Signals and Communication Technology

Walter Fischer

Digital Video and Audio Broadcasting Technology

A Practical Engineering Guide

Fourth Edition

Springer

Signals and Communication Technology

This series is devoted to fundamentals and applications of modern methods of signal processing and cutting-edge communication technologies. The main topics are information and signal theory, acoustical signal processing, image processing and multimedia systems, mobile and wireless communications, and computer and communication networks. Volumes in the series address researchers in academia and industrial R&D departments. The series is application-oriented. The level of presentation of each individual volume, however, depends on the subject and can range from practical to scientific.

"Signals and Communication Technology" is indexed by Scopus.

More information about this series at http://www.springer.com/series/4748

Walter Fischer

Digital Video and Audio Broadcasting Technology

A Practical Engineering Guide

Fourth Edition

Springer

Walter Fischer
Rohde&Schwarz GmbH & Co KG
Training Center
Munich, Germany

Translated by

István Szendro
SZOMEL Translation Agency

Csaba Szombathy
SZOMEL Translation Agency

ISSN 1860-4862 ISSN 1860-4870 (electronic)
Signals and Communication Technology
ISBN 978-3-030-32184-0 ISBN 978-3-030-32185-7 (eBook)
https://doi.org/10.1007/978-3-030-32185-7

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

Preface to the Fourth Edition

Eight years have elapsed since the last edition of this book, and the appearance of the first English edition dates even further back to 1.5 decades from now. In both periods many amazing technical innovations were introduced. The most important invention in the last decades was the smart phone and the tablet PC. Both products have changed the world in general and also the world of broadcasting. Movies, as well as TV and audio broadcast services are now transported via both traditional transmission techniques and smart phones or tablet PCs. Especially the young generation uses more and more the IP-based broadcast technology called ”streaming“.

This current version of the book has been completely revised and extended to the current broadcast technology standards. Practical examples from the introduction phase of DVB-T2 are included as well as new standards like 3DTV, HbbTV, HEVC/H.265/High Efficiency Video Coding, UHDTV Ultra High Definition, 4K, DOCSIS3.1, OTT/streaming, ATSC3.0 and LTE/5G-based broadcast. Concerning audio broadcasting, both its digital aspect such as DAB/DAB+ and its analog form like FM are described.

When the first edition of this book was published, analog television systems represented the technology of the era and nearly all the TV sets in the living rooms were heavy cathode ray tube equipment, featuring big dimensions with a typical screen diameter not wider than 32 inches. Now we are using big flat screens whose diameters often reach up to 60 inches, but are typically not smaller than 40 inches. Such flat screens are no longer heavy and they can also display ultra high definition pictures. Accordingly, the typical program materials are mostly distributed in high definition television resolution.

This work has been published in English and in German languages, and some editions have been even translated into Hungarian and Spanish languages. Many people all over the world on all continents have read this book, giving a lot of positive feedback.

Many participants in my numberless broadcast seminars all over the world have used this book as an additional source of information. On the other hand, I have included many inputs from my seminars, lessons at the

Munich University of Applied Sciences and the Deggendorf Institute of Technology (DIT, THD), as well as experiences and results from field trials and laboratory tests in this book.

Let me express my deep thanks to everybody who helped me to complete this book and who gave me feedback. I would like to express my special thanks to my colleagues at Rohde & Schwarz and to Springer. I am also very pleased to have met Csaba Szombathy from Budapest – he and his translation agency helped me to translate and correct some new chapters. I have also further extended my experience via intensive communication with different broadcasters and broadcast network providers all over the world.

