Advanced PCR Analysis with Stream Explorer and R&S DVMD or R&S DVRM

Application Note

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

This Application Note gives an overview of definitions, functions and use of PCR. It also explains the measurements specified by the current Measurement Guidelines and it gives detailed instructions for the use of the extended and modified PCR measurement functions of the new Stream Explorer software version (3.01).

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Contents

1 Introduction

When MPEG2 transport streams are transmitted, the program clock reference (PCR) is transmitted as a time reference. A sufficiently accurate and correctly received PCR is a precondition for correct data display in the receiver.

During revisions to the Technical Report TR 101 290 "Measurement Guidelines for DVB Systems" from ETSI (European Telecommunications Standards Institute), the recommended PCR measurements were modified and significantly expanded. The revisions are included in version 1.2.1 of May 2001.

The new Steam Explorer software version 3.01 from Rohde & Schwarz offers new and modified PCR measurement functions that comply with the new Measurement Guidelines.

This Application Note provides an overview of definitions, functions and use of the PCR. It also explains the measurements specified by the current Measurement Guidelines and, finally, provides detailed instructions for the use of the extended and modified PCR measurement functions of the new Stream Explorer software version.

2 What is the PCR and what is it required for?

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 clock reference (SCR). It is used as a correction value for the phase lock loop (PLL) in the receiver. The PCR therefore controls all time-referenced procedures in the receiver. These procedures include decoding and output times for elementary stream data, the SDI output signal clock (provided an SDI output is available) and the colour subcarrier frequency at the CCVS output.

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

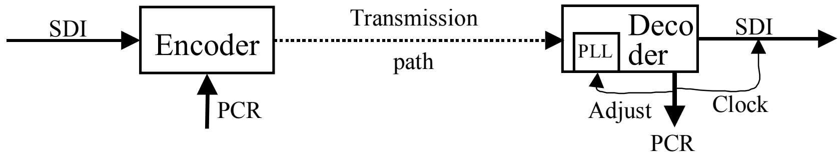

Fig. 1 Function of PCR

Function of PTS and DTS

The presentation time stamp (PTS) and the decoding time stamp (DTS) are transmitted in addition to the PCR. 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. This is necessary in case data is not decoded in the order in which it is received. The PTS also indicates the time when the decoded data should be output. This means that the PTS value is always higher than the current PCR value[1].

3 How is the PCR transmitted?

A PCR is transmitted with each program of a transport stream (TS). The PCR values are only transmitted in transport stream packets containing a special PID which is specified in the program map table (PMT). These TS packets are normally used to transport the video elementary stream of the program.

Not every TS packet containing the specific PID must also contain 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 The difference between the PCR and PTS value can also be measured with the Stream Explorer.

