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ADDITIVE MIXES OF NARROWBAND SIGNAL AND NOISE PARAMETRICALLY TRANSFORMATIONS IN NOT DIRECTIONAL ANTENNA HELICOPTER

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The main rotor rotation leads to the emergence the parametric system “standard antenna – body a helicopter”, in which outer radio interference and signal acquire spectral distortions. The features of new components of the signal spectrum and noises are identified. Indicated effects which may cause the appearance of these components.

Keywords: helicopter; effective length of the antenna; narrowband noise; parametric signal transformations; satellites; signal; frequency combinations; beats.

I. PROBLEM IDENTIFICATION

The rotation of the main rotor helicopter leads to a periodic variation of the configuration of its body, which together with the standard antenna is a general parametric antenna system. The signal of any type at its output in modes of transmission or reception undergoes frequency distortion, that are manifested in the occurrence of undesirable components in combinational frequencies harmonics of the useful signal and frequency configuration change of antenna system [1]. These components - satellites exist due to the energy useful signal, by reducing their existence its level. They appear as unwanted side components around every high-frequency components undistorted input radio signal which for them becomes partial carrier. Parametric effects discovered in [1], is typical of any radio signals necessary for the normal functioning of the regular and special equipment onboard helicopter. In [1] made an analysis of the spectral distortion of some signals (modulated and manipulated) in the absence of noises at the input of the radio receiver unit (RRU). In real conditions receiving antenna is always under influence of an additive mix the radio signal and noise of various origins. If RRU is appointed for processing digital information, then the system of regeneration some elements coded signal, which it assumed there is in more disadvantaged terms than in the case in which the fluctuations on its entrance is not suffered parametric transformations. In the case under consideration with the same threshold triggering regenerator probability of correct or erroneous decisions by him any pulse code sequence signal in mixed with noise reduced relative to the alternative case. Parametrical factor of the “standard antenna – helicopter” turned out its effective (active) length $\bar{h}(t)$. This follows from the known ratio for the electromotive force (EMF):

$$e(t)=\bar{E}(t)\,\bar{h}(t), \qquad (1)$$

which raises at the antenna output terminals RRU under the influence of electric field intensity $\bar{E}(t)$. Field $\bar{E}(t)$ is excited by antenna radio transmitter (RT), which is located at a distance r from the antennas RR, has an effective length $\bar{l}(t)$ and depends from strength of high-frequency electric current $I_A(t)$ with a wavelength λ, which reflects the law signal modulation radiated

$$\bar{E}(t)=\frac{60\,\pi I_A(t)}{r\lambda}\,\bar{l}(t). \qquad (2)$$

From the above ratios it follows that the effective length of the antenna are the only parameter that depends on its design features.

Normalized directivity diagram (DD) $F(\theta,\varphi)$ antenna system of the aircraft has irregularity form, which can be determined only on the basis of physical or mathematical simulation. Therefore, the function should be introduced in the above ratio as cofactors only conditionally, given the fact that the notion of DD antenna has a physical interpretation only in the wave zone of space. The results of mathematical modeling of the radiation field in the wave zone of the helicopter, which was made indicates that the rotation of the main rotor is accompanied by a notable three-dimensional spatial pulsations truncated DD without changing its essential geometric form. Pulsations DD in time are a consequence and proof parametric effective length of antenna system helicopter. Therefore, in equation (1) and (2) multiplier is scale for the selected spatial direction and can be omitted without any consequences for the further research of spectral features of oscillations that are generated on the input regenerator in the tract digital RR.

A mathematical model the effective length of parametric antenna system (PAS) proved in [1] and can be given in such a form:

$$h(t) = h_0 - \Delta h(t) = h_0\left[1 - \frac{\Delta h(t)}{h_0}\right]. \qquad (3)$$

