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COMPUTER AIDED INVESTIGATION OF THE DOMINANT MODE ON THE HOMOGENEOUSLY MAGNETIZED FERRITE IMAGE GUIDE

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Илияна Арестова. ЧИСЛЕНО ИЗСЛЕДВАНЕ НА ОСНОВНИЯ МОД В ХОМОГЕННО НАМАГНИТЕН ФЕРИТЕН ОГЛЕДАЛЕН ВЪЛНОВОД

Феритният огледален вълновод (ФОВ) е неотменима съставна част на ферито-диелектричните огледални структури, предназначени за приложение в милиметровия диапазон. Тези структури се разглеждат като основа за проектиране на управляващи устройства – изолатори, циркулатори, превключватели и др., при различни намагнитвания на феритния елемент. Тук е изследвано числено по метода на крайните елементи (МКЕ) разпределението на компонентите на полето на основния мод при три различни посоки на хомогенно намагнитване на феритния елемент: 1) намагнитване, перпендикулярно на посоката на разпространение и успоредно на огледалната равнина; 2) намагнитване, перпендикулярно на посоката на разпространение и на огледалната равнина; 3) намагнитване, успоредно на посоката на разпространение. Изследването показва, че във втория случай на намагнитване се наблюдава асиметрия на електричното поле на основния мод, което може да доведе до невзаимен ефект.

Iliyana Arestova. COMPUTER AIDED INVESTIGATION OF THE DOMINANT MODE ON THE HOMOGENEOUSLY MAGNETIZED FERRITE IMAGE GUIDE

The ferrite image guide (FIG) is an essential element of the ferrite-dielectric structures intended for use in the millimetre wavelength range. These structures are considered a basis for designing control devices – isolators, circulators, switches, etc. using various magnetizations of the ferrite

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element. Here the distribution of the electromagnetic field components of the dominant mode is numerically studied by finite element method (FEM). Three different directions of homogeneous magnetization of the ferrite element have been considered: 1) magnetization perpendicular to the direction of propagation and parallel to the ground plane (Case 1); 2) magnetization perpendicular to the direction of propagation and to the ground plane (Case 2); 3) magnetization parallel to the direction of propagation (Case 3). The investigation has shown that the most promising for nonreciprocal behaviour is Case 2 due to the asymmetry of the electric field distribution

Keywords: millimeter waves, ferrite devices, image guide, finite element method.

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1. INTRODUCTION

The ferrite image guide (FIG) together with the dielectric image guide structures represents a possible basis for the design of control devices for millimetre waves [1–7]. Different homogeneous magnetizations of the ferrite element have been investigated [1–6], as well as the inhomogeneous (mixed) magnetization [7]. The mixed magnetization is produced by a disk shaped permanent magnet and it contains two opposite longitudinal components at both ends of the ferrite element and a transverse component perpendicular to the ground plane in the middle of it. In order to clarify the processes taking place at this mixed magnetization, it is reasonable to study separately all three mutually perpendicular homogeneous magnetizations of the FIG.

A detailed study of the modes on the dielectric image guide has been done earlier in [8]. Here the FIG is modelled at three different directions of homogeneous magnetization. The field components of the dominant mode have been obtained numerically by finite element method (FEM) at each magnetization. The purpose of this research is to study the impact of each direction of magnetization on the electric and magnetic field components of the dominant mode on the magnetized FIG. This could improve understanding of the operating mechanism of the nonreciprocal ferrite-dielectric structures with inhomogeneous magnetization.

2. MODEL AND MAGNETIZATION

The investigated rectangular FIG has cross-sectional dimensions $a \times b$ = 1.82×0.99 mm^2 (Fig. 1) and is made of ferrite mark 1СЧ4 (Russia). The ferrite has the following electromagnetic parameters: relative permittivity ε_r = 11.1, tangent of the angle of dielectric losses tgδ_ε = 0.01 and saturation magnetization $4\pi M_s$ = 0.463 T. The homogeneous magnetization in the three mutually perpendicular directions with a field strength H = 40 kA/m has been set successively.

Some of results obtained numerically by FEM, namely the dispersion characteristic and the distribution of the electric field magnitude, have been reported in [9]. Here we have first defined points inside the model volume, situated at those transverse planes, at which maxima and minima of the electric field magnitude have been observed. After that we have calculated the values of all six electric and magnetic field components at each defined point. The resulting distributions of field components of the dominant mode along transverse axes x and y are shown in Figs. 2–7. The values of the electric and magnetic field components in Figs. 2–7 correspond to the transmitted power of 1 W.

