

**Digital TV  
Rigs and Recipes  
Part 2  
DVB-C**

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## 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.

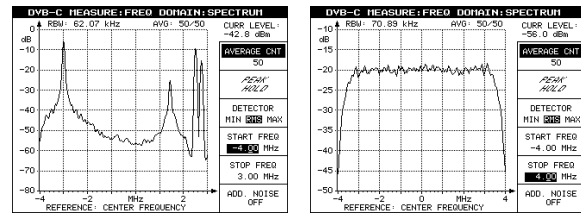


Fig. 2.1 Comparison of B/G PAL spectrum and DVB-C spectrum

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

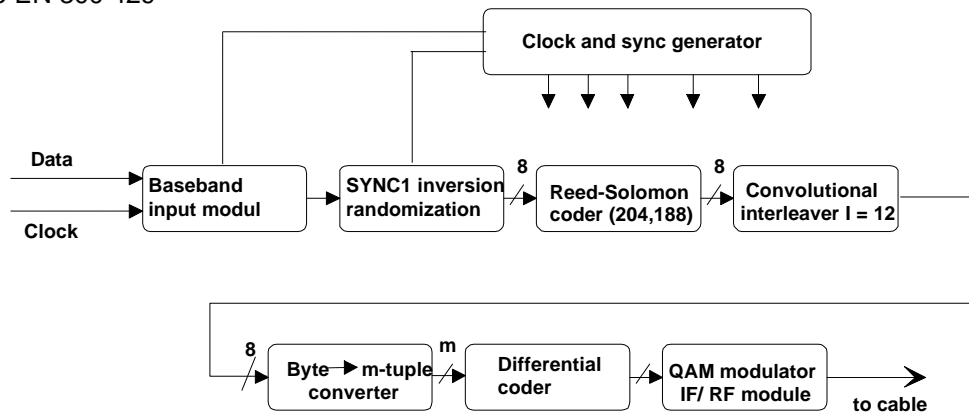


Fig. 2.2 Block diagram of DVB-C modulator/converter

#### 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.

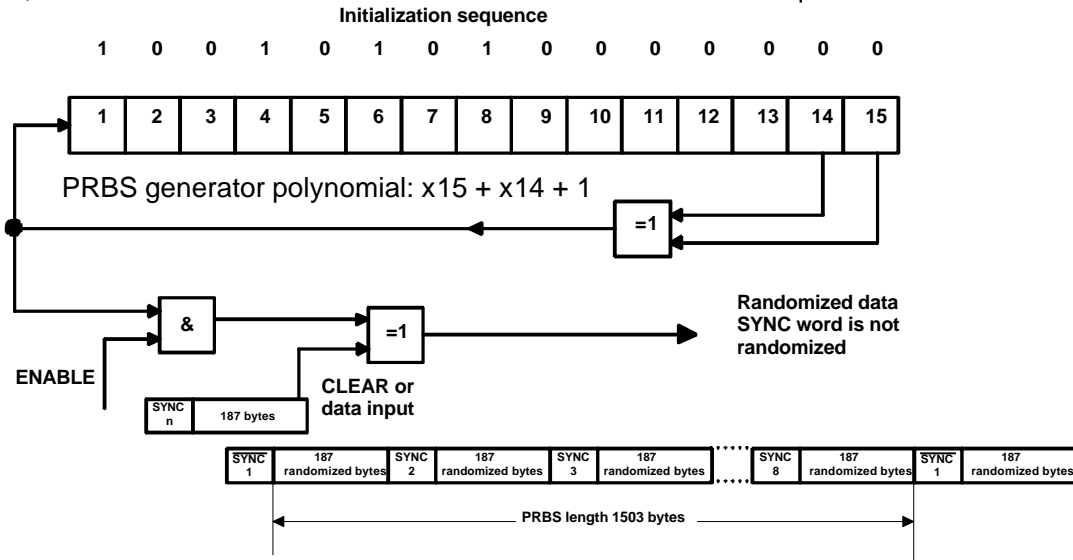


Fig. 2.3 Sync 1 inversion and randomization

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

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  $2 \cdot 10^{-4}$  can be corrected to obtain a quasi-error-free (QEF) data stream with residual BER of  $< 1 \cdot 10^{-11}$ .

