Qihua WU, Feng ZHAO, Tiehua ZHAO, Xiaobin LIU, Junjie WANG, Shunping XIAO, 2023. Stepped frequency chirp signal imaging radar jamming using two-dimensional nonperiodic phase modulation. *Frontiers of Information Technology & Electronic Engineering*, 24(3):433-446. https://doi.org/10.1631/FITEE.2200298

Stepped frequency chirp signal imaging radar jamming using two-dimensional nonperiodic phase modulation

Key words: Radar jamming; Stepped frequency chirp signal; Nonperiodic phase modulation; Wideband radar

Corresponding authors: Qihua WU, Feng ZHAO

E-mail: stevewoo1990@outlook.com, zhaofeng_nudt@163.com

ORCID: https://orcid.org/0000-0002-9998-2301

https://orcid.org/0000-0003-1275-3352

Motivation

1. Stepped frequency chirp signal obtains high-resolution radar images by synthesizing multiple narrowband chirp pulses. It has been one of the most commonly used wideband radar waveforms due to its lower demand for radar instant bandwidth. Hence, it is of vital significance to explore target protection methods against stepped frequency chirp signal radar.
2. The jamming method using conventional interrupted-sampling repeater jamming (ISRJ) technique is the “0–1” modulation in the amplitude domain, which inevitably brings energy loss.

Main idea

1. By nonperiodic phase modulation on the stepped frequency chirp signal in both fast and slow time domains, a flexible two-dimensional (2D) blanket jamming performance is obtained.
2. The proposed jamming method using "±1" modulation in the phase domain instead of the "0–1" modulation in the amplitude domain avoids the energy loss and makes a more efficient utilization of the jamming power.

Method

1. Jamming mechanism

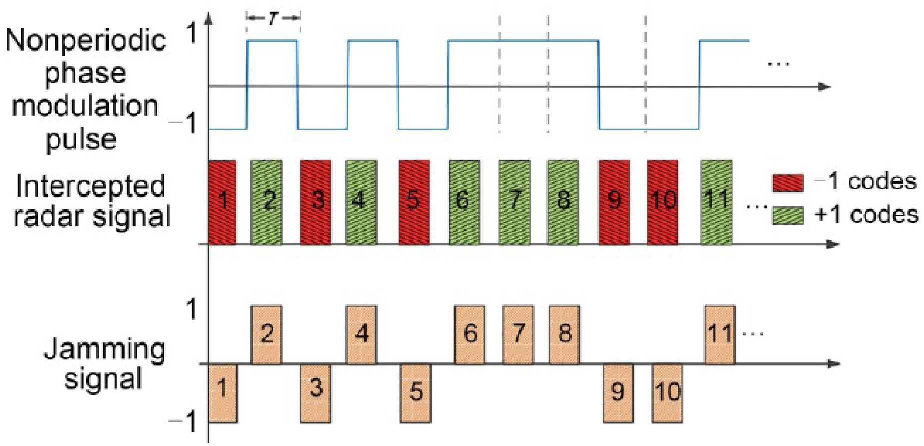


Fig. 4 Subpulse nonperiodic phase modulation in the fast time domain

The nonperiodic phase modulation brings continuous frequency removal. By using this unique property, the jamming method is proposed using 2D nonperiodic phase modulation on the intercepted stepped frequency chirp signal, which can generate high-level sidelobes that perform as a special blanket jamming along both the range and azimuth directions and make the target unrecognizable.

