1.11 Test Equipment for MPEG2 Protocol

1.11.1 MPEG2 Measurement Generator DVG

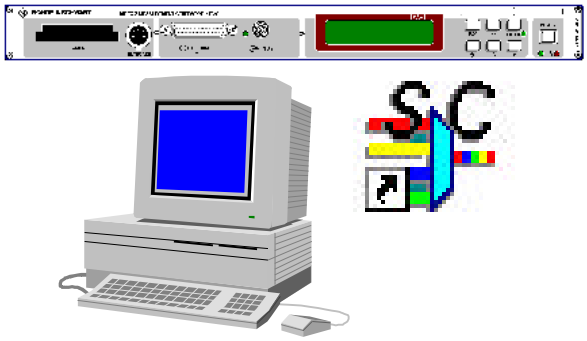
A transport stream generator is needed to simulate MPEG2-coded video, audio and data signals and tables and to ensure reproducible measurements. The generator should be able to produce the transport streams proposed by international standards, including moving picture sequences such as flower garden or table tennis, as well as special test sequences, e.g. for lip sync testing. MPEG2 MEASUREMENT GENERATOR DVG meets all these requirements.

Condensed data
MPEG2 MEASUREMENT GENERATOR DVG

Output signals	transport stream to ISO/IEC 13 818-1
Length of TS packets	
DVB	188/204 bytes
ATSC	188/208 bytes
Data rate of TS	0.6 Mbit/s to 160 Mbit/s
Signal outputs to DVB-A010	1x SPI, 2x ASI or 1x SPI, 1x ASI, 1x SMPTE 310 and for synchronous parallel MPEG2 data stream to RS422
Signals	525/625 line standard
Interfaces for internal PC	2 x RS232C (one for mouse), connectors for keyboard and VGA monitor, printer interface (parallel), PCMCIA interface

DVG supplies endless and seamless sequences, which are indispensable in development, production and acceptance testing. This is a prerequisite, for example, for carrying out transmitter acceptance tests at different locations of a single frequency network (SFN) under identical test conditions.

1.11.2 Stream Combiner® DVG-B1



For special investigations to be carried out on a transport stream after signal processing in a TS decoder, for example, or after DVB transmission, the optional DVG-B1 Stream Combiner® software is available. It generates new transport streams from existing elementary streams.

The associated tables are automatically generated and can be user-edited in the expert mode.
The ES2Loop (elementary stream to loop) software extension supplied with the Stream Combiner® matches the length of a video elementary stream to the length of the associated audio elementary stream, so producing endless and seamless video and audio sequences. With the ES2Loop option, DVG MPEG2 MEASUREMENT GENERATOR can deliver a virtually unlimited variety of signals.

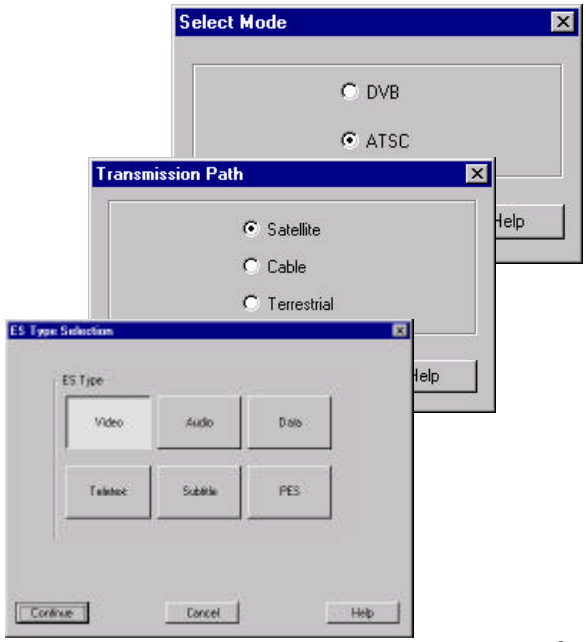


Fig. 1.5 Mode selection with Stream Combiner®

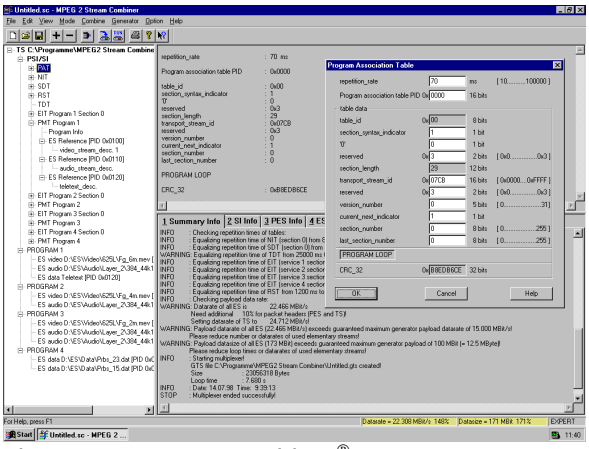


Fig. 1.6 Stream Combiner®: transport stream structure

1.11.3 DTV Recorder Generator DVRG

Whereas MPEG2 MEASUREMENT GENERATOR DVG supplies MPEG2 sequences with loop duration of a few seconds, DTV RECORDER GENERATOR DVRG is capable of recording and replaying transport streams over very long periods of time (up to 10 hours, depending on the data rate used).
Data volumes below 64 Mbyte are stored to the internal RAM, data volumes in excess of 64 Mbyte are recorded and replayed making direct access to fast 18 Gbyte hard disks. Files are stored in .trp format, which makes for exchangeability of data, i.e. the same transport streams can be recorded and replayed using equipment from different manufacturers.
An 18 Gbyte hard disk is installed as standard; a second one may be fitted as an option. Equipped with the appropriate option, DVRG even allows the recording and replay of uncompressed data streams to ITU-R BT.601/656 or SMPTE 259M at a data rate of 270 Mbit/s.
An optional CD-R R/W drive completes the range of hardware functions.

