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INCREASE OF STEALTH TRANSMISSION BASED ON TIMER SIGNALS AND LINEAR FREQUENCY MODULATION

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ПІДВИЩЕННЯ ПРИХОВАНОСТІ ПЕРЕДАВАННЯ НА ОСНОВІ ТАЙМЕРНИХ СИГНАЛІВ І ЛІНІЙНОЇ ЧАСТОТНОЇ МОДУЛЯЦІЇ

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ПОВЫШЕНИЕ СКРЫТНОСТИ ПЕРЕДАЧИ НА ОСНОВЕ ТАЙМЕРНЫХ СИГНАЛОВ И ЛИНЕЙНО-ЧАСТОТНОЙ МОДУЛЯЦИИ

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Abstract. Recently, much attention has been paid to the research of the properties and methods of forming complex noise-like signals to increase the noise immunity of radio communication systems operating in the conditions of electronic conflict. Using such signals, the tasks are resolved to improve the noise immunity and the main indicators of transmission stealth (energy, structural and information). For the task of the synthesis noise-like signals using timer signal designs in combination with the method of spreading the spectrum based on linear frequency modulation is proposed. The advisability of using timer signals is justified by their properties, which increase the noise immunity and stealth transmission. In contrast to positional codes, timer signals have more complex structure for construct signal construction. The initial parameters for constructing timer signals allow the formation of various sets of signal constructions. Such variational possibilities of constructing timer signals substantially increase the potential structural stealth of the transmission. Also based on timer signals, noise immunity coding is implemented without additional test elements. In the article A method for synthesizing noise-like signals based on linear frequency modulation and timer signal designs is proposed.
Key words: linear frequency modulation, interference protection, stealth, noise immunity, timer signal, spectrum.

Анотація. Останнім часом все більше уваги приділяють вивченню властивостей і методів формування складних шумоподібних сигналів для підвищення завадозахищеності систем радіозв'язку, що працюють в умовах радіоелектронного конфлікту. За допомогою таких сигналів вирішуються завдання щодо поліпшення завадостійкості й основних показників прихованості передавання (енергетична, структурна й інформаційна). Для завдання синтезу шумоподібних сигналів запропоновано використовувати таймерні сигнальні конструкції в поєднанні з методом розширення спектра на основі лінійної частотної модуляції. Доцільність застосування таймерних сигналів обґрунтовується їх властивостями, які підвищують завадостійкість і прихованість передавання. На відміну від позиційних кодів таймерні сигнали мають більш складну структуру побудови сигнальних конструкцій. Початкові параметри побудови таймерних сигналів дозволяють формувати різні безлічі сигнальних конструкцій. Такі варіаційні можливості побудови таймерних сигналів істотно підвищують потенційну структурну прихованість передавання. Також на основі таймерних сигналів реалізується завадостійке кодування без додаткових перевірочних елементів. В статті запропонований метод синтезу шумоподібних сигналів на основі лінійної частотної модуляції і таймерних сигнальних конструкцій.

Ключові слова: лінійна частотна модуляція, завадозахищеність, прихованість, завадостійкість, таймерний сигнал, спектр.

Аннотация. В последнее время все больше внимания уделяется исследованию свойств и методов формирования сложных шумоподобных сигналов для повышения помехозащищенности систем радиосвязи, работающих в условиях радиоэлектронного конфликта. С помощью таких сигналов решаются задачи по улучшению помехоустойчивости и основных показателей скрытности передачи (энергетическая, структурная и информационная). Для задачи синтеза шумоподобных сигналов предложено использовать таймерные сигнальные конструкции в сочетании с методом расширения спектра на основе линейной частотной модуляции. Целесообразность применения таймерных сигналов обосновывается их свойствами, которые повышают помехоустойчивость и скрытность передачи. В отличие от позиционных кодов таймерные сигналы 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 статье предложен метод синтеза шумоподобных сигналов на основе линейной частотной модуляции и таймерных сигнальных конструкций.

Ключевые слова: линейная частотная модуляция, помехозащищённость, скрытность, помехоустойчивость, таймерный сигнал, спектр.

