INDEPENDENT EXPERIMENTAL ESTIMATION
OF INSTABILITIES IN SIGNAL GENERATORS
AND MEASURING INSTRUMENTS

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Independent experimental estimation of the instabilities of signal generators and measuring instruments is considered.

Key words: independent estimation, instability, structure function, signal generator.

Recent decades have been characterized not only by an expansion in the range of devices used in measurement technology in practically every sphere of activity, and in the types and sub-types of measurements, but also by their “autonomization,” by which we will understand here the remoteness of the measuring instrument from the corresponding calibration systems (for example, graded standards) as well as the fact that these instruments are not immediately accessible in view of the specific way in which they function and, equally, the fact that it is not desirable to interrupt their working conditions.

In addition, there is practically no way of assuring preservation of the metrological characteristics of such measuring measurements within standard limits over the entire interval between inspections or calibrations (even where this is possible for an “independent” instrument). Therefore, the problem of monitoring the level of metrological reliability of measuring instruments by means of a structure and a specially developed technique that have been “built into” an “independent” instrument must be acknowledged as being of extraordinary importance. Such a structure and such a technique would make it possible for a user to observe the execution of a “self-test” of an active (signal generator) or passive (measuring device, transducer, measuring plant, or system) measuring instrument at any convenient time in the course of an observation time interval of arbitrary duration through the performance of quantitative estimation of the degree of instability, correspondingly, of an output signal of a calibration characteristic.

In view of the fact that, in the realm of theoretical metrology, efforts to monitor the metrological reliability of measuring instruments have only just begun, the principal focus in the present study will be on highly specialized questions related to methods for independent estimation of the transient instabilities of signal generators and measuring instruments, i.e., random instabilities and systematic local transient drifts of their information-bearing characteristics.

The term “instability” will be used here as the most common term for both generators and for measuring instruments, whereas the term “error” will relate most often to the latter and will virtually never be used in reference to generators.

In physical reality, the static transient instability of any of the linear radio electronic devices (signal generators of measuring instruments) being considered here is a common nonstationary random process [1]. In the localization of instability over time, a separation of the instability into its components is often employed, thus, additive instability or instability of the zero, progressive or drift instability $K_t (K_G t)$ and random instability. Such separation is not only an extremely common technique of analysis, but also corresponds to the structure of the mathematically rigorous representation of the static transient instability of a linear radio electronic device over a limited time interval [1, 2]. Moreover, it should be noted that in considering sample functions of the instabilities of a generator or measuring instrument obtained, for example, in the course of a control test, the “components” referred to above are physically observable and informationally distinguishable, that is, they
are metrologically significant [3]. Experience has shown that the fact of informational distinguishability fully allows for the possibility of the existence of procedures for processing a resultant signal that will make it possible to separate the statistical characteristics of these components on the measurement interval without recourse to standards.

The hypothesis that a standard-free hardware determination of the parameters of the basic components of the instability of a measuring instrument and of a signal generator is possible has led to formulation of the problem of independent experimental estimation of local (i.e., defined on a finite time interval) statistical characteristics of these components.

Rather simple engineering methods of independent estimation of the variances of the random instabilities and parameters $K_{MI}$ and $K_{G}$ that characterize progressive instabilities of a measuring instrument and of a signal generator are proposed here. Henceforth, to simplify the discussion, the instability coefficients of a measuring instrument and of a signal generator $K_{MI} \ll 1$ and $K_{G} \ll 1$ will be referred to as time trends.

Random Instabilities. A diagram of an experimental plant by means of which an independent estimation of the variances $\sigma_{G}^2(t)$, $\sigma_{MI}^2(t)$ of the random instabilities of signal generators and of measuring instruments $MI_i (i = 1, 2)$ may be performed is shown in Fig. 1. Note that the method is being presented here for the first time and is, we believe, simpler than a previously presented method [1, 4, 5] (disregarding the precision of the estimators that are obtained).

In this diagram of a plant that functions in a static regime, $x = \text{const}$ is an input nominal parameter that specifies the value of the output information-bearing parameter of the generator $f_{G}(x, t)$, for example, a voltage, frequency, etc. The function $f_{G}(x, t)$ as well as the instabilities (errors) of the measuring instruments $f_{MI}(x, t)$ are random processes with stationary increments [1, 4].

The values $f_i(x, t)$ of the information-bearing parameter that are observed at the output of the measuring instrument are related to the unobservable quantities $f_{G}(x, t)$, and $f_{MI}(x, t)$ by means of the relationships

$$f_i(x, t) = f_{G}(x, t) + f_{MI}(x, t), \quad i = 1, 2. \quad (1)$$

Henceforth, to simplify the notation, the parameter $x = \text{const}$ will be omitted from all the relations that follow from (1).

Since the random processes $f_1, f_2, f_{G},$ and $f_{MI}$ (possess the properties of a random process with stationary increments, their basic characteristics are the structure functions $D_1(\tau), D_{G}(\tau),$ and $D_{MI}(\tau),$ which serve to replace the concepts of correlation functions. Then within the framework of the implementation of conditions that are “standard” for signal generators and measuring instruments, for the mixed moments

$$\langle f_{G}(t + \tau) - f_{G}(t) - \langle f_{G}(t + \tau) - f_{G}(t) \rangle \rangle \left[ f_{MI}(t + \tau) - f_{MI}(t) - \langle f_{MI}(t + \tau) - f_{MI}(t) \rangle \right] = 0;$$

$$\langle f_{MI1}(t + \tau) - f_{MI1}(t) - \langle f_{MI1}(t + \tau) - f_{MI1}(t) \rangle \rangle \left[ f_{MI2}(t + \tau) - f_{MI2}(t) - \langle f_{MI2}(t + \tau) - f_{MI2}(t) \rangle \right] = 0$$

the following relations are easily derived from (1):