



Comprehensive PCR Analysis

Using the R&S[®]DVM Family from Rohde & Schwarz

R&S[®]DVM50/DVM100/DVM120/DVM400

Application Note

When MPEG-2 transport streams are transmitted, the program clock reference PCR is transmitted as a time reference in the receiver. A sufficiently accurate and correctly received PCR is a precondition for correct data display in the receiver.

This Application Note provides an overview of definitions, functions and use of the PCR. It also explains the recommended measurements of the current measurement guidelines and offers detailed instructions on how to use the PCR measurement functions of the R&S[®]DVM family.



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1 Introduction

When MPEG-2 transport streams are transmitted, the program clock reference (PCR) is transmitted as a time reference in the receiver. A sufficiently accurate and correctly received PCR is a precondition for correct data display in the receiver.

The R&S[®]DVM family provides PCR measurement functions implemented in accordance with the Technical Report TR 101 290 "Measurement guidelines for DVB systems" of the European Telecommunications Standards Institute (ETSI).

This Application Note provides an overview of definitions, functions and use of the PCR. It also explains the recommended measurements of the current measurement guidelines and offers detailed instructions on how to use the PCR measurement functions of the R&S[®]DVM family.

2 PCR – Explanation and Use

The PCR is a time reference that is continuously transmitted with each program of a transport stream. The PCR values of a program are permanently assigned to a packet identification (PID) in the transport stream.

The PCR is required in order to synchronize the transmitter and receiver and to transmit the uniform 27 MHz system time clock (STC). It is used in the receiver as a correction value for the phase lock loop (PLL). The PCR thus controls all time-referenced processes in the receiver. These processes include decoding and output times of elementary stream data, the SDI output signal clock (if an SDI output is available) and the color subcarrier frequency at the CCVS output.

If the PCR is correctly transmitted, decoding in the receiver is performed with the same speed as encoding in the encoder. However, decoding in the receiver is delayed. The delay is a function of the transmission time and of an offset determined by the PTS (see next page). The PCR function is illustrated in Fig. 1.

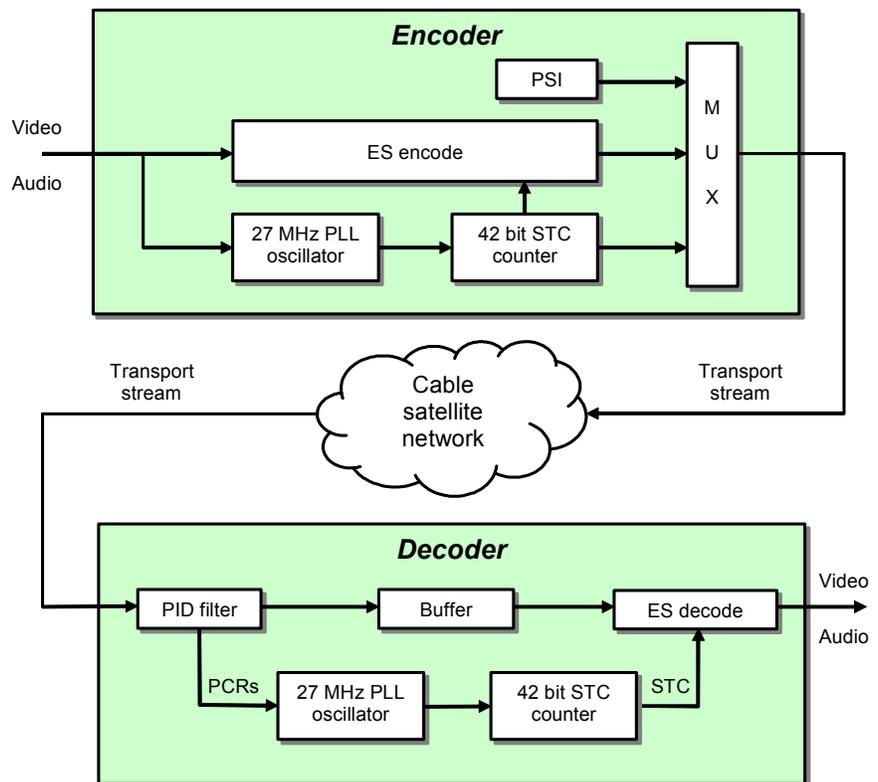


Fig. 1 PCR functions

PTS and DTS functions

In addition to the PCR, the PTS and DTS are transmitted. Both values are referenced to the PCR and control data processing in the receiver. The DTS indicates the PCR value at which the associated data is to be decoded. The DTS must be transmitted if the data is not decoded in the order in which it is received. The PTS indicates the time at which the decoded data is to be output. This means that the PTS value is always higher than the current PCR value. The difference between PCR and PTS represents the data dwell time in the receiver and is thus closely related to the buffer size of the receiver. According to MPEG-2, the dwell time must not exceed one second (see ISO/IEC 13818-1, section 2.5.2.3 Buffering).

