ROHDE&SCHWARZ

Digital TV
Rigs and Recipes
Part 4 DVB-T

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Contents

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4.1 Introduction

The expansion of multi-frequency networks (MFNs) and single-frequency networks (SFNs) for terrestrial digital video broadcasting (DVB-T) means growing demand for measuring technology for this modern means of transmission. The instruments we know from analog TV are not suitable for DVB, with a few exceptions like spectrum analyzers and thermal power meters. Not only are the instruments for DVB quite unlike those for analog technology, the parameters and methods of testing them are different too. This paper presents measurement techniques especially developed by Rohde & Schwarz for DVB-T.

The first topic focused on is the DVB-T transmitter to familiarize you with the special features of such a system. This will be followed by a description of test parameters, methods and instruments.

4.2 DVB-T Transmitter
4.2.1 DVB-T Modulator, Non-Hierarchical

In what follows, the signal processing steps will be explained based on the block diagram of a DVB-T transmitter shown below.
It can be seen that the DVB-T modulator uses in part the same function blocks as the related modulators for DVB-C (cable) to EN 300 429 and DVB-S (satellite) to EN 300 421. So certain test methods and parameters can also be adopted for these two DVB standards.

Data: MPEG2 transport packets
-from local MPEG2 encoder/studio
-from distribution links
-from multiplexer

identical with cable system to EN 300 429 and satellite system to EN 300 421

identical with satellite system to EN 300 421
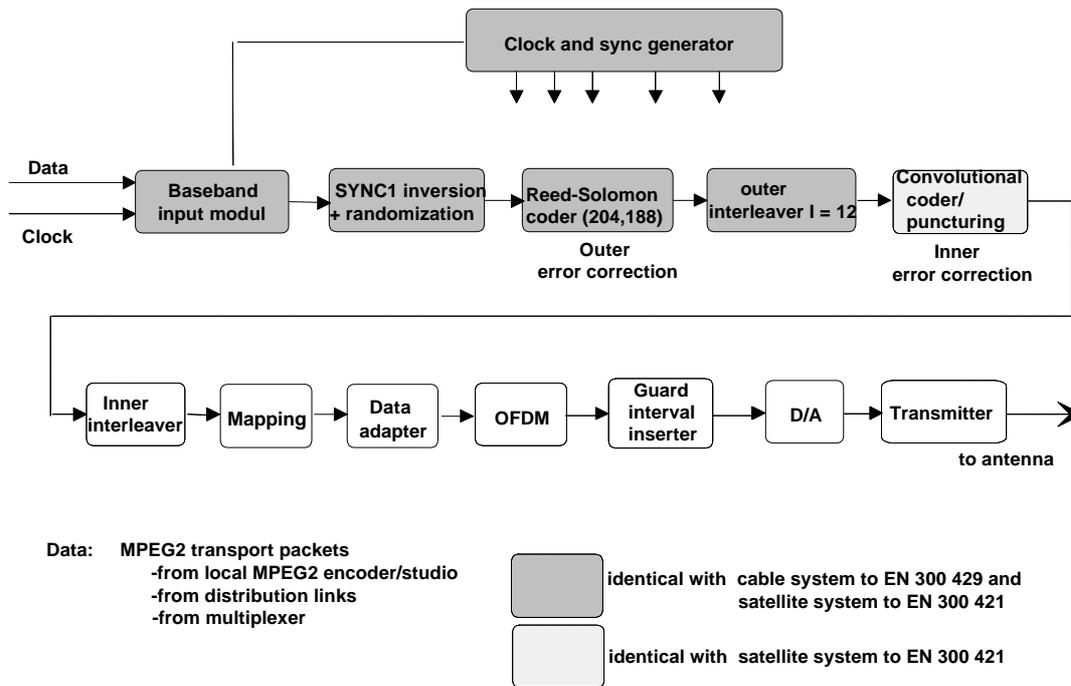
Fig 4.1 The DVB-T modulator / transmitter

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4.2.2 Baseband Input Module

MPEG2-coded data are fed to the baseband input module in the form of a packetized transport stream (TS). Here the following parameters have to be aligned:

- Return loss (e.g. at the ASI interface if possible)
- Amplitude and phase response versus frequency
- Data amplitude

At the output of the module the regenerated TS packet data are available for distribution to the subsequent function blocks of the DVB-T modulator.

First the data are applied to the clock and sync generator. This module supplies the required clock and sync information to all function blocks of the DVB-T modulator

Next, the TS packet data are fed to the sync word inversion and energy dispersal block.

4.2.3 Sync Word Inversion and Randomization for Energy Dispersal

As a first processing step, the TS packets undergo sync word inversion and randomization for energy dispersal. The PRBS polynomial $1 + x^{14} + x^{15}$ disperses the data but not the sync words (0x47) of the TS packets. The sync word is the first byte of each TS packet. The polynomial has a length of 1503 bytes. This exactly corresponds to eight TS packets minus the bit-wise inverted sync word of the first TS packet,
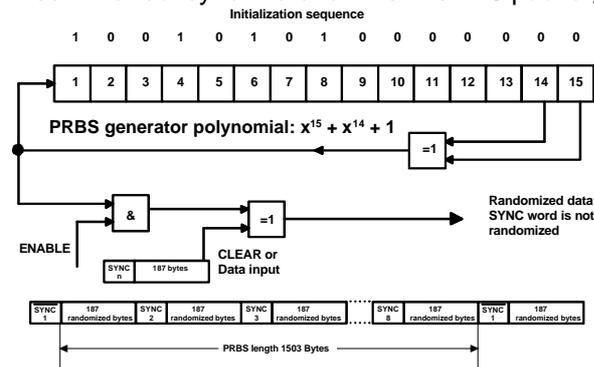
whose value is now 0xB8.

Fig. 4.2 Randomization for energy dispersal

The 15-bit PRBS register is loaded with the sequence "100101010000000" after each 8-packet cycle. The inverted sync word marks the beginning of the randomized sequence.

Randomization ensures a constant average modulator output level.

