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Instrumental virtual tools for measuring random signal characteristics

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Abstract. Based on modern computer technologies developed by National Instruments, a virtual device for adjusting, controlling and studying various noise characteristics has been developed. Signs helping identify the laws of random signal probability distribution are smoothness or sharpen-ing, asymmetry and uncertainty. Examples of identification of noise characteristics of elec-tronic devices are provided; instrument technologies are used to monitor the technical condi-tion of such devices.

1. Introduction

The relevance of the problem of measurement of characteristics of random signals is due to the complexity of choosing a random process model, technical implementation of the meter, sta-tionarity and non-stationarity, ergodicity and non-ergodicity.

The object is the existing methods and technical tools designed to measure probabilistic characteristics of random signals.

The methods for determining probabilistic characteristics of random signals are very diverse. They are based on the display of an indicator of the probability density distribution curve and determination of the distribution law, characteristics of the position and dispersion. Existing methods for measuring characteristics of random signals do not ensure operational control of smoothness, sharpening, asymmetry and uncertainty, as well as identification of the distribution law.

The scope of the meter is regulation, control and research of radio electronic devices accord-ing to noise characteristics and taking into account metrological requirements; these measuring instruments can be used in various industries. Therefore, the operational measurement of proba-bilistic characteristics of random signals taking into account metrological requirements is an ur-gent task.

Не используйте сноски и интерактивные ссылки.

2. Purpose of research

The purpose is to develop hardware and software for measuring probabilistic characteristics of random signals using computer technologies of virtual instruments developed by National In-struments (NI). The paper studies the procedure for identifying distribution laws using a priori and a posteriori information on the second, third and fourth order moments, characteristics of uncertainty, creates a working model and determines the scope of its application.

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3. Materials and methods

To determine the type of the law of distribution of random signals, it is necessary to establish signs or criteria by which the laws of distribution of random signals are identified. Distributions are quite diverse: limited or unlimited; with a flat top or round, with or round [1, 2, 3, 4, 5, 6].

J. Kendal and A. Stuart classified distributions into five types: symmetric single-mode; symmetric two-mode; oblique; extremely short; other [4].

Mathematical models and hardware for measuring the characteristics of random signals are discussed in [1, 3, 7, 8, 9, 10, 11, 12, 13]. The problem of measuring probabilistic characteristics of random signals which make them inaccurate is a limited observation time [12, 13, 14, 15].

For classification and determining a form of the distribution of random signals, it is necessary to select identification signs that would show the mutual proximity or distance of the distributions and could be quantified [4, 7].

As a smoothness or aggravation of the distribution curve near its mode [2], an excess is used:

$$\varepsilon = \frac{\mu_4}{\mu_2^2},\tag{1}$$

where $\mu_4 = \int_{-\infty}^{+\infty} x^4 \times p(x) dx$, $\mu_2 = \int_{-\infty}^{+\infty} x^2 \times p(x) dx$ central moments of the fourth and second order;

x is the value of the random signal; p(x) – the random distribution law.

The excess for various distributions varies infinitely from 1 to $+\infty$), therefore the excess is uncomfortable. Therefore, we will perform its nonlinear transformation into a counter-excess value:

$$\chi = \frac{1}{\sqrt{\varepsilon}} \tag{2}$$

The counterexcess for any distributions is in the range from 0 ($\varepsilon=\infty$) to 1 ($\varepsilon=\infty$). Therefore, as the first sign of identification of distributions, we take the value of counterexcess γ .

An analysis of the results of calculations in the Mathcad showed that the counterexcess values for symmetric distributions range from 0.68 to 0.73 for trapezoidal distributions, from 0.67 to 0.882 for arcsinusoidal distributions, from 0.05 to 0.71 for exponential two-sided distributions and in significantly overlap in the area of flat-top and peaked distributions.

For asymmetric distributions, the counterexcess value ranges from 0.628 to 0.655 for the Beta distribution, from 0.327 to 0.493 for the Gamma distribution, from 0.532 to 0.621 for the Nakagami distribution, from 0.481 to 0.634 for the Rayleigh distribution.

