ROHDE&SCHWARZ
BROADCASTING DIVISION

Digital TV
Rigs and Recipes
Part 5
ITU-T J.83/B

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Contents

5. 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 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"). Same as for the DVB standards, a comparison of analog modulation with digital modulation as used by the North American ITU-T J.83/B cable standard reveals that digital modulation yields a flat spectrum with a constant average power density across the 6 MHz channel bandwidth. The modulator (and, consequently, the demodulator) employed by the ITU-T J.83/B standard is of more complex design than the DVB-C modulator commonly used in Europe and many other countries. Using concatenated coding for the MPEG2 data, ITU-T J.83/B offers forward error correction better than that of DVB-C.

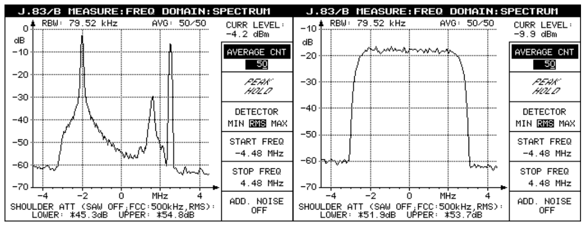

Fig. 5.1 Comparison of M/NTSC spectrum and ITU-T J.83/B spectrum

5.1 Modulation to ITU-T J.83/B (North American Cable Standard)

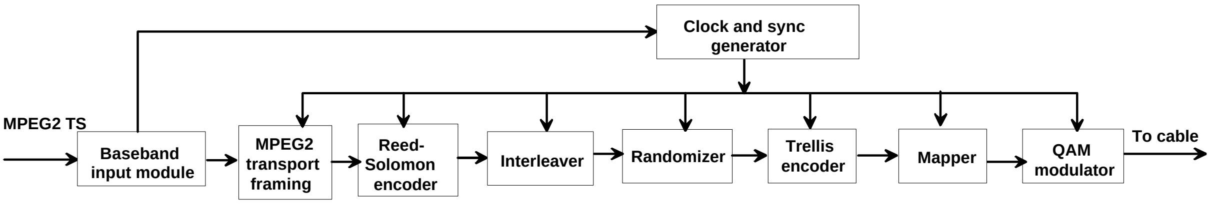

Fig. 5.2 Block diagram of ITU-T J.83/B modulator/converter

5.1.1 Baseband Input Module

The MPEG2 transport stream (TS) packets are routed to the first function block of the digital TV modulator, which is the baseband input module, via one of the following interfaces:

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 TS packets are transported to the baseband input module at the specified ITU-T J.83/B data rates of 26.97035 Mbit/s net for 64QAM and 38.81070 Mbit/s net for 256QAM. The standard does not provide for other QAM modes. 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 function block, which acts as a central clock generator for all other function blocks of the ITU-T J.83/B modulator. This 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 function block, i.e. MPEG2 transport framing.

5.1.2 MPEG2 Transport Framing

After the input module, the TS packets undergo the first processing step:
To ensure reliable synchronization at the receiver end and to provide additional error correction capability, the MPEG2 transport packet structure is modified by substituting a parity checksum for the 0x47 sync byte which, in line with MPEG2, is the first byte of each TS packet. The parity checksum byte is obtained by means of sliding computation, then the sync byte is deleted, and the parity checksum byte appended at the end of the remaining 187 bytes of the TS packet. In this way, a 188-byte packet is obtained again.

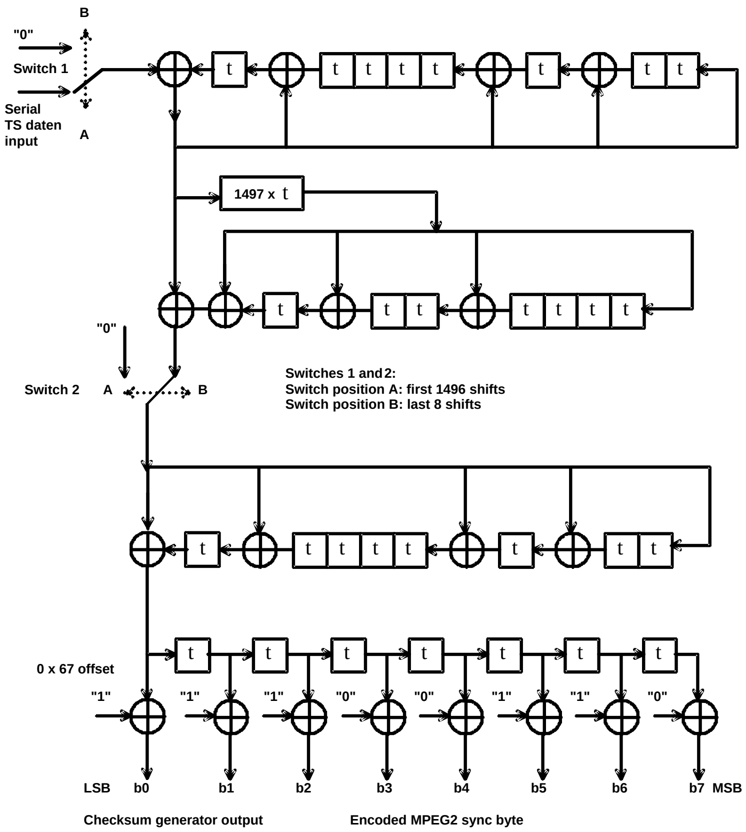

Fig. 5.3 Checksum generator for MPEG2 sync byte encoding

MPEG2 data is applied as serial data to the input of the checksum generator. This means that TS packets with a length of 188 ∗ 8 = 1504 bits are present. Checksum computation covers only 187 bytes however, so that the actual data volume is 1504 – 8 = 1496 bits.

The checksum generator is described by the following equation:

$$f(x) = \frac{1 + x^{1497} * b(x)}{g(x)} \quad \text{where}$$

$g(x) = 1 + x + x^5 + x^6 + x^8$ and
$b(x) = 1 + x + x^3 + x^7$

Prior to the start of the encoding operation, all clock buffers are set to zero. Then the 1496 bits are shifted into a feedback shift register. After the 1496 clock bits, the shift register is also set to zero by means of equation g(x). Using the last eight clock bits with the offset 0x67, the checksum, i.e. the coded sync byte, is generated. This sync byte, in turn, produces the original 0x47 sync byte at the decoder end. The syndrome generator employed for this purpose is illustrated below:

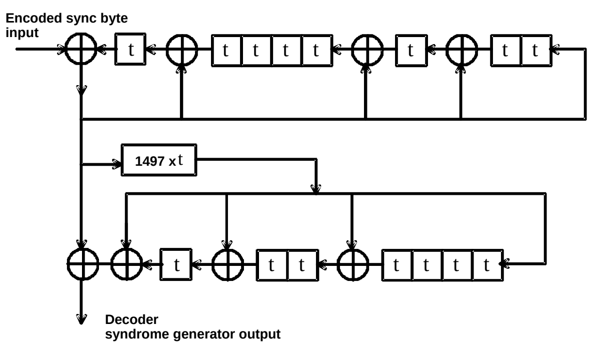

Fig. 5.4 Syndrome generator for MPEG2 sync byte decoding

If a valid code word is present at the syndrome generator input, the original 0x47 sync byte is restored at the generator output, i.e. the code word is replaced by the valid sync byte. In this way, a standard TS packet of 188 bytes length with the sync byte as the start byte is reproduced. It should be noted, however, that the sync byte is derived from the preceding TS packet and not from the 187 bytes following the sync byte.

Instead of the syndrome generator, a matrix operation can be employed at the decoder end to check whether a valid code word is present.
In this case, a vector R of 187 bytes of MPEG2 data and the checksum byte are applied to the decoder. Vector R has a size of 1 x 1504 (each TS packet contains 8 x 188 = 1504 bits). The vector is modulo 2 multiplied with a parity check matrix P of the size 1504 x 8. If data has been transmitted error-free, this operation yields a vector S of the size 1 x 8 and with the contents S = [0100 0111] = 0 x 47, which is the original sync byte of the TS packet.

For the parity check matrix P, a vector C of a size of 1 x 1497 has to be defined first. Vector C is structured as follows:

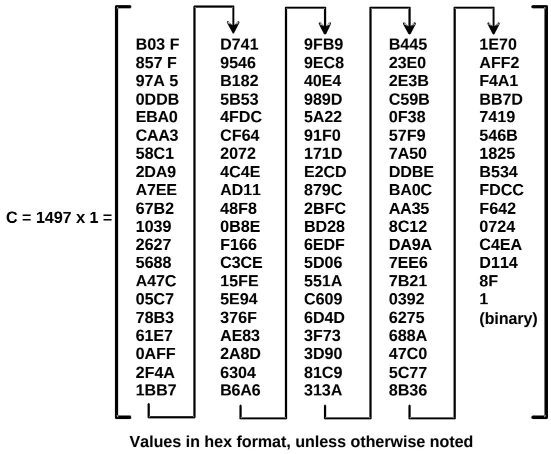

Fig. 5.5 Vector C

The hex values are entered serially bit by bit into the vector column, yielding a column length of 1497 bits.

Vector C is duplicated to produce the matrix P according to the following scheme:

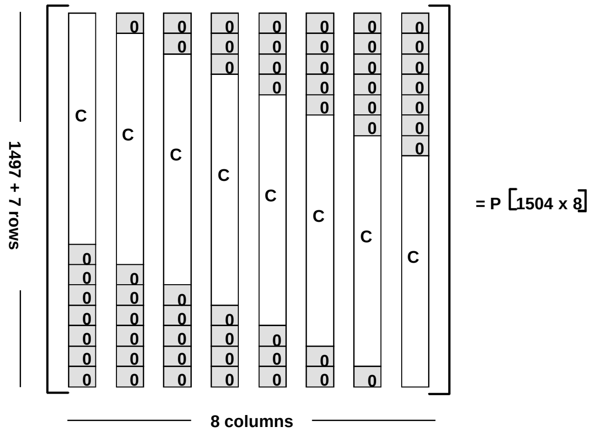

Fig. 5.6 Parity check matrix P

Vector C is extended by seven zero bits and duplicated into seven more columns, each column shifted down by one bit position relative to the previous column. In this way, the eight-column matrix P is obtained.
The matrix is modulo 2 multiplied with the received vector R to yield the original 0x47 sync byte.

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

The output of the checksum generator is applied to the input of the Reed-Solomon encoder block. In a first step for RS encoding, the TS packet data is divided into sections of 7 bits referred to as symbols. Of these 7-bit symbols, RS blocks are formed, each block consisting of 122 symbols plus six 6 appended RS FEC symbols. The resulting t = 3, (128, 122) RS FEC code is capable of correcting up to three errored symbols per block. This means that a quasi-error-free (QEF) data stream with approximately one uncorrected error event every 15 minutes will be obtained, assuming a BER of 7×10^{-5} or better before RS FEC (BER value determined empirically).

ITU-T J.83/B defines different FEC frame formats for the two modulation modes used, i.e. 64QAM and 256QAM.

5.1.3.1 FEC Frame Format for 64QAM

For 64QAM, an FEC frame is formed by 60 RS blocks, each containing 128 symbols, to which a frame sync trailer consisting of six 7-bit symbols is appended.

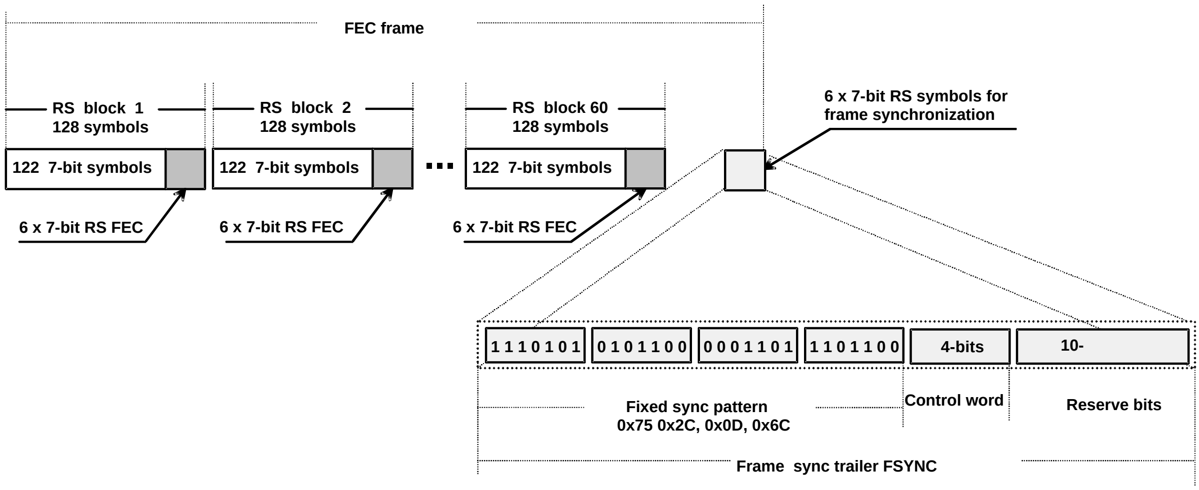

Fig. 5.7 FEC frame format for 64QAM

The frame sync word (FSYNC) consists of a fixed synchronization pattern of four 7-bit RS symbols (111 0101, 010 1100, 000 1101, 110 1100), followed by a 4-bit control word and 10 reserved bits that are set to zero.
The control word indicates the interleaving level and the interleaving mode. The meaning of the four bits is explained in Table 5.2.

