Designing Synchronization Patterns Based on Euler Graphs for Inaudible Sound Communication Systems

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1. Introduction

The inaudible sound communication system of our implementation estimates the correct positions of received symbols for the decoding process by calculating the correlations with the pre-defined synchronization patterns [1]. The conventional technique employs completely random sequences for designing the synchronization patterns. This paper describes that a novel approach based on Euler graphs may potentially provide more efficient synchronization patterns.

2. Proposed technique

Figure 1 shows an example of the synchronization pattern consisting of 24 symbols denoted as [A, B, D, C, B, D, A, C, D, B, C, D, A, B, C, A, D, B, A, C, B, A, D, C]. This pattern is designed by the proposed technique under a constraint condition that the sequences of consecutive three symbols must be unique in the pattern. It means that only three symbols are enough for estimating their correct positions. This characteristic is similar to that of De Bruijn Sequences [2]. The proposed technique also takes account of another constraint condition that the same symbols must not be selected consecutively. This deals with multi-path echo problems that might lengthen symbols, which cause undesirable interferences back and forth in the sound signals.

Figure 2 shows the evaluation of the proposed technique. When there was no noise, the synchronization pattern designed with the proposed technique required three consecutive symbols, although the conventional technique required six. When the SNR (signal-to-noise ratio) of the received symbols decreased, the number of the received symbols required for the correct estimation increased. Nevertheless, the proposed technique required only about half as many symbols as the conventional technique. It indicates that the proposed technique may outperform the conventional technique.

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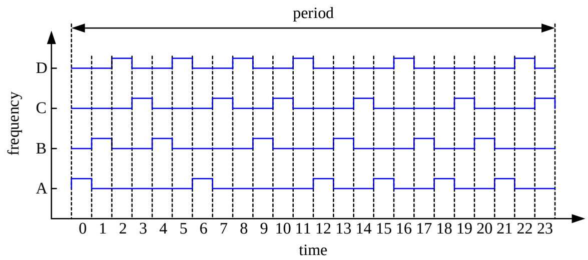

Fig. 1 An example of the synchronization pattern covering four frequency channels between A and D.

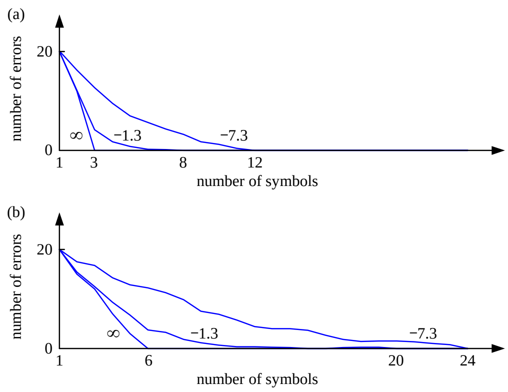

Fig. 2 The relationship between the number of symbols employed in the synchronization and the number of errors simulated with (a) the proposed and (b) the conventional technique. The numbers inside the graphs are SNR of the received symbols.

3. Conclusions

The proposed technique may potentially provide a better solution for the synchronization problem. One of the agendas of this study includes to investigate how to generate synchronization patterns of arbitrary length for given conditions.

References

[1] K. Ikeda, *et al.*, "Development and practice of sound communication technology," IEICE Technical Report, EA2022-24, 2022.
[2] N. Aoki, *et al.*, "A synchronization technique using De Bruijn sequences for inaudible sound communication systems," ICETC2020, 2020.