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Natural Environments Imitators for Data Protection Systems against Leakage through Optical Channels

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Abstract — **The aim of work was to develop natural environments imitators for data protection systems against leakage through optical channels. The article describes the investigation of the spectral and polarization characteristics of green leaves of plants, sand and peat. Spectral and polarization characteristics was studied using goniometric measuring unit G-5 and a spectropolarimeter Gemma MC-09 with resolution of at least 1.5 nm and a polarization attachment allowing to register spectral radiance of the samples at various positions of the polaroid axis. The spectral and polarization characteristics provided by the samples of different groups in the band of 370–1070 nm were obtained.**

Data protection, information leakage, optical channels, visible and near-infrared waves, spectral brightness coefficient, polarization.

I. INTRODUCTION

Nowadays the urgent problem is to reduce the visibility of objects used for military purposes, due to the rapid development of sensors and systems applied for remote sensing of the Earth's surface, which are placed on air and space vehicles. The use of aerosols and materials with different elemental composition and low spectral radiance factor forms main principles of its solution.

One of the perspective directions of materials creation with required properties is the formation of composite structures with elements whose dimensions are on the order of a few nanometers, which allows changing macroscopic properties of the material not only by changing the concentration of added components, as well as by varying the particles size.

Such materials should have spectral polarization characteristics similar to backgrounds, where the military objects are placed. This can be achieved by using different organic inclusions, as well as water-based fillers, which allow simulating the surrounding environment.

This research work is devoted to the creation of new composite materials used for electromagnetic radiation shields, as well as the determination of their spectral and polarization properties and the development of recommendations for their application.

In order to address this issue, we investigated spectral and polarization properties of water-containing materials which are known as effective absorbers of electromagnetic radiation. Widely available natural materials such as green leaves of plants, sand as well as peat were used as experimental samples.

II. EXPERIMENT

A. Preparation of samples

Analysis of the spectral and polarization properties of vegetation plays an important role. The relevance of these studies is determined by the need to reduce the visibility of objects on vegetation backgrounds, and in order to get minimum brightness and polarization contrasts of developed materials it is necessary to know spectral and polarization characteristics of vegetation backgrounds. Reduction of visibility ground objects, which are located on different backgrounds, is a topical issue at present moment. Thus, a material that reduces the visibility should have spectral and polarization properties similar to those of the underlying surface.

The experimental samples were prepared using green leaves of plants, peat, sand, silica gel powder and ground laurel leaf, fixed in silicon. Green leaf of a house plant geranium was used as a test sample. Received spectral and polarization properties of a geranium leaf are typical for all green leafy plants [1]. Peat was fixed in silicon which was used as a binder. Separate components of the synthesized material were thoroughly mixed in equal proportions to form a homogeneous mass. The uniformity of the distribution of peat in the binder was checked visually. The mass obtained was formed into sheets and dried at room temperatures. Sand was selected as a main component used for making a camouflage material. It was fixed in silicon which was used as a binder. Sand ensures visibility reduction of surface facilities which are located at gaunt landscape and sandy backgrounds. Separate components of the synthesized material were thoroughly mixed in equal proportions to form a homogeneous mass. The uniformity of the distribution of sand in the binder was checked visually. The mass obtained was formed into sheets and dried at room temperatures.

The most important task in creating absorbing materials is to expand the working range of the wavelengths. Taking into

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account the development of modern detecting devices, it is expedient to develop high efficient absorbing materials in both visible and near-infrared regions of the spectra and radio frequency range. Silica gel is a promising material for producing radio frequency absorbers. Silica gel is widely used in various spheres of human activity and is able to absorb moisture from the air. In the "dry" form it contains up to 20–30% water, depending on environmental conditions where it is placed. Water is an efficient absorber of electromagnetic radiation in a wide range of wavelengths, in accordance with this, the use of such material is acceptable. The investigated sample contains sand and silica gel powder in equal parts, fixed in the silicon. These components were thoroughly mixed to form a homogeneous mass. The uniformity of the distribution of the components in the binder was checked visually. The mass obtained was formed into sheets and dried at room temperatures. Sample made of ground laurel leaf, fixed in silicon was used to simulate the flora backgrounds. These components were thoroughly mixed to form a homogeneous mass. The uniformity of the distribution of the components in the binder was checked visually. The mass obtained was formed into sheets and dried at room temperatures.