*Note:*

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

### 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.

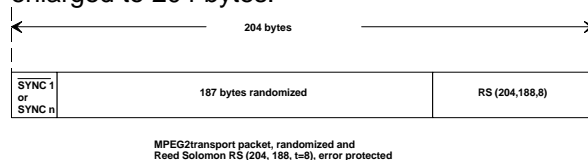


Fig. 2.4 204, 188,  $t = 8$  Reed-Solomon error control coding

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 $2 \cdot 10^{-4}$ to $1 \cdot 10^{-11}$

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.  $12 \times 8 = 96$  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

Convolutional interleaver I=12

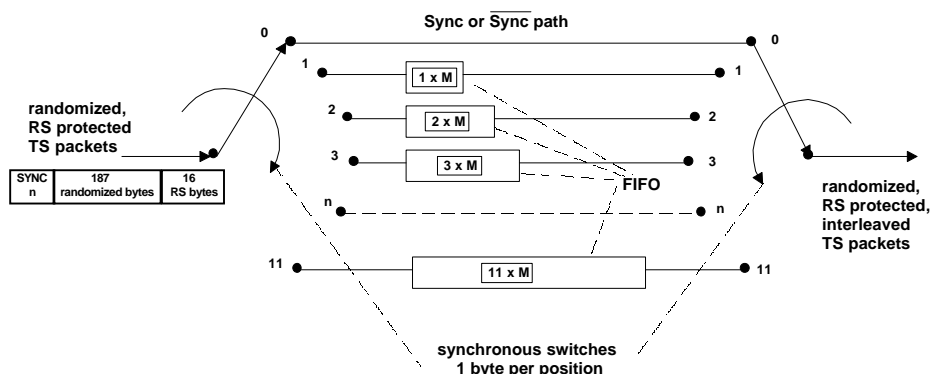


Fig. 2.5 Convolutional interleaver

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  $2^{2 \cdot n}$  possible states in the constellation diagram.  $2^m$  denotes the order of QAM, where  $m = 2 \cdot n$ .

Example:

For  $2^3 = 8$  different amplitudes for I and Q

the order of QAM is

$$2^{2 \cdot 3} = 2^6 = 64\text{QAM}$$

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
<b>16 QAM</b>	<b>4</b>
32 QAM	5
<b>64 QAM</b>	<b>6</b>
128 QAM	7
<b>256 QAM</b>	<b>8</b>

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:

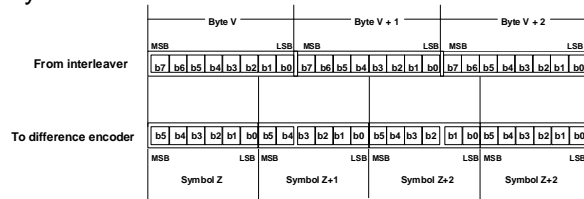


Fig. 2.6 Conversion of bytes to symbols

## 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**

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

**32QAM**

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

**64QAM**

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
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 <sup>1)</sup>

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

<sup>1)</sup> From: U. Reimers: "Digital Video Broadcasting"

Table 2.5

## 2.2 Bandwidth

The symbols are analog pulses similar to a  $\sin x/x$  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:

$$S = R \cdot \frac{204}{188} \cdot \frac{1}{m} \quad \text{Msymb/s} \quad \text{Equation 2.1}$$

The factor 204/188 takes into account Reed-Solomon error control coding.

In cable transmission, the bit rate

$$R = 38.1529 \text{ Mbit/s}$$

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

$$f_N = S = 6.900 \text{ MHz}$$

for the 64QAM symbols.