In this model h_0 is the effective length of antenna devices in the selected point designs; $\Delta h(t)$ is a component that is a periodic function of the angular velocity rotation the main rotor helicopter. The amplitude of the pulsation the effective length $\Delta h_{\max} < h_0$ and in other similar conditions depends on the electrical characteristics of the material from which made main rotor blades. This pulsation in the physical interpretation is a periodic sequence of identical shape and duration τ unipolar pulses, which border with one another, and their envelope is a smooth curve that has no jumps and tearing. Pulse duration τ equal to the period of their repetition T. Such a periodic sequence of pulses can be decomposed in a classic Fourier series in order to detect levels of the constant component and individual harmonic components in a mathematical model of effective length PAS (3). The frequency of the first harmonic F_1 periodic sequence of pulses determined by the ratio, Hz

$$F_1 = \frac{1}{T} = \frac{nN}{60}, \qquad (4)$$

where n is the number of revolutions of the shaft main rotor for one minute; N is number of blades of the screw. If the screw is coaxial, the frequency F_1 increases to four times. Based on the above individual pulses in a periodic sequence in the general case it is advisable to provide a smoothed form, in order to simplify analysis while maintaining the basic laws. Simply is cosine pulse shape. With such choice in the ratio (3) instant value pulsation given the schedule periodic sequence of pulses cosine in Fourier series [2]:

$$\begin{aligned}\Delta h(t) &= \Delta h \sum_{k=-\infty}^{\infty}\left|\cos\frac{\nu_1}{2}(t + kT)\right| \\ &= \frac{2}{\pi}\Delta h\left[1 + \sum_{p=1}^{\infty} 2\frac{(-1)^p}{1-(2p)^2}\cos p\nu_1 t\right]\end{aligned} \qquad (5)$$

in the ratio (5) $\nu_1 = 2\pi F_1$ is the first harmonic of angular frequency parametric transformation; p = 1, 2, 3, ... is number of harmonics frequency parametric transformation signal.

From the ratio (5) implies that growth p is accompanied by a rapid decrease in the amplitude corresponding harmonics.

It bear in mind that for antennas are not installed on the helicopter and at other objects in the ratio (3), (5) and other amplitude pulsations $\Delta h = 0$ (for antenna RR) and $\Delta l = 0$ (for antenna RT).

We assume that the signal is received in a mix with narrowband noise on a frequency ω_0, which is characterized by random phase $\tilde{\theta}(t)$ and envelope $\tilde{A}(t)$:

$$\begin{aligned}\tilde{a}(t) &= \tilde{A}(t)\cos\left(\omega_0 t + \tilde{\theta}(t)\right) \\ &= \tilde{A}(t)\left(\cos\tilde{\theta}(t)\cos\omega_0 t - \sin\tilde{\theta}(t)\sin\omega_0 t\right).\end{aligned} \qquad (6)$$

The density of the probability distribution for the envelope in the ratio (6) obeys, for example, the law of Gauss and phase – uniformly distributed in the range of possible values $[-\pi, \pi]$.

This noise focused on the frequency is most dangerous for narrowband radio signals, which are used in modern digital communication channels and data transmission [3].

II. FORMULATION OF THE PROBLEM

Identify the characteristics of the signal structure of any type of high-frequency tract RR, impressed narrowband noise with random values of characteristics, if the radio signal is distorted in PAS helicopter.

III. PROCEDURES FOR RESEARCH

In the presence noise at the input of the antenna RR may experience the following behaviors:

– in digital radio channel between two helicopters on input onboard RR receives additive mix radio signal, transformed twice into antennas helicopters and external noise, that has suffered one transformation;

– in digital radio channel between RT helicopter and RR, which are not installed on the helicopter, the signal at the input of radio receiver is such that has suffered parametric transformations and noise – no;

– in digital radio channel between the RT, installed not on a helicopter and RR installed on a helicopter, radio receiver input is under the influence additive mixture of radio signal and noise that suffer parametric transformations in the antenna RR helicopter.

First consider the general situation. For her, EMF $e_\Sigma(t)$ at the output of the antenna, which is caused by presence an additive mixes electric field intensity radio signal $E(t)$ (2) and noise (6) at the location of PAS, taking into account the relations (1), (2), (3) and (5) can be given as:

$$e_\Sigma(t) = E(t)h_0\left\{1-\frac{4}{\pi^2}\frac{\Delta l}{l_0}\frac{\Delta h}{h_0}-\frac{2}{\pi}\frac{\Delta l}{l_0}\left(1+\frac{2}{\pi}\frac{\Delta h}{h_0}\right)\right.\left[1+\sum_{p_l=1}^{\infty}2\frac{(-1)^{p_l}}{1-(2p_l)^2}\cos p_l \nu_l t\right]$$