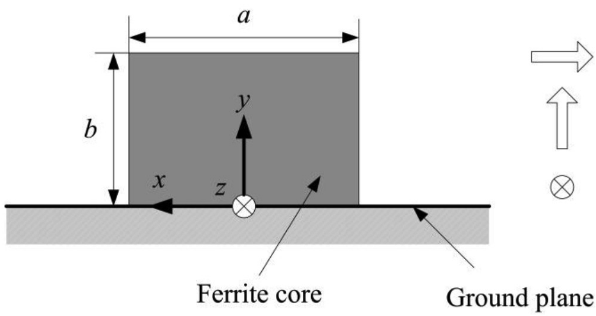

Fig. 1. The cross-sectional view of the FIG

3. RESULTS AND DISCUSSION

3.1. FIELD COMPONENTS AT MAGNETIZATION PERPENDICULAR TO THE DIRECTION OF PROPAGATION AND PARALLEL TO THE GROUND PLANE (CASE 1)

A maximum of the electric field magnitude distribution has been observed at $z = z_1 = 1.66$ mm, and a minimum at $z = z_2 = 3.34$ mm. The distributions of the six components of the dominant mode at these two transverse planes are given in Fig. 2 and Fig. 3 respectively. It can be seen that the main components of the dominant mode are E_y, E_z and H_x. There is a well-defined symmetry in the distributions about $x = 0$ (Fig. 2a, Fig. 3a,b).

In accordance with the boundary conditions the component E_y at $y = b = 0.99$ mm (Fig. 3c) and the component E_x at $x = \pm a/2 = \pm 0.91$ mm (Fig. 3a) have interruptions. The component H_z (Fig. 2b) have relatively weak extrema at $x = \pm a/2 = \pm 0.91$ mm and a maximum at $x = 0$ (Fig. 3a).

The resulting distributions show that the dominant mode on the FIG at magnetization perpendicular to the direction of propagation and parallel to the ground plane represents E^y_{11} according to the Markatili's classification [10].

At this magnetization a minimum of the electric field magnitude has been observed at $z = z_1 = 3.28$ mm, and a maximum at $z = z_2 = 5.03$ mm. The distributions of the six components of the dominant mode at these two transverse planes are given in Fig. 4 and Fig. 5 respectively.

