# Production and experimental study of a weakly reflecting absorbing metamaterial based on planar spirals in the microwave range

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## Abstract
The work aims to produce and experimentally study an absorbing and at the same time weakly reflecting metamaterial consisting of conducting planar two-turn spirals on a dielectric substrate. Such a pre-designed metamaterial is manufactured within the framework of printed circuit board technologies.

## Introduction
In articles [1, 2], metamaterials with 3D elements of a special configuration, commonly called planar spirals, were modeled based on the calculation method described in [3]. In contrast to article [1], article [2] designed a metamaterial with a reduced resonant frequency close to 2.5 GHz. The results obtained in article [2] during modeling demonstrate the optimality of a separate planar spiral and the metamaterial as a whole for the parameters found. These simulation results confirmed the high absorbing properties of such a structure and, at the same time, its weak reflecting properties near the resonant frequency (2.5 GHz) and for higher frequencies.

## Results of the experiment
Based on the modeling results carried out in article [2], we made an experimental sample of a weakly reflecting absorbing metamaterial consisting of planar spirals on a substrate (Fig.1), with which experimental studies were conducted. The sample material is double-sided FR4 fiberglass with a thickness of 2.93 mm with a copper foil with a thickness of 35 microns.
Article [2] performed the simulation only for the normal incidence of waves. This paper demonstrates experimental studies with an oblique incidence of waves, while the angle of incidence of waves reached 30 degrees. We measured the complex transmission and reflection coefficients in an anechoic chamber for the experimental characterization of the manufactured metasurface sample.
The experimental research was performed in the frequency range of 2 – 3 GHz in the anechoic chamber of Francisk Skorina Gomel State University, Belarus. The experimental setup for transmission coefficient measurement, as shown in Fig. 2, consists of two linearly polarized broadband horn antennas at a distance of 5 m from each other with the metasurface sample between them. The sample was installed into a window in the wall covered with microwave pyramidal absorbers. The antenna was connected to the first port of a vector network analyzer (VNA) by a 50 Ohm coaxial cable. The transmitted wave was detected by a receive horn antenna connected to the second port of the VNA, and S-parameters were stored.
The results of experimental studies are shown in Fig. 3 and 4.

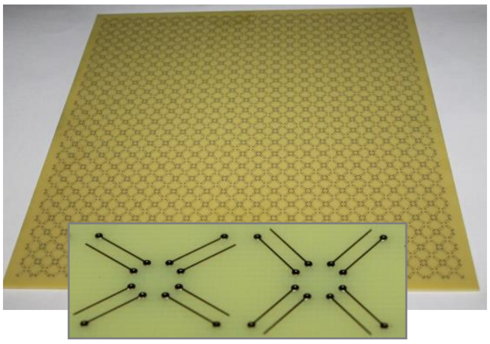

*Fig. 1. Photo of a manufactured weakly reflecting absorbing metamaterial in the microwave range and its element on an enlarged scale*

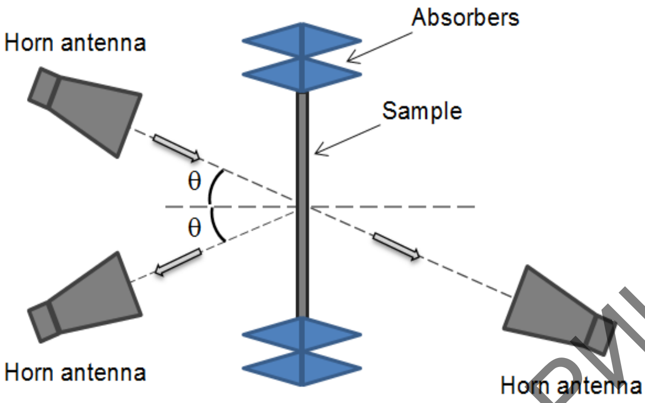


*Fig. 2. Experimental setups for measurements of transmission and reflection coefficients*

