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EVALUATING THE EFFECTIVENESS OF ADAPTIVE ANTENNA ARRAY IN WEIGHT COEFFICIENTS DISCRETIZATION

Представлена аналітична оцінка середнього коефіцієнту втрат при дискретизації квадратурних складових нормованих вагових коефіцієнтів в адаптивній антеній решітці. Визначено необхідну розрядність вагових коефіцієнтів адаптивної антенної решітки в залежності від відношення сумарної потужності перешкод завад до потужності внутрішнього шуму на вході смугового фільтра. Це зроблено виходячи з допустимої величини зменшення середнього вихідного відношення сигнал/перешкода завада+шум.

Ключові слова: *дискретизація квадратурних складових, вагові коефіцієнти, антенна решітка, коефіцієнт втрат.*

1. Introduction

Currently multichannel systems of signal reception on the background of interferences apply spatial filtration based on weight summing of output oscillations of spatially distributed channels. One of the factors reducing the efficiency of spatial filtration in comparison with the potential one is the discreteness of the control of the spatial filter (SF) weight coefficients (quantization of the weight coefficients). In a number of problems, it is important to evaluate the effectiveness of spatial filtration when the sources of interference are randomly located in the area of the side lobes of the directivity pattern in the constituent SF, and the quantization of the quadrature components of the complex weight coefficients w_i is preceded by their normalization by the value $w_{\max}=\max\limits_i(|\mathrm{Re}w_i|,|\mathrm{Im}w_i|)$. In a number of problems, it is of interest to evaluate the effectiveness of spatial filtration in the case when the interference sources are randomly located in the area of the side lobes of the directivity pattern of the constituent SF. The discretization of the quadrature components of the complex weight coefficients w_i is preceded by their normalization by the value:

$$w_{\max}=\max_i(|\mathrm{Re}w_i|,|\mathrm{Im}w_i|).$$

A number of studies [1–5] have been devoted to investigation of the influence of the error in setting weight coefficients on the effectiveness of spatial filtration, however, it is of interest to obtain an analytical solution of the problem in this formulation.

2. The object of research and its technological audit

Any property of the Adaptive Antenna Array (AAA) is achieved by the appropriate choice of the complex weight coefficients $(WC)_i$, $i=1,2,..N$, added at the output of the receiving antenna elements (AEs) and preceding the common adder (Fig. 1).

The object of research is the process of discretization of weight coefficients in the adaptive antenna array.

Due to the adaptive WC processor, an appropriate formation of the total directivity pattern (DP) and the polarization diagram is provided, i. e., the WC together with the common adder represent a beam-forming scheme.

At the same time, the determination of the WC assignment can be interpreted as the problem of forming such ratios between the received N-realizations of the useful signal $S_i(t)$ on the N-antenna elements, the sum j of narrow-band anisotropic interferences:

$$\sum_{j=1}^{J} n_j(t)$$

and noise $u(t)$.

After adding them to a common adder, it is needed to provide a maximum Signal-to-Interference-plus-Noise Ratio, a minimum standard deviation of the received signal from the given one or another criterion:

$$y(t)=\sum_{i=1}^{N} w_i x_i(t), \quad (1)$$

where

$$x_i(t)=s(t)+\sum_{j=1}^{J} n_{ij}(t)+\nu_i(t). \quad (2)$$

With the help of WC, their vectors are formed (VWC):

$$W^T(t)=\big(w_1(t),w_2(t),\ldots,w_N(t)\big). \quad (3)$$

In the general case, the VWC $w(t)$ must be able to change both the amplitudes and phases of the received signals, i.e., it must be complex. The rate of these changes must be consistent with the rate of change in the signal-interference condition. The range of changes is coordinated with the dynamic range of signal and interference level changes, as well as the phase relationships in different AAA elements.

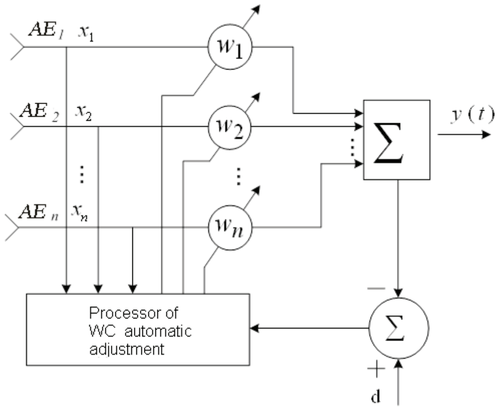

Fig. 1. Adding the vector of weight coefficients in the adaptive antenna array

Obviously, the situation is ideal when the rate of VWC changes is infinitely large, and the dynamic range of amplitude-phase characteristics changes is unlimited. However, in practice, based on the possibilities of technical feasibility and other reasons, it is needed to limit these characteristics, and this, generally speaking, leads to a corresponding decrease in AAA effectiveness. In this sense, we mean an AAA with limitations.

