AVIATION IN THE XXI-ST CENTURY

NATIONAL ACADEMY OF SCIENCES OF UKRAINE
MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
NATIONAL AVIATION UNIVERSITY

PROCEEDINGS

THE SEVENTH WORLD CONGRESS "AVIATION IN THE XXI-st CENTURY"

“Safety in Aviation and Space Technologies”

September 19-21, 2016
Kyiv, Ukraine

NATIONAL ACADEMY OF SCIENCES OF UKRAINE
MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
NATIONAL AVIATION UNIVERSITY

PROCEEDINGS

THE SEVENTH WORLD CONGRESS
"AVIATION IN THE XXI-st CENTURY"

Safety in Aviation
and Space Technologies

September 19-21, 2016

Kyiv

COFOUNDER

- ✈ National Aviation Academy "Azerbaijan Hava Yollari" Closed Joint-Stock Company, Azerbaijan
- ✈ Georgian Aviation University, Georgia
- ✈ Nanchang Hangkong University, China
- ✈ Vilnius Gediminas Technical University, Lithuania
- ✈ The State School of Higher Education in Chelm, Poland
- ✈ The International University of Logistics and Transport in Wroclaw, Poland
- ✈ Polish – Ukrainian Research Institute, Poland-Ukraine

* Authors are responsible for the content of the report

SYMPOSIA

SYMPOSIUM 1. MODERN SPACE AND AVIATION TECHNOLOGIES

1.1. Automation and energy saving on aviation transport
1.2. Modern technologies of aircrafts airworthiness support
1.3. Fatigue and fracture of aircraft structures
1.4. Modern tribotechnologies in aircraft and general-purpose mechanical engineering
1.5. Engines and Power Installations
1.6. Methods and facilities of technical and medical diagnostics
1.7. Automated process control systems
1.8. Information technology and systems in the aviation industry
1.9. The intellectual robot-technical measuring complexes and systems
1.10. Cybersecurity in civil aviation
1.11. Mathematical modeling and numerical methods
1.12. Computer systems
1.13. Advanced information technologies in aviation

SYMPOSIUM 2. UNMANNED AIRCRAFT SYSTEMS (UAS)

SYMPOSIUM 3. AIR NAVIGATION AND ATM SYSTEMS

3.1. Prospects aviation telecommunication systems
3.2. Aviation English for flight safety
3.3. Complex systems control
3.4. Avionics
3.5. Human Factors: engineering and technical, psychological and medical-biological aspects
3.6. Communication, navigation, surveillance

SYMPOSIUM 4. IEEE RADAR METHODS AND SYSTEMS WORKSHOP (RMSW-2016)

/September, 27-28, 2016/
http://ieee.nau.edu.ua/rmsw-2016/index.html

SYMPOSIUM 5. ENVIRONMENT PROTECTION

5.1. Biotechnology in aviation
5.2. Land management, cadastre and land monitoring
5.3. Chemical technology and engineering
5.4. Environmental protection

SYMPOSIUM 6. AVIATION CHEMMOTOLOGY

UDC 004.942

G.V. Martyniuk, L.M. Scherbak, Doctor of Technical Sciences
(National Aviation University, Ukraine),
M.E. Fryz, PhD
(Ternopil Ivan Pul'uj National Technical University, Ukraine)

Information support of computer measuring experiments in evaluating of the noise processes characteristics

The constructive model of non-stationary and stationary noise processes was considered. The algorithms of computer simulation of realizations noise processes using a histogram analysis and autoregression model were developed.

Introduction. The noise process refers to known information processes in various subject areas. Such processes distribute in different physical environments and create a total intensity, power, energy, motion of fluid particles, gases, etc.

The two main directions of noise processes research can be identified conditionally [1, 2]: noise processes that are interfering in combination with other information processes, which relate to useful; noise processes carry useful information about the operation of objects, systems, and thus become a useful process, ie, research objects.

