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METHODS FOR GENERATING NOISE-LIKE TIMER SIGNALS BASED ON PSEUDO-RANDOM TUNING OF THE OPERATING FREQUENCY

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МЕТОДИ ФОРМУВАННЯ ШУМОПОДІБНИХ ТАЙМЕРНИХ СИГНАЛІВ НА ПІДСТАВІ ПСЕВДОВИПАДКОВОГО ПЕРЕСТРОЮ РОБОЧОЇ ЧАСТОТИ

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МЕТОДЫ ФОРМИРОВАНИЯ ШУМОПОДОБНЫХ ТАЙМЕРНЫХ СИГНАЛОВ НА ОСНОВЕ ПСЕВДОСЛУЧАЙНОЙ ПЕРЕСТРОЙКИ РАБОЧЕЙ ЧАСТОТЫ

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Abstract. Among the most important scientific problems, which have been given much attention recently, is the research of the properties and methods of forming complex noise-like signals to increase the interference protection of radio communication systems, operating in the conditions of electronic conflict. Such signals have inherent properties that help solve problems of improving noise immunity, secrecy transmission and providing electromagnetic compatibility of various radio communication systems. For the synthesis task of noise-like signals, it is proposed to use timer signal constructions in combination with various methods of spectrum expansion based on random restructuring of the operating frequency. The expediency of using timer signals is justified by their properties which increase the noise immunity and secrecy of transmission. However, unlike the position codes, they have a more difficult structure for constructing signal constructions. The primary parameters for constructing timer signals allow the formation of the various sets of signal constructions. Such variational possibilities of constructing timer signals substantially increase the potential structural secrecy of the transmission. Also, based on timer signals, noise-immunity coding is implemented without additional test elements. In the article was carried out the analyses of methods synthesis based on random rebuild operating frequency, taking into account the non-positional timer signals.

Key words: interference protection, secrecy, noise immunity, timer signals, spectrum, signal.

Анотація. Серед найбільш важливих наукових задач, яким приділяється останнім часом значна увага, є дослідження властивостей і методів формування складних шумоподібних сигналів для підвищення завадозахищеності систем радіозв'язку, які працюють в умовах радіоелектронного конфлікту. Таким сигналам притаманні властивості, за допомогою яких вирішуються завдання покращення завадостійкості та прихованості передавання, а також забезпечується електромагнітна сумісність різних систем радіозв'язку. Для завдання синтезу шумоподібних сигналів запропоновано використовувати таймерні сигнальні конструкції в поєднанні з різними методами розширення спектра на підставі псевдовипадкового перестрою робочої частоти. Доцільність застосування таймерних сигналів обґрунтовується їх властивостями, які підвищують стійкість і прихованість передавання, проте на відміну від позиційних кодів мають більш складну структуру побудови сигнальних конструкцій. Початкові параметри побудови таймерних сигналів дозволяють формувати різні множини сигнальних конструкцій. Такі варіаційні можливості побудови таймерних сигналів істотно підвищують потенційну структурну прихованість передавання. Також на підставі таймерних сигналів реалізується завадостійке кодування без додаткових перевірочних елементів. В роботі проведено аналіз методів синтезу шумоподібних сигналів на основі псевдовипадкового перестрою робочої частоти з урахуванням непозиційних таймерних сигналів.

Ключові слова: завадозахищеність, прихованість, завадостійкість, таймерний сигнал, спектр, частота.

Аннотация. Среди наиболее важных научных задач, которым уделяется в последнее время большое внимание, является исследование свойств и методов формирования сложных шумоподобных сигналов для повышения помехозащищенности систем радиосвязи, работающих в условиях радиоэлектронного конфликта. Таким сигналам присущи свойства, с помощью которых решаются задачи по улучшению помехоустойчивости и скрытности передачи, а также обеспечивается электромагнитная совместимость различных систем радиосвязи. Для задачи синтеза шумоподобных сигналов предложено использовать таймерные сигнальные конструкции в сочетании с различными методами расширения спектра на основе псевдослучайной перестройки рабочей частоты. Целесообразность применения таймерных сигналов обосновывается их свойствами, которые повышают помехоустойчивость и скрытность передачи, однако в отличие от позиционных кодов имеют более сложную структуру построения сигнальных конструкций. Начальные параметры построения таймерных сигналов позволяют формировать различные множества сигнальных конструкций. Такие вариационные возможности построения таймерных сигналов существенно повышают потенциальную структурную скрытность передачи. Также на основе таймерных сигналов реализуется помехоустойчивое кодирование без дополнительных проверочных элементов. В работе проведен анализ методов синтеза шумоподобных сигналов на основе псевдослучайной перестройки рабочей частоты с учетом непозиционности таймерных сигналов.

