4.8 Measurements in Frequency Domain

4.8.1 Channel Amplitude and Phase Response

The theoretical amplitude and phase values of the scattered pilots of the COFDM symbol are stored in Test Receiver EFA and compared with the actual values of the pilots received. The resulting values yield the channel transfer function. Based on this function, the amplitude and phase response or group delay of the transmitter's RF output is to be measured, including all filters between the transmitter output and the antenna. So, EFA also verifies compliance with the requirements for amplitude and frequency response or group delay specified in 4.4.6, "Increasing Shoulder Distance".

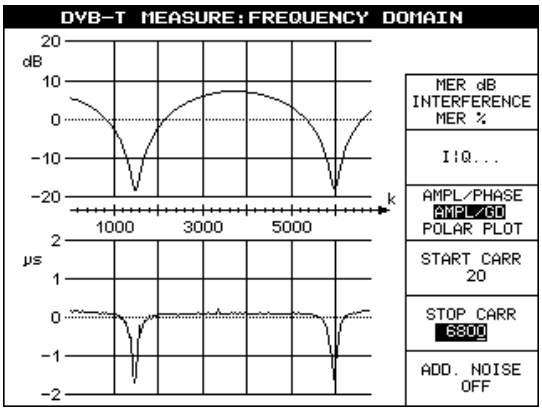


Fig. 4.50 Linear distortion (amplitude and phase) due to fading in transmission channel (with carrier number k plotted along abscissa)

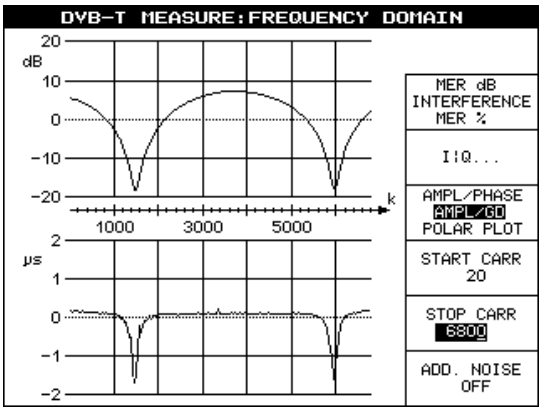


Fig. 4.51 Linear distortion (amplitude response and group delay) due to fading in transmission channel (with carrier number k plotted along abscissa)

Another way of presenting the above information is a polar diagram. Although this representation provides no reference to frequency, it does combine amplitude and phase information in a single diagram, so offering a fast overview of the conditions prevailing in a channel.

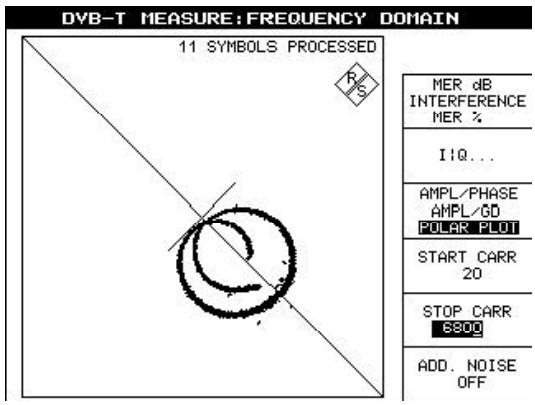


Fig. 4.52 Polar plot of chart shown in Fig. 4.50. Long diagonal: real component, short diagonal: imaginary component

In the ideal case of an undistorted channel spectrum, only a point would appear on the positive real axis.

4.8.2 Frequency Response Calculated with FFT

Calculating channel frequency response by means of FFT furnishes level deviation with much higher resolution than the complex comparison of pilots described above. Although FFT is not a full equivalent to spectrum analyzer measurement, it is adequate for analyzing the spectrum of a transmission channel and for determining out-of-band components as described in 4.4.6, "Increasing Shoulder Distance" above.

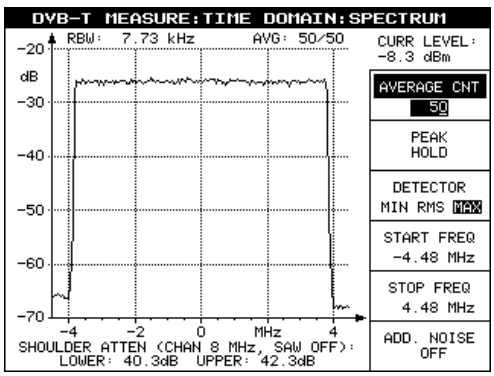


Fig. 4.53 Spectrum of DVB-T channel

Maximum level resolution is obtained by analyzing only the useful range of the spectrum (from -3.8 MHz to +3.8 MHz in the above example). EFA automatically selects maximum level resolution in this case, i.e. 2 dB/division, depending on the frequency response.

