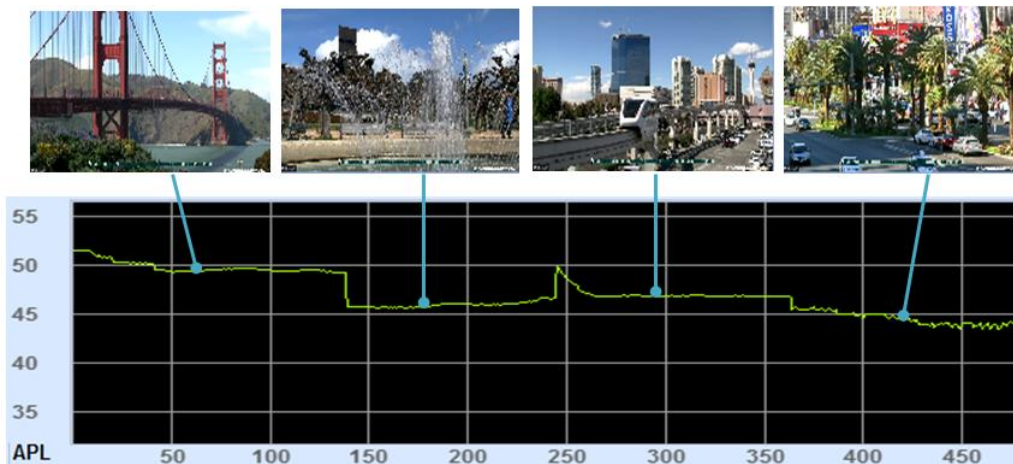


Figure 2-2: APL curve of a video sequence with four scene cuts

Sequences for which the APL value does not vary over time (or varies only slightly) are critical. This is often the case with test patterns having elements that move within a picture while the overall brightness value remains constant. In such cases, "Loop-APL Section" can be used to choose a region in which the APL is determined.

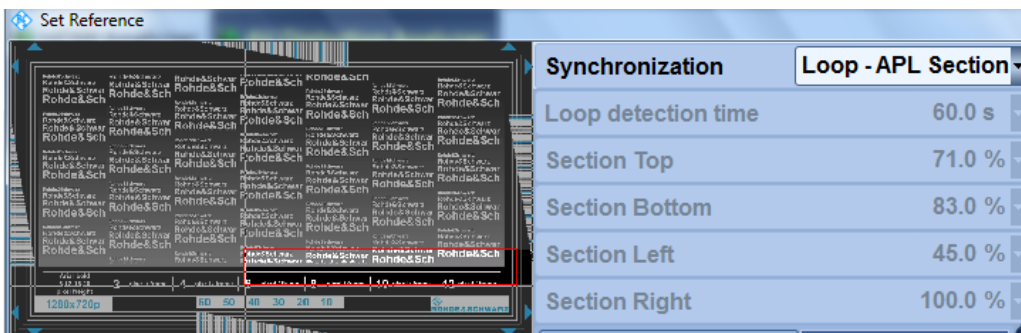


Figure 2-3: APL window configuration for synchronization to vertically scrolling text

In the figure, an excerpt (highlighted in red) was chosen such that the vertically scrolling text generates a repetitive APL sequence even though the APL value is constant for the overall picture.

If there is any doubt whether the APL curve for a sequence is suitable for synchronization, this can be easily verified. Just set the synchronization to "Self referenced" and display the APL curve in the trace view. This value should vary by at least 5%.

Important when using the APL method

Usage of the APL method presumes that the DUT outputs exactly the same number of video images in each loop when playing back the test sequence. This is generally true if the video sequence is output via a hardware decoder (example: TV set-top box).

Make sure, however, that the DUT does not modify the composition of the signal during playback. This often happens if a video is fed to the DUT in interlaced format and the output from there is in progressive format. Depending on the image processing strategy, images can be discarded or doubled. To prevent this from happening, always make sure the output format is identical to the input format.

DUTs that use a software decoder for image generation are entirely unsuitable for APL synchronization (example: smartphone).

In this case, it is generally not certain that the number of video images on the interface is identical to the number in the video signal. As a result, the number and the order of the images in a sequence can vary from one repetition to the next.

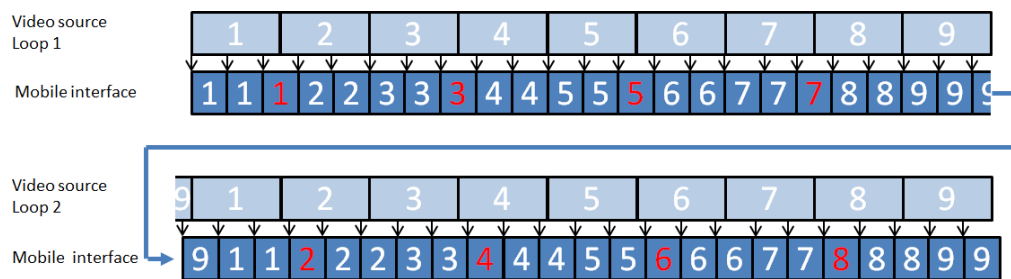


Figure 2-4: Playback of a video sequence with 24 images per second via a video interface with a refresh rate of 60 images per second

Here, it is not possible to record a reference.

In such situations, synchronization is possible using a timecode as described in the following section.

2.1.1.2 Timecode

To allow clear identification, each frame is assigned a timecode:

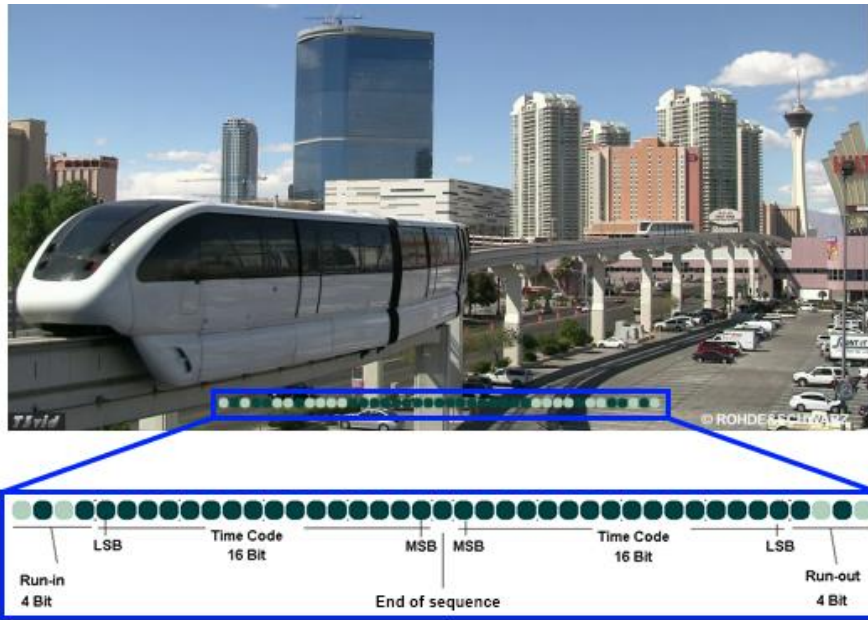


Figure 2-5: Timecode for clear identification of frames

This bit sequence uses a dark-green circle as a binary "0" and a light-green circle as a binary "1". The run-in and time code for the left half of the picture are mirrored in the right half in order to obtain the desired protection against picture errors. The first frame in the test sequence has the time code "0" while subsequent frames are numbered sequentially. For the last frame in the sequence, the end of sequence bit is also set.

Application Note 7BM84 (see 5.3) discusses how to automatically insert the time code with the R&S® time code inserter for a number of video formats. Transport streams (TS) with an inserted time code can be downloaded from the Rohde & Schwarz homepage under this Application Note ([search term: 7BM87](#)).

The timecode allows the frames to be uniquely identified. Unlike the APL method (2.1.1.1), it is possible to record the reference even if frames are doubled or skipped during playout of the test sequence by the DUT on the A/V output.

The time code method also has the following possibilities:

- ▶ **Ignore specific sections of a sequence**
If additional frames are inserted without a time code prior to the start or after the end of the test sequence, such content is ignored during the measurement. This is useful in cases where the A/V output from the DUT at the start and end of the test should not be evaluated. For example, this might be required due to initialization of an LTE connection.
- ▶ **Ignore specific picture areas**
Some DUTs overlay their A/V output with status information, e.g. during video telephony. This content changes over time independent of the test sequence content. This, however, would corrupt the measurement results. R&S® A/V distortion analysis can automatically detect such situations when recording the reference and suppress the affected areas during analysis. Here, special test images must be contained in the test sequence. Such images can be automatically added with the R&S® time code inserter

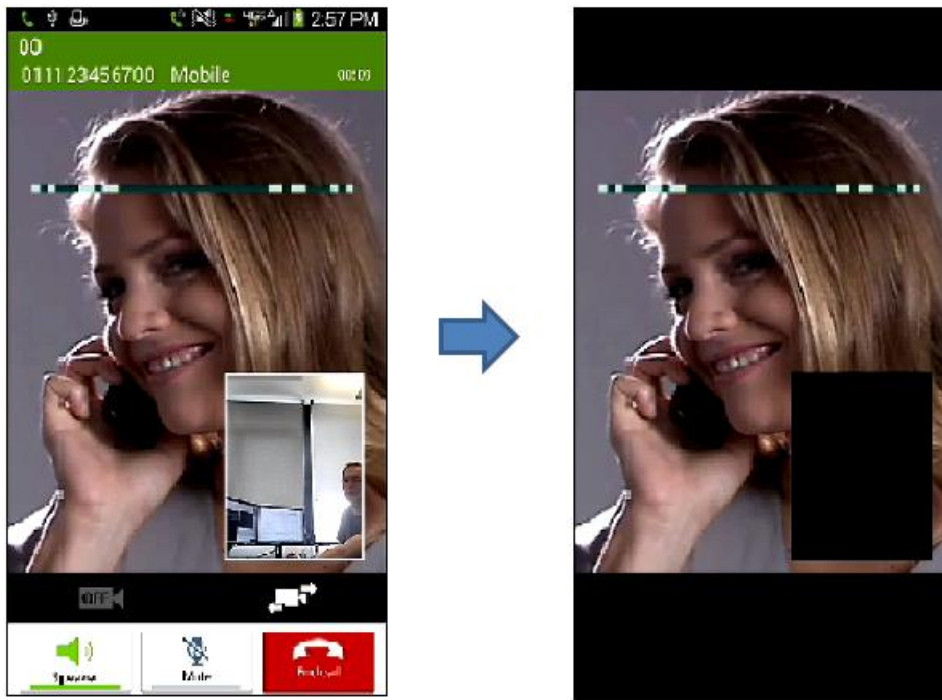


Figure 2-6: Automatic detection of overlays during reference recording (left: original picture; right: picture with overlay areas removed)

Another benefit of the timecode is the speed of synchronization. Unlike APL synchronization, this is possible with every video image - regardless of the picture content.

2.1.2 Requirements for the Test Sequence

The following issues must be kept in mind when selecting the test sequence:

- ▶ Image processing in the DUT (progressive / interlaced)
The selected image transmission technique for the test sequence format and A/V output format of the DUT must agree. Otherwise, the sequence can vary when repeated due to format conversion in the DUT. If this is not taken into account, the A/V distortion analysis will detect deviations even during undisturbed operation. Recording of a reference can also sometimes fail under such conditions.
- ▶ Sequence length
For the measurement, the video sequence is loaded as a reference in the system memory. As a result, the maximum possible length is limited. With the R&S®VTC/VTE, the limit is 1200 images and with the R&S®BTC, it is 900 images. However, the maximum number is guaranteed only in case of timecode synchronization. In case of APL synchronization, the start and end of the sequence must somewhat overlap in order to detect the sequence loop. The size of the required area is dependent on the APL curve. Typically, the maximum sequence length is reduced by 50 to 100 images.
- ▶ Synchronization method (2.1.1)
 - APL / APL section
For APL/APL section synchronization, the sequence must exhibit sufficient differences in the brightness curve (see 2.1.1.1). Otherwise, there is the risk that the sequence start and end will not be recognized in the reference recording. Longer sections with constant brightness can cause an increase in the synchronization time.

