Evaluation Quality Parameters Of Telecommunications Services. Informatyka, Automatyka, Pomiary W Gospodarce I Ochronie Środowiska, 12(2), 30–33. DOI: https://doi.org/10.35784/iapgos.2918.
3. Indyk S., Lysechko V. (2020) The study of ensemble properties of complex signals obtained by time interval permutation. Advanced Information Systems. Vol. 4, № 3. PP. 85-88. DOI: 10.20998/2522- 9052.2020.3.11.
4. Bagwari, A., & Tomar, G. S. (2013). Adaptive double-threshold based energy detector for spectrum sensing in cognitive radio networks. *International Journal of Electronics Letters*. 1(1): P. 24-32 DOI:10.1080/21681724.2013.773849

УДК 621.396.967
***Komar O.M.**, PhD. Associate Professor*
National Aviation University, Kyiv
***Veklych O. K.** PhD student*
State University of Telecommunications, Kyiv
***Shubina G.V.**, head of the educational department,*
Ivan Kozhedub Air Forces Kharkiv National University, Kharkiv

ANALYSIS OF FEATURES AND PROSPECTS OF IEEE 802.16 (WiMAX) IN COGNITIVE RADIO NETWORKS

The analysis of IEEE 802.16 (WiMAX) technology is necessary and relevant for several key reasons.

Firstly, although WiMAX did not achieve widespread adoption like LTE or 5G, it remains important for understanding the development of wireless technologies. Analyzing WiMAX allows us to explore technological advancements in wireless communication and compare them with modern standards. This helps to better understand the technological challenges faced by similar standards.

Secondly, WiMAX continues to be relevant in certain niches, such as remote regions or countries where LTE and 5G have not yet gained sufficient penetration. The technology provides wireless access in hard-to-reach areas thanks to its long-distance communication capabilities.

Thirdly, WiMAX has specific technical advantages, including the ability to dynamically use the frequency spectrum, making it an important subject of study for cognitive radio networks. Analyzing this technology can aid in developing new approaches to spectrum management, particularly in conditions of limited frequency resources. The main specifications of IEEE 802.16 are presented in Table 1.

Табл. 1 Main specifications of IEEE 802.16 (WiMAX)

Specification	Characteristics
IEEE 802.16 - 2004	The first version of the standard that defines wireless access technology over medium and long distances. This standard supports the microwave range and uses OFDM.
IEEE 802.16e-2005 (Mobile WiMAX)	This version expanded the standard to support mobile devices, allowing connectivity on the go. It also increased the supported data rates.
IEEE 802.16m (WiMAX 2.0)	This version has expanded network capabilities, improved service quality, increased data transfer speed and provided support for mobile devices
IEEE 802.16j (Multihop Relay)	This version of the standard includes support for relay technology to improve coverage and increase network efficiency.
IEEE 802.16p (Fixed Wireless Access Interface)	This version of the standard covers specifications for fixed wireless broadband Internet access systems.
IEEE 802.16s (Management Plane Procedures)	This version defines the network management and control procedures that support network operations.
IEEE 802.16t (Management Information Base):	This version of the standard defines the management information base for the IEEE 802.16 network.

The IEEE 802.16 standard, though not originally developed for cognitive radio systems, has found practical application in this context with certain limitations. The standard's built-in spectrum scanning capabilities enable the identification of available radio frequency resources and assess their potential for use. In cognitive radio mode, IEEE 802.16 offers mechanisms for dynamic resource management, allowing communication parameters to be adjusted based on real-time network conditions and operational requirements [1,2,3].

Some IEEE 802.16 implementations can incorporate reconfigurable, or «smart» antennas that adapt to changing channel conditions. These include [4].

1. Beamforming antennas. Dynamically adjust the direction of the antenna beam to improve signal quality and reduce interference, enhancing transmission efficiency in both mobile and stationary modes.

2. Adaptive antennas. Automatically modify tilt, polarization, and other parameters to optimize connectivity based on real-time channel conditions.