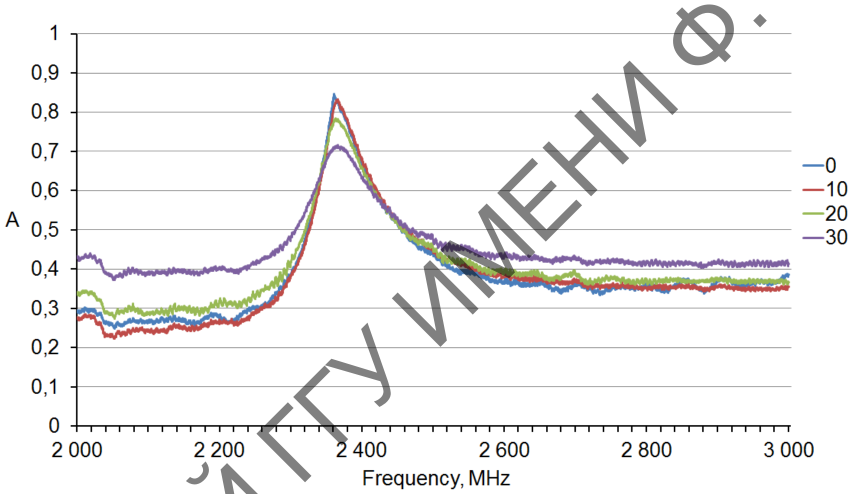


*Fig. 3. Frequency dependence of the absorption coefficient at different incidence angles of waves (θ)*

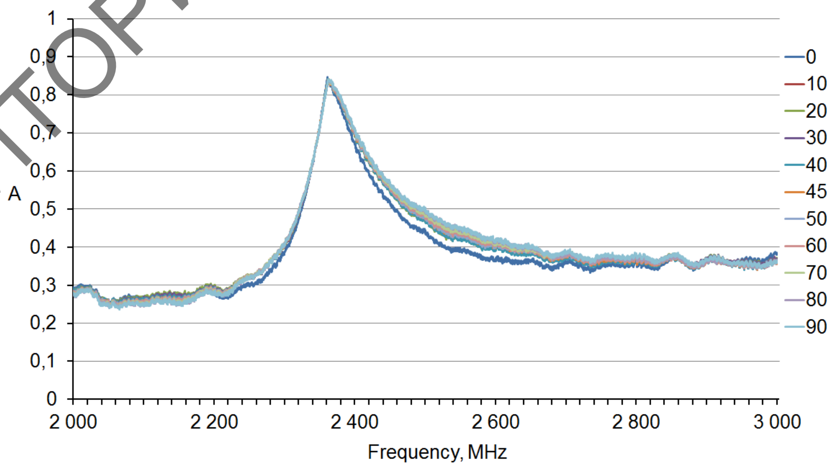


*Fig. 4. Frequency dependence of the absorption coefficient at different azimuth angle values on the polarization of the emitting and receiving antennas at normal incidence (the receiving planes of both antennas are rotated by the same azimuth angle relative to the vertical)*

## Conclusions

The frequency dependence of the absorption coefficient at different incidence angles of the wave on a weakly reflecting metamaterial consisting of conducting planar spirals on a dielectric substrate has been investigated. Good angular stability of the absorbing properties of the sample near the resonant frequency has been shown. When increasing the incidence angle of the wave to 30 degrees, the absorption coefficient of the metamaterial decreased by 15% compared to the normal incidence of the wave (Fig. 3). It has been verified experimentally that the absorbing properties of the metamaterial do not depend on the azimuth of the polarization plane of the incident wave (Fig. 4). Therefore, the manufactured metamaterial is isotropic in the plane of its surface.

As follows from Figures 3 and 4, the experimentally observed resonant absorption frequency is shifted by 0.115 GHz, that is, by 5%, compared with the simulation results. Such a shift in the resonant frequency can be explained by different values of the permittivity for the actual substrate material and the FR4 material considered in the standard software package for modeling.

## References


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