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RELIABILITY OF OBTAINING THE MEASURING INFORMATION BY MEASURING-COMPUTING COMPLEX OF PROVING GROUND

The requirements for the information, that obtained by the measuring-computing complex (MCC) of proving ground, are considered. On the basis of adoption the concept of independence and equal probability of events, it has been determined, that the components of concept the reliability of obtaining measurement information are: the own reliability of measurement system itself, the reliability of measurement information, that is, the probability that the measurement errors will not exceed a predetermined value, and the likelihood that the information will be correct processed by the information processing system. The requirements have been put forward and an estimation of required precision the range measurements has been carried out to provide the given reliability of obtaining the measuring information.

Keywords: *military proving ground, the measuring-computing complex, information and information-measuring system, information and measuring equipment, reliability of obtaining the measuring information.*

Introduction

Problem statement. The measuring-computing complex (MCC) is a permanent military proving ground equipment, used in favor of various types of weapons and military equipment (WME). Therefore, the complex must support automated command post with real-time objective information regarding air (target, aim), ground, surface, water, and radio jamming situation during testing the samples of weapons and tactical exercises with combat firing [1].

The main goals of the MCC functioning are: control of an air and ground dynamic operations implementation; air traffic control; aircraft on-board equipment control; flight target tasks implementation quality assessment; interaction with complexes that implement the aircraft targeted use. In essence, MCC can be considered as an information control, collecting, processing, storing, and issuing system.

The main tasks complete and high-quality execution depends upon the MCC system control quality. In regards with the statistical nature of control process, and taking into account the control process global nature, it seems to take mathematical expectation of loss the information during its functioning as most efficient general characteristics of MCC work quality.

The analysis of recent researches and publications. This indicator reflects the informational nature of the MCC. For specific radioelectronic systems (RS), which are part of the MCC, it is interpreted accordingly [2].

So that, for the motion parameters measuring system, the quality index is related to the accuracy level of the object state vector determination. The metric recognition system is estimated by the average number of losses in image recognition, taking into account their significance, that is, the total average risk. For the radio communication system, the indicator associated with the average loss in the transmission of information is introduced. For the global navigation system - the average number of unserved objects, etc. [3].

During the design of MCC there are a number of system problems, the main of which include the need to:

– development of methods to solve the target tasks of information interaction;

– substantiation and choice of the optimal composition and rational distribution RS network of the MCC for realization of the purposes of information interaction;

– substantiation of tactical and technical requirements (TTR) for the RS, which implements separate operations of information interaction, systems of processing, registration and information display, and for means of functioning control of MCC;

– harmonization all the inputs and outputs among all sub-systems of MCC, unification of signals of information exchange, program languages for general and specialized software development of the MCC computing structures.

All above mentioned, results in the fact that the basis of the MCC functioning is “receiving-transfering” of the measuring, command-program (semantic) and control data. The basic requirements for this information, first of all, is the quality of its use, which is evaluated according to following criteria:

– relevancy – the ability to describe one or another aspect of phenomena and problems that are associated with the testing of WME or tactical exercises with combat firing, and specific situations, that are requiring a decision;

– timeliness, which is determined by the time last between the receipt of data and the moment of usage, the possibility of adoption and implementation of a corresponding decision based on this data;

– veracity, which is characterized by the reliability of the means of the MCC has been used to receive the data, as well as its conformity to reality. However, it should be kept in mind that, in a number of cases, probabilistic information has no less value compared with reliable, especially when it is predictive;

– completeness – ability to display all significant aspects of phenomena, problems, decisions, and other issues that are discussed in the received information (information message);

– admissibility – the characteristic of information to serve as the basis for a decision, to inform the higher authorities, use in procedural actions or for other purposes;

– significance – the characteristic of information to maintain its consumer value for the recipient over time, that do not obsolete;

– value – a generalized characteristic of information, its importance for decision-making, practical significance for achieving specific results or the implementation of specific control functions.

During the process of testing it is necessary to solve a large number of evaluation tasks based on the measurements results. The objects of evaluation are physical and technical parameters and processes, characteristics of the state of an aircraft, input and output characteristics of the aggregates and systems, acting perturbations, as well as statistical and probabilistic characteristics.

The main task of measurement results primary processing (processing and interpretation phase) is to obtain measured parameters estimates: selection, decryption and time reference, as well as removal of abnormal measurements.

Secondary processing of the measurement results (phase of analysis and evaluation of test results) consists of:

– evaluating the whole set of processes parameters relevant to a specific unit test;

– comparison of obtained values with acceptable ones;

– analysis of detected deviations and generation data for decision-making (on the continuation of tests, carrying out modifying, etc.).

Complete secondary processing is carried out on the basis of results the series tests in order to statistically evaluate the whole complex of WME partial and generalized quality indicators, verification of conformity with the values, specified in the TTR, preparation of data for decision making (on acceptance for weapons, expediency of modernization, continuation of tests, etc.)

