PROBABILISTIC PROPERTIES OF DYNAMIC MODULATION CHARACTERISTICS OF QUARTZ OSCILLATORS

V. N. Roman'ko and Yu. S. Shmalii

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A probabilistic analysis of the dynamic modulation characteristics (DMCs) of quartz self-excited oscillators (QSOs) in the vicinity of anharmonic resonances of a resonator is made. It is shown that the probability density functions of the phase and frequency DMCs obey the generalized Rice law. The expected values and variances of the DMCs were investigated in a fluctuating field of parameters of signals of a generalized scheme of QSOs. Results enabling making a conclusion about the necessary level of the amplitude of the modulating signal for which the DMCs acquire stabilizing properties providing minimum instability of the frequency of the output oscillations of the reference QSOs using the modulation method of frequency stabilization are obtained.

When constructing quartz frequency stabilization (QFS) systems on the basis of the modulation method [1], one carries out modulation of the frequency ω_0 of the oscillations of the quartz self-excited oscillators (QSOs) being generated with frequency Ω and depth sufficient for increasing the energy of oscillations at the frequency ω_i of anharmonic resonance of mode h_{npq} to a value for which the forced oscillations of this mode would acquire standard properties sufficient for stabilizing the oscillations of the fundamental circuit of mode h_{n11}. It follows from an analysis of the essence of the modulation method that the standard model (SM) of the system is formed with the use of the stabilizing properties of the dynamic modulation characteristics (DMCs) of the QSOs, which, obviously, requires substantiating the correspondence of their properties proper to the properties of the frequency and phase characteristics of the quartz resonator (QR) within the frameworks of the necessary conditions of constructing an adaptive QFS system. To investigate the efficiency of QFS systems realizing the natural nonuniformity of the DMCs of QSOs within the frameworks of the modulation method, the probability density functions of the amplitude and phase DMCs of precision QSOs as a function of the signal-to-noise ratio (SNR) in the band of anharmonic circuits are determined in the work and their main moments are examined.

When investigating the effect of information or fluctuation signals on the frequency of the QSO, it is convenient to represent the output signal of the latter, neglecting higher harmonics of the generation ω_0 and modulation Ω frequencies, in the form [2]

$$s(t) = S_0 \{1 + m_A(t) \cos[\Omega t - \varphi_A(t)]\} \cos\{\omega_0 t - m_\varphi(t) \sin[\Omega t - \varphi_\omega(t)] + \varphi_0\}, \tag{1}$$

where $m_A = \varepsilon_A K_A$, $m_\varphi = \varepsilon_\omega \omega_0 K_\omega / \Omega$ are the spurious amplitude modulation (SAM) coefficient and FM index; S_0, ω_0 are the steady amplitude and frequency of oscillations; φ_0 is the initial phase shift; K_A, φ_A are the amplitude-frequency and phase-frequency modulation characteristics (AFMC and PFMC) of SAM; K_ω, φ_ω are the AFMC and PFMC of FM; ε_A, ε_ω are the relative deviations of the amplitude and frequency. Here the DMCs can be regarded as stationary stochastic processes, the spectra of which are in the region of frequencies much lower than the natural frequency ω_0.

Since all functions of the DMCs are determined mainly by the parameters of equivalent circuits of oscillators, to describe them we form the FM model of a precision QSO by a closed connection of a noisy nonlinear amplifier (NA) and parallel-connected fluctuating feedback (FB) circuits of the fundamental and anharmonic circuits. Being interested further only in the local modulation frequencies close to the difference between the anharmonic and fundamental oscillations, we reduce the FM model of the QSO to the form (Fig. 1), where $u_{in}(t)$ is the regular part of the voltage $e_{in}(t)$ of the most powerful upper component of the FM spectrum of oscillations

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