5.1.3.2 FEC Frame for 256QAM

For 256QAM, an FEC frame is formed by 88 RS blocks, each containing 128 symbols, to which a frame sync trailer of 40 bits is appended.

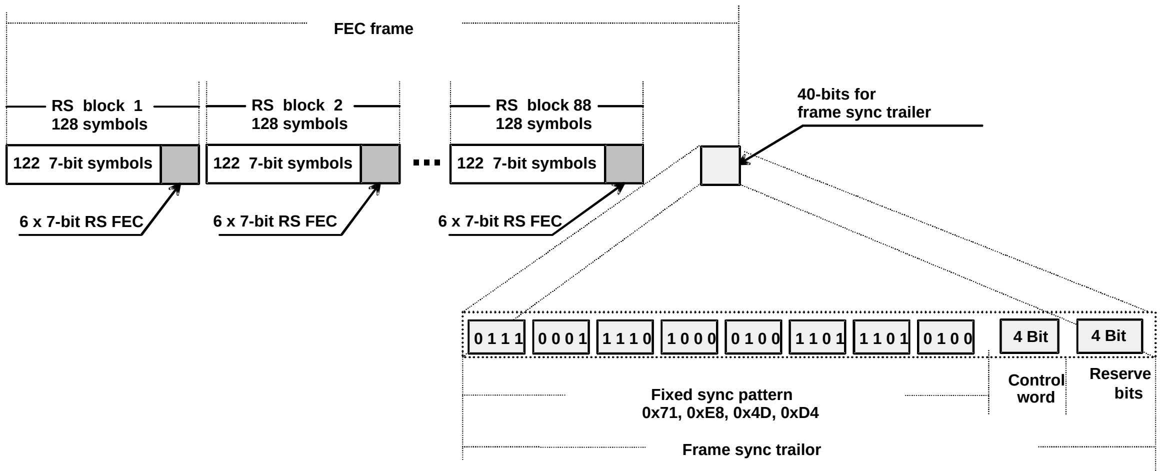

Fig. 5.8 FEC frame format for 256QAM

The frame sync trailer consists of a fixed synchronization pattern of four bytes (0x71, 0xE8, 0x4D, 0xD4), followed by a 4-bit control word and four reserved bits that are set to zero.

The control word indicates the interleaving level and the interleaving mode. The meaning of the four bits is explained in Table 5.2.

5.1.4 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 RS decoder correction capability of three symbols per RS block is insufficient in such cases. So an interleaver is used to insert – in the reduced interleaving mode – 8, 16, 32, 64 or 128 RS symbols (for the I = 8, 16, 32, 64 and 128 interleaver paths defined for the convolutional interleaver modes, see Fig. 5.9) from other RS blocks between neighbouring symbols of an RS block. This allows burst errors of max.

3 x 8	= 24	RS symbols
3 x 16	= 48	RS symbols
3 x 32	= 96	RS symbols
3 x 64	= 192	RS symbols
3 x128	= 384	RS symbols

to be corrected, provided that only three or fewer errored symbols per RS block occur after the deinterleaver in the receiver/decoder.

The enhanced interleaving mode provides for I = 128 paths with different memory depths of M = 1 to 8.

Reduced interleaving mode	
Paths	I = 8, 16, 32, 64, 128
Interleaving depth of FIFOs	M = 1, 2, 4, 8, 16
Enhanced interleaving mode	
Paths	I = 128
Interleaving depth of FIFOs	M = 1 to 8
Synchronization	At beginning of FEC frame via first path

Table 5.1 Level 2 interleaving

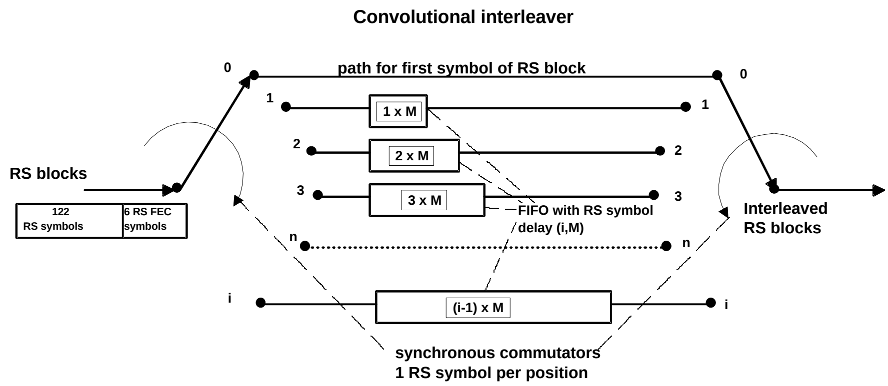

Fig. 5.9 Convolutional interleaver

The interleaving mode used (see Table 5.1) is indicated by the 4-bit control word of the frame sync trailer. Table 5.2 shows the interleaving level and the meaning of the control word in each case.

Depending on the interleaver configuration, level 1 (64QAM only) or level 2 (64QAM and 256QAM) interleaving capability is available.

Level 1 interleaving for 64QAM						
Control word (4 bits)	Paths (I)	Interleaving depth (M)	Max. length T_{Error} (µs) of an error burst		Latency T_L (ms) of interleaver	
			64QAM	256QAM	64QAM	256QAM
XXXX	128	1	94.92	65.98	4.018	
Level 2 interleaving for 64QAM and 256QAM						
Control word (4 bits)	Paths (I)	Interleaving depth (M)	Max. length T_{Error} (µs) of an error burst		Latency T_L (ms) of interleaver	
			64QAM	256QAM	64QAM	256QAM
0001	128	1	94.92	65.98	4.018	2.793
0011	64	2	47.46	32.99	1.993	1.386
0101	32	4	23.73	16.49	0.981	0.682
0111	16	8	11.86	8.25	0.475	0.330
1001	8	16	5.93	4.12	0.221	0.154
1011	Reserved					
1101						
1111						
0000	128	1	94.92	65.98	4.018	2.793
0010	128	2	189.8	132.0	8.036	5.586
0100	128	3	284.8	197.9	12.06	8.379
0110	128	4	379.7	263.9	16.07	11.17
1000	128	5	474.6	329.9	20.09	13.97
1010	128	6	569.5	395.9	24.11	16.76
1100	128	7	664.4	461.9	28.13	19.55
1110	128	8	759.4	527.8	32.15	22.35

Table 5.2 Interleaving levels and control words

5.1.5 Randomizer

The randomizer provides for even distribution of the 7-bit RS symbols in the constellation diagram. This ensures constant power density across the ITU-T J.83/B spectrum and allows the demodulator to maintain stable synchronization.

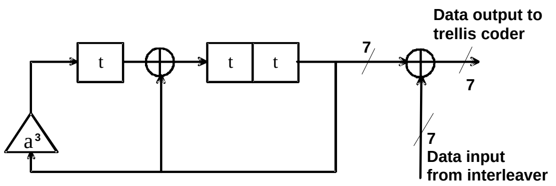

Fig. 5.10 Randomizer

The randomizer adds a PRBS over a Galois field(128) polynomial defined as follows:

$f(x) = x^3 + x + \alpha^3$
where $\alpha^7 + \alpha^3 + 1 = 0$

The resulting combinations are 7 bits wide, each constituting exactly one RS symbol.

For synchronization, the three buffers of the randomizer are reset to zero during the synchronization bits of the frame sync trailer at the end of the RS FEC frame (see 5.1.3 "Reed-Solomon (RS) Forward Error Correction (FEC)"). The randomizer is enabled at the first RS symbol of the RS FEC frame, i.e. after the trailer, and disabled after the last RS symbol of the last RS block of the FEC frame. Thus the synchronization bits are not randomized.

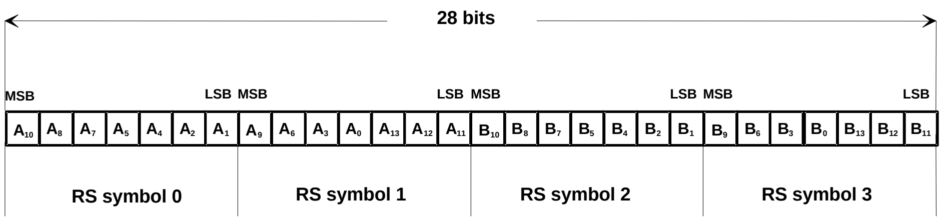

Fig. 5.11. 'A' and 'B' symbols for 64QAM

5.1.6 Mapping of Randomized Data to 64QAM and 256QAM Symbols

So far, we have discussed only bits and RS symbols. To transmit this data using 64QAM/256QAM (quadrature amplitude modulation), it has to be converted to QAM symbols. As a first step to this effect, trellis groups are formed from the randomizer output data.

5.1.6.1 Mapping of Randomized Data to 64QAM Symbols

With 64QAM, a trellis group consists of 28 bits, i.e. four randomized RS symbols. The bits of the four symbols are resorted and organized in 'A' symbols and 'B' symbols as shown in Fig. 5.11.

The trellis group thus obtained is applied to the input of the 64QAM trellis coded modulator. In the input block of the 64QAM modulator, the 'A' and 'B' symbols are resorted a second time and the four MSBs and the two LSBs for the QAM mapper are generated. The four MSBs are input to the mapper uncoded, the two LSBs undergo differential encoding.

The data has the following structure:

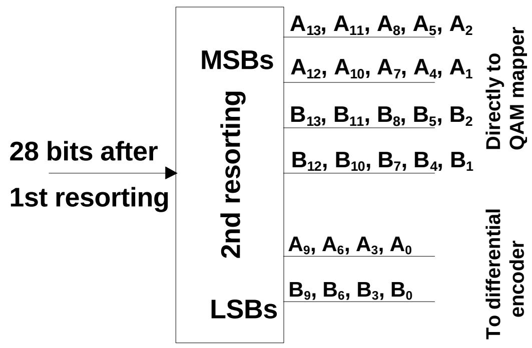

Fig. 5.12 Second resorting of 'A' and 'B' symbols of a trellis group

Tabular representation of trellis group symbols after second resorting:

	64QAM symbols				
	T_0	T_1	T_2	T_3	T_4
Directly to mapper	B_2	B_5	B_8	B_{11}	B_{13}
	B_1	B_4	B_7	B_{10}	B_{12}
	A_2	A_5	A_8	A_{11}	A_{13}
	A_1	A_4	A_7	A_{10}	A_{12}
To diff. encoder	B_0	B_3	B_6	B_9	
	A_0	A_3	A_6	A_9	
Time →					

Table 5.3 64QAM symbols of a trellis group

Table 5.3 shows that symbol T_4 has only four bits. The remaining two bits are generated by the trellis encoder and subsequent puncturing.
The above table also shows that the data of a trellis group corresponds to the five 6-bit 64QAM symbols T_0, T_1, T_2, T_3 and T_4.

Before being applied to the trellis encoder, the two LSBs undergo differential encoding, which considerably enhances decoding reliability of the ITU-T J.83/B receiver.

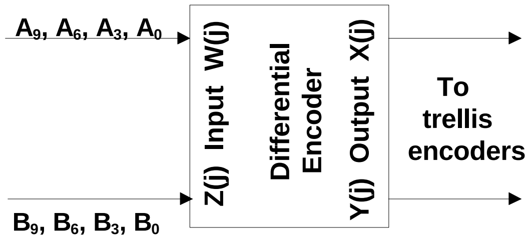

Fig. 5.13 Differential encoder

Differential encoding is based on the following equations:

$X(j) = W(j) + X(j-1) + Z(j)(X(j-1) + Y(j-1))$ and
$Y(j) = Z(j) + W(j) + Y(j-1) + Z(j)(X(j-1) + Y(j-1))$

After differential encoding, each of the two bits is applied to a separate trellis encoder (binary convolutional coder (BCC) with k = 5).
The following generating codes are employed:
G1 = 25 (octal) and G2 = 37 (octal).
Convolutional coding is followed by puncturing to a 4/5 code rate, i.e. the 2 x 4-bit BCC output data is converted to a serial data stream of 5-bit trellis groups.