Sync word inversion and randomization

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

Table 4.1

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

16 error control bytes are appended to the randomized TS packets. The extended TS packets now have a length of 204 bytes. The Reed-Solomon (204,188, t = 8) error control code allows correction of up to eight errored bytes per TS packet in the receiver/decoder. Using RS FEC, a bit error ratio (BER) of $2*10^{-4}$ can be corrected to obtain a quasi-error-free (QEF) data stream with residual BER of $1*10^{-11}$.

RS FEC

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

Table 4.2 Reed-Solomon forward error correction

4.2.5 Interleaver

Transmission errors 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 Reed-Solomon correction capacity of eight bytes per TS packet is usually insufficient in such cases. So an interleaver is used to insert at least 12 bytes from other TS packets between neighbouring bytes. This allows burst errors of max. 12 x 8 = 96 bytes to be corrected because only eight or fewer errored bytes per TS packet are obtained after the deinterleaver in the DVB receiver/decoder.

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Interleaver

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

Table 4.3
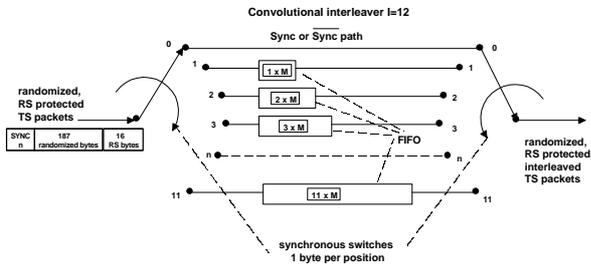
Fig. 4.3 Convolutional interleaver

Up to this point, the function blocks are identical for all DVB standards.

4.2.6 Convolutional Coder

In DVB-T, further error protection is added to the TS data by means of convolutional coding and (Viterbi) decoding.
The convolutional coder has the following characteristics:

Length (constraint length)	k = 7
Generator polynomials	G1 = 171 OCT (X) and G2 = 133 OCT (Y)

Table 4.4
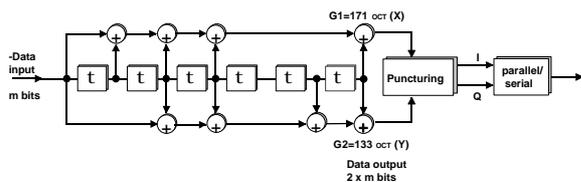
Fig. 4.4 Convolutional coder in DVB-T

The generator polynomials determine the outputs at the shift register with k = 7.

From k bit input data, 2 x k bit output data are obtained, i.e. the useful data rate decreases by a factor of 2. To reduce this high redundancy at least in part, the output data are punctured. Defined bits of the output data are deleted, so reducing the output data rate in accordance with the puncturing scheme explained below.

4.2.7 Puncturing Scheme

The bit-serial data are doubled between the input and the output of the convolutional coder. The scheme shown below illustrates what bits of the X or Y output are deleted, how the bits are sorted into a continuous data stream, and the puncturing rate P. The resulting serial bit stream is fed to the bit interleaver.

The Viterbi decoder of the DVB-T receiver can improve the BER based on the remaining redundancy. The puncturing rate, also referred to as code rate, indicates the ratio of input data rate to output data rate. Possible values are given in Fig. 4.5. The combined use of Viterbi FEC and RS FEC permits an input BER of about 2×10^{-2} depending on the puncturing rate:

The Viterbi decoder corrects the bit error ratio to

$$BER = 2 \times 10^{-4} \text{ and}$$

the RS FEC to $\qquad BER = 1 \times 10^{-11}$

Note:
The BER of 2×10^{-4} before RS FEC is the reference value in all measurements of transmission quality.

Up to this point, the processing steps for DVB-S and DVB-T are almost the same. Both use a convolutional coder. The difference is in the sorting of the punctured bits: with DVB-S the two outputs are directly applied to the I/Q inputs of the modulator, whereas the DVB-T coder has a bit-serial output.

| Input data	Output data of convolutional Coder k=7	Puncturing	Sorting and MUX 0utput of convolutional coder	Output data	Rate P
1xM: M	X1 / Y1	X1 / Y1	X1 Y1	2xM	$\frac{1xM}{2xM}=1/2$
2xM: M M	X1 X2 / Y1 Y2	X1 / Y1 Y2	X1 Y1 Y2	3xM	$\frac{4xM}{6xM}=2/3$
3xM: M M M	X1 X2 X3 / Y1 Y2 Y3	X1 X3 / Y1 Y2	X1 Y1 Y2 X3	4xM	$\frac{3xM}{4xM}=3/4$
5xM: M M M M M	X1 X2 X3 X4 X5 / Y1 Y2 Y3 Y4 Y5	X1 X3 X5 / Y1 Y2 Y4	X1 Y1 Y2 X3 Y4 Y5	6xM	$\frac{5xM}{6xM}=5/6$
7xM: M M M M M M M	X1 X2 X3 X4 X5 X6 X7 / Y1 Y2 Y3 Y4 Y5 Y6 Y7	X1 X5 X7 / Y1 Y2 Y3 Y4 Y6	X1 Y1 Y2 X3 Y4 Y5 Y6 X7	8xM	$\frac{7xM}{8xM}=7/8$

Fig. 4.5 DVB-T puncturing scheme

4.2.8 Byte-to-Symbol Mapping in DVB-T

Two modes are defined for the COFDM multicarrier method: 2k with 1705 carriers and 8k with 6817 carriers. COFDM can be optimally adapted to suit the conditions of terrestrial transmission. To ensure practically undisturbed reception even under extremely poor conditions (effects of weather, fading), further protection is added to the signal in the DVB-T modulator.

4.2.8.1 Inner Interleaver

In addition to the outer interleaver, which follows outer error correction (FEC) to Reed-Solomon, an inner interleaver is used in COFDM. Depending on the modulation mode – QPSK, 16QAM or 64QAM – the interleaver comprises two, four or six paths.
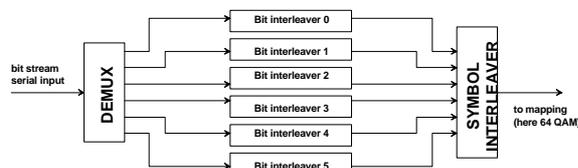
Fig. 4.6 Bit interleaver in 64QAM

In 8k mode, 48 blocks of 126 bits are processed in a 2-, 4- or 6-path bit interleaver using defined formulas for each path. In this way, all I/Q value pairs are defined for the 6048 data carriers in 8k.