The stealth of transmission (energy, structural, information and others) characterizes the ability of the radio communication system to operate in conditions of active resistance to radio intelligence (RI) and unauthorized access (UA) and perform their tasks in conditions of both accidental and intentional interference. The creation of new methods for the synthesis of noise-like signal structures is due to the requirements to ensure the stealth and noise immunity of radio channels, which are operating in conditions of radio electronic conflict [1]. To perform these tasks, it is necessary to take into account the modern achievements of the enemy's radio electronic intelligence, which recently begin to use spectral-correlation methods to detect and search for transmitted radio signals [2].

Known methods of generating noise-like signals [2] based on the expansion of the spectrum of the binary element using standard types of digital modulation do not provide the required level of stealth transmission. For this reason, the use of the complex noise-like signal-code structures with a controlled structure is justified. In articles [3 - 5] it was proved that for this task it is expedient to use non-positional signal constructions, in which for increasing the structural stealth noise-like signals it is proposed to use non-positional timer signal constructions (TSC) with variable structure. However, this problem is not fully solved, because it is aimed only at complicating only the structure of the extended digital signal. Thus, this area needs further research [12].

The method of forming broadband signal structures based on timer signals construction and linear frequency modulation (LFM) is proposed, which is important for the task of increasing structural and energy stealth. The use of such signals significantly complicates the process of their detection and recognition of the structure, so research in this direction is relevant.

The aim of the work is to develop a method of forming noise-like timer signals based on linear frequency modulation.

The classic approach in the synthesis of noise-like signals is to expand the spectrum of a binary element with the duration of the Nyquist interval t_0 of the position code. For this problem, various methods of spreading the spectrum are used [2, 3] with the help of: frequency hopping spread Spectrum (FHSS - Frequency Hopping Spread Spectrum); direct sequence spread spectrum (DSSS – direct sequence spread spectrum) is used in CDMA (Code Division Multiple Access); linear frequency modulation etc. For this reason, the synthesis of noise-like TSC based on LFM will be different from positional coding.

LFM represents a type of frequency modulation [6 - 8], in which the frequency of the carrier signal fluctuations changes according to linear law. The process of modulating the single element t_0 in the temporary area can be done using the following expression:

$$s_{\text{LFM}}(t) = U_0 \cos(\varphi_0 + \varphi(t)) = U_0 \cos\left(\varphi_0 + 2\pi\left(f_0 t + \frac{b}{2}t^2\right)\right), \quad (1)$$

where U_0 – signal amplitude; f_0 = $(F_{\max}+F_{\min})/2$ – central value carrier frequency; $b = (F_{\max}+F_{\min})/T_c$ – parameter equal to the rate of change of frequency over time; T_c – signal duration; $F_{\max}$, $F_{\min}$ – maximum and minimum value of the frequency of the radio signal; φ_0 – initial phase.

According to [6 - 8], the process of expanding the spectrum of positional symbols using LFM can be represented using two signal structures, one of which for transmission binary zero can be using LFM with a linearly increasing frequency law, and for transmission single state the other can be using LFM with a linearly decreasing frequency law. Thus, the methods of transmission are based on spreading the spectrum of binary positional code with duration Nyquist element t_0.

The construction of a non-positional TSC [5] is based on the fact that the significant moments of pulse modulation in the TSC, unlike the BDC, are not multiple t_0, and some basic temporary element Δ (where $\Delta = t_0/s$; $s = 1, 2, 3, \ldots$; l – integer). The duration of pulse TSC cannot be less than the Nyquist interval, i.e. $t_c = t_0 + k\Delta$ (where $k = 0, 1, 2, \ldots, s\cdot(n-2)$). More number of implementations N_δ on the interval T_c in comparison with BDC is achieved by reducing the energy distance between the signal constructions, which is determined by the value $\Delta < t_0$. The value of the interval Δ affects the noise immunity and the relative transmission rate, which is necessary to take into account when choosing the parameters for constructing TSC. The total number of implementations for TSC [5]:

$$N_p = \sum_{i=1}^{n} \frac{[(n\cdot s) - [(s-1)\cdot i]]!}{i! \cdot [[(n\cdot s) - [(s-1)\cdot i]] - i]!}, \quad (2)$$

where i – number of modulation information moments.

The example of constructing two TSC (TSC-1 and TSC-2) on the interval $T_c = 4t_0$, $t_c = 4\Delta$ is shown in Fig. 1 (*a, b*).

