

# The Development of Radiophysical Methods for the Polarization (Including Stereo) Images Acquisition in Millimeter Range Related to Problems of Objects Recognition, Navigation, Emergency Management, Security Control and Antiterroristic Activity

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**Abstract:** Arrangements and directions of investigations for application of polarization microwave imaging of different objects in millimeter wave range for purpose of object recognition, emergency management, security control, etc. are discussed. Preliminary experimental results in dual polarization imaging at frequency 94 GHz are presented. Possibilities to increase spatial resolution of the images in the millimeter band at the base of a priori information about spatial spectrum of investigated objects are discussed. Methods of object recognition from polarization microwave stereo images are under consideration..

**Keywords:** Polarization (including stereo) images acquisition, millimeter, increasing spatial resolution, microwave radiometry

## 1. Introduction

The studies and development of Radiovision systems are conducted over the last years in many countries. These studies are very significant for solution of problems dealing with objects recognition, navigation, emergency management, security control, especially under the threat of terrorism.

Radiowave imaging is very perspective for MM wavelength range since combinations between realizable image characteristics (for example, spatial resolution) and radio receiving system size are optimal just for these wavelengths.

Unlike visible and infrared ranges images for MM wavelengths can be acquired for the conditions of visibility absence (mist/fog, smoke, dust) and for objects concealed beneath clothes. In MM range it is possible not only to register image but to receive information about form and materials of object surface composed.

Available experience, new scientific and engineering ideas and practical results of IRE RAS team are used for achievement of the goal of this work.

### **The main objectives of the work are:**

firstly, development of the method for the polarization (including stereo) images acquisition in millimeter range for objects detection, observation and identification under bad weather conditions, and for unauthorized objects concealed beneath clothes of potential terrorists,

secondly, design of the hardware including receiving-registering-generating apparatus; and mathematical methods for acquisition of the polarization (including stereo) images of extra spatial resolution and for detected objects recognition,

thirdly, development of the more proper precise radiophysical models for the generation and transfer of radiation for polarization images registration in MM wavelength range (for different conitions of measurements).

The research group has basic equipment to fulfill these objectives.

### **This work accomplishment includes the following phases:**

- 1) Elaboration of theoretical basis for physics of the generation and transfer of radiation.
- 2) Computational modeling of radioimages generation, objects detection and recognition.
- 3) Development of stand multichannel passive scanning system for the polarization (including stereo) images acquisition in millimeter range.
- 4) Designing and creation of active stand system for radiovision in conditions of spatially incoherent object illumination.
- 5) Conducting experimental studies of different natural media objects mm images.
- 6) Acquired images quality enhancement using a priori information.
- 7) Identification of shape and materials of external surface of observed object.

8) Elaboration of recommendations to apparatus design.

**Expected Results and Their Application:**

1) Creation of experimental resources (scanning polarization radiometric and matrix receiving system, special generators of spatially-incoherent emission (scanning polarization radiometric and matrix receiving system, special generators of spatially-incoherent emission for observed objects illumination), preparation of test sites and objects and system of stereo images visualization.

2) Development of theoretical models for radiation transfer in case of passive and active object illumination and the interaction of radiation with different mediums taking into account dielectric characteristics, volume heterogeneities, moisture and roughness of its surfaces.

3) Elaboration and development of measurements techniques and calibration procedures for measuring complexes.

4) Creation and development of techniques, algorithms and software.

5) Computational modeling of MM range radio thermal image synthesis process.

6) Polarization and polarization difference images of different objects acquisition in passive and active regimes using stereovision and methods.

7) Objects detection and recognition using a priori information and neural networks multiway courseware.

8) Elaboration of recommendations for structure and technical characteristics of passive and active systems for in-real-time detection and recognition of objects.

**2. Preliminary Results of Investigations:**

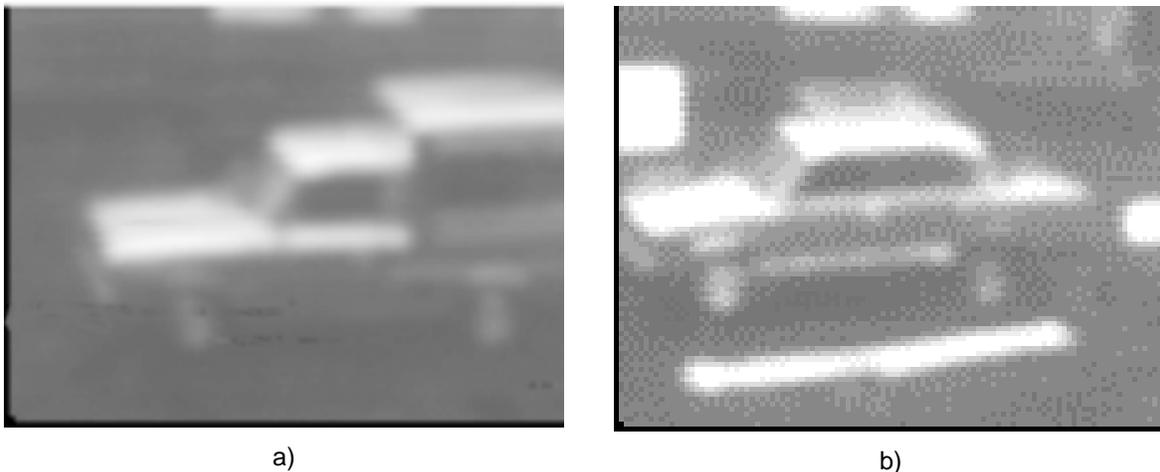
**1) Experimental Microwave Imaging of Various Objects**

