About Time-Frequency Filters, Challenges and Experiences

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***Abstract*— Optimal (Wiener) filter based on the results of time-frequency analysis in estimation of instantaneous frequency (IF) of the estimated nonstationary signals and on the correspondence of the estimated IF to the filter's region of support provide high quality estimation of the linear frequency modulated (FM) noisy signals. Signal adaptive multiple-clock-cycle and completely pipelined hardware designs of this filter, with the optimized time and hardware requirements and in the one-dimensional and two-dimensional form, have also been developed. However, the IF estimation-based filtering solutions do not provide satisfactory results in estimation of the non-liner FM signals. Development of the modified IF estimation algorithm suitable to provide high quality estimation of the non-linear FM signals represents our topic in progress.**

***Keywords*— Estimation, Instantaneous frequency, Non-linear FM signals, Time-varying filter.**

I. Introduction

Signals usually spread across a range of frequencies whose width grows with nonstationarity of their characteristics. Therefore, signals with stationary, or almost stationary, characteristics can be efficiently analyzed by using conventional time- or frequency-invariant approaches. However, efficient processing of nonstationary one-dimensional (1D) and two-dimensional signals, including their filtering, requires a time-varying, [1-2], or a space-varying approach, [3], respectively. Time-varying approach can be defined by using the common time-frequency (TF) domain tools based on TF distributions (TFDs), whereas space-varying approach can be defined by using the space/spatial-frequency (S/SF) domain tools based on the S/SF distributions. These solutions have usually been referred to as the TF and S/SF filters, respectively.

TF filters can be designed explicitly or implicitly. TF filters, whose regions of support (FRSs) are the best approximations of the transfer functions of the distributions used in their definitions, have explicit design. TF filters having implicit design are based on the calculation of a linear TF transformation of the input 1D signal, on the TFD-based FRS estimation, and on the output signal estimation from the calculated linear transformation multiplied by the estimated FRS. The implicitly designed filters using the FRS estimation based on linear TFDs involve only linear processing steps, as well as explicitly designed filters, so these solutions result in linear TF filters. The implicitly designed filters using the FRS estimation based on quadratic TFDs result in nonlinear TF filtering solutions.

Classical filtering solutions belong to the linear filters, since they have been designed either explicitly based on the Richaczek distribution and the Wigner distribution (WD) (Zadeh and Weyl filter, [1], respectively), or implicitly based on the linear short-time Fourier transform (STFT) and Gabor transform (STFT and Gabor filters, [1], respectively). However, these solutions suffer from the drawbacks introduced by the TFDs used in their definitions. The Zadeh filter cannot be used for nonstationary signals, the STFT and Gabor filters have limited resolution, whereas the Weyl filter is essentially restricted to halfband signals, [1]. To suppress the noted flaws and to extend the limits of classical solutions, their extended versions (the multiwindow STFT filter, the multiwindow Gabor filer, as well as the approximate halfband Weyl filter) have been defined, [1]. However, the extended versions increase calculation complexity of the classical solutions. Nonlinear filtering solutions, based on the WD or the smoothed WD, [1], improve resolution and selectivity, but at the expense of their complexity. The projection filter, [1], has extremely high selectivity, but also significantly higher complexity in comparison to the other solutions.

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Being numerically quite complex, TF filters require significant time for calculation. Therefore, they are usually unsuitable for real-time analysis and thus their application is severely restricted in practice. Hardware implementations, when possible, can overcome these problems. However, online algorithms for single-clock-cycle implementation (SCI) of linear TF filters from [1], the existing SCI design of the nonlinear TF filter from [4], and possible implementations of nonlinear TF filters from [2], require repeating of basic calculation elements if they need to be used more than once. Therefore, these implementation schemes can be so complex

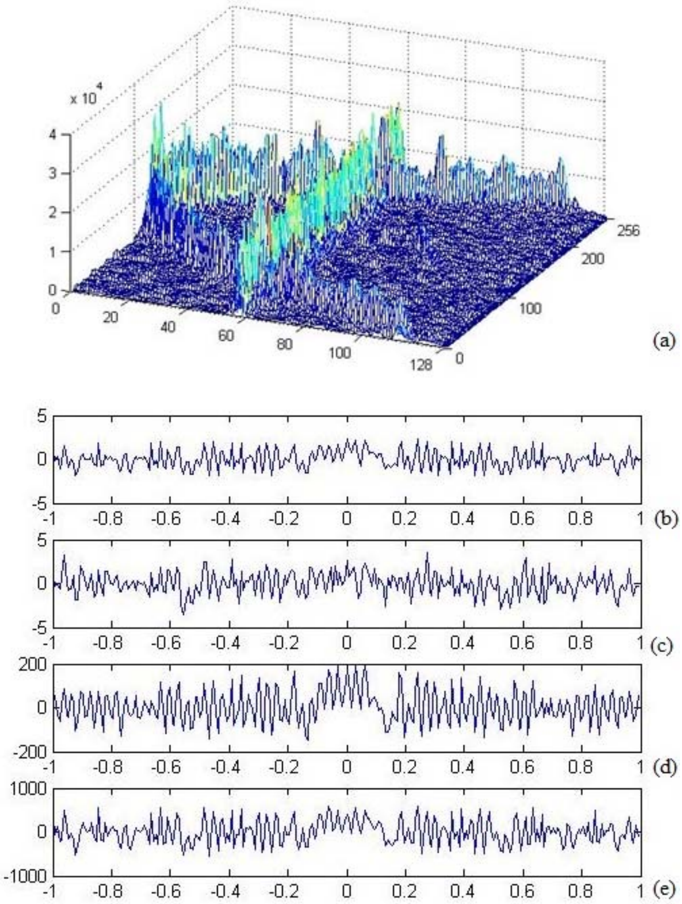

Fig. 1 (a) *CTFWD of the multicomponent noisy signal* (3), (b) *Original multicomponent signal* (3), (c) *Noisy signal* (3), (d) *The estimated signal obtained by using the state-of-the-art IF estimation algorithms from* [2, 5], (e) *The estimated signal obtained by using the modified IF estimation algorithm.*

