AN INTEGRAL EQUATION ANALYSIS OF THICK IRISES IN WAVEGUIDES OF A PHASED ARRAY ANTENNA

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One of the effective approaches for treating diffraction problems in waveguide structures is the mode-matching technique [1]. It is a convenient method for threating structures that can be divided on two or more separate regions. The integral equation method is also widely used for solving diffraction problems in waveguides due to its well-known advantages [2]. Electromagnetic field can be represented as integral equation by using Green's functions. In this case integral equation shows interconnection between sources of field and radiated or scattered field. The Schwartz alternating method and the overlapping partial domain method combine advantages of considered methods [3, 4]. These methods consist of dividing a whole field definition domain into simple overlapping partial domains, whose Green's functions are known. Through the use of Green's functions the initial problem is reduced to a Fredholm integral equation of second kind that is solved by iteration method. According to overlapping partial domain method the resulting integral equations are solved with the Galerkin's method. In present paper the method of overlapping partial domains is used for solving electromagnetic wave diffraction problem for irises placed in apertures of an infinite waveguide PAA.

Consider the unit cell of an infinite phased antenna array constituted by rectangular waveguides, whose apertures have matching irises (Fig. 1).

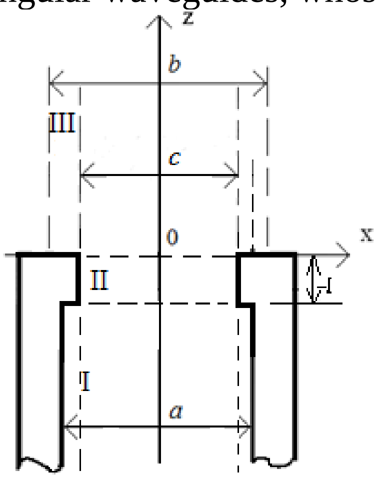


Figure 1. Irises in a single cell of PAA

Since the field in radiation region has periodic character one can take into account a unit PAA cell located at the origin. The PAA waveguides are excited by incident wave of type H_{10}. As shown in [2], if beam scanning is performed in the *H*-plane and waveguide walls which are normal to electrical field vector have infinitesimal thickness, only an E_y–component of electrical field has to be found satisfying two-dimensional Helmholtz equation. Next, we divide the whole field definition domain of the selected PAA cell into three overlapping partial domains. Domain I: $-a/2 \le x \le a/2$, $-\infty \le z \le -l$. Domain II: $-c/2 \le x \le c/2$, $-l \le z \le 0$. Domain III: $-b/2 \le x \le b/2$, $0 \le z \le \infty$. The H_{10} wave is excited in domain I at $z \to -\infty$. Suppose that the Green's functions of domains I, II and III are known. Then, we can set up a system of integral equations of fields for each domain using the Green's second identity:

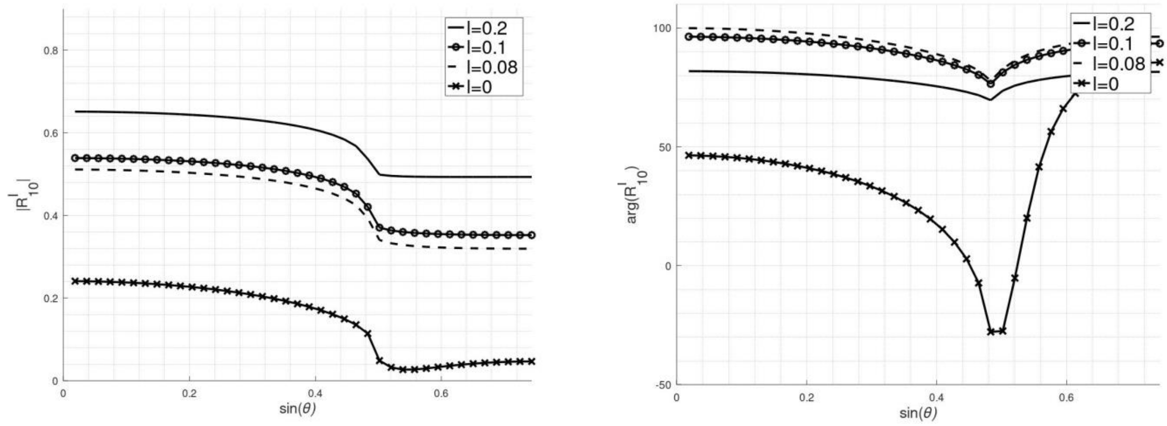
$$\begin{cases} \vec{E}_I(\vec{r}) = E_{inc}(x,z) - \int\limits_{-c/2}^{c/2} E_{II}(x',-l) \cdot \dfrac{\partial G^I(x,z;x',-l)}{\partial \vec{n}'} dx'; \\ \vec{E}_{II}(\vec{r}) = \int\limits_{-\infty}^{-l} E_I\left(-\dfrac{c}{2},z'\right) \cdot \dfrac{\partial G^{II}\left(x,z;-\dfrac{c}{2},z'\right)}{\partial \vec{n}'} dz' - \\ -\int\limits_{-\infty}^{-l} E_I\left(\dfrac{c}{2},z'\right) \cdot \dfrac{\partial G^{II}\left(x,z;\dfrac{c}{2},z'\right)}{\partial \vec{n}'} dz' + \\ +\int\limits_{0}^{\infty} E_I\left(-\dfrac{c}{2},z'\right) \cdot \dfrac{\partial G^{II}\left(x,z;-\dfrac{c}{2},z'\right)}{\partial \vec{n}'} dz' - \int\limits_{0}^{\infty} E_I\left(\dfrac{c}{2},z'\right) \cdot \dfrac{\partial G^{II}\left(x,z;\dfrac{c}{2},z'\right)}{\partial \vec{n}'} dz'; \\ \vec{E}_{III}(\vec{r}) = \int\limits_{-c/2}^{c/2} E_{II}(x',0) \cdot \dfrac{\partial G^{III}(x,z;x',0)}{\partial \vec{n}'} dx'. \end{cases} \quad (1)$$

