

Table of Contents

1	Introduction.....	1
2	Analog Television.....	7
2.1	Scanning an Original Black/White Picture	10
2.2	Horizontal and Vertical Synchronization Pulses	12
2.3	Adding the Color Information	14
2.4	Transmission Methods.....	17
2.5	Distortion and Interference	18
2.6	Signals in the Vertical Blanking Interval.....	20
2.7	Measurements on Analog Video Signals.....	24
2.8	Analog and Digital TV in a Broadband Cable Network.....	29
3	The MPEG Data Stream	31
3.1	The Packetized Elementary Stream (PES).....	35
3.2	The MPEG-2 Transport Stream Packet	38
3.3	Information for the Receiver.....	42
3.3.1	Synchronizing to the Transport Stream.....	43
3.3.2	Reading out the Current Program Structure	44
3.3.3	Accessing a Program	46
3.3.4	Accessing Scrambled Programs	46
3.3.5	Program Synchronization (PCR, DTS, PTS).....	48
3.3.6	Additional Information in the Transport Stream	51
3.3.7	Non-Private and Private Sections and Tables.....	52
3.3.8	The Service Information according to DVB (SI).....	60
3.4	The PSIP according to the ATSC	73
3.5	ARIB Tables according to ISDB-T	76
3.6	DTMB (China) Tables	78
3.7	Other Important Details of the MPEG-2 Transport Stream.....	78
3.7.1	The Transport Priority	78
3.7.2	The Transport Scrambling Control Bits	79
3.7.3	The Adaptation Field Control Bits	79
3.7.4	The Continuity Counter	80

4 Digital Video Signal According to ITU-BT.R.601 (CCIR 601).....	81
5 High Definition Television – HDTV	87
6 Transforms to and from the Frequency Domain	93
6.1 The Fourier Transform	95
6.2 The Discrete Fourier Transform (DFT).....	97
6.3 The Fast Fourier Transform (FFT)	99
6.4 Implementation and Practical Applications of DFT and FFT.....	101
6.5 The Discrete Cosine Transform (DCT)	101
6.6 Time Domain Signals and their Transforms in the Frequency Domain	105
6.7 Systematic Errors in DFT or FFT, and How to Prevent them	107
6.8 Window Functions.....	110
7 MPEG-2 Video Coding.....	111
7.1 Video Compression	111
7.1.1 Reducing the Quantization from 10 Bits to 8	115
7.1.2 Omitting the Horizontal and Vertical Blanking Intervals.....	115
7.1.3 Reduction in Vertical Color Resolution (4:2:0).....	116
7.1.4 Further Data Reduction Steps.....	117
7.1.5 Differential Pulse Code Modulation of Moving Pictures	118
7.1.6 Discrete Cosine Transform Followed by Quantization	123
7.1.7 Zig-Zag Scanning with Run-Length Coding of Zero Sequences	131
7.1.8 Huffman Coding	131
7.2 Summary	132
7.3 Structure of the Video Elementary Stream	136
7.4 More Recent Video Compression Methods.....	137
7.5 MPEG-4 Advanced Video Coding	138
8 Compression of Audio Signals to MPEG and Dolby Digital.....	147
8.1 Digital Audio Source Signal	147
8.2 History of Audio Coding	148
8.3 Psychoacoustic Model of the Human Ear.....	151
8.4 Basic Principles of Audio Coding	155
8.5 Subband Coding in Accordance with MPEG Layer I, II	157
8.6 Transform Coding for MPEG Layer III and Dolby Digital.....	159
8.7 Multichannel Sound.....	161
8.8 New Developments - MPEG-4	162
9 Teletext, Subtitles and VPS for DVB	165

