# Reduce The Noise in Speech Signals Using Wavelet Filtering

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## Abstract:

The capacity of the data channels is often reduced due to noise and distortion of the transmitted signals. Noise reduction is used in various areas (where from noise and distortion the transmitted signals cannot be isolated): speech / speaker recognition, image processing, mobile communication systems, medical signal processing, radio and radar systems, etc. This paper illustrates the problem of the presence of noise in speech signals. A model of additive white Gaussian noise is considered and adding it to the speech signal – modeling of noise process. The main features of wavelets, which used in noise reduction, are described. The main algorithm of the noise cancellation process using wavelet analysis techniques is considered. Carried out the practical implementation of noise reduction. The graphs of the original, noisy and cleaned signals are plotted. An analysis of the results of noise cancellation was carried out using different families of wavelets, graphs of the cross correlation of noisy and clean speech signals are plotted. Noise reduction carried out using Matlab programing.

**Keywords:** Digital Signal Processing (DSP), Noise reduction in speech signals, Matlab Wavelet Toolbox, Discrete Wavelet Ttransforms (DWT), Noise reduction.

## الخلاصة

تنخفض قدرة قنوات البيانات غالبا ما بسبب الضوضاء وتشوه الإشارات المرسلة . يستخدم تخفيض الضوضاء في مجالات مختلفة (حيث لا يمكن عزل الإشارات المرسلة من الضوضاء والتشويه): في التعرف على الكلام ومعالجة الصور وأنظمة الاتصالات المتنقلة ومعالجة الإشارات الطبية والأنظمة الراديوية والرادارية وما إلى ذلك. توضح هذه الورقة مشكلة وجود ضوضاء في إشارات الكلام. ويتم النظر في نموذج ضوضاء غوسية بيضاء مضافة وإضافته إلى إشارة الكلام – نمذجة عملية الضوضاء. حيث تم دراسة الميزات الاساسية للمويجات المستخدمة لتقليل الضوضاء. وتم النظر في الخوارزمية الاساسية لعميلة ازالة الضوضاء باستخدام تقنيات تحليل المويجات. تم بناء التنفيذ العملي للحد من الضوضاء. تم رسم الاشارة الاصلية والاشاره المشوهة والاشاره المستخلصه بعد تقليل الضوضاء. تم تحليل نتائج إلغاء الضوضاء باستخدام أسر مختلفة من المويجات، حيث تم رسم الاشكال للصلات المتبادلة بين إشارات الكلام المشوهة والنظيفة.تقليل الضوضاء نفذ باستخدام برنامج ماتلاب.

**الكلمات المفتاحية:** معالجة الاشارات الرقمية، تقليل الضوضاء في اشارة الكلام، ادوات ماتلاب المويجات، تحويل المويجات المنفصلة، تقليل الضوضاء.

## Introduction

Currently wavelets have wide application in the fields of analysis and processing of various signals: the compression and noise reduction, analysis of speech signals in speech recognition systems (Nishanthi *et.al.*,2017), psychological and medical research, such as assessment of Psychological tension, based on multi-level wavelet analysis of the speech signal, acoustic-graphic study of heart tones and sounds, sounds of the lungs, respiratory noises, etc. (Mehmet and O¨ zerdem, 2107, Mohammed *et.al.*,2017). In the analysis of images in digital data transmission systems, various approaches for noise reduction are used for detecting audio signals, etc. SNR is the power of the useful signal to the power of the noise ratio in which meaningful information characterizing the ratio of these power. SNR depended on an additive noise where the undistorted unquantized signal $s\,[i]$ and an additional quantization error $e\,[i]$ are superposition generated the quantized signal $s_q\,[i]$. SNR is usually specified in the logarithmic measure in decibels (dB) in order to cover a wide range of possible SNR values:

$$SNR_{dB} = 10\log\left(\frac{P_x}{P_e}\right) = 20\log\left(\frac{A_x}{A_e}\right) \qquad (1)$$

Where $P_x, P_e$ are the average powers of the corresponding signals, and $A_x$, $A_e$ is the average value of the amplitude. SNR is often called SQNR.