DTV RECORDER GENERATOR DVRG

Condensed data
DTV RECORDER GENERATOR DVRG

Signal inputs	1x SPI, 2x ASI to EN 50083 (DVB) or 1x SPI, 1x ASI, 1x SMPTE 310 (ATSC) TS to ISO/IEC 13 818-1 SDI data stream to ITU-R BT.601/656 or SMPTE 259M
Signal outputs	1x SPI, 3x ASI to EN 50083 (DVB) or 1x SPI, 2x ASI, 1x SMPTE 310 (ATSC) SDI data stream to ITU-R BT.601/656 or SMPTE 259M
Length of TS packets	
DVB	188/204 bytes
ATSC	188/208 bytes
Data rate of TS	0.6 Mbit/s to 90 Mbit/s
TS sequence length	endless or limited by hard disk size
Signal set	TS library with approx. 80 sequences
Hard disk storage capacity	18 Gbyte or 36 Gbyte
Operating system	Microsoft Windows Embedded NT™
Remote control interfaces	Ethernet 100baseT RS232C

1.11.3.1 Triggered TS Recording

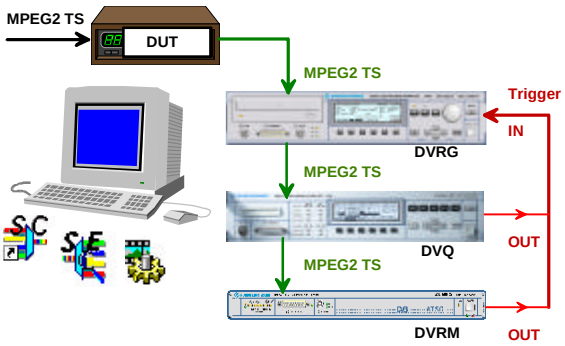


Fig. 1.7 Triggered TS recording

For error analysis, recording of a TS can be triggered by an external signal applied to the trigger input on the rear of the unit (Fig. 1.7). Data are written to the RAM continuously and cyclically even before the trigger event occurs.

Recording is completed after a settable delay following the trigger signal. Thus transport streams can be stored before (pretrigger) and after (posttrigger) the trigger time.

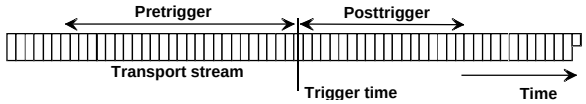


Fig. 1.8: The length of the pretrigger and posttrigger parts of a transport stream can be defined for a triggered recording with DVRG.

1.11.3.2 Test Signals

DVRG generates a large number of predefined MPEG2 transport streams to the DVB and ATSC standards at a keystroke. The transport streams contain several elementary streams and consist of video, audio and other data (e.g. teletext or PRBS). The signal set comprises sequences with moving picture contents and some static test signals. These include known test patterns such as colour bar signals, zone plate, CCIR17/18/331 and many others as well as the Rohde & Schwarz CODEC test pattern with ITU test lines in the upper and lower picture area. Using the CODEC test pattern, the analog outputs of a set-top box or an integrated receiver decoder (IRD) can be tested within seconds with the aid of a Video Analyzer VSA or UAF from Rohde & Schwarz.

Audio data streams with different sampling rates, coded to MPEG1 layer 2 or Dolby AC-3, contain the accompanying sound for the video sequences as well as special audio test signals. Of course, the transport streams include all program information, service and system tables (SI, PSI and PSIP) required by MPEG2 and ATSC or DVB as stipulated by the selected standard.
Any kind of transport stream can be recorded with DVRG. If a transport stream required for a special application is not found in the preconfigured signal set stored in DVRG, it can be created by means of the Stream Combiner® or an MPEG2 encoder and recorded on DVRG. This yields a virtually unlimited range of test signals.

1.11.3.3 Operation

Basic control operations are performed via the DVRG front panel keys and LC display. But DVRG also offers a complete PC platform running under Windows NT or Windows 95/98, which can be operated after connecting a VGA monitor, keyboard and mouse. This can be used, for example, to install further software packages for the analysis or generation of transport streams. Moreover, DVRG can easily be networked for remote control and the transmission of transport stream data via the standard Ethernet 100baseT interface.
The network protocol is TCP/IP with SCPI commands. Any sequences recorded or replayed on DVRG can be transferred from and to other PCs or DVRGs via this network interface.
Remote control via RS232 is possible using the same SCPI commands as via Ethernet.

