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Holeychuk Lyubomyr¹, PhD student

<https://orcid.org/0009-0006-5619-8230>

Trubchaninova Karyna¹, D.Sc., Professor

<https://orcid.org/0000-0002-8321-3583>

¹Ukrainian State University of Railway Transport, Kharkiv, Ukraine

FORECAST-OPTIMIZED SELECTION OF TIME SEGMENT LENGTH FOR IMPROVING THE INTERFERENCE ROBUSTNESS OF COMPLEX SIGNAL ENSEMBLES

Holeychuk L., Trubchaninova K. Forecast-Optimized Selection of Time Segment Length for Improving the Interference Robustness of Complex Signal Ensembles. This paper addresses the problem of coordinated selection of the time-domain segmentation length in the formation of ensembles of complex signals using time-domain permutations. While time permutations are known to reduce mutual correlation between ensemble signals, the segmentation length is typically predefined or selected empirically, without accounting for its simultaneous impact on correlation attenuation and spectral stability. To overcome this limitation, a predictive-optimization-based method for selecting the segmentation length is proposed. The method treats the segment length as a controllable parameter and evaluates its influence on ensemble properties through two quantitative metrics: a correlation-based metric characterizing the maximum mutual correlation and a spectral deviation metric assessing structural-spectral distortions caused by time permutations. These metrics are combined into an integrated objective function, enabling algorithmic determination of the optimal segmentation length that ensures a balanced trade-off between correlation reduction and spectral preservation. Experimental modeling using stochastic complex signal ensembles demonstrates that intermediate segmentation lengths provide the most favorable operating regime, yielding a significant reduction in mutual correlation while limiting spectral distortions. The obtained results confirm the effectiveness of the proposed approach and its applicability to the design of interference-robust signal ensembles in modern telecommunication systems.

Keywords: Time-domain permutation, Signal ensemble, Correlation analysis, Segmentation, Optimization, Interference robustness

Голейчук Л.В., Трубочанінова К.А. Метод прогнозно-оптимізаційного вибору довжини часових сегментів для підвищення завадостійкості ансамблів складних сигналів. У роботі розглядається задача узгодженого вибору довжини часової сегментації під час формування ансамблів складних сигналів із використанням часових перестановок. Хоча часові перестановки відомі як ефективний засіб зменшення взаємної кореляції між сигналами ансамблю, довжина сегментації зазвичай задається наперед або обирається емпірично, без урахування її одночасного впливу на ослаблення кореляційних зв'язків і збереження спектральної структури сигналів. Для усунення цього обмеження запропоновано прогнозно-оптимізаційний метод вибору довжини часових сегментів, у якому довжина сегментації розглядається як керований параметр. Вплив цього параметра на властивості ансамблю оцінюється за допомогою двох кількісних метрик: кореляційної метрики, що характеризує максимальний рівень взаємної кореляції, та метрики спектрального відхилення, яка оцінює структурно-спектральні спотворення, спричинені часовими перестановками. Зазначені метрики об'єднуються в інтегральну цільову функцію, що забезпечує алгоритмічне визначення оптимальної довжини сегментації та досягнення збалансованого компромісу між зменшенням кореляції та збереженням спектральних властивостей. Результати експериментального моделювання ансамблів стохастичних складних сигналів підтверджують ефективність запропонованого підходу та його придатність для підвищення завадостійкості телекомунікаційних систем.

Ключові слова: часові перестановки, ансамбль сигналів, кореляційний аналіз, сегментація, оптимізація, завадостійкість

Statement of a scientific problem.

One of the promising approaches to the formation of ensembles of complex signals is the use of time-domain permutations, which make it possible to modify the correlation structure of signals without significant interference with their energy characteristics. At the same time, the effectiveness of such approaches strongly depends on the parameters of time-domain decomposition, in particular on the length of signal segmentation in the time domain.

An analysis of existing methods shows that the length of time segments is usually specified in advance or selected empirically, without taking into account its influence on the consistency between correlation and structural-spectral properties of the formed ensemble. For small segmentation lengths, a more intensive weakening of correlation links is achieved; however, this may be accompanied by undesirable spectral distortions. Conversely, increasing the segmentation length contributes to preserving the spectral structure of the signals but limits the ability to reduce mutual correlation between ensemble signals.

Thus, in the problem of forming ensembles of complex signals, a scientific problem arises related to the coordinated selection of the time-domain segmentation length as a control parameter that allows achieving a compromise between the reduction of correlation links and the preservation of structural-

spectral characteristics of the signals. The absence of an algorithmic mechanism for such selection limits the effectiveness of time-domain permutations in telecommunication systems.

This determines the necessity of developing a predictive-optimization method for selecting the length of time segments, which is based on the quantitative evaluation of correlation and spectral characteristics of the ensemble and enables the algorithmic determination of the optimal time-domain segmentation regime for forming ensembles of complex signals with predefined properties.

Research analysis.

