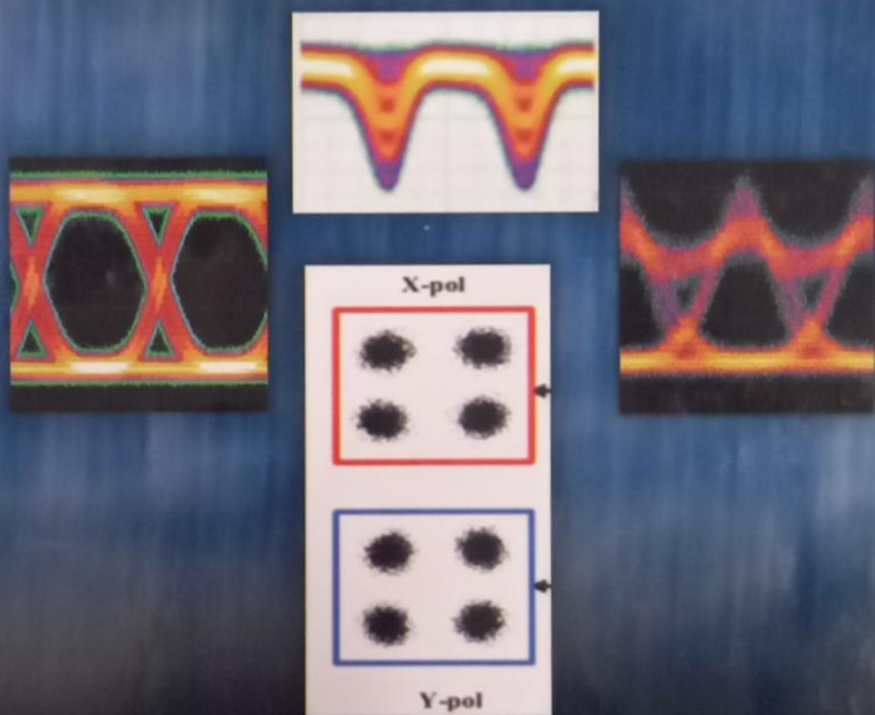


SECOND EDITION

Optical Fiber Communication Systems with MATLAB[®] and Simulink[®] Models



Le Nguyen Binh



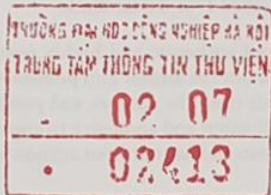
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Le Nguyen Binh

HUAWEI TECHNOLOGIES CO., LTD., EUROPEAN RESEARCH CENTER
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Preface

Written as self-contained material for the principles, practices, and modeling of optically amplified fiber communications systems using MATLAB® Simulink® platform, this book is intended for use in university and professional training courses in the specialized field of optical communications. This lecture-based book should also appeal to undergraduate students of engineering and science who have already taken courses in electromagnetic theory, signal processing, and digital communications and, as an introduction to the modeling, to optical engineers, designers, and practitioners in industry.

The contents of the first edition of this book were used as a set of lecture notes for senior students of bachelor of computer systems engineering and master of telecommunications engineering at Monash University, Melbourne, Australia, and it is not a compendium of all the multifaceted aspects of light wave optical fiber communications engineering. The tremendous advancement of reception techniques using coherent mixing of signals and a local oscillator in association with ultra-high-speed analog to digital converters and thence digital processors has allowed the transmission of several thousands of kilometers of single-mode optical fibers without using dispersion compensating modules, hence reducing the accumulated noises contributed by optical amplifiers. This edition puts more emphasis on these DSP-based coherent reception techniques in order to prepare the readers for short- and long-term optical transmission networks in the future. Thus, this is one of the main focus of this edition.

Optical fiber communications technology has been developing at a very fast pace since the 1970s and has, in combination with the advancement of digital processing technology, revolutionized global communications, but also the manner in which the fundamentals of telecommunications and information systems and networks are presented. Currently, the transmission of 40 Gb/s per channel in dense wavelength division multiplexed optical systems of 80 wavelength channels is a "done deal" matter leading to the possibility of a transmission capacity of 3–10 Tb/s per single single-mode fiber. The emerging technological development of 100 Gb/s Ethernet under either incoherent or coherent detection with incorporation of electronic processing will stretch further the speed and capacity of optical fiber communications and networks in terrestrial and intercontinental information transport networking.

The design of the contents is very vertical. The applications of optical fibers and related optical technology are built across all optical components of the optical communication engineering. The emphasis is on concepts and interpretation, mathematical procedures, and engineering applications. In this approach, the ground works in the propagation of light waves in planar slab optical waveguides and optical fibers are presented in the first two chapters. The single-mode fibers have reached its maturity, and thus, only the principal parameters of the fibers for operations and for identification of the structures are given rather than going deeply into the design of optical fibers as some textbooks have pursued.