1.11.4 MPEG2 Analyzer

A transport stream transmits data in conformance with the MPEG2 protocol. To be able to unambiguously decode the contents of the transport stream packets, compliance with the MPEG2 protocol has to be monitored. It is therefore indispensable to check, at the studio output, the accompanying tables and thus the programs transmitted, as well as the data rates and any errors occurring by means of an error statistics function. This applies analogously to the input of the data distribution network. Network operators must ensure that the correct programs, consistent with the protocol, are fed to the cable headends, the terrestrial transmitters of a single-frequency (SFN) or multifrequency network (MFN), or to the satellite uplink.

To verify consistency with the MPEG2 protocol, the European ETR290 standard has issued clearly defined measurement guidelines. Measurements are based on key parameters that fall into three main categories reflecting different fields of application. The parameters are listed in Table 1.8.

First priority (necessary for decodability)	
Parameter	Error description
TS SYNC LOSS	The TS packet structure is not adhered to or no TS is present.
SYNC BYTE ERROR	The sync byte is not equal to 0x47.
PAT ERROR	Tables with table ID 0x00 and PID 0x00 do not occur at least every 0.5 s. The scrambling control bits are not 00.
CONTINUITY COUNT ERROR	Incorrect TS packet order. A packet occurs more than twice. Lost packet.
PMT ERROR	Tables with table ID 0x02 (PMT) do not occur at least every 0.5 s on the PMT PID which is referred to in the PAT. The scrambling control bits in these tables are not 00.
PID ERROR	The referred PID does not occur for a selectable interval that should not exceed 5 s.
Second priority (for continuous or periodic monitoring)	
TRANSPORT ERROR	The TEI (transport error indicator) bit in the TS packet header is set to 1. (Forward error correction (FEC) in the demodulator of the set-top box is not capable of correcting all errors that have occurred; the packet cannot be processed.)
CRC ERROR	A CRC error has occurred in a PAT, CAT, PMT, NIT, EIT, BAT, SDT or TOT table.
PCR REPETITION ERROR	The interval between two consecutive PCR values is longer than 40 ms (to ETR290).
PCR DISCONTINUITY INDICATOR ERROR	The time difference between two consecutive PCR values is outside the range of 0 ms to 100 ms without the discontinuity indicator set.
PCR ACCURACY ERROR	The PCR value of the selected program is outside the ±500 ns tolerance window.
PTS ERROR	The PTS repetition period is longer than 700 ms.
CAT ERROR	Packets with scrambling control bits not 00 are present, but no table with table ID 0x01. Sections with table ID other than 0x01 (CAT) are found in the table with PID 0x01.
Third priority (selection of parameters for application-dependent monitoring)	
NIT ERROR	Sections with table IDs other than 0x40, 0x41, 0x72 (NIT or SDT) are found on tables with PID 0x10. No section with table ID 0x40 (NIT, actual TS) is found on a table with PID 0x10 for more than 10 s. Two sections with table ID 0x40 occur on PID 0x10 within a selectable interval (≤ 25 ms).
SI REPETITION ERROR	The repetition rate of the SI (service information) tables is outside specified limits (limits user-defined or to ETR290 or ISO/IEC 13818).
UNREFERENCED PID	A PID is found with a value not referred to by a PMT or a CAT within 0.5 s.
SDT ERROR	Sections with table IDs other than 0x42, 0x46, 0x4A or 0x72 (SDTs, actual TS) occur on tables with PID 0x1. No section with table ID 0x42 (SDT, actual TS) is found on a table with PID 0x11 for more than 2 s. Two sections with table ID 0x42 occur on PID 0x11 within a selectable interval (≤ 25 ms).
EIT ERROR	Section 0 with table ID 0x4E (valid EIT-P, actual TS) is not found on table with PID 0x12 (EIT) for more than 2 s. Section 1 with table ID 0x4E (next valid EIT-F, actual TS) is not found on table with PID 0x12 for more than 2 s. Sections with table IDs other than 0x4E to 0x6F or 0x72 are found on tables with PID 0x12. Two sections with table ID 0x4E (EIT-P/F, actual TS) occur on PID 0x12 within a selectable interval (≤25 ms). (EIT-P: present EIT EIT-F: following EIT)
RST ERROR	Sections with table IDs other than 0x71 or 0x72 are found on tables with PID 0x13 (RST). Two sections with table ID 0x71 (RST) occur on PID 0x13 within a selectable interval (≤ 25 ms).
TDT ERROR	No section with table ID 0x70 (TDT, actual TS) is found on a table with PID 0x14 for more than 30 s. Sections with table IDs other than 0x70, 0x72 (ST) or 0x73 (TOT) are found on PID 0x14. Two sections with table ID 0x70 (TDT) occur on PID 0x14 within a selectable interval (≤ 25 ms).
NIT OTHER ERROR	The interval between sections with the same section number and table ID 0x41 (NIT, other TS) on PID 0x11 is longer than the selected interval (i.e. > 10 s).
SDT OTHER ERROR	The interval between sections with the same section number and table ID 0x46 (SDT, other TS) on PID 0x11 is longer than the selected interval (i.e. > 10 s).
EIT OTHER ERROR	Section 0 with table ID 0x4F (valid EIT-P, other TS) is not present on table with PID 0x12 for more than 10 s (selected interval). Section 1 with table ID 0x4F (next valid EIT-F, other TS) is not present on table with PID 0x12 for more than 10 s (selected interval).
SI OTHER ERROR	The repetition rate of the NIT OTHER, the SDT OTHER or the EIT OTHER table of the other TS with other ID is outside specified limits (limits user-defined or to ETR290 or ISO/IEC 13818).
Other parameters	
DATA RATE ERROR	The data rates of null packets with PID 0x1FFF are higher or lower than the selected rates.
MULTIPLEX ERROR	The TS ID is outside the specified range of values.
MIP ERROR	The megaframe initialization packet (MIP) does not conform to standard in terms of formal requirements or plausibility.

