A New Twist on Maxwell

Since the advent of computer analysis, engineers and scientists have struggled to get accurate numerical solutions to Maxwell's equations. Robert Adams (Ph.D., '98) is the first person to develop an elegant method of simulating Maxwell's equations with consistently stable and correct results in all frequencies.

According to Adams, the computational difficulty has been most acute for people working in electromagnetic radiation and scattering and scalar wave theory. "Conventional simulations of Maxwell's equations are unstable as the frequency gets low. A number of people have published incorrect results as a consequence," he said.

"There is nothing wrong with Maxwell's equations — until you try to solve them on the computer," he said. "Until now, the implementations have been ill posed."

Maxwell's equations simply describe how fields behave, he said. "There is more than one way to say the same thing, however. What people have been doing with computational methods is to write them in the form most easily adapted to being implemented on the computer. These formulations have been ill posed."

When these ill-posed formulations become unstable, people have "tweaked" the simulations to approximate reasonable answers. "One problem with tweaking is that the code is more inefficient," he explained. "But the biggest problem is that you do not know when the tweaking will break down. You cannot trust your answers."

The ill-posedness of the original formulation is a problem at all frequencies, he said, but is a particular problem in low frequencies. "We've developed a well-posed formulation for all frequencies. People have developed different formulations for different frequencies, but ours works in all ranges," he said.

When discussing low frequency, Adams is referring to the size of an object relative to the electromagnetic wavelength. "A low frequency is one in which a radius is a small fraction (such as one-tenth) of a wavelength. With a sphere of radius 1 meter, low frequency would be around 30 MHz. With a sphere of radius 100 meters, low frequency would be 300 kHz."

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—Rob Adams

His results will be useful to anybody doing electromagnetic simulations and similar equations, such as those governing acoustics. Adams' work is generating significant interest in the field, he said. Hughes Electronics Corp. is incorporating the new formulation into their general code, as is the Lawrence Livermore National Laboratory. A group at the University of Kentucky is interested in using it to develop simulation codes for the microwave frequency in their work simulating printed circuits.

