Digital Radio DAB+

Marian Oziewicz

Digital Radio DAB+

Broadcasting Multimedia System

Springer

Marian Oziewicz
National Institute of Telecommunications
Wroclaw, Poland

ISBN 978-3-030-66477-0 ISBN 978-3-030-66478-7 (eBook)
https://doi.org/10.1007/978-3-030-66478-7

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

The author of the present book was a finalist at the International Mathematical Olympiad. He graduated from the Faculty of Electronics, Technical University of Gdańsk, Poland. Probationary period at the Technical University was paused to study quantum field theory in the Department of Theoretical Physics, University of Wroclaw. Introduction of the martial law in Poland interrupted work on completing a doctorate in theory of elementary particles.

The conditions of martial law forced him to change jobs and turn back to the problems of telecommunications. The opportunity to become familiar with system of the digital radio DAB in various stages of its development appeared in the leading European research centers. In 1992, he was invited to the Institute IRT in Munich, a member of the EU project Eureka 147 DAB, where he was introduced to the core concepts of signal processing in digital transmitter and receiver. This took place still before the final determination and standardization of the system. Presentation of the system was carried

out using a prototype of the variant parameters.

Further studies of the DAB system were conducted in the framework of the EU grant 'visiting scientist' in scientific and research multimedia laboratory in Hildesheim in Germany.
His Ph.D. in the field of telecommunications was completed at the Department of Radioelectronics, Warsaw University of Technology.

Preface

The work on digital radio in Europe started in the framework of the European Union (UE) project Eureka 147 DAB in 1987. The aim was to develop a fully digital radio system for fixed, portable, and mobile reception of multimedia. The work of members of the project resulted in the European Norm ETSI EN 300 401 highlighted as the EU digital radio standard DAB – Digital Audio Broadcasting. Further development of the system was conducted by the different working groups of international experts under the auspices of such organizations as EBU (European Broadcasting Union), focusing representatives of public broadcasters, and ETSI (European Telecommunication Standards Institute), responsible for the European standards in the field of telecommunications, further coordinating within JTC (Joint Technical Committee) and including later also CENELEC (Comite European de Normalisation ELECtrotechnique) responsible for standardizing radio.

The essential element of digital radio is the audio encoder, which reduces the number of audio parameters. In DAB, this is the MUSICAM encoder. However, with the development of audio compression techniques, a more efficient HE-AACv2 type encoder was introduced into the system along with a reduction of some other options.

This improved system is referred to as DAB+ radio.

In this book, we deal with the basic mechanisms of digital radio (technical details can be found in the System Specifications) – therefore, apart from the parts describing the audio encoders, the acronyms DAB and DAB+ can be treated equally.

The concepts and methods developed in the framework of the Digital Radio project in Europe were next used in digital television and the latest generations of mobile phones.

Apart from work on the technical core of the system in developed EU countries, action has been taken on developing multimedia applications of digital broadcasting. It is not only an extension of information accompanying program, but also audio independent so-called value-added services including messages of social relevance, such as a warning system for the civilian population, traffic and transport messages, information on local tourist services, and parking. The advertising information should be significantly expanded, taking advantage of the graphic exposure options.

The role of the radio – due to its universal access and the forms of communication – is not so completely absorbing as television or telephone. Radio is indispensable as a means of information of the drivers. Similarly, in situations of risk, flood, or fire, where the cellular communications are blocked due to an overload capacity of the cells by the number of entries, the optimal source of information is the radio.

Applications of digital radio will depend on the creativity of its operators: new technology can be used passively as replicate of the analog radio transmission limited to the verbal and musical programs, or actively exploited developing the possibilities of parallel services based on multimedia data.

