Methods of information systems protection

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METHOD OF ACCURACY INCREASE IN RADIO CONTROL SYSTEMS WITH ORTHOGONAL FREQUENCY MULTIPLEXISING AT THE CONSIDERATION OF THE TIMER SIGNAL CONSTRUCTIONS USE

The issue of improving the efficiency of radiocommunication systems and radiocommunication complexes in a complex radio-electronic environment is a prime scientific problem, which attracts attention of a large number of leading scientists. In this article, the author carried out research aimed at increasing the structural secrecy in radio-frequency communication systems with orthogonal frequency multiplexing using timer signal constructions, due to the development of a method of increasing the secrecy in radio-frequency systems with orthogonal frequency muxification due to the use of timer signal structures. In the course of the research carried out by the author, the basic provisions of the theory of communication, the theory of impedance protection, the theory of complex technical systems, the theory of antagonistic systems, the theory of noise immunity coding, the theory of chaotic processes, the theory of orthogonal systems, the theory of radio frequency planning and the theory of timer signal structures. The difference in the proposed methodology from the known, which determines its novelty are: the use of timer signal structures, in contrast to the traditional position signaling structures, it can increase the structural secrecy of signals with orthogonal frequency multiplexing; the use of expanding sequences of different types and with different autocorrelation properties allows for the operational adaptation of parameters of systems and radio communication equipment with orthogonal frequency multiplexing to the effect of destabilizing factors aimed at disclosing the properties of systems and radio communication equipment for electronic intelligence; application of the mechanisms of frequency adaptation to the effect of intentional obstacles allows you to determine the areas of the frequency range struck by them and conduct the intellectual planning of using the radio frequency resources by radio communication systems with orthogonal frequency multiplexing.

Keywords: radio communication systems, radio wave suppression, radio resources, signal-code structures, noise immunity, orthogonal frequency multiplexing, timer signal structures.

Introduction

The issue of improving the efficiency of radiocommunication systems and radiocommunication complexes in a complex radio-electronic environment is a prime scientific problem, which attracts the attention of a large number of leading scientists. The increase of the efficiency of radio communication systems and complexes takes place in the following directions [1]:

- increase of energy efficiency of systems and radio communication facilities;
- increase of frequency effectiveness of systems and devices of radio communication;
- simultaneous increase of frequency and energy efficiency of systems and radio communication facilities.

Orthogonal Frequency Division Multiplexing (OFDM) technology is widely used in telecommunication systems [1-5]. The analysis of the known scientific achievements in the mentioned subject field prove that OFDM technology allows to use the bandwidth of multi-channel radio communication channels as efficiently as possible [4], however the given transfer technology has a number of shortcomings [1-6]:

- high peak factor;
- nonlinear distortions in the radio path of radio communication;
- synchronization errors while establishing a connection;
- is subjected to harmful effects of deliberate disturbances;
- the absence of mechanisms for the protection of radiocommunication devices (RCD) from intelligence, revealing information about their state and status;
- high vulnerability to attacks such as "denial of service";
- high probability of interception of traffic by devices of electronic intelligence;
- vulnerability of synchronization channels.

One of the ways that can improve the efficiency of OFDM radio communication systems is to increase their stealthy use of timer signal constructions (TSC).

Taking into account the aforementioned, the purpose of the article is to develop a method of increasing the secrecy in radio communication systems with orthogonal frequency multiplexing OFDM due to the use of timer signals TSC.

Presentation of the main material

Tasks of unauthorized access (UAA) to information is to detect a signal, determine the structure of the detected signal and disclosure of information contained in the signal.

For the prevention of UAA information, signals must have, including, such a property as secrecy.

The indicated tasks of the UAA, respectively, are opposed to three types of secrecy of signals: energy, structural and informational.

Energy secrecy characterizes the ability to withstand measures aimed at detecting a signal by devices of unauthorized access. It is known [1-6] that one of the ways to increase energy secrecy is to increase the width of the spectrum of signals used, achieved by the use of noise-like signals (NLS) and chaotic signals in confidential information transmission systems.

Structural secrecy characterizes the ability to withstand UAA measures aimed at disclosing the structure of the signal, provided that the signal is already detected. This means recognizing the shape of the signal and measuring its parameters, that is, identifying the detected signal with one of the set of known transmitted symbols. Obviously, in order to increase structural secrecy, it is necessary to have a larger ensemble of signals used with variable-time parameters.

