Optimized Varactor Parasitic Modelling in the Millimeter-Wave Band

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This work explores the utilization of varactors in the millimeter-wave (mm-wave) band, specifically focusing on their application in voltage-controlled reconfigurable devices. Varactors, or variable capacitors, can adjust capacitance through voltage control, making them ideal for creating rapidly variable systems for radiofrequency (RF) applications. However, parasitic elements in varactors can significantly affect their performance when moving up to the millimeter-wave band and limit their efficiency. Therefore, this work aims to present an optimization approach that accurately calculates the parasitic model for these varactors.

The main problem often encountered when using nonlinear elements such as varactors is that, in general, simple circuit models are used, composed of a variable capacitance (C_j) and a series resistor (R_s). However, this behavior can only be assumed below the K-band, beyond which a model must include various parasitics influencing the device response. Among these parasitic elements, the most important ones are feed-line inductance (L_s), package capacitance (C_p), the capacitance between pads (C_{pp}), pad capacitance (C_{pad}), and inductance (L_{pad}). In turn, C_j and R_s can exhibit variant behavior with voltage and frequency, which causes the high-frequency varactor response to differing considerably from the simplified model that device manufacturers typically provide in their datasheets. To optimize the complete equivalent circuit, a parameter fitting has been performed, considering the proposed circuit model of the varactor and the capacitive effects of the gap over which the device is epoxy pasted. In this sense, three different varactor positions (top, side, and bottom) have been considered, modeling them as pad equivalent circuit variation. Once this adjustment has been considered, optimization processing has been carried out to establish a function that models the device's capacitance and series resistance variation. The equivalent model's results are similar to measurements over the entire operating range of the device studied.

By incorporating the proposed optimization approach, researchers can accurately predict the behavior of varactors and optimize the performance of reconfigurable devices in the mm-wave band. This work serves as a valuable resource for those working in the field of reconfigurable devices, providing a very accurate model of one of the most found varactors in the bibliography (Macom MAVR-011020-1411). The knowledge gained from this research can further contribute to developing high-performance, adaptive, and efficient mm-wave communication systems.

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