## 2.3 Symbol Rates and 2<sup>m</sup> QAM Spectrum in Cable Transmission

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

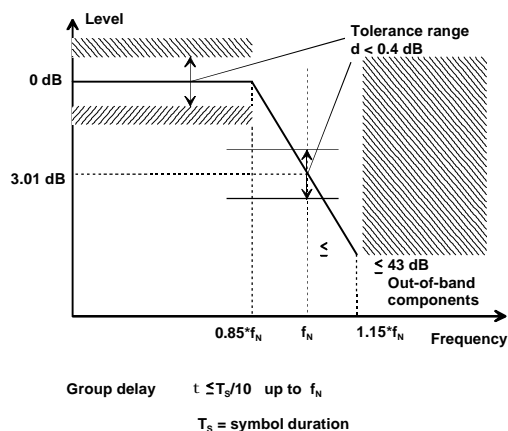


Fig. 2.7 DVB-C spectrum

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  $\sin x/x$  spectrum depends on the selected roll-off factor. The smaller this factor, the better the approximation to an ideal  $\sin x/x$  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:

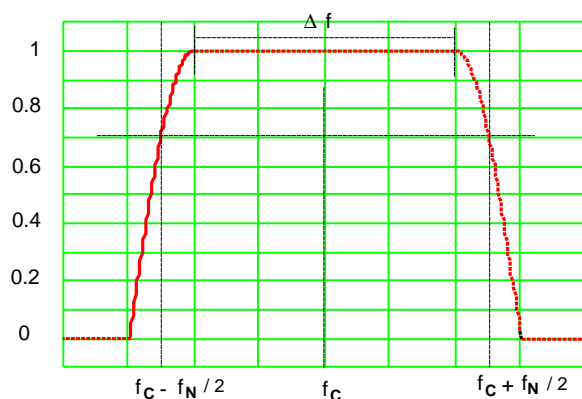


Fig. 2.8 Spectrum obtained by  $\sqrt{\cos}$  filtering

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.

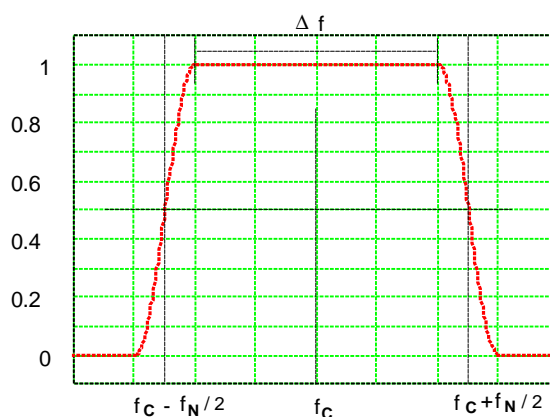


Fig. 2.9 Spectrum obtained by  $\cos$  roll-off filtering

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:

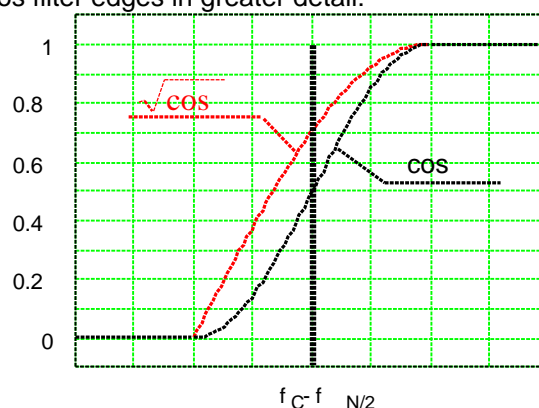


Fig. 2.10 Edges obtained with  $\sqrt{\cos}$  roll-off and  $\cos$  roll-off filtering

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

1. optimal approximation to an ideal  $\sin x/x$  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:

$$B_{Ch} = S \cdot (1 + r) \text{ MHz}$$

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

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

without any inherent additional distortion.