9.1 Teletext and Subtitles	165
9.2 Video Program System	169
9.3 WSS – Wide Screen Signalling	171
9.4 Practical examples	173
10 A Comparison of Digital Video Standards	175
10.1 MPEG-1 and MPEG-2, VCD and DVD, M-JPEG and MiniDV/DV	175
10.2 MPEG-3, MPEG-4, MPEG-7 and MPEG-21	178
10.3 Physical Interfaces for Digital Video Signals	182
10.3.1 Parallel and Serial CCIR 601	182
10.3.2 Synchronous Parallel Transport Stream Interface	184
10.3.3 Asynchronous Serial Transport Stream Interface (TS ASI)	185
10.3.4 SMPTE 310 Interface	186
10.3.5 DVI Interface	186
10.3.6 HDMI Interface	187
10.3.7 HD-SDI Interface	188
10.3.8 Gigabit Ethernet Interface as Transport Stream Distributor	188
11 Measurements on the MPEG-2 Transport Stream.....	189
11.1 Loss of Synchronisation (TS_sync_loss).....	191
11.2 Errored Sync Bytes (sync_byte_error)	192
11.3 Missing or Errored Program Association Table (PAT)	192
11.4 Missing or Errored Program Map Table (PMT) (PMT_error)	193
11.5 The PID_Error	194
11.6 The Continuity_Count_Error	195
11.7 The Transport_Error (Priority 2)	196
11.8 The Cyclic Redundancy Check Error	197
11.9 The Program Clock Reference Error	197
11.10 The Presentation Time Stamp Error (PTS_Error)	199
11.11 The Conditional Access Table Error (CAT_Error)	200
11.12 Service Information Repetition Rate Error	201
11.13 Monitoring the NIT, SDT, EIT, RST and TDT/TOT Tables....	202
11.14 Undefined PIDs (Unreferenced_PID).....	202
11.15 Errors in the Transmission of Additional Service Information	203
11.16 Faulty tables NIT_other_error, SDT_other_error, EIT_other_error	204
11.17 Monitoring an ATSC-Compliant MPEG-2 Transport Stream..	204
12 Picture Quality Analysis of Digital TV Signals	207
12.1 Methods for Measuring Video Quality	209
12.1.1 Subjective Picture Quality Analysis	210

12.1.2 Double Stimulus Continual Quality Scale Method DSCQS	211
12.1.3 Single Stimulus Continual Quality Evaluation Method SSCQE.....	211
12.2 Objective Picture Quality Analysis.....	211
12.3 Summary and Outlook.....	217
13 Basic Principles of Digital Modulation	219
13.1 Introduction.....	219
13.2 Mixer.....	221
13.3 Amplitude Modulator	223
13.4 IQ Modulator	225
13.5 The IQ Demodulator.....	233
13.6 Use of the Hilbert transform in IQ modulation.....	238
13.7 Practical Applications of the Hilbert Transform.....	240
13.8 Channel Coding/Forward Error Correction	242
13.9 A Comparison to Analog Modulation Methods.....	246
13.9.1 Amplitude Modulation	247
13.9.2 Variants of Amplitude Modulation.....	251
13.9.3 Frequency Modulation.....	252
13.9.4 Phase Modulation	255
13.10 Band Limiting of Modulated Carrier Signals	256
13.11 Summary	259
14 Transmitting Digital Television Signals by Satellite - DVB-S/S2 .	261
14.1 The DVB-S System Parameters.....	264
14.2 The DVB-S Modulator	266
14.3 Convolutional Coding.....	272
14.4 Signal Processing in the Satellite.....	277
14.5 The DVB-S Receiver	278
14.6 Influences Affecting the Satellite Transmission Link	281
14.7 DVB-S2	285
15 DVB-S/S2 Measuring Technology	293
15.1 Introduction.....	293
15.2 Measuring Bit Error Ratios.....	293
15.3 Measurements on DVB-S Signals using a Spectrum Analyzer ..	296
15.3.1 Approximate Determination of the Noise Power N.....	298
15.3.2 C/N, S/N and Eb/N ₀	299
15.3.3 Finding the E _b /N ₀ Ratio	300
15.4 Modulation Error Ratio (MER)	301
15.5 Measuring the Shoulder Attenuation	302
15.6 DVB-S/S2 Receiver Test	303

