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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 FashICA 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 interpulse 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

$$\boldsymbol{S}(t): s_1(t), s_2(t), \ldots, s_N(t), \tag{1}$$

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

$$\boldsymbol{X}(t): x_1(t), x_2(t), \ldots, x_M(t), \tag{2}$$

in which the $x_i(t)$ $(i = 1, 2, \ldots, M)$ 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

$$\boldsymbol{Y}(t): y_1(t), y_2(t), \ldots, y_N(t). \tag{3}$$

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

Mark A. Richards

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 *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

Electronic Intelligence, the Interception of Radar Signals Richard G. Wiley,1985 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 exercise 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 **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 Intrapulse Radar Signal Simulator John H. Bordelon,Georgia Tech Research Institute (1984-). Project no. A-4133,1985 **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 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

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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 **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 *Compressed Sensing in Radar Signal Processing* Antonio De

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Fundamentals of Radar Signal Processing, Second Edition Mark A. Richards,2013-12-02 The most complete current guide to the signal processing techniques essential to advanced radar systems Fully updated and expanded Fundamentals of Radar Signal Processing Second Edition offers comprehensive coverage of the basic digital signal processing techniques and technologies on which virtually all modern radar systems rely including target and interference models matched filtering

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