Table of Contents

1 Introduction **1**

2 Analog Television **7**

3 The MPEG Data Stream **11**
3.1 The Packetized Elementary Stream (PES) 13
3.2 The MPEG-2 Transport Stream Packet 17
3.3 Information for the Receiver 20
3.3.1 Synchronizing to the Transport Stream 21
3.3.2 Reading out the Current Program Structure 21
3.3.3 Accessing a Program 23
3.3.4 Accessing Scrambled Programs 24
3.3.5 Program Synchronisation (PCR, DTS, PTS) 26
3.3.6 Additional Information in the Transport Stream 28
3.4 The PSIP according to ATSC 35
3.5 Other Important Details of the MPEG-2 Transport Stream 39
3.5.1 The Transport Priority 39
3.5.2 The Transport Scrambling Control Bits 40
3.5.3 The Adaptation Field Control Bits 40
3.5.4 The Continuity Counter 40

4 Digital Video Signal According to ITU-BT.R.601 (CCIR 601) **43**

5 Transforms to and from the Frequency Domain **47**
5.1 Fourier Transform 49
5.2 Discrete Fourier Transform (DFT) 50
5.3 Fast Fourier Transform (FFT) 53
5.4 Implementation and Practical Applications of DFT and FFT 54
5.5 Discrete Cosine Transform (DCT) 55
5.6 Time-Domain Signals and their Transforms to the Frequency Domain 57
5.7 Systematic Errors Associated with DFT or FFT 60

5.8 Window Functions 62

6 MPEG-2 Video Coding 65
6.1 Video Compression 65
6.1.1 Reducing the Quantization from 10 Bits to 8 67
6.1.2 Omitting the Horizontal and Vertical Blanking Intervals 67
6.1.3 Reduction in Vertical Color Resolution (4:2:0) 68
6.1.4 Further Data Reduction Steps 69
6.1.5 Differential Pulse Code Modulation of Moving Pictures 70
6.1.6 Discrete Cosine Transform Followed by Quantization 75
6.1.7 Zig-Zag Scanning with Variable-Length Coding of Zero Sequences 82
6.1.8 Huffman Coding 84
6.2 Summary 84
6.3 Structure of the Video Elementary Stream 87

7 Compression of Audio Signals to MPEG and Dolby Digital 91
7.1 Digital Audio Source Signal 91
7.2 History of Audio Coding 92
7.3 Psychoacoustic Model of the Human Ear 94
7.4 Basic Principle of Audio Coding 99
7.5 Subband Coding in Accordance with MPEG Layer I, II 100
7.6 Transform Coding to MPEG Layer III and Dolby Digital 103

8 Teletext Transmission to DVB 107

9 A Comparison of Digital Video Standards 111
9.1 MPEG-1 and MPEG-2, VCD and DVD, M-JPEG, MiniDV/DV 111
9.2 MPEG-3, MPEG-4, MPEG-7 and MPEG-21 114
9.3 Physical Interfaces for Digital Video Signals 116
9.3.1 Parallel and Serial CCIR 601 117
9.3.2 Synchronous Parallel Transport Stream Interface 119
9.3.3 Asynchronous Serial Transport Stream Interface 120

10 Measurements on the MPEG-2 Transport Stream 123
10.1 MPEG-2 Measurements to DVB Measurement Guidelines 124
10.1.1 Loss of Synchronisation 125
10.1.2 Errored Sync Bytes 126
10.1.3 Missing or Errored Program Association Table 126
10.1.4 Missing or Errored Program Map Table 127
10.1.5 The PID_Error 128
10.1.6 The Continuity_Count_Error 129

10.1.7 The Transport_Error 130
10.1.8 The Cyclic Redundancy Check Error 131
10.1.9 The Program Clock Reference Error 131
10.1.10 The Presentation Time Stamp Error 132
10.1.11 The Conditional Access Table Error 134
10.1.12 Service Information Repetition Rate Error 134
10.1.13 Monitoring the NIT, SDT, EIT, RST, TDT/TOT Tables .. 135
10.1.14 Undefined PIDs 136
10.1.15 Errors in the Transmission of Additional Service Information 136
10.1.16 NIT_other_error, SDT_other_error, EIT_other_error 137
10.2 Monitoring an ATSC-Compliant MPEG-2 Transport Stream 137

11 Picture Quality Analysis of Digital TV Signals 139
11.1 Methods for Measuring Picture Quality 141
11.1.1 Subjective Picture Quality Analysis 142
11.1.2 Double Stimulus Continual Quality Scale Method 142
11.1.3 Single Stimulus Continual Quality Evaluation Method 143
11.2 Objective Picture Quality Analysis 143