The entropy coefficient [4] whose value is determined by the formula, is used as the second independent sign which characterizes the distribution form.

$$K = \frac{\Delta_3}{\sigma},\tag{3}$$

where $\Delta_{9} = \frac{1}{2} \cdot \exp(H(x))$ - the random signal entropy value;

 σ – the standard deviation of a random signal;

H(x) – random signal entropy.

The entropy of a random signal is a measure of its uncertainty, it depends on the type of distribution and is determined by formula:

$$H(x) = -\int_{-\infty}^{+\infty} p(x) \times \ln p(x) dx.$$
 (4)

For the most common symmetric distributions, the value of the entropy coefficient varies from 1.83 to 2.00 for trapezoidal distributions, from 1.11 to 1.88 for arcsinusoidal distributions, from 0.09 to 1.87 for exponential two-sided distributions, from 0.35 to 1.12 for antimodal distributions. The values

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of the entropy coefficient for symmetric distributions overlap in the areas of flat-top and sharp-top distributions.

For asymmetric distributions, the entropy coefficient ranges from 3.268 to 3.458 for the Beta distribution, from 1.318 to 2.22 for the Gamma distribution, from 1.317 to 1.435 for the Nakagami distribution, and from 1.288 to 2.409 for the Rayleigh distribution.

As the third feature characteristic of the asymmetry of the distribution curve relative [2] is the asymmetry determined by formula:

$$S = \frac{\mu_3}{\mu_2^{3/2}},$$
 (5)

where $\mu_3 = \int_{-\infty}^{+\infty} x^3 \times p(x) dx$ – the third central moment.

Symmetric distributions have an asymmetry equal to zero. For asymmetric distributions, the asymmetry ranges from -0.51 to -0.071 for the Beta distribution, from 1.564 to 2.988 for the Gamma distribution, from 1.574 to 1.645 for the Nakagami distribution, from 0.518 to 2.015 for the Rayleigh distribution.

Thus, when using the counterexcess and the entropy coefficient as identification signs characterizing the form and type of distributions, the image point (or some area) with coordinates χ and K will always be within the rectangle limited by the values of the entropy coefficient and counterexcess.

Studies have shown that the form of the density curve for asymmetric distributions depends on the shape and scale parameters which have a functional dependence on the counterexcess, the entropy coefficient, and the asymmetry.

The form of the Beta distribution density curve is sensitive to the asymmetry. The mathematical model of the functional dependence of parameter α (β) with shape index $\beta = 3$ ($\alpha = 3$) is as follows:

$$\alpha = 3 \times exp(-1.39 \times S) \tag{6}$$

$$\beta = 3 \times exp(1.39 \times S) \tag{7}$$

For the Nakagami distribution in the range of asymmetry changes from 1.574 to 1.645, the shape of the distribution density curve is sensitive to the counterexcess. The mathematical model of the functional dependence of shape parameter α on the counterexcess value with scale parameter $\beta = 1$ is as follows:

$$\alpha = 30.394 - 127.987 \times \chi + 135.135 \times \chi^2$$
(8)

Thus, after determining the type of asymmetric distribution according to three classification criteria, shape and scale parameters, it is possible to establish a specific type of asymmetric distribution.

4. Experimental results and discussion

The studies were carried out in the NI LabVIEW 2012 using real-noise recordings of electronic devices [16, 17, 18].

To conduct experimental studies, a virtual meter (VM) of probability characteristics was designed. Its structural diagram is shown in Fig. 1, and the appearance of the front panel (LP) is shown in Fig. 2.

The meter contains a normalizing amplifier (NA) - 1; a channel for measuring the mean square value (RMS MCH) - 2; an asymmetry measurement channel (A MCH) - 3; a channel for measuring the probability distribution density and the entropy coefficient (MCH PD and EC) - 4; a measuring channel for the counterexcess (MCH CA) - 5; a channel for measuring the parameters of the distribution form (MCH DCH) - 6; a decision making unit (DB) - 7; an indicator (I) - 8.

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Experimental and metrological studies of measuring probabilistic characteristics of random signals and identifying the type of distribution were carried out and verified by semi-natural modeling using real-life recordings of radio electronic devices (Table).



Figure 1. VM of probabilistic characteristics. Structural scheme.



Figure 2. VM of probabilistic characteristics. The VM FP fragment.

