NONCOHERENT DATA TRANSFER BY USING ORTHOGONAL NOISE SIGNALS

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ABSTRACT

The modern period of communications development is associated with the search and use of new broadband noise-like signals. One of the pressing problems in this area – large-power ensembles synthesis of broadband noise-like signals with good correlation and group properties. Another problem is the difficulty of isolating components from a mixture of several broadband noise-like signals under noise conditions, as well as the difficulty of reproducing such signals during correlation reception shape. The article discusses an incoherent correlation method of data transmission, based on the use of signals generated on the transmitter side by some noise generator. The noise signal is divided into parts (noise pulses) of a given duration. When the current noise pulse is transmitted, the next noise pulse is orthogonalized or collinearized depending on the transmitted data bit. On the receiver side, the mutual energy of the current and previous noise pulse is calculated. If this energy is less than the threshold, a decision is made to transmit zero, otherwise, to transmit one. Synchronization of the receiver and transmitter is carried out by changing the sign of the mutual energy of adjacent noise pulses.

KEYWORDS: *noncoherent data transfer, orthogonal noise signals, synchronization, receiver, transmitter.*

1 Introduction

The noncoherent communication systems based on the using of orthogonal noise signals is discussed. The noise signal is divided into pulses noise of the given duration *T*. When transmitting current pulse γ_i next pulse γ_{i+1} exposed orthogonalization or collinearization depending on each bit of data $\rho_i \in \{-1,+1\}$:

To synchronize transmitter and receiver is used a change of sign of mutual energy of the neighboring pulses [1-4, 8].

On the receiver side it is calculated the scalar product the current γ_{i+1} and previous received pulse noise γ_i. If the scalar product module is less than the threshold ε the transfer of zero is detected, otherwise, the transfer of unit is detected:

Receiver and transmitter synchronization is based on the identification of energy integral derivative gap when changing from one pulse noise to another:

$$t_i : \left| \frac{d}{dt} \left(\int_0^{T+\Delta T} \gamma_i(t) \times \gamma_{i+1}(t)\, dt \right) \right| = \pm\Delta \quad (i = \overline{1,N}),$$

where t_i – moment of the end of the pulse noise γ_i, ΔT – maximum synchronization error, ε – the threshold of clock signal. The proposed method allows achieving an arbitrarily small error probability by one bit.

2 Noise signals orthogonalization

Let noise pulses of duration *T* be given

$$\chi_i(t)\, (i = \overline{0,N},\ \ t \in [0,T]), \tag{1}$$

received from some noise generator. Define a vector space in which the operations of adding signals [5], multiplying a signal by a constant and scalar product are specified:

$$z = x + y\ ,\ \ z(t) = x(t) + y(t) \quad (t \in [0,T]);$$
$$z = \alpha\ x\ ,\ \ z(t) = \alpha \times x(t) \quad (t \in [0,T]);$$
$$(x, y) = \int_0^T x(t) \times y(t)\, dt\ ,$$

where operations on numbers are performed in some finite or infinite field *F*.

Perform Gram-Schmidt orthogonalization procedures for signals (1):

$$\gamma_i = \chi_i - \sum_{j=0}^{i-1} \frac{(\chi_i, \chi_j)}{(\chi_j, \chi_j)} \chi_j \quad (i = \overline{0,N}). \tag{2}$$

As a result, we obtain orthogonal noise signals (2) such that

$$\int_0^T \gamma_i(t) \times \gamma_j(t)\, dt = \begin{cases} 0, & i \neq j; \\ p_i, & i = j \end{cases} \qquad (i, j = \overline{0, N}), \tag{3}$$

where p_i – signal energy γ_i.

Equation (3) allows for correlation reception and detection of noise signals. However, for such reception it is necessary to have copies of all transmitted signals on the receiver side, which is practically impossible when using real noise generators.