Method

2. Jamming procedure

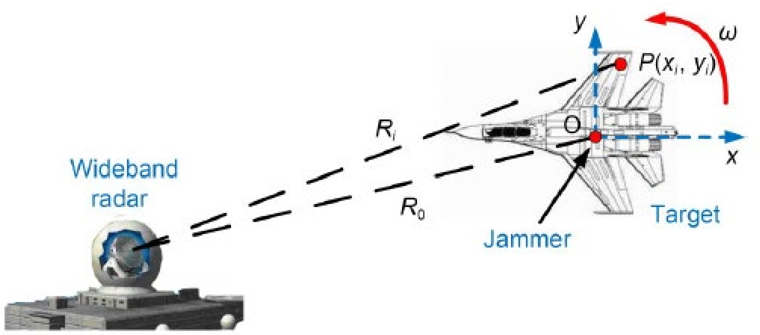


Fig. 5 Geometric relationship of the radar, target, and jammer

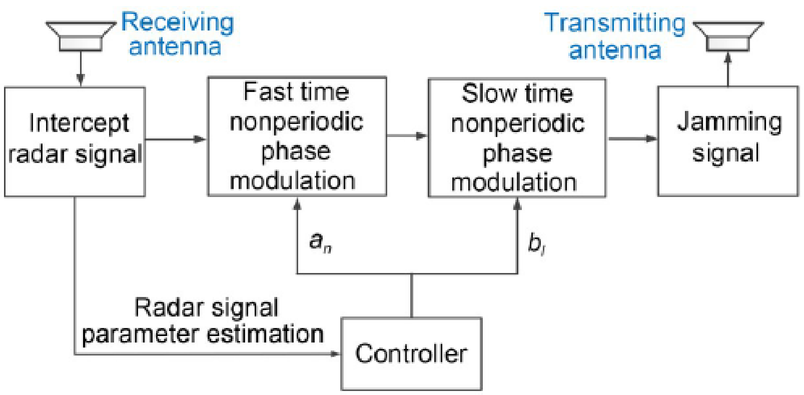


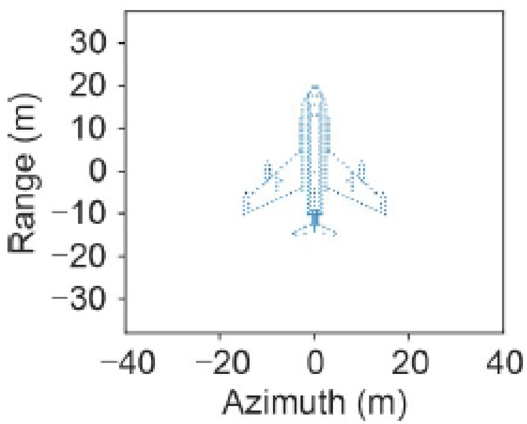
Fig. 6 The proposed jamming procedure

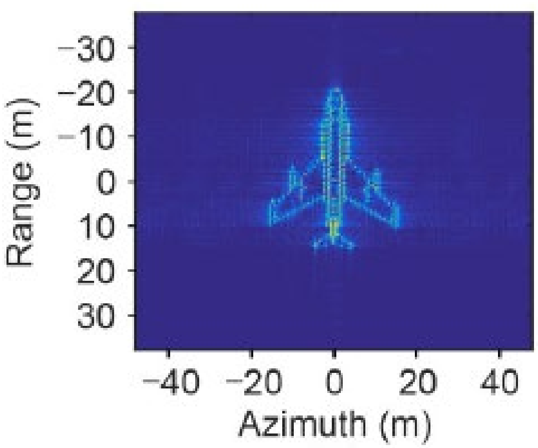
Jammer assumption:
The jammer is fixed on the center of the target, which intercepts and modulates the radar signal and protects the target by transforming the target image feature.

Jamming procedure:
First, the jammer intercepts the radar signal by the receiving antenna. Then the controller analyzes the signal parameter and modulates the radar signal in both fast and slow time domains with the phase codes a_n and b_l, respectively. Finally, the jamming signal is retransmitted back to the victim radar after power amplification.