In a number of problems of antenna equipment, the final result of the problems being solved is the synthesis of DP with various restrictions on the design, dimensions, spectral composition of signals and interference, and other parameters. At the same time, the ultimate goal of using AAA is to provide the necessary quality characteristics (maximize them) of useful signals at the antenna output, i. e., to obtain the output ratio:

$$y(t)=y(w_t,t)=(w(t),x^*(t))=W^T(t)x^*(t)=$$
$$=w_1(t)x_1(t)+w_2(t)x_2(t)+...+w_N(t)x_N(t), \qquad (4)$$

where the expression in parentheses denotes the scalar product of vectors satisfying a pre-selected criterion; the asterisk denotes complex conjugation. In this case, the total DP of AAA, as such, may not be considered at all, although it is certainly of interest as an intermediate characteristic. Thus, the AAA can be obtained using the scalar product of the VWC $w(t)$ by the vector $f(\theta)$:

$$F(\theta)=(W^T(t),f^*(\theta)), \qquad (5)$$

where

$$f^T(\theta)=(f_1(\theta),f_2(\theta)e^{i\phi_1\theta 1},...,f_N(\theta)e^{i\phi_N\theta 1});\ f_i(\theta)$$

is non-standardized DPs of AAA receiving elements; $\phi_{i\theta 1}$ is phases of the diffracted unitary wave counted from the phase of the signal from the output of the 1st element (at $\phi_{i\theta 1}=0$), which are fixed at the outputs of the receiving elements at the account of spatial differences.

Detection and evaluation of multidimensional signals requires comprehensive a priori information on the spatial and temporal characteristics of signals, noise and interference. However, in fact, only some of these characteristics are known, and therefore the missing information must be obtained during the system operation. The wide use of adaptation methods for this purpose has led to the creation of systems with adaptive space-time signal processing (ASTSP), in the synthesis of which the entire arsenal of adaptive methods is used: the expansion of the number of evaluated parameters, the use of iterative procedures, empirical evaluates, etc.

The implementation of the mapping of an arbitrarily distorted signal with arbitrary AA characteristics is only statistically possible by using matrix weighting of the input data, which adapts to the characteristics of the received signal. This is usually called the statistically optimal formation of DP, where the choice of weight vectors is based on the statistics of the received signal against the background of active noise and interference. In order to optimize the response, the choice of the weight coefficients of the beam former is carried out in the following manner. The antenna output should contain minimal noise components and signals coming from directions, which differ from the direction to the source of the useful signal. Therefore, the main direction of AAA quality analysis is to obtain an analytical evaluation of the average loss rate caused by the discretization of the quadrature components of the normalized weighting coefficients.

3. The aim and objectives of research

The aim of research is to obtain an analytical evaluation of the average loss rate for discretization of the AAA weight coefficients, taking into account a random location of the interference in the side lobe area of the directivity pattern. This will provide an opportunity for potential evaluating the limitations of the AAA in the process of discretization of weight coefficients for the current conditions of signal-noise situations.

To achieve the aim it is necessary:

1. To determine the required dimensionality of the weight coefficients, based on the allowable value of the decrease in the average output Signal-to-Interference-plus-Noise Ratio (SINR), depending on the ratio of the total interference power to the power of the internal noise (I/N ratio) at the SF input.
2. To obtain an evaluation of the dependence of the average loss rate on the input interference/noise ratio and the quantizer capacity under and without discretization.
3. To evaluate the required quantizer capacity.

4. Research of existing solutions of the problem

Among the main directions in the analysis of the effectiveness of AAA functioning based on the chosen criterion for evaluating the weight coefficients during quantization, the following works can be distinguished:

In [1], statistical characteristics of the normalized SINR, which determines the effectiveness of spatial filtration under the conditions of acting set of randomly located interference sources, are obtained on the mathematical model.

