Multipactor Modelling Using an Averaged Version of Furman's SEY Model

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Introduction

Multipactor [1,2] is a resonant phenomenon in which an electromagnetic field causes a free electron to impact a surface, resulting in the surface emitting one or more secondary electrons. If the surface geometry and electromagnetic fields are appropriately arranged, the secondary electrons can then be accelerated and again impact a surface in the bounding geometry. If the net number of secondary electrons participating in multipactor is non-decreasing, then the process can repeat indefinitely. This phenomenon is of considerable practical interest in the design and operation of radio frequency (RF) resonant structures, antennas, and supports structures.

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 typical SEY curve is shown in Figure 1 below, illustrating a low SEY at low and high impact energies, and a high SEY at an intermediate impact energy. Two SEY models are popular within different technical communities.

Vaugham’s model [3]

- Popular in the radio frequency (RF) and microwave source industry.
- More computationally simple.
- Does not include SEY contribution from low-impact energy electrons.
- Does not specify emission process (energy, angle, number of electrons, etc.).

Furman’s model [4]

- Popular in the particle accelerator community.
- More computationally complex.
- Includes SEY contribution from low-impact energy electrons.
- Stochastically specifies the emission process.
- Requires a Monte Carlo simulation approach in practice.

Numerical Multipactor Simulations

A coaxial cavity shown at both ends (Figure 2) was excited by a TEM mode specified by $V_0\cos(\pi h/4)-\sin(\pi z/L)$.

$V_0$ is the peak instantaneous voltage.

$h$ is the phase.

$z$ is the cavity-dependent resonant angular frequency.

$L$ is the position along the axis direction, measured from the cavity end.

Cavity length $L = 1.86$ m.

Cavity inner radius $a = 1$ cm.

Cavity outer radius $b = 5.65$ cm.

Mode resonant frequency is 80.5 MHz.

Cavity dimensions chosen to yield maximum SEY at $V_0 = 1000$ V.

For each voltage $V_0$ and phase $\theta$ to be simulated, single-particle simulations were performed for 10 cycles: either a boundary strike at a low RF period, whichever occurs first:

- Includes SEY contribution from low-impact energy electrons.
- More computationally simple.

Recent work has suggested that multipactor formation can be very sensitive to low impact energy electrons [5], as shown in Figure 3. This makes Furman’s model particularly appealing.

- However, Furman’s SEY model necessitates computationally costly Monte Carlo simulations to characterize multipactor susceptibility.

- Instead, consider using the (incident energy and angle dependent) median emission energy and emission angle, and running only one simulation.

This medianized SEY model will not explore the entire phase space: multipactor sustainability will be underestimated, but by how much?

- Respectable multipactor prediction agreement between SEY models is shown in Figure 4.

- We next examined a more complicated coaxial field environment.

- Previous work [6] explored multipactor in the presence of additive perturbative 3rd harmonic TEM mode, we will use this again.

- Perturbative mode expressed mathematically as $-3V_0\cos(3\pi h/4)+3V_0\cos(3\pi z/L)$.

- Predicted multipactor is shown for particles at $z=0.5L$ (Figure 5) and $z=0.2L$ (Figure 6).

- Both SEY models are in agreement over much of the search space.

Conclusions and Future Work

- For the cases we have examined, multipactor simulations based upon Furman’s fully stochastic SEY model can be well-approximated by a medianized SEY simplification.

- This will allow for considerable computational savings, for example a 100:1 speed increase over simulating 100 independent trials using Furman’s full model.

- Applications would include optimizing resonant structures for multipactor performance.

- Future work will assess the accuracy of the medianized Furman model in different geometries and field excitations.

- Future work will also explore the relative accuracy of the medianized Furman model when generalized to other median percentiles besides the 50th percentile median.

References


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