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Analysis of Frequency Deviation Changes over FM-Signal Spectrum during Discrete Message Transmission

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Abstract—The paper contains simple analytical formulas suitable for calculation and analysis of spectra of frequency-keyed signals. Also, it gives the solution to the problem of control of frequency deviation and of its instability based on analysis of levels, characterizing the spectral components of FM-signal.

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The signals with angular modulation of the carrier frequency and, particularly, FM signals have found wide application in communications, radiolocation, radio-relay lines, and other radio-engineering systems. Information on such applications can be obtained from numerous literature sources on the issue [1].

In actual systems, for such signals we have to choose optimal deviation of frequency. Stability of such deviation dictates the minimal band of reception and, therefore, the maximal sensitivity and potential of the system. However, some problems related to measurement of FM signal parameters, for example, control of the value and stability of deviation without additional instruments (deviometers), are still waiting for their resolution [2].

Three methods of frequency modulation are known: direct, indirect, and combined (CMFM) [3]. The indirect method, based on phase modulation of the carrier by some controlling signal (CS) passed through an integrator, has a number of disadvantages: instability of the middle frequency; the spectrum of transmitted information being limited from below; and impossibility of transmission of the dc component of CS. The direct method is distinguished with a low stability of carrier frequency, especially in the microwave range of frequencies. True enough, in recent years, owing to application of high-Q dielectric resonators in microwave generators, is has become possible to resolve the problem of improvement of long-term and short-term stability of carrier frequency. The combined methods of frequency modulation are based on phase modulation of carrier, show better technical characteristics, and possess improved reticence of information transmission [4].

In order to determine the deviation of frequency and its stability when using the above FM methods, we suggest a new method for deviation assessment with the aid of analysis of the energy spectrum (power spectrum, to be exact) of FM signal.

The main part of the discrete message represents a controlling signal in the form of a periodic sequence of rectangular pulses with an arbitrary pulse period–to–pulse duration ratio:

$$u_{\text{in}}(t) = U_0 \sum_{i=0}^{N} [\gamma(t - iT_{\text{p}}) - \gamma(t - iT_{\text{p}} - \tau_{\text{p}})], \tag{1}$$

where U_0 is the amplitude of rectangular pulses; T_{p} is the pulse repetition period; τ_{p} is duration of an individual rectangular pulse; $\gamma(t)$ is the Heaviside function; and $N = \varepsilon(t - T_{\text{p}})$, i.e., N equals the integral part of t/T_{p}.

Regardless of the above methods of frequency manipulation of the carrier by the controlling signal (1), the energy spectrum of FM signal can be characterized by expression

$$A_k = \frac{\lambda_1^2 \sin^2\left(k\dfrac{\pi}{Q} - \lambda_2\right)}{\left(k\dfrac{\pi}{Q} + \lambda_1\right)^2 \left(k\dfrac{\pi}{Q} - \lambda_2\right)^2} \quad \text{at} \quad \left(k\frac{\pi}{Q} + \lambda_1\right)\left(k\frac{\pi}{Q} - \lambda_2\right) \neq 0, \tag{2}$$