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Dimension of a fractal streamer structure

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Streamer corona plays an important role in formation of leader steps in lightning. In order to understand its dynamics, the streamer front velocity is calculated in a 1D model with curvature. We concentrate on the role of photoionization mechanism in the propagation of the streamer ionization front, the other important mechanisms being electron drift and electron diffusion. The results indicate, in particular, that the effect of photoionization on the streamer velocity for both positive and negative streamers is mostly determined by the photoionization length, with a weaker dependence on the amount of photoionization, and that the velocity is decreased for positive curvature, i.e., convex fronts. These results are used in a fractal model in which the front propagation velocity is simulated as the cluster growth probability [Niemeyer et al, 1984, doi:10.1103/PhysRevLett.52.1033]. Monte Carlo simulations of the cluster growth for various ratios of background electric field E to the breakdown field E_b show that the emerging transverse size of the streamers is of the order of the photoionization length, and at the larger scale the streamer structure is a fractal similar to the one obtained in a diffusion-limited aggregation (DLA) system. In the absence of electron attachment ($E_b = 0$), the fractal dimension is the same ($D \approx 1.67$) as in the DLA model, and is reduced, i.e., the fractal has less branching, for $E_b > 0$.