BROADCASTING DIVISION

Digital TV
Rigs and Recipes
Part 2
DVB-C

S. Grunwald
Graduate in Engineering

Contents

2. Introduction

For optimal transmission, data not only has to be coded to MPEG2 (Motion Picture Experts Group), which reduces the data rate of the ITU-R BT.601 interface from 270 Mbit/s to typically 3 Mbit/s to 5 Mbit/s, but also subjected to a special type of modulation (see "Digital TV Rigs and Recipes" – Part 1 "ITU-R BT.601/656 and MPEG2"). A comparison of analog modulation with the modulation used in digital video broadcasting (DVB) reveals that DVB modulation yields a flat spectrum with a constant average power density across the channel bandwidth.

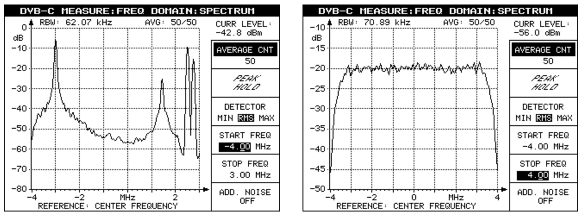


Fig. 2.1 Comparison of B/G PAL spectrum and DVB-C spectrum

This modulation mode results in optimal utilization of the transmission channel in all DVB modes, i.e. DVB-C (cable), DVB-S (satellite) and DVB-T (terrestrial). In this chapter, the special characteristics of DVB-C will be discussed.

2.1 DVB-C Modulation (Cable)

to EN 300 429

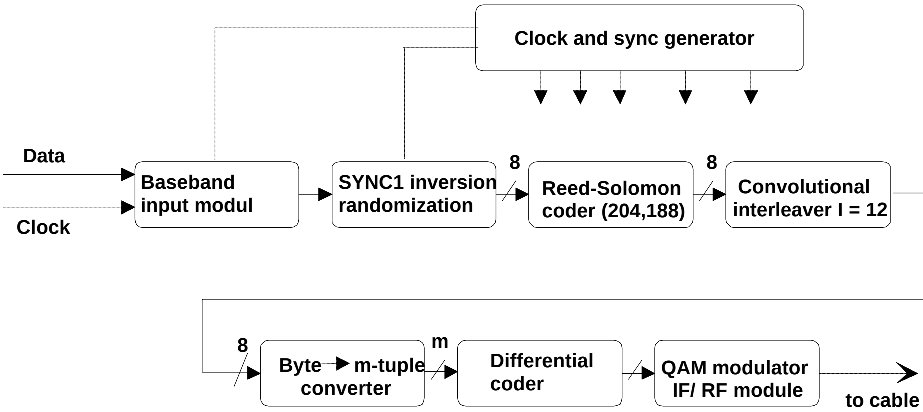


Fig. 2.2 Block diagram of DVB-C modulator/converter

2.1.1 Baseband Input Module

The MPEG2 transport stream (TS) packets are routed to the "DVB room" of the "digital TV house" via one of the following interfaces (see also "Digital TV Rigs and Recipes" – Part 1 "ITU-R BT.601/656 and MPEG2", "Introduction"):

- SPI (synchronous parallel interface)
- ASI (asynchronous serial interface)
- SSI (synchronous serial interface)
- SDTI (serial digital transport interface)
- HDB3 (high density bipolar of order 3)
- ATM (asynchronous transfer mode)

The baseband input module reconstructs the original TS data, optimizes return loss, and corrects amplitude and phase response versus frequency. It supplies all the required information to the clock and sync generator block, which acts as a central clock generator for all blocks of the DVB modulator. Information includes, for example, the data rate, which is derived from the incoming TS data, and in the case of the SPI interface, also sync byte signalling for the TS packet and data valid signalling via the data valid line. The reconstructed TS packets are taken from the baseband input module to the next block, i.e. sync word inversion and randomization.

2.1.2 Sync Word Inversion and Randomization for Energy Dispersal

After the input module, the TS packets undergo the first processing step: sync word inversion and randomization for energy dispersal.
Data randomization – or rather scrambling – ensures a constant average output level of the modulator signal.
The PRBS polynomial $1 + x^{14} + x^{15}$ disperses the data, but not the sync words (0x47), of the TS packets (for TS packet structure refer to "Digital TV Rigs and Recipes" – Part 1 "ITU-R BT.601/656 and MPEG2", section 1.8 "Transport Stream (TS)").

The polynomial has a length of 1503 bytes. This exactly corresponds to eight TS packets minus the bitwise inverted sync word of the first TS packet, whose value is now 0xB8. The 15-bit PRBS register is loaded with the sequence 100101010000000 after each 8-packet cycle. The inverted sync word marks the beginning of the randomized sequence.

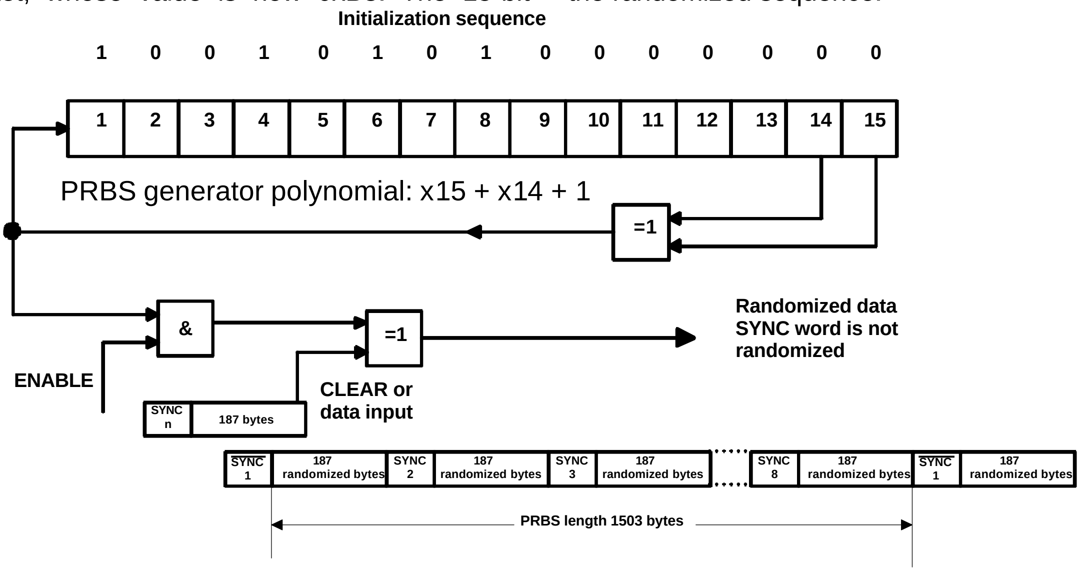


Fig. 2.3 Sync 1 inversion and randomization

This TS processing step is identical for the three DVB systems, cf Part 3 "DVB-S" and Part 4 "DVB-T".

Sync word inversion and randomization

PRBS polynomial	$x^{15} + x^{14} + 1$
Initialization of PRBS register	100101010000000
Length of polynomial	1503 bytes
Length of randomized sequence	1503 bytes + inverted sync byte = 8 TS packets
Sync word	0x47
Bitwise inverted sync word	0xB8

Table 2.1

2.1.3 Reed-Solomon (RS) Forward Error Correction (FEC)

Following randomization, 16 error control bytes are appended to the TS packets, which are thus enlarged to 204 bytes.

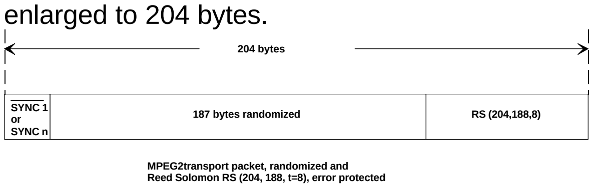


Fig. 2.4 204, 188, t = 8 Reed-Solomon error control coding

Using Reed-Solomon (204, 188, t = 8) error control coding, up to eight errored bytes per TS packet can be corrected in the receiver/decoder. Moreover, a bit-error ratio (BER) of $2*10^{-4}$ can be corrected to obtain a quasi-error-free (QEF) data stream with residual BER of $<1*10^{-11}$.

Note:
The BER of $2*10^{-4}$ is used as a reference in virtually all quality measurements in digital TV (DTV).

This TS processing step, too, is identical for the three DVB systems, cf Part 3 "DVB-S" and Part 4 "DVB-T".

RS FEC

TS packet length	188 + 16 = 204 bytes
Correction	Up to 8 errored bytes per TS packet
Corrective capacity	BER of $2*10^{-4}$ to $1*10^{-11}$

Table 2.2 Reed-Solomon forward error correction

2.1.4 Interleaver

Transmission errors usually corrupt not only a single bit but many bits following it in the data stream. Consequently the designation error burst, which may comprise up to several hundred bits. The bits may even be deleted. The Reed-Solomon correction capacity of eight bytes per TS packet is insufficient in such cases. So an interleaver is used to insert at least 12 bytes (the convolutional interleaver has 12 paths, see Fig. 2.5) and at most 2244 bytes from other TS packets between neighbouring bytes of a TS packet. This allows burst errors of max. 12 x 8 = 96 bytes to be corrected if only eight or fewer errored bytes per TS packet occur after the deinterleaver in the receiver/decoder.

Interleaver

Paths	I = 12
Memory depth of FIFOs	M = 17 (= 204 / I) bytes
Sync bytes	Always via path 0

Table 2.3

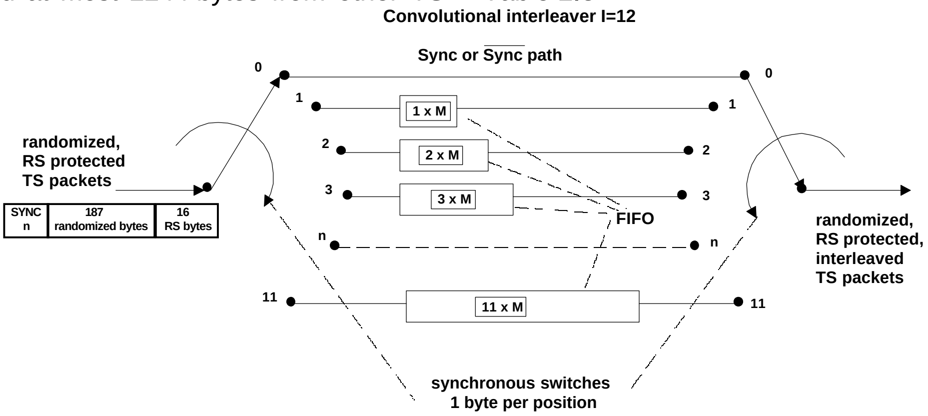


Fig. 2.5 Convolutional interleaver

This TS processing step, too, is identical for the three DVB systems, cf Part 3 "DVB-S" and Part 4 "DVB-T".

After the convolutional interleaver, TS processing is different for the different DVB standards.

2.1.5 Byte-to-Symbol Mapping in DVB-C

So far, we have been discussing only bits and bytes. To transmit the 8 bit wide TS data using quadrature amplitude modulation (QAM) as in a DVB-C cable network, the data has to be converted to symbols.
Symbols are cos roll-off filtered analog pulses with a spectrum approximating a sin (x)/x function and 2^n amplitude levels for the I and the Q component. The resulting signals, therefore, have a defined flat spectrum (see Fig. 2.1, right, and section 2.3 "Symbol Rates and 2^m QAM Spectrum in Cable Transmission").

