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Digital Television

Technology and Standards

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This book is dedicated to our wives

Gemma Arnold
Emma Frater
Kim Pickering

whose support made possible both this book and our numerous absences at international standards meetings which preceded it.

Preface

In the last 50 years, television has arguably become the dominant source of entertainment and information in many countries. In the western world, most households own at least one television. Many have two or more. Over this half century, television technology has proved to be very adaptable, able to accommodate upgrades taking advantage of new technology without requiring existing receivers to be replaced. Indeed, a 50-year-old television receiver could still be used in most countries. The maintenance of compatibility with the existing receivers has been achieved through incremental improvements in service quality. The transitions from black-and-white to color television and from mono to stereo audio are both examples of this.

Digital television offers a number of potential advantages over the older, analog technology. High-definition services, providing much greater resolution than the conventional standard-definition television, are possible, as is the packing of several standard definition programs into the same bandwidth as a single analog television channel. The current international move to digital television is more revolutionary in nature than the previous changes, requiring the phasing-in of digital receivers and the subsequent phasing-out of the existing analog receivers. Consumers will therefore be required to purchase new equipment, in the form of a digital television or a decoder, to convert digital signals into a form that can be passed to their existing analog receiver.

This book describes the technology and standards behind digital television. It introduces the basic techniques used in video coding, audio coding, and systems, which provide for the multiplexing of these services and other ancillary data into a single bit stream. The description of standards covers the north-American Advanced Television System Committee (ATSC) and the European Digital Video Broadcasting (DVB). Aspects relating to these standards are described independently, allowing the reader to cover only those parts relevant to one system if desired.

The first chapter provides an introduction to analog and digital television, setting up the basic division of functionality into the representation of video, the representation of audio, and the underlying systems that provide services such as multiplexing of video and audio onto a single channel and modulation. The remaining chapters are grouped into three parts, covering the video, audio, and systems aspects of digital television, respectively. Each of these parts is written so that it can be read independent of the other parts. The first part deals with the coding of digital video signals using the MPEG-2 standard to produce a compressed digital video bit stream.

Chapter 2 describes the characteristics of video material. Chapters 3 and 4 describe the signal processing used to reduce the spatial and temporal redundancy

of digital video signals, with Chapter 3 describing predictive coding and Chapter 4 transform coding. Chapter 5 describes the principles behind the syntax used to represent the various data elements carried in a compressed video bit stream, whereas Chapter 6 introduces the specific features of the MPEG-2 video standard.

The second part covers the coding and compression of digital audio, using a similar structure to the first part. Chapter 7 introduces the aspects of the human ear that are critical in determining subjective audio quality, followed in Chapter 8 by a description of the signal processing used for digital audio compression, including the use of subband filter banks in audio coding. Chapters 9 describes the specific methods used by the MPEG-1 and MPEG-2 standards, respectively, with Chapter 10 describing the Dolby AC-3 system used primarily by ATSC.

The third part describes the modulation of digital television services for transmission, the system protocols used for multiplexing, timing, and control, and the other components of a digital television service that provide a range of data services, including closed captioning (also known as subtitling) and teletext. In this part, separate descriptions are provided for the different techniques provided by DVB and ATSC. Chapter 11 describes MPEG-2 systems, which provide the multiplexing, timing, control data for digital television. MPEG-2 systems also carry a collection of data, known as program-specific information, which describes the contents of a systems' bit stream. ATSC and DVB each provide its own extensions to the program-specific information, which are described separately in Chapter 12. Chapter 13 describes the terrestrial broadcast modulation schemes of ATSC and DVB, including the use of channel coding to protect bit streams from errors introduced in transmission. Finally, the closed-captioning and teletext systems are described in Chapter 14.

This book might be used as a textbook supporting a variety of different types of courses. An undergraduate digital television course might be based on a selection of material from Chapters 1–3, 5, 6, and 11. A postgraduate course in digital television, for which background in digital signal processing and digital communications theory is assumed, could extend this to include all material from Chapters 1–3 on video, 5 and 6 on audio, and 10 and 11 on systems, incorporating selections from other chapters. A more specialized course on video coding could be based on Chapters 1–5.

