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Model of Receiving Channels of an Adaptive Antenna Array to Assess the Impact of Differences in their Characteristics on the Efficiency of Interference Suppression

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Abstract. The article proposes a mathematical model that allows us to evaluate the impact of differences in the characteristics of reception channels on the quality of noise suppression in radio devices equipped with antenna arrays.The influence of differences in the bandwidth of receiving channels, settings of their central frequencies and electrical lengths was studied. The dependences of the losses of the average interference suppression coefficient on the dispersion of parameters of differences in the characteristics of receiving channels are presented.It is advisable to use the proposed model when justifying the requirements for the permissible difference in the characteristics of reception channels of designed radio devices.

Keywords: antenna array, interference suppression, difference in characteristics of receiving channels, interference suppression coefficient.

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Spatial selection methods are currently considered the most effective methods of dealing with interference [1–4]. In this case, the maximum immunity to radio interference in the useful signal band is determined by the dynamic range of the radio path and the analog-to-digital converter.These elements must maintain linear operation at the maximum permissible radio

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interference power. Only in this case will the signal and interference be successfully converted into digital form and it will be possible to use methods for optimal filtering of useful signals and spatial selection of interference.If the power of the interfering signal is too high, the radio path cannot operate in linear mode and the receiver is practically blocked. In this case, optimal filtering or frequency division of signals does not help in suppressing interference. Expanding the dynamic range of the radio path and ADC is one of the main conditions for creating noise-resistant radio equipment [5, 6]. The effectiveness of interference suppression by spatial selection methods is largely determined by the degree of interference correlation between the receiving channels of the adaptive antenna array. This explains the high requirements for the identity of frequency and phase characteristics of receiving channels, nonlinearity parameters of paths, accuracy of calculation of weight coefficients and other decorrelating factors. In this case, the interference suppression coefficient in the adaptive antenna array depends on the modulus of the interchannel interference correlation coefficient. The closer the correlation coefficient is to unity, the higher the interference suppression coefficient [7]. Many methods for improving the noise immunity of radio devices are aimed at equalizing the characteristics of receiving channels. This is the equalization of time delays between antenna elements, taking into account the geometry of the location of antenna elements and the wave front of received interference oscillations, and correction of the frequency characteristics of receiving channels [8, 9].In addition, to form the required shape of the radiation pattern in the antenna array, it is necessary to take into account all the delays that arise in the receiving paths, starting from the feeds to the beamforming device, with an accuracy of several degrees in the phase of the carrier frequency [10, 11]. In a number of practical cases, it is quite difficult to ensure the fulfillment of the listed conditions, which inevitably entails a decrease in the efficiency of the adaptive antenna array. It is required to evaluate the impact of differences in the characteristics of receiving channels on the efficiency of interference suppression. This assessment will make it possible to justify the requirements for the permissible difference in the characteristics of the reception channels of the designed radio devices.

1. Mathematical description of the model of receiving channels of an adaptive antenna array

The block diagram of the model of the receiving channels of the adaptive antenna array and the assessment of the differences in their characteristics is shown in Fig. 1

Here it is assumed that the N-dimensional vector of complex amplitudes of a mixture of interference and internal noise $\mathbf{y}(t) = \{y_i(t)\}_{i=1}^N$, processed during spatial filtering, is the result of transforming the components of the interference vector from the output of the adaptive antenna array $\mathbf{y}_{AAA}(t) = \{y_m^{(AAA)}(t)\}_{m=1}^N$ in N linear filters having different impulse characteristics $\nu_m(t), m \in 1, N$. This difference in impulse characteristics decorrelates the interference in the receiving channels, as a result of which the possible level of their compensation is reduced. Assessing the impact of differences in the impulse characteristics of linear filters on the achievable level of noise compensation is the goal of further analysis.