In the proposed method of expanding the spectrum of the TSC based on LFM for the formation of broadband signal construction $S_{\text{LFM-TSC}}(t)$ uses two carrier signal $s_{\text{LFM-1}}(t)$ and $s_{\text{LFM-2}}(t)$ with center frequency f_0 (fig. 1 (в)): with linearly increasing and decreasing laws of frequency change within $f_{\min}$ and $f_{\max}$:

$$S_{\text{LFM-TSC}}(t) = x_{\text{TSC}}(t) \times s_{\text{LFM-1}}(t) + \bar{x}_{\text{TSC}}(t) \times s_{\text{LFM-2}}(t). \quad (3)$$

In Fig. 2 is a structural diagram of a transmitter, which includes: two signal generators G1 and G2 $s_{\text{LFM-1}}(t)$ and $s_{\text{LFM-2}}(t)$; switchboard generator SG.

The expansion of the TSC, in contrast to the BDC, is not carried out on the interval t_0, and on the duration of all signal structure $T_c = 4t_0$. Generator G1 is used to modulate the pulses of TSC with a high voltage level, and G2 modulates the pulses of TSC zero state (Fig. 1 (*в*)). The G1 and G2 generators are restarted at the beginning of each cycle T_c.

In Fig. 1 (*г*) and (*д*) show temporary diagrams of the spectrum expansion processes for TSC-1 and TSC-2, which shows that the components of the signals LFM-TSC-1 and LFM-TSC-2 use different carrier frequencies of generators G1 and G2. It is characteristic that the switching durations of the generators depend on the pulse components of the timer signals. The structural diagram of the receiver, where the restoration of the original spectrum of TSC is carried out, is presented in Fig. 3.

