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MATHEMATICAL MODELING OF THE INFLUENCE OF THE ESTABLISHMENT OF THE INITIAL PHASES AND CARRIER FREQUENCIES OF THE APERTURE CONFIRMED PHASED ARRAY ANTENNA

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ABSTRACT. The article discusses the influence of these instabilities on the peak power level, duration and repetition period of multifrequency spatio-temporal signals and estimates the maximum values of errors in the parameters of the laws of spatial-phase-frequency focusing, at which the specified characteristics of focused multifrequency spatio-temporal signals change by no more than 10%.

1. INTRODUCTION

When operating the means for generating pulses, signals (hereinafter referred to as means of generation), it is necessary to use multi-element phased antenna arrays. Fluctuations in the parameters of signals and antennas arising from various random factors limit the potential of the generation means and can lead to significant changes in the generated multifrequency spatio-temporal signals, a decrease in their peak power and, in general, to the impossibility of solving problems. Therefore, it is advisable to analyze the influence of typical errors arising during the operation of traditional antennas and elements of the antenna-feeder path on the characteristics of the radiation field, which has been well studied and considered in the known literature [1-15]. Therefore, the article discusses only the

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features of the requirements for the accuracy of the location of the phase centers of the emitters and the requirements for the discreteness and accuracy of setting the initial phases and carrier frequencies along the aperture of cylindrical phased antenna arrays, which are specific for spatial-phase-frequency focusing on the basis of equal-discrete V-shaped frequency distributions. The aim of the article is to conduct mathematical modeling of the effect of setting the initial phases and carrier frequencies of the aperture confirmed phased array antenna.

2. Main Results

The analysis of the proposed methods for the formation of sequences of short multifrequency spatio-temporal signals using single-stage and multi-stage V-shaped distribution laws of carrier frequencies over the aperture of cylindrical phased antenna arrays was carried out without taking into account possible errors in setting the initial phases and carrier frequencies in the forming channels. It is obvious that the technical implementation of the generation means is advisable to carry out using a digital element base. The available deviations from the specified discreteness of the carrier frequencies and the initial phases of the emitted signals can also significantly affect the formation of sequences of multifrequency spatio-temporal signals. When calculating the average normalized value of the electric field strength of a cylindrical phased antenna array, taking into account the errors in setting the carrier frequencies and the initial phases of the emitted signals, the initial data given above were used. The expression was used as a calculation:

$$\langle E(P_f,t)\langle = \frac{1}{E_{max}} \sum_{m=-\frac{M_x-1}{2}}^{\frac{M_x-1}{2}} \sum_{m=-\frac{M_y-1}{2}}^{\frac{M_y-1}{2}} \frac{A_{nm}F_{mn}(n,\Theta)}{R_{mn}} \sqrt{60\, P_{mn} G_{max\, mn}}$$
$$\times e^{\left(-j\left[2\pi f_{0mn}\left[t-\frac{R_{mn}}{c}\right]+n_{0mn}\right]\right)}\rangle.$$

Taking into account random errors in setting a given discreteness, the distribution law of the initial phases has the form:

$$f'_{0mn} = -2\pi f_{0mn}\left(\frac{z}{c} - \frac{R_{mn}}{c}\right) + \Delta f \Psi_1,$$

where $\Delta f-$ maximum value of the initial phase setting error in each radiating element of a phased array antenna; Ψ_1- random variable evenly distributed within an interval $[-1, 1]$. In this case, the one-stage V-shaped distribution law of carrier frequencies, taking into account errors, can be written as:

$$f_{0mn} = f_0 + n\Delta F + \frac{c}{2\pi} \frac{1}{R\left[1 - cos\left(\nu \frac{m}{\nu} \delta\alpha\right)\right]} + \Delta f \Psi_2$$

and the multistage V-shaped distribution law of carrier frequencies taking into account errors will have the form:

$$f_{0mn} = f_0 + \nu \left[\frac{m}{\nu}\right] \Delta F + \frac{c}{2\pi} \frac{1}{R\left[1 - cos\left(\nu \frac{m}{\nu} \delta\alpha\right)\right]} + \Delta f \Psi_2,$$

where

Δf - maximum value of the carrier frequency setting error in each radiating element of the phased array antenna;

Ψ_2 - random variable evenly distributed within an interval $[-1, 1]$.

