THEORY AND METHODS OF SIGNAL PROCESSING

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PULSATION COEFFICIENT DIRECTIVITY DIAGRAM PIN ANTENNA HELICOPTER

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Abstract—*The relative depth periodic pulsations irregular directivity diagram electromechanical formation with pin antenna body helicopter at other identical conditions depends on the establishment of standard vibrator. Based on numerical modeling are created graph dependencies relative levels of directivity diagram pulsation from time in three coordinate planes. Been found that reduced pulsation diagram when placing antenna under the fuselage near to its center, but increases if antenna placed above fuselage near the tail part of it. Within period of one form pulsing directivity diagram is almost independent on the number of blades main rotor helicopter.*

Index Terms—Helicopter fuselage; main rotor; antenna system; directivity diagram; unequal diagram; pulsations diagram; mathematical modeling.

I. INTRODUCTION

Pin vibrator installed on fuselage of the aircraft, it is kind of hybrid antenna system (AS). Directivity diagram (DD) such AS becomes irregularity, because transverse dimensions of the fuselage, which is part of AS, far exceeding height of regular geometric dipole antenna. The measure irregularity DD antenna aircraft is irregularity coefficient

$$k_{ir} = 20\lg\frac{E_{\max}}{E_{\min}}. \quad (1)$$

It is determined by the ratio maximum value electric field intensity $E_{\max}$ in the plane of azimuth angle φ to a minimum value $E_{\max}$ in the same plane in direction of flight and lateral directions [1]. If DD is normalized relative to its maximum value then this coefficient can be determined by the ratio, dB

$$k_{ir} = -20\lg F_{\min}, \quad (2)$$

in which $F_{\min} = \frac{E_{\min}}{E_{\max}}$ is minimum value directivity diagram $F(\varphi)$.

For on-board antennas of connected radio equipment coefficient of irregularity DD should not exceed 3dB.

If the aircraft is helicopter, then irregular DD AS is pulsating, as the main rotor rotation, which length of the blades is comparable with the size of the fuselage, periodically changing the geometric shape of its body, which also is radiating element of the hybrid AS. Pulsations DD AS helicopter are taking place regardless of metal or carbon manufactured its main rotor blades, because carbon also has very high electrical conductivity. The presence of pulsations DD AC, gives rise to parasitic modulation of the useful signal at frequency, Hz

$$F_N = \frac{1}{T_N} = \frac{nN}{60}, \quad (3)$$

that is to its amplitude-frequency distortions [2], [3]. In ratio (3) n is the number of rotations shaft the main rotor of the helicopter for one minute, and N - number of blades of the main rotor. Then the field intensity $E_{\max}, E_{\min}$ and k_{ir} (1), which are dependent on spatial angles φ and θ, are also periodic functions of time t. It is causes corresponding decrease of the maximum and minimum values electric field intensity in time and their periodic redistribution between spatial angles in the horizontal and vertical planes. It may happen that at a certain moment of time field intensity values do not meet requirements criterion (1). Therefore, the use of formulas (1) and (2) to AS of type "standard antenna - body helicopter" needs corresponding corrections. They belong to selection procedure maximal and minimal values electric field intensity in conditions pulsating DD.

Irregularity dynamic normalized DD AS helicopter can be evaluated by introducing pulsation coefficient, which can be given in such form, dB

$$k_{pul} = -20\lg F_{\min\min}. \quad (4)$$

In ratio (4) are compared one and minimum minimorum values $F(\varphi)$ of the normalized DD in azimuth plane, which in common case is observed

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from different angles φ, at different moment's time t from interval $0 \le t \le \frac{T_N}{N} = \frac{60}{nN^2}$. The angular position a particular blade main rotor in the plane its rotation relative to the longitudinal axis of helicopter at any moment in time is given by ratio:

$$\Delta(t) = 2\pi \frac{t}{T_N} \le \frac{2\pi}{N}. \qquad (5)$$

Ratio (5) shows that normalized DD in any direction $[\varphi, \theta]$ is a continuous periodic function of angular position particular blade main rotor within the angle $\Delta\left(\frac{T_N}{N}\right)$, which depends on the ratio $\frac{T_N}{N}$, and the value of electric field intensity E and functions $F(\varphi)$ depends on relative time $\frac{t}{T_N}$.