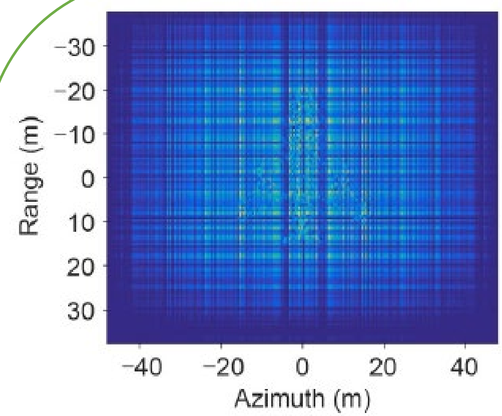
Major results

1. Simulation results with 330-point Yake-42 data

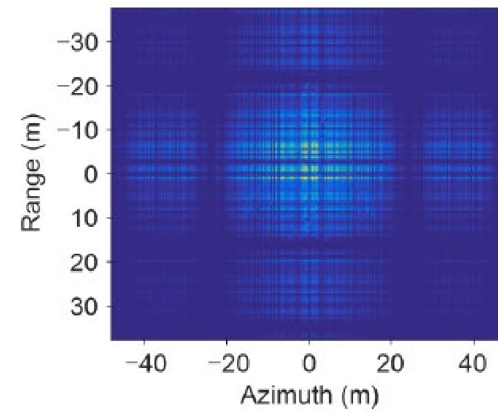




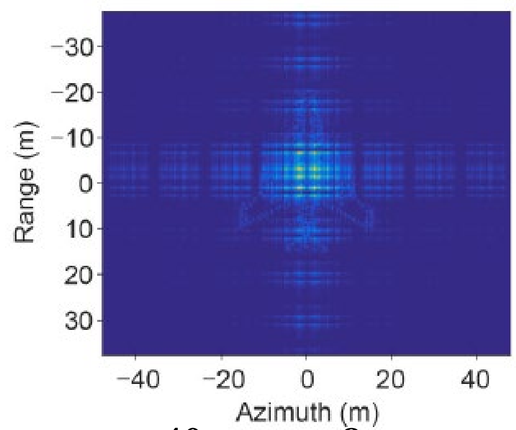
Original unjammed image



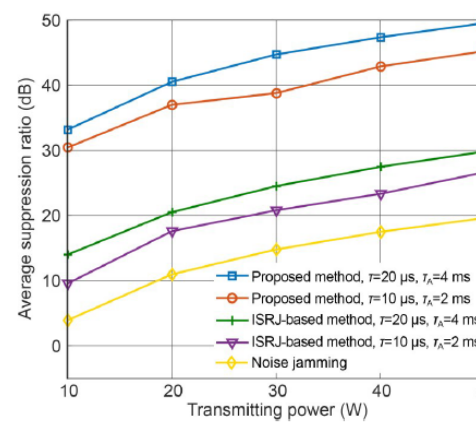
τ=10 μs, τ_A=2 ms



τ=20 μs, τ_A=4 ms



τ=40 μs, τ_A=8 ms

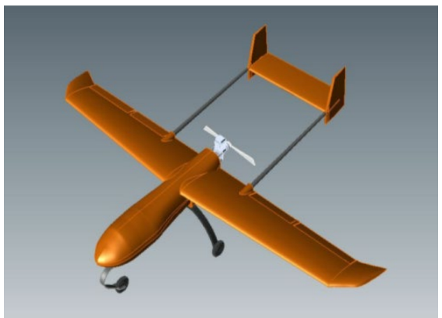


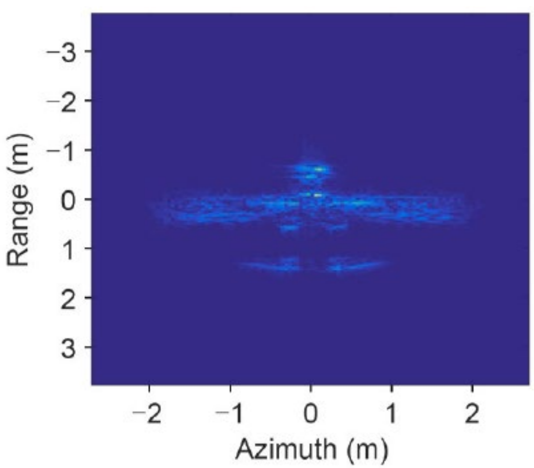
Average suppression ratio

Jamming results

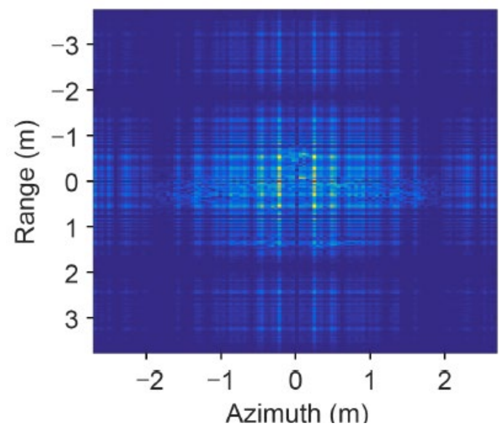
Major results

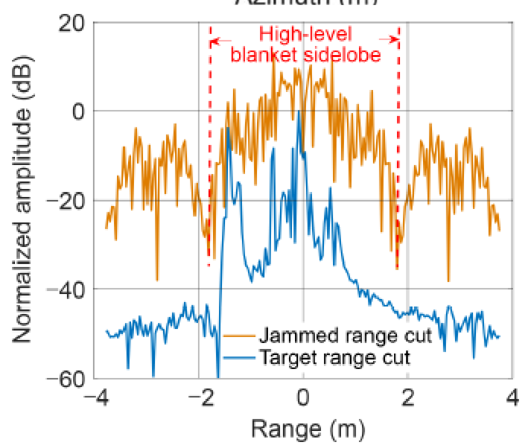
2. Jamming performance with the measured unmanned aerial vehicle (UAV) data.



