ROHDE&SCHWARZ
BROADCASTING DIVISION

# Digital TV
# Rigs and Recipes
# Part 1
# ITU-R BT.601/656 and MPEG2

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**Contents**

## 1.1 Introduction

In analog television, pictures are recorded with a camera in the form of R, G and B colour signals. In the studio, these signals are converted to CCVS signals in conformance with the PAL, SECAM or NTSC standard. The signals are IF-modulated and converted to the RF in the transmitter, and then taken to the antenna, which emits one program per channel. Analog TV measurement systems are well known from the baseband in the studio to the RF signal in the transmitter.

But what about digital TV?
To understand digital TV measurements, it is necessary to know how digital television works. Therefore, a complete and detailed description of the digital television system will be given in the following. This will be followed by a description of the relevant test parameters, methods, and appropriate measuring equipment.

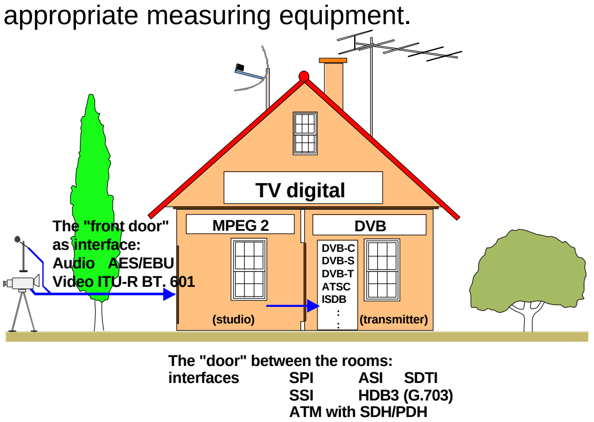



Fig. 1.1 "Digital TV house"

The RGB signals generated by the TV camera, as well as the corresponding audio channels, are immediately digitized in accordance with standards ITU-R BT.601/656 (International Telecommunication Union) for the video information and AES/EBU (Audio Engineering Society/European Broadcasting Union) for the audio information. The two signals are applied to the first "room", i.e. the MPEG2 (Motion Picture Experts Group) room of the "digital TV house", either via separate lines or with the audio information inserted in the digital blanking interval of the ITU-R BT.601/656 signal. At this point already, measurements are needed to verify and guarantee that digitization of the video and audio information is in line with relevant standards.

With the signals conforming to ITU-R BT.601/656 and AES/EBU, we enter the first room of the house, the MPEG2 room. Here we find the encoders for data compression of the video and audio signals. The digital ITU-R BT.601/656 video interface has a data rate of 270 Mbit/s, which is by far too high for TV channels of 7 MHz to 8 MHz bandwidth. Data can be compressed as required by means of video data coding to ISO/IEC 13818 (International Organization for Standardization/International Electrotechnical Commission), which provides detailed specifications of MPEG2 coding in nine parts, and audio data coding to ISO/MPEG 11 172 (this standard is referred to in ISO/IEC 13818-3 forr audio coding) using the MUSICAM (masking pattern adapted universal subband integrated coding and multiplexing) method. With MPEG2 coding, the data rate can be reduced from 270 Mbit/s to about 3 to 5 Mbit/s virtually without any visible degradation of picture quality. After digitization, MPEG2 coding and appropriate modulation, the above bandwidths are sufficient to transmit 6 to 12 programs in a channel.
As an alternative, sound may be Dolby AC-3 coded. In Australia, and possibly later in Europe too, both types of coding can be used. In the American ATSC system, only Dolby AC-3 coding is possible.
For video and audio information stored on DVD, the Dolby AC-3 system with Dolby surround up to the 5.1 mode (5 audio channels and one channel for very low frequencies) is used worldwide already now.

The video and audio signals are packetized to form packetized elementary streams (PES streams), multiplexed into transport stream (TS) packets, and information packets (tables) are added. Depending on the available data rate of the DVB (digital video broadcasting) system, several programs containing video and audio information may be combined in a transport stream.
The transport stream that leaves the "MPEG2 room" is monitored by means of suitable test equipment to verify compliance with the protocol and acceptable quality of the outgoing encoded video signal.

The transport stream thus generated is passed from the first room (MPEG2) of the digital TV house to the second room (DVB) via one of the following interfaces:

SPI (synchronous parallel interface)
SSI (synchronous serial interface)
ASI (asynchronous serial interface)
SDTI (serial digital transport interface)
HDB3 (high density bipolar of order 3) to ITU-T G.703
ATM with SDH/PDH (asynchronous transfer mode, synchronous digital hierarchy, plesiochronous digital hierarchy)

In the "DVB room" there are the modulators for the various types of modulation. Several systems are used worldwide today. These are

in Europe and other countries, e.g. Australia:

DVB-C for cable transmission
DVB-S for satellite transmission
DVB-T for terrestrial transmission

in North and Central America:

ITU-T J.83/B for cable transmission
ITU-R BO.1294/B for satellite transmission (also known by the American designation of DirecTV or DSS (direct satellite system))

and

DVB-S (common also in North America)
ATSC with 8VSB (advanced television systems committee, vestigial sideband) for terrestrial transmission

in Japan:

ISDB-T (integrated services digital broadcasting - terrestrial)
ISDB-S (integrated services digital broadcasting - satellite)

Many countries in the world have not yet decided in favour of one of the above standards.

After modulation and conversion to the RF, the exciter outputs the signal to the power amplifiers. From there, the signal is fed to the cable system, the satellite uplink or the terrestrial transmitting antenna. The signal has now left the digital TV house and is on its way to the viewers at home.
At this point, too, measurements are indispensable to make sure that modulation and transmission parameters comply with specified requirements at any time, so guaranteeing unimpaired reception quality of the programs transmitted at any time.

## 1.2 Digitization of Video Signals to ITU-R BT.601/656

The cameras used in modern studios digitally encode the R, G and B colour signals immediately after the RGB sensors to yield the Y, $C_B$ and $C_R$ components. The picture delivered by the camera, therefore, is already in the ITU-R BT.601 format and contains the digitized Y, $C_B$ and $C_R$ components. The corresponding transmission interface to ITU-R BT.601/656 has the following characteristics:

| | |
|---|---|
| Standard | ITU-R BT.601/656 (4:2:2)<br>SMPTE 125M / 259 M |
| Systems | 625 lines/50 Hz and<br>525 lines/59.94 Hz |
| Resolution<br>in the studio<br>in MPEG2 format | <br>10 bit<br>8 bit |
| Sync signals<br>(timing reference signals – TRSs) | FF.C, 00.0, 00.0, XY.0 |
| Parallel interface<br>Level<br>Connector | 27 Msample/s<br>ECL<br>25-pin D-SUB<br>(ISO 2110 - 1980) |
| Serial digital interface (SDI)<br><br>Level<br>Impedance<br>Connector<br>Coding | 270 Mbit/s in line with D1 format<br><br>$V_{PP}$ = 800 mV ±10 %<br>75 Ω<br>BNC<br>$G(x) = (x^9 + x^4 + 1)(x + 1)$, scrambled,<br>NRZI |

Table 1.1
Specifications of ITU-R BT.601/656 interface

Apart from the interface data, it is important to note the difference between the analog and the digital signal characteristic:

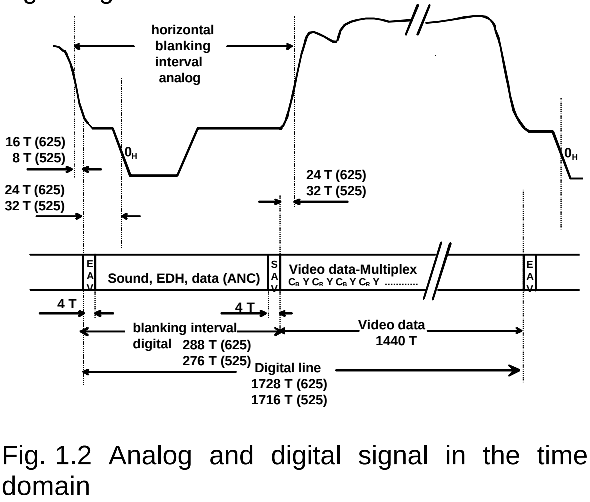



Fig. 1.2 Analog and digital signal in the time domain

Between the timing reference signals (TRV signals) EAV (end of active video) and SAV (start of active video), each comprising four cycles, there is the digital blanking interval, which is narrower than the analog one. In this interval, audio data, or any kind of data, or EDH data (error detecting and handling data) can be inserted for transmission along with the digitized video signal. The 10 (8) bit wide video data start at the beginning of the line with a $C_B$ value, this is followed by a Y value and a $C_R$ value, then by another Y value, and so on. This means that the luminance signal (Y) has double the bandwidth compared with the $C_B$ and $C_R$ colour components.

The sampling rates are as follows:

Y: 13.5 MHz
$C_B$ and $C_R$: 6.75 MHz each

Number of samples within active digital line:

Y: 720
$C_B$ and $C_R$: 360 each

Correct MPEG2 coding depends on the error-free digitization and conversion of the camera signal to the ITU-R BT.601/656 standard. This is, therefore, the first point where test equipment is required to measure and monitor the digital signal for compliance with the protocol and correct physical transmission data.

### 1.3 Test Equipment for ITU-R BT.601/656

The flexible generation of ITU-R BT.601/656 signals, including test signals recommended by ITU-R BT.801, is possible with CCVS GENERATOR SFF or CCVS+ COMPONENT GENERATOR SAF with the SxF-Z1 CCIR 601 option fitted in each case (CCIR is the old designation of ITU). The ITU-R BT.801 standard defines, with pixel accuracy, special signals for the measurements described in ITU-R BT.601/656. This includes, for example, the 100/0/75/0 colour bar signal, which enables reproducible, high-accuracy measurements of the time characteristic and time reference of the Y, $C_B$ and $C_R$ components.

CCVS + COMPONENT GENERATOR SAF

Condensed data of SFF/SAF

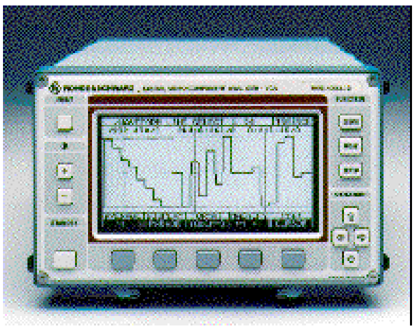
| | |
|---|---|
| Basic unit | |
| Inputs | 1 x program<br>2 x external data or test signals |
| Test signal outputs<br>SAF<br><br>SFF | <br>CCVS, Y/C (S-VHS), Y $C_B$ $C_R$, R G B<br><br>CCVS |
| TV standards | BG/PAL<br>M/NTSC<br>M/PAL<br>N/PAL |
| Signals | approx. 500 fixed values, any number of user-programmable values can be added with MEMORY CARD option |
| Teletext<br><br>Data line | 5 pages, header can be edited<br><br>user-programmable, direct input of VPS |
| Remote control | IEC 625 bus/IEEE488.2 |
| SFF-Z1 and SAF-Z1 options: DIGITAL VIDEO INTERFACE | |
| Standards | ITU-R BT. 601/656<br>SMPTE 125M/259 M |
| Signals | to ITU-R BT.801; all predefined stored signals can be edited as required |
| Outputs<br>Parallel<br><br>Serial | <br>1x10 bit / 27 Msamples/s, 25-pin D-SUB connector (ISO 2110 - 1980)<br>2x270 Mbit/s<br>75 Ω BNC connector |

Since the test signals recommended by ITU-R BT.801 are very important, they are listed in Table 1.2 together with the SAF/SFF-specific ITU-R BT.601 signals. A precise pixel-by-pixel definition of the signals is given in ITU-R BT.801. The signals printed *in italics* are special ITU-R BT.601 signals that can be produced by CCVS GENERATOR SFF or CCVS + COMPONENT GENERATOR SAF with SxF-Z1 CCIR 601 option fitted as part of the "CCIR 601" signal group. They include signals for testing cable equalizers or the subsequent PLL in the receiver section, as well as ramp signals for checking correct A/D and D/A conversion in signal processing. Signals not printed in italics are defined by the ITU-R BT.801 standard pixel by pixel and thus in the most accurate way possible.

| ITU-R BT. 601 | |
|---|---|
| **1 GREY LEVEL** | *21 PATHOL.SIGNAL Y=088h C=100h* |
| **2 ALTERNATING BLACK/WHITE** | *22 PATHOL.SIGNAL Y=044h C=080h* |
| **3 EOL PULSE** | *23 PATHOL.SIGNAL Y=022h C=040h* |
| **4 BLACK/WHITE** | *24 PATHOL.SIGNAL Y=011h C=020h* |
| **5 RAMP YELLOW/GREY** | *25 PATHOL.SIGNAL Y=008h C=210h* |
| **6 RAMP GREY BLUE** | *26 PATHOL.SIGNAL Y=198h C=108h* |
| **7 RAMP CYAN GREY** | *27 PATHOL.SIGNAL Y=004h C=300h* |
| **8 RAMP GREY RED** | *28 PATHOL.SIGNAL Y=0CCh C=180h* |
| **9 RAMP CB Y CR Y** | *29 PATHOL.SIGNAL Y=066h C=0C0h* |
| **10 EOL BAR WHITE** | *30 PATHOL.SIGNAL Y=033h C=060h* |
| **11 EOL BAR BLUE** | *31 PATHOL.SIGNAL Y=019h C=230h* |
| **12 EOL BAR RED** | *32 PATHOL.SIGNAL Y=00Ch C=318h* |
| **13 EOL BAR YELLOW** | *33 PATHOL.SIGNAL Y=006h C=18Ch* |
| **14 EOL BAR CYAN** | **34 DIG.COL.BARS 100/0/100/0** |
| 15 *SEQUENCE 1010* | **35 DIG.COL.BARS 100/0/75/0** |
| 16 *SEQUENCE 11001100* | *36 RAMP Y* |
| 17 *SEQUENCE 111000111000* | *37 RAMP Y CB CR* |
| **18 SDI CHECK FIELD** | *38 RAMP CB* |
| *19 PATHOL.SIGNAL Y=198h C=300h* | *39 RAMP CR* |
| *20 PATHOL.SIGNAL Y=110h C=200h* | |

Table 1.2 ITU-R BT.801 and SAF/SFF-specific signals

The ideal analyzer in an ITU-R BT.601/656 environment is
DIGITAL VIDEO COMPONENT ANALYZER VCA.



