SPECTRAL-DOMAIN MODELLING OF SUPERCONDUCTING MICROSTRIP STRUCTURES

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SUMMARY

The realistically achieved progress in the area of high-Tc superconductor microwave circuits has somewhat dampened the euphoric prognoses in the early nineties. However, this technology is still considered a powerful and cost-effective alternative to low-Tc niobium components on one hand, and, in order to achieve device miniaturization and loss reduction, to standard MIC's and MMIC's on the other. Although many papers appeared on this topic, most of the investigations were experimental in nature which indicates an urgent need for accurate analysis and design capabilities.

The numerical model chosen for the analysis of high-Tc superconductor structures must satisfy the requirements, first, for including the finite strip/ground-plane thickness and conductivity and, secondly, for fast computation in order to allow for iterative processes such as nonlinear device modelling and optimization. Although it is widely felt that the spectral-domain immittance approach incorporating the complex boundary condition is an appropriate technique for this task, its successful application to superconducting structures has been slowed down by employing surface impedance expressions for low or high strip thickness limits, and by relying on conductivities from the two-fluid model.

Therefore, this paper focuses on exactly these two issues. First, accurate expressions for the surface impedances within the Green's dyadic functions are derived. As expected in the case of thick conductors, the surface impedance is adequately represented by the wave impedance of that conductor. For thin conventional conductors or superconductors, however, different surface impedances are obtained for TE-to-y and TM-to-y modes (y being the direction normal to the planar circuit). This result shows that even known continuous functions of the surface impedance via strip thickness fail to accurately predict the behaviour of the electromagnetic field in cases where the strip thickness falls into the order of magnitude of the penetration depth.

Secondly, we address the dependence of the conductivity on both temperature T and tangential magnetic field H. Instead of emperically adjusting the well-known expression for the intrinsic London penetration depth, the Ginzburg-Landau equations are employed in order to obtain the conductivity σ as a function of H and T. By incorporating this expression in the surface impedance, the line parameters are iteratively solved for convergence of the magnetic field. The current densities are normalized by requiring the magnetic field not to exceed the critical field of the conductor at operating temperature.

The presentation will concentrate on the basic theoretical steps and their importance for the analysis of superconducting structures. Example calculations will be presented for single and coupled microstrip configurations as well as for patch resonators.