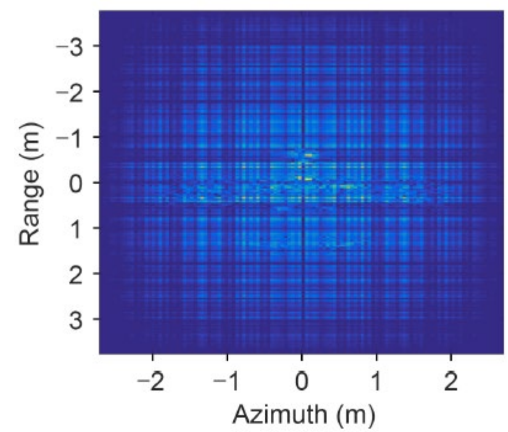


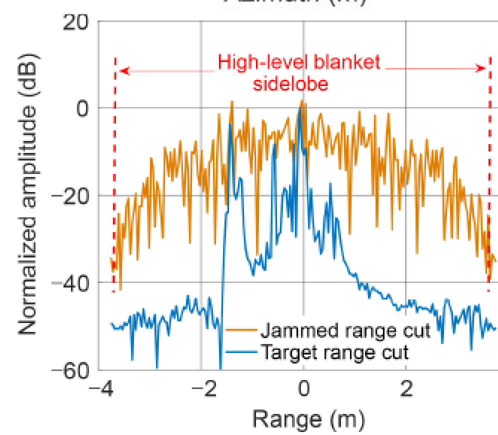
Original unjammed image





τ=20 μs, τ_A=6 ms





τ=10 μs, τ_A=4 ms

Jamming results

Conclusions

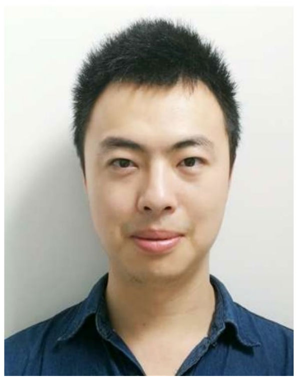
1. In this paper, a novel blanket jamming method against stepped frequency chirp radar is proposed using two-dimensional nonperiodic phase modulation.
2. By intercepting and modulating the radar signal with a nonperiodic phase modulation pulse, the radar image will be covered by high-level blanket sidelobes spreading along both the range and azimuth directions.
3. Both the Yake-42 plane data simulation and measured UAV data experiment results demonstrate the validity of the proposed method.

Qihua WU was born in Jiangsu, China, in 1990. He received the BS degree in communication engineering from Nanjing University, Nanjing, China, in 2013, MS and PhD degrees in information and communication engineering from the National University of Defense Technology, Changsha, China, in 2015 and 2019 respectively. He is currently a lecturer with the State Key Laboratory of Complex Electromagnetic Environmental Effects on Electronics and Information System. His research interests include radar imaging techniques and radar signal processing.

Feng ZHAO was born in Jiangsu, China, in 1978. He received the BS degree in electronic engineering and the PhD degree in information and communication engineering from the National University of Defense Technology (NUDT), Changsha, China, in 2001 and 2007, respectively. He is currently an associate professor with NUDT. His research interests include radar system design and detection techniques of tracking and guiding radar.

Tiehua ZHAO was born in Jiangsu, China, in 1997. He received the MS degree in information and communication engineering from the National University of Defense Technology (NUDT), Changsha, China, in 2022. He is currently pursuing the PhD degree with the NUDT. His research interests include radar imaging techniques and radar signal processing.

Xiaobin LIU was born in Henan, China, in 1990. He received the BS degree in communication engineering from Hunan University, Changsha, China, in 2012, MS and PhD degrees in information and communication engineering from the National University of Defense Technology (NUDT), Changsha, China, in 2014 and 2018 respectively. He is currently a lecturer with the State Key Laboratory of Complex Electromagnetic Environmental Effects on Electronics and Information System. His research interests include radar system simulation and radar signal processing.



Junjie WANG was born in Hunan, China, in 1991. He received the BS degree in communication engineering from Hunan University, Changsha, China, in 2014, MS and PhD degrees in information and communication engineering from the National University of Defense Technology, Changsha, China, in 2016 and 2019 respectively. His research interests include radar imaging and radar signal processing.

Shunping XIAO was born in Jiangxi, China, in 1964. He received the BS and PhD degrees in electronic engineering from the National University of Defense Technology (NUDT), Changsha, China, in 1986 and 1995, respectively. He is currently a professor with NUDT. His research interests include radar target recognition and radar signal processing. Dr. Xiao is a Senior Member of CIE.