Monopulse-Frequency Temporal Processing of Unknown Signals Based on LFM - Fourier Transform in Passive Systems Radiomonitoring

Volodymyr Antonyuk, Mykola Kalyuzhniy, Ivan Prudyus, Vitalij Nichoha

Abstract - **Principles of combination of dispersive-time and digital signal processing methods in problems of identification, evaluation parameters, recognition and identification of complex signals and means that they emit.**

Keywords - **Dispersion delay line, receiving-analyzing device, radio monitoring.**

I. INTRODUCTION

One of the promising ways to improve the competitiveness of passive systems radiomonitoring in the world market for these products is to introduce modern methods of signal processing. These methods allow for a short period of time and under conditions of a priori uncertainty of the type and parameters of input signals have to provide their identification, evaluation frequency-time parameters, recognition and identification as the signals themselves so the means that they emit. In the literature much attention is paid to time-dispersive spectral analysis of signals that at some extent meet the requirements of speed and resolution [1,2]. But the question of technical implementation of such methods for the simultaneous estimation of frequency and temporal parameters of complex structures with signal recognition functions, in terms of a priori uncertainty in the known sources is covered enough. Therefore the problem of technical realization of basic receiving-analyzing device for modern passive systems radiomonitoring through a combination of dispersive-time signal processing techniques with modern digital methods that allow to obtain in real-time the formats of time-frequency signal panoramas and forms of radiation with the data type identification of the signals and sources that they emit is timely and relevant.

II. THE PRINCIPLES OF COMBINING OF DISPERSION-TIME AND DIGITAL SIGNAL PROCESSING METHODS

The main directions of signals' complication in modern and perspective radar systems for civil and military purposes are [3]:

- The use of linear or nonlinear frequency and phase modulation.
- Change of the signals duration and increase of the rising and falling edges of the signals to make determination of the of radiation sources location using the hyperbolic methods more difficult;
- Adaptation of the radiation power of signals depending on the noise situation or tasks being solved;
- Rebuilding the operating frequency from pulse to pulse, from series to series and / or from inspection to inspection by deterministic or random law in the band up to 1000MHz in size of the step from 30 to 50MHz;
- Use of Multi-frequency (the number of frequency channels can reach several thousand, and frequency separation between them - from 30 to 50 MHz);
- Discrete or smooth retuning of the repetition rate of the deterministic or random law within 30% of its mean value.

Operating frequency range of modern passive systems radiomonitoring is in the range from 0.1 MHz to 40 GHz and above. In such difficult conditions of dynamic loading and changing of electromagnetic environment, the task of identification and evaluating frequency-time parameters of signals can be solved by covering the whole frequency range n by the frequency channels with the receiving abnd of each $\Delta f_к$. Viewing these channels can be realized by their serial connection using an electronic switch to the input of the basic high-speed broadband receiving-analyzing device (receiver) that uses the radio electronic systems principle and technique of compression signals for radiation receiving and analyzing.

To meet the conflicting requirements for accuracy estimation and signal bandwidth in terms of limited duration the monopulse method of measurement of radiation based on the effect of compression signals is proposed to use.

As it is known, the Fourier transformation of the signal s (t) can be performed using the circuit that contains LFM-heterodyne, mixer and DDL.

Spectral density of rectangular pulse duration $-\tau_и/2 < t < \tau_и/2$ has the form:

$$g(f) = \int_{-\frac{t_u}{2}}^{\frac{t_u}{2}} s(t)\, e^{-j2pft}\, dt \qquad (1)$$

By entering the auxiliary function $s_1(t) = s(t)e^{-jbt^2}$

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We will obtain

$$g(f)=\int_{-\frac{t_u}{2}}^{\frac{t_u}{2}} s_1(t)e^{-j(bt^2-2pft)}dt = \tag{2}$$
$$= e^{-jbq^2}\int_{-\frac{t_u}{2}}^{\frac{t_u}{2}} s_1(t)e^{-jb(q-t)^2}dt$$

Where $\theta=\pi f/b=f\tau_и/\Delta f$.

From the expressions obtained it follows that the dependence of the spectral density of frequency is reduced to the complex amplitude depending on the time *q*, linearly related to frequency *f*.