3 Ortho-noise transmitter

Transmitter output signal (transmitting data) $\rho_i \in \{-1,\ 1\}$ ($i = \overline{1, N}$) form in accordance with the following recurrent equation:

$$\begin{cases} \rho_0 = 1; \\ \gamma_0 = 0, \end{cases} \qquad \gamma_{i+1} = \chi_i + \rho_i \times \frac{(\gamma_i, \chi_i)}{(\gamma_i, \gamma_i)} \gamma_i \quad (i = \overline{0, N}), \tag{4}$$

where γ_i – *i*-th output noise pulse of the transmitter, χ_i – *i*-th input noise pulse of the noise generator. The mutual energy of adjacent noise pulses will be equal to (γ_{i+1}, γ_i),

$$(\gamma_{i+1}, \gamma_i) = \int_0^T \gamma_{i+1}(t) \times \gamma_i(t)\, dt = (\chi_i, \gamma_i) + \rho_i \times (\chi_i, \gamma_i)\,. \tag{5}$$

From (5) it follows that when $\rho_i = -1$ noise pulse γ_{i+1} will be orthogonal to the noise pulse γ_i, and when $\rho_i = 1$ – is collinear to it, i.e. The mutual energy of the pulses will either be zeroed or doubled.

The block diagram of an ortho-noise transmitter that implements the formulas is shown in Figure 1, and one of the ortho-noise signal implementations shown in Figure 2.

At the transmitter output, a signal normalization unit can be used, which allows the output signal to be obtained without a noticeable change in instantaneous power caused by orthogonalization or collinearization of noise pulses [6].

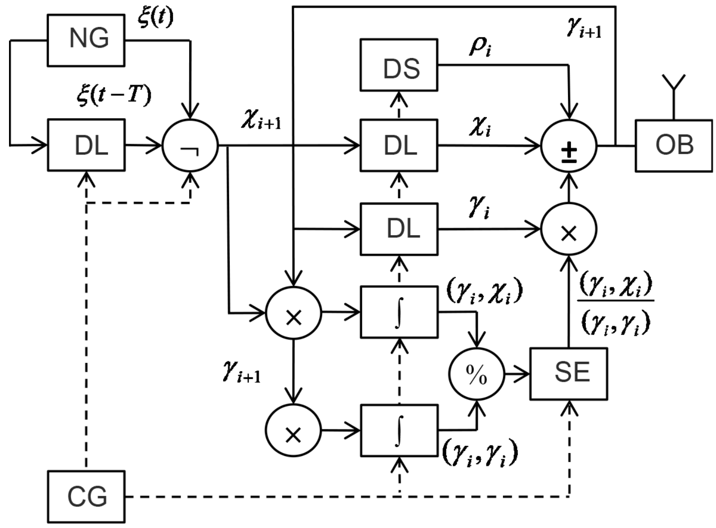

Fig. 1. Ortho-noise transmitter:
NG – noise generator, CG – clock generator, DS – data source, DL – delay line, SE – storage element, OB – output block, ¬ – inverter, ± – adder-subtractor, × – multiplier, % – divisor, ∫ – integrator with reset.

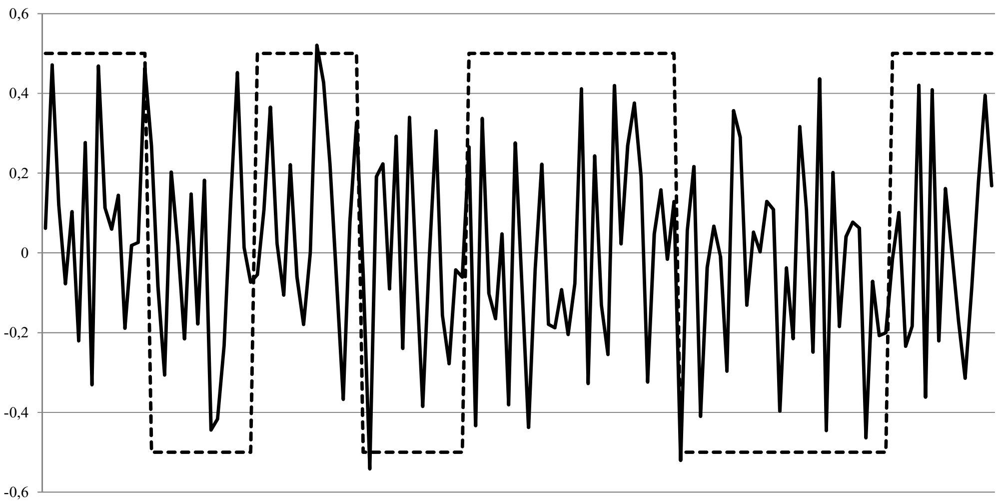

Fig. 2. The ortho-noise signal at the transmitter output during data transmission is 01011001, where the first transmitted noise pulse is starting one.