By the nature of the occurrence of the source distinguish mechanical, electric, acoustic, electromagnetic, and other noise. There is also an additional classification of noise based on the frequency and spectral characteristics: white noise, white noise with limited bandwidth, narrow band noise, colored noise, impulsive noise, temporal noise pulses, etc. An Uncorrelated random noise process known as white noise, which has the same energy at all frequencies in the range of therefore there must be an infinite energy, as a result of which this kind of noise is a purely theoretical concept (Bahoura and Rouat, 2006). However, the process of the noise with a uniform spectrum covers the all frequency ranges and a narrow bandwidth of the limited system, so it can practically be attributed to white noise. The noise is stationary (AWGN) in classical communication theory.

AWGN is added to the speech signal, a denoising method depends on wavelet analysis is performed using different wavelet families. Then the results are analyzed. Consider the proposed model and the results of a research paper.

## Wavelets characteristics

Wavelets have two characteristics: the scaling factor and the shift the relationship between them approximately corresponds to the scaling operation. Compressed wavelets are used, at high scales wavelets stretch, they correspond to slowly varying signals (low frequency). At low scales, they correspond to rapidly changing signals (high-frequency). Unlike other transformation tools (Fourier transforms, etc.) Used in signal processing, wavelets allow to analyze signals in both frequency and time domains. Wavelet transforms have two types: continuous and discrete wavelet transforms. Both transformations are continuous in time (analog), and with their help it is possible to represent analog signals. The continuous wavelet transforms (CWT) allows you to use all possible scaling factors and the shift, while the in discrete wavelet transforms (DWT) used their specific subset (grid). The number of zeros at $\pi$ when the coefficients of the wavelet functions are represented as a Z-transform will be matched to the number of vanishing moments.

The coefficients of the polynomial of the $n-th$ order will be zero at the presence of $n$ vanishing moments. Which means, all polynomial signals reach to $n-1$ order will be fully expressed in a scaled space. Theoretically, the scaling function can accurately represent a larger number of complex signals when the number of vanishing moments large. So the accuracy of the wavelet can be known as the number of vanishing moments $n$.

The Daubechies wavelets are discrete wavelet transforms that the most commonly used and they are a family of orthogonal wavelets. In each type of orthogonal wavelet, the scaling function performs a multiple-resolution analysis. Daubechies wavelets are selected in such a way that the number $Y$ of vanishing moments is highest (does not mean the better softness) for a specified support width $M = 2Y$ (Pandiaraj and Shankar, 2014). Among $2^{Y-1}$ possible solutions preferred embodiment is the wavelet whose scaling filter has an external phase.

Coiflets are discrete wavelets. These wavelets are almost symmetrical and having vanishing moments and scaling functions, their wavelet functions have scaling functions $M / 3 - 1$ and $M / 3$ vanishing moments.

Daubechies Wavelets the ninth and tenth orders (db9 and db10) are asymmetric (Mazurkin, 2014), orthogonal and biorthogonal, the wavelets Coiflets of the fifth order (coif5) is almost symmetric, orthogonal and biorthogonal.

## The way of filtering (details and approximations)

In most signals, their high-frequency and low-frequency components. Low-frequency components can be used to identify the signal so it is considered as the most important part (Sundararajan, 2015). The high-frequency component in turn carries the outlines of the signal. If a high-frequency component is removed from the human voice, then the voice will change, but the words will remain recognizable. However, if you remove a large number of low-frequency signal components of the human voice, the speech becomes unrecognizable. In wavelet analysis, approximations are investigated on a large scale, low-frequency components and detailing on small ones (Vikram and Sukhjinder, 2015). In Fig. 1 shows the decomposition of the signal for one step filtering by wavelet analysis, where HPF is a high-pass filter, LPF is a low-pass filter, D is the detail and A is the approximation.

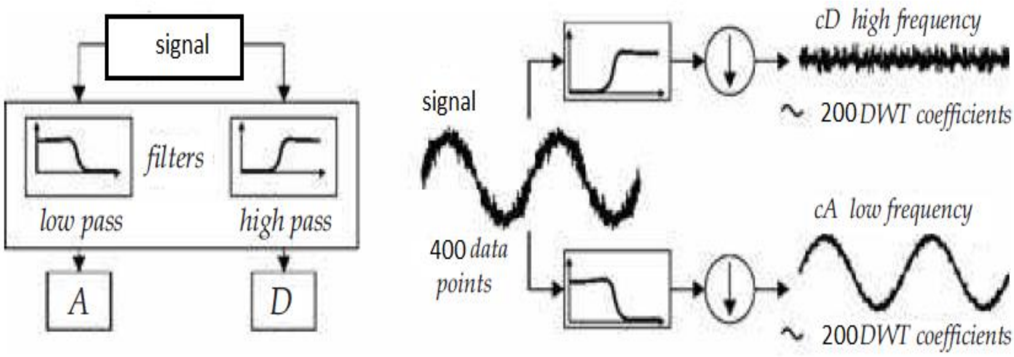


**Fig. 1. Decomposition of a signal by wavelet analysis**

Can be repeated iteratively the decomposition process, where the sequential decompositions decomposed in such a way that one signal is divided into many of signals of lower resolution.

