Analysis of Single Surface Multipactor Discharge in the Frequency Domain

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Abstract: *This work presents the frequency domain analysis of multipactor discharge on a dielectric surface with rf electric fields of single or two carrier frequencies, by using a one-dimensional multiparticle Monte Carlo (MC) simulator with adaptive time steps. The study shows that the single tone rf operation produces a normal electric field to the dielectric surface consisting of pronounced even harmonics of the driving rf frequency. The strength of a harmonic component is a function of the incident rf amplitude. For dual tone operation, the amplitude spectrum of the normal electric field reveals spectral peaks at various frequencies of intermodulation products of the rf carrier frequencies. Empirical equations are proposed to approximate the temporal profiles of the normal electric field in terms of its frequency components, for rf operation with either single or two carrier frequencies.*

Keywords: dual tone; frequency domain analysis; multipactor; multiparticle Monte Carlo; single surface; single tone.

Introduction

Multipactor [1-4] is a nonlinear phenomenon in which a high frequency rf field creates an electron avalanche sustained through secondary electron emission [5] from a metallic or dielectric surface. In this paper, we employ the multiparticle Monte Carlo (MC) simulation scheme to obtain the temporal profiles [6] of the normal electric field to the surface of a single dielectric that corresponds to the multipactor strength in the system. We perform Discrete Fourier Transform (DFT) on the temporal profiles and obtain the amplitude spectrum [7,8] of the normal electric fields in the ac saturation state. We characterize the normal electric field in the frequency domain for rf operation with both single and two rf carrier frequencies.

For rf electric fields with a single carrier frequency, we observe spectral peaks in the amplitude spectrum of the normal electric field, E_x, at the even harmonics of the fundamental rf frequency (Fig. 1). Figures 1(a)-(c) show that the heights of the spectral peaks decrease with harmonic orders. From Figs. 1(a) and 1(c) we note that the heights of the spectral peaks decrease as the input rf amplitude decreases. We can express the heights of the spectral peaks as functions of their respective harmonic numbers and the rf amplitude. The temporal profile of the normal electric field can then be expressed in terms of the DFT peaks by an empirical formula. Figure 1(d) shows the temporal profile of the normal electric field obtained from our proposed empirical equation (blue dashed lines), which is in very good agreement with that from the MC simulation (black solid lines).

For dual tone rf electric fields, spectral peaks are observed at various frequencies of intermodulation products [9] in the amplitude spectrum of the normal electric field (Fig. 2). Figures 2(a)-(c) show that for dual tone rf operation, the two strongest peaks with equal spectral heights appear at the sum and difference of the carrier frequencies, $f_2 \pm f_1$. The two next strongest peaks with equal heights appear at twice the carrier frequencies, $2f_{1,2}$. The third and fourth strongest peaks appear at twice the difference, $2(f_2 - f_1)$, and twice the sum, $2(f_2 + f_1)$, of the carrier frequencies respectively. A number of weaker peaks are also observed at various intermodulation products of the carrier frequencies (Figs. 2(a)-(c)). The temporal profile of the normal electric field can be approximated by an empirical equation in terms of these most prominent spectral peaks. Figure 2(d) shows that the temporal profile of the normal electric field for two-frequency multipactor obtained from the empirical equation (blue dashed lines) and from the MC simulation (black solid lines), which are in very good agreement.

The work was supported by AFOSR MURI Grant No. FA9550-18-1-0062.

