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On the evaluation of noise immunity of different classes of wideband signals

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ABSTRACT

The current stage of the development of the society is characterized by a continuous increase in remote interaction between subscribers and user requests for various types of multiservice services, with the required quality regardless of their location. This is mainly implemented on the basis of wireless communication systems (SBS) at the current time. A large number of various SBSs existing at the present leads to an increase in the level of various types of interference, which makes it necessary to increase the noise immunity of these systems. To improve the reliability of receiving information in the conditions of various types of interference, as is known, it is necessary to implement the information exchange by using channel signals with a large base, which primarily depends on the bandwidth they occupy. In this regard, in the present article, a comparative assessment of the noise immunity is carried out based on the obtained quantitative values of frequency characteristics of a number of modern classes of broadband channel signals, including a new class of broadband channel signals, and the use of eigenvectors of sub-band matrices.

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1. INTRODUCTION

The analysis of the existing approaches to the formation of broadband channel signals (PSS) [1-6] showed that the following methods are currently used for these purposes. The UWB technology, and in particular its impulse ra- dio (IR) version characterized by the transmission of a few nanoseconds duration pulses [7-12], offers an extraordinary resolution and localization precision in harsh environments, due to its ability to resolve multipath and penetrate obstacles [13-19]. Additional advantages include low power consump- tion, low probability of intercept, robustness to jamming, and coexistence with a large number of systems in the ever increasing spectrum exploitation [20-25].

2. METHODOLOGY

2.1. Direct spread spectrum

The essence of this method is as follows. Each element of the information sequence (“1” and “0”) is mapped to pseudo-random sequences (SRPs) different from each other, which then modulate in the phase of the high-frequency oscillation to obtain the SCNS. In the literature, such classes of signals are called t FM PSP signals. In mathematical form, FM PSP signals can be represented as follows:

$$S(t)=S_0\cdot\sum_{l=1}^{N}\nu_l\cdot rect\left\{\frac{t-(l-1)\cdot\tau_Э-\frac{T}{2}-\frac{\tau_Э}{2}}{\tau_Э}\right\} \quad (1)$$

where $\tau_э$ is the length of the element of the SRP; N is the number of elements in the SRP; ν_l is the coefficient characterizing the state of the SRP takes values +1 or -1, $rect(x)=1,\ npu\ |x|\le\frac{1}{2}; rect(x)=0,\ npu\ |x|>\frac{1}{2}$ –rectangular "cutting off" function. The type of SRP with the number of elements N=31, obtained at the output of the register with feedbacks, which are calculated by a special algorithm using a computer, is shown in Figure 1.

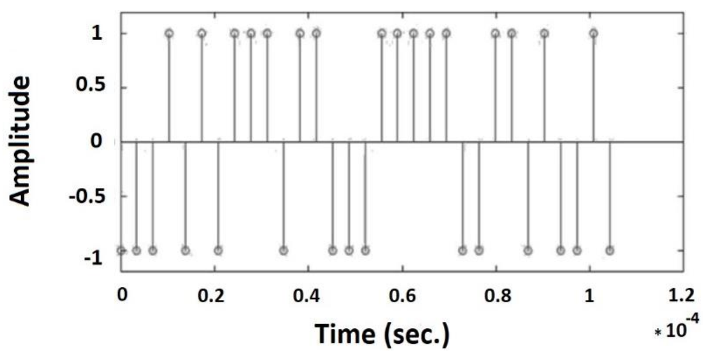

Figure 1. Type of pseudo-random sequence, (M-sequence) N=31

3. RESULTS

3.1. The method of forming pss using wavelet functions

One of the promising areas [7-9, 17, 22] that provides the formation of PSS with a bandwidth much higher than the width of the band provided by the direct spreading method, is the use of wavelet functions as the elements modulating the high-frequency oscillation. The analysis of a sufficiently large number of wavelet functions given in [8, 23] shows that the Morlet and Shannon wavelet functions are the most effective for the formation of the SCNS. Morlet's wavelet is asymmetric wavelet, and can be presented in the mathematical form as follows:

$$\phi(x)=\exp(-\frac{x^2}{2})\cdot Cos(5x) \quad (2)$$

where x is the values of current readings. The PLCS view obtained using the Morlet wavelet is shown in Figure 2.