Currently, most of the measurement tasks of the characteristics of the noise processes are solved within the correlation and spectral theory. This is due to the fact that is common to use a Gaussian stationary process as a noise process. This model confirms in practice in some cases. However, analysis of the results of many publications, including [3, 4] confirms that some of the noise signals are non-Gaussian stochastic processes. These signals are the result of superposition of a large number of elementary pulses with random parameters. And random parameters occur at random times. Signals have a nonstationary character in some cases.

Non-Gaussian noise processes cause the research not only in the correlation and spectral theory, but also in view of the higher moments. At the same time, we can construct the equivalent Gaussian stochastic process for any non-Gaussian process of the correlation and spectral theory. The first two moment functions will be equal to the studied non-Gaussian and its equivalent - Gaussian process.

Formulation of the problem. Information support of a wide range of computer simulation of the realizations of noise processes should be justified. The basis of modeling noise processes need to use their experimental measurements.

The main results. The model of noise process has to be described before describing the algorithm of computer simulation of the noise processes.

The structural model of the noise processes. Gaussian and non-Gaussian processes can be described by the following structural model [6]:

$$\xi(\omega,t)=\sum_{i=1}^{n}\eta_i(\omega,t)I(t,\Delta T_i)+\sum_{j=1}^{m}\zeta_j(\omega,t)I(t,\Delta T_j),\ \omega\in\Omega,\ t\in[0,T], \qquad (1)$$

where $\{\eta_i(\omega,t),\ i=\overline{1,n}\}$ - a sequence of homogeneous non-stationary (stationary) stochastic processes; $\{\zeta_j(\omega,t),\ j=\overline{1,m}\}$ - sequence of homogeneous random periodic processes; indicator function is given by:

$$I(t,\Delta T_j)=\begin{cases}1, & t\in\Delta T_j\\ 0, & t\notin\Delta T_j.\end{cases}$$

and it is formed by sentries instant change-point homogeneity of the test component in practice. In other words - the uniformity intervals $[0,\Delta T_1)\cup[\Delta T_1,\Delta T_2)\cup...\cup[\Delta T_{n-1},\Delta T_n]=[0,T]$ studying component (1).

For example, the model (1) becomes constructively in practice when as a component of the model was used Gaussian linear random processes [5].

In modeling tasks Gaussian linear random process can be represented as a structural model [6]:

$$\eta(\omega,t)=\int_0^t \varphi(t,\tau)x(\omega,\tau)d\tau\ , \tag{2}$$

where $\varphi(t,\tau)$ - impulse response function of a linear shaping filter, $x(\omega,\tau)$ - Gaussian white noise as a generalized derivative of a process with independent increments. For a stationary random process the expression (2) takes the form:

$$\eta(\omega,t)=\int_0^\infty \varphi(t-\tau)x(\omega,\tau)d\tau\ .$$

Gaussian linear random process $\zeta(\omega,t)$ is called periodic (T_0-periodic) if there exists a number $T_0>0$, in which the finite vectors $(\zeta(\omega,t_1),\zeta(\omega,t_2),...,\zeta(\omega,t_n))$ and $(\zeta(\omega,t_1+T_0),\zeta(\omega,t_2+T_0),...,\zeta(\omega,t_n+T_0))$ for all integers $n>1$ are stochastically equivalent

Classes of linear processes are selected depending on the formulation of the research problem. For example, a stochastic periodicity is accounted for in technical diagnostics of objects, systems and mechanisms.

Computer simulation. Two methods of computer simulation was suggested: using a histogram analysis; using autoregression model.

Computer simulations using a histogram analysis. Let $\xi_t,\ t\in\mathrm{Z}$ - a sequence of independent identically distributed random variables, and $(\xi_1,\xi_2,...,\xi_n)$ - repeated sample of observations (measurements) of the random sequence $\{\xi_t\}$. On the basis of the sample $\{x_i,i=\overline{1,n}\}$ as the implementation of $\{\xi_i,i=\overline{1,n}\}$ was needed to construct a histogram (the implementation of the empirical density distribution) by a known method [7].