Vectors $\mathbf{y}(t)$ and $\mathbf{y}_{AAA}(t)$ are related to each other by equalities

$$y(t) = \int_{-\infty}^{\infty} \mathbf{D}(\tau)\mathbf{y}_{AAA}(t-\tau)dt, \tag{1}$$

where $\mathbf{D}(t) = diag\ \{\ \mathbf{v}_m(t)\}_{m=1}^N$ is the diagonal matrix of impulse characteristics of receiving

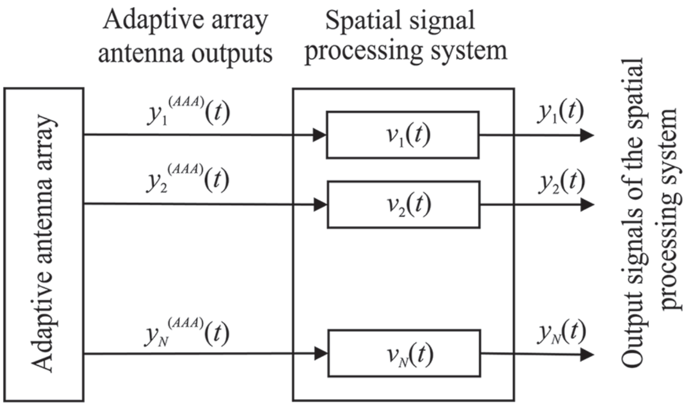

Fig. 1. Block diagram of the model of the receiving channels of the adaptive antenna array and assessment of the differences in their characteristics

channels. By integral of a vector we mean a vector of integrals of its elements. The correlation matrix of the vector $\mathbf{y}$(t), which determines the achievable level of interference compensation, in accordance with (1) is equal to:

$$\mathbf{\Phi} = \{\varphi_{pq}\}_{p,q=1}^{N} = \overline{\mathbf{y}(t)\mathbf{y}^*(t)} = \int\limits_{-\infty}^{\infty}\int\limits_{-\infty}^{\infty} \mathbf{D}(\tau)\mathbf{\Phi}_{AAA}(\tau,s)\mathbf{D}^*(s)d\tau ds \tag{2}$$

where

$$\mathbf{\Phi}_{AAA}(\tau,s) = \overline{\mathbf{y}_{AAA}(t-\tau)\ (\mathbf{y}_{AAA}(t-s))^*} - \tag{3}$$

correlation matrix of vector $\mathbf{y}_{AAA}(t)$ output signals of adaptive antenna array modules.

In the case under consideration, this vector corresponds to a mixture of Gaussian noise and stationary noise with a zero average value and a correlation matrix

$$\mathbf{\Phi}_{AAA}(\tau,s) = \mathbf{\Phi}_{AAA}\ \delta(\tau - s) \tag{4}$$

where $\delta(x)$ is the delta function. Under these conditions, the correlation matrix (2) has the form

$$\mathbf{\Phi} = \{\varphi_{pq}\}_{p,q=1}^{N} = \int_{-\infty}^{\infty} \mathbf{D}(s)\,\mathbf{\Phi}_{AAA}\,\mathbf{D}^*(s)\,ds, \tag{5}$$

$$\varphi_{pq} = \int_{-\infty}^{\infty} \nu_p(s)\,\varphi_{pq}^{(AAA)}\,\nu_q^*(s)\ ds = \varphi_{pq}^{(AAA)}\,a_{pq}, p,q \in 1,N, \tag{6}$$

$$\mathbf{A} = \{a_{pq}\}_{\,p,q=1}^{\,N} = \int_{-\infty}^{\infty} \mathbf{v}(t)\,\mathbf{v}^*(t)dt, a_{pq} = \int_{-\infty}^{\infty} \nu_p(t)\nu_q^*(t)dt. \tag{7}$$