4.9 Constellation Diagram

Test Receiver EFA 40/43 maps each DVB-T carrier to its baseband by means of FFT. All I/Q value pairs thus obtained are projected into the decision fields for QPSK, 16QAM or 64QAM (hierarchical or non-hierarchical), so producing a constellation diagram.

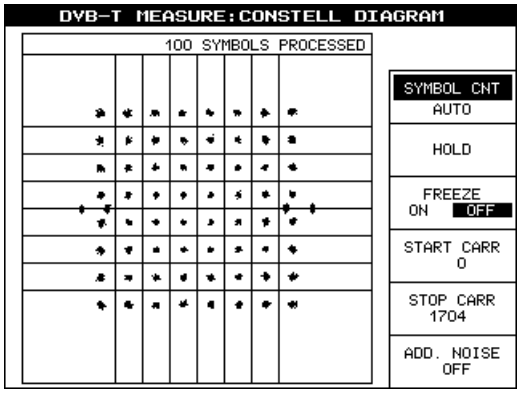


Fig. 4.54 Constellation diagram for 64QAM, 2k mode

The I/Q values of all carriers between START CARR and STOP CARR are included, so the pilots and TPS carriers too are plotted along the I axis. The TPS carriers show the mean power in a given constellation diagram, whereas the pilots appear with power higher by a factor of 16/9 = 1.777.

From the constellation diagrams of the individual carriers, various OFDM parameters can be determined.

4.9.1 MER Measurement

MER (modulation error ratio) summarizes all errors that can be measured within a constellation diagram. The definition of this parameter is illustrated by Fig. 4.55.

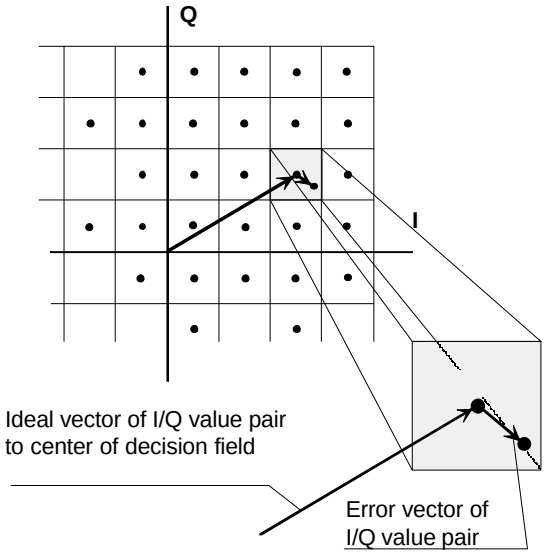


Fig. 4.55 Definition of MER

For each I/Q value pair of a constellation diagram there is exactly one theoretical target point located at the center of each decision field. But the actual point is not always located at the center. This is due to the effect of quantization in A/D conversion involving a limited number of bits, rounding errors in calculation, D/A conversion in the modulator, phase jitter of the converter clock and superimposed noise in transmission. From this an error vector can be formed combining all these effects. MER is calculated from the sum of the squares of ideal vectors and that of the error vectors (see Measurement Guidelines for DVB Systems ETR 290).

Test Receiver EFA 40/43 not only measures MER but also presents it as a function of frequency (MER(f)), i.e. MER is shown for each individual carrier of a COFDM channel, which is much more conclusive. Errors concerning just a few carriers of a COFDM symbol can immediately be located in this way.

This is illustrated by the following example:

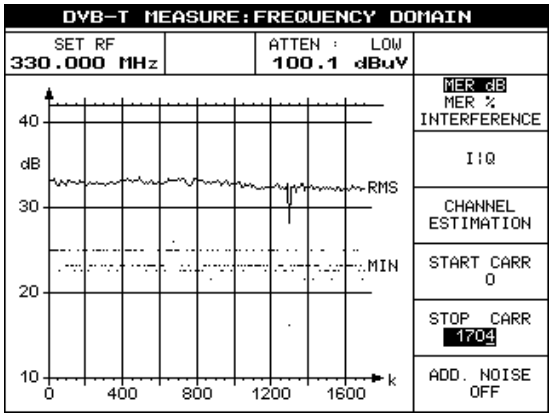


Fig. 4.56 MER(k) characteristic with narrowband interference

Fig. 4.56 shows a pronounced dip of MER in the carrier region about k = 1300 (k = index of COFDM carrier). To determine the disturbed carrier, select the start carrier a little below k = 1300 (e.g. k = 1280) and the stop carrier a little above (e.g. k = 1320). The disturbed carrier can thus be exactly identified; in this case it is k = 1299.