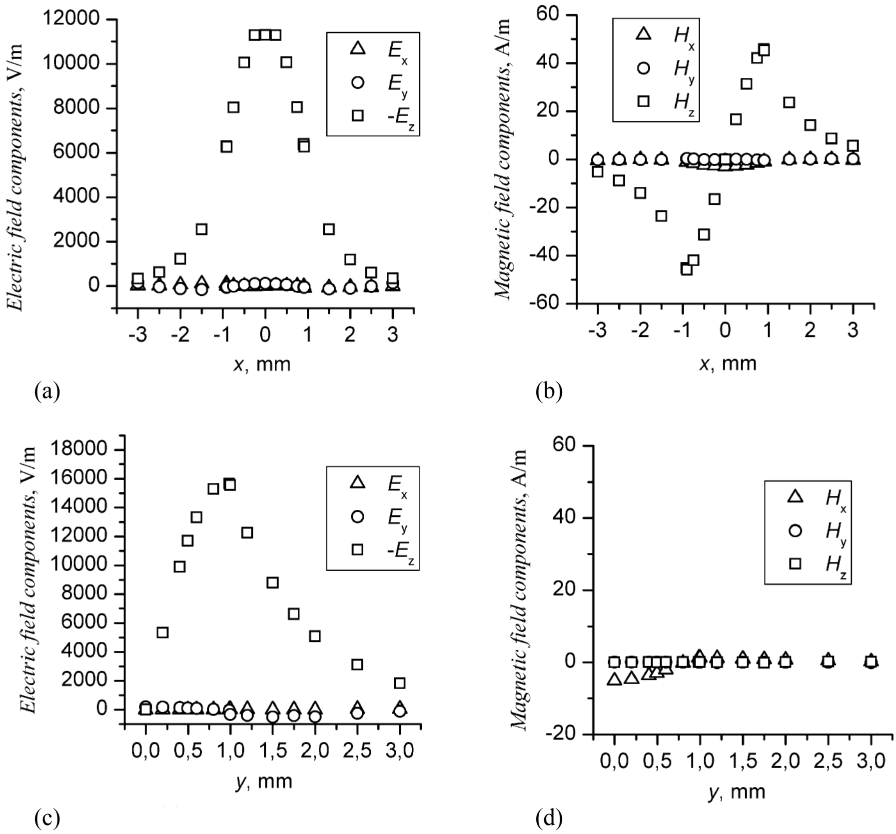

Fig. 2. Simulated distributions of the field components of the dominant mode at $z = 1.66$ mm: (a, b) $y = 0.495$ mm; (c, d) $x = 0$ mm

As can be seen from Fig. 4a, there is a shift of the maximum of the component E_y from the centre of the dielectric core ($x = 0$) to the left side wall located at $x = -a/2 = -0.91$ mm. The same figure shows the presence of a significant component E_x, which is symmetrical about $x = 0$. The comparison of Fig. 4c with Fig. 3c shows also a greater value of the component E_x in this case of magnetization. As in the previous case of magnetization, the component E_z has large values in a cross-section corresponding to a maximum of the electric field magnitude (Fig. 5a,c). It has a distribution which is symmetrical about $x = 0$ (Fig. 5a).

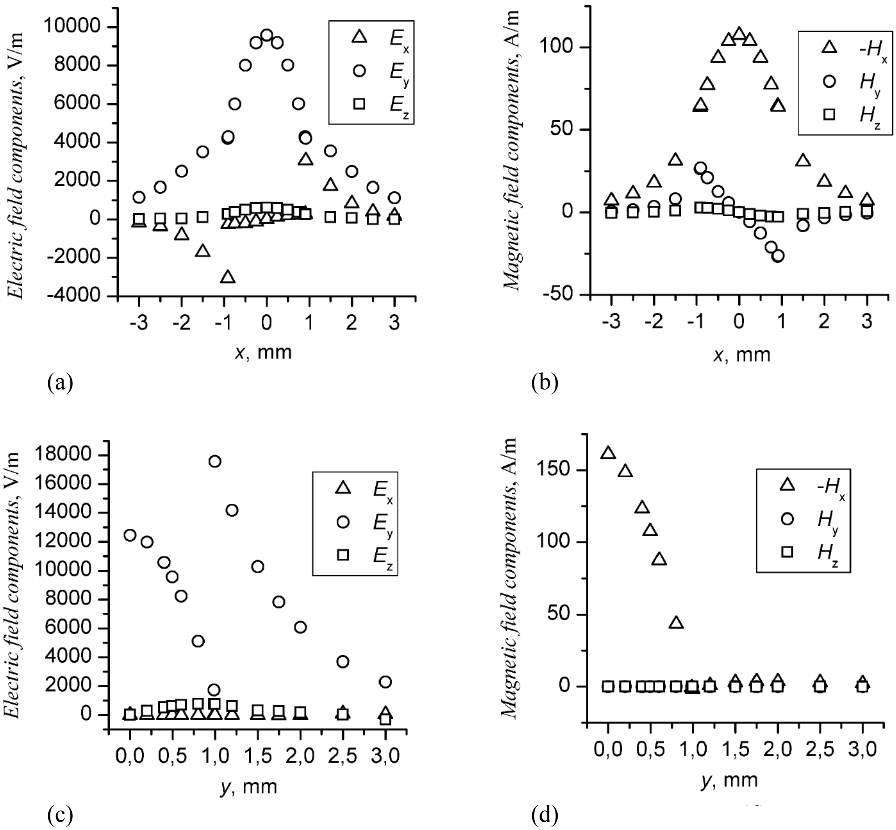

Fig. 3. Simulated distributions of the field components of the dominant mode at $z = 3.34$ mm: (a, b) $y = 0.495$ mm; (c, d) $x = 0$ mm

From Fig. 4b,d and Fig. 5b,d it can be seen that among the magnetic components the largest and similar in value are the components H_x and H_z. Thus, we can conclude that the main components of the dominant mode are E_y, E_z, H_x and H_z. The presence of an asymmetry in the transverse plane about the dielectric core centre $x = 0$, the occurrence of an additional main magnetic component H_z, as well as significant levels of component E_x, require differentiation from the dominant mode in the dielectric image guide E^y_{11}. The dominant mode at this magnetization could be called a modified mode E^y_{11}, characterized by asymmetry and increased components H_z and E_x.