that often cannot be implemented. Besides, complexity of these systems depends on the filtered signal duration, so they are capable of performing estimation of signals with the predefined duration only. To overcome flaws of the mentioned TF filters' designs, the multiple-clock-cycle, but also signal adaptive, [5], as well as the completely pipelined, [6], implementations of the IF estimation-based optimal (Wiener) TF filter have recently been developed. These solutions simultaneously optimize complexity and the execution time of the developed filter, making it suitable for real-time and on-a-chip implementation.

II. Problem Formulation

Optimal filtering of nonstationary 1D signals, related to the Wigner distribution framework, [1-2], and used to overcome distortion of the estimated FM signals has been defined and can be written, in the frequency domain, [2, 5], by:

$$(Hx)(n) = \sum_{k=-N/2+1}^{N/2} L_H(n,k) STFT_x(n,k) \qquad (1)$$

where $L_H(n,k)$ is the FRS (the Weyl symbol of the filter's impulse response), [1-2], $STFT_x(n,k)=DFT_m[w(m)x(n+m)]$ is the STFT of the noisy q-component signal,

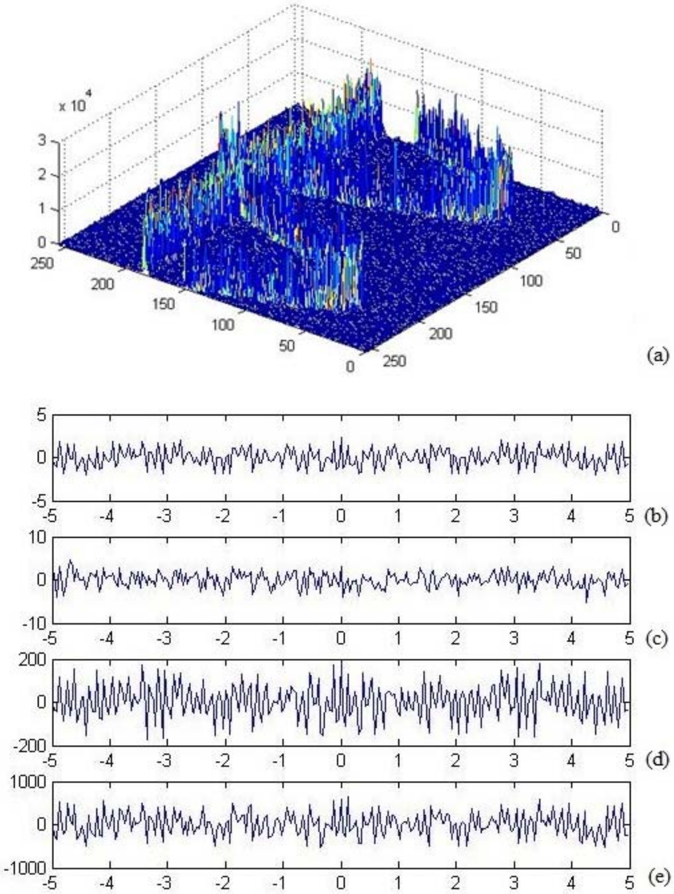

Fig. 2 (a) *CTFWD of the multicomponent noisy signal* (4), (b) *Original multicomponent signal* (4), (c) *Noisy signal* (4), (d) *The estimated signal obtained by using the state-of-the-art IF estimation algorithms from* [2, 5], (e) *The estimated signal obtained by using the modified IF estimation algorithm.*

$$x(n) = \mathrm{sum}_{i=1,..,q}(f_i(n)) + \varepsilon(n),$$

DTF_m[ ] is the operator of the discrete Fourier transform in m, $w(m)$ is a real-valued STFT lag window, and N is the windowed signal duration.

Following procedure for the stationary Wiener filter design in the case of signal not correlated with the additive noise $\varepsilon(n)$, of FM signals $f_i(n)$, $i=1,\ldots,q$, highly concentrated in the TF plane around their IFs, and of a widely spread white noise, the FRS $L_H(n,k)$ of the optimal (Wiener) nonstationary filter corresponds to the combination of IFs of signals $f_i(n)$, [2, 5]. Then, the optimal filtering problem of nonstationary FM signals can be reduced to the IF estimation in a noisy environment. This solution applied to (1) results in a high quality filtering of nonstationary FM signals highly concentrated in the TF plane and exposed to the widely spread white noise, [2, 5]. In the practically most important case of a single realization of noisy signals and the TF analysis framework, the IF estimation is performed by determining frequency points k_i, $i=1,\ldots,q$, in which TF representation of noisy signal has local maximum,

$$IF_i(n) = \arg[\max_{k \in Q_{k_i}} TFD_x(n,k)] \qquad (2)$$

where Q_{ki} is the basic frequency region in TF plane around $f_i(n)$, the IF of which is $IF_i(n)$.