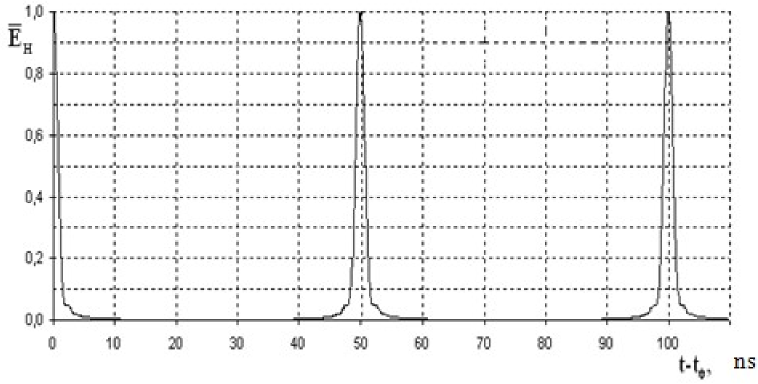
Figure 1 shows the values of the mathematical expectation of the normalized electric field strength of the radiation of a cylindrical phased antenna array $\tilde{\mathrm{E}}_{\mathrm{H}} = \langle \mathrm{E}(\mathrm{x}, \mathrm{y}, \mathrm{z}, \mathrm{t})/\mathrm{E}_{\mathrm{max}} \rangle$ in the plane of the generatrix without taking into account the errors of setting the carrier frequencies and initial phases $(\Delta_\varphi = 0; \Delta_f = 0; Q = 25)$ taking into account the maximum value of the error in setting the initial phases $\Delta_\varphi = \pi/2$ and taking into account the maximum value of the error in setting the carrier frequencies $\Delta_f = \Delta F_x/8 = \Delta F_y/8$ when using a single-stage V-shaped frequency distribution along the aperture for $R_f = 5km.$

Figure 2 shows the values $\tilde{\mathrm{E}}_{\mathrm{H}}$ for conditions similar to the previous case, but when using a multistep V-shaped law of frequency distribution over the aperture.

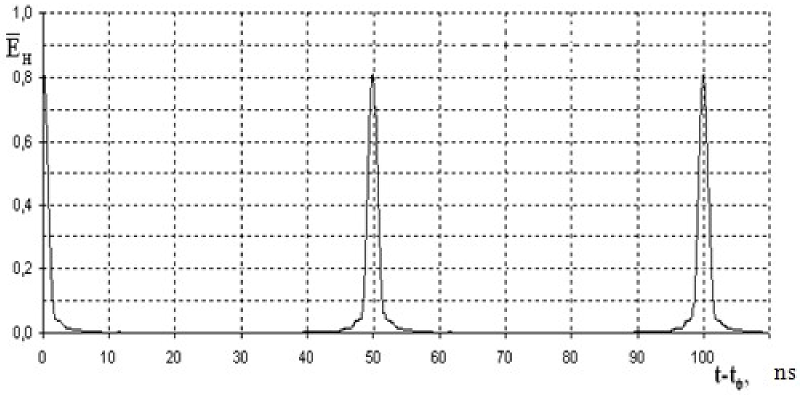
In this case, the influence of errors in setting a given discreteness of the initial phases on the characteristics of the generated sequence of multifrequency spatio-temporal signals does not depend on the radiation time. The influence of errors in setting a given discreteness of carrier frequencies depends on the emission time, since the phase errors:

$$\Delta f_{0mn} = 2\pi f_{0mn}(t - t\frac{f}{den})$$

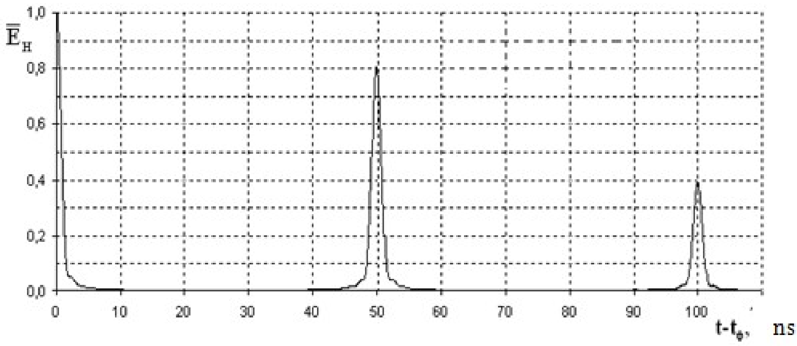
caused by inaccuracy in setting the carrier frequencies of the emitted signals, increase with time.