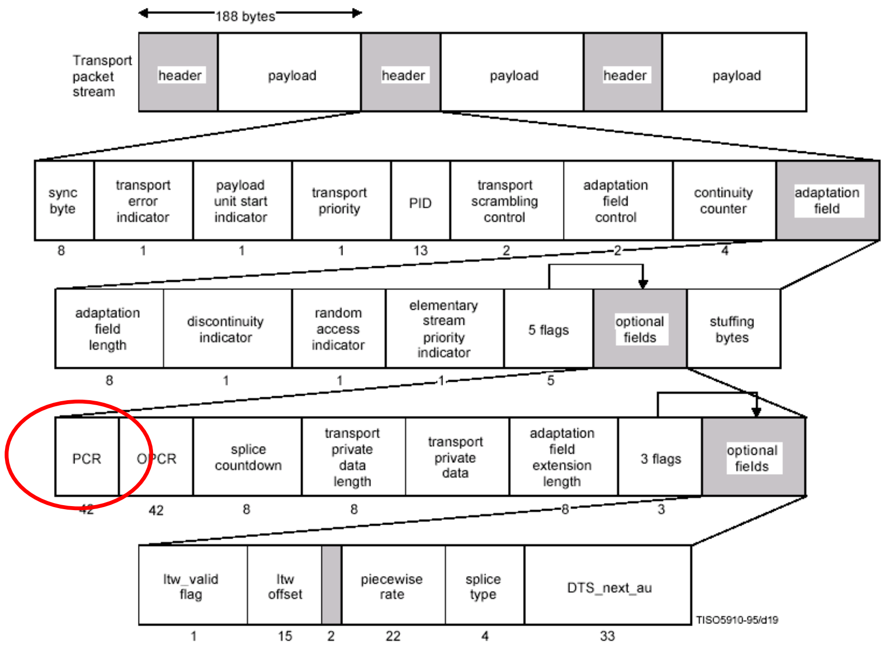

Fig. 2 TS syntax diagram

This means that in the case of an encrypted transport stream, data must be decrypted before the PCR values can be analyzed. If only the elementary stream is encrypted (this is usually the case), a measurement can be carried out without prior decryption.

The PCR value is 42 bits long and incremented with a frequency of 27 MHz. It should be noted 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 arrangement was chosen with reference to the MPEG1 definition, where the PCR is only 33 bits long.

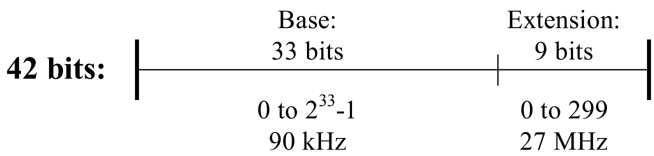

Fig. 3 42-bit PCR field

The 9-bit range is incremented with 27 MHz. However, the 9-bit range overflows after 300 steps (values 0 to 299) and not after the 2^9 = 512 possible steps. This means that the 33-bit range is clocked with 27 MHz / 300 = 90 kHz.

With the aid of these 42 bits, a PCR value can thus be represented with a 1-step accuracy. A value of (49/17) for instance corresponds to 49 * 300 +17 = 14717 clock pulses, i.e. 14700 / 27 MHz = 0.545 ms.

The period before the PCR value reaches 0 again is 2^{33} * 300 / 27 MHz = ~95443.72 seconds, i.e. ~26 1/2 hours.

The PTS and DTS values are 33 bits long and referenced to the program_clock_reference_base. Their resolution is therefore 300 / 27 MHz = ~11.1 µs.

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

4 Problems caused by a corrupt 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 data decoding is correct, problems might occur with 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 colour distortions or flicker. If the colour subcarrier is too heavily disturbed, only monochrome pictures will be displayed.

If the PCR is extremely corrupt, the PLL of the receiver might not be able to synchronize or only occasionally so that decoding is not possible at all. The result is a complete picture failure.

5 Reasons for a corrupt PCR

PCR values must be received with sufficient accuracy and regularity. Only under these conditions will the PLL in the receiver function correctly.

Possible reasons for a corrupt PCR:

- Inaccurate generation in the encoder.
- Faulty recalculation in the multiplexer / remultiplexer or transmitter. (A recalculation must not be performed in single frequency networks (SFNs)).
- Data jitter, e.g. transmission in ATM networks (data rate variations in the transmission channel).

6 Measurements in line with TR 101 290 of May 2001

PCR measurements are described in two sections of 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 MPEG2 Transport Streams in Networks).

6.1 PCR Measurements in Section 5.2.2

The measurements described in this section should be carried out continuously or periodically during monitoring. The PCR measurements are listed under 2.3, 2.3a, 2.3b and 2.4. An overview is provided in Table 1.

