RECENT DEVELOPMENTS IN TIME-DOMAIN ANTENNA THEORY MODELING OF LIGHTNING RETURN STROKES

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Abstract:

Analysis of the lightning-related problems requires an appropriate model for the return stroke channel. An appropriate model should be consistent with a number of physical considerations as well as measured data, such as current at the base of the channel, variation of light intensity with height, upward propagation speed of the luminosity front, and electromagnetic fields at various distances from the channel. Recently, we have presented a new model based on antenna theory (AT model) to describe the channel current and charge density profiles. In this model, the lightning channel is modeled as a lossy, straight, and vertical monopole antenna above a perfectly conducting ground which is excited by a source voltage at the base of the channel. This voltage source is a function of the current assumed at the ground level and the input impedance of the monopole antenna. The numerical solution of the governing EFIE by the MoM in the time domain provides the time-space distribution of current and line charge density along the antenna. The AT model has two adjustable parameters. First, the constant distributed resistive loads which are applied to the antenna to describe the channel current attenuation and, hence, better simulate the radiated electric field especially at near ranges. Second, the relative permittivity (år) of surrounding medium, which controls the propagation speed along the channel. The latter is also a constant parameter, resulting in a constant channel speed. The assumption år>1 for surrounding air is non-realistic and affects the ropagation speed of radiated electromagnetic fields. For this reason, the assumption of år>1 is only used to find the current distribution along the channel, which is then allowed to radiate into free space with the speed of light. This solution will neutralize the ability of simultaneously analyzing the return-stroke channel and its adjacent metal structure which is the greatest advantages of the AT model relative to the known engineering models of the channel and existing coupling models. More recently, we have enhanced our AT model by introducing the AT with Capacitive Loading, ATCL, model. This modified AT model employs distributed energy storing elements to control the propagation speed without changing relative permittivity of the medium. It is also capable of including a variable channel propagation speed by applying height variable inductive or capacitive loads.

In this paper, we review the AT model and its modifications, analyze the transient characteristics of the predicted lightning electromagnetic fields and compare them with their counterparts obtained using other models.