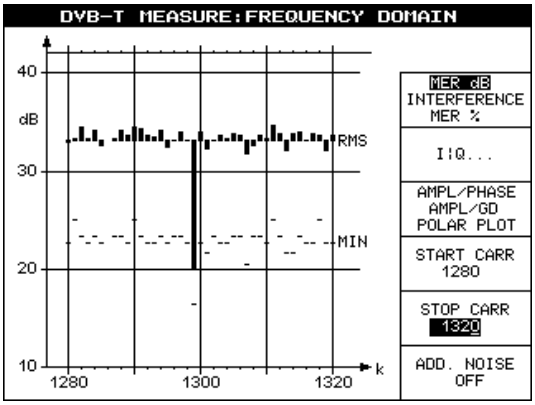


Fig. 4.57 Zoomed MER representation of 2k COFDM signal; the interference is on carrier 1299

DVB-T transmitter monitoring is therefore in the first place effected only by measuring MER in addition to BER. In the event of significant deviations from the linear characteristic, the cause of error will be examined in detail by zooming the carrier region in question or measuring the parameters defined in the COFDM menu.

MER, beside BER, is the primary parameter in a DVB transmission system as it provides information on transmission quality at a glance.

A good DVB-T transmitter should have

MER(f) > 35 dB.

4.9.2 I/Q Analysis

Another way of locating errors in the COFDM signal is by presenting I/Q versus frequency. The I component is shifted by 90° and superimposed on the Q component. Depending on the modulation (QPSK, 16QAM or 64QAM), two, four or eight I/Q bars are produced that directly indicate any deviation from ideal modulation and from which selective interferers can be determined. These bars should ideally be equidistant, parallel, horizontal lines located in the middle between the inner decision thresholds.

The example below shows the same signal as above for MER measurement, this time in I/Q presentation. The selective interferer on carrier 1299 is again identified by zooming.

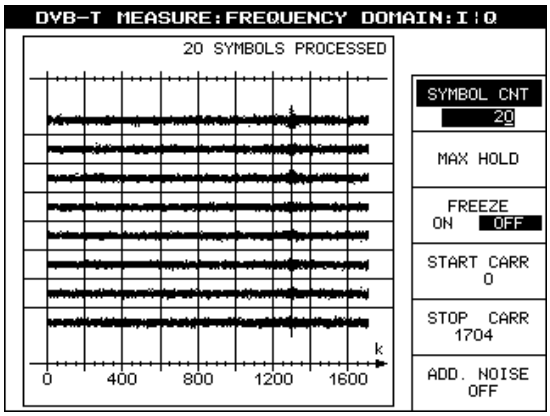


Fig. 4.58 I/Q analysis of 2k COFDM signal

In Fig. 4.59 a gap can be recognized at carrier k = 1286. At this point a TPS carrier is located that is not taken into account in the I/Q analysis. This is due to the modulation, i.e. the information is carried by the I component only; this method is, therefore, not comparable with the data carrier method.

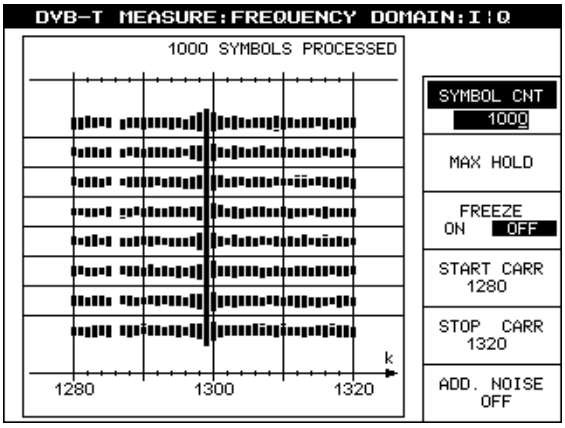


Fig. 4.59 Zoomed I/Q presentation of 2k COFDM signal; the interference is on carrier 1299

4.9.3 Measurement of I/Q Parameters in OFDM

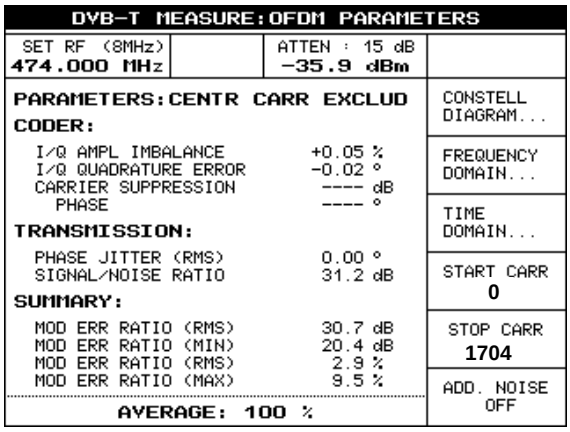


Fig. 4.60 Measurement of OFDM parameters without central carrier

Just as in DVB-C and DVB-S, any interference or disturbance in DVB-T is caused by the modulator and during transmission.

