A WAVEGUIDE MODEL OF THE RETURN STROKE CHANNEL WITH A METAMATERIAL CORONA

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Abstract

We model the return stroke channel as a three layer cylindrical waveguide, consisting of (1) highly conducting thin core channel; (2) "metamaterial" corona, i.e., corona with an effective bulk anisotropic dielectric permittivity tensor which is due to the fine structure of leaders branching away from the main channel; and (3) the surrounding non-conducting air. The lowest axially symmetric mode (TM mode) in this waveguide represents the return stroke current wave. We find time- and space- domain solutions for the current wave in a channel connected to the ground driven by an axial current of Bruce-Golde model temporal shape concentrated at the point of the channel connection to the ground. The front of the current wave is found to be dispersed, and the speed of the front is significantly (by a factor of 5-10 for some parameters) slower than the speed of light. The calculated radial electric field is found to be consistent with experimental measurements. When the second layer of the waveguide is filled with an isotropic material (isotropic corona), the slowdown of the wave front is found to be smaller. The time- and space- domain calculations are also supported by the numerical solution of a dispersion equation, which shows that the phase velocity may be significantly less than the speed of light. The transmission-line (TL) representation of such a waveguide is also discussed. Beside the attempt to find an explanation for the low speed of the return stroke, this study is also motivated by the results of the recently developed [e.g., Carlson et al, 2011, XXX URSI GASS, Lutfi Kirdar Convention and Exhibition Centre, Istanbul, Turkey] time-domain fractal lightning model (TDFL), which show short leaders branching away from the main channel of the return stroke.