Analysis of Substrate Integrated Waveguides by Transverse Resonant Technique

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***Abstract* - There have been many papers about applications of substrate integrated waveguide (SIW). Only a few related to the use of mathematical methods to analyze SIW, however, were reported. We present an analytical method that is easy, quick and also accurate to obtain the modal dispersion diagrams and field distributions of SIWs. The closed-form characteristic equations and field expressions provide us insights into the modal behavior of the SIW, providing us the knowledge of the impact and influences which the various parameters have on the SIW, thereby saving a great deal of time in engineering and design often entailing lengthy simulations by full-wave solvers or even trial-and-error practices. We compare the dispersion diagrams and modal field distributions obtained by using our analytical method with those generated by CST Microwave Studio.transverse resonant technique**

***Index Terms* — Periodic structure, substrate integrated waveguide (SIW), transverse resonant technique (TRT).**

I. INTRODUCTION

The substrate integrated waveguide (SIW) is an evolution in waveguide engineering technology. Not only does it retain the merits of traditional microstrip such as low cost, light weight and easy fabrication, it also includes the advantages of rectangular waveguides such as low radiation loss and high power handling capability. Therefore, the SIW has proven to be a successful innovation and continues to show promising potential as an important device for microwave planar circuits such as antennas, resonators and filters [1]–[3].

Different kinds of numerical methods such as the finite-difference frequency-domain (FDFD), method of lines (MoL), boundary integral-resonant mode expansion (BI-RME) method and mode matching analysis have been used to determine the propagation characteristics of the SIW structures [4]–[7]. Most of these methods are accurate but time and memory consuming. Although there is a paper using ABCD matrix to analyze the SIW [8], we provide another form of analysis by using classical vector potentials and the transverse resonant technique (TRT). The metallic posts of the SIW are herein modeled as metallic strips. It turns out that the speed of our analytical method is fast while maintaining its accuracy.

II. DISPERSION DIAGRAM

The mainframe analysis that we use for treating the SIW is the classical method of vector potentials. By this approach, we can obtain the electric and magnetic field equations in every region of the SIW. Once we know the fields expression at every region, we can acquire the surface impedance at every interface between every two connected regions. The characteristic equations are thereafter attained by enforcing the surface impedance equality in every two joint regions. For the purpose making the number of unknowns equal to the number of equations, we separate the modal fields within SIW into symmetric and asymmetric modes, the roots of which, being the eigen-modal resonant wavenumbers, can be numerically solved for. The SIW modal dispersion diagrams can subsequently be generated, comparison of which with those obtained by classical theory of the corresponding ordinary rectangular waveguide is shown in Fig. 1 for the following parameters: height of the entire structure = 7 mm, width of the central waveguiding portion = 30 mm, relative permittivity of all regions =1.

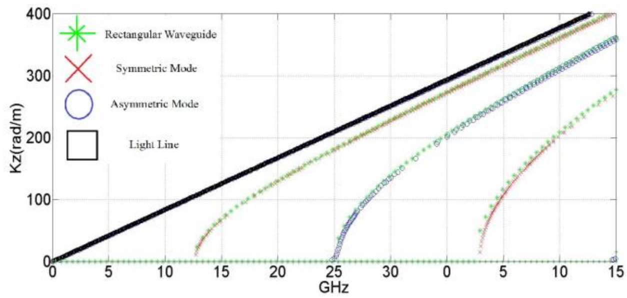

Fig. 1. Modal dispersion comparison between SIW by present analytical method represented by crosses and circles and corresponding ordinary rectangular waveguide represented by stars

As we can see that the dispersion diagram agreement between our SIW analysis and ordinary rectangular waveguide is high. The agreement is good enough to prove that periodic metallic strip gratings emulating a row of metallic pins can imitate a solid metallic wall by our analysis. After all, the SIW structure is not exactly the same as the rectangular waveguide. In pursuit of a truer comparison, the dispersion diagram generated by our asymptotic analytical technique is compared with the corresponding one simulated by a commercial full-wave software (CST Microwave Studio) in Fig. 2.

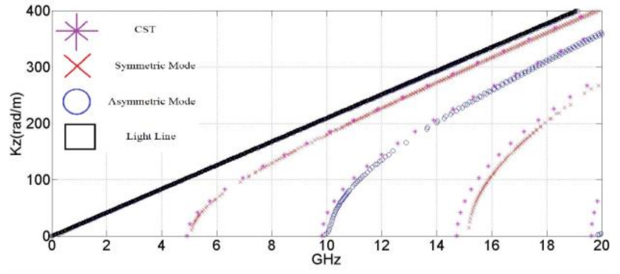

Fig. 2. Modal dispersion comparison between analytical method represented by red 'X' and blue 'O' and CST represented by purple '*' .

Obviously the analytical method and CST simulations have good agreement.

III. Fields Distributions

In order to further verify our analytical method, the closed-form electric and magnetic field expressions which are derived in the process are used to plot the dominant modal electric and magnetic field distributions over the cross section of the SIW, which are compared with those simulated by CST as shown from Fig. 3 through Fig. 6

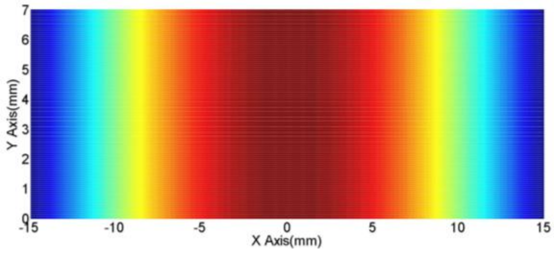

Fig. 3 electric field equations derived from analytical method and plot *Ey* field distributions by MATLAB.

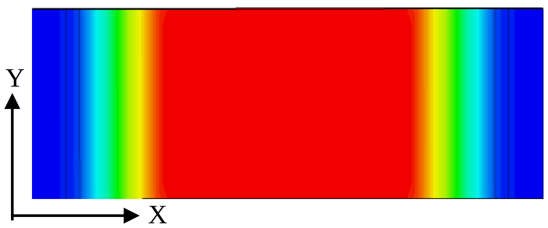

Fig. 4 *Ey* field distributions simulated by CST

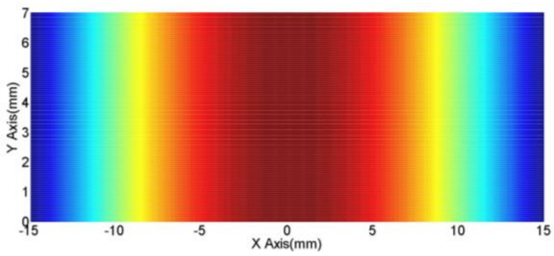

Fig. 6 magnetic field equations derived from analytical method and plot *Hx* field distributions by MATLAB.

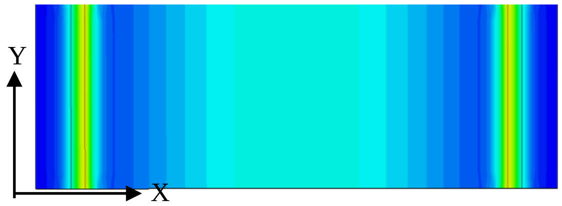

Fig. 7 *Hx* field distributions simulated by CST.

Clearly, the field distributions obtained by our analytical method are almost the same as those simulated by CST, further substantiating the validity and practicality of using our method to rapidly and accurately analyze the SIW.

IV. Conculusion

In this paper, we present a rapid and convenient way to analyze the SIW and obtain its dispersion diagram as well as modal field distributions. Compared to commercial software, this approach is much faster and yet without compromising accuracy.

V. Reference

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