Multipactor RF Breakdown Analysis in a Parallel-plate Waveguide partially filled with a Magnetized Ferrite

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1. Introduction

Multipactor is a high-power radio frequency (RF) electromagnetic field phenomenon that appears on devices operating under vacuum conditions [1]. Free electrons existing inside a microwave device are accelerated by the RF electric field, impacting against its metallic walls. If the electron impact energy is high enough, one or more secondary electrons may be released from the surface. When some resonant conditions are satisfied the electron population inside the device grows exponentially leading to a multipactor discharge, which has negative effects and degrade the RF perfomance.

In this work, we are interested on the multipactor analysis of a metallic parallel-plate waveguide partially filled with a ferrite slab, placed just above the bottom metallic wall, and transversally magnetized by a static (DC) magnetic field parallel to the waveguide walls (see Fig. 1).

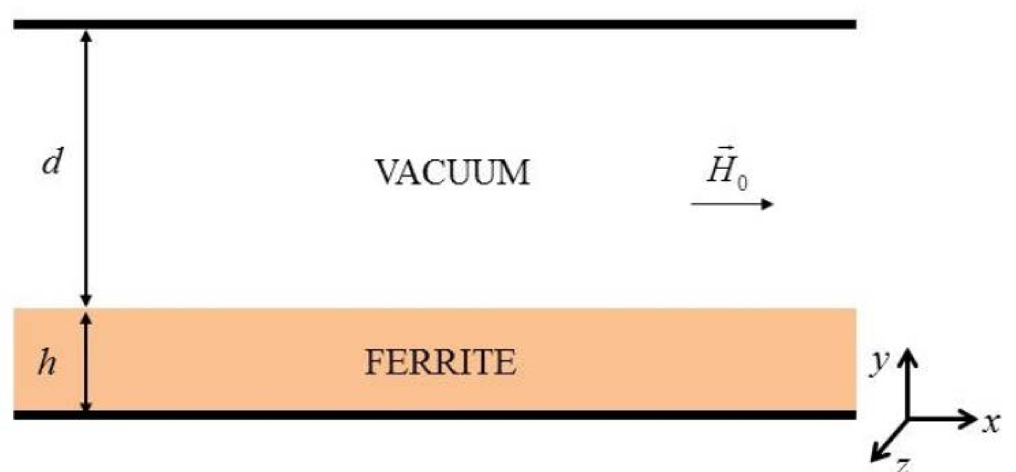

Fig. 1. Parallel-plate waveguide partially filled with a ferrite slab transversally magnetized by a static magnetic field. The ferrite slab thickness is *h*, *d* is the vacuum gap, and H_0 is the external magnetic field.

2. Theory

The waveguide structure under study is shown in Fig. 1. The RF electromagnetic field is assumed to propagate along the positive direction of the z axis, besides an harmonic time–dependance is implicitly assumed. An external static magnetic field H_0 is applied in order to magnetize the ferrite. When the ferrite is magnetized to saturation, it can be described by a gyrotropic permeability tensor µ (see formula 9.26 in [2]).

The RF electromagnetic fields supported by such a waveguide can be obtained analytically. The solution for the TM^z modes is given by

$$\varepsilon_r k_1 \sinh(k_1 d)\cos(k_2 h) - k_2 \cosh(k_1 d)\sin(k_2 h) = 0$$

$$k_1^2 \equiv \beta^2 - \omega^2 \mu_0 \varepsilon_0 \qquad k_2^2 \equiv \omega^2 \mu_0 \varepsilon_0 \varepsilon_r - \beta^2$$

$$E_y(y,z,t) = \frac{V_0 k_1}{\sinh(k_1 d)} \cosh\left[k_1\left((d+h)-y\right)\right]\cos(\omega t - \beta z)$$

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$$H_x(y,z,t) = -\frac{\omega \varepsilon_0}{\beta} E_y(y,z,t)$$

ε_0, is the vacuum dielectric permittivity, ε_r is the relative dielectric permittivity of the ferrite, V_0 is the amplitude voltage, β is the propagation factor.

To perform multipactor simulations, a code based on the Monte-Carlo algorithm has been developed to compute the RF voltage threshold. The software code employs the single effective electron model [3], which consists of tracking the individual trajectories of a certain number of effective electrons. When the electrons hit the device walls, secondary electrons may be released, this is taken into account by means of the Secondary Electron Yield (SEY) coefficient δ [4].

3. Simulations

The ferrite magnetization field effect in the multipactor RF voltage threshold has been analyzed. In Fig. 2 multipactor susceptibility charts are shown for several typical values of the magnetization field, for a ferrite whose magnetization saturation is $4\pi M_s$ = 1790 G.

