A Comparison of Three-Dimensional Simulations of Traveling-Wave Tube Cold-Test Characteristics Using CST MICROWAVE STUDIO and MAFIA

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Previously, it was shown that MAFIA (solutions of Maxwell’s equations by the Finite Integration Algorithm) [1, 2], a three-dimensional simulation code, can be used to produce accurate cold-test characteristics including frequency-phase dispersion, interaction impedance, and attenuation for traveling-wave tube (TWT) slow-wave structures [3]. In an effort to improve user-friendliness and simulation time, a model was developed [4] to compute the cold-test parameters using the electromagnetic field simulation software package CST MICROWAVE STUDIO (MWS) [2]. Cold-test parameters were calculated for several slow-wave circuits including a ferruled coupled-cavity, a folded waveguide, and a novel finned-ladder circuit using both MWS and MAFIA. Comparisons indicate that MWS provides more accurate cold-test data with significantly reduced simulation times.

Both MAFIA and MWS are based on the finite integration (FI) method; however, MWS has several advantages over MAFIA. First, it has a Windows based interface for PC operation, making it very user-friendly, whereas MAFIA is UNIX based. MWS uses a new Perfect Boundary Approximation (PBA), which increases the accuracy of the simulations by avoiding stair step approximations associated with MAFIA’s representation of structures. Finally, MWS includes a Visual Basic for Applications (VBA) compatible macro language that enables the simulation process to be automated and allows for the optimization of user-defined goal functions, such as interaction impedance. One present disadvantage of MWS is a lack of periodic boundary conditions, which requires the user to model several cavities of the slow-wave structure and to truncate each section with electric or magnetic boundaries in order to calculate the resonant frequencies at corresponding phase shifts per cavity [3]. However, periodic boundaries will be implemented into MWS in the future.

Cold-test simulations, including frequency-phase dispersion, interaction impedance, and attenuation, using MWS and MAFIA will be compared for three types of TWT slow-wave circuits: a ferruled coupled-cavity TWT circuit, a folded waveguide TWT circuit, and a novel finned-ladder TWT developed at NASA GRC [5]. For all cases, improvements in accuracy and dramatic savings in time were achieved. For example, the simulation time was 8.6 times faster for the finned-ladder circuit simulations with MWS on a PC compared to MAFIA on a Sun Ultra 80 Workstation. Figure 1 illustrates the user-friendly MWS graphical user interface (GUI) with a three-dimensional cutaway of three-cavities of the ferruled coupled-cavity circuit. The electric field is shown at a phase shift of 300° per cavity, with the size and color of the arrows proportional to the magnitude of the field.

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Figure 1.—MWS three-dimensional electric field plot for a TWT circuit. Size and color of three-dimensional arrows are proportional to magnitude of the field. Phase shift per cavity, $\beta L$, 300°.

2 Computer Simulation Technology (CST), www.cst.de
5 Patent filed.