Then the decomposition process is iterative, in practice, the process can continue as long as the individual details consist of a single pixel or sample. In theory, it can be continued indefinitely.

## Thresholding

Thresholding (Threshold Data Processing) is a technique for studying signals that contain noise, which decomposes the original signal into a wavelet spectrum, which is further processed. The wavelet spectrum is a function that contains two arguments (time and scale). The result of the discrete wavelet transform is N sequences in which the number is the coordinate of the scale, and the element number in the sequence is the time coordinate. For the original signals of a large length, $N$ is a small size (it is limited to $\log_2 N$, where $N$ is the number of samples of the signal). In a discrete wavelet spectrum, sequences may have a large value (of the order of $N^2$), which allows them to be processed independently of each other. Hard Thresholding (combined with the adaptive algorithm of threshold selection) allows to remove noise in the absence of auxiliary information about the signal.

## Noise reduction

First, for a noisy signal, a wavelet-packet transformation is performed, then a threshold processing (Thresholding) of the data is performed in the wavelet decomposition tree. Using the Daubechies Wavelets of the tenth order, the Daubechies Wavelets of the ninth order, Symlets of the fourth order and Coiflets fifth order. The practical implementation of noise reduction can explain where at the first the signal can be obtained by using the command (mtlb) then adding (AWGN) to the signal, using one of the three mother wavelets, using level (3), creating a tree and finally obtain de-noising signal. Cross correlation between de-noising signal and original signal to decide the best result.

## Analysis of results

The cross correlation function is used as the noise reduction analysis metric. Cross correlation function is a function that estimates the correlation level of two sequences (Tanmay and Mrinal, 2016). For continuous sequences are determined by the formula

$$(f * g)(t) = \int_{-\infty}^{\infty} f^*(\tau)\, g(t+\tau) d\tau \qquad \textbf{(2)}$$

For discrete:

$$(f * g)_i(t) = \sum_j f_j^*\, g_{i+j} \qquad \textbf{(3)}$$

The families of wavelets used showed the following results of the average values of the mutual correlation function at the point 0:

- The Daubechies Wavelets of the tenth order is 0.79382;
- The Daubechies Wavelets of the ninth order - 0.78865;
- Symlets of the fourth order - 0.78883;
- Coiflets fifth order - 0.78776.

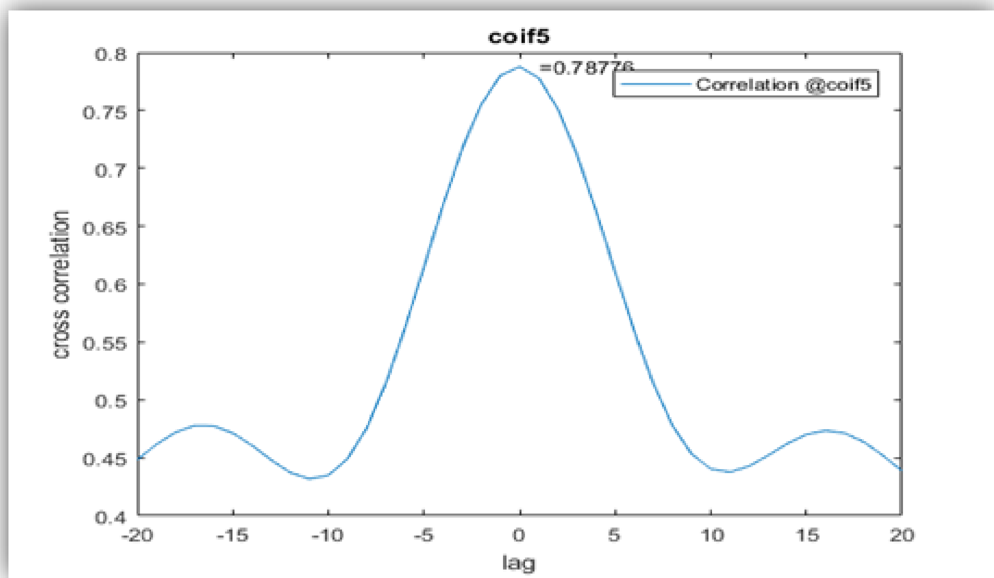


**Fig. 2. Graphs of the cross-correlation functions for noise cancellation using the Coiflets (the value at the zero point is 0.78776) of the fifth order**