As a result heterodyning of the input fluctuations s (t) turns out fluctuations $s_1(t)=s(t)e^{-jbt^2}$ which then undergoes filtration in dispersive filter (DDL), impulse response is coordinated with fluctuations LFM-heterodyne. Hereby the input radio pulse duration $\tau_и$, divided into a set composed of elementary LFM - radio pulses duration $\tau_{иэ}=T_г$ internal pulse frequency deviation equal to the band frequency heterodyne. As a result of processing the elementary LFM -radio pulses output DDL formed compressed sequence of radio-delay θ which (due to the presence of linear dependence of the output effect on the frequency of the input signal) with respect to its launch LFM -heterodyne frequency is proportional to the average elementary radio pulse (Fig. 1).

Output filter formed on the compressed pulse sequence compression by tethering them to a single timeline contain information not only on frequency but also on other parameters of the received signal (duration $\tau_и$ and repetition period $T_п$, the type and parameters intrapulse modulation and so on). Information about the parameters of the received signal is being "extracted" from these populations as a result of their further processing.

After the detecting the signal or a digital quadrature transformation the use of the digital processing allows to automate the detection and measurement of frequency and time periods (parameters) of elementary pulse.

The output special processor (SP) is formed by a matrix of digital codes [Npr] of frequency counts of elementary radio pulses of received signal N_f^{ij}, where i = 1,2, ..., m - number of total samples (compressed pulse) j = 1,2, ..., k - reference number in the aggregate:

$$[\,Npr\,] = \begin{vmatrix} N_f^{11} & N_f^{12} & \dots & N_f^{1k} \\ N_f^{21} & N_f^{22} & \dots & N_f^{2k} \\ \dots & \dots & \dots & \dots \\ N_f^{m1} & N_f^{m2} & \dots & N_f^{mk} \end{vmatrix} \tag{3}$$

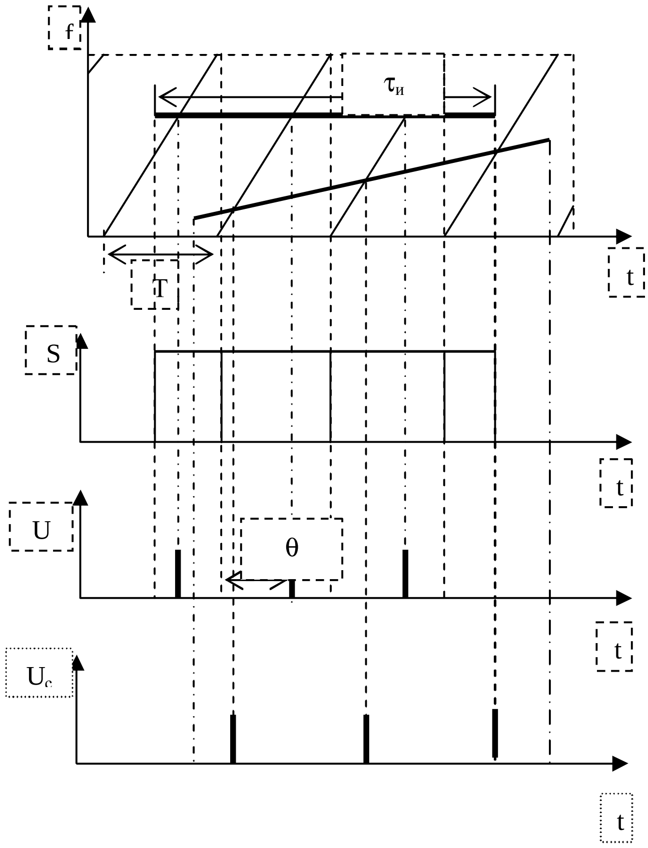

Fig.1. Frequency-time diagrams of signal processing in the receiving-parsing device based on pulse compression

Number of rows m of matrix determined by the ratio of observation time to the pulse repetition period of the input signal $m = T_н / T_п$) and the number of elements in row k - the ratio of pulse duration to the period of repetition heterodyne ($k = \tau_и / T_г$).

To bind rows of this matrix to the timeline simultaneously formed vector digital codes [Nt1, Nt2, ..., Ntm], elements which capture the moments of the beginning of the corresponding elementary pulse received signal. Herewith the relative time scale when $N_{t1} = 0$ can be used, that will result in other elements of this vector will contain information on time intervals between the beginning of the neighboring elementary pulses in the approved sequence.

As a result of analysis and set of frequency-time readings of electronic computers (using appropriate algorithms for analysis and measurement) is formed by the vector of the measured parameters of the received signal that contains the value (digital codes) carrier frequency N_f, duration N_τ, the period of repetition N_T, the width of the spectrum $N_{\Delta f}$ and other parameters as well as signs of the type of modulation intrapulse $П_{ВИМ}$ and between the impulse changes $П_{воб}$ parameters of the signal.

