90 DEGRE PHASE SHIFTER BASED ON A SQUARE WAVEGUIDE WITH DIAPHRAGMS

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Modern antenna systems with polarization signal processing are used to improve the information parameters of the signals processed in them [1, 2]. The basic elements of such systems are waveguide filters [3], phase shifters [4] and polarizers [5, 6]. Phase shifters provide the required phase values at the output. Polarizers provide a differential phase shift at the output of 90º [7]. The most common structures of waveguide polarizers are structures with diaphragms [8, 9], pins [10, 11], combined with pins and diaphragms [12, 13], and coaxial structures [14, 15] and ribbed structures [16, 17]. Differential phase shifter is used in the development of phased array antennas, in the formation of the beam in modern antenna systems and for power supply systems of modern antennas [18]. Modern 90º phase shifters [19, 20] have advanced functionality, simple compact geometric shape, resistant to amplitude imbalance, the ability to maintain a stable phase with multibeam propagation. In addition, such devices are sometimes used in 5G systems [21].

The aim of the work is to study the main characteristics of a phase shifter based on a square waveguide with diaphragms in the operating frequency range of 7-10 GHz.

The design of a phase shifter based on a square waveguide with three diaphragms, located symmetrically relative to the central diaphragm, is shown in Fig. 1. The height of the two extreme diaphragms is equal to h_1, and the height of the middle one is higher than the extreme ones h_2, the thickness of all diaphragms is w, and the distance between the diaphragms is the same and is l.

The created design of the phase shifting device provides the main phase and matching characteristics. Design optimization is carried out in a suitable commercial software environment by changing the geometric dimensions of the device design.