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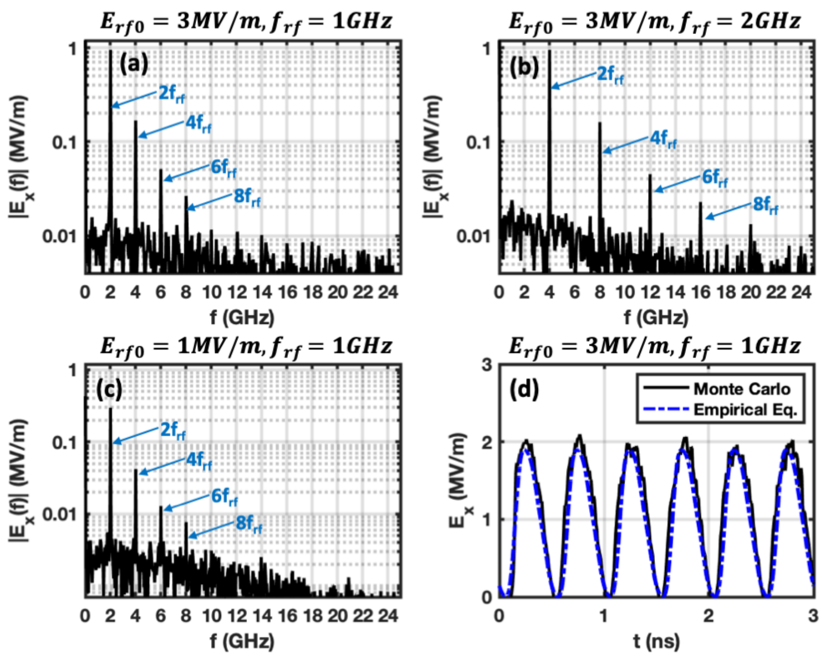

Figure 1. Amplitude spectrum of the normal electric field in the ac saturation state induced by an rf field with single carrier frequency with rf amplitudes and frequencies: (a) $E_{rf0} = 3MV/m$ and $f_{rf} = 1GHz$, (b) $E_{rf0} = 3MV/m$ and $f_{rf} = 2GHz$, (c) $E_{rf0} = 1MV/m$ and $f_{rf} = 1GHz$. (d) Temporal profiles of the normal electric field E_x in the ac saturation state obtained from the MC simulation (black solid lines) and the proposed empirical equation (blue dashed lines) for single tone rf fields with $E_{rf0} = 3MV/m$ and $f_{rf} = 1GHz$.

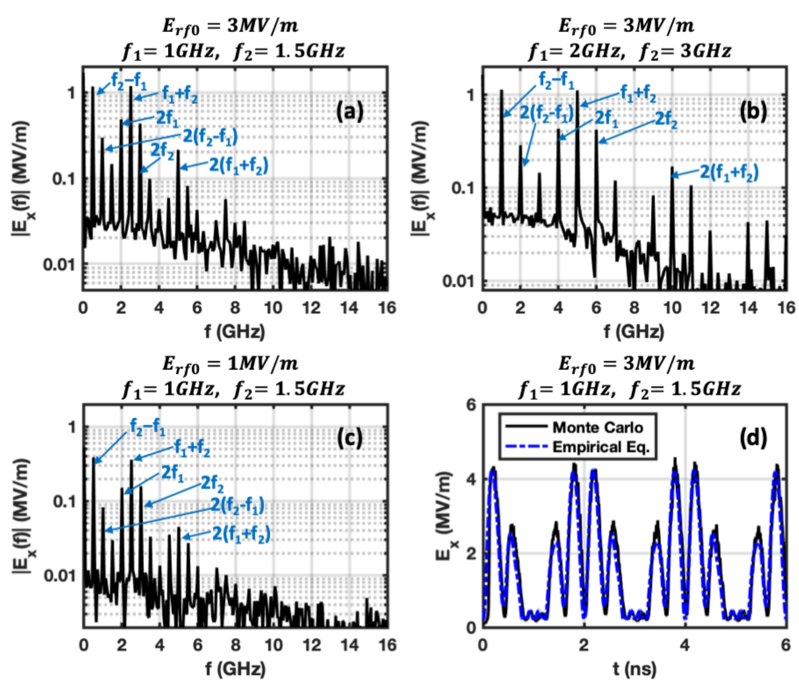

Figure 2. Amplitude spectrum of the normal electric field in the ac saturation state induced by an rf field with two carrier frequencies with amplitudes and frequencies: (a) $E_{rf0} = 3MV/m$ and $f_1 = 1GHz, f_2 = 1.5GHz$, (b) $E_{rf0} = 3MV/m$ and $f_1 = 2GHz, f_2 = 3GHz$, (c) $E_{rf0} = 1MV/m$ and $f_1 = 1GHz, f_2 = 1.5GHz$. (d) Temporal profiles of the normal electric field E_x in the ac saturation state obtained from the MC simulation (black solid lines) and the proposed empirical equation (blue dashed lines) for dual tone rf fields with $E_{rf0} = 3MV/m$ and $f_1 = 1GHz, f_2 = 1.5GHz$.