PCR	Program clock reference Time reference of a program in a transport stream
DTS	Decoding time stamp Point in time when the decoder is to decode the data
PTS	Presentation time stamp Point in time when the decoder is to output the decoded data

3 PCR Transmission

A PCR is transmitted with each program of a transport stream. The PCR values of a program are only transmitted in transport stream packets having a special PID, which is specified in the program map table (PMT). This is usually the video elementary stream of the program.

Not every TS packet containing the specific PID necessarily includes a PCR value. It is sufficient to insert a value into a TS packet every 40/100 ms (according to DVB/MPEG). For this reason, the PCR value is transmitted in an optional field of the extendable header (adaptation field) in the transport stream packet; see Fig. 2.

¹ You can measure the difference between the PCR and PTS value by using any instrument of the R&S®DVM family.

PCR Measurements

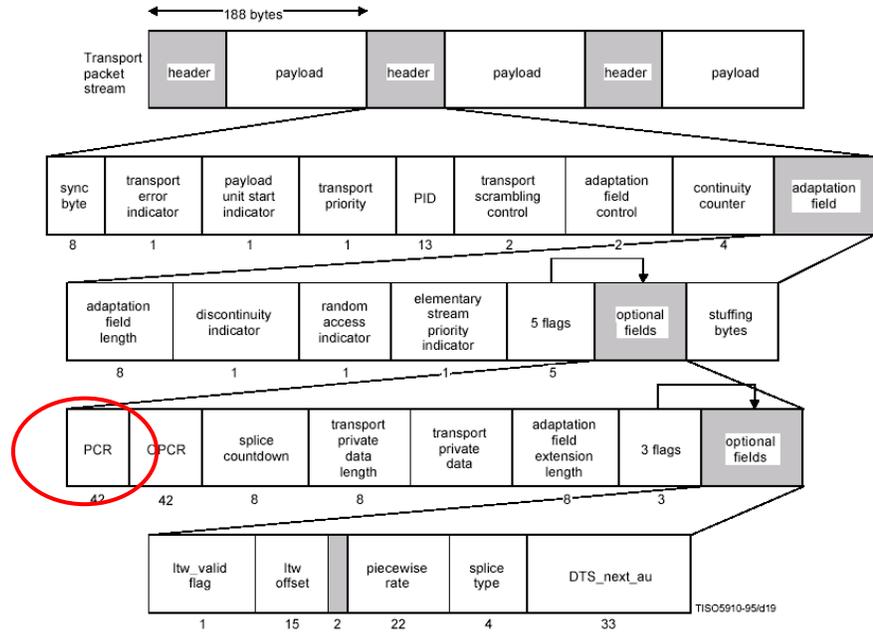


Fig. 2 TS syntax diagram

The PCR value is 42 bits long and incremented with a frequency of 27 MHz. Note that the PCR is made up of a 33-bit field (program_clock_reference_base) and a 9-bit field (program_clock_reference_extension). This configuration is based on the MPEG-1 definition, where the PCR is only 33 bits long.

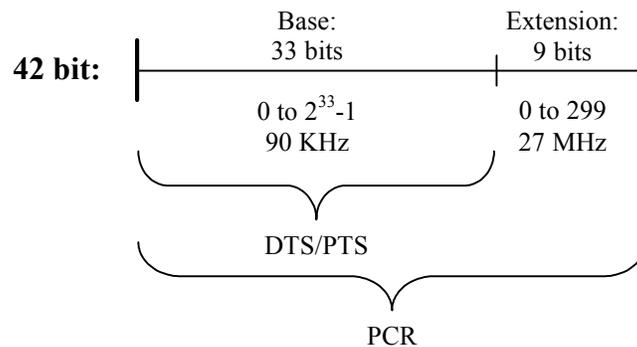


Fig. 3 42-bit PCR field

The PTS and DTS values are 33 bits long and referenced to the program_clock_reference_base.

Under special circumstances, the PCR may contain an unavoidable discontinuity, which may be caused by a switchover from one encoder to another in the transmitter during program emission (contents are obtained from another source). A PCR discontinuity of this type must be marked in the program by means of the discontinuity_indicator in the adaptation field.

4 Problems Caused by a Faulty PCR

A correctly received PCR ensures that decoding in the receiver is neither too fast nor too slow. If decoding is too fast, the buffer memory of the receiver might run empty because the receiver wants to process the data faster than it arrives at the receiver. In the second case, the buffer memory might overflow because the data is processed slower than it arrives at the receiver.

In both cases, program decoding would be impaired.

Even if the data is correctly decoded, problems may occur with the picture display. If the clock of the SDI signal is burdened with jitter, the picture may be distorted (line jitter). If the CCVS output is used, a PCR with jitter may cause color distortions or flicker. If the color subcarrier is too heavily impaired, only monochrome pictures will be displayed.