Currently, description of the DAB system is contained in more than 80 specifications. Working on a uniform, comprehensive description of the entirety, one should select its basic elements not found in analog radio system. The focus is therefore on description of the mechanisms extending the radio transmission on the multimedia content. The standards and specifications describe the exact organization of protocols, interfaces, and components of the physical and higher layers of the system, but do not devote space to explaining why and how such procedures are recommended. The book takes appropriate explanation on the assumed level and shows the current state of the general structure of the DAB and DAB+ systems.

Wroclaw, Poland Marian Oziewicz

Admission

The motivations for initiating work on the system Digital Audio Broadcasting (DAB), and its following version DAB+ with a new audio encoder, on the technical side are:

- Inclusion of the radio in the digital teletransmission world allowing for signal processing, extension of audio signals to multimedia messages, and archiving programs with digital methods
- Extending the coverage area of the radio program of single transmitter to broadcasting area of many transmitters connected in a Single Frequency Network (SFN)
- Optimal use of scarce goods such as radio frequency spectrum, by replacement of the channel bandwidth allocation by the grants of digital throughput adapted to the current needs of programs under a common block of spectrum

The DAB+ is a digital broadcasting system designed for reliable use also in mobile reception. The information transferred in this system can be of different kinds. The sound track in DAB radio, justifying its name, stems from organic incorporation of the audio encoder in the transmitter and decoder in the receiver. But it can also be transparent for other digital data with capacity allowed by its throughput.

In determining the relationship of DAB+ to earlier systems, it should be noted that digital audio broadcasting is a new value compared to the existing AM, FM, or FM stereo radios.

The implementation of DAB+ demands new transmitters and receivers: at homes, in cars, and, in the future, in cellular phones.

Services offered by this system can be extended for "information on demand" using text, graphics, images, and video. Tests with broadcasting a television program via the DAB system revealed that mobile reliability and stability of its reception is incomparably better than in analog systems under the same conditions.

DAB system helped optimize the use of frequencies for planning both local radio and networks of transmitters covering larger areas of the country.

As for any digital system, the transmission of DAB+ radio programs can be described in the most adequate way by the OSI system of layers: the physical layer, the network layer, the transport layer, management, and the presentation layer.

The physical layer of the radio describes the functional blocks of the system.

The network layer describes how to format the data in the logical frames of DAB+.

For the skillful use of the DAB+ opportunities, the transport layer describing the organization of the output signal of encoders of various applications is equally important.

The bit rate of individual applications is controlled by a management system organized and steered by the Fast Information Channel.

These layers, as in the description of the other digital tele-transmission systems, are interdependent and interconnected.

Our aim is to introduce to the indicated issues.

The encoder/decoder systems in DAB and DAB+ are different, but the principles of organization of both systems are alike, although not all elements apply in both cases. Because of this, after the part describing encoders, the acronyms DAB and DAB+ are used equally, unless otherwise stated.

Contents

1 Introduction 1
1.1 Why Digital Radio 1
1.2 Approaching Concept of Digital Radio 2
1.2.1 Frequency Blocks for DAB 3
1.2.2 Multimedia in the DAB+ System 3
1.2.3 Channels and Subchannels in the DAB System 4
1.2.4 The Environment for Transmission and Reception of Multimedia Services 5
References 6

2 Physical Layer of the DAB+ System 7
2.1 The Block Diagram of a Local Transmitter 7
2.2 Basic DAB Subsystems 9
2.2.1 Sound Track in Transmitter 9
2.2.2 Track of Multimedia Services 10
2.3 Basic Logical Frames of the DAB and DAB+ Systems 11
2.4 Audio Encoder in the DAB System (MPEG II) 11
2.4.1 Properties of the Ear: Static and Dynamic Sound Masking Thresholds 12
2.4.2 Quantization of Audio Signal: Quantization Noise 14
2.4.3 Masking Quantization Noise: Sub-band Encoding 15
2.4.4 Organization of the Outer Frame of the Encoder 17
2.4.5 Program Associated Data (PAD): F-PAD and X-PAD 25
2.5 Audio Encoder in the DAB+ System 28
2.6 Mechanisms Securing Quality of Transmission 32
2.6.1 The CRC Codes of the DAB Frames 33
2.6.2 Convolutional Encoder with Puncturing 34
2.6.3 Time Interleaving of the Frames of Encoder 37