The main strength of WiMAX is its high data transfer speeds, supporting both point-to-point and broadband access for multiple devices. Its versatility across different frequencies and compatibility with stationary and mobile devices make it suitable for a wide range of wireless applications.

Thus, WiMAX (IEEE 802.16) remains a relevant and versatile technology, particularly in cognitive radio networks and remote regions, offering high data transfer speeds, dynamic spectrum utilization, and adaptable communication capabilities, despite facing competition from LTE and 5G.

References

5. Shiang H., van der Schaar. Distributed resource management in multi-hop cognitive radio networks for delay sensitive transmission. IEEE Transactions on Vehicular Technology. Vol. 58(2). IEEE Transactions on Vehicular Technology. P. 941–953.

6. Ho-Van K. K. Influence of channel information imperfection on outage probability of cooperative cognitive networks with partial relay selection. 2017. Wireless Personal Communications. Vol. 94(4). P.89–91.

7. Miao L., Sun Z., Jie Z. The Parallel Algorithm Based on Genetic Algorithm for Improving the Performance of Cognitive Radio. 2018. Wireless Communications and Mobile Computing. Vol. 2.

8. Poroshenko A., Kovalenko A. Optimization of a basic network in audio analytics systems. *National Technical University «Kharkiv Polytechnic Institute». Advanced Information Systems.* 2023. Vol 7(1). P. 23-28.

УДК 621.396.967

***Perets K.G**, PhD student*
Ukrainian State University of Railway Transport, Kharkiv
***Zhuchenko O.S.**, PhD. Associate Professor*
Ukrainian State University of Railway Transport, Kharkiv

THE METHOD OF STEPWISE HYBRID TIME SEGMENTATION BASED ON BANDPASS FILTERING WITH TIME-FREQUENCY ADAPTATION

In modern conditions of increased requirements for communication quality and data transmission speed, especially in complex interference environments, it is necessary to ensure effective filtering and adaptive signal ensemble formation. This is required to minimize mutual correlation between signals, improve data transmission quality, and ensure resistance to interference. These challenges can be addressed using the method of stepwise hybrid time segmentation based on bandpass filtering with time-frequency adaptation.

The core idea of the method lies in the integration of time segmentation with filtering in the frequency domain, allowing the signal's behavior to be considered at each stage of formation. This approach provides a dynamic transition between the time and frequency domains, taking into account the mutual correlation properties of the signal and enabling improved signal characteristics.

The main steps of the algorithm for the method of stepwise hybrid filtering with domain transitions include the following.

1. Initial Stage. The signal undergoes bandpass filtering in the frequency domain to isolate the necessary frequency bands and reduce mutual correlation between components.

2.Time Shift. After each stage of spectral filtering, a time shift of the signal components is performed to preserve temporal connections and adapt the filtering according to changes in the time domain.

To ensure optimized modeling of signal characteristics, considering both linear and nonlinear changes, methods for signal ensemble formation, such as Volterra integral equations, can be used to model signal variations at each stage of filtering.

After each stage of frequency domain filtering, the signal transitions to the time domain for adaptive segmentation. This adaptive segmentation involves selecting optimal time intervals, where each segment is processed separately, allowing for the minimization of correlation between signal components.

For the analysis of time segments, it is advisable to use the Hilbert-Huang Transform (HHT), which can identify local oscillations and adapt further processing based on the detected characteristics.

At each stage of filtering (both in the frequency and time domains), it is effective to apply Lagrange multipliers to find the optimal filtering and segmentation parameters, considering constraints such as minimizing mutual correlation.

Additionally, after each transition between domains, L'Hôpital's rule(*) can be used to analyze the boundary values of signal parameters. This helps to avoid issues at critical points, where changes in the signal could lead to significant information loss.

A key feature of the method of stepwise hybrid time segmentation based on bandpass filtering with time-frequency adaptation is the combination of frequency-domain filtering with adaptive time shifts. This provides a comprehensive approach to signal ensemble formation, where each stage involves returning to the time domain for analysis and further adjustment.

The use of different transformations at each transition between the time and frequency domains (e.g., HHT in the time domain, DCT in the frequency domain)