PROCEEDINGS OF THE YEREVAN STATE UNIVERSITY

Physical and Mathematical Sciences 2023, **57**(2), p. 62–68

Physics

CIRCULAR POLARIZATION IN A 2D PERIODIC ARTIFICIAL ANISOTROPIC DIELECTRIC MEDIUM

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The phenomenon of polarization rotation in dielectric periodic structures is quite interesting. A similar structure was used in a sample with a 2D artificial periodic structure, where the plane wave propagation method was applied. Anisotropic dielectric constants were obtained, which were used for polarization rotation, and polarization rotation in an anisotropic medium was studied based on the dielectric permittivity of the effective medium. Those relationships, quantities, and parameters depending on the dielectric medium, dielectric permittivity, and 2D periodic structure have been studied and analyzed, which provide control of the degree of anisotropy, i.e. provide a distinction between fast and slow modes, which in turn provide the best polarization rotation per unit length.

https://doi.org/10.46991/PYSU:A/2023.57.2.062

MSC2010: Primary: 74F15; Secondary: 58Z05.

Keywords: anisotropic medium, dielectric periodic structure, dielectric permittivity, circular polarization, navigation, radar.

Introduction. The rapid development of wireless systems has increased the requirements for compact and high-performance antennas. One such antenna characteristic that needs to be achieved is circular polarization [1], which enhances the mitigation of multipath distortion.

An alternative possible method of achieving circular polarization performance of an antenna is to use an artificial anisotropic antenna substrate. The idea behind an artificial anisotropic antenna substrate is to achieve desired polarization properties [2], e.g. for mobile or wearable antennas. As for circular polarization antennas, it can be said that they cover different frequency ranges from L-band up to 60 *GHz* [1]. Some of the effective applications of circular polarization antennas are, for example, intelligent transportation systems, military communications, health monitoring, navigation, radar, or space and satellite systems.

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Materials and Methods.

Rotation of Polarization Plane. To observe the rotation of polarization plane, a 2D artificial periodic dielectric structure was used. The artificial media constitutes ceramic cordierite with dielectric permittivity of 4 ($\varepsilon_d = 4$), periodically perforated with rectangular holes (Fig. 1).

Fig. 1. A sample with a 2D periodic structure:
1 – sample's hole; 2 – dielectric walls.

The rotation of polarization plane was experimentally studied in the frequency range of 22–24 *GHz*, i.e. wavelength was 1.5–1.25 *cm*. In our case the period $a = 1$ *mm*, and the thickness of the dielectric wall was 0.3 *mm*. Our sample was a material whose period was much shorter than the wavelength used in the experiments, $a \leq \lambda$, i.e. we had a medium with anisotropic properties.

We had anisotropy along the x and y axes, so if a plane wave [3] propagates in these directions, then by rotating the sample around the axes, we can obtain rotation of the polarization plane. In this case, we can say that anisotropic porous dielectrics belong to the class of uniaxial media. And the dielectric permittivity has the appearance of a uniaxial tensor,

$$\varepsilon_d = \begin{pmatrix} \varepsilon_{xx} & 0 & 0 \\ 0 & \varepsilon_{yy} & 0 \\ 0 & 0 & \varepsilon_{zz} \end{pmatrix}.$$

which suggests that we are dealing with an artificially created uniaxial crystal, widely used in optics for polarization rotation [2].

We had axes with fast and slow modes; changing the input angle φ of the plane wave [3], in the output we received a superposition for these two fields. That is, the angle at the output was rotated by 2φ with respect to the x-axis, which led to a corresponding polarization rotation.

The block diagram of the devices used to observe polarization is shown in Fig. 2.

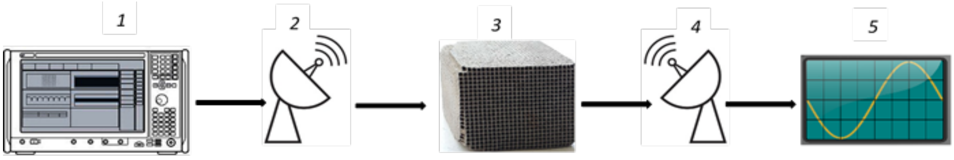


Fig. 2. Block diagram: 1 – generator 22–24 *GHz*; 2 – transmitting antenna with a polarizer; 3 – cordierite sample with a dielectric periodic structure; 4 – receiving antenna with a polarizer; 5 – recording device.