DIGITAL VIDEO COMPONENT ANALYZER VCA

Condensed data of VCA

| Basic unit | |
|---|---|
| Inputs | 1 x serial<br>1 x parallel |
| Outputs | actively looped through from inputs |
| Standards | ITU-R BT.601/656<br>SMPTE 125M/259M<br>8/10 bits<br>625/525 lines |
| Oscilloscope | waveform line select,<br>waveform,<br>numeric dump |
| Measurements | TRS error,<br>reserved code error,<br>video range error,<br>CRC error<br>C/L gain/delay error |
| Printer interface | RS-232-C/RS-422-A |
| Remote control (VCA-B1 option) | RS-232-C/RS-422-A |
| VCA-B11 option – DTL analysis (physical signal analysis) | |
| Additional input | 1 x serial |
| Measurements | data jitter,<br>amplitude spectrum,<br>return loss (with external SWR bridge VCA-Z1),<br>signal headroom,<br>signal delay |

VCA covers the complete range of protocol parameters and, with VCA-B11 DTL Analysis option, also the physical characteristics of a signal such as

spectrum,
signal amplitude,
jitter in time or frequency domain,
signal headroom

and other parameters. The VCA-B1 option enables remote control of the VCA as well as long-term monitoring of the TRS (timing reference signal), RCE (reserved code error), and CRC (cyclic redundancy check) information.

The basic unit performs the following measurements via the parallel and the serial interface:

data contents of signal in ITU-R BT.601 format (NUMERIC DUMP in hexadecimal or decimal notation), with Y, $C_B$, $C_R$ or R, G, B components displayed as an oscillogram for the selected TV line (WAVEFORM)

TRS ERROR
RESERVED CODE ERROR (RCE)
VIDEO RANGE ERROR
CRC ERROR

(the last four parameters are displayed numerically or as a histogram)

C/L DELAY ERROR

(level and delay measurements on 75/0/100/0 or 100/0/100/0 colour bar to ITU-R BT.801 specifications)

## 1.4 MPEG2 Data Coding to ISO/IEC 13818-2

The ITU-R BT.601/656 and AES/EBU interfaces open the door to the digital TV house, whose first room accommodates MPEG2 data compression. Compression is aimed at reducing the video data rate of 270 Mbit/s of the ITU-R BT.601/656 interface to 2 to 6 Mbit/s without any visible degradation of picture quality. This applies analogously to the audio signal, whose data rate is reduced from 728 kbit/s to typically 192 kbit/s without any audible loss in sound quality. If several audio channels are to be transported in a program data stream, audio data rates from 64 kbit/s to 384 kbit/s are possible.

To reduce the video data rate, the ITU-R BT.601 picture is divided into blocks of 8 x 8 pixels. Each block consists of 64 pixels as shown in Fig. 1.3.

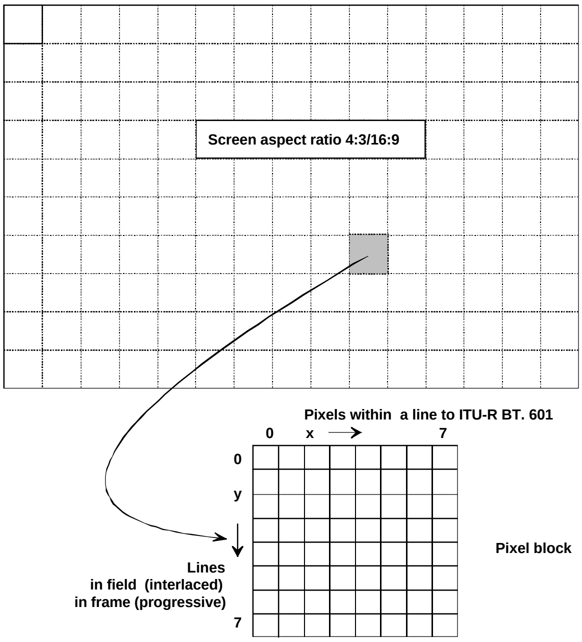



Fig. 1.3 Division of picture in 8 x 8 pixel blocks

The main elements of picture data reduction are:

**DCT** Discrete cosine transform with equation

$$G(f_x, f_y) = 0.25 * C(f_x) * C(f_y) * \sum_{x=0}^{7} \sum_{y=0}^{7} g(x,y) \cos((2x+1) f_x \frac{p}{16}) * \cos((2y+1) f_y \frac{p}{16})$$

$$C(f) = \begin{cases} 1/\sqrt{2} & \text{for } f = 0 \\ \text{and} & \\ 1 & \text{for } f > 0 \end{cases}$$

$f_x, f_y$ = frequency coordinates

$G(f_x, f_y)$ = DCT coefficient

x, y = pixel/frequency coordinates

g(x, y) = pixel values

With the above equation, 8 x 8 DCT coefficients in the frequency domain are obtained from the 8 x 8 pixel blocks in the time domain.

**Quantization** based on standard quantization tables for

intraframe-coded pictures (I pictures)

$\rightarrow$ x, $\downarrow$ y

$Q_I(x,y)$ =

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 8 | 16 | 19 | 22 | 26 | 27 | 29 | 34 |
| 16 | 16 | 22 | 24 | 27 | 29 | 34 | 37 |
| 19 | 22 | 26 | 27 | 29 | 34 | 34 | 38 |
| 22 | 22 | 26 | 27 | 29 | 34 | 37 | 40 |
| 22 | 26 | 27 | 29 | 32 | 35 | 40 | 48 |
| 26 | 27 | 29 | 32 | 35 | 40 | 48 | 58 |
| 26 | 27 | 29 | 34 | 38 | 46 | 56 | 69 |
| 27 | 29 | 35 | 38 | 46 | 56 | 69 | 83 |

and

forward predicted and bidirectional predicted pictures (P and B pictures), and for $C_B$ and $C_R$ components.

$\rightarrow$ x, $\downarrow$ y

$Q_{B,P}(x,y)$ =

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 |
| 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 |
| 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 |
| 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 |
| 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 |
| 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 |
| 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 |
| 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 |

**Zigzag scanning**

The quantized DCT coefficients, after conversion to integers F(x,y) by means of equation

$$F(x,y) = INT\left[\frac{G(f_x, f_y)}{Q_{I,P,B}(x,y)} + 0.5\right],$$

are scanned so that sequences with a very high number of zeros are obtained.

Here is a typical example:

F(x,y) =

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| DC | -17 | 0 | -1 | 0 | 0 | 0 | 0 |
| -17 | 5 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| -1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

The following coefficient sequences are obtained:

ZZ = (DC value
-17 -17 0 5 0 -1 0 0 -1 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0)

By means of variable length coding (VLC) and Huffman coding, the few DCT coefficients differing from zero and the typical, long zero sequences at the end of a zigzag row are reduced to transmit a minimum of information.

**Group of pictures (GOP) and prediction**

Further, suppression of redundant picture information is attained by means of forward predicted pictures (P pictures) and bidirectional predicted pictures (B pictures).

A GOP preferably consists of 12 pictures.
The first picture is intraframe-coded (I-coded). It removes all errors occurring at the end of the previous GOP as a result of lossy P and B coding. The I-coded picture is followed by forward predicted and bidirectional predicted (lossy) pictures (3 x P and 8 x B pictures). If and to what extent errors due to lossy coding become visible depends on the picture contents and the compression factor.

Possible types of picture coding in a GOP:

| | |
|---|---|
| I coding | picture information is derived solely from the current macroblock or picture; only DCT, quantization and VLC are used for data compression |
| P coding | is based on prediction with reference to the preceding field or frame, with motion compensation |
| B coding | is based on prediction with reference to the preceding and/or subsequent field or frame, with motion compensation |

Structure of a GOP with 12 pictures

Sequence: I-B-B-P-B-B-P-B-B-P-B-B
Duration: 12 x 40 = 480 ms
Typical data volume:
I picture 1000 kbit
P picture 300 kbit
B picture 100 kbit
Data rate of a coded program signal with good picture quality 5 Mbit/s to 6 Mbit/s
The data stream at the output of the video encoder is referred to as video elementary stream (video ES).

## 1.5 Audio Coding to ISO/IEC 13818-3 (ISO/MPEG 11172)

Not only the video data are compressed but also the accompanying audio data (mono, stereo, dual sound, as well as joint stereo for different audio channels). Masking effects obtained both as a function of time and frequency are utilized to compress data on the principle "Anything not audible is superfluous redundant information".

**Table 1.3 MPEG1 layer 1 coding**

| | |
|---|---|
| Splitting of audio bandwidth in | 32 subbands of equal width |
| Processing of blocks of | 12 samples |
| Sampling rates | 32 kHz, 44.1 kHz, 48 kHz |
| Duration of a block | 32 x 12 / 48000 = 8 ms<br>at typically 48 kHz sampling rate |
| Scale factor of a block | highest value of the 12 samples |
| Scale factor resolution | 6 bit |
| Resolution of samples | 2 bit to 15 bit (depending on permissible quantization noise) |

The 12 values of each block are divided by the scale factor and quantized taking into account the masking effects (MPEG1 layer 1). The masking threshold as a function of frequency is calculated using Fourier transform with 512 samples. Masking as a function of time always occurs with blocks of a length of 8 ms to 12 ms (depending on the sampling rate).

**Table 1.4 MPEG1 layer 2 coding**

| | |
|---|---|
| Splitting of audio bandwidth in | 32 subbands of equal width |
| Processing of blocks of | 36 samples |
| Sampling rates | 32 kHz, 44.1 kHz, 48 kHz |
| Duration of a block | 32 x 36 / 48000 = 24 ms<br>at typ. 48 kHz sampling rate |
| Scale factors | 2 to 3 per block and subband because of the short duration of masking as a function of time (premasking max. 20 ms) |
| Scale factor of a block | highest value of the 36 samples |
| Indicator for number of scale factors | 2 bit |
| Scale factor resolution | 6 bit |
| Resolution of samples | 2 bit to 15 bit (depending on permissible quantization noise) |
| Quantization in subbands 23 to 26 | 0 (cancellation), 3, 5, 65535 quantizing steps |
| Subbands 27 to 31 | suppressed because resulting frequency is > 20 kHz |

The 32 values of each block are divided by the scale factor and quantized taking into account the masking effects (MPEG1 layer 2). The masking threshold as a function of frequency is calculated using Fourier transform with 1024 samples. Masking as a function of time is not always effective with block duration > 20 ms.

## 1.6 Audio Coding to Dolby AC-3

Dolby AC-3 audio coding incorporates Dolby surround audio processing. With data compression typically higher than a factor of 13, the Dolby AC-3 surround system allows for up to 5 quasi-transparent audio channels plus one channel for very low frequencies (subwoofer). AC-3 coding, therefore, is the ideal method to guarantee high audio quality in the home cinema.
This is one of the reasons why AC-3 coding has already been included in the Australian DVB standard as an alternative audio channel. In Australia, all of the above coding types are possible: MPEG1 layer 1 and 2, and AC-3. Table 1.4 shows some typical AC-3 data:

**Table 1.5 Typical AC-3 data**

| | |
|---|---|
| Sampling rate | 32 kHz, 44.1 kHz, 48 kHz |
| Maximum sampling width | 24 bit |
| Bit rates | 19 different rates between<br>32 kbit/s and 640 kbit/s |
| Channel coding<br>without Dolby surround<br><br>with Dolby surround | 3 bit<br>dual-sound, mono, stereo, stereo with center channel<br>stereo,<br>stereo with center channel,<br>stereo with L/R surround,<br>stereo with L/R surround and center channel |
| Length of AC-3 frame | 1536 samples |
| Duration of AC-3 frame<br>32 kHz sampling rate<br>44.1 kHz sampling rate<br>48 kHz sampling rate | <br>48 ms<br>*34.83* ms<br>32 ms |

The data stream at the output of the audio encoder is referred to as audio elementary stream (audio ES).

## 1.7 Packetized Elementary Stream (PES)

The elementary data streams are packetized to produce packetized elementary streams (PES streams). Each packet of a PES is preceded by a header which begins with a packet start code (24 bits: 0000 0000 0000 0000 0000 0001) and carries the following information:

Contents of PES (stream ID) 8 bits

The many different PES contents are listed in a table in the ISO/IEC 13818-1 specifications, for example:
1110 xxxx refers to the xxxxth video data stream, or
1111 0000 identifies an ECM (entitlement control message) data stream

Length of PES 16 bits

Defines the number of bytes of a PES that follow these 16 bits.

In an optional field, the header contains further information announced by flags, for example:

Counter reading for synchronization of system PLL with 27 MHz clock signal 42 bits
The lowermost 9 bits count up to 300; the remaining 33 bits are clocked at 27 MHz/300 = 90 kHz (SCR - system clock reference; ESCR - elementary stream clock reference)

PTS and DTS time stamps 33 bits each
(PTS - presentation time stamp; DTS - decoding time stamp)
Define the time of output or decoding of TS data.

Data rate of ES 22 bits

The packetized video and audio elementary streams are coded. Since MPEG2 coding does not take into account the horizontal and vertical blanking intervals, no insertion test signals, teletext or data lines are transmitted in the coded MPEG2 data stream.
To compensate for this, the analog TV teletext and data line information can be inserted in the packetized data elementary streams. Generally, data of any kind can be transported in the data PES containers.

### 1.8 Transport Stream (TS)

The multiplexer splits the video, audio and data PES streams and the additional information, i.e. the PSI and SI tables (program specific information and service information), into packets of 184 bytes and adds a 4-byte header to each packet. This yields transport stream (TS) packets with a length of 188 bytes.

The TS header contains the following information:

Synchronization byte 0x47

TEI (transport error indicator) to indicate any TS packet data that cannot be fully corrected by the demodulator 1 bit

PID (packet identification number, packet ID) 13 bits
Flags announcing the optional adaptation field 2 bits

CC (continuity counter)
Counter reading for monitoring continuous packet transmission 4 bits

and other signalling bits.

The optional adaptation field of the header contains, besides many flags, the following information:

PCR (program clock reference)
Program-related counter reading, derived from STC (system time clock), for synchronization of system PLL 42 bits

or

OPCR (original program clock reference)
Original program-related counter reading 42 bits

This information in the optional adaptation field is likewise announced with a one-bit flag. If the flags are not valid, normal data can be transmitted instead of the PCR and the OPCR.