Information secrecy is determined by the ability of the system to withstand measures aimed at disclosing the content of a message transmitted using signals [8, 10]. Disclosure of the information contained in the message means its reproduction in comparison with the message that was transmitted.

The essence of the method under study is to select the values of the OFDM-signal parameters, which are optimal for the criterion for maximum structural stealth at a given bandwidth of the RCD.

Setting the objectives.

Given: P_c is the signal strength, L is the length of the expansion sequence; T_c is the time interval of the formation of timer signal constructions, n is the number of elementary parcels, N is the number of subcarriers, ΔF is the channel bandwidth. The values ΔF, T_c are constant.

It is necessary: to determine the value of the signal parameters (the number of active subcarriers, the type and parameters of the TSK, expansion parameters, transmitter power), which minimizes the probability of a bit error P_b in the execution of restrictions on the rate of transmission in the channel $v_i \geq v_{i\,доп}$.

Limit: The number of subcarriers of OFDM signal $4 \leq N \leq 128$.

The task of determining the parameters of the OFDM signal with a minimum probability of a bit error is reduced to a typical optimization problem. The system of equations for solving the optimization problem has the form [5-7]:

$$\begin{cases} P_b = F_1(v_i, \Delta F, M, n, R, d, P_c, N_A, Q_i^2, L) \to \min; \\ v_i = F_2(M, R, N_A, \Delta F, Q_i^2) \geq v_{i\,per}, \end{cases} \tag{1}$$

where P_c is the signal strength, M is the dimension of the ensemble of signals, R is the speed of the correction code ($R = k/n$), k is the number of information bits in the code combination with length n, d is the code distance, L is the duration of the expansion sequence; N is the number of subcarriers, ΔF is bandwidth of the channel. The values ΔF, T_c are constant.

The method of selecting the parameters of the OFDM signal, the algorithm of which is presented in fig. 1, consists of the following steps [7, 8].

Input of input data. The parameters of the transmitter and the communication channel $\Psi = \{\psi_i\}$ are entered, as well as the value of the minimum required transmission speed.

Selection of operating frequencies based on the RES strategy. Based on the algorithm developed in [5] for the selection of working frequencies for military radio communications under conditions of deliberate interference, the choice of operating frequencies with a minimum probability of a bit error occurs. The indicated algorithm is based on the representation of the process of radio-electronic confrontation in the form of two antagonistic systems [5]. In this case, the decision making on the management is taken taking into account the analysis of the electronic environment and the criterion for minimizing the probability of a bit error. To implement this algorithm, the use of the coefficient of working frequencies use by each of the antagonistic systems (the coefficient of overlapping with subcarrier noise) was chosen [5].

The main stages of the implementation of the algorithm:

1. Determination of the type and characteristics of intentional obstacles.
2. Check the value of the overlap factor.
3. Formation of the matrix of the game of radio-electronic conflict.
4. Formalization of the problem of linear programming.
5. Check the optimal control of the choice of operating frequencies.

Determine the number of subcarriers and the distance between them, as well as the duration of the symbol. The distance between subcarriers of the OFDM signal is chosen depending on the following parameters: Doppler spectrum scattering; minimum delay time of beams (reverb copies of the signal); the maximum possible symbol duration (the coherence time of the channel parameters).

Due to Doppler dispersion, as well as errors in the evaluation of the frequency of the transmitter on the receiving side, the orthogonality between the subcarriers is violated. In a number of papers, studies have been conducted on the equivalent loss in the required signal / noise ratio for a given Doppler dissipation, as well as the error of estimating the carrier at the reception [4-9]. For short-wave (SW) and ultra short-wave (USW) channels, the equivalent loss in signal / noise of no more than 0.5 dB Doppler scattering should not exceed 2-3% of the distance between subcarriers. A frequency shift of 7-8% of the distance between subcarriers results in an equivalent signal-to-noise reduction of 1 dB. After determining the minimum distance between subcarriers, you can calculate the length of the $T_c = 1/\Delta F$ character.

