Contents

Abbreviations used

Antiope	Acquisition numérique et télévisualisation d´images organisées en pages d´écriture
BBC	British Broadcasting Corporation
CATV	Cable Television
CBC	Canadian Broadcasting Corporation
CCETT	Centre Commun d'Études de Télédiffusion et Télécommunications
CCIR	Comité Consultatif International des Radiocommunications
CCITT	Comité Consultatif International de Télégraphie et Téléphonie
CEPT	Conférence Européenne des Administrations des Postes et des Télécommunications
Didon	Diffusion de données (par paquets)
DIN	Deutsches Institut für Normung
EBU (UER)	European Broadcasting Union (Union Européenne de Radiodiffusion)
EIA	Electronic Industries Association
ERP	Effective Radiated Power
FCC	Federal Communications Commission
FDM, TDM	Frequency/Time Division Multiplex
GOST	Standards system of the CIS (former USSR)
GPO	General Post Office
IBA	Independent Broadcasting Authority
ITU (UIT)	International Telecommunication Union (Union Internationale des Télécommunications)
ITU-R	ITU Regulatory Sector (formerly CCIR)
ITU-T	ITU Technical Standards Sector (formerly CCITT)
KtK	Kommission für den Ausbau der technischen Kommunikationssysteme
MAC	Multiplex Analogue Component
NTSC	National Television System Committee
OIRT	Organisation Internat. de Radiodiffusion-Télévision
PAL	Phase Alternating Line
SABC	South African Broadcasting Corporation
SECAM	Séquentielle à mémoire
TDF	Télédiffusion de France
WARC	World Administration Radio Conference

Basic standards

International TV standards

Ten international TV standards exist at present, all based on the same principles:
- Physiology of vision
- Line scanning
- Picture repetition
- Colour transmission as separate luminance and chrominance components

Vision characteristics
- Mean resolution 1´ (angle of sight)
- Optimum angle for viewing without fatigue of eye muscles 10°
- Optimum line number = viewing angle/angle of sight = 600 lines
- Field frequency without motion blurred >12/s
- Field frequency without flicker >50/s

Number of lines per picture

Pictures of 525 and 625 lines are still in use. Resolution being too weak with 405 lines and the frequencies required being too high with 819 lines, these two values have been replaced by 625 lines. These "odd" line numbers originate from the early times of television and are due to the frequency divider and multiplier techniques of the sync signal generators used in the past.

Field frequency

The crucial factors were the limit of flicker and the AC supply frequency (50 or 60 Hz), since the early scanners (Nipkow disc, Weiller wheel and film scanner) were all driven by AC supply-operated synchronous motors. Hum bars resulting from inadequate filtering and other AC line-frequency pickup were thus negligible.

Field frequencies of 50 Hz and 60 Hz in conjunction with 500 lines to 600 lines per frame led to a video frequency band of more than 10 MHz. This was not acceptable for the frequency channels available for TV transmitters and also because of TV receiver technology and cost. An ingenious trick (F. Schröter, 1927) cut the required frequency band down to half: interlaced scanning of a first field consisting of the odd lines and a second field consisting of the even lines (illustration below). Thus a frequency of 50 fields/s (no flicker) and as little as 25 pictures/s (frequency band) were obtained.

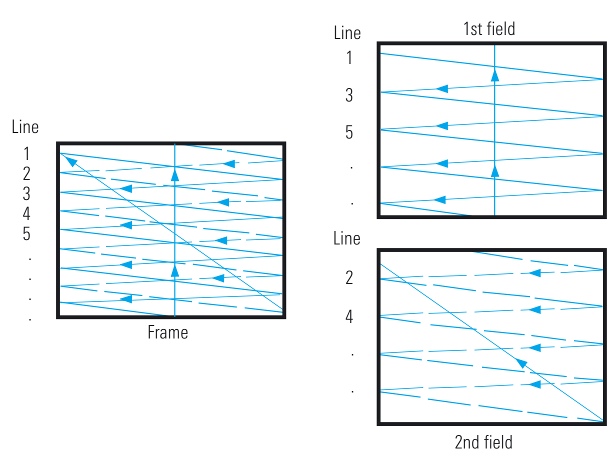
Colour transmission

Three colour TV systems were developed independently of each other regarding the number of lines and field frequency:
- NTSC 1948,
- PAL 1961,
- SECAM 1957.

The luminance signal is necessary for compatibility with the existing monochrome TV receivers. The three primary signals red/green/blue are transmitted in the form of colour difference signals (with reduced bandwidth) together with the luminance signal. Only two colour difference signals are necessary (the third being produced by electronic calculation in the receiver).

The two colour difference signals modulate a colour subcarrier – simultaneously with AM in the NTSC and PAL systems and successively with FM in the SECAM system. The modulation frequency spectrum of the colour subcarrier is inserted in the frequency spectrum of the luminance signal at the upper end of the video frequency band (half-line or quarter-line offset).

Observation of international TV standards is necessary in view of
- international exchange of programs,
- design of TV transmitters and transposers,
- production of TV receivers,
- design of video recorders,
- development of measuring instruments and systems.



Interlaced scanning with 50 fields (right) with 25 frames (left)

Basic TV standards

(Tables on pages 194 and 195)
Two basic standards have been adopted for the international exchange of TV programs:

	FCC standard	CCIR standard
Lines/frame	525	625
Fields/s	59.94	50
Colour system	NTSC	PAL/SECAM
Video bandwidth	4.2 MHz	5/5.5/6 MHz
Colour subcarrier	3.58 MHz	4.43 MHz

The different video bandwidths of the CCIR standard are not so much due to field and line scanning procedures, but rather to the bandwidth available in the TV transmitter channels (see broadcasting of TV programs below).

The main problem of standards conversion is the conversion of field frequency from 50 Hz to 59.94 Hz and vice versa. For this purpose, the picture information must be stored and then scanned at the new frequency. The previous electronic analog standards converter used the screen of a high-resolution display tube of suitable persistence and the display was picked up like an open scene in the new standard by a camera.

A digital standards converter converts the picture signal information from analog into digital form, reads it into a digital memory, reads it out at a new scanning rate and reconverts it into analog form.

In the standards converter for colour television, the incoming signal must be divided into its luminance and chrominance components, decoded and remodulated onto the other colour carrier. If only the colour system is to be converted, eg PAL into SECAM, the number of lines and the field frequency being equal, no picture memory is required. It then suffices to separate and transcode the chrominance signal and to modulate the new carrier as required (transcoder principle).

Broadcasting of TV programs

The public television service is operated by broadcasting picture and sound from picture transmitters and associated sound transmitters in three main frequency ranges in the VHF and UHF bands. By international ruling of the UIT/ITU, these ranges are exclusively allocated to television broadcasting. Subdivision into operating channels and their assignment by location are also ruled by international regional agreement. The Stockholm Plan of 1961 (table) is still valid in Europe:

Band	Frequency	Channel	Bandwidth
I	(41) 47 MHz to 68 MHz	2 to 4	7 MHz
II	87.5 (88) MHz to 108 MHz	VHF FM sound	
III	174 MHz to 223 (230) MHz	5 to 11 (12)	7 MHz
IV	470 MHz to 582 MHz	21 to 27	8 MHz
V	582 MHz to 790 (860) MHz	28 to 60 (69)	8 MHz
VI	10.7 GHz to 12.75 GHz	satellite TV	
Special channels	68 MHz to 82 (89) MHz	2 (3) S channels	7 MHz
DAB	113 MHz to 123 MHz	S 2/3	5 MHz
Cable TV	125 MHz to 174 MHz 230 MHz to 300 MHz 302 MHz to 470 MHz	S 4 to S 10 S 11 to S 20 MAC S 21 to S 41	7 MHz 7 MHz 12 MHz 8 MHz

Types of modulation

Vision: C3F (vestigial-sideband AM) vestigial-sideband ratios:
0.75 MHz/4.2 MHz = 1:5.6
0.75 MHz/5.0 MHz = 1:6.7
1.25 MHz/5.5 MHz = 1:4.4

The saving of frequency band is about 40%; negative polarity because of the susceptibility to interference of the synchronizing circuits of early TV receivers (exception: positive modulation); residual carrier with negative modulation: 10% (exception: 20%)

Sound: F3E; FM for better separation from vision signal in the receiver (exception: AM).

Sound carrier above vision carrier within RF channel, inversion at IF (exception: standard L in band I).

Dual-sound carrier systems

System parameters (for standards B/G)

	Channel 1	Channel 2
RF sound carrier		
Frequency	f_{vision} + 5.5 MHz (±500 Hz), eqvt. to 352 f_H	f_{vision} + 5.7421875 MHz (±500 Hz), eqvt. to 367.5 f_H
Vision/sound power ratio	13 dB	20 dB
Modulation	FM	FM
Frequency deviation	≤±50 kHz	≤±50 kHz
Preemphasis	50 µs	50 µs
AF bandwidth	40 Hz to 15000 Hz	40 Hz to 15000 Hz
Sound modulation		
Mono	mono	mono
Stereo	(L + R)/2 = M	R
Dual sound	mono	mono
Identification		
Pilot carrier frequency	—	54.6875 kHz (±5 Hz), eqvt. to 3.5 f_H
Modulation	—	AM (with identification frequency)
Modulation depth	—	50%
Identification frequency		
Mono	—	none
Stereo	—	117.5 Hz eqvt. to f_H/133
Dual sound	—	274.1 Hz eqvt. to f_H/57
Frequency deviation of transmitter carrier (due to pilot tone)	—	±(2.5 kHz ±0.5 kHz)
Synchronization	—	pilot carrier and identification frequency phase-locked with f_H

Typical characteristics of R&S TV transmitter systems using dual-sound-carrier technique

Spurious emissions	70 dB in the adjacent channel		
Crosstalk (selective measurement)	40 Hz	500 Hz	15 kHz
Stereo (with deemphasis), deviation 15 kHz/30kHz	43 dB	50 dB	54 dB
Channel (without deemphasis), deviation 50 kHz	81 dB	90 dB	90 dB
Intercarrier S/N ratio (with deemphasis) measured to CCIR Vol. X, Rec. 468-4			
Vision modulation 10% to 75%	44 dB		
Test picture	50 dB		
All-black picture	50 dB		

The two sound channels arrive from the studio via radio link with 15 kHz bandwidth at the TV transmitter where matrixing is performed for compatibility:

– (L + R)/2 for channel 1,
– R for channel 2.

An additional sound modulator is used to modulate the second sound carrier with sound channel 2 and with the AM-modulated pilot carrier.

The mode identification is transmitted in (data) line 16 (329) of a normal TV picture from the studio to the dual-sound coder of the TV transmitter via the conventional TV links (ie not the sound lines). From the 13 usable words of this data line the first two bits of word 5 are provided for mode identification in bi-phase code as follows:

Identification	Bit 1	Bit 2
Stereo	1	0
Mono	0	1
Dual sound	1	1
Fault	0	0

Vision/sound power ratio
3:1/4:1/5:1/10:1/20:1, depending on standard; 5:1 and 10:1 are conventionally used; 20:1 is used in the Federal Republic of Germany, its advantage being energy saving and low intermodulation distortion in TV transposers and TV transmitters with combined vision-sound amplification and in cable television; 20:1:0.2 for dual-sound broadcasts in the FRG.

Channel bandwidths
Depending on standard; conventional values are 6/7/8 MHz; the former values 5 MHz and 14 MHz are no longer used.

NICAM 728
Digital two-channel or stereo-sound transmission with PAL signals

The coding method NICAM 728 is used for sound transmission in the D2-MAC packet system but in particular as an alternative to the FM/FM dual-sound method for TV standards B, G, H and I. NICAM is an abbreviation for Near-Instantaneously Companded Audio Multiplex. 728 refers to the overall bit rate of 728 kbits/s for two sound channels or one stereo signal of 352 kbits/s each and a small additional data transmission capacity. It has been published as European standard EN 300163[1] and is based on the following technical parameters:

Sampling frequency	32 kHz
Initial resolution	14 bits
Compression	10 bits/sample in 32 sample blocks of 1 ms
Preemphasis	CCITT Rec. J.17
Modulation	DQPSK
Carrier frequency	5.85 MHz (standard B, G, H) 6.552 MHz (standard I)
Bandwidth	±250 kHz
Power referred to vision carrier	–20 dB (Standard B, G, H) –27 dB (Standard K1, L)

Besides transmitting the NICAM sound carrier above the analog FM sound carrier it is possible in some countries to transmit below the analog sound carrier so as to avoid interference with the adjacent channel.

[1] EN 300163, 1994, Specification for transmission of two-channel digital sound with terrestrial TV systems B, G, H, I and L.

TV broadcasting standards

Four broadcasting standards are in use at present (see also standards table for monochrome television on page 194):

Standard	FCC	CCIR	British	OIRT
Number of lines	525	625	625	625
Field frequency	59.94 Hz	50 Hz	50 Hz	50 Hz
Standard code	M	B/G	I	D/K
Channel width	6 MHz	7/8 MHz	8 MHz	8 MHz
Vision/sound carrier spacing	4.5 MHz	5.5 MHz 5.74 MHz (5.85 MHz)	6 MHz 6.552 MHz	6.5 MHz
Vestigial sideband	0.75 MHz	0.75 MHz	1.25 MHz (0.75 MHz)	0.75 MHz (1.25 MHz)
Vision IF	45.75 MHz	38.9 MHz	39.5 MHz	38.9 MHz (38 MHz)
Vision/sound ratio	5:1	10:1 20:1 20:1:0.2	10:1 (SA) 20:1 (UK)	10:1

The British modification of the 625-line CCIR standard, as one of the last systems introduced, represents today the best compromise:

- Optimum utilization of 8-MHz channel width
- Increase of vestigial sideband from 0.75 MHz to 1.25 MHz, as a result broadening of Nyquist slope from 1.5 MHz to 2.5 MHz and reduction of group-delay error near carrier to about 60 ns (half-correction); precorrection in the TV transmitter is thus not necessary in this part of the video band. In connection with the mixed mode I/PAL and DVB-T it is supposed to go over to 0.75 MHz residual side band
- Bandwidth of upper sideband of chrominance signal increased from 0.57 MHz to 1.07 MHz, thus no "second" vestigial-sideband system is necessary for colour transmission
- Increase of residual carrier from 10% to 20% so that highly saturated colours (yellow) with modulation of the TV transmitter to ultra-white are better reproduced, involving, however, a loss in useful-signal level of 1 dB, which can only be compensated for by a 20% increase of transmitter power (eg 10 kW to 12 kW)

Standard		B/G CCIR	D/K OIRT	H Belgium	I UK	K1[1] FOPTA*	L France	M FCC	N South America
Frequency		VHF/UHF	VHF/UHF	UHF	VHF/UHF	VHF/UHF	VHF/UHF	VHF/UHF	VHF/UHF
Number of lines per frame		625	625	625	625	625	625	525	625
Field frequency	Hz	50	50	50	50	50	50	59.94	50
Line frequency	Hz	15 625	15 625	15 625	15 625	15 625	15 625	15 750	15 625
Duration of line sync pulse	µs	4.7	4.7	4.7	4.7	4.7	4.7	5 (4.7)[2]	5
Duration of line blanking pulse	µs	12	12	12	12	12	12	10.8 (11)[2]	10.9
Front porch	µs	1.5	1.5	1.5	1.5	1.5	1.5	1.9 (1.75)[2]	1.9
Field blanking interval	Lines	25	25	25	25	25	25	19 to 21	19 to 25
Video bandwidth	MHz	5	6	5	5.5	6	6	4.2	4.2
RF channel width	MHz	7(B)/8(G)	8	8	8	8	8	6	6
Vision-sound carrier spacing[3]	MHz	+5.5/5.74/5.85	+6.5	+5.5	+6/6.552	+6.5	±6.5	+4.5	+4.5
Width of vestigial sideband	MHz	0.75	0.75	1.25	1.25	1.25 (0.75)	1.25	0.75	0.75
Spacing of vision carrier from nearest edge of channel	MHz	+1.25	+1.25	+1.25	+1.25	+1.25	+1.25	+1.25	+1.25
RF sync level	%	100	100	100	100	100	<6	100	100
RF blanking level	%	73[4]	75	75	76	75	30	75	75
RF white level (residual carrier)	%	10	12.5	10	20	10	100 (110)[2]	10	10
Type of vision modulation		C3F neg.	C3F neg.	C3F neg.	C3F neg.	C3F neg.	C3F pos.	C3F neg.	C3F neg.
Type of sound modulation		F3E F3EH[3]	F3E	F3E	F3E	F3E	A3E	F3E	F3E
Frequency deviation	kHz	±50	±50	±50	±50	±50	—	±25	±25
Preemphasis	µs	50	50	50	50	50	—	75	75
Vision/sound power ratio		10:1 to 20:1[5] 20:1:0.2[3]	10:1 to 5:1	5:1 to 10:1	10:1 (SA) 20:1 (UK)	10:1	10:1	10:1 to 5:1[6]	10:1 to 5:1

[1] Also designated K´.

[2] For colour transmission according to NTSC or SECAM.

[3] For dual-sound or stereo sound second value for 2nd sound carrier.

[4] 73% instead of nominal 75% applies to TV transmitters of high linearity also in the sync range (burst, chrominance signal).

[5] 20:1 in the Federal Republic of Germany as of April 1976 for all TV transmitters of the three programs.

[6] 6.7:1 and 2.9:1 in Japan.