We first observed the rotation of the plane of polarization by placing an 8 *cm* long sample of a two-dimensional periodic dielectric cordierite structure [4] in free space. The plane wave was controlled by a polarizing attenuator providing an accuracy of 0.05 *dB*. By changing the corresponding input angle, we received a superposition of these two fields at the output, which led to the corresponding rotation.

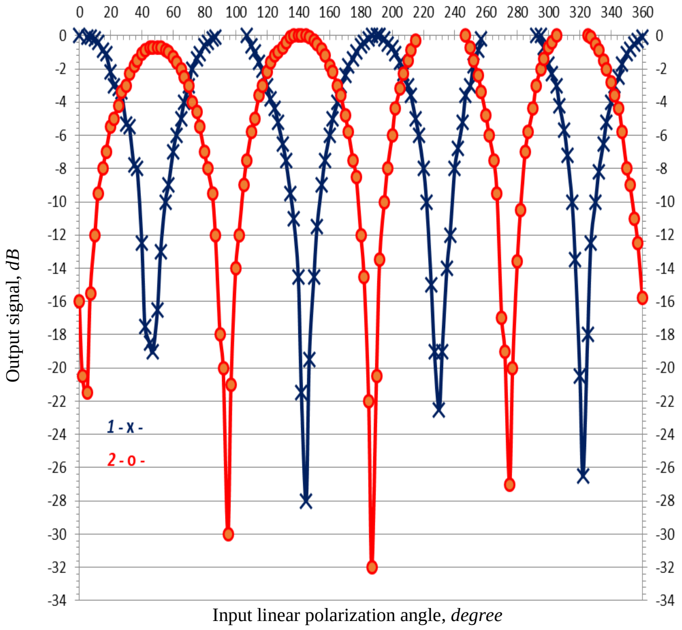


Fig. 3. Rotation of the plane of polarization: 1 – input rectangular waveguide is parallel to the analyzer-waveguide; 2 – input rectangular waveguide is orthogonally to the analyzer-waveguide.

Carrying out observations when the transmitter and the receiver are orthogonal to each other, we have a closed channel and the signal does not pass through, that is, it is in the zero position, and when we rotate it, i.e. we open it, then we get an amplification, which in this case is about -32 *dB*. Experiment were carried out not only by rotating the sample between orthogonal transmitting and receiving waveguides, but also between parallel transmitting and receiving waveguides. In both cases, we obtained a rotation of the plane of polarization, the combined graph of which is presented in Fig. 3.

Circular Polarization. We used a 4 *cm* long cordierite sample [4] with a dielectric periodic structure. The schematic description of the devices used for observing circular polarization is shown in Fig. 4.