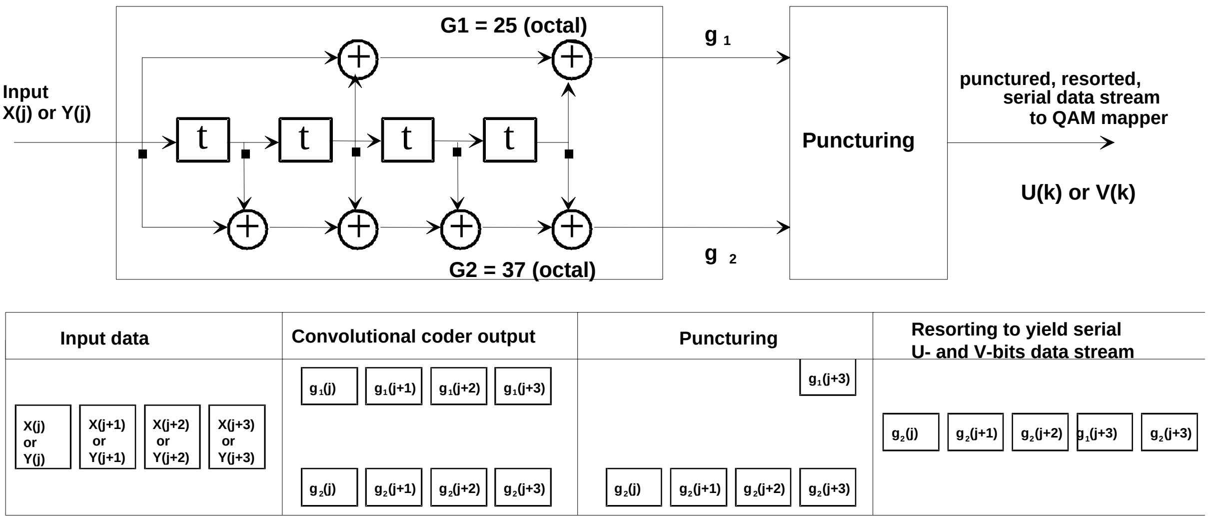

Fig. 5.14 Binary convolutional coder (BCC) and puncturing to code rate 4/5

All single function blocks of a 64QAM modulator with trellis coding have now been introduced.

Note the assignment of the uncoded "A" and "B" bits (MSBs) and the coded "U" and "V" bits (LSBs) to the C0 to C5 64QAM symbols in the overall block diagram:

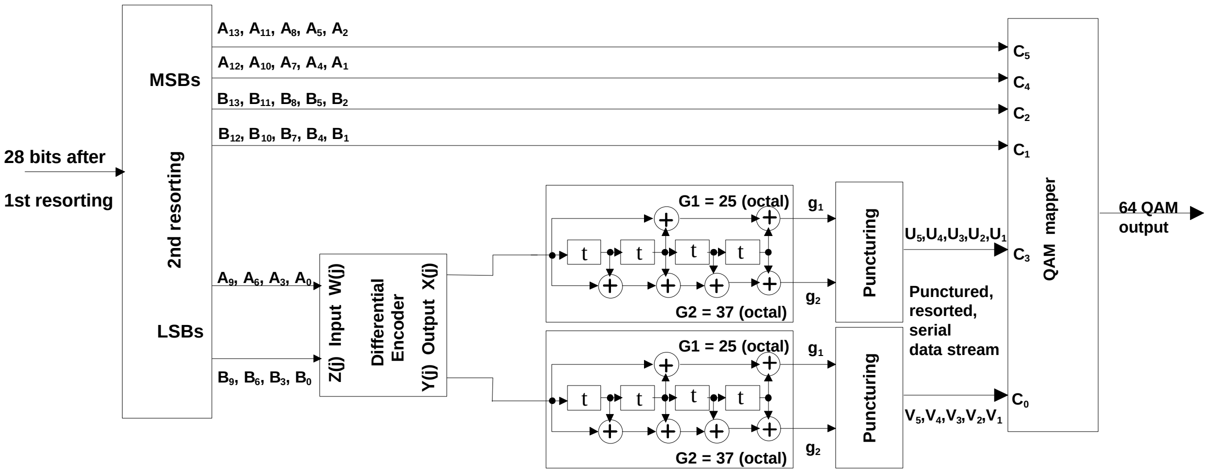

Fig. 5.15 64QAM modulator with trellis coding

The following overall code rate is obtained: 28/30 = 14/15

The 6-bit 64QAM symbols output by the QAM mapper are applied to the 64QAM modulator, which generates a constellation diagram with the 64QAM symbols mapped into bits as follows:

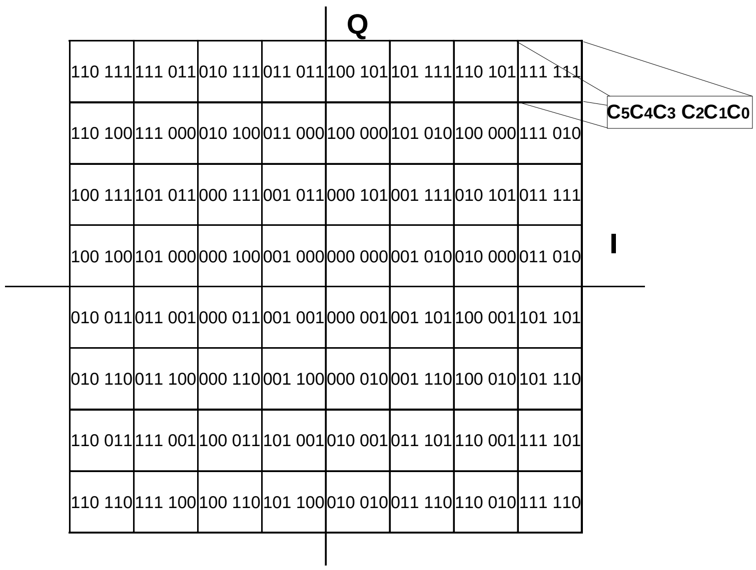

Fig. 5.16 64QAM constellation diagram for ITU-T J.83/B standard

The 64QAM symbols are $\sqrt{\cos}$ roll-off filtered analog pulses with a spectrum approximating a sin (x)/x function and eight amplitude levels for the I and the Q component. The eight amplitudes are represented by three bits each for I and Q.

Each symbol consists of a pair of I and Q values arranged orthogonally through modulation. 'I' stands for the in-phase and 'Q' for the quadrature component.
The resulting signals, therefore, have a defined flat spectrum (see Fig. 5.1 on the right).

5.1.6.2 Mapping of Randomized Data to 256QAM Symbols

For 256QAM, there are two types of trellis groups referred to as 'non-sync' and 'sync'. A non-sync trellis group consists of 38 data bits, a sync group of 30 data bits and 8 sync bits. Since each RS FEC frame comprises 88 RS blocks plus the 40-bit frame sync trailer, 2076 trellis groups per frame are obtained. The first 2071 trellis groups carry data bits only; the last 5 trellis groups carry 30 data bits and 8 sync bits each. The bits of the trellis groups are resorted and organized in 'A' symbols and 'B' symbols as shown in Fig. 5.17.

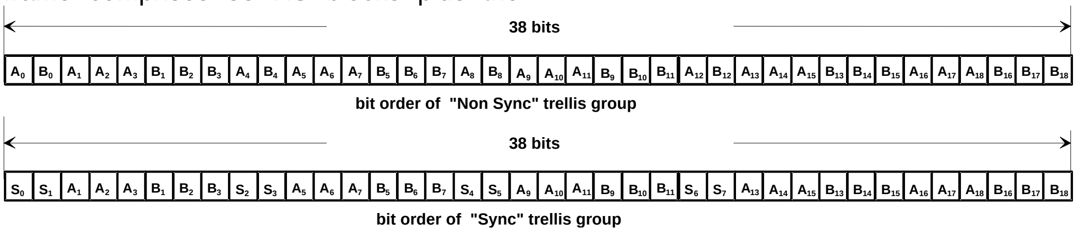

Fig. 5.17. 'A', 'B' and 'S' bits of 256QAM trellis groups

The trellis groups thus obtained are applied to the input of the 256QAM trellis coded modulator. In the input block of the 256QAM modulator, the 'A', 'B' and 'S' bits are resorted a second time, and the six MSBs and the two LSBs for the QAM mapper are generated. The six MSBs are input to the mapper uncoded, the two LSBs undergo differential encoding.

The data has the following structure:

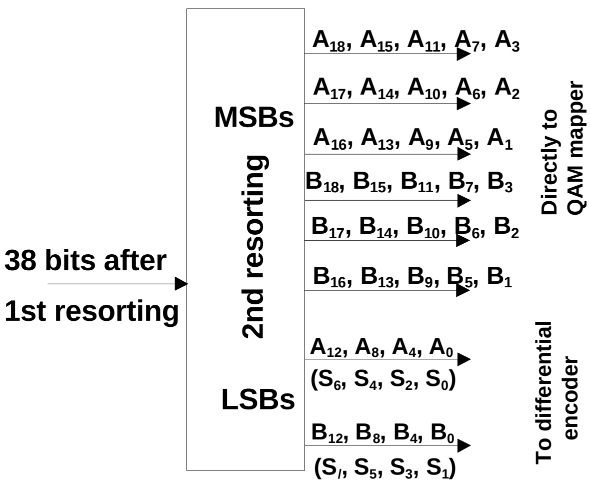

Fig. 5.18 Second resorting of bits of trellis groups

Tabular representation of trellis group symbols after second resorting:

	256QAM symbols of non-sync trellis group				
	T_0	T_1	T_2	T_3	T_4
Directly to mapper	B_3	B_7	B_{11}	B_{15}	B_{18}
	B_2	B_6	B_{10}	B_{14}	B_{17}
	B_1	B_5	B_9	B_{13}	B_{16}
	A_3	A_7	A_{11}	A_{15}	A_{18}
	A_2	A_6	A_{10}	A_{14}	A_{17}
	A_1	A_5	A_9	A_{13}	A_{16}
To diff. encoder	B_0	B_4	B_8	B_{12}	
	A_0	A_4	A_8	A_{12}	

Table 5.4 256QAM symbols of non-sync trellis group

	256QAM symbols of sync trellis group				
	T_0	T_1	T_2	T_3	T_4
Directly to mapper	B_3	B_7	B_{11}	B_{15}	B_{18}
	B_2	B_6	B_{10}	B_{14}	B_{17}
	B_1	B_5	B_9	B_{13}	B_{16}
	A_3	A_7	A_{11}	A_{15}	A_{18}
	A_2	A_6	A_{10}	A_{14}	A_{17}
	A_1	A_5	A_9	A_{13}	A_{16}
To diff. encoder	S_1	S_3	S_5	S_7	
	S_0	S_2	S_4	S_6	

Table 5.5 256QAM symbols of sync trellis group

Table 5.3 shows that symbol T_4 has only six bits. The remaining two bits are generated by the trellis encoder and subsequent puncturing.
The above tables also show that the data of a trellis group corresponds to the five 8-bit 256QAM symbols T_0, T_1, T_2, T_3 and T_4.

Before being applied to the trellis encoder, the two LSBs undergo differential encoding, which considerably enhances decoding reliability of the ITU-T J.83/B receiver.

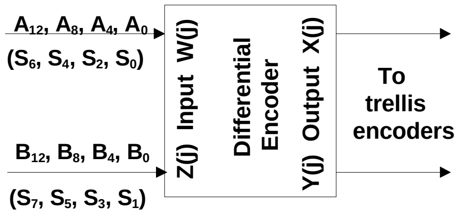

Fig. 5.19 Differential encoder

Differential encoding is based on the following equations:

X(j) = W(j) + X(j-1) + Z(j)(X(j-1) + Y(j-1)) and
Y(j) = Z(j) + W(j) + Y(j-1) + Z(j)(X(j-1) + Y(j-1))

After differential encoding, each of the two bits is applied to a separate trellis encoder (binary convolutional coder (BCC) with k = 5).

The following generating codes are employed:
G1 = 25 (octal) and G2 = 37 (octal)

Convolutional coding is followed by puncturing to a 4/5 code rate, i.e. the 2 x 4-bit BCC output data is converted to a serial data stream of 5-bit trellis groups.

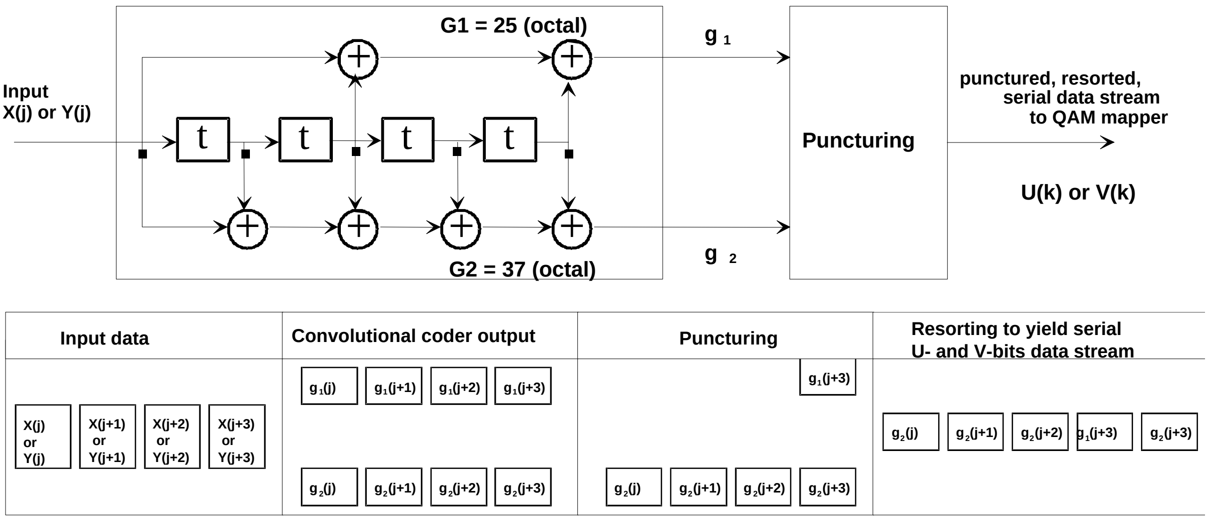

Fig. 5.20 Binary convolutional coder (BCC) and puncturing to code rate 4/5

All single function blocks of the 256QAM modulator with trellis coding have now been introduced.