### 1.9 MPEG2 Multiplexer

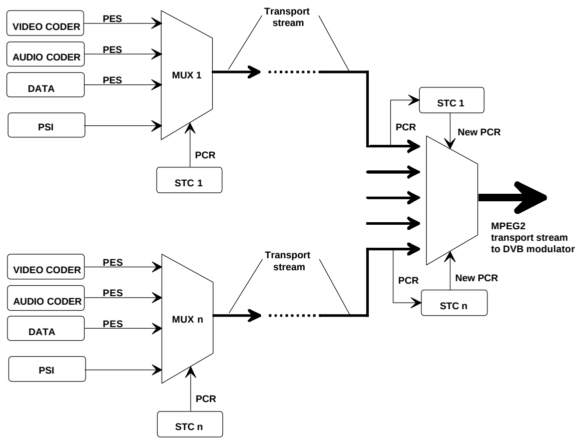



Fig. 1.4 MPEG2 multiplexer

A transport stream carrying one program has a data rate of about 4 Mbit/s to 7 (max.15) Mbit/s. This is made up of the following subrates:

| | |
|---|---|
| Video | 2 Mbit/s to 6 Mbit/s |
| Audio | 32 kbit/s to 384(+64) kbit/s |
| Data | as required |
| PSI/SI tables | up to 1 Mbit/s |
| and stuffing packets | |

The TS data rate varies according to the video and audio quality and the information entered in the tables.
At present, the following TS data rates are typically achieved for a DVB transmission channel:

| | |
|---|---|
| Cable | 38.153 Mbit/s (UHF) |
| Satellite | up to 38.015 Mbit/s for 27.5 Msymb/s |
| Terrestrial | 4.98 Mbit/s to 31.67 Mbit/s |

A transport stream can, therefore, carry between five programs of very high signal quality and ten programs of lesser signal quality via cable or satellite. For terrestrial transmission, this capacity is reduced to three to six programs. The actual data rate after program interleaving is normally always below the specified data rate for a given transmission medium to avoid data overflow. To use up the remaining data rate capacity, either TS stuffing packets with the PID 0x1FFF are inserted or "IP via DVB" packets for pure data transmission.
Program transmission efficiency can be boosted by means of **statistical multiplexing,** which balances the differences between the individual data rates of the programs transmitted in a transport stream. This means that programs requiring a low data rate at a given instant, for example because only frozen graphics are transmitted, make their extra capacity available to other programs requiring a high data rate. This method allows more programs of high picture quality to be packed into a transport stream.

## 1.10 Tables

(**PSI** Programme Specific Information,
**SI** Service Information)

The tables provide the demultiplexer of the DVB or ATSC receiver with all the necessary information regarding the transmission channel and the transport stream contents. Although the tables carry in part DVB- or ATSC-specific information, they still come under the MPEG2 standard as they are carried in MPEG2 transport stream packets.

### 1.10.1 PSI Tables to ISO/IEC 13818-1

**PAT** **Program Association Table**
(PID = 0x0000, table ID = 0x00):
List of all programs multiplexed in the transport stream, including reference to the PIDs (packet identifiers) of the PMTs of these programs.

**CAT** **Conditional Access Table**
(PID = 0x0001, table ID = 0x01):
Provides information on encrypted (scrambled) programs and their descrambling codes
(EMM: entitled management message and ECM: entitled control message).

**PMT** **Program Map Table**
(PID = 0x0020 to 0x1FFE, table ID = 0x02):
Includes reference to packets containing the PCR (program clock reference), contains a list of program providers, a PID list of the program elements (e.g. video, audio and data channels), copyright and other information.

**NIT** **Network Information Table**
(PID = 0x0010, table ID = 0x40):
Provides information on the physical transmission network, in the case of DVB-S for example the orbit position, transponder number, satellite frequency, etc.

**TSDT** **Transport Stream Description Table**
(PID = 0x0002, table ID = 0x03):
Describes the structure of programs and program elements, e.g. aspect ratio, picture frequency in transport stream.

### 1.10.2 SI Tables to ETS 300 468 for DVB

**BAT** **Bouquet Association Table**
(PID = 0x0011, table ID = 0x4A):
Contains information on a provider's bouquet of programs.

**EIT** **Event Information Table**
(PID = 0x0012, table ID = 0x4E and 0x50 to 05F):
"TV guide" containing data such as start time and end time of events.

**SDT** **Service Description Table**
(PID = 0x0011, table ID = 0x42):
Describes the programs offered as well as the program providers.

**RST** **Running Status Table**
(PID = 0x0013, table ID = 0x71):
Enables the fast and precise response to any changes to the scheduled program sequence, for example if an event is to start at a later time.

**TDT** **Time and Date Table**
(PID = 0x0014, table ID = 0x70):
Contains the UTC (universal time coordinated) time and date information as well as the reference time at longitude 0.

**TOT** **Time Offset Table**
(PID = 0x0014, table ID = 0x73):
Contains the UTC time and date information and the local time offset.

**ST** **Stuffing Table**
(PID = 0x0010 to 0x0014, table ID = 0x72)
Deletes or invalidates other SI tables.

If a program provider transmits not only one transport stream but occupies two DVB-C or DVB-T TV channels, for example, for the transmission of different transport streams, the first channel may carry information on the programs and services transmitted in the second channel and vice versa.

This is effected by adding tables carrying the extra designation "OTHER":

**NIT OTHER** **Network Information Table OTHER**
(PID = 0x0010, table ID = 0x41):
Provides information on the physical transmission network (in the case of DVB-S for example the orbit position, transponder number, satellite frequency, etc.) in the other channel occupied by a program provider.

**SDT OTHER** **Service Description Table OTHER**
(PID = 0x0011, table ID = 0x46):
Describes the programs and services offered in the other channel occupied by a program provider.

**EIT OTHER** **Event Information Table OTHER**
(PID = 0x0012, table ID = 0x4F and 0x60 to 0x6F):
"TV guide" containing data such as start time and end time of events in the other channel occupied by a program provider.

### 1.10.3 Special Tables

The following table was created to support the multimedia home platform (MHP):

**AIT** **Application Information Table**
(PID = 0x20 to 0x1FFE, same as PMT, table ID = 0x74):
Provides information for the DVB receiver to locate and identify data services in the transport stream and process them as required for a given application.

Two tables are provided for "partial" TSs. These include recorded TSs that contain only a subset of the original data stream or in which time shifts occur relative to the original data. The two tables replace the original SI tables. PSI tables for "partial" TSs are restricted to the PAT and the PMT.

**DIT** **Discontinuity Information Table**
(PID = 0x001E, table ID = 0x7E):
The DIT is inserted at points where time shifts occur in the TS.

**SIT** **Selection Information Table**
(PID = 0x001F, table ID = 0x7F):
Defines the TS as a "partial" TS coming from the digital interface of a TS storage device.

The DIT and the SIT may be used in partial TSs only; they must not be used in TSs to be broadcast.

**NST** **Network Status Table**
(PID = 0x001D, table ID = 0x0x14):
(see also 1.10.4, "Special TS Packets")
If, at a monitoring point of the transmission chain, signal elements such as video, audio or data elementary streams, or subtitles or SI tables are found to be missing, or other errors (errors to ETR 290, BER values) are detected, a table with PID 0x1D is generated and inserted into the TS at this point. In this way, the error status within the transmission network is signalled, including error location, time and description.

**RCT** **Remote Control Table**
(PID = 0x001D, table ID = 0x0x12):
(see also 1.10.4, "Special TS Packets")
From the point of signal distribution, this table controls switchover between local and national programs (and between program time and advertizing time) by announcing the switchover time.

### 1.10.4 Special TS Packets

Two transport stream PIDs were defined to cater for special applications. These PIDs are used, on the one hand, to establish a channel for test data transmission in the DVB system and, on the other hand, to distribute all information necessary for synchronization of a DVB-T single-frequency network.

The first TS packet with PID 0x1D is defined by the European Standard TR 101 291.

The second TS packet with PID 0x15 (referred to as megaframe initialization packet – MIP) is defined by TS 101 191.

The 0x1D packet carries the following information:

signal type (video, audio, data) to which the transmitted test data belong,

origin of data,

test signal used,

time of insertion of packet into TS to determine signal delays,

place of measurement, GPS-based (GPS – global positioning system),

program in which measurement was performed

and, last but not least:

test data.

The MIP with PID 0x15 carries the following information:

number of TS packets to be sent until start of next megaframe (2-byte pointer),

periodic or non-periodic transmission of pointer,

time, in 100 ns steps, due to elapse from last 1 pps (pulse per second) signal from GPS system until first bit of next megaframe (system time stamp – STS),

operating mode of DVB-T network (tps_mip), described by transmission parameter signalling (TPS) data.

### 1.10.5 Repetition Rates of Time Stamps and Tables in DVB

To ensure correct signal decoding by the set-top box (STB), the repetition rates of all tables inserted in the transport streams must be complied with.
ETR 290 and ISO/IEC 13818 recommend the following minimum and maximum intervals for the transmission of tables. The values are selected so as to avoid, on the one hand, long waiting times for the key data describing the contents of the incoming TS after switch-on of the STB. On the other hand, undue loss of data rate capacity resulting from high table repetition rates is to be avoided.

| Parameter | Minimum interval (ms) | Maximum interval (s) |
| --- | --- | --- |
| PAT | 25/25 | 0.5/0.5 |
| CAT | 25/25 | 0.5/0.5 |
| PMT | 25/25 | 0.5/0.5 |
| NIT | 25/25 | 10/10 |
| SDT | 25/25 | 2/2 |
| BAT | 25/25 | 10/10 |
| EIT | 25/25 | 2/2 |
| RST | 25/25 | ---/--- |
| TDT | 25/25 | 30/30 |
| TOT | 25/25 | 30/30 |
| | | |
| PCR | 0/0 | 0.04/0.10 |
| PTS | --- | 0.7/0.7 |

First value: recommended by DVB ETR 290

Second value: recommended by ISO/IEC 13818

Table 1.6

### 1.10.6 SI Tables for ATSC

The PSI tables meet the ISO/IEC 13 818-1 specifications also for the ATSC standard. Instead of the SI tables of the DVB standard, PSIP (program and system information protocol) tables are used in ATSC:

**MGT** **Master Guide Table**
(PID = 0x1FFB, table ID = 0xC7): Contains the version number, length in bytes and PIDs of all PSIP tables except for the system time table (STT), which is independent of the other tables.

**TVCT** **Terrestrial Virtual Channel Table**
(PID = 0x1FFB, table ID = 0xC8): "Private table" according to the protocol; describes all programs contained in the transport stream transmitted in the terrestrial virtual channel (TVC).

**CVTC** **Cable Virtual Channel Table**
(PID = 0x1FFB, table ID = 0xC9): "Private table" according to the protocol; describes all programs contained in the transport stream transmitted in the cable virtual channel (CVC).

**RRT** **Rating Region Table**
(protection of children and young people)
(PID = 0x1FFB, table ID = 0xCA): List of qualifications relating to the suitability of events for young viewers. This information is included in the MGT for all events. The RRT is valid for precisely defined regions (e.g. the whole of the USA or individual States).

**EIT-n** **Event Information Table**
(PID = 0x1FFB, table ID = 0xCB): EIT-0 to EIT-n (n is defined up to 127) describe the sequence of programs in a TS in a three-hour raster from 00:00 h to 24:00 h (universal time code – UTC), so providing an electronic TV guide.

**ETT** **Extended Text Table**
(PID = 0x1FFB, table ID = 0xCC): Each EIT-n is assigned an ETT, which gives a detailed description of each event.

**STT** **System Time Table**
(PID = 0x1FFB, table ID = 0xCD): Contains the current UTC time and date.

There are two optional tables:

**DCCT** **Directed Channel Change Table**
(PID = 0x1FFB, table ID = 0xD3)

**DCCSCT** **DCC Selection Code Table**
(PID = 0x1FFB, table ID = 0xD4)

The two tables support automatic channel switching if the viewer has signalled his interest in specific types of events from categorized services such as cinema, sports, age group, etc.

### 1.10.7 Repetition Rates of PSIP Tables in ATSC

Table 1.7 lists the repetition rates of PSIP tables as recommended by ATSC A/65.

| PSIP table | Maximum interval (ms) |
|---|---|
| STT | 1 000 |
| MGT | 150 |
| VCT (virtual channel tables) | 400 |
| RRT | 60 000 |
| EIT-0 | 500 |

Table 1.7 Repetition rates of PSIP tables

VCT in this table is meant to comprise the two tables for terrestrial (TVCT) and cable (CVCT) transmission. The ETT is coupled to the EIT and should therefore have the same repetition rate as the EIT.

## 1.11 Test Equipment for MPEG2 Protocol

### 1.11.1 MPEG2 Measurement Generator DVG

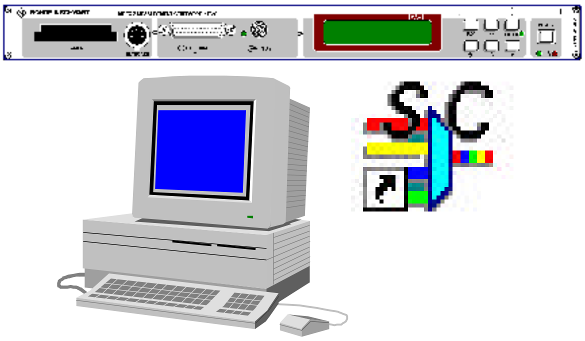
A transport stream generator is needed to simulate MPEG2-coded video, audio and data signals and tables and to ensure reproducible measurements. The generator should be able to produce the transport streams proposed by international standards, including moving picture sequences such as flower garden 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.

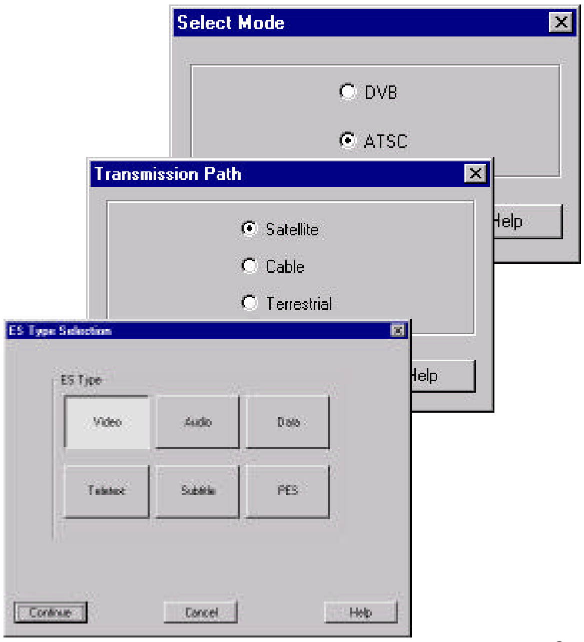



Fig. 1.5 Mode selection with Stream Combiner®

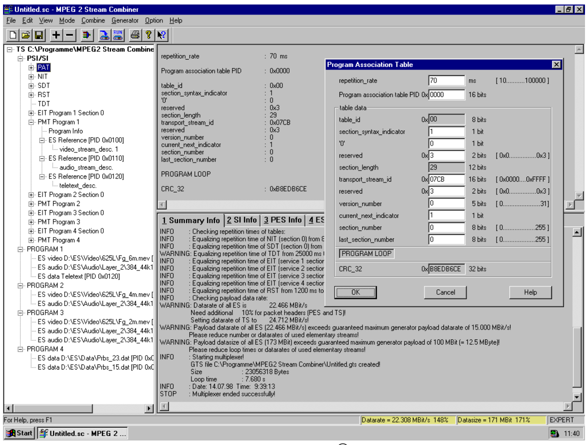
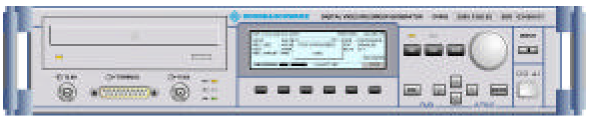


Fig. 1.6 Stream Combiner®: transport stream structure

### 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)<br>or<br>1x SPI, 1x ASI, 1x SMPTE 310 (ATSC)<br><br>TS to ISO/IEC 13 818-1<br><br>SDI data stream to<br>ITU-R BT.601/656 or<br>SMPTE 259M |
| Signal outputs | 1x SPI, 3x ASI to EN 50083 (DVB)<br>or<br>1x SPI, 2x ASI, 1x SMPTE 310 (ATSC)<br><br>SDI data stream to<br>ITU-R BT.601/656 or<br>SMPTE 259M |
| Length of<br>TS packets<br>DVB<br>ATSC | <br><br>188/204 bytes<br>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<br>RS232C |

#### 1.11.3.1 Triggered TS Recording

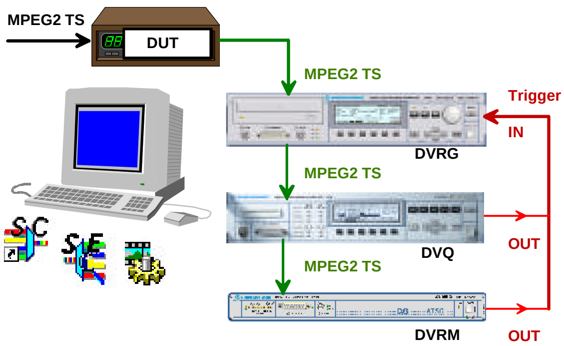



Fig. 1.7 Triggered TS recording

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.