"n" denotes the number of bits for each component. There is, consequently, a number of 2^{2*n} possible states in the constellation diagram.
2^m denotes the order of QAM, where m = 2∗n.

Example:

For $2^3 = 8$ different amplitudes for I and Q
the order of QAM is
$$2^{2*3} = 2^6 = 64\text{QAM}$$

The eight amplitudes are represented by three bits each for I and Q.

A symbol consists of a pair of I and Q values arranged orthogonally through modulation. "I" stands for the inphase and "Q" for the quadrature component. In the case of 64QAM, therefore, each symbol carries six bits.

Order of QAM 2^m		m bits per symbol
4	QAM	2
16	**QAM**	**4**
32	QAM	5
64	**QAM**	**6**
128	QAM	7
256	**QAM**	**8**

Table 2.4

The most common modes are 16QAM, 64QAM and 256QAM. 32QAM and 128QAM offer no significant advantages over 64QAM or 256QAM and are therefore hardly ever used.
Fig. 2.6 illustrates the conversion of bytes to 6-bit symbols:

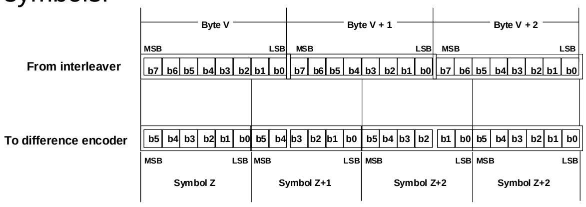


Fig. 2.6 Conversion of bytes to symbols

2.1.6 QAM Constellation Diagrams

The diagrams below show the allocation of the bits of the I/Q value pairs to the points of the constellation diagram. 128QAM and 256QAM are not represented here for reasons of space.

16QAM

Q

1011	1001	0010	0011	
1010	1000	0000	0001	I
1101	1100	0100	0110	
1111	1110	0101	0111	

32QAM

Q

	10111	10011	00110	00010		
10010	10101	10001	00100	00101	00111	
10110	10100	10000	00000	00001	00011	I
11011	11001	11000	01000	01100	01110	
11111	11101	11100	01001	01101	01010	
	11010	11110	01011	01111		

64QAM

Q

101100	101110	100110	100100	001000	001001	001101	001100	
101101	101111	100111	100101	001010	001011	001111	001110	
101001	101011	100011	100001	000010	000011	000111	000110	
101000	101010	100010	100000	000000	000001	000101	000100	I
110100	110101	110001	110000	010000	010010	011010	011000	
110110	110111	110011	110010	010001	010011	011011	011001	
111110	111111	111011	111010	010101	010111	011111	011101	
111100	111101	111001	111000	010100	010110	011110	011100	

2.1.7 Differential Coding of MSBs

The MSBs I_K and Q_K of the consecutive symbols A and B are differentially coded at the transmitter end to enable decoding independently of the quadrant's absolute position. This is necessary because the phase information is lost due to carrier suppression during modulation. The MSBs I_K and Q_K are buffered during one symbol clock after differential coding. The original position of the quadrant is obtained from the comparison of I_K and I_{K-1} and Q_K and Q_{K-1}.

Truth table for differential coding [1])

Inputs		Outputs		Rotation
A_K	B_K	I_K	Q_K	
0	0	I_{K-1}	Q_{K-1}	0°
0	1	$\overline{Q_{K-1}}$	$\overline{I_{K-1}}$	+90°
1	0	Q_{K-1}	$\overline{I_{K-1}}$	-90°
1	1	$\overline{I_{K-1}}$	$\overline{Q_{K-1}}$	180°

[1]) From: U. Reimers: "Digital Video Broadcasting"
Table 2.5

2.2 Bandwidth

The symbols are analog pulses similar to a sinx/x function with a 3 dB bandwidth in Hz corresponding to half the symbol rate S in symbols/s. After double-sideband modulation, the signal bandwidth is obtained as the symbol rate in Hz. The bit rate R in Mbit/s of the TS packets can be converted to the symbol rate of a 2^m QAM system by the following equation:

$$\mathbf{S = R * \frac{204}{188} * \frac{1}{m} \ Msymb/s} \qquad \text{Equation 2.1}$$

The factor 204/188 takes into account Reed-Solomon error control coding.
In cable transmission, the bit rate

R = 38.1529 Mbit/s

is frequently used. This results in a Nyquist bandwidth f_N of

f_N = S = 6.900 MHz

for the 64QAM symbols.

2.3 Symbol Rates and 2^m QAM Spectrum in Cable Transmission

The European Standard EN 300 429 defines the tolerances of the DVB-C spectrum as follows:

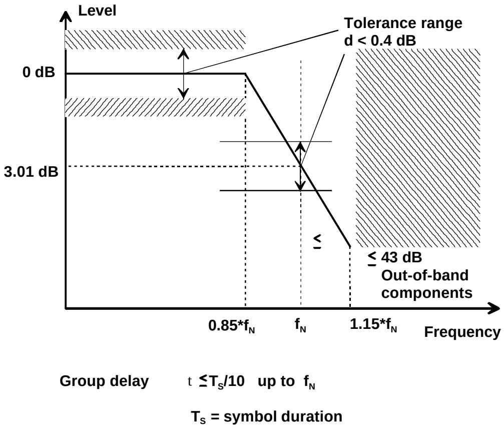


Fig. 2.7 DVB-C spectrum

The symbols shaped by $\sqrt{\cos}$ filters in the transmitter and the receiver yield a spectrum similar to a sin x/x function with a constant amplitude- and group-delay frequency response. $\sqrt{\cos}$ filtering in the transmitter and the receiver produces spectrum edges as shown in Fig. 2.9 "Spectrum obtained by cos roll-off filtering". The degree of approximation to an ideal sinx/x spectrum depends on the selected roll-off factor. The smaller this factor, the better the approximation to an ideal sinx/x spectrum.
Plotting the level along a linear scale, the following theoretical spectrum will be obtained at the output of a DVB-C or DVB-S modulator:

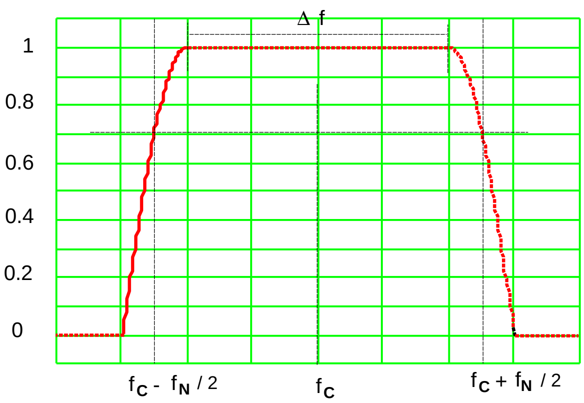


Fig. 2.8 Spectrum obtained by $\sqrt{\cos}$ filtering

Clearly discernible are the steep edges at low levels at the left and right boundaries of the spectrum produced by $\sqrt{\cos}$ filtering. Attenuation at the Nyquist frequencies $f_C \pm f_N/2$ is 3 dB. The roll-off factor r is derived from the ratio of the Nyquist bandwidth to the flat "rooftop" of the spectrum.

$$r = \frac{\Delta f}{f_N} - 1$$

$\sqrt{\cos}$ filtering in the transmitter and the receiver yields spectrum edges with a cos roll-off characteristic.

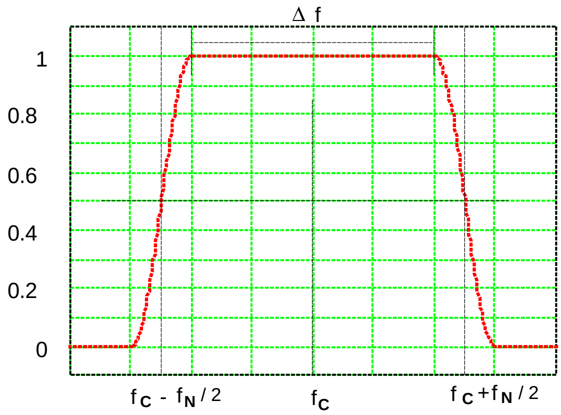


Fig. 2.9 Spectrum obtained by cos roll-off filtering

It can be seen that with cos filtering the edges at low levels at the left and right boundaries of the spectrum are flatter and rounder. Attenuation at the Nyquist frequencies $f_C \pm f_N/2$ is now 6 dB.

To illustrate this, Fig. 2.10 shows the $\sqrt{\cos}$ and cos filter edges in greater detail:

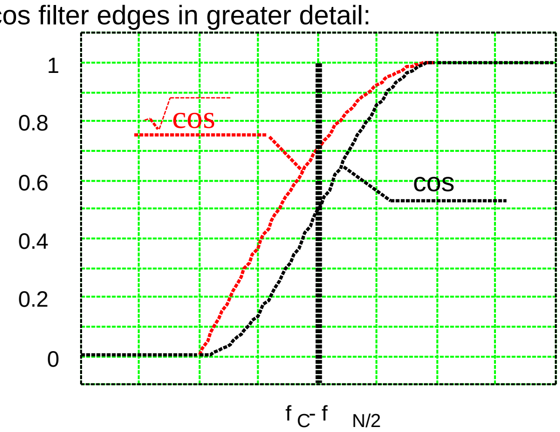


Fig. 2.10 Edges obtained with $\sqrt{\cos}$ roll-off and cos roll-off filtering

Combined filtering in the transmitter and the receiver serves two purposes:

1. optimal approximation to an ideal sinx/x spectrum and thus a flat useful spectrum,
2. signal filtering in the receiver and thus useful channel selection

The required bandwidth for the transmission channel (B_{Ch}) is derived from the symbol rate and the roll-off factor as follows:

$$\mathbf{B_{Ch} = S * (1 + r)\ MHz}$$

In a cable network, the VHF, UHF and special channels are already allocated defined bandwidths (B_{Ch}) of 7 MHz or 8 MHz . The 2^m QAM spectra should, with the required roll-off filtering, fit into these channels. The roll-off factor for cable transmission is r = 0.15.
An 8 MHz channel, therefore, allows the highest symbol rate of theoretically

$$\mathbf{S_{max} = \frac{B_{Ch}}{1 + r} = \frac{8\ MHz}{1.15} = 6.9565\ Msymb / s} \qquad \text{Equation 2.2}$$

without any inherent additional distortion.
The highest theoretical symbol rate for a 7 MHz channel is

$$\mathbf{S_{max} = \frac{7}{1.15} = 6.0870\ Msymb / s}$$

The symbol rate most frequently used in the 8 MHz UHF channel is 6.9 Msymb/s, as stated above, which leaves a small extra margin of bandwidth.

If a DVB-S signal is received in a cable head-end and the demodulated transport stream is to be fed to the DVB-C cable network without any modification (except for the PSI/SI tables being adapted – see "Digital TV Rigs and Recipes" – Part 1 "ITU-R BT.601/656 and MPEG2"), the symbol rate is calculated as follows:

A frequently used symbol rate in DVB-S is
$S_{satellite}$ = 27.5 Msymb/s

From this results the data rate of:

$$R = S * \frac{188}{204} * 2 * C\ \ Mbit / s \qquad \text{Equation 2.3}$$

Taking into account the second forward error correction incorporated in DVB-S (code rate C = 3/4), a second preferred symbol rate is obtained for 64QAM DVB-C by means of equation 2.3:

$$S_{cable} = 6.875\ Msymb/s$$

2.4 DVB-C Channel Frequencies

For a 64QAM signal transmitted in a cable network with 8 MHz ITU UHF channel spacing, the carrier frequencies of the digital signal are shifted upwards by 2.85 MHz relative to the analog signal. This is illustrated by Fig. 2.11, which shows the frequency scheme of an analog channel against that of a digital channel.