2.7 Role of Multiplexer: DAB Logical Frames . . . 38
2.8 OFDM Channel Modulator . . . 42
2.8.1 The Principle of Operation . . . 44
2.8.2 Implementation of the Digital OFDM Modulator . . . 49
2.8.3 Transforming the DAB Logical Frames into Modulating Vectors . . . 51
2.8.4 Peak to Average Power Ratio (PAPR): Energy Dissipation . . . 52
2.8.5 Output Physical Frame of the OFDM Modulator . . . 54
2.8.6 Mode of the OFDM Channel Encoder in the DAB+ System . . . 54
2.9 Mapping the Logical DAB Frames onto the Physical OFDM Frames . . . 56
2.10 Integrated Transmitter Output: The Output Filter . . . 59
2.10.1 The Output Frequency Mask . . . 59
2.11 Functional Description of the DAB Receiver . . . 59
2.11.1 Block Diagram of the DAB Receiver . . . 60
2.11.2 Recovering the Logical Frames from the OFDM Signal . . . 62
References . . . 63

3 Impact of the Propagation Channel on Reception Quality of the DAB Signal . . . 65
3.1 The Baseband Multipath Channel: Phasor Representation of the OFDM Signal . . . 66
3.1.1 Relations Between the Multipath Profiles, Phasor Representation, and Frequency Envelope of Resulting OFDM Signal . . . 68
3.1.2 The Impact of Multipath on the Signal Reception: Examples . . . 71
3.2 Inter-symbol and Inter-tone Interferences . . . 75
3.2.1 Phasor Representation of the OFDM Paths Outside the Guard Interval . . . 76
References . . . 78

4 Single-Frequency Networks (SFN) . . . 79
4.1 Concept of the Single-Frequency Network (SFN) . . . 79
4.2 Rules for Planning the Single-Frequency Network . . . 81
4.2.1 The SFN Synchronization . . . 83
4.2.2 Identification of Transmitters within SFN: Codes TII . . . 83
4.2.3 Role of Gap Fillers . . . 84
4.2.4 Local Programs in the SFN Networks . . . 85
4.3 SFN Signals in the Baseband Channel . . . 86
4.3.1 Intra-network Signals in the Large SFN Model Network . . . 86

References . . . 94

5 DAB Multiplexes . . . 95
5.1 Concept of Multiplexes . . . 95
5.2 Planning the Coverage Area for Multiplexes . . . 97
References . . . 99

6 Logical Channels: Layered Description of Transport in the DAB+ System . . . 101
6.1 Introduction . . . 101
6.1.1 The Control Process in the DAB+ System . . . 101
6.2 Transmission Channels in DAB+ System . . . 102
6.2.1 Organization of the DAB+ Logical Frames . . . 103
6.2.2 Channels and Subchannels . . . 104
6.3 Organization of Transport in the DAB+ System . . . 105
6.3.1 Audio in the Stream Mode . . . 106
6.3.2 Data in the Stream Mode . . . 107
6.3.3 Packet Mode in the MSC . . . 107
6.3.4 Packet Transport in the Channel Accompanying Program PAD . . . 108
6.3.5 Data Groups in the Main Service Channel (MSC) . . . 109
6.4 Identification of Services within the DAB Multiplex . . . 109
6.4.1 Identifiers of Programs and Services . . . 110
6.4.2 Labels of Services and Its Components . . . 112
6.5 The Startup Procedures in the Receiver . . . 113
6.5.1 Information About the Multiplex Organization . . . 113
6.5.2 Startup Algorithm after Changes of Service within Multiplex . . . 116
6.5.3 Reconfiguration of Subchannels and Services . . . 117
6.6 Optional Parameters of the Programs and Services . . . 118
6.6.1 Multiplex Parameters Described in the FIG Groups of Type 0 . . . 118
6.6.2 Selected Software Services . . . 120
References . . . 125

