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# MULTIPACTOR BREAKDOWN MODELLING USING AN AVERAGED VERSION OF FURMAN'S SEY MODEL*

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*Abstract*

Furman's seconday electron yield model is commonly used for the simulation of multipactor in accelerating cavities and other resonant structures. While accurate, the stochastic model requires many Monte Carlo simulations in order to characterize susceptibility to multipactor. This paper generalizes our previous research in characterizing a reduced-order Furman model, in which we replace the stochastic Furman model with a deterministic model based upon the Furman model's underlying statistics. Favorable comparisons between the full Furman model and the reduced-order Furman model are shown for multipactor simulations in a coaxial cavity, and the results are expected to generalize to other geometries.

## INTRODUCTION

Multipactor [1, 2] is a resonant phenomenon in which an electromagnetic field causes free electrons to impact a surface, resulting in the surface emitting secondary electrons which can sustain the cyclic process. The formation of multipactor is strongly dependent upon the secondary electron yield (SEY) of a surface, and the emission velocities of the emitted electrons. A popular SEY model proposed by Furman and Pivi [3] is frequently used to simulate multipactor. This model is based around a stochastic scattering process, which necessitates computationally costly Monte-Carlo simulations in order to simulate the formation of multipactor in a given system.

In our previous work [4], we presented an approximation to Furman's model, in which for a given particle impact velocity, a single weighted particle is emitted deterministically, thus avoiding Monte Carlo simulations to model multipactor current; this particle was chosen to be simply the median of the underlying stochastic parameters in the SEY model. In this present work, we examine other cumulative probability statistics other than the 50th percentile (median) statistic. The results were obtained through simulations in a coaxial geometry, but are expected to be generalizable to other geometries.

## SIMULATION DESCRIPTIONS

Consider a coaxial cavity shorted at both ends as shown in Fig. 1, which is excited by a TEM mode specified by $V_o \cdot \cos(\omega t+\theta) \cdot \sin(\pi z/L)$, where $V_o$ is the peak instantaneous voltage, $\theta$ is the phase, $\omega$ is the cavity-dependent resonant angular frequency, z is the position along the axial direction as measured from the cavity end, L = 1.86 m is the cavity length, a = 1 cm is the cavity inner radius, b = 5.65 cm is the cavity outer radius. These dimensions were chosen to yield maximum multipactor response for $V_o \approx 1000$ V at the fundamental TEM mode resonant frequency of 80.5 MHz.

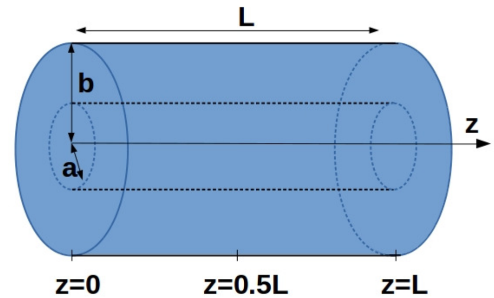


Figure 1: Coaxial Geometry

For each voltage $V_o$ and phase $\theta$ to be simulated, particle-tracking (single particle) simulations were performed for 10 cycles, where a cycle is defined to end whenever either a boundary strike or a complete RF period elapses, whichever occurs first. For each simulation, an electron starts from rest from the outer wall at the z=0.5L position, and the following loop is carried out for each cycle:

(1) Electron is accelerated by the cavity fields until it strikes a boundary.
(2) Record SEY for the impact.
(3) Generate a secondary electron from emission energy and angle distributions.
(4) Repeat from step #2.

For Furman's full model, the number of secondary electrons can randomly range from 0 to a maximum integer value. If no electrons are emitted, then the SEY is set to 0, and the simulation terminates. If more than one electron is emitted, then one of these electrons are randomly chosen to continue propagating the multipactor simulation. For more sophisticated multipactor simulations, we would need to track each emitted electron, but by running a large number of Monte Carlo trials (1000 for this investigation), we are still able to sample the entire multipactor initiation space while tracking only one particle for each simulation.