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Canberra, Australia
June 2007

Contents

Chapter 1

Introduction to Analog and Digital Television

1.1. INTRODUCTION

From small beginnings less than 100 years ago, the television industry has grown to be a significant part of the lives of most people in the developed world, providing arguably the largest single source of information to its viewers.

The first true television system was demonstrated by John Logie Baird in the 1920s. Further experiments were conducted in the following decade, leading to trial broadcasts in Europe and the United States, and eventually to the regular television service we know today. Originally, only monochrome pictures were supported. Color television was introduced in the United States in 1954 and in Europe in 1967.

Television systems have evolved as *simplex* transmission systems, as shown in Figure 1.1. The term simplex means that information flows only in one direction across the channel. A transmitter, whose antenna is usually mounted on a tall tower, broadcasts a signal to a large number of receivers. Each receiver decodes the transmission and passes it on to a display device. Sometimes, the receiver and display are integrated into a single device, such as in a standard television that incorporates a means for the user to select the channel to be viewed. Sometimes, the receiver and display are separate devices, such as when a signal is received through a video cassette recorder (VCR) and passed to an external display. This system is known as *terrestrial broadcast* television.

Satellite and cable television systems operate on similar models. Figure 1.2 shows the outline structure of a cable television system.

1.2. ANALOG TELEVISION

Traditional television services make use of analog technology to provide an audio-visual, broadcast service. The basic structure of an analog television transmitter is shown in Figure 1.3. Video and audio signals, which may be derived from live sources such as cameras and microphones or from storage devices such as video

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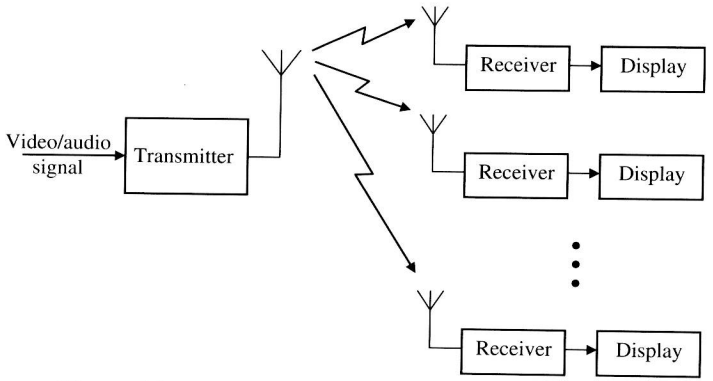

Figure 1.1 Simplex structure of terrestrial broadcast television.

recorders, are fed into separate modulators, whose output is multiplexed and upconverted to form the broadcast signal.

Various methods of modulating, multiplexing, and upconverting the signals to specific broadcast frequencies (as shown in Figure 1.3) are defined in the various analog television standards. Three of the major standards used for analog television are National Television System Committee (NTSC) [1], used primarily in North, Central, and South America, Systeme Electronique (pour) Couleur avec Memoire (SECAM), used in France and countries in eastern Europe such as Poland and Russia, and Phase Alternating Line (PAL) [2], used in many other countries including western Europe and Australia.

In this chapter, we discuss the operation of analog television with reference to three areas: the representation of video, the representation of audio, and the systems that provide the multiplexing of video and audio services into a single channel.

1.2.1. Video

An analog video signal is created by a time sequence of pictures, with 25 or 30 of these pictures displayed every second. Each picture consists of a number of lines,

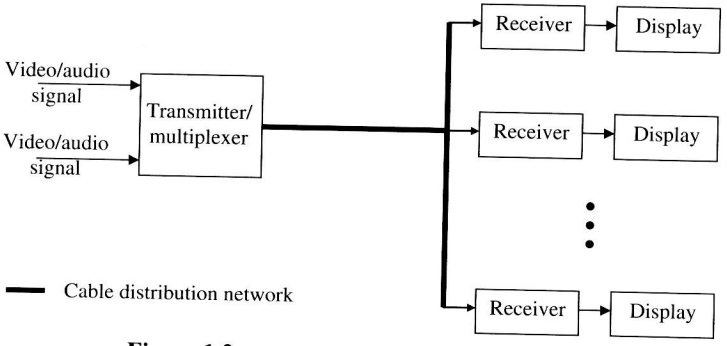

Figure 1.2 Structure of a cable television system.