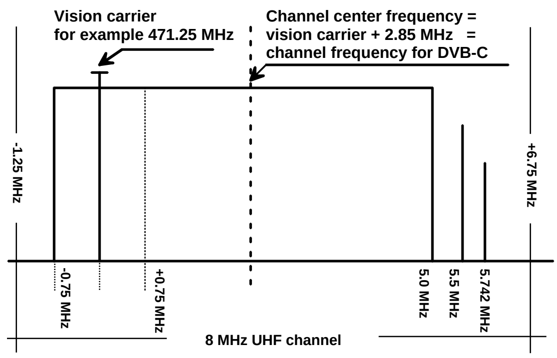


Fig. 2.11 Channel frequency scheme

Modern modulators calculate the baseband signal and convert it directly to the RF. If an intermediate frequency is used in DVB-C at all, it is usually 36 MHz, although the calculated center frequency of an 8 MHz channel is actually 38.9 MHz – 2.85 = 36.05 MHz.

2.5 DVB-C Key Data

2^m QAM mode	16 64 256	m = 4 m = 6 m = 8
Symbol form		Similar to $\frac{\sin x}{x}$ cos roll-off filtered
Roll-off factor		0.15
Most frequently used bit rates R	Mbit/s	38.152941 38.014706
Symbol rate S	Msymb/s	$S = R * \frac{204}{188} * \frac{1}{m}$
Most frequently used symbol rates S	Msymb/s	6.900 6.875

Table 2.6

2.6 Measurements in DVB-C Cable Networks

An MPEG2 multiplexer or MPEG2 generator supplies video, audio and other data in the form of TS (transport stream) packets with a defined data rate R. In the German cable network, for example, the data rate for 8 MHz channel bandwidth and 64QAM is

$$R = 38.1528 \text{ Mbit/s}$$

The corresponding symbol rate is 6.9 Msymb/s. In the 64QAM mode, each symbol carries six bits of the MPEG2 data stream, i.e. three bits for the I and three bits for the Q component.

TV Test Transmitter SFQ generates from the input transport stream the test signals for
DVB-C (digital video broadcasting – cable),
DVB-S (digital video broadcasting – satellite),
DVB-T (digital video broadcasting – terrestrial),
ATSC with 8VSB (advanced television systems committee with eight-level trellis-coded vestigial sideband)
and the American cable standard
ITU-T Rec. J.83/B

The TV Test Transmitter SFL was designed specially for applications in production. It comes in five models tailored to the above standards:

SFL-C	for DVB-C
SFL-S	for DVB-S
SFL-T	for DVB-T
SFL-V	for ATSC/8VSB
SFL-J	for ITU-T Rec. J.83/B

To optimally adapt to the TS signal parameters, TV Test Transmitters SFQ and SFL measure the data rate of the input transport stream and convert it to the current symbol rate as appropriate for the modulation mode used, or the data rate is calculated from a predefined symbol rate. Then the data is modulated in compliance with the DTV (digital television) standard in question and transposed to the RF.
For measurements to the DTV standards, SFQ and SFL modulate the TS data stream strictly in accordance with DTV specifications. In addition, defined modulation errors can be introduced into the ideal signal, so creating reproducible signal degradation. Such stress signals are indispensable in DTV receiver tests to determine system limits.

TV Test Transmitter SFQ

Condensed data

Frequency range	0.3 MHz to 3.3 GHz
Level range	-99.9 dBm to +4 dBm
MPEG2 inputs	ASI SPI TS PARALLEL
Error simulation	
I/Q amplitude imbalance	±25 %
I/Q phase error	±10 °
Residual carrier	0 % to 50 %
Special functions	scrambler, Reed-Solomon, all interleavers can be switched off
DVB-C	
Modulation	16QAM, 32QAM, 64QAM, 128QAM, 256QAM
DVB-S	
Modulation	QPSK
Code rate	1/2, 2/3, 3/4, 5/6, 7/8
DVB-T	
Modulation	QPSK,16QAM, 64QAM, non-hierarchical, hierarchical
FFT mode	8k and 2k
Bandwidth	6 MHz, 7 MHz, 8 MHz
Puncturing	1/2, 2/3, 3/4, 5/6, 7/8
ATSC	
Modulation	8VSB
Bandwidth	6 MHz
Data rate	19.392658 Mbit/s ±10 %
Symbol rate	10.762 Msymbol/s ±10 %
Internal test signals	null TS packets null PRBS packets PRBS (2^{23} -1 and 2^{15} -1)
Options	Fading simulator, noise generator, input interface, BER measurement

TV Test Transmitter SFL-C

Condensed data

Frequency range	5 MHz to 1.1 GHz
Level range	-140 dBm to 0 dBm
MPEG2 inputs	ASI SPI TS PARALLEL
Error simulation I/Q amplitude imbalance I/Q quadrature offset (phase error) Residual carrier	 ±25 % ±10 ° 0 % to 50 %
Special functions	scrambler, Reed-Solomon, all interleavers can be switched off
Modulation	16QAM, 32QAM, 64QAM, 128QAM, 256QAM
Internal test signals	null TS packets null PRBS packets PRBS (2^{23} -1 and 2^{15} -1)
Option	Noise Generator SFL-N on request

2.6.1 Important Requirements To Be Met By DVB-C Test Transmitters

This section deals in particular with the requirements to be met by TV Test Transmitter SFQ in DVB-C measurements. The statements made below in most cases also apply to TV Test Transmitter SFL-C.

Test transmitters are needed to simulate potential errors in the DTV modulator and distortions in the transmission channel. From the two types of signal degradation it is determined to what extent a receiver still operates correctly when non-standard-conforming signals are applied. For tests on a DVB-C set-top box (STB), for example, the test transmitter should be capable of producing defined deviations from the standard in addition to the common parameter variations of, for example, Tx frequency or output level.

STBs have to undergo function tests in at least three frequency ranges:

- in the lowest RF channel,
- in a middle RF channel, and
- in the highest RF channel.

TV Test Transmitter SFQ is capable of setting any frequency between 0.3 MHz and 3.3 GHz, thus offering a frequency range by far exceeding that of DVB-C. Frequencies of interest can also be stored in the form of a channel table.

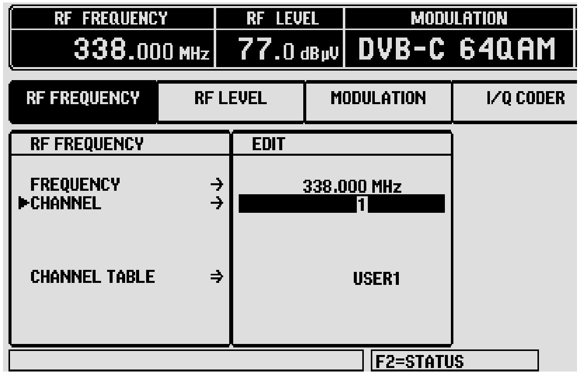


Fig. 2.12 Frequency setting on SFQ

Another test is for verifying error-free reception at a minimum level of typically -70 dBm. SFQ features a setting range between +6 dBm and -99 dBm, which in any case includes the required minimum level.

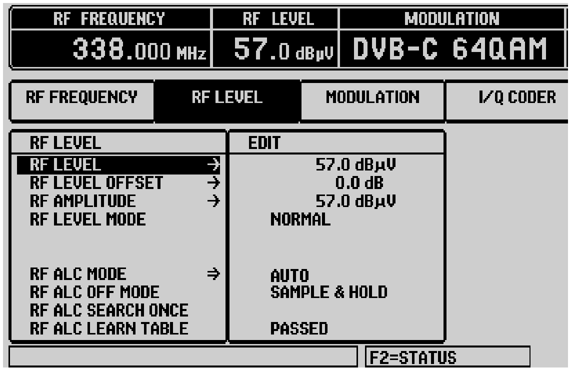


Fig. 2.13 Level setting on SFQ

In the DVB-C modulation mode, modulator- and transmission-specific settings can be made, including noise superposition and the generation of fading profiles. SFQ is thus capable of simulating all signal variations and degradations occurring in a real DVB-C system. The degraded signal generated by the "stress transmitter" SFQ is used for testing the STB's susceptibility to errors and interference.

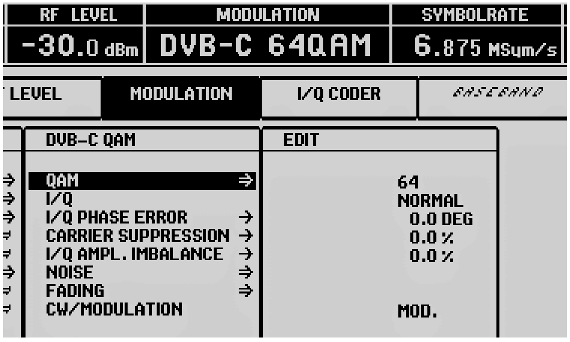


Fig. 2.14 Setting of modulator- and transmission-specific parameters in DVB-C mode

Detailed information on the above parameters will be found in section 2.7 "QAM Parameters". Further important settings for the DVB-C system can be made in the "I/Q CODER" menu. Here the TS parameters for the modulator can be selected.

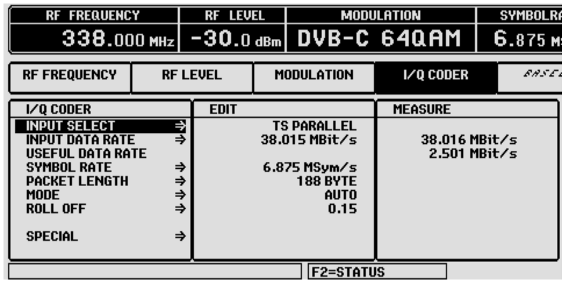


Fig. 2.15 DVB-C settings in I/Q CODER menu

2.6.2 Power Measurement

Measurement of the output power of a DVB transmitter is not as simple as that of an analog transmitter. In the analog world, the actual power of the sync pulse floor is measured at a sufficiently large bandwidth and displayed as the actual sync pulse peak power. A DVB signal, by contrast, is characterized by a constant power density across the Nyquist bandwidth (see Fig. 2.16), which results from energy dispersal and symbol shaping in the DVB modulator. Consequently, only the total power in a DVB channel is measured.

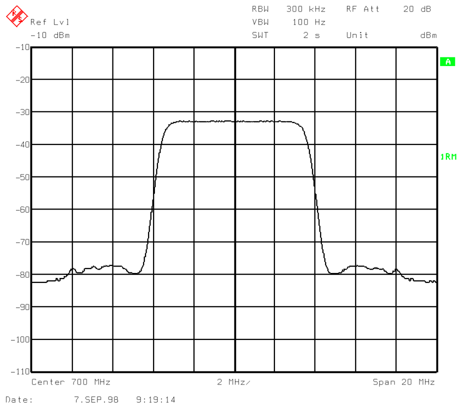


Fig. 2.16 Constant power density in DTV channel

Three methods of measuring DVB signal power are known to date:

2.6.2.1 Mean Power Measurement with Power Meter NRVS and Thermal Power Sensor

Condensed data of Power Meter NRVS with Thermal Power Sensor NRV-Z51

NRVS	
Frequency range	DC to 40 GHz
Level range	100 pW to 30 W (depending on sensor)
Readout	
Absolute	W, dBm, V, dBmV
Relative	dB, % W or % V, referred to a stored reference value
Remote control	IEC 625-2/IEEE 488.2 interface
Max. input voltage	50 V
NRV-Z51	
Power sensor	thermal
Impedance	50 O
Connector	N type
Frequency range	DC to 18 GHz
Level range	1 µW to 100 mW

Thermal power sensors supply the most accurate results if there is only one DVB channel in the overall spectrum.