Table 1.8 Protocol parameters in three priorities and other parameters

In addition, the quality of MPEG2 coding at the studio output is to be measured to ensure that the programs emitted meet appropriate video quality standards as defined by the program provider.

1.11.5 Measurements with DVMD and DVRM

First the TS protocol is to be analyzed. The optimal instrument for this is
MPEG2 MEASUREMENT DECODER DVMD or
REATIME MONITOR DVRM.

Condensed data
DVMD MPEG2 MEASUREMENT DECODER

Input signals	TS to ISO/IEC 13 818-1
Length of TS packets	
DVB	188/204 bytes
ATSC	188/208 bytes
Data rate of TS	up to 54 Mbit/s
Signal inputs	
DVB	1x SPI 2x ASI
ATSC	1x SPI 1x ASI 1x SMPTE 310
Measurements	parameters to ETR290 (adjusted for ATSC), TS protocol, data rates of overall TS, programs and substreams (PID), monitoring of TS_ID "other" tables (DVB), paradigma condition (ATSC only), trigger on error
Decoder outputs	
Video	2x CCVS, 1x Y/C 1x ITU 601
Audio	1x AES/EBU 2x analog audio R/L
Interfaces	RS232C

Where monitoring only is to be performed, the favourably priced MPEG2 REALTIME MONITOR DVRM is the preferable solution.

DVRM MPEG2 REALTIME MONITOR

DVRM performs protocol analysis same as DVMD; it differs from DVMD only in that no decoded video and audio signal outputs and no manual control unit are provided.
DVRM system compatibility is further enhanced by its COM (component object model) and DCOM (distributed COM) interfaces.

MPEG2 REALTIME MONITOR DVRM is designed for system operation, so all measurements and results are displayed on the monitor of the PC by which it is controlled.