Among all the TFDs, the recently defined cross-terms-free Wigner distribution (CTFWD), [5, 7], optimizes the IF estimation characteristics, [8]. In detail, it retains the optimal IF estimation characteristics of the Wigner distribution in the highly nonstationary mono-component signals case, [8]. However, it also produces the optimal IF estimation characteristics in the case of multicomponent signals whose components do not overlap in frequencies. In that case, the IF estimation characteristics of the CTFWD, obtained for each signal's component separately, remain the same as for the case when only that particular signal's component exists, [9]. This qualifies the CTFWD as an optimal base for an IF estimation-based TF filter (1)-(2) development that has be performed in [4-6].

Following characteristics of the classic Wigner distribution, the CTFWD produces optimal TF representation of the linear FM signals providing their highest quality estimation based on the IF estimation related filtering (1)-(2), [2, 5-6]. However, there is no a TF distribution which produces optimal representation of the non-linear FM signals. Besides, in a particular time instant and due to the frequency discretization, the non-linear FM signals can (and usually) occupy certain range of frequencies. Further, under the additive noise influence and depending on the selected Q_{ki} width, each frequency from the considered range can mask more or less the adjacent frequencies from same range of frequencies, disabling their estimation based on the definition (2) and, therefore, disabling efficient estimation of non-linear FM signals.

Taking into account the noted principles, the problem of the non-linear FM signals estimation can be efficiently solved. To this end, the IF estimation algorithm, based on the definition (2) and proposed in [5], should be modified in such a way to recognize the particular time instants in which the considered signal occupies the certain ranges of frequencies and to enable the IF estimation in all frequencies from the considered ranges. Result of the research activities in improvement of the IF estimation algorithm that provides estimation of the non-linear FM signals and the comparisons of the modified algorithm with the state-of-the-art IF estimation algorithms from [2, 5] are presented in examples given in the sequel.

III. EXAMPLES

The modified IF estimation algorithm, which principles are considered in the previous section, is verified through the estimation of the following multicomponent test signals:

$$f_1(nT) = e^{j300\pi(nT)^3} + e^{j400(nT)} + e^{-30(t-1/8)^2}\cos(625(nT+29)^2), \qquad (3)$$

$$f_2(nT) = e^{j700\pi\sin(nT)} + e^{j400(nT)} + e^{-30(t-1/8)^2}\cos(625(nT+29)^2). \qquad (4)$$

Each of the observed signals consists of the quite non-linear FM component combined by the linear FM component and the chirp component, Figs. 1(a), 2(a). These signals are considered within the ranges $-1 \le nT \le 1$ and $-5 \le nT \le 5$, respectively, and are masked by the high white noises such that $SNRin_1 = 10\log(P_{f1}/P_{\varepsilon1}) = 0.2086$[dB] and $SNRin_2 = 10\log(P_{f2}/P_{\varepsilon2}) = 0.2411$[dB], respectively. Within the simulation, the Hanning STFT lag window $w(m)$, width of $T_w=0.25$, is applied, as well as $N=256$, and $T=T_w/N$.

Filtering results obtained within the estimation of 3-component signals (3)-(4) are given in Fig. 1(b)-(e) and in Fig.2(b)-(e), respectively. Filtering efficiency achieved by using the modified IF estimation algorithm can easily be noticed by comparing Figs. 1(b) and 1(e), i.e. by comparing Figs. 2(b) and 2(e). As well, the improvement achieved by using the modified IF estimation algorithm can be recognized from Figs. 1(d) and 1(e), i.e. from Figs. 2(d) and 2(e).

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Quality Management System at an Enterprise in the Radio Electronic Industry

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***Abstract* – In the article there's presented the necessity, external and internal preconditions of building a quality management system (QMS) at the enterprises in the radio electronic industry. There're identified and substantiated industry-specific manufacturing and organizational peculiarities that should be taken into account while designing a QMS.**

Keywords – quality management system; radio electronic industry; ISO 9001; building a quality management system

Introduction

Under modern economic conditions the effectiveness of planning, realization and progressive advance of the activity of organizations in any branch of economics directly depends on the systematic character, openness and transparency of the applied methods and mechanisms of management. Moreover, the success is mainly achieved by means of introducing and maintaining a QMS by which there's understood a part of an enterprise management system in terms of quality. For Russian enterprises in the radio electronic industry the given task is one of the key ones.

The radio electronic industry is one of the key areas of focus of modern industry, the basis of high-technology products of many branches of industry. In any end-products there are either electronic components or radio electronic assemblies, units, modules, devices, systems.

The main technological tendencies in the market of electronic and radio electronic products can be considered microminiaturization, the increase in productivity, the microcircuit density, expanding the functional capabilities, the integration of different electronic and radio electronic products (ERPs) in one product, and the transition to new advanced materials. Together with these tendencies there can also be noted increasing requirements to the ERP qualitative characteristics, first of all to reliability, technological and operational capabilities, as well as service life and no-failure operation. The products of the electronic and radio electronic industry refer to high-technology, that's why there're placed high demands on their quality.

