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Simulation of the Stochastic Resonance Effect in a Nonlinear Device

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Abstract

The possibility to separate a useful signal from the realization of the random process representing the sum of the harmonic signal and Gaussian noise, using the method of stochastic resonance, is shown. The results of calculation of the signal-to-noise ratio at the output of a nonlinear device, creating an effect of stochastic resonance, are given. It is shown that the nonlinear device, described by the equation of stochastic resonance, operates as a stochastic low-pass filter. A simulation model of a non-linear device possessing effect of SR is constructed.

Index terms— stochastic resonance (SR), nonlinear device, signal-to-noise ratio (SNR), filter.

1 Introduction

t is considered that noise in a system is a negative factor and the fight against noise is one of actual problems of radio engineering systems. Low-noise devices and methods of noise reduction are developed, noiseproof codes, digital communication, signals with the necessary correlation properties are created.

However, research conducted recently in the field of theoretical and experimental physics has shown that in some cases an input weak signal can be amplified and optimized with the assistance of noise (Anishchenko et al, 1999;, Geraschenko, 2003). The integral characteristics of the process at the system output, such as the spectral power amplification (SPA), the signal-to-noise ratio (SNR) have a well-marked maximum at a certain optimal noise level.

The notion of stochastic resonance (SR) determines a group of phenomena wherein the response of a nonlinear system to a weak input signal can be significantly increased by appropriate tuning of the noise intensity. SR refers to a generic physical phenomenon typical for nonlinear systems.

This article discusses the simulation of the effect of SR in the case of additive sum of a harmonic signal and Gaussian noise at the nonlinear device input.

2 II.

3 Characterization of Stochastic Resonance

A weak input signal significantly increases with increasing intensity of noise and reaches its maximum at a certain noise level in nonlinear systems in which occurs.) ( ) ( ) (/ 3 . t x t t dt d + ? = ? ? ? ,**(1)**

where) (t x -input signal;) (t ? -output signal.

This formulais the first kind and has no analytical solution **??**Kamke, 1961). It is also impossible to find two-dimensional probability density of the output signal by using the exact solution of the Fokker -Planck equation even in the absence of an input harmonic signal (Middleton, 1996).

Therefore, the signal correlation functions and spectral density at the nonlinear system output can't be defined exactly. Naturally, there are additional difficulties in the analytical description of actual effects, if there is an additive sum of harmonic signal and Gaussian noise.

4 III.

Signal-to-Noise Ratio at the Nonlinear ystem Output Unlike linear systems, in which the energy spectrum at the output follows input energy, output spectrum of the non linear system has amore complicated structure (Levin, 1969 **??** Volochuk, 2005). Signal and noise are independent in ali near system. The output of the non linear device forms new spectral components due to the interaction of the components of the input process.

Moreover, the type of non-linear transformation and the statistical characteristics of the input signal determine the type and intensity of the additional component.

If the input processisan additivesum of the unmodulated carrier and noise, there are three main parts in the output power spectrum of the non linear device: The discrete part of the spectrum is complemented by the spectrallineat zero frequency, representing the DC component at the output, which is also determined by the beats of the signal components and noise. Consequently, the energy spectrum of the output of the nonlinear device is determined as (Levin, 1969, Voloshchuk, 2005):) (?) ( ) ( ) ( ) (? ? ? ? NxN SxN SxS F F F F + + = .

Practically the most convenient power indicator of the output signal is the signal-to-noise ratio (SNR). Since the output process is an in separable mixture of an input signal and noise, it is impossible to specify components, which would depend only on the signal and, accordingly, only on noise.

In order to evaluate the SNR at the output of the nonlinear system, it is necessary to determine the portion of the spectrum Having solvede quation (2) numerically, let'sde fine the SNR at the output of the nonlinear device (SNR output)as a function of frequency and SNR at the input (SNR input) . We can calculate SNR input asD A SNR input 2 / 2 = .

