An Open Platform Tool for 2D Multipactor Simulations in Metallic Microwave Components

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This poster presents a computer simulation software aimed at assessing the multipactor threshold power in a rectangular waveguide working with single tone excitation. Initial tests demonstrate a strong agreement between the simulation results obtained and those from commercial software. Contrary to the existing commercial software, our tool will be provided as Open Platform, for free use and popularisation of knowledge about physical phenomena resulting from interactions of microwaves with materials.

INTRODUCTION

Multipactor initiates when a free electron, accelerated by electromagnetic field propagating within the microwave component, impinges on a surface causing the emission of two or more secondary electrons, depending on the electron energy, incident angle, and surface roughness. These secondary electrons can be accelerated and impinge on another or the same surface emitting more secondary electrons. Under certain resonance conditions this process can be sustained leading to an avalanche phenomenon, which results in a cloud of free electrons resonating inside the device. As a result, it may detune a microwave signal and heat the surface, thus increasing noise level and causing damage. Under some circumstances multipactor may induce vacuum breakdown. Telecommunication satellite components and particle accelerators, among other applications, are commonly affected.

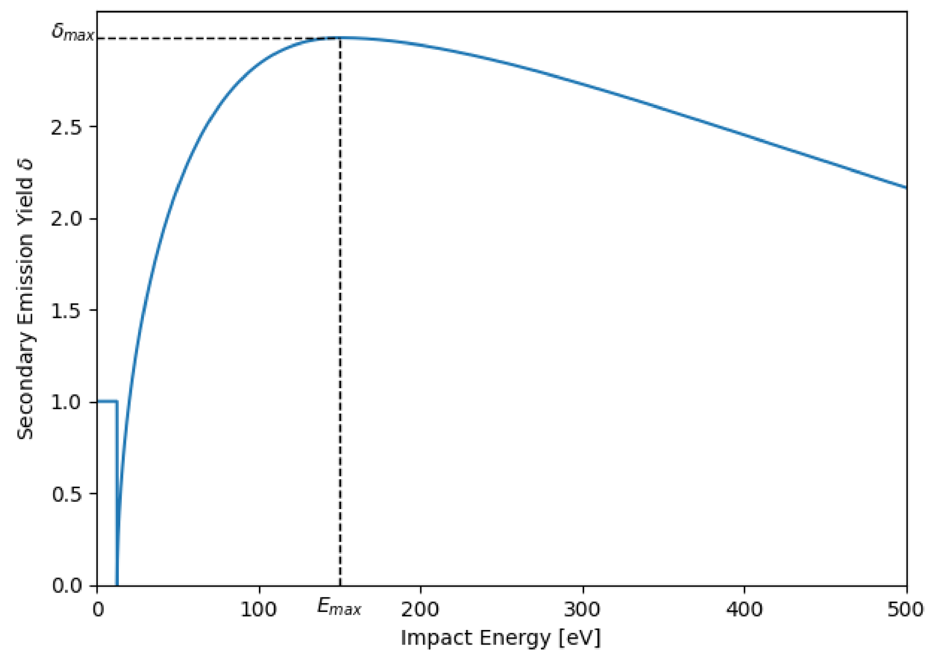
MODEL DESIGN

The simulation model consists of a rectangular waveguide with given width A and height B, operating in a TE10 mode. The Multipactor 2D simulation technique employs a particle-in-cell (PIC) approach, tracking each particle's interaction with the electromagnetic field through the Lorentz force. Instead of individual electrons, macroparticles (MP) are utilized, thereby reducing the level of complexity in the simulation. When the simulation starts, the initial positions, velocities and energies of primary macroparticles are randomly assigned within the waveguide cross-section, with kinetic energy ranging from 0 eV to 4 eV.