Ключевые слова: помехозащищённость, скрытность, помехоустойчивость, таймерный сигнал, спектр, частота.

Informatization of the world community, which has not passed Ukraine, poses new tasks for protection of confidential information. Therefore, the priority is to develop and improve the new and existing secure telecommunications and radio systems [1]. The solution to this problem is proposed using complex noise-like signal constructions which are implemented based on the expansion range of timer signals. The feature of the usage timer signals is that they belong to the class of non-positional signal constructions and have several advantages over positional ones. First, timer signals can be used to implement interfering coding without additional validation elements, which provides the increase in code speed compared to bit digital interfering codes [2,3]. Second, the variational capabilities of timer signals to create different sets of signal constructions that differ in structure allow implementing different algorithms to increase the structural secrecy of information transmission. Third, through the more efficient use of the bandwidth channel, the information capacity of the highest element is increased. Further development of the theory of timer coding is directed [4,6] to the task of increasing the energy secrecy of signal constructions by expanding the spectrum of timer signal constructions (TSC) by means of the random rebuild operating frequency (RROF).

The RROF methods provide the formation of noise-like signals with base $B >> 1$. Theoretically and practically, the RROF methods are sufficiently tested for position codes and are used in 802.11 spectrum expansion technology and military radio stations [2,4,6]. The noise-like signals with base $B >> 1$ are provide the transmission signal constructions when the signal/noise ratio is less than one, which allows the communication system to work in conditions of random and organized interference. Combining the technology of coding information of timer signals with the methods of spectrum expansion based on RROF will allow the achievement of the advantages of both methods for the realization problems of increasing noise immunity, structural and energy secrecy. The classic approach to the development of communication systems with RROF is to use position codesThe article proposes increasing the transmission speed and structural secrecy to use non-positional timer signals [5]. The expansion of the TSC spectrum based on RROF was considered in [6,7]. Unfortunately, there is no detailed classification of possible methods for TSC extension in these works. Therefore, the research of new methods of enhancing the protection of radiocommunication systems based on the synthesis of noise-like timer signals using RROF methods is an actual task.

The aim of the article is development the methods of expansion the spectrum of timer signals based on RROF.

When constructing the communication system with RROF, an important parameter is the factual time of operation at one frequency, which characterizes the energy secrecy of the transmission. The known methods of transmission with RROF are based on expanding the spectrum of positional binary signals with duration of Nyquist elements t_0 and don't apply to TSC. Compared with bit-digital codes (BDC), timer signals have possessed the following advantages [4]:

1) at the given interval of construction $T_c = t_0 m$, can form the number of TSC implementations more than the BDC, i.e. $N_{\text{imp TSC}} > N_{\text{imp BDC}}$;

2) based on the TSC, can organize the control of fidelity transmission without the use of additional test elements;

3) the joint use of the BDC and TSC allows to reduce the probability of the erroneous element by 3-4 orders of magnitude and compensates the redundancy of the noise immunity code.