Due to significance of these solutions, in technical requirements for trajectory and telemetry measuring systems are usually given their numerical characteristics. For example, in General Technical Requirements for Missile Arms (Application, item 1.4, item 2.2), it is determined, that the reliability of obtaining both trajectory and telemetric measurement information with the corresponding complexes of means, should be at least than $P_\Sigma = 0{,}98$ [4–5].

However, the term is not defined neither it is explained how this probability can be ensured. Thus, the **purpose of article** is to analyze and define the reliability (or the required probability) of obtaining trajectory information in MCC, to carrying out of estimation calculations the required precision of range measuring to provide a given reliability.

Exposition of basic material

In order to obtain the required reliability value P_Σ, all its components should be taken into account. The first component P_{sys} is related to the reliability (working capacity) of the system itself.

The second component is the reliability of information measurement, i.e. the probability that the measurement errors will not exceed some predetermined value P.

As a certain limit, as a rule, we must apply the allowable errors σ_{all}, and we will accept $2\sigma_{all}$ [6]:

$$P_{mea} = P\left(\lambda - 2\sigma_{all} < \hat{\lambda} < \lambda + 2\sigma_{all}\right). \quad (1)$$

The third component P_{ips} – is the probability that the data will be correctly processed by the processing system.

Taking into account that all listed events are incompatible, we can write generalized probability in the form:

$$P_\Sigma = P_{sys} P_{mea} P_{ips}. \quad (2)$$

Under assumption, that all components of expression (2) make an equal contribution, we can find the value of each of them as [7]:

$$P_{sys} = P_{mea} = P_{ips} = \sqrt[3]{P_\Sigma} \approx 0{,}9933. \quad (3)$$

Let's determine the RS possibilities to obtain data with probability $P_{mea} \approx 0{,}9933$. If the probability is less, we will assume that the work of the RS is abnormal.

To solve this problem, we assume that the measured parameter λ has a normal distribution and is encoded in the signal linearly. The system entrance receives a mixture of useful signal $S(t,\lambda)$ and white Gaussian noise $n(t)$ [8]:

$$y(t)=S(t,\lambda)+n(t), \quad (4)$$

where $\langle n(t)\rangle=0$, $\langle n(t)n(t)\rangle=0,5N_0\delta(\tau)$; $N(\omega)=N_0=const$ – spectral density of noise power; $\delta(\tau)$ – delta correlation function; τ – interval of correlation; t – time.

Considering the measurements uncorrelated, applied the Bernoulli scheme: we assume, that if in N measurements with probability p, the number of rejected measurements will be equal M_a, an abnormal work will come.

The number of measurements $N=625$ per time interval $T_i=1\,s$ will be taken, as, for example, in the radio engineering system (RES) "Kama", let $M_a=25$.

To calculate the probability of abnormal work we use the integral theorem of Muavre-Laplace [9–10]:

$$P(M_a\ge 25)=1-P(M_a\le 25)= \\ =1-P\left(\left(M_a-pN\Big/\sqrt{pNq}\right)\le \Phi^{-1}(0,9993)\right), \quad (5)$$

where $\Phi^{-1}(\cdot)$ – the inverse to Laplace integral function, $\Phi^{-1}(0,9993)=3,2$;

p – the probability that the k-th measurement will be rejected;

$q=1-p$.

Find the value p. Since $\frac{M_a-pN}{\sqrt{pNq}}=3,2$, then as solving a square equation, we get $p=0,073$.

This is occurring, when the *k*-th measurement is rejected, that is, the measurement error takes the value outside off interval $[-2\sigma_{all};+2\sigma_{all}]$.

According to the central limit theorem, the deviation is considered a normal random variable with an average value, equal to zero, and a modulus deviation: $|\sigma_{mea}|\le\sigma_{all}=2,\quad i=1...N$ [11].

Using the probability formula:

$$p=P\{|\sigma>2\sigma_{mea}|\}=1-P\{-2\sigma_{all}\le\sigma\le 2\sigma_{all}\}= \\ =1-\left[\Phi\left(\frac{2\sigma_{all}}{\Sigma}\right)-\Phi\left(\frac{2\sigma_{all}}{\Sigma}\right)\right]=2-2\Phi\left(\frac{2\sigma_{all}}{\Sigma}\right), \quad (6)$$

where $\Phi(x)=\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{x}e^{-\frac{t^2}{2}}dt$.

Since the known mean deviation module $M(\sigma)=2$ we will define Σ from this condition.