System	NTSC	PAL				SECAM
Standard	**M**	**B, G, H**	**I**	**M**	**N**	**B, G, H, D, K, K1, L**
Luminance signal	$E'_Y = 0.299\,E'_R + 0.587\,E'_G + 0.114\,E'_B$					
Colour difference signals (chrominance signals)	$E'_I = -0.27\,(E'_B - E'_Y) + 0.74\,(E'_R - E'_Y)$ $E'_Q = 0.41\,(E'_B - E'_Y) + 0.48\,(E'_R - E'_Y)$	$E'_U = 0.493\,(E'_B - E'_Y)$ $E'_V = 0.877\,(E'_R - E'_Y)$				$D'_R = -1.9\,(E'_R - E'_Y)$ $D'_B = 1.5\,(E'_B - E'_Y)$
Correction of colour difference signals	—	—				$D'^*_R = A \cdot D'_R$ $D'^*_B = A \cdot D'_B$ $\quad A = \left\lvert \dfrac{1 + j \cdot \frac{f_B}{85}}{1 + j \cdot \frac{f_B}{255}} \right\rvert$ (f in kHz)
Composite colour video signal	$E_M = E'_Y + E'_I\,(\cos \omega_F t + 33°) + E'_Q\,(\sin \omega_F t + 33°)$	$E_M = E'_Y + E'_U \sin \omega_F t \pm E'_V \cos \omega_F t$				$E_M = E'_Y + G \cdot \cos 2\pi(f_{oR} + D'^*_R \Delta f_{oR}) \cdot t$ or $E_M = E'_Y + G \cdot \cos 2\pi\,(f_{oB} + D'^*_B \Delta f_{oB}) \cdot t$ G = function of f_o and $f_{R,B}$; see chrominance subcarrier amplitude
Type of modulation	Quadrature modulation of amplitude with suppressed carrier					FM
Line frequency f_H	15 734.264 ± 0.05 Hz	15 625 ± 0.016 Hz		15 734.264 ±0.05 Hz	15 625 ±0.016 Hz	15 625 ± 0.016 Hz
Field frequency	59.94 Hz	50 Hz		59.94 Hz	50 Hz	50 Hz
Chrominance subcarrier freq. f_{SC}	3 579 545 ±10 Hz	4 433 618.75 ±5 Hz	4 433 618.75 ±1 Hz	3 575 611.49 ±10 Hz	3 582 056.25 ±5 Hz	f_{oR} = 4 406 250 ± 2 000 Hz f_{oB} = 4 250 000 ± 2 000 Hz (f_o = 4 286 ±20 kHz)
Relationship between f_{SC} and f_H	$f_{SC} = \left(\frac{455}{2} \cdot f_H\right)$	$f_{SC} = \left(\left(\frac{1135}{4} + \frac{1}{625}\right) \cdot f_H\right)$		$f_{SC} = \left(\frac{909}{4} \cdot f_H\right)$	$f_{SC} = \left(\left(\frac{917}{4} + \frac{1}{625}\right) \cdot f_H\right)$	$f_{oR} = 282 \cdot f_H$, $f_{oB} = 272 \cdot f_H$
Bandwidth/devation of colour difference signal	f_{SC} + 620/–1 300 kHz	f_{SC} + 570/ –1 300 kHz	f_{SC} + 1066/ –1 300 kHz	f_{SC} + 600/ –1 300 kHz	f_{SC} + 620/ –1 300 kHz	Δf_{oR} = 280 + 70/–226 kHz, Δf_{oB} = 230 + 276/–120 kHz
Amplitude of chrominance subcarrier	$\sqrt{(E'_I)^2 + (E'_Q)^2}$	$\sqrt{(E'_U)^2 + (E'_V)^2}$				$F = f_{R,B}/f_o - f_o/f_{R,B}$ $\quad M_o \cdot \left\lvert \dfrac{1 + j \cdot 16F}{1 + j \cdot (1.26F)} \right\rvert$ Mo = 11.5% of luminance amplitude
Duration of burst	min. 8 cycles	10 ±1 cycles		9 ±1 cycles		—
Phase of burst	180 °, relative to $(E'_B - E'_Y)$ axis	+13 ° for odd lines in 1st and 2nd fields –135 ° for even lines in 1st and 2nd fields +135 ° for even lines in 3rd and 4th fields –135 ° for odd lines in 3rd and 4th fields relative to E'_u				—
Identification	—	by E'_v component of burst				for lines D'_R: +350 kHz deviation at max. 540 mV for lines D'_B: –350 kHz deviation at max. 500 mV

E´and D´are signal values of the color portions E respectively the color difference signals D with γ correction

Broadcasting of special services

The following text communication systems using television screen display are in operation worldwide. They are technically the same or very similar despite their different names: The European systems are laid down in EN 300231, March 1996, Television Systems; Specification of the Domestic Video Programme Delivery Control System (PDC).

Country	Institute	Year	Via TV channel
FRG	KtK (DIN designation)	1976 1980	Videotext Teletext
UK	 BBC IBA GPO	 1972 1973 1975	Broadcast Teletext Ceefax Oracle
F	TDF, CCETT		Antiope, Didon
CDN	CBC		Telidon
(UIT/ ITU)	CCITT, CEPT		Broadcast Videotext

Videotext/Teletext

Teletext standard for the 625-line systems B/G (Federal Republic of Germany) and I:

Clock frequency	6.9375 MHz, eqvt. to 444 f_H
Half-amplitude duration	144.14 ns per bit
Data signal	H: 0.462 V_{pp} = 66% picture L: 0 V (blanking level)
Coding Code	8 bits/word incl. 1 parity bit NRZ (non-return to zero)
Words per line	45; incl. 2 for clock run-in, 1 for framing code, 2 for address code
Transmission time per line per page	45 words × 8 bits × 0.144 µs = 51.89 µs (TV line without blanking interval: 52 µs) 24 text lines per 8 to 10 TV lines/picture = 6 x 1/25 s = 0.12 s to 0.1 s
Wait time maximum average	 75 text pages x 0.1 s = 8 s approx. 4 s
Lines occupied	1st field: (12), 13, 14, 20/21, 2nd field: (325), 326, 327, 333/334

Digital coding of colour TV video signals and sound signals

International standardization of digital video and audio coding is now in its final stages.

For the digital TV studio the EBU and SMPTE have prepared the following common coding standard in the D1 format for video signals:

- Component coding (Y signal and two colour-difference signals)
- Sampling frequencies f_{sample} in the ratio 4:2:2 with 13.5 MHz for the luminance component and 6.75 MHz for each chrominance component
- Quantization q is 10 bit/amplitude value
- Data flow/channel
  13.5 x 106 values/s x 10 bit/amplitude value + 2 (6.75 x 106 values/s x 10 bit/amplitude value) = 135 Mbit/s + 2 x 67.5 Mbit/s = 270 Mbit/s

This data stream can be transmitted economically on internal studio links via coaxial cables or fiber optics and specified in the IUT-R recommendations BT.601 and BT.656 (formerly CCIR Rec. 601 and 656).

In state-of-the-art public communication networks the limits per channel lie at 34.368 Mbit/s or 139.264 Mbit/s depending on the digital hierarchical level. Therefore concentrated efforts have been made at reducing the bit rate with the aim of achieving satisfactory picture quality with 34.368 Mbit/s per channel, bearing in mind that PALplus is to be also transmitted in Europe.

Recording complete digital TV signals on magnetic tape is complicated because of the high bit rates involved. The TV signal components must be distributed to several parallel channels. As compared to previous analog methods, the quality has however been improved considerably.

The digital coding of **sound signals** for **satellite sound broadcasting** and for the digital **sound studio** is more elaborate than that for video signals as far as quantization is concerned.

A quantization q of 16 bit/amplitude value is required to obtain a quantizing signal-to-noise ratio S/N_q of 98 dB [S/N_q = (6 q + 2) dB].

The NICAM 728 coding method is a simple method yielding an acceptable compression rate, but techically obsolete. The most popular method today are the Dolby Digital and the MPEG coding (ISO/IEC 11172-3), which are employed in all modern transmission and storage systems.

Usual sound coding standards

	f_{sample}	Quantization q	Data flow/ channel
Direct satellite sound broadcasting with 16 stereo channels	32 kHz	16 bit	512 kbit/s
Digital sound studio, CD	44.1 kHz or 48 kHz	16 bit	768 kbit/s
NICAM 728	32 kHz	14/10 bit	728 kbit/s
MPEG	48 kHz	16 bit, subband coding	2x96 kbit/s

Satellite television and sound broadcasting

Communication services via satellite

In the particularly low-loss range 10.7 to 12.75 GHz, there are various communication services operating at different channel spacings and types of polarization:

- Point-to-point transmissions for fixed services
- Program distribution for fixed services (communication satellites)
- Satellite broadcasting for television and sound (broadcasting satellites)

Channel occupancy of satellite services

The frequency allocation plan for the channels of satellite broadcasting is the result of the World Administration Radio Conference – Satellite Broadcasting WARC-SB 1977 in Geneva and laid down in the Final Acts WARC 77 by CCIR (now ITU).

In the BSS band from 11.7 GHz to 12.5 GHz, the channel spacing is 38.36 MHz in each polarization plane, the bands of the two planes being shifted relative to each other by half the channel width (19.18 MHz). The signals have a bandwidth of 27 MHz, and in spite of an overlapping range of 7.82 MHz, excellent signal separation is obtained by polarization isolation (>20 dB). This applies to horizontal and vertical polarization and to righthand and lefthand circular polarization.

Five channels each were allocated by WARC to 19 countries, taken from a total of 40 channels and six orbit positions in the BSS range (37°, 31°, 19°, 7° and 1° west and 5° east). However, with satellites exchanged or hired out, the present-day situation does not correspond to these allocations (for tables see Rohde & Schwarz Sound and TV Broadcasting Catalog 1995).

Advances in technology have led to the FSS range too being used intensively for transmitting sound and TV signals via direct broadcasting satellites. The modulation parameters differ however from those used in the BSS range (see table).

Characteristic data of broadcasting satellites in 12-GHz FSS and BSS band

Frequency range (GHz)	Channel spacing (MHz)	Number of channels	Frequency and polarization of lowest channel	Frequency and polarization of highest channel
10.70 to 10.95	29.50	16	10.71425 H	10.93550 V
10.95 to 11.20	29.50	16	10.96425 H	11.18550 V
11.20 to 11.45	29.50	16	11.21425 H	11.43550 V
11.45 to 11.70	29.50	16	11.46425 H	11.68550 V
11.70 to 12.50	38.36	40	11.72748 H	12.47550 V
12.50 to 12.75	29.50	16	12.51425 H	12.73550 V

Characteristic data of broadcasting and communication satellites

Parameters	**DFS Kopernikus 1**	**DFS Kopernikus 2**	**DFS Kopernikus 3**	**ASTRA 1A to 1G**[1]	**Eutelsat II-F1 to F4**
Frequency downlink	11.5 to 11.7 GHz	12.5 to 12.7 GHz	19.8 GHz	10.7 to 11.7 GHz	10.95 to 11.7 GHz
Channel number	3	7	1	64	78
Channel spacing	150 MHz	67 MHz	–	29.5 MHz	41.67 MHz
Channel width	90 MHz	44 MHz	90 MHz	26 MHz	36 MHz
Polarization	linear horizontal and vertical			linear horizontal and vertical	linear horizontal and vertical
Type of modulation	FM	FM/PSK	FM/PSK	FM/QPSK	FM
Transponder power	14 W	12.5 W	11 W	45 W to 100 W (16 dBW to 20 dBW)	20 W (13 dBW)

Parameters	DFS Kopernikus			ASTRA 1A to 1G[1]	Eutelsat II-F1 to F4		
	1	2	3				
Antenna gain	42 dB	43 dB	41 dB	34 dB	32 dB		
EIRP				51 dBW	45 dBW		
Power flux density PFD_0	109	109	111		–118 dBW/m^2		
Diameter of receiving antenna	0.9 m	0.9 m	0.9 m	0.6 m (to 1.2 m)	0.6 m	0.8 m	3.7 m
Gain	39 dB	39 dB	43 dB	35 dB	34.8 dB	37.3 dB	50.6 dB
Figure of merit G/T of receiving equipment	15 dB/K	16 dB/K	20 dB/K	11 dB/K	11 dB/K	14 dB/K	28 dB/K
Carrier/noise ratio C/N	16 dB	17 dB	15 dB	12 dB	4 dB	7 dB	20 dB
Video S/N ratio (unweighted)	53 dB	54 dB	51 dB	44 dB	41 dB	44 dB	58 dB
Time of utilization	no specs			≥99.9%	≥99.9%	≥99.9%	≥99.9%
Attenuation due to rain	not considered			not considered	not considered		3.5 dB

1) The ASTRA satellites 1E to 1G (with 1H as backup satellite) broadcast digital sound and TV signals on 56 channels in the ranges 11.7 GHz to 12.5 GHz and 12.5 GHz to 12.75 GHz.

Communication satellites

Eutelsat II-F1, Spot West and Spot East	13° East
Eutelsat II-F4 with similar data, position	7° East
Number of countries	7 (channels: 1 or 2 each)
Available channels	6 + 6
Frequency range	10.95 GHz to 11.2 GHz, 11.45 GHz to 11.7 GHz
Channel spacing and channel width	83.333 MHz for both
Channel occupancy (see table below)	double
Polarization	linear horizontal (X) or vertical (Y)

Channel occupancy of communication satellites

Channel	Polarization	Vision carrier (GHz)	Country	Spot
1X	**hori-**	10.99167	Italy	West
2X	**zontal**	11.07500	FRG	East
3X		11.15833	Netherlands	West
4X		11.49167	France	West
5X		11.57500	–	East/Atlantic
6X		11.65833	Great Britain	West
7Y	**verti-**	10.99167	Switzerland	West
8Y	**cal**	11.07500	Luxemburg	East
9Y		11.15833	Belgium	West
10Y		11.49167	FRG	West
11Y		11..57500	–	Atlantic
12Y		11.65833	Great Britain	West

Satellite sound broadcasting

A common method is **sound broadcasting using the subcarriers of analog TV**. In satellite broadcasting of PAL and SECAM signals, the accompanying mono sound component is normally transmitted on a 6.5-MHz subcarrier and additionally as an analog-companded mono or stereo signal on two FM-modulated subcarriers of 7.02 MHz and 7.20 MHz. Two further stereo sound signals can be broadcast on the analog-companded subcarriers of 7.38 MHz, 7.56 MHz, 7.74 MHz and 7.92 MHz without any impairment of the TV signal and without the use of an extra transponder.

Another sound broadcasting system transmitting signals via TV transponders on subcarriers spaced 180 kHz is **ADR (ASTRA Digital Radio)**[1]. This is a digital system which requires only one subcarrier for broadcasting a complete stereo signal in CD quality and uses the same MPEG coding (ISO/IEC 11172-3 Layer II) as DAB (see page 199) and DVB. Thanks to the use of a convolutional coder in conjunction with a Viterbi decoder, ADR operates reliably up to a C/N of 9.5 dB referred to the 26-MHz channel and is thus as reliable as analog broadcasting.

1) ASTRA-ADR/Rev. 1.3, SYS-078/02-94, 15. Dec. 1994

Standards for digital video broadcasting (DVB)

Multiplexing ISO/IEC 13818-1

This is the first part of the MPEG2 standard. The standard describes how data streams from video and audio sources are to be processed to obtain a packet data stream in the specified form that is suitable for the transmission in an impaired channel.

For this purpose, the Packetized Elementary Streams (PES) are combined with certain additional information to form Program Streams (PS) or Transport Streams (TS).

The PES is an elementary data stream divided into packets. Each packet has a header with a fixed length of 6 bytes, a field for Elementary Stream Specific Information with a length of 3 bytes to 259 bytes and a payload with a variable length of up to 65526 bytes.

In a PS, so-called packet headers (13 bytes) and system headers (min. 12 bytes) are inserted between the PES packets. The TS consists of a frame with a fixed length (188 bytes), 4 bytes being reserved for the header. 184 bytes are available for the information proper.

Source coding
Baseband image coding
ISO/IEC 13818-2

The second part of the MPEG2 standard describes the tools used for generating a video data stream in compliance with the standard. The various possibilities of combining parameters in a useful way are defined in a "Profiles/Levels Matrix". The profiles contain staged levels of functionality, eg bidirectional prediction, SNR and resolution scalability. The levels essentially represent different stages of parameters, eg maximum number of pixels or the maximum bit rate.

For the purpose of coding, the video sequences are divided into groups of pictures, pictures, slices, macroblocks and pixel blocks. Data reduction is performed in the main by motion-compensated difference signal generation between pictures, a DCT (Discrete Cosine Transformation) of pixel blocks and a VLC (Variable Length Coding) of the following quantization for the sequence of numbers obtained.

Source coding
Baseband sound coding
ISO/IEC 13818-3

The third part of the MPEG2 standard describes the tools used for the generation of an audio data stream in conformity with the standard. The audio data compression itself is principally based on the subband coding methods described in the MPEG1 standard (ISO/IEC 11172-3) and on quantization using the psychoacoustic model of the human ear or the corresponding steps at the Dolby Digital coding.

The MPEG2 standard includes extensions which allow multiple-channel and surround-sound transmissions, full backward and limited forward compatibility being ensured for the methods included until now. Additional methods can be incorporated in the standard; such methods for which compatibility is not given since the coding techniques used are different.

Satellite transmission EN300 421

(Digital broadcasting systems for television, sound and data services; framing structure, channel coding and modulation for 11/12 GHz satellite services.)

This standard describes the modulation method and the channel coding system for the multi-TV-program transmission via satellite.

The input signal for the functional blocks defined here is the transport stream to MPEG2 standard. The signal passes through the following functional blocks:

- Multiplex adaptation and energy dispersal
- Outer coder (short Reed-Solomon code RS 204, 188)
- Convolutional interleaver
- Inner coder (convolutional coder)
- Baseband generation
- QPSK modulator

The output signal of the system described in the standard is a QPSK-modulated single-carrier signal at the RF which carries a data stream with a defined bit rate with an error protection adapted to the satellite channel.

Cable transmission EN 300 429

(Digital broadcasting systems for television, sound and data services; framing structure, channel coding and modulation cable systems.)

This standard describes the modulation method and the channel coding system for multi-TV-program transmission via cable.