Plus, they can easily be calibrated by performing a highly accurate DC voltage measurement, provided the sensor is capable of DC measurement. To measure the DVB power, however, the DVB signal should be absolutely DC-free.

2.6.2.2 Mean Power Measurement with Spectrum Analyzer FSEx, FSP or FSU

If a conventional spectrum analyzer is used to measure power, its maximum measurement bandwidth will not be sufficient for an 8 MHz QAM cable channel. State-of-the-art spectrum analyzers, by contrast, allow broadband power measurements between two user-selected frequencies. The large Nyquist bandwidth of DVB transmission channels poses therefore no problems. Moreover, all kinds of amplitude frequency response that may occur in a cable network are taken into account, whether these are just departures from flat or caused by echoes. Based on this principle, the Rohde & Schwarz Spectrum Analyzers FSEx, FSP and FSU measure mean power in a DVB channel with an accuracy of ≤ 1.5 dB.

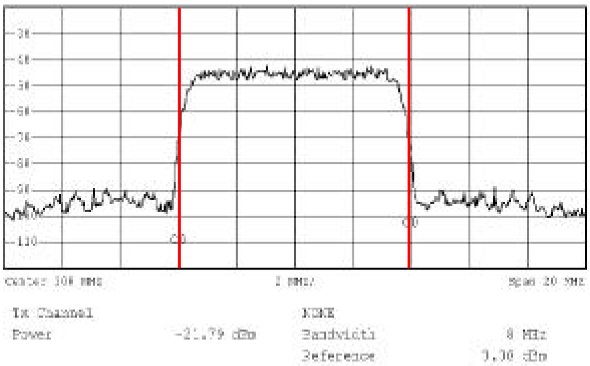


Fig. 2.17 Power measurement with frequency cursors

A frequency cursor is placed on the lower and another one on the upper frequency of the DVB-C channel. The spectrum analyzer calculates the power for the band between the cursors. The method provides sufficient accuracy as long as the channels are sufficiently spaced in frequency and thus clearly separated. Given the normal DVB-C channel assignment, i.e. without guard channels, results may be falsified however.
It is therefore recommended that power measurements be performed automatically by means of a test receiver as described in section 2.6.2.3.

SPECTRUM ANALYSER FSP

Condensed data of FSP

Frequency range (FSP3/7/13/30)	9 kHz to 3/7/13/30 GHz
Amplitude measurement range Amplitude display range	-140 dBm to +30 dBm 10 dB to 200 dB in steps of 10 dB, linear
Amplitude measurement error	<0.5 dB up to 3 GHz, <2.0 dB from 3 GHz to 13 GHz, <2.5 dB from 13 GHz to 20 GHz
Resolution bandwidth	1 Hz to 30 kHz (FFT filters), 10 Hz to 10 MHz in 1, 3 sequence; EMI bandwidths: 200 Hz, 9 kHz, 120 kHz
Detectors	Max Peak, Min Peak, Auto Peak, Quasi Peak, Sample, Average, RMS
Display	21 cm (8.4") TFT LC colour display, VGA resolution
Remote control	IEC 625-2/IEEE 488.2 (SCPI 1997.0) or RS232C
Dimensions (W x H x D) Weight (FSP 3/7/13/30)	412 mm x 197 mm x 417 mm 10.5/11.3/12/12 kg

SPECTRUM ANALYSER FSEx

Condensed data of FSEA/FSEB

Frequency range	20 Hz/9 kHz to 3.5 GHz/7 GHz
Amplitude measurement range	-155/-145 dBm to +30 dBm
Amplitude display range	10 dB to 200 dB in steps of 10 dB
Amplitude measurement error	<1 dB up to 1 GHz, <1.5 dB above 1 GHz
Resolution bandwidth	1 Hz/10 Hz to 10 MHz in 1, 2, 3, 5 sequence
Calibration	amplitude, bandwidth
Display	24 cm (9.5") TFT LC colour or monochrome display, VGA resolution
Remote control	IEC 625-2/IEEE 488.2 (SCPI 1997.0) or RS232C

Condensed data of EFA models 60 and 63

Frequency range	45 MHz to 1000 MHz, 5 MHz to 1000 MHz with RF Preselection option (EFA-B3)
Input level range	-47 dBm to +14 dBm, -84 dBm to +14 dBm (low noise) with RF Preselection option (EFA-B3)
Bandwidth	2/6/7/8 MHz
Demodulation	4/16/32/64/128/256QAM
BER analysis	before and after Reed Solomon
Measurement functions/ graphic display	level, BER, MER, carrier suppression, quadrature error, phase jitter, amplitude imbalance, constellation diagram, FFT spectrum
Output signals	MPEG2 TS: ASI, SPI
Options	MPEG2 decoder, RF preselection

2.6.2.3 Mean Power Measurement with TV Test Receiver EFA Model 60 or 63

EFA displays all important signal parameters in a status line. The righthand upper status field indicates mean power in various switchable units.

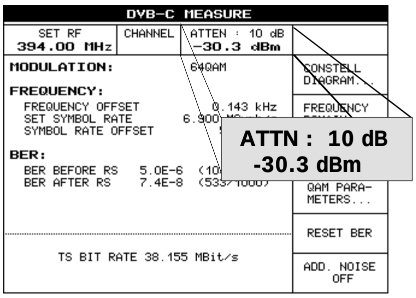


Fig. 2.18 Power measurement with TV Test Receiver EFA model 60 or 63

EFA Model 60/63

Investigations on channel spectra revealing pronounced frequency response have shown the high accuracy of the displayed level. A comparison of the levels obtained with EFA and NRVS with thermal power sensor yielded a maximum difference of less than 1 dB – the comparison being performed with various EFA models at different channel frequencies and on different, non-flat spectra. Thanks to EFA's built-in SAW filters of 6 MHz, 7 MHz and 8 MHz bandwidth for the IF range, highly accurate results are obtained even if the adjacent channels are occupied.

The following example illustrates a measurement performed in the above comparison.

An echo with 250 ns delay and 2 dB attenuation is generated by means of TV Test Transmitter SFQ with Fading Simulator option. This echo, plus the signal sent via the direct path, produce the channel spectrum shown in Fig. 2.19 with pronounced dips resulting from frequency response.

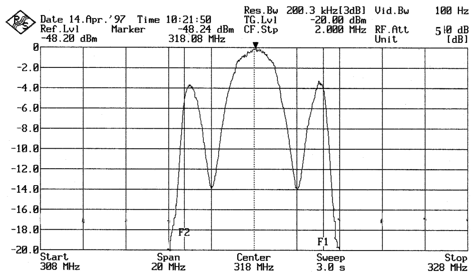


Fig. 2.19 Fading spectrum

Table 2.7 gives the results where the maximum difference between EFA and NRVS has occurred.

Level measurement with	NRVS	EFA
	-33.79 dBm	-33.0 dBm

Table 2.7 Comparison of results

Note:
The results of the above level measurements are specified in detail in Application Note 7MGAN15E (see also Annex 4A to Part 4 (DVB-T) of the "Digital TV Rigs and Recipes").
The measurements described there were made with EFA models 20 and 23. The successor models 60 and 63 feature even higher level accuracy, yielding a typical maximum difference of 0.5 dB.

2.6.3 Bit Error Ratio (BER)

Digital TV has a clearly defined range in which it operates correctly. Transition to total failure of a DVB-C system is abrupt. This is due to Reed-Solomon forward error correction, which is capable of correcting transport stream data to yield a nearly error-free data stream (BER < $1*10^{-11}$), but only for bit error ratios of 2×10^{-4} or better. The sources of the errors determining the bit error ratio are known. A distinction is made between errors originating from the DVB modulator/transmitter and errors occurring during transmission.

The following errors occur in the modulator/ transmitter:

- different amplitudes of the I and Q components,
- phase between I and Q axis deviating from 90 °,
- phase jitter generated in the modulator,
- insufficient carrier suppression in DVB modulation,
- amplitude and phase frequency response, distorting the I and Q pulses being shaped during signal filtering, and
- noise generated in the modulator and superimposed on the QAM signals.

Amplitude and phase response are aggravated during transmission by:

- nonlinearity of the line amplifiers in the cable networks, causing distortion of the DVB-C QAM signal,
- intermodulation with adjacent channels degrading signal quality,
- interference and noise superimposed on the useful signal, and
- reflection.

Whereas the errors produced outside the modulator can be simulated by means of auxiliary equipment, the distortion introduced by the modulator itself can be generated only with a professional test receiver. Here, TV Test Transmitter SFQ comes into its own as a stress transmitter. It allows defined errors to be set for each parameter to the extent of complete failure of the digital TV system.

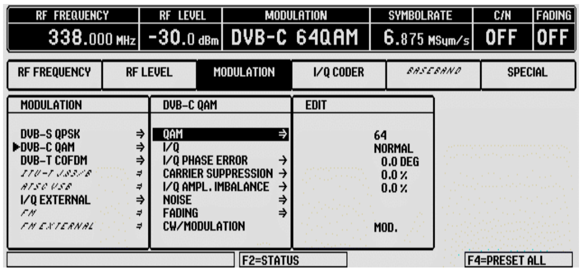
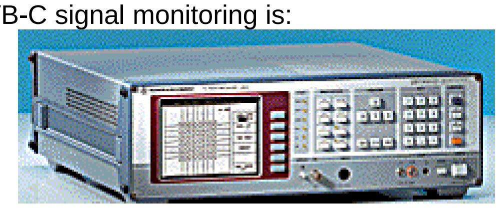


Fig. 2.20 SFQ menu for setting QAM parameters

But not only TV Test Transmitter SFQ is indispensable for checking the proper operation of a DVB system. After transmission of the DVB-C signal via the cable network, a test receiver is needed to monitor the digital TV signal received.

The solution offered by Rohde & Schwarz for DVB-C signal monitoring is:



TV Test Receiver EFA model 60 or 63

The most important parameter at the receiver end – apart from the channel center frequency and the level of the received DVB-C signal – is the bit error ratio (BER). To measure this parameter, the data before and after forward error correction (RS FEC) has to be compared at bit level. This comparison supplies accurate results to a BER of about $1*10^{-3}$, since up to this value forward error correction is capable of reconstructing an interpretable data stream.

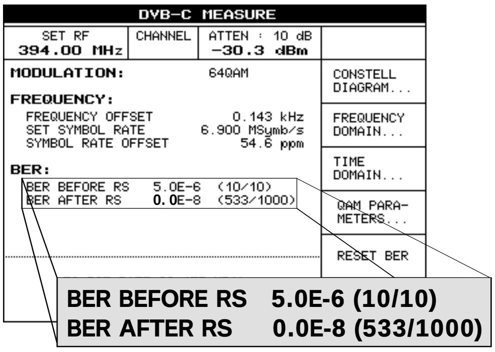


Fig. 2.21 QAM measurement menu: BER measurement

A defined BER can be generated by means of a noise generator with selectable bandwidth and level. The theoretical BER as a function of the signal-to-noise (S/N) ratio is described by calculated graphs for the four QAM modes.