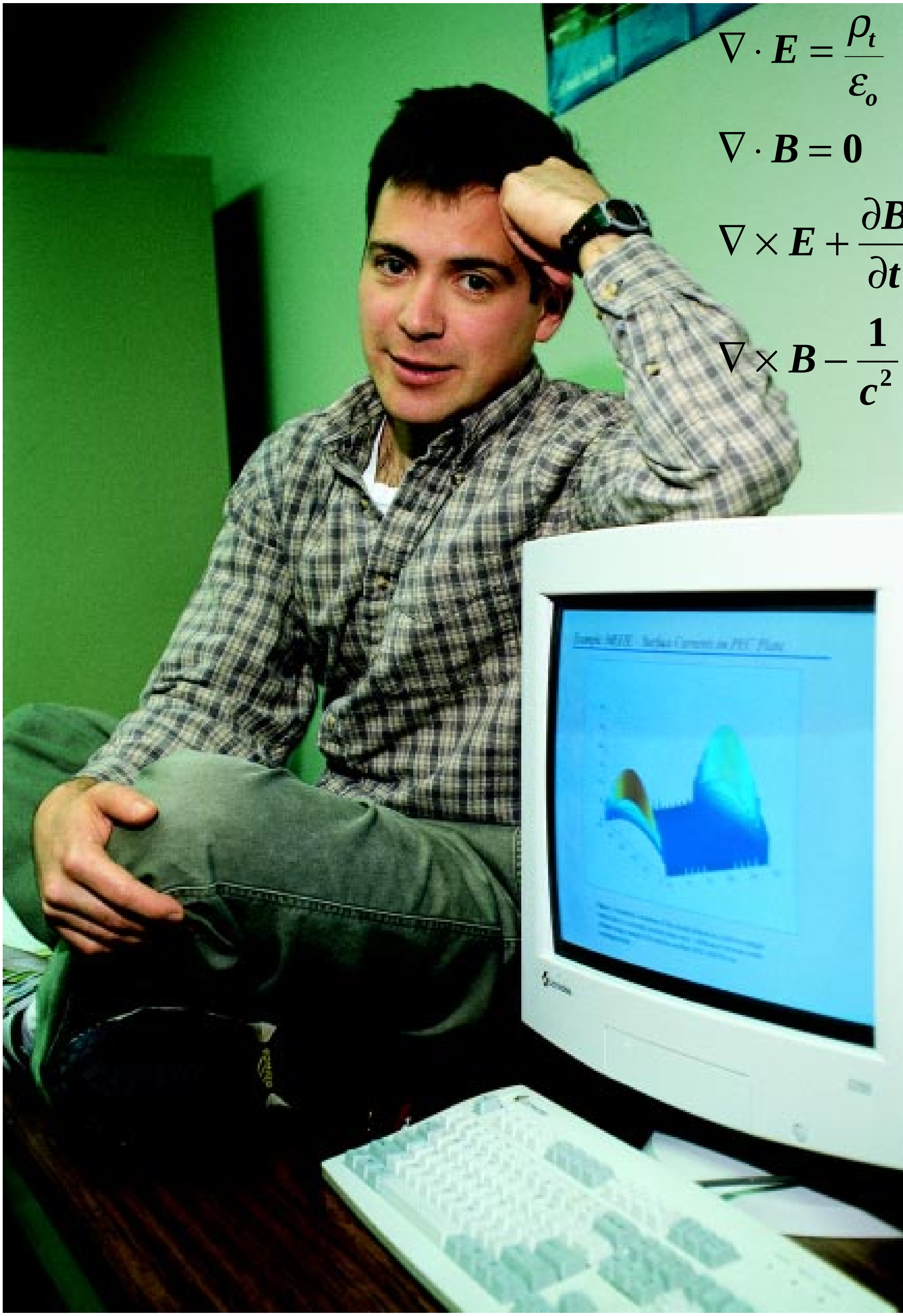
Adams developed the new formulation as a Bradley Fellow working on his dissertation in the department's ElectroMagnetic Interactions Laboratory (EMIL). He had earned his master's degree working on incoherent short pulse scattering from penetrable geophysical terrain. "I decided that my master's work was more phenomenological modeling, and I wanted to do some detailed basic work with Maxwell's equations. The best way to do that was with numerical methods, actually developing algorithms to implement equations on a computer.

"The Bradley Fellowship allowed me to do that. It is hard to find research funding at the Graduate Research Assistant level for theoretical work like that."

Adams' inclination toward the theoretical is long standing. He entered college at Michigan Tech to study applied physics. However, in college he decided that he would be more employable as an engineer. "I co-opped at a nuclear power plant and decided I didn't want to be that applied." So he decided to go to graduate school, and came to Virginia Tech to study communications. At Tech, he grew interested in the theoretical aspects of electromagnetics, and joined EMIL.

After finishing his dissertation, Adams decided to engage in post doctoral work to follow up on the applications of his Ph.D. research. "We had many ideas that were pretty new and needed an infrastructure to develop and implement them," he said.

The department offered him a Bradley Post-Doctoral Fellowship in order to further develop his fundamental work to the point where industrial funding was possible. "The initial fundamental ideas were not directly applicable to end users," he said. The post-doctoral fellowship allowed me to develop the work to the point where many people can apply it. Without the Fellowship, this work would not have been developed at Tech."



$$\nabla \cdot \boldsymbol{E} = \frac{\rho_t}{\varepsilon_o}$$

$$\nabla \cdot \boldsymbol{B} = 0$$

$$\nabla \times \boldsymbol{E} + \frac{\partial \boldsymbol{B}}{\partial t} = 0$$

$$\nabla \times \boldsymbol{B} - \frac{1}{c^2}\frac{\partial \boldsymbol{E}}{\partial t} = \mu_o \boldsymbol{J}_m$$

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