It follows that each element of the correlation matrix is equal to the product of the corresponding elements of the correlation matrix (2) of the vector $\mathbf{y}_{AAA}(t)$ and the correlation matrix (6) of the vector $\nu(t) = \{\nu_m(t)\}_{\,m=1}^{\,N}$ of the impulse characteristics of the receiving channels. Therefore, the matrix $\mathbf{\Phi}$ is the Schur–Hadamard product of the matrices $\mathbf{\Phi}_{AAA}$ and $\mathbf{A}$, which is usually denoted as

$$\mathbf{\Phi} = \mathbf{\Phi}_{AAA} \otimes \mathbf{A}. \tag{8}$$

In the particular case of identical impulse characteristics $\nu_m(t) = \nu_0(t)$, $m \in 1, N$, when

$$\begin{aligned} &\nu(t) = \nu_0(t)\ \mathbf{e}, \\ &\mathbf{e}^* = [\ 1\ ,\ 1\ ,\ \ldots\ ,\ 1\ ], \\ &\mathbf{A} = c \cdot\ \mathbf{e}\,\mathbf{e}^*, \\ &c = \int_{-\infty}^{\infty} |\nu_0(t)|^2 dt, \end{aligned} \tag{9}$$

matrix (4) is proportional to matrix (3), due to which the achievable interference suppression coefficient remains the same as when using directly the vector of output signals $\mathbf{y}_{AAA}(t)$ of the adaptive antenna array modules. However, in real conditions, the impulse characteristics of receiving channels are not identical, and the loss of the interference suppression coefficient is determined by matrix (7). This matrix depends on the magnitude of the differences in the impulse characteristics of the receiving channels of the antenna array.

2. Estimation of the dependence of the interference suppression coefficient on the magnitude of the differences between the characteristics of the receiving channels of the antenna array

Quantitative estimates of the influence of differences in impulse characteristics on the noise suppression coefficient were carried out for the case of Gaussian impulse characteristics of the form

$$\nu_m(t) = \exp(-\pi \cdot F_m^2 \cdot (t - \tau_m)^2) \cdot \exp(j\ \cdot 2\pi \cdot\ (f_0 + \delta f_m) \cdot (t - \tau_m)),\ \ m \in 1,\ N \tag{10}$$

whose parameters are:

- $F_m = 1/T_m$ — the width of the frequency response (bandwidth) of the m-th filter at level $exp(-\pi/4) \approx 0.456$ from the maximum, inverse to the time length T_m of its impulse characteristics at the same level;
- τ_m — delay associated with the "electrical length" of the m-th reception path;
- δf_m — shift of the center frequency of the m-th filter from the value f_0.

An additional parameter of the m-th filter in the general case is also its gain c_m. However, it does not affect the desired level of achievable interference suppression coefficient K_{IS}, which, when protecting the first (main) channel by a system of $N_k = N - 1$ auxiliary (compensation) channels, is equal to

$$K_{IS} = \varphi_{11}\omega_{11}, \tag{11}$$

where ω_{11} is the first diagonal element of the matrix inverse to the correlation matrix (2), (8)

$$\mathbf{\Psi} = \{\omega_{pq}\}_{p,q=1}^{N} = \mathbf{\Phi}^{-1}. \tag{12}$$

Indeed, let the impulse characteristics of the m-th filter be equal to $\tilde{\nu}_m(t) = c_m{\cdot}\nu_m(t)$, then the corresponding impulse characteristics vector is equal to $\tilde{\nu}(t) = \mathbf{C} \cdot \nu(t)$, where $\mathbf{C} = diag\{c_m\}_{m=1}^{N}$ is the real diagonal gain matrix. In this case, the matrix $\tilde{\mathbf{A}}$ a is equal to $\tilde{\mathbf{A}} = \int\limits_{-\infty}^{\infty} \tilde{\nu}(t)\tilde{\nu}^*(t)dt =$

$= \mathbf{C}\cdot\mathbf{A}\cdot\mathbf{C}$, so the matrices $\tilde{\mathbf{\Phi}}$ and $\tilde{\mathbf{\Psi}}$ are respectively equal to $\tilde{\mathbf{\Phi}} = \{\tilde{\varphi}_{pq}\}_{p,q}^{N} = \mathbf{\Phi}_{AAA}\otimes\tilde{\mathbf{A}} = \mathbf{C}\cdot\mathbf{\Phi}\cdot\mathbf{C}$ and $\tilde{\mathbf{\Psi}} = \{\tilde{\omega}_{pq}\} = \tilde{\mathbf{\Phi}}^{-1} = \mathbf{C}^{-1}\cdot\mathbf{\Psi}\cdot\mathbf{C}^{-1}$.