The frequency is set in the range of 0.05÷10Hz. Power SNR at the input is consideredequal, respectively: 0.005; 0.02; 0.5. The calculation result sare shown in Fig. 1a The figures show that the phenomenon of SR is best expresse dat low frequencies, thus a nonlinear device having the effect of SR, is astochasticlow-pass filter. In addition, there is a minimum SNR at the outputat a frequency of 2 . 0 = f Hz, and this effect is observedat any SNR at the input. SNR at the output is a nonlinear function of the external noise and the input harmonic signal. You can then make three-dimensional SNR graphs of the input noise power and harmonic signal amplitude. It should be noted that the numerical simulations were performed by summing the dataon limited time intervals (up to 50periods of frequency).Naturally, the time delay affects the results of (Middleton, 1996).

V. Model of the Nonlinear evice Having the Effect of CR Let's create a simulation model of the nonlinear device according to the graphical programming environment SIMULINK (intfig.2egrated with MATLAB), described by equation (2). This system has the SR effect. An additive mixture of the harmonic signal and Gaussian noise is sent to the input. Output signal stakes from the oscilloscope. This scheme can be the basis for practical implementation of the nonlinear filter (fig. 2). The response of the nonlinear on a weak external signal in case of SR noticeably increases with the height of the noise intensity in the system and arrives at a certain maximum at some level.

5 VI.

6 Conclusions

In this paper we discuss the work of the nonlinear device having the effect of SR at the input of the additive mixture of the harmonic signal and the white noise of short duration. The results make it clear that the device works as a stochastic low-pass filter. In addition, numerical analysis of the equation describing the effect of SR showed that the SNR at the output of the nonlinear device under certain conditions exceeds the SNR at the input. Hence, the nonlinear device operates as an amplifier.

In this paper we can build a simulation model of the nonlinear device, described by equation SR. We have used an additive mixture of the harmonic signal and noise with a duration of 10 s at the input of the nonlinear device. We have used the graphical programming environment SIMULINK (integrated with MATLAB) for building a simulation model.

These results demonstrate that the signal obtainedat the output of the nonlinear device has a lower noise level as compared with the input signal.

Prospects of development schemes of nonlinear filter based on the designed model are indicated. [1] [2]

