TV Test Transmitter R&S SFQ

Condensed data of R&S SFQ

Frequency range	0.3 MHz to 3.3 GHz
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 encoder, 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
Modulation	8PSK
Code rate	2/3, 5/6, 8/9
Modulation	16QAM
Code rate	3/4, 7/8
DVB-T	
Modulation	QPSK,16QAM, 64QAM; non-hierarchical, hierarchical
FFT mode	8k and 2k
Bandwidth	6 MHz, 7 MHz, 8 MHz
Puncturing	to code rate 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 Msymb/s ±10 %
ITU-T J.83/B	
Bandwidth	6 MHz
Modulation	64QAM, 256QAM
Input data rate	26.970 Mbit/s for 64QAM, 38.8107 Mbit/s for 256QAM
Symbol rate	5.0569 Msymb/s for 64QAM, 5.3605 Msymb/s for 256QAM
Setting range	symbol rate ±10 %
Data interleaver	level 1 and level 2
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 R&S SFL-J

Condensed data of R&S SFL-J

Frequency range	5 MHz to 1.1 GHz
Level range	0 dBm to -140 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 encoder, all interleavers can be switched off
Modulation	64QAM, 256QAM
Internal test signals	null TS packets, null PRBS packets, PRBS (2^{23} -1 and 2^{15} -1)
Option	Noise Generator R&S SFL-N on request

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5.4 Important Requirements To Be Met By ITU-T J.83/B Test Transmitters

This section deals in particular with the requirements to be met by TV test transmitters supplying signals for ITU-T J.83/B compliance measurements.

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-conforming signals are applied. For tests on an ITU-T J.83/B 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, transmit frequency and 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.

The TV Test Transmitters R&S SFQ and R&S SFL-J are capable of setting any frequency between 0.3 MHz and 3.3 GHz, thus offering a frequency range by far exceeding that of ITU-T J.83/B. Frequencies of interest can also be stored in channel tables.

Fig. 5.26 Frequency setting on R&S SFQ

Another test is for verifying error-free reception at a minimum level of typically -70 dBm. The R&S SFQ features a setting range between +6 dBm and -99 dBm, and the R&S SFL-J between 0 dBm and -140 dBm, which in any case includes the required minimum level.

Fig. 5.27 Level setting on R&S SFQ

In the ITU-T J.83/B modulation mode, modulator- and transmission-specific settings can be made, including noise superposition and the generation of fading profiles. The R&S SFQ and the R&S SFL-J are capable of simulating all signal variations and degradations occurring in a real ITU-T J.83/B system. The degraded signal generated by the R&S SFQ or R&S SFL-J "stress transmitter" is used for testing the STB's susceptibility to errors and interference.

Fig. 5.28   Setting of modulator- and transmission-specific parameters for ITU-T J.83/B standard on R&S SFQ

Detailed information on the above parameters will be found in section 5.8 "QAM Parameters".

Further important settings for the ITU-T J.83/B standard can be made in the I/Q CODER menu. Here the TS parameters for the modulator can be selected.

Fig. 5.29 Settings for ITU-T J.83/B standard in I/Q CODER menu on R&S SFQ

It is with respect to the INTERLEAVER MODE settings that the ITU-T J.83/B system greatly

differs from the DVB systems.

Whereas the convolutional interleaver mode is fixed for DVB (12 paths and FIFO interleaving depth of M = 17), the ITU-T J.83/B standard allows a variety of modes for the convolutional interleaver. A detailed description of the convolutional interleaver will be found in section 5.1.4.

Fig. 5.30 Interleaver settings on R&S SFQ

All parameter values listed in Table 5.2 "Interleaving levels and control words" can be set.

5.5 Power Measurement

Measurement of the output power of a DTV 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 DTV signal, by contrast, is characterized by a constant power density across the Nyquist bandwidth (see Fig. 5.31), which results from energy dispersal and symbol shaping in the DTV modulator. Consequently, only the total power in a DTV channel is measured.
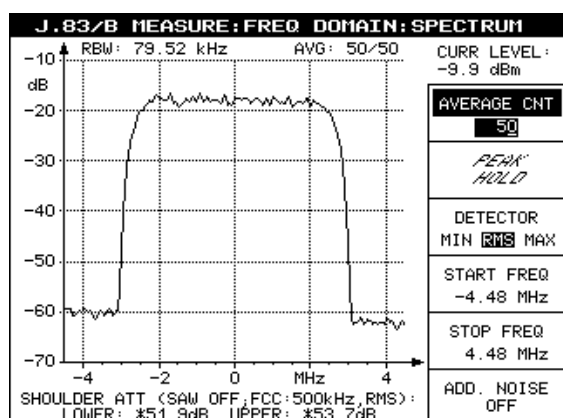

Fig. 5.31   Constant power density
                in ITU-T J.83/B channel

Three methods of measuring ITU-T J.83/B signal power are known to date:

5.5.1   Mean Power Measurement
with Power Meter R&S NRVS
and Thermal Power Sensor

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

R&S 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
R&S 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 meters supply the most accurate results if there is only one ITU-T J.83/B 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 ITU-T J.83/B power, however, the ITU-T J.83/B signal should be absolutely DC-free.