The author of [2] has obtained analytical relationships that provide the calculation of the parameters necessary to select the optimal value of the regularizer.

In [3], the optimal weighing of weight coefficients is considered for the purpose of using them for adaptive increase of signal-to-interference ratio (SIR) in signal processors. The accuracy required to calculate the weights is evaluated. It is shown that for the antenna adaptivity, the required accuracy of the weight coefficient increases with increasing values of achievable improvement of SIR and the number of auxiliary elements.

In [4], the necessary accuracy of computing the calculated optimal weights of the adaptive processor is shown, which was analyzed by studying the error effects in the calculation of the inverse matrix. It is shown that the required accuracy depends on the size of the matrix and an equation for the general case is obtained.

In [5], the results of the study of the influence of weight coefficients quantization on the performance of the antenna array adaptive processor, which uses perturbation methods to obtain the gradient required in the least-squares algorithm, are reported. The paper presents analytical and simulation results of the quantization effect on weight coefficients.

Analyzing a number of publications devoted to this subject [6–10], let's note that the relevance of the problematics of these tasks does not decrease, since at the present time there is an urgent need for applying high-performance adaptive space-time signal processing in AAA.

In these works, various approaches are proposed for finding an analytical evaluation of the effectiveness of the AAA operation with the quantization of weight coefficients. At the same time, many of the works devoted to this subject are of a private and applied nature with a number of restrictions on the impact of the surrounding signal-to-interference environment.

Within the scope of the problem, the author of this work performs a general analysis of the effectiveness of AAA functioning using quantization methods for weight coefficients.

5. Methods of research

The quantization of the weight coefficients in the general case leads to a change in the output power of the useful signal by a quantity, and the total power of the interferences and noise by a quantity ΔP_{i+n}. Therefore, taking into account the fact that the quantization is preceded by the normalization of the weight vector by $w_{\max}$, we have the relations:

$$P_{s\,qu} = P_s / w_{\max}^2 + \Delta P_s,$$

$$P_{i+n\;qu} = P_{i+n} / w_{\max}^2 + \Delta P_{i+n}, \qquad (6)$$

where P_s, ΔP_{i+n} are the signal power and the sum of the interferences and internal noise at SF output with unquantized weight coefficients (weight vector W) respectively; $P_{s\,qu}$, $\Delta P_{i+n\,qu}$ are the similar powers at SF output with quantized weight coefficients (weight vector W_{qu}).

In the case of interference in the side lobe area of the directivity pattern of the spatial filter constituent with the SF useful signal, the position of the main lobe maximum practically coincides with the direction of the useful signal arrival [6]. And since the change in the main lobe near the maximum caused by quantization is insignificant, then in evaluating the loss rate we can accept:

$$\Delta P_c \approx 0. \qquad (7)$$

In addition:

$$P_{i+n} \approx \Delta P_n, \qquad (8)$$

because under optimal spatial filtration, in the case when the number of interferences M is less than the number of SF channels N, almost complete interference cancellation occurs [7].

The decrease in the SINR due to the quantization of the weight coefficients is characterized by the loss coefficient:

$$K = \frac{Q_{qu}}{Q} = \frac{P_{squ} / P_{i+nqu}}{P_s / P_{i+n}}. \qquad (9)$$

Given (1)–(4):

$$K \approx \left(1 + \frac{\Delta P_{i+n}}{P_n / w_{\max}^2}\right)^{-1} = (1+\xi)^{-1}, \qquad (10)$$

where $\xi = \Delta P_{i+n} / (P_n / w_{\max}^2)$.

Let us find an evaluate of the average loss rate $\bar{K}$ for averaging over the locations of the interference sources. The function $(1+\xi)^{-1}$ is convex (taking into account that $\xi \geq 0$).

Therefore, in accordance with the Jensen inequality [8], the following lower evaluation is valid for the average loss rate:

$$\bar{K} \approx E\left\{\left(1 + \frac{\Delta P_{i+n}}{P_n / w_{\max}^2}\right)^{-1}\right\} \geq \left(1 + \left\{\frac{\Delta P_{i+n}}{P_n / w_{\max}^2}\right\}\right)^{-1}, \qquad (11)$$

where E is the symbol of mathematical expectation.