The parameters

I/Q IMBALANCE,
I/Q QUADRATURE ERROR,
CARRIER SUPPRESSION and
(RESIDUAL CARRIER) PHASE

are typical performance parameters of the exciter, whereas during transmission noise-like disturbance like

PHASE JITTER and
NOISE (S/N RATIO)

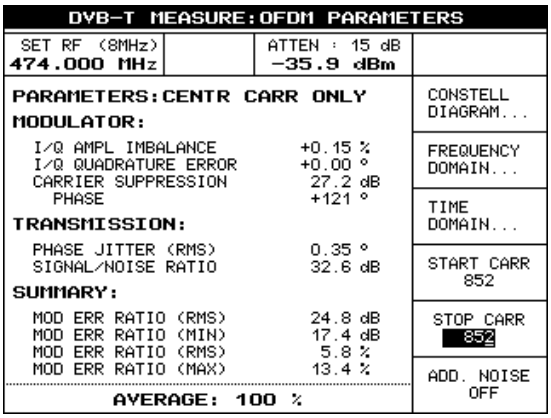
is superimposed on the useful signal.

MER is again obtained as a sum parameter (see also 4.9.1, "MER Measurement") and displayed under different designations.

4.9.4 Measurement of Residual Carrier

In residual carrier measurement some special features have to be taken into account. The residual carrier is a very narrowband interferer. Requirements regarding its spectral purity have already been described under 4.5.1, "Measurement of Phase Noise". Being very narrowband, the residual carrier has an effect only on the central carrier and so can only be measured on this carrier.
In 2k mode, the central carrier is a scattered pilot inserted in every fourth symbol whose index can be calculated by means of equation 1 (see 4.2.8.2). In 8k mode, the central carrier is assigned a continual pilot.

Fig. 4.61 Measurement of OFDM parameters on central carrier only



Despite these restrictions, Test Receiver EFA 40/43 measures the residual carrier with high accuracy using a patented computation standard. To determine the residual carrier, simply select the central carrier (852/2k or 3408/8k) in either 2k or 8k mode. The measurement is then performed automatically.

In DVB-T, the residual carrier is referred to the signal power of a single OFDM carrier in accordance with ETR 290. By contrast, in DVB-C and DVB-S, the residual carrier is referred to the mean power of the overall spectrum. For this reason, the logarithmic ratio obtained for the residual carrier in DVB-T is much smaller than that for DVB-C or DVB-S at the same absolute residual-carrier level:

2k mode $\Delta = 10 \times \log(1705) = 32.3$ dB

8k mode $\Delta = 10 \times \log(6817) = 38.3$ dB

Example:
While typical residual carrier suppression of about 60 dB can be expected in DVB-C, a value scarcely exceeding 20 dB will be measured in 8k mode in DVB-T.

4.10 Alarm Report

The above measurements cannot only be carried out manually at the transmitter site, results can also be queried from a remote control center via an RS232C interface and the IEC625/IEEE488 bus. Monitoring by single queries is time-consuming however, plus there is a large quantity of measured data to be handled.
Remote monitoring with Test Receiver EFA 40/43 greatly simplifies this procedure.
This is implemented by the ALARM menu.

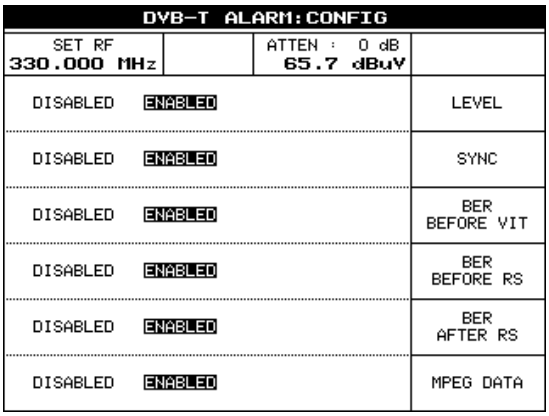


Fig. 4.62 Alarm configuration menu:
a variety of parameters can be monitored

Table 4.12 lists the parameters selectable in the ALARM CONFIGURATION menu:

Parameter	Explanation	Abbrev.
LEVEL	Input level	LV
SYNC	Indicates synchronization of OFDM symbols and MPEG2 transport stream	SY
BER BEFORE VIT		BV
BER BEFORE RS		BR
BER AFTER RS		BM
MPEG DATA	Data errors not correctable by Viterbi and RS	DE

Table 4.12

After selecting the parameters in the ALARM CONFIGURATION menu, the alarm thresholds have to be set. Thresholds can be set for LV, BV, BR and BM. Non-correctable data and synchronization failure are absolute events and are not assigned a threshold.