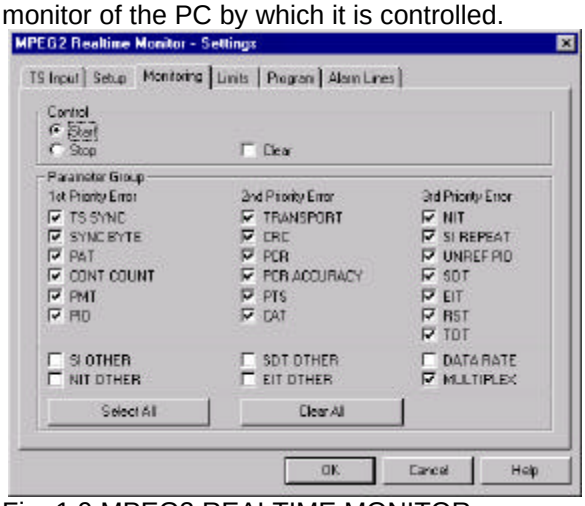


Fig. 1.9 MPEG2 REALTIME MONITOR:
Selection of parameters to be monitored

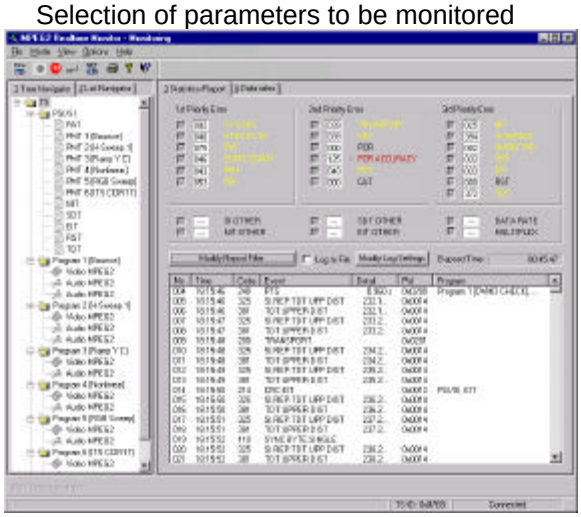


Fig. 1.10 MPEG2 REALTIME MONITOR:
Tree navigator, statistics and report

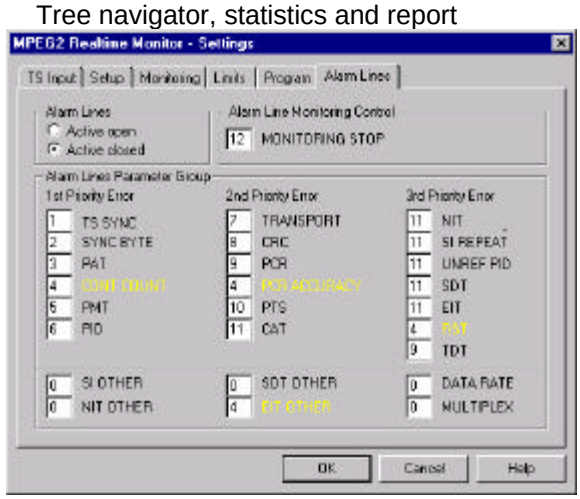
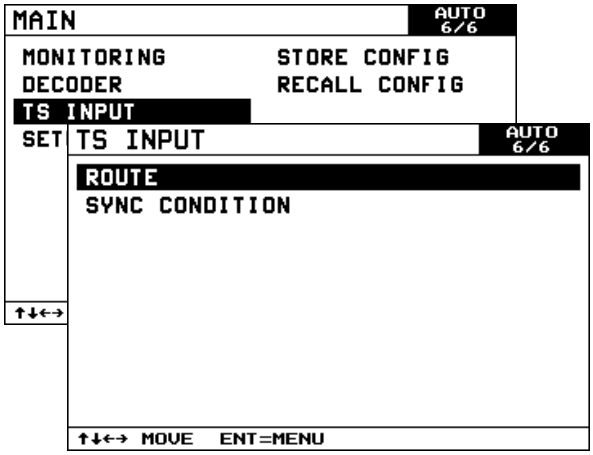


Fig. 1.11 MPEG2 REALTIME MONITOR:
Setting of alarm lines

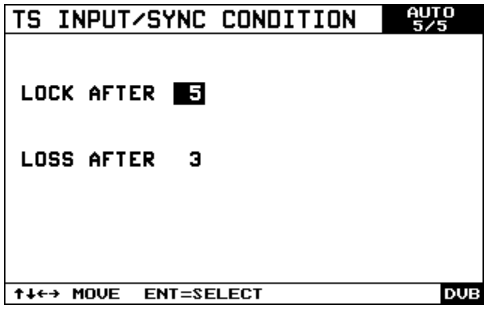
1.11.6 DVMD On-Screen Displays (OSDs) for Protocol Monitoring

A very helpful feature is on-screen display (OSD) of the DVMD settings and results on a large monitor.

First, the input for the transport stream has to be selected on DVMD:

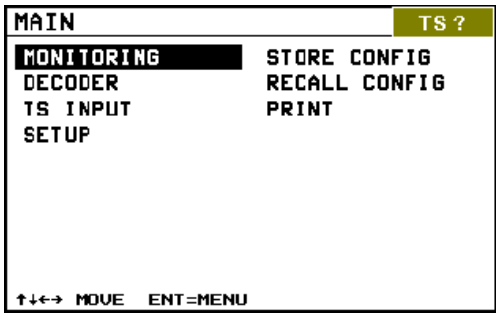


Three inputs can be selected under ROUTE:
- ASI on front or rear panel and
- SPI on front panel



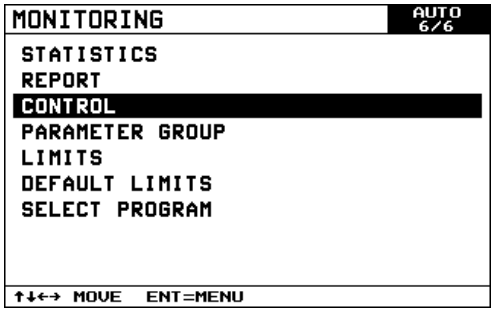
Synchronization conditions are freely selectable. The above figure shows the recommended setting.

The main menu provides an overview of the available test functions and settings:



If no TS is present, this is signalled in the yellow field in the top right. "TS?" indicates that no decodable MPEG2 data is present at the DVMD input.

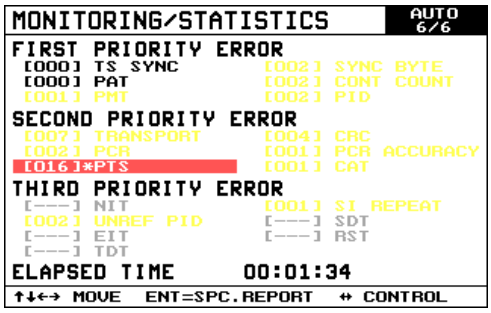
The TS status is queried also on the small OSD.



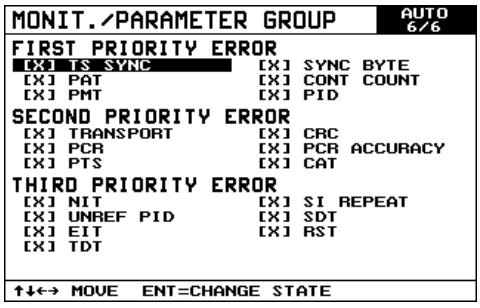
MONITORING produces an overview of available displays and settings.