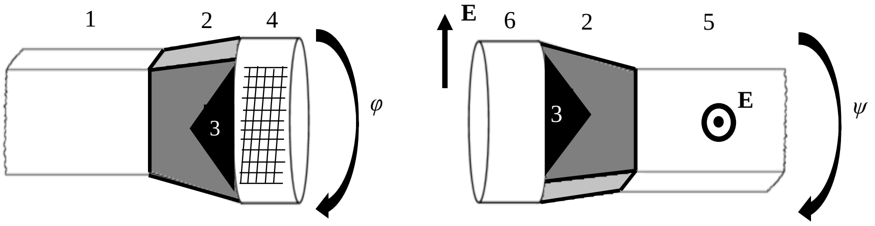
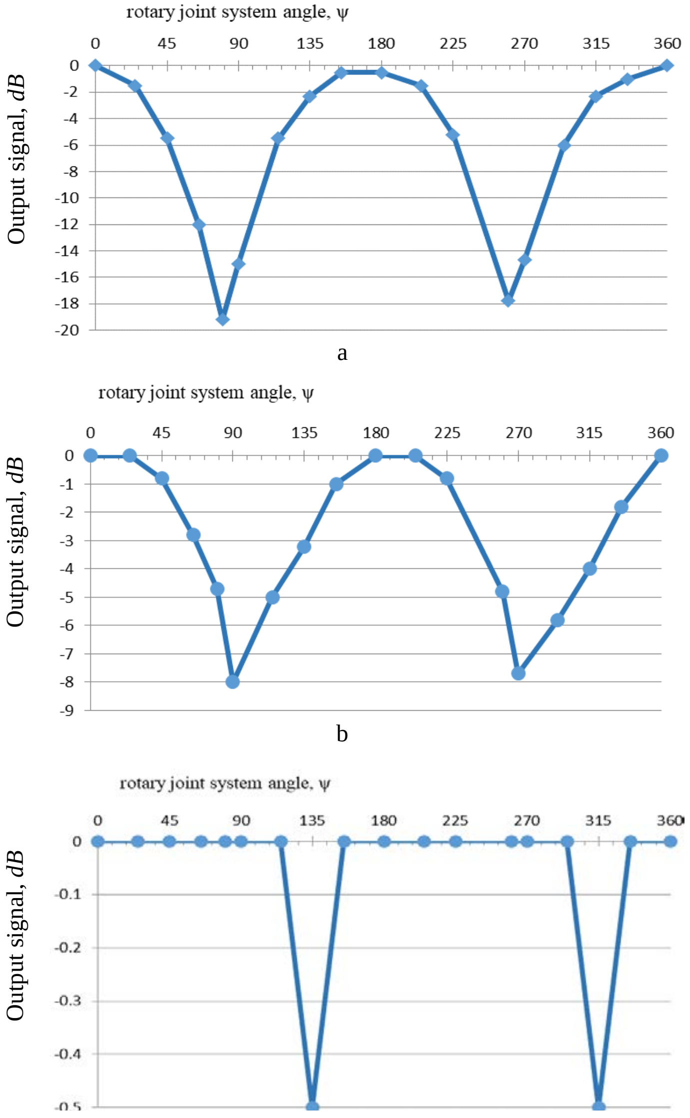


Fig. 4. Experiment scheme: 1 – input rectangular waveguide; 2 – transition from rectangular waveguide to round waveguide; 3 – matching cline; 4 – circular waveguide, on the flange of which a two-dimensional periodic cordierite dielectric is fixed; 5 – rectangular waveguide fixed to the analyzing waveguide rotary joint system, the ends of which have different polarizations; 6 – circular waveguide.

We have a transition from a rectangular waveguide to a circular waveguide connected to the generator. A round waveguide is designed for matching; a cordierite sample with a two-dimensional periodic dielectric structure is attached to it and can be rotated through an angle designated φ. We also took a similar waveguide with a transition from a rectangular waveguide to a circular waveguide, which is connected to the analyzer, and through the circular waveguide it is possible to rotate the system at an angle designated by ψ. That is, we have a rotary joint system. Our receiver is also a circular waveguide, but with a transition, one side of which is a rectangular waveguide, that is, when we rotate the rectangular waveguide, then the receiver is a detector, which is again rectangular. When we rotate the rotary joint system, we change the polarizations of these two waveguides relative to each other. The two waveguides are positioned orthogonal to each other, and each one transforms into a circular waveguide in its way.

Consider the case when the rotation angle of the sample is 0, i.e. $\varphi = 0$, in this case, rotating the rotary joint system at two points $\psi = 90^\circ$ and $\psi = 270^\circ$, we get minima of about -20 *dB*, that is, we get linear polarization (Fig. 5, a). Rotating the system again when the rotation angle of the sample is 25°, that is, $\varphi = 25^\circ$, in this case at the points $\psi = 90^\circ$ and $\psi = 270^\circ$, we find that the power has already changed six times -8 *dB*, that is, we have no linear or circular polarization, but elliptical one (Fig. 5, b).

When we change the angle, i.e. $\varphi = 45^\circ$, then we get circular polarization (Fig. 5, c) [1, 5]. Circular polarization is two linear polarizations that are orthogonal in phase to each other. Since circular polarization can always be represented as two orthogonal polarizations, no matter how we rotate the waveguide, one will coincide with and receive half of the linear polarization signal, meaning one-half of the signal is polarized in one direction and the other is polarized in the perpendicular direction.



a

b

c

Fig. 5. When the rotation angle of the sample is zero, $\varphi = 0$, linear polarization (a); when the rotation angle of the sample is 25°, $\varphi = 25°$, elliptical polarization (b); when the rotation angle of the sample is 45°, $\varphi = 45°$, circular polarization (c).

