Three-Dimensional Electromagnetics

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Contents

Gerald W. Hohmann (1940–1992)

The numerous possibilities for theoretical and programming errors make it necessary to compare results computed by different methods before a numerical solution can be considered valid.

Hohmann (1988)

Preface

In 1975 Jerry Hohmann published a paper[1] that described his numerical implementation of an integral-equation method for three-dimensional electromagnetic (3-D EM[2]) modeling. The matrix equation for the simple model that he studied—a half-space containing a rectangular body discretized into 100 cubic cells—barely fit into the computer (a UNIVAC 1108 at the University of Utah). Coaxing interesting and correct results from the model and method clearly comprised much of the art and fun of the paper. And winding through the paper's 50 or so equations and nearly 20 figures was a clear message: 3-D EM is different!

Three-dimensional electromagnetics is qualitatively different with new phenomena[3] and new challenges to our understanding of how electromagnetic fields interact with Earth and other conductive bodies (including our own). In subsequent years, Jerry with his students and colleagues pursued these challenges across many fields—mining geophysics, geothermal exploration, magnetotelluric crustal studies, environmental geophysics, oil and gas exploration—in both the time and frequency domains. Of his 51 articles[4] in journals and monographs, more than half dealt with three-dimensional electromagnetics.

In 1995, 20 years after Jerry's classic paper (and three years after his death from cancer in May, 1992), nearly 200 scientists from around the world gathered at Schlumberger–Doll Research in Ridgefield, Connecticut, for a symposium in his memory, the (first) International Symposium on Three-Dimensional Electromagnetics. More than 70 papers were presented in oral and poster sessions during three days organized

[1]Hohmann, Gerald W., 1975, Three-dimensional induced polarization and electromagnetic modeling: Geophysics, **40**, 309–324.

[2]The first of many appearances of these two acronyms—3-D, EM—which are used as adjectives (*three-dimensional, electromagnetic*) and nouns (*three dimensions, electromagnetics*) throughout this volume.

[3]Such as *current channeling*, now generally called *galvanic response:* "The surprising result is that decreasing the background resistivity increases the EM response. . . . The same effect has been observed in scale model experiments. However, this enhancement of response with decreasing background conductivity does not occur for a two-dimensional body excited by an infinite line source."

[4]See Appendix at the end of this book.

around the themes: Modeling, Inversion, and Practice. The quality of the work presented, the liveliness of the discussions, and the demand for the symposium proceedings were the impetus for this new volume. We invited the authors to submit longer, more tutorial versions of their articles for a book to be published by the Society of Exploration Geophysicists (SEG) in the series *Geophysical Developments*.

As is evident from the size of this volume, we were overwhelmed by the response. We hope that readers will find the contents equally weighty. The 44 articles collected here are the work of 97 authors, representing 55 different institutions (universities, government or industrial research labs) from 13 countries around the world. All have been reviewed and edited according to the strict standards of SEG's lead journal, *Geophysics*. They represent the state of the art in 3-D EM at the time final revisions were received (from the fall of 1997 through the spring of 1998).

The lead article addresses one of Jerry's favorite subjects—the need for independent checks on any numerical calculation; it shows how far we have come since 1975 and how far we still are from routine, confident use of 3-D EM models. We have grouped the remaining articles into nine sections:

Integral-equation modeling

Finite-difference modeling

Inversion

3-D EM and parallel computers

Magnetotellurics and global induction

Mining and exploration geophysics

Borehole geophysics and logging

Equipment

General

This division into techniques and applications is naturally very rough; many articles could easily appear in two or three different sections. The subjects covered in this volume touch, we believe, on every major technique being used today to compute, analyze, visualize, and understand 3-D EM fields in every major application of electrical geophysics (and in two applications outside geophysics: the interaction of 3-D EM fields with the human body and the non-destructive testing of aircraft). The late 1980's saw the rapid development of 3-D seismics, which has revolutionized exploration for oil and gas in the 1990's. The early years of the new millenium may see another revolution brought about by the rapid advances now occurring in 3-D EM.

Acknowledgments

Many people contributed to the success of 3-D EM Symposium and helped to bring together this volume. At Schlumberger-Doll Research, we thank especially Cathy Corris, the Symposium co-ordinator; Tarek Habashy, Carlos Torres-Verdín, and Vladimir Druskin, who helped with the selection and organization of articles; and Computing and Information Resources (especially Ken Scherwenik, Ray Kocian, Paul Gerardi, and Karyn Muller) for helping us handle the flood of electronic submissions. Schlumberger generously donated use of the facility and the time of all of the above. Eleanor Umali of Techbooks and Judy Hastings of SEG oversaw production of the

volume and ensured that it met SEG's high standards. We also thank Tom Oristaglio for collating and compiling the Index. Most of all, we thank the authors for contributing their work and for indulging our insistence on receiving everything electronically (and for patiently helping us get it right).

Frank Morrison first suggested the idea for a symposium honoring Jerry Hohmann; the idea gathered force under the auspices of the G. W. Hohmann Memorial Trust for Teaching and Research in Applied Electrical Geophysics and its trustees: Stanley H. Ward, Phillip Michael Wright, Louise Pellerin, and Charles M. Swift, Jr. The proceeds from this book will be donated to the Trust, which is funding scholarships (through the SEG Foundation) and awards in electrical geophysics.

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