Dipl.Ing.(FH) Walter Fischer
Moosburg an der Isar, near Munich, Germany, August 2019

Table of Contents

1 Introduction

Since about 2010 to 2012, television has really arrived in the age of high-definition TV (HDTV). For this purpose, enough channels have been available since the analog switch-off on satellites, and HDTV flat screens have meanwhile appeared in almost every living room. Screen diagonals have grown steeply compared to just a few years ago. Today, their size averages around 40 to 55 inches. Unpleasant side effects of the first flat screens, like restricted viewing angle and motion blur, have been eliminated; picture quality is now outstanding and incomparably better than that of CRT devices. "Smart TV" and "HbbTV" features are usually also integrated into the sets, merging the world of TV with the world of the Internet. Also, ultra-high-resolution television (UHDTV) has been advertised intensively since 2014, but, although UHDTV devices are on offer and the transmission chain is available, ultra-high-resolution content and the corresponding channel capacities are not yet widespread. However, television is only one part of the broadcasting scene, which, of course, also includes radio. The latter is still mostly received in analog form, although e.g. in Germany, DAB/DAB+ have seen strong growth since 2011, and a rich offering in terms of receivers and content is now available. The term "broadcasting" refers to the transmission of information, be it voice, image or sound, or data transmitted from a single point - the transmitter - to many points - the radio receivers. As a particular feature of broadcasting, the source is unaffected by the number of receivers, i.e. the channel capacity is not impacted as the number of receivers listening to that single transmitter increases. This is the big difference to a mobile radio link or an Internet connection where peer-to-peer communication is used. Also, broadcast networks have so far always been designed for high noise-tolerance and are hence robust in disaster situations. This makes broadcasting a safe medium for distributing information to the population even under difficult conditions.

This book discusses all analog and digital broadcasting standards with regards to both the baseband standards (MPEG) and the transmission standards (DVB, ATSC, ISDB-T, DAB, ...) they use. In addition, it discusses all necessary fundamentals, including

W. Fischer, *Digital Video and Audio Broadcasting Technology*,
Signals and Communication Technology,
https://doi.org/10.1007/978-3-030-32185-7_1

- analog audio and video signals,
- transforms between time domain and frequency domain,
- analog and digital modulation methods,
- multicarrier modulation methods, OFDM,
- digital video and audio signals,

detailed in their own chapters. The MPEG standards describe the most common source coding methods for multimedia and broadcasting applications, and are of course comprehensively covered in many sections, discussing the MPEG-2 Transport Stream protocol as well as video and audio coding, i.e. the compression of digital video and audio signals. In addition to an introduction to H.262/MPEG-2 video, H.264/MPEG-4/AVC and H.265 / HEVC will also be explained. The chapters that follow cover digital video broadcasting - ATSC, ISDB-T, DAB/DAB+ and DTMB - and discuss all transmission paths they use, including

- terrestrial transmission,
- the satellite transmission path,
- the broadcast broadband cable (CATV), and
- the two-wire cable,

as well as the corresponding transmission standards. Broadcasting is linear in the sense that the user can only choose a program by selecting one or the other channel. Within a specific physical or logical broadcast channel, the participant cannot influence the process. Nevertheless, VoD (Video on Demand), YouTube, etc. already enable "non-linear" TV enjoyment. TV broadcasting over IP in the form of IPTV or OTT (Over the Top TV), better known as "streaming" services, is also addressed, and a separate chapter on the use of the broadband cable for bidirectional services like telephony and Internet over DOCSIS (Data over Cable Service Interface Specification) is now also included.

Rather than simply "describing" standards, the aim was to clarify how they function and to explain them in practical terms wherever possible, using many examples. There are numerous chapters on the corresponding measurement technology, as well as sections on terrestrial broadcasting networks, transmitters and stations. This book also builds on the author's experiences gained in countless seminars, drive tests, presentations and lectures on all continents of the world, as well as on many intensive discussions with colleagues from Rohde & Schwarz, broadcasting corporations, and the industry. Often many phenomena could easily be tested and measured in practice at Rohde & Schwarz, in the field during coverage

measurements of DVB-T and DVB-T2 networks, during DVB-T2 field trials in Munich, or in the author's lab in the course of numerous experiments.