Radio electronics is the most rapidly-growing branch of industry in the world in which there're realized a great number of innovative projects; the growth rate of the industry for the past 30 years has been on the average about 8 per cent per year.

For today Russia's radio electronic industry comprises more than 1800 organizations occupied with the development and manufacturing of radio electronic equipment, radio electronic systems and devices of industrial, military, household and any other use. At present Russia's radio electronic industry provides 275 thousand working places and makes a great contribution into the country's gross domestic product (GDP).

According to the Russian Federation's State program "Development of the Electronic and Radio Electronic Industry, 2013-2025" (approved by the Decree of the Government of the Russian Federation dated December 15, 2012, No.2396-p) the main aim of the state policy in the sphere of the radio electronic industry is improving competitiveness of the radio electronic industry by means of creating the infrastructure for the development of the priority guidelines, integration into the international market and realization of innovative capacity.

In this regard, an important focal point in the state policy in this branch is the distribution in Russia of the world quality and effectiveness standards. In this case, one of the key mechanisms of managing (reducing) the risk of maintaining inefficiency and low entrepreneurial activity of the companies in the branch is introducing modern quality systems. This measure is aimed at increasing the companies' effectiveness as part of the product quality – one of the most important key

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success factors in the product priorities of the branch development.

MATERIALS AND METHODS

The analysis of the peculiarities, advantages and problems of building and perfecting a QMS is presented in the following papers: Dahlgaard-Park, & Dahlgaard [1], Oakland [2], Salgado, Silva, Mello, & Silva [3]; Jain, & Ahuja [4]; Alič [5]; Cagnazzo, Taticchi, & Fuiano [6]; Chatzoglou, Chatzoudes, & Kipraios [7], Salimova [8] and others.

The enterprises in the electronic industry all over the world actively implement and certify the QMS. In 2015 the share of the certificates given to the enterprises in the electronic industry was 9.5 per cent. According to ISO statistics, this branch is the second on the number of ISO 9001 certificates.

In all branches of economics by the beginning of 2016 there had been given more than 1.03 million certificates of conformity to ISO 9001 requirements in 197 countries in the world. There was observed an annual increase in the number of the given certificates; during the period from 1994 to 2015 the growth rate was from 2 to 81 per cent a year (with the exception of 2003 and 2011, that is during the late years of the transition to the new versions of the standard). The leading countries on the number of the given certificates are China, Italy, Germany, Japan and Great Britain (Table 1).

Table 1. The leading countries on the number of the given certificates in ISO 9001

Leading countries	Number of certificates
1. China	292514
2. Italy	131718
3. Germany	52347
4. Japan	46983
5. Great Britain	39950
6. India	36236
7. USA	33051
8. Spain	32526
9. France	27598
10. Romania	20504
Total	713427
Percentage of the total number	69 per cent

Source: ISO statistics: https://iso.org

The first ten countries accounted for 69 per cent of all the given certificates. Among the post-Soviet countries the obvious leader is Russia with the number of certificates about 9000, the rest countries have a far smaller number of certificates.

RESULTS

We have found out the prerequisites of building a QMS at the enterprises in radio electronic industry. The necessity of building a QMS at an enterprise in radio electronic industry arises under the influence of a great number of factors and prerequisites which are commonly divided into two groups: external and internal [9].

The external prerequisites of building a QMS include the following:

1) the availability of the state system of compulsory licensing certain operations, productions, products and services. For today, the presence of a QMS corresponding to the requirements of the industrial standards of management or its individual elements is necessary to get a license for the development, production, testing, storage, sales and recycling of ammunition and explosives;

2) taking part in tenders and other tendering procedures for the product supply both on the domestic and foreign market:

a) getting a state order in compliance with the requirements of the Federal Law No. 44 of 05.04.2013 “On contract systems in the sphere of procurement of goods, works and services for provisioning governmental and municipal needs” is in many respects connected with the presence at an enterprise a certified QMS:

b) providing supplies to the enterprises the procurement activities of which are regulated by the requirements of the Federal Law No. 223 of 18.07.2011 “On procurement of goods, works and services by different kinds of legal bodies”. For example, in the procurement documentation of the Public Joint-Stock Company “Gasprom”, the Public Joint-Stock Company “Russian Railways”, the Public Joint-Stock Company “Rostelecom” and so on, a potential supplier having a QMS is welcomed;

c) getting by an enterprise of subcontracts both from foreign customers and Russian export companies often depends on a company having a QMS;

3) the legislation of a series of countries, and since 2000 also Russian, in all disputable situations related to the quality and safety of products and services requires the confirmation of compliance of the product supplied to the market with the current scientific and technical level; in this case the availability of a certified QMS is considered as such a confirmation;

4) an enterprise-supplier having a certified QMS allows it without any extra financial, time and organizing costs clear a number of the set non-tariff (technical) barriers in trade. This practical activity is captured in the agreements developed at the level of the WTO, the Eurasian Economic Union and the international and regional organizations focusing on the issues of technical regulation in foreign trade;

5) The International Electrotechnical Commission (IEC) recommends implementing a QMS at the enterprises of the electronic industry. The ISO together with the IEC developed a number of standards and specifications containing recommendations and requirements to a QMS of the organizations of this branch and the procedures of the evaluation of a QMS;

6) the QMS certification gives an enterprise a necessary level of trust on the market and enhances its business

reputation because a conformity certificate is a generally accepted quality guarantee;

7) the opportunities for insurance, factoring, crediting and some other kinds of the support by the financial institutions of transactions on the product supply to both the foreign and domestic markets require the confirmation of the firm's stability, first of all as related to the risks connected with the quality and safety of products that to a certain extent can be confirmed by the availability of a certified QMS;

8) the prospects of establishing enterprises with foreign capital also depend on the partner enterprises having a certified QMS. In the prospective investors' opinion, the absence of a QMS questions investments security and the possibility of the expansion into new sales markets.