In works devoted to signal theory, noise immunity, and improving the efficiency of wireless communication channels, the main attention is focused on general principles of signal formation, filtering, and evaluation of interference effects, without a detailed analysis of the role of time-domain segmentation in shaping ensemble properties [1, 8, 15]. Studies in the field of cognitive radio systems address adaptation to a dynamically changing spectral environment and methods for detecting and utilizing frequency resources; however, the parameters of time-domain signal decomposition are usually fixed or selected empirically [3-5, 12]. In studies devoted to permutation-based and entropy-based signal analysis methods, the effectiveness of local time-domain processing for assessing signal complexity and structure has been demonstrated; however, these approaches are not aimed at forming ensembles with controllable correlation characteristics [2, 6]. Time-frequency segmentation methods enable the analysis of non-stationary processes and the reduction of interference effects, but they lack a mechanism for the coordinated selection of time-segment length with regard to ensemble correlation properties [9, 13, 14]. In works focused on forming ensembles of complex signals based on frequency and time-domain permutations, the possibility of reducing mutual correlation and increasing ensemble size has been shown; nevertheless, the time-domain segmentation length is not considered as a controllable optimization parameter [7, 10].

Thus, the analysis of publications [1-15] indicates the absence of approaches in which the time-domain segmentation length is determined algorithmically based on the coordinated consideration of correlation and structural-spectral characteristics of an ensemble of complex signals, which substantiates the relevance and necessity of developing the proposed method.

The purpose of the work.

The aim of the study is to develop a predictive-optimization method for selecting the time-domain segment length for permutations of complex signal ensembles, aimed at improving the noise immunity of ensemble characteristics under conditions of variable interference effects.

Presentation of the main material and substantiation of the obtained research results.

In well-known methods for forming ensembles of complex signals based on time permutations, the length of the time decomposition segment L is usually predefined or treated as a parameter of experimental analysis. At the same time, the choice of this parameter has a significant impact on the correlation and structural properties of the resulting ensemble, which substantiates the expediency of an algorithmically coordinated selection of this parameter.

Figure 1 illustrates the process of time segmentation of an ensemble of complex signals with the control parameter L , as well as examples of structural changes in signals after performing time permutations. Variation of the segment length determines the nature of local signal decomposition and, consequently, affects the resulting correlation and spectral characteristics of the ensemble.

As shown in Fig. 1, a decrease in the segment length L leads to a more intensive reduction in the level of mutual correlation between the signals of the ensemble; however, it may be accompanied by an increase in spectral deviations and local structural changes. Conversely, an increase in L provides better stability of the spectral structure of the signals, but limits the ability to reduce correlation relationships within the signal ensemble.

The presented dependencies confirm that the parameter L cannot be set arbitrarily and must be determined algorithmically as a control parameter that ensures coordination between the correlation and structural-spectral properties of the ensemble of complex signals.

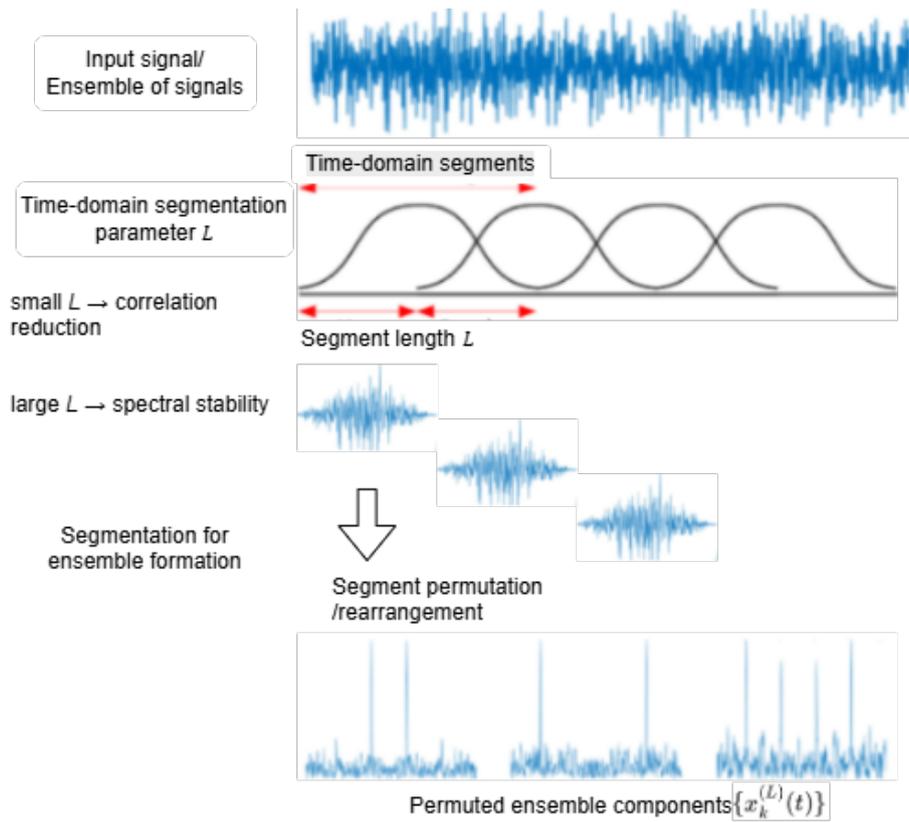


Fig.1 – Time-domain segmentation with controllable segment length L for ensemble permutation

The main parameters and variables of the predictive-optimization-based selection method are presented in Table 1.