The corresponding value of the achievable interference suppression coefficient (11) in this case is equal to $\tilde{K}_{IS} = \tilde{\varphi}_{11}\cdot\tilde{\omega}_{11} = c_1\cdot\tilde{\varphi}_{11}\cdot c_1\cdot c_1^{-1}\cdot\tilde{\omega}_{11}\cdot c_1^{-1} = \tilde{\varphi}_{11}\cdot\tilde{\omega}_{11} = K_{IS}$ and, therefore, coincides with the value obtained without taking into account different gain factors. Therefore, in what follows, impulse characteristics of the form (10) are used without unimportant additional amplification parameters.

Under these conditions, the elements of matrix (7) are equal

$$\begin{aligned}
&a_{pq} = \int_{-\infty}^{\infty} g_{pq}(t)\ dt,\\
&g_{pq}(t) = \nu_p(t)\cdot\nu_q^*(t) = \exp(-s_{pq}(t))\cdot\exp(j\cdot 2\cdot\pi\cdot\varphi_{pq}(t)),\\
&s_{pq}(t) = \pi\cdot(F_p^2\cdot(t-\tau_p)^2 + F_q^2\cdot(t-\tau_q)^2) =\\
&\qquad = \pi\cdot((F_p^2+F_q^2)\cdot(t-b)^2 + \frac{F_p^2\cdot F_q^2}{F_p^2+F_q^2}\cdot(\tau_p-\tau_q)^2),\\
&b = \frac{F_q^2\cdot\tau_q + F_p^2\cdot\tau_p}{F_q^2+F_p^2},\\
&\varphi_{pq}(t) = (\delta f_p - \delta f_q)\cdot t + \delta f_q\cdot\tau_p - \delta f_p\cdot\tau_q.
\end{aligned} \tag{13}$$

Using the well-known integral

$$\int_{-\infty}^{\infty}\exp(-a\cdot x^2)\exp(-j\cdot\beta\cdot x)dx = \int_{-\infty}^{\infty}\exp(-a\cdot x^2)\cdot\cos(\beta\cdot x)dx = \sqrt{\pi/a}\cdot\exp\left(-\frac{\beta^2}{4a}\right)$$

the elements of matrix (7) can be written in the form

$$\begin{aligned}
a_{pq} = \frac{c}{\sqrt{F_p^2+F_q^2}}\cdot\exp\left(-\pi\cdot\frac{\nu_q^2\cdot\nu_p^2(\chi_p-\chi_q)^2+(\mu_p-\mu_q)^2}{\nu_p^2+\nu_q^2}\right)\times\\
\times\exp\left(-j\cdot 2\pi\cdot\frac{(\nu_p^2\cdot\mu_q+\nu_q^2\cdot\mu_p)\cdot(\chi_p-\chi_q)}{\nu_p^2+\nu_q^2}\right),\\
p,\ q\in 1,\ N,
\end{aligned} \tag{14}$$

where $\nu_p = F_p/F_0 = 1+e_p$, $\mu_p = \delta f_p/F_0$, $\chi_p = \tau_p/T_0$, $p\in 1,\ N$ are the relative values of the corresponding filter parameters, c is a constant that does not affect the level of noise suppression. It is convenient to choose it so that, with the same filter parameters of all channels with nominal parameters, when $F_q^2 = F_p^2 = F_0^2$, $\nu_p = 1$, $\mu_p = \mu_q = 0$, $\tau_p = \tau_q$, $p, q\in 1, N$ the value of a = 1. This is done at the value $c = \sqrt{2\cdot F_0}$, at which

$$\begin{aligned}
a_{pq} = \frac{\sqrt{2}}{\sqrt{\nu_p^2+\nu_q^2}}\cdot\exp\left(-\pi\cdot\frac{\nu_q^2\cdot\nu_p^2(\chi_p-\chi_q)^2+(\mu_p-\mu_q)^2}{\nu_p^2+\nu_q^2}\right)\times\\
\times\exp\left(-j\cdot 2\pi\cdot\frac{(\nu_p^2\cdot\mu_q+\nu_q^2\cdot\mu_p)\cdot(\chi_p-\chi_q)}{\nu_p^2+\nu_q^2}\right),\\
p,\ q\in 1,\ N
\end{aligned} \tag{15}$$

