

Izabela JÓZEFczyk

Warsaw University of Technology, Engineering, Mechanics and Petrochemistry Department,
Technical and Social Science School
ul. Łukasiewicza 17, 09-400 Płock, Poland
Corresponding author. E-mail: izaj@pw.plock.pl

**WAVELET TRANSFORM OF SELECTED SIMULATION SIGNALS USING
DETAILS AS INFORMATION SOURCE**

Summary. Diagnostic signal is one of the information source on the technical device condition. It is assumed it is a sum of determined component and random component. Most often the determined part, i.e. approximation is being processed, omitting details. Random component gives information on noise and interferences occurring during device operation, but it also contains valuable diagnostic information. These are the subject of the article, and more precisely an answer to a question: whether determined component, i.e. pure signal from details may be recovered and whether the best results are somehow connected with signal obtained from approximation?

**TRANSFORMATA FALKOWA WYBRANYCH SYGNAŁÓW
SYMULACYJNYCH Z WYKORZYSTANIEM DETALI, JAKO ŹRÓDŁA
INFORMACJI**

Streszczenie. Sygnał diagnostyczny jest jednym ze źródeł informacji o stanie urządzenia technicznego. Przyjmuje się, że jest on sumą składowej zdeterminowanej oraz losowej. Najczęściej zajmuje się obróbką części zdeterminowanej, czyli aproksymacji, pomijając detale. Składowa losowa niesie informacje o szumach i zakłóceniach występujących podczas funkcjonowania urządzenia, lecz także zawiera ona wartościowe informacje diagnostyczne. To właśnie one są przedmiotem artykułu a dokładniej odpowiedź na pytanie: czy można odzyskać składową zdeterminowaną, czyli czysty sygnał z detali i czy najlepsze wyniki są w jakiś sposób związane z sygnałem uzyskanym z aproksymacji?

1. INTRODUCTION

Diagnostic signal is one of the information sources on technical device condition [1 - 3, 10, 12, 13]. It contains, however also much needless information, often called a noise. It is assumed the signal is a sum of determined component and random component.

The practice shows that determined component gives information on inaccuracy of execution and installation, and superficial and volumetric wear of device. Despite the fact these values are random, their existence and information about them are determined. Because diagnostic procedure's purpose is to obtain this information, separation of determined component from random component may facilitate signal handling and its decoding [4 - 9, 11].

Random component gives information on noise and interferences occurring during device operation. Although the valuable diagnostic information may be included in this component as well, it is usually omitted, and the separation is made by filtering the random component from determined component. Wavelet transform is used for such separation.

2. RESEARCH

The question has been asked: whether determined component, i.e. pure signal from details (noises) may be recovered and whether the best results are somehow connected with signal obtained from approximation?

To try to find answers to these questions the following experiment has been conducted: Two signals have been generated: stationary signal– sinusoid with random background from interval [0;0.8] and non-stationary signal with the form $\sin\left(\frac{2\pi t}{0.7 + 0.18\sqrt[3]{t}}\right)$ with the same random background.

Signals without random background have been assumed as standards, i.e. determined component. Random background in model of signal has been obtained by generating their values from random-number generator (los()) function from Excel spreadsheet multiplied by 0.8).

Signals with background were transformed with wavelet transform using dmey wavelet on first, second and third level of decomposition. This wavelet was selected for the sake of good results from previous research [7 - 9]. Wavelet transform coefficients were obtained then. They became the base for reproduction of signal first time considering details from given level of decomposition, and second time considering approximation from the same level. Signal was reproduced in part which was assumed as determined component and then correlation coefficient of this signal and determined part of simulating model was calculated. Juxtaposition of wavelet transform results with correlation coefficient of this two values was supposed to help to answer the questions. Graphical form of research is shown in diagrams 1-8 for stationary signal and 9-16 for non-stationary signal. Correlation coefficients are shown in table 1 for stationary signal and in table 2 - for non-stationary signal. In the first row of table signal correlation coefficient with and without background is shown, and in the next ones - correlation coefficients determining resemblance between the signal and the background, which has been transformed with wavelet transform using demy wavelet on first, second and third level of decomposition, with the same signal but without the background for signals obtained from approximations and then details.