Table 1 – Notation used in the proposed method

| Symbol | Description |
|-------------------|--|
| X | Ensemble of complex signals |
| $x_k(t)$ | k -th signal of the ensemble |
| K | Number of signals in the ensemble |
| t | Time variable |
| T | Observation interval duration |
| L | Length of time-domain segment (controllable parameter) |
| M | Number of time segments, $M = \lfloor T/L \rfloor$ |
| $x_k^{(m)}(t)$ | m -th time segment of the k -th signal |
| t_m | Starting time of the m -th segment $t_m = (m - 1)L$ |
| π | Permutation vector of segment indices |
| P_M | Set of all permutations of M elements |
| $\tilde{x}_k(t)$ | Signal obtained after time-domain permutation |
| $\tilde{X}^{(L)}$ | Ensemble of signals after permutation with segment length L |
| $\rho_{ij}(L)$ | Mutual correlation coefficient between the i -th and j -th signals after time-domain permutation with segment length L |
| $\Phi_{corr}(L)$ | Correlation-based metric characterizing the ensemble as a function of segment length L |
| $\Phi_{spec}(L)$ | Spectral deviation metric evaluating spectral stability after time-domain permutation with segment length L |
| $S(f)$ | Power spectrum of the original signal ensemble |
| $\tilde{S}(f; L)$ | Power spectrum of the ensemble after time-domain permutation with segment length L |
| $J(L)$ | Integrated objective function for optimal selection of the segment length L |
| w_1, w_2 | Weighting coefficients of the correlation and spectral terms in the objective function |
| L^* | Optimal value of the time-domain segment length selected by the proposed method |

| | |
|---------------|---|
| \mathcal{L} | The admissible set of time-segmentation lengths |
|---------------|---|

The block diagram of the algorithm implementing the predictive-optimization-based method for selecting the length of time segments is shown in Fig. 2.