Note the assignment of the uncoded "A" and "B" bits (MSBs) and the coded "U" and "V" bits (LSBs) to the C0 to C7 256QAM symbols in the overall block diagram:

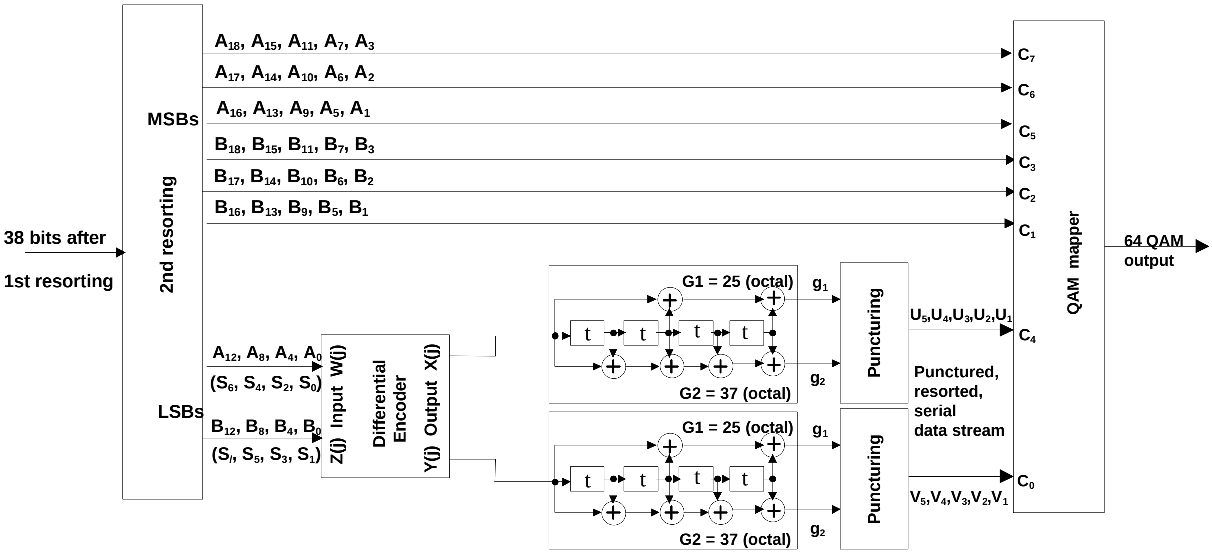

Fig. 5.21 256QAM modulator with trellis coding

The following overall code rate is obtained: 38/40 = 19/20

The 8-bit 256QAM symbols output by the QAM mapper are applied to the 256QAM modulator, which generates a constellation diagram with the 256QAM symbols mapped into bits as follows:

Q

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

I

$C_7C_6C_5C_4$
$C_3C_2C_1C_0$

Fig. 5.22 256QAM constellation diagram for ITU-T J.83/B standard

The 256QAM symbols are $\sqrt{\cos}$ roll-off filtered analog pulses with a spectrum approximating a sin (x)/x function and 16 amplitude levels for the I and the Q component. The 16 amplitudes are represented by four bits each for I and Q.

Each symbol consists of a pair of I and Q values arranged orthogonally through modulation. 'I' stands for the in-phase and 'Q' for the quadrature component.
The resulting signals, therefore, have a defined flat spectrum (see Fig. 5.1 on the right).

5.2 64QAM and 256QAM Signal Bandwidths

5.2.1 64QAM Signal Bandwidth

The bandwidth is determined based on the specified R_{N64} net data rate for 64QAM, which is 26.97035 Mbit/s. From the net data rate, the gross data rate is calculated as follows:

$$R_{G64} = R_{N64} * \frac{((122+6)*7*60)+42}{122*7*60} * \frac{15}{14}\ \text{Mbit/s}$$

= 30.34164375 Mbit/s

Each 64QAM symbol takes up 6 bits of the R_{G64} gross data rate. From this, the symbol rate S is obtained which, expressed in Hz, constitutes the signal bandwidth:

$$BW_{64} = \frac{30.34164375}{6} = 5.056940625\ \text{MHz}$$

The M/NTSC channel bandwidth is

$BW_{Channel}$ = 6 MHz

Based on the signal bandwidth

BW_{64} = 5.056940625 MHz

the optimal roll-off factor r is calculated as follows:

$$r = 1 - \frac{BW_{Channel}}{BW_{64}} = 1 - \frac{6.0}{5.056940625} = 0.186488$$

which is 18.6488 % expressed in percent. The ITU-T J.83/B standard defines an 18 % roll-off factor for 64QAM.

5.2.2 256QAM Signal Bandwidth

The bandwidth is determined based on the specified net data rate R_{N256} for 256QAM, which is 38.81070 Mbit/s. From the net data rate, the gross data rate is calculated as follows:

$$R_{G256} = R_{N256} * \frac{((122+6)*7*88)+40}{122*7*88} * \frac{20}{19}\ \text{Mbit/s}$$

= 42.884294869 Mbit/s

Each 256QAM symbol takes up 8 bits of the R_{G256} gross data rate. From this, the symbol rate S is obtained which, expressed in Hz, constitutes the signal bandwidth:

$$BW_{256} = \frac{42.884294869}{8} = 5{,}360536858625\ \text{MHz}$$

The M/NTSC channel bandwidth is

$BW_{Channel}$ = 6 MHz

Based on the signal bandwidth

BW_{256} = 5.360536858625 MHz

the optimal roll-off factor r is calculated as follows:

$$r = 1 - \frac{BW_{Channel}}{BW_{256}} = 1 - \frac{6.0}{5.360536858625} = 0.119291$$

which is 11.9291 % expressed in percent. The ITU-T J.83/B standard defines a 12 % roll-off factor for 256QAM.

5.2.3 $\sqrt{\cos}$ Filtering at Transmitter and Receiver End

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. 5.24 "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 an ITU-T J.83/B modulator:

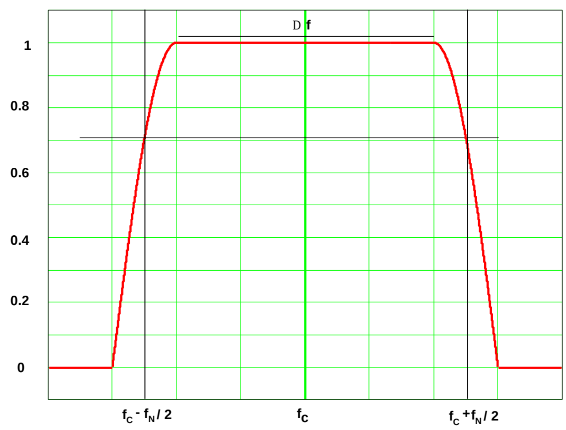

Fig. 5.23 Spectrum obtained by $\sqrt{\cos}$ filtering
Clearly discernible are the steep edges at low levels at the left and right boundaries of the

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 based on the ratio of the Nyquist bandwidth to the flat "rooftop" of the spectrum:

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

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

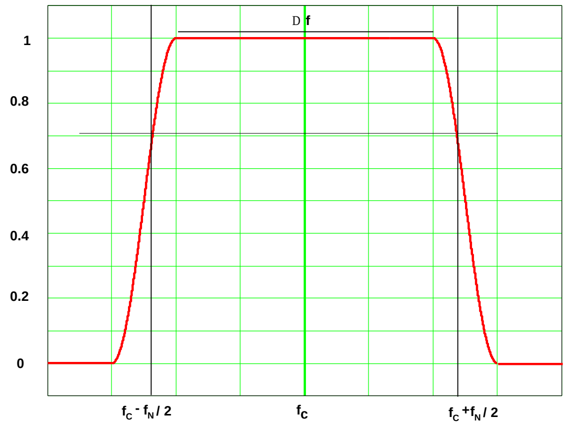

Fig. 5.24 Spectrum obtained by cos roll-off filtering

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. 5.25 shows the $\sqrt{\cos}$ and cos filter edges in greater detail:

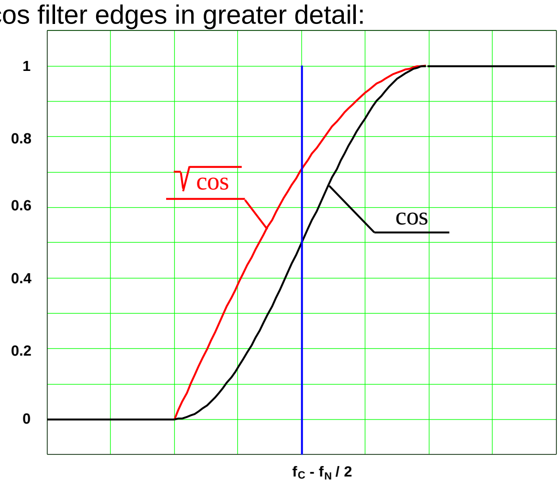

Fig. 5.25 Edges obtained with $\sqrt{\cos}$ roll-off and cos roll-off filtering

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

1. The Nyquist criterion is fully met, so the transmitted signal can be retrieved accurately and error-free at the receiver end.
2. In case of noisy transmissions, combined transmitter and receiver $\sqrt{\cos}$ filtering enables optimal noise filtering in the receiver.
3. By signal filtering in the receiver, useful channel selection is effected at the same time.

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

$$BW_{Ch} = S * (1+r) \text{ MHz}$$

5.3 ITU-T J.83/B Key Data

QAM mode	64 256	
Symbol form		Similar to $\frac{\sin x}{x}$ cos roll-off filtered
Roll-off factor	64QAM 256QAM	0.18 0.12
Net bit rate R (Mbit/s)	64QAM 256QAM	26.97035 38.81070
Gross bit rate R (Mbit/s)	64QAM 256QAM	30.34164375 42.884294869
Symbol rate S (Msymb/s)	64QAM 256QAM	5.056940625 5.360536858625

Table 5.6

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5.3 Data Rates and Symbol Rates in ITU-T J.83/B

An MPEG2 multiplexer or an MPEG2 generator supplies video, audio and other data in the form of TS (transport stream) packets with a defined data rate R. ITU-T J.83/B specifies two gross data rates:

Gross data rate for 64QAM:

R_{G64} = 30.34164375 Mbit/s

Gross data rate for 256QAM:

R_{G256} = 42.884294869 Mbit/s

Each symbol carries
6 bits for 64QAM or
8 bits for 256QAM
of the MPEG2 data stream, i.e. three or four bits each for the I and the Q component.

This yields the following symbol rates:

S_{64} = 5.056940625 Msymb/s
S_{256} = 5.360536859 Msymb/s

The above data rates and symbol rates must be accurately complied with. Deviations $> 1 * 10^{-5}$ might cause signal processing in the transmitter and, even more critically, in the receiver to fail, since the quartz PLLs reach the limits of their pull-in range. Monitoring and measuring the data and symbol rates is therefore a must.

The data rates specified by ITU-T J.83/B for 64QAM and 256QAM can be changed on the Rohde & Schwarz TV Test Transmitters R&S SFQ and R&S SFL-J by changing the symbol rate as follows:

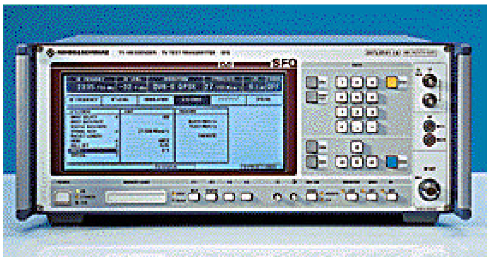
For 64QAM:
between 4.5 Msymb/s and 5.625 Msymb/s (corresponding to a variation of the gross data rate between 27.0 Mbit/s and 33.75 Mbit/s)

For 256QAM:
between 4.8 Msymb/s and 5.9 Msymb/s (corresponding to a variation of the gross data rate between 38.4 Mbit/s and 47.2 Mbit/s).

The pull-in range of the symbol rate PLL of set-top boxes (STBs) for the American ITU-T J.83/B cable standard can thus easily be monitored.

The setting range for the symbol rate is in either case much larger than the actual pull-in range of the STB's PLL.

