Time-Frequency Signal Analysis

Ljubiša Stanković, Miloš Daković, Thayananthan Thayaparan

The culmination of more than twenty years of research, this authoritative resource provides a practical understanding of time-frequency signal analysis. The book offers in-depth coverage of critical concepts and principles, along with discussions on key applications that are of great interest to engineers and researchers involved in a wide range of signal processing work, from communications and optics...to radar and biomedicine. Supported with over 140 illustrations and more than 1,700 equations, this detailed reference explores the topics professionals need to understand, such as Fourier analysis, linear time frequency representations, quadratic time-frequency distributions, higher order time-frequency representations, and analysis of non-stationary noisy signals. This unique book also serves as an excellent text for courses in this area, featuring numerous examples and problems at the end of each chapter. It is suitable for electrical engineers and researchers whose work involves signal processing and radar signal processing, as well as graduate students in related courses.

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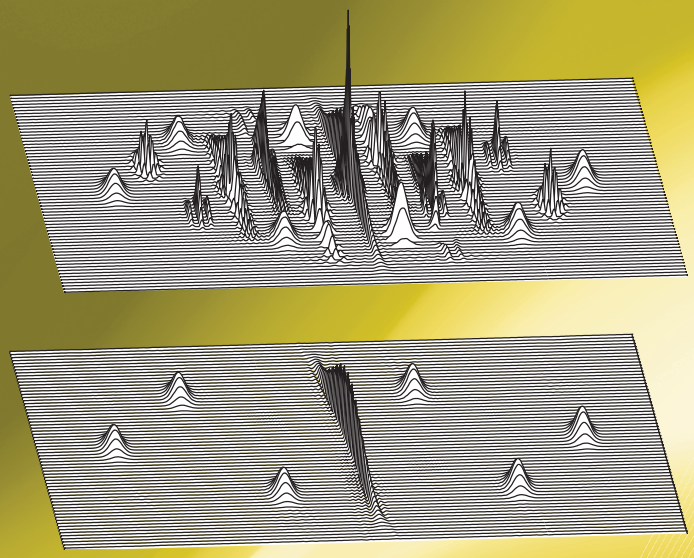
with Applications



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Thayananthan Thayaparan

Preface

This book is a result of more than twenty years of research and education in the area of time-frequency signal analysis and signal theory, in general.

The book presents time-frequency analysis, which is of crucial interest to a variety of researchers, students, and engineers dealing with any aspects of signal processing in their work. It deals with the theory, concepts, and applications of time-frequency analysis being at the core of some new technologies used in most fields of engineering, science, and technology, like information technologies, radar and sonar signal processing, biomedicine, multimedia, telecommunications, seismology, car engine technology, and optics.

After publishing several research monographs the authors concluded that there was a need for a textbook that could be used by students, researchers, and engineers who want to apply time-frequency tools in their work. Time-frequency analysis has been regarded as a part of advanced graduate courses on signal processing.

This book begins with the basic concepts needed to understand time-frequency techniques. An overview of Fourier analysis, presenting relations among the Fourier transform, the Fourier transform of discrete-signals, the Fourier series, and the discrete Fourier transform, is given. The sampling theorem is discussed as well. Next the book focuses on advanced techniques and methods needed for the analysis and processing of signals with time-varying spectral content. Chapter 2 deals with time localization of the spectral content of signals. The short-time Fourier transform is presented as the basic linear tool for the time-frequency analysis. Other linear signal transformations used for localization of the signal content in the time-frequency domain, including the local polynomial Fourier transform, the fractional Fourier transform, and their generalizations are studied as well.

Quadratic time-frequency distributions is the topic of Chapter 3. The Wigner distribution, as the basic quadratic distribution, is presented in detail. The generalized form of quadratic distributions, known as the Cohen class of distributions, is studied. This chapter concludes with a short overview of other approaches used for signal localization, such as time-scale distributions, empirical mode decomposition, and the reassignment method. Higher-order distributions are presented in Chapter 4. Their properties are studied along with various methods for construction and realization of highly concentrated distributions. Methods used for higher-order non-stationary signal analysis, such as higher-order ambiguity function methods, are also presented here. The noise analysis and instantaneous frequency estimation are considered in Chapter 5. An efficient algorithm for the adaptive analysis of noisy signals is presented. Robust forms of time-frequency representations are analyzed. This chapter ends with a presentation of some methods in time-frequency analysis of sparse signals.

The book concludes with numerous applications, including but not limited to radar signal processing, communications, movement analysis in video sequences, car engine data analysis, multidimensional signal analysis, watermarking in the time-frequency domain, array signal processing, and high-resolution time-frequency methods. Special attention has been paid to the radar signal analysis, due to the authors' intensive research work in this area during the last several years. The presentation of material is supported by numerous examples in each chapter and problems at the end. Problems sometimes cover several areas within one chapter. MATLAB codes of the most important methods and examples are included as well. The initial versions of all chapters in the book were written by Ljubiša Stanković.

We would like to thank to all collaborators who helped to make the presentation clearer, especially, we would like to thank colleagues who have worked on the same topic for years: Professor Zdravko Uskoković, Professor Srdjan Stanković, Professor Igor Djurović, Professor Veselin Ivanović, Dr. Vesna Popović, Dr. Slobodan Djukanović, Dr. Ervin Sejdić, Dr. Irena Orović, Dr. Nikola Žarić, Predrag Raković, and Marko Simeunović. We also thank to Professor Viktor Sučić and his colleagues for their valuable comments on this text. We thank postgraduate students, Miloš Brajović, Filip Radenović, and Stefan Vujović for their careful reading of the draft of this book. We thank the reviewer of the book for a thorough reading of the manuscript and numerous comments that helped us to improve the presentation.

The culmination of more than twenty years of research, this authoritative resource provides you with a practical understanding of time-frequency signal analysis. The book offers in-depth coverage of critical concepts and principles, along with discussions on key applications in a wide range of signal processing areas, from radar and communications to car engine, video, detection, and watermarking.

Supported with over 140 illustrations and more than 1,700 equations, this detailed reference explores the topics engineers need to understand for their work in the field, such as Fourier analysis, linear time-frequency representations, quadratic time-frequency distributions, higher-order time-frequency representations, and time-frequency analysis of noisy and sparse signals. This unique book also serves as an excellent text for university courses in this area, featuring about 250 examples and solved problems at the end of each chapter.

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