16 Broadband Cable Transmission According to DVB-C	305
16.1 The DVB-C Standard	306
16.2 The DVB-C Modulator	308
16.3 The DVB-C Receiver	309
16.4 Interference Effects on the DVB-C Transmission Link	310
17 Broadband Cable Transmission According to ITU-T J83B (US) 315	
17.1 J83B Transmission Parameters	317
17.2 J83B Baseband Input Signals	318
17.3 Forward Error Correction	318
17.4 Calculation of the Net Data Rate	320
17.5 Roll-off Filtering	321
17.6 Fall-off-the-Cliff	321
18 Measuring Digital TV Signals in the Broadband Cable.....	325
18.1 DVB-C/J83A, B, C Test Receivers with Constellation Analysis	326
18.2 Detecting Interference Effects Using Constellation Analysis....	330
18.2.1 Additive White Gaussian Noise (AWGN).....	330
18.2.2 Phase Jitter	333
18.2.3 Sinusoidal Interferer	334
18.2.4 Effects of the I/Q Modulator.....	334
18.2.5 Modulation Error Ratio (MER)	337
18.2.6 Error Vector Magnitude (EVM)	339
18.3 Measuring the Bit Error Ratio (BER)	339
18.4 Using a Spectrum Analyzer for Measuring DVB-C Signals	340
18.5 Measuring the Shoulder Attenuation	342
18.6 Measuring the Ripple or Tilt in the Channel	343
18.7 DVB-C/J83A,B,C Receiver Test	343
19 Coded Orthogonal Frequency Division Multiplex (COFDM)	345
19.1 Why Multi-Carrier?	347
19.2 What is COFDM?	350
19.3 Generating the COFDM Symbols.....	354
19.4 Supplementary Signals in the COFDM Spectrum	364
19.5 Hierarchical Modulation	366
19.6 Summary	367
20 Terrestrial Transmission of Digital Television Signals (DVB-T) 369	
20.1 The DVB-T Standard	371
20.2 The DVB-T Carriers	373
20.3 Hierarchical Modulation	379

20.4 DVB-T System Parameters of the 8/7/6 MHz Channel.....	381
20.5 The DVB-T Modulator and Transmitter.....	390
20.6 The DVB-T Receiver.....	393
20.7 Interference on the DVB-T Transmission Link and its Effects ..	398
20.8 DVB-T Single-Frequency Networks (SFN)	406
20.9 Minimum Receiver Input Level Required with DVB-T	414
21 Measuring DVB-T Signals	421
21.1 Measuring the Bit Error Ratio	423
21.2 Measuring DVB-T Signals Using a Spectrum Analyzer	425
21.3 Constellation Analysis of DVB-T Signals.....	429
21.3.1 Additive White Gaussian Noise (AWGN).....	430
21.3.2 Phase Jitter.....	430
21.3.3 Interference Sources	430
21.3.4 Echoes, Multipath Reception.....	431
21.3.5 Doppler Effect	431
21.3.6 I/Q Errors of the Modulator.....	431
21.3.7 Cause and Effect of I/Q Errors in DVB-T	435
21.4 Measuring the Crest Factor.....	444
21.5 Measuring the Amplitude, Phase and Group Delay Response ...	444
21.6 Measuring the Impulse Response	445
21.7 Measuring the Shoulder Attenuation	446
22 DVB-H/DVB-SH - Digital Video Broadcasting for Handhelds	451
22.1 Introduction.....	451
22.2 Convergence between Mobile Radio and Broadcasting	453
22.3 Essential Parameters of DVB-H	454
22.4 DSM-CC Sections	455
22.5 Multiprotocol Encapsulation.....	457
22.6 DVB-H Standard	458
22.7 Summary	462
22.8 DVB-SH	464
23 Digital Terrestrial TV to North American ATSC Standard.....	467
23.1 The 8VSB Modulator	472
23.2 8VSB Gross Data Rate and Net Data Rate	480
23.3 The ATSC Receiver.....	482
23.4 Causes of Interference on the ATSC Transmission Path.....	482
23.5 ATSC-M/H Mobile DTV.....	483
23.5.1 Compatibility with the Existing Frame Structure.....	483
23.5.2 MPEG-4 Video and Audio Streaming.....	485
23.5.3 ATSC M/H Multiplexer.....	487