In 2k mode, 12 blocks of 126 bits are processed in a 2-, 4- or 6-path bit interleaver using defined formulas for each path. In this way, all I/Q value pairs are defined for the 1512 data carriers in 2k.

The bit interleaver and the symbol interleaver in this way optimally support the bit-wise inner (Viterbi) error correction.

Note:
The designations "inner" and "outer" refer to the position of the function blocks relative to the antenna: "inner" designates the block closer to the antenna, "outer" the block further away from the antenna.

4.2.8.2 Symbol Interleaver

As described above, the interleaver output data words are grouped in 12 blocks of 126 bits in 2k mode and in 48 blocks of 126 bits in 8k mode. The symbol interleaver processes the bit groups to generate COFDM symbols.

At this point it is already defined on which useful carrier the I/Q value pairs should be modulated in QPSK or QAM. The mapping block that follows determines the constellation for each useful carrier.

The symbol interleaver already allows for the subsequent insertion of scattered pilots, continual pilots and transmission parameter signalling

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(TPS) carriers at defined points of the COFDM symbol, i.e. it leaves these positions free.

The continual pilots are for receiver synchronization in frequency and phase, the scattered pilots for channel regeneration in amplitude and phase, and the TPS pilots transmit important information about the modulation mode to the receiver/demodulator.

The entire information on all carriers in COFDM is represented by a symbol.

The structure of DVB-T symbols and their combination into a transmission frame of 68 symbols is shown by Fig. 4.7.

Number of	2k	8k
continual pilots	45	177
scattered pilots	131	524
TPS carriers	17	68
data carriers	1512	6048

k_{max}= 1 704 @ 2k mode
k_{max}= 6 816 @ 8k mode
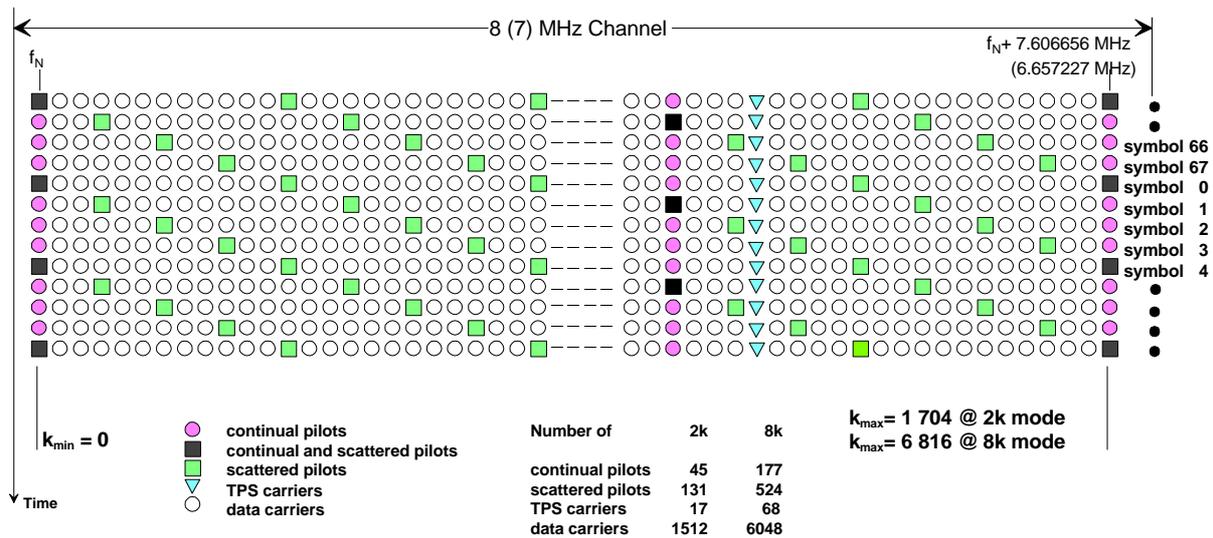
Fig. 4.7 Structure of DVB-T symbols

The number of scattered pilots is obtained with the following formula:

$$k = k_{min} + 3*(I \bmod 4) + 12*p \qquad \text{Equation 1}$$

where   k   is the index of the COFDM carrier defined as scattered pilot,

   I   is the index of the COFDM symbol with $0 < I < 67$,

   p   is the index of the COFDM carriers, with $k_{min} < p < k_{max}$ and $k_{min} = 0$ and k_{max} = 6816 for 8k mode and k_{max} = 1704 for 2k mode. The resulting value for k must be within the range $k_{min} < k < k_{max}$.

The result of the calculation shows that for the symbols with $(I \bmod 4) = 0$ the number of scattered pilots is 569, and for all other symbols it is 568.

In symbols with $(I \bmod 4) = 0$, 45 scattered pilots in 8k mode and 12 scattered pilots in 2k mode overlap with the fixed continual pilots, whereas in the other symbols only 44 scattered pilots in 8k mode and 11 scattered pilots in 2k mode overlap with the fixed continual pilots.

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4.2.9 Mapping
4.2.9.1 DVB-T Constellation Diagrams (Non-Hierarchical)

The values defined by EN 300 744 for the three modulation modes are shown in the Fig. below.

It should be noted that for DVB-T no differential coding is applied to the two MSBs (most significant bits). The value allocation does not therefore correspond to the definition applicable for DVB-C.

QPSK

Q

10	00

I

11	01

16QAM

Q

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

64QAM

Q

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

Fig. 4.8 I/Q value pairs in constellation diagram
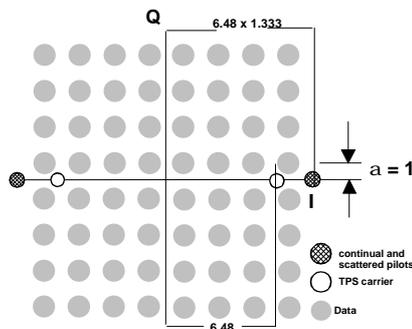
Fig. 4.9 Constellation diagram with pilots and TPS carriers, non-hierarchical

Although the carrier is suppressed in DVB, the phase information is easily recovered. The pilots and the TPS carriers are only modulated along the I axis and so are a direct indication of the phase. The amplitude of the TPS carriers corresponds to the average amplitude of the constellation (i.e. $U_{TPS} = \sqrt{42} = 6.48$) and are situated inside the constellation, while the amplitude of the pilots is boosted by the factor $\sqrt{\frac{16}{9}} = 1.333$ and are situated outside the constellation.