- Time code
The frames must contain a time code as discussed in [2.1.1.2](#).

2.1.3 Configuration of the DUT

In order to successfully record the reference, the DUT must play back the test sequence in an endless loop such that the A/V content is output identically in each repetition. The following must be taken into account:

- ▶ A/V output format
The selected image transmission technique must be identical to the format of the test sequence (see [2.1.2](#)). The same applies to the refresh rate if the test sequence does not contain a time code.
For example, if the output format on the set-top box is set to 1080i 50 Hz (1920x1080 interlace), the test sequence must also contain this format.
- ▶ Image enhancement algorithms
Such algorithms used in the DUT can modify the original test sequence content prior to arrival on the A/V output such that the content of the test sequence is not always output identically for each repetition in the endless loop. It is necessary to deactivate this functionality in some cases.
- ▶ Vertical synchronization (V-Sync)
With software players, there are cases where the image data is updated while the screen builds the image. This results in mixing of two different frames. To avoid this problem, software players support "V-Sync". This technique ensures that each frame is reproduced in its entirety on the A/V output. It must be activated in the DUT to avoid what is known as "tearing":

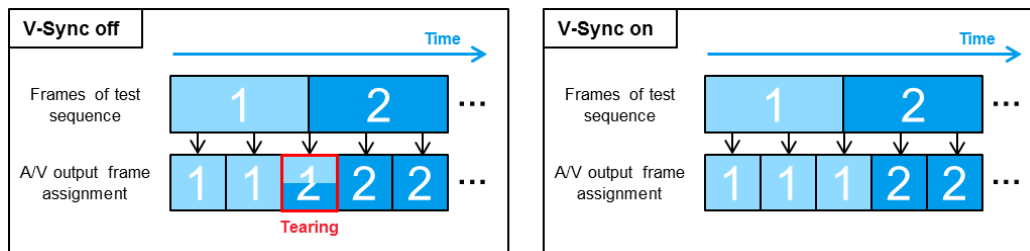


Figure 2-7: Activation of V-Sync technology to avoid tearing

2.1.4 Execution

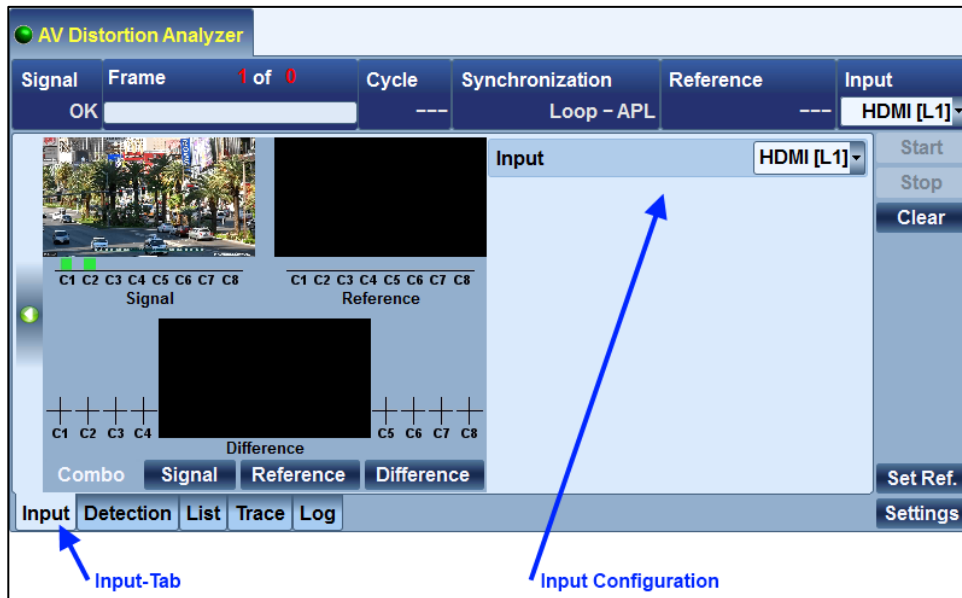


Figure 2-8: Input tab in R&S®A/V distortion analysis for configuration of the desired A/V analysis input interface

The "Input" tab in R&S®A/V distortion analysis allows selection of the desired input where the video to be analyzed is applied. If this is an analog interface, the aspect ratio, color range and synchronization must also be set correctly.

Then, click the "Set Ref." button in the right bar to access the "Set Reference" dialog:

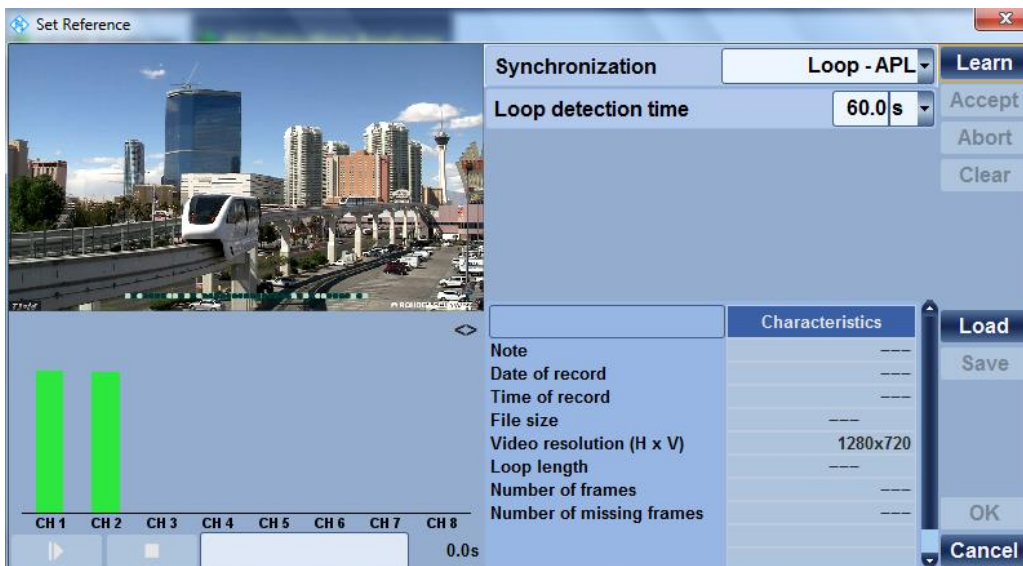


Figure 2-9: "Set Reference" dialog for recording the reference sequence

Usage of the "Set Reference" dialog (Figure 2-9) is divided into the following steps:

1. Deletion of current reference
If a reference was already selected in the past, it must first be deleted with the "Clear" button before recording a new reference.
2. Inspection of incoming A/V content
In the "Preview area", the incoming frames from the DUT as well as the individual audio levels are continuously updated. If the content is not the expected test sequence, check the configuration of the DUT and the Input tab (Figure 2-8).

3. Configuration of synchronization method

The desired synchronization method is set in the "Synchronization" drop-down list (see 2.1.1). Depending on the selection, some further values might be required:

- APL / APL Section
 - Loop detection time

This is the upper limit for the duration of the reference recording. If a repetition of the content is not detected during this time, the recording is aborted (unsuccessful). This value must be set greater than the length of the test sequence. A much larger value has no disadvantage in functional terms. However, there will be a longer wait before aborting if an error occurs.
 - Section position and size (only for APL section)

The section must be selected such that its APL value for the individual images in the sequence is highly variable (see 2.1.1.1).
- Timecode
 - Allowed missing frames

Based on evaluation of the timecode, it is possible during recording of the reference to precisely identify the frames in the test sequence that were not yet output by the DUT. Normally, recording cannot be successfully completed until all frames in the test sequence have been detected. However, many devices sporadically skip over frames, making it necessary to wait for the output of a few remaining frames over many sequence repetitions. Using this configurable tolerance, the wait time can be reduced in this case. Missing frames are skipped accordingly during the measurement.
 - Timecode position and size

This defines the area in the incoming frames where the time code should be looked for. This arrangement is supported by the "Preview area" since the incoming frames are displayed there with their time code along with the current search area using increased brightness values. If the selected search area is very large, the start of the measurement can be delayed by several hundred milliseconds. There is also a higher risk of random picture areas being interpreted as the time code.

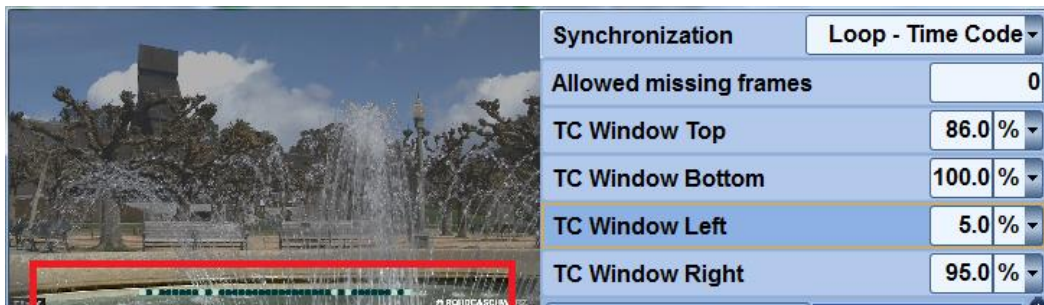


Figure 2-10: Selection of the timecode search area

- Self Referenced

No further settings required here. The measurement can start immediately without recording a reference
 - Still Image

With the start of recording, the currently applied video image is loaded as the reference
- ### 4. Recording start
- Click the "Learn" button to start recording the reference. A red circle in the top right corner of the frame preview indicates that recording is underway. The timing of the start is irrelevant since the DUT outputs the test sequence in an endless loop.

5. Recording end

During recording, the software checks continuously to see whether all frames in the test sequence were already detected. The technique that is used depends on the selected synchronization method:

– APL / APL Section

As soon as the first repetition of the frames occurs after the start of recording, this is detected based on the APL curve which now repeats. Be aware of possible "loop inside a loop" scenarios. For example, if the content of the test sequence has the pattern "ABABC", a successful recording will be indicated as soon as the second "A" appears. However, if this is not confirmed and recording is resumed, the correct end of the test sequence will be detected after the "C" occurs. As an additional check, the current detected sequence length is indicated following detection of a repetition in the "Reference properties area" by the "Number of frames". If this number is less than the actual value, recording should be resumed.

– Timecode

Based on evaluation of the timecode, the frames in the test sequence that were not yet detected can be precisely determined during recording. This is indicated in the "Reference properties area" by the "Number of missing frames". Unless a specific number of missing frames was allowed when configuring the synchronization method (step 3), successful conclusion of recording is not possible until all of the frames have arrived.

6. As soon as all frames in the sequence have been detected, the color of the circle in the frame preview switches from red to green. The recorded reference is now no longer extended by incoming frames. It should be confirmed by the user with the "Accept" button.

7. Saving the reference

Click the "Save" button to save the reference. You can enter a comment in the "Note" field in the "Reference properties area". The saved reference can now also be copied to other test instruments with R&S®A/V distortion analysis installed for fast loading with the "Load" button. Other references will need to be recorded only if the nominal content and format for the DUT change (e.g. due to different test cases) such that the saved reference can no longer be used.

2.2 Configuring the Measured Values and Starting the Measurement

The reference must be selected before the measurement can be started (see [Figure 2-1](#)).