Here: x, z are coordinates of the observation point, x', z' are coordinates of the source point, G_{I}, G_{II}, G_{III} are the Green's functions of domain I, II and III, $\vec{n}'$ denotes an outward unit normal vector to a partial domain boundary surface, a prime symbol denotes that differentiation is performed at source points.

In order to obtain a solution for system (1) we use the following approach [3, 4]. We represent unknown functions for each domain as a series of orthogonal eigenfunctions with unknown expansion coefficients, which have physical meanings of transmission and reflection coefficients:

$$\begin{aligned} E_{\text{I}}(x,z) &= E_{inc}(x,z) + \sum_{q=1}^{\infty} R_q^I \phi_q^I(x) \exp\left(j\gamma_q^I(z-l)\right); \\ E_{\text{II}}(x,z) &= \sum_{p=1}^{\infty} T_p^{II} \phi_p^{II}(x) \exp\left(-j\gamma_p^{II}(z-l)\right) + \sum_{p=1}^{\infty} R_p^{II} \phi_p^{II}(x) \exp\left(j\gamma_p^{II} z\right); \\ E_{\text{III}}(x,z) &= \sum_{m=-\infty}^{\infty} T_m^{III} \psi_m(x) \exp\left(-j\Gamma_m z\right). \end{aligned} \quad (2)$$

We substitute these representations into system (1) and fix coordinates of source and observation points. Then using a property of eigenfunctions orthogonality the system (1) is reduced to a system of linear equations for unknown expansion coefficients. The obtained system can be solved using direct or iterative method after limiting the number of unknowns to a finite value. The modulus of reflection coefficient of an incident H_{10} wave is determined by value of the R^{I}_{1} coefficient.



(a) (b)

Figure 2. The dependence of the reflection factor modulus (a) and phase (b) on the on the steering phase shift for PAA with *b*/λ=0.5714, *a*/*b*=0.937.

Fig. 2 depicts obtained dependence of the reflection coefficient magnitude (a) and phase (b) on the value of steering phase shift *sin*(θ) for PAA with waveguide dimensions *b*/λ=0.6724, *a*/*b*=0.937, *c*=0.8*a* for different values of *l*.

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Анотація

Показано застосування методу інтегральних рівнянь часткових областей, що перетинаються для розв’язання задачі дифракції електромагнітної хвилі на нескінченій фазованій антенній решітці, хвилеводи якої мають діафрагми кінцевої товщини. Отримано значення коефіцієнта відбиття для різних розмірів діафрагм.

Ключові слова: метод Шварца, функція Гріна, інтегральні рівняння.

Abstract

In this paper the integral equation method for overlapping partial domains has been applied to solving the electromagnetic wave diffraction problem on a phased array antenna, which waveguides have irises of a finite thickness. The dependences of the reflection coefficient magnitude and phase on the value of steering phase shift for different iris dimensions are obtained.

Keywords: Schwarz alternating method, Green`s function, integral equations.