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THE FEATURES OF THE USE OF THE WAVEGUIDE RADIATORS IN SMART ANTENNA SYSTEMS

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The features of the use of finite waveguide antenna arrays in the structure of modern smart antenna systems are considered. The paper deals with the problem of diffraction of an electromagnetic wave on a finite waveguide antenna array scanning in the E-plane. Antenna array consists of five radiating elements. The open ends of the waveguides are surrounded by a metal screen. The resonator coupling region was chosen as matching elements. The solution of the problem is carried out by the integral equation method on the basis of the selection of overlapping regions. The problem reduces to solving the Fredholm integral equation of the second kind. An array of infinitely thin plates and that of waveguides with a finite wall thickness are considered. The main regularities for choosing the optimal geometric dimensions of the antenna array are established. Studies were carried out for arrays with a number of elements from five to fifteen. The analysis of edge effects in the final antenna array is carried out. It is shown that the introduction of a resonator region into a five-element lattice makes it possible to expand the sector of the radiation angles and avoid the effect of blinding. It is shown that this statement is valid not only for five-element lattices, but also for arrays with a large number of radiating elements. The radiation patterns are calculated. The coefficients of mutual coupling in an array with five elements are investigated. General recommendations for choosing optimal sizes of the resonator coupling region of radiators are considered.

Keywords: antenna array, open end of waveguides, matching elements, scan sector, effect of blinding, integral equation.

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1. Introduction

Recently, smart antennas are used in mobile communication and navigation systems [1]. One of the constituent parts of the smart antenna is the final antenna array. An antenna array can contain various types of radiators. In most cases waveguides are used as radiating units. The main task in designing the radiating units is their matching with free space.

Most often in practice, a matching device is used in the feeder, providing a full matching for one of the corners in the scan sector.When using a dielectric coating, it must be taken into account that for sufficiently high values of the dielectric constant of the coating, the deflection of the beam from the normal leads to the existence of the wave type similar to a surface wave in an antenna lattice. This wave propagates inside the dielectric, but attenuates in free space. In this case, exceeding the thickness of the dielectric coating over a certain value causes the appearance of a resonant peak, whose maximum value in the general case is unity. This corresponds to the regime of "glare of phased arrays". A further increase in the thickness or value of the dielectric constant of the coating leads to the appearance of two or more peaks on the reflection coefficient curve. A dielectric insert in a waveguide can be used as a structural element (protection of waveguides from an external medium) and for the implementation of a matching device. It should be taken into account that the use of inserts with a high dielectric constant at certain thicknesses of inserts can lead to the appearance of peaks on the reflection coefficient curves associated with resonances of higher types of waves in inserts. In general, the use of a single-layer insert located directly at the radiator opening does not provide an improvement in the matching of the radiator, whereby it is necessary to use a multi-layered insert located at some distance from the opening. The coordination in the presence of a dielectric protective coating can be provided by using additional waveguide elements, for example, such as a common resonator region. Thus, the matching is achieved not by multilayer dielectric compositions, but by a combination of a purely protective dielectric coating and a resonator region with optimal geometric dimensions.

2. Formulation of the problem

At present, the analysis of waveguide antenna arrays, based on the model of an infinite periodic structure of radiators, is generally accepted; the excitation of radiators corresponds to the conditions of Floquet's theorem. It should be noted that the model of an infinite antenna array accurately describes the behavior of the radiator only in the central region of a large array, when homogeneity of its surroundings is ensured. At the edges of the array, the characteristics of the radiators (reflection coefficient, directional pattern) can differ significantly. According to the estimates of various sources [2, 3], the edge region for waveguide arrays can be from four to eight radiators, depending on the rate of decrease in the mutual coupling coefficient between the radiators. The finiteness of the structure of the antenna array affects the amplitude-phase distribution of the field along the entire surface of the array. Consequently, in order to form the required amplitude-phase distribution, it is necessary to correct the microwave power distribution circuits taking into account this influence [4, 5]. Finally, when calculating the directivity pattern of the array in the region of the side lobes and in determining the polarization characteristics, it is necessary to take into account the distortions of the radiation pattern due to the radiators belonging to the edge regions. In the model of an infinite antenna array, the "edge effect" is not taken into account, and in the array with the number of elements less than 300, it is necessary to take into account the "edge effect". The engineering approach to calculating the finite lattice, based on the model of an infinite periodic structure, is not correct. All these factors limit the use of the general model of an infinite antenna array with respect to the calculation of the final antenna array. All these factors limit the use of the general model of an infinite antenna array for the calculation of characteristics of the finite antenna array. Let's consider the inter-resonator coupling region of the radiators as a matching element (Fig.1).