In the mapping block, assignment of the I/Q value pair takes place (Fig. 4.8).
If, for a given symbol, all I/Q value pairs modulated on the data carriers and pilots are projected on a plane, a non-hierarchical constellation diagram as shown in Fig. 4.9 is obtained for 64QAM.

4.2.9.2 Block Diagram and Operating Principle of Hierarchical DVB-T

What is the advantage of hierarchical modulation?
First, two independent transport streams can be transmitted in the same RF channel.
Second, as the clouds of I/Q value pairs move closer together in a quadrant, their distance from the quadrant's I and Q axes increases. Consequently, the noise margin between the quadrants (referred to the distance of the clouds of I/Q value pairs from the quadrant's axes) increases by a factor depending on $\alpha = 1$, 2 or 4. The two bits of the high-priority path determine the quadrant of the I/Q coordinate system into which the clouds of I/Q value pairs of the low-priority path should be mapped. This means that the high-priority path is transmitted QPSK modulated via this quadrant, whereas the position of the I/Q value pairs in the quadrant represents the 16QAM modulated low-priority path.
Therefore, at least for $\alpha = 2$ and 4, the QPSK modulated clouds of I/Q value pairs have a distance from the I and Q axes 7/4 or 14/5 times greater than that of the 16QAM modulated clouds, which can easily be derived from the geometry of the constellation diagrams. This considerably enhances reliability of reception.
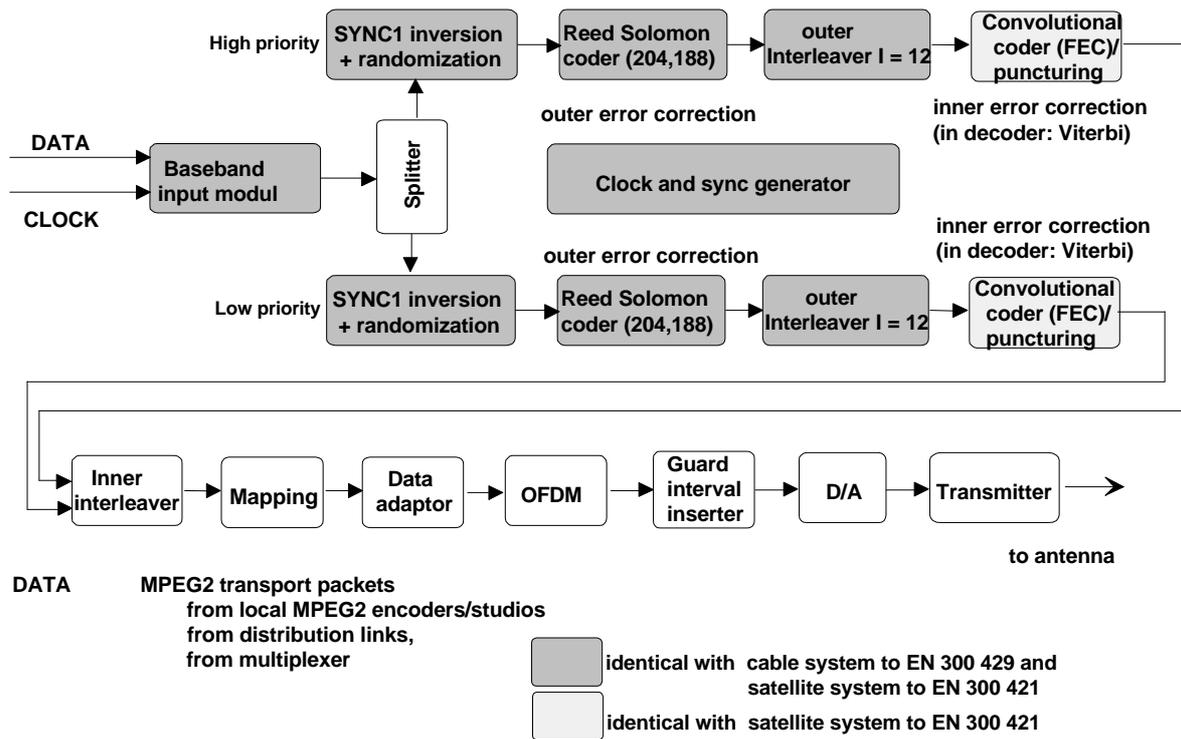
Fig. 4.10 Block diagram of hierarchical DVB-T transmitter

The TS packets are routed via the input module to a splitter, which separates the packets according to programs and assigns them to the high-priority and the low-priority path. It is also possible to feed two transport streams to be synchronized to the subsequent signal processing stages via two separate baseband input modules.

As in the non-hierarchical system, the signal processing modules in the high-priority and the low-priority path (from sync inverter and dispersal through to convolutional coder and puncturing) are in part identical with DVB-C and fully identical with DVB-S.

Hierarchical modulation is possible only with 16QAM or 64QAM in the DVB-T system. With 64QAM, two of the six bits of each I/Q value pair are used for the high-priority path and the remaining four bits for the low-priority path. With 16QAM, two out of four bits are allocated to each path.

