Preface

Fourier[1] Transformation for Pedestrians. For *pedestrians*? Harry J. Lipkin's famous "Beta-decay for Pedestrians" [1], was an inspiration to me, so that's why. Harry's book explains physical problems as complicated as helicity and parity violation to "pedestrians" in an easy to understand way. Discrete Fourier transformation, by contrast, only requires elementary algebra, something any student should be familiar with. As the algorithm[2] is a linear one, this should present no pitfalls and should be as "easy as pie". In spite of that, stubborn prejudices prevail, as far as Fourier transformations are concerned, viz., that information could get lost or that you could end up trusting a hoax; anyway, who would trust something that is all done with "smoke and mirrors". The above prejudices are often caused by negative experiences, gained through improper use of ready-made Fourier transformation programs or hardware.

This book is for all who, being laypersons—or pedestrians—are looking for a gentle and also humorous introduction to the application of Fourier transformation, without hitting too much theory, proofs of existence, and similar things. It is appropriate for science students at technical colleges and universities, but also for "mere" computer-freaks. It is also quite adequate for students of engineering and all practical people working with Fourier transformations. Basic knowledge of integration, however, is recommended.

If this book can help to avoid prejudices or even do away with them, writing it has been well worthwhile. Here we show how things "work". Generally we discuss the Fourier transformation in one dimension only. Chapter 1 introduces Fourier series and, as part and parcel, important statements and theorems that will guide us through the whole book. As is appropriate for pedestrians, we also cover all the "pits and pitfalls" on the way. Chapter 2 covers continuous Fourier transformations in great detail. Window functions are dealt with in Chap. 3 in more detail, as

[1] Jean Baptiste Joseph Fourier (1768–1830), French mathematician and physicist.

[2] Integration and differentiation are linear operators. This is quite obvious in the discrete version (Chap. 4) and is, of course, also valid when passing on to the continuous form.

understanding them is essential to avoid the disappointment caused by false expectations. Chapter 4 is about discrete Fourier transformations, with special regard to the Cooley–Tukey algorithm (Fast Fourier Transform, FFT). Finally, Chap. 5 will introduce some useful examples for the filtering effects of simple algorithms. From the host of available material we only pick items that are relevant to the recording and preprocessing of data, items that are often used without even thinking about them. This book started as a manuscript for lectures at the Technical University of Munich and at the University of Leipzig. That is why it is very much a textbook and contains many worked examples—to be redone "manually"—as well as plenty of illustrations. To show that a textbook (originally) written in German can also be amusing and humorous, was my genuine concern, because dedication and assiduity of their own are quite inclined to stifle creativity and imagination. It should also be fun and boost our innate urge to play. The two books "Applications of Discrete and Continuous Fourier Analysis" [2] and "Theory of Discrete and Continuous Fourier Analysis" [3] had considerable influence on the makeup and content of this book, and are to be recommended as additional reading for those "keen on theory".

This English edition is based on the third, enlarged edition in German [4]. In contrast to this German edition, there are now problems at the end of each chapter. They should be worked out before going to the next chapter. However, I prefer the word "playground" because you are allowed to go straight to the solutions, compiled in the Appendix, should your impatience get the better of you. In case you've read the German original, there I apologized for using many new-German words, such as "sampeln" or "wrappen"; I won't do that here, to the contrary, they come in very handy and make the translator's job (even) easier. Many thanks to Mrs. U. Seibt and Mrs. K. Schandert, as well as to Dr. T. Reinert, Dr. T. Soldner and especially to Mr. H. Gödel (Dipl.-Phys.) for the hard work involved in turning a manuscript into a book. Mr. St. Jankuhn (Dipl.-Phys.) did an excellent job in proofreading and computer acrobatics.

Last but not least, special thanks go to the translator who managed to convert the informal German style into an informal ("downunder") English style.

Recommendations, queries, and proposals for change are welcome. Have fun while reading, playing, and learning.

Leipzig Tilman Butz
April 2005

Preface of the Translator

More than a few moons ago I read two books about Richard Feynman's life, and that has made a lasting impression. When Tilman Butz asked me if I could translate his "Fourier Transformation for Pedestrians", I leapt at the chance—my way of getting a bit more into science. During the rather mechanical process of translating the German original, within its TEX-framework, I made sure I enjoyed the bits for the pedestrians, mere mortals like myself. Of course I am biased, I have known the author for many years—after all he is my brother.

Hamilton, New Zealand
2004

Thomas-Severin Butz

Preface for the Second Enlarged Edition

The second enlarged edition is based on the first edition with a focus on applications in signal analysis and processing. In a digital world, the discrete Fourier transformation plays a very important role. However, in order to avoid pitfalls, it is strongly recommended to learn about Fourier series and continuous Fourier transformation first. Two new chapters were added to the first edition for pedestrians that like to go a little further: the first deals with data streams and fractional delays, a topic which is important in a variety of fields ever since the development of fast digitizers; the second gives an introduction to tomography with focus on a common image reconstruction algorithm, the back-projection of filtered projections. Here, we shall use the spatial coordinate x and the "angular wave number" k instead of time t and angular frequency ω. Both topics are intimately related to Fourier transformation and deal with modern applications. Occasionally, series and integrals are needed which are beyond elementary calculus. For those who have access to a good library, references are given to verify the results. Those who have access to Mathematica [5] will prefer to use this tool instead. They will miss the admiration of human ingenuity of the pre-computer era but hopefully will admire Mathematica. Since the focus of this book is on signal processing, important issues like proofs of existence, convergence of infinite series, permutability of integration and differentiation, and integrability of functions are not addressed. Those pedestrians who want to step a little deeper into mathematics are encouraged to do so. A large number of typos and errors have been corrected (unfortunately you never get hold of all) and critical comments have been taken care of. It is a pleasure to thank Mr. St. Jankuhn (Dipl.-Phys.) for his excellent work to complete the second edition and Mr. M. Jäger (Dipl.-Inf.) for fruitful discussions on fractional delays. Recommendations, queries and proposals for change are always welcome. Have fun while reading, playing and learning.

Leipzig Tilman Butz

Springer

http://www.springer.com/978-3-319-16984-2

Fourier Transformation for Pedestrians
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2015, XVIII, 242 p. 148 illus., Softcover
ISBN: 978-3-319-16984-2