No.	Indicator	Precondition	Reference
2.1	Transport_error	Transport_error_indicator in the TS-Header is set to "1"	ISO/IEC 13818-1 [1]: clauses 2.4.3.2, 2.4.3.3
2.2	CRC_error	CRC error occurred in CAT, PAT, PMT, NIT, EIT, BAT, SDT or TOT table	ISO/IEC 13818-1 [1]: clauses 2.4.4, annex B EN 300 468 [7]: clause 5.2
2.3	PCR_error (note)	PCR discontinuity of more than 100 ms occurring without specific indication. Time interval between two consecutive PCR values more than 40 ms	ISO/IEC 13818-1 [1]: clauses 2.4.3.4, 2.4.3.5 ISO/IEC 13818-4 [2]: clause 9.11.3 TR 101 154 [4]: clause 4.5.4
2.3a	PCR_repetition_ error	Time interval between two consecutive PCR values more than 40 ms	TR 101 154 [4]: clause 4.1.5.3
2.3b	PCR_discontinuity_indicator_error	The difference between two consecutive PCR values ($PCR_{i+1} - PCR_i$) is outside the range of 0...100 ms without the discontinuity_ indicator set	ISO/IEC 13818-1 [1]: clauses 2.4.3.4, 2.4.3.5 ISO/IEC 13818-4 [2]: clause 9.1.1.3
2.4	PCR_accuracy_ error	PCR accuracy of selected programme is not within ±500 ns	ISO/IEC 13818-1 [1]: clause 2.4.2.2
2.5	PTS_error	PTS repetition period more than 700 ms	ISO/IEC 13818-1 [1]: clauses 2.4.3.6, 2.4.3.7, 2.7.4
2.6	CAT_error	Packets with transport_scrambling_control not 00 present, but no section with table_id = 0x01 (i.e. a CAT) present Section with table_id other than 0x01 (i.e. not a CAT) found on PID 0x0001	ISO/IEC 13818-1 [1]: clause 2.4.4
NOTE:	The old version of PCR_error (2.3) is a combination of the more specific errors PCR_repetition_error (2.3.a) and PCR_discontinuity_indicator_error (2.3.b) by a logical 'or' function. It is kept in the present document for reasons of consistency of existing implementations. For new implementations it is recommended that the indicators 2.3.a and 2.3.b are used only.		

Table 1 PCR measurements

For reasons of compatibility with existing implementations, the PCR_error measurement under 2.3 has been taken from the previous TR 101 290 version. The measurement is a combination of the measurements under 2.3a and 2.3b. For new implementations, the measurement under 2.3 should be replaced by measurements 2.3a and 2.3b. The following parameters are measured:

- PCR_repetition_error: Are the PCR values received with sufficient regularity (at least every 40 / 100 ms (DVB / MPEG))?
- PCR_discontinuity_indicator_error: Is there a difference between two consecutive PCR values of 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 in Section 5.3.2

The measurements in this section serve for an in-depth PCR jitter analysis and may be helpful to find PCR jitter sources. They have been newly included in the current TR 101 290. The following measurements are defined:

- Frequency offset
- Drift rate
- Accuracy
- Overall jitter

Frequency offset

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).

With this measurement, the system frequency can be checked.

Drift rate

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

Accuracy

With this measurement, the difference between the current PCR value and the value defined by its position in the TS is determined. A constant transport stream data rate is required for this measurement (see ETSI TR 101 290, page 29).

To state it more simply, 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. 4.

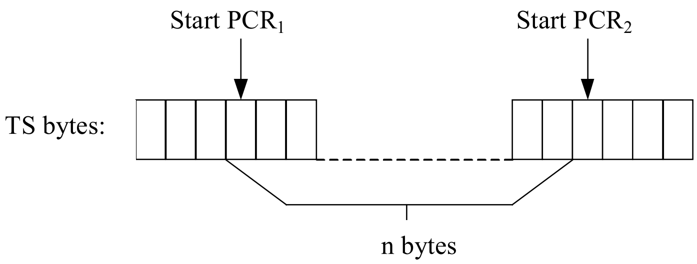

Fig. 4 Illustration of an accuracy measurement

The tolerance for the PCR accuracy as specified by ISO/IEC 13818-1 is ±500 ns. For this tolerance a constant data rate is assumed. Errors caused by the "packet arrival time" are therefore not considered. The Measurement Guidelines refer to this definition for the tolerance.

With the described measurement, a highpass filter is used for the measured values. Four different filter criteria are defined:

MGF1: 10 mHz

MGF2: 100 mHz

MGF3: 1 Hz

MGF4: can be defined

With the aid of the low limit frequencies, the low frequencies (drift) can be separately determined.

This measurement can also be carried out off-line since all values required for the measurement (PCR value and data quantity between the PCR values) can also be obtained from a stored TS.

Possible TS data rate variations are not considered in this measurement. In contrast, when the overall jitter is measured, variations of the TS data rate, i.e. the packet arrival time (time at which the TS packet pertaining to the PCR value is received), are taken into account.

Overall jitter

With this measurement, the difference between the time the PCR value is actually received (packet arrival time) and the theoretically correct arrival time is determined (see ETSI TR 101 290, page 29).