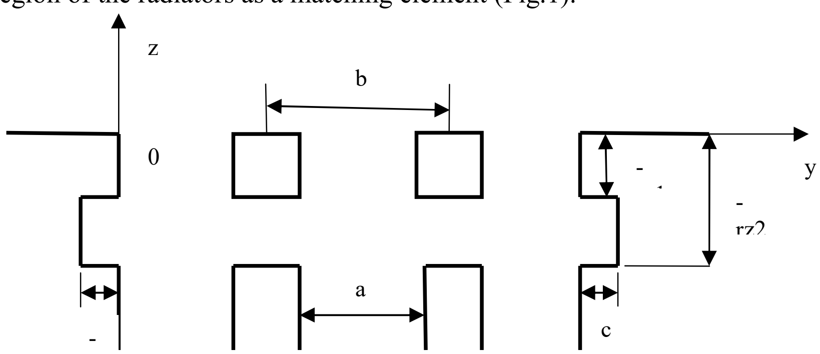

Fig. 1. The finite linear antenna array in the plane ZOY.

We consider an array with walls of finite thickness. It is established that for some dimensions rz1, rz2, c, a resonant structure that minimizes the reflection coefficient ($|R|$) in the waveguides can be obtained. Fig. 2 shows the dependence on the phase shift in waveguides with the numbers n = 1, 2, 3. The figure confirms that the change in the size c significantly changes $|R|$ in the central and in the extreme waveguides. In the central waveguide, a peak-like increase $|R|$ can be observed at a certain value of the phase shift φ between the waveguides. At the same time, in outside waveguides $|R|$ increases substantially for all φ. The influence of the width of the coupling region (rz2-rz1) on the value $|R|$ is investigated. It is established that a change in the width of the coupling region with both upward and downward directions relatively to the optimal size results in a shift of the dependences $|R|$= f (rz2-rz1) to the top (increases $|R|$ practically without changing the geometry of the curves), see Fig.3.

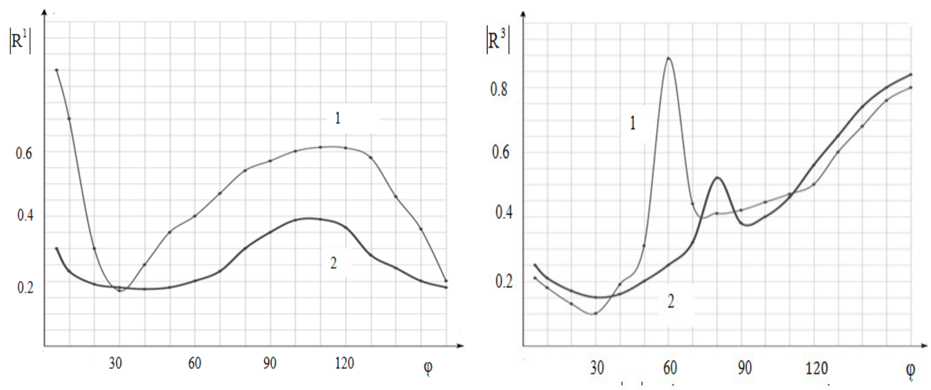

Fig. 2. Dependence of |R^n| on the phase shift φ for a fixed rz1/λ and rz2/λ at different c/λ: N=5; b=0.7λ; a=0.29λ; rz1=0.25λ; rz2=0.4λ; 1 – c=0.01λ; 2 – c=0.1λ.

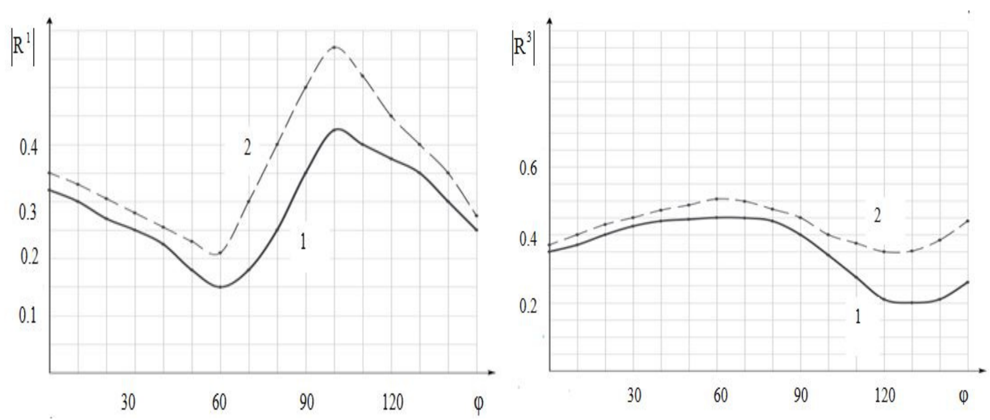

Fig. 3. Dependence of |R^n| on the phase shift φ for a fixed rz1/λ and different rz2/λ: N=5; b=0.6λ; a=0.1λ; rz1=0.25λ; c=0.15λ; 1 – rz2=0.45λ; 2 – rz2=0.5λ.