The principle of the formation non-positional TSC [4,5] is that the moments of modulation of pulses in the TSC, in contrast to the BDC, are not multiple t_0, and some basic temporary element Δ (where $\Delta = t_0/s$; $s = 1, 2, 3, ..., l$ – the whole numbers). The duration of TSC impulses can't be less than the Nyquist interval, i.e. $t_c = t_0 + k\Delta$ (where $k = 0,1,2,..,s\cdot(n-2)$). More number of implementations N_{imp} at the interval T_c compared with the BDC is achieved by reducing the energy distance between the signal structures, which is determined by the value $\Delta < t_0$. The interval value Δ affects the noise immunity and relative transmission speed, which is necessary to be considered when choosing the parameters for constructing TSC. The total number of implementations in TSC is [5]:

$$N_{\text{imp}} = \sum_{i=1}^{n} \frac{[(n\cdot s)-[(s-1)\cdot i]]!}{i!\cdot[[(n\cdot s)-[(s-1)\cdot i]]-i]!}, \quad (1)$$

where i – the number of modulation information moments. An example of constructing TSC on the interval $T_c = 4t_0$; $t_c = 4\Delta$ is shown in Fig. 1, *a*.

Consider the principle of expanding the spectrum of the TSC considering the following varieties of RROF: slow and fast. Given that the basic element of the construction of the TSC is the time interval Δ, we will use it when developing the method of spreading the spectrum using RROF. For the slow RROF, the rate of change of the carrier oscillation is more than the Nyquist interval t_0 in case, when it is used the bit extension BDC. In the timer signals $\Delta < t_0$, therefore the carrier frequency change time $T_{\text{S RROF}}$ for slow RROF will be determined taking into account the element Δ, i.e.

$$T_{\text{S RROF}} = \Delta z, \quad (2)$$

where $z = 2,3,...,M$ – the number of elements Δ on the interval $T_{\text{S RROF}}$; $M = ms$. When choosing the time interval for changing the carrier frequency, it should be taken into account that with larger value $T_{\text{S RROF}}$ the probability of defeat interference of the useful signal in the channel increases. In Fig. 1, *b* presents the process of spectrum expansion for slow RROF with the interval

$T_{\text{S RROF}} = 4\Delta$, where $z = 4$. If $z = M$, then the change in the carrier oscillation will occur in the interval

$$T_{\text{S RROF}} = T_{\text{c}}, \quad (3)$$

i.e. for each signal construction. Obviously, to highlight the significant moments of recovery (SMR) of the TSC fronts on the receiving side, it is necessary to use preliminary manipulation of the transmitter elements Δ, for example, PM-2 or PM-4. So, with PM-4 it is possible to provide the increase in the transmission rate since on one signal construction of the phase-manipulated signal are transmitted two elements Δ in comparison with PM-2. The use of more difficult types of modulation in order to increase the speed of information transfer, for example, QAM-8 (quadrature amplitude modulation) or QAM-16, will reduce the noise immunity of the communication system.

At fast RROF (Fig. 1, c) the temporary interval of carrier frequency $T_{\text{F RROF}}$ matches or less than element Δ:

$$T_{\text{F RROF}} \le \Delta. \quad (4)$$

It should be noted that the method of fast RROF is more resistant to interference, since in the case of the impact of narrowband interference, which suppresses the signal in the particular subchannel, the complete distortion of the signal constructionsdoes not occur since the impulse level is within the limits $t_{\text{c}} = t_0 + k\Delta$ is repeated by Δ several times in different frequency subchannels. As a rule, such distortion leads to the fragmentation of one or more impulses TSC, what is detected by the receiver during demodulation.

With slow RROF, the influence of narrow-band interference can lead to the significant distortion of the structure timer signal, which complicates the process of its restoration on the receiving side. However, this method is easier in implementation than the fast method RROF.

In Fig. 1, *d* presents the method of multichannel fast RROF based on TSC, which allows the noise immunity of the system to increase due to the transmission of one element Δ on different subcarriers frequencies F_i. Using odd number F_i, e.g, w = 3 (Fig. 1, *d*) will allow the realization of the quality assessment of the received element Δ on the majority principle. In this case, the final decision of the state received TSC is made by determining its membership in the subset of the allowed or not allowed signal constructions.