The input signal for the functional blocks defined here is the transport stream to MPEG2 standard. The signal passes through the following functional blocks:

- Multiplex adaptation and energy dispersal
- RS coder (short Reed-Solomon code RS 204, 188)
- Convolutional interleaver
- Byte symbol conversion
- Difference coder
- QAM modulator

The output signal of the system described in the standard is a QAM-modulated single-carrier signal at the RF which carries a data stream of defined bit rate with an error protection adapted to the cable channel. A European recommendation (ETR 154) has been issued for applying the MPEG2 standard to broadcasting via satellite and cable. Further standards exist for teletext in DVB (EN 300 472), service information (EN 300 468) and SMATV systems (EN 300 473).

Terrestrial transmission EN 300 744

(Digital broadcasting systems for television, sound and data services; framing structure, channel coding and modulation for digital terrestrial television.)

This standard describes the modulation method and the channel coding system for multi-TV-program transmission via terrestrial channels.

The input signal for the functional blocks defined here is the transport stream to MPEG2 standard. The signal passes through the following functional blocks:

- Multiplex adaptation and energy dispersal
- Outer coder (short Reed Solomon code (204,188))
- Outer interleaver, ie convolutional interleaver
- Inner coder for punctured convolutional code
- Inner interleaver
- Mapper
- Frame adaptation (with insertion of pilot and TPS signals; TPS = Transmission Parameter Signalling)
- OFDM modulator
- Guard interval insertion
- D/A converter

The functions of the first four blocks are the same as those of the corresponding functional blocks of the DVB standards for satellite and cable transmission.

A choice of options is available for selecting various parameters of the output signal:

- Number of carriers for OFDM signal: 1705 (2 k) or 6817 (8 k)
- Type of modulation: QPSK, 16-QAM or 64-QAM (the latter two also with non-uniform constellation (hierarchical 16-QAM and 64-QAM)
- Guard interval: 1/4, 1/8, 1/16 or 1/32
- Code rate of convolutional coder: 1/2, 2/3, 3/4, 5/6 or 7/8

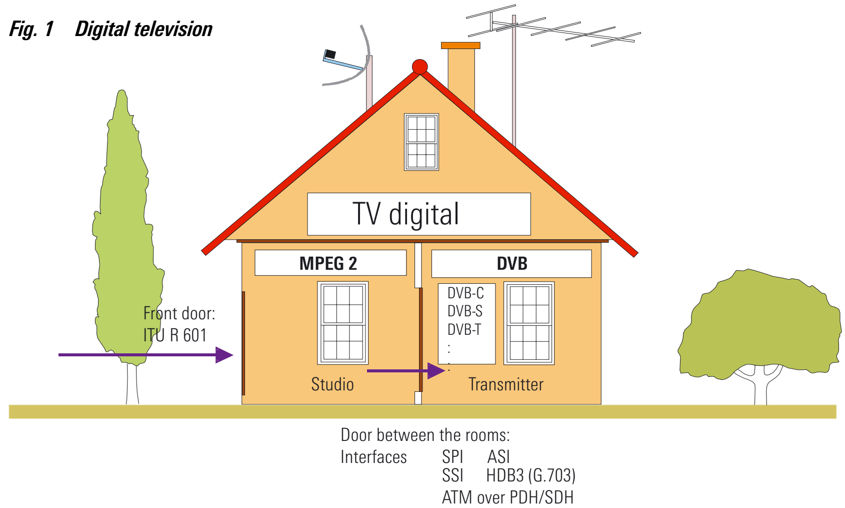
The system further enables hierarchical channel coding and modulation, allowing certain parts of the MPEG2 data stream to be provided with different error protection and placed on defined constellation points.

The transmission system defined by this standard was developed for 8-MHz channels. It can however be rescaled for 7-MHz channels requiring only minor modifications and in the future also for 6-MHz channels.

MPEG2 and DVB Data – Contents

MPEG2 and DVB Data

Fig. 1 Digital television



Summary of key parameters

In the analog TV world, the camera takes the picture as an R, G and B component signal. This signal is taken for further processing to the studio where it is converted into a CCVS (composite colour video signal) according to the PAL, SECAM or NTSC standard. The signal that is IF-modulated in the transmitter and converted to the RF is radiated by the antenna - one program per channel.
But what about digital television?

1 MPEG2

1.1 Video Coding

1.1.1 ITU-R BT. 601/656

The camera already furnishes the picture in ITU-R BT. 601/656-digitized component format YC_BC_R. The interface features the following data:

Standard	ITU-R BT.601 / 656 (4:2:2) SMPTE 125M / 259 M
Systems	625 lines/50 Hz and 525 lines/59.94 Hz
Resolution	10 (8) bits
Synchronization words TRS (timing reference signal)	FF.C, 00.0, 00.0, XY.0 (where X, Y define the location of the actual line)
Parallel interface	27 Msamples/s
Level	ECL
Connector	25-pin SUB-D (ISO 2110-1980)
Serial digital interface SDI	270 Mbit/s to D1-format
Level	V_{PP} = 800 mV ±10% @ 75 Ω
Impedance	75 Ω
Connector	BNC
Coding	$G(x) = (x^9 + x^4 + 1)(x + 1)$

1.1.2 MPEG2 Data Coding to ISO/IEC 13818-2

The interface opens the "front door" to digital television, the first block of which is MPEG2 data compression. Aim of the compression is to reduce the 270 Mbit/s of the ITU-R BT. 601 interface to between 2 Mbit/s and 6 Mbit/s without any discernible loss in picture quality.

For video data, the main elements of data compression are:

$$G(f_x, f_y) = 0{,}25(f_x)\, C(f_y) \sum_{x=0}^{7} \sum_{y=0}^{7} (x, y) \cos((2x+1) f_x\pi/16) \cos((2y+1) f_y\pi/16)$$

DCT (discrete cosine transform) following the equation

	$1/\sqrt{2}$ for f = 0	f_x, f_y	= frequency coordinates
C(f) =	and	$G(f_x, f_y)$	= DCT coefficient
	1 for f > 0	x, y	= pixel/frequency coordinates
		g(x, y)	= pixel values

Quantization with the standard quantization tables for intraframe-coded pictures (I frames)

		8	16	19	22	26	27	29	34
		16	16	22	24	27	29	34	37
		19	22	26	27	29	34	34	38
$Q_I(x,y)$	=	22	22	26	27	29	34	37	40
		22	26	27	29	32	35	40	48
		26	27	29	32	35	40	48	58
		26	27	29	34	38	46	56	69
		27	29	35	38	46	56	69	83

Forward predicted and bidirectional predicted pictures (P and B frames)

		16	16	16	16	16	16	16	16
		16	16	16	16	16	16	16	16
		16	16	16	16	16	16	16	16
$Q_C(x,y)$	=	16	16	16	16	16	16	16	16
		16	16	16	16	16	16	16	16
		16	16	16	16	16	16	16	16
		16	16	16	16	16	16	16	16
		16	16	16	16	16	16	16	16

with the specification $F(x, y) = INT[G(fx, fy) / Q_{I,C}(x, y) + 0.5]$

Zigzag scanning, by which the quantized DCT coefficients F(x, y) are transformed so as to give as long as possible zero strings. A typical example is shown below:

F (x,y) =

0	-17	0	-1	0	0	0	0
-17	5	0	0	0	0	0	0
0	0	0	0	0	0	0	0
-1	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0

The result is:

ZZ = (DC - DCT Coefficient)

−17 −17 0 5 0 −1 0 0 −1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0)

With the aid of Huffman coding the few DCT coefficients and the typical long zero strings at the end of the zigzag scan are reduced to a minimum of information to be transferred.

GOP (Group of Pictures)

With the aid of forward predicted and bidirectional predicted pictures (P and B frames) redundant picture information is further suppressed. A GOP typically comprises 12 pictures. The first one is always an intraframe-coded picture and eliminates all errors occurred until the end of the last GOP. It is followed by the forward predicted and bidirectional predicted pictures (3× P and 8× B frames) which are errored due to the prediction. Whether and to what degree these errors are visible depends on the picture contents and compression factor.

GOP Sequence	I B B P B B P B B P B B
Duration (typical)	12 × 40 = 480 ms
Typical data contents	I frame 1000 kbit P frame 300 kbit B frame 100 kbit
Data rate of program signal with good picture quality	5 MBit/s to 6 MBit/s

The data stream at the output of the video encoder is designated as the video elementary stream (ES video).

1.1.3 Audio Coding to ISO/IEC 13818-3

In addition to the video data, audio data – mono, stereo, dual sound and even joint stereo – are also coded. Temporal and spectral masking effects utilize the principle that "anything that is not audible is superfluous redundancy" for data compression.

Coding to Layer 1	
Splitting of audio bandwidth	32 subbands of uniform width
Block processing	12 samples
Block duration	32 × 12 / 48000 = 8 ms at (typ.) 48 kHz sampling rate
Scale factor of a block	maximum value of the 12 samples
Resolution of scale factor	6 bits
Resolution of samples	2 bits...15 bits (depending on permissible quantization noise)

All 12 samples are divided by the scale factor and quantized taking into account the masking effects. The characteristic of the spectral masking threshold is calculated using Fourier transform with 512 samples. The temporal masking is always effective for block durations of 8 ms to 12 ms (depending on sampling rate).

Coding to Layer 2	
Splitting up of audio bandwidth	32 subbands of uniform width
Block processing	36 samples
Block duration	32 × 36 / 48000 = 24 ms at 48 kHz sampling rate
Scale factors of a block	2 to 3 per block and subband due to the duration of the temporal masking (premasking max. 20 ms)
Scale factor of a block	maximum value of the 36 samples
ID number of scale factors	2 bits
Resolution of scale factor	6 bits
Resolution of samples	2 bits to 15 bits (depending on permissible quantization noise)
Quantization in subbands 23 to 26 at >50 kbit/s and 48 kHz sampling rate	0 (cancellation), 3, 5, 65535 quantization steps

Since at 48 kHz sampling rate the resulting frequency is >20 kHz, the subbands 27 to 31 are suppressed.
The data stream at the output of the audio coder is designated as the audio elementary stream (ES audio).

1.1.4 PES (Packetized Elementary Stream)

The elementary streams ES for video and audio are coded. After packetizing the PES is obtained. Each packet of the PES starts with a header which in addition to the packet start code (24 bits) contains the following information:

Contents of PES (stream ID)	8 bits
Length of PES	16 bits

In an optional field the following information is announced by flags:

Clock reference for synchronization	
of system PLL	42 bits (SCR, ESCR (elementary) system clock reference)
Time stamps PTS and DTS	33 bits each (presentation time stamp, decoding time stamp)
Data rate of ES	22 bits

Since with MPEG2 coding the line and field blanking intervals are suppressed, the coded MPEG2 data stream does not contain any insertion test signals, teletext or data lines. The ES data may contain for instance the teletext and data line information of analog television.

1.1.5 TS (Transport Stream)

The multiplexer splits the video, audio and data PES as well as the tables added for PSI (program specific information) and SI (service information) into packets of 184 bytes each and adds a header at the beginning of each packet. Transport stream packets TS with a length of 188 bytes are thus obtained. The TS header provides the following information:

Synchronization byte	0 x 47
Bit TEI (transport error indicator)	for indication of TS packet data that cannot be fully corrected
Packet identification number PID (packet ID)	13 bits
Flags for announcing the optional adaptation field	2 bits
Clock reference for monitoring continuous packet transmission (continuity counter CC)	4 bits

and in the optional adaptation field in addition to a variety of flags:

Program clock reference

PCR derived from STC (system time clock) for synchronization of system PLL	42 bits or
Original program clock reference OPCR	42 bits

1.2 MPEG2 Multiplexer

The TS data rate for a program is 2 Mbit/s to 7 Mbit/s (max. 15 Mbit/s). It is made up of the data rates for

Video	2 Mbit/s to 6 Mbit/s
Audio	32 kbit/s to 384 (+64) kbit/s
Data	as required
PSI/SI tables	up to 1 Mbit/s depending entries in the tables

Typical TS data rate for a transmission channel according to present state-of-the-art:

via cable	38.153 Mbit/s
via satellite	38.015 Mbit/s
terrestrial	approx. 20 Mbit/s

A TS can thus carry 5 programs with very high signal quality to 10 programs with lower signal quality via cable or satellite, and 3 to 6 programs via terrestrial links. Utilization can be further enhanced by statistical multiplexing, with a data rate compensation taking place between all programs multiplexed in the transport stream. Programs that currently need a lower data rate since they only transmit non-moving pictures or similar provide programs with high data rate with additional data capacity. Through this measure more programs can be packed into the TS.

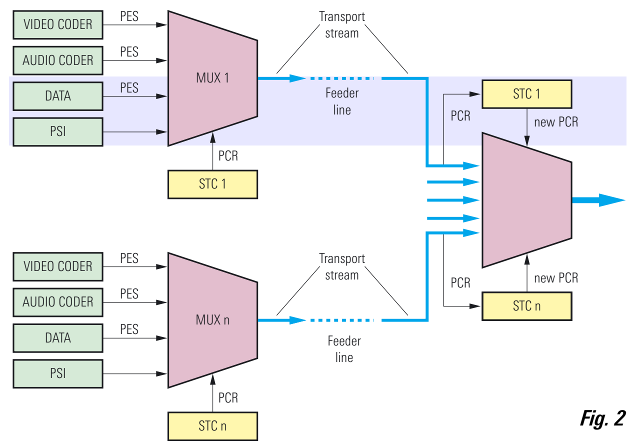


Fig. 2

1.3 PSI/SI Tables

With the aid of the tables listed below the demultiplexer in the DVB receiver receives all the necessary information about the transmission channel and the TS contents.

1.3.1 PSI Tables to ISO/IEC 13818-1

PAT	**Program Association Table**	(PID = 0x0000)
	List of all programs containedin TS multiplex with reference to PID of PMT	
CAT	**Conditional Access Table**	(PID = 0x0001)
	Reference to encrypted programs	
PMT	**Program Map Table**	(PID = 0x0020 to 0x1FFE)
	Reference to packets with PCR Name of programs, Copyright, Reference of data streams with PIDs etc belonging to the relevant program	
NIT	**Network Information Table**	(PID = 0x0010)
	Information about orbit, transponder number, etc	

1.3.2 SI Table to ETS 300 468

BAT	**Bouquet Association Table**	(PID=0x0011)
	Table describing a bouquet of programs offered by a broadcaster	
EIT	**Event Information Table**	(PID=0x0012)
	TV guide	
SDT	**Service Description Table**	(PID=0x0011)
	Description of programs offered	
RST	**Running Status Table**	(PID=0x0013)
	Accurate and fast adaptation to a new program if time changes occur in the schedule	
TDT	**Time and Date Table**	(PID=0x0014)
	UTC time and date	
TOT	**Time Offset Table**	(PID=0x0014)
	UTC time and date with indication of local time difference	

1.3.3 Repetition Rates of Time Stamps and Tables

Parameter	Minimum interval in ms	Maximum interval in s
PAT	25/25	0.5/0.5
CAT	25/25	0.5/0.5
PMT	25/25	0.5/0.5
NIT	25/25	10/10
SDT	25/25	2/2
BAT	25/25	10/10
EIT	25/25	2/2
RST	25/25	---/---
TDT	25/25	30/30
TOT	25/25	30/30
PCR	0/0	0.04/0.10
PTS	---	0.7/0.7

First value: recommended by DVB ETR 290
Second value: recommended by ISO/IEC13818

1.4 Interfaces to EN 50083-9

The signal interfaces open the door to the DVB room in the "digital television house" and apply the TS to the input of the respective DVB modulator.

1.4.1 SPI (Synchronous Parallel Interface)

Electrical characteristics LVDS (low voltage differential signalling)

Output	balanced (DATA X A = DATA X B inverted)
DC mean value	nominal 1.25 V (1.125 V to 1.375 V)
Signal amplitude	nominal 330 mV (247 mV to 454 mV)
Input	balanced
Maximum voltage	$V_{pp} = 2$ V
Minimum voltage	$V_{pp} = 0.1$ V
Connector	25-pin, type D (to ISO Doc. 2110 (1989))

Pin assignment

Pin #	Signal	Pin #	Signal
1	Clock A	14	Clock B
2	System ground	15	System ground
3	Data 7 A (MSB)	16	Data 7 B
4	Data 6 A	17	Data 6 B
5	Data 5 A	18	Data 5 B
6	Data 4 A	19	Data 4 B
7	Data 3 A	20	Data 3 B
8	Data 2 A	21	Data 2 B
9	Data 1 A	22	Data 1 B
10	Data 0 A	23	Data 0 B
11	DVALID A	24	DVALID B
12	PSYNC A	25	PSYNC B
13	Shield		

Clock frequency f_T	depending on TS data rate f_D: $f_T = f_D / 8$ (without Reed-Solomon error correction) $f_T = (204 / 188) \times f_D / 8$ (with Reed-Solomon error correction)

1.4.2 SSI (Synchronous Serial Interface)

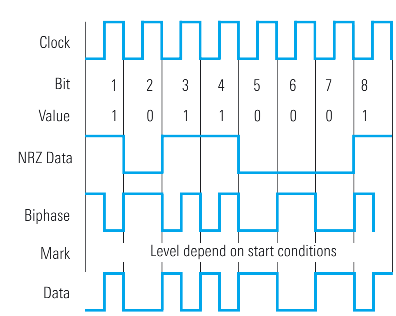


Fig. 3 Example of biphase mark coding

The parallel SPI data 0 to 7 are parallel-serial converted and sent with a clock 8 times higher than that of the SPI.