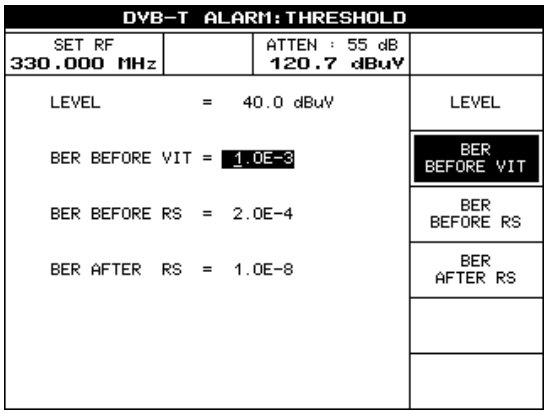


Fig. 4.63 Setting alarm thresholds

The activated alarms are combined to a sum signal brought out at a pin of X34 (USER PORT) on the rear of EFA. In the event of a sum alarm, the single alarms can be queried via the remote control interfaces.

On pressing the ALARM hardkey on the EFA front panel, the alarm list is displayed. The list may comprise up to 1000 lines in which each event is entered with its number, date and time and the parameter triggering the alarm. The time indicated is when a parameter first went out of tolerance or returned to tolerance.

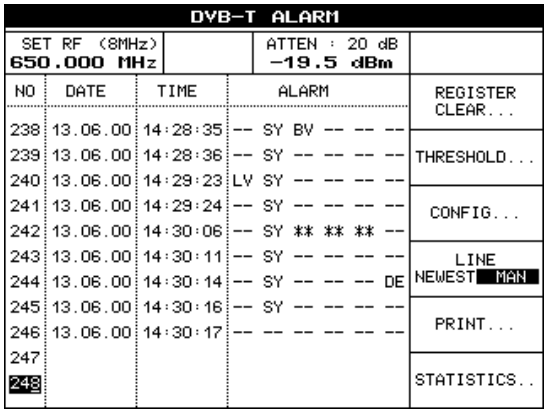


Fig. 4.64 Alarm list

If more than 1000 events occur in a monitoring period, the initial events are cleared and the current events added at the end of the list.
It may sometimes be necessary, for statistical purposes, to know the duration of the individual errors and the percentage taken up in overall monitoring time. This information is given under STATISTICS.

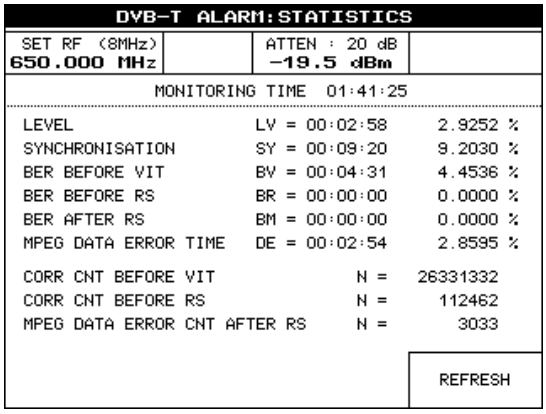


Fig. 4.65 Statistical evaluation of error periods

4.11 Measurements in VHF Band I and Band III

The European standard EN 300 744 has specified DVB-T so far only for the UHF band and 8 MHz channels. In notes, however, reference is made to 7 MHz channels, which are defined for VHF bands I and III and, in Australia, also used in band IV/V. For a 7 MHz channel, the DVB-T system clock has to be lowered from 64/7 MHz to 64/8 MHz. This increases useful symbol duration to 896 x 8/7 = 1024 µs and reduces useful signal bandwidth to 6.65625 MHz (with 976.5625 Hz carrier offset), so accommodating the data stream in a 7 MHz band. The length of the guard intervals is calculated on the basis of the useful symbol duration of 1024 µs. The useful data rate decreases by a factor of 7/8. The data rates given in Table 4.6 have to be multiplied by 7/8 for 7 MHz bands.
For DVB-T in 6 MHz channels, the system clock has to be reduced from 64/7 MHz to (64/8) x (6/7) = 48/7 MHz. The useful symbol duration is then (896 x 8/7) x 7/6 = 896 x 4/3 = 1194.667 µs, and the data rates and guard intervals have to be corrected accordingly.