Then, you can select the individual measured values that are desired. The configuration dialog is accessed with the "Settings" button in the bottom right corner of the user interface:

	Enable	Status Trace	Result Trace	Lower Limit	Upper Limit	Advanced
Signal	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>				
Loop Detection	<input checked="" type="checkbox"/>					
Loop Detection Time	<input checked="" type="checkbox"/>				1.000 s	
Frame Number	<input type="checkbox"/>					
Cycle Number	<input type="checkbox"/>					
Cycle Time	<input checked="" type="checkbox"/>			0.00 s	999.00 s	
External Start Trigger						Off
[+] Failure Point						
[+] Video						
Freeze	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>				
Relative Picture Freeze	<input checked="" type="checkbox"/>			0.00 %	99.00 %	
Dropped Frames	<input checked="" type="checkbox"/>		<input checked="" type="checkbox"/>		0	
Black Frame	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>				APL < 5 %
AveragePictureLevel	<input checked="" type="checkbox"/>					
Pixel Error Y	<input checked="" type="checkbox"/>				1000	

OK Cancel

Figure 2-11: "Settings" dialog for R&S®A/V distortion analysis

The desired measured values are activated in the first column ("Enable"). The next two columns determine which measured values will appear in the trace display (2.4.2). In the "Status Trace" column for a pass/fail indication, up to three measured values can be selected in addition to the standard "Signal" state. In the "Result Trace" column for numerical measured values, a maximum of two can be selected for VTE and three for VTC and BTC. Limits are indicated in the "Lower / Upper Limit" columns. If no value is displayed for a given measured value, this limit is not applicable and cannot be configured. The default values were selected to cover the majority of application cases.

To start the measurement, click the "Start" button.

2.3 Measured Values

This section describes the individual measured values produced by R&S®A/V distortion analysis along with the interpretation of the results. For the sake of clarity, the measured values in the user interface are divided into groups.

2.3.1 "Status" Measured Value Group

Signal	Frame	196 of 480	Cycle	Synchronization	Reference	
OK	<div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div></div>		10	Loop - Time Code	tmp.avr	
	Current	Worst	Fault	Lower Limit	Upper Limit	
Signal	OK					
Loop Detection	Passed					
Detection Time	00:00:00.145				1.000 s	
Frame Number	196	480				
Cycle Number	10	---				
Cycle Time	9.20 s	9.30 s	---	0.00 s	999.00 s	

Figure 2-12: Status-related measurement with R&S®A/V distortion analysis

2.3.1.1 Signal

Indicates whether the applied signal format is consistent and the A/V content can be accessed. Otherwise, no further measured values are available. Besides the normal result display (see 2.4), the signal sync status is shown additionally with "Signal" in the top status bar (see [Figure 2-12](#)).

2.3.1.2 Loop Detection

Indicates whether the applied signal could be synchronized with the reference. Otherwise, no further measured values are possible.

2.3.1.3 Loop Detection Time

When the measurement starts, the elapsed seconds are incremented until the incoming A/V content can be synchronized with the selected reference. This measured value can be used to analyze DUT response times, i.e. how long it takes from a given time (= measurement start) until the expected nominal content appears on the A/V output.

2.3.1.4 Cycle Time

A "cycle" is the time interval required for one pass through the complete test sequence. The "cycle time" indicates how long the last completed pass required. This value can be used to assess whether the DUT's A/V output is inconsistent over time.

2.3.1.5 Frame Number

Indicates which frame within the sequence was just detected and is being compared. In this manner, the status of the current measurement is visible at a glance. This "frame" indication appears also in the top status bar.

2.3.1.6 Cycle Number

Indicates how many times the complete sequence has already been analyzed. For long-term stability tests, this provides a fast indication of the run time already completed. This "cycle" indication appears also in the top status bar.

2.3.2 "Video" Measured Value Group

	Current	Worst	Fault	Lower Limit	Upper Limit
[-] Video					
Freeze	OK	OK	0		
Relative Picture Freeze	0.00 %	0.00 %	---	0.00 %	99.00 %
Dropped Frames	0	0	0		0
Black Frame	OK	OK	0		
Avg. Picture Level	47.0 %				
Pixel Error Y	0	0	0		1000
PSNR Y	100.0 dB	100.0 dB	0	25.0 dB	
SSIM	1.000	1.000	0	0.600	
Mos-V	5.00	5.00	0	2.00	
Rendering Rate	---	---	---	15.00 Hz	65.00 Hz
AVG Rend Rate	---	---	---	15.00 Hz	65.00 Hz
STD Rend Rate	---	---	---	0.00 Hz	2.00 Hz

Figure 2-13: Video-related measurements with R&S® A/V distortion analysis

2.3.2.1 Freeze

If the DUT outputs the same frame more than four times in a row, a "freeze" is detected:

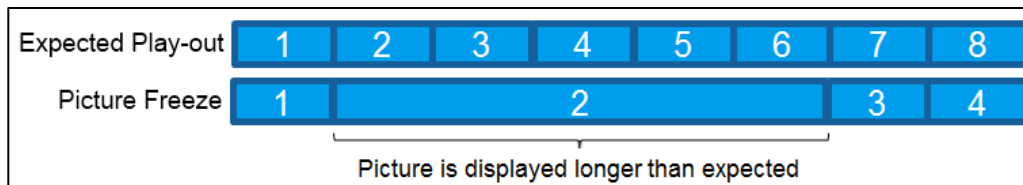


Figure 2-14: Definition of the "picture freeze" event

Whether consecutive frames are deemed identical is dependent on the selected synchronization method. With the time code method, the relevant criterion is an identical time code. With the APL / APL section method, it is an identical APL value. In the latter case, this means a picture freeze is reported during the measurement even if it already occurred during recording of the reference.

If a picture freeze occurs, the currently applied frame N is also no longer compared with reference image N but instead with reference image N+1. The associated degradation in the picture quality measured values (see 2.3.2.5 ff) serves as an indicator of how conspicuous the picture freeze is.

If the time code method is used for synchronization, it is possible to automatically ignore frames at the start and end of the test sequence. As described in 2.1.1.2, sequence sections without a time code can be inserted for this purpose. During output of these sequence sections, the measurement is paused. As a result, no direct picture freeze is reported if the DUT's A/V output freezes up in this part of the test sequence. Such a situation can be recognized indirectly based on the frame number (2.3.1.5) since the regular updating is delayed or does not happen at all.

2.3.2.2 Relative Picture Freeze

Indicates the total duration of all picture freezes in relation to the total measurement time.

2.3.2.3 Dropped Frames

This involves consecutive frames in the test sequence that the DUT skips over during output. This can occur, for example, due to short-term processing capacity bottlenecks in the architecture, input data errors or the need to adapt the synchronization after a picture freeze.

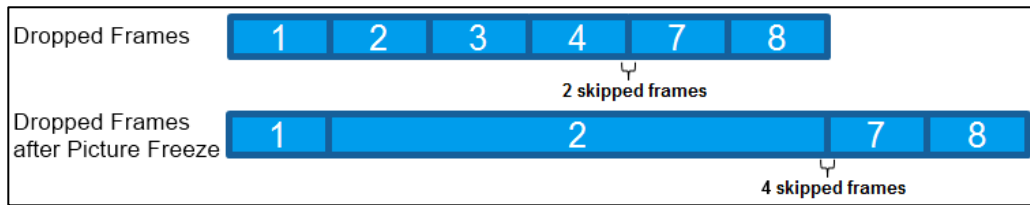


Figure 2-15: Example for dropped frames

When using the APL / APL section synchronization method, loss of up to two consecutive frames can be recognized as a frame drop. In actual practice, this is adequate because the APL / APL section method is used for DUTs with synchronized A/V output (2.1.1.1).

The time code synchronization method can detect dropped frames of any order of magnitude.

2.3.2.4 Black Frame

Black frames can occur if the DUT cannot determine the content of the next applied frame in the required time interval, e.g. due to short-term processing capacity bottlenecks in the architecture or input data errors. It is possible to specify the limit APL value for evaluating an incoming frame as a black frame. By default, a frame is evaluated as a black frame if the APL value falls below 5 %. Here, it does not matter if this already occurred while recording the reference.

2.3.2.5 Pixel Error

As discussed in 1.1, analysis of individual pixels in the frame involves scaling to 720x576 pixels and transformation to the Y / Cb / Cr 4:2:0 format. Overall, 414720 (720x576) brightness values and, respectively, 103680 color difference values are thus available for the comparison with the reference.

The "pixel error" measured value now indicates separately for the three components Y, Cb and Cr the number of pixels, which differ from the reference value in terms of their respective value. In this manner, it is possible to detect pixel errors that occur sporadically, e.g. on the A/V interface or during transmission.

Despite the upstream scaling to 720x576 pixels, even individual pixel errors in incoming frames with higher resolution are reliably detected. The intensity of the value deviation to be detected is lowered when the frame is scaled down but is generally not completely lost:

	Incoming frame with 1920x1080 pixels (excerpt)	Scaling result with 720x576 pixels (excerpt)	Detected pixel errors (red marking within grayscale display)
Error-free case			
Single pixel error			

2.3.2.6 Peak Signal-to-Noise Ratio (PSNR)

Calculation of the PSNR values is based on the same preprocessing as calculation of the "pixel error" values. For more details, see [2.3.2.5](#).

For the three components Y, Cb and Cr, the PSNR separately indicates the logarithmic ratio of the maximum possible total deviation of all pixels from the nominal value of the reference (MAX) and the current total deviation (mean square error, MSE):

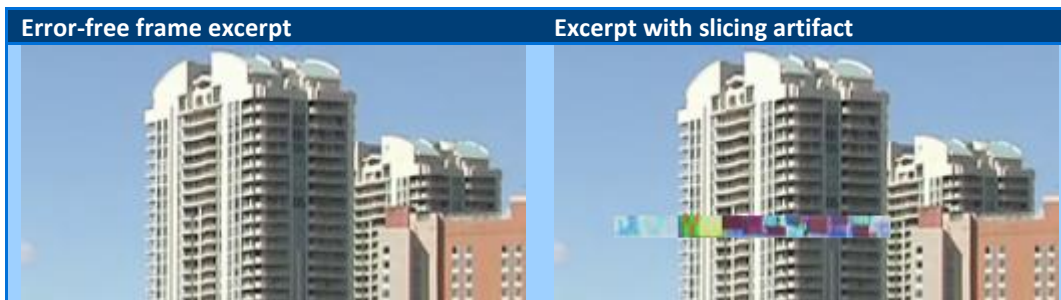
$$PSNR = 10 * \log_{10} \left(\frac{MAX^2}{MSE} \right) \quad , \text{ where } MSE = \frac{1}{m*n} * \sum_{i=0}^{m-1} \sum_{j=0}^{n-1} [I(i,j) - K(i,j)]^2$$

and:

- $I(i,j)$ = Nominal value of reference at position i,j
- $K(i,j)$ = Actual value of current frame at position i,j

The possible value range is thus from 0 dB (= maximum possible error) to ∞ dB (= perfect match). R&S®A/V distortion analysis has a limit of 100 dB in the latter case.

The PSNR value is a reliable indicator of disrupted transmission of compressed digital video content since in this case the characteristic slicing artifacts occur during decoding:



The decision threshold here is about 35 dB. Picture errors over this threshold affect only a handful of pixels and are thus generally not perceptible. However, impairment of only 1 % of all pixels due to slicing already results in a drop to about 26 dB.

2.3.2.7 Structural Similarity (SSIM)

The purpose and usage of SSIM are very similar to PSNR (2.3.2.6). However, a different metric is used and only the brightness component Y of the individual pixels is considered.

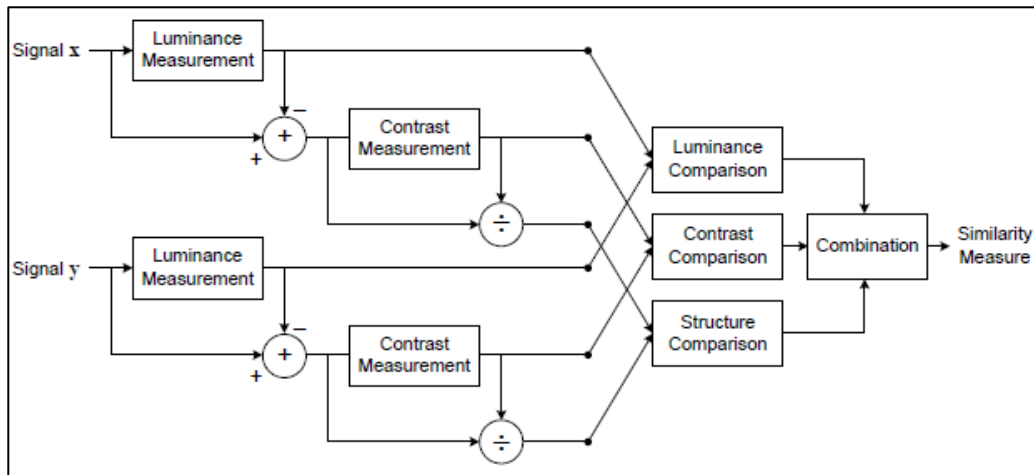


Figure 2-16: Diagram of the structural similarity (SSIM) measurement system [5].