Electrical characteristics	
Pulse shaping	squarewave, to defined masks
Maximum voltage	$V_{pp} = 1$ V $\pm 10\%$
Return loss	15 dB 3.5 MHz to 105 MHz
Jitter	$J_{pp} = 2$ ns

1.4.3 ASI (Asynchronous Serial Interface)

The 8-bit MPEG2 TS byte is converted into a 10-bit word via predefined tables. The data rate is 270 Mbit/s. Since the TS data rate is at present typically approx. 40 Mbit/s, the socalled sync bytes, also called fill bytes, are used to fill up the data rate to 270 Mbit/s. These bytes are generally designated K28.5 and are invalid data for the conversion of 8-bit to 10-bit words. The ASI receiver ignores the fill bytes.

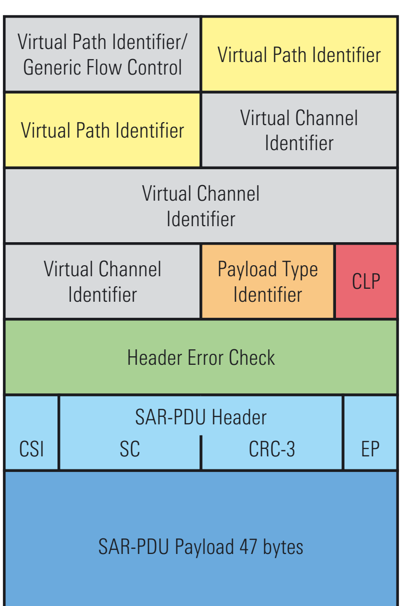
Electrical characteristics	
Coaxial cable	75 Ω/BNC
Return loss	≤–15 dB 5 to 270 MHz
Data amplitude	V_{pp} = 0.8 V ±10%

1.4.4 HDB3 (High Density Bipolar of 3rd Order)

This interface is defined in CCITT Rec. G.703 and describes 3-level signal coding. This interface is mainly used in telecoms. For connections between 0.5 and 30 m the most frequently used interfaces are SPI and ASI.

1.4.5 ATM over PDH/SDH

TV signals must be transmitted in realtime. Errors occurring in signal distribution cannot be remedied by way of query and retransmission. The realtime requirement in conjunction with the demand for a high data rate is met with the ATM mode, which utilizes the existing optical-fiber infrastructure of PDH and SDH systems for data distribution.



ATM packet structure at AAL1

Achievable data rates for PDH are about 139.264 Mbit/s (E4, Europe) and 44.736 Mbit/s (T3, U.S.). In SDH environments, data rates of 155.52 Mbit/s (STM1, Europe and STS3, U.S.) to 2 488.32 Mbit/s (STM16, Europe and STS48, U.S.) are common today. Data rates of up to 9 953.28 Mbit/s (STS 192, U.S.) are employed on a trial basis.

With ATM, the 188-byte TS packets at ATM adaptation layer 1 (AAL1) are divided into four sections of 47 bytes. To each section, a 5-byte ATM packet header and the 1-byte overhead for AAL1 are added, which yields an ATM packet of 5+1+47 = 53 bytes.

Featuring Reed-Solomon forward error protection (124, 4, 2) in conjunction with block interleaving at AAL1, the ATM mode is ideal for long-distance MPEG2 data transmission.

Layer AAL1 is used today, for example, in the distribution systems of the German ARD (Hybnet) and the German Telekom (Rundfunk Service Multiplexer) for interconnecting studio complexes and feeding TS data from the studio to the DVB transmission system.

2 Digital Video Broadcasting DVB

2.1 Modulation for

- DVB-C (Cable) to EN 300 429/
- DVB-S (Satellite) to EN 300 421/
- 8VSB (Terrestrial) to ATSC Digital Television Standard
- DVB-T (Terrestrial) to EN 300 744

2.1.1 Sync Word Inversion and Energy Dispersal

The MPEG2 transport stream packets TS are taken via the interfaces as described above to the DVB room of the digital television house.

The first step of processing the TS packets in the modulator is carried out in the "sync word inversion and energy dispersal" block. The PRBS polynomial $1 + x^{14} + x^{15}$ causes energy dispersal of the data in the TS packets, not however of the sync words (0 x 47). The length of the polynomial is 1503 bytes and hence exactly 8 TS packets less the bitwise inverted sync word 0 x B8 of the first TS packet.

The 15-bit PRBS register is loaded by the sequence "100101010000000". The inverted sync word marks the start of the dispersal sequence and the energy dispersal ensures a constant middle power density in the output spectrum of the modulator.

Sync word inversion and energy dispersal	
PRBS polynomial	$1 + x^{14} + x^{15}$
Initialization of PRBS register	100101010000000
Length of polynomial	1503 bytes
Length of energy dispersal sequence	1503 bytes + inverted sync byte = 8 TS packets
Sync word	0 x 47
Bitwise inverted sync word	0 x B8

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

16 error correction bytes are appended to the TS packets processed as described above. The enhanced TS packets now have a length of 204 bytes. This 204,188, 8 RS error correction code allows correction of up to 8 faulty bytes per TS packet in the receiver/decoder. It also allows correction of bit error ratios (BER) of 2 x 10^{-4} to give a quasi error-free (QEF) data stream with a residual BER of 1 x 10^{-11}.

RS-FEC	
TS packet length	188 + 16 = 204 bytes
Correction	up to 8 faulty bytes per TS packet
Scope of correction	BER of 2 x 10^{-4} reduced to 1 x 10^{-11}

2.1.3 Interleaver

If transmission errors occur, they usually do not affect just one bit in the data stream but many successive bits. This is denoted as "error bursts" which may affect hundreds of bits or even cancel them completely. The capabilities of the RS error correction, ie correction of 8 bytes per TS packet, would then be insufficient. Therefore an interleaver is used which inserts up to 2244 bytes from other TS packets between originally neighbouring bytes. Burst errors can thus be corrected provided that after deinterleaving in the receiver/decoder they exhibit less than 8 faulty bytes per TS packet. From this point, different procedures are prescribed by the various standards.

2.1.4 Byte-to-Symbol Mapping in Cable Standard DVB-C

So far, we have only been talking of bits and bytes. For transmitting the TS data with QAM (quadrature amplitude modulation) in the cable standard DVB-C, the bits and bytes have to be transformed into symbols. Symbols are $\frac{\sin x}{x}$-similar shaped analog pulses with 2^m amplitude levels for the I and Q components. n is the number of bits per component. Hence the number of possible states in the constellation diagram is 2^{2n}.
m = 2 x n defines the order of QAM.

For example, there are exactly $2^3 = 8$ different amplitudes each for I and Q with $2^{2 \times 3} = 2^6$ (m = 6) = 64 QAM. The 8 amplitudes are defined by 3 bits each for I and Q. A symbol consists of a pair of I and Q components which are orthogonally arranged for the modulation. I stands for inphase and Q for quadrature components. With 64QAM, each symbol carries 6 bits.

Bits per symbol for the various QAM modes:

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

The most frequently used modes are 16, 64 and 256 QAM.

2.1.5 Constellation Diagrams for DVB-C

16 QAM

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

32 QAM

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

64 QAM

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

2.1.6 Differential Coding of the Two Most Significant Bits

The two MSBs of the symbols A and B are differentially coded at the transmitter end so that upon decoding of successive symbols the quadrant in which these symbols are located can be determined. This is necessary because due to the carrier suppression during modulation the phase information is lost. The MSBs I_K and Q_K are buffered for a symbol clock after differential coding. The comparison between I_K and I_{K-1} or Q_K and Q_{K-1} yields the original quadrant.

Truth table of differential coding[1]				
Inputs MSBs		Output bits		Rotation
A_K	B_K	I_K	Q_K	
0	0	$I_{K\text{-}1}$	$Q_{K\text{-}1}$	0°
0	1	$Q_{K\text{-}1}$	$I_{K\text{-}1}$	+90°
1	0	$Q_{K\text{-}1}$	$I_{K\text{-}1}$	–90°
1	1	$I_{K\text{-}1}$	$Q_{K\text{-}1}$	180°

[1] U. Reimers: Digitale Fernsehtechnik

2.1.7 Bandwidth

The symbols are $\frac{\sin x}{x}$-similar shaped analog pulses whose bandwidth in Hz corresponds to half the symbol rate in symb/s. After double sideband modulation the bandwidth is obtained as the symbol rate expressed in Hz. Assuming the useful bit rate R of the TS packets in Mbit/s and converting it to the symbol rate S in a 2^m QAM system yields the following result:

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

The factor $\frac{204}{188}$ also takes account of the RS error correction.

A bit rate of R = 38.1529 Mbit/s is frequently used for the cable channel. The $\frac{\sin x}{x}$-similar shaped and 64 QAM symbols therefore have a Nyquist bandwidth of B = 6.900 MHz.

2.1.8 2^m QAM Spectrum in Cable Channel

$\frac{\sin x}{x}$-similar shaped symbols have a constant amplitude and group delay frequency response. Their bandwidth B in the transmission channel is thus accurately defined as

$B = S x (1 + r)$ MHz because of the double sideband AM (r = roll-off factor).

The VHF, UHF and special channels in B/G cable TV have a defined bandwidth B of 7 MHz or 8 MHz. The 2^m QAM spectra together with the prescribed roll-off filtering must fit into these channels. The roll-off factor of the cable system is r = 0.15. Therefore the theoretical maximum symbol rate of a 8 MHz channel is

$$S_{max} = \frac{B}{1+r} = \frac{8}{1,15} = 6,9565 \text{ MSymb/s}$$

without taking any additional interference because of band limiting into account. In the 7 MHz channel the theoretical maximum symbol rate is

$$S_{max} = \frac{7}{1,15} = 6,0870 \text{ Msymb/s}$$.

For the modulation of TS packets directly received via a satellite the preferable bite rate is 38.014706 Mbit/s (see "Byte-to-Symbol Mapping in Satellite Standard DVB-S"). Mapping to the cable standard yields a symbol rate of 6.875 Msymb/s.
Mostly an intermediate frequency of 36 MHz is used though the calculated center frequency of an 8 MHz channel is 38.9 – 2.85 = 36.05 MHz. This means that for 64 QAM signals transmitted in the 8 MHz CCIR channel spacing, the carrier frequencies have to be corrected upwards by 2.85 MHz.

2.1.9 Main Parameters

2^m QAM mode	16 64 256	m = 4 m = 6 m = 8
Symbol shape		$\frac{\sin x}{x}$-similar
Most frequently used bit rate R	Mbit/s	38.152941 (38.014706)
Symbol rate S	Msymb/s	$S = R \cdot \frac{204}{188} \cdot \frac{1}{m}$
Most frequently used symbol rate S	Msymb/s	6.900 (6.875)
Roll-off factor		0.15

2.2 Byte-to-Symbol Mapping in Satellite Standard DVB-S

Compared to satellite transmission, the cable system is very stable. Given a correctly installed system, the cable channel characteristics remain practically unchanged. Therefore, single RS error correction is sufficient for cable transmissions. With satellite transmission, the underlying conditions are completely different. Weather conditions play a very important role.

2.2.1 Convolutional Coder

With DVB-S, data are therefore provided with further error correction, namely the convolutional coder and associated (Viterbi) decoder. Characteristic data of convolutional coder:

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

The generator polynomials determine the number of taps a the shift registers with k = 7 taps.

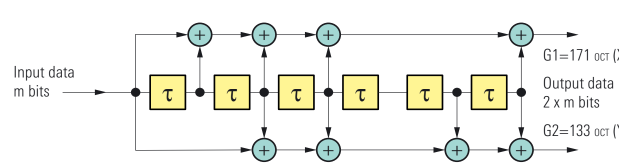


Fig. 4 Convolutional coder for DVB

The m-bit input data give 2 × m-bit output data. The net data rate is reduced by a factor of 2. To reduce this high redundancy somewhat, the output data are "punctured". By erasing defined bits of the output data, the output data rate is reduced according to the scheme below (see figure 5):

2.2.2 Puncturing Scheme

With the aid of the remaining redundancy the Viterbi decoder in the receiver/demodulator can improve the bit error ratio BER by up to 2 decades. The combination of Viterbi decoder and RS-FEC (forward error correction) allows an input BER of approx. 2×10^{-2}: the Viterbi decoder corrects the value to BER = 2×10^{-4} and RS-FEC to BER = 1×10^{-11}.

Up to this point, processes in DVB-S and DVB-T are identical.

While with 64 QAM in the cable the theoretical minimum value for C/N is 24 dB with data correction from BER = 2×10^{-4} to a quasi error-free BER = 1×10^{-11} using solely RS-FEC, this value is reduced in the case of DVB-S with QPSK (quadrature phase shift keying) modulation to approx. 4 dB depending on the puncturing rate (often also referred to as code rate).

Code rate P	C/N dB
1/2	3.3 + 0.8 = 4.1
2/3	5.1 + 0.8 = 5.9
3/4	6.1 + 0.8 = 6.9
5/6	7.1 + 0.8 = 7.9
7/8	7.7 + 0.8 = 8.5

These values may somewhat vary depending on the degradation of the received signal due to the existing receiving and demodulation conditions – which is referred to as implementation loss. An implementation loss of ≤0.8 dB is specified in the DVB-S standard.

2.2.3 Coding of I and Q Components

For retrieving the original position of the quadrants, the same rules as for QAM apply to QPSK. The constellation diagram shows the four states since each symbol carries 2 bits.

Q		I
I = 1 Q = 0	I = 0 Q = 0	
I = 1 Q = 1	I = 0 Q = 1	

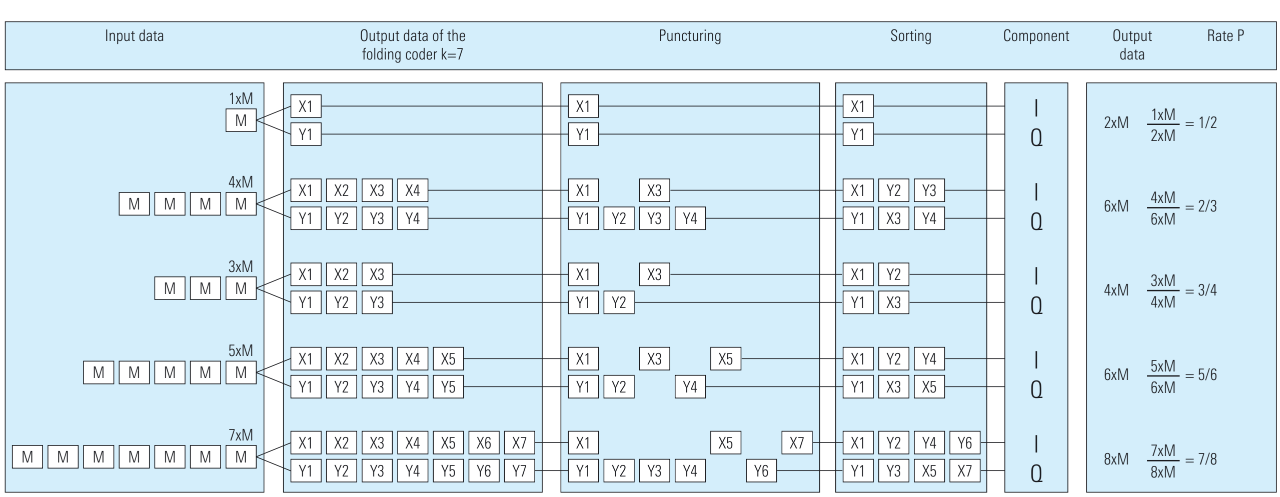
2.2.4 Bandwidth

The symbols that are again $\frac{\sin x}{x}$-similar shaped are QPSK-modulated. In this case, too, the bandwidth of the double-sideband-modulated symbols is equal to the symbol rate expressed in Hz. In a QPSK system the symbol rate S is calculated according to the following equation:

$$S = R \cdot \frac{1}{P} \cdot \frac{204}{188} \cdot \frac{1}{2} \ \text{Msymb/s}$$

where	R	TS packet net bit rate
	P	puncturing rate (code rate)
	$\frac{204}{188}$	effect of RS-FEC
	$\frac{1}{2}$	2 bits per symbol being taken into account

Fig. 5 Puncturing scheme



A frequently used symbol rate in DVB-S is 27.5 Msymb/s with a puncturing rate of 3/4. The associated net bit rate thus derived is R = 38.014706 Mbit/s.

The Nyquist bandwidth of the symbols is 27.5 MHz. Channel filtering has a roll-off factor of r = 0.35 according to specifications. The required transponder bandwidth is $B = S \cdot (1 + r) = 27,5 \cdot 10^6 \cdot 1,35 = 37,125\ \text{MHz}$ and hence distinctly greater than the present transponder bandwidth of 33 MHz or 36 MHz of the latest satellite Astra 1E. Computer simulations have shown however that with r = 0.27 interfering effects do not occur. The required bandwidth is calculated at to $B = 27,5 \cdot 10^6 \cdot 1,27 = 34,925\ \text{MHz}$ and need not be further limited to fit into the 36 MHz bandwidth of Astra 1E.