For measurements to the ITU-T J.83/B digital television (DTV) standard, the R&S SFQ and the R&S SFL-J modulate the TS data stream strictly in accordance with specifications. In addition, defined modulation errors can be introduced into the ideal signal, for example a symbol rate deviating from the ideal value, and thus reproducible signal degradation created. Such stress signals are indispensable in DTV receiver tests to determine the system limits.



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

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.

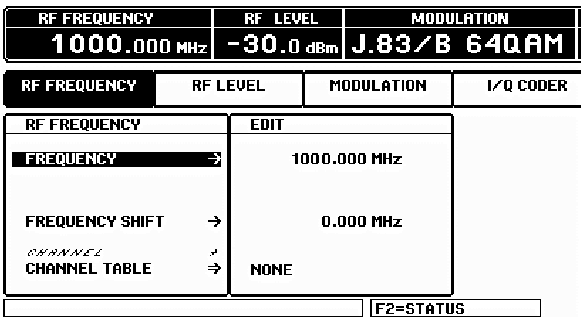


Fig. 5.26 Frequency setting on R&S SFQ

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.

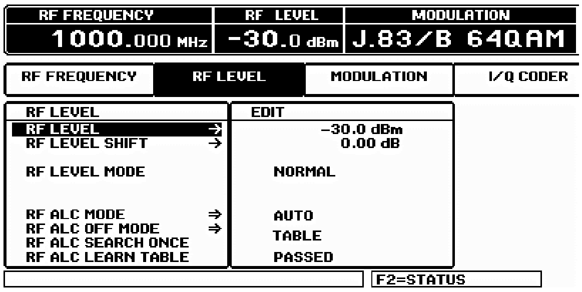


Fig. 5.27 Level setting on R&S SFQ

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.

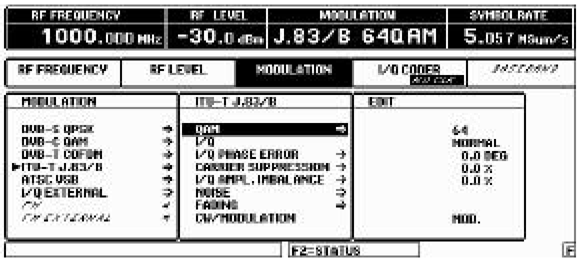


Fig. 5.28 Setting of modulator- and transmission-specific parameters for ITU-T J.83/B standard on R&S SFQ

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.

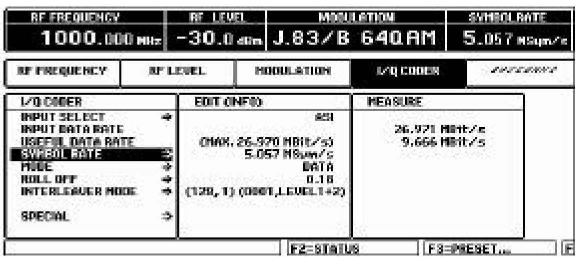


Fig. 5.29 Settings for ITU-T J.83/B standard in I/Q CODER menu on R&S SFQ

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.

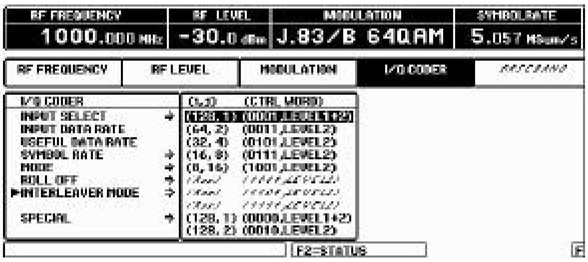


Fig. 5.30 Interleaver settings on R&S SFQ

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.

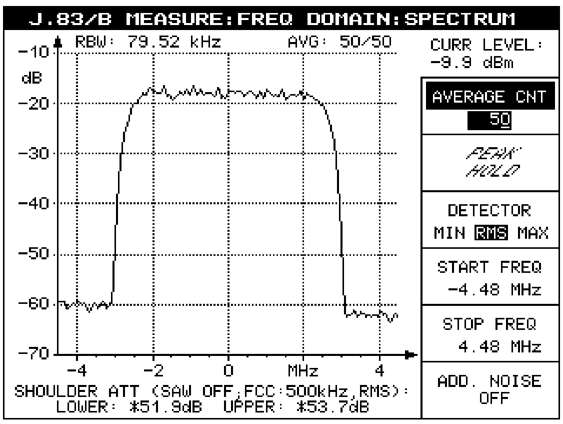


Fig. 5.31 Constant power density in ITU-T J.83/B channel

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.

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 ≤ 1.5 dB.

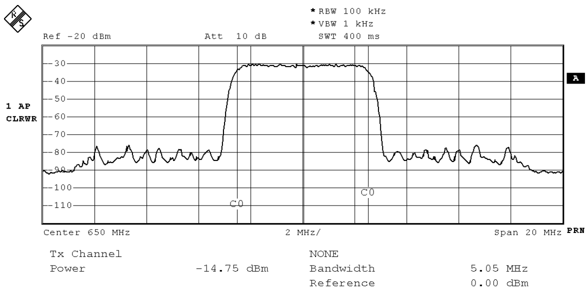


Fig. 5.32a Power measurement with frequency cursors covering Nyquist bandwidth

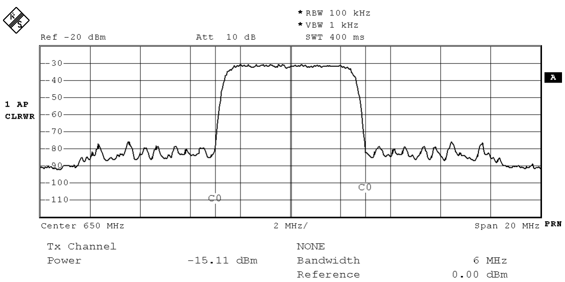


Fig. 5.32b Power measurement with frequency cursors covering channel bandwidth

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

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.

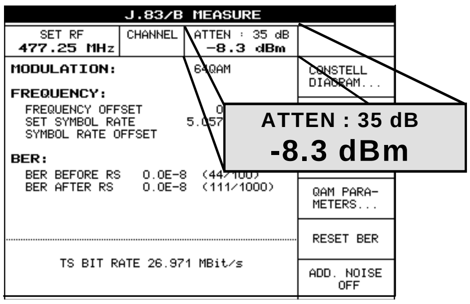


Fig. 5.33 Power measurement with TV Test Receiver R&S EFA model 70 or 73

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.

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.

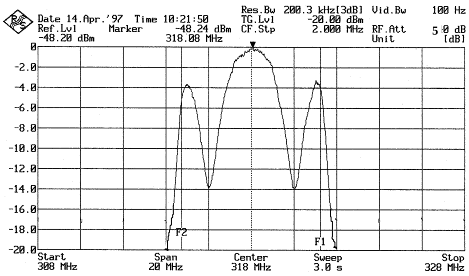


Fig. 5.34 Fading spectrum

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 < $1x10^{-11}$, i.e. one error every 15 minutes), but only for bit error ratios of 7 x 10^{-5} or better (value determined by measurements, not based on theoretical considerations, criterion is BER → 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.

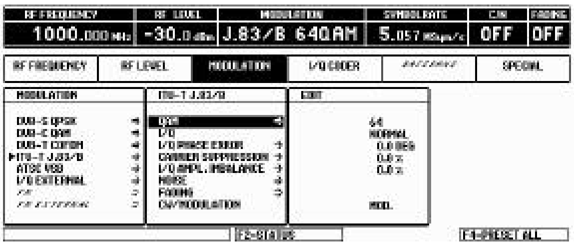
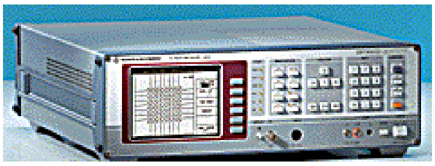


Fig. 5.35 R&S SFQ menu for setting ITU-T J.83/B parameters

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.

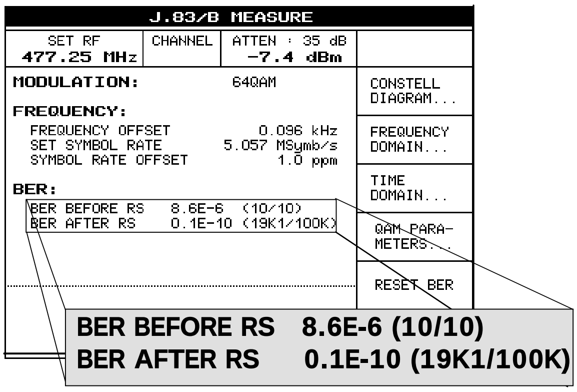


Fig. 5.36 ITU-T J.83/B measurement menu: BER measurement

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.

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.

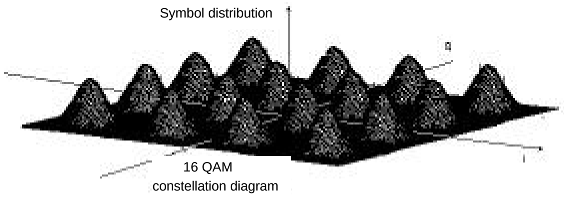


Fig. 5.37 Typical symbol distribution in a 16QAM constellation diagram

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.

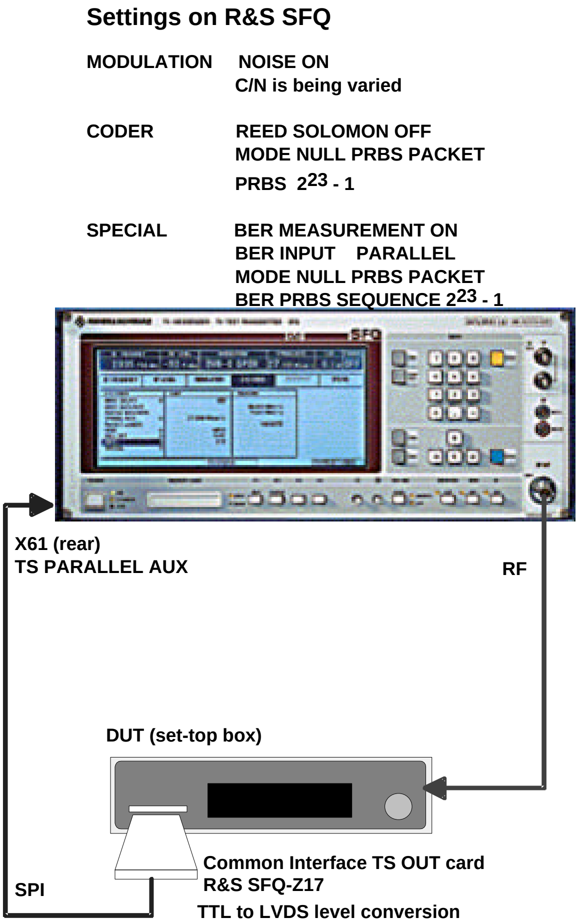


Fig. 5.38 Test setup for BER measurement

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.

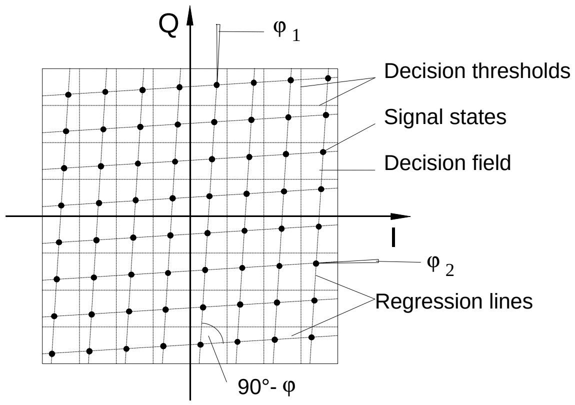


Fig. 5.38 64QAM constellation diagram

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.

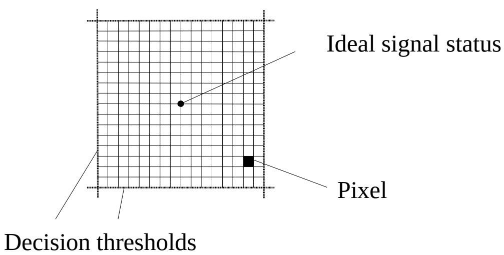


Fig. 5.39 Decision field after A/D conversion

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.