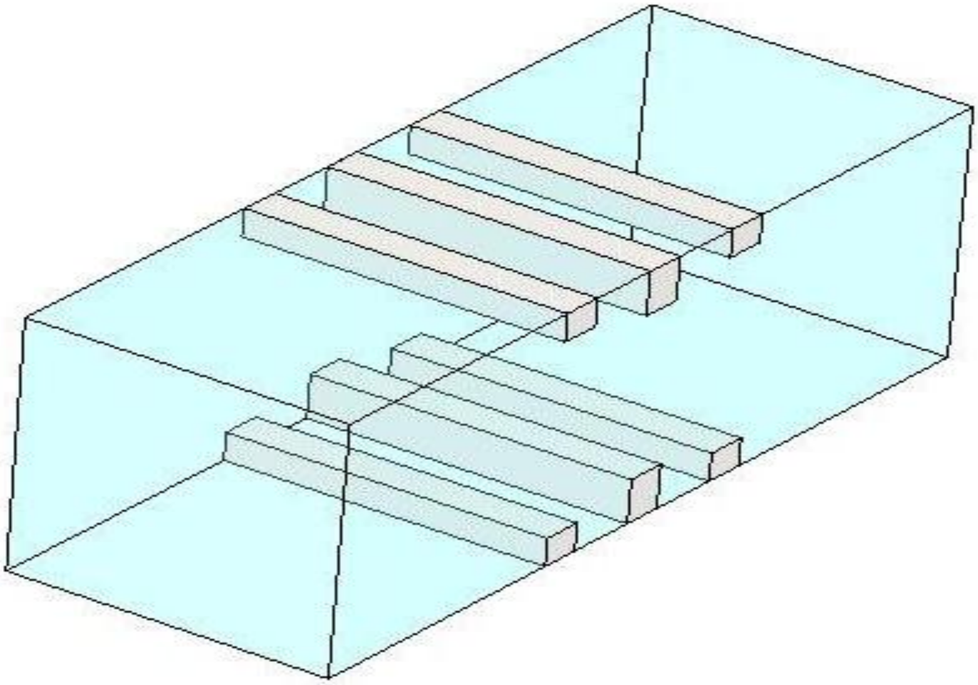

Fig. 1. Phase shifter design based on a square waveguide with three diaphragm

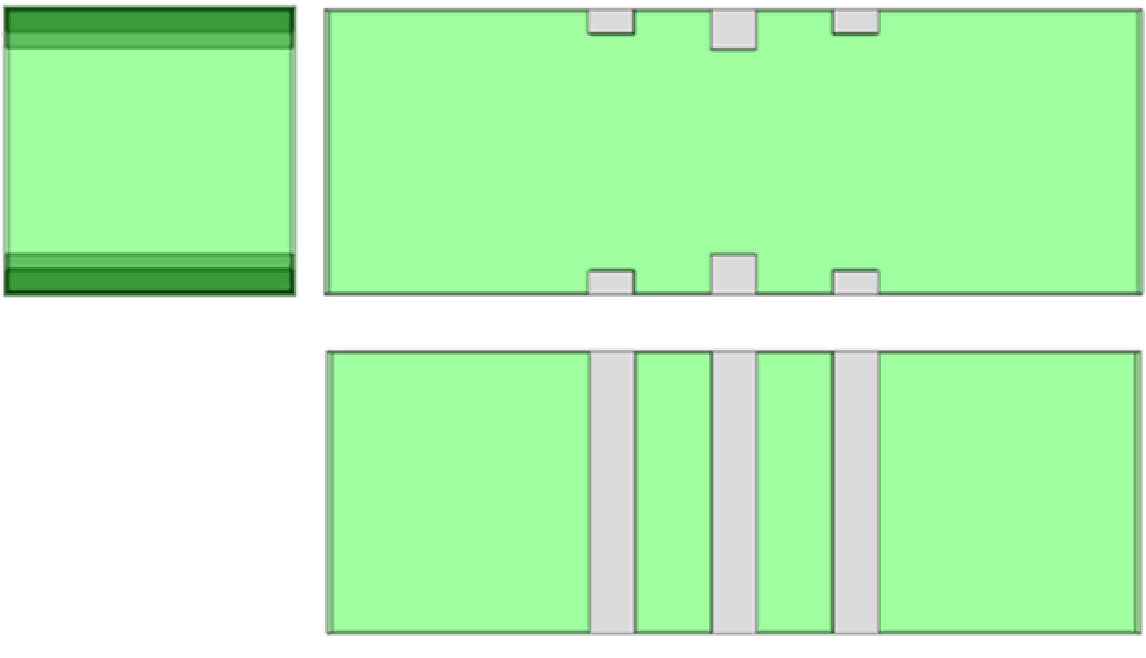

Fig. 2. Internal structure of phase shifter based on a square waveguide with three diaphragm

Using the method of wave matrices and equivalent circuits [22], the basic parameters of the wave matrix of phase scattering device were obtained

$$[S_\Sigma] = \begin{bmatrix} S_{11.\Sigma} & S_{12.\Sigma} \\ S_{21.\Sigma} & S_{22.\Sigma} \end{bmatrix}.$$

Thus, through the elements of the obtained scattering matrix of the bulges determined the differential phase shift of the device according to the formula

$$\Delta\varphi = \varphi_{21.\Sigma L} - \varphi_{21.\Sigma C}$$

The constant voltage wave coefficient (VSWR) was also determined according to the analytical expression

$$VSWR = \frac{1+|S_{11}|}{1-|S_{11}|}.$$

The frequency dependences of a phase shifter based on a square waveguide with three diaphragms in the operating frequency range 7–9 GHz for the given method and two known electrodynamic methods FDTD and FEM, respectively, are presented below.

Fig. 3 contains the dependence of the differential phase shift of the waveguide phase shifter in the frequency range 7-10 GHz. As can be seen, the differential phase shift of the device is 90° ± 5° for the given method, 90° ± 4° for the FDTD method and 90° ± 6° for the FEM method