In their turn, the internal prerequisites of the development and implementation of a QMS at the enterprises in the radio electronic industry may include the following:

1) establishing a modern system of management as in the ISO standards of 9000 series there's accumulated the best for the moment management practice based on the Deming cycle of continuous improvements (PDCA), TQM principles and providing the basis for creating the integrated management systems;

2) the availability of a QMS upgrades the quality of an enterprise management on the whole. An optimal combination of managerial functions and the scope of the delegated authority, the responsibility matrix and other tools offered by the ISO standards of 9000 series allow considerable improving the management quality and changing the role of the top management focusing their attention mainly on strategic management;

3) a QMS functioning presupposes the involvement of all the staff in quality assurance at all stages of the product life-cycle – from the demand analysis to the maintenance of the finished products that considerably increases responsibility for the labour quality;

4) a QMS allows considerable reducing rework costs and respectively reducing product costs. Being consumer- and other stakeholders-oriented, a QMS allows anticipating consumers' claims and complaints due to forming a precise mechanism of preventive and corrective measures in the sphere of the quality of the output products and provided services.

5) the QMS availability at an enterprise encourages the growth of its assets: a) intangible assets including good will may increase due to the value enhancement of the trademark of the producer consistently turning out high quality products; b) financial assets may increase due to the income capitalization resulted from the increase in working capital (rise in the prices of high quality products, capturing new sales markets and so on).

No matter which of the given above prerequisites will the key one when making a strategic decision on the development and implementation in a QMS, its basis must become the leadership approach of a company's management team and careful scheduling of all the project's measures on building a QMS.

Discussion and Conclusions

A QMS development is rather a labour-taking and long process. According to the requirements of the international standards ISO 9001, establishing a QMS requires an organization's strategic decision the making of which can be influenced by a company's internal and external environment, risks related to this environment, changing business needs, the status of the output products, employed operations, an organization's size, structure as well as particular goals and reasons for building a QMS. Success is achieved due to the observance of the key TQM principles: a) consumer orientation; b) leadership; c) the workers' cooperation; d) the process approach; e) improvement; f) evidence based decision-making; g) mutually beneficial relations with partners or relationships management.

The process of building a QMS at the enterprises of the radio electronic industry presupposes implementing a number of measures and works that can be conventionally broken into the following stages: set-up, principal, final, improvement. This variant of structuring a project corresponds to the Deming cycle of continuous improvements (PDCA) (Fig.1).

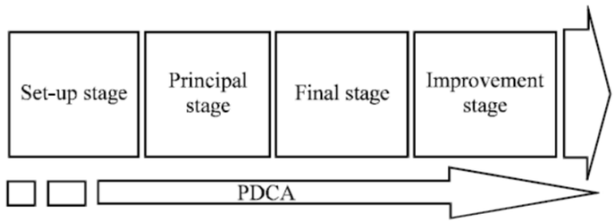

Figure 1. The project's structure on building a QMS of a corporation

At the first stage of the project an enterprise determines the demands and expectations of consumers, the owner and other stakeholders. At the second stage there're developed the strategies and policy in the sphere of quality management. Then there're determined necessary for the strategy implementation business processes as well as the methods and tools of the evaluation of their effectiveness and efficiency. Based on the results of monitoring and measuring the functioning of separate elements and a QMS of an enterprise on the whole there're developed and implemented the measures on the optimization of the organizational structure, business processes, their document support and resources' provision.

In the process of the development and implementation of a QMS it's necessary to take into account the peculiarities of a branch of industry. The peculiarities of building a QMS in the electronic and radio electronic industry follow from the specific character of the branch of industry; they can be divided into organizational and technological. The following technological peculiarities can be referred to the electronic and radio electronic industry:

The electronic and radio electronic branch of industry is the most science-intensive. It brings about a number of requirements: a high level of expenses on the Research and Development to the production output; a great staff number engaged in science and scientific services in relation to the production personnel; the usage of science-intensive products at the initial stage can be inefficient for a long time.

A sophisticated and in some cases unique technology to be developed partly guarantees that the competitors won't be able to copy easily a product and that a great number of the competitors won't enter the market in the nearest time. But on the other hand, if the rework of an article requires some time, it'll considerably increase costs while generating any profit will be delayed.

Scientific-technological progress leads to the quick moral ageing of production. Every year there are developed about 20 per cent new products that requires a quick rearrangement of production and the implementation of a new nomenclature in a relatively short time and with minimum expenses.

In this regard, the increase in the stakeholders' requirements to the product quality as well as the increased competition and scientific-technological progress require building such a QMS that responds to the changing external conditions as quickly as possible and allows ensuring a high level of customer satisfaction.