a) $\Delta_\varphi = 0;\ \Delta_f = 0;\ Q = 25$

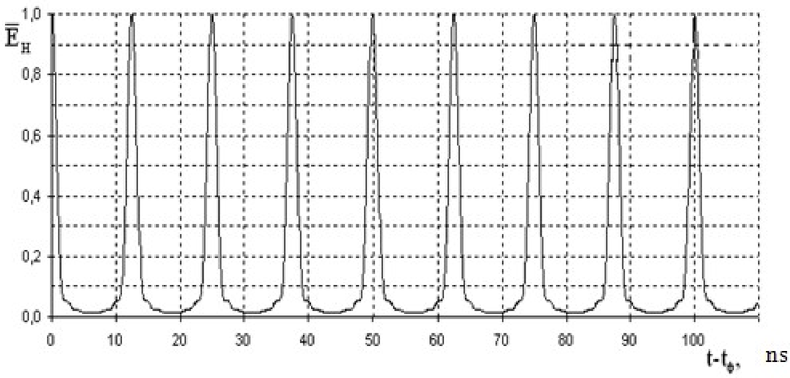


b) $\Delta_\varphi = \pi/2;\ \Delta_f = 0;\ Q = 25$

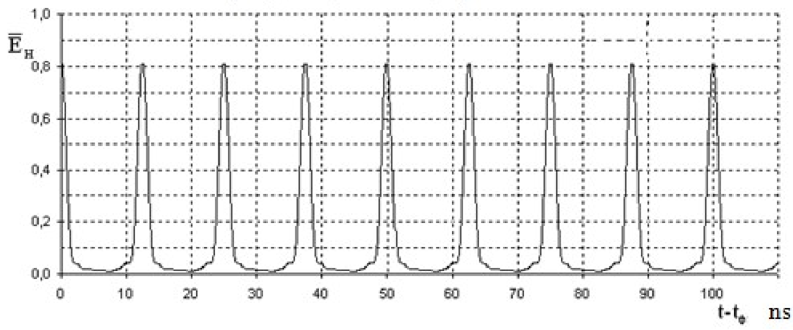


c) $\Delta_\varphi = \pi/2; \Delta_f = F_x/8; Q = 25$

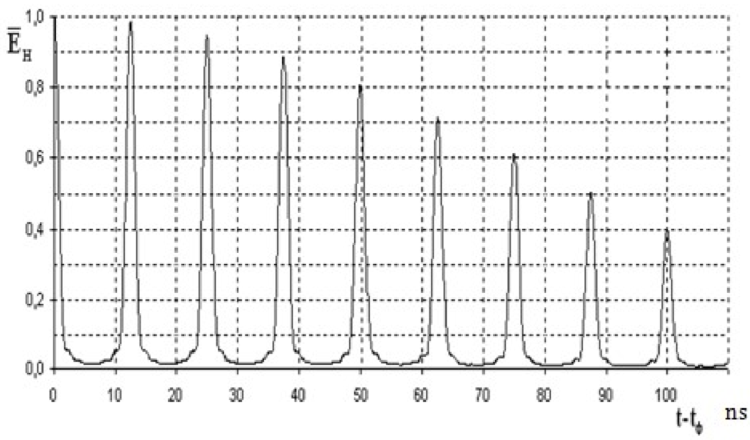
Figure 1. Dependencies of the mathematical expectation of the normalized electric field strength emitted by a cylindrical phased antenna array on errors Δ_φ and ΔF.



c) $\Delta_\varphi = 0;\ \Delta_{f=0};\ Q = 12$



(b) $\Delta_\varphi = \pi/2; \Delta_f = 0; Q = 12$



(c) $\Delta_\varphi = \pi/2;\ \Delta_f = F_x/8;\ Q = 12$

Figure 2. Dependencies of the mathematical expectation of the normalized electric field strength emitted by the cylindrical phased array antenna power of the phased array antenna on errors Δ_φ and ΔF with a decrease in wellness

Figure 3 shows the dependences of the mathematical expectation of the normalized value of the electric field strength emitted by a cylindrical phased antenna array $\vec{E}_H$, from the observation time, taking into account the maximum value of the error of the carrier frequencies $\Delta_f = 2,0\ MHz$ when using a multistage V-shaped frequency distribution law along the aperture with a maximum separation of carrier frequencies $\Delta F_{max} = 2\ GHZ$.

