

# Radar emitter intrapulse signal blind sorting under modified wavelet denoising

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**Abstract:** With the electromagnetic environment becoming more and more complex and the analysis demand of the radar emitter intrapulse signal presenting more and more urgent, a modified method of the radar emitter intrapulse signal blind sorting under wavelet denoising is proposed. This study aims to improve the weak adaptability to the noise of the fast independent component analysis (FastICA) algorithm and its blind source separating performance. In this method, a pre-processing of noise based on the modified wavelet denoising is added. Then the FastICA algorithm is used to sort the unknown radar emitter intrapulse signal for the next intrapulse signal analysis. Simulations and analysis indicate that the modified method improves the signal to noise ratio of the received intermediate signals and the blind sorting performance.

## 1 Introduction

In the radar reconnaissance and confrontation of modern electromagnetic warfare, the electromagnetic environment is more and more adverse and the signal becomes more and more complex. [1]. Radar signal sorting is the front part of radar emitter recognition [2], location, and tracking, whose result directly influences the latter reconnaissance counter-measure system's performance. Hence, it is vital to complete the radar signal sorting precisely and rapidly in the complicated environment. Radar signal sorting aims to separate a single radar signal from the random mixed signal flows by the radar reconnaissance equipment in the high-density signal environment. Radar signal sorting [3] mainly depends on signal parameters, including interpulse and intrapulse parameters. At present, most of researches on the radar signal sorting are based on the interpulse parameters: carrier frequency, pulse width (PW), pulse repetition frequency, time of arrival (TOA), angle of arrival, pulse amplitude, etc. Also, signal sorting [4] is finished according to the correlation of the same radar's parameters. Radar signal sorting based on the intrapulse parameters mainly selects distinctive features to represent each signal, such as multi-dimensional statistical features, time-frequency features, and entropy, by which the signal component is extracted in sequence.

In the complex electromagnetic environment, radar signal blind separation is an effective method for radar emitter intrapulse signal sorting [5]. Huang first applied the technology of blind signal extraction to radar signal sorting and found feasible [6]; Li analysed the FastICA algorithm, used it in radar signal sorting, and achieved good separating performance; Xiong raised a new improved algorithm combining the Newton method with negentropy as an objective function to optimise the FastICA algorithm and eliminate the influence of the initial value. Also, all these researches are centring on how to improve the blind separating effect in the complex electromagnetic environment:

- Find the initial value to eliminate its influence on the algorithm's convergence;
- Improve the iterative algorithm to be independent of the initial value and has a faster convergence speed;
- Add pre-denoising to improve the algorithm's anti-noise performance.

Therefore, lots of work have been done on the former two problems, and attained good performance, but they did not considerate the algorithm's anti-noise performance. In this work, we establish the model of radar emitter intrapulse signal blind

sorting, modify the wavelet denoising algorithm to improve the signal quality, and use the FastICA algorithm to realise the intrapulse signal blind sorting. The modified wavelet denoising (MWD) achieves improving the blind separating performance based on FastICA. This paper is organised as follows. Section 2 describes the problem, makes the hypothesis, and establishes the research model. In Sections 3 and 4, the FastICA algorithm is analysed and two MWD algorithms are proposed. Simulations and discussions are displayed in Section 5 to indicate the improvement of our work. The conclusion is given in Section 6.

## 2 Problem description and hypothesis

After the signals are pre-processed by the radar reconnaissance receiver, the mixed signals are sorted according to different parameters to attain the single radar emitter signal. Also, those are usually applied into the mixed radar emitter intrapulse signal sorting. However, it is also important to sort the mixed radar emitter intrapulse signal, for example, the radar emitter intrapulse signal analysis, the recognition on intrapulse signal modulations [2], and specific emitter identification.