2.2.5 Main Parameters

QPSK modulation		m=2 (1 bit per I/Q component)
Symbol shape		$\frac{\sin x}{x}$-similar
Most frequently used bit rate R	Mbit/s	38.014706
Symbol rate S	Msymb/s	$S = R \cdot \frac{1}{P} \cdot \frac{204}{188} \cdot \frac{1}{m}$
Most frequently used symbol rate S	Msymb/s	27.5
Roll-off factor		0.35 (0.27)

3 Conversion of C/N to E_b/N_0

Often, the bit error ratio diagrams are not referred to the C/N value, but to the energy per information bit E_b relative to the normalized noise power N_0. In converting the two quantities one to the other, some factors have to be taken into account as shown by the following equations:

$C/N = E_b/N_0 + k_{FEC} + k_{QPSK/QAM} + k_p$ dB or
$E_b/N_0 = C/N - k_{FEC} - k_{QPSK/QAM} - k_p$ dB or
$E_b/N_0 = S/N + k_{roll\ off} - k_{FEC} - k_{QPSK/QAM} - kp$ dB,

whereat is valid: $C/N = S/N + k_{roll\ off}$ dB

To determine S/N dB respectively C/N dB, the logarithmic ratio E_b/N_0 is to be corrected by the following factors:

$k_{FEC} = 10 \cdot \lg\frac{188}{204}$ ie the factor for Reed-Solomon FEC

$k_{FEC} = -0.3547$ dB

$k_{QPSK/QAM} = 10 \cdot \lg(m)$ ie the factors for QPSK/QAM modes

Mode	m	$k_{QPSK/QAM}$ dB
QPSK	2	3.0103
16 QAM	4	6.0206
64 QAM	6	7.7815
256 QAM	8	9.0309

$k_{roll\ off} = 10 \cdot \lg(1 - \alpha/4)$ ie the factor for the puncturing rate (P = 1 for QAM)

Mode	P	k_P dB
QPSK	1/2	–3.0103
	2/3	–1.7609
	3/4	–1.2494
	5/6	–0.7918
	7/8	–0.5799
QAM	1	0

$k_P = 10 \cdot \lg(P)$ ie the factor for $\sqrt{\cos}$ roll-off filtering in the demodulator/receiver

Mode	α	$k_{roll\ off}$ dB
DVB-C	0.15	–0.1660
DVB-S	0.35 (nominal)	–0.3977

The type of correction factors being required depends on whether

– E_b is to be treated as a pure information bit

and on whether measurement is made

– in the transmission channel before or after Viterbi or Reed-Solomon correction or
– with QAM or QPSK modulation.

4 Digital Television Standard to ATSC (8/16 VSB Vestigial Sideband Modulation)

This standard was adopted by the Advanced Television Systems Committee ATSC for terrestrial broadcasting of digital programs and uses 8VSB or 16VSB modulation.

4.1 Data Coding

The system uses MPEG2-conformal data streams as input signals. The video PES and TS packets feature the protocol described above and are data-compressed to MPEG2 standard.

Differences exist in the associated tables: the PSI tables are generated to IEC 13818-1. The SI tables are replaced by PSIP tables (Program and System Information Protocol):

MGT	Master Guide Table
TVCT	Terrestrial Virtual Channel Table
CVCT	Cable Virtual Channel Table
RRT	Rating Region Table
EIT	Event Information Table
ETT	Extended Text Table
STT	System Time Table

There are also differences in audio processing. Data are coded to ATSC standard A/52, system AC3. The audio data are generated with a sampling rate A = 48 kHz. The value of 48 kHz is derived from the equation

$A = \frac{2}{1125} \cdot 27 \cdot 10^6 [Hz]$ where 27 MHz is the system clock.

The intended data rates of a "Main Audio Service" or of an "Associated Audio Service" after coding are: D ≤384 kbit/s. For both services the maximum rate is D ≤512 kbit/s.

4.2 Modulator

In the data randomizer as the first data processing block in the modulator the TS packet bytes are XORed with 8 outputs of the 16-bit PRBS generator. Sync byte 0 x 47 is not scrambled. The PRBS polynomial follows the equation $G = x^{16} + x^{13} + x^{12} + x^{11} + x^7 + x^6 + x^3 + x + 1$ and is loaded during each data segment sync (see 4.2.4 **VSB data frame**) with the value 0 x F180.

4.2.1 Forward Error Correction FEC

The Reed-Solomon error correction code consists of 20 redundancy bytes which are added to the 188-byte TS packet. The extended TS packets thus have a length of 208 bytes. The sync byte 0 x 47 is not coded, therefore the error correction code is identified by 207, 187, 10. RS-FEC is able to correct 10 faulty bytes per packet.

4.2.2 Data Interleaver

To allow correction of error bursts, the scrambled and RS-FEC-protected TS packets are passed through an interleaver which has 52 branches. The sync information of the convolutional byte interleaver is furnished by the data segment sync (see 4.2.4 **VSB data frame**).

4.2.3 Trellis Coding

8VSB transmission uses trellis coding with a code rate of 2/3 for convolutional coding.

The output bytes of the data interleaver are bitwise interleaved so that two serial data streams are obtained. Data stream X1 contains bits 7, 5, 3, 1 (7 corresponding to the MSB) and X2 bits 6, 4, 2, 0. Bit stream X2 is "precoded" and X1 is subjected to two-stage convolutional coding.

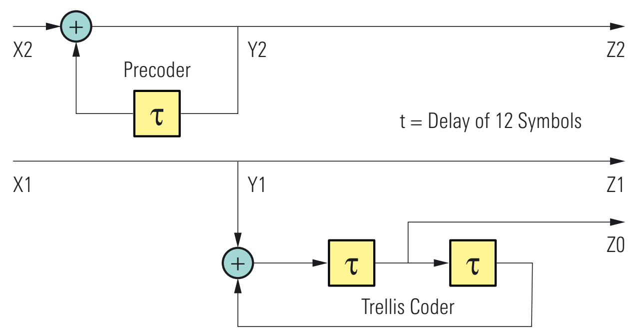


Fig. 6 Convolutional coder with ATSC

Trellis coder and precoder expand the data stream X1 and X2 to three data streams Z0, Z1 and Z2. The words now comprising three bits form at the same time a symbol at a code rate of 2/3. Twelve of these X1 and X2 coding blocks are interleaved by means of the trellis code interleaver. Each byte of the MPEG2 transport streams generates 4 symbols of 3 bits each.

Switches S1 and S2 follow a scheme that is accurately defined in ATSC.

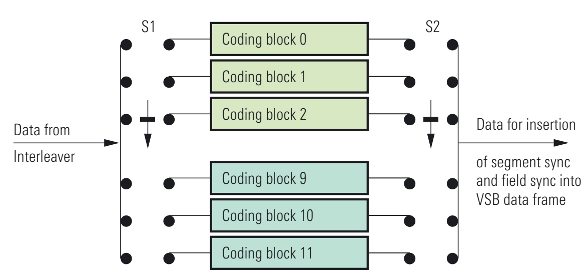


Fig. 7 Trellis code interleaver

4.2.4 VSB Data Frame

A multiplexer inserts the data segment sync and data field sync as shown in Fig. 8, the sync byte of the MPEG2 transport stream being replaced by a two-level (binary) sync signal. The symbol sequence of Z2, Z1, Z0 is 110, 001, 001, 110, corresponding to the values +5, –5, –5, +5. The segment syncs have a repetition rate of 77.30735 µs.

One byte generates 4 symbols of 3 bits each. With a puncturing rate of 2/3 a data segment including the segment sync contains (1 + (187 + 20)) x 4 = 4 + 828 = 832 symbols.

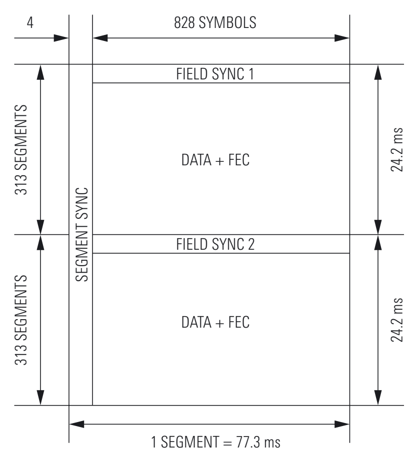


Fig. 8 Data frame

313 segments + 1 data field sync form a data subframe. Two subframes form a frame. The field sync contains learning sequences for the equalizer in the receiver, signalling of the 8/16 VSB mode as well as a precode which contains the last 12 symbols of the last 8VSB segment.

The output symbols of the multiplexer are taken to the direct symbol mapper whose truth table is as follows:

Bits Z_2, Z_1, Z_0			Symbol
0	0	0	–7
0	0	1	–5
0	1	0	–3
0	1	1	–1
1	0	0	+1
1	0	1	+3
1	1	0	+5
1	1	1	+7

4.2.5 16VSB Modulation

In the case of 16VSB there is neither trellis coding nor a trellis code interleaver. After the data interleaver, the bytes are split up into nibbles and taken to direct mapping:

Byte from data interleaver							
MSB 1st nibble				2nd nibble LSB			
X_{1a}	X_{1b}	X_{1c}	X_{1d}	X_{2a}	X_{2b}	X_{2c}	X_{2d}

Symbol	+15	+13	+11	+9	+7	+5	+3	+1	–1	–3	–5	–7	–9	–11	–13	–15
X_a	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0
X_b	1	1	1	1	0	0	0	0	1	1	1	1	0	0	0	0
X_c	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0
X_d	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0

The VSB modulator modulates the 3-bit or 4-bit symbols at 10.7622367 Msymb/s with suppressed carrier. By inserting a defined DC offset a pilot that is 11.3 dB below the mean channel power is obtained at the carrier frequency.

4.2.6 Main Parameters of 8/16 VSB

	8 VSB	**16 VSB**
Net data rate	19.39265845975 Mbit/s	38.7853169195 Mbit/s
TS packet length	1 + 187 bytes	1 + 187 bytes
RS error correction code	207, 187, 10	207, 187, 10
Bits per symbol	3	4
Symbol rate	4.5/286 × 684 = 10.7622367 Msymb/s	4.5/286 × 684 = 10.7622367 Msymb/s
Structure of data frame		
Length of a segment	(4 + 828) / 10.7622367 = 77.30735 µs	(4 + 828) / 10.7622367 = 77.30735 µs
Number of bits per segment	4 + 828 symbols = 2496 bits	4 + 828 symbols = 3328 bits
Number of bits per segment sync	4 × 3 = 12 bits	4 × 4 = 16 bits
Data subframes	313 segments	313 segments
Segments/s	12935.38064904	12935.38064904
Frames/s	20.66354736268	20.66354736268
Channel bandwidth in MHz	6	6
Roll-off factor	0.1152416356877 (defined by 2 × 310 kHz for $\sqrt{\cos}$ roll-off)	0.1152416356877 (defined by 2 × 310 kHz for $\sqrt{\cos}$ roll-off)
Pilot		
Level	–11.3 dB, referred to mean channel power	–11.3 dB, referred to mean channel power
Frequency	carrier frequency of channel	carrier frequency of channel

5 DVB-T for Terrestrial Broadcasting with COFDM

5.1 Byte-to-Symbol Mapping in Terrestrial Standard DVB-T

DVB-S and DVB-T use the same processing blocks at the input, ie from the sync word inversion and energy dispersal block through to the convolutional coder. After this stage, signal processing is completely different. Two modes are defined for the multicarrier method COFDM: the 2k mode with 1705 carriers and the 8k mode with 6817 carriers. Further protective measures are taken to ensure practically interference-free reception even under extremely adverse conditions (weather effects, fading).

5.2 Inner Interleaver

In addition to the outer interleaver following the outer Reed-Solomon error correction, the COFDM method also uses an inner interleaver. Depending on the modulation format – QPSK, 16 QAM or 64 QAM (without difference coding) – the inner interleaver is made up of 2, 4 or 6 interleaver branches. In each branch – one branch for each bit in the QPSK or QAM data word – the inner interleaver interleaves blocks of 126 bits and thus optimally supports the bitwise inner (Viterbi) error correction code.

The terms "inner" and "outer" always refer to the position of the transmission blocks relative to the antenna: "inner" means close to the antenna, "outer" away from the antenna.

5.3 Symbol Interleaver

In the 2 k mode 12 groups and in the 8 k mode 48 groups of the 126 interleaver output data words are combined in bit groups. These bit groups are interleaved by the symbol interleaver to generate the COFDM symbols. The data carrier upon which the QPSK or QAM symbols are to be modulated is defined here. Subsequent mapping defines the constellation on each data carrier. A symbol in this case means the total information on all carriers.

The symbol interleaver already takes into account that different types of pilots, ie scattered, continuous and TPS (transmission parameter signalling) have to be inserted at defined places in the COFDM symbol, leaving the respective carriers free. The scattered and continuous pilots are used for synchronization, while the TPS pilots transmit important information about the modulation structure to the receiver/demodulator.

Following OFDM modulation and insertion of the guard interval the data are taken to the D/A converter. The analog signal is converted to the RF, amplified and radiated via the antenna.

Fig. 9 shows the structure of the DVB-T symbols and their combination in a transmission frame.

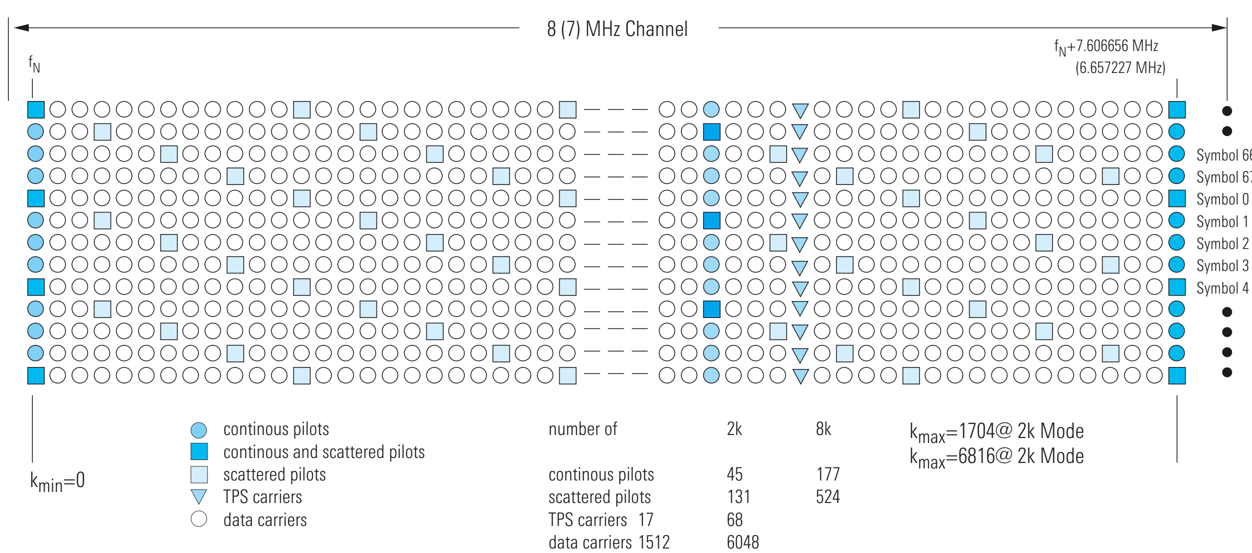


Fig. 9 Structure of DVB-T symbols and summary of transmission frames

5.4 Pilots in DVB-T Symbol

The number of scattered pilots is calculated from the equation $k = k_{min} + 3 \cdot (l \bmod 4) + 12p$, where

- k is the index of the COFDM carrier defined as scattered pilot
- l is the index of the COFDM symbol with 0 < l < 67
- p is the index of the COFDM carrier with $k_{min} < p < k_{max}$ and $k_{min} = 0$ and $k_{max} = 6816$ for the 8k mode and $k_{max} = 1704$ for the 2k mode.

Calculations show that in symbols with (l mod4) = 0 the number of scattered pilots is 569 whereas in all other symbols it is 568.

In symbols with (l mod4) = 0, 45 scattered pilots in 8k mode and 12 scattered pilots in 2k mode overlap with the defined continuous pilots, whereas in the other symbols 44 scattered pilots in 8k mode and 11 scattered pilots in 2k mode are coincident.

5.5 Guard Interval

During the guard interval all echoes due to multipath reception, reception from other transmitters in the SFN (single frequency network), Doppler effects in mobile reception, ie all fading effects must settle or die away. After this the transmitted symbol will be decoded.

5.6 Main Parameters of DVB-T

General DVB-T specs	Σ Carriers	Scattered pilots	Continuous pilots	TPS carriers	Number of data carriers C_{data}	Carrier spacing Hz	Total bandwidth Hz	Useful symbol period µs	Symbol period T_{Symbol} with guard interval	
DVB-T 2k mode	1705	131	45	17	1512	4 464.286	1705 × 4 464.286 = 7611 607	224	280 µs 252 µs 238 µs 231 µs	1/4 1/8 1/16 1/32
DVB-T 8k mode	6817	524	177	68	6048	1 116.071	6817 × 1 116.071 = 7608 259	896	1120 µs 1008 µs 952 µs 924 µs	1/4 1/8 1/16 1/3

5.7 Net Data Rates

The attainable net data rates can simply be calculated from the equation $BR_{Netto} = C_{Nutz} \cdot \mathrm{ld}(M) \cdot P \cdot \frac{188}{204} \cdot \frac{1}{T_{Symbol}}$
The same values are obtained for the DVB-T modes 2 k and 8 k since the relevant parameters are equalling each other by a factor of 4 in the case of carrier spacing and a factor of 1/4 in the case of useful symbol period and guard interval.

Net data rates BR_{net} Mbit/s	Guard interval	Puncturing 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
64 QAM (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

5.8 Non-Hierarchical and Hierarchical Modulation

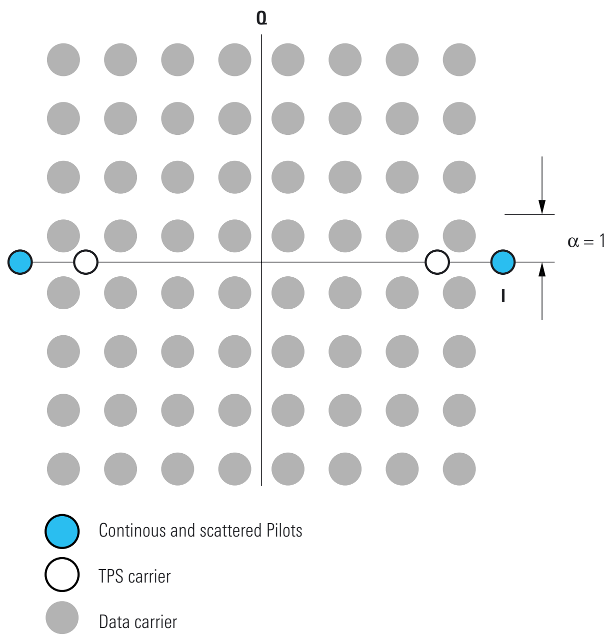


Fig 10: 64 QAM not hierarchical

Fig. 10 shows that with non-hierarchical modulation all center-points of the symbol clusters are equidistant in the constellation diagram of all carriers of a 2k or 8k system.