The net SEY is defined to be the product of all the single-impact SEY values, with the adjustment that if less than two boundary impacts occurred over the 10 simulation cycles, then the net SEY is automatically set to 0. This net SEY gives a proxy measure of whether or not multipactor can initiate, since net SEY less than unity

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would indicate that multipactor current would decay to zero, and net SEY equal or greater than unity would indicate that multipactor current can sustain itself or grow. The net SEY is averaged over all of the Monte Carlo trials to yield the final results using Furman's model. Figure 2 shows the net SEY for Furman's model examined over a field excitation space defined by the field strength (x-axis) and field phase at the start of the particle-tracking simulation (y-axis).

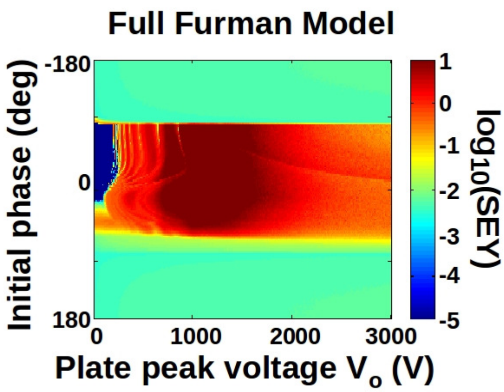


Figure 2: Net SEY using Furman's full model.

## REDUCED-ORDER FURMAN MODEL

Furman's SEY model, while accurate, necessitates computationally costly Monte Carlo simulations to characterize multipactor susceptibility. To reduce the computational cost, consider using the median values of the stochastic variables in Furman's model; this results in a deterministic (but still impact energy-dependent and angle-dependent) emission energy and emission angle. Such a deterministic SEY model will clearly not explore the entire phase space, but results so far suggest that it can do quite well in approximating the results of the full Furman model. Figure 3 shows the net SEY when using the median values of the stochastic variables.

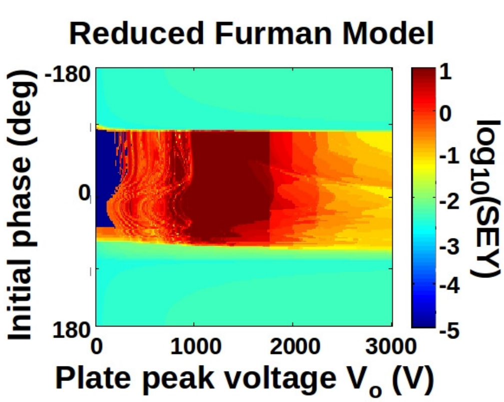


Figure 3: Net SEY using reduced-order Furman model with median (50th percentile) statistics.

As a generalization, consider using other percentiles instead of just the 50th percentile (median) values from the stochastic variable cumulative distributions. Figure 4 shows the RMS error between the medianized approximation and full Furman model as a function of the cumulative percentile statistic used. These plotted RMS error values are normalized by the RMS value of the SEY surface of the full Furman model.

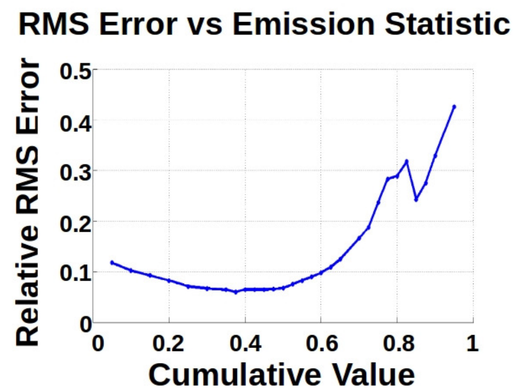


Figure 4: RMS error of reduced-order Furman model, as a function of cumulative percentile used.

## CONCLUSION

These results provided a generalization of the medianized variant of Furman's SEY model. This class of reduced-order Furman SEY models can be used to quickly perform multipactor simulations when simulation speed is more important than fully characterizing multipactor behavior, for example when carrying out swept-parameter simulations over a large space of possible designs for a given application. Once the design parameters are approximately determined, Furman's full model could be used to identify and optimize the final design. Future work will investigate other ways of generalizing these reduced order Furman models for increased accuracy, as well as examining different error metrics besides the RMS error, in order to determine the best metric to use with the reduced Furman models for a given end-user design goal.

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