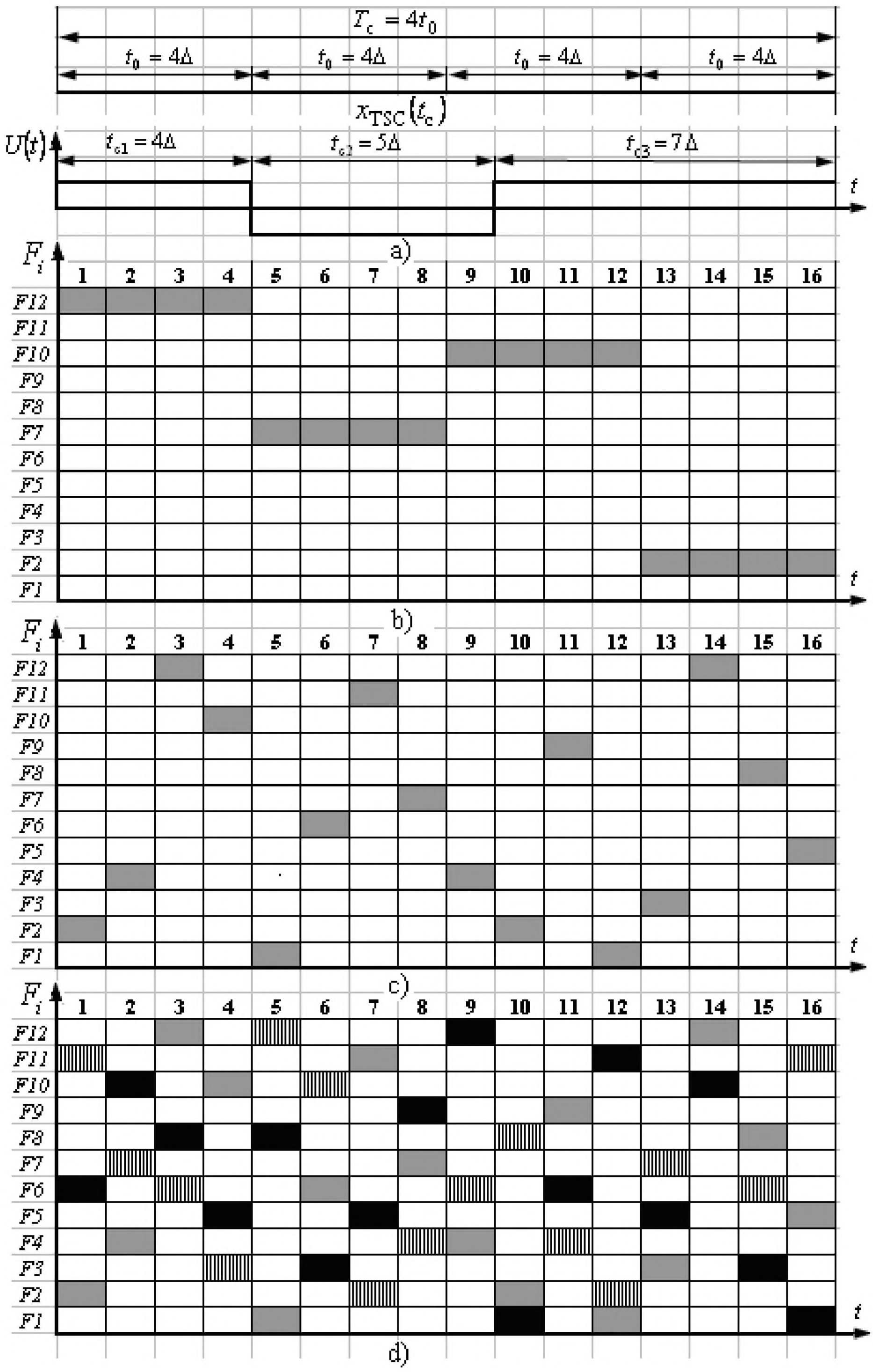

Figure 1 – Spectrum expansion TSC $x_{TSC}(t_c)$ *(a)* using slow RROF *(b)*, fast RROF по Δ *(c)*, multichannel RROF *(d)*

Conclusions. In the article, the various methods were proposed for expanding the TSC spectrum based on RROF. The use of timer signals increases the transmission speed in a separate radio channel which allows reducing the communication session time by almost half. The energy and structural secrecy indicators are influenced by the TSC construction parameters and the method of RROF, which is necessary to be considered when developing the noise-immune communication system.

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