Corresponding values DD can be detected by its numerical simulation. This idea is expedient be illustrated by helicopter grid virtual model that contains all basic constructive elements such aircraft (Fig. 1). Point 1 – 5 on the fuselage of helicopter virtual places marked pin antenna placements during the mathematical modeling pulsating DD hybrid AS.

II. Problem Statement

Make a quantitative estimate pulsations coefficient dynamic directivity diagram antenna system of type "standard dipole antenna – helicopter fuselage" and by mathematical modeling appropriate procedures identify its changing tendency depending on locations antenna on the fuselage aircraft.

Procedures for Research

Consider some possible options for placement pin antenna on fuselage helicopter. Numerical modeling of pulsating DD carries out in program FEKO.

1. The antenna installed in front gentle hemisphere of fuselage (Fig. 1, point 1). Figure 2 shows an example of calculated cross sections instantaneous values normalized DD hybrid AS in the three main planes angular coordinate system in one of the points in time t for grid model helicopter when $N = 4$.

a) DD cross section in the plane $X0Y$ – helicopter look at the above;

b) DD cross section in the plane $X0Z$ – side view of the helicopter;

c) DD cross section in the plane $Y0Z$ – front view of the helicopter.

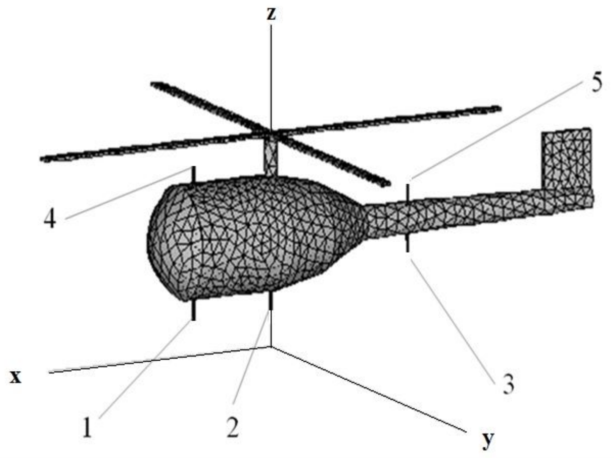

Fig. 1. Grid virtual model of helicopter

All DD form differ significantly from the theoretical, which are characteristic of pin vibrator installed on a plane screen. In addition diagrams become pulsating. Therefore it is advisable to give DD averaged values for each of azimuth angles at different positions main rotor blades. Figure 3 shows an example of averaged DD, built in $X0Y$ plane rectangular coordinate system.

Based on data contained in Fig. 3, calculate the coefficient normalized irregularity DD. Given the minimum value $F_{min} = 0.68$, based on the ratio (2) we obtain value of coefficient irregularity DD: $k_{ir} = 3.34$ dB.

Figure 4 shows graph pulsation DD in plane $X0Y$, for multiple azimuth angles shown in Fig. 2

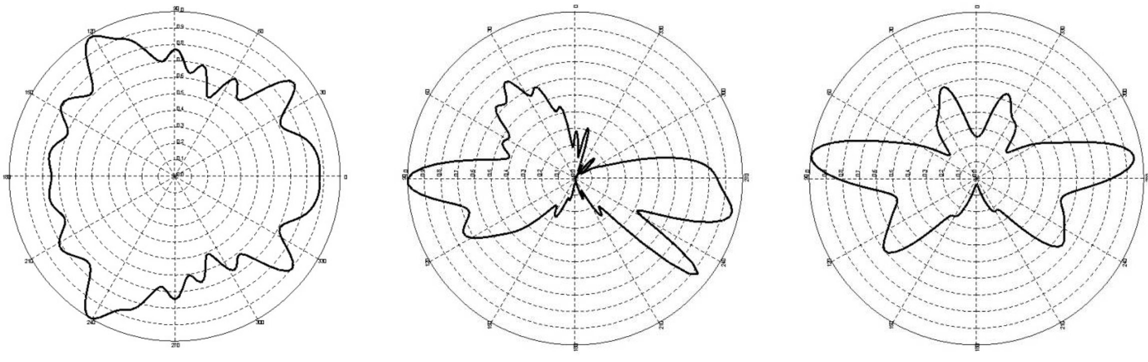

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Fig. 2. Angular dependence DD: (a) in the plane $X0Y$; (b) in the plane $X0Z$; (c) plane $Y0Z$

