Electromagnetic Modeling of Carbon Nanotubes and Their Application as Microwave Interconnects

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In the analysis and design of nano-systems, two important points should be considered. Specifically, the quantum effects contributing to the modification of material parameters must be included for the correct use and application of Maxwell's equations. Next, the resistivity of conventional materials increases significantly when their size shrinks to sub-micron sizes. On the nano scale, the carbon nanotubes (CNTs) have shown excellent electrical, thermal, and mechanical properties compared to the conventional materials. To this end, the better conductivity and larger current-carrying capacity are demonstrated with CNTs. These findings have led researchers to extend their interests into various applications of CNTs in science and engineering. That includes microwave applications as well as interconnection between nano-scaled systems and macroscopic world. To that extent, a number of serious practical issues have been reported including very high impedance when they are used individually.

In this paper, we apply the method of moments and the finite element method for electromagnetic (EM) modeling of metallic single-walled carbon nanotubes (SWCNTs). The verification of developed CNT models is carried out by careful execution of multiple validation steps. Various interconnects including individual CNT dipole antennas as wireless interconnects, single-wire transmission lines known as Goubau lines, and coaxial transmission lines are studied. The applications of EM models of SWCNTs are extended to the structures composed of CNT bundles such as monopole antennas and coaxial lines. The results show that the radiation gain of the antennas and the attenuation of the coaxial lines can be improved, and that the impedance of a CNT bundle can be reduced to the practical level.