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Crest factor reduction of spectrogram art signals based on clipping and filtering processes

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Abstract: Spectrogram art communications exchange visual messages drawn on sound signals. This study attempts to reduce the crest factor of spectrogram art signals to improve their visibility. This paper describes some experimental results examining our proposed technique that employs clipping and filtering processes.

Keywords: inaudible sound communication, spectrogram art communication, crest factor reduction

Classification: Fundamental Theories for Communications

References

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1 Introduction

Spectrogram art communications are expected to exchange visual messages drawn on sound signals by using microphones and speakers equipped in ordinary laptop computers. It enables near field communications without any advanced wireless radio devices. Transmitting such visual messages, we can realize robust communications that are directly understandable by human users.

Figure 1 shows our pilot implementation of a visual communication system that exchanges spectrogram art signals consisting of text messages. Text messages are easily understandable by human users even if some parts are inevitably degraded due to undesirable environmental noises. It is because text messages are very familiar symbols to human users.

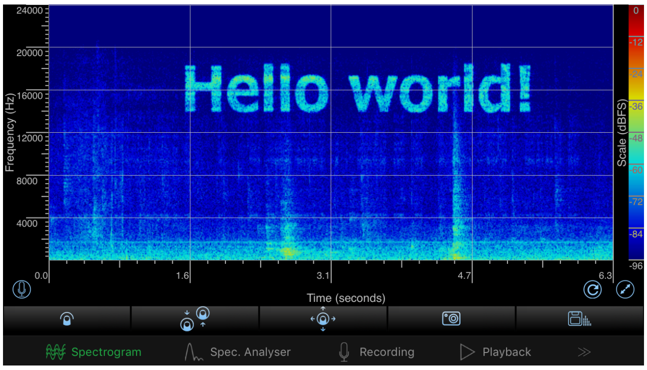

Fig. 1. Our pilot implementation of a visual communication system. Sound signals are emitted from a personal computer and received by a smartphone. This example employs a commercial software, SpectrumViewPlus for visualizing the text message.

2 Proposed technique

This study employs a DFT (discrete Fourier transform) filtering method to generate spectrogram art signals [1]. This method performs filtering source signals with mask patterns to generate spectrogram art signals. A white noise is one of the best candidates for the source signals. A mask pattern is a spectrogram art itself. Filtering a source signal with a mask pattern is equivalent to be the multiplication of these information in the frequency domain. The inverse transform of the multiplication is a resultant sound signal consisting of a spectrogram art.

The visibility of spectrogram art communications depends on the power of sound signals. If the power of sound signals decreases, the visibility of the messages must be degraded. It happens especially in the case of using low power loud speakers equipped in ordinary laptop computers. To improve the visibility of the messages as much as possible, the crest factor of spectrogram art signals should be reduced appropriately. The crest factor is defined as the peak amplitude of a waveform divided by the RMS (root mean square) value [2]. If the crest factor is minimized, the power of each frequency component included in spectrogram art signals is maximized.

To reduce the crest factor of spectrogram art signals, this study employs a clipping process, one of the approaches proposed for the crest factor reduction so far [3]. This technique is actually the same as a sound effect named compressor employed in the audio signal processing of music production. It is used for maximizing sound signals.

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The crest factor of sound signals is reduced by amplifying the sound signals with a compressor.

Even though it is a quite simple approach, such a clipping process surely reduces crest factor. However, this nonlinear process inevitably generates unnecessary frequency components decreasing the visibility of the spectrogram art signals as its side effect. Therefore, this study applies a filtering process to the resultant signals by using the same mask pattern employed in the generation of the spectrogram art signals to decrease such defects.

The proposed technique iterates these processes. Figure 2 shows that the iteration of these processes reduces further the crest factor. It indicates that just a few number of iteration may potentially be enough for obtaining the crest factor that is close to its convergence value.

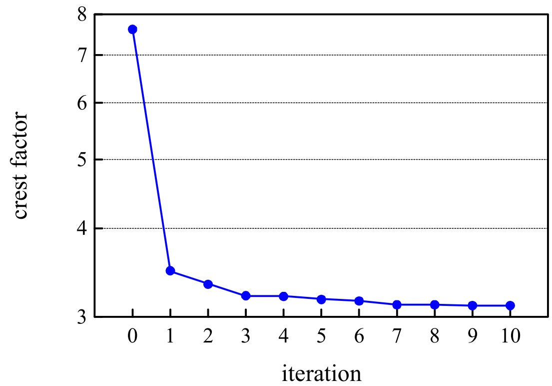

Fig. 2. Crest factor reduction by means of the iteration of clipping and filtering processes.