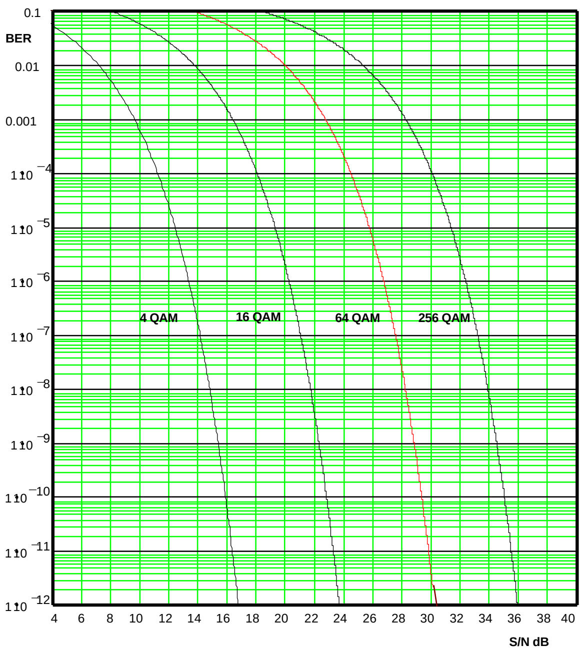


Fig. 2.22 Theoretical BER(S/N) for the four QAM modes

TV Test Receiver EFA and TV Transmitter SFQ both have integrated noise generators (optional in the case of SFQ).
The curves being very steep in the range BER $\leq 2*10^{-4}$, which is the reference value in all measurements connected with BER, the noise level can be determined very accurately.

This is done either using the method described in Application Note 7BM03_2E *(see Annex 4C to Part 4 (DVB-T) of the "Digital TV Rigs and Recipes")*, or by a direct measurement with TV Test Receiver EFA.
7BM03_2E also explains C/N to S/N conversion.

The high measurement and display accuracy offered by TV Test Receiver EFA ensures minimum deviation of measured values from real values also for the S/N ratio. To determine this ratio, the professional instrument makes use of the statistical noise distribution.

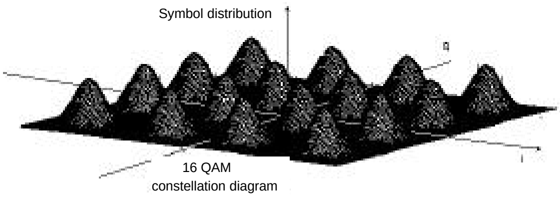


Fig. 2.23 Symbol distribution in a 16QAM constellation diagram

Each symbol cloud in a constellation diagram carries superimposed noise distributed according to statistical laws. QAM parameters can thus be calculated accurately to at least two decimal places provided that a sufficiently large number of symbols is evaluated per unit of time.

Before measurements are started, a synchronization process takes place in TV Test Receiver EFA: the receiver locks to the RF carrier, detects the symbol rate and synchronizes to it, the adaptive equalizer corrects amplitude and phase response, and the transport stream frame is identified by means of the sync byte. EFA indicates the progress of synchronization so that the operator knows when synchronization is completed and valid results are output.

For realtime monitoring systems, one measurement per second is sufficient. During this time, TV Test Receiver EFA calculates the parameters required by ETR290 Measurement Guidelines for DVB Systems based on about 70 000 symbols. This means that about 1100 symbols per second are available for each symbol cloud of the 64QAM constellation diagram, which is indispensable to satisfy the stringent demands existing for this measurement.

2.7 QAM Parameters

To explain measurement of the QAM parameters, the constellation diagram has to be discussed first. The diagram is divided in 2^m (m = 2 to 8) decision fields of equal size. Each symbol in these fields carries m bits as described in section 2.1.5. Noise superimposed during transmission causes the formation of symbol clouds. If these clouds are located within a decision field, the demodulator can reconstruct the original bits.
To ensure maximum accuracy in processing the symbols within the decision fields, the I and Q components are digitized, i.e. A/D-converted, immediately after demodulation.

For QAM parameter measurement, the digitized center points of the I/Q symbol clouds are connected by horizontal and vertical regression lines (see Fig. 2.24). Based on these lines, the following QAM parameters can be calculated: I/Q IMBALANCE, I/Q QUADRATURE ERROR and CARRIER SUPPRESSION. The SNR (signal-to-noise ratio) and PHASE JITTER parameters are calculated from the symbol clouds themselves.
The QAM parameters are described in the following sections.

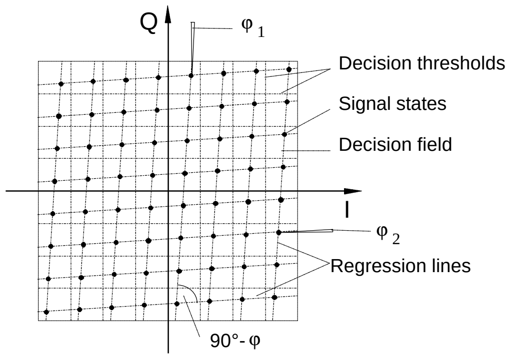


Fig. 2.24 64QAM constellation diagram

2.7.1 Decision Fields

In a QAM constellation diagram, the ideal status of a symbol (made up of a pair of I and Q values) is represented by the center point of the decision field. This ideal constellation is, however, never reached after demodulation and A/D conversion, because of inaccuracies in the QAM modulator, quantization errors in A/D and D/A conversion, and the superposition of noise during transmission.

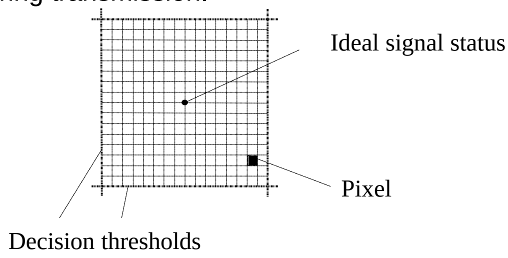


Fig. 2.25 Decision field after A/D conversion

After A/D conversion, the decision field shows all possible digital states, which are referred to as pixels in this context. The center of the decision field is formed by the point where the corners of the four middle pixels adjoin. The effect of digitization, i.e. the division into discrete pixels, is cancelled out by superimposed noise, which is always present and has Gaussian distribution, so that measurement accuracy is increased by several powers of ten.

2.7.2 Ideal 64QAM Constellation Diagram

If all QAM parameters have ideal values, an ideal 64QAM constellation diagram is obtained after demodulation.

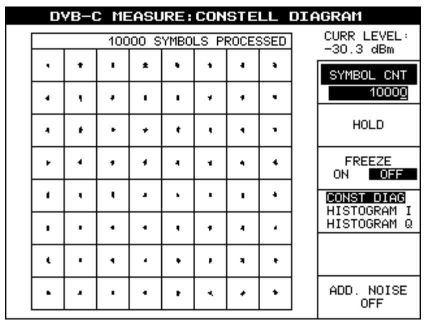


Fig. 2.26 Ideal 64QAM constellation diagram

An ideal QAM signal produces a constellation diagram in which all I/Q value pairs are located exactly at the center of the decision fields.
Four points representing I/Q value pairs form a square in each case.

For the diagram represented above, the absolute phases of the I and the Q component are not yet known because the phase information is not available due to carrier suppression. It cannot, therefore, be indicated in what direction the I and the Q axis point. Consequently, no coordinates are entered in the diagrams.

2.7.3 I/Q Imbalance

I/Q imbalance results from different amplification in the I and the Q path of the DVB-C modulator. This parameter is calculated by the following equation:

$$I/Q\ \text{IMBALANCE} = \left(\frac{v_2}{v_1} - 1\right) \cdot 100\%$$

where $v_1 = \min(v_I, v_Q)$ and $v_2 = \max(v_I, v_Q)$

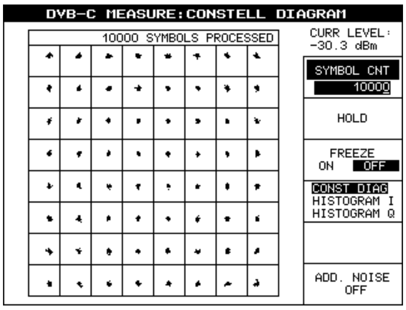


Fig. 2.27 64QAM constellation diagram with 10 % I/Q imbalance

A QAM signal with amplitude imbalance generates a constellation diagram with different spacing of the I/Q value pairs in the horizontal and the vertical direction: in the above example, the spacing is smaller in the horizontal direction. The I/Q value pairs are not located in the center of the decision fields.
Four points representing I/Q value pairs form a rectangle in each case.

2.8.4 I/Q Quadrature Error

If the I and the Q axis are not perpendicular to each other, an I/Q quadrature error is present. This parameter is calculated by the following equation (see also Fig. 2.24):

$$\varphi = \frac{180°}{p} \cdot \left| \overbrace{\arctan\left(\frac{v_Q}{v_I} \cdot \overline{a_Q}\right)}^{j_1} + \overbrace{\arctan\left(\frac{v_I}{v_Q} \cdot \overline{a_I}\right)}^{j_2} \right|$$

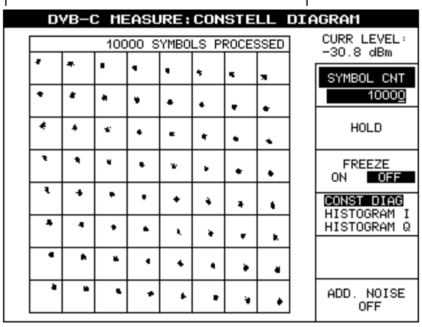


Fig. 2.28 64QAM constellation diagram with 8 ° I/Q quadrature error

A QAM signal with a phase error generates a constellation diagram in which the regression lines through the I/Q value pairs do not run parallel to the lines forming the decision thresholds. Four points representing I/Q value pairs form a rhombus in each case.

2.7.5 Carrier Suppression

DC voltage offset in the I and/or the Q path of the DVB-C modulator results in a residual carrier component. This parameter is calculated by the following equation (see also Fig. 2.24):

$$CS = -10 \cdot \lg\left(\frac{P_{rc}}{P_{sig}}\right)$$

P_{rc} = power of residual carrier
P_{sig} = power of DVB-C signal

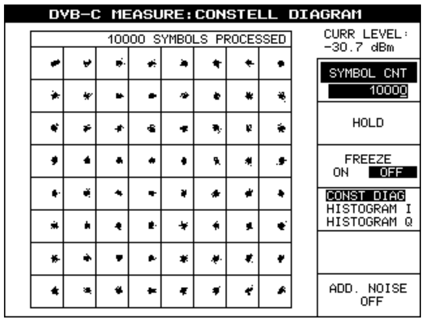


Fig. 2.29 64QAM constellation diagram with 24 dB carrier suppression

A QAM signal with insufficient carrier suppression generates a constellation diagram in which the I/Q value pairs are horizontally or vertically displaced (horizontally in the above example).
The I/Q value pairs are not located in the center of the decision fields. Four points representing I/Q value pairs form a square in each case.

2.7.6 Phase Jitter

In the presence of phase jitter, i.e. with unstable carrier phase, the constellation diagram does not stand still. It rotates back and forth about its center, depending on the jitter amplitude and spectrum.

