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A METHOD FOR OPTICAL IMAGING OF THE THREE-DIMENSIONAL MANIFOLD STRUCTURE

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***Abstract*—*The analytical models of optical control object's internal structure image obtaining were considered, and on their basis distortions, appearing in image depending on visualization system's parameters and emitting source type, were analyzed. The method developed for optical imaging of the inner structure of the three-dimensional manifold (hereinafter referred to as "the object monitored") allows a shadow of the three-dimensional manifold, exposed to electromagnetic radiation, to be obtained using an irradiation model.*

Index Terms—X-ray; Aviation Security Service; optical imaging; shadow of the three-dimensional manifold.

I. INTRODUCTION

The method developed for optical imaging of the inner structure of the three-dimensional manifold (hereinafter referred to as "the object monitored" or OM) allows a shadow of the three-dimensional manifold, exposed to electromagnetic radiation, to be obtained using an irradiation model. It has useful applications in different life spheres, as in medicine, manufacturing industry, in a process of customs supervision of goods and means of transport for commercial use etc. It allows the Aviation Security Service (ASS) to increase the probability of correct detection of hazardous materials and reduce false responses of its security system. For medicine the method may help to increase the probability of health hazard anomaly detection.

Insights of the direct visualization methods indicate that they are inherent in the same type of operations: primary radiation exposure of the OM as three-dimensional manifolds in configuration space (in the case of active method), reradiation reception (scattered or passed through the object), its conversion into an electrical signal, signal processing and electrical-to-optical signal conversion.

II. PROBLEM STATEMENT

Modern detection systems based on X-ray, computer tomography and spectroscopy of mobile ions have certain shortcomings [1] – [5], [8], [9]. Some of these systems can detect well-hidden explosives, but their implementation requires considerable funds. In addition, they have a high level of false alarms (0.2 ... 0.4).

Thus, the development of analytical models for the receipt of multidimensional shadows of translucent objects for further processing will allow the classification of OM, which will greatly facilitate the work of operators serving introscopes in ASS services, reducing the number of false alarms.

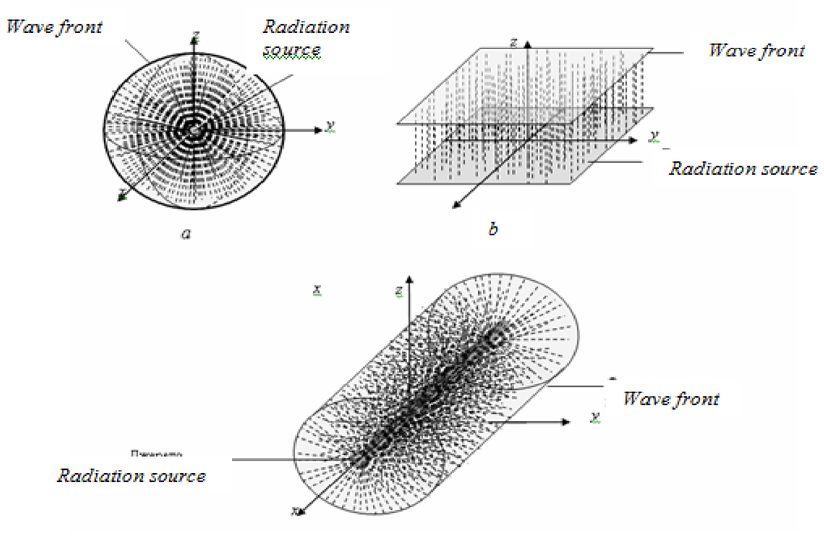
The simulation of the internal structure OM simple and complex forms using the point source of irradiation in the center, as well as with the bias relative to the center, is considered in the works [7]. Spectral analysis of simulated OM in works [8].

Consider visualized three-dimensional manifold irradiated by a primary radiation source. The source can be of three types: point, linear or plane (Fig. 1).

