Quantitative Analysis of Single-Surface Dielectric Multipactor Susceptibility with Dual Carrier Frequencies

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Abstract: *This paper presents quantitative threshold analysis of multipactor breakdown on single dielectric surface initiated with an radio-frequency signal consisting of two carrier frequencies. The statistical modeling of multi-carrier multipactor on a dielectric is conducted for multipactor susceptibility chart and threshold analysis. On that basis, the effect of the relative phase and strength, and the frequency difference of two carrier frequencies on multipactor threshold are analyzed to achieve performance optimization. The results indicate that additional carrier frequency may increase power transmission capacity of high-power dielectric window.*

Keywords: multipactor; dielectric window; dual frequencies; statistical modeling

Multipactor[1] is a harmful electromagnetic breakdown caused by secondary electron avalanche in many radio-frequency (RF) applications. As the principal failure mechanism of RF windows, single-surface multipactor discharge on a dielectric seriously limits the power capacity and operational reliability of high power microwave systems. Amongst existing approaches, statistical modeling is one critical prediction tool of multipactor breakdown levels with both excellent accuracy and efficiency[2], which has been commonly applied in multipactor investigation of microwave dielectric windows[3, 4]. In order to achieve maximum utilization of transmission power, the statistical modeling is conducted here to calculate multipactor threshold power for various combinations of relative phase and strength as well as the frequency separation between the two carrier frequencies of the RF electric field. This study is mainly for the validation and comparison of previous relative research work[5, 6].

Figure 1 shows the multipactor susceptibility boundaries for different relative phase (γ) with a fixed relative strength (β = 0.75) and frequency ratio (n = 2) of the second carrier to the fundamental one. As can be seen, multipactor threshold reaches maximum when γ equals to 0 and π, and the varying multipactor susceptibility versus the relative phase seems asymmetric at $\gamma = \pi$. Figure 2 compares multipactor susceptibility dependence on the relative phase for an integer or non-integer n respectively. Similar periodic variance can be observed in the integer case, but multipactor susceptibility turns constant against the relative phase when n is non-integer. This is because different relative phase can only engender less difference in the combined waveform of two carriers in the non-integer case. Though the threshold electric field of two-carrier case is smaller than that of single-carrier case (β = 0), but its total transmission power of the two-carrier case has still been increased.

In order to analyze the effect of the relative strength β on multipactor susceptibility, Fig. 3 also plots the multipactor susceptibility against β in the range (0, 1.5] with n = 2 and γ = 0. Note that the relative phase γ *is* set zero here is to obtain the maximum power transmission. According to the parabolic trend in Fig. 3, the total transmission power can reach up to 1.25 times of that of the single-carrier case when β is increased to 0.75. The effect of the second-carrier frequency on the multipactor susceptibility is further examined here. As shown in Fig. 4, multipactor susceptibility almost increases linearly against n in the rough range (0, 1.2] and then turns almost constant for a larger n. It is interesting that this pattern remains the same for different relative phase and relative strength, even with different SEY parameter.

This research was supported by the National Natural Science Foundation of China (Grant No. 61801370 and U1537210).

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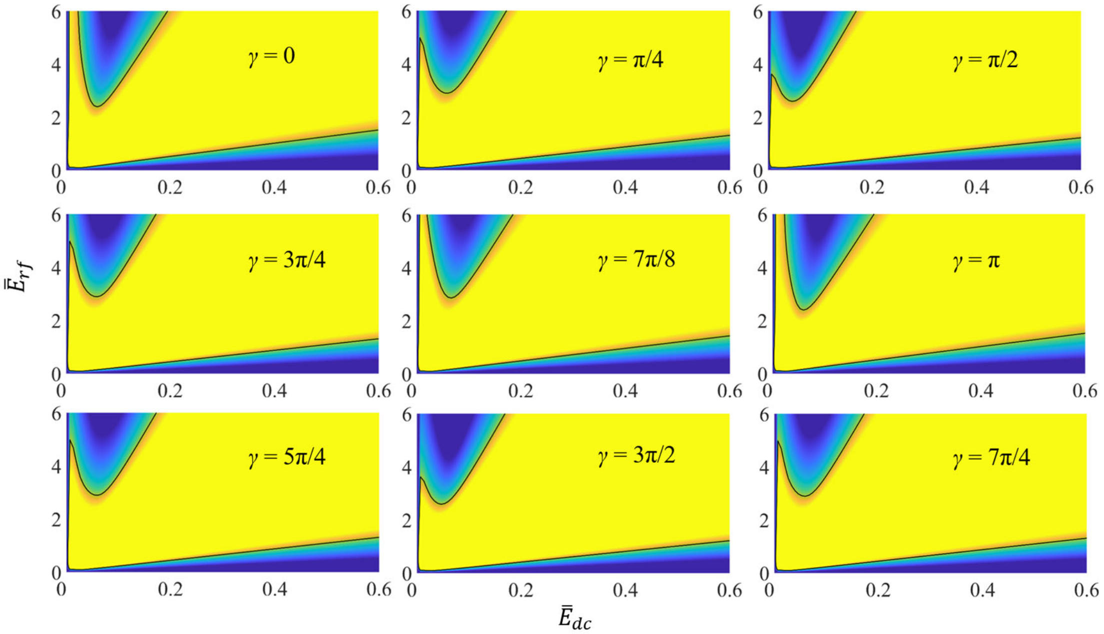