The STATISTICS window displays all errors detected in three priorities (see also Table 1.8) on the OSD:

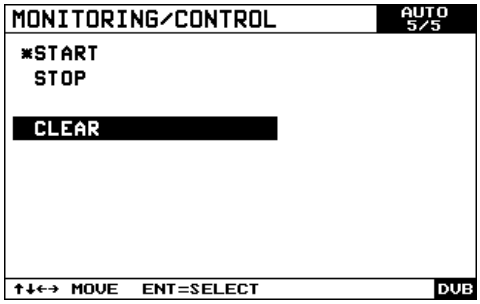
white	no error found during the monitoring period (shown in black in this example)
yellow	error persisting longer than 1 s
magenta	current error
grey	parameter not monitored



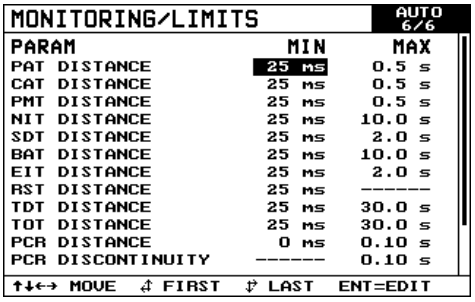
Under PARAMETER GROUP, the parameters to be monitored can be selected.



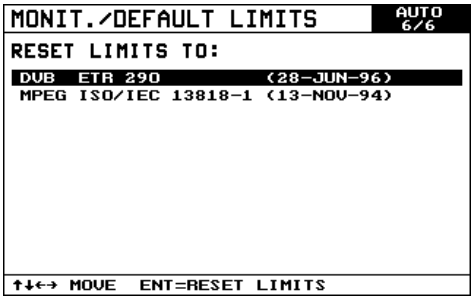
Under CONTROL, the error counts can be reset prior to a restart of STATISTICS or REPORT.



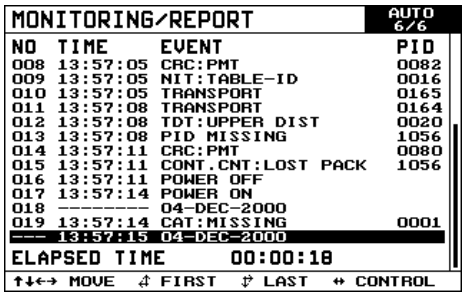
Moreover, compliance with tolerance limits for time intervals and repetition rates has to be checked.



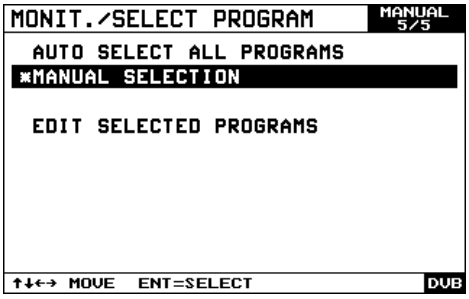
Tolerance limits can be user-selected separately for each parameter or set as recommended by standards (see also Table 1.6)



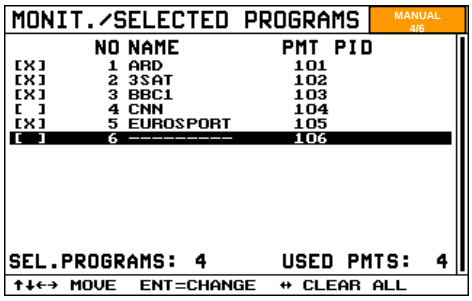
The REPORT gives detailed information about all events and errors that have occurred during the monitoring period. The list may contain up to 1000 entries describing the type of event or error, the PID under which the event or error occurred, as well as the date and time. It is a complete and objective record of the monitored TS.



If only some programs are of interest, these can be selected for monitoring.



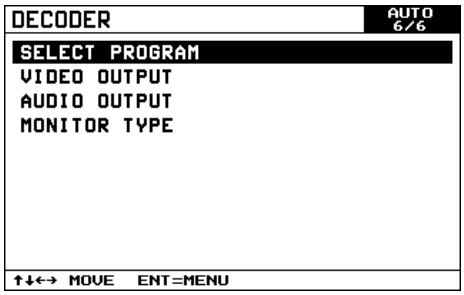
The selected programs are marked by an asterisk. The number of monitored programs against the total number of programs of a TS is shown by a status indication in the top right corner of the screen (in the example below this is "MANUAL 4/6", which means that four of a total of six programs have been selected for monitoring).



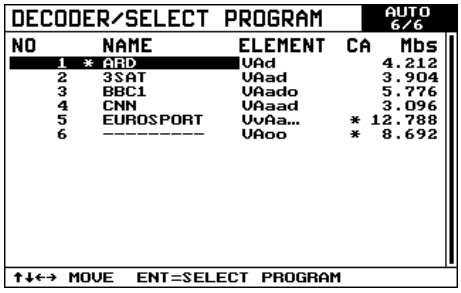
The small OSD displays the key data of the TS to be decoded.

So far, the settings and measurements under the MONITORING main menu have been discussed. The PSI and SI tables were checked for conformance with standards with respect to the parameters listed in Table 1.8. Now the MPEG2 protocol is to be analyzed also in terms of the signal contents of the programs carried in the TS.