$$\left.-\frac{2}{\pi}\frac{\Delta h}{h_0}\left(1+\frac{2}{\pi}\frac{\Delta l}{l_0}\right)\left[1+\sum_{p_h=1}^{\infty}2\frac{(-1)^{p_h}}{1-(2p_h)^2}\cos p_h \nu_h t\right]\right\}+\tilde{a}h_0\left\{1-\frac{2}{\pi}\frac{\Delta h}{h_0}\left[1+\sum_{p_h=1}^{\infty}2\frac{(-1)^{p_h}}{1-(2p_h)^2}\cos p_h \nu_h t\right]\right\}. \quad (7)$$

From the multiplier which are an expression is concentrated in the first curly braces relation (7) it follows that regardless of the type modulation useful signal $E(t)$ at the output of PAS his value decreases by an amount which is determined by the totality of three corresponding subtrahend. The energy is spent on the creation satellites that are inside noise on combinational frequencies. Satellites accompany all components of useful signal and distort its spectrum [1]. In this multiplier with a view to simplification, neglect the small by amplitudes components that arise on the order of combination frequencies order of $|p_l \nu_l \pm p_h \nu_h|$.

From the multiplier, which is an expression, concentrated in other curly brackets relation (7), it follows that the spectrum of noise also changes. When $\Delta h \neq 0$ creates new components focus noise on the combination frequencies $\omega_0 \pm p_h \nu_h$, which also fluctuate in amplitude and phase. But the overall noise power at the output of the antenna would remain unchanged. Therefore, the ratio at the output PAS is less than the ratio on its input (when $\Delta l = 0$ and $\Delta h = 0$).

For the second situation specified above, the ratio (7) we consider $\Delta h = 0$. In this case we obtain:

$$e_\Sigma(t) = \left\langle E(t)\left\{1-\frac{2}{\pi}\frac{\Delta l}{l_0}\right.\right.$$

$$\left.\left.\times\left[1+\sum_{p_l=1}^{\infty}2\frac{(-1)^{p_l}}{1-(2p_l)^2}\cos p_l \nu_l t\right]\right\}+\tilde{a}(t)\right\rangle h_0. \quad (8)$$

The third situation in the ratio (7) we consider $\Delta l = 0$. In this case we get:

$$e_\Sigma(t) = \left[E(t)+\tilde{a}(t)\right]\left\{1-\frac{2}{\pi}\frac{\Delta h}{h_0}\right.$$

$$\left.\times\left[1+\sum_{p_h=1}^{\infty}2\frac{(-1)^{p_h}}{1-(2p_h)^2}\cos p_h \nu_h t\right]\right\}h_0. \quad (9)$$

Suppose that there is a useful single-frequency signal with amplitude manipulation by meander [4]:

$$E(t) = \frac{1}{2}E_0\left(1+\frac{4}{\pi}\sum_{n=1}^{\infty}\frac{\sin n\frac{\pi}{2}}{n}\cos n\Omega t\right)\cos(\omega_0 t+\Psi_0)$$

$$=\frac{1}{2}E_0\left\langle\cos(\omega_0 t+\Psi_0)+\frac{2}{\pi}\sum_{n=1}^{\infty}\frac{\sin n\frac{\pi}{2}}{n}\left\{\cos\left[(\omega_0-n\Omega)t+\Psi_0\right]+\cos\left[(\omega_0+n\Omega)t+\Psi_0\right]\right\}\right\rangle. \quad (10)$$

In ratio (10) E_0 is the amplitude electric field intensity vector at the point of reception $\Omega = \frac{2\pi}{T_m}$; T_m is the period following rectangular pulses, n is number of harmonics; Ψ_0 is the initial phase of the carrier at the frequency ω_0. If the signal (10) and noise (6) substituted into ratio (7), for the first situation we get:

$$e_\Sigma(t) = \frac{1}{2}E_0 h_0\left\langle\cos(\omega_0 t+\Psi_0)+\frac{2}{\pi}\sum_{n=1}^{\infty}\frac{\sin n\frac{\pi}{2}}{n}\left\{\cos\left[(\omega_0-n\Omega)t+\Psi_0\right]+\cos\left[(\omega_0+n\Omega)t+\Psi_0\right]\right\}\right\rangle$$