23.5.4 ATSC M/H Modulator.....	490
23.5.5 Forming Single Frequency Networks	490
23.5.6 Summary.....	491
23.6 Closed Captioning	492
23.7 Analog Switch-off	493
24 ATSC/8VSB Measurements.....	495
24.1 Bit Error Ratio (BER) Measurement	495
24.2 8VSB Measurements Using a Spectrum Analyzer	496
24.3 Constellation Analysis on 8VSB Signals.....	497
24.4 Measuring Amplitude Response and Group Delay Response	500
25 Digital Terrestrial Television according to ISDB-T.....	503
25.1 Introduction.....	503
25.2 ISDB-T Concept	504
25.1 Forming Layers.....	506
25.2 Baseband Encoding	507
25.3 Changes in the Transport Stream Structure	507
25.4 Channel Tables	509
25.5 Performance of ISDB-T	510
25.6 Other ISDB Standards	511
25.7 ISDB-T measurements.....	512
25.8 Summary.....	513
26 Digital Audio Broadcasting - DAB	515
26.1 Comparing DAB and DVB.....	517
26.2 An Overview of DAB	520
26.3 The Physical Layer of DAB.....	525
26.4 DAB – Forward Error Correction	537
26.5 DAB Modulator and Transmitter.....	542
26.6 DAB Data Structure.....	546
26.7 DAB Single-Frequency Networks	551
26.8 DAB Data Broadcasting	553
26.9 DAB+.....	554
26.10 DAB Measuring Technology	554
26.10.1 Testing DAB Receivers	555
26.10.2 Measuring the DAB Signal.....	555
27 DVB Data Services: MHP and SSU	559
27.1 Data Broadcasting in DVB	560
27.2 Object Carousels.....	561
27.3 The Multimedia Home Platform MHP	563

27.4 System Software Update SSU	565
28 T-DMB	567
29 IPTV – Television over the Internet.....	569
29.1 DVB-IP	571
29.2 IP Interface Replaces TS-ASI.....	572
29.3 Summary	573
30 DRM – Digital Radio Mondiale	575
30.1 Audio source encoding	579
30.2 Forward Error Correction	579
30.3 Modulation Method	580
30.4 Frame structure	581
30.5 Interference on the transmission link.....	582
30.6 DRM data rates	583
30.7 DRM transmitting stations and DRM receivers.....	584
30.8 DRM+	585
31 Digital Terrestrial TV Networks in Practice.....	587
31.1 The DVB-T SFNs Southern and Eastern Bavaria.....	587
31.2 Playout Center and Feed Networks	590
31.3 Technical Configuration of the Transmitter Sites.....	591
31.3.1 Mount Wendelstein Transmitter	592
31.3.2 Olympic Tower Transmitter, Munich.....	606
31.3.3 Brotjacklriegel Transmitter.....	609
31.4 Measurements in DVB-T Single-Frequency Networks	612
31.4.1 Test Parameters.....	612
31.4.2 Practical Examples	620
31.4.3 Response of DVB-T Receivers.....	627
31.4.4 Receiver Test and Simulation of Receiving Conditions in Single-Frequency Networks	628
31.5 Network Planning	632
31.6 Filling the Gaps in the Coverage	632
31.7 Fall-off-the-Cliff	635
31.8 Summary	636
32 DTMB	637
32.1 DMB-T, or now DTMB	637
32.2 Some more Details.....	638
33 Return Channel Techniques	641