Test Receiver EFA 40/43 carries out selective measurements in the 7 MHz and 6 MHz bands by means of two options: 7 MHz SAW filter EFA-B12 and 6 MHz SAW filter EFA-B11, which can be fitted in addition to the internal 8 MHz IF SAW filter.
The system clock automatically adapts to the selected bandwidth.
The latter is displayed in the STATUS menu.

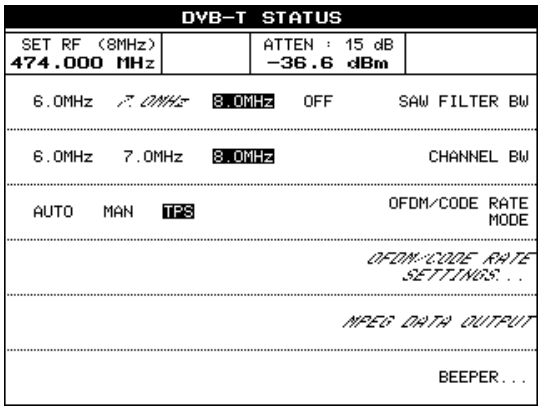


Fig. 4.66 STATUS menu

4.12 Measurements in DVB-T SFN or MFN
(Single Frequency Network, Multi Frequency Network)

The guard interval takes up all signals reflected or directly received from other transmitters during DVB-T reception in a single frequency network. The path delay of such signals must not exceed the duration of the guard interval. Path delay is determined with Test Receiver EFA 40/43. Depending on the application, EFA calculates the path delay in µs or the path length in kilometers or miles.

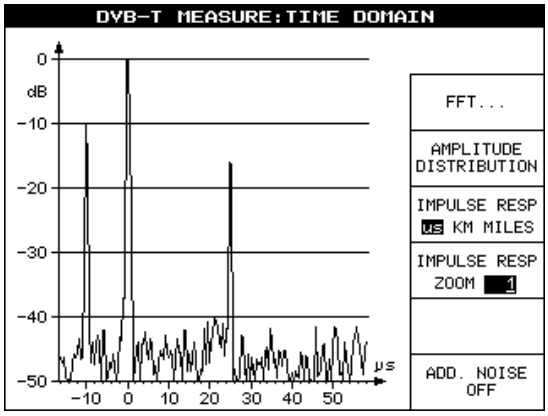


Fig. 4.67 Echo diagram

Fig. 4.67 shows that leading echoes too are possible in a DVB-T network, for example when receiving signals from a low-power gap-filler station located closer than a high-power transmitter. In this case the delay is -10 µs, i.e. the gap filler is about 3 km closer to the receiving station than the main transmitter, which is at 0 µs. At 25 µs, there is a lagging echo, which may result, for example, from reflection over a path of about 7.5 km. The above echo profile is valid for a DVB-T network with 8 MHz channel bandwidth and guard interval > 28 µs (2k guard interval: τ = 1/8; 8k guard interval: τ = 1/32).
Moreover, this measurement allows determination of the distance in km between the transmitters of an SFN, provided there is a line of sight between the transmitting antennas. The distance between transmitters in an SFN must not exceed the values specified in Table 4.13.

	Distance between transmitters (km)			
FFT	τ = 1/4	τ = 1/8	τ = 1/16	τ = 1/32
2k	16.8	8.4	4.2	2.1
8k	67.2	33.6	16.8	8.4

Table 4.13 Maximum distance between transmitters in SFN

4.13 Measurements with MPEG2 Decoder Option EFA-B4

The optional MPEG2 Decoder EFA-B4 covers only part of the functionality of MPEG2 Measurement Decoder DVMD and MPEG2 Realtime Monitor DVRM. The available measurement functions are adapted to monitor the demodulated MPEG2 transport streams at the transmitter. However, with EFA-B4 alone, the monitoring depth provided by DVMD or DVRM for MPEG2 specific parameters is not attained. If MPEG2 monitoring takes place already at the transmitter input, DVMD or DVRM is not needed at the output.
If Test Receiver EFA 40/43 is fitted with option EFA-B4 to analyze the MPEG2 protocol and the RF characteristics during DVB-T transmission, it alone will suffice to make the necessary measurements at the transmitter.
First, the time limits for the repetition rates of the tables and time stamps in the transport stream have to be set. The limits can be user-defined or selected in conformance with standards

ISO/IEC 13 818-1 for MPEG2
or
ETR 290 for DVB

for the parameters defined there.

