Cylindrical Phase Shifters with Solid-state Plasma

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The investigation results of n-InP cylindrical phase shifters with solid-state plasma are presented in this paper. Furthermore, dispersion characteristics of the main mode HE_{11} of phase shifters with different external dielectric layers are calculated. According to the results of the investigation, the use of TM-15 dielectric and without dielectric is more preferred for phase shifters, as far as they correspond to the phase shifters working range wider in the range of magnetic flux density (0–0.5) T.

Keywords and phrases: dispersion characteristics, phase shifters, dielectric layer, differential phase shift module.

Introduction

Gyrotropic (gyroelectric) cylindrical waveguides are usually used for manufacturing solid-state plasma cylindrical phase shifters in high frequencies. They have a wide working frequency range and good electro-dynamical parameters [1].

With such functions they can be integrated into radio frequency systems, receivers or transmitters and other microwave systems. There they can be used as phase shifters, where working range is controlled using differential phase shift module dependences on the magnetic flux density.

The investigation results of the cylindrical phase shifters with solid-state plasma by the usage of external dielectric layer with different permittivity are presented in this paper. The external dielectric layer is used for the reinforcement of waveguide core. The influence of dielectric layer on phase shifters with solid-state plasma has hardly been investigated. To investigate the working range of phase shifters, it is necessary to calculate the differential phase shift module.

The electrodynamical model of the open cylindrical round cross-section gyrotropic waveguides in cylindrical coordinate r, φ, z system is presented under the reference [1–4].

The gyrotropic waveguides dispersion equations can be expressed by the use of Maxwell's equations and partial area methods. The transcendental linear dispersion equation system of the 8th order determinant for open circular cylindrical gyrotropic waveguides with external dielectric layer is expressed by $D^s = \det[\underline{a}_{jk}] = 0$, where j is a column and k is a row index of determinant and $\underline{a}_{jk}$ are determinant complex elements. The non-zero complex determinant elements are presented in [1]. Having solved the dispersion equation, the phase characteristics of the modes and other electrodynamics parameters are obtained.

Analysis of the n-InP phase shifters

In order to calculate dispersion characteristics of the cylindrical phase shifters n-InP semiconductor (superscript s) and two types of external dielectric layer (superscript d) are used. The analysis of the semiconductor n-InP waveguides is performed by taking material background dielectric constant $\varepsilon_k^{s\,n} = 12.5$.

Effective mass of the n-InP semiconductor electron is $m^* = 0.08\ m_e$ and mobility $\mu = 5.4$ m²V⁻¹s⁻¹, here m_e is mass of free carrier [5]. For external dielectric layer, two type of dielectrics TM-15 and LiNbO$_3$ are used. The relative permittivity of the first dielectric $\varepsilon_r^d = 15$ and for the second dielectric $\varepsilon_r^d = 28$. The relative thickness of external dielectric layer is d/r$_s$ = 0.3. Here d is the absolute dielectric layer thickness and r_s is the core with solid-state plasma radius.

Here dispersion characteristics are presented as normalized phase constant — $h'r^s$ (here h' is the phase constant) dependences on the normalized frequency — fr^s, when the polarization of hybrid modes is left-hand $e^{+im\varphi}$, here m is the azimuthal index.

The algorithm for solving the dispersion equation has been tested by selecting a dielectric waveguide parameters for gyrotropic waveguide model. Test results are presented in [2]. Results presented here are obtained by the authors created program and with the "CST Microwave Studio 2010" software. The results of calculations are compared for both programs. Comparison results are presented in Fig. 1, when magnetic flux density is $B_0 = 0$ T and electron concentration is $N = 5 \cdot 10^{19}$ m^{-3} and when n-InP semiconductor is used.
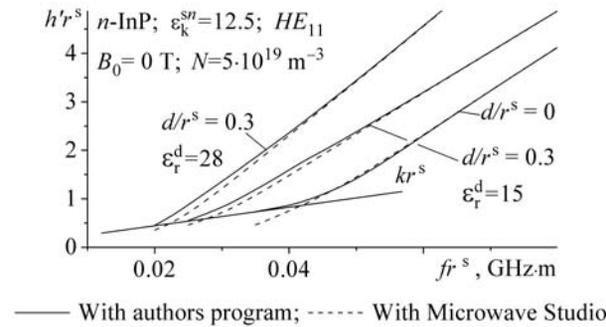

Fig. 1. The dispersion characteristics comparison.

The biggest differences between results are seen in lower frequencies side, with external dielectric layer and without it. The difference between results approximately is 8%. These differences between results are received because authors use the partial area and iterative methods and "CST Microwave Studio 2010" uses the numerical methods.