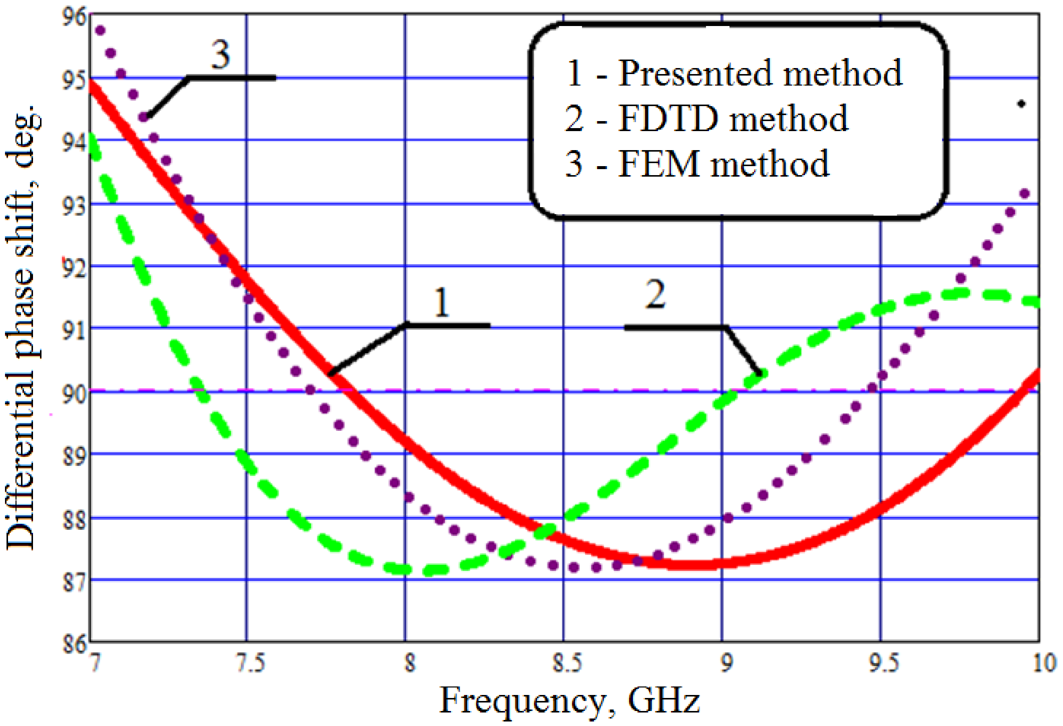

Fig. 3. Dependence of differential phase shift on frequency

Fig. 4 presents a graphical dependence of the reflection coefficient of the developed phase shift device for horizontal and vertical polarization for the given method, FDTD method, FEM method.

The solid line shows the vertical polarization, and the dot represents the horizontal polarization. As you can see, the maximum level of the reflection coefficient is 0.6 for the given method, 0.52 for the FDTD method and 0.63 for the FEM method.

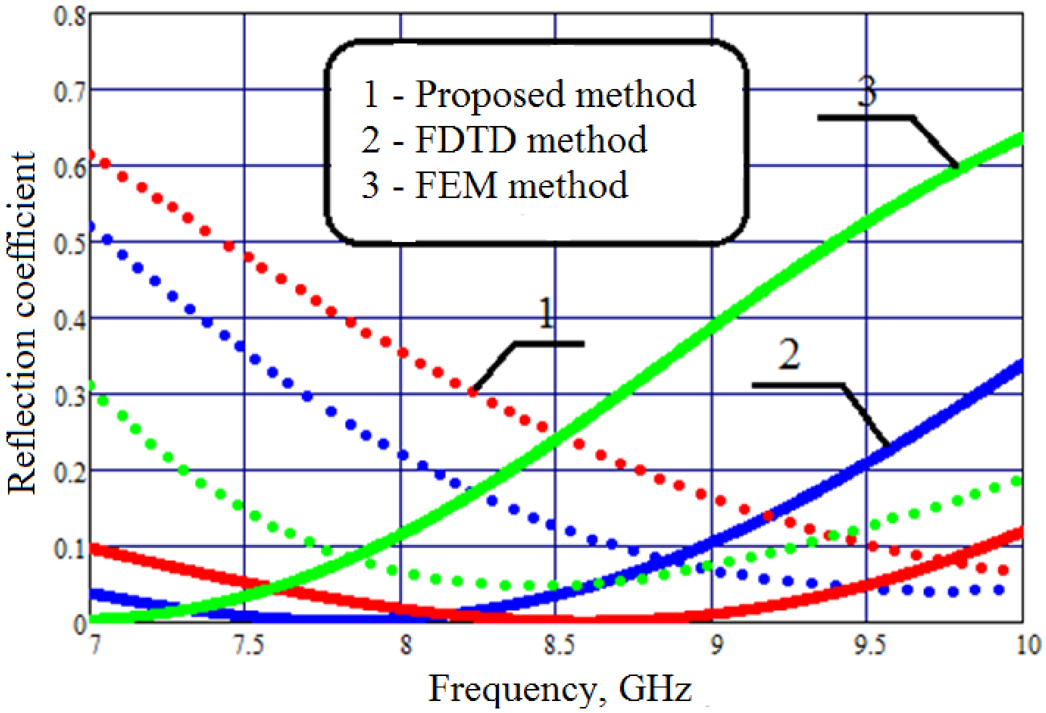

Fig. 4. The dependence of the reflection coefficient on the frequency for both polarizations

Therefore, the results of device design by the given method and known electrodynamic methods correlate well with each other.

Thus, in the course of scientific research, a phase-shifting device based on a square waveguide with three diaphragms in the operating range of 7-10 GHz was developed. The proposed device supports a differential phase shift of 90° ± 5°. The peak value of the reflection coefficient for vertical and horizontal polarizations is 0.52 at a frequency of 7 GHz. Therefore, the proposed device can be used in modern phased array antennas.

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