The two paths, coded independently up to this point, are combined in the inner interleaver, which is made up of demultiplexers, bit interleavers and the symbol interleaver.
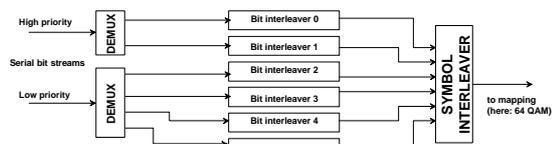

Fig. 4.11 Inner interleaver of hierarchical DVB-T transmitter

In the mapping block, hierarchical modulation is performed, which for 64QAM produces a constellation diagram over all carriers of a symbol as shown in the example below:
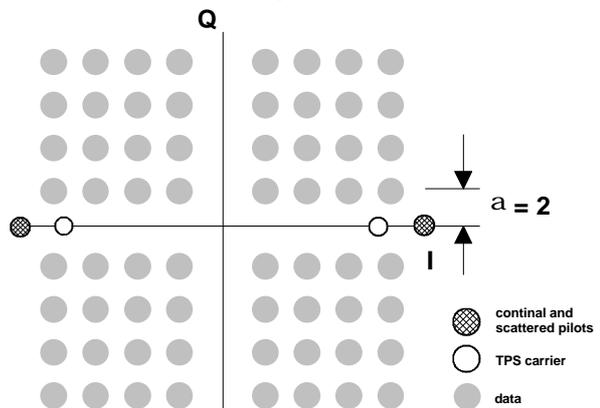

Fig. 4.12 Constellation diagram with pilots and TPS carriers, hierarchical, $\alpha = 2$

The distance of the clouds of I/Q value pairs from the I and Q axes is determined by the parameter α, which may take the value 1, 2 or 4.

So, α = 1 too is permissible in hierarchical modulation.

4.2.10 Data Adapter

In the symbol interleaver, gaps are left in the spectrum for the pilots and the TPS carriers. The data adapter fills these gaps. As to the pilots, a distinction is made between continual pilots, which are used for frequency synchronization of the DVB-T symbols in the receiver, and scattered pilots, which are used for channel estimation in amplitude and phase of the symbols.

The continual pilots are defined in a table in the EN 300 744 DVB-T standard, whereas the position of the scattered pilots is obtained by means of equation 1:

$$k = k_{min} + 3 * (I \bmod 4) + 12p$$

where

k   is the index of the COFDM carrier defined as scattered pilot,

I   is the index of the COFDM symbol with 0 < I < 67,

p   is the index of the COFDM carriers with
    k_{min} < p < k_{max} and
    k_{min} = 0 and k_{max} = 6816 for 8k mode and
    k_{min} = 0 and k_{max} = 1704 for 2k mode.
    The resulting value for k must be
    within the range k_{min} < k < k_{max} .

The result of the calculation shows that in 8k mode the number of scattered pilots is 569 for the symbols with (I mod4) = 0 and 568 for all other symbols, and in 2k mode the number of scattered pilots is 142 for the symbols with (I mod4) = 0 and 141 for all other symbols.

In symbols with (I mod4) = 0, 45 scattered pilots in 8k mode and 12 scattered pilots in 2k mode overlap with the fixed continual pilots, whereas in the other symbols only 44 scattered pilots in 8k mode and 11 scattered pilots in 2k mode overlap with the fixed continual pilots.

The TPS carriers too are defined in a table in EN 300 744. With 17 carriers in 2k mode and 68 carriers in 8k mode, DVB-T transmission parameters are signalled with maximum error protection.

4.2.11 OFDM Modulator and Guard Interval

OFDM modulation by IFFT (inverse fast Fourier transform) in conjunction with Hilbert transformation suppresses the image carrier of each carrier in 2k or 8k mode. The result is a time-domain signal in line with appropriate standards with defined length of 896 µs per useful symbol in 8k mode and 224 µs per useful symbol in 2k mode. Insertion of the guard interval extends symbol duration by 1/4, 1/8, 1/16 or 1/32 to give the total symbol duration T_{SYMBOL}. The time signal of length T_{SYMBOL}, so far still digital, is applied to the D/A converter.
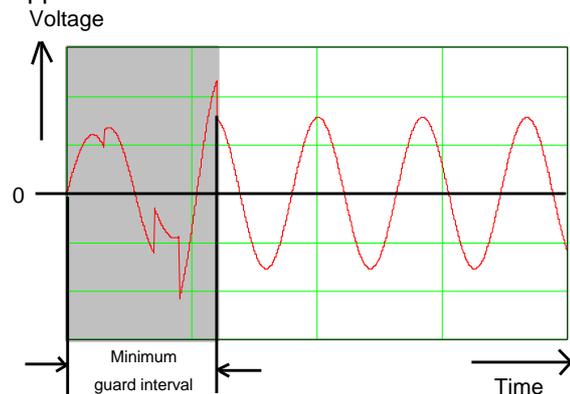
Fig. 4.13 Guard interval

Fig. 4.13 shows a direct incident sinewave starting at t = 0 to which four echoes with different delay and reflection phase are added. The start of the superimposed echoes can be recognized clearly and so the point until which the guard interval should extend at least.

By the end of the guard interval, all echoes caused by multipath reception, reception of other transmitters in the SFN or Doppler effects in mobile reception, i.e. all fading effects, must have settled or decayed. Only then can the transmitted symbol be evaluated.

The analog signal is converted to the RF, amplified and put on the air.

4.2.12 Table of Major DVB-T Parameters and Data

Table 4.5 shows that the signal bandwidth is identical for the two modes. The first and the last carrier of a symbol is a pilot carrying constant information, i.e. pure sinewaves of theoretically infinitely narrow bandwidth. So the overall bandwidth is determined only by the n-1 carriers.

The pilots and the TPS carriers reduce the number of carriers for useful data transmission by 11.3 %, the guard intervals additionally by 20 % (τ = 1/4), 11.1 % (τ = 1/8), 5.9 % (τ = 1/16) or 3.0 % (τ = 1/32). This means a substantial reduction of useful data transmitted, but a considerable improvement of transmission reliability.