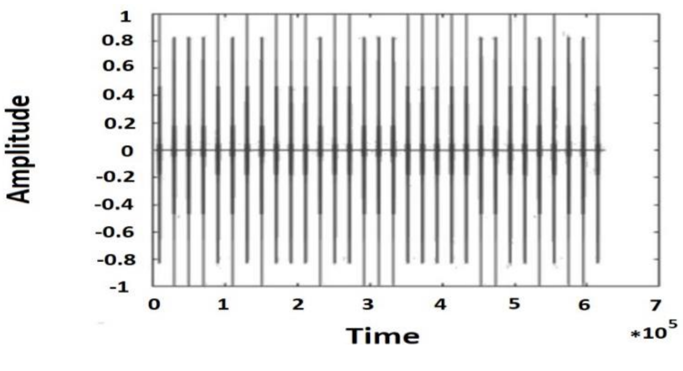

Figure 2. Type of PSS obtained using Morlet's wavelet

It should be noted that Morlet's wavelet can be represented in a complex form using (3) [8]:

$$\phi(x) = \frac{1}{\sqrt{\pi \cdot B}} \cdot \exp(j2\pi \cdot C \cdot x) \cdot \exp(-x^2 / B) \tag{3}$$

where B is a variable defining the bandwidth of frequencies, and C is a variable defining the center frequency. The type of PACS obtained by using the Morlet complex wavelet is shown in Figure 3.

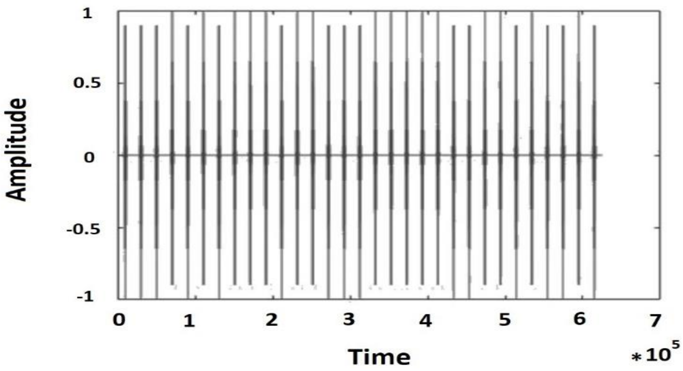

Figure 3. Type of PSSS obtained by using the Morlet complex wavelet

The complex Shannon wavelet in mathematical form can be represented as follows:

$$\varphi(x) = (\sqrt{F_b}) \cdot [Sins(F_b) \cdot \exp(2j\pi F_c x)] \tag{4}$$

where F_b is the value of the frequency band of the wavelet function, is the value of the center frequency of the wavelet function, x is the value of the current samples, while $F_c \leq F_b / 2$. The type of PACS obtained using the Shannon wavelet is shown in Figure 4.

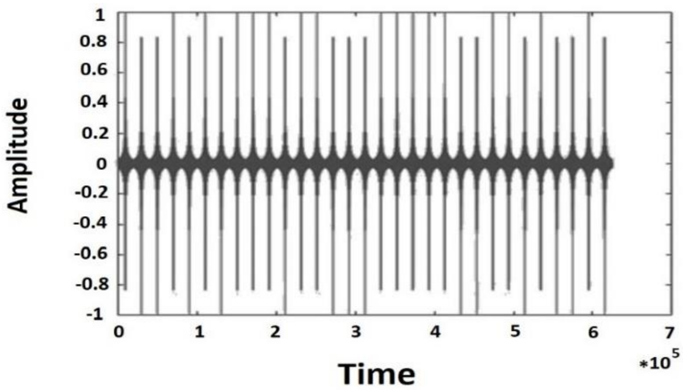

Figure 4. Kind of NLS obtained using a Shannon wavelet

3.2. The method for formation of nics using the eigenvectors of sub-band matrices

The method of generating PSS, using eigenvectors of sub-band matrices [10-14, 22, 24], is to use for transmission of information elements ("1" and "0") transmitting messages of different SRP, with each element of these sequences (1 and -1) proposed to transfer the opposite eigenvectors with eigenvalues close to unity, which are selected from the set of eigenvectors of the sub-band matrix with the elements of the form:

$$A_{i,j} = \begin{cases} \dfrac{Sin(v(i-j))}{\pi(i-j)}, i \neq j \\ v/\pi \qquad\qquad i = j \end{cases} \tag{5}$$

where the indices *i* and *j* take values with a step of 1 from 0 to L (the dimension of the matrix, i.e. the number of samples of the eigenvector), and *v*is the coefficient determining the bandwidth of the eigenvector being formed [15]. The PSCS view obtained using the eigenvectors of sub-band matrices is shown in Figure 5.

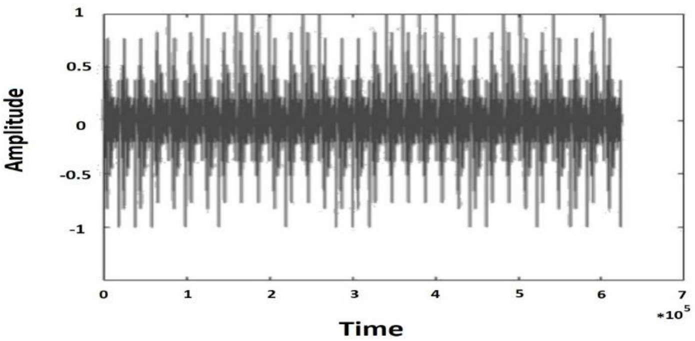

Figure 5. KINS type obtained using the eigenvectors of sub-band matrices

For a comparative analysis of the bandwidth that each of the studied signals occupies, the following parameters were used in the computational experiments [7]:

a. The information transfer rate v=9.6 * 103 kbit/s;
b. The frequency of discredit f_d=6 Ghz;
c. The carrier frequency f=1.646 Ghz;
d. The duration of the information sequence T=10^{-4}seconds

The results of computational experiments are presented in Figures 6 to 9, and they are summarized as well in Table 1. It should be noted that the probability of erroneous reception when using PACS in telecommunication systems is calculated by the following formula [16- 20, 22]:

$$P_{\text{ош}} = 0{,}5 \cdot \left(1 - F\left(\sqrt{\frac{P_{\text{c}}}{P_{\text{ш}}} \cdot \Delta F_{\text{c}} \cdot T_{\text{c}}}\right)\right) \tag{6}$$

where ΔF_c is signal bandwidth, T_c is the duration of PACS, P_c is the PSS power in the signal frequency band ΔF_c, $P_{ш}$ is the noise power in the signal bandwidth ΔF_c, F(*h*) is the Crump function [21].

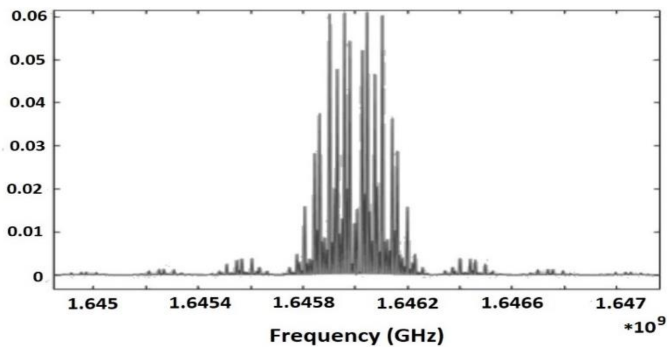

Figure 6. Frequency response of the FM PSP signal with the length of the PSP N=31