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5.8.2 QAM Constellation Diagram

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

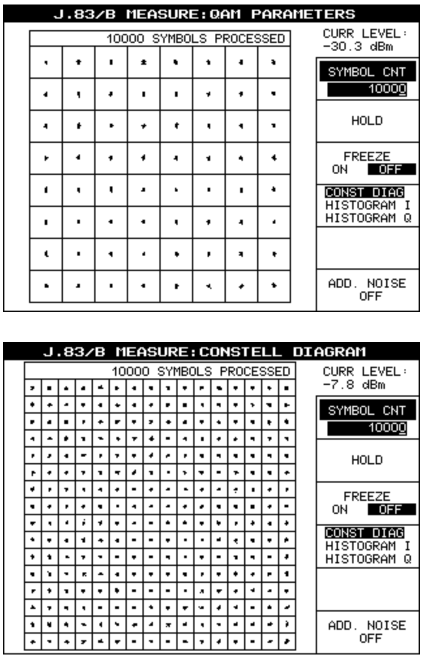


Fig. 5.40 Ideal 64QAM and 256QAM constellation diagrams

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:

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

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

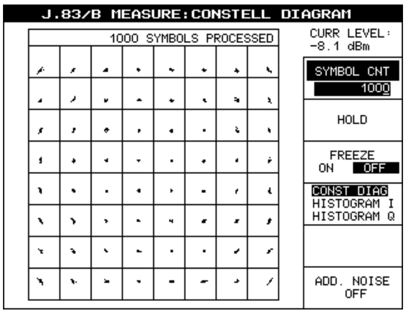


Fig. 5.41 64QAM constellation diagram with 10 % I/Q imbalance

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):

$$\varphi = \frac{180^\circ}{\pi} \cdot \left| \overbrace{\arctan\left(\frac{v_Q}{v_I} \cdot \overline{a_Q}\right)}^{\varphi_1} + \overbrace{\arctan\left(\frac{v_I}{v_Q} \cdot \overline{a_I}\right)}^{\varphi_2} \right|$$

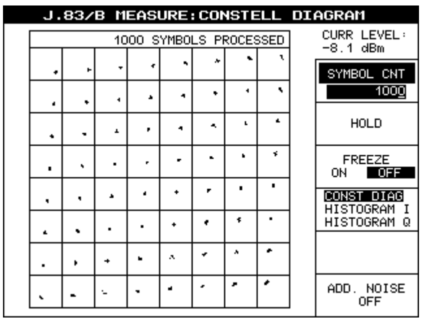


Fig. 5.42 64QAM constellation diagram with 8 ° I/Q quadrature error

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.

5.8.5 Carrier Suppression

DC voltage offset in the I and/or the Q path of the ITU-T J.83/B modulator results in a residual carrier component. This parameter is calculated by the following equation:

$CS = -10 * lg (P_{rc} / P_{sig})$

P_{rc} = power of residual carrier
P_{sig} = power of ITU-T J.83/B signal

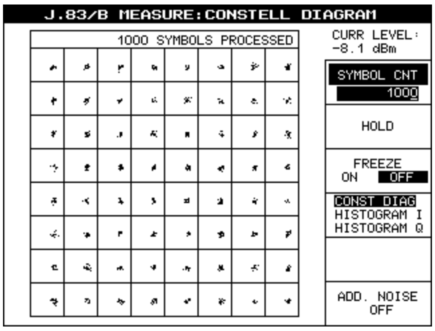


Fig. 5.43 64QAM constellation diagram with 24 dB carrier suppression

A QAM signal with insufficient carrier suppression generates a constellation diagram in which the I/Q value pairs are horizontally or vertically displaced (horizontally and to the right in the above example).
The four corner points of the diagram form a square whose center point is shifted relative to the center point of the diagram.

5.8.6 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:

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

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

where $M = 2^m$
$2d$ = width/height of each decision field
σ_{PJ} = standard deviation of symbol cloud, with noise component excluded

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.

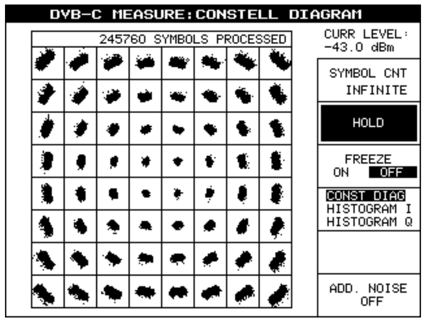


Fig. 5.44 64QAM constellation diagram with 2 ° phase jitter (rms)

A phase jitter of 2 ° (rms) means 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 the four corner segments form a square.

5.8.7 Phase and Amplitude Jitter Spectra

In addition to measuring phase jitter in the time domain, it is now also possible to measure the phase jitter and amplitude jitter spectra using TV Test Receiver R&S EFA model 70 or 73 with firmware version 5.10 or higher. The frequency range is from 1 kHz to 1 MHz.

The jitter spectrum is obtained by comparing the actual positions of a sequence of Rx I/Q data with the ideal positions (in the center of the decision fields). Depending on the measurement selected, the amplitude or phase jitter component is analyzed from the difference between the ideal position and the actual position of the symbols received:

- PHASE JITTER: In this measurement, the ratio of the amplitude of the received I/Q value to the amplitude of the ideal position is assumed to be 1 in each case (the symbols of the decision fields are located on circular segments about the center point of the constellation diagram). The phase jitter is determined by the sequence of phase errors φ(t). This measurement can be used to monitor the phase stability quality of the oscillators used to generate the QAM signal.

- AMPL JITTER: In this measurement, the error in the tangential direction φ(t) is assumed to be zero (the symbols of the decision fields are located on beams originating from the center point of the constellation diagram). The amplitude jitter is determined by the ratio of the amplitude of the received I/Q value to the amplitude of the ideal position in each case. The chronological sequence of amplitude ratios A(t) is processed further. This measurement is useful for checking amplifier control loops in the transmission path.

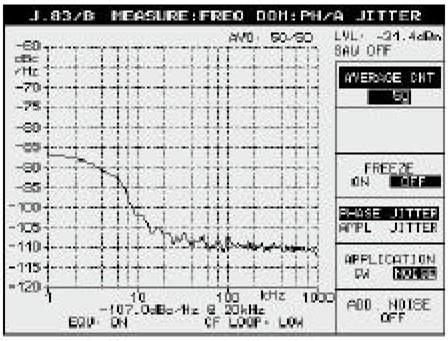


Fig. 5.45 Typical phase jitter spectrum

Depending on whether a noise-like spectrum or a spectrum with discrete interferences is expected, the measurement is performed in the NOISE or CW (continuous wave) mode that can be selected with the APPLICATION softkey.
In the NOISE mode, the frequency characteristic of the phase or amplitude jitter is displayed in dBc/Hz referenced to a bandwidth of 1 Hz. In the CW mode, the result is displayed in dBc, and the reference bandwidth is equal to the resolution bandwidth (RBW, indicated in the upper left of the diagram).
In the example of Fig. 5.46, the RBW is 4.77 kHz.

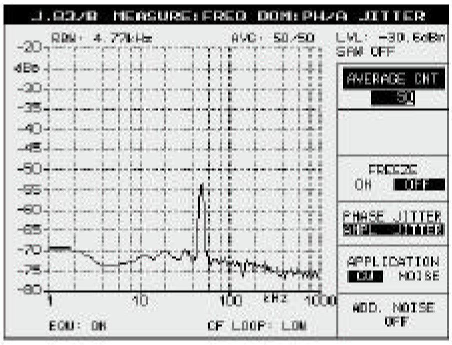


Fig. 5.46 Amplitude jitter spectrum with discrete interferer at about 50 kHz

The TV Test Receivers R&S EFA measure the phase jitter and amplitude jitter spectra in accordance with the ITU-T J.83/A, B and C standards and the DVB-C and ATSC 8VSB standards, thus making it possible to analyze and monitor the quality of the various mixer oscillators and amplifier loops of a transmitter. Jitter analysis can easily be performed during normal operation without switching off the carrier modulation.

Note:
While the phase jitter or amplitude jitter spectrum is being displayed, MER and EVM (ALARM, HISTORY, IEC 625/IEEE 488 bus) cannot be calculated in the background for technical reasons.

5.8.8 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. To minimize potential distortion of the SNR value by the influence of phase jitter, only the four innermost decision fields of the constellation diagram are used in the calculation.

In the case of the signal shown in Fig. 5.44, there is only minimal distortion of the SNR by phase jitter and other influences. If white noise is superimposed, which is normally the case in signal transmission, the I/Q value pairs have Gaussian (or normal) distribution.

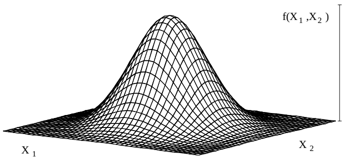


Fig. 5.47 Gaussian distribution of the I/Q value pairs

For an ITU-T J.83/B signal with 30 dB SNR, the following constellation diagram is obtained, with 100 000 symbols evaluated:

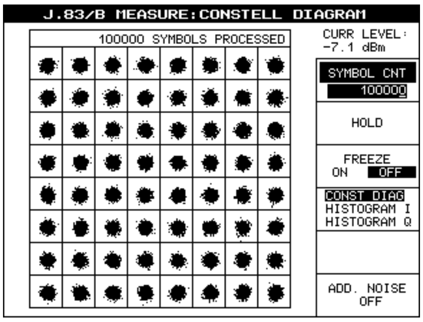


Fig. 5.48 64QAM constellation diagram for a signal with 30 dB SNR

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

5.9 Modulation Error Ratio (MER), Error Vector Magnitude (EVM)

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

To determine the MER/EVM, 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.

To determine the MER, the sum of the squares of all error vectors calculated during one second 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.

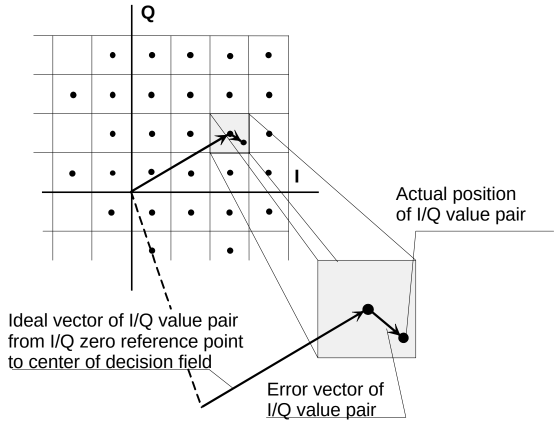


Fig. 5.49 Ideal vector and error vector used in calculating the EVM and MER sum parameters

To determine the EVM, the sum of the squares of all error vectors calculated during one second is formed. Then the ratio of this sum and the square of the longest ideal I/Q vector is determined. This ratio is converted to yield the EVM value in percent.

MER/EVM ratio conversion is performed as follows:

$$EVM_V = \frac{1}{MER_V * V}$$

where V is dependent on the QAM format, see table below.

QAM format	V (= ratio of peak voltage to rms voltage)
16	1.3416
64	1.5275

5.10 Bit Error Ratio (BER) Measurement

ITU-T J.83/B system margins can easily be determined by means of TV Test Transmitter R&S SFQ. System margins will be indicated for each individual quality parameter by deteriorating the parameters to a BER of $7*10^{-5}$ before RS FEC, which is the critical limit for system failure (this value is based on measurements, not derived by way of calculation, criterion is BER → QEF after RS with interleaver 128/1). The TV Test Transmitter R&S SFQ helps to find ITU-T J.83/B system margins in the laboratory, test shop, in production, quality management and during operation.

TV Test Transmitter R&S SFQ for ITU-T J.83/B cable standard and for DVB-C, DVB-S, DVB-T and ATSC 8VSB standards

If each ITU-T J.83/B signal parameter is deteriorated to the point the 64QAM transmission system may fail (BER > $7*10^{-5}$ before RS FEC), the following limit values will be found:

Parameter	Value
I/Q imbalance	< 18.5 %
I/Q phase error	< 9.5 °
Carrier suppression	< 13.0 %
SNR	< 22 dB

Table 5.8 Limit values for 64QAM ITU-T J.83/B

Here, too, the effect of trellis coding makes itself felt, allowing considerably poorer values for the individual signal parameters compared with DVB-C. For a BER better than $7*10^{-5}$ before RS FEC, the QAM Test Receiver R&S EFA measures the quality parameters listed in Table 5.8 because, up to this point, concatenated forward error correction supplies an interpretable TS data stream. Experience has shown that good 64QAM modulators and converters, as used in ITU-T J.83/B networks, should not exceed an MER of 0.9 % 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:

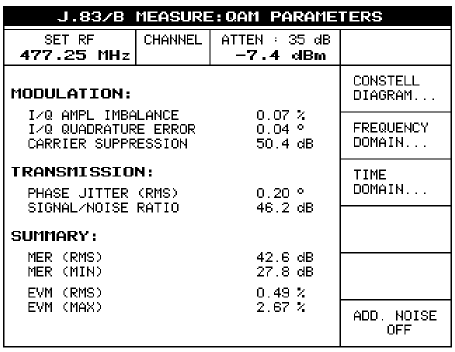


Fig. 5.50 Measurement menu for ITU-T J.83/B

The very positive S/N ratio of 46.2 dB alone means an MER of 0.49 % rms, assuming that no other QAM parameter affects the MER. This means that, in order to reach an MER of 42.6 dB rms (corresponding to 0.74 % rms), the remaining QAM parameters together must not deteriorate the MER by more than 0.25 %. 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 *5.8 "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.

5.11 Equivalent Noise Degradation (END) Measurement

The equivalent noise degradation (END) denotes the deviation of the actual SNR from the empirically determined SNR for a BER of $7*10^{-5}$ (SNR = 22 dB for 64QAM, criterion is BER → QEF after RS with interleaver 128/1).
To prevent influences from the test equipment invalidating results, two measurements are required to determine the END.