General DVB-T data	s carrier	Scattered pilots	Continual pilots	TPS carriers	Number of useful carriers C_{useful}
DVB-T 2k mode	1705	131	45	17	1512
DVB-T 8k mode	6817	524	177	68	6048

General DVB-T data	Distance from carrier Hz	Overall bandwidth Hz	Useful symbol duration µs	Symbol duration T_{symbol} µs for guard interval		Guard interval µs
DVB-T 2k mode	*4 464.286*	1704 x *4 464.286* = *7 607 142.9*	224	280 252 238 231	1/4 1/8 1/16 1/32	56 28 14 7
DVB-T 8k mode	*1 116.071*	6816 x *1 116.071* = *7 607 142.9*	896	1120 1008 952 924	1/4 1/8 1/16 1/32	224 112 56 28

Table 4.5

4.2.13 Achievable Net Data Rates

Achievable net data rates can be determined fast and easily by means of equation 2:

$$BR_{net} = C_{useful} * ld(M) * P * \frac{188}{204} * \frac{1}{T_{symbol}} \quad \text{Equ. 2}$$

Identical values are obtained for the 2k and 8k DVB-T modes. This is due to a factor of 4 being applied for the distance from carrier and a factor of 1/4 for the useful symbol duration and the guard interval, which balance each other.

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Net data rates BR$_{net}$ Mbit/s	Guard interval	Puncturing rate P				
		1/2	2/3	3/4	5/6	7/8
QPSK (M = 4)	1/4	4.9765	6.6353	7.4647	8.2941	8.7088
	1/8	5.5294	7.3725	8.2941	9.2157	9.6765
	1/16	5.8547	7.8062	8.7820	9.7578	10.2457
	1/32	6.0321	8.0428	9.0481	10.0535	10.5561
16QAM (M = 16)	1/4	9.9529	13.2706	14.9294	16.5882	17.4176
	1/8	11.0588	14.7451	16.5882	18.4314	19.3529
	1/16	11.7093	15.6125	17.5640	19.5156	20.4913
	1/32	12.0642	16.0856	18.0963	20.1070	21.1123
64QAM (M = 64)	1/4	14.9294	19.9059	22.3941	24.8824	26.1265
	1/8	16.5882	22.1176	24.8824	27.6471	29.0294
	1/16	17.5640	23.4187	26.3460	29.2734	30.7370
	1/32	18.0963	24.1283	27.1444	30.1604	31.6684

Table 4.6

The number of carriers, the guard interval, QPSK and QAM mode and the code rate (also referred to as puncturing rate) are precisely defined in DVB-T. For this reason, only precisely defined data rates are possible as listed in Table 4.6.

4.3 Digital Terrestrial TV -
from Studio to Transmitter

In the previous sections, the principle of operation of a DVB-T transmitter was discussed in detail based on the individual function blocks. The special features of a terrestrial transmitter for MPEG2-coded signals were described. In the following, the test points of a DVB-T transmitter network from the studio to the antenna will be described together with test instruments and methods, which considerably differ from those used in analog TV.
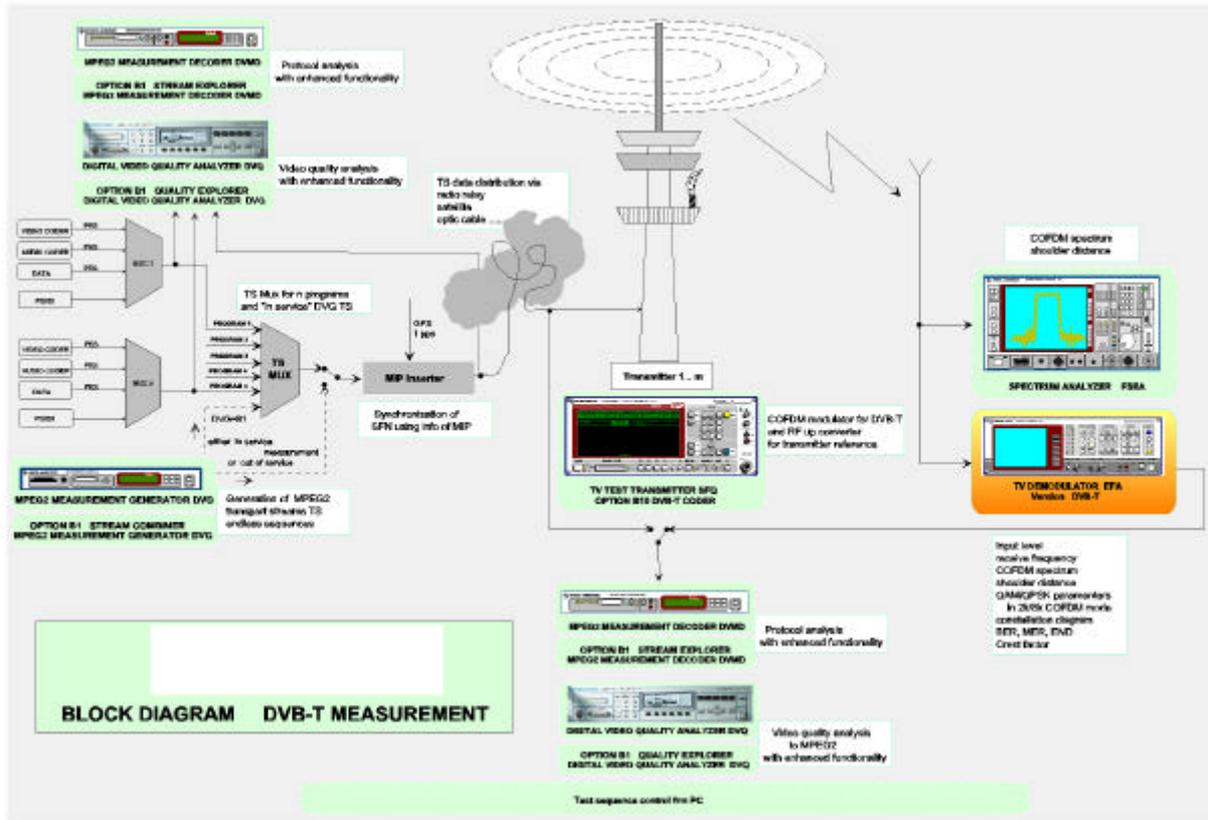
Fig. 4.14 DVB-T transmission scenario

Rohde & Schwarz offers suitable instruments for each test point and test parameter of a DVB-T transmitter network. To refresh your memory, refer to Part 1 of this paper, where MPEG2 measurements are described. The corresponding scenario is shown in the left part of Fig. 4.14.