To state it more simply, the error can be defined as the deviation of the difference between two consecutive PCR values from the time elapsed between the two values; see also Fig. 5

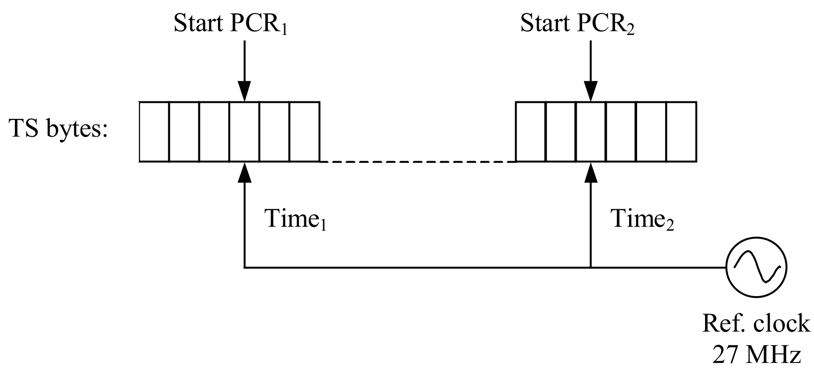

Fig. 5 Illustration of overall error

The filters defined for measuring the accuracy are also used for this measurement. No tolerances are defined by the Measurement Guidelines for this measurement.

The main difference between these two measurements is that the reference for the accuracy measurement is the received data quantity and the reference for the overall measurement is the elapsed time.

7 Measurements with Stream Explorer and R&S DVMD / DVRM

7.1 Analysis of PCR Data

The transmitted PCR values can be viewed with the Stream Explorer (SE). To this end, TS packets containing a PCR value are filtered out in the Dump mode and the content is viewed by means of the Packet Interpreter. An example is shown in Fig. 6.