The minimum delay time between the rays determines the degree of unevenness of the amplitude-frequency characteristic (AFC) of the channel. Hence, a greater delay between rays corresponds to a larger period of uneven frequency response. At a maximum delay of 4 ms between rays, the period of unevenness of the AFC is 250 Hz. Thus, the distance between subcarriers should be chosen in the assumption that the frequency response on each of them will be a channel with an additive white Gaussian noise (AWGN). Accordingly, the distance between the subcarriers should be considerably less than in the period of uneven frequency response of the channel. That is, from this point of view, the distance between subcarriers needs to be minimized. For the SW channel, the distance of 50 Hz is the maximum allowable, since larger values of the distance between the carriers lead to a significant distortion of the channel parameters, resulting in a distortion of the symbol [6, 7]. Another limitation on the length of a character is the assumption that the channel parameters must be constant over the length of the character.

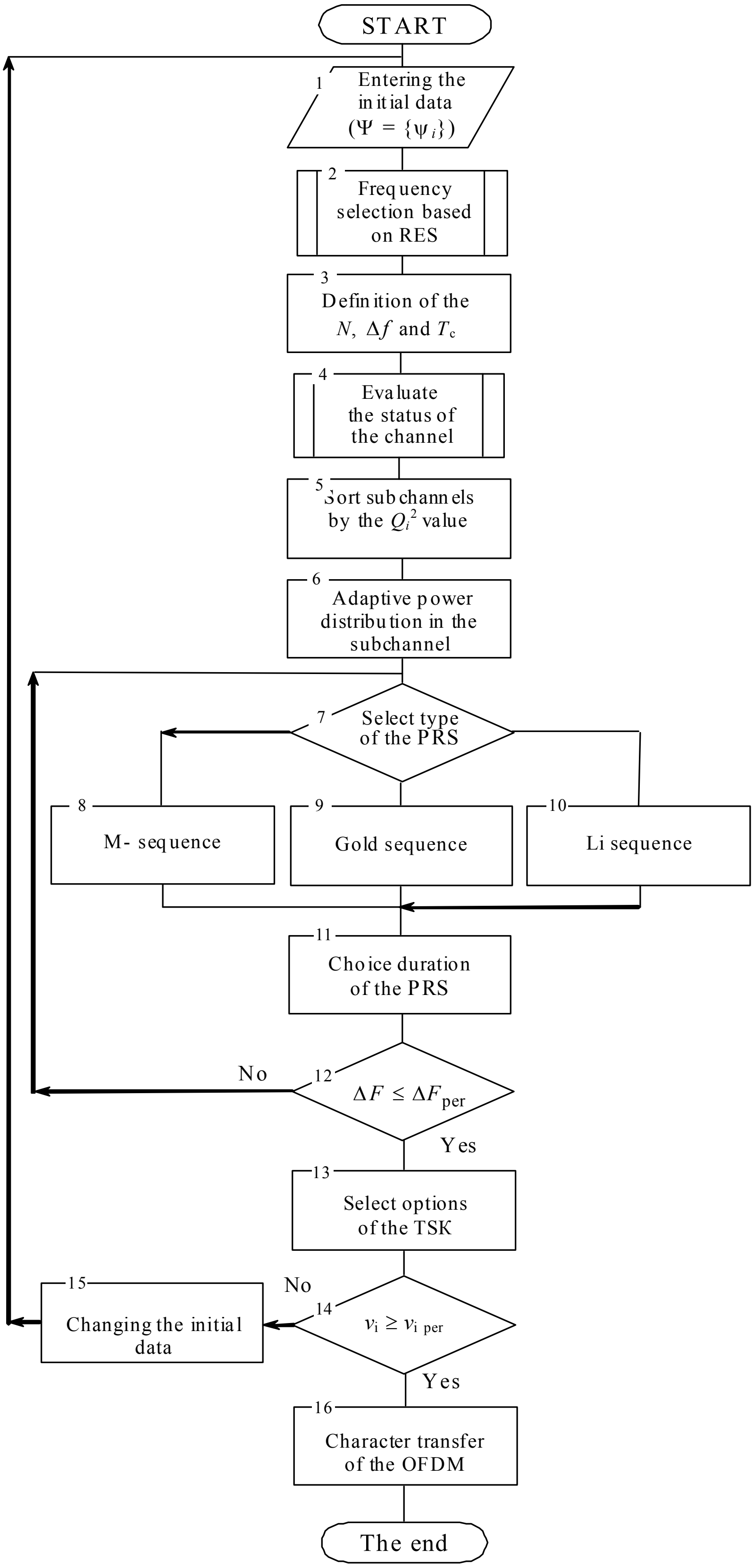

Fig. 1. Scheme of the algorithm for selecting signal parameters of radio communication with OFDM depending on the condition of the communication channel

This makes it possible to use a simple method for evaluating and compensating the AFC of the channel in the frequency domain on each symbol. The length limit for a character in the SW range can be taken as an order of hundreds of milliseconds.

