Multipaction Analysis in Traveling Wave Tubes

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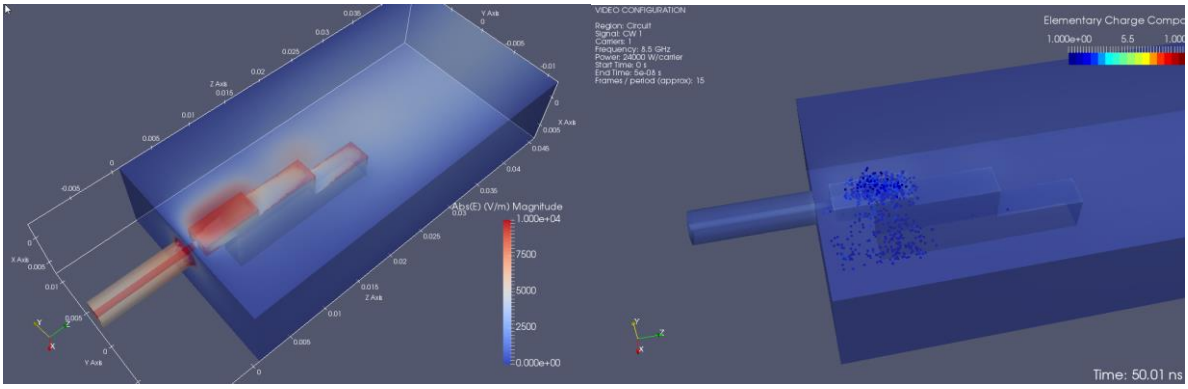
ABSTRACT

Multipaction is an electron avalanche phenomenon that can occur in vacuum in devices which guide or create high RF power[1]. Free electrons are accelerated by the RF fields and can impact the various surfaces of the device. Depending on the material, a number of secondary electrons are emitted from these impacts. The new electrons are in turn accelerated by the RF fields, can hit surfaces and cause additional secondaries. Depending on certain resonance conditions this can lead to an exponential increase in the number of free electrons. A device is especially sensitive to multipaction if there are gaps in which the product of the gap length (in mm) and the RF frequency (in GHz) is close to 1.
Multipaction can potentially cause damage to the device, as the impacting electrons deposit heat on the surfaces. Additionally, the free electron current causes parasitic signals, which can degrade the integrity of the signal that is being transmitted by the device (particularly important for a traveling wave tube, TWT). Therefore, any new TWT design has to be shown to be multipaction-free, either by measurement or by simulation.
There are analytical approximations for very simple structures, like coaxial lines or rectangular waveguides. These are insufficient for complex geometries (e.g. TWTs). In order to simulate multipaction in such a device, the movement of the electrons depending on the RF fields as well as static magnetic and electric fields must be tracked in the time domain. There must also be a model for the emission of the secondary electrons depending on the impact energy and the angle of incidence. The most commonly used commercial tool for this purpose is SPARK3D from the CST Studio Suite [2]. An example is shown in the figure below.
The multipaction analysis is critically dependent on the knowledge of the secondary emission properties of the various materials used in the device. These properties can vary greatly depending on the treatment (baking, electron/ion bombardment).



SPARK3D: RF electric field strenght (left) and multipaction free electron cloud (right) in an output coupler of a high-power TWT

References

[1] J.R.M. VAUGHAN, “Multipactor”, in IEEE Trans. on Electron Devices, 1988, 35, n.7, pp. 1172-1180
[2] https://www.3ds.com/products-services/simulia/products/spark3d/