Figure 1: SxSF-

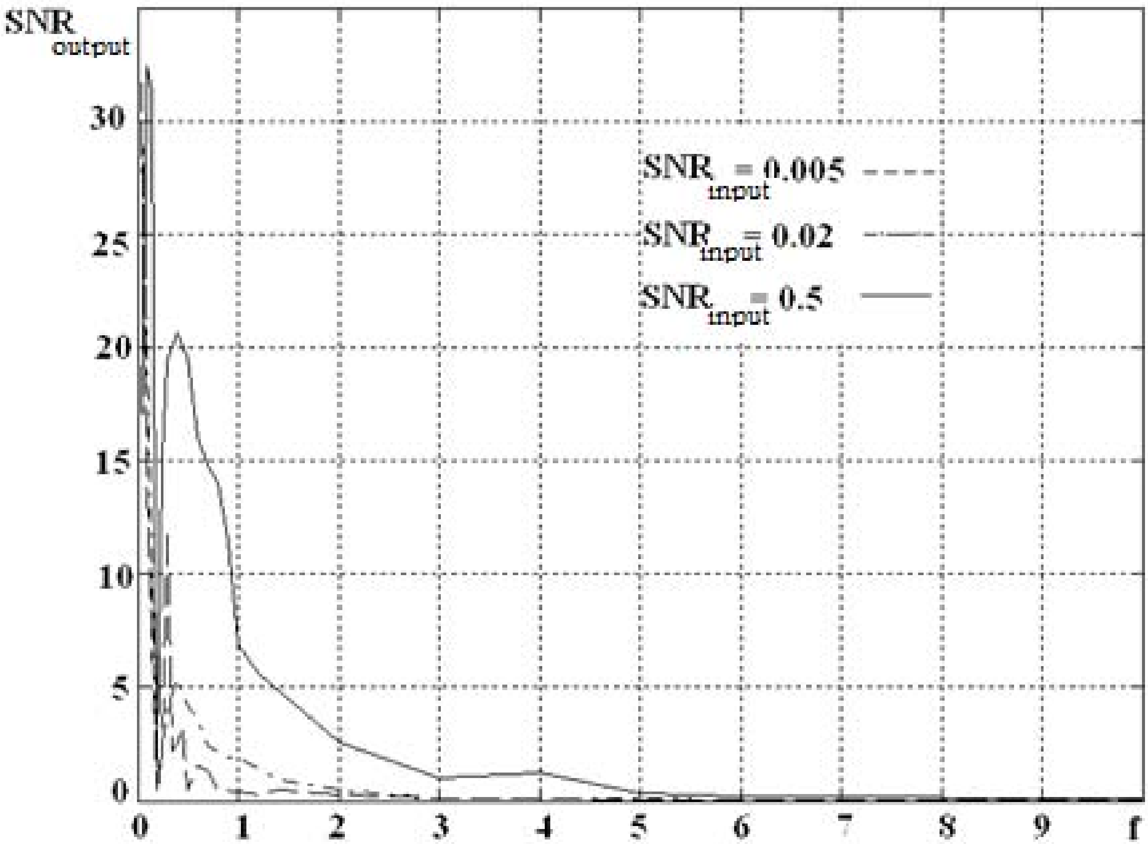

Figure 2:

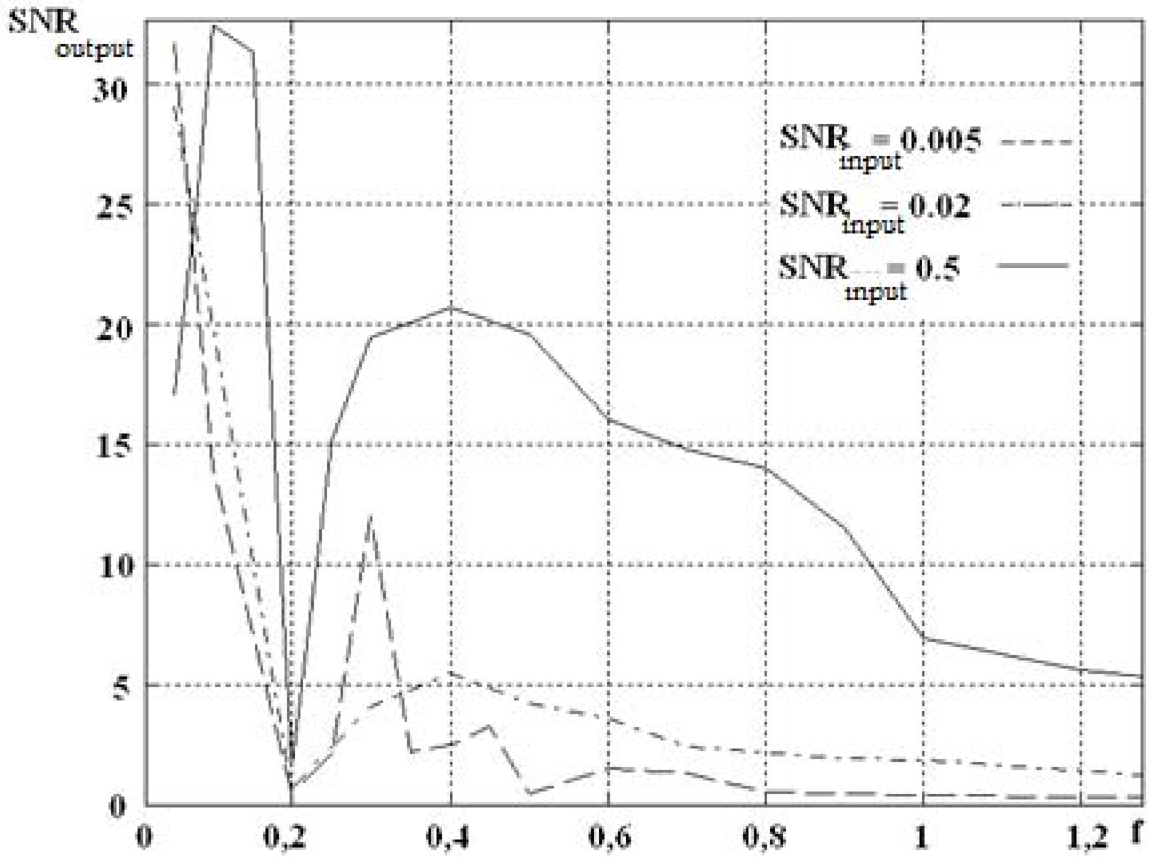

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Figure 3: Figure 1 :

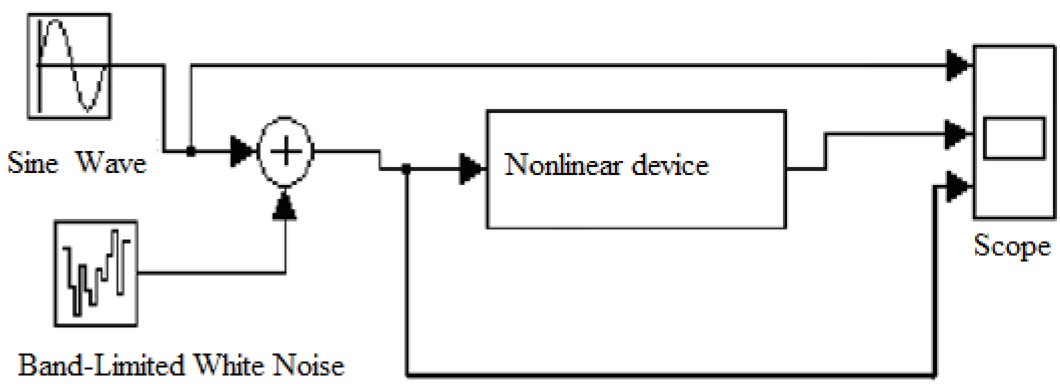

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Figure 4: Figure 2 :