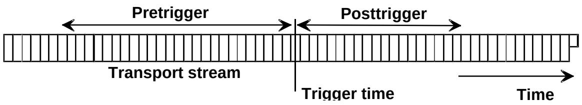



Fig. 1.8: The length of the pretrigger and posttrigger parts of a transport stream can be defined for a triggered recording with DVRG.

#### 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.

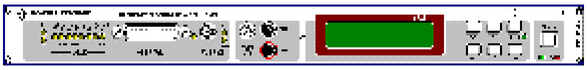
| First priority (necessary for decodability) | |
|---|---|
| Parameter | Error description |
| TS SYNC LOSS | The TS packet structure is not adhered to<br>or<br>no TS is present. |
| SYNC BYTE ERROR | The sync byte is not equal to 0x47. |
| PAT ERROR | Tables with table ID 0x00 and PID 0x00 do not occur at least every 0.5 s.<br>The scrambling control bits are not 00. |
| CONTINUITY COUNT ERROR | Incorrect TS packet order.<br>A packet occurs more than twice.<br>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.<br>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.<br>(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.<br>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.<br>No section with table ID 0x40 (NIT, actual TS) is found on a table with PID 0x10 for more than 10 s.<br>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.<br>No section with table ID 0x42 (SDT, actual TS) is found on a table with PID 0x11 for more than 2 s.<br>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.<br>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.<br>Sections with table IDs other than 0x4E to 0x6F or 0x72 are found on tables with PID 0x12.<br>Two sections with table ID 0x4E (EIT-P/F, actual TS) occur on PID 0x12 within a selectable interval (≤25 ms).<br>(EIT-P: present EIT<br>EIT-F: following EIT) |
| RST ERROR | Sections with table IDs other than 0x71 or 0x72 are found on tables with PID 0x13 (RST).<br>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.<br>Sections with table IDs other than 0x70, 0x72 (ST) or 0x73 (TOT) are found on PID 0x14.<br>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).<br>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<br>2x ASI |
| ATSC | 1x SPI<br>1x ASI<br>1x SMPTE 310 |
| Measurements | parameters to ETR290 (adjusted for ATSC),<br>TS protocol,<br>data rates of<br>overall TS,<br>programs and<br>substreams (PID),<br>monitoring of<br>TS_ID<br>"other" tables" (DVB),<br>paradigma condition (ATSC only),<br>trigger on error |
| Decoder outputs | |
| Video | 2x CCVS, 1x Y/C<br>1x ITU 601 |
| Audio | 1x AES/EBU<br>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.

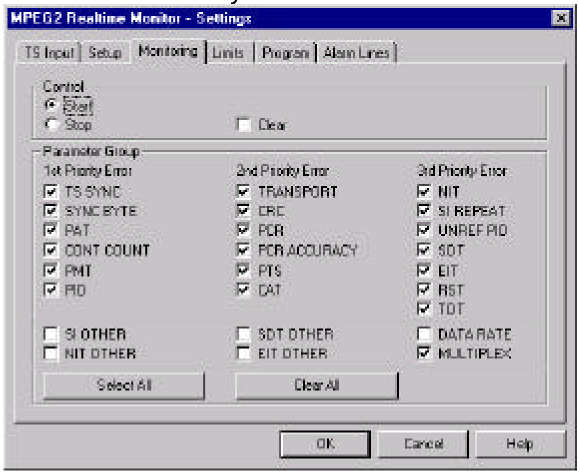



Fig. 1.9 MPEG2 REALTIME MONITOR:
Selection of parameters to be monitored

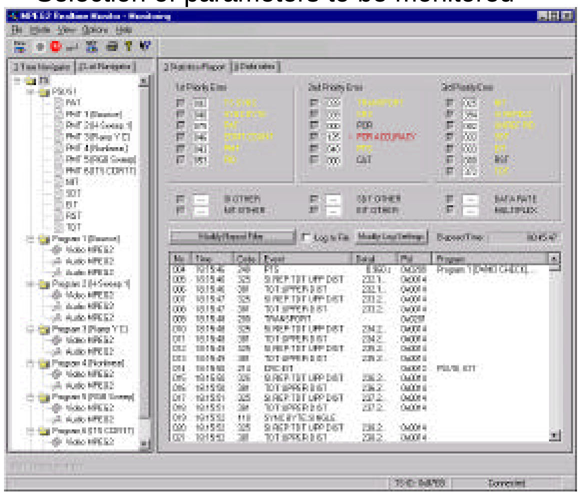


Fig. 1.10 MPEG2 REALTIME MONITOR:
Tree navigator, statistics and report

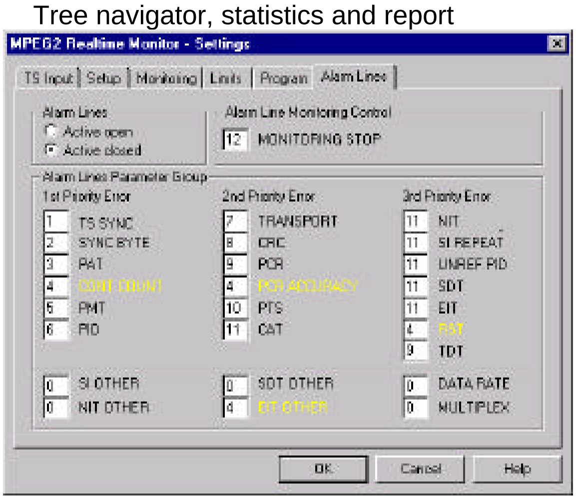
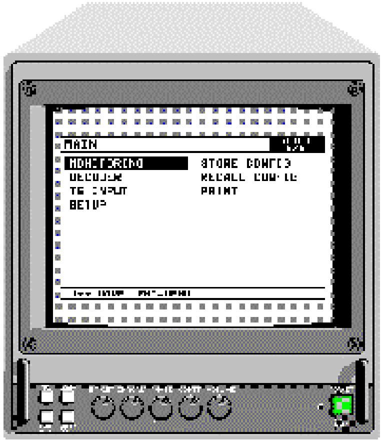


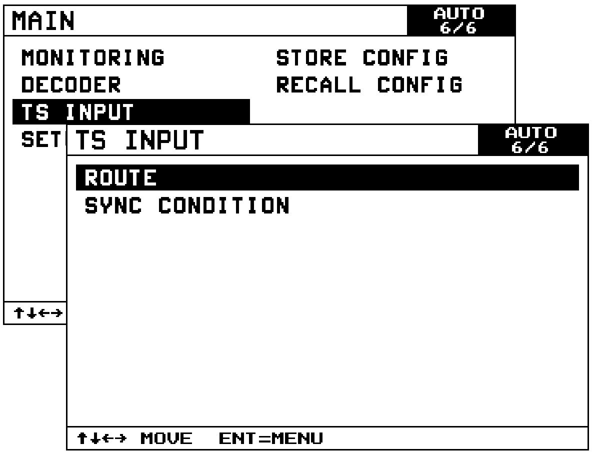

Fig. 1.11 MPEG2 REALTIME MONITOR:
Setting of alarm lines

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

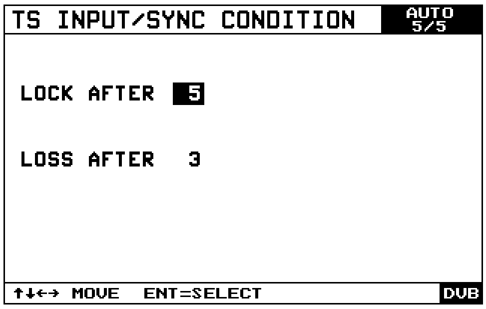
A very helpful feature is on-screen display (OSD) of the DVMD settings and results on a large monitor.



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

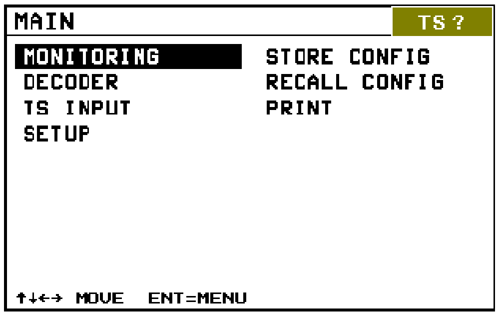



Three inputs can be selected under ROUTE:
ASI on front or rear panel and
SPI on front panel



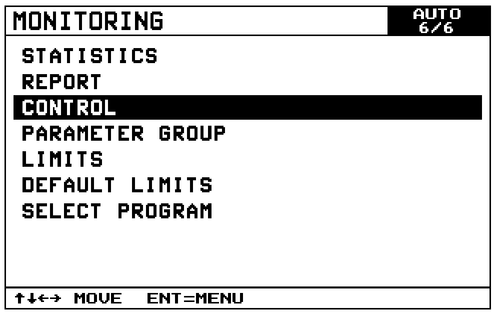

Synchronization conditions are freely selectable. The above figure shows the recommended setting.

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.

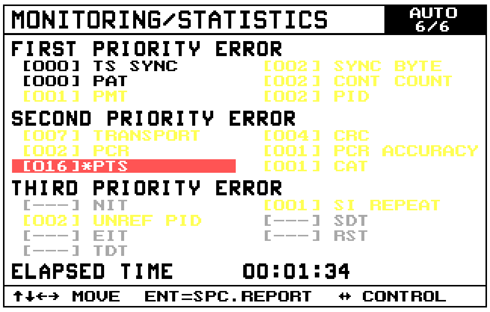

The TS status is queried also on the small OSD.



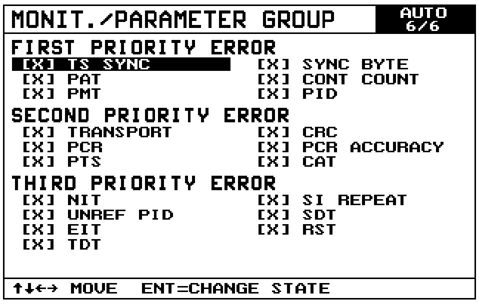

MONITORING produces an overview of available displays and settings.

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

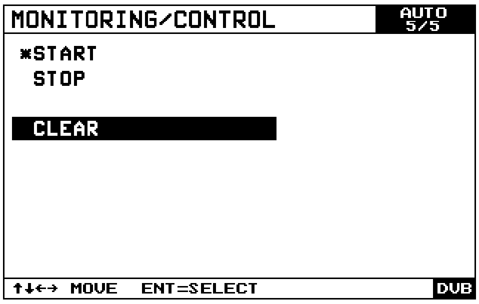
| | |
|---|---|
| white | no error found during the monitoring period (shown in black in this example) |
| yellow | error persisting longer than 1 s |
| magenta | current error |
| grey | parameter not monitored |



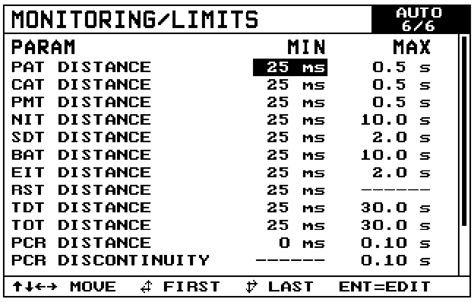

Under PARAMETER GROUP, the parameters to be monitored can be selected.



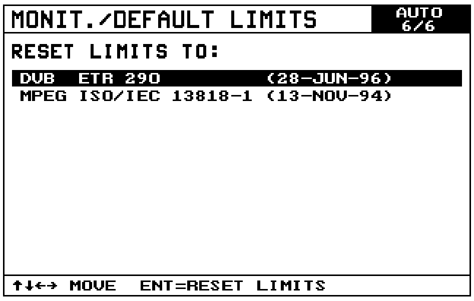

Under CONTROL, the error counts can be reset prior to a restart of STATISTICS or REPORT.



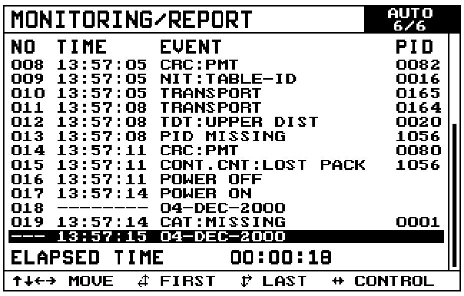

Moreover, compliance with tolerance limits for time intervals and repetition rates has to be checked.