The highest theoretical symbol rate for a 7 MHz channel is

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

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  $S_{satellite} = 27.5 \text{ Msymb/s}$

From this results the data rate of:

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

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:

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

## 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.

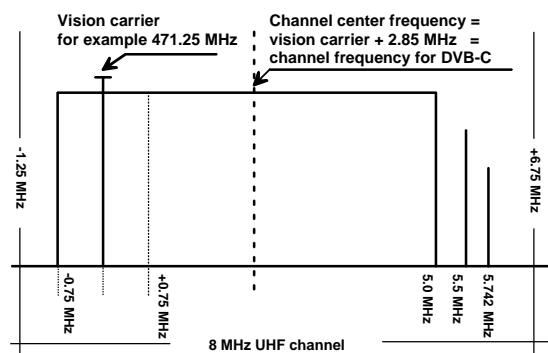


Fig. 2.11 Channel frequency scheme

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  $38.9 \text{ MHz} - 2.85 = 36.05 \text{ MHz}$ .

## 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	$S = R \cdot \frac{204}{188} \cdot \frac{1}{m}$
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 <sup>23</sup> -1 and 2 <sup>15</sup> -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	±25 %
I/Q quadrature offset (phase error)	±10 °
Residual carrier	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.

RF FREQUENCY	RF LEVEL	MODULATION
338.000 MHz	77.0 dBμV	DVB-C 64QAM

RF FREQUENCY	RF LEVEL	MODULATION	I/Q CODER
RF FREQUENCY	EDIT		
FREQUENCY →	338.000 MHz		
CHANNEL →	1		
CHANNEL TABLE →	USER1		
		F2=STATUS	

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.

RF FREQUENCY	RF LEVEL	MODULATION
338.000 MHz	57.0 dBμV	DVB-C 64QAM

RF FREQUENCY	RF LEVEL	MODULATION	I/Q CODER
RF LEVEL	EDIT		
RF LEVEL →	57.0 dBμV		
RF LEVEL OFFSET →	0.0 dB		
RF AMPLITUDE →	57.0 dBμV		
RF LEVEL MODE →	NORMAL		
RF ALC MODE →	AUTO		
RF ALC OFF MODE →	SAMPLE & HOLD		
RF ALC SEARCH ONCE →	PASSED		
RF ALC LEARN TABLE →			
		F2=STATUS	

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.

RF LEVEL	MODULATION	SYMBOLRATE	
-30.0 dBm	DVB-C 64QAM	6.875 MSym/s	
LEVEL	MODULATION	I/Q CODER	BASEBAND
	DVB-C QAM	EDIT	
⇒	QAM	⇒	64
⇒	I/Q	⇒	NORMAL
⇒	I/Q PHASE ERROR	⇒	0.0 DEG
⇒	CARRIER SUPPRESSION	⇒	0.0 %
⇒	I/Q AMPL. IMBALANCE	⇒	0.0 %
⇒	NOISE	⇒	
⇒	FADING	⇒	
⇒	CW/MODULATION	⇒	MOD.

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.

RF FREQUENCY	RF LEVEL	MODULATION	SYMBOL RATE	
338.000 MHz	-30.0 dBm	DVB-C 64QAM	6.875 M	

RF FREQUENCY	RF LEVEL	MODULATION	I/Q CODER	BASEBAND
BASEBAND				
I/Q CODER		EDIT	MEASURE	
INPUT SELECT	⇒	TS PARALLEL		
INPUT DATA RATE	⇒	38.015 Mbit/s	38.016 Mbit/s	
USEFUL DATA RATE	⇒		2.501 Mbit/s	
SYMBOL RATE	⇒	6.875 MSym/s		
PACKET LENGTH	⇒	188 BYTE		
MODE	⇒	AUTO		
ROLL OFF	⇒	0.15		
SPECIAL	⇒			

F2=STATUS	
-----------	--

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.

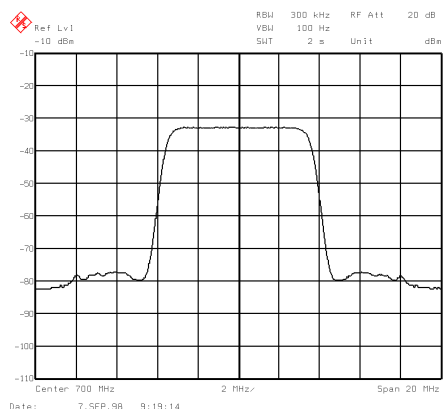


Fig. 2.16 Constant power density in DTV channel

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

<b>NRVS</b>	
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
<b>NRV-Z51</b>	
Power sensor	thermal
Impedance	50 Ω
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  $\leq 1.5$  dB.