The blind sorting of mixed radar emitter intrapulse signals uses distributed receivers to collect different mixed signals which are separated by the blind source separation algorithm. Finally, we get the single radar emitter intrapulse signals; the whole process is shown in Fig. 1.  $N$  radar emitter signals in complicated electromagnetic environment are described as

$$S(i): s_1(i), s_2(i), \dots, s_N(i), \quad (1)$$

and after they are mixed and then received by  $M$  distributed receiving equipment, it becomes

$$X(i): x_1(i), x_2(i), \dots, x_M(i), \quad (2)$$

in which the  $x_i(i)$  ( $i = 1, 2, \dots, M$ ) is the mixed unknown radar emitter intrapulse signal. Under the MWD, the FastICA algorithm based on negentropy separates the mixed signals and gets the estimation of source signals

$$Y(i): y_1(i), y_2(i), \dots, y_N(i). \quad (3)$$

In the process of sorting on mixed radar emitter intrapulse signals, radar general parameters are ignored. Also, the signal sorting problem is transformed into the blind source separation problem.

# Intrapulse Analysis Of Radar Signal Wit Press

**Richard G. Wiley**



## **Intrapulse Analysis Of Radar Signal Wit Press:**

**Computational Methods and Experimental Measurements XIV** C. A. Brebbia, G. M. Carlomagno, 2009 Containing edited versions of most of the papers presented at the Fourteenth International Conference on Computational Methods and Experimental Measurements this book reviews the latest work on these two approaches and the interaction between them

**Feature Extraction of Intra-Pulse Modulated Radar Signals Using Time- Frequency Analysis** Ioannis Moraitakis, 1999-09-01 This thesis applies time frequency transformations to radar signals Specifically it considers the feasibility of applying time frequency transformations to extract the intra pulse modulation parameters of radar signals In this work we consider radar signals with analog pulse compression specifically linear or hyperbolic intra pulse modulation Several time frequency transformations are investigated to identify which one gives the most accurate image representation for signals in noisy environments Next image processing techniques are applied in conjunction with an adaptive curve fitting method for the hyperbolic modulation scheme to extract the parameters of the frequency equation Results show that for the linear chip case the frequency equation can be estimated with small error down to SNR equal to 10dB The proposed method for the hyperbolic chirp modulation is less immune to noise degradation and it can be used down to SNR level equal to 2dB

Radar Signals Charles Cook, 2012-12-02 Radar Signals An Introduction to Theory and Application introduces the reader to the basic theory and application of radar signals that are designated as large time bandwidth or pulse compression waveforms Topics covered include matched filtering and pulse compression optimum predetection processing the radar ambiguity function and the linear frequency modulation waveform and matched filter Parameter estimation and discrete coded waveforms are also discussed along with the effects of distortion on matched filter signals This book is comprised of 14 chapters and begins with an overview of the concepts and techniques of pulse compression matched filtering with emphasis on coding source and decoding device The discussion then turns to the derivation of the matched filter properties in order to maximize the signal to noise ratio analysis of radar ambiguity function using the principle of stationary phase parameter estimation and the method of maximum likelihood and measurement accuracies of matched filter radar signals Waveform design criteria for multiple and dense target environments are also considered The final chapter describes a number of techniques for designing microwave dispersive delays This monograph will be a useful resource for graduate students and practicing engineers in the field of radar system engineering

Electronic Intelligence, the Interception of Radar Signals Richard G. Wiley, 1985

*Radar Signals* Nadav Levanon, Eli Mozeson, 2004-09-07 A text and general reference on the design and analysis of radar signals As radar technology evolves to encompass a growing spectrum of applications in military aerospace automotive and other sectors innovations in digital signal processing have risen to meet the demand Presenting a long overdue up to date dedicated resource on radar signals the authors fill a critical gap in radar technology literature Radar Signals features in depth coverage of the most prevalent classical and modern radar signals used today as well as new

signal concepts developed in recent years Inclusion of key MATLAB software codes throughout the book demonstrates how they dramatically simplify the process of describing and analyzing complex signals Topics covered include Matched filter and ambiguity function concepts Basic radar signals with both analytical and numerical analysis Frequency modulated and phase coded pulses Complete discussion of band limiting schemes Coherent LFM pulse trains the most popular radar signal Diversity in pulse trains including stepped frequency pulses Continuous wave signals Multicarrier phase coded signals Combining lucid explanation preferred signal tables MATLAB codes and problem sets in each chapter Radar Signals is an essential reference for professionals and a systematic tutorial for any seeking to broaden their knowledge base in this dynamic field