The following peculiarities can be referred to the organizational ones:

The branch is noted for a wide range of nomenclature including the products of the space industry; those designed for the military application; those for industrial and household use.

One enterprise can produce up to two thousand product names that requires a clear organization of the major and auxiliary processes with the focus on the unproductive expenditures optimization.

The branch embraces different types of production; the articles of the electronic and radio electronic industry can be both made in a single copy and mass-produced. The single-item production narrows down the potentialities of using standard constructions and technological decisions. At the production of unique articles there arises a need to use a large number of the original details, that's why technological processes are developed broadly. The same producing department has to be specialized in executing different manufacturing operations.

The greatest competitive power in the electronic and radio electronic industry is revealed by large enterprises. Almost half of the enterprises in the branch have the number of employees more than 1000 people. On the whole, the share of large and medium-sized (more than 200 employees) enterprises in the electronic and radio electronic industry exceeds 80 per cent of their total number. It brings about an intensive development of vertically integrated systems. In Russia there're built up enterprises according to the vertical type of integration (according to the cycle: research – development – production). At present there work five large integrated structures (OJSC "Air and Space Defense Concern "Almaz-Antey", JSC "Radio Engineering Concern "Vega", JSC "Concern "Sozvezdie", OJSC "Concern "Avtomatika", JSC "Concern "Control Systems" and three large holding companies within the state corporation "Rostec": JSC "Ruselectronics", JSC "Concern "Radio-electronic Technologies" and JSC "United Instrument Manufacturing Corporation".

The corporate structure brings about taking into account its peculiarities while developing a QMS: the presence of a corporate structure and independent business units, multilevel internal corporate communications, a complex system of centralization and decentralization of management functions, a great number and variety of business processes, regional and product diversification and others.

On the whole, a QMS as one of the most widely-spread management tools allows regulating the organizational structure, management mechanisms, optimizing main and secondary processes at the enterprises in radio engineering industry on the whole with a focus on meeting the expectations of the parties concerned that provides in the long run the increase in the competitive capacity of an organization.

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Evolutionary Algorithm for the Problem of Parameters Optimization of Complex Technical Systems

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Abstract – **The problem of parameters optimization of complex technical systems has been considered and the possibility of application of the evolutionary algorithm for its decision has been investigated. The scheme of optimization system functioning based on the evolutionary algorithm has been resulted. The algorithm of the optimization problem decision based on the evolutionary approach is offered. The example of application of the offered algorithm for the problem of the shooting planning of the objects' group with the acceptable time expenditures with some criteria of the shooting optimization has been given.**

***Keywords** – technical system, optimization, parameter, evolutionary approach, evolutionary algorithm.*

I. Introduction

The purpose of this research is the application of evolutionary approach to the problem of parameters optimization of complex technical systems by means of development of the software tool containing the mathematical models and the evolutionary algorithms and providing the search of the optimum parameter values of the optimization problem, which must satisfy to the large number of requirements and restrictions, with the acceptable time expenditures.

In this case the problem of parameters optimization of complex technical systems belongs to the class of multivariable one-criterion problems of the optimization search of the parameter values, allowing reaching the greatest possible efficiency of the system functioning.

II. The Evolutionary Approach to the Optimization Problem

Evolutionary approach to specific optimization problems allows applying the evolutionary algorithms (genetic algorithms, evolutionary strategies, evolutionary programming) as the optimization algorithms realizing the possibility of the simultaneous search among the several alternative solutions and choosing the best of them [1 – 3].

It is possible to mark out four main aspects which must be considered at the solution of the practical problems by means of the evolutionary algorithms:

- choice of a way of the decision representation (coding);
- choice (development) of the evolutionary operators;
- determination of laws of the decision survival;
- generating of the initial decision population.

The universality of the evolutionary approach is that only criteria of search depend on the specific optimization problem. All other actions in the case of application of the evolutionary algorithms for the optimization problems are realized similarly, but with the use of various evolutionary operators [2].

In the case of application of the evolutionary approach it is possible to present an optimization problem in the form of the subject domain model integrated into the evolutionary algorithms. The subject domain model is understood as the representation of the set of the problem parameters, and also the criterion of its optimization in the form, acceptable for the use of the evolutionary algorithm.

III. The Optimization System Based on the Evolutionary Algorithm

The key input parameters of optimization system based on the evolutionary algorithm are the following: the number of the optimization parameters with the ranges of their possible changes, the fitness function, the population size, the number of populations, the initial values of the crossing probability and the mutation probability, the number of iterations of the evolutionary algorithm for the fitness function calculation.

As any evolutionary algorithms, the evolutionary strategies assume the generating of the initial population of chromosomes which is exposed to selection and the evolutionary operators impact to get the most adapted chromosomes.

The diagram of the optimization system based on the evolutionary algorithm is represented in Fig. 1.

The connection lines between the blocks on the diagram implement the following functions:

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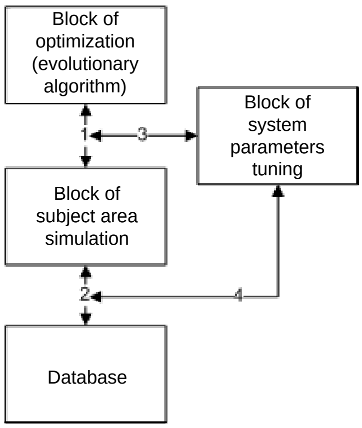

Figure 1. The diagram of the optimization system based on the evolutionary algorithm

- the connection 1 is the search of the decision on the base of the evolutionary algorithm;
- the connection 2 is the subject domain data presentation and the transfer of the received optimized parameter values by means of the optimization block;
- the connection 3 is the determination of the evolutionary algorithm search strategy;
- the connection 4 is the transfer of the optimized parameters values in the database by the evolutionary algorithm.