If the PCR is extremely faulty, the PLL of the receiver can synchronize only occasionally or not at all, so that decoding is not possible. The result is a complete picture failure.

5 Reasons for a Faulty PCR

PCR values must be received on a sufficiently accurate and regular basis. Only under these conditions can the PLL in the receiver be correctly readjusted.

Possible reasons for a corrupt PCR:

- Inaccurate generation in the encoder
- Faulty recalculation in the multiplexer or remultiplexer
- Faulty correction of the data jitter during transmission in cells and packet-oriented networks (IP, ATM)

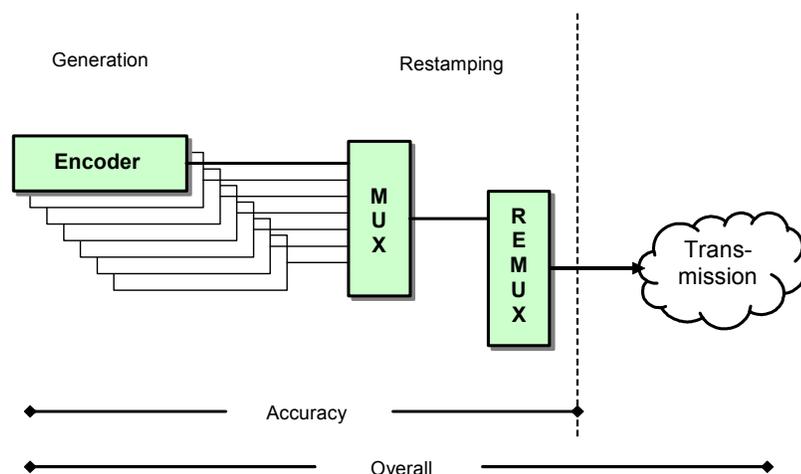


Fig. 4 Error sources of a corrupt PCR

6 Measurements acc. to TR 101 290 Standard Dated May 2001

PCR measurements are described in two sections of the TR 101 290:

- Section 5.2.2, Second priority: recommended for continuous or periodic monitoring (section 5.2, List of parameters recommended for evaluation), and
- Section 5.3.2, System clock and PCR measurements (section 5.3, Measurement of MPEG-2 transport streams in networks)

6.1 PCR Monitoring

The measurements described below are to be performed continuously or periodically, i.e. as part of a monitoring process. The following parameters are measured:

- PCR_repetition_error: Are the PCR values received on a sufficiently regular basis (at least every 40/100 ms (DVB/MPEG))?
- PCR_discontinuity_indicator_error: Is the difference between two consecutive PCR values greater than 100 ms, which is not indicated by the discontinuity indicator?
- PCR_accuracy_error: Does a received PCR value deviate by more than ± 500 ns from the value expected because of its position in the transport stream? A constant transport stream data rate is required for this measurement.

6.2 PCR Measurements

The measurements in this section are used for in-depth PCR jitter analysis and may therefore help to find PCR jitter sources. A limit frequency is required to differentiate between the frequency components of the drift rate and the jitter. For this purpose, the TR 101 290 has defined the following four measurement profiles:

Profile	Limit frequency	Description
MGF1	10 mHz	This profile takes into account all frequency components of the PCR deviations. It provides the most accurate results in combination with the tolerances specified in ISO/IEC 13818-1, section 2.4.2.1. If a measurement with a different profile yields results that are outside the specified range, verify the measurement by using this profile because of its higher accuracy.
MGF2	100 mHz	This profile is a compromise between profile MGF1 and profile MGF3. It provides acceptable settling time and takes the low frequency components of the PCR deviations into account to some extent.
MGF3	1 Hz	This profile has the minimum settling time. To determine the measurement result, only the higher frequencies of the PCR deviations are taken into account. This profile is sufficient for most applications.
MGF4	User-definable	

Table 1 Profiles for the PCR measurement

For more in-depth PCR jitter analysis, the following four measurements have been defined:

- Frequency offset
- Drift rate
- Accuracy
- Overall jitter

Frequency offset PCR_FO

To determine the frequency offset, the frequency is measured and compared with the theoretical 27 MHz system frequency (with the aid of the received PCR values). According to ISO/IEC 13818-1, the deviation should not be greater than ± 810 Hz (= 30 ppm).

Use this measurement to check the system frequency.

Drift rate PCR_DR

This measurement determines the drift of the measured frequency (first derivative). According to ISO/IEC 13818-1, the drift should not be greater than ± 75 mHz/s.

Accuracy PCR_AC

This measurement determines the difference between the current PCR value and the value defined by its position in the TS. A constant data rate is required for this measurement (see ETSI TR 101 290, section 5.3.2.6).

In simpler terms, the error can be defined as the deviation of the difference of two consecutive PCR values from the theoretically elapsed time (data quantity / data rate); see also Fig. 5.