The parameters described in Part 1, "MPEG2 Measurements", have already been measured and the MPEG2 protocol is monitored with the aid of the MPEG2 instruments from Rohde & Schwarz (plus corresponding software options for detailed status display):

DVMD MPEG2 MEASUREMENT DECODER or DVRM MPEG2 REALTIME MONITOR,

DVQ DIGITAL VIDEO QUALITY ANALYZER and DVG MPEG2 MEASUREMENT GENERATOR.

Likewise, the measurements on the feeder link between the studio output and the transmitter input are considered performed. What remains to be done is measuring the DVB-T transmitter.

First, the test points and associated parameters have to be defined.

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Condensed data of MPEG2 instruments whose functions are described in Part 1, "MPEG2 Measurements".

MPEG2 MEASUREMENT DECODER DVMD

Input signals	TS to ISO/IEC 13 818-1
Length of TS	
DVB	188/204 bytes
ATSC	188/208 bytes
Data rates of TS	up to 54 Mbit/s
Signal inputs	
DVB	1x SPI
	2x ASI
ATSC	1x SPI
	1x ASI
	1x SMPTE 310
Measurements	parameters to ETR290
	(adapted for ATSC),
	TS protocol,
	data rates of
	overall TS,
	programs,
	substreams (PID),
	monitoring of
	TS_ID,
	"other" tables (DVB),
	paradigma condition
	(ATSC only),
	trigger on error
Decoder outputs	
Video	2x CCVS, 1x Y/C
	1x ITU 601
Audio	1x AES/EBU
	2x analog audio R/L
Interfaces	RS232C

DIGITAL VIDEO QUALITY ANALYZER DVQ

Signal inputs	ASI (active loop-through)
	SPI
	ITU-R BT. 601 and AES/EBU
Video formats	MPEG2 MP@ML
	422P@ML
Audio formats	MPEG1 layers 1 and 2
	Dolby® AC-3
Events recorded	sound loss R/L, separately,
	picture loss,
	picture freeze,
	quality below threshold
Realtime measurements	temporal activity (TA),
	spatial activity (SA),
	digital video quality level
	unweighted and
	weighted corresponding to
	subjective assessment
Buffer for ES	32 Mbits
Remote control interfaces	RS232C
Alarm outputs	10BaseT (Ethernet)
	12 relay contacts

MPEG2 REALTIME MONITOR DVRM

Input signals	TS to ISO/IEC 13 818-1

Length of TS	
DVB	188/204 bytes
ATSC	188/208 bytes
Data rates of TS	up to 54 Mbit/s
Signal inputs	
DVB	1x SPI
	2x ASI
ATSC	1x SPI
	1xASI
	1x SMPTE 310
Measurements	parameters to ETR290
	(adapted for ATSC),
	TS protocol,
	data rates of
	overall TS,
	programs,
	substreams (PID),
	monitoring of
	TS_ID,
	"other" tables (DVB),
	paradigma condition
	(ATSC only),
	trigger on error
Decoder outputs	
Video	2x CCVS, 1x Y/C
	1x ITU 601
Audio	1x AES/EBU
	2x analog audio R/L
Interfaces	RS232C
Alarm outputs	12 relay contacts

MPEG2 MEASUREMENT GENERATOR DVG

Output signals	TS to ISO/IEC 13 818-1
Length of TS	
DVB	188/204 bytes
ATSC	188/208 bytes
Data rates of TS	0.6 to 160 Mbit/s
Overall data rate of ES	up to 32 Mbit/s
Overall data volume of ES	up to 228 Mbits
Signal set	live picture sequences,
	moving picture sequences,
	static test patterns with audio
	test signals,
	special test signals,
	TS with several programs
Signal outputs	
DVB	1x SPI
	2x ASI
ATSC	1x SPI
	1x ASI
	1x SMPTE 310
Interfaces of integrated PC	keyboard,
	VGA monitor,
	2x RS232C,
	parallel printer interface,
	PCMCIA

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4.3.1 Measurements at Transmitter Input

The first point of measurement is the transmitter input, from where the incoming MPEG2 transport streams (TS) received via radio relay, satellite, fiber-optic cable, etc are routed to the DVB-T modulator. For optimal transmitter monitoring, the MPEG2 parameters and the TS protocol should be evaluated. It must be ensured that the data intended for transmission contain the correct programs and data and that the quality of the outgoing picture meets appropriate standards. Especially in statistical multiplex mode, certain minimum quality standards as determined by the MPEG2 coding have to be met even under extremely poor conditions of reception. The following parameters are measured at the transmitter input:

- all events recorded in monitoring/report,
- PAT, CAT, NIT, PMT, SDT and EIT, which may reveal TS routing errors,
- MIP with relevant SFN synchronization data and modulator settings,
- agreement of NIT and MIP information,
- identification of TS, transmission media and transmission networks,
- data rates of incoming TS and elements of the individual programs,
- picture quality determined from MPEG2 artifacts.