This parameter is calculated by the following equation (see also Fig. 2.24):

$$PJ = \frac{180^\circ}{p} \cdot \arcsin\left(\frac{s_{PJ}}{\sqrt{2} \cdot \left(\sqrt{M} - 1 \right) \cdot d} \right)$$

$$s_{PJ} = \sqrt{s^2_{PJ+N} - s^2_N}$$

where M = 2^m
2d = width/height of decision fields
σ_{PJ} = standard deviation of symbol cloud examined, with noise component deducted

For the calculation, the symbol clouds in the four corners of the diagram are used because it is there where the maximum variation due to jitter occurs.

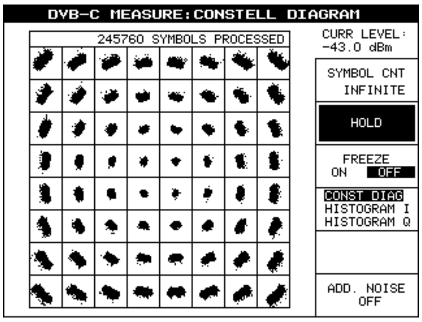


Fig. 2.30 64QAM constellation diagram with 2 ° phase jitter (rms)

A phase jitter of 2 ° (rms) results in a peak-to-peak jitter of 5.7 ° in the case of sinusoidal jitter.

A QAM signal with superimposed phase jitter generates a constellation diagram in which the I/Q value pairs appear as circular segments. The segments in the inner part of the diagram are shorter than those in the outer part; the jitter angle is constant. The center points of four segments form a square in each case.

2.7.7 Signal-To-Noise Ratio (SNR)

Noise is generated during any kind of signal processing or signal transmission and superimposed on the original signal. Noise is one of the key parameters in determining the quality of a signal or transmission path. The SNR is calculated from the distribution of the I/Q value pairs (symbols) within the decision fields. Only the four innermost decision fields of the constellation diagram are used in the calculation to minimize potential distortion of the SNR value by the influence of phase jitter.

In the case of the signal shown in Fig. 2.30, there is only minimal distortion of the SNR by phase jitter and other influences. If white noise is superimposed, which is normally the case during signal transmission, the I/Q value pairs have Gaussian (or normal) distribution.

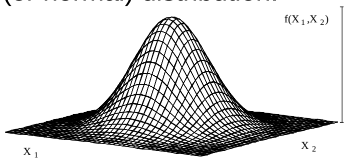


Fig. 2.31 Gaussian distribution of I/Q value pairs

For a DVB-C signal with 30 dB SNR, the following constellation diagram is obtained (with 50 000 symbols evaluated):

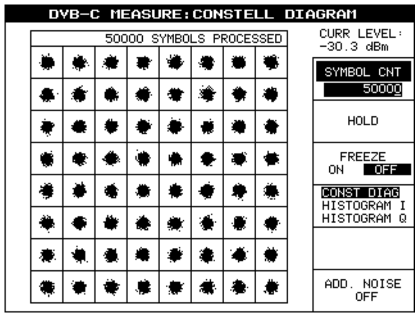


Fig. 2.32 64QAM constellation diagram for a signal with 30 dB SNR

A QAM signal with superimposed noise generates a constellation diagram with the I/Q value pairs in the form of symbol clouds. The center points of four clouds form a square in each case.

2.8 Modulation Error Ratio (MER)

The MER parameter encompasses all the parameters that can be determined by means of the constellation diagram. The MER is, therefore, the most important parameter to be monitored in a DVB system besides the BER. If the MER is within agreed tolerances, all other parameters are likewise within tolerances.

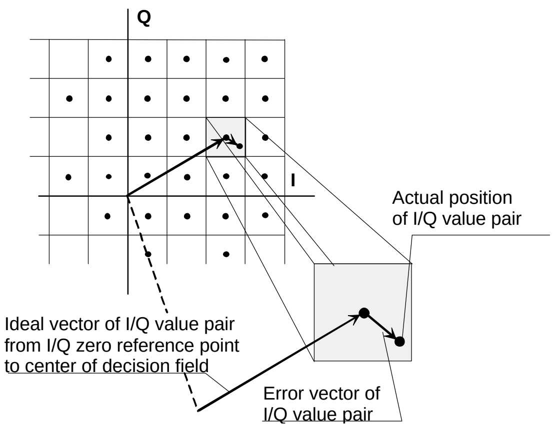


Fig. 2.33 Ideal vector and error vector used in calculating the MER sum parameter

To determine the MER, an error vector is calculated for each I/Q value pair. The length of this vector indicates the offset of the actual position of an I/Q value pair from the ideal position, i.e. the center of the decision field.
Of all error vectors calculated during one second, the sum of the squares is formed. The same is done with the ideal vectors of the decision fields. Then the ratio of the two sums is formed. This value is logarithmized, which yields the MER value in dB. The logarithmic ratio can also be expressed in percent.

The MER, which is defined by ETR290, is a parameter which provides very conclusive information and should therefore always be monitored. As to the MER, empirical data is available describing 64QAM system quality. The limit values stated in Table 2.8 can be used as guide values, although they mean no or only hardly perceptible signal degradation on the TV receiver:

MER Value		Quality	Remarks
% rms	dB		
MER < 1	MER > 40	Very good	Good modulator
1.5 < MER < 2.5	36.5 > MER > 32	Good	Value at output of cable headend
2.5 < MER < 4.0	32 > MER > 28	Normal operation	Servicing was carried out well
4.0 < MER < 5.0	28 > MER > 26	Satisfactory	Service staff should be ready to perform system check
MER > 5.0	MER < 26	Poor	Service staff should perform system check and correct errors immediately

Table 2.8 Limit values for 64QAM DVB-C

Example:
Only if the MER at the output of a cable headend (64QAM DVB-C) falls below 32 dB (2.5 % rms, see Table 2.8) is it necessary to measure the single parameters (see 2.7 "QAM Parameters") so that the cause of this condition can be determined.

2.9 Bit Error Ratio (BER) Measurement

DVB system margins can easily be determined by means of TV Test Transmitter SFQ. System margins will be indicated for each individual quality parameter by deteriorating them to a BER of $2*10^{-4}$, which is the critical limit for system failure. DVB Test Transmitter SFQ helps to find DVB system margins in the laboratory, test shop, in production, quality management and operation.

TV Test Transmitter SFQ for DVB-C, DVB-S, DVB-T, ATSC with 8VSB, and the American ITU-T Rec. J.83/B cable standard

If each DVB-C signal parameter is deteriorated to the point the 64QAM transmission system may fail (BER > $2*10^{-4}$), the following general limit values will be found:

Parameter	Value
I/Q imbalance	< 14.0 %
I/Q phase error	< 6.5 °
Carrier suppression	< 6.5 %
SNR	< 24 dB

Table 2.9 Limit values for 64QAM DVB-C

For a BER better than $1*10^{-3}$, QAM Test Receiver EFA can determine the quality parameters listed in Table 2.9, because up to this point an interpretable TS data stream is available due to forward error correction.
Experience has shown that good 64QAM modulators and converters, as used worldwide in DVB-C networks, should not exceed an MER of 1.0 % to 1.3 % rms. Plus, an MER significantly better, i.e. below, 1.5 % rms is not to be expected in public cable networks. The measurement menu below illustrates why this is so:

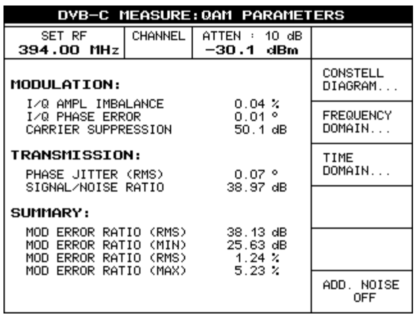


Fig. 2.34 Measurement menu for DVB-C

The good SNR of 38.97 dB alone means an MER of 1.13 % rms assuming that no other QAM parameters affect the MER. The remaining QAM parameters together, therefore, must not deteriorate the MER by more than 0.11 %. For a QAM test receiver this means:
the parameters are to be measured reliably and with very high accuracy. This is indispensable to determine the influence of the single parameters for a sum error as small as that.

The measurement method by which such a high accuracy is achieved is described in section 2.7 "QAM Parameters". The method relies, first, on a high number of symbols being processed per second and decision field and, second, on the phenomenon of noise (which is always present) and its statistical distribution, which allows the center points of the symbol clouds to be exactly determined.

2.10 Equivalent Noise Degradation (END) Measurement

The equivalent noise degradation (END) parameter denotes the deviation of the actual SNR from the theoretical SNR (SNR = 24 dB for 64QAM DVB-C, see Fig. 2.22) for a BER of $1*10^{-4}$.

Two measurements are required to determine the END to prevent that influences from the test equipment invalidate the results.

For the first measurement, the RF signal of a DVB-C modulator is applied to the RF input of TV Test Receiver EFA. EFA superimposes white noise on the signal by means of its internal noise generator, and measures the BER.

Example:
The BER of $1*10^{-4}$ is reached at C/N_1 = 24.8 dB (displayed in the ADD. NOISE field in the menu below). The theoretical SNR for the BER of $1*10^{-4}$ is 24.4 dB. The SNR is converted to C/N as follows:

C/N = SNR + 0.166 = 24.966 dB. The difference of roughly 0.57 dB constitutes the END of the measurement system, in this case consisting of TV Test Transmitter SFQ and TV Test Receiver EFA. Assuming that this value is equally distributed among the two instruments, each unit has an END of only 0.285 dB, which is a very good figure.

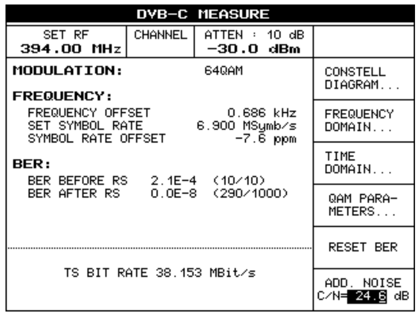


Fig. 2.35 ADD. NOISE on EFA

Note:
The theoretical curves shown in Fig. 2.22 present the BER as a function of the SNR. The following relationship exists for the S/N and the C/N ratio for DVB-C with a roll-off factor of r = 15 %:
$S/N = C/N + k_{roll\text{-}off} = C/N - 0.166$ dB.
With EFA models 20 and 23, the C/N ratio is still referred to the channel bandwidth (e.g. 8 MHz), which is determined by the internal SAW filter. With models 60 and 63, by contrast, the C/N ratio is referred to the symbol rate, i.e. the measurement is independent of the channel bandwidth.

For the second measurement, the RF signal of the DVB-C modulator is applied to the RF input of the device under test (DUT). As in the above measurement, EFA superimposes white noise on the RF signal and measures the BER. The BER of $1*10^{-4}$ is now attained at C/N_2 = 25.2 dB (displayed in the ADD. NOISE field).
The END of the device under test is calculated as follows:
END = C/N_2 – C/N_1 = 25.2 dB – 24.8 dB = 0.4 dB

As the END measurement is a differential measurement, measurement accuracy solely depends on the accuracy of the EFA's attenuator, which is in any case adequate for this purpose.

2.11 DVB-C Spectrum

2.11.1 Amplitude and Phase Spectrum

The european standard EN 300 429 defines in Annex A (preliminarily) the spectrum with amplitude and group delay.