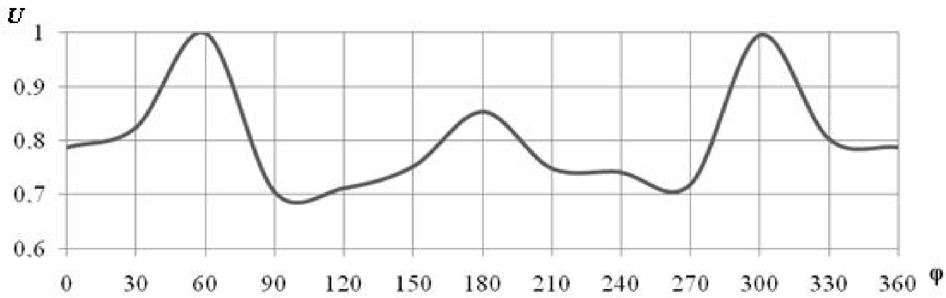

Fig. 3. Outline cross section averaged DD in the plane $X0Y$

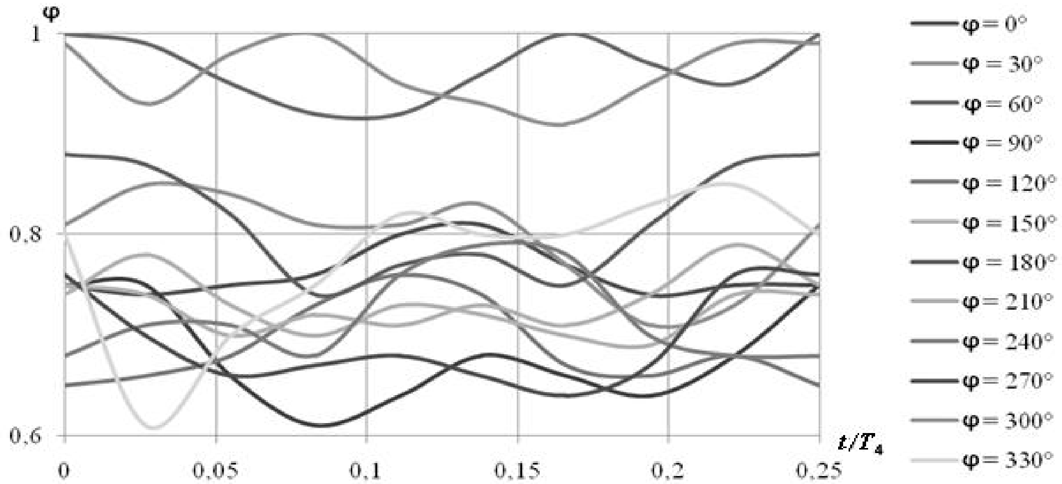

Fig. 4. Graphs pulsations DD in plane $X0Y$

From the graphs follows: when $\frac{t}{T_4} = 0$ $F\left(\frac{t}{T_4}\right) = F_{\max\max} = 1$ for the angle $\varphi = 60°$, and if $\frac{t}{T_4} = 0.07$, $F\left(\frac{t}{T_4}\right) = F_{\max\max} = 0.61$ for the angle $\varphi = 90°$. Therefore, on the basis of (4) is determined the pulsations coefficient $k_{pul} = 4.5$ dB. This value exceeds allowable 3 dB.

2. The antenna is installed in the lower hemisphere middle of the fuselage (Fig. 1, point 2).

In diagrams instant values that are characteristic for location of the antenna in the bottom middle of the fuselage, saved the main features of previous diagrams, so will continue to give averaged DD to the horizontal plane (Fig. 5).

Irregularity of normalized coefficient DD $k_{ir} = 5$ dB is calculated based on the ratio (2) to the minimum value $F_{\min} = 0.56$.

Pulsations DD in azimuth plane $X0Y$ are shown in Fig.6 as a series of graphic dependences.

