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Contemporary Coding Techniques and Applications for Mobile Communications

To our children

Bahadir and Bengisu Uçan, and Emre Osman

Preface

Contemporary Coding Techniques and Applications for Mobile Communications covers both classical well-known coding techniques and contemporary codes and their applications.

The first four chapters include general information on mobile communications. In Chapter 5, AWGN, flat fading, time varying multipath, Wide Sense Stationary Uncorrelated Scattering Channels and MIMO channels are explained. The chapters following cover modern and applicable coding techniques.

In Chapter 6, channel equalization; semi-blind and blind equalization with adaptive filters such as RLS, LMS, EVA, Kalman, ML, and genetic algorithms, are summarized. Turbo codes, introduced in 1993, are given in Chapter 7, supported with clearly drawn figures; performances are derived for various channel models.

Achievement of both continuous phase property and error performance improvement is vital in all mobile communication systems. Thus, phase and frequency are combined, and the continuous phase frequency shift keying (CPFSK) is developed. In Chapters 8 and 9, new contemporary coding techniques with continuous phase property are investigated, including low-density parity check codes, time-diversity turbo trellis-coded modulation (TD-TTCM), multilevel turbo coded-continuous phase frequency shift keying (MLTC-CPFSK), turbo trellis-coded-continuous phase frequency shift keying (TTC-CPFSK), and low-density parity check coded-continuous phase frequency shift keying (LDPCC-CPFSK).

Today, digital image transmission is becoming common in cell phones. The critical point is how to optimize the combination of two main scientific subjects of electronics engineering—image processing and communications. Digital image processing is based on the neighborhood relationship of pixels. However, the transmitted signals that are the mapped form of these pixels should be independent from each other, based on the maximum likelihood theory. Thus, the most important problem to be solved in the following years is the contradiction between the pixel neighborhood necessity required for image processing and the independent interleaving needed for higher performance in digital communications. The last chapter explains some new approaches on the very popular subject of image transmission.

We thank the editors of Taylor & Francis Group who helped us improve our book.

We appreciate the continuous and valuable support we've received throughout our careers from our wives, Birsen Uçan and Aygen Osman.

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Istanbul, Turkey

Authors

Osman Nuri Uçan was born in Kars, Turkey, in January 1960. He received BSc, MSc, and PhD degrees from the Electronics and Communication Engineering Department, Istanbul Technical University (ITU) in 1985, 1988, and 1995, respectively. From 1986 to 1997, he worked as a research assistant in the same university. He worked as supervisor at TUBITAK-Marmara Research Center in 1998. He served as chief editor of the *Proceedings of the International Conference of Earth Science and Electronics* (ICESE), held in 2001, 2002, and 2003.

He is chief editor of Istanbul University's *Journal of Electrical and Electronics Engineering (IU-JEEE)*, cited by the Engineering Index (EI). He is professor and head of the Telecommunications Section, Electrical and Electronics Engineering Department, Istanbul University, where he is also head of the Biomedical Section of the Science Institute of IU and supervisor of the Telecommunication Institute of Turkey. His current research areas include information theory-turbo coding, image processing-cellular neural networks, wavelet, and Markov random fields applications on real geophysics data, and biomedical- and satellite-based two-dimensional data. He is author or coauthor of six books and two book chapters.

Onur Osman was born in Istanbul in September, 1973. He graduated from the Electrical Engineering Department of Istanbul Technical University in 1994. He received his MSc degree in electrical engineering in 1998 and subsequently his PhD degree from the Electrical and Electronics Engineering Department of Istanbul University. He worked with a telecommunication firm for a year as an R&D engineer and is now an assistant professor at Istanbul Commerce University. He is on the advisory board of the Istanbul University *Journal of Electrical and Electronics Engineering (IU-JEEE).* His research area is information theory, channel coding, turbo coding, satellite communications, jitter performance of modulated systems, channel parameter estimation, neural networks, and image processing for biomedical and geophysics applications. He is the author or coauthor of five books and one book chapter.

Contents

Chapter 1

Introduction

1.1 Digital Communication Systems: An Overview

New improvements in wireless communication will increase the reliable exchange of information anywhere, anyplace, and anytime. Mobile communication environments are propagation characteristics, signal loss, multipath fading, and interference. Design countermeasures are design margins, diversity, coding, equalization, and error correction. Emerging wireless communications systems are based on contemporary coding, encryption, and channel estimation, where the main channel concept is frequency division, time division, spread spectrum.

The main scheme of a digital communication system, as in Figure 1.1, is composed of a source/channel encoder followed by a modulator. The modulated signals are passed through a noisy mobile channel. At the receiver, noisy signals are demodulated and decoded by source/channel decoders, and the estimated data is obtained.

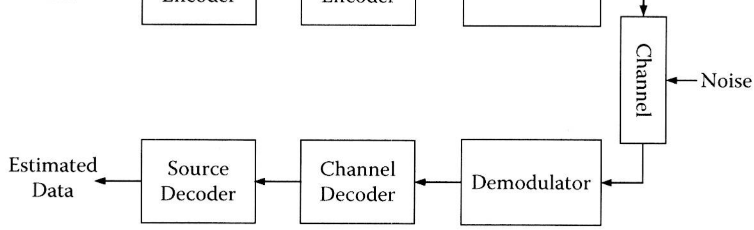

Figure 1.1 General block diagram of a digital communication system.

1.1.1 Source Coding

Original data is passed through a source encoder block. The main function of this block is to maximize entropy of the source. Entropy is symbolized by H, which shows average binary bits to represent each symbol. The replacement of the symbols with a binary representation is called source coding, which reduces the number of bits required to convey the information provided by original data. An instantaneous code is one that can be parsed as soon as the last bit of a codeword is received. An instantaneous code must satisfy the prefix condition. That is, no codeword may be a prefix of any other codeword. The best well-known source coding is Huffman coding. In image transmission, JPEG compression of digital images is based on this coding. It is assumed that both transmitter and receiver know the sequence set. The noiseless source coding theorem (also called Shannon's first theorem) states [1,2] that an instantaneous code can be found that encodes a source x of entropy $H(x)$ with an average number of bits per symbol B as

$$B \geq H(x) \tag{1.1}$$

1.1.2 Channel Coding

The task of source coding is to map the data source to an optimum number of symbols and to minimize error during their pass through the noisy channel. It is apparent that channel coding requires the use of redundancy. To detect or correct errors, the channel code sequence must be longer than the source sequence. To detect n bit errors, a coding scheme requires the use of codewords with a Hamming distance of at least $n + 1$. In the same manner, to correct n bit errors requires a coding scheme with at least a Hamming distance of $2n + 1$ between the codewords.

1.1.3 Modulation Systems

In classical analog communication; Amplitude Modulation (AM), Frequency Modulation (FM), Continuous Wave (CW) are commonly used. In AM, there is much to be gained in suppressing one of the sidebands and the carrier signal. Advantages are a reduction in band space, elimination of heterodyne whistles, and effective use of RF power. FM has a signal-to-noise-ratio advantage over amplitude modulation for the modulation index greater than 0.6 with a resulting bandwidth on speech considerably greater than that required for amplitude modulation. CW is a type of amplitude modulation [3].

In digital communication; frequency shift keying (FSK) and phase shift keying (PSK) are the main modulation types. FSK is a form of frequency