Parameter name	To DVB		To MPEG2	
	MIN	MAX	MIN	MAX
PAT distance	25 ms	0.5 s	25 ms	0.5 s
CAT distance	25 ms	0.5 s	25 ms	0.5 s
PMT distance	25 ms	0.5 s	25 ms	0.5 s
NIT distance	25 ms	10 s	---	---
SDT distance	25 ms	2 s	---	---
BAT distance	25 ms	10 s	---	---
EIT distance	25 ms	2 s	---	---
RST distance	25 ms	---	---	---
TDT distance	25 ms	30 s	---	---
TOT distance	25 ms	30 s	---	---
PCR distance	0 ms	0.04 s	0 ms	0.1 s
PCR discontinuity	---	0.1 s	---	---
PTS distance	---	0.7 s	---	---
PID distance	---	0.5 s	---	---
PID unref. duration	---	0.5 s	---	---

Table 4.14 Limit values for parameters to DVB and MPEG2

In DVB all parameters are predefined, in MPEG2 only a few. Parameters not defined by the standard must be user-defined. The largest discrepancy between DVB and MPEG2 is in PCR distance with 40 ms for DVB and 100 ms for MPEG2.
Fig. 4.68 shows the menu for setting the limit values on Test Receiver EFA 40/43. The DEFAULT softkey activates the predefined MPEG2 or DVB values. To ensure reproducible and comparable results, it is recommended to select the DVB limit values.

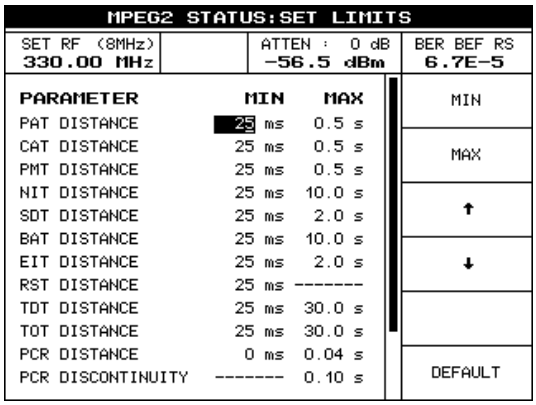


Fig. 4.68 Repetition rates for tables and time stamps

After defining the time limits, the parameters to be monitored for the MPEG2 alarm report have to be enabled. All parameters of the three priorities can be enabled.

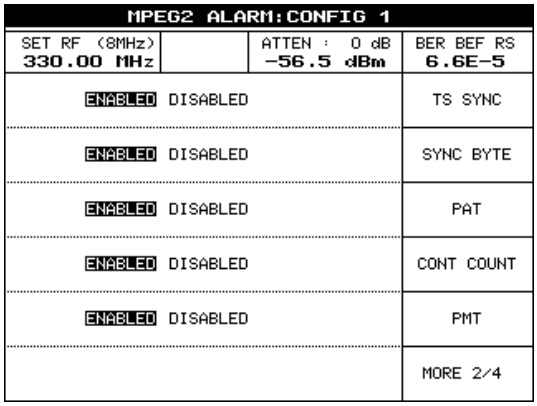


Fig. 4.69 First page of MPEG2 alarm menu

On pressing the ALARM key, the MPEG2 ALARM menu appears. In this menu, all results exceeding tolerances during the monitoring period are displayed.
For disabled parameters, "--" is indicated in brackets.

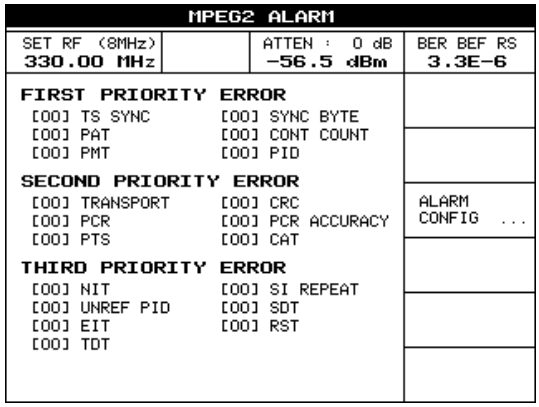


Fig. 4.70 MPEG2 ALARM menu

In the MEASURE menu, all parameters are evaluated in line with ETR290 irrespective of the settings made in the ALARM menu. An error counter can be started, stopped or cleared in this menu.

