What determines streamer speed and radius?

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We propose a new approach to unambiguous determination of parameters of positive and negative electric streamer discharges (streamers). We derive several relations between streamer parameters which allow us to express them in terms of the streamer length L and the external electric field E_e, as functions of streamer radius a. In particular, we find that the streamer velocity $V(a)$ has a maximum at a certain value of radius a_s.

We interpret the streamer as a nonlinear instability, whose behavior is determined by maximizing its growth rate, proportional to V. The radius of the streamer is therefore equal to a_s, which also fixes all other streamer parameters. Thus, we prove that the streamer parameters are completely determined by E_e and L and suggest a relatively simple way to calculate them that does not require hydrodynamic simulations. The parameters of streamers in air at sea level conditions, calculated in the proposed way, are compared and found to be compatible with experimental data [e.g., velocities obtained by Allen and Mikropoulos, 1999, doi:10.1088/0022-3727/32/8/012]. We also reproduce the correct values of streamer threshold fields of $\sim$0.45 MV/m for positive streamers and $\sim$0.75–1.25 MV/m for negative streamers.

An analytical solution of the above system gives a quick but less accurate answer. However, the qualitative behavior of parameters may be demonstrated in this way.