**Radar Signal Analysis and Processing Using MATLAB** Bassem R. Mahafza, 2016-04-19 Offering radar related software for the analysis and design of radar waveform and signal processing Radar Signal Analysis and Processing Using MATLAB provides a comprehensive source of theoretical and practical information on radar signals signal analysis and radar signal processing with companion MATLAB code Aft

**ELINT** Richard G. Wiley, 2006 Annotation In these times correctly and quickly identifying a stray electronic blip on a radar screen can have incalculable consequences Now more than ever radar electronic intelligence ELINT can be the first line of defense for the battlefield or the homeland Offering new insight into radar signal analysis this book ensures more reliable and timely gathering of electronic intelligence Combining and updating the author's two previous definitive books on ELINT this volume is the indispensable reference for every ELINT professional

**Introduction to Radar Analysis** Bassem R. Mahafza, 2017-11-23 Introduction to Radar Analysis Second Edition is a major revision of the popular textbook It is written within the context of communication theory as well as the theory of signals and noise By emphasizing principles and fundamentals the textbook serves as a vital source for students and engineers Part I bridges the gap between communication signal analysis and radar Topics include modulation techniques and associated Continuous Wave CW and pulsed radar systems Part II is devoted to radar signal processing and pulse compression techniques Part III presents special topics in radar systems including radar detection radar clutter target tracking phased arrays and Synthetic Aperture Radar SAR Many new exercises are included and the author provides comprehensive easy to follow mathematical derivations of all key equations and formulas The author has worked extensively for the U S Army the U S Space and Missile Command and other military agencies This is not just a textbook for senior level and graduates students but a valuable tool for practicing radar engineers Features Authored by a leading industry radar professional Comprehensive up to date coverage of radar systems analysis issues Easy to follow mathematical derivations of all equations and formulas Numerous graphical plots and table format outputs One part of the book is dedicated to radar waveforms and radar signal processing

**Intrapulse Radar Signal Simulator** John H. Bordelon, Georgia Tech Research Institute (1984- ). Project no. A-4133, 1985

*Radar Signal Analysis* William S. Burdick, 1967

[Handbook of Radar Signal Analysis](#) Bassem R. Mahafza, Scott C. Winton, Atef Z. Elsherbeni, 2021-08-16 This new handbook on radar signal analysis

adopts a deliberate and systematic approach. It uses a clear and consistent level of delivery while maintaining strong and easy to follow mathematical details. The emphasis of this book is on radar signal types and their relevant signal processing and not on radar systems hardware or components. This handbook serves as a valuable reference to a wide range of audience. More specifically, college level students practicing radar engineers as well as casual readers of the subject are the intended target audience of the first few chapters of this book. As the book chapters progress, these grow in complexity and specificity. Accordingly, later chapters are intended for practicing engineers, graduate college students, and advanced readers. Finally, the last few chapters contain several special topics on radar systems that are both educational and scientifically entertaining to all readers. The presentation of topics in this handbook takes the reader on a scientific journey whose major landmarks comprise the different radar subsystems and components. In this context, the chapters follow the radar signal along this journey from its birth to the end of its life. Along the way, the different relevant radar subsystems are analyzed and discussed in great detail. The chapter contributors of this new handbook comprise experienced academia members and practicing radar engineers. Their combined years of academic and real world experiences are in excess of 175. Together, they bring a unique, easy to follow mix of mathematical and practical presentations of the topics discussed in this book. See the Chapter Contributors section to learn more about these individuals.

**Time-frequency Transforms for Radar Imaging and Signal Analysis** Victor C. Chen, Hao Ling, 2002. Here's an innovative hands-on book on time frequency transforms for radar imaging and signal analysis. It teaches you more efficient ways to extract dispersive scattering features, detect and extract weak signals in noise, form clear radar images, estimate parameters, and perform motion compensation. Detect and track moving targets in the synthetic aperture radar and analyze vibration and rotation induced micro Doppler. This unique resource introduces a new image formation algorithm based on time frequency transforms, showing its advantage over the more conventional Fourier based image formation. Referenced with over 170 equations and 80 illustrations, the book presents new algorithms that help improve the result of radar imaging and signal processing. Moreover, the authors discuss future trends in time frequency to analyze micro Doppler and provide you with a newly developed time frequency approach to radar signal and image processing to help you solve problems associated with conventional approaches.

