Development of fast computational algorithm for solving electromagnetic problem including wireless communications and natural electromagnetic phenomena

Yoshiaki ANDO Laboratory

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Summary of Research

Research and Development Related to Computational Electromagnetics and its Application to Computers and Wireless Communications and Natural Electromagnetic Phenomena

Computational electromagnetics is essential to research and development of electric and electronic devices and investigation on unknown electromagnetic phenomena, and has a wide variety of applications involving the study of propagation of lightning-induced electromagnetic waves, optimization of designs of microwave/millimeter-wave circuits and antennas, and so on.

The current research topics of our laboratory are the electromagnetic simulation of low-frequency (LF) band radiowave propagation in the earth-ionosphere waveguide, the large- and global-scale electromagnetic compatibility (especially ultra-low-frequency band), and the development of general-purpose electromagnetic simulator with high precision and efficiency.

Research on LF Band Radiowave Propagation in the Earth-Ionosphere Waveguide

Among the electromagnetic waves emitted from lightning, those with low frequencies have a great deal of potential. Our laboratory focuses on low-frequency electromagnetic wave propagation in the earth-ionosphere waveguide. Since low-frequency electromagnetic waves have long wavelengths, they propagate over greater distances than high-frequency electromagnetic waves, allowing measurement at any location on Earth. Measuring low-frequency electromagnetic waves gives us various types of information on the lower ionosphere partially known. The electromagnetic simulation on such low-frequency wave propagation allows us to reconstruct the distribution of electrons in the lower ionosphere.

Research on the Optimization of the Design of Antennas and Microwave/Millimeter-wave Circuits

In designing antennas and microwave and millimeter-wave circuits under limited conditions, such as geometry, the number of components, etc., we often need to use stochastic optimization methods, for example, the genetic algorithm (GA) and the particle swarm optimization (PSO). The computational costs, however, strongly depend on the ones necessary to solve its forward problem related to the computational electromagnetics. Our research is the specialization of various computational techniques to solve particular forward problems, enhancing computational efficiency.

Development of General-Purpose Electromagnetic Simulator with High Precision and Efficiency

Computational Electromagnetics is the research field growing rapidly, and our research is to evaluate newly appeared techniques and to implement them to general-purpose electromagnetic simulators.

Advantages

An Effective Partner in Research Projects Related to Electromagnetism, and Wide Applicability

The University of Electro-Communications operates many laboratories engaged in research on various types of electromagnetic phenomena, ranging from seismo-electromagnetism to radar. Our research activities on computational electromagnetics connect our laboratory to other laboratories on our campus. Since our research is the very foundations of the technology through applications, we can provide platforms to boost our university's comprehensive strengths in the domain of technologies related

Keywords

Constrained interpolation profile (CIP) method, finite-difference time-domain (FDTD) method, antenna, seismo-electromagnetics, analysis of lightning-generated electromagnetic fields, electromagnetic field optimization problem/inverse problem, electromagnetic field simulators

Affiliations	Institute of Electrical and Electronics Engineers (IEEE); Institute of Electronics, Information and Communication Engineers; Institute of Electrical Engineers of Japan; Society of Atmospheric Electricity of Japan
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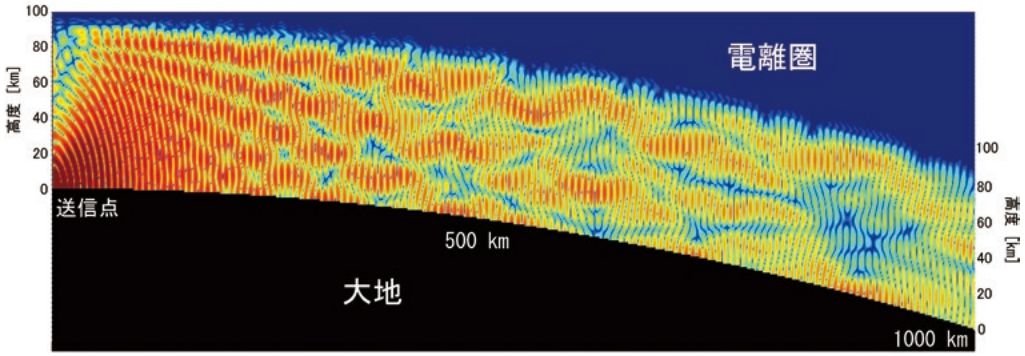
to electromagnetic fields.