Determination of the number of subcarriers N should be based on the information (and technical) speed of the group signal, taking into account the need to reserve part of the bandwidth of the channel for a variety of official information. In this case, N is selected from a number of values provided by the operation of the inverse Fast Fourier Transform (FFT). According to [6], the calculation of the required number of FFT points is carried out according to the formula

$$K = T_{\text{c}} f_{\text{d}} ,$$

and the sampling frequency f_{d} is defined as

$$f_{\text{d}} > 2\Delta F .$$

Next, you can determine the frequency range between the subcarriers and the number of $N = \Delta F / \Delta f$ subcarriers.

To eliminate the harmful effects of intersymbol interference into a signal structure, a cyclic prefix was introduced. The size of the prefix T_{p} was selected based on the values of the two parameters: the maximum possible time shift between the rays; the required ratio between the duration of the character without the prefix and the prefix itself (in the case where the prefix is used to find the clock synchronization). For the SW channel, the maximum multipath level is about 5 m/sec (maximum value for one-two-bit passage of the radio signal). For data transmission at short distances multipath is slightly smaller and is 1-2 m/sec. The value of the cyclic prefix is within range of

$$t_{\text{p}} \le T_{\text{p}} < 0,25 T_{\text{c}} .$$

Assessment of the transmission characteristics of the communication channel. At this stage, the use of the methods presented in [4, 5, 7, 9], the state of the multi-channel communication channel was evaluated and its transfer characteristic was determined. Thus, we can draw the following conclusions:

1. In the presence of sufficiently well-known information about transmitted information symbols, the best results for the criterion of the ratio of accuracy of estimation and complexity of implementation is demonstrated by the algorithm of linear estimation with a minimum of mean-square deviation.
2. In the absence of sufficiently well-known information about the transmitted symbols, the best-fitting unmatched version of the estimate for the minimum of the smallest squares is preferred.
3. In order to increase the accuracy of the evaluation of the transmission characteristics of the channels in the conditions of a complex electronic environment it is expedient to use iterative principles.

Adaptive distribution of signal power in subchannels. At this stage, according to the results of the evaluation of the transfer characteristics of the channel, the assignment of the sequence numbers to each subchannel in the order of reduction of the signal/noise ratios is carried out (worse subchannels have larger sequence numbers):

$$Q_1^2 \ge Q_2^2 \ge \ldots \ge Q_N^2 .$$

After this, the worst-case ratio is subtracted from the signal/noise ratio subwoofer. Disconnecting subcarriers with low signal/noise ratio reduces the harmful effects of frequency selective fading on bandwidth and allows you to redistribute the transmitter power among other subcarriers.

Choose the type and duration of the expansion sequence. To combat deliberate interference (especially imitation) spectrum expansion is used with the help of technology of expanding code sequences, the main principles of which is the expansion of the spectrum in combination with the code division of physical channels through the use of pseudorandom sequences (PRS). The indicated principle of controlling intentional interference is also implemented in the MC-CDMA (Multi-Carrier Code Division Multiple Access) method.

The key feature of MC-CDMA systems is that all chips that are mapped to the same bit of code are transmitted in parallel in the narrowband subchannels, using OFDM.

In the MC-CDMA technology, each bit of the signal stream is displayed on all subcarriers, and each subcarrier uses its phase-to-time phase shift, which is selected according to the law-defined encoding.

In the mentioned method, the code sequence is selected separately for each subcarrier, from the set of expanding sequences shown in Fig. 1

Different types of expansion sequences are used to expand the spectrum in OFDM systems: binary (Walsh sequences, Shapiro-Rudin sequences, Barker codes, Gold codes, M-sequences, Hadamard sequences) and multiphase (Frank and Zadov-Chu sequences, Milevsky sequences, Goley sequences) [10].