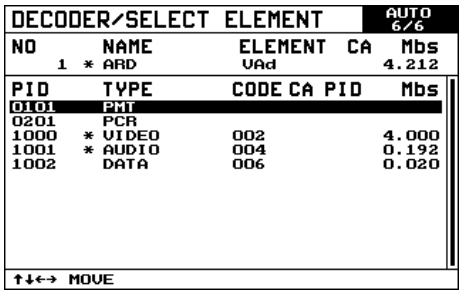
To this effect, the DECODER menu is opened from the MAIN menu.



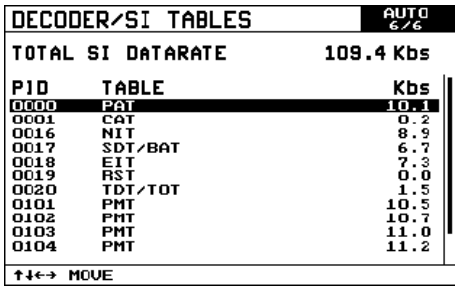
SELECT PROGRAM displays the already interpreted PAT as well as the PMTs of the transport stream.



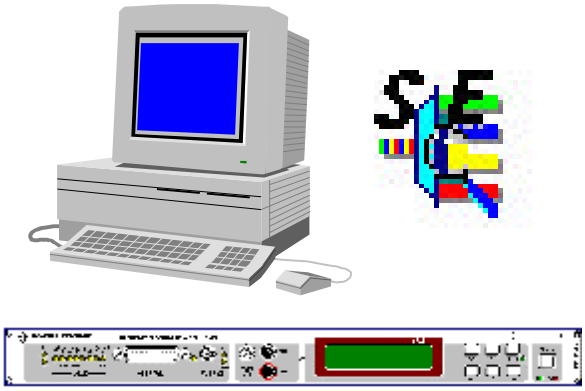
After selecting an item in the ELEMENT column and pressing ENTER, the PMT of the associated program comes up. Not only the PIDs of the program elements are listed but also, very importantly, the data rates measured in realtime.



The data rates of the PSI and the SI tables, too, are measured in realtime.



1.11.7 Stream Explorer® DVMD-B1



MPEG2 MEASUREMENT DECODER DVMD performs decoder functions as well as comprehensive protocol analysis. For a detailed investigation of the contents of transport stream packets and the overall transport stream structure, the DVMD-B1 Stream Explorer® software option is available.
The Stream Explorer® displays the complete transport stream contents with all syntax elements in the form of a structure tree. Transport stream packets are represented in hexadecimal format and at the same time as an interpreted contents list for the header and the adaptation field, so providing information down to bit level.

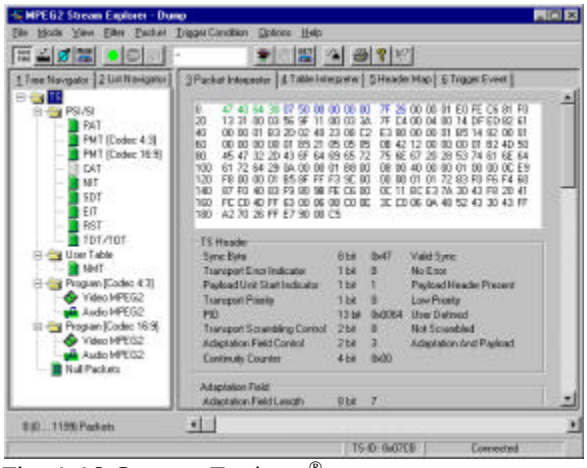


Fig. 1.12 Stream Explorer®:
Plain-text representation of TS header information in dump mode

The interpreted contents of the PSI and SI tables are of particular interest.

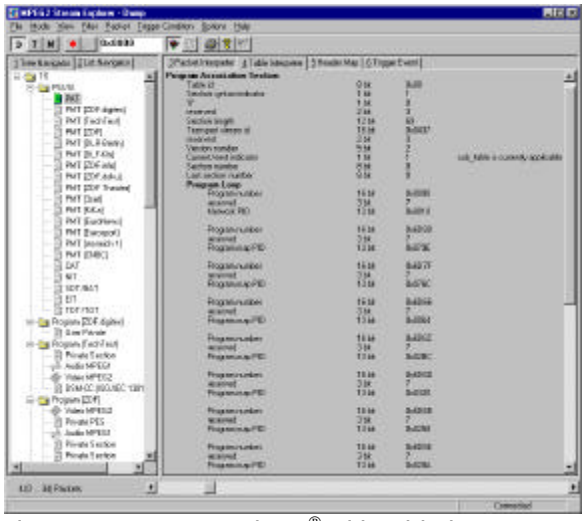


Fig. 1.13 Stream Explorer® with table interpreter

If an error occurs during MPEG2 signal processing, DVMD stores the TS packets in the region of the error by means of the TRIGGER ON ERROR function and transfers the data to the Stream Explorer® for evaluation. This allows the detailed analysis of the cause of an error or a defined trigger event. The Stream Explorer® can store 1200 up to TS packets. The packets may be filtered, for example according to PID.
In the MEASURE mode, the Stream Explorer® produces a clear-cut bargraph representation of TS system parameters. These include, for example, data rates of substreams, repetition rates of tables and of the PCR (program clock reference), as well as PCR jitter.