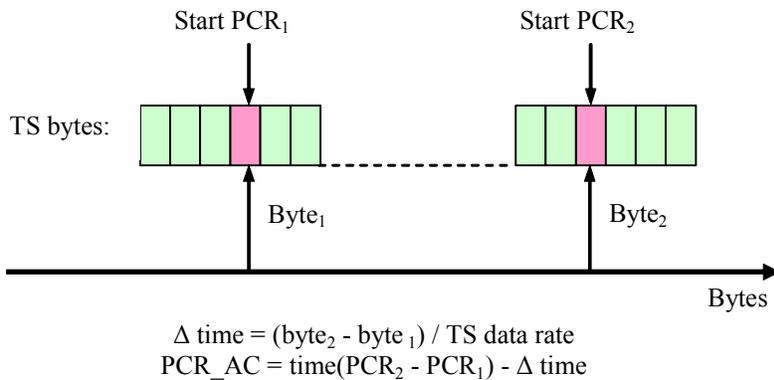


Fig. 5 Illustration of an accuracy measurement

ISO/IEC 13818-1 specifies ± 500 ns as the tolerance for the PCR_AC. A constant data rate is required for this tolerance. Errors caused by the packet arrival time are therefore not taken into account. The measurement guidelines refer to this tolerance definition.

With the described measurement, a highpass filter is used for the measured values. The four profiles MGF1 to MGF4 (see Table 1) are used for the different filter characteristics.

This measurement can also be performed offline, since all values required for the measurement (PCR values and the amount of data between the PCR values) can be obtained from a stored TS.

This measurement does not take into account any TS data rate variations that may occur.

Overall jitter PCR_OJ

This measurement determines the difference between the actual packet arrival time of a PCR value and the point in time which is theoretically correct (see ETSI TR 101 290, section 5.3.2.5). Thus, TS data rate variations are taken into account.

To state it more simply, the error can be defined as the deviation of the difference between two consecutive PCR values from the reception time elapsed between the two values; see also Fig. 6.

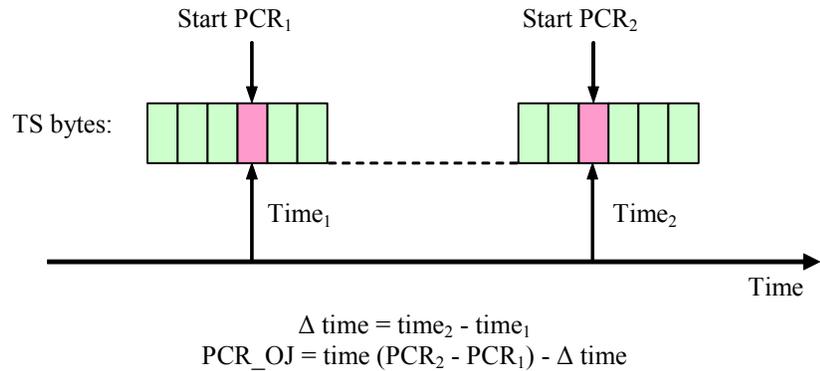


Fig. 6 Illustration of overall error

As with the accuracy measurement, highpass filters are used for this measurement. You can select a filter characteristic from the four profiles MGF1 to MGF4. The measurement guidelines do not define any tolerances for this measurement.

These two measurements differ mainly with regard to reference: the reference for the accuracy measurement is the amount of data received, and the reference for the overall measurement is the elapsed time.

7 Measurements Using the R&S® DVM

7.1 Monitoring

All monitoring functions described in section 6.1 are supported by the R&S® DVM family and can be user-configured. The tolerances defined by the measurement guidelines are already set. Configuration is effected in the "Monitoring" measurement display via the window shown in Fig. 7, which can be called up with the "Config ..." button.