It is shown that the thickness of the walls of the waveguides exerts a significant influence on the dimensions of the resonator coupling region. It is interesting to compare the dependence of the reflection coefficient on the phase shift φ between waveguides (the radiation angle) in arrays with a coupling region and without a coupling region of the radiators. Let us consider the behavior of the reflection coefficient in a central waveguide in a five-element lattice. It is shown that in an array without a coupling region, a "glare effect" is observed in certain phase shifts in the central radiator (Fig. 4), while in an array with a coupling region for a central radiator, the dependence $|R|$ on φ monotonically decreases with increasing φ. Thus, for a central radiator, the introduction of the resonator region allows either to avoid the "blinding effect" or to narrow its manifestation in a narrow sector of the radiation angles (Fig. 5). Consequently, the introduction of the resonator region of the radiators into the five- element array makes it possible to expand the sector of the radiation angles. This statement is valid not only for five-element array, but also for arrays with any finite number of radiating elements.

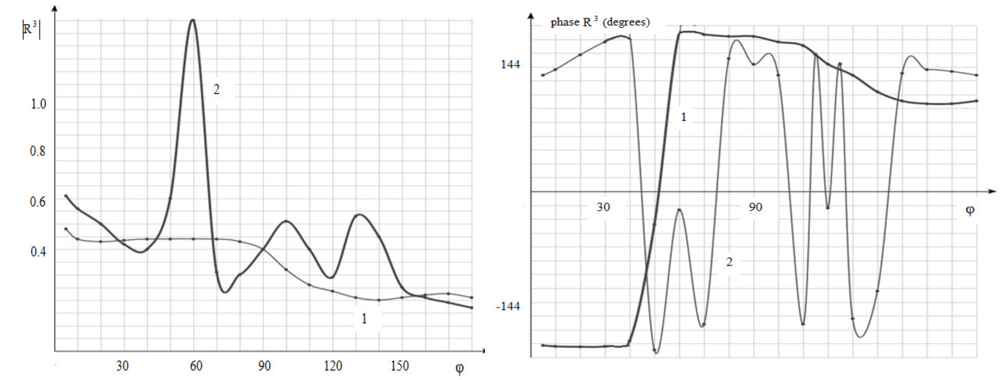

Fig. 4. Dependence R^3 on the phase shift φ: N = 5; b=0.6λ; a=0.1λ; rz1=0.25λ; rz2=0.45λ; c=0.15λ; 1 - array with a coupling region; 2 - array without a coupling region.

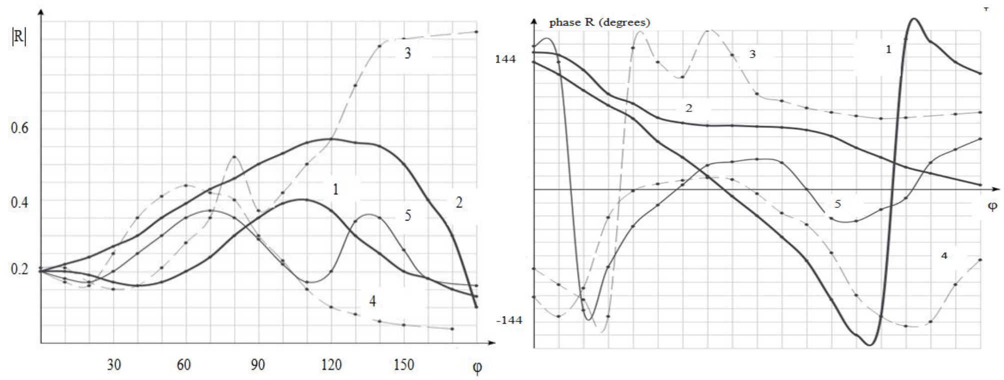

Fig. 5. Dependence R^n on the phase shift φ: N = 5; b=0.7λ; a=0.2λ; rz1=0.25λ; rz2=0.4λ; c=0.1λ; 1 – n=1; 2 – n=2; 3 – n=3; 4 – n=4; 5 – n=5.

3. Conclusions

1. The resonant coupling region allows the finite antenna array to be matching with the free space.

2. The resonator coupling region of the radiators allows expanding the scan sector and avoiding the "blinding effect".

3. In the finite antenna array, it is necessary to take into account the "edge effects" over the entire aperture of the array. One of the possible options for technical implementation is the use of rounding the edges around the perimeter of the antenna array.

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