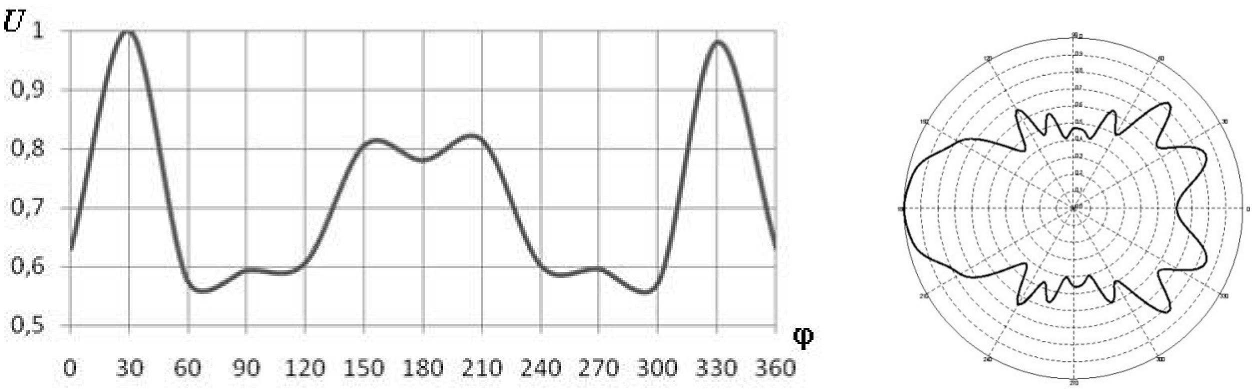

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Fig. 5. Drawing cross section DD in the horizontal plane: (a) the average DD; (b) instantaneous values

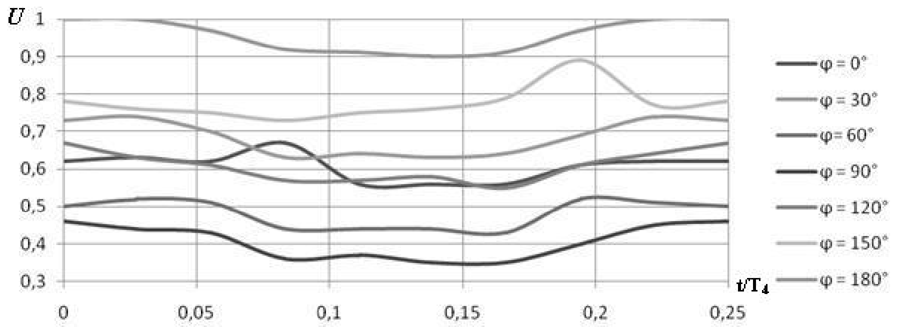

Fig. 6. Graphs pulsations DD in plane $X0Y$

Coefficient pulsations DD $k_{pul} = 9$ dB are defined for $F\left(\frac{t}{T_4}\right) = F_{\max\max} = 0.35$ in angle $\varphi = 90°$ in to relative moment time $\frac{t}{T_4} = 0.15$.

3. The antenna installed in gentle hemisphere rear fuselage (Fig. 1, point 3).

Consider the case where antenna is installed bottom at the rear of corpus of the aircraft (Fig. 7).

Irregularity coefficient of normalized averaged DD for given position antenna on the body of the helicopter is counting by formula (2) for the minimum value $F_{\min} = 0.56$ at an angle $\varphi = 70°$, then irregularity DD $k_{ir} = 5$ dB.

In Figure 8 are shown graphs pulsations DD in the horizontal plane.