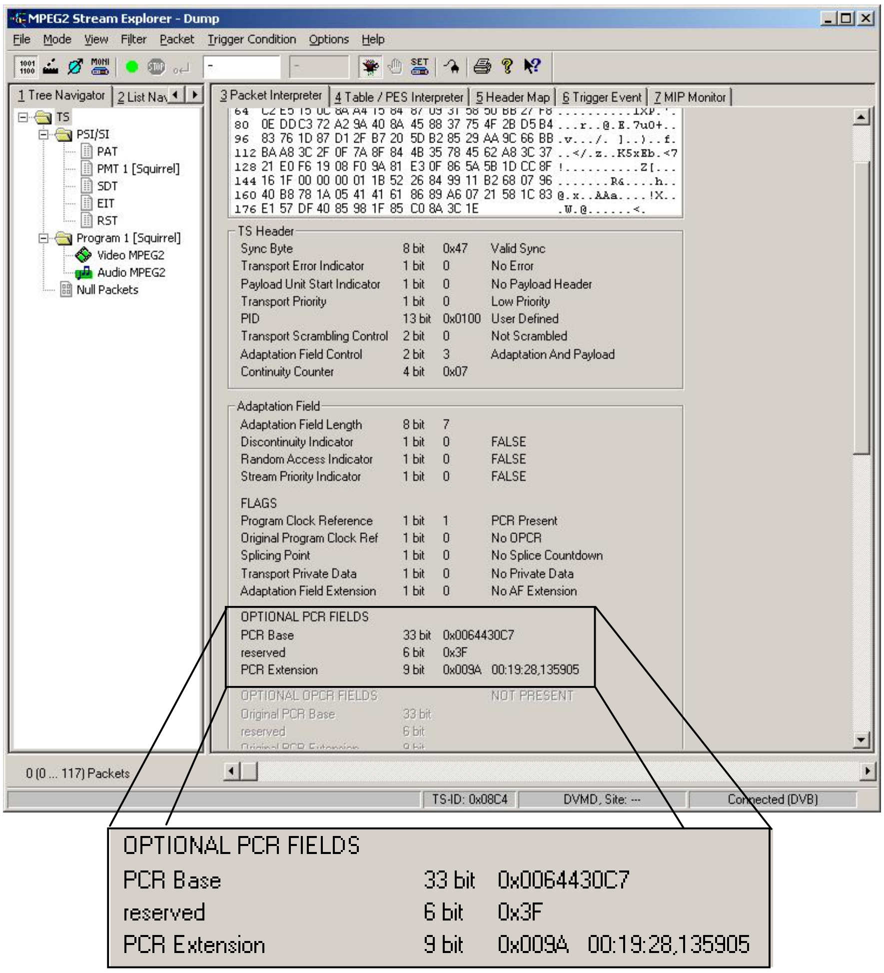

Fig. 6 Display of PCR value with Stream Explorer

The PCR base is 0x64430C7 = 105132231. The PCR extension is 0x9A = 154. The PCR therefore corresponds to approximately 19 ½ minutes ((105132231 * 300 + 154) / 27 MHz = ~1168.135905703 s = ~ 19 min and 28.136 s)

7.2 Monitoring

All measurement functions described in 6.1 are supported by the R&S DVMD/DVRM and can be configured as required by the user. The tolerances defined by the Measurement Guidelines are already set. The configuration can be set with the aid of the Stream Explorer or the Realtime Monitor in the window shown in Fig. 7. The window can be opened with the  button in the tool bar.

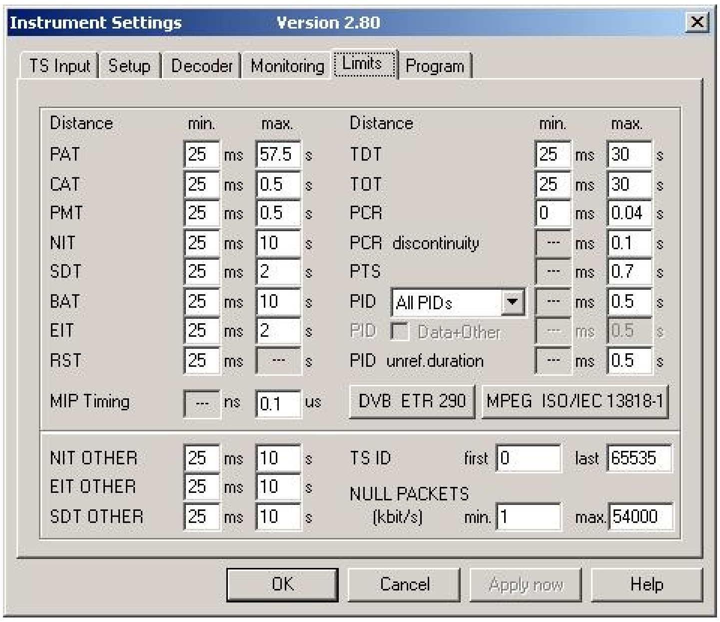

Fig. 7 Configuration of R&S DVMD / DVRM

These parameters can also be set on the R&S DVMD with the aid of keys and the display. The configuration can be set via the Monitoring/Limits and Monitoring/Parameter Group menus.

In the monitoring mode, the mentioned parameters are continuously monitored. If an error is detected, a report entry is generated and the error-specific seconds counter is incremented. An alarm line can also be activated (in R&S DVMD only if option DVMD-B5 is installed).

7.3 Detailed PCR Jitter Analysis

For detailed jitter analysis, the accuracy and overall measurements with the described filters are provided by the Stream Explorer. 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, is also measured when the accuracy and overall measurements are performed. In addition to measuring the PCR jitter, the Stream Explorer also graphically displays the intervals between the received PCR values.

Fig. 8 shows the measurement mode of the Stream Explorer. In this mode the following measurements can be performed:

- PCR jitter and distance
- PTS analysis and
- Table repetition

The different measurements can be selected on the respective tabs. Fig. 8 shows the PCR measurements.