The last formula, together with (8), (11), (12), allows us to obtain quantitative values of the interference suppression coefficient for arbitrary values of the parameters of the impulse characteristics of the filters (Fig. 1) of the receiving channels of the antenna array. In the general case, these parameters are random, so the values of the corresponding suppression coefficients (11) obtained on their basis are also random. What is practically important is its average value $\overline{K_{IS}} = \overline{\varphi_{11} \cdot \omega_{11}}$ over the set of filter parameters, which depends on their distribution laws. Below are the results of its assessment, obtained under the assumption that these parameters are mutually independent and have normal (Gaussian) distributions with zero means and variances σ_ε^2, σ_μ^2, σ_χ^2 respectively.

Fig. 2 and 3 show the dependence of the magnitude of the decrease in the average interference suppression coefficient $\overline{K_{IS}}$ from n = 2 to 5 active jammers on the dispersion $\sigma_\varepsilon^2 = \sigma_\mu^2 = \sigma_\chi^2 = \sigma^2$ of the parameters of the differences in the characteristics of the receiving paths:

$$\delta = \frac{\overline{K_{IS}(k_{\max}, \ell_{\max})}}{K_{ISa\nu}}, \quad K_{IS}(k_{\max}, \ell_{\max}) = (k_{\max}, \ell_{\max})^{-1} \cdot \sum_{k=1}^{k_{\max}} \sum_{\ell=1}^{\ell_{\max}} K_{ISk,\ell} \tag{16}$$

The terms of the sum in (16) are the values of the interference suppression coefficient for the k-th ($k \in 1$, $k_{max} = 500$) implementation of a random set of parameters for differences in the characteristics of receiving paths with a given dispersion in the ℓ-th ($\ell \in 1$, $\ell_{max} = 1000$) version of the random location of interference sources in space.The denominator (16) $K_{ISa\nu}$ corresponds to the average value of the interference suppression coefficient over the ℓ_{max} positions of active jammers under hypothetical conditions of complete coincidence of the characteristics of all receiving channels and the nominal value of their parameters ν_p, μ_p, χ_p. The ratio of the total interference power to the internal noise power in the main reception channel is $\eta = 20dB$ (Fig. 2) and $\eta = 30dB$ (Fig. 3).

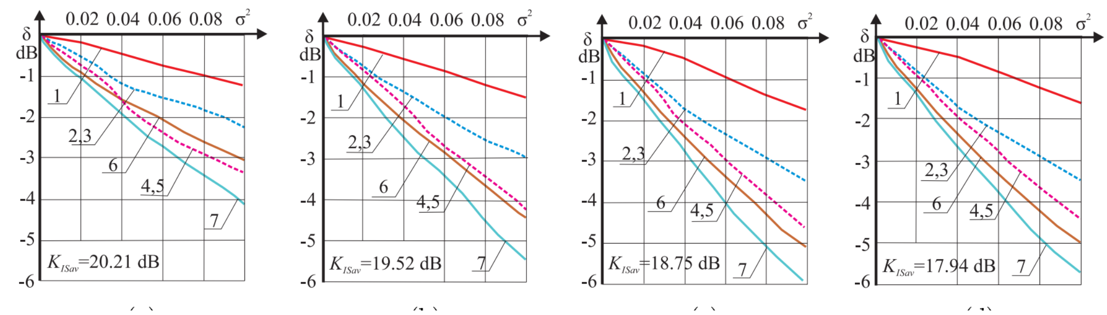

Fig. 2. Dependence of the magnitude of the reduction in the interference suppression coefficient on the dispersion of differences in the characteristics of receiving channels $(\eta{=}20dB): a-n{=}2;$ $b-n=3; c-n=4; d-n=5$

The dependence curves in these figures have the following meaning:

