

DISCRETE-STATE SIMULATED ANNEALING FOR TRAVELING-WAVE TUBE SLOW-WAVE CIRCUIT OPTIMIZATION

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Algorithms based on the global optimization technique of simulated annealing (SA) have proven useful in designing traveling-wave tube (TWT) slow-wave circuits for high RF power efficiency [1,2]. The characteristic of SA that enables it to determine a globally optimized solution is its ability to accept non-improving moves in a controlled manner. In the initial stages of the optimization, the algorithm moves freely through configuration space, accepting most of the proposed designs. This freedom of movement allows non-intuitive designs to be explored rather than restricting the optimization to local improvement upon the initial configuration. As the optimization proceeds, the rate of acceptance of non-improving moves is gradually reduced until the algorithm converges to the optimized solution. The rate at which the freedom of movement is decreased is known as the annealing or cooling schedule of the SA algorithm.

The main disadvantage of SA is that there is not a rigorous theoretical foundation for determining the parameters of the cooling schedule. The choice of these parameters is highly problem dependent and the designer needs to experiment in order to determine values that will provide a good optimization in a reasonable amount of computational time. This experimentation can absorb a large amount of time especially when the algorithm is being applied to a new type of design. In order to eliminate this disadvantage, a variation of SA known as discrete-state simulated annealing (DSSA) [3], was recently developed. DSSA provides the theoretical foundation for a generic cooling schedule which is problem independent. Results of similar quality to SA can be obtained, but without the extra computational time required to tune the cooling parameters.

Two algorithm variations based on DSSA were developed and programmed into a Microsoft Excel spreadsheet graphical user interface (GUI) to the two-dimensional nonlinear multisignal helix traveling-wave amplifier analysis program TWA3 [4]. The algorithms were used to optimize the computed RF efficiency of a TWT by determining the phase velocity profile of the slow-wave circuit. The mathematical theory and computational details of the DSSA algorithms will be presented and results will be compared to those obtained with a SA algorithm.

- [1] J. D. Wilson, "A Simulated Annealing Algorithm for Optimizing RF Power Efficiency in Coupled-Cavity TWTs," *IEEE Trans. Electron Devices*, December 1997.
- [2] J. D. Wilson, "Design of High-Efficiency Wide-Bandwidth Coupled-Cavity Traveling-Wave Tube Phase Velocity Tapers with Simulated Annealing Algorithms," *IEEE Trans. Electron Devices*, January 2001.
- [3] F. J. Cantelmi, "Discrete-State Simulated Annealing with Application to Preliminary Aircraft Design," PhD dissertation, Rutgers, January 2000.
- [4] D. M. MacGregor, "Two-Dimensional Nonlinear Multisignal Helix Traveling-Wave Amplifier Computer Program: User Manual, Version 5.02," Electrocon International, Inc., 1993.