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2P21 - Beam-Current Loss in Emittance-Dominated High-Frequency Tubes

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The next generation high frequency tubes will face significant challenge in focusing the beam into small aperture for beam-wave interaction. The efficiency of such tubes will depend largely on available beam energy that will interact with electromagnetic wave as the beam is transported. Unlike low frequency tubes, emittance is emerging as a major concern since beam loss at the wall or at the surface of the slow wave structures are expected to increase appreciably as the frequency increases. To determine the beam loss for a certain pipe size, typically numerical analysis of particle simulation is conducted which is often expensive and tedious. In addition, there has not been any concrete analysis demonstrating how the current profile evolves as the beam is transported in such tubes. In this paper, we apply the beam physics developed for linacs to high-frequency tubes for the first time. We provide necessary theoretical tools to determine the fundamental limit of the beam pipe sizes for a desired limit of beam interception. Specifically, the effect of both space charge and emittance are incorporated into iterative solution of equilibrium distributions of charge densities in the presence of a uniform focusing axial magnetic field. The effect of phase-space rotation and evolution of beam current is demonstrated through the calculation of beam divergence and maximum excursion of particles. Hence, the numerical solutions and tools provided here are complete analysis and can be used to determine the beam pipe size for any beam emittance. The theoretical formulation and results are expected to be particularly useful for devices operating from mm-wave to sub-THz frequency regimes.

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