Physical RF Circuit Techniques and Their Implications on Future Power Module and Power Electronic Design

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Abstract

Power module design, now more than ever, is being thrust forward into the realm of high frequency, specifically the lower end of the RF (radio frequency) spectrum (3kHz to 100MHz). The rise of wide-band gap (WBG) semiconductors, such as SiC and GaN, has accelerated the desire to shrink the volumetric size and weight of end applications that utilize power circuits and power modules containing this WBG technology in order to drive down cost and boost overall efficiency. Applications range from DC-DC converters and power inverters to medical equipment, military radar, and satellite communications. Therefore, it is essential that power package design becomes heavily integrated with the power circuit design on all levels in order to achieve optimum results. This means lowering parasitic effects that are capable of degrading operation efficiencies when high frequency switching is present.

The goal of this project is to examine physical RF circuit design techniques, such as the use of strip lines, ground planes, co-planar wave-guides, and types of faraday cage structures, and then study their power loss performance when used under voltage and current conditions typical of WBG power electronics. These RF techniques help support transverse electro-magnetic (TEM) mode propagation of waves along a conductor, and are therefore essential for low-loss performance. 3D CAD models of these RF topologies are developed in forms typical of current generation RF circuits, along with new forms that may prove suitable within a WBG power module or power electronic system. Next, electromagnetic simulations are performed on these models to analyze the electric fields and magnetic fields that occur within each topology over a range of frequencies. Power losses for each layout are then extracted and compared in order to understand which RF TEM mode geometries, if any, prove promising in power module and power electronic design for high frequency applications.

Keywords: high frequency, power electronics, power module, RF, wide-band gap