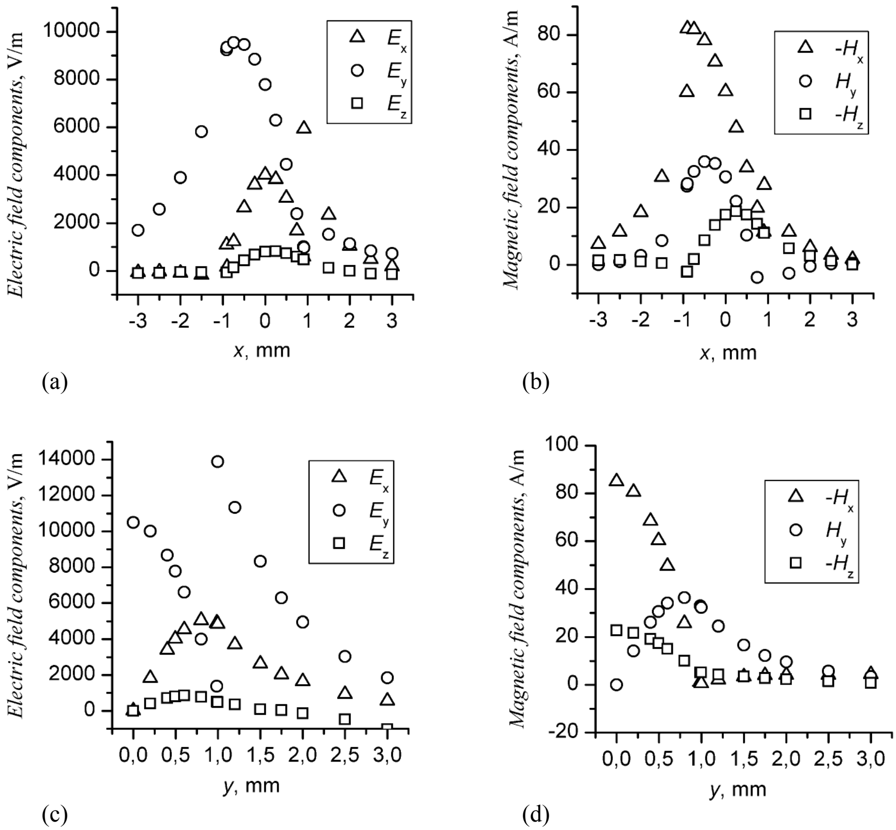

Fig. 4. Simulated distributions of the field components of the dominant mode at z = 3.28 mm: (a, b) y = 0.495 mm; (c, d) x = 0 mm

3.3. FIELD COMPONENTS AT MAGNETIZATION PARALLEL TO THE DIRECTION OF PROPAGATION (CASE 3)

The distributions of the six components of the dominant mode in the case of longitudinal magnetization at two transverse planes, where a maximum and a minimum of the electric field magnitude occur, are given in Fig. 6 and Fig. 7 respectively. As can be seen from Fig. 6a and Fig. 7a, the largest electrical components are respectively E_z and E_y, which both have symmetry about $x = 0$.