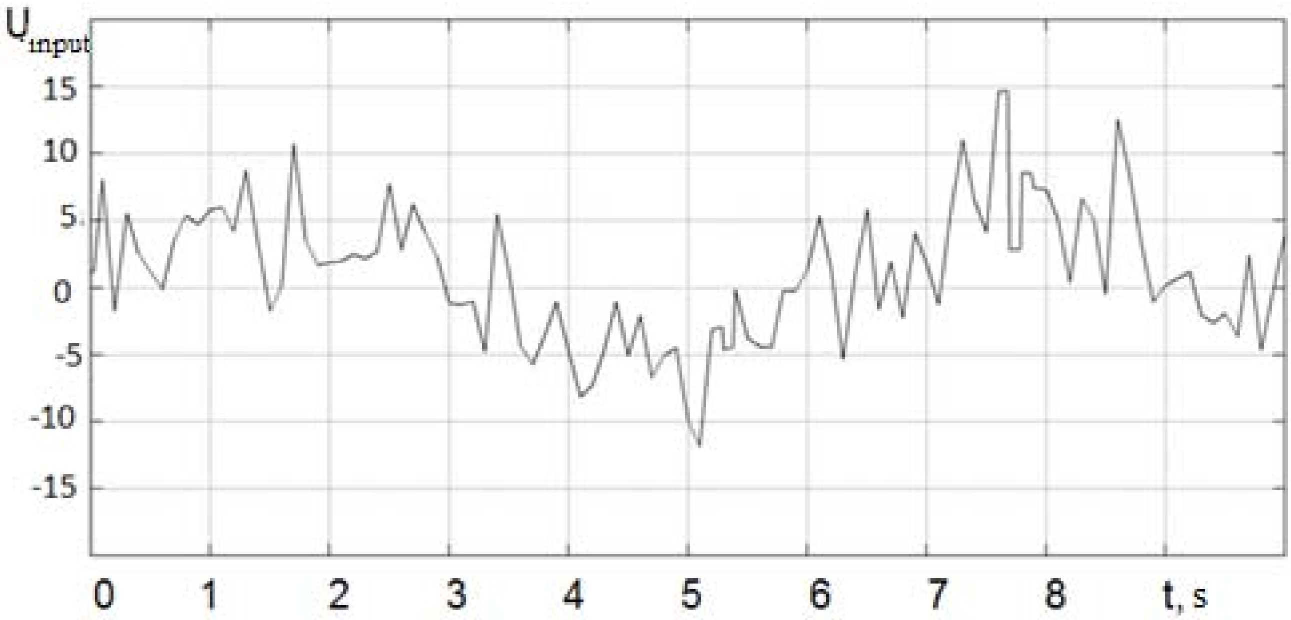

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Figure 5: Fig. 3 Figure 3 :

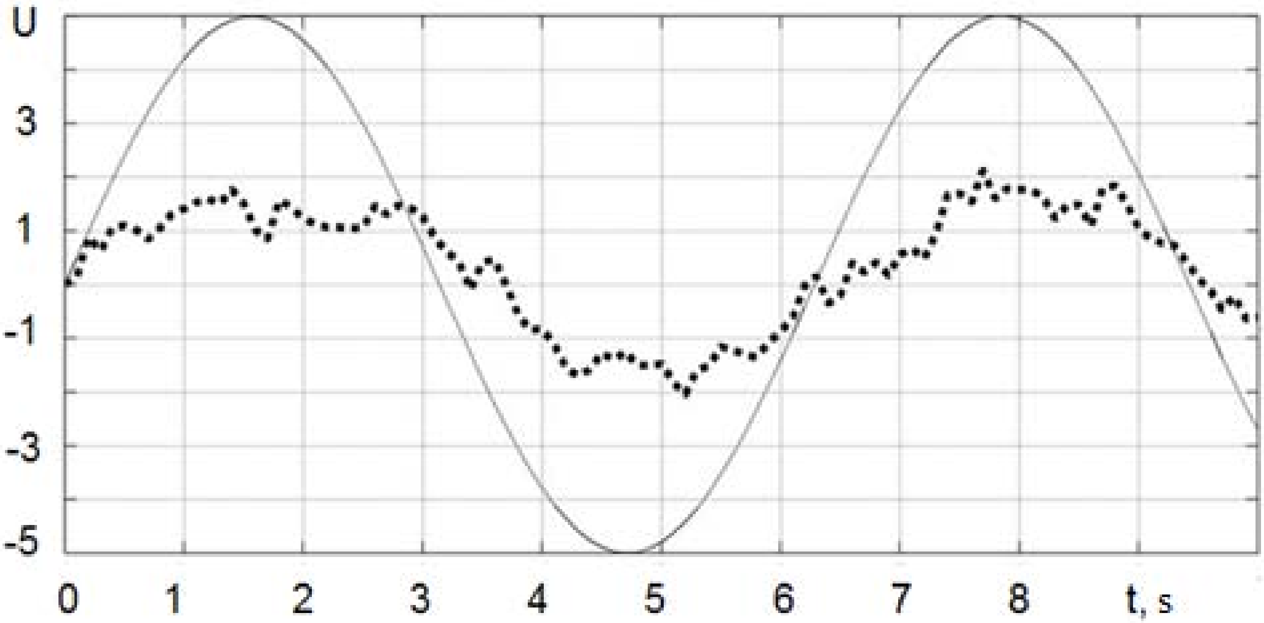

Figure 6:

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