B. *Measurements*

Spectral radiance is the ratio limit of radiance corresponding to narrow range of the spectrum, to the width of the range, (W/(cm^2·mm·cp)). To investigate the created samples of materials in visible and near infra-red ranges of wavelength 370–1070 nm we used a goniometric measuring unit G-5 and a spectropolarimeter Gemma MC-09 with resolution of at least 1.5 nm and a polarization attachment allowing to register spectral radiance of the samples at various positions of the polaroid axis [2]. Power spectral density limit of the ratio of brightness is the brightness of the energy corresponding to a narrow portion of the spectrum, the width of the plot.

Block diagram of the measuring unit is shown at Fig. 1, where 1 — goniometer G-5; 2 — MC-09; 3 — IBM-computer; 4 — polarizing filter; 5 — analyte sample; 6 — diaphragm; 7 — collimator; 8 — cooling system; 9 — quartz-halogen bulb KGM-250; 10 — power supply module SNP-40. A feed of the lighting lamp 9 was stabilized and controlled, that's why the brightness of the illumination source didn't change during the measurement. The spectropolarimeter *2* registered reflected spectral radiance from the samples 5 in a range of wavelength 370–1070 nm. The obtained data were used to calculate the spectral brightness coefficient (SBC).

To analyze the spectrum of reflection and calculation SBC of the investigated samples, spectrum of reflection for the test sample with uniform dispersion under conditions of measurements similar to conditions for the investigated sample has been received. The spectral brightness coefficient was calculated as the relation spectral radiance of the investigated material to one of the material with uniform indication of dispersion. Taking into account the spectral sensitivity of the test setup receiver and the spectral characteristics of the light source to eliminate the noise component in the reflection spectra, SBC values obtained in the wavelength range of 440–1040 nm were analyzed.

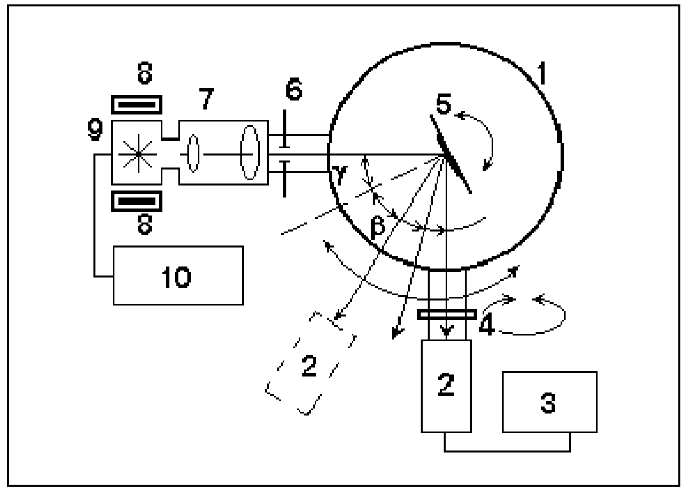

Figure 1. Block diagram of goniometric measuring unit,

III. RESULTS AND DISCUSSION

Maximum spectral radiance factor of geranium green leaf was observed at λ=540 nm, due to the presence of carotenoids in the leaf. Further, the spectral characteristic is monotonically decreasing and its minimum is observed at the wavelength 640 nm, which corresponds to the chlorophyll absorption band (the biotic minimum). The pronounced increase in the spectral radiance factor in the visible region of the spectrum (640–700 nm) changes to a uniform characteristic in the near IR range (700–940 nm), after which the spectral radiance the spectral radiance factor monotonically decreases. These parameters are preserved when changing the phase angle from 45 to 135°. The high reflectance of geranium leaf in the range λ=700–940 nm is characterized by absence of absorption bands from plant pigments.

Polarization property of the geranium leaf has its maximum at a wavelength of 535 nm and minimum at a wavelength of 580 nm (Fig. 2) [3]. Transparency of leaf pigments in the near-infrared range is the reason for polarization absence of the reflected wave in this wavelength range. Angle of the preferred polarization for the investigated sample is 0°.