The dispersion characteristics of cylindrical phase shifters with solid-state plasma of the main mode HE11, are shown in Fig. 2, when electron concentration is N = 5·10¹⁹ m⁻³, normalized dielectric layer thickness is $d/r_s = 0$ and the magnetic flux density is $B_0 = (0-1)$ T.
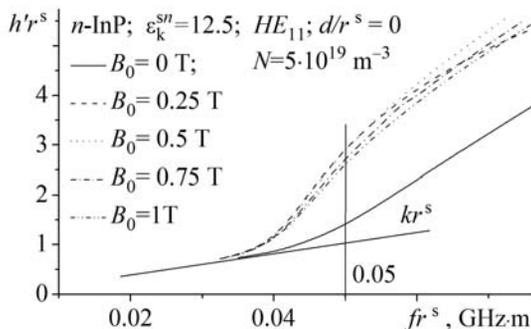

Fig. 2. The dispersion characteristics of n-InP phase shifters, when $d/r_s = 0$.

The dispersion characteristics of n-InP phase shifters are presented in Fig. 3, and Fig. 4, when external dielectric layer thickness is $d/r^s = 0.3$ and permittivities are $\varepsilon_r^d = 15$ and 28.

The external dielectric layer, when permittivity is $\varepsilon_r^d = 15$ change n-InP phase shifters cut-off frequency of the main mode HE_{11} and dispersion characteristics move to lower frequency side, when magnetic flux density B_0 is varied in range (0–1) T. The magnetic flux density B_0 changes the modes phase constant — h'.

The other situation is with the n-InP phase shifters, when dielectric layer permittivity is $\varepsilon_r^d = 28$, the cut-off frequencies of the mode HE_{11} move to the side of higher frequencies.

These dependences are important for microwave phase shifters when external dielectric layer is used. The n-InP phase shifters working range can be controlled by changing the magnetic flux density B_0. The phase shifters working range is the differential phase shift module, it can be calculated by drawing the vertical line in waveguide working normalized frequency range — Δfr^d. In Fig. 2–4 the vertical line is drawn at the normalized frequency 0.05 GHz·m.
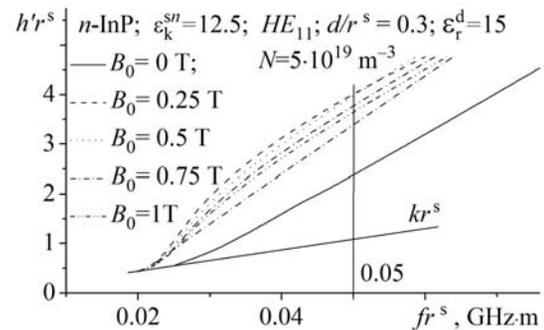

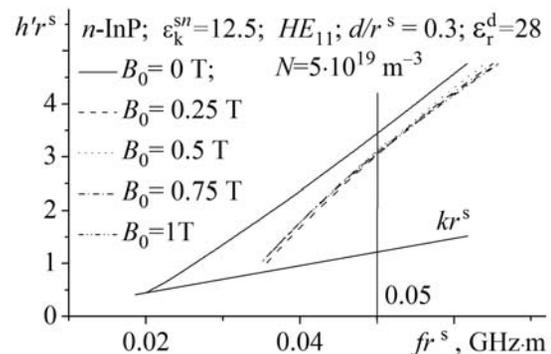Fig. 3. The dispersion characteristics of n-InP phase shifters, when $d/r^s = 0.3$ and $\varepsilon_r^d = 15$.

Fig. 4. The dispersion characteristics of n-InP phase shifters, when $d/r^s = 0.3$ and $\varepsilon_r^d = 28$.

The differential phase shift module expression is presented below [1]:

$$\left|\Delta\vartheta\right|\Big|_{fr^s=\text{const}}=\left|\left(h'_0\,r^s-h'_{B_0}\,r^s\right)\right|\Big|_{fr^s=\text{const}}\cdot L\cdot 360/2\pi,^\circ \quad (1)$$

where h'_0 is the wave phase constant, when $B_0 = 0$ T; h'_{B_0} is the wave phase constant, when $B_0 \neq 0$ T; L is the phase shifters length.

The differential phase shift module dependences on the magnetic flux density B_0 are shown in Fig. 5. The phase shifters working range is the biggest, when $d/r^s = 0$ and $d/r^s = 0.3$; $\varepsilon_r^d = 15$.
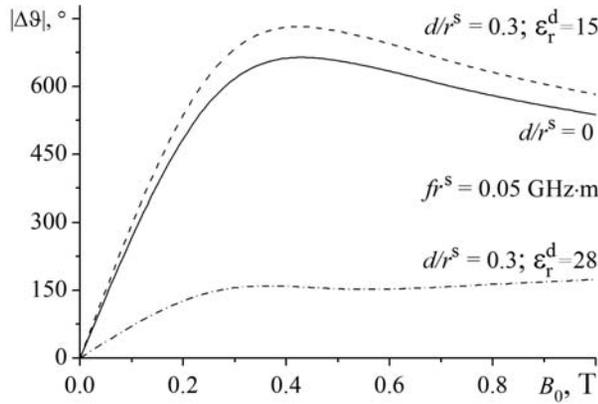

Fig. 5. The differential phase shift module dependences on the B_0.

There are two maximums in the dependences, when $B_0 = 0.4$ T after this value the differential phase shift module is decreasing and the phase shifters working range is decreasing as well. It causes problems for broadband phase shifters because the working frequency range is also decreasing in this situation. The TM-15 dielectric increases the working range of n-InP phase shifters.