A comparative analysis of these sequences has shown that in OFDM systems, the smallest peak factor is provided by ideal, many-phase sequences of Frank, Zadov-Chu, Milevsky ($\text{P} \le 2$ (3 dB)) [10,11]. The binary sequences of Shapiro-Rudin provide $\text{P} \le 4$ (6 dB). The disadvantage of the above-mentioned ideal sequences is that the volume of their alphabet increases with the growth of the number of subcarriers.

Also, in [5, 7] four-phase Li sequences with one zero are considered, ideal 8-phase single-zero hinges and ideal 8-phase sequences with two zeros. These sequences also show $\text{P} \le 2$.

Broad application in broadband systems has found so-called M-sequences. As a rule, binary M-sequences are used, the symbols of which $a(k)$ and $d(k)$ accept values $a(k)$ 1 and 0, $d(k)$, respectively -1 and 1 [5-7, 9].

Gold Codes have high value for autocorrelation function and low correlation value. These properties provide the ability to use these codes for the implementation of multiple access with code division [5].

Gold Codes with a 2^{l-1} period were formed on the basis of two M sequences with the selection of so-called "gear pairs", which have three-digit autocorrelation of the $(1,\phi(t),\phi(t),2)$ function, where

$$\phi(t)=\begin{cases}2(L+1)/2, \text{ where } L \text{ dual value;}\\ 2(L+2)/2, \text{ where } L \text{ odd value.}\end{cases} \qquad (2)$$

Gold codes were formed by adding in modulus 2 each character of two m-sequences. They are divided into three types: primary, secondary orthogonal Gold codes (256 bits long) and long code.

Gold's orthogonal Codes were formed on the basis of the *M*-sequence of 255 bits in length and the addition of one excess symbol. The primary sync code has an aperiodic auto-correlation function and was used to initialize the synchronization. The secondary sync code is an unmodulated Gold code, which was transmitted with the primary sync code. Each secondary sync code was selected from 17 different Gold codes [9].

Selection the parameters of the timer signal constructions.

The basic element in the formation of timer signal constructions is $\Delta = t_0/S$ [10]. Unlike the traditional positional signal-code structures, when the bit rate is determined by the energy of the elementary parcel (Nyquist element), the information in the TSK was laid out in the sequence of individual time intervals "*i*" with the duration of each $\tau_c = t_o + k\Delta$, where t_0 is the interval of the elementary Nyquist element, $k = 0,1,...,S(n-2)$ and their mutual placement on the code sequence T_c interval.

Changing the n,S,i parameters makes it possible at the output of the TSK encoder to receive different sets of signal constructions, each of which may vary in duration depending on the values n, the number of base elements Δ and the number of transitions i, that is, the structure of the signal. The frequency change of the parameters of the TSK encoder is chosen such that the amount of intercepted by the radioelectronic intelligence station of the implementation of a signal of a definite form with given parameters was not sufficient to reveal the structure of the signal over a period of time during which the indicated signal is of interest to the radioelectronic intelligence station. After selecting the signal parameters from the OFDM, the condition of the constraint on the transmission rate in the channel was checked. If this condition is not fulfilled, the initial data starts changing.

The evaluation of the effectiveness of the proposed methodology was carried out in the programming environment *MathCad* 14.

The estimation of the computational complexity of the implementation of the developed method showed that for the given output data and while using the ADSP-21261processor, the formation of a signal with optimal parameter values can be carried out in real time with the delay required for the transmission of information about these values through the service feedback channel .

Conclusion from the article

In the mentioned article the method of increasing the secrecy in radio communication systems with orthogonal frequency multiplexing was developed due to the use of timer signal constructions.

The essence of the proposed method is to increase the structural secrecy of signals with orthogonal frequency multiplexing.

The difference between the proposed methodology from the known, which determines its novelty are:

- the use of timer signal constructions unlike traditional positional signals, that allows to increase the structural secrecy of signals with orthogonal frequency multiplexing;
- the use of expanding sequences of different types and with different actor-correlation properties makes it possible to carry out operative adaptation of parameters of radio-communication systems with orthogonal frequency multiplexing under the influence of destabilizing factors;
- the use of frequency adaptation mechanisms to the effect of deliberate interferences that allows to determine areas of the frequency range that were affected by them and to conduct intellectual planning of the radio frequency resource use.