7 Multimedia Applications: Protocol MOT . . . 127
7.1 The Development of the Concept of "Value-Added Services" in the DAB System . . . 127
7.2 Multimedia in Broadcasting Systems . . . 127
7.2.1 Protocol of the Multimedia Objects Transfer (MOT) . . . 128
7.2.2 Segmentation of MOT Objects in the DAB System: Data Groups . . . 131
7.2.3 Transport of Individual MOT Objects in the DAB System . . . 134
7.3 Transmission of Slides in the DAB Channel . . . 134

7.3.1 Slide Transportation . . . 135
7.3.2 Parameters for the MOT SlideShow . . . 136
7.4 Transmission of Audio-Visual Objects: Video . . . 137
7.4.1 Video Transmission in the DAB System . . . 139
7.5 Carousel of MOT Objects: MOT Directory . . . 140
7.6 Broadcasting Websites . . . 141
7.6.1 Organization of Transmission . . . 142
7.7 Overview of Messages: TopNews Carousel . . . 142
7.7.1 Structure of the TopNews Applications . . . 142
7.7.2 Parameters of the MOT TopNews Carousel . . . 143
7.8 Electronic Program Guide EPG . . . 143
7.8.1 Specification of the EPG System . . . 144
7.8.2 Encoding and Transport of the Electronic Program Guide in the DAB System . . . 145
7.9 WorldDAB Digital Radio Receiver Profiles . . . 146
References . . . 148

8 Transmission of Services in the Cumulative DAB Network: Interface STI . . . 151
8.1 Service Transport Interface (STI): The Logical Layer . . . 152
8.1.1 Interface STI-C(LI) . . . 152
8.1.2 Logical Layer of the Service Transport Interface: The Data Part, Interface STI-D(LI) . . . 156
8.2 Adaptation Layer of the STI: The Control Part . . . 161
8.3 The Transport Layer of the Interface . . . 161
8.4 Physical Layer of the Interface STI . . . 161
References . . . 161

9 Transmission of Multiplex Signal to Broadcasting Network: Interface ETI . . . 163
9.1 Interface ETI(NI) . . . 163
9.2 Interface ETI-NA . . . 167
References . . . 168

10 Conditional Access Mechanisms in the DAB System . . . 169
10.1 Applications of the Conditional Access System . . . 169
10.2 Physical Implementation of the CA System . . . 170
10.3 Conditional Access in the DAB System . . . 172
10.4 Specification EUROCRYPT as a Variant of the CA System . . . 173
References . . . 175

11 Development of the DAB System . . . 177
References . . . 180

Appendixes 181
Appendix A. Basic Parameters of the DAB+ System 181
Appendix B. Grouping of Convolutional Code in Channels FIC and MSC 182
Appendix C. Preliminaries on the Phasor Model of the Multipath OFDM Signal 186
Appendix D. Transport of the Conditional Access Parameters in the DAB System 187
Appendix E. DAB Carrier Frequencies in Blocks in the VHF Band III 189

Norms and Specifications 191

Index 197

List of Acronyms

AAC	Advanced Audio Coding
ACS	Access Control System
AIC	Auxiliary Information Channel
AIFF	Audio Interchange File Format
ALC	Asynchronous Layered Coding
APNG	Animated Portable Network Graphics
ASCII	American Standard Code for Information Interchange
ASF	Advanced Streaming Format
ASCTy	Audio Service Component Type
ASu	Announcement Support (flags)
ASw	Announcement Switching (flags)
ATRAC	Adaptive Transform Acoustic Coding
AU	Access Unit
AV	Audio-Visual
A/V	Audio/Video
BER	Bit Error Ratio
BIFS	Binary Format for Scene
BNS	Broadcast Network Server
Bslbf	bit string, left bit first
BWS	Broadcast Web Site
CA	Conditional Access
CAT	Conditional Access Table
CCA	Component Conditional Access
CBMS	Convergence of Broadcast and Mobile Services
CEI	Change Event Indication
CGI	Common Gateway Interface
CI	Content Indicator
CIF	Common Interleave Frame
ClusterId	Cluster Identifier
CMD	Command code identifying the message category in STI interface
C/N	Carrier-to-Noise (Ratio)