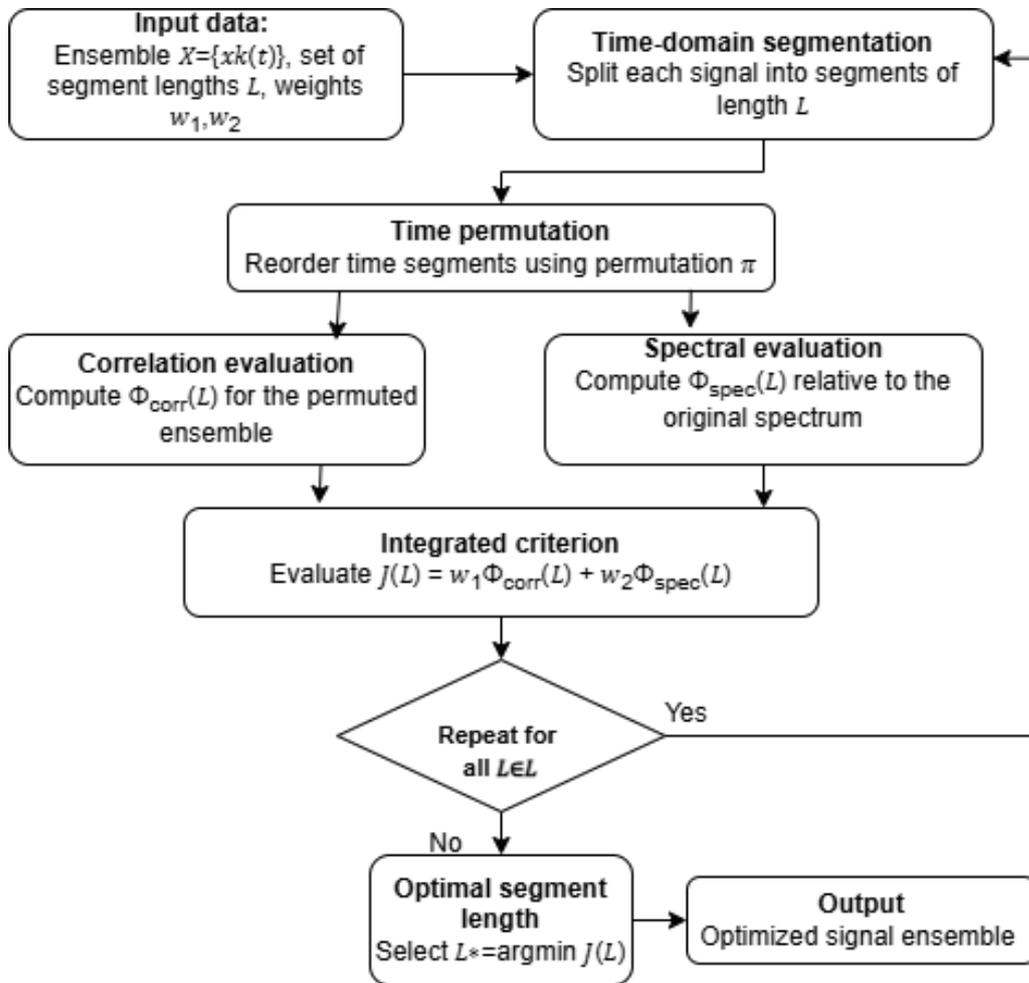


Fig. 2 – Block diagram of the proposed segment-length optimization algorithm

Let us consider in more detail the main stages of the algorithm implementing the proposed method and the corresponding mathematical formulation of the segmentation parameter selection problem.

Stage 1. Formation of time segmentation of the signal ensemble and execution of permutations.

At the first stage of the algorithm, the ensemble of complex signals is segmented in the time domain using the parameter L , which defines the length of the time segments and sets the scale of local time decomposition within which time permutations are performed. Thus, the parameter L influences the segmentation structure of the signals and the nature of the subsequent permutations. The ensemble of complex signals is considered as:

$$X = \{x_k(t)\}_{k=1}^K, \quad t \in [0, T]. \quad (1)$$

The time domain of each signal in the ensemble is divided into a sequence of segments of length:

$$x_k(t) \Rightarrow \{x_k^{(m)}(t)\}_{m=1}^M, \quad x_k^{(m)}(t) = x_k(t_m + t), \quad t \in (0; L). \quad (2)$$

Next, a time permutation of the segments is performed, which is defined by a permutation of the segment indices from the set $\{1, \dots, M\}$. For this purpose, a permutation vector π is introduced, which specifies the new ordering of the segments in the time domain.

$$\pi: \{1, \dots, M\} \rightarrow \{1, \dots, M\}, \quad \pi \in P_M. \quad (3)$$

As a result, a new permuted ensemble of complex signals is formed:

$$\tilde{x}_k(t) = \bigcup_{m=1}^M x_k^{\pi(m)}(t), \quad (4)$$

where the operator \bigcup denotes sequential concatenation of time segments in the time domain according to the permutation π .

At this stage, the parameter L is treated as a variable control parameter that determines the nature of local time decomposition of the signals. Thus, the first stage of the algorithm forms a parameterized set of permuted ensembles $\tilde{X}^{(L)} = \{\tilde{x}_k(t; L)\}_{k=1}^K$, for which the correlation and structural-spectral characteristics are evaluated at subsequent stages in order to enable the algorithmic selection of the optimal value of the segmentation parameter.

Stage 2. Evaluation of correlation properties of the permuted ensemble.

At the second stage of the algorithm, a quantitative assessment of the correlation properties of the signals is performed for the parameterized set of permuted ensembles $\tilde{X}^{(L)} = \{\tilde{x}_k(t; L)\}_{k=1}^K$ formed at the previous stage, as a function of the selected time-segment length L .

The objective of this stage is to establish the relationship between the segmentation parameter L and the level of mutual correlation between the signals of the ensemble after performing time permutations. Such an evaluation makes it possible to formalize the impact of local time decomposition on the correlation structure of the ensemble and provides the basis for the subsequent algorithmic selection of the control parameter.

For each pair of signals $\tilde{x}_i(t; L)$, $\tilde{x}_j(t; L)$, $i \neq j$ the mutual correlation coefficient after permutation is computed and is defined by the following mathematical expression:

$$\rho_{ij}(L) = \frac{\int_0^T \tilde{x}_i(t; L) \tilde{x}_j^*(t; L) dt}{\sqrt{\int_0^T |\tilde{x}_i(t; L)|^2 dt \int_0^T |\tilde{x}_j(t; L)|^2 dt}}, \quad (5)$$

where $(\cdot)^*$ denotes complex conjugation.

Since, in problems of forming ensembles of complex signals, it is necessary to ensure a uniform reduction of mutual correlation among all signals in the ensemble, the evaluation of correlation properties is expediently performed using a generalized metric that characterizes the limiting level of correlation dependence within the ensemble. Accordingly, further analysis is based on the maximum absolute value of the mutual correlation coefficient over all pairs of signals in the ensemble.

$$\Phi_{corr}(L) = \max_{i \neq j} |\rho_{ij}^{(L)}|. \quad (6)$$

The metric $\Phi_{corr}(L)$ provides a generalized characterization of the degree of correlation consistency of the ensemble after time permutations with segments of length L . Lower values of this metric correspond to more effective attenuation of undesirable correlation relationships among the signals of the ensemble.