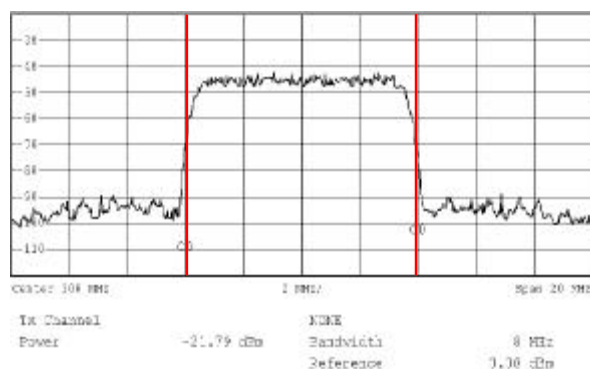


Fig. 2.17 Power measurement with frequency cursors

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	-140 dBm to +30 dBm
Amplitude display range	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)	412 mm x 197 mm x 417 mm
Weight (FSP 3/7/13/30)	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.

DVB-C MEASURE			
SET RF	CHANNEL	ATTEN : 10 dB	
394.00 MHz		-30.3 dBm	
MODULATION:		64QAM	CONSTELL DIAGRAM
FREQUENCY:		0.143 kHz	FREQUENCY
FREQUENCY OFFSET	6.900 MHz		
SET SYMBOL RATE			
SYMBOL RATE OFFSET			
BER:		ATTN : 10 dB	
BER BEFORE RS	5.0E-6	-30.3 dBm	
BER AFTER RS	7.4E-8		
		QAM PARAMETERS...	
		RESET BER	
		ADD. NOISE OFF	
TS BIT RATE 38.155 MBit/s			

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.

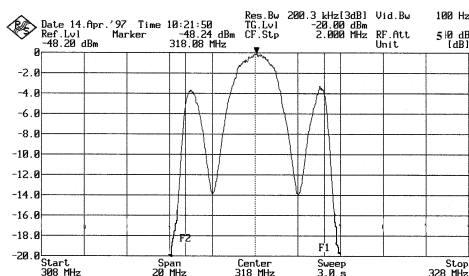


Fig. 2.19 Fading spectrum

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 ( $BER < 1 \times 10^{-11}$ ), but only for bit error ratios of  $2 \times 10^{-4}$  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  $90^\circ$ ,
- 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.

RF FREQUENCY	RF LEVEL	MODULATION	SYMBOL RATE	C/N	FADING
338.000 MHz	-30.0 dBm	DVB-C 64QAM	6.875 Msym/s	OFF	OFF
RF FREQUENCY	RF LEVEL	MODULATION	I/Q CODER	BASIS	SPECIAL
MODULATION		DVB-C QAM	EDIT		
DVB-S QPSK	→	QAM	→	64	
DVB-C QAM	→	I/Q	→	NORMAL	
DVB-T COFDM	→	I/Q PHASE ERROR	→	0.0 DEG	
ITU-T VSB/8	→	CARRIER SUPPRESSION	→	0.0 %	
ATSC VSB	→	I/Q AMPL. IMBALANCE	→	0.0 %	
I/Q EXTERNAL	→	NOISE	→		
FM	→	FADING	→		
FM EXTERNAL	→	CM/MODULATION	→	MOD.	
F2=STATUS				F4=PRESET ALL	

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  $1 \times 10^{-3}$ , since up to this value forward error correction is capable of reconstructing an interpretable data stream.

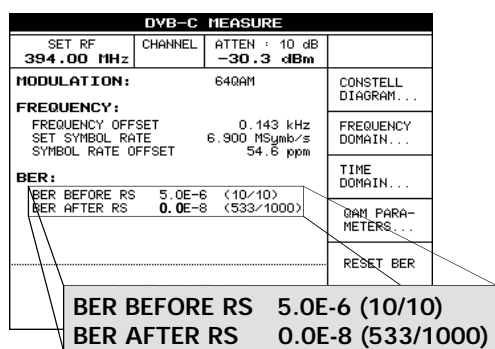


Fig. 2.21 QAM measurement menu: BER measurement

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.