2.1. Stationary signal

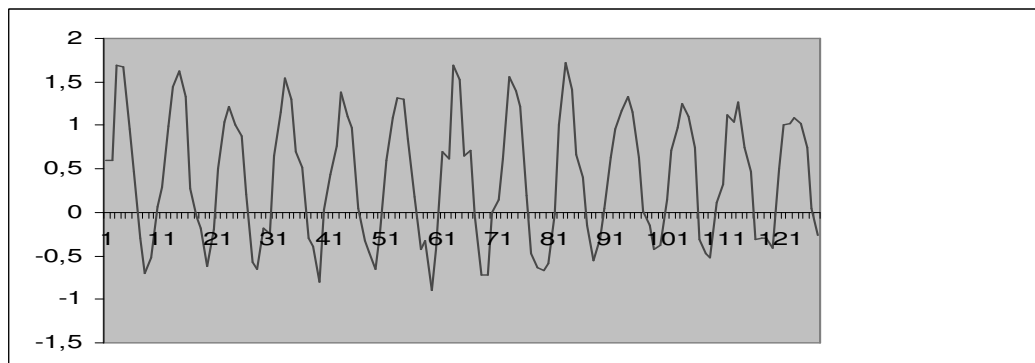


Fig. 1. Stationary signal under examination

Rys. 1. Badany sygnał stacjonarny

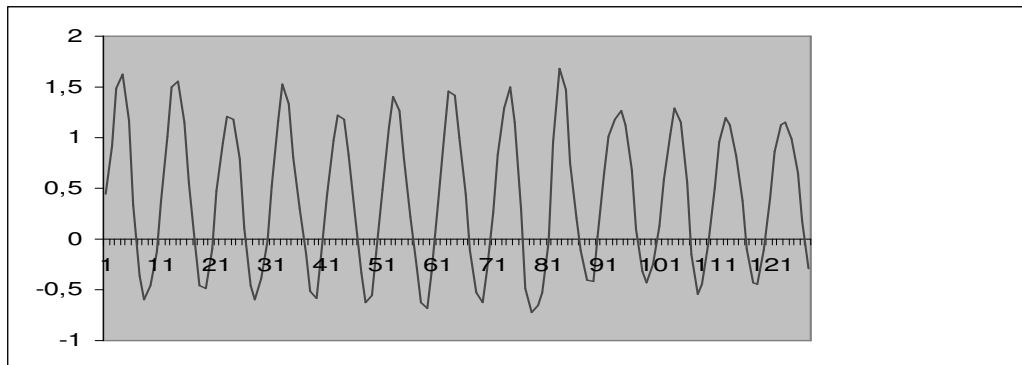


Fig. 2. Stationary signal approximation, dmey1

Rys. 2. Aproksymacja sygnału stacjonarnego, dmey1

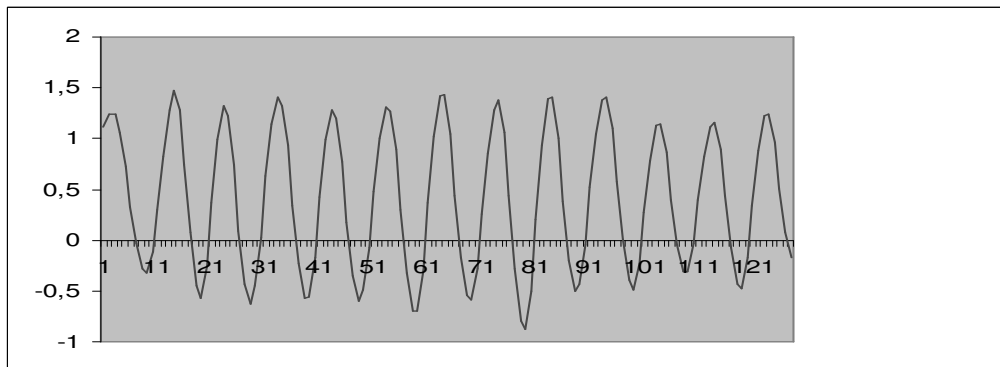


Fig. 3. Stationary signal approximation, dmey2

Rys. 3. Aproksymacja sygnału stacjonarnego, dmey2

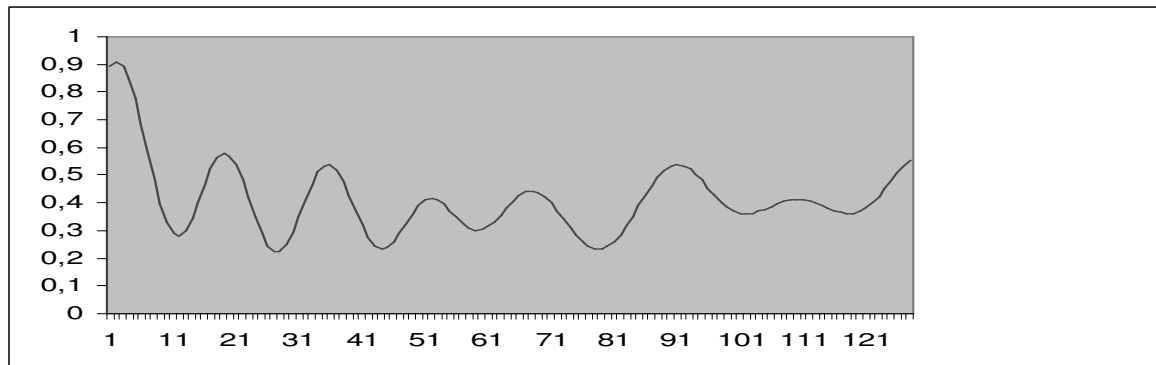