For experimental investigations it was used a specially designed scanning microwave radiometric system. Microwave radiometer is superheterodyne type with central frequency 94 GHz, bandwidth 4 GHz, fluctuation sensitivity 0.1 K and switching input polarizations (horizontal and vertical) [1]. Antenna is made as zone lens from polystyrene with diameter 0.6 m and focal length 1 m. It is possible to change the gap between lens and feeding horn in order to focus the antenna system at distance 20-100 m. Radiometric system is controlled by the computer, which also used as data acquisition device. The computer program allows to realize different scanning modes by the antenna movement as manually as in automatic regime.

In order to investigate the possibilities of microwave imaging by the designed system and to understand the main problems in their formation some test technical objects were used (cars “Moskvich”, “VAZ”, “UAZ”, caterpillar and excavator). Distance to this objects were about 20 m.

As an example, the polarization microwave images of the two different cars are shown in Fig. 1.

Microwave images include enough number of structure elements to identify objects clearly. The analysis of experimental microwave images shows that their quality is comparable with thermal images obtained in the infrared range.



**Fig. 1. Microwave images at the wavelength of 3 mm, a) car “Moskvich” and b) car “VAZ with luggage rack on the top.**

**2) Polarization Features of Microwave Images of Different Objects and the Earth Surface.**

The emissivity coefficient of material is determined by its dielectric properties, type of the polarization and falling angle. Consequently using of two orthogonal polarizations enriches information content of the microwave image. It

allows, for example, to reveal dielectric and geometric properties of the objects and also to identify under some conditions the concrete and water surfaces.

The examples of polarization images are shown in the Fig. 2. Regions where vertical component is higher than horizontal one are indicated by the blue color and opposite situation by the red color. This car "UAZ" with tarpaulin roof was placed ahead of the metal sheet and the car door was illuminated by another metal sheet not visible in the image.

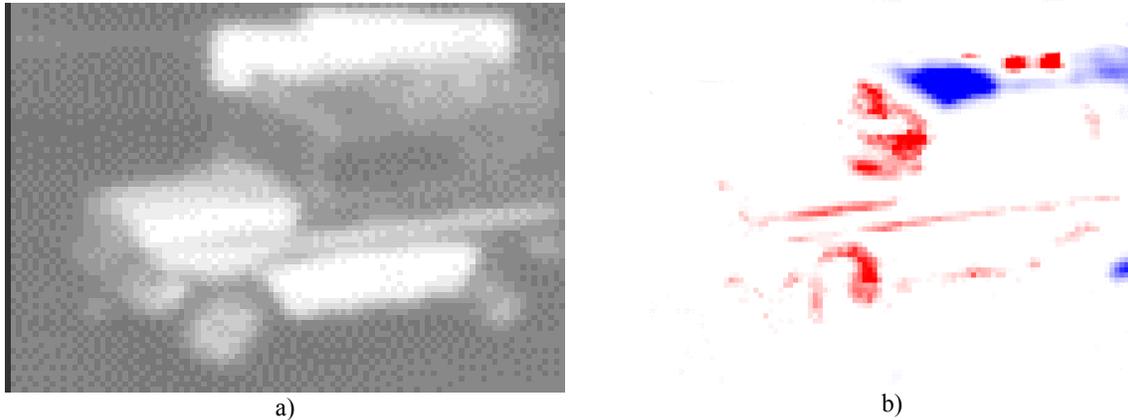


Fig. 2. Microwave images of the car "UAZ" at wavelength of 3 mm, a) horizontal polarization, b) polarization difference.

### 3) Space Incoherent Illumination of the Objects

Active microwave (radar) image of the objects represents an ensemble of bright points. Bright points are caused by specular reflection of the falling wave and interference interaction of spatial coherent radiation scattered by different parts of the object. In general, radar image of the object (in contradiction to passive microwave one) doesn't resemble optical image and doesn't allow to identify the object. Importance of this problem increases in case of objects detection under the clothes.

The problem can be solved by using of spatial incoherent sources generating stochastic fields with transverse correlation radius comparable with wavelength. Now such spatial incoherent sources are under development.

