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STUDYING THE SYNCHRONIZATION OF ENSEMBLE OF OSCILLATORS WITH GLOBAL AND NONLINEAR COUPLING AND EXTERNAL FORCE

ABSTRACT

dissertation for the degree of Doctor of Philosophy (Ph.D.) in the specialty «6D071900-Radio Engineering, Electronics and Telecommunications"

The object of study is synchronization in an ensemble of oscillators with global and nonlinear coupling.

Relevance of the work: A problem of dynamics of coupled self-oscillators (self-oscillators) is a fundamental problem in the theory of oscillations and nonlinear dynamics. Description of various systems in terms of interacting oscillators used in radio physics, microwave electronics, biophysics, chemistry. Synchronization can also be regarded as one of the scenarios for appearance of order from chaos.

Ensembles of oscillating systems with non-linear relationships have been investigated insufficiently. However, study of such assemblies is important as nonlinear relationships significantly affect dynamic properties of the system. Moreover, due to use of non-linear relationships can significantly change collective dynamics of an ensemble and get its new properties, which at linear relationships does not exist. For example, non-linear connection of the phase-locked to the ensembles can improve their dynamic characteristics (swath, filtering properties, performance, etc.), to solve problems related to the processing of complex signals, frequency synthesizer, etc.

Real electronic system is always under the influence of fluctuations in voltage or current. Usually, such fluctuations include various noises and they are considered as negative factors in computing systems and telecommunications. Even weak such effects can play a very important role in the behavior of the system. The impact of noise on a dynamical system leads to a variety of phenomena.

A special place in study of the effects of noise exposure is the question of the impact of noise on the ensemble of coupled oscillators.

The above confirms the relevance of the chosen field of research and serves as a basis for the formulation of goals and objectives of the dissertation research.

Research goals of this work is the experimental study of synchronization modes in an ensemble of globally coupled oscillators, depending on the coupling strength and the phase difference, as well as an experimental study of the peculiarities of the dynamics of the ensemble of globally coupled oscillators under the influence of periodic and noise signals.

Research Objectives of the study:

– Assemble electronic system Wien bridge oscillators, globally coupled through the total resistance and provides statistical regularities;

– Develop and create linear and nonlinear phase-shifting circuits for the purpose of modulating the phase feedback;

– Select stabilization technique and measuring the frequency of the mean field, the oscillator;

– Investigate the dynamics of an ensemble of oscillators, depending on the coupling strength ;

– Investigate the dynamics of an ensemble of oscillators, depending on the linear and nonlinear phase shift;

– Experimentally investigate the possibility of the phenomenon of frequency locking of the mean field external periodic force;

– Experimentally investigate the effects of external noise signal on the dynamics of an ensemble of globally coupled oscillators.

Methods of study. Synchronization of globally coupled oscillators has been studied in a full-scale radio physical experiment. Data is recorded in a medium LabView. The experimental data were used in the methods of statistical physics, theory of dynamical systems, computer analysis in MatLab.

The novelty of the research

– In this paper it was experimentally demonstrated the existence of quasi-periodic self-organized state, depending on the change of the phase shift of the shifting circuit;

– It is shown that an increase in the coupling strength value of the phase shift occurs in which mode of self-organized quasi-periodicity is shifted toward lower values;

– Dependence of synchronization modes under the noise intensity was experimentally found. The natural experiment shows the dynamics of an ensemble of oscillators on the root mean square amplitude of the noise. The following synchronization modes are observed: partial synchronization, full synchronization and asynchronous mode. For small values of the amplitude of the noise can synchronizes the ensemble, and for large values of the amplitude the noise desynchronizes the ensemble.

– An experiment study on the impact of an ensemble of globally coupled oscillators of external periodic signal with added noise. By increasing the root mean square noise amplitude synchronization area narrows

Basic states for the defence

1. As a result of the phase shift in the global and non-linearly coupled oscillators a regime of self-organized quasi-periodicity appears. In this mode, the average field frequency is different from the frequency of oscillators themselves.

2. The system of globally non-linearly coupled oscillators increase in the coupling strength leads to a narrowing of the asynchronous mode and the broadening of the full synchronization and self-organized quasi-periodicity.

3. The noise signal is not always a destructive factor for the system. Under certain limited values of the rms value of the amplitude of the noise (0,611 <δ <1,522), the noise signal can synchronize the system.

4. Impact of external periodic force in the presence of noise on the ensemble of globally coupled oscillators will reduce the synchronization region.

The theoretical and practical significance of the work. The obtained results can be used to make new radio-electronic, telecommunication devices, wireless sensor networks in which a significant role can be played synchronization phenomenon.

Synchronization of large ensembles - neural networks - is an actual problem, as there is no sufficient knowledge in this area, which is the foundation to build powerful high-performance computing information networks. Knowledge of synchronization in neural networks offer the potential to build a more sophisticated control system, similar to the brain. Studies of external influence on these systems are key in the direction of the search techniques of management and the suppression of the collective dynamics of the system elements. Perhaps this knowledge will help to solve many problems of artificial intelligence.

Publication. According to the materials of the dissertation published 13 publications, including 1 - in the peer-reviewed journal with a high impact factor (Physical Review E), 5 - in publications, recommended by the Committee for Control of Education and Science of RK, 6 abstracts in international conferences, 1 thesis in the Republican conference. Also according to the survey was filled application for a patent.