COFDM	Coded Orthogonal Frequency Division Multiplex
CRC	Cyclic Redundancy Check
CU	Capacity unit
CW	Control Word
DAB	Digital Audio Broadcasting
DAB+	DAB with AAC codec
DFT	Digital Fourier Transform
DG	Data Group
DGCA	Data Group Conditional Access
DGI	DAB Gateway Interface
DLS	Dynamic Label Segment
DMB	Digital Multimedia Broadcasting
D-PSK	Differential Phase Shift Keying
DRM	Digital Radio Mondiale
DSCTy	Data Service Component Type
DSP	Digital Signal Processor
DVB	Digital Video Broadcasting
DVB-H	DVB-Handheld
DVB-T	DVB-Terrestrial
EBU-UER	European Broadcasting Union - Union Europeenne de RadioTV
ECC	Extended Country Code
ECM	Entitlement Checking Message
ED	Energy Dispersal
EMM	Entitlement Management Message
EOF	End of Frame
EOH	End of Header
EPG	Electronic Programme Guide
EPID	Ensemble Provider Identifier
EPM	Enhanced Packet Mode
ES	Elementary Stream
ESG	Electronic Service Guide
ESM	Enhanced Stream Mode
ETI	Ensemble Transport Interface
ETI(NA)	ETI Network Adaptation
ETI(NI)	ETI Network Independent
ETS	European Telecommunication Standard
ETSI	European Telecommunications Standards Institute
FC	Frame Characterization
FEC	Forward Error Correction
FFT	Fast Fourier Transform
FIB	Fast Information Block
FIC	Fast Information Channel
FIDC	Fast Information Data Channel
FIDCCA	Fast Information Data Channel Conditional Access

FIG	Fast Information Group
FLUTE	File de Livery over Unidirectional Transport
F– PAD	Fixed Programme Associated Data
FRPD	Frame Padding
GCA	Group Customer Address
GIF	Graphic Interchange Format
GNSS	Global Network Satellite System
HDTV	High Definition Television
HE AAC	High-Efficiency Advanced Audio Coding
HF	High Frequency
HTML	Hypertext Markup Language
HTTP	Hyper Text Transfer Protocol
I signal	In-phase
ICI	Inter-Carrier-Interference
IEC	International Electrotechnical Committee
IETF	Internet Engineering Task Force
IFFT	Inverse Fast Fourier Transform
IK	Issuer Key
IM	Initialization Modifier
INS	Interaction Network Server
IOD	Initial Object Descriptor
IP	Internet Protocol
IPDC	IP Data Casting
IPDC	International Programme for the Development of Communication
ISI	Inter-Symbol Interference
ISO	International Standardization Organization
ITU	International Telecommunications Union
IW	Initialization Word
JFIF	JPEG File Interchange Format
JPEG	Joint Photographic Expert Group
JTC1	Joint Technical Committee on Information Technology
LCT	Layered Coding Transport
LTO	Local Time Offset
MainId	Main Identifier
MBMS	Multimedia Broadcast/Multicast Service
MCI	Multiplex Configuration Information
MDP	Multipath Delay Profile
MEMO	Multimedia Environment for Mobiles
MFN	Multiple Frequency Network
MHEG	Multimedia and Hypermedia Information Coding Expert Group
MIME	Multipurpose Internet Mail Extensions
MJD	Modified Julian Date
MNS	Multiple Network Server
MOT	Multimedia Object Transfer protocol
MOT BWS	MOT Broadcast Website

