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Informational essence of flicker-noise

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Abstract

It was presented the computer simulation results of chaotic motion. They showed that flicker-constituent noises were contained the information about explored system features of internal structure. The criterion for estimation the change of mentioned structure by means of flicker-noises was offered.

Keywords: flicker-noise, spectral density, internal structure, time of relaxation.

Informacyjna zawartość fliker-szumu

Streszczenie

Podano wyniki komputerowego modelowania chaotycznego ruchu, które pokazują, że fliker-składowa szumu zawiera informację o osobliwościach wewnętrznej struktury badanego systemu. Zaproponowano kryteria oceny zmiany wewnętrznej struktury na podstawi fliker-szumów.

Słowa kluczowe: fliker-szum, gęstość widmowa, struktura wewnętrzna, czas relaksacji.

1. Statement of a problem

Rather small chaotic diversions from medial significance of measurands (noises), and also parameters of many processes are the obstacle at the increase of precision of measuring, at the increase of sensitivity of receiver or measuring equipment. The study of physic of noises enables to find the methods of their diminution, and also give the confirmation that they are informing signals [1], which can be used for a quantitative and qualitative estimation of separate parameters and a whole system. An example of using of noises for a quantitative assessment of an energy state of system is the finding of temperature using a level of thermal noises [2], which is found on medial frequencies in actual conditions (from ones kHz - up to tens MHz [3]). For the estimation of a qualitative state of system the noise can be used which is observed on low frequencies (from ones kHz and below [3]), - flicker-noise (noise such as 1/f), as in a series of the publications, which concern the flicker-noise [4-7], there are pointed on his connection with the structure of the system. Basis on this, it is useful to make the investigations to find out the dependence between features of internal structure of system and its flicker-noise.

2. The analysis of last examinations and publications

In publication [8] there were examined the perspective of using of chaotic series of dynamic variables of different essence which are received during the examinations of different natural processes and structures and are presented mainly as a time series or spatial series and cards, for receiving the information about a state of explored system, the specificity of its evolution, the features of its structure organization. And the accent is made on the analysis of flicker-noise dependences of a spectrum of power of a signal, which is forming by a sequence of ^-functions [9]. It is offered to determine the information about processes, which occur in the system, using the interpolation of a resulting spectrum of power, determined on the basis of experimental values of a time series, by expression [8]:

$$S(f) = \frac{S(0)}{1 + (2\pi f T_0)^n}, \qquad (1)$$

where $S(0)$, T_o and n - phenomenological parameters („the passport parameters"), which help to distinguish the explored complex structures or the dynamic of explored evolution of open dissipative systems. Parameter n characterizes the velocity of „lose of memory" (the correlation connections) in the sequence of splashes on time intervals; parameter T_o has the content of time of a correlation; $S(0)$ - the spectral density on medial frequencies. So at n- 4 in the explored system there is a turbulent diffusion; at n = 5/3 - there is completely advanced turbulence etc. [8]. The comparison of values of „passport parameters", received at the analysis of time series, with their values, defined for special cases, enables qualitatively to present character those complex processes, which cause explored evolution.

A method of flicker-noise diagnostics (flicker-noise spectroscopy - FNS-method), offered in [8], has also obvious defects: finding (selection) values of the parameters T_o and n, at which the expression (1) with satisfactory precision would approximate an actual spectrum, are inconvenient.

In [10] the effects(results) of computer modeling of a chaotic motion of fundamental particles are presented and on the basis of the analysis of their spectrums can be said, that for the formation of flicker-component of a spectrum of noises the most important is the internal structure of explored system. In [11] the hypothesis of rising of a flicker-component of a spectrum of noises in systems is substantiated, which are in a no equilibrium state and the

empirical expression for spectral density of noises in no equilibrium systems is given:

$$S(f) \sim \frac{a * e^{f*\tau}}{e^{f*\tau} - 1}, \qquad (2)$$

where a - value of spectral density in the field of medial frequencies; τ- time of relaxation of system.

In contrast to (1) expression (2) enables unambiguously to find a relaxation time of system τ basis on experimentally determined *S(f)*. It is obvious that from [10] τ is structurally sensing quantity and using τ and its change it is possible to make the deductions about features of internal structure of explored system and its(her) change.

3. The purpose of the work

The purpose of the work is the examination of influence of features of internal structure of explored system on its relaxation time and determination of criterion, basis on which using a flicker-component of experimentally solved spectrum of noises it is possible to make the conclusion about the internal structure of exploring system and its change.

4. Examinations

There were used computer modeling of a chaotic motion of fundamental particles and method described in [10]. The objects of examinations were the systems with ordered structures and unordered structures. The flat rectangle with placed in the particular order 40 vertical opaque bafflers of identical length in it correspond the ordered structure. The chaotic arrangement of the same bafflers corresponds the unordered structure.

In fig. 1 the rectangle with placed 1000 balls and vertical bafflers and the energy spectrums, which correspond the medial velocity of balls 20 mps and 200 mps at root-mean-square diversions of velocity accordingly 10 mps and 100 mps is presented.

There are given the values of quantities a and τ in the table 1, determined at spectrums of a fig. 1, which are in the formula (2): $a = S(50)$, as $(f>50) = \text{const}$, $\tau = 1/2\pi f_0$, where f_0 is spotted from a requirement: $S(f_0) = 1{,}58a$.