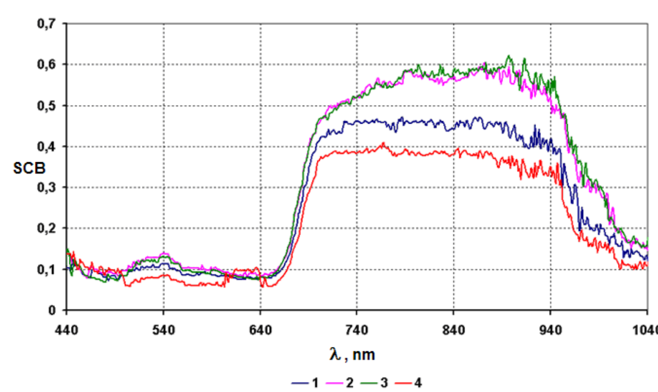

Figure 2. Spectral properties of geranium leaf with polarization angle of the reflected wave equals to 90° and the following observation angles: 1 — β=0°, 2 — β=20°, 3 — β=60°, 4 — β=90°

Spectral characteristics of the peat based composite material have a resonant character (Fig. 3). In the visible wavelength range there is an increase of spectral radiance factor from 0.2–0.3 to 0.35–0.4 with entrance to the 'plateau' in the near infrared wavelength range and the value of spectral radiance factor reaches 0.6. Spectral characteristics of the synthesized material are similar to the spectral characteristics of vegetation. A distinctive feature of the received characteristics is the lack of biotic minimum in chlorophyll absorption band (635–680 nm) and a maximum at the wavelength range of 530–575 nm due to the interaction of light with carotenoids.

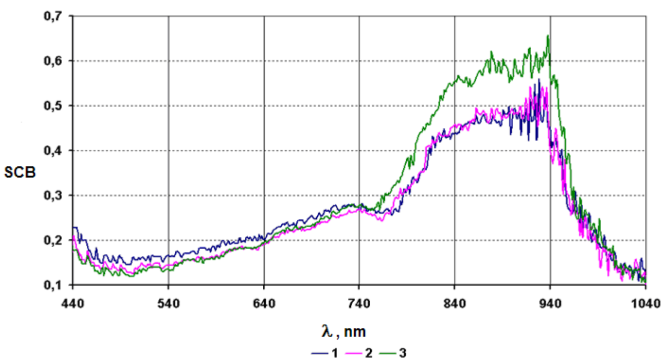

Figure 3. Spectral properties of a peat based composite material with polarization angle of the reflected wave equals to 90° and the following observation angles: 1 — β=0°, 2 — β=20°, 3 — β=45°

Spectral radiance factor of the sand based composite material did not exceed 0.3 (Fig. 4), which corresponds to spectral radiance factor values for such backgrounds as sand. It was found out that the synthesized material at the wavelength range of 440–1040 nm does not polarize the incident radiance from the light source, and scatters it diffusely. The degree of polarization in the studied wavelength range does not exceed 0.18. Spectral radiance factor depends on the viewing angle, and this parameter is decreasing with an increase of the viewing angle from 45° to 90°.

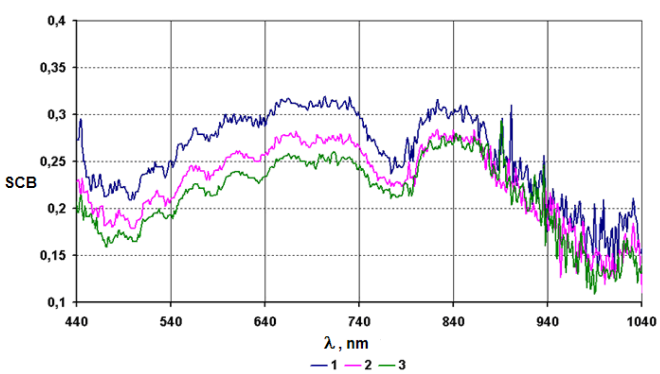

Figure 4. Spectral properties of a sand based composite material with polarization angle of the reflected wave equals to 90° and the following observation angles: 1 — β=0°, 2 — β=20°, 3 — β=45°

It was shown that the synthesized material contains water, which is confirmed by the well-defined minimum on spectral characteristics at the reflected wavelength of 770 nm. Reduction of spectral radiance factor from 0.3 to 0.25 indicates small amount of water, containing in the binder. At the wavelength range of 860–1040 nm a decrease of spectral radiance factor from 0.3 to 0.15 is observed. It happens due to the penetration of the incident wave into the material and its dispersion inside the material due to multiple reflections.