$$\times\left\langle\left\{1-\frac{4}{\pi^2}\frac{\Delta l}{l_0}\frac{\Delta h}{h_0}-\frac{2}{\pi}\frac{\Delta l}{l_0}\left(1+\frac{2}{\pi}\frac{\Delta h}{h_0}\right)\right.\right.\left[1+\sum_{p_l=1}^{\infty}2\frac{(-1)^{p_l}}{1-(2p_l)^2}\cos p_l \nu_l t\right]$$

$$-\frac{2}{\pi}\frac{\Delta h}{h_0}\left(1+\frac{2}{\pi}\frac{\Delta l}{l_0}\right)\left[1+\sum_{p_h=1}^{\infty}2\frac{(-1)^{p_h}}{1-(2p_h)^2}\cos p_h\nu_h t\right]\Bigg\}\Bigg\rangle$$

$$+\tilde{A}(t)h_0\cos\left(\omega_0 t+\tilde{\theta}(t)\right)\left\{1-\frac{2}{\pi}\frac{\Delta h}{h_0}\left[1+\sum_{p_h=1}^{\infty}2\frac{(-1)^{p_h}}{1-(2p_h)^2}\cos p_h\nu_h t\right]\right\}.$$

(11)

In ratio (11) high frequency ω_0 in the future should be changed to an intermediate frequency ω_i. The process will be formally transferred to the input of the demodulator.

Assuming $\Psi_0=0$, marking $0{,}5E_0h_0=U_0$ and $\tilde{A}(t)h_0=\tilde{U}_n(t)$, ratio (11) can be interpreted as a mathematical model corresponding voltage $u_\Sigma(t)$:

$$u_\Sigma(t)=U_0\left\{\cos\omega_i t+\frac{2}{\pi}\sum_{n=1}^{\infty}\frac{\sin n\frac{\pi}{2}}{n}\left[\cos(\omega_i-n\Omega)t+\cos(\omega_i+n\Omega)t\right]\right\}$$

$$\times\Bigg\langle\Bigg\{1-\frac{4}{\pi^2}\frac{\Delta l}{l_0}\frac{\Delta h}{h_0}-\frac{2}{\pi}\frac{\Delta l}{l_0}\left(1+\frac{2}{\pi}\frac{\Delta h}{h_0}\right)\left[1+\sum_{p_l=1}^{\infty}2\frac{(-1)^{p_l}}{1-(2p_l)^2}\cos p_l\nu_l t\right]$$

$$-\frac{2}{\pi}\frac{\Delta h}{h_0}\left(1+\frac{2}{\pi}\frac{\Delta l}{l_0}\right)\left[1+\sum_{p_h=1}^{\infty}2\frac{(-1)^{p_h}}{1-(2p_h)^2}\cos p_h\nu_h t\right]\Bigg\}\Bigg\rangle$$

$$+\tilde{U}_n(t)\left(\cos\tilde{\theta}(t)\cos\omega_i t-\sin\tilde{\theta}(t)\sin\omega_i t\right)\left\{1-\frac{2}{\pi}\frac{\Delta h}{h_0}\left[1+\sum_{p_h=1}^{\infty}2\frac{(-1)^{p_h}}{1-(2p_h)^2}\cos p_h\nu_h t\right]\right\}. \quad (12)$$

From the resulting ratio is it follows:

– spectral components of the useful signal (10) at frequencies ω_i and $\omega_i\pm n\Omega$ are accompanied by satellites, that arise at combination frequencies $\omega_i\pm p_{h(l)}\nu_{h(l)}$ and $\omega_i\pm n\Omega\pm p_{h(l)}\nu_{h(l)}$ at any combinations of signs "+" and "-";

– component of the signal at the intermediate frequency is masked from focused noise and by fluctuating amplitudes and phases satellites that arise at frequencies ω_i and $\omega_i\pm p_h\nu_h$, if RR installed on the helicopter.