For the first measurement, the RF signal of an ITU-T J.83/B modulator is applied to the RF input of TV Test Receiver R&S EFA model 70 or 73. The R&S EFA superimposes white noise on the signal by means of its internal noise generator and measures the BER.
This measurement can also be performed using the test setup described under *5.7 "BER Measurement with R&S SFQ and R&S SFQ-B17 or R&S SFL-J and R&S SFL-K17"*, the noise being superimposed in this case by the noise generator option of the respective test transmitter, i.e. R&S SFQ-B5 or R&S SFL-N.
Example:
The BER of $7*10^{-5}$ is reached at C/N_1 = 22.7 dB (displayed in the ADD. NOISE field of TV Test Receiver R&S EFA). The empirically determined SNR for the BER of $7*10^{-5}$ is 22 dB. The SNR is converted to C/N as follows:
C/N = SNR + 0.2 = 22.2 dB

Note:
The following relationship exists for the S/N and the C/N ratio for 64QAM ITU-T J.83/B with a roll-off factor of r = 18 % (a = 0.18):
$C/N = S/N - k_{roll\text{-}off} = S/N - (-0.2)$ dB
$k_{roll\text{-}off} = 10 \times \log(1 - a/4)$

With R&S EFA models 70 and 73, the C/N ratio is referenced to the selected symbol bandwidth (= symbol rate, e.g. 5.057 MHz), i.e. the measurement is independent of the channel bandwidth.

The difference (22.7 dB – 22.2 dB) of roughly 0.5 dB is the END of the measurement system itself, in this case of TV Test Transmitter R&S SFQ and TV Test Receiver R&S EFA. Assuming that this value is equally distributed among the two instruments, each unit has an END of only 0.25 dB, which is a very good figure.

For the second measurement, the RF signal of the ITU-T J.83/B modulator is applied to the RF input of the device under test (DUT). As in the first measurement, the R&S EFA superimposes white noise on the RF output signal and measures the BER. The BER of $7{*}10^{-5}$ is now attained at C/N_2 = 23.1 dB (displayed in the ADD. NOISE field).

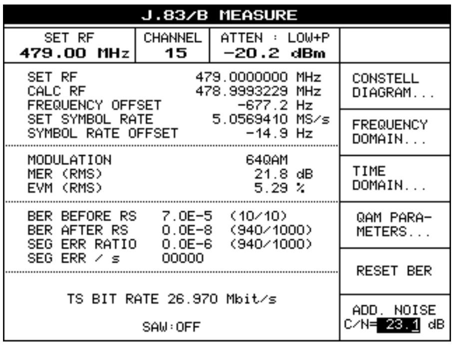


Fig. 5.51 ADD. NOISE on R&S EFA

The END of the device under test is calculated as follows:
$END = C/N_2 - C/N_1$ = 23.1 dB – 22.7 dB = 0.4 dB

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

5.12 ITU-T J.83/B Spectrum

5.12.1 Amplitude and Phase Spectrum

During transmission of the ITU-T J.83/B signal, its spectrum is distorted in amplitude and phase as a function of frequency. TV Test Receiver R&S EFA corrects this by means of a complex channel correction filter. As a result, a spectrum with optimal, flat amplitude and phase frequency response is available for further processing.
An inverse fast Fourier transform (IFFT) covering the coefficients of the channel correction filter yields 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 frequency response information can be used to generate a polar plot.

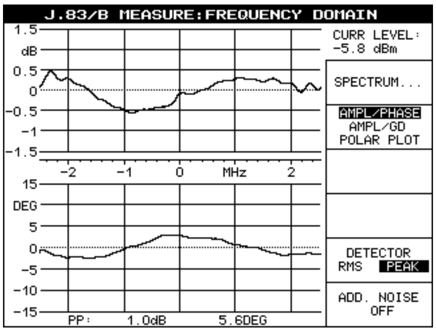


Fig. 5.52 Amplitude and phase frequency response of an ITU-T J.83/B signal

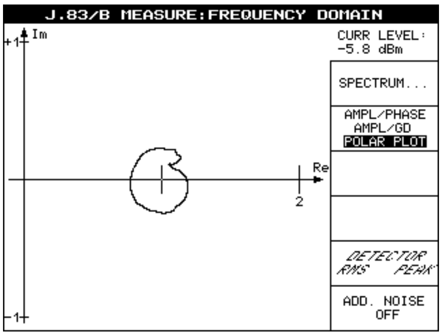


Fig. 5.53 Polar plot of an ITU-T J.83/B signal

Test Receiver R&S EFA model 70/73 in this way also monitors the effects of the transmission medium on an ITU-T J.83/B signal.

5.12.2 Spectrum and Shoulder Distance

Calculating channel frequency response by means of a fast Fourier transform (FFT) yields a much wider dynamic range for level measurements than is obtained by means of 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.

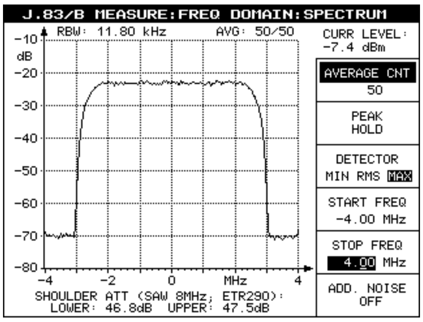


Fig. 5.54 Amplitude frequency response calculated in compliance with TR 101 290

Maximum level resolution is obtained if only the useful range of the spectrum is analyzed (in this example from –2.5 MHz to +2.5 MHz for a symbol rate of 5.056940625 Msymb/s). Level resolution is automatically selected, as a function of the frequency response, to a minimum value of 2 dB/div.
To determine the shoulder distance in compliance with TR 101 290, the 8 MHz SAW filter is to be switched on and the frequency range from –4.0 MHz to +4.0 MHz to be selected.

5.13 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 ITU-T J.83/B 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.

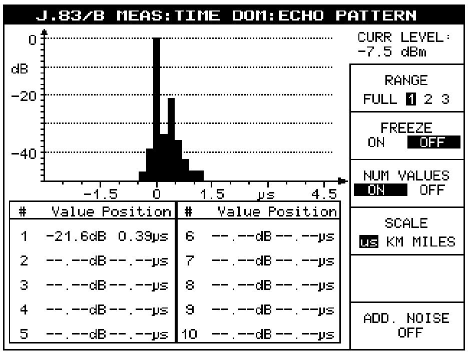


Fig. 5.55 Echo diagram

In the example shown in Fig. 5.55, the main pulse is at 0 µs, and the echo follows with an attenuation of 21.6 dB and a lag of 0.39 µs.

From the echo delay, the distance from the point of discontinuity causing the reflection is calculated. In the above example, the result is 117 m. After switchover to the MILES scale (1 mile = 1.61 km), the R&S EFA displays the distance with 0.07 miles resolution.
This measurement accuracy is sufficient to locate impedance discontinuity in large cable systems in buildings as described above.

5.14 Crest Factor of ITU-T J.83/B Signal

ITU-T J.83/B signals have a structure similar to that of white noise. An important parameter for describing ITU-T J.83/B 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 11.0 dB for 64QAM was measured with TV Test Receiver R&S EFA. The crest factor is displayed here using the complementary cumulative distribution function (CCDF). It can be seen that the amplitude distribution follows exactly the theoretical function (horizontal lines plotted at intervals of 1 dB, indicating the theoretical reference values). From this it can be deduced that there are no limiting effects in the ITU-T J.83/B system under test.

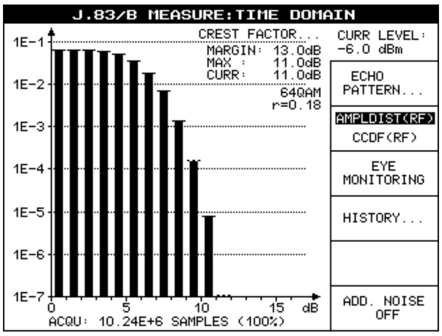


Fig. 5.56 Crest factor of an ITU-T J.83/B signal

Any limitations of the ITU-T J.83/B signal would mean that information is missing, with the consequence of increasing BER. Correct level adjustment of the ITU-T J.83/B system, therefore, helps to avoid an unnecessary reduction of the system's safety margin.

5.15 History

The HISTORY function of TV Test Receiver R&S EFA allows long-term monitoring of an ITU-T J.83/B system for compliance with specified levels, BER before and after RS FEC, non-correctable errors and loss of data without requiring an external PC.
The RF level is continuously monitored. The lower screen can be switched between measuring BER before or after RS FEC and measuring MER (or EVM) in the time domain. In addition, the RF level, the BER before and after RS FEC, and the MER (or EVM) can be output in the form of a list with the average, maximum and minimum values obtained during a given measurement interval.

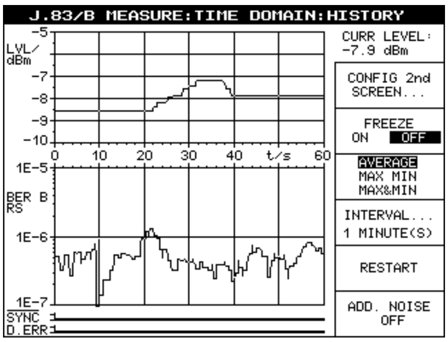


Fig. 5.57 HISTORY display with RF level and BER before RS FEC as a function of time

5.16 Alarm Report

Measurement reports are not only available on site at the cable headend, but can also be queried from a remote control center. System monitoring is very easy using TV Test Receiver R&S EFA model 70/73.

The network operator first chooses the parameters to be monitored. Fig. 5.58 shows a configuration in which all parameters are included in monitoring.

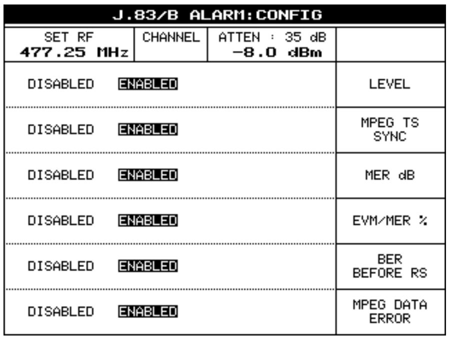


Fig. 5.58 Alarm configuration menu:
all possible parameters are monitored

Table 5.10 lists the parameters (with their short forms) that can be selected in the ALARM:CONFIG menu:

Parameter	Explanation	
LEVEL	Input level below threshold	LV
MPEG TS SYNC	Synchronization of ITU-T J.83/B symbols and MPEG2 transport stream packets	SY
MER dB	MER below threshold	ME
EVM/MER %	EVM (alternatively MER) above threshold	EV
BER BEFORE RS	BER below threshold	BR
MPEG DATA ERROR	Data errors that cannot be corrected by Reed-Solomon forward error correction	DE

Table 5.10

After selecting the ALARM parameters, the alarm thresholds have to be set. Thresholds can be set for LV, ME, EV and BR (see Table 5.10). Since non-correctable data and synchronization failure are absolute events, they are not assigned a threshold.

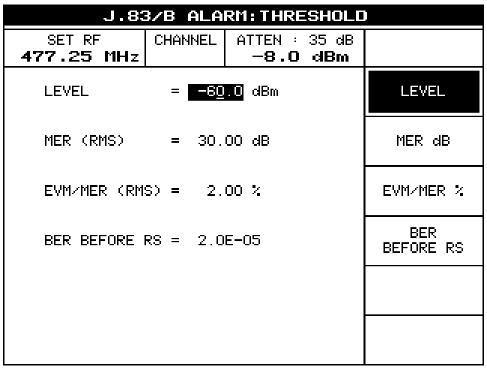


Fig. 5.59 Setting alarm thresholds

The MER alarm threshold can be selected in dB and, same as the error vector magnitude (EVM), also in %. There exist, therefore, two alarm parameters for the MER which may be regarded as an inner and an outer tolerance. The EVM, by contrast, can be expressed in % only and is therefore assigned only one alarm message.

Activated alarms are brought out as single alarms and as a sum alarm at connector X34 (USER PORT) on the rear of the R&S EFA. In addition, alarms can also be triggered via relays. In the event of a sum alarm, the single alarms are queried via the remote control interface.

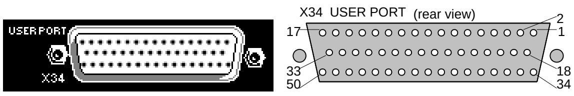


Fig. 5.60 Connector X34 USER PORT

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

Table 5.11 Pin assignment of connector X34 in ITU-T J.83/B mode

Professional monitoring calls for error reports. The R&S EFA not only records the key parameters LV (RF input level below threshold) and SY (loss of synchronization), but also the MER (ME, and additionally the EVM (error vector magnitude, EV)), the BER (BR), as well as non-correctable data errors (DE), the latter indicating the safety margin of an ITU-T J.83/B system. All errors are recorded with date and time.