In fact, the histogram can be viewed as an estimate piecewise constant approximation of the unknown density distribution. Therefore, the simulation algorithm for each element of the test sequence will be as follows:

- generates a pseudo-random number $\alpha^{(1)}$ by one of the known methods;

- generates the implementation of a discrete random variable η with the distribution obtained on the basis of the histogram;
- generates a pseudo-random number $\alpha^{(2)}$;
- generates the realization of a random variable $\xi = h\alpha^{(2)} + x_{\eta-1}$, which will have uniform distribution in the range $[x_{\eta-1}, x_\eta)$, where x_η - the point of interval partitioning $\left[\min\limits_{k=\overline{1,n}} \xi_k, \max\limits_{k=\overline{1,n}} \xi_k\right]$.

The proposed algorithm is based on method of piecewise approximation used for the simulation of random variables with known (given) density distribution. However, in this case, the estimation of the piecewise approximation of the unknown density distribution is found from the empirical data as a histogram, and the evaluation of the probability of the simulated values falling in the corresponding subinterval Δ_j is $\frac{\mu_j}{n}$, where μ_j - the number of sample points falling within j-th subinterval, $j = \overline{1,m}$.

To verify the simulation model can be used two-sample nonparametric uniformity criteria: the criterion of the Kolmogorov-Smirnov, criterion ω^2, criterion χ^2 etc.

Computer simulation using autoregression model. Let $\xi_t, t \in \mathrm{Z}$ - stationary random sequence (random process with discrete time), $m = \mathbf{M}\xi_t$ - mean and $R_\tau, \tau \in \mathrm{Z}$ - correlation function of the sequence ξ_t.

In the first stage of modeling is necessary to obtain statistical estimates of the mean and the correlation function of the process studied. Namely:

$$\hat{m} = \frac{1}{n}\sum_{k=1}^{n}\xi_k ,$$

$$\hat{R}_\tau = \frac{1}{n-\tau}\sum_{k=1}^{n-\tau}(\xi_k - \hat{m})(\xi_{k+\tau} - \hat{m}), \ \tau = 0, 1, 2, ..., n_1 << n .$$

Without loss of generality, we will continue to assume $m = 0$.

Autoregression sequence has the form:

$$\xi_t = -\sum_{k=1}^{p} a_k \xi_{t-k} + \zeta_t, \quad t \in \mathrm{Z}, \tag{3}$$

where $a_k, k = \overline{1,p}$ - real parameters; ζ_t - centered stationary white noise with variance $\mathbf{D}\zeta_t = \sigma^2$; p - order of autoregression model.

So to build a regression model of the studying process is necessary to evaluate parameters $a_k, k = \overline{1,p}$, σ^2, and the order p.

To obtain estimates of the parameters $a_k, k=\overline{1,p}$, it is necessary to substitute the assessments $\hat{R}_\tau, \tau=\overline{0,p}$ in the Yule-Walker equations and solve it for the unknown $a_k, k=\overline{1,p}$, σ^2. As a rule, the Yule-Walker system of equations is solved using a fast algorithm of the Levinson-Durbin. The required solutions will be consistent estimators of the parameters of the AR-model. Note that the estimates of the parameters of AR-model by the above method are always lead to the construction of sustainable AR-models, that have very important tasks in the use of these models for computer simulation.

The order p of AR-model is also unknown in practice. It is possible to use a set of criteria for its assessment [8].

Akaike criterion, called "the final prediction error" consists of statistics analysis

$$K_1(p)=\hat{\sigma}^2(p)\frac{(n+(p+1))}{(n-(p+1))},$$

where $\hat{\sigma}^2(p)$ - white noise variance estimate of AR-model by order p.