As the frequency ω_i and $\omega_i\pm p_{h(l)}\nu_{h(l)}$, and also $\omega_i\pm n\Omega$ and $\omega_i\pm n\Omega\pm p_{h(l)}\nu_{h(l)}$ are different only slightly, between the respective components arising beats with periods following $2\pi/p\nu$ at frequencies ω_i and $\omega_i\pm n\Omega$. These circumstances, given the existence of noise at the same frequencies may result to distortion characteristics of pulse signals, degrade the accuracy of their detection and reproduction in subsequent cascades RR.

If the RR all functional elements are perfect, then on the demodulator output voltage arises, which contains components at frequencies $n\Omega$ envelope of the useful signal (10), and also on frequencies $n\Omega\pm p_{h(l)}\nu_{h(l)}$ and $p_{h(l)}\nu_{h(l)}$, which in the spectrum of the input signal was not. Therefore the beats arise in low frequency radio receiver tract.

From ratio (12) also follows, that useful signal at the output of the low pass filter demodulator is accompanied by noise:

$$\tilde{u}_n(t)=\tilde{U}_n(t)\left\{1-\frac{2}{\pi}\frac{\Delta h}{h_0}\right.$$

$$\left.\times\left[1+\sum_{p_h=1}^{\infty}2\frac{(-1)^{p_h}}{1-(2p_h)^2}\cos p_h\nu_h t\right]\right\}\cos\tilde{\theta}(t). \quad (13)$$

Both components of the total voltage noise (13), which are independent of frequency, envelope of narrowband noise are correspond (6), that affects antenna RR, and weaken one another. The components of noise (13), which depend on the frequency of pulsation antenna effective length $\Delta h(t)$ (5), arising from the energy difference between these noises and combined with other components.

From the ratios (7) – (9) it follows that the characteristics that are inherent parametric transformation signal $E(t)$ (10) in the antenna helicopter is analogous to the radio emission of any class.

The negative effects of distortion signal spectrum in PAS helicopter may be the cause of errors in a block of available data about his identity and whereabouts, if, in order to improve air traffic management procedures, provides for the use of automatic dependent satellite surveillance-broadcast (ADS-B), or ground system multilateration (MLAT). These errors may be additional factors that negatively affect on the value such normalized parameters specified systems like the accuracy, integrity, data availability for the user [5].

IV. CONCLUSIONS

The results of the research are as follows:

– if the radio communication channel installed between a pair of helicopters, then useful signal is transformed into him twice, and noise – once;

– in the process of the parametric transformation signal and narrowband noise arise parasitic components of satellites that exist at the expense energy of the useful signal and noise, respectively;

– frequency of satellites are combination in their origin, they are only slightly different from the frequency of their "energy donor" and therefore make with them appropriate beats;

– the presence of beats in mixed with transformed noise hinders unmistakable regeneration pulses, that are applied as elements of codes in the implementa tion digital data transmission from board or to board helicopter;

– distortion of the useful signal spectrum in PAS helicopter can negatively affect the quality evaluation of air situation, if for this supposed to use systems ADS-B and MLAT.

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В. О. Іванов, О. С. Задорожний. Параметричні перетворення адитивної суміші вузькосмугових сигналу та завади у слабонаправленій антені гелікоптера

Обертання несучого гвинта призводить до виникнення параметричної системи «штатна антена – корпус гелікоптера», в якій сигнал і зовнішня радіозавада зазнають спектральних змін. Виявлено особливості нових складових спектрів сигналу і завади. Вказано наслідки, до яких може призвести поява цих складових.

Ключові слова: гелікоптер; ефективна довжина антени; вузькосмуговий шум; параметричні перетворення сигналів; сателіти; сигнал; комбінаційні частоти; биття.

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В. А. Иванов, А. С. Задорожный. Параметрические преобразования аддитивной смеси узкополосных сигнала и помехи в слабонаправленной антенне вертолета

Вращение несущего винта приводит к образованию параметрической системы «штатная антенна – корпус вертолета», в которой сигнал и внешняя радиопомеха претерпевают спектральные изменения. Выявлены особенности новых составляющих спектров сигнала и помехи. Указаны последствия, к которым может привести их появление.

Ключевые слова: вертолет; эффективная длина антенны; узкополосный шум; параметрические преобразования сигналов; сателлиты; сигнал; комбинационные частоты; биение.

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