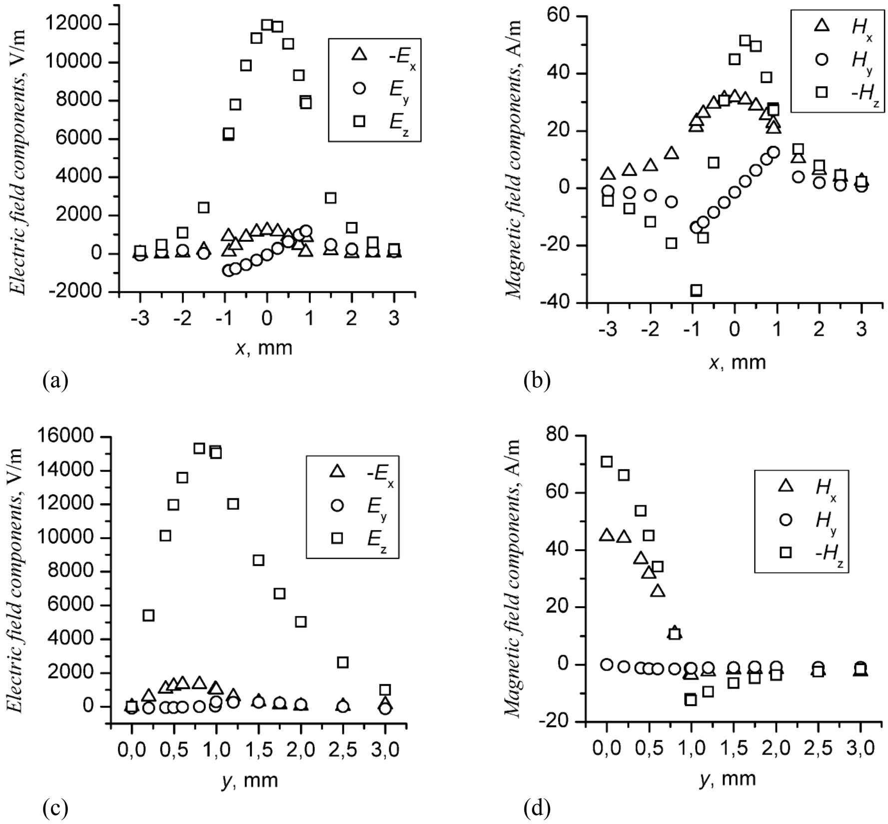

Fig. 5. Simulated distributions of the field components of the dominant mode at z = 5.03 mm: (a, b) y = 0.495 mm; (c, d) x = 0 mm

The three magnetic components shown in Fig. 6b,d and Fig. 7b,d are comparable to each other. This gives grounds to conclude that the dominant mode on the longitudinally magnetized FIG represents a modified E^y_{11} mode, in which all three magnetic components H_x, H_y and H_z should be taken into account.

3.4. DISCUSSION

The transverse distributions of field components of the dominant mode corresponding to a maximum of the electric field magnitude are shown in Figs. 2, 5 and 6 for Case 1, Case 2 and Case 3, respectively. These figures show that the E_z component is the largest among the electric field components and reveal that the maxima of the electric field magnitude coincide with the maxima of the E_z component.

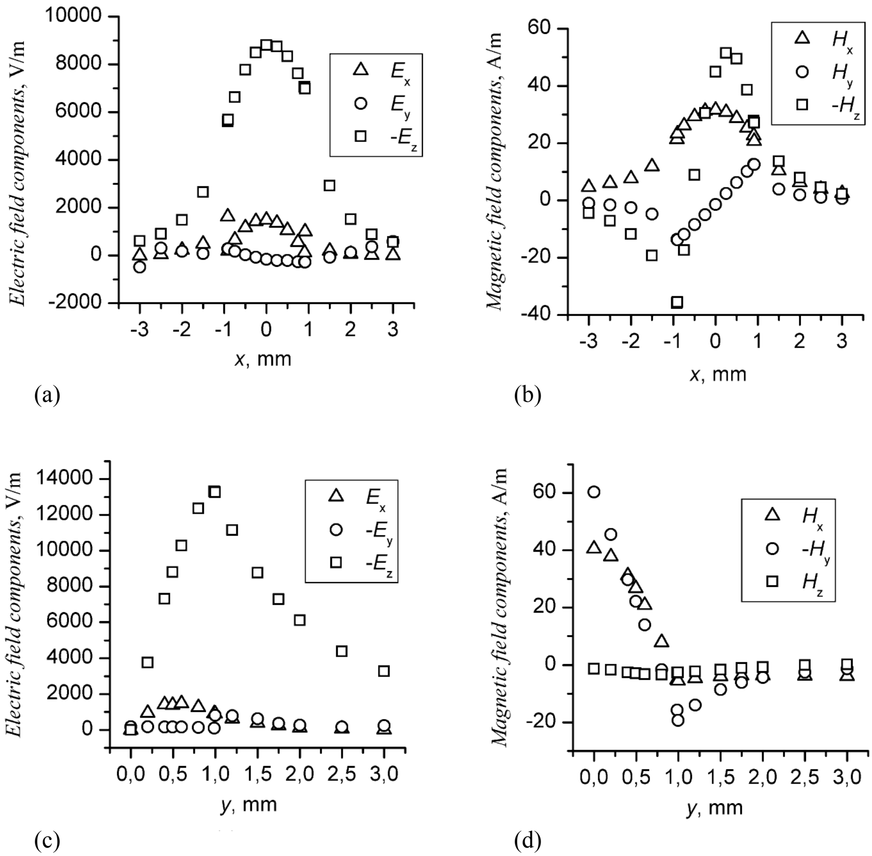

Fig. 6. Simulated distributions of the field components of the dominant mode at z = 1.74 mm: (a, b) y = 0.495 mm; (c, d) x = 0 mm

The obtained distributions of field components of the dominant mode corresponding to a minimum of the electric field magnitude are shown in Figs. 3, 4 and 7 for Case 1, Case 2 and Case 3, respectively. It is evident that the minima of the electric field magnitude coincide with the maxima of the E_y component.