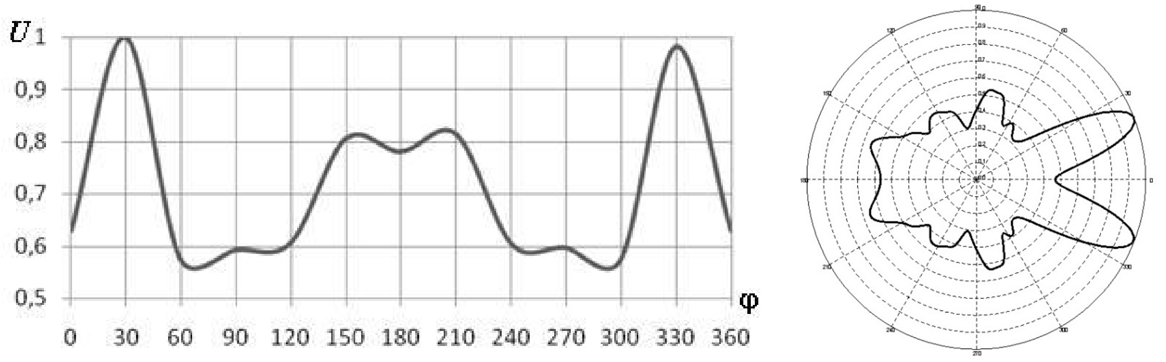

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Fig. 7. Drawing cross section DD in the horizontal plane: (a) the average DD; (b) instantaneous values

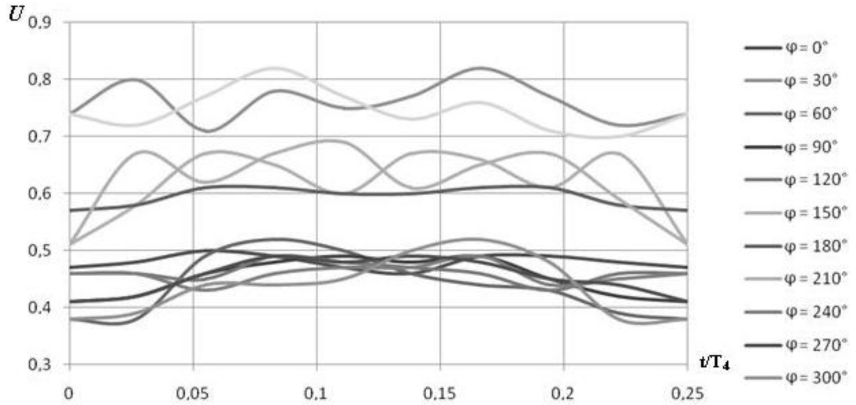

Fig. 8. Graphs pulsations DD in plane $X0Y$

Coefficient pulsations DD $k_{pul} = 8.6$ dB are defined for $F\left(\frac{t}{T_4}\right) = F_{\max\max} = 0.37$, the angle $\varphi = 60°$ at relative instant of time $\frac{t}{T_4} = 0.025$.

4. The antenna installed in the upper hemisphere front part of the fuselage (Fig. 1, point 4).

We perform mathematical modeling antenna installed in the top front part of the fuselage (Fig. 9). Obviously in this case greatly will increase influence main rotor helicopter on the AS.

Irregularity coefficient of normalized averaged DD for given position antenna on the body of the helicopter is counting by formula (2), the minimum value F_{min} = 0.28 at an angle φ = 180°, then irregularity DD k_{ir} = 11 dB.

In Figure 10 are shown graphs pulsations DD in the horizontal plane.

Coefficient pulsations DD $k_{pul} = 13.2$ dB are defined

for $F\left(\frac{t}{T_4}\right) = F_{\max\max} = 0.22$ in angle $\varphi = 180°$ at relative instant of time $\frac{t}{T_4} = 0.25$.

5. The antenna is installed above in tail section of the helicopter (Fig.1, point 5).

In abstract helicopter pin antenna is installed above on the tail (Fig. 11).

Irregularity coefficient of normalized averaged DD for given position antenna on the body of the helicopter is counting by formula (2), the minimum value F_{min} = 0.27 at an angle φ = 180°, then irregularity DD k_{ir} = 11,4 dB.

In Figure 12 are shown graphs pulsations DD in the horizontal plane.

