A study on data hiding scheme for digital audio in amplitude-modulation domain

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Data hiding techniques such as audio watermarking play an important role not only in copyright protection and information security of public digital content but also in delivering additional data in host signals. The host audio signal is modified in a special way to embed data (e.g. text message, image, sound) so that listeners cannot distinguish distortion in the audio signal. Many approaches to audio watermarking have been proposed in recent years and it was shown that they have had significant results. The hidden-message could be securely sent to particular receivers or broadcast to everybody in addition to the audio.

Amplitude modulation (AM) is one of the most popular techniques used in communication systems to deliver information over radio waves. Since AM is a simple technique, it is widely applied in radio broadcasting services. In conventional AM radio systems, a receiver tunes up the frequency up or down to match with the frequency of an expected radio station. It means that radio receivers know only the radio frequency and the audio content but not the service information such as the station name.

Some emergency alert systems (EASs), on the other hand, have been relying on AM radio systems to broadcast emergency messages to audiences. These messages are used to alert a coming disaster or to broadcast an

announcement of the president. The regular AM radio programs are temporarily stopped and replaced by announcements. However, these kinds of messages sometimes disturb somebody who is being very far from the disaster. EAS systems would be improved if we could control to send the alerts to only the target users as well as broadcast the announcement and the regular program simultaneously.

In this thesis, we propose a data hiding scheme for AM radio broadcasting system to transmit additional data in AM signals via a radio link. The audio signal is embedded with data by using a proposed method of audio watermarking and is then modulated with a carrier signal. The modulated signal or AM signal which conveys both the audio content and embedded data is broadcast to AM radio receivers. On the receiver side, the audio content and embedded data is extracted from the received AM signal. There are some challenges to the proposed scheme, for example, the watermarked signal may be distorted due to processes of modulation/demodulation. The accuracy of the watermark detection could be reduced as an affection of watermarked signal distortion. A non-blind watermarking scheme requires double transmission bandwidth to transfer both the host and watermarked signals which is an expensive cost in broadcasting systems. In spite of this inconvenience of non-blind watermarking, it has some advantages to be well applied to the proposed scheme, e.g., high sound quality and robustness. Therefore, it is demanded to account for transmitting the host and watermarked signals simultaneously. The proposed scheme must be compatible with a vast majority of conventional AM receivers so that it can extensively be applied to realistic broadcasting systems. Last but not least, high capacity of embedded data is also an important factor in this scheme to transmit the media data of large size.

This thesis is divided into two main tasks, the first one is to construct a data hiding scheme and the second one is to improve capacity of embedded data. In the first task, we propose two novel modulation and demodulation techniques called double-modulation and double-demodulation which based on double-sideband with carrier (DSB-WC) AM to modulate both the host and watermarked signals as lower sideband (LSB) and upper sideband (USB) with the carrier. The second task focuses on improving the employed method of audio watermarking to increase its embedding capac-

ity so that the proposed scheme could be used to transmit much more data or kinds of media data having large size.

We objectively evaluate the proposed data hiding scheme and the improved method of watermarking with SNR, LSD, PEAQ, and bit-detection rate measures. The proposed double-modulation and double-demodulation are evaluated to check that they can work properly. We also reconfirm the inaudibility of the watermarked signals that receivers extract from the AM signals. We calculate bit-detection rate to investigate the accuracy of detected data at the receivers. The compatibility of the proposed scheme is also assessed by evaluating sound quality of the signals that are extracted by using standard AM demodulators. Finally, we evaluate the improvement of the proposed approach to increasing capacity of embedded data in comparison with the original employed method.

The experimental results have revealed that the proposed data hiding scheme works well. They confirmed that the proposed scheme can convey inaudible embedded data in addition to audio signals in AM signals and that the embedded data can be precisely detected. The results also confirmed the improvement of the proposed approach to increasing embedding capacity. The proposed scheme has possibility of a message-hidden AM radio broadcasting system and could be applied to construct an efficient EAS system as well as an intelligent AM radio service.