For hierarchical modulation, the transport streams of MPEG2-coded programs are split up into two data streams: one with high priority and the other with low priority. The two data streams that are independent regarding their contents are hierarchically modulated.

Fig. 11 shows the relevant constellation diagram.

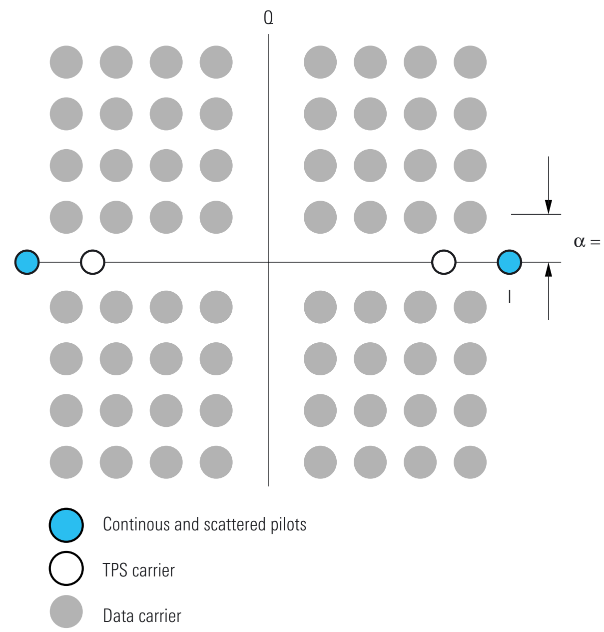


Fig 11: 64 QAM hierarchical

The value $\alpha = 1$, 2 or 4 determines the hierarchical level. $\alpha = 1$ designates non-hierarchical and explizit also hierarchical modulation.

The diagram reveals that with decreasing S/N value the symbol clusters of the 16QAM quadrants rapidly merge to a large symbol cluster. Due to $\alpha = 2$ or even 4, these large symbol clusters however have a noise reserve compared with the 16QAM symbols. The large symbol clusters carry the QPSK-modulated high-priority data stream and can be decoded quasi error-free (QEF) even under adverse receiving conditions. The QPSK component therefore is intended for mobile reception.

The 16QAM symbol clusters of the quadrant carry the low-priority data stream, but imply twice the data rate compared with the high-priority data stream.

5.9 Mapping

In contrast to mapping in DVB-C, DVB-T does not use differential coding to recover the I/Q phase information. With DVB-T, the pilots immediately show the I axis so that differential coding is not necessary.

Satellites received in Europe

The table below provides information on transmitting satellites, whose numbers are continually increasing. The table contains satellites operating in the 12-GHz band as well as those for the C, S and X bands.

Satellite		Band			
Position	Name	Ku	C	S	X
45° W	PAS-1	x	x		
41° W	TDRS 4 (East)		x		
40° W	Intelsat 502	x	x		
37.5° W	Orion 1	x			
34.5° W	Intelsat 603	x	x		
31.5° W	Intelsat 506		x		
30° W	Hispasat 1A/1B	x	x		
27.5° W	Intelsat 601	x	x		
24.5° W	Intelsat 605	x	x		
21.5° W	Intelsat K/515	x	x		
18.8° W	TDF1/TDF2	x			
18° W	Intelsat 515	x	x		
14° W	Eskpress 02	x	x		
11° W	Gorizont 26	x	x		
8° W	Telecom 2A	x	x		
5° W	Telecom 2B	x	x		
1° W	Intelsat 702	x	x		
0.8° W	Thor	x			
0.6° W	TV-Sat	x			
3° E	Telecom 1C	x			
5° E	Sirius/Tele-X	x			
7° E	Eutelsat II F4	x			
10° E	Eutelsat II F2	x			
13° E	Eutelsat II F1/Hot Bird	x			
16° E	Eutelsat II F3	x			
19.2° E	ASTRA 1A,1B,1C,1D,1E	x			
20° E	Arabsat 1DR	x	x		
21.5° E	Eutelsat I F5	x			
23.5° E	DFS Kopernikus 3	x			
25.4° E	Eutelsat I F4	x			
28.5° E	DFS Kopernikus 2	x			
31° E	Arabsat 1C	x		x	
34° E	Gorizont 17	x	x		
35° E	Raduga 28		x		
40° E	Gorizont 22	x	x		
42° E	Turksat 1B	x			
45° E	Raduga 23		x		
47° E	Intelsat 507	x	x		
48° E	Eutelsat I F1	x			
49° E	Raduga C		x		
53° E	Gorizont 27	x	x		
57° E	Intelat 510	x	x		
60° E	Intelsat 604	x	x		
63° E	Intelsat 602	x	x		
64.9° E	Intelsat 505	x	x		
65° E	Raduga 32 C		x		x
66° E	Intelsat 704		x		
68.5° E	PAS-4	x	x		
70° E	Radugar 32		x		
71° E	Gals 1/2		x		
74° E	Insat 2A		x		
78.5° E	Thaicom 1&2	x	x		
80° E	Gorizont 24		x		
82.9° E	Insat 1D		x	x	
85° E	Raduga 30		x		x
85° E	TDRS 3	x	x	x	
87.5° E	Chinasat 1		x		
90° E	Statsionar 6		x		
91.5° E	Intelsat 501		x		
93.5° E	Insat 2B		x		
95° E	Stasionar 14		x		
100.5° E	Asiasat 2		x		
103° E	Statsionar 21		x		
105.5° E	Asiasat 1		x		
108° E	Palapa-B2R		x		
109° E	Yuri 3A/3N/3B	x			
110° E	Dong Fung Hong 25		x		
113° E	Palapa-B2P		x		
116° E	Munghwa		x		
118° E	Palapa B4		x		
128° E 3	JC Sat 3	x	x		
129° E	Palapa B1		x		
130° E	Gorizont 29	x	x		
131° E	Sakura 3A	x			
132° E	N Star A	x	x	x	
136° E	Sakura 3B		x		
138° E	Apstar 1		x		
140° E	Gorizont 18	x	x		
142° E	Gorizont 30	x	x		
145° E	Gorizont 21	x	x		

Table of countries

Systems and standards for monochrome and colour television and AC supply data

The information given in the following table is based on:

- Green Book of CCIR, Volume XI-1, Broadcasting service (television), 1990, Report 624-2, "Characteristics of television systems";
- Green Book of CCIR, Volume X/XI-2, Broadcasting-satellite service (sound and television), 1990, Report 215-7, "Systems for broadcasting-satellite service" (sound and television);
- Electric Current Abroad, list of usual AC supply voltages and frequencies. Issed by: US Department of Commerce, USA 1991;
- Technical documentation issued by telecommunication administrations and television and broadcasting organizations.

Some of these documents have become obsolete, some items of other documents are only expressions of intention. A compromise was aimed at in the compilation of the following table. In the countries of the European Union, the voltage of 220/380 V will be gradually increased to 230/400 V.

Country	Standard for VHF	UHF	Colour	AC supply Nom. voltage V	Freq. Hz
A					
Afghanistan	D		SECAM	220/380	50/60
Albania	B	G	PAL	220/380	50
Algeria	B	G	PAL	127/220 220/380	50
Angola	I		PAL	220/380	50
Argentina	N		PAL	220/380	50
Australia	B	B	PAL	240/415	50
Austria	B	G	PAL	220/380	50
B					
Bahrein	B	G	PAL	230/400	50/60
Bangladesh	B		PAL	220/380	50
Belgium	B	H	PAL	220/380	50
Benin	K1	K1	SECAM	220/380	50
Bermuda	M		NTSC	120/240 120/208	60
Bolivia	M	M	NTSC	220/380 230/400 115/230	50
Botswana	I	I	PAL	231/400	50
Brit. Virgin Islands	M		NTSC	230/400	60
Brazil	M	M	PAL	127/220 220/380	60
Brunei	B		PAL	240/415	50
Bulgaria	D	K	SECAM	220/380	50
Burkina Faso	K1	K1	SECAM	220/380	50
Burma	M		NTSC	230/400	50
Burundi	K1	K1	SECAM	220/380	50
C					
Cameroon	B	G	PAL	127/220 220/380 230/400	50
Canada	M	M	NTSC	120/240	60
Centr. African Rep.	K1	K1	SECAM	220/380	50
Chad	K1	K1	SECAM	220/380	50
Chile	M	M	NTSC	220/380	50
China	D	D	PAL	220/380	50
CIS (formerly USSR)	D	K	SECAM	220/380	50
Colombia	M	M	NTSC	110/220 150/240 120/208	60
Congo	K1	K1	SECAM	220/380	50
Costa Rica	M	M	NTSC	120/240	60
Cuba	M	M	NTSC	115/200	60
Cyprus	B	G	SECAM	240/415	50
Czechoslovakia (successor states)	D	K	SECAM	220/380	50
D					
Denmark, Greenland and the Faroes	B	G	PAL	220/380	50
Djibouti	B		SECAM	220/380	50
Dominican Rep.	M		NTSC	110/220	60
E					
Ecuador	M		NTSC	120/208 127/220	60
Egypt	B	G	SECAM	220/380	50

Country	Standard for			AC supply	
	VHF	UHF	Colour	Nom. voltage V	Freq. Hz
Equatorial Guinea	B		PAL	220	50
Ethiopia	B	G		220/380	50
F					
Finland	B	G	PAL	220/380	50
France	L	L	SECAM	220/380 (115/200 127/220)	50
G					
Gabon	K1	K1	SECAM	220/380	50
Germany, Fed. Rep. of	B	G	PAL	220/380	50
Ghana	B	B	PAL	230/400	50
Gibraltar	B	G	PAL	240/415	50
Great Britain and Northern Ireland		I	PAL	240/415 (240/480)	50
Greece	B	G	SECAM	220/380	50
Guatemala	M		NTSC	120/240	60
Guinea	K1	K1	SECAM PAL	220/380	50
H					
Haiti	M		NTSC	110/220	60
Honduras	M		NTSC	110/220	60
Hong Kong		I	PAL	200/346	50
Hungary	D	K	SECAM	220/380	50
I					
Iceland	B	G	PAL	220/380	50
India	B		PAL	230/400	50
Indonesia	B		PAL	127/220 220/380	50
Iran	B	G	SECAM	220/380	50
Iraq	B	G	SECAM	220/380	50
Ireland	I	I	PAL	220/380	50
Israel	B	G	PAL	230/400	50
Italy	B	G	PAL	127/220 220/380	50
Ivory Coast	K1	K1	SECAM	220/380	50
J					
Jamaica	N		NTSC	110/220	50
Japan	M	M	NTSC	100/200	50/60
Jordan	B	G	PAL	220/380	50
K					
Kenya	B	G	PAL	240/415	50
Korea (North), Dem. Rep.	D	K	PAL	110/220 220/380	60

Country	Standard for			AC supply	
	VHF	UHF	Colour	Nom. voltage V	Freq. Hz
Korea (South), Rep.	M	M	NTSC	110/220 220/380	60
Kuweit	B	G	PAL	240/415	50
L					
Lebanon	B	G	SECAM	110/190 220/380	50
Lesotho	I	I	PAL	220/380	50
Liberia	B	G	PAL	120/208 120/240	60
Libya	B	G	SECAM	127/220 230/400	50
Luxemburg	B	G L	PAL SECAM	220/380	50
M					
Madagascar	K1	K	SECAM	127/220 220/380	50
Malawi	I	I	PAL	230/400	50
Malaysia	B	G	PAL	240/415	50
Maldives	B		PAL	230/400	50
Mali	B	G	SECAM	220/380	50
Malta	B		PAL	240/415	50
Mauretania	B	B	SECAM	220/380	50
Mauritius	B	G	SECAM	230/400	50
Mexico	M	M	NTSC	127/220	60
Monaco	L	G G	SECAM PAL	127/220 220/380	50
Mongolia	D		SECAM	220/380	50
Montserrat	M		NTSC	230/400	60
Morocco	B	G	SECAM	127/220 220/380	50
Mozambique	G	G	PAL	220/380	50
N					
Netherlands	B	G	PAL	220/380	50
Netherlands Antilles	M		NTSC	120/220 127/220 220/380	60 50 50
New Zealand	B	G	PAL	230/400	50
Nicaragua	M		NTSC	120/240	60
Niger	K1	K1	SECAM	220/380	50
Nigeria	B	I	PAL	230/415	50
Norway	B	G	PAL	230	50
O					
Oman	B	G	PAL	240/415	50

Country	Standard for VHF	UHF	Colour	AC supply Nom. voltage V	Freq. Hz
P					
Pakistan	B	G	PAL	220/380	50
Panama	M	M	NTSC	110/220 120/240	60
Papua New Guinea	B	G	PAL	240/415	50
Paraguay	N		PAL	220/380	50
Peru	M	M	NTSC	220/(110)	60
Philippines	M		NTSC	110/220	60
Poland	D	K	SECAM	220/380	50
Portugal	B	G	PAL	220/380	50
Q					
Qatar	B	G	PAL	240/415	50
R					
Romania	D	K	PAL	220/380	50
Rwanda	K1	K1	SECAM	220/380	50
S					
Saudi Arabia	B	G	SECAM	127/220	60
Senegal	K1	K1	SECAM	127/220	50
Sierra Leone	B	G	PAL	230/400	50
Singapore	B	G	PAL	230/400	50
South Africa	I	I	PAL	220/380 230/400 240/415 250/433	50
Spain	B	G	PAL	127/220 220/380	50
Sri Lanka	B		PAL	230/400	50
St. Christ. and Nevis	M		NTSC	230/400	60
Sudan	B	G	PAL	240/415	50
Surinam	M		NTSC	127/220	60
Sweden	B	G	PAL	220/380	50
Switzerland	B	G	PAL	220/380	50
Syria	B	G	PAL	220/380	50
T					
Tanzania	I	I	PAL	230/400	50
Thailand	B	G	PAL	220/380	50
Togo	K1	K1	SECAM	220/380 127/220	50
Tunisia	B	G	PAL SECAM	127/220 220/380	50
Turkey	B	G	PAL	220/380	50
U					
Uganda	B		PAL	240/415	50
United Arab Emirates	B	G	PAL	220/380 230/400 240/415	50
Uruguay	N		PAL	(127)/220	50
USA	M	M	NTSC	120/240 120/208	60
V					
Venezuela	M		NTSC	120/240	60
Vietnam	D	K	PAL	127/220 220/380	50
Y					
Yemen	B		PAL	220/380 230/400	50
Yugoslavia (successor states)	B	G	PAL	220/380	50
Z					
Zaire	K1	K1	SECAM	220/380	50
Zambia	G	G	PAL	220/380	50
Zimbabwe	G	G	PAL	220/380	50

Group delay

Group-delay characteristics in TV systems

The group-delay characteristics of TV systems are determined by various amplitude-frequency responses within the transmission path:

– in cables of extensive length in studios, switching centres and distribution points,
– in radio relay systems,
– in TV transmitters, transposers and domestic receivers.

Group-delay errors of video cables and repeaters are precorrected just once at the studio end of the TV system, using well-known techniques involving small residual errors, whilst correction of the errors in the TV transmitter/TV receiver subsystem requires a greater outlay due to the tighter band limitation of radio transmission and leads to higher costs because of the large number of receivers involved.

The group-delay error of a **TV transmitter** originates in the vestigial-sideband filter (IF-RF), in the video lowpass filter for limitation of the out-of-band radiation (VF) and in the diplexer combining the vision and sound transmitters (RF). One-time correction to a residual error of 25 ns to 50 ns – corresponding to a quarter to a half picture element – is possible in modern TV transmitters at an acceptable expenditure.

The largest group-delay errors within the TV system occur in the domestic receivers because of the high selectivity required (especially with the occupation of adjacent channels in a fully developed cable television network of the future). These errors are caused by

– the Nyquist slope (approx. 180 ns at 0.75 MHz vestigial sideband, approx. 110 ns at 1.25 MHz vestigial sideband),
– the sound-carrier attenuation (400 ns to 800 ns depending on S/N ratio),
– the traps for adjacent vision and sound carriers.

Before the SAW filter was conceived, full group-delay correction would imply a prohibitive increase in the price of every individual receiver. The CCIR Plenary Assembly in Warsaw 1956 therefore issued a recommendation proposing correction by precorrection of the group-delay characteristic in the transmitter so that such type of error is eliminated in the TV receivers.

With the introduction of colour television, a group-delay precorrection of –170 ns between the luminance and chrominance signals was adopted at an international level for the standards M/N and B/G.

As group-delay measurements on TV transmitters are complex and require elaborate procedures, it has been laid down in Technical Specifications for **Nyquist demodulators** that they should be switchable to **two group-delay characteristics**:

– maximally flat for measuring purposes,
– compensatory for precorrection in the transmitter, using the demodulator as a standard reference receiver to simulate the response of domestic receivers to the TV transmitter.

The following tables indicate group-delay characteristics and, if known, their tolerance limits for Nyquist demodulators to different standards.

These specifications do not necessarily agree with those of the available R&S equipment (refer to relevant data sheet).

Standard B/G

Group-delay characteristics of Nyquist demodulators for use as standard reference receivers; (half = half correction; full = full correction).