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5.5.2 Mean Power Measurement with Spectrum Analyzer R&S FSEx, R&S FSP or R&S FSU

If a conventional spectrum analyzer is used to measure power, its maximum measurement bandwidth will not be sufficient for a 6 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 DTV signals 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. The Rohde & Schwarz Spectrum Analyzers R&S FSEx, R&S FSP and R&S FSU thus measure mean power in a DTV channel with an accuracy of $\leq$ 1.5 dB.
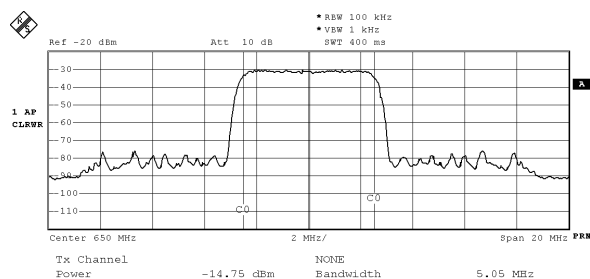

Fig. 5.32a Power measurement with frequency cursors covering Nyquist bandwidth
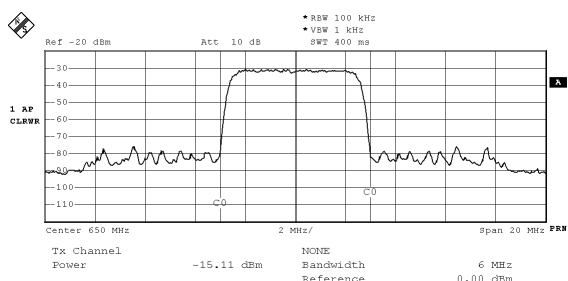

Fig. 5.32b Power measurement with frequency cursors covering channel bandwidth

A frequency cursor is placed on the lower and another one on the upper frequency of the ITU-T J.83/B 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 ITU-T J.83/B 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 5.5.3.

SPECTRUM ANALYZER R&S FSP

Condensed data of R&S FSP

Frequency range (R&S 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 logarithmic scaling, 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 RS-232-C
Dimensions (W x H x D)	412 mm x 197 mm x 417 mm
Weight (R&S FSP3/7/13/30)	10.5/11.3/12/12 kg

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SPECTRUM ANALYZER R&S FSEx

Condensed data of R&S FSEA/R&S 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 logarithmic scaling
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 RS-232-C

5.5.3 Mean Power Measurement with TV Test Receiver R&S EFA Model 70 or 73

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

Fig. 5.33   Power measurement with TV Test Receiver R&S EFA model 70 or 73

TV Test Receiver R&S EFA Model 70/73

Condensed data of R&S EFA models 70 and 73

Frequency range	45 MHz to 862 MHz, 5 MHz to 1000 MHz with RF Preselection option (R&S EFA-B3)
Input level range	-47 dBm to +14 dBm -84 dBm to +14 dBm (low noise) with RF Preselection option (R&S EFA-B3)
Bandwidth	2/6/8 MHz
Demodulation	64/256 QAM
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

Investigations on channel spectra revealing pronounced frequency response have shown the high accuracy of the displayed level. A comparison of the levels obtained with TV Test Receiver R&S EFA and Power Meter R&S NRVS with a thermal power sensor yielded a maximum difference of less than 1 dB – the comparison being performed with various R&S EFA models at different channel frequencies and on different, non-flat spectra. Thanks to the R&S EFA's built-in SAW filters of 2 MHz, 6 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 R&S SFQ with the fading simulator option.

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This echo, plus the signal sent via the direct path, produce the channel spectrum shown in Fig. 5.34 with pronounced dips resulting from frequency response.
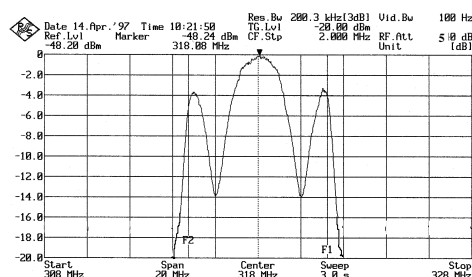

Fig. 5.34 Fading spectrum

Table 5.7 gives the results where the maximum difference between the R&S NRVS and R&S EFA has occurred.

