The 4th International Conference on Electrical Engineering and Informatics (ICEEI 2013)

BER Performance of Audio Watermarking using Spread Spectrum Technique

Shervin Shokri*, Mahamod Ismail, Nasharuddin Zainal, Abdollah Shokri
Dept. Of Electrical, Electronic and System Engineering, Universiti Kebangsaan Malaysia, 43600 UKM Bangi, Malaysia

Abstract

Sending the private data is always one of the fundamental problems in the communication systems. Therefore, information hiding was presented to protect the data. The evolutionary process has been continued until the watermarking as a new technique was generated to promote the copyright marking. Watermarking is trying to embed the private data such as text or numbers as a guest signal in the host signal with minimal effect on it. Audio watermarking was introduced as one of watermarking techniques against the attackers and hackers that were raised on social networks. This paper presents an audio watermark algorithm with a blind detection which is based on a spread spectrum (SS) technique. A series of simulations were done on the proposed algorithm to estimate the Bit Error Rate (BER) for various values of signal-to-watermarking ratio (SWR) and bit rate. The simulation results show that by decreasing the SWR ratio, the BER ratio is reduced to less than $10^{-3}$.

Keywords: Watermark, Spread Spectrum (SS), signal-to-watermark ratio (SWR); Audio Watermarking

1. Introduction

Digital watermarking started as a part of information hiding in 1990. At the beginning just images and videos and then audio were considered by the researchers at 2001. Information hiding can be classified as like a family tree, which the watermark system is one of the sub layers of the robust copyright marking [1].

The main aims of the watermarking system can be split into three parts: un-detect ability (inaudibility), capacity (data rate) and robustness, as show in Fig. 1 [2]. In audio watermarking technique audio is used as a digital host signal to hide the watermarks (private data). One of the robust techniques in watermarking is a spread spectrum (SS). Spread spectrum audio watermarking (SSW) is able to generate the conditions for implementing the embedding watermarks in any transform domain [3].

* Corresponding author.
E-mail address: shervin_shokri@yahoo.com
SSW, as an effective technique, converts narrow-band signal (a message which should be transmitted) to the wideband signal by modulating a broadband carrier signal. The watermark information can spread over a larger set of samples with uses the chip-rate parameter.

This mission will be accomplished by PN sequence. The PN sequence also can be used as a secret key to protect the authorized users’ data on both sides of the system. The gain \((g)\) module can adjust the signal-to-watermark-ratio (SWR) to achieve a better BER at the receiver side. This paper mainly focuses on the BER ratio in output from various gains \((g)\) at the transmitter.

2. System overview

Watermark system consists of a Direct Sequence Spread Spectrum (DSSS) technology and a simple amplifier with some gain. The spread spectrum (SS) approach was chosen after so many studies that show this method is robust against channel noise [4]. The block diagram for the transmitter (encoder) and receiver side (decoder) is shown in Fig. 2.

In encoder side, first the watermarks are broadened by spread spectrum sequence \((s)\), in the next step the SWR is adjusted as a function of time to make amends for the abrupt power variations in an audio signal. This module provides the possibility to control the SWR between the watermarked signal and the audio signal. The watermark signal is embedded into the host signal (audio signal) and then can be transmitted over an additive white Gaussian noise (AWGN) channel [5].

At the receiver side (decoder), the process to extract the watermark data from the audio signal will be carried out. The receiver is created with the correlation demodulator and de-spreading [6].

3. System operation

The watermark spreading signal \(w(n)\) is achieved by spreading the \(M\) bits \(k\) (in \(\{0,1\}\)) of watermark sequence by using a spread spectrum signals \(s(n)\) that is combined of the \(N_b\) samples (as a vector \(s = [s(0), s(1), \ldots, s(N_b - 1)]^T\)) as shown in Fig 2. The \(s(n)\) signal is presented the vector \(s\) which is made by the PN sequence with values in\([-1, +1]\).

\[
w(n) = \sum_{m=0}^{M-1} a_m s(n - mN_b)
\] (1)
where $a_m$ a symbol in $\{-1, +1\}$ is given by $a_m = 2k - 1$ and can be adjusted The vector direction. Equation (2) and Fig. 3 shows the vector direction $w(n)$.

$$w_m = \begin{cases} 
+ & \text{if } a_m = +1 \\
- & \text{if } a_m = -1 
\end{cases}$$

(2)

The $w(n)$ signal is amplified by the gain ($g$) and then added to the audio signal $x(n)$, so the watermarked signal ($W_d$) will be ready for transmission over the channel. Since 1 bit is transmitted with $N_b$ samples, so the bit rate is $R = F_s / N_b$ (bits/s). The signal received $y(n)$ carries the noise of the AWGN channel. The Probability Density Function (PDF) of channel noise given by $N(0, \sigma^2)$. In this case is assumed the received samples from $y(n)$ are soundly synchronized with the transmitted samples $x(n)$.

$$y_m = g \cdot w_m + x_m = \begin{cases} 
+gs + x_m & \text{if } a_m = 1 \\
-gs + x_m & \text{if } a_m = -1 
\end{cases}$$

(3)

Where:

$$y_m = [y(mN_b), y(mN_b + 1), ..., y(mN_b + N_b - 1)]^T$$

(4)

And

$$x_m = [x(mN_b), x(mN_b + 1), ..., x(mN_b + N_b - 1)]^T$$

(5)

where $m$ is the frame index. A maximum a posteriori (MAP) detector is used For the optimal detector [7] which maximizes the probability of each received bit $\hat{R}$, given the corresponding received vector $y_m$.

Fig. 2. Block diagram of watermarking system.