For the case of quantization with a constant step, let's evaluate the average increment of the interference power ΔP_{i+n} using the technique applied by Hudson in [9]. The increment in the interference power is:

$$\begin{aligned}\Delta P_{i+n} &= P_{i+nqu} - P_{i+n} = W_{qu}^* R W_{qu} - W^* R W = \\ &= (W + \Delta W)^* R (W + \Delta W) - W^* R W = \\ &= \Delta W^* R \Delta W + 2\mathrm{Re}(\Delta W^* R \Delta W) = \\ &= tr(\Delta W \Delta W^* R) + 2\mathrm{Re}[tr(W \Delta W^* R)],\end{aligned} \qquad (12)$$

where $\Delta W = W - W$ is the error vector of weight coefficients quantization;

$$R = \frac{1}{2} E\{XX^*\}$$

is the covariance matrix of the complex envelopes X in the vector of the sum of interferences and noise; * is the sign of the Hermitean conjugation; $tr(\cdot)$ is the trace of the matrix. Let's average (12), taking into account that for a sufficiently large number of quantizer digits (greater than six [5]), the following random variables can be considered statistically independent: the vectors ΔW and W; components Δw_i of the vector ΔW; matrices $\Delta W \Delta W^*$ and R.

The average increment in the interference power is:

$$\Delta P_{i+n} = tr(E\{\Delta W \Delta W^*\} E\{R\}) = tr(2 R_{\Delta W} E\{R\}), \qquad (13)$$

where the covariance matrix of the quantization error vector ΔW is:

$$R_{\Delta W} = \frac{1}{2} E\{\Delta W \Delta W^*\}, \qquad (14)$$

$\sigma_{\Delta W}^2$ is the variance of the vector ΔW components; I is the unity matrix.

Substituting (14) into (13) and using the fact that the trace of the covariance interference matrix $tr(R)$ does not depend on the location of the interference sources and is equal to $N P_{i+n\ input}$ [6], obtain:

$$\Delta P_{i+n} = \sigma^2_{\Delta W} P_{i+n\ input} N. \quad (15)$$

In most of spatial filtering problems $P_{i\ input} >> P_{n\ input}$, therefore, the average increase in the interference power is approximately equal to:

$$\Delta P_{i+n} = \sigma^2_{\Delta W} P_{i\ qu} N. \quad (16)$$

It should be noted that another evaluation of the average increment in the interference power due to quantization is known, which exceeds the evaluation (16) by N times [3, 6]:

$$\Delta P_{i+n} < \sigma^2_{\Delta W} P_{i\ qu} N^2. \quad (17)$$

The evaluation (17) is obtained by averaging the known inequality for Hermitean forms:

$$\Delta P_{i+n} = \Delta W^* R \Delta W \le \lambda_{\max} \left\|\Delta W\right\|^2,$$

taking into account the fact that for the positively defined covariance matrix the largest eigenvalue is:

$$\lambda_{\max} < tr(R) = N \Delta P_{i\ input} \text{ and } \lambda_{\max} E\left\{\left\|\Delta W\right\|^2\right\} = N\sigma^2_{\Delta W}.$$

Let's return to the evaluation of the average loss rate (11). Let's assume that the internal noise powers in the SF channels are the same and equal to $P_{n\ input}$. Then:

$$\frac{P_n}{w^2_{\max}} = \frac{1}{w^2_{\max}} \sum_{i=1}^{N} P_{n\ input} |w_i|^2 = = P_{n\ input} \frac{\|W\|^2}{w^2_{\max}} = P_{n\ input} \|W_{norm}\|^2, \quad (18)$$

where W_{norm} is the normalized weight vector. The vector is statistically independent from the quantization error vector ΔW, therefore (given (12) and (18)), the random variables $P_n / w^2_{\max}$ are also independent. Consequently, ΔP_{i+n}:

$$E\left\{\frac{\Delta P_{i+n}}{P_n / w^2_{\max}}\right\} = \overline{\Delta P}_{i+n} E\left\{\frac{1}{P_n / w^2_{\max}}\right\}. \quad (19)$$

By substituting (18) and (19) into (7) receive the inequality:

$$\bar{K} \ge \left(1 + \sigma^2_{\Delta W} Q_{n\ input} N E\left\{\frac{1}{\|W_{norm}\|^2}\right\}\right)^{-1}, \quad (20)$$

where $Q_{i\ input} = P_{i\ input} / \mathrm{P}_{n\ input}$ is the SINR at the SF input.