### 4) Image Processing

Variety of methods for automated image processing is now well-organized, subdivided into separate classes, which have been and keep being actively studied. However, it is the lack of practical approaches to estimate and compare the effectiveness of this or that known method in every particular case that makes the researcher sort out and test numerous algorithms to solve the problem. Hence, the significant attention should be focused to the preliminary qualitative analysis of the experimental data in order to discriminate those data features, which will allow realizing the optimal scheme of data processing.

The preliminary analysis of first experimental data has been carried out, which determines the features significant for the further development of methods for automated processing of radio-images. These features guide the research in several basic directions, briefly described below, namely:

- 1) Image recovering employing apparatus function
- 2) Usage of polarization contrasts
- 3) Implementing stereovision

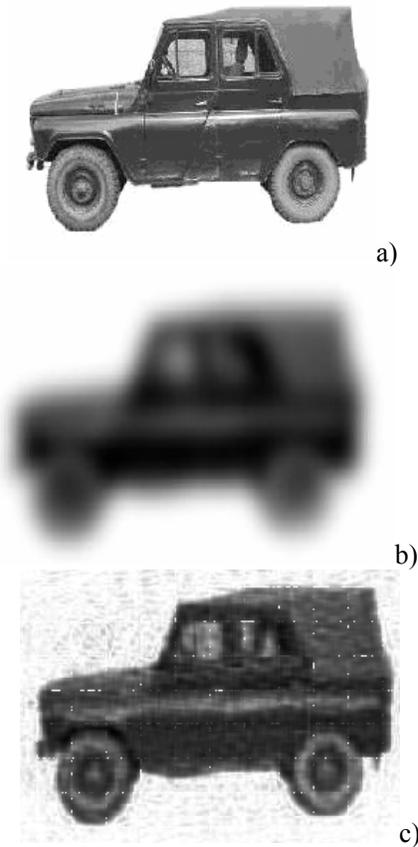
### 5. Digital Simulation of Microwave Image Reconstruction

Traditional and used till now is a method of image reconstruction based on a two dimensional Fourier transform. The main idea of it is in supposition that antenna influence in image distortion may be interpreted as modulation of spatial spectrum of original image. So, if you know the spectrum of distorted image and the modulation transform function of antenna it is possible to reconstruct the spectrum of original image and consequently the original image. The main problem in application of this method is that in a high frequency region of the spectrum the absolute values of spectral components may be close to zero and dividing of them causes a false intensities, which may exceed the real values in many times. It causes the essential distortion of the reconstructed image and in some cases this errors may fully destroy it.

Usually it is used the simplest method of filtration by cutting the spectrum in high spatial frequencies. But this method is too rough because with the false values it removes the important spectral components which have information about the image details and consequently reduces the spatial resolution of the reconstructed image. It is important to find optimal filtration algorithm adapted to our case. For this purpose a new algorithm for spatial spectrum filtration before it inversion is proposed. It is based on taking into account the expected spectral intensities and their statistical characteristics of the investigated objects. Knowledge of such statistical characteristics allows to replace the false spectral intensities to the mean expected ones.

To estimate the efficiency of the proposed method the digital simulation was made. As a basic image it was used an optical photo of the car. This image was smoothed to simulate distortion analogous to influence of the microwave radiometer antenna. Reconstruction was made with different values of uncertainty in knowledge of the expected spatial spectrum of the object.

An example of digital simulation of the proposed method is presented in Fig. 3. It shows a promising result of reconstruction.



**Fig. 3. An example of digital simulation of the proposed method; a) photo of the car, b) smoothed image simulating distortion analogous to influence of the microwave radiometer antenna, c) result of reconstruction.**

## **6. Stereovision**

The main advantage of stereovision is in the possibility to a three dimensional perception and estimation of distance to the object. Stereovision in MM wave band may be realized by two identical receivers placed in two different points or by the one receiver when there is a relative movement of the antenna and object. We obtained some microwave stereo images of technical object which can be viewed on computer monitor with use the special switching glasses.

Stereovision may provide an additional information about objects, such as cross and along size ratio, distance to the object and other.

Some stereo pairs of the microwave images were registered in our experiments. Special subsystem allows displaying them on the computer monitor.

It was discovered that stereo effect exists even for highly smoothed images and lower (in comparison to optics) clearness of image does not put obstacle for stereoradiovision.

Special software for the development of techniques for microwave image analysis in multidimensional space of parameters including polarization contrasts and stereo effects was developed. In addition, some numerical experiments for microwave imaging of different objects were made.

The variety of microwave images of the same or several different objects with different predefined texture over undefined or predefined background were simulated in numeric experiment on object recognition.

Quality of object detection and recognition may be enhanced by proper selection and use of the most effective parameters for the characterization of the investigated objects. The factor analysis algorithms were used for estimation of efficiency of parameter selection. The neural network techniques were applied as an independent test for the quality of developed data processing algorithms [7, 8]. Developed software allows incorporating "hybrid" schemes which may include different number of data processing steps and include as strictly analytically based techniques (different algorithms of digital filtration, ...) as methods developed in artificial intelligence investigations (classification, recognition, neural network algorithms, and fuzzy logic algorithms) [8,9].

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