Modulation Transfer Function in Optical and Electro-Optical Systems

Second Edition

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Glenn D. Boreman

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Introduction to the Series

The *Tutorial Text* series provides readers with an introductory reference text to a particular field or technology. The books in the series are different from other technical monographs and textbooks in the manner in which the material is presented. True to their name, they are tutorial in nature, and graphical and illustrative material is used whenever possible to better explain basic and more-advanced topics. Heavy use of tabular reference data and numerous examples further explain the presented concept. A grasp of the material can be deepened and clarified by taking corresponding SPIE short courses.

The initial concept for the series came from Jim Harrington (1942–2018) in 1989. Jim served as Series Editor from its inception to 2018. The *Tutorial Texts* have grown in popularity and scope of material covered since 1989. They are popular because they provide a ready reference for those wishing to learn about emerging technologies or the latest information within a new field. The topics in the series have grown from geometrical optics, optical detectors, and image processing to include the emerging fields of nanotechnology, biomedical optics, engineered materials, data processing, and laser technologies. Authors contributing to the series are instructed to provide introductory material so that those new to the field may use the book as a starting point to get a basic grasp of the material.

The publishing time for *Tutorial Texts* is kept to a minimum so that the books can be as timely and up-to-date as possible. When a proposal for a text is received, it is evaluated to determine the relevance of the proposed topic. This initial reviewing process helps authors identify additional material or changes in approach early in the writing process, which results in a stronger book. Once a manuscript is completed, it is peer reviewed by multiple experts in the field to ensure that it accurately communicates the key components of the science and technologies in a tutorial style.

It is my goal to continue to maintain the style and quality of books in the series and to further expand the topic areas to include new emerging fields as they become of interest to our readers.

Jessica DeGroote Nelson
Optimax Systems, Inc.

Contents

Preface to the Second Edition

It had been 19 years since the first edition of this book, when the extended quarantine period of 2020 afforded me the rare opportunity of quiet time away from my usual administrative and research activities. I have significantly expanded the treatment of several topics, including bar-target measurements, noise-target measurements, effects of aberrations, and slant-edge measurements. I have been gratified by the recent industrial and government-lab interest in the speckle techniques, which, after all, comprised a good portion of my dissertation at University of Arizona some 36 years ago. All other topics in the book were reviewed and updated, with recent references added. I have kept my original emphasis on practical issues and measurement techniques.

I acknowledge with pleasure discussions about MTF with colleagues and their students here at UNC Charlotte, among whom are Profs. Angela Allen, Chris Evans, and Thomas Suleski. During the writing process, I appreciated receiving daily encouragement by telephone from Dot Graudons, daily encouragement via WhatsApp from Prof. Mike Sundheimer of the Universidade Federal Rural de Pernambuco in Recife Brazil, and weekly encouragement via Zoom from Skye Engel. I am grateful for the permissions granted for reproductions of some of the figures from their original sources, to the two anonymous reviewers for their insightful and helpful comments, and to Dara Burrows of SPIE Press for her expert copyediting.

Last but surely not least, I want to thank Maggie Boreman – my wife of 30 years, my main encourager, and technical editor. You have graciously taken time from your equestrian pleasures to struggle, once again, with turning my writing into something approaching standard English. Thanks.

Glenn D. Boreman
Emerald Rose Farm
23 November 2020

Preface to the First Edition

I first became aware that there was such a thing as MTF as an undergraduate at Rochester, scurrying around the Bausch and Lomb building. There was, in one of the stairwells, a large poster of the Air Force bar target set. I saw that poster every day, and I remember thinking... gee, that's pretty neat. Well, more than 25 years later, I still think so. I have had great fun making MTF measurements on focal-plane arrays, SPRITE detectors, scanning cameras, IR scene projectors, telescopes, collimators, and infrared antennas. This book is an outgrowth of a short course that I have presented for SPIE since 1987. In it, I emphasize some practical things I have learned about making MTF measurements.

I am grateful for initial discussions on this subject at Arizona with Jack Gaskill and Stace Dereniak. Since then, I have had the good fortune here at Central Florida to work with a number of colleagues and graduate students on MTF issues. I fondly recall discussions of MTF with Arnold Daniels, Jim Harvey, Didi Dogariu, Karen MacDougall, Marty Sensiper, Ken Barnard, Al Ducharme, Ofer Hadar, Ric Schildwachter, Barry Anderson, Al Plogstedt, Christophe Fumeaux, Per Fredin, and Frank Effenberger. I want to thank Dan Jones of the UCF English Department for his support, as well as Rick Hermann, Eric Pepper, and Marshall Weathersby of SPIE for their assistance and enthusiasm for this project. I also appreciate the permissions granted for reproductions of some of the figures from their original sources.

Last but surely not least, I want to thank Maggie Boreman – my wife, main encourager, and technical editor. Once again, Meg, you have wrestled with my occasionally tedious expository and transformed it, if not into poetry, then at least into prose. Thanks.

GDB
Cocoa Beach
15 March 2001