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III. BLOCK DIAGRAM OF THE BASIC RECEIVING-ANALYZING DEVICE

Simplified block diagram of a basic receiving-analyzing device (PAP) is shown in Figure 2.

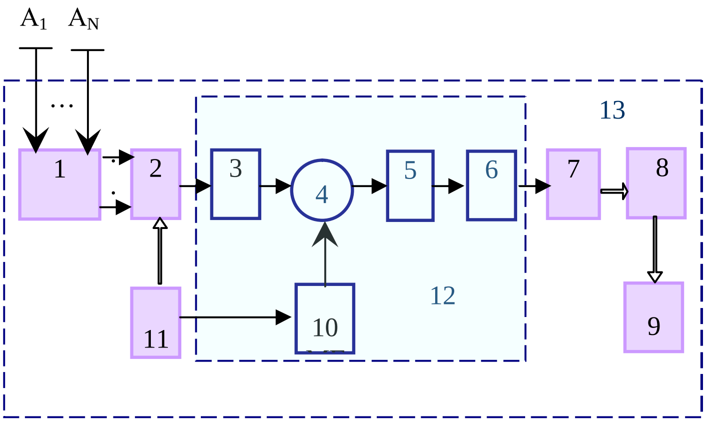

Figure 2. Simplified block diagram of a basic receiving-analyzing device

1 - mixing unit frequency MUF;
2 - electronic switches ES;
3 - intermediate frequency amplifier IFA;
4 - change mixer (CM);
5 - dispersion delay line (compression filter) DDL;
6 - detector (Quadrature converter);
7 - digital special processor (DSP);
8 - personal electronic computer (PC);
9 - display indication of frequency-time panoramas, such as radio systems and the objects on which they located (DI);
10 - LFM -heterodyne;
11 - block control (BC);
12 - Receiver with pulse compression (RPC);
13 - basic receiving-analyzing device (BTAD).

The principle of operation of BTAD using a receiver with pulse compression is as follows.

Operating frequency range of passive radio frequency overlaps n selective channels of each band receiving instant $\Delta f_к$. Viewing these channels is realized sequentially by connecting them with an electronic switch to the exiting ES block frequency converters. Power frequency converters MUF provides frequency conversion of signals received by different frequency channels, the intermediate frequency, which is the same for all frequency channels. At this frequency the subsequent processing of received signals is realized.
The structure and parameters of the signal after the Fourier transformation in the receiver with pulse compression RPC and processing in digital special processor DSP and personal computers PC on-screen panoramic display DI and if necessary may be issued to external customers [4].

The possibility of shared principles and taking on various types of signals in a wide band of frequencies controlled was tested in the practical application of experimental samples panoramic speed devices such as "Sirius" instant analysis of the bands Δfa = 100, 300 and 500 MHz, developed at the Academy of Air Defense (Fig. 3).

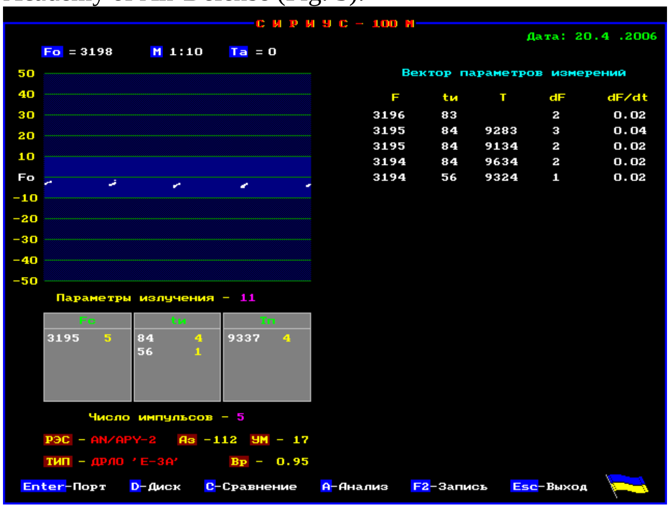

Figure 3. Screenshot of receiving-analyzing device for analyzing radar AN/APY-1, of the remote radar detection system "AWACS".

IV. CONCLUSIONS

1. The combination of time-dispersive techniques and digital signal processing in passive systems radiomonitoring provide intelligence in real-time detection, assessment of the frequency-time parameters, recognition and identification of not only simple but also complex, including noise-like signals.
2. Based on the considered methods and the availability of relevant databases and knowledge bases the recognition of the types of radiation sources and types of objects to which these sources are located can be made.

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