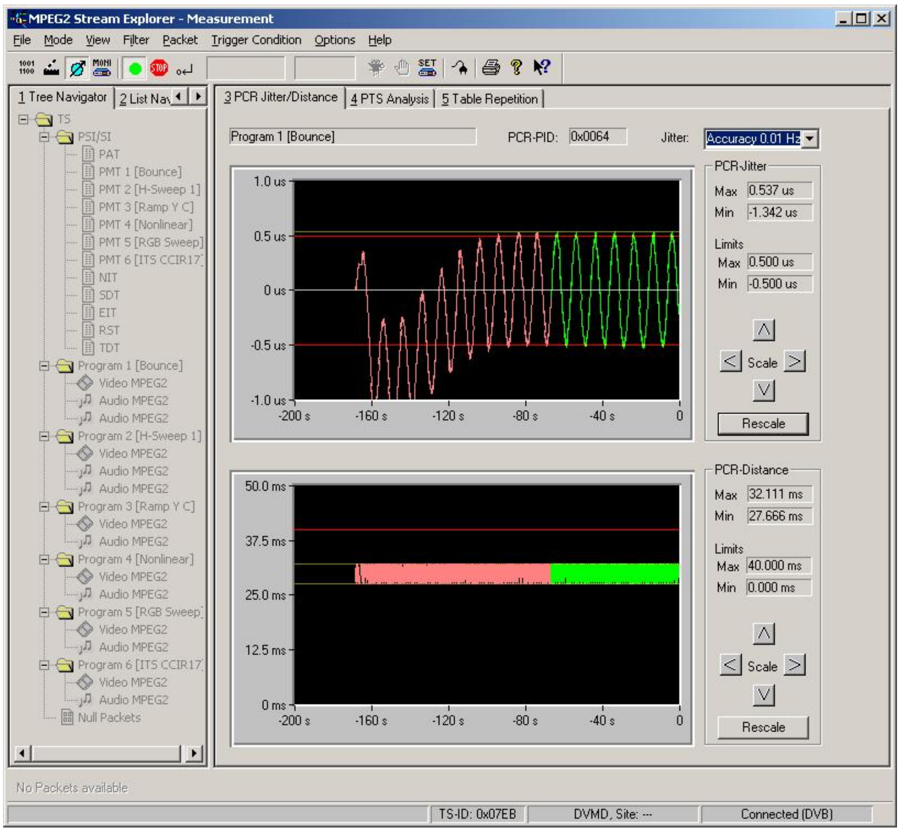

Fig. 8 Measurement mode of Stream Explorer

The PCR of the element selected in the field at the left is checked. In the example shown in Fig. 8, this is Program1 (Bounce). The results of jitter analysis are displayed in the upper diagram and the PCR distance in the lower diagram. The type of measurement (Accuracy / Overall) and the filters are selected at the top right. During settling of the measurement filter, the measured traces are displayed in red (required only for the overall jitter measurement). During settling the determination of max. and min. values is disabled. The lower the limit frequency, the longer the settling time, but in this case low frequencies are also considered in the measurement and the results are more accurate. Fig. 8 shows filter settling. The red horizontal lines in the diagram mark tolerances. For measuring the overall jitter, a free-running PLL is required so that a reference frequency independent of the transmission system is obtained. Since a free-running PLL will most probably cause decoding errors or even a decoding failure, picture decoding in the R&S DVMD is switched off for this measurement.

When the overall jitter is measured, it should be noted 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 DVMD / DVRM should be warmed up for this measurement and should not be exposed to temperature variations. This is irrelevant for accuracy measurements that are performed, as a reference frequency is not required in this case.

7.4 Examples of Detailed PCR Jitter Measurement

An example of detailed PCR jitter measurement with the Stream Explorer is shown in Fig. 8 In this case the measurement of an artificial sinusoidal jitter signal produced by a generator was displayed. Fig. 9 and Fig. 10 show examples encountered in practical applications.

Fig. 9 shows the measurement of a program transmitted via satellite. If the overall jitter is measured with a 0.01 Hz filter, it can be seen that the PCR only slightly deviates from zero, i.e. that it is quite accurate. The individual values are received sufficiently often but it can be seen that the individual PCR values arrive at quite irregular intervals.