Thus, at the second stage of the algorithm, the parameter L is considered simultaneously as a geometric parameter of time segmentation and as a control parameter that directly determines the correlation properties of the formed ensemble.

Stage 3. Evaluation of structural-spectral properties of the permuted ensemble.

At the third stage of the algorithm, the impact of time segmentation and permutations on the structural-spectral characteristics of the ensemble of complex signals is evaluated. The necessity of this stage arises from the fact that local time decomposition, which is employed to control the correlation properties of the ensemble, significantly affects the spectral structure of the signals.

The objective of this stage is to quantitatively assess the degree of deviation of the spectral characteristics of the permuted ensemble from those of the original ensemble as a function of the

segmentation length L , and to establish a compromise between correlation attenuation and preservation of the spectral structure.

For this purpose, for each value of the segmentation parameter L the power spectrum of the ensemble after time permutations $\tilde{S}(f; L)$ is computed and compared with the original ensemble spectrum $S_0(f)$. To generalize the measure of structural-spectral changes, a spectral metric is introduced in the form of a normalized energy deviation:

$$\Phi_{spec}(L) = \frac{\|\tilde{S}(f; L) - S_0(f)\|_2}{\|S_0(f)\|_2}, \quad (7)$$

where $\|\cdot\|_2$ denotes the Euclidean norm.

The metric $\Phi_{spec}(L)$ enables a quantitative assessment of the influence of the segmentation parameter L on the spectral stability of the ensemble. Small values of this metric correspond to preservation of the structural-spectral properties of the signals, whereas an increase in its value indicates the emergence of spectral distortions caused by excessive localization of the time segments.

Stage 4. Predictive-optimization-based selection of the segmentation length using an integral criterion.

The fourth stage of the algorithm is aimed at the coordinated selection of the optimal value of the segmentation parameter L by simultaneously accounting for the correlation and structural-spectral characteristics of the ensemble of complex signals. For this purpose, an integral optimality criterion is introduced in the form of a weighted function:

$$J(L) = w_1 \Phi_{corr}(L) + w_2 \Phi_{spec}(L). \quad (8)$$

The proposed integral criterion makes it possible to mathematically formalize the balance between the effectiveness of correlation attenuation within the ensemble and the preservation of its structural-spectral properties. In contrast to approaches in which the segmentation parameter is predefined, within the proposed method the parameter L is determined as a control parameter that minimizes the integral criterion:

$$L^* = \arg \min_{L \in \mathcal{L}} J(L). \quad (9)$$

Since the dependencies $\Phi_{corr}(L)$ and $\Phi_{spec}(L)$ exhibit non-monotonic behavior, the optimal value L^* corresponds to a region of compromise between the correlation and spectral properties of the ensemble rather than to an extremum of only one of the metrics.

Thus, at the fourth stage, a predictive-optimization mechanism for selecting the length of time segments is implemented, which ensures a balanced regime of forming ensembles of complex signals in terms of correlation and structural-spectral characteristics and provides a foundation for further experimental verification of the effectiveness of the proposed method.

To verify the proposed predictive-optimization-based method for selecting the length of time segments and the algorithm for its implementation, experimental modeling was conducted to investigate the influence of the segmentation length parameter L on the correlation and structural-spectral characteristics of ensembles of complex signals formed using time-domain permutations. The experimental ensemble consisted of complex signals generated using stochastic models that are widely employed for studying correlation and spectral properties of signals in ensemble formation problems [1-15].

At the first stage of the experiment, the correlation properties of the signal ensemble after performing time-domain permutations were evaluated for different values of the segmentation length L (Table 2, Fig. 3).

Table 2 – Calculated correlation metric versus segment length

| L | 8 | 16 | 32 | 64 | 128 | 256 | 512 |
|------------------------------------|--------|--------|--------|--------|--------|--------|--------|
| No permutation | 0,1690 | 0,1690 | 0,1690 | 0,1690 | 0,1690 | 0,1690 | 0,1690 |
| Permutation (shared π) | 0,1690 | 0,1690 | 0,1690 | 0,1690 | 0,1690 | 0,1690 | 0,1690 |
| Permutation (independent π_k) | 0,1633 | 0,1668 | 0,1413 | 0,1490 | 0,1444 | 0,1628 | 0,1690 |

