Information Aspects of Multispectral Active-Passive Radio Monitoring System

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Abstract - **Methodology for structural-functional construction of multispectral radio monitoring system by the criterion of information efficiency is proposed. Requirements to the main elements of the structure are determined.**

Keywords - **multispectral monitoring system, radiolocation image, radiometric image.**

I. INTRODUCTION

Paper [1] presents application of the maximum likelihood method to engineering synthesis of the optimal multispectral monitoring system structure in which integration of partial spectral channels with transducers of various sections of electromagnetic waves spectrum is performed at the level of per-channel statistical solutions. In a general case, the output of every partial spectral channel can be considered as a formed image of the observed object (or scene) in the space of a certain system of coordinates. While solving the tasks of searching and locating objects in an assigned zone of responsibility it is expedient to tie the origin of the coordinate system to the point of location of monitoring equipment. While solving the tasks of identification it is rational to use the system of coordinates connected with the object, i.e. to form signature features (image) unambiguously connected with the form-creating surface (structure) of the observed object. In a radio range, with the aim of achieving all-weather, any-time working conditions and high noise protection, it is expedient to consider methodology of creating an integrated active-passive monitoring system including both active (radiolocation) and passive (radiometric) channels of observation.

II. MAIN PART

The optimal structure of the integrated active-passive system of radio monitoring is presented in fig.1.

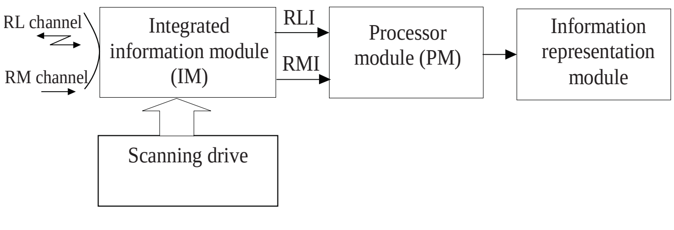

Fig.1 The structure of the integrated active-passive radio monitoring system

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The integrated information module (IM) includes:

- a single pattern-forming arrangement of radiolocation (RL) and radiometric (RM) channels;
- a coherent-impulse RL channel transmitter;
- an RL channel receiver;
- a multi-channel radiometer;
- a synchronization- and- control module.

The single pattern-forming arrangement must meet the following requirements:

- to ensure inter-positioned scanning of the observation zone by RL and RM channels to provide inter-consistency of the formed radiolocation and radiometric images (RLI, RMI) by angular coordinates;
- to ensure formation of the directional patterns of RL and RM channels in a considerably frequency-dispersed sections of microwave range to achieve the necessary information content and noise protection of radio monitoring at acceptable antenna aperture sizes (for example, in 3mm and 8mm atmosphere “transparency windows”).

Practically, a single pattern-formation can be realized on the basis of a Cassegrainian antenna with polarization isolation of RL and RM channels [2].

The formed RLI and RMI are the output signals of the integrated information module. When multi-frequency coherent-impulse method [3] is used, at the output of RL channel there are formed RLI of the following type:

- Doppler “portrait”

$$Y_l(n,l) = \frac{1}{2\pi}\left|\sum_{i=0}^{I} S(i,n)\cdot e^{-j\frac{2\pi}{I}l_i}\right| \qquad (1),$$

where $S(i,n)$ is a complex envelope of echo-signal at the output of RL channel, n is a present range resolution element, i is number of across-period sampling in the range of coherent accumulation time (of a Fourier transform calculation cycle);

- distance “portrait”

$$g(r_i) = \frac{1}{2\pi}\sum_{i=0}^{M} S(i)\cdot e^{-j\frac{2\cdot r_i\cdot\omega_i}{c}} \qquad (2),$$

where $\omega_i = \omega_0 + k(i)\cdot\Delta\omega$, ω_0 is the initial value of the probing signal carrying frequency, $\Delta\omega$ is a discrete of the carrying frequency per-period adjustment, $k(i)$ is a pseudorandom law of the probing signal carrying frequency readjustment, $i = 1...M$ is number of the distance element within the limits of physical dimensions of the observed object.

The algorithm of forming RMI G in the spectral area of spatial frequencies [4] is:

$$G = k\cdot F\cdot H + B + N \qquad (3),$$

where k is a coefficient of proportionality, F, H, B, N are Fourier transforms of the input image, apparatus function of RM channel, additive level shift and additive noise, respectively.

The processor module (PM) realizes algorithms of complex processing of RLI and RMI which, in a general case, include:

- format and scale alignment of RLI and RMI;
- compensation of RL and RM channels optical axes relative to drift;
- compilation – receiving the integrated image from RLI and RMI.

Format and scale alignment of RLI and RMI can be achieved only if angular resolution and running speed of RL and RM channels are matched. The angular resolution of RL and RM channels is limited by the Rayleigh boundary:

$$\Delta\varphi \approx \frac{\lambda}{D} \quad (4),$$

where D is an antenna aperture.

On the other hand, there is a great difference in the speed of RLI and RMI formation. In paper [3] it is shown that when the angle of probing is changed, stability margin of the distance "portrait" is ±0.25 degrees and this corresponds to the width of the directional pattern with the aperture size of about 0.5m in 3mm wave range. Considering the fact that the speed of RLI formation is much higher, it is rational to increase the frequency of RL channel. At this, when using one aperture, the loss of angular resolution in RL channel can be compensated by mathematical processing of the formed RMI with methods of non-linear super-resolution for restoring RMI [4]. But for matching angular resolutions and speed, format and scale alignment of RLI and RMI is achieved by:

- placing IM on a rotating device that, together with a single pattern-formation, allows to align angular observation sectors of RL and RM channels;
- limiting the maximum speed of scanning to the time necessary for forming RMI;
- time synchronizing the channels forming RLI and RMI.

Because RLI and RMI significantly differ as to their physical nature of formation (radiolocation and radio thermal contrast), the canonic brightness presentation during compilation needs modification. The following are the major requirements to the method of compilation:

- a compiled image must differ from the output images of partial channels by better quality (visual for observation, by features for identification);
- the quality of the compiled image must not be worse than the quality of the partial channel image during blocking (injuring with noise) of another partial channel;
- the method must be maximally invariant to static characteristics of signals and noise of partial channels.

The general structure of the processor module presented in fig.2 takes account of all the above considerations.

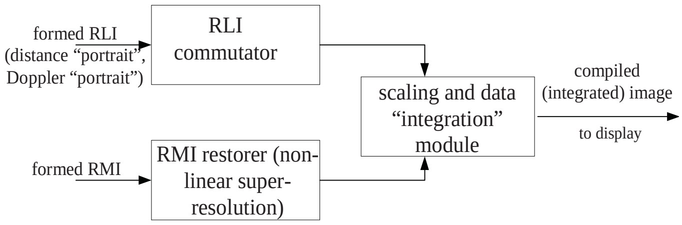

Fig.2. Structure of the processor module.

III. CONCLUSIONS

The developed methodology of a multi-spectral radio monitoring system information construction:

- allows to optimize requirements to structural and functional characteristics of the projected aperture;
- allows to expand to multi-spectral systems with various types of physical transducers of information.

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