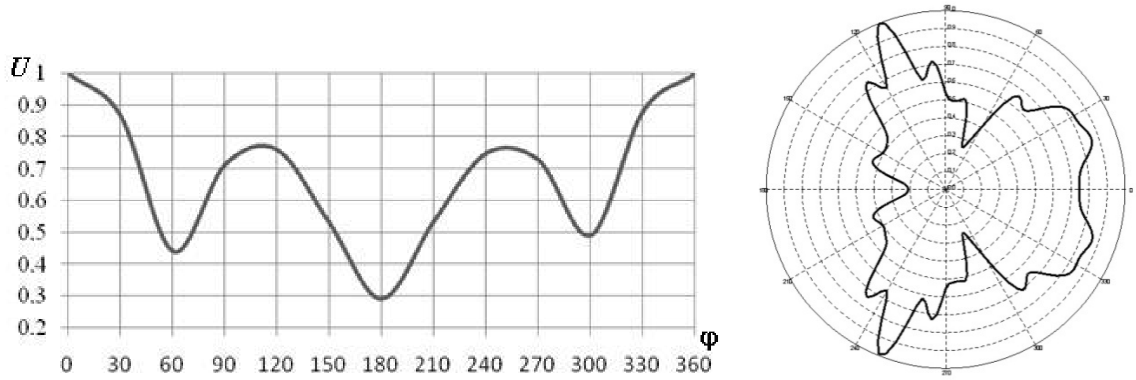

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Fig. 9. Drawing cross section DD in the horizontal plane: (a) the average DD; (b) instantaneous values

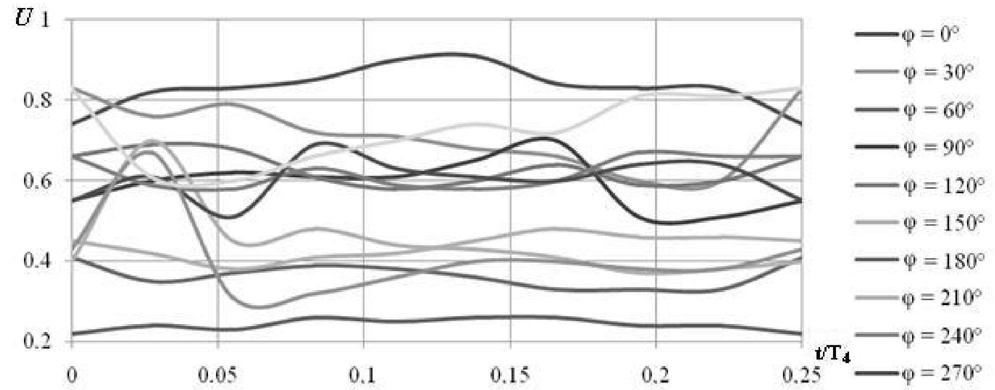

Fig. 10. Graphs pulsations DD in plane $X0Y$

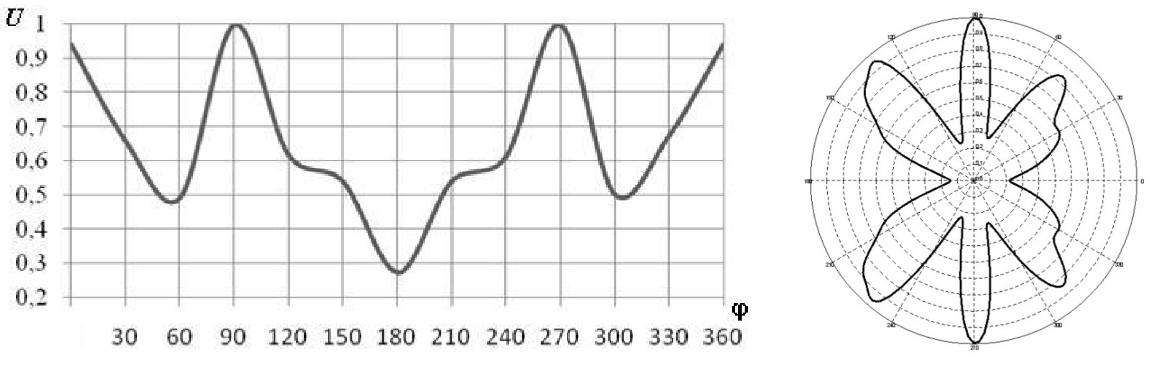

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Fig. 11. Drawing cross section DD in the horizontal plane: (a) the average DD; (b) instantaneous values