The calculation method involves a combination of three equally weighted individual results. The first result is generated by comparing the average brightness (APL) of the actual and nominal pictures. The second influence factor is the contrast difference which follows from the standard deviations of Y . Finally, as the third factor the structural difference is taken into account by calculating the normalized standard deviations. The range of values is from 1 (= perfect match) to 0 (= maximum error). Visible errors begin at about ≤ 0.98 . For more details on the calculation process, see [5].

2.3.2.8 Mean Opinion Score – Video (MOS-V)

The purpose and usage of MOS-V are very similar to PSNR (2.3.2.6) and SSIM (2.3.2.7). However, the metric is based on the specification in ITU-T recommendation BT.500 [6] for the subjectively determined MOS:

Quality	Bad	Poor	Fair	Good	Excellent
MOS	1	2	3	4	5

The calculation involves transformation of the average SSIM value (MSSIM) in line with the characteristic from [5] followed by linear scaling of the range of values from [0,100] to [1,5]:

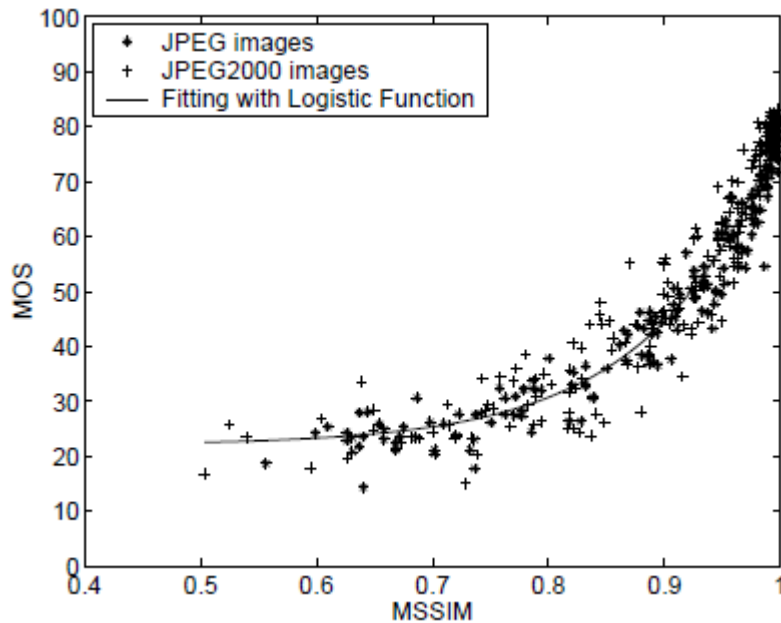


Figure 2-17: Empirical correlation of MSSIM and MOS-V [5]

2.3.2.9 Rendering Rate

The rendering rate is the rate at which the DUT outputs consecutive frames in the test sequence. In case of decoding with hardware decoders (e.g. TV set-top box), this is always identical to the refresh rate of the interface. However, if decoding is handled by a software decoder (e.g. smartphone), this value can differ from the refresh rate of the interface.

Note: This measurement requires the timecode synchronization method.

Fluctuations in the rendering rate over time indicate inconsistent processing of the test sequence frames by the DUT, e.g. due to short-term processing capacity bottlenecks in the architecture or inaccurate clocks.

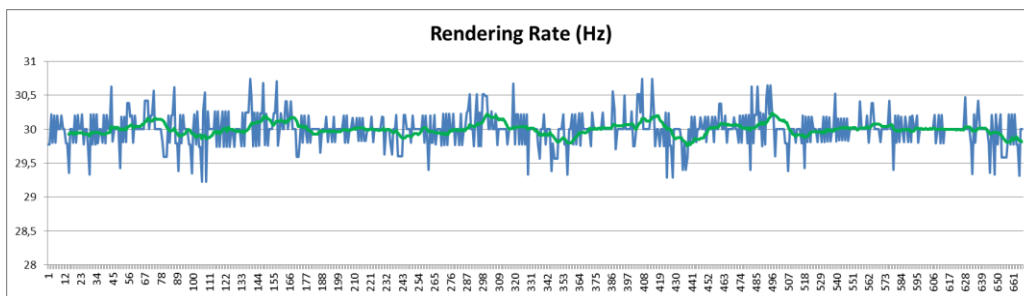


Figure 2-18: Example of deviations in the rendering rate at the end of a wireless video transmission

To determine the value, R&S®A/V distortion analysis counts the frames that are doubled (Figure 2-19) and forms the ratio with the update rate for the A/V interface.

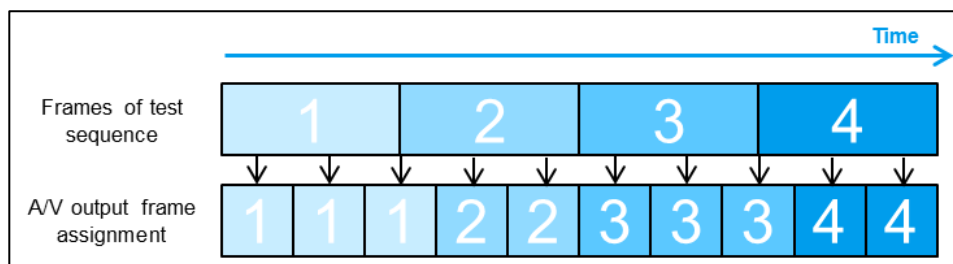


Figure 2-19: Frame assignment when the A/V output refresh rate is higher than the test sequence refresh rate

$$\text{Rendering rate} = \frac{\text{AV interface frame rate}}{\text{Average repetitions of same frame}}$$

The length of the sliding measurement window for calculation of the average in the above formula can be configured in the "Rendering Rate Settings" dialog. The default value is 2 seconds:

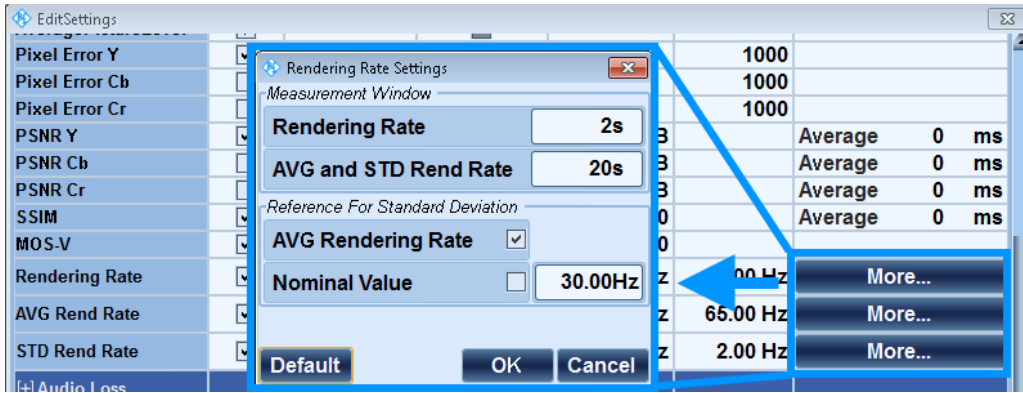


Figure 2-20: "Rendering Rate Settings" dialog called by one of the "More" buttons in the general R&S®A/V distortion analysis settings

Based on the normal rendering rate, two additional measured values are available:

- ▶ **AVG Rendering Rate**
The normal rendering rate is somewhat reactive for short-term changes with its default window length of 2 seconds for the average calculation. However, a time-stable reference value is required for the "STD rendering rate" described below. Accordingly, the "AVG rendering rate" is also available with a default window length of 20 seconds for the average calculation.
- ▶ **STD Rendering Rate**
This measured value represents the standard deviation of the expected rendering rate and is a customary measure of the fluctuation intensity. The refresh rate of the test sequence should be used as the reference value. This value can be directly entered in the configuration dialog under "Nominal Value" (Figure 2-20). Alternatively, the current measured AVG rendering rate can also be used as the reference

2.3.3 "Audio" Measured Value Group

2.3.3.1 Audio Loss

Analogous to picture freezes, dropped frames and black frames for video (2.3.2.1 ff), audio dropouts occur when the DUT loses audio data due to a short-term processing capacity bottleneck in the architecture or input data errors.

Regardless of the recorded nominal content of the reference, audio dropouts with a configurable minimum duration ("Upper Limit") and level threshold ("Advanced") are detected in parallel for up to eight channels:

EditSettings						
	Enable	Status Trace	Result Trace	Lower Limit	Upper Limit	Advanced
[-] Audio Loss						
CH 1	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		10000 ms	< -40.0 dBFS
CH 2	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		10000 ms	< -40.0 dBFS
CH 3	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		10000 ms	< -40.0 dBFS
CH 4	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		10000 ms	< -40.0 dBFS
CH 5	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		10000 ms	< -40.0 dBFS
CH 6	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		10000 ms	< -40.0 dBFS
CH 7	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		10000 ms	< -40.0 dBFS
CH 8	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		10000 ms	< -40.0 dBFS

Figure 2-21: Configuration of audio loss detection in the general R&S®A/V distortion analysis settings

2.3.3.2 Audio Level Deviation

Deviations with respect to the recorded nominal levels of the reference are detected in parallel for up to eight channels according to the configurable limits ("Lower / Upper Limit"):

EditSettings						
	Enable	Status Trace	Result Trace	Lower Limit	Upper Limit	Advanced
[-] Audio Level Dev.						
CH 1	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	-99.9 dB	10.0 dB	
CH 2	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	-99.9 dB	10.0 dB	
CH 3	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	-99.9 dB	10.0 dB	
CH 4	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	-99.9 dB	10.0 dB	
CH 5	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	-99.9 dB	10.0 dB	
CH 6	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	-99.9 dB	10.0 dB	
CH 7	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	-99.9 dB	10.0 dB	
CH 8	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	-99.9 dB	10.0 dB	

Figure 2-22: Configuration of audio level deviation detection in the general R&S®A/V distortion analysis settings

Analogous to the PSNR / SSIM / MOS-V results for video (2.3.2.6 ff), this value is used to quantify audio-related disruptions in the DUT's output.

2.3.4 "Failure Point" Measured Value Group

Depending on the test case, a certain proportion of A/V errors must be tolerated in the DUT's output, e.g. during analysis of the susceptibility to interference. This is because the limits in test specifications such as NorDig [2] and DTG D-Book [6] generally apply to an error event that causes an unacceptable drop in the A/V quality as perceived by a human ("failure point").

The capabilities provided by R&S®A/V distortion analysis in this area are presented below:

	Current	Worst	Fault	Lower Limit	Upper Limit
[-] Failure Point					
Visible Error	OK	OK	0		
Picture Failure Point	OK	OK	---		
Audio Failure Point	OK	OK	---		

Figure 2-23: Failure point related measurements with R&S®A/V distortion analysis

The "visible error" event that is mentioned involves an upstream interpretation of the detected picture errors on which the picture failure point test is then based.

After the measurement begins, unlike all the other measured values the PASS/FAIL result for the picture and audio failure point is determined only once and then frozen. As a result, repetition of a failure point test requires restarting the measurement.

2.3.4.1 Visible Error

The "visible error" measured value imitates the perception of a subjective observer. In other words, an error is reported if a human observer would have perceived the disruption. Whether a disruption is perceived is dependent on the size of the disruption as well as the duration.