As an input the model takes A and B values, initial number of electrons N, number of MP, frequency of the electromagnetic signal f, power of the signal $P10$ and number of time-steps to be executed in the simulation process (time-step is predefined in the present version of the tool and equals $10{-}12\ s$).

$$\frac{v^{n+1}-v^n}{\Delta t} = \frac{q}{m}\left(E^n + \frac{v^{n+1}+v^n}{2} \times B^n\right)$$

$$\frac{r^{n+1}-r^n}{\Delta t} = v^{n+1}$$



$$\delta(E,\theta) = \delta_{max}(\theta)(V \cdot \exp(1-V))^k \ for\ V \le 3.6$$

$$\delta(E,\theta) = \delta_{max}(\theta) \cdot 1.125/v^{0.35} \ for\ V > 3.6,$$

where

$$V = \frac{E - E_0}{E_{max}(\theta) - E_0},$$

$$k = 0.56 \ for\ V < 1,$$

$$k = 0.25 \ for\ 1 < V \le 3.6,$$

$$\delta_{\max}(\theta) = \delta_{\max}(1 + k_E\theta^2/2\pi),$$

$$E_{max}(\theta) = E_{max}(1 + k_\theta\theta^2/2\pi),$$

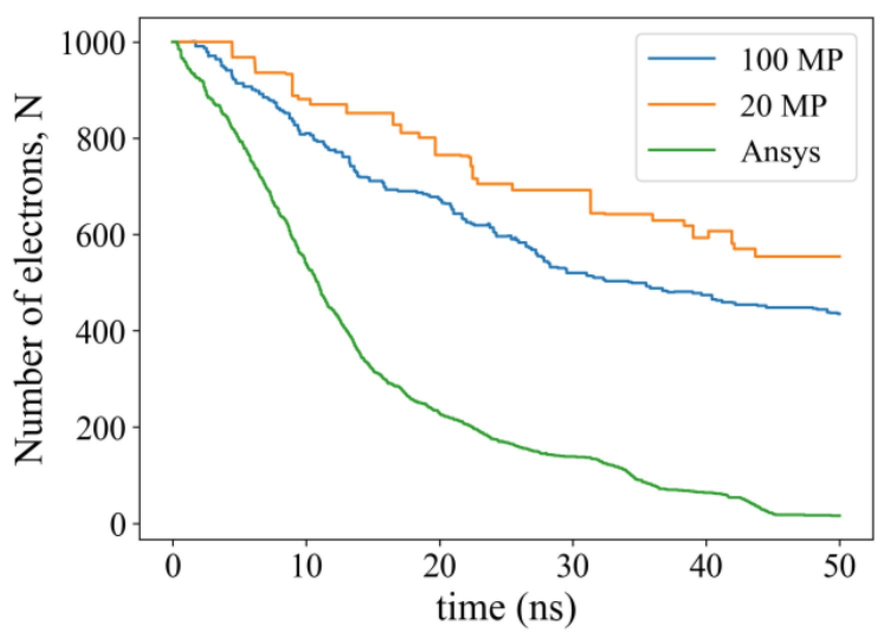
SIMULATION RESULTS

In Multipactor 2D model the threshold power of rectangular waveguide with $A = 22.86mm$ and $B = 3mm$ was simulated and the results were compared with Ansys HFSS multipactor module. Additionally, simulations have been conducted with varying numbers of macroparticles (MP) while keeping N fixed. For the SEY model the following values are being used (the same as in Ansys software): $\delta max = 2.98$, $Emax = 150\ eV$, $E0 = 12.5\ eV$, kE and $k\theta$ are equal to 1.

