

Chapter 16

Theoretical Methods of Images Processing in Optoelectronic Systems

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ABSTRACT

The chapter covers development of mathematical model of signals in output plane of optoelectronic system with registration of optical signals from objects. Analytical forms for mean values and dispersion of signal and interference components of photo receiver response are given. The mathematical model can be used as a base with detection algorithm development for optical signal from objects. An algorithm of signals' detection in output plane of optoelectronic system for the control is offered. The algorithm is synthesized taking into account corpuscular and statistical properties of optical signals. Analytical expressions for mean values and signal and noise components dispersion are cited. These expressions can be used for estimating efficiency of the offered algorithm by the criterion of detection probabilistic characteristics and criterion of signal/noise relation value. The possibility of signal detection characteristics improvement with low signal-to-noise ratio is shown.

1. PURPOSE AND METHODS OF IMPROVING OPTOELECTRONIC SYSTEMS

In recent decades the dynamic development of equipment and technologies has provided a way for technical realization of the potentially high possibilities of optoelectronic systems. The main advantages of optoelectronic systems are as follows: a great accuracy of objects coordinates determination, a high resolution in range, angular resolution. All the above allows a widespread use of television systems in many fields of science and technology, for example, in astronomy, vision systems, biology and medicine.

DOI: 10.4018/978-1-5225-0983-7.ch016

The development of modern optoelectronic systems provides an opportunity to deepen knowledge about the surrounding world and allows you to make discoveries in the field of natural sciences. A deep understanding of physical processes of emergence, propagation of optical radiation and also the theory of receiving and processing of optical signals with consideration of the peculiarities of their spatial-temporal structure, wave, corpuscular and statistical properties lies in creating systems with improving.

There are possible ways to improve and expand the capabilities of optoelectronic systems:

1. Reducing of sensitivity thresholds in the primary information processing devices through the improvement of individual system components, for example, development of new technologies of photodetector elements having higher energy sensitivity.
2. Development of new technologies for creation of elements of an optical link, and also the use of spectral and neutral density filters for matching the dynamic range of the systems during registration of optical signals.
3. Design and development of methods for describing information converted in optoelectronic systems.
4. Improvement of algorithms for data processing, taking into account the statistical characteristics of the received signals in the information processing systems.

The basis of each direction is a rigorous physical and mathematical description of the model of optical signals reception and image processing

Reasoning from the concepts of geometrical optics, image formation in optoelectronic systems is due to employing light rays, which are independent and straightforward in a homogeneous medium and refracted (reflected) on the boundaries of media with different optical properties. The apparatus of geometrical optics makes it possible to describe the process of the image formation, to estimate some parameters of the optical system (the angular field of view, linear magnification, etc.). However, the use of the geometrical optics does not make it possible to consider energy, statistical, spectral characteristics of optical signals.

The formation of signals and images in the systems can be viewed from the position of the wave theory, which is based on the system of differential Maxwell's equations describing electric and magnetic fields strength, electric displacement, magnetic induction and the electric charge density. The system of Maxwell's equations also includes constitutive relations that characterize the behavior of different media in the electromagnetic field. Taking into account the constitutive relations and boundary conditions, the system of Maxwell's equations is a complete one and it allows describing all the properties of the electromagnetic field and many of the processes of interaction of a field with a matter. From the standpoint of the wave theory it is convenient to describe diffraction phenomena, interference, spectral and polarization properties of optical signals. However, the wave theory application to description of the optical signals of low intensity leads to the results contradictory to the experimental data, when a small number of photons is recorded during the observation time.

Also the processes of signals and images formation in the systems can be considered from the position of the corpuscle (photon) optics, when light is represented as a stream of discrete particles (photons). Using the photon representation of the optical radiation, it is possible to describe phenomena that have a probabilistic nature (the generation of radiation, absorption in the neutral filters and in the substance of the photocathode). The corpuscular representation enables the analysis of the statistical properties of optical signals and applying methods of the theory of solutions when solving problems of detection, reception of signals and their parameters measurement.

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