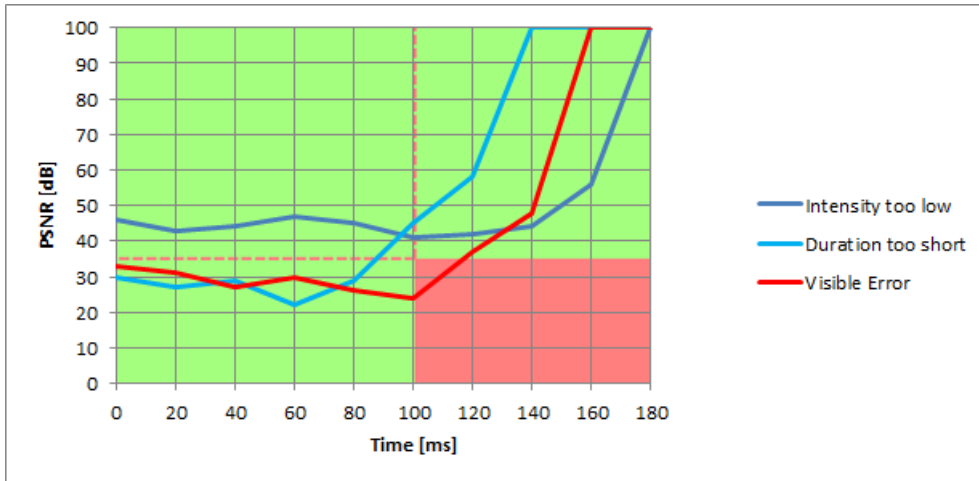


Figure 2-24: Visible error determination based on PSNR and duration thresholds

This is also implemented in R&S®A/V distortion analysis in such a manner. The PSNR value or the SSIM value can be used as the interference quantity. The thresholds for the interference quantity and duration can be user-configured. This is helpful because the perception of a disruption can be highly dependent on the test environment.

The instrument's default settings are useful as a starting point.

Threshold SSIM 0.98; duration 100 ms or

Threshold PSNR 35.0 dB; duration 100 ms

This was determined empirically with the following parameters.

Screen size 42"; H.264 coding; DVB-S2 transmission with 25 frames per second, AWGN interference profile

Picture freezes and dropped frames indirectly affect the visible error determination since such events cause a PSNR/SSIM degradation (2.3.2.1 / 2.3.2.3).

These limits can be user-configured or reset to the default values for digital or analog interfaces with a single click:

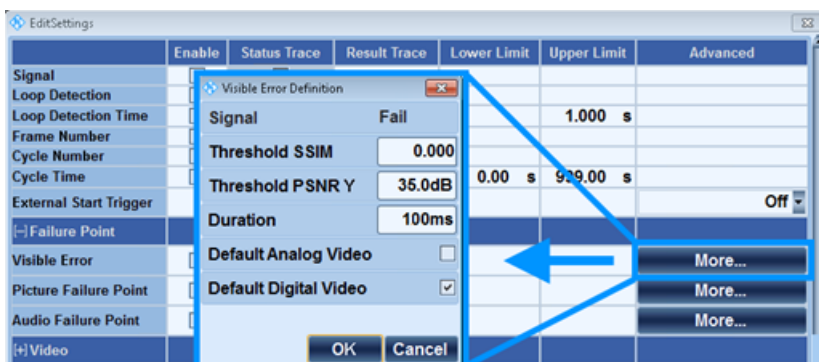


Figure 2-25: "Visible Error Definition" dialog called by the related "More" button in the general R&S®A/V distortion analysis settings

2.3.4.2 Picture Failure Point

The picture failure point indicates when a transmission is considered to be erroneous. This measured value is used whenever this limit needs to be detected in a reproducible manner.

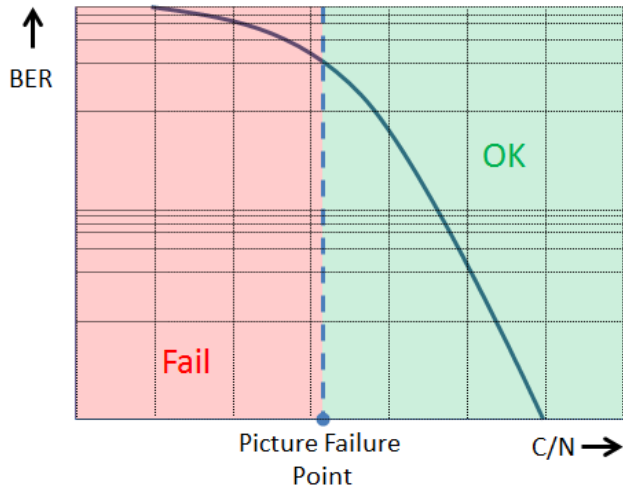


Figure 2-26: Picture failure point as a function of the bit error rate (BER) vs. the carrier-to-noise (C/N) ratio [7]

The basis for the definition of the picture failure point is the visible error event (2.3.4.1). However, taken in isolation its occurrence does not lead to reproducible results in many tests. For this purpose, a precise definition is required for the measurement duration as well as the number of tolerated errors. This is the only way to prevent statistically rare events from potentially impacting the measurement result.

In order to prevent such a misinterpretation and simultaneously enable reliable and reproducible detection of all representative errors in the shortest possible time, the following procedure is now well-established in a number of test specifications:

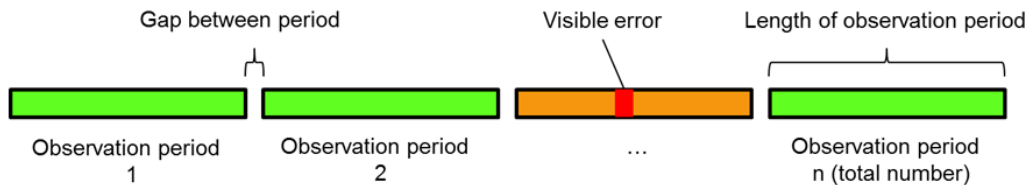


Figure 2-27: Principle of the picture failure point criteria

First, an observation period is defined with a fixed duration. The total measurement time is then composed of a specific number of consecutive observation periods between which there is a defined observation gap. If any number of visible errors now occurs within an observation period, this period is deemed to be faulty. The gap between periods prevents individual errors that affect multiple consecutive images from being evaluated twice.

The picture failure point is ultimately reached if a defined number of periods was evaluated as faulty.

All of these parameters can be user-configured in R&S®A/V distortion analysis. In addition, up-to-date parameter sets for common test specifications (NorDig [2], etc.) can be activated at the press of a button:

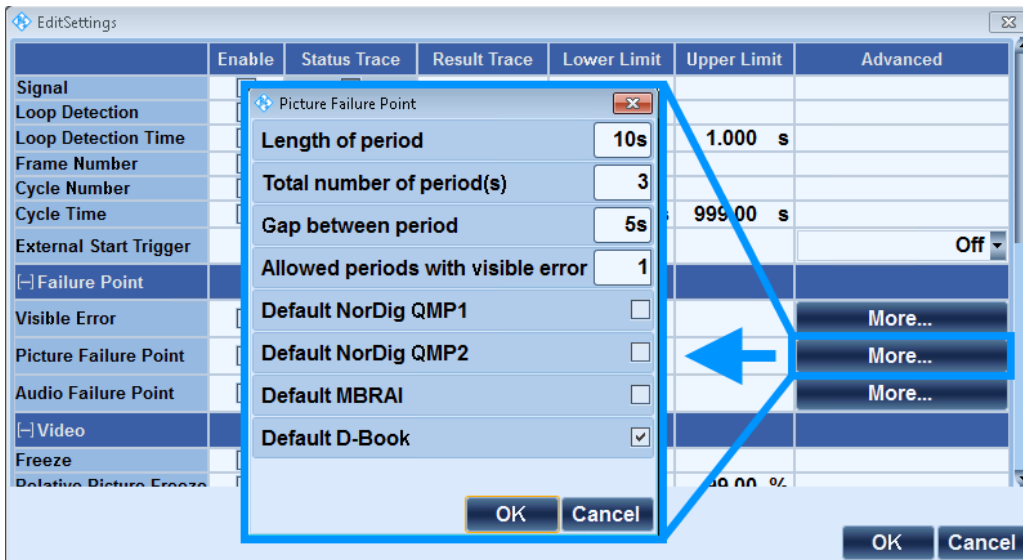


Figure 2-28: "Picture Failure Point" dialog called by the related "More" button in the general R&S®A/V distortion analysis settings

2.3.4.3 Audio Failure Point

Analogous to the picture failure point (2.3.4.2), there is also a test of the audio failure point.

To determine the audio failure point, the deviation of the audio level in respect to the reference audio level is measured. If this value is higher than 0.08dB, the system reports a "Fail".

The measurement time can be user-configured:

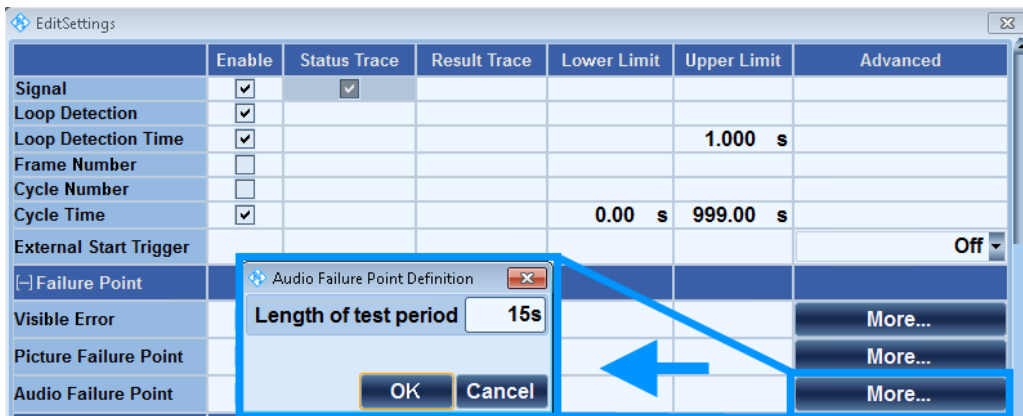


Figure 2-29: "Audio Failure Point Definition" dialog called by the related "More" button in the general R&S®A/V distortion analysis settings

2.3.5 "A/V Delay" Measured Value Group

This test verifies the timing relationship between the audio and video (lip-sync). Humans perceive A/V delay starting at about < -20 ms or > 40 ms. Negative numbers mean that the audio arrives before the video.

The AV Distortion analyzer offers two different methods to check A/V delay. This is described as follows.

2.3.5.1 Measurement in relation to a golden device

With this method, the R&S®AV distortion analysis checks A/V delay with respect to a previously recorded reference signal. This is useful if the device under test is to be tested against a "golden device" or for testing

of its long-term behavior. This method works with synthetic and natural sound and with APL and time code synchronization.

The audio signal for the channels must exhibit a periodic amplitude fluctuation as shown in the following view. Speech or rhythmic music are both suitable for this purpose, for example. In contrast, a continuous tone is not suitable.

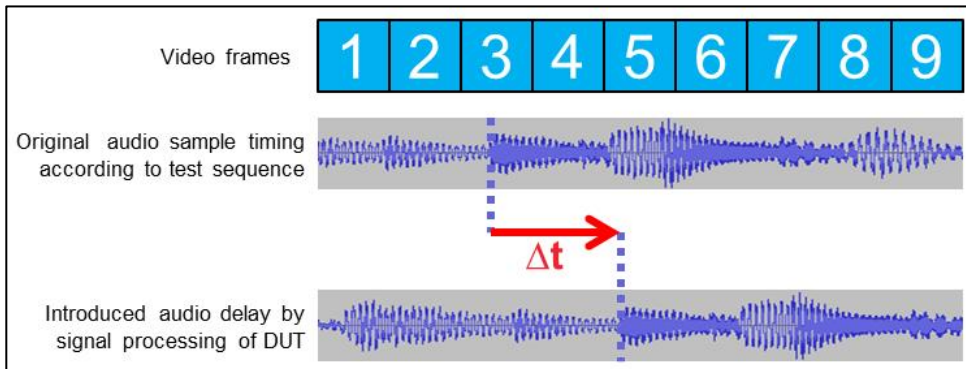


Figure 2-30: A/V delay example with natural test tone

To select this method, set "Tone for AV Testing with Time Code Synchronisation" to "Natural".

