TRANSVERSE PROPAGATION IN DIELECTRIC WAVEGUIDE ARRAY

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Received January 22, 2002

ABSTRACT

Transverse propagation eigen equations for dielectric waveguide array (DWA) are derived and eigen solutions can be uncoupled into TE and TM modes. Numerical results shows that much stronger space harmonic interaction exists so that a series of interesting physical effect of canonical two-dimensionally periodic (2DP) medium can obviously be observed in DWA and related devices can be predicted, designed and realized much easier.

INTRODUCTION

Though the theory of canonical 2DP medium [1] has established for years, many interesting effects in the medium are not clearly revealed so far because of effect weakness for typical modulation parameter and involvement in the numerical processing. This situation is changed since DWA is investigated as a particular kind of 2DP medium. DWA should have all general properties of 2DP medium, but with much stronger piece wise modulation nature, the useful physical effects may become very strong so that easier to illustrate. And such strong modulation will not cause particular numerical difficulties invoking the novel theory of 2DP media and DWA[2]. This paper is concentrated on the transverse propagation in which the wave vector has no longitudinal component. Strong effects such as anisotropic guidance, space and

The project supported by National Science Foundation of China
frequency filtering, beam focusing and steering \cite{3} are emphasized because of their widespread applications in many kinds of infrared and millimeter wave planar waveguide devices or others.

**EIGENSOLUTIONS**

DWA can be considered as piecewise uniform (PU) 2DP media with the unit cell shown in Fig. 1 that

\[
\begin{align*}
\varepsilon_r(x,y) &= \begin{cases} 
\varepsilon_1 & \text{in region 1} \\
\varepsilon_2 & \text{in region 2} \\
\vdots & \\
\varepsilon_q & \text{in region q}
\end{cases} \\
\end{align*}
\]

where \(\varepsilon_{rp}, p=1,2,\ldots, q,\) is the relative permittivity in region \(p\), \(s = a + b + c + \ldots + s_q\) is the area of unit cell, and \(s_p, p=1,2,\ldots, q,\) is the area of region \(p\), it has established \cite{2} that the eigen equation is given by

\[
(k_{ij} \bullet k_{ij} - k_{ij} k_{ij}) E_{ij} - k_0^2 \sum_{mn}^{3} \sum_{p=1}^{q} \epsilon_{rp} \psi_{mn} \psi_{ij}^* ds E_{mn} = 0
\]  

Unit dyad 1 is always omitted where there is no possible misunderstanding.

Denoting \(k = k_0 + z_0 k_0\), where \(k_0 = x_0 k_x + y_0 k_y\), and noticing \(kk = k_0(k_0 + z_0 k_0) + k_0^2 z_0 k_0\), it is obvious for transverse propagating wave \((k_{ij}=0)\) that all coupling terms above and \(k_0^2 z_0 k_0\) disappear, and Eq. (1) can be decomposed into two uncoupled relations that

\[
(k_{ij} \bullet k_{ij} - k_{ij} k_{ij}) E_{ij} - k_0^2 \sum_{mn}^{3} \sum_{p=1}^{q} \epsilon_{rp} \psi_{mn} \psi_{ij}^* ds E_{mn} = 0
\]  

and

\[
(k_{ij} \bullet k_{ij}) E_{xij} - k_0^2 \sum_{mn}^{3} \sum_{p=1}^{q} \epsilon_{rp} \psi_{mn} \psi_{ij}^* ds E_{xm} = 0
\]

where \(E_i = x_0 E_x + y_0 E_y\).

Two kinds of non-trivial solution can be derived from Eqs 2 and 3:

\[
\sum_{mn} E_{mn} \psi_{mn} \text{ from (2) with all } E_{mn} = 0, \text{ it is nothing but TE solution}
\]