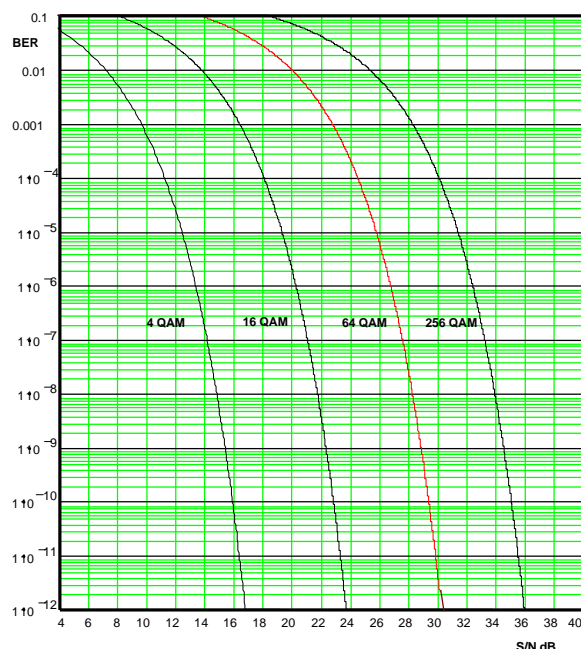


Fig. 2.22 Theoretical BER(S/N) for the four QAM modes

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  $\text{BER} \leq 2 \times 10^{-4}$ , 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.

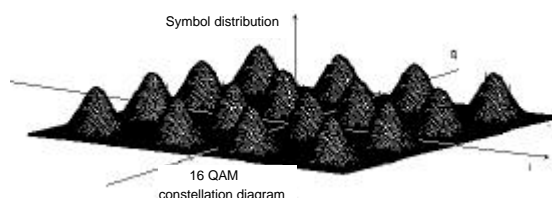


Fig. 2.23 Symbol distribution in a 16QAM constellation diagram

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.

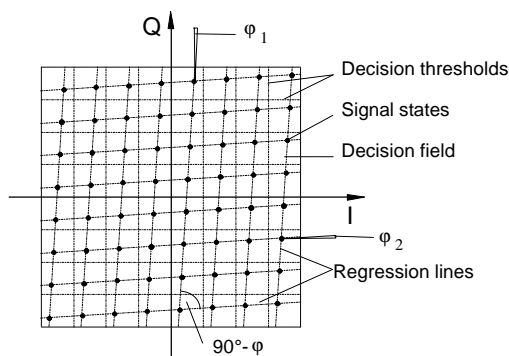


Fig. 2.24 64QAM constellation diagram

### 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.

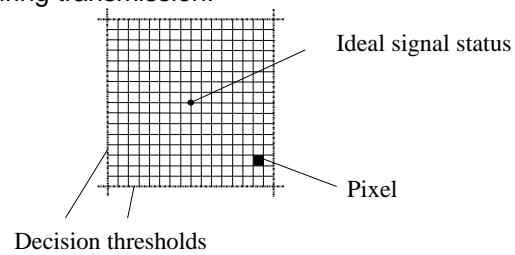


Fig. 2.25 Decision field after A/D conversion

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.

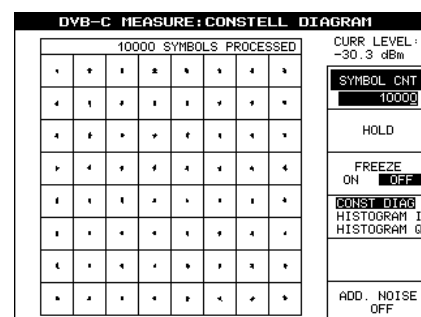


Fig. 2.26 Ideal 64QAM constellation diagram

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.