Statistic $K_1(p)$ is calculated for the values $p=1,2,3,\ldots$ to select the order of the AR model with the specified criterion. The order of value is selected such that the value $K_1(p)$ is minimized.

A technique of using other criterion is a similar. Akaike Information Criterion has the form:

$$K_2(p)=n\ln(\hat{\sigma}^2(p))+2p.$$

The criterion of "minimum description length":

$$K_3(p)=n\ln(\hat{\sigma}^2(p))+p\ln(n).$$

Criterion Parzen, called "transfer function regression criterion" has the form:

$$K_4(p)=\frac{1}{n}\sum_{j=1}^{p}\frac{n-j}{n\hat{\sigma}^2(j)}-\frac{n-p}{n\hat{\sigma}^2(p)}.$$

Differences of using these criteria by the real processes were analyzed in [10]. It should be noted that for the simulated AR-processes all four criteria give the same results.

Computer simulation algorithm will be as follows [8]:

- parameters $a_k, k=\overline{1,p}$, σ^2 of the simulated AR-process, which correspond to estimates obtained previously are set;
- sequence for centered stationary white noise $\zeta_t, t=-p,-p+1,-p+2,\ldots,-1,0,1,2,\ldots$ with a given distribution and variance σ^2 is generated;
- AR-sequence is generated by the formula (3) for $t=0,1,2,\ldots$, assuming $\xi_t=0$ for $t=-p,-p+1,-p+2,\ldots,-1$ (zero initial conditions).

The damped transitional process takes place by choosing the zero initial conditions $\xi_t = 0, t = \overline{-p,-1}$ in the simulated sequence. Therefore, samples ξ_t of the desired stationary AR-sequence will be obtained only for $t = t_1, t_1 + 1, t_1 + 2, ...$ where $t_1 >> p$.

The evaluation of the correlation functions the studied process (simulated process) and it generated AR model can be compared to verify the resulting computer simulation model.

Conclusions. Information support of computer measuring experiment in the evaluation of noise processes characteristics is given. Structural model of the noise signal based on a linear random process was considered. Algorithms of a computer simulation of the noise processes using histogram analysis and autoregression model were proposed. The simulation was performed on the basis of real (experimental) data noise processes measurement.

References

1.Martyniuk, G.V. Metrological monitoring of measurement systems of characteristics of noise processes / G.V. Martyniuk, L.M. Scherbak // Information processing systems: collection of scientific papers. – Kharkiv, I. Kozhedub’s Kharkiv National University of Air Force. – V. 6(143). – pp. 82-85.

2. Gupta, S. Application of electrical noise // IEEE. – V. 63. - № 9. – pp. 5-21.

3. Babak, S.V. Statistical diagnostics of electrical equipment: a monograph / S.V. Babak,, M.V. Myslovich, R.M. Sysak. - K .: Institute of Electrodynamics National Academy of Sciences of Ukraine, 2015. - 456 p.

4. Krasilnikov, A.I. Models of noise signals in the diagnostics heat and power equipment engines. - K .: Institute of Engineering Thermophysics, NAS of Ukraine, 2014. - 112 p.

5. Marchenko, B.G. Linear periodic processes // Power. 1999. - Vol. 3. - pp. 172-185.

6. Martyniuk, G.V. Constructive noise signals model and its main characteristics / G.V. Martyniuk, N.B. Marchenko, L.M. Scherbak // Integrated intellectual robototechnical complexes (IIRTC-2016): 9th International Science and Technical Conference, May 17-18th, 2016 – pp. 114-116.

7. Babak, V.P. Probability theory, stochastic processes and mathematical statistics / V.P. Babak, B.G. Marchenko, M.E. Fryz. - K: Technology, 2004. - 288 p.

8. Marple S.L. Digital Spectral Analysis with Applications. – NJ: Prentice Hall Englewood Cliffs, 1987. – 462 p.