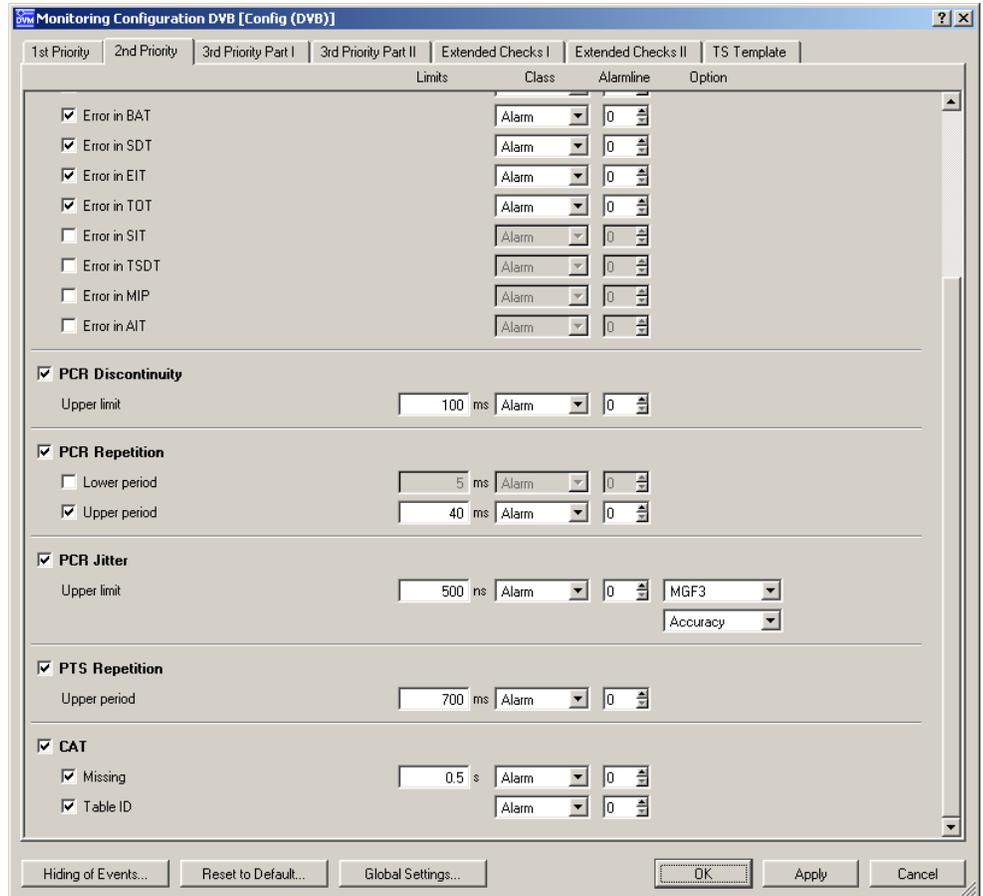


Fig. 7 R&S® DVM configuration

PCR Measurements

If monitoring is active, the specified parameters are continuously monitored. If an error is detected, a report entry is generated and the error-specific seconds counter is incremented. The element causing the PCR error is marked in the TS tree (see Fig. 8). You can also activate an alarm line, send a trap via SNMP and trigger the capture function. With the R&S[®]DVM family you can also monitor a settable tolerance in the PCR_OJ instead of monitoring the PCR_AC as required by the measurement guidelines.

The screenshot displays the 'Monitoring * Statistics & Log @ 00:90:48-14-02:07' window. The interface is divided into several sections:

- Left Panel (SITE):** Shows a tree view of the monitoring setup for 'Port 1' and 'Port 4'. Under 'INPUT', the 'TS (ID: 207)' tree is expanded, showing various services. 'Video MPEG2 (PID 0...)' is circled in red, with an arrow pointing to the label 'Element with PCR error (video PID)'.
- Top Panel (Statistics & Log):** Displays error counts for different categories. The '2nd Priority Error' section shows 'PCR Jitter' with a value of 54, circled in red. An arrow points to this value with the label 'Error seconds counter'.
- Bottom Panel (Log Table):** A table of error events. One entry is circled in red:

No.	Time/Date	Class	Event	Detail	PID	Service
222	08:07:07...	Alarm	SI Repetition - CAT missing		0001	
223	08:07:08...	Alarm	PCR Jitter - Accuracy out of limit	-506 ns	0200	2
224	08:07:08...	Alarm	PCR Jitter - Accuracy out of limit	503 ns	0300	3
225	08:07:08...	Alarm	PCR Jitter - Accuracy out of limit	-503 ns	0500	5
226	08:07:08...	Alarm	SI Repetition - CAT missing		0001	
227	08:07:09...	Alarm	PCR Jitter - Accuracy out of limit	-503 ns	0100	1
228	08:07:09...	Alarm	PCR Jitter - Accuracy out of limit	501 ns	0400	4
229	08:07:09...	Alarm	PCR Jitter - Accuracy out of limit	502 ns	0200	2
230	08:07:09...	Alarm	PCR Jitter - Accuracy out of limit	-504 ns	0500	5
231	08:07:09...	Alarm	SI Repetition - CAT missing		0001	
232	08:07:10...	Alarm	PCR Jitter - Accuracy out of limit	502 ns	0100	1
233	08:07:10...	Alarm	PCR Jitter - Accuracy out of limit	502 ns	0600	6
234	08:07:10...	Alarm	PCR Jitter - Accuracy out of limit	501 ns	0200	2
235	08:07:10...	Alarm	PCR Jitter - Accuracy out of limit	502 ns	0300	3
236	08:07:10...	Alarm	PCR Jitter - Accuracy out of limit	501 ns	0400	4
237	08:07:10...	Alarm	PCR Jitter - Accuracy out of limit	503 ns	0500	5
238	08:07:10...	Alarm	SI Repetition - CAT missing		0001	
239	08:07:11...	Alarm	PCR Jitter - Accuracy out of limit	-502 ns	0100	1
240	08:07:11...	Alarm	PCR Jitter - Accuracy out of limit	-506 ns	0400	4
241	08:07:11...	Alarm	SI Repetition - CAT missing		0001	

 An arrow points to this entry with the label 'Report entry (service 4)'.