Level measurement with	R&S NRVS	R&S EFA
	-33.79 dBm	-33.0 dBm

Table 5.7 Comparison of results

Note:
The results of the above level measurements are specified in detail in Application Note 7BM12 (see also Annex 4A to Part 4 (DVB-T) of the "Digital TV Rigs and Recipes"). The measurements described there were made with the R&S EFA models 20 and 23. The successor models 60 and 63 feature even higher level accuracy, yielding a typical maximum difference of less than 1.0 dB.

5.6 Bit Error Ratio (BER)

Digital TV has a clearly defined range in which it operates correctly. Transition to total failure of an ITU-T J.83/B system is abrupt. This is due to concatenated forward error correction with trellis coding and Reed-Solomon FEC.

The (128, 122, 3) RS FEC is capable of correcting transport stream data to yield a nearly error-free data stream (BER < 1×10^{-11}, i.e. one error every 15 minutes), but only for bit error ratios of 7×10^{-5} or better (value determined by measurements, not based on theoretical considerations, criterion is BER $\rightarrow$ QEF ater RS with interleaver 128/1). The sources of error determining the bit error ratio are known. A distinction is made between errors originating from the ITU-T J.83/B 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 ITU-T J.83/B 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.

This is aggravated by further amplitude and phase response during transmission caused by:

- nonlinearities of the line amplifiers in the cable networks, causing distortion of the ITU-T J.83/B QAM signal,
- intermodulation with adjacent channels degrading signal quality,
- interference and noise superimposed on the useful signal,
- reflection distorting the frequency characteristic, and
- laser clipping causing bit errors in fiber-optic networks.

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, the TV Test Transmitter R&S 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. 5.35   R&S SFQ menu for setting ITU-T J.83/B parameters

But not only the TV Test Transmitter R&S SFQ is indispensable for checking the proper operation of a DTV system. After transmission of the ITU-T J.83/B signal via the cable network, a test receiver is needed to monitor the digital TV Rx signal.

The solution offered by Rohde & Schwarz for ITU-T J.83/B signal monitoring is:

TV Test Receiver R&S EFA model 70 or 73

The most important parameter at the receiver end – apart from the channel center frequency and the level of the received ITU-T J.83/B 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.

Fig. 5.36 ITU-T J.83/B measurement menu: BER measurement

Bit comparison supplies accurate results to a BER of about $1*10^{-3}$ before Reed-Solomon, since up to this value the forward error correction employed by the ITU-T J.83/B system is capable of reconstructing an interpretable data stream.

A defined BER can be generated by means of a noise generator with selectable bandwidth and level. Since for the ITU-T J.83/B system no calculated graphs are available to date that describe the theoretical BER as a function of the signal-to-noise (S/N) ratio, empirical values are given below. The standard allows for an error rate of one error per 15 minutes for a quasi-error-free (QEF) data stream.

Conclusions regarding 64QAM
The S/N ratio of the QEF data stream measured after Reed-Solomon FEC is about 22.0 dB, and the BER before RS is about $7*10^{-5}$.
Comparing these values with the calculated (theoretical) values of the DVB-C system, it can be seen that, in ITU-T J.83/B, trellis coding allows for an S/N ratio 2 dB poorer for 64QAM, and that RS FEC can correct about one decade BER less.

Conclusions regarding 256QAM
The S/N ratio of the QEF data stream measured after Reed-Solomon FEC is about 28 dB, and the BER before RS about $7*10^{-5}$.
Comparing these values with the calculated (theoretical) values of the DVB-C system, it can be seen that, in ITU-T J.83/B, trellis coding allows for an S/N ratio 2 dB poorer for 256QAM, and that RS FEC can correct about one decade BER less.

The TV Test Receiver R&S EFA and the TV Test Transmitter R&S SFQ both have integrated noise generators (optional in the case of the R&S SFQ). The curves being very steep in the range BER $\leq 7*10^{-5}$, which is assumed as the reference value for BER-related measurements in ITU-T J.83/B, the noise level can be determined very accurately.

This is done either using the method described in Application Note 7BM03 (see Annex 4C to Part 4 (DVB-T) of the "Digital TV Rigs and Recipes"), or by a direct measurement with the TV Test Receiver R&S EFA.
7BM03 also explains C/N to S/N conversion.

