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# BEATS IN THE HELICOPTER RADIO CHANNEL OF ONE-BAND SIGNAL

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***Abstract***

*The frequency distortion of a one-way signal at the output of a non-directional antenna helicopter, which arises during rotation of the helicopter main rotor, is detected. The power loss of a useful signal for the existence of satellites is appreciated. They arise in near each spectral component of a useful signal. In this case, they exist due to the energy of a useful signal. Therefore, the signal/noise ratio at the output of the non-directional antenna of the helicopter becomes lower than at its input. Reducing the power of a useful signal will result in a corresponding deterioration in the quality of the radio communication.*

**Keywords**: beats; helicopter; effective length; main rotor; pulsations; radio channel

## 1. Formulation of the problem

On planes and helicopters of dimensional load capacity, as a rule, identical electronic equipment, and the corresponding antenna devices, is installed. The structure of the near and far electromagnetic fields of the side-poor antenna depends not only on its type, but also on the structural features of the body (metal or carbon) of the aircraft. The body is an integral part of the hybrid non-directional antenna. Helicopter main rotor rotation is periodically changing the geometric form of the conductive body of the aircraft. In this case, the hybrid system "regular non-directional antenna - helicopter body" acquires parametric quality. Its irregular directional diagram becomes pulsing. The useful signal at the antenna output undergoes irreversible amplitude-frequency distortion. As a result, the channel of radio communications with the helicopter, in terms of its qualitative characteristics, is worse than a similar radio channel for the aircraft.

In long-distance radio systems, signals with one-band amplitude modulation with suppressed carrier are common. It is therefore advisable to investigate the distortion that affects the signal in the helicopter radio channel.

## 2. The purpose of work

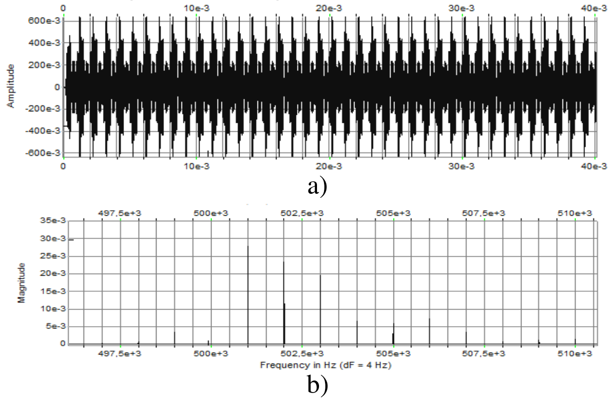
Evaluate power loss and spectral distortion of a one-band signal at the output of non-directional antenna of the helicopter that arise during main rotor rotation.

## 3. Signal distortion by the helicopter antenna system

The instantaneous value of the electric field strength at the point of location of the antenna of the radio receiver in multi-tone single-band modulation with the upper buoy stripe is determined by the ratio [1]:

$$E(t)=\frac{E}{2}\sum_{n=1}^{\infty}M_n\cos\left[\left(\omega_0+\Omega_n\right)t+\Psi_0+\theta_n\right] \qquad (1)$$

where: E – the amplitude of the electric field strength at the point of supervision, $\omega_0$ and $\psi_0$ – circular frequency of the carrier and its initial phase, $M_n$ – partial coefficients modulation depth, $\Omega_n$ – circular frequency of the n-th component modulating signal, $\theta_n$ – corresponding initial phase. A typical oscillogram and spectrograph of the signal (1) are shown in Fig. 1 a and Fig. 1 b.



a)

b)

Fig.1. Multi-tone single-band modulation

The momentary value of the electromotive force (EMF) at the antenna output in the receive mode is determined by the ostensible ratio:

$$U(t) = E(t) \cdot h_e(t) \qquad (2)$$

Effective length $h_e$ is the coefficient of proportionality between the intensity of the electric field *E(t)* and the corresponding EMF *U(t)* at the antenna output terminals. It differs from that known by the fact that it becomes a periodic function of time – $h_e(t)$. In this case, the helicopter hybrid antenna system acquires parametric properties. The system is also parametric in the radiation mode.