As the modeling has shown:

$$\sqrt{D\left\{\left\|W_{norm}\right\|^2\right\}} / E\left\{\left\|W_{norm}\right\|^2\right\} << 1,$$

in particular, under $N = 10$ and $Q_{i\ input} = 20...50$ dB this value does not exceed 0.15.

That is why:

$$E\left\{1 \big/ \left\|W_{norm}\right\|^2\right\} \approx 1 \big/ E\left\{\left\|W_{norm}\right\|^2\right\},$$

and the evaluation (20) can be rewritten as:

$$\bar{K} \ge \left(1 + \sigma^2_{\Delta W} Q_{i\ input} / \bar{\alpha}\right)^{-1},$$

where $\bar{\alpha} = E\left\{\left\|W_{norm}\right\|^2\right\} \big/ N$.

To obtain an evaluation of the average loss rate in the completed form, it is necessary to determine the values $\sigma^2_{\Delta W}$ and $\bar{\alpha}$.

Let's determine the variance of the components of the quantization error vector $\sigma^2_{\Delta W}$. The quadrature components of the components Δw_i are distributed uniformly in the interval $[-d/2,\ d/2]$, where α is the value of the quantization step. Therefore:

$$\sigma^2_{\Delta W} = E\{(\mathrm{Re}\,\Delta w_i)^2\} + E\{(\mathrm{Im}\,\Delta w_i)^2\} = \frac{d^2}{6}. \quad (21)$$

In the considered SF the boundary of the linear section of the quantizer characteristics for the normalized quadrature components of the weighted coefficients are –I and +I. Thus the quantization step is:

$$d = 2 / 2^{i\ qu}, \quad (22)$$

where n_{qu} is the number of digits of the quantizer.

By substituting (22) into (21), obtain:

$$\sigma^2_{\Delta W} = \frac{1}{6}\left(\frac{2}{2^{n\ qu}}\right)^2 = \frac{1}{3 \cdot 2^{2\ n\ q-1}}. \quad (23)$$

The value $\bar{\alpha}$ entering in (21) I cannot be determined analytically, and therefore it is evaluated on the mathematical model of the SF.

6. Research results

Fig. 2 shows the values $\bar{\alpha}$ depending on M obtained by averaging 100 implementations under $N = 10$ and 20 for values of $Q_{i\ input}$ 20 dB and 50 dB. It is obvious that $\bar{\alpha}$ depends mainly on the number of interferences and is practically independent of the interference-to-noise ratio and number of channels. If we assume that the amount of interference that is of practical interest does not exceed 20, then the dependence $\bar{\alpha}(M)$ is fairly well approximated by the function:

$$\tilde{\alpha}(M) = 0.48 + 0.52\exp(-0.17M), \quad (24)$$

the graph of which is also shown in Fig. 2.

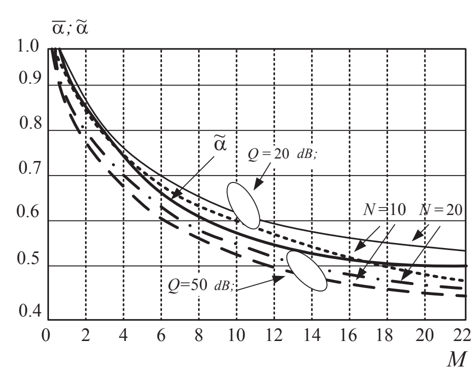

Fig. 2. Dependence of the value $\bar{\alpha}$ on M

Substituting (23) and (24) in (21), obtain the final expression for evaluating the average lower loss rate:

$$\bar{K} \geq \tilde{K} = \left(1 + \frac{Q_{i\,input}}{3 \cdot 2^{i\,qu-1} \cdot \tilde{\alpha}(M)}\right)^{-1}, \qquad (25)$$

which is valid at least under:

$N = 10...20,\ M \leq N,\ Q_{i\,input} = 20...50$ dB.

If the value $\bar{K}$ should only be evaluated, then (25) can be simplified by replacing the function $\tilde{\alpha}(M)$ with its mean value of approximately 0.7:

$$\bar{K} \geq \tilde{K} = \left(1 + Q_{i\,input} / 2^{i\,qu}\right)^{-1} = \tilde{\tilde{K}}. \qquad (26)$$

Let's compare the evaluations (25) and (26) with the values of the average loss rate obtained on the model under the following conditions:

$Q_{i\,input} = 30$ dB, $n_{qu} = 5...8$, $N = 10...20$.