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The high measurement and display accuracy offered by TV Test Receiver R&S 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.
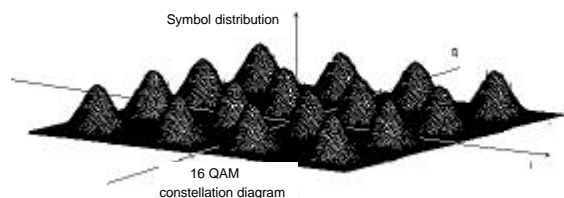

Fig. 5.37   Typical symbol distribution in a 16QAM constellation diagram

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 R&S 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. The R&S 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 R&S EFA calculates the parameters required by the ETSI TR 101 290 standard "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 a 64QAM constellation diagram, which is indispensable to satisfy the stringent demands for measuring S/N ratio (SNR) and the other relevant parameters.

5.7 BER Measurement with R&S SFQ and R&S SFQ-B17 or R&S SFL-J and R&S SFL-K17

The TV Test Transmitters R&S SFQ and R&S SFL-J generate internal PRB sequences (PRBS = pseudo random binary sequence) of different lengths. The lengths specified by the standard are 2^{23}-1 and 2^{15}-1. A PRBS is added to the signal, the signal is modulated in accordance with ITU-T J.83/B, and then demodulated by a device under test (DUT), e.g. a set-top box. If no errors occur during transmission and demodulation, the output data is identical to the PRBS signal generated in the test transmitter. The output data can be fed back to the test transmitter and checked for errors by means of the R&S SFQ-B17 or R&S SFL-K17 option.

Settings on R&S SFQ

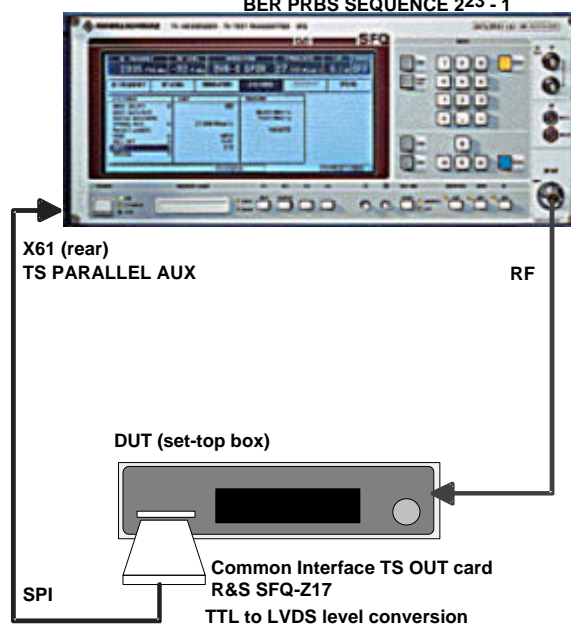|	
MODULATION	**NOISE ON** **C/N is being varied**
CODER	**REED SOLOMON OFF** **MODE NULL PRBS PACKET** **PRBS 2^{23} - 1**
SPECIAL	**BER MEASUREMENT ON** **BER INPUT PARALLEL** **MODE NULL PRBS PACKET** **BER PRBS SEQUENCE 2^{23} - 1**

Fig. 5.38 Test setup for BER measurement

The TV Test Transmitter R&S SFQ or R&S SFL-J modulates the null PRBS packets (null packets whose payload consists of PRBS bytes).

The Reed-Solomon encoder is switched off, otherwise channel coding is performed completely.

Since the six error control bytes are missing, the Reed-Solomon decoder in the DUT detects more than three bytes as errored. The Reed-Solomon decoder consequently sets the transport error indicator (TEI) flag and lets the transport stream pass unchanged. The BER before the Reed-Solomon decoder can thus easily be measured.

STBs output the transport stream as a TTL signal via their common interface. The TTL signal is converted to an LVDS signal by an adapter card. The LVDS signal is applied to the R&S SFQ via the TS PARALLEL AUX input or the R&S SFL-J via the TS PARALLEL or SPI input for bit-error ratio measurement. With the NULL PRBS PACKET setting selected on the test transmitter, the four-byte header of the transport packets is removed in the R&S SFQ-B17 or R&S SFL-K17 option (BER Measurement). The remaining 184 bytes of payload contain the original PRBS of 2^{23}-1, which is analyzed to determine the bit error ratio.

The above test setup can also be used for serial data BER measurements if an appropriate clock signal is available.

5.8 QAM Parameters

To explain measurement of the QAM parameters, the constellation diagram has to be discussed first. The ITU-T J.83/B constellation diagram is divided in 64 or 256 decision fields of equal size. Each symbol of these fields carries 6 or 8 bits. 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. 5.38). 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.

