The Empirical Formula to Calculate an Equivalent Surface Impedance of Artificial Impedance EM Surfaces Based on Microstrip Reflectarrays

Alexander Kasyanov, Sergey Strochkov

Abstract - **The anisotropic microstrip reflectarray is considered in this paper. The printed element of this reflectarray has an arbitrary shape. Such reflectarray is a design which allows to create artificial electromagnetic surfaces. Impedance properties of an artificial EM surface are set by the developer.**

Keywords - **Printed Reflectarray, Artificial Impedance Surfaces, Integral Equation, Empirical Formula.**

I. INTRODUCTION

Research of impedance and polarizing properties of three models of infinite anisotropic reflectarrays is the purpose of this paper. We shall assume that a homogeneous substrate from a dielectric material is located above an infinite ideally conducting plane (screen). Microstrip re-radiators are periodically located on a surface of a dielectric substrate. The shape of reflectarray re-radiators is arbitrary. The controllable loads which shunt in N points each radiator of a reflectarray, are located in a slab of a dielectric substrate. This reflectarray is excited by plane wave of linear polarization. It is required to determine impedance properties and to make the equivalent circuit the microstrip reflective type antenna array.

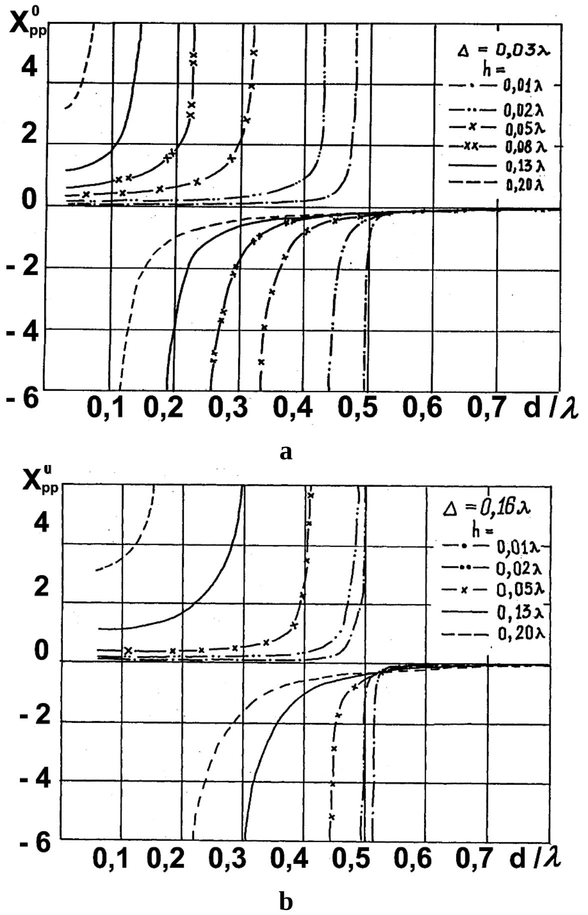
II. EMPIRICAL FORMULA

This problem has been solved by integral equations method. Due to using of a periodicity condition for the solution of a boundary problem it was required to find only currents inside the Floquet channel. The solution is obtained as system of integral equations. Surface currents in elements of a reflectarray are unknown values of these equations. The currents distributions, which have been found as a result of the numerical solution of integral equation system, have been used to determine a polarizing scattering matrix of a reflectarray [1].

The tensor of equivalent surface impedance $\hat{Z}$ is determined for single – wave range of reflectarray periodicity due to its polarizing scattering matrix. The elements of this tensor are determined from equality of a reflectarray fields and an equivalent anisotropic impedance surface in a far zone [2].

Impedance properties of reflectarrays from rectangular microstrip radiators without loads in a single – wave range are numerically investigated. Numerical results (one of examples is shown in Fig. 1) have shown that each of such reflectarrays is equivalent to a short – circuited waveguide with characteristic impedance W_e and phase delay ξ, which depend on reflectarray geometry [3].