Fig. 4. Stationary signal approximation, dmey3

Rys. 4. Aproksymacja sygnału stacjonarnego, dmey3

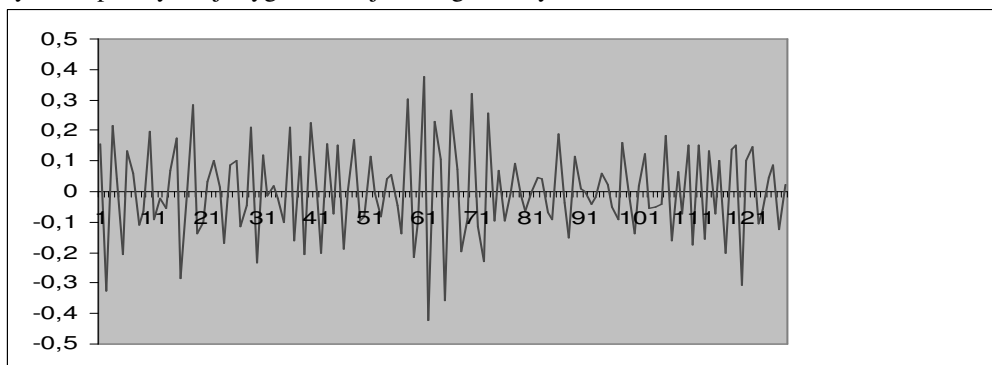


Fig. 5. Stationary signal detail, dmey1

Rys. 5. Detal sygnału stacjonarnego, dmey1

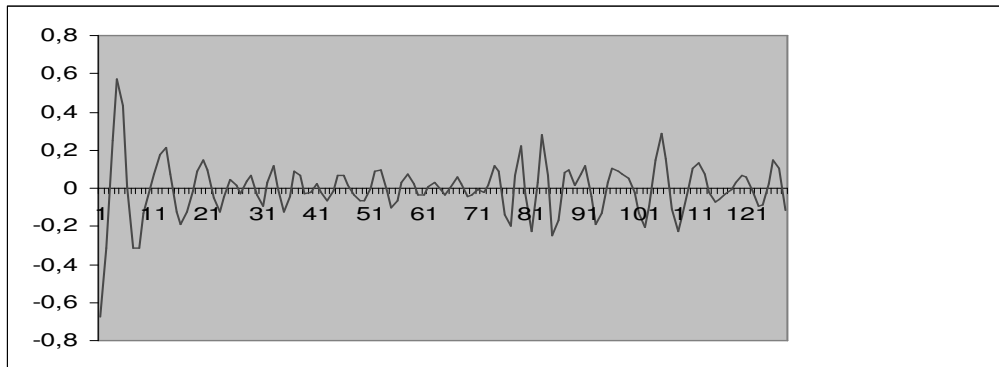


Fig. 6. Stationary signal detail, dmey2
Rys. 6. Detal sygnału stacjonarnego, dmey2

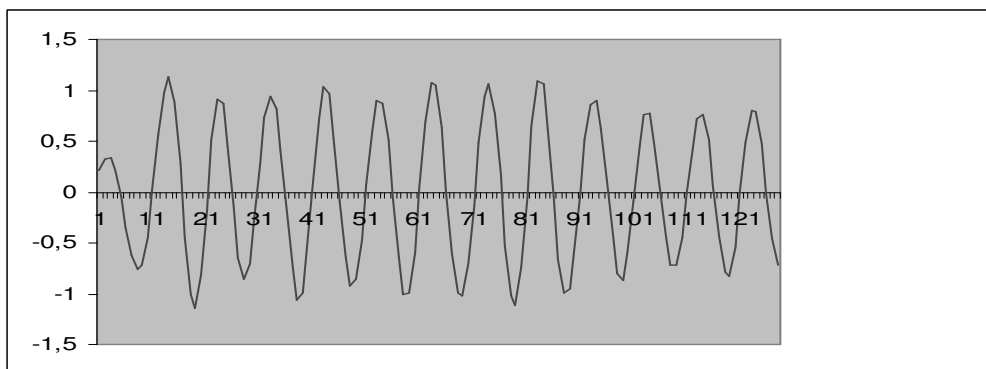


Fig. 7. Stationary signal detail, dmey3
Rys. 7. Detal sygnału stacjonarnego, dmey3

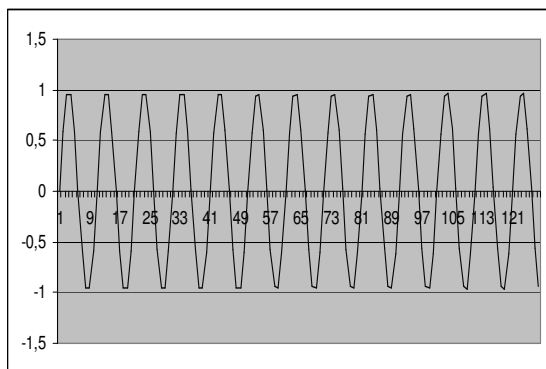


Fig. 8. Determined component of stationary signal
Rys. 8. Składowa zdeterminowana sygnału stacjonarnego

Table 1

	correlation coefficient of
signal with signal with background	0,95358676
signal with approximation dmey1	0,99985645
signal with approximation dmey2	0,97482215
signal with approximation dmey3	0,096016526
signal with dmey1 detail	-0,000663391
signal with dmey2 detail	0,118736605
signal with dmey3 detail	0,972224383