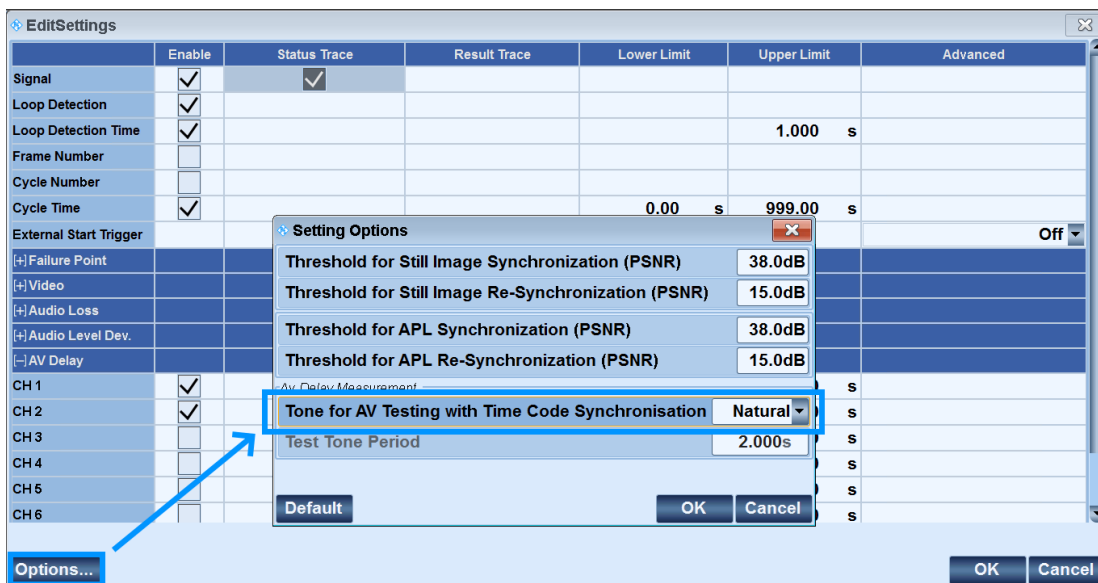


Figure 2-31: Setting for A/V Delay testing with natural test tone

2.3.5.2 Absolute measurement with audio test tone

This method captures the absolute difference in runtime between audio and video. A test tone synchronous to the video is used for this purpose. This must consist of alternating loud and soft sections of equal length. The length of the sections should be selected in such a way that a period duration of one to a maximum of four seconds results. Sinusoidal tones in the audible range are suitable as sound signals.

The video must contain a time code [3]. Figure 2 33 shows an example of a test video with a sound duration of 1 second and a resulting period of 2s. The refresh rate is 30 frames per second. Since two periods are included, this results in a video signal with a length of 120 frames.

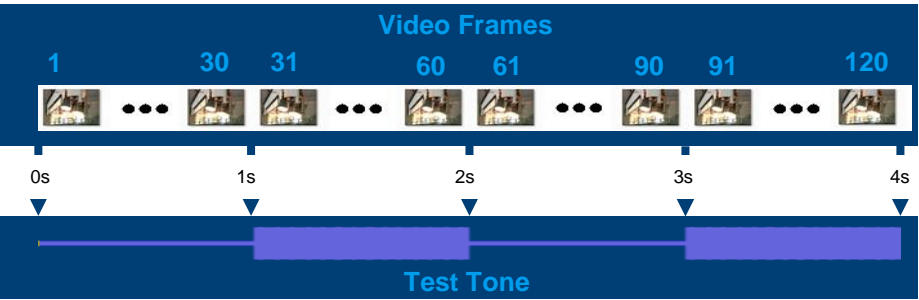


Figure 2-32: Example for a test sequence with timecode and test tone with a test period of 2 seconds

To select this method, set "Tone for AV Testing with Time Code Synchronisation" to "Test Tone", see [Figure 2-33](#). The video signal is recorded at the output of the test object with the synchronization "Time Code" as reference. However, this only serves to record the video and the volume. The temporal position of the audio signal in relation to the video signal is derived from the Test Tone Period setting.

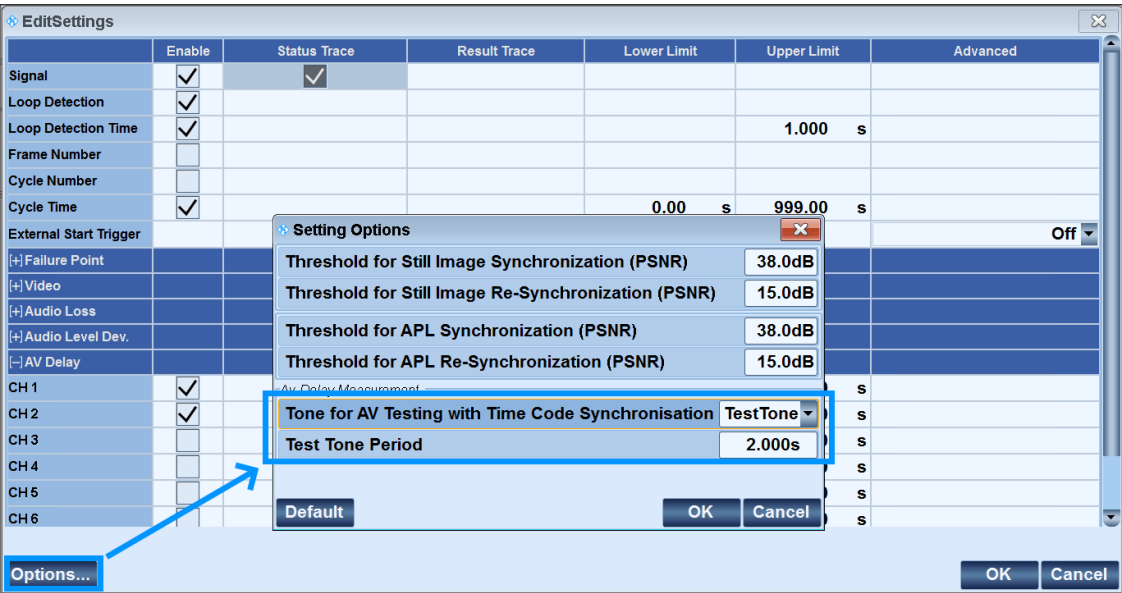


Figure 2-33: Menu for setting up the test tone

2.4 Presentation of Measurement Results

Three different views that are accessed with the tabs in the lower left corner are discussed in further detail in the following subchapters.

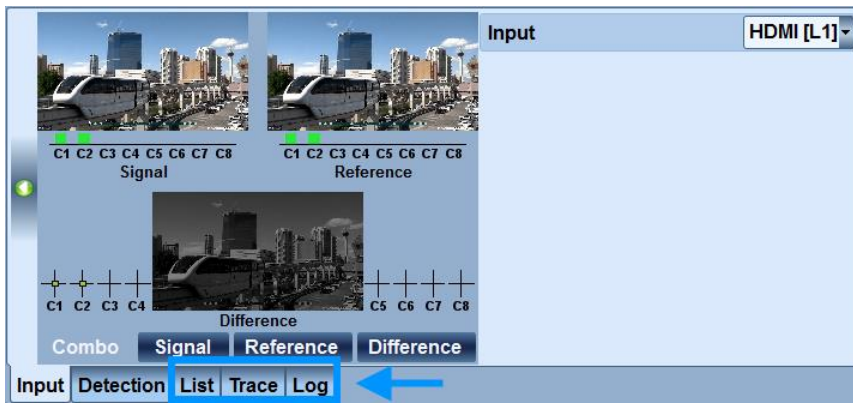


Figure 2-34: Tab control to select the desired measurement result view

Using the green control button at the left center of the screen, the A/V comparison display on the left half of the screen can be closed in order to expand the display of measurement results on the right to fill the whole screen.

2.4.1 List

Signal	Frame	391 of 480	Cycle	Synchronization	Reference	Input
OK			3	Loop - Time Code	tmp.avr	HDMI [L1]
	Current	Worst	Fault	Lower Limit	Upper Limit	
Signal	OK					Start
Loop Detection	Passed					Stop
Detection Time	00:00:00.384				1.000 s	Clear
Cycle Time	8.02 s	8.12 s	---	0.00 s	999.00 s	
[-] Failure Point						
Visible Error	OK	OK	0			
Picture Failure Point	OK	OK	---			
Audio Failure Point	OK	OK	---			
[-] Video						
Freeze	OK	OK	0			
Relative Picture Freeze	0.00 %	0.00 %	---	0.00 %	99.00 %	
Dropped Frames	0	0	0			
Black Frame	OK	OK	0			

Fig. 2-35: Measurement result list view.

The current measurement results are displayed in the "Current" column. The "Worst" column shows the worst value that has occurred so far. The "Fault" column contains error counters that are incremented each time a limit violation is observed (see "Lower / Upper Limit" columns). The cycle and frame counters in the status bar provide a relative reference for these absolute counters. After the measurement is completed, the "Worst" and "Fault" values can be reset with the "Clear" button on the right edge of the screen.

2.4.2 Trace

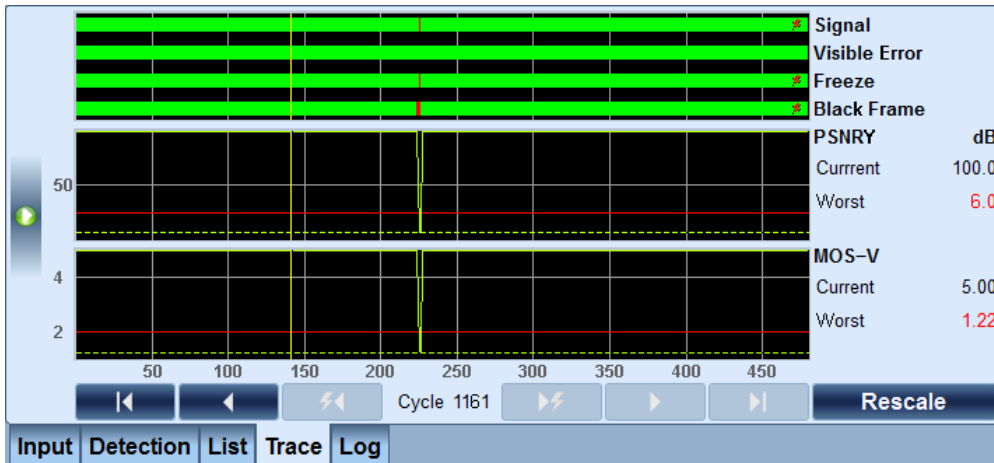


Figure 2-36: Measurement result trace view

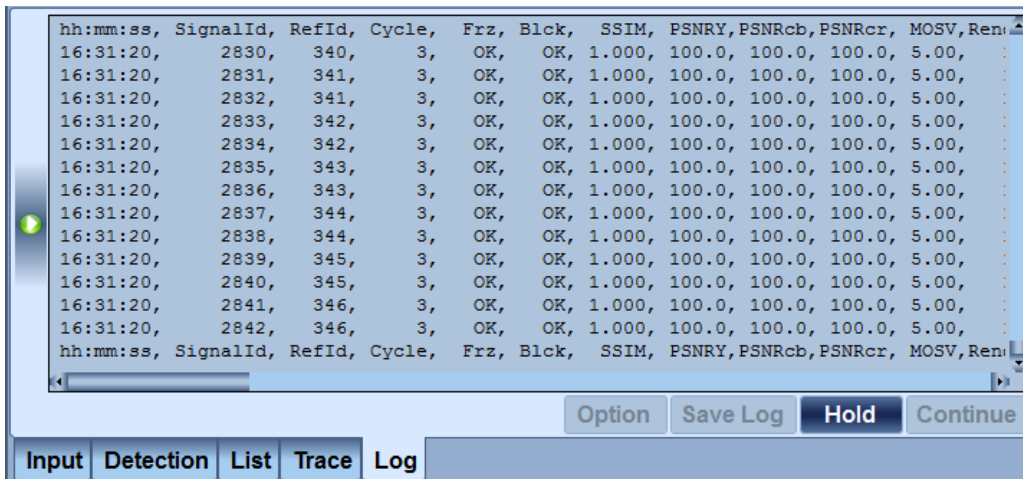
This view allows fast analysis of measured value changes vs. time. It also provides information about whether observed A/V impairments are limited to certain sub ranges of the test sequence. The time axis that is used corresponds to the frame count in the reference sequence. When the incoming video jumps from the last frame back to the first due to the endless loop, all of the traces are also recorded again from the left. Navigation is possible among the displays of the current and past sequence passes using the lower "Cycle" control bar. If the current measurement lasts more than one hour, the data records for the oldest sequence passes are overwritten successively. If a failure or a limit violation occurred for a measured value, this is indicated in the trace with a red lightning icon. The "Cycle" navbar has special buttons to directly display affected sequence passes.