Let a point source be defined as one that produces a spherical wave front. If the point source is centered at the origin of the Cartesian coordinate system, as shown in the Fig. 1a, beams radiated from this source will come from the origin and go in every direction. A wave front in a spherical shape is shown in the Fig. 1a. A plane source of radiation is illustrated in the Fig. 1b. A front of its waves is a plane, emitted rays are parallel with each other, but normal to radiation surface and the front. The Figure 1c shows a linear source of radiation. It has a cylindrical wave front. For the linear source, specified as shown in a three dimensional coordinate system, a wave front's cross section on the plane $Y0Z$ is a circle, a wave front's cross section on the plane $X0Y$ is rectangular. Ideally the linear source of radiation is of a cylindrical shape with a diameter approaching zero and an infinite height.

III. PROBLEM SOLUTION

For mathematical description of the radiation source a model structure shown in the Fig. 2 is introduced.



c

Fig. 1. Types of the primary radiation sources: (a) is a point source; (b) is a plane source; (c) is a linear source

The model of the three-dimensional manifold in configuration space involves several stages of mathematical description. Firstly the radiation source has to be described, parameters of the OM are the next.

For mathematical description of the radiation source a model structure shown in the Fig. 2 is introduced.

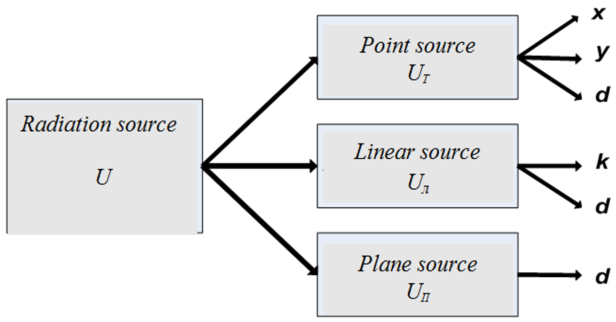


Fig. 2. A Structure of radiation source modeling

Mathematical formulation for general description of the radiation source is the following:

$$\vec{U} = (x, y,\ k,\ b_0)\,. \tag{1}$$

For point, linear and plane sources description the following will be used:

$$U{:}\vec{U} = (x, y,\ 0,\ 0,\ b_0)\,, \tag{2}$$

$$U{:}\vec{U} = (0,\ 0,\ k,\ b_0,\ d)\,, \tag{3}$$

$$U{:}\vec{U} = (0, 0,\ 0,\ 0,\ d)\,, \tag{4}$$

where x, y is a height of the point coordinates on a radiation plane; d is a distance to the OM; k is a slope of the straight line, b_0 is the fixed factor of the straight line.

For mathematical description of the OM different parameters should be taken into account. Among these are a form, geometry, physical parameters, level angle relative to the plane of receivers (detectors) etc.

The object monitored is an object of regular or irregular shape. Objects of irregular shapes can be considered as a matter of combination of regular shaped objects. The parameters of the OM are introduced in the Fig. 3.

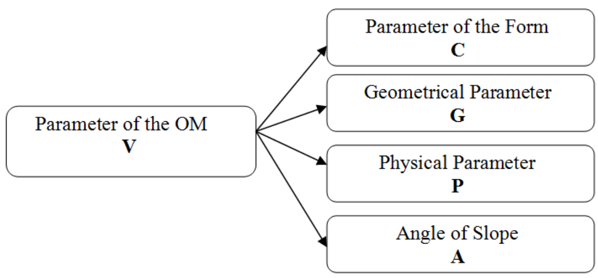


Fig. 3. A Structure of OM's parameters modeling

Mathematical description of the OM's parameters is given by expression:

$$\vec{V} = f(\ \vec{C},\ \vec{G},\ \vec{P},\ \vec{A}\ )\,, \tag{5}$$

where $\vec{C}$ is the parameter of the form that determines a complexity of an object

$$\vec{C} = f(a,b)\,, \tag{6}$$

where a, for an object of regular shape; b, for an object of irregular shape; $\vec{G}$ is the geometrical parameter that determines measurements of OM; $\vec{P}$

is the physical parameter (consistence, extinction, absorption coefficient, dispersion coefficient)

$$\overrightarrow{P} = \mu\lambda, \tag{7}$$

$$\mu\lambda = \alpha\lambda + m\lambda + \pi\lambda, \tag{8}$$

where $\alpha\lambda$ is the spectral absorption coefficient; $m\lambda$ is the spectral dispersion coefficient; $\pi\lambda$ is the spectral absorption coefficient with electron-positron pairs.

$$\overrightarrow{\mathrm{A}} = \{\alpha, \beta, \gamma\} \tag{9}$$

where $\{\alpha, \beta, \gamma\}$ are angles relative to the axes of the coordinate system x, y, z.

