



# Fractional Fourier Transform, Signal Processing and Uncertainty Principles

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## Abstract

The fractional Fourier transform (FrFT) is one of the generalizations of the Fourier transform (FT). This paper is centered on the compression of different forms of signal in FrFT domain in order to extract some properties of each one with a comparison between the FrFT and the usual FT. Also, our focus here will be on two qualitative uncertainty principles for the fractional Fourier transform: The Cowling–Price’s theorem and the  $L^p - L^q$  version of Morgan’s theorem for the FrFT. These two results estimate the decay of two fractional Fourier transforms  $F_\alpha(f)$  and  $F_\gamma(f)$ , with  $\gamma - \alpha \neq n\pi, \forall n \in \mathbb{Z}$ , which allows us to deduce the usual uncertainty principles between a function  $f$  and its fractional Fourier transform  $F_\gamma(f)$ .

**Keywords** Fractional Fourier transform · Signal processing · Fractional  $L^p - L^q$  version of Morgan’s theorem · Fractional Cowling–Price’s theorem

## 1 Introduction

Uncertainty principles are mathematical results that give limitations on the simultaneous concentration of a function and its Fourier transform [13]. This idea has been studied first by Heisenberg [14] then by Faris, Donoho and Stark [25, 26], so-called quantitative uncertainty principles. They are just an other name for some special

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# Fractional Fourier Transform

**Waleed Abdelmaguid**



## **Fractional Fourier Transform:**

**The Fractional Fourier Transform with Applications in Optics and Signal Processing** Haldun M. Ozaktas, 2001

**Fractional Fourier Transform & Its Optical Applications** Hossein Sarafray Yazdi, 2012 A definition of fractional Fourier transform as the generalization of ordinary Fourier transform is given at the beginning. Then, due to optical reasons, the fractional transform of a so-called chirp function is considered in both theory and practical simulations. Because of a quadratic phase factor which is common in the definition of the transform and some optical concepts, a comparison between these concepts such as Fresnel diffraction, spherical wave, thin lens, and free space propagation and the transform has been done. Finally, an optical setup for performing the fractional transform is introduced.

**Fractional Fourier Transform Techniques for Speech Enhancement** Prajna Kunche, N. Manikanthababu, 2020-04-16 This book explains speech enhancement in the Fractional Fourier Transform (FRFT) domain and investigates the use of different FRFT algorithms in both single channel and multi channel enhancement systems, which has proven to be an ideal time-frequency analysis tool in many speech signal processing applications. The authors discuss the complexities involved in the highly non-stationary signal processing and the concepts of FRFT for speech enhancement applications. The book explains the fundamentals of FRFT as well as its implementation in speech enhancement. Theories of different FRFT methods are also discussed. The book lets readers understand the new fractional domains to prepare them to develop new algorithms. A comprehensive literature survey regarding the topic is also made available to the reader.

*Fractional Fourier Transform* Yigal Bitran, 1995

[The Fractional Fourier Transform in Optics](#) Rainer Georg Dorsch, 1995

*Fractional Fourier Transform* Kassandra Haak, 1997

**Transforms and Applications Handbook** Alexander D. Poularikas, 2018-09-03 Updating the original *Transforms and Applications Handbook* Third Edition solidifies its place as the complete resource on those mathematical transforms most frequently used by engineers, scientists, and mathematicians. Highlighting the use of transforms and their properties, this latest edition of the bestseller begins with a solid introduction to signals and systems, including properties of the delta function and some classical orthogonal functions. It then goes on to detail different transforms, including lapped Mellin wavelet and Hartley varieties. Written by top experts, each chapter provides numerous examples and applications that clearly demonstrate the unique purpose and properties of each type. The material is presented in a way that makes it easy for readers from different backgrounds to familiarize themselves with the wide range of transform applications. Revisiting transforms previously covered, this book adds information on other important ones, including Finite Hankel, Legendre, Jacobi, Gegenbauer, Laguerre, and Hermite Fractional Fourier, Zak, Continuous and discrete Chirp Fourier, Multidimensional discrete unitary Hilbert, Huang. Most comparable books cover only a few of the transforms addressed here, making this text by far the most useful for anyone involved in signal processing, including electrical and communication engineers, mathematicians, and any other scientist working in this field.