Fig.1. Multipactor susceptibility zones (multipactor boundaries are delimited by black lines) of single-surface dielectric multipactor with two carrier frequencies obtained from statistical modeling in the plane of ($\bar{E}_{dc}$, $\bar{E}_{rf}$), where $\bar{E}_{dc}$ = $E_{dc}[\text{MV/m}] \times (f/\text{GHz})^{-1} \times (E_{\text{max0}}/400\text{eV})^{-1/2}$ and $\bar{E}_{rf}$ = $E_{dc}[\text{MV/m}] \times (f/\text{GHz})^{-1} \times (E_{\text{max0}}/400\text{eV})^{-1/2}$. These results are for different relative phase γ with fixed relative strength β = 0.75 and second-carrier frequency ratio *n* = 2. The other parameters are $\sigma_{\max}$ = 3.0, $E_{\max0}$ = 400 eV and E_t = 2 eV.

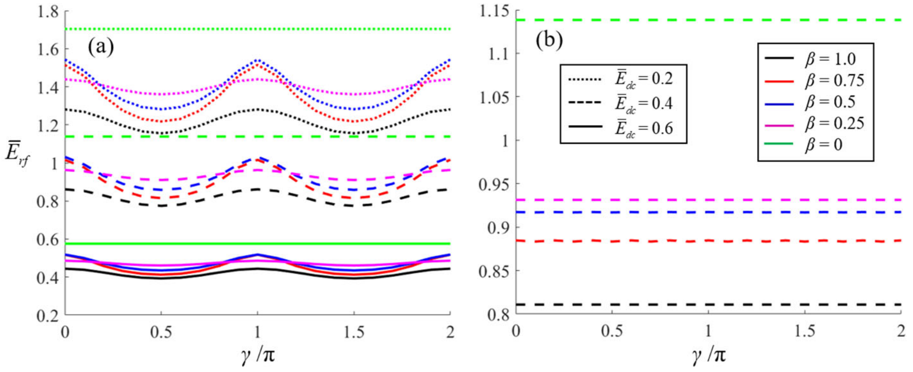

Fig.2. Multipactor susceptibility against the relative phase γ for different β when $\bar{E}_{dc}$ is set with 0.2 (dotted), 0.4 (dashed) and 0.2 (solid) respectively. The left (a) and right (b) figure accounts for the integer (*n* = 2) and non-integer (*n* = 1.6)

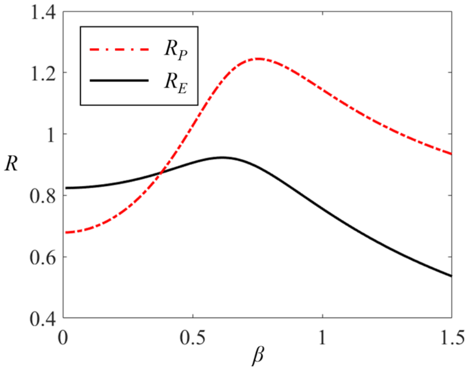

Fig.3. The ratio of multipactor threshold electric field R_E and power R_P between two-carrier and single-carrier case against β with γ = 0 and $\bar{E}_{dc}$ = 0.4.

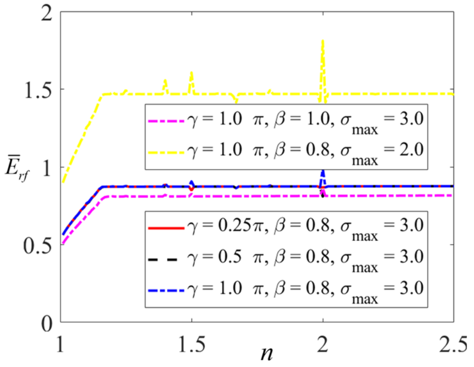

Fig.4. Multipactor susceptibility against the second-carrier frequency ratio *n* for different relative phase γ, relative strength β and SEY parameter $\sigma_{\max}$.