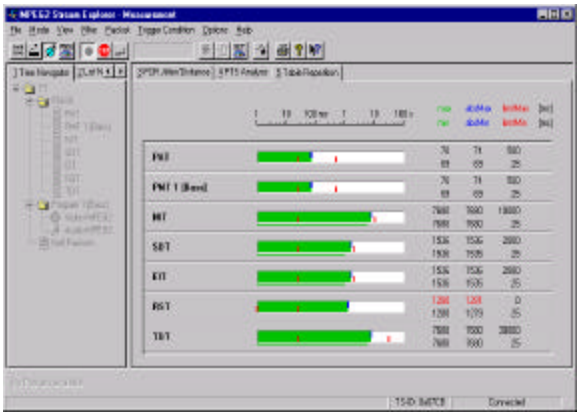


Fig. 1.14 Stream Explorer® measurement mode:
Repetition rates of tables

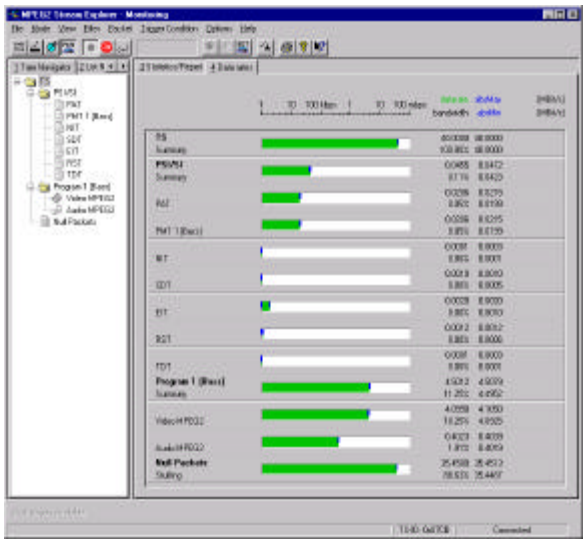


Fig. 1.15 Stream Explorer® measurement mode: Data rates of substreams

PCR jitter and PCR repetitions rates, too, are measured. In the example below it can be seen clearly that PCR jitter remains within the specified tolerance of ±500 ns (min. actual value -259 ns, max. actual value +222 ns) and the PCR repetition rate is constantly at 38.5 ms (min. actual value 38.177 ms, max. actual value 38.933 ms; these small deviations being due to measurement tolerances).

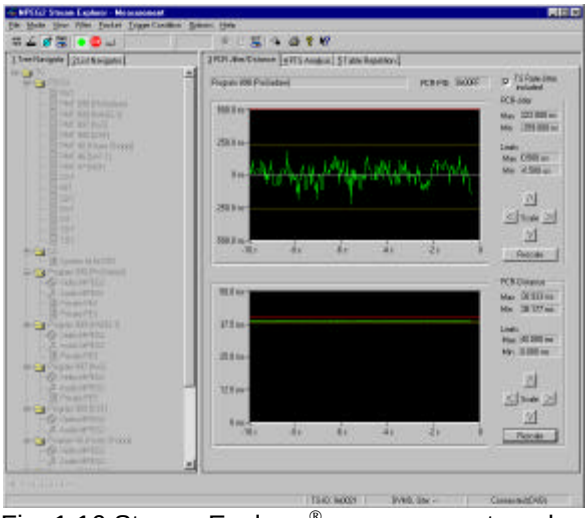


Fig. 1.16 Stream Explorer® measurement mode: PCR monitoring

The above results show nearly ideal PCR calculation and insertion into the adaptation fields of a TS received via satellite.

In contrast to this, the following measurement on a cable-transmitted TS shows that the required recalculation of PCR values was obviously not carried out in the remultiplexer of the cable headend, and the PCR repetition rate is likewise far below standard:

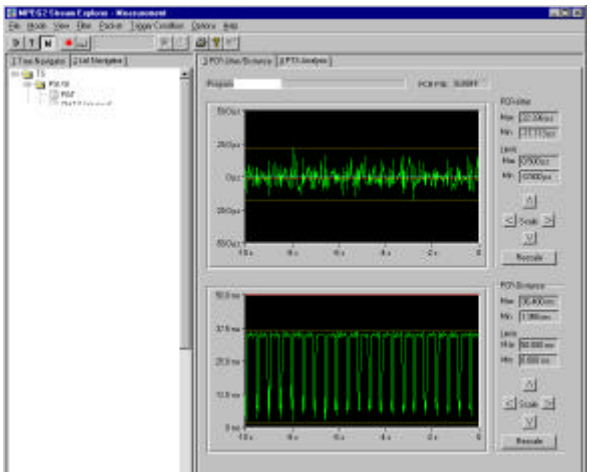


Fig. 1.17 Stream Explorer® measurement mode: PCR monitoring

PCR jitter: min. actual value -17.113 µs
max. actual value +22.336 µs

PCR repetition rates:
min. actual value 1.955 ms
max. actual value 36.400 ms

Signals like the one shown above that are by far outside specified tolerances limits can be decoded only by high-quality PCR filters in the digital PLL of the set-top box.