In Case 2 an electric field asymmetry has been obtained. This asymmetry can produce a nonreciprocal field distribution in coupled ferrite-dielectric image guide structures at transverse magnetization perpendicular to the ground plane. It gives reason to suppose that it is possible to expect a nonreciprocal behaviour in the coupled ferrite-dielectric image guide structures at this type of magnetization.

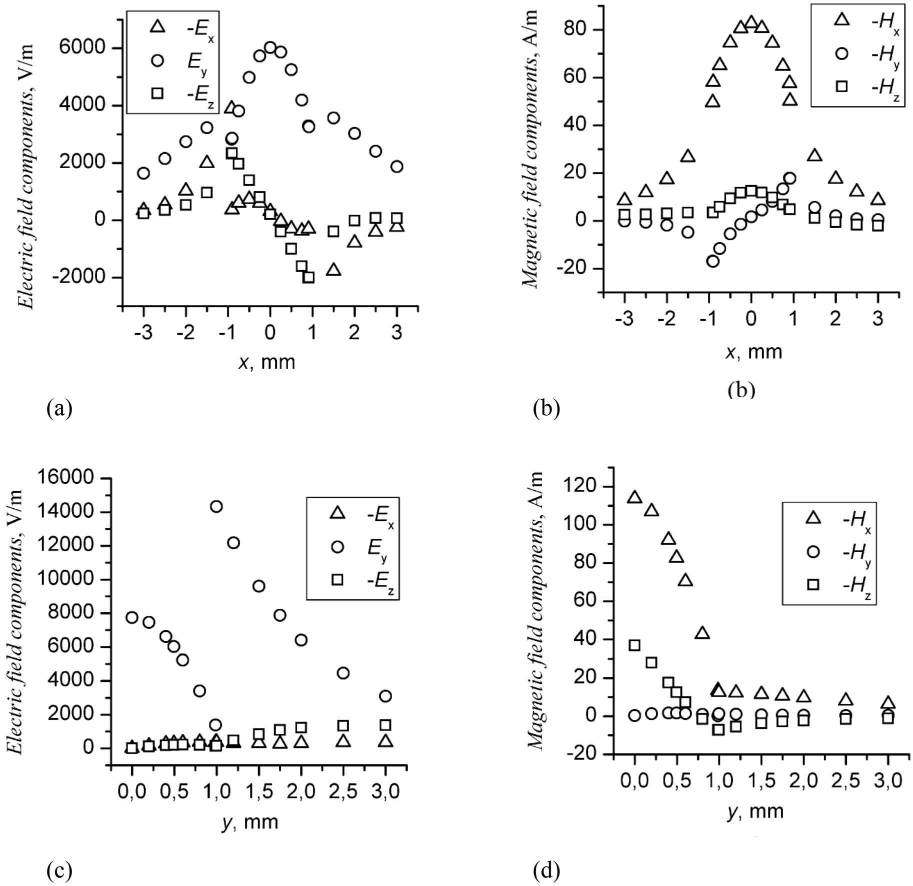

Fig. 7. Simulated distributions of the field components of the dominant mode at $z = 3.91$ mm: (a, b) $y = 0.495$ mm; (c, d) $x = 0$ mm

4. CONCLUSION

The transverse distributions of all six components of the dominant mode on the magnetized FIG have been obtained numerically. The results showed that only at magnetization perpendicular to the direction of propagation and parallel to the ground plane the dominant mode is pure E^y_{11} with main components E_y E_z and H_x, according to the Markatili's classification An asymmetry about the middle of the ferrite core appears at transverse magnetization perpendicular to the ground plane, as well as a growth of the components H_z и E_x. All three components of the magnetic field prove to be significant at longitudinal magnetization. The next step of the investigation could be the simulation of the coupled ferrite-dielectric IG structures.

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