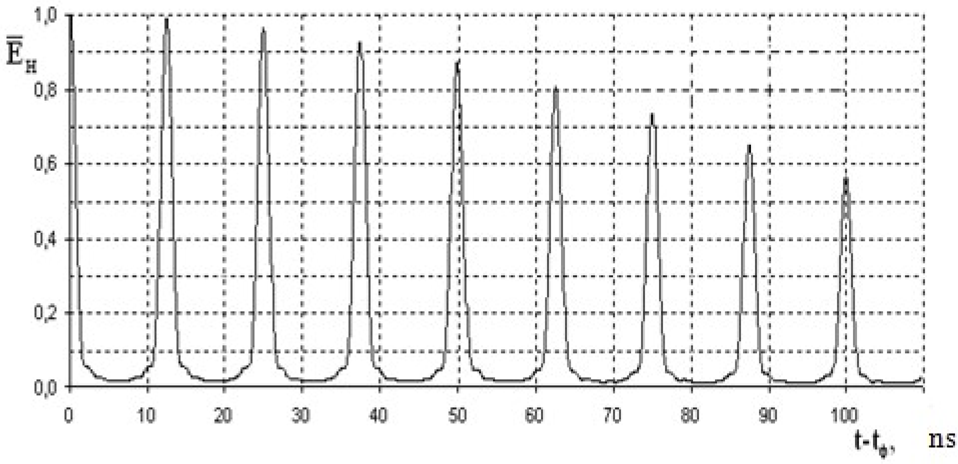


Figure 3. Dependence of the mathematical expectation of the normalized value of the electric field strength emitted by a cylindrical phased antenna array on the radiation time at $\Delta_f = 2,0\ MHz$ for $\Delta \mathrm{F}_{\max} = 2GHZ$.

Analysis of Figure 3 shows that the effect of carrier frequency setting errors does not depend on the selected value of the maximum carrier frequency spacing over the aperture and is determined by the carrier frequency setting error value in the radiating elements. Δ_f (or absolute frequency instability. Figure 4 shows the dependence of the mathematical expectation of the normalized value of the electric field strength radiated by a cylindrical one on the values of the absolute frequency instability Δ_f and different values of the duration of the burst of multi-frequency spatio-temporal signals and its cross section for different values Δ_f and the duration of the pack.)