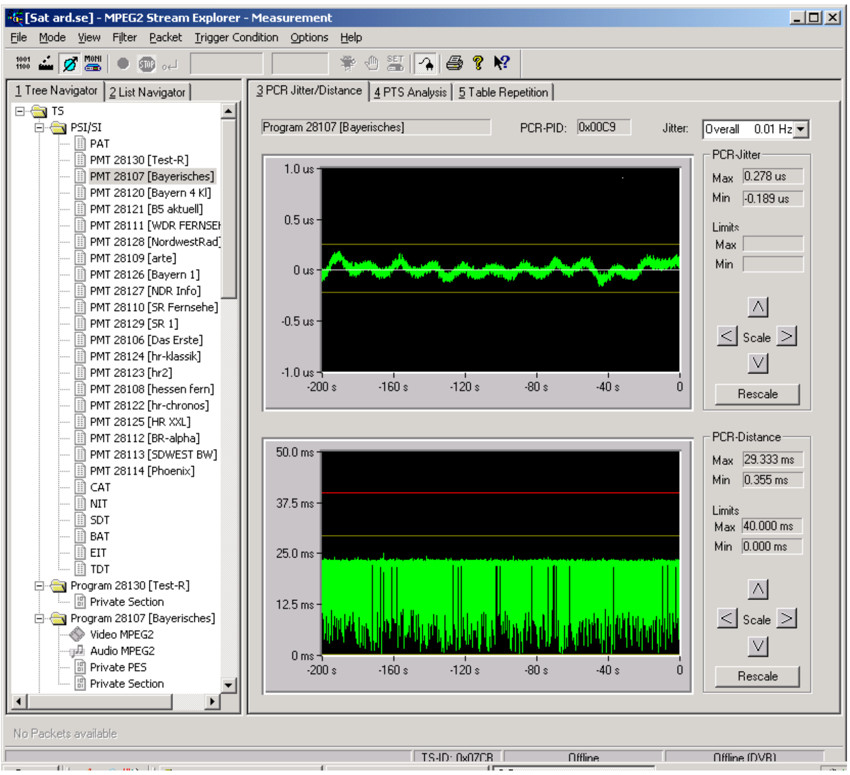

Fig. 9 Transmission via satellite

Fig. 10 provides an example of transmission on an ATM link. The jitter measurements shows that the PCR values vary considerably. In the displayed section, variation of up to –3.1 µs occurs. It is known that ATM transmission characteristics are likely to cause problems regarding the PCR accuracy.

It can also be seen that the individual PCR values are received sufficiently often and at quite regular intervals.

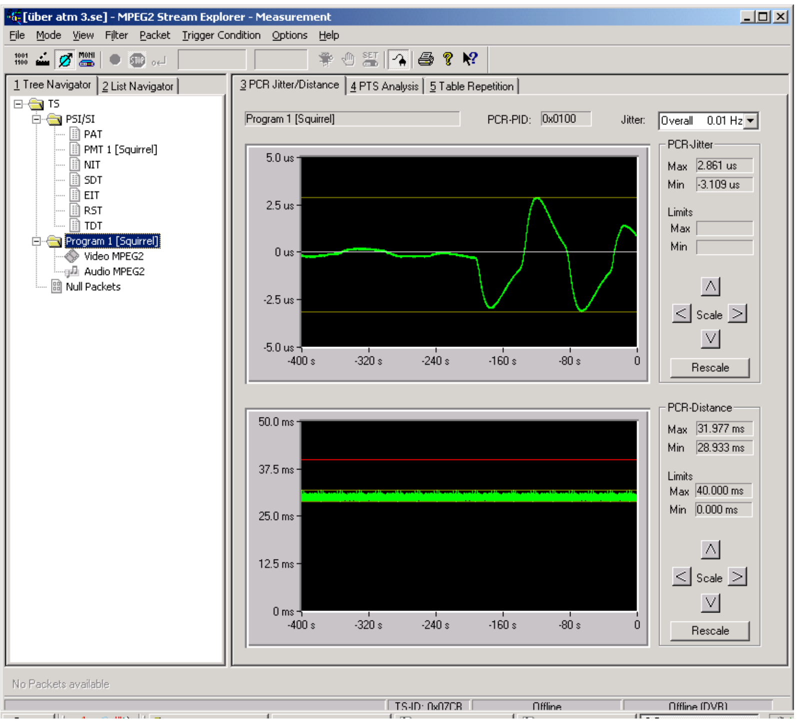

Fig. 10 Transmission via an ATM network

8 Ordering Information

MPEG2 Measurement Decoder	R&S DVMD	2068.8597.02
MPEG2 Realtime Monitor	R&S DVRM	2068.8580.02
Stream Explorer Software	R&S DVMD-B1	2068.9406.02

9 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

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