MPE	Multi-Protocol Encapsulation
MPEG	Moving Pictures Expert Group
MPEG-2 TS	MPEG-2 Transport Stream
MP2	Multimedia Protocol, Layer 2
MP3	Multimedia Protocol, Layer 3
MSC	Main Service Channel
MST	Main Stream Characterization; Main Stream data
MUSICAM	Masking Pattern Adapted Universal Sub-band Integrated Coding and Multiplexing
NIT	Network Information Table
OD	Object Descriptor
OFDM	Orthogonal Frequency Division Multiplex
O&M	Operation and Management System
PACT	President's Advisory Committee on Future Technology
PAD	Programme Associated Data
PAT	Programme Association Table
PCM	Pulse Code Modulation
PCR	Programme Clock Reference
PDA	Personal Digital Assistant
PDK	Programme Distribution Key
PES	Packetized Elementary Stream
PI	Punctured Index
PID	Packet Identifier
PLI	Parameter Length Indicator
PMT	Programme Map Table
PNG	Portable Network Graphics
PPID	Programme Provider Identifier
PPUA	Programme Provider Unique Address
PRBS	Pseudo Random Binary Sequence
PS	Parametric Stereo
PSI	Programme-Specific Information
PSNR	Peak Signal-to-Noise Ratio
PTy	Programme Type
Q signal	Quadrature signal
RDS	Radio Data System
RFC	Request for Comments
Rfa	Reserved for future addition
Rfu	Reserved for future use
RS	Reed-Solomon (code)
SA	Service Address
SAT	Sub-channel Assignment Table
SBR	Spectral Band Replication
SCCA	Service Component Conditional Access
SCTy	Service Component Type
SDP	Session Description Protocol

SDT	Service Description Table
SI	Service Information
Sid	Service Identifier
SIV	Service Information Version
SK	Service Key
SL	Synchronization Layer
SPID	Service Provider Identifier
SPS	Service Provider Server
SRTP	Secure Real-Time Transport Protocol
SSCTy	Specific Service Component Type
STC	Stream Characterization
STI	Service Transport Interface
STI-C	STI-Control Part
STI-C(LI)	STI-C Logical Interface
STI-D	STI-Data Part
STI-D(LI)	STI-D Logical Interface
Subsid	Sub-Identifier
Subsid	Sub-channel Identifier
TC	Technical Committee
TCP	Transmission Control Protocol
TCId	Transmission Component Type Identifier
TDC	Transparent Data Channel
TDT	Time and Date Table
TII	Transmitter Identification Information
TIST	Time Stamp
TN	Top News
TMId	Transport Mode Identity/Transport Mechanism Identifier
TPEG	Transport Protocol Experts Group
TS	Transport Stream
TSDT	Transport Stream Description Table
UA	User Application
UA	Unique Address
UDP	User Datagram Protocol
Umsbf	Unsigned Integer, Most Significant Bit First
UMTS	Universal Mobile Telecommunications System
URI	Uniform Resource Identifier
URL	Uniform Resource Locator
URN	Uniform Resource Name
UTC	Universal Time Coordinated
VBR	Variable Bit Rate
XML	eXtensible Markup Language
X-PAD	eXtended Programme Associated Data

Internet Addresses Associated with the DAB

events@worlddab.org	– Information on conferences organized under the auspices of WorldDAB
http://www.worlddmb.org/	– Address of the Digital Mobile Broadcasting association
http://docbox.etsi.org/reference	– Documents of the ETSI organization
http://tech.ebu.ch	– Information about the EBU's activities, including publications on DAB, DAB+, DMB
http://www.tpeg.org/	– Information about the organization TPEG
http://www.adept.eu.com/	– Information about the association ADEPT