On pressing the ALARM hardkey on the R&S 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.

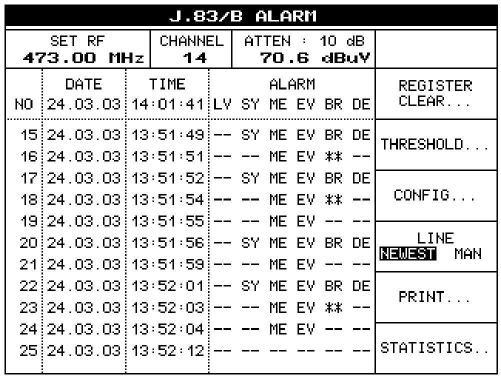


Fig. 5.61 Alarm list

The double asterisk (✳✳) means that the parameter is cleared from the monitoring list. The time and date of clearance are 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.

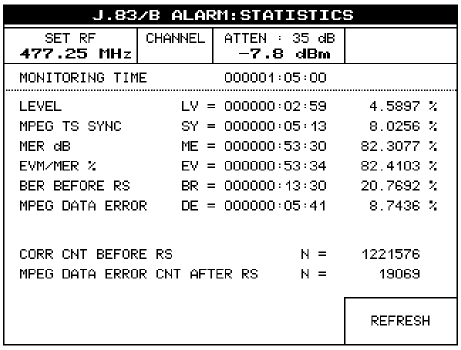


Fig. 5.62 Statistical evaluation of error periods

If errors occur more and more frequently in the alarm report, this indicates instability, and possibly even imminent failure, of the ITU-T J.83/B system.

Operators of digital cable networks know:
If the picture on a TV receiver shows visible degradation, transmission reliability in a DTV 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 R&S EFA, therefore, warns the operator early and reliably of an imminent failure of the ITU-T J.83/B system.

5.17 Options for TV Test Receiver (QAM Demodulator) R&S EFA Model 70/73

5.17.1 RF Preselection Option R&S EFA-B3 (for R&S EFA Model 73)

The ITU-T J.83/B cable 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 R&S EFA-B3 allows channel selection between 5 MHz and 1000 MHz and, in addition, enhances input sensitivity of the R&S EFA front end. The lower frequency limit of 5 MHz makes TV Test Receiver R&S EFA model 73, equipped with R&S EFA-B3, capable of upstream-channel communication.
The minimum input level is lowered to –67 dBm to –70 dBm in the VHF and the UHF range as a function of the RF attenuator setting (Low Noise, Low Distortion, High Adjacent Channel Power).
The RF Preselection option turns the R&S EFA model 73 into a selective test receiver of very high quality capable of demodulation despite low input levels.

5.17.2 Measurements with MPEG2 Decoder Option R&S EFA-B4

The MPEG2 Decoder option R&S EFA-B4 covers part of the functionality of MPEG2 Measurement Decoder R&S DVMD and MPEG2 Realtime Monitor R&S DVRM. The R&S EFA measurement functions are optimized for monitoring the demodulated transport stream at the cable headend.
ITU-T J.83/B uses the same MPEG2 protocol as DVB-C. All MPEG2 measurements are, therefore, identical to those described in Part 2 (DVB-C) of the "Digital TV Rigs and Recipes".

If TV Test Receiver R&S EFA model 70/73 is fitted with option R&S EFA-B4, it alone will suffice to analyze the MPEG2 protocol and the RF characteristics during ITU-T J.83/B transmission.

First, the time limits for the repetition intervals 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 the standards
ISO/IEC 13 818-1 for MPEG2
or
TR 101 290 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 5.12 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 defined by the user. The largest discrepancy between DVB and MPEG2 is in PCR distance with 40 ms for DVB and 100 ms for MPEG2.

Fig. 5.63 shows the menu for setting the limit values on TV Test Receiver R&S EFA fitted with MPEG2 Decoder option R&S EFA-B4. The DEFAULT softkey activates the predefined MPEG2 or DVB values. It is recommended to select the DVB limit values to ensure reproducible and comparable results throughout.

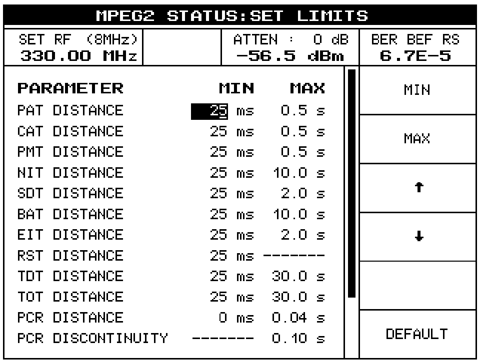


Fig. 5.63 Repetition intervals for tables and time stamps

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 defined by TR 101 290 can be enabled.

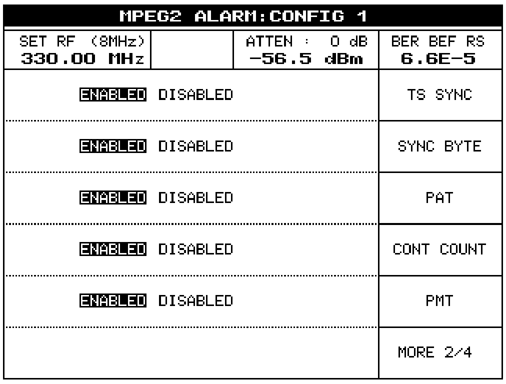


Fig. 5.64 First page of MPEG2 alarm menu

On pressing the ALARM key, the MPEG2 ALARM menu comes up. In this menu, all results exceeding tolerances during the monitoring period are displayed. Disabled parameters are marked by "--" in brackets.

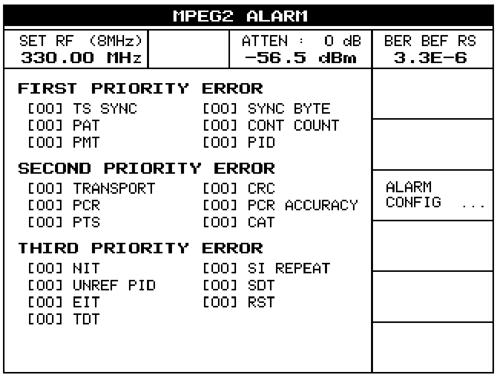


Fig. 5.65 MPEG2 ALARM menu

In the MEASURE menu, the parameters are evaluated in line with TR 101 290 irrespective of the settings made in the ALARM menu. An error counter can be started, stopped and cleared in this menu.

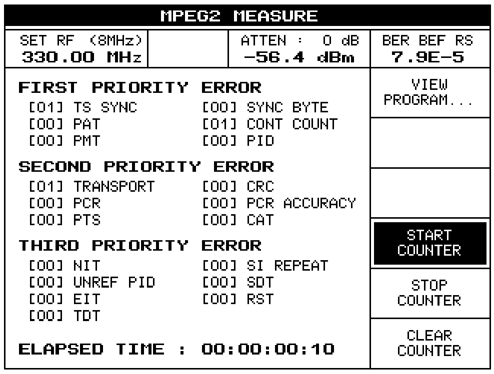


Fig. 5.66 MPEG2 MEASURE menu

Same as in the ITU-T J.83/B mode, the alarms in the MPEG2 mode are brought out at connector X34 of TV Test Receiver R&S EFA. Table 5.13 shows the pin assignment for the MPEG2 mode.

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 5.13 Pin assignment of connector X34 in MPEG2 mode

In the MPEG2 mode, too, alarms can additionally be triggered via relays.

The VIEW PROGRAM COMP... softkey opens the PAT (Program Association Table) 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.

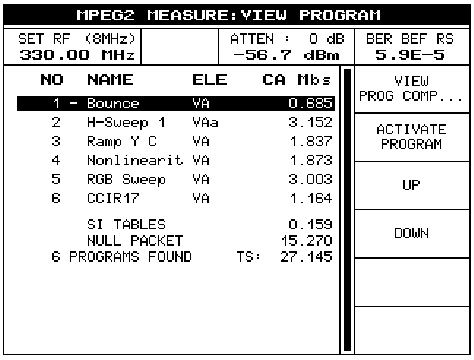


Fig. 5.67 PAT of a transport stream with key parameters

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 including associated PID (Packet IDentifier) numbers. The PID numbers of the PMT and the PCR (Program Clock Reference) are listed too.

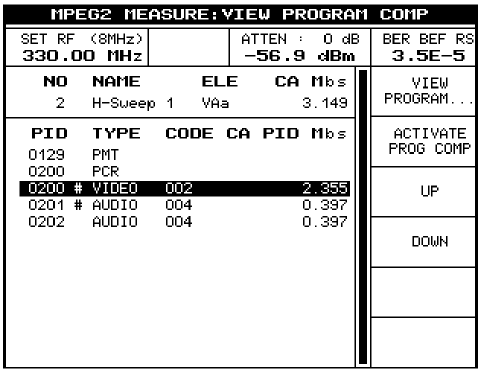


Fig. 5.68 PMT of a program with key parameters

TV Test Receiver R&S EFA model 70/73 with MPEG2 Decoder option R&S 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.

5.17.3 SAW Filters
2 MHz R&S EFA-B14, 6 MHz R&S EFA-B11
8 MHz R&S EFA-B13

The ITU-T J.83/B standard does not define the channel bandwidth, so the complete VHF and UHF range is available for transmission.
The preferred channel bandwidths are 2 MHz, 6 MHz and 8 MHz, i.e. those defined for the analog standards. For upstream-channel communication in interactive television, 2 MHz is commonly used. To ensure that each operator has the bandwidth configuration matching their application, the SAW filters for TV Test Receiver R&S EFA are available as options. The desired filter should, therefore, always be specified when placing an order.
One SAW filter should always be fitted. Two more SAW filters can be installed optionally.

2 MHz SAW Filter R&S EFA-B14

Expands the R&S EFA functionality to include an ITU-T J.83/B upstream channel. The option supports a 2 MHz channel bandwidth. Various symbol rates are possible.

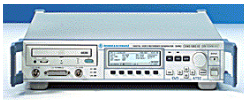
2MHz SAW Filter R&S EFA-B11
6 MHz SAW Filter R&S EFA-B12
8 MHz SAW Filter R&S EFA-B13

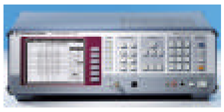
One of these filters can be inserted in the third SAW slot. The 6 MHz filter supports the channel bandwidths defined by Standard M, the 7 MHz filter either VHF channels or the UHF channel bandwidths used in Australia. The 6 MHz SAW filter is the filter most frequently used in ITU-T J.83/B.

The filters fitted are displayed in the status menu.

The 8 MHz SAW filter plays a very important role also in ITU-T J.83/B, although the 6 MHz filter is most commonly used there, because it is needed for automatic shoulder distance measurement.

5.18 Overview of ITU-T J.83/B Measurements

Instrument, Test Point	Test Parameter
At input of cable headend, TS source for production MPEG2 MEASUREMENT GENERATOR R&S DVG 	Test signal generator for reproducible MPEG2 measurements, various test sequences
DTV RECORDER GENERATOR R&S DVRG 	Test signal generator for reproducible MPEG2 measurements, various test sequences, recording of user-defined transport streams, recording of error events
MPEG2 MEASUREMENT DECODER R&S DVMD 	Realtime MPEG2 transport stream protocol analysis
MPEG2 REALTIME MONITOR R&S DVRM 	Realtime MPEG2 transport stream protocol monitoring
DIGITAL VIDEO QUALITY ANALYZER R&S DVQ 	Measurement of signal quality after MPEG2 coding and decoding
At test transmitter/ cable headend, in production  SPECTRUM ANALYZER R&S FSEx  SPECTRUM ANALYZER R&S FSP  SPECTRUM ANALYZER R&S FSU	LO harmonics ITU-T J.83/B spectrum Shoulder distance Roll-off factor Crest factor (via signal envelope) Output power

Instrument, Test Point	Test Parameter
At test transmitter/ cable headend  **Power Meter R&S NRVS with Thermal Power Sensor R&S NRV-Z51**	High-precision thermal measurement of output power
Monitoring receiver at cable headend Test receiver in production  ITU-T J.83/B TEST RECEIVER R&S EFA Model 70/73 with option R&S EFA-B4	**Basic unit** Order of QAM Symbol rate ITU-T J.83/B amplitude, phase and group-delay spectrum Output power END, BER, MER Crest factor Shoulder distance (to TR 101 290) Frequency offset Echo diagram Constellation diagram QAM I/Q parameters Alarm report **Option R&S EFA-B4** Measurements to TR 101 290: parameters of the three priorities Alarm report PAT and PMT
Simulation of ITU-T J.83/B cable headend  TV TEST TRANSMITTER R&S SFQ Options: NOISE GENERATOR FADING SIMULATOR	C/N setting for END measurement Simulation of defined receive conditions and impedance discontinuities Simulation of transmitter defects
ITU-T J.83/B test transmitter for production  TV TEST TRANSMITTER R&S SFL-J	Test transmitter for production Simulation of transmitter defects for testing set-top boxes in production