Fig. 8 Monitoring measurement display

7.2 PCR Data Analysis

The R&S®DVM allows you to view the transmitted PCR values in the "Packet Interpreter" measurement display, which is part of the R&S®DVM-K10 option (in-depth analysis). For this purpose, set the filter to "Adaptation field with and without payload" and repeat reading the TS packet until a packet with PCR is displayed in the "Packet Interpreter" measurement display (see Fig. 9).

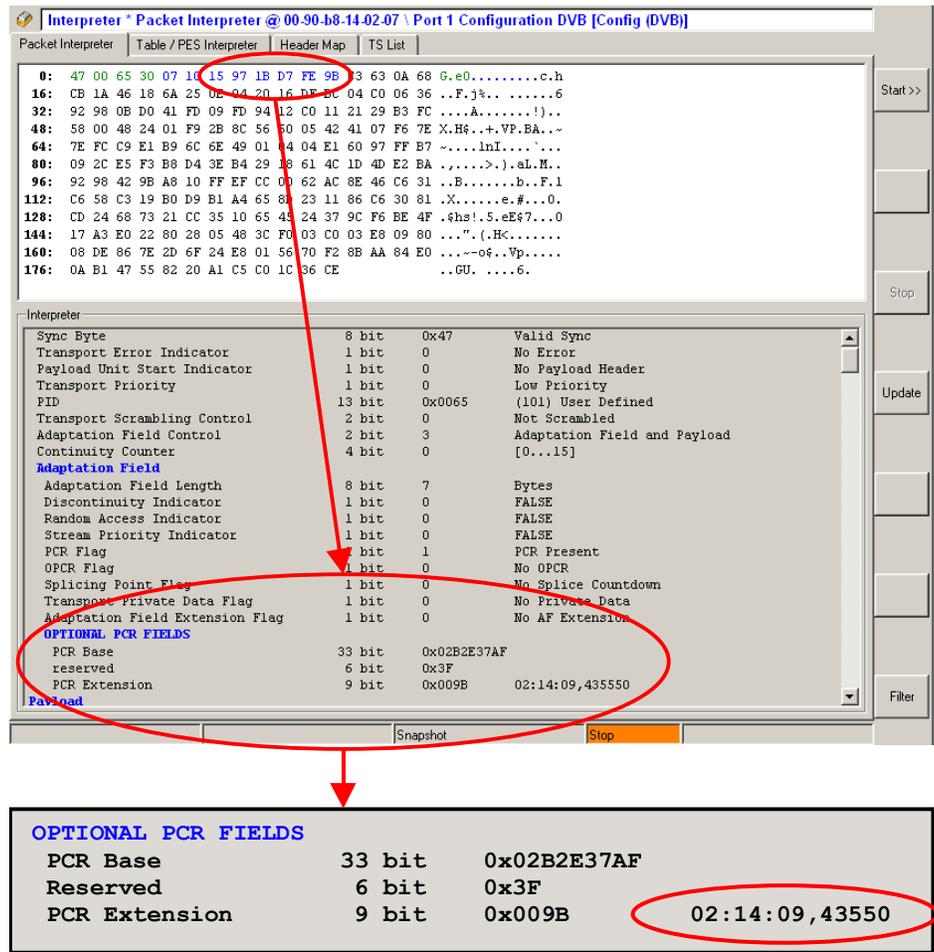


Fig. 9 PCR value display with the R&S®DVM

The PCR base is $0x02B2E37AF = 724449199$.
 The PCR extension is $0x009B = 155$. Thus, the PCR value is
 $(724449199 * 300 + 155) / 27 \text{ MHz} = 8049.435550 \text{ s} = 2:14:09.435550$

7.3 Detailed PCR Jitter Analysis

The R&S®DVM is equipped with the R&S®DVM-K10 option (in-depth analysis) to allow a detailed PCR jitter analysis for accuracy and overall measurements using the described filters. Measurements for checking the system frequency or its derivative are not supported. The system frequency measurement would only check whether the encoder uses the correct frequency, and system frequency variations, i.e. a derivative unequal to zero, are also measured when the accuracy and overall measurements are

PCR Measurements

performed. In addition to measuring the PCR jitter, the R&S®DVM also graphically displays the intervals between the received PCR values.

Fig. 10 shows the "Advanced" mode of the R&S®DVM. This mode allows the following measurements:

- PCR jitter and distance
- PTS analysis
- Buffer analysis

The different measurements can be selected by means of the respective tabs. Fig. 10 shows the PCR measurements.