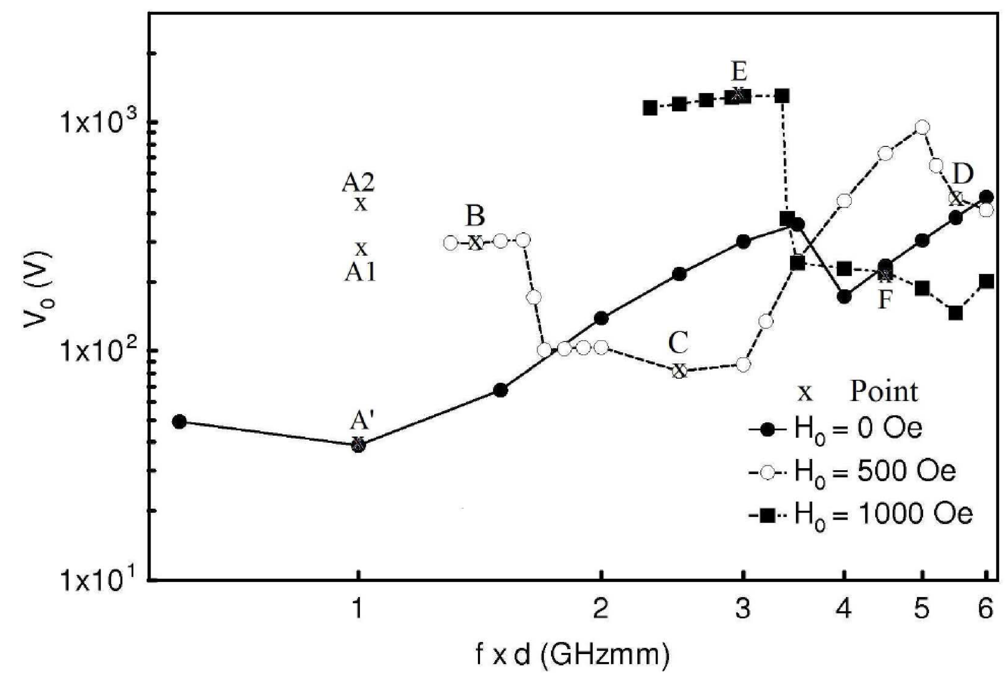

Fig. 2. Multipactor voltage threshold for several values of the external ferrite magnetization field. Waveguide dimensions: *d* = 1 mm and *h* = 3 mm.

It is noticed that, when the magnetization field is present, the multipactor susceptibility regions are shifted to higher frequency gap values. In fact, the starting frequency gap value for the multipactor zones becomes higher if the magnetization field strength is increased. In Fig. 3, it is shown the effective electron trajectories, as well as the SEY coefficient value, for some relevant points marked in Fig. 2.

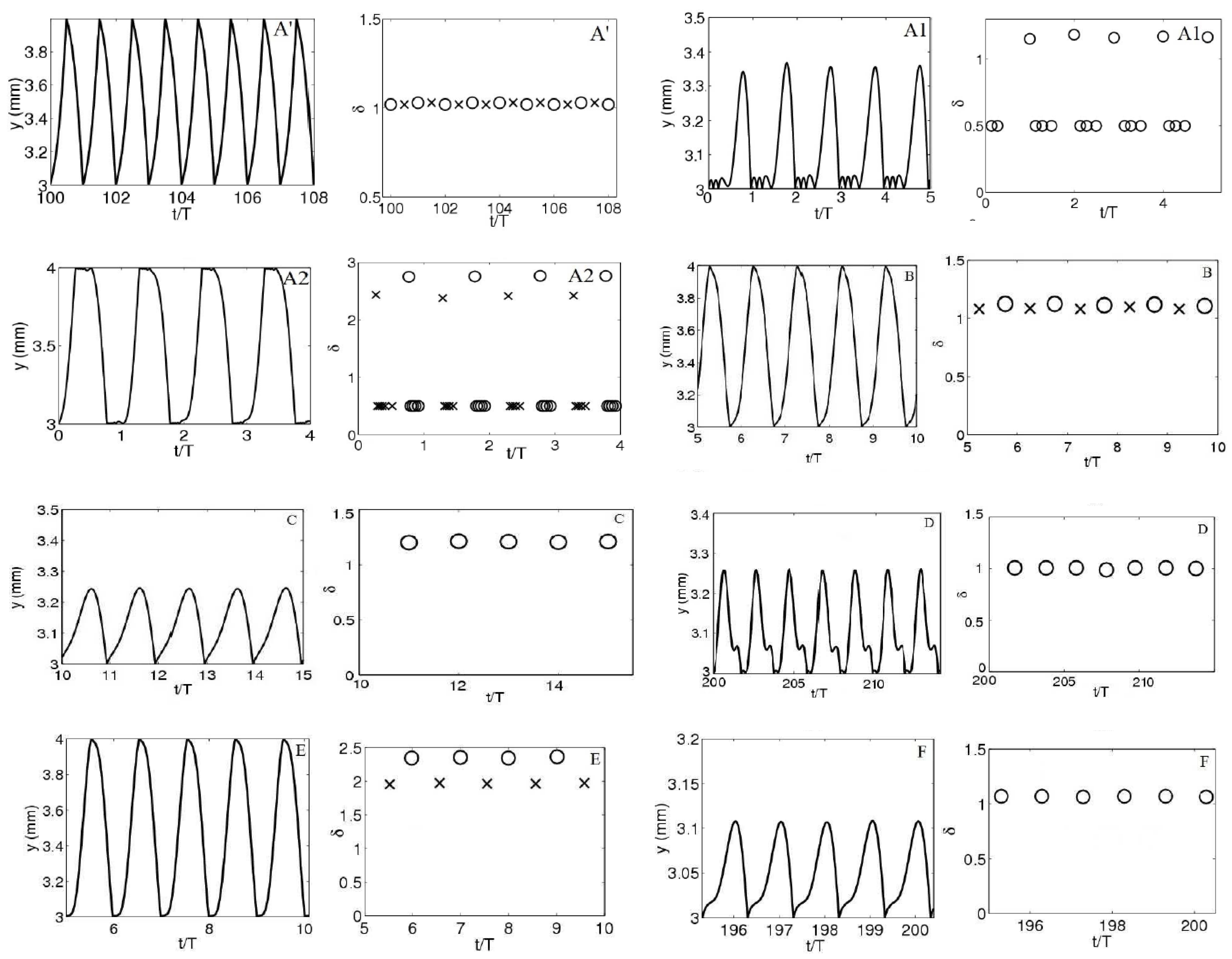

Fig. 3. Effective electron trajectories for points marked in Fig. 2 and the corresponding SEY values at the impacts with the walls..

4. References

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