**Fundamentals of Radar Signal Processing** Mark A. Richards, 2005-07-15. Advances in DSP (digital signal processing) have radically altered the design and usage of radar systems, making it essential for both working engineers as well as students to master DSP techniques. This text, which evolved from the author's own teaching, offers a rigorous in-depth introduction to today's complex radar DSP technologies. Contents: Introduction to Radar Systems, Signal Models, Sampling and Quantization of Pulsed Radar Signals, Radar Waveforms, Pulse Compression Waveforms, Doppler Processing, Detection Fundamentals, Constant False Alarm Rate (CFAR) Detection, Introduction to Synthetic Aperture Imaging.

*Basic Radar Analysis, Second Edition* Mervin C. Budge, Shawn R. German, 2020-04-30. This highly anticipated second edition of an Artech House classic covers several key

radar analysis areas the radar range equation detection theory ambiguity functions waveforms antennas active arrays receivers and signal processors CFAR and chaff analysis Readers will be able to predict the detection performance of a radar system using the radar range equation its various parameters matched filter theory and Swerling target models The performance of various signal processors single pulse pulsed Doppler LFM NLFM and BPSK are discussed taking into account factors including MTI processing integration gain weighting loss and straddling loss The details of radar analysis are covered from a mathematical perspective with in depth breakdowns of radar performance in the presence of clutter Readers will be able to determine the noise temperature of a multi channel receiver as it is used in active arrays With the addition of three new chapters on moving target detectors inverse synthetic aperture radar ISAR and constant false alarm rate CFAR and new MATLAB codes this expanded second edition will appeal to the novice as well as the experienced practitioner

**Radar Systems Analysis and Design Using MATLAB** Bassem R. Mahafza, 2005-03-09 An introduction to radar systems should ideally be self contained and hands on a combination lacking in most radar texts The first edition of Radar Systems Analysis and Design Using MATLAB provided such an approach and the second edition continues in the same vein This edition has been updated expanded and reorganized to include advances in t Radar Signals Charles Emerson Cook, Marvin Bernfeld, 1947 Radar signals Charles E. Cook, Marvin Bernfeld, 1987 *Radar Ambiguity Function for Random Intrapulse-modulated Radar Signals* Herman Neil Hebert (MAJ, USAF.), 1974 **Information-Theoretic Radar Signal Processing** Yujie Gu, Yimin Zhang, 2024-12-17 A comprehensive introduction to the emerging research in information theoretic radar signal processing Signal processing plays a pivotal role in radar systems to estimate visualize and leverage useful target information from noisy and distorted radar signals harnessing their spatial characteristics temporal features and Doppler signatures The burgeoning applications of information theory in radar signal processing provide a distinct perspective for tackling diverse challenges including optimized waveform design performance bound analysis robust filtering and target enumeration Information Theoretic Radar Signal Processing provides a comprehensive introduction to radar signal processing from an information theory perspective Covering both fundamental principles and advanced techniques the book facilitates the integration of information theory into radar signal processing broadening the scope and improving the performance Tailored to the needs of researchers and students alike it serves as a valuable resource for comprehending the information theoretic aspects of radar signal processing Information Theoretic Radar Signal Processing readers will also find Presentation of alternative hypotheses in adaptive radar detection Detailed discussion of topics including resource management and power allocation Direction of arrival DOA estimation and integrated sensing and communications ISAC Information Theoretic Radar Signal Processing is ideal for graduate students scientists researchers and engineers who work on the broad scope of radar and sonar applications including target detection estimation imaging tracking and classification using radio frequency ultrasonic and acoustic methods **Radar Principles** Nadav Levanon, 1988-05-19 An advanced

treatment of the main concepts of radar Systematic and organized it nicely balances readability with mathematical rigor Many techniques and examples have been chosen from the radar industry Rayleigh fluctuating targets are used as they yield simple expressions for the probability of detection and others for their pedagogical value Costas signals lead the coded radar signals because their ambiguity function can be intuitively deduced Ordered statistics is covered in more depth than other CFAR techniques because its performance can be obtained analytically without resorting to simulation methods Contains many exercises An Instructor's Manual presenting detailed solutions to all the problems in the book is available from the Wiley editorial department

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