4 Synchronization signal transmission

A delay line and an inverter are used to synchronize the receiver and transmitter [7] ensuring a sign change of the neighboring noise pulses mutual energy:

$$\chi(t) = \sigma \times \xi(t) \quad (t \in [0, \infty)),$$

where $\xi(t)$ – signal from the noise generator, σ – inverting multiplier, $\chi(t)$ – a synchronized noise signal such that the mutual energy of adjacent pulses changes its sign at each clock interval (Fig. 3):

$$\sigma = \begin{cases} -\tau, & \xi(t)\times\xi(t-T)<0; \\ +\tau, & \xi(t)\times\xi(t-T)\geq 0, \end{cases} \qquad \tau = \begin{cases} -1, & t\in[2nT,\,(2n+1)T); \\ +1, & t\in[(2n+1)T,\,2nT), \end{cases} \qquad n=0,1,2,\ldots$$

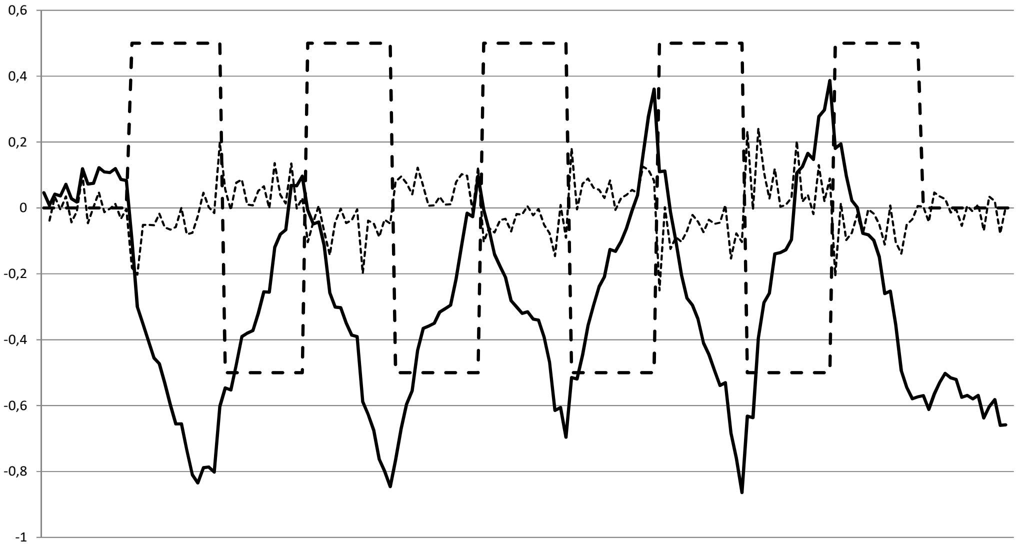

Fig. 3. Integral of the instantaneous mutual energy of the direct and delayed noise signal with noise in the communication channel (solid curve), first derivative of the mutual energy (dashed curve), original clock signal (dashed curve)

5 Ortho-noise receiver

Transmitted data ρ_i on the receiving side are detected as follows:

$$\rho_i = \begin{cases} -1, & |(\gamma_i,\gamma_{i+1})| < \dfrac{\varepsilon}{2}\times(\gamma_i,\gamma_i); \\ +1, & |(\gamma_i,\gamma_{i+1})| \geq \dfrac{\varepsilon}{2}\times(\gamma_i,\gamma_i), \end{cases} \qquad t_i : \frac{d}{dt}\left(\int_0^{T+\Delta T}\gamma_i(t)\times\gamma_{i+1}(t)\,dt\right) = \pm\Delta \quad (i=\overline{1,N}), \qquad (6)$$

where γ_{i+1} (γ_i) – current (previous) noise pulse, t_i – impulse end moment γ_i, ΔT – maximum synchronization error, Δ – clock signal threshold, ε – minimum value of the relative mutual energy modulus of the noise generator adjacent noise pulses,

$$\varepsilon = \min_{i=0}^{N}\frac{|(\chi_i,\chi_{i+1})|}{(\chi_i,\chi_i)}.$$

The block diagram of an ortho-noise receiver that implements formulas (6) is shown in Figure 4.