Fig. 3. Vector direction $w(n)$ with value of $a_m$.
\[ \tilde{k} = \arg \max_{b \in [0,1]} p(b | y_m) \] (6)

In other words, \( \tilde{K} \) is achieved from the received vector \( y_m \) and the spreading code \( S \) with the scalar product \( < y_m, S > \).

\[
\tilde{K} = \begin{cases} 
0 & \text{if } < y_m, S > \leq 0 \\
1 & \text{if } < y_m, S > > 0
\end{cases}
\] (7)

The BER rate and probability of error are estimated as the ratio between wrong bits and all transmitted bits:

\[
BER[\%] = \frac{\text{NumWrongBits}}{\text{NumAllBits}}
\] (8)

\[
P_e = Q \left( \sqrt{\frac{F_s g^2 \sigma_s^2}{R \sigma_b^2}} \right), \quad Q(u) = \int_u^\infty \frac{1}{\sqrt{2\pi}} \exp \left( -\frac{t^2}{2} \right) dt
\] (9)

where \( \sigma_b^2 = \|s\|^2 / N_b \) is an estimate of the power of the spreading sequence \( S \).

4. Results And Discussion

The watermark message as a text with sample frequency \( F_s = 44.1 \text{kHz} \) and bit rate of \( R = 100 \text{ bps} \) (\( R = F_s / N \), \( N \) is the number of samples per bits) is embedded in an audio signal. The gain \( (g) \) is adjusted by the value of SWR between the watermark and audio signal power. AWGN channel is simulated by adding a constant noise to the watermarked signal \( (w_D) \). A text message as a input signal, shown in below.

```plaintext
message = 'audio watermarking by spread spectrum technique, this program is written for ICEEI 2013,.'
```

The audio sound is recorded by the Wavepad Sound Editor Masters Edition v. 5.33 which sets to 44100 kHz sample rate in mono channel. Fig. 4 Shows the WavePad Sound Editor Masters software. A Philips SHM3100U/97 In-ear Earphone microphone is used in our experiments for voice recording in the laboratory.
Fig. 4. Wavepad Sound Editor Masters Edition v 5.33.

Fig. 5(a), shows the steps of making a watermarked signal. The top is a watermark signal which achieved by converting the text message to binary form. Centre is also shows the original audio that is intended to cover the watermark signal and bottom shows the watermarked signal where made by covering the audio signal and amplified by the gain \((g)\). To better explain, Fig. 5b shows the watermarked signal that obtained from the embedding the watermark signal to the audio signal.

![Waveform diagrams](image)

**Fig. 5.** Watermark, audio and watermarked Signals (a); Watermarks embedded in an audio signal (b)
The watermarked signal now is ready to transfer into the AWGN channel. In this work, the simulation channel and the effect of that on the watermarked signal is done by adding a constant value of noise to the watermarked signal (Fig. 6).

The watermarked signal received after the AWGN channel and then demodulated by correlation demodulator. The extraction bits from 80 to 130 of a frame are shown in the Fig. 7. The received message shown in below.

\[ \text{received\_message} = \text{audio\ watermarking\ by\ spre'd'snectRu} \text{ technique, dhas\ program\ is\ written\ for\ ICEEI\ 2013.} \]

Fig. 7. Top: input watermark signal (transmitter) - Bottom: output watermark in SWR = 20dB (receiver) (a) Top: input watermark signal (transmitter) - Bottom: output watermark in SWR = 16dB (receiver) (b)
Shervin Shokri et al. / Procedia Technology 11 (2013) 107 – 113

Fig. 8. BER vs. SWR (gain).

By adjusting the gain the better BER [%] will be appearing.

received_message = audio watermarking by spread spectrum technique, has program is written for ICEEI 2013.

The Fig. 8 shows the BER plotting for various values of bit rate ($R$) and different range of the SWR. The simulation results show by decreasing the SWR the BER value is also reduced.

5. Conclusion

The audio watermarking using the spread spectrum (SS) technique was implemented to BER estimation for a typical SWR range. This study shows that the BER ratio and SWR have a direct relationship. Looking to simulation results shows, we get a reduction in the BER ratio to less than $10^{-3}$ by reducing the SWR values. Note that, the effects of the message length and various value of noise in the channel has not been included in this study, so for future work, other factors such as coding, masking signal and equalizing techniques in watermarking algorithm will be investigated.

References

[1] C. C. Chang, A., G. M. Chen, A., M. H. Lin, B. Information hiding based on search-order coding for VQ indices. Pattern Recognition Letters 2004; 25: 1253-1261.
[2] N. Cveje, A., T. Seppanen, B. Channel capacity of high bit rate audio data hiding algorithms in diverse transform domains. Communications and Information Technology (ISCIT) - IEEE International Symposium 2004; 1: 84-88.
[3] M. Davarynejad, A., C. W. Ahn, B., J. Vranken, A., J. van den berg, A., C.A. Coello Coello, C. Evolutionary hidden information detection by granulation-based fitness approximation. Applied Soft Computing 2010; 10: 719-729.
[4] S. Jung, A., J. Seok, B., J. Hong, C. An improved detection technique for spread spectrum audio watermarking with a spectral envelope filter. ETRI journal 2003; 25: 52-54.
[5] S. Babu, A., S. R. KV, B. Evaluation of BER for AWGN, Rayleigh and Rician Fading Channels under Various Modulation Schemes. International Journal of Computer Applications 2011; 26: 23-28.
[6] A. Deshpande, A., K. Prabhu, B. A substitution-by-interpolation algorithm for watermarking audio. Signal Processing 2009; 89: 218-225.
[7] Proakis J, A. Digital communications, 4th ed. New York,:McGraw-Hill: 2001.