Before getting into the technology in the next chapter, a glimpse into the history of this field is given. Video transmissions started already around 1884 with the development of the Nipkow disk by Paul Nipkow. Using a rotating disk with a series of holes along a helical curve, he could decompose images into elements - "lines" - and transfer them from a rotating transmitter disk to a synchronously rotating receiver disk. Both disks were driven by synchronous motors, with a mains frequency of 50 Hz or 60 Hz, depending on the country. A few years before, Heinrich Hertz proved the existence of electromagnetic waves predicted mathematically by Maxwell. Based on these achievements, Marconi made the first information transmissions around 1895. Initially, broadcasting was primarily used to transmit short pieces of information over longer distances wirelessly, rather than using cable telegraphy, to fixed targets on land or mobile targets on water. The 1920s saw the first music transmissions, starting the age of broadcasting as we understand it today. Some of the first attempts to transfer music were made from the transmitter station of Königs-Wusterhausen south of Berlin, regarded as the cradle of radio broadcasting. Broadcast transmissions first used amplitude modulated long-, medium- and short waves. The sound quality left much to be desired, primarily due to the low bandwidth of about 5 kHz and atmospheric disturbances. At the time, such narrowband radio channels were also used to broadcast narrowband TV signals — using Nipkow disks on both ends of the transmission chain — to so-called "Fernsehstuben" (TV viewing rooms) (see also "NBTV" = narrow band TV, John Logie Baird), with about 30 lines per screen. The reason for selecting the mains frequency (50 Hz, 60 Hz) as the refresh rate was the synchronization of the synchronous motors of the Nipkow disks. The 1930s saw the appearance of the first "broadband television" transmissions at a few hundred lines per screen. However, the age of black-and-white television started only after World War II. In Europe the foundations were laid down by adopting the “Gerber standard”. This resulted in two separate TV worlds: one was using 50 Hz with 50 fields and 25 frames per second, the other 60 Hz with 60 fields and 30 frames per second. Frequency shortage at the end of the 1940s prompted Europe to also open up the VHF FM band (VHF band II, 87.5 - 108 MHz) for radio use. The modulation method used in the FM band was frequency modulation that was considerably less susceptible to atmospheric disturbances, resulting in a radio standard which is still used to this day in VHF endpoint equipment in many households, and it doesn't look like that it will completely be replaced by digital broadcasting until around 2030. The initially mono VHF

FM broadcasting was followed in the 1950s by stereo VHF FM broadcasting, somewhat later supplemented by an RDS (Radio Data System) signal. The 1960s saw the advent of color television with three different color transmission methods - NTSC, PAL and SECAM - integrated in a compatible manner into the black-and-white transmission scheme. Teletext appeared in the 1980s, supplementing aired programs with data for the first time. Teletext was developed by the BBC as "British Teletext". The first attempts at high-definition television, HDTV, emerged already in the 1980s, but it took a long time, a further 30 years, to actually introduce it. Further milestones included the D2MAC process (about 1990) and PALplus (about 1991). The D2MAC system first failed due to the deficiency of the "TV-Sat1" satellite, and then disappeared completely. Digital audio broadcasting (DAB) was developed at the end of the 1980s, with the first digital DAB radio transmitters entering into operation even before the advent of the age of digital television. The end of the 1980s saw the addition of satellites and broadband cables to the long-standing terrestrial transmissions. In the mid-1990s, the era of digital television began with the release of the MPEG, DVB and ATSC standards. MPEG is a collection of various baseband norms for digital broadcasting signals (video and audio), aimed at preparing the signals for storage (e.g. DVD) and distribution (broadcasting) through source coding and multiplexing. "MPEG" is the acronym for "Moving Pictures Expert Group". The European "DVB" (Digital Video Broadcasting) project resulted in a series of broadcasting standards for the distribution of TV signals with accompanying sound and data services: the DVB-S standard covers digital TV transmission via satellite, DVB-C is a standard for digital TV transmission via broadband cable, and the DVB-T standard is used for terrestrial digital TV transmission. DVB has also been adopted by many countries outside Europe. At the beginning of the 2000s, digital television in the form of SDTV (Standard Definition Television) had already been launched in some countries using satellite, cable and terrestrial broadcasting. The ATSC (USA), IDSB-T (Japan) and DTMB (China) standards appeared simultaneously and in the wake of DVB. The specifications for H.264/AVC video coding and DVB-S2 as the second generation of digital satellite television, both published in 2003, were used to implement HDTV systems in many countries. But the age of HDTV really arrived only after 2010, when content as well as suitable and affordable TV devices became finally available. Meanwhile, from about 2004, attempts to make television mobile with DVB-H, MediaFLO and T-DMB were undertaken. However, although these were technically functional systems, they failed economically. From 2011, digital radio was expanded further via DAB+, and from this point onwards, significantly more radio content and digital radio devices were available. The appearance of