The impedance loads addition to a microstrip element of a reflectarray changes its impedance properties. Due to impedance load in the impedance characteristic of a reflectarray there is an additional pole. The pole of the impedance characteristic can be considered as a resonance. Occurrence of an additional pole in the impedance characteristic of a reflectarray shows, that at connection of loads to sides of a microstrip element the length of an equivalent waveguide increases. Hence, due to change of a load connection place, it is possible to control "border of reflection" the wave penetrating under a microstrip element.



a

b

Fig. 1 Impedance characteristics of the first model of an artificial impedance electromagnetic surface

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Due to the numerical analysis of reflectarray impedance properties the empirical formula is obtained. This formula enables to obtain eigen values of an equivalent surface impedance tensor $Z^0_{11,\,22}$. Due to this formula, elements of an equivalent surface impedance tensor are expressed through reflectarray constructional parameters. The empirical formula is obtained for reflectarrays, which are made of the square microstrip elements located in nodes of a grid with a square unit cell. The important feature of such impedance radar covers is equality $Z^0_{11} = Z^0_{22}$ and the least anisotropy, is especial at the small reflectarray step d/l. Let's designate $Z^0_{11} = Z^0_{22} = Z^0_{\mathrm{pp}}$, p = 1, 2. The empirical formula is obtained on set of functions:

$$Z^0_{pp} = iX^0_{pp}; \quad X^0_{pp} = W_e \frac{\Delta}{d} tgx \qquad (1)$$

where

$$x = k\left(1 + a\frac{a}{l}\right)(h + ba),\ k = \frac{2p}{l},\ \Delta = d - a, \qquad (2)$$

a — size of a microstrip element side; h — thickness of a dielectric substrate; W_e, a, b — parameters – functions which should be determined. The structure of expression (1) occurs, as from behavior of impedance characteristics of the reflectarrays, as the obvious physical assumption of averaging Z^0_{pp} in the unit cell of a reflectarray. The parameters – functions a, b are determined by a method of the chosen points [4]. Thus conditions of a resonance Z^0_{pp} such as a parallel oscillatory contour which are determined by formula (1), when $x = p/2$, and break points of the graphs in Fig. 1 were compared. For parameters a, b it is possible to write down empirical formulas as

$$a = \frac{1 - 6{,}844\Delta/l}{0{,}089 + 1{,}13\Delta/l}; \quad b = \frac{0{,}071 + \Delta/l}{1 - 4{,}13\Delta/l}; \qquad (3)$$

These expressions are fair, if such restrictions as $0{,}02 \le \Delta/l \le 0{,}16$ and $0{,}005 \le \Delta/l \le 0{,}1$ take place.

The parameter – function W_e is determined by comparison of the values Z^0_{pp} calculated from expressions (1), (2), and the values Z^0_{pp} found from schedules which are shown Fig. 1.

The relationships between values W_e and geometry of a microstrip reflectarray unit cell are shown in Fig. 2. It is shown, that at small slots between strips $\Delta/l \approx 0{,}03$ for a microstrip reflectarray, which thickness is equal $h \ge 0{,}01\ l$, values W_e will exceed unit. If the slot increases, value W_e is reduced, and when $\Delta/l > 0{,}1$ value W_e will be already less 1. The value of parameter W_e falls, when the size of a microstrip re – radiator increases. It occurs in a case $\Delta/l \approx 0{,}16$.

The equivalent circuits of the microstrip impedance loads consisting of lumped elements have been constructed by authors in [5].

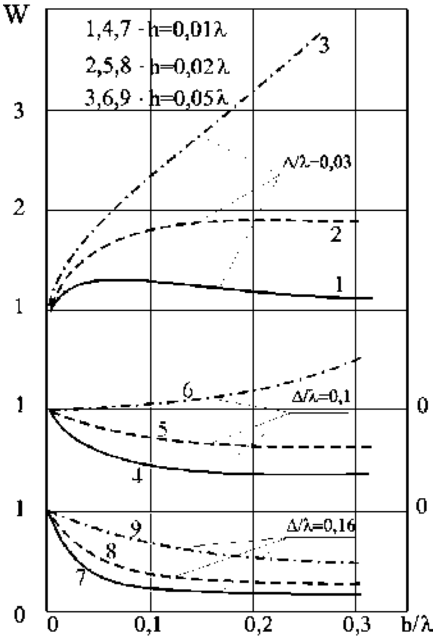

Fig. 3 The parameter – function $W_e(b/l)$ in expression for eigen values of impedance tensor

III. CONCLUSION

These numerical results can be used at synthesis of thin artificial impedance anisotropic substrates, printed antenna polarizers and high-tech microstrip absorbing radar covers.

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