IV. THE EVOLUTIONARY ALGORITHM FOR SOLVING THE OPTIMIZATION PROBLEM

The evolutionary algorithm for solving the optimization problem is represented in Fig. 2.

The block of the algorithm called as “The setting of the parameters and the restrictions of the optimization problem” represents a problem definition stage at which it is necessary:

- to set the parameters the change of which must provide the maximum efficiency of the optimization problem decision in the context of obtaining of the optimum value of the used criterion (the fitness function);
- to set the criterion (the fitness function) which mustl allow reflecting the interrelation between the problem parameters and providing the accomplishment of comparison of the received decisions versions to determine the “best” of them;
- to set the variation ranges of the parameters of the optimization problem;
- to determine the extreme values of the parameters of the optimization problem by imposing the restrictions (“equality” or “inequality”).

The block of the algorithm called as “The evolutionary algorithm implementation for the specified parameters” is responsible for implementation of the evolutionary optimization algorithm. In this block the sets of the values of the varied parameters are generated and the chromosomes after application of the evolutionary operators for the set number of iterations are determined.

The blocks of the algorithm called as “The fitness function calculation and the results ordering” and “The choice of chromosomes with the best values of the fitness function (the sets of the parameters values) for the next iteration” perform the fitness function calculation that allows comparing and choosing the “best” sets of the values of the optimized parameters with the aim to use them for the next iteration of the evolutionary algorithm. Besides, the check on the observance of all restrictions of the subject domain imposed on the values of the varied parameters and the fitness function is made here.

The block of the algorithm called as “The results display” is responsible for output of the values list of the fitness function which provide the achievement of the optimization criterion goal) and sets of the values of the optimized parameters and restrictions corresponding to this values list of the fitness function.

V. THE PROBLEM OF THE SHOOTING PLANNING OF THE OBSERVATION OBJECT

For the functional testing of the evolutionary algorithm and the software optimization system the practical optimization problem of the covering with the shooting system of the observation objects was considered.

Previously, the planning of shooting of the observation objects was made for the chosen area with the purpose of receipt of the initial parameters values of the shooting of the observation objects.

The criterion of the optimum covering of the observation object is the minimum value of a difference between the covering area and the object area.

It is necessary to find the values of the shooting parameters providing the optimum covering of the observation object. To solve this optimization problem the evolutionary algorithm described above is applicable.

A herewith, previously it is necessary to implement the representation of the subject domain of the optimization problem using the evolutionary algorithm terminology. The required decision of the optimization problem of the covering with the shooting of the observation object can be presented in the form of a chromosome in which the parameters, such as the latitude and the longitude of the initial shooting point, the shooting start time, the shooting duration, the image motion speed and the azimuth, which are the points in the search space, are coded.

When solving the optimization problem of the covering with the shooting system of the observation objects using the evolutionary algorithm it is expedient to apply:

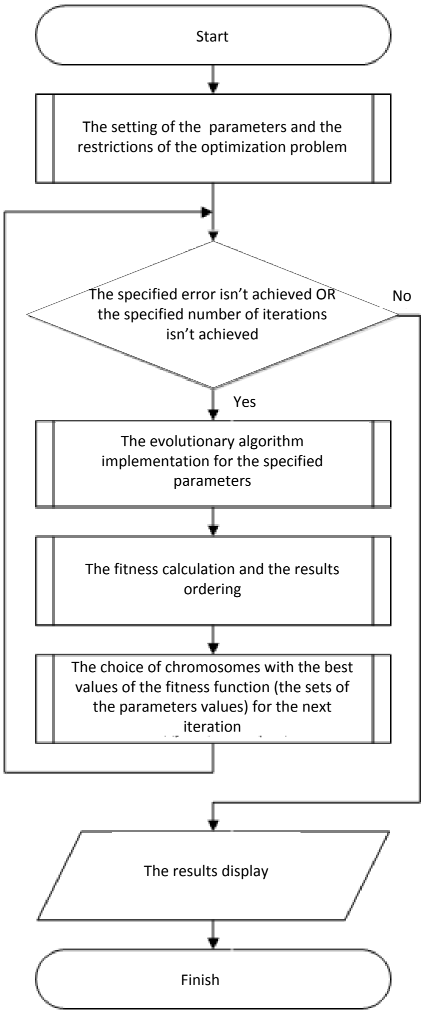

Figure 2. Evolutionary algorithm to solve the optimization problem

- the several populations of the fixed size;
- the fixed size of population corresponding to the number of the decisions of the optimization problem representing the sets of the values of the shooting parameters;
- the fixed length (digit capacity) of chromosomes, equal to six, to match the number of the optimized parameters;
- the identical combinations of strategies of selection and formation of the next generation in the each population;
- the random selection of chromosomes for the crossing;
- the single-point crossover (crossing) and the single-point mutation.