Fig. 3 shows that the solid line represents the dependence of the evaluation $\tilde{K}$ on M; the dashed line represents the evaluation $\tilde{\tilde{K}}$; separate symbols show the values of the average loss rate obtained on the model.

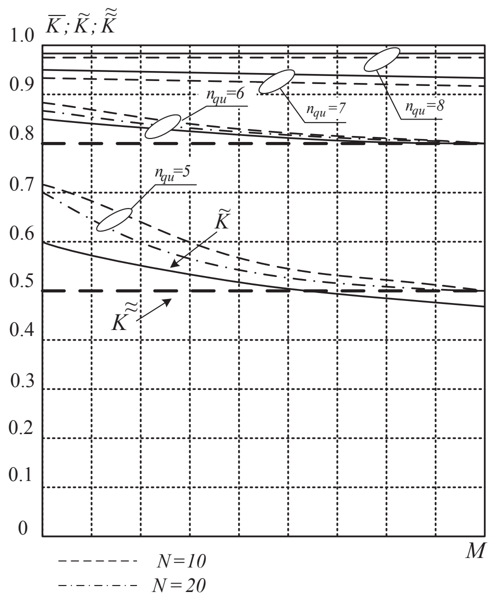

Fig. 3. Dependence of the evaluation $\tilde{K}$ on M

It is obvious that with the large quantizer ($n_{qu} = 6...8$), when $\bar{K} > 0.8$ the evaluation $\tilde{K}$ and simulation results coincide, and the error of the evaluation $\tilde{\tilde{K}}$ does not exceed 5 % under $n_{qu} = 5$ when the ratio:

$$E\left\{\Delta P_{i+n} / (P_n / w_{\max}^2)\right\} << 1,$$

is not held. The calculated values are less than those obtained on the model, which is explained by the fact that $\tilde{K}$ is the lower evaluation. Note that if n_{qu} and $Q_{i\,input}$ are such that $\bar{K} > 0.8$, then $\bar{K}$ does not practically depend on M, and the value $\tilde{\tilde{K}}$ can be used as the average loss rate. Fig. 4 shows a family of dependencies on the average loss rate $Q_{i\,input}$ obtained on the model $N = 10$, $M = 5$, $n_{qu} = 5...11$, $Q_{i\,input} = 10...80$ dB (solid line), as well as its evaluation $\tilde{K}$ calculated according to the formula (23) (dashed line). It can be seen that in this whole wide range of quantizer capacity and I/N ratio values, the calculation results practically coincide with the simulation if $\bar{K} > 0.5$, and differ by not more than 0.1 for smaller values of $\bar{K}$.

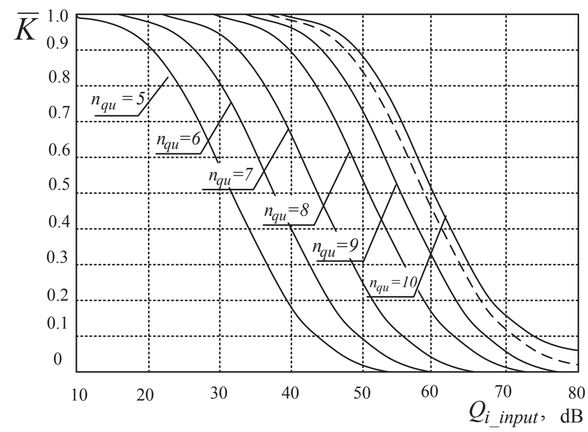

Fig. 4. Dependence of $\bar{K}$ on Q_{i_input}

The evaluation (26) makes it possible to obtain a simple analytic expression for the required quantizer capacity:

$$n_{qu}^{req} \approx \frac{1}{2}\log_2 \frac{Q_{i\,input}}{1/\bar{K}^{add} - 1}, \qquad (27)$$

where $\bar{K}^{add}$ is the permissible value of the average loss rate. If we express the allowable value of the relative decrease in the average loss rate $\delta\bar{K}^{add} = 1/\bar{K}^{add} - 1$ and the I/N ratio $Q_{i\,input}$ – in decibels, then the required weight dimensionality will be:

$$n_w^{req} \approx \frac{1}{6}(Q_{i\,input[\text{dB}]} - \delta\bar{K}_{[\text{dB}]}^{add}). \qquad (28)$$