The mathematical model of the effective height $h_e(t)$ can be given as:

$$h_e(t) = h_{eo} - \Delta h_e(t) = h_{eo}\left[1 - \frac{\Delta h_e(t)}{h_{eo}}\right], \qquad (3)$$

where: $h_{eo}$ is the amplitude value of the effective length of the hybrid antenna system, and $\Delta h_e(t)$ is the instantaneous value of the function pulsations $h_e(t)$ [2]. They depend from the main rotor rotation speed, the design features of the helicopter body and the direction of signal receiving or transmission. The pulsations are periodic sequences of video pulses of identical duration τ that are adjacent to each other, that is:

$$\tau = T\frac{60}{mkN} \qquad (4)$$

where: *m* – the number of rotations of the shaft helicopter main rotor in one minute (200 ÷ 300 rpm), *N* = (2 ÷ 6) is the number blades of the main rotor in one tier of the coaxial circuit, *k* = (1 ÷ 2) is the number of tiers. The amplitudes of the video pulses $\Delta h_e$ and the shape of their bypass under the same conditions depend on the direction relative to the longitudinal axis of the helicopter. But the first harmonic of the periodic sequence of such video pulses does not depend on their shape. Therefore, a convenient mathematical model of the pulsations of the effective length of the hybrid antenna system (3) can be considered a periodic sequence of cosine-like pulses:

$$\Delta h_e(t) = \Delta h_e \left|\cos\frac{\pi}{\tau}t\right| = \Delta h_e \left|\cos\frac{\nu}{2}t\right|, \qquad (5)$$

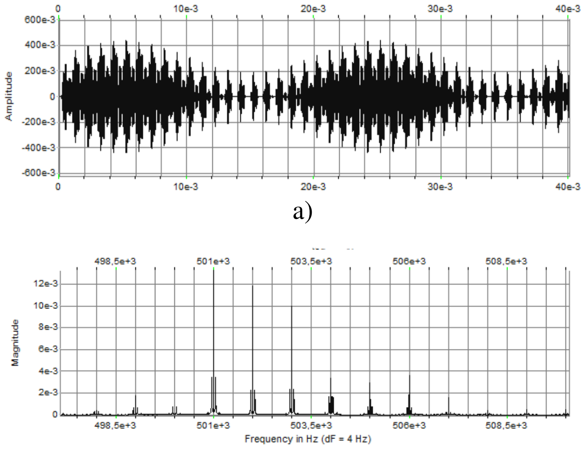
in which ν is the angular frequency of the pulsations, which is determined by the ratio:

$$\nu = 2\pi\frac{mkN}{60} \qquad (6)$$

The decomposition of the function (5) into a Fourier series leads to the relation given in [3]:

$$\Delta h_e(t) = \frac{2}{\pi}\Delta h_e\left[1 + \sum_{p=1}^{\infty} 2\frac{(-1)^p}{1-(2p)^2}\cos p\nu t\right], \qquad (7)$$

in which *p* is the number of harmonics of the angular frequency of the ripple ν of the effective length hybrid antenna system (3). The pulsations in the effective length of the hybrid antenna system (3) cause the corresponding pulsations of the antenna system directional diagram "regular non-directional antenna - helicopter body”. If the values (1) and (3), (7) are substituted in relation (2), then by numerical simulation one can obtain an oscillogram and an spectrograph at the output of the hybrid antenna system of the helicopter, that is shown in Fig. 2 a and Fig. 2 b, respectively.



a)

b)

Fig. 1. Multi-tone single-band modulation at the output of the hybrid antenna system

Oscillograms and spectrographs, shown in Fig.1 and Fig. 2, differ significantly in shape and frequency composition. At the output of the hybrid antenna system, there are beats (Fig. 2a), which are due to the emergence of satellites at the side frequencies near each spectral component of the output signal (Fig. 2b). Obviously, satellites exist at the expense of energy, which they select from the corresponding components of a useful signal.

The relation (7) can be simplified if we take into account that in it amplitudes of harmonics quickly decrease with increasing numbers, for example:

$$\frac{(-1)^p}{1-(2p)^2} = \begin{cases} \frac{1}{3}\text{of} \quad p=1 \\ -\frac{1}{15}\text{of} \quad p=2 \\ \frac{1}{35}\text{of} \quad p=3 \end{cases}$$

Therefore, if in the decomposition (7) we leave only the first harmonic, we get the following:

$$\Delta h_e(t) \approx \frac{2}{\pi}\Delta h_e\left(1+\frac{2}{3}\cos\gamma t\right) \qquad (8)$$

After substituting (8) into (3), we obtain a simplified mathematical model of the effective length hybrid antenna system:

$$\Delta h_e(t) \approx \Delta h_e\left[1-\frac{2}{\pi}\frac{\Delta h_e}{h_e}\left(1+\frac{2}{3}\cos\gamma t\right)\right] \qquad (9)$$