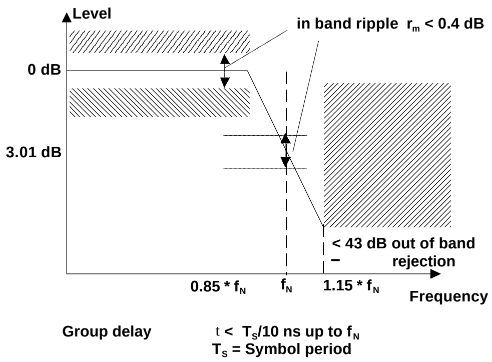


Fig. 2.36 DVB-C spectrum

During transmission of the DVB-C signal, the spectrum is distorted in amplitude and phase as a function of frequency. This is corrected by TV Test Receiver EFA by means of a complex channel correction filter. The result is a spectrum with optimal, flat amplitude and phase frequency response. The filter coefficients represent the inverse channel transfer function, which is then converted to the amplitude and phase frequency response. The spectrum thus calculated is displayed.
From the phase frequency response, the group delay frequency response can be determined by way of differentiation. The amplitude and phase response information can be used to generate a polar plot.

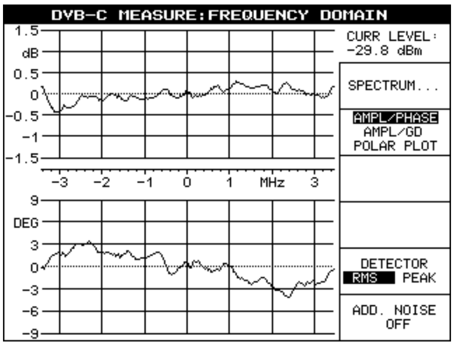


Fig. 2.37 Amplitude and phase frequency response with DVB-C

TV Test Receiver EFA model 60/63 in this way also monitors the effects of the transmission medium on the DVB-C signal.

2.11.2 Spectrum and Shoulder Distance

Calculating channel frequency response by means of a fast Fourier transform (FFT) yields a much higher resolution of level errors than is obtained by evaluation based on the coefficients of a complex channel correction filter as described above. While the FFT method does not offer the high measurement accuracy of a spectrum analyzer, it is sufficiently accurate for evaluating the Tx spectrum of a channel and to determine the out-of-band components.

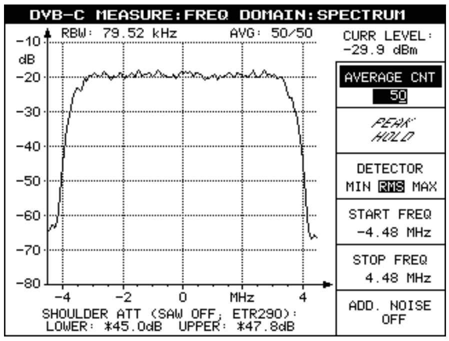


Fig. 2.38 Amplitude frequency response with DVB-C, calculated with an FFT

Maximum level resolution is obtained if only the useful range of the spectrum is analyzed (in this example from -3.45 MHz to +3.45 MHz with a symbol rate of 6.9 Msymb/s). Level resolution is automatically selected as a function of frequency response to a minimum value of 2 dB/div.

To determine the shoulder distance in compliance with ETR290, the largest possible frequency range, i.e. -4.48 MHz to +4.48 MHz, is to be selected. The peak level of the out-of-band components each above and below the useful spectrum is to be measured. The smaller of the two values is the valid shoulder distance.

2.12 Echoes in Cable Channel

Any echoes caused by mismatch in the cable channel can likewise be calculated by means of the coefficients of the channel correction filter. For example, there may be mismatch in the cable system distributing the DVB-C signal to the apartments of a building. Any junction boxes that were manipulated can in this way be accurately identified and located. Points of mismatch are located by means of the echo delay information in µs, or the distance in electrical length in km or miles.

In the example shown in Fig. 2.38, the main pulse is at 0 µs, and the echo follows with an attenuation of 21.0 dB and a lag of 0.29 µs.

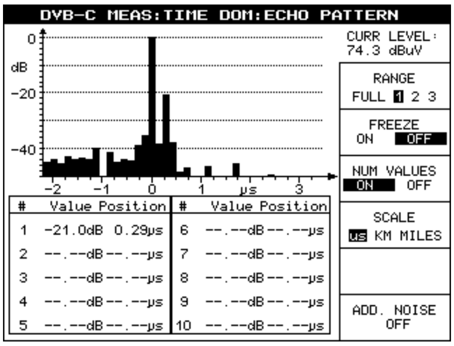


Fig. 2.39 Echo diagram

From the echo delay, the distance from the point of discontinuity causing the reflection is calculated. In the above example, the result is 87 m. The EFA measurement accuracy allows the distance to be displayed with 10 m resolution. For this reason, a distance of 90 m is displayed after switchover to the "KM" scale.

This measurement accuracy is sufficient to locate impedance discontinuity in large cable systems in buildings as described above.

2.13 Crest Factor of DVB-C Signal

DVB-C signals have a structure similar to that of white noise. An important parameter for describing DVB-C signals is, therefore, the crest factor, which is defined as the quotient of the peak voltage value and the root-mean-square (rms) voltage value. In the example below, a maximum crest factor of 11.1 dB was measured with TV Test Receiver EFA. The crest factor is displayed using the complementary cumulative distribution function (CCDF). It can be seen that the amplitude distribution follows exactly the theoretical function (vertical lines plotted at intervals of 1 dB). From this it can be deduced that there are no limiting effects in the DVB-C system under test.

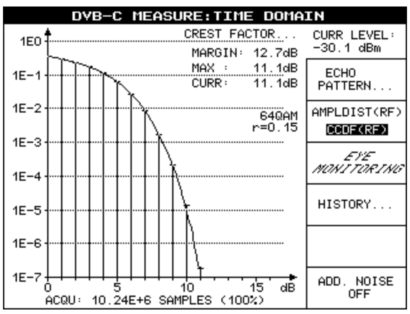


Fig. 2.40 Crest factor of a DVB-C signal

Any limitations of the DVB-C signal would mean that information is missing, with the consequence of increasing BER. Correct level adjustment, therefore, helps to avoid an unnecessary reduction of the system's safety margin.

2.14 Alarm Report

Measurement results are not only displayed on site at the cable headend, but can also queried from a control center via a remote interface. System monitoring is very easy using TV Test Receiver EFA model 60/63.

The network operator first chooses the parameters to be monitored. Fig. 2.40 shows a configuration in which all parameters are included in monitoring.

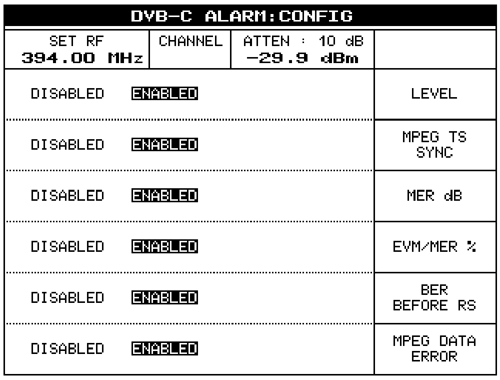


Fig. 2.41 Alarm configuration menu:
all possible parameters are monitored

Table 2.10 lists the parameters (with short forms) selectable in the ALARM:CONFIG menu:

Parameter	Explanation	
LEVEL	Input level below threshold	LV
SYNC	Indicates synchronization of DVB-C symbols and MPEG2 transport stream packets	SY
MER	MER below threshold	ME
EVM	EVM below threshold (alternatively MER)	EV
BER	BER below threshold	BR
MPEG DATA ERROR	Data errors not correctable by Reed-Solomon forward error correction	DE

Table 2.10 Alarm parameters

After selecting the alarm parameters, the alarm thresholds have to be set. Thresholds can be set for LV, ME, EV and BR (see Table 2.10). Non-correctable data and synchronization failure are absolute events and are not assigned a threshold.

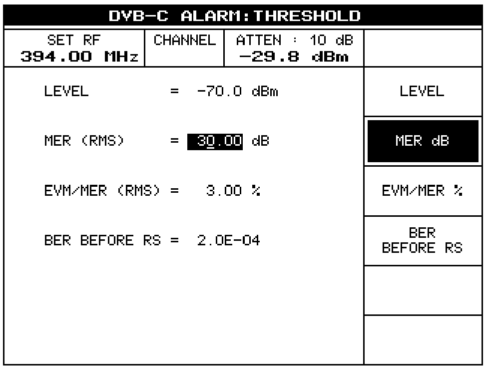


Fig. 2.42 Setting alarm thresholds

The MER can be expressed in dB or, alternatively, as error vector magnitude (EVM) in %. For this reason, there are two alarm parameters for MER, which may be regarded as the inner and outer tolerance. For EVM, by contrast, there exists only one alarm parameter as it can be expressed in % only.

Activated alarms are brought out both as single alarms and as a sum alarm at connector X34 (USER PORT) on the rear of EFA. In the event of a sum alarm, the single alarms are queried via the remote control interface.

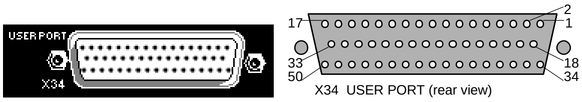


Fig. 2.43 Connector X34 USER PORT

X34 Pin No.	Alarm designation (EFA 60/63)	Alarm designation (EFA 20/23)
1	Sum alarm	Sum alarm
2	Level alarm	Level alarm
3	Sync alarm	Sync alarm
4	MER alarm	BER alarm
5	EVM alarm	Data error
6	BER alarm	
7	Data error	
40 to 48	Ground	Ground
49, 50	+5 V (200 mA)	+5 V (200 mA)

Table 2.11 Pin assignment of connector X34 in DVB-C mode for EFA models 60/63 and 20/23

Professional monitoring calls for error reports. EFA not only records the key parameters LV (input level below threshold) and SY (loss of synchronization), but also the MER (ME, and additionally EVM (error vector magnitude, EV), the BER (BE), and non-correctable data errors (DE), the latter indicating the safety margin of a DVB-C system. All errors are recorded with date and time.

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.

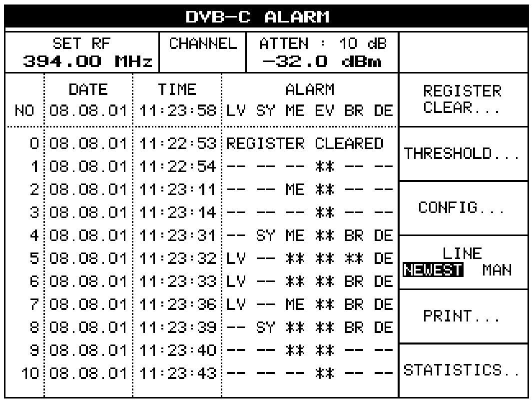


Fig. 2.44 Alarm list

The double asterisk ("✳✳") means that the parameter is cleared from the monitoring list. The time and date of clearance is indicated the first time the sign is displayed for a given parameter.

If more than 1000 events occur during 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 they take up in overall monitoring time. This information is given under STATISTICS.

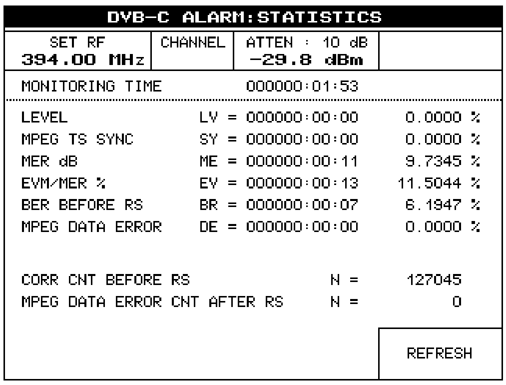


Fig. 2.45 Statistical evaluation of error periods

If errors occur more and more frequently in the alarm report, this indicates instability, and possibly even imminent failure, of the DVB-C system.