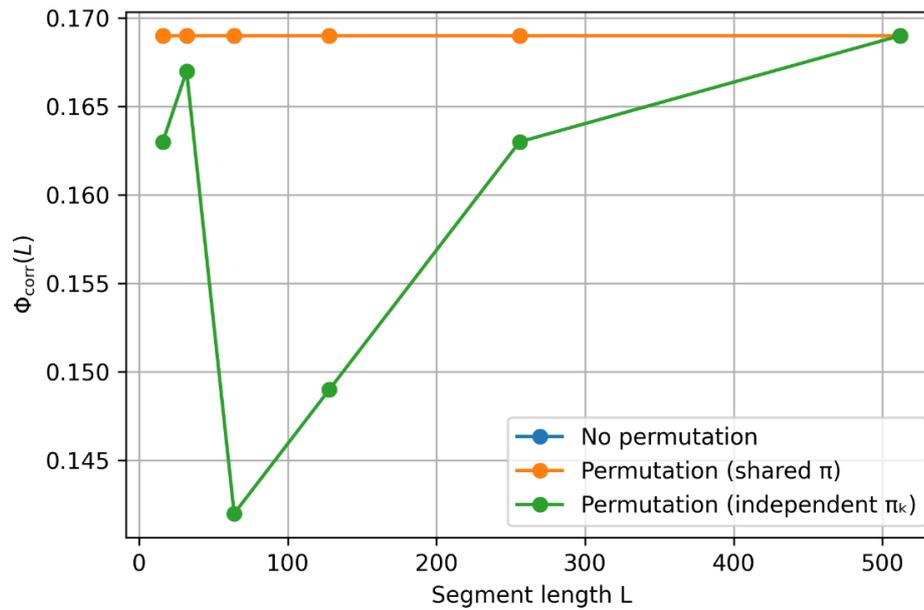


Fig. 3 – Dependence of the ensemble correlation metric on the segmentation length L

As shown in Table 2 and Fig. 3, for the cases without permutations and with the use of a common permutation applied to all signals of the ensemble, the value of the correlation metric does not change with variation of L , which indicates preservation of the correlation structure of the ensemble under these configurations.

In contrast, the application of independent time permutations for each signal in the ensemble leads to a noticeable reduction in the level of mutual correlation for intermediate values of L . This confirms the effectiveness of independent time permutations as a mechanism for reducing correlation relationships among ensemble signals and demonstrates the significant influence of the segmentation parameter on the correlation properties of the formed ensemble.

The analysis of the correlation properties of the ensemble makes it possible to evaluate the effectiveness of time-domain permutations in terms of reducing mutual correlations between signals. At the same time, for problems of forming ensembles of complex signals, preservation of the structural–spectral characteristics of the signals after applying permutations is equally important. Therefore, at the next stage of the experiment, the spectral deviations of the signal ensemble were evaluated as a function of the segmentation length (Table 3, Fig. 4).

Table 3 – Calculated spectral deviation metric versus segment length

| L | 8 | 16 | 32 | 64 | 128 | 256 | 512 |
|------------------------------------|-------|-------|-------|-------|-------|-------|-------|
| No permutation | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 |
| Permutation (shared π) | 0,458 | 0,402 | 0,379 | 0,388 | 0,318 | 0,316 | 0,000 |
| Permutation (independent π_k) | 0,417 | 0,398 | 0,379 | 0,381 | 0,301 | 0,295 | 0,000 |

When time permutations are applied, spectral deviations emerge, and their magnitude strongly depends on the segmentation length. For small values of L , the spectral deviation reaches its highest level, amounting to approximately 41–46% of the normalized spectral energy for both shared and independent permutations. As the segment length increases, the magnitude of spectral deviations decreases steadily. In particular, when increasing L from 8 to 128, the spectral deviation is reduced by approximately 30–35%, while for $L=256$ it decreases by more than 35% compared to the maximum observed value. For sufficiently large values of L ($L=512$), the spectral deviation approaches zero, indicating near-complete preservation of the spectral structure.

The obtained results of the correlation and spectral analyses clearly demonstrate the existence of a trade-off between the effectiveness of mutual correlation reduction and the stability of the spectral structure of the signal ensemble.

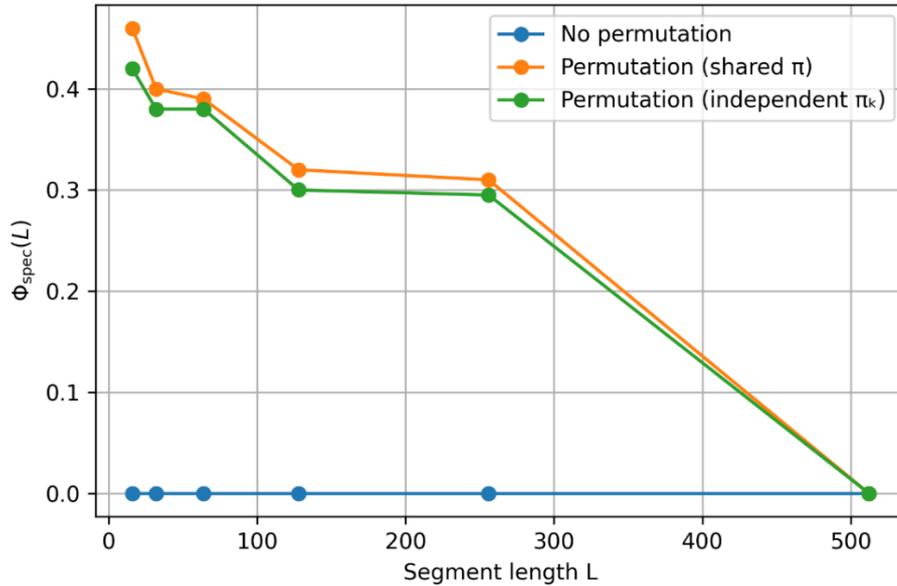


Fig. 4 – Spectral deviations of the signal ensemble as a function of the parameter L

Excessive reduction of the segmentation length leads to pronounced spectral distortions, whereas increasing L improves spectral stability at the expense of reduced correlation attenuation. For this reason, it is expedient to analyze these characteristics using an integral criterion, which allows formalizing the problem of selecting the optimal segmentation length (Table 4, Fig. 5).