The spectral properties of the composite materials based on sand and silica gel powder are similar to the spectral characteristics of the sand-based composite materials (Fig. 5).

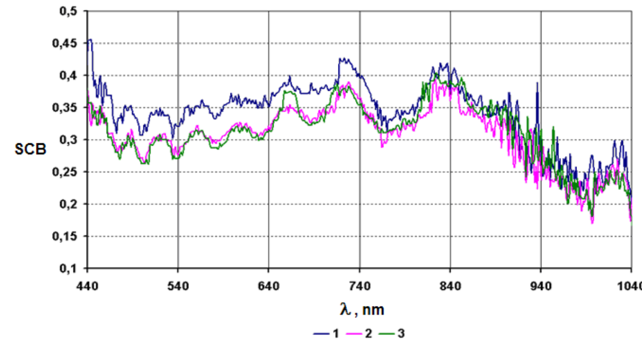

Figure 5. Spectral properties of a composite material based on sand and silica gel powder with polarization angle of the reflected wave equals to 45° and the following observation angles: 1 — β=0°, 2 — β=20°, 3 — β=45°

Reduction of spectral radiance factor at a wavelength of 770 nm is characterized by the presence of water in the sample. Besides, in contrast to the previous material, this material contains more water, which results in increase of spectral radiance factor at a wavelength of 770 nm from 0.34 (composite material without silica gel) to 0,44 (composite material with silica gel). Moisture increasing in the synthesized material occurs due to the adsorbed moisture from the air by silica gel. It is established that the addition of silica does not significantly increase spectral radiance factor of the synthesized material from 0.32 to 0.44 in comparison with the same material which does not contain silica gel (Fig. 5).

The synthesized material does not polarize the reflected wave, as the degree of polarization does not exceed 0.11 (Fig. 6) and diffuse component dominates in the reflected emission.

Spectral characteristics of the synthesized material (Fig. 7–8) are similar to the spectral characteristics of vegetation (Fig. 2). It was established that that in the spectrum of the synthesized material, there is a maximum due to carotenoids at the reflected wavelength 600 nm, while a "biotic" minimum is observed at λ=640 nm. This suggests that the pigments are retained in the leaf during drying. The presence of water in the synthesized material, due to the use of silicone as the binder, was determined by the minimum spectral radiance factor at λ=770 nm. In the range λ=840–940 nm, the value of the spectral radiance factor goes to goes to a "plateau" and is 0.65–0.70, which is also typical for vegetation. The spectral radiance factors at the indicated wavelengths for the synthesized materials are practically independent of the viewing angle, and are insignificantly higher (by 0.10–0.15) than the spectral radiance factor for vegetation.

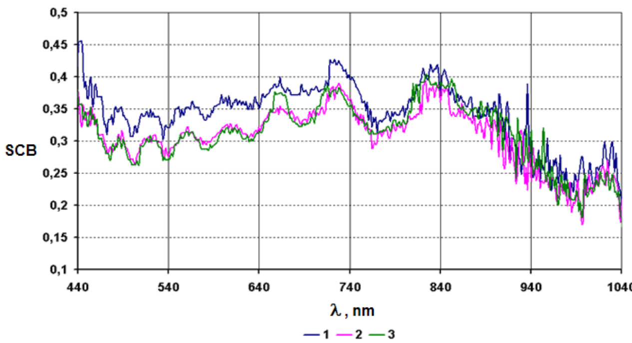

Figure 6. Polarization characteristics of a composite material based on sand and silica gel powder with the following observation angles: 1 — β=0°, 2 — β=20°, 3 — β=45°

The polarization characteristic for the material obtained is substantially different from the analogous characteristic for vegetation. Absence of a cuticle of the dried laurel leaf leads to the predominance of diffuse component of reflected radiation, and the degree of polarization does not exceed 0.2.