- dependence curve 1. The electrical lengths of the receiving paths are the same, there is no shift in their central frequencies, and only the widths of their passbands differ, i.e., $\nu_p^2 \neq \nu_q^2$, $\mu_p = \mu_q = 0$, $\chi_p = \chi_q$, and in accordance with (15)

$$a_{pq} = \sqrt{2}/\sqrt{\nu_p^2 + \nu_q^2}, \quad p, q \in 1, \ldots, N \tag{17}$$

- dependence curve 2. The electrical lengths and bandwidths of the receiving paths are the same, but the settings of the central frequencies differ, i.e. $\nu_p^2 = \nu_q^2 = 1$, $\mu_p \neq \mu_q$, $\chi_p = \chi_q$,

$$a_{pq} = \exp(-\frac{\pi}{2}(\mu_p - \mu_q)^2), \quad p, q \in 1, \ldots, N; \tag{18}$$

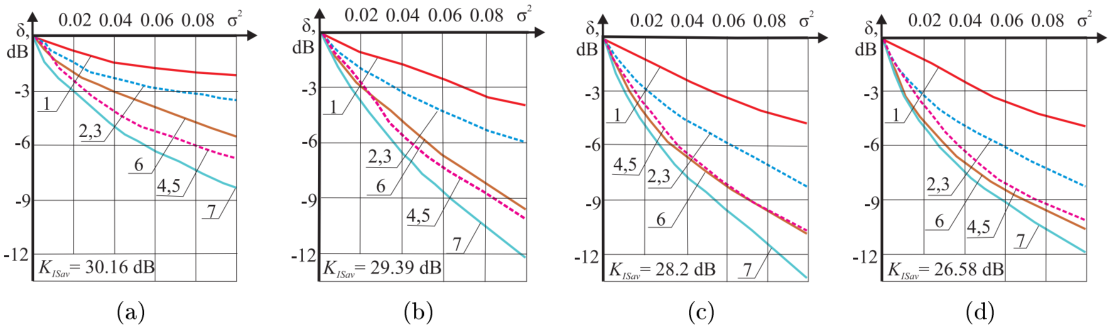

Fig. 3. Dependence of the magnitude of the reduction in the interference suppression coefficient on the dispersion of differences in the characteristics of receiving channels ($\eta = 30dB$) : $a - n = 2$; $b - n = 3$; $c - n = 4$; $d - n = 5$

- dependence curve 3. The settings of the central frequencies and bandwidth of the receiving paths are the same, but their electrical lengths differ, i.e. $\nu_p^2 = \nu_q^2 = 1$, $\mu_p = \mu_q = 0$, $\chi_p \neq \chi_q$,

$$a_{pq} = \exp(-\frac{\pi}{2}(\chi_p - \chi_q)^2), \quad p, q \in 1, \ldots, N; \tag{19}$$

- dependence curve 4. The electrical lengths of the receiving paths are the same, but the settings of their central frequencies and bandwidths differ, i.e. $\nu_p^2 \neq \nu_q^2$, $\mu_p \neq \mu_q$, $\chi_p = \chi_q$,

$$a_{pq} = \frac{\sqrt{2}}{\sqrt{\nu_p^2 + \nu_q^2}} \cdot \exp(-\pi \cdot \frac{(\mu_p - \mu_q)^2}{\nu_p^2 + \nu_q^2}), \quad p, q \in 1, \ldots, N \tag{20}$$

- dependence curve 5. The setting of the central frequencies is the same, but the passbands and electrical lengths of the receiving channels differ, i.e. $\nu_p^2 \neq \nu_q^2$, $\mu_p = \mu_q = 0$, $\chi_p \neq \chi_q$,

$$a_{pq} = \frac{\sqrt{2}}{\sqrt{\nu_p^2 + \nu_q^2}} \cdot \exp(-\pi \cdot \frac{\nu_p^2 \cdot \nu_q^2 (\chi_p - \chi_q)^2}{\nu_p^2 + \nu_q^2}), \quad p, q \in 1, \ldots, N \tag{21}$$