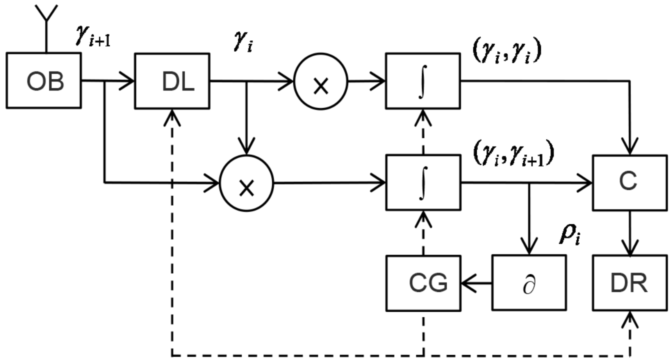

Fig. 4. Ortho-noise receiver: RIB – receiver input block, ISDL – input signal delay line, CG – clock generator, C – comparator, DR – data receiver, × – multiplier, ∫ – integrator with reset, ∂ – low pass filter and differentiator

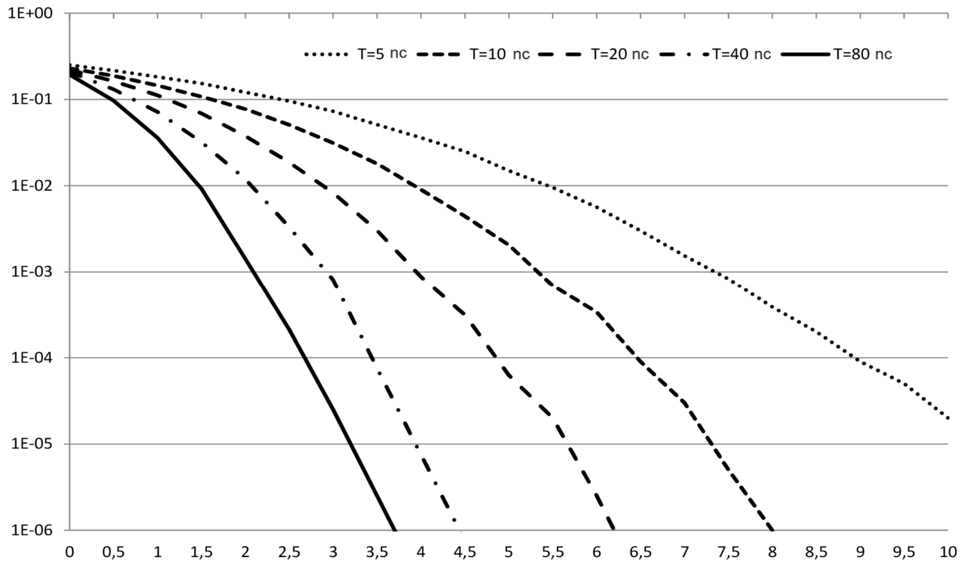

Fig. 5. Dependence of the erroneous reception probability of one bit of data on the signal energy ratio to spectral noise density in the 2.1 GHz frequency band (dB)

6 Conclusion

Good correlation, spectral and statistical properties of noise signals will allow them to be effectively used in advanced communications. The results of an experimental test of the noise immunity of ortho-noise data transmission are shown in Figure 5. The graph shows that for a given signal-to-noise ratio, by increasing the duration of the noise pulses, an arbitrarily small probability of erroneous reception of one bit of data can be achieved. It should be noted that the transformations of the original noise signals used in the transmitter do not significantly affect the correlation, spectral and statistical characteristics of the noise source.

To increase transmission secrecy, you can use normalization of transmitted noise pulses, as well as random or pre-agreed changes in the duration of noise pulses and the phase of the synchronization signal. There are also no obstacles to using a chaotic signal generator instead of a master noise generator.

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