Let's define the required dimensionality of the weight coefficients for two typical values of the allowable average loss rate:

For $\bar{K}^{add} = 0.8$;

$$n_{qu}^{req} \approx (Q_{i\,input[\text{dB}]} + 6)/6; \qquad (29)$$

For $\bar{K}^{add} = 0.9$:

$$n_{qu}^{req} \approx (Q_{i\,input[\text{dB}]} + 10)/6. \qquad (30)$$

From the above relations it follows that regardless of the value of allowable losses, the required quantizer capacity is increased by 1 bits with an increase in the input SINR by 6 dB. As it is known, the similar relation lies between the capacity and the dynamic range of the quantizer in the quantization of oscillations in various problems of digital signal processing [9].

7. SWOT analysis of research results

Strengths. Among the strengths of this research, it is necessary to point out the results of the analytical evaluation of the average loss rate for the spatial filter with quantization of the quadrature components of the normalized AAA weight coefficients with a random interference location. As a result, it is possible to show that the loss rate depends only on the input I/N ratio and the quantizer capacity. As the I/N ratio increases, the necessary requirement for ensuring the needed loss rate increases the quantizer's capacity. When using a quantizer with a large capacity n_{qu}=6...8 at K>0.8, the results of simulation coincide with the mathematical model of the SF with the 5 % error.

In comparison with analogues, this will allow to optimize the rate of computing the varying amount of processed information.

Weaknesses. The weaknesses of this study are related to the fact that there are certain limitations when implementing space-time access (STA). As a rule, these limitations are mainly associated with the characteristics of AAA and the feasibility of adaptive space-time processing algorithms (ASTSP) synthesized by various criteria.

The characteristics of AAA depend not only on the control algorithms of the VWC, but also on the parameters of the antenna array itself:

– the number of antenna elements (AEs);
– directional pattern (DP);
– polarization characteristics of AE;
– mutual influence of AEs;
– array configurations, etc.

In addition, all these factors lead to the decrease in the achievable signal-to-interference-plus-noise ratio (SINR) to some extent, and some can also cause a decrease in the rate of convergence of the adaptation process.

In this statement, issues in a comprehensive evaluation of the various impact-limiting factors of the AAA STSP characteristics and the evaluation of its effectiveness, taking into account the limitations under consideration, remain relevant for research.

The negative internal factor inherent in this research will ultimately be an increase in value when it is implemented into production.

Opportunities. Additional opportunities to achieve the aim of research lie in the following systemic approaches. For STSP systems designed to solve problems of optimal detection and evaluation of signal parameters, it is typical to use joint realization of optimal spatial and temporal filtration of signals. In this case, the optimization of spatial filtration is carried out using a multidimensional filter that takes into account spatial properties of the signal and noise fields. The multidimensional filter of the optimal STSP system implements the optimum amplitude-phase frequency-dependent distribution on the AA elements, by means of which the directivity pattern of the AA is controlled and, thus, the spatial filtration procedure is optimized. Consequently, different signal-interference situations must correspond to their complex frequency characteristics of the multidimensional filter.

If the noise is isotropic, and the realizations of its field on the AA elements will be correlated, then the spatial filtration reduces only to the traditional phasing of the AA. Phasing of AA will be carried out in the direction of the arrival of the signal and evaluation of the loss rate in the weight coefficients discretization.

When implementing this research object in practice, the main additional opportunity will be the improvement of the quality parameters of the AAA functioning.

Threats. The difficulties in implementing the results of the research are related to the following main factors. To implement the above-considered optimal STSP systems providing detection and evaluation of multidimensional signals, exhaustive a priori information on the spatial and temporal characteristics of the signal fields, noise and interference is required. However, in fact, only some of these characteristics are known, and therefore the missing information must be obtained during the system operation.

The widespread use of adaptation methods for this purpose led to the creation of adaptive STSP systems (ASTSP). When synthesizing ASTSP systems, the whole arsenal of adaptive methods is used: the expansion of the number of evaluated parameters, the use of iterative procedures, empirical evaluates, etc.