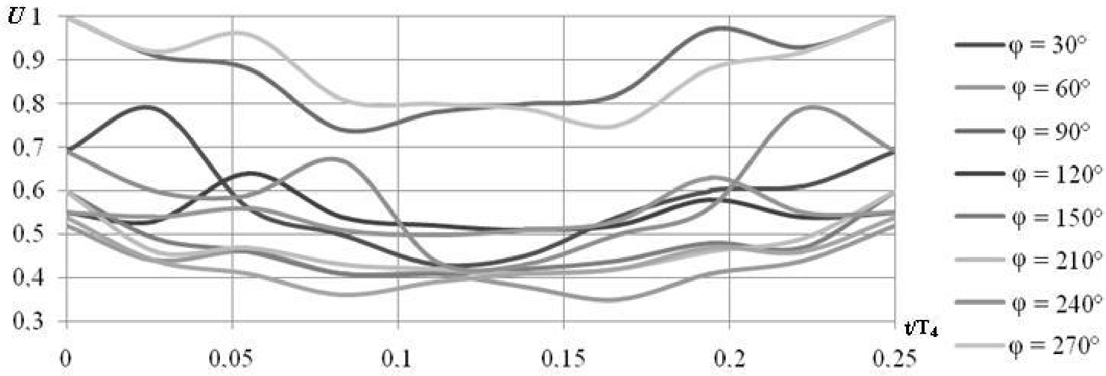

Fig. 12. Graphs pulsations DD in plane $X0Y$

Coefficient pulsations DD $k_{pul} = 9.1$ dB are defined for $F\left(\frac{t}{T_4}\right) = F_{\max\max} = 0.35$ in angle $\varphi = 60°$ at relative instant of time $\frac{t}{T_4} = 0.17$.

III. CONCLUSIONS

1. Irregularity of normalized DD AS of the helicopter expedient to evaluate by formula (4), which considers the smallest value DD, which changes periodically in time.

2. Level of Irregularity pulsating DD AS of the helicopter increases when antenna bias toward the tail of the helicopter.

3. In the upper fuselage hemispheres irregularity pulsating DD AS is much greater than in the lower.

4. The lowest level of pulsations is observed at the location pin vibrator on middle of the fuselage in its lower part.

5. The level of DD pulsations is largely dependent of the position antenna relative to main rotor and is (5…11) dB.

6. Rational location weakly directional antenna for allowable pulsations criterion for both the abstract, so, obviously, and for concrete construction fuselage, in conditions of applying several antennas it is expedient to determine based on mathematical modeling DD individual emitters, while perceiving other antenna construction elements of the helicopter fuselage.

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В. О. Іванов, О. С. Задорожний. Коефіцієнт пульсацій діаграми спрямованості штирової антени гелікоптера

Відносна глибина періодичних пульсацій зрізаної діаграми спрямованості електромеханічного утворення із штирової антени та корпусу гелікоптера при інших однакових умовах залежить від місця встановлення штатного вібратора. На основі чисельного моделювання побудовані графіки залежностей відносних рівнів пульсацій діаграми спрямованості від часу в трьох координатних площинах. Виявлено, що пульсації діаграми зменшуються при розміщенні антени під фюзеляжем ближче до його центру, але зростають, якщо антену розміщувати понад фюзеляжем ближче до його хвостової частини. У межах одного періоду форма пульсуючої діаграми спрямованості практично не залежить від кількості лопотів несучого гвинта гелікоптера.
Ключові слова: фюзеляж гелікоптера; несучий гвинт; антенна система; діаграма спрямованості; нерівномірна діаграма; пульсації діаграми; математичне моделювання.

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В. А. Иванов, А. С. Задорожний. Коэффициент пульсаций диаграммы направленности штыревой антенны вертолета

Относительная глубина периодических пульсаций изрезанной диаграммы направленности электромеханического образования из штыревой антенны и корпуса вертолета при прочих равных условиях зависит от места установки штатного вибратора. На основе численного моделирования построены графики зависимостей относительных уровней пульсаций диаграммы направленности от времени в трех координатных плоскостях. Выявлено, что пульсации диаграммы уменьшаются при размещении антенны под фюзеляжем ближе к его центру, но растут, если антенну размещать над фюзеляжем ближе к его хвостовой части. В пределах одного периода форма пульсирующей диаграммы направленности практически не зависит от количества лопастей несущего винта вертолета.
Ключевые слова: фюзеляж вертолета; несущий винт; антенная система; диаграмма направленности; неравномерная диаграмма; пульсации диаграммы; математическое моделирование.

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