2.2. Non-stationary signal

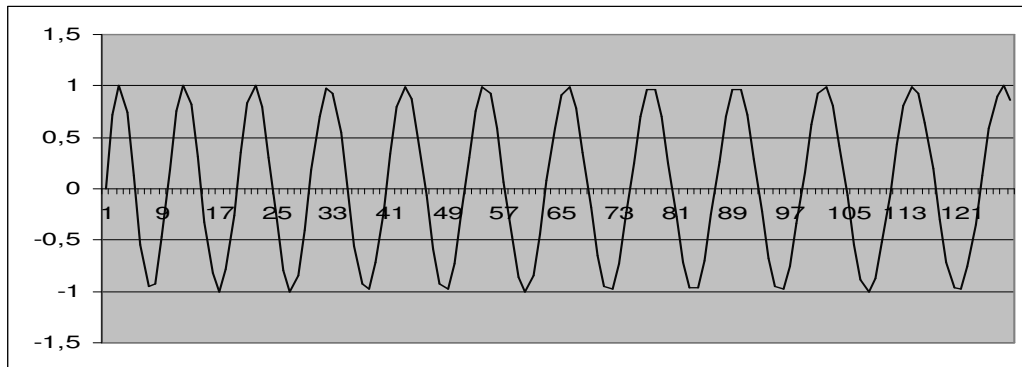


Fig. 9. Determined component of non-stationary signal

Rys. 9. Składowa zdeterminowana sygnału niestacjonarnego

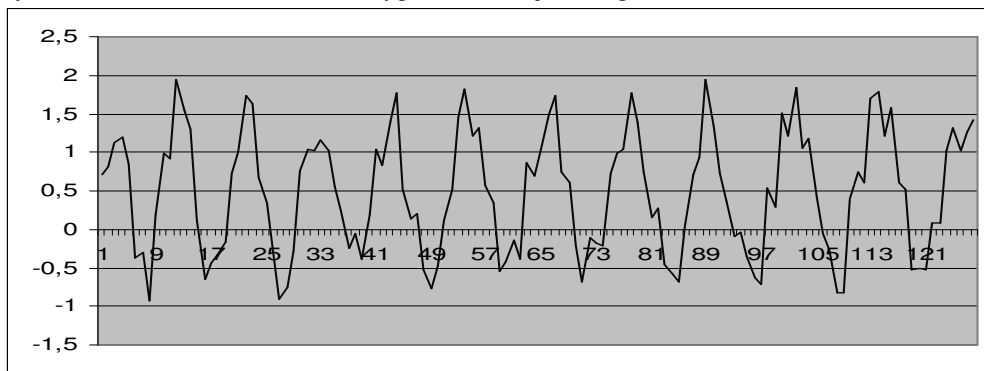


Fig. 10. Non-stationary signal under examination

Rys. 10. Badany sygnał niestacjonarny

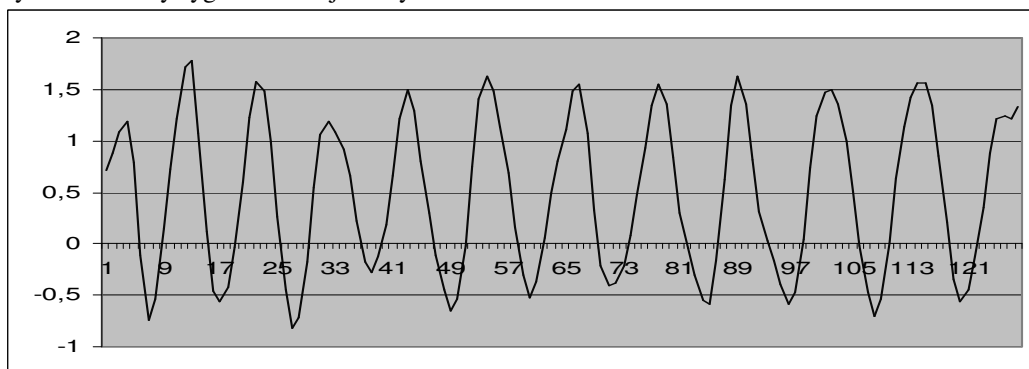


Fig. 11. Non-stationary signal approximation, dmey1

Rys. 11. Aproksymacja sygnału niestacjonarnego, dmey1

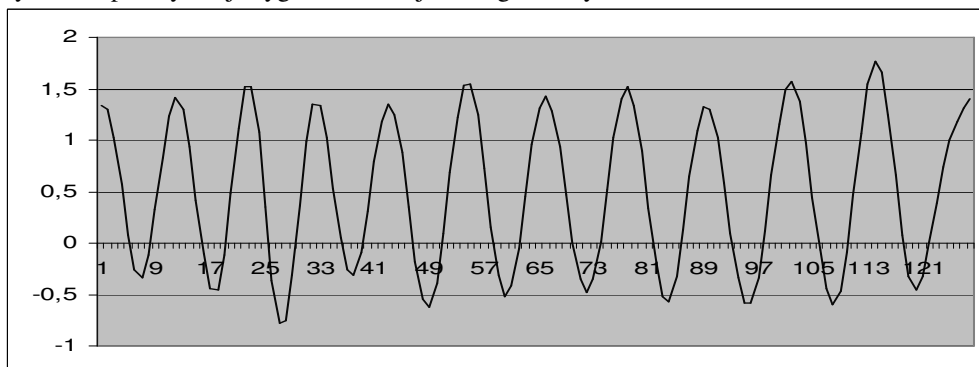


Fig. 12. Non-stationary signal approximation, dmey2

Rys. 12. Aproksymacja sygnału niestacjonarnego, dmey2

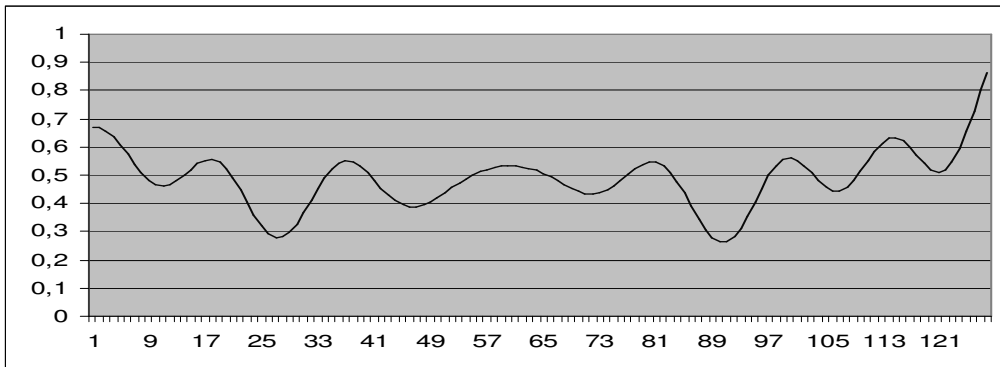


Fig. 13. Non-stationary signal approximation, dmey3

Rys. 13. Aproksymacja sygnału niestacjonarnego, dmey3