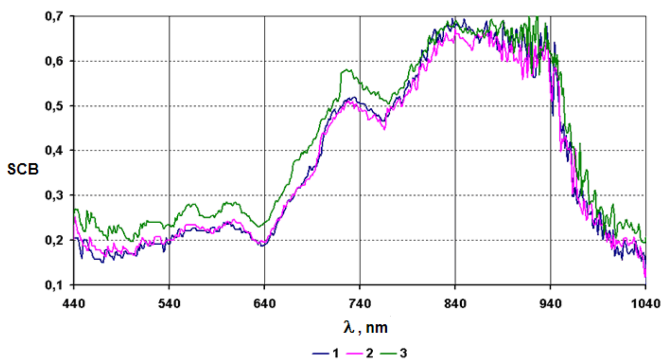

Figure 7. Spectral properties of vegetation based composite material with polarization angle of the reflected wave equals to 0° and the following observation angles: 1 — β=0°, 2 — β=20°, 3 — β=45°

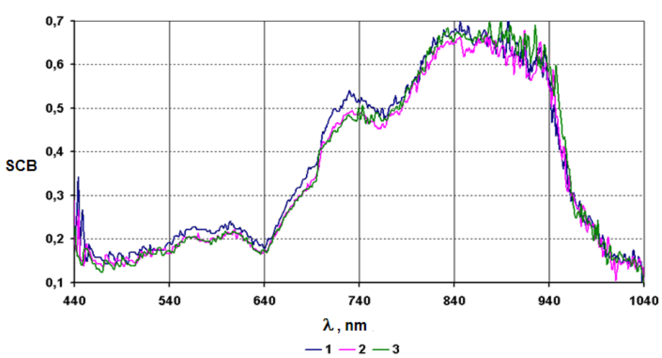

Figure 8. Spectral properties of vegetation based composite material with polarization angle of the reflected wave equals to 90° and the following observation angles: 1 — β=0°, 2 — β=20°, 3 — β=45°

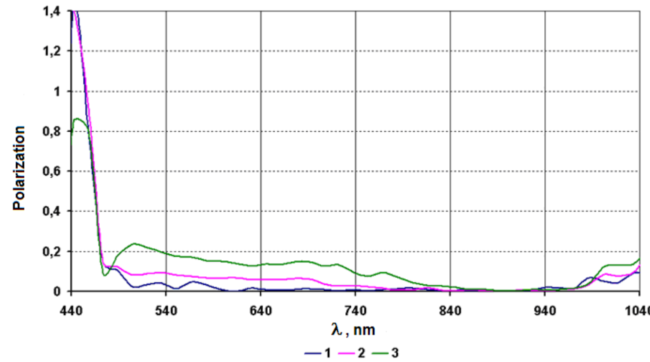

Figure 9. Polarization characteristics of a composite material based on sand and silica gel powder with the following observation angles: 1 — β=0°, 2 — β=20°, 3 — β=45°

Thus, spectral characteristics of the synthesized material allow simulating natural plant environment.

IV. Conclusions

The electromagnetic radiation shields on the basis of green leaves, peat, sand and silica gel to mask military objects in the optical range are proposed. These shields are characterized by a reasonable price/performance ratio.

The interaction of radiation in the optical range with peat-based soil containing materials embodied in silicon, leads to the change of polarization degree from 0.2 to 0.35 in the range of 470–800 nm with maximum spectral radiance factor which is equal to 0.6 in the range of 840–940 nm. Spectral radiance factor of peat-based composites is comparable with spectral radiance factor of different soils.

It was found out that the interaction of electromagnetic radiation in the optical range with sand containing materials embodied in silicon, leads to the depolarization of the reflected wave (polarization degree <0.1) with spectral radiance factor of 0.15–0.3 in the range of 440–1040 nm. Spectral radiance factor of sand-based composites is comparable with spectral radiance factor of sandy backgrounds.

Also, the interaction of electromagnetic radiation in the optical range with powdery materials based on dry leaves (laurel) embodied in silicon, leads to the depolarization of the reflected wave (polarization degree <0.2) with spectral radiance factor of 0.15–0.25 in the range of 440–650 nm. Spectral radiance factor of composites based on dry leaves is comparable with radiance factor of vegetation backgrounds.

References

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