34 Display Technologies	643
34.1 Previous Converter Systems - the Nipkow Disk.....	645
34.2 The Cathode Ray Tube (CRT).....	647
34.3 The Plasma Screen.....	651
34.4 The Liquid Crystal Display Screen.....	652
34.5 Digital Light Processing Systems.....	654
34.6 Organic Light-Emitting Diodes	654
34.7 Effects on Image Reproduction	654
34.8 Compensation Methods	657
34.9 Test Methods	657
34.10 Current State of the Technology	658
35 The New Generation of DVB Standards.....	661
35.1 Overview of the DVB Standards	662
35.2 Characteristics of the Old and the New Standards.....	663
35.3 Capabilities and Aims of the New DVB Standards	664
36 Baseband Signals for DVB-x2.....	667
36.1 Input Signal Formats.....	667
36.1.1 MPEG-2 Transport Streams - TS	668
36.1.2 Generic Fixed Packetized Streams - GFPS	669
36.1.3 Generic Continuous Streams - GCS	669
36.1.4 Generic Encapsulated Streams - GSE.....	670
36.2 Signal Processing and Conditioning in the Modulator Input Section	670
36.2.1 Single Input Stream	671
36.2.2 Multiple Input Streams	674
36.3 Standard-related Special Features.....	677
36.3.1 DVB-S2	677
36.3.2 DVB-T2	678
36.3.3 DVB-C2	684
37 DVB-T2	687
37.1 Introduction.....	687
37.2 Theoretical Maximum Channel Capacity	688
37.3 DVB-T2 - Overview	690
37.4 Baseband Interface.....	690
37.5 Forward Error Correction	691
37.6 COFDM Parameters	695
37.6.1 Normal Carrier Mode	697
37.6.2 Extended Carrier Mode.....	699
37.7 Modulation Patterns.....	700

37.7.1 Normal Constellation Diagrams	701
37.7.2 Definition of 'Cell'	701
37.7.3 Rotated Q-delayed Constellation Diagrams	702
37.8 Frame Structure	704
37.8.1 P1 Symbol.....	706
37.8.2 P2 Symbols	707
37.8.3 Symbol, Frame, Superframe	709
37.9 Block Diagram.....	709
37.10 Interleavers	710
37.10.1 Types of Interleaver.....	711
37.10.2 DVB-T2 Time Interleaver Configuration.....	712
37.11 Pilots	715
37.12 Sub-Slicing	717
37.13 Time-Frequency-Slicing (TFS).....	718
37.14 PAPR Reduction.....	719
37.15 SISO/MISO Multi-Antenna Systems.....	720
37.15.1 MISO according to Alamouti	721
37.15.2 Modified Alamouti in DVB-T2	722
37.16 Future Extension Frames	726
37.17 Auxiliary Data Streams.....	726
37.18 DVB-T2-MI.....	726
37.19 SFNs in DVB-T2	726
37.20 Transmitter Identification Information in DVB-T2.....	728
37.21 Capacity	728
37.22 Outlook	729
38 DVB-C2 – the New DVB Broadband Cable Standard	731
38.1 Introduction.....	731
38.2 Theoretical Maximum Channel Capacity	733
38.3 DVB-C2 – An Overview	734
38.4 Baseband Interface.....	735
38.5 Forward Error Correction	735
38.6 COFDM Parameters	735
38.7 Modulation Pattern	737
38.8 Definition of a Cell	739
38.9 Interleavers	739
38.10 Variable Coding and Modulation (VCM).....	740
38.11 Frame Structure	740
38.12 Channel Bundling and Slice Building	741
38.13 Preamble Symbols	742
38.14 Pilots in DVB-C2.....	745
38.15 PAPR	746
38.16 Block Diagram.....	746

38.17 Levels in Broadband Cables	746
38.18 Capacity	748
38.19 Outlook	748
39 DVB-x2 Measuring Techniques.....	749
39.1 DVB-S2	749
39.2 DVB-T2	750
39.3 DVB-C2.....	752
39.4 Summary.....	753
40 CMMB – Chinese Multimedia Mobile Broadcasting	755
41 Other Transmission Standards.....	757
41.1 MediaFLO.....	757
41.2 IBOC - HD Radio	758
41.3 FMextra.....	759
41.4 Effects of the Digital Dividend on Cable and Terrestrial TV Networks.....	759
41.4.1 Anatomy of the Mobile Radio Signals	760
41.4.2 Terrestrial TV Networks and Mobile Radio	761
41.4.3 Broadband Cable TV Networks and Mobile Radio.....	761
41.4.4 Electromagnetic Field Immunity Standard for Sound and Television Broadcast Receivers.....	763
41.4.5 Summary.....	764
42 Digital Television throughout the World - an Overview	765
Bibliography	769
Definition of Terms	777
TV Channel Tables	791
Europe, Terrestrial and Cable	791
Australia, Terrestrial	794
North America, Terrestrial.....	795
North America, Cable	797
Europe, Satellite.....	801
Index.....	803