- dependence curve 6. The bandwidths of the receiving paths are the same, but the settings of their central frequencies and electrical lengths differ, i.e. $\nu_p^2 = \nu_q^2 = 1$, $\mu_p \neq \mu_q$, $\chi_p \neq \chi_q$,

$$a_{pq} = \exp\left(-\pi \cdot \frac{(\chi_p - \chi_q)^2 + (\mu_p - \mu_q)^2}{2}\right) \cdot \exp(-j \cdot \pi \cdot (\mu_p + \mu_q) \cdot (\chi_p - \chi_q)), \quad p, q \in 1, \ldots, N; \tag{22}$$

- dependence curve 7. All characteristics of receiving paths differ — bandwidths, center frequency settings and electrical lengths. The elements a_{pq} are calculated using (15).

In Fig. 4 and 5 show the empirical distribution functions of the reduction in the interference suppression coefficient (16) over a set of $L = 1000$ locations of two ($n = 2$) (a, b) and four ($n = 4$) (c, d) active jammers with values of dispersion parameters of the differences in the characteristics of receiving paths of $\sigma^2 = 0.02(a, c)$ and $\sigma^2 = 0.1(b, d)$. The ratio of the total interference power to the internal noise power in the main reception channel is $\eta = 20dB$ (Fig. 4) and $\eta = 30dB$ (Fig. 5). They provide more complete information about the statistical properties of losses, allowing one to estimate their confidence intervals in the analyzed situations.

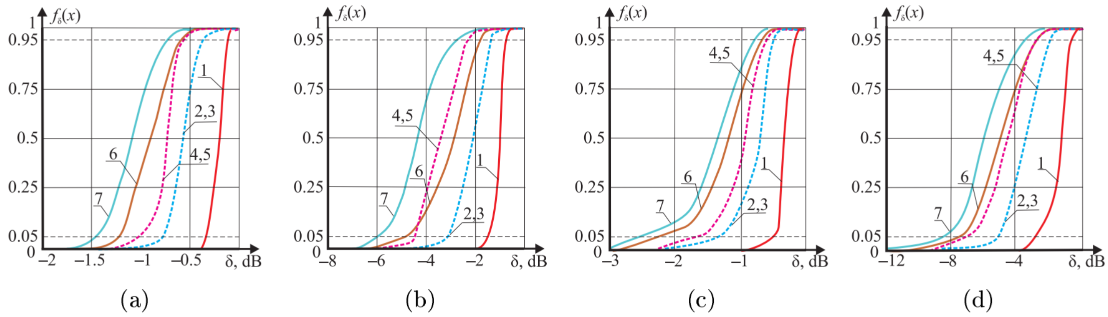

Fig. 4. Empirical distribution functions for the reduction in interference suppression coefficient due to differences in the characteristics of receiving channels $(\eta = 20dB) : a - n = 2,\ \sigma^2 = 0.02$; $b - n = 2,\ \sigma^2 = 0.1$; $c - n = 4\,\sigma^2 = 0.02$; $d - n = 4,\ \sigma^2 = 0.1$

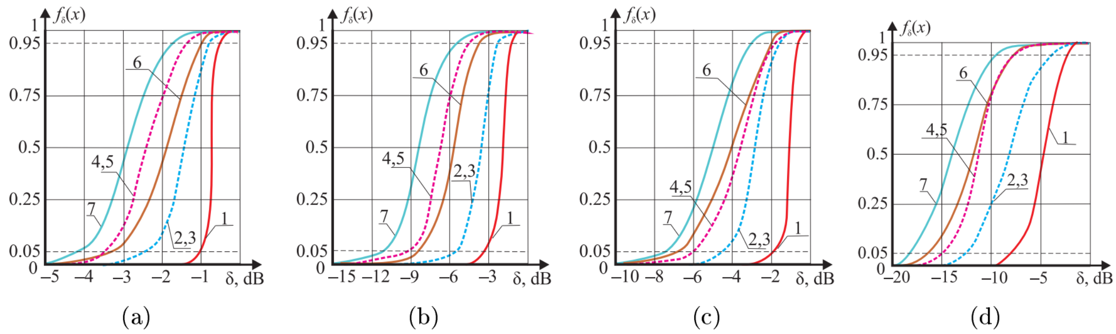

Fig. 5. Empirical distribution functions for the reduction in interference suppression coefficient due to differences in the characteristics of receiving channels $(\eta = 30dB) : a - n = 2, \sigma^2 = 0.02$; $b - n = 2,\ \sigma^2 = 0.1$; $c - n = 4,\ \sigma^2 = 0.02$; $d - n = 4,\ \sigma^2 = 0.1$

