Abstract. The work is devoted to development of the polarizer for terahertz frequency range. Chiral medium was simulated using the software package CST Microwave Studio by the method of Finite-Differences in Frequency Domain. The influence of geometry of chiral unit cell on the polarization of incident plane wave was investigated.

1. Introduction

Nowadays there is a great interest to explorations of materials, which have chirality effect. An object or a structure is chiral if it is distinguishable from its mirror image, it can’t be superposed onto it, at no translation or rotation. Conversely, a mirror image of an achiral object, such as a sphere, cannot be distinguished from the object. It is important to note that it is not just a mathematical model. It exists in real world. DNA molecules, some amino acids, liquid crystals, spiral metallic conductors and other molecules have this feature.

Chiral elements have several interesting properties such as mutual bianisotropy [1], optical activity [2], cross-polarization [3], which makes them promising for various applications. The most important demonstrations of bianisotropy are birefringence and gyrotropy. Each of these effects is caused by the presence of certain parts (недиагональные компоненты) in permittivity and permeability tensors. For birefringence it is symmetrical real part, for gyrotropy it is asymmetric imaginary part. Optical rotation (also known as optical activity or rotary polarization) is the turning of the plane of linearly polarized light relative to the direction of propagation as the light travels through certain materials. Cross-polarization is a phenomenon in which there is a change of reflected wave polarization. It lies in the fact that orthogonally polarized component to incident radiation is appeared in reflected wave.

Nowadays, terahertz (THz) frequency range and THz technology are extremely attractive research fields [4-9]. Because of fast development of biomedicine, necessity of design of THz compact controllable components for time-domain THz spectroscopy/ imaging / tomography, radiation generators has appeared. As well as there is need to develop methods of timely diagnostics and therapy in THz frequency range. One of the most important components for solving these problems are polarizers. Such polarizers can be realized by using chiral media. Single chiral elements such as intersection crosses [2], U-shaped resonators [10], and spiral [11] were considered by others researchers. In addition, there are other ways of using chiral materials in THz frequency range, for example, space-time cloaking devices based on chiral structure cause interest.
2. Description of model

In this paper, the simulation of terahertz polarizer based on optical activity of chiral material in the form of rosettes was considered. Chiral elements of similar form were investigated at microwaves [12]. In THz frequency range, the research of these structures has not been done yet.

The Figure 1 shows the single chiral element. The side of the foursquare, in which the single chiral element placed (d) was 450 μm. Rosette consists of 4 elements. For basic structure that element was a part of the circle with the following dimensions: the external radius (R max) of 150 μm, the internal radius (r min) of 123.3 μm, the thickness (H) of 0.1 μm. The thickness of substrate (PH) was 150 μm. The material of chiral element was perfect electric conductor (PEC). As a substrate the dielectric with permittivity of ε=3.67 was used.

“Unit cell” was chosen as boundary conditions in performed modeling (see Fig.1). The size of mesh cell was $\Delta = d/N = 450/90 = 5$ μm. The simulation of two-dimensional (planar) array of chiral elements is more interesting than a single element due to the fact that it is more applicable in practice. The “Unit cell” boundary condition allows to simulate periodic structure of identical single elements. Primarily, the basic structure of chiral element has been numerically simulated for preliminary estimate of the chiral effect. THz radiation normally incidents on to the object under study, i.e. the emission ports are located so that the wave vector $\vec{k}$ is perpendicular to the plane of chiral element. For the simulation the plane-wave was used for the frequency range of 0.1 - 1 THz. Spectral characteristics of reflection and transmission coefficients can be obtained by using this simulation.

3. Simulation results

As a result of such simulations for single basic chiral structure there were some features in the spectrum – the typical frequencies, where given material shows itself like a chiral material. Therefore, the electric field distribution was simulated for the structure. The results show, that the electric field vector $\vec{E}$ changes the polarization from linear to elliptical at these frequencies. This effect confirms that the structure really shows the chiral properties at the following frequencies: 0.778, 0.865, 0.980 THz. At consideration of the magnetic field vector $\vec{H}$ polarization changes were not revealed.

In order to find the form, which most strongly affects on incident wave, the geometry of structural unit of chiral element was modified.

The first modification as “circle” is a scaled version of the original structure. Here the radius of underlying circle was reduced in 2 times and it has a form of half-circle (see Fig 2b). The second modification as “ellipse” in which the element of rosette has a form of half-ellipse (see Fig 2c). The third modification as “circle-ellipse” is a mixture of the first and the second modifications (see Fig 2d).

The same steps that were used to obtain the spectral characteristics of basic chiral element were performed for various modifications of the basic structure.
Figure 2. Spectra of reflection and transmission coefficients for 4 different chiral structures. (a) Basic structure. (b) “Enlarged circle” structure. (c) “Ellipse” structure. (d) “Circle-ellipse” structure.

On Figure 2, S11 and S22 lines are graphs of reflection coefficient. S11 line means that the radiation emerged from the first port and registered by the first port. S22 line means that the radiation emerged from the second port and registered in the second port. S12 and S21 lines were graphs of transmission...
Coefficient. S12 line means that the radiation emerged from the first port and registered in the second port. S21 line means that the radiation emerged from the second port and registered in the first port.

By comparing the obtained results it can be noted that the best chiral properties were shown by the second modification of the structure “ellipse”. Because for this modification there is the least reflection of 18.5 dB at 0.778 THz among all structures. The rotation of electric field vector after passing through the structure is shown for all modifications (see Fig 3).

![Before the structure](image1)

![Behind basic structure](image2)

![Behind “circle”](image3)

![Behind “ellipse”](image4)

![Behind “circle-ellipse”](image5)

**Figure 3. Rotation of the electric field vector** $\vec{E}$.

The rotation of the electric field vector $\vec{E}$ at 0.778 THz is illustrated in Figure 3 before and behind the structure for four types of chiral media. After passage of the chiral structure the field vector $\vec{E}$ becomes elliptically polarized.

4. Conclusion

Thus, the chiral structure based on rosettes for the THz frequency range was designed and the change of polarization of the electric field $\vec{E}$ from linear to elliptical was observed. The various modifications of the chiral elements such as “circle”, “ellipse” and “circle-ellipse” have been investigated to identify the most effective one. The results of simulation showed that the chirality effect is most strongly manifested for “ellipse” modification. These results may be used for development of a polarizer for time-domain THz spectroscopy/imaging/tomography.

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