A Study on Eigenmode Analysis of Electromagnetic Wave Propagation in Post-Wall Waveguide

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Post-wall waveguides (PWWs, also known as substrate integrated waveguides) are widely used in millimeter and sub-millimeter regions. The PWWs are formed between two parallel metal planes and the fields propagates along the cylindrical posts arranged between the metal plates. Usually, the distance between two metal planes is much smaller than the wavelength and the metal plates are regarded as perfect conductors. The electric field is therefore directed perpendicular to both plates and the fields between the plates are uniform in this direction. This implies that the fields propagating in the PWW are treated as a two-dimensional problem. Various PWW devices are realized by cascading post-wall elements or adding some cylindrical posts. Many of these devices can be thought as multilayered structures, in which each layer contains several cylindrical posts, and their properties are often characterized by numerical approaches for the multilayer structure scatterings.

This study deals with a straight PWW and consider a numerical method to obtain a practical set of the eigenmode fields in it. If the PWW devices have the input/output ports in the form of straight PWW, the eigenmode expansion expression of the fields in the straight PWW is required to give the input/output conditions. The structure under consideration is periodic in the propagation direction and the Floquet theorem asserts that the eigenmode fields have a pseudo-periodic property. The eigenmode fields propagating in the straight PWW are usually calculated by the following method. The eigenmode fields are pseudo-periodic, and the fields in homogeneous region can be therefore expressed in the Floquet-Fourier expansion. The post-walls are periodic array of circular cylinders and the scattering-matrices for the post-walls can be derived by the recursive transition-matrix algorithm with lattice sum technique. Then, the dispersion equation for the eigenmode fields are derived from the existence condition of the fields. The dispersion equation is numerically solved by using such as Müller's method and the eigenmode fields are obtained. This method provides very accurate results for each eigenmode, but it is not easy to obtain a practical set of eigenmodes to express arbitrary fields in the PWW.

The formulation under consideration introduces the periodic boundary conditions and the fields are expressed in the Fourier series expansions [1]. Then, a set of eigenmode fields are simultaneously obtained by an eigenvalue/eigenvector analysis of the transfer matrix for the periodicity cell in the propagation direction. We also use the cylindrical-wave expansion expressions for the fields to treat the boundary conditions on the cylinder surface in an adequate manner and accelerate the convergence [2]. Main difficulty is to evaluate the leakage from the waveguiding structure. We use the perfectly matched layer [3] for this purpose.

References

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