MATLAB software packages have now been a common computing platform for students in global university systems. It is thus sensible to make available programs and simulation models in MATLAB, so that students and instructors can be used for laboratory experiments as well as for further research developments. Therefore, in this book, we provide a detailed description of MATLAB Simulink models. We also

provide samples of the models for readers to download on the book's Web site, <http://www.crcpress.com/product/isbn/9781482217513>. Thus, the principles of operation of all optical components and optical systems are much more important than their detailed mathematical descriptions.

Chapter 1 gives an overview of the development of optical fiber communications technology over the last three decades of the twentieth century. Readers can skip Chapters 2 and 3 and proceed to other chapters on optical transmitters and receivers if the fundamental understanding of light waves transmission through optical fibers is not required. The transmitters and receivers are treated independently and they form the basic elements of optical communications systems.

Chapters 3 and 4 describe the optical transmitters for direct and external modulation techniques, respectively. It is no doubt that the combination of coherent detection and digital signal processing will play a major role in next-generation ultra-high-speed optical transmission systems. Therefore, the detection of optical signals under direct coherent and incoherent receptions is described in Chapters 9 and 10. They are followed by two chapters on lumped erbium-doped and distributed Raman optical amplifiers (Chapters 9 and 10) with extensive models for the amplification of signals and structuring the amplifiers on Simulink platform.

Thence, Chapter 12 discusses the optical transmission systems design and MATLAB Simulink models with dispersion and attenuation budget methodology. Chapter 13 gives an introduction to advanced modulation formats for long-haul optical fiber transmission systems with accompanied Simulink models. With the significant progresses of the advanced optical communications systems over the last decade for extremely long and extremely high bit rate transmission employing an advanced modulation format, we thus present in this chapter the techniques for the generation of modulation formats and optical transmission. These chapters will deal with the advanced aspects of optical communications engineering for long-haul optical communications systems and intercontinental networks, and emphasis will be focusing on the design and implementation of these optical communications beyond the dispersion limits and networks.

Coherent reception techniques and transmission systems in association with digital processing are introduced in Chapters 13 through 15 (processing algorithms), the three new chapters of this edition.

A number of appendices are used to supplement materials common for all the chapters. In particular, the relationship between the frequency response and its time domain sequence is presented to allow readers to identify the unknown spectral or frequency response when observing the eye pattern obtained by a sampling oscilloscope and the effects of any cable connected between the output of an electrical system and the input port of a high-speed sampling system.

Further emphasis is also placed on "wavelength division multiplexed optical fiber communications systems and networks," which will also give the most advanced aspects to date and beyond the first decade of the twenty-first century (2010) of networking of multi-carrier optical multiplexed communications systems engineering. Although research and development of flexible grids with bit rates of 100G and 400G, and 1, 2, 4, and even 10 Tb/s per wavelength channel for optical networks emerges, the technology is not matured enough to be introduced into practice. I hope to introduce this technological development into the next edition of this book.

The contents of the book have been taught to undergraduate students at Monash University over the last decade. Many contributions and questions from many undergraduate and postgraduate students have enriched the writing of this set of notes. In particular,

Dr. Ngo Q. N. (now with NTU Singapore), Dr. Nguyen D. N., Dr. Lam Q. H., K.-Y. Chin, Ho S. C., and D. Lam, who undertook honors and doctoral projects in the modeling of optical fiber communications, have contributed to several software sections of the Monash Optical Communications Systems Simulator using both MATLAB and Simulink as well as an experimental platform setup. I also wish to thank many colleagues at Huawei Technologies Co. Ltd. for helping me understand the modern transmission technologies using coherent receptions and digital signal processing.

Furthermore, many challenging questions from my former undergraduate and post-graduate students studying this subject have made us think and understand deeply the field of optical communications.

Over the last decade, the course developed at Monash University has gone through a number of changes during the last few lectures on the advanced aspects of optical communications engineering, in order to give students at honors level a deeper understanding of the future development of these optical systems and networks. Several fundamental issues involving coherent optical communications were taught. However, we are now more certain in the development and deployment of optical systems and networks in the next few decades of the twenty-first century. They will be long-haul and wavelength multiplexed optical systems and distribution optical networks.

The contents of the chapters given in these lecture notes are thus focused on the practical understanding and fundamental issues that students can use for their future engineering careers. Readers, especially lecturers who are interested in some samples of the basic Simulink models described in this book, can contact the publisher.

It is no doubt that there would be mistakes in the book and we would like to receive fruitful comments from readers and scholars in order to improve the next edition.

Last but not least, I would like to sincerely thank my wife Phuong and our son Lam for their understanding while I have been busy preparing this edition. My parents always supported their son's endeavors to completion with discipline. This book is thus dearly dedicated to my parents.

Le Nguyen Binh
Muenchen, Deutschland

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