**The Fractional Fourier Transform and Its Application to Fault Signal**

**Analysis** Xiao Duan,2012 To a large extent mathematical transforms are applied on a signal to uncover information that is concealed and the capability of such transforms is valuable for signal processing One such transforms widely used in this area is the conventional Fourier Transform FT which decomposes a stationary signal into different frequency components However a major drawback of the conventional transform is that it does not easily render itself to the analysis of non stationary signals such as a frequency modulated FM or amplitude modulated AM signal The different frequency components of complex signals cannot be easily distinguished and separated from one another using the conventional FT So in this thesis an innovative mathematical transform Fractional Fourier Transform FRFT has been considered which is more suitable to process non stationary signals such as FM signals and has the capability not only of distinguishing different frequency components of a multi component signal but also separating them in a proper domain different than the traditional time or frequency domain The discrete time FRFT DFRFT developed along with its derivatives such as Multi angle DFRFT MA DFRFT Slanted Spectrum and Spectrogram Based on Slanted Spectrum SBSS are tools belonging to the same FRFT family and they could provide an effective approach to identify unknown signals and distinguish the different frequency components contained therein Both artificial stationary and FM signals have been researched using the DFRFT and some derivative tools from the same family Moreover to accomplish a contrast with the traditional tools such as FFT and STFT performance comparisons are shown to support the DFRFT as an effective tool in multi component chirp signal analysis The DFRFT taken at the optimum transform order on a single component FM signal has provided higher degree of signal energy concentration compared to FFT results and the Slanted Spectrum taken along the slant line obtained from the MA DFRFT demonstration has shown much better discrimination between different frequency components of a multi component FM signal As a practical application of these tools the motor current signal has been analyzed using the DFRFT and other tools from FRFT family to detect the presence of a motor bearing fault and obtain the fault signature frequency The conclusion drawn about the applicability of DFRFT and other derivative tools on AM signals with very slowly varying FM phenomena was not encouraging Tools from the FRFT family appear more effective on FM signals whereas AM signals are more effectively analyzed using traditional methods like spectrogram or its derivatives Such methods are able to identify the signature frequency of faults while using less computational time and memory

**Time-frequency Methods Based on the Fractional Fourier Transform** Chris G. Capus,2002 **The Fractional Fourier Transform in Optics** Rainer Georg Dorsch,1995 **Fractional Integral Transforms** Ahmed I. Zayed,2024-03-28 Fractional Integral Transforms Theory and Applications presents over twenty five integral transforms many of which have never before been collected in one single volume Some transforms are classic such as Laplace Fourier etc and some are relatively new such as the Fractional Fourier Gyrator Linear Canonical Special Affine Fourier Transforms as well as continuous Wavelet Ridgelet and Shearlet transforms The book provides an overview of the theory of fractional integral transforms with examples of such transforms before

delving deeper into the study of important fractional transforms including the fractional Fourier transform Applications of fractional integral transforms in signal processing and optics are highlighted The book s format has been designed to make it easy for readers to extract the essential information they need to learn the about the fundamental properties of each transform Supporting proofs and explanations are given throughout Features Brings together integral transforms never before collected into a single volume A useful resource on fractional integral transforms for researchers and graduate students in mathematical analysis applied mathematics physics and engineering Written in an accessible style with detailed proofs and emphasis on providing the reader with an easy access to the essential properties of important fractional integral transforms Ahmed I Zayed is a Professor of Mathematics at the Department of Mathematical Sciences DePaul University Chicago and was the Chair of the department for 20 years from 2001 until 2021 His research interests varied over the years starting with generalized functions and distributions to sampling theory applied harmonic analysis special functions and integral transforms He has published two books and edited seven research monographs He has written 22 book chapters published 118 research articles and reviewed 173 publications for the Mathematical Review and 81 for the Zentralblatt f r Mathematik zbMath He has served on the Editorial Boards of 22 scientific research journals and has refereed over 200 research papers submitted to prestigious journals among them are IEEE SIAM Amer Math Soc Math Physics and Optical Soc Journals

**Discrete Fractional Fourier Transform and Its Engineering Applications** Waleed Abdelmaguid,2016-10-16

Introduction to Fractional Fourier Transform Pooja Mohindru,Rajesh Khanna,S.S. Bhatia,2013 This book gives an introduction to Fractional Fourier Transform Fractional Fourier Transform has one extra degree of freedom that comes from the rotation angle parameter It can be used in every area where ordinary Fourier transform can be used and provides better results This book is useful for engineering students in the field of electronics and communication The language is simple and easy to understand

Fourier Transforms Goran Nikolic,2011-04-11 This book aims to provide information about Fourier transform to those needing to use infrared spectroscopy by explaining the fundamental aspects of the Fourier transform and techniques for analyzing infrared data obtained for a wide number of materials It summarizes the theory instrumentation methodology techniques and application of FTIR spectroscopy and improves the performance and quality of FTIR spectrophotometers

2022 Applied Mathematics and Statistics – Editor’s Pick Charles K. Chui,Eric Chung,Jianfeng Cai,Raluca Eftimie,Hong-Kun Xu,Daniel Potts,Young Shin Aaron Kim,Axel Hutt,2023-04-06 *Proceedings of the national conference on advances in contemporary physics and energy* S. C. Kaushik,2002 In Indian context *The Fractional Fourier Transform and Its Relation to Wigner Optics. A Review* A. Torre,2005

**Holography, Diffractive Optics, and Applications** Dahsiung Hsu, Jiabi Chen, Yunlong Sheng,2002 *The Fractional Fourier Transform* Universitat Tel-Aviv. Faculty of Engineering,1995

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