When implementing the crossing in the evolutionary algorithm, at first, the random choice of parents (two chromosomes) is carried out, then the crossing point is randomly selected and, at last, the crossing (exchange of parts) of chromosomes-parents and receiving two chromosomes-descendants is performed.

When implementing the mutation in the evolutionary algorithm, at first, the mutation point for some chromosome-parent is randomly selected, and then the mutation and receiving the chromosome-descendant is performed.

Periodically (for example, through the assigned number of iterations of the evolutionary algorithm) the accidental exchange of chromosomes between the populations is made, that allows implementing the different type of the parallel evolutionary algorithm having some properties of the island model of the genetic algorithm.

The analysis of the subject optimization problem of the covering with the shooting system of the observation objects, shows that initially the formula for the fitness function can be written down as:

$$S_s - S_{ob} \rightarrow min\,, \tag{1}$$

where S_s is the shooting area, S_{ob} is the object area.

It is necessary to provide the maximum approximation of the shooting area to the area of the observation object so that vertices of the observation subject were in the borders of the optimum shooting, and the shooting area differed from the area of the observation object at the minimum value. Therefore, the specified formula for the fitness function takes the form:

$$(S_s - S_{ob}) + N \cdot N_{kr} \rightarrow min\,, \tag{2}$$

where S_s is the shooting area, S_{ob} is the object area; N is the number of vertices, which do not fall into the shooting boundaries; N_{kr} is the numerical value, which is much greater than the difference of areas and is required to achieve the significant deterioration in the fitness function in the case of non-compliance of condition of hit of all vertices of the object in the shooting area.

As the difference of the area of shooting and the area of the observation object will strive for the minimum value of the square kilometers, it is possible to accept the numerical value N_{kr} equal to 100000, that will allow increasing the difference of the areas of hundreds of times and will provide the rejection of decisions in which not all vertices of the object are captured.

As the shooting area must to cover the area of the observation object, it is necessary to provide the performance of the condition of positivity for the fitness function:

$$((S_s - S_{ob}) + N \cdot N_{kr}) > 0\,. \tag{3}$$

The optimization evolutionary algorithm of the covering with the shooting system of the observation objects can be described by the following sequence of steps.

1. To form M initial n-size populations with the chromosomes P_i ($i = \overline{1, n}$).

2. To make the random choice of the chromosomes parents from populations, if the current number g of iterations of the evolutionary algorithm iterations is less than the maximum number G of iterations, and then to the go to the step 3 is carried. To go to the step 6, if maximum number G of iterations is achieved.

3. To make the crossing and mutation operators in each population, if the current number g of iterations is not a multiple of some number I ($I < G$). To choose randomly from M populations T ($T \le M/2$) pairs of populations, if the current number g of iterations is a multiple to number I, to create in the each pair of populations the pair of chromosomes with the best values of the fitness function, and to apply the crossing operation for this pair of chromosomes.

4. To form the intermediate population from the parents and the descendants. To calculate for each chromosome the value of the fitness function calculating using the formula (2) and to check the restriction (3).

5. To form the new n-size population by an exception of chromosomes with the worst values of the fitness function. To go to the step 2.

6. To choose the "best" chromosome (with the smallest value of the fitness function (2)), which defines the set of the parameters values. To output the received set of the parameters values.

When the execution of the evolutionary algorithm is over it is recommended to use the decision received by means of this algorithm (the set of the found values of the shooting parameters values) or to increase the number of iterations of the evolutionary algorithm for the further search.

The calculation with the use of the offered evolutionary algorithm of the optimum values of the shooting parameters for the observation objects for the specified set of the values of the initial parameters and specified set of the values of the restrictions was done.

The dependency of the values of the fitness function on the number of iterations of the evolutionary algorithm is presented in Fig. 3. A herewith, the improvement (decreasing) of the fitness function in the case of increasing of the iteration number is shown.

The obtained results demonstrate the feasibility of application of the evolutionary algorithm for solving the optimization problem of the covering with the shooting of the observation object when the difference between the area of the object and the area of the shooting shall be minimum and the area of the shooting shall cover the area of the object with the specified number of iterations of the algorithm.

VI. Conclusions

The developed software optimization system based on the evolutionary algorithm is the instrument of searching of the optimum parameters values of the complex technical systems thanks to the representation of the optimization problem in the form of model of the subject domain integrated into the evolutionary algorithm. A herewith, it is interesting to consider the possibilities of application, in particular, of the particle swarm optimization algorithm [4] in the context of solving the optimization problem as individually as in a hybrid, for example, with the genetic algorithm.

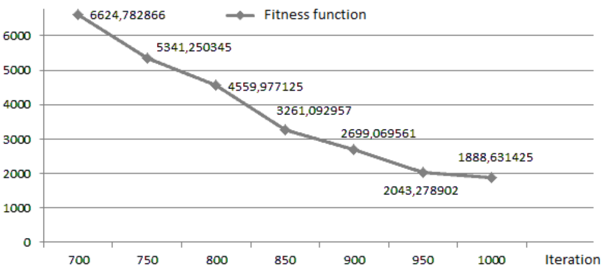

Figure 3. The dependency of the values of the fitness function on the number of iteration

The reviewed practical example of the optimization problem of the covering with the shooting system of the observation object clearly shows the possibilities of the offered software optimization system and the prospects of its further development.

The results of shooting, in particular, can be applied for the problems of the image segmentation [5] and the objects identification [6].

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