12 Digital Modulation Basics 149
12.1 Introduction 149
12.2 Mixer 151
12.3 Amplitude Modulator 152
12.4 IQ Modulator 154
12.5. IQ Demodulator 161
12.6 Use of Hilbert Transform in IQ Modulation 165
12.7. Practical Applications of the Hilbert Tansform 168

13 Transmitting Digital Television Signals by Satellite - DVB-S 171
13.1 The DVB-S System Parameters 173
13.2 The DVB-S Modulator 176
13.2.1. How Does Convolutional Coding Work? 181
13.3 The DVB-S Receiver 187
13.4 Influences Affecting the Satellite Transmission Link 190

14 DVB-S Measuring Technology 195
14.1 Introduction 195
14.2 Measuring Bit Error Rates 196
14.3 Measuring DVB-S Signals using a Spectrum Analyzer 197
14.4 Measuring the Shoulder Attenuation 201
14.5 DVB-S Receiver Test 202

15 Broadband Cable Transmission of Digital TV Signal (DVB-C)...203
15.1 The DVB-C Standard 204
15.2 The DVB-C Modulator 206
15.3 The DVB-C Receiver 207
15.4 Interference Effects on the DVB-C Transmission Link 208

16 Broadband Cable Transmission According to ITU-T J83B 213

17 Measuring Digital TV Signals in the Broadband Cable.....215
17.1 DVB-C/J83A,B,C Test Receivers with Constellation Analysis . 216
17.2 Detecting Interference Effects Using Constellation Analysis..... 220
17.2.1 Additive White Gaussian Noise (AWGN)..... 220
17.2.2 Phase Jitter..... 223
17.2.3 Sinusoidal Interferer 224
17.2.4 Effects of the I/Q Modulator..... 224
17.2.5 Modulation Error Ratio (MER) 227
17.2.6 Error Vector Magnitude (EVM) 228
17.3 Measuring the Bit Error Rate (BER) 229
17.4 Measuring the DVB-C/J83ABC Carrier Power and Estimating the Signal-to-Noise Ratio Using a Spectrum Analyzer 230
17.5 Measuring the Shoulder Attenuation 233
17.6 Measuring the Ripple or Tilt in the Channel 233
17.7 DVB-C/J83A,B,C Receiver Test 234

18 Orthogonal Frequency Division Multiplex (OFDM) 235
18.1 Introduction..... 235
18.2 Why Multi-Carrier? 237
18.3 What is OFDM?..... 239
18.4 Generating the OFDM Symbols 243
18.5 Supplementary Signals in the OFDM Spectrum..... 252
18.6 Hierarchical Modulation 255
18.7 Summary..... 255

19 The Terrestrial Transmission of DTV Signals (DVB-T) 257
19.1 The DVB-T Standard..... 259
19.2 The DVB-T Carriers 261
19.3 Hierarchical Modulation 267
19.4 DVB-T System Parameters of the 8-/7-/6-MHz Channel..... 269
19.5 The DVB-T Modulator and Transmitter..... 278
19.6 The DVB-T Receiver..... 281
19.7 Interference on the DVB-T Transmission Link and its Effects .. 286
19.8 The Transmission Path 289

19.9 DVB-T Single-Frequency Networks (SFN) 294

20 Measuring DVB-T Signals 303
20.1 Measuring the Bit Error Rates 305
20.2 Measuring the DVB-T Signals Using a Spectrum Analyzer 307
20.3 Constellation Analysis of DVB-T Signals 310
20.3.1 Additive White Gaussian Noise (AWGN) 311
20.3.2 Phase Jitter 312
20.3.3 Interference Sources 312
20.3.4 Echoes, Multipath Reception 312
20.3.5 Doppler Effect 313
20.3.6 I/Q Errors of the Modulator 313
20.3.7 Cause and Effect of I/Q Errors in DVB-T 316
20.3.8 Modulation Error Ratio (MER) 323
20.4 Measuring the Crest Factor 326
20.5 Measuring the Amplitude, Phase and Group Delay Response 327
20.6 Measuring the Impulse Response 328
20.7 Measuring the Shoulder Attenuation 329

21 Digital Terrestrial TV to North American ATSC Standard 331
21.1 ATSC Standard 331
21.2 8VSB Modulator 336
21.3 8VSB Gross Data Rate and Net Data Rate 345
21.4 ATSC Receiver 345
21.5 Causes of Interference on ATSC Transmission Path 346

22 ATSC/8VSB Measurements 349
22.1 Bit Error Rate (BER) Measurement 349
22.2 8VSB Measurements by Means of a Spectrum Analyzer 350
22.3 Constellation Analysis on 8VSB Signals 351
22.4 Measurement of Amplitude and Group Delay Response 355

23 Digital Terrestrial Television according to ISDB-T 357

24 Digital Television throughout the World - an Overview 361

Bibliography 365

Definition of Terms 369

Index 381