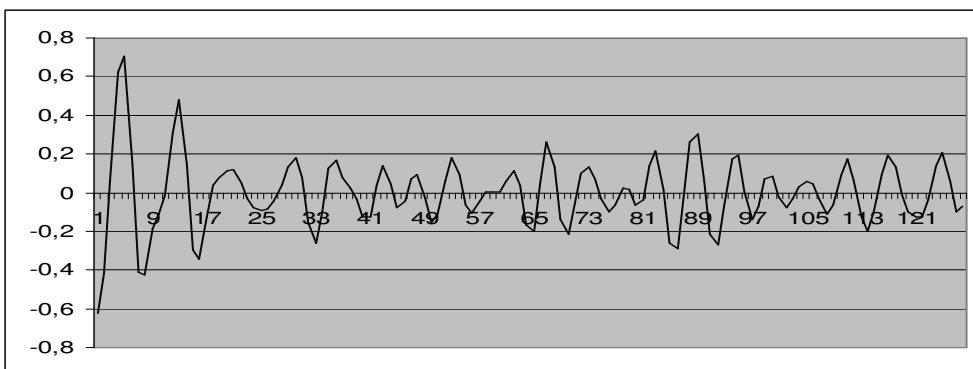


Fig. 14. Non-stationary signal detail, dmey1

Rys. 14. Detal sygnału niestacjonarnego, dmey1

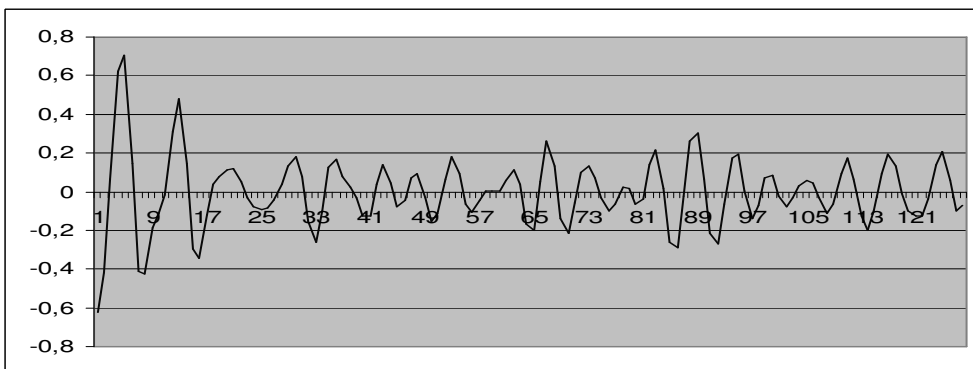


Fig. 15. Non-stationary signal detail, dmey2

Rys. 15. Detal sygnału niestacjonarnego, dmey2

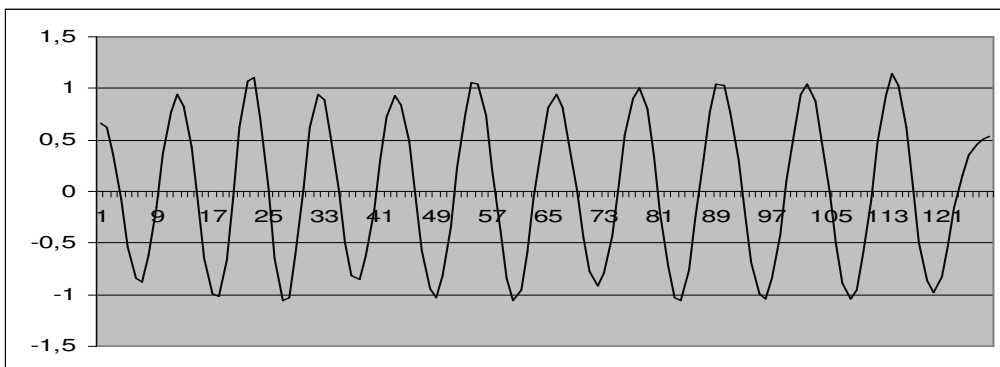


Fig. 16. Non-stationary signal detail, dmey3

Rys. 16. Detal sygnału niestacjonarnego, dmey3

Table 2

	correlation coefficient of:
signal with signal with background	0,930167942
signal with approximation dmey1	0,969856193
signal with approximation dmey2	0,965098257
signal with approximation dmey3	0,157919549
signal with dmey1 detail	0,001306072
signal with dmey2 detail	0,142297235
signal with dmey3 detail	0,963454674

3. CONCLUSIONS

Determined component may be also obtained based on details, i.e. noises, whereas the fact the best results in determined component recovery were for example on first level of decomposition does not imply the best results in obtaining this component from details are also on this level. Reverse dependence may be rather observed, i.e. when correlation coefficient for approximation decreases, then it increases for detail, what should have been expected.

Research mentioned in this work and works listed in bibliography [4-9] incline the conclusion that better results are obtained using wavelet transformation considering approximation, not detail.

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