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Estimation of the Energy Spectrums of Reflections in Pulse Doppler Weather Radars. Part 1. Modifications of the Spectral Estimation Algorithms

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Abstract—This is the first paper in a series of papers devoted to the peculiarities of estimation of the continuous energy spectra of random processes of different nature, which are defined by their samples at discrete moments of time. In the paper we consider two kinds of the generalized spectrum analyzers (GSA), whose structure fits the majority of classical (nonparametric) and modern noneigenstructured spectral estimation (SE) methods. It has been demonstrated that a number of known superresolution SE methods may be considered as particular cases of parametric GSA based on whitening or inversing filters of the input process. We focus on the autoregressive models of analyzed processes with continuous energy spectrums, for which the whitening or inversing filters are the transversal filters of various structures with proper parameters. The utilized interpretation allows one to modify the well-known superresolution SE methods for the problem of continuous spectrums reconstruction and, what is more important, to establish their new varieties with practically useful properties, that are going to be explored in the following two papers.

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INTRODUCTION AND PROBLEM STATEMENT

The identification of meteorological objects in pulse Doppler weather radar (DWR) is based on the estimations of their reflectivity, mean velocity and turbulence [1–5]. These parameters are defined by the moments of a priori unknown energy spectrum of interperiod pulse fluctuations of M-dimensional packets of reflections from meteorological objects (MO), therefore, the quality of its evaluation plays an important role in solving of the DWR problems.

The spectrum estimation of random processes of different nature is paid and continues to be paying a great attention in the literature, whose list is not limited by the references in this article. Intensive researches over the last few decades have significantly expanded the arsenal of spectral estimation (SE) methods compared to the classical period charts (correlation charts) methods based on the discrete Fourier transform (DFT–FFT), which appeared at the beginning of the last century [6–16]. The main purpose of their creation was the intention to increase the resolution capability of SE compared to the one achievable using the classical methods.

However, the consequently created numerous superresolution techniques of SE are still not used in DWR, although the possibilities of a modern and next-generation digital hardware components allow us to rely on their practical implementation. One of the reasons for this consists in a great variety of the proposed methods, that formulates a complicated task of choosing of the most expedient among them for the implementation into existing or next-generation DWR.

Complexity of the choice is caused by the fact that these techniques were designed to solve "… many different spectral analysis problems, … corresponding to different kinds of prior information about the phenomenon being observed, different kinds of data, different kinds of perturbing noise, and different objectives. It is, therefore, quite meaningless to pass judgment on the merits of any proposed method unless one specifies clearly: 'In what class of problems is this method intended to be used?'" [11]. A sufficiently complete from the perspectives of [11] answer to this question is absent even in the publications by the