Therefore introscope system input receives a signal as a function $f(\overrightarrow{U}, \overrightarrow{V})$.

To determine a position of the radiation source, the OM and the screen with a point source it is appropriate to use cylindrical coordinate system applied to the Fig. 4. Internal visualization of the OM with a simple form, in this case a rectangular, designed with point source is shown in the Fig. 5.

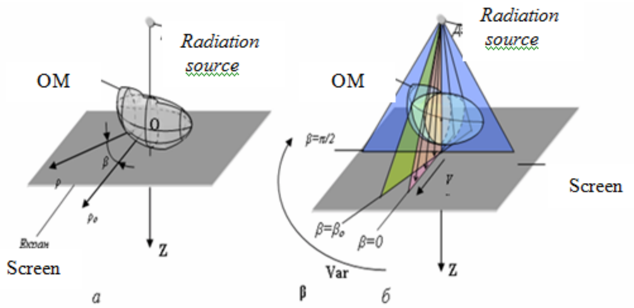


Fig. 4. Object monitored scanning: (a) is the setting a cylindrical coordinate system; (b) is the setting a scanning beam position

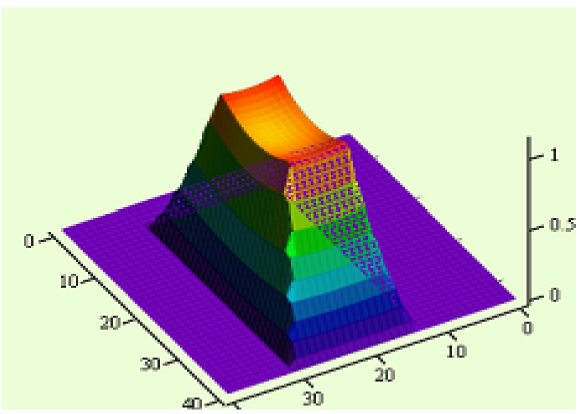


Fig. 5. Object monitored inner structure imaging

Methods of analytical modelling of the OM with different shapes, geometrical dimension, foreshortening, substance and appropriate extinction coefficients, used to develop procedures for identifying dangerous objects under security supervision of passengers and baggage, allow to image OM inner structure.

VII. Conclusion

To provide aircraft tracking based on measurement data of Multilateration surveillance system the algorithm of optimal stochastic filtering was synthesized.

The algorithm presented in this article is based on the recurrent linearized Kalman filter, and it can be used for aircraft tracking in automated air traffic control systems having multiposition surveillance system MLAT.

Special attention was paid to the analytical derivation of a priori initial values of the elements of the covariance matrix in Kalman filter.

Computer simulation has demonstrated a significant performance improvement in multilateration aircraft surveillance and tracking using stochastic filtering techniques.

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В. І. Чепіженко, Л. Ю. Терещенко. Метод оптичного зображення внутрішньої структури тривимірного багатовиду

Розглянуто аналітичні моделі отримання оптичного зображення внутрішньої структури об’єктів контролю та на їх основі проаналізовано спотворення, які набувають зображення в залежності від параметрів системи візуалізації та типу джерел випромінювання. Метод, розроблений для оптичного зображення внутрішньої структури тривимірного багатовиду (далі «контрольований об’єкт»), дозволяє отримати тіні тривимірного багатовиду.

Ключевые слова: рентген; служба авіаційної безпеки; оптичне зображення; тінь тривимірного багатовиду.

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В. И. Чепиженко, Л. Ю. Терещенко. Метод оптического изображения внутренней структуры трехмерного многообразия

Рассмотрены аналитические модели получения оптического изображения внутренней структуры объектов контроля и на их основе проанализированы искажения, которые приобретают изображения в зависимости от параметров системы визуализации и типа источников излучения. Метод, разработанный для оптического изображения внутренней структуры трехмерного многообразия (далее «контролируемый объект»), позволяет получить тени трехмерного многообразия.

Ключевые слова: рентген; служба авиационной безопасности; оптическое изображение; тень трехмерного многообразия.

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