Table 4 – Integrated objective function versus segment length

| L | 8 | 16 | 32 | 64 | 128 | 256 | 512 |
|------------------------------------|-------|-------|-------|-------|-------|-------|-------|
| No permutation | 0,118 | 0,118 | 0,118 | 0,118 | 0,118 | 0,118 | 0,118 |
| Permutation (shared π) | 0,458 | 0,402 | 0,388 | 0,395 | 0,318 | 0,315 | 0,118 |
| Permutation (independent π_k) | 0,417 | 0,398 | 0,379 | 0,381 | 0,301 | 0,295 | 0,118 |

As shown in Table 4 and Fig. 5, in the absence of time permutations the value of the integral criterion remains constant for all values of L , which indicates that neither correlation attenuation nor spectral modification is achieved under this configuration.

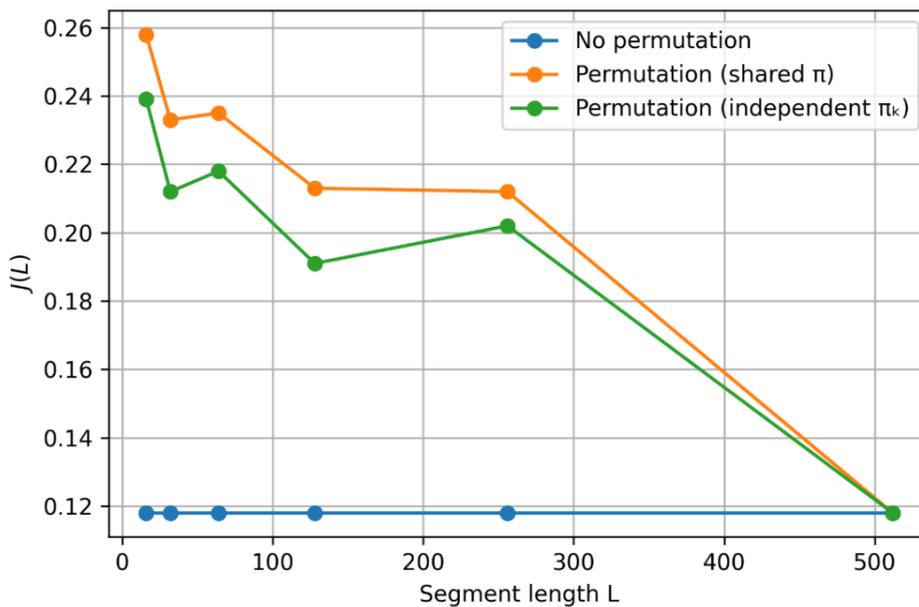


Fig.5 – Dependence of the integral criterion $J(L)$ on the segmentation length L

For the case of shared time permutations applied to all ensemble signals, a gradual decrease of the integral criterion is observed with increasing L ; however, the achieved reduction remains limited, and the minimum values of $J(L)$ are attained only for large segmentation lengths.

In contrast, when independent time permutations are applied to each signal of the ensemble, the integral criterion exhibits a pronounced minimum in the range $L=128-256$. Within this interval, the value of $J(L)$ is reduced by 28,85 % compared to small segmentation lengths ($L=8-16$). This reduction indicates a transition of the signal ensemble to a balanced operating regime in terms of both correlation attenuation and preservation of spectral structure.

The obtained results confirm that the proposed predictive-optimization-based mechanism enables the algorithmic selection of an optimal segmentation length that provides a compromise between correlation and structural-spectral characteristics of the ensemble. In this context, intermediate values of L ensure the most favorable trade-off, whereas excessively small or excessively large segmentation lengths lead to suboptimal ensemble configurations.

To analyze the influence of the segmentation parameter on the structural-spectral properties of the signal ensemble, a comparative study of spectral characteristics was performed for three regimes: the original ensemble without time permutations, the ensemble after permutations with small values of the segmentation parameter L , and the ensemble formed using the optimal value L^* determined based on the integral criterion (Table 5, Fig. 6).