Note, that the distribution density $p(t)$ of a random variable σ, is a pair function [12]:

$$\int_{-\infty}^{\infty}|t|\,p(t)dt=2\int_{0}^{\infty}|t|\,p(t)dt. \quad (7)$$

We will have:

$$M(\sigma)=2=\frac{\sqrt{2}}{\sqrt{\pi}\Sigma}\int_0^{\infty}t\exp\left(-\frac{t^2}{2\Sigma}\right)dt= \\ =\frac{\sqrt{2}}{\sqrt{\pi}\Sigma}\Sigma^2\exp\left(-\frac{t^2}{2\Sigma}\right)\Bigg|_0^{\infty}=\sqrt{\frac{2}{\pi}}\Sigma, \quad (8)$$

so that $\Sigma=2\sqrt{\frac{\pi}{2}}\approx 2,5$.

The probability that an abnormal *k*-th measurement will appear is: $p=2-2\Phi\left(\frac{2\sigma_{all}}{2,5}\right)\approx 0,073$. Because $\Phi\left(\frac{2\sigma_{all}}{2,5}\right)=0,9635$, henceforth, we will determine the required accuracy of range measurements: $2\sigma_{all}\approx 4,5$ meters.

Conclusion

In this paper, on the basis of analysis the functioning of MCC in testing process, it is determined that the components of concept the reliability of obtaining measurement information are: the own reliability of measurement system itself, the reliability of measurement information, that is, the probability that the measurement errors will not exceed a predetermined value, and the likelihood that the information will be correct processed by the information processing system.

The requirements have been put forward and an estimation of required precision the range measurements has been carried out to provide the given reliability of obtaining the measuring information. Calculations show, that to ensure the measurement of the required reliability trajectory information reliability $P_\Sigma=0,98$, measurement accuracy is required within $\sigma_{mea}\le 4,5$ meters.

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НАДІЙНІСТЬ ОТРИМАННЯ ВИМІРЮВАЛЬНОЇ ІНФОРМАЦІЇ ПОЛІГОННИМ ВИМІРЮВАЛЬНО-ОБЧИСЛЮВАЛЬНИМ КОМПЛЕКСОМ

Б.О. Чумак, В.М. Романюк

Полігонний вимірювально-обчислювальний комплекс повинен забезпечувати проведення вимірювань, збору та математичної обробки вимірювальної інформації з метою об'єктивної оцінки льотно-технічних характеристик виробів, що випробовуються, а також оцінки контрольно-серійних і навчально-бойових пусків ракет з полігонів Міністерства оборони і об'єктів Замовника. ПВОК як складна організаційно-технічна система характеризується високим рівнем автоматизації процесів отримання, збору і обробки інформації, а також процесів управління зовнішнім і внутрішніми контурами інформаційної взаємодії, великими інформаційними потоками, складною багаторівневою ієрархічною структурою. Це вимагає методологічного системного підходу до вирішення задач проектування, аналізу і синтезу ПВОК, без чого неможлива оптимізація процесів його створення і цільового застосування та експлуатації. Повне і якісне виконання основних завдань залежить від якості системи управління ПВОК. У зв'язку із статистичним характером процесу управління, а також з урахуванням його глобальності, за загальну характеристику якості функціонування ПВОК в роботі прийняте математичне сподівання втрат інформації, що відображає переважно інформаційний характер його функціонування. Розглянуті вимоги до інформації, що отримується полігонним вимірювально-обчислювальним комплексом. На основі прийняття концепції незалежності і рівної ймовірності подій визначено, що складовими поняття надійності отримання вимірювальної інформації є власна надійність самої системи вимірювання, надійність вимірювальної інформації, тобто ймовірність того, що похибки вимірювання не перевищать деяку наперед задану величину, та ймовірність того, що інформація буде вірно оброблена системою обробки інформації. Висунуті вимоги та проведена оцінка потрібної точності вимірювань дальності для забезпечення заданої надійності отримання вимірювальної інформації.

Ключові слова: *полігонний вимірювально-обчислювальний комплекс, інформаційна та інформаційно-вимірювальна система, інформаційно-вимірювальне забезпечення, надійність отримання вимірювальної інформації.*

НАДЕЖНОСТЬ ПОЛУЧЕНИЯ ИЗМЕРИТЕЛЬНОЙ ИНФОРМАЦИИ ПОЛИГОННЫМ ИЗМЕРИТЕЛЬНО-ВЫЧИСЛИТЕЛЬНЫМ КОМПЛЕКСОМ

Б.А. Чумак, В.М. Романюк

Рассмотрены требования к информации, получаемой полигонным измерительно-вычислительным комплексом. На основе принятия концепции независимости и равной вероятности событий определено, что составляющими понятия надежности получения измерительной информации являются: собственная надежность самой системы измерения, надежность измерительной информации, то есть вероятность того, что погрешности измерения не превысят некоторой, заранее заданной величины, и вероятность того, что информация будет верно обработана системой обработки информации. Выдвинуты требования и проведена оценка требуемой точности измерений дальности для обеспечения заданной надежности получения измерительной информации.

Ключевые слова: *полигонный измерительно-вычислительный комплекс, информационная и информационно-измерительная система, информационно-измерительное обеспечение, надежность получения измерительной информации.*