Up to four "Status" traces for measured values with a pass/fail characteristic are shown in the top part of the view. They are sectionally colorized in red or green to reflect the frame results. Underneath, there are up to two (for VTE) or three (for VTC and BTC) "Result" traces for plotting numerical measured values. Configuration of the measured values to display in the trace view is described in section 2.2.

2.4.3 Log

This view allows in-depth analysis of the reasons behind the disruptions and deviations that occurred. The data can be exported in CSV format for separate statistical evaluation.

Each row in the table represents an analyzed frame and contains the results for all measurements that were performed.



hh:mm:ss	SignalId	RefId	Cycle	Frz	Blck	SSIM	PSNRY	PSNRcb	PSNRcr	MOSV	Ren
16:31:20	2830	340	3	OK	OK	1.000	100.0	100.0	100.0	5.00	
16:31:20	2831	341	3	OK	OK	1.000	100.0	100.0	100.0	5.00	
16:31:20	2832	341	3	OK	OK	1.000	100.0	100.0	100.0	5.00	
16:31:20	2833	342	3	OK	OK	1.000	100.0	100.0	100.0	5.00	
16:31:20	2834	342	3	OK	OK	1.000	100.0	100.0	100.0	5.00	
16:31:20	2835	343	3	OK	OK	1.000	100.0	100.0	100.0	5.00	
16:31:20	2836	343	3	OK	OK	1.000	100.0	100.0	100.0	5.00	
16:31:20	2837	344	3	OK	OK	1.000	100.0	100.0	100.0	5.00	
16:31:20	2838	344	3	OK	OK	1.000	100.0	100.0	100.0	5.00	
16:31:20	2839	345	3	OK	OK	1.000	100.0	100.0	100.0	5.00	
16:31:20	2840	345	3	OK	OK	1.000	100.0	100.0	100.0	5.00	
16:31:20	2841	346	3	OK	OK	1.000	100.0	100.0	100.0	5.00	
16:31:20	2842	346	3	OK	OK	1.000	100.0	100.0	100.0	5.00	

Buttons: Option, Save Log, Hold, Continue

Navigation: Input, Detection, List, Trace, Log

Figure 2-37: Measurement result log view

While the measurement is running, click the "Hold" button to pause the updates. The results that are generated will continue to be logged in the background. The table view contains a maximum of 1000 rows; however, older data can be accessed with the export function (see below). Click the "Continue" button to resume updating.

Once the measurement is complete, the entire data set can be exported in CSV format for external processing. Click the "Option" button to set the desired decimal separator. In addition, a filter can be activated here prior to the start of the measurement in order to only log frame results with a failure or a limit violation.

If the measurement time is very long, very large quantities of data can accumulate. To avoid problems during subsequent processing with spreadsheet software, a new file is created for every 40,000 measurements. When the data is saved, a separate directory is always created for all log files from the last measurement.

Filenames are automatically generated with the date and time of day when the measurement began.

"distortion_analyzer_log_2013-02-26_ 7-13-36.csv"

Figure 2-38: Example of an automatically generated filename for a log file

Each log file begins with a heading for the columns representing the individual measurements. The names are abbreviated in order to compact the data as much as possible.

Abbreviation	Name	Remark
hh:mm:ss		
SignalId	Signal number	Consecutive number for images arriving on the interface. Reset when measurement is started
RefId	Reference number	Number of reference image used for analysis
Cycle	Cycle	Number of completed sequence cycles. Reset when measurement is started
Frz	Freeze frame	OK = No repetition Fail = Repetition
Blck	Black frame	OK = No black frame Fail = Black frame
SSIM	SSIM	SSIM test result
PSNRY	PSNR Y	PSNR Y test result
PSNRcb	PSNR Cb	PSNR Cb test result
PSNRcr	PSNR Cr	PSNR Cr test result
MOSV	MOS-V	MOS-V test result
RendRate	Rendering rate	Rendering rate test result. The value "0" is output if a valid measured value is not yet present.
VisER	Visible error	OK = No visible error Fail = Visible error
Drop	Dropped frames	Number of dropped frames
PErrY	Pixel error Y	Number or erroneous Y pixel
PErrCb	Pixel error Cb	Number or erroneous Cb pixel
PErrCr	Pixel error Cr	Number or erroneous Cr pixel
A1Lss ... A8Lss	Audio loss CH1 Audio loss CH8	OK = Audio present Fail = Audio loss
A1Lvl ... A8Lvl	Audio level deviation CH1 Audio level deviation CH8	Audio level deviation test results for channels 1 to 8. The value "0" is output if a valid measured value is not present.
A1LInf ... A8LInf		Indicates whether the audio level deviation value is valid. Wait = Measurement not yet complete NA = Audio not available in this channel OK = Measured value is valid
A1Dly ... A8Dly	Audio delay CH1 ... Audio delay CH8	Audio delay test results for channels 1 to 8. The value "0" is output if a valid measured value is not present.
A1DInf ... A8DInf		Indicates whether the audio delay value is valid. Wait = Measurement not yet complete NA = Audio not available in this channel OK = Measured value is valid

3 Applications

3.1 Go/NoGo Tests

In this scenario, the test environment for the DUT is such that either perfectly stable or totally faulty A/V output is expected. This includes the following test cases mentioned in section 1.3:

- ▶ Handling of specified A/V input formats
- ▶ Receiver output of specified A/V formats
- ▶ Functional test after production

The recommended measured values here are as follows:

- ▶ Signal sync (2.3.1.1)
For checking the validity of the DUT's A/V output signal
- ▶ Loop detection time (2.3.1.3) with PSNR Y, Cb, Cr
For checking whether the A/V content conforms to expectations

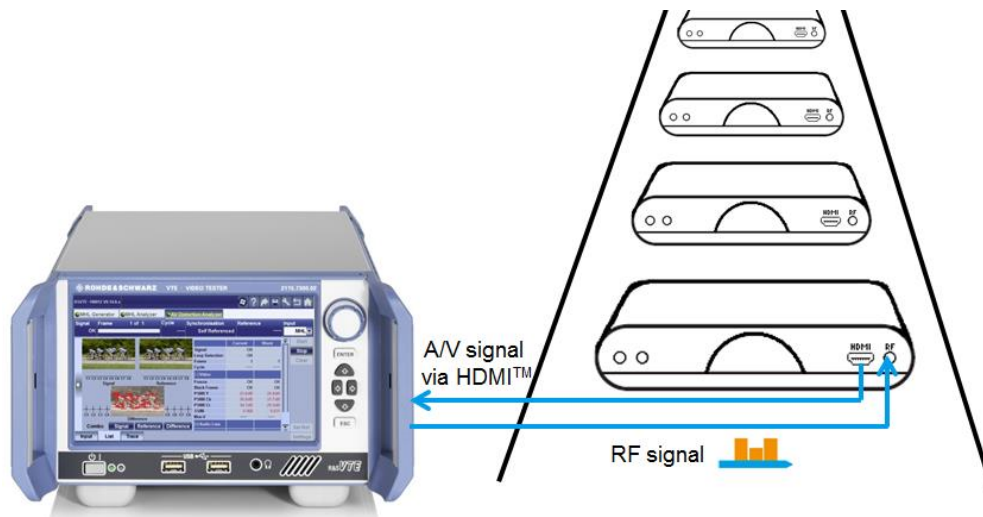


Figure 3-1: Example of functional test for quality assurance: Manufacturing of set-top boxes

3.2 Zero Error Tolerance

These tests are characterized by operating situations for the DUT which, given adequate dimensioning of the system, should have no negative effects on the content of the A/V output:

- ▶ Long-term stability
- ▶ Environmental: Temperature, shock, EMI

The lack of errors can be verified based on the following measured values:

- ▶ Pixel error (2.3.2.5)
Indicates deviations within frames
- ▶ Picture freeze (2.3.2.1) & dropped frames (2.3.2.3)
Indicate deviations in the frame sequence

- ▶ Audio loss (2.3.3.1) & audio level deviation (2.3.3.2)
Indicate deviations in individual audio channels

For a quick check, the "Fault" counter column in the list view (2.4.1) summarizes all errors that occurred at a glance.

Usage of a digital interface is recommended for such tests since analog signal transmission will often introduce a number of smaller errors. However, the latter case is also acceptable if the limits for the stated measured values can be relaxed accordingly.



Figure 3-2: Zero error tolerance tests used for interface testing, e.g. on mobile phones or set-top boxes

3.3 Perceived A/V Quality Assurance

Tests related to "handling of input signal impairments" generally contain disturbance intensities based on a statistical distribution function (2.3.4.2). For this reason, single errors can occasionally occur even under acceptable operating conditions. Instead of a "zero error tolerance" approach (3.2), in such cases the target quality criterion is defined in terms of errors that can be perceived by humans. This involves the following measured values:

- ▶ Picture failure point (2.3.4.2)
Indicates perceptible errors in the incoming video data
- ▶ Rendering rate (2.3.2.9)
Indicates timing fluctuations in the frame output
- ▶ Audio failure point (2.3.4.3)
Indicates perceptible errors in the incoming audio data

For a detailed discussion of "Fully automated D-Book RF testing of DVB T / DVB T2 receivers" in the broadcasting sector, see [8].

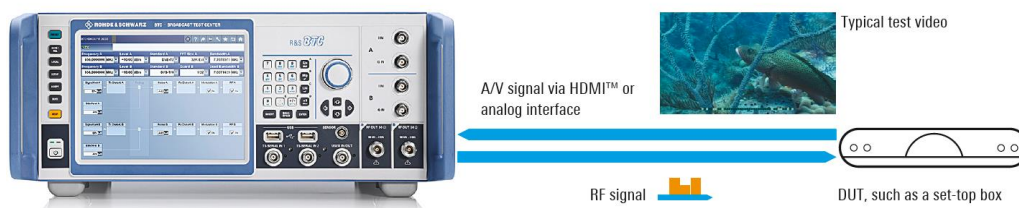


Figure 3-3: Example 3 using perceived A/V quality assurance: Drive test with mobile phone to check the quality of video received via an LTE link



Fig. 3-4: Example 2 using perceived A/V quality assurance: R&S®TS8980 test system for testing the quality of video applications on LTE user equipment under realistic RF conditions

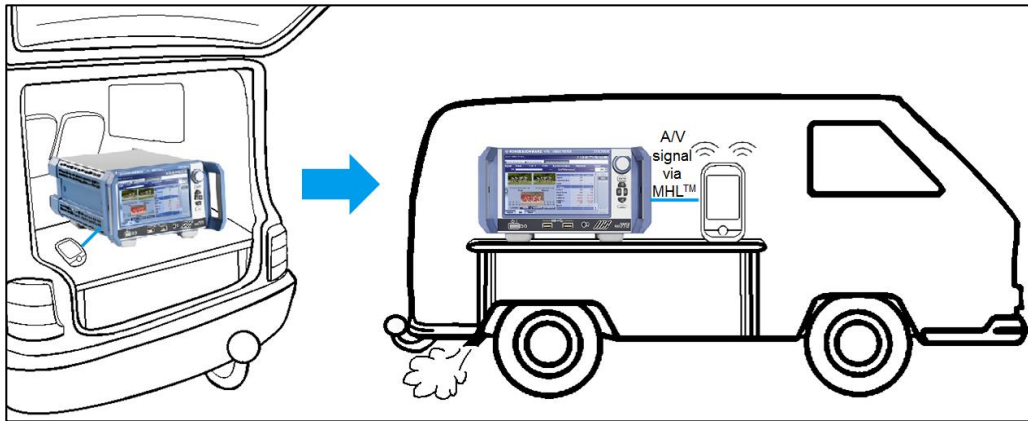


Fig. 3-5: Example 3 using perceived A/V quality assurance: Drive test with mobile phone to check the quality of video received via an LTE link

3.4 Speed Analysis with Latency test

3.4.1 Switching Time between Different A/V Inputs

A well-known example is the switching time required by a receiver between two broadcast signals at different frequencies. Depending on the level of optimization of the signal processing, there can be differences between individual products that lie in the clearly perceptible seconds range. This switching time can be measured as follows:

1. The DUT receives frequency A with A/V content A.
2. The DUT receives the command to switch to frequency B with A/V content B. Concurrently, R&S A/V distortion analysis is started with the reference sequence that corresponds to A/V content B.
3. As soon as the DUT outputs A/V content B, the loop detection time (2.3.1.3) automatically halts, yielding the desired switching time.
4. It is recommended to use the time code synchronization method here since the alternative APL / APL section method must analyze more than one frame before it can confirm synchronization.