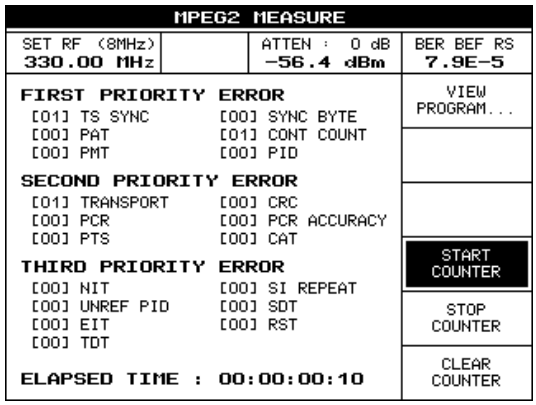


Fig. 4.71 MPEG2 MEASURE menu

The VIEW PROGRAM... softkey opens the PAT of the received transport stream listing the programs transmitted. The data rates of the overall transport stream, the individual programs, the tables and the null packets of the transport stream are displayed as well.

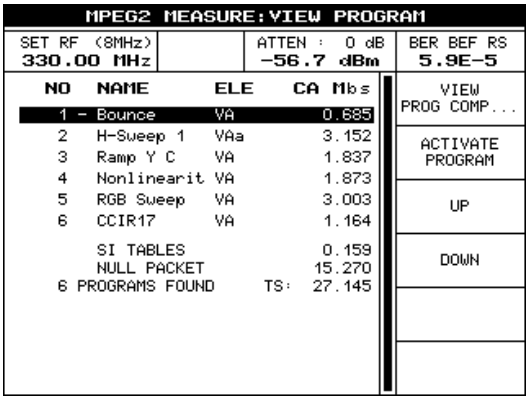


Fig. 4.72 PAT of transport stream with key parameters

ACTIVATE PROGRAM opens the PMT of the selected program with information on the number of video, audio, data and "other" data streams of the program including associated PID numbers. The PID numbers of the PMT and the PCR are listed too.

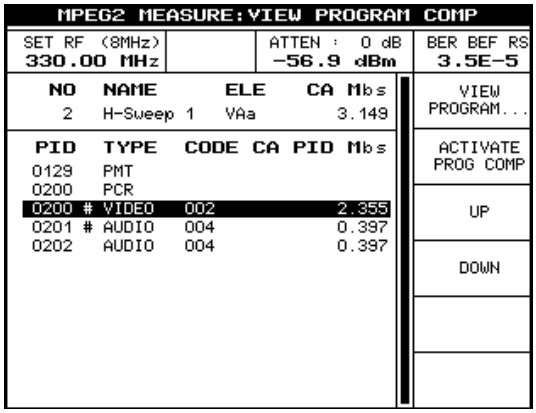
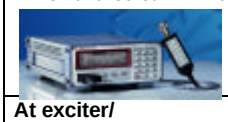


Fig. 4.73 PMT of program with key parameters

Test Receiver EFA 40/43 with optional MPEG2 Decoder EFA-B4 offers adequate functionality for MPEG2 monitoring, although it does not provide the same analysis depth as an extra MPEG2 Measurement Decoder DVMD or MPEG2 Realtime Monitor DVRM. The outputs for analog CCVS video and analog audio allow aural and visual monitoring of the programs put on the air.

4.14 Overview of DVB-T Measurements

Instrument, Test Point	Test Parameter
At transmitter input DVG MPEG2 MEASUREMENT GENERATOR  DVMD MPEG2 MEASUREMENT DECODER  DVRM MPEG2 REALTIME MONITOR  DVQ DIGITAL VIDEO QUALITY ANALYZER 	Test signal generator for reproducible MPEG2 measurements, various test sequences Realtime MPEG2 transport stream protocol analyzer Realtime MPEG2 transport stream protocol monitoring Measurement of signal quality after MPEG2 coding and decoding
At exciter/ transmitter output SPECTRUM ANALYZER FSP or FSEx 	LO phase noise LO harmonics COFDM spectrum Shoulder distance Spectrum masks Crest factor Transmitter output power

Instrument, Test Point	Test Parameter
At exciter/ transmitter output NRVS Power Sensor NRV-Z51 	High-precision thermal measurement of transmitter output power
At exciter/ transmitter output EFA Model 40/43 DVB-T TEST RECEIVER with option EFA-B4 	**Basic unit** 2k and 8k 6 MHz, 7 MHz, 8 MHz channels Display of modulator settings COFDM spectrum Shoulder distance Spectrum masks Crest factor (to definition) Transmitter output power Amplifier failure END, BER, MER Offsets of frequency and data rate Channel transfer function Echo diagram Constellation diagram I/Q parameters in COFDM Residual carrier measurement Alarm report **Option EFA-B4** Measurements to ETR290: parameters of the three priorities alarm report, PAT and PMT
Simulation of DVB-T transmitter SFQ TV TEST TRANSMITTER Option NOISE GENERATOR FADING 	C/N setting for END measurement Simulation of defined receive conditions Simulation of transmitter defects