The VM identifies the following types of symmetric distributions: uniform, triangular, arcsinusoidal-I, II, III, trapezoidal-I, II, III, antimodal-I, II, two-way exponential with a power factor of 1/4 to 7, Laplace and normal, asymmetric - Beta, Nakagami, Rayleigh, Gamma. The indicator displays a graph of the distribution curve, as well as information about the type and parameters of the distribution.

5. Conclusion

Probability characteristics meter allows for identification of 16 types of symmetric distributions, 5 types of asymmetric distributions, and 7 parameters. The probability of distribution identification is 0.95, the accuracy of parameters measurement is \pm 1%. Accuracy of measurement and identification of the type of distribution increases with increasing time of observation of a random signal. The results establish a relationship between the results of measurements and identification in the data of the probabilistic characteristics meter and the real probabilistic characteristics of noise.



Figure 3. Experimental studies of random signals

References

- [1] Bendat J, Piersol A 1974 *Measurement and analysis of random processes* (Moscow: Mir).
- [2] Wentzel E S 1962 *Probability Theory* (Moscow: Physics and Mathematics).
- [3] Zhovinsky V N 2009 Express engineering analysis of random processes (Moscow: Energy).
- [4] Novitsky P V, Zograf I A 1991 *Error estimation of measurement results* (Leningrad: Energoatomizdat).
- [5] Sytko, I. I., & Kremcheeva, D. A. (2017). Instrumentation for measuring the parameters and characteristics of four-poles. *International Journal of Mechanical Engineering and Technology*, 8(10), 844-854.
- [6] Vystrchil, M., & Novozhenin, S. (2017). Estimation of autolock mode accuracy of robotic total stations with various configurations reflectors. Paper presented at the *International Multidisciplinary Scientific GeoConference Surveying Geology and Mining Ecology Management, SGEM, , 17*(22) 281-288.
- [7] Antsev G V, Sytko I I, Sarychev V A, Sokolov G P 2006 A device for measuring characteristics of random processes, Patent No. 2280278 of the Russian Federation.
- [8] Sytko I I, Shumakov P P, Naumenko N S, Latiy O V 2008 A device for measuring characteristics of random processes // Patent No. 2336562 of the Russian Federation.
- [9] Sytko I I 2014 Characterization of random processes distributed according to the Nakagami law *Components and Technologies* **1** 172-173.
- [10] Vinogradova A A, Leontyuk S M (2018) Evaluation of current status in field of electrical voltage measurements *Journal of Physics: Conference Series* 1118(1) DOI: 10.1088/1742-6596/1118/1/012048.
- [11] Kremcheev E A, Kremcheeva D A 2017 Methodological approaches to controlling the feed breakage process in drum and tube mills based on the results of vibroacoustic diagnostics

Journal of Industrial Pollution Control 33(1) 787-791.

- [12] G V Rudianov, E I Krapivsky, S M Danileiv 2018 Evalution of signal properties when searching for cavities in soil under concrete slabs by radio detection stations of subsurface investigation *Journal of mining institute* 231 245-253.
- [13] Manzhos V N, Shirman Ya D 2011 *Theory and technology of radiolocation information processing under noises* (Moscow: Radio and communication).
- [14] Voytyuk, I. N., & Bolshunova, O. M. (2019). Ensuring energy efficiency of the belt-type conveyor electric motor drive operation due to noncontact control of mass discharge of cargo during its transport in mining condition. Paper presented at the *Proceedings of the 2019 IEEE Conference of Russian Young Researchers in Electrical and Electronic Engineering, ElConRus 2019*, 736-739.
- [15] Sytko I I, Kremcheev E A, Makhov V E 2017 Device for measuring relative amplitudefrequency characteristics // Patent No. 2668951 of the Russian Federation.
- [16] Makhov V E 2014 Nondestructive optical control diamonds on the basis of computer technology National instruments *Journal of mining institute* **209** 119-123.
- [17] Vasil'ter Yu V, Zheltov S Yu, Knyaz V A, Khodarev A N, Morzhin A V 2007 *Processing and analysis of digital images with examples on LabVIEW IMAQ Vision* (Moscow: DMK Press).
- [18] Zhambalova S T, Vinogradova A A 2018 Accuracy increase of self-compensator IOP Conference Series: Materials Science and Engineering 327(2) DOI: 10.1088/1757-899X/327/2/022109