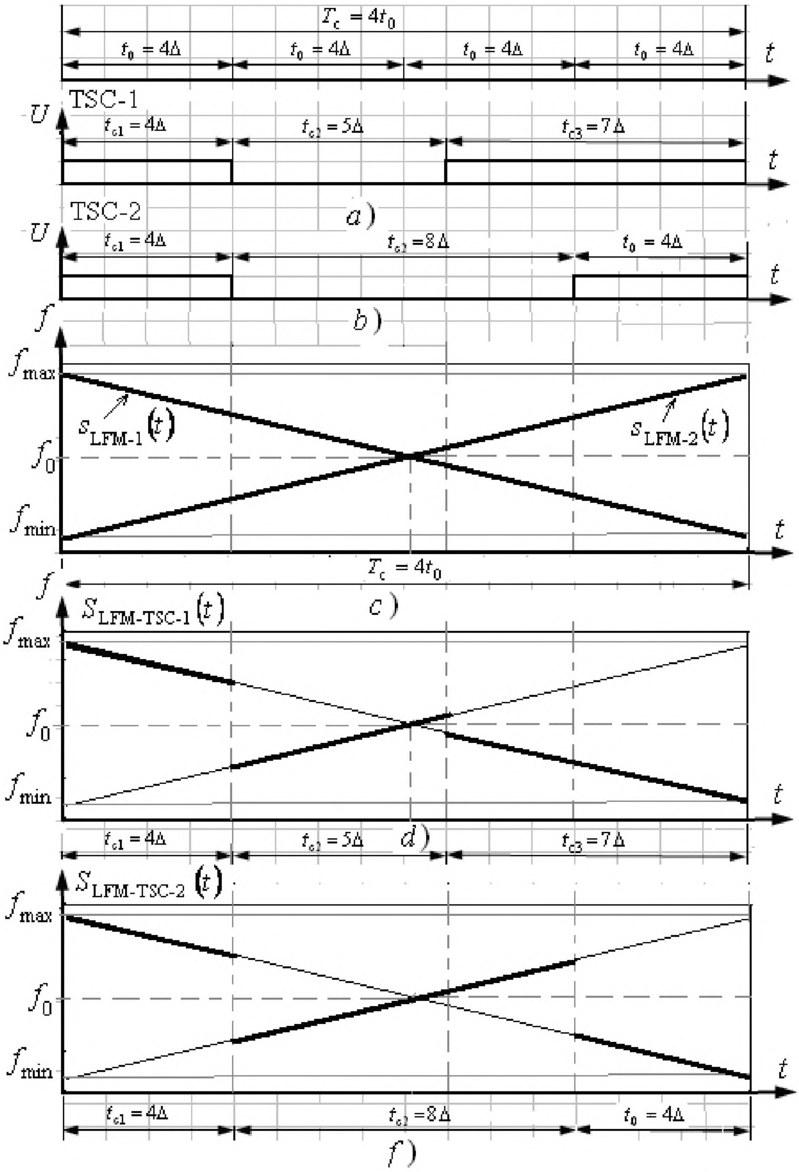

Figure 1 – Temporary diagrams of the formation of broadband TSC based on LFM

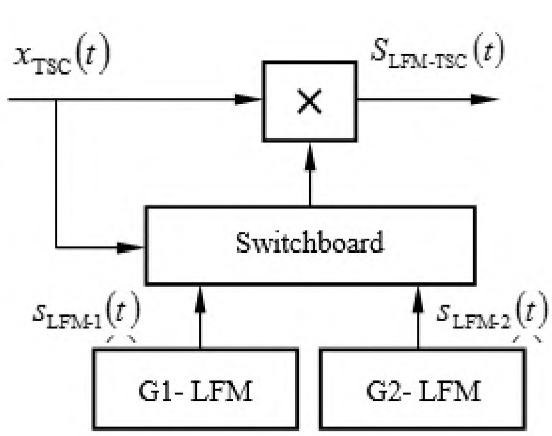

Figure 2 – Structural diagram of the transmitter of broadband TSC based on LFM

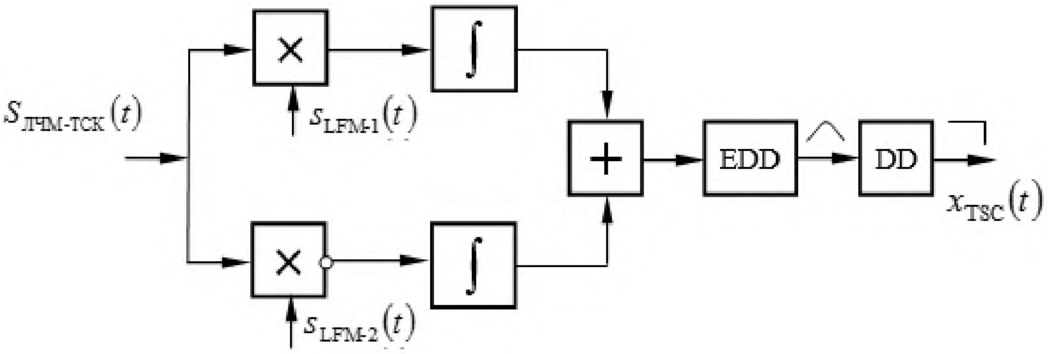

Figure 3 – Structural diagram of the receiver of broadband TSC based on LFM

It is assumed that the transmission system has perfect clock synchronization by elements Δ, and recovery of the fronts of the TSC is carried out on the interval $T_c = 4t_0$. For this, the scheme contains two correlation receivers, in one of which is used supporting LFM signal $s_{\text{LFM-1}}(t)$, and in other $s_{\text{LFM-2}}(t)$. The resulting signal from the output of the addition device is fed to the input of the extremum determination device (EDD). From the output of the EDD according to the maximum and minimum values of the signal within the interval Δ using decisive device (DD) decision is made on the appearance of the front and rear fronts of the TSC. In this case, at each time interval $T_c = 4t_0$, the state of the receiver integrators is zeroed by pulses of cyclic synchronization.

Conclusions. Timer signals in comparison with bit-digital codes (BDC) have the following advantages:

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

2) based on the TSC, it is possible to organize control of fidelity of transmission without use the additional test elements,

3) joint use of the BDC and TSC makes it possible to reduce the probability of an erroneous element by 3-4 orders of magnitude and compensate for the redundancy of the error-correcting code.

Received results make it possible to increase the stealth of transmission in radio communication lines using non-stationary signal constructions in comparison with traditional broadband signals with respect to spectral and correlation analysis. This allows to provide the stability of the transmission process in organized interference. It is explained by the fact that the spectrum of the proposed multicomponent signal has continuous extended spectrum in comparison with the spectrum of classical LFM fluctuations.

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