The procedure for quantizing the weight coefficients of AAA and other factors lead to the decrease in the achievable signal-to-interference-plus-noise ratio (SINR) to varying degrees, and some can also cause the decrease in the rate of convergence of the adaptation process. Considering the above-mentioned information, it is worth noting that the main difficulty in implementing the research results is the performance of the digital computer realizing the algorithm for space-time processing, including the procedures of WC discretization and AAA pattern control. As similar studies of this problem show, for the formation of one AAA partial ray, it is necessary to perform $1436 \cdot 10^3$ operations, and to form a three-beam DP it is necessary $1759 \cdot 10^8$ operations.

8. Conclusions

1. The analytical lower evaluation of the average loss rate caused by quantization with a random location of interference in the area of the side lobes of the directivity pattern is obtained for the spatial filter with quantization of the quadrature components of the normalized weight coefficients at Q_{i_input}=20...50 dB and N=10...20.

2. It is shown that in the first approximation, the average loss rate depends only on the input I/N ratio $Q_{i\,input}$ and quantizer capacity n_{qu}:

$$\bar{K} = E\{Q_{qu} / Q\} \approx (1 + Q_{i\,input} / 2^{i\,qu})^{-1},$$

where Q_{qu} and Q are, respectively, the output I/N ratio under and without quantization. For those values $\bar{K} > 0.8$, which are of greatest practical interest, the error of this evaluate does not exceed 5 %.

3. On the basis of the evaluation, the approximate formula is proposed for the required quantizer capacity:

$$n_{qu}^{req} \approx (Q_{i\,input\,[\mathrm{dB}]} - \delta \bar{K}_{[\mathrm{dB}]}^{add}) / 6,$$

where $Q_{i\,input}$ is the input I/N ratio in dB; $\delta \bar{K}_{[\mathrm{dB}]}^{add}$ is the value of the permissible relative decrease in the average loss rate $(1-\bar{K})/\bar{K}$ expressed in dB. It is shown that regardless of the value of allowable losses, the required quantizer capacity is increased by 1 bit with under the increase in the input I/N ratio by 6 dB.

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ОЦЕНКА ЭФФЕКТИВНОСТИ АДАПТИВНОЙ АНТЕННОЙ РЕШЕТКИ ПРИ ДИСКРЕТИЗАЦИИ ВЕСОВЫХ КОЭФФИЦИЕНТОВ

Представлена аналитическая оценка среднего коэффициента потерь при дискретизации квадратурных составляющих нормированных весовых коэффициентов в адаптивной антенной решетке. Определена требуемая разрядность весовых коэффициентов адаптивной антенной решетки в зависимости от отношения суммарной мощности помех к мощности внутреннего шума на входе полосового фильтра. Это сделано исходя из допустимой величины уменьшения среднего выходного отношения сигнал/помеха+шум.

Ключевые слова: дискретизация квадратурных составляющих, весовые коэффициенты, антенная решетка, коэффициент потерь.

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Mohammad Alhawawsha

A COMPARISON OF THE E-GOVERNMENT SYSTEM ARCHITECTURE IN JORDAN WITH THE E-GOVERNMENT SYSTEM OF THE UNITED STATES

Дане дослідження націлене на вивчення структури системи електронного уряду в Йорданії і її зіставлення з системою Сполучених Штатів. Дослідження показує, що система електронного уряду в Йорданії поліпшила надання послуг громадянам, оскільки вона забезпечує своєчасні, менш дорогі і ефективні послуги. Однак дана система схильна до інформаційних загроз і потребує постійного поліпшення шляхом додавання нових технологій та інфраструктури.

Ключові слова: *архітектура системи електронного уряду, сервіси електронного уряду, система електронного уряд Йорданії.*

1. Introduction

In the past decade, governments across the world have been under intensive pressure to adopt and use technologies that improve service delivery to their citizens. In particular, the increasing use of information and communications technology (ICT) as well as the related practices in the education, commercial and organizational sectors and the penetration of the internet among the citizens have increased the need for governments to move at par with the dynamism of the society. Currently, most governments across the world are leading societies that are increasingly globalized, interconnected and information consuming. Most people look upon electronic services and expect their governments to provide the same. Further, the governments are increasingly making efforts to meet the expectations of their citizens. They look to provide electronic based services as a means of improving public service, increasing efficiency, increasing the degree of transparency, and above all, cutting costs. They face a major problem because they have to come up with effective e-government system that services the people as they would like but also meets the objectives of the government, especially in terms of reducing costs [1]. Further, the e-government system must be safe from threats as well as retain their use over a lengthy period or allow