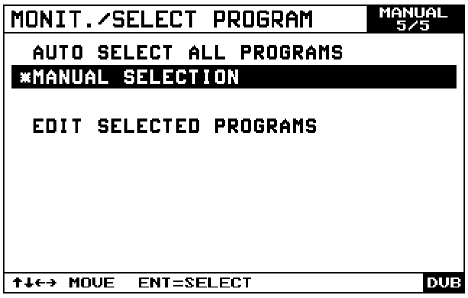

Tolerance limits can be user-selected separately for each parameter or set as recommended by standards (see also Table 1.6)



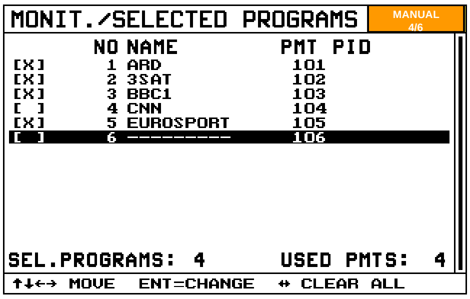

The REPORT gives detailed information about all events and errors that have occurred during the monitoring period. The list may contain up to 1000 entries describing the type of event or error, the PID under which the event or error occurred, as well as the date and time. It is a complete and objective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



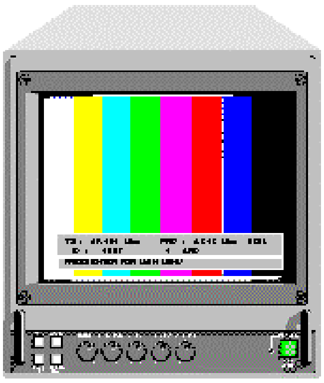
If only some programs are of interest, these can be selected for monitoring.




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).

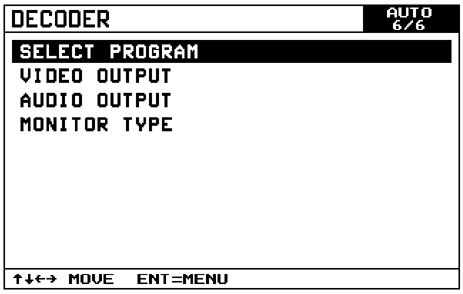



The small OSD displays the key data of the TS to be decoded.

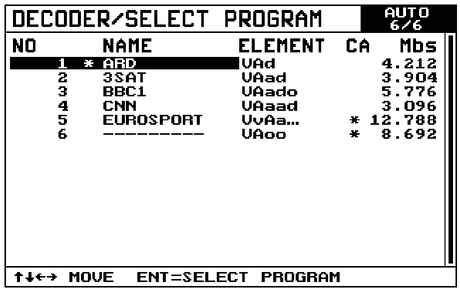


So far, the settings and measurements under the MONITORING main menu have been discussed. The PSI and SI tables were checked for conformance with standards with respect to the parameters listed in Table 1.8. Now the MPEG2 protocol is to be analyzed also in terms of the signal contents of the programs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

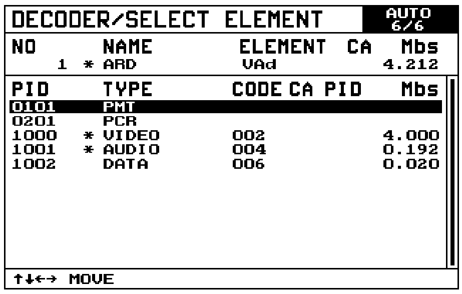
To this effect, the DECODER menu is opened from the MAIN menu.



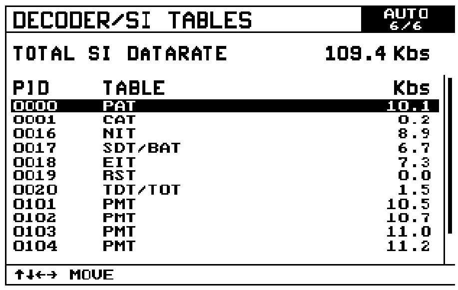

SELECT PROGRAM displays the already interpreted PAT as well as the PMTs of the transport stream.



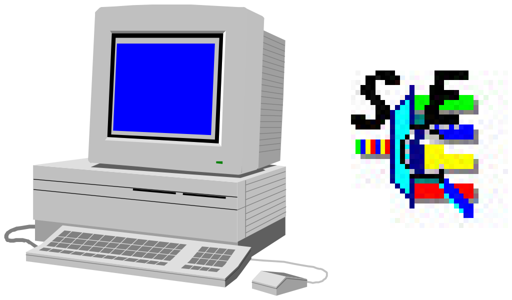

After selecting an item in the ELEMENT column and pressing ENTER, the PMT of the associated program comes up. Not only the PIDs of the program elements are listed but also, very importantly, the data rates measured in realtime.

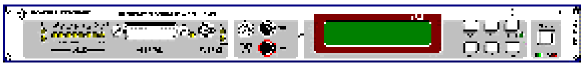



The data rates of the PSI and the SI tables, too, are measured in realtime.



### 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.

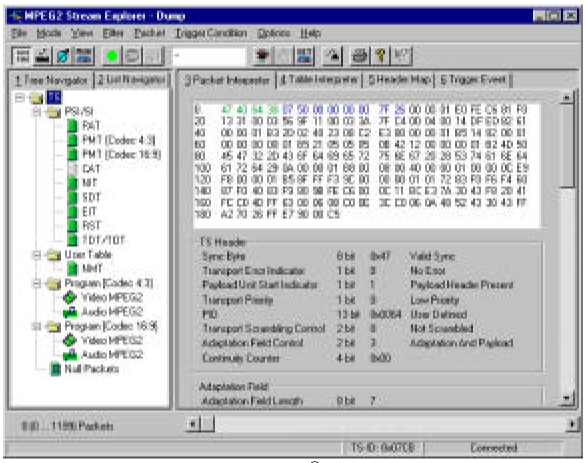


Fig. 1.12 Stream Explorer®: Plain-text representation of TS header information in dump mode

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

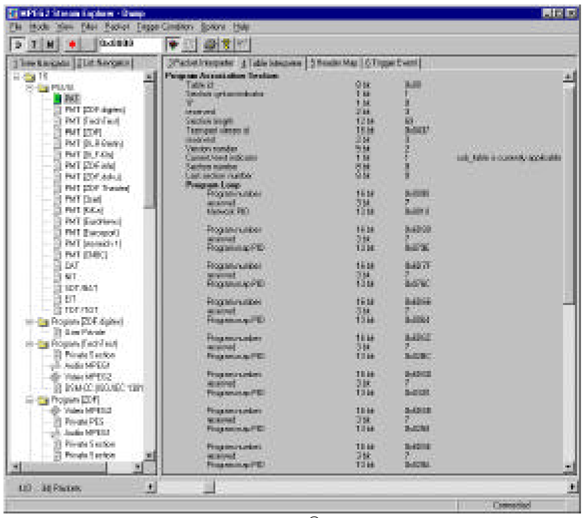


Fig. 1.13 Stream Explorer® with table interpreter

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.

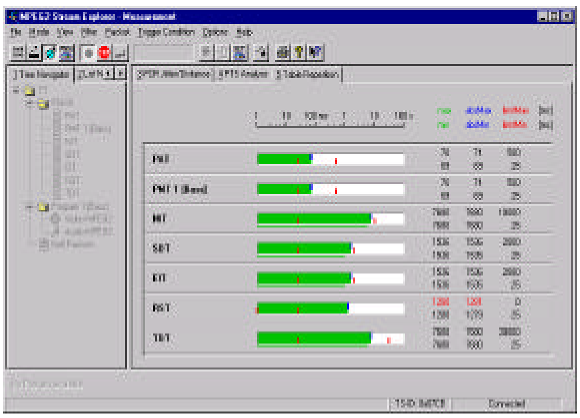


Fig. 1.14 Stream Explorer® measurement mode: Repetition rates of tables



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BROADCASTING DIVISION

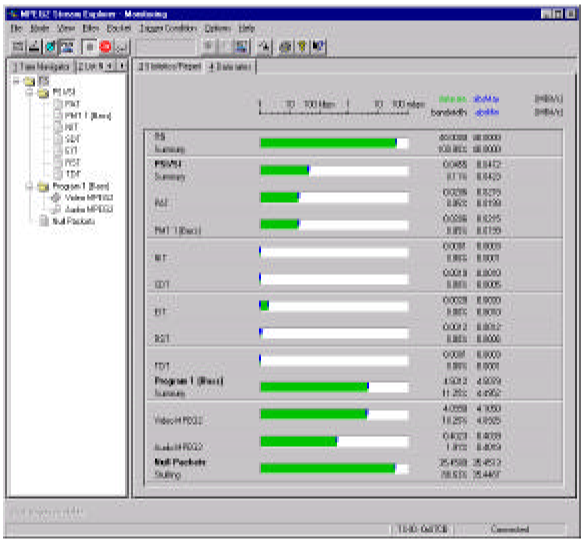


Fig. 1.15 Stream Explorer® measurement mode: Data rates of substreams

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).

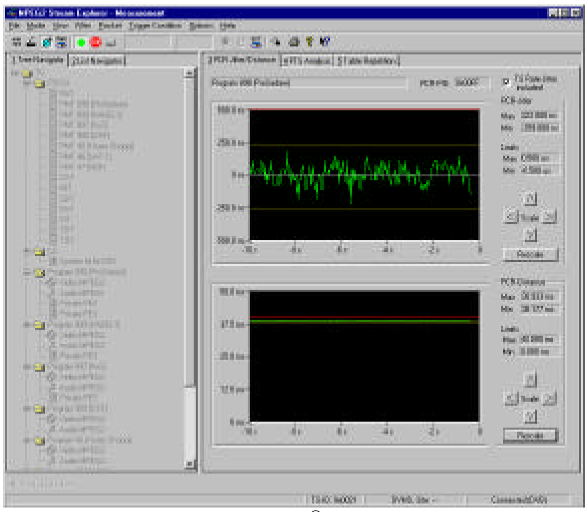


Fig. 1.16 Stream Explorer® measurement mode: PCR monitoring

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:

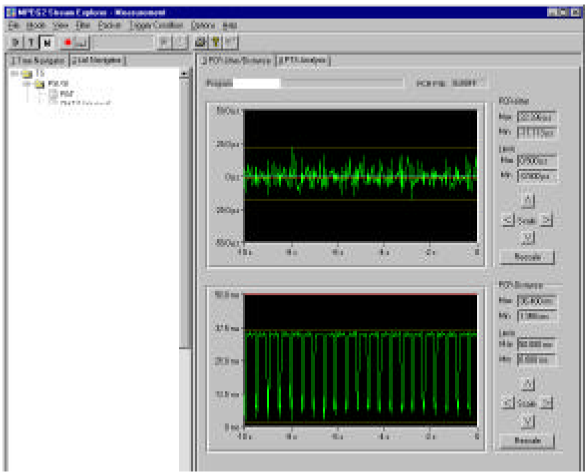


Fig. 1.17 Stream Explorer® measurement mode: PCR monitoring

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.

## 1.12 Video Quality Analysis

Any programs broadcast must meet defined video quality standards when they leave the studio. These standards are specified by the program providers to ensure a minimum acceptable video quality for the programs received by TV viewers at home. Therefore, in addition to MPEG2 protocol analysis with DVMD MPEG2 MEASUREMENT DECODER or DVRM MPEG2 REALTIME MONITOR, the quality of MPEG2 coding is to be measured at the studio output.

ITU-R BT.500 describes two methods of subjective video quality assessment.
The first method is based on the direct comparison with a reference picture to determine the quality of a processed picture with high accuracy. This method is known as DSCQS (double stimulus continuous quality scale). It supplies very accurate results in the off-line mode but cannot be employed during the active (running) program.
The second method determines video quality directly from the processed picture during the active program. A reference picture is not needed. This method is referred to as SSCQE (single stimulus continuous quality evaluation). It is optimal for quality monitoring, for example at the studio output, where only the MPEG2-coded, packetized picture is available, but no reference picture.

ITU-R BT.500 has defined a five-level rating scale for the video quality:
excellent, good, fair, poor and bad.
The five quality levels are also displayed on a numerical scale ranging from 100 to 0.

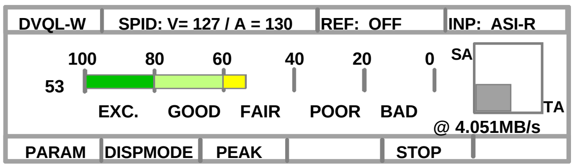



Fig. 1.18 Quality rating scale to ITU-R BT.500

A method has therefore to be found that simulates, based on the decoded MPEG2 data, the subjective perception of an average human eye and the processing of information conveyed by the optic nerve to the brain. This is done by means of a weighting equation, from which the objective picture quality is calculated.

Important parameters of this equation are, for example:

TA temporal activity and
SA spatial activity

TA describes the instantaneous motion (i.e. the variation of the picture contents versus time) of a decoded picture, whereas SA reflects the structural complexity of the picture. Both parameters have an impact on picture quality after MPEG2 coding.

The perception of information by an average human eye and the processing of this information in the brain are such that coding errors occurring during fast movements (i.e. with high TA) are usually masked. While with widely splashing water, for example, where picture contents are very close to white noise (high SA), a high degree of blocking effects will be measured objectively, the weighted picture quality will still be adequate. However, if TA is so high that practically no correlation can be established from frame to frame in MPEG2 coding (frame-to-frame coding being the common method used), picture quality at those instants will be low. An example of this is shown in Fig. 1.20.

DIGITAL VIDEO QUALITY ANALYZER DVQ uses a patented method of video quality assessment. This is based on objectively measurable MPEG2 artefacts obtained after coding and decoding. It can be demonstrated that the amplitude differences between neighbouring pixels located within a pixel block remain within narrow tolerance limits and are smaller than the amplitude differences between neighbouring pixels extending across pixel block or macroblock boundaries.

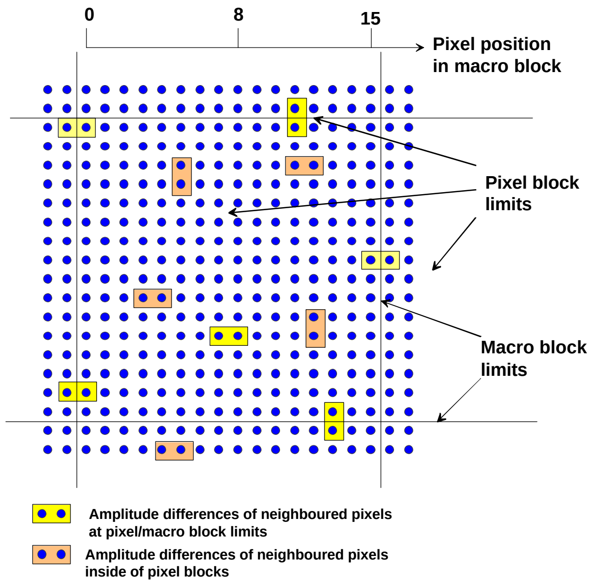



Fig. 1.19 Amplitude difference between neighbouring pixels

The above effect results from the quantization of the DC coefficients during MPEG2 coding. Substantial amplitude differences at the block boundaries make themselves felt as "blocking", which strongly affects picture quality.