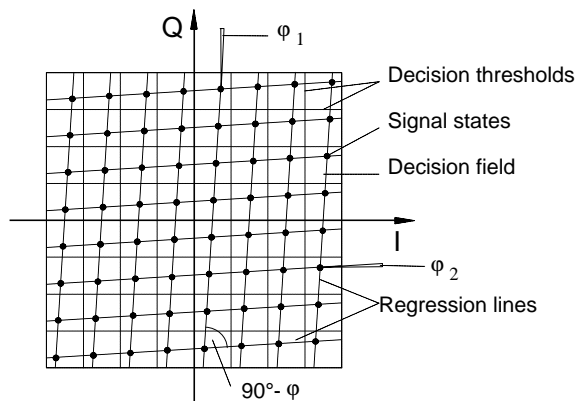The QAM parameters are described in the following sections.

Fig. 5.38   64QAM constellation diagram

5.8.1 Decision Fields

In a QAM constellation diagram, the ideal signal status is attained if the symbols (each consisting of a pair of I and Q values) are mapped into 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.
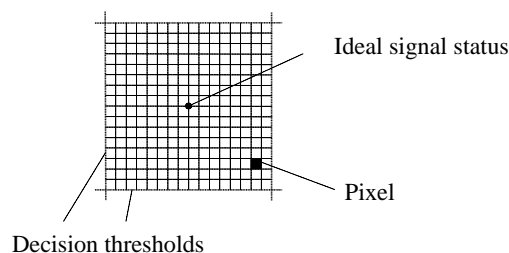

Fig. 5.39   Decision field after A/D conversion

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, and so the measurement accuracy is increased by several powers of ten.

5.8.2 QAM Constellation Diagram

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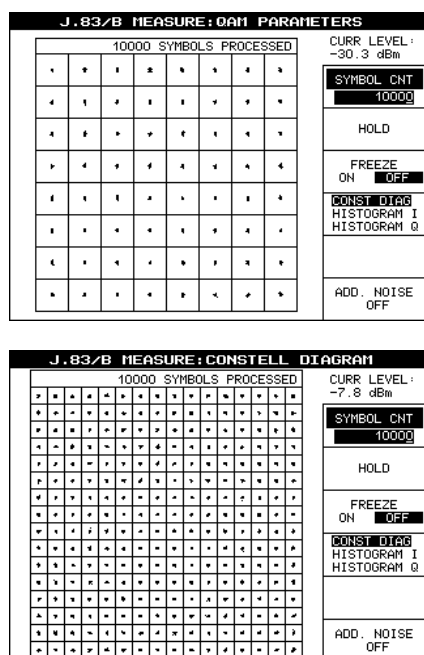

Fig. 5.40   Ideal 64QAM and 256QAM constellation diagrams

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

For the diagram represented above, the absolute phases of the I and the Q components 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 axes point. Consequently, no coordinate axes are entered in the diagram.

5.8.3 I/Q Imbalance

I/Q imbalance results from different amplification in the I and the Q path of the ITU-T J.83/B modulator. This parameter is calculated by the following equation:

I/Q IMBALANCE = $(v_2 / v_1 - 1) * 100 \%$

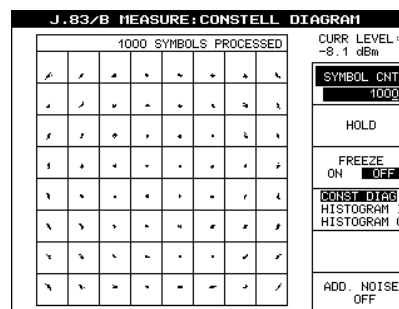with $v_1 = \min (v_I, v_Q)$ and $v_2 = \max (v_I, v_Q)$

Fig. 5.41   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 greater in the horizontal direction. The I/Q value pairs are not located in the center of the decision fields.
The four corner points of the diagram form a rectangle.

5.8.4 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. 5.38):

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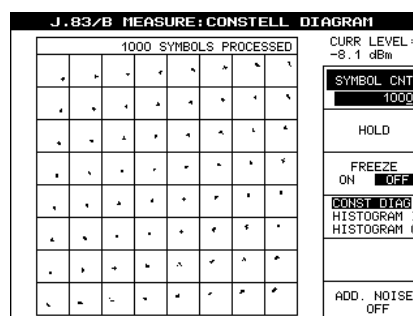

Fig. 5.42   64QAM constellation diagram with 8 ° I/Q quadrature error

A QAM signal with a phase error generates a constellation diagram in which the regression lines connecting the center points of the /IQ symbol clouds do not run parallel to the lines forming the decision thresholds.
The four corner points of the diagram form a rhombus.