Tab. 1. The value of parameters a and τ, which were determined using the spectrums on fig. 1 and formula (2)
Tab. 1. Wartości parametrów a oraz τ, wyznaczone według widma rys. 1 oraz wzoru (2)

Energy spectrum	*a, Joule*		*τ , s*	
	v=20 m/s	v=200 m/s	v=20 m/s	v=200 m/s
Fig. 1a	0,17	2,80	0,21	0,15
Fig. 1b	0,17	2,27	0,20	0,04
Fig. 1c	0,18	2,71	0,18	0,03
Fig. 1d	0,18	2,78	0,08	0,04
Fig. 1e	0,18	2,82	0,09	0,05
Fig. 1f	0,18	2,40	0,12	0,03

The analysis of the results given in the table 1, gives the possibility to say the following:

1) spectral density of noises $S(f)$ in a region of medial frequencies (f = 50 GHz for the this model) does not depend on the internal structure of system, noises of which are explored; on medial frequencies $S(f)$ depends only on the velocity of a motion of particles, and can be approximated by the known formula of Nyjkvist [12]: $S(f) \sim 4kT$;
2) the time of relaxation τ, that influences on rising of spectral constituents in the field of low frequencies (2), at small velocities of a motion of particles (v=20 m/s) particularly depends on the internal structure of explored system, and for systems with ordered structure (fig. 1a, b, c) the time of relaxation is major, than for systems with unordered structure (fig. 1d, e, f). Besides the value τ is different for different structures, (against to the value a, which is practically identical), that is coordinated with known experimental results [4, 13] about unique spectrum of flicker-noise (to provide the identity of internal structures of actual explored samples is a difficult task).
3) the time of relaxation τ depends also on the velocity of a motion of particles v: these dependence is inversely and weaker than the dependence a from v. With increasing of velocity v the time of relaxation τ decreases (tab. 1), that causes according to (2) the rising of spectral constituents on low frequencies (fig. 1).

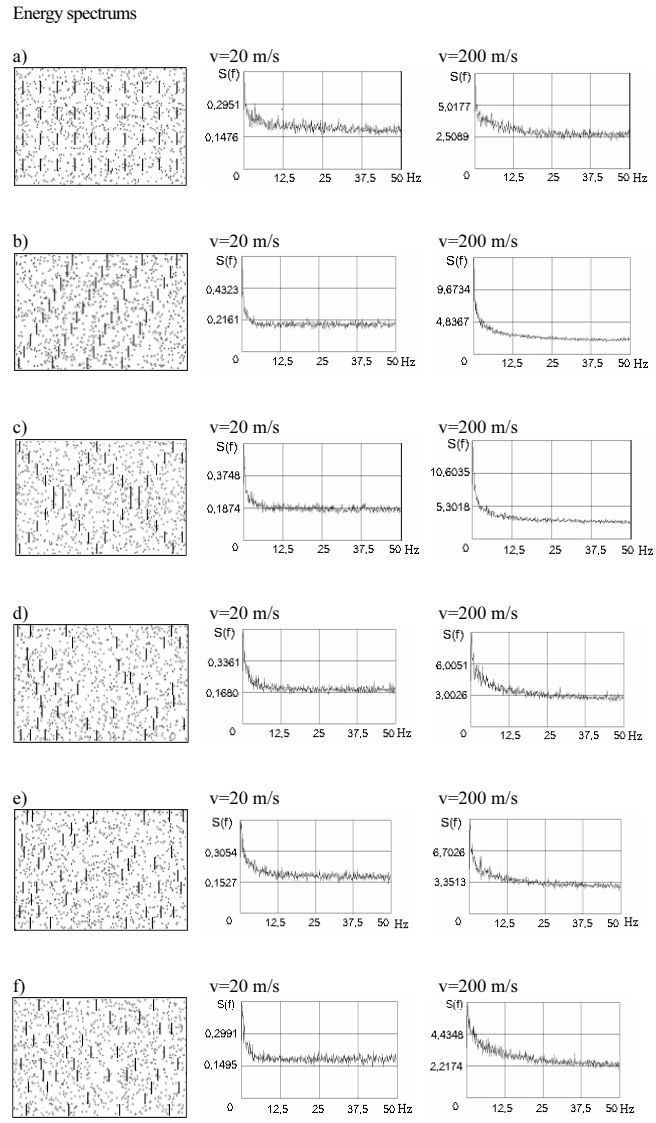

Fig. 1. Ordered structures (a, b, c) and unordered structures (d, e, f) and corresponding energy spectrums to them
Rys. 1. Uporządkowane struktury (a, b, c) i nie uporządkowane struktury (d, e, f) oraz odpowiadające im widma energetyczne

5. Conclusions

The information substance of flicker-noise, as comes up from the presented results, consist in its sensitivity to internal structure of explored system. Using the experimental determined flicker-component of a spectrum of noises it is possible to find from (2) the time of relaxation τ of system, which depends on the features of her internal structure: for systems with ordered internal structure the time of relaxation is major, than for systems with unordered structure. Basis on it the criterion of an estimation of change of internal structure of explored system using its flicker-noise can be offered: if the time of relaxation τ of system decreases, her structure degradates, and on the contrary - at the increasing τ the structure of the system become ordered.

The offered criterion can be used for an estimation of reliability of system without its dismantling and without influence of tested signals on it.

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Artykuł recenzowany

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