ABSTRACT

This chapter is a comprehensive presentation of spread spectrum-based digital audio watermarking methods. The problem is viewed as the realization of a basic communications system, where the host signal presents the available channel and the watermark presents the transmitted information that needs to survive and be recovered in conditions that include noise distortion, signal transformation, standard compression, and deliberate attacks. Basic spread spectrum theory as it relates to audio watermarking is introduced followed by state-of-the-art improvements. The important synchronization problem is analyzed in detail, existing techniques are presented, and a novel, precise synchronization method is included. Finally, the role of psychoacoustics in effective watermarking is emphasized and an enhanced psychoacoustic model based on the discrete wavelet packet transform (DWPT), which ensures efficiency and transparency is included.

INTRODUCTION

The increase in computational power and the proliferation of the Internet, witnessed over the last decade, have facilitated the production and distribution of unauthorized copies of copyrighted multimedia information. It is now easy to make a perfect digital illegal copy and distribute it overnight to millions of people via the Internet, resulting in large revenue loses to the movie and record industries every year. As a result, the problem of effective copyright protection has
attracted the interest of the worldwide scientific and business communities. The most promising solution seems to be the watermarking process where the original data is marked with ownership information hidden in an imperceptible manner in the original signal.

Compared to embedding watermarks into still images, audio watermarking is significantly more challenging due to the extreme sensitivity of the human auditory system (HAS) to changes in the audio signal (Cox, Miller, & Bloom, 2002). As a result, a psychoacoustic model of the HAS is usually integrated in the audio watermarking scheme in order to ensure transparency of any changes to the original audio.

Several techniques in audio watermarking systems have been proposed in the past decade including low-bit coding (Cvejic, 2004), phase coding (He, Iliev, & Scordilis, 2004; Kuo, Johnston, Turin, & Quackenbush, 2002), echo coding (Gruhl, Lu, & Bender, 1996), patchwork coding (Bender, Gruhl, Morimoto, & Lu, 1996), and spread spectrum (Kim, 2003; Kirovski, & Attias, 2002; Kirovski & Malvar, 2001, 2003; Meel, 1999; Swanson, Zhu, Tewfik, & Boney, 1998). Among those, spread spectrum-based techniques are the most widely used because they can provide high robustness and low interference with the host signal.

In this chapter we will first illustrate the basic theory underlying the spread spectrum approach, followed by a review of the uses of spread spectrum in digital watermarking. The next section focuses on techniques that improve the detection of spread spectrum watermarking as well as the mechanisms for fighting against desynchronization attacks. It also presents a fast synchronization method for watermarking. Then we present the psychoacoustic models available for audio watermarking, and focus on one developed by He and Scordilis (2006) with an example of its incorporation in spread spectrum audio watermarking. This chapter concludes with a summary and suggests possible improvements and future trends in spread spectrum for audio watermarking. In this chapter, message or secret message refers to the original information to be inserted in the host signal, and watermark refers to the encoded or modulated message to be embedded or hidden into the host audio signal.

Figure 1. Watermarking as a communication process