Electro-Thermal Model for the Design of Schottky Diode Based Circuits

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Abstract

The planar GaAs Schottky diode frequency multiplier is a critical component for the local oscillator for submillimeter wave heterodyne receivers. They provide low mass, electronic tunability, broad bandwidth, long life time, and room temperature operation. The use of a W-band (75GHz – 110 GHz) power amplifier followed by one or more frequency multipliers is the most common implementation of submillimeter-wave sources from 200 GHz to 2000 GHz.

Recently, W-band GaN-based MMIC power amplifiers and power-combined GaAs power amplifiers have provided the possibility of generating watt level powers at W-band. As more power at W-band is available to the multipliers, the power handling capability of multipliers becomes more important. High operating temperature due to the high input power leads to degradation of conversion efficiency.

Therefore, electro-thermal models have to be used to optimize the performance of the devices themselves but also the multipliers. We have developed a circuit simulator that couples the embedding circuit with a numerical physics-based electro-thermal model for Schottky diodes. This model takes into account both the electrical limiting transport mechanisms and also self-heating. The thermal characteristics are taken into account by adding the heat conduction equation to an existing physics-based electrical model based on the drift-diffusion theory. This additional equation applies conservation of energy to the composite system consisting of electrons, holes, and phonons.

Thermal phenomena are strongly affected by 3D propagation effects, and are relevant on lengths much larger than what is needed for an accurate electrical description. This property makes a direct numerical solution of the coupled electro-thermal problem unnecessary. An accurate and efficient approach is thus required, based on the full numerical solution of the transport equations coupled to the heat transfer equation in a reduced volume. This reduced volume includes all areas of the device where electrical effects take place. Thermal effects from the excluded device volume are accounted for by using appropriate thermal transport boundary conditions, derived based on a lumped approximation of heat transfer in the corresponding areas.

This tool can be used to design appropriate Schottky diodes taking into account not only geometrical aspects but also different materials (GaAs diode on diamond, GaN diode on SiC). However, the main objective is to develop high performance Schottky-based circuits working at millimeter bands and above based on simulation tools with increasing capabilities.