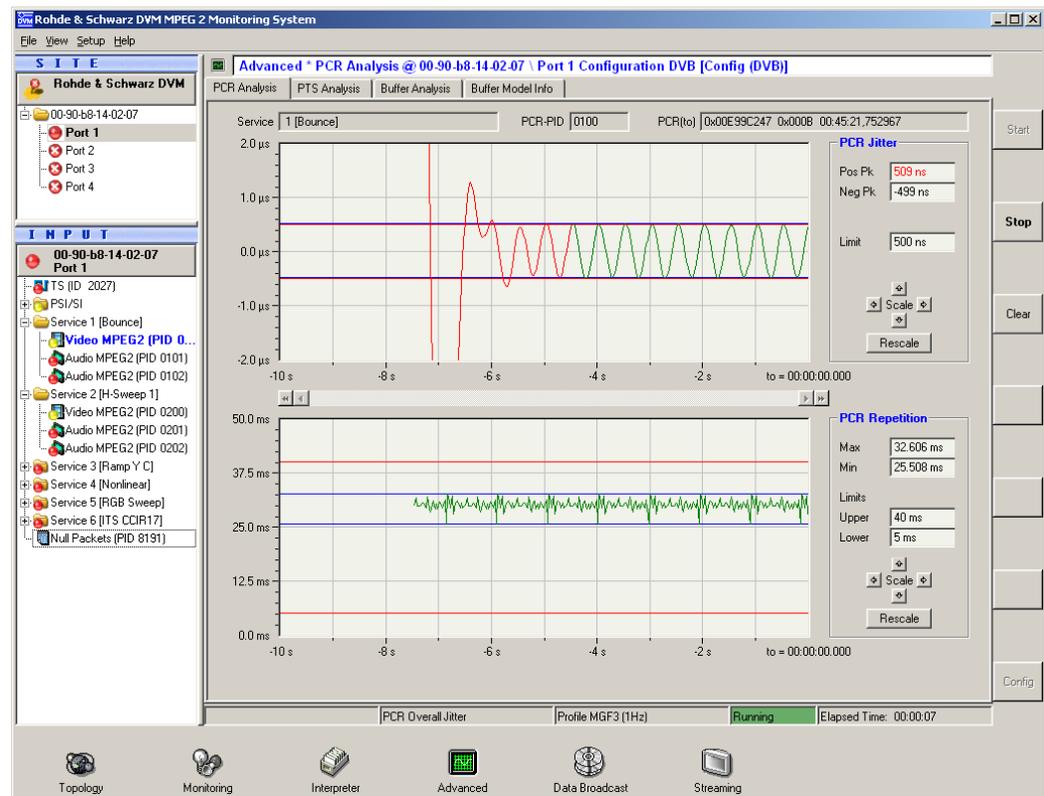


Fig. 10 PCR analysis of the R&S®DVM

The PCR of the element selected in the field at the left (blue font) is checked. In the example shown in Fig. 10, this is the video of service 1. The jitter analysis results are displayed at the upper right, the PCR distance at the lower right of the screen. The type of measurement (Accuracy/Overall) and the filters are selected by means of the Config button. The traces are displayed in red during the settling time of the measurement filter. During settling, the determination of max. and min. values is disabled. The lower the limit frequency, the longer the settling time; in this case, however, low frequencies are also included in the measurement and the results are more accurate. Fig. 10 shows filter settling. The red horizontal lines in the diagrams show the selected tolerances. The blue horizontal lines show the peak values since the beginning of the measurement. A reference frequency that is independent of the transmission system is required to measure the overall jitter. The reference frequency in the R&S®DVM has an

accuracy of 2×10^{-6} . You can connect an external frequency standard to the 10 MHz reference input of the R&S[®]DVM.

When the overall jitter is measured, note that measurement results are easily influenced by reference frequency variations at the very low limit frequency of 0.01 Hz. For this reason, the R&S[®]DVM should be warmed up before performing this measurement and not be exposed to even slight temperature variations. This does not apply to accuracy measurements, since they do not require a reference frequency.

7.4 Examples of a Detailed PCR Jitter Measurement

Fig. 10 shows an example of a detailed PCR jitter measurement with the R&S[®]DVM, where the measurement of an artificial sinusoidal jitter signal produced by a generator is displayed.

Fig. 11 shows the measurement on a program received via satellite. You can see that, if the overall jitter is measured with a 0.01 Hz filter, the PCR deviates only slightly from zero, i.e. is quite accurate. The individual values are received sufficiently frequently, and they occur at regular intervals