The further research will be directed to the development of methodological bases for increasing the efficiency of the systems and radio communication complexes with timer signal constructions use.

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Методика підвищення скритності в системах радіозв’язку з ортогональним частотним мультиплексуванням за рахунок використання таймерних сигнальних конструкцій

В. В. Гордійчук

Питання підвищення ефективності систем і комплексів радіозв’язку в складній радіоелектронній обстановці є споконвічною науковою проблемою, до якої прикута увага великої кількості провідних вчених. В зазначеній статті автором проведено дослідження, що спрямоване на підвищення структурної скритності в системах радіозв’язку з ортогональним частотним мультиплексуванням з використанням таймерних сигнальних конструкцій, завдяки розробки методики підвищення скритності в системах радіозв’язку з ортогональним частотним мультиплексуванням за рахунок використання таймерних сигнальних конструкцій. В ході проведеного автором дослідження використані базові положення теорії зв’язку, теорії завадозахищеності, теорії складних технічних систем, теорії антагоністичних систем, теорії завадостійкого кодування, теорії хаотичних процесів, теорії ортогональним систем, теорії радіочастотного планування та теорії таймерних сигнальних конструкцій. Відмінністю запропонованої методик від відомих, що визначає її новизну полягає в наступному: використання таймерних сигнальних конструкцій на відміну від традиційних позиційних сигнальних конструкцій дозволяє підвищити структурну скритність сигналів з ортогональним частотним мультиплексуванням; використання розширювальних послідовностей різного типу і з різними автокореляційними властивостями дозволяє проводити оперативну адаптацію параметрів систем і засобів радіозв'язку з ортогональним частотним мультиплексуванням до впливу дестабілізуючих чинників, спрямованих на розкриття властивостей систем і засобів радіозв'язку для засобів радіоелектронної розвідки; застосування механізмів частотної адаптації до впливу навмисних перешкод дозволяє визначити ділянки частотного діапазону, вражені ними і провести інтелектуальний планування використання радіочастотного ресурсу системами і засобами радіозв'язку з ортогональним частотним мультиплексуванням.

Ключові слова: системи радіозв’язку, радіоелектронне подавлення, радіоресурс, сигнально-кодові конструкції, завадозахищеність ортогональне частотне мультиплексування, таймерні сигнальні конструкції .

Методика повышения скрытности в системах радиосвязи с ортогональным частотным мультиплексированием за счет использования таймерных сигнальных конструкций

В. В. Гордейчук

Вопросы повышения эффективности систем и комплексов радиосвязи в сложной радиоэлектронной обстановке является исконной научной проблемой, к которой приковано внимание большого количества ученых. В указанной статье автором проведено исследование, направленное на повышение структурной скрытности в системах радиосвязи с ортогональным частотным мультиплексированием с использованием таймерных сигнальных конструкций, благодаря разработке методики повышения скрытности в системах радиосвязи с ортогональным частотным мультиплексированием за счет использования таймерных сигнальных конструкций. В ходе проведенного автором исследования использованы основные положения теории связи, теории помехозащищенности, теории сложных технических систем, теории антагонистических систем, теории помехоустойчивого кодирования, теории хаотических процессов, теории ортогональным систем, теории радиочастотного планирования и теории таймерных сигнальных конструкций. Отличием предлагаемой методики от известных, определяет ее новизну заключается в следующем: использование таймерных сигнальных конструкций в отличие от традиционных позиционных сигнальных конструкций позволяет повысить структурную скрытность сигналов с ортогональным частотным мультиплексированием; использования расширительных последовательностей разного типа и с разными автокорреляционной свойствами позволяет проводить оперативную адаптацию параметров систем и средств радиосвязи с ортогональным частотным мультиплексированием к воздействию дестабилизирующих факторов, направленных на вскрытие свойств систем и средств радиосвязи для средств радиоэлектронной разведки; применение механизмов частотной адаптации к воздействию преднамеренных помех позволяет определить участки частотного диапазона, поражены ими и провести интеллектуальное планирование использования радиочастотного ресурса системами и средствами радиосвязи с ортогональным частотным мультиплексированием.

Ключевые слова: системы радиосвязи, радиоэлектронное подавление, радиоресурс, сигнально-кодовые конструкции, помехозащищенность ортогональное частотное мультиплексирование, таймерные сигнальные конструкции.