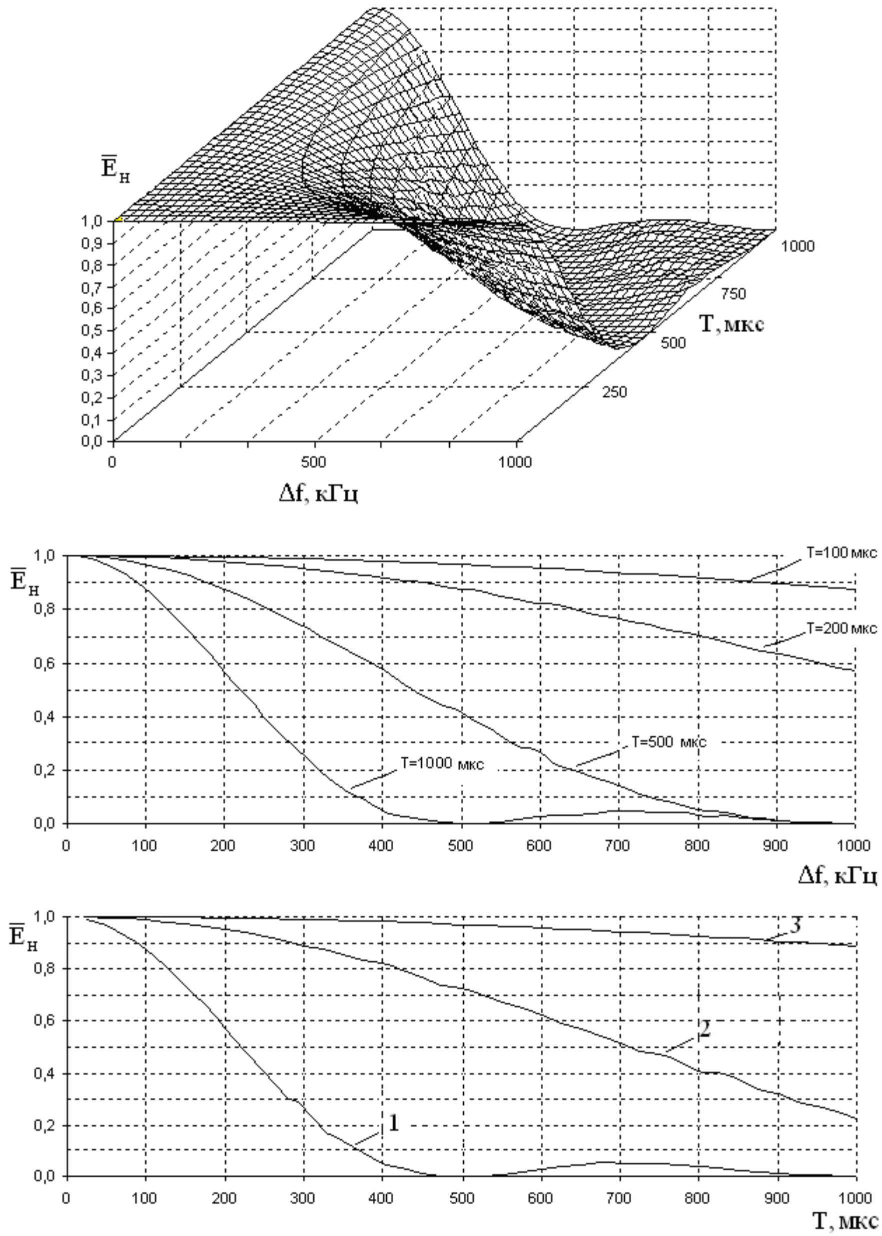


Figure 4. Dependence of the mathematical expectation of the normalized value of the electric field strength radiated by a cylindrical phased antenna array on Δf and the duration of the burst of multifrequency space-time signals $(1 - \Delta_f = 1000\, kHz, \Delta_f = 300\, kHz,\ \Delta_f = 100\, kHz,)$

As can be seen from Fig. 4, when taking into account the influence of errors in setting the carrier frequency in the radiating elements, it is necessary to take into account the duration of the formed packet of multifrequency space-time signals. As is known, in existing transmitting devices of the centimeter wavelength range, the value of the long-term (several hours and up to a day) relative frequency instability is provided at the level $10^{-5} \dots 10^{-6}$, and short-term (up to units of minutes) - can reach values $10^{-10} \dots 10^{-12}$.Taking this into account, the duration of a burst of multifrequency spatio-temporal signals, at which the electric field strength decreases by no more than 10 % due to errors in setting the carrier frequency in the radiating elements of the antenna, can be selected from the condition $\Delta FT \leq 0,1$. (Figure 4), where $T = nTs$ - the duration of a burst of a periodic sequence of n acting spatially temporal impulses. Figure 5 shows the dependence in the direction of the normal to the aperture of the phased antenna array from the maximum values of the errors in setting the initial phases for $R = 5\,km$

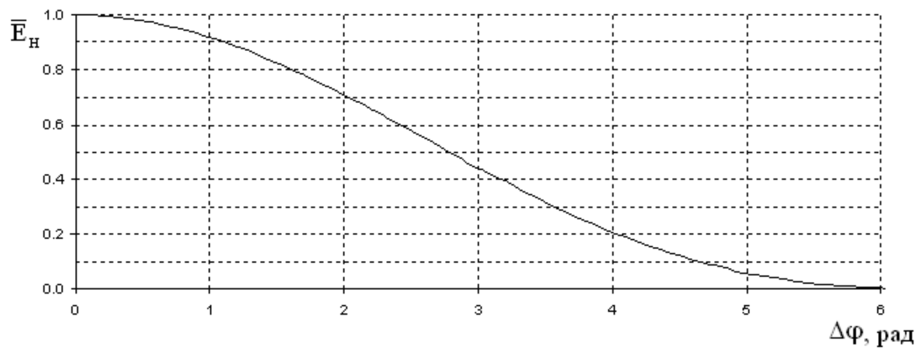


Figure 5. Dependence of the mathematical expectation of the normalized value of the electric field strength on the phase setting error As can be seen from Figure 1, the range of admissible values of the maximum errors in setting the initial phases over the aperture of the cylindrical phased antenna array, in which the decrease in the value $\vec{E}_H$ does not exceed 10%, is determined from the condition: $\Delta_f \leq \pi/3$.

The performed mathematical modeling shows that the discreteness and random errors in setting the initial phases of signals in the transmitting channels of a cylindrical phased array antenna are equal $\Delta_f \leq \pi/3$ to, have practically no effect on the duration and repetition period of the signal sequence.

3. Conclusion

The influence of errors in setting the initial phases on the characteristics of the generated sequence of multifrequency space-time signals does not depend on the radiation time. The range of admissible values of the maximum errors in setting the initial phases Δ_f by the aperture of a cylindrical phased antenna array, in which the decrease in the value of the electric field strength does not exceed 10%, is determined from the condition $\Delta_f \leq \pi/3$. Discreteness and random errors in setting the initial phases of individual radiation sources of a cylindrical phased antenna array, equal to $\Delta_f = \pi/3$, practically do not affect the duration and repetition period of the sequence of multifrequency space-time signals.

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