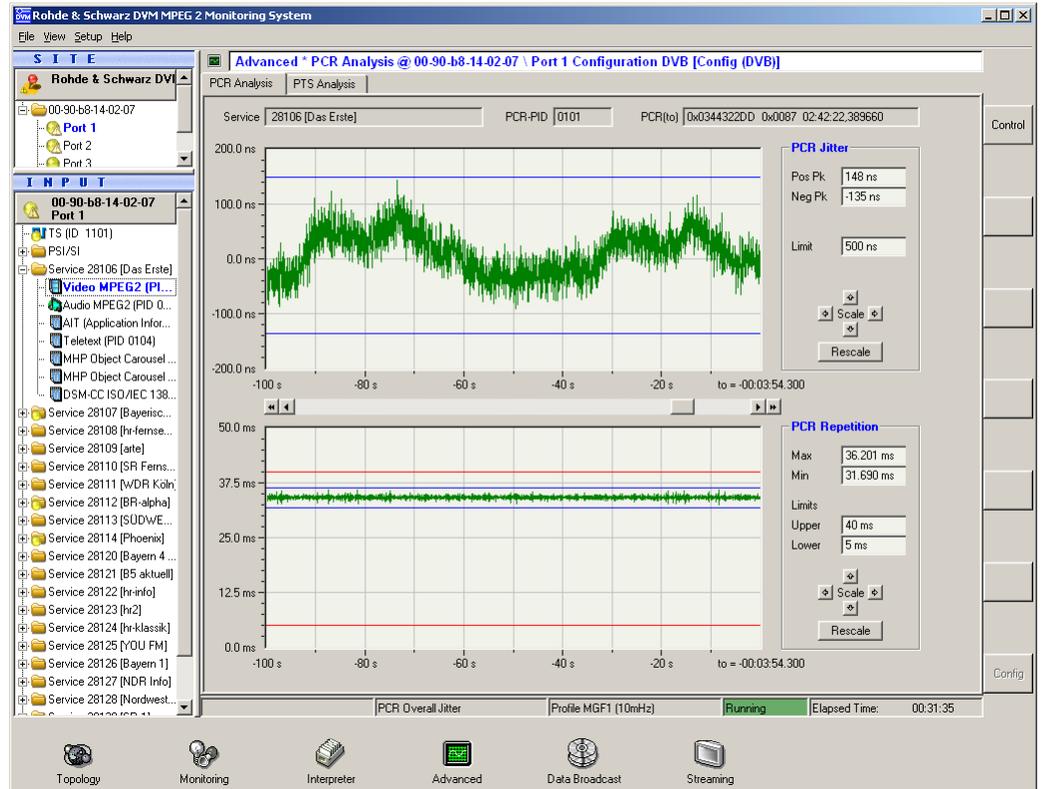


Fig. 11 Transmission via satellite

8 Additional Information

Our application notes are updated from time to time. Please visit the Rohde & Schwarz website to download new versions.

Please send any comments or suggestions about this application note to Broadcasting-TM-Applications@rohde-schwarz.com.

9 Ordering Information

DVM50	MPEG-2 Monitoring System	2085.1900.02
DVM-K1	Additional TS Input	2085.5211.02
DVM50-K10	In-Depth Analysis	2085.5434.02
DVM-K11	Data Broadcast Analysis	2085.5311.02
DVM100	MPEG-2 Monitoring System	2085.1600.02
DVM120	MPEG-2 Monitoring System	2085.1700.02
DVM-B1	Analyzer Board	2085.3283.02
DVM-K1	Additional TS Input	2085.5211.02
DVM-K10	In-Depth Analysis	2085.5228.02
DVM400	Base Unit	2085.1800.02
DVM400-B1	Analyzer	2085.5505.02
DVM-K1	Additional TS Input	2085.5211.02
DVM-K2	TS Capture	2085.5234.02
DVM-K11	Data Broadcast Analysis	2085.5311.02
DVM400-B2	TS Generator	2085.5511.02
DVM400-B3	Upgrade TS Recorder up to 90 Mbit/s	2085.5528.02
DVM400-B4	Upgrade TS Recorder up to 214 Mbit/s	2085.5534.02
DV-ASC	Advanced Stream Combiner	2085.8804.02
DV-DVBH	DVB-H Stream Library	2085.8704.01
DV-HDTV	HDTV Sequences	2085.7650.02
DV-TCM	Test Card M Streams	2085.7708.02
DVM-DCV	Documentation of Calibration Values	2082.0490.29
	Service Manual	2085.1839.02

10 References

ETSI TR 101 290

Digital Video Broadcasting (DVB); Measurement guidelines for DVB systems; V1.2.1 May 2001

ISO/IEC 13818-1 : 2000 (E) / ITU-T Recommendation H.222.0

Information technology – Generic coding of moving pictures and associated audio information: Systems; February 2000

11 Abbreviations

CCVS	Color composite video signal
DTS	Decoding time stamp
DVB	Digital video broadcast
MPEG	Motion Picture Experts Group
PCR	Program clock reference
PCR_AC	PCR accuracy
PCR_DR	PCR drift rate
PCR_FO	PCR frequency offset
PCR_OJ	PCR overall jitter
PID	Packet identification
PLL	Phase lock loop
PMT	Program map table
PTS	Presentation time stamp
SCR	System clock reference
STC	System time clock
SDI	Serial digital interface
SFN	Single frequency network
TS	Transport stream



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