The same differential phase shift module can be obtained by increasing external dielectric thickness (d/r^s). It means that the semiconductor core can be reinforced by using thicker external dielectric layer with permittivity $\varepsilon_r^d = 15$.

When external dielectric layer is LiNbO$_3$ the phase shifters working range is increasing in almost all range of B_0. The phase shifters working range is around 5 times

smaller, when $B_0 = 0.4$ T and 4 times when magnetic flux density is 1 T.

Conclusions

The dispersion characteristics of the solid-state plasma n-InP phase shifters in wide frequency range with different external dielectric layers have been calculated.

Modes cut-off frequencies move to lower frequency side, when external dielectric layer TM-15 is used, and the magnetic flux density is changed in range (0–1) T.

The external dielectric layer LiNbO$_3$ changes electromagnetic field in the phase shifter core, and the modes cut-off frequencies move to higher frequencies. When B_0 is increasing, the dispersion characteristics move to lower frequencies, which is an interesting phenomenon.

The external dielectric layer LiNbO$_3$ reduces the working range of the phase shifters. The investigation results have shown that the phase shifters work better, when magnetic flux density is in range from (0–0.5) T in all investigation cases. Consequently, (0–0.5) T range the external dielectric layer TM-15 and without dielectric is more preferable for phase shifters than LiNbO$_3$ dielectric.

References

[1] Nickelson, L., et al. *The Open Cylindrical Gyrotropic Waveguides*. Monograph. Vilnius: Technika, 2007.
[2] Plonis, D., V. Malisauskas, and A. Serackis. "Semi-automatic Analysis of Gyrotropic Semiconductor Waveguides using Neural Network." *Acta Physica Polonica A* 119.4 (2011): 542.
[3] Malisauskas, V. and D. Plonis. "Dispersion Characteristics of the Propagation Waves in the Gyroelectric Semi-conductor Waveguides." *Electronics and Electrical Engineering* 106.10 (2010): 87.
[4] Nickelson, L., et al. "The Dependence of Open Cylindrical Magnetoactive *p*-Ge and *p*-Si Plasma Waveguide Mode Cut-off Frequencies on Hole Concentration." *J. Plasma Physics* 75.1 (2009): 35.
[5] Sze, S. *Physics of Semiconductor Devices*. USA: John Wiley & Sons, 1981.

Electronics and Information Technology

Analysis of pressure force between two cylinders

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Cylinders are very important elements in an offset printing machine because after being supplied with ink they transfer a printing image on paper. A type of setting as regards the stress between cylinders affects quality of printouts as well as rate of wear and tear of operating materials and machine's elements. It is of great importance to provide for accurate calculation of stress force between two cylinders because this allows for setting an adequate contact zone width and cylinders indentation. In the printing unit of the offset machine there occurs contact between a metal cylinder and cylinder with fixed rubber blanket. The said blanket is composed of some layers, where one of them is a compressible layer. Therefore, the problem is not of trivial nature, as the blanket is made of a non-linear material.

Keywords and phrases: contact problem, offset, blanket cylinder, rubber blanket.

Introduction

Offset printing is based on two main assumptions: flat printing plate and presence of a blanket cylinder in the printing unit, where the cylinder transfers ink from plate cylinder to paper. First, ink and a dampening solution (in offset with dampening) are put on the printing plate with printing and non-printing areas which is fixed on the plate cylinder. Then, a printing image is transported onto the blanket cylinder coated with rubber blanket and, subsequently, the image is printed on paper pressed to the blanket cylinder by the impression cylinder.

In the printing unit there are 3 cylinders: a plate cylinder, a blanket cylinder and an impression cylinder. It is very important to ensure that an adequate stress is set between the cylinders.

The stress affects quality of printouts and as well as rate of wear and tear of operating materials and machine's elements.

Printing unit construction

In a single color offset printing machine the printing unit is composed of a plate cylinder, a blanket cylinder and an impression cylinder (Fig. 1). A sheet-fed offset machine includes a number of such moduluses which are inter-connected by the conveying mechanisms. A multi-color offset printing machine construction can involve another solution, which is less frequently used and the idea of which consists in that one common impression cylinder remains in contact with more than one contacting plate cylinder. Usually, this is a five-cylinder printing unit (one impression cylinder, two blanket cylinders and two plate cylinders). There is also another possible configuration where two blanket cylinders remain in mutual contact and the sheet is running between them, which is referred to as the so called blanket-to-blanket system. Each of the said blanket cylinders is in contact with a separate plate cylinder. Another configuration regarding the printing unit consists in the blanket cylinder contacting with two plate cylinders [1, 3].

All of these cylinders have to be in mutual contact to provide for ink transfer. A place where they are in contact is called a contact zone (contact area, nip). For proper quality of print-outs it is necessary to set up an adequate contact zone width. All of the printing unit cylinders mesh with each other through gear wheels [2].

Plate cylinder

On the plate cylinder there is fixed a printing plate which transfers ink image onto the blanket cylinder.