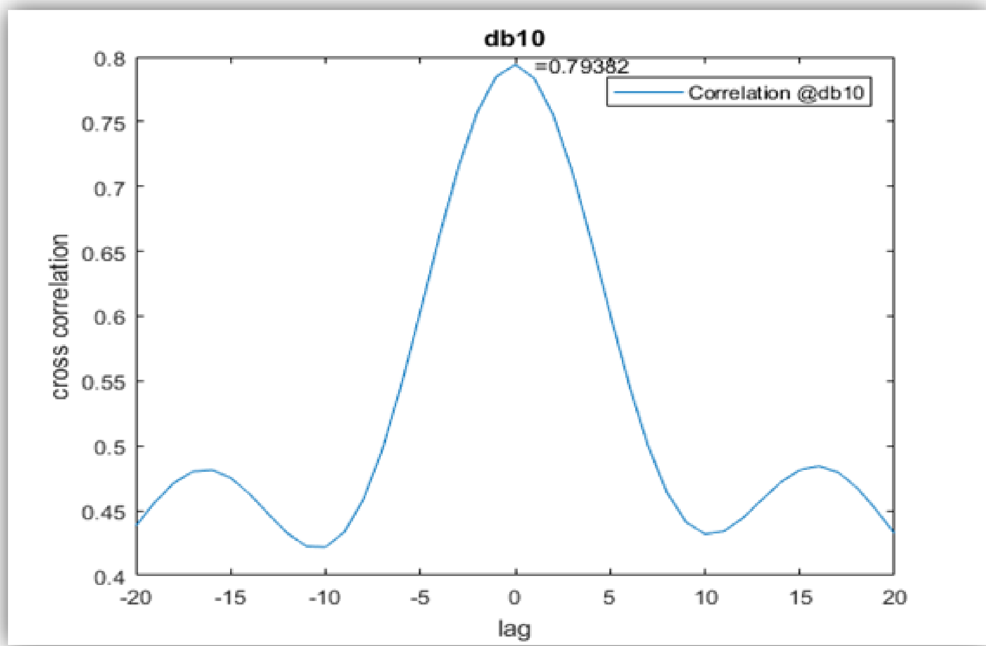


**Fig. 3. Graphs of the cross-correlation functions for noise cancellation using the Daubechies wavelet (the value the zero point is 0.79382) of the tenth order**

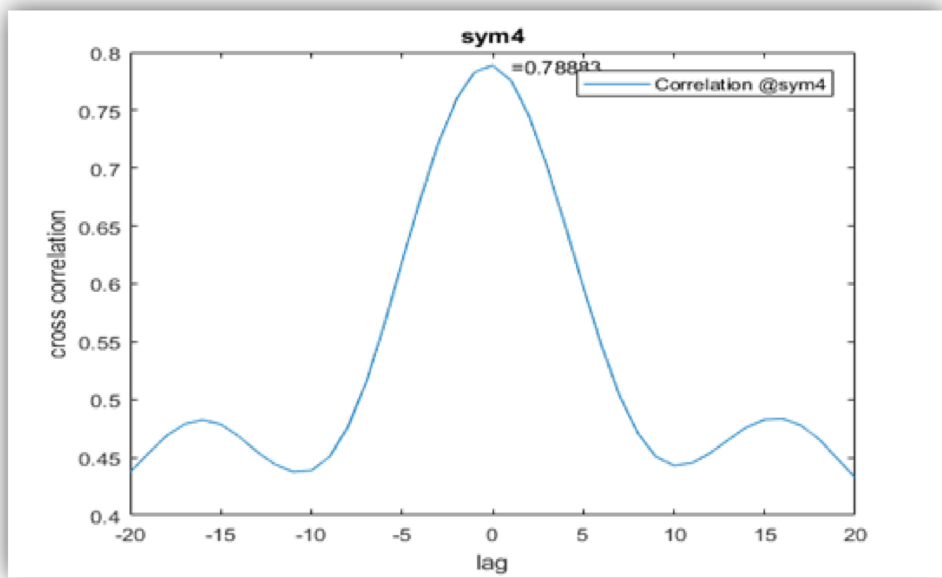


**Fig. 4. Graphs of the cross-correlation functions for noise cancellation using the at fourth-order Symlets (the value at the zero point is 0.78883)**