Regardless of the rotation position of the rotary joint system, half of the signal will be received and transmitted unchanged, that is, the rotation of the system does not matter, it remains the same, which leads to circular polarization. There is a slight change in only two points (-0.5 *dB*). This is because the anisotropic dielectric permittivity in the 2D structure is different in the x and y directions and $\varepsilon_{xx} \neq \varepsilon_{yy}$. In the 2D structure, the dielectric walls are in the direction of **E** (see Fig. 4) in one case, i.e. they have the greatest influence, in the other case, when we rotate, the walls become perpendicular to **E** and have no influence. This is the reason we get such a small change, that is, the effective dielectric constant is slightly different, and since it is very sensitive near zero, it is felt at two points -0.5 *dB*. This leads to the fact that when we rotate 360°, we get the same result with a slight difference in different quarters of the circle.

Conclusion. The experiments were carried out with the sample in free space, that is, in the absence of boundaries and restrictions, at a short distance of 4 *cm*, in the frequency range 22–24 *GHz*. Since the anisotropy of the sample was constant, the period was 1 *mm*, and the photonic band gaps started at about 94 *GHz*, our sample can be said to be applicable up to 77 *GHz*.

Note that obtaining circular polarization is very important for an antenna system. We have performed experiments from linear to circular polarization, that is, we have a transformation.

Received 18.05.2023
Reviewed 26.06.2023
Accepted 10.07.2023

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ՇՐՋԱՆԱՁԵՎ ԲԵՎԵՌԱՑՈՒՄԸ 2D ՊԱՐԲԵՐԱԿԱՆ ԱՐՀԵՍՏԱԿԱՆ ԱՆԻՋՈՏՐՈՊ ԴԻԷԼԵԿՏՐԻԿ ՄԻՋԱՎԱՅՐՈՒՄ

Բևեռացման պտույտի երևույթը դիէլեկտրիկ պարբերական կառուցվածքներում բավականին հետաքրքրական է: Նմանատիպ կառուցվածք օգտագործվել է 2D արհեստական պարբերական կառուցվածքով նմուշ, որտեղ կիրառվել է հարթ ալիքի տարածման մեթոդը: Ստացվել են անիզոտրոպ դիէլեկտրիկ թափանցելիություններ, որոնք օգտագործվել են բևեռացման պտույտի համար և էֆֆեկտիվ միջավայրի դիէլեկտրիկ թափանցելիության հիման վրա անիզոտրոպ միջավայրում ուսումնասիրված է բևեռացման պտույտը: Ուսումնասիրված, վերլուծված և գտնված են այն հարաբերությունները, մեծությունները և պարամետրերը կախված դիէլեկտրիկ միջավայրից, դիէլեկտրիկ թափանցելիությունից և 2D պարբերական կառուցվածքից, որոնք ապահովում են անիզոտրոպիայի աստիճանային ղեկավարումը, այսինքն ապահովում են արագ և դանդաղ մոդերի տարբերությունը, որն էլ իր հերթին ապահովում է լավագույն բևեռացման պտույտը միավոր երկարության վրա:

А. Н. САРГСЯН

КРУГОВАЯ ПОЛЯРИЗАЦИЯ В ДВУМЕРНОЙ ПЕРИОДИЧЕСКОЙ ИСКУССТВЕННОЙ АНИЗОТРОПНОЙ ДИЭЛЕКТРИЧЕСКОЙ СРЕДЕ

Довольно интересно явление вращения поляризации в диэлектрических периодических структурах. Аналогичная структура использовалась в образце с двумерной искусственной периодической 2D структурой, где применялся метод распространения плоской волны. Были получены анизотропные диэлектрические проницаемости, которые использовались для вращения поляризации, а вращение поляризации в анизотропных средах изучалось на основе диэлектрической проницаемости эффективной среды. Изучены, проанализированы и найдены те соотношения, величины и параметры, зависящие от диэлектрической среды, диэлектрической проницаемости и двумерной периодической 2D структуры, которые обеспечивают управление степенью анизотропии, т.е. обеспечивают различие между быстрыми и медленными модами, которые в свою очередь обеспечивают наилучшее вращение поляризации на единицу длины.