The proposed technique is rather similar to the conventional iterative clipping and filtering algorithm used to reduce PAPR (peak-to-average power ratio) in OFDM (orthogonal frequency division multiplexing) radio signals [4]. One main difference is that the conventional technique uses a time-invariant rectangular window for the filtering process, while the proposed technique uses time varying mask patterns.

To examine the effectiveness of the proposed technique, a computer simulation was conducted. Figure 3 (a) shows the spectrogram art of a sound signal without applying any crest factor reduction techniques. Its crest factor became 7.6.

Figure 3 (b) shows the spectrogram art of a sound signal after the clipping process. Since our simulation employed a signum function for the clipping process, the crest factor of the resultant signal became 1.0, the theoretically smallest value of the crest factor. However, unnecessary frequency components appear instead. Such annoying noises are not only audible but also decrease the visibility of the spectrogram art signal.

Figure 3 (c) shows the spectrogram art of a sound signal after the clipping and filtering processes of the proposed technique. The number of the iteration was 10. Its crest factor became 3.1. Even though the crest factor increases, the visibility of the spectrogram art signal is much clarified compared with the original one.

Figure 3 (d) shows the spectrogram art of a sound signal after the clipping and

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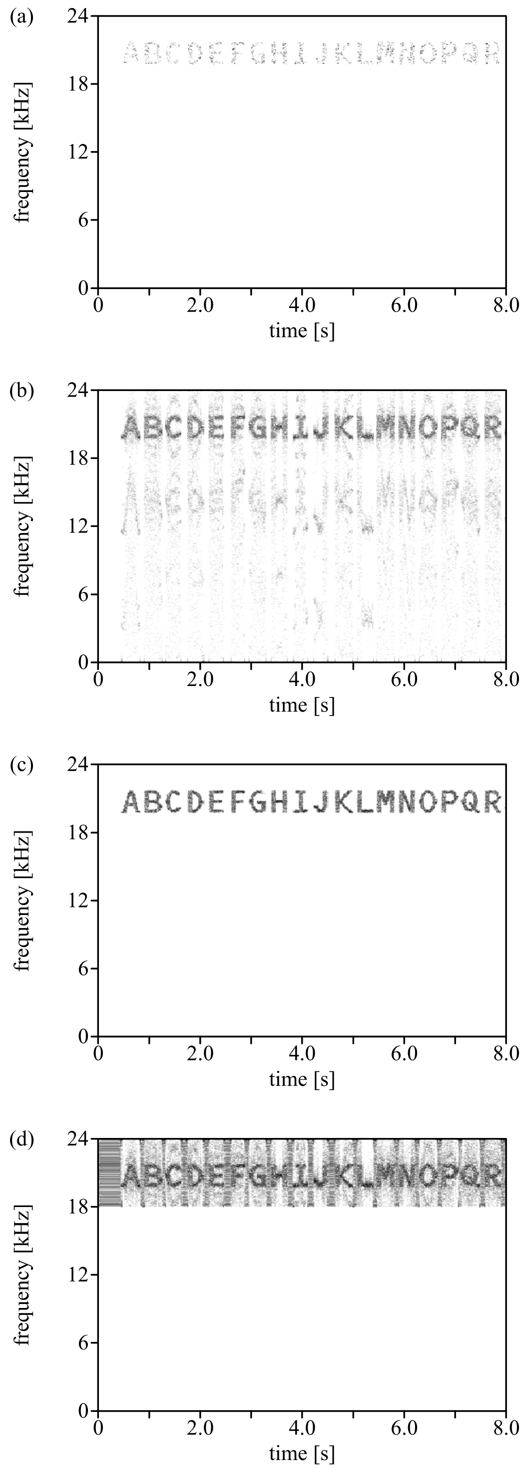

Fig. 3. Spectrogram arts obtained in a computer simulation: (a) the original, (b) with clipping process, (c) with clipping and filtering processes of the proposed technique, and (d) with clipping and filtering processes of the conventional technique. The crest factors are 7.6, 1.0, 3.1, and 2.0 respectively.

filtering processes of the conventional technique using a time-invariant rectangular window for the filtering process. To reduce audible noises under 18 kHz, the high pass filter of 18 kHz cut-off frequency was employed. The number of the iteration

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was 10. Its crest factor became 2.0. As shown in the figure, the spectrogram art is contaminated with noises, even though its crest factor is reduced much more than the proposed technique. It indicates that the conventional technique cannot reduce unnecessary frequency components very well, so that it may not be suitable for improving the visibility of the spectrogram art signals.

3 Conclusions

The simulation indicates that the proposed technique may potentially be an appropriate method that improves the visibility of spectrogram art signals. Further quantitative experiments will be performed to confirm how the proposed technique appropriately works in real situations.

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