HbbTV (Hybrid Broadband Broadcast TV) and "Smart TV" marked the beginning of the convergence of television and the Internet: flat screen TVs were increasingly equipped with WLAN or Ethernet connection, and corresponding software or "middleware" as well as preinstalled and downloadable applications. The appearance of UHDTV gave the kickstart to ultra-high-definition television. Analog terrestrial, satellite and now also analog cable television was switched off. The next few years saw a migration from first-generation DVB-T to the second generation DVB-T2. DVB-T2 was closely followed by the release of DVB-C2, a new standard for digital broadcasting over broadband cable. Broadband cable transmission based on DOCSIS has been used since the end of the 1990s also for telephony and Internet. The latest DOCSIS 3.1 standard, released in 2013, is expected to revolutionize the utilization of broadband cable. Broadcasting has meanwhile also discovered the advantages of using twisted pair lines with xDSL and offering streamed services over the Internet, giving rise to a new buzzword: "OTT" (Over-the-Top TV). This concludes the story, and we can now start explaining the technical standards. These are the milestones of radio and TV broadcasting from the discovery of electromagnetic waves to the present (2019):

- Maxwell's equations, 1864
- Heinrich Hertz, proof of the existence of electromagnetic waves, 1886
- Marconi, first news transmissions over electromagnetic waves, 1895
- Nipkow disk, 1884
- Radio over long-, medium and shortwave, 1923
- Narrow-bandwidth television, John Logie Baird, 1926
- Black and white television, 1934
- VHF radio, 1949
- Color television, 1967
- Teletext, early 1980s
- First attempts at HDTV, mid-1980s
- D2MAC, PALplus, early 1990s
- Cable TV, from the mid-1980s
- Satellite television, from the end of the 1980s
- DAB - Digital Audio Broadcasting, developed towards the end of the 1980s
- DAB services available in Germany from mid-1990s
- MPEG, mid-1990s
- DVB, ATSC, mid-1990s

- SDTV, late 1990s
- xDSL, two-wire line, early 2000s
- DOCSIS = Data over Cable System Interface Specification, late 1990s
- DAB expansion from about 2005 onwards in the UK
- DAB+ from about 2008 in Australia, Scandinavia
- DAB/DAB+ — Expansion from 2011 in Germany
- HDTV, high-definition television since 2010 (first steps from 2002)
- HbbTV = Hybrid Broadcast Broadband TV, Smart TV, from 2010 onwards
- UHDTV, ultra-high-definition television from 2014 onwards
- "Linear" and "nonlinear" television
- OTT=Over-the-Top TV, video and audio streaming from about 2010

Table 1.1. Methods and standards for digital television and digital radio

Methods/ standards	Application
JPEG	Still image compression, photography, Internet
Motion JPEG	DVPRO, MiniDV, digital home video camera
MPEG-1	Video CD
MPEG-2	Baseband signal for digital television, DVD-Video
MPEG-4	New video and audio compression algorithms
MPEG-H	See HEVC, High Efficiency Video Coding
H.262	Video encoding (see MPEG-2 video)
H.264	Video encoding, AVC (see MPEG-4, Part 10 Video)
H.265	Video encoding, HEVC (see MPEG-H video)
DVB	Digital Video Broadcasting
DVB-S	Digital television via satellite
DVB-S2	New DVB satellite standard
DVB-C	Digital television over broadband cable
DVB-T	Digital terrestrial television
J83A	= DVB-C
J83B	North American cable standard
J83C	Japanese cable standard
ATSC	North American standard for digital terrestrial television (USA, Canada)