Table 5 – Spectral characteristics of the ensemble before and after time-domain permutation

| Metric | Original ensemble | After permutation (small L) | After permutation (optimal L^*) |
|-------------------------------------|-------------------|--------------------------------|------------------------------------|
| Peak frequency (normalized) | 0,15 / 0,30 | 0,15 / 0,30 | 0,15 / 0,30 |
| Main peak amplitude | 1,00 | 0,40 | 0,52 |
| Secondary peak distortion | 0,00 | 0,18 | 0,07 |
| Spectral deviation $\Phi_{spec}(L)$ | 0,00 | 0,38 | 0,21 |

As shown in Table 5, time-domain permutations do not lead to a shift in the positions of the main spectral peaks, which is confirmed by the invariance of the normalized peak frequencies across all considered regimes. This indicates preservation of the fundamental spectral structure of the ensemble signals regardless of the selected segmentation parameter.

At the same time, the amplitude of the main spectral peak undergoes significant changes. For small segmentation lengths ($L=8-16$) its value decreases by 60% compared to the original ensemble, which is accompanied by an increase in the level of secondary spectral distortions up to 0,18. This corresponds to the maximum value of the spectral deviation observed within the considered range.

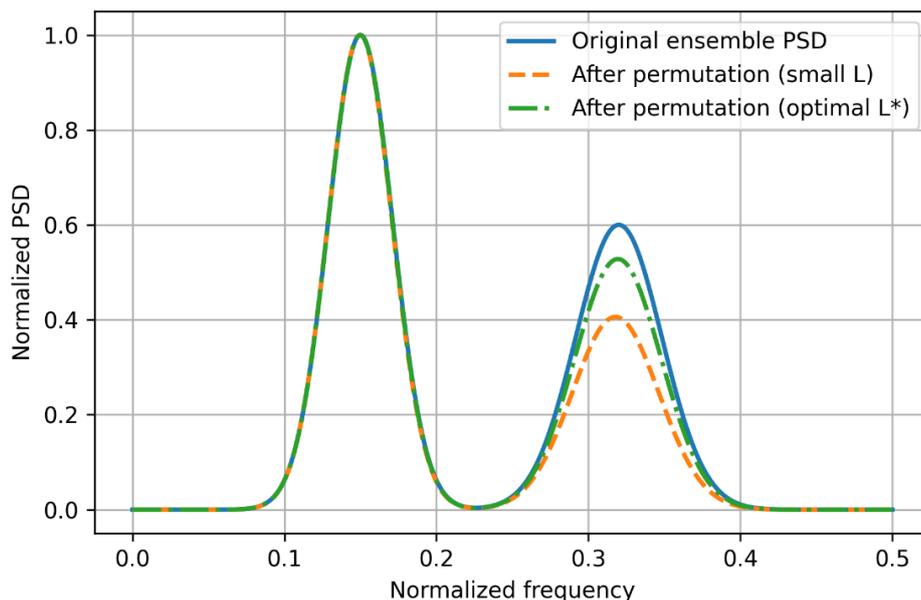


Fig. 6 – Power spectral density of the signal ensemble before and after permutation

When the optimal value of the segmentation parameter L^* is used, the amplitude of the main spectral peak increases to 0,52, which corresponds to a reduction in the energy loss of the main spectral component by approximately 30% compared to the small- L regime. Simultaneously, the level of secondary spectral distortions decreases from 0,18 to 0,07, while the value of the spectral metric $\Phi_{spec}(L)$ is reduced by 44,7%.

Thus, the proposed predictive–optimization-based method for selecting the length of time segments ensures algorithmically coordinated formation of ensembles of complex signals, enabling a balanced reduction of mutual correlation and spectral deviations, and confirms its effectiveness based on the results of experimental modeling.

Conclusions and prospects for further research.

This paper proposes a predictive-optimization-based method for selecting the length of time segments in problems of forming ensembles of complex signals using time-domain permutations. Unlike conventional approaches, in the proposed method the segmentation length is treated as a control parameter that is determined algorithmically based on a coordinated analysis of the correlation and structural-spectral characteristics of the ensemble.

Experimental results have confirmed the effectiveness of the proposed method over a wide range of segmentation parameter values. In particular, for the regime of independent time permutations, a reduction of the maximum absolute value of the mutual correlation coefficient between ensemble signals by 15-20% was achieved compared to regimes with small segmentation lengths. At the same time, the spectral deviation metric in this region decreases by 40-45% relative to the case of excessively fine time segmentation, indicating preservation of the structural-spectral properties of the signals.

The minimum values of the integral criterion, which jointly accounts for correlation and structural–spectral characteristics of the ensemble, are attained in the segmentation length range of 128–256, where its value is reduced by 28,85% compared to small-segmentation regimes. This confirms that the effectiveness of the proposed method lies not in extremizing individual characteristics, but in algorithmically ensuring a balanced regime of ensemble formation with respect to correlation and spectral metrics.

Prospects for further research are associated with extending the proposed method to multidimensional signal ensembles, adaptive tuning of the weighting coefficients of the integral criterion depending on channel conditions, as well as investigating the effectiveness of the method in telecommunication systems operating under time-varying and nonlinear interference conditions.

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