Operators of digital cable networks know:

If the picture on a TV receiver already shows visible degradation, transmission reliability in a DVB-C system has fallen far below acceptable limits. As in any digital system, the transition from reliable operation to total failure is a very abrupt one because of forward error correction. TV Test Receiver EFA, therefore, warns the operator early and reliably of an imminent failure of a DVB-C system.

2.15 Options for TV Test Receiver (QAM Demodulator) EFA Model 60/63

2.15.1 RF Preselection EFA-B3 (EFA Model 63)

The DVB-C system does not provide for guard channels. All available channels come one after the other without any guard interval in between. To measure and monitor individual channels of a cable system, the channel of interest has to be selected.
The RF Preselection option EFA-B3 allows channel selection between 5 MHz and 862 MHz and, in addition, enhances input sensitivity of the EFA front end.
The lower frequency limit of 5 MHz makes TV Test Receiver EFA with option EFA-B3 capable of back-channel communication.
The minimum input level is reduced to -67 dBm to -70 dBm in the VHF and the UHF ranges as a function of the RF attenuator setting (Low Noise, Low Distortion, High Adjacent Channel Power).
The RF Preselection option turns EFA model 63 into a selective test receiver of very high quality capable of demodulation despite low input levels.

2.15.2 Measurements with MPEG2 Decoder EFA-B4

The MPEG2 Decoder option EFA-B4 covers only part of the functionality of MPEG2 Measurement Decoder DVMD and MPEG2 Realtime Monitor DVRM. The EFA measurement functions are optimized for monitoring the demodulated transport stream at the cable headend.

If TV Test Receiver EFA 60/63 is fitted with option EFA-B4 to analyze the MPEG2 protocol and the RF characteristics during DVB-C transmission, it alone will suffice to make the necessary measurements.

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
ETR290 for DVB

for the parameters defined there.

Parameter name	To DVB MIN	To DVB MAX	To MPEG MIN	To MPEG 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 2.11 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. 2.45 shows the menu for setting the limit values on TV Test Receiver EFA fitted with MPEG2 Decoder option EFA-B4. 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.

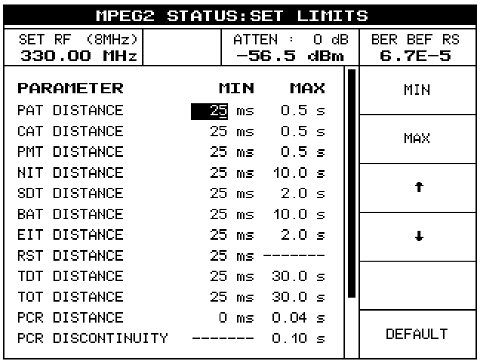


Fig. 2.46 Repetition rates for tables and time stamps

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 as defined by ETR290 can be enabled.

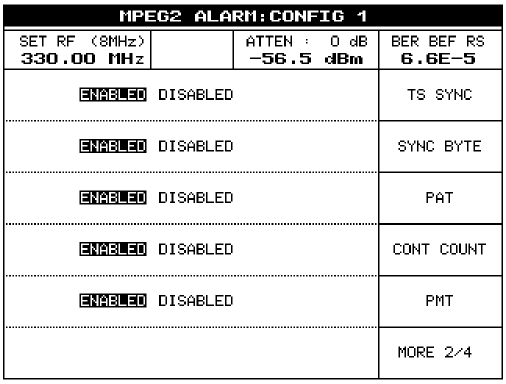


Fig. 2.47 First page of MPEG2 alarm menu

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.

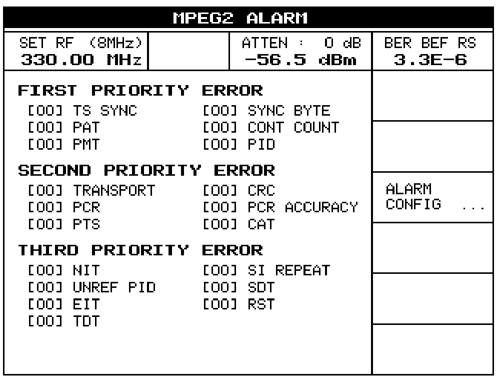


Fig. 2.48 MPEG2 ALARM menu

In the MEASURE menu, the 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.

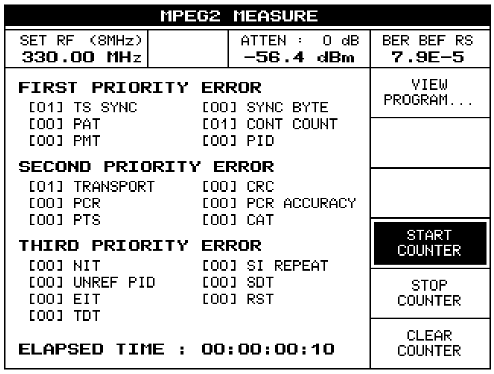


Fig. 2.49 MPEG2 MEASURE menu

Name	**Output (pin No.)**
Sum alarm	1
First priority alarm (sum)	2
Second priority alarm (sum)	3
Third priority alarm (sum)	4
Ground	40 to 48
+5 V (200 mA)	49, 50

Table 2.12 Pin assignment of connector X34 (alarm lines) for MPEG2 mode

Connector X34 of TV Test Receiver EFA is assigned alarm lines both for the DVB-C mode and the MPEG2 mode. Table 2.12 shows the pin assignment for the MPEG2 mode.

The VIEW PROGRAM COMP... 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

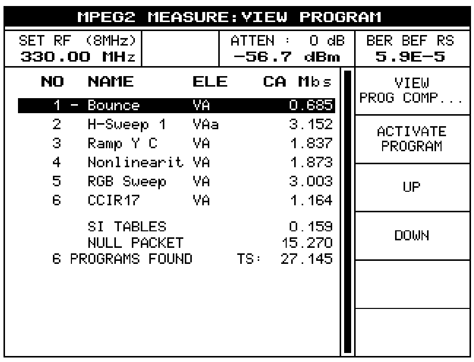


Fig. 2.50 PAT of a transport stream with key parameters

ACTIVATE PROGRAM opens the PMT (program map table) of the selected program with information on the number of video, audio, data and "other" data streams of the program including associated PID (packet identifier) numbers. The PID numbers of the PMT and the PCR (program clock reference) are listed too.

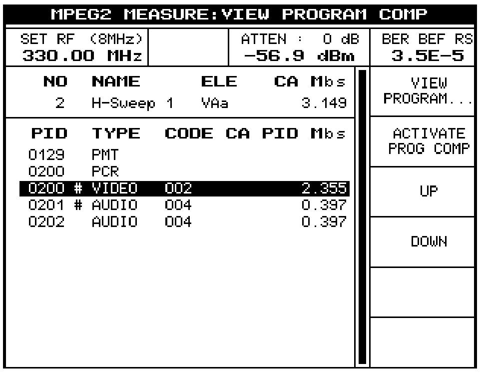


Fig. 2.51 PMT of a program with key parameters

TV Test Receiver EFA model 60/63 with MPEG2 Decoder option EFA-B4 offers functionality optimized for MPEG2 monitoring at the output of a cable headend. The outputs for analog CCVS video and analog audio allow aural and visual monitoring of the programs fed into the cable network.

2.15.3 SAW Filters
2 MHz EFA-B14, 6 MHz EFA-B11
7 MHz EFA-B12, 8 MHz EFA-B13

The DVB-C standard does not define the channel bandwidth, so the complete VHF and UHF range is available for signal transmission.
The preferred channel bandwidths are 6 MHz, 7 MHz and 8 MHz, i.e. those defined for the analog standards. For back-channel communication in interactive television, 2 MHz are commonly used. To ensure that each operator has the bandwidth configuration matching his application, the SAW filters for TV Test Receiver EFA are available as options. The desired filter should, therefore, always be specified when placing an order.
One SAW filter must always be fitted. Two more SAW filters can be installed optionally.

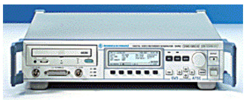
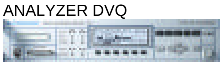
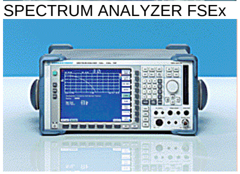
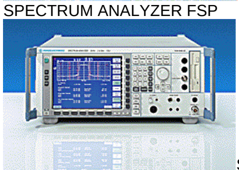
2 MHz Filter EFA-B14
Expands the EFA functionality to include a DVB-C back channel as defined by EN 300 800 Summary (Upstream) Table 7. The option supports 2 MHz channel bandwidth. Various symbol rates are possible.

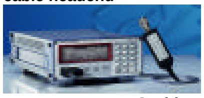
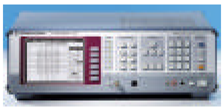
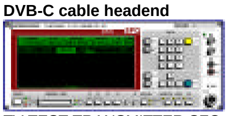
6 MHz Filter EFA-B11, 7 MHz Filter EFA-B12, 8 MHz Filter EFA-B13

One of these filters can be inserted in the third SAW slot. The 6 MHz filter supports the channel bandwidths defined by Standard M, the 7 MHz filter either VHF channels or the UHF channel bandwidths used in Australia. The 8 MHz SAW filter is the filter most frequently used in DVB-C.

The filter(s) fitted are displayed in the status menu.

2.16 Overview of DVB-C Measurements

Instrument, Test Point	Test Parameter
At input of cable headend **TS source for production**	
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 of user-defined transport streams, recording of error events
MPEG2 MEASUREMENT DECODER DVMD 	Realtime MPEG2 transport stream protocol analysis
MPEG2 REALTIME MONITOR DVRM 	Realtime MPEG2 transport stream protocol monitoring
DIGITAL VIDEO QUALITY ANALYZER DVQ 	Measurement of signal quality after MPEG2 coding and decoding
At test transmitter/ **cable headend** **Analyzers for production**  SPECTRUM ANALYZER FSEx  SPECTRUM ANALYZER FSP  S SPECTRUM ANALYZER FSU	LO harmonics DVB-C spectrum Shoulder distance Roll-off factor Crest factor Output power

Instrument, Test Point	Test Parameter
At test transmitter/ **cable headend**  **Power Meter NRVS with Thermal Power Sensor NRV-Z51**	High-precision thermal measurement of output power
Monitoring receiver **at cable headend** **Test receiver in production**  EFA Models 60/63 DVB-C TEST RECEIVER with option EFA-B4	**Basic unit** Order of QAM Symbol rate DVB-C amplitude and phase spectrum Output power END, BER, MER Frequency offset Echo diagram Constellation diagram I/Q parameters in QAM Alarm report **Option EFA-B4** Measurements to ETR290: parameters of the three priorities Alarm report PAT and PMT
Simulation of **DVB-C cable headend**  TV TEST TRANSMITTER SFQ Options NOISE GENERATOR FADING SIMULATOR	C/N setting for END measurement Simulation of defined receive conditions and impedance discontinuities Simulation of transmitter defects
DVB-C test transmitter for production  SFL-C TV TEST TRANSMITTER	Test transmitter for production Simulation of transmitter defects for testing set-top boxes in production