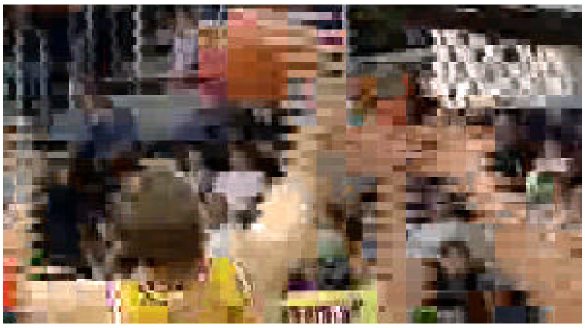
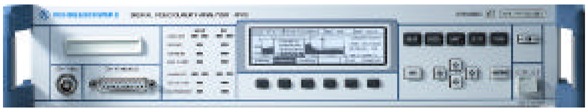


Fig. 1.20 Strong blocking effects

Such poor coding results are reliably detected with DIGITAL VIDEO QUALITY ANALYZER DVQ. The analyzer outputs an alarm if video quality falls below specified tolerance limits, so guaranteeing at any time a minimum acceptable picture quality for the programs received by TV viewers.



Condensed data
DIGITAL VIDEO QUALITY ANALYZER DVQ

| | |
|---|---|
| Signal inputs | ASI<br>SPI<br>ITU-R BT.601 and<br>AES/EBU |
| Coding formats<br>Video | <br>MPEG2 MP@ML,<br>MPEG2 4:2:2P@ML |
| Audio | MPEG1 layers 1 and 2<br>Dolby® AC-3 |
| Events recorded<br>in REPORT<br>(and signalled by LEDs) | picture loss,<br>picture freeze,<br>quality below threshold,<br>sound loss left,<br>sound loss right |
| Measurements | temporal activity (TA),<br>spatial activity (SA),<br>unweighted video quality,<br>weighted video quality |
| Alarm outputs | 12 floating relay contacts |
| Decoder outputs<br>Video | <br>1x CCVS,<br>1x ITU-R BT.601 |
| Audio | 2x analog audio R/L,<br>1x AES/EBU |
| Interfaces | RS232C,<br>Ethernet 10baseT |

### 1.12.1 Measurements with DVQ and DVQM

The SCAN function of DIGITAL VIDEO QUALITY ANALYZER DVQ allows the consecutive quality analysis of all programs contained in a TS. This method is suitable as long as only two or three programs are to be monitored. With a measurement time of only 10 s per program, a test cycle will be completed after about 20 s. However, if a larger number of programs is to be analyzed, a test cycle may well take up to two minutes, which is not acceptable for monitoring purposes. For such applications, parallel monitoring of all programs of a TS is mandatory.

*To refresh you memory: Data rates in the 8 MHz UHF DVCB-C channel and the 33 (36) MHz DVB-S transponder are about 38 Mbit/s, which corresponds to seven to ten programs in a transport stream.*

The solution to this problem is MULTICHANNEL QUALITY ANALYZER DVQM, which allows the simultaneous monitoring of up to 12 programs of a transport stream. DVQM accommodates up to 12 DVQ measurement boards in a 19" rack. If a TS contains encrypted (scrambled) programs, these can be decrypted and analyzed by means of the descrambling options. With these options fitted, the number of encrypted programs that can be monitored with DVQM is reduced to six (see also condensed data of DVQM).

DVQM provides straightforward status indication for all of the 12 programs monitored by means of an LED field on the front panel.
The DTV NetView software supplied as standard enables remote query of all quality parameters (DVQL as an option).

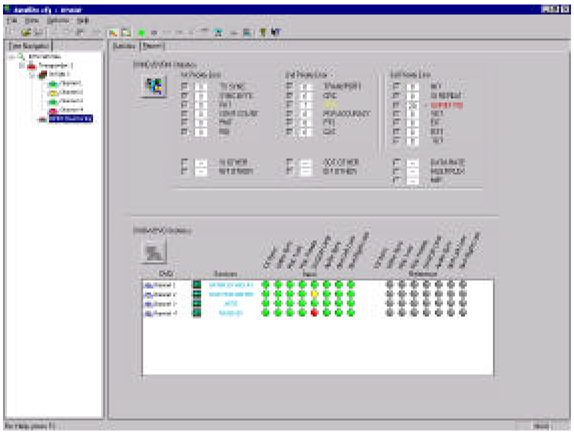


Fig. 1.21 DTV NetView menu for parallel channel monitoring

Moreover, the QUALITY MONITOR software is available on the Rohde & Schwarz homepage. This software, which can be used with DVQ and DVQM, allows long-term monitoring of the following parameters:

| | |
|---|---|
| DVQL-W | digital video quality level weighted (optional with DVQM) |
| TA | temporal activity |
| SA | spatial activity |
| Bit rate | |

This function can be performed on all programs, irrespective of whether the transport stream is coded with constant bit rate (CBR) or variable bit rate (VBR) in the statistical multiplex.

QUALITY MONITOR with CBR-coded TS

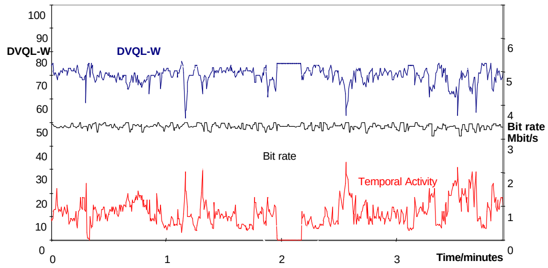



Fig. 1.22 Long-term monitoring of CBR-coded TS with QUALITY MONITOR

There is an obvious relationship between short-term TA peaks and short-term low video quality, as occurs in abrupt changes of scene. Another remarkable point is at TA = 0 (at 2 min), where maximum video quality is obtained with constant, specified data rate.

QUALITY MONITOR with VBR-coded TS

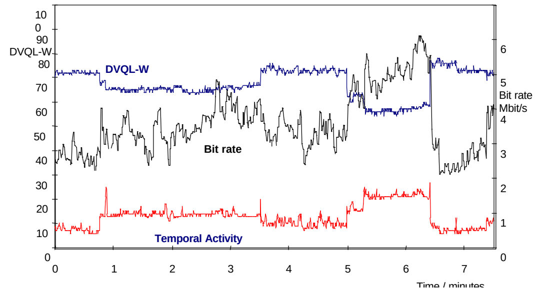



Fig. 1.23 Long-term monitoring of VBR-coded TS (statistical multiplex) with QUALITY MONITOR

With low TA, video quality is high. As TA increases, video quality decreases (see intervals from 40 s to 3 min 30 s and 5 min to 6 min 30 s). In the above example it is attempted to improve video quality by using higher data rates in the statistical multiplex, which however fails.

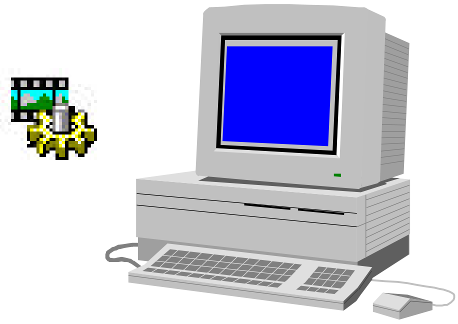
The data rate is changed in this process from approx. 2 Mbit/s to approx. 6 Mbit/s.

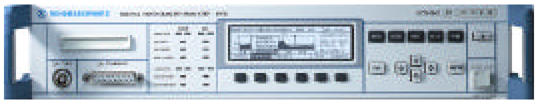

MULTICHANNEL QUALITY ANALYZER DVQM

Condensed data
MULTICHANNEL QUALITY ANALYZER DVQM

| | |
|---|---|
| Signal inputs,<br>signal outputs<br>coding formats,<br>etc | same as DVQ |
| Measurements | same as DVQ,<br>optionally:<br>weighted video quality |
| Signal processing | DVB and ATSC standard |
| Descrambler system<br>(optional) | Conax, NagraVision or<br>Viaccess,<br>Irdeto,<br>Mediaguard |
| Decoder outputs<br>Video<br><br>Audio | <br>1x CCVS<br>1x ITU-R BT.601,<br>2x analog audio R/L<br>1x AES/EBU |
| Interfaces | RS232C<br>Ethernet 10baseT<br>SNMP |

### 1.12.2 QUALITY EXPLORER® DVQ-B1





The QUALITY MONITOR software, which is available on the Rohde & Schwarz homepage, monitors video quality after MPEG2 coding as well as the data rate, the rate of change of the picture contents (temporal activity, TA), and the structural complexity of the picture (spatial activity, SA). To analyze the structure of sequences, GOPs and macroblocks, and to check header assignment for these picture elements, QUALITY EXPLORER® DVQ-B1 with ELEMENTARY STREAM ANALYZER ESA is available.

DVQ stores a selectable number of TS packets, e.g. 4000. These packets are transferred to a PC via the RS232C or the Ethernet interface for evaluation. In the following example, somewhat more than three sequences (GOPs) with a length of 12 pictures are obtained for 4000 TS packets.

In the following, the headers of sequences, GOPs and I, P and B pictures can be called from the "Diver" transport stream stored in DVG or DVRG.

The first figure shows the interpreted header of a sequence.

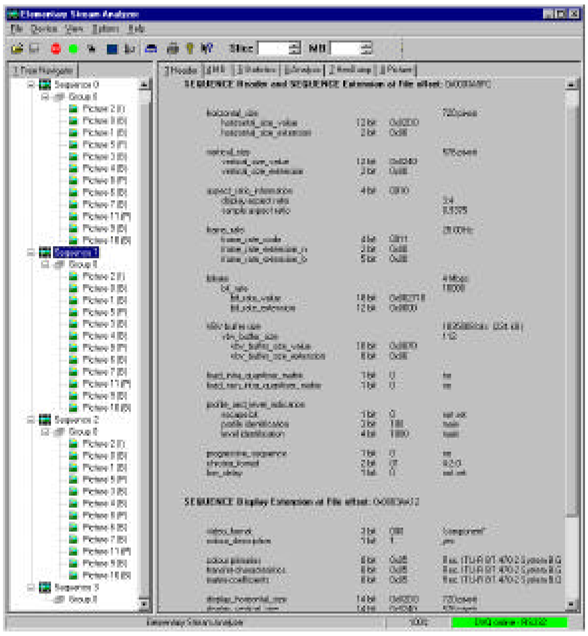


Fig. 1.24 Sequence header

The second figure shows the interpreted header of a GOP (group of pictures).

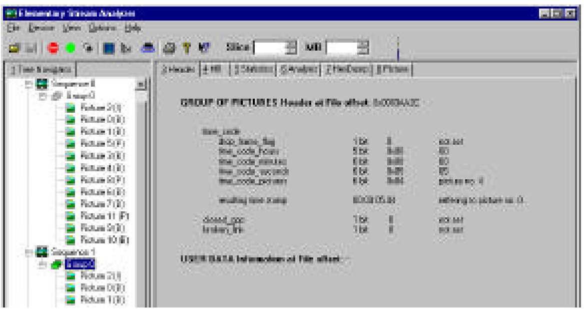


Fig. 1.25 GOP header

The third figure shows the interpreted header of an intraframe-coded picture.

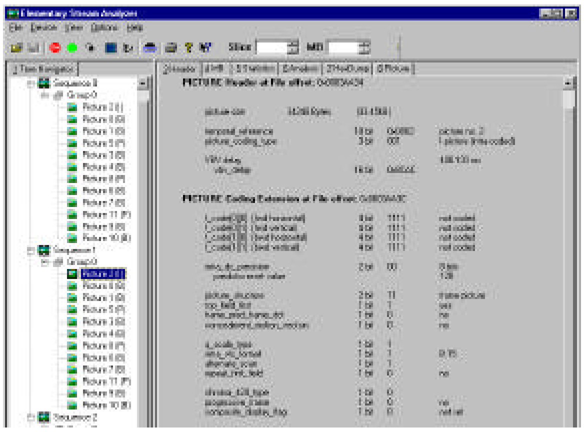


Fig. 1.26 Header of an intraframe-coded picture

Another display shows the tree structure of the GOPs and pictures of a TS as well as a selected picture analyzed according to macroblock types of the "Flower garden" test TS.

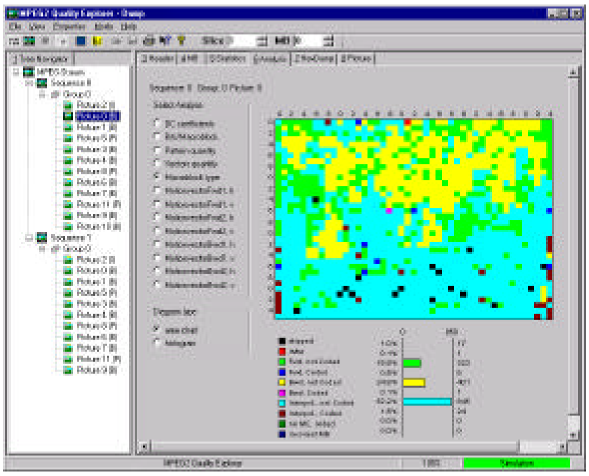


Fig. 1.27 Tree structure of GOP and analysis of B picture according to macroblock types
(GOP: group of pictures,
B picture: bidirectional predicted picture)

In the above figure it can be seen that not all macroblocks of the B picture bidirectionally coded. P and I coded macroblocks exist too. Some macroblocks are skipped because the information they carry has been transmitted before or can be obtained by way of calculation.

Not only the macroblock type is of interest but also the distribution of the numerical DCT coefficients in a macroblock.
In addition to other important information regarding macroblock structure, the DCT coefficients can be displayed in various modes:

| | |
|---|---|
| QFS (n) | Display of DCT coefficients after zigzag scanning |
| QF (v)(u) | Display of DCT coefficients before zigzag scanning |
| F (v)(u) | Display of DCT coefficients after quantization and before zigzag scanning |

The decoded pixel values of a pixel block can be displayed too:

f (y)(x)  Spatial representation of pixels

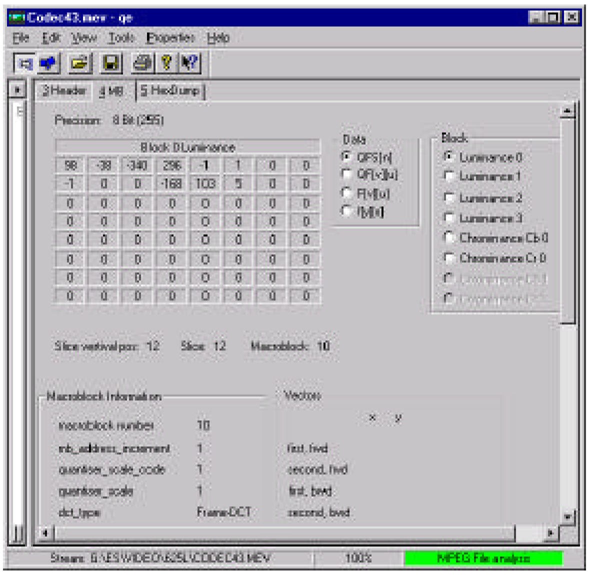



Fig. 1.28 Macroblock analysis

Further important information on video quality is obtained from the distribution of the DC coefficients of the macroblocks in intraframe-coded pictures (I pictures), for example in the "CODEC 4:3" test TS.

