A calculation of radio electronic devices own noises in the range of low frequencies

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Abstract - **formula for calculation of own noises level of radio electronic devices in the range of low frequencies.**

Keywords - **flicker-noise, spectral power density, relaxation time of system.**

INTRODUCTION

During calculation of sensitivity of radio electronic devices (RED) it is calculated the level of own noise of the device using the well-known formula of Nyquist in most cases, which takes into account the temperature of element (T) and its dissipative properties (REZ). However it is known, that on low frequencies except thermal noise, that is produced by the thermal motion of elementary particles (electrons, ions), there are other sources of noises: generation-recombination noise (GRSH), bursting, avalanche, flicker-noise. GRSH is connected with the principle of work of semiconductor elements and can be diminished only to the certain limit. In general the level of GRSH, explosive and avalanche noise is less than the level of thermal noise, that is why in many cases, at the calculation of level of own noises of devices they are not taken into account. Only one type of noise - that is flicker-noise (FN) – in the range of low frequencies exceeds the level of thermal noise, it increases inversely to frequency *f*: $S(f) \sim \frac{1}{f}$, where *S(f)* is a spectral density of power (SDP) of noise. For the calculation of FN mainly it is used the empiric formula of Hooge:

$$S_U(f) = \frac{\alpha \cdot U^2}{N \cdot f},$$

where –Hooge's constant ($\alpha \approx 2 \cdot 10^{-3}$); U – noise potential; N- total amount of charge carriers in the standard. However, in many cases a difference between the real level of noises and the level defined using Hooge's formula is greater after 100%. Therefore Hooge's formula can be used rather for the noise level estimation, than for the precise calculation of noise level in the range of low frequencies.

EXPERIMENT

During finding formula accepted for *S(f)* it was takes into account that the real elements of RED are the systems that are in the thermodynamics non-equilibrium state [1] they are characterized by SDP of fluctuations of parameters (by noise) $S_H(f)$. Connection between SDP of system parameters fluctuations that is in the non-equilibrium state, and SDP of system parameters which is in the equilibrium state $S_P(f)$:

$$S_P(f) = P_H \cdot S_H(f), \qquad (1)$$

where P_H is probability of fluctuations in the non-equilibrium system.

At P_H=1 (probability of fluctuations is equal to one), the system reached the equilibrium state and $S_P(f) = S_H(f)$.

At P_H=0 (probability of fluctuations is equal to zero) parameters fluctuations of the system are absent and

$$S_H(f) = \frac{1}{P_H} \cdot S_P(f) = 2 \cdot \pi \cdot A_0 \cdot \delta(f),$$ where $\partial(f)$

is delta function. That is the value of system parameters when P_H=0 is equal to A_0 (an analogue in the electrical engineering is SDP of harmonic oscillation with amplitude *of* A_0 or SDP of constant current or potential).

Using the main statements of thermodynamics the expression for P_H was found:

$$P_H = 1 - e^{-f \cdot \tau} = \frac{e^{f \cdot \tau} - 1}{e^{f \cdot \tau}},$$

where f is fluctuations frequency (noises); **τ**- relaxation time of system.

Final expression for SDP of noises in the electronic elements:

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

where ***a*** - value of spectral density in the range of medium frequencies;

Using the defined expression for SDP of fluctuations (2) for the range of frequencies from $f_1 \rightarrow 0$ till $f_2 \leq 10^9$ Hz and when ***a*** = 4kT the final expression for middle square of noises potential of electronic elements will be:

$$\overline{U^2} = \int_{f_1}^{f_2} \frac{4kT \operatorname{Re} Z e^{f\tau}}{e^{f\tau} - 1} df \cdot \qquad (3)$$

The noises level for a resistor of MLT type with resistance 1000 Ohm in the range of frequencies from f_1 = 10 Hz to f_2 = 100 Hz that is calculated using Nyquist's formula is on 240 % less than the level of noises calculated using formula (3) at τ_{MLT} = 0,005c.

CONCLUSIONS

The proposed formula for calculation of root-mean-square potential value of electronic elements own noises unlike the well-known Nyquist's formula takes into account the real level element's noise. A calculation of noises level using proposed formula is especially important in the range of low frequencies.

REFERENCES

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