3. Analysis of the calculation results for reducing the level of interference suppression coefficient caused by differences in the characteristics of receiving channels

Analysis of the results of calculations performed to reduce the value of the interference suppression coefficient caused by differences in the characteristics of receiving channels allows us to draw the following conclusions:

1. The average (over multiple positions of active jammers) reduction in the achievable level of interference compensation due to differences in the characteristics of receiving channels depends on: - the nature and extent of differences; - number and intensity of interference sources.

2. The difference in the bandwidths of receiving channels has the least influence (dependence curve 1). With dispersion $\sigma_\varepsilon^2 = 0.01$ of random relative bands $\nu_p = F_p/F_0 = 1 + \varepsilon_p$, $p, q \in 1, N$, the average loss of the interference suppression coefficient K_{IS} when changing the number of active jammers from 2 to 5 is from 1 to 1.7 dB with a ratio of interference power to internal noise power of $\eta = 20dB$ (Fig. 2) and from 2.2 up to 5 dB with $\eta = 30dB$ (Fig. 3).

3. Differences in the setting of central frequencies and electrical lengths of receiving paths with equal dispersions $\sigma_\mu^2 = \sigma_\chi^2$ of random delays $\chi_p = \tau_p/T_0$ and relative shifts of the central frequency $\mu_p = \delta f_p/F_0$, $p \in 1$, N have almost the same effect on the amount of losses (dependence

curves 2 and 3). The reason for this is the coincidence in this case of the elements a_{pq}(18) of the "decorrelation matrix" A(7). These elements are on average smaller than in the previous case, which is why the negative impact of the factors caused by them is greater.

4. Under practically important conditions of "small" dispersions $\sigma_\varepsilon^2 = 0.01$, the elements of the a_{pq} (20) and (21) do not have significant differences. Because of this, the influence of differences in passbands simultaneously with a shift in the center frequency or with a difference in the electrical lengths of the receiving paths (dependence curves 4 and 5) is approximately the same and has greater weight than the influence of the previous factors. At the same time, the combined effect of differences in the central frequencies and electrical lengths of the receiving paths with the same passbands (dependence curve 6) can reduce the value of K_{IS} both more and less than in the previous case.

5. The average reduction in the interference suppression coefficient K_{IS} under the isolated and combined action of the factors under consideration increases with increasing intensity and number n of interference sources. As follows from the analysis of Fig. 4 and 5, the confidence intervals are maximum under the combined action of the factors under consideration and increase with increasing dispersion σ^2 of the parameters of differences in the characteristics of receiving paths, the number and relative intensity of interference.

It is advisable to use the proposed model and the program that implements it when justifying the requirements for the permissible value of differences in the characteristics of the receiving channels of the designed radio devices.

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Модель приемных каналов адаптивной антенной решетки для оценки влияния различия их характеристик на эффективность подавления помех

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Аннотация. В статье предложена математическая модель, позволяющая оценить влияние различий в характеристиках приемных каналов на качество подавления шумовых помех в радиотехнических устройствах, оснащенных антенными решетками. Исследовано влияние различий в ширине полосы пропускания приемных каналов, настройки их центральных частот и электрических длин.Приведены зависимости потерь величины среднего коэффициента подавления помех от дисперсии параметров различий в характеристиках приемных каналов. Предложенную модель целесообразно использовать при обосновании требований к допустимой величине различий характеристик приемных каналов проектируемых радиотехнических устройств

Ключевые слова: антенная решетка, подавление помех, различие характеристик приемных каналов, коэффициент подавления помех.