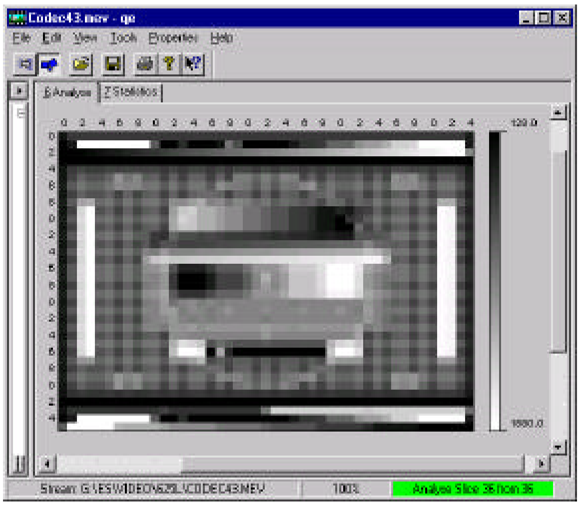



Fig. 1.29 Distribution of DC coefficients in I picture

Another important criterion for video quality assessment are the different macroblock types encountered in forward predicted (P) pictures and bidirectional predicted (B) pictures.

The prevailing type (yellow, backwards, not coded) cannot be used in the lower part of the picture (as can be seen in the example in Fig. 1.27) because there exists no correlation between consecutive pictures (brown, interpolated, coded).

In this picture area of the "DVTS" MPEG2 test TS stored in DVG/DVRG there is white noise.

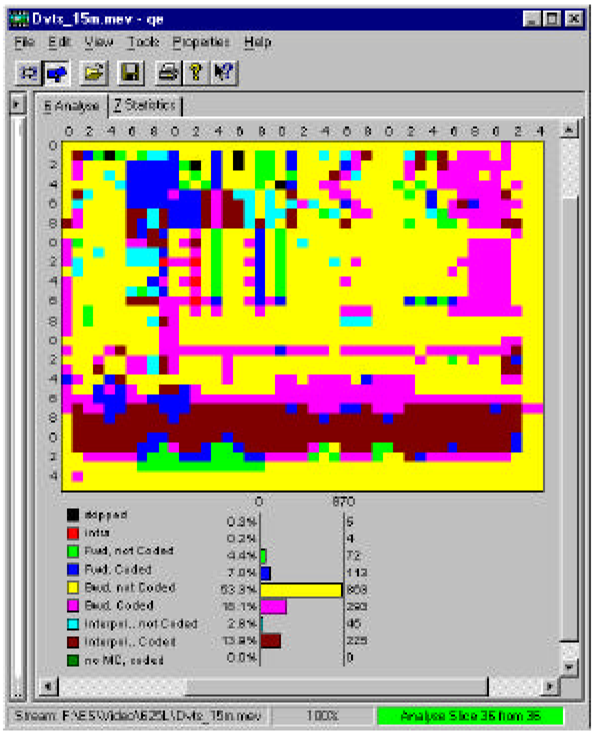



Fig. 1.30 Macroblock types in B pictures

The "HexDump" function provides information on the data volume carried in a macroblock. Fig. 1.31 shows the contents of the header of the first P picture of sequence 1 as well as the contents of macroblock 35 of slice 4.

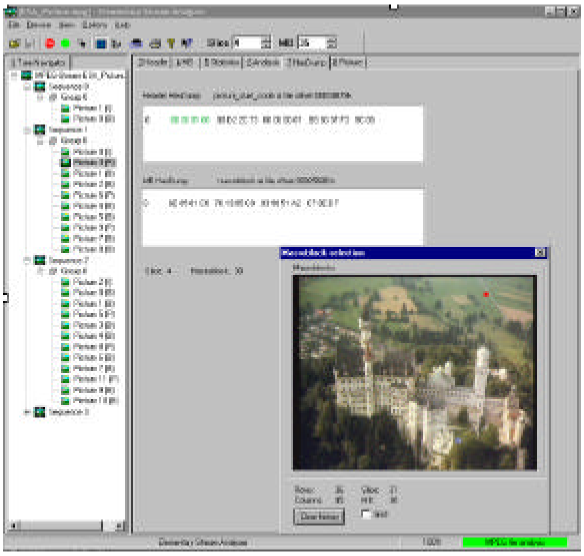


Fig. 1.31 Data within macroblock marked red shown as hex dump

QUALITY EXPLORER® DVQ-B1 enables detailed protocol analysis of all elementary streams as well as analysis of the picture contents at macroblock level, including the evaluation of DCT coefficients, and additionally furnishes a representation of the decoded pixel blocks. It is ideal for checking MPEG2 encoder functionality.

In the "Picture" mode, Elementary Stream Analyzer ESA displays a selected decoded picture of a stored sequence. This display allows the most accurate analysis of errors occurring in MPEG2 coding and subsequent decoding, for example of pronounced blocking effects in the central area of a picture of the "Squirrel" sequence.

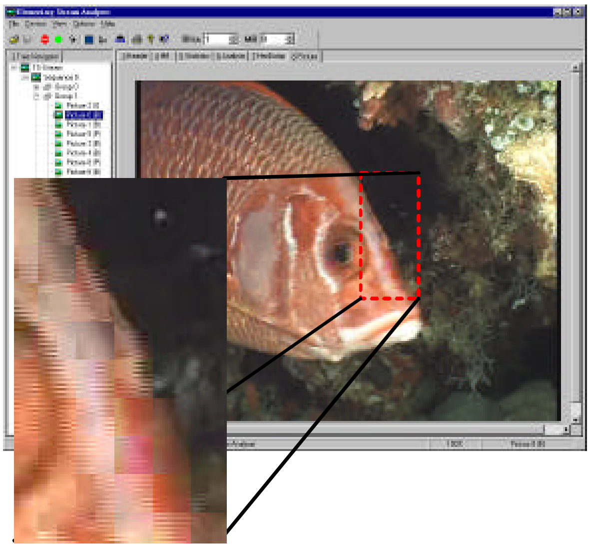


Fig. 1.32 B picture of the "Squirrel" sequence showing strong blocking effects

## 1.13 Interfaces to EN 50 083-9

The signal interfaces open the door to the "DVB room" of the "digital TV house" (see 1.1, Introduction), where the transport stream is applied to a DVB or ATSC modulator.

### 1.13.1 SPI Synchronous Parallel Interface

| Electrical characteristics | |
|---|---|
| Technology used | LVDS (low voltage differential signalling) |
| Connector | 25-contact D-SUB (to ISO Doc. 2110 (1989)) |
| Cable | 25-contact ribbon cable (with twisted-pair wires) |
| Max. cable length | approx. 10 m |
| Output | balanced (DATA X A = $\overline{\text{DATA X B}}$) |
| Common-mode voltage | nominal 1.25 V (1.125 V to 1.375 V) |
| Signal amplitude | nominal 330 mV (247 mV to 454 mV) |
| Input | balanced |
| max. voltage | 2 $V_{pp}$ |
| min. voltage | 0.1 $V_{pp}$ |

Table 1.7 Data of SPI interface

| Pin # | Signal | Pin # | Signal |
|---|---|---|---|
| 1 | Clock A | 14 | Clock B |
| 2 | System ground | 15 | System ground |
| 3 | Data 7 A (MSB) | 16 | Data 7 B |
| 4 | Data 6 A | 17 | Data 6 B |
| 5 | Data 5 A | 18 | Data 5 B |
| 6 | Data 4 A | 19 | Data 4 B |
| 7 | Data 3 A | 20 | Data 3 B |
| 8 | Data 2 A | 21 | Data 2 B |
| 9 | Data 1 A | 22 | Data 1 B |
| 10 | Data 0 A | 23 | Data 0 B |
| 11 | DVALID A | 24 | DVALID B |
| 12 | PSYNC A | 25 | PSYNC B |
| 13 | Cable shield | | |

Table 1.8 Contact assignment of SPI interface

The clock, DVALID (data valid) and PSYNC (TS packet sync byte) signals enable immediate synchronization to the byte clock and the start of the TS packets. PLLs are not essential for data regeneration.
The clock frequency $f_T$ (byte clock) is dependent on the TS data rate $f_D$:

$f_T = f_D / 8$ (without Reed Solomon error protection)

$f_T = (204 / 188) \times f_D / 8$ (with Reed Solomon error protection)

*Note:*
*In the MPEG2 standard, mention is made only of 188 bytes per TS packet.*

### 1.13.2 SSI Synchronous Serial Interface

The parallel SPI data (bits 0 to 7) undergo parallel-to-serial conversion and are transmitted at a clock rate eight times that of SPI data. Bits with the value "1" are biphase mark coded. Bits with the value "0" have a constant level for the duration of the bit. If several consecutive bits with the value "0" occur, the polarity of these bits is alternately reversed.

Data coding:

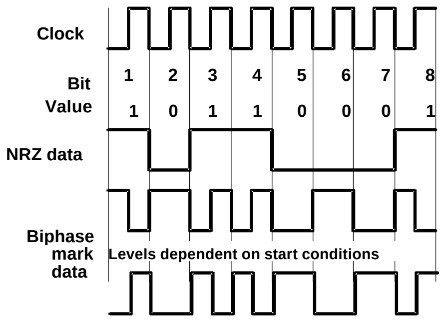



Fig. 1.33 Biphase mark coding

This type of coding yields a data signal that contains at least one edge per bit so that PLLs can easily synchronize.

| Electrical characteristics | |
|---|---|
| Coaxial or fibre-optic cable | 75 Ω BNC |
| Cable type and max. cable length | RG 59 BU 100 m<br>RG 216 U 220 m |
| Pulse shape | rectangular, conforming to masks defined by EN 50083-9 |
| Max. voltage | 1 $V_{pp}$ ±10 % |
| Return loss | 15 dB (from 3.5 MHz to 105 MHz) |
| Jitter | $J_{pp}$ = 2 ns |

Table 1.9 Data of SSI interface

### 1.13.3 ASI Asynchronous Serial Interface

The 8-bit MPEG2 TS data are converted to 10-bit words using predefined tables. The data transmission rate is 270 Mbit/s in the serial mode. The typical TS data rate is today less than 50 Mbit/s (see section 1.8, Transport Stream (TS)), so comma bytes are used for stuffing the data rate up to 270 Mbit/s. There are several predefined comma bytes.

The bytes commonly used are designated K28.5. They are invalid characters after 8-bit/10-bit conversion. The ASI receiver ignores the comma bytes.

The eye opening for SDI transmission should be within the mask defined by EN 50083-9.

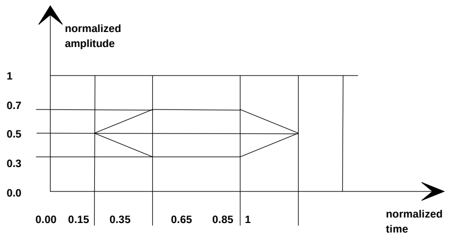



Fig. 1.34 Typical eye diagram of ASI transmitter to EN 50083-9

| Electrical characteristics | |
|---|---|
| Coaxial (or fibre-optic cable) | 75 Ω BNC |
| Cable type and max. cable length (with cable equalizer, otherwise not specified) | Beldon 8281 280 m |
| Output voltage | 800 $mV_{pp}$ ±10 % |
| Effective jitter | 8 % of bit duration ⇒ 300 ps |
| Return loss | ≤-15 dB (from 5 MHz to 270 MHz) (preliminary) |
| Max. rise/fall time 20 % to 80 % | 1.2 ns |

Table 1.10 Data of ASI interface

### 1.13.4 SDTI Serial Digital Transport Interface to SMPTE 326M

Modern studios use digital technology to ITU-R BT.601 throughout and so have the optimal infrastructure for the transmission of SDI data at a rate of 270 Mbit/s.

While the ASI interface is capable of handling the same data rate and can therefore use the same interface chips, i.e. to ITU-R BT.601/656, it is subject to the restriction that only the non-inverting signal outputs of the driver chips can be used. This means that on average only 50 % of the existing 75 Ω coaxial cable infrastructure can be used. The SDTI interface, by contrast, transports MPEG2 data using both the inverting and the non-inverting signal outputs and will therefore be the preferable choice in the digital studios of the future.

The SDTI interface is based on the SDI protocol for the transmission of TS data at 270 Mbit/s. The MPEG2 coded video and audio data and the contents of the data container are transmitted to MPEG2 specifications in the active line between SAV (start of active video) and EAV (end of active video). The last byte of each active line is the CRC value for the line.
SDI employs 10-bit words. In SDTI transmission, the lowermost 8 bits carry MPEG2 data; bits 9 and 10 are set to "1". Between EAV and SAV, a header is inserted in the first field that announces that not SDI data but MPEG2 transport stream data will be transported. The header is inserted for the duration of the lines used for data transmission, i.e. in the 625-line standard from line 9 to the last data-transmitting line in the first field.

Standards SMPTE 305M and SMPTE 326M provide a detailed description of the transmission protocol and data processing.

The simplest SDTI transmission model is illustrated by Fig. 1.32 below:

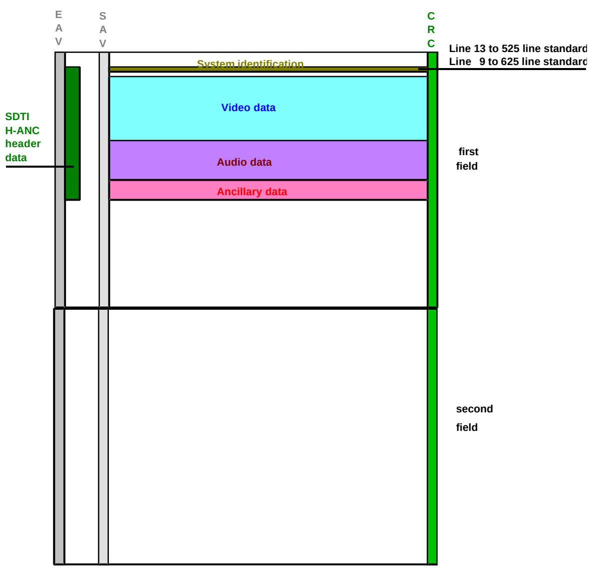



Fig. 1.35 Structure of SDTI data

The four interface types discussed above are suitable in particular for short-distance transmission. For SPI, connectors should not be more than 3 m to 5 m apart (even if larger distances could be bridged using special flat cables). With SSI, the length of the coaxial cable depends on the data transmission rate and is in the order of several 10 m. With ASI and SDTI, the 75 Ω cable may have a maximum length of about 280 m.