Based on our laboratory's extensive store of know-how in electromagnetic field analysis, we understand why we can or cannot solve certain issues related to electromagnetic fields, and we can select suitable computation methods for solving problems. Hence, our research lends itself to applications that contribute to design optimization.



Earth-ionosphere waveguide propagation from very low frequency and low frequency (VLF/LF) transmitter station

In our research on natural electromagnetic phenomena, we confirmed that the distance from lightning to the observation point can be calculated using measurements of low frequencies. The results obtained by this method closely correspond to results obtained with lightning observation equipment onboard artificial satellites. Increasing the number of observation points will enable more accurate determination of lightning source locations.

Electromagnetic field technology links engineering to science and is cross-disciplinary in nature, making it highly useful across a broad range of fields. We believe research in this field holds great promise.

Future Prospects

Developing an Electromagnetic Field Simulator Based on the CIP Method

Electromagnetic fields are key factors across a broad range of activities, ranging from the design and engineering of mobile phone antennas to scientific research on earthquakes and other geophysical phenomena. It is our hope that the research undertaken by our laboratory will find a wide range of applications through active collaborations with researchers and corporations.

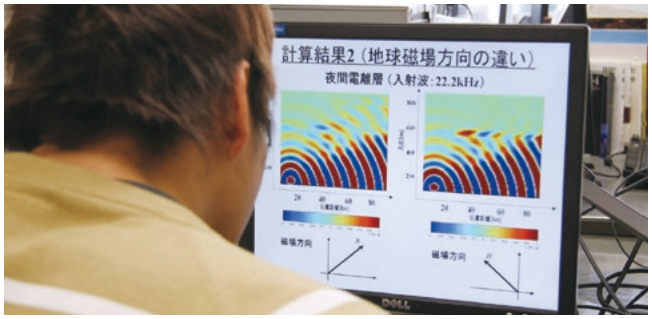
We also plan to address research on the constrained interpolation profile (CIP) method (a higher-order accuracy finite difference method) based on new calculation methods. While the scope of applicability of the existing CIP method is limited with respect to actual electromagnetic field problems, we believe the CIP method has more to offer. Ultimately, our goal is to develop a new type of electromagnetic field simulator based on a new CIP method. We expect a simulator based on the CIP method to be faster and more accurate than existing simulators based on the finite-difference time-domain (FDTD) method.

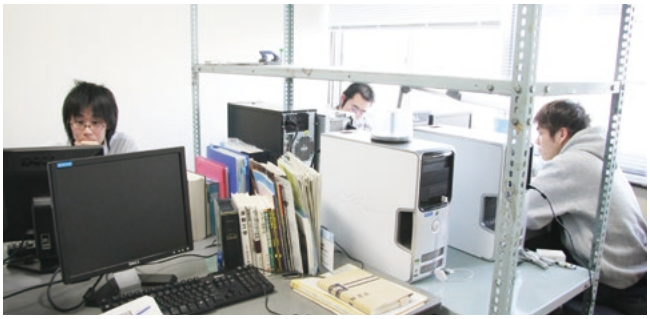
Our position as a university laboratory provides access to and the ability to incorporate the latest research results into software. Faster and easier analysis and calculations related to electromagnetic fields will allow companies to make better use of analysis and calculation results in product design.

Research on computational electromagnetics offers significant potential in numerous fields. We look forward to hearing from those with an interest in our research. We are confident our laboratory can provide assistance and cooperation in various ways.

University students participate actively in research and development.

Verification experiment





Examination of a physical phenomenon based on calculation results. This requires basic academic skills.