Physical Principles of Antenna Systems

Michel T. Ivrlač

LECTURE NOTES

Technische Universität München
Associate Professorship for Methods of Signal Processing

Berichte aus der Hochfrequenztechnik

Michel Ivrlač

Physical Principles of Antenna Systems

Shaker Verlag
Aachen 2017

Bibliographic information published by the Deutsche Nationalbibliothek
The Deutsche Nationalbibliothek lists this publication in the Deutsche Nationalbibliografie; detailed bibliographic data are available in the Internet at http://dnb.d-nb.de.

Printed in Germany.

ISBN 978-3-8440-5094-3
ISSN 0945-0793

Shaker Verlag GmbH • P.O. BOX 101818 • D-52018 Aachen
Phone: 0049/2407/9596-0 • Telefax: 0049/2407/9596-9
Internet: www.shaker.de • e-mail: info@shaker.de

This book serves as the principle text for the graduate course
»Physical Principles of Electromagnetic Fields and Antenna Systems«
that its author, PD Dr.-Ing. Michel T. Ivrlač, teaches at the
Technische Universität München (TUM),
Munich, Germany.

PD Dr.-Ing. Michel T. Ivrlač earned his Dr.-Ing. degree in 2005 from TUM
for his dissertation on models, performance and optimization
of wireless MIMO systems.
He started his *habilitation* work in 2008, earned his
Facultas Docendi for »Circuit Theory and Communication« in 2013
and was granted his *venia legendi* in 2014, both from TUM.
He lives with wife and children in Munich.

I dedicate this book to

my wife Lai-U and our children Gallus and Felina.

In the beginning God created the heavens and the earth. The earth was formless and void, and darkness was over the surface of the deep, and the Spirit of God was moving over the surface of the waters. Then God said, »Let there be light«, and there was light. God saw that the light was good. Moses

And thus is the universe knit together. The atomic motions of a distant star still have sufficient influence at this great distance to set the electrons in our eye in motion, and so it is that we see the stars and the galaxies. Richard P. Feynman

One cannot escape the feeling that these mathematical formulae have an independent existence and an intelligence of their own, that they are wiser than we are, wiser even than their discoverers. Heinrich Hertz

The theory I propose may therefore be called a theory of the electromagnetic field because it has to do with the space in the neighbourhood of the electric or magnetic bodies, and it may be called a dynamical theory, because it assumes that in the space there is matter in motion, by which the observed electromagnetic phenomena are produced. James C. Maxwell

---

1 *The Bible, Genesis,* 1:1

2 *The Feynman Lectures on Physics*, vol. 1, 28-1.

3 From »Mathematics in the Physical Sciences« by Freeman Dyson.

4 »A Dynamical Theory of the Electromagnetic Field« (1865), *The Scientific Papers of James Clerk Maxwell*, vol. 2, 527, 1890.

Contents