Standard, Precorrection	**B/G, half general**		**B/G, half Australia**		**B/G, half Denmark**		**B/G, full Norway**		**B/G, full Sweden (A)**		**B/G, half Sweden (B)**	
Frequency (MHz)	Nominal (ns)	Tolerance (ns)	Nominal (ns)	Tolerance (ns)	Nominal (ns)	Tolerance (ns)	Nominal (ns)	Tolerance (ns)	Nominal (ns)	Tolerance (ns)	Nominal (ns)	Tolerance (ns)
0.1	0	Ref.	0	Ref.	0	Ref.	0	Ref.	0	Ref.	0	Ref.
0.25	–5	±12			–5			±15		±40	0	±5
0.5			–7									
1.0	–53	±12	–20		–53						–53	±40
2.0	–90	±12	–56		–75						–90	±40
2.25			–60									
3.0	–75	±12	–40		–75		0	±15				
3.5			0									
3.6							+20	±20	0	±40		
3.75	0	±12			0						0	±40
4.0			+90				+50	±30				
4.43	+170	±25	+170	±25	+170		+170	±15	+170	±20	+170	±40
4.8 (5.0)	+400	±90	+230		+400		+350	±100	(+350)	±80	+400	±90

Standard D/K´

Standard, Precorrection	**D/K**, half OIRT, CIS GOST 20532-75		**D/K**, half CCIR Report 308		**D/K**, half OIRT, TK-III-830 Czechoslovakia		**D/K**, half OIRT, TK-III-830, Hungary	
Frequency (MHz)	Nominal (ns)	Tolerance (ns)	Nominal (ns)	Tolerance (ns)	Nominal (ns)	Tolerance (ns)	Nominal (ns)	Tolerance (ns)
0.1	0	Ref.	0	Ref.	0	Ref.	0	Ref.
0.25	–5	±15	–5	±12		±10		±10
0.5	–10							
1.0	–40		–53		–40		–40	
1.5	–70							
2.0	–80		–87		–75		–75	±10
3.0	–80		–85		–90	±10	–90	±15
4.0	–40		–50		–70	±20	–70	±20
4.43	0	±15	0	±12				
5.0	+80	±50	+90	±30	0	±30	0	±30
5.5							+90	±40
5.8							(+175)	
6.0							(+225)	

Standard, precorrection	**I**, full BBC system without receiver precor-rection		**I**, full SABC, TVT 191.5 demodulator		**I**, full SABC, TVT 12.2 relay receiver	
Frequency (MHz)	Nominal (ns)	Tolerance (ns)	Nominal (ns)	Tolerance (ns)	Nominal (ns)	Tolerance (ns)
0.01	0	Ref.	0	Ref.		
0.1	0	±40	0	±12	0	Ref.
0.2	0	±40	0	±12	0	±12
<3.6	0	±40	0	±12	0	±12
>3.6	0	±20	0	±12	0	±12
4.0	0	±20	0	±12	0	±12
4.43	0	±20	0	±12	+40	±20
4.8	0	±20	0	±50	+100	±30
<5.2	0	±20				
>5.2	0	±80				
5.5	0	±80				

Standard I

In Great Britain no group-delay characteristic for receiver precorrection is specified for standard I and therefore no compensatory characteristic for the Nyquist demodulator. The first column of the table gives the group-delay characteristic of the overall system including the TV transmitter, measured with a demodulator of constant group delay.

Standard, precorrection	**L, full TDF**		**K1, full**		**K´, full Tx. + demodul.**	
Frequency (MHz)	Nominal (ns)	Tolerance (ns)	Nominal (ns)	Tolerance (ns)	Nominal (ns)	Tolerance (ns)
0.1	0	Ref.	0	Ref.		
0.2	0	±15	0	±15	0	Ref.
2	0	±15	0	±15	0	±30
4	0	±15	0	±15	0	
4.43	0	±15	+15	±30	0	±30
4.6	0	±15			0	
4.8	+20	±35			0	
5.0	+57.5	±42.5	+90	±50	0	±30
5.2					0	±50
5.25	+100	±42.5	+140	+∞/–65	0	
5.5	>+100				0	±80

Standards L, K1, K´

Standards K1 and K´ are used in formerly French Territories especially in central Africa. They are based on standard L.

Standard, precorrection	**M, full FCC, EIA 1977**		**M, full CBC 1976**	
Frequency (MHz)	Nominal (ns)	Tolerance (ns)	Nominal (ns)	Tolerance (ns)
0	0	±25	0	±25
0.1	0	Ref.	0	Ref.
>0.1	0	±25	0	±25
1	0	±25		
2	0	±25		
3	0	±25	0	±25
3.58	+170	±25	+170	±15
3.9			+264	±200
4.0	+293	±50		
4.18	+346	±100		

Standard M

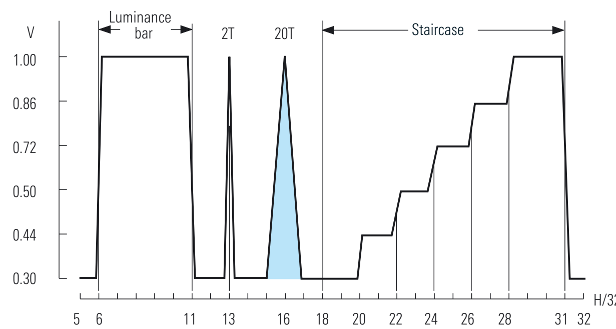
Legend for insertion test signals on right-hand page:
(1) = Figure number

CCIR insertion test signals for lines 17 (1) and 18 (2) (in parentheses: frequencies in the area of the Telekom) of 1st field and lines 330 (3) and 331 (4) (with and without staircase) of 2nd field.

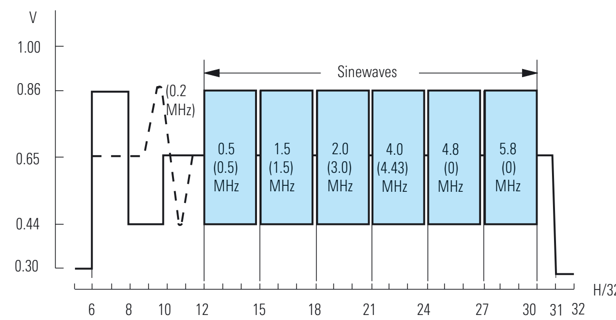
Insertion test signals for standard M for line 17 of 1st field (5) and for line 17 of 2nd field (6) (corresponds to line 280 of frame)

Insertion test signals (for legend see left-hand page)

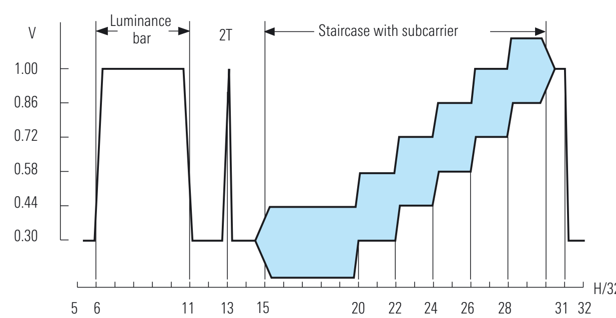
1



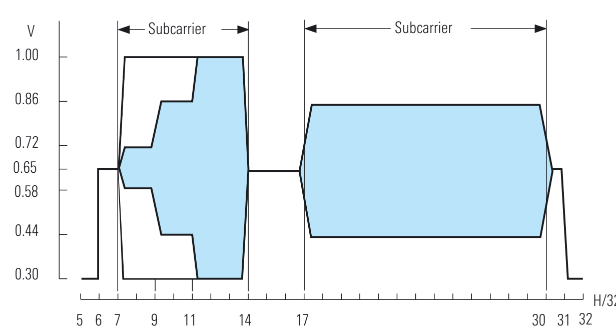
2



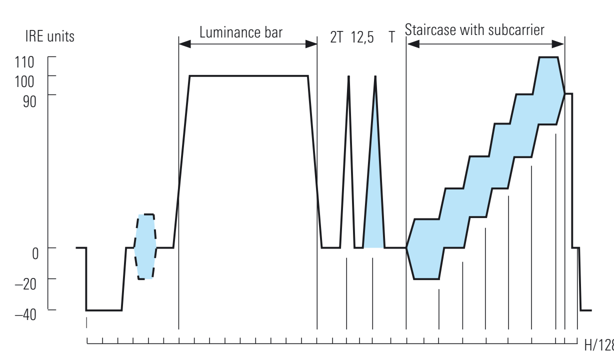
3



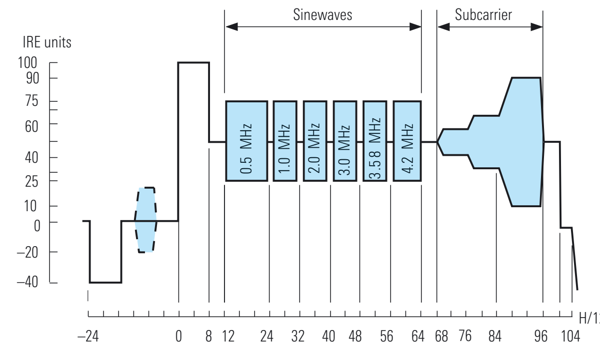
4



5

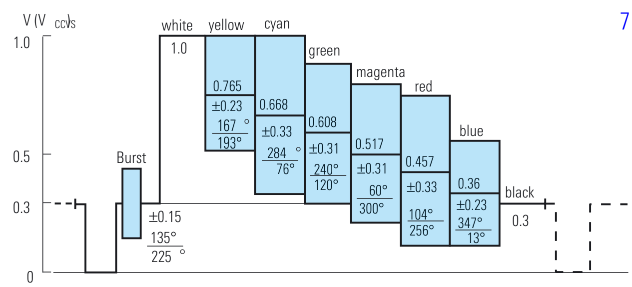


6

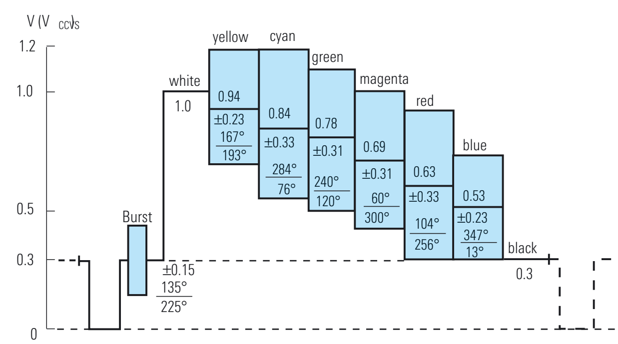


Colour-bar signals

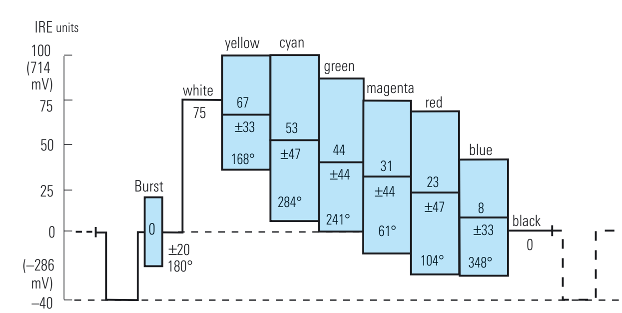
7



8



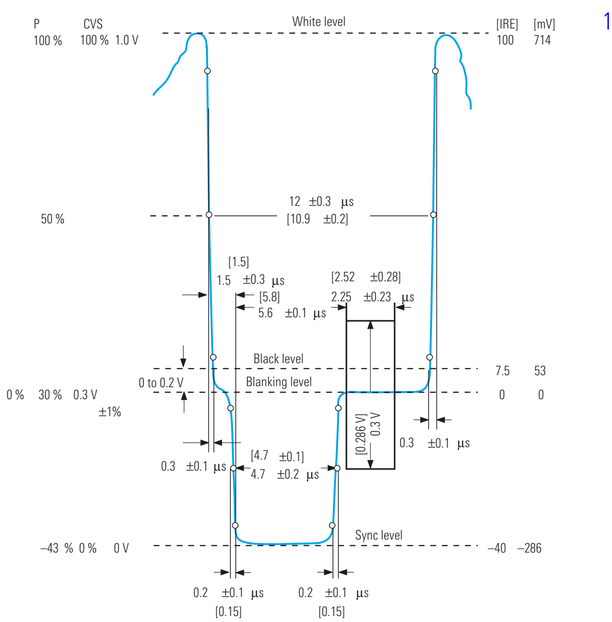
9

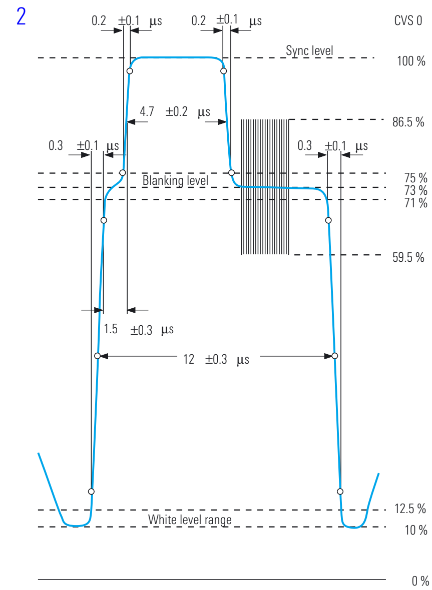


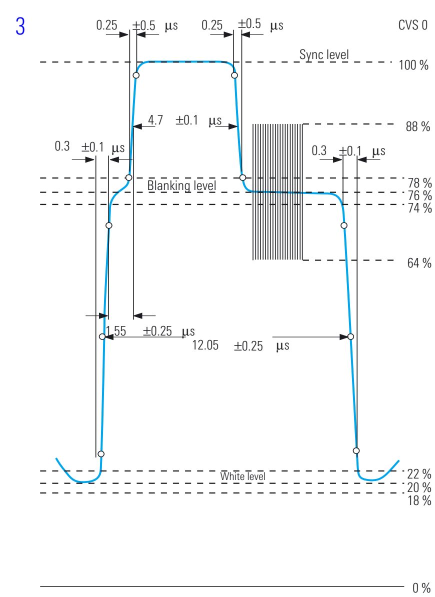
Colour-bar signals

(7) **EBU colour-bar signal:** 100/0/75/0 for standard B/G, PAL
(8) **EBU colour-bar signal:** 100/0/95/0 for standard I, PAL
(9) **FCC/EIA colour-bar signal:** 75/0/100/0 for standard M, NTSC

Level patterns







(1) Video level pattern (standards B, D, G, H, N, I) values in [ ] for standard M

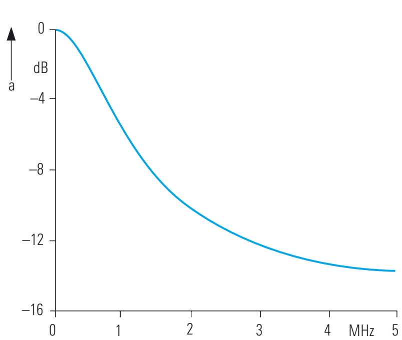
(2) RF level pattern for 10% residual carrier (standards B, D, G, H)

(3) RF level pattern for 20% residual carrier (standard I)

Noise measurement/ weighting filter

Video noise measurement has been largely standardized internationally. Luminance noise is weighted by means of a 200-kHz highpass filter and a standard-independent weighting filter.

Chroma noise results from amplitude (AM) and phase (φM) variations of the chrominance signals in colour TV systems, because NTSC as well as PAL colour decoders are subject to both effects. AM and φM noise exist simultaneously and are equal in magnitude. Since they are measured separately, each measured value must be 3 dB below the overall chroma noise power aimed at.



Characteristic of standard-independent filter (S/N measurement in VSA and UAF) in conformity with CCIR Rec. 567

Test signal	**75%-saturated red signal (PAL 625 lines, CCIR Rec. 471)**
Luminance component	157 mV picture
Chrominance component	664 mV_{pp}
S/N ratio	$V_{noise\ (AM\ +\ \varphi M)\ rms}/V_{chrom\ (peak\text{-}to\text{-}peak)}$ (IEC Publ. 883)
Frequency range	approx. 100 kHz to 500 kHz

Channel definitions

The tables present the definitions of channels for various countries, grouped by standards.

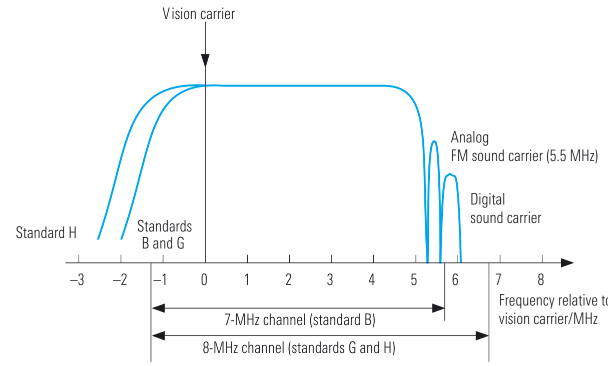
Occupancy of satellite channels see page 197.

(**1** and 2)
Relation of vision and sound carriers with NICAM dual-sound transmission for standards B, G, H, and I.

(3)
Relation of VC, CC, SC1 and SC2 and of VSB and USB for standard G with dual sound.

(4, 5, 6)
Relation of vision, colour and sound carriers (VC, CC, SC) and of vestigial sidebands (VSB) and upper sidebands (USB) within channels of 6, 7 and 8 MHz bandwidth for various standards.