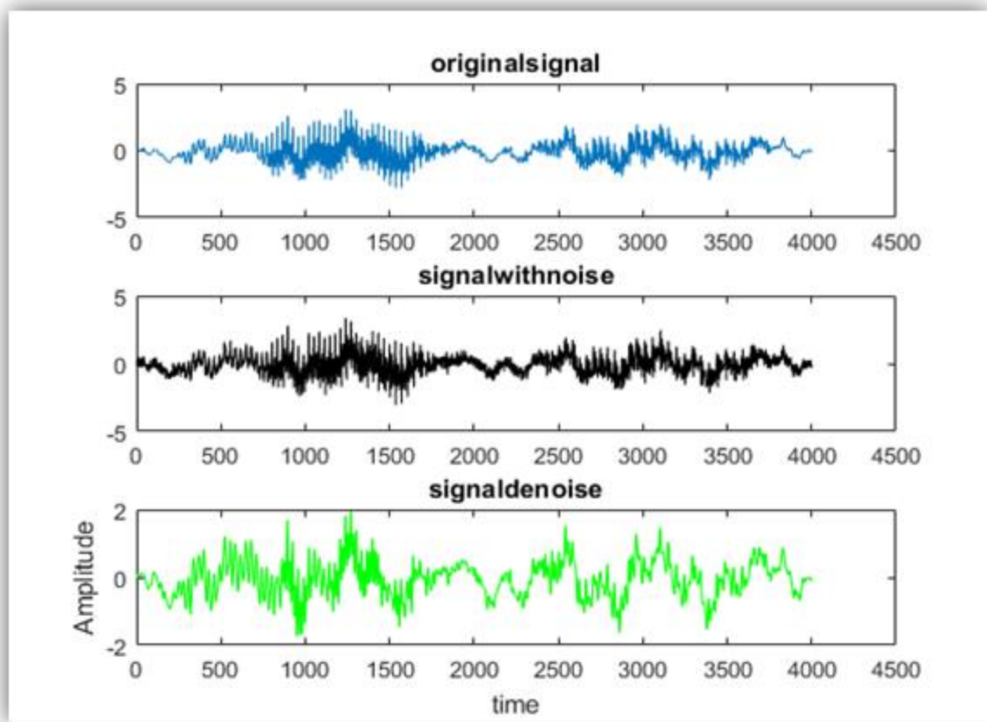


**Fig. 5. Noise reduction with the use of the wavelet Coiflets of the tenth order**

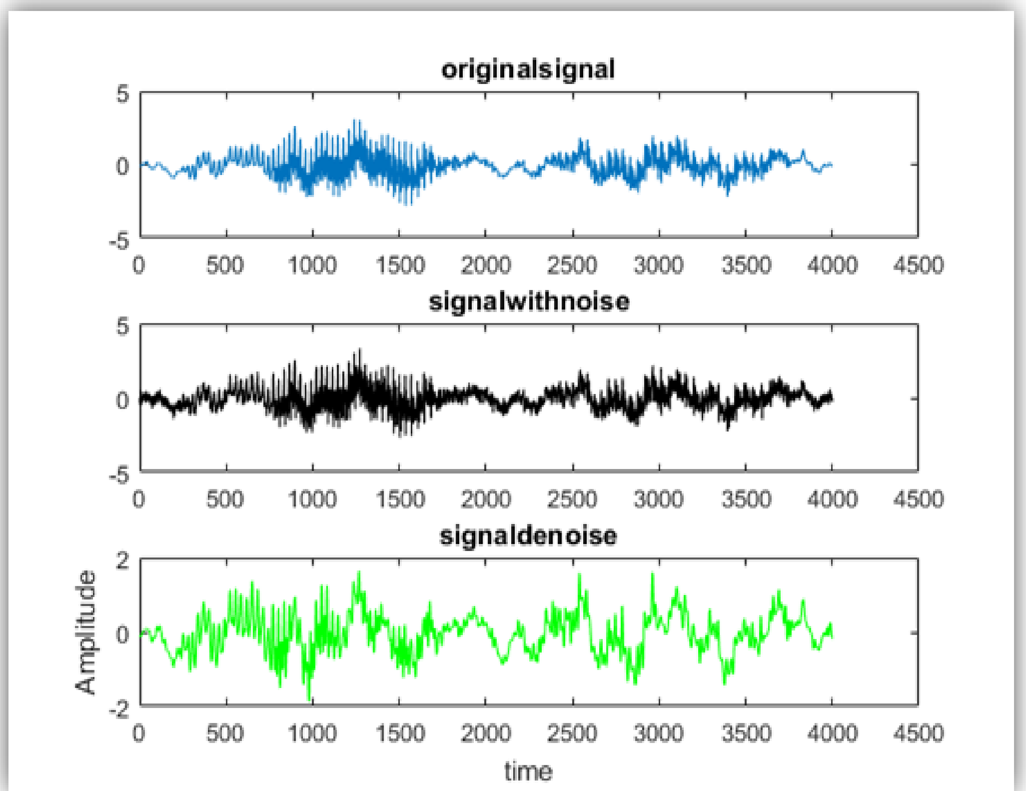


**Fig. 6. Noise reduction with the use of the Daubechies wavelet of the tenth order**

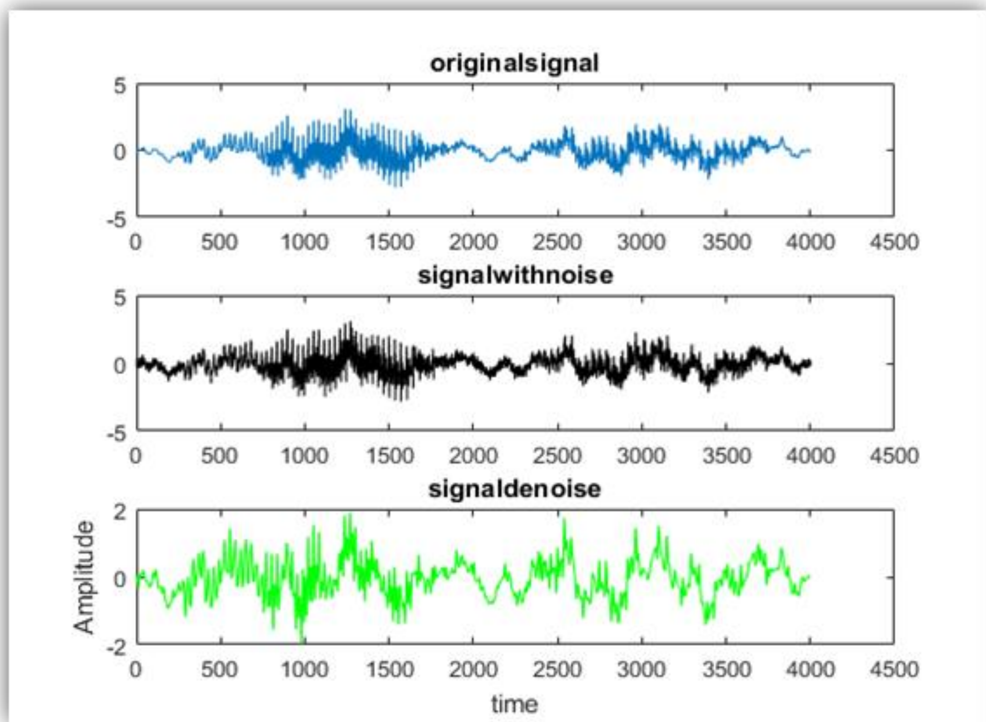


**Fig. 7. Noise cancellation using a fourth-order Symlets**

The greatest significance was for the Daubechies wavelet of the tenth order and the fifth-order coiflets (Figures 2-7).

## Conclusion

This article describes the practical implementation of noise cancellation in speech signals based on wavelet analysis**.** A comparison is made between the use of wavelets of various families: nine and tenth order Daubechies wavelets, a fourth order Symlets, and fifth order wavelet Coiflets. The value of the cross-correlation at the point 0 for all families is of the order of 0.8, the graphs of the functions have the correct form, taking into account that the original signal contained some noise component, and in addition to it, white Gaussian additive noise was added, the results of noise suppression are sufficiently high.

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