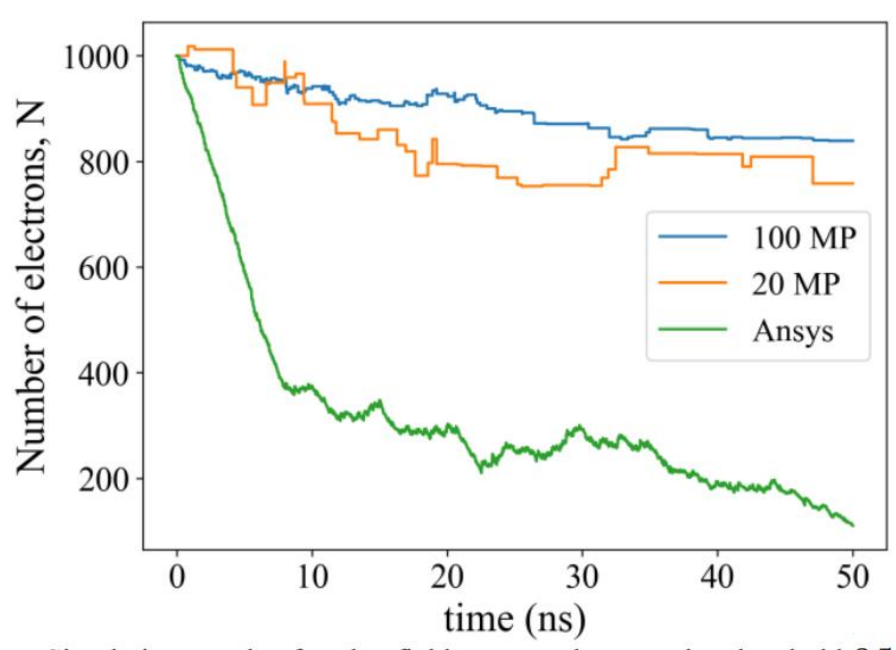
To approximate the simulated problem to that of our 2D solver, a feature of the Ansys software was utilized, allowing simulation of a restricted section within the 3D domain. The effect to changing the length of simulated section of the waveguide on simulated results was examined. Even so, the differences in the threshold power estimated by software remain within ±3%, with the average value of 8.28 kW, which we shall further use as a reference for our 2D model and simulations. In further tests, we shall limit the waveguide length to 0.1 mm.

SIMULATION RESULTS VARYING THE LENGTH OF WAVEGUIDE SECTION AS SIMULATED IN ANSYS SOFTWARE

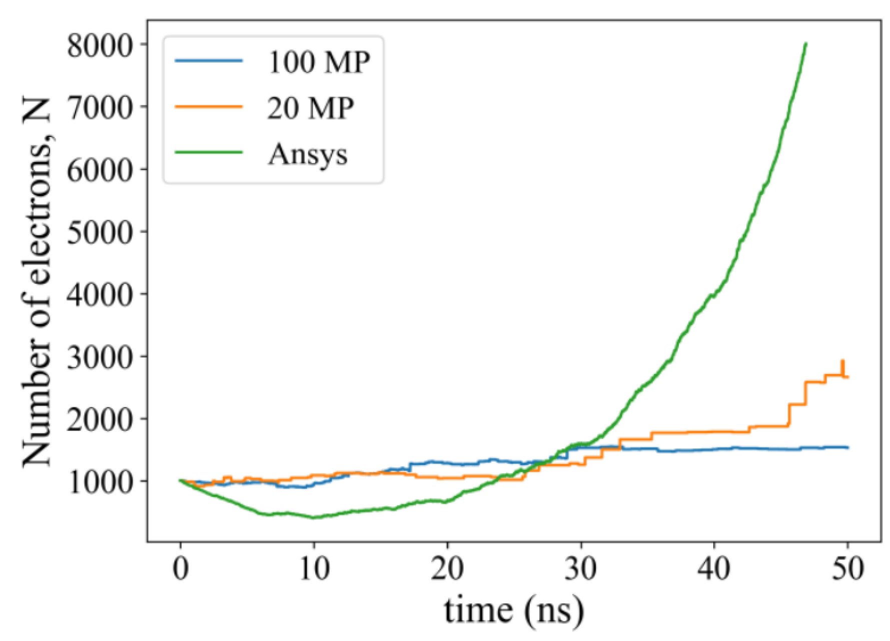
Length of the section (mm)	*Threshold Power (kW)*
0.1	8.48
0.5	8.33
1	8.48
3	8.02
5	8.33
10	8.02



Simulation results for the field power 2 kW.



Simulation results for the field power close to the threshold 8.5 kW.



Simulation results for the field power 12 kW.

CONCLUSIONS

We observe that for all simulations with power values well below the threshold, the number of electrons substantially decreases over time, even if a minor increase maybe sporadically observed. Close to the threshold, cyclical increases in the number of electrons can be seen, which indicate a high probability of the multipactor effect. For values well above the threshold, the number of electrons tends to increase exponentially. Our Multipactor 2D simulations qualitatively agree with the commercial software and allow estimating the power threshold values for the multipactor phenomenon.

ACKNOWLEDGMENT

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