1



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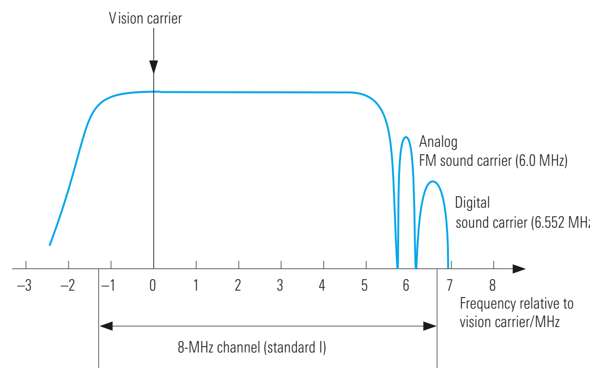
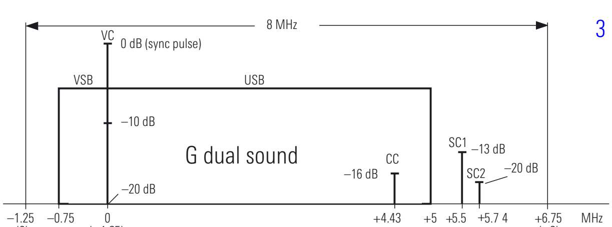
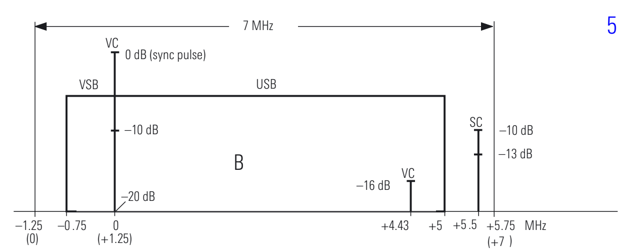


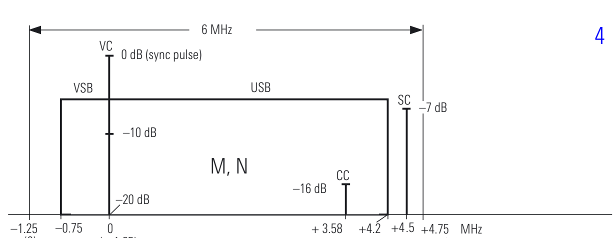
3



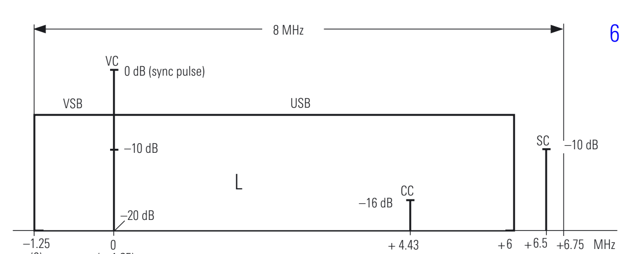
5



4



6



VHF channel definitions

Band	Channel	Channel limits (MHz)	Vision carrier (MHz)	Sound carrier (MHz)
Standard B (7 MHz), Australia				
IF	–	33.15 to 40.15	38.9	33.4
I	0	45 to 52	46.25	51.75
	1	56 to 63	57.25	62.75
	2	63 to 70	64.25	69.75
(II)	3	85 to 92	86.25	91.75
	4	94 to 101	95.25	100.75
	5	101 to 108	102.25	107.75
	5A	137 to 144	138.25	143.25
III	6	174 to 181	175.25	180.75
	7	181 to 188	182.25	187.75
	8	188 to 195	189.25	194.75
	9	195 to 202	196.25	201.75
	10	208 to 215	209.25	214.75
	11	215 to 222	216.25	221.75
Standard B (7 MHz), Europe				
IF	–	33.15 to 40.15	38.9	33.4
I	E 2	47 to 54	48.25	53.75
	E 3	54 to 61	55.25	60.75
	E 4	61 to 68	62.25	67.75
III	E 5	174 to 181	175.25	180.75
	E 6	181 to 188	182.25	187.75
	E 7	188 to 195	189.25	194.75
	E 8	195 to 202	196.25	201.75
	E 9	202 to 209	203.25	208.75
	E 10	209 to 216	210.25	215.75
	E 11	216 to 223	217.25	222.75
	E 12	223 to 230	224.25	229.75
Standard B (7 MHz), Italy				
IF	–	33.15 to 40.15	38.9	33.4
I	A	52.5 to 59.5	53.75	59.25
	B	61 to 68	62.25	67.75
(II)	C	81 to 88	82.25	87.75
(III)	D	174 to 181	175.25	180.75
	E	182.5 to 189.5	183.75	189.25
	F	191 to 198	192.25	197.75
	G	200 to 207	201.25	206.75
	H	209 to 216	210.25	215.75
	H_1	216 to 223	217.25	222.75
	H_2	223 to 230	224.25	229.75

Band	Channel	Channel limits (MHz)	Vision carrier (MHz)	Sound carrier (MHz)
Standard B (7 MHz), Europe Special cable TV channels (CATV)				
IF	–	33.15 to 40.15	38.9	33.4
<III (S_u)= L[1)]	S 2	113 to 123	Digital Audio Broadcasting	
	S 3			
	S 4	125 to 132	126.25	131.75
	S 5	132 to 139	133.25	138.75
	S 6	139 to 146	140.25	145.75
	S 7	146 to 153	147.25	152.75
	S 8	153 to 160	154.25	159.75
	S 9	160 to 167	161.25	166.75
	S 10	167 to 174	168.25	173.75
>III (S_o)= U[1)]	S 11	230 to 237	231.25	236.75
	S 12	237 to 244	238.25	243.75
	S 13	244 to 251	245.25	250.75
	S 14	251 to 258	252.25	257.75
	S 15	258 to 265	259.25	264.75
	S 16	265 to 272	266.25	271.75
	S 17	272 to 279	273.25	278.75
	S 18	279 to 286	280.25	285.75
	S 19	286 to 293	287.25	292.75
	S 20	293 to 300	294.25	299.75
Standard B (7 MHz), Morocco				
IF	–	33.15 to 40.15	38.9	33.4
III	M 4	162 to 169	163.25	168.75
	M 5	170 to 177	171.25	176.75
	M 6	178 to 185	179.25	184.75
	M 7	186 to 193	187.25	192.75
	M 8	194 to 201	195.25	200.75
	M 9	202 to 209	203.25	208.75
	M 10	210 to 217	211.25	216.75

Band	Channel	Channel limits (MHz)	Vision carrier (MHz)	Sound carrier (MHz)
Standard B (7 MHz), New Zealand				
IF	–	33.15 to 40.15	38.9	33.4
I	1	44 to 51	45.25	50.75
	2	54 to 61	55.25	60.75
	3	61 to 68	62.25	67.75
III	4	174 to 181	175.25	180.75
	5	181 to 188	182.25	187.75
	6	188 to 195	189.25	194.75
	7	195 to 202	196.25	201.75
	8	202 to 209	203.25	208.75
	9	209 to 216	210.25	215.75
	10	216 to 223	217.25	222.75
Standard D (8 MHz), China (People´s Rep.)				
IF	–	31.25 to 39.25	38.0	31.5
I	1	48.5 to 56.5	49.75	56.25
	2	56.5 to 64.5	57.75	64.25
	3	64.5 to 72.5	65.75	72.25
	4	76.0 to 84.0	77.25	83.75
	5	84.0 to 92.0	85.25	91.75
III	6	167 to 175	168.25	174.75
	7	175 to 183	176.25	182.75
	8	183 to 191	184.25	190.75
	9	191 to 199	192.25	198.75
	10	199 to 207	200.25	206.75
	11	207 to 215	208.25	214.75
	12	215 to 223	216.25	222.75
Standard D (8 MHz), OIRT				
IF[2)]	–	32.15 to 40.15	38.9	32.4
I	R I	48.5 to 56.5	49.75	56.25
	R II	58 to 66	59.25	65.75
	R III	76 to 84	77.25	83.75
(II)	R IV	84 to 92	85.25	91.75
	R V	92 to 100	93.25	99.75
III	R VI	174 to 182	175.25	181.75
	R VII	182 to 190	183.25	189.75
	R VIII	190 to 198	191.25	197.75
	R IX	198 to 206	199.25	205.75
	R X	206 to 214	207.25	213.75
	R XI	214 to 222	215.25	221.75
	R XII	222 to 230	223.25	229.75

Band	Channel	Channel limits (MHz)	Vision carrier (MHz)	Sound carrier (MHz)
Standard I (8 MHz), Ireland				
IF	–	32.15 to 40.15	38.9[3]	32.9[3]
I	I A	44.5 to 52.5	45.75	51.75
	I B	52.5 to 60.5	53.75	59.75
	I C	60.5 to 68.5	61.75	67.75
III	I D	174 to 182	175.25	181.25
	I E	182 to 190	183.25	189.25
	I F	190 to 198	191.25	197.75
	I G	198 to 206	199.25	205.25
	I H	206 to 214	207.25	213.25
	I J	214 to 222	215.25	221.25
Standard I (8 MHz), South Africa				
IF	–	32.15 to 40.15	38.9	32.9
III	4	174 to 182	175.25	181.25
	5	182 to 190	183.25	189.25
	6	190 to 198	191.25	197.25
	7	198 to 206	199.25	205.25
	8	206 to 214	207.25	213.25
	9	214 to 222	215.25	221.25
	10	222 to 230	223.25	229.25
	11	230 to 238	231.25	237.25
	(12)	238 to 246	not allocated	
	13	246 to 254	247.43	253.43

Band	Channel	Channel limits (MHz)	Vision carrier (MHz)	Sound carrier (MHz)
Standard K1 (8 MHz), French Overseas Post and Telecomm. Agency				
IF	–	31.45 to 39.45	39.2[4]	32.7
III	4	174 to 182	175.25	181.75
	5	182 to 190	183.25	189.75
	6	190 to 198	191.25	197.75
	7	198 to 206	199.25	205.75
	8	206 to 214	207.25	213.75
	9	214 to 222	215.25	221.75
Standard L (8 MHz), France				
IF	–	31.45 to 39.45	39.2[4]	32.7
I	A	41 to 49	47.75	41.25
	B	49 to 57	55.75	49.25
	C	57 to 65	63.75	57.25
	C 1	53.75 to 61.75	60.50	54.00
III	1	174.75 to 182.75	176.0	182.50
	2	182.75 to 190.75	184.0	190.50
	3	190.75 to 198.75	192.0	198.50
	4	198.75 to 206.75	200.0	206.50
	5	206.75 to 214.75	208.0	214.50
	6	214.75 to 222.75	216.0	222.50
Standard M (6 MHz), Japan				
IF	–	41.0 to 47.0	45.75	41.25
(II)	J 1	90 to 96	91.25	95.75
	J 2	96 to 102	97.25	101.75
	J 3	102 to 108	103.25	107.75
III	J 4	170 to 176	171.25	175.75
	J 5	176 to 182	177.75	181.75

Band	Channel	Channel limits (MHz)	Vision carrier (MHz)	Sound carrier (MHz)
	J 6	182 to 188	183.25	187.75
	J 7[5]	188 to 194	189.25	193.75
	J 8[5]	192 to 198	193.25	197.75
	J 9	198 to 204	199.25	203.75
	J 10	204 to 210	205.25	209.75
	J 11	210 to 216	211.25	215.75
	J 12	216 to 222	217.25	221.75
Standards M, N (6 MHz), USA				
IF	–	41.0 to 47.0	45.75	41.25
I	A 02	54 to 60	55.25	59.75
	A 03	60 to 66	61.25	65.75
	A 04	66 to 72	67.25	71.75
	A 05	76 to 82	77.25	81.75
	A 06	82 to 88	83.25	87.75
III	A 07	174 to 180	175.25	179.75
	A 08	180 to 186	181.25	185.75
	A 09	186 to 192	187.25	191.75
	A 10	192 to 198	193.25	197.75
	A 11	198 to 204	199.25	203.75
	A 12	204 to 210	205.25	209.75
	A 13	210 to 216	211.25	215.75

1) L = lower, U = upper channels

2) CIS: 31.25 to 39.25/38.0/31.5 MHz.

3) Gr. Brit. also 39.5 and 33.5 MHz resp.

4) Also 32.7 or 38.9 MHz.

5) Channel spacing 4 MHz.

UHF channel definitions

Band	Channel	Europe-China	Channel limits (MHz)	Vision carrier (MHz)	Sound carrier (MHz) G	HIK	L
Standards G, H, I, K, L (CCIR standard, 8 MHz)							
IF	–		same as VHF for corresponding country				
IV	21	13	470 to 478	471.25	476.75	477.25	477.75
	22	14	478 to 486	479.25	484.75	485.25	485.75
	23	15	486 to 494	487.25	492.75	493.25	493.75
	24	16	494 to 502	495.25	500.75	501.25	501.75
	25	17	502 to 510	503.25	508.75	509.25	509.75
	26	18	510 to 518	511.25	516.75	517.25	517.75
	27	19	518 to 526	519.25	524.75	525.25	525.75
	28	20	526 to 534	527.25	532.75	533.25	533.75
	29	21	534 to 542	535.25	540.75	541.25	541.75
	30	22	542 to 550	543.25	548.75	549.25	549.75

Band	Channel	Europe-China	Channel limits (MHz)	Vision carrier (MHz)	Sound carrier (MHz) G	HIK	L
	31	23	550 to 558	551.25	556.75	557.25	557.75
	32	24	558 to 566	559.25	564.75	565.25	565.75
	33	not allocated	566 to 574	567.25	572.75	573.25	573.75
	34	not allocated	574 to 582	575.25	580.75	581.25	581.75
	35	not allocated	582 to 590	583.25	588.75	589.25	589.75
	36	not allocated	590 to 598	591.25	596.75	597.25	597.75
	37	not allocated	598 to 606	599.25	604.75	605.25	605.75
V	38	25	606 to 614	607.25	612.75	613.25	613.75
	39	26	614 to 622	615.25	620.75	621.25	621.75
	40	27	622 to 630	623.25	628.75	629.25	629.75
	41	28	630 to 638	631.25	636.75	637.25	637.75
	42	29	638 to 646	639.25	644.75	645.25	645.75
	43	30	646 to 654	647.25	652.75	653.25	653.75
	44	31	654 to 662	655.25	660.75	661.25	661.75

Band	Channel Europe	Channel China	Channel limits (MHz)	Vision carrier (MHz)	Sound carrier (MHz) G	H, I, K	L
	45	32	622 to 670	663.25	668.75	669.25	669.75
	46	33	670 to 678	671.25	676.75	677.25	677.75
	47	34	678 to 686	679.25	684.75	685.25	685.75
	48	35	686 to 694	687.25	692.75	693.25	693.75
	49	36	694 to 702	695.25	700.75	701.25	701.75
	50	37	702 to 710	703.25	708.75	709.25	709.75
	51	38	710 to 718	711.25	716.75	717.25	717.75
	52	39	718 to 726	719.25	724.75	725.25	725.75
	53	40	726 to 734	727.25	732.75	733.25	733.75
	54	41	734 to 742	735.25	740.75	741.25	741.75
	55	42	742 to 750	743.25	748.75	749.25	749.75
	56	43	750 to 758	751.25	756.75	757.25	757.75
	57	44	758 to 766	759.25	764.75	765.25	765.75
	58	45	766 to 774	767.25	772.75	773.25	773.75
	59	46	774 to 782	775.25	780.75	781.25	781.75
	60	47	782 to 790	783.25	788.75	789.25	789.75
	61	48	790 to 798	791.25	796.75	797.25	797.75
	other channels with 8-MHz spacing						
	68	55	846 to 854	847.25	852.75	853.25	853.75
	69	56	845 to 862	855.25	860.75	861.25	861.75
	not allocated	57	862 to 870	863.25			869.75
		58	870 to 878	871.25			877.75
		59	878 to 886	879.25			885.75
		60	886 to 894	887.25			893.75
		61	894 to 902	895.25			901.75
		62	902 to 910	903.25			909.75

Band	Channel USA Japan	Channel Canada	Channel limits (MHz)	Vision carrier (MHz)	Sound carrier (MHz)
Standards M, N (6 MHz), USA; Standard M (6 MHz), Japan					
IF	–		same as VHF for corresponding country		
IV	14	13	470 to 476	471.25	475.75
	15	14	476 to 482	477.25	481.75
	other channels with 6-MHz spacing				
	41	40	632 to 638	633.25	637.75
	42	41	638 to 644	639.25	643.75
V	43	42	644 to 650	645.25	649.75
	44	43	650 to 656	651.25	655.75
	45	44	656 to 662	657.25	661.75

Band	Channel USA Japan	Channel Canada	Channel limits (MHz)	Vision carrier (MHz)	Sound carrier (MHz)
	46	45	662 to 668	663.25	667.75
	47	46	668 to 674	669.25	673.75
	48	47	674 to 680	675.25	679.75
	49	48	680 to 686	681.25	685.75
	50	49	686 to 692	687.25	691.75
	51	50	692 to 698	693.25	697.75
	52	51	698 to 704	699.25	703.75
	53	52	704 to 710	705.25	709.75
	54	53	710 to 716	711.25	715.75
	55	54	716 to 722	717.25	721.75
	56	55	722 to 728	723.25	727.75
	57	56	728 to 734	729.25	733.75
	58	57	734 to 740	735.25	739.75
	59	58	740 to 746	741.25	745.75
	60	59	746 to 752	747.25	751.75
	61	60	752 to 758	753.25	757.75
	62	61	758 to 764	759.25	763.75
	63	62	764 to 770	765.25	769.75
	64	not allocated	770 to 776	771.25	775.75
			other channels with 6-MHz spacing		
	82		878 to 884	879.25	883.75
	83		884 to 890	885.25	889.75
Standard B (7 MHz), Australia					
IF	–		33.15 to 40.15	38.9	33.4
IV	28		526 to 533	527.25	532.75
	29		533 to 540	534.25	539.75
	30		540 to 547	541.25	546.75
	31		547 to 554	548.25	553.75
	32		554 to 561	555.25	560.75
	33		561 to 568	562.25	567.75
	34		568 to 575	569.25	574.75
	35		575 to 582	576.25	581.75
V	36		582 to 589	583.25	588.75
	37		589 to 596	590.25	595.75
	38		596 to 603	597.25	602.75
			other channels with 7-MHz spacing		
	67		799 to 806	800.25	805.75
	68		806 to 813	807.25	812.75
	69		813 to 820	814.25	819.75