Taking into account the ratio (9), the expression (2) for the EMF for $\varphi_0 = 0$ and $\Theta_n = 0$ takes the form:

$$\begin{aligned} u(t) \approx \frac{E}{2}h_e\Bigg[&\left(1-\frac{2}{\pi}\frac{\Delta h_e}{h_e}\right)\sum_{n=1} M_n\cos(\omega_0+\Omega_n)t - \\ &\frac{2}{3\pi}\frac{\Delta h_e}{h_e}\cdot\sum_{n=1}\cos(\omega_0+\Omega_n-\gamma)t - \qquad (10) \\ &-\frac{2}{3\pi}\frac{\Delta h_e}{h_e}\sum_{n=1}\cos(\omega_0+\Omega_n-\gamma)t\Bigg] \end{aligned}$$

The first component of the ratio (10) characterizes the weakened one-band signal. And the negatives at the combination frequencies are satellites the products of its parametric transformations in the hybrid antenna system. The set of satellites creates angles at the angular frequency $2y \le \omega_0+\Omega_n + y$ difference between satellites. Beats also occur between the weakened one-way signal and the individual satellites at the angular frequency (6) $\gamma \le \omega_0+\Omega_n$. These circumstances explain the features of oscillograms and spectrographs, which are shown in Fig. 2.

## 4. Signal power loss on hold satellites

The average signal power (10) at the output of the hybrid antenna system, which is allocated to a load equal to one ohm, is based on the known ratio:

$$\begin{aligned} P_{ave} &= \lim_{n\to\infty}\frac{1}{T}\int_0^T u^2(t)dt \approx \\ &\approx \frac{E^2h_e^2}{8}\left[1-0{,}5\left(\frac{\Delta h_e}{h_e}\right)^2\right]\sum_{n=1}M_n^2 \end{aligned} \qquad (11)$$

Subtrahend in ratio (11) defines the average power $\Delta P_{ave}$, which is lost on hold satellites - beating components, which arise in the helicopter radio channel:

$$\Delta P_{ave} = \frac{E^2h_e^2}{16}\left(\frac{\Delta h_e}{h_e}\right)^2\sum_{n=1}M_n^2 \qquad (12)$$

The power $\Delta P_{ave}$ (12) is added to the power of noise other origin, which at the antenna input always exists. Therefore, the ratio *signal/noise* at the output of the regular non-directional helicopter antenna becomes lower than at its input. From ratio (11) it follows that if the relative pulsations of the effective length hybrid helicopter antenna system are maximal that is $\frac{\Delta h_e}{h_e} = 1$, then the average power of the signal is reduced by half relative to the case in which no pulsations (aircraft).

## 5. Conclusions

The rotation of the helicopter main rotor led to the emergence of a parametric antenna effect, the consequences of which are:

- attenuation of the output signal, and its frequency distortion;
- deterioration of the *signal/noise* ratio at the output of regular antenna helicopter;
- reducing the range of high-quality radio communication.

The effect of parametric distortion of a signal in a non-directional helicopter antenna is manifested in any form of its modulation.

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**Биття односмугового сигналу у радіоканалі гелікоптера**

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Виявлені частотні спотворення односмугового сигналу на виході слабоспрямованої антени гелікоптера, які виникають при обертанні його несучого гвинта. Оцінені витрати потужності корисного сигналу на утримання складових-сателітів, що виникають біля кожної спектральної складової корисного сигналу та існують за рахунок їх енергії. Тому відношення *сигнал/завада* на виході слабоспрямованої антени гелікоптера стає нижчим, ніж на її вході. Зменшення потужності корисного сигналу призведе до відповідного погіршення якості радіозв'язку.

**Ключові слова:** биття; гелікоптер; ефективна висота; несучий гвинт; пульсації; радіоканал

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**Биения однополосного сигнала в радиоканале вертолета**

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Обнаруженные частотные искажения однополосного сигнала на выходе слабонаправленной антенны вертолета, которые возникают при вращении его несущего винта. Оценены затраты мощности полезного сигнала на содержание составляющих-сателлитов, возникающих около каждой спектральной составляющей полезного сигнала и существуют за счет их энергии. Поэтому отношение *сигнал/помеха* на выходе слабонаправленной антенны вертолета становится ниже, чем на ее входе. Уменьшение мощности полезного сигнала приведет к соответствующему ухудшению качества радиосвязи.

**Ключевые слова:** биения; вертолет; эффективная высота; несущий винт; пульсации; радиоканал

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