3.4.2 Introduced Processing Latency

The Latency measurement measures the time between the following two events with a resolution in milliseconds:

- ▶ APL transition between consecutive frames at the incoming HDMI signal and the
- ▶ Level change at the external trigger input.

The following parameters must be set prior to starting the measurement:

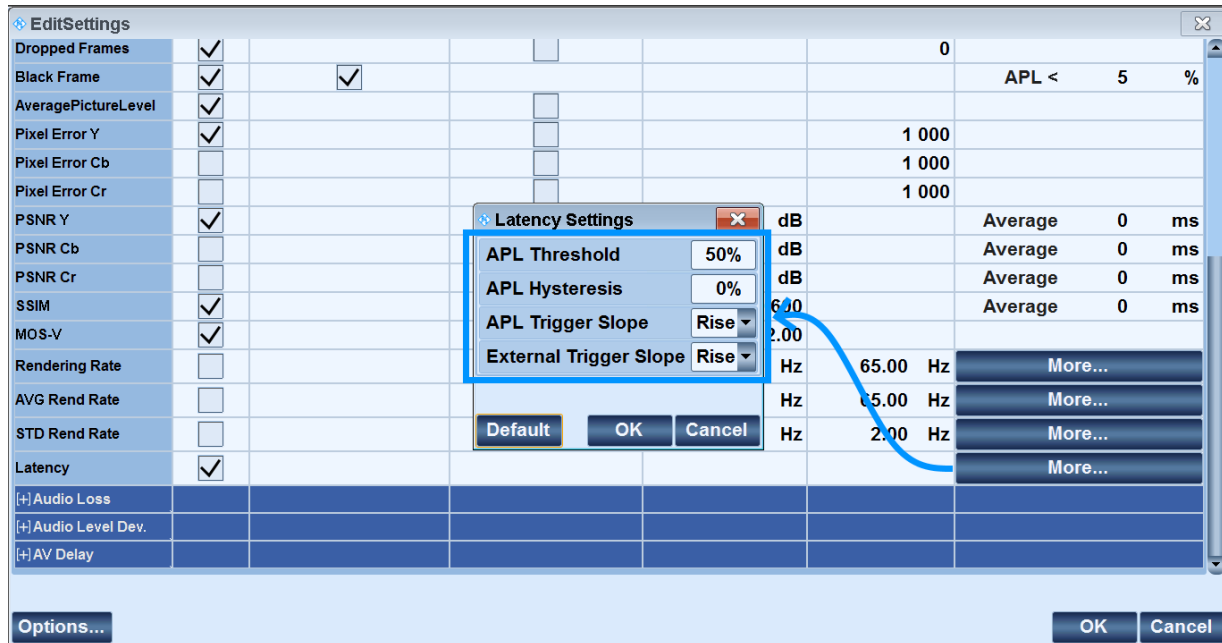


Fig. 3-6: Settings for Latency measurement

This functionality is also available via the remote control interface.

Parameter	Remote command	Explanation
APL Threshold	CONF:AVDA:TTV:APL:THR <val>	Threshold for detection of APL transition as a percent. The default value is 50 %
APL Hysteresis	CONF:AVDA:TTV:APL:HYST <val>	Switching hysteresis for detection of APL transition as a percent. The default value is 0 %
APL Trigger Slope	CONF:AVDA:TTV:APL:SLOP <val>	Edge of APL curve (RISE FALL) to trigger the transition event
External Trigger Slope	CONF:AVDA:TTV:TRIG:SLOP <val>	Edge of trigger signal (RISE FALL) to trigger the trigger event

The Latency measurement runs with all types of synchronization. Via remote interface, the results are available as follows:

Result	Remote command	Explanation
Status	READ:AVDA:TTV:STAT?	Valid flag ("1" indicates a valid measured value was determined)
Measured value	READ:AVDA:TTV:VAL?	Measured time offset. Measuring interval: +/- 1 s
Measured value counter	READ:AVDA:TTV:COUN?	7-bit counter incremented for each further evaluation of trigger events to indicate measured value was updated

Two application examples are discussed below.

3.4.2.1 Output Delay of Display Equipment with an HDMI™ Input

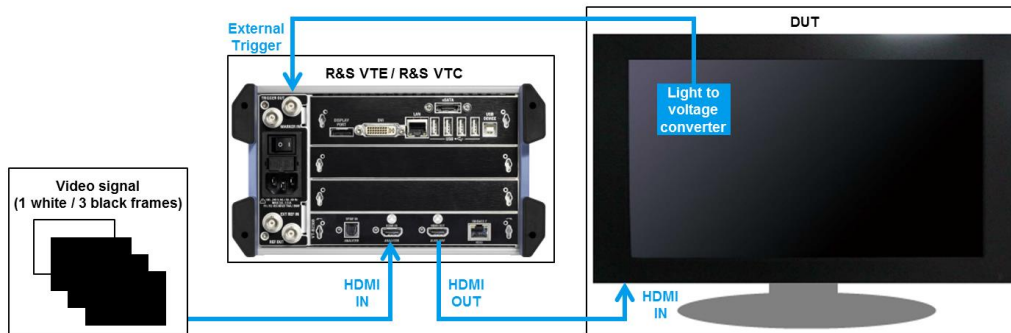


Figure 3-7: Setup to measure output delay of HDMI™ monitors

The test signal consists of black frames with a single white frame. It is output in an endless loop. For example, this signal can be internally generated with an HDMI™ generator module (see chapter 7). Before the signal is fed to the DUT, it is looped through the HDMI™ analysis module to allow R&S A/V distortion analysis to detect the time of each APL transition from black to white. The response by the DUT is fed back to the external LVTTTL trigger input via a simple light to voltage converter (basically a phototransistor). Since the time offset is calculated by subtracting the APL transition time from the external trigger time, the sign of the measurement result must be inverted. In gaming applications, measured values on the order of 30 ms already have a significant influence on the user response time. However, for ordinary A/V output without constant user interaction, values of several hundred milliseconds are tolerable.

3.4.2.2 Transmission Delay

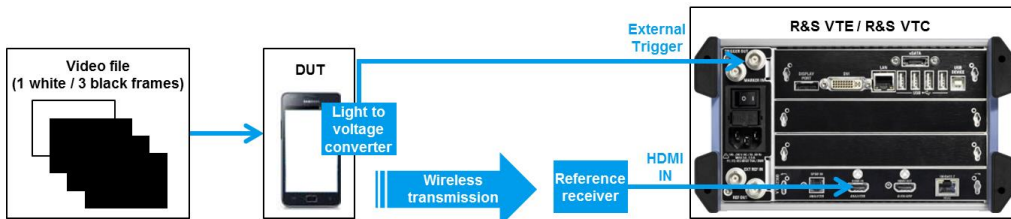


Fig. 3-8: Setup to measure transmission delay

Fig. 3-8 shows an application example for determining the delay of a wireless connection through a smartphone under test (e.g. in line with the Miracast standard [9]). The test signal consists of black frames with a single white frame. It is output in an endless loop on the DUT. The time of display of the white frame on the DUT's display is used as a reference. It is signaled to the external LVTTTL trigger input of the R&S VTE / R&S VTC via a light to voltage converter (basically a phototransistor). The wireless A/V content emitted in parallel by the DUT is converted to HDMI™ by an external reference receiver with a known delay and fed to the HDMI™ analysis module. The measured time offset between the external trigger signal and the incoming APL transitions is equal to the transmission delay of interest. The delay of the HDMI™ transmission is equal to approx. 1 ms and can thus be neglected.

4 Abbreviations

A/V	Audio / Video
APL	Average picture level
EMI	Electromagnetic interference
HDMI	High-Definition Multimedia Interface
LVTTL	Low voltage transistor-transistor logic
MHL	Mobile High-Definition Link
MOS (-V)	Mean opinion score (-video)
MSE	Mean square error
PFP	Picture failure point
PSNR	Peak signal-to-noise ratio
(M)SSIM	(Mean) Structural similarity
V-Sync	Vertical synchronization

5 References

[1]	Rohde & Schwarz EMC & Field Strength Test Solutions www.rohde-schwarz.com -> Search "EMC & Field Strength Test Solutions"
[2]	NorDig Standard 2.2.2 www.nordig.org
[3]	R&S®Time Code Inserter: Time Code-Based A/V Distortion Analysis www.rohde-schwarz.com -> Search "7BM84"
[4]	ITU-T recommendation BT.500 "Mean opinion score" http://www.itu.int/rec/R-REC-BT.500/en
[5]	"Image quality assessment: From error visibility to structural similarity" Z. Wang, A. C. Bovik, H. R. Sheikh and E. P. Simoncelli IEEE Transactions on Image Processing, vol. 13, no. 4, pp. 600-612, Apr. 2004.
[6]	Digital TV Group (DTG) D-Book 7 Standard http://www.dtg.org.uk/ -> DTG Publications
[7]	http://en.wikipedia.org/wiki/File:Standard_deviation_diagram.svg
[8]	R&S application brochure www.rohde-schwarz.com -> Search "Fully automated D-Book RF testing"
[9]	Wi-Fi CERTIFIED Miracast™ http://www.wi-fi.org -> Search "Miracast"

6 Additional Information

Our application notes are regularly revised and updated. Check for any changes at <http://www.rohde-schwarz.com>.

7 Ordering Information

Designation	Type	Order no.
Base unit		
Video Tester	R&S®VTE	2115.7300.02
Video Test Center	R&S®VTC	2115.7400.02
Broadcast Test Center	R&S®BTC	2114.3000.02
Input modules		
Analog AV RX ²	R&S®VT-B2370	2115.7600.06
MHL RX/TX ³	R&S®VT-B2350	2115.7622.06
HDMI RX/TX 600 MHz module	R&S®VT-B2363	2115.7697.02
Analysis options		
AV Distortion Analysis	R&S®VT-K2111	2115.8041.02
HDMI RX (together with R&S®B2363)	R&S®VT-K2364	2115.8587.02
Optional test signal generator		
Broadcast TX Modulator ⁴	R&S®VT-B600	2115.7522.06
HDMI TX (together with R&S®B2363)	R&S®VT-K364	2115.8570.02

² Requires R&S®VT-K2371 (2115.8258.02) for support of component signals.

³ Not available for R&S®BTC. For PackedPixel signals, use R&S®VT-B2351 (2115.7645.06) instead.

⁴ Requires further options; for details see R&S®VTC datasheet. Not available for R&S®BTC.

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