In the following, long-distance links of up to 100 km and more will be discussed.

### 1.13.5 HDB3 High Density Bipolar of Order 3

The HDB3 interface defined in CCITT Rec. G.703 is based on DC-free three-level signal coding. This interface is today mainly used by telecommunication network operators for the transmission of digitized CCVS signals at a rate of 34.368 Mbit/s (also known as E3 mode in PDH (plesiochronous digital hierarchy) networks in Europe). This infrastructure too is suitable for the transmission of TS packets. While the data rate is somewhat too low for DVB-C and DVB-S, it is adequate for DVB-T. The HDB3 interface is ideal for feeding data from the studio to the DVB-T transmitter, taking into account that today's analog TV parent transmitters and tomorrow's DVB-T transmitters in an SFN (single frequency network) will practically always be accommodated in the same building.
Fig. 1.27 illustrates a short section of an HDB3-coded signal.

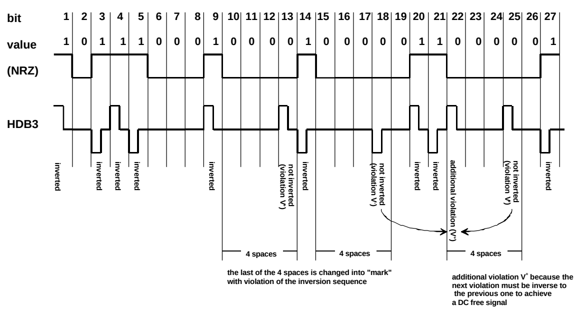



Fig. 1.36 Example of HDB3 coding

### 1.13.6 ATM with SDH/PDH
Asynchronous Transfer Mode
Synchronous/Plesiochronous Digital Hierarchy

TV signals must be transmitted in realtime. Errors occurring in signal distribution cannot be remedied by way of query and retransmission. The realtime requirement in conjunction with the demand for a high data rate is met with the ATM mode, which utilizes the existing optical-fibre infrastructure of PDH and SDH systems for data distribution.
A broadcaster who intends to use ATM data transmission concludes a contract with a PDH/SDH network operator in which limit values are specified to guarantee the desired performance. These are known as QoS (quality of service) values and include the following:

Cell loss — defines whether or not the loss of cells should be tolerated during peak-load periods of a network.

Cell delay — defines the maximum delay to be expected until a cell arrives at the point of destination.

Cell delay variation — defines the permissible deviation from cell delay.

Compliance with agreed QoS values guarantees the correct transmission of ATM cells, so optimally supporting the fulfilment of the realtime requirement.
Achievable data rates for PDH are about 139.264 Mbit/s (E4, Europe) and 44.736 Mbit/s (T3, U.S.). In SDH environments, data rates of 155.52 Mbit/s (STM1, Europe and STS3, U.S.) to 2 488.32 Mbit/s (STM16, Europe and STS48, U.S.) are common today. Data rates of up to 9 953.28 Mbit/s (STS 192, U.S.) are employed on a trial basis.

With ATM, the 188-byte TS packets at ATM adaptation layer 1 (AAL1) are divided into four sections of 47 bytes. To each section, a 5-byte ATM packet header and the 1-byte overhead for AAL1 are added, which yields an ATM packet of 5+1+47 = 53 bytes.

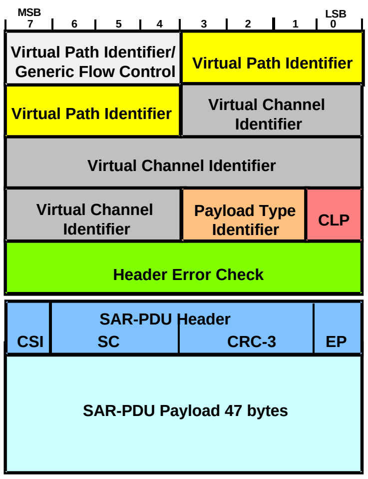



Fig. 1.37 Structure of ATM packet at AAL1
Featuring Reed Solomon forward error protection (124, 4, 2) in conjunction with block interleaving at AAL1, the ATM mode is ideal for long-distance MPEG2 data transmission.

Layer AAL1 is today used, for example, in the distribution systems of the German ARD (Hybnet) and the German Telekom (Rundfunk Service Multiplexer) for interconnecting studio complexes and feeding TS data from the studio to the DVB-T transmitter.

#### 1.13.7 Summary

The interfaces most widely used today are SPI for very short distances (3 m to 5 m) and ASI for distances of up to 280 m (length depending on cable type used). ATM with SDH/PDH and fibre-optic cable will increasingly be used in the future for signal distribution from the studio to cable headends, satellite uplinks and DVB-T transmitters. At present, these links are frequently implemented as radio relay links.

## 1.14 Measurement Systems for MPEG2

### 1.14.1 Triggered Data Recording

Frequently, signals not conforming to standard occur for a very brief period during data transmission. These events are so short that they usually go unnoticed by the operating personnel. To examine them in detail, they have to be stored. This is done by means of the trigger-on-event functionality of DTV RECORDER GENERATOR DVRG.

As described in section 1.11.3, TS recording can be triggered by an external signal for error analysis. The trigger signal can be delivered, for example, by DVQ, which signals video quality below threshold, or by DVMD, which detects nonconformance with ETR290, for example. The TS section recorded by DVRG includes user-selectable periods before (pretrigger) and after (posttrigger) the trigger event. The recorded TS data streams can subsequently be examined off-line for coding errors, for example in the lab.

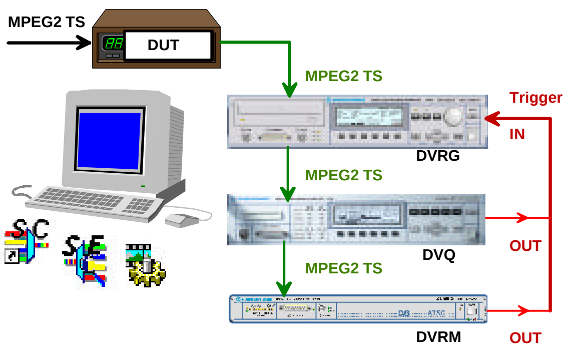



Fig. 1.38 Triggered data recording

Detailed analysis is supported by optional software available for DVMD, DVRM and DVQ.

The STREAM EXPLORER® DVMD-B1 software performs in-depth analysis of recorded transport streams. It allows detailed investigation of the contents of TS packets and the structure of all data contained in a TS. DVMD-B1 outputs the packet contents in hexadecimal format and displays the interpreted header information, adaptation field contents and interpreted PSI and SI tables, so enabling any violations of the MPEG2 protocol to be traced down to the last detail.

Moreover, the tree structure of the overall TS including all syntax elements is displayed, providing an overview of the MPEG2 data stream down to bit level.

The STREAM EXPLORER® DVMD-B1 option is available for both MPEG2 MEASUREMENT DECODER DVMD and MPEG2 REALTIME MONITOR DVRM.

For a detailed description of DVMD-B1 refer to section 1.11.7.

Where special TS data streams are needed for error simulation, the STREAM COMBINER® DVG-B1 option generates new transport streams from existing elementary streams. In the DVG-B1 "Expert" mode, the TS protocol can be modified as required to simulate any deviations from standard that might occur in a transport stream. However, due care should be exercised when working in the "Expert" mode since DVG-B1 comprises no automatic function for error-free TS generation.

### 1.14.2 TS Monitoring at the Studio Output

Program providers should monitor, at the studio output, all their programs to be carried in a transport stream before these are fed to the cable headend, the satellite uplink or the DVB-T transmitter. This is to ensure good video quality and conformance with the MPEG2 protocol. Monitoring is absolutely necessary with the statistical multiplex method widely used today. After tolerance limits for video quality are specified and corresponding permissible maximum intervals of low video quality (in the order of a few seconds) are defined, any deviation from specified quality levels will be recorded and signalled via alarm contacts.

Monitoring is required not only at the outputs of the multiplexers for the individual programs but also at the output of the multiplexer for the overall transport stream to be broadcast at a high data rate (e.g. 38.153 Mbit/s for DVB-C with 6.9 Msymb/s and 64 QAM).

In the case of DVB-T, an additional test point is provided in the SFN (single frequency network) at the output of the MIP (megaframe initialization packet) inserter. This is to monitor the contents and repetition periods of the MIP packet, which serves for synchronization of the SFN.

All the above measures are taken by the program provider to ensure that

his programs broadcast via a given distribution network (DVB-C, DVB-S, DVB-T or ATSC/8VSB) arrive at TV viewers at home with the guaranteed quality;

any misrouted transport stream signals are detected immediately, and specified video quality levels are guaranteed by applying quality analysis.

The solution to these problems is DVQM (see also section 1.12.1) with the DTV NetView software for simultaneous quality monitoring of up to 12 programs, and DVRM with the associated monitoring software.
As shown in Fig. 1.36, DTV RECORDER GENERATOR DVRG may be added for the triggered recording of transport streams, so providing in-depth signal analysis. It is thus ensured that only transport streams of a defined quality leave the studio for transmission to the viewers.

For the initial measurement of studio equipment, reproducible TS sequences should be used exclusively. Only by using such sequences can comparative measurements be performed at different locations and at different times. MPEG2 coded endless sequences are available on the hard disks of MPEG2 MEASUREMENT GENERATOR DVG or DTV RECORDER GENERATOR DVRG. They can be used to perform measurements either in service, i.e. with the sequences inserted in the transport stream as a separate "program", or out of service with the sequences inserted directly into the feeder link to the distribution network, so bypassing the TS MUX.

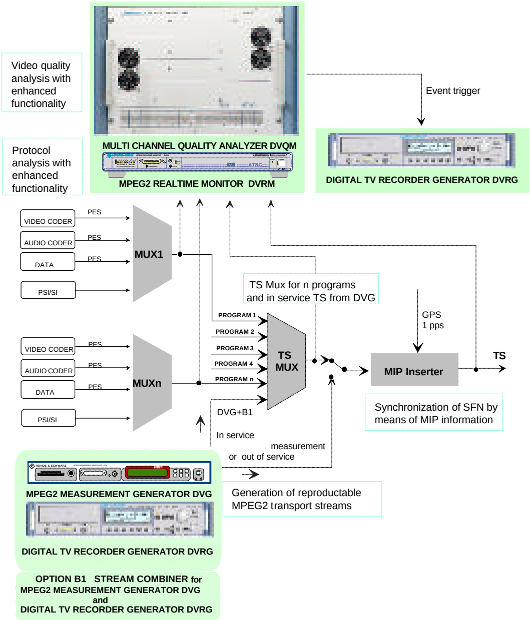



Fig. 1.39 Transport stream monitoring system

### 1.14.3 Monitoring of Few Programs at the Studio Output

If only a few (i.e. two or three) programs are to be monitored, DIGITAL VIDEO QUALITY ANALYSER DVQ is the most cost-effective solution. Used in conjunction with DVRM and DVRG, it offers measurement functionality identical to that described in 1.14.2. For a more in-depth analysis, the optional QUALITY EXPLORER® DVQ-B1 and QUALITY MONITOR software should be added. Here, too, triggered TS recording is possible by means of DVRG, with trigger signals delivered by DVQ and DVRM.
The programs are tested one after the other. The time required for each program is about 10 s, so that a complete test cycle takes no more than 20 s to max. 30 s. While this cannot be regarded as realtime monitoring, the periods during which the individual programs are interrupted are so short that all critical events and errors are detected.

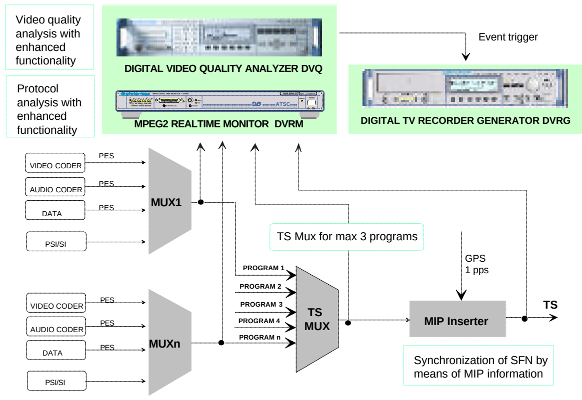
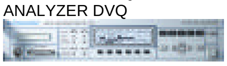



Fig. 1.40 Transport stream monitoring for a few programs only

## 1.15 Overview of MPEG2 Specific Measurements

| Instrument | Measurements and Parameters |
|---|---|
| MPEG2 MEASUREMENT GENERATOR DVG  | Test signal generator for reproducible MPEG2 measurements, various test sequences |
| DTV RECORDER GENERATOR DVRG  | Test signal generator for reproducible MPEG2 measurements, various test sequences; recording and playback of MPEG2 and ITU-R BT.601 data streams; triggered recording |
| STREAM COMBINER®<br>Option for DVG and DVRG | Generation of endless and seamless TS sequences of video, audio and additional data from existing ESs (elementary streams); ES2Loop (elementary stream to loop) software matches length of video ES to length of audio ES |
| MPEG2 MEASUREMENT DECODER DVMD  | Realtime protocol analysis of MPEG2 transport stream |
| MPEG2 REALTIME MONITOR DVRM  | Realtime protocol monitoring of MPEG2 transport stream |
| STREAM EXPLORER®<br>Option for DVMD and DVRM | Display of<br>- tree structure of overall TS with all syntax elements,<br>- header information of TS packets,<br>- packet contents in hexadecimal format,<br>- interpreted tables |
| DIGITAL VIDEO QUALITY ANALYZER DVQ  | Measurement of signal quality after MPEG2 coding and decoding; signalling of picture loss, picture freeze; measurement of data rate, temporal and spatial activity; audio monitoring, signalling of sound loss L/R; optionally: descrambling |
| MULTI CHANNEL QUALITY ANALYZER DVQM  | For up to 12 programs:<br>signalling of picture loss, picture freeze;<br>audio monitoring, signalling of sound loss L/R;<br>optionally:<br>descrambling<br>simultaneous monitoring of video quality |
| QUALITY EXPLORER®<br>Option for DVQ and DVQM | Detailed analysis of elementary streams in terms of protocol, DCT coefficients and decoded pixel blocks |
| QUALITY MONITOR<br>Freeware for DVQ and DVQM | Long-term monitoring of video quality, TA , SA and data rates of programs included in TS |
| DTV NET VIEW | Remote controlled monitoring of up to 12 programs within one TS by means of DVQM (or DVQ) and DVRM or DVMD via Ethernet including STREAM EXPLORER® (optional) and QUALITY MONITOR |