ISDB-T	Japanese standard for digital terrestrial television
DTMB	Chinese standard for digital terrestrial television (Digital Terrestrial Multimedia Broadcasting)
CMMB	Chinese Mobile Multimedia Broadcasting
DAB	Digital Audio Broadcasting
IBOC – HD Radio	Hybrid radio (digital radio)
FMextra	Digital radio broadcasting
T-DMB	South Korean standard for mobile transmission of MPEG video and audio based on DAB (Terrestrial Digital Multimedia Broadcasting)
DVB-H	Digital Video Broadcasting for Handhelds
MHP	Multimedia Home Platform
DRM	Digital Radio Mondiale
MediaFLO	Media Forward Link Only, a mobile TV standard
DVB-SH	DVB for handheld terminals via satellite and terrestrial
DVB-T2	Second Generation Digital Terrestrial Video Broadcasting
DVB-C2	Second Generation Digital Video Broadcasting – Cable
IPTV	Internet TV, TV over xDSL
DOCSIS	Data Over Cable System Interface Specification, IP and telephone over broadband cable

Note: Many terms listed in the table are protected by copyright ©.

Broadcasting means the transmission of information from a transmitter to the receivers (see Fig. 1.1.). The information, motion pictures, associated lip-synchronous sound and complementary data must first be prepared for transmission. During this process, called source coding, video and audio signals are compressed using e.g. the MPEG algorithm in order to achieve acceptable data rates. Subsequently, the video and audio signals are combined into a single data signal — the multiplex signal "MUX" — which is then channel-coded by the modulator to prepare it for the transmission channel.

This is generally understood to mean error protection, Forward Error Correction, FEC. Subsequently, the error-protected data are modulated onto a sinusoidal high-frequency carrier (RF signal). The RF signal is then amplified and transmitted terrestrially, via satellite, or over cable. The receiver then demodulates the RF signal to extract the data stream which is

usually affected by transmission errors caused by interference sources (noise, etc.). Channel decoding then repairs these errors to whatever degree possible by applying the transmitter procedures in reverse order. The subsequent source decoding, i.e. decompression, restores the video and audio signals which are then outputted or presented to the users (viewers, listeners). All digital broadcasting standards can be described and represented by the above steps.

For analog TV (ATV), source coding simply means limiting the bandwidth of the video and audio signals and technically implementing this process (CCVS signal, mono, L/R signal, etc.). The video and audio signals are fed to the picture and sound modulator, and the resulting single RF signal containing exactly one program is then transmitted to the receiver. The ATV receiver is tuned to a specific reception channel and plays exactly one program.

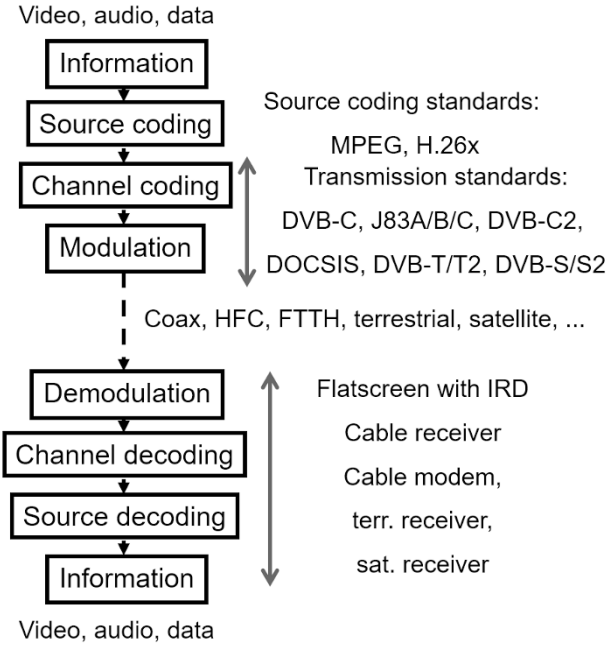

Fig. 1.1. Principle of information transmission in broadcasting

In the case of digital television, some programs or services are source-coded and combined into a digital multiplex signal ("MUX" e.g., an MPEG-2 Transport Stream). This multiplexed signal is then fed to the digital broadcast modulator where error protection is added to the data