In an SFN with m transmitters, the above tasks can be handled by a small, PC-controlled remote monitoring system.
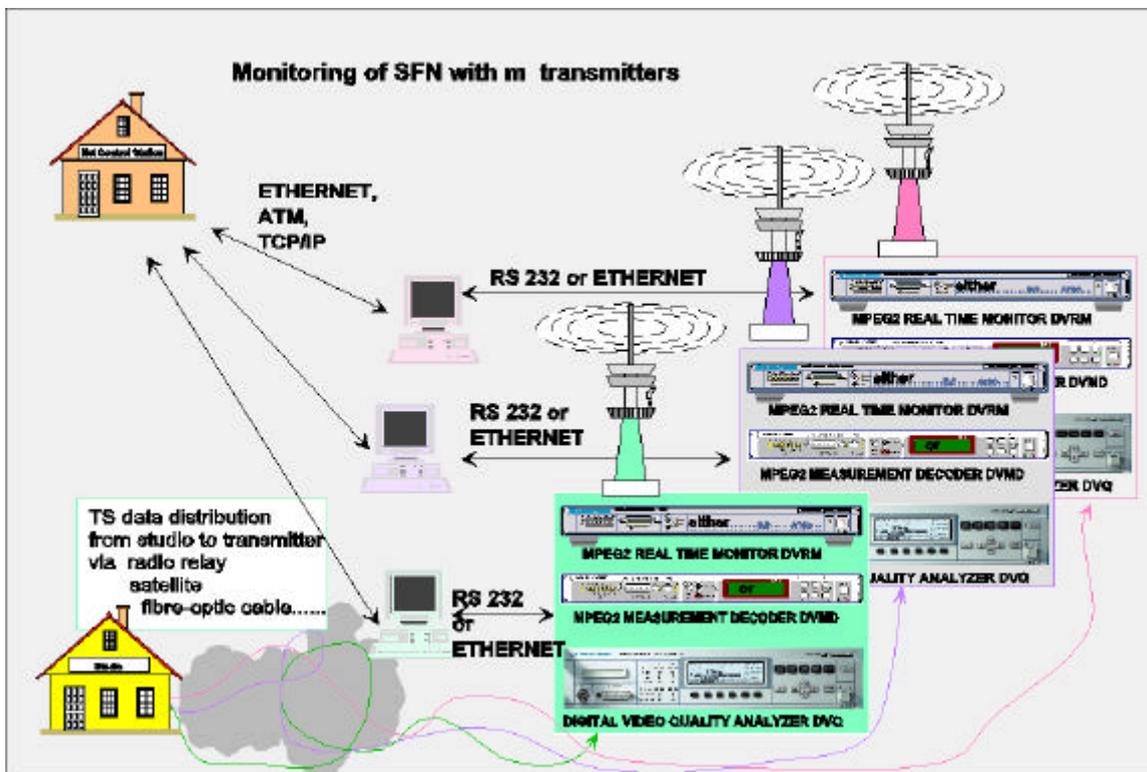

Fig. 4.15 Transmitter input monitoring in SFN

Each transmitter in an SFN is assigned such a monitoring system, which consists of a PC, MPEG2 Measurement Decoder DVMD or MPEG2 Realtime Monitor DVRM, and Digital Video Quality Analyzer DVQ. This configuration provides optimal monitoring of the TS at each transmitter input to ensure compliance with a program provider's specifications. At the transmitter input it is sufficient to analyze the programs and data of the TS one after the other by calling the PIDs of the associated PMTs. At the studio output, on the other hand, each program should be assigned a Decoder DVMD or Realtime Monitor DVRM or Video Quality Analyzer DVQ to provide comprehensive monitoring (see also Part 1, "MPEG2 Measurements"). To analyze the picture quality of several programs, it is advisable to use Multichannel Video Quality Analyzer DVQM, which integrates up to 12 DVQs in a highly compact configuration.

The measurement and monitoring data are taken via remote-control interfaces to the station computer. This not only manages the TS input

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data but also controls all other measurement and organization tasks of the station. From here the data are transmitted in ATM mode, using SDH or PDH protocols, by the Internet or another medium to the SFN master station for central analysis. This gives the operator an overview of the status of the entire network.

Not only the protocol of the MPEG2-coded programs and data of the TS are evaluated in this way, the MIP (megaframe initialization packet) contents too are subjected to a final check at the transmitter input before they are put on the air. Decoder DVMD opens the TS packets with the address 0x15 and displays the information required for synchronization of the SFN in interpreted form, e.g. in plain-text tables (see also Part 1, "MPEG2 Measurements").

4.4 Measurements on DVB-T Exciter

The transport stream to be transmitted is routed to the input of the DVB-T exciter via an ASI interface. First the contents of the MIP are decoded. The packet includes the configuration data for the DVB-T coder and modulator. So this information can also be used to set the operating mode. This requires due care, however, since the NIT (network information table) also transmits these data, and agreement between the MIP and NIT data is essential. This is checked already at the transmitter input (see section 4.3.1). The DVB-T receiver evaluates the NIT data and, if they differ from the MIP data, can neither demodulate nor decode.

The DVB-T modulator synchronizes to the SFN timing conditions by means of the STS (system time stamp) of the MIP. This is followed by signal processing in conformance with EN 300 744. The digital baseband signal generated by the above procedure is applied in the form of real and imaginary components to the digital precorrector of the exciter. The precorrector ensures optimal equalization of amplitude frequency response, group delay and linearity of the power amplifiers. By varying the instantaneous amplitude and phase, the required high linearity of the DVB-T transmitter characteristic and frequency response is obtained at the output of the power amplifiers. The digitally precorrected DVB-T signal is D/A converted and then directly converted to the RF without any intermediate IF stage.

DVB-T Exciter SV700
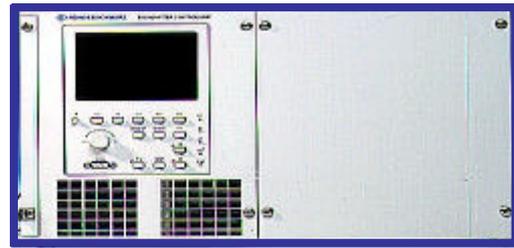
Condensed Data of SV700

DVB-T encoder	
Input signal	MPEG2 transport stream
Coding/modulation	To EN 300 744
Bandwidth	6 MHz, 7 MHz or 8 MHz
Parameter setting	by RS232C or MIP
Input signal monitoring	TS present, TS synchronized, TS data rate
SFN capability	to TS 101 191
Delay correction	max. 1000 ms, automatic or manual for LP and HP data streams
Hierarchical coding	optional
Digital precorrector	
Group delay equalizer	in baseband (optional)
Linearity precorrector	in baseband
Synthesizer	
Frequency bands	III, IV and V
Internal stability	1.2×10^{-7} / 4 months
Reference	internal: OXCO (10 MHz) external: GPS external reference
I/Q modulator	
Modulation	direct conversion to RF
Inputs	
HP	ASI
LP	ASI
Outputs	
RF	DVB-T, band III, IV or V, 13 dBm thermal power, SMA, 50 Ω
Monitoring outputs	
RF	DVB-T, band III, IV or V, -7 dBm thermal power, SMA, 50 Ω
Frequency reference	10 MHz OXCO, 0 dBm, SMA, 50 Ω
I/Q	complex analog baseband signal, 0 dBm, SMA, 50 Ω
Interfaces	RS232C

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