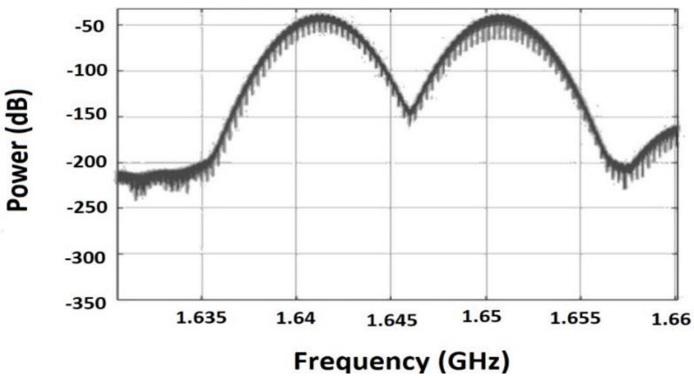

Figure 7. Frequency response of PSS using Morlet wavelet

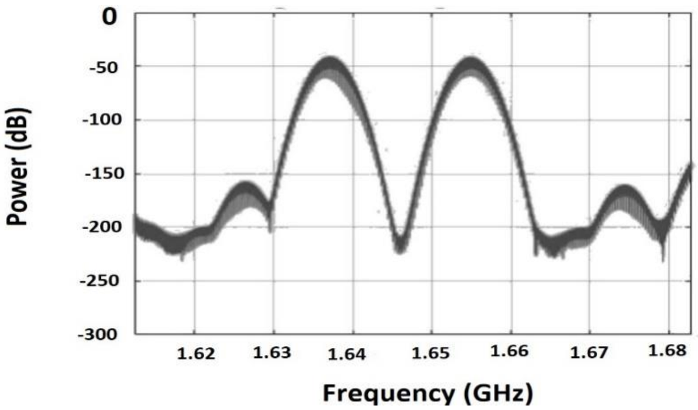

Figure 8. Frequency response of PSS using the Morlet complex wavelet

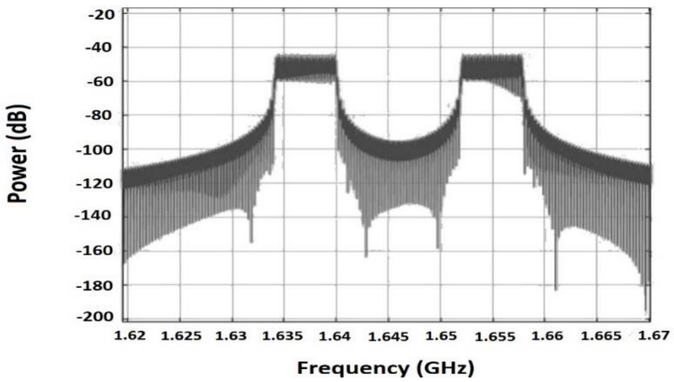

Figure 9. Frequency response of the SCNS using the Shannon wavelet

Table 1. Values of the bandwidth of the studied signals

Type PAS	PSP length, bit					
	31	63	127	511	1023	2047
FM PSP signals	0.3	0.6	1.2	4.8	9.6	19.2
PSCS obtained using Morlet's wavelet	20	42	84	336	672	1344
PSTS obtained using the complex Morlet wavelet Fb=1; Fc=1.5.	28	56	112	448	896	1792
The PACS obtained using the Shannon wavelet Fb=1; Fc=1.5.	24	48	96	387	768	1559
NLS obtained using the eigenvectors of the subband matrices L=1024	48	100	200	800	1600	3200

4. CONCLUSION

Undoubtedly today, communication and information exchange in its various forms plays a fundamental role in the creation and development of industrial infrastructure. Without the minimum of communication, one can never have proper management at the level of a large industrial project. It is important, of course, to maintain a reliable and uninterrupted communication in pursuit of the goals of the industrial complex. The technical nature of various communication systems, the relevance of communication equipment to other telecommunications networks, and the possibility of disconnection for a variety of reasons make us look for an idea that can provide a secure and stable connection that will meet the communication needs in all circumstances. This is mainly implemented on the basis of wireless communication systems (SBS) at the current time.

In the current study, it was tried to improve the reliability of receiving information in the conditions of various types of interference. For this reason, in the present paper, a comparative assessment of the noise immunity is carried out based on the obtained quantitative values of frequency characteristics of a number of modern classes of broadband channel signals, including a new class of broadband channel signals, and the use of eigenvectors of sub-band matrices. From the analysis of the data presented in Table 1, it can be seen that the broadband channel signals based on the use of the eigenvectors of sub-band matrices, have significantly greater bandwidth than other types of SCNRs whose properties were presented in this article. Consequently, their use in wireless communication systems will significantly improve the reliability of information exchange.

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